# APPENDIX G

## STANDARD OPERATING PROCEDURES

## Standard Operating Procedures (SOPs)
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# PHOSPHORIC ACID ADDITION AT CONTROL STATION 2 SOP

SOP #111

Rev: 0.0

Date: 01/31/2018

# SOP VERSION CONTROL

| Revision No | Revision Date | Page No(s) | Description | Approved by |
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# STAFF ACKNOWLEDGEMENT

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# APPROVAL SIGNATURES

Prepared by: Arcadis U.S., Inc. Date: 01/31/2018

Approved by: ______________________ Date: __________

# 1 DEFINITIONS AND ACRONYMS

| | |
|---|---|
| CSII | Control Station 2 |
| GLWA | Great Lakes Water Authority |
| gph | gallons per hour |
| lb/gal | pounds per gallon |
| MGD | million gallons per day |
| mg/L | milligrams per liter |
| mL | milliliter |
| mL/min | milliliters per minute |
| mL/hr | milliliters per hour |
| $PO_4$ | phosphate |
| PPE | personal protective equipment |

# 2 KEY PERSONNEL AND RESPONSIBILITIES

- Operator:
  - Complete <u>daily</u> check of phosphate dose and pumping equipment, including metering pump, tote, and hose fittings for drips and leaks.
  - Adjust feed rate to achieve target phosphate residual concentration.

# 3 SCOPE/PURPOSE

The purpose of this SOP is to operate and adjust (as needed) the phosphate feed system flowrate at Control Station 2 to achieve the target phosphate residual in the finished water.

# 4 HEALTH AND SAFETY

The following PPE is required while inside the building where the bulk phosphoric acid is stored:

- Chemical resistant apron
- Chemical resistant gloves
- Face shield

Additionally, the facility is equipped with an emergency eyewash station.

# 5 PROCEDURE

**Equipment Required:**

- One 220-gallon tote of 75% phosphoric acid with containment
- Two 4 gph LMI feed pumps (one in service, one on standby)
- One 1000 mL calibration column
- Two digital timers (one is needed for the procedure, plus one spare)
- Daily record sheet

**Procedure:**

1. Read the influent supply flow from control panel in CSII. Record the flow on the daily sheet.
2. Check stroke and speed on feed pump. Record stroke and speed on the daily sheet.
3. Determine feed rate in milliliters per minute (mL/min):
    a. Open the fill valve on the calibration column, fill calibration column to slightly above the 1000 mL mark and close the fill valve.
    b. Close the valve on the supply line from the tote and reopen the valve to the calibration column.
    c. Watch the level drop in the calibration column. When it reaches the 1000 mL mark, start the timer.
    d. After one minute, close the valve to the calibration column and open the valve to the tote. Read the liquid level (mL) in the calibration column. Subtract the liquid level reading from 1000 mL. The difference is the feed rate in mL/min.
    e. Record the feed rate on the daily sheet.
4. Determine the feed concentration in mg/L (or parts per million, ppm):
    a. Multiply the influent flow rate (MGD) by the density of water, 8.34 lb/gal, to obtain million pounds of water being treated per day. Divide this result by 24 to obtain million pounds of water treated in one hour.
    b. Take the mL/min calculated above, multiply by 60 to get mL/hour, then divide by 3785 mL/gal to convert to gallons of phosphate fed per hour. Multiply by the density of phosphate (13.14 lb/gal), and multiply by 0.75 (the percent strength of the phosphate solution). This yields the pounds of pure phosphate fed per hour.
    c. Divide the pounds of pure phosphate by the million pounds of water, and this gives you the concentration for the hour in mg/L.
5. Adjust pump feed rate as needed. If the calculated $PO_4$ concentration is outside of the target residual concentration, adjust the pump feed rate and repeat steps 2 and 3.

# 6 DATA RECORDING AND MANAGEMENT

Following the procedure, record the following data on the daily log sheet:

- Initial and final phosphate pump feed rate in mL/min and lb/hr
- Influent flow rate (MGD)
- Initial and final calculated $PO_4$ concentration

# 7 REFERENCES

None.

# SODIUM HYDROXIDE ADDITION AT CONTROL STATION 2 SOP

SOP #121

Rev: 0.0

Date: 01/31/2018

## SOP VERSION CONTROL

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Prepared by: Arcadis U.S., Inc. Date: 01/31/2018

Approved by: ______________________ Date: __________

# 1 DEFINITIONS AND ACRONYMS

| | |
|---|---|
| CSII | Control Station 2 |
| GLWA | Great Lakes Water Authority |
| gph | gallons per hour |
| lb/gal | pounds per gallon |
| MGD | million gallons per day |
| mg/L | milligrams per liter |
| mL | milliliter |
| mL/min | milliliters per minute |
| mL/hr | milliliters per hour |
| NaOH | sodium hydroxide (caustic soda) |
| PPE | personal protective equipment |

# 2 KEY PERSONNEL AND RESPONSIBILITIES

- Operator:
  - Complete daily check of sodium hydroxide dose and pumping equipment, including metering pumps, tote, and hose fittings for drips and leaks.
  - Adjust feed rate to achieve target pH concentration.

# 3 SCOPE/PURPOSE

The purpose of this SOP is to operate and adjust (as needed) the sodium hydroxide feed system flowrate at Control Station 2 to achieve the target pH of the finished water.

# 4 HEALTH AND SAFETY

The following PPE is required while inside the building where the bulk sodium hydroxide is stored:

- Chemical resistant apron
- Chemical resistant gloves
- Face shield

Additionally, the facility is equipped with an emergency eyewash station.

# 5 PROCEDURE

**Equipment Required:**

- One 273-gallon tote of 25% caustic soda with containment
- Two 10 gph LMI feed pumps (one in service, one on standby)
- One 1000 mL calibration column
- Two digital timers (one is needed for the procedure, plus one spare)
- Daily record sheet

**Procedure:**

1. Prior to traveling to CSII, read the pH from the online analyzer at the lab tap. Record the pH on the daily sheet.
2. Read the influent supply flow from control panel in CSII. Record the flow on the daily sheet.
3. If a change in dosage is needed, calculate the new settings using the CHEAT SHEET and adjust the feed pumps accordingly.
4. Check stroke and speed on feed pump. Record stroke and speed on the daily sheet.
5. Determine feed rate in milliliters per minute (mL/min):
    a. Open the fill valve on the calibration column, fill calibration column to slightly above the 1000 mL mark and close the fill valve.
    b. Close the valve on the supply line from the tote and reopen the valve to the calibration column.
    c. Watch the level drop in the calibration column. When it reaches the 1000 mL mark, start the timer.
    d. After one minute, close the valve to the calibration column and open the valve to the tote. Read the liquid level (mL) in the calibration column. Subtract the liquid level reading from 1000 mL. The difference is the feed rate in mL/min.
    e. Record the feed rate on the daily sheet.
6. Determine the feed concentration in mg/L (or parts per million, ppm):
    a. Multiply the influent flow rate (MGD) by the density of water, 8.34 lb/gal, to obtain million pounds of water being treated per day. Divide this result by 24 to obtain million pounds of water treated in one hour.
    b. Take the mL/min calculated above, multiply by 60 to get mL/hour, then divide by 3785 mL/gal to convert to gallons of sodium hydroxide solution fed per hour. Multiply by the density of caustic soda (10.7 lb/gal), and multiply by 0.25 (the percent strength of the sodium hydroxide solution). This yields the pounds of pure sodium hydroxide fed per hour.
    c. Divide the pounds of pure sodium hydroxide by the million pounds of water, and this gives the concentration for the hour in mg/L.

7. Adjust the pump feed rate as needed. If the pH is outside of the target range, adjust the pump feed rate and repeat steps 3 through 6.

# 6 DATA RECORDING AND MANAGEMENT

Following the procedure, record the following data on the daily log sheet:

- Initial and final sodium hydroxide feed rate in mL/min and lb/hr
- Influent flow rate (MGD)
- Initial and final pH

# 7 REFERENCES

None.

# SODIUM HYPOCHLORITE ADDITION AT CONTROL STATION 2 SOP

SOP #131

Rev: 0.0

Date: 01/31/2018

# SOP VERSION CONTROL

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Approved by: ______________________ Date: ____________

# 1 DEFINITIONS AND ACRONYMS

| | |
|---|---|
| CSII | Control Station 2 |
| GLWA | Great Lakes Water Authority |
| gph | gallons per hour |
| lb/gal | pounds per gallon |
| MGD | million gallons per day |
| mg/L | milligrams per liter |
| mL | milliliter |
| mL/min | milliliters per minute |
| mL/hr | milliliters per hour |
| NaOCl | sodium hypochlorite |
| PPE | personal protective equipment |

# 2 KEY PERSONNEL AND RESPONSIBILITIES

- Operator:
  - Complete daily check of chlorine dose and pumping equipment, including metering pumps, tote, and hose fittings for drips and leaks.
  - Adjust feed rate to achieve target chlorine residual concentration.

# 3 SCOPE/PURPOSE

The purpose of this SOP is to operate and adjust (as needed) the sodium hypochlorite feed system flowrate at Control Station 2 to achieve the target finished water free chlorine concentration.

# 4 HEALTH AND SAFETY

The following PPE is required while inside the building where the bulk sodium hypochlorite is stored:

- Chemical resistant apron
- Chemical resistant gloves
- Face shield

Additionally, the facility is equipped with an emergency eyewash station.

# 5 PROCEDURE

**Equipment Required:**

- One 220-gallon tote of 12.2 percent sodium hypochlorite with containment
- Two 4 gph LMI feed pumps (one in service, one on standby)
- One 1000 mL calibration column
- Two digital timers (one is needed for the procedure, plus one spare)
- Daily record sheet

**Procedure:**

1. Prior to traveling to CSII, read the free chlorine residual (in mg/L) from the online analyzer (i.e., Hach CL17) in the water treatment plant basement. Record the free chlorine residual on the daily sheet. **Note that the target free chlorine residual leaving CSII may vary seasonally.**
2. Read the influent supply flow from control panel in CSII. Record the flow on the daily sheet.
3. Calculate the dosage needed to reach the target residual:
    a. (dosage needed) = (target residual) – (residual at basement analyzer)
4. If a change in dosage is needed, calculate the new settings using the CHEAT SHEET and adjust the feed pumps accordingly.
5. Check stroke and speed on feed pump. Record stroke and speed on the daily sheet.
6. Determine feed rate in milliliters per minute (mL/min):
    a. Open the fill valve on the calibration column, fill calibration column to slightly above the 1000 mL mark and close the fill valve.
    b. Close the valve on the supply line from the tote and reopen the valve to the calibration column.
    c. Watch the level drop in the calibration column. When it reaches the 1000 mL mark, start the timer.
    d. After one minute, close the valve to the calibration column and open the valve to the tote. Read the liquid level (in mL) in the calibration column. Subtract the liquid level reading from 1000 mL. The difference is the feed rate in mL/min.
    e. Record the feed rate on the daily sheet.
7. Determine the feed concentration in mg/L (or parts per million, ppm):
    a. Multiply the influent supply flow rate (MGD) by 8.34 to obtain million pounds of water being treated. Divide this result by 24 to obtain million pounds of water treated in one hour.
    b. Take the mL/min calculated above, multiply by 60 to get mL/hour, then divide by 3785 to convert to gallons of sodium hypochlorite solution fed per hour. Multiply by the weight of bleach (10.15 lb/gal), and multiply by the percent strength of the

   chlorine solution (for example, for 12.2% strength, multiply by 0.122). This gives the pounds of pure chlorine fed per hour.

   c. Divide the pounds of pure chlorine by the million pounds of water, and this gives the feed rate for the hour in mg/L.

8. Adjust the pump feed rate as needed. If the free chlorine residual concentration from the online analyzer in the water treatment plant basement is outside of the target residual concentration, adjust the pump feed rate and repeat steps 3 through 7.
9. Record the free chlorine residual (in mg/L) from the online analyzer (i.e., Hach CL17) in the water treatment plant basement.

# 6 DATA RECORDING AND MANAGEMENT

Following the procedure, record the following data on the daily log sheet:

- Initial and final sodium hypochlorite pump feed rate in mL/min and lb/hr
- Influent flow rate (MGD)
- Initial and final free chlorine residual concentration

# 7 REFERENCES

None.

# SODIUM HYPOCHLORITE ADDITION AT DISTRIBUTION STORAGE FACILITIES SOP

SOP #132

Rev: 0.0

Date: 01/31/2018

# SOP VERSION CONTROL

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Approved by: ______________________ Date: ____________

# 1 DEFINITIONS AND ACRONYMS

| | |
|---|---|
| CSII | Control Station 2 |
| GLWA | Great Lakes Water Authority |
| gph | gallons per hour |
| lb/gal | pounds per gallon |
| MGD | million gallons per day |
| mg/L | milligrams per liter |
| mL | milliliter |
| mL/min | milliliters per minute |
| mL/hr | milliliters per hour |
| NaOCl | sodium hypochlorite |
| PPE | personal protective equipment |

# 2 KEY PERSONNEL AND RESPONSIBILITIES

- Operator:
  - Complete a weekly check of the chlorine injection system, including all piping and connections for leaks.
- Operations Foreman:
  - Calculate applied dosage and injection system settings and communicate to operator.

# 3 SCOPE/PURPOSE

The purpose of this SOP is to operate and adjust (as needed) the sodium hypochlorite feed system flowrate at the Westside and Cedar Street Reservoirs to achieve the target distribution system free chlorine concentration.

# 4 HEALTH AND SAFETY

The following PPE is the minimum required while on-site at the pump stations and reservoirs:

- General
  - Closed-toed shoes
  - City employee identification
- While inside the building where the bulk sodium hypochlorite is stored
  - Chemical resistant apron

- Chemical resistant gloves
- Face shield

Additionally, each facility is equipped with an emergency eyewash station.

# 5 PROCEDURE

**Prior to entering the premises, note surroundings and exterior building condition including exterior lights, doors, windows, and individuals. Do not enter the facility if it appears unsafe.**

1. The Operations Foreman calculates the applied dosage and injection system settings using the CHEAT SHEET and notifies the Operator.
2. Enter the reservoir and disarm the alarm.
3. **Start the injection system:**
    a. Open the sodium hypochlorite barrel valve.
    b. Open feedline valve.
    c. Turn on the LMI pump with appropriate setting.
4. Perform a draw down calibration ensuring the pump is working and the proper dosage is being injected into the reservoir. If dosage is incorrect, adjust the speed and stroke of the chemical feed pump accordingly.
5. **Note: If the injection system fails to start, notify the Operations Foreman immediately so that filling of the reservoir can be halted until the system is operating properly.**
6. Perform a chemical inventory of amount of sodium hypochlorite solution on hand and report to the Operations Foreman.
7. Manually check the injection lines and fittings for deformation and wear.
8. Visually inspect the chemical feed pump for leaks and proper operation.
9. Notify the Operations Foreman the time in which the injection system was turned on and the settings.
10. Prior to exiting the facility, ensure that the surrounding area is safe and re-arm the alarm, turn out the lights, and verify that the reservoir entry door is locked.
11. Return to check that the injection system after it has been running for 2 to 3 hours, noting any concerns with the pump or injection lines.
12. **Turn off the injection system when filling is almost completed:**
    a. Turn power off.
    b. Close injection valve.
    c. Ensure proper operation.

   d. Notify the Operations Foreman time of shut-off.

13. Report back to the water treatment plant.
14. **Chlorine Injection System Failure Contingency Plan:**
   a. The operator is to notify the Operations Foreman immediately. The Operations Foreman will close the valve at the reservoir to avoid reduced chlorinated water from entering the reservoir. The operator will then assess to see why the failure occurred and make a plan to rectify the situation. If repair is needed and time is an issue than the original chlorinator can be used as a backup.

# 6 DATA RECORDING AND MANAGEMENT

Following the procedure, record the following data on the daily log sheet:

- Time injection system was turned on.
- Dosage of chlorinator solution.
- Inventory of sodium hypochlorite solution on site.
- Notes of any wear, deformation, or malfunction of equipment.
- Time injection system was turned off.

# 7 REFERENCES

None.

# SODIUM HYPOCHLORITE TESTING SOP

SOP #133

Rev: 0.0

Date: 01/31/2018

## SOP VERSION CONTROL

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Approved by: ____________________ Date: ____________

# 1 DEFINITIONS AND ACRONYMS

| | |
|---|---|
| g/L | grams per liter |
| PPE | personal protective equipment |
| mL | milliliter |
| N | normal (equivalent per liter) |

# 2 KEY PERSONNEL AND RESPONSIBILITIES

- Laboratory Technician:
  - Confirm sodium hypochlorite strength and record to calculate correct dosing.

# 3 SCOPE/PURPOSE

This SOP uses the iodometric method to determine the percent concentration of sodium hypochlorite (concentrated liquid bleach) used as a disinfectant at the water treatment plant and reservoirs.

Under acidic conditions, hypochlorite reacts with iodide to produce an equivalent amount of triiodide ($I^{3-}$). The released $I^{3-}$ is titrated with standard thiosulfate solution to a colorless end point. The number of digits of thiosulfate required is proportional to the hypochlorite concentration in the original bleach sample.

Samples of concentrated sodium hypochlorite solution should be stored in a cool, dark place until analyzed and should be analyzed as soon as practical.

# 4 HEALTH AND SAFETY

The following personal protective equipment (PPE) is required while inside the building where the bulk sodium hypochlorite is stored:

- Chemical resistant apron
- Chemical resistant gloves
- Face shield

Additionally, the facility is equipped with an emergency eyewash station.

Once the sample is collected and taken to the lab for analysis, the following PPE is required:

- Chemical resistant gloves
- Laboratory coat
- Safety glasses

# 5 PROCEDURE

**Equipment Required:**

- Glass sample bottle
- One 125 mL Erlenmeyer flask
- Reagents:
    - Potassium iodide powder pillow (Hach Catalog No. 2059996)
    - Acid reagent powder pillow, 25 mL (Hach Catalog No. 104299)
    - 2.26 N thiosulfate titrant solution cartridge (Hach Catalog No. 2686901)
- Starch indicator solution (Hach Catalog No. 34932)
- Titrator (Hach Catalog No. 1690001)
- Piston pipet, 0.1 – 1.0 mL

**Procedure:**

1. Collect a sample from the concentrated sodium hypochlorite solution (approximately 5-10 mL) in a clean glass sample bottle. Take the bottle to the lab for analysis.
2. Insert a clean delivery tube into the 2.26 N thiosulfate titrant solution cartridge. Attach the cartridge to the titrator body.
3. Flush the delivery tube by turning the deliver knob to eject a few drops of titrant. Reset the counter to zero and wipe off the tip.
4. Fill the 125-mL Erlenmeyer flask to the 75-mL mark with deionized or tap water.
   *Note: The level of residual chlorine found in tap water will not interfere in the test.*
5. Add the contents of one potassium iodide powder pillow to the flask and swirl to mix.
6. Add the contents of one acid reagent powder pillow to the flask and swirl to mix.
7. Attach a clean tip to a calibrated piston pipet.
8. Use the pipet to dispense 0.2 mL of the sodium hypochlorite sample below the solution level in the flask.
9. Swirl to mix. The solution will turn dark brown.
10. Place the delivery tube tip into the solution and swirl the flask while titrating with the thiosulfate titrant until the solution is pale yellow.
11. Add one dropper of starch indicator solution to the flask and swirl to mix. A dark blue or green color will develop.
12. Continue the titration until the solution becomes colorless. Record the number of digits required.
13. Calculate the g/L chlorine:
    a. g/L chlorine = Digits Required x 0.5
    b. Divide the g/L chlorine by 10 to obtain the % (by volume) chlorine (trade percent).

# 6 DATA RECORDING AND MANAGEMENT

Record the results of the test on the daily test log sheet.

# 7 REFERENCES

Method adapted from ASTM Method D2022.

# DISTRIBUTION STORAGE AND PUMPING STATION OPERATION AND MAINTENANCE SOP

SOP #211

Rev: 0.0

Date: 04/13/2018

# SOP VERSION CONTROL

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Prepared by: Arcadis U.S., Inc. Date: 04/13/2018

Approved by: ______________________ Date: __________

# 1 DEFINITIONS AND ACRONYMS

| | |
|---|---|
| AWWA | American Water Works Association |
| CSII | Control Station 2 |
| EAM | enterprise asset management |
| PPE | personal protective equipment |
| PS | pump station |
| PS#3 | Pump Station No. 3 |
| PS#4 | Pump Station No. 4 |
| psi | pounds per square inch |
| min | minute |
| SCADA | supervisory control and data acquisition |
| SOP | standard operating procedure |

# 2 KEY PERSONNEL AND RESPONSIBILITIES

- Operator:
  - Fill and pump from reservoirs using the pressure and demand information from SCADA

# 3 SCOPE/PURPOSE

The purpose of this SOP is to reduce water age, increase mixing, promote water quality within the reservoir and pumping station, and maintain sufficient pressures within the distribution system during reservoir filling operations.

This SOP covers the filling and pumping of Cedar Street Reservoir to induce a clockwise flow of water throughout the city. Note that reversing this process will not result in a counterclockwise flow.

The following operating requirements apply to the operations of the reservoir and pump station:

- Maintain system pressures of 40 psi +/- 2 psi while filling reservoir
- PS#3 reservoir level: High = 12 ft. Low = 5 ft. Fill valve range: 0-7% psi based
- Open fill valve at Cedar St. over a duration of 10-15 min
- Close fill valve at Cedar St. over a duration of 10-15 min

Considerations: Filling is primarily performed when demand drops. Typically, starting at 11 pm and ending at 5 am. Note that demand changes as the seasons change and when system usage patterns change, such as children starting school and ending school. The changing of daylight hours, holidays and weekends also impact demand. Filling times should be adjusted accordingly.

# 4 HEALTH AND SAFETY

The following PPE is the minimum required while on-site at the pump station and reservoir:

- General
    - Closed-toed shoes
    - City employee identification
- During chlorine sample collection and analysis
    - Chemical resistant apron
    - Chemical resistant gloves
    - Face shield

Additionally, the facility is equipped with an emergency eyewash station.

# 5 PROCEDURES

## 5.1 Cedar Street Reservoir Filling and Pumping

The following actions are completed from the Water Treatment Plant control room.

- **Filling:** Start by opening the fill valve at Cedar Street Reservoir to 4%. While doing so, watch to ensure that distribution system pressure monitors indicate that pressures are holding at or above 40 psi.

**Pumping:** Wait at least 30 minutes after filling, then turn on Pump 1 or Pump 2. (There are three pumps at Cedar Street Reservoir. Pumps 1 and 2 have capacity of 9 MGD. Pump 3 has a capacity of 12 MGD.) Only one pump should be used at any given time. Operation of the pumps should be rotated to ensure operability and reduce wear on a single pump.

**Filling and Pumping Schedule:**

- Cedar Street Reservoir is pumped during 1st shift between 7:00 am and 3:00 pm.
- Cedar Street Reservoir is filled between 10:30 pm and 6:00 am Monday through Saturday and 10:30 pm and 10:30 am on Sunday.
- Exceptions to the above recommendations:
    - In the event of a fire emergency when additional pressure is required in the distribution system, fill valves must be closed.
    - Pumping should be adjusted from June 1 to August 31 such that the 15 MGD GLWA peak hour and maximum day flow limitations are not exceeded.

## 5.2 Routine Maintenance and Inspection of Reservoir

The reservoir should be maintained and inspected in accordance with procedures outlined in AWWA M42. (Note AWWA M42 is a steel tank manual of practice, however, it is applicable to concrete structures where inspection frequency is concerned.) The following actions should be performed monthly (or weekly, if possible) to ensure safe operation:

- Structural integrity:
  - Inspect exposed components of the reservoir for leaks, crumbling concrete, vandalism, structural damage, or cracking.
  - Note any areas with visible damage.
- Overflow, manholes, and vents:
  - Inspect integrity of overflow and vent screens and check for evidence of animal or insect nesting or damage.
  - Inspect any entrance points such as roof manhole seals and the security lock integrity.
  - Note any screens, locks, or appurtenances requiring repair.

## 5.3 Dry Inspection and Maintenance

Every 3 to 5 years, the reservoir should be taken off-line, isolated, and emptied for a more complete inspection of the interior and exterior in accordance with AWWA M42. This task is typically completed by a professional services contractor. The following components should be included in this thorough inspection and maintenance:

- Interior and exterior structural integrity:
  - Inspect condition of all supports, walls, and ceilings.
  - Note the presence of cracks, gaps, and potential leak points.
- Sanitary conditions:
  - Evaluate the tank inlet, outlet, drain, and overflow for potential cross-connections.
  - Inspect all manways, hatches, vents, and openings for damage and evidence of bacterial activity.
  - Verify that all manways and hatches are properly secured and sealed.
- Safety and operational requirements:
  - Inspect all level gauges, ladders, safety railings, platforms for deterioration and ensure they comply with any local, state, or federal regulations.
- Perform interior high-pressure cleaning of all surfaces and remove and properly dispose of sediment.

## 5.4 Disinfection, Testing, and Returning Reservoir to Service

Disinfection and testing of water storage facilities should be completed in accordance with AWWA Standard C652 prior to returning to service. Satisfactory chlorine residual, turbidity, and bacteriological results are required prior to placing the reservoir back into service.

### 5.5 Pump Maintenance

Service pumps at the reservoir and pumping station should be operated and maintained on a regular basis. Specific inspections and maintenance requirements should be determined in conjunction with the pump manufacturer and performed on a regular basis in accordance with pump manufacturer's recommendations. All pump inspection and maintenance records should be recorded and tracked in the enterprise asset management (EAM) system.

If inspections indicate that maintenance to a pump is required, notify the Water Treatment Plant Supervisor to generate a work order for the work. Proper documentation of all maintenance activities should be completed and incorporated into the appropriate asset management database including:

- Name of facility where work will be performed.
- Pump number, manufacturer, model, and serial number
- Specific details of the work completed.
- Name of the individual(s) performing the maintenance work.
- Date(s) of when maintenance was performed.
- List of parts and their part numbers used to complete the maintenance work.

## 6 DATA RECORDING AND MANAGEMENT

When filling the reservoir, the following information must be recorded:

- Time of fill start
- Reservoir level at start
- For each time the valve is adjusted:
    - % open
    - System pressures
    - Total time at that % open
- Time of fill finish
- Level of reservoir at finish

## 7 REFERENCES

American Water Works Association. (2011). *C652-11: Disinfection of Water Storage Facilities.* Denver, CO: AWWA.

American Water Works Association. (2013). *M42: Steel Water-Storage Tanks.* Denver, CO: AWWA.

# EMERGENCY REPAIR OF WATER MAINS SOP

SOP #311

Rev: 0.0

Date: 01/31/2018

## SOP VERSION CONTROL

| Revision No | Revision Date | Page No(s) | Description | Approved by |
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## STAFF ACKNOWLEDGEMENT

I certify that the requirements of this SOP have been communicated to me and that I am trained in its use. A copy of this page will be distributed to the employee training record file.

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# APPROVAL SIGNATURES

Prepared by: Arcadis U.S., Inc. Date: 01/31/2018

Approved by: ______________________ Date: ____________

# 1 DEFINITIONS AND ACRONYMS

| | |
|---|---|
| AWWA | American Water Works Association |
| EAM | enterprise asset management |
| OSHA | Occupational Safety and Health Administration |
| PPE | personal protective equipment |
| mg/L | milligram per liter |

# 2 KEY PERSONNEL AND RESPONSIBILITIES

- Water Distribution Foreman:
  - Oversee main repair and disinfection
  - Determine and implement any follow-up activities
  - Document the break, including the type, repair conditions and activities, process used for disinfection and all sampling results, in the enterprise asset management (EAM) system
- Water Distribution Operator (2-4):
  - Conduct repairs and field disinfection process
  - Collect and analyze samples for disinfectant residual and document results
  - Collect bacteriological samples and deliver to the water quality laboratory for analysis
- Laboratory Technician:
  - Analyze bacteriological samples and report results to Water Distribution Foreman

# 3 SCOPE/PURPOSE

The purpose of this SOP is to outline the procedures for repairing a main break, including any necessary flushing, disinfection and water quality testing to be conducted before a main is placed back into service. The procedures presented herein are based on the *Water Research Foundation Report #4307 – Effective Microbial Control Strategies for Main Breaks and Depressurization* (2014) and should be used in conjunction with AWWA Standard C651 – Disinfecting Water Mains. As not all breaks can be repaired in the same manner, crews should use their best judgment when implementing the procedures below.

# 4 HEALTH AND SAFETY

Main repair often involves several types of hazards, including:

- Traffic Hazards: The field service team should use trucks, temporary signs, and traffic cones, barricades, and flashers to prevent automotive accidents and injury to staff. In

addition, a flag crew may be needed to direct traffic in some locations. Trucks should be parked between oncoming traffic and the work area when possible to provide a barrier.
- Heavy Construction / Mechanized Equipment Hazards: Heavy or mechanized equipment may be needed for excavation, trenching, grading, etc. Staff operating the equipment must have the proper training and licensure. Ensure proper distances from the equipment are maintained. Use hand signals / radios to communicate with the operator and spotters as needed when moving equipment. Make eye contact with the operator before coming in the vicinity of the equipment.
- Trenching and Confined Space Entry: If trench work is required, consult the relevant excavation procedures for benching, sloping and shoring depending on depth and conduct work in accordance with the Occupational Safety and Health Administration (OSHA) standards for trenching and excavation. Where applicable, staff working in the trench must have the proper confined space entry training and certification.
- Hazardous Chemicals: Disinfection procedures involve the use of chlorine, which can present various hazardous to staff and the public. Staff should be trained in the use of the specific chemicals to be used and how to address any emergencies that may arise. In addition, staff should follow all precautions when working with chlorine solutions.

Crews should be able to recognize and respond to the potential hazards, and must have the proper training, including knowledge of proper sanitary procedures during repair, and certifications to the complete the applicable tasks. In addition, proper PPE should be worn at all times and will vary depending on the specific repair activity. PPE may include:

- City employee identification
- Chemical resistance apron
- Face Shield
- Hard hat
- High visibility safety vest
- Knee pads
- Safety glasses
- Steel-toed boots
- Work gloves and/or chemical resistant gloves

# 5 PROCEDURE

**Equipment Required:**

- Traffic cones, barricades, and flashers
- Temporary signs/arrow boards (warning lights, strobe lights, arrow boards, traffic maintenance signs)
- Water system maps
- Field tools for isolating and repairing the pipe section (e.g., pry bar, valve key or valve box keys for all saws, pipe wrenches, buckets, shovels, welding equipment, pick axes, ladders, flashlights, pipe clamps, couplings, etc.)

- One percent chlorine solution in spray bottles
- One of the following NSF/ANSI 60 certified disinfection chemicals:
    - Chlorine gas
    - Sodium hypochlorite solution
    - Calcium hypochlorite tablets
- NSF/ANSI 60 certified dechlorination chemical, if needed
- Sterile sample bottles treated with sodium thiosulfate, transport cooler, ice packs
- Field chlorine test kit
- Night lights
- Portable dewatering pumps and accessories
- Surface runoff diversionary equipment (sandbags, trench covers, etc.)
- Backfill material or bedding (sand, crushed stone, etc.)

**Procedure:**

An overview of the procedure based on break type is summarized in Table 1. As not all breaks will fall into these categories and as site conditions (i.e., ability to locate and operate appropriate valves and hydrants) impact the ability to implement the procedures below, crews should use their best judgment when modifying the procedures below and ensure practices comply with AWWA Standard C651. Additional details are provided below.

**Table 1: Categories of Main Break Types and Repair Response Procedures (Adapted from Kirmeyer et al., 2014 and AWWA Standard C651-15)**

| **Main Break Type** | **Type 1** | **Type 2** | **Type 3** | **Type 4** |
|---|---|---|---|---|
| **Description** | | | | |
| **Description** | Controlled pipe repair without depressurization | Controlled pipe repair with depressurization after shutdown | Uncontrolled pipe break with possible water contamination or loss of sanitary conditions during repair | Uncontrolled pipe break with a likelihood of water contamination or loss of sanitary conditions during repair |
| **Pressure Conditions** | Positive pressure maintained during break and repair | Pressure maintained during break and excavation, followed by controlled shutdown for repair | Loss of pressure at break site / possible local depressurization (less than 20 psi) adjacent to the break (e.g., severe erosion requires pressure to be reduced prior to exposing the pipe) | Loss of pressure at break site / widespread depressurization (less than 20 psi) in the system (e.g., pipe blowout and loss of pressure prior to shutdown) |

| **Main Break Type** | **Type 1** | **Type 2** | **Type 3** | **Type 4** |
|---|---|---|---|---|
| **Risk of Microbiological Contamination** | No signs of contaminant intrusion | No signs of contaminant intrusion | Possible contaminant intrusion | Possible / actual contaminant intrusion |
| **Procedures** | | | | |
| **Assess Break** | Excavate to at least 1' below the pipe invert<br>No shutdown needed; maintain pit water level below break | Excavate to at least 1' below the pipe invert<br>Perform controlled shutdown after pipe is exposed and secured from trench soil/water contamination and maintain pit water level below break | Uncontrolled shutdown<br>Document possible contamination<br>Shut-off customer services in affected area | Immediate or uncontrolled shutdown<br>Document likely contamination<br>Shut-off customer services in affected area |
| **Repair** | Repair pipe under positive pressure<br>Disinfect repair parts<br>Swab accessible components with 1% chlorine solution | Repair pipe following controlled shutdown<br>Disinfect repair parts<br>Swab accessible components with 1% chlorine solution | Repair pipe following partial of uncontrolled shutdown<br>Disinfect repair parts<br>Swab accessible components with 1% chlorine solution | Repair pipe following uncontrolled or immediate shutdown<br>Disinfect repair parts<br>Swab accessible components with 1% chlorine solution |
| **Disinfection** | Not required | Not required | Conduct slug chlorination (CT of 100 mg/L-min)[1] | Conduct slug chlorination (CT of 100 mg/L-min)[1] |
| **Flushing** | Conduct scour flush at 3 fps for a minimum of 3 pipe volumes and confirm water is visually clear<br>Dechlorinate if needed | Conduct scour flush at 3 fps for a minimum of 3 pipe volumes and confirm water is visually clear<br>Dechlorinate if needed | Conduct scour flush at 3 fps for a minimum of 3 pipe volumes and confirm water is visually clear<br>Dechlorinate if needed | Conduct scour flush at 3 fps for a minimum of 3 pipe volumes and confirm water is visually clear<br>Dechlorinate if needed |

| Main Break Type | Type 1 | Type 2 | Type 3 | Type 4 |
|---|---|---|---|---|
| **Disinfectant Residual Sampling** | Check free chlorine level at break site; continue flushing until residual levels have returned to typical levels[3] | Check free chlorine level at break site; continue flushing until residual levels have returned to typical levels[3] | Check free chlorine level at break site; continue flushing until residual levels have returned to typical levels[3] | Check free chlorine level at break site; continue flushing until residual levels have returned to typical levels[3] |
| **Public Notification** | No boil water advisory needed | No boil water advisory needed | Instruct customers to flush premise plumbing upon return to service<br>Determine if boil water advisory is needed based on depressurization extent and presence of contamination[2] | Instruct customers to flush premise plumbing upon return to service<br>Issue boil water advisory or "Do Not Drink" Order |
| **Bacteriological Sampling** | No sampling needed | If a full pipe section is required during the repair, collect one set of samples; however, the pipeline may be returned to service prior to obtaining the results | Collect bacteriological samples; main may be returned to service prior to completion of the testing depending on the depressurization extent and presence of contamination[2] | Collect bacteriological samples; await confirmation of sample results before placing line back into service |

1. In highly tuberculated pipes, a higher CT should be considered to compensate for possible lower flushing efficiency.  If exposure of customers to high levels of chlorine cannot be controlled, a minimum free chlorine level of 4 mg/L must be maintained for at least 16 hours in conjunction with flushing, coliform sampling and public notification.
2. If depressurization is limited to the pipe section, or area flushed or disinfected, then a boil water advisory is not needed and main can be returned to service prior to receiving the bacteriological sample results. However, if the area of depressurization is larger than the treated area, then a precautionary boil water advisory should be considered and/or the main should not be released for service until the sample result is confirmed to be absent of coliforms.
3. Residual levels should be at least 90% of ambient or pre-break levels and not more than 4.0 mg/L as required by State and Federal regulations.

1. Upon arrival at the site, evaluate the site for safety (including the appropriate PPE) and set up the appropriate traffic control measures. This may include: warning lights, strobe lights, arrow boards, traffic maintenance signs, cones, flagmen (if necessary), safety vests and/or other PPE. Locate and mark buried utility lines and valves in the vicinity. Check for potential contamination sources, such as septic systems, underground storage tanks, service connections without proper backflow prevention devices, and presence of multistory buildings.
2. If necessary, isolate the pipe section by slowly adjusting valve settings, maintaining positive pressure to reduce backflow or runoff contamination. Where possible, service disruptions should be minimized; however, it may be necessary to isolate certain areas to minimize the potential for contamination. Close or throttle valves, particularly service connections that do not have proper backflow prevention, as needed, to isolate the repair area. If possible, notify impacted customer of the potential disruption. Use caps or covers to protect existing mains or service connections.
3. Excavate the break. Provide the necessary benching, sloping and/or shoring depending on depth and conduct work in accordance with the Occupational Safety and Health Administration (OSHA) standards for trenching and excavation. Install temporary devices to divert surface water runoff around the repair site. Use portable dewatering pumps to maintain water levels at least one foot below the pipe invert during repair.
4. Repair the pipe using the appropriate materials (i.e., fittings, joints, gaskets, clamps), sizes and other necessary repair equipment. During the repair:
    a. Maintain positive pressure, where possible, to prevent contamination from backflow into the pipe. At the start of, at least once during and at the end of the repair, confirm and document if positive pressure is maintained in the immediately vicinity of the break site by visually observing a steady flow or spray of water coming from the pipe, or observation of a hose bib or hydrant located near and at a higher elevation than the break site. Pressure above 20 psi should be maintained outside the immediate repair area. If pipe cannot be repaired under pressure, do no depressurize the pipe until the pipe is exposed.
    b. Maintaining a dewatered trench to at least 1’ below the pipe invert.
    c. Visually inspect the interior and exterior of all new materials (pipes, fittings, valves, etc.) to ensure there is no visible damage, debris or contamination.
    d. Remove any visible debris from exposed areas of the existing pipe.
    e. Keeping all parts, tools and materials used in the repair in a clean and sanitary condition. Clean and disinfect prior to use or installation with a 1 percent chlorine solution. If any interior areas of the pipe were exposed to the environment during the repair, spray or swab any accessible upstream and downstream interior of the existing pipe areas with a 1 percent chlorine solution. If the repair requires new piping to be installed in any section, the new pipe must be inspected, cleaned and disinfected from both ends by swabbing with 1 percent chlorine solution.
    f. Maintain pipe caps, plugs or other protective coatings until materials are ready to be installed.

   g. Complete all pipe and fitting joints in the trench before stopping work. If work requires more than one day, store materials on-site in a secure area.

5. If needed, disinfect the pipe in accordance with the described outlined in AWWA Standard C651. For disinfection of repaired mains, the following methods can be used:
   a. Tablet method: involves the use of calcium hypochlorite tables in the repaired or replaced pipe section and contact time with an initial free chlorine concentration of 25 milligrams per liter (mg/L). Note that pipe materials must be evaluated for compatibility and that this method may only be used when pipes and appurtenances are kept clean and dry during construction. Cleaning and flushing of the main prior to disinfection cannot be performed with this method.
   b. Continuous feed method: involves filling the main with potable water to remove air pockets, then flushing to remove particulates, and refilling the main with chlorinated water at a dose of 25 mg/L until stable concentrations are reached within the pipe (i.e., a free chlorine residual of not less than 10 mg/L after a holding period of 24 hours).
   c. Slug method: involves filling the main with potable water to remove air pockets, flushing to remove particulates, followed by slow flush with a high concentration of chlorine – 100 mg/L – for at least 3 hours. The use of cross connection control and backflow prevention must be used to ensure the high chlorine concentration does not affect the distribution system.
   d. Spray method: involves a 30-minute exposure to free chlorine at not less than 200 mg/L. Refer to chlorination method 2 in AWWA Standard C652 – Disinfection of Water Storage Facilities.

   The slug method may be preferable as it requires reduced contact time. However, alternative methods (tablet method, continuous feed method, or spray disinfection) are available. Evaluate the scene and select the best method for disinfection based on site conditions, length and diameter of the main, type of joints present, available materials and equipment, type of break and associated risk for microbiological contamination. If highly chlorinated water is likely to impact fish or plant life or other downstream users), dechlorination must be performed to neutralize the remaining chlorine residual prior to discharge. If dechlorination is necessary, follow the procedures outlined in AWWA Standard C655 – Field Dechlorination.

6. Target a unidirectional flush towards the water main break. Open the necessary hydrants to complete the flush. Flush with potable water at a velocity of 3.0 feet per second (fps) in the pipe for a minimum of three pipe volumes to remove debris, and verify that the discharge is visually clear.
7. Check for typical system chlorine residual in the main using a field chlorine test kit and flush the pipe section until typical system residuals are detected (i.e., to at least 90% of ambient or pre-break levels and not more than 4.0 mg/L as required by State and Federal regulations). Collect samples from the immediate and surrounding areas around the repair site.
8. For high risk breaks (Types 3 and 4), notify affected customers about the break, schedule, and concerns. Instruct customers to flush their home plumbing after repairs

are completed. If contamination was likely to occur, perform issue a precautionary boil water notice. In the event that a boil water advisory is needed, the Water Distribution Superintendent should immediately contact the appropriate staff the Geneseee Coutny Health Department and Michigan Department of Environmental Quality to notify them of the situation and to coordinate the public notification.

9. For medium risk breaks (Type 2) where a full pipe section was required and high risk breaks (Types 3 and 4), conduct coliform sampling in accordance with AWWA Standard C651. For Type 2 and some Type 3 breaks, the main may be returned to service prior to the completion of the bacteriological results. For Type 4 results, await until sample results are received and show the absence of coliforms. In the event that coliforms organisms are detected, repeat the flushing and resample for coliforms. If the confirmation coliform sample also shows the presence of coliforms, repeat disinfection using the continuous-feed or slug method until no coliform organisms are present. For any positive coliform results, the Water Distribution Superintendent should immediately notify Michigan Department of Environmental Quality and follow any required procedures.
10. Flush hydrants, if needed, to remove any debris.
11. Return the main to service by opening any closed valves, using a sequence that avoids low or negative pressures.
12. Backfill and compact pipe bedding per applicable AWWA pipe installation standard.
13. Repair ground surface to at least original conditions.

# 6 DATA RECORDING AND MANAGEMENT

Following a main break, enter all necessary information into the EAM system. This includes:

- Date and approximate type of break
- Nature of break (i.e., circumferential, longitudinal, both, shear, hole, split, blowout, joint, sleeve, other)
- Apparent cause of break (i.e., water hammer, defective pipe, corrosion, deterioration, improper bedding, operating pressure, temperature, differential settlement, improper installation, other)
- Type of break (based on Table 1 above)
- Location and field conditions (paved/unpaved, traffic conditions, type of soil, side of street, weather conditions,)
- Pipe data (type of main, class, length, diameter, bedding, backfill, compaction)
- Type of repair (clamp, sleeve, etc.)
- Repair materials used
- Potential contamination issues (e.g., muddy trench water flowing into broken pipe, leaking sewer pipe in trench, catastrophic pipe failure where pipe is open)
- Problems encountered
- Water quality test results
- Field observations, including inoperable valves or hydrants or incorrect locations of mains, valves, hydrants, underground utility locations, service connections, etc.

- Estimate the cost associated with the repair (materials, manpower, time, overtime, etc.)

The Water Distribution Superintendent shall assign work orders for any follow-up items, such as valve replacements.

# 7 REFERENCES

AWWA. (2015). *C651-14 Disinfecting Water Mains.* AWWA

AWWA. (2011). *C652-11 Disinfection of Water Storage Facilities.* AWWA

Kirmeyer, G. J., Thomure, T. M., Rahman, R., Marie, J. L., LeChevallier, M. W., Yang, J., … & Schneider, O. (2014). Effective Microbial Control Strategies for Main Breaks and Depressurization. Denver, CO: Water Research Foundation.

# HYDRANT INSPECTION, TESTING, AND MAINTENANCE SOP

SOP #321

Rev: 0.0

Date: 01/31/2018

# SOP VERSION CONTROL

| Revision No | Revision Date | Page No(s) | Description | Approved by |
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# STAFF ACKNOWLEDGEMENT

I certify that the requirements of this SOP have been communicated to me and that I am trained in its use.  A copy of this page will be distributed to the employee training record file.

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# APPROVAL SIGNATURES

Prepared by: Arcadis U.S., Inc. ______________________ Date: 01/31/2018

Approved by: ______________________ Date: ______________

# 1 DEFINITIONS AND ACRONYMS

| | |
|---|---|
| AWWA | American Water Works Association |
| EAM | enterprise asset management |
| GIS | geographic information system |
| GPS | global positioning system |
| PPE | personal protective equipment |

# 2 KEY PERSONNEL AND RESPONSIBILITIES

- Water Distribution Superintendent:
  - Maintain schedule and generate work orders for hydrant inspection, testing and maintenance.
  - Identify additional planning/scheduling activities and resources for each hydrant (such as establishing additional traffic control measures, coordinating with valve exercising, performing customer notification, and assessing the hydraulic impact).
  - Maintain records of hydrant maintenance.
  - Ensure all repairs, map discrepancies, and other issues are properly communicated to the responsible parties and ensure identified repairs/replacements are executed within a timely manner.
- Water Distribution Operator (2):
  - Perform field inspection, testing and maintenance of hydrants as generated by work orders.
  - Prepare records of field testing, inspection and maintenance for each hydrant and enter into enterprise asset management (EAM) system.

# 3 SCOPE/PURPOSE

The purpose of this SOP is to ensure regular and consistent execution of the preventive maintenance, inspection, and testing of hydrants throughout the distribution system. The hydrant maintenance program shall be conducted in accordance with the American Water Works Association (AWWA) Manual M17 Fire Hydrants: Installation, Field Testing, and Maintenance. Per the referenced publication, “all hydrants should be inspected regularly, at least once a year, to ensure their satisfactory operation (most manufacturers recommend twice per year).” In addition, “it is good practice to conduct flow tests on all parts of the distribution system approximately every 10 years to identify the service areas affected by significant changes in the distribution system. An accurate and digital record should be kept of each flow test so it is readily available.”

The City of Flint owns a number of different fire hydrant models; therefore, maintenance and testing practices may vary. Service personnel should apply maintenance practices consistent with the make and model of the hydrant in accordance with manufacturer's recommendations.

This SOP should be used in coordination with a comprehensive asset management plan and hydraulic model. Any updates to condition, status, or operation of valves shall be relayed to the appropriate staff so that information is consistent across distribution system operations.

This SOP does not cover hydrant installation and replacement procedures, which would include inspection before installation, installation or replacement, and testing and/or inspection after installation.

# 4 HEALTH AND SAFETY

One of the most significant health and safety risks during hydrant maintenance is vehicle traffic. The field service team should use trucks, temporary signs, and traffic cones to prevent automotive accidents and injury to staff. In addition, a flag crew may be needed to direct traffic in some locations. Trucks should be parked between oncoming traffic and the work area to provide a barrier. In addition, the following personal protective equipment (PPE) should be worn during maintenance activities:

- City employee identification
- Hard hat
- High visibility safety vest
- Knee pads (as needed)
- Safety glasses
- Steel-toed boots
- Work gloves

# 5 PROCEDURE

**Equipment Required:**

- Water system map (with clear labels for pipe diameter, street names, parcel addresses, critical water users, and all hydrant/appurtenance identification numbers)
- Traffic cones
- Temporary signs/arrow boards (warning lights, strobe lights, arrow boards, traffic maintenance signs)
- Pruning shears
- Wrench
- Approved lubricating oil (and funnel)
- Spare parts (cap, stem, nut, bonnet, etc.)
- Scraper, wire brush, and/or sand-paper

- Spray paint and primer (if applicable)
- Plastic tarp or newspaper
- Approved cleaning agent and paper towels
- GPS unit (optional)
- Digital camera (optional)

**Procedure:**

Once a work order is received from the Water Distribution Superintendent, identify the 2-person maintenance crew to perform the hydrant maintenance.

1. Prior to driving to the site, perform the necessary pre-planning activities. This includes reviewing system maps, GIS, as-builts, and asset history to identify hydrants that are in busy intersections, high-profile of sensitive customers, or may result in a potential hydraulic impact as well as reviewing the manufacturer's manual for the specific hydrants to be inspected. Notify the Water Service Center Supervisor if additional planning/coordination is needed.
2. Identify the best route to conduct the work. This includes identifying the starting and ending point (hydrant location), sequence of hydrants to be completed for the day, and potential parking areas.
3. Upon arrival to the site, assess the site for safety (including the appropriate PPE) and set up the appropriate traffic control measures. This may include: warning lights, strobe lights, arrow boards, traffic maintenance signs, cones, flagmen (if necessary), safety vests and/or other PPE. Document the following information on the work order:
    - Operator last name
    - Inspection date
    - Arrival time

4. Locate and access the fire hydrant identified on the work order. Identify the unique identification number for the hydrant on the appropriate water system map and confirm the actual field location is a correct match. Verify the following information in the field and document it on the work order:
    - Hydrant ID number
    - Map grid/page number
    - Street
    - Cross street
    - Address
    - GPS position (if applicable)
    - Other location notes (i.e. measurements from the property line)
    - Hydrant source main size
    - Map discrepancies (if applicable)

5. Clear the area of excessive debris, vegetation, or dirt (within a 3-foot clearance). There should be no obstructions, including the ground, preventing easy coupling of hoses or turning of spanners. The hydrant should be visible from all approaches. There should be

no brush or tree limbs that could interfere with anyone approaching the hydrant and attempting to connect to it or operate it. Where needed, perform minor corrections, such as pruning and minor digging. Document more significant work on a new work order.

6. Check hydrant information against records (to be provided on work order) and note any discrepancies. Document the following information on the work order:
   - Manufacturer[1]
   - Model
   - Year
7. Visually inspect hydrant for leaks, rust, or any obvious cap/chain defects. Caps should be free from cracks and turn freely. Chains should be attached to caps and the hydrant body and turn freely.
8. Loosen the top cap and open the hydrant a few turns to allow air to vent, and then tighten the cap and open the hydrant fully. A full tear down is required to look for internal damage, gasket, and tread conditions. Pay special attention to all seals and threads, and note any wear.
9. Replace any components, if required.
10. Before putting the hydrant back together, make sure the operating nut, all nozzle outlets, and all seals/threads are cleaned and lubricated (in compliance with manufacturer recommendations).
11. Re-assemble the hydrant and fully tighten all caps.
12. Locate, access, and exercise the fire hydrant isolation valve in accordance with manufacturer recommendations. Valves should open and close properly and should not leak at either the stem or the nozzle. Tighten leaky packings on older hydrants. Document any valves that are difficult to operate, have bent stems, or do not open/close fully on the work order for follow-up.
13. Turn on the hydrant fully and test for adequate, sustained water pressure and proper drainage. Also check for any leaks around the operating stem, nozzles, any seals or packing, and at the flanges. Replace the o-rings if necessary.
14. Open and close the hydrant with the nozzle caps in place to check for seal leakage. Verify that hydrant main (bottom) valve completely closes. Refer to appropriate manufacturer's manual for step by step instructions.
15. If a wet barrel hydrant, drain the hydrant in accordance with manufacturer's instructions.
16. Thoroughly clean the exterior of the hydrant, washing off any dirt, bird droppings, or loose debris.
17. Confirm paint is in good condition. Touch up hydrants with chips or rust using an approved spray paint. A plastic tarp or newspaper should use used to protect sidewalk or nearby vegetation. Remove any surface rust using scraper or wire brush. Roughen

[1] The City of Flint estimates approximately six various hydrant manufacturers are currently in-use (all dry barrel). This includes the following: A.P. Smith, Darling, E.J., Mueller, T.C. and Waterous.

any shiny surfaces with light sanding (to improve paint adhesion). Apply spot primer to coat areas of bare metal. Apply a top coat with a polyurethane enamel compatible paint as directed by the hydrant manufacturer (typically sprayed to minimum 4 mil dry coat thickness).

18. Visually inspect the hydrant for damaged or missing parts. Document any operational deficiencies, leaks, vandalism, and other relevant observations in addition to the following information on the work order:
    - Operated (yes/no)
    - Drained (yes/no)
    - Flow observed (yes/no)
    - Close direction
    - Number of turns
    - Fire hydrant condition (operable/inoperable)
    - Specific hydrant discrepancy (by category and details)
    - Specific repair activity required to return the hydrant to full operability
    - Picture taken (for raises or other conditions)
    - Time work order completed
    - Comments (other relevant observations or items requiring additional maintenance on the work order)
19. Restore the area to a clean and safe condition. This includes clearing the area of any tools/materials used and any traffic control devices.

# 6 DATA RECORDING AND MANAGEMENT

Following completion of a hydrant test, inspection or maintenance work order, enter all necessary information, including the date of maintenance, hydrant identification, condition, test results and personnel completing the maintenance, into the EAM system.

The Water Distribution Superintendent must be notified of any additional required maintenance or if the hydrant is inoperable or in disrepair. The Water Distribution Superintendent shall assign work orders for any follow-up items and coordinate updates to the asset management plan.

# 7 REFERENCES

American Water Works Association. (2016). *M17 Fire Hydrants: Installation, Field Testing, and Maintenance, Fifth Edition.* Denver, CO: AWWA

# VALVE INSPECTION, EXERCISING, AND MAINTENANCE SOP

SOP #331

Rev: 0.0

Date: 01/31/2018

# SOP VERSION CONTROL

| Revision No | Revision Date | Page No(s) | Description | Approved by |
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# STAFF ACKNOWLEDGEMENT

I certify that the requirements of this SOP have been communicated to me and that I am trained in its use. A copy of this page will be distributed to the employee training record file.

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# APPROVAL SIGNATURES

Prepared by: Arcadis U.S., Inc. Date: 01/31/2018

Approved by: ______________________________ Date: ______________

# 1 DEFINITIONS AND ACRONYMS

| | |
|---|---|
| AWWA | American Water Works Association |
| EAM | enterprise asset management |
| GIS | geographic information system |
| GPS | global positioning system |
| PPE | personal protective equipment |

# 2 KEY PERSONNEL AND RESPONSIBILITIES

- Water Distribution Superintendent:
  - Maintain schedule and create work orders for valve inspection, exercising and maintenance.
  - Identify additional planning/scheduling activities and resources for each valve (such as establishing additional traffic control measures, performing customer notification, and assessing the hydraulic impact).
- Water Distribution Operator (2-4):
  - Perform field inspection, exercising and maintenance of valves as generated by work orders.
  - Prepare records of field testing, exercising and maintenance for each valve and enter into enterprise asset management (EAM) system.

# 3 SCOPE/PURPOSE

The purpose of this SOP is to ensure regular and consistent execution of the preventative maintenance, inspection and exercising of valves throughout the distribution system. Valve exercising and maintenance shall be performed in accordance with American Water Works Association (AWWA) Manual M44 – Distribution Valves: Selection, Installation Field Testing and Maintenance.

Care should be taken to prioritize maintenance on those valves that are most critical to distribution system performance and those impacting sensitive populations while continuing a 3 to 5-year rotation schedule for all gate valves. Valves affecting hospitals, schools, and valves on water mains of diameter 16-inches or greater should be given priority, and should be exercised/assessed once per year.

This SOP should be used in coordination with a comprehensive asset management plan and hydraulic model. Any updates to condition, status, or operation of valves shall be relayed to the appropriate staff so that information is consistent across distribution system operations.

This SOP does not cover valve installation and replacement procedures, which would include inspection before installation, installation or replacement, and testing and/or inspection after installation.

# 4 HEALTH AND SAFETY

One of the most significant health and safety risks during valve inspection, exercising and maintenance is vehicle traffic. The field service team shall use trucks, temporary signs, and traffic cones to prevent automotive accidents and injury to staff. In addition, a flag crew may be needed to direct traffic in some locations. Trucks should be parked between oncoming traffic and the work area to provide a barrier. In addition, the following personal protective equipment (PPE) should be worn during maintenance activities:

- City employee identification
- Hard hat
- High visibility safety vest
- Knee pads (as needed)
- Safety glasses
- Steel-toed boots
- Work gloves

# 5 PROCEDURE

**Equipment Required:**

- Valve key or valve box keys for all sizes (and extension kits if needed)
- Valve exerciser tool. There are portable, truck-mounted, or trailer-mounted exercising tools. A combination of one portable and either a truck-mounted or trailer-mounted model is desirable. These tools can be powered by electric, hydraulic, or pneumatic means. Keep in mind that for the portable valve exerciser, you have to provide the power supply (i.e., a generator for an electric tool, a hydraulic pump for hydraulic, or an air compressor for the pneumatic).
- Water system map (with clear labels for pipe diameter, street names, parcel addresses, critical water users, and all valve/appurtenance identification numbers)
- Flashlight
- Oversized screw driver
- Probing rods and/or metal detector
- Pry bar
- Tape measure (25-foot and 100-foot real)
- Shovel
- Traffic cones
- Temporary signs/arrow board (warning lights, strobe lights, arrow boards, traffic maintenance signs)

- Spare parts (valve boxes, lids/covers, etc.)
- Vacuum equipment and water pump
- Blue marking paint
- GPS unit (optional)
- Digital camera (optional)

**Procedure:**

1. Once a work order is received from the Water Distribution Superintendent, identify the maintenance crew to perform the valve maintenance. Note that:
   - Two (2) maintenance resources should be dispatched for work on residential streets.
   - Up to four (4) resources may be required on main arterial roads or busy intersections.

2. Prior to driving to the site, perform the necessary pre-planning activities. This includes reviewing system maps, GIS, as-builts, and asset history to identify valves that may meet the following criteria:

| Criteria | Action |
|---|---|
| Busy Intersection | Notify the Water Distribution Superintendent that work will need to be performed at night or additional traffic control measures will be needed. |
| High-Profile or Sensitive Customers<br>• Hospitals/medical facilities<br>• Large water users<br>• Special manufacturing process facilities | Notify the Water Distribution Superintendent to confirm if additional planning/coordination is required. Advance customer notification may also be needed. |
| Potential Hydraulic Impact<br>• Pumping stations<br>• Reservoirs<br>• Special pipe or valve configurations | Notify the Water Distribution Superintendent to confirm if additional planning or coordination is required. |
| Valves Located in Vault | Requires staff with confined space entry certification. |
| Pipe Diameters Larger than 14-inches | Notify the Water Distribution Superintendent to confirm special equipment to be used (valve turning machine). |

3. Identify the best route to conduct the work. This includes identifying the starting and ending point (valve location), sequence of valves to be completed for the day, and potential parking areas.

4. Upon arrival at the site, evaluate the site for safety (including the appropriate PPE) and set up the appropriate traffic control measures. This may include: warning lights, strobe lights, arrow boards, traffic maintenance signs, cones, flagmen (if necessary), safety vests, and/or other PPE. Document the following information on the work order:

    - Operator last name
    - Inspection date
    - Arrival time

5. Locate the valve to be exercised. This is completed by visual inspection, probing rods and metal detectors. If the valve cannot be located expeditiously (within 15 minutes), label the valve as “cannot locate”. Valves that are believed to be “paved over” should also be documented on the work order.

6. Once the valve is located, identify the unique identification number for the valve on the map and confirm the actual field location is a correct match. Information to be field-verified and documented on the work order include:

    - Valve ID number
    - Map grid/page number
    - Street
    - Cross street
    - Address
    - GPS position (if applicable)
    - Other location notes (i.e. measurements from the property line)
    - Size (per map)
    - Surface cover
    - Valve use (i.e., potable water)
    - Map discrepancies (if applicable)

7. Remove the cover/lid in order to gain access to the valve. If the cover is tightly stuck, a screwdriver, pry bar, sledge hammer, or other tools may be used. If the cover is damaged in the process of accessing the valve or has a hole in it, it should be replaced using spare parts in the truck.

8. Clean the valve box or vault, removing any debris or water, so that the operating nut and bonnet bolts can be seen visually for inspection. Where water is present, use an industrial vacuum equipment or water pumps capable of de-watering a vault. Exercise caution with snakes, spiders, or other potential hazards.

9. Visually inventory the valve specifications. Document the following information on the work order:

    - Manufacturer[1]
    - Model
    - Serial number (for 12-in and larger)

- Other information stamped on the valve cover plate (such as Rated Working Pressure or special coating)
- Valve type (i.e., gate, butterfly, cone, check, air valve, blow-off)
- Function/use (in-line main, hydrant isolation, service line, bypass, division, pressure reducing, etc.)
- Structure (i.e., box, vault)
- Operating nut depth
- Cleaning equipment required (i.e., vacuum, pump)
- Map discrepancy (if applicable)

10. Once clean, inspect the stem and nut for damage or obvious leakage. If applicable, document the following findings in the appropriate work order fields:
    - Stopped packing leak (yes/no)
    - Replacement recommendations
    - Comments
    - Picture taken (for raises or other conditions)

11. After valve casing is clean, exercise the valve. As recommended by AWWA M44 (2015), every valve should be operated through a full close and open cycle on a regular schedule to clear the operating stem and wedge guides of naturally occurring encrustation or other debris. In general, the AWWA operating formula for opening/closing a gate valve is 3 times the nominal valve size plus 2 or 3 turns of the operating nut. (Example; 6 x 3 = 18 plus 2 or 3 = 20 to 21). However, each valve manufacturer has detailed operation and maintenance procedures for each of the various types of valves[1].

| Valve Diameter (in) | Approximate Number of Turns (full 360-degree rotation) | Recommended Tool |
|---|---|---|
| 2 | 8 | Valve Key (Manual) |
| 3 | 11 | |
| 4 | 14 | |
| 6 | 20 | |
| 8 | 26 | |
| 10 | 32 | |
| 12 | 38 | |
| 14 | 44 | |

[1] The City of Flint estimates approximately 17 various valve manufacturers currently in-use. This includes: A.P. Smith, Clow, Crane, Darling, DeZurik, East Jordan, Flower Stevens, Henry Pratt Co, Kennedy, Ludlow, M.I.W Co., Michigan Laydown, MJ, Mueller, T. S. & W., T.C., and Waterous. Once information is collected on model/serial numbers, details from the corresponding operation manuals should be integrated into this SOP.

| Valve Diameter (in) | Approximate Number of Turns (full 360-degree rotation) | Recommended Tool |
|---|---|---|
| 16 | 50 | |
| 18 | 56 | |
| 20 | 62 | |
| 24 | 74 | |
| 30 | 92 | Actuator or Valve Turning Machine[2] |
| 36 | 110 | |
| 42 | 128 | |
| 48 | 146 | |
| 72 | 218 | |

Tips to be aware of before exercising a valve:

- Because debris can be stirred up during valve exercising, notify the public before starting the process. This will reduce dirty water complaints.
- Specify open left (counter-clockwise) or open right (clockwise). Wrench nuts on valves that open to the right are painted red for identification purposes.
- The valve should be opened and closed with a steady amount of pressure in the pipeline. Slow closure is critical to minimize the potential for operational failure of the valve or water hammer. The valve should function freely with no binding or vibration.
- Begin with rotating 5 to 10 rotations, then reverse for two or three rotations. Reverse again and rotate 5 to 10 more turns in the closing direction. Repeat this procedure until full closure is obtained.
- Make sure to accurately count the number of turns to fully closed. This will reveal an obstruction if the correct number of turns are not achieved.
- Listen closely. Sometimes you can hear the flow change when operating a valve. This will help determine if the valve is moving.
- Do not operate valves in systems that exceed the rated working pressure of the valve.
- Do not close the valve too tight as it will damage the valve and cause the valve to leak.
- If the valve is resistant, avoid using a T-handle or extension to force the valve closed; this could cause damage to the valve.
- To determine if a valve is closed, an aquaphone or other listening device can be used.

12. Once the valve is fully closed, compare the actual number of turns to the approximate number of turns from the table in Step 11 based on the valve size as found on the map. If the operating nut continues to rotate even after you have reached the proper number of

[2] See equipment operating instructions for full details.

turns, the valve may be larger than shown on the plans. Continue to operate based on the next size valve. Document the following information on the work order:

- Found position (open, closed, partially open)
- Direction to close (close right, close left)
- Torque (beginning)
- Turns
- Initially operable (yes/no)
- Torque (final)

13. Once the valve is fully closed, it should be opened a few turns so that high velocity water flowing under the gates can move the remainder of the sediment downstream with more force and clear the bottom part of the valve body for seating. Coordination with hydrant flushing is also recommended.

14. Once potential sediment has been flushed, the valve should be re-opened to reestablish system flows (or returned to the original state). Some manufactures recommend that a valve stem never be left in a fully open position. They recommend that after fully opening a valve, back off the stem by one turn. Consult the appropriate manufacturer's operation and maintenance manual.

15. A valve condition score should be identified and documented on the work order. The following examples and scoring system definitions should be used as a guide to ensure consistency:

| Condition | Definitions |
|---|---|
| Inoperable | • Broken teeth or stem<br>• Main valve or by-pass that spins free<br>• Frozen at operating torque limit<br>• Additional work order item required |
| Poor | • Packing leak that cannot be "snugged"<br>• High torque level, >300 ft-lbs<br>• Unstable torque (such as a bent stem that was reduced by exercising)<br>• Open and closed positions may not be clearly seen on a torque chart |
| Fair | • Valve had to be left in "snugged" position to stop a packing leak<br>• Required multiple exercise cycles to reduce torque (more than 3)<br>• Intermediate torque level, >200 ft-lbs<br>• Stable torque<br>• Open and close positions can be clearly seen on a torque chart<br>• Valve works, has a small problem, will likely stop water flow |

| Condition | Definitions |
|---|---|
| Good | • Operating nut is able to be backed off a ¼ turn after last exercise to relieve pressure on packing gland without water leaking<br>• Low torque, <200 ft-lbs<br>• Stable torque |

Document the following additional details on repairs or recommendations on the work order:

- Stopped packing leak (yes/no)
- Replacement recommendations
- Comments
- Picture taken (for raises or other conditions)
- Difficulty of repair notes (optional)

16. In addition to exercising the valve, other maintenance tasks should also be completed in accordance with the manufacturer’s operation and maintenance manual. This may include:

    - Check all gaskets and joints for leakage and tightness.
    - With the valve closed and pressure against the wedge, check for leakage by “listening” to the valve for flow. A stethoscope will help in this procedure. Attached actuators should be inspected per manufacturer’s recommendations provided with those units.
    - Some valves should have the exposed stem lubricated at each inspection. Check stuffing box bolts for tightness.

17. Restore the area to a clean and safe condition. This includes replacing the valve cover and clearing the area of any traffic control devices.

18. Mark the completed valve cover with blue marking paint.

19. Document the following information on the work order:

    - Time work order completed
    - Comments (other relevant observations or items requiring additional maintenance on the work order)

# 6 TROUBLESHOOTING

| Problem | Cause / Corrective Action |
|---|---|
| When closing the valve, you do not achieve the proper number of turns | Tuberculation/Debris may have built up in the seat area, particularly in the double disc valve. Create flow through the valve (open a nearby downstream hydrant) then exercise the valve to loosen/remove the debris. |

| Problem | Cause / Corrective Action |
|---|---|
| The operating nut continues to rotate even after you have reached the proper number of turns | • The valve may be larger than shown on the plans. Continue to operate based on the next size valve. The valve may have a bevel or spur gear to help during operation. Check the plans to see if it a gear was installed on the valve. The typical gear ratio is 4 or 4.5 to 1. Multiply the standard number of turns by the gear ratio.<br>• Excessive torque may have been applied to the operating nut at some point and damaged the stem or stem nut. Expose the valve and inspect the stem and stem nut. Replace if necessary.<br>• Potential diameter discrepancies will be documented and further reviewed and/or researched. If confirmed, update asset attribute data in GIS. |
| The operating nut will not turn in either direction | • The valve box may be interfering with the operating key. Look down the valve box to see if it is too close to the operating nut. Reposition if necessary.<br>• The stuffing box bolts and nuts may have been tightened down unevenly during assembly. Loosen and retighten stuffing box bolts and nuts evenly.<br>• Debris/corrosion may have built up between the stem and stuffing box due to lack of operation or gritty backfill. Remove the stuffing box (stem if needed) and clean and/or replace the stem and stuffing box.<br>• Debris could be wedged under the disc. Expose the valve. Remove the bonnet. Clean out the debris. |
| The gate valve is leaking from between the body and bonnet flange | • Make sure the bonnet bolts and nuts are tight.<br>• The bonnet gasket o-ring may be damaged or pinched. Remove the bonnet. Replace the gasket<br>• The body or bonnet flange may be cracked or broken. Inspect the valve body and bonnet flanges. Replace damaged items. |
| The gate valve will not pass a pressure test | • Be sure the valve is completely closed. Count the number of turns.<br>• Compare to the manufactures published information.<br>• The disc may have been closed on some debris. Create flow through the valve (open a nearby downstream hydrant) then exercise the valve to loosen/remove the debris.<br>• Air may be trapped in the line. Flush the line to remove the trapped air. Add an Air release valve if necessary. |

| **Problem** | **Cause / Corrective Action** |
|---|---|
| Valves found closed | Notify the Water Distribution Superintendent immediately. Leave the valve in the same position found until a decision is made to operate and what position to leave it in. |
| By-pass valves (16" and larger double disc gate valves will typically have an associated by-pass valve) | The by-pass valves will be exercised before the main valve is exercised. If the by-pass valve is inoperable (e.g., spins free, frozen) crew is to exercise the main valve ¾ of the expected turns and note this in the valve database. An inoperable by-pass valve will be a significant factor in determining if the entire valve assembly (by-pass and main valve unit) should be recommended to be replaced. |
| Stuck/inoperable Valve | Consult the Water Distribution Superintendent to determine whether to further increase torque and attempt to rehabilitate valve into working condition (at the risk of breaking valve). The Water Distribution Superintendent should indicate which valves will be used to shut down the location should a valve failure occur (bonnet lifts off of the valve). At that time, the torque will be increased, as necessary, with no upper limit, until the valve is either operable or fails.<br>• 4-in (crew limit is 200 ft-lbs turn and count only - hand turn)<br>• 6-12in (crew limit is 300 ft-lbs)<br>• 16-in & larger (crew limit is 500 ft-lbs)<br>• Butterfly (crew limit is 200 ft-lbs turn and count only - hand turn) |
| Packing leaks | A number of packing leaks will be found in the field, most of which can be stopped by "snugging" the valve up to the packing gland. Valves that are "snugged up" in order to stop a packing leak will be documented in the work order because these valves may take more torque to shut after they have been "snugged up." |
| Map discrepancies<br>• "Found" valves that are not on the map<br>• Valves with turn/size conflicts<br>• Street name changes<br>• Other | Document information on the work order and update asset attribute data in GIS. |

# 7 DATA RECORDING AND MANAGEMENT

Following completion of a valve inspection, exercise or maintenance work order, enter all necessary information, including the date of maintenance, valve identification, condition, test results, and personnel completing the maintenance, into the EAM system.

The Water Distribution Superintendent must be notified of any additional required maintenance or if the valve is inoperable or in disrepair. The Water Distribution Superintendent shall assign work orders for any follow-up items and coordinate updates to the asset management plan.

# 8 REFERENCES

American Water Works Association. (2015). *M44 Distribution Valves: Selection, Installation, Field Testing, and Maintenance, Third Edition*. Denver, CO: AWWA

# BACKFLOW PREVENTER TESTING AND REPAIR SOP

SOP #341

Rev: 0.0

Date: 01/31/2018

# SOP VERSION CONTROL

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# APPROVAL SIGNATURES

Prepared by: Arcadis U.S., Inc. Date: 01/31/2018

Approved by: ______________________________ Date: ______________

# 1 DEFINITIONS AND ACRONYMS

| | |
|---|---|
| AWWA | American Water Works Association |
| CCRM | Cross Connection Rules Manual |
| MDEQ | Michigan Department of Environmental Quality |
| PPE | personal protective equipment |

# 2 KEY PERSONNEL AND RESPONSIBILITIES

- Cross-Connection Control / Backflow Prevention Program Administrator:
  - Oversee cross-connection and backflow prevention control program
  - Generate work orders for inspection, testing, maintenance, and repair of backflow prevention assemblies
- Operator or contractor with valid Michigan journey or master plumbing license with documented training that complies with the requirements of the cross-connection and backflow prevention program for testing, repair, and maintenance of backflow prevention assemblies:
  - Complete work orders generated by the Cross-Connection Control / Backflow Prevention Program Administrator
  - Follow up field work by recording maintenance or repair in established database, or return of field documents to the utility

# 3 SCOPE/PURPOSE

The purpose of this SOP is to outline the procedures for regular testing and as-needed repair of backflow prevention devices. Refer to the Michigan Department of Environmental Quality (MDEQ) Cross Connection Rules Manual (CCRM), latest edition for guidance on backflow prevention rules promulgated by the State of Michigan.

This SOP does not cover the comprehensive cross-connection program, which should be maintained in parallel for an up to date record of existing backflow prevention assemblies within the distribution system including the following information. (Refer to AWWA M14, latest edition for more detail.)

- Location of backflow preventer
- Description of hazard isolated
- Type, size, make, model, static line pressure, and serial number

# 4 HEALTH AND SAFETY

Backflow prevention assemblies are often located on customer property and may be installed in hazardous areas including confined spaces. Prior to any work, the area should be evaluated for hazardous conditions and personal safety by the operator maintainer. Additionally, the following PPE should be worn:

- City employee identification or a City-approved contractor identification card
- Hard hat or bump cap (as needed for overhead hazards)
- Safety glasses
- Steel-toed boots
- Work gloves

In the event that a confined space entry is required, refer to the appropriate safety standard for air monitoring and support personnel.

# 5 PROCEDURE

**Equipment Required:**

- Use only equipment approved by the manufacturer of the backflow prevention assembly.
- All field test kits must be calibrated prior to use and must be recalibrated as needed according to the manufacturer's recommendations to ensure that the instruments are operable and accurate when used.

**Procedure:**

1. All backflow assemblies are to be tested in accordance with the MDEQ CCRM and AWWA M14. Testing must occur under the following circumstances:
    a. At the time of installation or relocation, including assemblies re-installed seasonally.
    b. After any repairs.
    c. At a minimum of every 3 years, or in accordance with the approved cross-connection control program.
2. Individual testing procedures will depend on the make, model, and type of the backflow preventer. Use only tools approved by the manufacturer of the assembly to service and test the unit.
3. If a repair is required, obtain the repair information from the manufacturer of the backflow assembly and complete according to their recommendations. Document the repair type and completion date.
4. Prior to testing or repair of a device, provide notice to the property owner of date and approximate time of inspection.

5. Reference AWWA M14 for field test procedures for a variety of backflow prevention assemblies.

# 6 DATA RECORDING AND MANAGEMENT

Following the test, generate a report including the following records (AWWA M14, MDEQ CCRM):

- Assembly owner's name and mailing address (if customer-owned)
- Assembly location building address and physical location within the building
- Type of device including manufacturer's name, model number, serial number, and size of assembly
- Description of application (i.e. equipment or system served)
- Initial test results (pass-fail of first check and second check, relief valve discharge, air inlet opening, static line pressure)
- Test equipment manufacturer, model number, serial number, and calibration information.
- Repair history, repairs made during test, repair parts used, and/or cleaning performed
- Final test results after repair, as applicable
- Printed name, signature and certification number of the tester
- Date and time of test

Upon the receipt of results from an assembly testing event, the Cross-Connection Control / Backflow Prevention Program Administrator should review the results and order repairs or investigate inconsistencies as necessary.

# 7 REFERENCES

American Water Works Association. (2015). *M14 Backflow prevention and Cross-Connection Control Recommended Practices, Fourth Edition*. Denver, CO: AWWA.

Michigan Department of Environmental Quality. (2008). *Cross Connection Rules Manual, Fourth Edition*. Lansing, Michigan: Michigan Department of Environmental Quality.

# METER INSTALLATION, INSPECTION, AND TESTING SOP

SOP #351

Rev: 0.0

Date: 01/31/2018

# SOP VERSION CONTROL

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Prepared by: Arcadis U.S., Inc. Date: 01/31/2018

Approved by: ______________________ Date: ____________

# 1 DEFINITIONS AND ACRONYMS

| | |
|---|---|
| AWWA | American Water Works Association |
| EAM | enterprise asset management |
| PPE | personal protective equipment |

# 2 KEY PERSONNEL AND RESPONSIBILITIES

- Water Distribution Superintendent:
  - Maintain water meter testing schedule and record database.
  - Generate work orders for routine water meter testing and repairs as well as investigations into water meter complaints.
- Water Distribution Operator:
  - Perform field tests of water meters as generated by work orders.
  - Prepare records of field testing and repairs for each meter and enter into enterprise asset management (EAM) system.

# 3 SCOPE/PURPOSE

The accuracy of water meters is directly related to utility revenue and should be monitored and tested regularly. A comprehensive field testing program schedule should be set up to ensure the timely repair and replacement of malfunctioning meters, giving priority to large meters that account for a larger share of water use and revenue. Water meters can be tested in the field or temporarily removed from service for shop testing.

- Residential water meters – The accuracy of new meters should be certified by the manufacturer, in accordance with American Water Works Association (AWWA) Manual M6, Water Meters - Selection, Installation, Testing and Maintenance. Meters should be scheduled for regular replacement as a component of the asset management program.
- Commercial water meters – The program determines the accuracy of representative samples of existing and newly purchased meters on an ongoing basis to maintain operation within applicable AWWA accuracy standards through a program of repair and/or replacement. The program should also include a review of meter type and size. The accuracy of new meters should be certified by the manufacturer in accordance with AWWA M6.

Meters throughout the distribution system may vary by type and manufacturer. This SOP covers the general guidelines for water meter testing and record keeping and should be used in conjunction with manufacturer's recommendations and instructions and AWWA M6.

# 4 HEALTH AND SAFETY

Water meters are often located on customer property. Provide advance notice to the customer for any meter testing and assess the area for personal safety. Additionally, the following PPE should be worn:

- City employee identification
- Safety glasses
- Steel-toed boots
- Work gloves

# 5 PROCEDURE

**Equipment Required:**

- Test equipment and kits as recommended by the meter manufacturers.
- All test kits must be calibrated prior to use and must be recalibrated as needed according to the manufacturer's recommendations to ensure that the instruments are operable and accurate when used.

**Procedure:**

1. Prior to arrival, provide the customer with written notice of date and approximate time of meter field testing or meter removal for shop testing.

2. If field testing, complete the test and document any observations about the condition or performance of the meter.

3. If the meter is to be shop tested, collect the meter from the property installing a temporary bypass and documenting the date and time that the water meter is removed.

4. Whether utilizing on-site or shop testing, conduct tests in accordance with manufacturer recommendations.

5. Compare the results of the test to the appropriate AWWA standard for accuracy standards for the specific type of meter being tested.

6. Document any required or performed repairs to bring meter into AWWA accuracy standards. Replace meter if necessary.

7. For shop tested meters, provide the customer with written notice of date and approximate time for reinstallation of the meter.

# 6 DATA RECORDING AND MANAGEMENT

Following the completion of a water meter testing work order, enter the test results into the EAM system along with any completed or necessary repairs or replacements. Add any newly installed commercial meters to the EAM system for future tracking.

# 7 REFERENCES

American Water Works Association. (2012). *M6 Water Meters – Selection, Installation, Testing, and Maintenance, Fifth Edition.* Denver, CO: AWWA.

# CUSTOMER COMPLAINT TRACKING SOP

SOP #421

Rev: 0.0

Date: 01/31/2018

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Prepared by: Arcadis U.S., Inc. Date: 01/31/2018

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# 1 DEFINITIONS AND ACRONYMS

| | |
|---|---|
| EAM | enterprise asset management |
| GIS | geographic information system |
| PPE | personal protective equipment |

# 2 KEY PERSONNEL AND RESPONSIBILITIES

- Administrative / Call Center Staff:
  - Receive calls on technical quality customer concerns related to the distribution system (i.e., complaints associated with water quality, taste, odor, appearance, pressure, main breaks, and disruptions of water service) and record initial call information into the enterprise asset management (EAM) system.
  - Generate work orders for follow up investigation.
- Water Distribution Operator:
  - Investigate and address concerns through operations or field visits.
  - Enter results from any response follow-up or remedial actions taken into the EAM system.
  - Track customer complaints and performance against distribution system levels of service goals (once established).

# 3 SCOPE/PURPOSE

Information from customers on water quality issues, leaks, main breaks, and other observations of the distribution system can be used to manage the system effectively. Implementation of the below procedure is intended to track the distribution system performance against established goals for the number of distribution system technical quality complaints (i.e., complaints associated with water quality, taste, odor, appearance, pressure, main breaks, and disruptions of water service) collected annually. The AWWA Partnership for Safe Water Distribution System Optimization Program (2011) states that: “Benchmarking surveys consistently show the best performing systems have less than 2.5 technical quality complaints per 1,000 customer accounts annually.”

If chronic challenges are identified through the periodic review of collected data, a program should be developed to improve the distribution system performance such as localized flushing, hydraulic monitoring, or additional sampling.

# 4 HEALTH AND SAFETY

Water Distribution staff entering the community to investigate complaints should be aware of their surroundings at all times. Always carry appropriate City of Flint identification or a City approved contractor identification card. Where possible, customer visits should be conducted in pairs. If analytical samples are required, the following PPE should be used:

- Chemical resistant gloves
- Safety glasses

# 5 PROCEDURE

**Administrative / Call Center Staff Procedure:**

1. Upon receipt of a customer complaint phone call, collect the following information:
   a. Date
   b. Name and contact information of caller
   c. Address of observation/complaint
   d. Nature of the call:
      i. Water quality complaint: If the customer is calling to report a water quality issue, record the general description from the customer and collect any of the following information, if available:
         1. Temperature (approximate)
         2. Taste
         3. Odor
         4. Appearance
            a. Color
            b. Cloudy or milky
            c. Presence and description of particulate matter
         5. Length of time experiencing the problem
         6. If the problem occurs with hot water, cold water, or both
      ii. Pressure complaint – too high or too low
      iii. Leak or main break
         1. Street address nearest to the observed leak or main break
         2. Description of flow
            a. Quantity
            b. Color
            c. Odor
      iv. Disruption of service
      v. Other observation

1. Hydrant malfunction or tampering
2. Vandalism
3. Other – please describe

e. Any additional notes or pertinent information from caller

2. If there are known conditions causing the complaint (e.g., main break in the area), convey that information to the caller.
3. If the caller is reporting a main break or disruption to their water service, call the Water Service Center immediately to inform them of the issue.
4. Enter the information collected in Step 1 into the EAM and generate a work order for the Water Service Center to follow up with the complaint.

**Water Distribution Staff Procedure:**

1. Upon receipt of a customer complaint work order, designate a staff member to follow-up or investigate the complaint in a timely manner based on the severity of the complaint. **Reports of main breaks or disruptions to service must be investigated immediately.**
2. For field visits, use the following procedure:
    a. Prior to a customer visit, contact the complainant to notify them of anticipated time of arrival, name of personnel, and any identifying features (city identification badge, field truck, etc.).
    b. Upon arrival to the site, evaluate the surroundings for safety. Only when it is deemed safe, approach the area indicated on the work order.
    c. Identify all personnel on site to the customer and explain the nature of the investigation or follow-up including:
        i. Any samples to be collected and analyses to be completed, either on-site, by a laboratory or at the Water Service Center.
        ii. Known issues in the area that may have contributed to the complaint.
        iii. Estimated timeframe to resolve the complaint, if available.
    d. Collect samples and/or photographs as needed for records. Refer to the appropriate SOP for water quality sampling and analysis in the field. Record the results of any field analyses (chlorine, turbidity, etc.).
3. After an investigation has been completed, follow-up with the customer in writing indicating the possible reason for the observation and any corrective measures implemented as a result. If no problem can be determined, then advise the customer that the problem may be an internal plumbing issue.

**Planned and Unplanned Service Interruptions:**

1. In the event of a planned service interruption, notify all impacted parties in writing as far in advance as possible, before the outage. Communication shall include the anticipated time and duration of the outage, as well as any potential outcomes or anticipated water

quality impacts. Where possible, multiple communication methods should be employed (e.g. radio, social media, newspaper).

2. In the event of an unplanned service interruption, approach affected customers only if it is deemed safe to do so based on a field evaluation of the area. As soon as possible, notify the affected customers of the interruption including the anticipated duration and effects to their service.

# 6 DATA RECORDING AND MANAGEMENT

All data recorded from the initial customer complaint call shall be entered into the EAM system and separated based on the category of the complaint. Categories include:

- Water quality compliant
- Pressure compliant
- Leak
- Main break
- Disruption of service
- Other observation

Water Distribution Operator shall:

- Review the complaints monthly based on category and location to identify problem areas within the distribution system and track performance against established goals.
- Communicate trends and potential problem areas of the distribution system to the Water Plant Superintendent as well as the Water Distribution Superintendent.
- Track challenges identified through the monthly analysis each year to identify seasonal trends and evaluate long-term performance.

# 7 REFERENCES

AWWA. (2015). *G200-15 Distribution Systems Operation and Management*. AWWA.

AWWA. (2011). *Partnership for Safe Water Self-Assessment Guide for Distribution System Optimization.* Denver, CO: AWWA.

# CONTROL CHARTING OF WATER QUALITY PARAMETERS

SOP #422

Rev: 0.0

Date: 01/31/2018

# SOP VERSION CONTROL

| Revision No | Revision Date | Page No(s) | Description | Approved by |
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# STAFF ACKNOWLEDGEMENT

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# APPROVAL SIGNATURES

Prepared by: Arcadis U.S., Inc. & Cornwell Engineering Group ______ Date: 01/31/2018

Approved by: ____________________________________________ Date: ____________

# 1 DEFINITIONS AND ACRONYMS

| | |
|---|---|
| CSII | Control Station 2 |
| LCL | lower control limit |
| RTCR | Revised Total Coliform Rule |
| UCL | upper control limit |
| WEWQPM | weekly enhanced water quality parameter monitoring |
| WQP | water quality parameter |

# 2 KEY PERSONNEL AND RESPONSIBILITIES

- Water Quality Laboratory Supervisor:
  - Enter data into control chart spreadsheets
  - Review control charts to identify if there are any observed variances that may have an attributable cause
  - If variances are observed that may have an attributable cause, convey that information to the Operations Supervisor so that actions to resolve the variance can be implemented.
- Water Plant Superintendent:
  - Based on information provided by the Water Quality Laboratory Supervisor, take appropriate actions to increase or decrease the system pH, chlorine residual, or orthophosphate residual as needed to bring the system back into control.

# 3 SCOPE/PURPOSE

The purpose of this SOP is to outline the procedures for using the control chart tools developed by the Cornwell Engineering Group to generate control charts of water system data. These tools consist of three Microsoft Excel-based spreadsheets:

- Flint Distribution System WQP Control Charts v1.2
- Flint Distribution System Chlorine Residual Control Charts v1.2
- Flint CSII and Tap WQP Control Charts v1.2

The first tool generates monthly median control charts for orthophosphate residual, pH, and alkalinity at the ten Enhanced Water Quality Parameter Monitoring Sites that the City of Flint maintains in the distribution system. The second tool generates monthly median control charts for chlorine residual at the twenty-five Revised Total Coliform Rule (RTCR) Monitoring Sites that the City of Flint maintains in the distribution system. The last tool generates weekly median control charts for orthophosphate residual and pH at Control Station 2 (CSII) and tap sampling locations at the Flint Water Treatment Plant.

The charts generated by these tools are Shewhart control charts, which are statistical tools originally developed to manage manufacturing processes by monitoring parameter variability. Control charts use subgroups (aka "binning") to reduce the inherent variability of each sampled parameter. Because these tools are designed to assess data recorded on a weekly or daily basis, these data have been sub-grouped by month (for weekly data) or by week (for daily data). Each chart displays the median of the monthly or weekly subgroup, as well as an upper control limit (UCL) and a lower control limit (LCL) based on the historical trends of the entire data set.

Control charts reduce the variability inherent in monitoring water quality parameter (WQP) data and instead display the monthly trend relative to historical performance. If the monthly median is plotted above the UCL or below the LCL, it suggests that the observed change in that WQP is not due to natural variability. Therefore, it is likely that there is an attributable cause (e.g. chemical feed pump is not dosing accurately, change in treatment chemical used, etc.) for the observed change in the WQP.

The distance between the UCL and LCL will narrow as more data are available in a subgroup (e.g. more than four samples per month) and will increase as fewer data are available. Therefore, the UCL/LCLs may appear "wavy" because more data were collected in some months than in others. The locations of the UCL and LCL will also change over time as more data are added to the historical record. As the treatment processes become more stable, the UCL and LCL will converge towards one another.

Control charts are most useful when compared to corrosion control treatment goals. If the goal is to maintain a minimum orthophosphate residual, the LCL should be maintained above that value. If the goal is to stay within a desired pH range, the UCL and LCL should fall within that range.

For more information on control charts and how they can be applied to evaluate data for the Lead and Copper Rule please see: "Controlling Lead and Copper Rule Water Quality Parameters" (Cornwell, Brown, and McTigue 2015).

# 4 HEALTH AND SAFETY

There are no inherent health or safety risks from using the control chart tools to analyze data. Water system staff implementing treatment or operations changes in response to observed variances that may have an attributable cause should follow the SOPs for those operations.

# 5 PROCEDURE

The following procedures outline how data are to be entered into the control chart tools.

**Flint Distribution System WQP Control Charts:**

1. This tool is designed to allow for easy generation of monthly control charts for WQP data (pH, alkalinity, and orthophosphate residual) recorded in the Weekly Enhanced Water Quality Parameter Monitoring (WEWQPM) spreadsheets. The Data Entry form is arranged similarly to the WEWQPM spreadsheets to allow data to be copied directly from the WEWQPM spreadsheets into this tool.
2. On the Data Entry worksheet, click the hyperlink in Cell C2 to navigate to the first empty column.
3. Copy the sample date data from Column C of the WEWQPM spreadsheet and paste into the empty Sample Date column for pH (Rows 5 - 15), orthophosphate residual (Rows 19 - 29), and alkalinity (Rows 33 - 43).
4. Copy the pH data from Column G in the WEWQPM spreadsheet and paste into the empty pH column on the Data Entry worksheet (Rows 5 - 15).
5. Copy the Phosphate data from Column N in the WEWQPM spreadsheet and paste into the empty Phosphate column on the Data Entry worksheet (Rows 19 - 29).
6. Copy the Total Alkalinity data from Column H in the WEWQPM spreadsheet and paste into the empty Total Alkalinity column on the Data Entry worksheet (Rows 33 - 43).
7. After all data have been entered into the Data Entry worksheet, return to the Dashboard using the hyperlink in Cell B2.
8. At the Dashboard, select the WQP to be charted using the upper left dropdown.
9. Select the time period for charting the WQP data. Buttons are provided to quickly display the last six months or last one year of data, or select a custom range start and end date by using the left-right scroll buttons.
10. The tool can allow for side-to-side comparisons between two WQP monitoring locations. Use the drop down menus for WQP Site I and WQP Site II to select the sites for comparison.
11. The tool also allows comparison of median values for the three parameters (pH, Orthophosphate and Alkalinity) between two WQP monitoring locations and all locations to evaluate the whole system. For a selected WQP (from the dropdown) and selected time period (from the dropdown), the tool generates a single (third) chart showing the data for all of the WQP locations.

**Flint Distribution System Chlorine Residual Control Charts:**

1. This tool is designed to allow for easy generation of monthly control charts for MOR data (chlorine residual) recorded in the Monthly Operating Report (MOR) spreadsheets. The Data Entry form is arranged similarly to the MOR spreadsheets to allow data to be copied directly from the MOR spreadsheets into this tool.
2. On the Data Entry worksheet, click the hyperlink in Cell C2 to navigate to the first empty row.
3. Copy the Free Chlorine Residual data from Column BL to CJ in the MOR spreadsheet and paste into the empty columns on the Data Entry worksheet (Columns E to AC) with the corresponding dates.

4. After all data have been entered into the Data Entry worksheet, return to the Dashboard using the hyperlink in Cell B2.
5. Select the time period for charting the WQP data. Buttons are provided to quickly display the last six months or the last one year of data, or select a custom range start and end date by using the left-right scroll buttons. Data prior to 1/01/2016 have not been entered into this tool so start dates prior to 1/31/2016 cannot be selected.
6. The tool can allow for side-to-side comparisons between two WQP monitoring locations. Use the drop down menus for WQP Site I and WQP Site II to select the sites for comparison.

**Flint CSII and Tap WQP Control Charts:**

1. This tool is designed to allow for easy generation of monthly control charts for WQP data (pH, orthophosphate residual, and chlorine residual) recorded in the Monthly Operating Report (MOR) spreadsheets. The Data Entry form is arranged similarly to the MOR spreadsheets to allow data to be copied directly from the MOR spreadsheets into this tool.
2. On the Data Entry worksheet, click the hyperlink in Cell B1 to navigate to the first empty row.
3. Using the MOR monthly spreadsheet, copy pH data for the CSII and Tap locations from Columns AE and AF, respectively, from the MOR monthly spreadsheet and paste into Columns E and F on the Data Entry worksheet. Copy orthophosphate data for the CSII and Tap locations from Columns C and E, respectively, and paste into Columns G and H in the Data Entry worksheet. Copy chlorine residual data for the CSII and Tap locations from Columns W and AB, respectively, and paste into Columns I and J in the Data Entry worksheet.
4. After all data have been entered into the Data Entry worksheet, return to the Dashboard using the hyperlink in Cell A1.
5. Select the time period for charting the WQP data. Buttons are provided to quickly display the last six months or last one year of data, or select a custom range start and end date by using the left-right scroll buttons.
6. The tool allows for charting of pH, orthophosphate residual or chlorine residual data at the two WQP sites (CSII and Tap). Select the WQP from the dropdown to choose which WQP to evaluate.

# 6 DATA RECORDING AND MANAGEMENT

After the control charts have been generated, they should be reviewed to identify points that are above the UCL or below the LCL. Such points are outside the natural variation to be expected, so the Water Treatment Superintendent may need to make process adjustments to bring the system back into control. Such adjustments might be increasing or decreasing chemical feed targets, calibrating chemical feed pumps or flow meters, verifying proper operation of equipment, etc.

# 7 REFERENCES

Cornwell, D., Brown, R., & McTigue, N. (2015). *Controlling Lead and Copper Rule Water Quality Parameters.* Journal-American Water Works Association, 107(2), E86-E96.

# CONVENTIONAL FLUSHING FOR WATER TURNOVER SOP

SOP #431

Rev: 0.0

Date: 01/31/2018

## SOP VERSION CONTROL

| Revision No | Revision Date | Page No(s) | Description | Approved by |
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## STAFF ACKNOWLEDGEMENT

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# APPROVAL SIGNATURES

Prepared by: Arcadis U.S., Inc. & Confluence Engineering Group LLC Date: 01/31/2018

Approved by: ______________________________________________ Date: ____________

# 1 DEFINITIONS AND ACRONYMS

| | |
|---|---|
| CF | conventional flushing |
| CWI | clean water interface |
| FPS | feet per second |
| GIS | geographic information system |
| GPM | gallons per minute |
| GPS | global positioning system |
| PPE | personal protective equipment |
| PSI | pounds per square inch |
| TDS | total dissolved solids |
| UDF | unidirectional flushing |

# 2 KEY PERSONNEL AND RESPONSIBILITIES

- Water Distribution Superintendent:
    - Maintain schedule and generate work orders (based on objectives listed in scope/purpose section) for flushing areas and events.
    - Identify additional planning/scheduling activities and resources for each flush (such as establishing additional traffic control measures, coordinating pre-flush hydrant inspection, performing customer notification, assessing the hydraulic impact and water quality impact, equipment organization and other planning steps).
    - Maintain records of flush events, including hydrants used, nearest clean water interface (CWI), general direction of water movement, flow rates, duration, start and finish water quality (including chlorine residuals and turbidity measurements).
    - Ensure all problem hydrants, map discrepancies, water quality issues, and other issues are properly communicated to the responsible parties and ensure identified repairs/replacements and/or further remediation steps are executed within a timely manner.
- Water Distribution Operator (2):
    - Perform flushing pre-inspection to ensure operable assets, assemble required flushing and traffic control equipment, and perform flushing efforts as generated by work orders.
    - Prepare records of flushing efforts, issues or maintenance concerns for each hydrant, record all water quality data on standardized forms, and enter into flushing log/database.

# 3 SCOPE/PURPOSE

The purpose of this SOP is to ensure proper goals and objectives are realized with targeted execution of conventional flushing (CF) for bulk water turnover. It is important to distinguish between bulk water turn over vs. main cleaning using unidirectional flushing (UDF), which is described in a separate SOP. Since valve isolation is not used during CF for bulk water turnover, it is imperative to avoid stirring up sediments that could be pulled into a customer's home.

The Water Distribution Superintendent should consider the following three objectives/situations when scheduling and preparing work orders:

1. CF in response to water quality complaints.
2. CF as part of meeting ongoing water quality goals and regulatory requirements (orthophosphate, chlorine, pH, etc.)
3. CF as part of a hydrant winterization program

For each of the three scenarios listed above the Water Distribution Superintendent should implement the following steps to ensure proper response is affected:

**Situation 1 – Customer Complaints**

See separate SOP for Customer Complaint Tracking. Prior to conducting any water quality response flushing, the City should conduct monitoring in the localized vicinity of the complaint in an attempt to identify the origin and spatial extent of the water quality upset, as described below.

- Conduct local distribution system water quality "canvass monitoring" to define the spatial extent of the upset. This involves sample collection and field analysis for key parameters (at a minimum: turbidity, color, total dissolved solids (TDS)/conductivity, and chlorine residual) at hydrants/sample stands that are located in the vicinity of the complaint location.
- Sample locations should start at the complaint location and gradually move outwards in each potential flow direction until the water appears clear and field-measured water quality is within desired conditions.
- Based on the results, the affected area should be delineated on a map and the CWIs to be used for CF should be identified.
- Attempt to determine the cause of the upset/release. For example, identify any unusual chemistry conditions in the field dataset. Also, identify any unusual activities in the area that may have caused a hydraulic or physical disturbance, such as construction activity, main break or repair work, a pressure transient, etc. Document such conditions.
- Establish target water quality conditions/criteria to be achieved within the affected area. These should be based on the canvass results for the nearby CWIs. At a minimum, these criteria should include visual clarity (with the white-cup test), turbidity (≤ 5 NTU or same as the CWI), and chlorine residual (≥ 0.5 mg/L or same as the CWI).
- All data collected during water quality response flushing should be entered into the flushing log/database.

**Situation 2 – In Support of Water Quality Goals/Regulatory Requirements**

Based on the data collected through the city's ongoing Enhanced Water Quality Monitoring Program (and customer complaint response flushing listed in section 1 above), the Water Distribution Superintendent should utilize bulk water turnover to assist with meeting water quality goals (orthophosphate, pH, chlorine residual) through an integrated data collection and response program. This program should involve:

- Create a city-wide GIS map outlining routine problem areas (low orthophosphate, chlorine residual, pH).
- Routine response protocols for areas know to have frequent fluctuations in water quality.
- Integration of field data with customer complaint data.
- Use to support a more comprehensive system wide UDF program.

**Situation 3 – Hydrant Winterization**

The City of Flint carries out a comprehensive hydrant winterization program, implemented each late summer/early fall to prepare assets for the winter months. CF can be used to support this effort. The following steps should be taken:

- The distribution system should be divided into specific areas for the purpose of hydrant winterization.
- For each area, or grid, the CWIs should be identified.
- A systematic plan, based on these sources, should be outlined which will allow hydrants to be exercised starting with those closest to the clean water source and proceeding out through the established area or grid, according to pipe size, valving, or pressure zone limitations.
- Water quality data, including chlorine residual and turbidity, should be collected and recorded throughout the area at defined intervals and added to the flushing log/database.

# 4 HEALTH, SAFETY, AND PUBLIC AWARENESS

Public awareness is key to any successful flushing program. Posted placard, sign boards, or community mailers have been proven effective in keeping residents of the possible water quality side-effects of both CF and UDF activities. One of the most significant health and safety risks during CF is vehicle traffic. The field service team should use trucks, temporary signs, and traffic cones to prevent automotive accidents and injury to staff. In addition, a flag crew may be needed to direct traffic in some locations. Trucks should be parked between oncoming traffic and the work area to provide a barrier. In addition, the following personal protective equipment (PPE) should be worn during maintenance activities:

- Hard hat
- High visibility safety vest
- Safety glasses

- Work gloves
- Steel-toed boots
- Knee pads (as needed)

# 5 PROCEDURE

**Equipment Required (per flushing crew of 2):**

- Water system map (with clear labels for pipe diameter, street names, parcel addresses, critical water users, and all hydrant/appurtenance identification numbers)
- Traffic cones
- Temporary signs/arrow boards (warning lights, strobe lights, arrow boards, traffic maintenance signs)
- Hydrant wrench
- Two (2) 50' sections of 2.5" hose
- 1 Pollard LPD-250 diffuser
- Dechlor pucks for diffuser
- One (1) 2.5" flowmeter
- One (1) Hach colorimeter II for free & total chlorine
- One (1) Hach 2100q turbidimeter
- Data sheets
- GPS unit (optional)
- Digital camera (optional)

**Procedure:**

1. Once a work order is received from the Water Distribution Superintendent, identify the 2-person maintenance crew to perform the hydrant maintenance.
2. Prior to driving to the site, perform the necessary pre-planning activities. This includes reviewing system maps, GIS, as-builts, and asset history to identify hydrants that are in busy intersections, high-profile of sensitive customers, or may result in a potential hydraulic impact as well as reviewing the manufacturer's manual for the specific hydrants to be inspected. Notify the Water Service Center Supervisor if additional planning/coordination is needed.
3. Based on objectives, identify the best route to conduct the work. This includes identifying the starting and ending point (hydrant location), sequence of hydrants to be completed for the day, and potential parking areas.
4. Upon arrival to the site, assess the site for safety (including the appropriate PPE) and set up the appropriate traffic control measures. This may include: warning lights, strobe lights, arrow boards, traffic maintenance signs, cones, flagmen (if necessary), safety vests and/or other PPE. Document the following information on the work order:
    - Operators' last names
    - Flush date
    - Arrival time

5. Locate and access the fire hydrant identified as the starting point for the work order. Identify the unique identification number for the hydrant on the appropriate water system map and confirm the actual field location is a correct match. Verify the following information in the field and document it on the work order:
   - Hydrant ID number
   - Map grid/page number
   - Street
   - Cross street
   - Address
   - GPS position (if applicable)
   - Other location notes (i.e. measurements from the property line)
   - Hydrant source main size
   - Map discrepancies (if applicable)

6. Attach flowmeter and the required length of 2.5" hose to allow for proper water disposal. Attach Pollard LPD-250 to hose end. Check dechlor chamber and make sure there is a puck sufficient to last the expected duration of the flush.

7. Open the hydrant and set the flow to roughly 20 gpm and allow the hydrant barrel to clear (time duration for this will depend on estimated barrel length; at least 2 minutes should be provided; this can usually be ascertained by a visual inspection). Once the barrel has cleared, at a minimum, total chlorine and turbidity measurements should be taken if the hydrant is marked for monitoring. Measurement of other parameters may be appropriate based on CF objective. See item 11 below regarding water quality goals. Record the data on the representative data sheets.

8. Once data is recorded, increase the flowrate using the following guide:
   - 200 gpm for all flushes with adjacent pipe size 6-inch diameter or larger, regardless of pipe type;
   - 100 gpm for all flushes with adjacent pipe size smaller than 6-inch diameter.
   - For transmission lines larger than 12-inch diameter, the flow rate can be increased above 200 gpm, but the flushing velocity (calculated, assuming all flow comes from one direction) should be kept below 2 fps at all times.
   - Note: flow rates can be increased as long as turbidity remains ≤ 5 NTU.

9. Flush at least 2 minutes for every 100 feet of distance from the nearest upstream hydrant that was flushed.

10. Periodically check the water quality during the flush. Because of the nature of CF, there is no industry standard for monitoring frequency during flushing. In practice, the optimal frequency will depend on distance to the clean water source, pipe diameter, and the extent to which valving is used to improve process control. At a minimum, it is recommended that samples be collected and analyzed at least once every 10 minutes. More frequent monitoring may be warranted in certain cases.

11. Continue the flush until established goals have been reached. However, if a given flush lasts more than 30 minutes and water quality criteria are still not met, then the use of strategic valving and/or using multiple hydrants in sequence should be pursued to accelerate the process and conserve resources. Generally, the following water quality goals should be achieved, depending on CF objective described above:
    - Turbidity ≤ 5 NTU
    - Chlorine ≥ 0.5 mg/L
    - Orthophosphate ≥ 3.0 mg/L PO4
    - pH ≥ 7.2
12. End flush. Remove gear and proceed to next designated hydrant.
13. Continue through designated area or grid from clean water source moving out by decreasing pipe size.

# 6 DATA RECORDING AND MANAGEMENT

Following completion of a CF area work order, enter all necessary information, including the date of flush, hydrant identification, flowrate achieved, duration of flush, water quality results and personnel completing the maintenance into the flushing log/database.

The Water Distribution Superintendent must be notified of any hydrant is inoperable, whether expected flowrates were achievable, and any customer complaints or unexpected water quality upsets. The Water Distribution Superintendent shall assign work orders for any follow-up items and coordinate updates to the asset management plan.

# 7 REFERENCES

City of Flint. Standard Operating Procedure 421: Customer Complaint Tracking.

City of Flint. Standard Operating Procedure 432: Unidirectional Flushing.

# UNIDIRECTIONAL FLUSHING SOP

SOP #432

Rev: 0.0

Date: 01/31/2018

## SOP VERSION CONTROL

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# APPROVAL SIGNATURES

Prepared by: Arcadis U.S., Inc. & Confluence Engineering Group LLC Date: 01/31/2018

Approved by: ____________________________________________ Date: ____________

# 1 DEFINITIONS AND ACRONYMS

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|---|---|
| CF | conventional flushing |
| CWI | clean water interface |
| FPS | feet per second |
| GIS | geographic information system |
| GPM | gallons per minute |
| GPS | global positioning system |
| PPE | personal protective equipment |
| PSI | pounds per square inch |
| PV | pipe volume |
| UDF | unidirectional flushing |

# 2 KEY PERSONNEL AND RESPONSIBILITIES

- Water Distribution Superintendent:
  - Maintain schedule and generate work orders (based on objectives listed in scope/purpose section) for flushing areas and events.
  - Identify additional planning/scheduling activities and resources for each flush (such as establishing additional traffic control measures, coordinating pre-flush hydrant and valve inspection, performing customer notification, assessing the hydraulic impact and water quality impact, equipment organization and other planning steps).
  - Maintain records of flush events, including hydrants used, nearest Clean Water Interface (CWI), general direction of water movement, water used, start and finish water quality (including chlorine residuals and turbidity measurements).
  - Ensure all problem hydrants and valves, map discrepancies, water quality issues, and other issues are properly communicated to the responsible parties and ensure identified repairs/replacements, and/or further remediation steps are executed within a timely manner.
- GIS Specialist or other support staff:
  - Assist in developing flush area delineations working with modeling and GIS support staff.
  - Once flush areas are described, construct specific flushing run descriptions to be detailed in the flush loop book. Coordinate with modeling and GIS to confirm acceptable flows and pressures can be maintained with planned runs.

  - Interface with Water Distribution Operator to set up and review valve sequences, pipe diameters and types, run descriptions, water disposal constraints, traffic logistics, and other field related logistics.
- Water Distribution Operator (3):
  - Perform flushing pre-inspection, assemble required flushing and traffic control equipment, and perform flushing efforts as generated by work orders.
  - Prepare records of flushing efforts, issues or maintenance concerns for each hydrant, record all water quality data on standardized forms, and enter into the flushing GIS database.

# 3 SCOPE/PURPOSE

The purpose of this SOP is to ensure proper goals and objectives are realized for regular and consistent execution of a system-wide or area-wide unidirectional flushing (UDF) program. The Water Distribution Superintendent should consider the following five steps necessary for developing a successful UDF program:

1. Flush Area Delineation
2. Flushing Run Development
3. Preliminary Inspection
4. Customer Notification
5. Implementation of UDF field effort (this is discussed in Section 5 - Procedure)

Unlike conventional flushing (CF), UDF is a tool that the Water Distribution Superintendent can use over the long term as a periodic preventative maintenance practice to limit deposit buildup and remove readily mobilized solids. The purpose of UDF is to remove loose and destabilized deposits from pipe wall surfaces in a controlled, organized manner. With proper planning, UDF provides control over the origin, direction, and velocity of flow. UDF is not intended to removal all deposits from pipe walls; rather, it is focused on application of an optimal flushing velocity to remove hydraulically-mobile deposits without damaging pipe scales. Although higher velocities are used compared to CF, flushing velocities should be kept low enough to avoid destabilizing pipe corrosion scales/tubercles on unlined iron pipe. A well-managed UDF program has been shown to reduce incidents of water quality upsets and customer complaints, improve system water quality stability, while assisting in asset management and upkeep.

The following SOP is intended to assist the Water Distribution Superintendent in all stages of the development and implementation of a successful UDF program. The 5 steps mentioned above should be addressed consecutively and will be used as a roadmap for this SOP. The Water Distribution Superintendent should consider each of the steps below and assign the appropriate individual or set of individuals to handle each task. Overlap is not essential, but may assist in the success of the program. Steps 3-5 should be assigned to the crews intended to complete the actual field work.

### 1) Flush Area Delineation

UDF is typically employed on an area-wide basis, not on a spot basis. Development of a UDF plan requires breaking a large system or pressure zone into smaller flush areas. Flush areas are user-defined portions of the system that can be flushed independent of and without adverse hydraulic or water quality impacts to other nearby portions of the system. Flush areas consist of a set of sequestered flushing runs that provide coverage of all mains in the area along with one or more nearby CWIs.  Flush areas should be defined using the following criteria:

- Located entirely within a single pressure zone. UDF is not performed across booster pump stations or zone valves, and is only performed across pressure-reducing valves in cases where the down-gradient zone is pressure-regulated and does not “float” on storage (even in such cases, the down-gradient area is typically defined as a separate flush area).
- Directly served by at least one clean water source that interfaces with the flush area. This can either be an original clean water source or an extension of a previous clean water source. Collectively these are referred to herein as clean water interfaces or CWIs.
    - A CWI is defined as a source that will provide sufficient flow of “fresh” (e.g., good chlorine residual), low-turbidity water when flowed at the maximum flow rate anticipated for the area it serves. Typical CWIs include: finished water storage reservoirs (if adequately turned-over and cleaned), system or zone entry-points (e.g., treatment plants, interties, pump stations), and most commonly, large diameter transmission lines (typically 12-in. or larger).
    - If a large-diameter transmission main is intended for use as a CWI, at the time of field work, flushing should first be conducted to assess whether it is suitably clean. In some cases, these mains may need to be pre-flushed (starting back at an established original clean water source) in order to extend the CWI up to the target flush area. This process typically involves UDF at the maximum flow rate (gpm) anticipated for the flush area.  When flushing large diameter mains, flow should always proceed in the direction of normal system flow.
- Small enough to enable the area to be flushed with a reasonably short and uninterrupted effort. Typical flush areas are less than 10 pipe-miles, although they can be larger as needed or desired.

### 2) Flushing Run Development

Flushing runs are defined segments or stretches of pipe that are flushed in a highly-organized sequence through strategic valve operations. Flushing runs are typically developed for all mains ≤ 12-inch diameter within a given flush area (as well as larger mains for the purpose of extending the CWI, as discussed in the previous section). Flushing run development is part science, part art, and part iteration. Specific criteria and guidelines for flushing loop development are as follows:

1. Identify the primary source(s) of water serving the flush area to be designated as the CWI(s). These should conform to routine flow directions for mains ≥ 12-inch diameter.
2. Identify opportunities to extend the CWI along 12-inch lines to create multiple interfaces with the flush area. The presence of multiple interfaces to the flush area facilitates a “surround-and-conquer” or a “divide-and-conquer” approach, while also helping to ensure that service is maintained to all customers at all times. The process of extending the CWI should follow routine flow directions in mains ≥ 12-inch diameter.
3. Associate the extended CWI with smaller areas of piping to be flushed, as follows:
   - Sub-divide the flush area based on the concept of working from larger diameter mains to smaller ones, so that flow rates also proceed from larger to smaller.
   - “Center” the flush area extremities between the CWIs to promote the desired “source-to-extremity” flushing approach.
4. Create sequential flushing runs that meet the following requirements and preferences:
   - Service must be maintained to all customers at all times. Valves should not be closed in such a way that they completely isolate customer(s) from water supply.
   - Residual pressure should be maintained above 20 psi at all times throughout the flush area.[1]
   - Inspect the flush area to assist with optimal run development. Identify areas that may present challenges with disposal, traffic, topography, etc. and plan accordingly.
   - Each loop should end with a hydrant (or blowoff) and line valve that can be used to isolate downstream sources of supply. It is preferable to terminate runs at hydrants that have a large port as opposed to only two small ports.
   - All adjacent, non-dead-end mains should be isolated by valving, to ensure flow originates solely from a previously cleaned upstream pipe segment or CWI.
   - To improve efficiency, maximize the loop length subject to other constraints and criteria herein. Typical loop lengths are 500–2,000 feet.
   - Identify opportunities to stay mobilized at a given hydrant and simply adjust valving to clean multiple loops in sequence.
   - Downstream loops must have a nominal diameter that is either the same or smaller than the current loop.
   - Each loop must have a constant pipe diameter throughout its length to ensure a uniform flushing velocity. Avoid spanning lengths of unlined iron and “non-scale-forming” pipe within a single loop since scale buildup on unlined iron pipe can reduce its effective diameter.
   - Ensure adequate water disposal capability at the discharge hydrant. Runs can be shortened to reduce flush time and thus discharge volume in locations with

[1] Residual pressure is often lowest at the flowing hydrant. However, the minimum pressure criterion should be based on the line pressure prior to flow throttling, which may not be readily-measured if either the auxiliary or main stem valve is used to throttle. Alternate approaches include field-measurement of residual pressure at the nearest upstream hydrant and/or the hydrant of maximum elevation, as well as hydraulic modeling of residual pressure throughout the area.

disposal limitations. Alternately, runs can be lengthened to “skip over” localized areas of disposal challenges.

Hydraulic modeling should be used to: (a) identify routine flow directions; and (b) verify that acceptable residual pressures can be maintained at target flushing rates and with valves appropriately positioned. For instances where modeling indicates that target flow rates and/or pressures cannot be achieved, alternate flushing run arrangements should be explored and evaluated with modeling in an attempt to meet these targets.

Flushing runs should be documented to provide an easy-to-follow plan for field crews, and to ensure that the significant time needed to develop them is made to be a “one-time” planning activity. Flushing run documentation should include the following:

- System map that depicts flushing run sequence, individual run start and endpoints, asset locations, and disposal locations. System maps should be complete, up-to-date, and include all relevant assets, pipe sizes/types, and asset IDs for reference.
- Flushing Book narrative that contains all pertinent pipe details and valve operations information for each individual run.
  - Targeted main to be cleaned, including key characteristics (length, diameter, and material)
  - Hydrant ID to mobilize at
  - Discharge disposal location
  - Pre- and post-flush valve instructions
- Valve sequencing master tracking chart. This allows crew members to easily track valve positioning for each run of the area. In cases where completion of a given flush area requires multiple days or shifts, it enables crew to quickly identify valves that need to be opened at the end of each shift and the specific valves that need to be closed to resume flushing at the start of the next shift.

### 3) Preliminary Inspection

The City should conduct a field walk-through pre-inspection of each flush area prior to flushing. This reconnaissance is especially critical for the first time that UDF is performed in a given area to identify potential flushing run issues and revision needs. Typical pre-inspection activities and objectives are:

- Verify the location, accessibility, and operability of valves, hydrants, and blow-off assemblies. It should not be assumed that all assets listed on system maps exist or are located as depicted. The pre-inspection should ideally include all assets, not simply those targeted for use in the UDF plan. Crews should perform maintenance as needed and update GIS records and system maps based on field findings.
- Identify the preferred water disposal option for each flushing run. Crews should also clean sewer inlets/lines as needed to ensure they are free of leaves or other clogging debris.
- Identify and document site-specific challenges that will require special measures and/or impact feasibility of specific flushing runs. Examples include: traffic control needs, steep slopes, water disposal challenges, sensitive environments, map errors, assets that cannot

be found or are not operable, etc. Crews should identify potential solutions to address feasibility issues where they are encountered.

- Pre-inspection should be performed several weeks in advance of scheduled flushing to allow ample time for asset maintenance and loop refinement, if necessary.

### 4) Customer Notification

Customer notification prior to each scheduled flushing event is important because of the highly visible nature of flushing and the potential for undesirable and unanticipated impacts. The most effective means of customer notification are direct mailings and door tags, while other potential methods include notices in City/utility newsletters, water bills, and on the City's website. For sensitive customers such as hospitals and schools, direct phone contact should be provided. Notification should include a description of the reason for flushing, steps that customers can take to address discoloration at the tap, the anticipated timeframe that crews will be in their neighborhood, frequently-asked questions (FAQs) and answers, and a phone number that customers can call with questions or to report issues.

During flushing, the crew should post large signs on-site indicating their activities, and have on-hand copies of the mailed/posted notification materials to give to inquiring public or customers.

# 4 HEALTH, SAFETY, AND PUBLIC AWARENESS

See section above for customer notification procedures.

One of the most significant health and safety risks during UDF is vehicle traffic. The field service team should use trucks, temporary signs, and traffic cones to prevent automotive accidents and injury to staff. In addition, a flag crew may be needed to direct traffic in some locations. Trucks should be parked between oncoming traffic and the work area to provide a barrier. In addition, the following personal protective equipment (PPE) should be worn during maintenance activities:

- Hard hat
- High visibility safety vest
- Knee pads (as needed)
- Safety glasses
- Steel-toed boots
- Work gloves

# 5 PROCEDURE

**Equipment Required (per flushing crew of 3):**

- Flushing Book with run narratives and valve sequencing chart (with clear labels for pipe diameter, street names, parcel addresses, critical water users, and all hydrant/appurtenance identification numbers)

- Valve status master tracking reference
- Flush area system map
- Hydraulic Conversion Chart, showing relationship between flow rate and flushing velocity for various pipe diameters
- Traffic cones
- Temporary signs/arrow boards (warning lights, strobe lights, arrow boards, traffic maintenance signs)
- Valve keys
- Hydrant wrench
- Various lengths of 2.5" hose
- Various lengths of 4.5" hose with appropriate adapters to diffusers
- 1 Pollard LPD-250 diffuser
- 1 Hose Monster BigBoy diffuser with pitot-less nozzle
- Dechlor pucks for Pollard LPD-250 diffuser
- Dechlor mats for use with Hose Monster
- One (1) Hach colorimeter II for free & total chlorine
- One (1) Hach 2100q turbidimeter
- Data collection forms
- GPS unit (optional)
- Digital camera (optional)

**Procedure:**

1. Once a work order is received from the Water Distribution Superintendent, the Water Distribution Supervisor will identify the 3-person maintenance crew to perform the UDF work.
2. Prior to travel to the site, perform the necessary pre-planning activities. This includes reviewing system maps, GIS, and asset history to identify hydrants that are in busy intersections, neighborhood of sensitive customers, or may result in a potential hydraulic impact. Review Flushing Books and associated run narratives and valve status sheets. Notify the Water Distribution Superintendent if additional planning/coordination is needed.
3. Locate and access the fire hydrant identified as the starting point for the work order. Identify the unique identification number for the hydrant on the appropriate water system map and confirm the actual field location is a correct match. Identify the valving sequence for the first run and send two team members out to close or open valves according to the valve sequencing chart. Verify the following information in the field and document it on the appropriate UDF data collection form:
    - Hydrant ID number
    - Area-run number
    - Pipe material, or unlined iron versus "non-scale-forming"
    - Nominal pipe diameter and assumed effective pipe diameter
    - Run length, in feet
    - Target velocity, in fps. Unless site-specific determination has been made, a target flushing velocity of 4 to 5 fps should be applied.

- Target flowrate, in gpm, based on the Hydraulic Conversion Chart
- Map discrepancies (if applicable)

4. Determine the appropriate diffuser and hose connection setup based on the target flushing rate and site constraints. For flushing of mains that are 8-in. nominal diameter or smaller, the City should attempt to use the large hydrant port with matching-size fire hose and an adapter down to the Pollard directional diffuser. If the 5 fps target flushing velocity cannot be attained with this setup, the BigBoy Hose Monster diffuser should be used per the setup described below (assuming the non-directional nature of discharge can be tolerated). If the hydrant does not have a large port and/or if directional discharge is required, an alternate setup involving the use of the two smaller hydrant ports leading to parallel Pollard diffusers should be implemented. For mains larger than 8-in. diameter, the BigBoy Hose Monster diffuser should be used with the large hydrant port and matching hose to improve the likelihood of achieving the target flushing velocity. When flushing from blowoffs, if possible, the City should avoid using a diffuser altogether to maximize the attainable flow rate (since blowoffs are typically flow-limited).
5. Identify the intended location for water disposal and direct the hose and diffuser assembly accordingly. Stabilize the diffuser. Avoid crossing private property and areas of vehicle traffic with hose, or if needed, use a hose ramp.
6. If discharging to a storm drain catch basin or drainage ditch, remove leaves and other debris from the flow path to improve drainage. Lay down dechlor mats as necessary.
7. If discharging to a sanitary sewer, maintain an air gap to eliminate the risk of cross-connection.
8. When using the Pollard LPD diffuser, place dechlor tablets within diffuser cell. When using the Hose Monster, lay down a dechlor mat in front of the intended disposal location.
9. Plumb a sidestream sample tap assembly into a spare 2½" hydrant port, to be used for sample collection.
10. Control flow with the hydrant foot valve (also known as auxiliary valve). To prepare for the flush, slowly close the hydrant foot valve and fully open the main stem hydrant valve.
11. Crack the foot valve to produce a low flow rate (< 20 gpm) for 3 to 5 minutes to allow the hydrant barrel and lateral to clear. Once the barrel and lateral have cleared, collect a baseline sample for turbidity and chlorine residual.
12. Determine the target flow rate (in gpm) based on the effective pipe diameter and the target flushing velocity.
13. Slowly open the hydrant foot valve to achieve the target flow rate reading on the diffuser gauge. If the target cannot be attained and there is an opportunity to modify the hydrant setup to improve flow, discontinue the flush and change the hydrant setup to improve flow (as described in step 5 above). In some cases, the maximum attainable flow rate may be lower than target, in which case the flow should be maxed out.
14. Record the flow rate achieved and calculate/record the corresponding flushing velocity.

15. Determine the time (in seconds) per pipe volume (PV) turnover based on the flushing velocity achieved. The time per PV turnover should be calculated as the length of the run (in feet) divided by the actual flushing velocity (in FPS).
16. Start a timer and continue flushing until “flush-terminating” criteria have been met, as described below.
17. Collect water samples from the discharge (using the sidestream sample tap assembly) and analyze immediately onsite, when possible, to assess flushing effectiveness and water quality restoration. Basic parameters to be monitored for all runs include visual clarity, turbidity, and chlorine residual. Regarding timing of sample collection, once high-rate flushing has begun, turbidity samples should be collected to correspond with discrete pipe volume (PV) turnovers, starting at time zero (zero PV) and at each PV turnover, i.e., at one PV, two PV, and so on, until the flush-terminating criteria provided below have been met. In cases where each PV turnover time is less than two minutes, it is recommended to sample for turbidity every two minutes. Prior to terminating the flush, a final chlorine residual and turbidity measurement should be obtained to confirm that background chlorine residual conditions have been restored.
18. Collect samples for any other analyses that are desired, as well as photographs. Record visual observations of discharge water.
19. Data collection and management are important to assess flushing effectiveness. A new data collection form should be used for each run, and all pertinent hydraulic data and water quality results should be documented on the form.
20. Water quality results and disposal constraints should be used to determine when to terminate a flush. In the absence of disposal constraints, flushing should be continued until all of the following “flush-terminating criteria” have been met:
    - At least two PV have been turned over.
    - Discharge chlorine residual is similar to that of the CWI.
    - Discharge turbidity is low and stable for at least 2 consecutive measurements. For unlined iron pipe, an appropriate end-of-flush turbidity criterion is less than 10 ntu. For “non-scale-forming” pipe, an appropriate end-of-flush turbidity is less than 5 ntu.
    - The water is visually clear.
21. As flushing proceeds, check downstream flows to ensure that water is being drained properly and that there are no major water backups. If water accumulation is an issue, slowly reduce or shut off flow. Use flow start/stop cycles as needed to dissipate discharge and complete flushing.
22. Measure the chlorine residual of the discharge prior to its disposal to ensure that chlorine is fully neutralized.
23. Prior to discontinuing the flush, conduct any sampling desired, including chlorine residual. Note the elapsed flush time at the end of flush.
24. To terminate the flush: (a) slowly close the hydrant foot valve; (b) close the main stem hydrant valve; and (c) slowly open the hydrant foot valve to fully open.

25. Complete the data collection form. Document any issues confronted and follow-up action needed.
26. Disconnect and remove equipment. Gather equipment, signs, and field notes.
27. Restore the site to its original condition.
28. Conduct the designated “post-flush” valve operations.
29. At the end of each shift, re-open all line isolation valves in the area. Refer to the valve status master tracking reference for the area.

# 6 DATA RECORDING AND MANAGEMENT

Following completion of a UDF area work order, enter all necessary information into the flushing GIS database, including the area/runs flushed, date of flushing, water volume used, and personnel completing the work order. Enter the baseline and end-of-flush water quality results in the flushing GIS database. All notes pertaining to each run should be stored in the Flushing Book to be readily available for future staff and efforts.

The Water Distribution Superintendent should be notified of any hydrant found to be inoperable, whether expected flow rates were achievable, and any customer complaints or unexpected water quality upsets. The Water Distribution Superintendent shall assign work orders for any follow-up items and coordinate updates to the asset management plan.

# 7 REFERENCES

None.

# MAINTAINING DISTRIBUTION SYSTEM CHLORINE RESIDUAL

SOP #441

Rev: 0.0

Date: 04/13/2018

# SOP VERSION CONTROL

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# STAFF ACKNOWLEDGEMENT

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# APPROVAL SIGNATURES

Prepared by: Arcadis U.S., Inc. & Confluence Engineering Group Date: 04/13/2018

Approved by: ______________________________________________ Date: ____________

# 1 DEFINITIONS AND ACRONYMS

| | |
|---|---|
| CIP | Capital Improvement Plan |
| CRM | Chlorine Residual Management |
| CSII | Control Station 2 |
| DBP | Disinfection Byproduct |
| MDEQ | Michigan Department of Environmental Quality |
| MOR | Monthly Operating Report |
| RTCR | Revised Total Coliform Rule |
| WQP | Water Quality Parameter |

# 2 KEY PERSONNEL AND RESPONSIBILITIES

- Water Quality Laboratory Supervisor:
  - Oversee sample collection and analysis of data using provided spreadsheet tools.
  - Communicate with Water Plant Superintendent and Distribution Superintendent when distribution system chlorine residual goal of 0.5 mg/L in ≥ 95% of monthly samples is not met.
- Water Plant Superintendent:
  - Based on information provided by the Water Quality Laboratory Supervisor, modify dosage at CSII or Cedar Street Reservoir as needed to meet distribution system residual goal.
- Distribution Superintended:
  - Implement operations and maintenance strategies to improve residuals locally or regionally.

# 3 SCOPE/PURPOSE

Maintenance of an adequate disinfectant residual throughout the distribution system is paramount to protecting public health. In addition to providing microbial control, disinfectant residuals provide oxidizing conditions to help stabilize pipe scales, and can serve as an indicator of distribution system integrity. Therefore, a key aspect of distribution system water quality management and optimization is to identify appropriate disinfectant residual level(s) and strategies for monitoring and maintaining them on an on-going basis. The purpose of this SOP is to outline the procedures for tracking and maintaining chlorine residual within the distribution system. Several Microsoft Excel-based spreadsheet tools have been developed to track residual levels at the plant tap and throughout the distribution system, specifically:

- Flint CSII and Tap WQP Control Charts v1.2 (refer to SOP#422)
- Flint Distribution System Chlorine Residual Control Charts v1.2 (refer to SOP#422)
- Chorine Residual Management Tool v4

The first tool generates weekly median control charts for chlorine residual (as well as orthophosphate and pH) at CSII and tap sampling locations at the Flint Water Treatment Plant. The second tool generates monthly median control charts for chlorine residual at the twenty-five Revised Total Coliform Rule (RTCR) Monitoring Sites that the City of Flint maintains in the distribution system. Control charts are particularly useful for assessing variability in process control within treatment plants, and success meeting the desired finished water chlorine residual goal.  Consult *SOP 422: Control Charting of Water Quality Parameters* for additional information and instructions for use.

The CRM Tool was developed to allow for tracking and analysis of chlorine residual levels and comparison to the free chlorine residual goal of 0.5 mg/L in ≥ 95% of the monthly samples collected. Review of the graphics created in this tool allow for seasonal and site-specific analysis compared to the goal. The CRM Tool also tracks disinfection byproduct (DBP) sampling and performs DBP compliance calculations.

# 4 HEALTH AND SAFETY

There are no inherent health or safety risks from using the CRM Tool to analyze data. Water system staff implementing treatment or operations changes or conducting additional water quality sampling should follow the SOPs for those operations.

# 5 PROCEDURE

1. Collect and analyze chlorine residual measurements from all RTCR and chlorine residual only surveillance monitoring locations within the distribution system each week. A minimum of 100 chlorine residual measurements should be collected each month distributed across the RTCR monitoring locations. HACH Pocket Colorimeter II, HACH DR 900 or equivalent colorimetric methods are acceptable.
2. Enter the free chlorine residual sample results from the RTCR monitoring into the Monthly Operating Report (MOR).
3. Enter the MOR data from distribution system and plant tap sites into the CRM Tool (see CRM Tool Instructions tab for step-by-step instructions).
4. Enter data into the control chart spreadsheets (see corresponding SOPs and spreadsheet tools for instructions).
5. Review the charts to verify:

   a. Free chlorine residual at the plant tap is at or above the minimum finished water target.
   b. 95% of monthly samples are ≥ 0.5 mg/L as free chlorine.

6. Take appropriate steps to rectify issues when identified. These may include:
   a. Chlorine dose modifications – regional or system-wide improvements
      i. At Plant – Increase or decrease the system chlorine dose at CSII. Consult *SOP 131: Sodium Hypochlorite Addition at Control Station 2* and *SOP 133: Sodium Hypochlorite Testing*.
      ii. At Storage Facilities – Increase or decrease chlorine dose at Distribution Storage Facilities. Consult *SOP 132: Sodium Hypochlorite Addition at Distribution Storage Facilities* and *SOP 133: Sodium Hypochlorite Testing*.
      iii. Track potential unintended consequences of increased dose, such as customer complaints (consult *SOP 421: Customer Complaint Tracking*) and formation of disinfection byproducts (using CRM Tool).
      iv. Consider cost-benefit of increased dosing versus water age and pipe wall demand management options summarized below.
   b. Reduce water age – localized, regional, or site-specific improvements (Consult *SOP 442: Water Age Management*)
      i. Install/move auto-flushers to problematic areas and conduct gentle bulk water turnover flushing. Consult *SOP 431: Conventional Flushing for Water Turnover*.
      ii. Modify reservoir operations to improve mixing and turnover.
      iii. Verify valve positions to minimize artificial dead-ends and improve water circulation.
   c. Reduce pipe wall demand – localized, regional or site-specific improvements
      i. Conduct unidirectional flushing where feasible to remove accumulated sediments that may be exerting a disinfectant demand. Consult *SOP 432: Unidirectional Flushing*.
      ii. Determine timing for pipe repair and replacement in affected area per the Capital Improvement Plan/Asset Management Plan.
7. Document dates of response strategies and verify site-specific, local, regional, or system-wide impacts using statistics and charts developed in CRM and control chart tools. Modify response strategies, as needed, and as system operations evolve.

# 6 DATA RECORDING AND MANAGEMENT

The Water Quality Laboratory Supervisor should review chlorine results on a daily basis and enter into MORs. Data from MORs should be uploaded into spreadsheet tools each month to review site-specific and monthly trends, confirm that plant and distribution system residual goals are met, and assess effectiveness of response strategies.

# 7 REFERENCES

City of Flint. Standard Operating Procedure 131: Sodium Hypochlorite Addition at Control Station 2.

City of Flint. Standard Operating Procedure 132: Sodium Hypochlorite Addition at Distribution Storage Facilities.

City of Flint. Standard Operating Procedure 133: Sodium Hypochlorite Testing.

City of Flint. Standard Operating Procedure 421: Customer Complaint Tracking.

City of Flint. Standard Operating Procedure 422: Control Charting of Water Quality Parameters.

City of Flint. Standard Operating Procedure 431: Conventional Flushing for Water Turnover.

City of Flint. Standard Operating Procedure 432: Unidirectional Flushing.

City of Flint. Standard Operating Procedure 442: Water Age Management.

# WATER AGE MANAGEMENT

SOP #442

Rev: 0.0

Date: 4/13/2018

# SOP VERSION CONTROL

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# APPROVAL SIGNATURES

Prepared by: Arcadis U.S., Inc. Date: 4/13/2018

Approved by: ______________________________ Date: ______________

# 1 DEFINITIONS AND ACRONYMS

| | |
|---|---|
| PPE | personal protective equipment |
| SOP | Standard Operating Procedure |

# 2 KEY PERSONNEL AND RESPONSIBILITIES

Water Distribution Superintendent shall:

- Understand the detention time that provides an adequate water age within the City and at what detention time water quality may drop below desired targets.
- Identify methods to increase demand in areas of high water age, such as a remote tanker bulk water fill station.
- Maintain a plan for maintaining adequate water age with declining demands. This may include taking storage facilities offline, replacing water mains with smaller diameter pipes and reducing system piping redundancies. Superintendent shall balance methods to improve water age with the requirements to delivery adequate quantity of water for normal consumption, leaks and fire protection demands.

Water Distribution Operator shall:

- Perform system operations in a manner that proactively considers water age. For example, controlling storage tank and reservoir supply and pumping in a way that forces adequate turnover and maintains consistent water age.
- Perform all flushing operations – both scheduled proactive means to manage water quality and as-needed reactionary means to address localized areas with inadequate water quality – in accordance with *SOP 431: Conventional Flushing for Water Turnover* and *SOP 432: Unidirectional Flushing.*
- Maintain a log of all manual flushing events and automatic flushing devices.

# 3 SCOPE/PURPOSE

Finished water entering the distribution system continues to react with the constituents remaining in the water following treatment, and additional reactions occur along the pipe wall as water travels through the distribution system. Chlorine residual also decays over time, increasing the potential for microbial regrowth. For these reasons, minimizing water age throughout the distribution system is a primary objective to maintaining adequate water quality throughout the distribution system.

Water age, or detention time, is a basic calculation comparing the system production flow rate with the storage volume in the distribution system (including clearwell, storage tanks and reservoirs, and pipe volume). Water age management consists of: (1) Understanding the flow of water through the system and focusing on the areas with highest water age, (2) Periodic review of changes to system water age (e.g., the impact of a large user changing demands, etc.), and (3) Methods to improve water age such as flushing or modifications to operations.

# 4 HEALTH AND SAFETY

Management of water age cannot be directly sampled if not conducting a tracer study. However, field sampling of water quality may be considered in the areas of highest water age to confirm estimated water age. Water Distribution staff entering the community to investigate water age should be aware of their surroundings at all times. Always carry appropriate City of Flint identification or a City approved contractor identification card. Where possible, customer visits should be conducted in pairs. If analytical samples are required, follow all necessary procedures for water quality sampling.

It may be necessary for manual flushing and/or automatic flushing devices to be utilized as a method for improving water age in a localized area within the system. If flushing is deemed appropriate, follow applicable procedures, including health and safety, from the appropriate flushing and water quality sampling SOPs and utilize proper PPE.

# 5 PROCEDURE

Procedures for water age management consist of system flushing to maintain adequate water quality. Personnel shall follow the specific procedures defined in the following SOPs:

- SOP 431: Conventional Flushing for Water Turnover
- SOP 432: Unidirectional Flushing
- SOP 441: Maintaining Distribution System Chlorine Residual

# 6 DATA RECORDING AND MANAGEMENT

Any data that may be used by the Water Distribution Superintendent to maintain knowledge of water age should be collected and summarized for periodic review. This data management is essential for reference when evaluating any water quality anomalies and/or customer complaints.

Water Distribution Superintendent shall:

- Maintain a representation of typical system water age conditions with periodic updates, at least quarterly as demands within the system change.
- Understand the water age within the system which correlates to adequate water quality by maintaining record of the water age-water quality correlation and changes over time to the correlation.
- Track and maintain all estimated and measured water discharge from manual flushing events and automatic flushing devices. This water volume shall be included in the calculation of non-revenue water.

- Record all water age management strategies performed by Operators and associated results.

Water Distribution Operator shall:

- Review customer complaints monthly based on category and location to identify problem areas within the distribution system and track performance against water age.
- Communicate trends and potential problem areas of the distribution system to the Water Distribution Superintendent.
- Maintain a log of all manual flushing events and automatic flushing devices. The log shall include, at a minimum:
    - Flush date
    - Flush start time and stop time
    - Operator name
    - Estimated flush volume
    - Disinfection residual concentration before (pre-flush) and after (post-flush) each flush event
    - Any notes applicable to the flush event such as abnormal results or recent water demands

# 7 REFERENCES

American Water Works Association. (2018). *M32 Computer Modeling of Water Distribution Systems, Fourth Edition.* Denver, CO: AWWA.

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City of Flint. Standard Operating Procedure 431: Conventional Flushing for Water Turnover.

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United States Environmental Protection Agency. (2002). *Effects of Water Age on Distribution System Water Quality.* Washington, DC: USEPA Office of Ground Water and Drinking Water, Standards and Risk Management Division.