M E M O R A N D U M

TO: Mayor and Council Members

FROM: Rey Arellano, Assistant City Manager

DATE: October 2, 2019

SUBJECT: Response to Resolution 20181115-041
Colorado River After Action Report and Corrective Action Plan

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The purpose of this memo is to respond to Resolution 20181115-041 regarding the October 2018 Colorado River flooding event that resulted in Austin Water issuing a boil water notice over a seven day period from October 22 – 28, 2018. Attached is the formal *After Action Report and Corrective Action Plan*, as well as Austin Water's *October 2018 Flood Event Engineering Review and Recommendations*. This memo also provides a summary of prior reports per Council direction in the Resolution.

Colorado River After Action Report and Corrective Action Plan

The City of Austin, in conjunction with Travis County, hired Hagerty Consulting, Inc. to complete an After-Action Report (AAR) and Corrective Action Plan (CAP) after the Emergency Operations Center (EOC) activation during the 2018 Colorado River flooding and subsequent boil-water notice. See Attachment (1). The AAR and CAP identified 161 recommended corrective actions for the City and County in seven focus areas including: operations, direction and control, water points of distribution (PODs), resource management, emergency procurement, communications, and recovery. The AAR process examined the eighth focus area, City and County resilience, related to this specific incident and more broadly for other hazards, threats, and stressors that resulted in 37 distinctive recommendations.

Key highlights of the AAR include the following identified areas for improvement/enhancement and next steps:

- Clarification of the process of identification and request of reassigned employees to make the process easier and more stream-lined.
- Enactment of an interlocal agreement that would establish the lead purchasing office for shared expenses.

- Establishment of a dedicated emergency management GIS analyst in order to have a greater ability to utilize GIS as a tool for emergency management.
- Consideration of standby contracts to fulfill personnel resource needs and high-priority resources.
- Development of a language access plan specific to the emergency management related activities.
- Alignment of activation levels of the City and the County in the context of a joint EOC.

The AAR and CAP process involved a diverse set of City and County stakeholders who were involved in the response operations for the Colorado River flooding and/or the boil-water notice, including representatives from more than 20 City and County departments and agencies. These stakeholders were able to provide input into the AAR and CAP process at several points in the planning process, including an online survey, focus area meetings, the After-Action Conference (AAC), and the CAP review meeting.

The AAR documentation includes the following components:

- The final Austin-Travis County Emergency Management Colorado River Flooding AAR
- AAR /CAP Appendices
  - Stakeholder survey summary results
  - CAP Action Prioritization Ranking
  - Acronyms and Abbreviations
- AAR attachments
  - CAP, which includes specific actions, timeframes, and responsible parties for implementation.

For more information regarding the Colorado River Flooding AAR and CAP, please contact: Juan Ortiz, Homeland Security and Emergency Management Director (juan.ortiz@austintexas.gov).

Austin Water October 2018 Flood Event Engineering Review and Recommendations

In conjunction with the City's After Action Report process, Austin Water conducted a separate engineering study of the event. To conduct the study, Austin Water assembled a team consisting of internal engineering and operating staff, Carollo Engineers, Inc., and Professors Desmond Lawler and Lynn Katz of the University of Texas.

Attachment (2) is the completed study report, along with a transmittal memo by Greg Meszaros, Austin Water Director. Key findings and recommendations include:

- Raw water conditions associated with the October 2018 flooding were unprecedented and the duration of raw water upset was significantly longer than past events.
- To prepare for future extreme turbidity events, Austin Water will need to enhance treatment options to improve flexibility to operate during water quality upset episodes. The recommended strategy is to add polymer-based treatment technologies at all three drinking water plants.
- Improve operator instrumentation capability to precisely measure water particle charge and adjust treatment processes.
- Enhance internal extreme event operating procedures and guidelines to document lessons learned from the October flooding and provide staff improved resources to manage future water quality upset events.

For more information regarding the October 2018 Flood Event Engineering Review and Recommendations, please contact: Greg Meszaros, Austin Water Director (Greg.Meszaros@austintexas.gov).

Prior Reports to City Council

Resolution 20181115-041 contained several elements of direction to the City Manager. The following table summarizes staff's response to the respective elements.

Direction	Covered by
BE IT RESOLVED: The Council supports the City Manager's and Austin Water's commitment to fully assess the event and identify areas of improvement, by way of an "After Action Report," and further directs the City Manager to provide a preliminary report and public briefing to the City Council, no later than December 11, 2018, providing information detailing the events leading up to and through the water boil disaster, including but not limited to:	
An overview of Austin's water treatment facilities' ages, conditions, output capacities, water treatment technologies, why these technologies were chosen during planning and construction, and how we may update these technologies to address future needs; and	Covered by Austin Water Assistant Director Rick Coronado on December 11, 2018 City Council Work Session, Item B3. This information is available from 8:05 to 19:15 on this video. This is also addressed in the October 16, 2018 Flood Event Report and Resulting Recommendations that was commissioned by Austin Water (see Attachment (2)).
A timeline detailing the foreseeability of the water turbidity issue, Austin Water's knowledge and response to the crisis, as well as when and how the decision to boil water was communicated to residential and commercial customers (this is to include insight into the interim decisions about increased water restrictions and the final decision and communication about ceasing the boil water notice); and	This was provided in Assistant City Manager (ACM) Rey Arellano's memo on November 9, 2018 and presented at Council work session on November 13, 2018 by ACM Rey Arellano on Item B2. This information is available from 2:02 to 33:25 on this video.
A detailed account of water quality data as a result of the boil water crisis between October 22 and October 28, including turbidity, bacteria testing and results, and other relevant water quality data; and	A graph of relevant data was provided to City Council on December 11, 2018 at the Council Work Session and presented by Assistant Director Rick Coronado on Item B3 of that agenda. This information is available from 19:40 to 31:20 on this video.

Direction	Covered by
Comparative data on turbidity levels experienced in the last ten (10) years with analysis of how this October's spike compared to previous periods of high turbidity outliers; and	This was presented by Austin Water Director Greg Meszaros on December 11, 2018 at City Council work session during Item B3. This information is available from 3:32 to 5:50 on this video.
Analysis of whether the introduction of zebra mussels may have contributed to the ability of our water treatment infrastructure to process turbid water; and	This information was provided by Assistant Director Rick Coronado on December 11, 2018 at City Council work session during Item B3. This information is available from 31:20 to 32:20 on this video.
An overview of intergovernmental cooperation and communications throughout the crisis; and	A preliminary overview was provided in ACM Rey Arellano's memo of November 9, 2018. An examination of the communications during this event are in the After Action Report (Attachment (1)) beginning on page 36. The section specifically addressing interagency communication begins on page 39.
A forecast of the future of Austin's water planning and supply.	Director Greg Meszaros and members of the Water Forward Task Force presented the Water Forward Plan at Council work session on November 13, 2018 on Item B2. This information is available from 33:45 to the end on this video.
BE IT FURTHER RESOLVED: In order to improve our communications in times of emergency, the City Manager should:	
Acknowledge any gaps in City communications, and initial plans for bridging those gaps in the future; and	An examination of the areas for improvement for our communications during this event are in the After Action Report (Attachment (1)) beginning on page 39.
Ensure cohesive messaging from partner agencies; and	Recommendations 134-145 relate to this in the Corrective Action Plan on page 145 of the After Action Report (Attachment (1)) and work is underway on these recommendations.

Direction	Covered by
Identify segments of the population and economy that are most greatly impacted by a loss of readily available clean water supply, and affirmatively provide those with consistent, specifically targeted and dedicated information and guidance.	Staff continues to work with community partners to identify individuals and areas most vulnerable to specific hazards, including utility interruptions. Staff is developing methods to provide preparedness information to these groups to ensure they have appropriate information to be prepared for a variety of hazards. This work is underway.

cc: Spencer Cronk, City Manager
Executive Team
Greg Meszaros, Austin Water Director
Juan Ortiz, Homeland Security and Emergency Management Director

Attachments:

(1) Colorado River Flooding After Action Report
(2) October 2019 Flood Event Engineering Review and Recommendations

Colorado River Flooding

After Action Report

Austin Homeland Security and Emergency Management
Travis County Office of Emergency Management

May 20, 2019

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Executive Summary

Overview

The Colorado River flooding and subsequent boil water notice response was initiated as widespread rainfall occurred throughout the central Texas region in early October 2018. The Lake LBJ and Lake Buchanan watershed basins received heavy rainfall causing significant damage to surrounding areas. Much of this rainfall drained to the Colorado River through Lake Travis from the Llano River. As a result, the Lower Colorado River Authority (LCRA) commenced flood response operations for the Buchanan Dam, Mansfield Dam, and Tom Miller Dam on Tuesday, October 16, 2018. Concurrently, Austin Water commenced flood operations on the Longhorn Dam in coordination with the LCRA.

On this same day, the City of Austin Office of Homeland Security and Emergency Management (HSEM) stationed a Situation Assessment Team in the Emergency Operations Center (EOC) to support the Travis County Office of Emergency Management (OEM) flood response operation. On Wednesday, October 17, 2018, LCRA anticipated the need to open four additional gates at Mansfield Dam, which would result in flooding along Lake Austin, Lady Bird Lake, and areas downstream of Longhorn Dam because of the volume of water released. On Thursday, October 18, 2018, the joint Austin-Travis County EOC was activated to prepare for the anticipated effects of the additional flood gates opening.

As the EOC was activated, Austin Water placed its Departmental Operations Center (DOC) to standby mode. The water draining through the Colorado River was fed by water from the Llano River which had a significant amount of silt, dirt, and debris as a result of the extremely dry summer conditions in the area. On Friday, October 19, 2018, water treatment plants (WTPs) were still operating as normal; however, Austin Water noticed increased turbidity levels at raw water intakes. By Saturday, October 20, 2018, the increased water turbidity began to impact WTP operations and water production fell as clogged filtration systems were addressed. On Sunday, October 21, 2018, the Austin Water DOC was activated as WTP capacity was diminished as Austin Water was challenged to maintain output water turbidity. Austin Water called for the community to reduce water consumption. By 8:00 p.m. the night of Sunday, October 21, 2018, the Austin Water Director recommended the Austin City Manager initiate a boil water notice preemptively.

Austin HSEM and Travis County OEM staff worked overnight to notify key stakeholders of the situation, identify a communication strategy, and identify sources of water to provide to the community. At 6:00 a.m. on Monday, October 22, 2018, a press conference was held at Austin City Hall to announce the boil water notice. At 5:25 p.m. the same day the Reverse 9-1-1 system was used to send out water conservation and boil water notices to all Austin Water customers. On Tuesday, October 23, 2018, the turbidity levels leaving the filters at one of the WTPs triggered a mandatory boil water notice by the Texas Commission on Environmental Quality (TCEQ).

The impact of the boil water notice was felt throughout the city and county. Restaurants, schools, and hospitals were all impacted. Many restaurants did not open, especially initially, and many of those that did open could not offer all of their normal services. Schools remained open, but Austin Independent School District (AISD) worked tirelessly to ensure operations could continue as normal. Parents were requested to boil water for their children to bring to school. Hospitals were heavily impacted – Austin HSEM and Travis County OEM were able to provide hospitals with adequate water supply, but surgeries requiring sterile equipment were initially put on hold prior to when equipment manufacturers could be contacted to ensure the safety of the equipment. Austin HSEM and Travis County OEM provided potable water to the community through seven water points of distribution (PODs) which distributed bottled or bulk drinking water. Five of these PODs were run by the City of Austin, one of the PODs was run by Travis County, and one POD was run by Williamson County.

The boil water notice lasted for seven days. On Sunday, October 28, 2018, TCEQ informed Austin Water that all the criteria required to lift the boil water notice had been met. At 3:30 p.m. that Sunday, Austin Water released a press release to inform the public that the boil water notice was over. At 4:15 p.m., a press conference was held at City Hall to officially announce the boil water notice's end.

After-Action Report Development

Methodology

Austin HSEM and Travis County OEM, in partnership with Hagerty Consulting[1], coordinated to form a Project Management Team. The Project Management Team identified eight unique focus areas of response within the joint Austin and Travis County response to the Colorado River flooding and subsequent boil water notice incident. The Project Management Team worked with the City, County, and regional partners, including other departments and responding organizations to identify one to two representatives per focus area to serve as Focus Area Leads. These Leads were tasked with providing guidance for the after-action process and for the after-action report (AAR) itself.

The first step in the AAR process was to invite relevant employees and stakeholders to participate in an online survey. This survey solicited targeted information about the role each respondent played in the regional response to the Colorado River flooding and subsequent boil water notice and asked respondents to rate and comment on critical components of the response (e.g., operations, resource management, planning documents, training, and communication processes). The results of the online survey are captured in the Survey Summary Analysis appendix to this report. Respondents were invited to attend the Focus Area Meetings at the same time as filling out the survey.

[1] Hagerty Consulting is a third-party emergency management consulting firm contracted to facilitate the after-action process and develop the full After-Action Report and Corrective Action Plan.

Based on of the results of the survey, the Project Management Team along with the Focus Area Leads developed the critical elements of the response for facilitation for the Focus Area Meetings, including key themes, strengths, and areas of improvement. At the end of each Focus Area Meeting, participants were provided a menu of three to five key action items identified during the meeting and asked to select the one action item which should receive priority over the others. The results of this voting process are captured in the Action Prioritization Ranking appendix to this report.

An initial draft of this AAR was prepared based on information gathered from online survey responses and Focus Area Meetings. The initial draft was presented to the Project Management Team and Focus Area Lead, and then to other critical stakeholders for comment at an After-Action Conference (AAC). AAC participants were also invited to provide written feedback on the draft through a Comment Tracking Sheet. These comments were subsequently incorporated into a final draft.

An initial draft of the Corrective Action Plan (CAP) was developed in parallel with this report to assign responsibilities for implementing the identified recommendations. Following the AAC, the draft CAP was presented to the Planning Team at a CAP Conference, during which participants agreed upon the City, County, or regional partner departments, agencies, or responding organizations that would maintain primary or supporting responsibility for the implementation of each corrective action. The CAP can be found at the conclusion of this report.

Finally, both the AAR and CAP were finalized and approved by Austin HSEM and Travis County OEM. They were then presented to the City Manager, and formally accepted by the City and the County.

AAR Focus Areas

The Project Management Team identified eight unique Focus Areas of response to the Colorado River flood. Each Focus Area comprises a different aspect of the response, each with a unique narrative and a distinct set of stakeholders, actors, plans, processes, and outcomes. While overlap exists across some Focus Areas, these divisions provide a mechanism to break the overall response into accessible elements and establish a framework for a set of focused and achievable actions. This AAR recommends the City, the County, and/or their regional partners implement these actions in order to capture strengths and remedy areas of improvement observed during the response to the Colorado River flood. The Focus Areas are:

- Operations
- Direction and Control
- Water Points of Distribution (PODs)
- Resource Management
- Emergency Procurement
- Communications
- Recovery
- Resilience

Summary Analysis

Strengths

Through feedback captured during eight Focus Area Meetings, as well as through responses to the online survey, the Planning Team identified strengths evident across the joint city and county response to the Colorado River flood. These strengths were sorted by focus area and analyzed to identify actions and processes Austin, Travis County, and their regional partners should continue or incorporate into future response plans. The strengths organized by Focus Area are:

- Operations
- Direction and Control
- Water Points of Distribution (PODs)
- Resource Management
- Emergency Procurement
- Communications
- Recovery
- Resilience

Areas for Improvement

Through feedback captured during eight Focus Area Meetings, as well as through responses to the online survey, the Planning Team identified areas for improvement evident across the joint city and county response to the Colorado River Flooding. These areas for improvement were sorted by Focus Area and analyzed to identify actions and processes that Austin, Travis County, and their regional partners should incorporate into future response plans as remedy for the following areas of improvements, organized by Focus Area:

- Operations
- Direction and Control
- Water Points of Distribution (PODs)
- Resource Management
- Emergency Procurement
- Communications
- Recovery
- Resilience

Core Capabilities

Presidential Policy Directive 8 (PPD-8) describes the Nation's approach to preparing for the threats and hazards that pose the greatest risk to the United States. The Directive sets forth the National Preparedness Goal of: *"A secure and resilient nation with the capabilities required across the whole community to prevent, protect against, mitigate, respond to, and recover from the threats and hazards that pose the greatest risk."* To achieve this goal, 32 Core Capabilities[2] have been established with associated capability targets to aid the whole community in achieving this goal. These Core Capabilities provide for collective goals across emergency management planning and exercises, and as such, have been incorporated into this report to assist both the City and County in aligning their future planning, training, and exercise initiatives. The Core Capabilities included in this report and their associated definitions are included below.

Core Capability	Definition
Economic Recovery	Return economic and business activities (including food and agriculture) to a healthy state and develop new business and employment opportunities that result in an economically viable community.
Environmental Response/Health and Safety	Conduct appropriate measures to ensure the protection of the health and safety of the public and workers, as well as the environment, from all-hazards in support of responder operations and the affected communities.
Logistics and Supply Chain Management	Deliver essential commodities, equipment, and services in support of impacted communities and survivors, to include emergency power and fuel support, as well as the coordination of access to community staples. Synchronize logistics capabilities and enable the restoration of impacted supply chains.
Operational Communications	Ensure the capacity for timely communications in support of security, situational awareness, and operations by any and all means available, among and between affected communities in the impact area and all response forces.
Operational Coordination	Establish and maintain a unified and coordinated operational structure and process that appropriately integrates all critical stakeholders and supports the execution of core capabilities.

[2] A full list of Core Capabilities can be found at: https://www.fema.gov/core-capabilities.

Core Capability	Definition
Planning	Conduct a systematic process engaging the whole community as appropriate in the development of executable strategic, operational, and/or tactical-level approaches to meet defined objectives.
Public Information and Warning	Deliver coordinated, prompt, reliable, and actionable information to the whole community through the use of clear, consistent, accessible, and culturally and linguistically appropriate methods to effectively relay information regarding any threat or hazard, as well as the actions being taken, and the assistance being made available, as appropriate.

Response Analysis

Focus Area 1: Operations

Focus Area Introduction

Summary

On October 17, 2018 and October 18, 2018, Travis County and the City of Austin activated the Austin-Travis County EOC in response to the Colorado River flooding. For the next 21 days, the EOC served as Area Command, operating 24 hours a day, with roughly 25 agencies from across the City and County departments and regional partners. From the EOC, the City, County, and their regional partners coordinated water PODs and prepared for potentially catastrophic flooding around the Colorado River. Many of the City and County departments contributed personnel and resources to Logistics, Planning and Public Information, in addition to the entire range of operational activities. EOC staff were adaptable and flexible to address the situation. Additionally, Austin Communications and Technology Management (CTM) Geographic Information Systems (GIS) Emergency Response Team (ERT) was able to provide spatial data in real-time to help EOC staff plan for potential impacts of the disaster.

Many City, County, and regional partner personnel also maintained responsibilities in their day-to-day roles, causing Area Command to struggle with staffing shortfalls. At times, operational coordination was hampered by a lack of familiarity (or practice) with the Incident Command System (ICS) among some City and County personnel staffing the EOC. EOC staff were unsure of processes for requesting activation of reassigned employees and missed the existence of agency traffic control and POD plans that would have aided incident planning. Through all of this, employees in the EOC were able to work through these difficulties.

Related Core Capabilities

- Situational Assessment
- Operational Coordination
- Operational Communications
- Planning

Strengths

Coordination with GIS ERT (Situational Assessment):

- CTM (GIS ERT), a team of interagency GIS specialists who provide support to the EOC during incidents, was effectively mobilized during this activation. CTM (GIS ERT) was utilized to plan for potential impacts during the incident for the first time. The floodplain group was able to provide information regarding flood risk due to dam operations to CTM (GIS ERT) in order to map potential impacts in real-time. This information was then distributed to relevant agencies/departments.

- **Recommendation 1.1:** The City and County should expand GIS capability for application during incidents and planning.
- **Recommendation 1.2:** The City and County should simplify the process of City and County staff sharing and updating data with CTM (GIS ERT) for production of maps and other geospatial information.

City/County Coordination (Operational Coordination):

- Coordination between the City and County staff was strong throughout the activation, partially attributed to the strong operational relationship between the Austin HSEM Director and the Travis County OEM Chief Emergency Management Coordinator.
  - **Recommendation 1.3:** The City and County should continue to foster the relationship between City and County staff for enhanced coordination in future EOC activations.
  - **Recommendation 1.4:** Work with lifeline critical infrastructure stakeholders (e.g., water, energy, transportation) to develop proactive and preventative trigger points to mitigate cascading impacts.
- The Capital Area Medical Operations Center (CAMOC) during the incident was fully operational. The CAMOC was staffed by representatives from Austin Public Health, Hospital liaisons from St. David's and Seton Family of Hospitals and Capital Area Trauma Regional Advisory staff. The water needs of the hospitals were determined very quickly due to the working history of this group.
  - **Recommendation 1.5:** The City and County should maintain full operations of the CAMOC during incidents.

Institutionalizing Knowledge (Planning):

- Some response partner agencies brought inexperienced personnel into the EOC to shadow their more experienced counterparts as on-the-job-training, providing these personnel with hands-on real-world incident observation experience.
  - **Recommendation 1.6:** The City and County should include shadowing as a standard practice for responding agencies and departments.

EOC Personnel (Operational Coordination):

- Having a variety of agencies and departments in the EOC benefited the operation by improving coordination. This also included representation from the state (Texas Division of Emergency Management (TDEM) and Disaster District Committee (DDC), and Austin CTM, which maintained a presence in the EOC (or were on call) for the majority of the activation to provide immediate technical assistance.

- **Recommendation 1.7:** The City and County should continue to encourage representation for all relevant agencies/departments in the EOC in order to strengthen coordination during EOC activations.

Situational Awareness (Operational Communications):

- The schedule of meetings and calls was displayed every day in the EOC. This was a great method to maintain the broader organization of the EOC and maintain situational awareness for the EOC staff. The posted schedule contributed to the situation report (SitRep) to summarize what happened during that operational period to inform future operational periods.
  - **Recommendation 1.8:** The City and County should continue the practice of posting the call and meeting schedule daily in the EOC to maintain EOC staff situational awareness.

Areas for Improvement

Mobilization (Operational Coordination, Operational Communications):

- The timing of the activation was not clear among City and County staff. This was partially attributed to the unprecedented nature of the incident and partially to the differences in the operational levels by the City and County. Examples of the differences include but are not limited to: The City's reduced operational level (not fully staffing EOC), and the County having fewer activation levels compared with the City.
  - **Recommendation 1.9:** Austin HSEM and Travis County OEM should work together to align their activation levels and interagency coordination in the context of a joint EOC.
- There was an inconsistency amongst agencies and organization representatives as to notification, both in timing and in the method of contact.
  - **Recommendation 1.10:** EOC leadership needs to strengthen and refine the notification process, particularly in complex incidents where scaling-up and scaling-down is needed.
  - **Recommendation 1.11:** The City and County should use a multi-method form of notification including pagers for initial notification and email for large amounts of information. The list of those notified should be periodically updated.

EOC Personnel (Operational Coordination):

- This incident required a large amount of coordination with the LCRA. The LCRA hosted daily conference calls to bridge the gap between the numerous jurisdictions involved in this incident and the LCRA EOC, but even with this, the amount of coordination was limited for the needs of joint Austin-Travis County EOC for this incident. This incident highlighted a need for more coordinated efforts with key external entities (in this case the LCRA). To fill the specific gap identified in this incident, the LCRA has invited a liaison from the City/County to be present in the LCRA EOC during incidents, if desired.

- **Recommendation 1.12:** The City and County should institute a practice providing the information provided in this call to all EOC staff in executive briefings.
- **Recommendation 1.13:** The City and County should coordinate and assign City and/or County staff to be a liaison between key external agencies to coordinate a seat in the host EOC as needed.
- **Recommendation 1.14:** Departments represented in the EOC should identify additional liaisons to work at external sites in order to improve communications, specifically during complex cross-jurisdictional events.

- During the incident, the responsibilities for reassigning employees were not clear. It was a challenge for EOC staff to identify how many reassigned employees were available to activate, which reassigned employees had specific qualifications necessary for incident operations, and to maintain visibility on the activations of reassigned staff, resulting in some staff having too many assigned shifts. EOC staff expected Austin Human Resources Department (HRD) to play a critical role in leading staffing of reassigned employees for emergency field operations. However, HRD's role in the activation was unclear and they were expected to meet requests that they had not been in charge of for previous activations. The speed of onset of the crisis limited the amount of time HRD had available to take strategic action to reassign employees. Many employees needed to be activated after traditional business hours, which made it a challenge to reach people. As HRD began reassigning employees, they were unaware that there were additional details of the activation (e.g., reassigned employees at the water PODs needed to be able to lift). Fleet Services was able to assist in identifying potential reassigned employees as they were aware of employees with the right certifications.
    - **Recommendation 1.15:** City and County staff should clarify the process of identifying and requesting reassigned employees in order to make the process easier and more stream-lined.
    - **Recommendation 1.16:** The City and County should clarify the role and expectations of City and County Human Resources (HR) departments in the context of an EOC activation and their timeline in the EOC activation process. This will allow for staff in the EOC and City and County HR to prepare accordingly and ensure reassigned employees are certified, safe, and not overworked.
    - **Recommendation 1.17:** The City and County should explore developing and making a consolidated list of skill-sets by department available to EOC staff in order to streamline the activation of reassigned employees in the field.
    - **Recommendation 1.18:** The City and County should explore the creation of a local incident management team (IMT) that is pre-trained for specific positions and can support meeting the needs of operational resource requirements.
    - **Recommendation 1.19:** City HRD has proactively initiated the development of an EOC activation standard operating procedures (SOPs). Austin HSEM should provide input on the SOP for EOC activation by City HRD to provide context to an EOC activation. Similarly,

Travis County Human Resources Management Department (HRMD) should develop an EOC activation SOP with input from Travis County OEM.

- **Recommendation 1.20:** City and County HR should include an incident assessment process in their EOC SOP to assist them in assessing the need for organizing and contacting reassigned employees during the work day.
- **Recommendation 1.21:** City and County HR should be included in any planned logistics exercises. Austin and Travis County Purchasing Offices and Finance Departments are currently discussing plans to hold a joint logistics exercise.
- **Recommendation 1.22:** The City and County should compile a list of external labor contracts and memorandum of understandings (MOUs) readily available for use and establish a trigger point for utilizing outside labor resources versus reassigned employees.
- **Recommendation 1.23:** HRMD should staff representatives in the EOC throughout the duration of emergency incidents.
- **Recommendation 1.24:** The City and County should assign an EOC Staffing Coordinator who would act as a centralized employee to manage the task of reassigning employees.

- The Central Texas School Safety Consortium did not have a representative, apart from AISD, in the EOC during the Boil Water response phase of the incident. This presented challenges for the AISD emergency operations staff as they were not able to comprehensively inform and act for AISD, specifically, and the Central Texas School Safety Consortium.
  - **Recommendation 1.25:** Austin HSEM and Travis County OEM should work with the Central Texas School Safety Consortium on the protocol for mobilizing a school representative to serve in the EOC, to ensure consideration is given to the impact of a given emergency on the selected representative's district.

EOC Staffing (Operational Coordination):

- Operating the EOC while maintaining day-to-day operations of departments/agencies and DOCs was challenging during this incident due to resource limitations. Some personnel were overworked and burned out, particularly when operations became 24/7. Additionally, not all EOC staff integrated easily into the EOC. EOC staff had not all received an initial briefing and did not have all of the same training for EOC operations; this was particularly true for staff who were placed in unfamiliar roles.
  - **Recommendation 1.26**: Austin HSEM and Travis County OEM staff should expand EOC orientation, coordination, and training. Those eligible for training should include staff who are not expecting to work in the EOC. This should include scripted "just-in-time" training to allow staff training during an activation.
  - **Recommendation 1.27:** Austin HSEM and Travis County OEM should build out agency director communication to include emergency management training.
  - **Recommendation 1.28:** Austin HSEM and Travis County OEM should develop a staffing plan for activations in order to be better prepared for activation needs. This plan should include: a schedule, roles needed, and potential agencies/individuals to fill those roles.

The City and County should consider using standby contracts to fulfill resource needs in the staffing plan.

- **Recommendation 1.29**: The City and County should create a designation of "essential" or "critical" employees to ensure employees who are responsible for activating to the EOC understand their role.
- **Recommendation 1.30:** City and County agency and department continuity of operations (COOP) plans should acknowledge agency and departmental staffing challenges during activations, accounting for staff that may be activated to the EOC or assisting with the disaster in some way even if normal agency and departmental operations are suspended.

Resource Awareness (Planning):

- City and County staff underutilized existing plans during this incident. This included, but is not limited to, traffic control plans, maintained by City of Austin Department of Transportation, and POD Plans, maintained by Austin Public Health (APH).
    - **Recommendation 1.31:** The City and County should conduct an assessment and catalog City and County department/agency plans related to emergency management. Austin HSEM and Travis County OEM should then utilize identified plans in future activations and develop a plan for updating of this assessment.
    - **Recommendation 1.32:** The City and County should review the POD plan produced by APH in order to produce a plan that is more flexible for numerous POD types, and to identify pre-determined POD locations, as well as considerations for just-in-time locations. The City should look to the Austin Office of Real Estate Services for support in the pre-identification of future POD locations.
- Long term care facilities, dialysis centers, home health and hospice agencies have not been active members of the Capital Area Public and Medical Preparedness Coalition and have not been involved in the CAMOC. This event showed the need for them to be active members similar to what hospitals have been doing for years. We need current contact information and involved the Department of State Health Services to impress upon these groups that they need to be involved as part of the requirement of the Center for Medicare and Medicaid Emergency Rules.
    - **Recommendation 1.33:** The City and County should work with long term care facilities, dialysis centers, and home health and hospice agencies to get them more involved in the Capital Area Public and Medical Preparedness Coalition and the CAMOC to be more prepared during incidents.

GIS Capability (Situational Assessment):

- During the activation, there were a number of GIS data issues identified. Data that CTM (GIS ERT) had access to was not always up-to-date and departments/agencies had data or datasets relevant to emergency management that CTM (GIS ERT) did not have knowledge of. Staff did not have compatible systems for sharing data and data was emailed between GIS personnel. There were also compatibility issues between the outputs produced by the GIS tool used by the City and the

GIS tool being utilized by the County. These data challenges resulted in additional processing time for CTM (GIS ERT) representatives to produce accurate and relevant products.

- **Recommendation 1.34:** Austin HSEM and Travis County OEM should then work with City and County GIS staff to ensure there is mutual knowledge of relevant datasets.
- **Recommendation 1.35:** The City and County should establish a dedicated emergency management GIS analyst in order to have a greater ability to utilize GIS as a tool for emergency management, resolve challenges in utilization of GIS during activations, and be a liaison between CTM (GIS ERT) and the EOC staff.

Utilizing WebEOC (Operational Communications, Situational Assessment):

- WebEOC was not regularly updated by all departments/agencies and there were WebEOC accessibility issues, where some staff with the same title did not have the same access to WebEOC. Additionally, not all pertinent remote staff in DOCs have access to WebEOC.
  - **Recommendation 1.36:** A WebEOC controller position should be established. They would be responsible for updating WebEOC with command and control decisions.
  - **Recommendation 1.37:** Austin HSEM and Travis County OEM should work with the Capital Area Council of Governments (CAPCOG) in order to update and improve WebEOC boards.
  - **Recommendation 1.38:** Austin HSEM and Travis County OEM should review the assignment of WebEOC login information and remote access capability during an activation to promote collaboration and situational awareness.

Demobilization (Operational Coordination):

- The demobilization planning process did not include all relevant agencies, which led to challenges. Not all agencies were informed of their role in the demobilization process and other agencies were not able to include specific needs into the demobilization plan. For example, APH was not sufficiently involved in the demobilization planning process and did not realize their role in public messaging after the boil water notice was lifted.
  - **Recommendation 1.39:** EOC representatives should create a more transparent demobilization process. While all EOC representatives cannot be included in the demobilization planning process, the demobilization plan should be communicated to all in the EOC, and some allowance for feedback should be made. Additionally, the demobilization process should include demobilization of mutual aid resources.

Focus Area 2: Direction and Control

Focus Area Introduction

Summary

On October 18, 2018, the City of Austin, in conjunction with Travis County and regional partners, activated the Austin-Travis County EOC as the Colorado River was flooding. The response to the Colorado River flooding incident transitioned into a complex incident when the boil water notice was initiated, as a large area was significantly impacted and required numerous agencies and stakeholders to affect a response. Throughout this complex incident, the EOC served as Area Command. Although the EOC was deactivated on October 29, 2018, a limited staff remained in the EOC to continue coordinating recovery efforts, including establishing two Multi-Agency Resource Centers (MARCs) to provide assistance to those impacted by the flooding. Numerous agencies stepped up to lead various parts of the response, such as Austin Water closely monitoring and managing the impact of the floods on water treatment facility operations and Austin Fire Department (AFD) taking command and control over the five City PODs. Overall the coordination between agencies was strong and effective, as many of these same partners had worked together during the Harvey response in 2017 and continued building upon their relationship in the months leading up to the Colorado River flooding.

The City and County had never experienced an event such as this, which, as expected, exposed some operational challenges. The City and County have separate emergency response plans which contain different language and activation levels. This created confusion for some personnel as to whether they were officially activated for the response or were to continue with their day-to-day operations. In the initial stages of the response, there was a general lack of decision makers present in the EOC. A call was made to bring department and agency heads together to the same room to rectify this, but they should have been brought into the EOC earlier. Staffing challenges at the EOC led individuals to be assigned to roles they had neither training nor experience in.

Related Core Capabilities

- Operational Coordination
- Planning
- Situational Assessment
- Operational Communications

Strengths

Coordination Between Agencies (Operational Coordination, Planning):

- Operations at the Delco Center staging site went smoothly. Despite having a limited staff and being the only school district represented, AISD managed the Regional Staging Areas (RSAs) very well while also facilitating day-to-day operations. As APH does a lot of work with Central Texas Voluntary Organizations Active in Disaster (VOAD) on a regular basis, medical operations had good representation with external partners and facilities, which enabled effective coordination for water tracking and distribution at long-term care facilities.

- **Recommendation 2.1:** Austin HSEM and Travis County OEM should facilitate planning meetings and exercises that bring regional partners together outside of emergency incidents. This will help to continue building upon established working relationships to enhance communication and coordination effectiveness in future responses.
- **Recommendation 2.2:** The City and County should identify and coordinate with nontraditional community partners (e.g., H-E-B, Tito's Vodka) who may be able to provide assistance during future responses.

POD Command and Control (Operational Coordination):

- AFD very successfully operated as command and control at the PODs. However, in many other instances, AFD might not be able to provide the same amount of personnel to external operations as they were able to during this incident.
    - **Recommendation 2.3:** The City and County should use internal resources in the short term up to 48 hours, or until external resources from the State or private sector can be mobilized.
    - **Recommendation 2.4:** The City and County should train additional staff in operational command and control in order to augment other trained staff (e.g. AFD) in the event they are not available for a future deployment.

Donations Management (Logistics and Supply Chain Management):

- Field personnel at the water PODs successfully utilized the ICS structure to manage donations. Donations that were not directed by the EOC were redirected or referred to the EOC for verification and acceptance. This allowed for proper donations management and decision making by the City and County.
    - **Recommendation 2.5:** The City and County should explore having a shared emergency donations policy and specify whether all donations should be handled through non-governmental organizations (NGOs), Central Texas VOAD, or other community partners.
    - **Recommendation 2.6:** The City and County should continue utilizing a single approval authority/entity (i.e. the EOC) to direct donations. This will allow the EOC to accurately manage and track donations while preventing external sites from accepting potentially illegitimate donations.
    - **Recommendation 2.7:** City and County Public Information Officers (PIOs) and executives should provide proactive messaging to the media and public regarding acceptance of donations.

Incident Command and Control (Operational Coordination):

- The EOC used unified command and applied the National Incident Management System (NIMS) throughout the response. Departments and agencies that have a deep knowledge of and experience in ICS, such as AFD, consistently perform well during responses and are able to adapt to changes in roles and responsibilities more effectively.
    - **Recommendation 2.8:** Austin HSEM and Travis County OEM should continue encouraging ICS and NIMS training and utilization to the utmost degree possible. Additionally, facilitating exercises utilizing ICS will help relevant City and County personnel have a better understanding of ICS during responses.

Information Sharing from PODs (Intelligence and Information Sharing, Public Information and Warning):

- AFD received hourly updates from the PODs they had command and control over, as well as regular updates from the other two sites. EOC representatives provided timely information to the POD sites on when trucks were coming in with more water. This allowed the dissemination of updated information to the public, such as how long the lines were at the PODs.
    - **Recommendation 2.9:** The City and County should record these capabilities and practices to sustain this regular communication between field sites and the EOC in order to provide an accurate situational awareness among response personnel. Moreover, the City and County should explore automating this process.

Areas for Improvement

Personnel Staffing (Operational Coordination):

- Some personnel served in roles in the EOC with no prior experience or training in that role. These individuals often had to learn in the moment, which was difficult as the operations tempo of the response was high and complex.
    - **Recommendation 2.10:** City and County agencies and departments should develop job action sheets with information on specific roles when assigning representatives to the EOC.
    - **Recommendation 2.11:** Austin HSEM and Travis County OEM should provide continued EOC training to regular employees who activate to the EOC. This training should be additionally offered to untrained employees who will eventually be activated to the EOC as they progress in their careers.
    - **Recommendation 2.12:** City and County agencies and departments should develop operational structures for activation staffing that are clearly defined and communicated to EOC personnel in advance.

Approval Authority (Operational Coordination, Situational Assessment):

- In the initial stages of the Colorado River flooding response, often the people who make decisions for various agencies or departments were not present in the EOC or in meetings where decisions needed to be made. This resulted in a delay of operational decision-making.
  - **Recommendation 2.13:** City and County departments and agencies need to establish the level of decision-making authority their personnel in the EOC have, and their process for gaining rapid departmental approval for decisions that are above their level. Establishing and communicating this in advance will help facilitate decision making early in future responses.

Plans and Planning Language (Planning):

- Austin HSEM and Travis County OEM have separate emergency response plans, which complicated operations during this unprecedented incident. These plans contain different language and operational levels, such as disaster declaration procedures, activation levels, and EOC staffing levels. This created confusion among some EOC personnel such as to whether they were officially activated, or if they should proceed conducting day-to-day operations as normal.
  - **Recommendation 2.14:** Although political and organizational differences between the City and County complicate the development of joint emergency response plans, Austin HSEM and Travis County OEM should collaborate to make the language and processes of each more uniform, such as providing clarification on respective activation and staffing levels in the context of a joint EOC.
  - **Recommendation 2.15:** The City and County should facilitate planning meetings between counterpart departments and agencies in order to share understanding of their emergency plans, capabilities, and responsibilities in advance of emergency incidents.

Command Roles and Response (Operational Coordination, Planning):

- There was confusion regarding who was in charge of the unified command. In some instances, multiple individuals thought they were in charge of certain aspects of the response based on their roles in prior experiences. Additionally, personnel were often briefed individually over the phone, rather than conducting a group briefing to provide a shared understanding on specific roles and responsibilities. Operationally, this incident was not handled like a true complex incident where a transition of unified command over time may be the best fit for the operation.
  - **Recommendation 2.16:** Austin HSEM and Travis County OEM should facilitate tabletop discussions and associated planning on complex incidents (e.g., Branch Tactical Planning), command roles and functions (e.g., Unified Command versus Area Command; Area Commander versus Incident Commander), and staffing.

Bulk Resource Ordering (Logistics and Supply Chain Management):

- When City and County purchasing office personnel were ordering bottled water in bulk quantities, there was a lack of understanding of specific terminology as this was a new process that was unfamiliar to purchasing personnel. Purchasing personnel had to learn on the fly to ensure bottled water was correctly ordered, which added an extra layer of complexity to this already complex incident.
    - **Recommendation 2.17:** City and County purchasing office personnel should review the lessons learned from this incident in order to have a better understanding of this purchasing process, to include contract language and restrictions, in advance of future emergency incidents. These lessons should be incorporated into future planning and operations.
    - **Recommendation 2.18:** The City and County should explore standby contracts with vendors for bulk resource ordering containing emergency clauses and emergency contact information for high-priority resources to be on standby at all times of day throughout the year.

Personnel Presence in EOC (Operational Coordination, Planning):

- Travis County Emergency Services Districts (ESD) maintained a representative in the EOC during the initial flood response, but a representative was not present in the EOC for the boil water response. The ESD representative de-activated from the EOC after the potential need for a water rescue response had passed. Additionally, AISD staff were slated to support RSA operations and were unable to maintain representation in the EOC, establishing a hole not only for AISD, but for the Central Texas School Safety Consortium, as other districts were not requested to backfill. City and County HR's presence was inconsistent for the need throughout the operation due to lack of understanding of need and roles and responsibilities.
    - **Recommendation 2.19:** Austin HSEM and Travis County OEM should conduct regular training on EOC roles, specifically tailored to joint Austin-Travis County EOC operations for EOC personnel. This training should highlight the process for demobilizing to ensure adequate staffing is maintained and/or positions can be quickly reactivated if required.
- AFD provided a detailed initial briefing to EOC personnel on the first day of POD operations that would have been beneficial to all participating departments, agencies, and partners. However, several agencies were brought into the response after the first day and were not a part of the initial briefing.
    - **Recommendation 2.20:** Austin HSEM and Travis County OEM should develop a standardized EOC informational briefing that should be conducted as personnel are assigned to the EOC.

Communications (Operational Communications):

- There was confusion on some of the communications channels. For example, AFD was operating on a specific channel and water PODs were operating on a different channel. AFD personnel were leading the five City PODs but were unsure whether they should have used the AFD or POD channel. While a 205 was developed for the incident, it was not shared repeatedly throughout the incident, leading to response partners not having clarity on appropriate communications channels.
    - **Recommendation 2.21:** The EOC and Incident Command Post (ICP) should conduct an operational period briefing of the Incident Action Plan (IAP) at the beginning of each operational period.
    - **Recommendation 2.22:** Austin HSEM and Travis County OEM should facilitate exercises to practice communications procedures during incident response involving multiple agencies and departments across multiple cities and counties.

Personnel Shift Transitioning (Planning):

- EOC and external site personnel from different departments and agencies had different reporting requirements and shift schedules. Some POD personnel whose shift ended at night did not adequately communicate with the next shift reporting in the morning. Information sheets were supposed to be left at the sites for replacement personnel to gain situational awareness, but this happened sporadically.
    - **Recommendation 2.23:** The City and County should consider developing shift transition guidelines to accompany job action sheets and training initiatives.

Focus Area 3: Water Points of Distribution (PODs)

Focus Area Introduction

Summary

On October 21, 2018, as flood waters were having an increasing impact on water treatment plant operations, Austin Water issued an advisory notice to the city asking residents to reduce their water usage. Early in the morning on October 22, 2018, Austin Water issued a boil water notice for all customers as they worked to stabilize the water treatment system and continued to urge residents to reduce their water usage. The notice advised residents that tap water used for cooking and consumption should be boiled first, or to use bottled water. In response, the City of Austin, Travis County, and Williamson County purchased millions of gallons of bottled water, shipped it to seven PODs throughout the area, and distributed them to residents. Coordination between the City, County, and regional partners to identify locations for the PODs and their subsequent establishment went very well, particularly as this was the first time the City and County had run water POD operations. However, as water distribution operations were being conducted, uncoordinated staffing of personnel at the PODs as well as a lack of communication between the EOC and the PODs generated confusion among some of the POD personnel. Additionally, logistics and resource shortfalls created what should have been preventable complications.

Related Core Capabilities

- Planning
- Operational Coordination
- Situational Assessment
- Operational Communications
- Logistics and Supply Chain Management
- Environmental Response/Health and Safety

Strengths

Coordination for PODs (Operational Coordination, Planning):

- City and County personnel, as well as regional partners, showed tremendous adaptability in setting up and operating the water PODs. Existing POD plans, although not referenced for this event, are centered around school-based PODs for the distribution of medication. As area schools remained open and the need was for bulk water distribution rather than medicine, alternative options were successfully identified and utilized. AFD and various other partners went to the POD sites in advance to plan for water distribution operations. Additionally, the POD planning team looked at potential sites with GIS analysts to determine certain characteristics and limitations. This enabled a smoother flow for water distribution and pickup by citizens.

- **Recommendation 3.1:** Austin HSEM and Travis County OEM should develop a joint plan on the distribution of commodities, to include elements of direction and control.
- **Recommendation 3.2:** Austin HSEM and Travis County OEM should continue identifying and inspecting potential POD sites for future use, with an emphasis on creating a running list of site characteristics and limitations and matching these characteristics and limitations to the type of POD site. Additionally, incorporating and utilizing GIS resources in the planning process will further improve future POD establishment and operations.

Reporting (Situational Assessment, Operational Communications):

- Personnel at the Williamson County POD composed a daily SitRep that was different than the one composed at the EOC. This report provided additional information that the EOC was able to incorporate into their daily SitRep.
    - **Recommendation 3.3:** The City and County should evaluate the SitRep used and consider standardizing the modified SitRep for future operations.

Areas for Improvement

POD Communications (Operational Communications, Situational Assessment):

- Although the PODs were tracking the number of pallets of water that were being distributed, this statistic did not aid with judging the flow of operations (e.g., wait times at the PODs). Wait times during the incident were estimated every two hours, but accuracy of the estimations was not measured.
    - **Recommendation 3.4:** The City and County should explore alternative options for distributing information about wait times at POD sites. This should include City and County websites and social media. An example of an effective system was the voter wait time map that Travis County produced during the elections that occurred at the same time as the Colorado River flooding and boil water response. As participants voted, they were asked to report how long they had waited in line. This information allowed others to see approximate wait times at the various sites in real-time.
    - **Recommendation 3.5:** Austin HSEM and Travis County OEM should explore a similar technology to what Williamson County used to track check in and out times of personnel at POD sites, in order to provide accurate real-time tracking of staff at external sites.

VOADs and Vulnerable Populations (Operational Coordination, Planning):

- VOADs could have been utilized to a greater extent at the water PODs and during other operations (e.g., leveraging unmet needs assessments to assist in County decision-making); however, there was very little response when asked to help staff the water PODs. As VOADs work directly with local populations on a daily basis, they are a valuable source of knowledge on the area demographics and could have helped to better identify the areas of greatest need. Additionally, knowing VOAD resource capabilities in advance would have been beneficial to ensure adequate resource availability.

  - **Recommendation 3.6:** Austin HSEM and Travis County OEM should increase communication and coordination with VOADs and nontraditional community partners both in advance of and during emergency incidents. Facilitating planning meetings and exercises will allow Austin HSEM and Travis County OEM opportunities to understand available resources and capabilities, which will be beneficial for easily identifying surge resources when needed.

- There was concern that vulnerable populations, such as the in-home population, individuals requiring oxygen, and those with limited access, were not able to adequately procure safe drinking water, whether bottled or boiled. It was also estimated that seven percent of households in Austin do not have vehicles, which would make transporting multiple gallons of water from the PODs to their homes difficult. Organizations such as Meals-on-Wheels and Travis County Health and Human Services distributed water to homebound populations during the incident. However, Travis County Health and Human Services found that water they ordered for delivery was redirected to Water PODs so there was limited water availability for homebound populations.
  - **Recommendation 3.7:** The City and County should aggregate demographic assessments conducted by various departments and agencies in order to better understand the potential locations of greater need for assistance and where there may be a need to conduct more thorough demographic assessments to identify locations of vulnerable populations (not individuals). The City and County should implement a system to update this aggregated data on a quarterly basis. Organizations such as Meals-on-Wheels and CapMetro were stated examples of expanded sources for information on vulnerable populations.
  - **Recommendation 3.8:** The City and County should understand the methods of mobile distribution of resources for those individuals with limited ability to travel (e.g., homebound population) currently utilized and explore how to improve this process.
  - **Recommendation 3.9:** The City and County should consider the prioritization of resources for distribution to the community during incidents.

POD Logistics and Resources (Logistics and Supply Chain Management):

- Some of the sites were not well equipped to receive large tractor-trailers and were better suited for box truck deliveries, resulting in logistical challenges and time constraints. Further, the lack of understanding in the procured resource constraints (e.g., how contract drivers are permitted to operate) complicated logistics further to avoid any breaches of contract or liability issues.
  - **Recommendation 3.10:** The City and County should create a checklist with considerations for POD sites. Knowing what site layout needs are in advance can prevent logistical limitations and the need for significant changes when time is critical.
- The Circuit of the Americas (COTA) POD site, operated by Travis County, obtained maps with identified traffic points which helped personnel at this site to direct vehicular traffic in and out.

Similarly, the Williamson County POD had detailed maps of their site, which they produced and distributed to the public prior to the start of distribution operations. However, the City sites did not have maps with this type of information. One site instituted signs and barricades in its plan to direct traffic, but during operations, had to create additional signs and find additional barricades to handle the unexpectedly high volume of traffic.

- **Recommendation 3.11:** Field site managers should ensure that gaps and deficiencies in resources (e.g., necessary signage and barricades) are clearly communicated to the EOC. Additionally, the EOC should coordinate consistently with all sites to ensure that other field sites do not have the same gaps or deficiencies, and that all sites have access to and knowledge of available resources and their locations.

- To meet initial assistance needs, over 1.5 million gallons of water had to be ordered at 2:00 a.m. on Monday, October 22, 2018, for distribution at the PODs. However, without existing contracts in place or warehouses with resources on standby notice, it was not feasible that the entire order would be able to be delivered on the first day.
    - **Recommendation 3.12:** The City and County should explore standby contracts with vendors containing emergency clauses and emergency contact information for high-priority resources to be on standby at all times of day throughout the year.
    - **Recommendation 3.13:** The City and County should meet with the business community (e.g., H-E-B and Wal-Mart) in a non-disaster setting to discuss resources that can be provided during an emergency and to establish how communications will be handled in an emergency. In discussions with these partners, consideration to become additional distribution points should be discussed as they are at times large and can potentially handle such an operation.

POD Staffing (Planning, Operational Coordination):

- The City and County had challenges staffing the PODs. Initially Austin HSEM considered 10 PODs located at the city centers, but this was determined to be logistically unfeasible. Austin HSEM then wanted to open seven PODs, however this was again determined to be unfeasible due to staffing. Austin HSEM finally decided to open five PODs throughout the city, with Travis County and Williamson County each deciding to operate a separate POD, bringing the total number of sites to seven. Spontaneous volunteers showed up wanting to help, not having been directed by any particular department or agency, creating confusion among some POD personnel as to who was supposed to work where. Other issues of confusion included POD staff not understanding their respective roles and responsibilities, and the unclear communication of staff shift schedules at each site.
    - **Recommendation 3.14:** The City and County should establish aligned POD procedures, and ensure they are followed during operations. Just-in-time training should be instituted for on the job training. Pre-identified personnel who may be involved in POD operations should, at minimum, complete and familiarize themselves with FEMA's Emergency Management Institute (EMI) course IS-26, "Guide to Points of Distribution".

- **Recommendation 3.15:** The City and County should develop and utilize POD manager kits to outline the staff and resources required to operate a POD (in a manner similar to the way existing shelter manager kits are organized and utilized).

Safety (Environmental Response/Health and Safety):

- There was an initial lack of guidance from the EOC to the City PODs on issues related to safety, such as conducting site safety training and the provision of safety equipment and materials. While one of the three AFD employees at the POD sites was assigned to safety, several participating departments and agencies did not receive safety training upon arriving to the POD sites. Also, safety vests were not initially issued at PODs nor was there guidance on safety measures such as wearing closed-toe shoes when working on site. The EOC provided these after personnel at the sites reported this. Some departments and agencies were also unsure if there was a safety officer in the EOC responsible for ensuring sites complied with necessary safety requirements, and if so, who the safety officer was.
    - **Recommendation 3.16:** The City and County should consider a safety officer in the EOC. Among items the safety officer should be responsible for are: (1) identifying whether reassigned employees need to have specific certifications, qualifications, be able to physically lift a certain weight, or any other criteria in order to perform the task being assigned to them; (2) identifying safety officers at all field sites to provide safety training and equipment to personnel; and (3) assessing EOC schedule to ensure adequate rest is provided to those involved in the operation.

Waste Removal (Environmental Response/Health and Safety):

- Management of resource byproducts was a challenge during the incident. Bottled water was delivered to the PODs by the pallet. Once off-loaded and the water distributed, the pallets remained at the site, resulting in large numbers of pallets at multiple sites which were difficult to properly dispose of. While there was some amount of communication about recycling, as a community committed to reducing the amount of trash sent to landfills by 90% by 2040, additional messaging would have further promoted the commitment to zero waste.
    - **Recommendation 3.17:** City and County purchasing office personnel should ensure that contracts include clauses for the removal of byproducts.
    - **Recommendation 3.18:** City and County PIOs should collaborate with waste removal organizations to ensure the public has access to information on proper waste disposal methods and site locations.

Demobilization (Operational Coordination):

- The demobilization of the POD sites was not centralized. It was not clear to reassigned staff who would be letting them know when they were demobilized and when this issuing would occur.

- **Recommendation 3.19:** The City and County should provide a structure for POD demobilization. This structure should be integrated into a POD plan produced by these jurisdictions.

Focus Area 4: Resource Management

Focus Area Introduction

Summary

After the boil water notice was announced, resource management became a primary function of the EOC. Staff in the EOC primarily needed to manage reassigned employees and manage resources going to and operating the water PODs in order to ensure effective and efficient distribution of water to the community. EOC staff primarily relied on HRD to schedule and reassign employees in order to support the activation. Reassigned employees were primarily utilized at water PODs. Ultimately this process of reassigning employees was successful, but it came with some clear logistical challenges. HRD was not involved in the activation from the beginning and they were expected to complete tasks that they had not been previously assigned to complete. This meant the process of resource management of personnel was not as efficient or effective as ideally it would have been.

In addition to the reassigned employees, resource management at the water PODs was a primary issue of EOC staff. This involved managing water deliveries and the personnel and equipment required for the process. This also involved donations management at the POD sites and EOC. Resource management at the water POD sites was overall successful, as AFD assisted in ensuring leadership was maintained at the PODs and donations and other resource management issues were directed through the EOC.

AISD had significant challenges with resource management. The RSAs that AISD were running eventually became managed by the state. This was a challenge as it meant that the processes for resource requests and communication were made unclear as AISD began routing requests directly to the State and not through the EOC, Austin HSEM, and Travis County OEM.

Related Core Capabilities

- Logistics and Supply Chain Management
- Operational Coordination
- Operational Communications

Strengths

Purchasing (Logistics and Supply Chain Management):

- The City of Austin Purchasing Office was present in Logistics in the EOC. This has been a recurring practice with recent EOC activations that has been successful. The Travis County Purchasing Office was also present in the EOC. This was one of the first activations where the Travis County Purchasing Office was present and this aided in operations.

- **Recommendation 4.1:** The City and County should make it standard practice and continue to have the Austin and Travis County Purchasing Offices present in the EOC during activations.

Resource Tracking (Logistics and Supply Chain Management):

- Resource tracking was successful during the incident, largely attributed to the role Fleet services played during this activation.
  - **Recommendation 4.2:** Austin HSEM and Travis County OEM should work with CAPCOG in order to develop WebEOC boards for resource tracking. This should include automated tracking of resources, equipment, people, and costs to provide real-time information should be explored and developed. Implementing this will improve the demobilization process.
  - **Recommendation 4.3:** The City and County should compile a list of available logistics resources that are ready to use in an emergency. A gap analysis of should also be developed in order to develop sources for resources that are not readily available. The EOC should develop its role as a Multi-Agency Coordination Center (MACC) and catalog types of available resources by agencies.

Areas for Improvement

Donations Management (Logistics and Supply Chain Management):

- Austin HSEM and Travis County OEM were operating in "trusted source mode" because of the nature of the donations. This meant that none of the donations were tested, except the two tankers of water donations. This revealed the challenge that would have occurred if Austin HSEM and Travis County OEM could not operate in this trusted source mode.
  - **Recommendation 4.4:** The City, the County, and their regional partners should revise the Donations Management Annex pre-disaster to identify which agencies, departments, and/or organizations will lead, and which will play supporting roles in donations management.
  - **Recommendation 4.5:** The City and County, with guidance from the City and County health departments, should expand their donations management policies to include food and water safety standards.
  - **Recommendation 4.6:** Travis County OEM does not accept donations; rather the County directs donations to NGOs or VOADs. Austin HSEM should explore this option for managing donations.
- AISD and hospitals received a multitude of donated resources that were logistically burdensome. These were donated by the private sector to the RSAs as well as via direct donation to schools by parents. AISD and hospitals ended up with too many resources compared with their needs and had to balance the management of these resources.

- **Recommendation 4.7:** Facilities that receive direct donations, such as schools and hospitals, should expand their donations management policy to account for these donations and educate decision makers about the importance of these policies.

Resource Request Process (Logistics and Supply Chain Management):

- AISD resource fulfillment changed over the course of the operation and resulted in delays. At first, with a more concentrated presence in the EOC, AISD requested that Austin HSEM and Travis County OEM submit a State of Texas Assistance Request (STAR) on their behalf; however, the request did not leave the City/County because AISD submitted it through WebEOC and not by calling the EOC. Once exclusively located in the RSAs, AISD was working more closely with the TDEM and FEMA on resource requests, which were being filled more efficiently. However, this shift resulted in a disconnect between AISD and the EOC with the Central Texas School Safety Consortium not represented.
    - **Recommendation 4.8:** Austin HSEM, Travis County OEM, and the Central Texas School Safety Consortium members should clarify and formalize the resource request process whether or not the State is involved in the incident in order to better support their disaster operations.
- Security was an issue at the AISD RSAs. This was an additional resource request issue, as security presence was requested and eventually filled in a limited way through State Troopers. AISD requested four patrol officers and only ever received two at a time.
    - **Recommendation 4.9:** The City and County should pre-identify areas of staffing gaps to utilize contract staffing during activations to help fill staffing gaps.

Focus Area 5: Emergency Procurement

Focus Area Introduction

Summary

As the flood and boil water response progressed, there was a need to procure additional resources. Overall the ability for response participants to purchase and utilize emergency resources went well. Purchasing personnel in the EOC were given clear and deliberate guidance on individual responsibilities. The additional presence from various partners in the EOC allowed for more effective communication and coordination than what was seen during the Harvey response.

Experience gained from the Harvey response helped strengthen interdepartmental and interagency relationships and provided lessons learned that were incorporated in the Colorado River flooding response. Assistance was requested from and provided by neighboring jurisdictions, including San Antonio, Williamson County, and Fort Worth, to provide water and POD site help. Despite these lessons, gaps and challenges inevitably presented themselves. The differences in purchasing processes between the City and County created challenges, namely in deciding if certain expenses should be shared or should fall on one entity. Although the City was the primary lead for the response, there were instances when both the City and County required the same resources to be procured but without requiring duplications in orders. As WebEOC was greatly underutilized for purchase requests and tracking, it was discovered that the City and County were often ordering similar supplies. Had there been a larger emphasis for purchase requests to be input on WebEOC, these duplicate orders could have been reduced.

Additionally, challenges in utilizing procurement cards created some complications in acquiring emergency resources. There is no established policy for using the City of Austin emergency procurement cards versus individual City of Austin procurement cards. It was identified that Travis County does not have an adequate number of procurement cards, and there is a lack of clarity as to whether procurement cards and costs can be shared between the City and County.

Related Core Capabilities

- Logistics and Supply Chain Management
- Planning
- Operational Coordination
- Operational Communications

Strengths

Collaboration / Teamwork (Planning, Operational Coordination):

- Experience from the Harvey response helped establish rapport and a stronger working relationship between the City and County logistics and purchasing office personnel working in the EOC. Purchasing office personnel from the City and County were better organized and prepared before the EOC was up and running. There was a clear delineation established for each personnel's responsibilities. This enabled them to get ahead of the curve instead of having to play catch up once response operations fully began. The City and County logistics and purchasing office personnel adapted quickly and effectively, as they had never experienced or planned for an event like this.
  - **Recommendation 5.1:** City and County departments and agencies should continue encouraging regular communication and coordination between their counterparts outside of emergency incidents, such as through planning meetings and exercises.

EOC Representation (Planning, Operational Coordination):

- During the Colorado River flooding response, most activated departments and agencies placed only one or two representatives in the EOC. This allowed for improved coordination and communication, as compared to the Harvey response when some departments and agencies had as many as five or six representatives that often rotated in and out.
  - **Recommendation 5.2:** City and County departments and agencies that staff personnel in the EOC should ensure that they have a dedicated team of personnel within their office who can respond to the EOC. This should also include exploring a policy whereby their regular positions are backfilled while they are deployed during the emergency. Utilizing consistent personnel will help build stronger working relationships, thereby increasing communication and coordination effectiveness.
- Having Travis County Purchasing Office personnel located in the EOC during the response helped improve communication and coordination with Austin Purchasing Office to efficiently and promptly meet procurement needs. Austin Fleet Services Department's presence in the EOC and on the ground as the Ground Transportation Unit was extremely valuable, particularly utilizing their CDL-certified drivers in distribution operations. Similarly, having additional necessary representatives in the EOC, such as hospital personnel, was beneficial.
  - **Recommendation 5.3:** Austin Fleet Services Department and Travis County Purchasing Office should continue to staff personnel in the EOC during related emergency incidents.
- Purchasing decision makers were present in the EOC and purchasing approval authority was established immediately. This was an improvement over the Harvey response, when purchasing decision makers were not immediately present, and subsequently it took several days to establish purchasing approval authority.

- **Recommendation 5.4:** City and County purchasing office leadership should ensure that relevant decision makers from their respective offices are involved in responses from the beginning and are made available throughout the duration.

Areas for Improvement

Procurement and Purchasing Processes (Logistics and Supply Chain Management):

- City and County purchasing offices have different purchasing processes, such as purchasing thresholds and policies on reimbursement, as these processes are constituted under different bodies of law. One example in which this made purchasing efforts difficult was in determining if purchases should be shared or if one office should be the purchaser.
  - **Recommendation 5.5:** During the Harvey response, purchasing personnel had a flow chart to direct them on reimbursement policies and processes. City and County purchasing office personnel should collaborate to develop a similar tool template that can be modified for utilization during future incident responses.
  - **Recommendation 5.6:** City and County leadership should enact an interlocal agreement that would establish the lead purchasing office for shared expenses.
  - **Recommendation 5.7:** Purchasing authority and thresholds, as well as the process for increasing them, should be established prior to the next emergency.
- During the Colorado River flooding response, personnel frequently made procurement requests by verbally telling their respective purchasing offices. The purchasing office personnel would then fill out the procurement forms, often at a later time due to the high tempo of operations. Not only is this against the actual processes for the City of Austin Purchasing Office, this method is inefficient and can increase the likelihood of errors and missing documentation for purchases.
  - **Recommendation 5.8:** During the Harvey response, personnel requesting resources filled out their own procurement forms which would then be processed by the City of Austin Purchasing Office. Austin HSEM should ensure that this method continues to be utilized, and supervisors should ensure that their personnel know the correct processes for requesting resources and adhere to them.

Procurement Card Utilization (Logistics and Supply Chain Management):

- The City and County both possess a procurement card system, specific to their jurisdiction. There are a limited number of procurement cards (five) made available by the City of Austin for emergency use by any City employee. Similarly, Travis County has three procurement cards, but is currently working on obtaining procurement cards for all 24 of their buyers. Purchasers had to use their own procurement cards, instead of general-use procurement cards, if the purchase was over a certain amount. These amounts can be increased, but it requires authorization and activation, both of which can take time. Additionally, these cards are assigned to specific individuals and only these individuals are authorized to use the cards. Austin HSEM procurement cards are activated in an emergency, the purchase limit is decided at the time of activation and can be increased or decreased throughout the event.

- **Recommendation 5.9:** City and County departments and agencies should identify personnel who may need access to procurement cards in emergencies, provide these individuals with initial procurement card training, issue procurement cards, and provide annual procurement card refresher training.
- **Recommendation 5.10:** The City and County should enact an interlocal agreement that authorizes procurement card usage and cost sharing between specific agencies and departments to facilitate purchasing requests. This agreement should allow personnel with purchase approval authority to authorize purchases on their procurement cards for personnel of a different agency or department and should contain points of contact for procurement card usage and authorization. The process of tracking receipts and attaching them to the relevant procurement card should also be addressed.

WebEOC Utilization (Operational Communications, Situational Assessment):

- Some agencies and departments did not utilize WebEOC for purchase requests, which would have allowed for real-time updates. Often City and County departments were ordering the same supplies as their counterparts, as these requests did not show up in WebEOC.
  - **Recommendation 5.11:** City, County, and other emergency response agencies and departmental leadership should ensure that personnel who require access to WebEOC have the ability to receive adequate training on WebEOC. Additionally, supervisors should ensure these personnel have accounts setup and are consistently utilizing WebEOC to input purchase requests. WebEOC should be utilized for purchase requests to help avoid double-ordering of supplies by providing situational awareness of current requests. Lastly, a process should be outlined for departmental operations centers to add their information in WebEOC in a way that provides extra logistical awareness but that is separate from EOC logistics.
- Some purchasing personnel with the same responsibilities had different “roles” in WebEOC, which gave them different abilities. Similarly, some agencies and departments did not have the same access as their counterparts.
  - **Recommendation 5.12:** The City and County should work with the CAPCOG WebEOC Administrator to modify “roles” in WebEOC to provide similar roles with the same access. These roles should be pre-identified and updated regularly outside of emergency incidents.
- Serial numbers and other identifying information for equipment, mainly vehicles, was not input to WebEOC. This made essential elements of demobilization and cost recovery (including tracking equipment and their status) difficult as personnel had to physically go out to locate and verify serial numbers for equipment that was being demobilized or needed to be replaced.

- **Recommendation 5.13:** The City and County should explore the use of GIS and WebEOC integration to support collecting and entering detailed information on serialized equipment into WebEOC to include last known location and status.

WebEOC Capabilities (Operational Communications, Situational Assessment):

- Currently WebEOC only shows purchasing request tasks as a checklist with entries for accepted, assigned, working, and completed, with no specific information on who, what, when, or the allowance for additional information to be input. WebEOC can display a summary for individual stations, but not an overall summary screen for the entire logistics section to show status and updates.
  - **Recommendation 5.14:** Austin HSEM and Travis County OEM personnel should collaborate with City and County purchasing office personnel and CAPCOG to explore and/or create updates to WebEOC that can provide additional purchasing request task assignment and status information, as well as to provide a logistical overview for an operation that can be displayed throughout the EOC.

Leveraging Resources (Logistics and Supply Chain Management):

- There were issues in locating necessary resources in a timely manner, specifically personnel with specialized qualifications, as well as understanding the requirements needed for these personnel. For example, some departments initially contacted non-logistical departments to locate personnel with certain logistical qualifications (e.g., forklift drivers), rather than first contacting logistics who can locate these individuals and also know the requirements and restrictions for specific qualifications and certifications. Mutual aid requests bypassed the Logistics request system and the demobilization process.
  - **Recommendation 5.15:** City and County departments and agencies should create lists of available resources and assets that are regularly updated and shared with others. Reusable resources should be shared among departments before purchasing new resources.
  - **Recommendation 5.16:** The City and County should explore establishing additional requirements contracts for routine use that have emergency clauses that can be tapped for emergency needs. For example, Austin Water has requirement contracts for their routine needs. These contracts have an emergency provision that requires the contractor to provide 24-hour point-of-contact and an “emergency response” surcharge rate.
  - **Recommendation 5.17:** The City and County need to better understand mutual aid processes and develop a policy and process for accepting and providing mutual aid, to include approval, demobilization planning, legal, and cost recovery issues.

Focus Area 6: Communications

Focus Area Introduction

Summary

Communications were critical throughout the Colorado River flooding and subsequent boil water notice incident. As flooding began, communication between the LCRA, Austin HSEM, and Travis County OEM was critical for Austin HSEM and Travis County OEM to be able to start to understand potential impacts on the City and County as flooding occurred at the Llano River and Colorado River. Public information grew in importance as flooding around Lake Travis began to occur and the first residents in the region were directly affected.

Communications became most critical on Sunday, October 21, 2018, when the Austin Water Director recommended to the Austin City Manager to initiate a pre-emptive boil water notice. This created the need for increased public information and notification of the boil water notice. Public notice included usage of the Warn Central Texas regional notification system and a press conference at 6 a.m. on Monday, October 22, 2018. Additionally, social media and existing relationships with media outlets were effectively utilized to inform residents of the situation and available assistance. Initially, there were some interagency coordination challenges which resulted in not all agencies and departments receiving word of the boil water notice as early as they would have hoped. There was a communications gap between the EOC and Austin 3-1-1. Once the communication processes about the boil water notice got going, however, things went smoothly. Public information services quickly dropped off however after the boil water notice was lifted on Sunday, October 28, 2018.

While communications overall went smoothly, major communication decisions came primarily from the City. The City has a dedicated PIO that when activated remains in the position until the end of the EOC activation. Travis County on the other hand does not. County resources were stressed and not all communication services were effectively conducted. Additionally, operational communications between AISD and the EOC became a major challenge. The State stepped in to support the RSA efforts of AISD, which resulted in limited communications between Austin HSEM and Travis County OEM.

Related Core Capabilities

- Public Information and Warning
- Operational Coordination
- Planning

Strengths

Public Information (Public Information and Warning):

- Once communication with the public was initiated, it was well-executed. In press conferences, staff provided useful information and it appeared organized. Staff involved with public information in the EOC were actively supporting operations and flexible. Throughout the region, those who fill the PIO role all maintain strong personal relationships which helped coordination and effective public information. Messaging was developed in six languages. Additionally, the City and County have developed good relationships with the media which allowed for accurate and swift dissemination of public information through media outlets.
    - **Recommendation 6.1:** Austin PIO should maintain relationships with regional PIOs in order to maintain effective regional public information coordination.
    - **Recommendation 6.2:** The City and County should continue to maintain strong relationships with the media in order to maintain public information dissemination channels.
- AFD effectively instituted appropriate press interaction protocol at the water POD sites, referring press back to the EOC for centralized management of messaging.
    - **Recommendation 6.3:** Austin HSEM and Travis County OEM should conduct training with POD managers regarding how to manage media relations.
- State (TCEQ) rules require specific language be included in written notices to the public (customers), along with some latitude to include additional language. The City PIO was able to interpret this technical language into simpler terms to effectively convey the message to the public. Austin Water was also able to provide this language in an email mailer after the incident, in a non-intimidating way to ease the minds of the public.
    - **Recommendation 6.4:** City and County staff should use this as an example for simplifying complex information to the public and continue this practice.
    - **Recommendation 6.5:** City and County staff should work with those who have the technical knowledge to ensure the simplified language disseminated to the public is accurate and sufficient, in addition to the language that is being disseminated to meet regulatory requirements.
- Approaching Sunday, October 28, 2018, when the boil water notice was to be lifted, Austin HSEM and Travis County OEM carefully considered the test results coming from the TCEQ prior to addressing the public though media was producing news implying the boil water notice would certainly be lifted on Sunday.
    - **Recommendation 6.6:** The City and County should continue to utilize technical data when communicating with the public and media, involving agencies with subject matter expertise in a particular area in the development and dissemination of the communication.

  - **Recommendation 6.7:** The City and County should keep the media apprised of the decision-making process, when possible, related to operations in order to provide consistent messaging.
- The use of social media during the incident for communication with the public was better than previous incidents. Posts were more frequent, relatable, and used less formal language to speak to the public. In addition, the County was able to coordinate with the Travis County Information Technology Services Web Team to provide situational awareness to the responders in the EOC.
  - **Recommendation 6.8:** City and County Staff should continue to utilize accessible and relatable social media communication. This should include creative communications, including videos and other visual communication.
  - **Recommendation 6.9:** The City and County should develop a proactive approach to social media, including assigning employees to monitor social media in support of agency coordination. The City and County should develop a digital operations center where these assigned employees would activate to.

Coordination with Public Officials (Public Information and Warning):

- Throughout the EOC activation, the majority of city, county, state, and federal staff and officials were up-to-date on the status of operations in the EOC and in field operations during the boil water notice response. Intergovernmental relations representatives for the City were in the EOC and able to provide a connection point for local and elected officials. However, while these representatives were the primary source of information from the EOC, they were not always the source from which elected and appointed officials were seeking information.
  - **Recommendation 6.10:** Austin HSEM and Travis County OEM should continue to maintain good coordination with state and federal staff during EOC activations.
  - **Recommendation 6.11:** The process for engaging intergovernmental relations staff in the EOC should be documented, clarified, and socialized with elected and appointed officials.
  - **Recommendation 6.12:** Austin HSEM and Travis County OEM should meet with state personnel in a non-disaster setting to better understand state processes in an emergency, to include mutual aid.

Language Access (Public Information and Warning)

- Even with resource challenges, the language access personnel were able to use the City's language access to plan to identify the six most commonly spoken language in Austin, outside of English and Spanish, and translate critical information into those languages.

Areas for Improvement

Interagency Coordination (Planning, Operational Communications, Public Information and Warning):

- The decision to establish the precautionary boil water notice was made when Austin Water arrived at the EOC on the evening of Sunday, October 21, 2018, but agencies and departments were informed about the boil water notice at different times. This was a challenge because some agencies/departments (Austin 3-1-1, Travis County Sheriff's Office) felt like they were not informed early enough and with enough detail to prepare for the consequences of the boil water notice, which made planning for and responding to the announcement of the boil water notice challenging.
    - **Recommendation 6.13:** Austin HSEM and Travis County OEM should consider a process to inform all City and County staff when an activation occurs to create an understanding that the City and County are responding. From there, Austin HSEM and Travis County OEM can communicate with agencies that need to mobilize to the EOC.
    - **Recommendation 6.14:** Austin HSEM and Travis County OEM should create a process of informing agencies and departments as soon as possible of incident information, making note of information that is public, or that is "For Official Use Only."
    - **Recommendation 6.15:** City and County health departments should identify public health information for internal agencies and departments, concurrently with that for residents and commercial businesses to support continuity within government operations.
- There was a specific gap in communication with Austin 3-1-1. Austin 3-1-1 is the first point of contact for the community, but Austin 3-1-1 did not have a representative in the EOC until the morning of Monday, October 22, 2018. Austin 3-1-1 had sufficient information for residential calls, however they did not have sufficient information for commercial calls and information was slow getting to wholesale customers. Austin 3-1-1 was unaware that APH was in the process of developing the commercial customer information but had encountered a barrier related to the Health Authority approval process.
    - **Recommendation 6.16:** Austin HSEM and Travis County OEM should request an Austin 3-1-1 presence in the EOC earlier to ensure they can communicate accurate, timely, and helpful information to the public.
    - **Recommendation 6.17:** The City and County should continue to utilize third-party groups, such as professional associations, to assist in collecting and disseminating information. Communicating and coordinating with these groups outside of emergency incidents through planning meetings and exercises will increase efficiency during future responses.
    - **Recommendation 6.18:** The City and County should consider the development and use of a communication diagram to map out audiences and message flow to support crisis communications.
- There was a challenge in the approval process for APH in providing information to Austin 3-1-1. APH staff needed approval from leadership who was unavailable and as they were at the EOC.

This delayed the information being sent to Austin 3-1-1. There was no communication between Austin 3-1-1 and APH during this time.

- **Recommendation 6.19:** APH should streamline the process of getting information approved to send to and updating Austin 3-1-1.

- CTM personnel who maintain the City's website were not initially notified of the incident and the role the website would be playing in the provision of public information. As a result, the website was not prepared to receive the amount of traffic that it did when it was being used for information about the boil water notice and it crashed. Austin HSEM has already revised notification processes to ensure CTM is included early on.
  - **Recommendation 6.20:** Austin HSEM and Travis County OEM should coordinate with all public information partners, including digital, to ensure effective preparation for the increased inquiries and web traffic.
- There was a breakdown of operational communications between the EOC and POD sites (including the Travis County and Williamson County sites). There does not seem to be a reliable way for real-time, on-the-ground, consistent information to make its way back to the EOC for digestion, analysis, and redistribution. Moreover, Williamson County POD operations were caught off guard by the end of the boil water notice.
  - **Recommendation 6.21:** The EOC should reevaluate situational awareness protocols, including interagency communications, to establish communication channels for all operational areas during activations.
- The back section of the EOC is very crowded during activations between the PIO desk, the GIS desk, and the Austin 3-1-1 desk. This creates a challenge for employees to effectively fulfill their assigned mission during the EOC activation and productively collaborate. That said, not all public information officers were consistently present for EOC operations which created challenges in disseminating information in a cohesive fashion.
  - **Recommendation 6.22:** The City and County should evaluate the allocation of space in and around the EOC to be inclusive of a Joint Information Center (JIC), and to support GIS needs.
  - **Recommendation 6.23:** Applicable City and County agencies and departments and the State should assign a public information liaison to the EOC to assist in more effective operational communication.
- Public information from the EOC is strongly led by the City Communications & Public Information Office's (CPIO). There is a lack of a dedicated PIO during EOC activation for the County; representatives from the County maintain their normal workloads. Many decisions related to public information dissemination were made by the City and conveyed to the County afterwards, making it challenging to provide a full range of public information services for the County.
  - **Recommendation 6.24:** Travis County should identify employees to fill PIO positions during EOC activations.

  - **Recommendation 6.25**: The City and County should implement additional training for individuals filling the PIO positions. The City and County should consider implementing mutual aid and standby contracts for PIO support.
- A virtual JIC was activated during the incident; however, it was primarily run and utilized by the City rather than the County resulting in a reduction of communication during the recovery phase of operations which impacted the County more than the City.
  - **Recommendation 6.26:** The use of a virtual versus physical JIC should be examined to ensure all public information-related operational needs are met in all phases of an incident.
  - **Recommendation 6.27:** The JIC plan should be re-examined to ensure all key partners are included in the planning, and operational processes. Where gaps are identified, the City and County should prioritize, and determine how to best fill those key gaps.

Public Notification (Public Information and Warning):

- The Warn Central Texas notification was not disseminated in a timely manner, going out at 5:25 p.m. on Monday, October 22, 2018, when it should have gone out in the morning when the boil water notice was announced. Additionally, Warn Central Texas subscribers are limited compared to the impacted population in this incident.
  - **Recommendation 6.28:** The City and County should continue to work towards maximizing the use of already existing warning tools.
  - **Recommendation 6.29:** Austin HSEM and Travis County OEM should work with agencies with customers in the region to utilize their customer information for public notification (e.g., Austin Energy collaborating with Austin HSEM and Travis County OEM staff to subscribe customers; work with APH to notify permitted buildings related to food safety standards).

Public Information (Public Information and Warning):

- There were inconsistencies in messaging regarding the amount of time required to boil water and a lack of language in the public notification noting the dangers associated with boiling water (e.g., the caution of using gas to boil if oxygen-dependent). These two considerations resulted in confusion from the public regarding the boil water requirements.
  - **Recommendation 6.30:** The EOC should clarify the language used to direct the public during incidents and consider the safety information required for their notices.
- The EOC SOP identifies a Warning Officer, but this role is not currently staffed. Other EOC personnel had to write public notices in addition to their other tasks, stressing resources.
  - **Recommendation 6.31:** Austin HSEM and Travis County OEM should staff the Warning Officer whose role is to document and understand the situation and produce public notices.

- Public information services quickly fell off once the boil water notice was lifted. This presented a challenge for maintaining effective public communication about ongoing recovery operations pertinent to community members (e.g., MARC).
    - **Recommendation 6.32:** EOC staff, including those in the JIC, should monitor operations and continue support throughout the recovery phase. The expectation for maintaining operations throughout recovery should be included into all EOC trainings and personnel role documentation.
- Communication to the public regarding water conservation actions was not well publicized and limited to reactive measures.
    - **Recommendation 6.33:** The City and County should work with infrastructure partners to establish a public communications plan inclusive of timely and proactive conservation practices to mitigate potential system compromise.

Language Translation and Accessibility Services (Public Information and Warning):

- The process for translation services was not well understood and led to an inconsistency with translated documentation throughout the operation. Not all agencies/departments were able to get materials translated efficiently during the incident. During this incident, two Spanish-speaking PIOs happened to be in the EOC and were able to translate some materials. However, as this was not their primary role in the EOC, their focus needed to be on their dedicated role. Each agency in Austin is charged with developing a language access plan to support their vital services. Currently, outside of leveraging the CPIO standby contracts for language access services, this does not exist for the EOC. CPIO did activate their standby contracts during this incident, but these contracts are not written for emergency situations and therefore, were not able to provide the amount of support needed.
    - **Recommendation 6.34:** Austin HSEM and Travis County OEM, supported by CPIO and the CPIO Language Access Program Coordinator, should develop a language access plan specific to the emergency management related activities. The language access plan should include measures for how responders should submit requests for translation support during incidents, as well as a management framework for language access support. This plan should be supplemented by pre-established standby contracts.
    - **Recommendation 6.35:** Austin HSEM and Travis County OEM staff should consider organizing a specific City / County translation services team who can activate with the EOC and devote time and resources to translation services. This team could consist of VOAD members if they have been certified through the language access program or vendors that the CPIO's office has already contracted with.
- Warn Central Texas allows for users to select whether they want to receive alerts via phone call or text message, but does not meet the needs of the full access and functional needs (AFN) population, such as those who are blind, deaf, and hard-of-hearing, to receive alerts in the manner that is most suited to their needs. During this incident, the City was able to access DeafLink

through the City of San Antonio, which helped to disseminate accessible communications. However, the City does not have access to this service itself.

- **Recommendation 6.36:** The City and County should re-examine policies and limitations to notification systems and modify existing systems or procure new systems to ensure there is a streamlined process of providing notification and information to AFN communities. If the current system is identified as appropriate, the City should seek to expand the registry for this system to include more of the AFN community.

Focus Area 7: Recovery

Focus Area Introduction

Summary

After the EOC was deactivated on October 29, 2018, a limited staff remained in the EOC to continue the coordination of recovery efforts. Austin HSEM Office of Financial Services had their personnel involved early in the recovery phase, which was a major improvement from the Harvey response when they were brought in later on and had to essentially play catch up. On November 5 and 7, 2018, respectively, MARCs were established in Lago Vista and Lakeway in conjunction with regional partners to provide information and services such as financial assistance, long-term recovery assistance, and case management to those impacted by the flooding. The planning and operation of the MARCs went very well, and MARC personnel were able to adapt easily to changes that arose. Communication regarding the MARCs, both to the public and to City and County leadership, was the main challenge stemming from the MARC operations. Information regarding the MARCs should have been released to the public earlier to allow them sufficient time to take advantage of their resources.

The assistance provided by VOADs in setting up and working in the MARCs was invaluable. They were able to provide thorough assistance to the community and should be utilized in planning future responses. However, communication with VOADs and other regional partners was challenging during the subsequent damage assessment process. There were numerous damage assessments conducted with delays in information sharing. Increased communication and coordination during this process could have facilitated a more comprehensive and better-aligned assessment among partners.

Related Core Capabilities

- Economic Recovery
- Planning
- Operational Coordination
- Infrastructure Systems

Strengths

Multi-Agency Resource Centers (Planning, Operational Coordination):

- MARC planning and operations went very well, improving from lessons learned experienced during Hurricane Harvey. The time between the decision to activate MARCs and the MARCs' setup was sufficiently short. Additionally, MARCs were able to adapt easily as operational changes occurred.
    - **Recommendation 7.1:** Austin HSEM and Travis County OEM should continue to encourage regular coordination and communication between personnel involved in

MARC operations, to include regional partners, outside of emergency incidents, such as through planning meetings, workshops, and exercises.

VOADs (Operational Coordination):

- VOAD members were able to provide thorough assistance to community members. Previous working experience with these VOAD partners, such as the Harvey response, enabled effective communication and coordination.
  - **Recommendation 7.2:** The City and County should collaborate with VOAD partners to build a pre-identified list of available resources that each VOAD would be able and willing to contribute to future responses.

Finance (Operational Coordination, Planning):

- City of Austin financial personnel were involved early in the response and provided templates, instructions for compiling expenses, and a repository on SharePoint for gathering documentation. Finance managers city wide showed a tremendous level of flexibility. Getting state-level finance personnel involved in conversations with City and County finance staff provided them with clarification on finance issues.
  - **Recommendation 7.3:** The City and County should continue to engage their respective finance personnel early in future responses, as well as facilitate meetings and exercises outside of emergency incidents. The City and County should continue to proactively coordinate with state partners to ensure effective collaboration during response operations. City and County finance should explore where their processes and tools align so that the EOC Finance Officer can provide financial direction to representatives of both jurisdictions, rather than solely communicating City of Austin codes and processes, as was the case in this event.
  - **Recommendation 7.4:** Emergency-focused financial capability should be enhanced so that financial activities, such as modification of expense templates and instructions for a specific event, can continue while the EOC Finance Chief is still activated in the EOC. Explore developing separate roles for different emergency-focused financial activities (e.g., providing city and county wide financial direction and tools, creating the daily burn rate, developing the Disaster Summary Outline, and providing financial support for Logistics). Depending on the scale of the event, these activities may require multiple personnel to complete. Training should be given to personnel in these areas.

Areas for Improvement

Damage Assessment (Planning, Economic Recovery):

- Windshield surveys and other damage assessments conducted following the flooding did not correspond with one another, creating challenges in understanding who was eligible for assistance. Both the American Red Cross (ARC) and Travis County conducted damage assessments but did not coordinate their efforts resulting in some amount of duplication and potential gaps in information. Damage assessments conducted by Travis County were not used to inform the need or location of local recovery facilities (e.g., MARCs), rather they were exclusively used in coordination with state and federal agencies. Had coordination and communication of damage assessment processes and reports been more uniform among the involved stakeholders, MARCs could potentially have opened earlier.

- **Recommendation 7.5:** The City and County should facilitate damage assessment tabletop discussions and exercises outside of emergency incidents in order to improve coordination and communication among stakeholders, particularly VOADs and other regional partners.
- **Recommendation 7.6:** Damage assessment planning should incorporate an assessment of the unmet needs of the community, instead of solely focusing on infrastructure, to inform need for facilities and debris pick up and communication with VOADs to reduce duplication of efforts.

Multi-Agency Resource Center Planning and Communication (Planning, Public Information and Warning):

- There are multiple plans that address family assistance. This needs to be streamlined across the City and County.
  - **Recommendation 7.7:** The City and County should identify and align the recovery related plans across City and County agencies. The City and County should maintain awareness of the respective planning cycles for recovery related plans to ensure participation by the appropriate agencies in the plan update process.
- There were issues surrounding the release of information about the MARCs to the public. Initially there was no media presence at the first MARC located in Lago Vista, which would have been ideal at the beginning of the MARC operations. This would have increased the public’s initial awareness of the resources and services available to those impacted. There was an increased media presence at the second MARC located in Lakeway after it appeared on social media, and as a result this MARC had a larger turnout for individuals seeking assistance.
  - **Recommendation 7.8:** City and County PIOs should ensure that information regarding the recovery centers is advertised to the public early on in an incident. PIOs should follow up through the entire recovery process to ensure the public receives regular information updates.
  - **Recommendation 7.9:** The City and County should explore and develop plans for establishing a mobile MARC, as well as having an online presence to provide information to the public.
- The MARCs were operating in parallel with VOAD resource centers, although the resource centers began operations before the activation of MARCs.

  - **Recommendation 7.10:** The process for identifying the need of MARCs should be coordinated and consolidated with VOADs and other partners so as to limit logistical needs, duplication of efforts, and confusion to the public.

Multi-Agency Resource Center Location (Planning):

- The location of MARCs was not optimal. This was due to multiple factors including the lack of a consolidated picture of where the impacted community members lived, the absence of a damage assessment informing MARC operations, the lack of collaboration between government and non-governmental entities on unmet needs assessments, and a general misunderstanding of which homes were primary versus secondary properties.
  - **Recommendation 7.11:** The City, County, and VOADs responsible for setting up MARCs should collaborate with other organizations that can assist in identifying areas with greater potential need for assistance. For example, Travis County Transportation & Natural Resources (TNR) can help identify which areas would most likely consist of primary residences versus areas that would most likely consist of non-primary residences. Gaining a better demographic understanding of those impacted will help predict demand for assistance.
  - **Recommendation 7.12:** City and County departments and agencies should work together to develop a cohesive process for determining impacted community members and unmet community needs throughout response and recovery. The City, County, and other departments and agencies should coordinate with partner agencies in advance to determine impacted community members and the unmet needs of the community.
  - **Recommendation 7.13:** The City and County should use applicable data sets to determine the impacted areas and how that compares with identifying needs (e.g., secondary homes will require different, most likely limited, recovery services).

Cost Tracking and Reimbursement (Economic Recovery):

- FEMA requires supporting documentation to back up expense and damage estimates and determine if expense reimbursement thresholds have been met. The State was under their necessary threshold, so there was increased pressure on the City and County to rapidly (during the activation and immediately after) identify all eligible expenses to see if they reached the necessary threshold.
  - **Recommendation 7.14:** Austin HSEM and Travis County OEM should explore automating cost tracking processes and utilizing contractors in order to reduce the burden of compiling supporting documentation for FEMA.
  - **Recommendation 7.15:** Travis County OEM and Travis County Planning & Budget Office should develop plans to track volunteer hours. Travis County OEM and Travis County Planning & Budget Office should become familiarized with the supporting documentation required to track volunteer hours.

- Effective cost tracking requires continuous and specific data collection throughout the incident. To be able to receive maximum reimbursement following an activation, the City and Travis County personnel, outside of Austin HSEM and Travis CountyOEM personnel who manage recovery on a regular basis, need to be aware of reimbursable costs and cost tracking processes and policies. Simple technological improvements, such as an electronic sign-in system, can further expedite the compilation of documentation.
    - **Recommendation 7.16:** A Disaster Cost Recovery Plan should be developed by the City and County, clearly identifying all roles, responsibilities, triggers, and operations for cost recovery functions, beginning with pre-disaster activities, through conclusion of said activities (e.g., closeout activities). All pertinent departmental representatives should be trained on the plan and their specific responsibilities to ensure procedures are effectively implemented.
    - **Recommendation 7.17:** City and County finance personnel should receive cost recovery training and should have an opportunity to coordinate and communicate outside of emergency incidents through planning meetings and exercises, particularly the planned logistics exercise. Additionally, instructions on how to accurately read payroll reports should be provided and trained on in a non-disaster setting.
    - **Recommendation 7.18:** The City and County should explore utilizing automated check-in/check-out systems in the EOC. This will ensure more accurate personnel time and compensation tracking.

Debris Removal (Infrastructure Systems, Operational Coordination):

- There was confusion among departments as to the time and frequency that debris would be picked up by TNR. TNR had to get permission from the Commissioners Court to go on private property.
    - **Recommendation 7.19:** City and County agencies involved with debris removal should provide a brief of the debris management process to the EOC staff during activations.
- There was an overarching lack of information disseminated to the public on debris removal, such as the amount and type of debris to be collected.
    - **Recommendation 7.20:** The City and County should facilitate planning meetings with City and County agencies involved with debris removal and City and County PIOs outside of emergency incidents to gain a more comprehensive understanding of their debris removal procedures. Subsequently, Austin HSEM, Travis County OEM, and TNR should collaborate to develop a joint plan on debris removal procedures for future responses.
    - **Recommendation 7.21:** City and County PIOs should communicate information regarding debris removal to the public as early as possible, with an emphasis on identifying outreach methods to individuals in the impact area. This will help alleviate debris build-up and make removal more manageable for TNR.

Economic Impact (Economic Recovery, Planning):

- During the boil water notice, numerous businesses were impacted. However, an overall economic impact analysis was not being conducted by any official City or County agency, at the time of this report writing. The ability to show the cost and economic impact of an emergency incident, or even an estimate, would be beneficial in preparing for future responses and recovery efforts.
    - **Recommendation 7.22:** The City and County should update their damage assessment plan to make sure businesses are assessed post-incident.

Focus Area 8: Resilience

Summary of Workshop Outcomes
January 17, 2019
Austin, TX

Executive Summary

The Colorado River flooding and subsequent boil water notice in October 2018 caused a series of cascading impacts in Austin and Travis County that exposed the need for the City and County to prioritize developing a culture of resilience throughout their government departments and agencies and broader community as a whole, in order to be better prepared for hazards and threats as well as be more adaptable for a changing climate. While the City has worked to develop a definition for climate resilience, Austin HSEM and Travis County OEM need to come together with the Austin Office of Sustainability as well as governmental agencies and departments in order to develop a holistic definition of resilience, discuss what a resilient community would look like, and collectively create a plan for moving towards resilience.

As a part of this process, in conjunction with the Colorado River flooding AAR process, a Resilience Discovery Workshop was conducted. On January 17, 2019, a self-selected group of 15 participants from agencies and departments impacted by the Colorado River flooding and subsequent boil water notice worked to think through the cascading impacts of potential hazards to improve resilience in the City and County.

Summary of Workshop Outcomes

The following sections provide a general overview of the themes discussed, identify where the City and County currently are in relation to the theme, and describe the priorities discussed during the workshop. The bulleted points are actions the City and County should consider moving forward in order to move towards resilience.

Defining Resilience for the Austin-Travis County Region

The City of Austin's Office of Sustainability has been working to define climate resilience for the City, where "a climate resilient Austin is prepared for and responsive to extreme weather events and changing climate conditions" (City of Austin Office of Sustainability). This definition was strategic, outlining the need for Austin to be both prepared for an event before it happens, and also build back better after the event occurs. Defining climate resilience for the City has allowed for the theme to become integrated into all elements of the City's government. Moving forward, Austin and Travis County should consider:

- **Expanding the definition of resilience:** The City's definition of climate resilience is a valuable launching point; however, resilience should incorporate more than climate. Critically, a resilience definition should include acute technological and adversarial hazards as well as long term stressors such as the economy and how these hazards and stressors affect the community. This definition should include language outlining the need to build back better after an incident. This will assist to bridge the gap from the initiatives that the Austin Office of Sustainability initiating and the standard operations of Austin HSEM and Travis County OEM.

- **Define framework for resilience analysis:** A comprehensive framework for analysis of resilience should be created and applied in order to define the founding principles of resilience for the City and County. Consider defining priorities for resilience, e.g., lifeline sectors or the economy, to focus analysis of City and County resilience. This will help to unite stakeholders around common goals and provide a frame of reference for thinking through resilient issues.
- **Define metrics for resilience assessment:** A variety of matrices or methodologies exist for resilience assessment. Determining metrics for resilience, which align to the determine framework for understanding resilience in the context of the City of Austin and Travis County is critical to understand if the City and County are succeeding in efforts to become more resilient. Metrics allow for measurement resilience of overtime.

Infrastructure

Currently, infrastructure in the City of Austin and Travis County effectively services its community members. However, this does not mean that it is resilient. The Colorado River flooding and subsequent boil water notice provides one example of a vulnerability in Austin and Travis County's infrastructure network. This was illustrated through the cascading impact from the flooding event of the boil water notice. Austin HSEM and Travis County OEM staff considered the gravity of an incident involving a power grid failure or a cyber security incident. Austin HSEM has a critical infrastructure committee which has initially considered these issues, but it has not met in about a year and a half because of numerous competing priorities, real-world incidents, and special events. Considering resilience for infrastructure agencies is currently a second priority, staffing shortages and resource limitations prevent long-term resilience planning. Moving forward, Austin and Travis County should consider:

- **Reconvening and enhancing the Austin HSEM critical infrastructure committee:** Considering critical infrastructure preparedness is a key component of resilience. Austin HSEM should reconvene the critical infrastructure committee to reprioritize this amongst the other preparedness practices.
- **Prioritizing restoration of critical facilities and infrastructure redundancies:** Austin HSEM, Travis County OEM, the Office of Sustainability, and relevant agencies and departments should come together to understand critical infrastructure interdependencies and make decisions about what priorities exist for service restoration. This can be helpful to plan ahead of time in order to reduce the burden hazard events have on infrastructure.
- **Develop a conservation-based approach to infrastructure stressors:** The City and County, when faced with infrastructure stressors, should take a proactive conservative approach to mitigate potential system compromise.

- **Enhance critical infrastructure assessments:** Enhance existing infrastructure assessments to determine the vulnerabilities in the infrastructural system. This will help to determine what needs to be enhanced in the COOP plan.
- **Transition critical facilities to function off the grid:** Explore how to take Austin and Travis County's critical facilities off the energy and water grid. The first step in this process would be to address government owned buildings as an example for best practices in the City and County. This is both a sustainable practice and increases disaster preparedness. This would minimally allow the ability to provide external sources of energy and water should the grid fail.
- **Planning for investment in resilient infrastructure:**
    - **Developing shared priorities for infrastructure investments:** Evaluate shared resilience priorities of diverse government agencies and departments in order to establish where shared goals are.
    - **Conducting an assessment of assets:** Expand an assessment of government assets to determine the current state of government infrastructure. Determining the current state of government infrastructure will assist in developing an argument for capital investment and help to bridge the gap between goals and funding.
    - **Considering priorities for investment:** Establish priorities for investment by considering costs and benefits associated with projects. Consider the options for assessment; amongst those options, consider which are cost effective now, which are necessary for their life-saving nature, which should be utilized in new construction. This will help uncover which specific projects should be pursued and help the best projects be prioritized.
    - **Establishing co-benefits of infrastructure projects enhancing resilience:** It is often hard to fund forward looking infrastructure projects, especially in non-disaster times. By establishing co-benefits, additional benefit and additional funding can be established, which reduces burden of the cost of projects.
    - **Providing opportunities for leaders to hear information about the resilience philosophy:** Allow decision makers opportunities to be brought into the benefits and necessities of resilience. This will help to create buy-in for forward leaning concepts with co-benefits, and ultimately a more enhanced culture of resilience throughout Austin and Travis County.
- **Considering the network impacts on traffic:** Roadway infrastructure should be considered during discussions of hazard events. There are national examples of major cascading impacts of traffic jams from traffic not being considered when decisions related to preparedness are made (e.g. early school release).

- **Integrating the resilience hub concept throughout the region:** The Office of Sustainability has been investigating resilience hubs, community facilities that are designed to support residents in their own neighborhood by providing resources and services before, during, and after hazard and threat events, as a method of building resilience in the region. Strategies for funding and implementing resilience hubs should be further developed. This would allow for dual use structures to enhance resilience.

Community Assets

Schools

Currently, AISD schools may have some focus on resilience, but a major challenge is that their first priority will be children, teachers and education – which leaves limited resources for resilience building. Leaders in the school system do not prioritize disaster preparation, therefore when hazard events occur, they are under-prepared and often unwilling to utilize resources to assist them. AISD is underprepared for hazard events. During this incident, they did not have enough information to understand the extent to which Austin High would be affected with its proximal location to the water. Moreover, AISD was not capable of individually addressing the impacts of the boil water notice with their capacity to boil water and serve food. A consortium of schools exists to support with regional school district preparedness, but AISD is the only district to participate in preparation and activations. Moving forward, Austin and Travis County should consider:

- **Understanding the full extent of services schools perform:** AISD emphasized that schools provide three meals a day for many students. Additionally, they allow parents to go work in the community. When AISD schools close, this sends a rippling impact throughout the City as employees have to stay home from work, and children may miss meals they traditionally depend on. Schools are also bound by a calendar, therefore becoming more able to function outside of their day to day norms in off-seasons, though with a reduction in personnel to support supplemental operations. Fully understanding the extent of services schools perform will help the City and County prioritize and plan for hazard events and more broadly understand the cost and impact of their decisions.
- **Considering need:** Schools had a lack of understanding of their need in this situation. Schools should include planning for various types of infrastructure disruption or failure during hazard events to in turn communicate need to Austin HSEM and Travis County OEM better.
- **Encouraging additional participation in the school consortium:** Gaining additional buy-in from school consortium members would help create collaboration and support towards greater preparedness throughout the region.
- **Utilizing schools as a method to promote community resilience:** Schools have constant contact with a large quantity of community members. Schools should be utilized to promote community resilience, prevent public panic, and help communities understand the government's role and plans during hazard events. Schools are a particularly great opportunity to promote resilience amongst community members for whom language is a second language as students are able to pass along information to their parents.

Health Care Facilities

There were 13 hospitals affected by the boil water notice. By law, hospitals in the State of Texas are required to have 500 gallons of water, or 12 gallons of water per patient bed, stored on site. However, not all hospitals have this on site. During the incident, ensuring hospitals had sufficient water was seen as an initial immediate need and high priority. Surgeries were cancelled during the first days of the boil water notice, until they could work with vendors to determine if they could use their sterilization equipment. Moving forward, Austin and Travis County, in conjunction with the local hospital community, should consider:

- **Retrofitting health care facility infrastructure:** The majority of hospitals did not have a method to accept bulk water from a tanker. Retrofitting hospitals to be able to accept and store large quantities of water will directly improve preparedness. The necessity of water pressure should be considered.
- **Identifying need:** Hospitals had a lack of understanding of their need in this and other critical infrastructure loss situations. Hospitals should include planning for infrastructure loss during hazard events to be able to communicate need to Austin HSEM and Travis County OEM better. Moreover, other care facilities, such as nursing homes, should be accounted for better during incidents.

Food Establishments

Food establishments (restaurants, cafés, bars, etc.) were heavily impacted by the boil water notice. Based on limited discussions with this community, Austin HSEM and Travis County OEM observed that many were not prepared for this type of incident, resulting in the establishments closing until the resolution of the event. The full extent of the impacts on restaurants or the economy overall has not been determined, or, if it has, it has not been widely shared. Moving forward, Austin and Travis County should consider:

- **Conducting an impact assessment to the business community:** The extent of the impacts of the boil water notice on the business community are not well known. The City and County should complete a comprehensive assessment of the impacts of the boil water notice on the business community. Currently these impacts are not well understood, there was a lack of communication with food establishments during this boil water notice. Completing an impact assessment will aid in creating additional concrete corrective actions to enhance resilience and may further provide information needed to request state and federal support in future cases, like SBA disaster assistance.
- **Expanding the impact assessment for other hazard events:** The extent of the impacts of hazards and threats in general on the business community are not well known. The City and County should complete an assessment to understand the potential impacts and cascading impacts of other hazards on the business communities. This includes a database of microenterprises (especially home-based businesses) vulnerable to hazards and threats. Targeted outreach should then be implemented based on the results of this assessment.
- **Inviting additional community partners to the planning table:** There is limited interaction between Austin HSEM, Travis County OEM, and EOC representatives and the business community. The City and County should invite members of BOMA, the restaurant association, and/or chambers of commerce to become partners for resilience building in Austin and Travis County. Utilize their knowledge and connection to fill the gap in knowledge for the cascading impacts from this incident and to prepare for future incidents.

Correctional Facilities

There are several current issues with preparedness at the County correctional facilities, such as not having a plan and method of quickly evacuating inmates. Approximately 2,300 – 2,400 inmates were affected in the boil water notice incident and correctional facilities were unable to boil enough water for their inmates. County correctional facility personnel used trial-by-error to determine the best source of bottled water for their facilities. Moving forward, Austin and Travis County should consider:

- **Evaluating the preparedness of correctional facilities:** County correctional facilities discovered issues with their location and their ability to respond to hazard events during this incident. This event uncovered the value of conducting a comprehensive evaluation of the preparedness of City and County correctional facilities.
- **Developing a correctional facility evacuation plan:** Correctional facilities are not easily evacuated. Travis County has some regional agreements in place to redistribute inmates should the situation arise that inmates needed to be moved. Additionally, Travis County Sheriff's Office could work with the courts to get inmates released who are pre-trial or are close to completing their sentences. A comprehensive evacuation plan inclusive of these contingencies would increase the preparedness of correctional facilities and decrease the stress of a hazard event.

Connection between Preparedness and Resilience

Currently the City and County are working to bridge the gap between preparedness and resilience in order to create a more comprehensive program. There are currently examples of Regional, County, and City initiatives that are engaged to move towards resilience. Regionally, a Recovery Resilience Workgroup within the Homeland Security Taskforce at CAPCOG has been newly developed. The goal of this taskforce is to educate regional emergency management leaders about best practices for recovery resilience, in order to maintain communities that will recover faster. There are currently four to five counties participating from the COG. The City of Austin conducted resilience exercises several years ago where the aftermath of a power outage was considered. Austin Water is also now required to do a vulnerability assessment and ERP. Moving forward, Austin and Travis County should consider:

- **Supporting the Recovery Resilience Workgroup at CAPCOG:** Increasing participation in conversation between emergency management professionals and experts on the impacts of cascading disaster impacts will directly increase preparedness and improve recovery efforts to directly impact regional resilience.
- **Enhancing the resilience assessment conducted by the City of Austin:** Expand the resilience assessment already completed in order to be more comprehensive and to address a revised definition of resilience. Goals and metrics related to the resilience assessment should be developed to minimize gaps identified in the assessment and work towards improving resilience of the City and County.
- **Establishing a resilience initiative for Austin and Travis County:** This would involve identifying the lead of the program, for example a Chief Resilience Officer, who would have enough authority

to oversee the resilience efforts of the City and County. This would include implementation and assessment of resilience-related activities.

- **Developing a risk and resilience exercise initiative:** Repeat and enhance resilience exercises that were previously conducted. This will improve brainstorming of previously unknown potential impacts of disaster and also help agencies and departments prepare for potential incidents.
- **Utilizing technology to improve preparedness:** The City should fund a dedicated GIS position for emergency management. This would assist the City to understand the impact of climate change, natural hazards, and man-made threats using the best practices and best tools for the most effective decision making. This position would work collaboratively with agencies and organization in order to assist them to understand the geospatial impacts of hazard events. The City and County should also consider utilizing emergency management software for critical information and response management.
- **Building on the Office of Sustainability's Climate Resilience Action Plan for City Assets and Operations:** The City and County should build on the Austin Office of Sustainability's efforts to evaluate and prepare City Assets and Operations for climate change. This should include a broader definition of resilience and integration with additional plans and policies.
- **Integrating resilience into policy:** Preparedness guidance is often defined by policy, such as building codes, and can often determine project types that get funded. The City and County should work to create pro-resilience policies to create more resilient buildings and infrastructure in the region.

Integration of City and County Planning Efforts

Existing City and County planning already incorporates resilience thinking. During the Discovery Workshop, a variety of relevant plans were discussed, including: The City and County Hazard Mitigation Plans, the Water Forward Plan, the City Assets and Operations Plan, and Business COOP Plans. Currently, the City and County complete Hazard Mitigation Plans separately and on a separate schedule. The City has collaborated with the Office of Sustainability to utilize new climate projections in the mitigation plan, however that is the limit of the collaboration. Moving forward, Austin and Travis County should consider:

- **Increasing familiarity with currently available plans:** Planning affecting the resilience of Austin and Travis County is happening; either directly or indirectly. Conducting a comprehensive analysis of the existing plans is a critical step for understanding how planning can be integrated with resilience in the region. Travis County is in the process of completing such an analysis; this should be completed and updated. This should also be considered for the City of Austin.
- **Understanding interconnection between existing plans:** Through analysis or exercise of plans, Austin HSEM and Travis County OEM, in coordination with relevant agencies/departments need to understand all of the cascading impacts of plan operations, including interdependencies amongst the plans. Consideration of individual COOP plans is a particularly relevant area for analysis given this specific incident.

- **Increasing the breadth of pre-disaster recovery planning:** Pre-disaster recovery planning should be utilized as a core tool for defining short-term, interim, and long-term priorities for recovery. These goals should be directly tied into the resilience goals for the City and County. Moreover, pre-disaster recovery planning can tackle the issue of disaster boundaries and provide a framework for regional recovery that is targeted towards resilience.
- **Utilizing hazard mitigation planning as a tool for resilience building:** Hazard mitigation planning is a tool for generating resilience. At the federal level, there is a shift in funding from recovery to mitigation. The City and County have many opportunities for utilizing the mitigation planning process to generate a more resilient region. This includes:
  - More closely collaborating with the Austin Office of Sustainability throughout the planning and plan maintenance process
  - Coordinating the City and County hazard mitigation plan update timelines to generate a more regional outlook on mitigation measures and resilience
  - Integrate additional agency, departmental, and organization stakeholder partners in the planning process in order to develop a more comprehensive, actionable plan

Appendices

Survey Summary Analysis

Response Stakeholder Survey

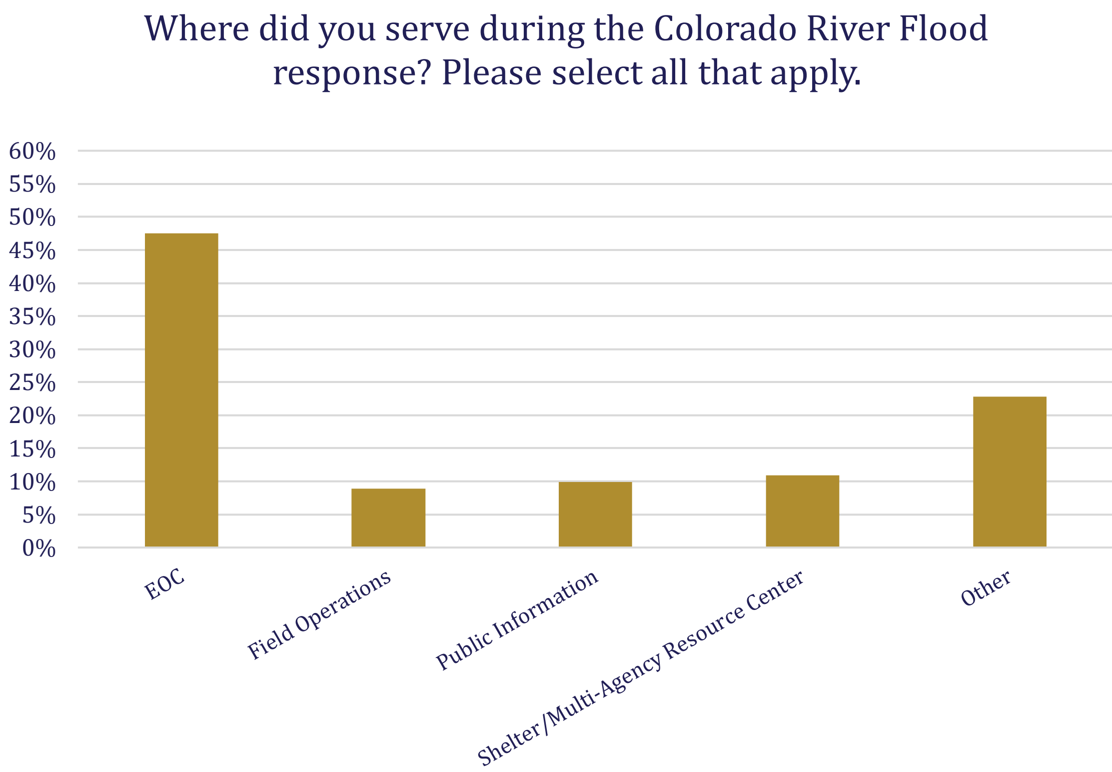
As part of the after-action process, the Planning Team invited all identified key stakeholders and actors in the response to the Colorado River flooding to participate in an online survey, which solicited targeted information about the role each respondent played in and asked respondents to rate and comment on critical components of the response, such as communications, resource management, and training. Not every respondent was asked to answer every question; instead, certain questions were included or excluded based on the answers provided to certain other questions earlier in the survey. Therefore, although a total of 114 respondents participated, the number of responses is not uniform across each individual question. A summary of the results of the online survey are captured in this appendix and are organized by the order in which the questions appeared in the survey.

Role During Colorado River Flood Response

Respondents were first asked whether they were involved in the response to the Colorado River flooding. The intent of this question was to filter out respondents who were only involved in the boil water notice response. Of the 114 total participants to the survey, 70 indicated that they were involved in the response to the Colorado River flooding (61.4 percent), while 44 indicated they were not (38.6 percent).

Respondents were then asked where they served during the flood response. There was a total of 101 responses to this question as respondents who served in more than one location were able to select all that applied. These responses are summarized in Figure 1.

Figure 1: Response Stakeholder Survey



Respondents were asked to identify their primary roles during the Colorado River Flood response. While responses varied, most fit into one of seven themes:

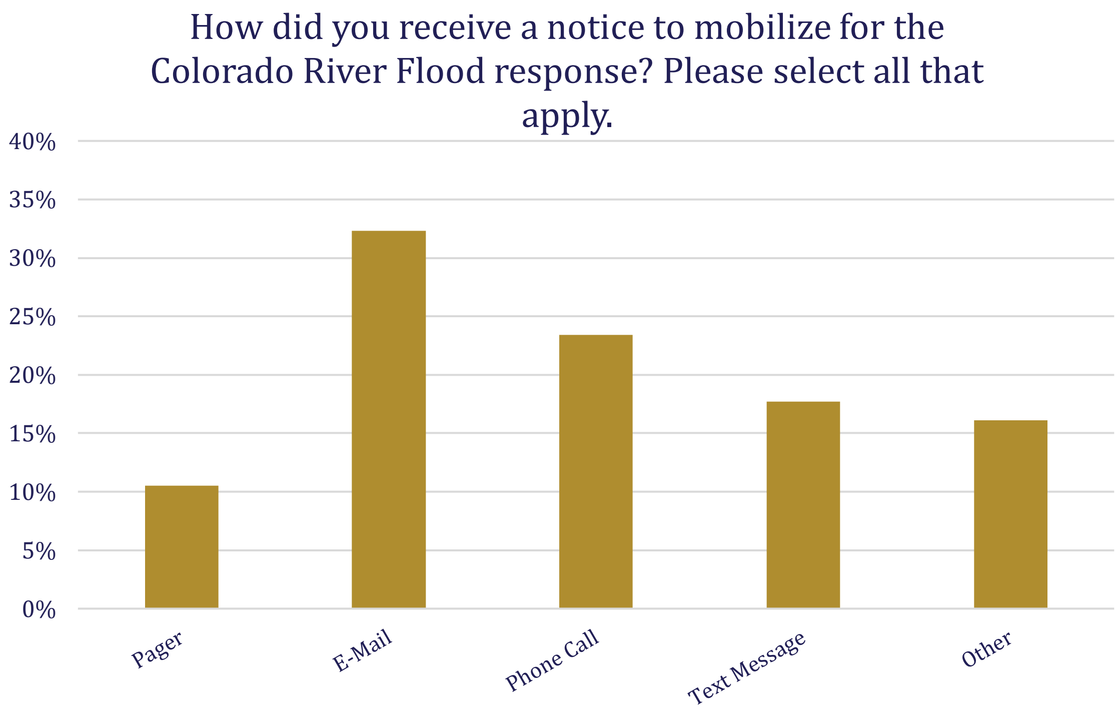
- Direction and Control (15 responses)
- Planning (11 responses)
- Logistics (four responses)
- Information Operations (13 responses)
- External Site Operations (13 responses)
- Recovery (three responses)
- Liaison (14 responses)

Participants in the Colorado River flooding response were asked if they were provided with sufficient information to effectively serve in their respective roles. Of the 74 responses received, 64 indicated that the information they received was sufficient (86.5 percent), while 10 indicated they received insufficient information to effectively serve in their respective roles (13.5 percent). Nine of these negative responses provided clarifying information, some of which are summarized below as entered by the respondents.

- This hasn't been done before in Austin. We knew water was coming in to our site, and we knew we needed to get water to the pods. We developed a plan and adjusted it as needed.
- Late in receiving it [information] or not in dual languages to inform the community.
- There wasn't any communication about the environment, possible weather, shelter or food for volunteers.
- POCs & roles with ESDs for evacuation were not clear.

Respondents were then asked how they had received the notification to mobilize for the Colorado River Flood response. Respondents were afforded the opportunity to select all methods that applied to them. From the 75 respondents to this question, 124 responses were received. These responses are summarized in Figure 2.

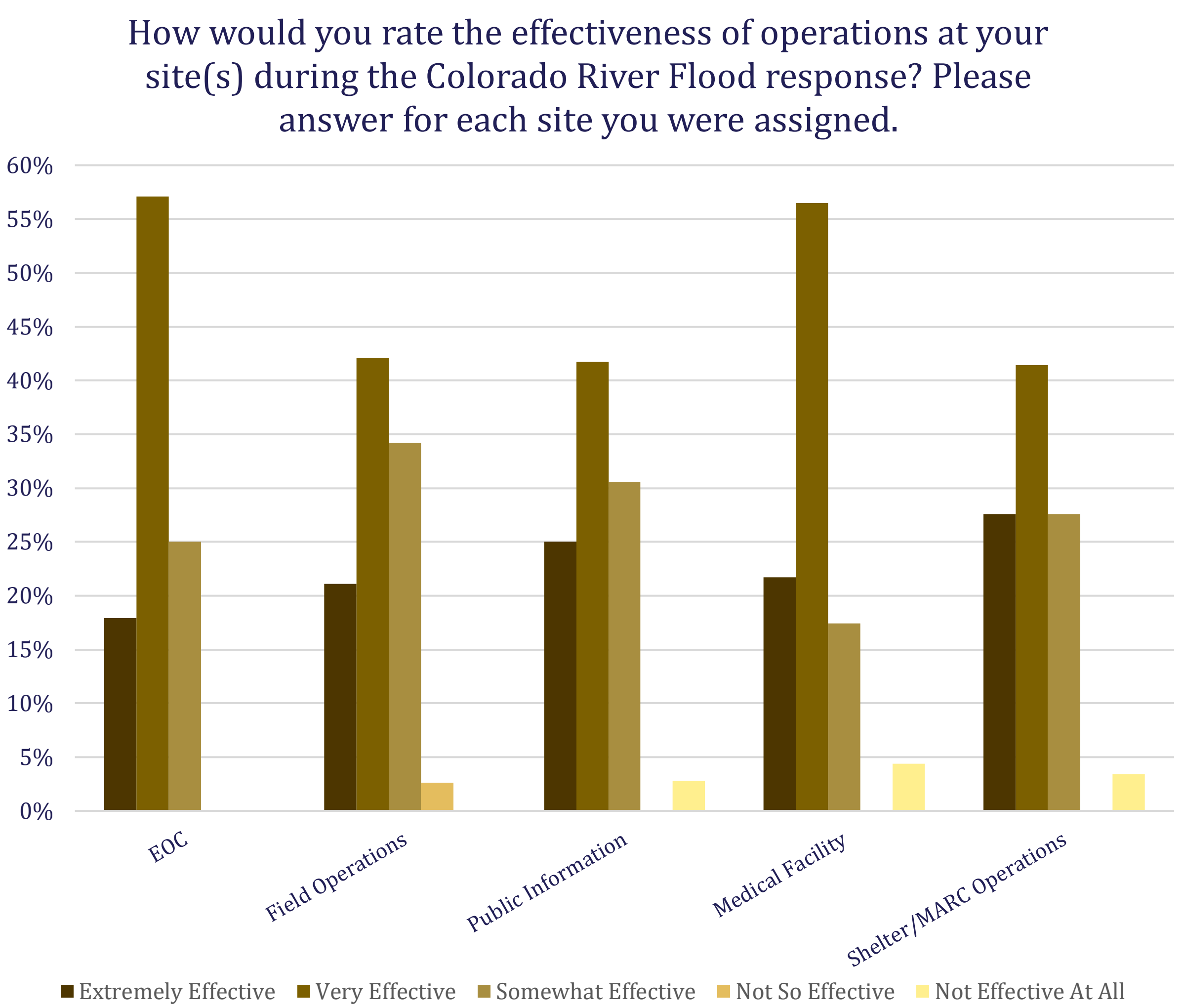
Figure 2: Response Stakeholder Survey



Operations and Direction and Control

Respondents were then asked to rate the effectiveness of operations at their respective sites during the Colorado River Flood response. Respondents were given the opportunity to rate the effectiveness for each site they served at. Responses for each site are summarized in Figure 3.

Figure 3: Response Stakeholder Survey



Respondents were given the opportunity to provide clarifying information, some of which is summarized below as entered by the respondents.

- Central Texas Food Bank was very effective in our operations of distributing water.
- Although we [POD site] ended up in a level parking lot with sufficient space, we were located in the far NE of Austin. Turnaround time from dispatch to delivery to restock would have been quicker and more efficient if the main distribution center was more centrally located.
- I thought the EOC was very well organized and response was extremely timely.
- Austin Water Department Emergency Operations Center - very effective.

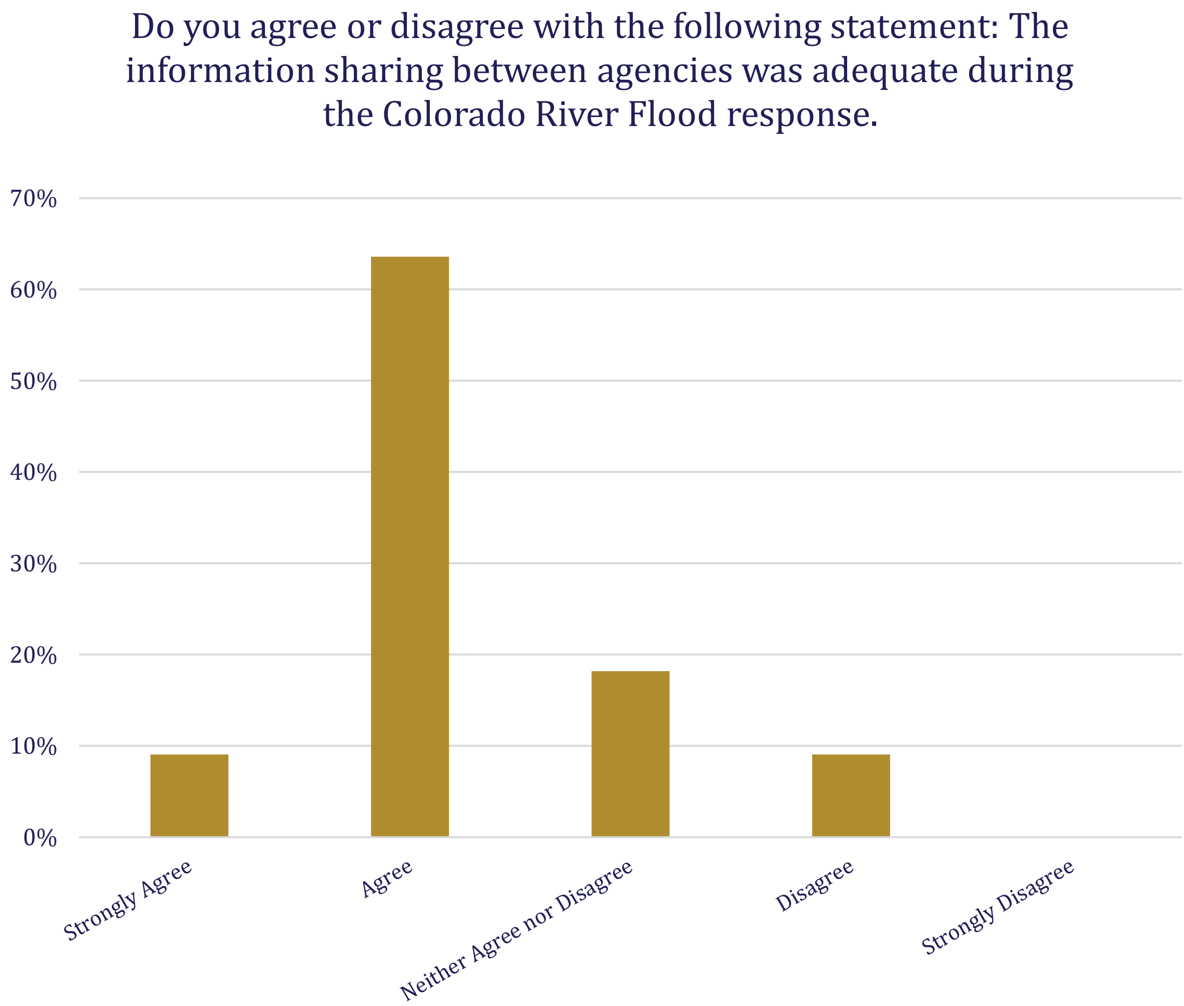
- As Lead Trauma Service Area for EMTF-7 CATRAC coordinated and notified response agencies for deployment of Ambulance Strike Teams, MIST (Medical Incident Strike Teams), and AmBUS resources to flooded areas.

Respondents were then asked to provide some areas of improvement they observed while at their respective sites during the Colorado River Flood response. Some of the selected responses are listed below, as entered by the respondents and separated by the respective sites.

- EOC (26 responses):
  - Increase utilization of WebEOC, awareness of IAP process, assign liaison with LCRA.
  - We need to make sure we have EOC training for all staff that come to the EOC.
  - Logistics personnel need more training and exercises. A written process is needed. Proper procedures need to be used for incoming requests.
  - Clearer announcement that PODs were being set up.
  - Training of staff in the Incident Command Structure.
  - Delegate objectives to operational teams.
- Field Operations (10 responses):
  - Leaders need to be identified.
  - More communications, better shelter for the elements, food for volunteers.
  - Centrally located main distribution site.
- Public Information (nine responses):
  - Making certain there is one POC for providing info to elected officials.
  - Clear Chain of Command and On Call Schedule, Clearer communication about posts, Use of Emergency Info Page.
  - Dedicated County PIO representation.
  - Though the process to send a public health alert message (BWN) was previously discussed and agreed upon - that process did not work as planned. There was a significant delay in the BWN being sent by Austin HSEM.
- Medical Facility (four responses):
  - Increase water conservation plan reserves.
  - Getting an up to date list of long-term care facilities was difficult.
- Shelter/MARC Operations (nine responses):
  - Site headcount information.
  - Approval of debris removal and pertinent questions prior to hosting MARC, Shelters being set up without public health knowledge.
  - More advertisement of the MARCs could have helped our low turnout.
- Other (six responses):
  - Better communication between outside agency was needed.
  - Create a standardized process for tracking meal receipts and flooding hours from the onset of the incident.

Respondents were asked if they agree or disagree, and to what scale, with the statement that "The information sharing between agencies was adequate during the Colorado River Flood response". These results are summarized in Figure 4.

Figure 4: Response Stakeholder Survey



Respondents were asked to provide some of the strengths in information sharing that were observed. Some of these strengths are summarized below, as entered by the respondents.

- Communications have improved so much over the years, it shows a strong connection between recognizing what is important information for each agency to gather in order to effectively communicate.
- The situation report at the end of the day was extremely helpful in preparing briefings to the court.
- The conference calls are helpful. And being present at the EOC is always the best way to know what is going on.
- The initial MARC planning meeting was very informative and set the stage for the successful implementation of the MARCs.

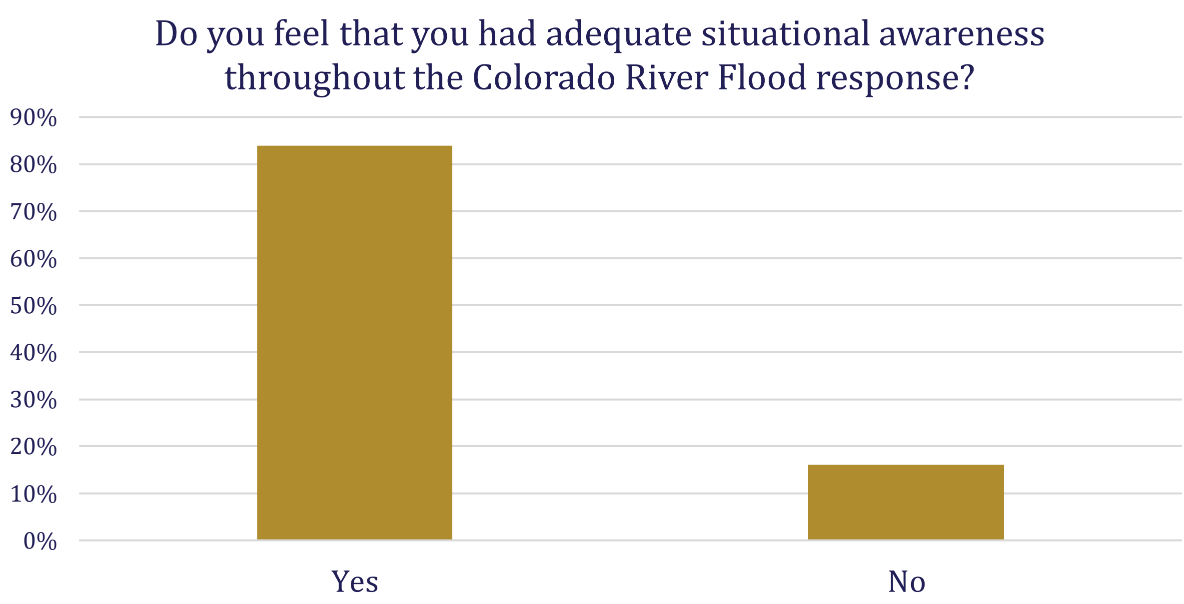
- APH DOC and EOC kept each other well informed.
- WebEOC was used a lot by many agencies, so it was easy to stay up-to-date with their actions and progress.
- Good relationships between agencies helped information flow.
- The side-by-side collaboration and cooperation between Travis County and City of Austin was a decisive factor in overall effectiveness of the response.

Similarly, respondents were asked to provide ways in which information could have been better shared. Some of these suggested improvements are summarized below, as entered by the respondents.

- The biggest issue identified was a lack of accurate and updated information on the GIS/technical side of operations from the Austin Energy and Austin Water maps that would have been a better resource had the data for potentially affecting public works (Schools for example).
- Having a big board with the issues and the agency assigned to it, clearly identify leaders on the field.
- Certainly, we could be using WebEOC more effectively to communicate with the State and among local governments in the region.
- It would help to ensure that all decision makers are in the room during planning. It is challenging when meetings are held, plans are made, and an absent decision maker then changes the plan.
- Educating and training staff on their specific roles and responsibilities during an incident is critical.

In line with information sharing, respondents were then asked if they had adequate situational awareness throughout the Colorado River flooding response. These responses are summarized in Figure 5.

Figure 5: Response Stakeholder Survey



There were 15 comments from respondents providing clarifying information, some of which are summarized below, as entered by the respondents.

- It's always difficult to get as much situational awareness as one would like but we needed: -Better A/V in the EOC -Mapping of the area that could be impacted (and put on the screen in the EOC), with ability to add flood scenarios -Knowledge of risk, map of critical infrastructure and key assets, awareness of impacts if those CIKR are affected # of meetings in EOC was good and helped increase information sharing and awareness among key positions in EOC.
- In logistics, keeping up with information is difficult. There are no written procedures so different people do things differently. WebEOC is not always used properly. A status report generated by WebEOC cannot be effective if the requests are not updated.
- Medical operations with site presence was not activated.
- I worked in the EOC daily and still felt as if I didn't know what was truly going on.
- I really appreciated that Austin HSEM's notifications prior to the public boil water advisory included reaching out to ASO as our operations were significantly impacted.

Transition from Flood Response to Boil Water Notice Response

Respondents were asked if they were involved in the transition from the flood response to the boil water notice response. Of the 104 responses received, half indicated that they were involved in the transition and the other half indicated they were not.

For the respondents that answered affirmatively, they were then asked to identify strengths they observed in transitioning from the flood response to the boil water notice response. Some of these are summarized below, as entered by the respondents.

- EOC was up and active for other issues (F1 and flooding) so the transition seemed pretty seamless [numerous responses indicated this].
- Staff in all agencies mobilized quickly and began communications.
- Getting information about water PODs was quickly dispersed.
- The media spread the word pretty effectively.
- Adapting in a dynamic environment, developing response plans on short notice.
- The change in focus was obvious and the tasks were clearly defined of where we should focus time and energy.
- It was impressive to see the teams move from the original crisis to the follow-up crisis late in the day Sunday. Everyone was tired and mentally moving on from the flood activation but got right back in gear when the boil notice became necessary and inevitable.
- County purchasing dept was present in Logistics to assist with purchases and transport.

Respondents were then asked how the transition could have been improved based on their observation during the response. Some of these are summarized below, as entered by the respondents.

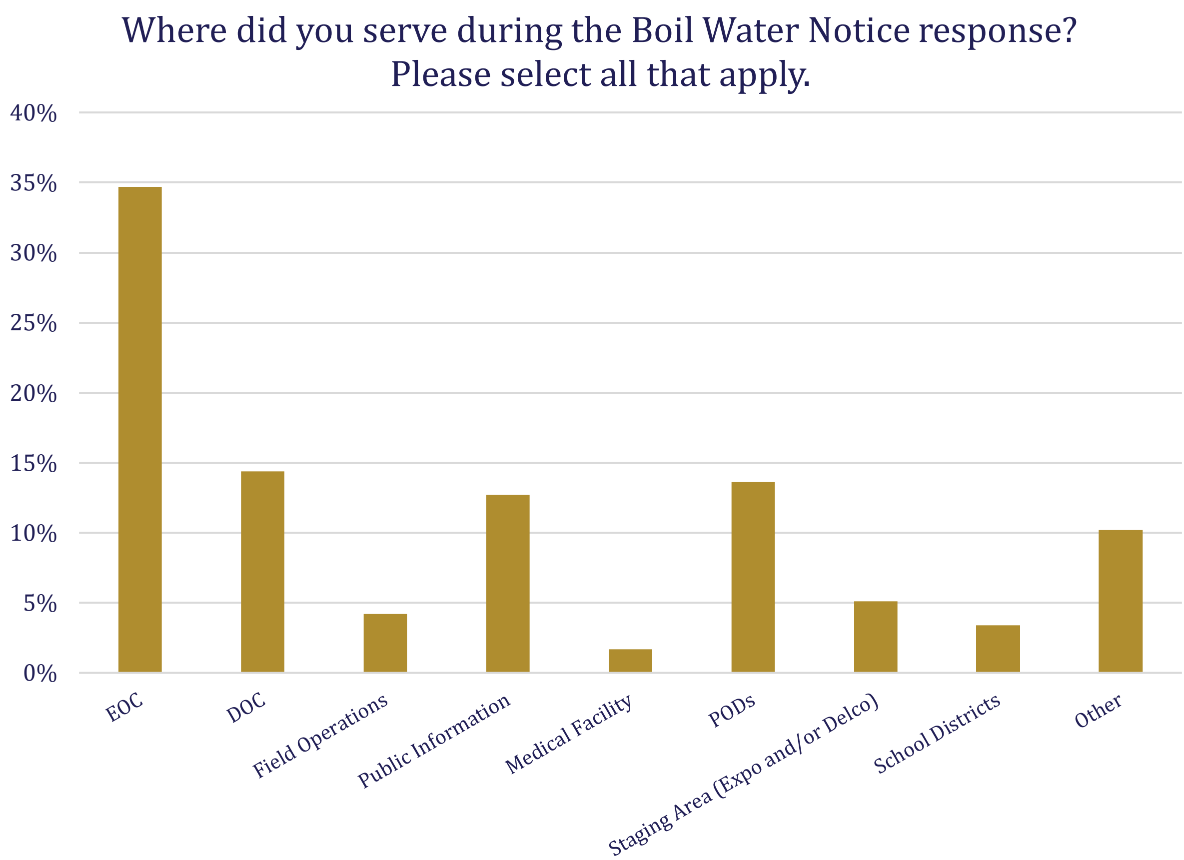
- Need to understand that this was not a separate incident - this was a complex incident, within and incident. The BWN was a direct consequence of the flood.
- Selected pre-storage facilities.
- Transitions in overall management of the event between COA and Travis County were not well coordinated or communicated between the two entities.
- There was a lack of clarity around roles and responsibilities. In particular, related to setting up traffic control at the distribution sites, and staffing the expo center and distribution sites.
- Families with little social media presence, no televisions or internet service were at a disadvantage to receiving the news to boil water.
- Agencies need to have EOC staffing schedules ready to go and initial reliance on NGOs needs to be realistic (they can't mobilize and start operations quickly enough by themselves).
- City HR Department presence in EOC would have been helpful.

Role During Boil Water Notice Response

All respondents to the survey were then asked whether or not they were involved in the boil water notice response. Of the 103 responses received, 75 (72.8 percent) indicated that they were involved while 28 (27.2 percent) indicated they were not involved.

For those who answered affirmatively, they were asked where they served during the boil water notice response. There was a total of 118 responses to this question as respondents who served in more than one location were able to select all that applied. These responses are summarized in Figure 6.

Figure 6: Response Stakeholder Survey



Respondents were asked to identify their primary role during the boil water notice response. While the 73 responses received varied in specificity, most fit into one of nine themes:

- Direction and Control (11 responses)
- Planning (eight responses)
- Logistics (seven responses)
- Public Information (13 responses)
- POD Operations (14 responses)
- Purchasing (two responses)

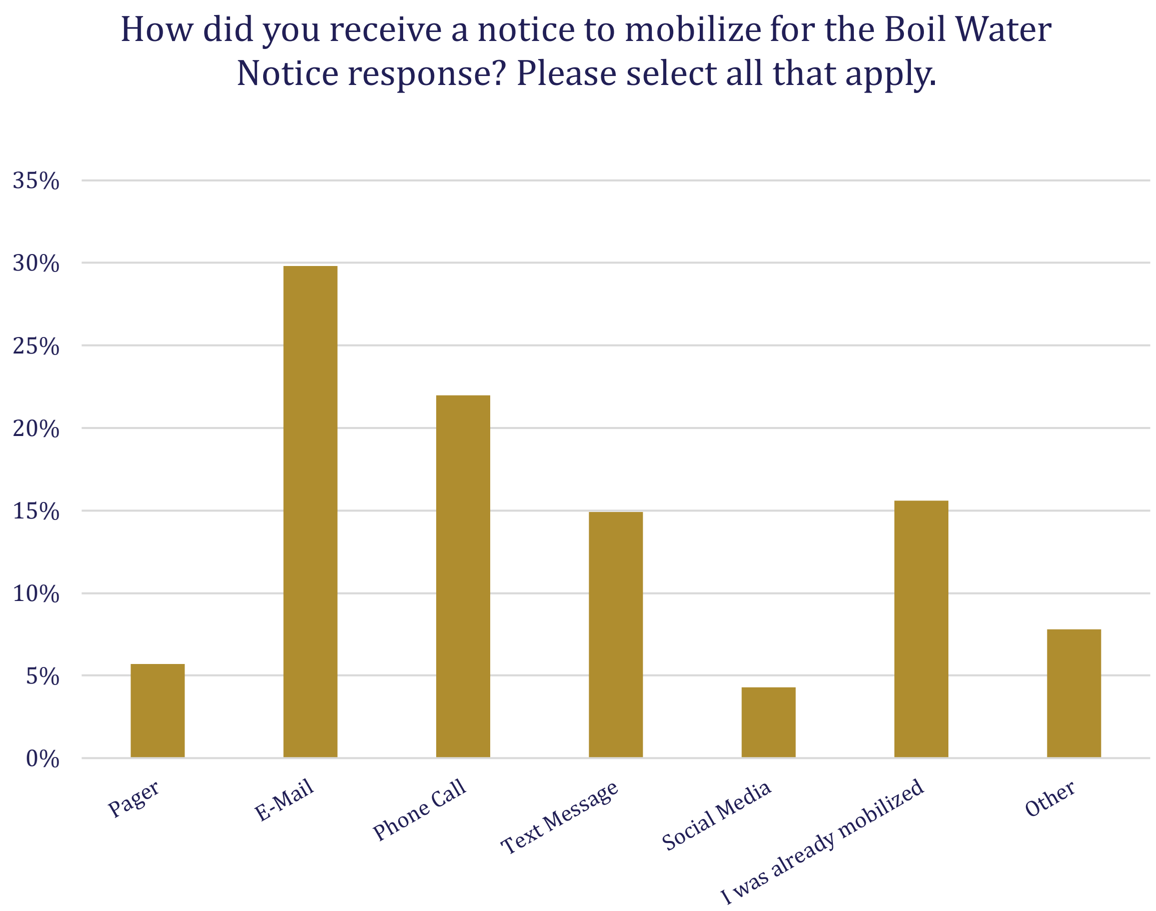
- Liaison (15 responses)
- Staffing (two responses)
- Staging Area Operations (one response)

Participants in the boil water notice response were asked if they were provided with sufficient information to effectively serve in their respective roles. Of the 73 responses received, 57 indicated that the information they received was sufficient (78.1 percent), while 16 indicated they received insufficient information to effectively serve in their respective roles (21.9 percent). Participants that responded negatively were given the opportunity to provide clarifying information, some of which are summarized below, as entered by the respondents.

- There was a lack of clarity around roles and responsibilities. We were planning traffic control, and APD and AFD were doing some planning, but there was not coordination. Also, not having HRD at the EOC was a huge problem and led to confusion around staffing needs, particularly at the Expo Center.
- WebEOC is not always used properly. Updates are not always done so it's hard to keep up with requests. WebEOC request status reports are useless if the data is not there.
- I was not given a sufficient briefing of the expectations for the position.
- The initial communication on the locations of the water distribution sites was inaccurate. This caused scheduled water handlers to be dispatched to the wrong locations. There was inconsistency in the requests for the numbers of people needed at each location.
- I am the coordinator of shelter managers for my department, however instead of communications of activation and needs coming through me so we can track our employees time, my employees were being contacted directly...this caused a lot of confusion.

Respondents were then asked how they had received the notification to mobilize for the boil water notice response. Respondents were afforded the opportunity to select all methods that applied to them or indicate if they had already been mobilized from the Colorado River Flood response. From the 72 respondents to this question, 141 responses were received. These responses are summarized in Figure 7.

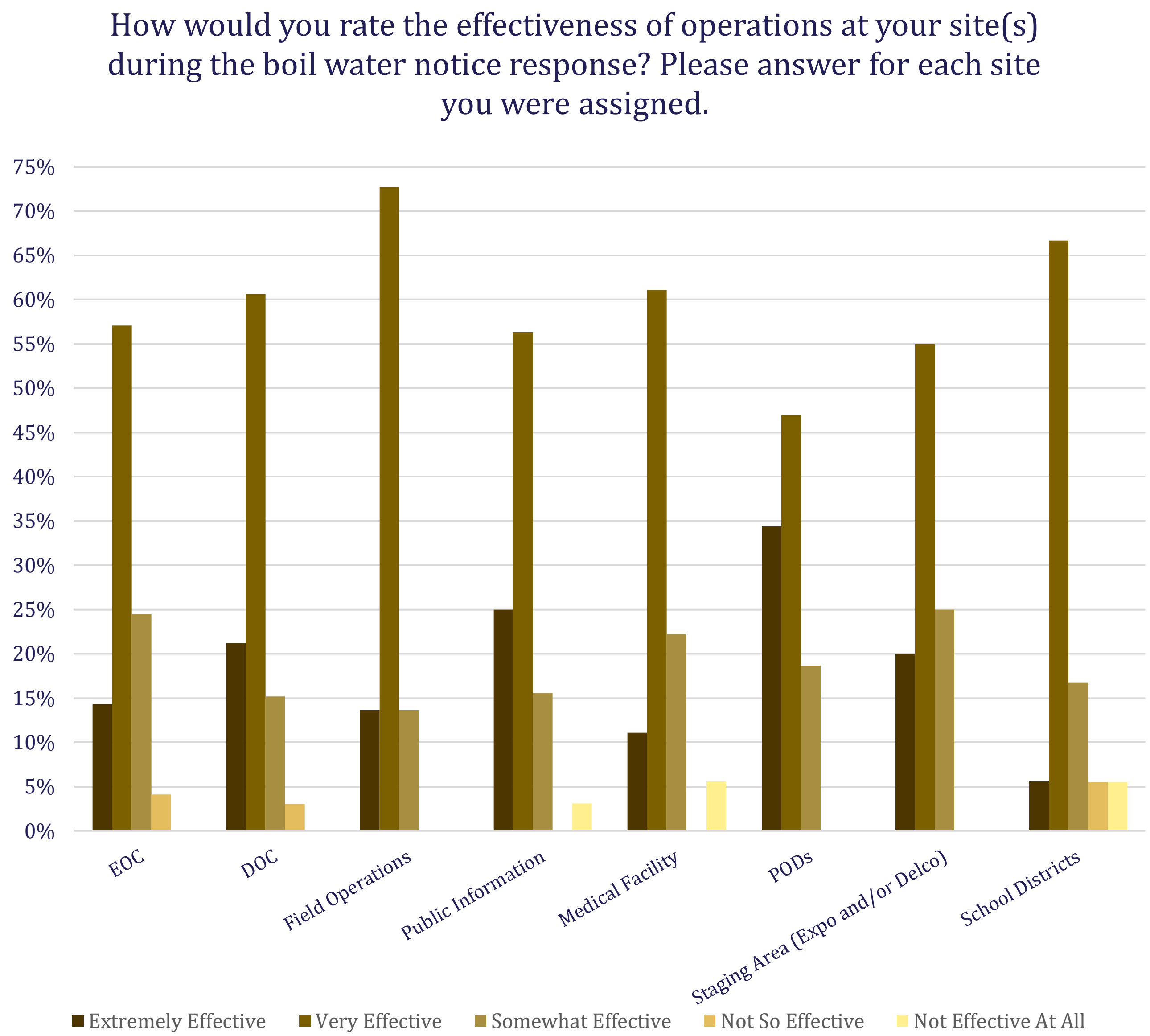
Figure 7: Response Stakeholder Survey



Operations and Direction and Control

Respondents were then asked to rate the effectiveness of operations at their respective sites during the boil water notice response. Respondents were given the opportunity to rate the effectiveness for each site they served at. Responses for each site are summarized in Figure 8.

Figure 8: Response Stakeholder Survey



Respondents were then asked to provide some areas of improvement they observed while at their respective sites during the boil water notice response. Some of the selected responses are summarized below, as entered by the respondents and separated by the respective sites.

- EOC (20 responses):

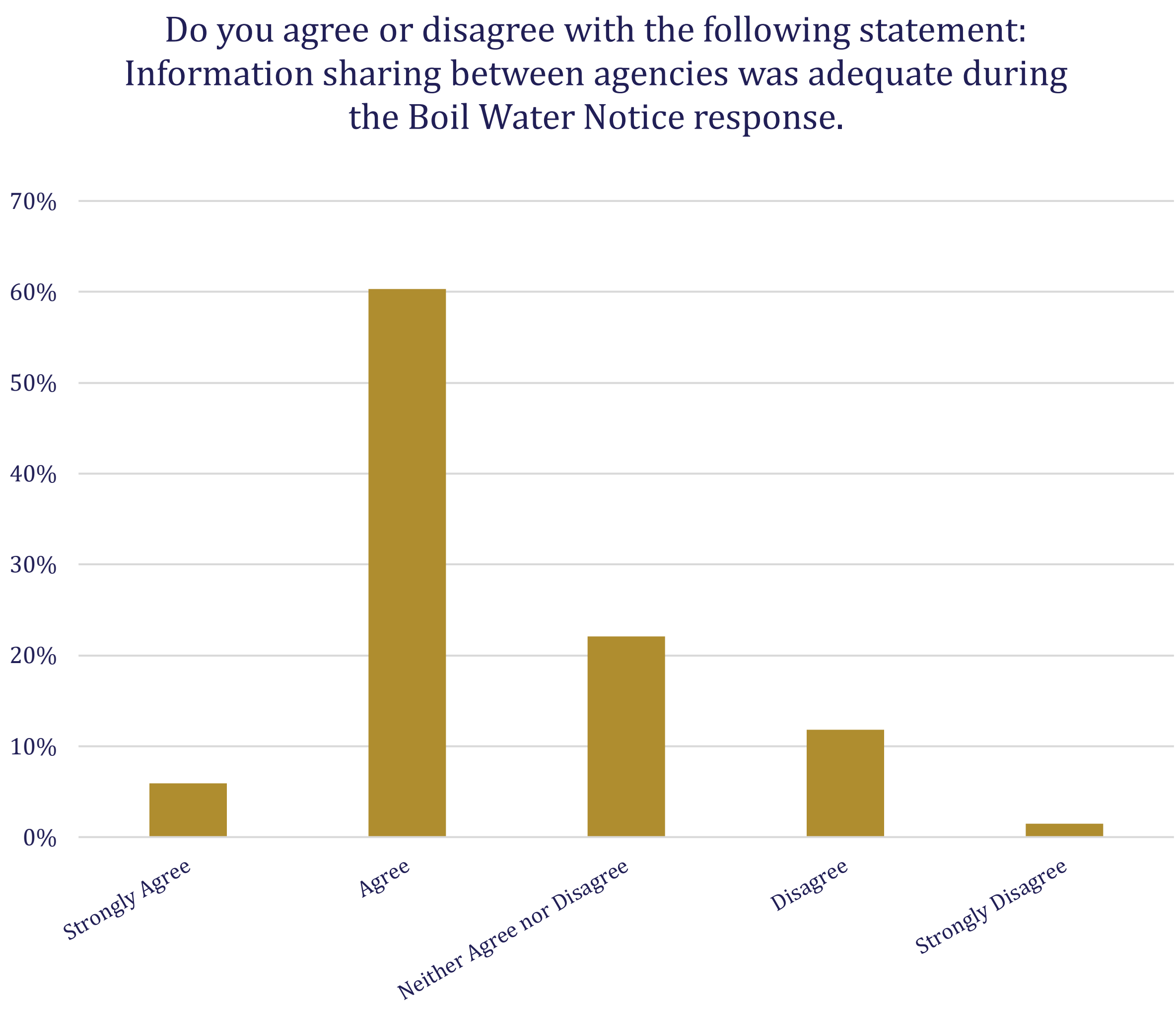
- Logistics adaptations and communications throughout the response.
- Use WebEOC, have written procedures, follow them, train responders in their specific role. Don't make them work their regular job after a 12-hour shift in the EOC.
- Training of staff in the Incident Command Structure; need for more flexible purchasing capability for Travis County OEM.
- Better coordination with Williamson County and Williamson County ISDs affected by water outage.
- Needed more clarity on the final decision makers and the decisions made.

- DOC (seven responses):
  - Caution in using terms like "undetermined", "handful", "couple" to express the potential duration of an incident. This leaves room for a broad interpretation by the public, private sector, school districts or other government agencies resulting in confusion.
  - DOC could have had better communication with APH sites when requesting water for their staff and clients.
  - Enhance communication strategies, establish dedicated DOC facility.
- Field Operations (two responses):
  - Greater command and control of water logistics.
- Public Information (10 responses):
  - Clearer Information and Chain of Command, More timely information.
  - It was unclear on a few occasions who was making decisions and who was in charge. Additionally, requests for information from other departments and elected officials became overwhelming at points during this event.
  - Coordinating consistent messages to public i.e. number of minutes to boil water from Austin Water and Austin Public Health to food establishments.
- PODs (11 responses):
  - Clarity around who is planning traffic control is needed.
  - Better communications to the volunteers about possible environment, shelter and weather. Also, provide food or snacks to volunteers.
  - HRD was engaged late in the process and this created challenges with fulfilling our role. Also, needed clarity on who was ultimately responsible for confirming the number of resources needed at each distribution location and the roles.
- Staging Area (Expo and/or Delco) (six responses):
  - Clarity around who is in charge and who is coordinating staffing needs.
  - We [POD] were in the NE corner of Austin. A more centrally located distribution center would have been more efficient.
  - Lack of coordination of forklift operators created problems.
- School Districts (three responses):
  - More updated information/locations on schools is needed for future incidents where potentially hazardous conditions would affect this sector. I am currently in the process of collecting and organizing such information.
  - Need to be informed in a timelier manner.

- Other (four responses):
    - Stakeholder notification.
    - Medical Operations Center - Lack of knowledge by healthcare facilities on the use of ICS forms. Hospitals not clear on ability to accept alternate water sources to buildings.

Respondents were asked if they agree or disagree, and to what scale, with the statement that "Information sharing between agencies was adequate during the Boil Water Notice response". These responses are summarized in Figure 9.

Figure 9: Response Stakeholder Survey



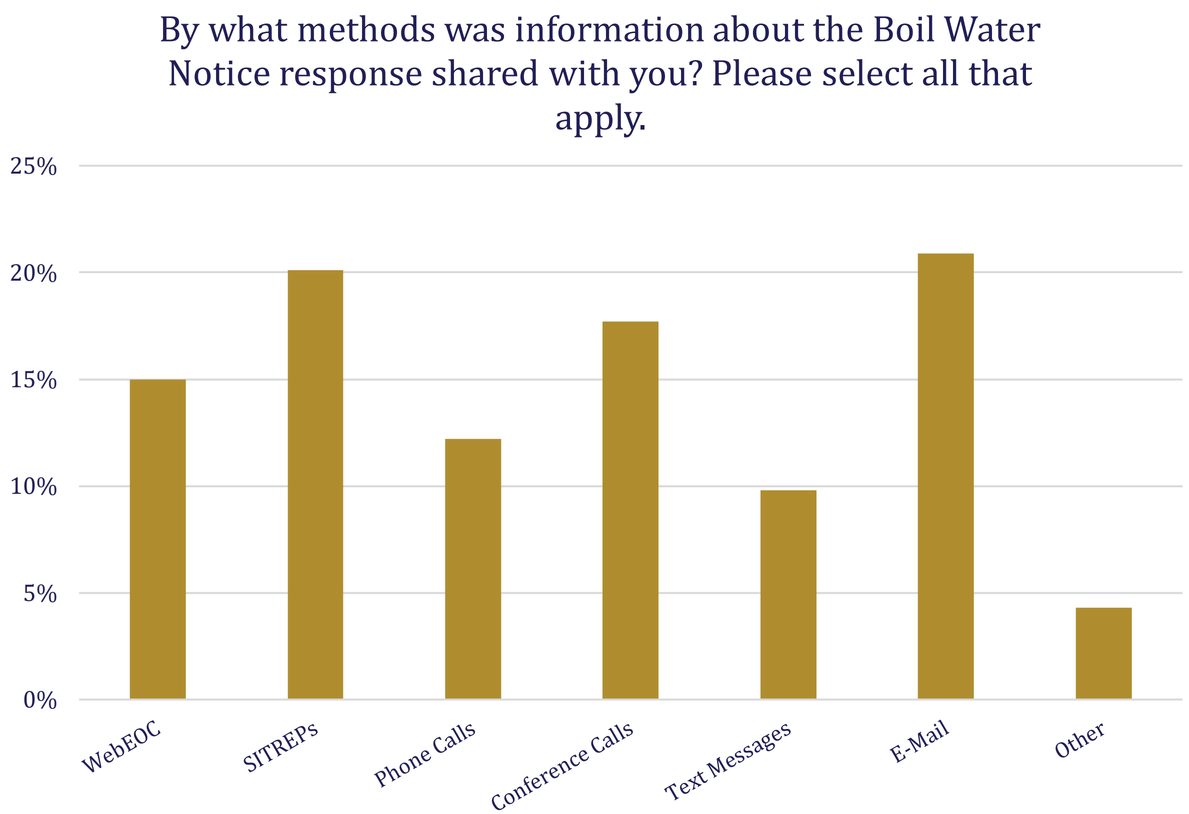
14 respondents provided clarifying information, some of which are summarized below, as entered by the respondents.

- We struggled significantly with HRD being the point of contact for staffing needs, but they were not in the EOC and not aware of the staffing needs. We received conflicting messages, and this led to problems with staffing and overworked staff.

- Listened into multiple conference calls where Williamson County was not included in situation updates or needs assessments.
- Information sharing could have been a little bit better. The key messages were not shared to all executives or speakers on these issues. We could have done a better job making sure all agencies were on message.
- Information regarding potential timelines and steps to be taken by residential and commercial customers was either slow/late in coming or nonexistent.
- Better communications are needed between the various agencies on-site at the PODs.

Respondents were then asked by what methods information was shared about the boil water notice response with them. They were given the opportunity to select all methods that applied. Of the 69 respondents to this question, there were 254 responses received. These results are summarized in Figure 10.

Figure 10: Response Stakeholder Survey



Respondents were asked to provide some of the strengths in information sharing that were observed. Some of these strengths are summarized below, as entered by the respondents.

- Situation reports and EOC communications.
- Having representatives in the EOC makes it easier for information to be shared.

- Updates to the community, information gathering to plan for the needs of clean water, professionalism within the EOC.
- Many of the agency's reps knew each other prior so working together was easy.
- Once up and running and water was being distributed, ordering of pallets of water and situation updates became timelier.
- Communicating disposition of distribution sites.
- WebEOC was a very efficient way to share information between various agencies.
- As with the flood response, I observed strong, friendly, positive, and transparent information sharing between County and City.

Similarly, respondents were asked to provide ways in which information could have been better shared. Some of these suggested improvements are summarized below, as entered by the respondents.

- A better understanding of who the key players were in this type of event.
- Pre-determined storage and transportation needs.
- I recommend looking at how to use WebEOC more effectively across the region and in cooperation with the State.
- HRD needed to be present.
- Inform ALL school districts, not just Austin ISD. It should not be Austin ISD's responsibility to inform other districts.
- During initial stages of response and after lead coordination roles were established, better coordination with all aspects of IC and C&G staff between Williamson County and City of Austin could have occurred through regular inclusion in planning meetings and conference calls. The dispatching of a department liaison to CTECC attempted to bridge this gap, however further improvement in this area could be achieved.
- Earlier coordination of response policies.
- All impacted agencies and decision makers should be in one room during the planning and operational decision makers. When this does not occur, we are wasting resources.

Water Distribution

Respondents were asked whether they were involved with the response at the water distribution sites. Of the 69 respondents, 25 responded "Yes" (36.3 percent), while 44 answered "No" (63.7 percent).

For those who answered affirmatively, they were then asked to list strengths they observed at the PODs. Some of the selected responses are summarized below, as entered by the respondents.

- Communications between them [PODs] and AFD.
- Quickly assembling an overview to discriminate to each site for the basic needs/requirements per POD to operate and interagency communications.
- Effective traffic control, signage, quick distribution of water, and logistics for staging. Kelly Reeves had a real-time water distribution tracking spreadsheet that was integrated with google forms for minute by minute water distribution and zip code tracking of areas served by the POD site. This helped establish very accurate burn rates and establish future needs.
- Good locations were selected. Media communication was effective. Once received, water supply was plentiful.
- Excellent turnout at the COTA POD by County employees and outside volunteers. Everyone worked hard and was friendly, focused on good customer service.

Similarly, respondents were also asked how the PODs could have been improved. Some of the selected responses are summarized below, as entered by the respondent.

- Identify types of schools and a point of contact that may be potentially affected by similar situations in the future that should be updated on an annual basis. More site security per POD to ensure access points and assets are better monitored/controlled.
- If POD sites became overwhelmed, improvements to the distribution operation could have been improved with multiple lanes serving multiple vehicles concurrently. This was ultimately not needed at Kelly Reeves but was observed for future planning operations.
- Consultation with APH on POD operations. We are tasked with this response for meds. Not so much a weakness but we now know that many city employees are capable of running such operations too.
- Needed clarity on who was ultimately responsible for confirming the number of resources needed at each distribution location and everyone's roles.
- More efficient movement of water from staging areas to the PODs.
- Better communication regarding over staffing/under staffing to allow for adjustments.

Respondents were also asked whether they were involved with the boil water notice response at the water staging areas, Expo Center and/or Delco. Of the 69 responses received, only seven answered "Yes" (10.1 percent) and 62 answered "No" (89.9 percent).

Those that answered affirmatively were then asked to identify the strengths observed at the water staging areas. There were six responses, some of which are listed below as entered by the respondents.

- Unified Command at Delco RSA had great communication and information sharing and fluid operations.
- The command post was well-established for all parties to share information.
- The existence of the staging areas was key in the planning.

Similarly, respondents were asked to identify ways in which the water staging areas could have been improved. There were seven responses, some of which are summarized below.

- Internal emergency operations plans for school districts should be updated to plan for future PODs that are flexible to accommodate multiple asset needs/incident types.
- Have a plan in place that allows for clear chain of command at the emergency response sites. It should be clear to everyone that the site manager is directing the employees (not their day-to-day supervisor) while they work at the site…Have a plan in place to ensure employees are fed and have access to restrooms when they are working at a remote site…Develop a clear plan for communicating critical information between the EOC and the distribution/staging sites.
- A heavier security presence could have helped. People stealing cases of water became an issue. Better outfit the command posts with food, water, coffee, etc.
- The initial space limitations at the Expo Center significantly slowed down the operations and caused a backlog of trucks waiting to be unloaded.

Respondents were then asked whether they were involved with water access/distribution at alternative locations during the boil water notice response. Of the 69 responses received, 17 indicated they were involved at alternative locations (24.6 percent), while 52 indicated they were not (75.4 percent). Some selected alternative locations included:

- Congregate living centers.
- Long-term care facilities.
- Nursing homes and assisted living facilities.
- Homeless shelters/programs serving persons experiencing homelessness.
- Correctional facilities.
- Austin-Bergstrom International Airport.

Respondents were asked to identify strengths observed at alternative locations. Some selected responses are summarized below, as entered by the respondents.

- When I was in the EOC the Ops chief told us Long-Term Care Facilities were a priority and came in and checked on us often to see updates that were needed to ensure that water was available. Also, easily explained process for pick up or if delivery was needed what was needed for the delivery to occur (for example to the ARCH).
- Spring water conservation plan in place and recently updated and reviewed.
- Sharing of storage space and water between different healthcare systems. Excellent working relationship between different agencies such as Austin Fire Department and Healthcare facilities to problem solve issues that came up in water distribution.

- Procurement securing large water tanks to be at the Correctional Facility and having bulk water distributed.
- City made pallets of bottled water available to city departments which was helpful for our field staff.

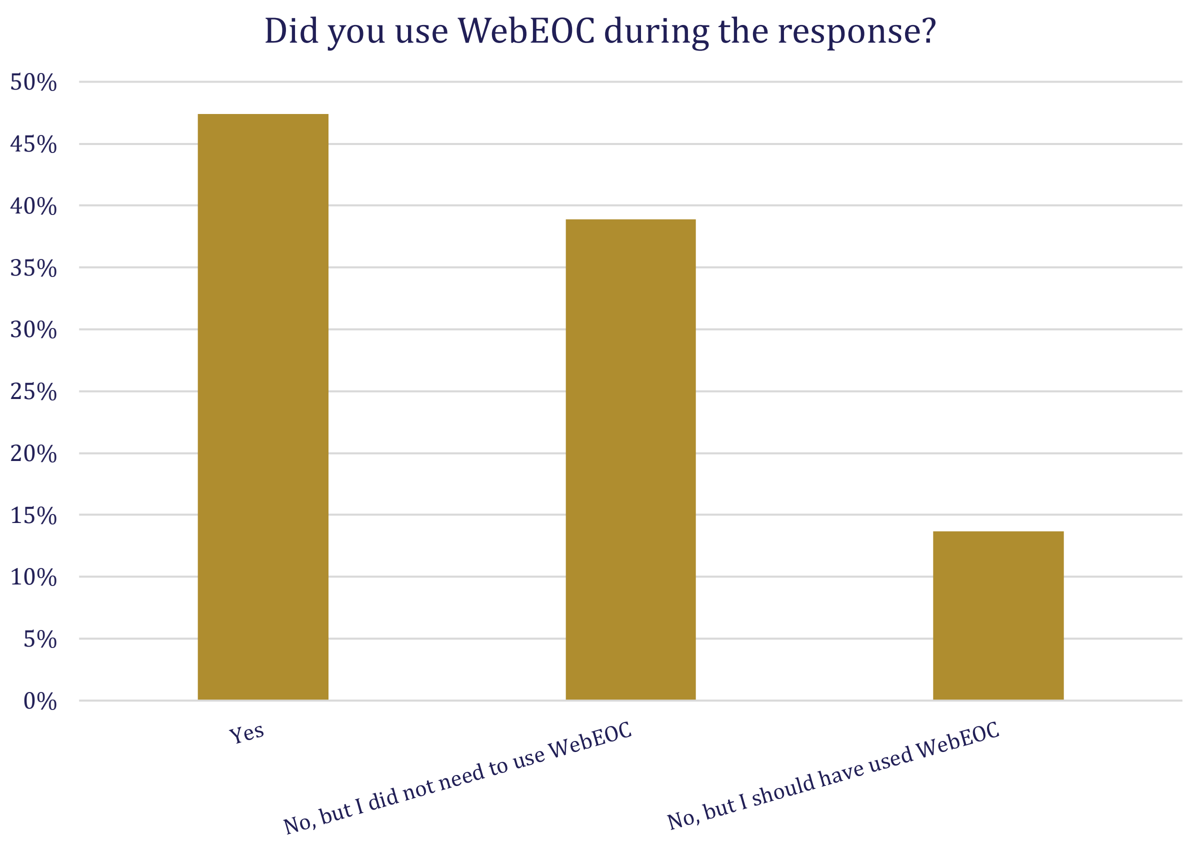
Similarly, respondents were then asked to identify ways in which water access/distribution could have been improved at alternative locations. Some selected responses are listed below, as entered by the respondents.

- Parmer [location]: We wish we knew when water would be delivered, especially on the first day of operations.
- The old Home Depot location on I.H. 35 was bombarded with people trying to get in to that location. The access road was so heavy with cars coming from all directions. Maybe have traffic control help out.
- Knowledge of locations requiring vehicles with lift gates for water placement. Pre-knowledge of water requirements for different facilities. Knowledge of water supplies on site. Better coordination of incoming water requests across regions from different agencies to minimize excess water after the event has ended.
- Clearer communication to facilities that need to pick up their own water because some assumed water could be delivered when we did not have that capacity.
- Better understanding of handling of potable water for commercial/food serving facilities.

WebEOC

All respondents were asked whether they used WebEOC during the response. Of the 95 responses to this question received, 45 indicated that they used WebEOC (47.4 percent), 37 indicated that they did not need to use WebEOC (38.9 percent), and 13 indicated that they did not use WebEOC, but they should have used it during the response (13.7 percent). These responses are summarized in Figure 11.

Figure 11: Response Stakeholder Survey

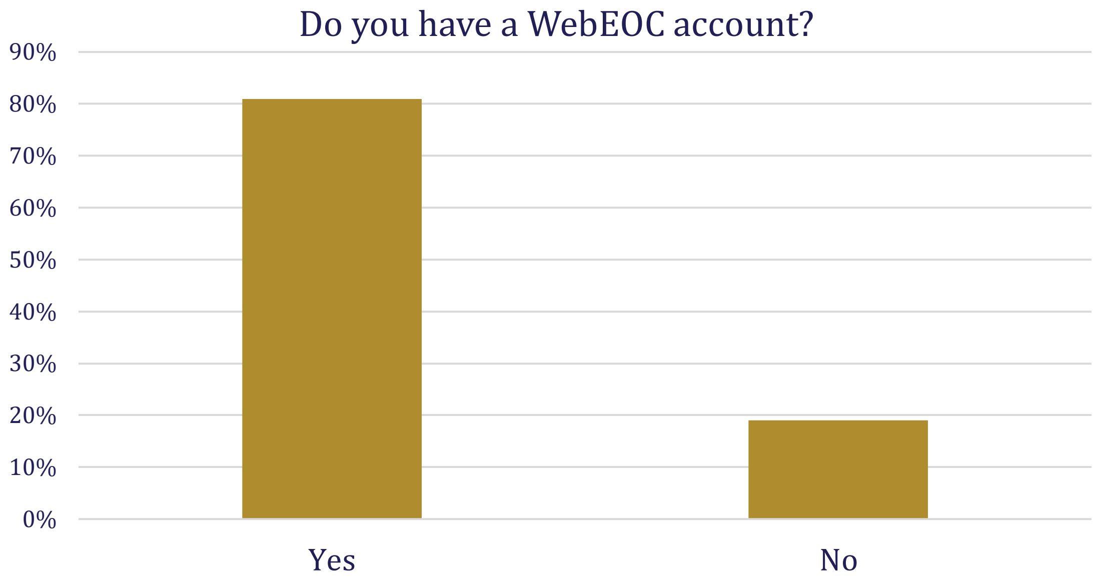


Respondents were given the opportunity to comment on WebEOC usage. Some selected responses are summarized below, as entered by the respondents.

- This area needs lots of training.
- Team manager is on WebEOC, As the point person, I was not.
- WebEOC had locked out accounts randomly. I did not have access during the first week of the flooding event.
- Other employees were making entries for our agency.

Participants who either answered “Yes” to using WebEOC or “No, but I should have used it” were then asked whether they have a WebEOC account. These responses are summarized in Figure 12.

Figure 12: Response Stakeholder Survey



Respondents were asked to list some of the strengths with WebEOC observed during this incident. Some of these strengths are summarized below, as entered by the respondents.

- It's one central repository for all response activity.
- Real-time updates on other area command agencies that may be too much information to share during an operational brief, as well as high importance updates in between briefings were easily accessible.
- Common operating picture and provides situation reports and documentation of the event.

Similarly, respondents were asked to list some of the areas for improvement to WebEOC they observed. Some of these are summarized below, as entered by the respondents.

- More training opportunities so users can access full utility.
- More use and education on the utilization of the resource request page.
- It should be used for entering and submitting STAR requests (to the State, for resources). It should be used across the region, by all local CAPCOG EOC's, so that we all have the same situational awareness.
- The biggest problem I see with WebEOC is that it needs to be used regularly (daily) or folks forget how to use it. Then, we get into incidents and it's not being used widely and lacks sufficient information - so folks use other platforms, like smartphone applications. Need to improve some boards too - to make them more useful.

Respondents were asked to list some potential enhancements to WebEOC that would better enable them to accomplish their duties. Some of these enhancements are listed below, as entered by the respondents.

- I need to know what its capabilities are, but I believe resource tracking needs to be more robust. It is not currently used as the main tracking tool for resources. People enter in resource information after the fact. We should be able to use it to return resources to their owners, as well as to track costs.
- There was a GIS dashboard used by Travis county that would be helpful in providing visual information. Not sure if it can be incorporated.
- WebEOC and EMResource should auto-populate each other in the bed resources area.
- Ability to reset your account without having to find an administrator. The person listed on the CAPCOG contact list was no longer our contact but luckily still worked for the city and still had rights to update the account. (This was actually for F1 but played into Boil Water since I was already at the EOC) Had I not already reset my account for F1 I would have had to for EOC response.
- Is it available for use on cell phones - that could help for staff in the field?

Resource Management

All respondents were asked to list some of the strengths they observed regarding the process by which personnel were being assigned. Some of these are summarized below, as entered by the respondents.

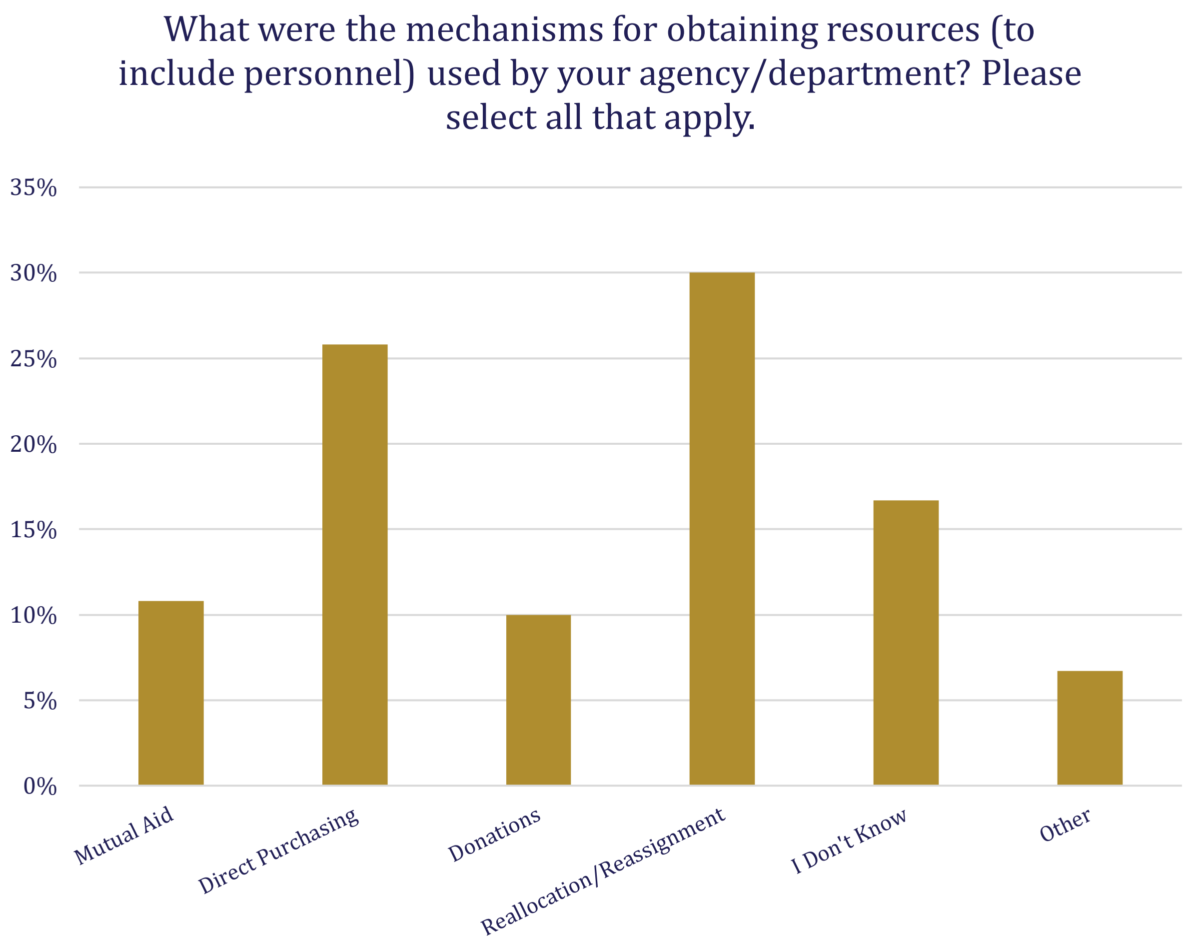
- Good collaboration among City departments to identify and dispatch individuals comfortable with the duties required.
- Employees were well training in incident command. Previous desk top training exercises were value added. Organizational boundaries did not get in the way.
- Staff was able to receive their schedule in advance of the day they were assigned.

Respondents were then asked in what ways the personnel assignment process could have been improved. Some of these responses are summarized below, as entered by the respondents.

- Many times, people are assigned based on availability and willingness to work. May or may not translate into how adept they are with the ways of the EOC. More EOC training with a "qualification" to be able to be assigned to the EOC should be explored.
- Pre-identify personnel from other agencies who can fill in and support HSEM/OEM personnel. Make arrangements with their home agency to use them as needed.
- A Safety Liaison needs to be utilized and that position can assist with scheduling.
- Have a clear point of contact for recruiting staff city-wide. This contact needs to have representation in the EOC to ensure they have a pulse on the current needs. HRD was designated the point of contact for staffing the distribution and staging sites. However, communication break downs were occurring when HRD was not aware of the current staffing needs. A city-wide emergency response staffing plan be created that draws on the expertise of all departments.
- Focused discussion regarding the specific personnel requirements should occur early in the planning process and engage all City departments who employ individuals with those skill sets/roles.
- Have volunteers in place before an emergency. Ask for volunteers now, have a training for several types of emergencies/disaster. Keep an updated list and review every 3-6 months to make sure volunteers are still interested or work for the agency. Have a cell phone list to gather individuals quickly for a briefing, assigning locations and shifts and provide a quick refresher on what volunteers are supposed to do.

Respondents were asked to identify the mechanisms for obtaining resources, including personnel, utilized by their respective agency/department. They were given the opportunity to select all mechanisms that applied. Of the 74 respondents to this question, there were 120 responses received. These responses are summarized in Figure 13.

Figure 13: Response Stakeholder Survey



Respondents were asked to list the strengths in obtaining and tracking emergency resources and costs they observed during the response. Some of these are summarized below, as entered by the respondents.

- Departments have become very familiar with disaster tracking. Initially a reporting code was not set up while the magnitude of the event was still being assessed. Departments were overall fairly flexible and able to use and switch from internal task orders to a citywide reporting code.
- Guidance from personnel in the logistics section was awesome. Additionally, the ease of the digital Forms in WebEOC to document and submit forms will always be an upgrade from pen and paper.
- I followed the chain of command to request services. If I needed to elevate a request, it was sent to the DOC and ultimately the EOC if needed. I did submit requests for translation of communications via this route.

Respondents were also asked to list the ways in which obtaining, and tracking emergency resources and costs could have been improved. Some of these are summarized below, as entered by the respondents.

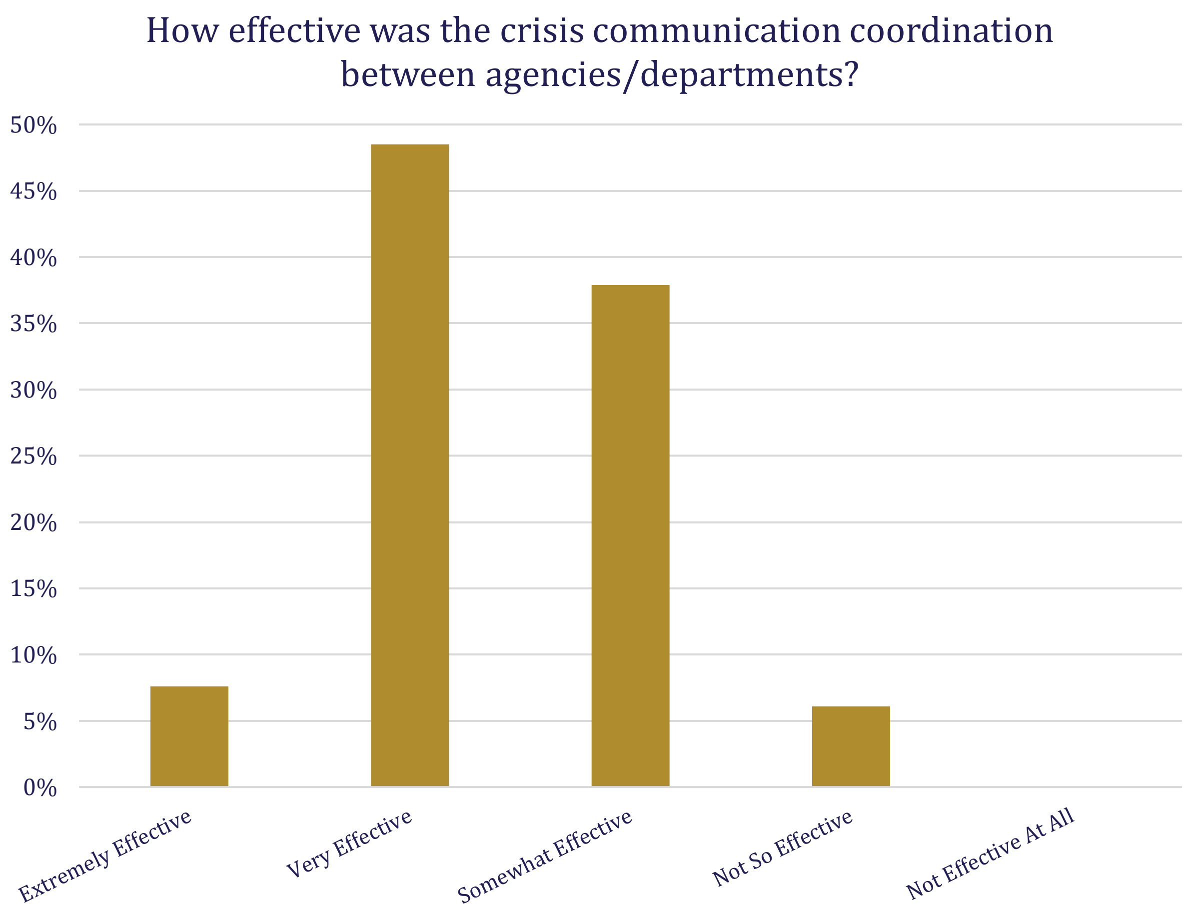
- We need a way to figure out the extent of resources being used in real-time during the event. We do not have good overall situational awareness of what resources are where and how much it is costing. We need some kind of program to track this, along with tracking of personnel so we are not relying on assigned employees to sign in/sign out, report their own time and activity manually.
- County needs to create a code that is county wide and we need to come up with a mechanism for better tracking equipment usage.
- WebEOC should be useful for accomplishing this.
- Pre-identify vendors for basic necessities and have contracts already approved and in effect.
- Have a pre-planned process and have work orders in place for disaster and emergency responses. Have supervisors and managers familiar with that process. Conduct table top exercises at least every couple of years for this kind of response.

Communication and Public Information

Respondents were asked whether their agency/department had sufficient information to answer requests for information regarding the response. Of the 38 responses received, 32 indicated “Yes” (84.2 percent), three indicated “No” (7.89 percent), and three indicated “No, but their agency department directed the request to another agency/department” (7.89 percent).

Respondents were then asked how effective the crisis communication coordination was between agencies and departments. The 66 responses received are summarized in Figure 14.

Figure 14: Response Stakeholder Survey



Respondents were asked to list strengths in the crisis communication coordination between agencies and departments they observed during the response. Some of these are summarized below, as entered by the respondents.

- Being in the EOC, we were able to directly coordinate with PARD, AFD, APD, and others and work to be on the same page.
- PIOs were available and capable of quick information sharing.

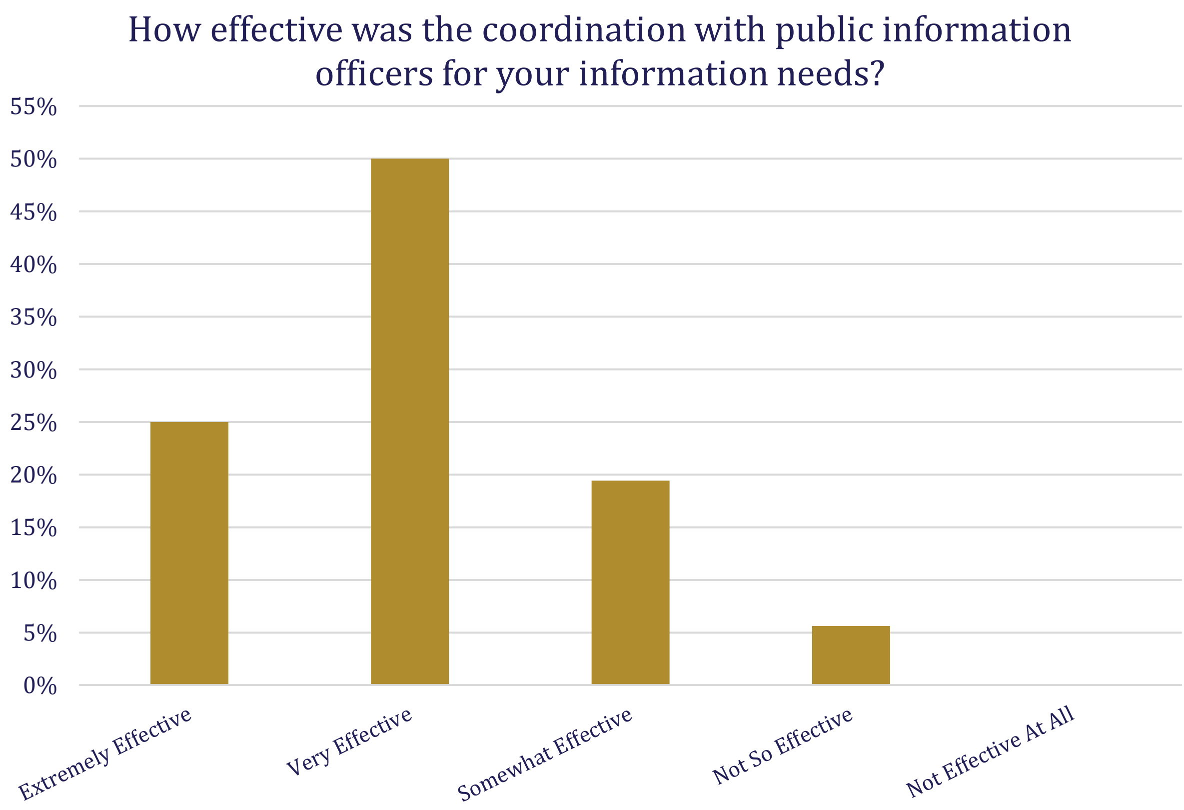
- Communication from HSEM, City Manager and Assistant City Manager provided information that was needed and useful. Identified employees were willing to be re-assigned.
- Pre-existing relationships with other EOC responders helped greatly in getting information to and from other agencies.

Respondents were also asked how crisis communication coordination between agencies and departments could have been improved. Some of these responses are summarized below, as entered by the respondents.

- It was sometimes difficult to get updates in between scheduled conference calls, and these updates (e.g., when water trucks will arrive) are important to our staffing of the sites.
- SOPs for water boil events of both types: line break/ service interruption; and Citywide turbidity-based events.
- Understanding the roles and responsibilities when the EOC is activated is important for all executives and city council members. Also, a point of contact for council to go for information about and beyond what is being provided to the public needs to be established.
- More table top and functional exercises involving departments besides the public safety agencies.

Respondents were asked to rate the effectiveness of the coordination with public information officers to meet their information needs. The 36 responses received are summarized in Figure 15.

Figure 15: Response Stakeholder Survey



Respondents were asked to list strengths regarding communication with external stakeholders they observed during the response. Some of these are summarized below, as entered by the respondents.

- News outlets appear to have the information as soon as it was available.
- Schools notified families through their out calling system, which brought in people for water.
- Press releases, website updates, and social media seemed to suffice.
- APH–Environmental Health Services Division utilizes Constant Contact for communicating electronically with permitted facilities and stakeholders. Distribution lists were already in place.

Respondents were also asked how communication with external stakeholders could have been improved. Some of these responses are summarized below, as entered by the respondents.

- JIC concept needs to be strengthened.
- All messaging should come from the JIC.
- Maintenance of accessible, up-to-date contact lists for each type of stakeholder; better info regarding which agency is responsible to maintain which contact list.
- Having a clear policy surrounding the use of reverse 911 would be important for future emergencies.
- Sending out a Warn Central Texas text early on the morning of Monday, Oct. 22 would have helped spread the word more quickly.

Recovery

Respondents involved in recovery operations were asked to list strengths they observed during the recovery operations. Some of these responses are summarized below, as entered by the respondents.

- MARC was set up well and organized with lots of resources.
- The MARCs had a good representation of varying agencies.
- Predetermined and existing cost codes.
- Good coordination among teams in the field.

Respondents were also asked how recovery operations could have been improved. Some of these responses are summarized below, as entered by the respondents.

- MARC: More planning lead time to prepare for the MARC deployment and allow for better community awareness of the MARC. Also, more clarity and quantity of posted signage to inform community of MARC location and directions. Door-to-door: Would have provided more complete services to community if door-to-door assessment, information dissemination and emotional/spiritual care could have been planned and conducted.
- We need real-time reporting on expenses, more COA personnel involved in managing the disaster Finance function, a financial disaster policy and procedures, and mutual aid procedures.
- Have a pool of finance personnel available to assist other agencies as needed.

Training

All respondents were asked to identify the types of training they had received prior to the response that were relevant to their respective roles in the response. They were given the opportunity to select all the types of training that applied. Of the 78 respondents to this question, there were 236 responses received. These responses are summarized in Figure 16.

Figure 16: Response Stakeholder Survey

Respondents were asked if they desired to participate in future training/exercise initiatives based on their experience during this response. Of the 76 respondents who answered, 62 indicated they desire additional training/exercise participation (81.2 percent).

Respondents were then asked how they prefer to receive training. They were given the opportunity to select all methods of training that they prefer. Of the 61 respondents to this question, there were 223 responses received. These responses are summarized in Figure 17.

Figure 17: Response Stakeholder Survey

Respondents were then asked to identify stakeholders that do not traditionally participate in training/exercises that they believe should be included in future training/exercises. Some of the responses are listed below, as entered by the respondents.

- Elected officials and media.
- HRD needs to be present.
- Volunteer groups and vendors.
- All city departments that don't traditionally manage emergency incidents.
- County staff from Auditor's Office, Purchasing, HRMD, FMD.

Action Prioritization Ranking

Overview

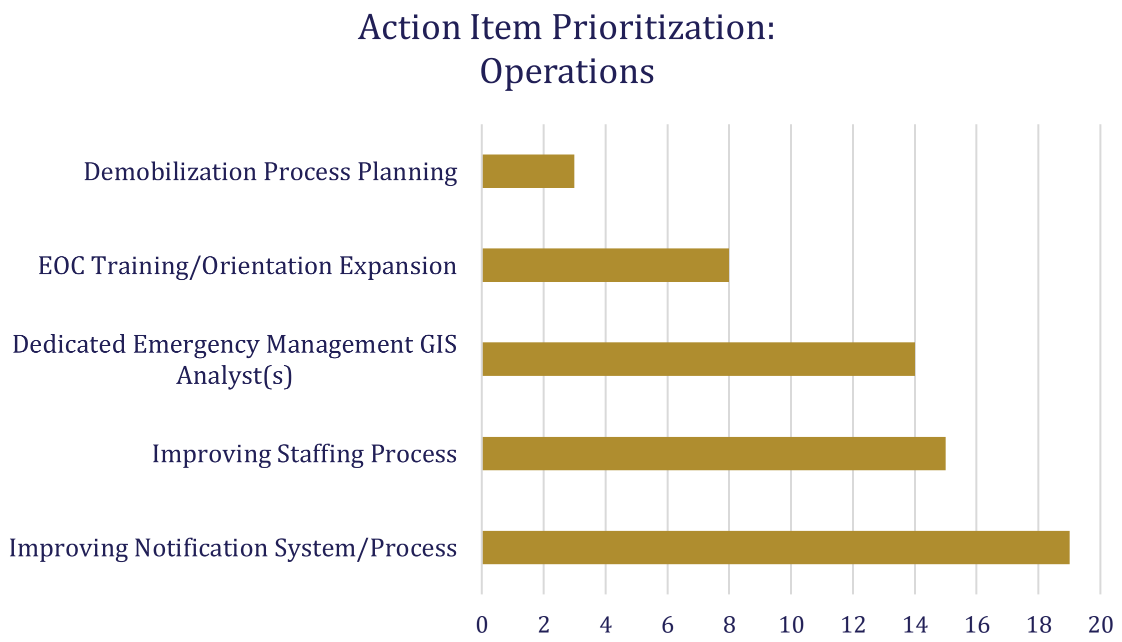
As part of the after-action process, the Project Management Team invited stakeholders and actors to participate in a series of 8 Focus Area Meetings to discuss critical elements of the response. At the conclusion of each Focus Area Meeting,[3] participants were provided a menu of three to six key action items identified during the meeting and were asked to select one or two action items which should receive priority over the others. The results of these polls are captured in this appendix and are organized by Focus Area.

[3] Polls were not conducted at the end of the Water PODs and Community Assets and Infrastructure Focus Area Meetings.

Operations

Discussion at the Operations Focus Area Meeting indicated that potential action items include improving the notification system and/or process for activation and mobilization, improving the staffing process for the EOC, having dedicated emergency management GIS analyst(s), improving and implementing EOC training and orientation, and improving the demobilization process planning. Of the 59 responses to the poll received, 19 indicated that improving the staffing process for the EOC should be a priority action item for the City and the County. Figure 18 summarizes the responses to this poll.

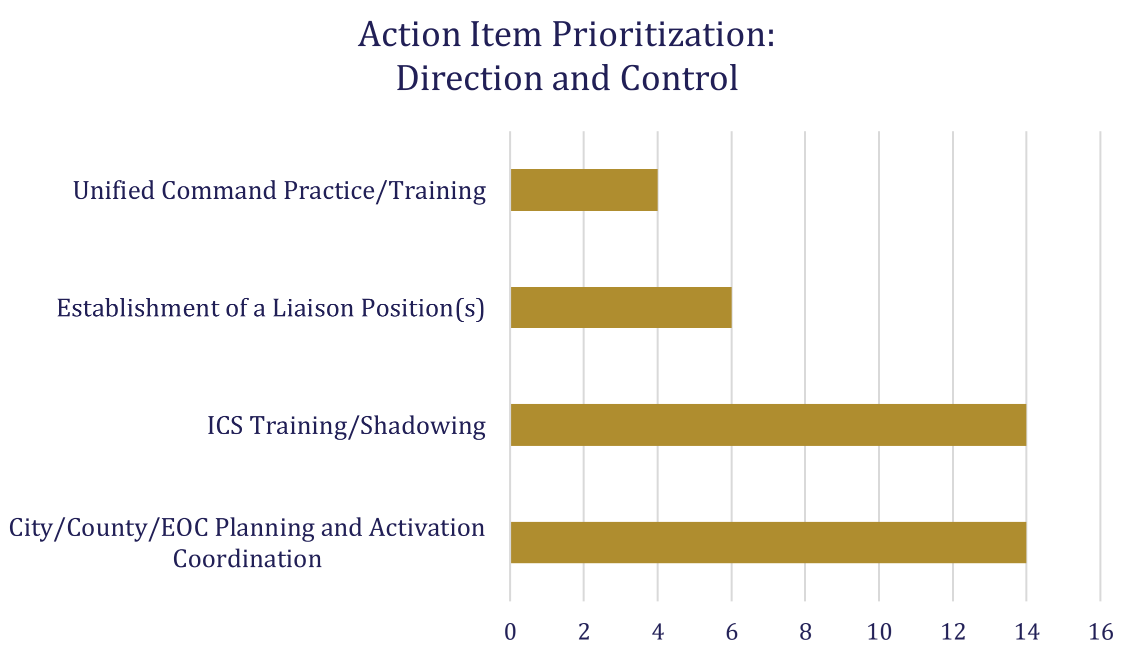
Figure 18: Action Item Prioritization: Operations



Direction and Control

Discussion at the Direction and Control Focus Area Meeting indicated that potential action items include improving the planning and activation coordination of the EOC by the City and the County, more emphasis on ICS training and role shadowing, establishing additional liaison positions with various partners, and increasing practice and training on unified command during incidents involving multiple departments and agencies across multiple counties and cities. Of the 38 responses to the poll, 14 indicated that improving the planning and activation coordination of the EOC by the City and the County should be a priority action item for the City and the County. Similarly, 14 responses also indicated that the City and County should place more emphasis on ICS training and role shadowing. Figure 19 summarizes the responses to this poll.

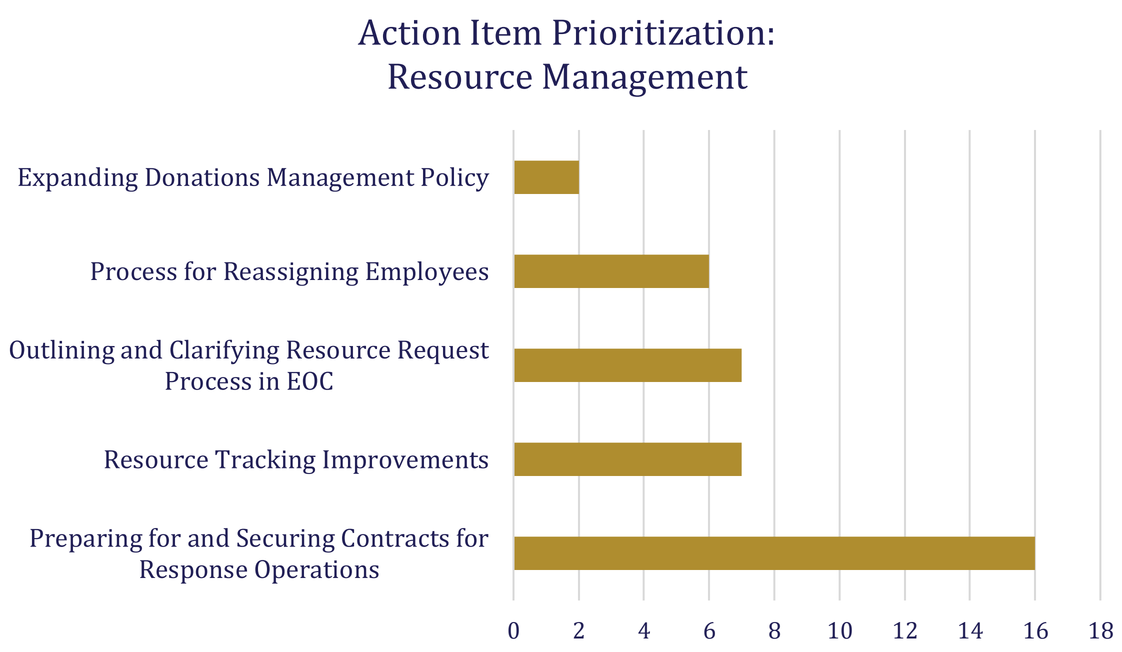
Figure 19: Action Item Prioritization: Direction and Control



Resource Management

Discussion at the Resource Management Focus Area Meeting indicated that potential action items include establishing a process for reassigning employees, preparing for and securing contracts for response operations, outlining and clarifying a resource request process in the EOC, expanding the current donations management policy, and improving resource tracking. Of the 38 responses to the poll received, 16 indicated that preparing for and securing contracts for response operations should be a priority action item for the City and the County. Figure 20 summarizes the responses to this poll.

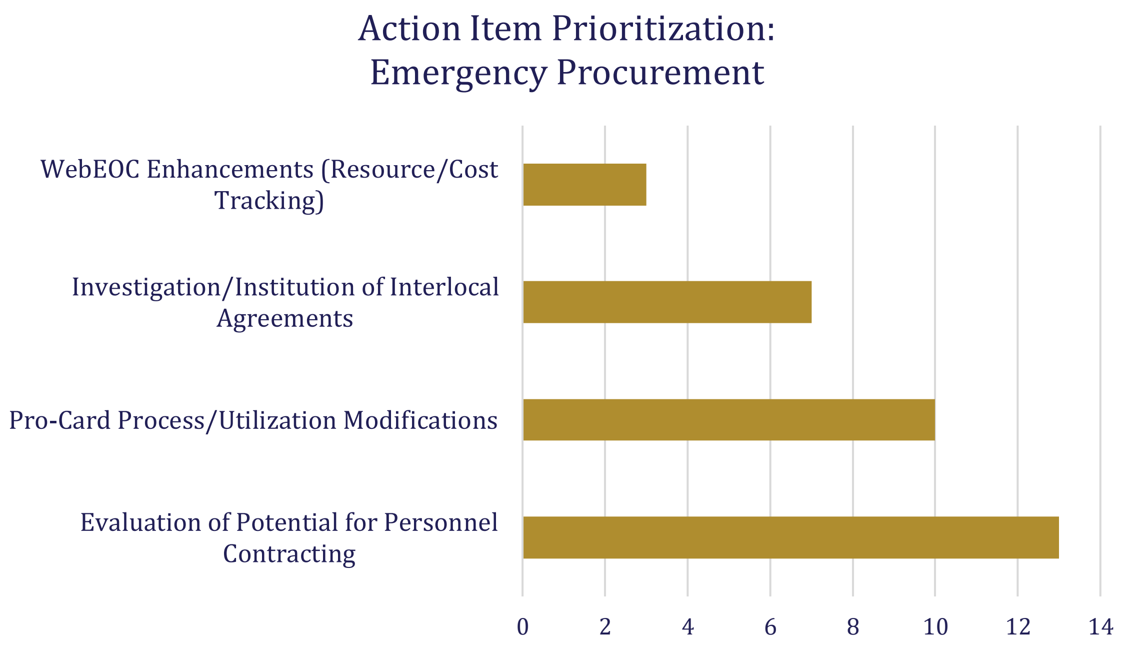
Figure 20: Action Item Prioritization: Resource Management



Emergency Procurement

Discussion at the Emergency Procurement Focus Area Meeting indicated that potential action items include exploring enhancements to WebEOC such as resource and cost tracking, the evaluation of potential for personnel contracting, investigating existing interlocal agreements and/or the institution of new interlocal agreements, and modifying the current Pro-Card process and utilization. Of the 33 responses to the poll received, 13 indicated that evaluating the potential for personnel contracting should be a priority action item for the City and the County. Figure 21 summarizes the responses to this poll.

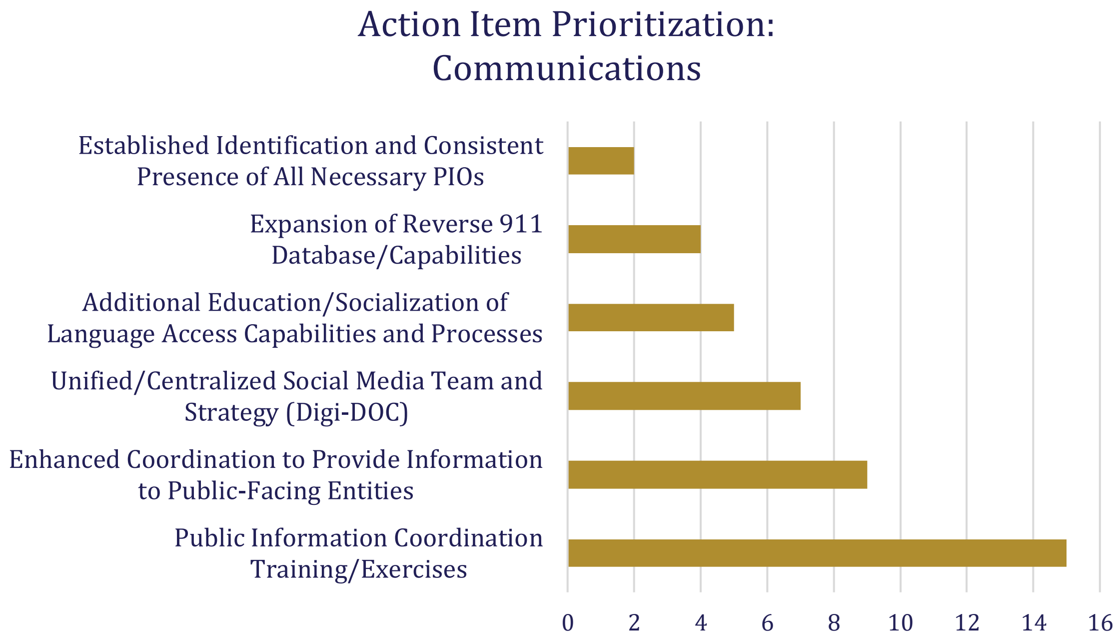
Figure 21: Action Item Prioritization: Emergency Procurement



Communications

Discussion at the Communications Focus Area Meeting indicated that potential action items include establishing a unified or centralized social media team and strategy, having additional education and socialization of language access capabilities and processes, enhancing coordination to provide information to public-facing entities, increasing public information coordination training and exercises, expanding the reverse 911 database and capabilities, and establishing the identification and consistent presence of all necessary PIOs. Of the 42 responses to the poll received, 15 indicated that increasing public information coordination training and exercises should be a priority action item for the City and the County. Figure 22 summarizes the responses to this poll.

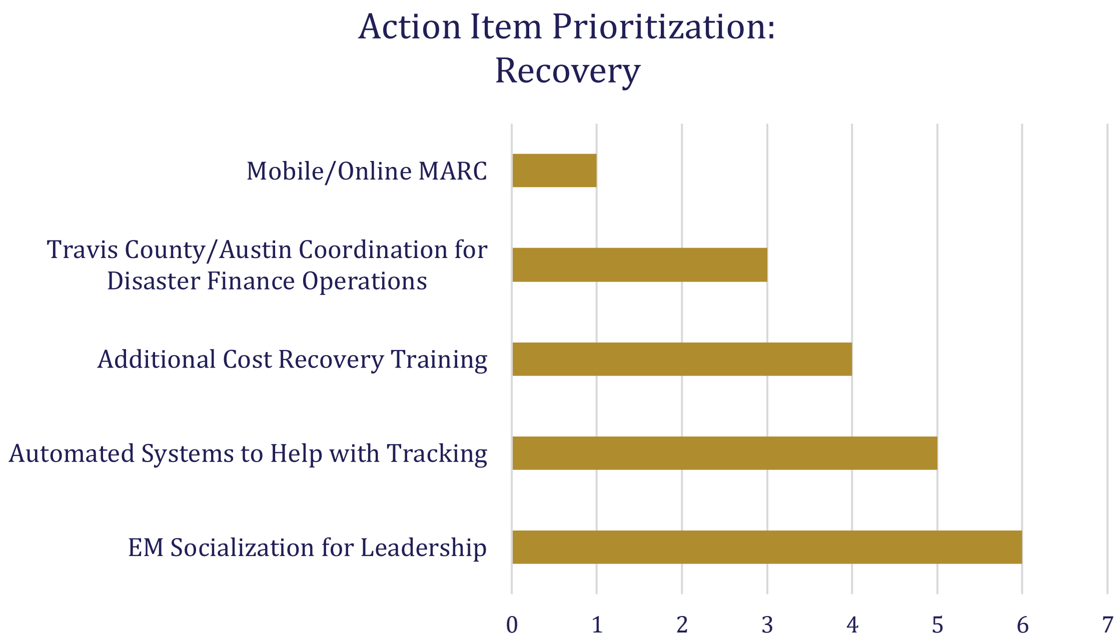
Figure 22: Action Item Prioritization: Communications



Recovery

Discussion at the Recovery Focus Area Meeting indicated that potential action items include having additional cost recovery training, establishing automated systems to help with tracking, improved coordination between Austin and Travis County for disaster finance operations, providing emergency management socialization for leadership, and establishing mobile and/or online Multi-Agency Resource Centers. Of the 19 responses to the poll received, 6 indicated that providing emergency management socialization to personnel in leadership positions should be a priority action item for the City and the County. Figure 23 summarizes the responses to this poll.

Figure 23: Action Item Prioritization: Recovery



Acronyms and Abbreviations

Acronym	Meaning
AAC	After-Action Conference
AAR	After-Action Report
AFD	Austin Fire Department
AFN	Access and Functional Needs
AISD	Austin Independent School District
APH	Austin Public Health
ARC	American Red Cross
CAMOC	Capital Area Medical Operations Center
CAP	Corrective Action Plan
CAPCOG	Capital Area Council of Governments
CATRAC	Capital Area Trauma Regional Advisory Council
COOP	Continuity of Operations
CPIO	City of Austin Communications and Public Information Office
CTECC	Austin/Travis County Combined Transportation, Emergency & Communications Center
CTM	City of Austin Communications and Technology Management
DDC	Disaster District Committee
DOC	Department Operations Center
EMI	Emergency Management Institute
EOC	Emergency Operations Center
ERT	Emergency Response Team
ESD	Emergency Services District
FEMA	Federal Emergency Management Agency
GIS	Geographic Information Systems
HR	Human Resources
HRD	City of Austin Human Resources Department
HRMD	Travis County Human Resources Management Department
HSEM	City of Austin Office of Homeland Security and Emergency Management
IAP	Incident Action Plan

Acronym	Meaning
ICP	Incident Command Post
ICS	Incident Command System
IMT	Incident Management Team
JIC	Joint Information Center
LCRA	Lower Colorado River Authority
MACC	Multi-Agency Coordination Center
MARC	Multi-Agency Resource Center
MOU	Memorandum of Understanding
NGO	Non-Governmental Organization
NIMS	National Incident Management System
PIO	Public Information Officer
POD	Point of Distribution
PPD	Presidential Policy Directive
RSA	Regional Staging Area
SitRep	Situation Report
SOP	Standard Operating Procedure
STAR	State of Texas Assistance Request
TCEQ	Texas Commission on Environmental Quality
TCOEM	Travis County Office of Emergency Management
TDEM	Texas Division of Emergency Management
TNR	Travis County Transportation & Natural Resources
VOAD	Voluntary Organizations Active in Disaster
WTP	Water Treatment Plant

Attachment:

Austin Water – Colorado River Flood 2018

AUSTIN WATER – COLORADO RIVER FLOOD 2018

OCTOBER 16 THROUGH 29, 2018

AFTER ACTION REPORT/IMPROVEMENT PLAN

REPORT FINALIZED MARCH 25, 2019

HANDLING INSTRUCTIONS

1. The title of this document is **Austin Water – Colorado River Flood 2018 - After Action Report, Improvement Plan**.

2. The information gathered in this document is a review of the emergency response and coordination efforts conducted by Austin Water. It is not a technical review of operational conditions, decisions, or performance; which will be completed by another division. This document does not review response efforts conducted by any other department of the City of Austin or Travis County.

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Executive Summary

On Tuesday, October 16, 2018, heavy rains and flooding to the west and north of Austin were creating a potential flood hazard for facilities and locations owned and operated by Austin Water. Though all Austin Water facilities were aware of and preparing for the possible flooding, specific planning was focused on and being conducted by the Longhorn Dam operators.

On Thursday, October 18, the Handcox water treatment plant began to notice an increase in raw water turbidity and began making adjustments to their treatment process. The storm was so concerning that the utility pre-staged its Department Operations Center (DOC), placing it on standby, in anticipation of flooding. On Friday, October 19, water treatment plants were still operating normally, but AW operations staff reported high source water turbidities at all three water treatment plants. On Saturday, October 20, the situation was worsening, and the decision was made to activate the Incident Management Team (IMT) and DOC on Sunday morning, October 21, to provide coordination, planning, and support. Eventually, the incoming raw water was so inundated with particulate matter that the plants were unable to meet operational demands. The Director of Austin Water, in consultation with the Incident Manager and IMT, made the recommendation to issue a Boil Water Notice (BWN) Sunday evening.

Austin Water communicated situational awareness and the decision to issue the BWN with City of Austin executive leadership and the City Emergency Operations Center (EOC). Austin Water began disseminating the BWN information on their social media outlets on Monday, October 22. The BWN was in effect until Sunday, October 28. AW suspended DOC operations on Monday, October 29.

The purpose of this report is to analyze this incident, identify strengths to be maintained and built upon, identify potential areas for further improvement, and support development of an improvement plan.

Methodology

This report was developed by staff from the Austin Water Emergency Management program. Information was gathered from all response participants by conducting group forums. We spoke with each individual facility or program area involved including, Pumping and Reservoirs, Longhorn Dam, Davis Water Treatment Plant, Ullrich Water Treatment Plant, Handcox Water Treatment Plant, Department Operations Center/Incident Management Team participants, wholesale customers, and the AW Executive team. Additionally, anyone who was not able to or did not attend one of the forums was provided an opportunity to speak with EM program staff personally, to report their feedback, or to provide written feedback. All feedback obtained was summarized into this report and Improvement Plan.

SECTION 1: INCIDENT OVERVIEW

Incident Details

Incident Name
Colorado River Flood - 2018

Type of Incident
Flood Incident – resulting in Boil Water Notice

Incident Start Date
October 16, 2018

Incident End Date
October 29, 2018

Duration
Approximately 13 days

Location
Greater Austin area of Central Texas

Responsible Agency
Austin Water

Program
Water Treatment Operations

Mission
Manage water treatment and distribution operations in response to heavy rain and flood
Maintain production and delivery of potable water for consumption and fire suppression capabilities

Participating Organizations

Austin Water

Responding Organizations

Austin Parks and Recreation Department
Austin Police Department
Austin Public Works
Texas Commission on Environmental Quality

SECTION 2: ANALYSIS OF OPERATIONS

Major Strengths

The major strengths identified during this incident are as follows:

- A strongly coordinated effort ensured public safety, with no verified reports of serious illness or death attributable to consuming City-provided water.
- Austin Water IMT members and operations staff responded quickly and provided a full-throated effort to address the effects of the heavy rains and flooding that were experienced during this incident.
- A constant water supply and a pressurized system were maintained throughout this incident, ensuring fire suppression capabilities and an uninterrupted availability for customers.
- Prior training in the Incident Command System, the establishment of a department IMT, and previous exercises aimed at developing a utility-wide understanding of the application of that system resulted in a well-coordinated and effective response.
- Technical applications for coordinated communications, specifically Skype and the contracted service "SendWordNow" (a mass communications application), were extremely useful for information sharing and situational awareness.

Focus Area Feedback

South First Street Support Center:

Longhorn Dam Operations:

Tuesday, October 16, 2018 marks the day Longhorn Dam (LHD) operations became aware of pending weather issues associated with this incident. They began receiving weather and operational updates from the Lower Colorado River Authority (LCRA) and the National Weather Service (NWS). Updates from LCRA were relative to the dams upstream of the LHD, and contained forecast and flow information, and operations status related to the pending heavy rains. NWS was reporting weather forecasts and a Flash Flood Watch in the Hill Country.

LCRA River Operations began placing status update calls to LHD as operational changes occurred. These calls went directly to the Dam Operator, at their work station, and did not always get relayed to a supervisor. The Superintendent for LHD contacted LCRA River Operations and coordinated information flows more efficiently, ensuring contact with him when updates were made.

LHD utilized email, text, and phone calls to communicate with AW and the DOC, which seemed to work well. However, as the incident progressed, other information sharing platforms were introduced, causing confusion. Specifically, the smartphone application “WhatsApp”. Not all participants had this platform, which was a noted deficiency.

Prior to activation of the DOC, LHD coordinated requests for support and status updates through the AW Emergency Management team. Once the AW DOC was activated, resource coordination went through the DOC and worked very well. LHD was able to communicate their needs and the DOC/IMT was responsive. Food procurement for staff on 12 hour shifts were difficult for LHD operations and they suggest having the IMT coordinate ordering and delivery of all food for all response personnel, regardless of location.

The DOC used Skype for video conferencing with remote locations, to include the South First Street Support Center, LHD Operations, and treatment plants. LHD reports having a poor understanding of Skype operations at the beginning of this incident, but felt that they became more proficient as the incident progressed. They liked the audio/video capability but request more Skype specific training in the future. The current DOC configuration (set up at time of incident in a conference room) presented difficulties with audio feedback, too many people in the room and other technical issues. At the outset of the incident, status conferences were too long and did not follow a standard protocol for each call. LHD recommends setting agendas for calls and sharing agendas with all participants prior to the calls.

DOC and IMT activation were very beneficial for LHD staff as they responded to this incident. Centralized command and coordination eased their planning burden and they appreciated knowing what was happening throughout the rest of the utility. They felt like the activation followed their previous training and exercise experiences and are very supportive of a continued training effort. They echo sentiments in favor of a full-time dedicated DOC with improved technical capabilities.

At one point during this incident, LHD personnel reported threatening contact with civilians at the dam site. They requested enhanced police patrol and contact, through the DOC. Austin Police Department did respond to the dam and provided information and assistance to LHD personnel. No arrests or other police interventions were made. Austin Parks and Recreation Department also assisted in this effort by providing barricades for use at the dam site. They also utilized a portable trailer, supplied by City Fleet Services, to coordinate on-site operations and provide shelter. This resource was very valuable but was needed at multiple locations within the city. LHD Management suggests a permanent trailer be purchased by AW for their future use.

Pumping and Reservoirs:

The Pumping and Reservoirs (P&R) division was receiving weather warnings and informational updates as they came into the South First Street Support Center. The updates contained Flash Flood Warnings from NWS and dam operations information from LCRA. It did not contain alerts, warnings or other information relative to water quality on the Colorado River. P&R first became aware of water quality issues on Thursday, October 18 when Handcox Water Treatment Plant (Handcox) reported elevated raw water turbidity. P&R worked with all AW treatment plants to ensure sufficient pressure in the distribution system throughout this incident.

P&R also appreciated the activation of the DOC/IMT for coordinating response efforts. They reiterate concerns with Skype difficulties including audio feedback, and poor understanding of technical operations of the platform at the beginning of the incident. They also request expanded Skype training, and conference agendas to improve reporting processes.

P&R concurred with LHD staff on need to have food and other resources coordinated through the IMT, emphasized the value of prior Incident Command System training and exercises, and appreciated the efforts of the IMT within the DOC.

Albert Davis Water Treatment Plant:

Plant management and staff were preparing for possible impacts from the storm. On Thursday, October 18, they received information from Handcox on increased raw water turbidity. As turbidity rose, the plant staff became overwhelmed with issues related to treating the water. DOC activation and coordination helped them by providing response objectives and requested support resources. Some specific examples were the IMT requesting assistance from other AW divisions when Davis overflowed a grit trap and when they experienced printer issues. The IMT was able to provide timely and supportive assistance.

Davis did report issues at the outset with some logistical needs. When original requests were made for bottled water and food at the plant, the logistics section seemed to place the request back onto the plant. This was eventually fixed and the DOC support proved very beneficial.

Davis reported some issues with command and control at the outset of the activation. Davis, and other field entities were using a smartphone application called "WhatsApp" to share information, but the DOC was not. The plants felt like the app was a good communication platform, but it presents many problems. Davis Superintendent requests a single information sharing platform to upload documents and provide situational awareness.

Davis staff felt there was some early confusion as to who was in charge of the overall activation. The Water Operations Manager, who normally serves the IMT as an Operations Section Chief, took over supervision of the Ullrich plant. Davis staff felt like this created a bit of a void for them with regard to who was directing their response activities. Once the IMT and Incident Manager were established, that seemed to clear up. DOC operations were viewed as very helpful, especially when coordinating support resources.

Skype status calls were beneficial, but were a bit clunky at the beginning. Each Incident Manager would run the calls slightly differently, and there was a learning curve for use of Skype. Once the calls became more formatted, and plants were asked for specific information prior to the calls, they felt like the calls went more smoothly and flowed better. It is suggested to develop a set agenda for these calls in the future. The DOC set-up, in Waller Creek Center room 104 contributed to issues on the calls. There was distracting background noise and a lack of privacy during the calls. Davis staff felt reassured by Director Meszaros' presence during status calls.

Davis did experience some wireless internet issues during the incident. Most staff were on mobile devices and Wi-Fi was less than optimal at some times. They would like to have their on-site Wi-Fi strengthened in the future.

Albert Ullrich Water Treatment Plant:

Plant leadership and staff had been watching news updates related to incoming weather and were receiving National Weather Service updates from Emergency Management. Staff altered their scheduled activities that week due to the potential for flooding at the plant. They report good information sharing between plants and the DOC, when activated, but had poor familiarity with the WebEOC platform.

Plant leadership reports challenges with recording and passing along information regarding activities at the plant. On-shift personnel were more focused on operations, and were not adequately recording what was being done in real time. No one served as a scribe or recorder at the plant level. Most information was being noted on a whiteboard and turnover briefings were lacking substance and accuracy. Much of the real time operational planning was being done "by the seat of the pants" at the plant level.

Operations and plant leadership said they felt like the DOC was not adequately listening to their reported inability to meet operational demands. Plant operators and line supervisors were frustrated by the demands put upon them by the DOC. They said they tried to communicate difficulties in maintaining production levels with elevated turbidity, however plant shutdowns still occurred. The technical aspects of this process are discussed in the Austin Water Technical AAR and are not detailed in this report. The reported communications difficulties are noted here as response gaps and as an opportunity for improvement with future responses.

Skype calls were beneficial and were a great way to share information across all treatment plants and operations areas. Once those calls got into full swing, this plant felt like they had a better understanding of what was occurring across the utility. They also report having little experience with the platform and request additional training and use during exercises to increase their proficiency with the tool.

Resource coordination through the DOC was very helpful, but communication lacked a bit. In one case Ullrich had requested assistance from AW pipeline services, but were not informed that resources were en route to them. They also request greater support from the Logistics Section for personal resources like food and water.

There was a single safety issue during response operations. A lock-out/tag-out "near-miss" occurred while an electrician was working on a piece of electrical equipment. No injuries were sustained and the incident was reviewed by the AW Safety group.

This plant also reports wireless connectivity issues and requests upgrades to their on-site capabilities. Most, if not all, plant personnel were using mobile devices and experienced difficulties throughout the incident.

Leadership at this plant reports limited experience with the ICS and requests additional training and exercises. They would also like to see improvements in situational awareness tools, specifically the ability to display SCADA information on a big screen and a single site for information sharing.

Berl Handcox Water Treatment Plant:

This plant receives raw water from intakes in Lake Travis and were the leading indicators of potential problems with the incoming water. They recognized this on Thursday October 18 and shared that information with plant leadership at both Davis and Ullrich. This is an important fact to understand for possible future incidents.

This plant seems to be the genesis for using the information sharing platform, "WhatsApp". They relied heavily on the application for communications within the plant and with the other two plants and pumping operations. They report that email and text messaging were less effective, as staff were rarely at their computers to receive email. Texts have limitations on how many people can effectively be included in a given message group. The "WhatsApp" application is more user friendly, was quicker, and allowed them to share operational updates. This plant's staff reports low understanding and competency with WebEOC, which they did not use during the incident.

Handcox staff felt like the Skype status conference calls were very helpful, but would like to receive more training on Skype and would like a more defined agenda for use during conferencing. They also reported that having the calls so close to shift change proved challenging. They suggest reviewing the possibility of setting another schedule for these calls.

Staff at Handcox request more internal communications to enhance situational awareness. They suggest expanded use of the Send-Word-Now application to provide information within the utility. They were not aware that the BWN was being recommended, and so were not prepared for that internally, until they saw it on television.

Handcox staff were very concerned with having Operational Directions in writing, to alleviate confusion and set direct operational parameters. They did not feel like they were receiving written Operational Period Objectives, but were more being told – do what you have to do to stay online. Staff failed consistently to record operational orders or actions taken, on either ICS form 214 or any other format.

Handcox requested expanded and improved support from the Logistics Section. Specifically Handcox wanted administrative support, someone to help with documenting time worked, and scribing decisions and historical data, and assistance with obtaining fuel and food. This was the first time this plant had interfaced with an operational DOC and they did not fully understand what the DOC/IMT could do for them. Their geographical distance from the DOC made some logistics needs a challenge. They would like to be more involved in process and procedure as the Logistics Section is upgraded and improved.

Austin Water Department Operations Center/Incident Management Team:

Two after action sessions were conducted for the DOC/IMT staff to provide feedback from this incident. The consensus of opinion was that IMT staff had a low understanding of the possibility for negative impacts from this rain incident, prior to activation of the team. The primary issues first associated with the flooding were occurring in another county and turbidity issues were not predicted, so many IMT staff were not anticipating the activation of the AW DOC.

IMT staff with prior training and exercise experience felt like they were largely prepared for DOC operations and were relatively comfortable with the activation. Many AW personnel were called into service at the DOC without prior training and exercise experience. They generally reported a steep learning curve and nervousness with serving in new positions or in the organized ICS structure. All have requested continued training and exercises going forward.

Skype was a great tool for status conferencing, but there were learning curves for some staff on the IMT. It is requested that Skype training be made available for all AW personnel. The DOC set-up was not conducive to effective Skype meetings because there are too many people in the background and too much background noise. When a permanent DOC is developed, consider a more private area for Skype meetings. Many of the laptops brought into the DOC by IMT members were not adequately prepared for Skype and required formatting, which slowed the process. When the permanent DOC is developed, laptops for each IMT position should be in place, energized, and receiving the appropriate software updates.

WebEOC was not adequately utilized during this activation. The DOC Managers were posting updates ad hoc, but were not coordinated with the Incident Managers to post uniformly throughout the incident. EOC Representatives also posted intermittently during the entire activation, but updates and information within those updates were not generally coordinated. WebEOC training for all AW IMT staff should be conducted going forward.

Some IMT positions were understaffed, and some had not been thoroughly developed for this response. For a number of positions, EOC Responder, DOC Manager, and Plans Section, we were forced to bring in staff without previous training in these positions and provide them with "Just-in-Time" training to fill roles. Some Sections were not fully developed, necessitating the creation of units within those sections at time of response. Specifically, the Plans Section Situation Unit was constructed on the fly by bringing in Systems Planning division staff and assembling equipment and space. The Logistics Section was also put together at time of response. All ICS Sections should be evaluated and necessary units developed, going forward.

There were a few notable "Single-Points-of-Failure" as well. A special liaison with TCEQ, outside the normal Liaison Officer role, was established to work through the boil water conditions and to determine what benchmarks would need to be met in order for us to rescind the order. Only one AW member was able to meet this need sufficiently, and ended up working every day of the activation. Also, the Wholesale Customers staff member was a single source of contact between the utility and our wholesale customers. Both of these positions should be better developed, to include depth for response or identified AW staff who can serve as back-ups.

It was also noted that we utilized all three pre-designated Incident Managers for the duration of this activation. Further development of this and other critical positions should be considered going forward.

Executive Team:

An information feedback session was held with the Austin Water Executive team. Members felt that communications and status updates were lacking at the outset of this activation. Some Executives are not on the IMT and so did not receive timely updates. We need to develop better messaging and include all Executive team members when activations occur and when providing updates to DOC activities.

Incident Managers became aware that staff were using the "WhatsApp" platform for group messaging. This application is not an authorized communications platform for official utility business or use. IMT members and Emergency Management staff will work with AW IT personnel to develop better mass communications strategies. It was suggested that we work with the Capital Area Council of Governments (CAPCOG) to further develop WebEOC boards which could be used for communications during activations. We will also work with the IT division to further develop Skype capabilities and training.

All Executive team members were in full agreement that a permanent and dedicated Department Operations Center is necessary and a priority. The current DOC setup, ad hoc in Waller Creek Center room 104, presents a number of challenges to managing a crisis response. The physical setup of the room is not conducive to proper planning, having quiet and confidential status conferences, unit level discussions, monitoring of situational awareness, etc. The Emergency Management group is actively working on an in-house solution which will provide a dedicated and properly equipped space for a permanent DOC.

Incident Managers recommend developing status call agenda templates for future activations. Share the agendas with all concerned parties so that conferences are more streamlined and efficient. Then, utilize those templates for all status conferences and stick to the agendas.

The Executive Team would like to see development of more interactive maps which could be used for customer coordination and strategic incident response planning. All would also like to see continued ICS and IMT training and exercises. All who have attended training and exercises in the past, list that experience as relevant and very beneficial in their ability to respond during this incident.

Executive Team members also recognized the threat of single-point-failure in the Regulatory Liaison and Wholesale Customer positions. They would also like to see more interaction or development of a liaison position for contact with the Lower Colorado River Authority (LCRA) as well.

Wholesale Customers:

The AW Wholesale Customers Program Manager conducted several feedback sessions with our wholesale customers. These were primarily phone conference calls. These groups reported positive impressions of the response, praising the Program Manager and noting that she may be a single-point-failure during responses, as she does not have identified back-up for response operations. There was praise for our rapid response and amount of communication overall with wholesale customers during this incident, however we were a little slow at the outset of the incident.

Most of the complaints voiced by our wholesale customers were related to the regulations for rescission of the BWN, as determined by the Texas Commission for Environmental Quality (TCEQ). Our program manager and our environmental liaison officer were the conduits between TCEQ and our customers. These two positions should be further developed, with the generation of specific units within the AW IMT, and included in future training and exercises.

Noted Needs Improvements

Throughout the incident, several opportunities for improvement were identified and recommendations for improvements are noted by general category below.

Notifications

- Notification of activation for AW IMT members was reported as generally sufficient, however, many participants reported being under informed as to the concerns for storm consequences and preparedness steps taken by the utility.

- It is recommended that AW Emergency Management develop protocols for alerting all AW personnel when DOC/IMT activations are made.
- Currently, pre-incident awareness messages are shared at the Executive, Operations Management, and Division Management levels, and include certain specific groups like Safety, Security and PIO. It is recommend that these groups forward all pre-incident updates, alerts, and messages throughout their chains of command, to all subordinate personnel.

Communications

- Skype for Business was used as an application for conducting meetings during this response, by the AW IMT, for the first time. There were issues with creating invitations to meetings, sound and video coordination, and general Skype use. AW personnel are generally not aware of Instant Message/Group Messaging. Absent an official communications platform, personnel utilized the free messaging application, WhatsApp. This platform is not consistent with accepted mass communications standards. It does not provide for open records requests, is an open source application, and is not sanctioned for use by AW.
  - It is recommended that the AW IT Division prepare and disseminate training specifically related to Skype use, to include use on personal devices, like tablets and smartphones. It is also recommended that AW computers/laptops that would be used during responses be continually updated for these applications.
  - It is recommended that AW CIO develop policy for mass communications processes and defines acceptable platforms for communicating information which contains operational data, orders, reports, and other information as specified.
  - It is recommended that AW Emergency Management and AW IT develop an information sharing SharePoint site for response communications and better situational awareness. This would be used in coordination with the AW IMT and DOC.
  - Most AW personnel are not familiar with WebEOC and how to use that platform. It is recommended that WebEOC training and use be expanded to include plant and field level supervision and all IMT

members.

Incident Command System/Incident Management Team

- Gaps were noted during this response, including shortages of pre-trained personnel and under-developed units, within many of the ICS Sections that were activated. There is not a permanent and dedicated DOC for use during incident activations, which adds difficulty to the incident management process. Undefined triggers delayed the process of activation and implementation of mitigating actions. Many responders, throughout the utility, lack sufficient understanding of the application of incident command principles.
    - It is recommended that a dedicated and permanent DOC be established for use during training, exercise, and response activities. The DOC should be equipped to support each IMT position, and have all necessary audio/video connections to ensure situational awareness.
    - It is recommended that the IMT adhere to ICS principles, including the production and distribution of an Incident Action Plan for each operational period containing written incident objectives, and assignments and contact information for all active positions. Incident Management should be alert to operational restrictions, always remembering the SMART principle of objective development.
    - It is recommended that AW Emergency Management develop activation and alert triggers to aid in pre-incident decision making. These triggers should allow for earlier identification and activation for mitigation actions.
    - It is recommended that the IMT is expanded to include detailed units within the Logistics and Planning Sections. This expansion should include the identification of personnel to staff each unit and necessary training to provide sufficient service. This should also include identifying non-traditional units such as Environmental Liaison and Wholesale Customer.
        - Special consideration should be made regarding the Situation Unit within the Planning Section.
        - Special consideration should be made regarding development of Logistical support units with the Logistics Section.
    - It is recommended that the AW Emergency Management team continue to provide in-house ICS training and IMT exercises. Exercises should not be limited to past experiences within the utility but should also include scenarios which might possibly occur in the future.

    - It is recommended that DOC status conference calls be conducted by agenda, which is pre-developed and disseminated to all remote locations participating with the IMT. This agenda should include timing, required information, reporting order, follow-up and other information as needed.

SECTION 3: CONCLUSION

The complex and swift-moving nature of disasters make them challenging to deal with. These challenges are even greater when major events take place in metropolitan communities where hundreds of thousands of people will be adversely affected. Anticipation, planning and preparation are key to the safety of people, the protection of property and infrastructure, and to ensuing recovery of the community. It takes a multitude of resources and cooperation to manage such events.

The 2018 Colorado River Flooding in central Texas and the subsequent exceptionally high raw water turbidities locally were historical incidents that were unpredicted. The severity of this situation necessitated Austin Water, in conjunction with external partners, to issue a Boil Water Notice in the eleventh largest city in the nation. This was truly an unprecedented event.

The seven-day boil water notice and continuous flood control dam operations impacted over a million residents. Despite the enormity of this endeavor, throughout this incident there were no verified reports of serious illness or death associated with consuming City-provided water.

Under the direction of Greg Meszaros, Austin Water's Director, the utility's Incident Managers, and the Emergency Management Team, this report sets out to analyze this incident, identify strengths to be maintained and built upon, identify potential areas for further improvement, and support development of an improvement plan.

The lessons learned from this incident will help the City of Austin and other communities better prepare for potential disasters like floods and poor raw water quality in the future. It should be noted that some of the early lessons are already being applied to Austin Water's Emergency Management activities, dam operations, and treatment facilities including:

- Improving notification and alerts
- Advancing water quality predictions
- Improving resource planning and logistics
- Increasing readiness training
- Expansions in IMT staffing
- Improving internal and external communications
- Creating a comprehensive emergency response plan

Austin Water is exceedingly grateful to our staff and all the agencies within the region that collaborated on multiple initiatives to ensure a positive outcome for all effected. The utility has begun to identify and has started working on treatment, operations, and service delivery enhancements specific to flood and turbidity related incidents, and to overall emergency response. Infrastructure and process improvements have begun and are in the proposal, evaluation, planning, or implementation stages throughout the utility, and will continue. Austin Water is committed to reviewing and improving our processes and procedures, and to continuing to provide the highest quality services for residents and visitors.

Appendix A: Improvement Plan

This IP has been developed specifically for Austin Water as a result of the Colorado River Flood 2018 incident. These recommendations are drawn from the After Action Review.

Recommendation	Capability Element	Primary Responsible	Agency POC	Start Date	Completion Date
Develop protocols for sending alert notifications utility wide, including all internal stakeholders	Notifications	AW EM	Chapman, C	November, 2018	June 1, 2019
Develop information sharing platform to improve situational awareness during incidents	Communications	AW EM – AW IT – AW PIO	Chapman, C	November, 2018	June 1, 2019
Develop policy/protocols for mass communications and social media – use of smartphone applications	Communications	AW CIO	Stewart, C	November, 2018	June 1, 2019
Develop and disseminate Skype training to include use on laptops, smartphones, tablets, workstations, etc.	Situational Awareness	AW IT	Stewart, C	November, 2018	June 1, 2019
Provide WebEOC training for AW personnel	Situational Awareness/ Communications	AW EM	Chapman, C	November, 2018	June 1, 2019
Develop a dedicated Department Operations Center for AW	Command and Control	AW EM	Chapman, C	November, 2018	Mar 31, 2020
Continue to provide ICS training and exercise for all IMT and other staff as required	Training	AW EM	Chapman, C	November, 2018	Review Annually by Oct 1
Expand IMT staffing to include Situation Unit and Logistics, and to create depth across entire IMT	Command and Control	AW EM	Chapman, C	November, 2018	Apr 30, 2019

Develop pre-incident “Triggers” to enhance early activation and mitigation decision making for use in all-hazards planning	Command and Control	AW EM	Chapman, C	November, 2018	Apr 30, 2019
Develop IMT Meeting Agenda templates for use during activations; provide training on use	Command and Control	AW EM	Chapman, C	November, 2018	Apr 30, 2019
Mitigate single point failures in Environmental Regulation and Wholesale Customer Services for IMT	Command and Control	AW EM	Chapman, C	November, 2018	Apr 30, 2019

Appendix B: Acronyms

FOR OFFICIAL USE ONLY (FOUO)
AFTER ACTION REPORT/IMPROVEMENT PLAN

Table B.1: *Acronyms*

Acronym	Meaning
AAR	After Action Report
AW	Austin Water
BWN	Boil Water Notice
CAPCOG	Capital Area Council of Governments
CIO	Chief Information Officer
DOC	Department Operations Center
EM	Emergency Management
EOC	Emergency Operations Center
FOUO	For Official Use Only
ICS	Incident Command System
IMT	Incident Management Team
IP	Improvement Plan
IT	Information Technology
LCRA	Lower Colorado River Authority
LHD	Longhorn Dam
NWS	National Weather Service
P&R	Austin Water Pumping and Reservoirs
PIO	Public Information Officer
SCADA	Supervisory Control and Data Acquisition
SMART	Specific, Measureable, Action, Realistic, Timely
TCEQ	Texas Commission on Environmental Quality

Corrective Action Plan

HSEM
City of Austin Office of Homeland Security and Emergency Management

Corrective Action Plan

EOC					
Rec. #	**Corrective Action(s)**	**Report Location**	**Responsible Agencies (Primary)**	**Responsible Agencies (Supporting)**	**Target Completion Date**
	Operations				
1	HRD has proactively initiated the development of an EOC activation SOPs. Input on the SOP for EOC activation by HRD should be provided by HSEM to provide context to an EOC activation. Similarly, an EOC activation SOP should be developed with input from TCOEM.	1.19	HRD		05/2020
2	Maintain full operations of the CAMOC during incidents.	1.5	COA and TC		11/2019, Ongoing
3	Develop and conduct a standardized EOC informational briefing as personnel are assigned to the EOC.	2.20	HSEM, TCOEM		11/2019
4	Conduct an operational period briefing of the Incident Action Plan (IAP) at the beginning of each operational period.	2.21	HSEM, TCOEM, and AFD		11/2019, Ongoing
5	Evaluate and modify the SitRep utilized during this incident for use as a standard during future operations.	3.3	COA and TC		11/2019
	Coordination				
6	Continue to foster the relationship between City and County staff for enhanced coordination in future EOC activations.	1.3	COA and TC		11/2019, Ongoing
7	Work with lifeline critical infrastructure stakeholders (e.g. water, energy, transportation) to develop proactive and preventative trigger points to mitigate cascading impacts.	1.4	City/County Public Works, Austin Water, Austin Energy, LCRA, TNR		05/2020
8	Continue to post the call and meeting schedule daily in the EOC to maintain EOC staff situational awareness.	1.8	COA and TC		11/2019, Ongoing

EOC					
Rec. #	**Corrective Action(s)**	**Report Location**	**Responsible Agencies (Primary)**	**Responsible Agencies (Supporting)**	**Target Completion Date**
9	Align the activation levels and interagency coordination between HSEM and TCOEM in the context of a joint EOC.	1.9	HSEM, TCOEM		05/2020
10	Although political and organizational differences between the City and County complicate the development of joint emergency response plans, collaboration between HSEM and TCOEM should occur to make the language and processes of each more uniform, such as providing clarification on respective activation and staffing levels in the context of a joint EOC.	2.14	HSEM, TCOEM		05/2020
11	Compile a list of available logistics resources that are ready to use in an emergency. Develop a gap analysis in order to develop sources for resources that are not readily available. Develop the EOC's role as a MACC and catalog available resources by agency.	4.3	HSEM, TCOEM	City/County Procurement Departments, HRD, HRMD, Central Texas VOAD	11/2019
12	Maintain good coordination with state and federal staff during EOC activations.	6.10	HSEM, TCOEM		11/2019, Ongoing
13	Document, clarify, and socialize the process for engaging intergovernmental relations staff in the EOC with elected and appointed officials.	6.11	EOC Sections		11/2019
14	Meet with State personnel in a non-disaster setting to better understand State processes in an emergency, to include mutual aid.	6.12	HSEM, TCOEM		11/2019
15	Evaluate the potential allocation of space in and around the EOC to be inclusive of a JIC, and to support GIS needs.	6.22	COA and TC		05/2020
16	Build a pre-identified list of available resources that each VOAD would be able and willing to contribute to future responses.	7.2	Central Texas VOAD	HSEM, TCOEM	05/2020

EOC					
Rec. #	**Corrective Action(s)**	**Report Location**	**Responsible Agencies (Primary)**	**Responsible Agencies (Supporting)**	**Target Completion Date**
	Training				
17	Planned logistics exercises should include City and County HR. City and County Purchasing Offices and Finance Departments are currently discussing plans to hold a joint logistics exercise.	1.21	HSEM, TCOEM, City/County Purchasing Offices, HRD, HRMD		05/2020, Ongoing
18	Conduct EOC orientation, coordination, and training. Those eligible for training should include staff who are not expecting to work in the EOC. This should include scripted "just-in-time" training to allow staff training during an activation.	1.26	HSEM, TCOEM		11/2019, Ongoing
19	Facilitate planning meetings and exercises that bring regional partners together outside of emergency incidents. This will help to continue building upon established working relationships to enhance communication and coordination effectiveness in future responses.	2.1	HSEM, TCOEM		05/2020, Ongoing
20	Continue to provide EOC training to regular employees who activate to the EOC. This training should be additionally offered to untrained employees who will eventually be activated to the EOC as they progress in their careers.	2.11	HSEM, TCOEM	All EOC Partners	11/2019, Ongoing
21	Conduct regular training on EOC roles, specifically tailored to joint Austin-Travis County EOC operations for EOC personnel. This training should highlight the process for demobilization to ensure adequate staffing is maintained and/or positions can be quickly reactivated if required.	2.19	HSEM, TCOEM		11/2019, Ongoing
22	Facilitate tabletop discussions and associated planning on complex incidents (e.g., Branch Tactical Planning), command roles and functions (e.g., Unified Command versus Area Command; Area Commander versus Incident Commander), and staffing.	2.16	HSEM, TCOEM		05/2020, Ongoing

EOC					
Rec. #	**Corrective Action(s)**	**Report Location**	**Responsible Agencies (Primary)**	**Responsible Agencies (Supporting)**	**Target Completion Date**
23	Facilitate exercises to practice communications procedures during incident response involving multiple agencies and departments across multiple cities and counties.	2.22	HSEM, TCOEM		05/2020, Ongoing
24	Continue to encourage training on and utilization of ICS and NIMS to the utmost degree possible. Additionally, facilitating exercises utilizing ICS will help relevant City and County personnel have a better understanding of ICS during responses.	2.8	HSEM, TCOEM		11/2019, Ongoing
	Demobilization				
25	Create a more transparent demobilization process for the EOC. While all EOC representatives cannot be included in the demobilization planning process, the demobilization plan should be communicated to all in the EOC, and some allowance for feedback should be made. Additionally, the demobilization process should include demobilization of mutual aid resources.	1.39	EOC Sections		11/2019

Technology					
Rec. #	**Corrective Action(s)**	**Report Location**	**Responsible Agencies (Primary)**	**Responsible Agencies (Supporting)**	**Target Completion Date**
	Personnel Management				
26	Explore a similar technology to what Williamson County used to track check in and out times of personnel at POD sites in order to provide accurate real-time tracking of staff at external sites.	3.5	HSEM, TCOEM	CTM, TC ITS, City Controller's Office, County Auditor, APH, TC HHS, CATRAC, HRD, HRMD	05/2020

Technology					
Rec. #	**Corrective Action(s)**	**Report Location**	**Responsible Agencies (Primary)**	**Responsible Agencies (Supporting)**	**Target Completion Date**
27	Explore automated check-in/check-out systems for utilization in the EOC. This will ensure more accurate personnel time and compensation tracking.	7.18	HSEM, TCOEM, CTM	HRD, HRMD, City Controller's Office, County Auditor	05/2020
GIS					
28	Expand GIS capability for application during incidents and planning.	1.1	CTM (GIS ERT), TNR, TC ITS	HSEM, TCOEM	05/2020, Ongoing
29	Simplify the process of sharing and updating data with the GIS ERT for the production of maps and other geospatial information.	1.2	CTM (GIS ERT), TNR, TC ITS	All City/County Agencies, LCRA, State, CAPCOG, Regional Partners	11/2019, Ongoing
30	Work with City and County GIS staff to ensure there is mutual knowledge of relevant datasets.	1.34	CTM (GIS ERT), TNR, TC ITS	All City/County Agencies, CAPCOG, LCRA	11/2019, Ongoing
31	Establish a dedicated emergency management GIS analyst position in order to have a greater ability to utilize GIS as a tool for emergency management, resolve challenges in utilization of GIS during activations, and act as a liaison between the GIS ERT and the EOC staff.	1.35	HSEM, TCOEM	CTM (GIS ERT)	05/2020
WebEOC					
32	Establish a WebEOC controller position. They will be responsible for updating WebEOC with command and control decisions.	1.36	COA and TC		05/2020
33	Work with CAPCOG in order to update and improve WebEOC boards.	1.37	HSEM, TCOEM		11/2019, Ongoing
34	Review the assignment of WebEOC login information and remote access capability during an activation to promote collaboration and situational awareness.	1.38	HSEM, TCOEM		11/2019, Ongoing

Technology					
Rec. #	**Corrective Action(s)**	**Report Location**	**Responsible Agencies (Primary)**	**Responsible Agencies (Supporting)**	**Target Completion Date**
35	Develop WebEOC boards for resource tracking. This should include automated tracking of resources, equipment, people, and costs to provide real-time information should be explored and developed. Implementing this will improve the demobilization process.	4.2	HSEM, TCOEM		11/2019
36	Personnel who require access to WebEOC should have the ability to receive adequate training on WebEOC. Additionally, these personnel should have accounts setup and are consistently utilizing WebEOC to input purchase requests. WebEOC should be utilized for purchase requests to help avoid double-ordering of supplies by providing situational awareness of current requests. Lastly, a process should be outlined for departmental operations centers to add their information in WebEOC in a way that provides extra logistical awareness but that is separate from EOC logistics.	5.11	Responding Agencies, City/County Departmental leadership		11/2019, Ongoing
37	Work with the CAPCOG WebEOC Administrator to modify "roles" in WebEOC to provide personnel with similar roles the same access. These roles should be preidentified and updated regularly outside of emergency incidents.	5.12	COA and TC		11/2019, Ongoing
38	Explore the use of GIS and WebEOC integration to support collecting and entering detailed information on serialized equipment into WebEOC to include last known location and status.	5.13	CAPCOG, CTM (GIS ERT)	HSEM, TCOEM	11/2019
39	Explore and/or create updates to WebEOC that can provide additional purchasing request task assignment and status information, as well as to provide a logistical overview for an operation that can be	5.14	HSEM, TCOEM, CAPCOG	City/County Purchasing Offices	11/2019

Staffing

Rec. #	Corrective Action(s)	Report Location	Responsible Agencies (Primary)	Responsible Agencies (Supporting)	Target Completion Date
	EOC Staffing				
40	Identify additional EOC liaisons to work at external sites in order to improve communications, specifically during complex cross-jurisdictional events.	1.14	EOC Sections		11/2019
41	Clarify the role and expectations of City and County HR departments in the context of an EOC activation and their timeline in the EOC activation process. This will allow for staff in the EOC and City and County HR to prepare accordingly and ensure reassigned employees are certified, safe, and not overworked.	1.16	HSEM, TCOEM, HRD, HRMD		11/2019
42	Explore the creation of an "EOC Support Team" that is pre-trained for specific positions and can support meeting the needs of operational resource requirements.	1.18	HSEM, TCOEM	EOC Sections, City/County Agencies outside of Public Safety	05/2020
43	Staff representatives from HRMD in the EOC throughout the duration of emergency incidents.	1.23	HRMD, TCOEM		11/2019
44	Assign an EOC Staffing Coordinator who would act as a centralized employee to manage the task of reassigning employees.	1.24	HSEM, TCOEM, HRD, HRMD		11/2019
45	Develop a protocol for mobilizing a school representative from the Central Texas School Safety Consortium to serve in the EOC to ensure consideration is given to the impact of a given emergency on the selected representative's district.	1.25	HSEM, TCOEM		11/2019
46	Develop a staffing plan for activations in order to be better prepared for activation needs. This plan should include: a schedule, roles needed, and potential agencies/individuals to fill those roles. The City and County should consider using standby contracts to fulfill resource needs in the staffing plan.	1.28	HSEM, TCOEM		05/2020

Staffing					
Rec. #	**Corrective Action(s)**	**Report Location**	**Responsible Agencies (Primary)**	**Responsible Agencies (Supporting)**	**Target Completion Date**
47	Encourage relevant agencies/departments to provide representation in the EOC in order to strengthen coordination during EOC activations.	1.7	HSEM, TCOEM	All City/County Agencies, County Executive, CMO	11/2019, Ongoing
48	Develop job action sheets with information on specific roles when assigning representatives to the EOC.	2.10	All City/County Agencies		11/2019
49	Develop operational structures for staffing activation that are clearly defined and communicated to EOC personnel in advance.	2.12	HSEM, TCOEM	EOC Sections	05/2020
50	Ensure that EOC personnel have appropriate decision-making authority and/or establish a process for rapid departmental approval for decision-making. Establishing and communicating this in advance will help facilitate decision making early in future responses.	2.13	CMO, County Executive	HSEM, TCOEM	11/2019, Ongoing
51	Consider the development of shift transition guidelines to accompany job action sheets and training initiatives.	2.23	COA and TC		11/2019
52	Consider staffing a safety officer in the EOC. Among items the safety officer should be responsible for are: (1) identifying whether reassigned employees need to have specific certifications, qualifications, be able to physically lift a certain weight, or any other criteria in order to perform the task being assigned to them; (2) identifying safety officers at all field sites to provide safety training and equipment to personnel; and (3) assessing EOC schedule to ensure adequate rest is provided to those involved in the operation.	3.16	HRD Risk Management Division/Office, HRMD - Risk Management	HSEM, TCOEM, City/County Fire Departments, City/County Public Works	11/2019

Staffing

Rec. #	Corrective Action(s)	Report Location	Responsible Agencies (Primary)	Responsible Agencies (Supporting)	Target Completion Date
53	Ensure that relevant City and County departments and agencies that staff personnel in the EOC have a dedicated team of personnel within their office who can respond to the EOC. This should also include exploring a policy whereby their regular positions are backfilled while they are deployed during the emergency. Utilizing consistent personnel will help build stronger working relationships, thereby increasing communication and coordination effectiveness.	5.2	CMO, County Executive	HSEM, TCOEM	05/2020
54	Continue to staff personnel from the City Fleet Services Department, as well as City and County Purchasing Offices, in the EOC during related emergency incidents.	5.3, 4.1	City Fleet Services Department, City/County Purchasing Offices	HSEM, TCOEM	11/2019, Ongoing
55	Involve relevant decision makers from City and County Purchasing Offices in responses from the beginning and ensure they are made available throughout the duration.	5.4	City/County Purchasing Offices leadership		11/2019, Ongoing
56	Request an Austin 3-1-1 presence in the EOC earlier to ensure they can communicate accurate, timely, and helpful information to the public.	6.16	HSEM, TCOEM		11/2019, Ongoing
57	Assign a public information representative to the EOC from applicable City and County agencies and departments to assist in more effective operational communication.	6.23	HSEM, TCOEM	CMO, County Executive	05/2020
58	Identify County employees to fill PIO positions during EOC activations.	6.24	County Executive, HRMD, County PIO	TCOEM	11/2019
59	Staff a Warning Officer in the EOC whose role is to document and understand the situation and produce public notices.	6.31	HSEM, TCOEM		05/2020

Staffing					
Rec. #	Corrective Action(s)	Report Location	Responsible Agencies (Primary)	Responsible Agencies (Supporting)	Target Completion Date
60	Consider the use of a specific City/County translation services team who can activate with the EOC and devote time and resources to translation services. This team could consist of VOAD members if they have been certified through the language access program or vendors that the CPIO's office has already contracted with.	6.35	HSEM, TCOEM	CPIO, CPIO Language Access Program Coordinator, HRD, HRMD	11/2020
61	Coordinate and assign City and/or County staff to be a liaison between key external agencies to coordinate a seat in the host EOC as needed.	1.13	COA and TC		11/2019
62	Create a designation of "essential" or "critical" employees to ensure employees who are responsible for activating to the EOC understand their role.	1.29	COA and TC		11/2019
	Reassignment of Employees				
63	Clarify the process of identifying and requesting reassigned employees in order to make the process easier and more streamlined.	1.15	CMO, County Executive	HSEM, TCOEM, HRD, HRMD	11/2019
64	Develop and make available a consolidated list of skill-sets by department to EOC staff in order to streamline the activation of reassigned employees in the field.	1.17	HRD, HRMD, CTM, TC ITS	County Auditor	05/2020
65	Include incident assessment processes in City and County EOC SOPs to assist them in assessing the need for organizing and contacting reassigned employees during the work day.	1.20	EOC Logistics and Planning partners		05/2020
	Training				
66	Continue to build out agency director communication, to include emergency management training.	1.27	HSEM, TCOEM		11/2019, Ongoing
67	Include shadowing as a standard practice for responding agencies and departments.	1.6	EOC Sections		11/2019, Ongoing

Staffing

Rec. #	Corrective Action(s)	Report Location	Responsible Agencies (Primary)	Responsible Agencies (Supporting)	Target Completion Date
68	Train additional staff in operational command and control in order to augment existing trained staff (e.g. AFD) in the event they are not available for a future deployment.	2.4	EOC Sections		11/2019
69	Conduct training with POD managers regarding how to manage media relations.	6.3	HSEM, TCOEM		05/2020
70	Provide cost recovery training to City and County Finance personnel. Facilitate the coordination and communication of these personnel outside of emergency incidents through planning meetings and exercises, particularly the planned logistics exercise. Provide instructions on how to accurately read payroll reports and train on this in a non-disaster setting.	7.17	City/County Finance Offices		11/2019
71	Implement additional training for individuals filling the PIO positions. Consider implementing mutual aid and standby contracts for PIO support.	6.25	COA and TC		11/2019

Procurement

Rec. #	Corrective Action(s)	Report Location	Responsible Agencies (Primary)	Responsible Agencies (Supporting)	Target Completion Date
	Procurement				
72	Review the lessons learned from this incident in order to have a better understanding of this purchasing process, to include contract language and restrictions, in advance of future emergency incidents. These lessons should be incorporated into future planning and operations.	2.17	City/County Purchasing Offices		11/2019

Procurement					
Rec. #	Corrective Action(s)	Report Location	Responsible Agencies (Primary)	Responsible Agencies (Supporting)	Target Completion Date
73	Utilize internal resources in the short-term up to 48 hours, or until external resources from the State or private sector can be mobilized.	2.3	COA and TC		11/2019, Ongoing
74	Include clauses for the removal of byproducts in contracts.	3.17	City/County Purchasing Offices		11/2019, Ongoing
75	Clarify and formalize the resource request process for the Central Texas School Safety Consortium, whether or not the State is involved in the incident, in order to better support their disaster operations.	4.8	HSEM, TCOEM, Central Texas School Safety Consortium		11/2019
76	Consider the development of an interlocal agreement that authorizes procurement card usage and cost sharing between specific agencies and departments to facilitate purchasing requests. This agreement should allow personnel with purchase approval authority to authorize purchases on their procurement cards for personnel of a different agency or department and should contain points of contact for procurement card usage and authorization. The process of tracking receipts and attaching them to the relevant procurement card should also be addressed.	5.10	City/County Purchasing Offices	City/County Legal Departments	05/2020
77	Create lists of available resources and assets that are regularly updated and shared with others. Share reusable resources among departments before purchasing new resources.	5.15	City/County Purchasing Offices	HSEM, TCOEM	11/2019, Ongoing
78	Explore additional requirements contracts for routine use that have emergency clauses that can be tapped for chemical needs. For example, Austin Water has requirement contracts for their routine chemical needs. These contracts have an emergency provision that requires the contractor to provide 24-hour point-of-contact and an "emergency response" surcharge rate.	5.16	COA and TC		05/2020

Procurement					
Rec. #	**Corrective Action(s)**	**Report Location**	**Responsible Agencies (Primary)**	**Responsible Agencies (Supporting)**	**Target Completion Date**
79	Mutual aid processes need to be better understood and a policy and process needs to be developed for accepting and providing mutual aid, to include approval, demobilization planning, legal, and cost recovery issues.	5.17	HSEM, TCOEM, City Law Department, City Controller's Office, County Auditor, City/County Purchasing Offices		05/2020
80	Enact an interlocal agreement that would establish the lead purchasing office for shared expenses.	5.6	City/County Purchasing Offices	City/County Legal Departments	05/2020
81	Establish purchasing authority and thresholds, as well as the process for increasing them, prior to the next emergency.	5.7	City/County Purchasing Offices	City/County Legal Departments	11/2019
82	During the Harvey response, personnel requesting resources filled out their own procurement forms which would then be processed by the City Purchasing Office. Continue to utilize this method, and supervisors need to ensure that their personnel know the correct processes for requesting resources and adhere to them.	5.8	HSEM		11/2019, Ongoing
83	Identify personnel who may need access to procurement cards in emergencies. Provide them with initial procurement card training, issue procurement cards, and provide annual procurement card refresher training.	5.9	City/County Purchasing Offices	City/County Legal Departments	11/2019
	Standby Contracts				
84	Compile a list of external labor contracts and a list of MOUs should be readily available for use. Establish a trigger point for utilizing outside labor resources versus reassigned employees.	1.22	City/County Purchasing Offices	City/County Agencies with standby contracts	11/2019

Procurement

Rec. #	Corrective Action(s)	Report Location	Responsible Agencies (Primary)	Responsible Agencies (Supporting)	Target Completion Date
85	Explore standby contracts with vendors for bulk resource ordering containing emergency clauses and emergency contact information for high-priority resources to be on standby at all times of day throughout the year.	2.18	City/County Purchasing Offices	All City/County Agencies	11/2019
	Private Sector Coordination				
86	Identify and coordinate with private sector community partners (e.g. H-E-B, Tito's Vodka, Wal-Mart) who may be able to provide assistance during future responses. Establish how communications will be handled in an emergency. Discuss the possibility of these partners becoming additional distribution points if needed.	2.2, 3.13	HSEM, TCOEM	City/County Purchasing Offices, City/County Logistics, City Economic Development Department, County Office of Economic Development & Strategic Investments, City/County Agencies with private-sector relationships	11/2019

Planning					
Rec. #	**Corrective Action(s)**	**Report Location**	**Responsible Agencies (Primary)**	**Responsible Agencies (Supporting)**	**Target Completion Date**
	Coordination				
87	Conduct an assessment and catalog City and County department/agency plans related to emergency management. HSEM and TCOEM should then utilize identified plans in future activations and develop a plan for updating this assessment.	1.31	COA and TC		05/2020
88	Facilitate planning meetings between counterpart departments and agencies in order to share understanding of their emergency plans, capabilities, and responsibilities in advance of emergency incidents.	2.15	HSEM, TCOEM	Responding Agencies	05/2020, Ongoing
89	Develop a joint plan on the distribution of commodities, to include elements of direction and control.	3.1	HSEM, TCOEM		05/2020
90	Clearly communicate gaps and deficiencies in resources (e.g., necessary signage and barricades) at external sites to the EOC. Additionally, consistent coordination should occur with all sites to ensure that other field sites do not have the same gaps or deficiencies, and that all sites have access to and knowledge of available resources and their locations.	3.11	Field site managers		11/2019, Ongoing
91	COOP should acknowledge agency and departmental staffing challenges during activations, accounting for staff that may be activated to the EOC or assisting with the disaster in some way even if normal agency and departmental operations are suspended.	1.30	All City/County Agencies		05/2020

Planning					
Rec. #	**Corrective Action(s)**	**Report Location**	**Responsible Agencies (Primary)**	**Responsible Agencies (Supporting)**	**Target Completion Date**
	POD Planning				
92	Review the POD plan produced by APH in order to produce a plan that is more flexible for numerous POD types, and to identify pre-determined POD locations, as well as considerations for just-in-time locations. Consider utilizing the Austin Office of Real Estate Services and the Travis County Facilities Management Department for support in the pre-identification of future POD locations.	1.32	COA and TC		05/2020
93	Create a checklist with considerations for POD sites. Knowing site layout requirements in advance can prevent logistical limitations and the need for significant changes when time is critical.	3.10	COA and TC		11/2019
94	Establish aligned POD procedures. Ensure that they are followed during operations. Institute "just-in-time" training for on the job training. Pre-identified personnel who may be involved in POD operations should, at minimum, complete and familiarize themselves with FEMA's EMI course IS-26, "Guide to Points of Distribution".	3.14	HSEM, TCOEM	Responding Agencies, ARC	05/2020
95	Develop and utilize POD manager kits to outline the staff and resources required to operate a POD (in a manner similar to the way existing shelter manager kits are organized and utilized).	3.15	COA and TC		11/2019
96	Provide a structure for POD demobilization. This structure should be integrated into a POD plan produced by these jurisdictions.	3.19	COA and TC		05/2020

Planning					
Rec. #	**Corrective Action(s)**	**Report Location**	**Responsible Agencies (Primary)**	**Responsible Agencies (Supporting)**	**Target Completion Date**
97	Continue to identify and inspect potential POD sites for future use, with an emphasis on creating a running list of site characteristics and limitations and matching these characteristics and limitations to the type of POD site. Additionally, incorporating and utilizing GIS resources in the planning process will further improve future POD establishment and operations.	3.2	HSEM, TCOEM		11/2019, Ongoing
98	The methods of mobile distribution of resources should be understood for those individuals with limited ability to travel (e.g., homebound population) currently utilized and explore how to improve this process.	3.8	HSEM, TCOEM, APH	CTM (GIS ERT), TC ITS, Central Texas VOAD, CATRAC	11/2019
99	Consider the prioritization of resources based on community need for distribution to the community during incidents.	3.9	COA and TC		11/2019, Ongoing
Donations Policy and Procedure					
100	Explore a shared emergency donations policy. It should specify whether all donations will be handled through NGOs, VOADs, or other community partners.	2.5	COA and TC		05/2020
101	Continue to utilize a single approval authority/entity (i.e. the EOC) to direct donations. This will allow the EOC to accurately manage and track donations while preventing external sites from accepting potentially illegitimate donations.	2.6	HSEM, TCOEM	Austin Resource Recovery, City/County Legal Departments	11/2019, Ongoing
102	Revise the Donations Management Annex pre-disaster to identify which agencies, departments, and/or organizations will lead, and which will play supporting roles in donations management	4.4	HSEM, TCOEM	Central Texas VOAD, City Economic Development Department, City/County Executive Staff	05/2020

Planning					
Rec. #	**Corrective Action(s)**	**Report Location**	**Responsible Agencies (Primary)**	**Responsible Agencies (Supporting)**	**Target Completion Date**
103	Expand the donations management policies of the City and County to include food and water safety standards.	4.5	HSEM, TCOEM	APH in conjunction with Central Texas VOAD	05/2020
104	TCOEM does not accept donations; rather the County directs donations to NGOs or VOADs. This option should be explored for the City for managing donations.	4.6	TCOEM		11/2019
105	Expand the donations management policy for facilities that receive direct donations, such as schools and hospitals, to account for these donations and educate decision makers about the importance of these policies.	4.7	Central Texas School Safety Consortium	ARC	05/2020
	Community Planning				
106	Work with long-term care facilities, dialysis centers, and home health and hospice agencies to get them more involved in the Capital Area Public and Medical Preparedness Coalition and the CAMOC to be more prepared during incidents.	1.33	CATRAC, APH		11/2019, Ongoing
107	Increase communication and coordination with VOADs and nontraditional community partners both in advance of and during emergency incidents. Facilitate planning meetings and exercises to allow opportunities to understand available resources and capabilities, which will be beneficial for easily identifying surge resources when needed.	3.6	HSEM, TCOEM		05/2020

Planning

Rec. #	Corrective Action(s)	Report Location	Responsible Agencies (Primary)	Responsible Agencies (Supporting)	Target Completion Date
108	Aggregate the demographic assessments conducted by various departments and agencies in order to better understand the potential locations of greater need for assistance and where there may be a need to conduct more thorough demographic assessments to identify locations of vulnerable populations (not individuals). Implement a system to update this aggregated data on a quarterly basis. Organizations such as Meals-on-Wheels and CapMetro were stated examples of expanded sources for information on vulnerable populations.	3.7	City Office of Sustainability, City Neighborhood Housing and Community Development Department, APH	CTM (GIS ERT), TC HHS, CATRAC	05/2020, Ongoing
	Recovery				
109	Update the City and County damage assessment plans to make sure businesses are assessed post incident.	7.22	COA and TC		05/2020
110	Damage assessment planning should incorporate an assessment of the unmet needs of the community (versus just infrastructure) to inform need for facilities and debris pick up and communication with VOADs to reduce duplication of efforts.	7.6	HSEM, TCOEM	Austin Code Compliance, TNR, City/County Public Works, Fire Marshal, Austin Resource Recovery, ARC	05/2020
111	Facilitate planning meetings with City and County agencies involved with debris removal and City and County PIOs outside of emergency incidents to gain a more comprehensive understanding of their debris removal procedures. Develop a joint plan on debris removal procedures for future responses.	7.20	Austin Resource Recovery, City/County Public Works, TNR	Austin Parks and Recreation Department, HSEM, TCOEM, CPIO	05/2020
112	Develop plans to track volunteer hours in the County. Familiarize County personnel on the supporting documentation required to track volunteer hour.	7.15	TCOEM, County PBO		11/2019

Communications

Rec. #	Corrective Action(s)	Report Location	Responsible Agencies (Primary)	Responsible Agencies (Supporting)	Target Completion Date
	Public Information				
114	Provide proactive messaging to the media and public regarding acceptance of donations.	2.7	City/County PIOs		11/2019, Ongoing
115	Explore alternative options for distributing information about wait times at POD sites. This should include City and County websites and social media. An example of an effective system was the voter wait time map that Travis County produced during the elections that occurred at the same time as the Colorado River flooding and boil water response. As participants voted they were asked to report how long they had waited in line. This information allowed others to see approximate wait times at the various sites in real-time.	3.4	HSEM, TCOEM	CTM, TC ITS, APH, CATRAC, CPIO, 311, Transportation, City Fleet Services	11/2019
116	Identify public health information for internal agencies and departments, concurrently with that for residents and commercial businesses, to support continuity within government operations.	6.15	HSEM PIO		11/2019, Ongoing
117	Examine the use of a virtual versus physical JIC to ensure all public information-related operational needs are met in all phases of an incident.	6.26	N/A		11/2019
118	Continue to work towards the use of already existing warning tools.	6.28	COA and TC		11/2019
119	Utilize utility customer information for public notification (e.g., Austin Energy collaborating with HSEM and TCOEM staff to subscribe customers; work with APH to notify permitted buildings related to food safety standards).	6.29	HSEM, TCOEM	Austin Energy	05/2020

Communications

Rec. #	Corrective Action(s)	Report Location	Responsible Agencies (Primary)	Responsible Agencies (Supporting)	Target Completion Date
120	Establish a public communications plan inclusive of timely and proactive resource practices to mitigate potential infrastructure systems compromise.	6.33	Regional PIO group	HSEM, TCOEM	11/2019
121	Examine policies and limitations to notification systems. Modify existing systems or procure new systems to ensure there is a streamlined process of providing notification and information to AFN communities. If the current system is identified as appropriate, expand the registry for this system to include more of the AFN community.	6.36	HSEM, TCOEM	CATRAC, APH, CAPCOG	05/2020
122	City and County staff should use this incident as an example for simplifying complex information to the public and continue this practice.	6.4	All City/County Agencies		11/2019
123	Continue to utilize technical data when communicating with the public and media, involving agencies with subject matter expertise in a particular area in the development and dissemination of the communication.	6.6	COA and TC		11/2019, Ongoing
124	Keep the media apprised of the decision-making process related to operations in order to provide consistent messaging, when possible.	6.7	COA and TC		11/2019, Ongoing
125	Utilize accessible and relatable social media communication. This should include creative communication including videos and other visual communication.	6.8	All City/County Agencies		11/2019, Ongoing
126	Develop a proactive approach to social media. Assign employees to monitor social media. Social media monitoring should support agency coordination. Develop a digital operations center where this assigned employee would activate to.	6.9	Regional PIO group	CPIO	11/2019
127	Communicate information regarding debris removal to the public as early as possible, with an emphasis on identifying outreach methods to individuals in the impact area. This will help	7.21	City/County PIOs		11/2019, Ongoing

Communications					
Rec. #	Corrective Action(s)	Report Location	Responsible Agencies (Primary)	Responsible Agencies (Supporting)	Target Completion Date
	alleviate debris build-up and make removal more manageable for TNR.				
128	Ensure that information regarding the recovery centers is advertised to the public early on in an incident. Follow-up through the entire recovery process to ensure the public receives regular information updates.	7.8	City/County PIOs		11/2019, Ongoing
129	Clarify the language used to direct the public during incidents, with consideration for the safety information required for their notices.	6.30	The EOC		11/2019
130	The simplified language disseminated to the public should be accurate and sufficient, in addition to the language that is being disseminated to meet regulatory requirements.	6.5	All City/County Agencies		11/2019, Ongoing
EOC Notification					
131	Strengthen and refine the EOC notification process, particularly in complex incidents where scaling-up and scaling-down is needed.	1.10	EOC leadership		11/2019
132	Use a multi-method form of notification including pagers for initial notification and email for large amounts of information. The list of those notified should be periodically updated.	1.11	HSEM, TCOEM		11/2019
133	Consider a process to inform all City and County staff when an activation occurs to create an understanding that the City and County are responding. From there, agencies that need to mobilize to the EOC can be communicated with.	6.13	HSEM, TCOEM		11/2019
Coordination					
134	Institute a practice of providing the information from external coordination calls to all EOC staff in executive briefings.	1.12	COA and TC		11/2019
135	The capabilities and practices to sustain regular communication between field sites and the EOC should be recorded in order to	2.9	COA and TC		11/2019

Communications

Rec. #	Corrective Action(s)	Report Location	Responsible Agencies (Primary)	Responsible Agencies (Supporting)	Target Completion Date
	provide an accurate situational awareness among response personnel. Moreover, automating this process should be explored.				
136	Collaborate with waste removal organizations to ensure the public has access to information on proper waste disposal methods and site locations.	3.18	City/County PIOs		11/2019, Ongoing
137	Continue to encourage regular communication and coordination between City and County department and agencies outside of emergency incidents, such as through planning meetings and exercises.	5.1	All City/County Agencies		11/2019, Ongoing
138	Maintain relationships with regional PIOs in order to maintain effective regional public information coordination.	6.1	CPIO		11/2019, Ongoing
139	Create a process of expediently informing agencies and departments of incident information, making note of information that is public or that is "For Official Use Only."	6.14	HSEM, TCOEM		05/2020
140	Continue to utilize third-party groups, such as professional associations, to assist in collecting and disseminating information. Communicating and coordinating with these groups outside of emergency incidents through planning meetings and exercises will increase efficiency during future responses.	6.17	COA and TC		11/2019, Ongoing
141	Consider the development and use of a communication diagram to map out audiences and message flow to support crisis communications.	6.18	COA and TC		11/2019
142	Improve the process of getting information approved by APH to send to and update Austin 3-1-1.	6.19	APH		11/2019
143	Continue to maintain strong relationships with the media in order to maintain public information dissemination channels.	6.2	COA and TC		11/2019, Ongoing

Communications

Rec. #	Corrective Action(s)	Report Location	Responsible Agencies (Primary)	Responsible Agencies (Supporting)	Target Completion Date
144	Coordinate with all public information partners (including digital) to ensure effective preparation for increased inquiries and web traffic.	6.20	HSEM, TCOEM	CTM, TC ITS, APH, CATRAC, CPIO, 311, Transportation, City Fleet Services	11/2019, Ongoing
145	Reevaluate the situational awareness protocols, including interagency communications, to establish communication channels for all operational areas during activations.	6.21	HSEM and TCOEM		05/2020
	Language Access				
146	Develop a language access plan specific to the emergency management related activities. The language access plan should include measures for how responders should submit requests for translation support during incidents, as well as a management framework for language access support. This plan should be supplemented by pre-established standby contracts.	6.34	HSEM, TCOEM	CPIO, CPIO Language Access Program Coordinator	11/2020

Recovery

Rec. #	Corrective Action(s)	Report Location	Responsible Agencies (Primary)	Responsible Agencies (Supporting)	Target Completion Date
	EOC Operations				
147	Monitor recovery operations. Continue to provide support throughout the recovery phase.	6.32	EOC Sections		11/2019, Ongoing

Recovery					
Rec. #	**Corrective Action(s)**	**Report Location**	**Responsible Agencies (Primary)**	**Responsible Agencies (Supporting)**	**Target Completion Date**
148	Continue to engage City and County Finance personnel early in future responses. Continue to facilitate meetings and exercises outside of emergency incidents. Continue to proactively coordinate with State partners to ensure effective collaboration during response operations.	7.3	HSEM, TCOEM		11/2019, Ongoing
149	Explore where City and County finance processes and tools align so that the EOC Finance Officer can provide financial direction to representatives of both jurisdictions (rather than just communicating City of Austin codes and processes, as was the case in this event).	7.3, 7.4	City/County Finance Offices		11/2019
	MARC				
150	Continue to encourage regular coordination and communication between personnel involved in MARC operations, to include regional partners, outside of emergency incidents, such as through planning meetings, workshops, and exercises.	7.1	HSEM, TCOEM		11/2019, Ongoing
151	Coordinate and consolidate the process for identifying the need of MARCs with VOADs and other partners so as to limit logistical needs, duplication of efforts, and confusion to the public.	7.10	MARC Work Group		05/2020
152	Collaboration between the City, County, and VOADs responsible for setting up MARCs should occur with other organizations that can assist in identifying areas with greater potential need for assistance (e.g., TNR can help identify which areas would most likely consist of primary residences versus areas that would most likely consist of non-primary residences). Utilize applicable data sets to determine the impacted areas and how that compares with identifying needs.	7.11	MARC Work Group	TNR, GIS ERT, CATRAC	05/2020
153	Explore and develop plans for establishing a mobile MARC, as well as having an online presence to provide information to the public.	7.9	MARC Work Group	HSEM, TCOEM	11/2019

Recovery

Rec. #	Corrective Action(s)	Report Location	Responsible Agencies (Primary)	Responsible Agencies (Supporting)	Target Completion Date
	Damage Assessments				
154	Coordinate with partner agencies in advance to enable a cohesive process for determining impacted community members and assessing the unmet needs of the community.	7.12	TC HHS, APH	HSEM, TCOEM, Central Texas VOAD	11/2019, Ongoing
155	Facilitate damage assessment tabletop discussions and exercises outside of emergency incidents in order to improve coordination and communication among stakeholders, particularly VOADs and other regional partners.	7.5	HSEM, TCOEM	Central Texas VOAD	05/2020
156	Provide a brief of the debris management process to the EOC staff during activations.	7.19	All City/County Agencies		11/2019, Ongoing
	Cost Recovery				
157	During the Harvey response, purchasing personnel had a flow chart to direct them on reimbursement policies and processes. Develop a similar tool template that can be modified for utilization during future incident responses.	5.5	City/County Purchasing Offices		11/2019
158	Develop a Disaster Cost Recovery Plan that clearly identifies all roles, responsibilities, triggers, and operations for cost recovery functions, beginning with pre-disaster activities, through conclusion of said activities (e.g., closeout activities). Train all pertinent departmental representatives on the plan and their specific responsibilities to ensure procedures are effectively implemented.	7.16	County Auditor, HSEM, City Controller's Office, City Purchasing Office	TCOEM, County Purchasing Office, HRMD, TNR, TCSO, HRD, City/County Legal Departments, Austin Resource Recovery, City Budget Office	11/2020

Recovery					
Rec. #	**Corrective Action(s)**	**Report Location**	**Responsible Agencies (Primary)**	**Responsible Agencies (Supporting)**	**Target Completion Date**
159	Additional emergency-focused financial capability outside of the EOC needs to be developed so that expense templates and instructions can be modified to the specific event and distributed city and county wide while the EOC Finance Chief is still activated in the EOC. Explore developing separate roles for providing city and county wide financial direction and tools versus creating the daily burn rate versus developing the Disaster Summary Outline versus providing financial support for Logistics. In a small event this can be one person, but in a large event this needs to be split out into multiple roles and for personnel to be trained in these areas.	7.4	CTM, City Purchasing Office, City Controller's Office, HSEM, County Auditor, TNR	TCOEM	05/2020
160	Explore automating cost tracking processes and utilizing contractors in order to reduce the burden of compiling supporting documentation for FEMA.	7.14	CTM, TC ITS	City/County Purchasing Offices, HSEM, TCOEM, City Controller's Office, County Auditor	05/2020

MEMORANDUM

To: Mayor and Council Members

From: Greg Meszaros, Director, Austin Water

Date: September 19, 2019

Subject: October 2018 Flood Event Engineering Review and Recommendations

As part of Austin Water's after-action review of the October 2018 Colorado River Flooding and Boil Water Notice, the Utility commissioned an engineering study of the event. To conduct the study, Austin Water assembled a team consisting of internal engineering and operating staff, Carollo Engineers, Inc., and Professors Desmond Lawler and Lynn Katz of the University of Texas.

Austin Water has completed the study work and I have enclosed the two reports that were produced. The first, entitled "October 16, 2018 Flood Event Report and Resulting Recommendations" provides a detailed analysis of the October flooding impacts on the Utility's drinking water plants and associated recommendations for improving plant performance during future events. The second report, entitled "Bench Testing Report" provides the analytical results of testing various treatment strategies on banked raw water that was preserved from the October flooding event. The Bench Testing Report was third party reviewed by Professors Lawler and Katz and provides the analytical framework for treatment process recommendations. Key findings and recommendations include the following:

- Raw water conditions associated with the October 2018 flooding were unprecedented and the duration of raw water upset was significantly longer than past events.
- To prepare for future extreme turbidity events, Austin Water will need to enhance treatment options to improve flexibility to operate during water quality upset episodes. The recommended strategy is to add polymer-based treatment technologies at all three drinking water plants. The report estimates the capital cost for a polymer system at approximately $9.3M. Other more capital-intensive changes, such as the addition of presedimentation basins or a conversion away

from lime softening, were considered but not warranted based on the results of the Bench Testing study.

- Improve operator instrumentation capability to precisely measure water particle charge and adjust treatment processes.
- Enhance internal extreme event operating procedures and guidelines to document lessons learned from the October flooding and provide staff improved resources to manage future water quality upset events.

Austin Water is expeditiously moving forward with these recommendations. We have begun the process of developing a scope of services to design and construct polymer feed systems at all three of our plants. We have placed orders to purchase zeta-potential meters (a device that precisely measures water particle charge) to support operations. We have updated internal procedures and guidelines and will continue to enhance these as we integrate zeta-potential meters and polymer technologies.

Should you have any questions or would like any additional information please contact me.

cc: Spencer Cronk, City Manager
Rey Arellano, Assistant City Manager

Attachments: October 16, 2018 Flood Event Report and Resulting Recommendation
Bench Testing Report

City of Austin
Process Treatment Recommendation Resulting from October 2018 Flood Event

OCTOBER 16, 2018 FLOOD EVENT REPORT AND RESULTING RECOMMENDATIONS

FINAL | July 2019

carollo

TBPE No. F-882

City of Austin

Process Treatment Recommendation Resulting from October 2018 Flood Event

OCTOBER 16, 2018 FLOOD EVENT REPORT AND RESULTING RECOMMENDATIONS

FINAL | July 2019

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EXECUTIVE SUMMARY

An extreme flood event in October 2018 dramatically changed the characteristics of the raw water supply to the City of Austin's three Water Treatment Plants (WTPs). The change in raw water quality was unprecedented based on historical data from previous events. The change in quality made the water challenging to treat while meeting plant production requirements, and resulted in the City of Austin (City) issuing a mandatory Boil Water notice on October 24, 2018.

During the flood event, the City retained Carollo Engineers, Inc. (Carollo) to help provide on-site support at the Ullrich WTP. Carollo's efforts during the flood included: evaluating treatment plant operations and capabilities to understand limitations and options to operate the plant while the raw water quality remained challenging to treat; conducting bench tests to assess treatment options available to the WTP and to support recommendations for WTP operational adjustments; and, providing technical support, including mobilization of a temporary polymer feed system to improve treatment at the Ullrich WTP. This report documents observations and findings from Carollo's engagement at the Ullrich WTP during the October 2018 flood event, including:

- The impact of the flood event on raw water quality, treatability, and residuals handling,
- Limitations of the WTPs to treat the water at full plant capacity,
- Results from bench and demonstration tests conducted during the flood event and resulting recommendations for operational adjustments,
- Lessons learned from the flood event as well as from other water utilities that experience similar raw water quality challenges and operate lime softening plants,
- Conceptual level costs to implement recommended process / infrastructure modifications, and
- Conclusions and recommendations.

The October 2018 flood event resulted in drastic and sustained differences in raw water quality from what is considered typical at all three of the City's WTPs. The turbidity, a measurement of the concentrations of particles or solids in the water, increased almost 100-fold within 36 hours and remained high for several weeks. The turbidity peaked at 415 Nephelometric Turbidity Units (NTU) and needed to be reduced to 0.3 NTU to meet TCEQ requirements. This change meant that the WTPs suddenly needed to adjust operations to remove a substantial quantity of solids from the water prior to distribution to its customers. Coupled with the increase in turbidity was a decrease in the concentrations of alkalinity and hardness, two parameters that drive typical operation of the City's WTPs.

Austin’s WTPs are designed to treat Lower Colorado River water as reflected by previous historical norms. The existing WTP facilities are equipped to adjust several operational set points to respond to a change in water quality. However, additional tools that are incorporated at other lime softening plants in the country that experience high turbidity loading similar in magnitude to the October 2018 flood event are not available at the City's WTPs because there is no previous precedent that would indicate those tools are needed. As an example, lime softening plants that treat the Missouri River (nicknamed the "Big Muddy" for apt reasons), incorporate horizontal collection wells, pre-sedimentation basins, and/or two-stage softening to help remove particles through the WTP. Some plants also include polymers to aid in particle removal.

In the absence of those tools, the City needed to make what operational adjustments they could to produce water to meet customer/system demands. Early in the flood event, City Plant Operations staff observed improved treatability by increasing the lime dose to achieve a softened water pH > 10.5, with additional improvement from increasing the ferric sulfate dose. The City also reduced flow through the WTPs to the extent possible to reduce the surface overflow rates through each clarifier. Bench testing confirmed that all of these steps (i.e., increasing the softening pH, increasing the ferric sulfate dose, and decreasing the flow) resulted in optimal water quality during the flood event. Bench testing also indicated improved settleability of the solids with the addition of a coagulant aid polymer, and/or a flocculant aid polymer. Based on those results, a temporary coagulant aid polymer feed system was implemented for one of the upflow solids contact clarifiers at the Ullrich WTP with positive outcomes.

The City made a decision to collect approximately 100 gallons of raw water on October 25, 2018, when the quality remained challenging with elevated turbidity and depressed alkalinity and hardness. This turned out to be very beneficial as the "banked" water was used to further assess recommended operational strategies and required WTP improvements to respond to similar extreme raw water quality events that may occur in the future. Results from those tests are documented in the Bench Testing Report (Carollo, 2019) and factored into recommended improvements presented herein.

The 2018 October flood event reset the bar in terms of the range of raw water quality that may be observed at the City's WTPs. Further, the event changed expectations in terms of the range of water quality that the WTPs need to be capable of treating. The following major steps are recommended for the City to prepare for similar future water quality events:

- Provide additional treatment options to improve flexibility to operate during extreme weather-related events. Based on observations during the October 2018 flood event and jar tests with the banked water, the following improvements are recommended:
  - Add cationic coagulant aid polymer feed capabilities at the three WTPs.
  - Add the capability to feed the same cationic polymer to the filter influent at the three WTPs.
  - Add flocculant aid polymer feed capabilities at the three WTPs.
  - Add the capability to feed the same bridging (flocculant aid) polymer to the gravity thickener influent at Ullrich and Handcox WTPs.
  - Class 5 construction cost estimates for the new polymer feed systems are approximately $9.3 million.
- Develop a water quality event response plan, which includes Standard Operating Procedures (SOP) for stepwise and incremental adjustments in operations to optimize treatment in response to the change in water quality.

The recommended improvements represent WTP upgrades that could be made to improve resiliency to extreme events with only minor infrastructure modifications. While other options could be (and have) been considered, such as conversion from softening to coagulation or addition of a presedimentation basin, these improvements would require major changes to infrastructure that may not be needed nor warranted. The data collected during the October 2018 event as well as subsequent testing using banked water (see Bench Testing Report, Carollo 2019) highlighted the potential for improving resiliency without such drastic changes.

Abbreviations

AWWA	American Water Works Association
Carollo	Carollo Engineers, Inc.
CCPP	calcium carbonate precipitation potential
cf	cubic feet
cfs	cubic feet per second
DBP	disinfection by-product
DOC	dissolved organic carbon
F	Fahrenheit
ft	feet
ft^3	cubic feet
gpm	gallons per minute
HCW	horizontal collector well
hrs	hours
LT2ESWTR	Long Term 2 Enhanced Surface Water Treatment Rule
µg/L	micrograms per liter
MG	million gallons
µg/L	micrograms per liter
mg/L	milligrams per liter
mgd	million gallons per day
NTU	Nephelometric Turbidity Units
NOM	natural organic matter
PEA	polymer - flocculant aid
PEC	polymer - cationic
PHD	peak hour demand
PS	pump station
lbs	pounds
psi	pounds per square inch
RO	Reverse Osmosis
SCADA	supervisory control and data acquisition
SCC	solids contact clarifier
SHMP	sodium hexametaphosphate
SOP	Standard Operating Procedure
SOR	surface overflow rate
S.U.	standard units
s	second
TCEQ	Texas Commission on Environmental Quality
TOC	total organic carbon
WTP	water treatment plant

INTRODUCTION

An extreme flood event in October 2018 dramatically changed the characteristics of the raw water supply to the City of Austin's three water treatment plants (WTPs). The change in raw water quality made the water challenging to treat, impacting the ability of the WTPs to meet the City of Austin (City) finished water quality goals at full plant capacity. Significant additional effort from City staff was required to operate the WTPs during the flood event. The City retained Carollo Engineers, Inc. (Carollo) to help provide on-site support at the Ullrich WTP. Carollo's efforts during the flood event consisted primarily of the following:

- Evaluating treatment plant operations and capabilities to understand options to operate the plant while the raw water quality remained challenging to treat.
- Setting up and conducting bench tests to assess treatment options available to the WTP and to support recommendations for WTP operational adjustments.
- Providing technical support including implementation of a temporary cationic polymer (PEC) feed system to enhance particle neutralization and removal through the Ullrich WTP.

This Technical Memorandum documents:

- The observed impacts of the flood event on raw water quality and why those differences impacted the City's ability to operate the WTPs at typical production capacity,
- Limitations of existing WTPs including residuals handling facilities constraining plant production during the flood event,
- Results from jar tests conducted during the flood event and resulting recommendations for adjustments,
- Lessons learned from the October 2018 flood event, and
- Lessons learned from other lime softening water utilities that experience similar raw water quality challenges and operate lime softening plants.

Conceptual level cost opinions to implement recommended process / infrastructure modifications are also presented, along with conclusions and recommendations.

Section 1

FLOOD EVENT IMPACT ON WATER QUALITY

The October 2018 flood event resulted in drastic differences in raw water quality from what is considered typical at all three of the City's WTPs. Table 1 displays historical raw water quality measured at Ullrich WTP compared to the extreme values measured during the flood event. The raw water quality trends observed at Ullrich were similar at both the Davis and Handcox WTPs. Figures 1 through 7 display the historical versus the flood event raw water quality for the following parameters:

- Turbidity.
- pH.
- Alkalinity.
- Hardness.
- Calcium.
- Magnesium.
- Total organic carbon (TOC).

While past significant rain events have resulted in short term spikes in turbidity and TOC combined with reduced hardness and alkalinity, the magnitude of the flooding, the condition of the lakes being full, and the duration of the October 2018 event was greater than past events, making it difficult for the City's WTPs to treat the water at typical flows. A detailed evaluation of historical water quality is presented in the City of Austin's After Action Report.

Table 1 Historical Raw Water Quality at the Ullrich WTP vs. Flood Event Extremes

Parameter	Flood Event Extreme	Historical Average(1)	Minimum(1)	5th Percentile(1)	95th Percentile(1)	Maximum(1)
Total Alkalinity (mg/L as $CaCO_3$)	100	179	138	161	208	229
pH (SU)	7.92	8.21	7.70	8.10	8.40	8.50
Turbidity (NTU)	415	4.54	0.56	2.03	7.27	125.0
Total Hardness (mg/L as $CaCO_3$)	88	216	144	190	258	280
Calcium (mg/L)	29	51	38(2)	41	69	78
Magnesium (mg/L)	4	21	10	16	24	26(2)
TOC (mg/L)	7.78	4.20	3.27	3.45	4.99	12.60

Notes:
(1) Data collected between January 1, 2013 and December 31, 2015.
(2) Discarded June 3, 2013 measurement as potentially erroneous outlier. Next lowest Ca and highest Mg values provided.

The discussion below lists each of the key water quality parameters and how each one impacted water treatability during the flood event.

1.1 Turbidity

Turbidity is a measurement of the light-scattering properties of water. Turbidity in drinking water supplies is commonly caused by the presence of suspended matter, such as clays, silts, finely divided organic and inorganic matter, plankton, and other microorganisms with the highest sensitivity being in the 0.1 to 0.5 micron particle range. High turbidity may also correlate with a high concentration of negatively charged particles which requires destabilization to facilitate removal by agglomeration followed by settling and filtration treatment processes. Therefore, turbidity is used as an indicator of drinking water quality and as an indicator of the efficiency of drinking water coagulation and filtration processes.

The typical average turbidity of the City's raw water is less than 5 NTU. Starting on October 18, the raw water turbidity at Ullrich WTP increased from 4.8 NTU to 305 NTU over the course of the first 36 hours of the flood event, as shown in Figure 1. The turbidity finally peaked at 415 NTU on October 21 and remained well above historical norms for multiple weeks after the flood event. The increase in turbidity presented several inter-related challenges for WTP operation:

1. The WTPs struggled to maintain low settled water turbidity values. A majority of the excess turbidity present in the raw water was removed during the softening process and was incorporated into the precipitated solids, resulting in solids with a lower specific gravity than typical. A lower specific gravity likely reduced the settling rate of the solids, requiring a reduction of flow through the WTPs to meet the settled water turbidity targets. Additional details of the impact of raw water and treatment approaches on solids density and settleability are provided in Section 5.
2. Higher solids loading to the filters resulted in increased backwashing frequency to meet filtered water turbidity goals. The increased filter backwashing frequency challenged the ability of the plant to meet plant production goals.
3. Capacity of the residuals handling facilities was exceeded. The mass of solids removed through the softening process increased two fold based on calculations accounting for raw water turbidity and chemical feed during the flood event. The volume of residuals conveyed to the gravity thickeners and washwater basins also increased due to changes in sedimentation basin blowdown and filter backwashing frequency as the WTPs adjusted operations to respond to the different water quality.

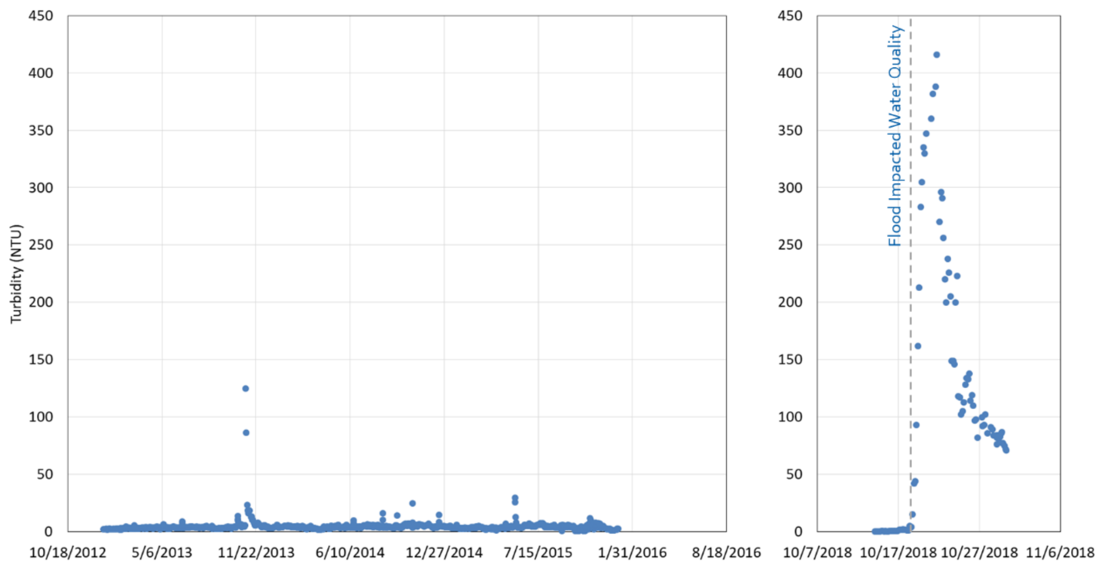


Figure 1 Raw Water Turbidity - Historical (Left) and Flood Event (Right)

1.2 pH and Alkalinity

pH is an expression of the negative log of the hydrogen ion concentration in water. A pH of 7.0 represents a neutral condition, a pH of greater than 7.0 represents a basic (alkaline) condition, and a pH of less than 7.0 represents an acidic condition. pH is an important parameter governing many chemical reactions in water treatment, including softening, coagulation, disinfection, and disinfection by-product (DBP) formation. The alkalinity (or buffering capacity) of a water supply moderates changes in pH. In general, the higher the alkalinity, the more resistant the water is to a change in pH.

The pH and alkalinity of the raw water typically average 8.2 and 180 mg/L as $CaCO_3$, respectively. During the flood event, pH values were below historical 5th percentile values (Figure 2), and the alkalinity dropped from approximately 160 mg/L as $CaCO_3$ to a low of 100 mg/L as $CaCO_3$, as shown in Figure 3. The low alkalinity of the raw water resulted in insufficient carbonate (CO_3^{-2}) to precipitate the same amount of $CaCO_3$ that is typical of the City's WTP softening process.

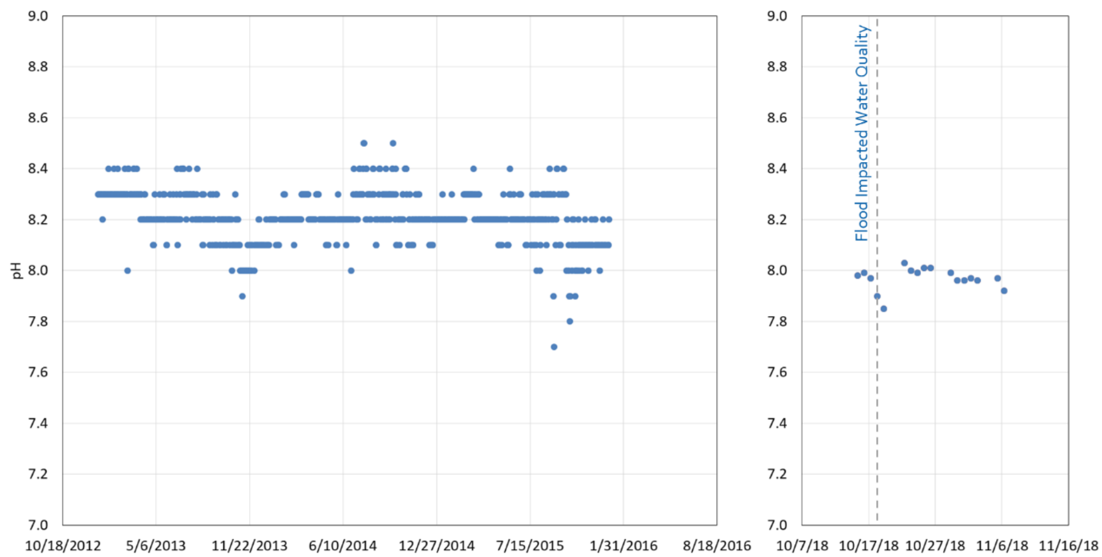


Figure 2 Raw Water pH - Historical (Left) and Flood Event (Right)

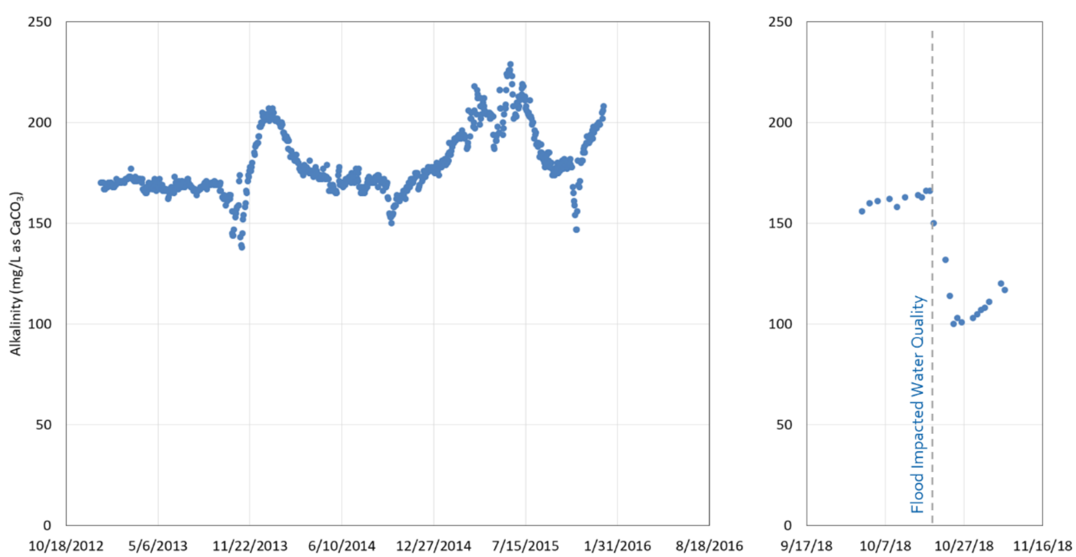


Figure 3 Raw Water Alkalinity - Historical (Left) and Flood Event (Right)

1.3 Hardness

Hard water may be characterized as a water that does not lather well, causes scum in the bathtub, and leaves hard, white, crusty deposits on coffee pots and water heaters. The primary components of total hardness are dissolved calcium and magnesium ions (divalent cations). Total hardness is expressed as an equivalent quantity of calcium carbonate ($CaCO_3$). Waters having less than 75 mg/L as $CaCO_3$ are generally considered soft; levels between 75 and 150 mg/L as $CaCO_3$ are considered moderately hard, and levels greater than 150 mg/L as $CaCO_3$ are considered hard.

Figure 4 shows that during the flood event, total hardness dropped from 190 mg/L as $CaCO_3$ to a low of 88 mg/L as $CaCO_3$. As expected, the decrease in total hardness was accompanied by a drastic decrease in the calcium (Figure 5) and magnesium (Figure 6) concentrations in the raw water.

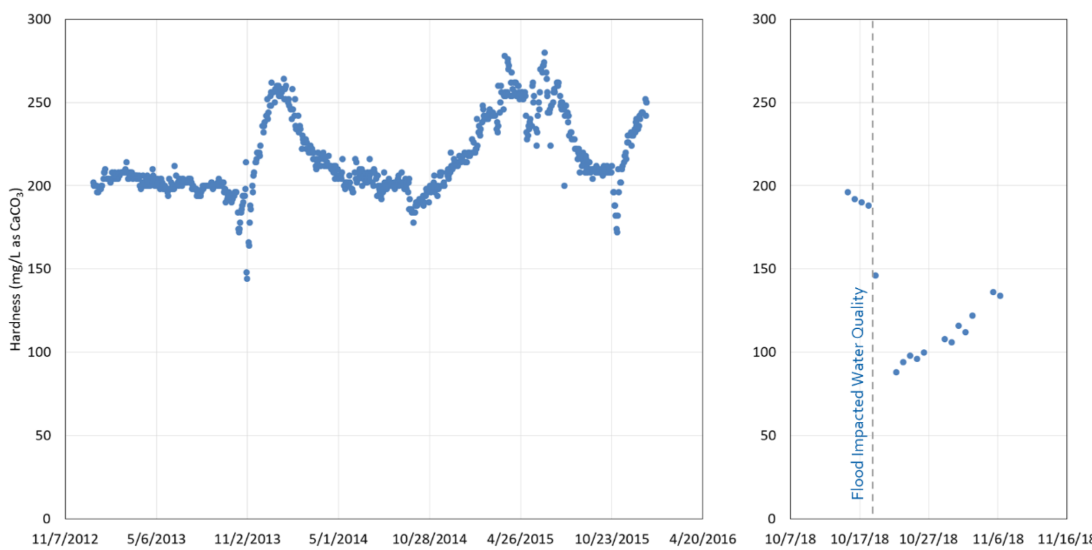


Figure 4 Raw Water Total Hardness - Historical (Left) and Flood Event (Right)

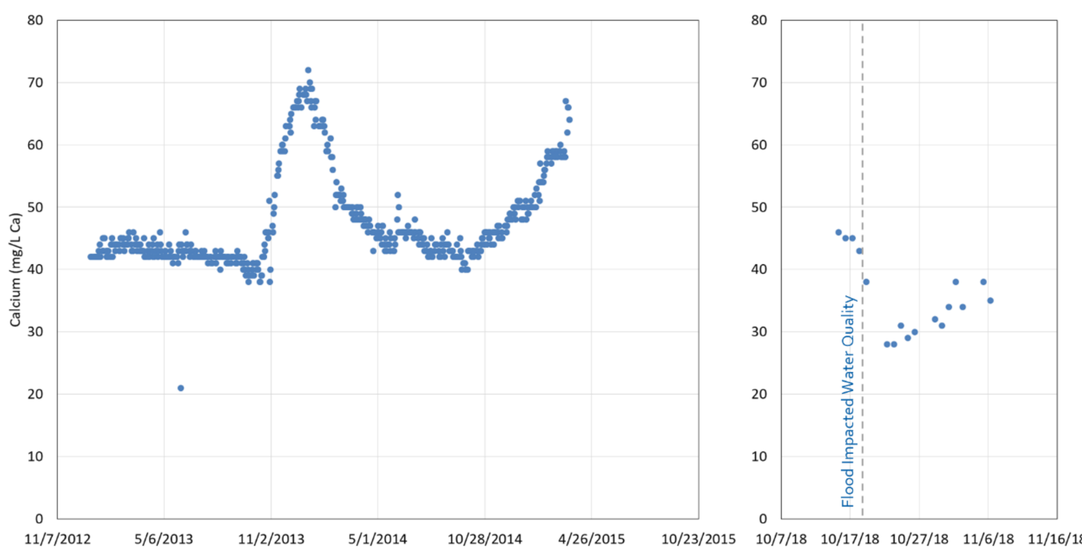


Figure 5 Raw Water Calcium - Historical (Left) and Flood Event (Right)

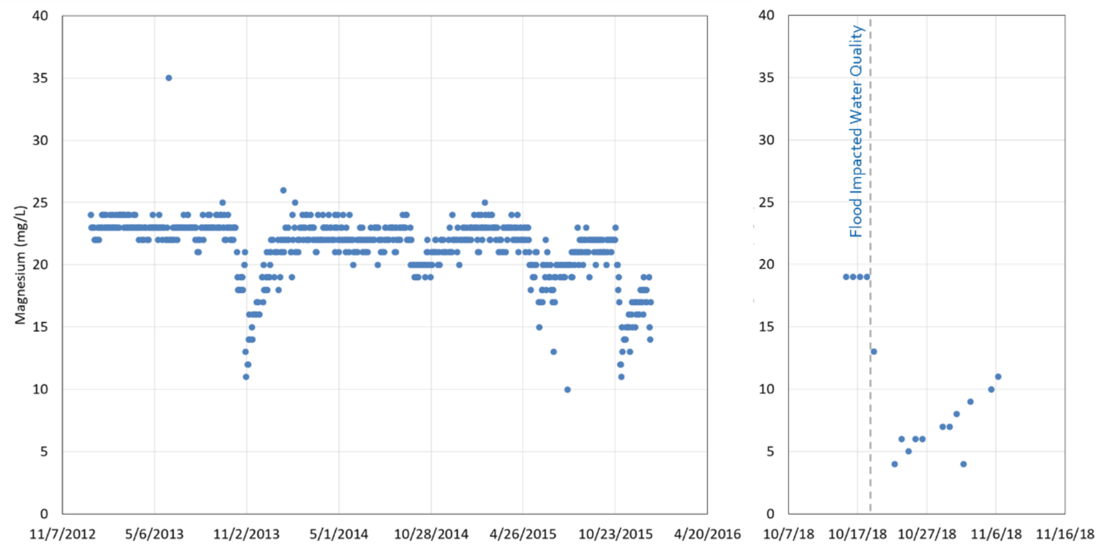


Figure 6 Raw Water Magnesium - Historical (Left) and Flood Event (Right)

1.4 TOC

Total organic carbon (TOC) is a measure of the organic carbon, both particulate and dissolved, in a water. TOC is a useful parameter in gauging natural organic matter (NOM) concentrations in water. Some TOC constituents are precursors to the formation of regulated disinfection by-products (DBPs) and can also result in colored water. Increased TOC concentrations generally result in higher coagulant demand to achieve TOC removal goals.

Figure 7 shows that the TOC concentration doubled during the flood event from 3.44 to a peak of 7.78 mg/L. The TOC slowly decreased for weeks after the event.

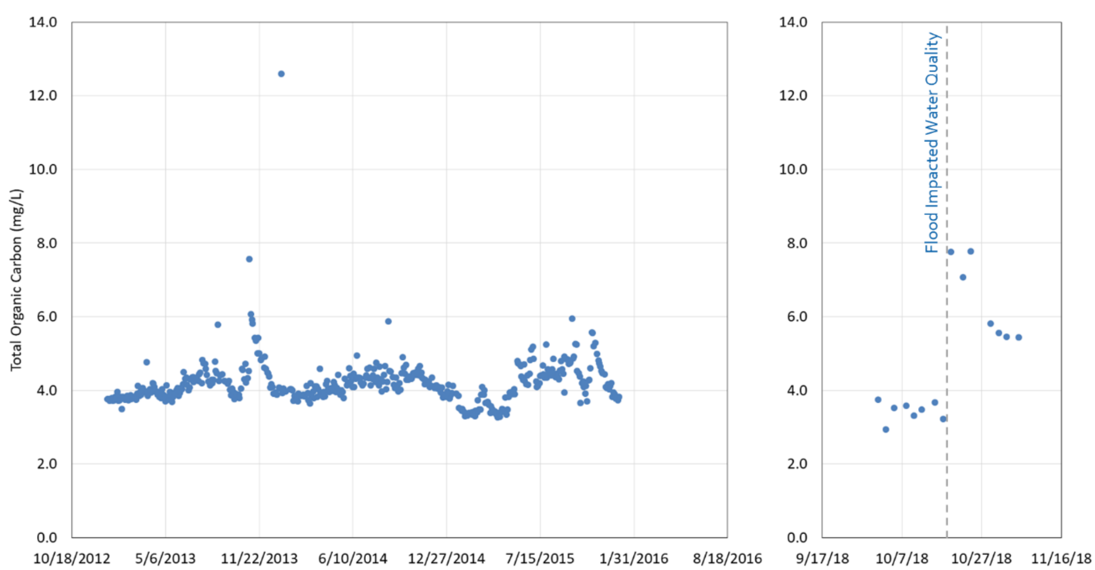


Figure 7 Raw Water Total Organic Carbon (TOC) - Historical (Left) and Flood Event (Right)

Section 2

LIMITATIONS OF EXISTING WTP FACILITIES

All three of the City's WTPs use lime softening coupled with filtration and chemical disinfection to treat water from the Lower Colorado River to meet all of the federal and state drinking water regulations. The City is a long-time member of the Partnership for Safe Drinking Water Program, historically producing filtered water with turbidities below 0.10 NTU.

Figure 8 and Figure 9 show the process flow diagrams for Ullrich (167 mgd), Handcox (50 mgd), and Davis (120 mgd) WTPs. The treatment processes for the WTPs are similar with the main exception being the use of conventional sedimentation basins at Davis WTP in contrast to upflow solids contact clarifiers at Ullrich and Handcox WTPs. Chlorine and ammonia are added to the raw water to form chloramines for disinfection. Ferric sulfate is added, typically at a low dose of approximately 15 mg/L as solution, to assist in organics removal and particle destabilization. This ferric sulfate solution is approximately 12 percent iron by weight, yielding a typical dose of 1.8 mg/L as Fe. Lime is added after ferric sulfate to raise the pH for precipitative softening of calcium carbonate ($CaCO_3$) to meet finished water hardness goals. Lime is typically added at the WTPs to achieve a settled water pH of 10.0 to 10.2, corresponding to a minimum settled water calcium concentration and minimal magnesium precipitation. The softened water is recarbonated to a pH of approximately 9.6 prior to filtration to meet finished water stability goals. Sodium hexametaphosphate (SHMP, a sequestering agent) is also added prior to filtration to prevent excessive scale formation on filter media, underdrains, and distribution system piping. The calcium carbonate precipitation potential (CCPP) in finished water from the City's WTPs is typically 14 mg/L as $CaCO_3$. CCPP is an index that provides an indication of the $CaCO_3$ scale forming tendency of water. The American Water Works Association (AWWA) recommends a CCPP range of 4-10 mg/L as $CaCO_3$ in finished water to minimize pipe corrosion, while avoiding excessive scale formation (but this recommendation does not consider the effects of SHMP).

At Ullrich and Handcox WTP, solids settled in the solids contact clarifiers are conveyed to gravity thickeners. Supernatant from the gravity thickener is conveyed to the washwater recovery basins. The thickened solids are further concentrated through centrifuges. Cake from the centrifuges is hauled offsite.

Sedimentation basin solids at the Davis WTP are conveyed to an equalization tank. A portion of the residuals are recycled to the head of the plant, while the remainder is sent to the centrifuges for dewatering.[1] Overflows from the solids handling process are routed to the sewer.

Spent filter backwash water at all three WTPs is conveyed to washwater recovery basins. The decant from the recovery basins is recycled to the head of the plant at less than 10 percent recycle rate in compliance with the Filter Backwash Recycling Rule.

[1] Approximately 2/3 is recycled to the head of the WTP and 1/3 sent to the solids dewatering facility (Source: Davis Water Treatment Plant Solids Management Evaluation. Kennedy Jenks Consultants. August 20, 2009.

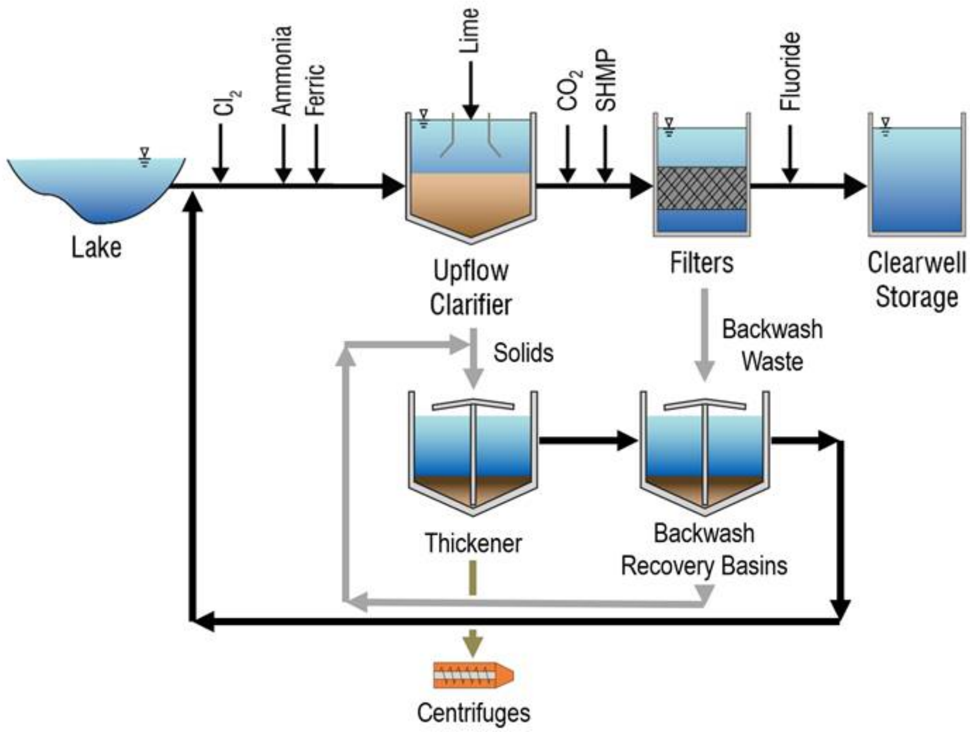


Figure 8 Process Flow Diagram for Ullrich WTP (167 mgd) and Handcox WTP (50 mgd)

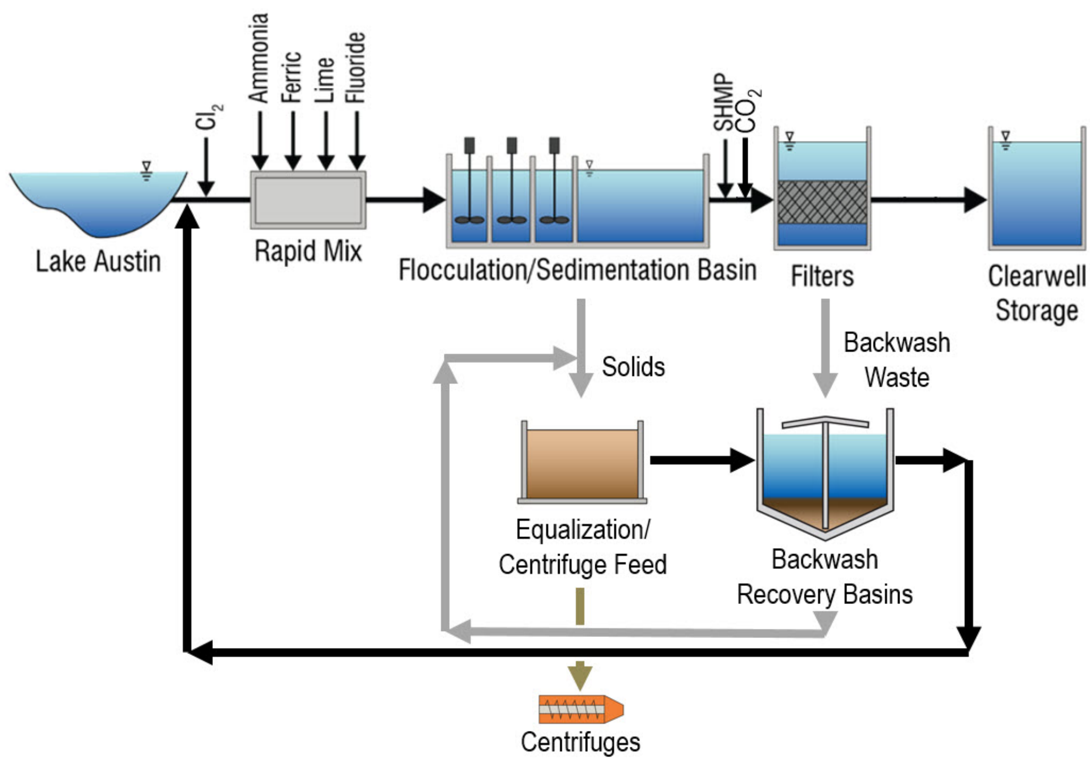


Figure 9 Process Flow Diagram for Davis WTP (120 mgd)

Table 2 and Table 3 list the design criteria for the clarifiers and filters at the Ullrich and Handcox WTPs, and the Davis WTP, respectively. Design criteria for the gravity thickeners and centrifuges are provided in Section 5 along with a discussion of the impact of the flood event on the residuals handling capacity.

The clarifiers at the Ullrich and Handcox WTPs operate at higher surface overflow rates than those at the Davis WTP, reflecting the fact that solids contact clarifiers are designed differently and are capable of higher loading rates compared to conventional sedimentation basins. All three plants typically operate with mixing speeds selected to keep the relatively dense $CaCO_3$ solids in suspension to continue growing prior to sedimentation.

Table 2 Design Criteria for Ullrich WTP and Handcox WTP

WTP	Clarifier Loading Rate (gpm/ft^2)	Center Well Mixing Energy, G (s^{-1})	Max Filter Loading Rate (gpm/ft^2)
Ullrich	1.2 – 1.4	100(1)	7.6
Handcox	1.6	55(2)	7.6

Notes:
(1) Calculated from turbine speed.
(2) Handcox WTP upflow clarifier O&M manual.

Table 3 Design Criteria for Davis WTP

WTP	Sedimentation Basin Loading Rate (gpm/ft^2)	Flocculation Mixing Energy, G (s^{-1})(1)	Max Filter Loading Rate (gpm/ft^2)
Davis	0.75	Stage 1 = 80 Stage 2 = 65 Sage 3 = 56	5.0

Notes:
(1) Davis WTP flocculator O&M manual.

The Ullrich and Handcox WTPs are designed to operate as lime softening plants with operation targeted towards reduction in hardness. Under typical operation, influent turbidities are low and hardness is moderate to high. Dense, highly settleable $CaCO_3$ solids are formed in the clarifiers. The high mixing speed and high surface overflow rate reflect those typical operational conditions. During the flood event, the influent water quality was not directly conducive to operating under these original design assumptions. Turbidities were high and hardness was low; therefore the performance requirements shifted from hardness removal to turbidity removal. High concentrations of watershed-derived particles that translate to high influent turbidity are less dense than $CaCO_3$ particles and negatively charged. Charge neutralization is a key mechanisms for removing these negatively-charged particles in the coagulation process, requiring a different operational philosophy than typical for all three WTPs. Continued operation to achieve a settled water pH of 10.2 at a low ferric sulfate dose was not sufficient to neutralize and remove the negatively charged particles associated with the flood event. Thus, the WTPs either needed to operate at a significantly reduced flow and/or be equipped to neutralize charge without using ferric sulfate, due to its acidic nature and low density particle production.

Several aspects of the existing WTP facilities constrained the ability to make operational adjustments to respond to the change in raw water quality during the flood event. The characteristics listed below focus primarily on Ullrich WTP since that was where Carollo engineering staff focused their efforts during the flood event. Where common limitations are known for the Davis and Handcox WTPs, those similar constraints are noted as well.

- The City's WTPs currently have five variables or "knobs" to adjust for the softening and sedimentation process:
  - Lime dose.
  - Ferric sulfate dose.
  - Mixing speed.
  - Recirculation rate (solids removal rate, duration, and solids concentration in the center cone).
  - Flow (surface overflow rate).

  Provision of additional tools to aid in particle destabilization and removal could provide operational flexibility needed for a more robust process during a similar extreme water quality event.

- The filtration process at the City's WTPs have two primary operational variables:
  - Flow (filter loading rate).
  - Filter run times before a backwash.
- The clarifier impellers/turbines at the Ullrich and Handcox WTPs are designed and typically operated at higher mixing speeds than targeted for a plant designed for conventional coagulation and removal of higher concentrations of watershed-derived particles (i.e., higher influent water turbidities) via metal salt (ferric sulfate) coagulation. Due to constant speed equipment, adjusting the turbine mixing speed requires physical replacement of mechanical gears, which cannot be done quickly. The inability to quickly reduce the mixing speed hindered successful operation and conversion to a conventional coagulation approach, which in theory, could be a successful way to treat water exhibiting the characteristics observed during the October 2018 flood event as long as the hydraulic loading rates of the clarifiers were also reduced.
- The capacity of the gravity thickeners were exceeded due to the increase in the volume and mass of solids that were less settleable than those of typical operation.
- Filter run times were reduced due to the challenge associated with particle removal in the clarifiers and carryover of particles. The backwash recovery basins were overwhelmed by the need to backwash the filters more frequently and the overflow could not be managed onsite. Additional capabilities to remove those residuals or reduce the filter solids loading would provide flexibility during a similar extreme water quality event.

One of the operational changes that worked during the flood event was to add sufficient lime to promote magnesium hydroxide ($Mg(OH)_2$) precipitation (corresponding to a settled water pH > 10.5). However, a drawback of this operational approach was the potential for $CaCO_3$ re-precipitation in the filter influent water as illustrated in Figure 10. This operational approach resulted in a higher calcium concentration in the settled water because all of the raw water carbonate was exhausted. Because of the higher calcium concentration and settled water pH, a lower recarbonation pH was required to limit the precipitation of $CaCO_3$ particles in the settled water prior to filtration. Recarbonation adds carbonate back to the water. During the flood event, the CO_2 feed system capacity limited the ability to add sufficient CO_2 to reduce the pH and prevent $CaCO_3$ from precipitating in the filter influent water during operation at higher softened water pH. Due to kinetics of the precipitation process, even with sufficient recarbonation capacity, precipitation may still occur as the pH is reduced. Precipitating minerals on the filter media could impact processes by reducing filter runtimes and increasing headloss.

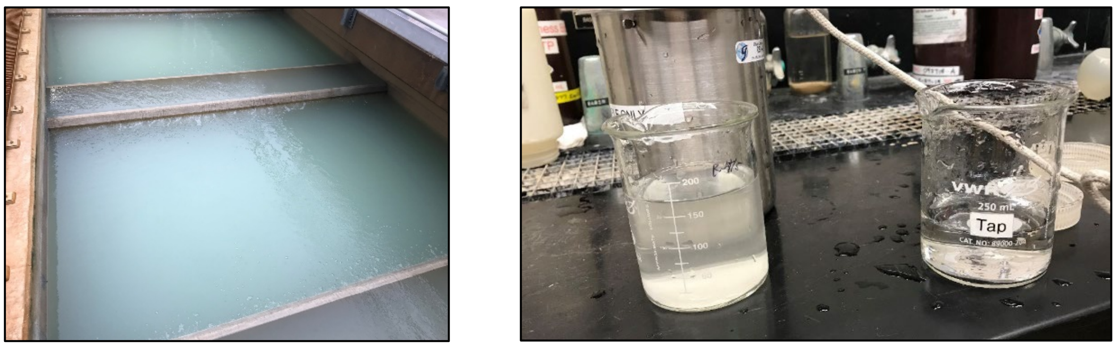


Figure 10 Precipitation in Filter Supernatant

Section 3

BENCH-SCALE TESTS

Testing was conducted during the flood event both at bench- and full-scale to identify optimal operational conditions to keep the plants running to meet system demands and TCEQ finished water quality requirements. Tests focused on operational conditions that could be rapidly employed during the flood event and included an assessment of the optimal lime and ferric sulfate dose, solids contact clarifier recirculation and blowdown rate, and the use of coagulant and flocculant aid polymers. Table 4 shows the raw water quality during bench scale testing. The turbidity was highest on the first day of testing and gradually decreased as the impact of the flood event on water quality lessened throughout the next 10 days. Likewise, the hardness concentration was lowest on the first day of testing and gradually increased over the next 10 days.

Table 4 Raw Water Quality during Bench Scale Testing

Parameter	10/23	10/24	10/25	10/26	10/29	10/31	11/1	11/2
pH, s.u.	8.00	7.99	8.01	8.01	7.99	7.96	7.97	7.96
Turbidity, NTU	199	118	124	98	84	54	44	---
Alkalinity, mg/L $CaCO_3$	114	100	103	101	103	107	108	111
Total Hardness, mg/L $CaCO_3$	94	98	96	100	108	116	112	122
Calcium, mg/L	28	31	29	30	32	34	38	34
TOC, mg/L	---	7.78	---	---	5.82	5.56	---	5.46

The 2-liter jars of a standard jar test apparatus have a sample tap located 10 cm below the top of the water to allow the sampling of small quantities of settled water for turbidity measurements. The location of the tap facilitates sample collection and analysis of settled water turbidity at times that correspond to the surface overflow rate in the WTP clarifiers, depending on plant production rates. Table 5 shows the settling time versus simulated surface loading rate.

Table 5 Simulated Surface Loading Rate for Jar Testing

Settling Time (minutes)	Simulated Surface Overflow Rate (SOR, gpm/ft^2)(1)
4	0.61
5	0.49
6	0.41
10	0.25
20	0.12

Notes:
(1) Sample port located 10 cm below the water surface.

The 2-L jars used for testing are not a perfect representation of solids contact clarifiers, since in jars, solids are only formed in a batch after chemical addition and solids do not build size over time. In solids contact clarifiers, solids are continuously formed and recirculated to achieve high solids concentrations and size. However, jar tests are still useful as a benchmark for relative comparison of settleability between different treatment options.

3.1 Softening at pH > 10.5

Early in the flood event, City process engineers observed improved settleabilty by adding lime to achieve a softened water pH > 10.5, with additional improvement from increasing the ferric sulfate dose. Jar tests were conducted to assess whether similar results were observed when compared to a range of conditions for lime and ferric sulfate addition. Figure 11 and Figure 12 show that softening in the high pH range where $Mg(OH)_2$ precipitates (i.e., pH > 10.5) resulted in lower settled water turbidity. Decreasing the surface overflow rate (SOR) from 0.56 gpm/sf to 0.40 gpm/sf improved settled water quality, reducing the settled water turbidity by approximately half. Increasing the ferric sulfate dose from 80 to 180 mg/L as solution did not have a large impact on settled water turbidity. Variations of the same test were conducted almost every day to confirm that those same operating conditions continued to result in optimal settled water turbidity.

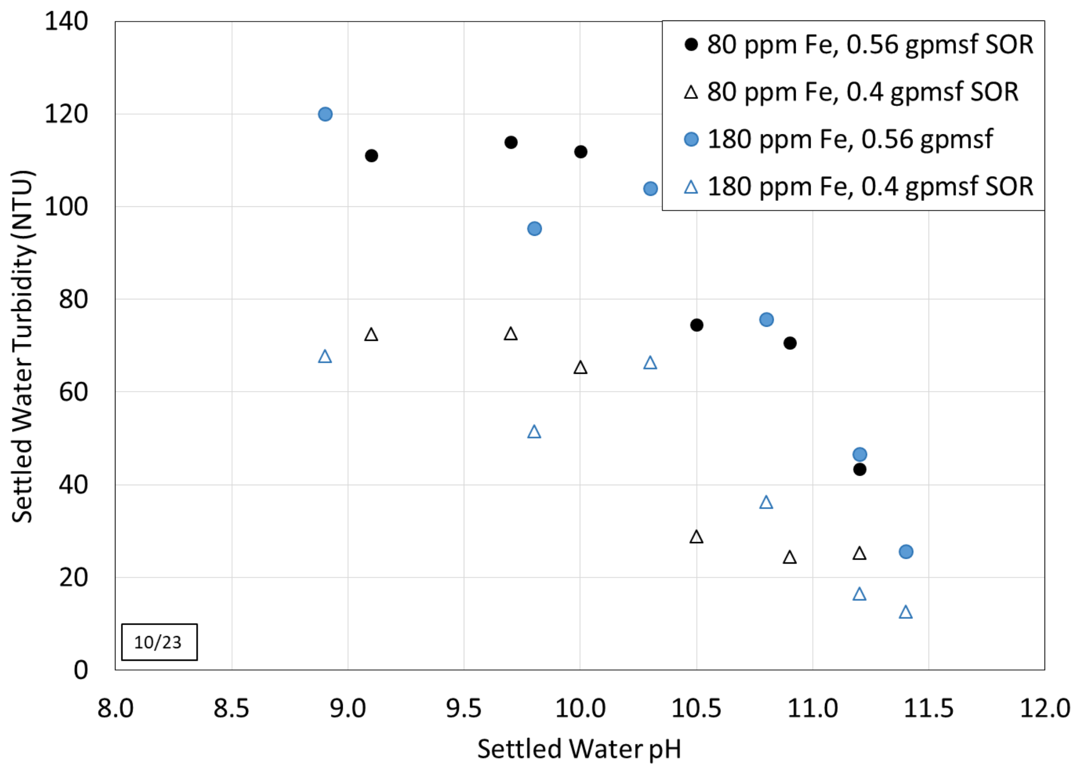


Figure 11 Impact of Ferric Dose (High Range), SOR, and pH on Settled Turbidity - 10/23/18

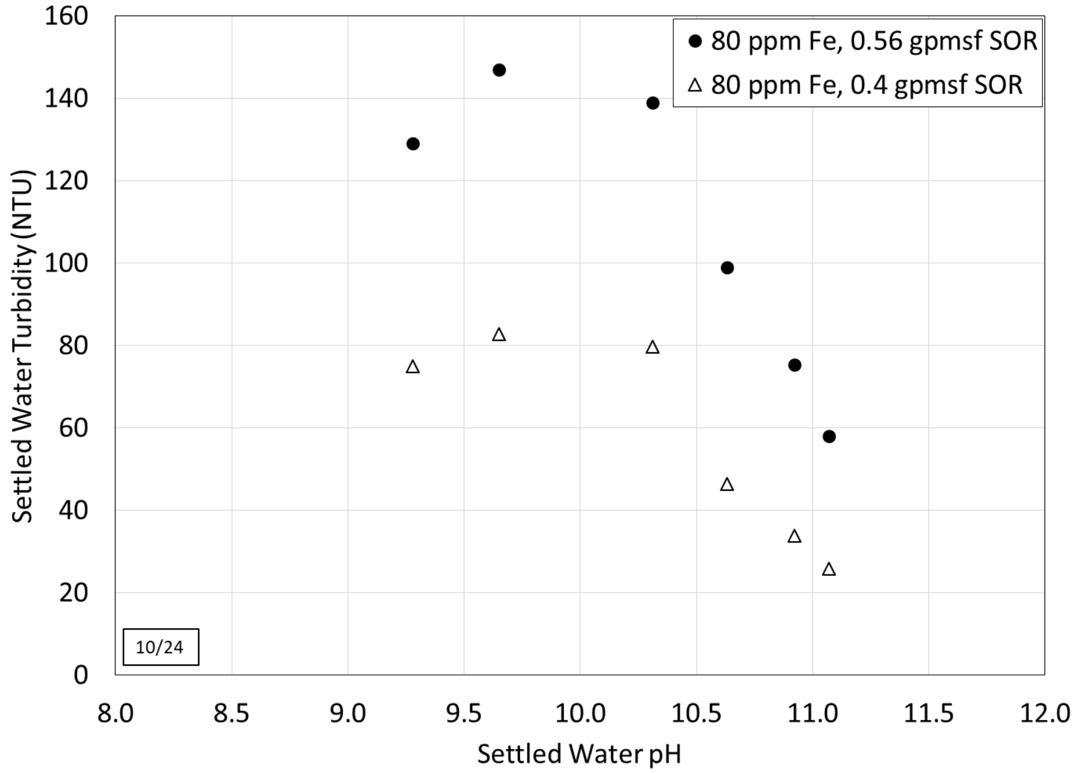


Figure 12 Impact of SOR and pH on Settled Turbidity - 10/24/18

On October 25, 2018, lower ferric sulfate doses were tested to assess whether the WTPs could reduce the dose in response to the gradually lower raw water turbidity. Figure 13 and Figure 14 show that increasing the ferric sulfate dose from 20 to 60 or 80 mg/L as solution, increasing the pH to over 10.5, and decreasing the surface overflow rate from 0.56 gpm/sf to 0.4 gpm/sf continued to improve settled water turbidity. The tests showed no clear benefit of operating at 80 versus 60 mg/L ferric sulfate as solution.

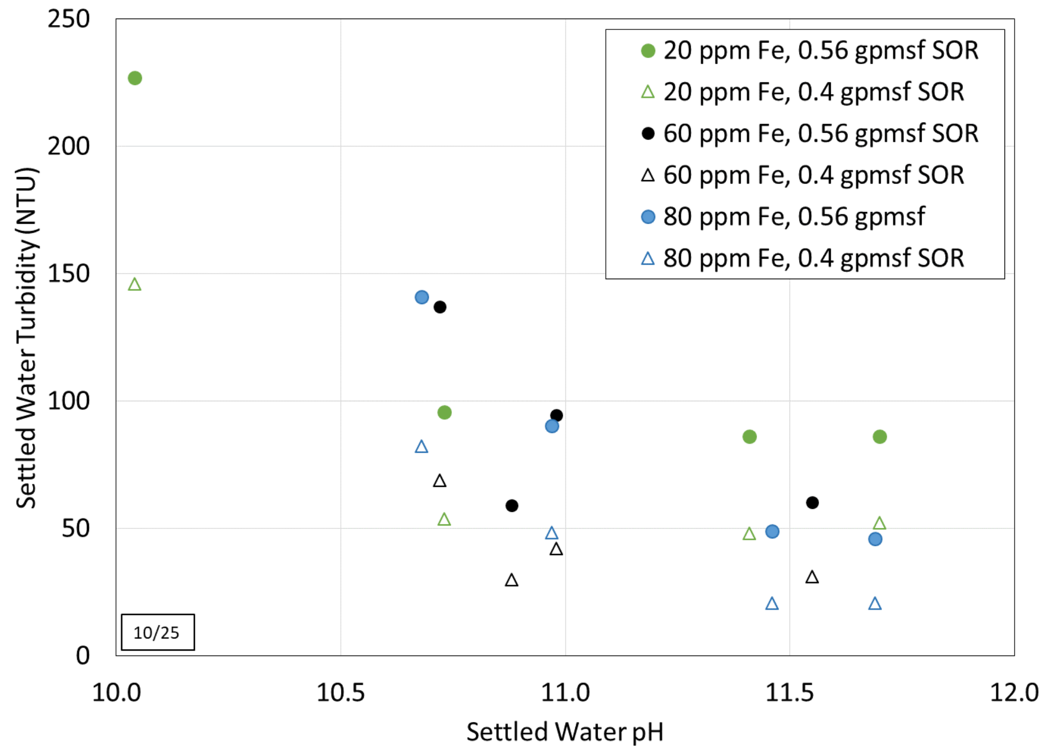


Figure 13 Impact of Ferric Dose, SOR, and pH on Settled Turbidity - 10/25/18

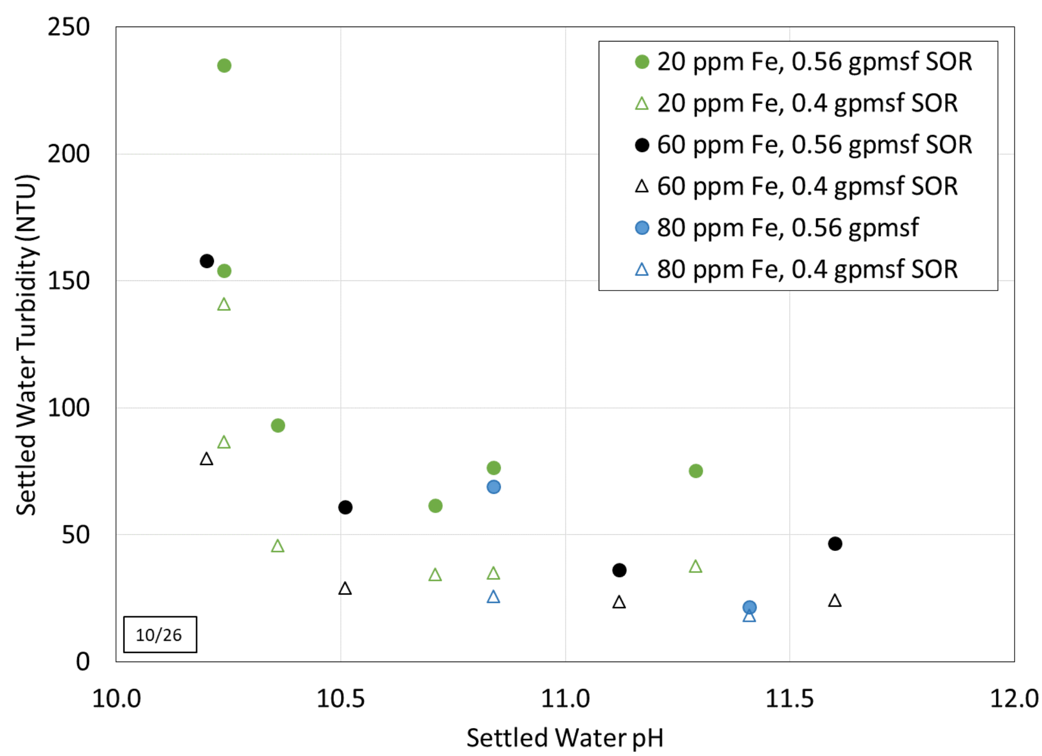


Figure 14 Impact of Ferric Dose, SOR, and pH on Settled Turbidity - 10/26/18

As the water quality slowly improved with lower turbidity and TOC in the days following the flood event, jar tests to find the optimal ferric sulfate dose to minimize settled water turbidity continued. Figure 15 shows that a ferric sulfate dose of 60 mg/L as solution achieved the best results for relative settled water turbidity for the November 1 raw water quality shown in Table 4.

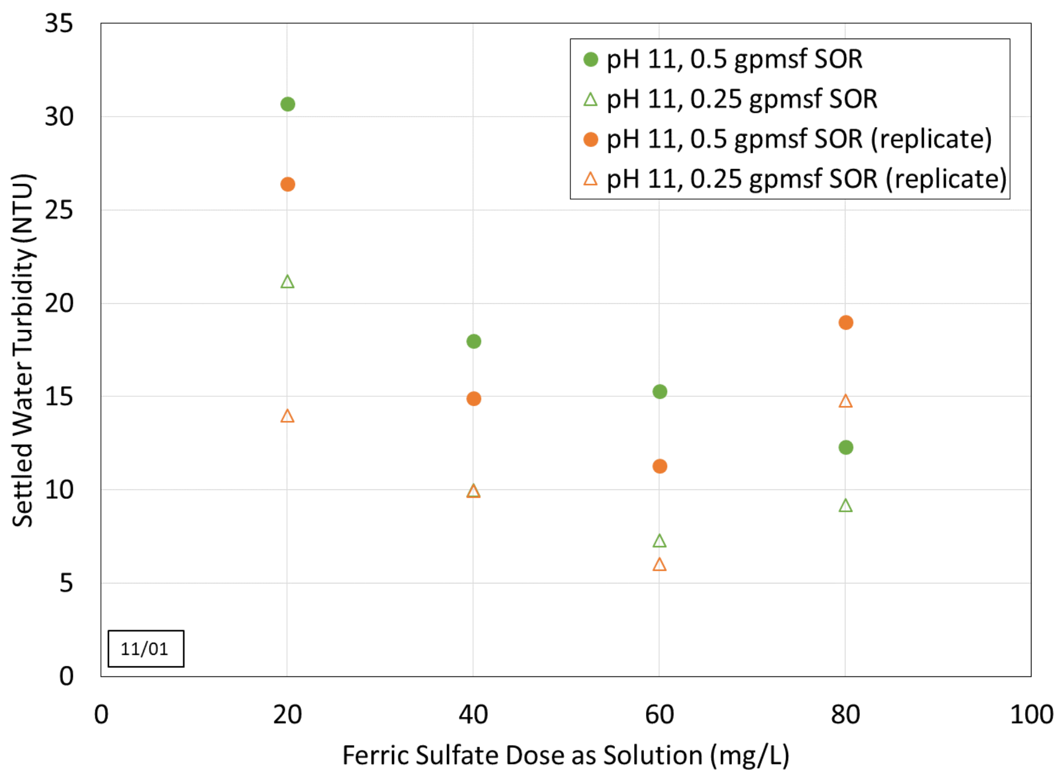


Figure 15 Impact of Ferric Dose on Settled Turbidity - 11/1/18

3.2 Conventional Treatment with Ferric Sulfate

Jar tests were performed to evaluate the effectiveness of conventional treatment with high ferric sulfate doses. Figure 16 and Figure 17 show that increasing the ferric dose from 15 to 200 mg/L as solution resulted in lower settled turbidity. In these jars, the pH was not adjusted and the settled water pH ranged from 7.5 to 6.2 (for ferric sulfate doses ranging from 15 and 200 mg/L, respectively). Comparing Figure 17 to Figure 18 shows that iron coagulation without pH adjustment (corresponding to settled water pH values from 6.2 to 7.5) achieved lower turbidities than coagulation with pH adjusted to 8.5-9.0, probably due to the charge neutralization capabilities of lower pH water.

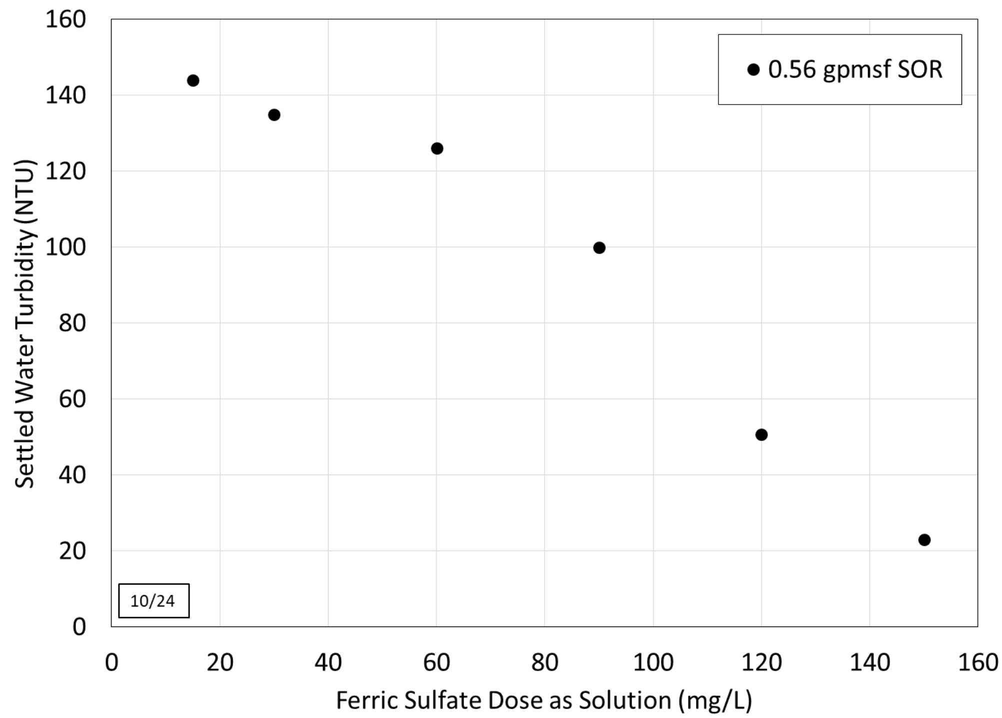


Figure 16 Impact of Ferric Dose on Settled Turbidity without pH Adjustment

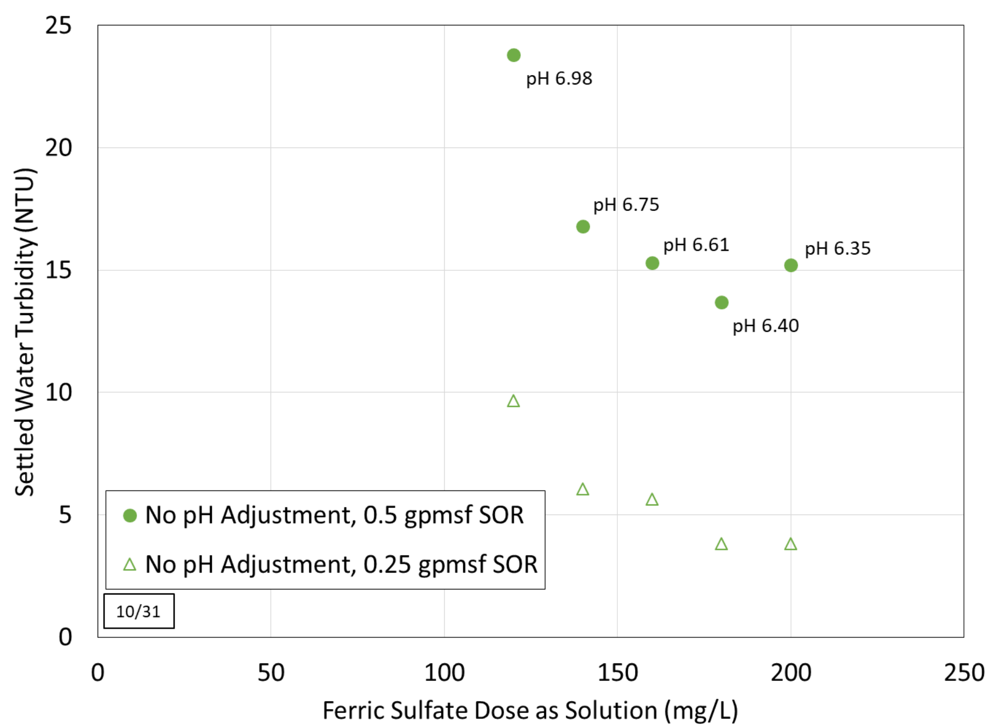


Figure 17 Impact of Ferric Dose (High Range) and SOR on Settled Turbidity without pH Adjustment

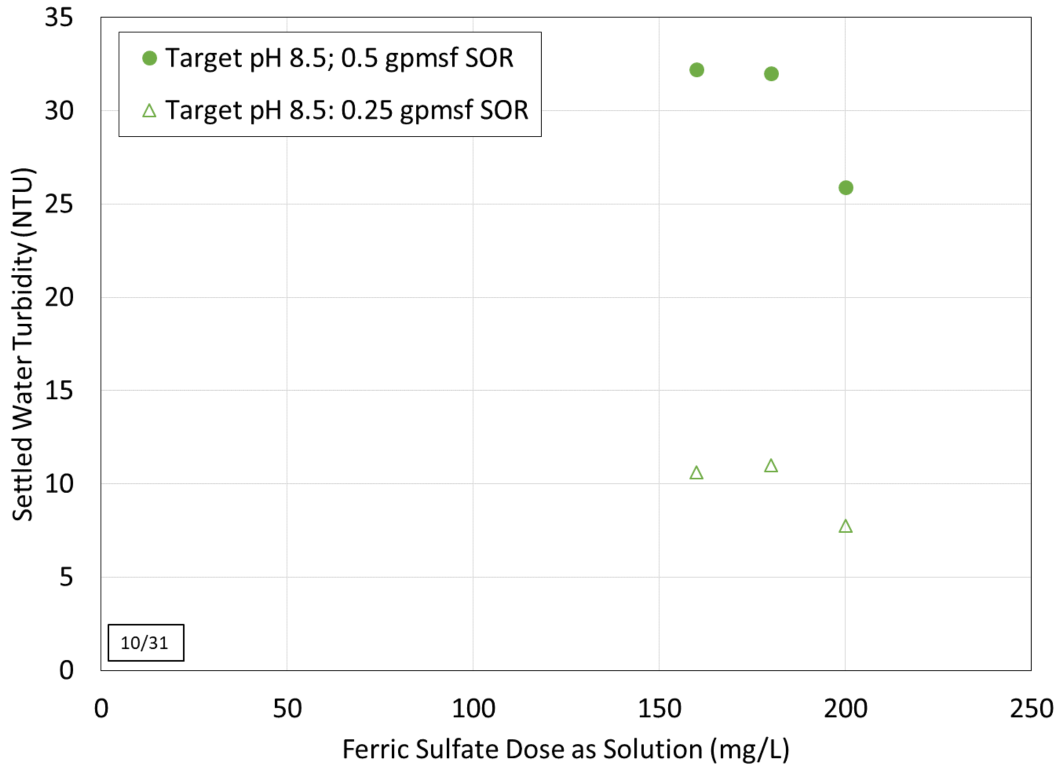


Figure 18 Impact of Ferric Dose (High Range) and SOR on Settled Turbidity at pH 8.5 - 9.0

The impact of the velocity gradient (G-value, sec^{-1}) on treatment performance with iron coagulation was also evaluated. Normal operations at Davis WTP include three-stage tapered flocculation for 30 minutes consisting of velocity gradients of 80 sec^{-1}, 65 sec^{-1}, and 56 sec^{-1}. The solids contact clarifiers (SCCs) at Ullrich and Handcox WTPs are designed for precipitation of dense calcium carbonate solids and normally operate at velocity gradients equal to 100 and 55 sec^{-1}, respectively. The SCCs have limited turndown capabilities due to their intent to precipitate dense calcium carbonate solids rather than flocculating the light, more fragile solids formed from coagulation with ferric sulfate. For comparison, 3-stage tapered G-values typical of conventional treatment with ferric sulfate are 40-50 sec^{-1}, 20-30 sec^{-1}, and 10-15 sec^{-1}. Figure 19 shows the impact of velocity gradient on turbidity at the optimal ferric sulfate dose for conventional treatment at pH 9. The results demonstrated that high velocity gradients sheared the floc formed and reduced the settleability compared with operation at lower G-values more typically used for conventional coagulation.

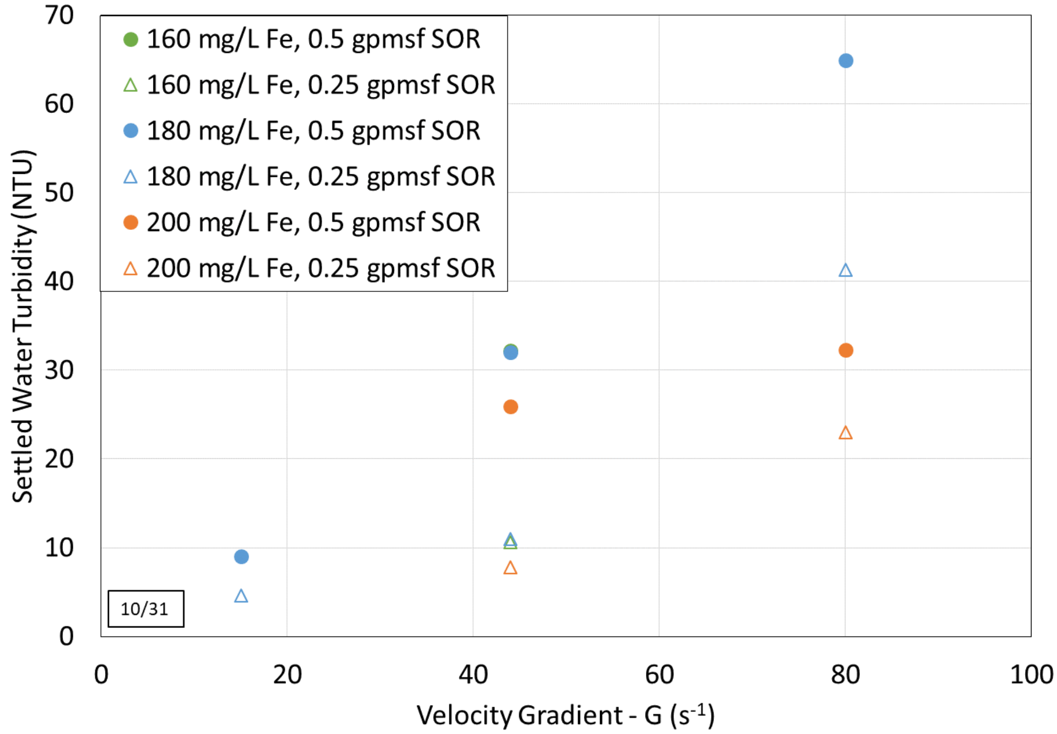


Figure 19 Impact of Ferric Sulfate Dose (Optimal Dose Range), SOR, and Velocity Gradient on Settled Turbidity at pH 9

While the jar tests conducted during the October 2018 flood event (and with banked water, Carollo 2019) illustrated that iron coagulation could in theory be a promising approach to treat flood event water, major changes to existing infrastructure would be required to make this operational scenario feasible full-scale. Switching to conventional treatment (coagulation with metal salts) will reduce pretreatment and filtration capacities, which would de-rate plant capacities because settling rates of conventionally coagulated particles are slower than lime softened particles. For example, in rectangular sedimentation basins, TCEQ requires a lower surface overflow rate for conventional treatment (0.6 gpm/ft^2) than softening (1.0 gpm/ft^2). To recover the lost capacity, plate settlers could be installed in the sedimentation basins at Davis WTP and in the clarifiers at Ullrich WTP. Plate settlers are not required at Handcox because the clarifiers are designed for 75 mgd, while the WTP is rated for 50 mgd. The conversion would also require changes to chemical storage and feed systems in response to different chemical requirements. For example, the addition of sodium hydroxide would likely be required after clarification to raise the pH higher than the settled water pH typical of iron coagulation to limit the likelihood of destabilizing pipe scale in the distribution system.

3.3 Polymer Addition

Polymer addition can help with managing water quality upset events. Polymers have several advantages over conventional metal salts, including forming stronger flocs that improve sludge dewatering performance (bridging polymers), reducing sludge volume due to lower dosages of metal coagulants (using low-molecular weight cationic polymers), and working effectively over a wide pH range (Kim 1995)[2]. Polymers can be anionic, nonionic, or cationic with regards to charge and vary in terms of molecular weight, ranging from 10^4 to 10^7 Daltons. Adding a polymer with a charge opposite that of particles in the water can aid in charge neutralization and coagulation/flocculation. Coagulant aid polymers (PEC) are typically low-molecular-weight and cationic. PEC destabilize colloidal suspensions through the same charge neutralization mechanism as metal salts like ferric sulfate, and may replace metal salts while reducing sludge volume[2]. Flocculant aid polymers (PEA) are typically high-molecular-weight and can be anionic, nonionic, or cationic. PEAs improve the flocculation process by bridging, forming larger flocs that settle more quickly[2]. Filter aid polymers are applied to the filter influent to improve particle filterability. The dose of filter aid polymers is typically low, reflecting the relatively low concentration of particles in the water applied to the filters.

Figure 20 shows the typical points at which polymer could be applied at the City's Ullrich and Handcox WTPs. Coagulant aid polymer can be applied before, simultaneously, or after the coagulant. The chemical application sequence can have a large impact on charge neutralization and corresponding settled water quality and chemical usage. Generally, waiting at least 5 seconds after dosing a coagulant to dose a coagulant aid polymer helps with charge neutralization and waiting at least 5 minutes after dosing a coagulant is necessary for optimal floc formation if using a flocculant aid, improving both the size and weight of the floc (Kawamura 1991)[3]. While not shown, a bridging polymer (PEA) could also be added to the influent to the gravity thickeners to augment the residuals handling capacity.

Coagulant aid and flocculant aid polymers were tested at the bench-scale for their impact on settleability during the flood event, either through charge neutralization or bridging.

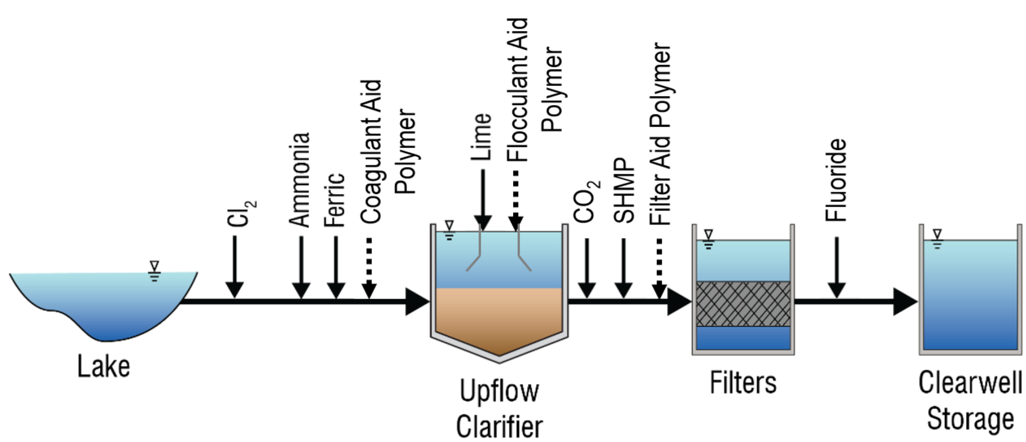


Figure 20 Typical Polymer Application Points for Ullrich and Handcox WTPs

[2] Kim, Yong H. (1995). *Coagulants and Flocculants: Theory and Practice*. Tall Oaks Publishing, Inc.
[3] Kawamura, Susumu. (1991). *Integrated Design of Water Treatment Facilities.* John Wiley and Sons, Inc.

A Zetasizer (Malvern Panalytical) was mobilized to the Ullrich WTP during the flood event to characterize the charge of particles present in the raw water and the impact of coagulant and PEC dose on charge neutralization. Figure 21 shows the results of zeta potential titrations with ferric sulfate and various PECs. Most of these PECs came from nearby utilities and local vendors. The positive charge of these cationic polymers neutralizes the negative charge of particles in the water, reducing repulsion and allowing them to flocculate when they collide and filter when passed through a dual media filter. Over 300 mg/L of ferric sulfate was required to neutralize particle charge at ambient pH (dosing 320 mg/L ferric sulfate depressed pH from 8.0 to 5.5), corresponding to a zeta potential of 0 mV. However, less than 20 mg/L of PEC was required to neutralize charge to a zeta potential near 0 mV. Table 6 shows that each one (1) mg/L dose of the various PEC tested was equivalent to approximately 15 or 30 mg/L of ferric sulfate in terms of particle charge neutralization.

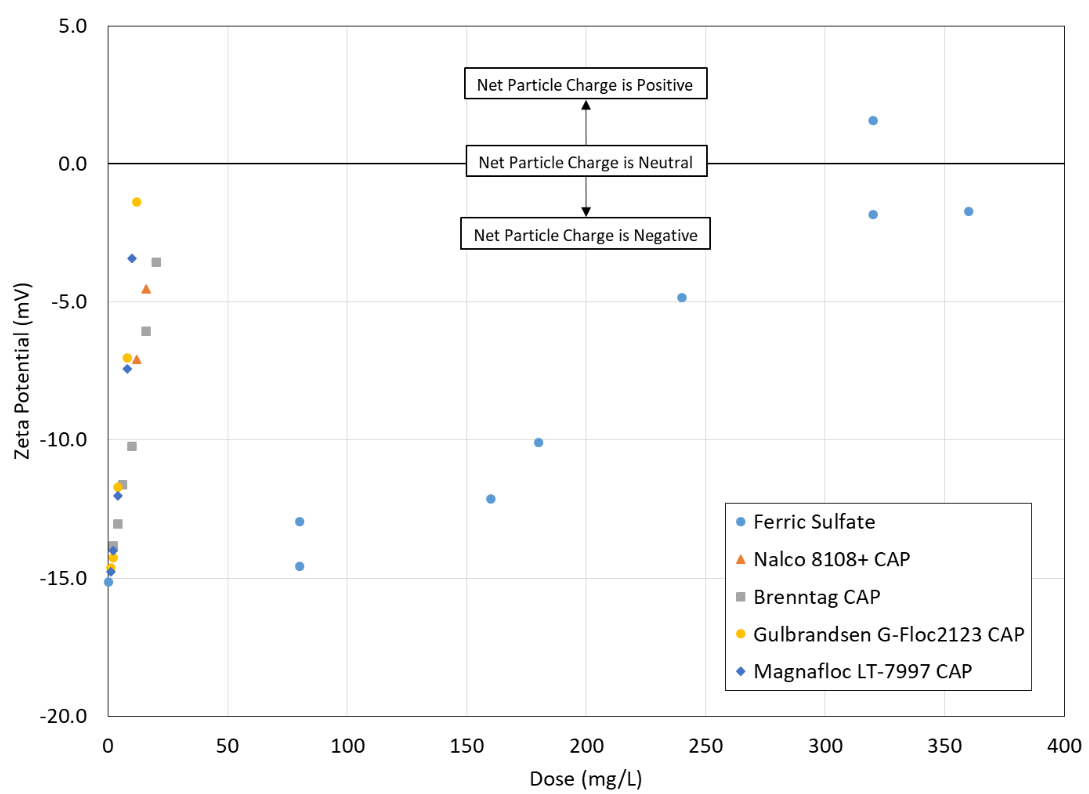


Figure 21 Zeta Potential Titration with Ferric Sulfate and Cationic Polymers

Table 6 Charge Equivalence

1 mg/L as product Cationic Polymer	Equivalent Ferric Sulfate Dose (mg/L as solution)
Nalco 8108+	15
Brenntag	15
Gulbrandsen G-Floc 2123	30
Magnafloc LT-7997	30

The coagulant aid polymers shown in Table 6 were evaluated in jar tests for their ability to neutralize highly negatively charged raw water and offset high doses of ferric sulfate. Adding a small dose of PEC can neutralize a large amount of charge and decrease the required ferric sulfate dose. Trading off ferric sulfate for polymer can result in more settleable solids with a lower total sludge volume and does not consume alkalinity (ferric sulfate is acidic and consumes alkalinity). Most of these jar tests simulated dosing polymer to the upflow clarifier raw water piping, based on available full-scale injection points. PEC was dosed during the rapid mix, followed by ferric sulfate 30 seconds later, then lime, and finally the rpm was reduced to 50 to target a velocity gradient of 60 sec^{-1}.

In the initial offset tests shown in Figure 22 and Figure 23, dosing 12 mg/L cationic polymer with only 20 mg/L ferric sulfate as solution achieved similar settled water turbidities to dosing 80 mg/L ferric sulfate.

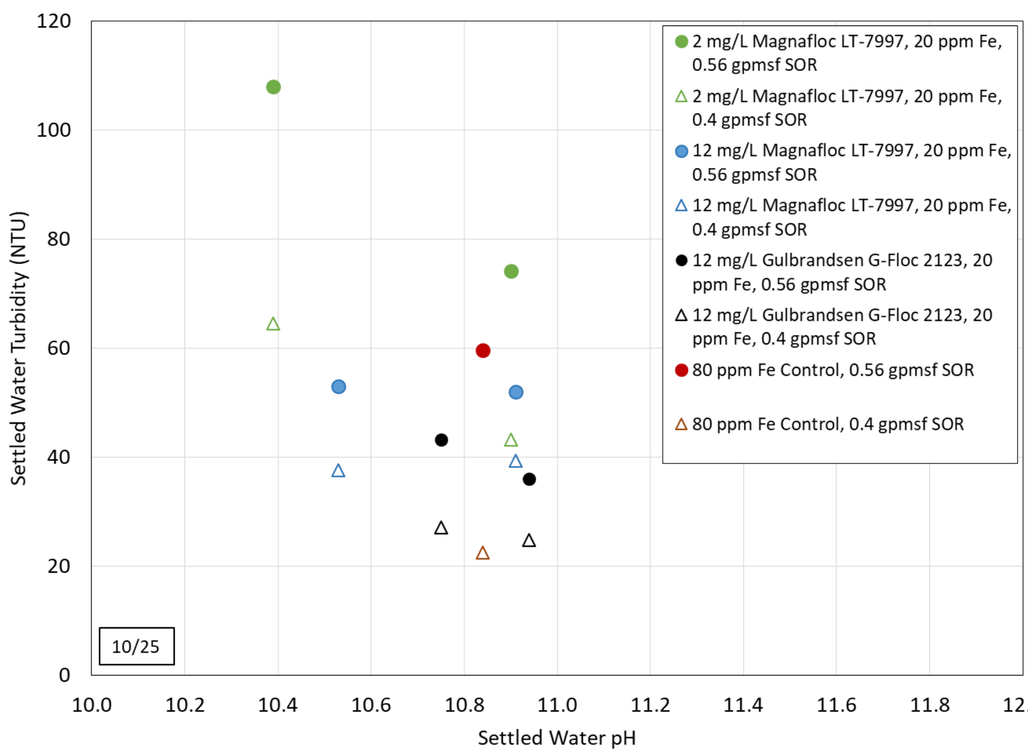


Figure 22 Impact of Offsetting Ferric Sulfate with Cationic Polymers on Settled Turbidity

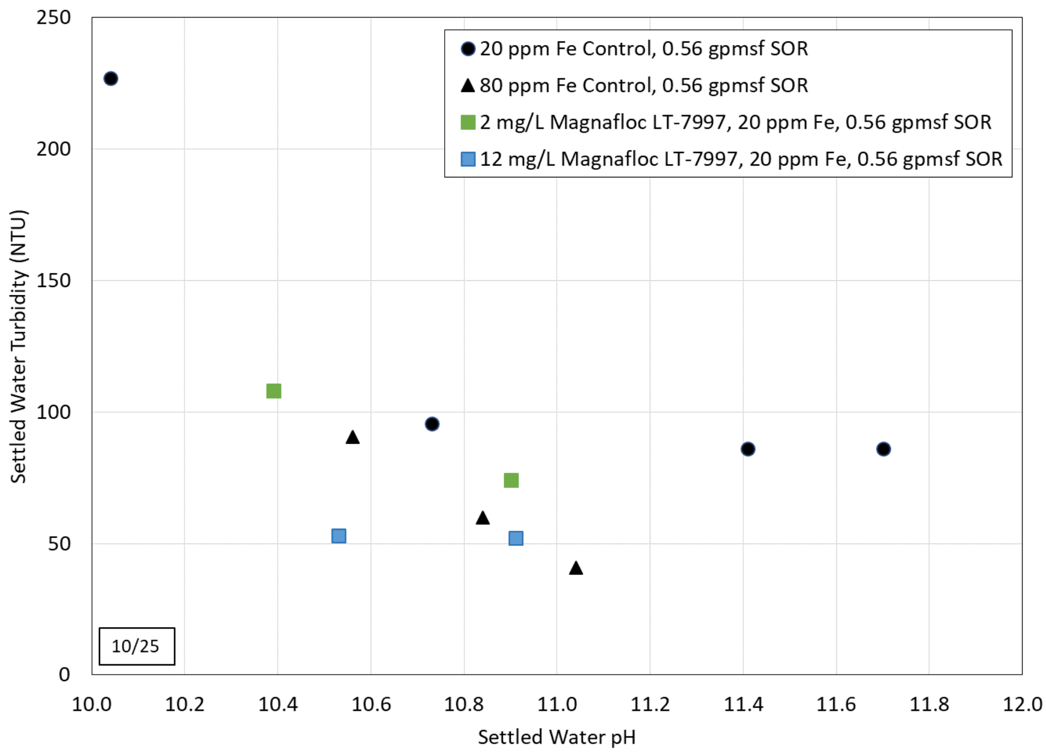


Figure 23 Impact of Offsetting Ferric Sulfate with Cationic Polymers on Settled Turbidity

Figure 24 and Figure 25 show that adding the Nalco Cat-floc 8108+ coagulant aid polymer with 20 mg/L ferric sulfate achieved a lower settled water turbidity than dosing 80 mg/L ferric sulfate or the other polymers tested above. The optimal dose of the Nalco 8108+ PEC was approximately 10 to 20 mg/L. Offsetting ferric sulfate with Nalco 8108+ PEC improved settled water turbidity at both pH 10.3 and 11 (Figure 25).

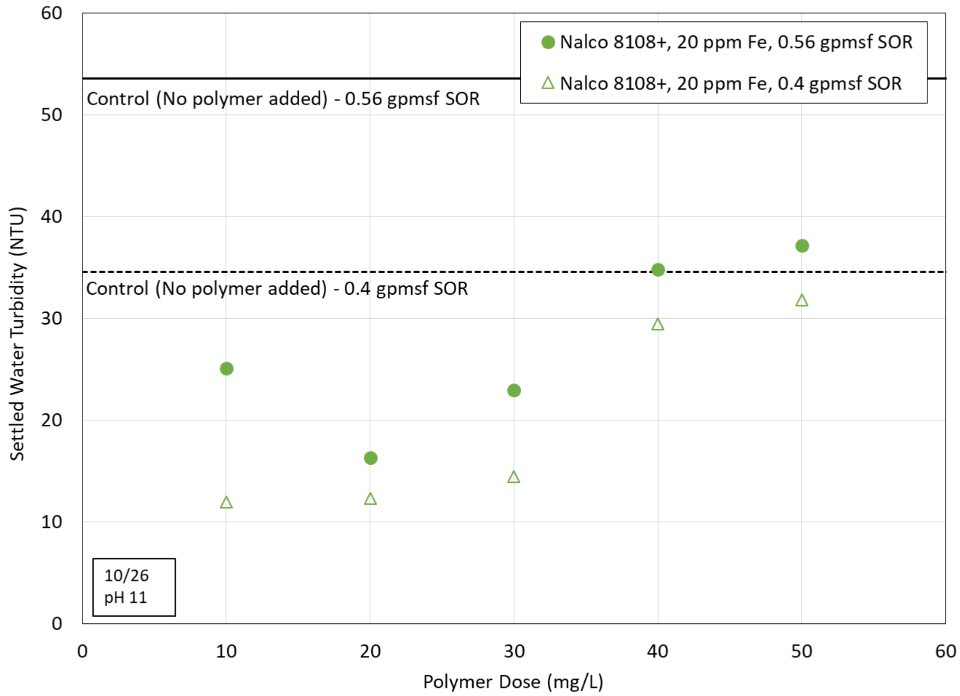


Figure 24 Impact of Offsetting Ferric Sulfate with Nalco 8108+ PEC (High Range) on Settled Turbidity

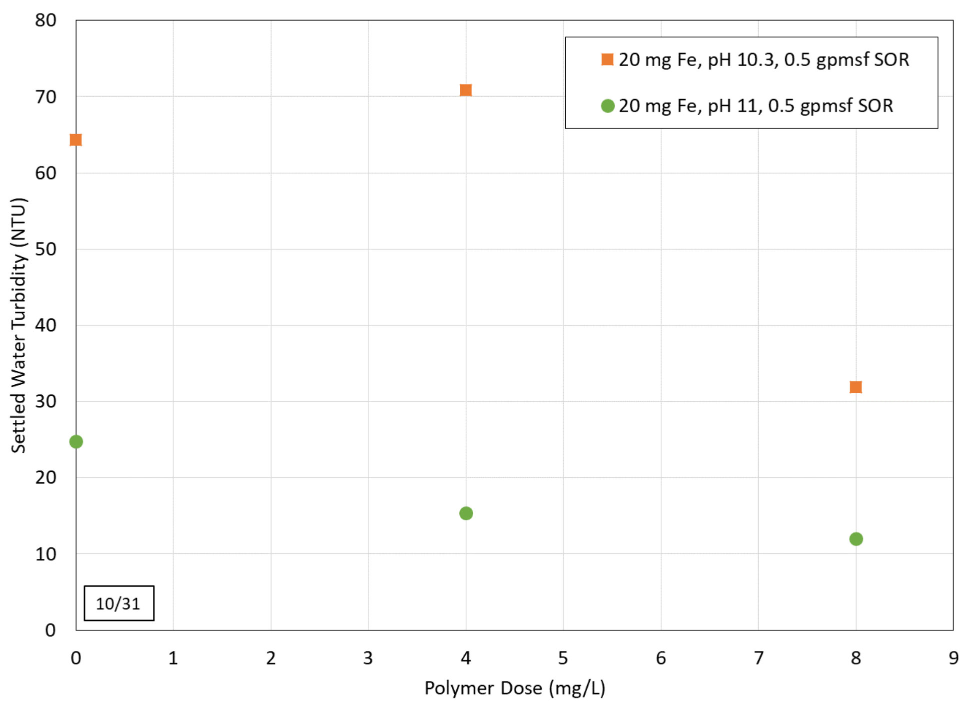


Figure 25 Impact of Offsetting Ferric Sulfate with Nalco 8108+ PEC (Low Range) on Settled Turbidity

Jars were filled with solids collected from the basin center wells to test the impact of chemical addition to center wells at the bench-scale. These jar tests simulated solids behavior in the solids contact clarifier mixing wells. Solids were collected from the top of the mixing wells of Basins 6-8. The Nalco 8108+ PEC was selected for testing with mixing well solids based on the low settled water turbidity results it achieved with raw water. Figure 26 and Figure 27 show the results for simulating polymer addition to the solids contact clarifier mixing well after ferric sulfate and lime addition. The controls shown are for settled water turbidity of mixing well solids without polymer addition. Figure 27 shows that adding Nalco 8108+ PEC to mixing well solids vastly improved solids settling at doses as low as 1 mg/L.

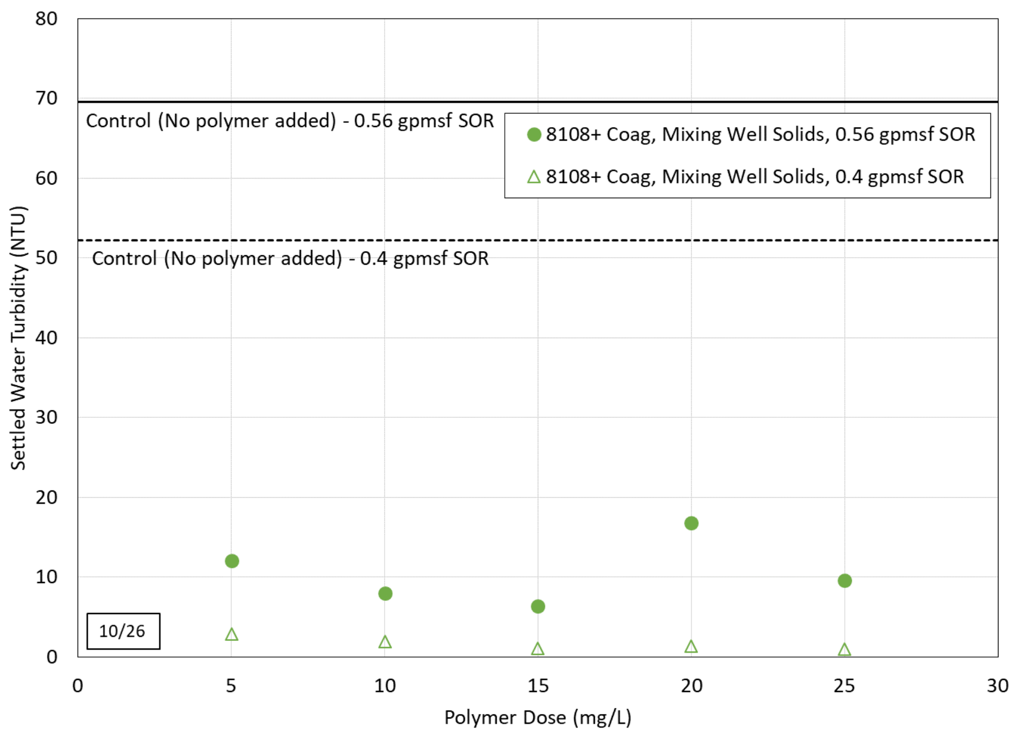


Figure 26 Impact of Offsetting Ferric Sulfate with Nalco 8108+ PEC (High Range) on Mixing Well Solids Settling

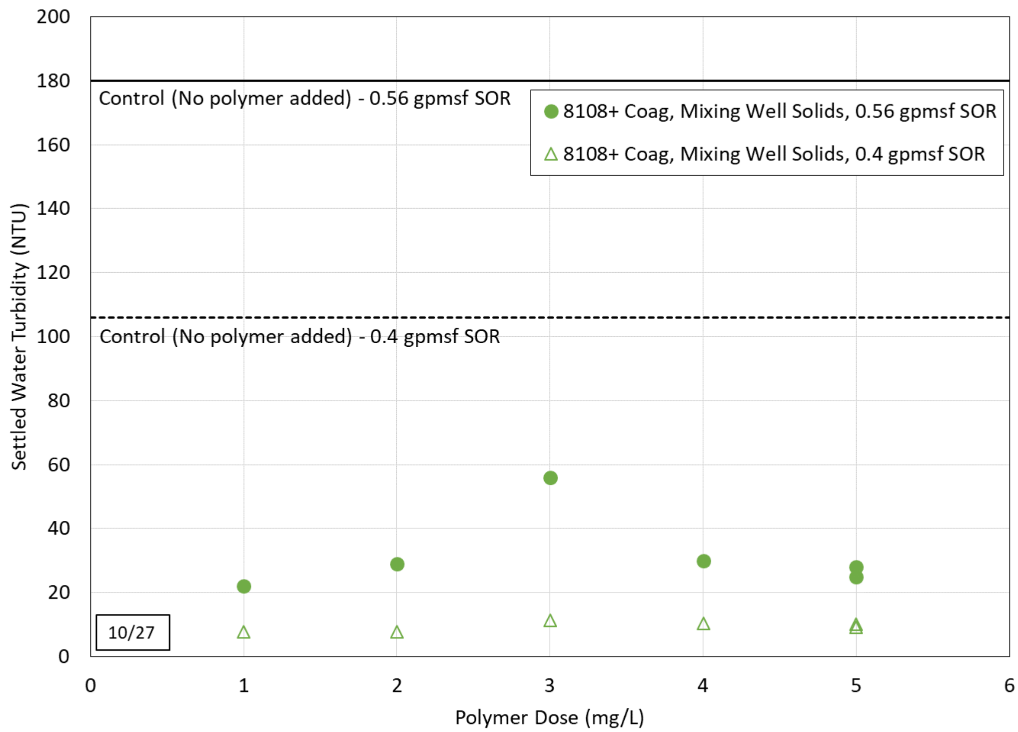


Figure 27 Impact of Offsetting Ferric Sulfate with Nalco 8108+ PEC (Low Range) on Mixing Well Solids Settling

Two non-ionic polyacrylamide flocculation aid polymers, Nalco Nalclear 8181 and Nalco Optimer 7128, were evaluated for their impact on settled water turbidity. Low doses of floc aid polymer were added after 80 mg/L of ferric sulfate and lime targeting pH 10.2 and 11, experiments with and without magnesium removal, respectively. Figure 28 and Figure 29 show that these floc aid polymers had minimal impact on settled water turbidity. Due to the large proportion of small particles formed in a conventional jar test and since flocculation aid polymer dose should be proportional to the number of flocs, this test was not representative of the potential benefits of floc aid polymer. Therefore, the next test involved adding floc aid polymer directly to a jar of center well solids to simulate a solids contact clarifier center well.

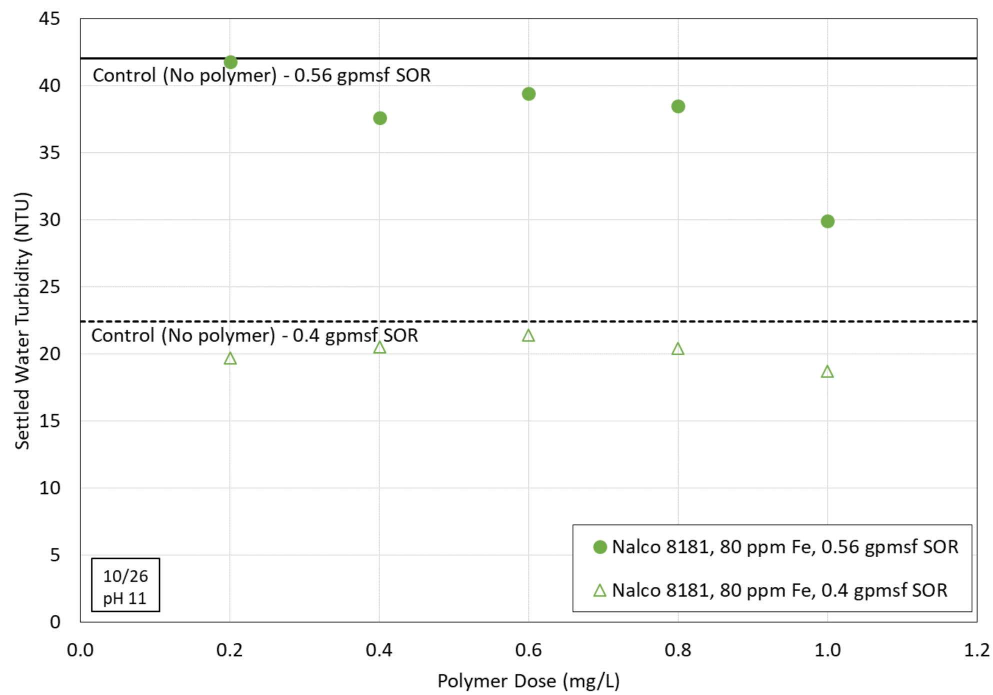


Figure 28 Impact of Nalco 8181 Flocculation Aid Polymer on Settled Turbidity

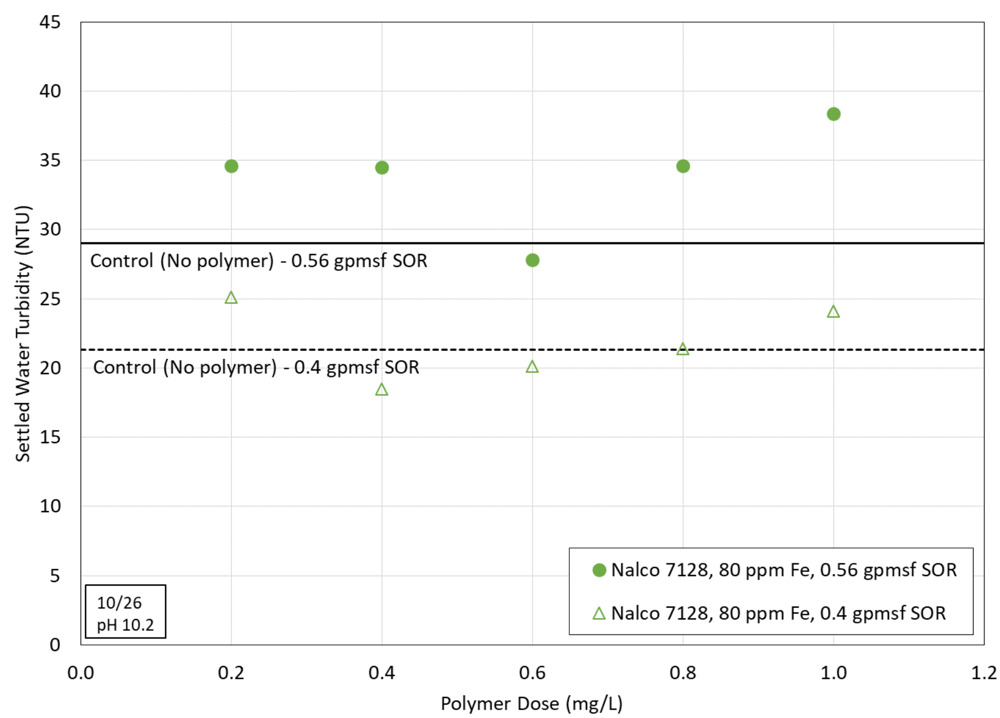


Figure 29 Impact of Nalco 7128 Flocculation Aid Polymer on Settled Turbidity

The Nalco 7128 floc aid polymer was selected for testing with solids contact clarifier mixing well solids. Figure 30 shows the results for simulating floc aid polymer addition to the mixing well after ferric sulfate and lime addition. The controls shown are for settled water turbidity of mixing well solids without polymer addition. Dosing Nalco 7128 floc aid polymer to mixing well solids vastly improved solids settling at doses as low as 0.2 mg/L, and even more at doses up to 1 mg/L. Due to the reactions in the center cone of the solids contact clarifier a low dose may react more like a higher dose in the jar test because the polymer will remain in the center well and continue to provide benefits due to solids recirculation.

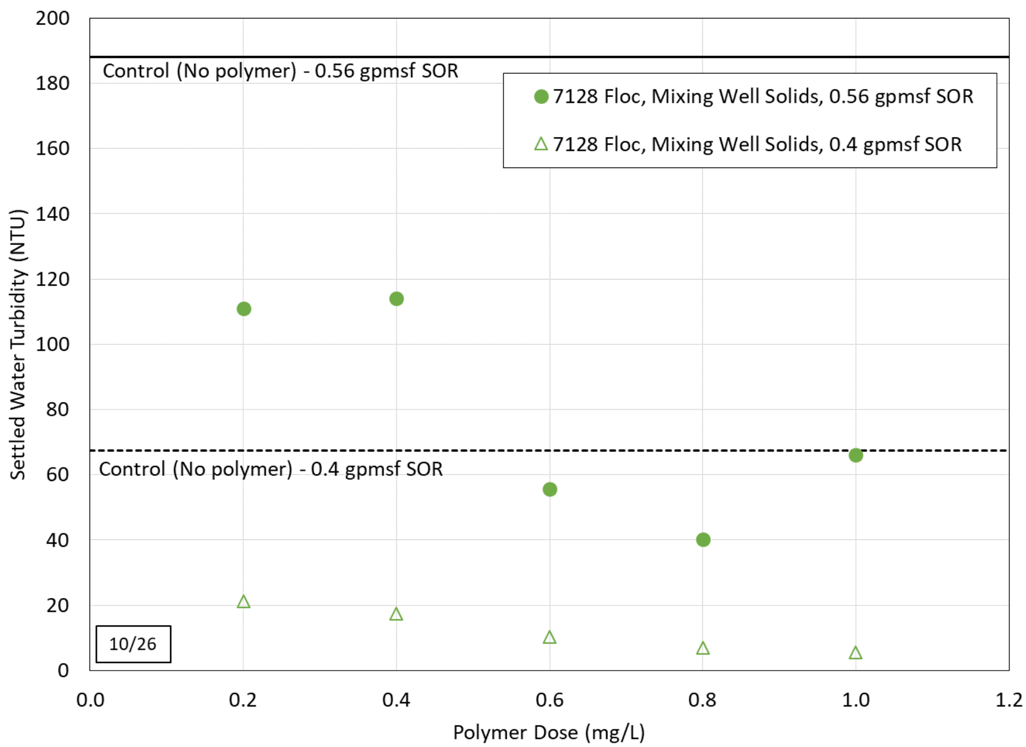


Figure 30 Impact of Nalco 8181 Flocculation Aid Polymer on Mixing Well Solids Turbidity

Section 4

DEMONSTRATION-SCALE POLYMER (PEC) ADDITION

Based on the promising results of coagulation aid polymer addition to center well solids at the bench-scale, a demonstration-scale polymer addition feed system was set up to feed Basin (clarifier) 8 at Ullrich WTP. Figure 31 shows the polymer injection location at the raw water inlet piping to the basin prior to ferric sulfate addition. Based on bench-scale results and availability, Nalco Cat-floc 8108 Plus, a cationic p-DADMAC polymer with a max NSF 60 dose of 50 mg/L, was selected for PEC demonstration-scale testing.

Figure 31 Demonstration-Scale Polymer Injection System

Figure 32 shows a timeline of turbidity measured after letting mixing well solids settle for 10 minutes for Basins 6-8. PEC was dosed to Basin 8 beginning the morning of October 30, while Basins 6 and 7 served as controls. When PEC dosing started, the flow rate for each of the three basins was set to approximately 10 mgd. The polymer dose was gradually increased from 2 to 5 mg/L over three days. A carrier water system was installed to improve polymer dosing the morning of October 31. On November 1, the flow rate to Basin 8 was increased to 12 mgd, while that of control Basins 6 and 7 was held at 10 mgd. The settled turbidity for the Basin 8 center well solids was generally lower than that of Basins 6 and 7 while PEC was fed. After polymer feed was stopped, the settled turbidity for the Basin 8 center well solids increased to near that for Basin 6. Table 7 shows that the basins had similar average pH values of 10.76, 10.74, and 10.77 during demonstration-scale polymer addition.

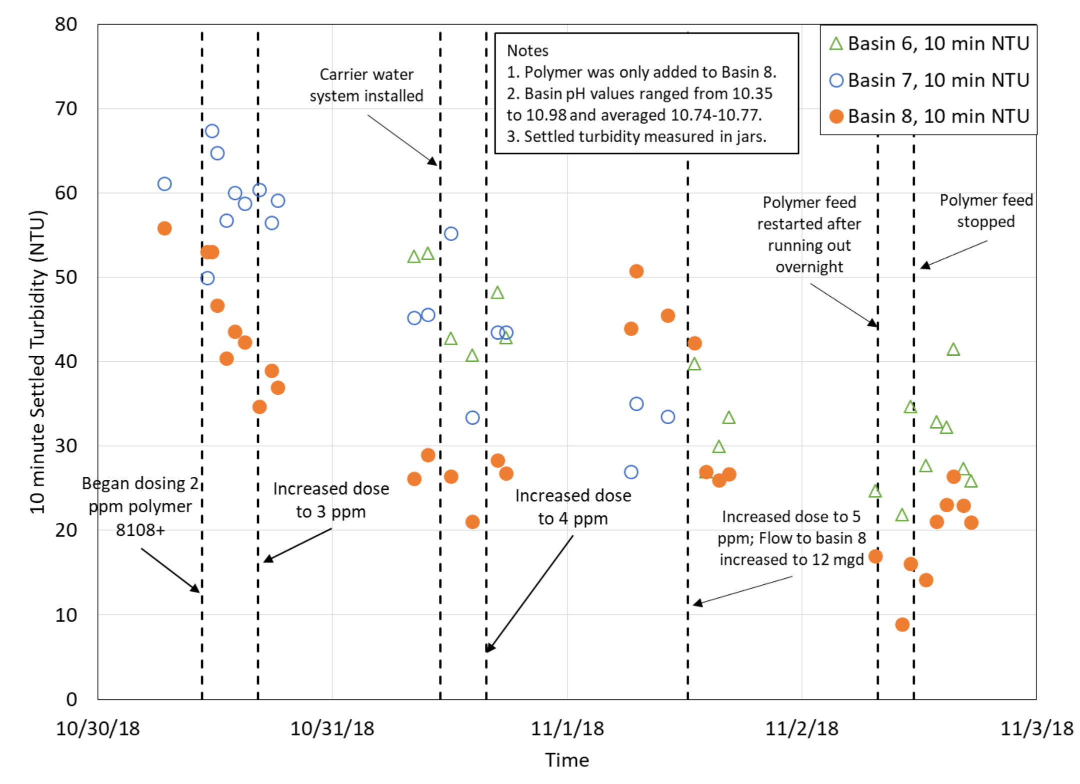


Figure 32 Demonstration-Scale Polymer Addition Timeline: Mixing Well Solids Settled Turbidity

Table 7 Basin pH During Demonstration-Scale Polymer Addition

	Basin 6	Basin 7	Basin 8
Minimum	10.60	10.35	10.62
Average	10.76	10.74	10.77
Maximum	10.91	10.94	10.98

Figure 33 shows a timeline of effluent turbidity for Basins 6-8. In the early morning of October 31, the effluent turbidity dropped in Basin 8. It is likely that polymer built up in the feed line and finally reached the raw water inlet piping at this time. The effluent turbidity of Basin 8 remained approximately half that of Basins 6 and 7 while PEC was dosed, and rose to match that of Basin 6 shortly after polymer feed was stopped.

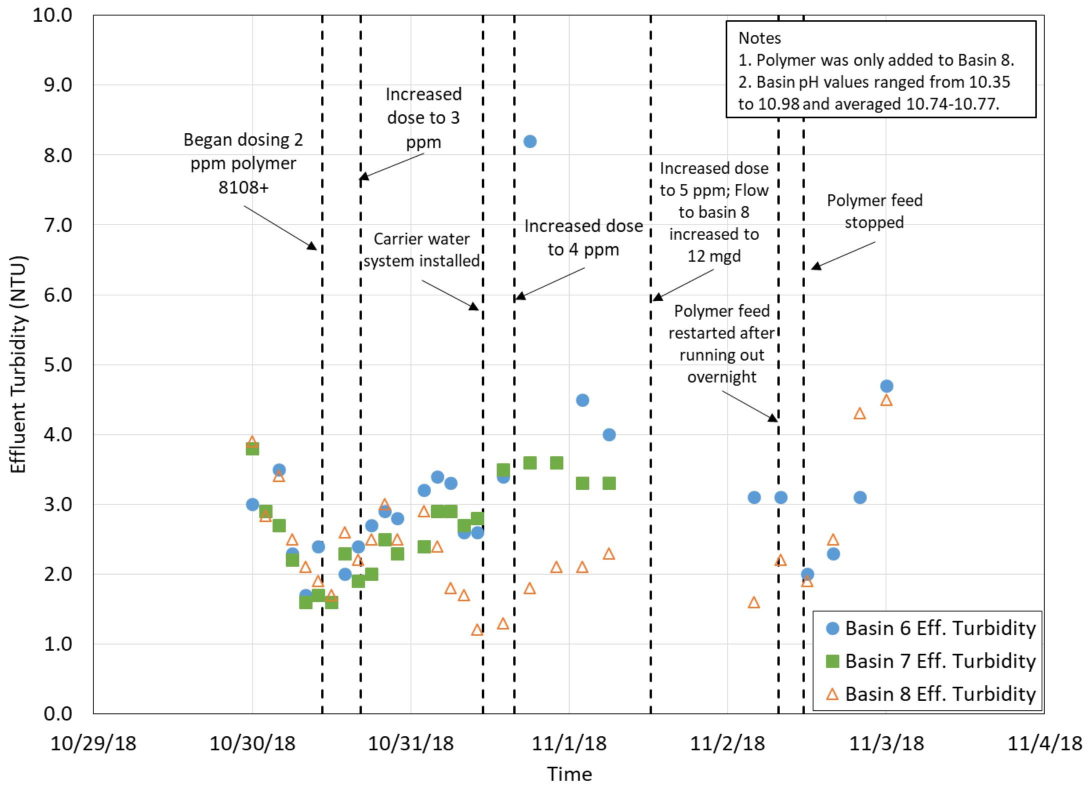


Figure 33 Demonstration-Scale Polymer Addition Timeline: Settled Water Turbidity

A near-neutral zeta potential in settled water indicates that charge neutralization occurred and that filtration would likely remove many of the remaining particles. Settled waters with zeta potentials far from neutral are likely to have high numbers of negatively charge colloidal particles that would be difficult to remove by filtration. Figure 34 shows the impact of demonstration-scale polymer addition on center well zeta potential measured the morning of October 31. Basins 6-8 had non-settled zeta potentials ranging from -10.5 to -8.5 mV. While Basins 6 and 7 had settled water zeta potentials similar to those of the non-settled samples, PEC addition to Basin 8 neutralized the zeta potential in the settled water to near zero. It is assumed that the interference of calcium carbonate, which has a negative surface charge, resulted in negative readings in non-settled samples and that the calcium carbonate particles settled out and were not measured in the settled samples. Across six mixing well settled water zeta potential samples collected on October 31, Basins 6-8 had average zeta potentials of -10.8, -9.2, and -5.7, respectively. The lower effluent turbidity for Basin 8 reinforced the improved charge neutralization attributed to addition of the cationic PEC.

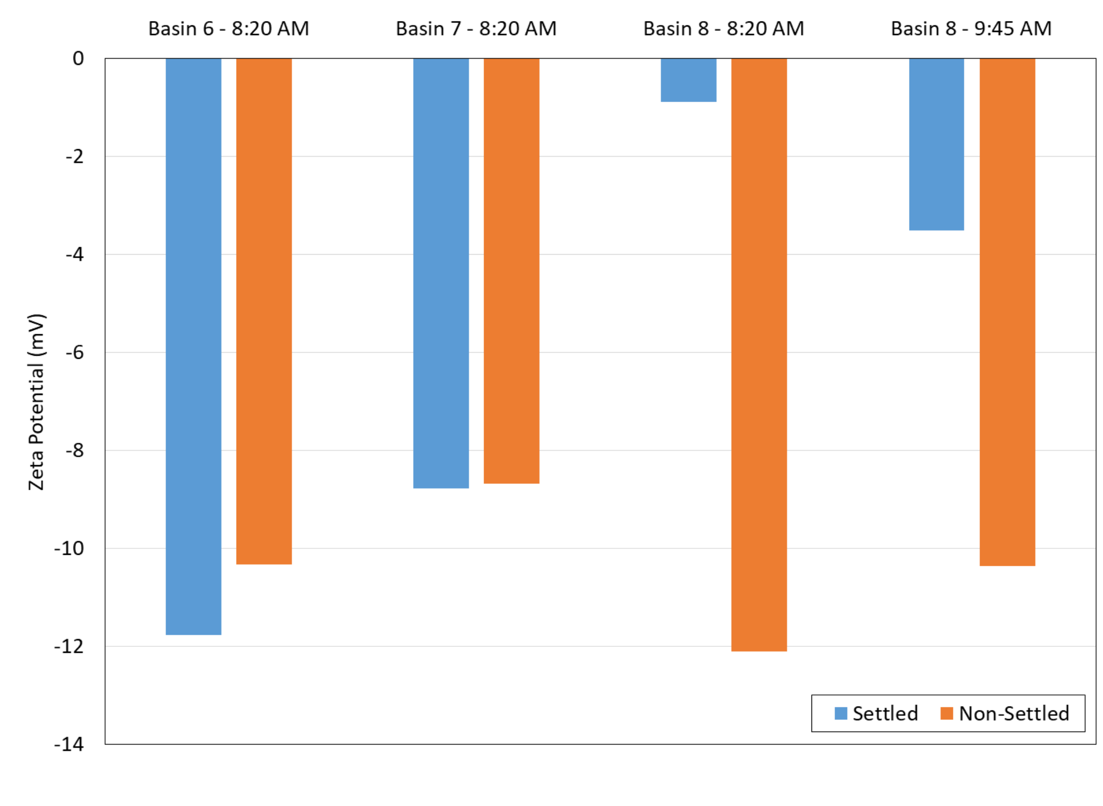


Figure 34 Impact of Demonstration-Scale Polymer Addition on Zeta Potential

Section 5

LESSONS LEARNED FROM AUSTIN'S OCTOBER 2018 FLOOD EVENT

There are several "lessons learned" from the October 2018 flood event that can help inform how the City may prepare for and respond to a future extreme raw water quality event.

1. The WTPs are currently constrained by only having five "knobs" to turn to optimize the first core step of treatment in response to a drastic change in raw water quality.
   a. During the October 2018 flood event, the optimal approach to handle the increased turbidity and TOC, and decreased hardness and alkalinity was to soften at a pH > 10.5, increase the ferric sulfate dose to improve particle destabilization, and decrease the flow through the clarifiers.
   b. Provision of additional tools to destabilize particles, and form settleable/filterable solids would help the City be able to respond to a similar future event, potentially providing flexibility to operate at higher capacity. Proposed additional tools include coagulant, flocculant, and filter aid polymer feed capabilities. Conceptual level costs to incorporate those improvements are provided in a Section 7.

2. Operation of clarifiers at reduced flow rates improved settled water quality.
3. During the event, Ullrich WTP operation was constrained by the ability to handle increased residuals due to an increase in the mass of solids produced, and increase in the clarifier blowdown and filter backwash rate. As discussed below, the ability to feed PEA to the gravity thickener influent could improve solids handling capabilities during a flood event.
4. The City already has procedures in place to respond to emergencies, including extreme weather-related events. The City's Emergency Operation Plan includes activation of the Austin-Travis County Emergency Operation Center and Department Operation Centers (DOC), steps that the City took in response to the October 2018 flood event. The City's Emergency Operations Plan should be supplemented with specific plans for the WTPs to take in response to a future extreme water quality event, drawing from the experience from the October 2018 flood. The plan should include Standard Operating Procedures (SOP) for stepwise and incremental adjustments in operations to optimize treatment in response to a significant change in raw water quality. An SOP for jar tests should be included for City staff or a consultant to evaluate changes at bench scale as a first step to identify recommended adjustments for full-scale operation at the WTP.
5. Unintended consequences of operational adjustments should be considered. For example, during the October 2018 flood event, an increase in the softened water pH resulted in post-precipitation of calcium carbonate in the recarbonated water (see Figure 10). In response, the target recarbonation pH was lowered slightly, but with careful consideration of the impact on the finished water CCPP. City staff remained cognizant of the need to maintain stable water quality in the distribution system. These types of targets and considerations should be included in a written plan for the WTPs to follow in response to an extreme raw water quality event.

5.1 Consideration of Charge Neutralization and Solids Density

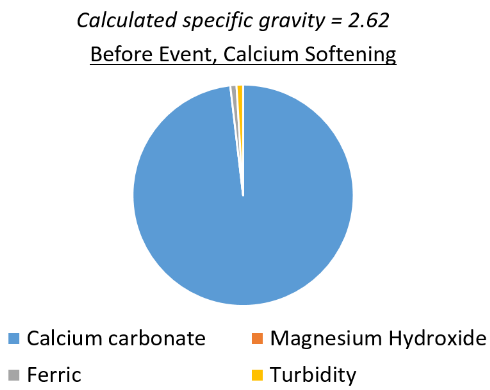
The primary challenge associated with the change in water quality during the October 2018 flood event was how to remove a high concentration of negatively charged watershed-derived particles with relatively low specific gravity in WTPs designed to precipitate and remove high density calcium carbonate particles. The tools that worked during the flood were increasing the softening pH and adding cationic polymer, two steps that aided in charge neutralization. A review of the impact of the various operating scenarios also highlighted the importance of accounting for solids density, which impacts the settleability of the particles.

Figure 35 and Figure 36 show the estimated solids composition and calculated solids density before and after the flood event with different operating scenarios. The solids density calculations were based on literature values for density of the respective solids when wet (not dried). The characteristics of the solids formed under the varying conditions can be generalized as follows:

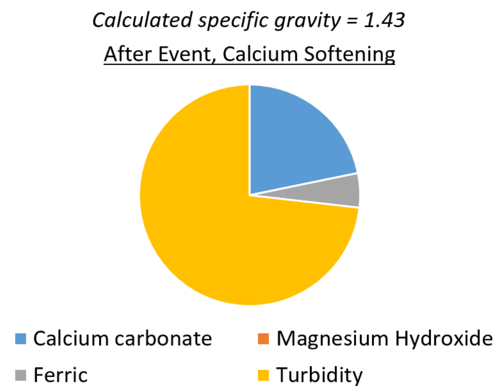
- $CaCO_3$ - Dense particles that are negatively charged at pH 10 to 10.2 and therefore do not provide charge neutralization benefits for NOM and turbidity removal
- $Mg(OH)_2$ - Gelatinous, high surface area solids that enhance NOM and turbidity removal but are difficult to settle
- $Fe(OH)_3$ - Low density flocs that enhance NOM and turbidity removal, but are more difficult to settle than $CaCO_3$.
- Watershed-derived particles - Comprised of negatively-charged organics and silts, with relatively low density

Figure 35 (a) shows how the particles formed during normal operation are made up of mostly calcium carbonate and have a high density, with a calculated specific gravity of 2.62. Figure 35 (b) shows how lime softening during the flood event with an increased ferric sulfate dose resulted in less dense particles due to the lower specific gravity of particles that make up turbidity. At the high turbidity levels of 300 NTU or greater seen during the flood event, turbidity made up three-quarters of solids volume with lime softening and resulted in a low specific gravity of 1.43. While floc size also impacts settling velocity, the decrease in particle density likely translated to reduced settleability of the solids during the flood event.

Figure 36 (a) shows particle composition during flood event conditions with a turbidity of 100 NTU, seen a few days after the peak turbidity, and lime added to achieve a softening pH close to 11 and. As illustrated in Figure 36 (a), this softening condition translated to a calculated specific gravity of 2.07. Figure 36 (b) shows solids composition under the same water quality conditions, but replacing the ferric sulfate dose of 80 mg/L with 4 mg/L of a coagulant aid polymer. Replacing the ferric sulfate with polymer results in a slightly higher specific gravity due to a reduction in the low density ferric hydroxide solids component.

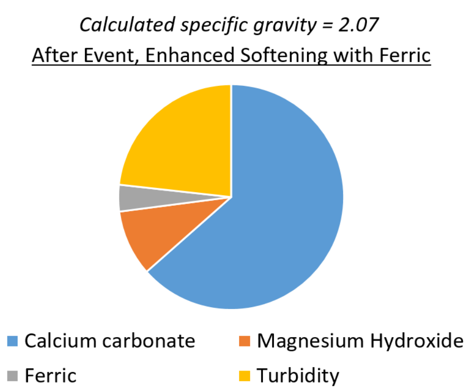


Assumptions:
- Turbidity – 2.2 NTU
- Lime dose – 115 mg/L as CaO
- Raw calcium – 208 mg/L as $CaCO_3$
- Ferric dose = 10 mg/L
- Calcium only softening

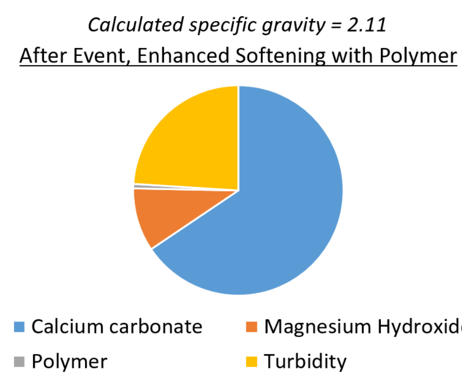


Assumptions:
- Turbidity – 300 NTU
- Lime dose – 115 mg/L as CaO
- Raw calcium – 70 mg/L as $CaCO_3$
- Ferric dose = 100 mg/L
- Finished Calcium = 60 mg/L as $CaCO_3$

Figure 35 Solids Density (a) Before Event, Calcium Softening and (b) After Event, Calcium Softening



Assumptions:
- Turbidity – 100 NTU
- Lime dose – 220 mg/L as CaO
- Raw calcium – 70 mg/L as $CaCO_3$
- Ferric dose = 80 mg/L
- Magnesium = 22 mg/L as $CaCO_3$



Assumptions:
- Turbidity – 100 NTU
- Lime dose – 220 mg/L as CaO
- Raw calcium – 70 mg/L as $CaCO_3$
- Polymer dose = 4 mg/L
- Magnesium = 22 mg/L as $CaCO_3$

Figure 36 Solids Density (a) After Event, Enhanced Softening with Ferric Sulfate and (b) After Event, Enhanced Softening with Polymer

While primarily a paper exercise, these calculations illustrate the impact of operational changes on particle density (and settleability, factoring in floc size), which impacts the plant production capacity that can be achieved while meeting settled water turbidity goals. Based on this evaluation, one tool that was considered and tested on the banked water is to add the ability to feed carbon dioxide and potentially caustic soda to the raw water to facilitate precipitation of more calcium carbonate solids during a flood event, which in theory could improve particle settleability and the ability to operate at SORs closer to typical conditions. However, results from the tests (summarized in Section 5.2 and detailed in The Bench Testing Report) indicated only marginal improvement that does not justify the operational complexity and costs (see Appendix A) of carbon dioxide and caustic soda addition.

5.2 Summary of Results from Banked Water Testing

Bench testing using the banked water was conducted in February / March 2019 to evaluate additional treatment strategies that were not available to the operations staff during the flood event. Results are included in the Bench Testing Report (Carollo, 2019). The four identified strategies selected for study included:

- Addition of coagulant aid polymer (PEC).
- Addition of flocculation aid polymer (PEA).
- Addition of carbon dioxide and sodium hydroxide to allow the WTPs to develop solids that are closer to the characteristics of typical lime softening solids.
- Enhanced coagulation with ferric sulfate.

The testing demonstrated that the optimal strategy to treat challenging raw water during a flood event includes the addition of both PEC and PEA. The testing also demonstrated that enhanced coagulation, softening at pH > 10.5, and/or feeding CO_2 and sodium hydroxide upstream of softening are not preferred. The tests further illustrated the benefit of maintaining solids in the center well of the SCCs.

Based on the additional testing, the following treatment approach is recommended to improve the settleability and filterability of the softening process during a flood event:

- Feeding ferric sulfate at doses typical of normal operation (i.e., 15 mg/L as solution).
- Feeding PEC 30 seconds or more after ferric sulfate to maximize charge neutralization (e.g., 12 mg/L of Magnafloc LT 7995 as solution for the banked water tested though dose will be dependent on the specific polymer used).
- Softening at pH typical of normal operation (i.e., pH 10.0- 10.2).
- Feeding PEA to the center well of the upflow clarifiers to provide particle bridging.

The recommended approach requires minimal WTP improvements (relatively low capital cost) and maintains operations (i.e., ferric sulfate dose and softening pH) near typical operation. Therefore, this approach is more easily implemented than strategies that would require a complete shift from normal operations. The recommended approach also results in finished water quality similar to that of typical operations with respect to pH, magnesium, and calcium carbonate precipitation potential (CCPP), thereby minimizing potential disruptions to water quality in the distribution system.

5.3 Residuals Handling Considerations

As discussed in Section 1.1, the increase in turbidity and impact to plant operations also affected the residuals handling facilities. Table 8 contrasts the mass of solids produced under typical operating conditions relative to the flood event. Based on these calculations, the solids produced during the flood event increased more than two-fold. The proposed future flood event operation strategies will produce less solids than the approach used during the flood event and improve the effectiveness of the residuals handling systems as follows:

- The addition of PEC to offset the ferric sulfate dose will decrease the mass of solids produced and reduce the amount of $Fe(OH)_3$ precipitated, which does not settle as well as calcium carbonate.
- Operation at pH 10.0-10.2 will also decrease the mass of solids produced and minimize the amount of $Mg(OH)_2$ precipitated, a gelatinous high surface area precipitate that does not settle as well as calcium carbonate.
- The improvement in settled water turbidity and charge neutralization achieved via PEC addition is expected to translate to improved filter run times compared to those experienced during the October 2018 flood event and reduce the backwashing frequency. Provisions to feed PEC as a filter aid polymer will also help improve filter performance with respect to turbidity removal.

Table 8 Estimated Solids Production Rate

Operation Scenario	Mass of dry solids produced (lb/MG)
Typical Operation (15 mg/L ferric sulfate; Softening pH = 10.2; Raw water turbidity = 5 NTU)	2,650
Flood Event Operation (80 mg/L ferric sulfate; Softening pH = 11.0; Raw water turbidity = 350 NTU)	5,700
Proposed Future Flood Event Operation (15 mg/L ferric sulfate; 10 mg/L PEC; Softening pH = 10.2; Raw water turbidity = 350 NTU)	5,000

The thickeners at Handcox and Ullrich WTPs were designed to treat up to approximately 100 dry lbs/ft^2/day of solids at hydraulic loading rates of less than 300 gpd/ft^2. At times during the flood event, excessive solids removal from the clarifiers at the Ullrich WTP resulted in a thickener hydraulic loading rate exceeding 2,000 gpd/ft^2. The improvements to the pretreatment process described above should allow the solids removal, and therefore, the hydraulic loading rate to the thickener to be reduced. However, the solid handling capacity may still be exceeded.

Table 9 and Table 10 compare operation of the thickener and centrifuges at Ullrich and Handcox WTPs under typical conditions to residuals handling conditions that may occur during future flood events. Based on calculations shown in Table 9, both of the design parameters (i.e., solids and hydraulic loading rate) will be exceeded at Ullrich WTP during a flood event. Feeding PEA polymer to thickener influent will improve settling and will allow the thickener to operate at higher solids and hydraulic loading rates (approximately double typical rates). Therefore, it is recommended to feed PEA polymer to the thickener influent to improve thickener performance during flood events.

The increase in solids produced during flood events will also impact centrifuge operations. Based on calculations shown in Table 10, the proposed operation strategy should allow the solids to be processed if the centrifuges are operated 24 hours per day. However, the hauling requirements at each WTP approximately double.

Table 9 Gravity Thickener Operation

Parameter	Ullrich	Handcox
No.	1	1
Diameter (ft)	70	70
Normal Operation		
Solids Loading Rate (dry lbs/ft^2/day)	91	94(1)
Hydraulic Loading Rate (gpd/ft^2)(2)	267	240
Flood Event Operation (80 mg/L ferric sulfate; Softening pH = 11.0)		
Solids Loading Rate (dry lbs/ft^2/day)(3)	245	74
Hydraulic Loading Rate (gpd/ft^2)(4)	584	175
Proposed Future Flood Event Operation (15 mg/L ferric sulfate; 10 mg/L PEC; Softening pH = 10.2)		
Solids Loading Rate (dry lbs/ft^2/day)(3)	215	65
Hydraulic Loading Rate (gpd/ft^2)(4)	511	153

Notes:
(1) At 150 mgd; 31 dry lbs./ft2/day@ 50 mgd.
(2) At 5% solids and max flow rate (167 mgd for Ullrich and 150 mgd for Handcox). Loading rate for Handcox @ 50 mgd = 80 gpd/ft^2.
(3) At 167 mgd at Ullrich and 50 mgd at Handcox.
(4) At 5% solids and max flow rate (167 mgd for Ullrich and 50 mgd for Handcox).

Table 10 Centrifuge Operation

Parameter	Ullrich	Handcox
No.	4	2
Design Flow, ea. (gpm)	2@140; 2@250	143
Operating Period (hrs/day)[(1)]		
Normal Operation	10	10
80 mg/L Ferric Sulfate; Softening pH 11.0	23	25
15 mg/L Ferric Sulfate; 10 mg/L Polymer; Softening pH 10.2	20	22
Truck trips (trips per day)[(2)]		
Flood Event Operation	16	5
80 mg/L Ferric Sulfate; Softening pH 11.0	43	13
15 mg/L Ferric Sulfate; 10 mg/L Polymer; Softening pH 10.2	38	11

Notes:
(1) Assumes 15% dry solids in thickened feed sludge; largest centrifuge out of service.
(2) Assumes 55% solids cake; 20 ton truck capacity.

Residuals from the sedimentation basins at the Davis WTP are conveyed to an equalization tank. A portion of the residuals are recycled to the head of the plant, while the remainder is sent to the centrifuges for dewatering.[4] Overflows from the solids handling process are routed to the sewer. During the flood event, excess residuals that could not be processed at the WTP were sent to the sewer and treated at the wastewater treatment plant. Therefore, during future food events, should the capacity of the residual system be exceeded, excess residuals may be sent to the sewer and not adversely impact the capacity of the Davis WTP.

[4] Approximately 2/3 is recycled to the head of the WTP and 1/3 sent to the solids dewatering facility (Source: Davis Water Treatment Plant Solids Management Evaluation. Kennedy Jenks Consultants. August 20, 2009.

Section 6

LESSONS LEARNED FROM OTHER UTILITIES

Table 11 presents a number of softening (and coagulation) WTPs from around the country which frequently experience periods of high turbidity. In addition to the average water quality and the characteristics of each plant, the table also outlines the operational adjustments that each plant implements to respond to extreme water quality events. The table illustrates that other lime softening plants in the country are susceptible to high turbidity events; in fact, several lime softening WTPs on the Missouri River can experience turbidity events greater than 10,000 NTU. However, they all have additional treatment processes to help respond to these types of events. In some cases, raw water is passed through presedimentation basins where turbidity is reduced with the help of cationic polymer prior to softening. In other cases, horizontal collector wells are constructed to induce aquifer recharge from the river, essentially utilizing the river bank as a prefilter. In many cases, sedimentation basins are much larger than upflow solids contact clarifiers, with surface overflow rates (SORs) at or below 0.5 gpm/sq ft. For reference, the design surface overflow rate at Handcox and Ullrich is between 1.2-1.4 gpm/sq ft. Davis was designed as a conventional flocculation/sedimentation plant and has an SOR at design capacity of 0.75 gpm/sq ft.

Of note, most of the WTPs listed in Table 4 that have horizontal collection wells, presedimentation basins, and/or two-stage softening have average turbidity values similar or higher than historical maximum values observed at the City of Austin's WTPs and a history of sustained high turbidity events, which the City has not experienced. Given historical water quality conditions and durations in Austin, there was not previously a need for additional operational features to respond to extreme water quality events. However, the October 2018 flood highlighted the potential for this type of event in Austin and the need to assess plant capabilities and potential improvements to respond to any similar future event.

Utilities that regularly experience high turbidity events on a continuous basis have tools to manage them and state agencies in states where these types of events regularly occur have codified particular treatment criteria and processes needed to deal with such events. Table 12 outlines the specific requirements for each state in addition to the Ten-States Standards requirements. While many states (including Texas) require presedimentation or pretreatment for waters that experience high turbidity, only three states (Kansas, North Carolina, and Wyoming) lay out a threshold turbidity at which pretreatment is required. The requirements for Kansas reflect the susceptibility of multiple rivers, including the Kansas River and Missouri River, in that state to high turbidity events.

Table 11 Characteristics of Other Lime Softening Plants that Experience Extreme Turbidity / Weather Events

Plant	Source Water	Average Water Quality			Plant Characteristics							Types of Extreme WQ Events Observed (qualitative)	Operational Responses to Extreme Events
		Turbidity (NTU)	Calcium (mg/L as $CaCO_3$)	Alkalinity (mg/L $CaCO_3$)	Horizontal collection wells (HCW)	Presedimentation Basin	Type of softening process: conventional vs. solids contact clarifiers, single vs. two-stage	Surface overflow rate (SOR)	Solids recirculation? (% solids for contact clarifier)	Coagulant dose (mg/L)	Polymer feed capabilities (type, dose, and locations fed)		
Jefferson City, MO	Missouri River – Subsurface Intake	100-200	250	200	No	1 presed	Softening- Solids contact clarifier, two stage	1 gpm/sq ft – presed 1.5 gpm/sq ft clarifier	No, but would be useful	10-15 mg/L Fe	5-15 mg/L to presed/intake	Do have a subsurface intake, but can get alkalinity drops and turbidity events that exceed 10,000 NTU	Increase polymer dose and ferric dose through testing and back off on softening pH. Add some polymer between primary and secondary to assist with turbidity increase in secondary basins.
Kansas City, MO	Missouri River	200-500	250	200	Yes, 60 mgd capacity	6 preseds, designed for surface loading rate of 1 gpm/sq ft	Softening - Conventional, two stage	0.5 gpm/sq ft	0.5% solids	10 mg/L Fe	Low MW cationic 5-10 mg/L at presed, 1-2 mg/L at influent, 0.5 mg/L following 1st stage	Turbidity as high as 10,000-20,000 NTU	Increase flow to horizontal wells. Turn on more preseds to lower rate. Add more cationic polymer at intake. Increase solids recycle to the preseds.
Edmond, OK	Arcadia Lake	15-20	225	185	No	No	Softening- Solids contact clarifier, single stage, have pre and post ozone.	1.5 gpm/sq ft	2-5% solids	0-15 mg/L Fe	Low MW cationic 2-5 mg/L at center cone. High MW nonionic for filter aid.	Up to 300 NTU when river currents take floodwater to intake	Monitor river turbidity and lake turbidity/alkalinity. When these drop: lower plant flowrate, increase solids recycle, increase preozone, add more polymer, and turn on wells in town. Add filter aid as last resort.
Norman, OK	Lake Thunderbird "Dirty Bird"	20-30	230	170	No	No	Softening- Solids contact clarifier, single stage	1.0 gpm/sq ft	No	0-28 mg/L Fe	Low MW cationic at raw water line feed (0-10 mg/L) during spring/fall	Alkalinity drop and highly charged organics	Monitor alkalinity, reduce plant flowrate, decrease ferric, increase polymer dose. Decrease lime dose to avoid oversoftening.
Missouri American Water – North and Central WTPs	Missouri River	200-500	250	200	No	North WTP has 3 preseds, Central WTP has 4 preseds	Softening- Conventional, two stage softening process	0.25 gpm/sq ft 0.33 gpm/sq ft secondary	Yes	10-35 mg/L Fe	Low MW cationic 5-15 mg/L at intake prior to presed, 2-5 mg/L at primary basins, 1-2 mg/L at secondary basin flocculators	Up to 10,000-20,000 NTU	Increase polymer dose in primary basins and recycle more solids. Small dose of polymer to secondary basins takes care of carryover.
Colorado Springs Mesa WTP(1)	Local Sources Pike's Peak 33rd Street Intake	7 NTU	50 mg/L as $CaCO_3$	30 mg/L as $CaCO_3$	No	No	Conventional WTP	0.5 gpm/sq ft	No	9 mg/L alum	Cationic, 4.4 mg/L	Turbidity > 100 NTU	Add cationic polymer directly on top of filters

Table 11 Characteristics of Other Lime Softening Plants that Experience Extreme Turbidity / Weather Events (continued)

Plant	Source Water	Average Water Quality			Plant Characteristics								Types of Extreme WQ Events Observed (qualitative)	Operational Responses to Extreme Events
		Turbidity (NTU)	Calcium (mg/L Ca)	Alkalinity (mg/L $CaCO_3$)	Horizontal collection wells (HCW)	Presedimentation Basin	Type of softening process: conventional vs. solids contact clarifiers, single vs. two-stage	Surface overflow rate (SOR)	Solids recirculation? (% solids for contact clarifier)	Coagulant dose (mg/L)	Polymer feed capabilities (type, dose, and locations fed)			
Olathe, KS	Kansas River	12 NTU	275 mg/L as $CaCO_3$	200 mg/L as $CaCO_3$	Yes	No	Softening- Solids contact clarifier	1.5 gpm/sq ft	10%	NA	Nonionic, 0.1 mg/L	High turbidity	HCW reduces turbidity to levels that can be accommodated at the WTP
Board of Public Utilities [1,2]	Missouri River	400 NTU	280 mg/L as $CaCO_3$	250 mg/L as $CaCO_3$	Yes[2]	Yes	Conventional WTP	<<0.5 gpm/sq ft	No	20 mg/L alum	8 mg/L average to presedimentation basin	High turbidity (up to 70,000 NTU)	Presedimentation basin knock turbidity down from 400 NTU to 36 NTU
Clifton Water District (Soften with RO)	Colorado River	94 NTU	50-400 mg/L as $CaCO_3$	40-380 mg/L as $CaCO_3$	No	Yes. 8 hours of settling time - Goal of <50 NTU.	Conventional WTP - Membrane Softening	0.3 gpm/sq ft (plate rise rate)	No	35 mg/L alum	Cationic, 3.5 mg/L average, as much as 8 mg/L, presed basin	High Turbidity (up to 54,000 NTU)	More polymer

Notes:
HCW - horizontal collection well; WTP - water treatment plant.
(1) Not a softening plant.
(2) Quindaro WTP was decommissioned and did not have a HCW, Nearman WTP constructed as replacement and does have a HCW.

Table 12 Summary of State Specific Requirements for Addressing High Turbidity Water Sources

State(1)	Petreatment / Presettling Basin Required?	Notes
Texas	Yes	• Reservoirs for pretreatment or selective quality control shall be provided where complete treatment facilities fail to operate satisfactorily at times of maximum turbidities or other abnormal raw water quality conditions exist.
California	Yes	• Presedimentation used for *Cryptosporidium* log removal credit (LT2ESWTR)
Colorado	Yes	• Up to water utility to determine intended service of presedimenation basin (e.g., intermittent, full time). • Presedimentation basins must be designed to reduce raw water turbidity to levels which can be adequately and effectively treated using selected downstream treatment processes. • Minimum 3 hour detention time for presedimentation basins.
Idaho	Yes	• Waters exhibiting high turbidity may require pretreatment, usually sedimentation with or without the addition of coagulation chemicals.
Kansas	Yes	• Source waters with turbidity in excess of 1,000 NTU should have pretreatment. Presedimentation, with or without chemicals recommended. • Presedimentation basins must have minimum 45 min. detention time, except for the Kansas and Missouri River sources, for which 2 and 3 hours, respectively are recommended. • Conventional sedimentation basins on the Kansas, Missouri, and Neosho Rivers must have the following detention times: • With Presedimentation: 3 hours • Without Presedimentation: 4 hours
Louisiana	Yes	• Waters containing high turbidity "may require pretreatment, usually sedimentation, with or without the addition of coagulation chemicals." • Detention time shall consider removal requirements for the unit.
Missouri	Yes	• Systems treating surface water require two stages of treatment, provided as primary rapid mix, flocculation and sedimentation followed by secondary rapid mix, flocculation and sedimentation, operated in series. • Presedimentation recommended for systems taking water from navigable rivers. • For solids contact clarifiers treating surface water, the detention time shall be no less than 2.5-4 hours. • For solids contact clarifiers, the maximum upflow rate shall not exceed 1.0 gpm/sq ft.
North Carolina	Yes	• Pre-settling or pre-treatment reservoir required where wide and rapid variations in turbidity, bacterial concentrations or chemical qualities occur or where the following raw water quality standards are not met: turbidity - 150 NTU, coliform bacteria - 3000/100 mL, fecal coliform bacteria - 300/100 mL, color - 75 CU.
Oklahoma	Yes	• Presedimentation required for raw waters that exceed certain coliform bacteria counts. • Surface water containing an excessive amount of suspended material requires pre-sedimentation and possibly other preliminary treatment prior to conventional treatment.
Ten-State(2)	Yes	• "Waters containing high turbidity may require pretreatment, usually sedimentation, with or without the addition of coagulant chemicals." • Three hours detention is the minimum period recommended.
Tennessee	Yes	• Waters containing high turbidity or silica particles may require pretreatment, usually sedimentation with or without the addition of coagulation chemicals. • Pre-sedimentation basins should be designed to hold maximum 3-day usage.
Utah	Yes	• Waters containing heavy grit, sand, gravel, leaves, debris, or a large volume of sediments may require pretreatment, usually sedimentation with or without the addition of coagulation chemicals.
Wyoming	Yes	• Raw waters which have episodes of turbidity in excess of 1,000 TU for a period of one week or longer shall be presettled. • Basins without mechanical sludge collection shall have minimum 3 day detention time. Basins with mechanical sludge collection shall have minimum 3 hour detention time.

Notes:
(1) At the time this report was written, pretreatment / presettling basin requirements for Alabama, Alaska, Arizona, Montana, Nebraska, Nevada, South Carolina, Virginia, Washington were either not codified or were not found.
(2) The following states also adhere to the Ten-States Standard: Illinois, Indiana, Iowa, Michigan, Minnesota, Missouri, New York, Ohio, Ontario, Pennsylvania, and Wisconsin.

Section 7

CLASS 5 COST OPINIONS

During the October 2018 flood event, the WTPs were able to operate to meet finished water goals and TCEQ requirements, but only at significantly reduced capacity. As discussed above, provision of additional tools to destabilize particles, and form dense, settleable solids would help the City be able to respond to a similar future event, potentially providing flexibility to operate at higher capacity. Based on observations and bench testing during the October 2018 flood event coupled with bench tests conducted on banked water (see Bench Testing Report, Carollo 2019), the following operating conditions are recommended to increase the resiliency of the City's WTPs to respond to future flood events:

- Feeding ferric sulfate at doses typical of normal operation (i.e., 15 mg/L as solution).
- Feeding PEC thirty (30) seconds or more after ferric sulfate to maximize charge neutralization (i.e., 12 mg/L as solution for the banked water tested).
- Softening at pH typical of normal operation (i.e., pH 10.0- 10.2).
- Feeding PEA to the center well of the upflow clarifiers to provide particle bridging.
- Including the ability to add PEC to the filter influent.
- Adding PEA to the gravity thickener influent (Ullrich WTP and Handcox WTP only).

Process modifications required to operate under those conditions include:

- **Coagulant and filter aid polymer storage and feed**. Dosing PEC neutralizes charge, allowing for a lower ferric sulfate dose and a reduction in the total sludge volume produced. This same PEC could be dosed ahead of the filters as a filter aid polymer to further neutralize the charge and improve filterability if pretreatment processes did not keep up with the dynamics of changing flood waters. Utilities such as Colorado Springs Utilities and the City of West Palm Beach utilize this method of dealing with high charge events.
- **Flocculant aid polymer storage and feed**. Dosing flocculant aid polymer to the center well of the solids contact clarifiers at Ullrich WTP and Handcox WTP, and to the second stage of flocculation at Davis WTP may result in formation of larger, stronger, more settleable particles. Testing with banked water from the flood demonstrated the benefit of PEA on particle settleability. The ability to feed PEA to the gravity thickener influent at Ullrich WTP and Handcox WTP should be included. Based on engineering experience, addition of PEA can double the hydraulic capacity of gravity thickeners.

This section provides conceptual level costs for implementing those process modifications. Costs to facilitate CO_2 and NaOH addition were developed (Appendix A), but those modifications are not recommended since bench testing with banked water showed minimal improvement in treatment from addition of those chemicals.

Costs were developed at an alternatives analysis / planning level of detail, consistent with an AACE Class 5 estimate suitable for study or feasibility analyses, with an expected accuracy of +50/-30 percent. Cost estimates are typically refined as projects move into preliminary and final design, with increasing levels of accuracy associated with the greater level of detail available for use in estimating. Costs are shown in 2019 dollars.

Capital costs include construction of new bulk chemical storage, feed pumps, piping, and containment areas for liquid feed systems at each plant. An allowance for electrical/instrumentation and controls costs was included as 50 percent of equipment costs. Multiplier assumptions to reach the total estimated project costs include 40 percent for unidentified items, and 15 percent for general contractor overhead, profit, and risk. Engineering, legal, and administration fees are not included. Costs for chemicals and operations and maintenance of each respective system were not calculated as part of this analysis as they would be relatively insignificant due to the small duration of these emergency events.

In consultation with the City, the following assumptions were made in developing the costs for each system:

- WTPs would be operated at 80% capacity during future flood events for determination of chemical storage requirements.
- 7 days on-site storage required for flood event chemical storage requirements.
- Chemicals will be fed to each basin (seen as most conservative for estimating piping and feed pump requirements).

7.1 Coagulant and Filtration Aid Polymer (PEC) Storage and Feed System Cost Estimate

The assumptions specific to the coagulant and filter aid polymer system costs are:

- Coagulant aid polymer dose requirements: 20 mg/L as product.
- Feed points will be added to each primary treatment basin's influent piping.
- Feed points will be added to allow adding polymer just prior to filtration (basin effluent piping).

Table 13 outlines the costs associated for a coagulant aid polymer system at each WTP.

Table 13 Cost Estimate for Coagulant Aid Polymer System

Element	Davis	Handcox	Ullrich
General Conditions(1)	$303,000	$288,000	$304,000
Chemical Storage Containment Area	$81,000	$81,000	$81,000
Process Mechanical(2)	$689,000	$193,000	$583,000
EI&C Allowance(3)	$216,000	$61,000	$181,000
Total Direct Cost	**$1,289,000**	**$624,000**	**$1,150,000**
Unidentified Key Elements (40%)	$516,000	$250,000	$460,000
Contractor OH&P (15%)	$271,000	$132,000	$242,000
Total Construction Cost	**$2,076,000**	**$1,006,000**	**$1,852,000**
Allowance for Change Orders (5%)	$104,000	$51,000	$93,000
Total Estimated Project Cost	**$2,180,000**	**$1,057,000**	**$1,945,000**

Notes:

(1) General conditions assume: 9 month duration with full time project manager, superintendent, and field engineer; a half-time clerk; $40,000 for mobilization/demobilization; a construction trailer for 9 months at $5,000 per month; and bonding and insurance for 3.25% of the project direct cost.

(2) Process mechanical costs assume 18 feed points for Davis (2x for 9 basins), 14 feed points for Ullrich (2x for 7 basins) and 4 feed points for Handcox (2x for 2 basins).

(3) Electrical costs and instrumentation costs are assumed to be 35% and 15%, respectively, of the direct cost of equipment requiring electrical and instrumentation design (e.g., pumps, level monitoring for storage tanks, etc.).

Based on the above costs, the total estimated cost for a coagulant/filter aid polymer system at all three WTPs is approximately $5.2 million.

7.2 Flocculant Aid Polymer Storage and Feed System Cost Estimate

The assumptions specific to the flocculant aid polymer system costs are:

- Flocculant aid polymer dose requirements: 1 mg/L as product to the solids contact clarifiers at Ullrich and Handcox WTPs and to the second stage of the flocculation process to Davis WTP.
- Feed points will be added to each basin (either the center cone or 2nd stage of flocculation).
- Feed points also added to the influent piping at the thickener at Ullrich WTP and Handcox WTP (one at each plant).
- Flocculant aid polymer systems require a blending system (for polymer activation) and aging tank.

Table 14 outlines the costs associated with implementing a flocculant aid polymer system at each WTP.

Table 14 Cost Estimate for Flocculant Aid Polymer System

Element	Davis	Handcox	Ullrich
General Conditions(1)	$297,000	$290,000	$296,000
Chemical Storage Containment Area	$81,000	$81,000	$81,000
Process Mechanical(2)	$373,000	$220,000	$356,000
EI&C Allowance(3)	$140,000	$80,000	$130,000
Total Direct Cost	**$891,000**	**$671,000**	**$863,000**
Unidentified Key Elements (50%)	$357,000	$269,000	$346,000
Contractor OH&P (15%)	$188,000	$141,000	$182,000
Total Construction Cost	**$1,436,000**	**$1,081,000**	**$1,391,000**
Allowance for Change Orders (5%)	$72,000	$55,000	$70,000
Total Estimated Project Cost	**$1,508,000**	**$1,136,000**	**$1,461,000**

Notes:
(1) General conditions assume: 9 month duration with full time project manager, superintendent, and field engineer; a half-time clerk; $40,000 for mobilization/demobilization; a construction trailer for 9 months at $5,000 per month; and bonding and insurance for 3.25% of the project direct cost.
(2) Process mechanical costs assume 9 feed points for Davis (1x for 9 basins), 8 feed points for Ullrich (1x for 7 basins and 1x for the thickener), and 3 feed points for Handcox (1x for 2 basins and 1x for the thickener).
(3) Electrical costs and instrumentation costs are assumed to be 35% and 15%, respectively, of the direct cost of equipment requiring electrical and instrumentation design (e.g., pumps, level monitoring for storage tanks, etc.).

Based on the above costs, the total estimated cost for a flocculant aid polymer system at all three WTPs is approximately $4.1 million. As noted, the costs include pumps and piping needed to feed polymer to the solids thickener at Ullrich WTP and Handcox WTP. The cost associated with adding this portion of the system is approximately $85,000 at each WTP.

7.3 Summary of Costs to Implement Recommended Improvements

Each of the process modifications outlined above should be designed and constructed in the near term to maximize operational flexibility at the WTPs in response to the likelihood of future extreme raw water quality events. In summary, those improvements include: 1) adding PEC polymer feed systems and storage for application just downstream of ferric sulfate and also to the filter influent, and 2) adding PEA polymer feed systems and storage for application to the center well at Ullrich and Handcox WTPs and the second stage of flocculation at Davis WTP, and to the gravity thickener influent at Ullrich WTP and Handcox WTP. The total estimated capital costs for these improvements are: $3.7 million at Davis WTP, $2.2 million at Handcox WTP, and $3.4 million at Ullrich WTP. The cost for improvements at all three WTPs is estimated to be $9.3 million.

If staged implementation of the recommended improvements is needed to allow the most critical improvements to be implemented more quickly, then PEC addition should be included in the first implementation stage. Results from the bench-scale testing with banked water (Carollo 2019) showed that PEC fed upstream of lime addition was critical to optimizing treatment. Testing showed that PEA addition provided additional treatment benefits, and improvements to feed PEA are also recommended. However, PEA addition is needed, but less critical, and could be implemented subsequently.

Section 8

CONCLUSIONS AND RECOMMENDATIONS

The October 2018 flood event resulted in an unprecedented temporary change in source water quality for the City's three WTPs. Record high concentrations of turbidity and total organic carbon along with lows of hardness and alkalinity were observed. Further, the impact of the flood on source water quality was for a longer duration than previously experienced. Water quality did not return to typical conditions for several weeks.

The change in water quality prevented treatment to the City's normal standard of quality without a significant reduction in plant production. While the City issued a recommended and subsequently, mandatory, reduction in water use, plant production required to meet demands exceeded the operational capacity of the WTPs under the water quality conditions observed throughout the flood event. Recognizing the challenges, the City quickly mobilized an increased staffing plan. This decision enabled the WTPs to operate fully staffed around the clock to regain operational control at higher rates of production.

Several factors contributed to the constraints on WTP operation:

- The unprecedented change in water quality;
- Constraints on ability to discharge solids as an emergency approach to keep the WTPs operational under the flood conditions;
- Limitation on filter backwashing due to the inability to process backwash water;
- Calcium carbonate precipitation onto the filters when operating at a higher softening pH of approximately 11.

To respond to the change in water quality, the WTPs had to change their operational philosophy from typical goals of maintaining a settled water pH of 10.2, a finished water pH of approximately 9.6, normal solids handling practices, and a finished water hardness that is 100 mg/L less than the influent value. The WTPs currently have five "knobs" they can turn to optimize the first core step of the treatment process (i.e., solids contact or coagulation, flocculation, and sedimentation) in response to a change in influent water quality:

- Lime dose.
- Ferric sulfate dose.
- Mixing speed (depending on WTP).
- Recirculation rate (blowdown).
- Flow (surface overflow rate).

Filter operation can also be adjusted by changing the filter loading rate (flow) and adjusting filter run times. Other softening plants in the country experience high turbidity events, but they tend to have additional tools to mediate those events, such as horizontal collection wells, presedimentation basins, two-stage softening, and/or coagulant aid polymer feed capabilities. Some of these plants also reduce flow to continue meeting finished water quality goals under extreme water quality events.

Jar tests were conducted at Ullrich WTP throughout the flood event to continually assess optimal settings on those "knobs" as the water quality changed during the flood event. Throughout the event, the following steps resulted in improved treatability of the flood water:

- Reducing basin flow rates (decreasing the surface overflow rate).
- Adjusting the softening process (i.e., lime dose) to target a settled water pH between 10.8 - 11.2, facilitating magnesium hydroxide ($Mg(OH)_2$) precipitation. It is assumed that this helped with treatability because of the cationic nature of magnesium hydroxide and not improvements in settleability.
- Increasing the ferric dose from a typical dose of 15 mg/L to 60-80 mg/L as solution.

It should be noted that while those conditions worked during the October 2018 flood event, different settings may be optimal under different extreme water quality events. Additionally, further testing (see Bench Test Report, Carollo 2019) highlighted the benefits of adding coagulant aid polymer to offset the ferric sulfate dose, enabling operation at typical ferric sulfate dose (15 mg/L as solution) and lime dose to achieve a softening pH of 10 to 10.2.

Jar tests during the October 2018 flood event indicated that a conversion to enhanced coagulation (i.e., pH ≤ 8.5, ferric dose > 180 mg/L as solution) translated to improved settled water turbidity compared to softening without $Mg(OH)_2$ precipitation. However, a lower mixing speed than typically targeted for the softening process is needed to prevent shearing of the ferric hydroxide flocs and lower surface loading rates would be required (more consistent with conventional coagulation of approximately 0.5 gpm/ft^2). Further, the WTPs would not be able to operate at the low pH required for coagulation with ferric sulfate to be effective without resulting in finished water quality that could destabilize pipe scale in the distribution system (unless sodium hydroxide was implemented at the end of the treatment process).

Coagulant aid polymer addition in combination with a ferric sulfate dose near the typical range currently used (e.g., 15 mg/L as solution) was identified as a beneficial approach to neutralize particle charge, translating to improved settleability (and assumed filterability) of the solids. Addition of the coagulant aid polymer to Basin (clarifier) 8 at Ullrich WTP correlated with lower settled water turbidity from that basin than other basins operated without polymer and at similar surface overflow rates. It took about 5 days to mobilize polymer addition just to one basin. Based on that experience, a more permanent system for polymer addition is recommended to facilitate rapid implementation during a flood event.

8.1 Recommendations

A flood event can occur at any time, and one of the best things the City can do is to prepare in advance to facilitate rapid response. The City has already taken an important step in that process by having the foresight to collect approximately 100 gallons of the water during the flood for testing, and requesting that the testing be conducted, with third party review by Professors Desmond Lawler and Lynn Katz from the University of Texas at Austin. Results from those tests are summarized in the Bench Testing Report (Carollo 2019) and factor into the recommended operating conditions and process modifications detailed below.

The following steps are recommended to prepare for future flood events:

- Add coagulant aid polymer feed capabilities at the three WTPs. Include the capability to feed the PEC polymer to the filter influent at the three WTPs to provide another tool in case charge neutralization cannot be maintained in the pretreatment process due to the dynamics of the changing source water quality.
- Add flocculant aid polymer (PEA) feed capabilities at all three WTPs.
- Include the capability to feed PEA to the gravity thickener influent at Ullrich and Handcox WTPs.
- Purchase a bench-top instrument to measure zeta potential at the three WTPs.
- Develop a water quality event response plan, which includes Standard Operating Procedures (SOP) for stepwise and incremental adjustments in operations, including for the new polymer feed systems, to optimize treatment in response to the change in water quality.

These improvements can be implemented incrementally. If a stepwise approach is taken, addition of PEC polymer feed upstream of the upflow clarifiers/sedimentation basins, procurement of benchtop instruments for zeta potential measurement, and development of a water quality event response plan should be completed first at all three WTPs. Filter aid polymer and PEA feed could be added subsequently.

During an extreme water quality event such as the October 2018 flood, the following general guiding principles should be considered when evaluating changes to the softening process:

- Adjust chemicals (primarily PEC dose) to neutralize particle charge for improved settling and filterability,
- Target higher density solids (i.e., $CaCO_3$ and not $Mg(OH)_2$ by not exceeding a pH of 10.2) to aid in settling at flows required to meet demands,
- Factor in the impact of any treatment change on solids production and residuals handling,
- Be mindful of the impacts of water chemistry changes on distribution system scale, and
- To the extent possible, reduce clarifier flow (SOR) rates.

Appendix A

COST ESTIMATE FOR CO_2 AND NAOH ADDITION

Adding CO_2 prior to the softening process would allow the plants to precipitate more of the dense, fast-settling $CaCO_3$ solids during a flood event. NaOH addition in conjunction with CO_2 may be needed, depending on the chemical dose and feed location to achieve pH greater than 7 for chloramine formation without forming di- and trichloramine. Adding NaOH for pH adjustment would also enable the WTPs to dial in a target finished water alkalinity. Based on bench testing with banked water (see Bench Test Report, Carollo 2019), CO_2 and NaOH addition is not recommended at this time. However, costs are included should a future event prompt the City to reconsider CO_2 and/or NaOH addition.

The assumptions specific to the carbon dioxide and sodium hydroxide system costs are:

- CO_2 dose requirements: 65 mg/L (based on precipitating an additional 230 mg/L of calcium carbonate in order to match or exceed "typical" calcium carbonate removal).
- NaOH dose requirements: 45 mg/L (based on achieving finished water CCPP of 14-15 mg/L as $CaCO_3$ with a finished water pH of 9.6.
- New CO_2 feed points can utilize existing storage to feed new points.
- Carbon dioxide storage is based on 7-day storage at maximum use. Existing storage available for new feed points assumes 15 day storage at maximum Handcox design dose (20 mg/L) and 80% plant capacity. Estimated storage requirements include:
  - Approximately 100 tons of additional storage required at Davis.
  - No additional storage required at Handcox. CO_2 system was designed for future expansion.
  - Approximately 250 tons of additional storage required at Ullrich.
- NaOH system will only be constructed if a new CO_2 system is constructed, not as a standalone system.

Table A.1 outlines the costs associated with expanding the CO_2 system at each WTP.

Table A.2 outlines the costs associated with implementing a NaOH system in addition to expanding the CO_2 system at each WTP. The total estimated cost for expansion of the CO_2 system at each all three WTPs is approximately \$16.5 million. The total estimated cost for expansion of the CO_2 system and the addition of a NaOH system at each all three WTPs is approximately \$21.2 million.

Table A.1 Cost Estimate for CO_2 System Improvements

Element	Davis	Handcox	Ullrich
General Conditions(1)	$342,000	$221,000	$352,000
Chemical Storage Containment Area(2)	$104,000	$-	$243,000
Process Mechanical(3)	$2,556,000	$810,000	$2,745,000
EI&C Allowance4	$978,000	$292,000	$1,133,000
Total Direct Cost	**$3,980,000**	**$1,323,000**	**$4,473,000**
Unidentified Key Elements (40%)	$1,592,000	$530,000	$1,790,000
Contractor OH&P (15%)	$836,000	$278,000	$940,000
Total Construction Cost	**$6,408,000**	**$2,131,000**	**$7,203,000**
Allowance for Change Orders (5%)	$321,000	$107,000	$361,000
Total Estimated Project Cost	**$6,729,000**	**$2,238,000**	**$7,564,000**

Notes:
(1) General conditions assume: 9 month duration with full time project manager, superintendent, and field engineer; a half-time clerk; $40,000 for mobilization/demobilization; a construction trailer for 9 months at $5,000 per month; and bonding and insurance for 3.25% of the project direct cost.
(2) Handcox requires no additional storage.
(3) Process mechanical costs assume 9 feed points for Davis (1x for 9 basins), 7 feed points for Ullrich (1x for 7 basins) and 2 feed points for Handcox (1x for 2 basins).
(4) Electrical costs and instrumentation costs are assumed to be 35% and 15%, respectively, of the direct cost of equipment requiring electrical and instrumentation design (e.g., pumps, level monitoring for storage tanks, etc.).
(5) Handcox WTP does not require additional storage.

Table A.2 Cost Estimate for CO_2 and NaOH System

Element	Davis	Handcox	Ullrich
General Conditions(1)	$377,000	$235,000	$389,000
Chemical Storage Containment Area(2)	$320,000	$108,000	$459,000
Process Mechanical(3)	$3,201,000	$1,066,000	$3,437,000
EI&C Allowance(4)	$1,200,000	$366,000	$1,360,000
Total Direct Cost	**$5,098000**	**$1,775,000**	**$5,645,000**
Unidentified Key Elements (40%)	$2,040,000	$710,000	$2,258,000
Contractor OH&P (15%)	$1,071,000	$373,000	$1,186,000
Total Construction Cost	**$8,209,000**	**$2,858,000**	**$9,089,000**
Allowance for Change Orders (5%)	$411,000	$143,000	$455,000
Total Estimated Project Cost	**$8,620,000**	**$3,001,000**	**$9,544,000**

Notes:
(1) General conditions assume: 9 month duration with full time project manager, superintendent, and field engineer; a half-time clerk; $40,000 for mobilization/demobilization; a construction trailer for 9 months at $5,000 per month; and bonding and insurance for 3.25% of the project direct cost.
(2) Handcox storage containment area requirements only include the containment area for NaOH.
(3) Process mechanical costs assume 9 feed points for Davis (1x for 9 basins), 7 feed points for Ullrich (1x for 7 basins) and 2 feed points for Handcox (1x for 2 basins).
(4) Electrical costs and instrumentation costs are assumed to be 35% and 15%, respectively, of the direct cost of equipment requiring electrical and instrumentation design (e.g., pumps, level monitoring for storage tanks, etc.).

City of Austin
Process Treatment Recommendation Resulting from October 2018 Flood Event

BENCH TESTING REPORT

FINAL | July 2019

TBPE No. F-882

City of Austin

Process Treatment Recommendation Resulting from October 2018 Flood Event

BENCH TESTING REPORT

FINAL | July 2019

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EXECUTIVE SUMMARY

In October 2018, the City of Austin (City) experienced a flood event that resulted in significant and persistent changes in the raw water quality to its three Water Treatment Plants (WTPs). The flood event resulted in raw water quality characterized by higher turbidity and total organic carbon (TOC) concentrations, and lower alkalinity and hardness than historically observed at the WTPs. The change in water quality challenged the ability to operate the City's WTPs to meet demands while complying with federal and state drinking water regulations and City water quality goals.

During the flood, Carollo Engineers, Inc. (Carollo) provided onsite support to the City at the Ullrich WTP, conducting bench testing and providing input on operational adjustments that could improve the ability to treat the water. Observations and recommendations from that experience are provided in the October 16, 2018 Flood Event Report and Resulting Recommendations (Carollo, 2019). During the event, the City collected 100 gallons of raw water from the Ullrich WTP on October 25, 2018 to store for future testing. This water, referred to as "banked" water, was stored in a low temperature environment to preserve the integrity of the sample. Based on input from the City and Professors Desmond Lawler and Lynn Katz from the University of Texas at Austin (UT-Austin), Carollo conducted extensive bench testing on the collected water to further vet operational strategies that showed promise during the flood and to test additional strategies to treat the water during similar extreme raw water quality events. This report presents results from those tests and provides recommendations for treatment strategies to improve the ability of the City's WTPs to treat challenging source water during future flood events. Additional detail and conceptual level cost estimates of the recommended strategies are included in the October 16, 2018 Flood Event Report and Resulting Recommendations (Carollo, 2019).

Prior to conducting the bench testing, the water was tested to monitor changes in water quality that might have occurred during temperature controlled storage. Baseline testing was also conducted to confirm trends from tests performed during the flood event at the Ullrich WTP. Baseline testing confirmed that softening at higher pH values, consistent with conditions appropriate for $Mg(OH)_{2(s)}$ precipitation, and feeding higher doses of ferric sulfate resulted in improved turbidity and TOC removal in the Banked Water when compared to operation at historical setpoints.

Additional bench testing (beyond what was discussed in the October 16, 2018 Flood Event Report and Resulting Recommendations) was conducted to evaluate additional treatment strategies that were not available to the operations staff during the flood event. The four identified strategies selected for study included:

- Addition of coagulant aid polymer (PEC).
- Addition of flocculation aid polymer (PEA).
- Addition of carbon dioxide and sodium hydroxide to promote conditions suitable for precipitation of solids typical of those formed during normal operations.
- Enhanced coagulation with ferric sulfate.

The testing demonstrated that the optimal strategy to treat challenging raw water during a flood event includes the addition of both PEC and PEA while maintaining a typical ferric sulfate dose and softening pH value. The testing also demonstrated that enhanced coagulation, enhanced softening (i.e., softening at pH > 10.8), and/or feeding CO_2 and sodium hydroxide upstream of softening are not preferred.

Based on the additional testing, the following treatment approach is recommended to improve the settleability and filterability of the softening process during a flood event:

- Feeding ferric sulfate at doses typical of normal operation (i.e., 15 mg/L as solution).
- Feeding PEC 30 seconds or more after ferric sulfate to maximize charge neutralization (i.e., 12 mg/L as solution for the polymer tested in the Banked Water).
- Softening at pH values typical of normal operation (i.e., pH 10.0- 10.2).
- Feeding PEA to the center well of the upflow clarifiers to provide particle bridging.

Conceptually, this treatment strategy relies on lime addition to achieve softening and pH targets, iron addition for TOC removal, PEC for charge neutralization, and PEA for particle bridging. The strategy minimizes solids generation and formation of low density solids (e.g. ferric hydroxide and magnesium hydroxide). Further, the recommended approach requires minimal WTP improvements (relatively low capital cost) and maintains treatment (i.e., ferric sulfate dose and softening pH) near typical operation. Therefore, this approach is more easily implemented than strategies that would require a complete shift from normal operations. The recommended approach also results in finished water quality similar to that of typical operations with respect to pH, magnesium, and calcium carbonate precipitation potential (CCPP), thereby minimizing potential disruptions to water quality in the distribution system.

Abbreviations

$CaCO_3$	calcium carbonate
CaO	Lime (calcium oxide)
Carollo	Carollo Engineers, Inc.
CCPP	calcium carbonate precipitation potential
cf	cubic feet
cfs	cubic feet per second
CO_2	carbon dioxide
DBP	disinfection by-product
EDS	energy-dispersive X-ray spectroscopy
F	Fahrenheit
ft	feet
gpcd	gallons per capita day
gpd/ac	gallons per day per acre
µg/L	micrograms per liter
L	liter
MG	million gallons
NaOH	sodium hydroxide
µg/L	micrograms per liter
mg/L	milligrams per liter
mgd	million gallons per day
PEA	flocculation aid polymer
PEC	coagulant aid polymer
psi	pounds per square inch
SEM	scanning electron micrograph
SiO_2	silica (silicon dioxide)
SCADA	supervisory control and data acquisition
SHMP	sodium hexametaphosphate
SOR	surface overflow rate
TCEQ	Texas Commission on Environmental Quality
TOC	total organic carbon
WTP	water treatment plant

Section 1

INTRODUCTION

1.1 Background

An extreme flood event in October 2018 dramatically changed the characteristics of the raw water supply to the City of Austin's three water treatment plants (WTPs). The change in raw water quality resulted in treatment challenges and impacted the ability of the WTPs to meet the City of Austin (City) finished water quality goals at full plant capacity. The City retained Carollo Engineers, Inc. (Carollo) to help provide support during and after the flood event. Findings from the testing conducted on-site during the flood and resulting recommendations are documented in a separate report[1].

On October 25, 2018, when the raw water remained challenging to treat, the City collected approximately 100 gallons of raw water from Lake Austin to store for future bench-scale testing. Following the flood event, Carollo developed a plan to use the water to further test strategies that worked during the flood, and to assess additional tools to facilitate a planned response to similar future extreme raw water quality events. The City and University of Texas at Austin (UT-Austin) professors Desmond Lawler and Lynn Katz provided input on the plan during a November 26, 2018 workshop and following review of a draft Bench Testing Protocol (Appendix A). This report presents results from the tests conducted on the stored water, and recommendations based on the testing.

1.2 Objectives

The overall goal of the bench tests was to identify treatment recommendations for the WTPs to be prepared for future flood events. That goal was met through the following specific objectives:

- Conduct jar tests to evaluate options to treat water during an extreme raw water quality event similar to the October 2018 flood.
- Identify recommended options for responding to a similar event and any needed Capital Improvement Program (CIP) projects.

1.3 Approach

A Bench Testing Protocol (Appendix A) was developed to use the challenging water stored to evaluate strategies to treat the water at the City's WTPs. Testing focused on the following steps:

- Conduct initial water quality analyses to confirm that the water quality did not change during storage, and to conduct initial quality assurance and control (QA/QC) on the laboratory analyses outlined in the protocol.

[1] "October 16, 2018 Flood Event Report and Resulting Recommendations", Carollo Engineers, Inc., June 2019.

- Conduct initial testing to determine the operational baseline with Typical Water quality (typical) as well as with the stored water from the flood. Baseline testing with stored water was also conducted to confirm trends from previous tests conducted during the flood event, including the impact of softening pH (magnesium removal) and increased ferric sulfate addition.
- Conduct jar testing to evaluate the impact of coagulant aid polymer (PEC) addition.
- Conduct jar testing to evaluate the impact of flocculation aid polymer (PEA) addition.
- Conduct jar testing to evaluate the impact of adding carbon dioxide (CO_2) and sodium hydroxide (NaOH) as a strategy to precipitate a greater mass of $CaCO_3$ solids and operate closer to typical softening conditions in terms of the composition and density of solids generated.
- Evaluate the impact of enhanced coagulation without softening.

Details of the bench testing approach are provided in Appendix A. Combinations of 200-mL and 2-L jars were used. The smaller jars were used to evaluate the effect of water chemistry, chemical selection, and doses on coagulation, while conserving the stored water. Larger 2-L Gator jars were used to assess physical parameters such as the impact of different test conditions on settleability of the solids. In the majority of the jars, the mixing speed (G value) during coagulation was set at close to 100 sec^{-1} (correlating to 85 rpm in the 2-L Gator jars) to mimic operation at the Ullrich WTP. However, slower mixing speeds were used in some jars to assess mixing at lower G values. The test conditions are listed on the graphs so that each graph can be independently examined without the report.

The following parameters were analyzed in each of the tests:

- pH,
- alkalinity,
- settled water zeta potential,
- settled water turbidity,
- calcium,
- magnesium,
- iron,
- silica (SiO_2), and
- Total organic carbon (TOC).

For some jars, the UV absorbance at 254 nanometers (nm) was also measured. In a select set of jars, scanning electron micrograph (SEM) images were taken of the solids to assess the impact of different operational conditions on particle size and morphology.

Zeta potential was also measured in settled water from all of the jar tests. Zeta potential is a measurement of the surface charge of particles using an instrument that induces a current in the water sample and measures the movement of particles towards the positive and negative poles. During the flocculation/sedimentation process, particles with a near neutral surface charge are more likely to aggregate and fall out of suspension, or be removed subsequently by filtration. Particles with a negative (or positive) surface charge will repel each other, hindering aggregation and removal. Therefore, zeta potential can be used to help determine the effectiveness of treatment chemicals or processes in neutralizing negatively charged raw water particles as a first step to facilitate removal through sedimentation and filtration.

The sections below follow the outline for testing, presenting results from the initial water quality analyses (Section 2), baseline testing (Section 3), and tests evaluating different improvement strategies (Section 4) such as PEC, PEA, and CO_2 and NaOH addition or conversion to enhanced coagulation. Section 5 presents information on the finished water stability depending on the operational conditions. Section 6 presents the recommended treatment approach based on the test results and findings from the October 2018 flood.[2]

Section 2

WATER QUALITY

Two types of water were used during bench testing:

- "Banked Water" - raw water that was collected from the Low Service Pump Station at the Ullrich WTP during the flood event on October 25, 2018 and stored in a refrigerated trailer until use. The Banked Water was used for the majority of the tests to assess the impact of treatment strategies to respond to similar future flood events.
- "Typical Water" - Lake Austin water collected from the Low Service Pump Station at Ullrich WTP on January 31 and February 13, 2019. At the time, this water was representative of what has historically been observed in Lake Austin.

Before using the Banked Water, samples were collected and analyzed to determine if the water quality changed while the water was held in cold storage (~ 4 degrees Celsius). Table 1 compares the original water quality recorded by Austin Water when the Banked Water was collected, and results from analyses conducted on the Banked Water after it had been stored for approximately 3 months. Also shown are the water quality extremes measured during the flood event as well as the historical Lake Austin average water quality. As can be seen in the table, the water quality of the Banked Water was not significantly changed by long term cold storage. The TOC in the banked water may have changed slightly. However, the water sample analyzed on 10/25/2018 was collected on 10/24/2018, whereas the banked water was collected on 10/25/2018. Therefore, TOC may have decreased in storage, and/or may have been lower upon sample collection. Regardless, TOC concentrations in the banked water remained above historical average TOC concentrations and the experiments with banked water can be considered as being conducted on the 'same' water the WTPs were treating during the flood event.

[2] Ibid.

Table 1 Historical and Flood Event Raw Water Quality

Parameter	Historical Lake Austin Average(1)	Flood Event Extreme	Flood Event(2) Analyzed 10/25/2018	Flood Event(2) Analyzed Jan.-Feb. 2019
Total Alkalinity (mg/L as $CaCO_3$)	179	100	103	102
pH (SU)	8.21	7.92	8.01	8.04
Turbidity (NTU)	4.77	415	124	117
Total Hardness (mg/L as $CaCO_3$)	215	88	81	95
Calcium (mg/L)	51	29	29	30
Magnesium (mg/L)	21	4	8(3)	5
TOC (mg/L)	4.14	7.78	7.78(4)	5.75
Iron, total (mg/L)	0.15(5)	NA	NA	4.13
Iron, dissolved (mg/L)	NA	NA	NA	0.011
Silica, total (mg/L as SiO_2)	10(6)	NA	NA	12.5

Notes:
(1) Data collected between 1/1/2013 and 12/31/2015.
(2) Sample collected 10/25/2018.
(3) Result for sample collected 10/29/2018.
(4) Result for sample collected 10/24/2018.
(5) City of Austin quarterly grab sample data from 2014-16.
(6) Source: Morabbi, M. and Clark, S. (1999). "Methods for Assessing the Effects of pH Reduction on Lime Softening Distribution Systems." City of Austin – Water and Wastewater Utility.
(7) NA = Not analyzed.

In addition to conducting water quality analyses to confirm that the Banked Water remained relatively unchanged following storage, results from jar tests conducted in February 2019 using the Banked Water were compared to results from similar tests conducted during the October 2018 flood event. Figure 1 compares the 5-min settled water turbidity for jars conducted October 24 and 25, 2018 to jar tests conducted February 18, 2019 with the Banked Water. The turbidity results for the Banked Water mirror the trends observed during the October 2018 jar tests, further indicating that any changes that could have occurred during storage (e.g., slight degradation of organic matter) had negligible impact on the observed treatability.

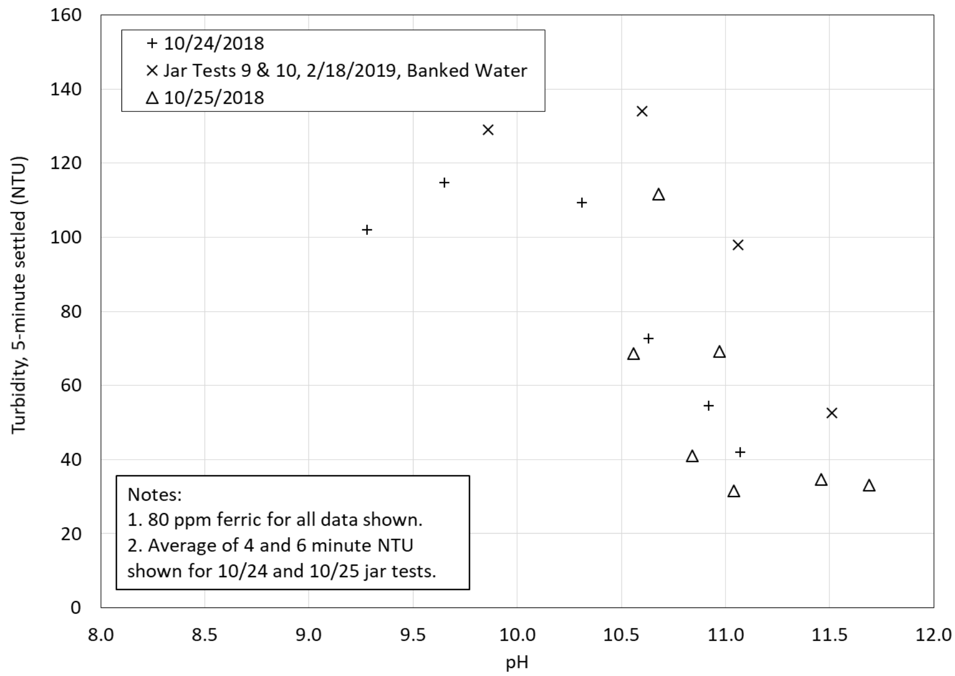


Figure 1 Settleability of Flood Event Raw Water in October 2018 and re-tested in February 2019

The Lake Austin water collected January 31 and February 13, 2019 was used to establish baseline treatment with Typical Water quality during normal operations. It was also used to test the impact of incorporating flood event response strategies (e.g., coagulant aid polymer addition) as part of day-to-day operations at the City's WTPs if deemed beneficial both for ongoing treatment and mobilization for flood event response. Table 2 compares the characteristics of the water collected on January 31 and February 13, 2019 with the historical Lake Austin average water quality. As can be seen in the table, the water collected is similar to the historical averages and it is reasonable to consider it as representing 'typical' raw water quality.

Table 2 Comparison of Historical, January 2019 and February 2019 Raw Water Quality

Parameter	Historical Lake Austin Average(1)	Lake Austin Jan. 31, 2019(2)	Lake Austin Feb. 13, 2019(3)
Total Alkalinity (mg/L as $CaCO_3$)	179	157	NA
pH (SU)	8.21	8.17	8.03
Turbidity (NTU)	4.77	3.65	3.56
Total Hardness (mg/L as $CaCO_3$)	215	182	189
Calcium (mg/L)	51	46	46
Magnesium (mg/L)	21	16	18
TOC (mg/L)	4.14	3.58	3.60
Iron, total (mg/L)	0.15(4)	0.104	0.064
Iron, dissolved (mg/L)	ND	<0.005	<0.005
Silica, total (mg/L as SiO_2)	10(5)	8.99	NA

Notes:
(1) Data collected between 1/1/2013 and 12/31/2015.
(2) Measured by AWU lab.
(3) Measured at UT Austin lab.
(4) City of Austin quarterly grab sample data from 2014-16.
(5) Source: Morabbi, M. and Clark, S. (1999). "Methods for Assessing the Effects of pH Reduction on Lime Softening Distribution Systems." City of Austin – Water and Wastewater Utility.
(6) NA = Not analyzed.

Prior to starting the bench testing, Austin Water staff collected and analyzed samples of the Banked Water and the Typical Water at the City's laboratory to serve as a check on the analytical equipment at the University of Texas. The Austin Water results concurred with the measurements recorded at the University of Texas. For example, the TOC concentration measured in the Banked Water by Austin Water was 5.75 mg/L in comparison to the measured value at the University of Texas of 5.66 mg/L. These results can be found in Appendix B.

Section 3

BASELINE TESTING

Baseline testing was conducted with Typical Water (collected February 13, 2019) as well as with the Banked Water to characterize softening chemistry under typical and flood event conditions. These tests focused on providing the following information:

- The lime dose and softening pH corresponding to the minimum calcium concentration using both Typical and Banked Water.
- The softening pH at which magnesium hydroxide ($Mg(OH)_2(s)$ begins to precipitate based on a measured decrease in settled water magnesium concentrations under typical as well as flood event conditions.

- Settled water turbidity under typical as well as flood event conditions at the typical operating set point for the Ullrich WTP, specifically, settled water pH of 10.2 and 15 mg/L ferric sulfate addition (as solution).
- Impact of ferric sulfate addition during typical as well as flood event conditions.

Results from the tests were also used to confirm that similar trends were observed using the Banked Water after it had been stored for approximately 3 months relative to jars run under the same conditions in October 2018 (see Figure 1)[3].

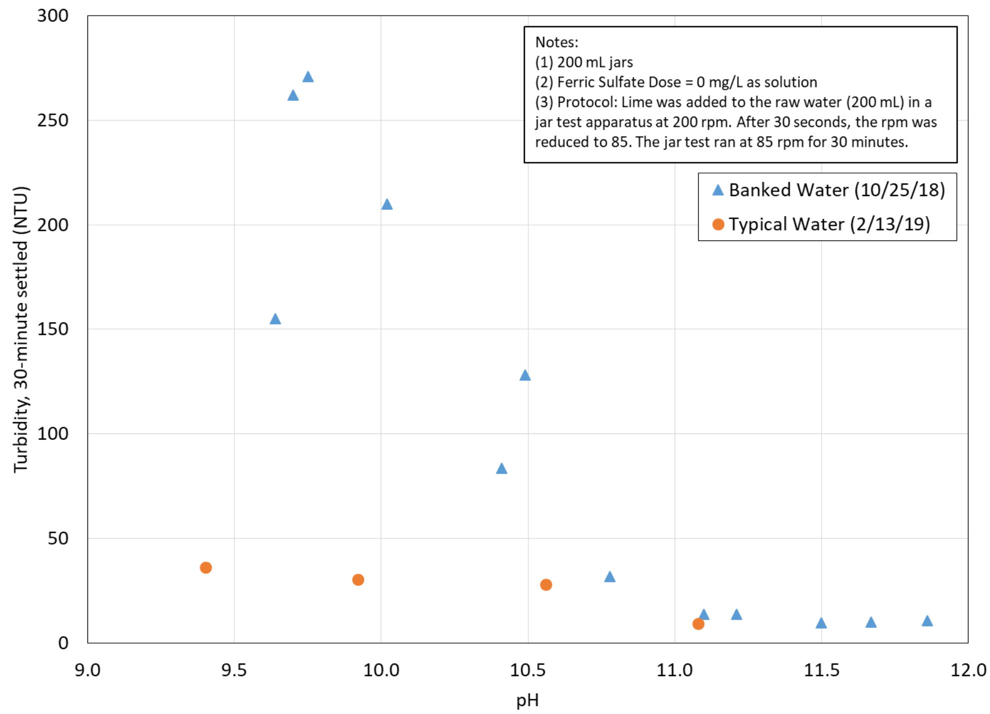
Appendix C provides graphs summarizing the impact of lime dose on settled water pH, alkalinity, calcium, and magnesium concentrations in the Typical and Banked Water with and without ferric sulfate addition. The results confirm that adding lime to achieve a pH of 10.0 - 10.4 corresponds to softening conditions where calcium concentrations are minimized from calcium carbonate precipitation, but magnesium hydroxide precipitation is minimal. Higher lime doses (i.e., corresponding to settled water pH values > 10.6) resulted in magnesium hydroxide precipitation, as expected based on calculated values for $Mg(OH)_2$ saturation (Q) exceeding the solubility constant ($Ksp=10^{-11.16}$).

3.1 Impact of Iron Addition in Typical and Banked Water

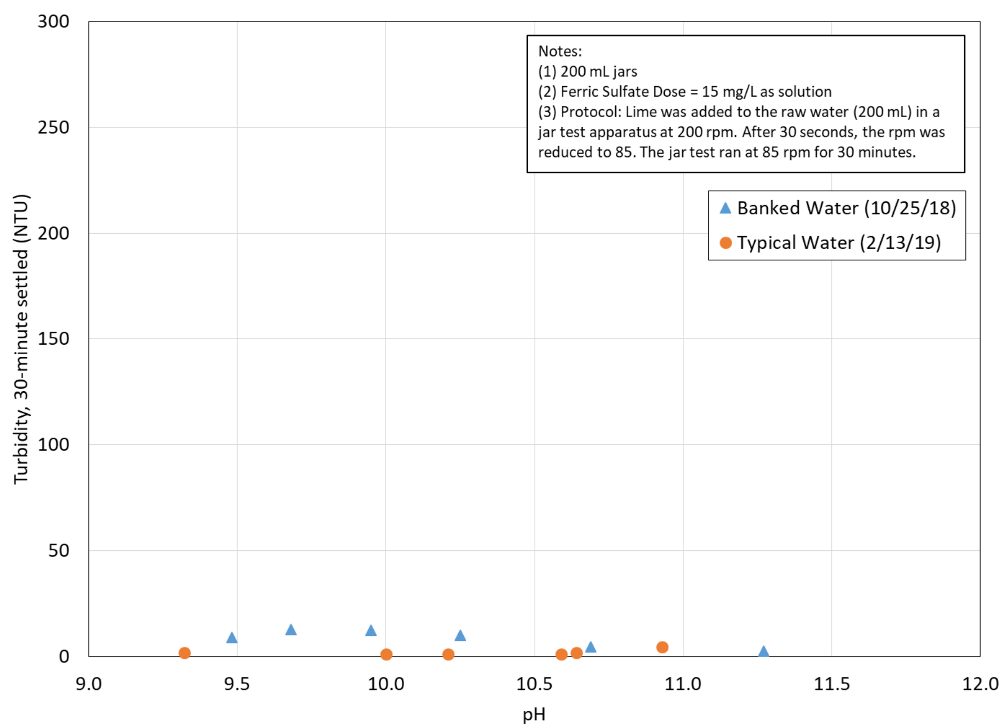
Figure 2 shows the settled water turbidity in Typical and Banked Water without (Part A) and with (Part B) ferric sulfate addition. Several trends are apparent from the graphs:

- Turbidity is higher in the Banked Water reflecting the challenging raw water quality conditions during the October 2018 flood.
- Without iron addition, softening at higher pH values correlating to $Mg(OH)_2(s)$ precipitation is required to achieve a substantial reduction in the settled water turbidity in the Banked Water (Part A).
- Addition of 15 mg/L ferric sulfate (as solution) dramatically reduces the settled water turbidity in both the Typical and Banked Water across the range of softening conditions evaluated (Part B).

[3] Several sets of conditions (e.g., varying lime and ferric sulfate doses) were tested with the Banked Water as were evaluated during the flood event; in all cases, the trends are consistent.



PART A



PART B

Figure 2 Settled Water Turbidity in Typical and Banked Water without (Part A) and with (Part B) Ferric Sulfate Addition

A set of tests were conducted to evaluate the impact of higher ferric sulfate doses applied during the October 2018 flood for pH values ranging from 9 to 12 in the Banked Water. The results of the test (see Figure 3) further highlight that higher pH (> 10.5) is required for substantial reduction in turbidity without iron (presumably due to the positive charge contributed by the precipitated magnesium hydroxide). At pH values closer to 10.0 - 10.2 where Ullrich WTP typically operates, addition of 80 mg/L ferric sulfate (as solution) or higher translated to lower settled water turbidities than addition of 15 mg/L (or 0 mg/L) ferric sulfate.

Figure 4 illustrates the impact of ferric sulfate addition on the zeta potential measured in settled water from the same set of tests conducted with the Banked Water. As shown in the figure, ferric sulfate aids in charge neutralization, improving floc formation, settling, and resulting settled water turbidity (Figure 3). Iron addition also reduced the total organic carbon (TOC) concentration in Banked Water (Figure 5) and in Typical Water (see Appendix C). These tests demonstrate that the particles in the raw water during this event were highly negatively charged and required the addition of a corresponding amount of positive charge to result in proper treatment.

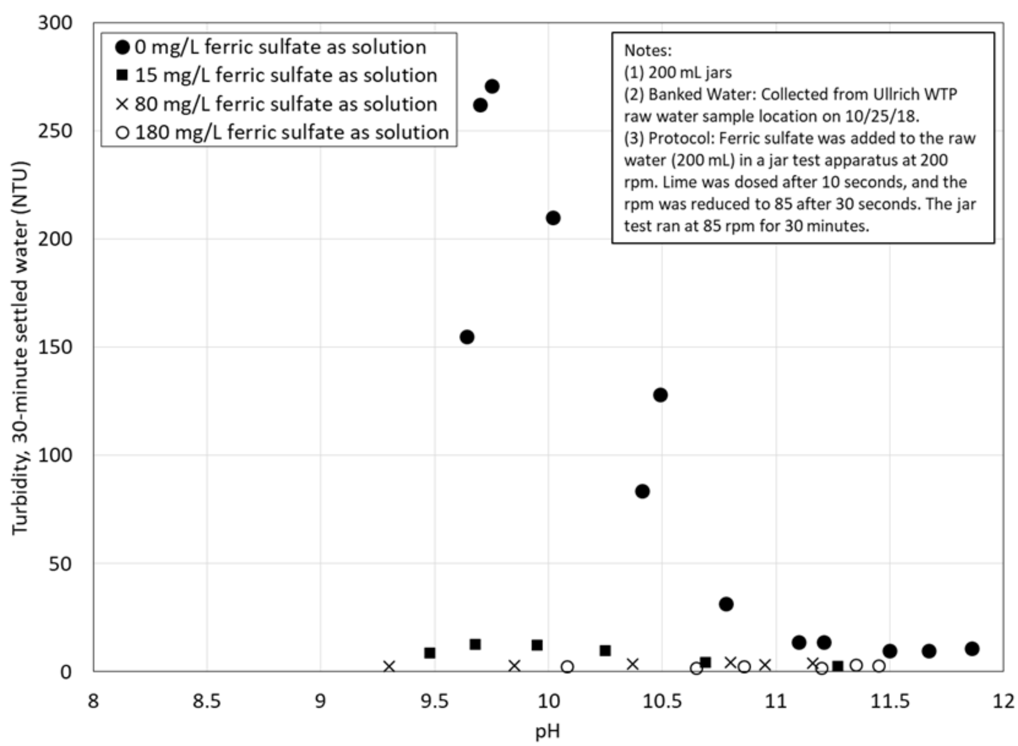


Figure 3 Impact of Higher Ferric Sulfate Doses and pH on Settled Water Turbidity in Banked Water

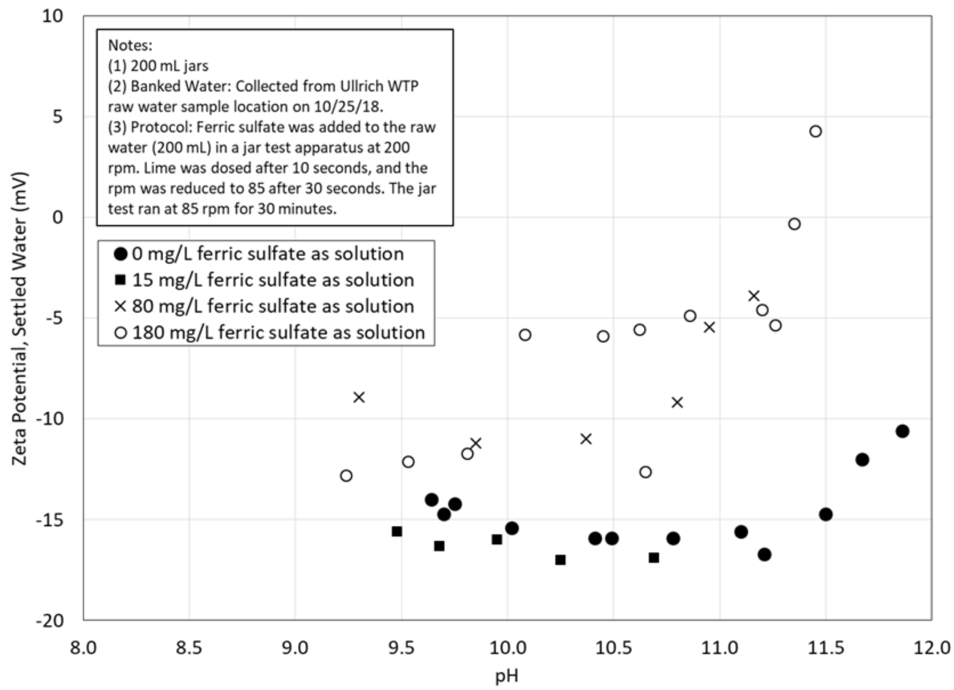


Figure 4 Impact of Ferric Sulfate Dose and pH on Zeta Potential in Banked Water

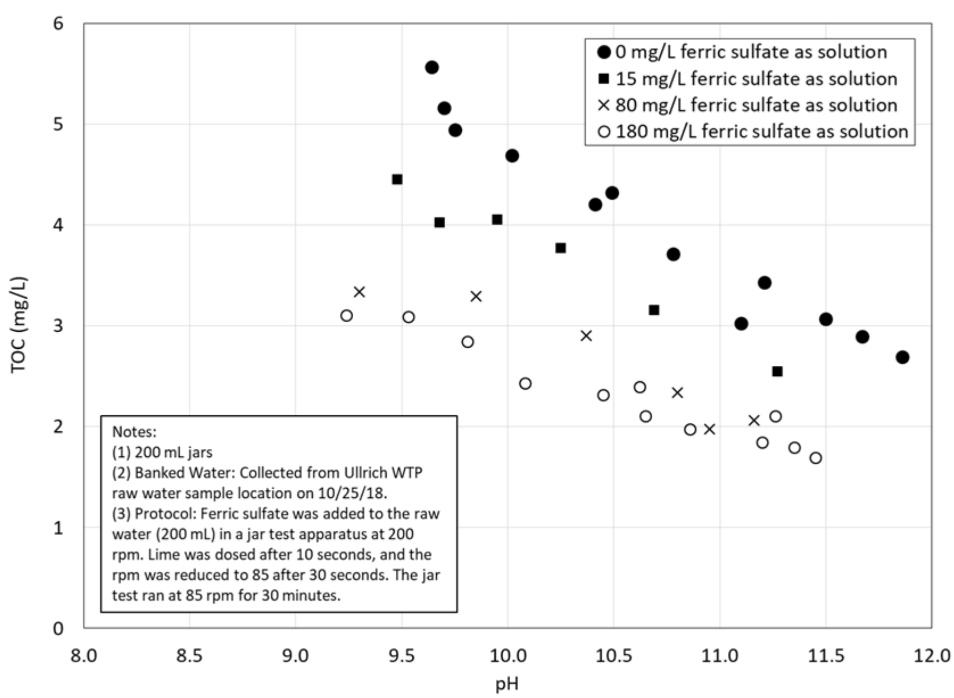


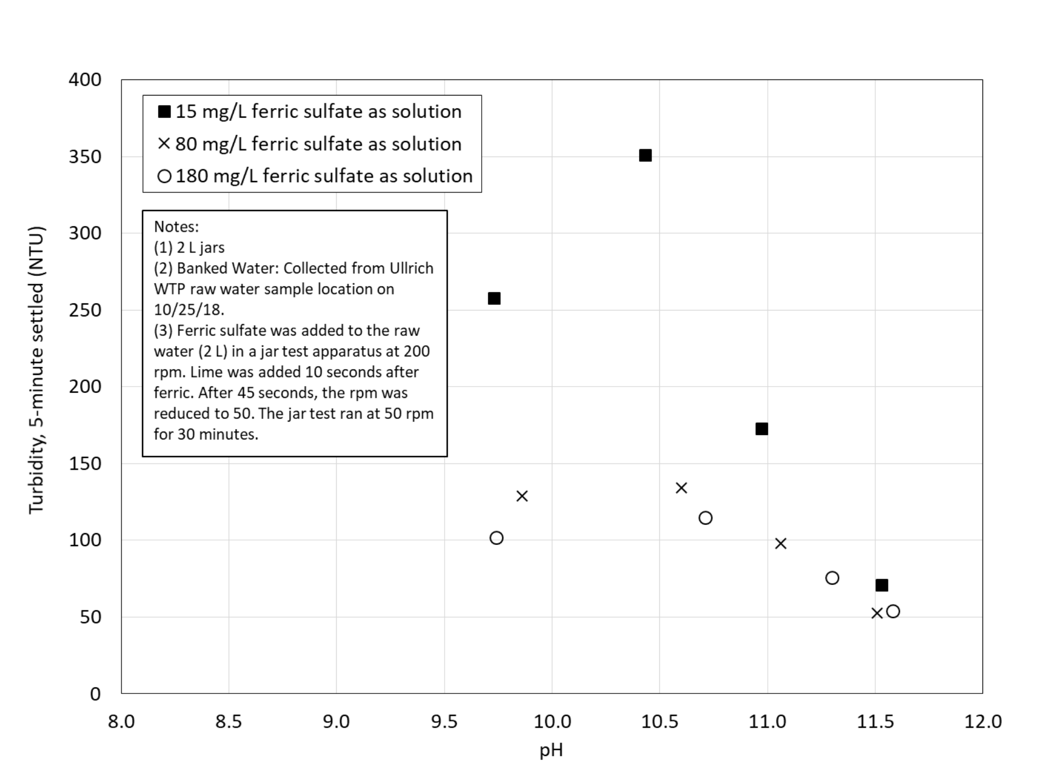
Figure 5 Impact of Ferric Sulfate Addition and pH on TOC Removal in Banked Water

All of the baseline tests presented above (and in Appendix C) were conducted in 200 mL jars to conserve water while evaluating the impact of a broader range of conditions on softening chemistry (i.e., pH, alkalinity, calcium and magnesium concentrations, zeta potential and TOC). In the 200 mL jars, settled water turbidity was measured at 30 minutes. A subsequent set of tests were conducted using 2-L gator jars to assess settled water turbidities corresponding to the operating conditions at Ullrich WTP (i.e., surface overflow rates (SOR) of 0.25 gpm/sf to 0.5 gpm/sf). Figure 6 shows the settled water turbidity measured in the 2-L gator jars after 5 and 10 minutes of settling, corresponding to an SOR of 0.5 gpm/sf and 0.25 gpm/sf, respectively (this does not consider bulk rotation that continues for a period of time after mixing stops). The data confirm the benefit of adding a higher iron dose (e.g., 80 mg/L ferric sulfate as solution) during the flood conditions than typically used (i.e., 15 mg/L ferric sulfate as solution) to achieve a lower settled water turbidity particularly at pH values in the range where Ullrich WTP typically operates. Settled water turbidity was also reduced at higher pH values corresponding to $Mg(OH)_2$ precipitation for all iron doses evaluated. These trends were consistent with findings from bench tests conducted at Ullrich WTP during the flood event (October 16, 2018 Flood Event Report and Resulting Recommendations).

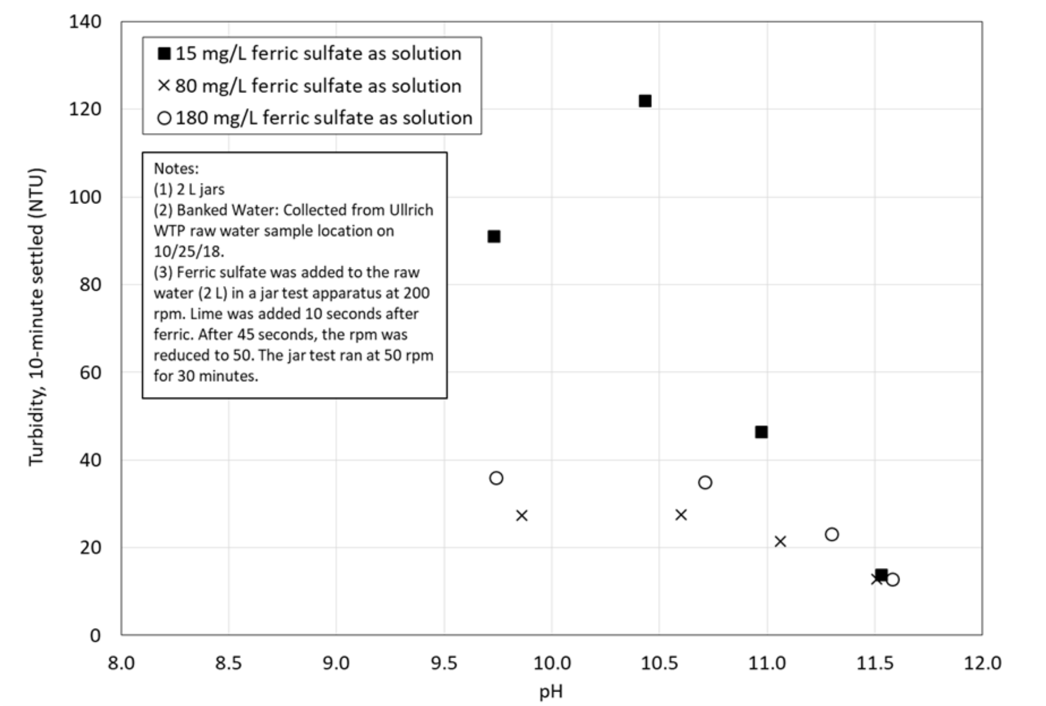
3.2 Summary from Baseline Testing

The baseline tests confirmed consistent trends as were identified during the October 2018 flood, namely:

- The particles in the raw water during the flood event were highly negatively charged and required the addition of a corresponding amount of positive charge to result in proper treatment.
- Operating at higher pH values associated with $Mg(OH)_2$ precipitation and/or with higher ferric sulfate doses improved settled water turbidity in the Banked Water due to the positive charge contributions of both constituents.
- Ferric sulfate addition has a clear benefit for both typical and extreme raw water quality. Improved settled water turbidities and lower TOC concentrations were observed when adding ferric sulfate in both Typical and Banked Water compared to jars run at the same pH without ferric sulfate. It should be noted that solids were not added to these jar tests so these results are not directly relatable to a solids contact clarifier.
- Ferric sulfate and magnesium hydroxide aid in charge neutralization, which can improve floc formation, settling, and corresponding settled and filtered water turbidities.



PART A



PART B

Figure 6 Impact of Ferric Sulfate Dose and pH on Turbidity in Banked Water

Section 4

BENCH TESTING TO EVALUATE TREATMENT IMPROVEMENT STRATEGIES

Bench testing was conducted to investigate the effectiveness of four potential treatment improvement strategies. The strategies identified by the project team for further evaluation included:

- Addition of coagulation aid polymer (PEC).
- Addition of flocculation aid polymer (PEA).
- Addition of carbon dioxide and sodium hydroxide to the softening process.
- Enhanced coagulation without softening.

4.1 Coagulant Aid Polymer (PEC)

Coagulant aid polymers (PEC) can range from low to high -molecular-weight and are typically cationic. The charge of cationic PEC polymer is opposite that of the particles in Lake Travis/Austin water (which are negative). Therefore, adding PEC polymer can displace the requirements for ferric sulfate addition or magnesium hydroxide precipitation and aid in charge neutralization and coagulation/flocculation, and improve settling. During the flood event, operation with relatively high ferric sulfate doses (60-80 mg/L) and softening at a high pH (pH > 10.8) was required to neutralize charge and improve settling and filterability. Bench testing using the Banked Water was conducted to determine if PEC could be used to reduce the ferric sulfate dose to a more typical value (e.g., 15 mg/L) while maintaining softening operations at pH 10.2. In essence, this operational strategy focused on use of lime to achieve softening and pH goals, iron for organics removal, and PEC for charge neutralization. This operational strategy is expected to result in more settleable solids, reduce the total sludge volume, and not consume as much alkalinity (ferric sulfate is acidic and consumes alkalinity) compared to the operation approach used during the flood event. This approach also does not remove magnesium, which may help maintain the integrity of the scale in the distribution system[4].

Figure 7 shows the results of zeta potential titrations with ferric sulfate and various PECs tested with the Banked Water. Approximately 300 mg/L of ferric sulfate (with no pH adjustment) was required to neutralize charge (zeta potential of 0 mV). Significantly lower doses of PEC, ranging between 15 to 22 mg/L as solution, were required (Figure 8). Therefore, adding a small dose of PEC can neutralize a large amount of charge and decrease the required ferric sulfate dose or amount of magnesium precipitation required. Similar results were observed during testing in October during the flood event (October 16, 2018 Flood Event Report and Resulting Recommendations). To neutralize the same charge, ferric sulfate generates more than 10 times the solids when compared to cationic polymer.

[4] Distribution system scale is predominately composed of magnesium silicate material (Morabbi, M. and Clark, S. 1999. Methods for Assessing the Effects of pH Reduction on Lime Softening Distribution Systems." City of Austin Water and Wastewater Utility. Austin, Texas)

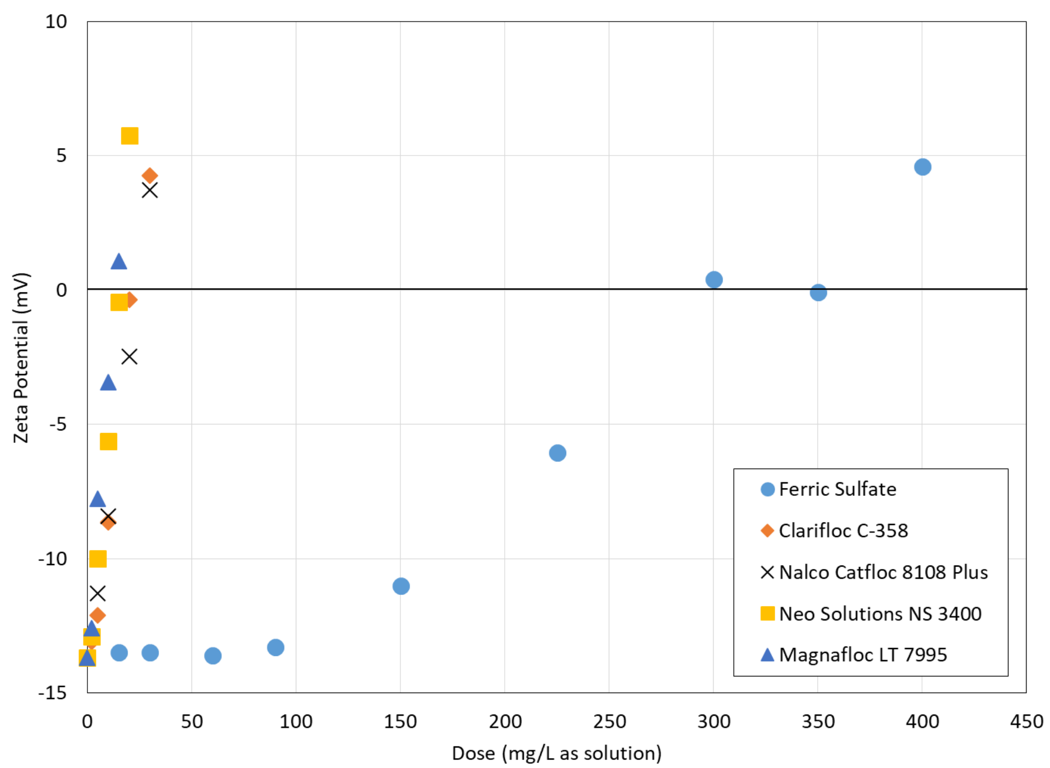


Figure 7 Zeta Potential Titration with Ferric Sulfate and Cationic Polymers (PEC)

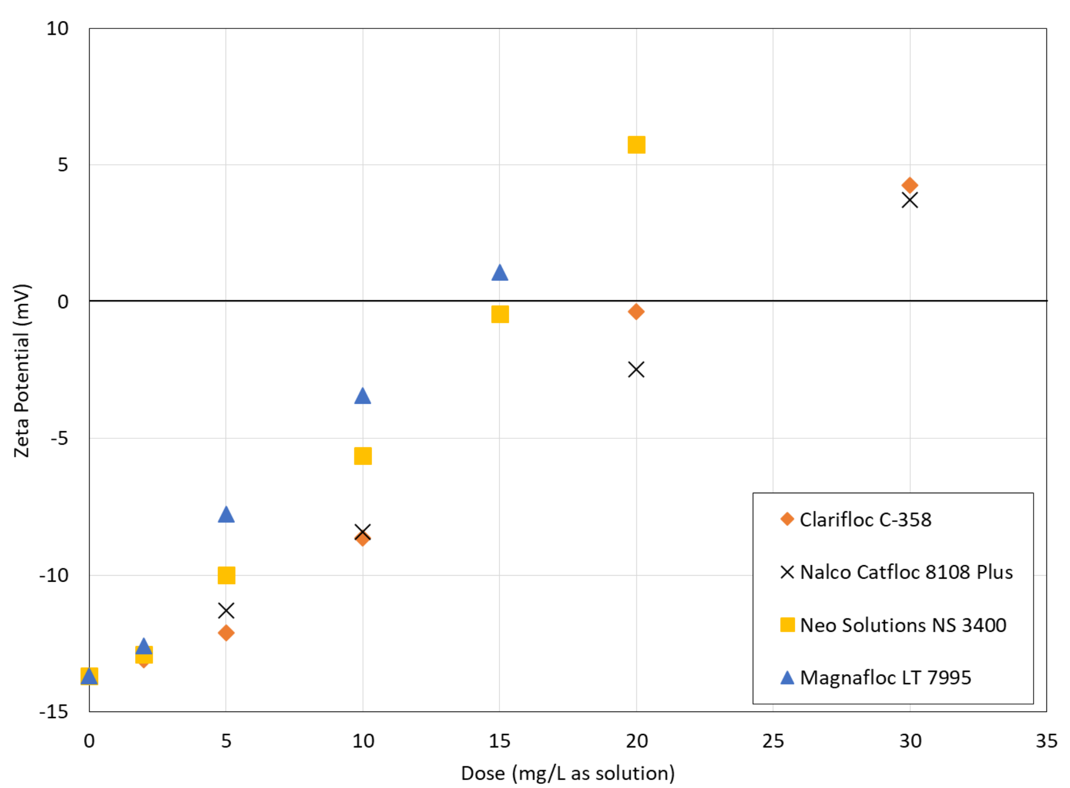


Figure 8 Impact of PEC Dose on Charge Neutralization

A summary of the charge neutralization capacity of each of the polymers tested is provided in Table 3. Each of the polymers tested were either 20- or 40-percent active product (which is also reflected in the maximum allowable dose from NSF). Accounting for the percent of active polymer in each different solution normalized the charge neutralization capacity of each polymer tested (Figure 9). PEC doses ranging between 4 and 6 mg/L as active polymer were required to neutralize the charge to near zero. Since available PEC solutions vary in the amount of charge neutralization they provide as well as the percent active polymer contained in each solution, the use of zeta potential may be a useful innovative approach to compare the effectiveness of polymers and evaluate bids during procurement. This approach would allow the City to bid polymers on the basis of their charge neutralizing capacity instead of their weight.

The impact of polymer dose on charge neutralization was also measured in Lake Austin water collected February 13, 2019 to determine dose requirements to neutralize charge under typical conditions. Results are shown in Appendix F. As expected, lower doses, ranging from 4-8 mg/L as solution were required.

Table 3 Maximum Allowable Dose, Percent Active Product, and Charge Equivalence for 1 mg/L of Cationic Polymer (PEC)

Cationic PEC	Maximum NSF 60 Dose (mg/L)	Percent Active %	Equivalent Ferric Sulfate Dose (mg/L)(1)
Nalco Cat-floc 8108 Plus	50	20	15
Magnafloc LT-7995	25	40	25
Neo Solutions NS 3400P	25	40	23
Clarifloc C-358	50	20	18

Notes:
(1) 1 mg/L PEC neutralizes as much charge as the listed ferric sulfate dose (PEC dose as mg/L as solution and ferric sulfate dose as solution).

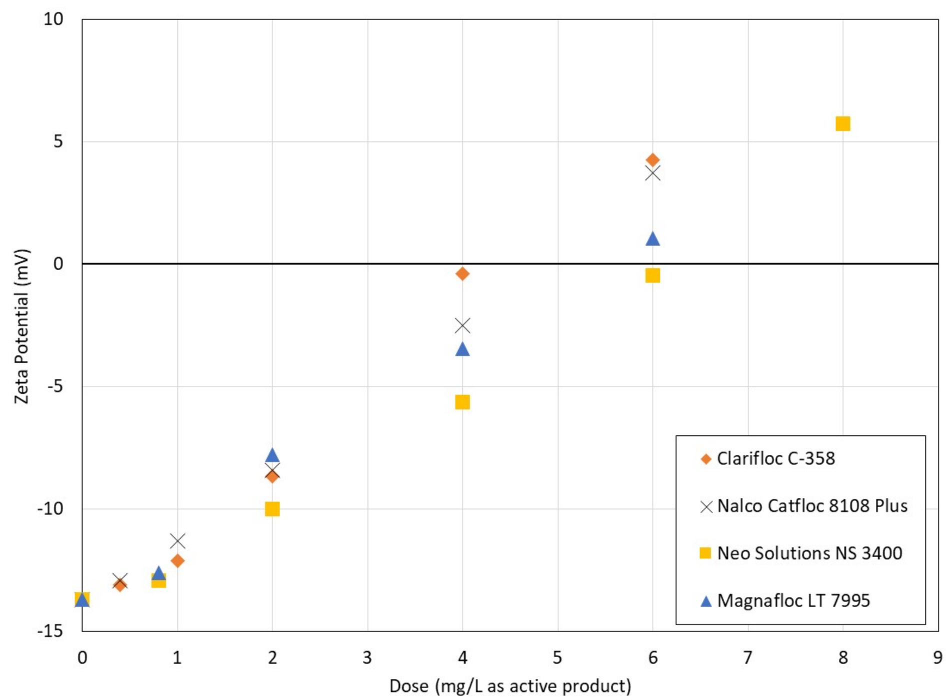


Figure 9 Impact of PEC Dose on Zeta Potential (Normalized for Percent Active Polymer)

Experiments were conducted to investigate the impact of feeding PEC in conjunction with ferric sulfate prior to the softening process. Three doses of ferric sulfate were investigated:

- 15 mg/L to represent typical operation,
- 80 mg/L to represent the dose fed full-scale during the October flood event, and
- 180 mg/L.

The resulting settled water turbidity and zeta potential are shown in Figure 10 and Figure 11, respectively. These results indicate that PEC aids in charge neutralization and reduces the settled water turbidity. The lowest settled water turbidities were observed with low ferric sulfate doses (15 mg/L) and PEC doses of 10-15 mg/L as solution. Higher doses of ferric sulfate resulted in higher settled water turbidity, even when the charge neutralization achieved was similar to that observed at the lower ferric sulfate dose with PEC. This trend reflects the lower specific gravity of a ferric hydroxide dominated floc as compared to a polymer floc which is denser. Additionally, ferric sulfate generates more than 10 times the mass of solids, which will result in more turbidity after settling (assuming the same particle removal efficiency).These data also show the potential adverse effects of overfeeding PEC, resulting in a positive settled water zeta potential. For example, feeding 10 mg/L of PEC in conjunction with 180 mg/L of ferric sulfate resulted in settled water zeta potential of +8.5 and offered minimal improvement to the settled water turbidity when compared to feeding 180 mg/L of ferric sulfate alone.

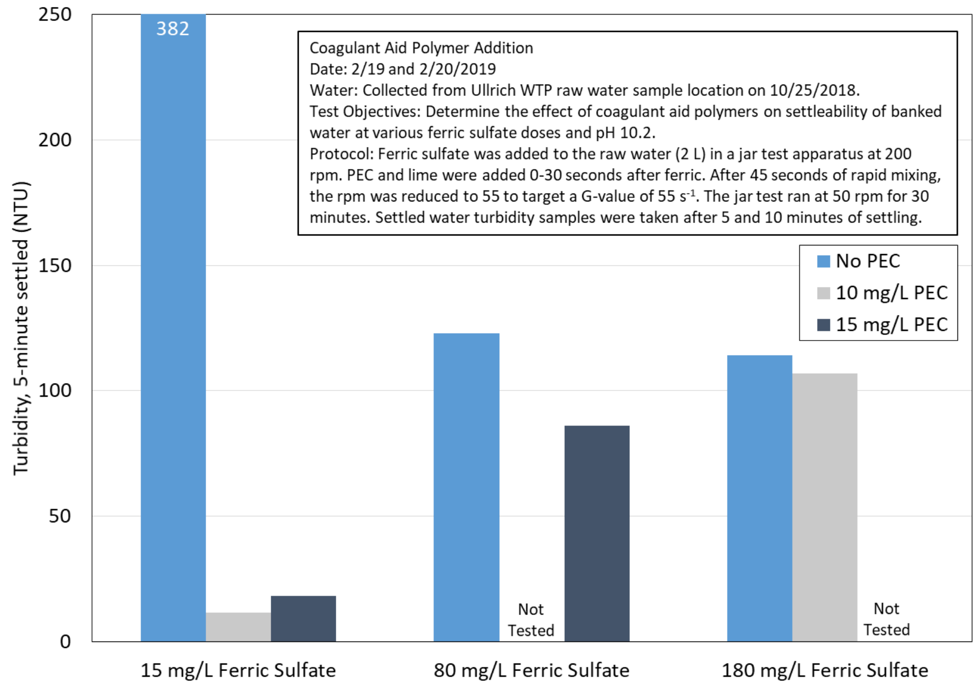


Figure 10 Impact of Offsetting Ferric Sulfate Demand with PEC on Settled Turbidity

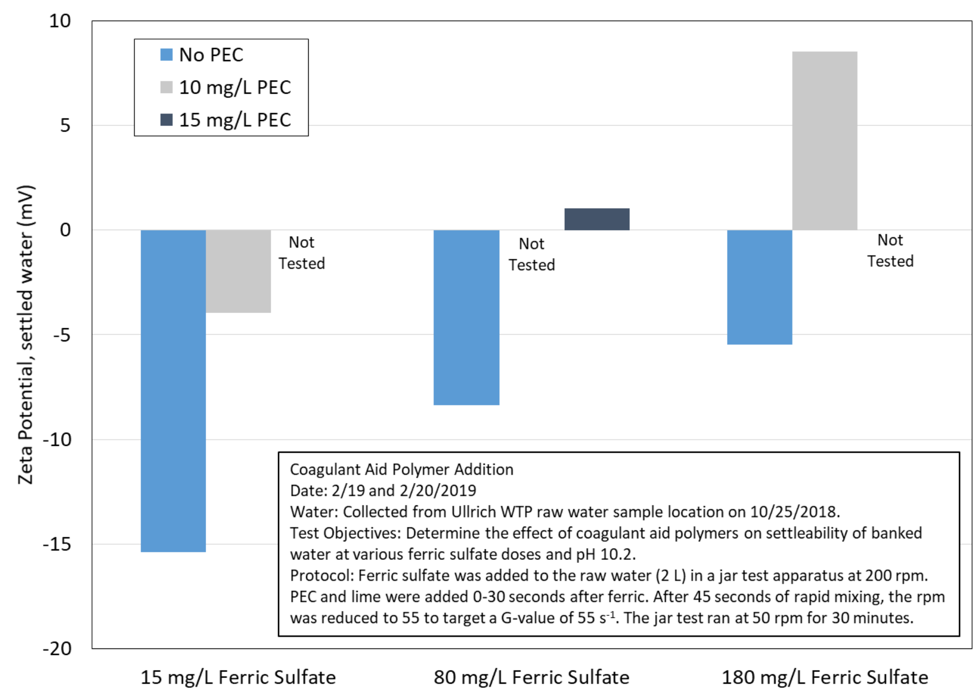


Figure 11 Impact of Offsetting Ferric Sulfate Demand with PEC on Settled Zeta Potential

The impact of PEC addition was also investigated at high softening pH since softening at high pH precipitated magnesium hydroxide, provided more charge neutralization, and improved settled water turbidity full-scale during the October 2018 flood event. The settled water turbidity and zeta potential resulting from different PEC doses at pH 10.2 and 11.0 are compared in Figure 12 and Figure 13. These results indicate that:

- Softening at pH 11.0 in the absence of PEC addition reduces the settled water turbidity. This impact can likely be attributed to the precipitation of magnesium hydroxide, which also serves to neutralize charge.
- Feeding PEC resulted in significantly lower settled water turbidity at both pH 10.2 and 11.0.
- The lowest settled water turbidity was achieved by feeding PEC and softening at pH 10.2. This is likely because magnesium hydroxide (unlike calcium carbonate) is a gelatinous high surface area precipitate that does not settle well.

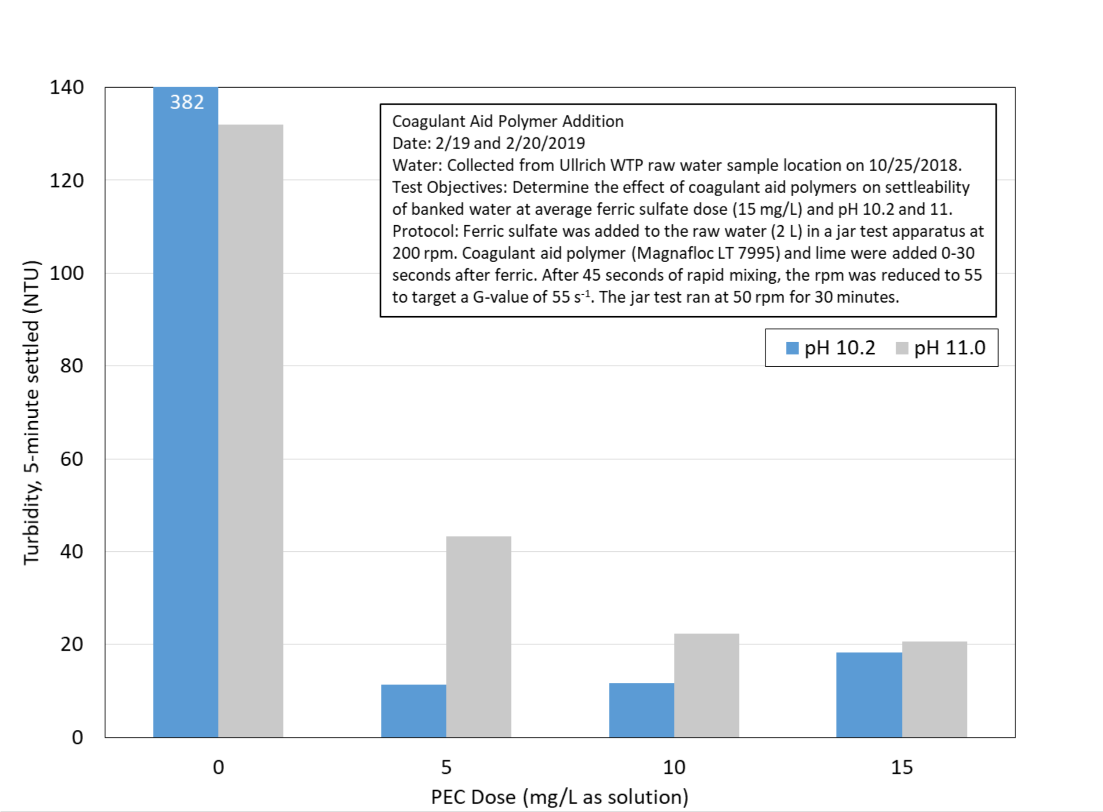


Figure 12 Impact of PEC Dose on Settled Turbidity

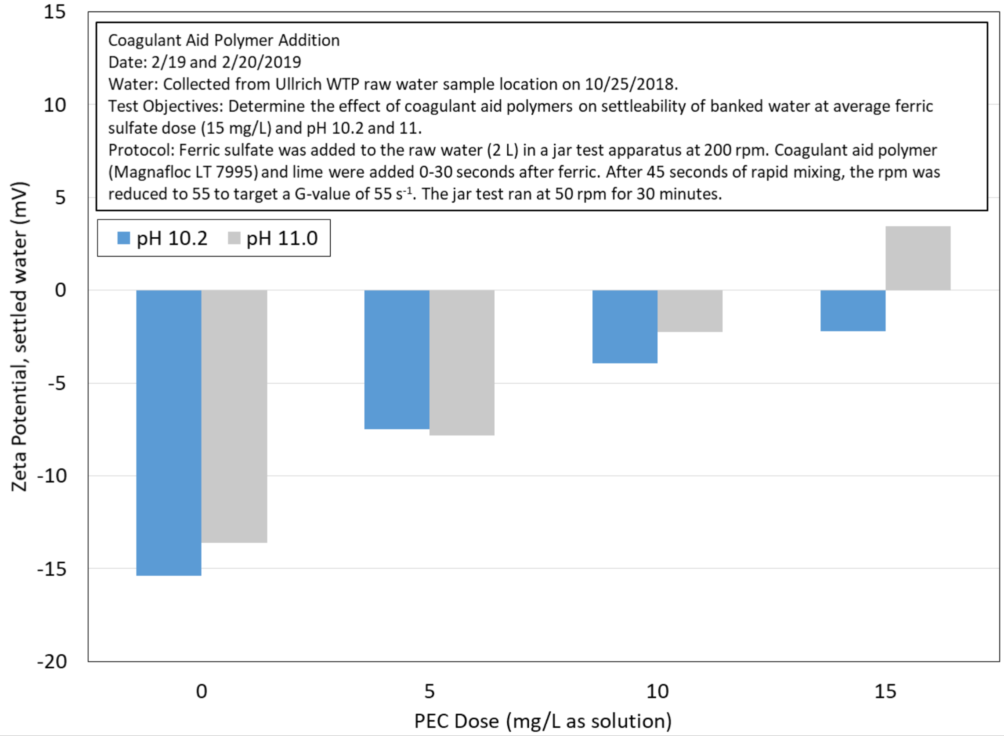


Figure 13 Impact of PEC Dose on Settled Zeta Potential

The impact of feeding PEC to Typical Water was also investigated to determine if PEC provided value during normal operation. Results of these experiments are shown in Figure 14 and Figure 15. Based on these results, feeding low doses of PEC (i.e., 1 mg/L) in conjunction with ferric sulfate resulted in improved settled water turbidity compared to feeding ferric sulfate alone. These results also show that feeding ferric sulfate alone resulted in improved settled water turbidity compared to feeding PEC alone. For example, feeding 3 mg/L of PEC and 0 mg/L ferric sulfate resulted in a higher settled water turbidity than feeding 15 mg/L of ferric sulfate alone even though similar levels of charge neutralization were achieved with each approach. Therefore, the addition of ferric sulfate is important and cannot be completely replaced by feeding PEC.

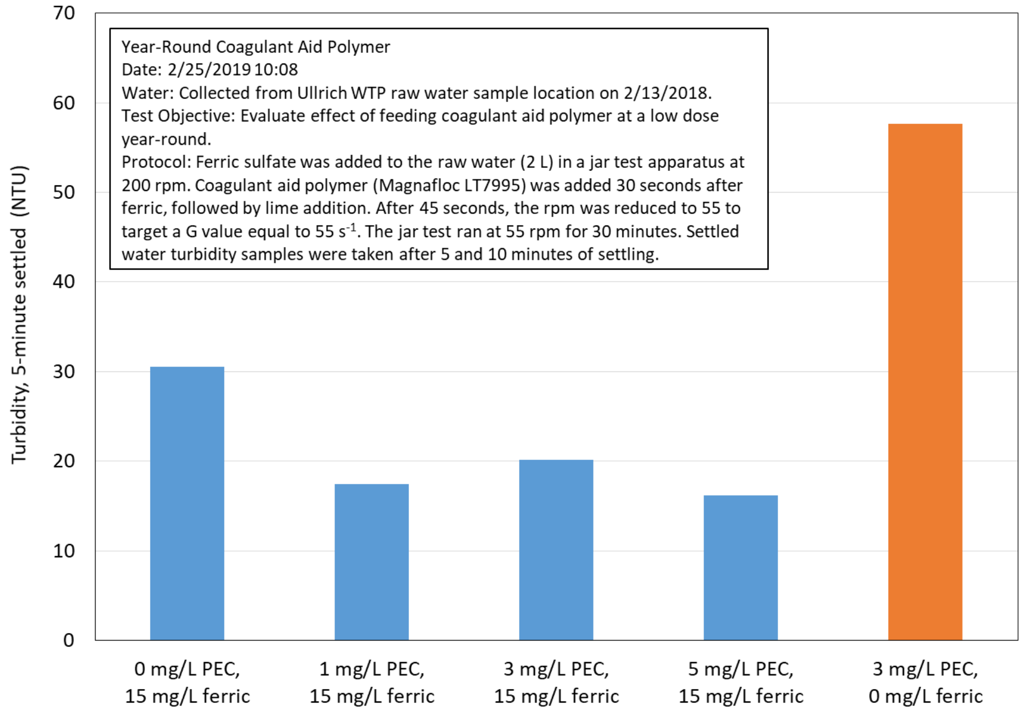


Figure 14 Impact of PEC on Turbidity with Typical Raw Water

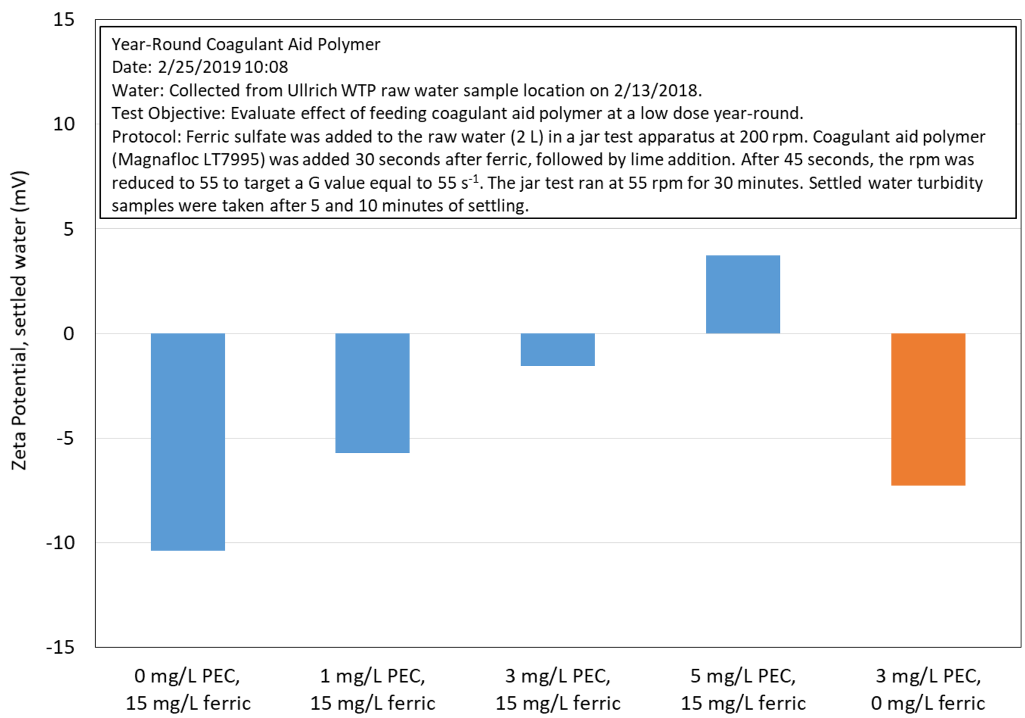


Figure 15 Impact of PEC on Zeta Potential with Typical Raw Water

The order of chemical addition is also important when feeding PEC. Figure 16 compares the zeta potential observed from feeding: 1) 15 mg/L of ferric sulfate, 2) 10 mg/L of PEC, 3) 10 mg/L PEC 30 seconds upstream of 15 mg/L ferric sulfate, and 4) 15 mg/L ferric sulfate 30 seconds upstream of PEC. These results indicate that the optimal location of PEC feed is downstream of ferric suflate addition. Figure 17 compares the resulting zeta potential from feeding ferric sulfate/PEC simultaneously to feeding ferric sulfate 30 seconds and 90 seconds prior to PEC. A benefit to charge neutralization was observed when separating the ferric sulfate and PEC addition from zero to 30 seconds. This observation may be a result of the cationic polymer adsorbing to the iron floc particles, which are likely negatively charged at the pH values tested. However, no additional benefit to charge neutralization was observed from increasing the separation between ferric sulfate and PEC to 90 seconds. During an event, adopting this sequence of timing of chemical addition would reduce the polymer dose by approximatley 5 mg/L of polymer (based on the zeta potential presented in Figure 8 and comparing a Zeta Potential of -5 mV versus a Zeta Potential of -2.5 mV).

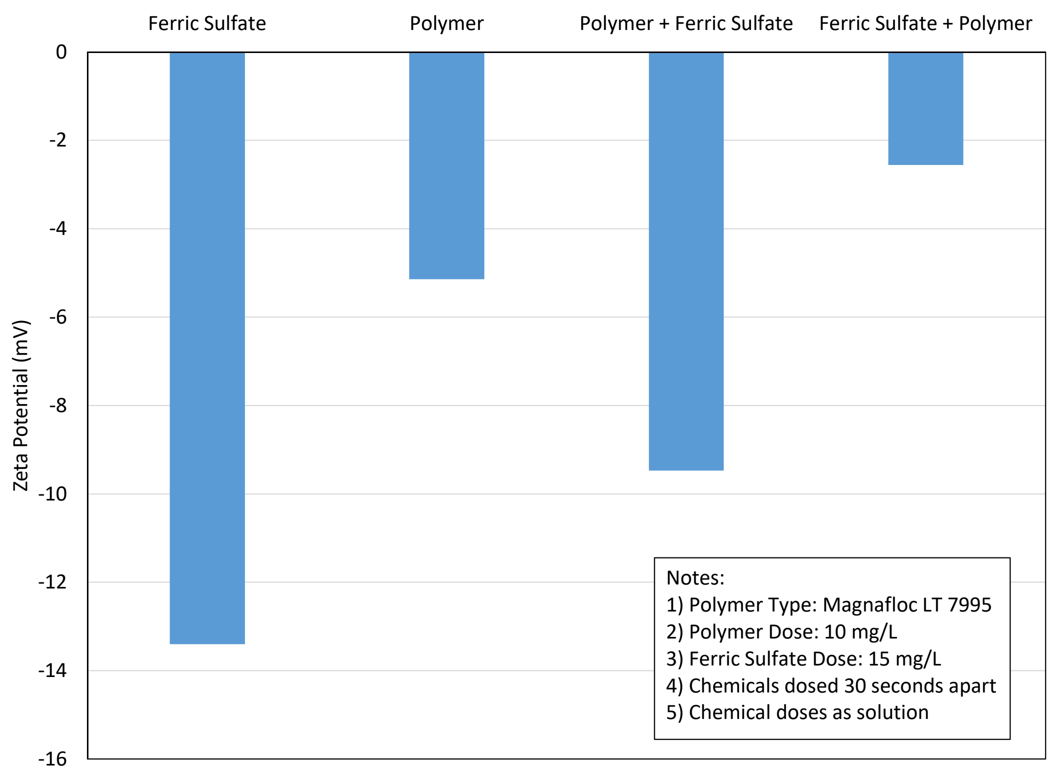


Figure 16 Impact of Order of PEC Addition on Zeta Potential

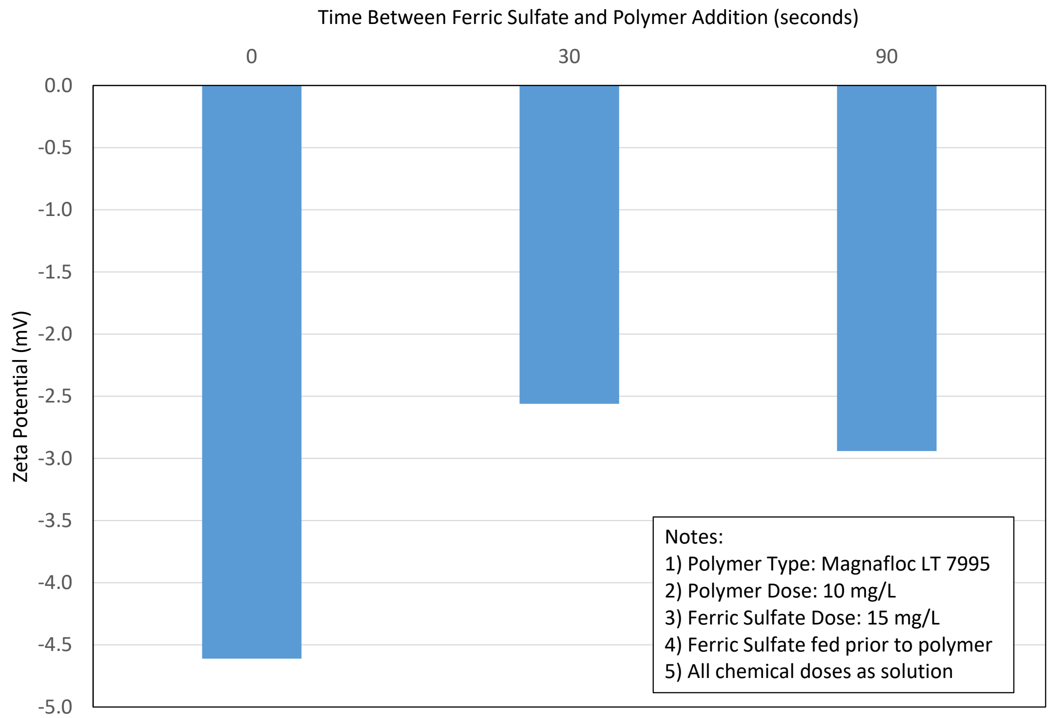


Figure 17 Impact of Time Delay between Ferric Sulfate and PEC addition on Zeta Potential

The impact of the order of chemical addition on settled water turbdity is shown in Figure 18. The scenarios shown in the figure represent potential options for implementing polymer feed at the Ullrich WTP, and can be applied to both the Davis and Handcox WTPs as well. Feeding ferric sulfate and PEC simultaneously (simulating feeding polymer near the typical ferric sulfate feed points at the Ullrich WTP) resulted in the highest settled water turbidity. Feeding PEC and lime simultaneously (simulating feeding PEC in the clarifier centerwell) resulted in lower settled water turbidity than feeding PEC simultaneously with ferric sulfate. However, feeding PEC 30 seconds after ferric sulfate addition and prior to lime addition (simulating feeding ferric sulfate and PEC in the raw water pipeline prior to the clarifiers) resulted in the lowest settled water turbidity.

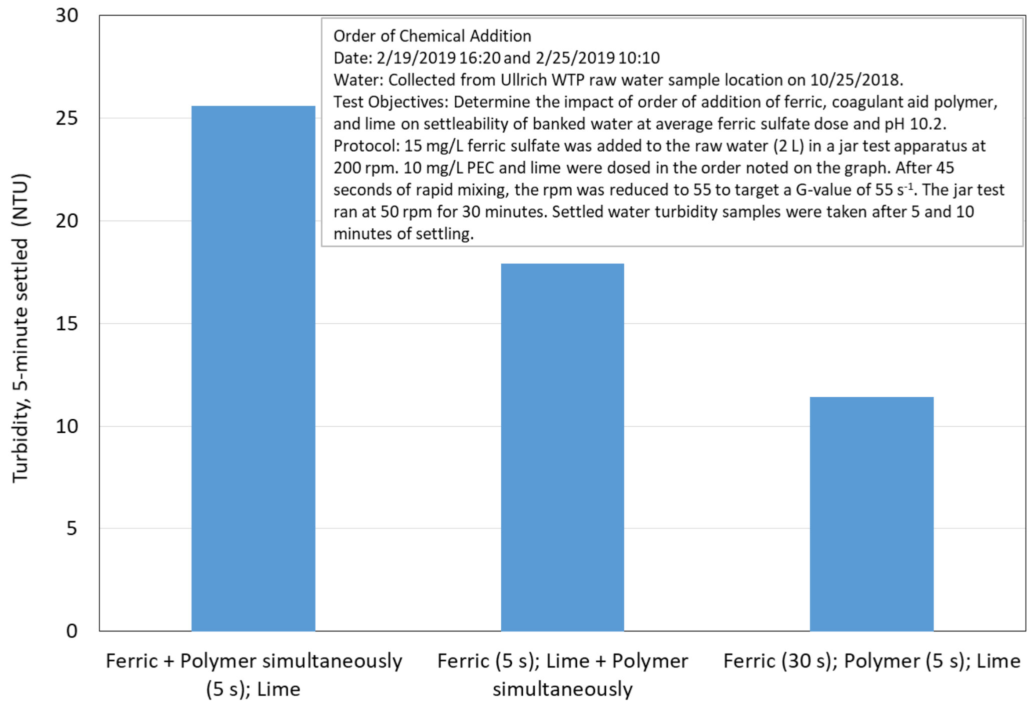


Figure 18 Impact of Order of Chemical Addition on Settled Water Turbidity

Additional experiments were performed to further investigate the optimal polymer dose while feeding PEC under optimal conditions. In these experiments, PEC was added 30 seconds after ferric sulfate, followed by lime addition 5 seconds later. Results are shown in Figure 19 and Figure 20. These results indicate that the optimal dose of the tested PEC may range from 10-12 mg/L for the Banked Water.

In general, PEC addition in combination with a low ferric sulfate dose significantly improved settled water turbidity by neutralizing particle charge. This result may not only translate to improved settleability full-scale, but also potentially improve the filterability of the solids that carry over onto the filters from the sedimentation basins or solids contact clarifiers.

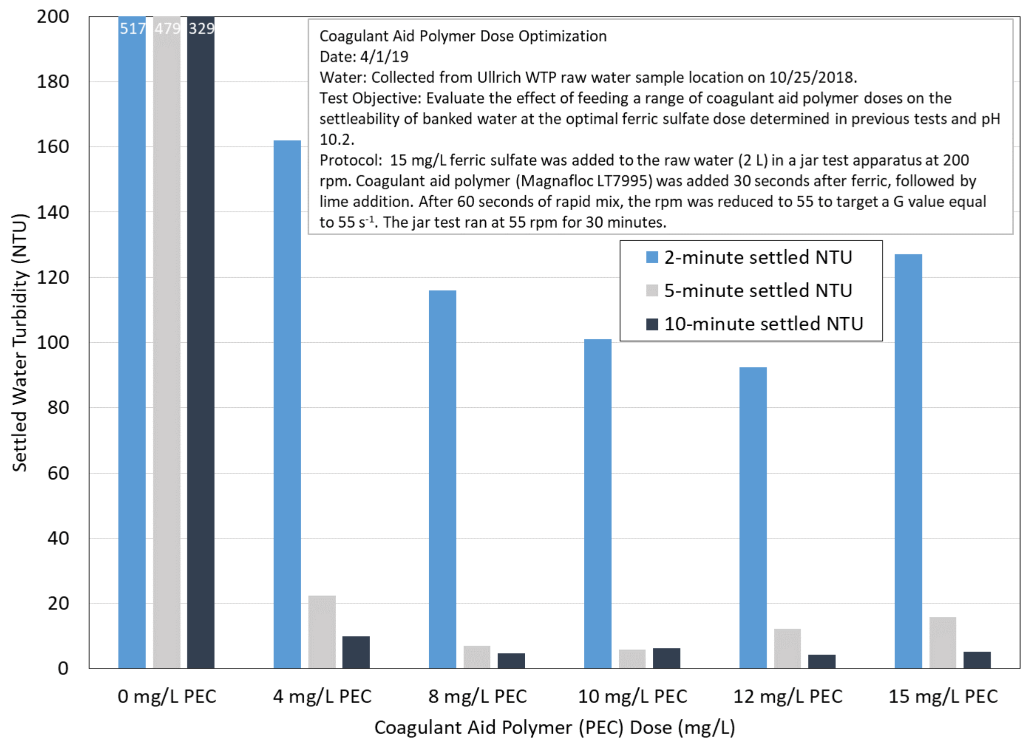


Figure 19 Impact of PEC Dose on Settled Turbidity

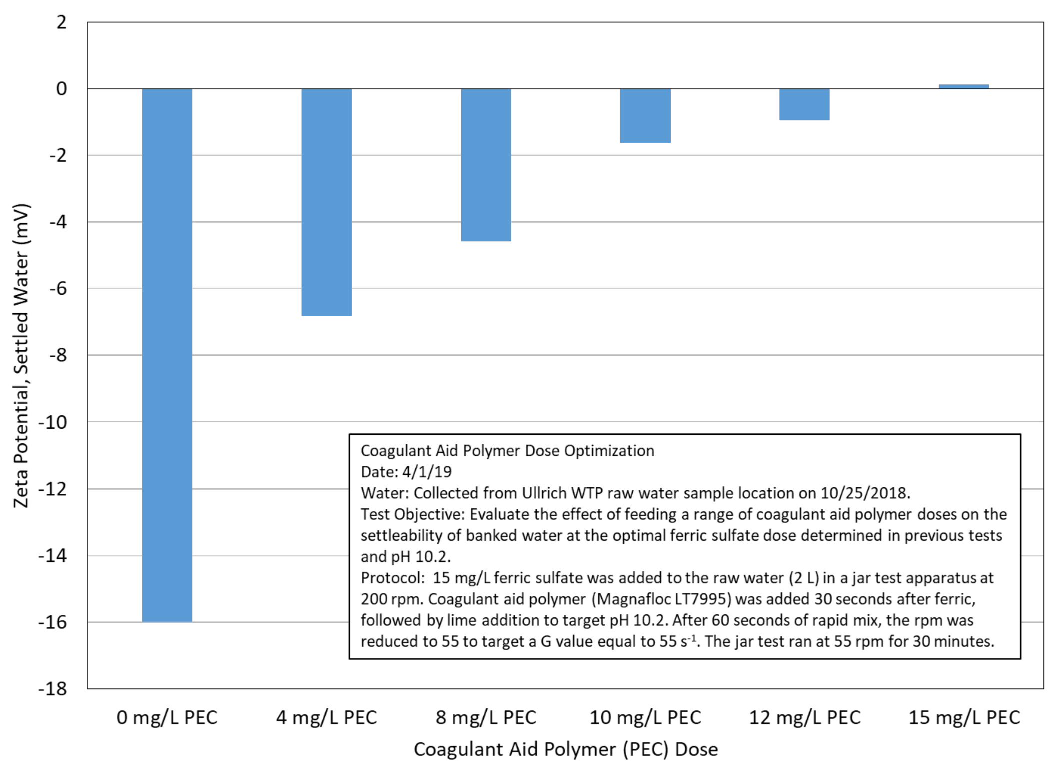


Figure 20 Impact of PEC Dose on Zeta Potential

4.2 Flocculant Aid Polymer (PEA)

Flocculant aid polymers (PEA) are typically high-molecular-weight long-chain molecules that can be anionic, nonionic, or cationic. PEAs improve the flocculation process by bridging, forming larger particles that settle more quickly. Experiments were conducted to determine if PEA addition would further improve settling rates from those observed by feeding 15 mg/L of ferric sulfate and 10-15 mg/L of PEC prior to softening at pH 10.2. All of the polymers tested were polyacrylamides. Table 4 summarizes the PEA polymers tested.

Table 4 Flocculant Aid Polymers (PEA) Tested

PEA	Company	Charge Type	Maximum NSF 60 Dose (mg/L)	Molecular Weight
Nalclear 7766 Plus	Nalco	Nonionic	1	---
Clarifloc A-6330	Polydyne	Anionic	1	Very High
Clarifloc C-6220	Polydyne	Cationic	3	High

Experiments were first conducted by feeding PEA in conjunction with lime, or 10 minutes after lime addition (Figure 21). In these experiments 15 mg/L of ferric sulfate was added 30 seconds prior to 10 mg/L PEC. Lime and PEA were added 5 seconds after PEC. The addition of PEA did not improve settled water turbidity in this scenario. Since floc aid polymer dose should be proportional to the number of particles, the lack of improvement observed may be due to the large proportion of small particles formed in a conventional jar test. Therefore, this test may not be representative of the potential benefits of floc aid polymer.

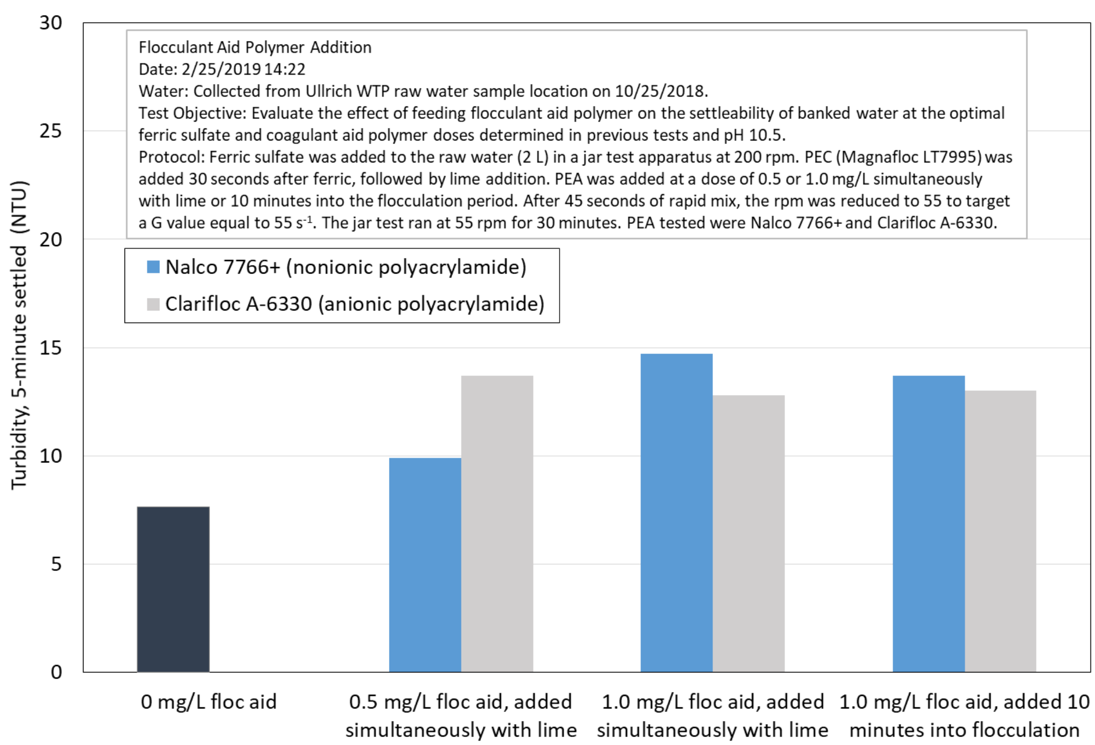


Figure 21 Impact of PEA on Banked Water Settled Turbidity

Additional testing was performed with solids collected from the Handcox WTP to test whether PEA would offer benefits if fed to solids more representative of those typical of a solids contact clarifier (SCC) like those at Ullrich and Handcox WTPs. All three types of PEA (nonionic, cationic, and anionic) were tested. Results are summarized in Figure 22. These experiments indicate that PEA addition did improve settleability when solids from the full-scale WTP were present. The anionic PEA performed better than the other polymers tested, potentially a result of its higher molecular weight. Therefore, the anionic PEA was selected for further study.

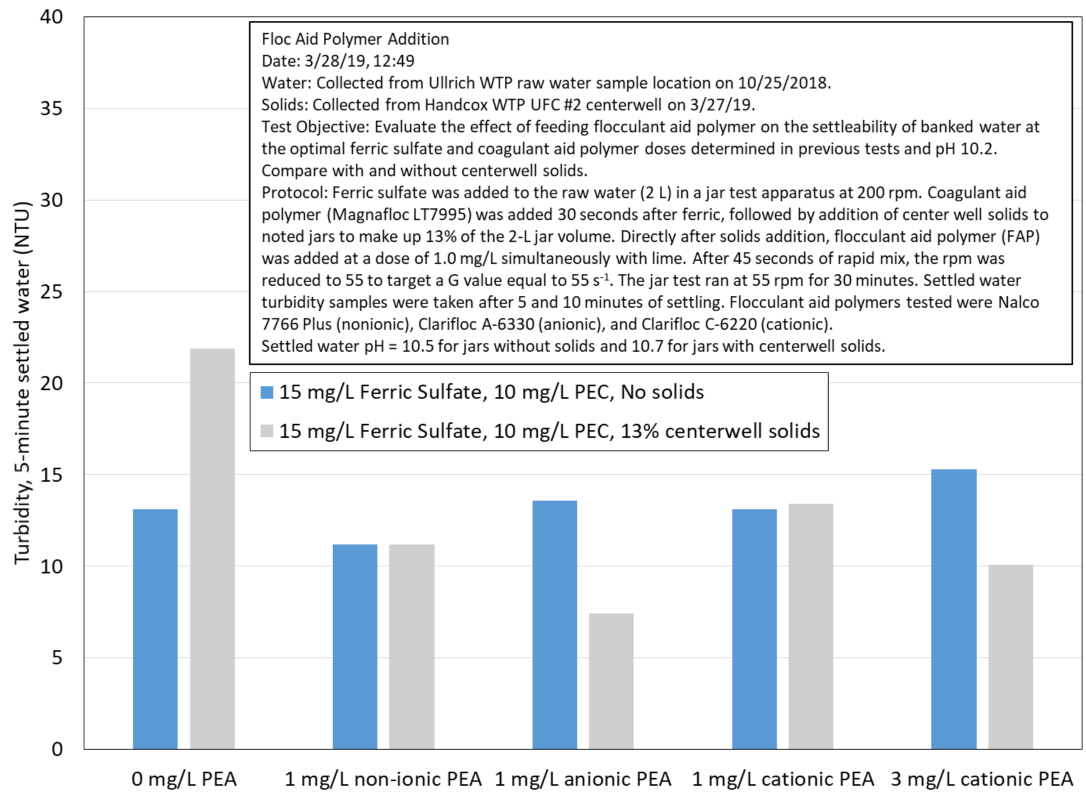


Figure 22 Impact of PEA on Banked Water Settled Turbidity - Seeded with SCC Solids

4.2.1 Iterative Generation of Solids

To better simulate an upflow solids contact clarifier, an iterative approach to solids generation was used during the jar testing. In these experiments, the chemical feed to the first iteration included 15 mg/L of ferric sulfate dosed 30 seconds before 12 mg/L of PEC addition. Lime and PEA were dosed 5 seconds after PEC addition. After settling, the settled water was decanted and the solids were collected. It should be noted that a 2 minute settling time is equivalent to a SCC rise rate of 1.23 gpm/ft^2. In all subsequent iterations, 15 mg/L of ferric sulfate was dosed 30 seconds before 12 mg/L of PEC addition. Lime, PEA, and solids from the previous iteration were then dosed 5 seconds after PEC addition. Results of the settled water turbidity during this iterative approach without PEA addition, and with 1 mg/L and 0.1 mg/L PEA addition are shown in Figure 23, Figure 24, and Figure 25, respectively. The resulting settled water turbidity upon achieving 3-percent solids (approximately 5 iterations) to match typical concentrations maintained in the full-scale SCCs (which range from 3 to 5-percent), is summarized in Figure 26. These results indicate that:

- Settled water turbidity improved as the solids concentration increased, even in the absence of PEA. The improved settling rates are likely a function of increased particle size.
- Even at low doses (e.g., 0.1 mg/L) PEA addition improved settled water turbidity.
- PEA reduced the variability of settled water turbidity.
- These were the only tests that matched normal operating settled water turbidities (i.e., 3 NTU or less), indicating that this approach to bench testing is more representative of SCCs than traditional jar testing procedures.
- The use of a PEA might also be of value if the solids concentration in the center well of a SCC is low.

Based on these results, the optimal treatment approach to reducing the settled water turbidity includes:

- Feeding PEC 20 - 30 seconds after ferric sulfate addition prior to softening at pH 10.2 to neutralize charge, and
- Feeding low doses of PEA to the clarifier center well to further aid in settling the particles formed in the treatment process.

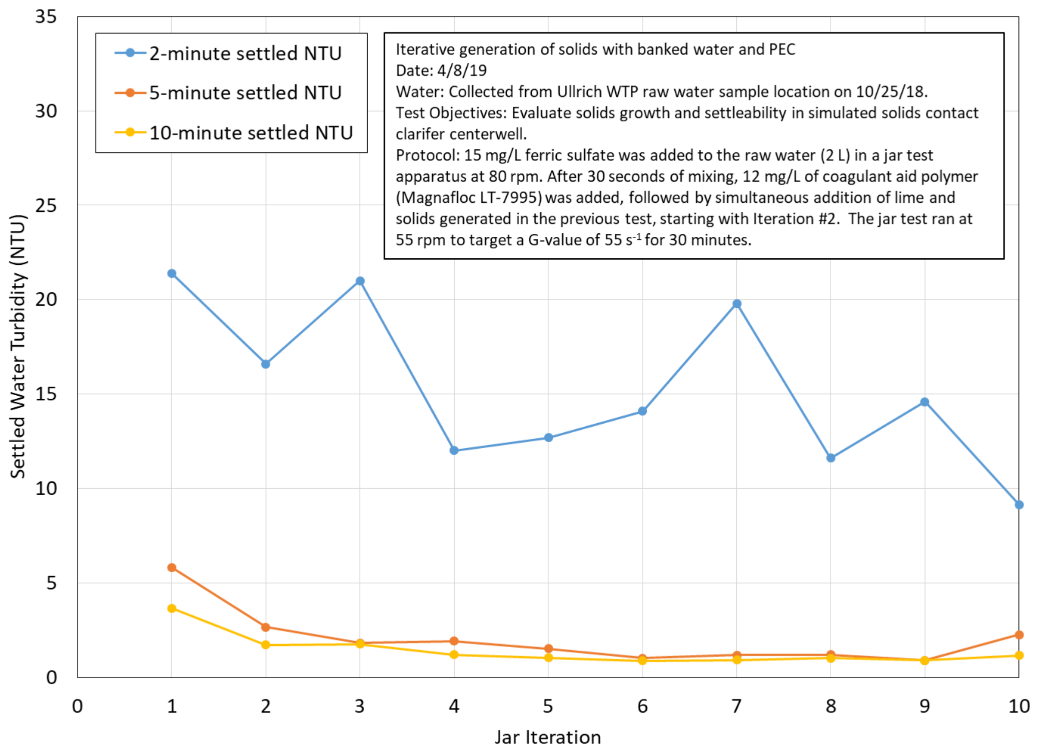


Figure 23 Iterative Generation of Solids with 0 mg/L PEA

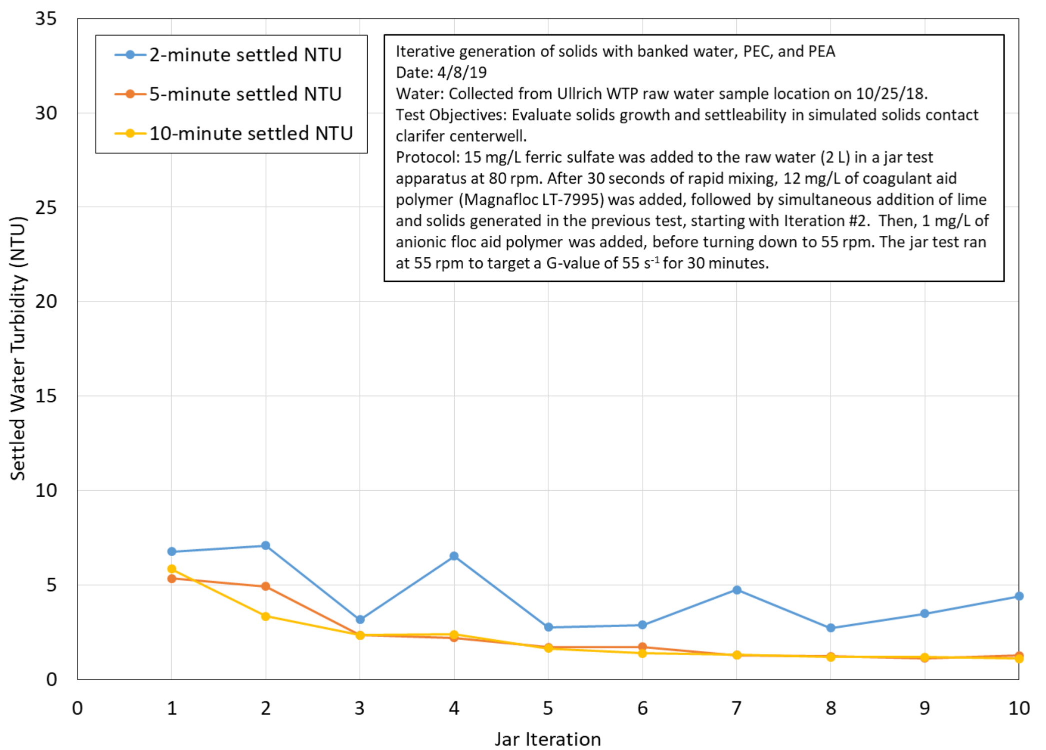


Figure 24 Iterative Generation of Solids with 1 mg/L PEA

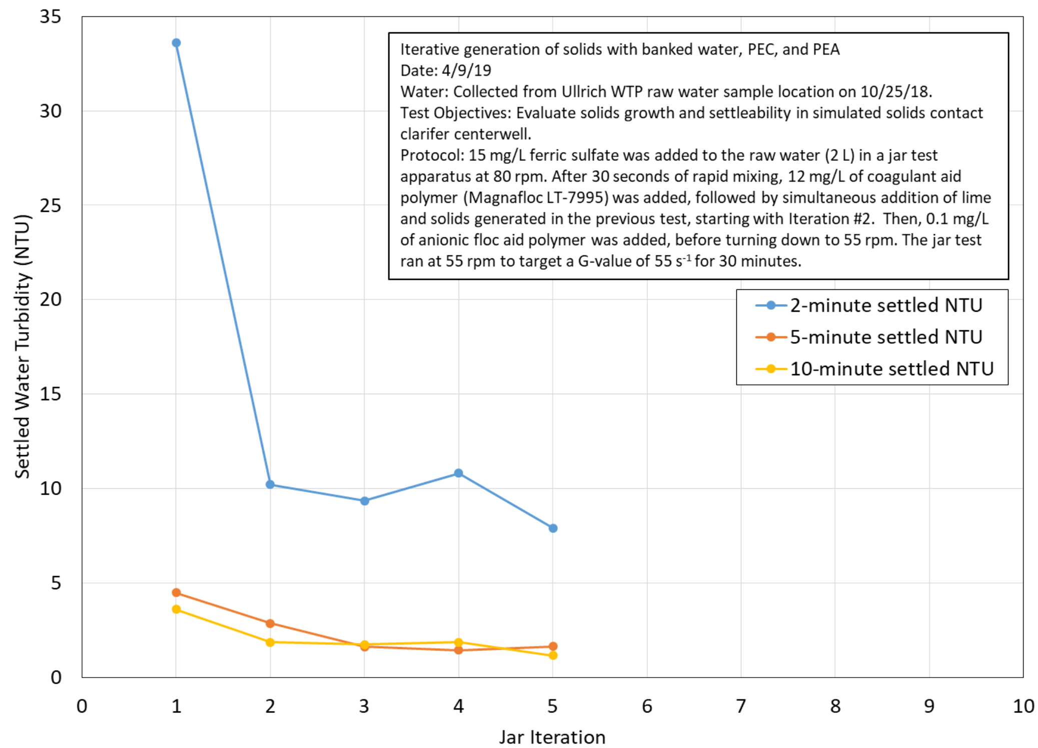


Figure 25 Iterative Generation of Solids with 0.1 mg/L PEA

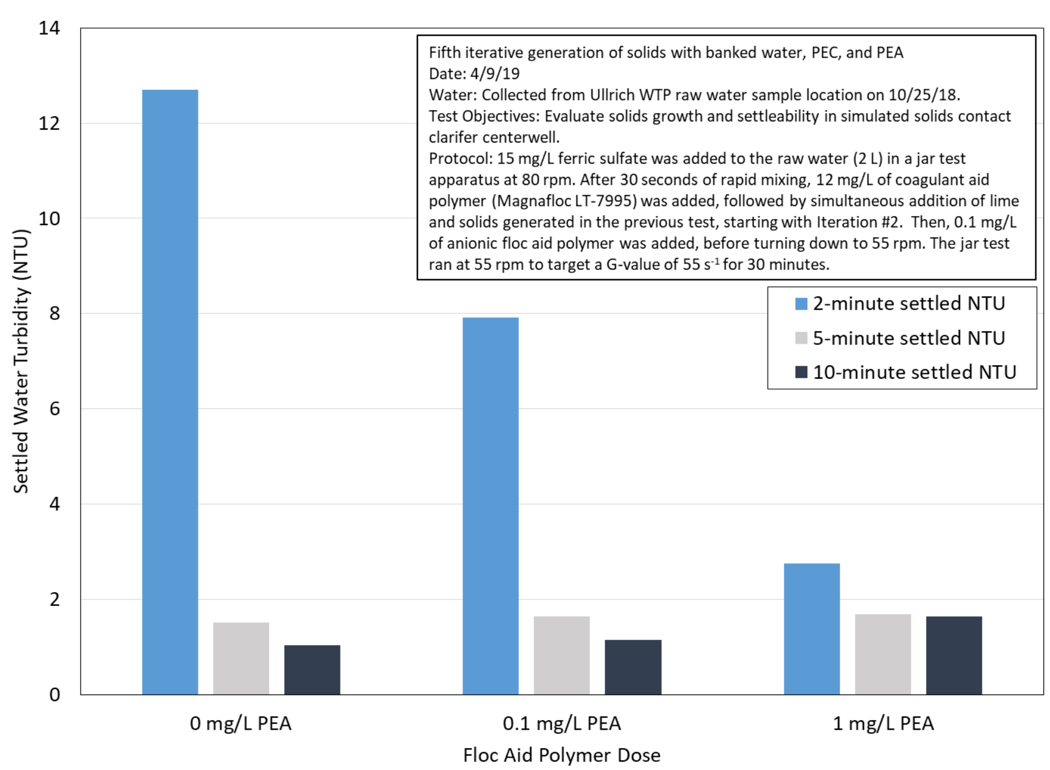


Figure 26 Impact of PEA Dose on Settled Turbidity for 3% Solids Generated from Banked Water

4.3 Carbon Dioxide and Caustic Soda Addition

During the October 2018 flood, the raw water alkalinity and hardness concentrations dropped well below historical norms, resulting in little carbonate or calcium available for precipitation of $CaCO_3$ solids. The ability to add carbon dioxide (CO_2) and potentially caustic soda (NaOH) prior to softening was identified as a potential approach to allow the WTPs to operate closer to typical conditions during a similar extreme raw water quality event while simultaneously maintaining finished water alkalinity goals. This operational scenario would result in precipitation of more calcium carbonate solids which would increase the specific gravity and settleability of the solids during a flood event (assuming the same size particles). NaOH addition would allow the operators to dial in the settled water alkalinity if needed to meet finished water stability goals, and could provide flexibility in terms of where CO_2 is added.

Figure 27 shows potential locations where CO_2 and NaOH could be added at the Ullrich WTP. Part A shows CO_2 addition after ammonia, but prior to ferric sulfate addition. In the absence of NaOH addition, CO_2 would need to be added after ammonia to avoid formation of dichloramine at low pH conditions. Part B shows CO_2 and NaOH addition after chlorine but before ammonia. Other alternatives are possible for CO_2 and NaOH addition. Under either scenario (with or without NaOH), polymers (PEC and PEA) would also be added.

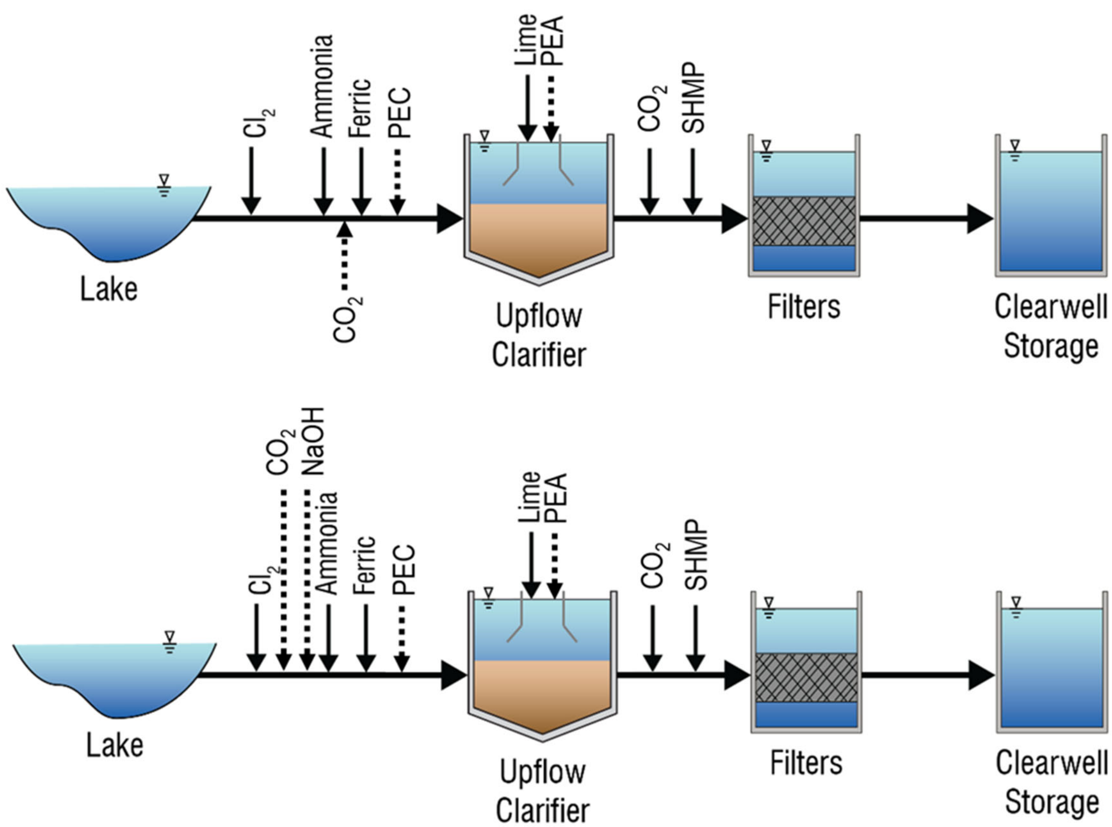


Figure 27 Potential Locations for CO_2 and NaOH Addition at Ullrich WTP

Bench tests were conducted to evaluate the impact of adding CO_2 with and without NaOH on particle settleability, and resulting settled water quality. PEC was also added in some of the tests, and some tests were conducted with center well solids collected from either the Ullrich or Handcox WTPs to simulate the impact of CO_2 under solids contact conditions. Table 5 summarizes the different test conditions that were evaluated with CO_2 and NaOH addition. Results from the tests are summarized in the paragraphs below; the full set of results can be found in Appendix E.

Table 5 Summary of Jar Tests Conducted to Assess Impact of CO_2 and NaOH Addition

Jar Test ID	Jar Size	CO_2 Dose (mg/L)	Settled pH	NaOH Dose (mg/L)	PEC Dose (mg/L)	Center Well Solids (%)
JT18 and JT19	200 mL	0 - 65	10.0-10.7	0	0	0
JT22	200 mL	44	9.8-10.3	30	0	0
JT23	2 L	44-65	10.1-10.5	30-45	0 & 10	0
JT2.2 and JT2.3	2 L	0-88	9.7-10.5	0	0 & 10	0 & 13

A 44 mg/L CO_2 dose was used as a baseline for assessing the impact of CO_2 addition. That dose corresponds to the molar equivalent of the deficit in total carbonate concentrations during the October 2018 flood event relative to typical conditions (0.001 M). CO_2 addition was simulated by adding sodium bicarbonate ($NaHCO_3$) to the Banked Water, followed by an equivalent amount of hydrochloric acid (HCl) prior to initiating rapid mix. After initiating rapid mix, ferric sulfate, PEC, center well solids, and/or lime were added depending on the target test condition. When NaOH was added, the dose was determined based on the target settled water alkalinity to achieve a finished water CCPP of 15 mg/L as $CaCO_3$ at pH 9.6 (typical operational value). Additional details on the jar testing procedures are provided in the Bench Testing Protocol (Appendix A).

Figure 28, Figure 29, Figure 30, and Figure 31 show results from the first set of jar tests using 200-mL jars to evaluate the impact of adding 22, 44, and 65 mg/L CO_2. Addition of CO_2 translated to an increased mass of $CaCO_3$ solids precipitated, as expected (Figure 28). Between 44 - 65 mg/L CO_2 addition resulted in close to the same amount of $CaCO_3$ precipitated as with Typical Water at the same softening pH although the increased raw water solids in the Banked Water likely result in water with a different final solids specific gravity. Addition of CO_2 also increased the degree of saturation at the initiation of softening (Figure 29).

The greater mass of $CaCO_3$ precipitated translated to a higher calculated solids density for the jars to which CO_2 was added (Figure 30). While the 30 minute settled water turbidity was not impacted (results in Appendix E), a difference was observed in the settling rate (Figure 31).

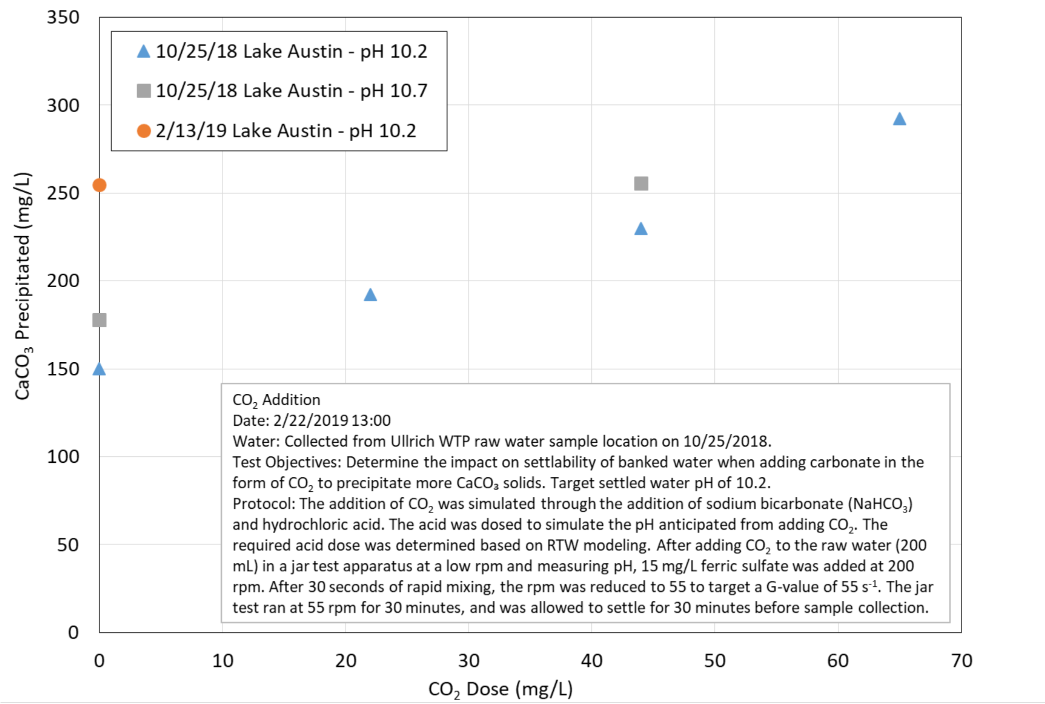


Figure 28 Impact of Carbon Dioxide Addition on Calcium Carbonate Precipitation

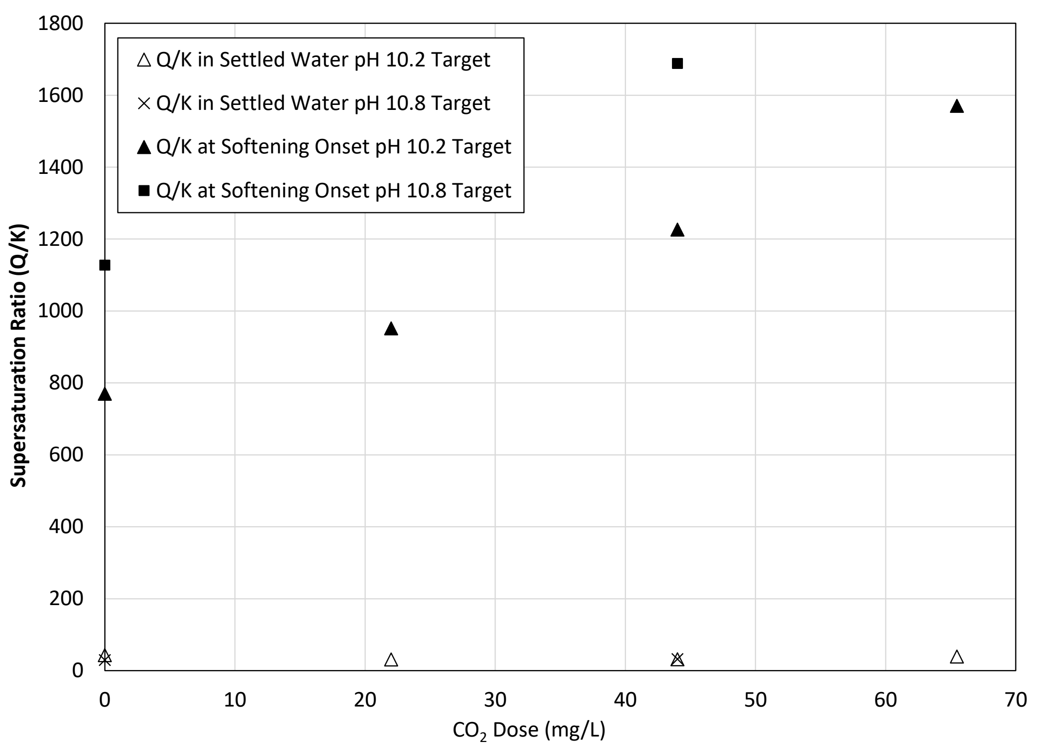


Figure 29 Impact of Carbon Dioxide Addition on $CaCO_3$ Saturation

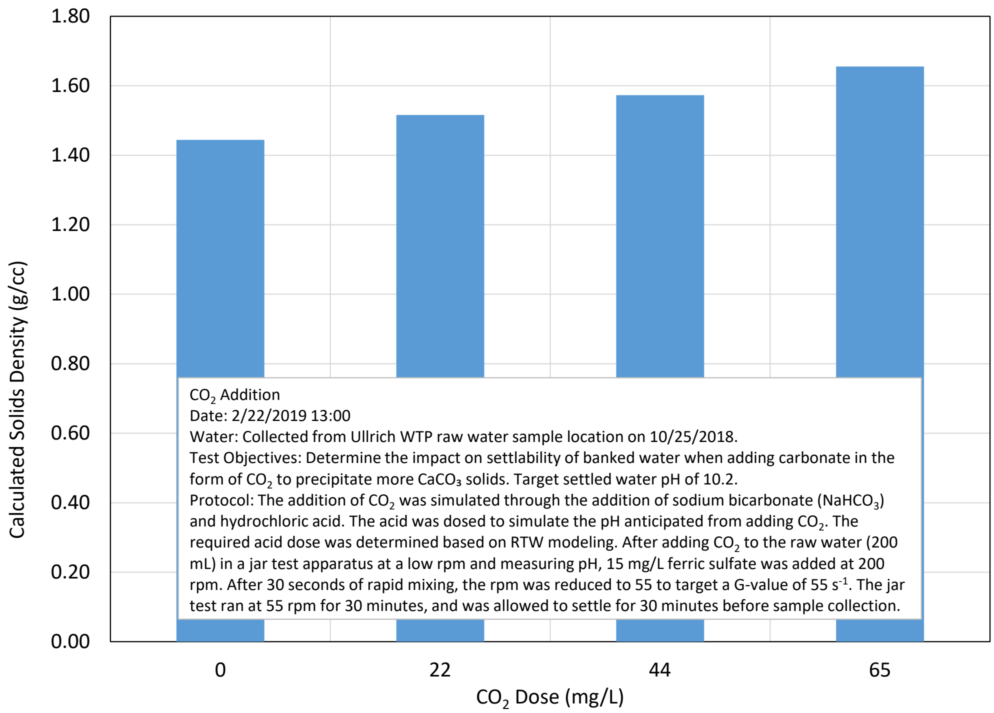


Figure 30 Impact of Carbon Dioxide Addition on Calculated Solids Density[5]

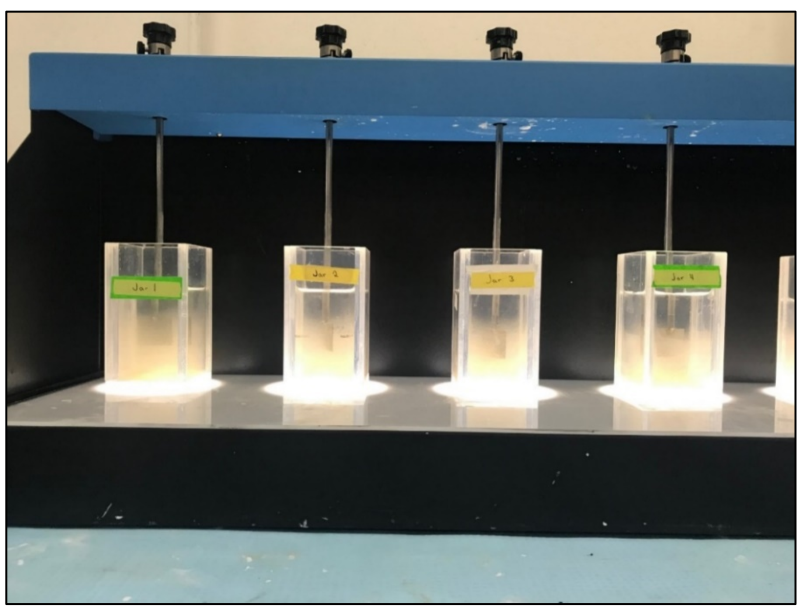


Figure 31 Image of Solids Settling in 200-mL Jars with CO_2 Doses Increasing (left to right) from 0 to 65 mg/L

[5] The solids density calculations were based on solids composition (estimated based on mass balance calculations from the jar test results) and literature values for density of the respective solids when wet (not dried).

To further assess the impact on settleability, similar conditions were tested in 2-L jars. As illustrated in Figure 32 , a slight difference in the 5-minute settled water turbidity was observed between the jar in which no CO_2 was added (275 NTU) compared to the jar to which 65 mg/L CO_2 was added (230 NTU). In contrast, the addition of 10 mg/L PEC resulted in turbidity 1/10 than that achieved without PEC regardless of CO_2 dose. Given the cost and complexity of CO_2 addition prior to rapid mix, this operational strategy is not recommended as an improvement to help the City respond to similar future extreme raw water quality events.

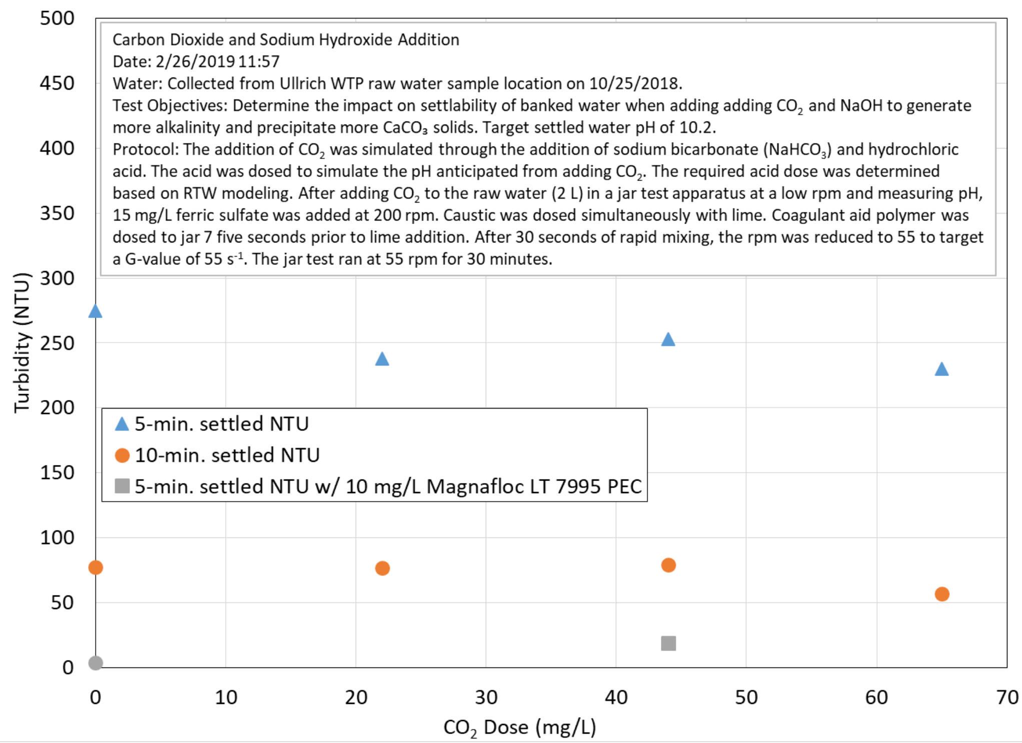


Figure 32 Impact of Carbon Dioxide Addition on Settled Turbidity

As illustrated in Figure 33, if CO_2 addition were reconsidered in the future, NaOH addition may not be needed to achieve target finished water CCPP values. However, NaOH addition could provide benefits in terms of achieving a higher finished water alkalinity, and feeding NaOH would provide flexibility for the CO_2 feed point relative to the location of ammonia addition by allowing the pH to be maintained in the optimal range for chloramine formation.

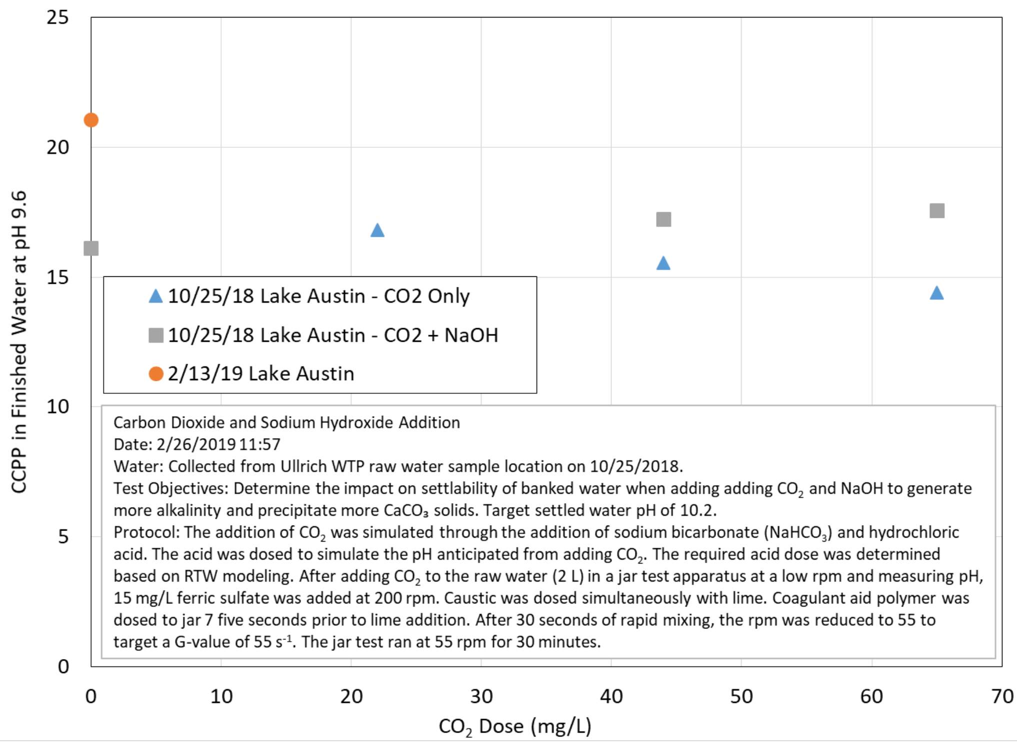


Figure 33 Impact of NaOH Addition on Finished Water CCPP Values

4.4 Enhanced Coagulation

Enhanced coagulation relies on coagulation with a metal salt (i.e., ferric sulfate) under conditions that target organics removal. Jar tests were performed to evaluate the effectiveness of enhanced coagulation with higher ferric sulfate doses while maintaining a coagulation pH between 6 and 7 (the raw water pH of 8.0 was depressed by ferric sulfate addition and adjusted to pH 6 - 7 as needed by adding lime). Since the coagulation pH was maintained between 6 and 7, softening (e.g., hardness removal via calcium carbonate precipitation) did not occur.

Figure 34 shows that increasing the ferric sulfate dose from 80 to 280 mg/L had minimal impact on the 5-minute settled water turbidity. Figure 34 also shows a data point from softening at optimal conditions, where lime softening at a pH of 10.2 with 15 mg/L of ferric sulfate and 10 mg/L of coagulant aid polymer resulted in a settled water turbidity 1/5 that achieved by enhanced coagulation. According to zeta potential titrations, a ferric sulfate dose of approximately 300 mg/L was required to neutralize charge at ambient pH (Figure 7). Figure 35 shows that increasing the ferric sulfate dose generally resulted in a more neutral settled water zeta potential. Figure 36 shows that increasing the ferric sulfate dose from 80 to 280 mg/L improved settled water TOC from 3.4 to 1.4 mg/L, respectively. Increasing the ferric sulfate dose also improved settled water specific UV-absorbance (SUVA).

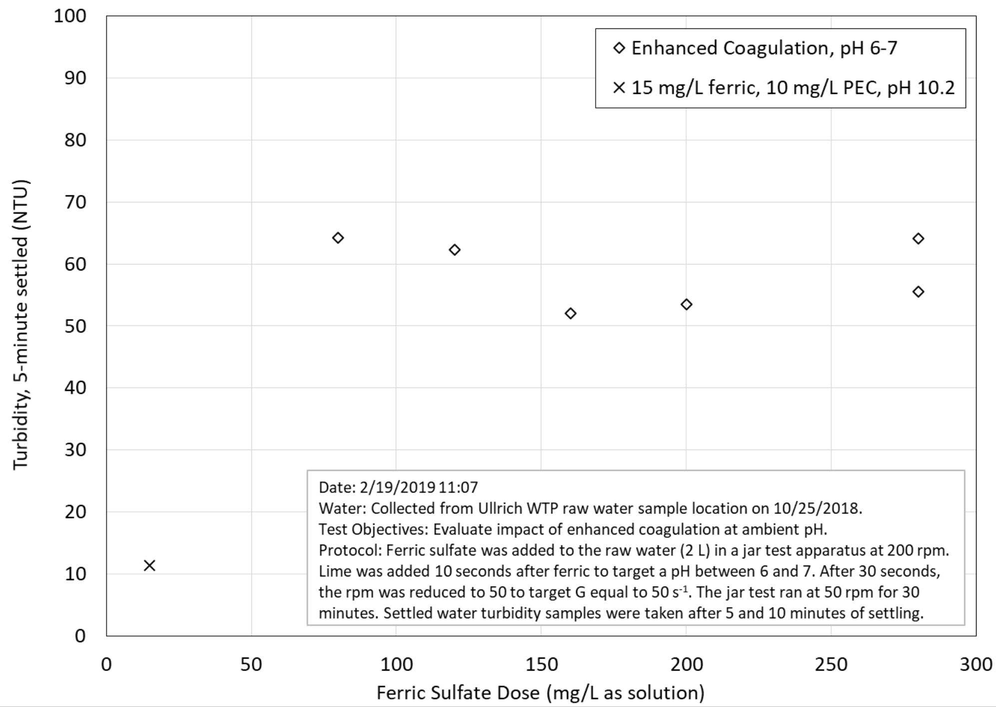


Figure 34 Impact of Ferric Sulfate Dose on Settled Turbidity at a Coagulation pH of 6-7

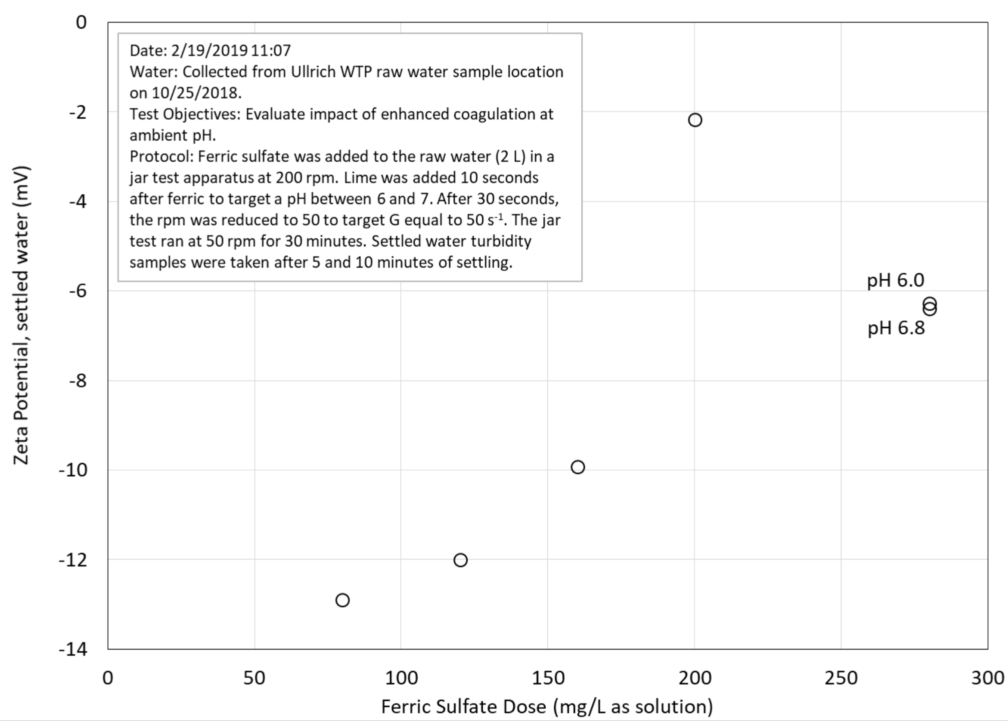


Figure 35 Impact of Ferric Sulfate Dose on Settled Zeta Potential at a Coagulation pH of 6-7

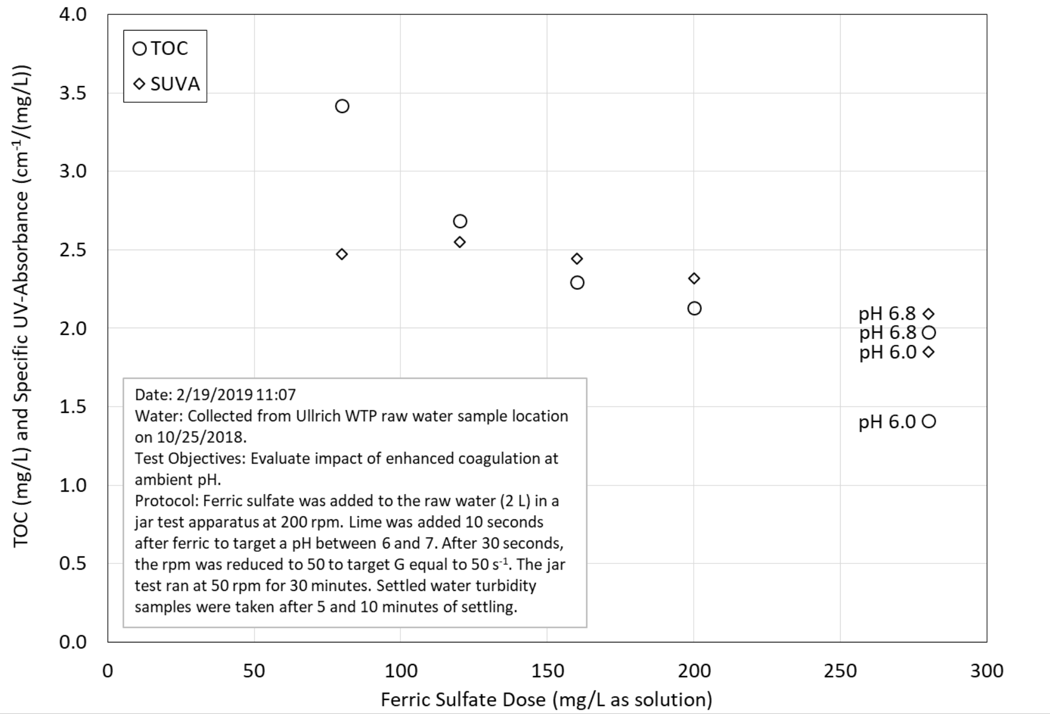


Figure 36 Impact of Ferric Sulfate Dose on TOC and SUVA at a Coagulation pH of 6-7

Operating with enhanced coagulation conditions would not be feasible at full-scale due to the required settling time of low specific gravity ferric hydroxide solids and high G-value imparted by the solids contact clarifiers at Ullrich and Handcox WTPs that demonstrate shearing of the ferric hydroxide solids. A lower mixing speed than typically targeted for the softening process would be needed to prevent shearing of the ferric hydroxide flocs. Lower surface loading rates of approximately 0.5 gpm/ft^2, which are more consistent with conventional coagulation operation, would be required, necessitating a significant reduction in flow and plant production capacity at the Ullrich and Handcox WTPs. Further, the WTPs would not be able to operate at the low pH required for effective enhanced coagulation with ferric sulfate without resulting in finished water quality that could destabilize pipe scales in the distribution system, unless sodium hydroxide was implemented at the end of the treatment process to raise the pH.

4.5 Summary

Bench testing was conducted to investigate the effectiveness of four potential treatment improvement strategies in treating raw water during a food event:

- Addition of coagulation aid polymer (PEC).
- Addition of flocculation aid polymer (PEA).
- Addition of carbon dioxide and sodium hydroxide.
- Enhanced coagulation without softening.

These strategies, excluding PEA addition, are compared to both typical operation (15 mg/L ferric sulfate; softening at pH 10.2) and the most effective strategy used full-scale during the flood event (80 mg/L ferric sulfate; softening at pH 11.0) in Figure 37. These jar tests results show the optimal strategy to treat challenging raw water during a flood event includes the addition of PEC (15 mg/L ferric sulfate; 10 mg/L PEC; softening at pH 10.2). Subsequent testing with PEA showed additional settleability benefits. Therefore, the following treatment approach is recommended to improve the settleability of the softening process during a flood event:

- Feeding ferric sulfate at doses typical of normal operation (i.e., 15 mg/L as solution).
- Feeding PEC 30 seconds or more after ferric sulfate to neutralize charge (i.e., 12 mg/L as solution for the polymer tested and the Banked Water).
- Softening at pH typical of normal operation (i.e., pH 10.0- 10.2).
- Feeding low doses of PEA to the centerwell of the solids contact clarifiers at Ullrich and Handcox WTPs (or to the flocculation basins at the Davis WTP) (i.e., bench testing showed improved settling at doses as low as 0.1 mg/L as solution).

Conceptually, this treatment strategy relies on lime addition to achieve softening and pH targets, iron addition for TOC removal, PEC for charge neutralization, and PEA for particle bridging. Testing also showed that PEC and PEA could be fed during normal operations and adjusted as required during a flood event. Additional discussion pertaining to operations during both normal and storm conditions are discussed in Section 6 of this report.

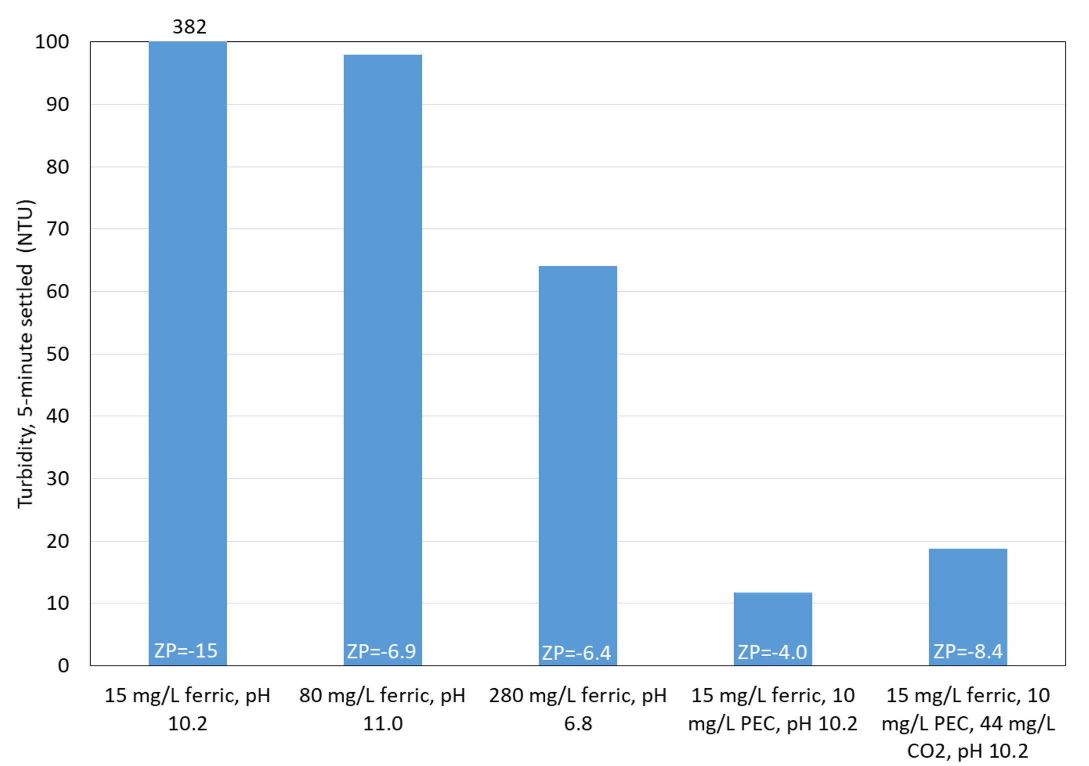


Figure 37 Summary of Settleability of Different Treatment Approaches

Section 5

IMPACT ON FINISHED WATER STABILITY

The City targets a finished water pH of approximately 9.6 or higher to minimize re-dissolution of pipe scales in the distribution system. Operation at this pH under typical finished water quality conditions (i.e., calcium and alkalinity concentrations) translates to an average calcium carbonate precipitation potential of 16 mg/L as $CaCO_3$[6]. The City adds sodium hexametaphosphate (SHMP) at the WTPs to sequester calcium and inhibit formation of calcium carbonate scale in the distribution system. Previous studies have indicated that the pipe scales are primarily composed of a magnesium silicate mineral identified as either chrysotile or lizardite[7,8]. Based on these characteristics, best practices to reduce the potential for a disruption in pipe scales are to:

- Avoid fluctuations in the finished water pH of more than 0.2 log units,
- Maintain a finished water CCPP close to 16 mg/L (by maintaining an elevated pH).
- Avoid disruptions in the solubility of the magnesium silicate scale, by avoiding significant pH changes (see first bullet) and changes in the finished water magnesium and silicate concentrations.

Table 6 lists the estimated finished water quality characteristics corresponding to the various operating scenarios that were implemented at full-scale during the October 2018 flood event and/or were tested in the laboratory on Banked Water as a potential option to respond to similar future extreme raw water quality events. All of the scenarios result in estimated finished water CCPP values in range of typical values at a finished water pH of 9.6.

Softening at a pH ≥ 10.8 results in lower finished water alkalinity relative to the scenarios where a softening pH closer to typical conditions (i.e., softening at pH 10 - 10.2) is targeted. Higher finished water alkalinity can be preferable since it provides buffering capacity and reduces potential impacts of chemical or microbial reactions (like nitrification) at the pipe surface.

Softening at higher pH also results in lower finished water magnesium (since magnesium is removed through $Mg(OH)_2$ precipitation) and slightly lower silicate concentrations (via co-precipitation with magnesium hydroxide). Combined, these finished water conditions could impact the solubility of the magnesium silicate scale in the distribution system. While modeling using MINEQL+ (or similar equilibrium chemistry software) may help elucidate the impact of the different operational scenarios on the solubility of the magnesium silicate scale, the comparative analysis illustrates the benefit of softening at pH 10 - 10.2 on finished water stability.

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[6] Alternative Process Evaluation for Austin's Water Treatment Plants, Final report submitted to the City of Austin, June 2017.

[7] Morabbi, M. and Clark, S. 1999. Methods for Assessing the Effects of pH Reduction on Lime Softening Distribution Systems." City of Austin Water and Wastewater Utility. Austin, Texas.

[8] Snoeyink, V.L. and Price, M. 1996. Assessment of pH, Corrosion and Scaling," Technical Memorandum prepared for the City of Austin - Water and Wastewater Utility, February 28, 1996.

Table 6 Impact of Flood Event Operations on Finished Water Quality

Parameter	Enhanced Softening (pH ≥ 10.8)	Softening at pH 10 - 10.2 with PEC	Softening at pH 10 - 10.2 with CO_2	Softening at pH 10 - 10.2 with CO_2 and NaOH	Historical Finished Water Average (2013-2015)
Plant Operation (Jar Test)	JT10-1	JT14-3	JT23-3	JT22-5	Lime Softening
Ferric sulfate dose, mg/L	80	15	15	15	15(2)
Initial CO_2 dose, mg/L	0	0	44	44	0
Settled pH	11.1	10.2	10.2	10.2	10.1(3)
Recarbonation CO_2 dose (1), mg/L	27	11	11	13	(4)
Post-recarbonation pH	9.6	9.6	9.6	9.6	9.6
Alkalinity, total, mg/L as $CaCO_3$	50	60	60	75	63
Calcium, total, mg/L	31	21	16	13	13
Magnesium, total, mg/L	2	7	6	6	16
SiO_2, total, mg/L	6	8	10	11	10(3)
LSI	1.4	1.3	1.1	1.1	1.1
CCPP, mg/L as $CaCO_3$	16	17	15	17	16

Note:
(1) Calculated using Rothberg, Tamburini and Winsor (RTW) Model for Corrosion Control and Process Chemistry.
(2) Approximate average operation.
(3) Source: Morabbi, M. and Clark, S. (1999). "Methods for Assessing the Effects of pH Reduction on Lime Softening Distribution Systems." City of Austin – Water and Wastewater Utility.
(4) Dosed to target post-recarbonation pH equal to 9.6.

Section 6

RECOMMENDED TREATMENT APPROACH

Additional tools to destabilize particles while minimizing solids, and forming dense, settleable solids would help the City be able to respond to a similar future event, potentially providing flexibility to operate closer to the rated capacity. The following WTP improvements are recommended:

- Provide the ability to add PEC upstream of softening at pH 10.2 (and to the filter influent to act as a filter aid polymer).

- PEC should be added after ferric sulfate, with the chemical addition points ideally separated by 30 seconds or greater.
- Measure zeta potential of settled water to confirm the PEC dose required to neutralize charge. Over time the correct zeta value will be determined but an initial target would be between - 4 and +4 mV.
- Provide the ability to add PEA to the center well of the upflow clarifier at doses ranging from 0.1 to 1 mg/L. This type of polymer requires activation.

Several additional operational scenarios were confirmed:

- Ferric sulfate addition at doses close to the typical operational condition is beneficial and should be maintained.
- Continue to soften at pH 10 - 10.2.
- Maintain solids in the center well since improved settling rates were observed in the iterative jar tests with Banked Water. PEA can provide additional settleability especially when solids in the center well cannot be maintained.

The tests with Banked Water also confirmed that the following scenarios are not preferred:

- Enhanced coagulation at lower pH (6-7).
- Enhanced softening (i.e., softening at pH > 10.8).
- Feeding CO_2 and caustic upstream of softening.

The recommended approach requires minimal WTP improvements and maintains operations (i.e., ferric sulfate and softening pH) near typical operation. Therefore, this approach is more easily implemented than strategies that would require a complete shift from normal operations. The recommended approach also results in finished water similar to that of typical operations with respect to pH and CCPP, thereby minimizing potential re-dissolution of existing scale in the distribution system.

The impact of an extreme rain event / flood can vary depending on the intensity, duration, and portion of the watershed that is affected. Thus, a critical step for the City's response to an event will be to test the raw water quality and use zeta potential to determine the optimal PEC dose since either underfeeding or overfeeding may result in poor performance. Those tests could be supplemented by jar testing with raw water and center well solids and/or close analysis of settled water turbidity and zeta potential, and filtered water turbidity, with incremental changes in PEC and PEA dose. These tests are recommended to inform plant operations since raw water quality likely deteriorates rapidly during a flood event and then improves slowly (i.e., weeks) after a storm passes through.

Appendix A

BENCH TESTING PROTOCOL

City of Austin
Process Treatment Recommendation
Resulting From October 2018 Flood Event

BENCH TESTING PROTOCOL

DRAFT FINAL | February 2019

carollo
TBPE No. F-882

City of Austin
Process Treatment Recommendation
Resulting from October 2018 Flood Event

BENCH TESTING PROTOCOL

DRAFT FINAL | February 2019

This document is released for the purpose of information exchange review and planning only under the authority of Phillip G. Pope, 02/06/2019, State of Texas PE# 104762.

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Section 1

PURPOSE AND OBJECTIVES

An extreme flood event in October 2018 dramatically changed the characteristics of the raw water supply to the City of Austin's three water treatment plants (WTPs). The change in water quality impacted the ability to treat the water to meet the finished water quality goals depending on the target plant production rate. Testing was conducted during the flood event both at bench- and full-scale to identify optimal operational conditions to keep the plants running to meet demands and TCEQ requirements. Tests focused on operational conditions that could be rapidly employed during the flood event and included an assessment of the optimal lime and ferric dose, sedimentation basin recirculation and blowdown rate, and the use of coagulant and flocculant aid polymers.

The City collected and stored 100 gallons of raw water on October 24, 2018 characterized by high turbidity and TOC, and low alkalinity and hardness. The City requested that Carollo Engineers, Inc. conduct testing on the banked water to meet the following objectives:

1) Further evaluate the optimal treatment approach during similar future challenge events, and
2) Identify potential facility improvements that would enhance the City's ability to respond to such events.

Testing will be completed in two phases. Phase 1 will consist of initial screening tests of various treatment strategies identified as potential approaches to respond to extreme raw water quality changes similar to the October 2018 event. Phase 2 will consist of additional testing to further vet promising alternatives identified in Phase 1 as well as additional strategies proposed based on the initial test results.

This document outlines the experimental matrix and approach for conducting the Phase 1 tests.

Section 2

EQUIPMENT

The following equipment will be provided by the University of Texas and will be used by Carollo Engineers, Inc. for the testing:

1. One (1) standard jar testing apparatus.
2. Twelve (12) 200 mL rectangular jars with specially constructed mixing paddles.
3. pH and temperature meter with electrode (buffers for 3-point calibration = 4.0, 7.0, 10.0).
4. Titration apparatus for alkalinity including prepared acid solution.
5. Spectrophotometer (Hach DR/4000 or equivalent) with cell for UV254 measurement.

6. ICP-OES for Ca, Mg, and Fe analysis and associated standard solutions for instrument calibration.
7. TOC analyzer and standard solutions for instrument calibration.
8. One (1) stir plate and various sized stir bars.
9. Cold storage space for up to 100 gallons of water in 20 L containers.
10. Trace metal grade nitric acid for preservation of samples for metals analysis.
11. Analytical grade phosphoric acid for preservation of TOC samples.
12. Analytical grade sodium hydroxide.
13. Analytical grade sodium bicarbonate.
14. Analytical grade hydrochloric acid.
15. Miscellaneous glassware.
16. Deionized water for miscellaneous lab use (up to 10 L).

The following equipment will be provided by Austin Water (AW) and will be used by Carollo Engineers, Inc. for the testing:

1. "Banked" raw water from during the water quality event.
2. Five (5) gallons of raw water sample to be used as representative of "typical" water quality.
3. Two (2) standard jar testing apparatuses.
4. Twelve (12) 2-L gator jars for use with the jar testing apparatuses.
5. Ferric sulfate.

The following equipment will be provided by Carollo Engineers, Inc. for the testing:

1. Turbidimeter (visible light) and sample cell.
2. Zetasizer and sample cell.
3. One (1) 10 mL autopipette with tips.
4. One (1) 1000 µL autopipette with tips.
5. Five hundred (500) 15 mL falcon tubes to be used as sample containers for use with ICP-OES.
6. One hundred forty four (144) 40 mL glass sample containers with PP caps and PTFE septa for use with TOC analyzer.
7. Analytical grade calcium hydroxide.
8. Six funnels (plastic).
9. Six 1000-mL plastic beakers.
10. Six 250-mL Erlenmeyer flask (plastic).
11. One hundred (100) 1-mL syringes.
12. One hundred (100) 3-mL syringes.
13. One hundred (100) 5-mL syringes.
14. One hundred (100) 10-mL syringes.
15. One hundred (100) 25-mm PES syringe filters (0.45 µm pore size).
16. Two timers.
17. One measuring spoon.
18. Paper towels.

Section 3

PROCEDURES

3.1 Jar Testing

Two types of tests will be conducted: water chemistry and charge tests, and settleability tests. Water chemistry tests will be conducted in specially constructed 200-mL jars with matching paddles. Water chemistry tests will be conducted to determine the effect of varying softening and coagulation conditions (i.e., lime and ferric dose) on precipitate characteristics (e.g., zeta potential and calculated composition and solids density) and settled water quality (i.e., pH, calcium, magnesium, alkalinity, and TOC concentrations, and UV254 absorbance).

Settleability tests will be conducted with a standard jar test apparatus with six rectangular 2-liter "gator" jars. This equipment uses previously developed relationships that correlate mixing energy with stirrer speed and water temperature (that is, velocity gradient (G)) at the bench-scale level (Figure 3.1). The specially designed gator jars have a sample tap located at a precise distance (10 cm) from the top of the water to allow the sampling of small quantities of settled water for turbidity measurements.

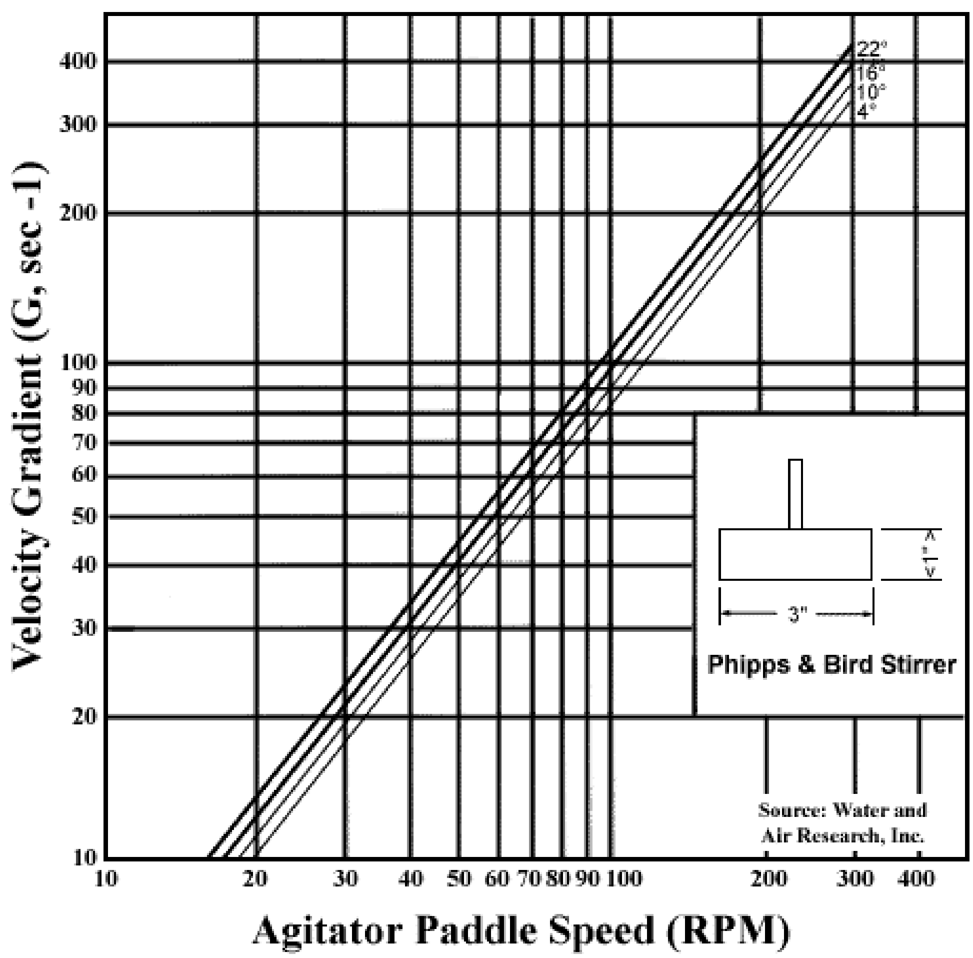

Figure 3.1 Velocity Gradient vs. RPM for 2 Liter Square Jars

The general methodology of the jar test procedure is outlined below:

- Stock solutions of primary treatment chemicals will be prepared as follows:
  - Lime slurry will be prepared by adding a specified mass of dry calcium hydroxide to 1 mL deionized water for the water chemistry tests (200 mL jars) and 10 mL deionized water for the settleability tests (2 L jars). Methods outlined in Roalson et al (2003) will be followed.
  - Ferric sulfate solution will be prepared from recent stocks obtained from the WTP.
  - Polymer solutions will be prepared from chemicals obtained from chemical vendors.
  - Caustic and sodium bicarbonate solutions will be prepared from reagent grade chemicals at UT Austin.
- 200 mL of raw water will be added to each jar for the water chemistry tests; two liters of raw water will be added to each jar for the settleability tests.
  - The jars will be flash mixed using a G value of 300 $seconds^{-1}$ for 30 seconds during which the chemicals will be dosed to each jar. The order of chemical addition will generally follow the sequencing illustrated in process flow diagrams from the November 26, 2018 meeting with the City and UT Austin. Additional details on timing of chemical addition are provided below for each set of tests.
- The mixing speed will then be reduced to simulate flocculation.
  - For most tests, flocculation conditions will be as follows:
    - G = X sec^{-1} simulating the typical recirculation speed in the solids contact clarifiers at Ullrich WTP.
    - Three stage tapered flocculation to simulate conditions at the Davis WTP. The flocculation conditions at the Davis WTP will be simulted for a majority of the testing since the jars cannot directly simulate the age, growth, and resulting composition of solids that form in the solids contact clarifiers used at Ullrich and WTP4. The flocculation conditions at Davis include:
      - Stage 1: 80 sec^{-1}
      - Stage 2: 65 sec^{-1}
      - Stage 3: 56 sec^{-1}
    - 30 minutes, consistent with the floc basin detention time at Davis WTP at design flow. The flocculation time for Davis WTP is used since the jars cannot directly simulate the age, growth, and resulting composition of solids that form in the solids contact clarifiers used at Ullrich and WTP4.
  - For tests evaluating the impact of flocculation conditions, the mixing speed and duration will be varied as described in Section 3.6.
- The mixing will then be stopped and the water will be gravity settled for 30 minutes in the 200 mL jars and for 5 to 10 minutes in the 2 L jars.
- Following settling, water will be collected through the sampling port and analyzed for turbidity and other water quality parameters. For the 2 L jars, turbidity samples will be taken at 5 and 10 minutes following cessation of fluid rotation and start of settling. The jars used for the testing have a sample tap located 10 cm from the top of the water to allow the sampling of small quantities of settled water for turbidity measurements. The location of the sample tap allows the theoretical surface loading rate of the sedimentation to be estimated. Table 3.1 shows the settling time versus simulated surface loading rate.

Table 3.1 Simulated Surface Loading Rate for Jar Testing - 2 L jars

Settling Time (minutes)	Simulated Surface Loading Rate (gpm/ft2)
5	0.49
10	0.25

Notes:
(1) Sample point located 10 cm below the water surface.

Table 3.2 lists the parameters that will be analyzed in settled water from the jar tests. The experimental matrix for each set of jar tests is provided in the following sections.

Table 3.2 General Settled Water Quality for Jar Testing

Parameter	Laboratory Requirements	Sample Volume Requirement
pH(1)	UT	100 mL
UV254(2)	UT	30 mL
TOC(3)	UT	50 mL
Metals via ICP-OES (Ca, Mg, and Fe)	UT	10 mL
Alkalinity	UT	100 mL
Zeta Potential	UT	5 mL
Turbidity	UT	50 mL
SUVA(3)	Calculation	N/A
Solids Density/Mass	Calculation	N/A
Finished Water Stabilization Requirements	Calculation	N/A
Total sample volume required(4)	-	245 mL

Notes:
(1) Measured in the same volume of sample used for alkalinity analysis.
(2) UV254 will be measured on samples that have been filtered through 0.45 µm syringe filters that have been pre-rinsed with deionized water.
(3) Not included for 200 mL jars due to sample volume constraints; TOC will be used for calculation.
(4) Total volume is for 2 L jars. Volume assumes pH and alkalinity measured from same sample volume. Sample volume requirements for 200 mL jars approximately 195 mL if TOC is not measured.

3.2 Baseline Testing

Testing will be conducted to:

- Determine operational baseline with typical water quality treated with an average ferric sulfate dose while varying pH (Test 1).
- Assess softening chemistry during flood event, identifying lime doses corresponding to the minimum calcium concentration and point of magnesium hydroxide precipitation (Test 2).
- Evaluate the impact of ferric addition at lime doses bracketing the softening conditions targeted during the October 2018 flood event (pH ~10.2 and 11) (Test 3 and 4).
- Evaluate the impact of softening at optimal ferric doses on settleability using 2 L jars (Test 5).
- Evaluate impact of enhanced coagulation at ambient pH (Test 6).

The analytical results will be reviewed for:

- Settled water quality, specifically, pH, alkalinity, calcium, and magnesium concentration, UV254, and turbidity.
- Precipitate charge, composition (based on a mass balance of raw and settled water quality), and density (calculated).
- Potential need for post-stabilization under the varying conditions based on calculated values for CCPP and LSI.

Tests 3 - 6 are similar to the tests conducted during the October 2018 flood event (presented during the November 8, 2018 meeting at Ullrich WTP with the City and UT Austin) and focus on confirming previous findings and carefully evaluating the softening chemistry corresponding to the varying operational conditions. While the primary focus of the Phase 1 and 2 bench tests is to identify alternate approaches to flood event response for the City's water treatment plants than those employed during the October 2018 event (which were already demonstrated), Tests 3 - 6 are included as a starting point to fully assess the softening chemistry and precipitate characteristics under the range of ferric and lime doses that could be employed. The results are expected to provide a baseline of the particle density, charge, and settleability that could be achieved with the current "knobs" that the City can turn, and then use that data to compare alternate approaches to be evaluated in subsequent tests.

Details for each test are provided in Table 3.3 to Table 3.7. In all of the tests, ferric will be added approximately 5 seconds before lime.

Table 3.3 Test 1 - Operational Baseline at Typical Water Quality (200 mL jars)

Jar	Lime Dose (mg/L) (1)	Ferric Sulfate Dose(2) (mg/L)	Target pH	Settling Test
1	0	AVG	Ambient	-
2	30	AVG		-
3	60	AVG	-	-
4	100	AVG	-	-
5	130	AVG	-	-
6	160	AVG	-	-
7	185	AVG	-	-
8	210	AVG	-	-
9	235	AVG	-	-
10	260	AVG	-	-
11	285	AVG	11.5	-
12 (dupl)	160	AVG	-	-

Notes:
(1) Lime doses target increased resolution around anticipated points of minimum calcium and magnesium hydroxide precipitation. Dose range will be selected based on a target pH range and corresponding lime dose estimated from a softening chemistry model. The doses shown are based on data from Roalson et al. (2003) and Kalscheur et al. (2006) and will be updated based on the raw water characterization of the typical water quality.
(2) Dosed as solution. Based on current operating conditions.

Table 3.4 Test 2 - Impact of pH on Banked Water (200 mL jars)

Jar	Lime Dose (1) (mg/L)	Ferric Sulfate Dose(2) (mg/L)	Target pH	Settling Test
1	0	0	Ambient	-
2	30	0		-
3	60	0		-
4	100	0		-
5	130	0		-
6	160	0		-
7	185	0		-
8	210	0		-
9	235	0		-
10	260	0		-
11	285	0	11.5	-
12 (dupl)	160	0		-

Notes:
(1) Lime doses target increased resolution around anticipated points of minimum calcium and magnesium hydroxide precipitation. Dose range will be selected based on a target pH range and corresponding lime dose estimated from a softening chemistry model. The doses shown are based on data from Roalson et al. (2003) and Kalscheur et al. (2006) and will be updated based on the raw water characterization of the banked water quality.
(2) Dosed as solution.

Table 3.5 Test 3 - Impact of Ferric Dose Bracketing Softening Conditions Around pH 10.2 and 11: Lower Fe doses (200 mL jars)

Jar	Lime Dose (mg/L)	Ferric Sulfate Dose(1) (mg/L)	Target pH	Settling Test
1	TBD	30	9.6	-
2	TBD	30	10	-
3	TBD	30	10.2	-
4	TBD	30	10.4	-
5	TBD	30	10.8	-
6	TBD	30	11.2	-
7	TBD	60	9.6	-
8	TBD	60	10	-
9	TBD	60	10.2	-
10	TBD	60	10.4	-
11	TBD	60	10.8	-
12	TBD	60	11.2	-

Notes:
(1) Dosed as solution.

Table 3.6 Test 4 - Impact of Ferric Dose Bracketing Softening Conditions Around pH 10.2 and 11: Higher Fe doses (200 mL jars)

Jar	Lime Dose (mg/L)	Ferric Sulfate Dose[1] (mg/L)	Target pH	Settling Test
1	TBD	90	9.6	-
2	TBD	90	10	-
3	TBD	90	10.2	-
4	TBD	90	10.4	-
5	TBD	90	10.8	-
6	TBD	90	11.2	-
7	TBD	180	9.6	-
8	TBD	180	10	-
9	TBD	180	10.2	-
10	TBD	180	10.4	-
11	TBD	180	10.8	-
12	TBD	180	11.2	-

Notes:
(1) Dosed as solution.

Table 3.7 Test 5 - Settleability Test at Optimal Softening Range and Ferric Dose (2 L jars)

Jar	Lime Dose (mg/L)	Ferric Sulfate Dose[1] (mg/L)	Target pH	Settling Test
1	TBD	Low (TBD)	9.7	X
2	TBD	Low (TBD)	10.0	X
3	TBD	Low (TBD)	10.3	X
4	TBD	Low (TBD)	10.6	X
5	TBD	Low (TBD)	10.9	X
6	TBD	Low (TBD)	11.2	X
7	TBD	High (TBD)	9.7	X
8	TBD	High (TBD)	10.0	X
9	TBD	High (TBD)	10.3	X
10	TBD	High (TBD)	10.6	X
11	TBD	High (TBD)	10.9	X
12	TBD	High (TBD)	11.2	X

Notes:
(1) Dosed as solution. Based on current operating conditions.

Table 3.8 Test 6 - Impact of Enhanced Coagulation at Baseline Mixing Speed (2 L jars)

Jar	Lime Dose (mg/L)	Ferric Sulfate Dose(1) (mg/L)	Target pH	Settling Test
1	0	120	Ambient	X
2	0	160	Ambient	X
3	0	200	Ambient	X
4	0	240	Ambient	X
5	0	280	Ambient	X
6	TBD	120	8 - 8.5	X
7	TBD	160	8 - 8.5	X
8	TBD	200	8 - 8.5	X
9	TBD	280	8 - 8.5	X

Notes:
(1) Dosed as solution. Target dose range will be confirmed based on a charge titration. During the October 2018 flood event, approximately 300 mg/L ferric as solution was required to neutralize the charge of particles in solution.

3.3 Coagulant Aid Polymer Testing

Coagulant aid polymer will be tested in banked water at two pH values, 10.2 to represent optimum softening conditions, and 11.2 to represent enhanced softening conditions. Tests utilizing coagulant aid polymer will be conducted to evaluate the following:

- Determine the coagulant aid polymers which best neutralize charge.
- Determine the effect of coagulant aid polymers on settleability of banked water at average ferric sulfate dose and pH 10.2 and 11.0.
- Determine the effect of coagulant aid polymers on settleability of banked water at varying ferric sulfate dose and pH 10.2.

Test number 1 will consist of titrations of banked water with coagulant aid polymer and ferric sulfate to determine the concentration of each chemical required to neutralize the charge of the particles in the banked water. The two polymers which neutralize the most charge per unit mass will be utilized in jar tests to determine their overall effect on settleability. Titrations of banked water with ferric sulfate, and the order of chemical addition will also be evaluated. Titration testing includes:

- Polymer A.
- Polymer B.
- Polymer C.
- Ferric Sulfate.
- Optimum polymer dose added 30 seconds before ferric sulfate.
- Optimum polymer dosed 1.5 minutes after ferric sulfate.
- Simultaneous addition of optimum polymer and ferric sulfate.
- Ferric sulfate dosed 30 seconds before polymer.

Tests 2 through 6 will be jar tests to determine the effect of coagulant aid polymer on the settleability of banked water. For Tests 2- 5, coagulant aid polymer will be added first at initiation of rapid mix. Ferric will be added approximately 5 seconds after polymer and lime will be added approximately 5 seconds after ferric. Test 6 will investigate alternate orders and timing of chemical addition.

The following parameters will be measured after settling in each jar:

- pH.
- UV-254.
- TOC.
- Metals by ICP-OES (Ca, Mg, and Fe).
- Alkalinity.
- Turbidity.
- Zeta potential.

Details for each test are provided in Table 3.9 to Table 3.13 Settling tests described above will also be conducted.

Table 3.9 Test 2 - Coagulant Aid Polymer A at Typical Ferric Sulfate Dose and pH 10.2 (2 L jars)

Jar	Lime Dose (mg/L)	Ferric Sulfate Dose(1) (mg/L)	Target pH	Polymer Type(2)	Polymer Dose(3) (mg/L)	Settling Test
1	TBD	Avg (TBD)	10.2	A	0	X
2	TBD	Avg (TBD)	10.2	A	TBD	X
3	TBD	Avg (TBD)	10.2	A	TBD	X
4	TBD	Avg (TBD)	10.2	A	TBD	X
5	TBD	Avg (TBD)	10.2	A	TBD	X
6	TBD	Avg (TBD)	10.2	A	TBD	X

Notes:
(1) Dosed as solution. Based on current operating conditions.
(2) Polymer type may be changed based on titration tests.
(3) Dosed as solution.

Table 3.10 Test 3 - Coagulant Aid Polymer B at Typical Ferric Sulfate Dose and pH 10.2 (2 L jars)

Jar	Lime Dose (mg/L)	Ferric Sulfate Dose(1) (mg/L)	Target pH	Polymer Type(2)	Polymer Dose(3) (mg/L)	Settling Test
1	TBD	Avg (TBD)	10.2	B	TBD	X
2	TBD	Avg (TBD)	10.2	B	TBD	X
3	TBD	Avg (TBD)	10.2	B	TBD	X
4	TBD	Avg (TBD)	10.2	B	TBD	X
5	TBD	Avg (TBD)	10.2	B	TBD	X
6	TBD	Avg (TBD)	10.2	B	TBD	X

Notes:
(1) Dosed as solution. Based on current operating conditions.
(2) Polymer type may be changed based on titration tests.
(3) Dosed as solution.

Table 3.11 Test 4 - Coagulant Aid Polymer A at Typical Ferric Sulfate Dose and pH 11.0 (2 L jars)

Jar	Lime Dose (mg/L)	Ferric Sulfate Dose(1) (mg/L)	Target pH	Polymer Type	Polymer Dose(2) (mg/L)	Settling Test
1	TBD	Avg (TBD)	11.0	--	0	X
2	TBD	Avg (TBD)	11.0	OPT(TBD)	TBD	X
3	TBD	Avg (TBD)	11.0	OPT(TBD)	TBD	X
4	TBD	Avg (TBD)	11.0	OPT(TBD)	TBD	X
5	TBD	Avg (TBD)	11.0	OPT(TBD)	TBD	X
6	TBD	Avg (TBD)	11.0	OPT(TBD)	TBD	X

Notes:
(1) Dosed as solution. Based on current operating conditions.
(2) Dosed as solution.

Table 3.12 Test 5 - Coagulant Aid Polymer Offset at Varying Ferric Sulfate Doses and pH 10.2 (2 L jars)

Jar	Lime Dose (mg/L)	Ferric Sulfate Dose(1) (mg/L)	Target pH	Polymer Type(4)	Polymer Dose(5) (mg/L)	Settling Test
1	TBD	0	10.2	A	TBD	X
2	TBD	Mid (TBD)(2)	10.2	A	TBD	X
3	TBD	High (TBD)(3)	10.2	A	TBD	X
4	TBD	0	10.2	B	TBD	X
5	TBD	Mid (TBD)(2)	10.2	B	TBD	X
6	TBD	High (TBD)(3)	10.2	B	TBD	X

Notes:
(1) Dosed as solution. Based on current operating conditions.
(2) Approximately 2x the average plant dose.
(3) Approximately 5-10x the average plant dose. TBD based on results from Baseline Testing.
(4) Polymer type may be changed based on titration tests.
(5) Dosed as solution.

Table 3.13 Test 6 - Coagulant Aid Polymer with and without Ferric Sulfate Varying Addition Sequence and Duration Between Chemical Addition (2 L jars)

Jar	Lime Dose (mg/L)	Ferric Sulfate Dose(1) (mg/L)	Target pH	Polymer Type	Polymer Dose(3) (mg/L)	Settling Test
1	TBD	0	Opt(2)	A(8)	TBD	X
2	TBD	0	Opt(2)	B(8)	TBD	X
3(4)	TBD	0	Opt(2)	A(8)	TBD	X
4(5)	TBD	Opt	Opt(2)	A(8)	TBD	X
5(6)	TBD	Opt	Opt(2)	A(8)	TBD	X
6(7)	TBD	0	Opt(2)	A(8)	TBD	X

Notes:
(1) Dosed as solution. Optimal dose determined during previous testing.
(2) Optimal pH determined during previous testing.
(3) Optimal dose determined during previous testing.
(4) Polymer to be added 30-60 seconds before lime addition.
(5) Polymer to be added 90 seconds after ferric sulfate addition. Lime to be added 30 seconds after polymer.
(6) Polymer to be added after ferric sulfate and at the same time as lime.
(7) Polymer to be added at the same time as lime.
(8) Polymer type may be changed based on results from previous testing.

3.4 CO_2 and NaOH Addition Testing

One issue during the flood event was the alkalinity and hardness of the raw water dropped well below historical norms and the turbidity increased significantly, resulting in little carbonate available for precipitation as $CaCO_3$ solids and a significant increase in source water solids. A possible remedy for such water quality is addition of carbonate to the raw water prior to flocculation and sedimentation. One method of adding carbonate at all three Austin water treatment plants is to add a CO_2 feed point upstream of the flocculation process. CO_2 is already used in the recarbonation step of the treatment process. CO_2 could be added alone or in conjunction with sodium hydroxide (NaOH), which would also add alkalinity. Soda ash was also considered for testing but was not included because it can inhibit organics removal and result in an increased number of negatively charged particles, which is the opposite of the goal of this testing.

This set of tests will be initiated by modeling target conditions for CO_2 addition with and without NaOH addition, factoring in impact on solids concentration and density. Jar tests will then be conducted to simulate:

- The impact on settlability of banked water when adding carbonate in the form of CO_2 to precipitate more $CaCO_3$ solids.
- The impact on settleability of banked water when adding CO_2 and NaOH to generate more alkalinity and precipitate more $CaCO_3$ solids.

The addition of CO_2 will be simulated through the addition of sodium bicarbonate ($NaHCO_3$) and acid (hydrochloric or sulfuric). The acid will be dosed to simulate the pH anticipated from adding CO_2. The required acid dose will be determined based on Rothberg, Tamburini, and Winsor (RTW) modeling. The following parameters will be measured after settling in each jar:

- pH.
- UV-254.
- TOC.
- Metals by ICP-OES (Ca, Mg, and Fe).
- Alkalinity.
- Turbidity.
- Zeta potential.

Details for each jar test are outlined in Table 3.14 to Table 3.18. Settling tests will also be conducted as described above.

Prior to conducting the jar tests with CO_2 and NaOH, preliminary tests will be conducted to evaluate the affect of the order of CO_2, NaOH, ferric, and lime addition on the zeta potential of settled water. The order of chemical addition to be evaluated takes into account what is feasible at the WTPs based on current process configurations. The specific conditions for the jar test are oulined in Table 3.14, and the order of chemical addition is outlined below.

- Jar 1: CO_2 → Ferric → Caustic → Lime
- Jar 2: CO_2 → Ferric → Caustic & Lime
- Jar 3: CO_2 → Caustic → Ferric → Lime

Results will be discussed with the Project Team to determine preferred order of chemical addition for Tests 2 through 5 below.

Jar tests 2 and 3 will be conducted using the 200 mL jars to confirm water chemistry. Tests 4 and 5 will then be conducted with the 2 L jars to test settleability based on target conditions from the previous two tests.

Note: Since CO_2 will depress the pH, it should be added after chloramines have formed to avoid dichloramine formation and degradation of the disinfectant residual.

Table 3.14 Test 1 - Assessment the Order of Chemical Addition on Settled Water with CO_2 and NaOH (2 L jars)

Jar	Lime Dose (mg/L)	Ferric Sulfate Dose(1) (mg/L)	Target pH	CO_2 Addition(2)	NaOH (mg/L)	Settling Test
1	TBD	Avg	TBD	X	TBD	X
2	TBD	Avg	TBD	X	TBD	X
3	TBD	Avg	TBD	X	TBD	X
4(3)	TBD	TBD	TBD	TBD	TBD	-
5(3)	TBD	TBD	TBD	TBD	TBD	-
6(3)	TBD	TBD	TBD	TBD	TBD	-

Notes:
(1) Dosed as solution.
(2) Sodium bicarbonate will be added in eq/L to precipitate excess calcium. X is the difference in calcium carbonate precipitated under typical conditions relative to the amount precipitated during the flood event without the addition of excess carbonate to facilitate precipitation of additional solids
(3) No tests currently planned for jars 4 through 6. Discussions with the project team may determine additional jars are needed.

Table 3.15 Test 2 - Initial Assessment of Water Chemistry with CO_2 (200 mL jars)

Jar	Lime Dose (mg/L)	Ferric Sulfate Dose(1) (mg/L)	Target pH	CO_2 Addition(2)	NaOH (mg/L)	Settling Test
1	TBD	Avg (or zero)	10.2	0	0	-
2	TBD	Avg (or zero)	10.2	0.3X	0	-
3	TBD	Avg (or zero)	10.2	0.6X	0	-
4	TBD	Avg (or zero)	10.2	1.0X	0	-
5	TBD	Avg (or zero)	TBD(3)	0	0	-
6	TBD	Avg (or zero)	TBD	0.3X	0	-
7	TBD	Avg (or zero)	TBD	0.6X	0	-
8	TBD	Avg (or zero)	TBD	1.0 X	0	-
9	TBD	TBD	TBD	TBD	0	-
10	TBD	TBD	TBD	TBD	0	-
11	TBD	TBD	TBD	TBD	0	-
12	TBD	TBD	TBD	TBD	0	-

Notes:
(1) Dosed as solution.
(2) Sodium bicarbonate will be added in eq/L to precipitate excess calcium. X is the difference in calcium carbonate precipitated under typical conditions relative to the amount precipitated during the flood event without the addition of excess carbonate to facilitate precipitation of additional solids
(3) A slightly higher pH corresponding to minimal calcium concentrations but below the point of magnesium hydroxide addition will be targeted.

Table 3.16 Test 3 - Initial Assessment of Water Chemistry with NaOH and CO_2 (200 mL jars)

Jar	Lime Dose (mg/L)	Ferric Sulfate Dose(1) (mg/L)	Target pH	CO_2 Addition(2)	NaOH (mg/L)	Settling Test
1	TBD	Avg (or zero)	10.2	0	0	-
2	TBD	Avg (or zero)	10.2	0.3X	TBD	-
3	TBD	Avg (or zero)	10.2	0.6X	TBD	-
4	TBD	Avg (or zero)	10.2	1.0X	TBD	-
5	TBD	Avg (or zero)	TBD(3	0	0	-
6	TBD	Avg (or zero)	TBD	0.3X	TBD	-
7	TBD	Avg (or zero)	TBD	0.6X	TBD	-
8	TBD	Avg (or zero)	TBD	1.0 X	TBD	-
9	TBD	TBD	TBD	TBD	TBD	-
10	TBD	TBD	TBD	TBD	TBD	-
11	TBD	TBD	TBD	TBD	TBD	-
12	TBD	TBD	TBD	TBD	TBD	-

Notes:
(1) Dosed as solution.
(2) Sodium bicarbonate will be added in eq/L to precipitate excess calcium. X is the difference in calcium carbonate precipitated under typical conditions relative to the amount precipitated during the flood event without the addition of excess carbonate to facilitate precipitation of additional solids
(3) A slightly higher pH corresponding to minimal calcium concentrations but below the point of magnesium hydroxide addition will be targeted.

Table 3.17 Test 4 - Evaluate the Impact of Adding CO_2 to precipitate more $CaCO_3$ solids (2 L jars)

Jar	Lime Dose (mg/L)	Ferric Sulfate / Polymer Dose(1) (mg/L)	Target pH	CO_2 Addition(2)	NaOH (mg/L)	Settling Test
1	TBD	Opt (TBD)	Opt (TBD)	Ca Precip	0	X
2	TBD	Opt (TBD)	Opt (TBD)	Ca Precip	0	X
3	TBD	Opt (TBD)	Opt (TBD)	Ca Precip	0	X
4	TBD	Opt (TBD)	Opt (TBD)	Ca Precip	0	X
5	TBD	Opt (TBD)	Opt (TBD)	Ca Precip	0	X
6	TBD	Opt (TBD)	Opt (TBD)	Ca Precip	0	X

Notes:
(1) Dosed as solution.
(2) Sodium bicarbonate will be added in eq/L to precipitate excess calcium.

Table 3.18 Test 5 - Evaluate the Impact of Adding NaOH and CO_2 (2 L jars)

Jar	Lime Dose (mg/L)	Ferric Sulfate / Polymer Dose(1) (mg/L)	Target pH	CO_2 Addition(2)	NaOH (mg/L)	Settling Test
1	TBD	Opt (TBD)	Opt (TBD)	Ca Precip	TBD	X
2	TBD	Opt (TBD)	Opt (TBD)	Ca Precip	TBD	X
3	TBD	Opt (TBD)	Opt (TBD)	Ca Precip	TBD	X
4	TBD	Opt (TBD)	Opt (TBD)	Ca Precip	TBD	X
5	TBD	Opt (TBD)	Opt (TBD)	Ca Precip	TBD	X
6	TBD	Opt (TBD)	Opt (TBD)	Ca Precip	TBD	X

Notes:
(1) Dosed as solution.
(2) Sodium bicarbonate will be added in eq/L to precipitate excess calcium.

3.5 Flocculant Aid Polymer Testing

Tests on banked water utilizing flocculant aid polymer will be conducted to evaluate its effect on the settleability of banked water utilizing the optimal ferric sulfate and coagulant aid polymer doses determined in previous tests. Flocculent aid polymer will be activated in distilled water up to 12 hours prior to use. Fresh polymer dosing solutions will be prepared each day. Flocculent aid polymer will be added toward the middle of the flocculation period in order to allow for the formation of larger particles prior to polymer addition. Results from each test will be used to inform the experimental parameters of subsequent tests. The tests will be conducted at the following conditions:

- Enhanced softening conditions - pH 11.0.
- Optimal softening conditions - pH 10.2.
- Enhanced coagulation conditions - pH 8.0-8.5.

The following parameters will be measured after settling in each jar:

- pH.
- UV-254.
- TOC.
- Ca.
- Mg.
- Alkalinity.
- Turbidity.
- Zeta potential.

Details for each test are outlined in Table 3.19 to Table 3.22. Settling tests described above will also be conducted.

Table 3.19 Test 1 - Flocculent Aid Polymer Evaluation

Jar	Ferric Sulfate Dose(1) (mg/L)	Target pH(2)	Coag Polymer Type(1)	Coag Polymer Dose(1) (mg/L)	Floc Polymer Type	Floc Polymer Dose(3) (mg/L)	Settling Test
1	TBD	11.0	--	--	--	0	X
2	TBD	11.0	--	--	A	TBD	X
3	TBD	11.0	--	--	B	TBD	X
4	TBD	10.2	--	--	--	TBD	X
5	TBD	10.2	--	--	A	TBD	X
6	TBD	10.2	--	--	B	TBD	X

Notes:
(1) Optimized from previous testing.
(2) Lime dose optimized from previous testing to achieve target pH
(3) Dosed as solution; Maximum NSF dose for each polymer will be used.

Table 3.20 Test 2 - Flocculent Aid Polymer Evaluation

Jar	Ferric Sulfate Dose(1) (mg/L)	Target pH(2)	Coag Polymer Type(1)	Coag Polymer Dose(1) (mg/L)	Floc Polymer Type	Floc Polymer Dose(3) (mg/L)	Settling Test
1	TBD	10.2	A or B	TBD	A	0	X
2	TBD	10.2	A or B	TBD	B	TBD	X
3	TBD	11.0	A or B	TBD	A	TBD	X
4	TBD	11.0	A or B	TBD	B	TBD	X
5							
6							

Notes:
(1) Optimized from previous testing.
(2) Lime dose optimized from previous testing to achieve target pH
(3) Dosed as solution.

Table 3.21 Test 3 - Flocculent Aid Polymer Evaluation at Enhanced Coagulation Conditions

Jar	Ferric Sulfate Dose(1) (mg/L)	Target pH(2)	Coag Polymer Type(1)	Coag Polymer Dose(1) (mg/L)	Floc Polymer Type	Floc Polymer Dose(3) (mg/L)	Settling Test
1	TBD	8.0-8.5	--	--	A	0	X
2	TBD	8.0-8.5	--	--	A	TBD	X
3	TBD	8.0-8.5	--	--	A	TBD	X
4	TBD	8.0-8.5	--	--	B	TBD	X
5	TBD	8.0-8.5	--	--	B	TBD	X
6	TBD	8.0-8.5	A or B	TBD	B	TBD	X

Notes:
(1) Optimized from previous testing.
(2) Lime dose optimized from previous testing to achieve target pH
(3) Dosed as solution.

Table 3.22 Test 4 - Flocculent Aid Polymer Evaluation with Optimized CO_2 NaOH Doses

Jar	Ferric Sulfate Dose(1) (mg/L)	Target pH(1)	Coag Polymer Dose(1) (mg/L)	Floc Polymer Type	Floc Polymer Dose (mg/L)	CO_2 Addition(1)	NaOH(1) (mg/L)	Settling Test
1	TBD	TBD	TBD	A	0	TBD	TBD	X
2	TBD	TBD	TBD	A	TBD	TBD	TBD	X
3	TBD	TBD	TBD	A	TBD	TBD	TBD	X
4	TBD	TBD	TBD	B	TBD	TBD	TBD	X
5	TBD	TBD	TBD	B	TBD	TBD	TBD	X
6	TBD	TBD	0	B	TBD	TBD	TBD	X

Notes:
(1) Optimized from previous testing.

3.6 Mixing Rate Testing

The final set of tests for Phase 1 testing will explore the effect of mixing rate, or the velocity gradient (G), on the settleability of coagulated solids. The tests will evaluate the effect of mixing rate on the settleability of solids formed under the following conditions:

- Ferric sulfate coagulation at optimal coagulation conditions (e.g., pH~8) with no polymer addition.
- Enhanced softening at pH~11, potentially with and without polymer addition pending findings from previous tests.

Water chemistry analyses will not be conducted as the purpose of the tests are to evaluate settleability only. Velocity gradients at the existing WTPs will be verified and used as the baseline for conducting the tests. Additional test will be run at optimal mixing speeds to determine impacts on settling, focusing primarily on lower mixing speeds to avoid floc shear when targeting ferric hydroxide and magnesium hydroxide floc formation.

Section 4

SOURCE WATER QUALITY

The parameters listed in Table 4.1 will be measured to characterize the source water quality. In addition to the samples analyzed at AWU, samples will also be analyzed at UT for the following parameters to serve as a quality management check on the equipment and methods:

- pH.
- UV254.
- TOC.
- Calcium.
- Magnesium.
- Iron.
- Alkalinity.

Table 4.1 Source Water Quality

Parameter	Laboratory Requirements
Temperature	On-site
pH	On-site
Alkalinity	AW
Hardness	AW
Calcium	AW
Magnesium	AW
Turbidity	On-site
TOC	AW
DOC	AW
UV254	On-site
Fe, total	AW
Fe, dissolved	AW
Mn, total	AW
Mn, dissolved	AW
Ammonia	AW
Chloride	AW
Fluoride	AW
Sulfate	AW
TDS	AW
Color	AW
Bromide	AW
Silica	AW
Zeta Potential	On-site

Appendix B

SPLIT SAMPLING ANALYTICAL RESULTS

Table B.1 Flood Event and January 2019 Water Quality - Split Sampling

Parameter	Jan. 2019 AWU Lab Results	Jan. 2019 UT Lab Results	Banked Water AWU Lab Results	Banked Water UT Lab Results
Sample Date	1/31/19	1/31/19	10/25/18	10/25/18
pH	8.17	8.09	8.04	8.04
Turbidity, NTU	3.65	3.56	117	148
Alkalinity, mg/L as $CaCO_3$	157	160	102	105
Calcium, mg/L	46	45	30	36
Magnesium, mg/L	16	17	5	8
Iron, total, mg/L	0.104	NA	4.13	3.71
Iron, dissolved, mg/L	< 0.005	NA	0.011	0.02
Silica, mg/L	8.99	NA	8.1	7.6
TOC, mg/L	3.58	3.74	5.75	5.66
DOC, mg/L	3.46	NA	3.40	NA

Notes:
(1) NA = Not analyzed.

Appendix C

BASELINE TESTING

Figure C.1 shows the settled water pH for the range of lime doses evaluated using both the Typical Water (collected 2/13/19) and the Banked Water (collected 10/25/18). As expected, the pH increased with increasing lime dose.[9] A slightly lower lime dose was required to achieve the same settled water pH in Banked Water compared to Typical Water, reflecting the lower alkalinity in the Banked Water. For example, a lime dose of less than 60 mg/L as CaO resulted in a settled water pH above 10.2 in the Banked Water whereas close to 120 mg/L of CaO was required to achieve a similar settled water pH in the Typical Water.

Figure C.2 shows the calcium concentrations with increasing settled water pH for both Typical and Banked Water, with (Part A) and without (Part B) ferric sulfate addition at the dose typically applied at Ullrich WTP (i.e., 15 mg/L as product). As expected, a lower softening pH is required to precipitate calcium carbonate and achieve minimum settled water calcium concentrations in the typical compared to the Banked Water. Based on the data, calcium concentrations are at a minimum at a settled water pH < 10 in the Typical Water, whereas a pH of 10 or higher is required to achieve minimum calcium concentrations in the Banked Water. Since the influent hardness concentration during the flood event was equivalent to typical targets for the *finished* water, it shows that the only calcium hardness removed during the event was the calcium added by lime addition. Iron addition slightly inhibited calcium carbonate precipitation, as expected based on literature (Katz et al., 1993[10]). Additionally, tests conducted with ferric required higher lime doses because the ferric sulfate is acidic.

At settled water pH values above 10.5, settled water magnesium concentrations started to decrease reflecting precipitation of magnesium hydroxide, consistent with a degree of saturation (Q/K) exceeding 1.0. At pH values above 11.5, most of the magnesium was removed (Figure C.3). The addition of ferric sulfate resulted in lower magnesium levels at the same settled water pH. This is most likely due to the coagulation and removal of some of the magnesium hydroxide particles.

Figure C.4 shows the impact of ferric sulfate dose and magnesium removal on TOC and SUVA in Typical Water.

The series of figures included at the end of this appendix summarizes the impact of lime dose on settled water pH, alkalinity, calcium, and magnesium concentrations in the Typical and Banked Water with and without ferric sulfate addition.

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[9] The pH at 170 mg/L CaO in current water was slightly lower than the pH at 150 mg/L CaO. These results reflect challenges associated with maintaining a thoroughly mixed lime slurry and applying small doses. Generally, the settled water pH is considered a more accurate representation of softening conditions than the applied lime dose.

[10] Katz, J.L., Reick, M.R., Herzog, R.E., Parsiegla, K.L. 1993. Calcite Growth Inhibition by Iron, *Langmuir*, 9:1423-1430.

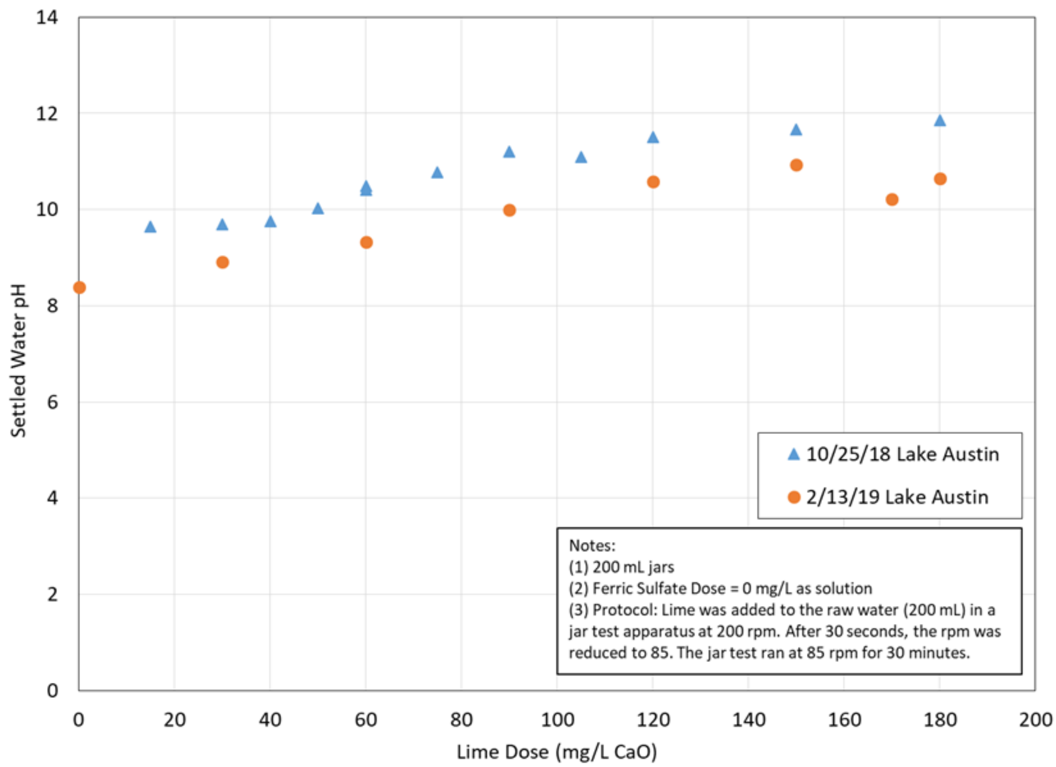
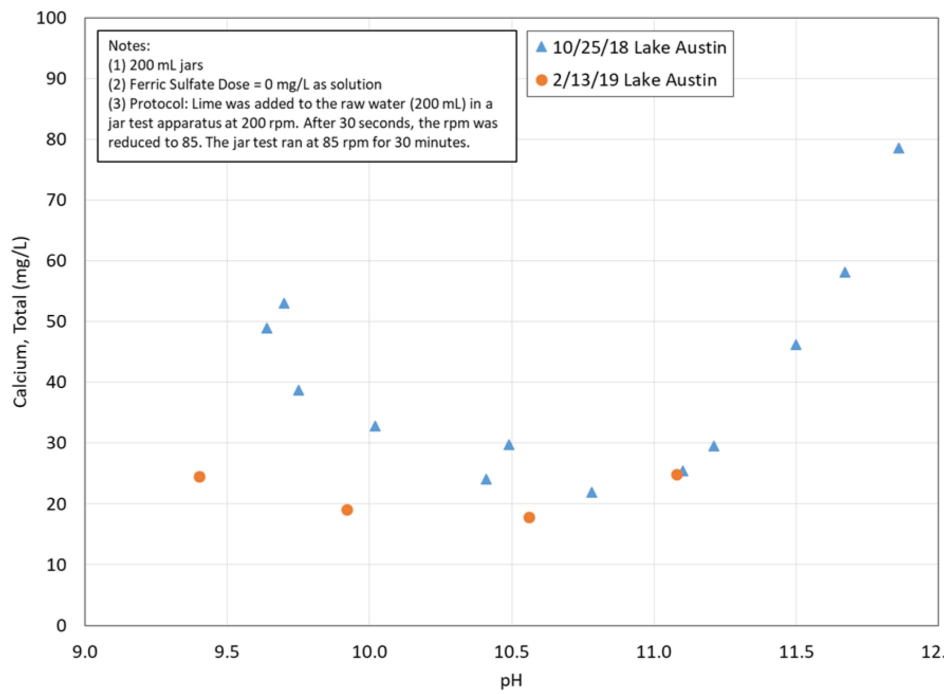
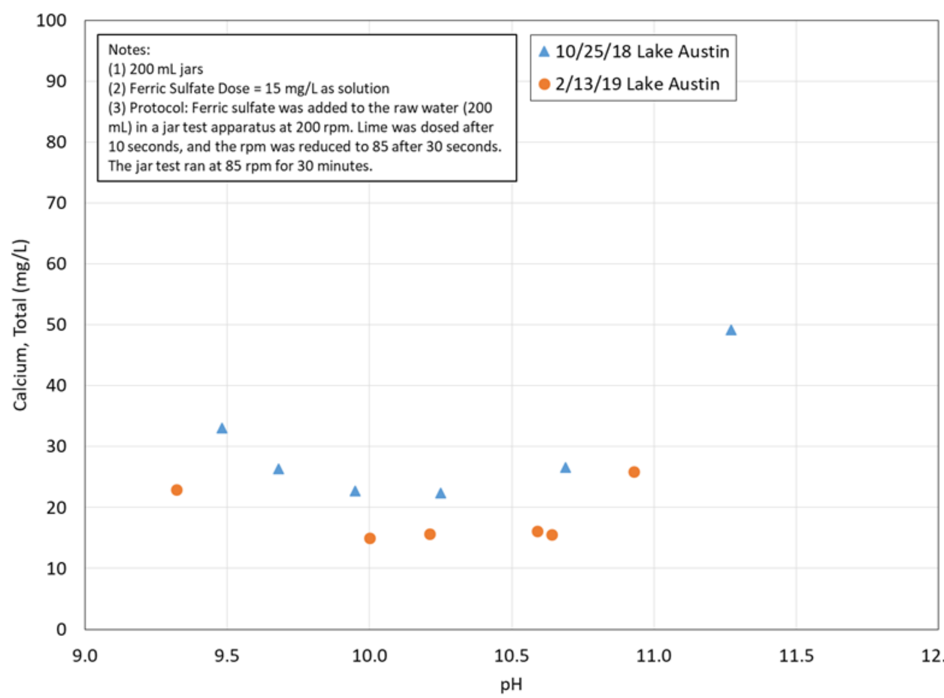


Figure C.1 Impact of Lime Dose on Settled Water pH for Typical and Banked Water

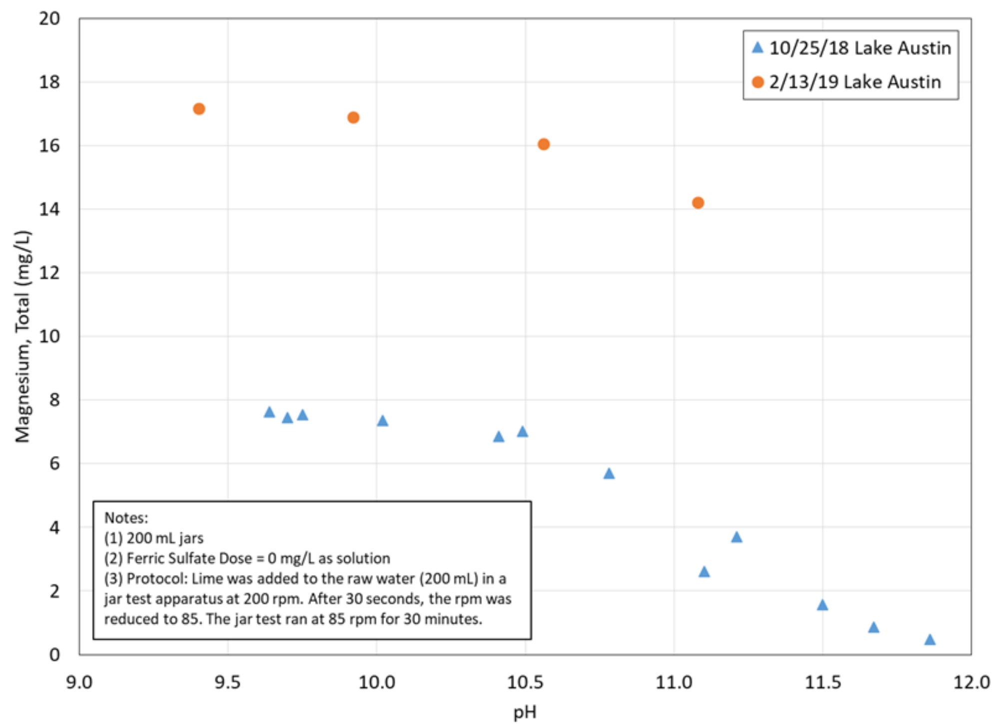


PART A

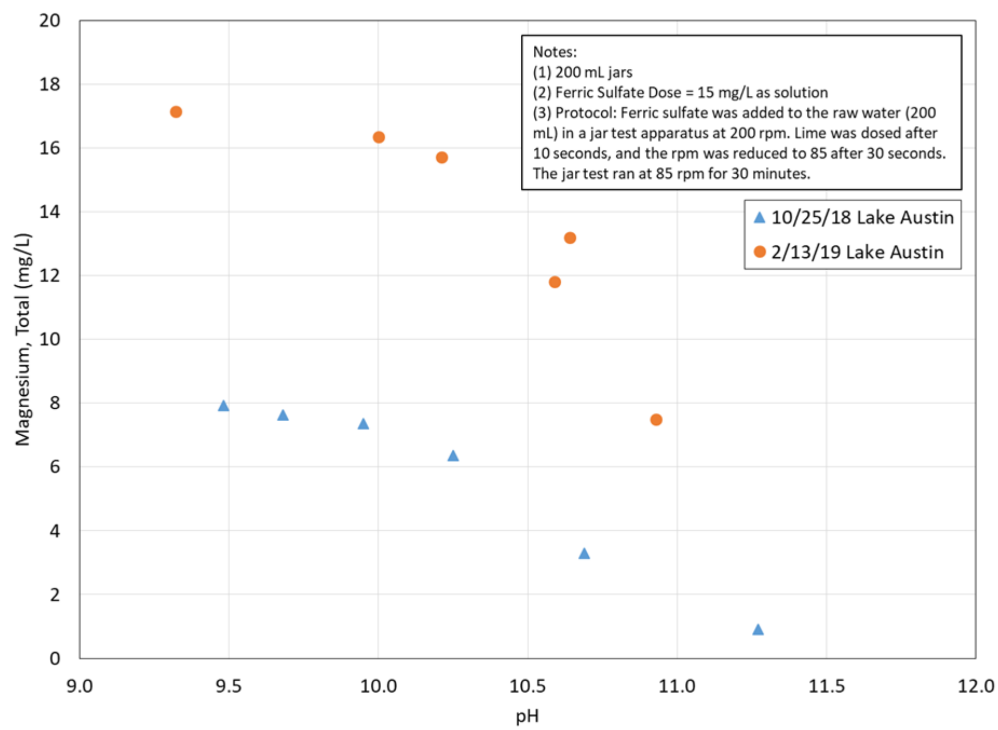


PART B

Figure C.2 Calcium Concentrations with Increasing pH in Typical and Banked Water without (Part A) and with (Part B) Ferric Sulfate Addition



PART A



PART B

Figure C.3 Magnesium Concentrations with Increasing pH in Typical and Banked Water without (Part A) and with (Part B) Ferric Sulfate Addition

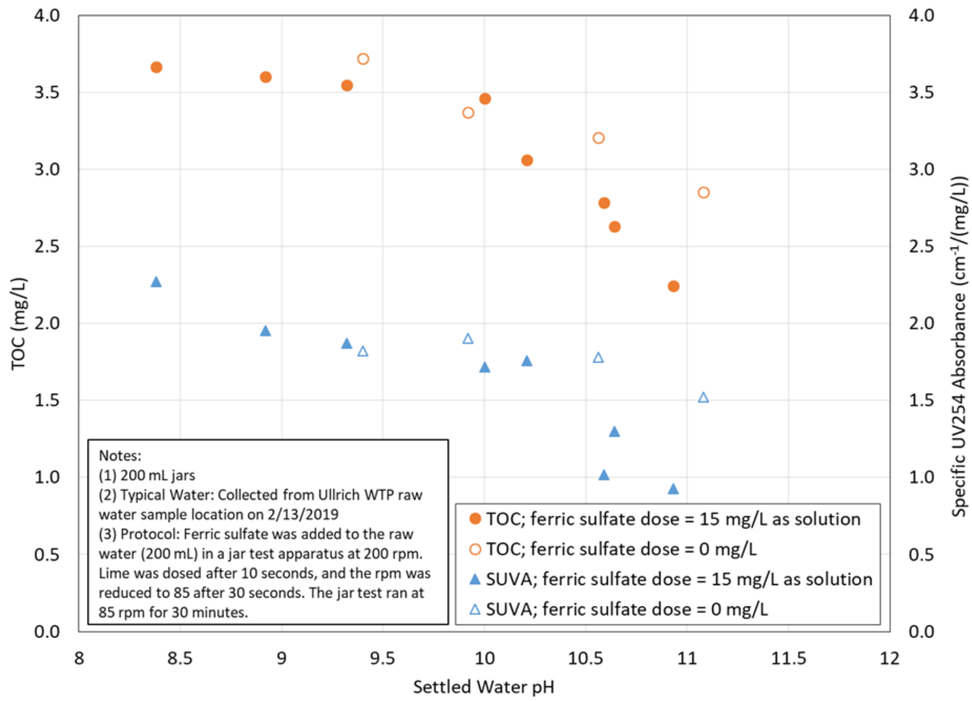
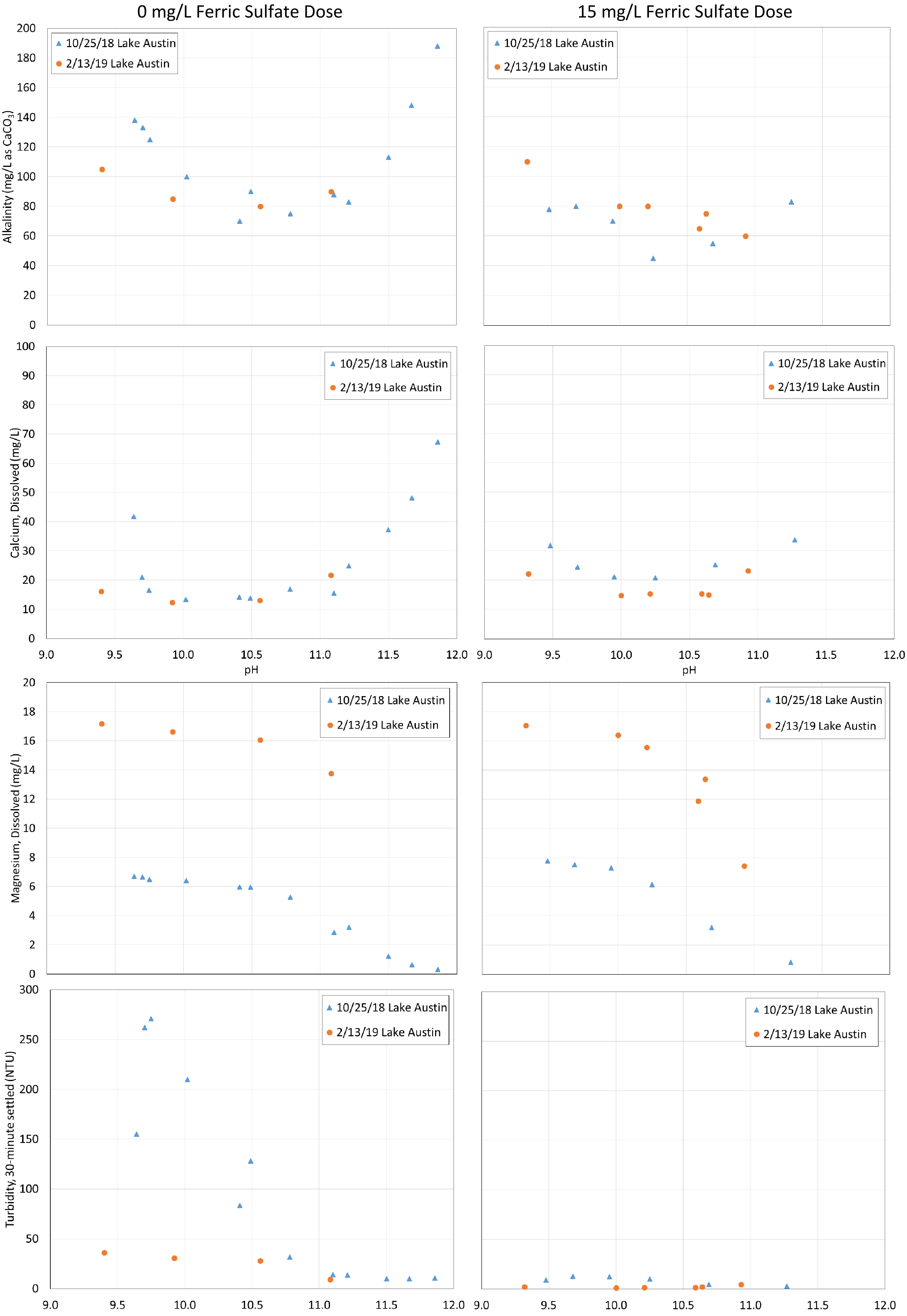
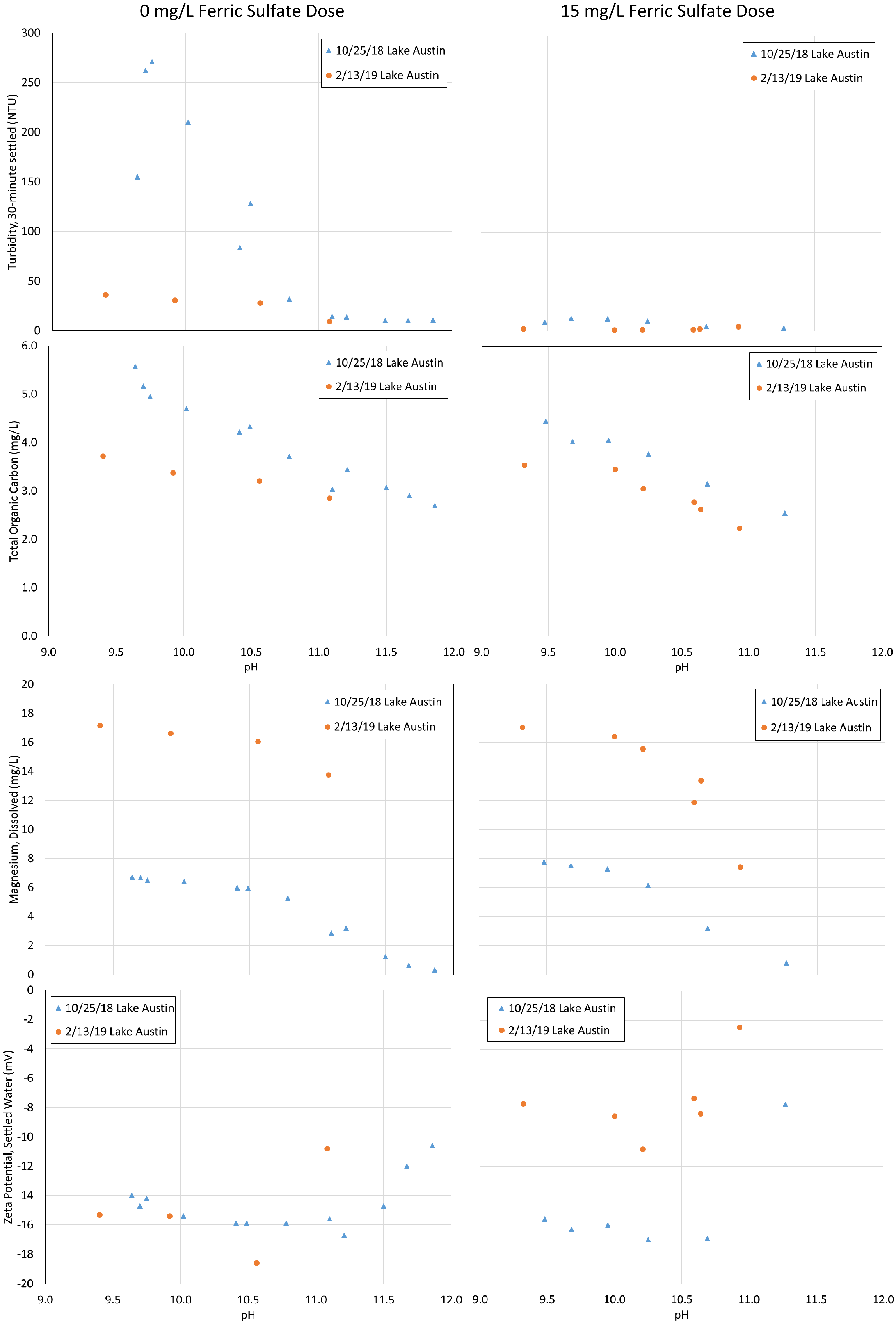


Figure C.4 Impact of Ferric Sulfate Dose and Magnesium Removal on TOC and SUVA in Typical Water

Baseline Testing Summary



Baseline Testing Summary



Appendix D

SEM/EDS ANALYSIS OF SOLIDS PRODUCED DURING JAR TESTS AND ITERATIVE SOLIDS GENERATION EXPERIMENTS

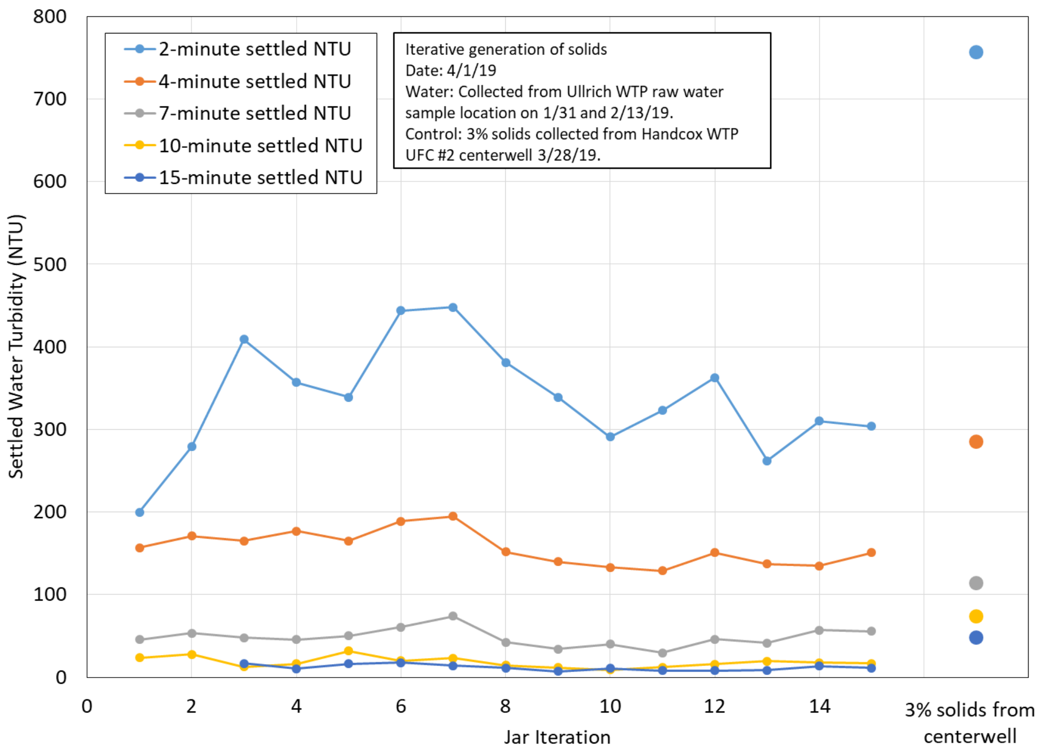


Figure D.1 Iterative Generation of Solids Versus Control (15 mg/L Ferric Sulfate at pH 10.2)

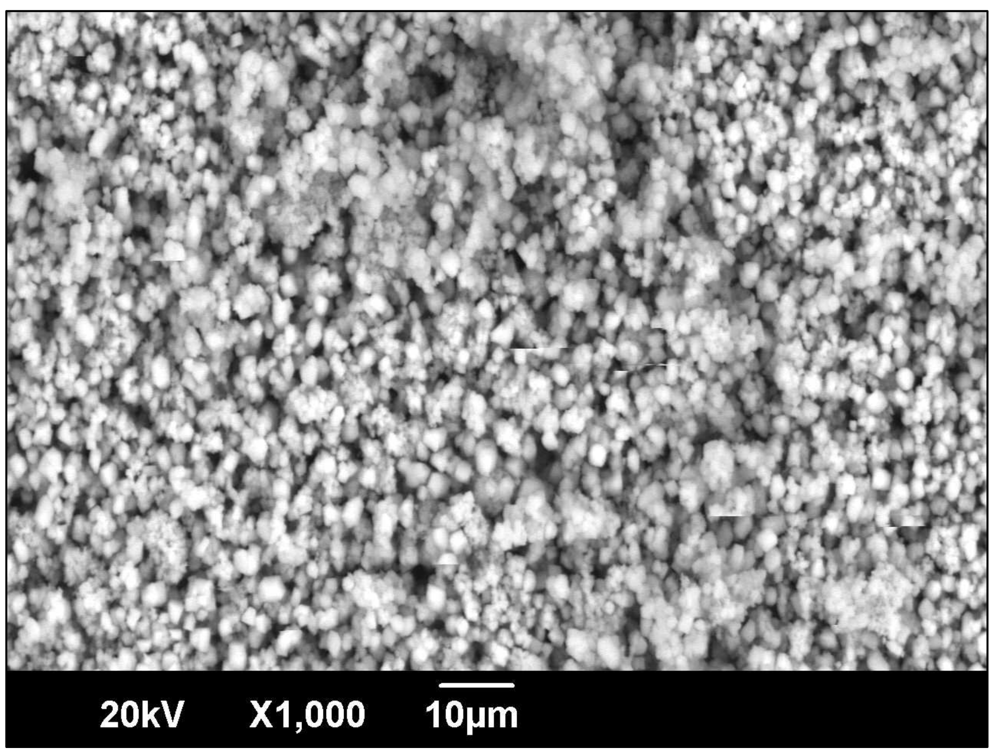


Figure D.2 SEM Image of Solids Produced with Raw Water Collected in January and February, 2019 Softened at pH 10.2 with 15 mg/L Ferric Sulfate (Solids Generation Iteration #1)

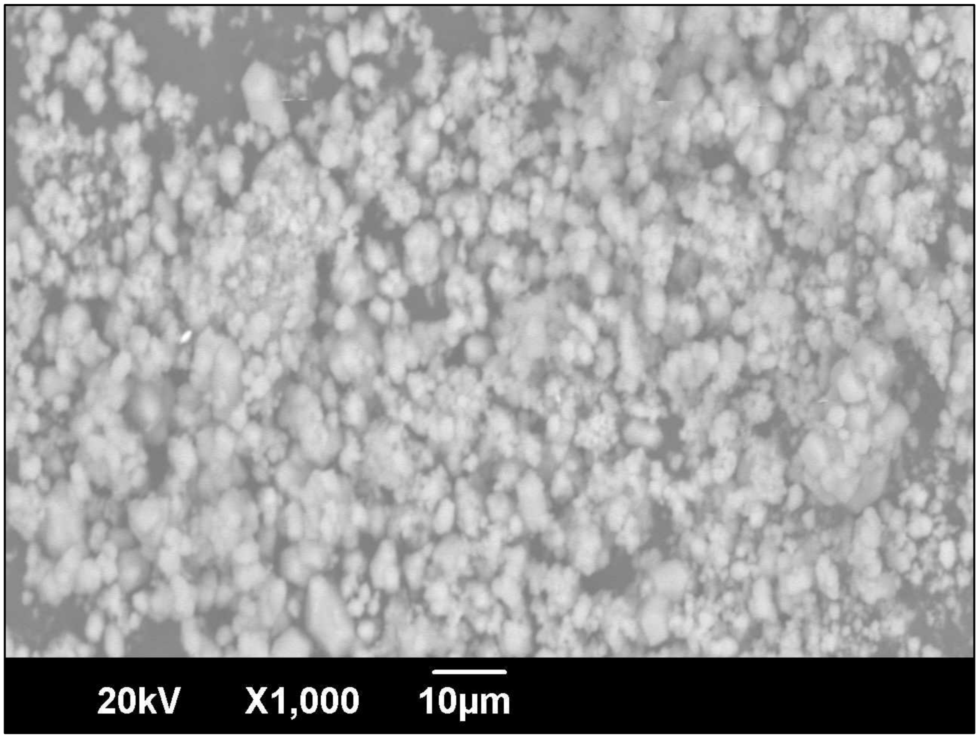


Figure D.3 SEM Image of Solids Produced with Raw Water Collected in January and February, 2019 Softened at pH 10.2 with 15 mg/L Ferric Sulfate (Solids Generation Iteration #15)

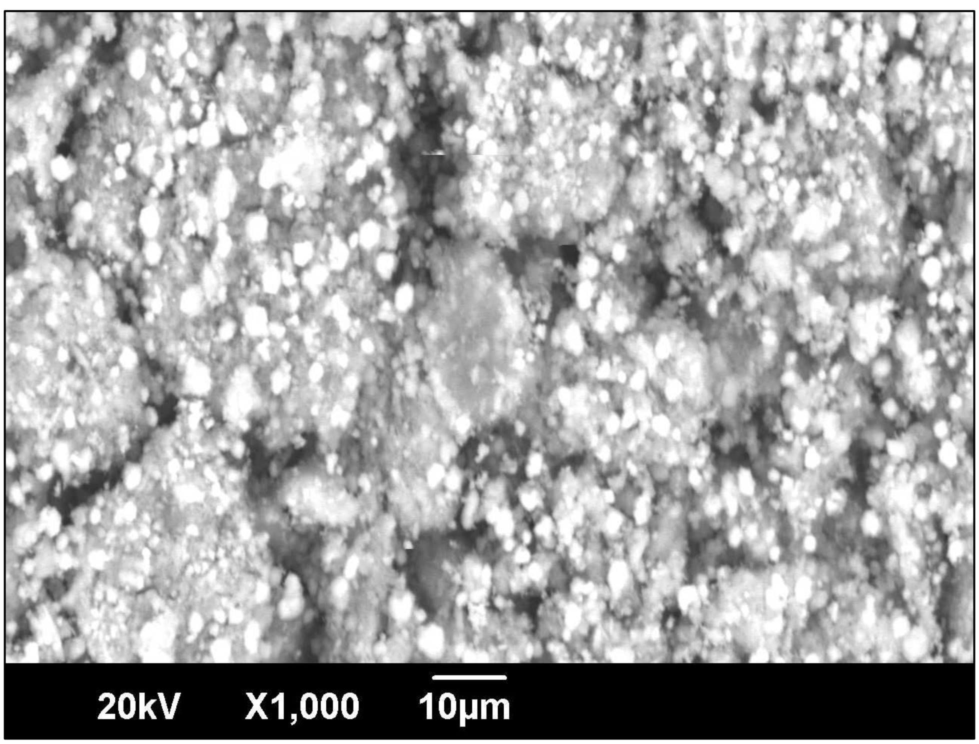


Figure D.4 SEM Image of Solids Produced with Banked Water Softened at pH 10.2 with 15 mg/L Ferric Sulfate and 12 mg/L PEC (Solids Generation Iteration #1)

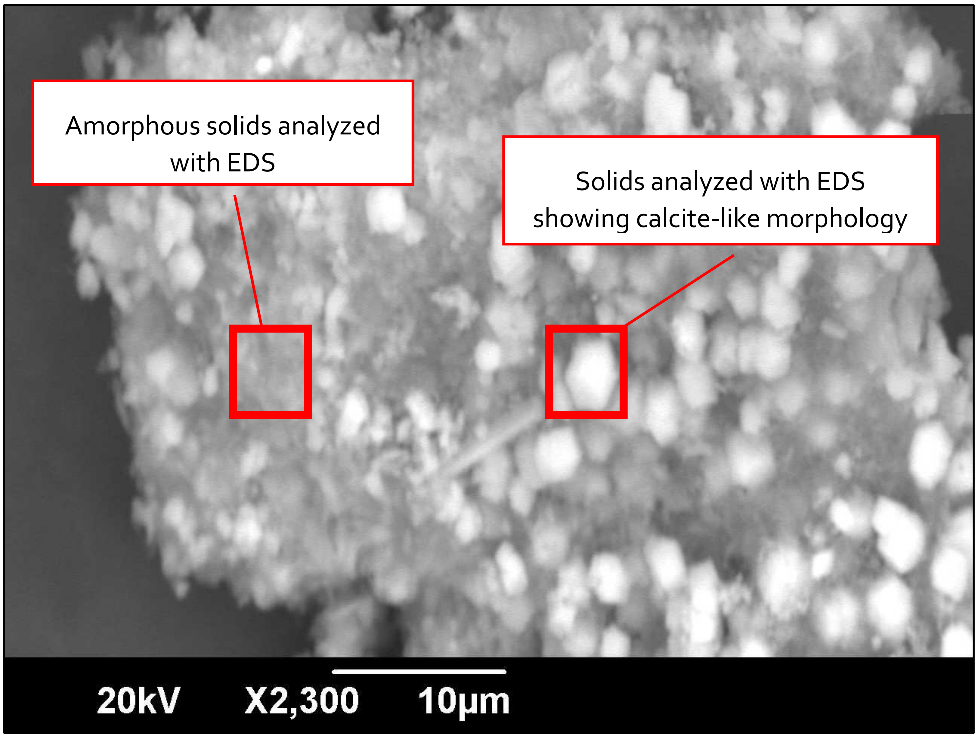


Figure D.5 SEM Image Showing Locations of EDS Analyses of Solids Produced with Banked Water Softened at pH 10.2 with 15 mg/L Ferric Sulfate and 12 mg/L PEC (Solids Generation Iteration #1)

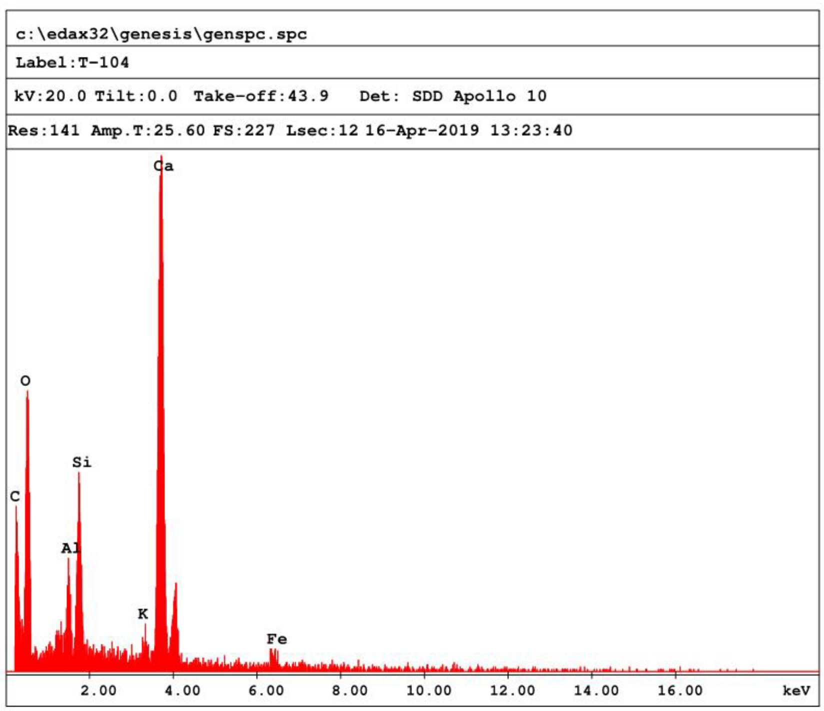


Figure D.6 EDS Spectrum of Solids Showing Calcite-like Morphology Produced with Banked Water Softened at pH 10.2 with 15 mg/L Ferric Sulfate and 12 mg/L PEC (Solids Generation Iteration #1)

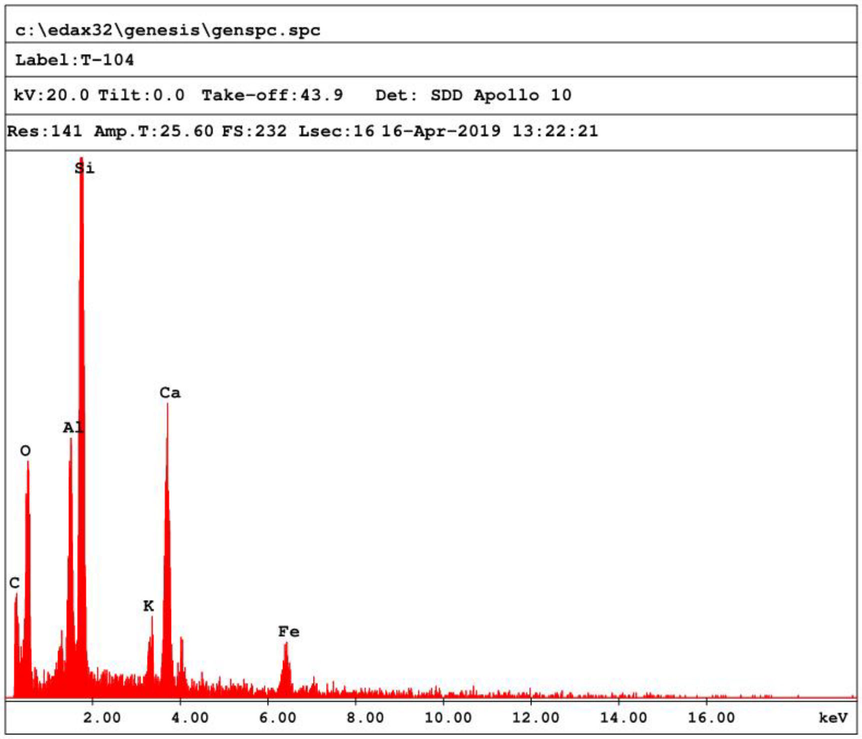


Figure D.7 EDS Spectrum of Amorphous Solids Produced with Banked Water Softened at pH 10.2 with 15 mg/L Ferric Sulfate and 12 mg/L PEC (Solids Generation Iteration #1)

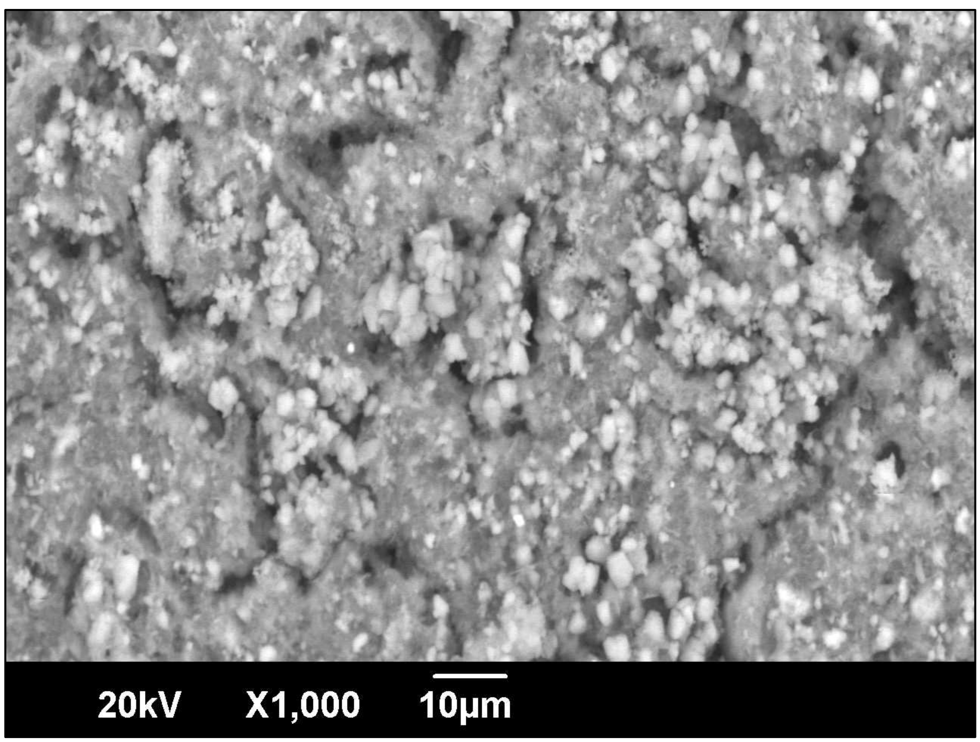


Figure D.8 SEM Image of Solids Produced with Banked Water Softened at pH 10.2 with 15 mg/L Ferric Sulfate and 12 mg/L PEC (Solids Generation Iteration #10)

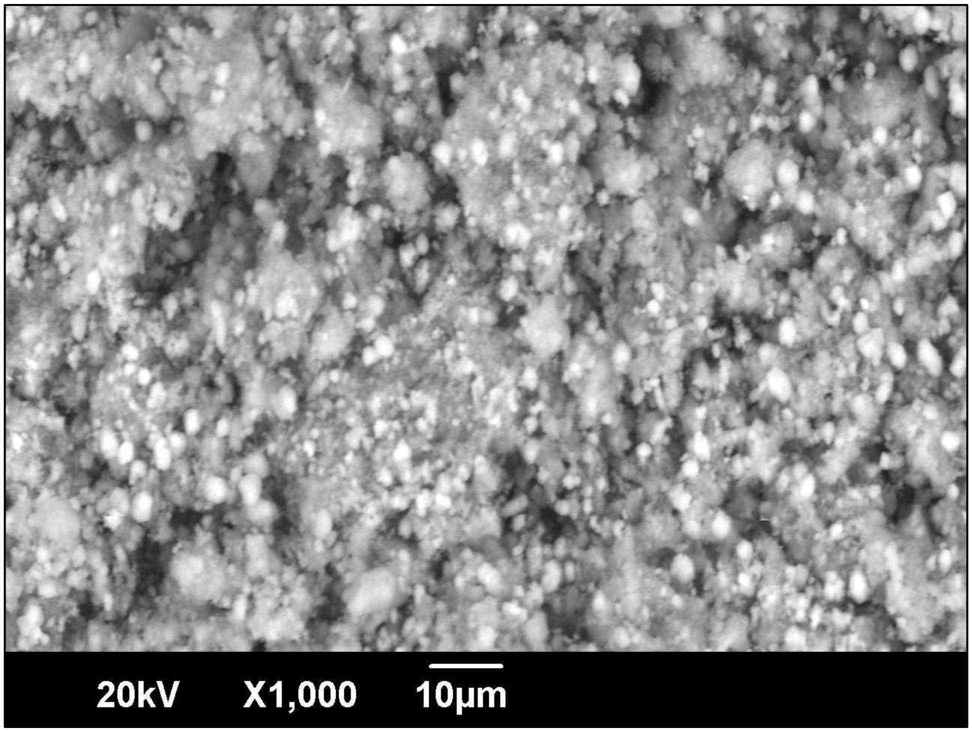


Figure D.9 SEM Image of Solids Produced with Banked Water Softened at pH 10.2 with 15 mg/L Ferric Sulfate, 12 mg/L PEC, and 1 mg/L PEA (Solids Generation Iteration #1)

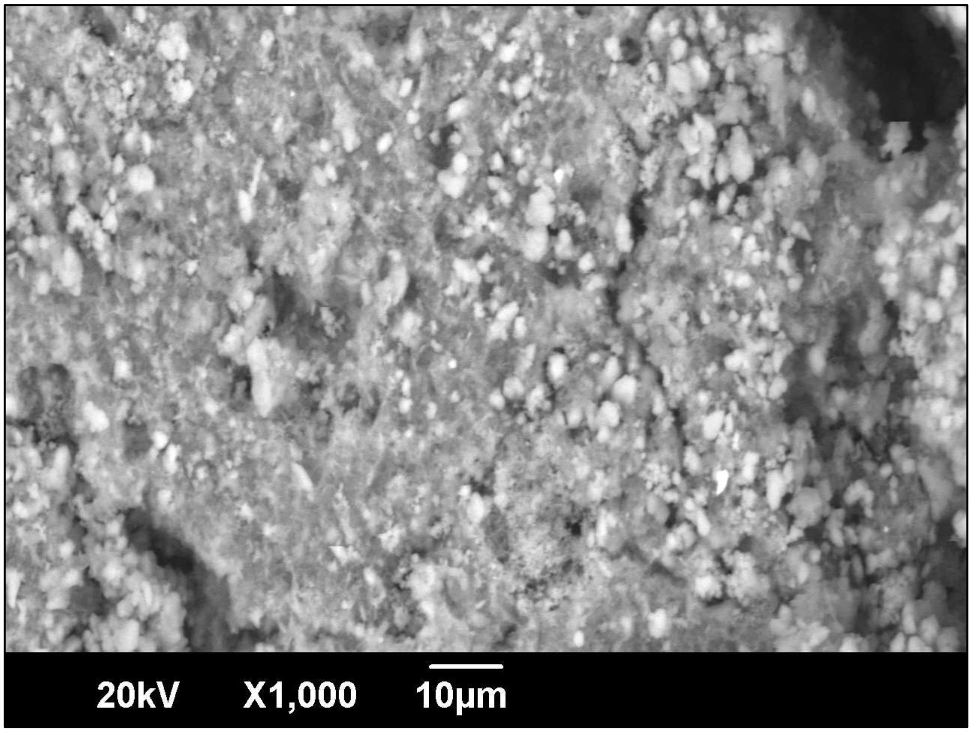


Figure D.10 SEM Image of Solids Produced with Banked Water Softened at pH 10.2 with 15 mg/L Ferric Sulfate, 12 mg/L PEC, and 1 mg/L PEA (Solids Generation Iteration #10)

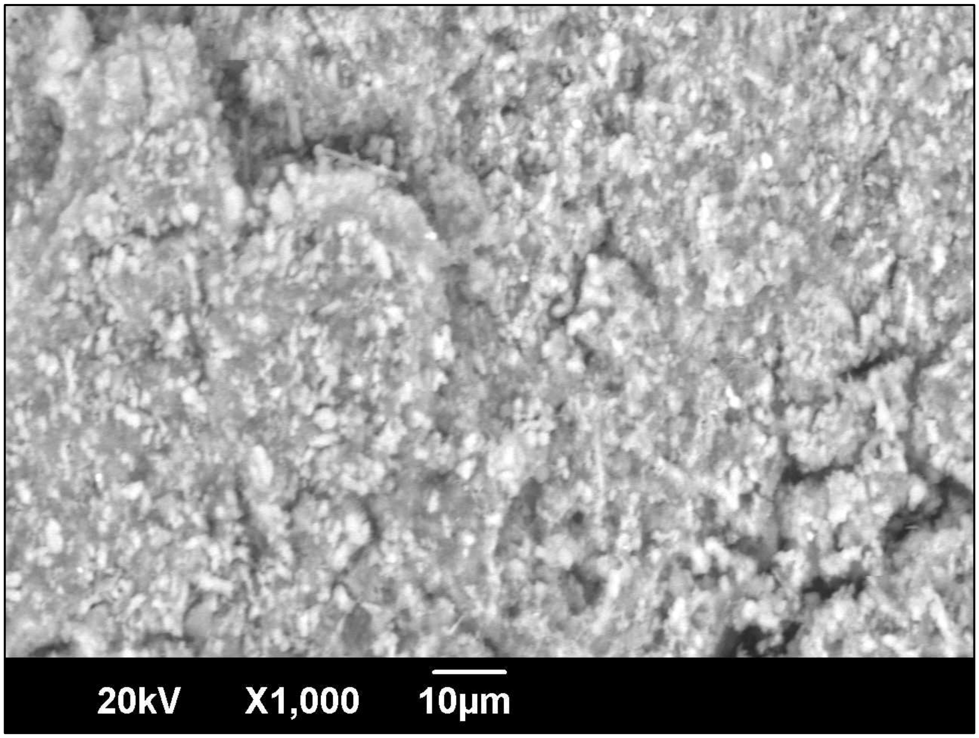


Figure D.11 SEM Image of Solids Produced with Banked Water Softened at pH 10.2 with 10 mg/L PEC, and no Ferric Sulfate

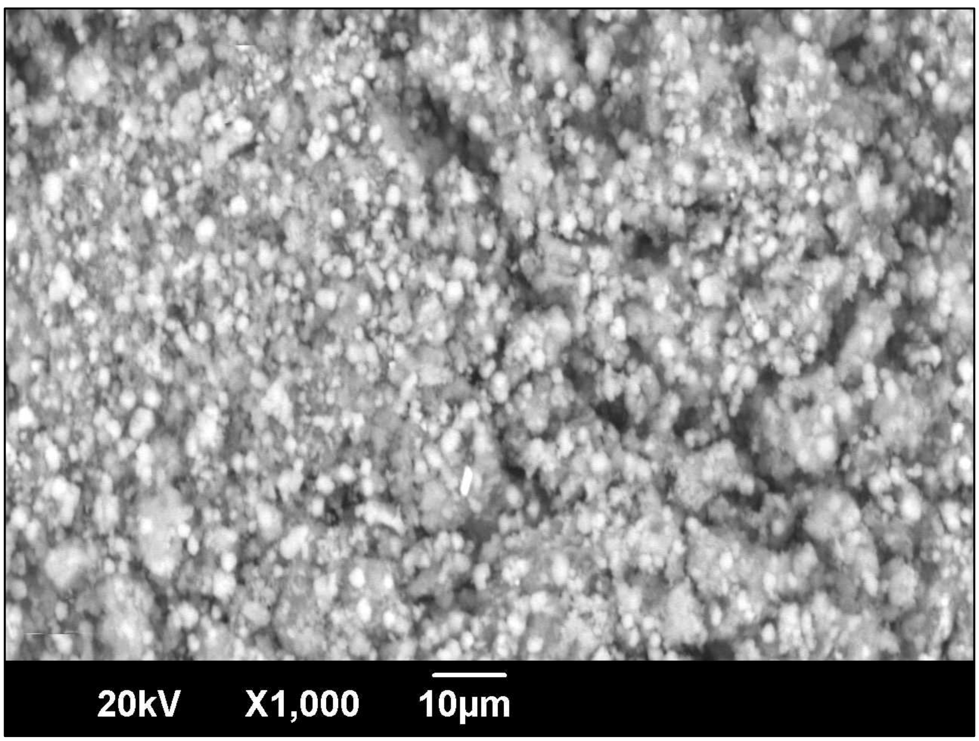


Figure D.12 SEM Image of Solids Produced with Banked Water Softened at pH 10.2 with 80 mg/L Ferric Sulfate and 10 mg/L PEC

Appendix E
JAR TEST DATA

Phase 1 Jar Testing

Jar Test #	Water Supply	Jar Type	General Description	Ferric?	Center Well Solids?	Coag Aid Polymer?	Floc Aid Polymer?	CO2?	NaOH?
1 & 2	Current water	200 mL	Baseline Current Water	Yes	No	No	No	No	No
3 & 4	Banked water	200 mL	Baseline - Lime Only	No	No	No	No	No	No
5, 6, 7, & 8	Banked water	200 mL	Baseline - Varying Ferric	Yes	No	No	No	No	No
9 & 10	Banked water	2 L	Baseline - Settleability	Yes	No	No	No	No	No
11	Banked water	2 L	Enhanced Coagulation	Yes	No	No	No	No	No
12	Current water	2 L	Center well solids	Yes	Yes	No	No	No	No
13, 14, 15, & 16	Banked water	2 L	Effect of coagulant aid polymer	Yes	No	Yes	No	No	No
17	Banked water	2 L	Center well solids	Yes	Yes	Yes	No	No	No
18 & 19	Banked water	200 mL	Impact of CO2 addition	Yes	No	No	No	Yes	No
20	Current water	2 L	Impact of coagulant aid polymer year round	Yes	No	Yes	No	No	No
21	Banked water	2 L	Impact of flocculant aid polymer	Yes	No	Yes	Yes	No	No
22	Banked water	200 mL	Impact of CO2 and NaOH - Chemistry	Yes	No	No	No	Yes	Yes
23	Banked water	2 L	Impact of CO2 and NaOH - Settleability	Yes	No	Yes(1)	No	Yes	Yes

(1) One condition only

Jar Test #	1
Date	2/13/2019
Start Time	12:00

Jar Size 200 mL

Date: 2/13/2019 12:00
Water: Collected from Ullrich WTP raw water sample location on 2/13/2019 at 8:00 am.
Test Objective: Determine the settled turbidity and pH after different doses of lime. Determine operational baseline with typical water quality treated with an average ferric sulfate dose and without ferric while varying pH.
Protocol: Ferric sulfate was added to the raw water (200 mL) in a jar test apparatus at 200 rpm. Lime was dosed after 10 seconds, and the rpm was reduced to 85 after 30 seconds. The jar test ran at 85 rpm for 30 minutes. The jar test was allowed to settle for 30 minutes before settled water turbidity samples were taken.

	Chemical Dose		**Chemical Dosing Time**		**Settled Water Quality**													
Jar	**Lime**	**Ferric Dose**	**Ferric**	**Lime**	**pH**	**Turbidity**	**Zeta**	**UV 254**	**TOC**	**SUVA**	**Alkalinity**	**Calcium**	**Ca (Filt)**	**Iron**	**Fe (Filt)**	**Mg**	**Mg (Filt)**
Units	**mg/L CaO**	**mg/L as solution**			**SU**	**NTU**	**mV**	**1/cm**	**mg/L**		**mg/L**	**mg/L**	**mg/L**	**ug/L**	**ug/L**	**mg/L**	**mg/L**
1	0	15	0sec	5sec	8.38	0.89	-8.74	8.32E-02	3.67	2.27	145	45.6	45.7	341.1	3.3	17.6	17.8
2	30	15	0sec	5sec	8.92	2.35	-9.76	7.03E-02	3.60	1.95	140	40.7	36.8	90.6	7.6	17.4	16.8
3	60	15	0sec	5sec	9.32	1.91	-7.68	6.64E-02	3.55	1.87	110	22.9	22.1	80.4	3.7	17.2	17.1
4	90	15	0sec	5sec	10.00	1.15	-8.56	5.94E-02	3.46	1.72	80	15.0	14.8	65.6	3.8	16.4	16.4
5	120	15	0sec	5sec	10.59	1.21	-7.32	2.83E-02	2.78	1.02	65	16.1	15.4	14.7	2.5	11.8	11.9
6	150	15	0sec	5sec	10.93	4.35	-2.47	2.08E-02	2.24	0.93	60	25.9	23.1	13.4	2.0	7.5	7.4

Jar Test #	2
Date	2/13/2019
Start Time	16:00

Jar Size 200 mL

Date: 2/13/2019 16:00
Water: Collected from Ullrich WTP raw water sample location on 2/13/2019 at 8:00 am.
Test Objective: Determine the settled turbidity and pH after different doses of lime. Determine operational baseline with typical water quality treated with an average ferric sulfate dose and without ferric while varying pH.
Protocol: Ferric sulfate was added to the raw water (200 mL) in a jar test apparatus at 200 rpm. Lime was dosed after 10 seconds, and the rpm was reduced to 85 after 30 seconds. The jar test ran at 85 rpm for 30 minutes. The jar test was allowed to settle for 30 minutes before settled water turbidity samples were taken.

	Chemical Dose		Chemical Dosing Time		Settled Water Quality													
Jar	**Lime (mg/L CaO)**	**Ferric Dose (mg/L)**	**Ferric**	**Lime**	**pH**	**Turbidity**	**Zeta**	**UV 254**	**TOC**	**SUVA**	**Alkalinity**	**Calcium**	**Ca (Filt)**	**Iron**	**Fe (Filt)**	**Mg**	**Mg (Filt)**
1	170	15	0sec	5sec	10.21	1.21	-10.8	5.38E-02	3.06	1.76	80	15.6	15.3	64.8	2.2	15.7	15.6
2	180	15	0sec	5sec	10.64	1.92	-8.36	3.42E-02	2.63	1.30	75	15.5	15.0	24.4	2.9	13.2	13.4
3	60	0	0sec	5sec	9.40	36.1	-15.3	6.77E-02	3.72	1.82	105	24.6	16.1	30.5	2.2	17.2	17.2
4	80	0	0sec	5sec	9.92	30.5	-15.4	6.42E-02	3.37	1.90	85	19.1	12.4	25.9	2.3	16.9	16.6
5	100	0	0sec	5sec	10.56	28.1	-18.6	5.71E-02	3.21	1.78	80	17.8	13.1	19.8	2.5	16.0	16.1
6	130	0	0sec	5sec	11.08	9.33	-10.8	4.34E-02	2.85	1.52	90	24.8	21.7	10.0	3.1	14.2	13.8

Jar Test # 3
Date 2/14/2019
Start Time 10:00

Jar Size 200 mL

Date: 2/14/2019 10:00
Water: Collected from Ullrich WTP raw water sample location on 10/25/18.
Test Objective: Assess softening chemistry during flood event, identifying lime doses corresponding to the minimum calcium concentration and point of magnesium hydroxide precipitation
Protocol: Lime was added to the raw water (200 mL) in a jar test apparatus at 200 rpm. After 30 seconds, the rpm was reduced to 85. The jar test ran at 85 rpm for 30 minutes to target a velocity gradient equal to 100 sec^{-1}. The jar test was allowed to settle for 30 minutes before settled water turbidity samples were taken.

	Chemical Dose		Chemical Dosing Time		Target pH	Settled Water Quality													
Jar	Lime (mg/L CaO)	Ferric Dose (mg/L)	Ferric	Lime	RTW	pH	Turbidity	Zeta	UV 254	TOC	SUVA	Alkalinity	Calcium	Ca (Filt)	Iron	Fe (Filt)	Mg	Mg (Filt)
1	30	0	0sec	5sec	8.5	9.7	262	-14.7	1.52E-01	5.17	2.93	133	53.0	21.0	1560.6	31.2	7.5	6.7
2	60	0	0sec	5sec	9.7	10.49	128	-15.9	1.27E-01	4.32	2.94	90	29.8	13.8	1708.8	25.3	7.0	6.0
3	90	0	0sec	5sec	10.8	11.21	13.7	-16.7	8.90E-02	3.44	2.59	83	29.6	24.9	198.5	6.4	3.7	3.2
4	120	0	0sec	5sec	11.3	11.5	9.75	-14.7	6.98E-02	3.07	2.27	113	46.2	37.2	92.2	4.5	1.6	1.2
5	150	0	0sec	5sec	11.6	11.67	9.82	-12	6.17E-02	2.90	2.13	148	58.1	48.2	54.4	3.4	0.9	0.6
6	180	0	0sec	5sec	11.7	11.86	10.7	-10.6	5.35E-02	2.69	1.99	188	78.5	67.3	33.4	3.4	0.5	0.3

Jar Test #	4	
Date	2/14/2019	
Start Time	12:30	
Vary pH		
Jar Size	200	mL

Date: 2/14/2019 12:30
Water: Collected from Ullrich WTP raw water sample location on 10/25/18.
Test Objective: Assess softening chemistry during flood event, identifying lime doses corresponding to the minimum calcium concentration and point of magnesium hydroxide precipitation
Protocol: Lime was added to the raw water (200 mL) in a jar test apparatus at 200 rpm. After 30 seconds, the rpm was reduced to 85. The jar test ran at 85 rpm for 30 minutes to target a velocity gradient equal to 100 sec^{-1}. The jar test was allowed to settle for 30 minutes before settled water turbidity samples were taken.

	Chemical Dose		**Chemical Dosing Time**		**Settled Water Quality**													
Jar	**Lime (mg/L CaO)**	**Ferric Dose (mg/L)**	**Ferric**	**Lime**	**pH**	**Turbidity**	**Zeta**	**UV 254**	**Alkalinity**	**TOC**	**SUVA**	**Calcium**	**Ca (Filt)**	**Iron**	**Fe (Filt)**	**Mg**	**Mg (Filt)**	**Filtered Zeta**
1	15	0	0sec	5sec	9.64	155	-14	1.69E-01	138	5.57	3.04	49.0	41.8	2213.2	14.0	7.6	6.7	
2	40	0	0sec	5sec	9.75	271	-14.2	1.45E-01	125	4.95	2.93	38.7	16.6	2258.5	10.3	7.5	6.5	
3	50	0	0sec	5sec	10.02	210	-15.4	1.37E-01	100	4.69	2.92	32.8	13.4	2396.7	7.2	7.4	6.4	-12.1
4	60	0	0sec	5sec	10.41	83.5	-15.9	1.26E-01	70	4.21	2.98	24.1	14.3	1742.1	7.9	6.9	6.0	
5	75	0	0sec	5sec	10.78	31.6	-15.9	1.10E-01	75	3.71	2.96	22.0	16.9	524.2	4.1	5.7	5.3	
6	105	0	0sec	5sec	11.1	13.8	-15.6	8.72E-02	88	3.03	2.88	25.4	15.6	119.3	3.5	2.6	2.9	-8.01

Jar Test #	5
Date	2/15/2019
Start Time	9:00
	Low ferric dose, vary pH
Jar Size	200 mL

Date: 2/15/2019 9:00
Water: Collected from Ullrich WTP raw water sample location on 10/25/18.
Test Objective: Evaluate the impact of 15 mg/L ferric addition at lime doses bracketing the softening conditions targeted during the October 2018 flood event (pH ~10.2 and 11).
Protocol: Ferric sulfate was added to the raw water (200 mL) in a jar test apparatus at 200 rpm. Lime was dosed after 10 seconds, and the rpm was reduced to 85 after 30 seconds to target a velocity gradient equal to 100 sec^{-1}. The jar test ran at 85 rpm for 30 minutes. The jar test was allowed to settle for 30 minutes before settled water turbidity samples were taken.

	Chemical Dose		**Chemical Dosing Time**		**Settled Water Quality**													
Jar	**Lime (mg/L CaO)**	**Ferric Dose (mg/L)**	**Ferric**	**Lime**	**pH**	**Turbidity**	**Zeta**	**UV 254**	**Alkalinity**	**TOC**	**SUVA**	**Calcium**	**Ca (Filt)**	**Iron**	**Fe (Filt)**	**Mg**	**Mg (Filt)**
1	30	15	0sec	5sec	9.48	8.82	-15.6	1.40E-01	78	4.46	3.14	33.1	31.7	360.8	19.1	7.9	7.8
2	40	15	0sec	5sec	9.68	12.7	-16.3	1.36E-01	80	4.02	3.38	26.3	24.4	530.3	38.6	7.6	7.5
3	50	15	0sec	5sec	9.95	12.3	-16	1.29E-01	70	4.06	3.18	22.7	21.1	511.7	39.6	7.4	7.3
4	60	15	0sec	5sec	10.25	9.83	-17	1.13E-01	45	3.77	2.99	22.4	20.8	412.8	21.2	6.4	6.2
5	80	15	0sec	5sec	10.69	4.48	-16.9	7.89E-02	55	3.16	2.50	26.5	25.2	109.8	2.8	3.3	3.2
6	120	15	0sec	5sec	11.27	2.6	-7.73	5.34E-02	83	2.55	2.10	49.1	33.7	25.3	0.0	0.9	0.8

Jar Test # 6
Date 2/15/2019
Start Time 13:00
Medium ferric doses, vary pH
Jar Size 200 mL

Date: 2/15/2019 13:00
Water: Collected from Ullrich WTP raw water sample location on 10/25/18.
Test Objective: Evaluate the impact of 80 mg/L ferric addition at lime doses bracketing the softening conditions targeted during the October 2018 flood event (pH ~10.2 and 11).
Protocol: Ferric sulfate was added to the raw water (200 mL) in a jar test apparatus at 200 rpm. Lime was dosed after 10 seconds, and the rpm was reduced to 85 after 30 seconds. The jar test ran at 85 rpm for 30 minutes to target a velocity gradient equal to 100 sec^{-1}. The jar test was allowed to settle for 30 minutes before settled water turbidity samples were taken.

	Chemical Dose		Chemical Dosing Time		Settled Water Quality													
Jar	**Lime (mg/L CaO)**	**Ferric Dose (mg/L)**	**Ferric**	**Lime**	**pH**	**Turbidity**	**Zeta**	**UV 254**	**TOC**	**SUVA**	**Alkalinity**	**Calcium**	**Ca (Filt)**	**Iron**	**Fe (Filt)**	**Mg**	**Mg (Filt)**
1	50	80	0sec	5sec	9.30	2.68	-8.92	1.03E-01	3.34	3.09	55	30.8	30.0	116.0	1.8	7.4	7.4
2	70	80	0sec	5sec	9.85	3.04	-11.20	9.31E-02	3.30	2.83	43	24.9	24.4	90.5	2.7	6.6	6.6
3	90	80	0sec	5sec	10.37	3.64	-11.00	6.49E-02	2.90	2.23	45	31.0	30.0	104.0	0.0	2.9	2.8
4	110	80	0sec	5sec	10.80	4.23	-9.19	4.90E-02	2.34	2.09	55	42.0	40.1	70.4	1.5	0.7	0.7
5	130	80	0sec	5sec	10.95	3.33	-5.46	4.32E-02	1.98	2.18	75	53.5	51.0	69.6	0.0	0.4	0.3
6	150	80	0sec	5sec	11.16	3.80	-3.89	4.05E-02	2.07	1.96	103	65.0	60.8	74.0	2.2	0.2	0.2

Jar Test #	7	
Date	2/15/2019	
Start Time	15:00	
	High ferric dose, vary pH	
Jar Size	200	

Date: 2/15/2019 15:00
Water: Collected from Ullrich WTP raw water sample location on 10/25/18.
Test Objective: Evaluate the impact of 180 mg/L ferric addition at lime doses bracketing the softening conditions targeted during the October 2018 flood event (pH ~10.2 and 11).
Protocol: Ferric sulfate was added to the raw water (200 mL) in a jar test apparatus at 200 rpm. Lime was dosed after 10 seconds, and the rpm was reduced to 85 after 30 seconds to target a velocity gradient equal to 100 sec^{-1}. The jar test ran at 85 rpm for 30 minutes. The jar test was allowed to settle for 30 minutes before settled water turbidity samples were taken.

	Chemical Dose		**Chemical Dosing Time**		**Settled Water Quality**													
Jar	**Lime (mg/L CaO)**	**Ferric Dose (mg/L)**	**Ferric**	**Lime**	**pH**	**Turbidity**	**Zeta**	**UV 254**	**TOC**	**SUVA**	**Alkalinity**	**Calcium**	**Ca (Filt)**	**Iron**	**Fe (Filt)**	**Mg**	**Mg (Filt)**
1	100	180	0sec	5sec	10.08	2.39	-5.81	6.06E-02	2.43	2.49	30	37.0	37.2	116.2	0.0	4.3	4.3
2	120	180	0sec	5sec	10.65	1.95	-12.6	4.53E-02	2.11	2.15	40	48.0	47.7	131.7	0.3	1.3	1.3
3	140	180	0sec	5sec	10.86	2.44	-4.87	4.14E-02	1.98	2.09	68	57.4	56.5	104.1	0.0	0.6	0.6
4	160	180	0sec	5sec	11.20	1.78	-4.57	3.75E-02	1.85	2.03	105	70.5	68.9	100.3	0.0	0.3	0.2
5	180	180	0sec	5sec	11.35	3.33	-0.284	3.53E-02	1.80	1.96	138	82.0	80.1	155.7	2.7	0.2	0.1
6	200	180	0sec	5sec	11.45	3.03	4.31	3.37E-02	1.70	1.99	155	89.3	82.2	175.6	3.5	0.2	0.1

Jar Test #	8
Date	2/18/2019
Start Time	9:45
	High ferric dose, vary pH, order of chem addition
Jar Size	200

Date: 2/18/2019 9:45
Water: Collected from Ullrich WTP raw water sample location on 10/25/18.
Test Objective: Evaluate the impact of 180 mg/L ferric addition at lime doses bracketing the softening conditions targeted during the October 2018 flood event (pH ~10.2 and 11). Evaluate the impact of the order of chemical addition.
Protocol: In four jars, ferric sulfate was added to the raw water (200 mL) in a jar test apparatus at 200 rpm. Lime was dosed after 10 seconds, and the rpm was reduced to 85 after 30 seconds. In two jars, the dosing order was switched. The jar test ran at 85 rpm for 30 minutesto target a velocity gradient equal to 100 sec^{-1}. The jar test was allowed to settle for 30 minutes before settled water turbidity samples were taken.

	Chemical Dose		**Chemical Dosing Time**		**Settled Water Quality**														
Jar	**Lime (mg/L CaO)**	**Ferric Dose (mg/L)**	**Ferric**	**Lime**	**pH**	**Turbidity**	**Zeta**	**UV 254**	**TOC**	**SUVA**	**Alkalinity**	**Calcium**	**Ca (Filt)**	**Iron**	**Fe (Filt)**	**Mg**	**Mg (Filt)**	**SiO2**	**SiO2 (Filt)**
1	70	180	0sec	5sec	9.24	1.89	-12.8	7.79E-02	3.11	2.51	50	33.1	33.6	144.1	2.9	7.0	7.1	3.4	3.4
2	80	180	0sec	5sec	9.53	1.19	-12.1	7.48E-02	3.09	2.42	40	28.7	28.9	112.0	1.8	6.8	6.9	3.2	3.2
3	90	180	0sec	5sec	9.81	1.44	-11.7	6.49E-02	2.85	2.28	30	27.7	28.0	111.7	1.8	6.4	6.6	3.2	3.2
4	110	180	0sec	5sec	10.62	2.33	-5.55	3.78E-02	2.40	1.58	38	37.7	36.2	52.7	0.7	2.1	2.1	5.8	3.7
5	110	180	5sec	0sec	10.45	0.83	-5.87	4.17E-02	2.32	1.80	60	35.4	36.0	52.4	0.9	2.4	2.4	3.4	3.5
6	140	180	5sec	0sec	11.26	1.68	-5.33	3.00E-02	2.11	1.42	70	56.4	41.9	143.6	0.8	0.5	0.5	3.8	3.9

Jar Test # 9 and 10
Date 2/18/2019
Start Time 14:25
Settleability Test
Jar Size 2000 mL

Date: 2/18/2019 14:25
Water: Collected from Ullrich WTP raw water sample location on 10/25/2018.
Test Objectives:
Evaluate the impact of softening at optimal ferric doses on settleability using 2 L jars.
Correlate results from 200 mL jars to results from tests run in October.
See if similar settleability is observed at 5 and 10 minutes (e.g., correlating to full-scale SOR) under same/similar conditions now as in October.
Confirm the optimal iron dose under October 2018 water quality conditions.
Assess whether settled water turbidity goals could be met with iron and lime at pH 10.2 (i.e., is high pH needed at representative SORs?)
Confirm through wet chemistry what iron is doing under these conditions as first step to see if iron impact can be achieved with polymer instead.
Protocol: Ferric sulfate was added to the raw water (2 L) in a jar test apparatus at 200 rpm. Lime was added 10 seconds after ferric. After 45 seconds, the rpm was reduced to 50. The jar test ran at 50 rpm for 30 minutes. Settled water turbidity samples were taken after 5 and 10 minutes of settling.

	Chemical Dose		**Chemical Dosing Time**		**Target pH**	**Settled Water Quality**														**Turbidity (NTU)**	
Jar	**Lime (mg/L CaO)**	**Ferric Dose (mg/L)**	**Ferric**	**Lime**	**RTW**	**pH**	**Zeta**	**UV 254**	**TOC**	**SUVA**	**Alkalinity**	**Calcium**	**Ca (Filt)**	**Iron**	**Fe (Filt)**	**Mg**	**Mg (Filt)**	**SiO2**	**SiO2 (Filt)**	**5-min**	**10-min**
1	35	15	0sec	5sec	9.6	9.73	-14.5	1.30E-01	4.19	3.10	85	31.4	27.3	501.1	29.6	7.5	7.4	8.8	7.3	258	91
2	60	15	0sec	5sec	10.2	10.43	-17.7	1.15E-01	4.17	2.75	58	21.3	17.3	613.3	42.7	7.1	6.9	8.8	7.4	351	122
3	80	15	0sec	5sec	10.7	10.97	-16.2	7.51E-02	3.20	2.35	58	23.2	20.6	159.6	6.8	3.9	3.5	8.0	7.6	173	46
4	110	15	0sec	5sec	11.2	11.53	-13.8	5.40E-02	2.63	2.05	88	38.8	36.1	54.7	2.4	1.5	1.3	7.4	7.4	71	14
5	60	80	0sec	5sec	9.6	9.86	-11.8	7.05E-02	3.58	1.97	48	24.6	22.9	274.4	2.5	7.1	4.1	5.7	5.8	129	27
6	85	80	0sec	5sec	10.2	10.60	-9.2	1.00E-01	3.15	3.18	43	40.1	22.5	284.2	4.2	4.7	7.1	6.1	5.5	134	28
1	105	80	0sec	5sec	10.7	11.06	-6.94	5.84E-02	2.87	2.03	50	30.9	30.6	120.7	3.2	1.6	1.6	6.0	6.0	98	21
2	150	80	0sec	5sec	11.2	11.51	-5.16	4.38E-02	2.31	1.89	118	63.5	59.0	373.5	3.8	0.5	0.3	5.9	5.8	53	13
3	80	180	0sec	5sec	9.6	9.74	-7.87	8.86E-02	3.13	2.83	40	36.5	29.0	1839.6	2.4	7.0	6.7	3.9	3.2	102	36
4	105	180	0sec	5sec	10.2	10.71	-6.49	6.72E-02	2.76	2.44	40	38.6	31.8	1399.0	2.0	4.3	3.9	4.2	3.6	115	35
5	125	180	0sec	5sec	10.7	11.30	-3.59	5.49E-02	2.43	2.26	58	48.2	42.4	956.4	2.5	1.4	1.1	4.1	3.8	76	23
6	160	180	0sec	5sec	11.2	11.58	-4.76	5.10E-02	2.24	2.28	105	69.4	61.5	488.8	3.9	0.5	0.3	4.1	4.1	54	13

Jar Test #	11
Date	2/19/2019
Start Time	11:07
	Enhanced Coagulation
Jar Size	2000

Date: 2/19/2019 11:07
Water: Collected from Ullrich WTP raw water sample location on 10/25/2018.
Test Objectives: Evaluate impact of enhanced coagulation at ambient pH.
Protocol: Ferric sulfate was added to the raw water (2 L) in a jar test apparatus at 200 rpm. Lime was added 10 seconds after ferric to target a pH between 6 and 7. After 30 seconds, the rpm was reduced to 50 to target G equal to 50 s^{-1}. The jar test ran at 50 rpm for 30 minutes. Settled water turbidity samples were taken after 5 and 10 minutes of settling.

	Chemical Dose		**Chemical Dosing Time**		**Target pH**	**Settled Water Quality**																**Turbidity (NTU)**	
Jar	**Lime (mg/L CaO)**	**Ferric Dose (mg/L)**	**Ferric**	**Lime**		**pH**	**Zeta**	**UV 254**	**TOC**	**SUVA**	**Alkalinity**	**Calcium**	**Ca (Filt)**	**Iron**	**Fe (Filt)**	**Mg**	**Mg (Filt)**	**SiO2**	**SiO2 (Filt)**	**5-min**	**10-min**
1	5.3	80	0sec	5sec	8	7.20	-12.90	8.45E-02	3.42	2.47	90	40.7	39.4	1051.2	46.7	7.7	7.6	8.3	7.0	64.2	19.1
2	9.1	120	0sec	5sec	8	7.11	-12.00	6.85E-02	2.69	2.55		43.9	43.8	752.0	13.5	7.7	7.7	7.0	6.8	62.3	21.2
3	15.1	160	0sec	5sec	8	7.00	-9.92	5.60E-02	2.29	2.44	85	47.2	46.6	795.9	5.7	7.6	7.6	6.6	6.4	52.1	14.9
4	20.4	200	0sec	5sec	8	5.83	-2.17	4.94E-02	2.13	2.32		52.2	51.5	801.5	2.8	7.8	7.7	6.2	6.1	53.5	21.9
5	30.3	280	0sec	5sec	8	6.77	-6.39	4.14E-02	1.98	2.09	85	59.6	58.7	1412.8	1.3	7.8	7.7	6.1	5.9	64.1	25.6
6	0	280	0sec	5sec		6.02	-6.27	2.61E-02	1.41	1.85	50	41.6	41.8	1404.7	329.1	7.9	8.0	6.9	7.0	55.5	24.7

Jar Test # 12 and 13
Date 2/19/2019
Start Time 10:00
Impact of Center Well Solids
Jar Size 2000 mL

Date: 2/19/2019 10:00 and 14:30
Water: Collected from Ullrich WTP raw water sample location on 2/13/2019 at 8:00 am.
Solids: Collected from Ullrich WTP UFC center well on 2/19/2019 at 7:30 am, included PAC.
Test Objective: Mimic some of the conditions tested so far (with and without iron, using current water as well as banked water) to see if the presence of solids makes a notable difference in chemistry and settleability. Assess whether ferrihydrite solids are providing a seed for $CaCO_3$ precipitation or complexing organics that would otherwise inhibit $CaCO_3$ crystal growth.
Protocol: Concentrated center well solids were added to noted jars to make up 13% of the 2-L jar volume. Solids were either added before rapid mix or 10 seconds after ferric addition. At the start of rapid mix, ferric sulfate was added to the raw water (2 L) in a jar test apparatus at 200 rpm. After 30 seconds, lime was dosed and the rpm was reduced to 85 in Jar Test 12 and 55 in Jar Test 13. The jar test ran for 30 minutes. The jar test was allowed to settle for 30 minutes before settled water turbidity samples were taken.

	Chemical Dose			**Chemical Dosing Time**			**Target pH**	**Settled Water Quality**			**Turbidity (NTU)**	
Jar	**Lime (mg/L CaO)**	**Center well solids**	**Ferric Dose (mg/L)**	**Ferric**	**Lime**	**Solids**		**pH**	**Turbidity**	**Zeta**	**5-min**	**10-min**
1	0.0	100%	0	0sec		pre-mix	Ambient	9.505		-12.9	422	80.1
2	105.0	0%	15	0sec			10.3	10.408	8.77	-12.4	207	14.6
3	105.0	13%	15	0sec		pre-mix	10.3	10.494		-4.76	69.8	6.62
4	90.0	13%	0	0sec		pre-mix	10.3	10.205		-16.4	230	51.5
1	105	13%	15	0sec	30sec	5sec	10.4	10.5		-11.00	15.1	6.01
2	90			0sec	30sec		10.2	10.07		-17.90	329	181
3	140	13%	15	0sec	30sec	5sec	10.8	10.96		-6.25	27	8.52
4	140	13%	15	0sec	30sec	pre-mix	10.8	10.98		-3.33	26.1	6.85
5	140		15	0sec	30sec		10.8	10.91		-5.00	66	17.4
6	125			0sec	30sec		10.8	10.93		-15.50	460	144

Jar Test # 14
Date 2/19/2019
Start Time 16:20
Polymer
Jar Size 2000 mL

Date: 2/19/2019 16:20
Water: Collected from Ullrich WTP raw water sample location on 10/25/2018.
Test Objectives: Determine the effect of coagulant aid polymers on settleability of banked water at average ferric sulfate dose and pH 10.2.
Protocol: Ferric sulfate was added to the raw water (2 L) in a jar test apparatus at 200 rpm. In jars 2-4, lime was added 30 seconds after ferric, followed by polymer addition. In jar 5, ferric and polymer were added simultaneously, followed by lime addition. In jar 6, ferric was added, followed by simultaneous addition of polymer and lime. After 45 seconds of rapid mixing, the rpm was reduced to 55 to target a G-value of 55 s^{-1}. The jar test ran at 50 rpm for 30 minutes. Settled water turbidity samples were taken after 5 and 10 minutes of settling.

	Chemical Dose					**Chemical Dosing Time**		
Jar	**Lime (mg/L CaO)**	**Ferric Dose (mg/L)**	**Label**	**Polymer Type**	**Polymer Dose**	**Ferric**	**Polymer**	**Lime**
1	57	15	Ferric (30 s); Lime	Magnafloc LT7995	0	0sec	0	30sec
2	57	15	Ferric (30 s); Lime (5 s); Polymer	Magnafloc LT7995	5	0sec	35sec	30sec
3	57	15	Ferric (30 s); Lime (5 s); Polymer	Magnafloc LT7995	10	0sec	35sec	30sec
4	57	15	Ferric (30 s); Lime (5 s); Polymer	Magnafloc LT7995	15	0sec	35sec	30sec
5	57	15	Ferric + Polymer simultaneously (5 s); Lime	Magnafloc LT7995	10	30sec	30sec	35sec
6	57	15	Ferric (5 s); Lime + Polymer simultaneously	Magnafloc LT7995	10	30sec	35sec	35sec

	Target pH	**Settled Water Quality**														**Turbidity (NTU)**	
Jar		**pH**	**Zeta**	**UV 254**	**TOC**	**SUVA**	**Alkalinity**	**Calcium**	**Ca (Filt)**	**Iron**	**Fe (Filt)**	**Mg**	**Mg (Filt)**	**SiO2**	**SiO2 (Filt)**	**5-min**	**10-min**
1	10.2	10.2	-15.4	1.21E-01	3.65	3.31	65	19.6	16.9	451.7	28.7	6.8	6.6	8.8	7.3	382.0	130.0
2	10.2	10.23	-7.49	9.80E-02	3.26	3.00	65	20.3	19.7	64.4	4.0	6.6	6.7	7.4	7.4	11.3	5.3
3	10.2	10.23	-3.95	8.67E-02	3.16	2.74	60	20.5	19.7	86.6	2.9	6.7	6.7	7.5	7.3	11.7	4.2
4	10.2	10.23	-2.2	7.34E-02	3.13	2.35	60	20.7	18.8	157.5	2.1	6.8	6.8	7.7	7.3	18.2	7.3
5	10.2	10.3	-3.53	8.63E-02	3.12	2.76	55	18.4	17.6	47.8	1.6	6.6	6.5	7.4	7.3	25.6	10.8
6	10.2	10.26	-2.87	8.95E-02	3.91	2.29	60	21.8	20.4	115.1	3.0	6.6	6.7	7.6	7.3	17.9	8.6

Jar Test #	15
Date	2/20/2019
Start Time	9:32
Polymer	
Jar Size	2000 mL

Date: 2/20/2019 9:32
Water: Collected from Ullrich WTP raw water sample location on 10/25/2018.
Test Objectives: Determine the effect of coagulant aid polymers on settleability of banked water at average ferric sulfate dose and pH 10.8-11.
Protocol: Ferric sulfate was added to the raw water (2 L) in a jar test apparatus at 200 rpm. In jars 2-4, polymer was added 30 seconds after ferric, followed by lime addition. In jar 5, ferric and polymer were added simultaneously, followed by lime addition. In jar 6, ferric was added, followed by simultaneous addition of polymer and lime. After 45 seconds of rapid mixing, the rpm was reduced to 55 to target a G-value of 55 s^{-1}. The jar test ran at 50 rpm for 30 minutes. Settled water turbidity samples were taken after 5 and 10 minutes of settling.

	Chemical Dose				**Chemical Dosing Time**		
Jar	**Lime (mg/L CaO)**	**Ferric Dose (mg/L)**	**Polymer Type**	**Polymer Dose**	**Ferric**	**Polymer**	**Lime**
1	90	15	Magnafloc LT7995	0	0sec	0	30sec
2	90	15	Magnafloc LT7995	5	0sec	30sec	35sec
3	90	15	Magnafloc LT7995	10	0sec	30sec	35sec
4	90	15	Magnafloc LT7995	15	0sec	30sec	35sec
5	90	15	Magnafloc LT7995	10	30sec	30sec	35sec
6	90	15	Magnafloc LT7995	10	30sec	35sec	35sec

	Target pH	**Settled Water Quality**														**Turbidity (NTU)**	
Jar		**pH**	**Zeta**	**UV 254**	**TOC**	**SUVA**	**Alkalinity**	**Calcium**	**Ca (Filt)**	**Iron**	**Fe (Filt)**	**Mg**	**Mg (Filt)**	**SiO2**	**SiO2 (Filt)**	**5-min**	**10-min**
1	11	10.83	-13.6	7.01E-02	2.75	2.55	65	26.7	24.8	98.2	8.6	2.8	2.6	7.6	7.4	132.0	23.8
2	11	10.84	-7.81	6.38E-02	2.57	2.48	65	26.5	25.4	30.2	4.3	3.2	3.1	7.4	7.3	43.2	5.6
3	11	10.83	-2.25	5.80E-02	2.50	2.32	65	26.8	25.6	48.0	5.7	3.3	3.2	7.4	7.3	22.4	4.9
4	11	10.87	3.46	5.03E-02	2.51	2.01	70	26.6	25.7	61.9	6.4	3.3	3.3	7.4	7.2	20.6	5.7
5	11	10.8	-0.295	5.68E-02	2.48	2.29	70	25.5	25.1	42.1	61.9	3.4	3.3	7.3	7.2	14.3	4.6
6	11	10.76	-0.717	5.97E-02	2.48	2.41	60	24.6	24.0	59.5	34.5	3.6	3.7	7.4	7.4	12.5	4.1

Jar Test #	16
Date	2/20/2019
Start Time	1:35
Polymer	
Jar Size	2000 mL

Date: 2/20/2019 13:35
Water: Collected from Ullrich WTP raw water sample location on 10/25/2018.
Test Objectives: Determine the effect of coagulant aid polymers on settleability of banked water at various ferric sulfate doses and pH 10.2.
Protocol: Ferric sulfate was added to the raw water (2 L) in a jar test apparatus at 200 rpm. Polymer was added 30 seconds after ferric, followed by lime addition. After 45 seconds of rapid mixing, the rpm was reduced to 55 to target a G-value of 55 s^{-1}. The jar test ran at 50 rpm for 30 minutes. Settled water turbidity samples were taken after 5 and 10 minutes of settling. Polymer types included Magnafloc LT7995 and Clarifloc C-358.

	Chemical Dose				**Chemical Dosing Time**		
Jar	**Lime (mg/L CaO)**	**Ferric Dose (mg/L)**	**Polymer Type**	**Polymer Dose**	**Ferric**	**Polymer**	**Lime**
1	83	80	Magnafloc LT7995	0	0sec	30sec	35sec
2	83	80	Magnafloc LT7995	15	0sec	30sec	35sec
3	100	180	Magnafloc LT7995	0	0sec	30sec	35sec
4	100	180	Magnafloc LT7995	10	0sec	30sec	35sec
5	57	15	C-358	10	0sec	30sec	35sec
6	57	15	C-358	15	0sec	30sec	35sec
7	57	15	C-358	20	0sec	30sec	35sec

	Target pH	**Settled Water Quality**														**Turbidity (NTU)**	
Jar		**pH**	**Zeta**	**UV 254**	**TOC**	**SUVA**	**Alkalinity**	**Calcium**	**Ca (Filt)**	**Iron**	**Fe (Filt)**	**Mg**	**Mg (Filt)**	**SiO2**	**SiO2 (Filt)**	**5-min**	**10-min**
1	10.2	10.28	-8.36	7.59E-02	2.74	2.77	40	22.5	21.7	138.6	10.6	4.4	4.4	5.6	5.7	123.0	24.2
2	10.2	10.34	1.03	5.11E-02	2.43	2.10		21.2	20.9	119.7	17.2	4.7	4.6	5.5	5.5	86.1	6.3
3	10.2	10.17	-5.46	6.48E-02	2.45	2.65	35	31.3	30.7	301.3	10.3	5.2	5.3	3.1	3.1	114.0	35.4
4	10.2	10.12	8.52	4.76E-02	2.29	2.08		30.2	28.9	441.9	13.8	5.5	5.5	3.1	3.0	107.0	35.1
5	10.2	10.05	-9.19	9.04E-02	3.21	2.81	65	19.1	18.6	79.0	9.7	6.7	6.5	7.3	7.2	7.5	3.0
6	10.2	10.06	-5.79	8.55E-02	3.22	2.65		18.2	17.8	69.4	21.4	6.5	6.5	7.4	7.3	9.1	3.8
7	10.2	10.10	-1.89	7.90E-02	3.22	2.45		18.5	17.6	85.3	25.8	6.6	6.5	7.6	7.4	14.5	3.4

Jar Test #	17
Date	2/21/2019
Start Time	11:53
	Impact of Center Well Solids
Jar Size	2000 mL

Date: 2/21/2019 11:53
Water: Collected from Ullrich WTP raw water sample location on 10/25/2018.
Solids: Collected from Handcox WTP UFC center well on 2/21/2019 at 7:30 am.
Test Objective: Mimic some of the conditions tested so far (15 and 30 mg/L ferric, using banked water) to see if the presence of solids makes a notable difference in chemistry and settleability. Assess whether ferrihydrite solids are providing a seed for $CaCO_3$ precipitation or complexing organics that would otherwise inhibit $CaCO_3$ crystal growth.
Protocol: At the start of rapid mix, ferric sulfate was added to the raw water (2 L) in a jar test apparatus at 200 rpm. After 30 seconds, coagulant aid polymer was dosed to jars 4 and 5, lime was dosed to all jars, solids were added to jars 2, 3, and 6, and the rpm was reduced to 55 to target a G value equal to 55 s^{-1}. Concentrated center well solids were added to noted jars to make up 13% of the 2-L jar volume simultaneously with lime. The jar test ran for 30 minutes. Settled water turbidity samples were collected after 5 and 10 minutes of settling.

	Chemical Dose						**Chemical Dosing Time**			
Jar	**Lime (mg/L CaO)**	**Center well solids**	**Ferric Dose (mg/L)**	**Description**	**Polymer Type**	**Polymer Dose**	**Ferric**	**Polymer**	**Lime**	**Solids**
1	85	0%	80	80 mg/L ferric, no solids	None	0	0sec		30sec	
2	85	13%	80	80 mg/L ferric, solids added 2nd	None	0	0sec		30sec	30sec
3	60	13%	15	15 mg/L ferric, 15 mg/L CAP, solids added last	Magnafloc	15	0sec	30sec	35sec	35sec
4	60	0%	15	15 mg/L ferric, 15 mg/L CAP, no solids	Magnafloc	15	0sec	30sec	35sec	
5	130	0%	80		None	0	0sec		30sec	
6	130	13%	80		None	0	0sec		30sec	30sec

	Target pH	**Settled Water Quality**															**Turbidity (NTU)**	
Jar		**pH**	**Zeta**	**UV 254**	**TOC**	**SUVA**	**Alkalinity**	**Calcium**	**Ca (Filt)**	**Iron**	**Fe (Filt)**	**Mg**	**Mg (Filt)**	**SiO2**	**SiO2 (Filt)**		**5-min**	**10-min**
1	10.2	10.46	-8.41	7.28E-02	3.009	2.42	45	22.0	21.2	122.8	4.1	4.2	4.1	5.7	5.7		177.0	43.8
2	10.2	10.71	-12.1	5.62E-02	2.677	2.10	45	24.4	23.4	65.1	2.9	3.5	3.4	6.0	5.9		40.4	9.1
3	10.2	10.52	0.69	5.76E-02	2.862	2.01		15.8	15.9	38.7	1.3	6.5	6.4	7.5	7.3		10.1	1.7
4	10.2	10.29	-0.354	7.06E-02	3.207	2.20	60	15.9	16.0	59.9	1.4	6.6	6.5	7.4	7.3		8.6	4.2
5	11	11.3		4.25E-02	2.269	1.87	90	45.4	44.1	56.8	3.0	0.3	0.3	6.4	6.4		69.5	19.7
6	11	11.26	-4.88	3.77E-02	2.185	1.72		47.5	46.6	34.3	3.3	0.3	0.3	6.6	6.7		21.7	6.3

Jar Test #	18
Date	2/21/2019
Start Time	16:30
	CO2 addition
Jar Size	200 mL

pH undershot target
Date: 2/21/2019 16:30
Water: Collected from Ullrich WTP raw water sample location on 10/25/2018.
Test Objectives: Determine the impact on settlability of banked water when adding carbonate in the form of CO_2 to precipitate more $CaCO_3$ solids. Target settled water pH of 10.2.
Protocol: The addition of CO_2 was simulated through the addition of sodium bicarbonate ($NaHCO_3$) and hydrochloric acid. The acid was dosed to simulate the pH anticipated from adding CO_2. The required acid dose was determined based on RTW modeling. After adding CO_2 to the raw water (200 mL) in a jar test apparatus at a low rpm and measuring pH, 15 mg/L ferric sulfate was added at 200 rpm. After 30 seconds of rapid mixing, the rpm was reduced to 55 to target a G-value of 55 s^{-1}. The jar test ran at 55 rpm for 30 minutes, and was allowed to settle for 30 minutes before sample collection.

	Chemical Dose					**Initial pH**	**Settled Water Quality**													
Jar	**Lime (mg/L CaO)**	**Ferric Dose (mg/L)**	**Simulated CO2 Dose (mg/L)**	**NaHCO3 as soln (mg/L)**	**HCl (eq/L)**		**pH**	**Turbidity**	**Zeta**	**UV 254**	**TOC**	**Alkalinity**	**Calcium**	**Ca (Filt)**	**Iron**	**Fe (Filt)**	**Mg**	**Mg (Filt)**	**SiO2**	**SiO2 (Filt)**
1	60	15	0	0	0.0000	8.05	10.03	7.43	-16.5	1.18E-01	3.975	55	16.8	16.3	290.1	21.8	6.4	6.4	8.4	7.3
2	80	15	22	42	0.0005	7	9.77	8.61	-17	1.20E-01	4.017	55	16.5	15.5	521.6	29.6	6.8	6.7	9.4	7.2
3	100	15	44	84	0.0010	6.68	9.2	7.54	-16.9	1.18E-01	3.91	65	17.6	17.0	449.2	21.7	6.8	6.7	9.1	7.1
4	135	15	65	125	0.0015	6.48	9.38	7.46	-18.9	1.10E-01	3.73	55	16.9	14.7	419.9	18.2	6.6	6.5	8.8	7.1
5	76	15	0	0	0.0000	8.02	9.98	4.19	-17.2	9.01E-03	3.408	55	19.5	17.9	150.4	7.8	4.3	4.1	8.0	7.5
6	115	15	44	84	0.0010	6.72	9.69	7.09	-17.5	1.07E-01	3.68	50	15.4	14.7	390.0	14.3	6.2	6.1	8.8	7.2

Jar Test # 19
Date 2/22/2019
Start Time 13:00
CO2 addition, JT18 redo
Jar Size 200 mL

JT 18 redo for pH
Date: 2/22/2019 13:00
Water: Collected from Ullrich WTP raw water sample location on 10/25/2018.
Test Objectives: Determine the impact on settlability of banked water when adding carbonate in the form of CO_2 to precipitate more $CaCO_3$ solids. Target settled water pH of 10.2.
Protocol: The addition of CO_2 was simulated through the addition of sodium bicarbonate ($NaHCO_3$) and hydrochloric acid. The acid was dosed to simulate the pH anticipated from adding CO_2. The required acid dose was determined based on RTW modeling. After adding CO_2 to the raw water (200 mL) in a jar test apparatus at a low rpm and measuring pH, 15 mg/L ferric sulfate was added at 200 rpm. After 30 seconds of rapid mixing, the rpm was reduced to 55 to target a G-value of 55 s^{-1}. The jar test ran at 55 rpm for 30 minutes, and was allowed to settle for 30 minutes before sample collection.

	Chemical Dose					**Chemical Dosing Time (sec)**			
Jar	**Lime (mg/L CaO)**	**Ferric Dose (mg/L)**	**Simulated CO2 Dose (mg/L)**	**NaHCO3 as soln (mg/L)**	**HCl (eq/L)**	**HCl Stock (mL)**	**Ferric**	**Polymer**	**Lime**
1	57	15	0	0	0.0000	0	0		5
2	80	15	22	42	0.0005	1	0		5
3	100	15	44	84	0.0010	2	0		5
4	135	15	65	124	0.0015	3	0		5
5	76	15	0	0	0.0000	0	0		5
6	115	15	44	84	0.0010	2	0		5

	Initial pH	**Settled Water Quality**													
Jar		**pH**	**Turbidity**	**Zeta**	**UV 254**	**TOC (mg/L)**	**Alkalinity**	**Calcium**	**Ca (Filt)**	**Iron**	**Fe (Filt)**	**Mg**	**Mg (Filt)**	**SiO2**	**SiO2 (Filt)**
1		10.36	8.94	-18	1.13E-01	3.87	60	16.7	16.5	318.8	21.1	5.9	6.1	7.9	7.2
2	6.99	10.15	12.4	-16.8	1.15E-01	3.83	50	16.3	15.4	387.7	26.4	6.3	6.3	7.7	7.1
3	6.71	10.09	10	-17.1	1.12E-01	3.71	55	15.5	14.9	341.1	22.4	6.4	6.3	7.7	7.0
4	6.54	10	8.57	-17	1.08E-01	3.69	50	15.5	14.5	325.7	16.3	6.3	6.3	7.6	7.0
5		10.71	6.41	-18.6	8.23E-02	3.20	50	19.1	18.7	86.8	6.1	3.4	3.4	7.5	7.2
6	6.76	10.31	7.52	-17.4	9.94E-02	3.71	50	15.9	14.9	225.1	7.9	5.6	5.4	7.8	7.1

Jar Test # 20
Date 2/25/2019
Start Time 10:08
Polymer
Jar Size 2000 mL

Jar Test 20, Jars 1-5
Date: 2/25/2019 10:08
Water: Collected from Ullrich WTP raw water sample location on 2/13/2018.
Test Objective: Evaluate effect of feeding coagulant aid polymer at small dose year-round.
Protocol: Ferric sulfate was added to the raw water (2 L) in a jar test apparatus at 200 rpm. Coagulant aid polymer (Magnafloc LT7995) was added 30 seconds after ferric, followed by lime addition. After 45 seconds, the rpm was reduced to 55 to target a G value equal to 55 s^{-1}. The jar test ran at 55 rpm for 30 minutes. Settled water turbidity samples were taken after 5 and 10 minutes of settling.

Jar Test 20, Jars 6-8
Date: 2/25/2019 10:08
Water: Collected from Ullrich WTP raw water sample location on 10/25/2018.
Test Objective:
Compare polymer addition before and after lime addition as follow-up to JT14.
Protocol: Ferric sulfate was added to the raw water (2 L) in a jar test apparatus at 200 rpm. Coagulant aid polymer (Magnafloc LT7995) was added 30 seconds after ferric, followed by lime addition. in Jar 8, the order of lime and polymer addition was reversed. After 45 seconds, the rpm was reduced to 55 to target a G value equal to 55 s^{-1}. The jar test ran at 55 rpm for 30 minutes. Settled water turbidity samples were taken after 5 and 10 minutes of settling.

	Chemical Dose					**Chemical Dosing Time**		
Jar	**Lime (mg/L CaO)**	**Ferric Dose (mg/L)**	**Description**	**Polymer Type**	**Polymer Dose (mg/L)**	**Ferric**	**Polymer**	**Lime**
1	105	15	0 mg/L PEC, 15 mg/L ferric	Magnafloc LT7995	0	0sec	30sec	35sec
2	105	15	1 mg/L PEC, 15 mg/L ferric	Magnafloc LT7995	1	0sec	30sec	35sec
3	105	15	3 mg/L PEC, 15 mg/L ferric	Magnafloc LT7995	3	0sec	30sec	35sec
4	105	15	5 mg/L PEC, 15 mg/L ferric	Magnafloc LT7995	5	0sec	30sec	35sec
5	90	0	3 mg/L PEC, 0 mg/L ferric	Magnafloc LT7995	3	0sec	30sec	35sec
6	57	15	Ferric (30 s); Polymer (5 s); Lime		0	0sec	30sec	35sec
7	57	15	Ferric (30 s); Polymer (5 s); Lime	Magnafloc LT7995	10	0sec	30sec	35sec
8	57	15	Ferric (30 s); Lime (5 s); Polymer	Magnafloc LT7995	10	0sec	35sec	30sec

	Target pH	**Settled Water Quality**														**Turbidity (NTU)**	
Jar		**pH**	**Zeta**	**UV 254**	**TOC**	**SUVA**	**Alkalinity**	**Calcium**	**Ca (Filt)**	**Iron**	**Fe (Filt)**	**Mg**	**Mg (Filt)**	**SiO2**	**SiO2 (Filt)**	**5-min**	**10-min**
1	10.2	10.71	-10.4	6.37E-02	3.025	2.10	80	19.3	18.2	89.2	1.1	16.8	16.7	7.9	7.9	30.5	14.0
2	10.2	10.66	-5.71	5.93E-02	2.939	2.02		19.6	18.2	59.6	0.8	16.9	16.7	7.9	7.9	17.4	10.5
3	10.2	10.67	-1.57	5.41E-02	2.916	1.86		18.8	17.1	47.1	0.1	16.4	16.6	7.7	7.9	20.1	9.8
4	10.2	10.65	3.74	4.98E-02	2.948	1.69	85	18.1	16.8	56.7	0.1	16.4	16.7	7.8	7.9	16.2	9.7
5	10.2	10.41	-7.28	5.87E-02	3.308	1.78	55	22.8	15.9	9.8	-0.3	17.3	17.3	8.4	8.4	57.6	40.1
6	10.2	10.23	-16.5	1.20E-01	3.921	3.07	65	22.0	17.2	472.9	20.3	6.9	6.8	8.6	7.1	460.0	196.0
7	10.2	10.17	-7.53	8.06E-02	3.371	2.39	75	23.4	21.7	71.7	1.9	6.8	6.7	7.3	7.0	11.4	5.6
8	10.2	10.35	-6.78	8.20E-02	3.574	2.30		24.0	22.3	82.0	1.3	6.8	6.8	7.3	7.2	10.7	6.7

Jar Test # 21
Date 2/25/2019
Start Time 14:22
Floc Aid Polymer
Jar Size 2000 mL

Jar Test 21
Date: 2/25/2019 14:22
Water: Collected from Ullrich WTP raw water sample location on 10/25/2018.
Test Objective: Evaluate the effect of feeding flocculant aid polymer on the settleability of banked water at the optimal ferric sulfate and coagulant aid polymer doses determined in previous tests and pH 10.5.
Protocol: Ferric sulfate was added to the raw water (2 L) in a jar test apparatus at 200 rpm. Coagulant aid polymer (Magnafloc LT7995) was added 30 seconds after ferric, followed by lime addition. Flocculant aid polymer was added at a dose of 0.5 or 1.0 mg/L simultaneously with lime or 10 minutes into the flocculation period. After 45 seconds of rapid mix, the rpm was reduced to 55 to target a G value equal to 55 s^{-1}. The jar test ran at 55 rpm for 30 minutes. Settled water turbidity samples were taken after 5 and 10 minutes of settling. Flocculant aid polymers tested were Nalco 7766+ and Clarifloc A-6330.

	Chemical Dose			**Coag Aid**		**Floc Aid**		**Chemical Dosing Time (sec)**				**Target pH**	**Settled Water Quality**		**Turbidity (NTU)**	
Jar	**Lime (mg/L CaO)**	**Ferric Dose (mg/L)**	**Description**	**Polymer Type**	**Polymer Dose (mg/L)**	**Polymer Type**	**Polymer Dose (mg/L)**	**Ferric**	**Coag Aid**	**Floc Aid**	**Lime**		**pH**	**Zeta**	**5-min**	**10-min**
1	57	15	0 mg/L floc aid	Magnafloc LT7995	10			0	30		35	10.2	10.53	-5.6	7.64	3.9
2	57	15	0.5 mg/L floc aid, added simultaneously with lime	Magnafloc LT7995	10	Nalco 7766+	0.5	0	30	35	35	10.2	10.63	-5.26	9.9	4.62
3	57	15	1.0 mg/L floc aid, added simultaneously with lime	Magnafloc LT7995	10	Nalco 7766+	1	0	30	35	35	10.2	10.59	-6.6	14.7	6.87
4	57	15	1.0 mg/L floc aid, added 10 minutes into flocculation	Magnafloc LT7995	10	Nalco 7766+	1	0	30	600	35	10.2	10.58	-11.7	13.7	8.52
5	57	15	0.5 mg/L floc aid, added simultaneously with lime	Magnafloc LT7995	10	Clarifloc A-6330	0.5	0	30	35	35	10.2	10.61	-6.15	13.7	6.19
6	57	15	1.0 mg/L floc aid, added simultaneously with lime	Magnafloc LT7995	10	Clarifloc A-6330	1	0	30	35	35	10.2	10.6	-12.2	12.8	9.86
7	57	15	1.0 mg/L floc aid, added 10 minutes into flocculation	Magnafloc LT7995	10	Clarifloc A-6330	1	0	30	600	35	10.2	10.58	-12.1	13	9.93

Jar Test #	22
Date	2/26/2019
Start Time	11:57
	CO2 & caustic
Jar Size	200 mL

Date: 2/26/2019 11:57
Water: Collected from Ullrich WTP raw water sample location on 10/25/2018.
Test Objectives: Determine the impact on settlability of banked water when adding adding CO_2 and NaOH to generate more alkalinity and precipitate more $CaCO_3$ solids. Target settled water pH of 10.2.
Protocol: The addition of CO_2 was simulated through the addition of sodium bicarbonate ($NaHCO_3$) and hydrochloric acid. The acid was dosed to simulate the pH anticipated from adding CO_2. The required acid dose was determined based on RTW modeling. After adding CO_2 to the raw water (200 mL) in a jar test apparatus at a low rpm and measuring pH, 15 mg/L ferric sulfate was added at 200 rpm. Caustic was dosed simultaneously with or 5 seconds prior to lime, as noted. After 30 seconds of rapid mixing, the rpm was reduced to 55 to target a G-value of 55 s^{-1}. The jar test ran at 55 rpm for 30 minutes, and was allowed to settle for 30 minutes before sample collection.
Jars 4-6 hit target settled water pH of 10.2.

	Chemical Dose							**Chemical Dosing Time (sec)**		
Jar	**Lime (mg/L CaO)**	**Ferric Dose (mg/L)**	**Simulated CO2 Dose (mg/L)**	**NaHCO3 as soln (mg/L)**	**HCl (eq/L)**	**NaOH (mg/L)**	**NaOH (eq/L)**	**Ferric**	**Caustic**	**Lime**
1	65	15	44	84	0.001	30	0.00075	0	30	35
2	65	15	44	84	0.001	30	0.00075	0	30	30
3	65	15	44	84	0.001	30	0.00075	15	0	20
4	84	15	44	84	0.001	30	0.00075	0	30	35
5	84	15	44	84	0.001	30	0.00075	0	30	30
6	84	15	44	84	0.001	30	0.00075	15	0	20

	Initial pH	**Settled Water Quality**												
Jar		**pH**	**NTU**	**Zeta**	**TOC (mg/L)**	**Alkalinity**	**Calcium**	**Ca (Filt)**	**Iron**	**Fe (Filt)**	**Mg**	**Mg (Filt)**	**SiO2**	**SiO2 (Filt)**
1	6.79	9.90	13.8	-17.9	7.56	90	14.9	13.5	1008.6	66.1	6.3	6.2	9.9	6.9
2		10.03	9.95	-17.1	5.14	85	14.9	13.3	761.8	54.0	6.3	6.1	8.6	6.9
3		9.79	12.8	-19.2	4.29	90	15.9	14.8	789.8	35.2	6.3	6.3	10.2	6.8
4		10.24	19.6	-20.3	4.06	75	12.3	10.6	1031.4	43.2	6.0	5.7	11.3	6.9
5		10.23	20.2	-20.5	4.20	75	12.7	10.6	1052.1	41.7	5.9	5.7	11.3	6.9
6		10.28	15.8	-21.4	4.18	75	12.7	10.0	741.2	31.8	5.9	5.6	9.6	6.7

Jar Test #	23
Date	2/27/2019
Start Time	10:34
	CO2 & caustic
Jar Size	2000 mL

Date: 2/26/2019 11:57
Water: Collected from Ullrich WTP raw water sample location on 10/25/2018.
Test Objectives: Determine the impact on settlability of banked water when adding adding CO_2 and NaOH to generate more alkalinity and precipitate more $CaCO_3$ solids. Target settled water pH of 10.2.
Protocol: The addition of CO_2 was simulated through the addition of sodium bicarbonate ($NaHCO_3$) and hydrochloric acid. The acid was dosed to simulate the pH anticipated from adding CO_2. The required acid dose was determined based on RTW modeling. After adding CO_2 to the raw water (2 L) in a jar test apparatus at a low rpm and measuring pH, 15 mg/L ferric sulfate was added at 200 rpm. Caustic was dosed simultaneously with lime. Coagulant aid polymer was dosed to jar 7 five seconds prior to lime addition. After 30 seconds of rapid mixing, the rpm was reduced to 55 to target a G-value of 55 s^{-1}. The jar test ran at 55 rpm for 30 minutes. Settled water turbidity samples were taken after 5 and 10 minutes of settling.

	Chemical Dose						**Coag Aid**		**Chemical Dosing Time (sec)**			
Jar	**Lime (mg/L CaO)**	**Ferric Dose (mg/L)**	**NaHCO3 as soln (mg/L)**	**HCl (eq/L)**	**NaOH (mg/L)**	**NaOH (eq/L)**	**Polymer Type**	**Polymer Dose**	**Ferric**	**Caustic**	**CAP**	**Lime**
1) 0 mg/L CO2	55	15	0	0.0000	0	0		0	0			30
2) 22 mg/L CO2	80	15	42	0.0005	0	0		0	0			30
3) 44 mg/L CO2	105	15	84	0.0010	0	0		0	0			30
4) 65 mg/L CO2	140	15	125	0.0015	0	0		0	0			30
5) 44 mg/L CO2	84	15	84	0.0010	30	0.00075		0	0	30		30
6) 65 mg/L CO2	94	15	125	0.0015	45	0.001125		0	0	30		30
7) 44 mg/L CO2	105	15	84	0.0010	0	0	Magnafloc LT7995	10	0		30	35

	pH	**pH HQ40D**				**Settled Water Quality**												**Turbidity (NTU)**	
Jar	**Target**	**Initial pH**	**Start of Flocculation**	**End of Flocculation**	**Settled**	**pH Orion**	**Zeta**	**TOC (mg/L)**	**Alkalinity**	**Calcium**	**Ca (Filt)**	**Iron**	**Fe (Filt)**	**Mg**	**Mg (Filt)**	**SiO2**	**SiO2 (Filt)**	**5-min**	**10-min**
1) 0 mg/L CO2	10.2	8.3	10.58	10.46	10.39	10.28	-16.5	4.33	60	16.6	15.4	842.4	60.1	6.4	6.3	10.4	7.1	275.0	77.3
2) 22 mg/L CO2	10.2	7.23	10.59	10.46	10.43	10.25	-17.1	4.03	60	16.1	15.0	668.4	47.7	6.3	6.2	9.5	7.1	238.0	76.9
3) 44 mg/L CO2	10.2	6.95	10.46	10.32	10.29	10.09	-17.1	3.94	60	15.5	14.3	691.6	38.7	6.2	6.2	9.7	7.0	253.0	79.3
4) 65 mg/L CO2	10.2	6.72	10.86	10.75	10.69	10.52	-16.9	3.78	55	14.7	13.9	308.8	14.2	5.4	5.2	7.9	7.0	230.0	57.1
5) 44 mg/L CO2	10.2	6.93	10.65	10.56	10.52	10.29	-20.6	4.08	80	10.9	9.5	1023.0	56.7	5.9	5.7	11.2	7.0	263.0	80.7
6) 65 mg/L CO2	10.2	6.73	10.5	10.41	10.39	10.17	-21.2	4.15	95	9.8	8.5	851.5	58.8	6.0	5.8	10.1	6.8	239.0	62.7
7) 44 mg/L CO2	10.2	6.89	10.65	10.51	10.41	10.24	-8.39	3.49	55	15.3	15.0	66.8	3.5	5.9	6.0	6.9	6.9	18.8	3.6

Phase 2 Jar Testing

Jar Test #	Water Supply	Jar Type	General Description	Ferric?	Center Well Solids?	Coag Aid Polymer?	Floc Aid Polymer?	CO2?	NaOH?	pH
1	Banked water	2 L	Impact of flocculant aid polymer	Yes	Handcox	Yes	Yes	No	No	10.5
2 & 3	Banked water	2 L	Impact of CO2 with solids and PEC	Yes	Handcox	Yes	No	Yes	No	9.7-10.5
4	Banked water	2 L	Coagulant aid polymer dose optimization	Yes	No	Yes	No	No	No	10.3
5 & 6	Banked water	2 L	Impact of pH	Yes	No	Yes	No	No	No	9.6-10.5
7	Current water	2 L	Impact of velocity gradient (G)	Yes	Handcox	No	No	No	No	10.1-10.3
S1	Current water	2 L	Iterative generation of solids with current water	Yes	Generated	No	No	No	No	10.1-10.3
S2	Banked water	2 L	Iterative generation of solids with PEC	Yes	Generated	Yes	No	No	No	9.9-10.2
S3	Banked water	2 L	Iterative generation of solids with PEC & 1 mg/L PEA	Yes	Generated	Yes	Yes	No	No	9.9-10.2
S4	Banked water	2 L	Iterative generation of solids with PEC & 0.1 mg/L PEA	Yes	Generated	Yes	Yes	No	No	9.9-10.1
S5	Banked water	2 L	Iterative generation of solids with PEC & 0.3 mg/L PEA	Yes	Generated	Yes	Yes	No	No	9.8

Jar Test # 1 Phase 2
Date 3/28/2019
Start Time 12:49
Floc Aid Polymer
Jar Size 2000 mL

Floc Aid Polymer Pretests
Date: 3/28/19, 12:49
Water: Collected from Ullrich WTP raw water sample location on 10/25/2018.
Solids: Collected from Handcox WTP UFC #2 centerwell on 3/27/19.
Test Objective: Evaluate the effect of feeding flocculant aid polymer on the settleability of banked water at the optimal ferric sulfate and coagulant aid polymer doses determined in previous tests and pH 10.2. Compare with and without centerwell solids.
Protocol: Ferric sulfate was added to the raw water (2 L) in a jar test apparatus at 200 rpm. Coagulant aid polymer (Magnafloc LT7995) was added 30 seconds after ferric, followed by addition of center well solids to noted jars to make up 13% of the 2-L jar volume. Directly after solids addition, flocculant aid polymer (FAP) was added at a dose of 1.0 mg/L simultaneously with lime. After 45 seconds of rapid mix, the rpm was reduced to 55 to target a G value equal to 55 s^{-1}. The jar test ran at 55 rpm for 30 minutes. Settled water turbidity samples were taken after 5 and 10 minutes of settling. Flocculant aid polymers tested were Nalco 7766 Plus (nonionic), Clarifloc A-6330 (anionic), and Clarifloc C-6220 (cationic).
Settled water pH = 10.5 for jars without solids and 10.7 for jars with centerwell solids.

	Chemical Dose			**Coag Aid**		**Floc Aid**					**Chemical Dosing Time (sec)**			
Jar	**Lime (mg/L CaO)**	**Ferric Dose (mg/L)**	**Label**	**Polymer Type**	**Polymer Dose**	**Polymer Type**	**Charge**	**Polymer Dose**	**CW Solids**	**CW Solids**	**Ferric**	**Coag Aid**	**Floc Aid**	**Lime**
1	55	15	0 mg/L PEA	Magnafloc LT7995	10			0	0%		0	30		60
2	55	15	1 mg/L non-ionic PEA	Magnafloc LT7995	10	Nalco 7766+	Non-ionic	1	0%		0	30	60	60
3	55	15	1 mg/L anionic PEA	Magnafloc LT7995	10	Clarifloc A-6330	Anionic	1	0%		0	30	60	60
4	55	15	1 mg/L cationic PEA	Magnafloc LT7995	10	Clarifloc C-6220	Cationic	1	0%		0	30	60	60
5	55	15	3 mg/L cationic PEA	Magnafloc LT7995	10	Clarifloc C-6220	Cationic	3	0%		0	30	60	60
6	55	15	0 mg/L PEA	Magnafloc LT7995	10			0	13%	35-60	0	30		60
7	55	15	1 mg/L non-ionic PEA	Magnafloc LT7995	10	Nalco 7766+	Non-ionic	1	13%	35-60	0	30	60	60
8	55	15	1 mg/L anionic PEA	Magnafloc LT7995	10	Clarifloc A-6330	Anionic	1	13%	35-60	0	30	60	60
9	55	15	1 mg/L cationic PEA	Magnafloc LT7995	10	Clarifloc C-6220	Cationic	1	13%	35-60	0	30	60	60
10	55	15	3 mg/L cationic PEA	Magnafloc LT7995	10	Clarifloc C-6220	Cationic	3	13%	35-60	0	30	60	60

	Target pH	**Settled Water Quality**												**Turbidity (NTU)**	
Jar		**pH-HQ40D**	**pH-OrionStarA214**	**Zeta**	**TOC**	**Calcium**	**Ca (Filt)**	**Iron**	**Fe (Filt)**	**Mg**	**Mg (Filt)**	**SiO2**	**SiO2 (Filt)**	**5-min**	**10-min**
1	10.2	10.53	10.52	-12.3	4.17	20.3	18.1	69.5	0.6	6.9	6.3	7.2	6.9	13.1	5.2
2	10.2	10.54		-10.1	3.45	25.5	22.2	94.2	0.3	7.0	6.8	7.3	7.1	11.2	6.3
3	10.2	10.56	10.50	-8.69	3.24	27.8	23.1	98.5	-0.2	6.9	6.8	7.3	7.2	13.6	7.5
4	10.2	10.53		-3.29	3.49	23.8	21.8	88.6	0.4	6.7	6.9	7.3	7.2	13.1	8.6
5	10.2	10.49	10.48	-5.52	3.51	28.4	22.7	123.5	0.8	6.8	6.7	7.2	7.2	15.3	9.2
6	10.2	10.76	10.73	-3.12	3.36	17.6	16.7	40.5	0.0	7.1	6.9	7.1	7.1	21.9	3.8
7	10.2	10.78	10.74	-4.06	3.13	18.9	17.5	65.5	1.9	7.1	6.8	7.1	7.1	11.2	3.0
8	10.2	10.74	10.75	-5.71	3.39	19.3	18.5	68.4	1.0	7.1	7.0	7.2	7.1	7.4	4.5
9	10.2	10.81	10.77	-6.83	3.22	18.7	17.8	73.6	0.9	6.9	6.9	7.2	7.0	13.4	4.0
10	10.2	10.73	10.70	-10.8	3.59	21.5	19.8	116.6	1.8	7.0	7.1	7.1	7.1	10.1	6.5

Jar Test # 2 Phase 2
Date 3/29/2019
Start Time 9:58
CO2
Jar Size 2000 mL

CO2 Addition Pretests
Date: 3/29/19
Water: Collected from Ullrich WTP raw water sample location on 10/25/2018.
Solids: Collected from Handcox WTP UFC #2 centerwell on 3/27/19.
Test Objectives: Determine the impact on settlability of banked water when adding adding a high CO_2 dose to precipitate more $CaCO_3$ solids. Target settled water pH of 10.2.
Protocol: The addition of CO_2 was simulated through the addition of sodium bicarbonate ($NaHCO_3$) and hydrochloric acid. The acid was dosed to simulate the pH anticipated from adding CO_2. The required acid dose was determined based on RTW modeling. After adding CO_2 to the raw water (2 L) in a jar test apparatus at a low rpm and measuring pH, 15 mg/L ferric sulfate was added at 200 rpm. Coagulant aid polymer was dosed to jars 4-6 five seconds prior to lime addition. After 30 seconds of rapid mixing, the rpm was reduced to 85 to target a G-value of 100 s^{-1}. The jar test ran at 85 rpm for 30 minutes. Settled water turbidity samples were taken after 5 and 10 minutes of settling.

	Chemical Dose					**Coag Aid**		**Chemical Dosing Time (sec)**			
Jar	**Lime (mg/L CaO)**	**Ferric Dose (mg/L)**	**Simulated CO2 (mg/L)**	**NaHCO3 as soln (mg/L)**	**HCl (eq/L)**	**Polymer Type**	**Polymer Dose**	**Center well solids**	**Ferric**	**CAP**	**Lime**
1	53	15	0	0	0.0000	Magnafloc LT7995	0		0		60
2	105	15	44	84	0.0010	Magnafloc LT7995	0		0		60
3	150	15	88	168	0.0020	Magnafloc LT7995	0		0		60
4	53	15	0	0	0.0000	Magnafloc LT7995	10		0	30	60
5	105	15	44	84	0.0010	Magnafloc LT7995	10		0	30	60
6	150	15	88	168	0.0020	Magnafloc LT7995	10		0	30	60
7	48	15	0	0	0.0000	Magnafloc LT7995	0	35-60	0		60
8	103	15	44	84	0.0010	Magnafloc LT7995	0	35-60	0		60
9	148	15	88	168	0.0020	Magnafloc LT7995	0	35-60	0		60

	pH	**pH HQ40D**	**Settled Water Quality**												**Turbidity (NTU)**	
Jar	**Target**	**Initial pH**	**pH Orion**	**Zeta**	**TOC (mg/L)**	**Alkalinity**	**Calcium**	**Ca (Filt)**	**Iron**	**Fe (Filt)**	**Mg**	**Mg (Filt)**	**SiO2**	**SiO2 (Filt)**	**5-min**	**10-min**
1	10.2	8.01	10.31	-15.7	3.94	85	19.1	16.0	415.2	39.7	6.8	6.6	7.6	7.1	499	252
2	10.2	7.11	10.07	-16.6	4.01	70	18.8	15.8	435.4	32.5	6.8	6.7	7.5	7.1	589	245
3	10.2	6.62	9.66	-18.8	3.73	65	20.7	18.2	360.6	19.9	6.7	6.7	7.5	7.0	579	216
4	10.2		10.37	-9.05	3.43	65	17.9	17.4	35.2	1.2	6.7	6.5	7.1	7.1	14.8	5.5
5	10.2	7.07	10.09	-6.00	3.34	65	16.7	16.8	28.5	0.1	6.5	6.6	7.0	7.1	16.7	3.0
6	10.2	6.65	9.72	-8.17	3.42	65	18.6	18.2	22.3	0.0	6.7	6.6	6.9	7.0	18.4	4.2
7	10.2		10.36	-17.7	3.46	65	23.7	15.7	358.8	4.5	7.6	7.3	7.5	6.9	153	54
8	10.2	6.99	10.51	-15.7	3.43	60	33.5	14.0	485.1	0.9	7.4	6.3	7.7	7.8	170	62
9	10.2	6.62	10.51	-13.1	3.39	65	17.5	14.0	160.3	1.3	6.5	6.4	7.2	6.8	215	61

Jar Test #	3	Phase 2
Date	4/1/2019	
Start Time	10:47	
	CO2 with solids and PEC	
Jar Size	2000	mL

CO2 Addition Pretests
Date: 4/1/19
Water: Collected from Ullrich WTP raw water sample location on 10/25/2018.
Solids: Collected from Handcox WTP UFC #2 centerwell on 3/27/19.
Test Objectives: Determine the impact on settlability of banked water when adding adding a high CO_2 dose to precipitate more $CaCO_3$ solids. Target settled water pH of 10.2.
Protocol: The addition of CO_2 was simulated through the addition of sodium bicarbonate ($NaHCO_3$) and hydrochloric acid. The acid was dosed to simulate the pH anticipated from adding CO_2. The required acid dose was determined based on RTW modeling. After adding CO_2 to the raw water (2 L) in a jar test apparatus at a low rpm and measuring pH, 15 mg/L ferric sulfate was added at 200 rpm. Coagulant aid polymer was dosed 30 seconds after ferric addition, followed by solids addition and lime addition. After at least 60 seconds of rapid mixing, the rpm was reduced to 85 to target a G-value of 100 s^{-1}. The jar test ran at 85 rpm for 30 minutes. Settled water turbidity samples were taken after 5 and 10 minutes of settling.

	Chemical Dose					**Coag Aid**		**Chemical Dosing Time (sec)**			
Jar	**Lime (mg/L CaO)**	**Ferric Dose (mg/L)**	**Simulated CO2 (mg/L)**	**NaHCO3 as soln (mg/L)**	**HCl (eq/L)**	**Polymer Type**	**Polymer Dose**	**Center well solids**	**Ferric**	**CAP**	**Lime**
1	46	15	0	0	0.0000	Magnafloc LT7995	10	35-60	0	30	60
2	99	15	44	84	0.0010	Magnafloc LT7995	10	35-60	0	30	60
3	144	15	88	168	0.0020	Magnafloc LT7995	10	35-60	0	30	60

	pH	**pH HQ40D**	**Settled Water Quality**													**Turbidity (NTU)**	
Jar	**Target**	**Initial pH**	**pH HQ40D**	**Zeta**	**TOC (mg/L)**	**Alkalinity**	**Calcium**	**Ca (Filt)**	**Iron**	**Fe (Filt)**	**Mg**	**Mg (Filt)**	**SiO2**	**SiO2 (Filt)**		**5-min**	**10-min**
1	10.2	8.1	10.47	-5.66	2.97	60	17.5	17.0	35.6	0.0	7.5	7.4	6.8	6.8		9.7	3.6
2	10.2	7.4	10.46	-8.79	3.11	60	15.7	15.5	27.1	0.0	7.2	7.1	6.8	6.8		14.9	4.0
3	10.2	7.1	10.25	-4.68	3.10	55	16.8	15.5	37.8	0.0	7.2	7.2	6.7	6.7		31.4	3.9

Jar Test #	4 Phase 2
Date	4/1/2019
Start Time	14:40
	Coag Aid Polymer
Jar Size	2000 mL

Coagulant Aid Polymer Dose Optimization
Date: 4/1/19
Water: Collected from Ullrich WTP raw water sample location on 10/25/2018.
Test Objective: Evaluate the effect of feeding a range of coagulant aid polymer doses on the settleability of banked water at the optimal ferric sulfate dose determined in previous tests and pH 10.2.
Protocol: 15 mg/L ferric sulfate was added to the raw water (2 L) in a jar test apparatus at 200 rpm. Coagulant aid polymer (Magnafloc LT7995) was added 30 seconds after ferric, followed by lime addition. After 60 seconds of rapid mix, the rpm was reduced to 55 to target a G value equal to 55 s^{-1}. The jar test ran at 55 rpm for 30 minutes. Settled water turbidity samples were taken after 2, 5 and 10 minutes of settling.

	Chemical Dose		**Coag Aid**			**Chemical Dosing Time (sec)**			**Target pH**	**Settled Water Quality**		**Turbidity (NTU)**		
Jar	**Lime (mg/L CaO)**	**Ferric Dose (mg/L)**	**Description**	**Polymer Type**	**Polymer Dose**	**Ferric**	**Coag Aid**	**Lime**		**pH**	**Zeta**	**2-min**	**5-min**	**10-min**
1	52	15	0 mg/L PEC	Magnafloc LT7995	0	0	30	35	10.2	10.35	-16	517	479	329
2	52	15	4 mg/L PEC	Magnafloc LT7995	4	0	30	35	10.2	10.33	-6.83	162	22.5	10
3	52	15	8 mg/L PEC	Magnafloc LT7995	8	0	30	35	10.2	10.35	-4.57	116	7.02	4.7
4	52	15	10 mg/L PEC	Magnafloc LT7995	10	0	30	35	10.2	10.33	-1.62	101	5.9	6.4
5	52	15	12 mg/L PEC	Magnafloc LT7995	12	0	30	35	10.2	10.33	-0.94	92.4	12.1	4.3
6	52	15	15 mg/L PEC	Magnafloc LT7995	15	0	30	35	10.2	10.36	0.113	127	15.8	5.1

Jar Test # 5 Phase 2
Date 4/2/2019
Start Time 11:48
pH Optimization
Jar Size 2000 mL

Effect of pH (Jars 1-4)
Date: 4/2/19
Water: Collected from Ullrich WTP raw water sample location on 10/25/2018.
Test Objective: Evaluate the effect of pH (9.8-10.2) on the settleability of banked water at the optimal coagulant aid polymer and ferric sulfate doses determined in previous tests.
Protocol: 15 mg/L ferric sulfate was added to the raw water (2 L) in a jar test apparatus at 200 rpm. Coagulant aid polymer (Magnafloc LT7995) was added 30 seconds after ferric, followed by lime addition. After 60 seconds of rapid mix, the rpm was reduced to 55 to target a G value equal to 55 s^{-1}. The jar test ran at 55 rpm for 30 minutes. Settled water turbidity samples were taken after 2, 5 and 10 minutes of settling.

	Chemical Dose		Coag Aid		Chemical Dosing Time (sec)		
Jar	**Lime (mg/L CaO)**	**Ferric Dose (mg/L)**	**Polymer Type**	**Polymer Dose**	**Ferric**	**Coag Aid**	**Lime**
1	37	15	Magnafloc LT7995	10	0	30	35
2	40	15	Magnafloc LT7995	10	0	30	35
3	43	15	Magnafloc LT7995	10	0	120	35
4	46	15	Magnafloc LT7995	10	0	30	35
5	43	0	Magnafloc LT7995	0	0	30	35
6	60	80	Magnafloc LT7995	0	0	30	35

	Target pH	Settled Water Quality												Turbidity (NTU)		
Jar		**pH**	**Zeta**	**TOC**	**Alkalinity**	**Calcium**	**Ca (Filt)**	**Iron**	**Fe (Filt)**	**Mg**	**Mg (Filt)**	**SiO2**	**SiO2 (Filt)**	**2-min**	**5-min**	**10-min**
1	9.9	10.13	-3.67	3.26	95	31.9	28.1	72.4	0.0	6.8	6.8	7.1	6.9	57	4.92	3.64
2	10.0	10.20	-3.59	3.43	95	28.7	25.8	75.4	0.0	6.7	6.6	7.1	6.9	57.1	5	3.13
3	10.1	10.25	-4.86	3.42	85	28.7	25.5	73.5	0.0	6.7	6.8	7.1	6.9	24	4.12	3.38
4	10.2	10.44	-2.74	3.36	80	26.9	23.3	74.4	0.0	6.7	6.7	7.1	6.9	24.4	5.14	3.37
5	10.2	10.40	-15.4	4.50		77.7	16.9	705.2	16.1	7.6	6.8	9.9	7.4			388
6	10.2	10.24	-14.4	3.59		23.1	22.1	186.6	0.2	6.4	6.5	5.2	5.0			54.3

Jar Test # 6 Phase 2
Date 4/2/2019
Start Time 15:15
pH Optimization - low
Jar Size 2000 mL

Effect of pH
Date: 4/2/19
Water: Collected from Ullrich WTP raw water sample location on 10/25/2018.
Test Objective: Evaluate the effect of pH (9.8-10.2) on the settleability of banked water at the optimal coagulant aid polymer and ferric sulfate doses determined in previous tests.
Protocol: 15 mg/L ferric sulfate was added to the raw water (2 L) in a jar test apparatus at 200 rpm. Coagulant aid polymer (Magnafloc LT7995) was added 30 seconds after ferric, followed by lime addition. After 60 seconds of rapid mix, the rpm was reduced to 55 to target a G value equal to 55 s^{-1}. The jar test ran at 55 rpm for 30 minutes. Settled water turbidity samples were taken after 2, 5 and 10 minutes of settling.

	Chemical Dose		Coag Aid		Chemical Dosing Time (sec)		
Jar	**Lime (mg/L CaO)**	**Ferric Dose (mg/L)**	**Polymer Type**	**Polymer Dose**	**Ferric**	**Coag Aid**	**Lime**
1	23	15	Magnafloc LT7995	10	0	30	35
2	27	15	Magnafloc LT7995	10	0	30	35
3	31	15	Magnafloc LT7995	10	0	120	35
4	35	15	Magnafloc LT7995	10	0	30	35

	Target pH	Settled Water Quality												Turbidity (NTU)		
Jar		**pH**	**Zeta**	**TOC**	**Alkalinity**	**Calcium**	**Ca (Filt)**	**Iron**	**Fe (Filt)**	**Mg**	**Mg (Filt)**	**SiO2**	**SiO2 (Filt)**	**2-min**	**5-min**	**10-min**
1	9.9	9.61	-2	3.812	115	32.9	33.7	67.6	0.0	6.9	7.1	7.2	7.1	27.8	2.79	1.75
2	10.0	9.69												25.0	2.68	1.87
3	10.1	9.77	-3.62	3.525	90	28.0	28.1	69.0	0.0	7.0	6.9	7.2	7.0	28.9	3.26	1.94
4	10.2	9.86	-3.06	3.473	90	26.1	25.5	68.4	0.0	7.0	6.8	7.2	7.1	24.5	2.63	2.17

Jar Test # 7 Phase 2
Date 4/8/2019
Start Time 9:00
Impact of G-value
Jar Size 2000 mL

Impact of G-value
Date: 4/8/19
Water: Collected from Handcox WTP raw water sample location on 4/5/2019.
Solids: Collected from Handcox WTP UFC centerwell on 4/5/2019.
Test Objective: Evaluate the effect of G-value on the settleability of current water at the average ferric sulfate dose.
Protocol: Concentrated solids were added to make up 2% of jar volume as noted either before ferric sulfate or simultaneously with lime. 15 mg/L ferric sulfate was added to the raw water (2 L) in a jar test apparatus at 200 rpm. Lime was added 30 seconds after ferric. After 60 seconds of rapid mix, the rpm was reduced to 85 or 45 to target G-values equal to 100 s^{-1} and 40 s^{-1}. The jar test ran for 30 minutes.

	Chemical Dose				**Chemical Dosing Time (sec)**			**rpm**	**Settled Water Quality**	**Turbidity (NTU)**		
Jar	**Lime (mg/L CaO)**	**Ferric Dose (mg/L)**	**Label**	**CW Solids**	**CW Solids**	**Ferric**	**Lime**		**pH**	**2-min**	**5-min**	**10-min**
1	82	15	G=100 1/sec, no solids, ferric 1st, lime 2nd	0%		0	35	85	10.35	218	70.7	13.8
2	82	15	G=100 1/sec, solids 1st, ferric 2nd, lime 3rd	3%	pre	0	35	85	10.15	402	166	85.2
3	82	15	G=40 1/sec, no solids, ferric 1st, lime 2nd	0%		0	35	45	10.25	28.3	5.7	5.7
4	82	15	G=40 1/sec, solids 1st, ferric 2nd, lime 3rd	3%	pre	0	35	45	10.22	288	66.5	20.2
5	82	15	G=40 1/sec, ferric 1st, then solids and lime simultaneously	3%	35	0	35	45	10.10	316	54.2	9.63

Jar Test # S1
Date 4/1/2019

Jar Size 2000 mL

Iterative generation of solids
Date: 4/1/19
Water: Collected from Ullrich WTP raw water sample location on 2/13/19.
Protocol: 15 mg/L ferric sulfate was added to the raw water (2 L) in a jar test apparatus at 200 rpm. After 30 seconds of rapid mixing, lime and solids generated in the previous test were added, starting with Iteration #2. The jar test ran at 85 rpm to target a G-value of 100 s^{-1} for 30 minutes.

	Chemical Dose		pH	pH HQ40D													Turbidity (NTU)				
Jar	Lime (mg/L CaO)	Ferric Dose (mg/L)	Target	Initial pH	Settled pH	Zeta	TOC (mg/L)	Alkalinity	Calcium	Ca (Filt)	Iron	Fe (Filt)	Mg	Mg (Filt)	SiO2	SiO2 (Filt)	2-min	4-min	7-min	10-min	15-min
1	85	15	10.2	10.65	10.32	-7.64	3.351	105	22.5	19.3	84.4	0.0	17.2	17.1	7.8	7.7	200.0	157.0	45.7	23.7	
2	83	15			10.34	-5.94		100									279.0	171.0	53.4	27.8	
3	83	15			10.15	-7.5											409.0	165.0	47.8	12.5	17.0
4	83	15			10.15	-7.62											357.0	177.0	45.7	16.1	10.5
5	83	15			10.15	-5.84	3.379	85	14.7	13.6	65.9	0.0	17.1	16.7	7.7	7.6	339.0	165.0	50.1	32.1	16.5
6	83	15			10.1	-6.26											444.0	189.0	60.7	19.8	17.5
7	83	15			10.19	-9.84											448.0	195.0	74.2	23.1	14.2
8	83	15			10.21	-7.66											381.0	152.0	42.2	14.3	11.1
9	83	15			10.22	-4.09	3.247		14.5	11.7	85.1	0.0	17.1	16.7	7.6	7.6	339.0	140.0	34.2	11.7	7.3
10	83	15			10.13	-3.72											291.0	133.0	40.0	9.0	11.0
11	83	15			10.3	-5.88											323.0	129.0	29.7	12.0	7.9
12	83	15			10.29	-6.22											363.0	151.0	46.2	15.7	8.0
13	83	15			10.18	-4.52											262.0	137.0	41.6	19.4	8.5
14	83	15			10.29	-7.42											310.0	135.0	57.1	17.5	13.4
15	83	15			10.16	-11.5	3.702		13.0	10.5	73.9	0.0	16.9	16.7	7.6	7.5	304.0	151.0	55.6	16.6	11.5
3% solids					10.26	-8.13											757.0	285.0	114.0	73.8	48.4
S1-1.2							3.13		25.2	20.6	139.4	0.0	17.4	17.3	7.8	7.9					

Jar Test # S2
Date 4/8/2019
Start Time 10:00

Jar Size 2000 mL

Iterative generation of solids with banked water and PEC
Date: 4/8/19
Water: Collected from Ullrich WTP raw water sample location on 10/25/18.
Test Objectives: Evaluate solids growth and settleability in simulated solids contact clarifer centerwell.
Protocol: 15 mg/L ferric sulfate was added to the raw water (2 L) in a jar test apparatus at 80 rpm. After 30 seconds of rapid mixing, 12 mg/L of coagulant aid polymer (Magnafloc LT-7995) was added, followed by simultaneous addition of lime and solids generated in the previous test, starting with Iteration #2. The jar test ran at 55 rpm to target a G-value of 55 s^{-1} for 30 minutes.

	Chemical Dose		Coag Aid		Chemical Dosing Time (sec)			
Jar	Lime (mg/L CaO)	Ferric Dose (mg/L)	Polymer Type	Polymer Dose	Center well solids	Ferric	PEC	Lime
1	43	15	Magnafloc LT-7995	12	40	0	30	40
2	43	15	Magnafloc LT-7995	12	40	0	30	40
3	43	15	Magnafloc LT-7995	12	40	0	30	40
4	45	15	Magnafloc LT-7995	12	40	0	30	40
5	45	15	Magnafloc LT-7995	12	40	0	30	40
6	49	15	Magnafloc LT-7995	12	40	0	30	40
7	49	15	Magnafloc LT-7995	12	40	0	30	40
8	54	15	Magnafloc LT-7995	12	40	0	30	40
9	43	15	Magnafloc LT-7995	12	40	0	30	40
10	43	15	Magnafloc LT-7995	12	40	0	30	40

	pH	pH												Turbidity (NTU)				
Jar	Target	Settled	Zeta	TOC (mg/L)	Alkalinity	Calcium	Ca (Filt)	Iron	Fe (Filt)	Mg	Mg (Filt)	SiO2	SiO2 (Filt)	2-min	5-min	10-min	Solids (inches)	% solids
1	10.1	10.18	-0.83	3.41		25.6	23.2	105.5	0.0	6.7	6.7	7.2	7.1	21.4	5.82	3.65		
2	10.1	10.02	-1.75		75									16.6	2.66	1.71		
3	10.1	9.94	-4.27											21	1.81	1.75	0.15	2.5%
4	10.1	10.01	-1.76											12	1.91	1.2		
5	10.1	9.98	-1.04											12.7	1.52	1.03		
6	10.1	9.93	-4.21	3.44	60	16.2	16.2	33.3	0.0	6.7	6.5	7.1	7.0	14.1	1.02	0.87	0.21	3.5%
7	10.1	9.86	-5.33											19.8	1.18	0.92		
8	10.1	9.96	-3.94											11.6	1.19	1.01		
9	10.1	9.86	-4.66											14.6	0.89	0.9		
10	10.1	9.64	-5.24	3.44	65	16.7	16.8	25.1	0.0	6.9	6.9	7.0	7.0	9.14	2.26	1.15	0.29	4.9%

Jar Test # S3
Date 4/8/2019
Start Time 10:00

Jar Size 2000 mL

Iterative generation of solids with banked water, PEC, and PEA
Date: 4/8/19
Water: Collected from Ullrich WTP raw water sample location on 10/25/18.
Test Objectives: Evaluate solids growth and settleability in simulated solids contact clarifer centerwell.
Protocol: 15 mg/L ferric sulfate was added to the raw water (2 L) in a jar test apparatus at 80 rpm. After 30 seconds of rapid mixing, 12 mg/L of coagulant aid polymer (Magnafloc LT-7995) was added, followed by simultaneous addition of lime and solids generated in the previous test, starting with Iteration #2. Then, 1 mg/L of anionic floc aid polymer was added, before turning down to 55 rpm. The jar test ran at 55 rpm to target a G-value of 55 s^{-1} for 30 minutes.

	Chemical Dose		Coag Aid		Floc Aid			Chemical Dosing Time (sec)			
Jar	Lime (mg/L CaO)	Ferric Dose (mg/L)	Polymer Type	Polymer Dose	Polymer Type	Charge	Polymer Dose	Center well solids	Ferric	PEC	Lime
1	43	15	Magnafloc LT-7995	12	Clarifloc A-6330	anionic	1	40	0	30	40
2	43	15	Magnafloc LT-7995	12	Clarifloc A-6330	anionic	1	40	0	30	40
3	43	15	Magnafloc LT-7995	12	Clarifloc A-6330	anionic	1	40	0	30	40
4	45	15	Magnafloc LT-7995	12	Clarifloc A-6330	anionic	1	40	0	30	40
5	45	15	Magnafloc LT-7995	12	Clarifloc A-6330	anionic	1	40	0	30	40
6	49	15	Magnafloc LT-7995	12	Clarifloc A-6330	anionic	1	40	0	30	40
7	49	15	Magnafloc LT-7995	12	Clarifloc A-6330	anionic	1	40	0	30	40
8	54	15	Magnafloc LT-7995	12	Clarifloc A-6330	anionic	1	40	0	30	40
9	50	15	Magnafloc LT-7995	12	Clarifloc A-6330	anionic	1	40	0	30	40
10	43	15	Magnafloc LT-7995	12	Clarifloc A-6330	anionic	1	40	0	30	40

	pH	pH													Turbidity (NTU)				
Jar	Target	Settled	Zeta	TOC (mg/L)	Alkalinity	Calcium	Ca (Filt)	Iron	Fe (Filt)	Mg	Mg (Filt)	SiO2	SiO2 (Filt)	2-min	5-min	10-min	Solids (inches)	% solids
1	10.2	10.17	-4.74	3.33		30.9	25.5	122.0	0.0	6.8	6.7	7.3	7.1	6.8	5.4	5.9		
2	10.2	10.12	-3.6		75									7.1	4.9	3.3		
3	10.2	9.93	-4.93											3.2	2.3	2.3	0.14	2.4%
4	10.2	10.06	-4.28											6.5	2.2	2.4		
5	10.2	9.94	-5.83											2.8	1.7	1.6		
6	10.2	10.06	-2.92	3.58	60	18.4	18.6	58.8	0.0	6.7	6.7	7.2	7.0	2.9	1.7	1.4	0.20	3.4%
7	10.2	9.92	-4.19											4.7	1.3	1.3		
8	10.2	10.03	-4.09											2.7	1.2	1.2		
9	10.2	9.92	-6.66											3.5	1.1	1.2		
10	10.2	9.71	-7.51	3.39	65	17.5	17.5	45.3	0.0	6.9	6.9	7.1	7.0	4.4	1.3	1.1	0.29	4.9%

Jar Test # S4
Date 4/9/2019
Start Time 10:00

Jar Size 2000 mL

Iterative generation of solids with banked water, PEC, and PEA
Date: 4/9/19
Water: Collected from Ullrich WTP raw water sample location on 10/25/18.
Test Objectives: Evaluate solids growth and settleability in simulated solids contact clarifer centerwell.
Protocol: 15 mg/L ferric sulfate was added to the raw water (2 L) in a jar test apparatus at 80 rpm. After 30 seconds of rapid mixing, 12 mg/L of coagulant aid polymer (Magnafloc LT-7995) was added, followed by simultaneous addition of lime and solids generated in the previous test, starting with Iteration #2. Then, 0.1 mg/L of anionic floc aid polymer was added, before turning down to 55 rpm. The jar test ran at 55 rpm to target a G-value of 55 s^{-1} for 30 minutes.

	Chemical Dose		Coag Aid		Floc Aid			Chemical Dosing Time (sec)				pH			Turbidity (NTU)				
Jar	Lime (mg/L CaO)	Ferric Dose (mg/L)	Polymer Type	Polymer Dose	Polymer Type	Charge	Polymer Dose	Center well solids	Ferric	PEC	Lime	Target	Settled	Zeta	2-min	5-min	10-min	Solids (inches)	% solids
1	48	15	Magnafloc LT-7995	12	Clarifloc A-6330	anionic	0.1	40	0	30	40	10.2	9.96	-0.855	33.6	4.47	3.6		0.00
2	54	15	Magnafloc LT-7995	12	Clarifloc A-6330	anionic	0.1	40	0	30	40	10.2	10.09	-4.64	10.2	2.85	1.86		
3	50	15	Magnafloc LT-7995	12	Clarifloc A-6330	anionic	0.1	40	0	30	40	10.2	10.01	-1.25	9.35	1.61	1.73		
4	50	15	Magnafloc LT-7995	12	Clarifloc A-6330	anionic	0.1	40	0	30	40	10.2	9.73	-6.84	10.8	1.44	1.86	0.15	2.5%
5	60	15	Magnafloc LT-7995	12	Clarifloc A-6330	anionic	0.1	40	0	30	40	10.2	10.04	-2.83	7.91	1.64	1.15		

Jar Test # S5
Date 4/9/2019
Start Time 14:00

Jar Size 2000 mL

Iterative generation of solids with banked water, PEC, and PEA
Date: 4/8/19
Water: Collected from Ullrich WTP raw water sample location on 10/25/18.
Test Objectives: Evaluate solids growth and settleability in simulated solids contact clarifer centerwell.
Protocol: 15 mg/L ferric sulfate was added to the raw water (2 L) in a jar test apparatus at 80 rpm. After 30 seconds of rapid mixing, 12 mg/L of coagulant aid polymer (Magnafloc LT-7995) was added, followed by simultaneous addition of lime and solids generated in the previous test, starting with Iteration #2. Then, 0.3 mg/L of anionic floc aid polymer was added, before turning down to 55 rpm. The jar test ran at 55 rpm to target a G-value of 55 s^{-1} for 30 minutes.

	Chemical Dose		Coag Aid		Floc Aid			Chemical Dosing Time (sec)				pH	pH		Turbidity (NTU)		
Jar	Lime (mg/L CaO)	Ferric Dose (mg/L)	Polymer Type	Polymer Dose	Polymer Type	Charge	Polymer Dose	Center well solids	Ferric	CAP	Lime	Target	Settled	Zeta	2-min	5-min	10-min
1	48	15	Magnafloc LT-7995	12	Clarifloc A-6330	anionic	0.3	40	0	30	40	10.2	9.78	-3.27	13.8	2.67	2.43

Appendix F

PEC TESTING IN TYPICAL LAKE AUSTIN WATER

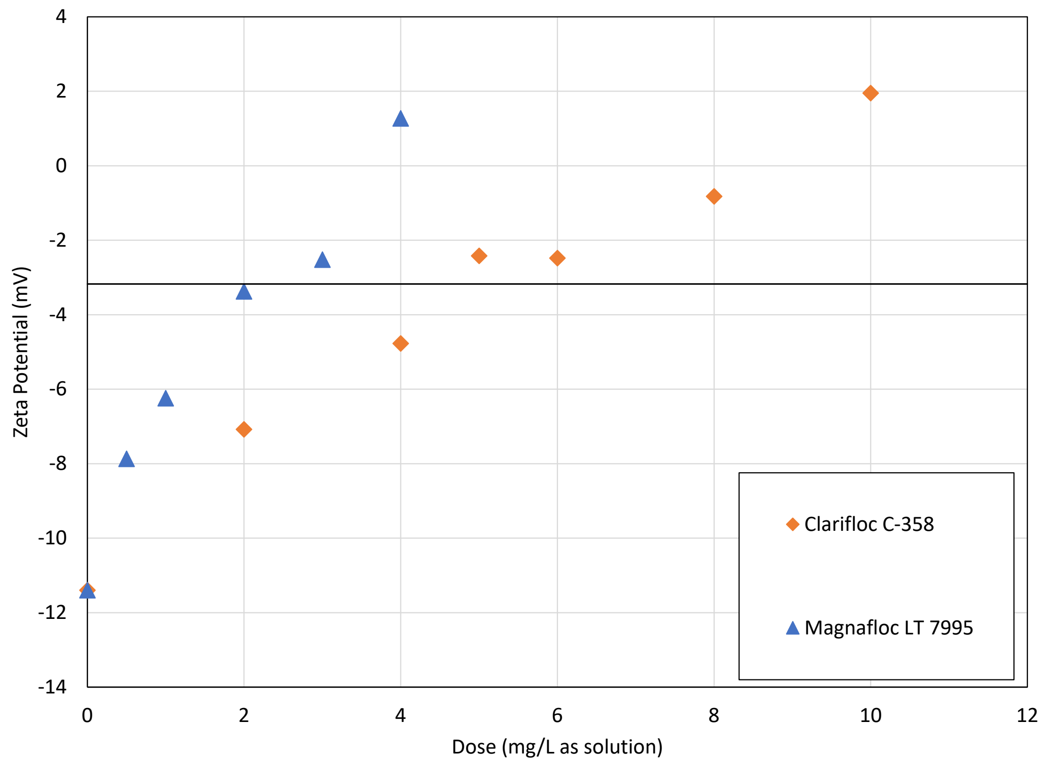


Figure F.1 Impact of PEC Dose on Zeta Potential in Typical Water

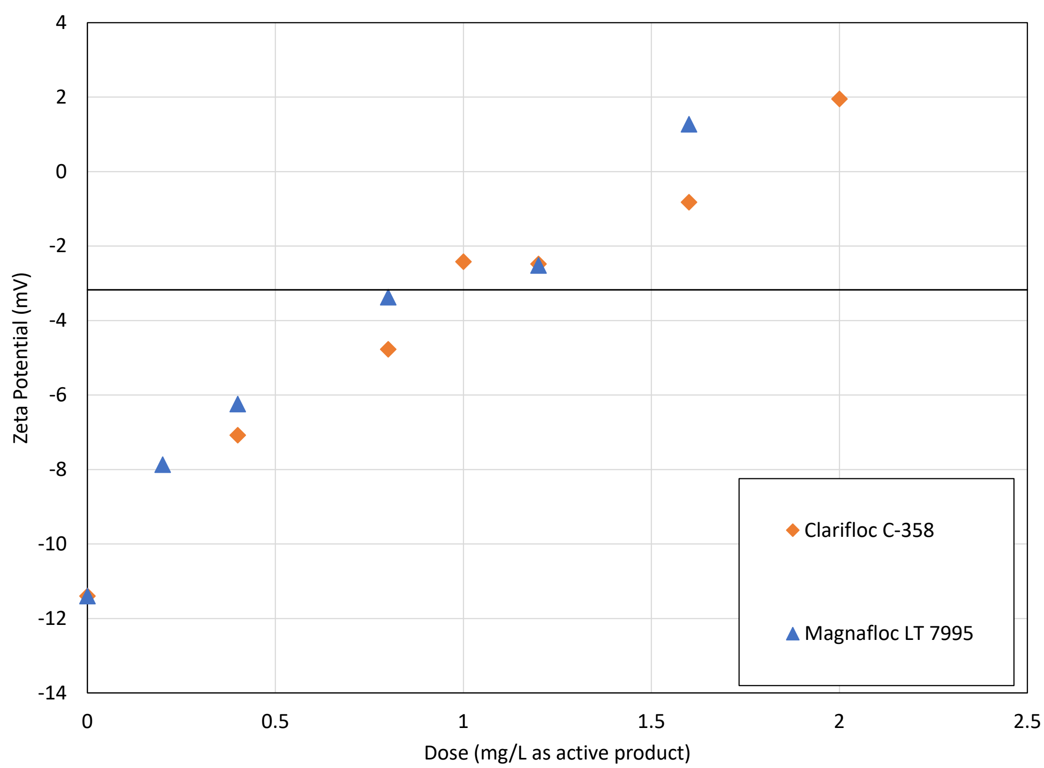


Figure F.2 Impact of PEC Dose on Zeta Potential in Typical Water