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Water Infrastructure Resiliency Planning for the City of Norfolk

Chris Harbin

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Water Infrastructure Resiliency Planning for the City of Norfolk

Chris Harbin, Water Production Manager, Department of Utilities
Agenda

1. City of Norfolk Resiliency Efforts
2. Norfolk’s Water System
3. Resilience of Norfolk’s Water System
4. Next Steps
5. Conclusions
City of Norfolk Resiliency Efforts
Current Challenge

- 90% developed area
- 12 feet above MSL

Highest Relative SLR on East Coast
Approx. SLR = 14 inches since 1930
Resiliency Efforts

• 2015 Dutch Dialogues
• 100 Resilient Cities (Rockefeller Foundation)
  • Resilience Strategy
  • Vision 2100
• Flood Risk Study (with USACOE)
• Ohio Creek Project
• Water Infrastructure Resiliency Planning
Norfolk’s Water System
Norfolk’s Water System – the Early Days

Moores Bridges mid-1870s

Lake Prince construction
Norfolk’s Water System Today

Norfolk’s raw water sources are located throughout southeast Virginia:
- 5 Reservoirs in Norfolk and Virginia Beach
- 3 Reservoirs in Suffolk and Isle of Wight
- 2 River Sources on Nottoway and Blackwater Rivers
- 4 Deep Wells in Suffolk

Norfolk operates two water treatment plants: 37th Street and Moores Bridges with a combined capacity of 136 MGD.
Resilience of Norfolk’s Water System
How Can We Improve Resilience of Norfolk’s Water System?

For over 140 years, the City of Norfolk has consistently treated and delivered drinking water to our customers.

Recent events with widespread flooding:

- 2009: Tropical Depression Ida and a Nor’eastern
- 2011: Hurricane Irene
- 2012: Hurricane Sandy
- 2016: Hurricane Matthew
Flood and Wind Vulnerability Assessment and Hazard Mitigation Plan

Evaluate vulnerabilities to the City’s water production infrastructure and develop adaptation measures to improve resiliency

• Moores Bridges Water Treatment Plant
• 37th Street Water Treatment Plant
Risk Based Evaluation

Phase 1
Climate Analysis

Climate Analysis
What future climate and storm surge conditions should Norfolk prepare for?

Phase 2
Vulnerability Analysis

Facility Vulnerability Analysis
What are the critical flood pathways and buildings at risk?

Infrastructure Vulnerability Analysis
What assets are at risk and what are they worth?

Phase 3
Adaptation Analysis

Adaptation Analysis
What protective measures should be implemented to reduce risk while balancing cost?

Critical, Unprotected Infrastructure

Final Steps
Implement robust design standards and harden infrastructure through capital projects.
Benefits of Risk Management Approach

- Provides transparent, accountable and defensible business case for resiliency implementation
- Quantifies potential risks and impacts
- Facilitates analyses of tradeoffs
- Streamlines evaluation of multiple alternatives
Phase 1: Climate Analysis

Climate Analysis
What future climate and storm surge conditions should we prepare for?

Critical Flood Elevation

- Established to evaluate what is at risk
- The elevation to which assets must be protected may vary depending on funding agency requirements
Storm Levels Considered

- 100 Year Storm Recurrence: El 7.6 ft
- City of Norfolk Building Code Ordinance: El 10.6 ft
- Hurricane Storm Surge – Category 3: El 13.7 ft
Moores Bridges WTP

MOORES BRIDGES WTP
FLOOD POTENTIAL MAP

Elevation at 13.0 ft (NAVD 88)
Elevation at 14.0 ft (NAVD 88)
Category 3 Storm Surge at 13.7 ft
* Elevations on figure reference City of Norfolk datum
37th Street WTP

Category 3 Storm Surge at 13.7 ft

Elevations on figure reference City of Norfolk datum

Elevation at 13.0 ft (NAVD 88)
Elevation at 14.0 ft (NAVD 88)
Phase 2: Vulnerability Analysis

Holistic understanding of magnitude of impact

- Field Survey, Facility Database, Asset Database, and Storm Surge Placards
Investigate Flood Pathways and Establish Threshold Flood Elevations

Other flood pathways: open process tanks, outfalls, storm drains and plant drains, wet wells, and interconnected buildings.
Facility Analysis – Flood Pathway Assessment

High Pressure Pump Station

Flood Pathway Key:
- Non-Vulnerable
- Vulnerable
Critical Flood Elevation

Figure 3.5: Different Elevations of a Facility Analysis
Facility Analysis – Field Survey

Figure 3.2: Flood Pathway Elevations for Moore’s Bridges WTP Facilities
Phase 3: Adaptation Analysis

- Prioritize processes/assets for adaptation
- Discuss stakeholder objectives
- Evaluate alternative adaptation strategies, including feasibility, costs and levels of protection provided

Adaptation Analysis
What protective measures should be implemented to reduce risk while balancing cost?

Recommended Adaptation Strategies

Final Steps
Implement robust design standards and harden infrastructure through capital projects.
Asset Criticality Assessment

**High Criticality**
Impact conveyance, disinfection, or power generation

*E.g.: Influent Motors, Effluent Pumps, Emergency Generators, Main Plant Feed and Transformers, Chlorination or UV Equipment*

**Moderate Criticality**
Reduce level of service

*E.g.: Collectors for Settling Tanks, Sludge Pumps, Aeration Blowers*

**Low Criticality**
Minor or no impact to process

*E.g.: Odor Control Blowers and Scrubbers, Maintenance Equipment*
<table>
<thead>
<tr>
<th>Facility</th>
<th>Vulnerable FPE (NAVD 88)</th>
<th>Critical ADE (NAVD 88)</th>
<th>Vulnerable Assets(s)</th>
<th>Criticality Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical Distribution System</td>
<td>11.04’</td>
<td>12.04’</td>
<td>Electrical Distribution System</td>
<td>5</td>
</tr>
<tr>
<td>Generators</td>
<td>12.03’</td>
<td>12.03’</td>
<td>Electrical Equipment</td>
<td>5</td>
</tr>
<tr>
<td>High Pressure Pumping Building</td>
<td>11.54’</td>
<td>10.04’</td>
<td>High Pressure Pumps</td>
<td>5</td>
</tr>
<tr>
<td>Lake Wright Pump Station</td>
<td>9.74’</td>
<td>9.74’</td>
<td>Pumps</td>
<td>5</td>
</tr>
<tr>
<td>Main Plant Substation</td>
<td>10.53’</td>
<td>10.53’</td>
<td>Electrical Equipment</td>
<td>5</td>
</tr>
<tr>
<td>Main Plant Switchgear</td>
<td>11.50’</td>
<td>11.50’</td>
<td>Electrical Equipment</td>
<td>5</td>
</tr>
<tr>
<td>Sodium Hypochlorite</td>
<td>13.04’</td>
<td>13.04’</td>
<td>Motor Control Center</td>
<td>5</td>
</tr>
<tr>
<td>Solids Handling - Centrifuge</td>
<td>10.17’</td>
<td>10.87’</td>
<td>Polymer Feed Pumps</td>
<td>3</td>
</tr>
<tr>
<td>Solids Handling - Gravity Thickening</td>
<td>10.50’</td>
<td>11.33’</td>
<td>Transfer Pumps</td>
<td>4</td>
</tr>
<tr>
<td>Trim Pump Building</td>
<td>12.77’</td>
<td>13.02’</td>
<td>Variable Frequency Drive</td>
<td>5</td>
</tr>
<tr>
<td>Wash Water Transfer Basin</td>
<td>12.74’</td>
<td>14.24’</td>
<td>Pump</td>
<td>3</td>
</tr>
</tbody>
</table>
Asset Level Adaptation Strategies

**Individual Asset**
- Elevate Equipment
- Flood Proof Equipment
- Install Static Barrier

**Multiple Assets**
- Provide Emergency Generator
- Seal Building
- Sandbag

**Resiliency/Effectiveness**
- Low: Elevate Equipment, Flood Proof Equipment, Install Static Barrier, Seal Building, Sandbag
- High: Provide Emergency Generator

**Cost**
- Low: Elevate Equipment, Flood Proof Equipment, Install Static Barrier
- High: Provide Emergency Generator, Seal Building, Sandbag

Does not protect equipment but facilitates rapid service recovery.
Adaptation Recommendations

- **Sand Bags**
- **Stop Logs**
- **Permanent Flood Wall With Removable Stop Logs**
- **Temporary Flood Wall**
- **Flood Wall & Earthen Berm**

**Legend**
- Sand Bags
- Stop Logs
- Permanent Flood Wall With Removable Stop Logs
- Temporary Flood Wall
- Flood Wall & Earthen Berm

**Flood Vulnerability Mitigation for Moores Bridges WTP Water Production Infrastructure**
<table>
<thead>
<tr>
<th>Facility</th>
<th>Mitigation Alternative</th>
<th>Mitigation Strategy Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical Distribution System</td>
<td>Berm with flood wall</td>
<td>$158,000</td>
</tr>
<tr>
<td>Generators</td>
<td>Temporary flood barrier</td>
<td>$20,000</td>
</tr>
<tr>
<td>High Pressure Pump Station</td>
<td>Permanent flood barrier with removable stop logs</td>
<td>$53,000</td>
</tr>
<tr>
<td>Lake Wright Pump Station</td>
<td>Permanent flood barriers with removable stop log sections. Seal old entrance.</td>
<td>$12,000</td>
</tr>
<tr>
<td>Main Plant Substation</td>
<td>Temporary flood barrier</td>
<td>$50,000</td>
</tr>
<tr>
<td>Main Plant Switchgear</td>
<td>Flood stop plate at one door, permanent flood barrier with stop logs on other door</td>
<td>$27,000</td>
</tr>
<tr>
<td>Sodium Hypochlorite Building</td>
<td>Sand Bag at doors below flood elevation</td>
<td>$1,000</td>
</tr>
<tr>
<td>Solids Handling - Centrifuge Building</td>
<td>Flood stop plates and permanent flood barriers with removable stop log sections</td>
<td>$16,000</td>
</tr>
<tr>
<td>Solids Handling - Gravity Thickening</td>
<td>Flood stop plates and permanent flood barriers with removable stop log sections</td>
<td>$13,000</td>
</tr>
<tr>
<td>Trim Pump Building</td>
<td>Flood stop plates and permanent flood barriers with removable stop log sections</td>
<td>$16,000</td>
</tr>
<tr>
<td>Wash Water Transfer Basin</td>
<td>Concrete improvements to raise curb around grates</td>
<td>$5,000</td>
</tr>
</tbody>
</table>
Implementation

High pressure pump station with flood wall
Implementation

Overall cost of implementation of protective measures at Moores Bridges: $520K
Storm Surge Placards

Emergency Preparedness:

These charts allow plant staff to quickly determine vulnerability to flood from approaching storms and begin implementing temporary adaptation strategies, such as sandbags.

<table>
<thead>
<tr>
<th>Storm Surge Advisory*</th>
<th>Floodplain and elevations</th>
<th>Elevations and areas to be protected</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>NAVD 88 Datum (to convert to City of Norfolk Datum, add 101.96')</td>
</tr>
<tr>
<td>16'</td>
<td>17.0'</td>
<td>Flocculation-Sedimentation Basins #5 and 6, Front Office, Filter Basins-General, Flocculation-Sedimentation Basins #2, 3, 4, 7, and 8</td>
</tr>
<tr>
<td>15'</td>
<td>16.0'</td>
<td>Low Lift Pump Station</td>
</tr>
<tr>
<td>14'</td>
<td>15.0'</td>
<td>Corrosion Inhibitor Feed, Basin 1 Equalization, Chemical Feed Building</td>
</tr>
<tr>
<td>13'</td>
<td>14.0'</td>
<td>Water Transfer Basin, Trim Pump Building, Sodium Hypochlorite System</td>
</tr>
<tr>
<td>12'</td>
<td>13.0'</td>
<td>Generators</td>
</tr>
<tr>
<td>11'</td>
<td>12.0'</td>
<td>Main Plant Switchgear, High Pressure Pumping Building, Storage Building</td>
</tr>
<tr>
<td>10'</td>
<td>11.0'</td>
<td>Main Distribution Switchgear</td>
</tr>
<tr>
<td>9'</td>
<td>10.5'</td>
<td>Solids Handling-Gravity Thickeners</td>
</tr>
<tr>
<td>8'</td>
<td>10.0'</td>
<td>Lake Wright Pump Station, Solids Handling-Centrifuge</td>
</tr>
<tr>
<td>7'</td>
<td>9.0'</td>
<td></td>
</tr>
<tr>
<td>6'</td>
<td>8.0'</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>100 yr. 7.6'</td>
</tr>
<tr>
<td></td>
<td></td>
<td>100 yr. + 3'</td>
</tr>
</tbody>
</table>

*Storm surge adds to Mean Higher High Water at City of Norfolk, which is 101.96' NAVD 88 Datum
Next Steps
New Moores Bridges WTP Emergency Entrance
Integrating Asset Management and Resiliency Planning

• An Asset Management Plan was completed for Moores Bridges in 2017

• Asset Management and Resiliency Planning include similar evaluations of the same assets

• Combining AM and Resiliency together reduces redundancy and improves capital planning

• City of Norfolk will incorporate Resiliency Planning into Asset Management Program for City sewer and water infrastructure
Resiliency Planning Dashboard

Critical Flood Elevation is based on:
Base Flood Elevation + 2' Sea Level Rise (SLR) + 1' Freeboard + 0.25' Subsidence

<table>
<thead>
<tr>
<th>Flood Event</th>
<th>Critical Flood Elevation (ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 Year</td>
<td>7.60</td>
</tr>
<tr>
<td>500 Year</td>
<td>8.50</td>
</tr>
<tr>
<td>Category 1 Storm</td>
<td>10.40</td>
</tr>
<tr>
<td>Category 2 Storm</td>
<td>12.10</td>
</tr>
<tr>
<td>Category 3 Storm</td>
<td>13.70</td>
</tr>
</tbody>
</table>

Facility Replacement Cost Adaptation Cost Mitigated Risk

<table>
<thead>
<tr>
<th>Facility</th>
<th>Replacement Cost</th>
<th>Adaptation Cost</th>
<th>Mitigated Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dewatering Building</td>
<td>$314,835</td>
<td>$75,000</td>
<td>$239,835</td>
</tr>
<tr>
<td>Emergency Electrical</td>
<td>$2,000,000</td>
<td>$150,000</td>
<td>$1,850,000</td>
</tr>
<tr>
<td>Pumping Station</td>
<td>$2,405,000</td>
<td>$400,000</td>
<td>$2,005,000</td>
</tr>
<tr>
<td>Thickening System</td>
<td>$464,900</td>
<td>$100,000</td>
<td>$364,900</td>
</tr>
</tbody>
</table>

Mitigated Risk

<table>
<thead>
<tr>
<th>Risk Level</th>
<th>Mitigated Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>$2,458,235</td>
</tr>
<tr>
<td>Low</td>
<td>$330,500</td>
</tr>
<tr>
<td>Moderate</td>
<td>$1,471,000</td>
</tr>
</tbody>
</table>
Conclusions
Resiliency Adaptation Requires Balance

- Meet permits and regulations
- Protect infrastructure
- Protect the environment
- Protect public health

- Ease of Implementation
- Ease of Maintenance
- Schedule Constraints
- Budget Constraints
Conclusions

• **Increases water production reliability during extreme storm events for Norfolk citizens and customers**

• Reduces risk of flood damage and costly repair / replacement of infrastructure

• Provides a cost effective solution to improve resilience to many potential storm events

• Provides a framework for Department of Utility infrastructure moving forward
Acknowledgements:

Dwayne Amos, Associate Vice President, Hazen and Sawyer

Cherryl Barnett, P.E., Engineering Manager, Norfolk Utilities

Questions?