SOO LOCKS
AUTOMATED INSTRUMENTATION

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US Army Corps of Engineers
BUILDING STRONG®

Presentation Overview

- Background
- Purpose of Instrumentation
- Design Considerations
- Areas of Concern (AOC)
- Questions

Background

- Four Existing Parallel Locks (U.S. Side) – One Canadian Lock
- Located at the St. Mary's Falls Canal on the St. Mary's River

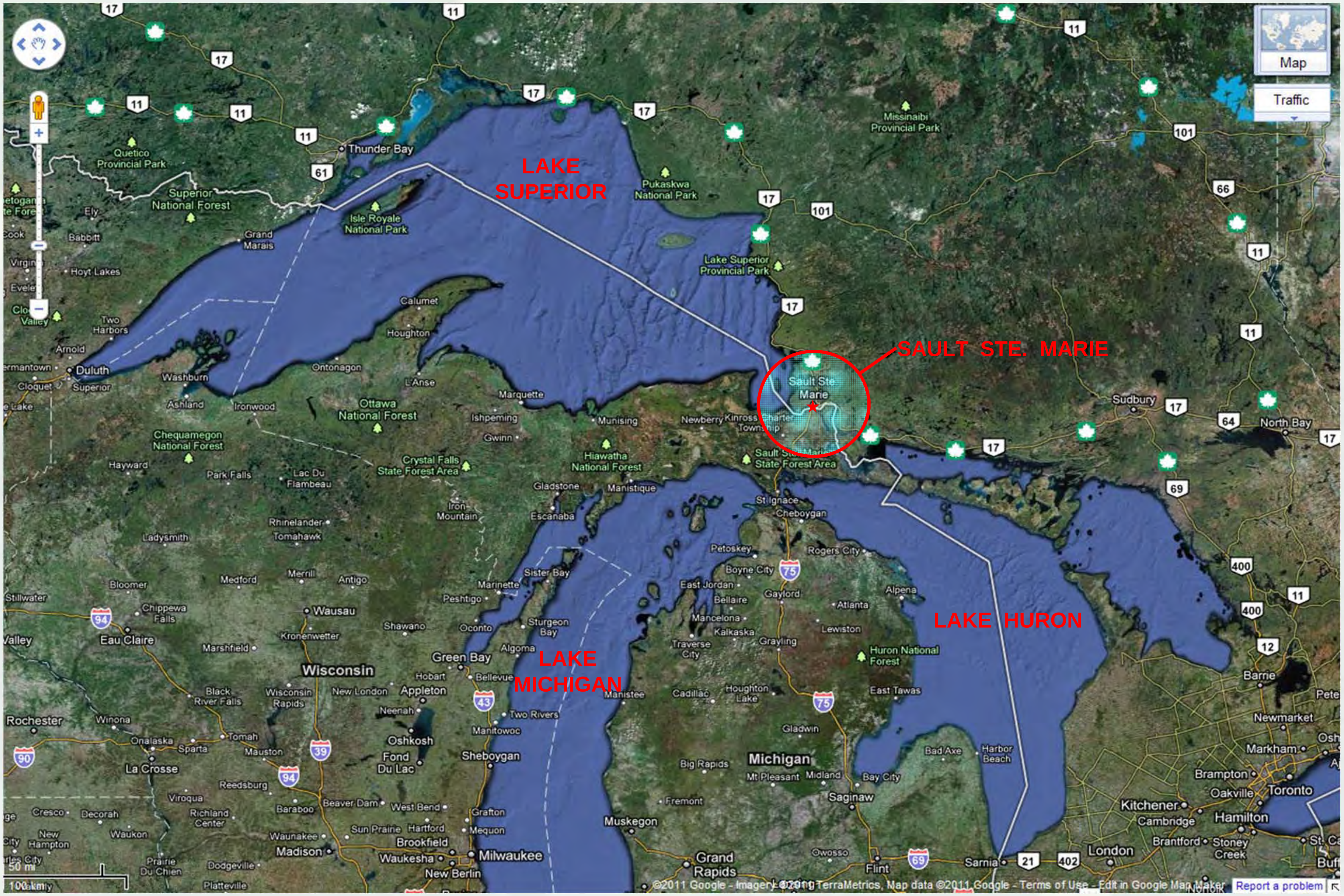
  Sabin (North Canal – 80'W x 1350'L x 23'D) – Inactive with Coffer Cells

  Davis (North Canal - 80'W x 1350'L x 23'D) - Rarely Utilized

  Poe (South Canal – 110' W x 1200' L x 32' D) Only lock capable of passing 1000' Lakers, the Great Lake Fleets largest vessels

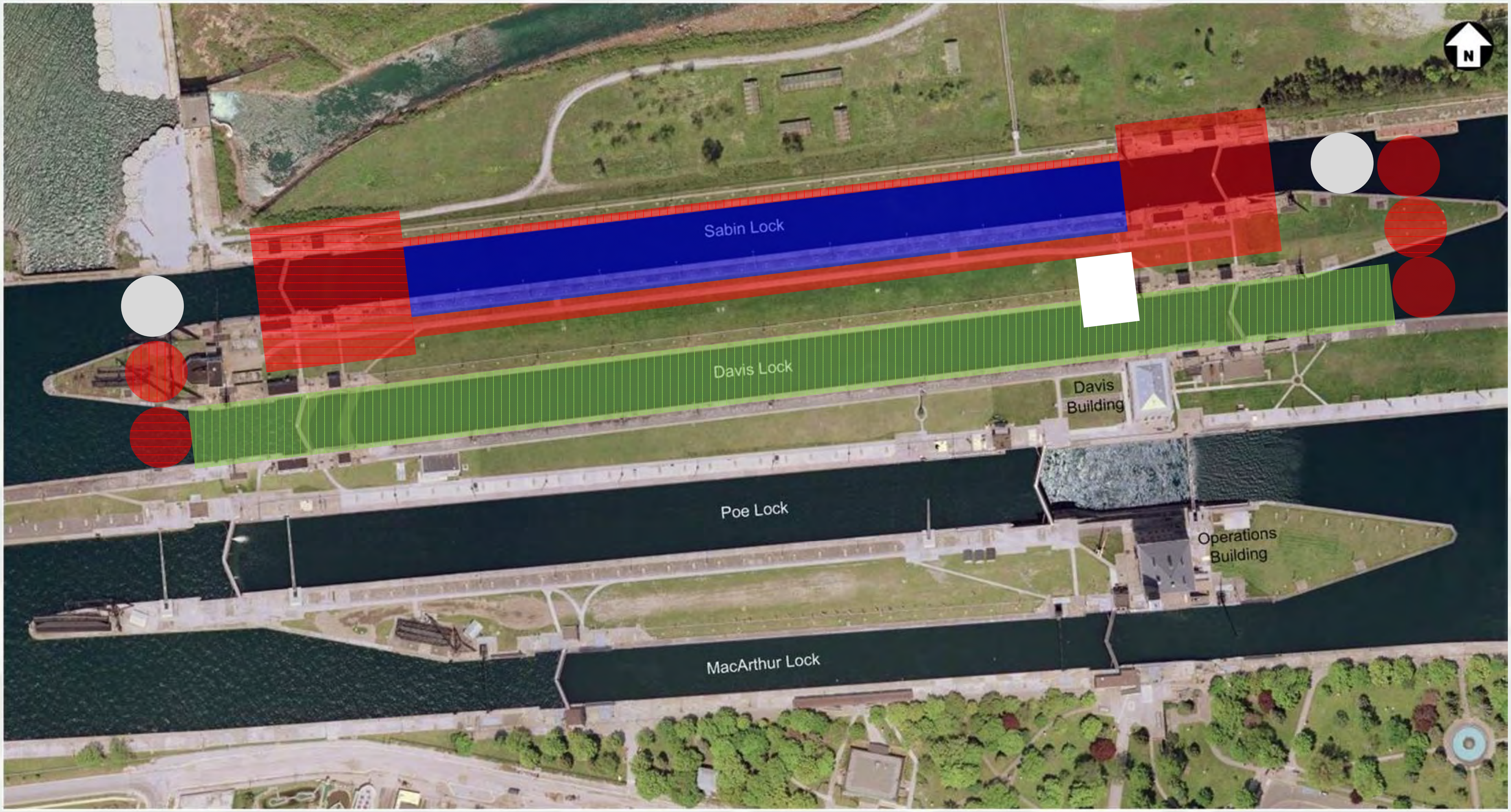
  MacArthur (South Canal – 80'W x 800'L x 29.5' D) Active, passing smaller vessels
- Only passage between Lake Superior and the lower Great Lakes
- Locks an average of 10,000 ships annually
- Closed from January through March due to Ice
- Listed on National Register of Historic Places
- Elevated viewing stands for summer crowds

Critical Inland Navigation Passage Way

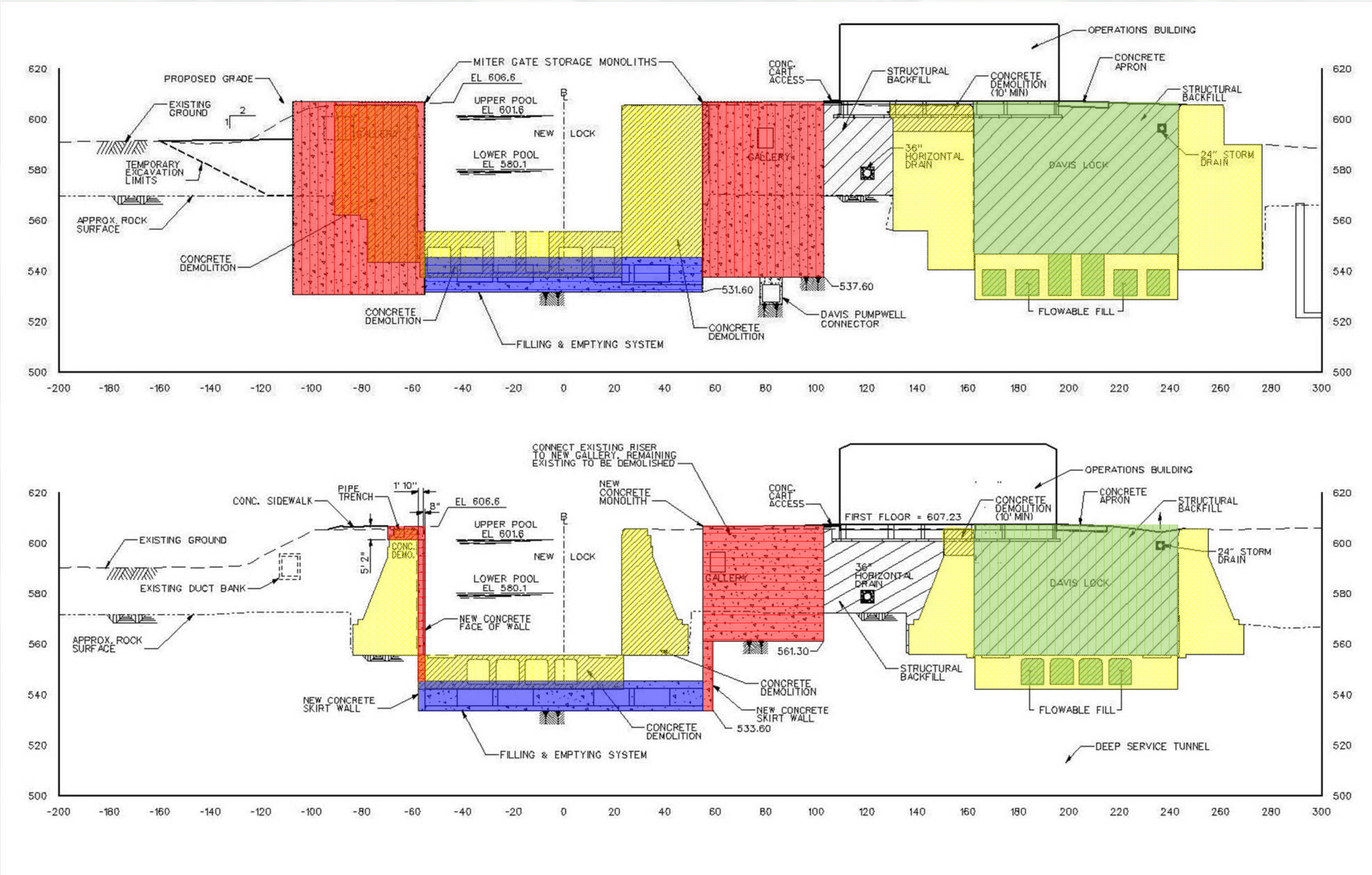


Complex, High Profile Site

Complex, High Profile Design

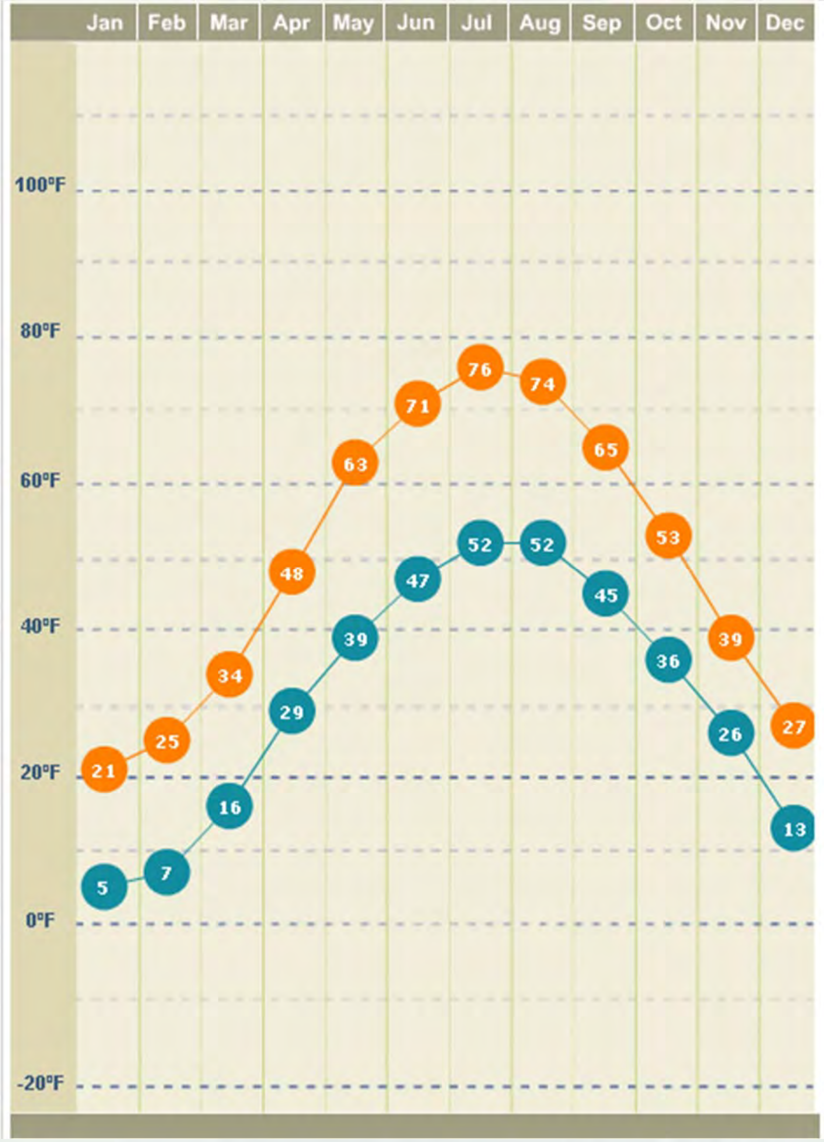


Complex, High Profile Design



Complex Weather Conditions

Complex Weather Conditions



<u>Long Cold Winter Season</u>

- 6 Months = Average Low < 32°
- 3 Months = Average High < 32°
- Highest Summer Month < 80°
- Only a few days annually > 90°
- Locks closed from January through March due to ice on the river

<u>One of Snowiest Locations in Michigan</u>

- Average 128” of Snow / Year
- Average 34” of Rain / Year

Presentation Overview

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Purpose of Instrumentation

Risk Management

- Our main priorities are to effectively identify and manage the risk associated with construction in such a manner that we insure the safety of on-site personnel and maintain the integrity, stability and operability of the Soo Locks.
- **No other issues can supersede these priorities.**

Purpose of Instrumentation

Risk Management

Monitor Changing Site Conditions

(Construction Control)

- The system is designed so that all potential concerns can be monitored via the automated system.
- The system design also incorporates monitoring of all potential concerns via manual instrumentation for verification of automated instruments and redundancy.
- Mobotix Cameras for remote observation / validation of extreme readings.

Purpose of Instrumentation

Risk Management

Monitor Changing Site Conditions

Cofferdam Early Warning Capabilities

- Audible / visual alarming as well as individual notifications as a result of threshold exceedance.
- Webpage hosting for all automated instruments including long term instrument data graphs for trend evaluations.

Purpose of Instrumentation

Risk Management

Monitor Changing Site Conditions

Cofferdam Early Warning Capabilities

Design Verification

- Affirm assumptions made during design were appropriate. Factors of safety, site conditions, etc.
- Portions of the system can be left in place for long term performance monitoring.

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Design Considerations

Automated Data Acquisition System (ADAS)

- Adequate configurability and expandability.
- Compatibility with various types of sensors to be utilized.
- Ability to withstand anticipated vibrations.
- Flexible and resilient communications system.
- Low power operation.
- Rugged construction / ability to perform in extreme cold weather conditions.
- Proven record of reliable performance in similar construction monitoring installations.

Design Considerations

Automated System Types Evaluated

- Real Time System
  (Supervisory Control and Data Acquisition – SCADA)
  - Network of rugged remote computers monitoring numerous sensors of various types.
  - Easy to network with higher bandwidth and power requirements.
  - Threshold exceedance alarming capability.
  - Will continue to collect and evaluate data even if communications with CMU have stopped. Remote programming capability.
  - Real time monitoring. Most commonly used to acquire large numbers of sensor readings very quickly. 100 data value sets per second.
  - Typically utilized for fast response, equipment control applications.
  - Not as suitable for long term, unattended application w/potential high hazard failure due to higher bandwidth / power requirements.

Design Considerations

Automated System Types Evaluated

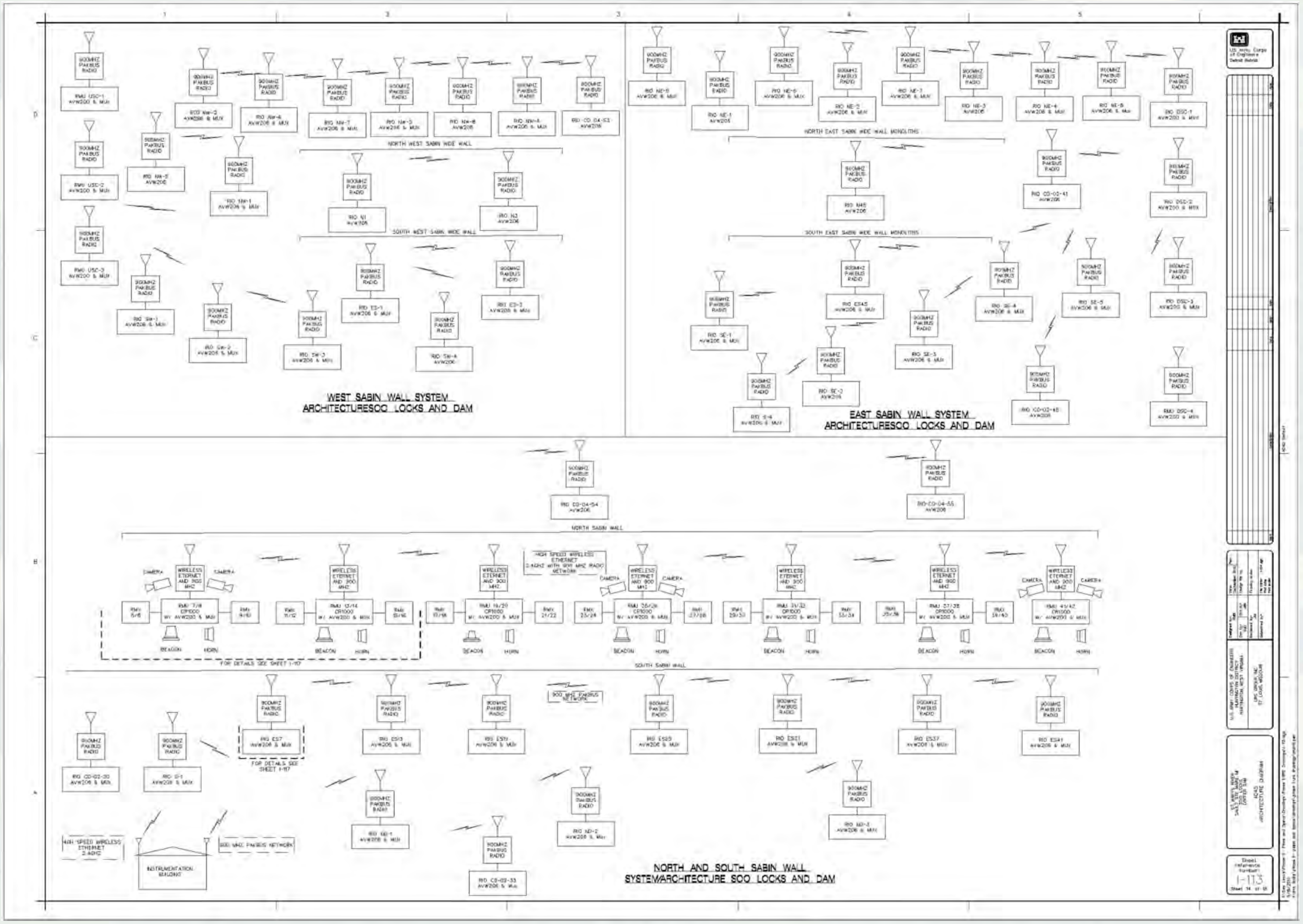
- Distributed Intelligence Logger
  - Network of rugged remote computers monitoring numerous sensors of various types.
  - Easy to network with low bandwidth and power requirements.
  - Threshold exceedance alarming capability.
  - Will continue to collect and evaluate data even if communications with CMU have stopped. Remote programming capability.
  - Near real time monitoring but not as fast as SCADA. One data value set per second.
  - Suitable for outdoor applications in harsh environments.
  - Suitable for long term, unattended application w/potential high hazard failure.

Design Considerations

Automated System Type Selected

- Distributed Intelligence Logger
  (Campbell Scientific CR1000 Dataloggers)
  - Recognized as industry standard datalogger for Geotechnical / Structural monitoring.
  - Long successful record of use in similar monitoring applications.
  - Field proven interface module for automated readings from Vibrating Wire Instruments (AVW200 & AVW206).
  - Field proven interface module for automated readings from MTDR Cables (TDR100).
  - Wide range of communication options.
  - Local and remote monitoring units (LMU & RMU).
  - Communicate with hardwired and wireless remote multiplexers (RMX & RIO).

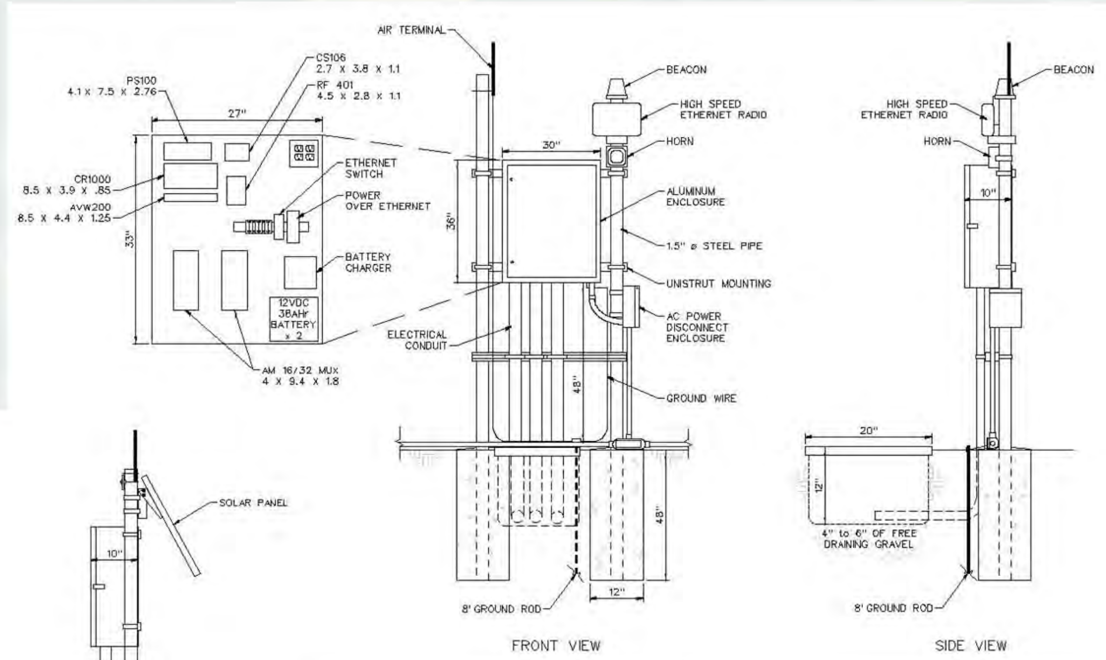
Design Considerations
Network Architecture

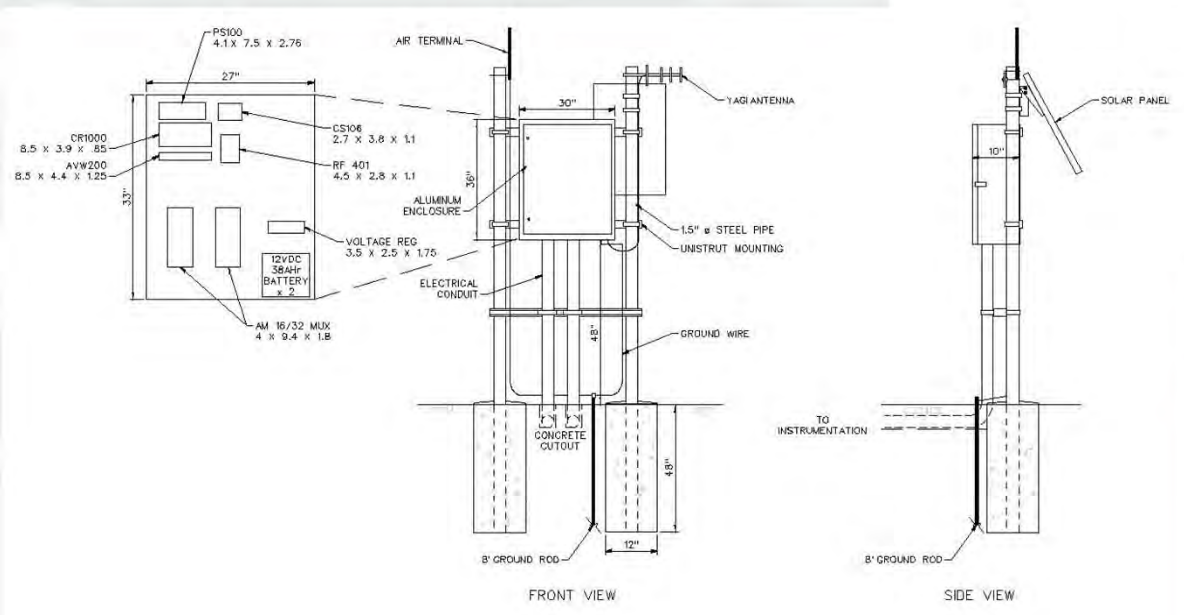


<u>Monitoring Units</u>

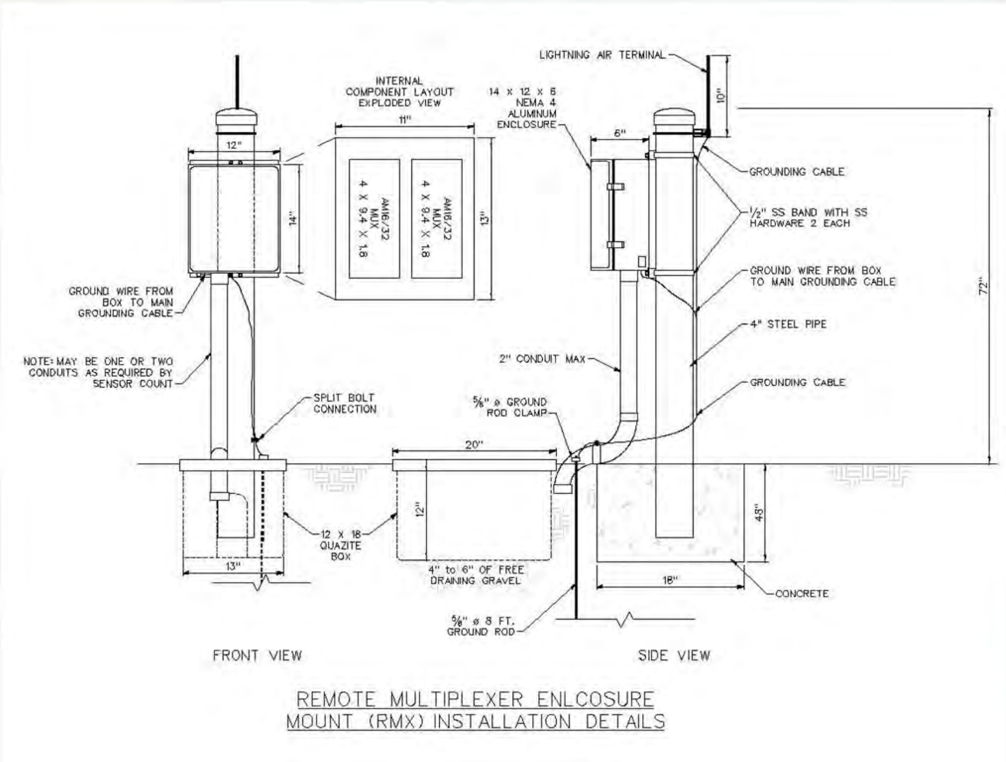
LMU	1 Total
RMU	9 Total
RMX	12 Total
RIO	57 Total

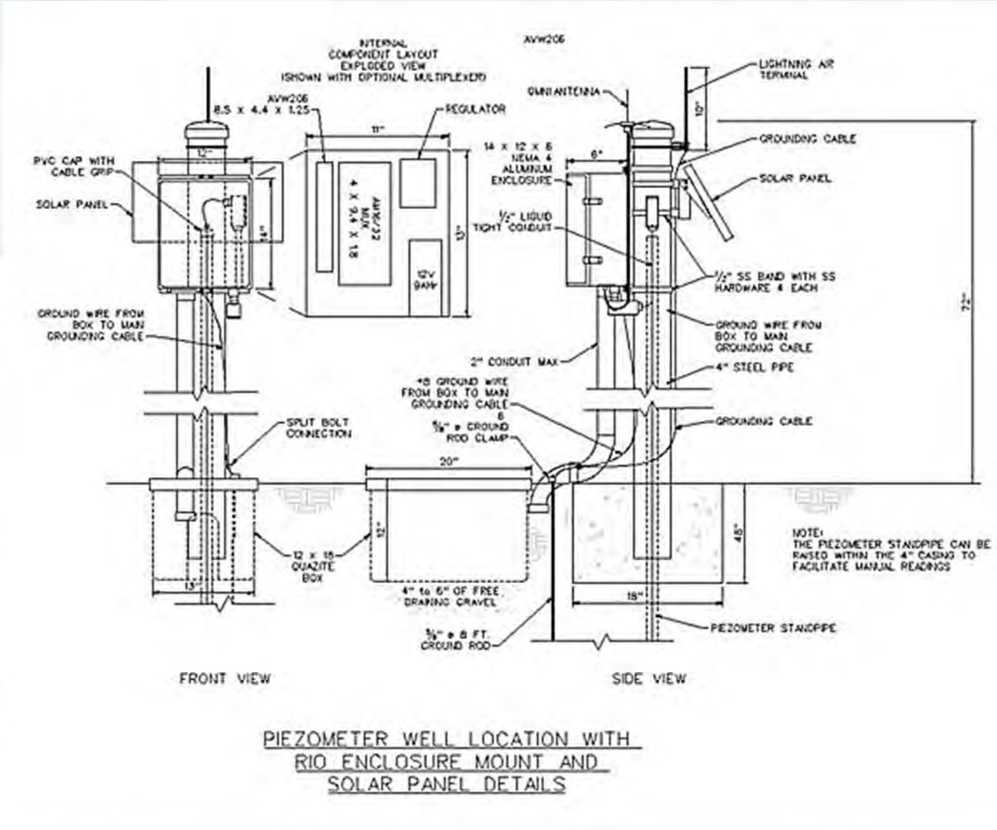
Design Considerations
CR1000 Remote Monitoring Unit (RMU)





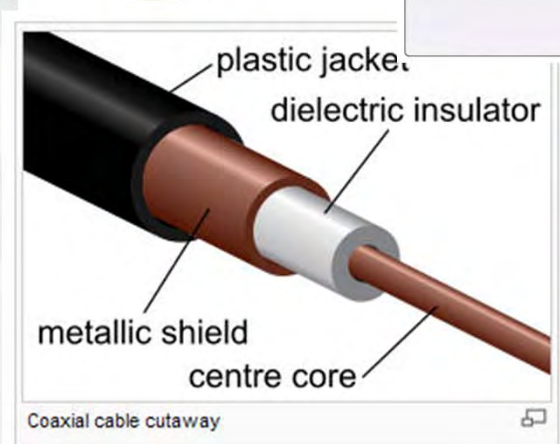
Design Considerations
Wired (RMX) and Wireless (RIO) Multiplexers





Design Considerations

Instruments



Coaxial cable cutaway

Design Considerations

Instrument Types Selected

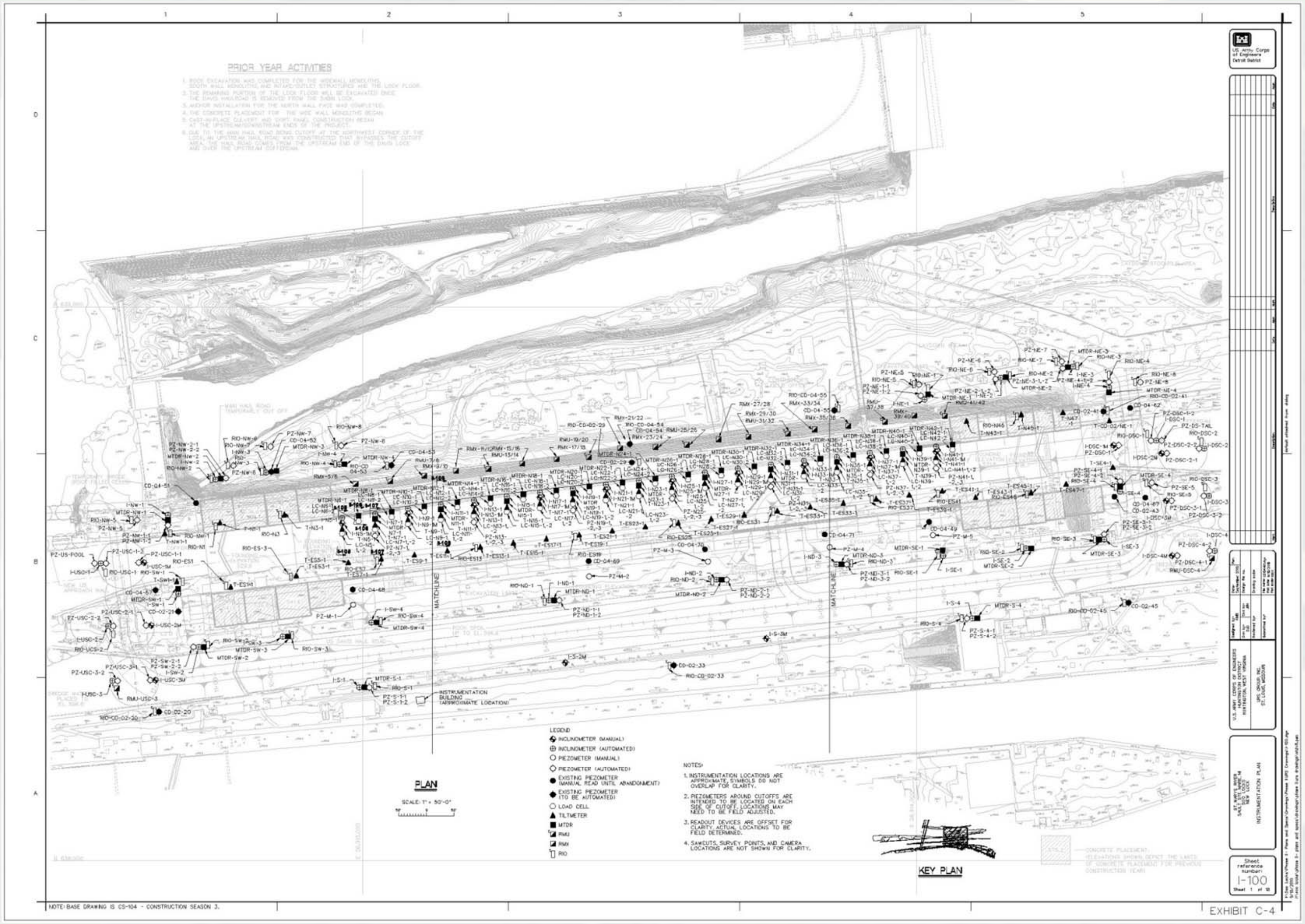
- Inclinometers (In-Place & Manual)
  Overturning, Sliding & Deformation
- Metallic Time Domain Reflectometry Cables (MTDR)
  Overturning, Sliding & Deformation
- Tiltmeters Overturning
- Load Cells Tieback Loading
- Piezometers (Vibrating Wire & Casagrande) Seepage
- Crackmeters (Manual) Crack Formation, Vibration
- Alignment and Settlement Pins / Saw Cuts Settlement, Rebound, Deflection, Overturning & Sliding

Design Considerations

Instrument Types Considered But Excluded

- Optical Time Domain Reflectometry Cables (OTDR)
  - Readout equipment and fiber optic cable are cost prohibitive.
- Shape AccelArrays (SAA)
  - Relatively new instrument type lacking long term record of field performance. Cost prohibitive.
- Terrestrial Position System (TPS)
  - Reduced capability during long winter season due to ice / snow buildup on prisms. Line of site required.
- Global Positioning System (GPS)
  - Antennas susceptible to ice / snow buildup.
  - Cost prohibitive.

Design Considerations
Instrument Summary



<u>Instruments</u>

IPI	282
Inclinometer	19
MTDR	49
Tilt Meter	52
Load Cell	76
VW Piezo	83
Pool Trans	4
A&SP	608
Saw Cut	184
Mobotix	6

550 Automated
800 Manual

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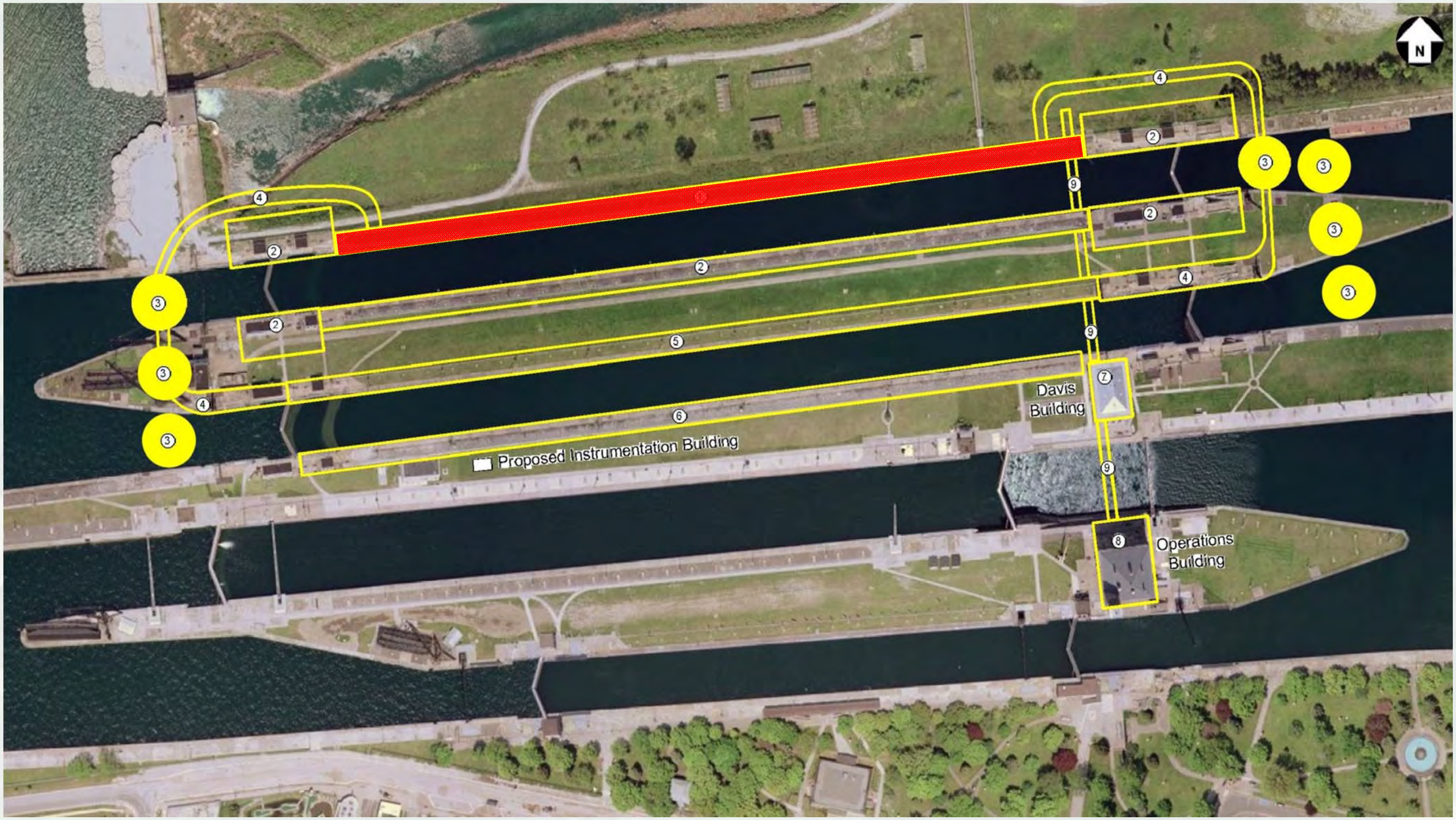
Areas of Concern (AOC)

Seven Areas Of Concern Identified

- AOC 1 – North Sabin Chamber Monoliths
- AOC 2 – North Sabin Wide Wall and South Sabin Chamber and Wide Wall Monoliths
- AOC 3 – Cofferdam Cells
- AOC 4 – Cutoff Walls
- AOC 5 – North Davis Chamber Monoliths
- AOC 6 – South Davis Chamber Monoliths
- AOC 7 – Historic Davis, Administration Building / Service Tunnel

AOC1 – North Sabin Chamber Monoliths

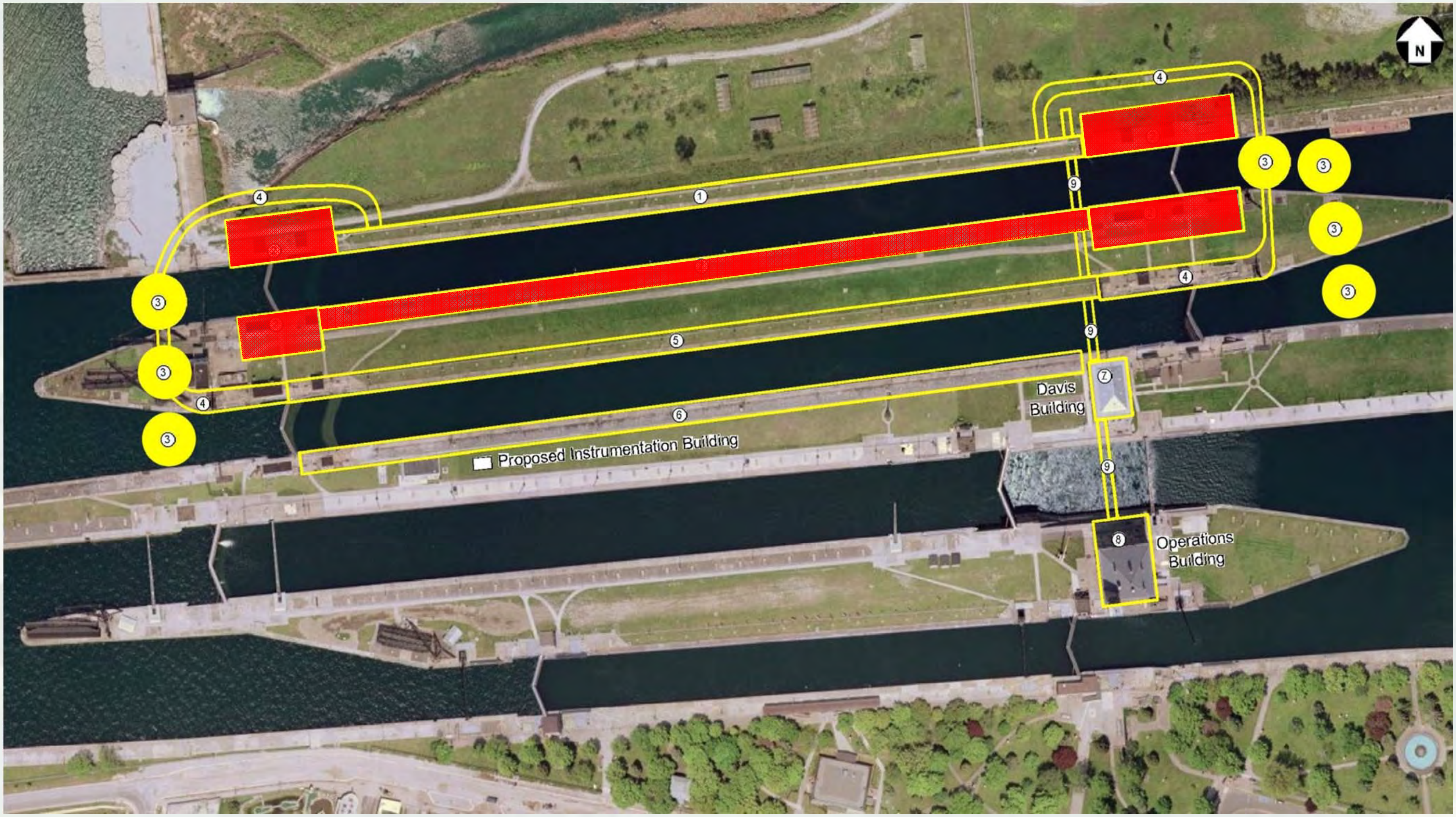


AOC1 – North Sabin Chamber Monoliths

Construction Concerns

- Overturning (Dewatering / reface and chamber deepening)
  - IPI (19), Inclinometers (10), MTDR (28), Uniaxial Tilt Meters (19), Survey Points (117), Saw Cuts (39)
- Seepage (North groundwater through exposed rock)
  - Piezometers (23)
- Settlement / Rebound (Construction activities)
  - Survey Points (117)
- Sliding (Dewatering / construction activities / chamber deepening)
  - IPI (19), Inclinometers (10), MTDR (28), Tilt Meters (19), Survey Points (117), Saw Cuts (39)
- Tieback Loading (Anchors)
  - Load Cells (76)

AOC2 – N Sabin Wide Wall and S Sabin Chamber & Wide Wall Monoliths

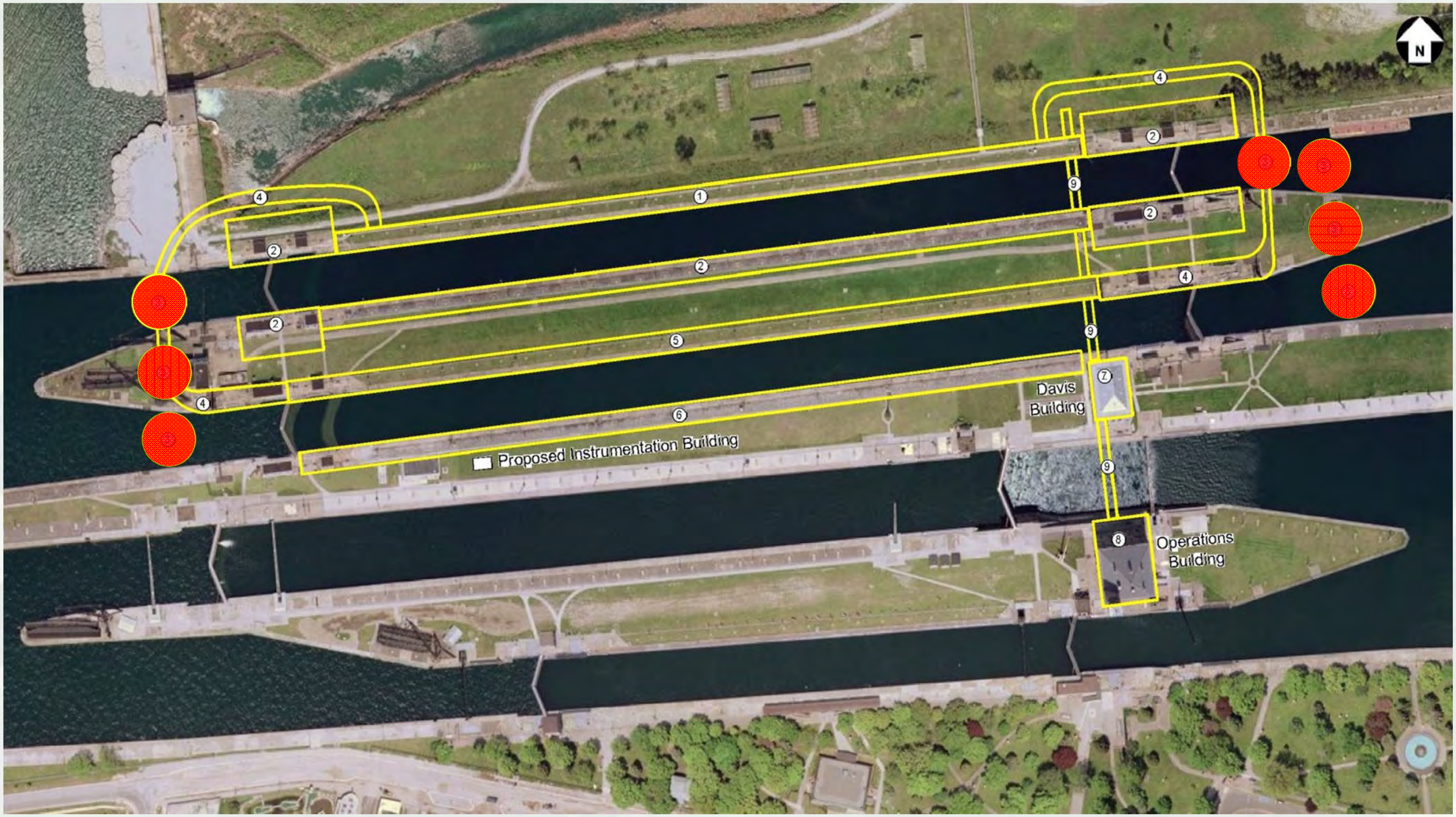


AOC2 – N Sabin Wide Wall & S Sabin Monoliths

Construction Concerns

- Overturning (Dewatering)
  - Biaxial Tilt Meters (29), Survey Points (159), Saw Cuts (53)
- Seepage (North groundwater and pansey bed)
  - Piezometers (23)
- Settlement / Rebound (Construction activities)
  - Survey Points (159)
- Sliding (Dewatering / construction activities)
  - Tilt Meters (29), Survey Points (159), Saw Cuts (53)

AOC3 – Cofferdam Cells

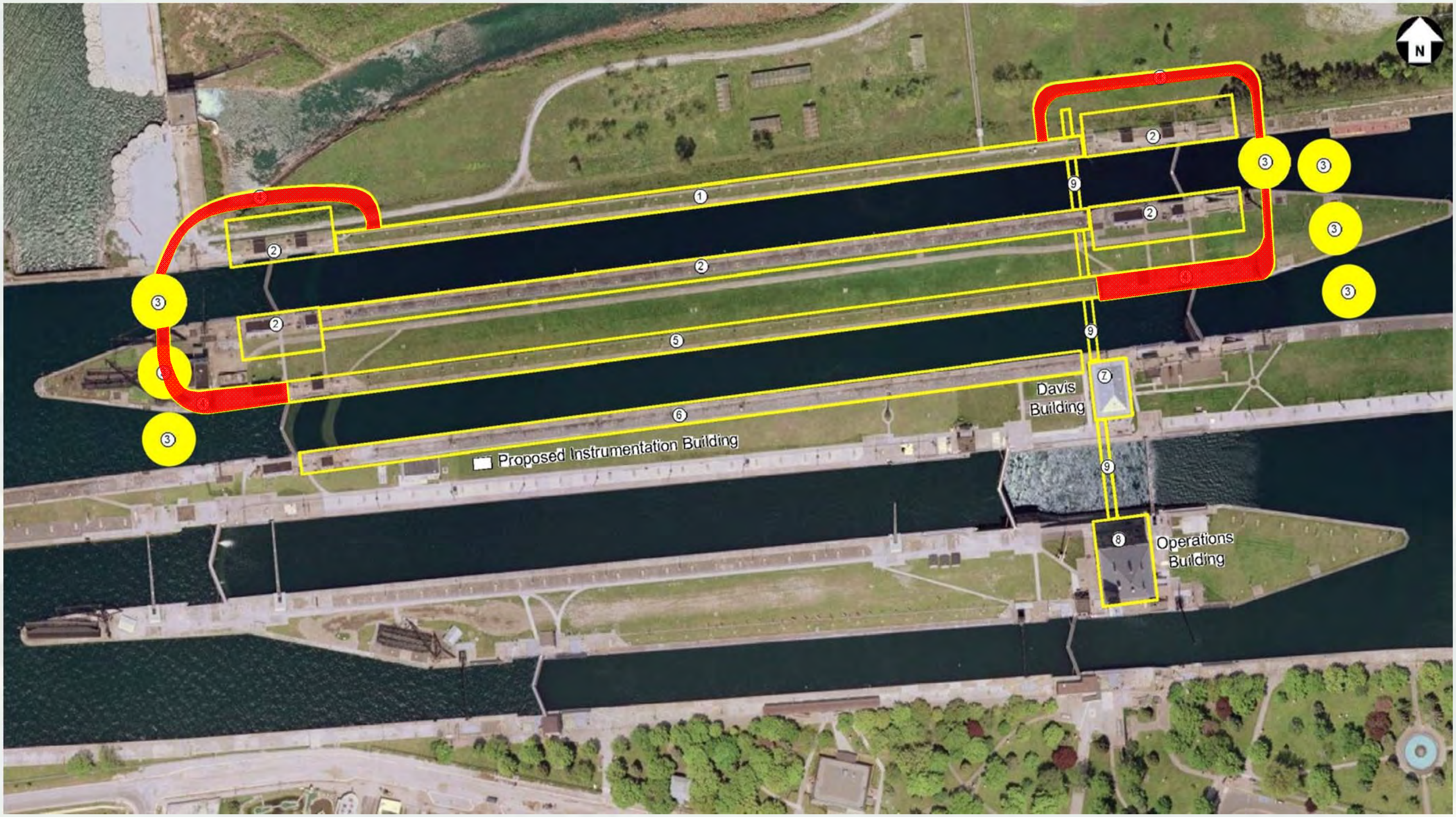


AOC3 – Cofferdam Cells

Construction Concerns

- Overturning (Dewatering)
  - IPI (7), Inclinometers (7), Survey Points (56)
- Seepage (Upper and lower pools)
  - Piezometers (16)
- Sliding (Dewatering)
  - IPI (7), Inclinometers (7), Survey Points (56)

AOC4 – Cutoff Walls

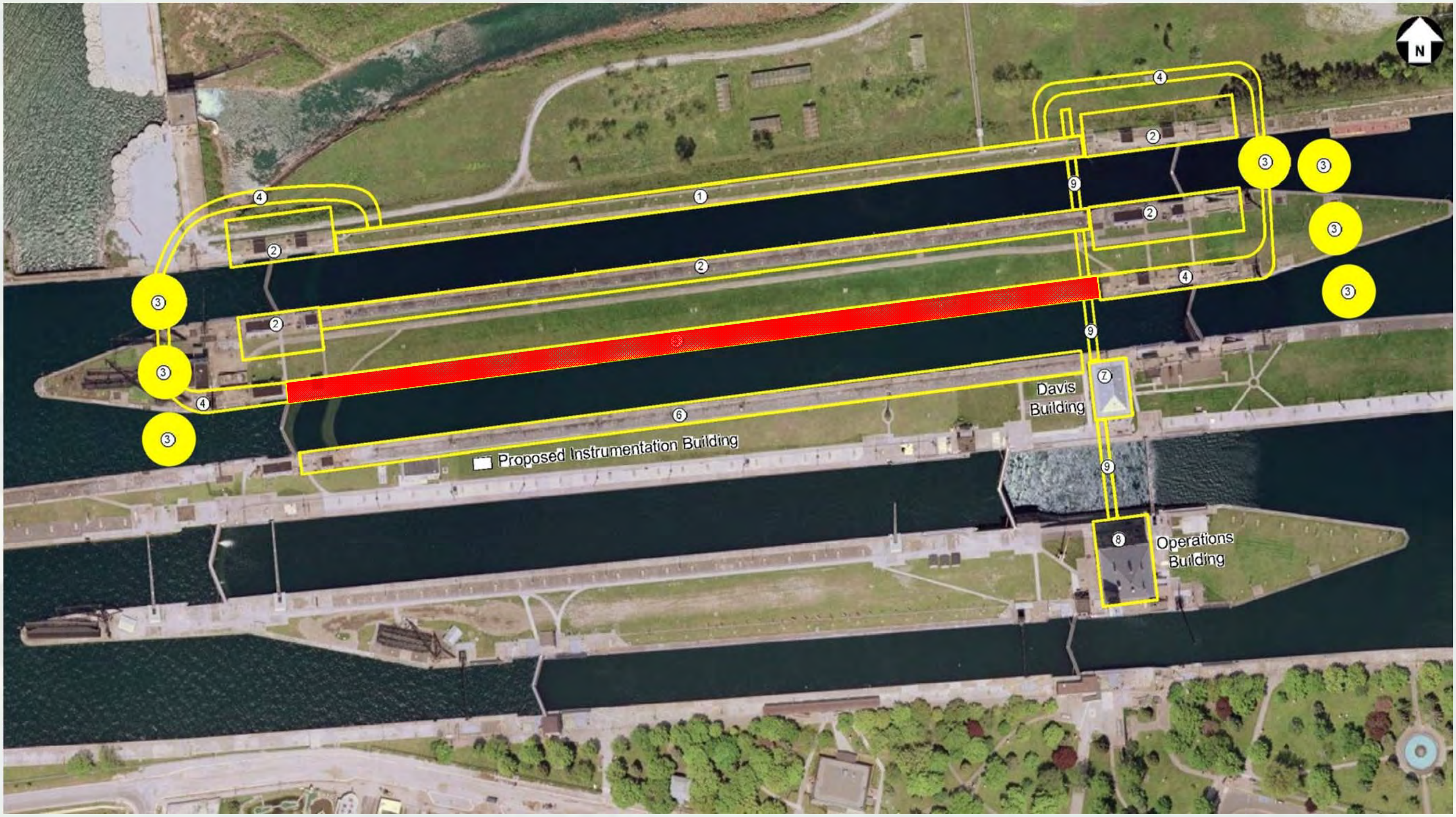


AOC4 – Cutoff Walls

Construction Concerns

- Deformation (Construction Activities)
  - IPI (16), MTDR (16), Biaxial Tilt Meters (4)
- Seepage (Upper and lower pools)
  - Piezometers (24)

AOC5 – North Davis Chamber Monoliths

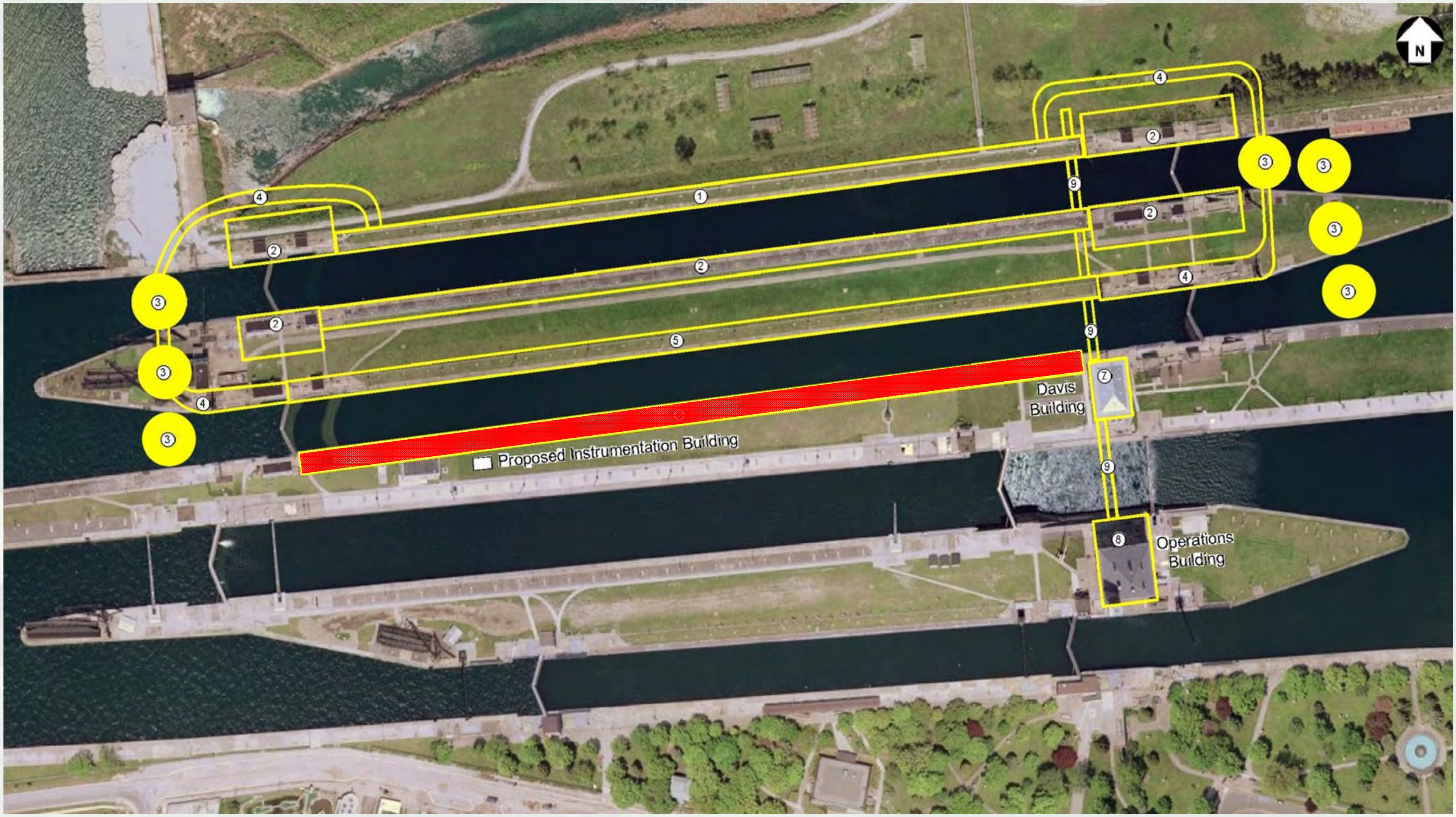


AOC5 – North Davis Chamber Monoliths

Construction Concerns

- Overturning (Dewatering / Pansey bed excavation / Davis backfill)
  - IPI (3), MTDR (3), Survey Points (138), Saw Cuts (46)
- Seepage (Upper and lower pools)
  - Piezometers (3)
- Deflection (Davis backfill)
  - IPI (3), MTDR (3), Survey Points (138), Saw Cuts (46)
- Sliding (Dewatering / Pansey bed excavation / Davis backfill)
  - IPI (3), MTDR (3), Survey Points (138), Saw Cuts (46)

AOC6 – South Davis Chamber Monoliths

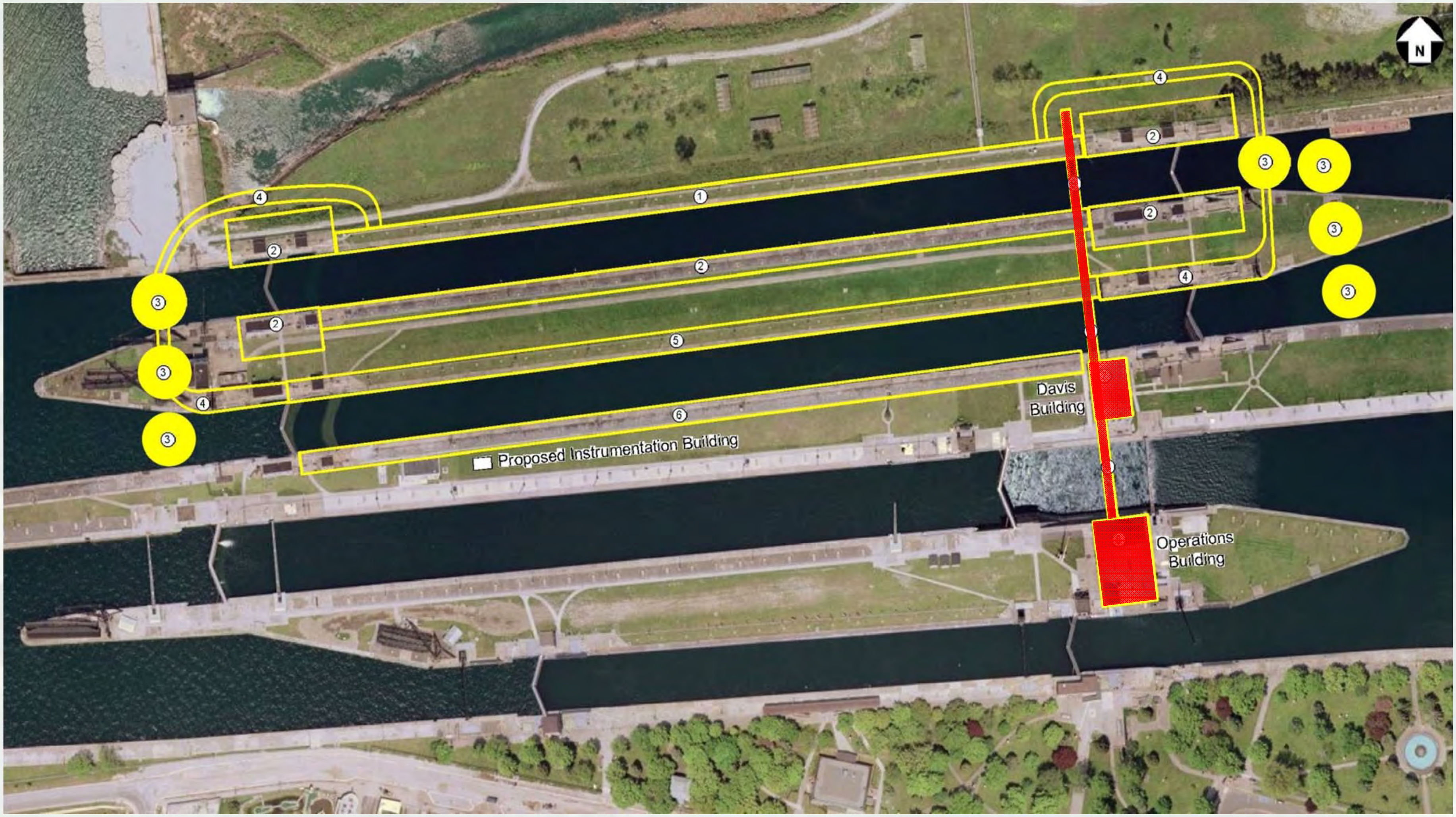


AOC6 – South Davis Chamber Monoliths

Construction Concerns

- Overturning (Dewatering / Construction activities)
  - IPI (2), Inclinometers (2), MTDR (2), Survey Points (138), Saw Cuts (46)
- Seepage (Poe Lock)
  - Piezometers (7)
- Deflection (Dewatering / Construction activities / Davis backfill)
  - IPI (2), Inclinometers (2), MTDR (2), Survey Points (138), Saw Cuts (46)
- Sliding (Dewatering / Construction activities)
  - IPI (2), Inclinometers (2), MTDR (2), Survey Points (138), Saw Cuts (46)

AOC7 – Historic Davis Building, Administration Building / Service Tunnel



AOC7 – Historic Davis Building, Administration Building / Service Tunnel

Construction Concerns

- Crack Formation (Blasting / Construction activities)
  - Pre Construction Surveys / Avongard Crack Meters
    VW Crack Meters if necessary
- Vibration (Blasting / Construction activities)
  - Pre Construction Surveys / Avongard Crack Meters
    VW Crack Meters if necessary

QUESTIONS

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