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resources & energy

# Combining Risk Management and Targeted In-Situ Remediation to Facilitate Brownfield Redevelopment

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# Outline

- ▶ Overview
- ▶ Site Setting and History
- ▶ Brownfield Redevelopment
  - Risk Management Plan
  - Targeted In-Situ Remediation
- ▶ Challenges

# Environmental Management

- ▶ **WorleyParsons involvement**
  - Approval renewal
  - Regulatory water monitoring
  - Remediation system operation and optimization
- ▶ **Previous phases of work**
  - Several other consulting companies
  - University of Calgary





# Site Setting

- ▶ 180 ha Brownfield site in South Calgary
  - Shopping centre and natural area
- ▶ Located on Bow River flood plain
- ▶ Overlies gravel domestic use aquifer
- ▶ Preferential groundwater flow paths
- ▶ Dynamic hydrology



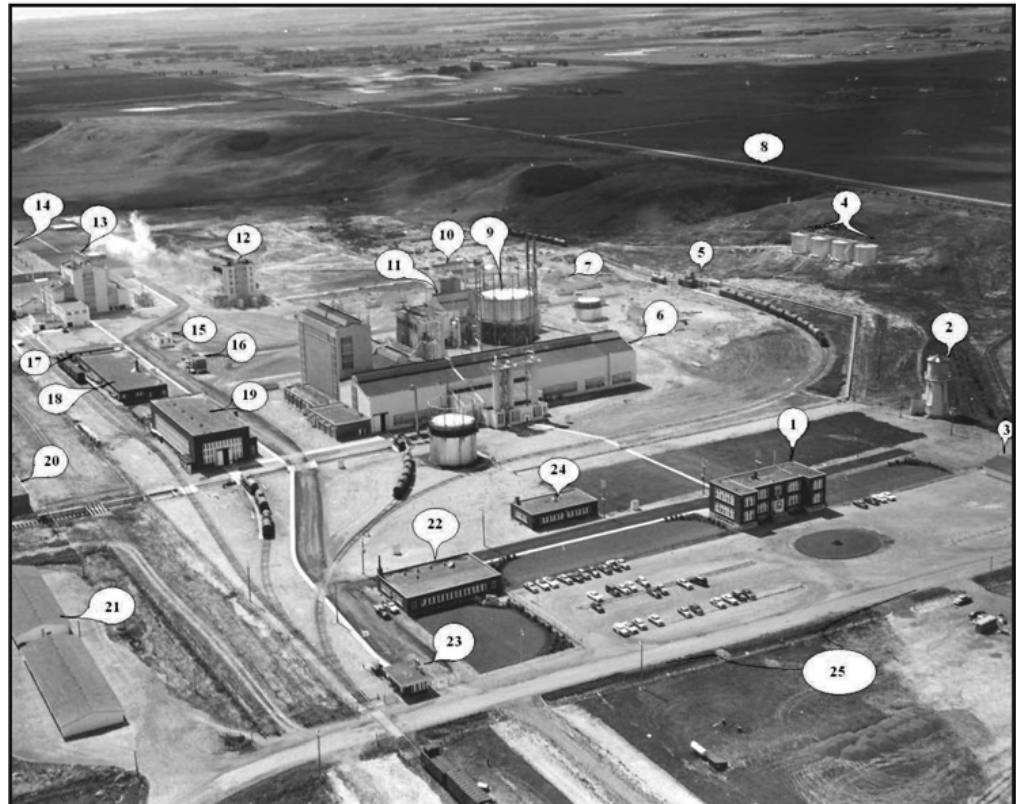
# Site History

## ▶ Fertilizer manufacturing plant

- Operations began in 1942, shut down completed in 1992
- 35 ha plant area

## ▶ Production

- Ammonia
- Gas and steam
- Nitric acid
- Ammonium nitrate
- Urea



# Site History

- ▶ 40 areas of potential environmental concern identified
- ▶ Multi-year, multi-phase characterization program
- ▶ Source elimination and soil remediation
  - Excavation and off-site disposal
  - Landspreading
  - Soil blending
  - Seeding



Soils generally remediated  
to 1991 CCME  
Commercial/Industrial  
Criteria

Soils generally remediated  
to Alberta Tier 1 Criteria



# Site History

- ▶ 1994: Remediation initiated
  - Three extensive programs followed by geotechnical characterization
- ▶ 2003: Obtained Reclamation Certificate for two areas
  - Residential development
  - Commercial development



# Site History

## ▶ Groundwater flow

- Residual impacts remain below water table
- Groundwater flow velocity H600 m/year
- 210 ha plume extends to the east and southeast
  - Copper
  - Ammonia-N
  - Nitrate-N
  - Nitrite-N

### Legend

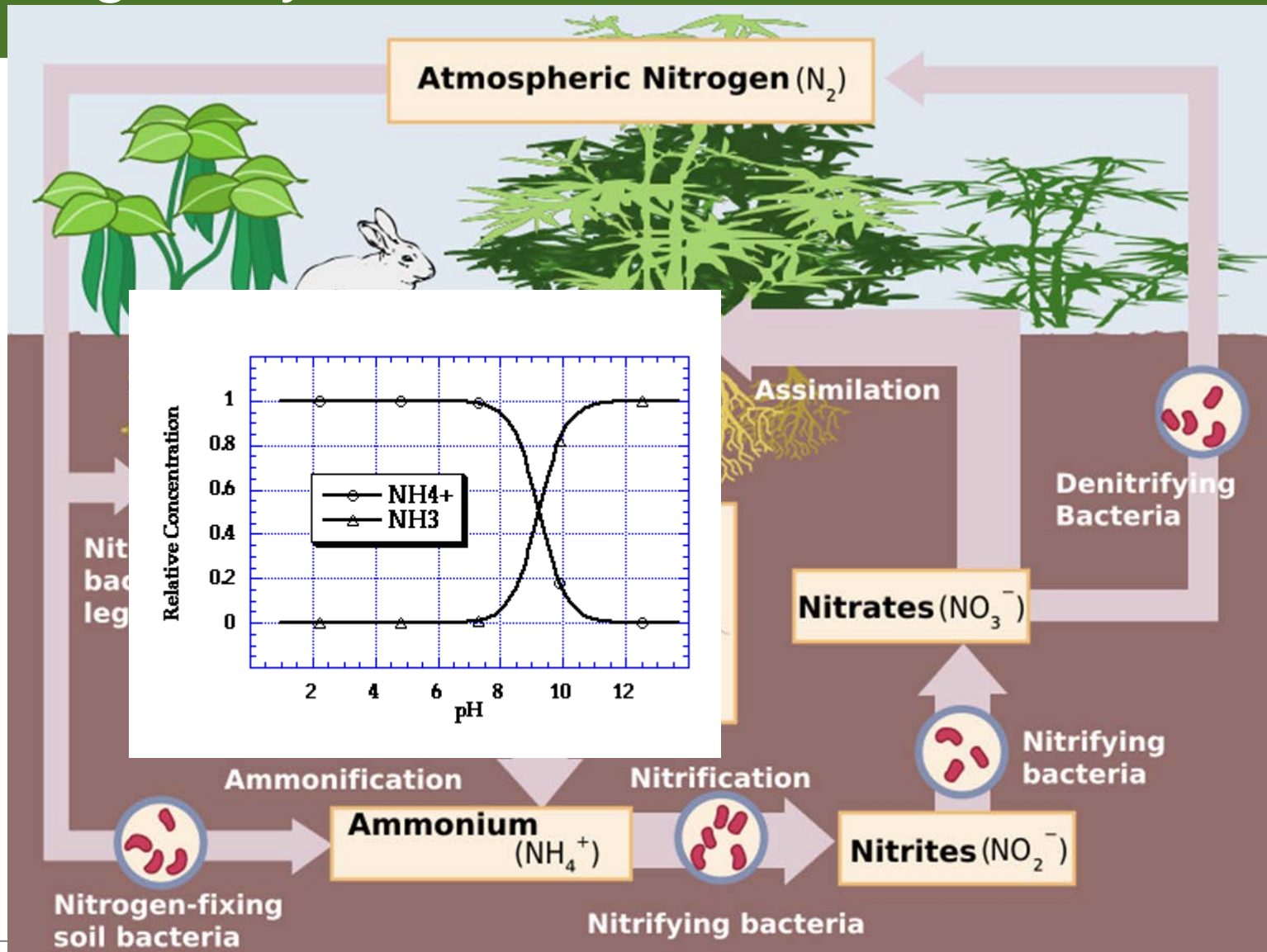


Groundwater monitoring well  
Surface water sampling location





# Nitrogen Cycle



# Monitoring Locations

- ▶ Surface water
  - 10 locations
  - 3 times per year
- ▶ Groundwater
  - 28 monitoring wells
  - 2 times per year
- ▶ Analytical Schedule
  - Routine potability
  - Nitrogen parameters
  - Dissolved and total metals





# Regulatory Criteria

## ▶ Guidelines

- Alberta Tier 1
- Site-specific surface water guidelines
  - Based on background water quality
  - Calculated from pH, hardness, and temperature

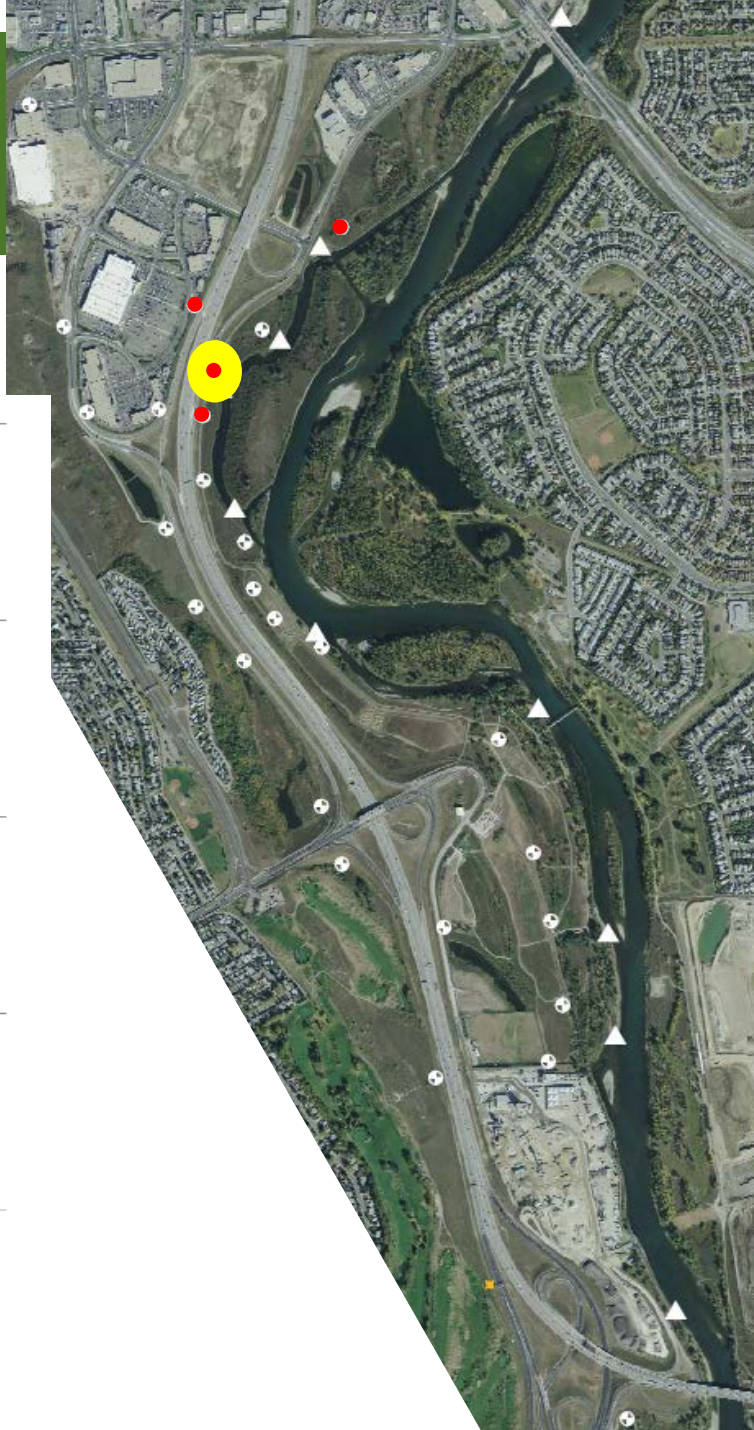
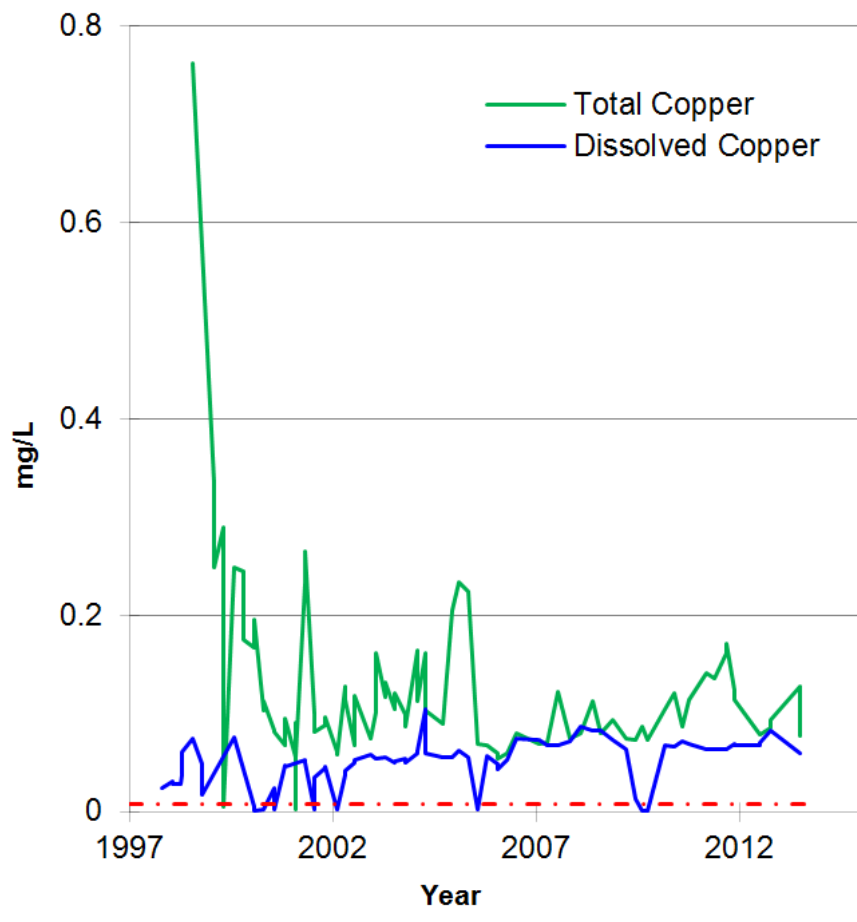
## ▶ Contingency plan based on trigger values





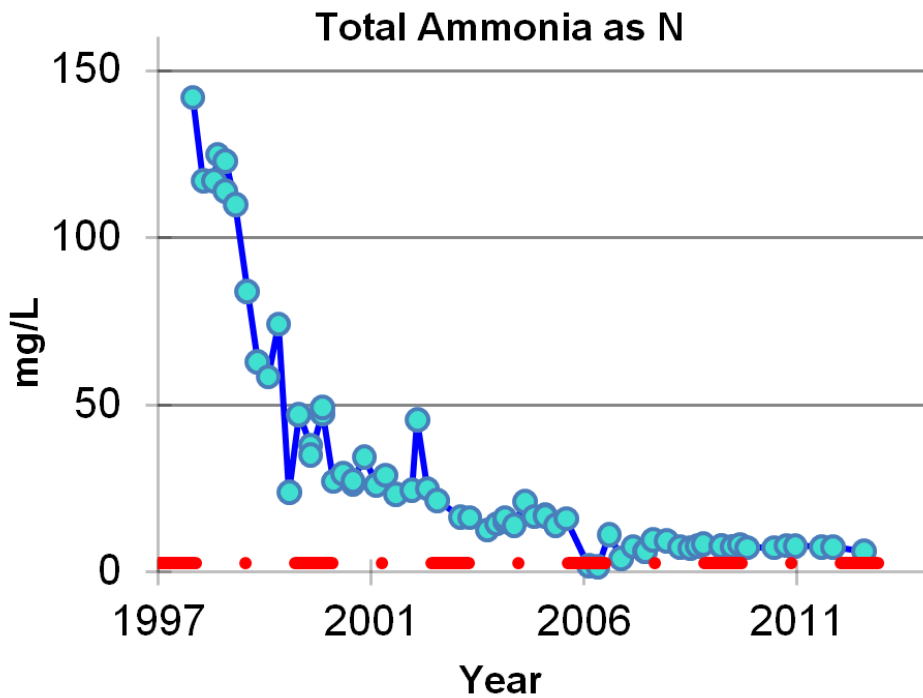
# Copper

## ▶ 2012 Exceedances



# Ammonia-N

## ► 2012 Exceedances

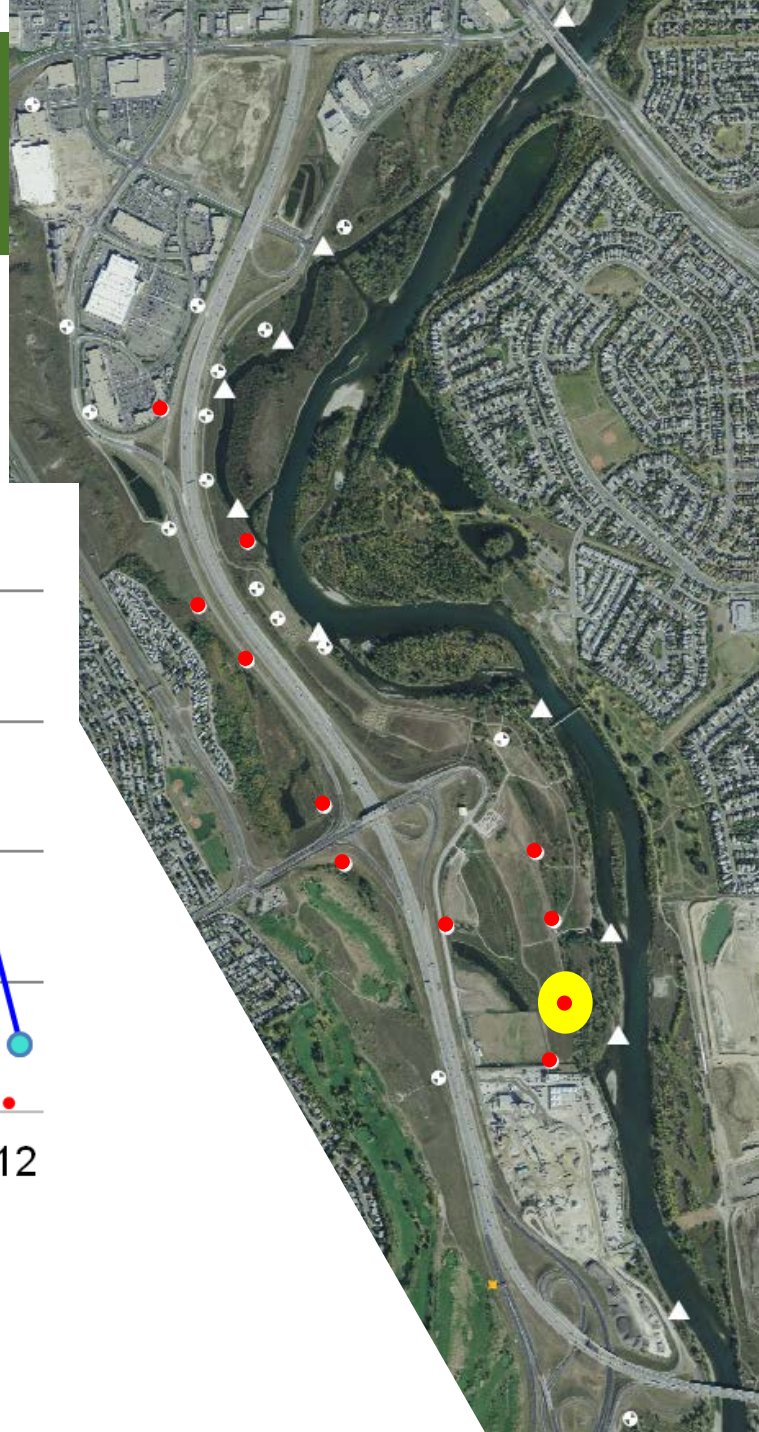
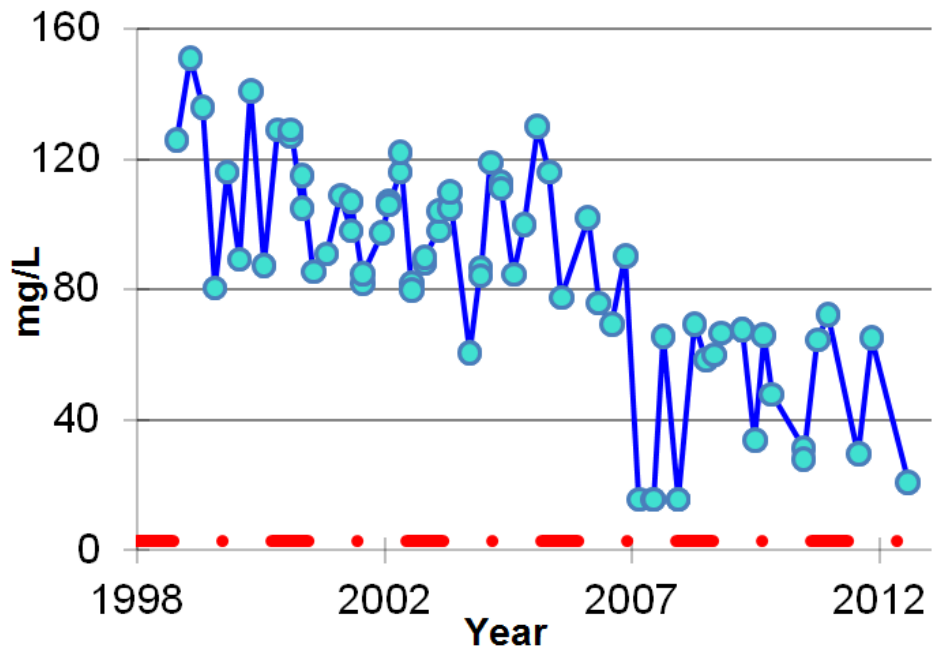




# Ammonia-N

## ► 2012 Exceedances

Total Ammonia as N



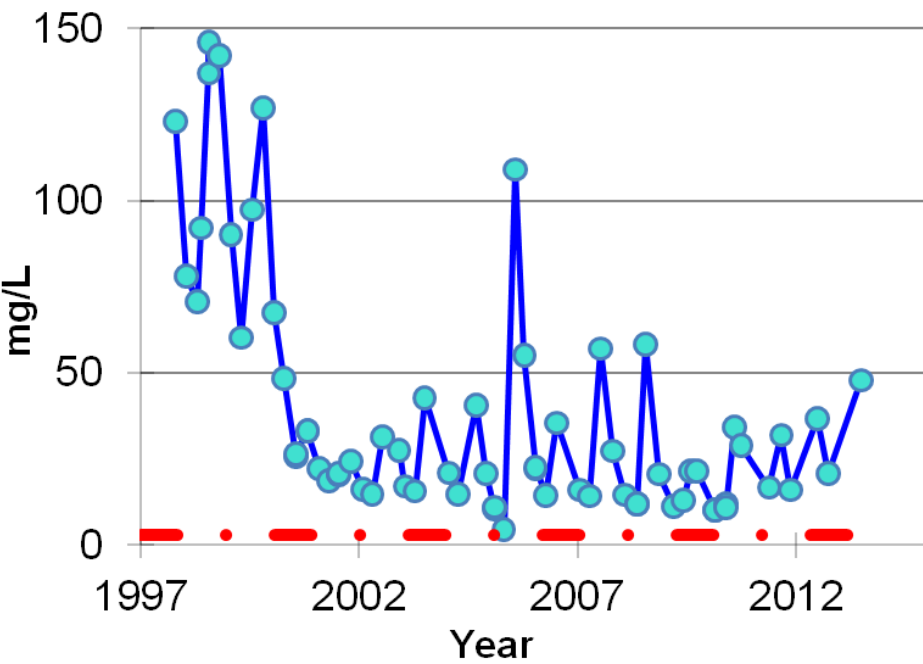


# Nitrate-N

## ► 2012 Exceedances

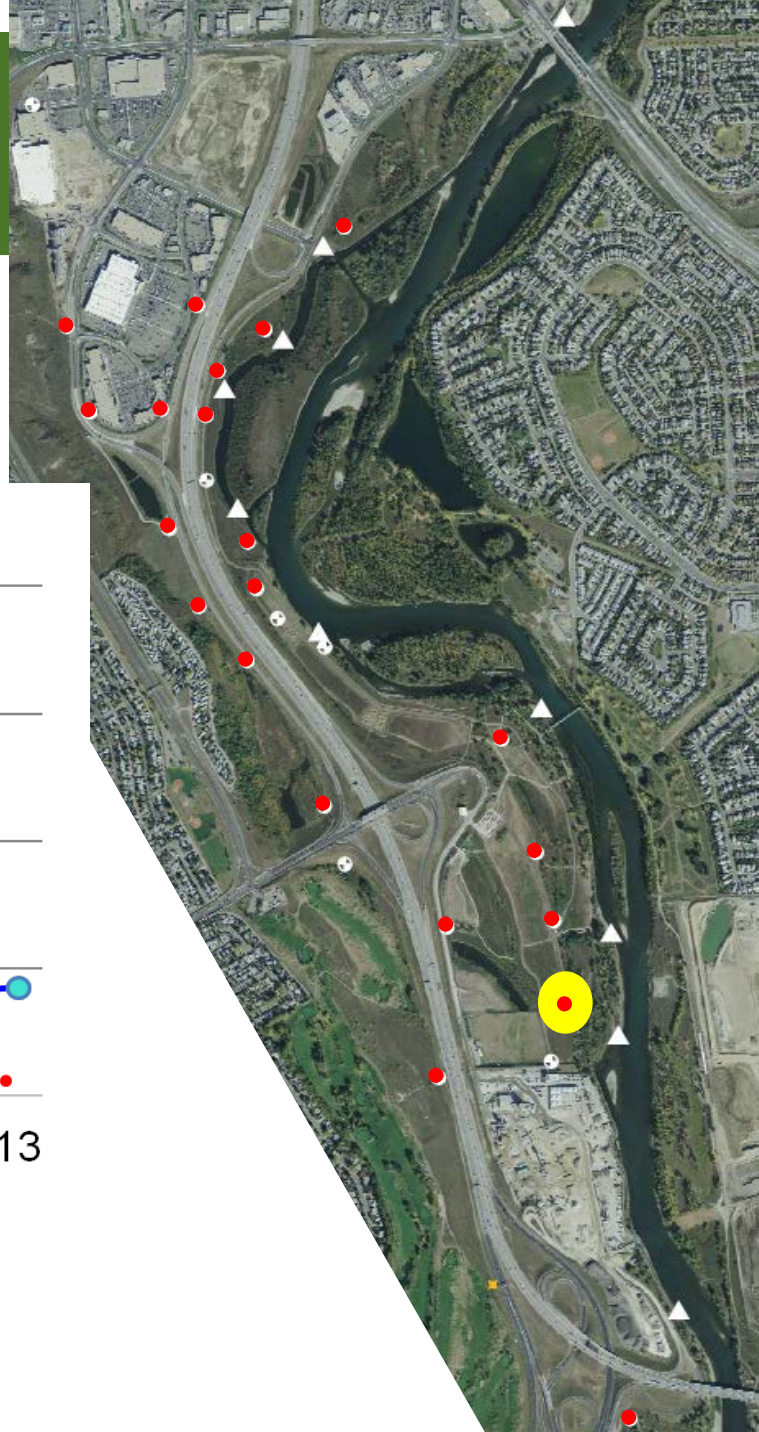
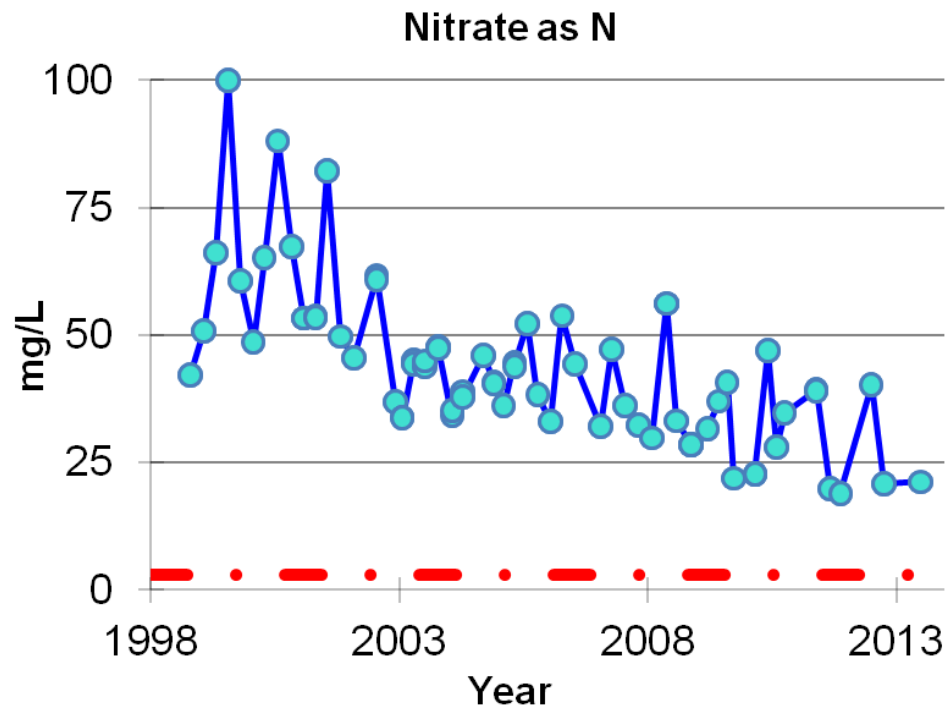


Nitrate as N



# Nitrate-N

## ► 2012 Exceedances





# Nitrogen Plume

- ▶ Plume migration
  - Source material mostly removed or attenuated
  - Evidence suggests repeating cycles of adsorption and dissolution of nitrogen species
- ▶ Nitrogen species transformation
- ▶  $\text{NH}_4^+ \rightarrow \text{N}_2$ 
  - Natural Attenuation
  - Active Remediation





# Brownfield Redevelopment Strategy

Risk Management Plan  
+  
Targeted In-Situ Remediation

# Risk Management Plan

- ▶ Developed in 2001 by Bel•MK
- ▶ Land use restrictions
  - Reflect remediation guidelines and residual impacts
  - West of Deerfoot Trail
    - Commercial and light industrial
  - East of Deerfoot Trail
    - Partial commercial and light industrial
    - Natural park area
  - Receptor Protection
    - **Signage**

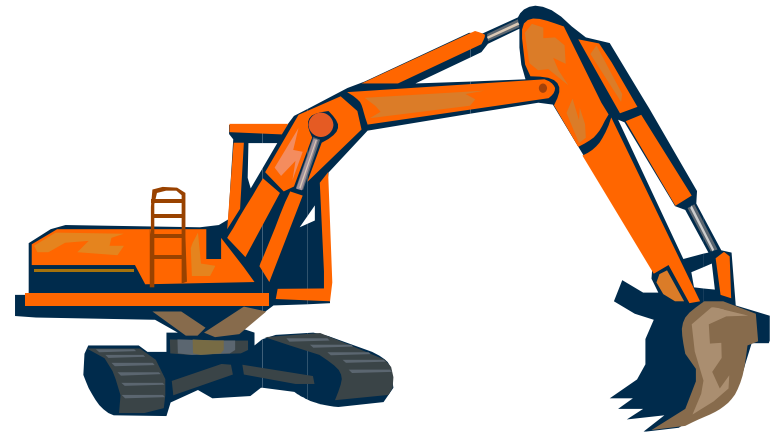




# Risk Management Plan

## ► Management controls

- Use of groundwater for potable purposes not permitted
- Agricultural-based activities not permitted
- Construction activity restrictions
  - Landscaping
  - Utility and foundation construction
  - Worker protection
  - Reporting requirements



# Brownfield Redevelopment Strategy

Risk Management Plan  
+  
Targeted In-Situ Remediation



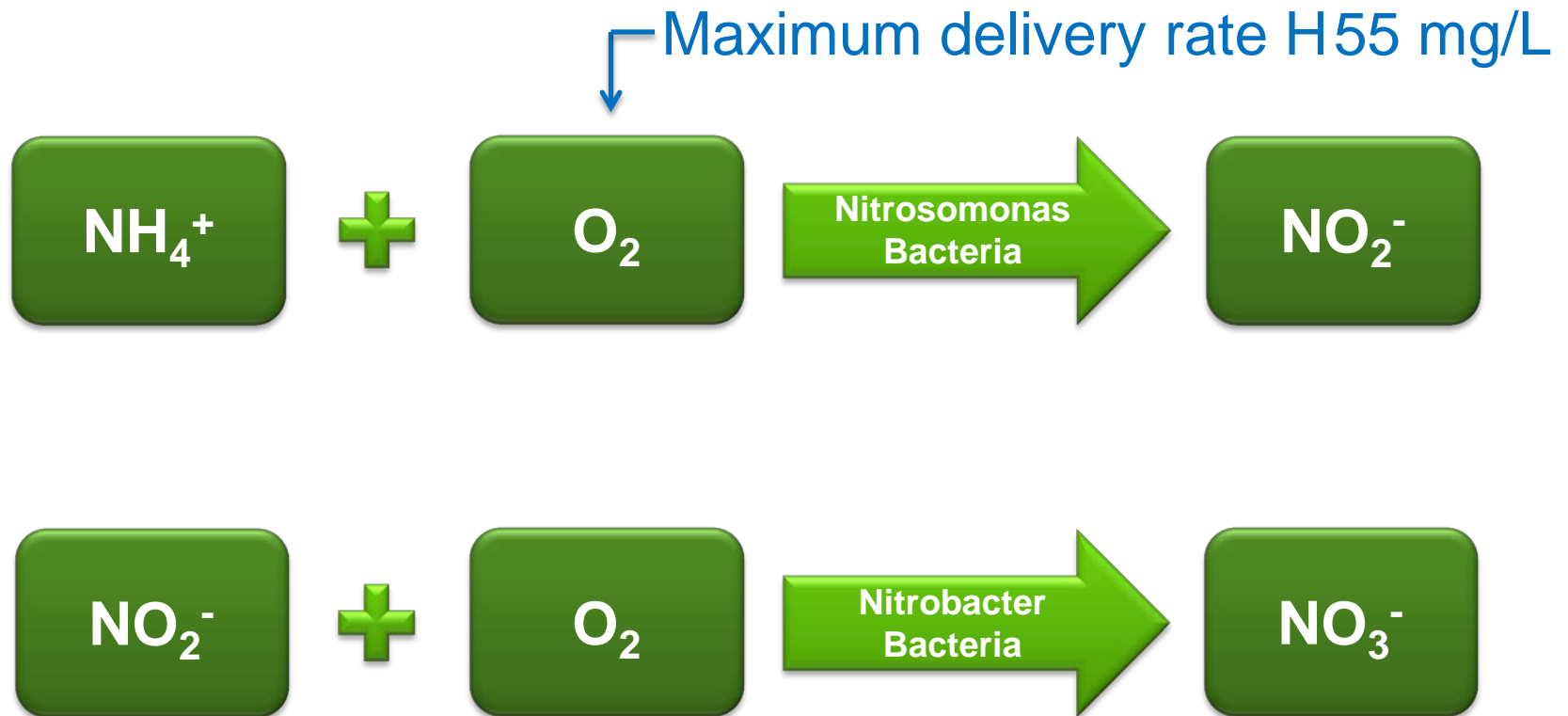
# In-Situ Remediation

- ▶ Custom designed in-situ nitrification and denitrification system
- ▶ Collaborative design between consultants and University of Calgary
- ▶ Topic of several university studies
- ▶ On-going study and optimization



# In-Situ Remediation

## ► Nitrification





# In-Situ Remediation

## ► Denitrification

- Bacterially mediated



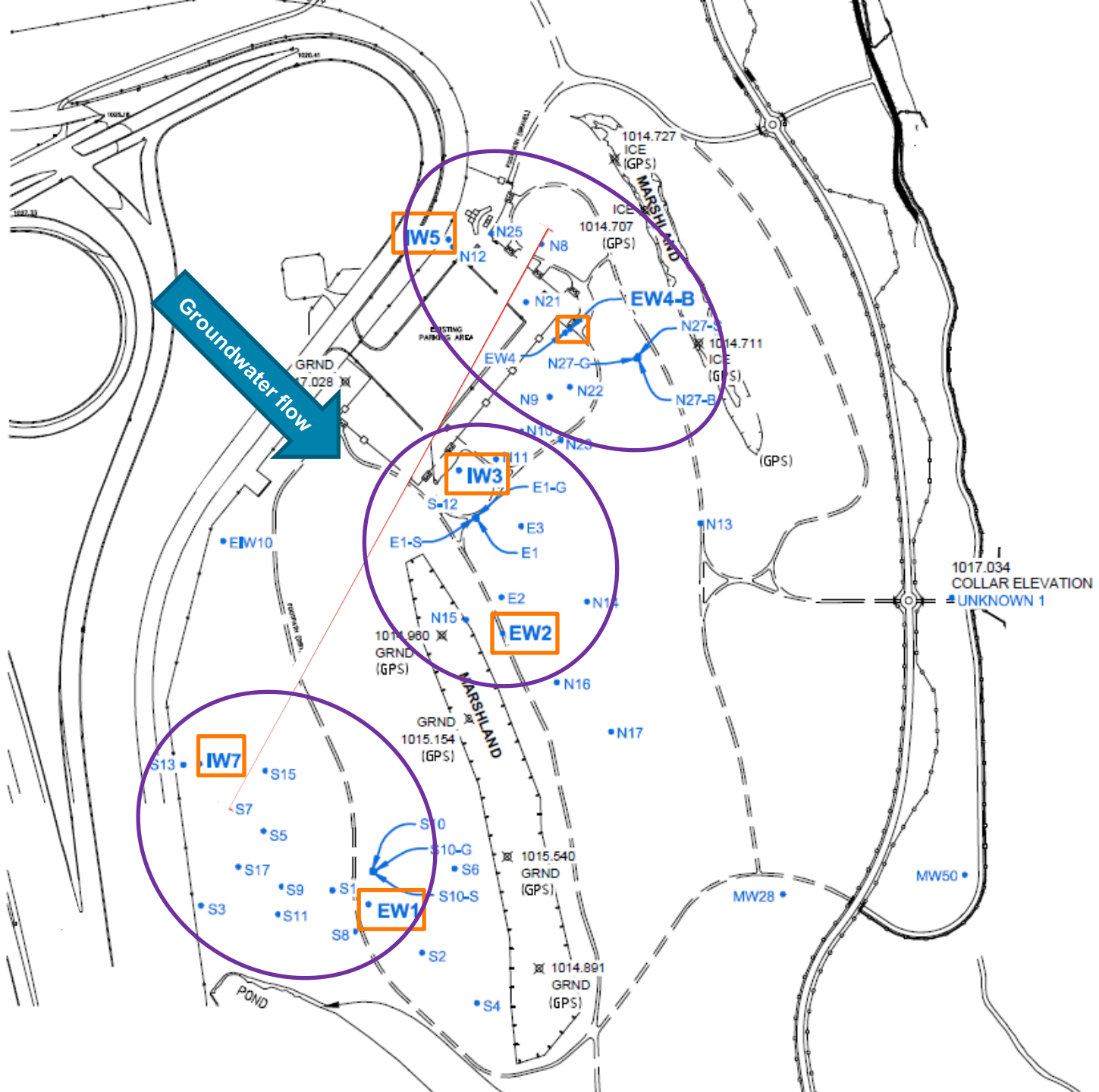
↑ No practical limit to carbon addition

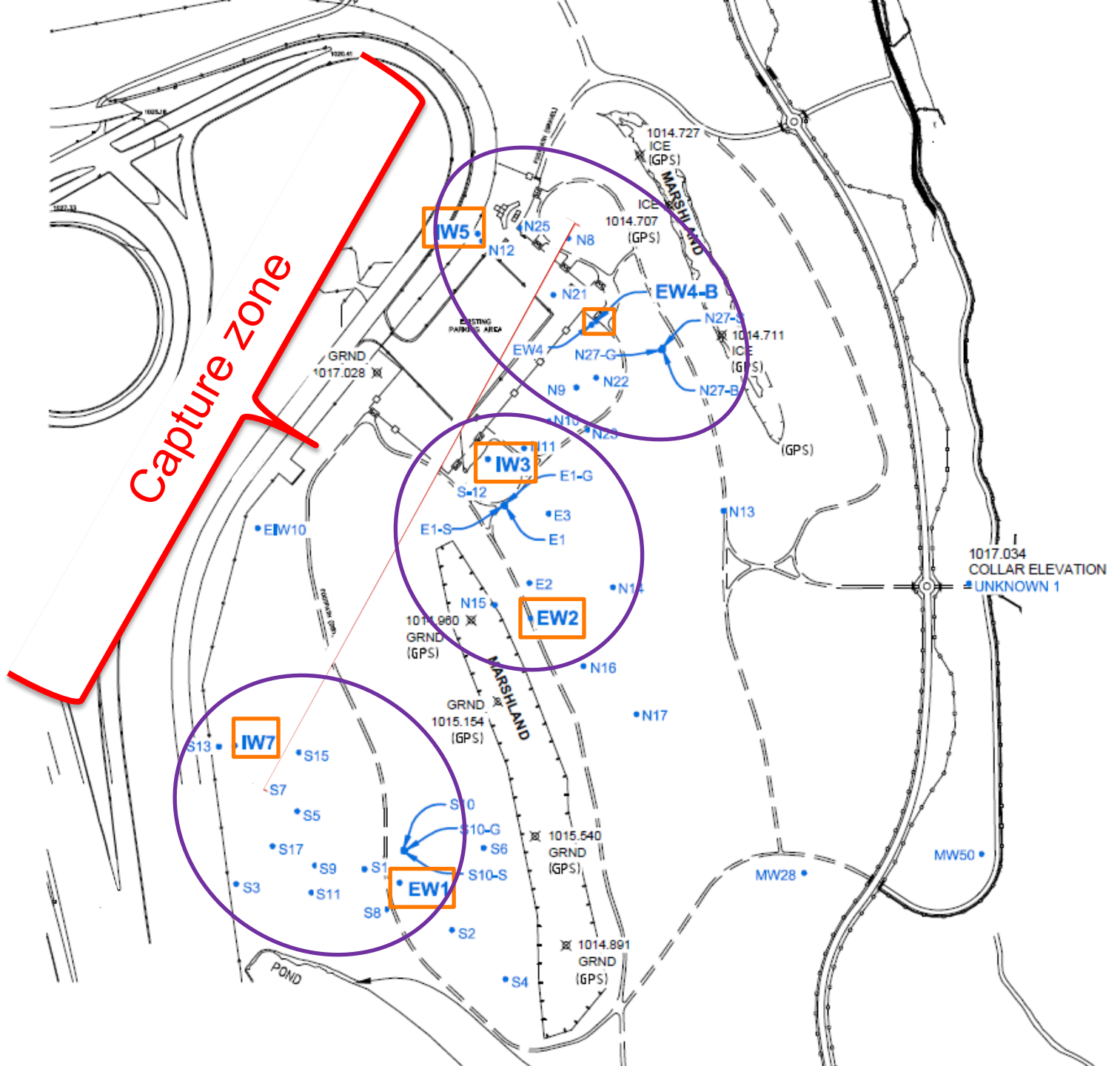
# In-Situ Remediation



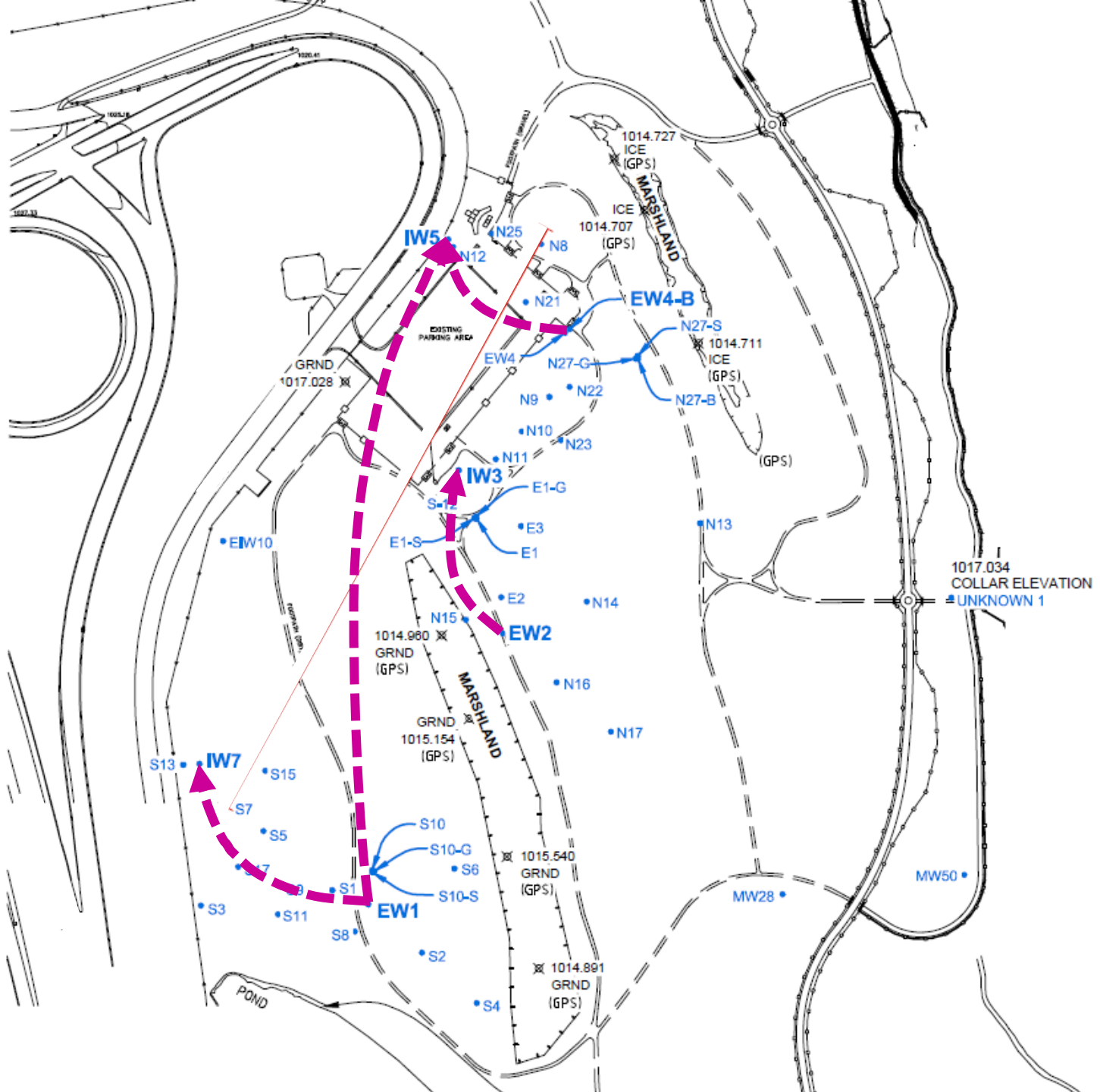












# In-Situ Remediation

## ▶ Evidence of Anammox

**ANAerobic AMMonium OXidation**



- ▶ Ammonia and nitrite transformed to water and nitrogen
- ▶ Only occurs over a narrow range of dissolved oxygen concentrations (H 1 to 2 ppm)
- ▶ Only occurs over a narrow pH range (H 6.5 to 8.5)



# Challenges



# Challenges

- ▶ Frequent sampling requirements
- ▶ Guidelines
  - Total vs. dissolved
- ▶ Biomass buildup around injection wells



# Challenges

- ▶ Preferential flow through buried channels
- ▶ Investigation and interpretation
  - Follow up mapping
  - Geophysics
  - Groundwater modelling





# Challenges

- ▶ Data reproducibility and trend analysis affected by dynamic flow conditions
  - Groundwater/surface water interaction





# Challenges

- ▶ Other anthropogenic nitrogen sources
  - Industrial areas
  - Golf courses and driving ranges
  - Dog park
- ▶ Chloride from street salting used to differentiate between surficial nitrogen and groundwater plume



# Challenges

- ▶ Background surface water nitrogen loading
  - Treatment plant approximately 4 km upstream
    - May be adding H 1.1 mg/L nitrogen to the river (2012)
  - Groundwater flux contributions to the river
    - H0.7% of total ammonia
    - H0.1% of total nitrate





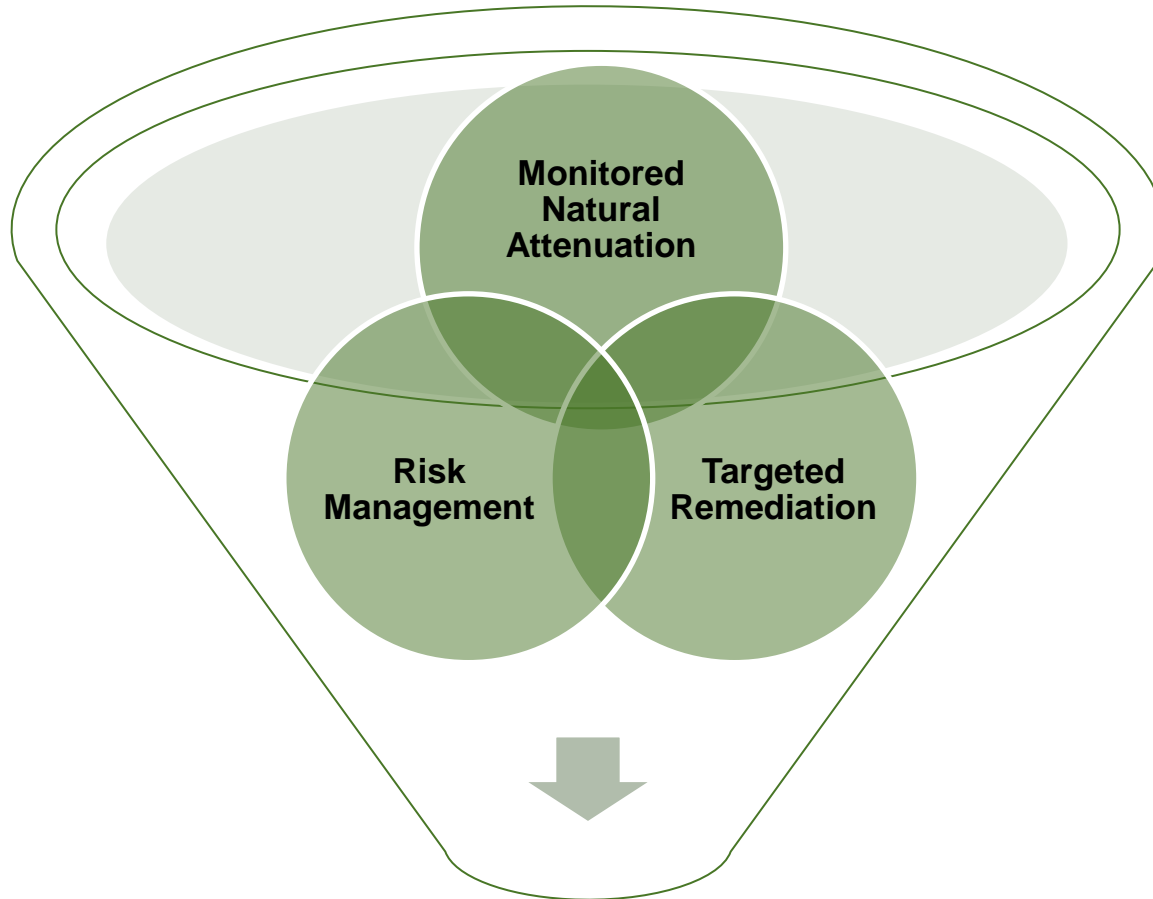
# Challenges

- ▶ Background surface water nitrogen loading
  - Assessed through triad study
    - Sediment sampling
    - Surface water sampling
    - Benthic invertebrate assessment
  - Additional assessments
    - Microtox and Chironomid survival testing
    - Hyporheic zone porewater sampling





# Conclusion



## Successful Brownfield Redevelopment



Thank you. Questions?