Road Salt and Groundwater – *Monitoring, Management and Mitigation Strategies*

October 2019

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AWWA Turf
2019 Annual Conference

What's the Problem?

– Road salt use continues to rise despite efforts to reduce application rates.

– Road salt in runoff is a problem in a surface-water supply for a few months of the year*.

– Road salt in groundwater supplies is a problem that can persist for decades.

Why Should You Care?

- Elevated sodium can affect people with high blood pressure.
- High chloride levels can have an unpleasant taste.
- Elevated chlorides can increase levels of corrosion in a water distribution system and in home pipes and appliances.
- Sodium and chloride treatment/removal is expensive and often impractical.

Overview

- Health and Environmental Risks
- Salt Budget for a Well Field
- Monitoring
- Management
- Mitigation

Health and Environmental Risks

Water Standards

Drinking Water

- Chloride CTDPH Secondary Drinking Water Maximum Contaminant Level (MCL) 250 milligrams per liter (mg/L) or parts per million (ppm)
- Sodium CTDPH notification level 28 mg/L, recommended limit (no MCL) 270 mg/L

Surface Water

- Chloride CTDEEP Surface Water-Aquatic Life Criteria, acute 860 mg/L, chronic 230 mg/L
- Sodium CTDEEP Surface Water – Class AA not to exceed 20 mg/L, Class A and below “none other than of natural origin”

Health Risks

- Excessive sodium consumption can cause hypertension.
- Increased corrosivity in a water distribution system from elevated chlorides can lead to increased lead concentrations.

> Chloride increases the electrical conductivity of water and thus increases its corrosivity. In metal pipes, chloride reacts with metal ions to form soluble salts (8), thus increasing levels of metals in drinking-water. In lead pipes, a protective oxide layer is built up, but chloride enhances galvanic corrosion (14). It can also increase the rate of pitting corrosion of metal pipes (8).
>
> World Health Organization 2003 – Chloride in Drinking-Water

- Taste threshold for chloride is 200 mg/L to 300 mg/L.
- Taste threshold for sodium is about 200 mg/L.

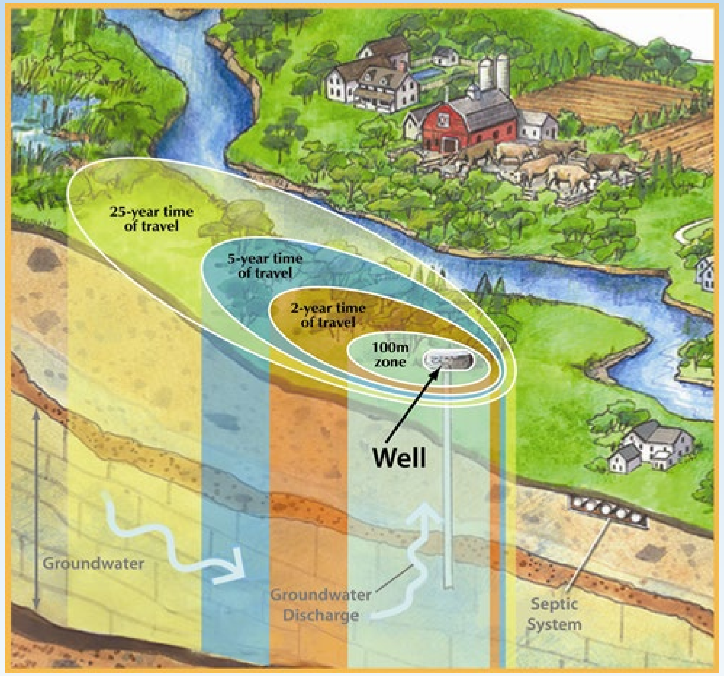
Environmental Risks

Infrastructure	• Corrosion of concrete reinforcing rods in road, bridges, parking structures, etc. • Corrosion costs estimated at $3.5 to $7 billion per year in the U.S. • Corrosion protection practices increase the cost of auto manufacturing by nearly $4 billion/year • Corrosion protection costs estimated at $8.3 billion/year for highway bridges, and $109 billion for epoxy coating;
Vegetation	• Osmotic imbalance in plants, inhibiting water absorption and reducing root growth • Inhibition of seed germination and root growth for grasses and wildflowers (for NaCl as low as 100 ppm in soil) • Competition to native species from salt-tolerant invasive species
Soil	• Inhibition of soil bacteria (for NaCl concentrations as low as 90 ppm), compromising soil structure and increasing erosion • Accumulation of salt, particularly sodium, in soil over time, reduces soil fertility and affects soil chemistry
Groundwater	• Remediation of salt contamination in drinking water estimated at $10 million nationally
Wildlife	• Compromised health in birds ingesting salt at 266 mg/kg; median lethal dose in birds and mammals is 3,000 mg/kg
Aquatic life	• Decreased dissolved oxygen and increased nutrient loading, promoting eutrophication • Release of toxic metals from sediment into the water column • Reduction of number and diversity of macroinvertebrates • Critical tolerance values in 10% of aquatic species exceeded for prolonged exposure to chloride concentrations >220 mg/L • Median lethal dose (7 days exposure to salt) for 17 species of fish, amphibians, crustaceans ranges from 1,440 – 6,031 mg/L (mean value of 3,345 mg/L)

From City of Madison Salt Report 2006

– Infrastructure (structural) corrosion
– Inhibit plant growth and seed germination
– Reduces soil fertility
– Inhibits soil bacteria growth
– Groundwater contamination
– Acute and chronic toxicity to aquatic species

Salt Budget for a Well Field



Road Salt

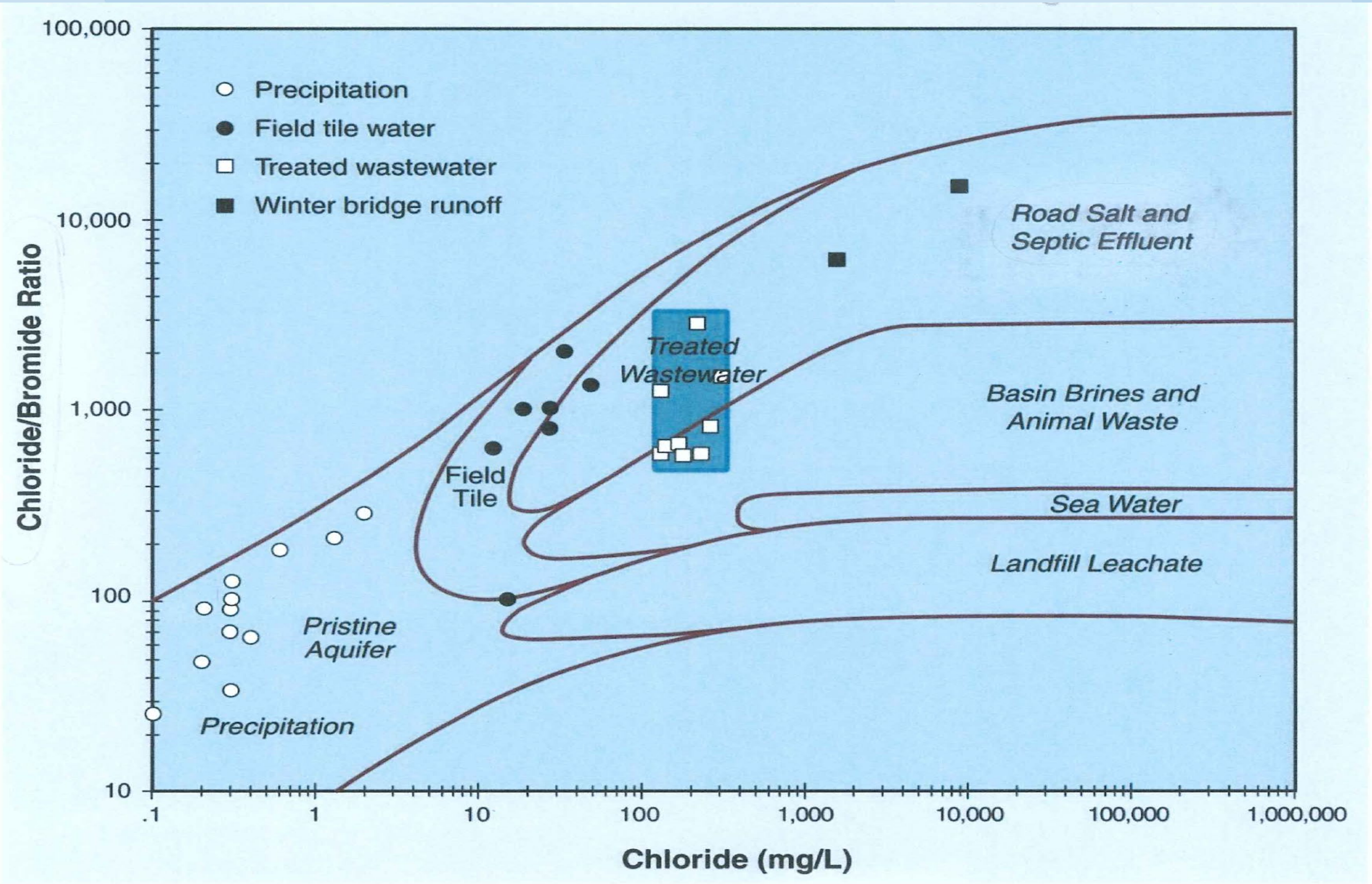
Why is salt applied?

- Salt lowers the freezing/melting point of water. A 10% salt solution freezes at 20^{o}F and a 20% solution freezes at 2^{o}F.
- However, if the temperature of the roadway is less than about 15^{o}F, the salt will have no effect. The solid salt cannot enter the solid water (ice) to start the dissolving process to create a solution.
- In 2006, the CT DOT began using pre-wetted salt (pre-wetted with CaCl and MgCl) to prevent scattering of salt crystals, increasing effectiveness.

Potential Sources of Chlorides

- Snow and Ice Control
  - *sodium chloride (NaCl), magnesium chloride (MgCl), and calcium chloride (CaCl)*
- Fertilizers
  - *potassium chloride (KCl)*
- Water Softeners
  - *potassium chloride (KCl) and sodium chloride (NaCl)*
- Municipal Sewer Discharge
  - *treated wastewater*
- Industrial Waste and Landfills
- Salt Water Intrusion
- Natural Salt Deposits
  - *Halite*

Ion Ratio

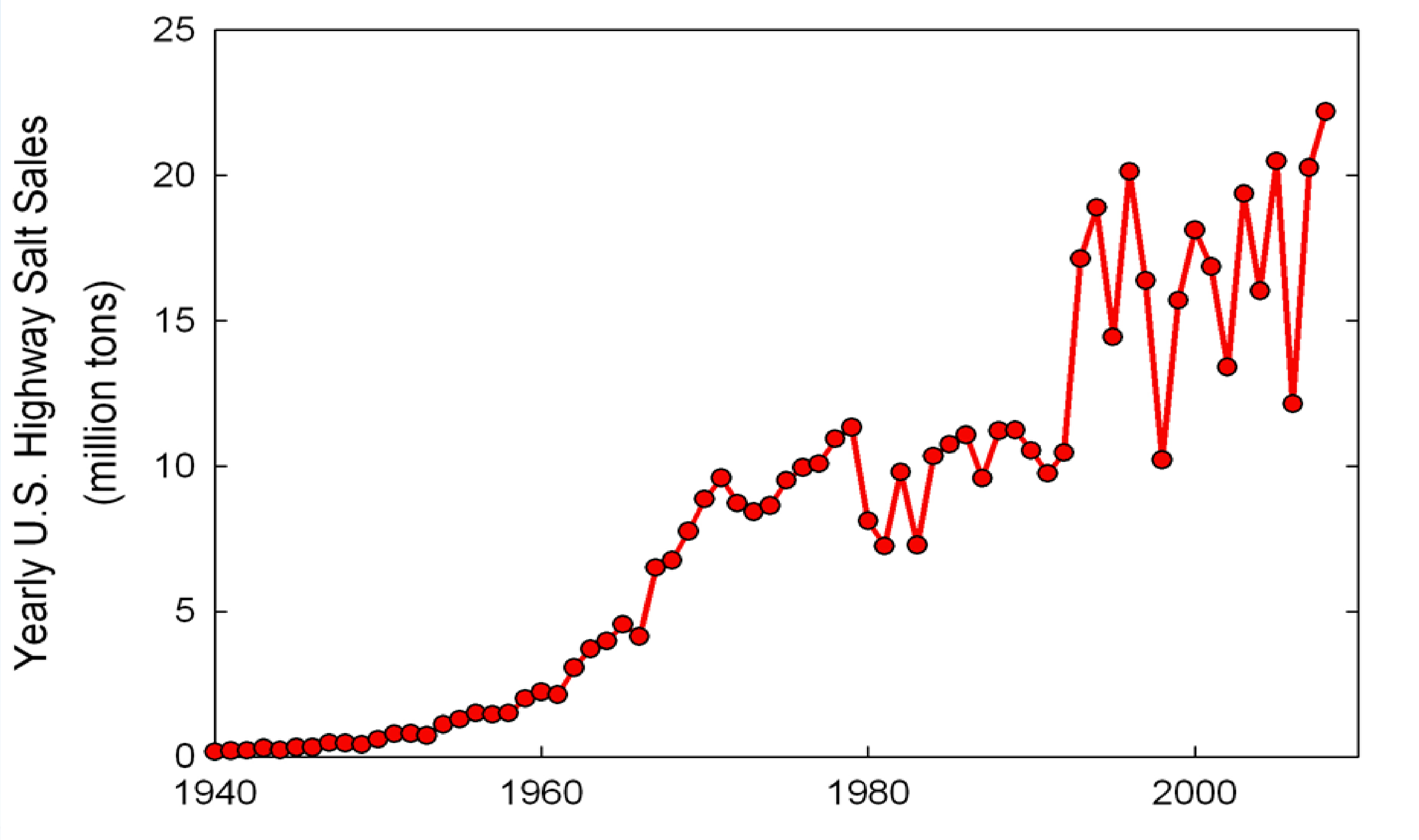


Panno, S.V., et al., 2006. *Ground Water* 44:176-187.
Kelly, W.R., et al., 2010. *Applied Geochem.* 25:661-673.

Road Salt

- U.S. road salt use was over 22 million tons in 2010
- National application rates have tripled since 1980
- Most states apply in the 5 to 10 tons/mile range
- Parking lots have much higher application rates, up to 40 tons/acre (one acre equals about one lane mile)
- CT DOT application rate in 2010-2011 was approx. 179,000 tons (358 million pounds) of sodium chloride and 2,300 tons of calcium chloride
- These numbers do not include applications by local (municipal) or private entities

Annual Salt Sales



Data from the Salt Institute, 2011

Salt Budget

Do you have a problem?

- Baseline Concentrations – check your historical sampling record.
- How long has it been since the last samples were collected?
- What months/seasons were your samples collected?
- Do you sample routinely (quarterly, semi-annually, annually) from production wells, monitoring wells, surface water?

Salt Budget

Yes, there's a problem, what next?

Salt Budget – Desktop Evaluation, start simply and expand complexity, if warranted

- Well recharge area (topographic area); soil types/thickness; published groundwater recharge rates; highway/road length and parking areas in watershed; check DOT or municipal loading rates; regional precipitation rates; identify potential sources

*more complex evaluation, well specific transport and capture area modeling

Look for potential sources of sodium and chloride near your well field

- Surface water (rivers, ponds, lakes), surface-water runoff and snow disposal
- Salt storage/snow stockpiling
- Salt application: parking lots, local roads, highways (storm-water runoff)
- Wastewater discharges

Look at your well location and construction

- Bedrock or sand and gravel wells
- Well casing length, screen setting, fracture depths, well depth

Monitoring/Management/Mitigation

Initial Salt Budget Assessment

Well Recharge Area

- topographic recharge contribution area, can also conduct fracture-trace analysis to assess whether significant bedrock fracture lineations cross topographic boundaries

Soil Types/Thickness – till or stratified drift

- Till – thick or thin
- S/D – sand and gravel or silt and clay

Published Groundwater Recharge Rates

- based on soil and/or bedrock types

Regional Precipitation Rates –

- published by NOAA

Length and Density of Roads/Parking Areas in Watershed

DOT or Municipal Salt Loading Rates

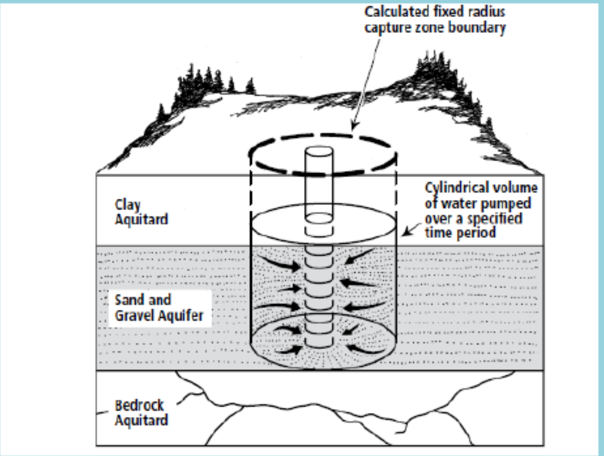
- how much is being applied

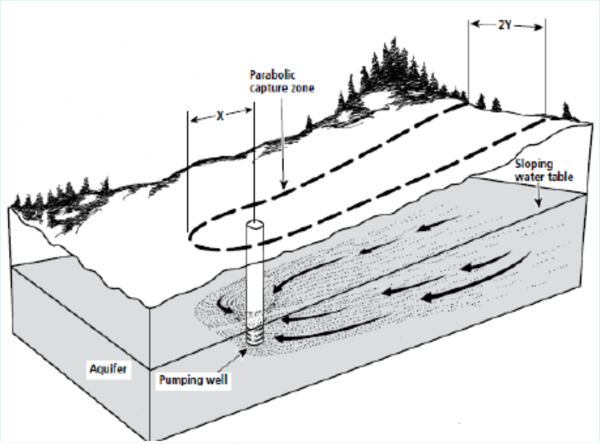
Identify Potential Sources in the Watershed

- could be more than one source
- Surface-water bodies, storm-water management areas, salt storage facilities, application to roads/parking lots

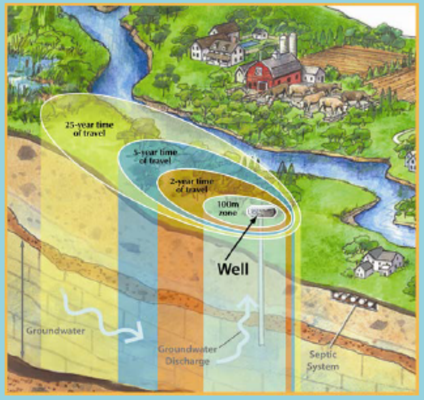
Salt Budget – More Complex Evaluation

Know Where Your Water Is Coming From

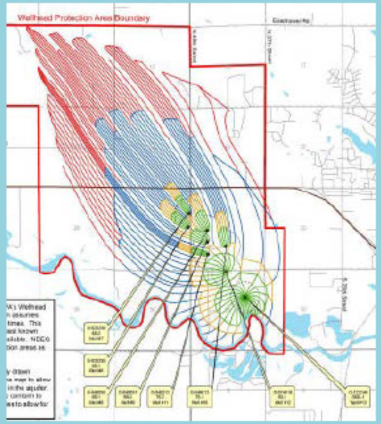




- Define Reliable Capture Zone for Well Field
  - Use Methods with Enough Complexity to Describe Define Reliable Capture Zone
  - Arbitrary Fixed Radius or Simplistic Methods May Not Be Good Enough
  - Need to Account for Aquifer Boundaries
  - Need to Account for Multiple Wells

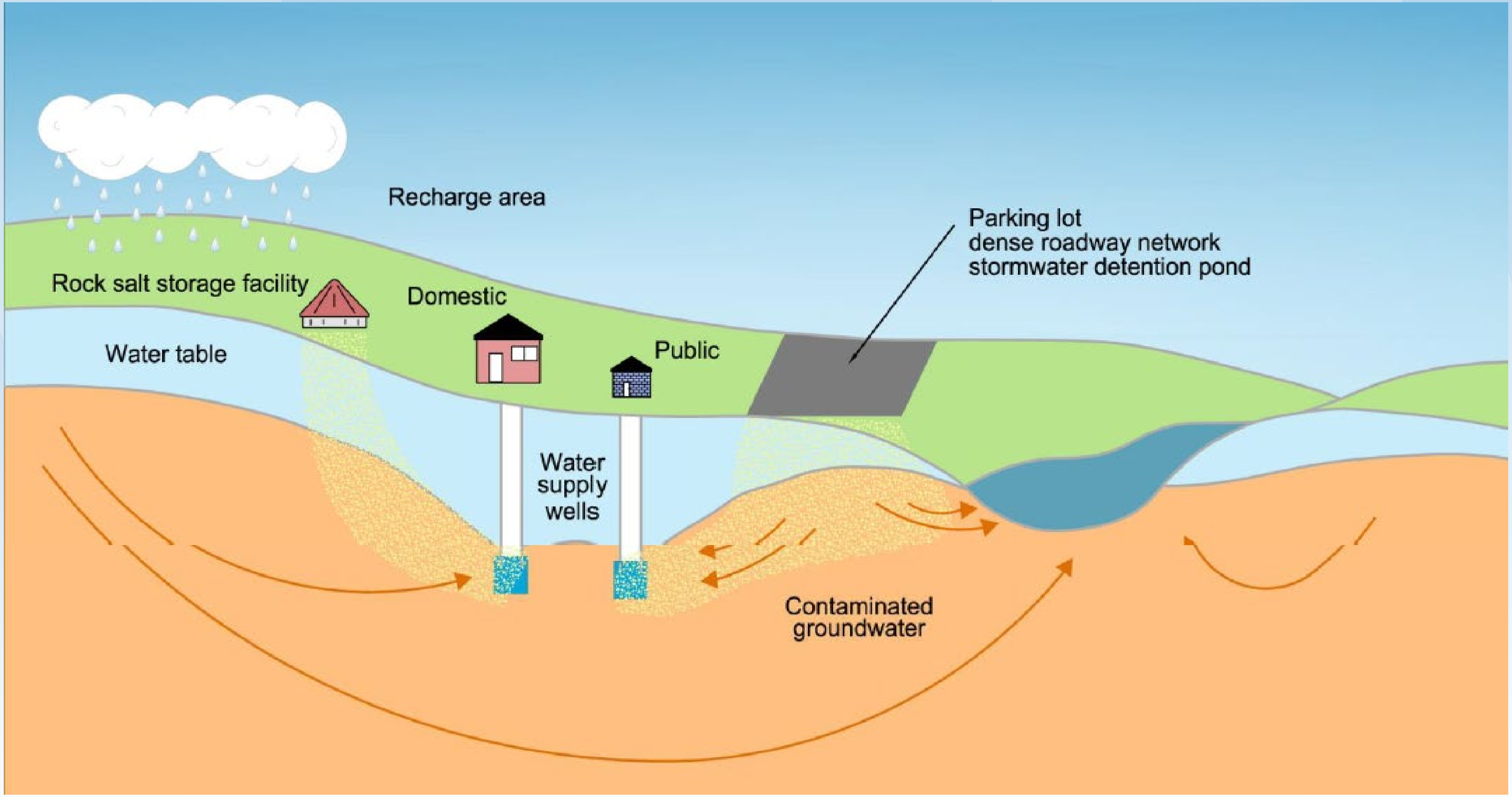


http://www.protectingwater.ca/uploads/Planning/WHPA%20cartoon.png



http://www.ci.norfolk.ne.us/water/Images/NorfolkWest2011.jpg

Pathways for Groundwater Contamination by Road Salt



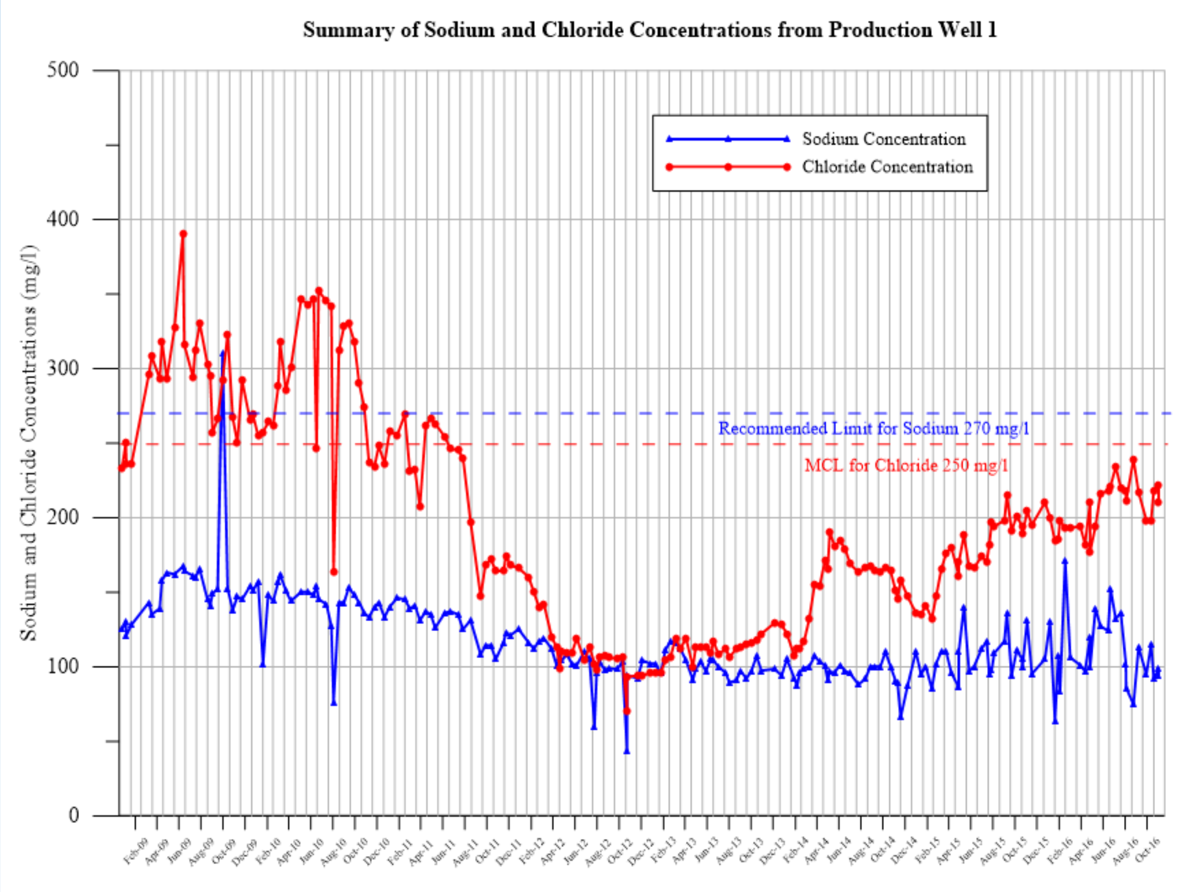
Groundwater Resources at Risk from Road Salt Effects

- Sand and gravel aquifers which are shallow and permeable are at higher risk of road salt contamination.
- Fractured bedrock aquifers exposed at the surface or covered by a thin overburden mantle are also at higher risk of road salt contamination.
- Production wells in close proximity to major roads and highways, large parking lot areas, and/or salt storage areas that contribute direct runoff to the recharge area or zone of contribution of the wells.
- Aquifers hydraulically connected to surface-water bodies that receive runoff from treated roads and other impervious surfaces.

Monitoring

Sample your Production Wells for Sodium and Chloride

- Many wells do not have current data
- Take annual samples (at least) for Na and Cl from each well
- Compare to initial results
- Track concentrations over time for each production well
- Increase frequency to quarterly/monthly if you have a problem



Bi-monthly sodium and chloride concentrations from sand and gravel production well, 2009 through 2016

Additional Monitoring May Be Needed to Identify or Narrow Down Source(s)

Sample existing monitoring wells

- know your monitoring well construction: screen depth, completion depth, it can make a difference in interpreting the results

Installation of additional monitoring wells

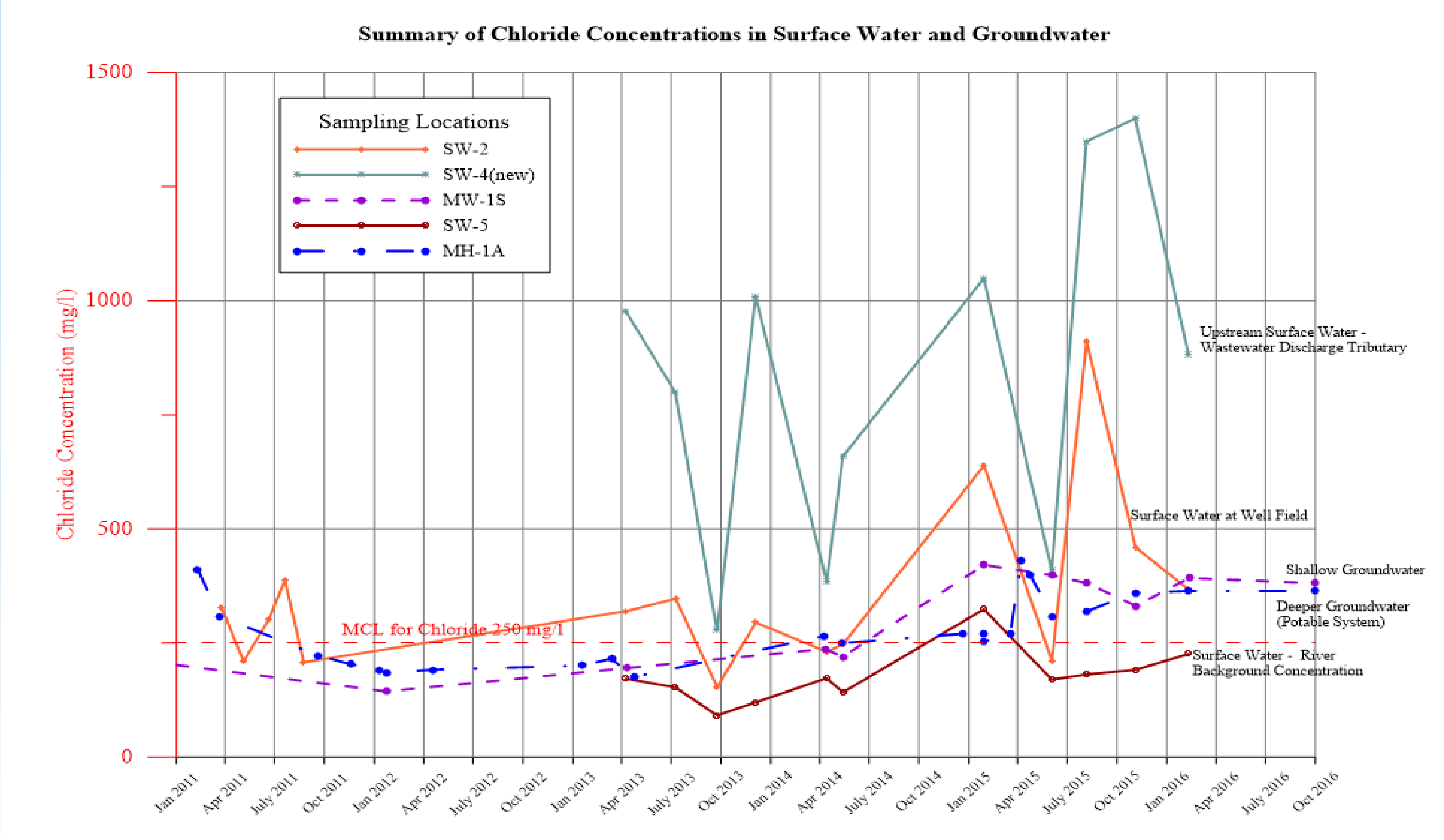
- nested pairs, targeted screened intervals, new locations that target source areas

Surface-water sampling

Conductivity/TDS Monitoring

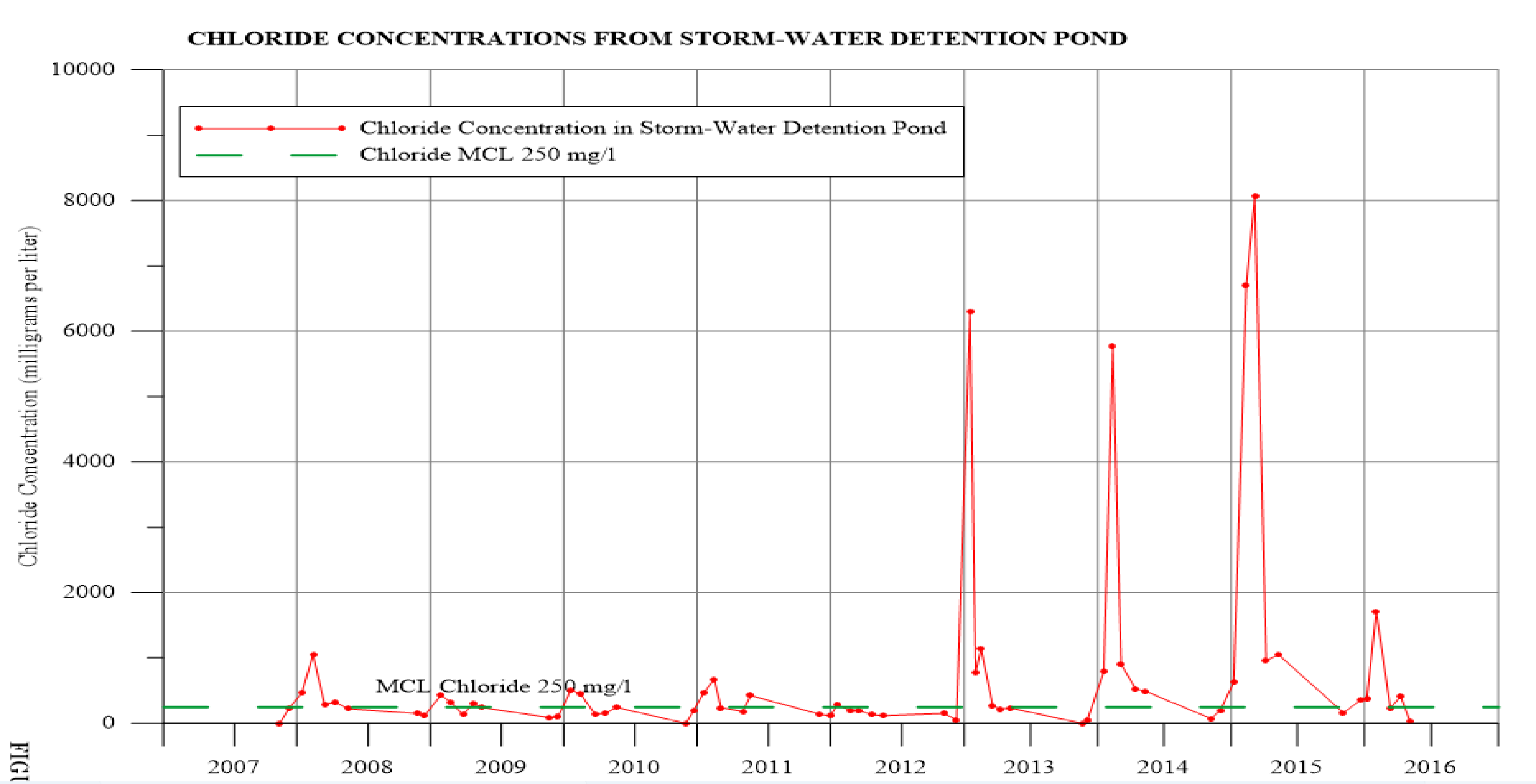
- general chloride concentrations can be monitored without having to analyze water samples

Example from a Surface-Water and Groundwater Monitoring Program

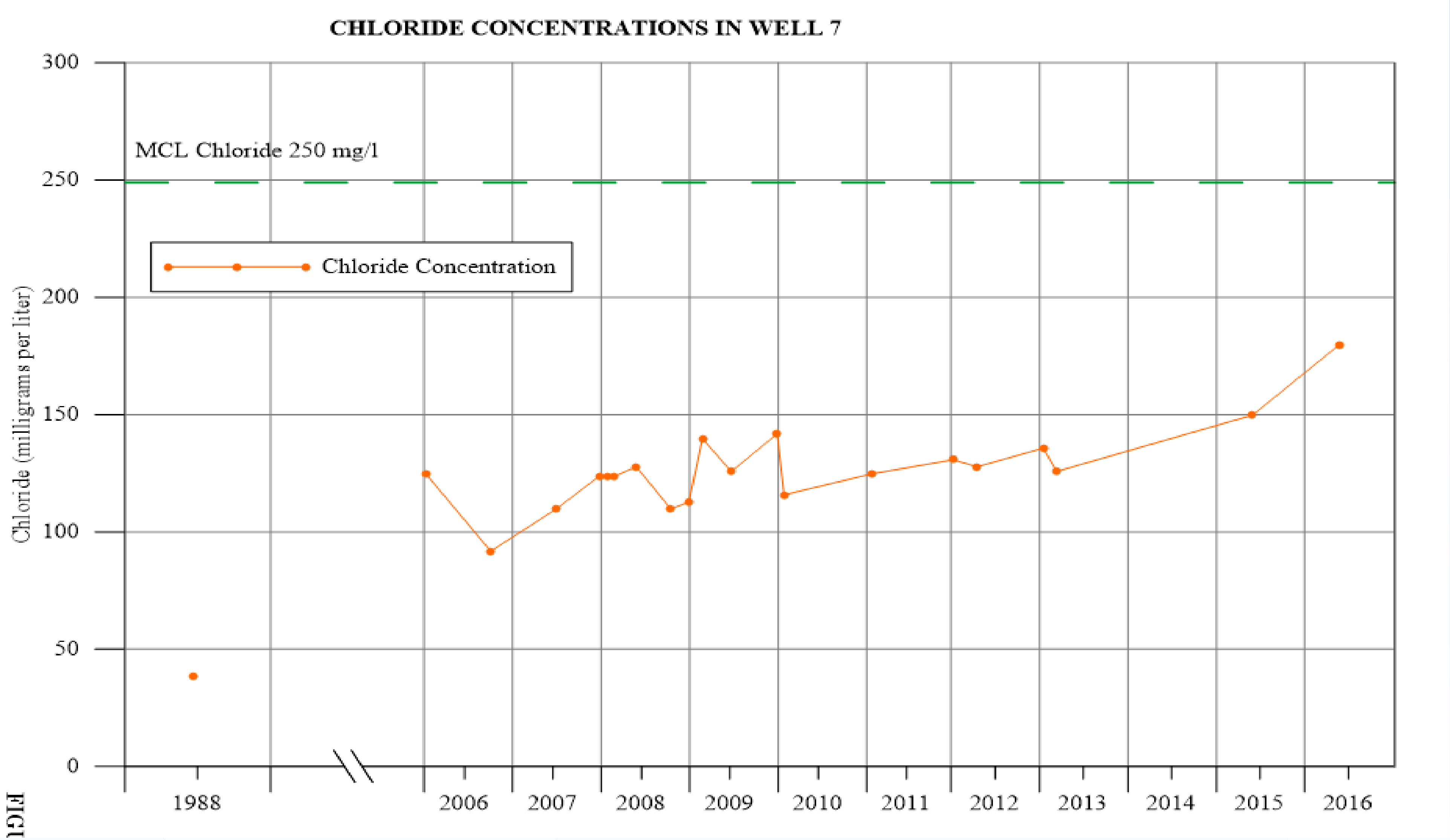


If your answer before was NO, my well field has no problem

New Shopping Plaza 300 feet from production well agreed to use a 4:1 sand/salt ratio application to parking areas and no salt storage onsite



Chloride Concentration in Nearby Production Well



WSP Project Summary

- Surface-water monitoring program was implemented as part of the approval to construct a new shopping center near an existing well field.
- Surface-water runoff from the parking lot is directed to a detention basin near an existing bedrock supply well.
- Surface-water samples for Na and Cl are collected monthly from November through May from the detention basin.
- Annual samples for Na and Cl are collected from the bedrock production well.
- Initially, parking lot snow removal contractors were adhering to requested conditions, 4:1 sand to salt ratio, salt can only be stored onsite in a covered structure and stored salt cannot be in direct contact with the ground.
- Graph of surface-water annual peaks in Cl concentration have increased as application and storage procedures became lax.
- Slow but steady rise in bedrock groundwater chloride concentration.

Management

Management

- Engineering controls
- Removal of unnecessary, leaky, or uncovered sources (salt storage)
- Manage or reduce application – BMPs
- Anti-icing (pre) versus Deicing
- Assess well construction
- Don’t stockpile plowed snow in well capture zone or dispose of it in surface water near well fields

http://voices.washingtonpost.com/capitalweathergang/images/homedepot_web.jpg

Engineering Controls

- Redirecting storm-water runoff
- Changing catch basin locations
- Change storm-water discharge location
- Paving and curbing (to prevent recharge of salt laden water in sensitive recharge areas)

Best Management Practice

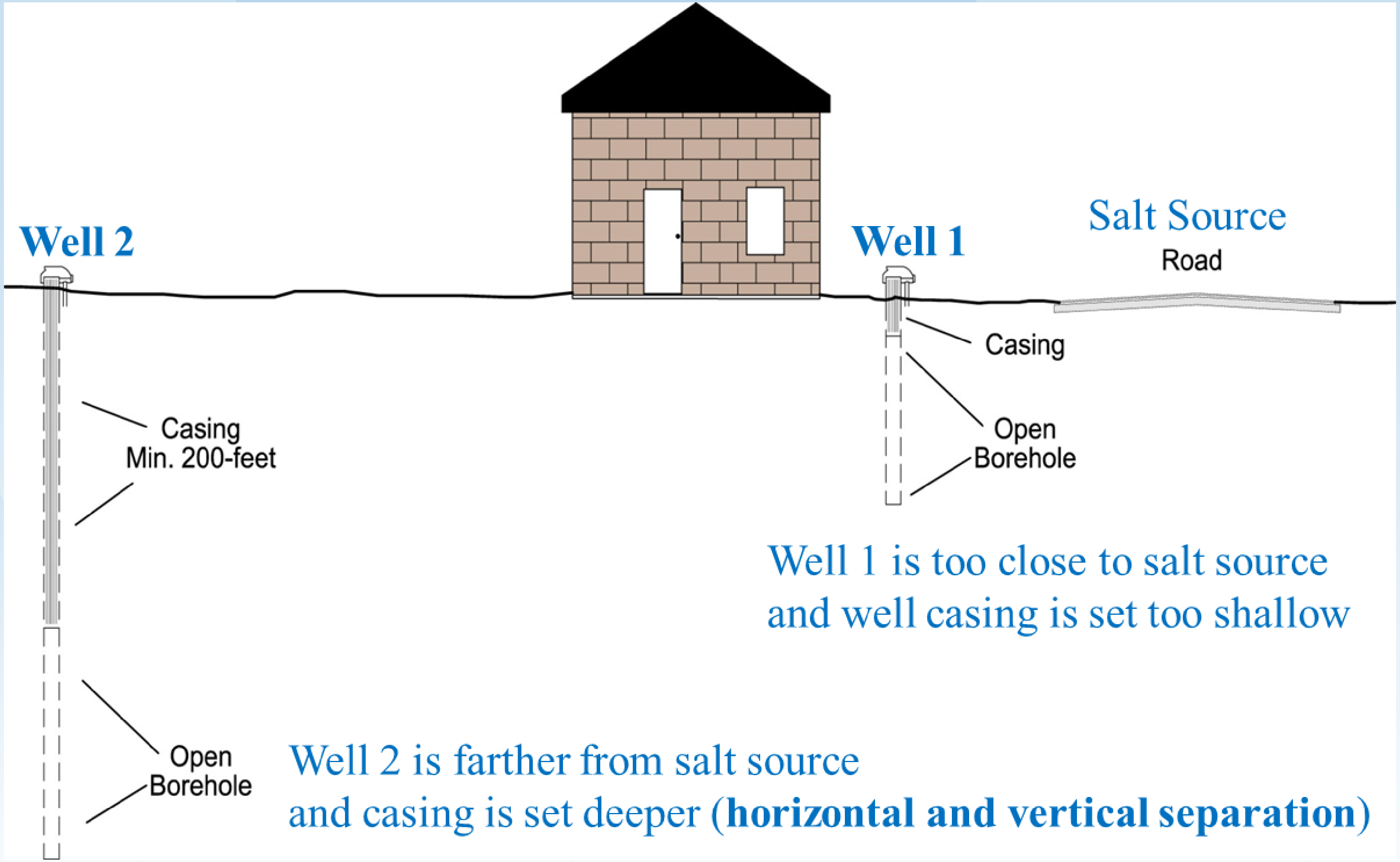
- "Best Management Practice" can reduce the negative environmental impacts of road salt without compromising public safety
- Many states and municipalities have adopted best management practices

During storage, road salt should be covered to prevent salt from lumping together or being lost with storm water runoff

Anti-Icing Versus Deicing

- Preventing snow and ice accumulation (anti-icing) is cheaper and more effective than removing snow and ice after (deicing)
  - This practice of pre-application has been adopted in CT (for the most part)
- It can take up to 4 times more chemicals to remove ice than to prevent it

Problematic Well Construction



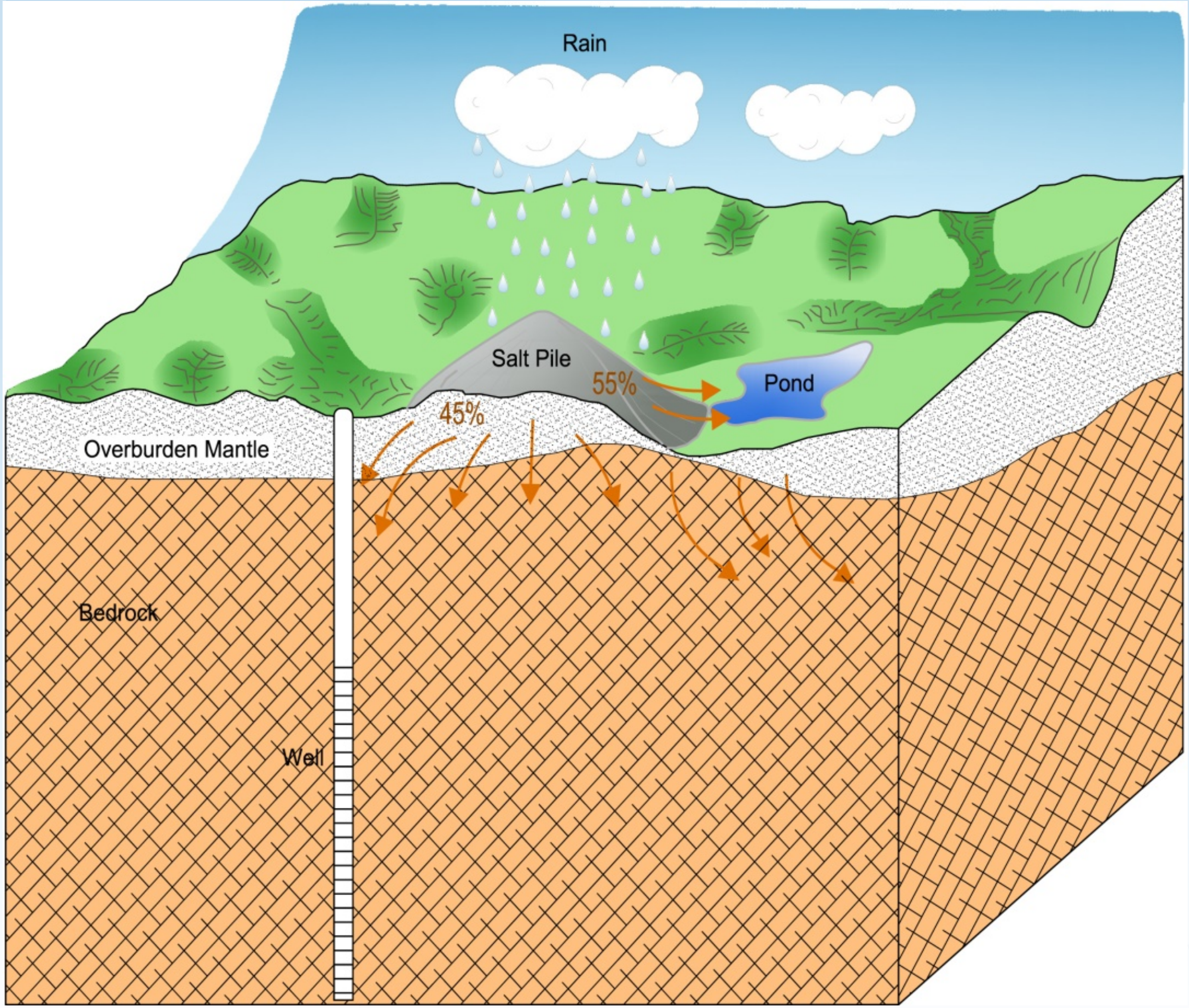
Not to scale

Mitigation

Mitigation

- Eliminate the source of chloride
- Modify storm-water infiltration system
- Remove contaminated soil
- Install extraction wells
- Treatment:
  - Reverse osmosis
  - Mixing/dilution

Eliminate Source

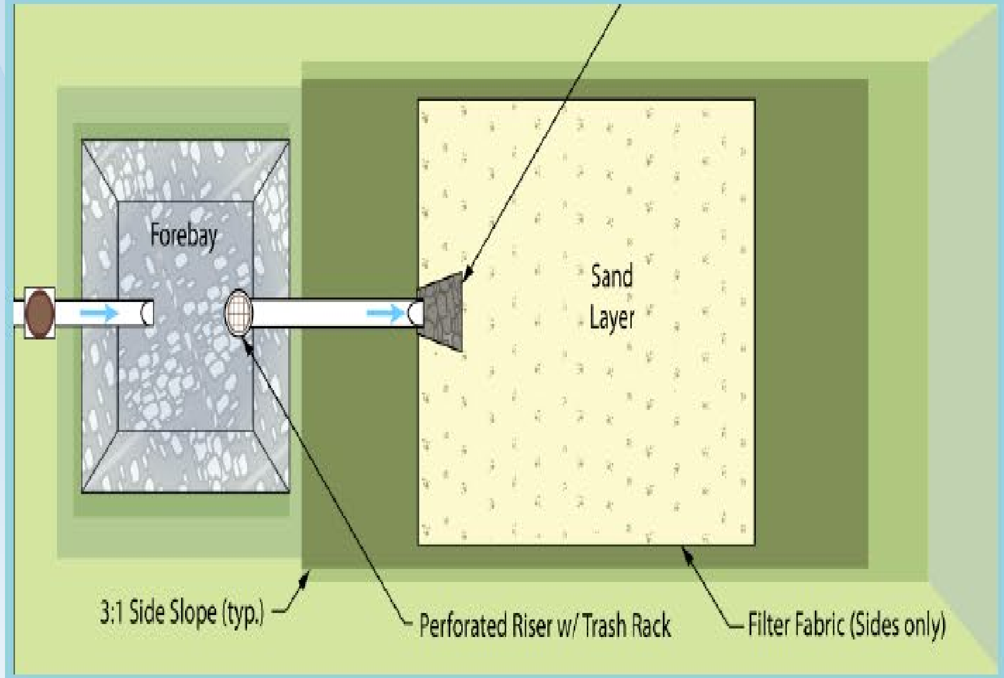


Alternative Deicers

Most popular alternative deicers are other chloride salts

- Calcium chloride and magnesium chloride melt snow and ice quickly, but are far more expensive.
- Urea can melt snow but adds nutrients to surface water and hastens oxygen depletion in the water.
- Calcium magnesium acetate (CMA) can also cause oxygen depletion in surface water, CMA and some other liquid deicers can be more toxic to fish than regular salt brine.
- Beet Juice can be mixed with salt to reduce the amount of chloride used, but it’s expensive and messy.

Rethinking Stormwater Infiltration

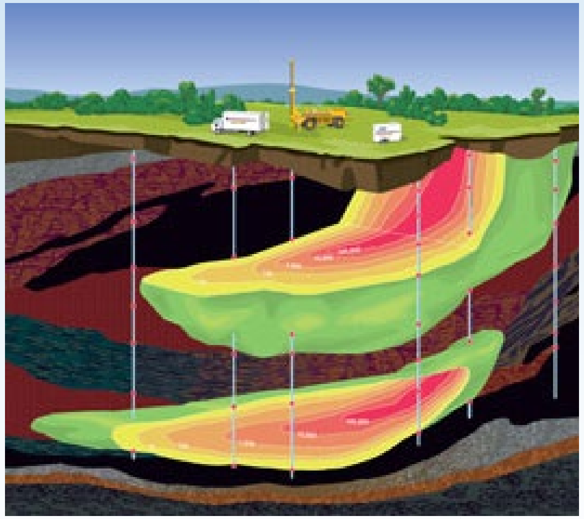


http://www.njstormwater.org/bmp_manual/NJ_SWBMP_9.5.pdf

- Putting Storm Water in the Ground is Good
- Putting Road Salt in the Ground is Bad
- We need to Rethink How We Recharge Storm Water
- One Suggestion: Sequester Run Off in Detention Basins
- Low Conductivity Water Goes to Infiltration Basin
- High Conductivity (Salty) Water Gets Slowly Released to Surface Water

Identify Hot Spots and Salt Sinks

http://www.bearenviro.com/images/geoprobe-6620DT.jpg


http://www.stone-env.com/images/prostratigraphy.jpg

- Inventory Salt Sources and Sinks in Capture Zone
  - *Geoprobe Grab Water Samples*
  - *Vertical Water Profiling*
  - *Monitoring Wells for Long-Term Monitoring*
  - *Soil Samples in Storm Water Ponds and Drainage Swales*
- Dig Up Contaminated Soils
- Pump Out "Hot Plumes"
- Stormwater Management – Dilution/Mounting
- Use Scavenger Wells as Appropriate

Treatment Options

- Blending with low salt water
  - Requires suitable water source and piping to blending point
- Reverse osmosis
  - High energy requirements
  - Brine disposal issues
  - High cost

To be avoided if at all possible

Summary

- Road salt has been recognized as a problem since the late 1960’s.
- Decades of study and reduction programs have not worked.
- Road-salt use is rising despite management efforts and efforts to find alternative deicers.
- Historic/cumulative use has resulted in concentrations reaching harmful levels in surface water and groundwater.
- Groundwater systems have long storage times so we will be dealing with these impacts for years to come.
- Although road salt is often considered the least expensive deicing alternative for road treatment, the true cost includes environmental effects, water-quality impact, and infrastructure damage and the mitigation implemented to correct these effects.
- These costs may make the use of alternative deicers more attractive.
- Best to understand the current state of your groundwater quality to address existing concerns and head off situations that could arise.

Presentation Reference Material Citations

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- WSP Project Files

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Thank You

Questions & Answers