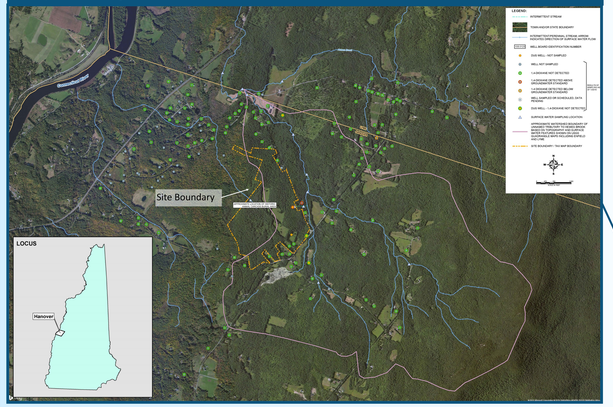
Investigation and Remediation of Groundwater Contaminated with 1,4-Dioxane
Former Medical Waste Disposal Area, Hanover, New Hampshire

GEOTECHNICAL | ENVIRONMENTAL | ECOLOGICAL | WATER | CONSTRUCTION MANAGEMENT

Proactive By Design.
Our Company Commitment

Locus/Site Vicinity Plan

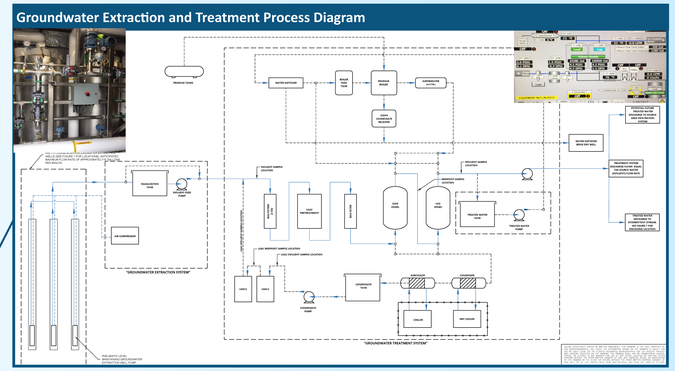


Former Animal Carcass Burial Area

2011 Animal Carcass Removal

Removed
- 10 tons of animal carcasses and soil
- 26 tons of radiological soils
- 4 tons of laboratory waste
- 100 tons of chemically contaminated soil (not anticipated)

Groundwater Extraction and Treatment Process Diagram

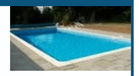


Water Supply Sampling

Sampled
- >140 individual wells
- >400 samples
- 1 municipal reservoir
- 7 surface water locations
- 1 swimming pool

Results
- 1 well with1,4-dioxane detected related to site (3 - 10 µg/L)
- 1 well with1,4-dioxane detected not related to site (up to 0.48 µg/L)

Action
- 2 homes supplied with POEs (1 determined to not be site related)



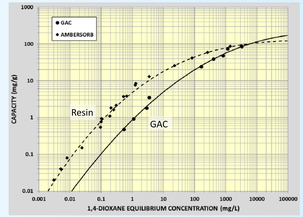
Remedial System Design/Construction/Results

Constraints
- Dissolved source
- Glacial till/fractured bedrock
- Remote location
- Single-phase electrical service
- Accelerated schedule to limit liability (winter construction)
- Public trust

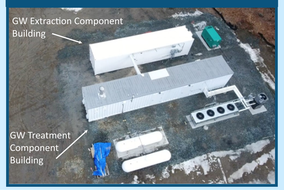
Remedial Alternatives Considered
- In-situ AOP
- Ex-situ
  - GAC
  - AOP
  - Resin

Remedial Alternative Selected
- Resin/GAC

Results
- Capture of source area and on-site plume
- Average 40 % reduction in 1,4-dioxane concentration after 8 months of full operation
- Treatment system meeting 0.25 µg/L effluent limit under EPA Region One RGP



Remedial System Layout



Background—Rennie Farm Site

Setting
- 224-acre undeveloped rural property (Rennie Farm)
- Acquired by Dartmouth College during 1960s
- Local topographic relief 130 – 150 feet
- Depth to bedrock <10 – >100 feet
- Overburden – glacial till
- Bedrock – fractured metamorphic

Site Use
- Agricultural use prior to 1960s
- <0.5 acres used as medical school waste disposal area 1966 – 1978
- Medical school disposed of animal carcasses – radioisotopes
- Approved disposal method – permitted through NHBRH

Investigation and Remediation Timeline

- **2003 - 2011** - Research and investigation
- **2009** - Monitoring wells GZ-1 - GZ-4 installed, groundwater monitoring begins
- **2011** - Excavation of animal carcasses (chemical waste encountered)
- **2012 (April)** - 1,4-dioxane detected in well GZ-2
- **2012 - 2013** - Monitoring of wells continues (1,4-dioxane at low concentrations attenuating)
- **2013** - Radiological Site Closure
- **2014** - Phased site investigation to confirm limits of transport above 3 µg/L
- **2015 (August)** - 1,4-dioxane detected (520 µg/L) in sample from well 300 feet from site boundary
- **2015 (August–September)** - off-site water supply wells sampled
- **2015 (September)** - 1,4-dioxane detected in private water supply well (9 Rennie Road), POE and bottled water provided
- **2015 - 2016** - Source area and off-site investigation and remedial planning
- **2016 (June)** - Limited residual animal carcasses identified
- **2016 (August)** - Residual animal carcasses removed
- **2016 - 2017** - Remedial system construction
- **2017 (February/May)** - Remedial system startup
- **2017** - Present remedial system operation and water quality monitoring

Site COC 1,4-Dioxane

Only contaminant of concern at site; VOC; emerging contaminant

Properties
- Miscible
- Limited tendency to attach to soil (organic C partition coefficient 1.23 log Koc)
- Limited tendency to biodegrade
- Low volatility (Henry's Law Constant 4.80 X 10^{-6} atm-m^3/mol)

Properties allow rapid transport with little retardation or transformation

Subsurface attenuation principally due to hydrodynamic dispersion

Health

Reasonably anticipated to be a human carcinogen; EPA cancer risk estimates, based on studies of liver cancer in mice
- 0.35 µg/L results in 1 excess cancer death in 1,000,000
- Assumes a 154-pound man drinking 2 liters of water per day for 70 years

No MCL (EPA health based guidance level 0.35 µg/L [ingestion])

NH AGQS = 3 µg/L (ingestion) (0.3 µg/L [MA]; 3 µg/L[CT]; 20 µg/L [VT])

Future NH AGQS 0.32 µg/L

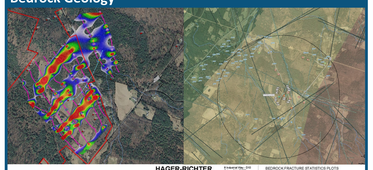
Sources
- Solvents (used as a stabilizer; 1,1,1-TCA)
- Radiological laboratory use (scintillation fluid) **Site (Rennie Farm)**
- Personal care products, paints, and many more…

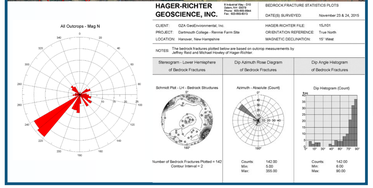
Site Investigation

Methods
- Geologic mapping
- Surficial and borehole geophysics (ERI, VLF, GPR, OTV, ATV, HPFM, caliper, temperature, and conductivity)
- Soil sampling (borings and excavations)
- Bedrock and overburden monitoring well installation
- Groundwater and surface water sampling
- Hydraulic testing

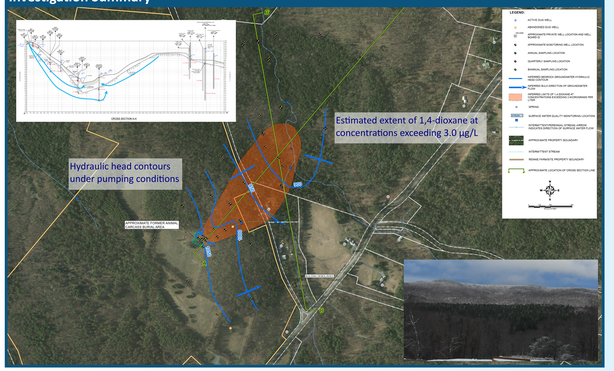
Quantities/Conditions
- 91 monitoring wells
- 49 soil borings and excavations
- 12 surface water sampling stations
- 12 Groundwater extraction wells
- >4,430 feet of borings (2,027 feet of rock boring)
- Up to 42 feet (18.5 psi) of head above ground surface

Bedrock Geology





Investigation Summary



Challenges/Lessons Learned/Solutions

Challenges
- **Technical** - 1,4-dioxane properties limits remedial alternatives
- **Unrelated Sources** - Prevalence of 1,4-dioxane in consumer products and manufacturing create low level sources that must be evaluated and communicated
- **Schedule** - Rapid response required due to neighbor concerns
- **Location** - Limited site access in rural location; topography; limited infrastructure
- **Weather** - Winter construction necessary due to aggressive schedule
- **Communication** - Limited public knowledge = fear/anger

Lessons Learned/Solutions
- **Rapid response is best** - Concurrent investigation and remediation
- **Frequent communication is essential**
  - Formal public meetings
  - Informal drop-in meetings
  - System tours
  - Dartmouth Rennie Farm website
    - Summaries
    - Periodic updates
    - Document access
  - Email updates
  - Individual communication
- **Low concentration (unrelated) sources must be identified**
  - Swimming pool liner
  - Subsurface disposal system
- **Neighbor Concerns Addressed (Good Neighbor Policy)**
  - Water supply well sampling
  - Bottled water supplied
  - Property value concerns addressed through value assurance plan including purchase of properties
- **Technical**
  - Resin combined with GAC can be an effective combination
  - GAC can be effective for a residential POE when 1,4-dioxane is primary contaminant

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