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Performance Based Evaluation and Design in Wyoming

WSWRA 2016

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Regulatory Information

- Wyoming Solid Waste Rules require landfills to be lined with either a composite liner and leachate collection system or a PBD.
- PBD rules were Codified in 2011 under W.S 35-11-523 & 35-11-524
- Solid Waste Guideline #20, "Fate-and-Transport Modeling for Solid Waste Disposal Facilities"
- Solid Waste Guideline #22 "Performance Based Design Demonstrations." rev. 2013
- Solid Waste Guideline #23 "Site Characterization for Landfill Siting and Design."
- Subtitle D formed the basis for our current regulations

What is a PBD?

- A PBD is a scientific study that demonstrates that a landfill can be protective of groundwater without the need for a composite liner and leachate collection system.
- The demonstration includes:
  - Detailed Site Characterization
  - HELP Modeling to determine potential leachate generation rates
  - Fate-and-Transport Modeling of contaminates and comparing results to the Primary Drinking Water Standard
  - Evaluating other factors such as:
    - Landfill gas
    - Waste types
    - Operational Practices and Design

Site Characterization

- Starts with the Development of a List of Action Items. What are the site issues?
  - Planning with the Owner, Consultant, and the WDEQ
  - Important to get stakeholder "buy-in" to the critical elements of the project
- Site Characterization Work Plan will likely include:
  - Methods to investigate and resolve any existing groundwater issues

Site Characterization Cont.

- Collection of site specific geology and hydrogeology information
  - Minimum of 1 boring per 5 acres
    - Continuous sampling & coring to the water table
    - Detailed geologic logs with particular attention to fracturing and indications of water movement through the formation (secondary mineralization)
    - Geotechnical and Chemical data (Multiple data from similar rock/soil from varying depths)
      - Sieves, Atterbergs, Hydrometers
      - Saturated hydraulic conductivity (Flexible wall)
      - Field Capacity
      - Density
      - Porosity
      - Ph
      - Iron & Aluminum concentrations
      - TOC concentration

Site Characterization Cont.

- Groundwater
  - Install Monitoring Well Network
  - Baseline Data Collection
  - Aquifer Hydraulic conductivity, thickness, gradient and velocity
  - Site Hydrogeology and Geochemistry
- Report
  - Detailed findings of vadose zone and saturated zone
  - Boring logs, wells schematics, geotechnical and lab data
  - Geologic Cross Sections
  - Water table map, flow direction, velocity
- WDEQ involvement throughout

Leachate Generation

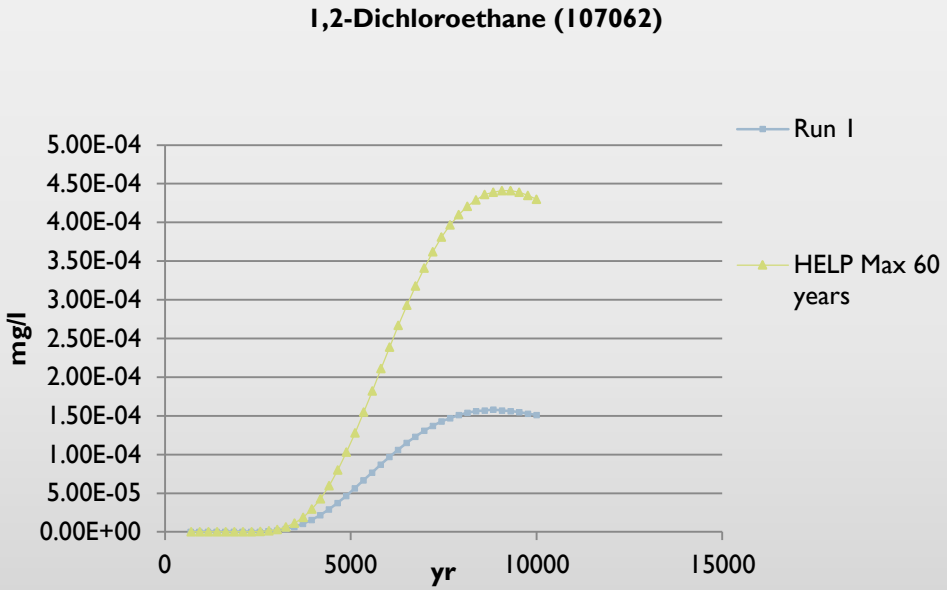
- HELP Model:
  - Varying scenarios
    - 6-inch daily cover over refuse
    - 18-inches over refuse
    - Multiple layers based on the landfill design
    - Model with cap
- Leachate generation data from regional facilities
  - Maximum leachate generation (130 gallons/day/acre)
- Leachate generation data from on-site (pan lysimeter)

Fate-and-Transport Modeling

- Model Construction (Input):
  - Geologic layers (thickness and geotechnical/chemical data)
    - Worst-case data and a conservative, yet authentic, approach
  - Characteristics of Leachate
    - Worst-case text book data and concentration data from the WDEQ
    - Regional leachate generation rates and HELP rates
    - Compared relevant parameters to National Primary Drinking Water Standards
  - Size of facility and operations
    - How the landfill will be constructed?
  - Point of Compliance Determination
  - Vary scenarios to test model

Fate-and-Transport Modeling

- Model Output:
  - Scenarios
    - Maximum leachate generation (worst-case)
    - "Authentic" approaches



Other Factors

- Operations
  - Covering refuse with intermediate cover ASAP
  - Design to cap as you go (minimize length of time refuse is exposed).
  - Design slopes so stormwater does not collect on or against refuse.
  - Leachate/stormwater collection

Case Study: Torrington

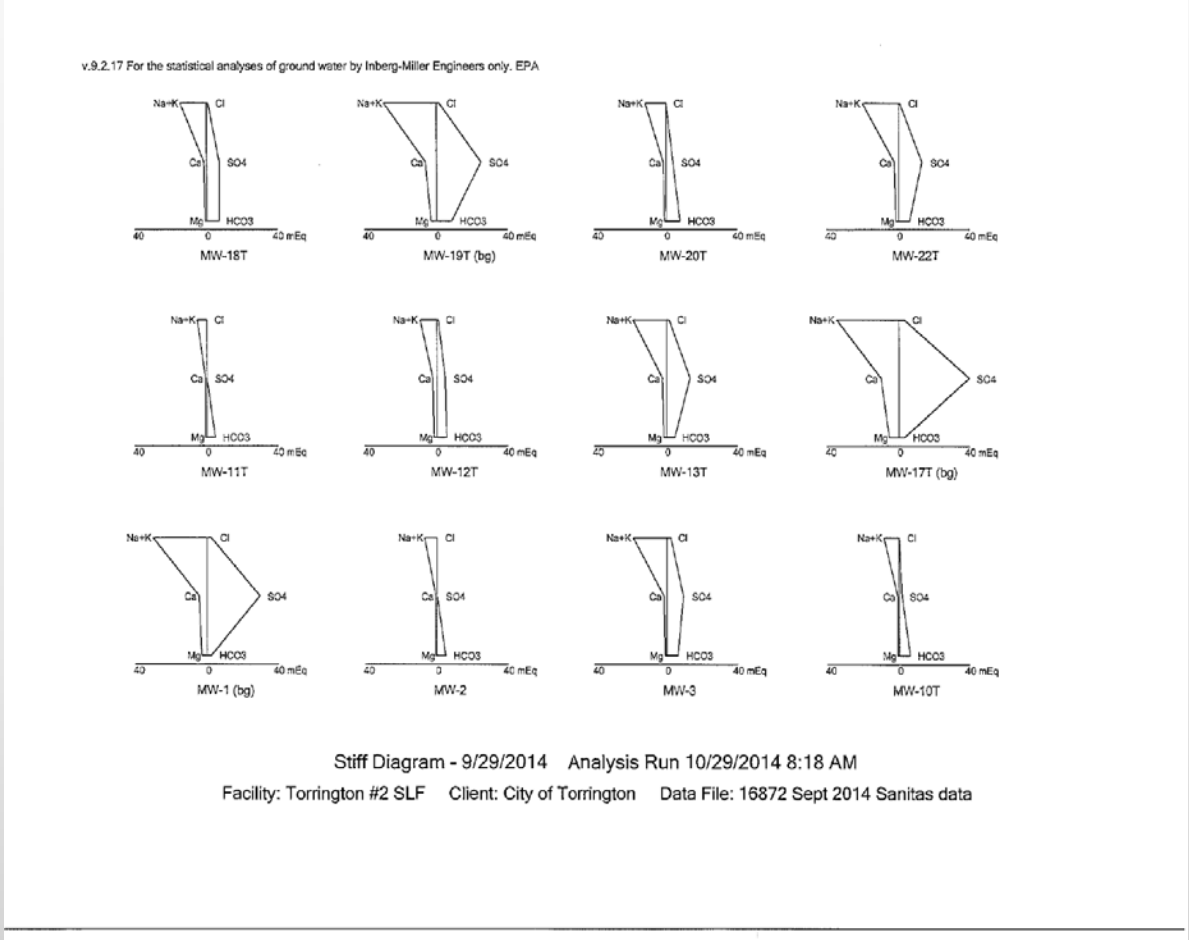
- PBD approved
  - First site to go through the process under the new regulation
- Site Characteristics:
  - 17 acre site upgradient of a 40 acre pre-existing landfill
  - Depth of groundwater below base of refuse 60-100 feet
  - Tertiary White River, Brule Formation. Mostly massive siltstone bedrock (volcanic ash). One vadose layer to model
  - Low permeable substrate, but high field capacity, no fracturing, favorable geology and geotechnical conditions for a PBD
  - Average linear velocity of groundwater is approximately 0.04 ft/year
  - Point of Compliance is established at 150 feet down gradient
  - Lots of groundwater characterization work had to be done

Case Study: Torrington

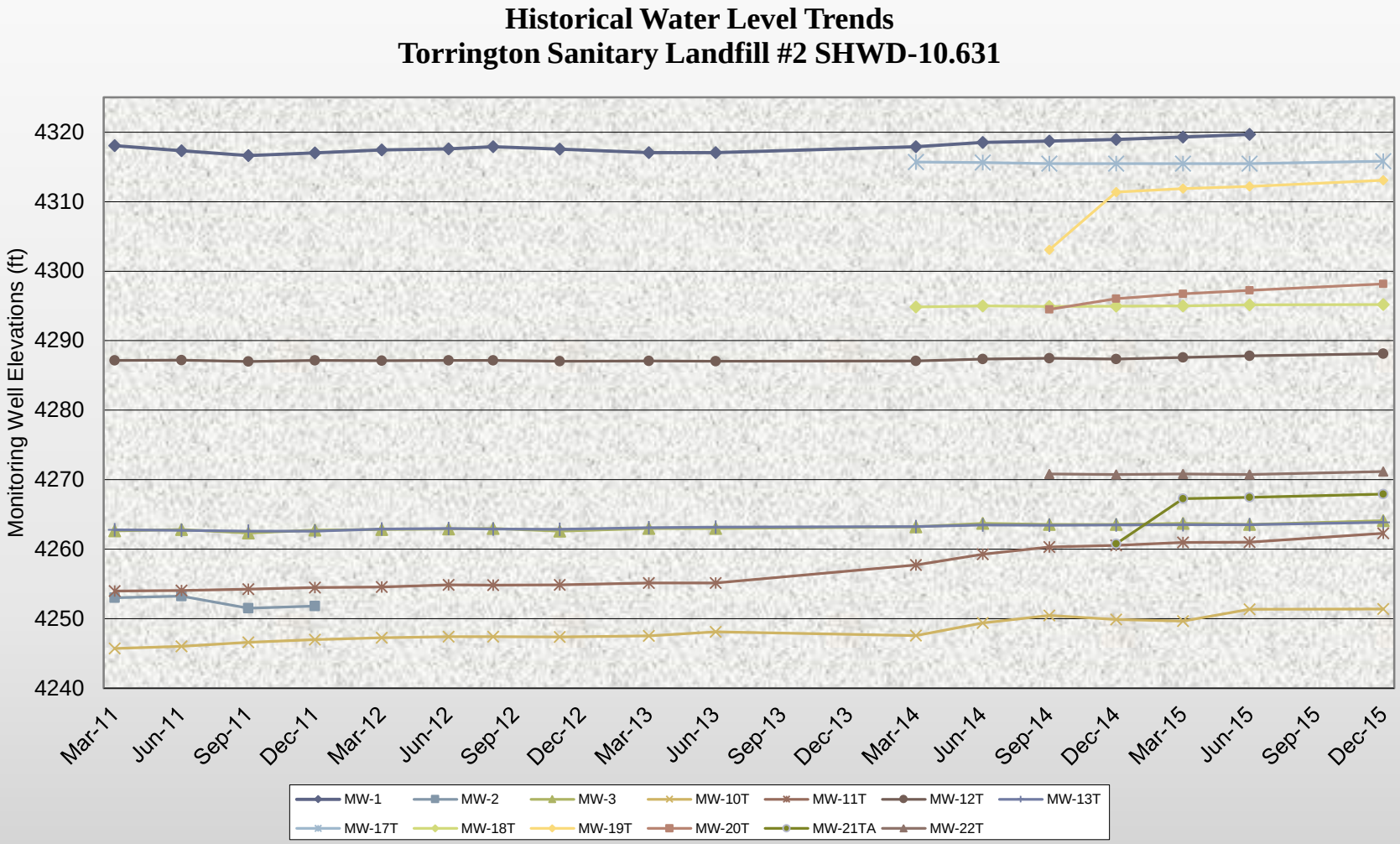
- Leachate Generation
  - Average annual precipitation is 13.8 in/year.
  - HELP indicates that over the 17 acre footprint, on average 6,500 gallons/acre/year of leachate would be produced between years 0-15. Between years 15 and 31, 635 gallons/acre/year would be produced, and between years 32 and 100, 14 gallons/acre/year. Modeled has if the landfill was capped in year 32.
  - 47,450 gallons/acre/year (130 gallons/acre/day) used to test model (Regional data)
- Fate-and-Transport Results
  - Modeling does indicate migration of contaminants with peak concentrations occurring past 3000 years with HELP Model Generation Rates and between 300 and 400 years at 130 gallons/acre/day.
  - In most instances, the resulting concentrations are below levels that are detectable with today's technology, and all are below the MCLs established by the Primary Drinking Water Regulations.

Torrington Groundwater Characterization

- Variations in geochemistry and water table fluctuations between monitoring wells

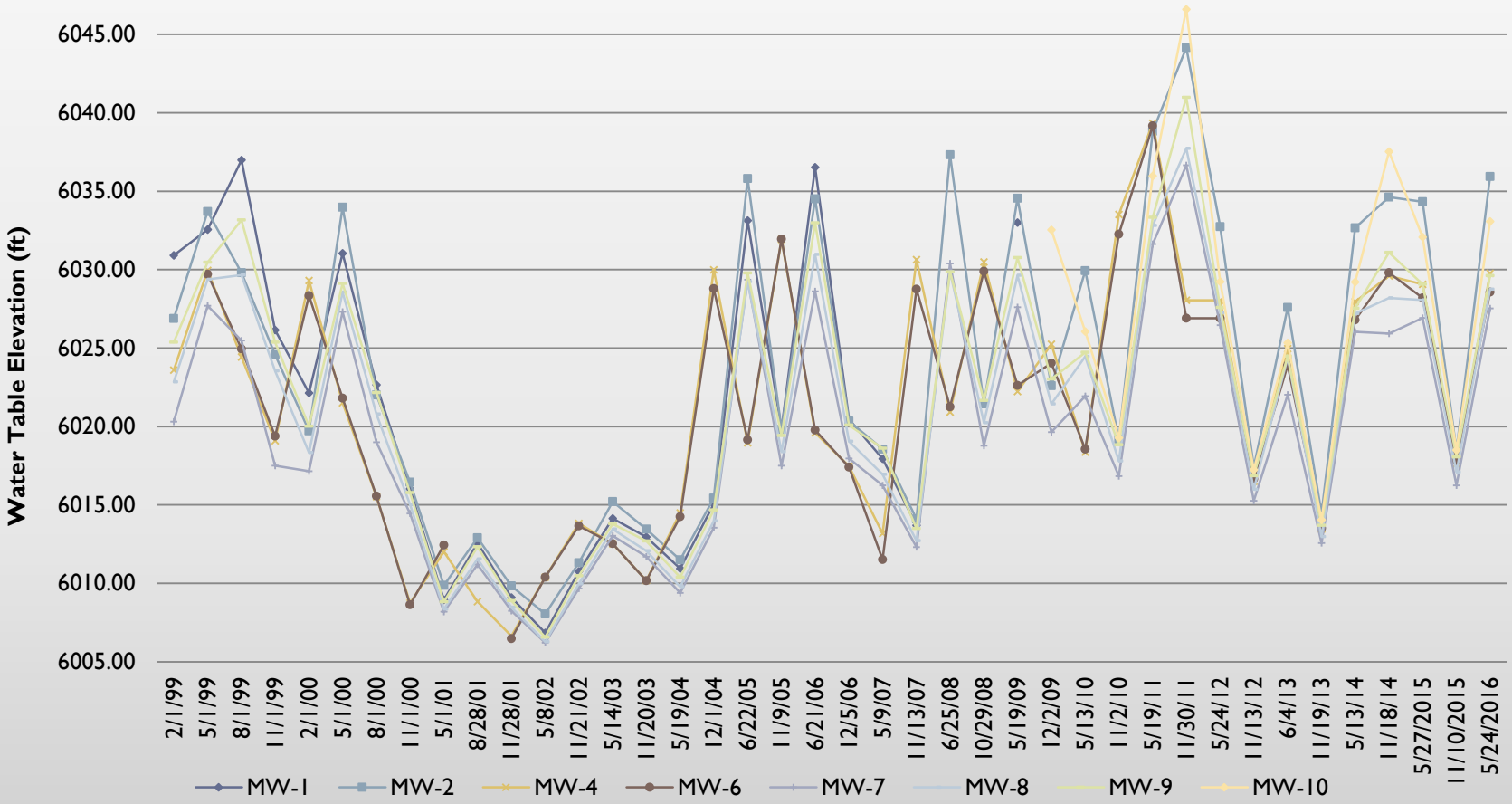


Torrington Groundwater Characterization



Groundwater Characterization

- Seasonality- if your site has seasonal changes in groundwater levels and chemistry it probably not a PBD candidate.



Torrington Groundwater Characterization

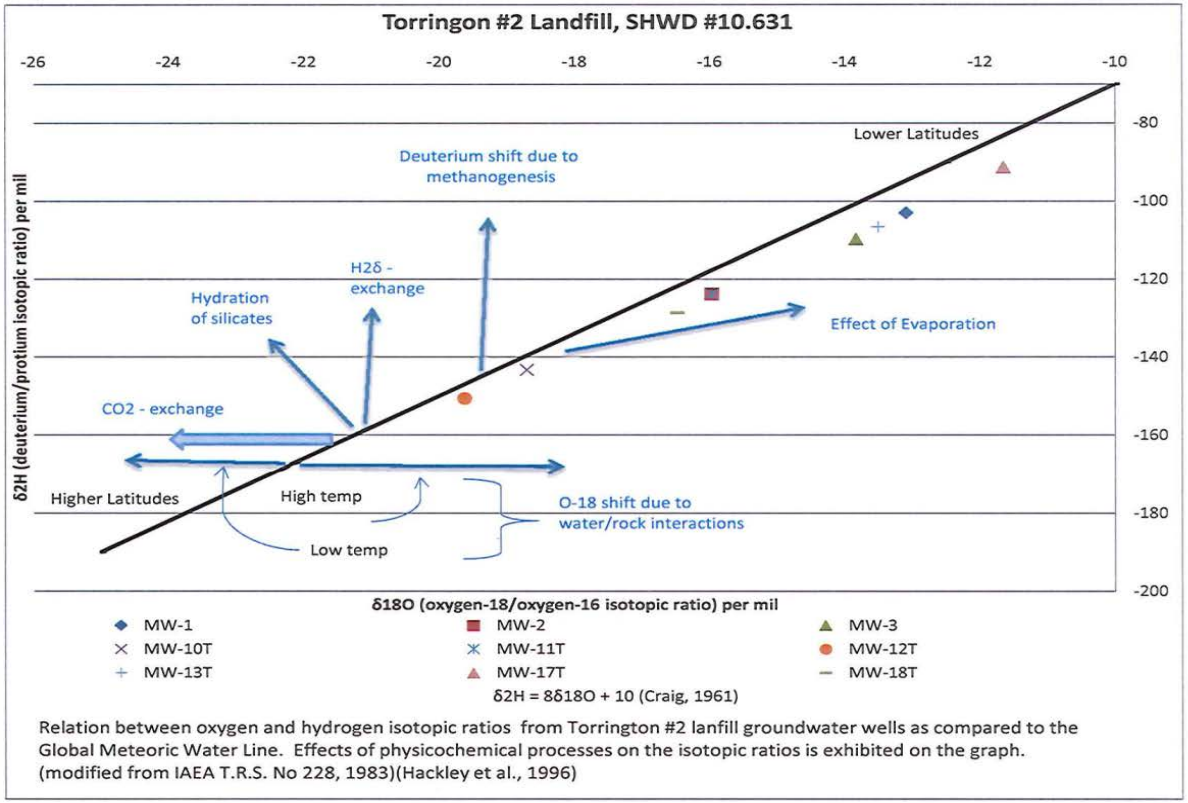
- **Landfill Gas Evaluation**

- *Carbon isotopes*
- Hackley, et.al., 1996, determined that the landfill gases CO_2 and CH4 (and leachate) tend to become enriched in Carbon-13 (^{13}C). While the $^{12}C/^{13}C$ ratios will vary based on a variety of processes within the landfill and the origin of the carbon, the basic concept is if landfill gas or leachate is impacting groundwater at the site, then the ratio should be different than unaffected water. The carbon isotopes were analyzed using dissolved inorganic carbon (DIC). Results were compared across the site and differences evaluated.
- *Results*
- $^{12}C/^{13}C$ of DIC ranged from -16.8 to -5.7 $^{o}/_{oo}$ and are significantly less than published concentrations for impacted groundwater caused by landfill gas.
- Some wells did exhibit an slight increase over background levels indicating a possible influence of CO2 and/or methane.

Torrington Groundwater Characterization

- *Hydrogen and oxygen isotopes*
- Similarly to Carbon-13, Hydrogen-2 (deuterium) also becomes enriched in groundwater due to landfill impacts.
- Plotting the $^{18}O/^{16}O$ ratio and the $^{1}H/^{2}H$ ratios leachate impacted ground water has a unique plot characteristic above the Global Meteoric Water Line.
- $^{18}O/^{16}O$ ratios and the $^{1}H/^{2}H$ ratios at Torrington Landfill fall below the Global Meteoric Water Line (GMWL) and plot similarly to other studies performed on the High Plains Aquifer in Wyoming. No upward deviations occurred in the data that would suggest a potential landfill impact had occurred.

Torrington Groundwater Characterization



Relation between oxygen and hydrogen isotopic ratios from Torrington #2 lanfill groundwater wells as compared to the Global Meteoric Water Line. Effects of physicochemical processes on the isotopic ratios is exhibited on the graph. (modified from IAEA T.R.S. No 228, 1983)(Hackley et al., 1996)

Torrington Groundwater Characterization

- *Hydrogen-3*
- Large mounts of tritium were released to the atmosphere between 1954-1964 during thermonuclear testing.
- Based on a half-life of tritium (12.3 years), groundwater recharged in 1954 that would initially had a tritium concentration of 1000 TU, would have a tritium concentration of 31 TU in 2015.
- Tritium concentrations in the 3 water types at the site were all non-detect (<1TU). These results suggest that the water beneath the landfill is at least pre-bomb. If significant mixing of recent water has occurred, we would have expected some tritium to be present.
- However, small amounts of recent water could have been diluted to a point where it was not detectable through the methods employed.

Torrington Groundwater Characterization

- Determining if the nitrate at the site was naturally occurring or anthropogenic was a significant component of our site characterization work.
- High concentrations in upgradient wells (50-80 mg/l), but the concern was that if nitrate impacted groundwater at an upgradient location, it could happen at the landfill.
- Several landfill monitoring wells had little or no nitrate complicating the problem.
- The Brule Formation was tested at 20 foot intervals to the water table for Total Kjeldahl Nitrogen (organic nitrate and ammonia), ammonium, and nitrate.
  - Results of this testing show TKN concentrations range from 122 to 240 mg/kg in site soil and rock. Ammonia was detected at 2 to 3 mg/kg and nitrate+nitrite ranged from ND to 20.8 mg/kg. While organic nitrogen itself is not readily leachable, it is converted to ammonia (ammonification) and nitrate (nitrification) in nature by bacteria.
  - Four of the six test borings showed lower organic nitrogen concentrations at or near the water table, suggesting the possibility of naturally occurring conversion of organic nitrogen might be occurring, locally, at depth. Both ammonia and nitrate are very soluble and would be leached from soil if contacted by groundwater.
  - The concentrations of organic nitrogen, ammonia, and nitrate+nitrite in the siltstone, combined with the low flow indicates a local, potentially natural source of the high nitrate concentrations found in some of the site monitoring wells.

Torrington Groundwater Characterization

- *Nitrogen Isotopes*
  - $^{15}N/^{14}N$ ratio can be used to determine if the nitrogen is derived from animal waste, organic soil material (natural), or from fertilizer. The highest ratios range from +9 $^{o}/_{oo}$ to +22 $^{o}/_{oo}$ and are typically associated with animal waste. Mid range ratios range from +4 $^{o}/_{oo}$ to +9 $^{o}/_{oo}$ and are associated with organic soil nitrogen (natural occurring). The lowest ratios range from -4$^{o}/_{oo}$ to +2$^{o}/_{oo}$ and are associated with ammonium or nitrate- based fertilizers.
  - Nitrogen isotopes ranged from +3.6 $^{o}/_{oo}$ (MW-1) to +7.1 $^{o}/_{oo}$ (MW-17) and mostly fall within the organic nitrogen source range of +4 $^{o}/_{oo}$ to +9 $^{o}/_{oo}$. Given the organic nitrogen detected in site soil and rock, the results are not surprising and seem logical.
  - The average result of +5.1 $^{o}/_{oo}$ is on the low side of the range and may indicate bacteria-related denitrification of organic nitrogen is occurring.

Case Study-Evanston No.2

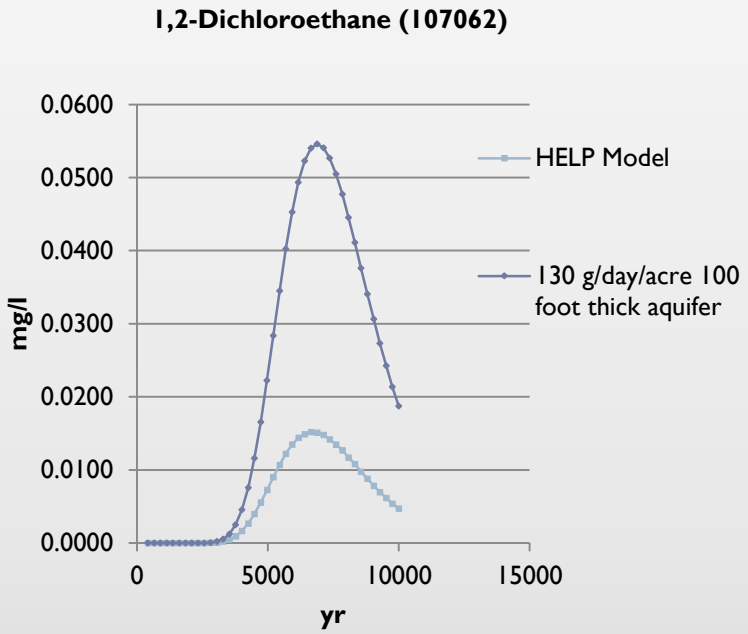
- Originally permitted in 2002 with a "Alternative Design"
- Lifetime permit with a PBD in granted in 2016
- Had to "calibrate" previous modeling based on new procedures
- Site Characteristics:
    - 23 acre site inside a 317 acre parcel
    - Built on previous site characterization work
    - Depth of groundwater below base of refuse 200 feet
    - 6 different vadose zones and a water bearing zone modeled and varied from loose gravel to sandstone and claystone; Quaternary alluvial overburden underlain by Tertiary Wasatch Formation.
    - Permeability varied, mostly low permeable substrate, little fracturing, favorable geotechnical conditions for a PBD
    - Average linear velocity of groundwater is approximately 2 ft/year
    - Point of Compliance is established at 50 feet down gradient, but the landfill boundary was 1600 feet down gradient.

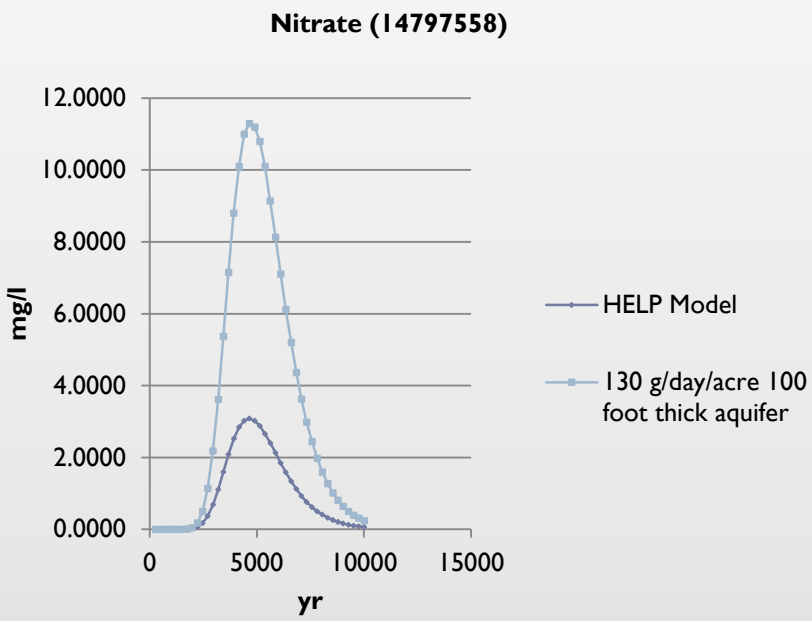
Case Study-Evanston No. 2

- Leachate Generation
  - Average annual precipitation is 12.2 in/year.
  - HELP 40,000 gallons/acre/year at startup to 5,164 to 106 gallons/acre/year during intermediate and final phases (approx. 100 feet of waste)
  - 100 x 100 pan lysimeter installed in 2002 showed 9.5 gallons of leachate during the 1st year and essentially no leachate production since that time. Sump model assumed 44 gallons/acre/year
  - 47,450 gallons/acre/year used to test model (Regional data)
- Fate-and-Transport Results
  - Modeled as if sections would be capped in 10 year intervals.
  - At 47,450 gallons/acre/year that 3 parameters, 1,2 Dichloroethane, methylene chloride, and nitrate would exceed MCLs at 4247 years, 4228 years, and 4163 years, respectively.
  - Modeling using HELP Model leachate production rates indicate that 1,2 Dichloroethane and methylene chloride would exceed MCLs at 4729 years and 4952 years, respectively. Nitrate does not exceed using the HELP Model assumptions.
  - No exceedences at 44 gallons/acre/year

Case Study-Evanston No.2

- (See Cross Section A-A)





Case Study: Worland Landfill

- PBD (in process)
  - Site Characteristics:
    - Depth of groundwater below proposed base of refuse 111 feet
    - Quaternary clayey sand and gravel (9 ft) overlying interbedded sandstone (18ft), siltstone (2ft) and claystone (82) of the Tertiary Willwood Formation.
    - Very low permeable substrate, little fracturing, favorable geologic and geotechnical conditions for a PBD
    - Average linear velocity of groundwater is approximately 2 ft/year
    - Point of Compliance is 60 feet down gradient.
  - HELP Model Results (pending)
    - Average annual precipitation is 7.7 in/year.
  - Fate-and-Transport Results (pending)

Case Study: Worland Landfill

- (See Cross-Section)

Performance Based Evaluation and Design in Wyoming

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