Leveraging Soil Conditions to Close Sites

SAME Southeast JETS

Savannah, Georgia

June
2024

bhate

Agenda

Systematic Development of Multiple Lines of Evidence

- Introduction
- Natural Source
- Geogenic and Pedologic Processes
- Supporting Site-Specific Physical and Geochemical Characteristics
- Case Study

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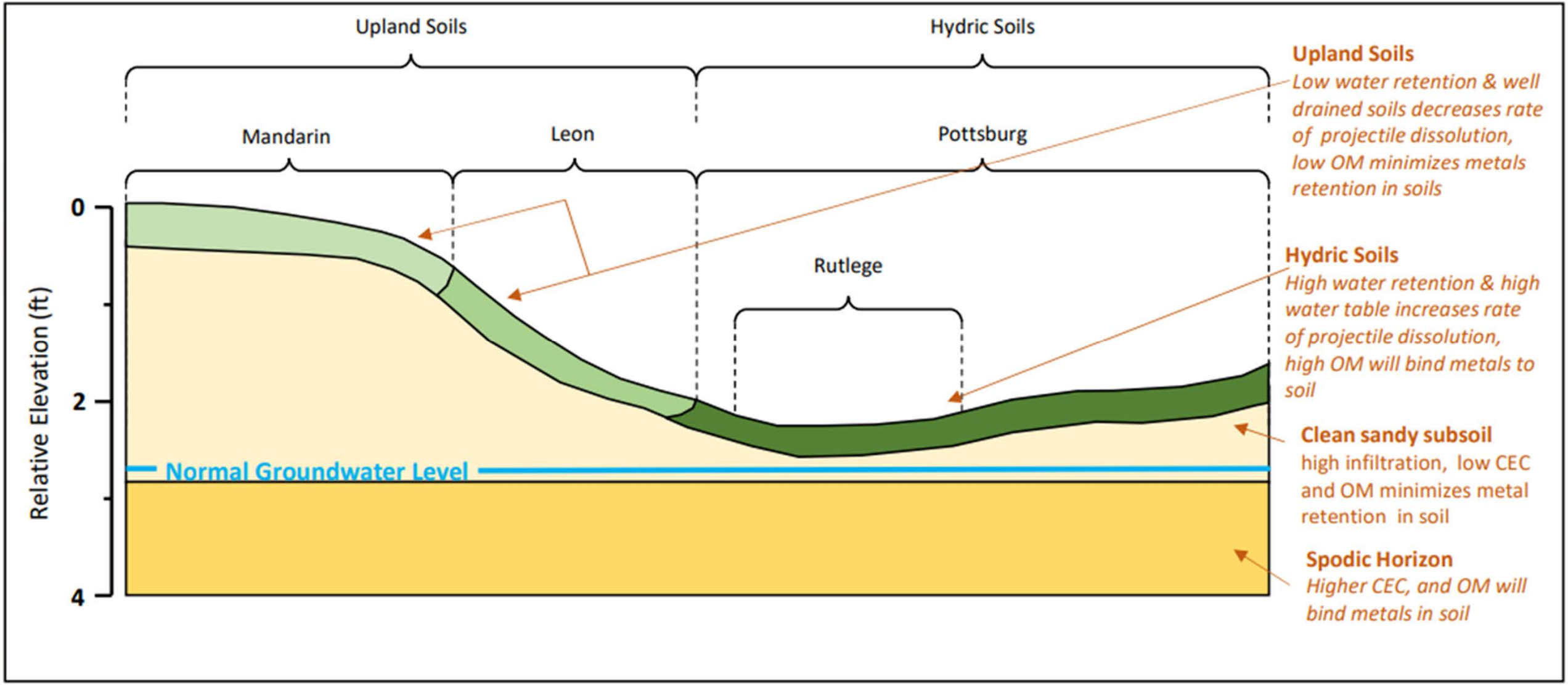
Introduction

- Under a performance based acquisition (PBA) contract, Arcadis identified spodic soil horizons at several Florida sites, presenting lines of evidence that this soil layer led to the elevated presence of iron and manganese.
- Under a follow-on PBA, Bhate continued to use these same lines of evidence to advance sites, coupling the data with the basewide conceptual site model.


Upland Soils
Hydric Soils
Mandarin
Leon
Pottsburg
Rutlege
0
2
4
Relative Elevation (ft)
Normal Groundwater Level
Upland Soils
Low water retention & well drained soils decreases rate of projectile dissolution, low OM minimizes metals retention in soils
Hydric Soils
High water retention & high water table increases rate of projectile dissolution, high OM will bind metals to soil
Clean sandy subsoil
high infiltration, low CEC and OM minimizes metal retention in soil
Spodic Horizon
Higher CEC, and OM will bind metals in soil

What are spodosols?

- Spodosols are characterized by high acidity, and have a subsoil accumulation of organic matter, along with aluminum and iron oxides, called a spodic horizon
- These soils are typically low in natural fertility (basic cations, Ca^{2+}, Mg^{2+}, and K^{+}) and high in soil acidity (H^{+}, Al^{3+})
- Spodosols are typically associated with a cool and wet climate, but also occur in warmer climates such as in Florida

Natural Source

Understand the soil type and behavior of those soils

- Related association with relic spodic horizons that are characterized by elevated organic matter and iron and aluminum sesquioxides
- Common co-precipitation of arsenic with iron and aluminum sesquioxides
- Lack of elevated lead concentrations in groundwater
- Lack of any correlation of arsenic with lead levels in groundwater
- Relationship of arsenic with elevated iron and aluminum in groundwater

Geogenic and Pedologic Processes

Identify how the soil characteristics influence mobility of compounds

- Characteristics that influence mobility include: pH, infiltration rate, iron and aluminum hydroxides, clay content, organic matter content, phosphorus, and sulfide
- Acidic soils are conducive to dissolving the metal oxides
- Organic matter (OM) enhances sorption rates and reduces mobility, countering some of the effects of the low pH and shallow groundwater levels
- Constituent properties including sorption, solubility, precipitation and co-precipitation reactions, and biotic and abiotic degradation also influence mobility

Supporting Site-Specific Physical and Geochemical Characteristics

- Acidic conditions
  - pH at or below 6.0
- Elevated OM
- Elevated iron and aluminum concentrations (comparison of dissolved versus total inorganics)
- Vertical distribution of inorganics in soil

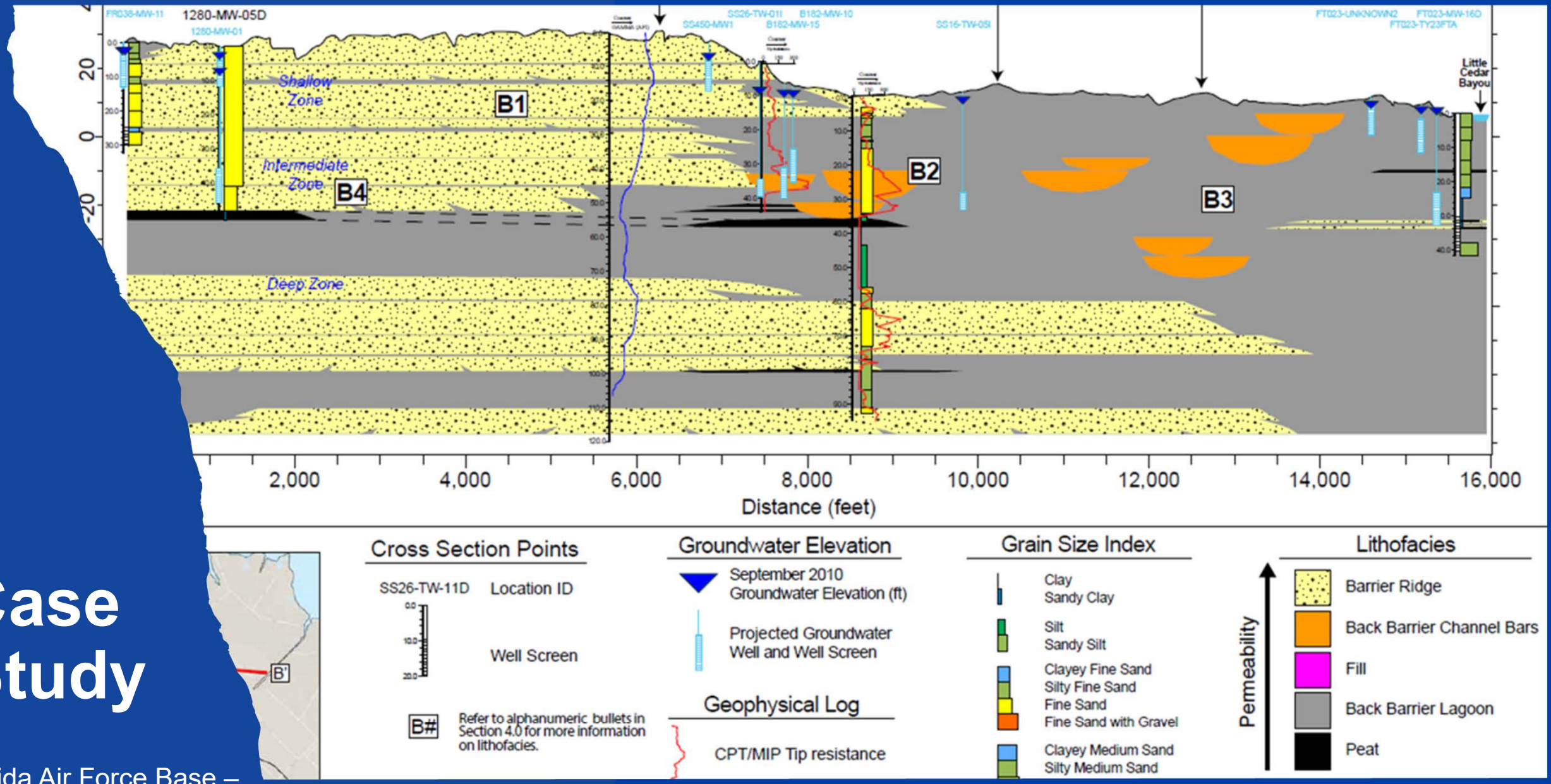
Supporting Site-Specific Physical and Geochemical Characteristics

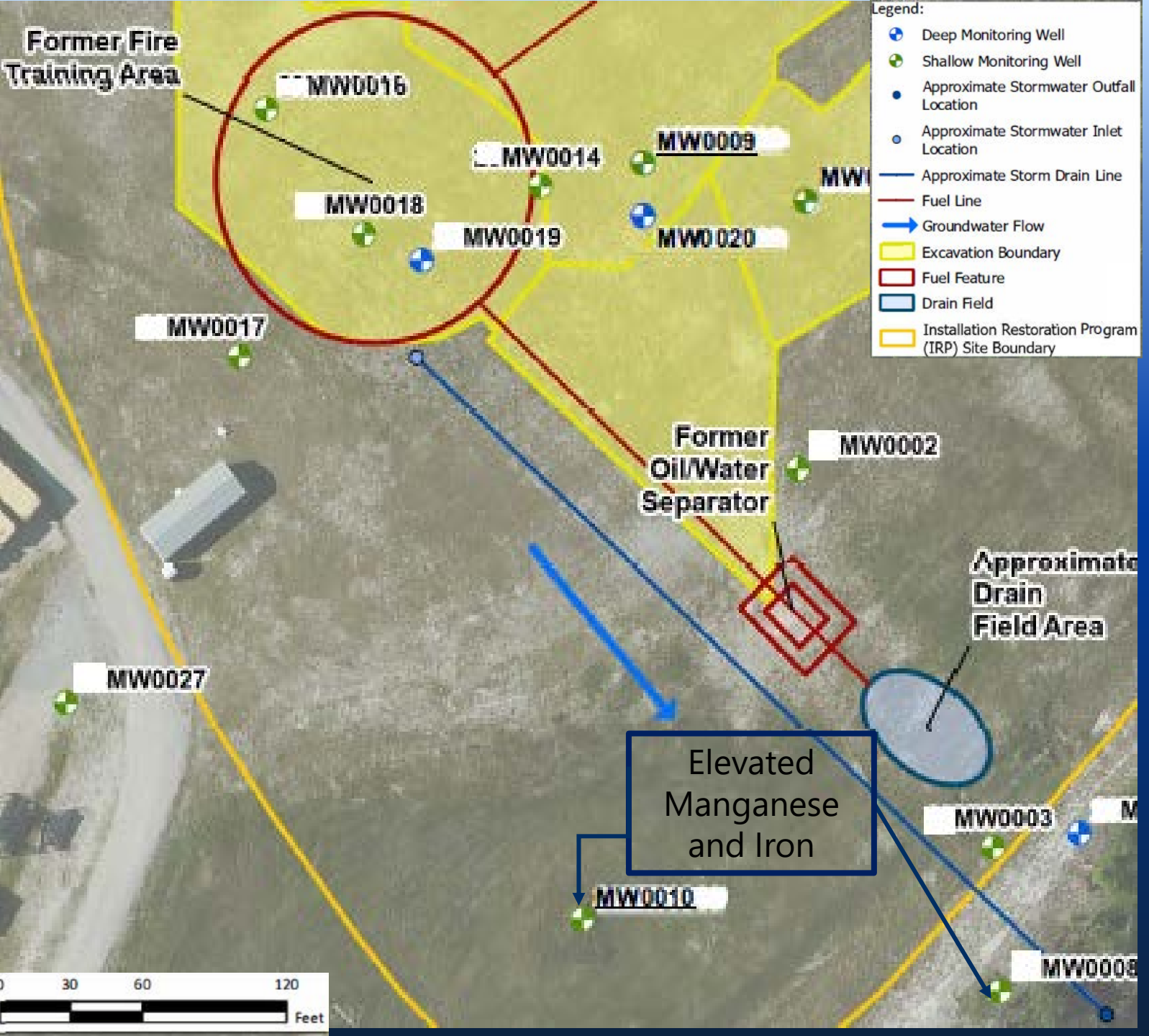
- Fieldwork:
  - Soil borings are evaluated for visual signs of OM indicative of spodic soil
- Laboratory Analysis
  - Soil samples are analyzed for aluminum, arsenic, calcium, iron, magnesium, manganese, potassium, sodium, zinc, phosphorus, cation exchange capacity (CEC), bromide, chloride, fluoride, nitrate, nitrite, sulfate and sulfide
  - Groundwater samples are analyzed for select metals (aluminum, arsenic, iron, lead manganese, and/or vanadium) and dissolved organic carbon (DOC)

Case Study

Florida Air Force Base –

Elevated Iron in Groundwater





Elevated Iron and Manganese

- Previous removal action and Modified Fenton's Reagent treated soil and groundwater contamination, respectively
- Elevated iron and manganese in groundwater located cross-gradient from historical releases

Groundwater Analytical Results

Well Identification	Sample Date	Total Organic Carbon (2016)/ Dissolved Organic Carbon (2022/2023) (µg/L)	Aluminum (µg/L)	Aluminum (Dissolved) (µg/L)	Iron (µg/L)	Iron (Dissolved) (µg/L)
23MW0003	2/16/2016	NA	111 J	NA	880	NA
23MW0008	2/16/2016	NA	403	NA	15,500	NA
	7/28/2022	18,000	331	NA	21,400	NA
	12/20/2022	13,500	183 J	37.1 J	20,900	5,100
23MW0010	2/16/2016	NA	779	NA	33,900	NA
	7/27/2022	30,000	1,160	NA	27,600	NA
	12/20/2022	27,400	854	102 J	38,700	21,000
23MW0033	7/27/2022	3800	1,780 J	NA	2,590	NA
23MW0041	1/24/2023	16,700	780	NA	2,930	NA
23MW0042	12/20/2022	11,000	2,100	NA	4,990	NA

µg/L – micrograms per liter

Spodic Soil Evaluation

Location ID	Sample Depth Interval (feet)	Aluminum	Iron	Manganese	Cation Exchange Capacity
		mg/kg	mg/kg	mg/kg	meq/100g
SB0126	0.00-0.50	3,870	1,210	2.2	10.4 [b]
	0.50-2.00	3,010	1,720	1.4	NA
	2.00-4.00	2,030	449	1	NA
SB0127	0.00-0.50	2,220	1,260	3.2	NA
	0.50-2.00	5,840	1,750	4.7	2.2 [b]
	2.00-4.00	2,040	375	1.2	NA
SB0128	0.00-0.50	1,820	564	4.3	NA
	0.50-2.00	2,560	1,720	1.1	2.7 [b]
	2.00-4.00	4,190	549	1.6	NA
SB0129	0.00-0.50	1,340	515	1.4	3.4 [b]
	0.50-2.00	2,140	1,750	2	NA
	2.00-4.50	1,560	285	1.1	NA
SB0130	0.00-0.50	833	505	1.4	NA
	0.50-2.00	339	243	0.43	1.5 [b]
	2.00-4.00	2,320	489	1.5	NA

b Calculated as: (CEC Na mg/L from flame * Final volume) / (Initial weight * 22.99 * 10). Analysis performed at SGS Scott, LA.

mg/kg – milligrams per kilograms
meq/100g - milliequivalents per 100 grams of soil

Line of Evidence 1: Acidic conditions

- MW0008 was mildly acidic at pH of 5.8
- MW0010 was also mildly acidic at just below pH of 6.0
- MW0033 at pH of 5.4
- Recently installed wells in this area are more neutral
  - MW0042 at pH 6.5
  - MW0043 at pH 6.6
  - MW0044 at pH 6.8

Line of Evidence 2: Elevated Organic Matter in Soil

- Visual – Surficial soils are “very dark grayish brown”, “Clay” and can be white if oxidized
- Higher CEC indicates more OM
  - CEC >1.5 meq/100g is considered elevated OM
  - SB0126 (closest boring to MW0010) – 10.4 meq/100g
  - SB0128 – 2.7 meq/100g
  - SB0130 – 1.5 meq/100g

Line of Evidence 2: Elevated Organic Matter in Groundwater

- DOC is high
  - Median DOC is 0.7 milligrams per liter (mg/L) in groundwater
  - MW0010 – 27.4 mg/L
  - MW0008 – 13.5 mg/L
  - MW0033 – 3.8 mg/L
- Water is in contact with carbon rich environment, resulting in elevated DOC detections
- Turbidity is low, less than 10 nephelometric turbidity units (NTU)

Line of Evidence 3: Elevated Iron and Aluminum Concentrations

- MW0008
  - Total Al – 183 µg/L; dissolved Al – 37.1 µg/L
  - Total Fe – 20,900 µg/L; dissolved Fe – 5,100 µg/L
- MW0010
  - Total Al – 854 µg/L; dissolved Al – 102 µg/L
  - Total Fe – 38,700 µg/L; dissolved Fe – 21,000 µg/L
- Variations are not due to turbidity

Line of Evidence 4: Vertical Distribution of Inorganics in Soil

- At soil borings SB0126 through SB0130 a soil sample was collected at three discreet depths (0 – 0.5 feet bgs, 0.5 – 2.0 feet bgs, and 2.0 – 4.0 feet bgs)
  - Inorganic detections at each soil boring location were generally highest within the 0.5 - 2.0 foot depth interval
  - Inorganic detections in the soil are significantly lower in the 2.0-4.0 foot depth interval

Line of Evidence 5: Basic Ions

- Spodic soils are typically low in cations such as calcium, magnesium, and potassium as well as in anions such as sulfate, chloride, and fluoride
  - Chloride, nitrate, nitrite, sulfide, and sulfate in soil samples were non-detect
  - Calcium ranged from 15.5 mg/kg to 683 mg/kg. The Michigan State University considers low calcium levels in soil to be less than 300 mg/kg. Only one boring had a calcium level above 300 mg/kg.
  - Magnesium levels ranged from 13 mg/kg to 297 mg/kg. The Oregon State University considers low magnesium to be below 60 mg/kg and moderate levels to be between 60 mg/kg and 300 mg/kg.
  - Potassium ranged from not detected in SB0130 to 139 mg/kg in SB0127. The Oregon State University considers low potassium to be under 150 mg/kg.

Limited Area of Spodic Soils Resulting in Elevated Inorganics in Groundwater

- Detected iron concentrations are due to spodic soils
  - Low pH, high CEC and DOC
  - Low turbidity but significant difference in total and dissolved inorganics in groundwater
  - Iron detected at top of saturated zone in observed spodic soils
  - Basic ions support that soil contains very few nutrients which is also typical for spodic soils
  - Known back barrier lagoon area resulting in low oxidation reduction potential and dissolved oxygen in groundwater (reducing conditions)
- Elevated iron concentrations are not the result of a CERCLA release
  - Regulators (EPA and FDEP) agreed, and site achieved unrestricted closure

THANK YOU!

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