Steam Enhanced Extraction (SEE) at the Former Williams AFB ST012

Gorm Heron, Steffen Griepke Nielsen,
Devon Phelan, TerraTherm, Inc.
Stuart Pearson, Amec Foster Wheeler

November 18, 2015

TERRATHERM

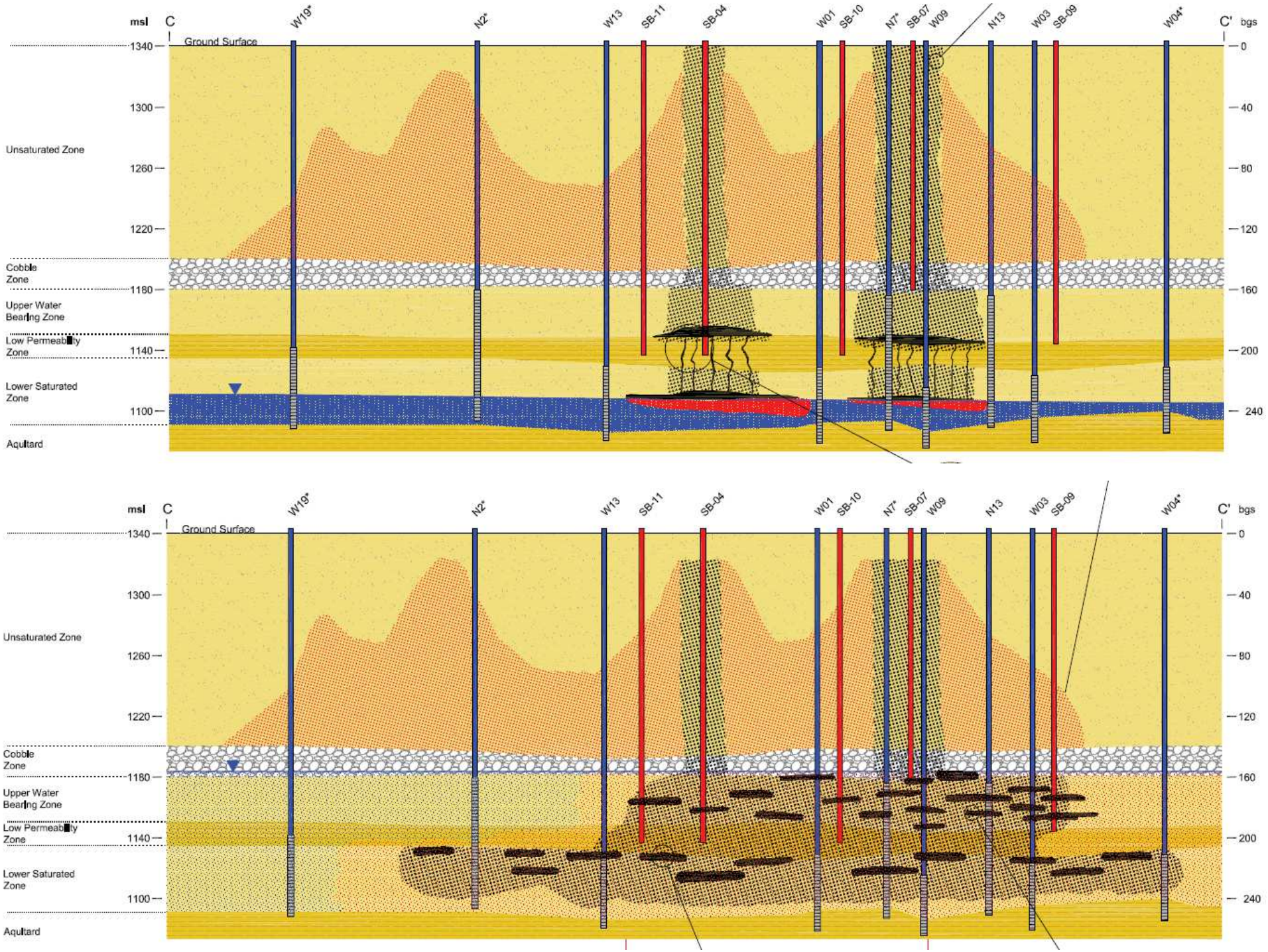
amec foster wheeler

Site Background

- Former Liquid Fuels Storage Facility
- Historic releases of both JP-4 and Avgas
  - Release volume estimate ranges from 84,000 - 11,100,000 gallons
- Contaminants of Concern (COCs):
  - JP-4, Avgas, naphthalene, benzene, toluene, ethylbenzene and xylene
- Amec Foster Wheeler teamed with TerraTherm to select SEE as part of a site-wide groundwater remedy to address LNAPL contamination
- A TEE pilot test was performed at ST012 in 2008-2009 - positive proof of concept for steam injection

TERRATHERM

amec foster wheeler


msl
C
C'
bgs
Ground Surface
W19*
N2*
W13
SB-11
SB-04
W01
SB-10
N7*
SB-07
W09
N13
W03
SB-09
W04*
1340
1300
1260
1220
1180
1140
1100
0
40
80
120
160
200
240
Unsaturated Zone
Cobble Zone
Upper Water Bearing Zone
Low Permeability Zone
Lower Saturated Zone
Aquitard

Video

Combined remedies

1. Thermal (1.5 years)

2. Enhanced Bioremediation (several years)

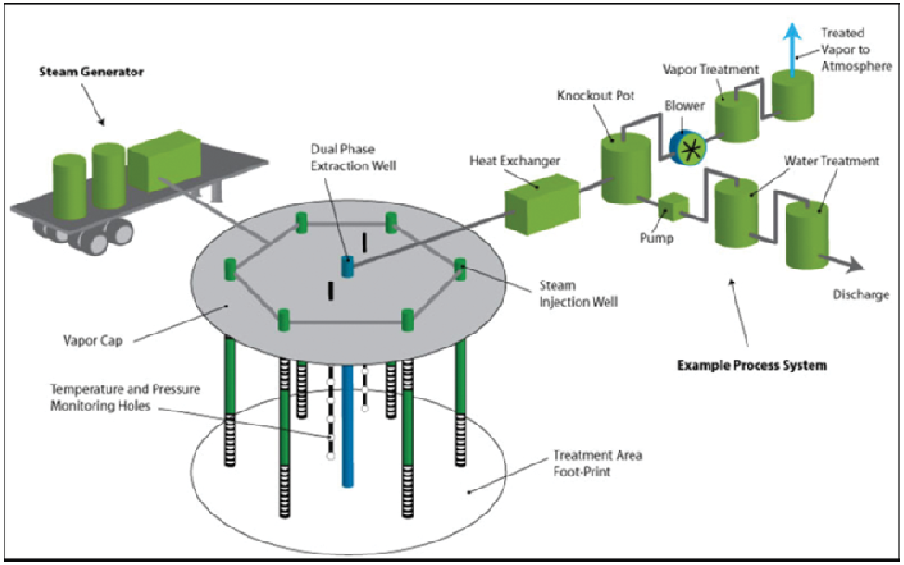
3. MNA (complete by 2033)

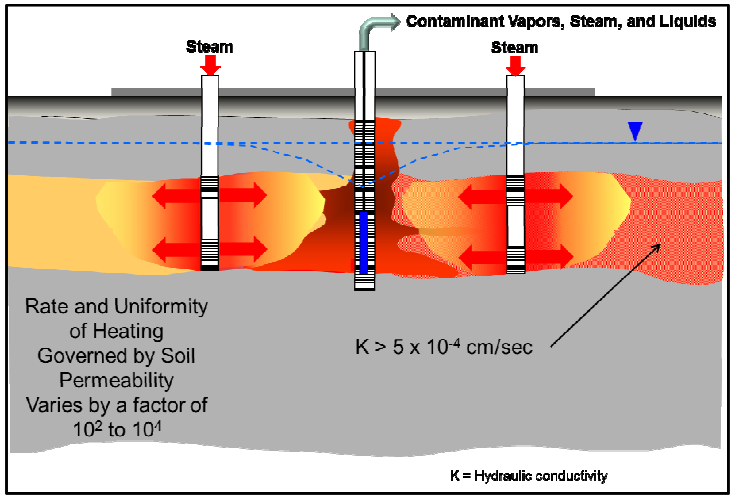
SEE Remedial Objective

Thermally enhance LNAPL recovery of the petroleum hydrocarbons at the Site and to reduce concentrations of benzene in the source area

Technology Background

- **SEE** – injection of steam produced by a steam generator into a network of injection wells and extraction of hot fluids and vapors through a network of MPE wells
- **Steam propagation** is governed by the horizontal and vertical permeability of the soil and is particularly well suited for application in high permeability zones bounded by lower permeability regions





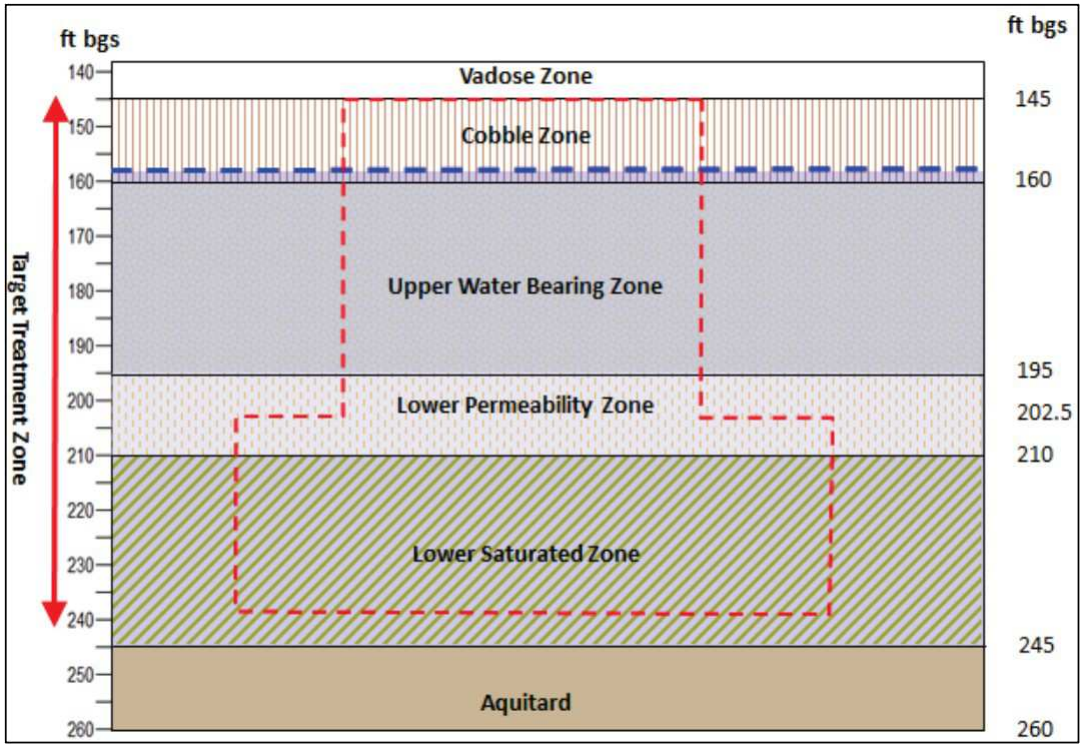
TERRATHERM

amec foster wheeler

Site ST012 Geology

Treatment interval comprised of four geologic layers:

- Cobble Zone: 145-160 ft bgs
- Upper Water Bearing Zone: 160-195 ft bgs
- Lower Permeability Zone: 195-210 ft bgs
- Lower Saturated Zone: 210-245 ft bgs



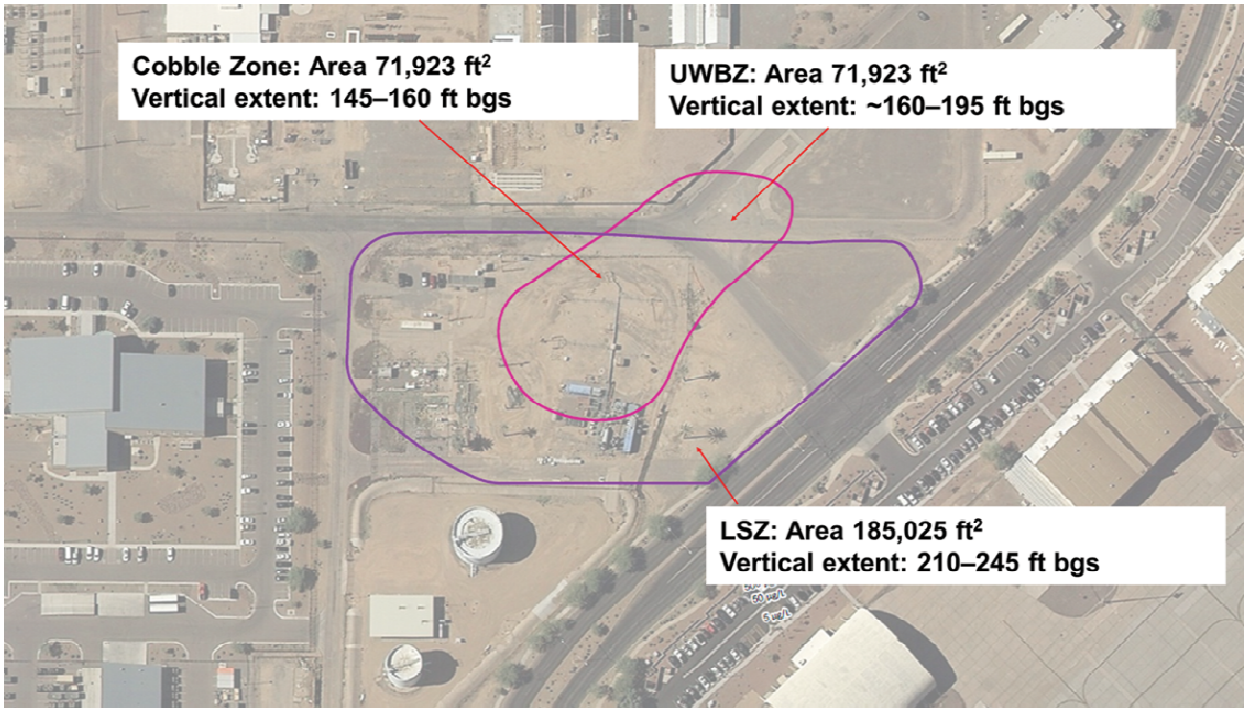
TERRATHERM

amec foster wheeler

SEE Treatment Zone

Thermal Target Treatment Zone (TTZ):

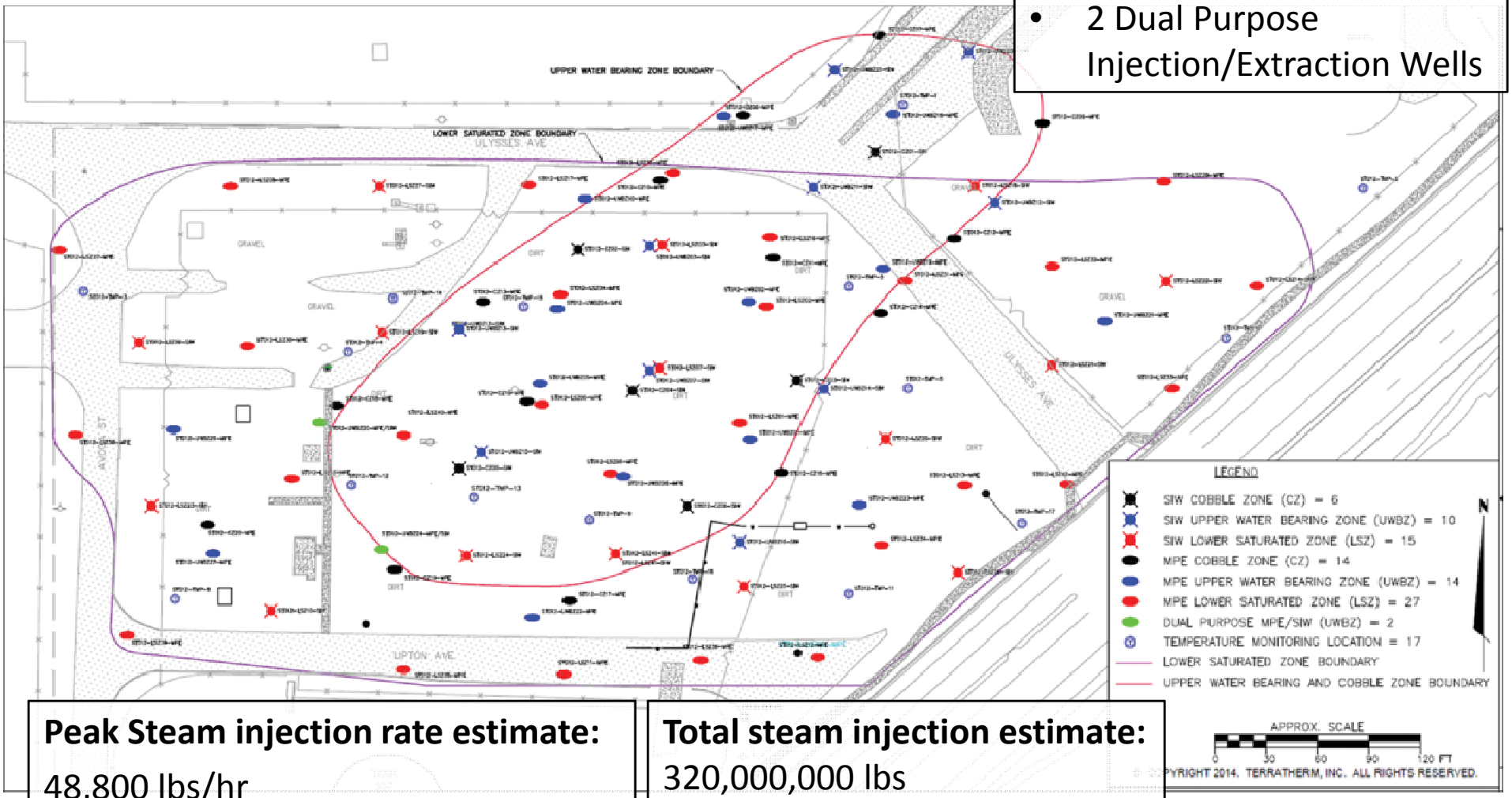
- 410,000 cy
- 180,000 ft^2 (4.1 acres)
- Treatment depth 145-245 ft bgs
- 95% of the TTZ is located below the water table



SEE Wellfield and Steam Injection Design

SEE operational wells include:

- 31 Steam Injection Wells
- 55 MPE Wells
- 2 Dual Purpose Injection/Extraction Wells



Peak Steam injection rate estimate:
48,800 lbs/hr

Total steam injection estimate:
320,000,000 lbs

SEE Extraction System Design

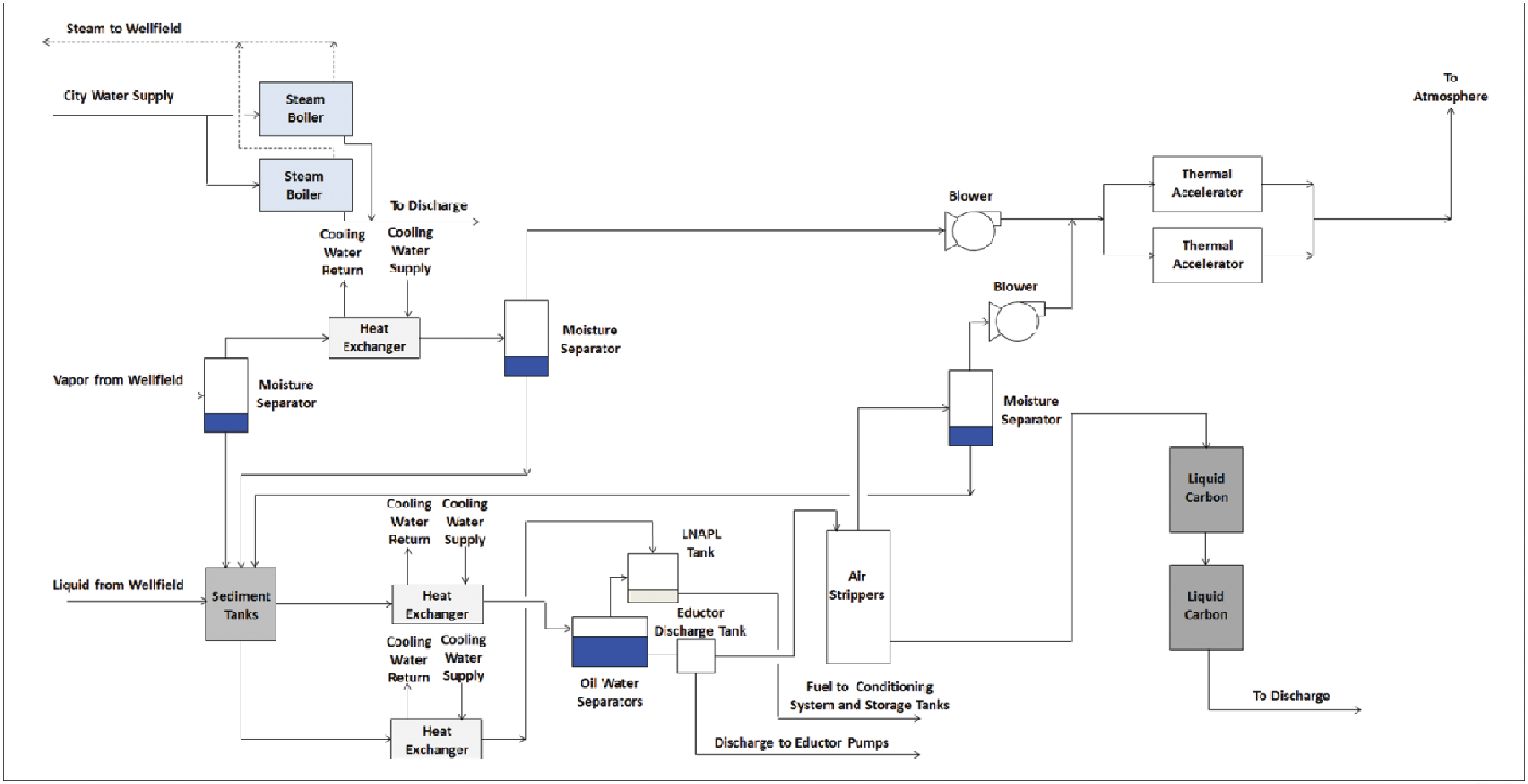
Peak liquid extraction system design rate:

- 507 gpm - both motive water for extraction pumps and water extracted from the formation
- Motive water eductor pumps were selected for groundwater extraction based on the high hydraulic head, high flow, high temperature, and limited well diameter

TERRATHERM

amec foster wheeler

SEE Liquid and Vapor Treatment System Design



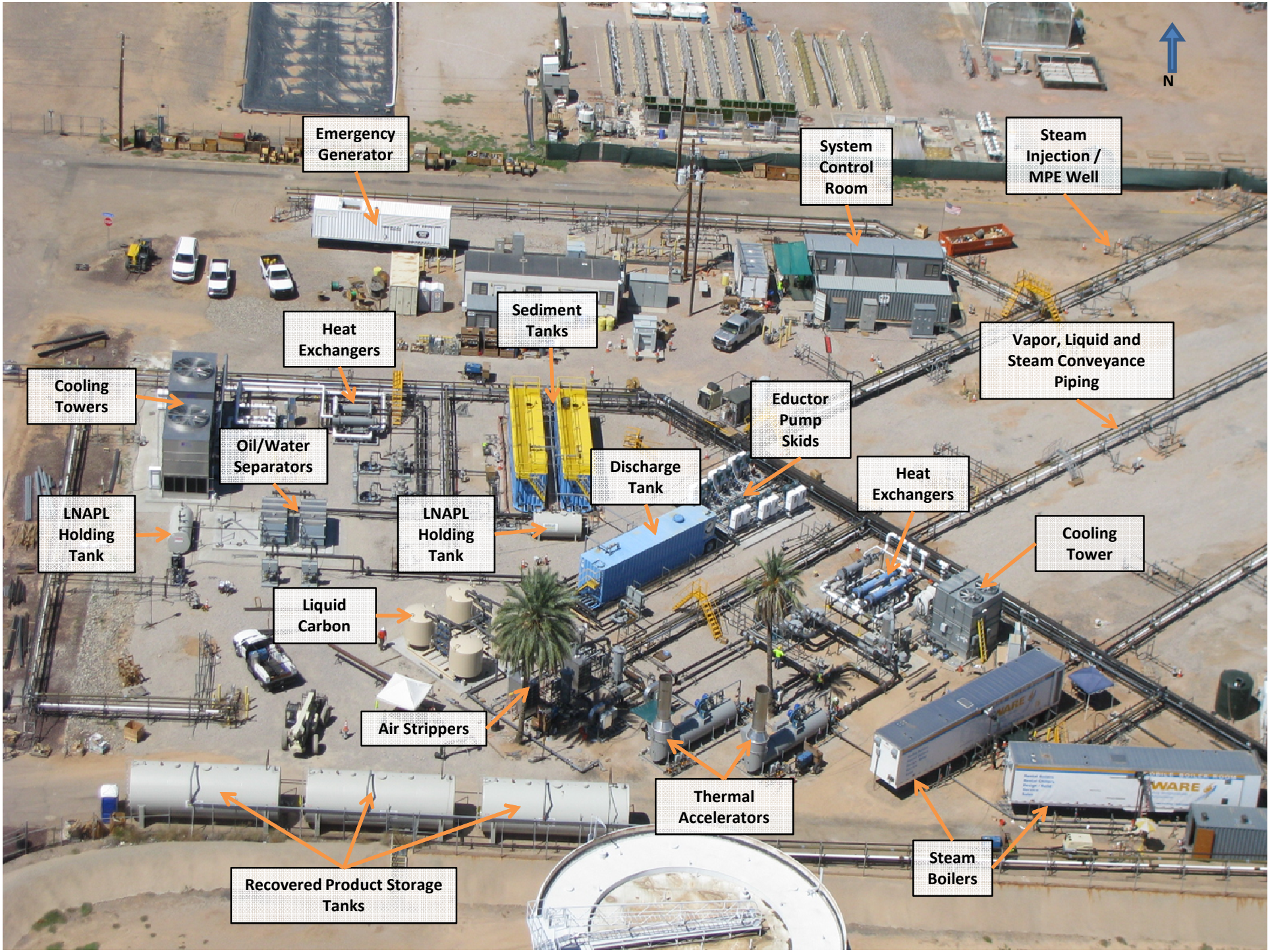
SEE System

The as-built SEE system includes:

- >2.5 miles of piping
- >5.5 miles of wire cable
- 60,000 gallons of recovered fuel storage
- Recovered JP4 conditioned and reused onsite as supplemental fuel for the thermal accelerators

TERRATHERM

amec foster wheeler


N
Emergency Generator
System Control Room
Steam Injection / MPE Well
Sediment Tanks
Heat Exchangers
Vapor, Liquid and Steam Conveyance Piping
Cooling Towers
Eductor Pump Skids
Oil/Water Separators
Discharge Tank
Heat Exchangers
LNAPL Holding Tank
LNAPL Holding Tank
Cooling Tower
Liquid Carbon
Air Strippers
Thermal Accelerators
Steam Boilers
Recovered Product Storage Tanks


System Control Room
Vapor, Liquid and Steam Conveyance Piping
Steam Injection / Multi-Phase Extraction Well

Boiler

Steam Injection Well

Multi-Phase Extraction Well

Eductor Pump skids

Bag Filters/ Heat Exchangers/ Cooling Towers

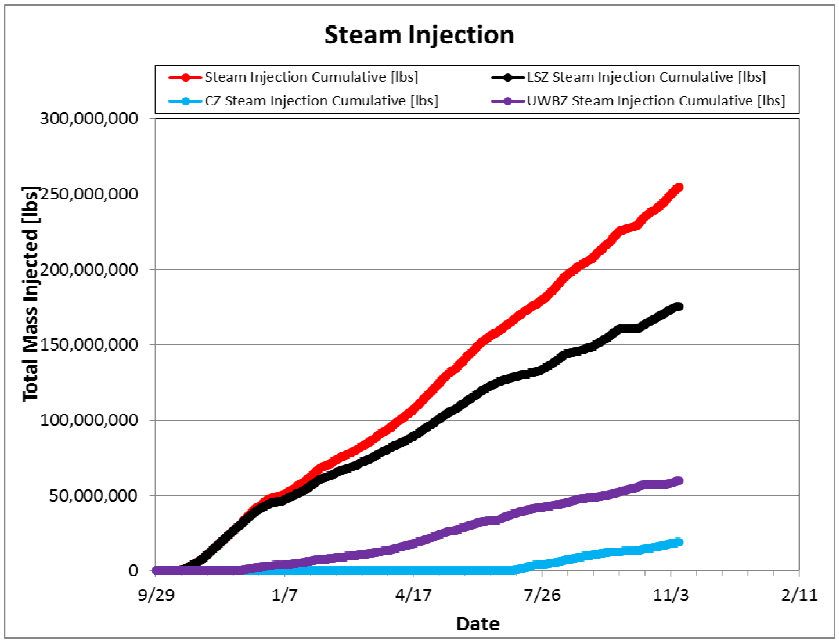
Oil/Water Separators

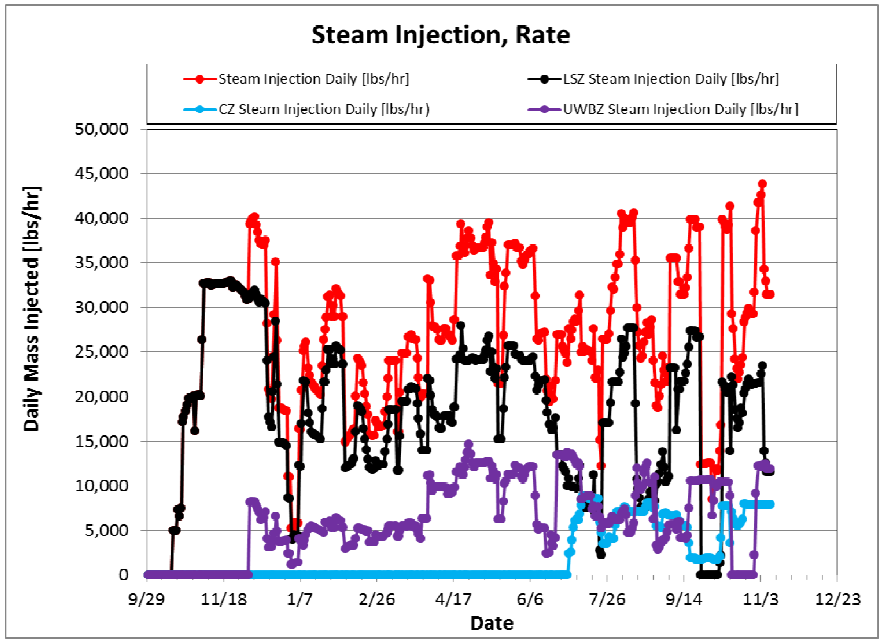
Air Strippers

GAC Tanks

Thermal Accelerators

SEE Operational Progress
Steam Injection





- Total steam injection: 254 million lbs (design 320 million)
- Average steam injection rate: 26,000 lbs/hr

TERRATHERM

amec foster wheeler

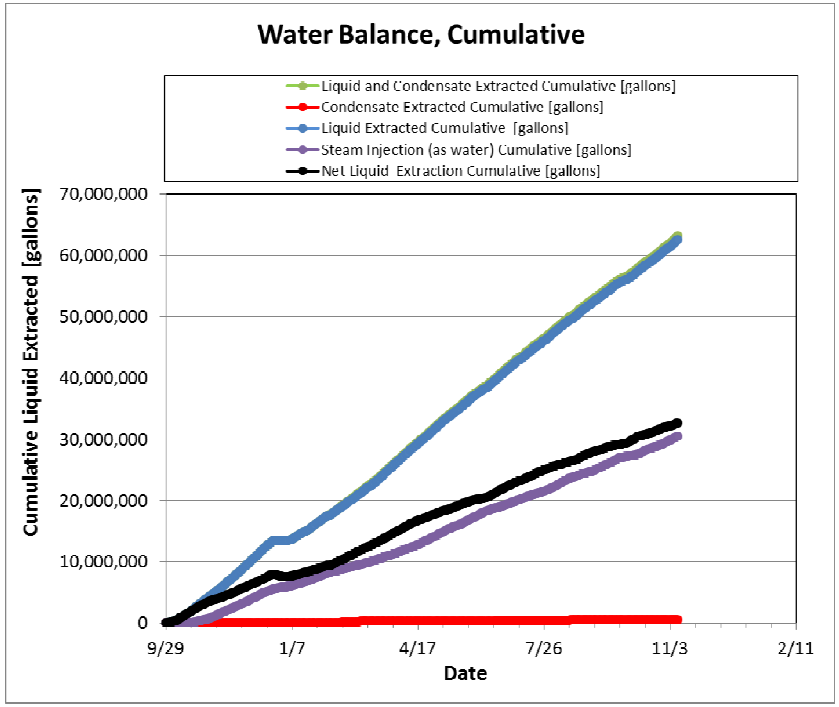
Operational Challenges

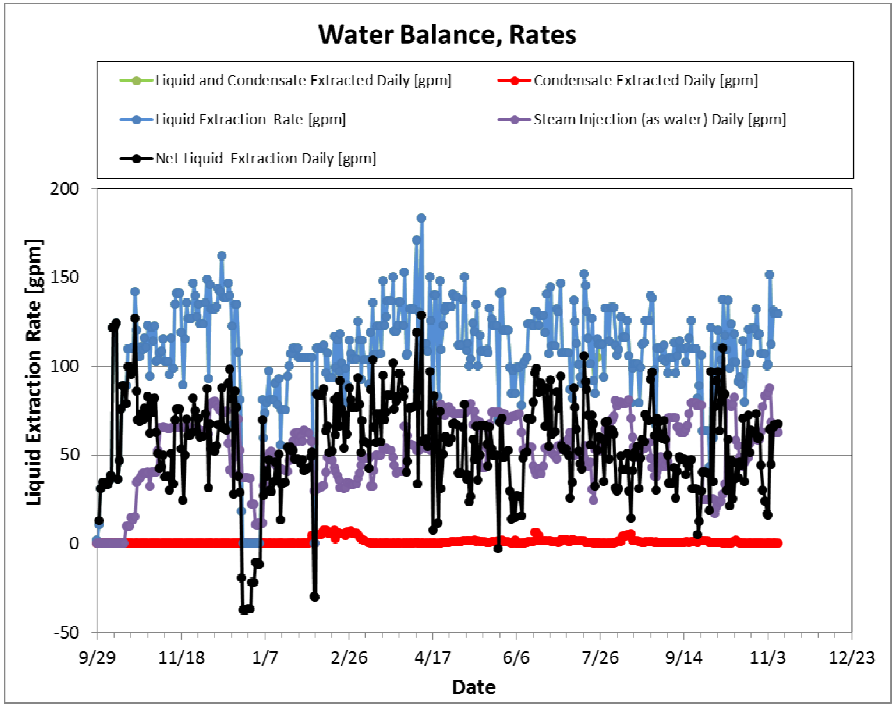
- Iron Fouling
- Bio Fouling
- Perimeter Water Levels and Temperatures
- Boiler Maintenance

TERRATHERM

amec foster wheeler

SEE Operational Progress
Water Extraction



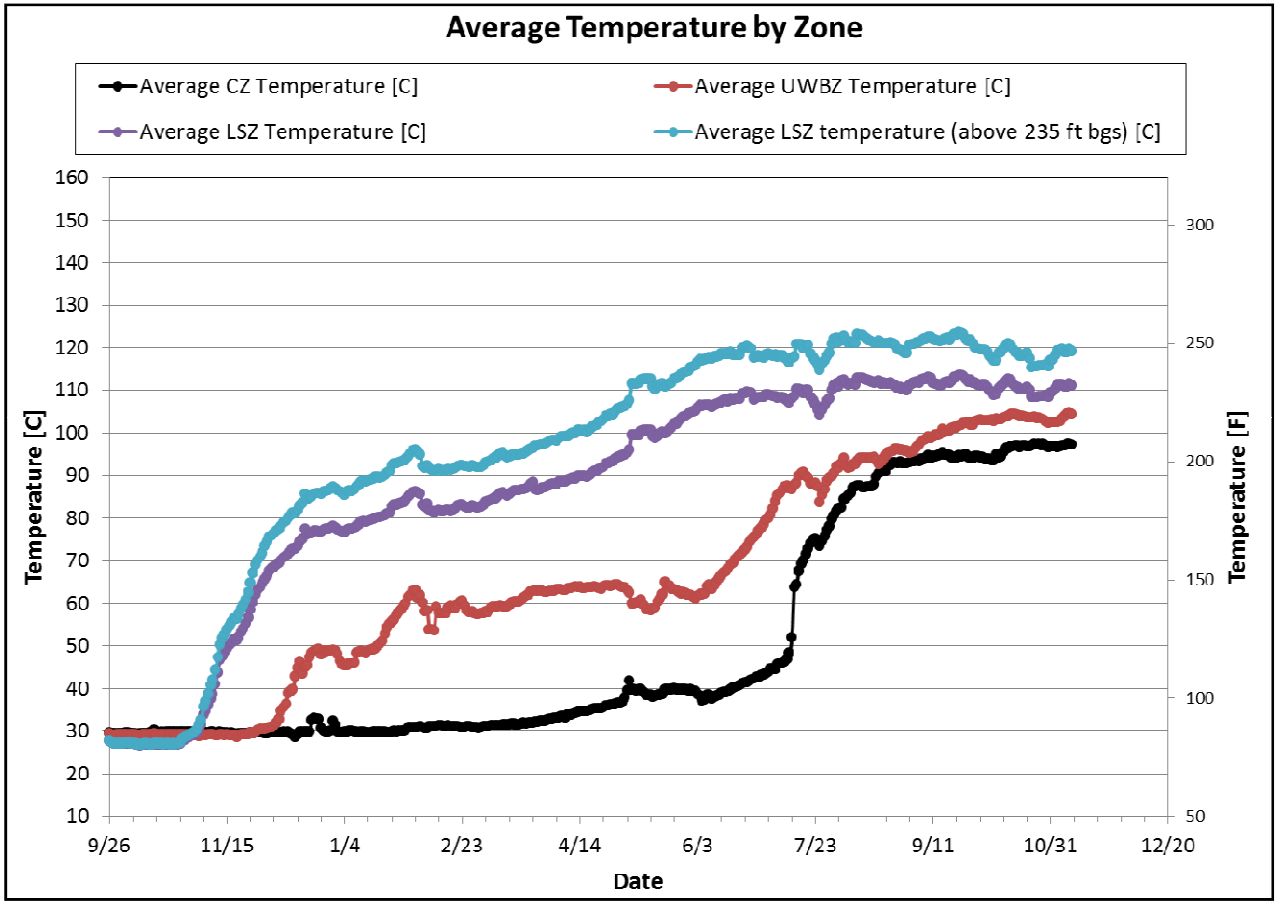


	CZ [gallons]	UWBZ [gallons]	LSZ [gallons]
Water extracted	9,532,000	21,517,000	49,389,000
Water injected (as steam)	2,278,000	7,192,000	21,073,000
Net extraction	7,254,000	14,325,000	28,316,000

TERRATHERM

amec foster wheeler

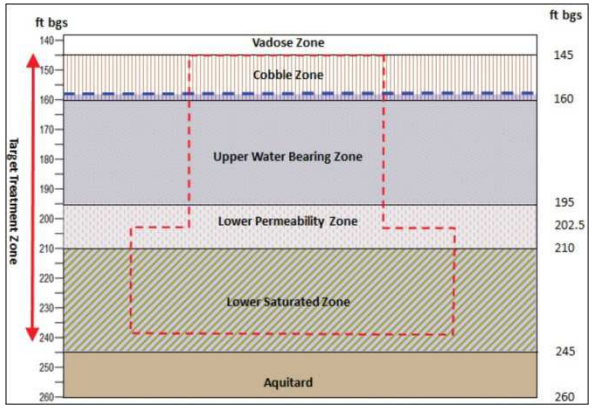
SEE Operational Progress Temperature



CZ Target Treatment Temperature: ~100°C

UWBZ Target Treatment Temperature: ~114°C

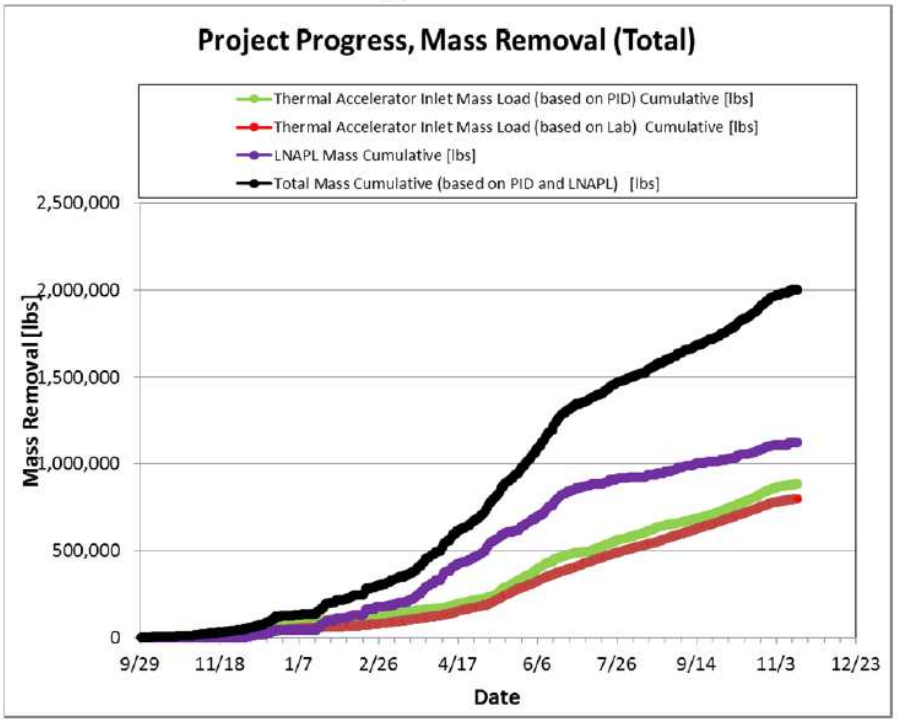
LSZ Target Treatment Temperature: ~134°C

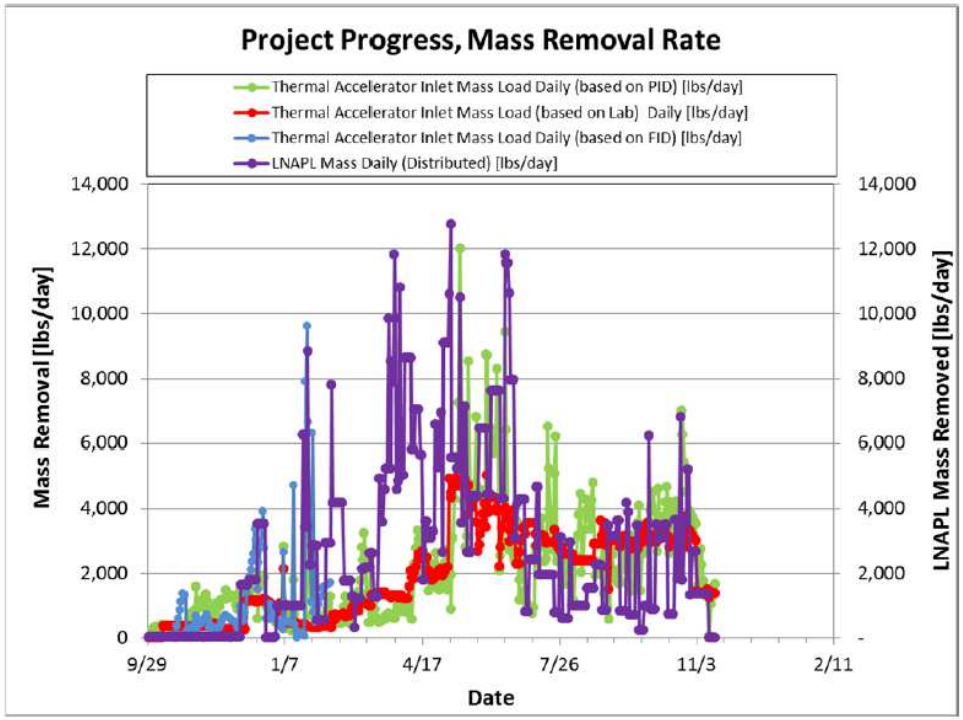


TERRATHERM

amec foster wheeler

SEE Operational Progress
Mass Removal





- Total Contaminant Mass Removal: 2.0 million lbs removed
  - An estimated 1.1 million lbs (168,000 gallons) as NAPL
  - An estimated 0.9 million lbs (133,000 gallons) in vapor phase

TERRATHERM

amec foster wheeler

Site Closure Plan

- Continue steam pressure cycling – SEE operations anticipated to end Q1 2016
- Amec Foster Wheeler to implement enhanced bioremediation to target additional NAPL depletion and benzene removal
- MNA – MCLs by 2033