



Bioremediation of Volatile Petroleum Hydrocarbons (VPH) and Extractable Petroleum Hydrocarbons (EPH)

iSOC Diesel Range Organic Compounds Case Study



Objectives of the Case Study

- Place bioremediation in the overall context of combined remedial actions to achieve site objectives
- Provide remedial performance data for consideration of bioremediation in remedial action feasibility studies and as a basis for remedy selection

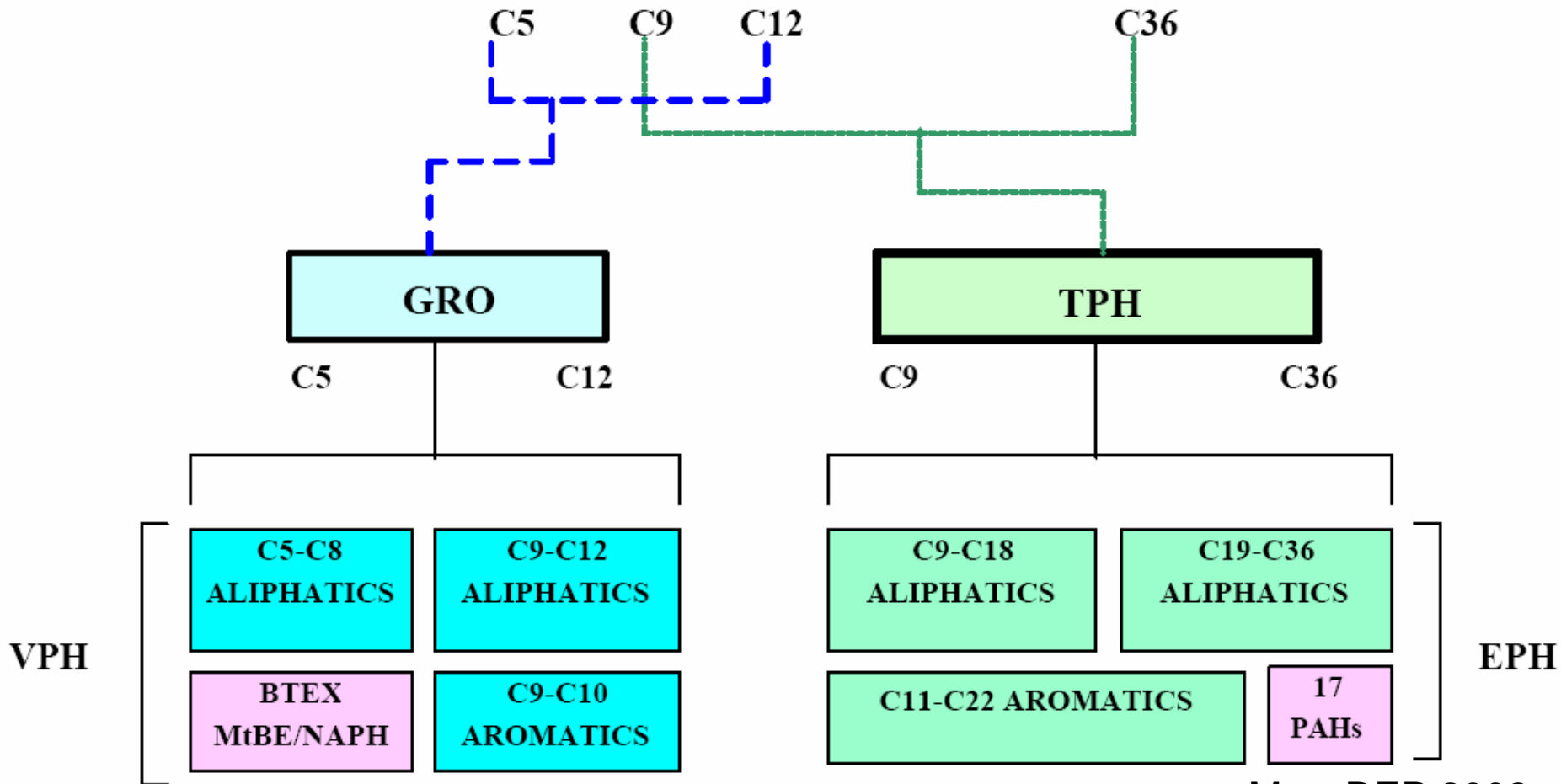


Remediation of VPH and EPH Hydrocarbon Ranges

- Developed by the state of Massachusetts Department of Environmental Protection as hydrocarbon ranges of interest for risk assessment
- Identified risk drivers with numerical standards
- Used as remedial objectives
- Method adopted by regulators in many countries and states



**Universe of Petroleum Hydrocarbons
(C5-C36+)**



MassDEP 2002



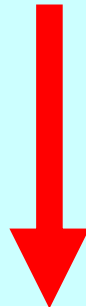
Biodegradability of Hydrocarbons

- Degradation rate affected by:
 - solubility in water (bioavailability)
 - rate of metabolism by microbes

Relative Biodegradability of Aliphatic Hydrocarbons

| Equivalent Carbon Number* | Solubility (mg/L) | Molecular Weight (g/mole) |
|---------------------------|-------------------|---------------------------|
| >C5-C6 | 36 | 81 |
| >C6-C8 | 5.4 | 100 |
| >C8-C10 | 0.43 | 130 |
| >C10-C12 | 0.034 | 160 |
| >C12-C16 | 0.00076 | 200 |
| >C16-21 | 0.0000025 | 270 |

Biodegradability



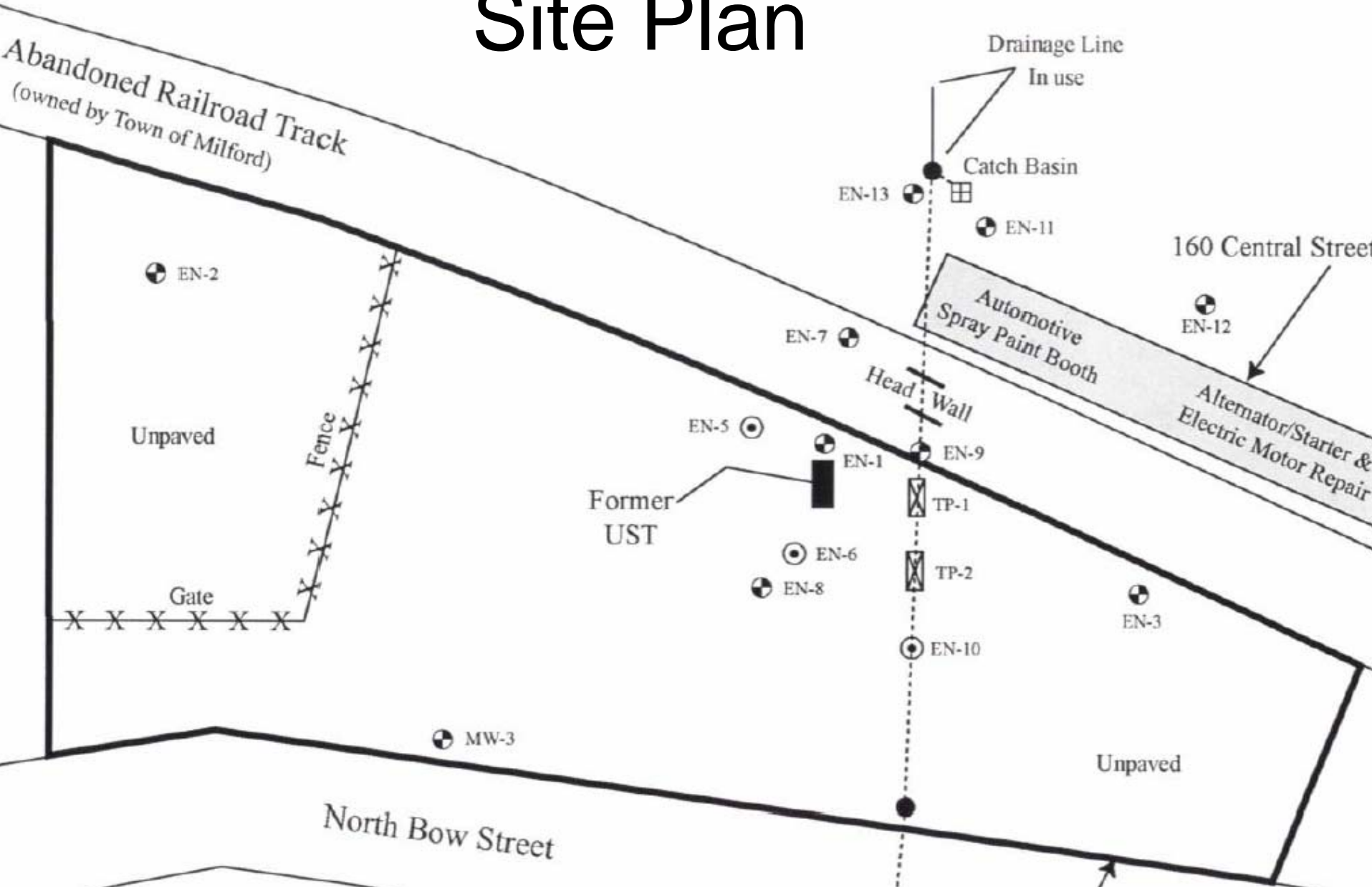
*Modified From: Weisman, W.H., "Total Petroleum Hydrocarbon Criteria Working Group: A Risk-Based Approach for the Management of Total Petroleum Hydrocarbons in Soil," 1998, Journal of Soil Contamination, Vol. 7, No. 1,

The Site: Former Shoe Factory - Future Milford Massachusetts Senior Center





Site Plan





Petroleum Releases

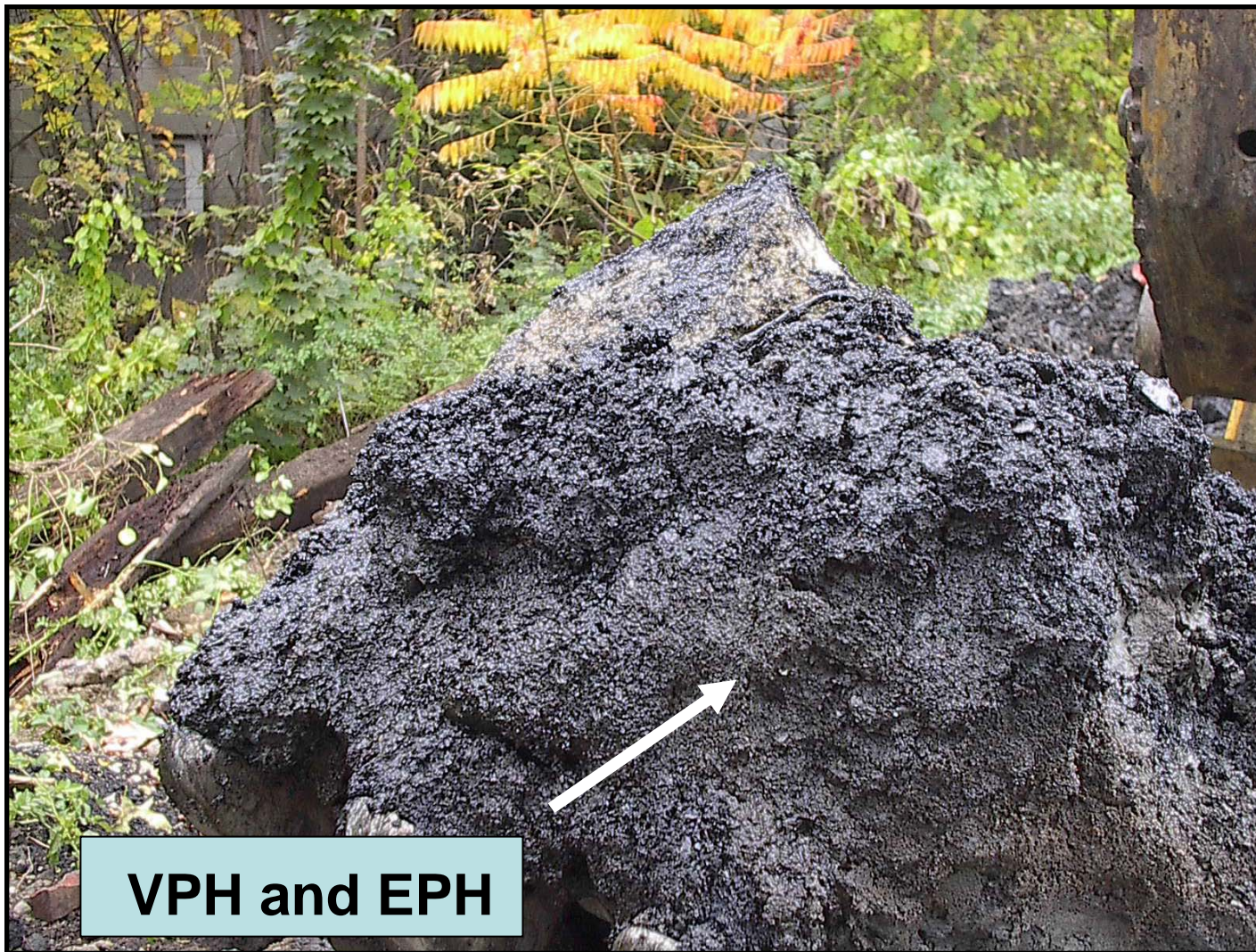
- No. 2 fuel oil
- No. 6 fuel oil
- 30 ft x 30 ft area of heavily contaminated soil
- up to 3 feet of LNAPL oil in monitoring wells



Selected Remedial Actions

- USTs excavated and removed
- 2,165 tons of fuel oil-contaminated soil excavated
- 30,000 gallons of water generated during dewatering of the excavation treated and discharged
- in situ bioremediation of residual EPH/VPH in groundwater





VPH and EPH



Potential Receptors

- Charles River located approximately 600 feet east
- Site located in the zone of contribution to two public drinking water supply wells



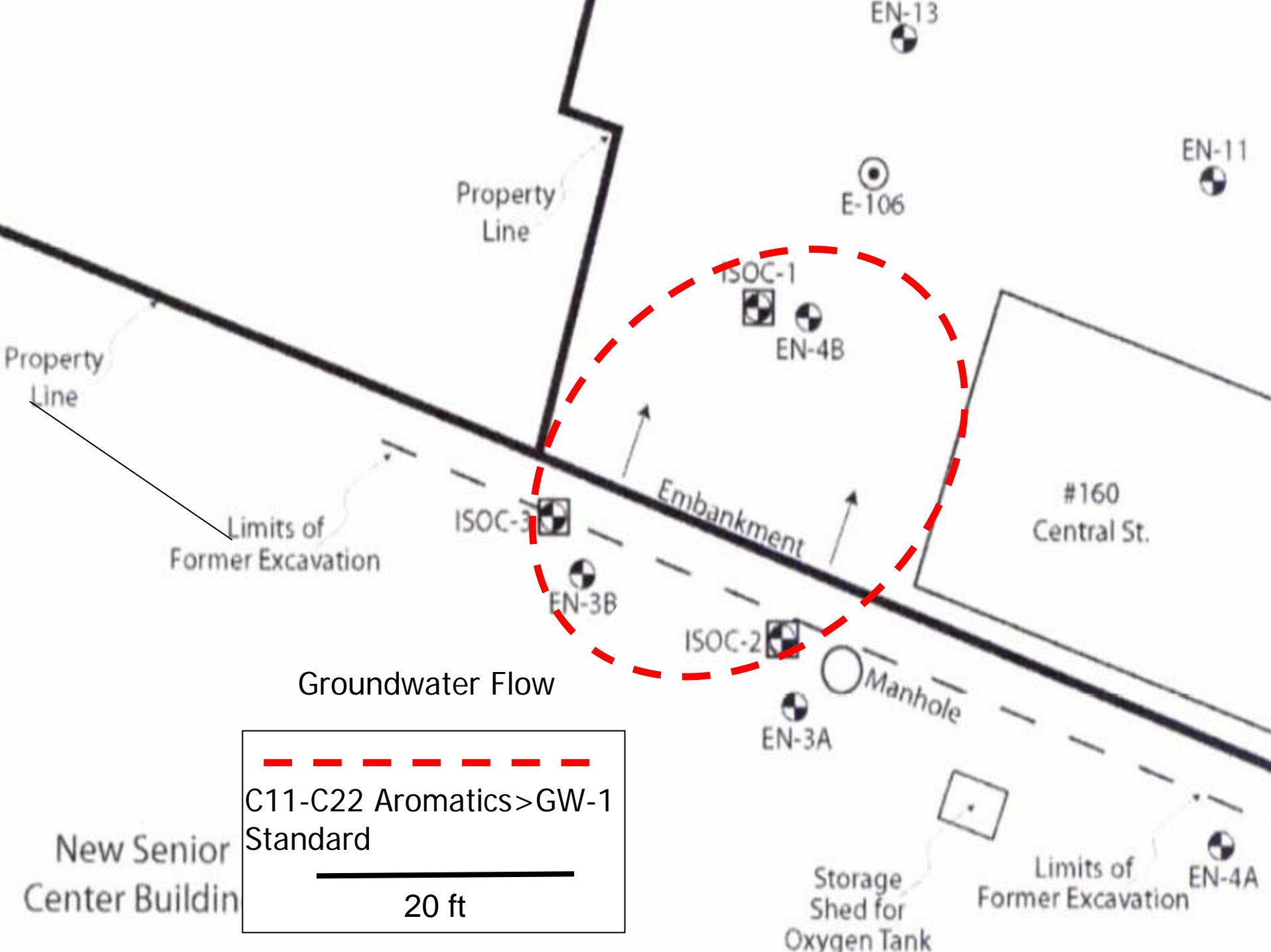
VPH and EPH concentrations above the Applicable Standards

- EPH C11-C22 Aromatics: Monitoring Wells EN-3B and EN-4B
- Target PAHs (naphthalene and 2-methylnaphthalene): Monitoring Well EN-4B
- VPH C9-C10 Aromatics: Monitoring Well EN-4B



Hydrogeologic Conditions

- Shallow groundwater (3 to 7 ft bls)
- Mixed fill up to 8 ft bls
- Fine to medium sand with silt 8-10 ft bls
- Lenses of dense silt, and medium to coarse sand with gravel 10-17 ft bls
- Groundwater velocity ~ 0.065 ft/day



C11-C22 Aromatics > GW-1 Standard

20 ft



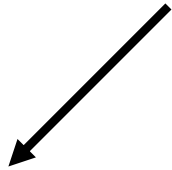
Groundwater Bioremediation System

- Oxygen delivered to groundwater by mass transfer using iSOC (initial conditions - $O_2 < 2$ mg/L)
- 3 treatment wells located to enhance natural attenuation in the heart of the plume (screened 3 to 15 ft bls)
- Installed and started in January 2005



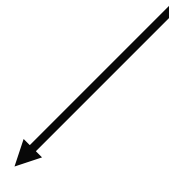
iSOC O₂ Mass Transfer System

Flow Controller



+

Mass Transfer Device



=

Final
iSOC
Assembly



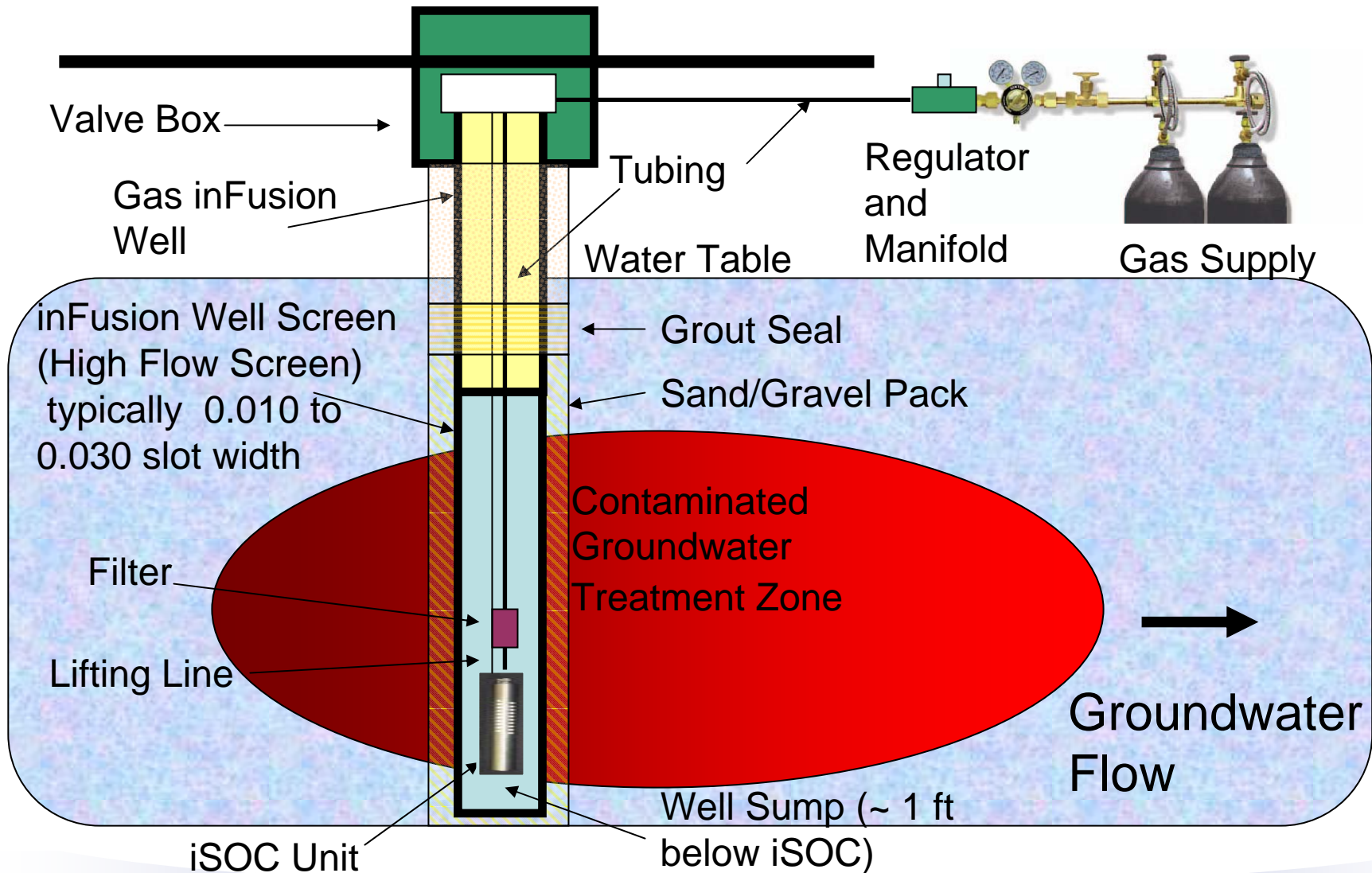


Gas inFusion Process

Direct aerobic treatment:

- iSOC unit microporous hollow fiber supplied with oxygen in treatment well
- Saturates well (DO— 40 to 200 PPM depending on groundwater depth)
- DO disperses into groundwater stimulating bioremediation

Typical iSOC Well Schematic





Milford Site



Oxygen Supply Bin

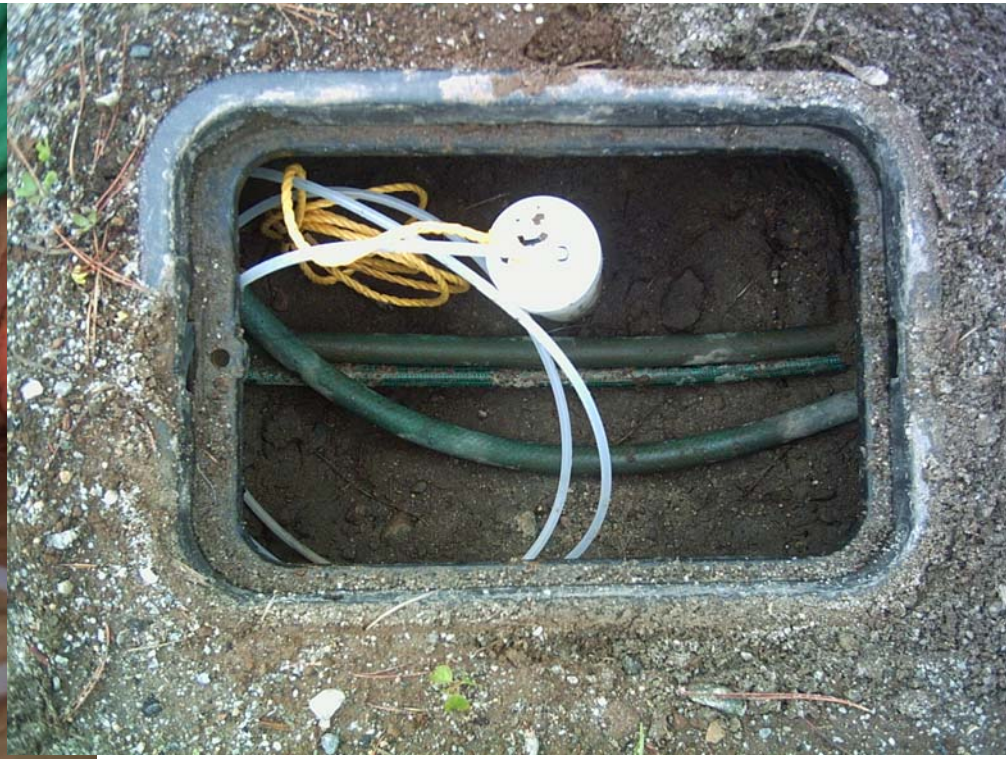


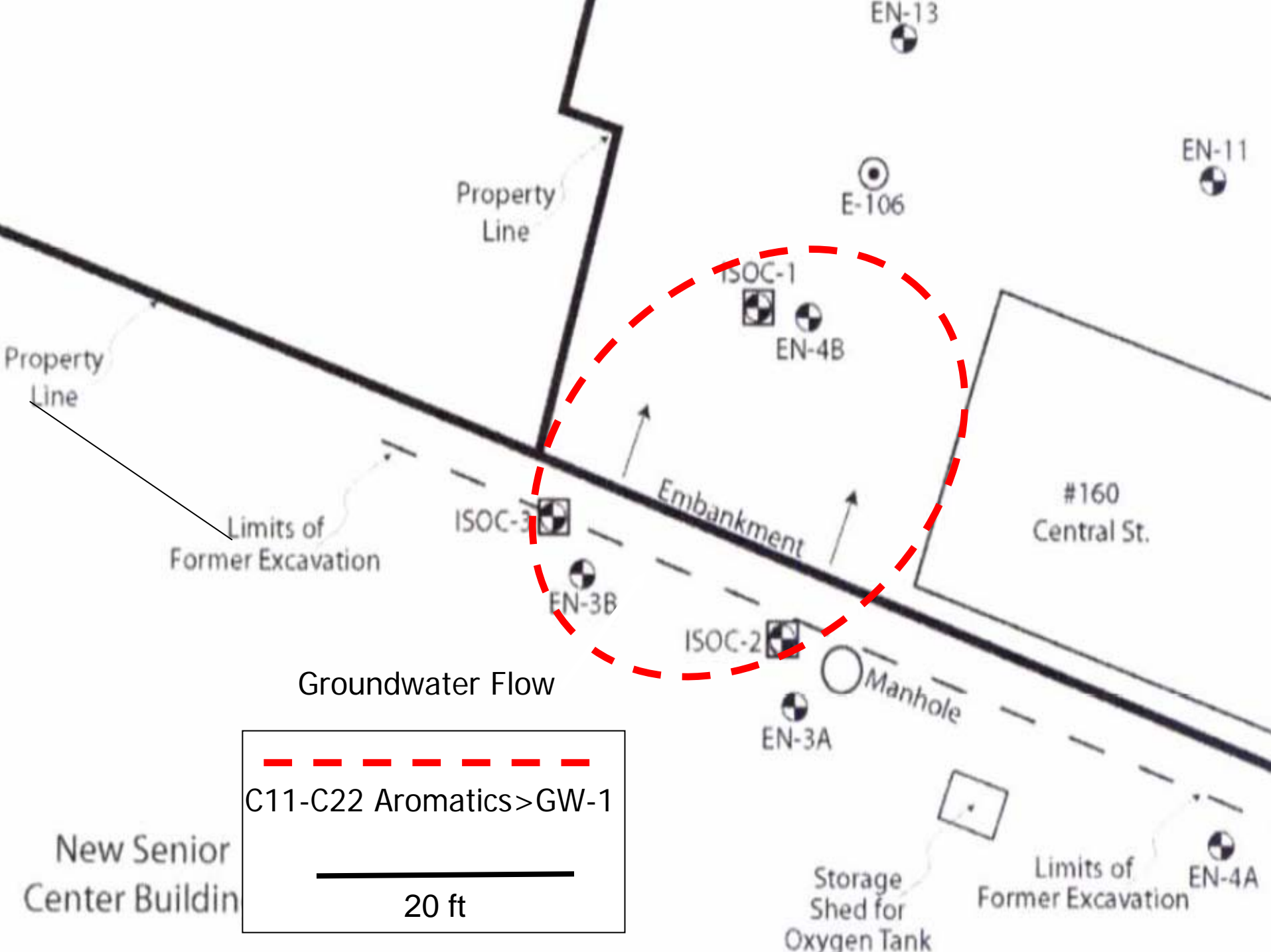
iSOC Oxygen Supply





iSOC Oxygen Distribution Header and Treatment Well





Groundwater Flow

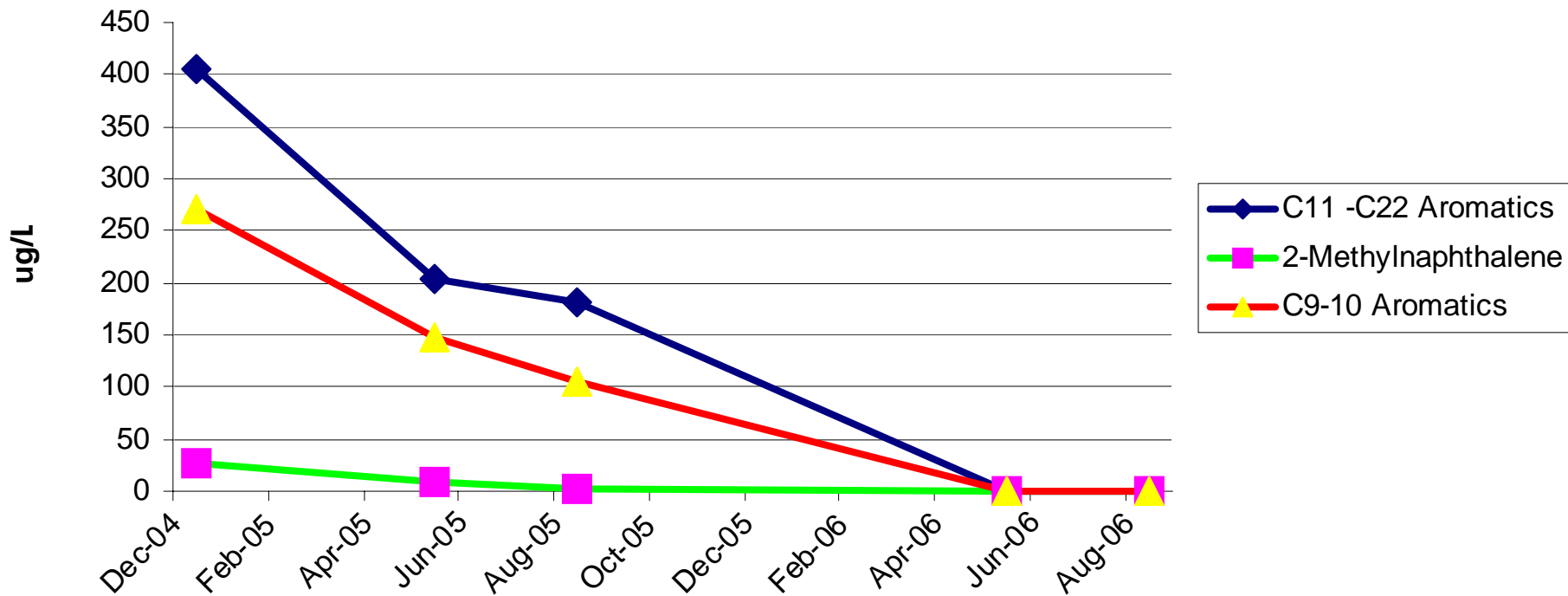
C11-C22 Aromatics > GW-1

20 ft



Groundwater Data

Monitoring Well EN-3B



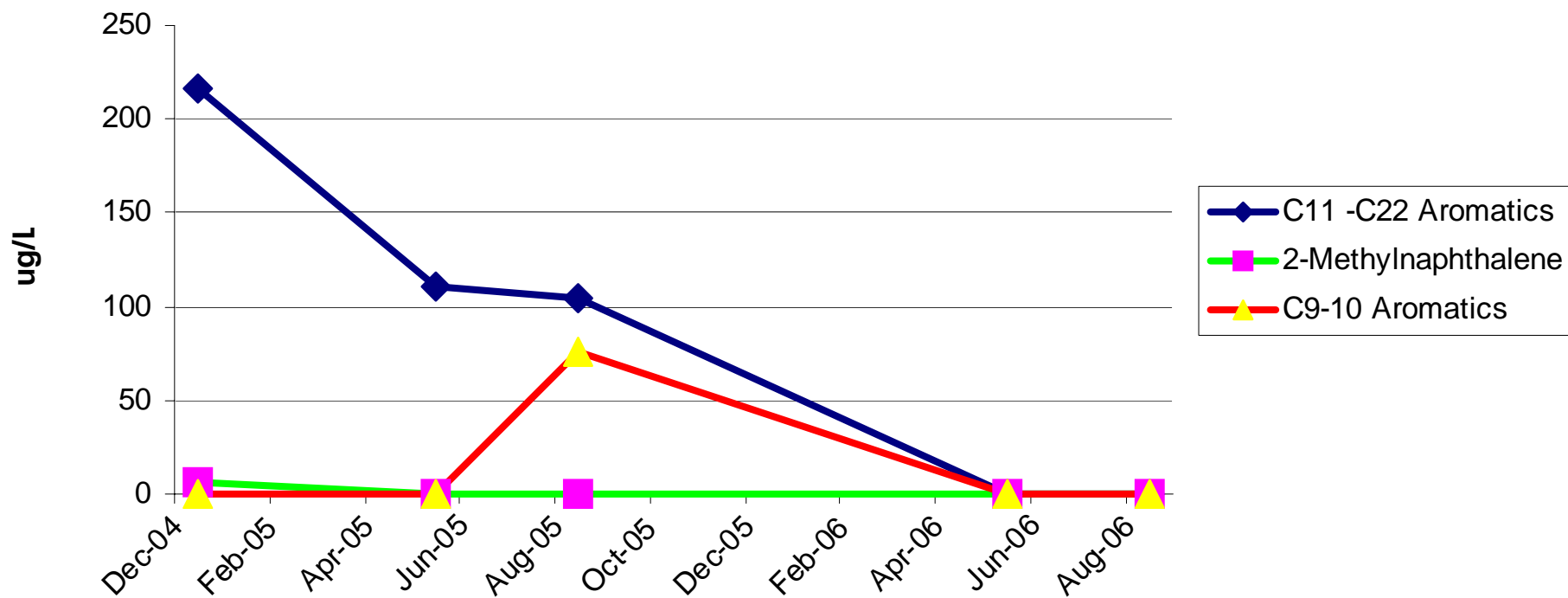
System Startup Jan 05

| GW-1 Standards | (ug/L) |
|---------------------|--------|
| C11 -C22 Aromatics | 200 |
| 2-Methylnaphthalene | 10 |
| C9-10 Aromatics | 200 |



Groundwater Data

Monitoring Well EN-4B



System Startup Jan 05

| GW-1 Standards | (ug/L) |
|---------------------|--------|
| C11 -C22 Aromatics | 200 |
| 2-Methylnaphthalene | 10 |
| C9-10 Aromatics | 200 |



Final Dissolved Oxygen in Groundwater

August 2006

| <u>WELL</u> | <u>DO (mg/L)</u> |
|-------------|------------------|
|-------------|------------------|

| | |
|--------|----|
| iSOC-1 | 51 |
|--------|----|

| | |
|--------|----|
| iSOC-2 | 45 |
|--------|----|

| | |
|--------|----|
| iSOC-3 | 46 |
|--------|----|

| | |
|-------|---|
| EN-3A | 6 |
|-------|---|

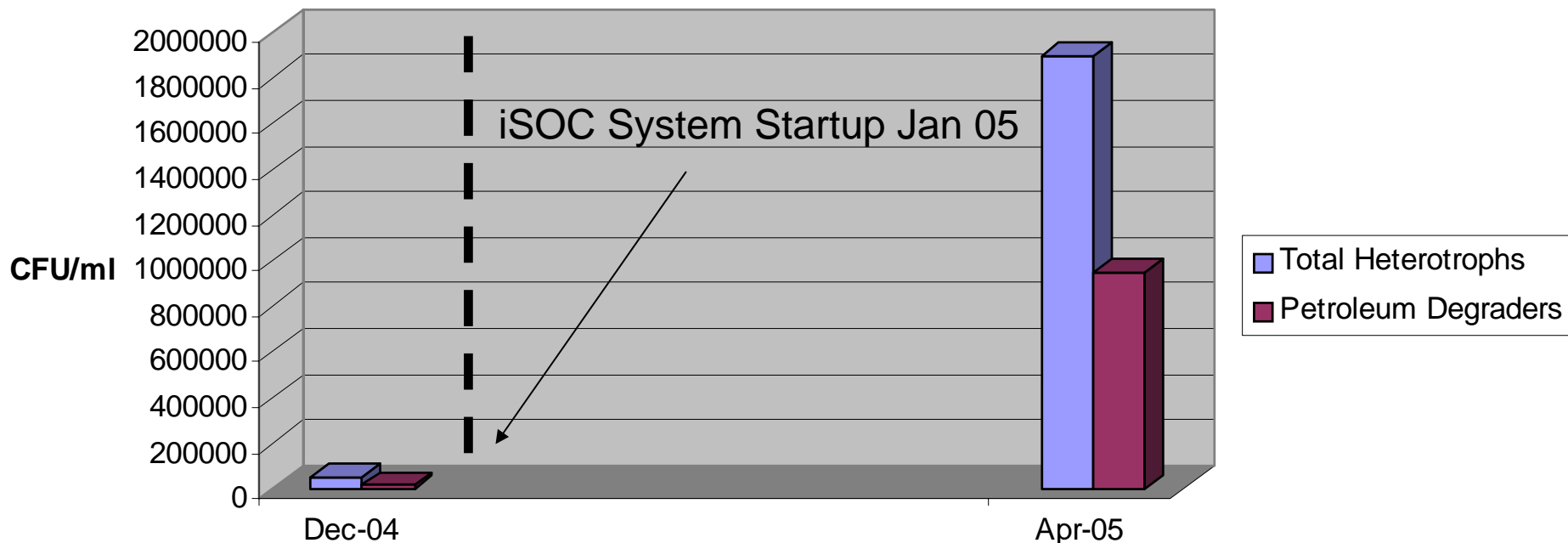
| | |
|-------|---|
| EN-3B | 4 |
|-------|---|

| | |
|-------|---|
| EN-4B | 4 |
|-------|---|



Treatment Well Microbe Levels

Bacterial Enumeration iSOC -1





Current Status

- Standards Met - treatment system continuing to operate
- Plans for monitoring phase in development
- Site closure expected following one year of monitoring

