Headquarters U.S. Air Force

Integrity - Service - Excellence

Section 3
Designing Long-Term Monitoring Programs

U.S. AIR FORCE

Presented by

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Long-Term Monitoring

- **In Order for Natural Attenuation to Remain as the Selected Remedial Approach, It Will be Necessary to (EPA, 1999):**
  - **Demonstrate that Natural Attenuation is Occurring According to Expectations;**
  - **Identify any Potentially Toxic Transformation Products Resulting from Biodegradation**

Long-Term Monitoring - Con't

- **Requirements - Con't**
  - **Determine if the Plume is Expanding**
  - **Ensure no Impact to Downgradient Receptors**
  - **Detect New Releases of Contaminants or Changes in Environmental Conditions that Could Impact the Efficacy of Natural Attenuation**
  - **Verify Attainment of Cleanup Objectives**

Long-Term Monitoring - Con't

- **A Contingency Plan Must be Developed in Case Natural Attenuation Fails to Perform as Expected**

Protocol Being Developed by AFCEE:

- **The Air Force Center for Environmental Excellence - Technology Transfer Division Developed a Protocol to Aid in the Design of Scientifically Defensible and Cost Effective Long-Term Monitoring Programs**

Designing Monitoring Programs to Effectively Evaluate the Performance of Natural Attenuation

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January 2000

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LTM Protocol

- **www.afcee.brooks.af.mil/er/ert/download/DesignMonProgs.pdf**

Protocol Designed to Provide Guidance on:

- **Effectively Placing and Constructing Sample Collection Points**
- **Specifying an Analytical Protocol and Sampling Frequency**
- **Data Evaluation - Evaluating Plume Stability**
- **Developing Contingency Plans**
- **Developing an “Exit Strategy”**

Types of Monitoring

- According to the EPA (1997) there are Three Types of Monitoring for Natural Attenuation

  1) Site Characterization Monitoring

  2) Validation Monitoring

  3) Long-Term Monitoring

Site Characterization Monitoring

- Site Characterization Monitoring is Used to Describe the Disposition of Contamination and Forecast Its Future Behavior. This is Essentially Site Characterization and the Initial Evaluation of Natural Attenuation

- Site Characterization Monitoring and Data Collection/Evaluation are Described in the Air Force and EPA Protocols

Site Characterization Monitoring Analytes

- Contaminants
- Dissolved Oxygen
- Nitrate
- Fe(II)
- Sulfate
- Methane
- Ethane/Ethene
- Chloride
- Hydrogen (Optional)
- Total Organic Carbon
- Oxidation-Reduction Potential
- Alkalinity
- pH
- Temperature

Validation Monitoring

- **Validation Monitoring is Used to Determine if the Predictions Made by Site Characterization Activities are Accurate**

Validation Monitoring Analytes

- Contaminants
- Dissolved Oxygen
- Nitrate
- Fe(II)
- Sulfate
- Methane
- Ethane/Ethene
- Chloride
- Hydrogen (Optional)
- Total Organic Carbon
- Oxidation-Reduction Potential
- Alkalinity
- pH
- Temperature

Long-Term Monitoring

- Long-Term Monitoring is Used to Ensure the Behavior of the Contaminant Plume Does Not Change.

Long-Term Monitoring

- There are Two Types of Monitoring to be Completed Under Long-Term Monitoring
  - Performance Monitoring
  - Compliance Monitoring

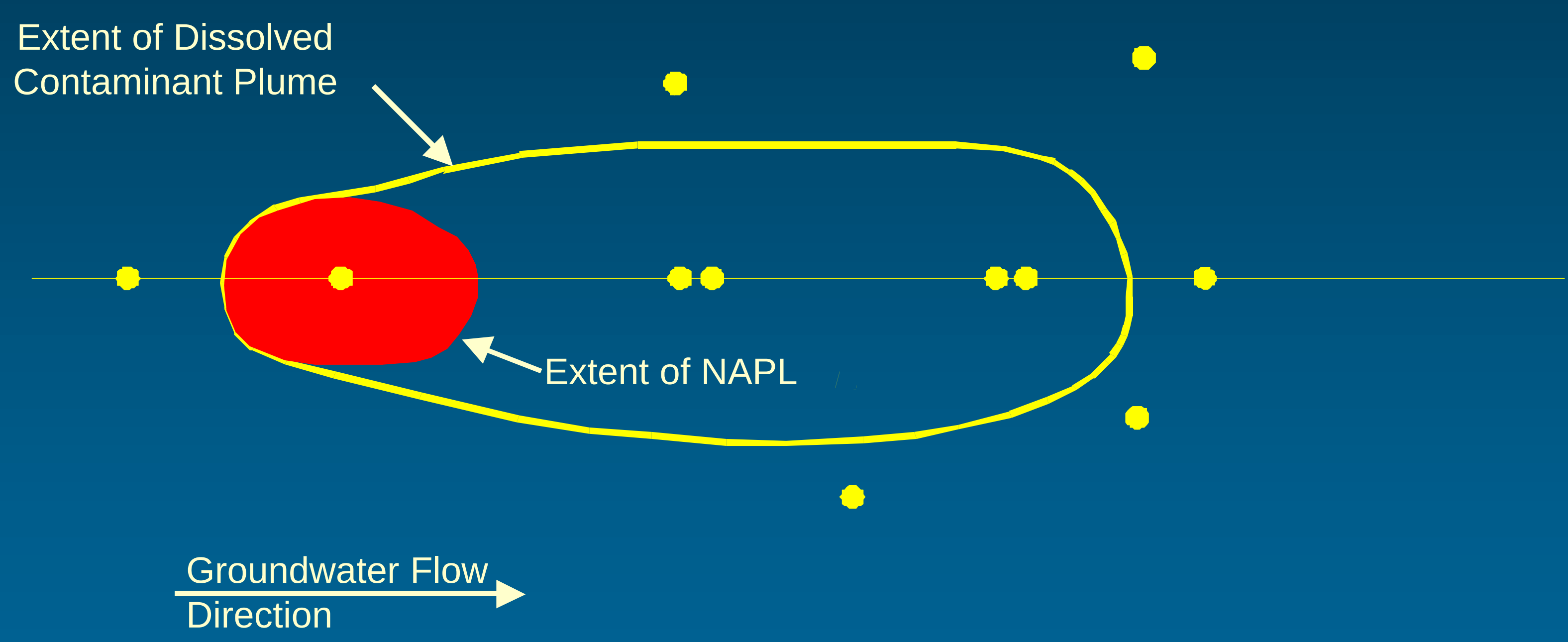
Performance Monitoring

- **Performance Monitoring Wells are Located Upgradient, Within, and Downgradient From the Plume.**
- **Used to Verify the Predictions Made by the Evaluation of Natural Attenuation**

Performance Monitoring Wells

- At a Minimum, Performance Monitoring Wells Should Include
  - One Well Upgradient of the Plume
  - One Well in the NAPL Source Area
  - Three Wells Along Plume Centerline
  - One Well Downgradient from Plume

Performance Monitoring Wells



Compliance Monitoring

- Used to Ensure that the Plume is not Expanding Past Pre-Established Boundaries

- Two Types of Wells
  - Point-of-Action
  - Sentry Wells

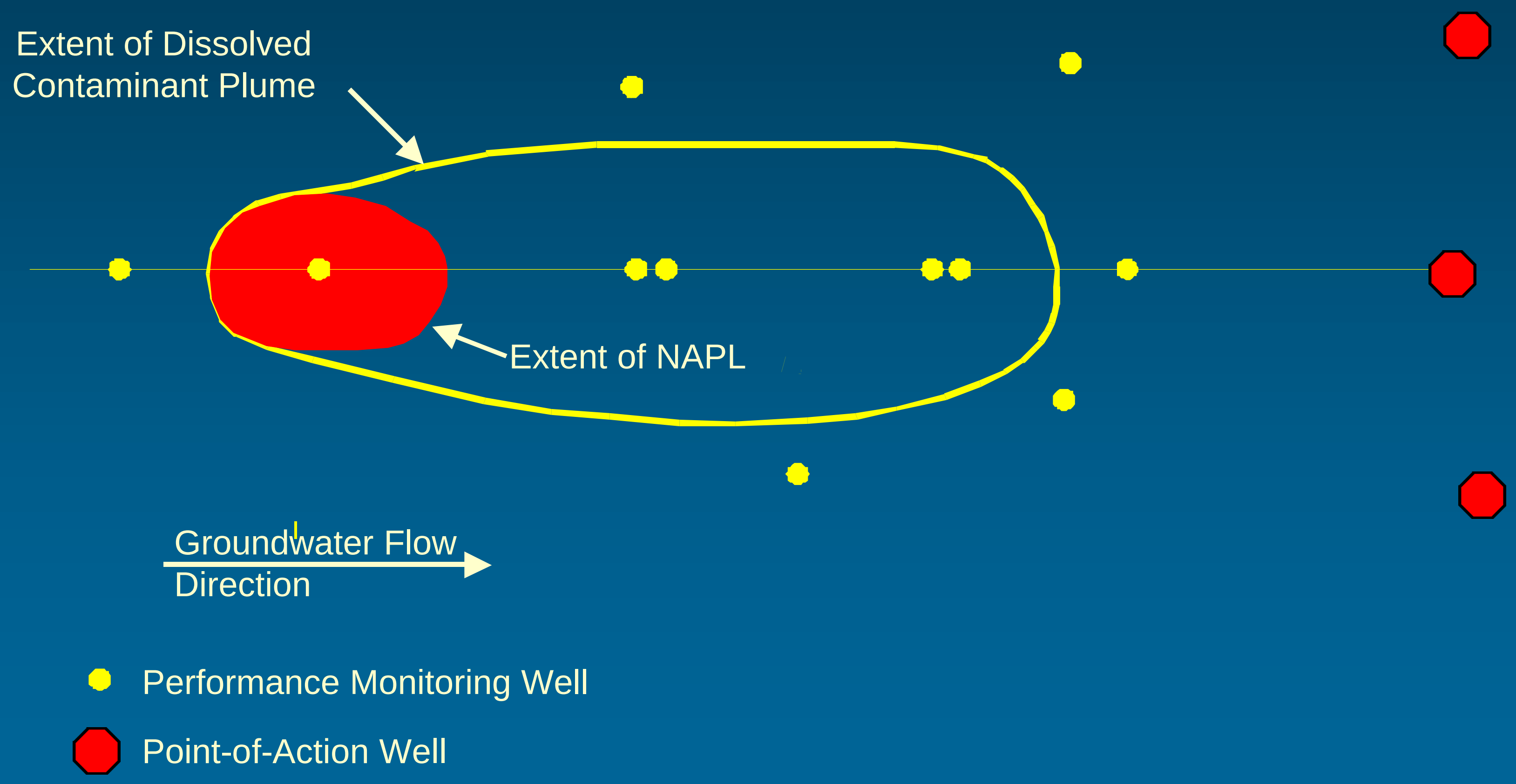
Point-of-Action Wells

- Point-of-Action Wells Should be Located at a Predetermined Location Past Which Plume Migration will not be Allowed
- These Wells Are Used to Trigger the Contingency Remedy
- Also Called Contingency Wells

Point-of-Action Wells - Con't

- **Must be Located Far Enough Upgradient of a Potential Receptor to Allow Implementation of the Contingency Remedy in a Timely Manner**

Point-of-Action Wells

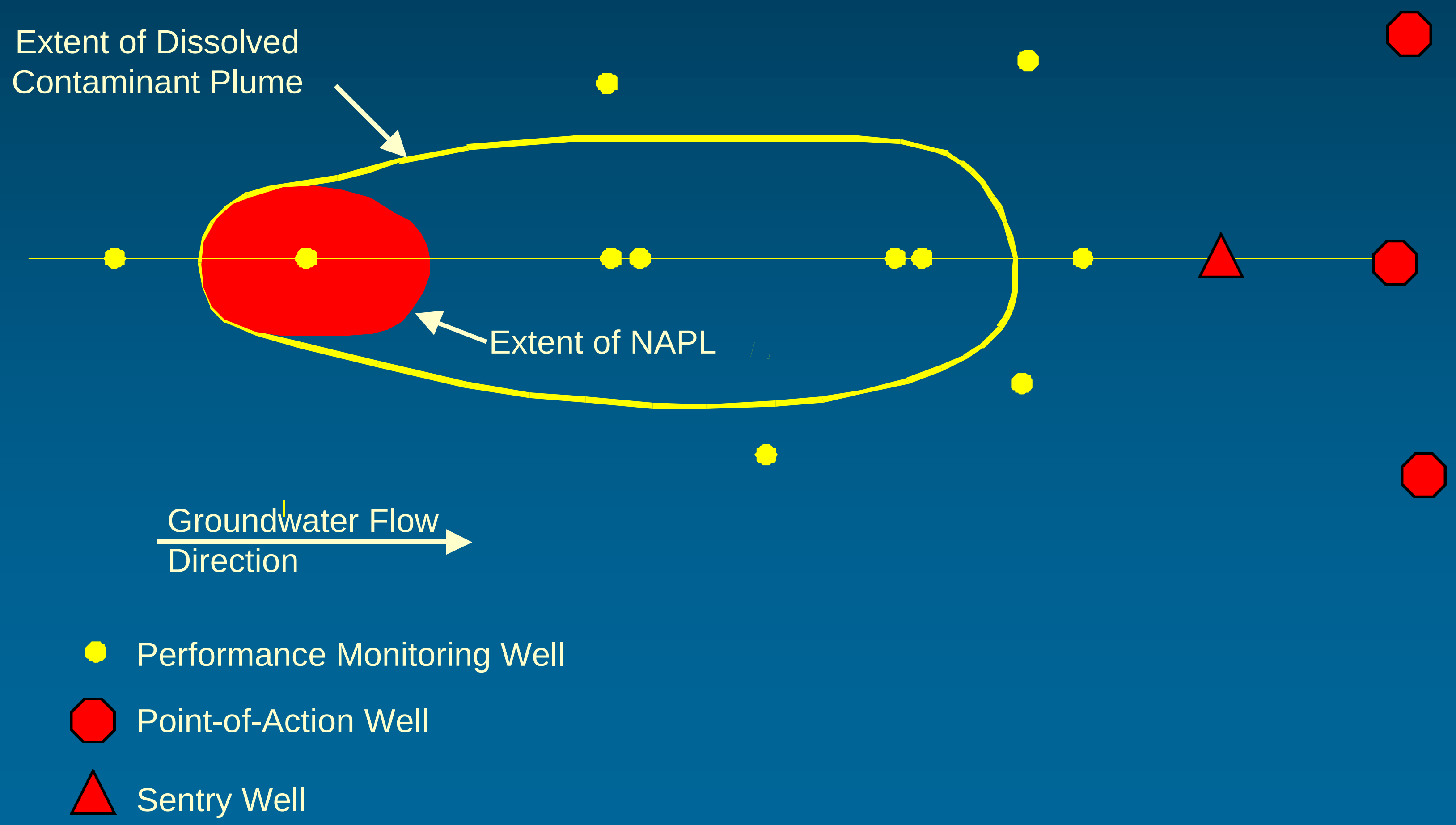


Sentry Wells

- Sentry Wells are Used in Conjunction with the most Downgradient Performance Monitoring Wells to Provide Early Detection of Plume Migration.

- Should be Located Between the Most Downgradient Performance Monitoring Wells and the Point-of Action Wells

Sentry Well(s)



Surface Water Samples

- If a Plume Discharges to Surface Water then Surface Water Sampling May be Required

Guidelines for Placement of Sampling Locations

- Sampling Locations MUST be in the Flow Path of the Contaminant Plume
- Use Results of Site Characterization and Modeling to Determine Sampling Locations and Frequency
  - Identify Preferential Flow Paths
  - Models can be Useful for Predicting Contaminant Migration
  - Geochemical Data can be very Useful

Use of Geochemical Data for Sampling Location Placement

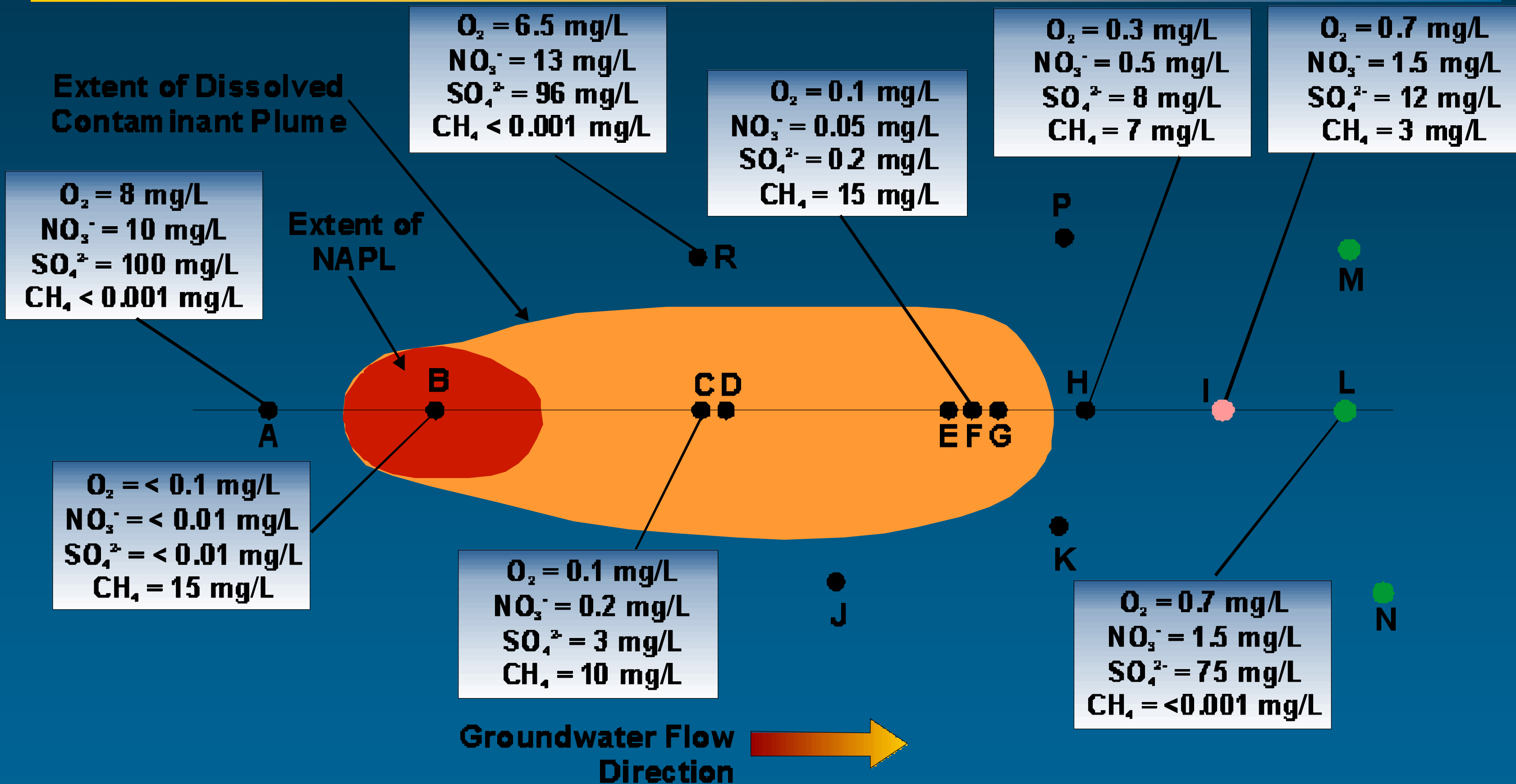
"Smoking Guns"

- **Elevated Concentrations of Metabolic Byproducts and/or Lowered Concentrations of Electron Acceptors Downgradient from Contamination**

“Smoking Guns” - Con’t

- Conclusive Evidence that Sampling Locations are in “Treated” Groundwater (i.e., in the path of the plume)
- Especially Useful for Siting Wells Downgradient of the Contaminant Plume
- Ensures Detection of Plume Migration Should the Plume Start to Migrate

Well Placement Example - LNAPL

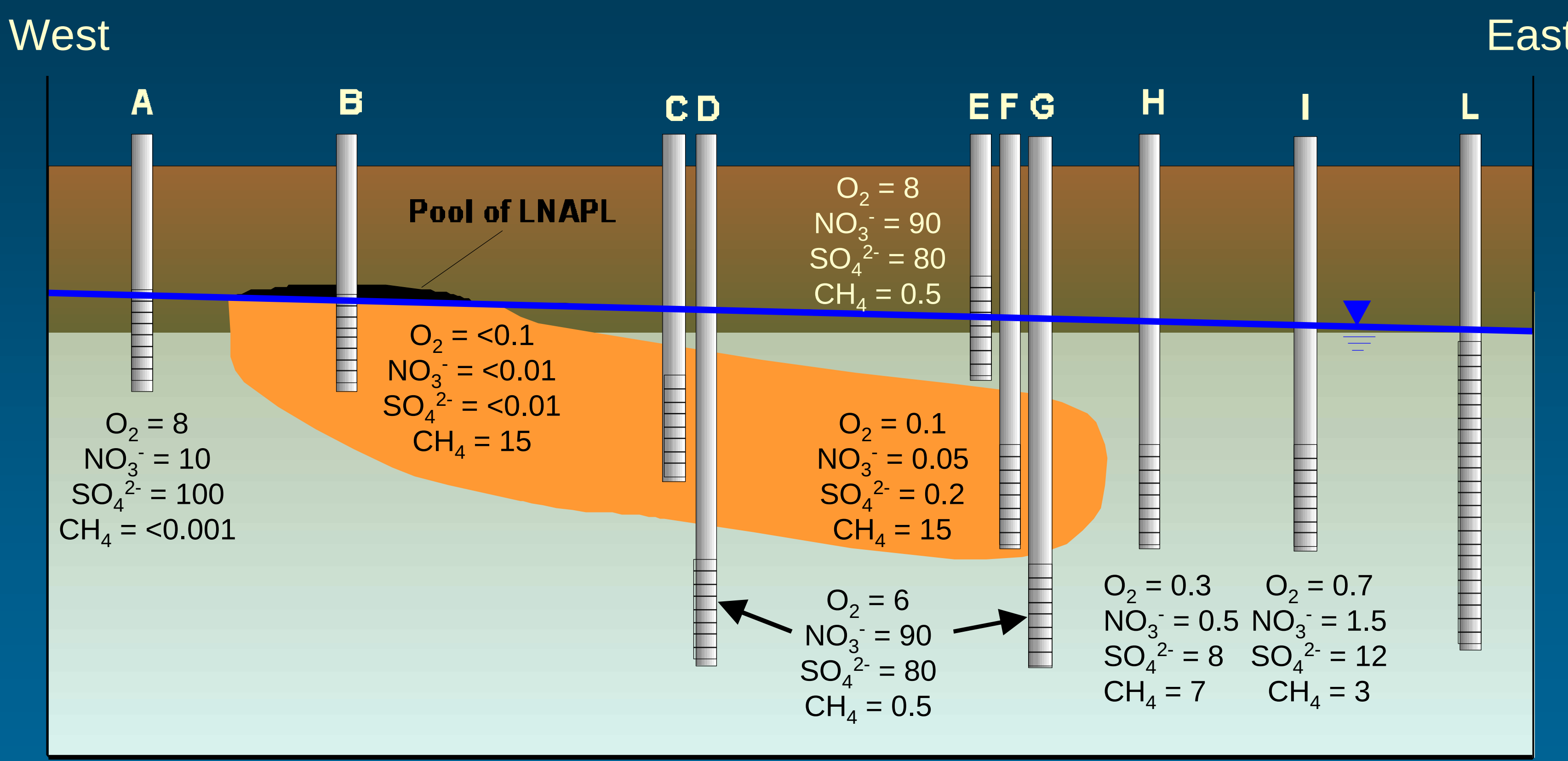


Wells D, E, G, J, and P Have Geochemistry Similar to Wells A and R (i.e., Background) so They Probably Are Not in the Flowpath

Legend

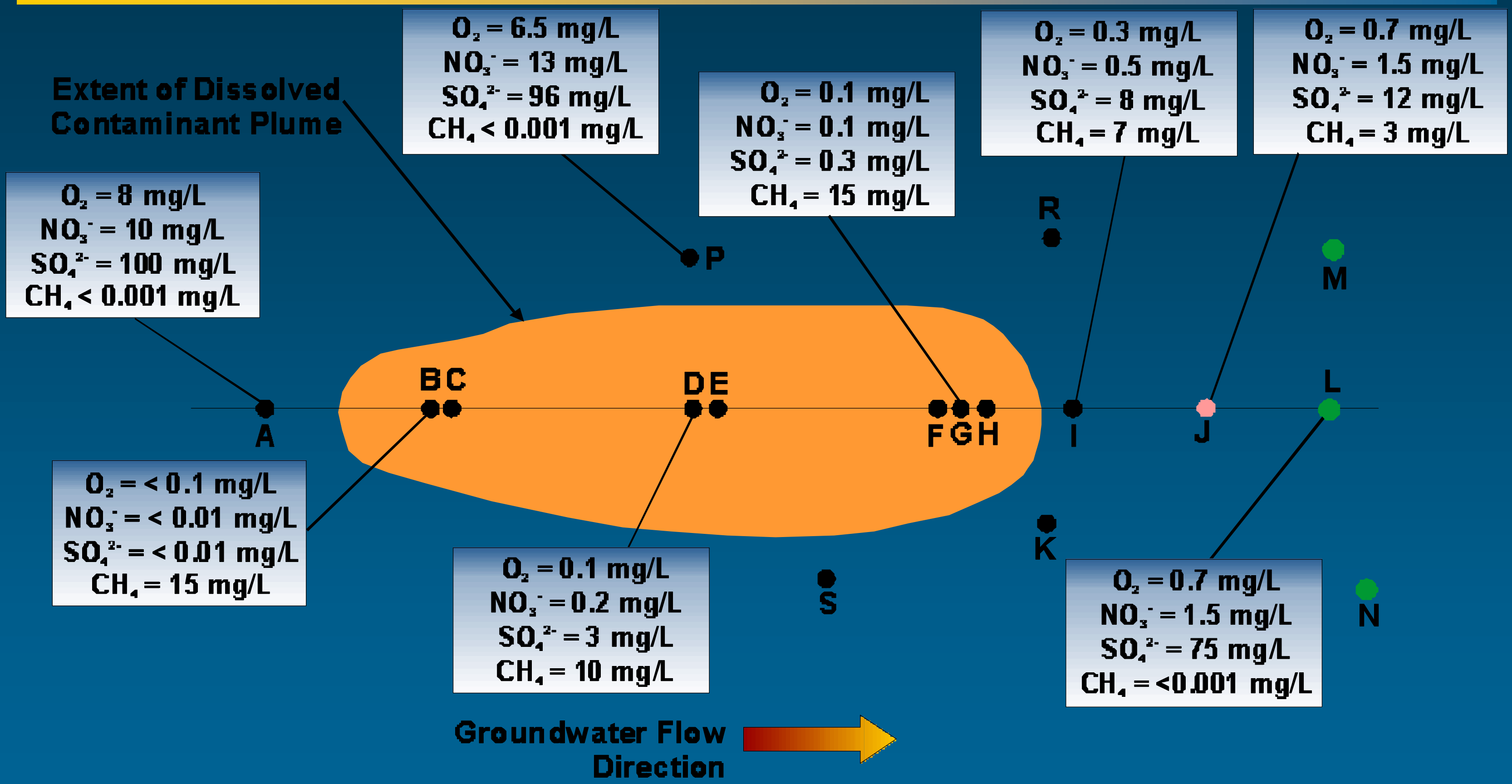
● Performance Monitoring Well ● Sentry Well ● Point-of-Action Well

Well Placement Example - LNAPL



All Concentrations in mg/L

Well Placement Example - DNAPL

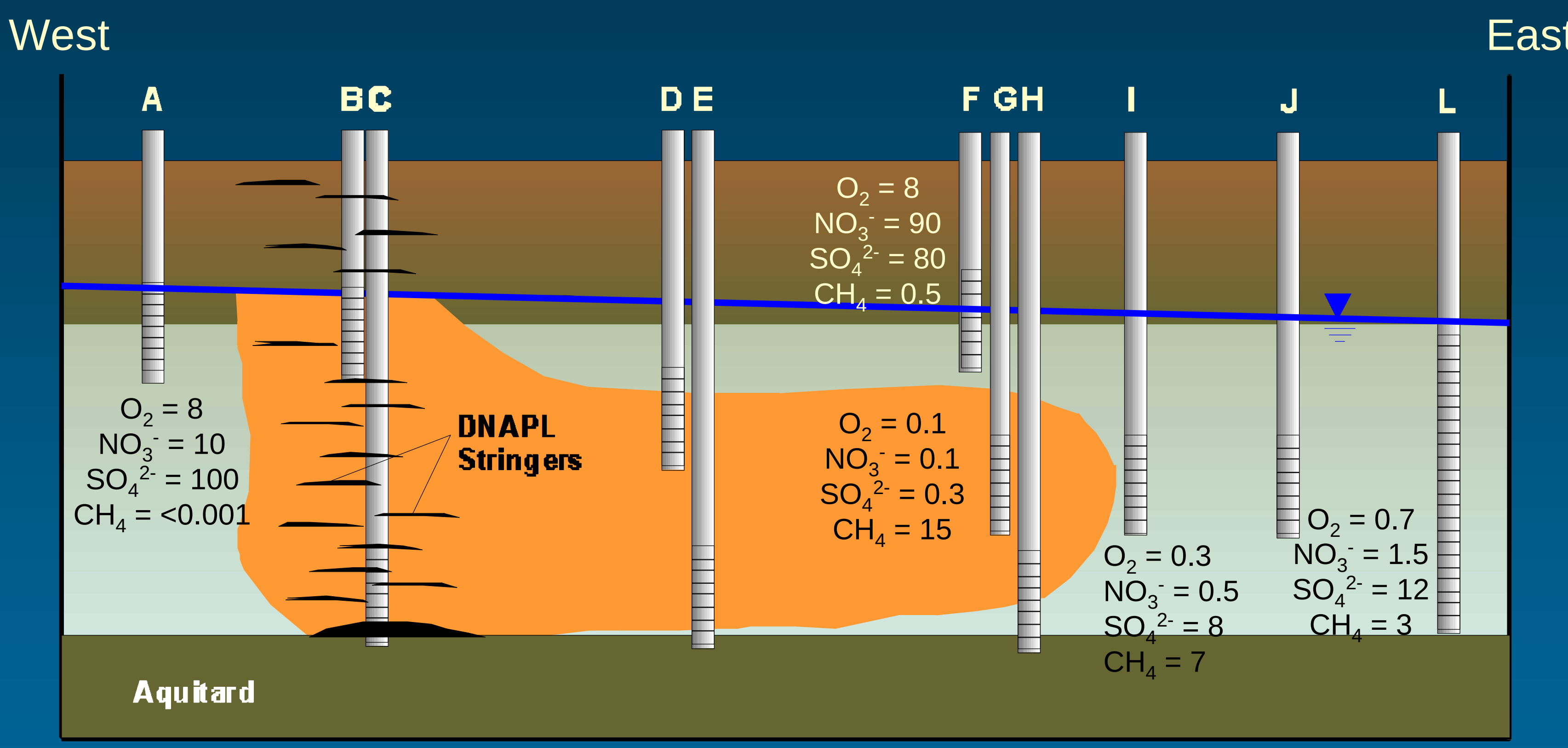


Wells F, R, and S Have Geochemistry Similar to Wells A and P (i.e., Background) so They Probably are Not in the Flowpath

Legend

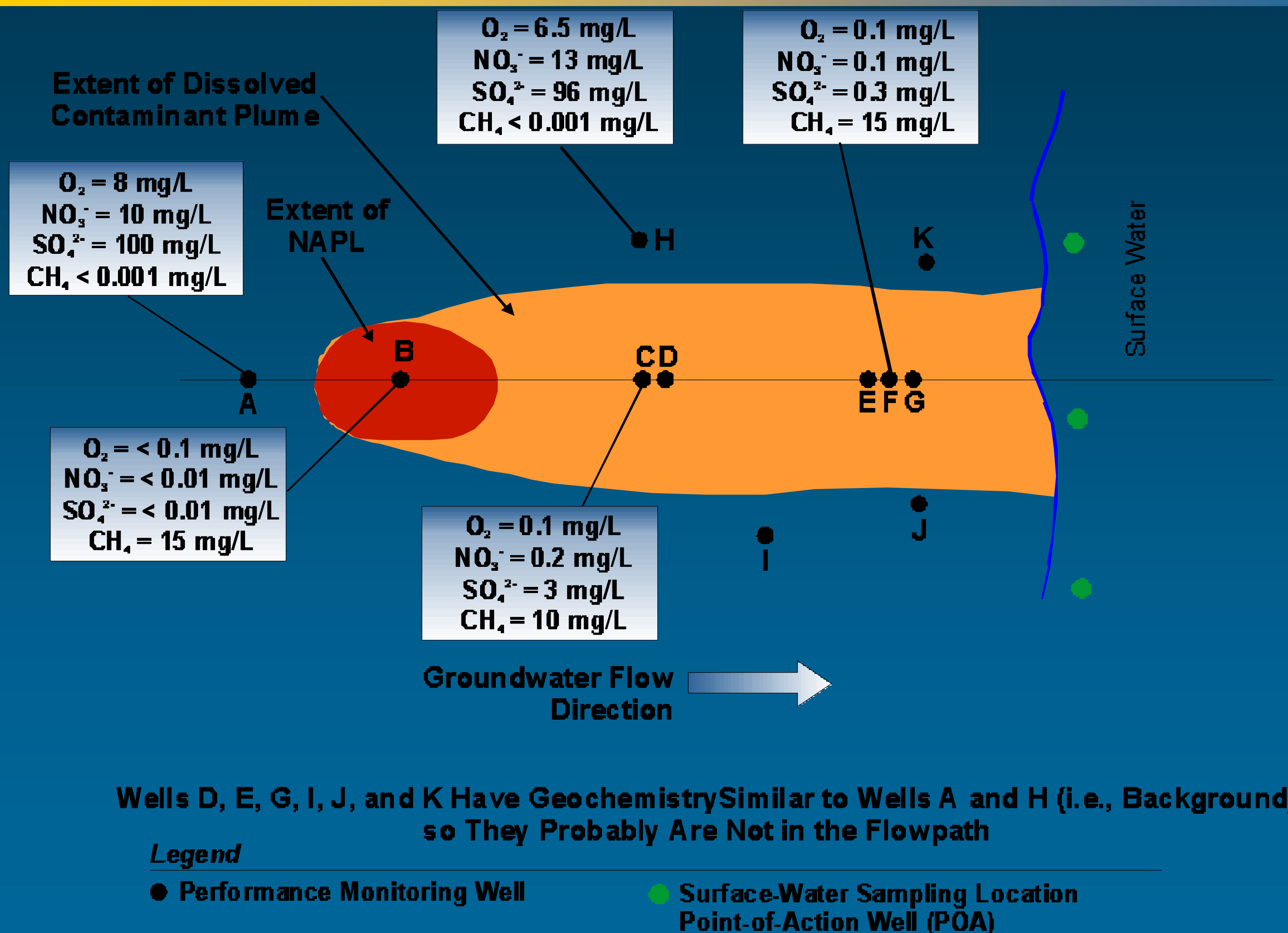
● Performance Monitoring Well ● Sentry Well ● Point-of-Action Well

Well Placement Example - DNAPL

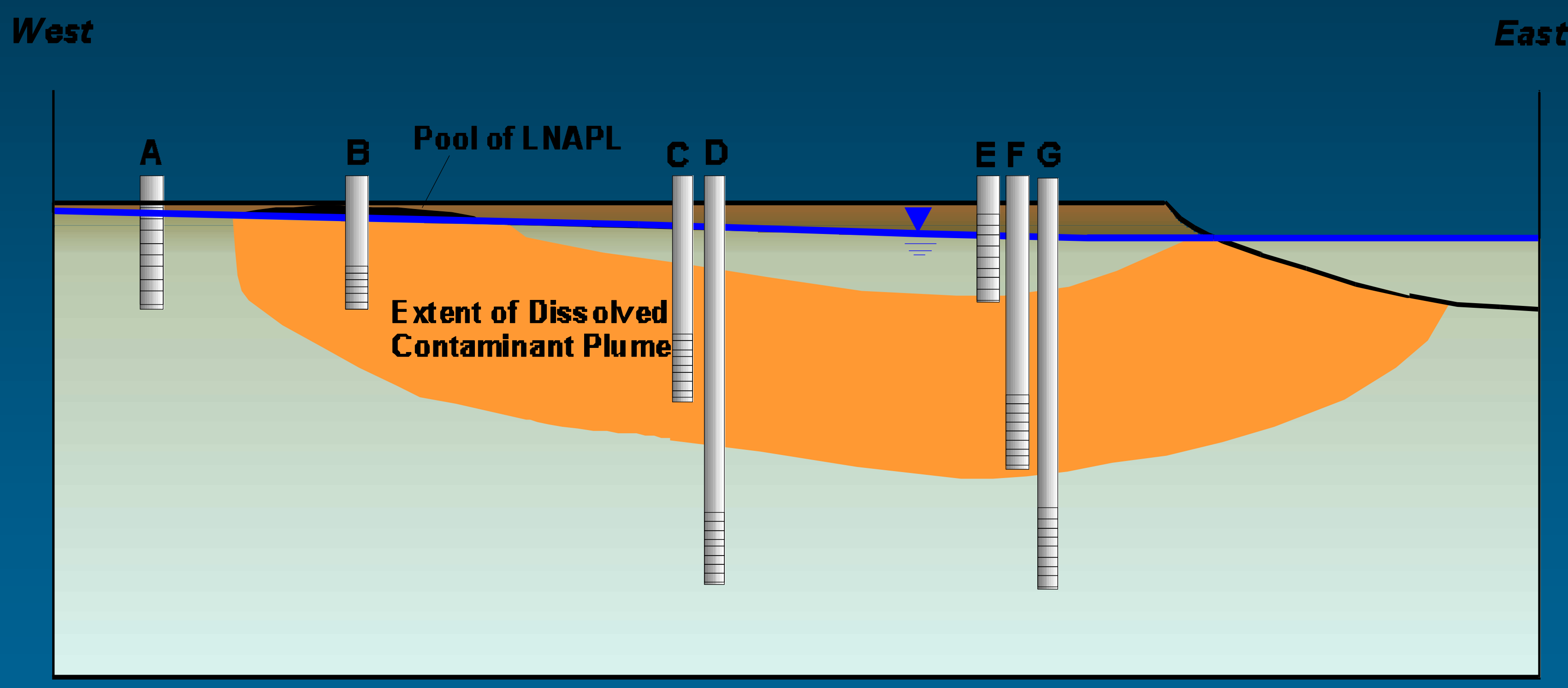


All Concentrations in mg/L

Well Placement Example - Surface Water Discharge



Well Placement Example - Surface Water Discharge



Analytical Protocol

- Sample for Contaminants of Concern
- Sample for DOMINANT Electron Acceptors and Metabolic Byproducts
- Analytical Protocol Will be Different for Fuels versus Solvents

Potential Groundwater Analytes

- Contaminants
- Dissolved Oxygen
- Nitrate
- Fe(II)
- Sulfate
- Methane
- Ethane/Ethene
- Chloride
- Hydrogen (Optional)
- Total Organic Carbon
- Oxidation-Reduction Potential
- Alkalinity
- pH
- Temperature

Sampling Frequency

- **Should Depend on:**
  - **Groundwater Seepage Velocity**
  - **Solute Transport Velocity**
  - **Plume Stability**
  - **Distance to Receptors**

- **Quarterly Sampling Probably Not Necessary in Many Cases**

Sampling Frequency - Example

- **Groundwater Seepage Velocity=100ft/yr**
- **Estimated Retarded Solute Transport Velocity (Sorption Only) = 80 ft/yr**
- **Plume is Stable**
- **Distance to Receptor = 2,400 feet**
- **Worst Case = 24 Years to Receptor**
- **Sampling Every 2 - 5 years probably adequate**

Evaluating Plume Stability

- **Visual Techniques**
  - **Isopleth Maps**
  - **Plots of Contaminant Concentration versus Time**
  - **Plots of Contaminant Concentration versus Distance**
- **Statistical Techniques**
  - **Mann-Kendall and Others**

Visual Techniques

- Qualitative Evaluation of Plume Stability
- Isopleth Maps over Time are Valuable for Identifying Plume Expansion

Statistical Techniques

- Quantitative Evaluation of Plume Stability
- Allows Non-Biased Data Interpretation
- Data that “Looks” Like it Shows a Trend May Not be Statistically Significant

Contingency Plans

- Changing Site Conditions Can Result in Variable Plume Behavior
- Must Have a Contingency Plan Should Natural Attenuation Fail
- Make Sure Changes in Plume Configuration are "Statistically Significant" Before Implementing the Contingency Plan

Contingency Plans

- Contingency Action must be Carefully Selected to:
  - Prevent Plume Migration to Potential Receptors
  - Minimize Detrimental Impacts to the Natural Treatment System

Contingency Plans

Bottom Line

- **The Monitoring Network, Analytical Protocol, and Sampling Frequency Must be Adequate to Detect Plume Migration Before Receptor Impact**

Exit Strategy

- Must Have a Plan to End Monitoring
- Must Have Enough Data to Show that Natural Attenuation Will Remain Effective After Monitoring Ends

Conclusions

- **Natural Attenuation has Emerged in Recent Years as a Viable Remedial Option at Many Sites**
- **Once Natural Attenuation is Applied to all or Part of a Given Site, It Must be Monitored**