Welcome to

Soil Treatability Study

Energy Technology Engineering Center • U.S. Department of Energy

Wendy Green Lowe, Facilitator

U.S. DEPARTMENT OF ENERGY

How we will approach this meeting

Suggested ground rules:

1. Treat others with respect
2. Focus on what unites us rather than on what divides us

"Never underestimate the power of a small group of committed people to change the world. In fact, it is the only thing that ever has."
(Margaret Mead)

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Why we need this study

John Jones, Federal Project Director

Stephanie Jennings, Deputy Federal Project Director

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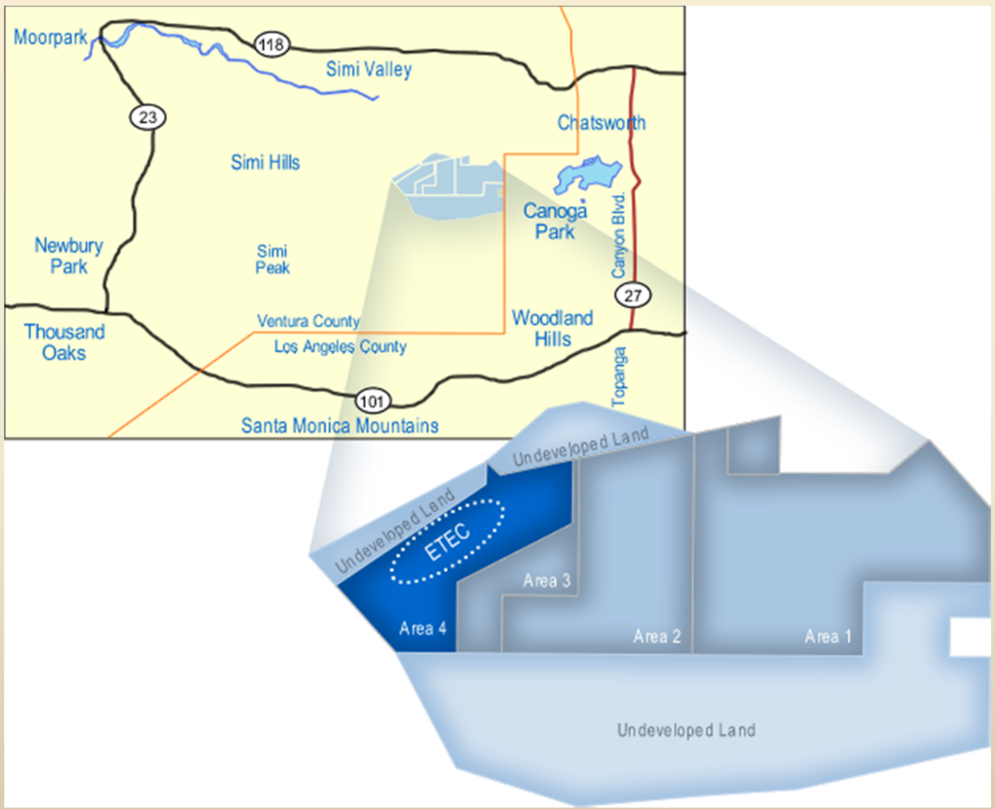

ETEC 1988

ETEC 2005

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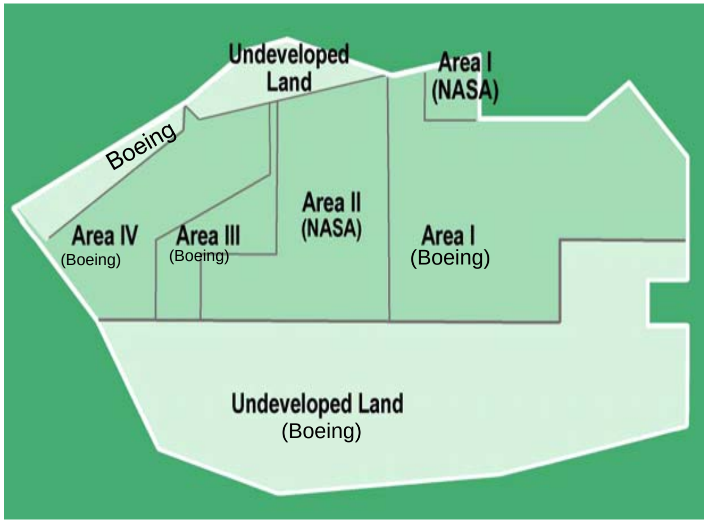
4 Administrative Areas & 2 Buffer Zones

- **Boeing** owns
  - Area I (671 acres)
  - Area III (114 acres)
  - Area IV (290 acres)
  - North Undeveloped Land (182 acres)
  - South Undeveloped Land (1143 acres)
- **NASA** owns
  - Area I (42 acres)
  - Area II (410 acres)
- **DOE** *leases*
  - 90 acres within Area IV
  - Energy Technology Engineering Center (ETEC)

SSFL Administrative Areas

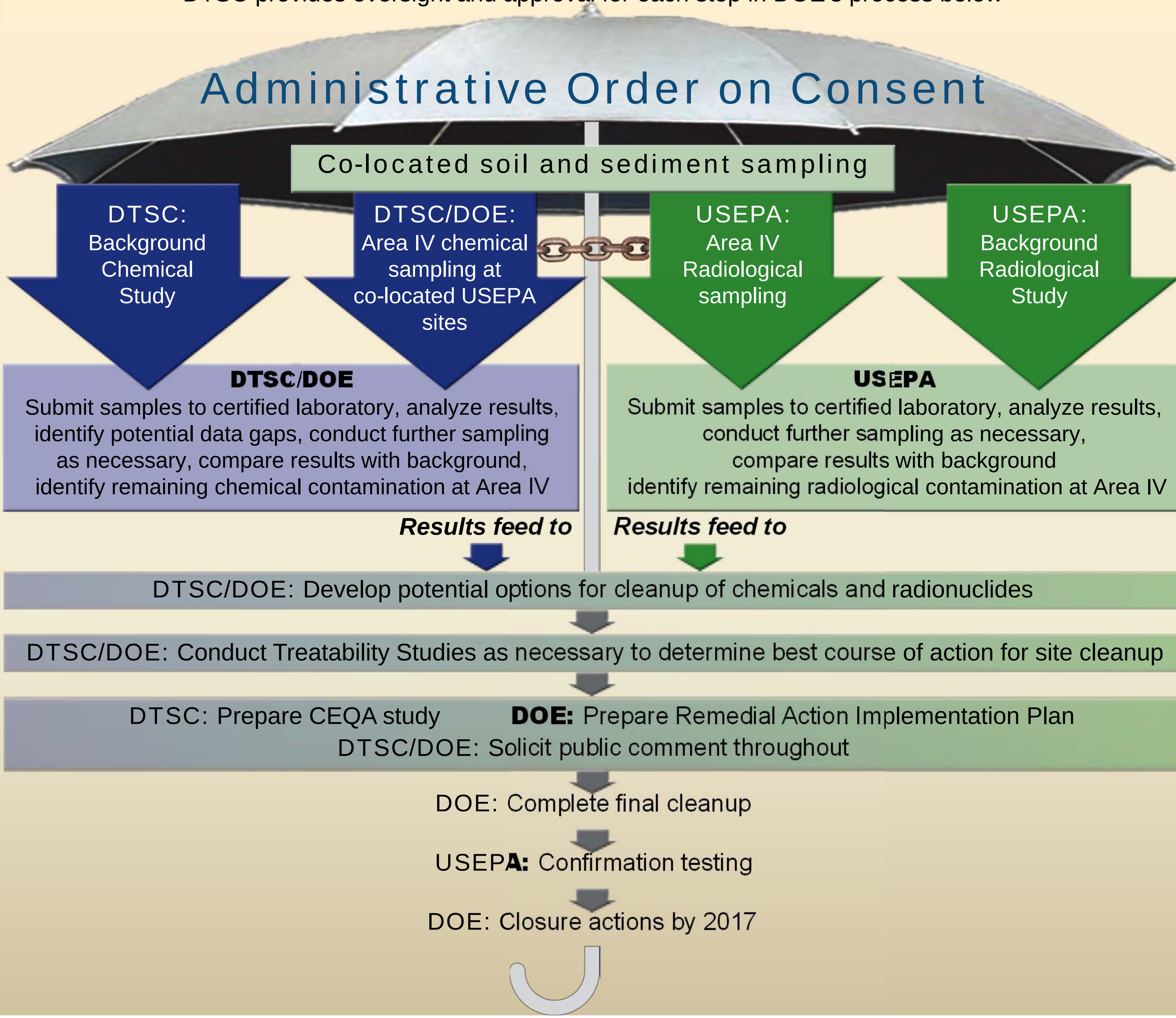


Why are we doing a Soil Treatability Study?

- The 2010 Administrative Order on Consent (AOC) established the goal of cleanup to background for the Energy Technology Engineering Center
- DOE is committed to full compliance with the AOC
- The purpose of the Soil Treatability Study is to investigate the possibility of finding one or more in-situ treatment technologies that could help us comply with the AOC

Process for SSFL Area IV Studies Under AOC

DTSC provides oversight and approval for each step in DOE's process below



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Where we are now?

- The quantity of soil to clean is yet to be determined
- Investigations are on-going
  - EPA investigation of radiological contamination
  - DTSC investigation of chemical contamination
- DTSC is establishing Look-Up Tables
- The Look-up Tables will be used to evaluate the results from the laboratory analysis of soil samples and determine which portions of the site are clean and which will need to be cleaned up

A look ahead

- Once it is clear what portions of the site require clean-up, DOE will determine how best to meet the requirements of the AOC
- In many cases, excavation will be required
- Excavation could entail
  - risk to workers
  - transportation of soil to off-site licensed disposal site(s)
  - risk to on-site archaeological resources
  - risk to habitat for plants and wildlife found at the site.

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The Results of the Soil Treatability Study

- Will help us determine when excavation is the only way we could comply with the AOC and when and if other approaches could help us get there
- Will inform decisions about how to best accomplish the requirements in the AOC
- Will be documented, along with other plans for meeting the requirements in the AOC, in a Soils Remedial Action Implementation Plan – an enforceable document that will drive the cleanup of the soils at ETEC

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What we hope to find

- One or more technologies that could reduce levels of contamination significantly enough to:
  - Reduce the overall quantity of soil that will have to be excavated and transported to off-site disposal site(s)
  - Reduce the level of contamination to allow selection of different off-site disposal site(s)

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Introducing Our Contractors

- Sandia National Laboratories
  - Dr. Christi Leigh
  - Tricia Johnson
  - Janis Trone
- P2 Solutions
  - Wendy Green Lowe

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Tonight's Agenda

Welcome	6:30 – 6:50 pm
Wendy Lowe (P2 Solutions) and John Jones & Stephie Jennings (DOE)	
How Sandia will Conduct the Soil Treatability Study	6:50 – 7:10 pm
Christi Leigh (Sandia)	
Common Contaminants: Chemical Types & Properties	7:10 – 7:30 pm
Laura Rainey (DTSC)	
On-site Soil Remediation Alternatives	7:30 – 7:50 pm
Tricia Johnson (Sandia)	
How the Public can Participate in this Process?	7:50 – 8:00 pm
Wendy Green Lowe (P2 Solutions)	

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How Sandia Will Conduct the Soil Treatability Study

ETEC Public Meeting; October 25, 2011

Christi D. Leigh, PhD

Repository Performance Department, 6212

SAND2011-8055P

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NNSA National Nuclear Security Administration

Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

What is the goal of clean-up?

- Soils that contain chemical and/or radiological contaminants will be cleaned-up to background levels.
- Soils that can not be cleaned-up to background will be removed.
- Clean-up to background will not include "leave in place", onsite burial or landfilling.
- Clean-up alternative in place by 2017.

(Per the Agreement in Principle, September 2010)

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What are the remediation standards?

- Environmental Protection Agency (EPA) will determine local background levels and minimum detection limits (for those contaminants whose minimum detection limits exceed local background concentrations) for radioactive contaminants.
- California Department of Toxic Substances Control (DTSC) will determine local background levels and minimum detection limits (for those contaminants whose minimum detection limits exceed local background concentrations) for chemical contaminants.
- EPA and DTSC will conduct verification sampling to confirm clean-up.

What is an optimum strategy?

- One that returns the soil to background levels for COIs
  - Most technologies address a single type of contaminant (i.e. organics, metals or volatiles).
  - Many technologies are limited in their ability to completely remediate.
  - Some technologies may interfere with the application of other technologies.
- One that does not amplify the problem or create another problem
- One that minimizes the volume of soil to be removed from the site

How will we select viable technologies for the ETEC site?

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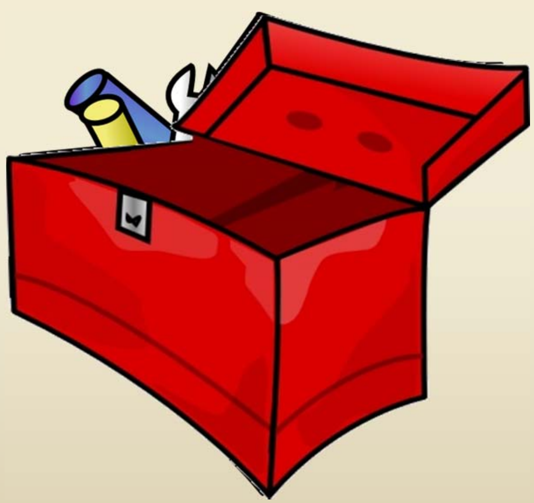

Soils Remedial Action Implementation Plan

How do we put that toolbox together?

→

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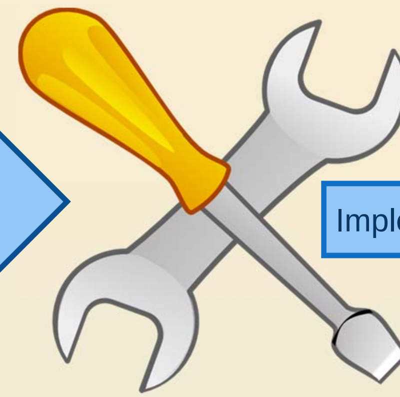

→ Implementation

Many Technologies are Available	Many Criteria Must be Considered	Technology Groupings will Emerge
Phase I *Literature Search* *Stakeholder Input*	Phase II *Down Select Based on Criteria*	Phase III *Choose Technologies for Bench- or Pilot-Scale Testing*

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Phase II criteria may include

- Technology Description – Does the technology fit the definition of "IN-SITU" or "ON-SITE."
- Development Status – What is the maturity of the technology (emerging, in development, or proven)?
- Targeted Contaminants – What contaminants does the technology treat?
- Effectiveness and Dependability - To what degree can the technology reliably remediate the targeted contaminants?
- Applicability – Under what conditions is this technology applicable?
- Time to Treat – How long does it take to treat a typical area or site?
- Availability – How many vendors offer this technology?

Possible technology groups

- Type of Technology
  - Biological (including Phytoremediation)
  - Physical/Chemical
  - Thermal
  - Other
- Type of Contaminant
  - VOCs
  - SVOCs
  - TPHs
  - PCBs
  - Metals
  - Dioxins
  - Explosives

Bench- and pilot-scale testing

- Bench-Scale Testing
  - Generally conducted in a laboratory under very controlled conditions.
  - Used as a general “proof-of-principle” test.
  - Considered for technologies that have not been fielded or that are being considered for use in an application that is unproven.
- Pilot-Scale Testing
  - Will be conducted on the ETEC site.
  - Used as specific “proof-of-principle” test.
  - Considered for technologies that have been fielded in conditions similar (site characteristics and contaminants) to those at ETEC.

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What will the toolbox include?

- Will Recommend
  - Technologies for a given contaminant.
  - Technologies for representative soil types, depths, and conditions.
  - These are the technologies that could be used.
- Will Not Recommend
  - Technology to be used on a specific contaminant.
  - Technology to be used on a specific ETEC area.
  - What the DOE should do.

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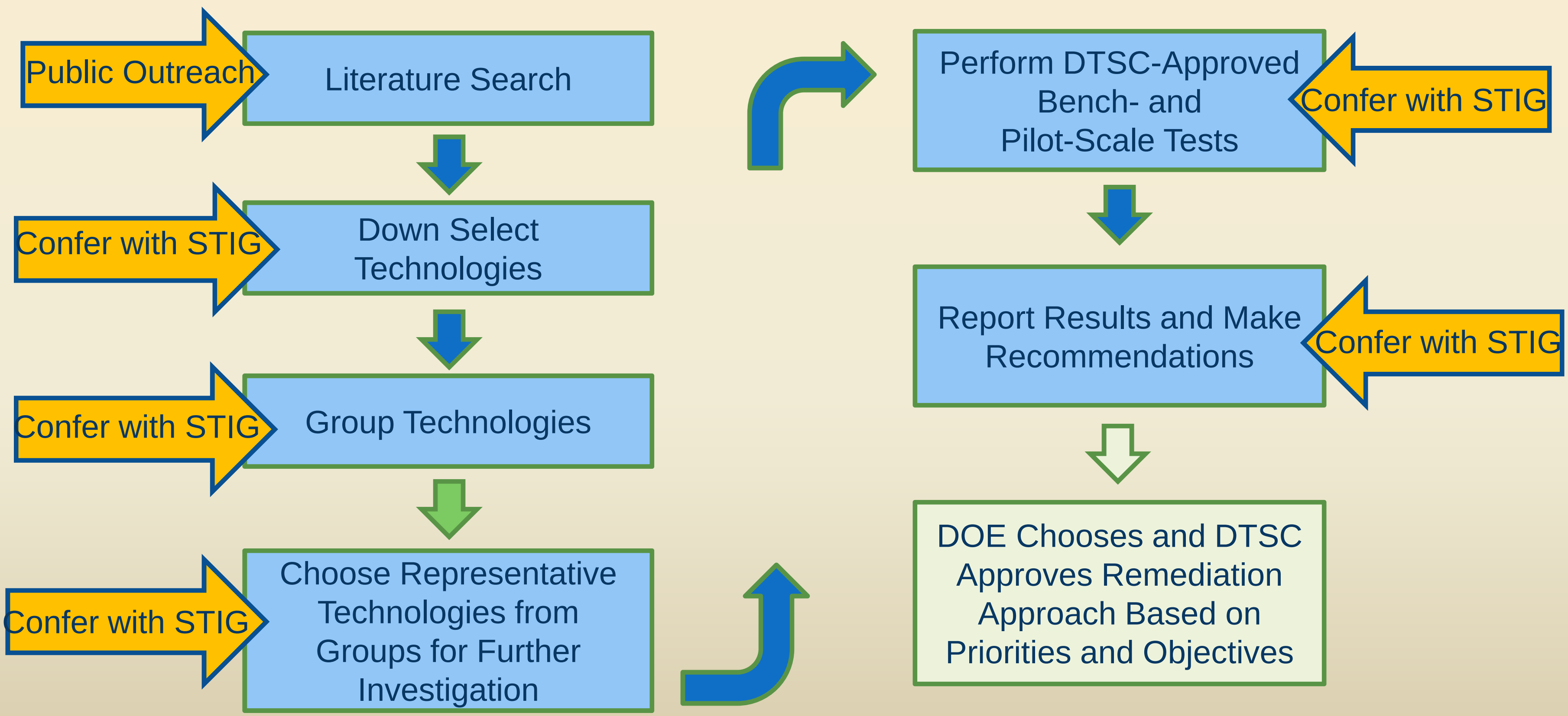
The process includes public involvement at each stage



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Common Contaminants: Chemical Types and Properties

Laura Rainey

California Department of Toxic Substances Control

California Department of Toxic Substances Control

Recent Chemical Results

- This overview is based on a review of the most recent chemical co-located sampling results – About 600 surface and subsurface soil samples
- The first subareas sampled are less contaminated than other subareas, but trends are similar to prior data

ETEC Research Background

- ETEC – major focus on liquid metals testing – cooling and heat transfer purposes:
  - Sodium
  - Potassium
  - Mercury
- ETEC also had a focus on studies of the properties of metals:
  - Many metals tested for compatibility and durability – extreme heat and pressure
- ETEC focus on component testing – needed to know when piping, valves, vessels, fixtures could possibly fail

Common Contaminants—Metals

- **Common metal contaminants**
  - Mercury
  - Lead
  - Silver
  - Chromium
  - Cadmium
- **Important Properties**
  - Not volatile – except mercury
  - Typically of low solubility
  - Cannot be destroyed

Common Contaminants—VOCs

Volatile Organic Compounds (VOCs)

Chemicals that typically are liquid at room temperature – but can quickly volatilize – become gaseous

- Chlorinated solvents such as trichloroethylene (TCE)
- Fuel constituents such as benzene and toluene (also used as solvents)
- Alcohols such as ethanol and methanol (used as solvents and represent degradation of other organic chemicals)

VOCs —Properties

- VOC Properties
  - Readily convert to gaseous state
  - Typically soluble in water
  - Most mobile of chemical types
  - Chlorinated VOCs tend to be more persistent than non-chlorinated VOCs

Common Contaminants—Semi-Volatile Organic Chemicals

- As their name indicates, the SVOCs exhibit volatility, but less than the VOCs
- The SVOCs analyzed are actually a complex group of large chemical molecules that are grouped for chemical analysis purposes
  - Includes:
    - Chemicals that are chlorinated
    - Chemicals that are more petroleum based – not chlorinated
    - Chemicals that have nitrogen as an element in their structure

Common Contaminants—PAHs

- Polycyclic Aromatic Hydrocarbons (PAHs) most frequently observed SVOC at site
  - Have both a natural and man-made origin
    - Occur in tars, asphalt, creosote, etc
    - Created from burning of organic matter
  - Many different PAH chemicals with varying degrees of volatility and solubility
- Less mobile than VOCs – adsorb to soil
- More easily degradable than chlorinated SVOCs

Common Contaminants—Chlorinated SVOCs

- Chlorinated SVOCs
  - Solvents, process chemicals, and pesticides
  - Varying solubility and volatility
  - Typically persistent – long lasting – due to chlorination
  - Also adsorb to soil and exhibit low mobility

Common Contaminants—NDMA

N-Nitrosodimethylamine (NDMA)

- Contains nitrogen
- Found in water and rubber products
- Properties
  - Violatility
    - If released to surface soil, a substantial proportion of NDMA will volatilize
    - If incorporated into subsurface, the rate of volatilization will be greatly reduced
  - Solubility - Highly soluble in water
  - Persistence - Microbial degradation could be a significant factor in the removal process

Common Contaminants—PCBs

Polychlorinated Biphenyls (PCBs)

- A universally used industrial chemical prior to the 1970s
  - Transformers
  - Electronics
  - Hydraulic fluids
- Used because PCBS are highly stable under pressure and high temperatures
- PCBs are a complex mixture of chemicals differing in the degree of chlorination
- Use of PCBs stopped due to their persistence in the environment

Common Contaminants--PCBs

- Properties
  - Typically of low volatility
  - Typically of low solubility
  - Adsorb strongly to soil, reduces mobility
  - Very stable, difficult to destroy

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Common Contaminants—Dioxins

Dioxins –dibenzo-p-dioxins and furans

- Complex group of chlorinated chemicals
- Created industrially as impurities in chlorinated chemicals, pesticides, and herbicides
- Created naturally when organic matter burns
- Therefore observed frequently in surface soil
- Properties
  - Low solubility and volatility
  - Adsorb strong to soil
  - Very persistent

Common Contaminants- Perchlorates

- Chemical found in explosives, fuels, and fertilizers
- Localized detects observed in soil in Area IV
- Properties
  - Low volatility
  - High solubility
  - Very persistent
  - Conducive to microbial degradation
- Bio-remediation project successful at Santa Susana in Area I

Common Contaminants– Petroleum Hydrocarbons

- Long-chain organic molecules found in fuel oils, diesel, and gasoline
- Observed at waste disposal areas at SSFL
- Properties
  - Volatility varies with complexity of molecules
  - Solubility also varies, typically low
  - Degradable in the environment

Path Forward

Some examples of the kinds of questions that the Treatability Study needs to consider:

- Volatility:
  - Does it have sufficient volatility to remove contaminants?
- Solubility
  - Is it soluble enough to induce mobilization?
- Persistence—Biodegradation
  - Is it amenable to degradation by bacteria?

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On-Site Remediation Alternatives

ETEC Public Meeting; October 25, 2011

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On-Site Remediation Alternatives

- In order to reduce or eliminate the amount of soil that needs to be excavated, the following on-site remediation alternatives will be evaluated for their feasibility:
  - Phytoremediation
  - Bioremediation
  - Physical/Chemical
  - Thermal
  - Other - Nanotechnology

Phytoremediation

- Process whereby plants intake or hyperaccumulate contaminants into the plant, thereby reducing the concentrations of contaminants in the soil
- Phytoremediation Video.flv
- Ideal Application – Typically effective for clean up of metals, radionuclides, PCBs, solvents, explosives, and hydrocarbons
- Pros/Cons
  - Pros – Green technology, visually appealing, low impact, passive
  - Cons – Extended clean-up period, limited by depth and soil types, additional technology required for plant disposal, potential use of non-native plant species, maintenance of plants, select plants will phytorespire contaminants

Phytoremediation Examples

- Metals reduction utilizing indian mustard, paulownia trees, poplar trees, willow trees, vetvier grass, sunflowers, alpine pennycress (especially effective for nickel), and lupine (releases citrate that stimulates uptake by other species)
- Uranium reduction utilizing beet, indian mustard, and blue stem varieties
- Explosives and dioxin reduction utilizing poplar, cottonwood, and paulownia trees
- Solvent/TCE reduction utilizing poplar and paulownia trees
- PCB reduction utilizing osage orange and mulberry trees
- Hydrocarbon reduction utilizing wheat and gramma grasses
  - phytopet.usask.ca includes a list of hydrocarbon specific species

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Bioremediation

- The use of microorganisms to enhance biodegradation or removal of contaminants; through stimulation of naturally existing species or introduction of non-natural species to enhance biodegradation.
- Bioremediation Video.flv
- Ideal Application – Typically effective for clean up in low permeability soils for petroleum hydrocarbon, solvent, metals, and radioactive contaminants
- Pros/Cons
  - Pros – Relatively low impact, in-situ reduction of COIs, enhancement of natural processes
  - Cons – Limited by soil types, possible lack of control of stimulated microbes, introduction of bacteria

Bioremediation Examples

- Slurry-phase bioremediation - Soils are mixed in water to form a slurry to keep solids suspended and microorganisms in contact with the soil contaminants
- Solid-phase bioremediation - Soils are placed in a cell or building and tilled with added water and nutrients and include land farming, biopiles, and composting
- In-situ bioremediation - Techniques stimulate and create a favorable environment for microorganisms to grow and use contaminants as a food and energy source.
  - Digestion technology - a symbiotic consortium of anaerobic bacteria retained as an attached biofilm on a non-clogging vertical spindle array of geo-textile panels.

Physical/Chemical

- Physical/chemical treatment uses the physical properties of the contaminants or the contaminated medium to destroy (i.e., chemically convert), separate, or contain the contamination.
- Ideal Application – Typically effective for confined areas of well-defined soils with contamination that includes solvents, hydrocarbons, organics, and metals
- Pros/Cons
    - Pros – Effective, faster clean up alternatives that can be completed in-situ, and required equipment is typically readily available
    - Cons – Typically requires an extensive well network, treatment wall involves introduction of substances in-situ, select methods sensitive to soil type, treatment residuals will require treatment or disposal, extraction fluids from soil flushing will increase the mobility of the contaminants, so provisions must be made for subsurface recovery.

Physical/Chemical Examples

- Soil vapor extraction - Uses the contaminant's volatility to separate it from the soil.
- Soil flushing - Uses the contaminant's solubility in liquid to physically separate it from the soil, surfactants may be utilized to increase the solubility of a contaminant.
- Solidification/stabilization – Solidification encapsulates the contaminant, while stabilization physically alters or binds with the contaminant.
- Pneumatic fracturing - An enhanced technique that physically alters the contaminated media's permeability by injecting pressurized air to develop cracks in consolidated materials.
- Electrokinetic separation - Relies upon application of a low-intensity direct current between ceramic electrodes that are divided into a cathode array and an anode array. This mobilizes charged species, causing ions and water to move toward the electrodes.

Thermal

- In-Situ - Application of heat to polluted soil and/or groundwater in-situ to destroy or volatilize organic chemicals. As the chemicals change into gases, their mobility increases, and the gases can be extracted via collection wells for capture and cleanup in an ex situ treatment unit.
- Ex-Situ – Involves the destruction or removal of contaminants through exposure to high temperature in treatment cells, combustion chambers, or other means used to contain the contaminated media during the remediation process.
- Ideal Application – Typically effective for defined areas of contamination that include organics, PCBs, solvents, pesticides, and polyaromatic hydrocarbons (PAHs)
- Pros/Cons
  - Pros – Particularly useful for dense or light nonaqueous phase liquids (DNAPLs or LNAPLs), effective reduction/removal, short time periods (particularly for ex-situ)
  - Cons – Off-gas systems typically required, well network may be required, labor and energy intensive, select technologies are limited in depth and size of area

Thermal (In-Situ) Examples

- Electrical resistance heating - Uses arrays of electrodes installed around a central neutral electrode to create a concentrated flow of current.
- Hot air/steam/water injection - Completed via injection wells, heats the soil and ground water and enhances contaminant release. Hot water injection also displaces fluids and decreases contaminant viscosity.
- Radio frequency heating - Uses electromagnetic energy to heat soil and enhance soil vapor extraction.
- Thermal conduction/desorption - Supplies heat to the soil through steel wells or with a blanket (for shallow contamination) that covers the ground surface. As the polluted area is heated, the contaminants are destroyed or evaporated.
- Vitrification - Uses an electric current to melt contaminated soil at elevated temperatures. Upon cooling, the product is a chemically stable, leach-resistant, glass and crystalline material similar to obsidian or basalt rock. Vitrification can be conducted in situ or ex situ.

Thermal (Ex-Situ) Examples

- Thermal desorption - Application of heat to excavated wastes to volatilize organic contaminants and water.
- Incineration – High temperatures are used to volatilize and combust (in the presence of oxygen) halogenated and other refractory organics.
- Hot gas decontamination - Involves raising the temperature of contaminated solid material or equipment, and the gas effluent from the material is treated in an afterburner system to destroy all volatilized contaminants.
- Plasma high-temperature recovery - Uses a thermal treatment process applied to solids and soils that purges contaminants as metal fumes and organic vapors. The vapors can be burned as fuel, and the metals can be recovered and recycled.
- Pyrolysis - Chemical decomposition induced in organic materials by heat in the absence of oxygen, which forms gases that may require further treatment.
- Thermal off-gas treatment - Used to cleanse the off-gases generated from primary treatment technologies, such as air stripping and soil vapor extraction.
- Vitrification - Uses an electric current to melt and solidify contaminated soil.

Other - Nanotechnology

- Use of nanoscale materials and taking advantage of highly reactive materials because of the large surface area to volume ratio and the presence of a larger number of reactive sites. These properties allow for increased contact with contaminants, thereby resulting in rapid reduction of contaminant concentrations.
- Ideal Application – Research indicates effective clean-up for tetrachloroethene (PCE), TCE, cis-1,2-dichloroethylene (c-DCE), vinyl chloride (VC), and 1-1-1-tetrachloroethane (TCA), polychlorinated biphenyls (PCBs), halogenated aromatics, nitroaromatics, metals such as arsenic and chromium, and nitrate, perchlorate, sulfate, and cyanide.

Other - Nanotechnology

- Proven technology – Utilized since the early 1990s, properties of metallic substances such as elemental iron have been used to degrade chlorinated solvent plumes in groundwater.
- One example of an *in situ* treatment technology for chlorinated solvent plumes is the installation of a trench filled with macroscale zero-valent iron (ZVI) to form a permeable reactive barrier (PRB).

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How to Stay Involved

Wendy Green Lowe, Facilitator

U.S. DEPARTMENT OF ENERGY

Public Participation Opportunities

- Public Meetings
  - Kick-off Meeting, October 25, 2011
  - Overview presentation on in-situ soil remediation technologies, TBD (still looking for the right presenter)
  - Report on the Final Results of the Study, Summer of 2013
- Soil Treatability Investigation Group (STIG)
  - Interested members of the public
  - DTSC, Boeing, NASA, other interested agencies, and industry representatives
  - Representatives from Sandia, DOE and its contractor staff

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STIG Meetings

Convening soon and will meet every other month:

- Provide suggestions for technologies to evaluate and criteria to use in the down-selection process
- Discuss the results of screening processes
- Review and discuss bench study plans and the results the from bench studies
- Review and discuss pilot study plans
- Make site visits/field trips to visit the pilot studies
- Review and discuss results from pilot studies
- Advise DOE on communication about the Soil Treatability Study with the broader public.

Stay involved

- Sign up tonight for the project specific mailing list
- If you are interested in sitting on an advisory body that will stay very involved, sign up to be a member of the Soil Treatability Investigation Group