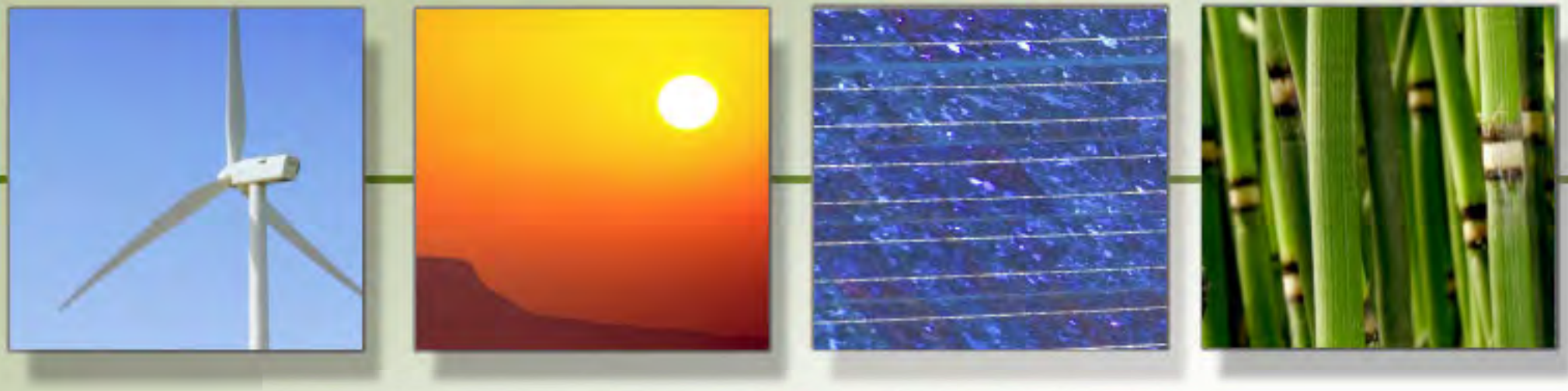

green remediation solutions

VEG Mobile Thermal Treatment Technology

2021

Tim Naughton, PE
www.endpoint-inc.com

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COMPANY OVERVIEW-Endpoint Consulting, Inc.

Endpoint Consulting, Inc., is a small, woman-owned business enterprise (WBE), certified by the SBA.

We provide:

- Environmental Investigation and Risk Management Services
- Environmental Resource Protection
- Regulatory Compliance
- Patented Green & Sustainable Technologies
  - VEG Mobile Thermal Desorption Technology Award-winning soil remediation and enhanced oil/NAPL recovery technology

Environmental Consulting

VEG Soil Remediation Technology

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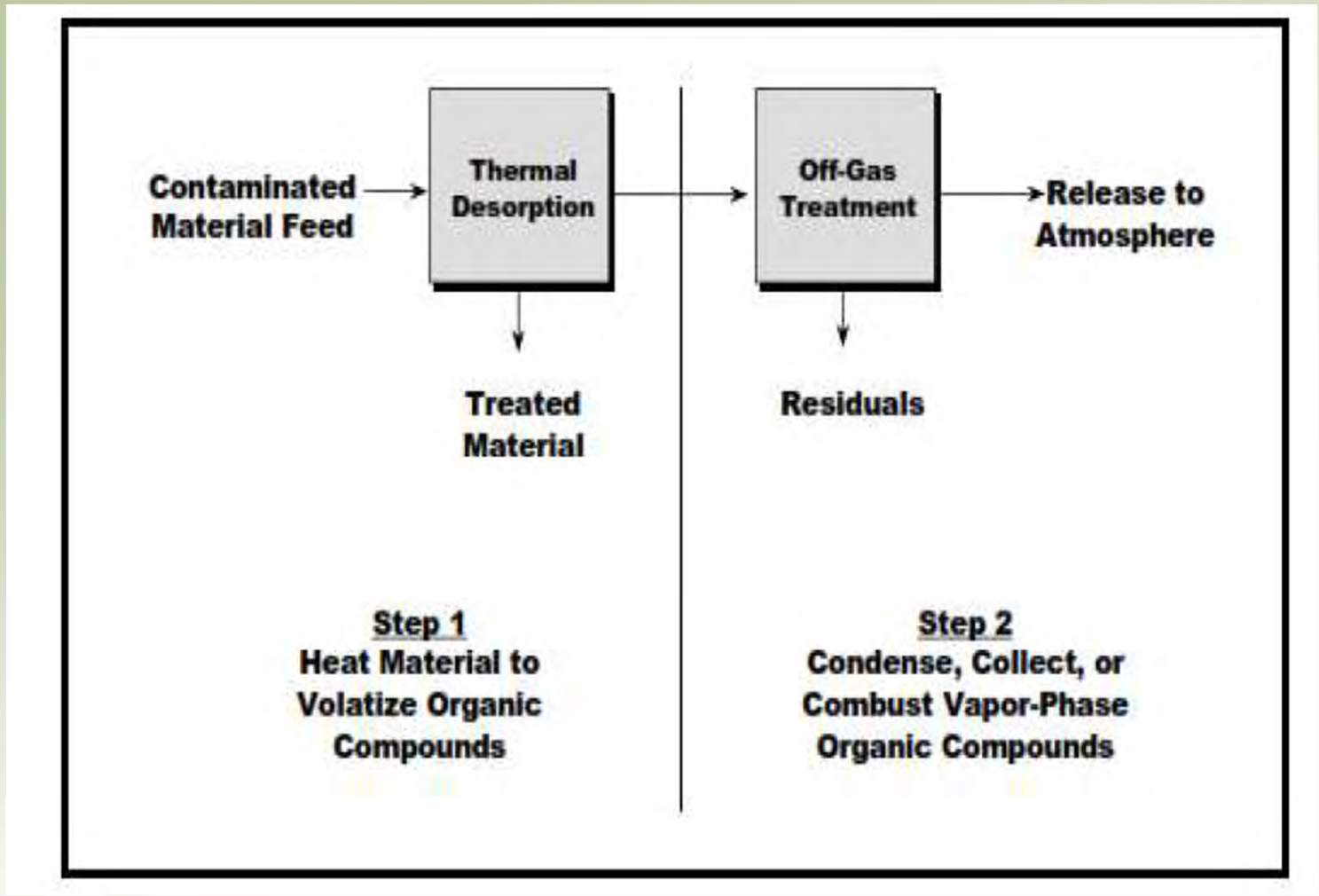
OVERVIEW OF THERMAL DESOPRTION TECHNOLOGY

Generic Thermal Desorption Process



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OVERVIEW OF THERMAL DESOPRTION TECHNOLOGY

Soil Properties Impacting Thermal Desorption

- **Particle Size distribution** - fine-grained material (<0.075mm) may be carried over (exit via the gas phase rather than the treated residue)
- **Soil Composition** - Degree of sand, clay, silt, rock, debris important to both heat transfer and material handling
- **Soil Plasticity** - Degree of material deformation without shearing affects slumping and formation of larger particles with low surface area to volume ratios
- **Soil Bulk Density** - Important for conversion between cubic yards and tons (Vendors typically estimate heat and mass balance relationships using weight- rather than volume-basis, while volume is typically used as the basis for payment)
- **Permeability** - Important to in-situ applications (e.g, thermal conductive heating) and ex-situ applications involving heat induction
- **Soil Homogeneity** - Important to in-situ applications
- **Moisture Content** - The most critical physical property of all, governing the ability of altering soil temperature to induce thermal desorption

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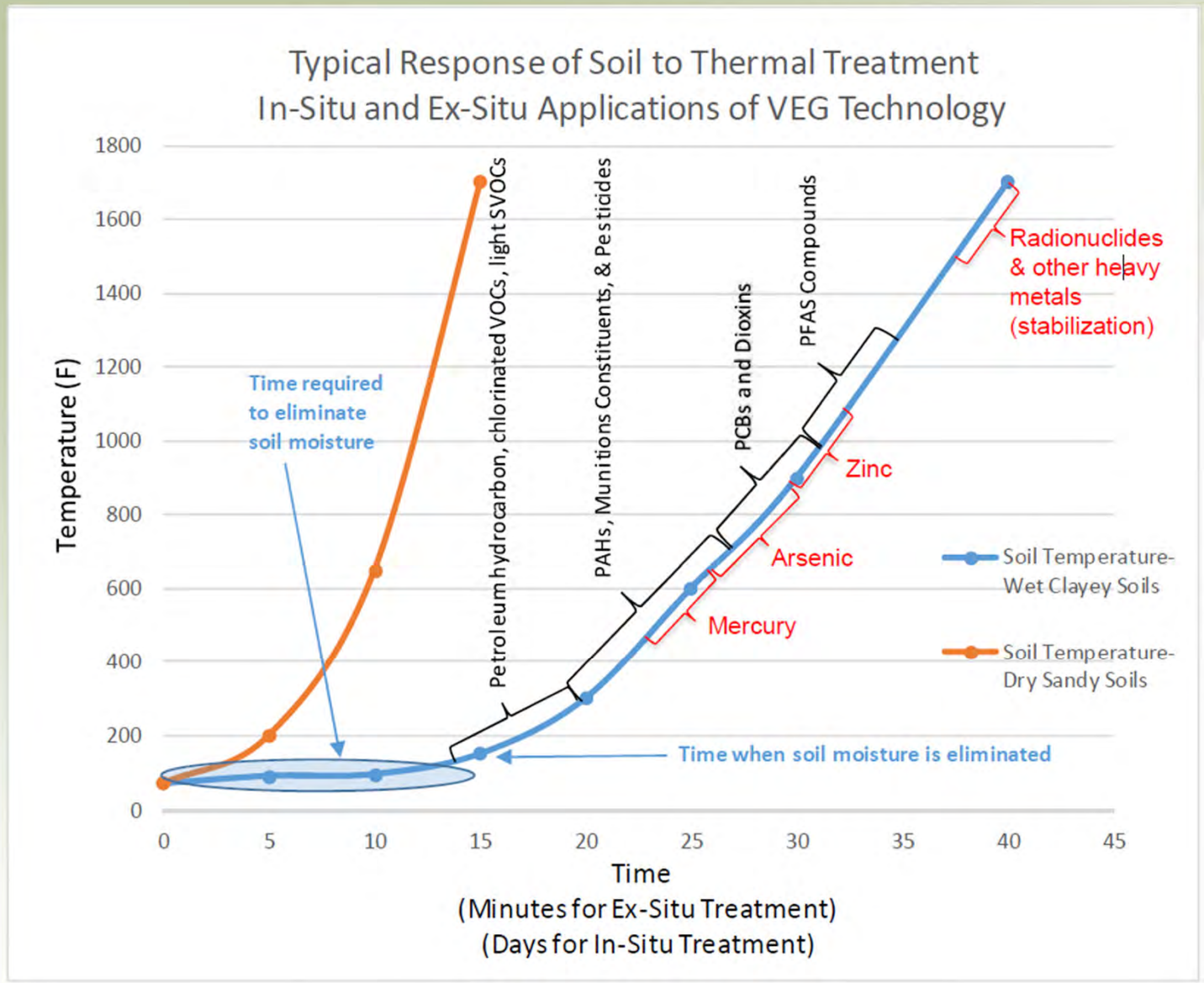
OVERVIEW OF THERMAL DESOPRTION TECHNOLOGY

Ex-Situ Thermal Treatment of Organic Compounds & Select Metals



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OVERVIEW OF THERMAL DESOPRTION TECHNOLOGY

Chemical-Specific Properties Impacting Thermal Desorption

Chemical	Molecular Weight (g/mol)	Boiling Point (F)	Vapor Pressure (Pa @ 20 to 25 C)	Typical Thermal Treatment Temperature Range (F)
Benzene	78.1	176	1.00E+04	150-200
TCE	131.4	189	7.80E+03	150-200
PCE	165.8	250	1.90E+03	150-200
Naphthalene	128.2	424	1.10E+01	200-230
Benzo(a)Pyrene	253	923	6.40E-07	200-230
TNT	227	563	1.60E-04	650-750
RDX	222	453	4.00E-07	650-750
Pentachlorophenol	266	588	1.50E-02	500-650
Dieldrin	380.9	N/A	1.80E-07	650-725
Chlordane	409.8	347	1.30E-03	650-725
Aroclor 1260	376	759	3.08E-04	700-900
PFOA	414	414	6.90E+01	700-800
PFOS	500.1	550	2.60E-03	800-1000

Patented VEG Technology

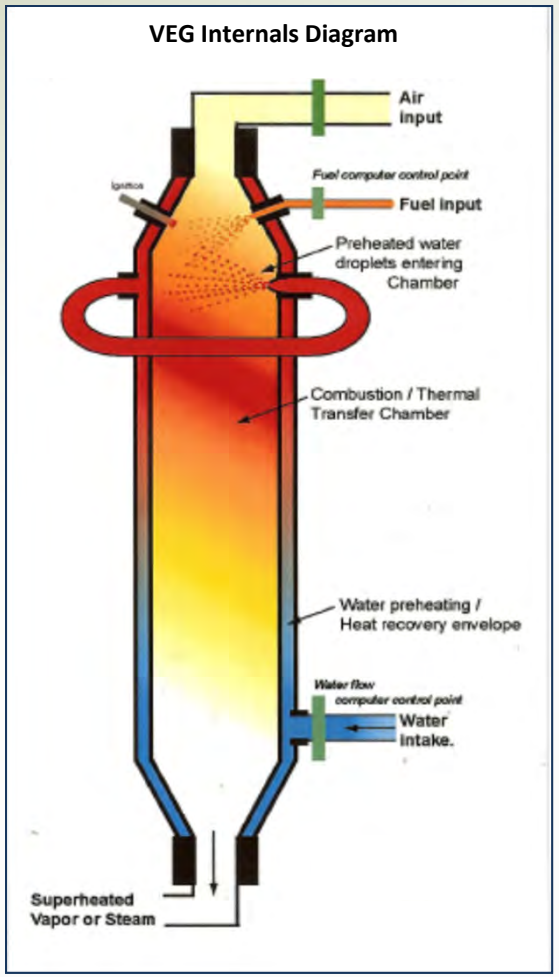
At its core: A mobile, compact, high efficiency vapor generator

– Air, recycled water and propane used to generate steam at 1800 F°

Various In-Situ and Ex-Situ Applications

- **Onsite remediation of soil and construction debris for unrestricted reuse**
  - Full range of TPH's, waste oils, crude oils, refined oils
  - VOCs and SVOCs- BTEX, MTBE, TCE, PCE, VC, PAHs
  - Pesticides, PCBs, PFAS, Munitions constituents- (e.g., TNT, RDX, HMX)
  - Select metals (As, Zn, Hg)
  - Asbestos containing materials-Chrysolite (90% of world production)
  - Per- and Polyfluoroakyl Substances (PFAS and PFOS)

- **Enhanced oil recovery**
  - Unclog and recover refined oil from old, abandoned, and/or frozen aboveground pipelines.
  - Enhanced crude oil recovery from deep oil wells
  - In-situ LNAPL (gasoline and diesel) mobilization and recovery
  - In-Situ steam-enhanced SVE, DPE, alkaline hydrolysis



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VEG Thermal Remediation Technology

VEG In-Situ Soil Remediation System

VEG Ex-Situ Soil Remediation System

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VEG THERMAL REMEDIATION TECHNOLOGY

VEG Ex-Situ Soil Remediation System: Continuous-Feed System

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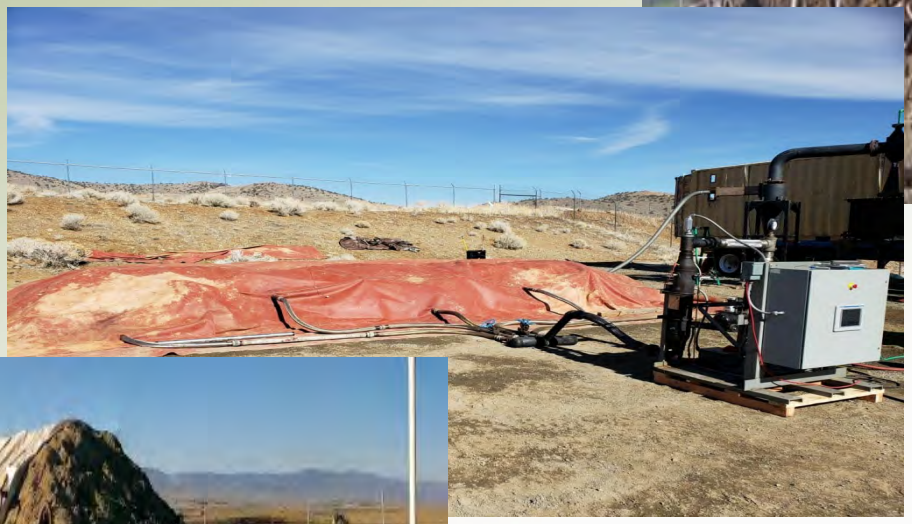
VEG THERMAL REMEDIATION TECHNOLOGY

VEG Ex-Situ Soil System: In-Pile Remediation



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VEG THERMAL REMEDIATION TECHNOLOGY

VEG Ex-Situ Soil Remediation System: Batch-Feed System

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VEG THERMAL REMEDIATION TECHNOLOGY

VEG In-Situ Soil Remediation System

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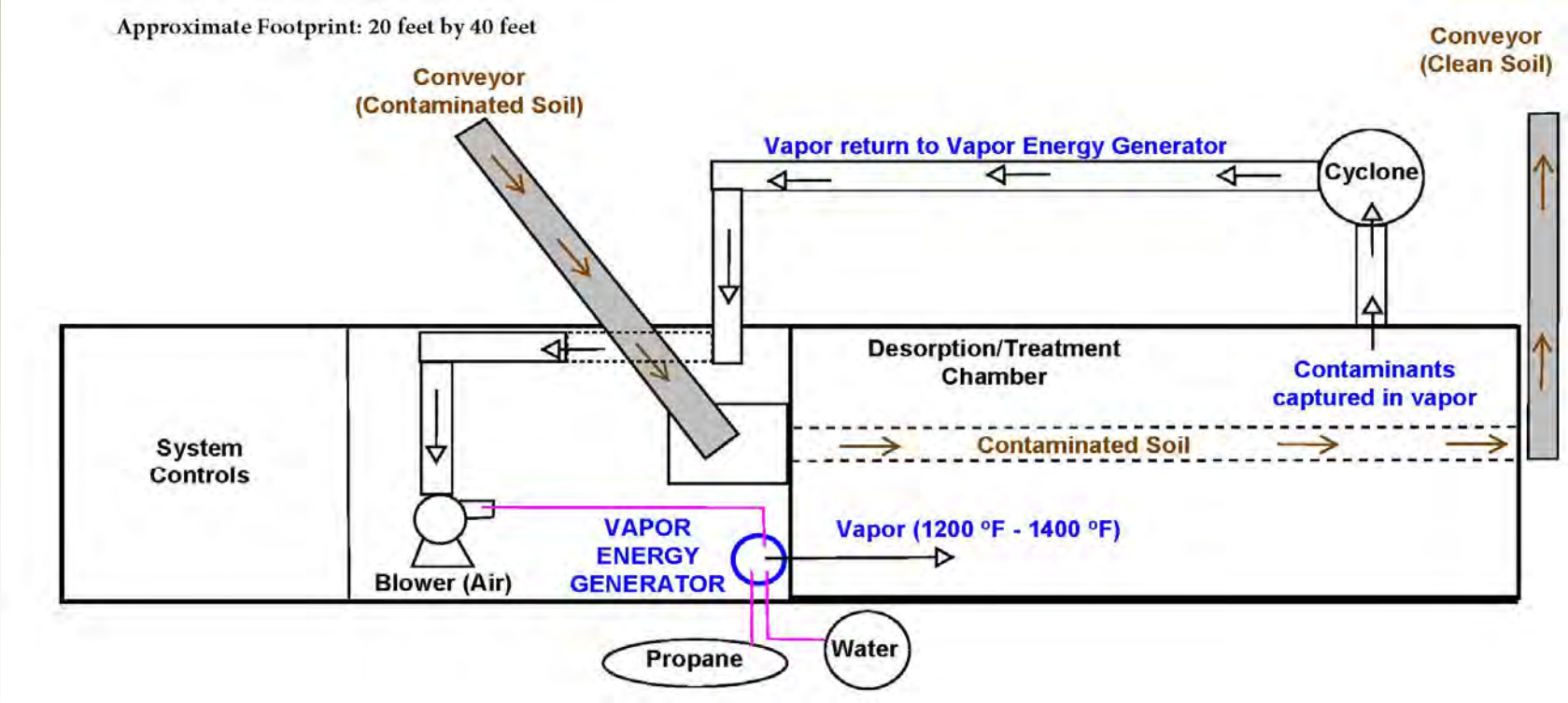
VEG THERMAL REMEDIATION TECHNOLOGY

VEG can be configured to treat specific contaminants

- Petroleum Hydrocarbons: Recycle hot vapor to VEG as syngas, serving as a renewable source of fuel to replace propane and run operations.
- Chlorinated Compounds: Patented Filtration System (engineered mixture of caustic soda, ZVI, lime, water, steam).
- Other combustible contaminants: Secondary treatment using a Thermal or Catalytic Oxidizer.

Fig: Mobile Treatment Unit Configured with Vapor Recycling



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VEG THERMAL REMEDIATION TECHNOLOGY

Attributes and Benefits

- Easily transportable, mobile system for onsite applications
- Highly efficient, Closed-Loop emission-reducing system
- Conversion of desorbed contaminants into renewable fuel
- Treatment of contaminated soil, sediments, adsorbent media, concrete, and other building material/debris
- Treatment rate ranges from 100 to 250 CY/day
- Eliminates offsite transport and landfill of soils/waste material & associated costs
- Eliminates landfill waste generator liability
- Eliminates need to import clean soils for backfilling
- Allows for unrestricted reuse of soils/concrete (no LUCs)
- Significantly reduces remediation costs (typically >50%)
- Reduces remediation carbon footprint (>90%)

Ex-Situ VEG Application for Remediation of Chlorinated Solvents in Soil
USACE ERDC Facility, Vicksburg, MS

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Applications and Success Stories-VEG Remediation Technology

- Application on approximately 50 projects across the US
  - Over a dozen DoD projects
  - More than 10 Army projects (ARNG and USACE Omaha, Los Angeles, Louisville, and Alaska Districts)
- Over 35 bench- and pilot-scale tests across the US
- Studies and/or Collaborations with Academia
  - Colorado School of Mines
  - Johns Hopkins University Applied Physics Lab
  - University of Nevada Reno Desert Research Institute
- International Applications
  - Europe
  - Asia
  - Australia (Pending)
- Subcontractor to AECOM for PFAS Treatability Studies (USACE-Baltimore District)
- Alaniz-Endpoint 8a-JV (three ongoing ARNG contracts)
- **LRM Consulting, Inc. (8a-Certified)**

Application Results

Chemical	Pre-VEG Treatment (mg/kg)	Post-VEG Treatment (mg/kg)
TPH-g	500,000	<50
TPH-d	550,000	<50
BTEX	8,500	<0.05
MTBE	800	<0.05
PAHs	20,000	<0.01
TCE/PCE/VC	5000	<0.001
PCBs/Dioxins/Furans	8000	<0.02
Pesticides	15,000	<0.001
TNT/RDX/HMX	55,000	<0.015
Mustard Agent Simulant	3,500	<0.00053
PFAS Compounds	87	<0.0001
As/Hg/Zn	450/50/25,000	<0.3/<0.03/ <100

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RECOGNITION

USACE ERDC Newsletter (November 2014)

US Army Corps of Engineers
BUILDING STRONG®

Site cleanup demonstrates unique technology

Posted 11/18/2014

By Kerry Larsen, ERDC Public Affairs

VICKSBURG, Miss. - Cleanup efforts on the former motor pool site at the U.S. Army Engineer Research and Development Center (ERDC) in Vicksburg, Mississippi, were recently completed and incorporated some new, cutting-edge technology, making the process more environmentally friendly and economical.

The motor pool operation utilized mechanics to perform maintenance and repairs on vehicles and heavy equipment from the early days of the Waterways Experiment Station until 1996, when the station transitioned to leased and rented vehicles and equipment. The motor pool building served a variety of other purposes, including logistics offices, until 2009, after which time it remained empty until its demolition in 2012.

The ERDC enlisted the assistance of the U.S. Army Corps of Engineers (USACE) Omaha District and its Environmental Remediation Branch to conduct a three-phase cleanup project on the motor pool site.

Photos

Twenty-five hundred cubic yards of soil were excavated, treated for contaminants and replaced during recent cleanup efforts on the former motor pool site at the U.S. Army Engineer Research and Development Center in Vicksburg, Miss. The Vapor Energy Generator soil remediation system was used for the project, coordinated by the U.S. Army Corps of Engineers Omaha District. (Photo by U.S. Army Corps of Engineers)

VEG Technology Discussed by Ross et. al., 2018

RESEARCH ARTICLE — WILEY

A review of emerging technologies for remediation of PFASs

Ian Ross | Jeffrey McDonough | Jonathan Miles | Peter Storch | Parvathy Thelakkat Kochunarayanan | Erica Kalve | Jake Hurst | Soumitri S. Dasgupta | Jeff Burdick

Abstract

The need for remediation of poly- and perfluoroalkyl substances (PFASs) is growing as a result of more regulatory attention to this new class of contaminants with diminishing water quality standards being promulgated, commonly in the parts per trillion range. PFASs comprise >3,000 individual compounds, but the focus of analyses and regulations has generally been PFASs termed perfluoroalkyl acids (PFAAs), which are all extremely persistent, can be highly mobile, and are increasingly being reported to bioaccumulate, with understanding of their toxicology evolving. However, there are thousands of polyfluorinated "PFAA precursors", which can transform in the environment and in higher organisms to create PFAAs as persistent daughter products.

Some PFASs can travel miles from their point of release, or they are mobile and persistent, potentially creating large plumes. The use of a conceptual site model (CSM) to define risks posed by specific PFASs to potential receptors is considered essential. Granular activated carbon (GAC) is commonly used as part of interim remedial measures to treat PFASs present in water. Many alternative treatment technologies are being adapted for PFASs or ingenious solutions developed. The diversity of PFASs commonly associated with use of multiple PFASs in commercial products is not commonly assessed. Remedial technologies, which are adsorptive or destructive, are considered for both soils and waters with challenges to their commercial application outlined. Biological approaches to treat PFASs report biotransformation which creates persistent PFAAs, so PFASs can biodegrade. Water treatment technologies applied ex situ could be used in a treatment train approach, for example, to concentrate PFASs and then destroy them on-site. Dynamic groundwater recirculation can greatly enhance contaminant mass removal via groundwater pumping. This review of technologies for remediation of PFASs describes that:

- GAC may be effective for removal of long-chain PFAAs, but does not perform well on short-chain PFAAs and its use for removal of precursors is reported to be less effective;
- Anion-exchange resins can remove a wider array of long- and short-chain PFAAs, but struggle to treat the shortest chain PFAAs and removal of most PFAA precursors has not been evaluated;
- Ozonfractionation has been applied for PFASs at full scale and shown to be effective for removal of total PFASs;
- Chemical oxidation has been demonstrated to be potentially applicable for some PFAAs, but when applied in situ there is concern over the formation of shorter chain PFAAs and ongoing rebound from sorbed precursors;
- Electrochemical oxidation is evolving as a destructive technology for many PFASs, but can create undesirable by-products such as perchlorate and bromate;
- Sonolysis has been demonstrated as a potential destructive technology in the laboratory but there are significant challenges when considering scale up.

SAME Omaha Newsletter (2016)

Society of SAME American Military Engineers — OmahaPost

Site Cleanup Demonstrates Unique Technology

By: Kerry Larsen, ERDC Public Affairs

VICKSBURG, Miss. - Cleanup efforts on the former motor pool site at the U.S. Army Engineer Research and Development Center (ERDC) in Vicksburg, Mississippi, were recently completed and incorporated some new, cutting-edge technology, making the process more environmentally friendly and economical.

Twenty-five hundred cubic yards of soil were excavated, treated for contaminants and replaced during recent cleanup efforts on the former motor pool site at the U.S. Army Engineer Research and Development Center in Vicksburg, Miss. The Vapor Energy Generator soil remediation system was used for the project, coordinated by the U.S. Army Corps of Engineers Omaha District. (Photo by U.S. Army Corps of Engineers).

SAME Omaha Post General Membership Meeting Follow-up

The VEG Process was the topic of the September 12, 2013 General Membership meeting.

high as 1,100 degrees Fahrenheit into the chamber. As an internal auger rotates the soil, the steam causes contaminants to be released and captured by a vacuum system inside the enclosed treatment chamber. The captured gases are then run through a series of patented acid gas and emission-reducing filters before being routed back to the generator to be burned as fuel to run the treatment system.

Using this process, the plant actually uses less and less fuel as project time goes on. The system operates completely on recycled water, making it environmentally friendly. Most significantly, once the contaminated soil is treated - in this case to achieve non-detectable levels for all chemicals of potential concern at the site - the clean-treated soil is then placed back into its original location and compacted for reuse, eliminating the need and expense of offsite transportation and disposal of soils at a landfill. Using this soil remediation system resulted in the removal and onsite treatment of a significant amount of contaminant mass that otherwise was slated for disposal at a landfill. As a result, fully treated soils were reused onsite without restrictions, generating significant reductions in cost, liability, vehicle traffic through residential areas, and significant reductions in carbon dioxide and other atmospheric emissions that would otherwise have occurred throughout the soil

USACE Omaha Newsletter (January 2015)

The Corps **Environment**

VOLUME 16, ISSUE 1 — JANUARY 2015

Motor pool cleanup demonstrates unique technology

U.S. Army Corps of Engineers Engineer Research and Development Center

Cleanup efforts on the former motor pool site at the U.S. Army Engineer Research and Development Center (ERDC) in Vicksburg, Mississippi, were recently completed and incorporated some new, cutting-edge technology, making the process more environmentally friendly and economical.

The motor pool operation used mechanics to perform maintenance and repairs on vehicles and heavy equipment from the early days of the Waterways Experiment Station until 1996, when the station transitioned to leased and rented vehicles and equipment. The motor pool building served a variety of other purposes, including logistics offices, until 2009, after which time it remained empty until its friendly. Most significantly, once the contaminated soil is treated — in this case to achieve non-detectable levels for all chemicals of potential concern at the site — the clean-treated soil is then placed back into its original location and compacted for reuse, eliminating the need and expense of offsite transportation and disposal of soils at a landfill.

At ERDC, the need to purchase fill soils was eliminated through full reuse of treated soils, and the organization's liability for contamination was eliminated through complete treatment rather than by

Some 2,500 cubic yards of soil were excavated, treated for contaminants and replaced during cleanup of a former motor pool site at the U.S. Army Engineer Research and Development Center in Vicksburg, Mississippi. The Vapor Energy Generator soil remediation system was used for the project, coordinated by the Omaha District. (Photo by Kerry Larsen)

were above migration to groundwater risk-based screening levels. They were contributing to a small groundwater plume at the site. As such, we understood soils would have to be cleaned up to below migration to groundwater risk-based screening levels.

"It is relatively easy to achieve a large mass reduction of contaminants with a technology when contaminant levels are high, however, it is often difficult to treat contaminated media down to very low levels. We were optimistic that the VEG technology would allow us to treat soils to the very low required levels. The team was especially pleased when we were able to treat the soils down to no detectable contamination, which were even better results than we had originally hoped to achieve," Simpleman added.

The final phase of the cleanup involves routine monitoring of groundwater quality to ensure that the treatment efforts,

US Army National Guard (Foundations of Readiness, 2018)

Cleaning Up

USING THE LATEST TECHNOLOGIES, THE ARMY NATIONAL GUARD CLEANS UP THE HAZARDOUS SUBSTANCES, POLLUTANTS AND CONTAMINANTS LEFT BY PREVIOUS GENERATIONS AT ITS ACTIVE AND FORMERLY USED INSTALLATIONS

REMOVING MUNITIONS CONSTITUENTS AT CAMP WITHYCOMBE

REMEDIATING THE SOIL AT CAMP GARDNER

"Today's mission is conducted in a much more sustainable way and we take all the necessary precautions to ensure that we are not making those same mistakes."

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VEG Application – Camp James A. Garfield, Ravenna, OH

Bench-Scale Testing

- Bench-Scale testing of PAH-impacted soils using VEG at Endpoint's laboratory
- Two objectives of testing:
  - Determine the potential and magnitude of reductions in Polycyclic Aromatic Hydrocarbon concentrations using the VEG.
  - Identify Optimal Treatment Conditions (e.g, temperature and treatment time)
- All treatment runs resulted in reduction of all PAH constituent concentrations below Facility-Wide Clean-up Goals

Pilot Study

- Atlas Scrap Yard Area of Concern
- Excavated soil separated into three stockpiles of 25 to 30 yards, each
- Two soil treatment test runs
  - 600°F for 20 minutes, one stockpile
  - 650°F for 22 minutes, two stockpiles
- All tests were successful at reducing concentrations to below screening levels (residential)
- PAH concentrations reduced by over 99%

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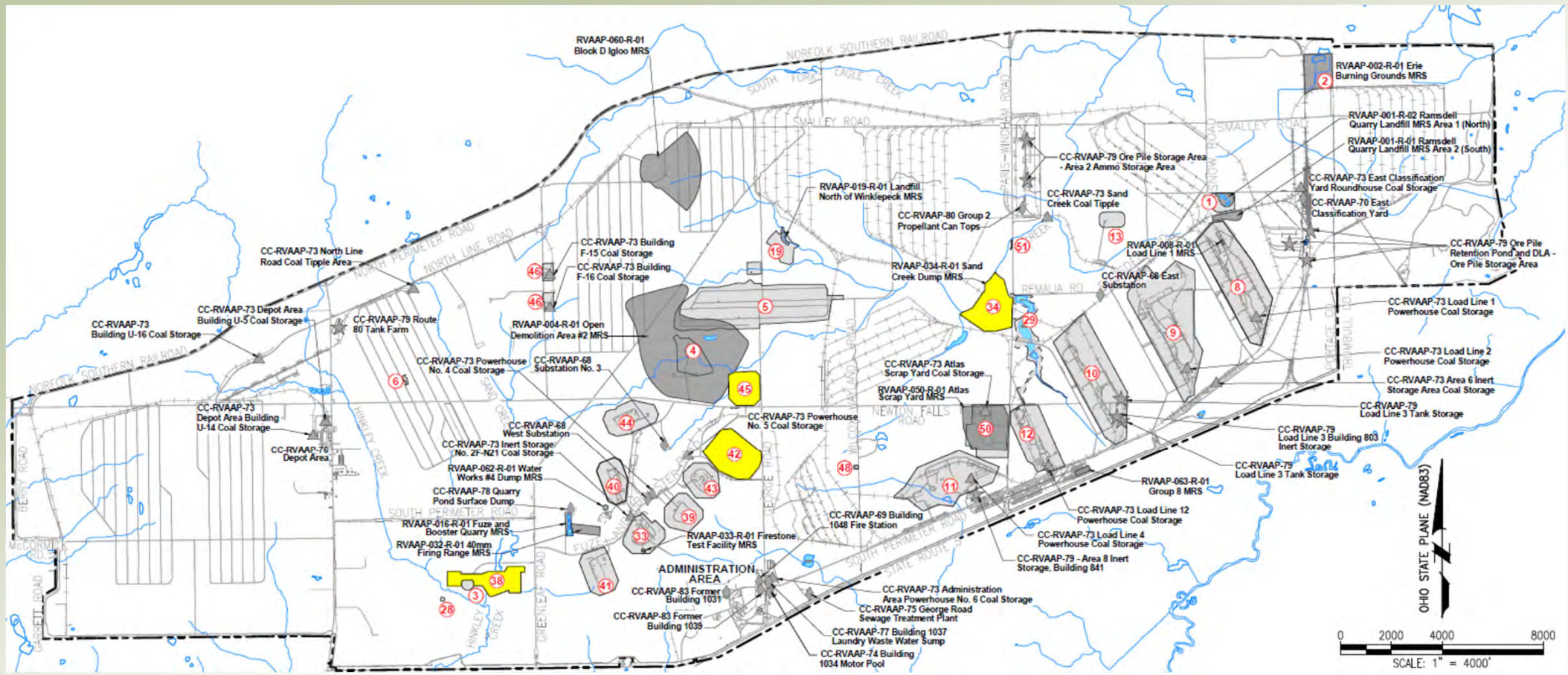
Planned VEG Remediation – Camp James A. Garfield, Ravenna, OH



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Planned VEG Remediation – Camp James A. Garfield, Ravenna, OH

VEG remediation of soil from four locations:

- RVAAP-34 Sand Creek Road Landfill
- RVAAP-38 NACA Test Area
- RVAAP-42 Load Line 9
- RVAAP-45 Wet Storage Area

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Planned VEG Remediation – Camp James A. Garfield, Ravenna, OH

Centralized Stockpile and Treatment Area:

NACA TEST AREA

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Planned VEG Remediation – MOBILIZATION OF VEG SYSTEM

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Planned VEG Remediation – SOURCE AREA EXCAVATION

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Planned VEG Remediation – SOIL STOCKPILE MANAGEMENT

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Planned VEG Remediation – INITIATION OF EX-SITU THERMAL TREATMENT

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Planned VEG Remediation – THERMAL MONITORING

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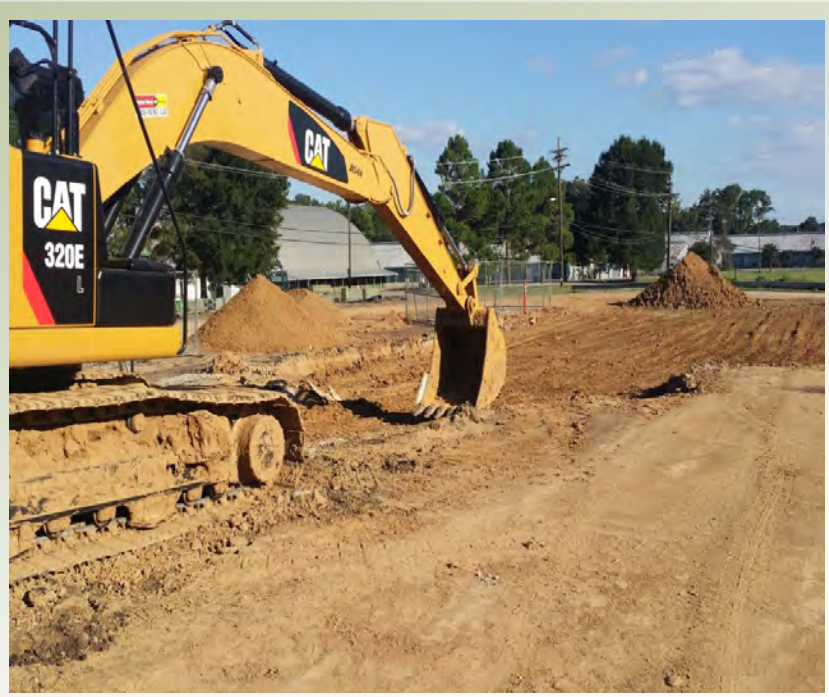
Planned VEG Remediation – SOIL BACKFILLING AND COMPACTION



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Planned VEG Remediation – VEG TREATMENT OF IDW DECONTAMINATION WASTES

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QUESTIONS?

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