

Air Force Center for Engineering and the Environment

Integrity - Service - Excellence



AFCEE Sustainable Remediation Tool (SRT)



John Claypool

***International Conference on
Green Remediation***

June 16, 2010





Project Team

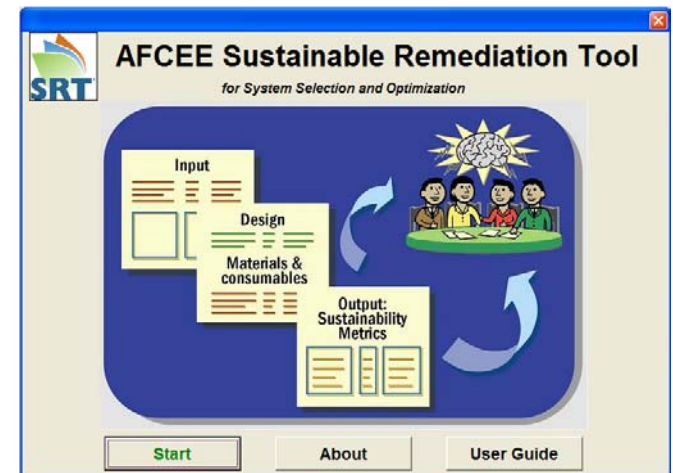
- **Air Force Center for Engineering and the Environment**
Erica Becvar

- **AECOM**
Doug Ruppel, John Claypool, Dave Woodward

- **GSI Environmental**
Chuck Newell, Tiffany Swann, Lila Beckley, Ata Rahman

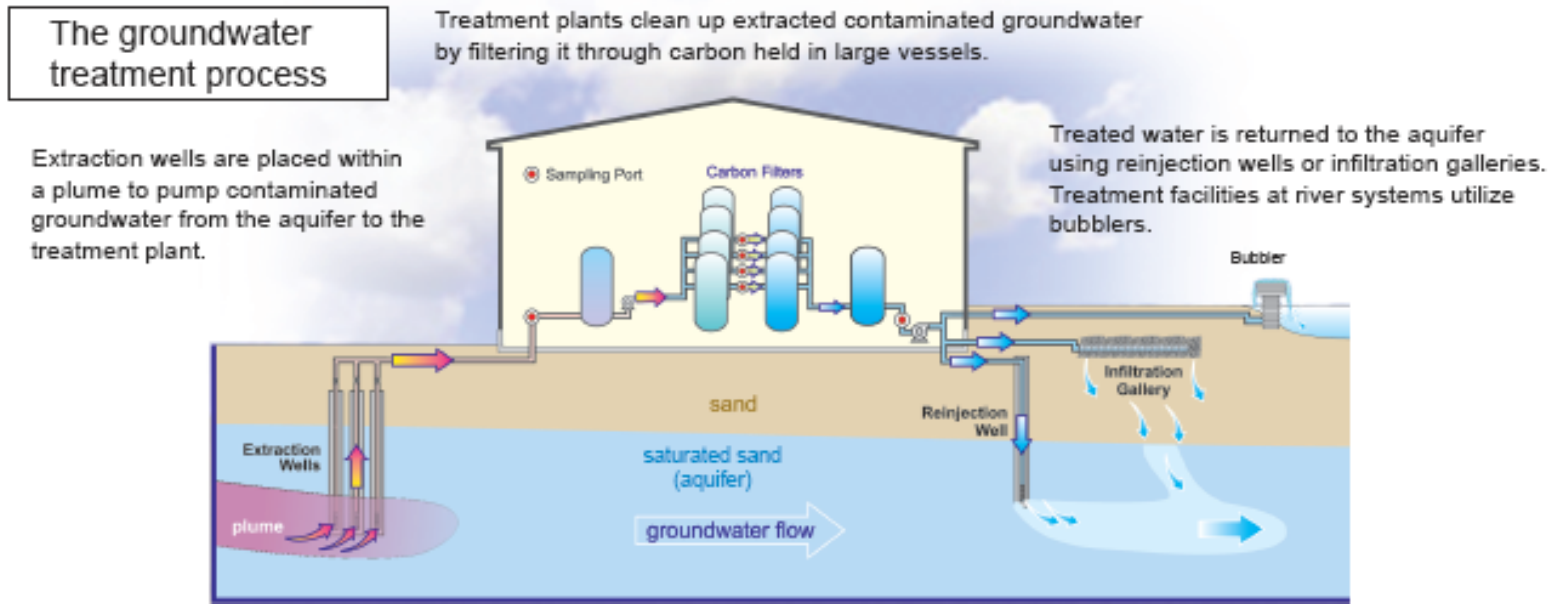
- **CH2M Hill**
Doug Downey, Paul Favara, Brad Woodard

- ➔ ***Motivation and Purpose***
- **Tool Functionality**
- **Optimization Scenario**
- **Conclusions**



The Problem...

Historical approach to contaminated sites does not fully consider sustainability concepts. Plus, remediation system performance not routinely tracked.



Solutions...



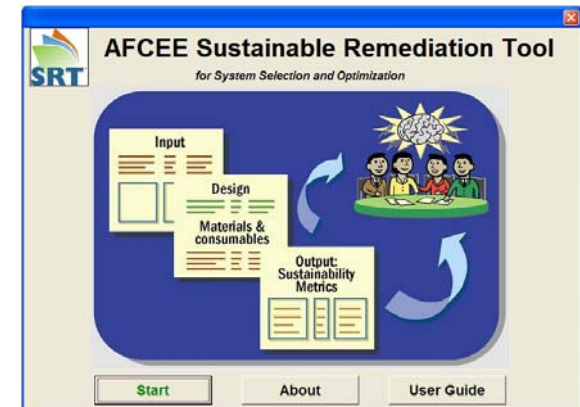
Develop **tools** to help AFCEE environmental professionals **incorporate sustainability concepts into their remediation decision making process** (e.g., Performance Based Management, Remedial Risk Management, Environmental Restoration Program – Optimization) and **track performance**

i) Plan future remediation implementation

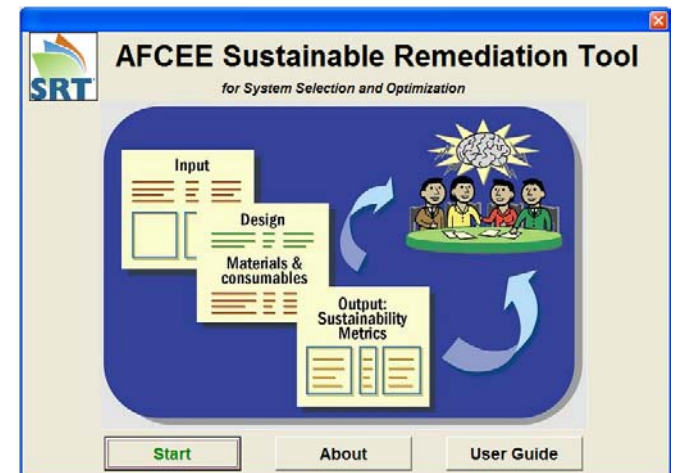
ii) Optimize operating remediation sites

Tools...

- ✓ Sustainable Remediation Tool (SRT)
- ✓ Performance Tracking Tool (PTT)
- ✓ Alternative Energy Siting Tool
- ✓ Environmental Restoration Program-Optimization (ERP-O) Initiative



- Motivation and Purpose
- ➡ ***Tool Functionality***
- Optimization Scenario
- Conclusions





SRT Functionality

SRT Design Principles:

- **No replication of design tools (simply calculate metrics)**
- **Develop with tiered approach for parameter inputs**
 - **Easy Tier 1 with Rules of Thumb for technology estimates**
 - **Tier 2 can estimate but not intended to replace design tools**
 - **Allow user override of estimated values at any time to accommodate real design parameters**
- **Include cost as a sustainability metric**



SRT Functionality

Technologies in the SRT:

- **Excavation**
- **Soil Vapor Extraction (SVE)**
- **Pump and Treat (P&T)**
- **Enhanced Bioremediation**
- **In Situ Chemical Oxidation (ISCO)**
- **Permeable Reactive Barrier (PRB)**
- **Long-term Monitoring (LTM) / Monitored Natural Attenuation (MNA)**
- **Thermal Treatment**

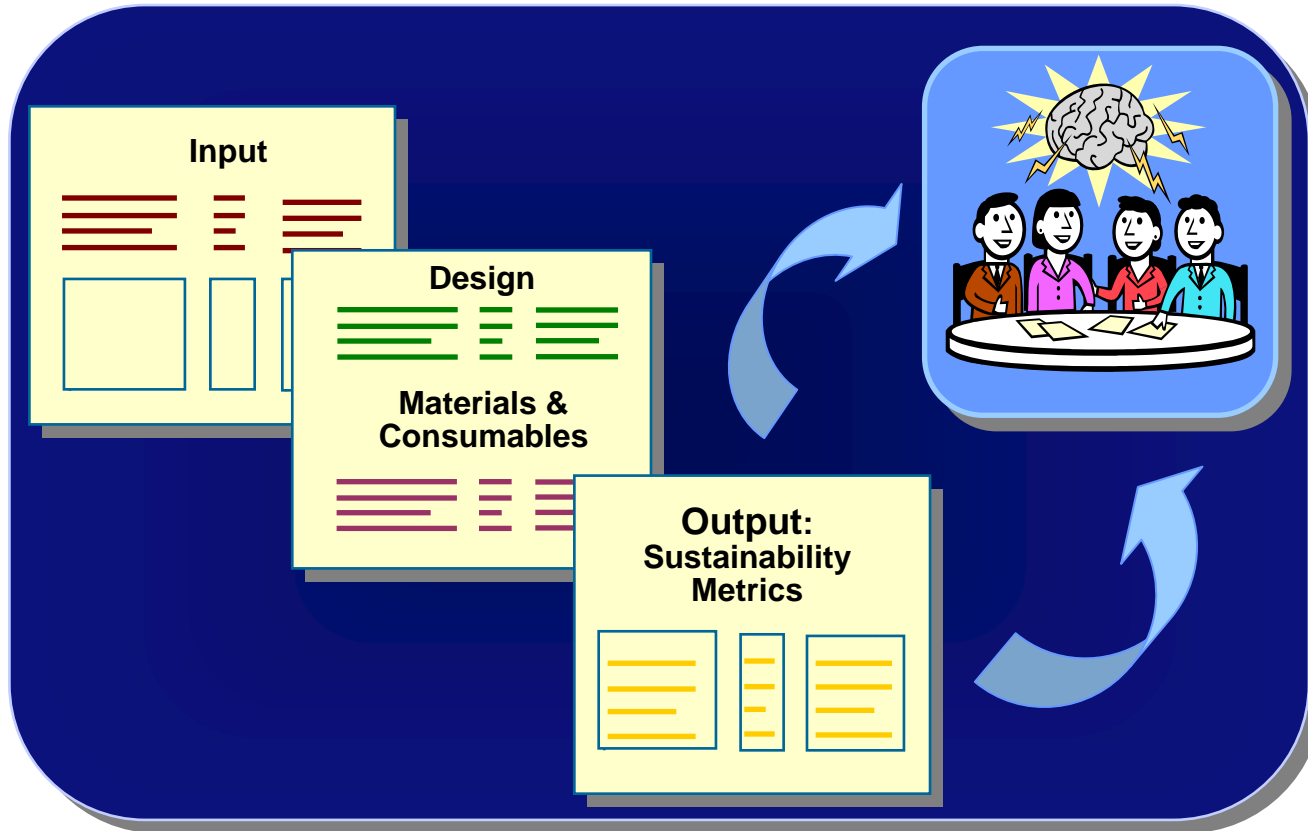


SRT Functionality

Sustainability metrics estimated by SRT:

- **Emissions to atmosphere**
 - **CO₂**
 - **NO_x**
 - **SO_x**
 - **PM₁₀**
- **Total energy consumed**
- **Change in resource service**
- **Technology cost**
- **Safety / Accident risk**

Tool Structure





SRT Functionality

Framework: Tiers of Varying Detail

	Tier 1	Tier 2
Calculation Basis:	“Rules of Thumb”	User-entered detailed design
Time Required:	1 - 2 hrs	1 - 2 days
	Tier 1 Advantages	Tier 2 Advantages
	<ul style="list-style-type: none"> ✓ Shorter execution than Tier 2 ✓ Extensive built-in defaults ✓ Simpler user inputs ✓ Most appropriate before a Feasibility Study (FS) 	<ul style="list-style-type: none"> ✓ More site-specific results ✓ More default user-overrides ✓ Most appropriate after an FS ✓ More appropriate for optimizing existing systems

SRT General Inputs

SRT rev2_1.xls [Compatibility Mode] - Microsoft Excel

Home Insert Page Layout Formulas Data Review View Developer

SUSTAINABLE REMEDIATION TOOL

1. Enter Project Information.

Site Name:

Location:

Site/Project Phase for Calculation:

Tier 1 Tier 2

Fuel Costs		
Gasoline	\$2.00	\$/gallon
Diesel	\$2.00	\$/gallon
Electricity	\$0.10	\$/kWh
Natural gas	\$11.00	\$/mcf


Instructions:

- = Enter your data here. Click button to the right of the cell for help.
- = Use this default value or override with **your own**.
- = Calculated value. You cannot change this.

For help, click on the square gray buttons located throughout the SRT.

New users: Fill in the boxes as indicated above. Choose Soil or Groundwater. Click buttons on Recommended Flow to proceed through the screens.

Advanced users: Follow Recommended Flow, or click on tabs to navigate.



2. Choose Environmental Media

Soil...

Recommended flow:

```

graph LR
    Main --> SoilInput[Soil Input]
    SoilInput --> Excavation
    SoilInput --> SVE
    SoilInput --> ThermalTreatment[Thermal Treatment]
    Excavation --> Output
    SVE --> Output
    ThermalTreatment --> Output
    
```

...or Groundwater.

Recommended flow:

```

graph LR
    Main --> GWInput[GW Input]
    GWInput --> PumpTreat[Pump & Treat]
    GWInput --> Bioremediation[Enhanced Bioremediation]
    GWInput --> ISCO[In Situ Chem. Oxidation (ISCO)]
    GWInput --> PRB[Permeable Reactive Barrier (PRB)]
    GWInput --> LTM[MNA / LTM]
    PumpTreat --> Output
    Bioremediation --> Output
    ISCO --> Output
    PRB --> Output
    LTM --> Output
    
```

Copyright AFCEE 2010. All rights reserved.
21 May 2010

MainScreen InputSoil EXDesign SVDesign ThermalDesign OutputSoil InputGW PTDesign EBDesign ISCODesign PRBDesign MNADesign OutputGW

Ready 100%

SRT rev2_1.xls [Compatibility Mode] - Microsoft Excel

SOIL/SOURCE INPUT

Example Site
Denver, CO

Area of Affected Soil	10000	ft ²
Depth to Top of Affected Soil	0	ft
Depth to Bottom of Affected Soil	15	ft
Depth to Groundwater	25	ft

Soil Type: Sand (well graded)

Contaminant Class: CVOCs

Max Concentration	10	mg/kg
Typical Concentration	1.25	mg/kg

Contaminant mass: 19. lbs

Calculate natural resource service? Yes No

Instructions:

- = Enter your data here. Click button to the right of the cell for help.
- = Use this default value or override with **your own**.
- = Calculated value. You cannot change this.

Paste Tier 2 Example

Clear Soil Inputs

Recommended flow:

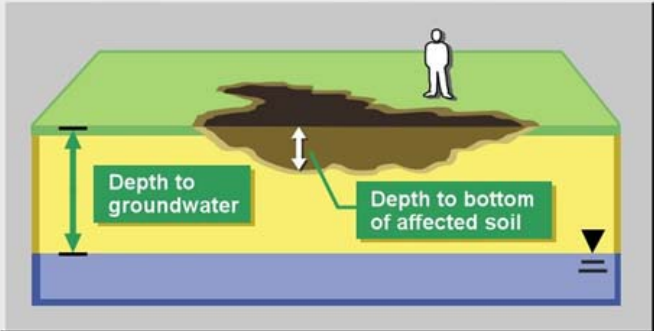
You are here

```

Main -- Main --> Input --> Results
    
```

Next: Choose Technologies

- Excavation
- Soil Vapor Extraction
- Thermal Treatment



Depth to groundwater

Depth to bottom of affected soil

MainScreen | **InputSoil** | EXDesign | SVDesign | ThermalDesign | OutputSoil | InputGW | PTDesign | EBDesign | ISCODesign | PRBDesign | MNADesign | OutputGW

Ready | 95%



SRT Tier 1 - Excavation

SRT rev2_1.xls [Compatibility Mode] - Microsoft Excel

Home Insert Page Layout Formulas Data Review View Developer

EXCAVATION - TIER 1

Example Site
Denver, CO
CAPITAL and O&M

Design for Managing Soil

Airline miles flown by project team (total miles for all travelers)	10000	miles over proj lifetime
Average Distance Traveled by Site Workers per one-way trip	12	miles one-way
Trips by Site Workers during construction	400	# over project lifetime
Trips by Site Workers after construction	20	# over project lifetime

Distance to Disposal (one-way) miles

Type of Disposal

Volume of affected soil cu ft

Volume of affected soil cu yd

Total hours to excavate person-hours

Number of loads for disposal #

Total miles driven for disposal miles

Total hours for fill dirt placement hours

Number of loads of fill dirt #

Total miles driven for fill miles

Instructions:

- = Enter your data here. Click button to the right of the cell for help.
- = Use this default value or override with **your own**.
- = Calculated value. You cannot change this.

Restore Defaults
Show Inputs

Recommended flow:

```

Main --> Input --> Technology Design --> Results
    
```

Technology Design **You are here**

- Excavation
- Soil Vapor Extraction
- Thermal Treatment

Materials and Consumable Amounts used for Metrics

Diesel	42,000.	gal
Gasoline	690.	gal

Technology Cost

Capital	2,600,000.	\$
O&M	n/a	\$

Project-specific Metrics (Add & Subtract/Offsets)

Yes No

Additional Technology Cost	<input type="text"/>	\$
Total Energy Consumed	<input type="text"/>	Megajoules
CO ₂ Emissions to Atmosphere	<input type="text"/>	tons CO ₂
Safety / Accident Risk	<input type="text"/>	lost hours

MainScreen InputSoil **EXDesign** SVDesign ThermalDesign OutputSoil InputGW PTDesign EBDesign ISCODesign PRBDesign MNADesign OutputG

Ready 100%



SRT Tier 2 - Excavation

SRT rev2_1.xls [Compatibility Mode] - Microsoft Excel

Home Insert Page Layout Formulas Data Review View Developer

Design Calculations - Excavation

Area of Affected Soil	10,000.	ft ²	Volume of affected soil: Area * (Depth to Bottom - Depth to Top of Affected Soil).	Return to Summary
Total Thickness of Affected Soil	15.	ft		
Volume of affected soil	150,000.	ft ³	Total hours to excavate: Volume of affected soil * soil density * (1 ton / 2000 lbs) * (1/rate of excavation in ton/hr).	Restore Defaults (Detail Section)
Volume of affected soil	5,556.	cu yd		
Soil density	100.	lb/ft ³	Loads for disposal: Volume of affected soil * fluff factor * (1/dump truck volume) * (1 yd ³ / 27 ft ³ unit conversion)	
Excavation rate	53.	tons/hr		
Total hours to excavate	140.	person-hours	Total miles driven for disposal: Number of loads for disposal * 2 * Distance to disposal (input above).	
Fluff factor (excavated soil)	1.15			
Dump truck volume for disposal	12.	cu yd	Loads of fill dirt: Volume of affected soil (above) * fluff factor * (1/dump truck volume) * (1 yd ³ / 27 ft ³).	
Number of loads for disposal	530.	# loads		
Total miles driven for disposal	320,000.	miles	Total hours for fill dirt placement, is the sum of: (1) Area (user input) * (1 yd ² / 9 ft ²) / fill spread rate in yd ³ /hr. (2) Number of loads of fill dirt (calculated above) * dump truck volume (above) / rate of water compaction in yd ³ /hr. (3) Total volume of fill dirt / spread & compaction rate in yd ³ /hr.	
Fluff factor (fill)	1.3			
Dump truck volume for moving fill	12.	cu yd	Total miles driven for fill: Number of loads of fill dirt * 2 * Distance from site to fill source.	
Number of loads of fill dirt	600.	# loads		
Fill spread rate	448.5	cu yd/hr		
Water compaction rate	174.3	cu yd/hr		
Spread/compaction rate	654.	cu yd/hr		
Total hours for fill dirt placement	55.	hrs		
Distance from site to fill source (one way)	10.	miles		
Total miles driven for fill	12,000.	miles		

Materials and Consumable Calculations - Excavation

Excavator fuel consumption rate	3.	gal/hr	Total diesel: (Total hours to excavate & place fill * Excavator fuel consumption rate) + (Total miles driven for disposal * Dump	Return to Summary
Dump truck fuel use rate	8.	mpg		

MainScreen InputSoil EXDesign SVDesign ThermalDesign OutputSoil InputGW PTDesign EBDesign ISCODesign PRBDesign MNADesign OutputG

Ready 100%



SRT Results Screen

SRT rev2_1.xls [Compatibility Mode] - Microsoft Excel

Home | Insert | Page Layout | Formulas | Data | Review | View | Developer

SOIL/SOURCE RESULTS

Instructions:

- = Enter your data here.
- = Use this default value or override with **your own**.
- = Calculated value. You cannot change this.

Recommended flow:

```

    Main -> Input -> Technology -> F
    
```

Show Inputs << Last Screen

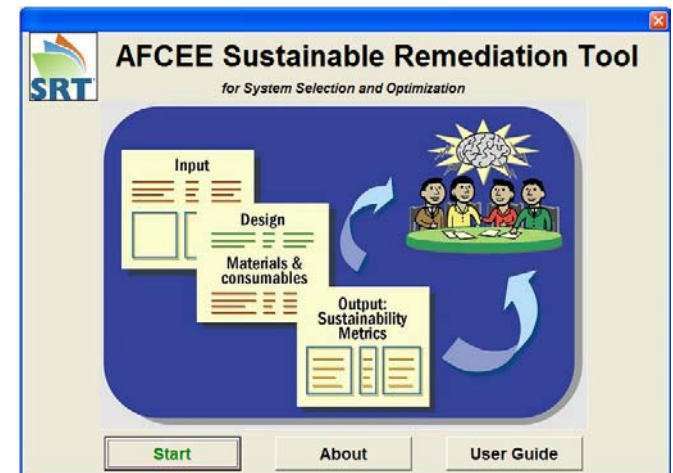
* Normalize metrics to see more, go back to Inputs to adjust & or go back to Main (Tier 1/2 or GW), or Exit.

Non-normalized
Calculations in natural units

	Carbon Dioxide Emissions to Atmosphere		NO _x *	SO _x	PM ₁₀	Total Energy Consumed		Technology	
	tons CO ₂	lbs CO ₂ per lb contam	tons NO _x	tons SO _x	tons PM ₁₀	Megajoules	kWh	dollars	dk
Excavation	550	58,000	4.4	0.0043	0.21	7,200,000	2,000,000	2,600,000	
SVE	-	-	-	-	-	-	-	-	
Thermal	-	-	-	-	-	-	-	-	

*: See SRT v.2 Known Issues

- Motivation and Purpose
- Tool Functionality
- ➡ *Optimization Scenario*
- Conclusions





Optimization Scenario

Tier 2 Scenario – Soil Vapor Extraction

Inputs:

- Primary contaminant: trichloroethene (TCE)
- 300,000 ft³ zone of contamination
- Typical concentration: 100 mg/kg; 3,000 lbs TCE
- Well-graded sand
- Average contaminated thickness: 12 ft
- 2-year duration
 - Year 1: Thermal Oxidizer
 - Year 2: Thermal Oxidizer or GAC?

Evaluation:

- **Thermal Oxidizer** (Year 2)
compared with
- **GAC** (Year 2)

Key Question: What are the changes in sustainability metrics that would result from optimizing vapor treatment to GAC in Year 2?

Optimization Scenario

SUSTAINABLE REMEDIATION TOOL

1. Enter Project Information.

Site Name: Optimization Scenario - SVE
 Location: USA
 Site/Project Phase for Calculation: O&M Only
 Tier 1 Tier 2

Fuel Costs		
Gasoline	\$2.00	\$/gallon
Diesel	\$2.00	\$/gallon
Electricity	\$0.10	\$/kWh
Natural gas	\$11.00	\$/mcf



Instructions:

- = Enter your data here. Click button to the right of the cell for help.
- = Use this default value or override with **your own**.
- = Calculated value. You cannot change this.

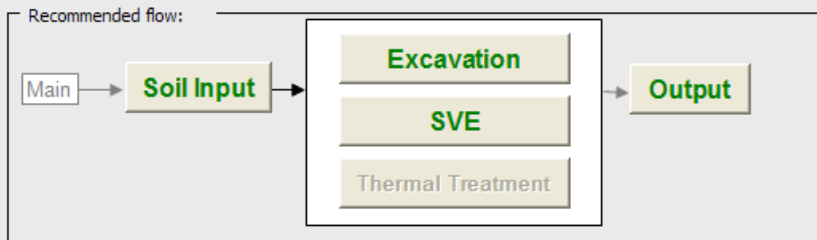
For help, click on the square gray buttons located throughout the SRT.

New users: Fill in the boxes as indicated above. Choose Soil or Groundwater. Click buttons on Recommended Flow to proceed through the screens.

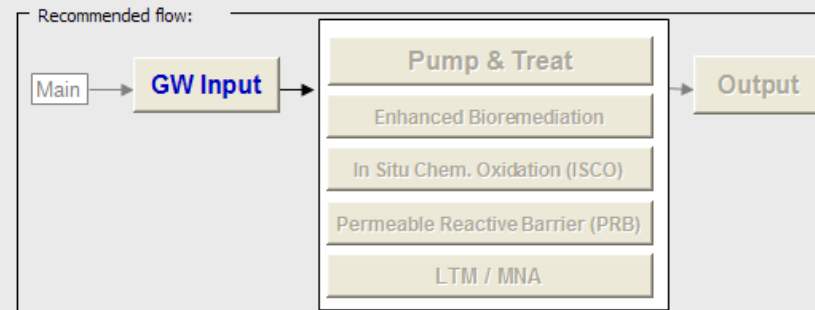
Advanced users: Follow Recommended Flow, or click on tabs to navigate.

2. Choose Environmental Media

Soil...



...or Groundwater.





Optimization Scenario

SOIL VAPOR EXTRACTION - TIER 2

Optimization Scenario - SVE
USA
O&M

Design for Managing Soil

Airline miles flown by project team (total miles for all travelers)	1500	miles over proj lifetime
Average Distance Traveled by Site Workers per one-way trip	10	miles one-way
Trips by Site Workers during construction	4	# over project lifetime
Trips by Site Workers after construction	24	# over project lifetime

Duration years

Number of wells #
Length of manifold ft

Vapor treatment method

Remediation efficiency (% contaminant removed) %, displayed as decimal

Tier 2: Change Calculated Values (dark gray cells)

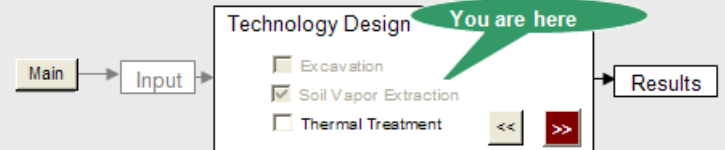
Instructions:

- = Enter your data here. Click button to the right of the cell for help.
- = Use this default value or override with **your own**.
- = Calculated value. You cannot change this.

Restore Defaults

Show Inputs

Recommended flow:



Materials and Consumable Amounts Used for Metrics

PVC	0.	lbs
Activated carbon	0.	lbs
Electricity	31,000.	kWh
Diesel (Capital)	0.	gal
Diesel (O&M)	0.	gal
Gasoline (Capital)	0.	gal
Gasoline (O&M)	34.	gal
Natural gas	1,800.	mcf

Technology Cost

Capital	0.	\$
O&M	88,000.	\$ over project

Project-specific Metrics (Add & Subtract/Offsets)

Yes No



Optimization Scenario

Year 2 Thermal Oxidizer: “Non-normalized” Metrics

CO ₂ Emissions.....	130 tons
lb CO ₂ / lb contaminant.....	1,700 lb / lb
NO _x Emissions.....	0.3 tons
SO _x Emissions.....	0.24 tons
PM ₁₀ Emissions.....	0.047 tons
Energy Consumed.....	2,100,000 Megajoules
Cost.....	\$88,000
Cost / lb contaminant.....	\$300 / lb
Safety / Accident Risk.....	4 x 10 ⁻⁴ injury risk
Lost work-time.....	0.021 lost hours
Change in Resource Service	
Economic.....	Net gain
Ecologic.....	Net gain



Optimization Scenario

Year 2 Thermal Oxidizer: “Normalized” Metrics

CO ₂ Emissions.....	\$260
Energy Consumed.....	\$23,000
Cost (minus energy costs).....	\$65,000
Change in Resource Service.....	-\$1,600
<hr/>	
TOTAL	\$87,000

**Gains
reduce the
total cost**

Converting metrics to dollars gives a common baseline.



Optimization Scenario

Year 2 GAC: “Non-normalized” Metrics

CO ₂ Emissions.....	27 tons
lb CO ₂ / lb contaminant.....	360 lb / lb
NO _x Emissions.....	0.13 tons
SO _x Emissions.....	0.24 tons
PM ₁₀ Emissions.....	0.044 tons
Energy Consumed.....	370,000 Megajoules
Cost.....	\$68,000
Cost / lb contaminant.....	\$230 / lb
Safety / Accident Risk.....	5 x 10 ⁻⁴ injury risk
Lost work-time.....	0.025 lost hours
Change in Resource Service	
Economic.....	Net gain
Ecologic.....	Net gain



Optimization Scenario

Year 2: **GAC** vs. **Therm Ox**: “Normalized” Metrics

	<u>GAC</u>	<u>ThermOx</u>
CO ₂ Emissions.....	\$54	\$260
Energy Consumed.....	\$3,400	\$23,000
Cost (minus energy costs).....	\$65,000	\$65,000
Change in Resource Service.....	-\$1,600	-\$1,600
<hr/>		
TOTAL	\$67,000	\$87,000

Stakeholders can then decide which metrics are most important for the given site.

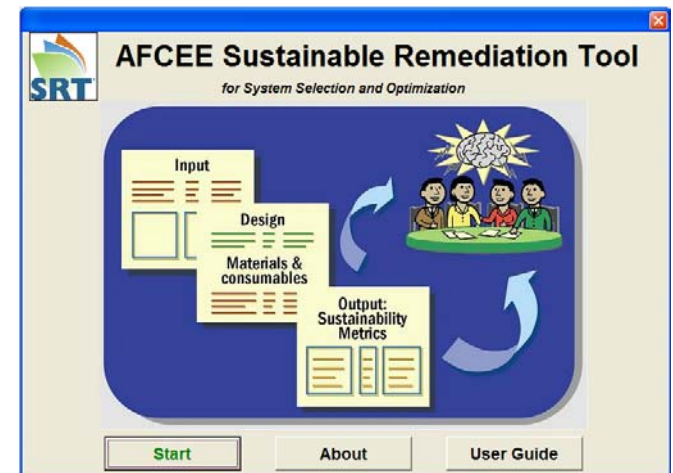
Stakeholder Roundtable Feature: Reaching a Consensus



SOIL/SOURCE ROUND TABLE - WEIGH THE RESULTS

	Person 1	Person 2	Person 3	Person 4	Person 5
Carbon Dioxide Emissions to Atmosphere	High	Medium	Low	Don't Use	Medium
Total Energy Consumed	Medium	Low	Don't Use	High	Medium
Technology Cost	Low	Don't Use	High	Medium	Low
Change in Resource Service for Land	High	Medium	Low	Don't Use	High

- Motivation and Purpose
- Tool Functionality
- Optimization Scenario
- ➡ **Conclusions**





Conclusions

Sustainable Remediation Tool (SRT) Distribution

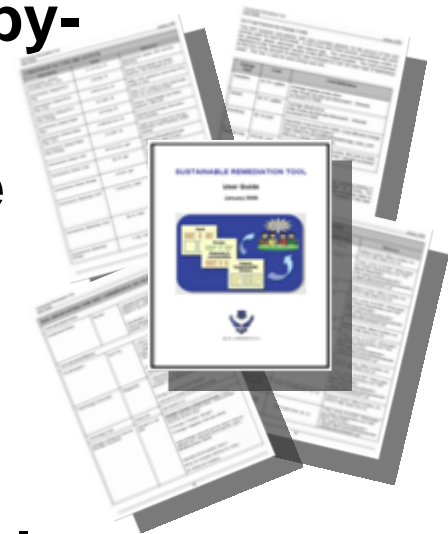
Available as free download from US Air Force (AFCEE)

[www.afcee.af.mil/resources/technologytransfer/
programsandinitiatives/sustainableremediation](http://www.afcee.af.mil/resources/technologytransfer/programsandinitiatives/sustainableremediation)



➤ SRT Strengths

- Evaluates sustainability metrics
- Screens / Compares technologies side-by-side
 - Up to 8 different technologies at once
- Two tier options for user
- Scenarios feature
- Stakeholder roundtable feature
- Capable of using inputs from design tools
- Will have validated costing model (RACER™) interaction in next release





Questions / Discussion