ONE GENERATION PLANTS A TREE – ANOTHER ONE GETS THE SHADE

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Introduction

This demonstration is part of an initiative being conducted by the Air Force Center for Environmental Excellence/Technology Transfer Division (AFCEE/ERT) in conjunction with Parsons Engineering Science, Inc. (Parsons). AFCEE/ERT is currently implementing a multi-site program to independently evaluate phytostabilization of contaminated groundwater. Phytostabilization or "phytohydraulics," is the use of plants to remove groundwater through uptake and consumption in order to contain or control the migration of contaminants (US Environmental Protection Agency [USEPA], 2000). The primary goal of this multi-site initiative is to develop a systematic process for scientifically investigating and documenting the potential for hydraulic control of groundwater contaminant plumes by the use of tree plantings. A total of six Air Force Bases (AFBs) (i.e., Travis AFB, California; Altus AFB, Oklahoma; Fairchild AFB, Washington; Ellsworth AFB, South Dakota; Hill AFB, Utah; and Vandenberg AFB, California) have been selected for this demonstration.

The two primary objectives for this demonstration are:

1. Demonstrate the ability or inability of tree plantings to hydraulically control groundwater through field measurements; and
2. Utilizing the field measurements, refine and calibrate a water balance model to be used as a screening and evaluation tool for phytostabilization at other Air Force sites.

Methods

Sites for the demonstration were selected using a number of different criteria including location west of the Mississippi, suitable climatic conditions (low precipitation and high evaporation), available planting area, depth to groundwater, and presence of groundwater contaminated with trichloroethene. A variety of site conditions were desired to provide a good data set to evaluate the performance of phytostabilization in various settings. A summary of pertinent demonstration site information is as follows:

Location	Annual Precipitation (inches)[a/]	Annual Evaporation (inches)[a/]	Ratio (Evap/Precip)[a/]	Depth to Groundwater (ft bgs)	Range of TCE Concentrations (µg/L)
Travis AFB, CA	18	49	2.7	15	5-15,000
Altus AFB, OK	26	65	2.5	7	4-4,800
Fairchild AFB, WA	16	38	2.4	9	21-1,00
Ellsworth AFB, SD	16	40	2.5	20	6-240
Hill AFB, UT	22	36	1.6	10	100-1,000
Vandenberg AFB, CA	14	45	3.2	5	ND-67

[a/] Mitretek, 2001.

Plantings at the six sites occurred between 1998 and 2001. Over 4,000 trees have been planted using various methods such as conventional root ball/planting pit, shallow and deep cutting techniques. Site-specific information for the tree plantings is summarized as follows:

Location	Planting Dates	Planting Area	Number of Trees	Tree Type
Travis AFB, California	1998/2000	2.2	380	Eucalyptus
Altus AFB, Oklahoma	1999	0.5	109	Cottonwood
Fairchild AFB, Washington	2001	1	1,130	Hybrid poplars
Ellsworth AFB, South Dakota	2001	1	1,027	Hybrid poplars
Hill AFB, Utah	2001	1	143	Hybrid poplars
Vandenberg AFB, California	2001	1	1,260	Hybrid poplars

Plantings at Travis and Altus AFBs consisted of typical root ball/planting pit techniques using trees (with root ball) ranging from 1 to 15 gallons in size. Additionally, some planting pits at these locations were constructed in an attempt to create a preferential pathway for root growth to the water table. Twelve (12) inch diameter holes were drilled from grade to the top of the water table and backfilled with a native soil/compost mix. In addition, a vent pipe was installed in these locations to provide oxygen to roots growing near the water table. This construction method required more time and money to complete, however, it will provide an indication of the value of the capital investment over the long-term when compared to more conventional methods.

Plantings at Fairchild, Ellsworth and Vandenberg AFB used techniques developed in the pulp and paper industry where large, low cost plantings have been on-going for years. These methods use “cuttings” from mature tree stock at nursery locations. These cuttings, which are 9-inches long, are pushed into the ground after some site preparation (shallow tilling, application of weed control, etc.). Advantages of this technique are the reduced material cost and planting pit preparation required (i.e., reduced capital investment).

Plantings at Hill AFB used cuttings as described above. However, cuttings used at this location were 10-feet in length. Pilot holes (6-inch diameter) were augured to a depth of approximately 10 feet below grade. The longer cuttings were placed into the pilot holes and backfilled with a native soil/compost mix. As was done at Travis and Altus AFBs, vent tubes were placed at each of the locations. This method will be used to evaluate the potential for this type of installation to more actively use the groundwater during the early growing seasons (i.e., potentially eliminate need for an irrigation system).

Drip irrigation systems were installed at all sites (excluding Hill AFB which was watered manually). Supplemental water is being applied at all sites during the first two to three growing seasons. The presence of a drip irrigation system in the plant stand leaves open the possibility of converting the sites into “pump and irrigate” systems where contaminated groundwater is actively recovered and applied to the plant stand as a treatment alternative. Additionally, various weed control measures are being used at each location including bark mulch, weed barrier, and chemical and physical methods.

Prior to or during tree planting installations, monitoring wells were constructed and baseline sampling was completed for both volatile organics and natural attenuation parameters as a baseline metric (Lee, 2000). In addition, on-site data acquisition systems and weather stations were installed at most of the sites to provide real time data that could be accessed locally or remotely. The data acquisition systems consist of soil moisture (potentiometric and volumetric) sensors, soil temperature sensors, water level indicators, and also provided the ability to measure sap flow when required. The weather stations record precipitation, air temperature, wind speed, solar radiation, and relative humidity allowing for the calculation of the potential evapotranspiration rate.

A limited monitoring program was put into place during the early growing seasons. Annual groundwater sampling has been completed as well as some limited sap flow and plant tissue analysis.

Discussion

The title of the presentation, *One Generation Plants a Tree – Another One Gets the Shade*, certainly provides a catchy title but also rings true (to some extent) regarding the use of phytoremediation technology in the manner discussed. Mother nature takes her time when it comes to developing a plant stand capable of significantly impacting the movement of groundwater in the subsurface. This has been seen at number of field locations (planted in mid-1990s) where measurements have shown some seasonal impact, but are not considered to be at there highest efficiency (Ferro *et al*., 2001; Hong *et al*., 2001; Landmeyer, 2001; Lee *et al*., 2000; Quinn *et al*., 2001; Schneider *et al.,* 2002). Modeling predictions using some site-specific data are used to evaluate the potential impact of these types of plantings in the future. Depending on growth/climatic/site conditions, significant contribution from the plant stand to the overall remedial effort could take 3 to 10 growing seasons.

With this time frame in mind, AFCEE has taken a more conservative approach with respect to monitoring during the first few growing seasons. The first priority has been establishing a healthy and vibrant plant stand at each demonstration site. Mortality rates have been relatively low (less than 10-percent) at most of the sites with the exception of Altus and Hill AFB where site and planting conditions have caused a large loss rate to occur (greater than 40-percent). Tree growth at Travis and Fairchild AFB has been high, moderate at Ellsworth and Vandenberg AFB, and low at Altus and Hill AFB. Canopy closure has not occurred at any site. Irrigation continued at all sites through 2002. It is expected that supplemental water will not be added to the Travis and Fairchild AFB sites during the 2003 growing season. The remaining sites will receive supplemental water on an as needed basis.

Tree water use at Travis and Hill AFB has been measured using stem heat balance methods (SapFLow2® system produced by Dynamax [Houston, Texas]) during the second and third growing seasons. Measured usage has ranged from 3 to 35 L/day/tree at the two sites. This is consistent with measured water use at other phytostabilization field locations (Parsons, 2003). Plant tissue sampling conducted in 2002 indicates there are some low levels (near the detection limit) of TCE and TCE metabolites found within the plant stands.

Water level and groundwater monitoring results to date have not shown any direct influence by the plant stands on the groundwater system. As indicated above, more aggressive monitored is expected to occur at the more promising sites in the coming growing seasons to evaluate any potential effects.

Capital and operation and maintenance costs are also being tracked as part of the demonstration effort. Actual capital costs and actual/estimated (in *italics*) operation and maintenance costs for the six sites are as follows (Parsons, 2003):

Location	Capital + 1st Growing Season	2nd Growing Season	3rd Growing Season	4th Growing Season	5th Growing Season	6th Growing Season	7th Growing Season
Travis AFB	$43,520	$28,877	$20,697	*$37,630*	*$39,680*	*$39,680*	*$39,680*
Altus AFB	$21,900	$30,985	$19,088	*$37,630*	*$39,680*	*$39,680*	*$39,680*
Fairchild AFB	$23,200	*$32,532*	*$39,104*	*$41,154*	*$41,154*	-	-
Ellsworth AFB	$23,600	*$32,532*	*$39,104*	*$41,154*	*$41,154*	-	-
Hill AFB	$26,500	*$32,532*	*$39,104*	*$41,154*	*$41,154*	-	-
Vandenberg AFB	$39,300	*$32,532*	*$39,104*	*$41,154*	*$41,154*	-	-

Results of the demonstration through 2001 have been detailed in the report titled *Phytostabilization of Shallow Contaminated Groundwater Using Tree Plantings at Multiple Air Force Demonstration Sites, Technology Demonstration Interim Technical Reports and Interim Cost and Performance Reports, Volumes I and II* (Parsons, 2003). This interim report will be updated on an annual basis for the six sites.

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