Evaluation of Phytoremediation for Groundwater Control at a Landfill Site in California

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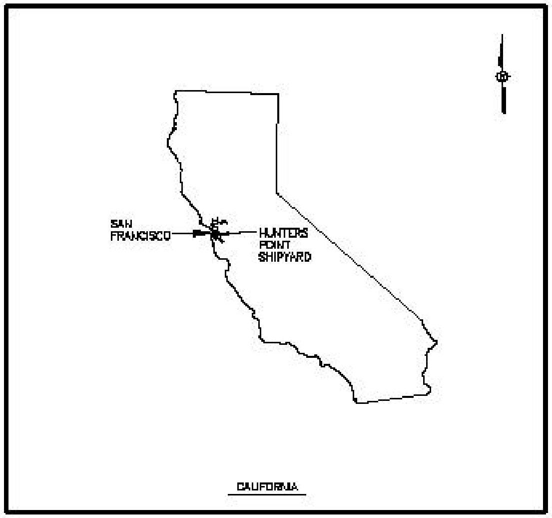
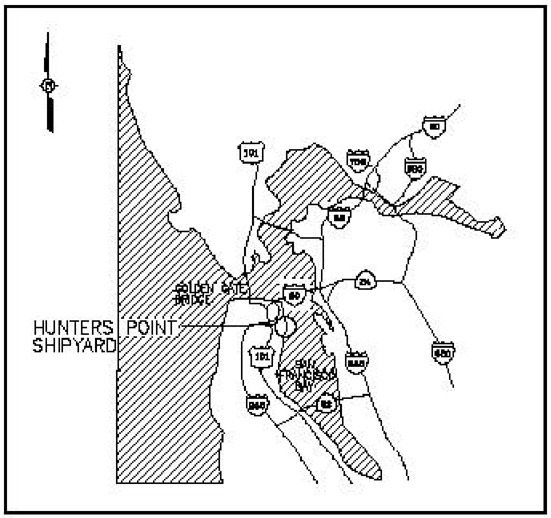


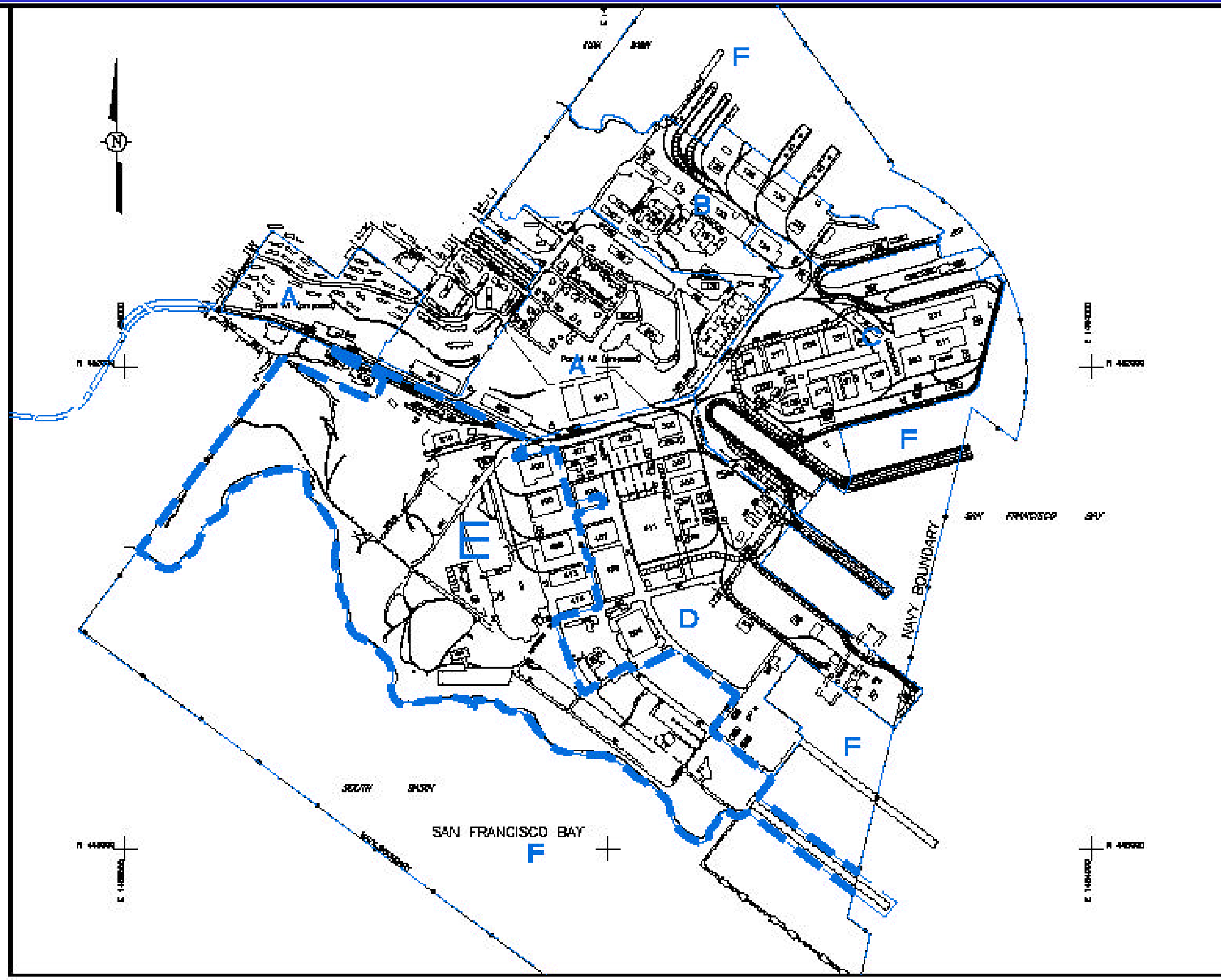
REGIONAL LOCATION

NOT TO SCALE



VICINITY MAP

NOT TO SCALE



SITE LOCATION MAP

SCALE

0 1000 2000 FEET

SITE CONDITIONS

Hydrogeology

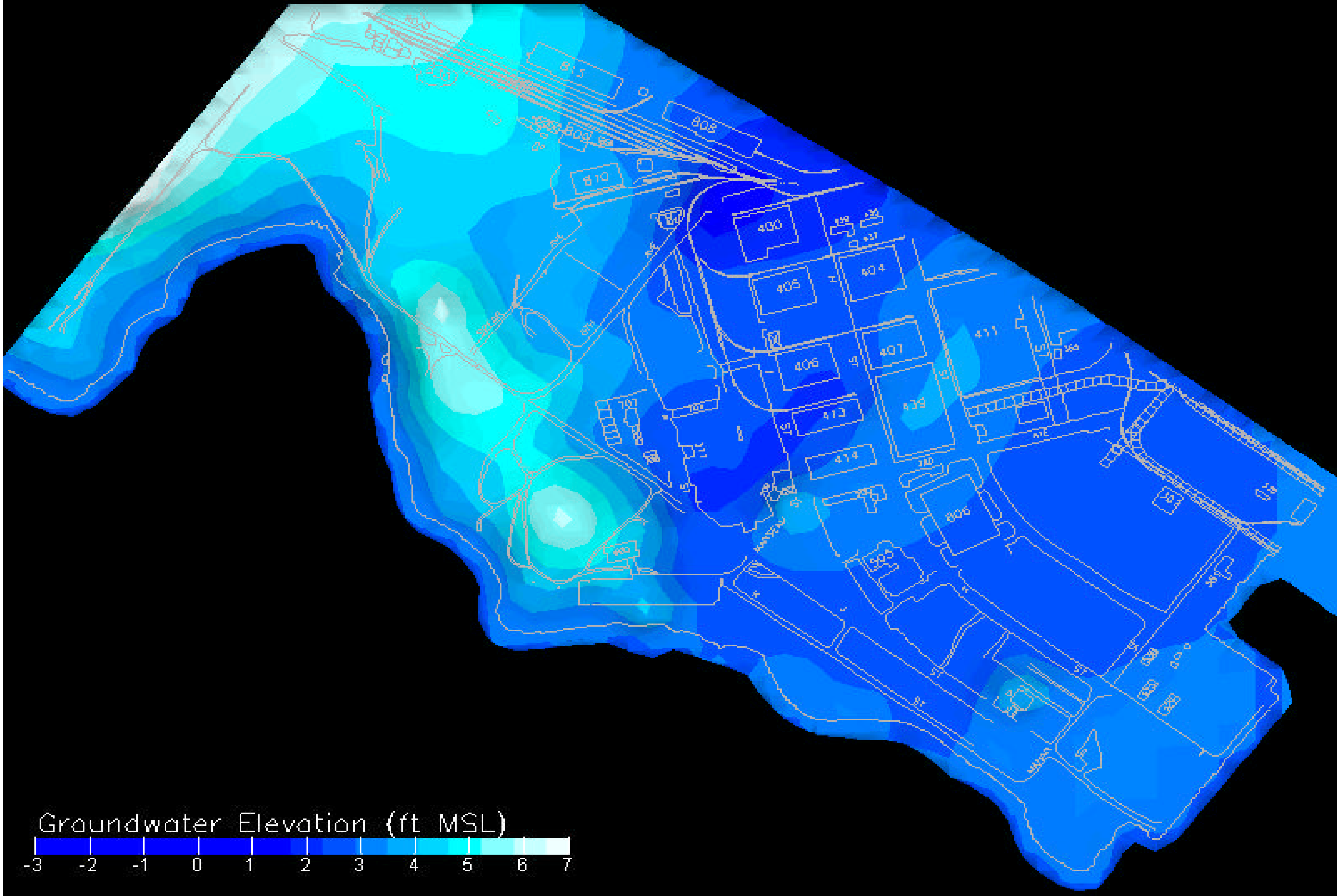
- Shallow Thin Unconfined Aquifer
  - 2 to 5 feet thick
  - Fill Material, clay, sand, silt gravel
  - Low to Moderate Hydraulic Conductivity

- Laterally Continuous Aquitard
  - Pleistocene Bay Mud Sediments
  - Very low Hydraulic Conductivity
- Deep Confined Aquifer
  - Pleistocene sand
  - Moderate Hydraulic Conductivity

Groundwater Conditions:

- Low concentrations of VOCs and PCBs in Shallow Aquifer
- Brackish Groundwater

Site Water Table Elevation



EXISTING GROUNDWATER CONTROL SYSTEM

Purpose:

- Prevent Migration of PCBs into SF Bay

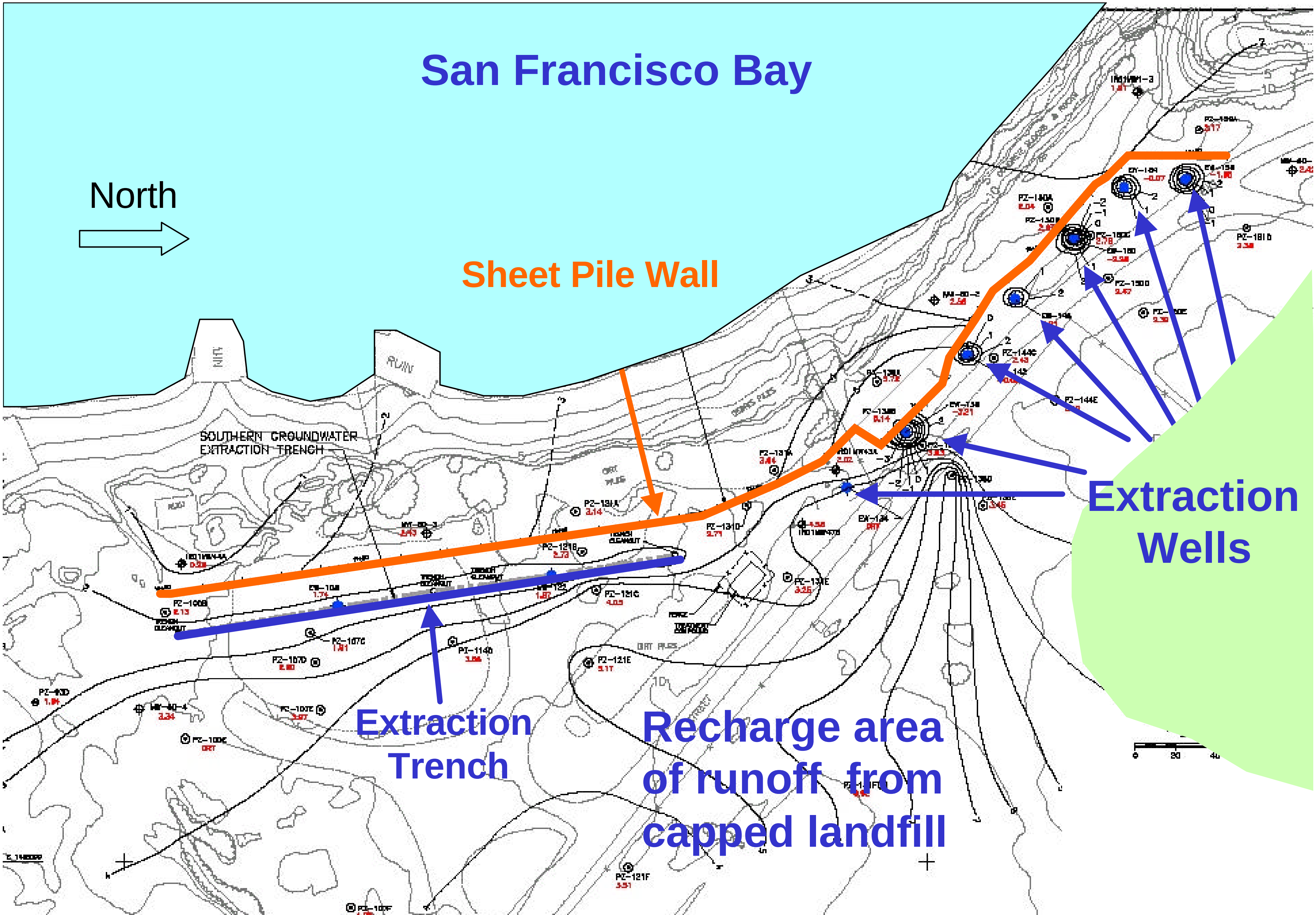
Sheet Pile Wall:

- Approximately 600 feet Long
- Installed 15 to 50 Feet Total Depth Below Land Surface

GROUNDWATER EXTRACTION SYSTEM (GES):

Purpose of GES: Prevent groundwater mounding behind sheet pile wall

- 7 Extraction Wells
- 1 Extraction Trench (including 2 sumps)
- Individual Flow Rates - 0.1 to 9 Gallons Per Minute
- Total Flow Rate - Approximately 10 GPM
- Radius of Influence Less Than 15 Feet
- Almost all flow comes out of one well
- Water discharged to POTW.



GES -Sheet Pile Wall Layout

Landfill
Sheet Pile Wall (Approximate)


GES Wells
Landfill


GES Wells
Sheet Pile Wall (Approximate)


Groundwater Recharge Area

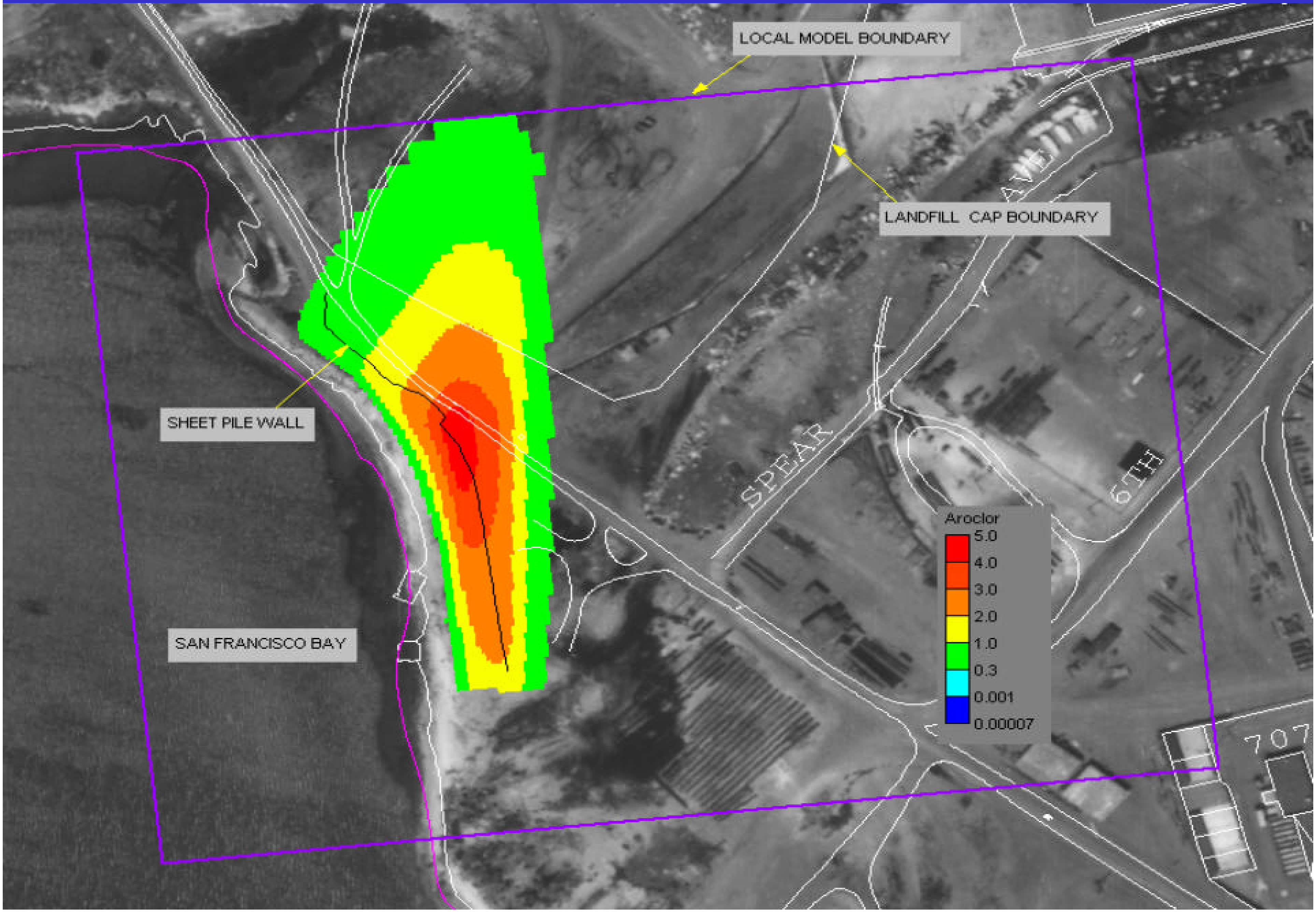

APPROXIMATE LOCATION
OF SHEET PILE WALL
SOUTHWEST EDGE
OF LANDFILL CAP


Landfill
APPROXIMATE LOCATION OF SHEET PILE WALL
EXTRACTION WELLS

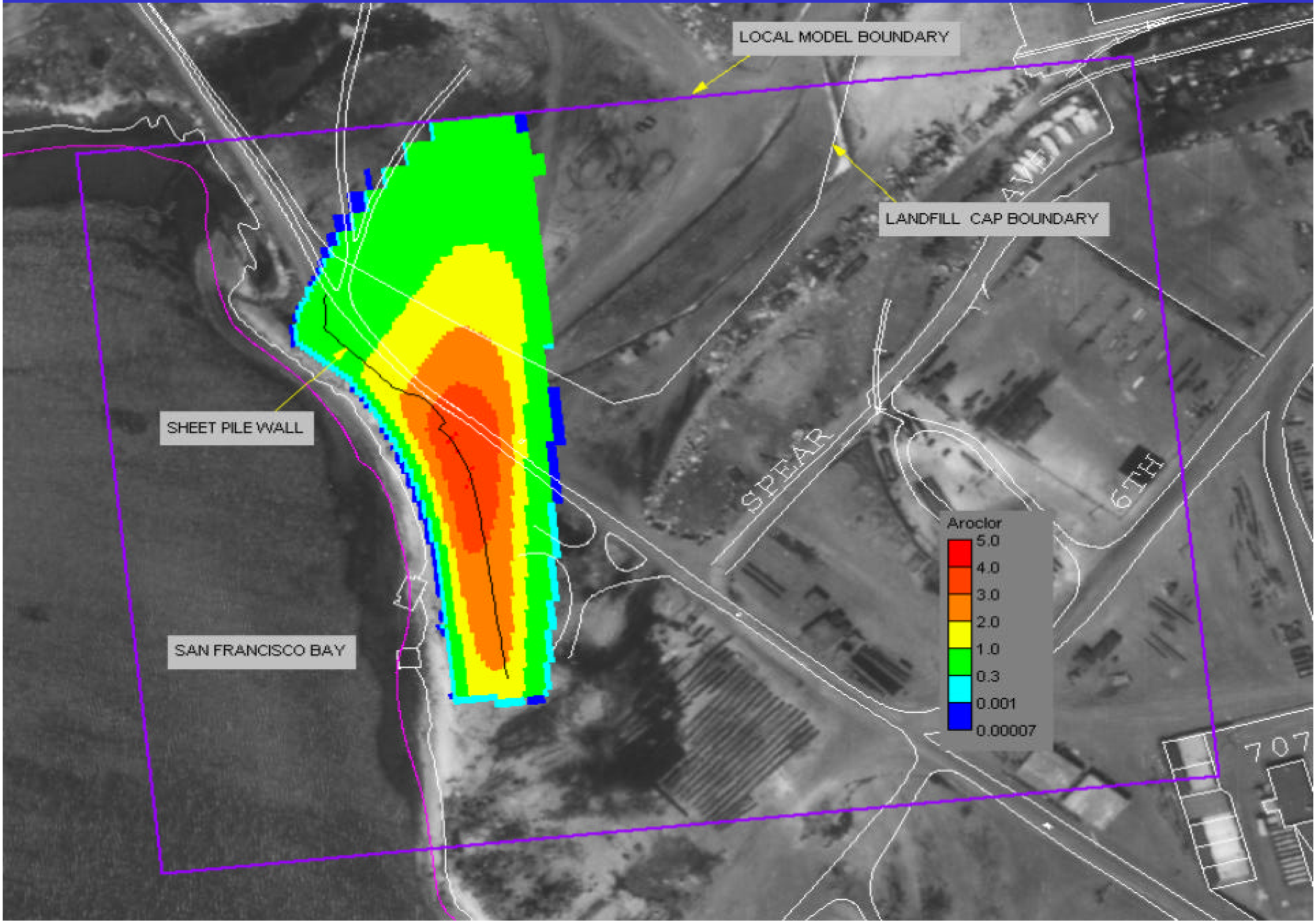
PRELIMINARY INVESTIGATION:

- **Evaluated PCB Migration to Bay**
- **Used Modflow MT3D for transport**
- **Assumed GES not operating**
- **Used conservative input parameters**

CONCEPTUAL AROCLOR 1260 PLUME – SIMULATED INITIAL CONCENTRATIONS (ppb) FOR MARCH/APRIL 2001 DATA



SIMULATED AROCLOR 1260 CONCENTRATIONS (ppb) FOR MARCH/APRIL 2001 DATA – AFTER 50 YEARS



Contaminant Transport Modeling Results:

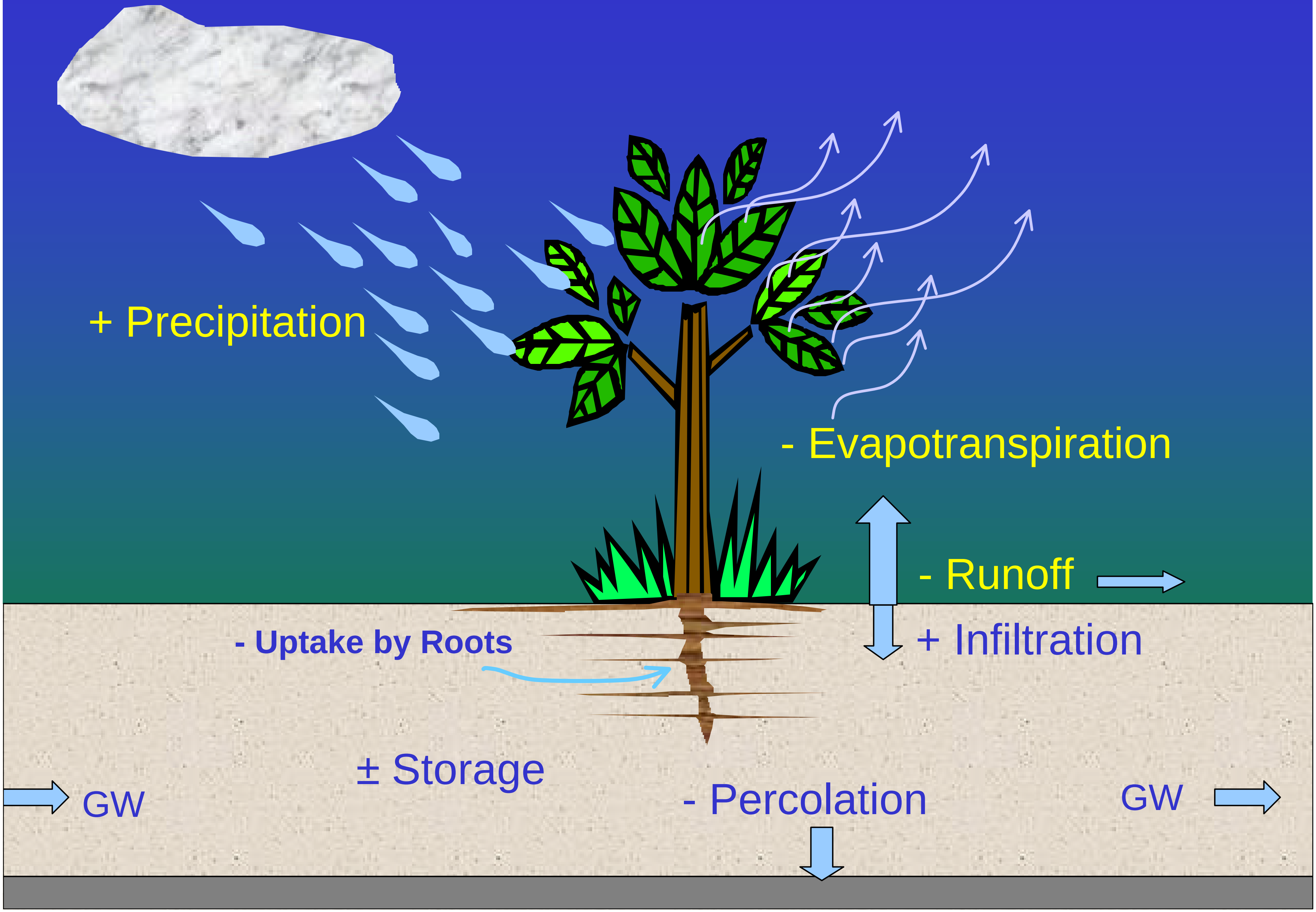
- PCBs tend to bind very strongly to soils.
- The rate of PCB migration is very low.
- Radius of influence of groundwater extraction wells is fairly small.
- Runoff from landfill reduces effectiveness of GES.
- The GES does not substantially reduce the migration rate for PCBs to the Bay.
- GES is not cost effective method for groundwater control.
- Recommend evaluation of passive groundwater control system

EVALUATION OF PHYTOREMEDIATION:

- **Tree Selection**

- **Groundwater Modeling**

Water Balance



Qualities of Trees Evaluated:

- Salt Tolerance
- Daily Water Uptake
- Growth Rate
- Planting Density
- Area of Water Extraction
- Root Depth
- Reproduction

Scientific Name	Eucalyptus	Tamarix	Populus
Common Name	Eucalyptus	Tamarisk, Saltcedar	Poplar, Cottonwood
Growth Form	Tree	Shrub/Tree	Tree
Salt Tolerance	Very High (1200-15000 ppm)	Very High (6000-15000 ppm)	Moderate-High (3600 ppm)
Water Uptake	20-150 L/day	50-700 L/day	30-150 L/day
Growth Rate	Rapid (3-12 ft/yr)	Rapid (up to 10-12 ft)	Rapid (4-10 ft/yr)
Planting Density	200-1200/acre	800-1200/acre	600-1000/acre
Area of Water Extraction (extent of roots)	15-40 ft diameter	5-12 ft diameter	10-30 ft diameter
Root Depth	2-20 ft	3-9 ft or more	3-12 ft
Leaf Retention	Evergreen	Deciduous	Deciduous

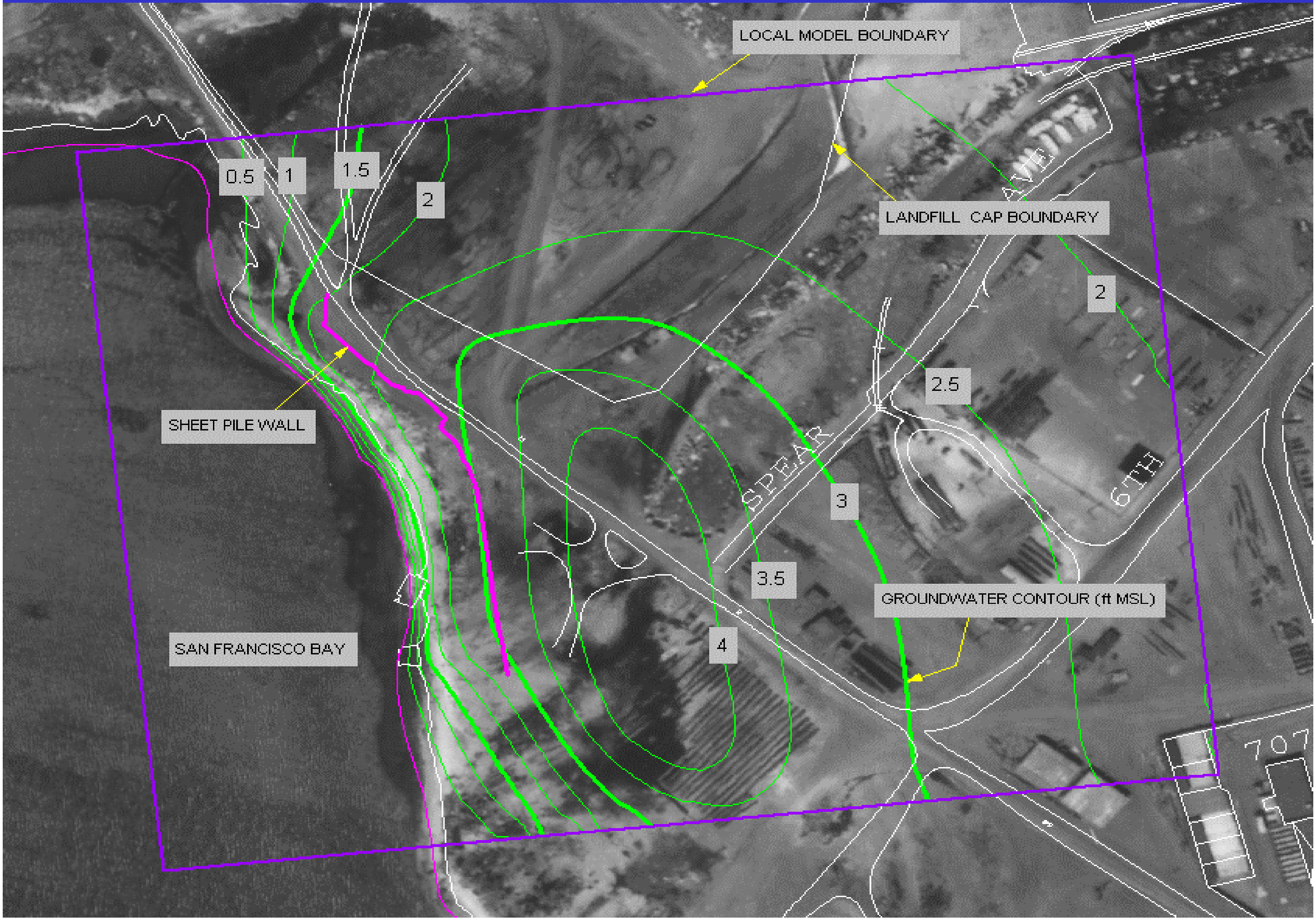
Data sources included: USDA, 2001; Treeguide, 2001. Water uptake rates from Hatton et al., 1998; ITRC, 2001; Tossell et al., 1998.

GROUNDWATER MODELING:

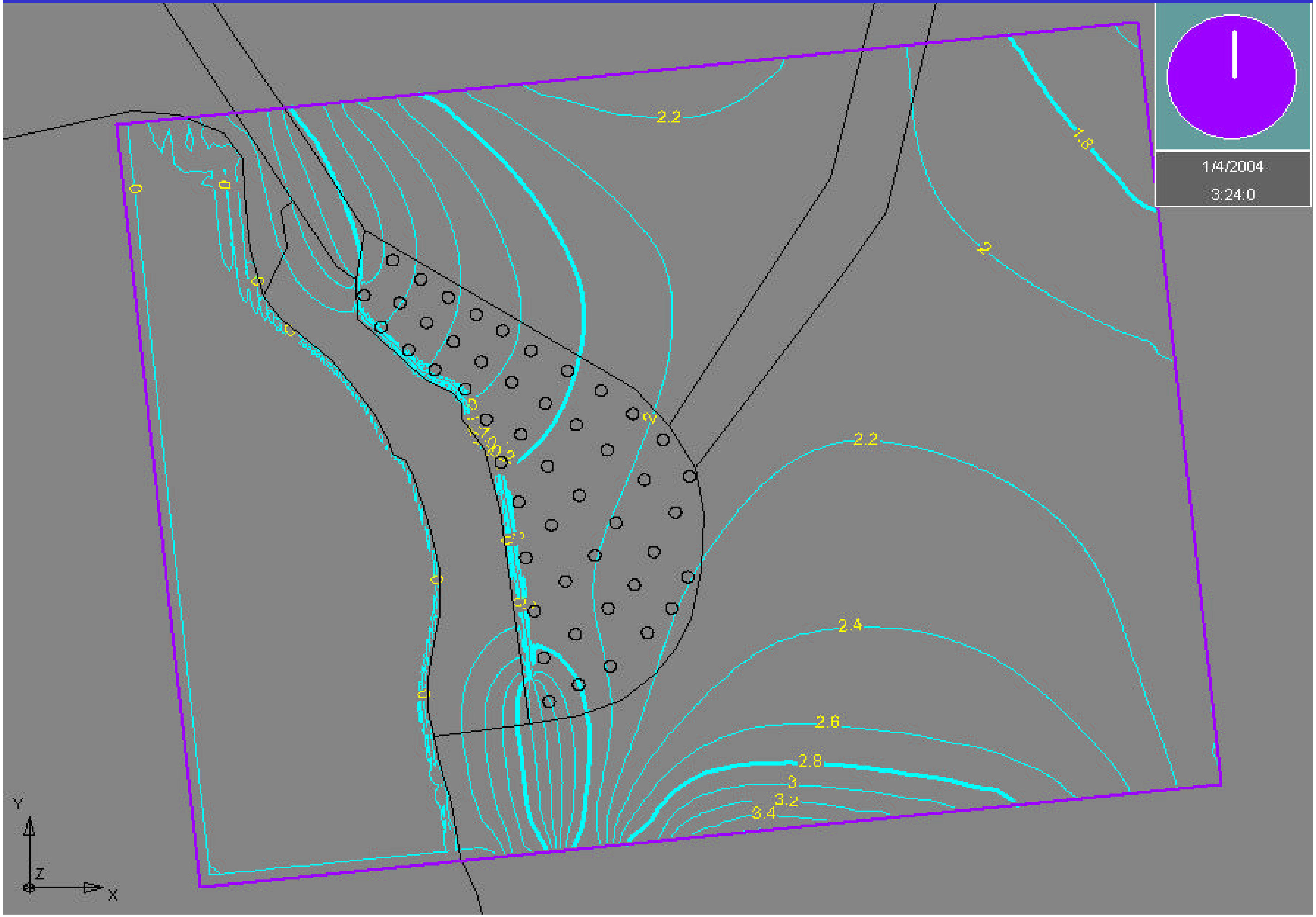
Steady State Simulation

- Assumed Site Capped (no infiltration)
- Simulated Eucalyptus Trees
- Evapotranspiration package
- Extinction Depth - 3 feet
- Transpiration rates of 20, 40, 80, 125 Liters/Day/Tree

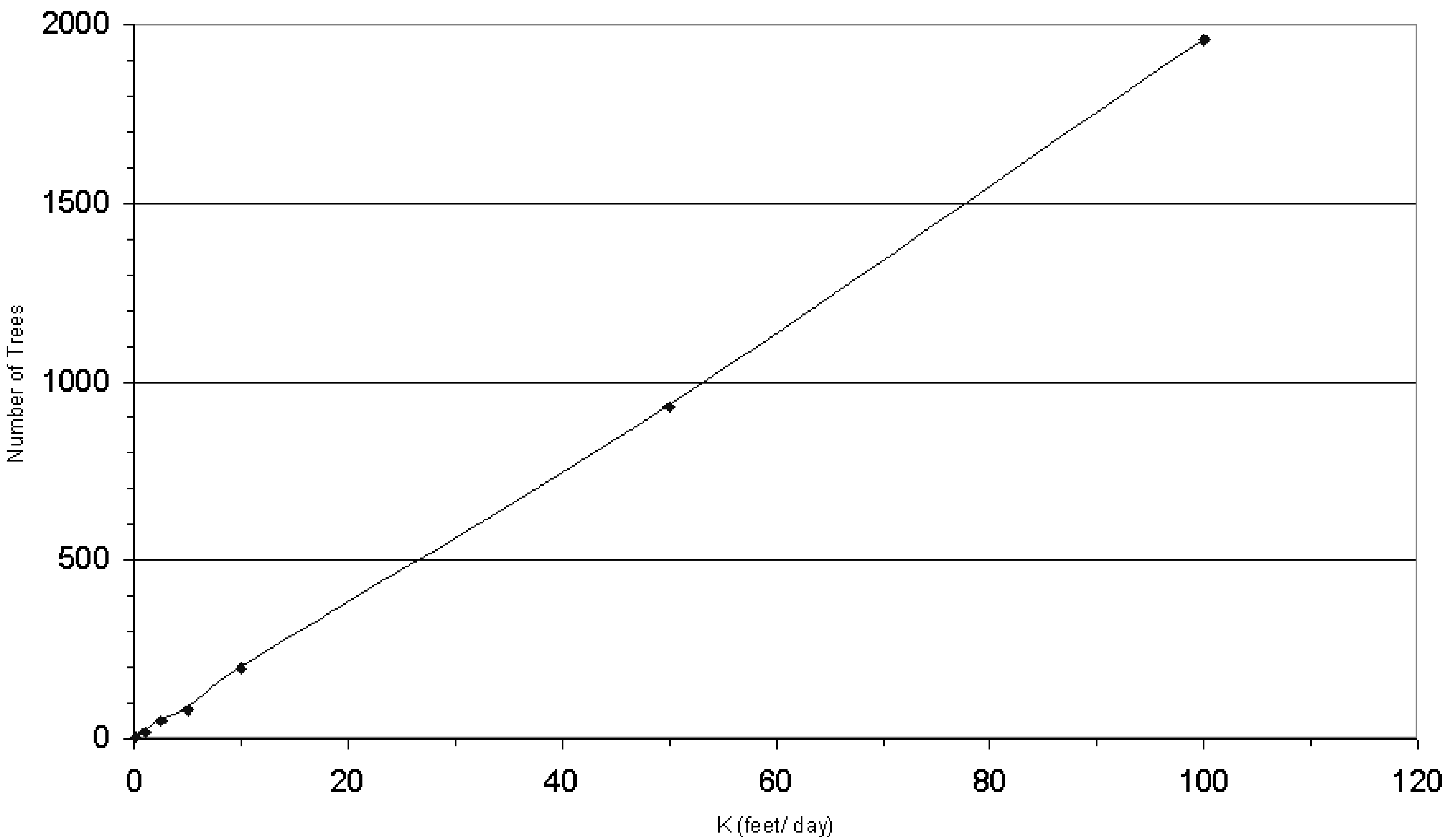
SIMULATED GROUNDWATER ELEVATION CONTOURS (feet mean sea level) – LOCAL MODEL



Seasonal Groundwater Fluctuation Simulation



Number of trees required to achieve hydraulic control in phytoremediation area as a function of hydraulic conductivity (K). Trees are assumed to transpire at a rate of 80 L/day.



GROUNDWATER MODELING:

Transient Simulation

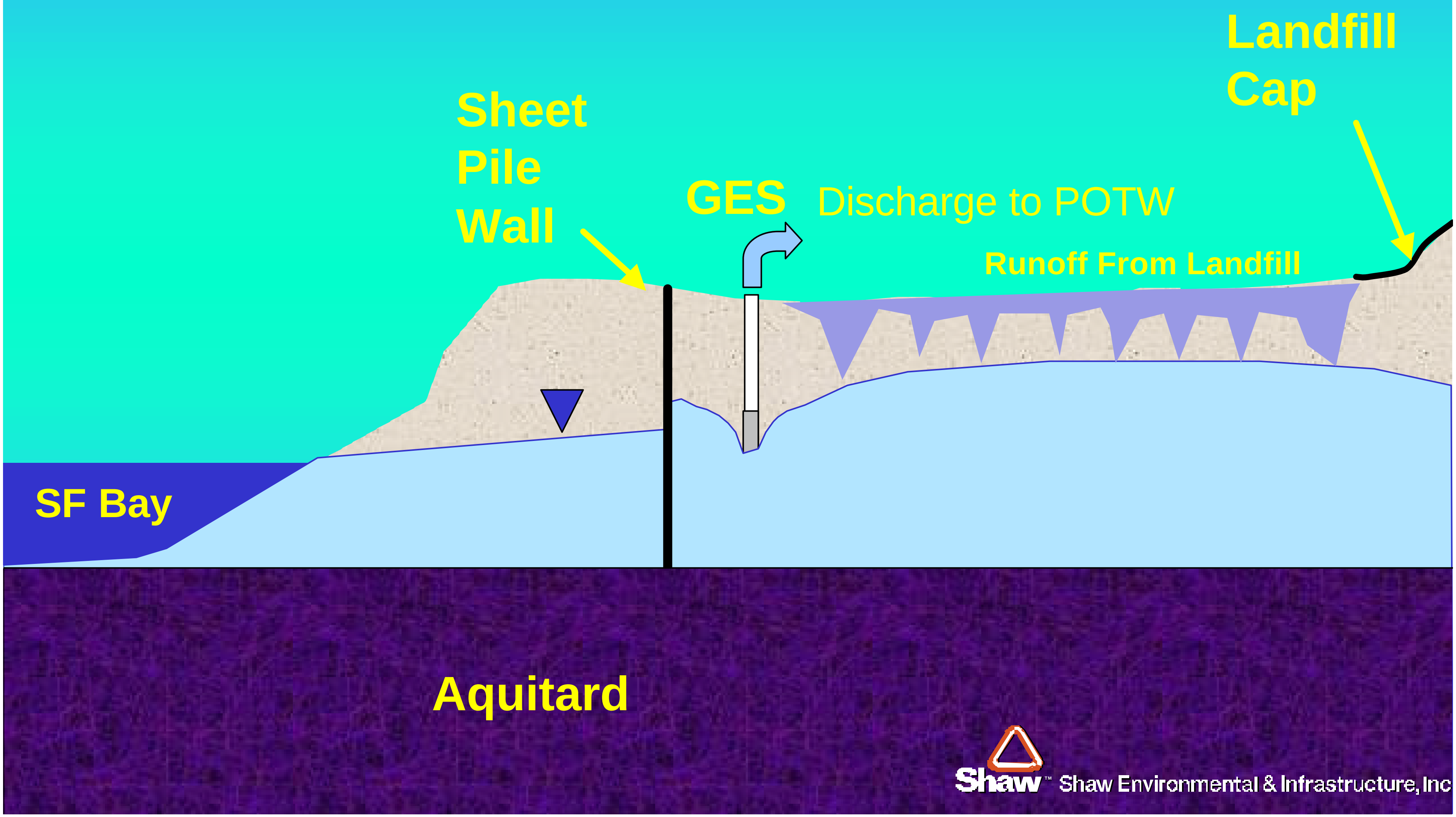
- Year 1 to 3 – Roots reaching water
- Year 3 & 4 – Roots from immature trees in groundwater
- Years 5 and 6 – Roots from mature trees in groundwater
- K = 2.5 feet/day
- 49 trees
- Transpiration rate of 80 L/Day
- 15 foot radius of influence
- Seasonal Fluctuations in Evapotranspiration Rates

Modeled Transpiration Rates

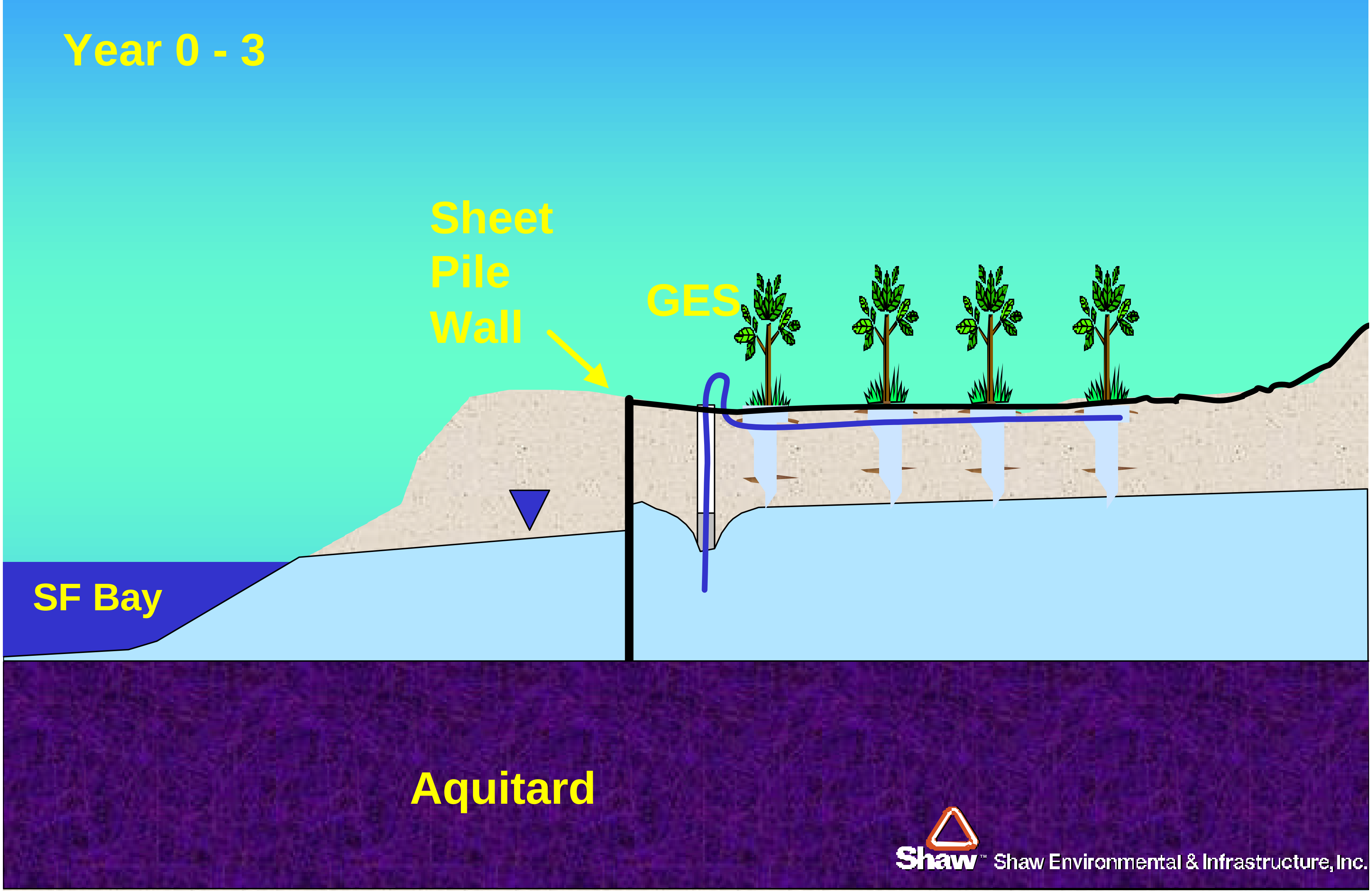
Transpiration Rate (Liters/day)	Year	0	1	2	3	4
	Jan	0	5	10	20	25
	Feb	0	5	10	15	20
	Mar	0	10	20	30	40
	Apr	1	12	25	35	45
	May	2	15	30	45	60
	Jun	3	20	40	55	75
	Jul	5	20	40	60	80
	Aug	3	20	40	60	80
	Sep	2	17	35	50	65
	Oct	2	11	25	35	45
	Nov	2	5	10	15	20
	Dec	3	5	10	15	15
Root Depth	feet	0.5	2	4	6	8
Root Diameter	feet	0.5	4	8	12	15

Conceptual Model of Phytoremediation Process

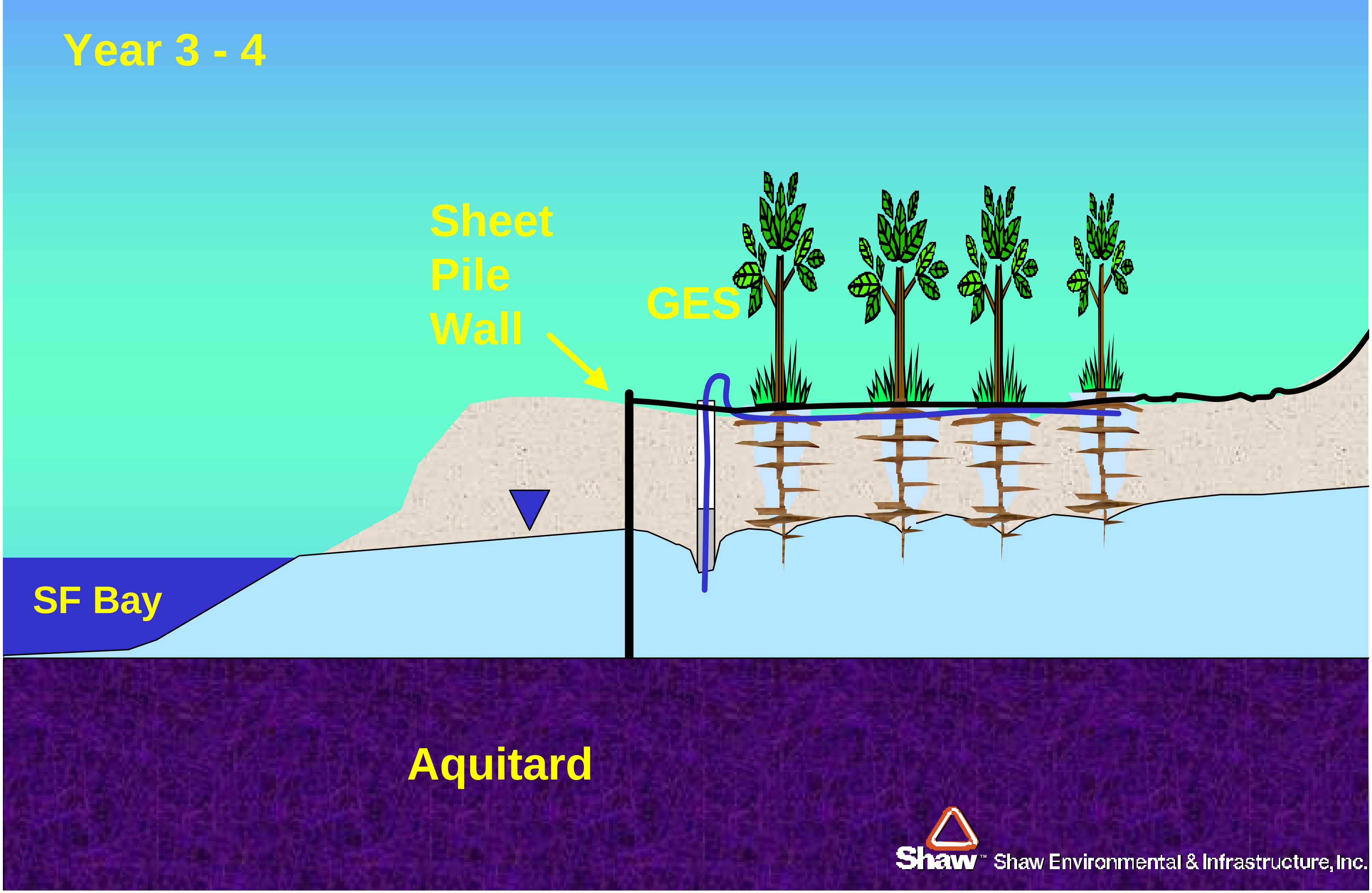
Present



Conceptual Model of Phytoremediation Process (cont.)

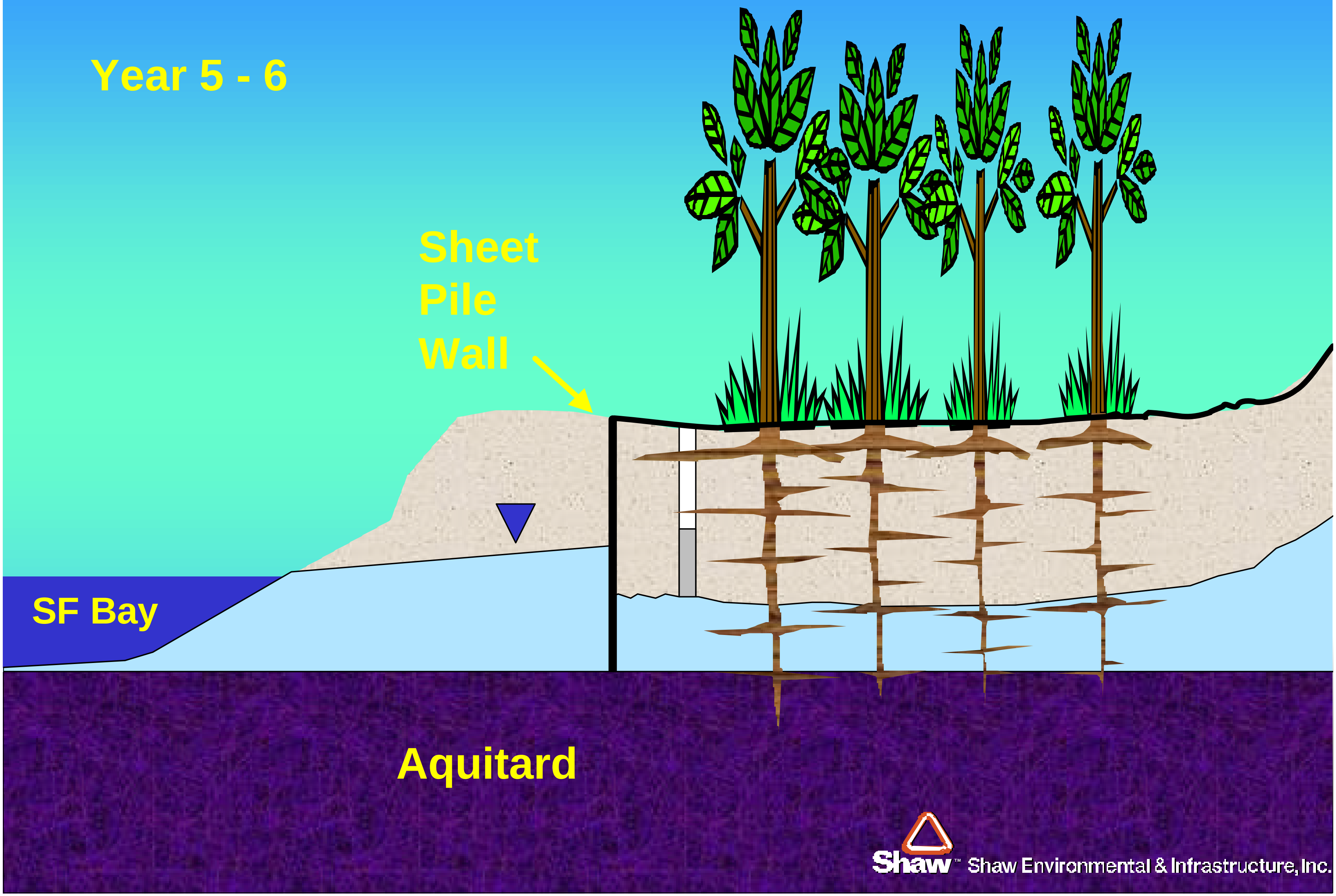


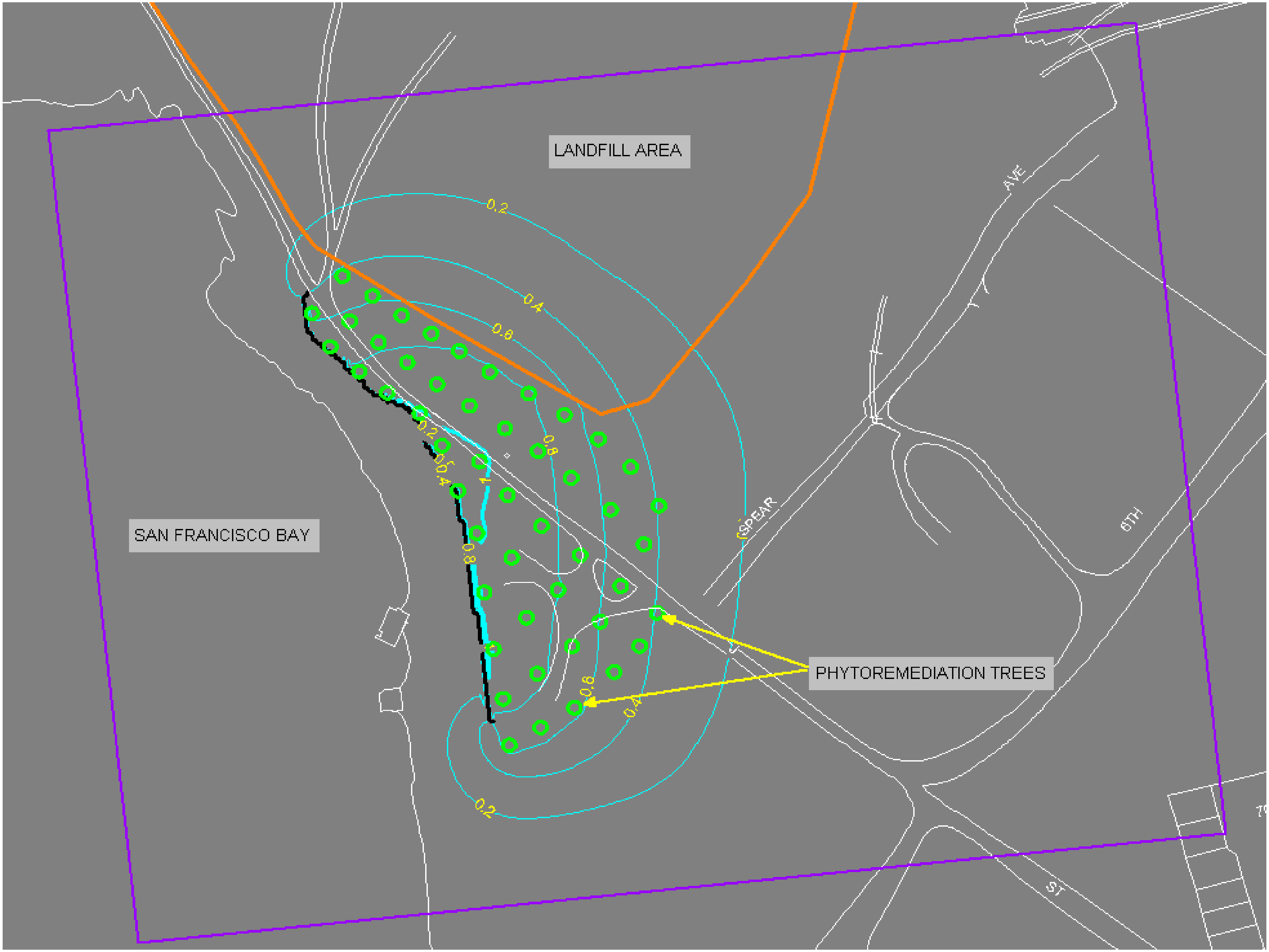
Conceptual Model of Phytoremediation Process (cont.)



Conceptual Model of Phytoremediation Process (cont.)

Year 5 - 6





LANDFILL AREA
SAN FRANCISCO BAY
PHYTOREMEDIATION TREES
SPEAR
AVE
6TH
ST
0.2
0.4
0.6
0.8

CONCLUSIONS:

- **Number of trees required largely controlled by hydraulic conductivity.**
- **Capping recharge area reduces mounding.**
- **Groundwater uptake by trees is sufficient to control groundwater flow at landfill.**
- **Phytoremediation is a cost-effective means of groundwater control.**
- **FUTURE WORK**
- **Field Demonstration 2003**