Natural Attenuation of Petroleum Hydrocarbons in a Prolific Outwash Sand and Gravel Aquifer

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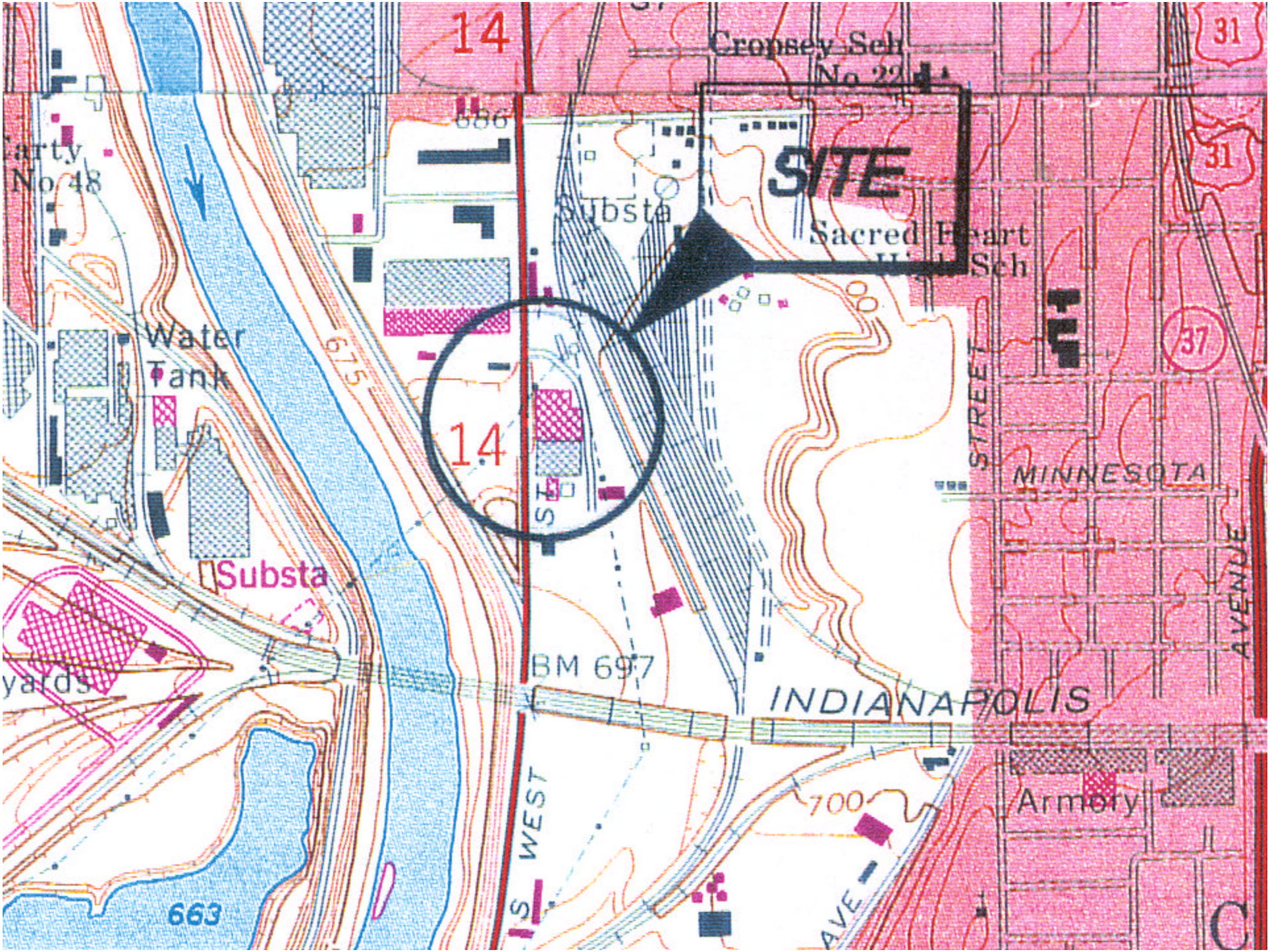
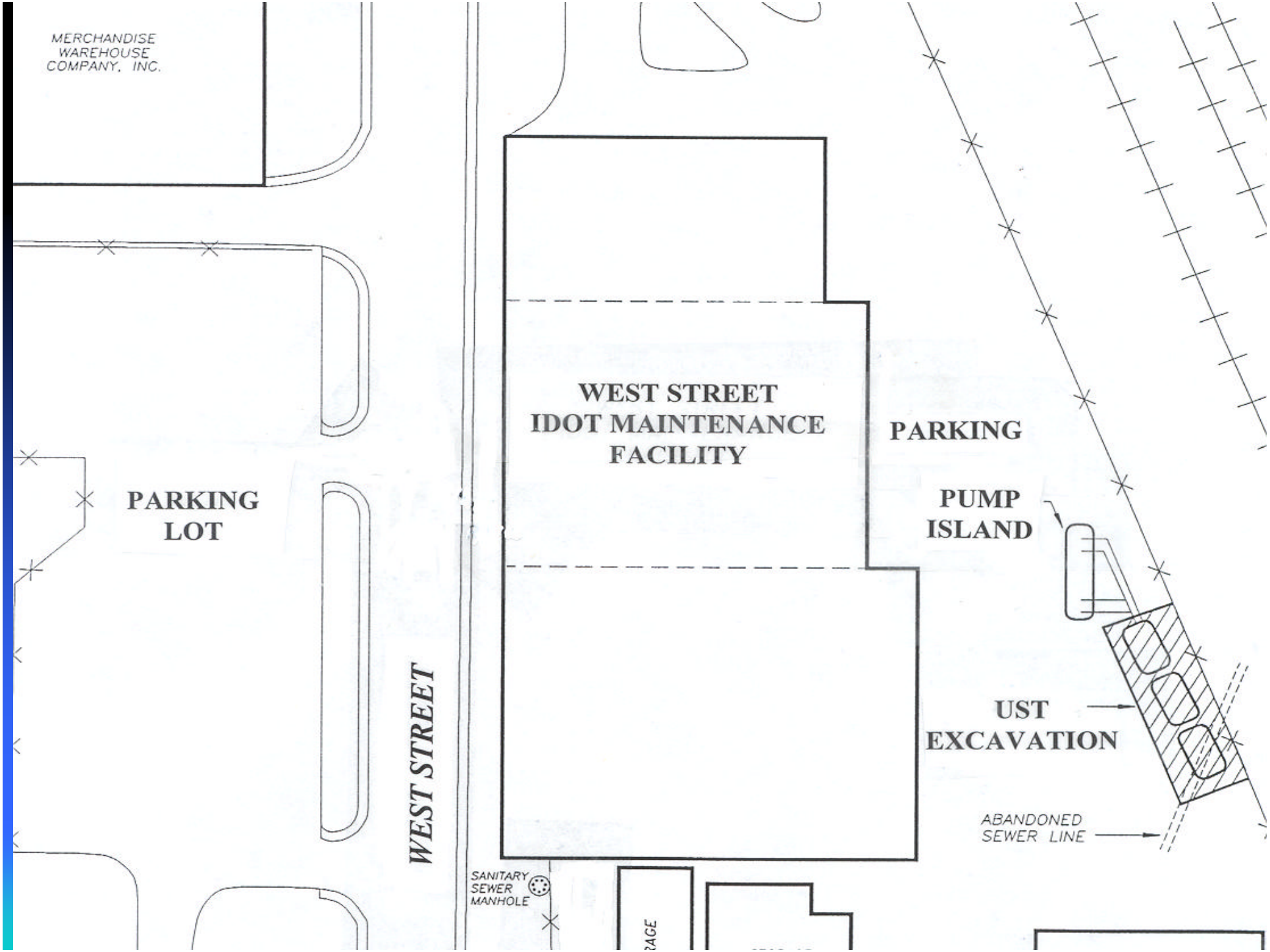
Significance of this Presentation

- Case history presentation of observed natural attenuation of gasoline release in Indiana outwash sands and gravels.
- Calibration of observed plume behavior with apparent contaminant degradation rates.
- Long-term plume stability resulted in no significant environmental impacts, even without active plume remediation.

Indianapolis Department of Transportation's West Street Maintenance Facility

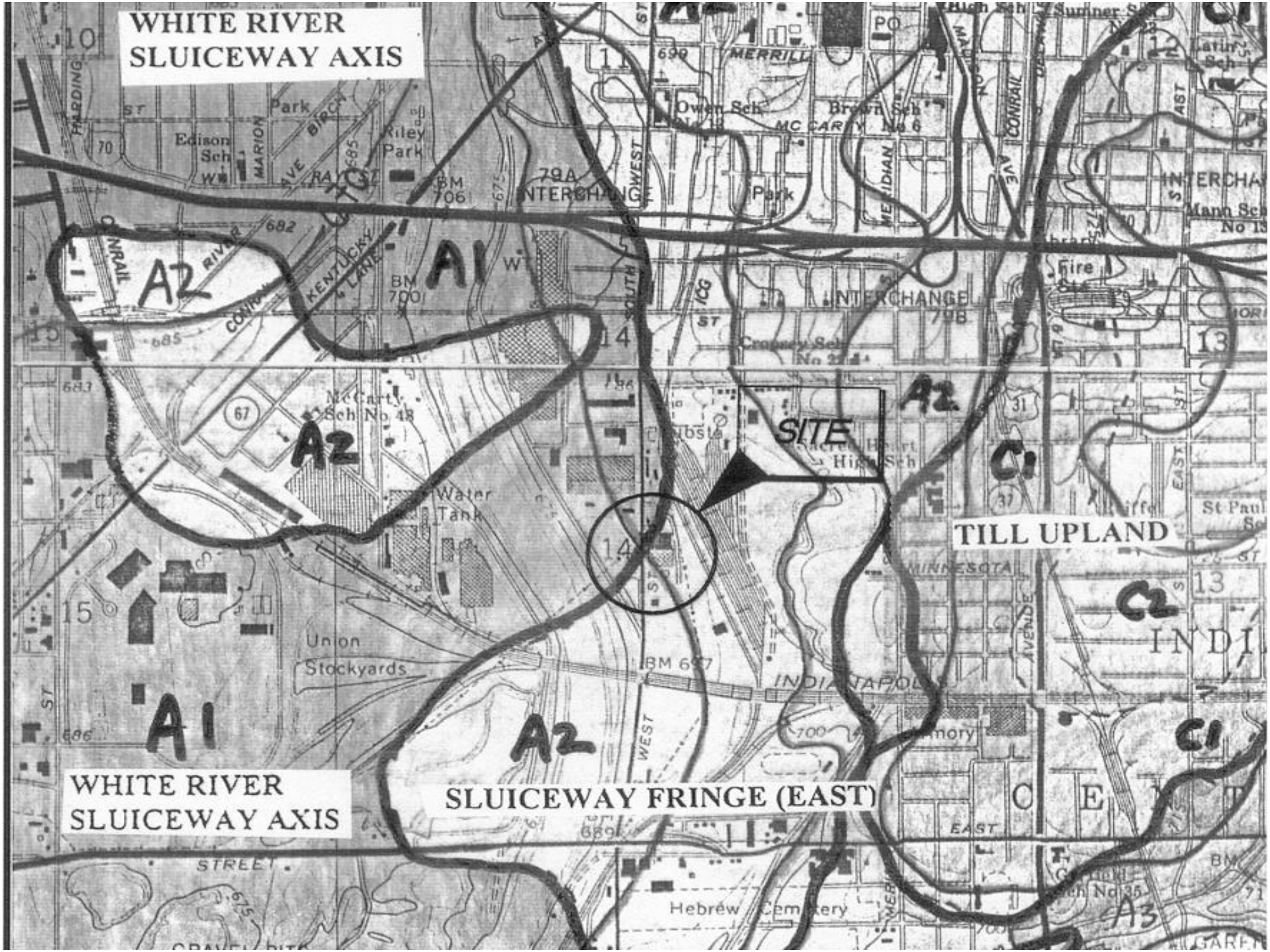
- 14 acre site, 9 acres covered by parking lot.
- Located within 400 ft of the east bank of the White River southwest of downtown Indianapolis.
- December 1989 to January 1990, 5 underground storage tanks were removed from a pit east of Building 4 along the site's eastern boundary.
- Four USTs contained gasoline, the fifth contained diesel fuel.


14
Cropsey Sch
No 22
SITE
Sacred Heart
Sch
31
37
Water
Tank
675
14
Substa
STREET
MINNESOTA
AVENUE
Substa
BM 697
INDIANAPOLIS
WEST
700
Armory
663


MERCHANDISE
WAREHOUSE
COMPANY, INC.
PARKING
LOT
WEST STREET
IDOT MAINTENANCE
FACILITY
PARKING
PUMP
ISLAND
WEST STREET
UST
EXCAVATION
ABANDONED
SEWER LINE
SANITARY
SEWER
MANHOLE

Site Geology

- Locally dissected Tipton Till Plain by fluvial and glacio-fluvial sand and gravel outwash deposits along the White River.
- Site sits on top of a glacial terrain boundary separating the outwash sluiceway axis of primary meltwater from the sluiceway "fringe area".
- Sluiceway axis contains thick sections of unconfined sand and gravel.

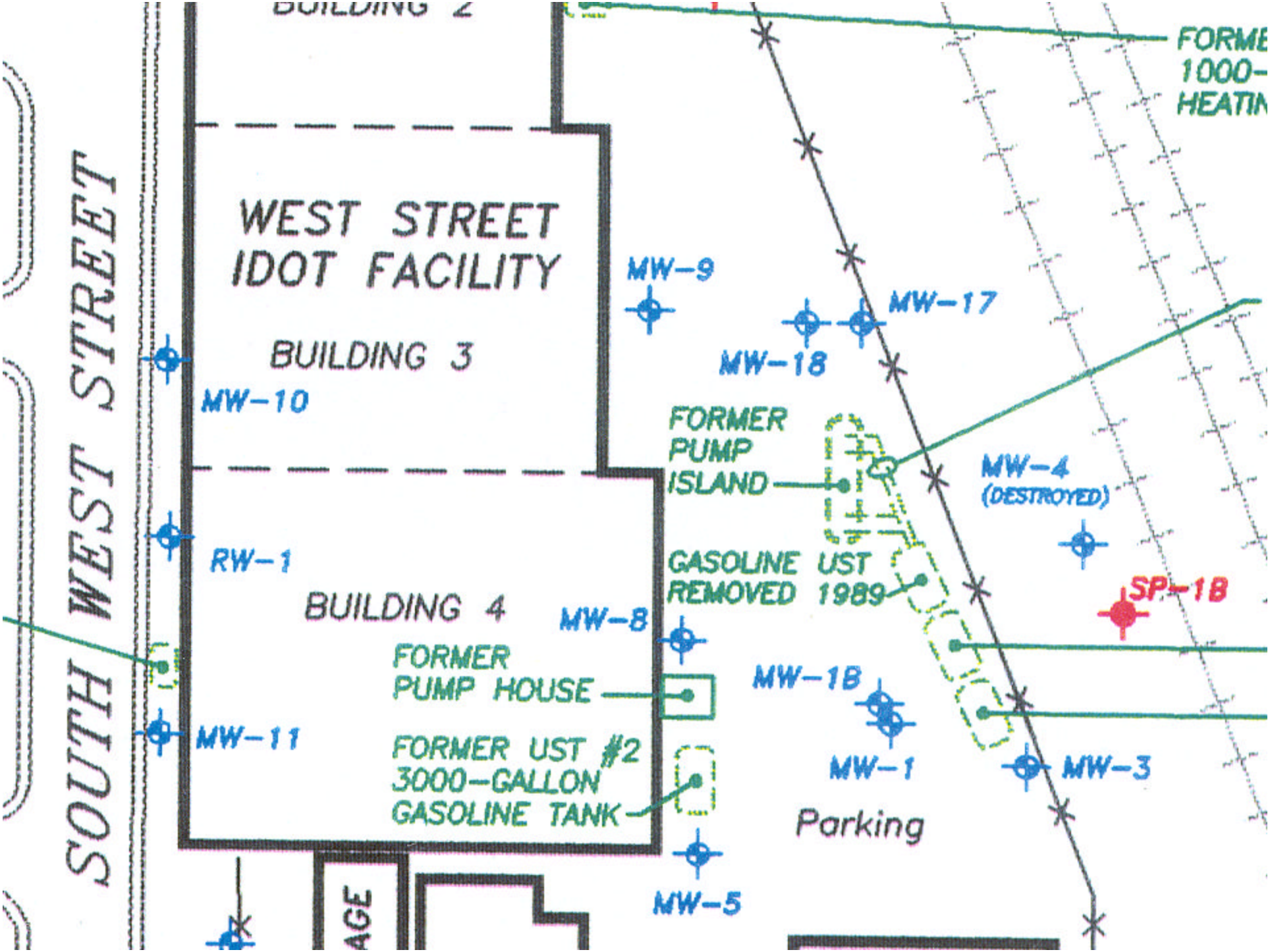

WHITE RIVER
SLUICEWAY AXIS
SITE
TILL UPLAND
A1
A2
C1
C2
A3
WHITE RIVER
SLUICEWAY AXIS
SLUICEWAY FRINGE (EAST)

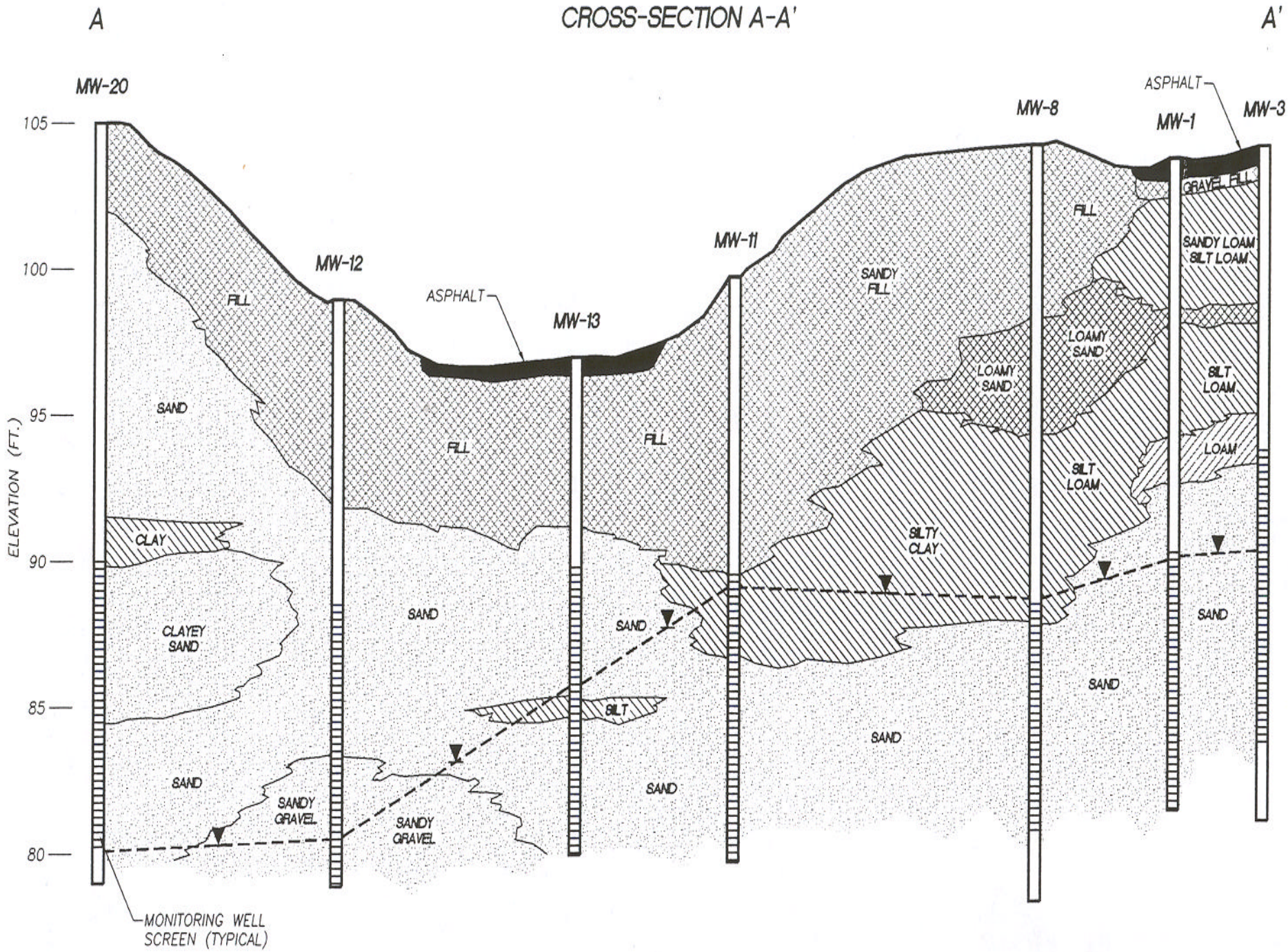
Site Hydrogeology

- Sluiceway “fringe area” contains outwash bodies interspersed with multiple glacial till units.
- Aquifer is 70 to 80 ft thickness beneath site.
- Groundwater flow is west-southwest toward White River.
- Aquifer transmissivity range from 50,000 to 100,000 gpd/ft; hydraulic conductivity between 40 to 425 ft/day.

Source Removal and Investigation

- 815 cubic yards of soil were excavated and disposed of off site; floating product observed in the UST excavation; product bailing
- Multiple environmental investigations included soil and groundwater sampling; installation of monitoring well network, geophysical survey, aquifer hydraulic testing.
- Delineation of petroleum impact to site.


BUILDING 2
WEST STREET
IDOT FACILITY
BUILDING 3
BUILDING 4
SOUTH WEST STREET
MW-9
MW-17
MW-18
MW-10
FORMER
PUMP
ISLAND
MW-4
(DESTROYED)
RW-1
GASOLINE UST
REMOVED 1989
SP-1B
MW-8
FORMER
PUMP HOUSE
MW-1B
MW-11
FORMER UST #2
3000-GALLON
GASOLINE TANK
MW-1
MW-3
Parking
MW-5


A
CROSS-SECTION A-A'
A'
MW-20
MW-12
MW-13
MW-11
MW-8
MW-1
MW-3
ASPHALT
ASPHALT
105
100
95
90
85
80
ELEVATION (FT.)
FILL
SAND
CLAY
CLAYEY SAND
SAND
SANDY GRAVEL
SANDY GRAVEL
FILL
FILL
SILT
SAND
SAND
SANDY FILL
LOAMY SAND
SILTY CLAY
SAND
FILL
LOAMY SAND
SILT LOAM
SAND
GRAVEL FILL
SANDY LOAM SILT LOAM
SILT LOAM
LOAM
SAND
MONITORING WELL SCREEN (TYPICAL)

Impacted Groundwater

- Benzene, toluene, ethylbenzene, xylenes
- Near effective solubilities near source
- Free product initially in source area
- Impacts in direction of groundwater flow.

Development of Corrective Action Plan

- Preliminary feasibility analysis evaluated pump and treat; early regulatory pressure.
- Aquifer pump test; capture zone analysis; high capacity well (50 to 100 gpm) would control plume.
- Installed recovery well; continued monitoring.
- No downgradient receptors.

Development of Corrective Action Plan

- BTEX levels began dropping after initial source removal and product bailing.
- Groundwater monitoring continued for four years; bailed product when it appeared.
- New Corrective Action Plan looked at *Natural Attenuation with Monitoring* as the selected remediation technology of choice.

Natural Attenuation Modeling

- Groundwater Flow Modeling
- 2-D Contaminant Transport Modeling
- Prediction of BTEX concentrations with distance from source over time.

Groundwater Flow Modeling

- Used calibrated regional model from White River Groundwater Assessment (Mundell et al., 1995) as starting point.
- Site-specific groundwater modification of geologic boundaries and calibration to site groundwater levels.
- Used to install “sentinel” wells and as input to 2-D contaminant transport model.

667.0
666.0
White River
Pathlines
Boundary Between
Sluiceway Axis
And Fringe Areas
(See Figure 3)
674.0
673.0
672.0
671.0
670.0
669.0
668.0

Contaminant Transport Analysis

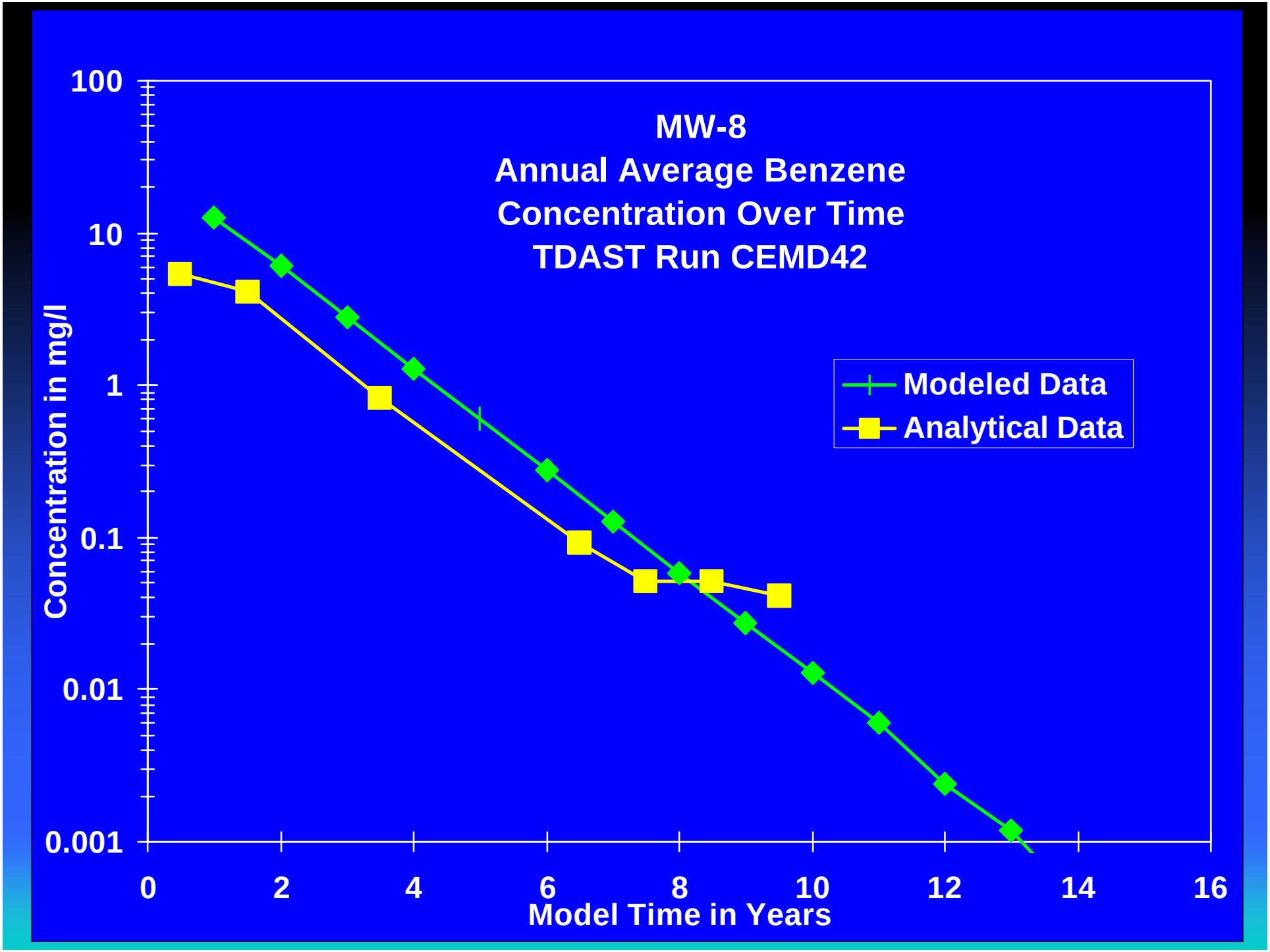
- For CAP and closure approval, used 2-D analytical solution (TDAST), allows source decay and biodecay using unidirectional assumption.

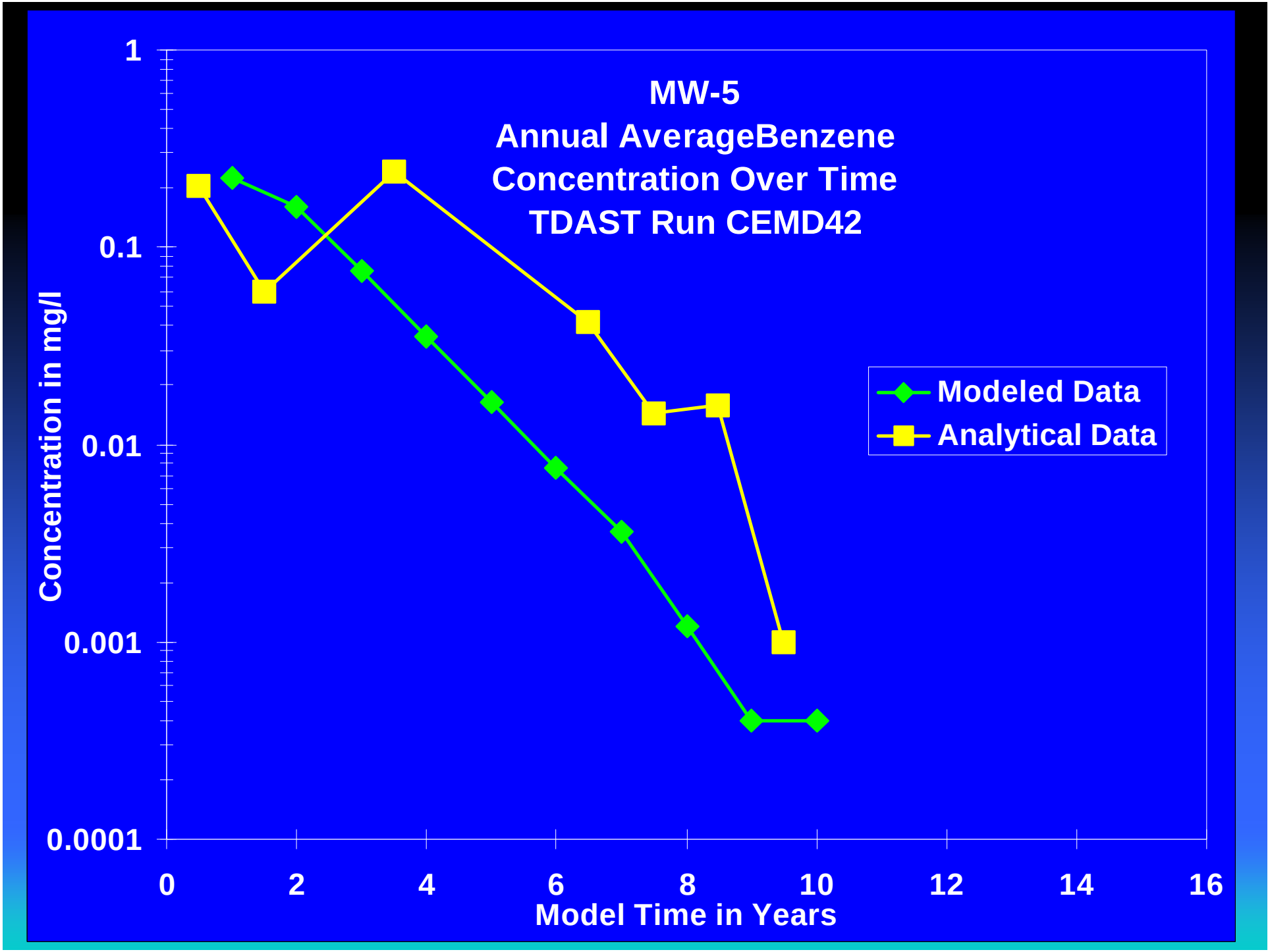
Contaminant Transport Model

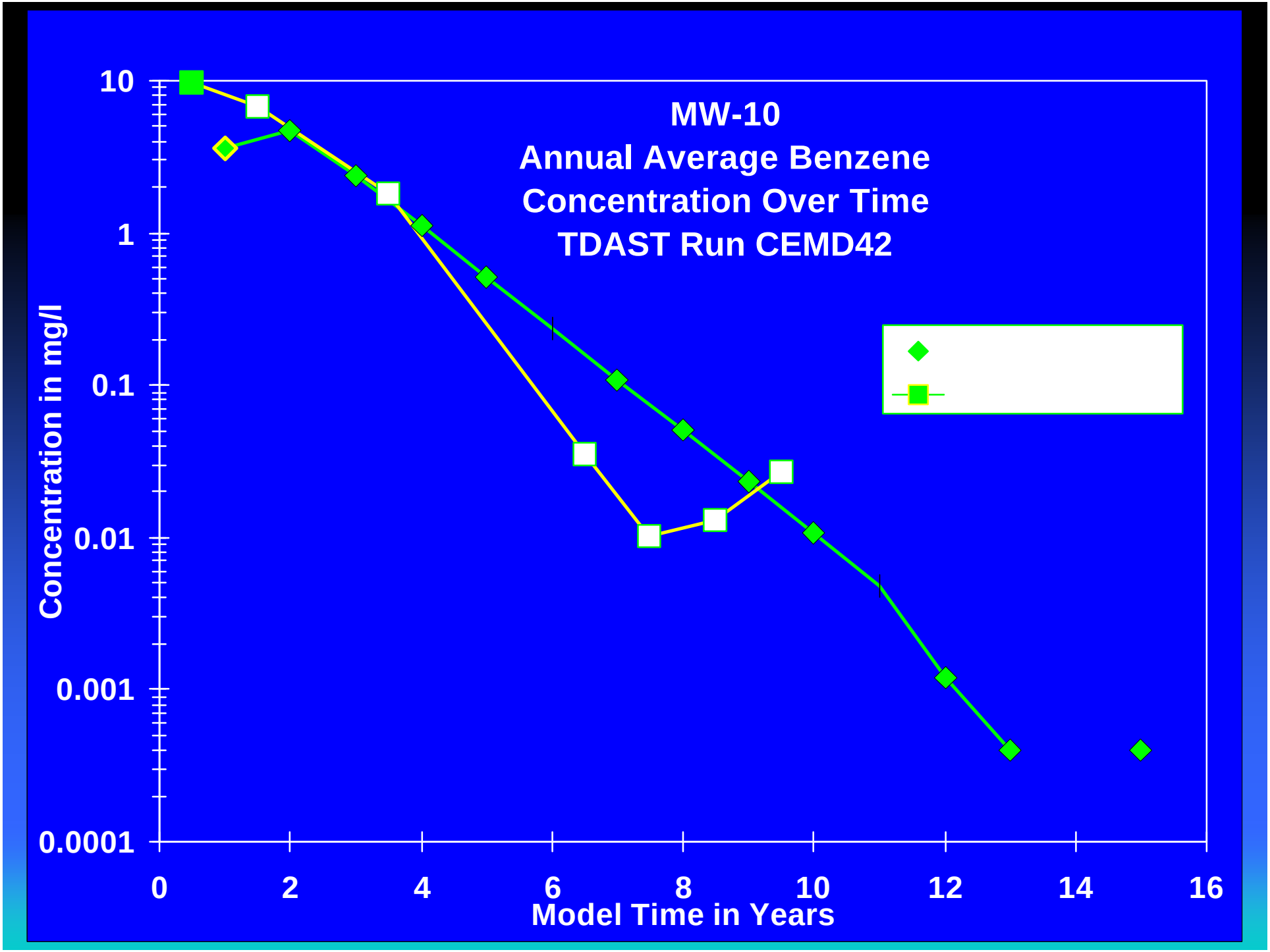
- Source size identification
- Source concentrations (effective solubilities of BTEX)
- Source Decay (using observed levels)
- Biodegradation rates (published levels validated with calibrated plume).

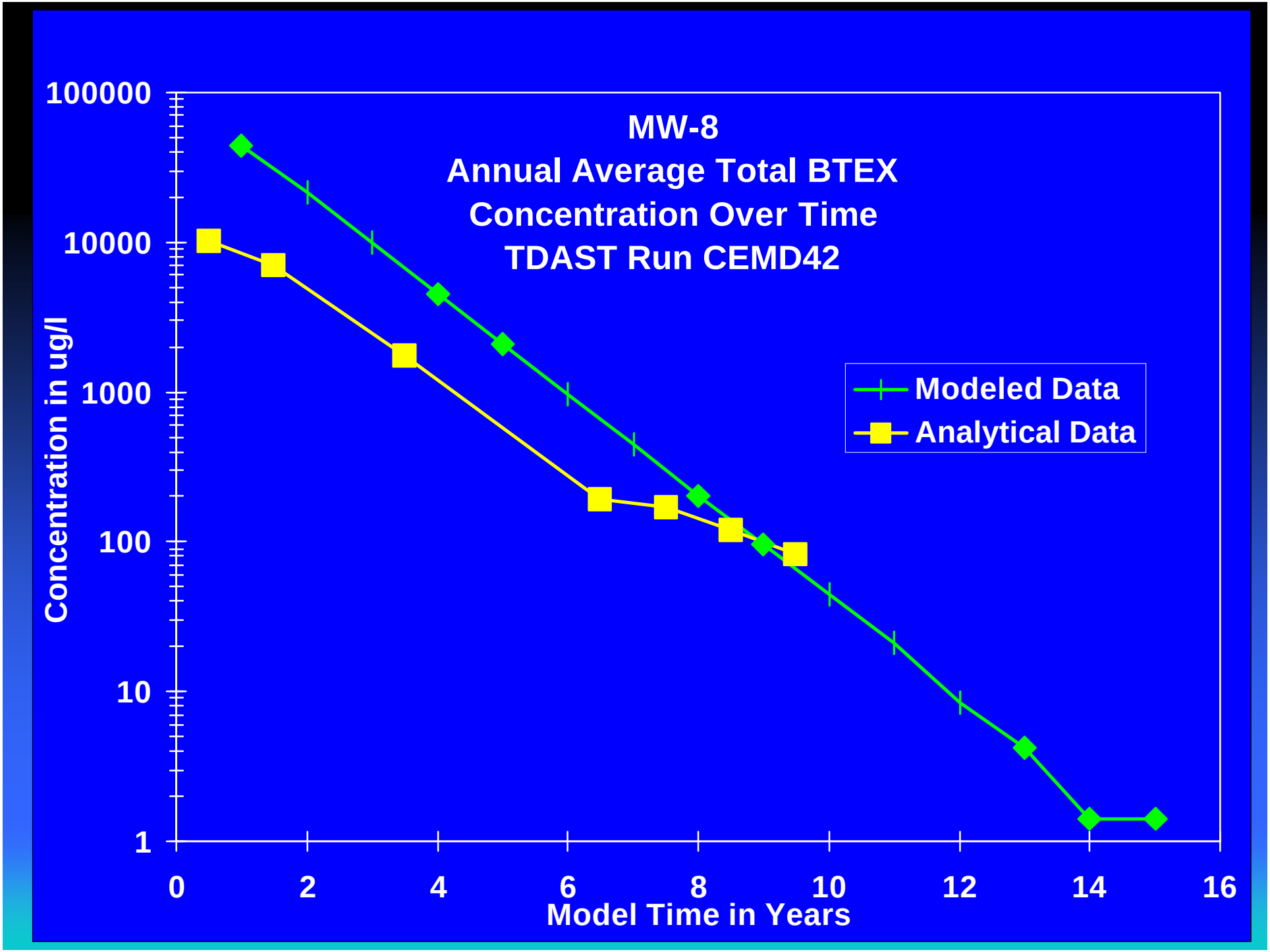
Predicted Plume Movement

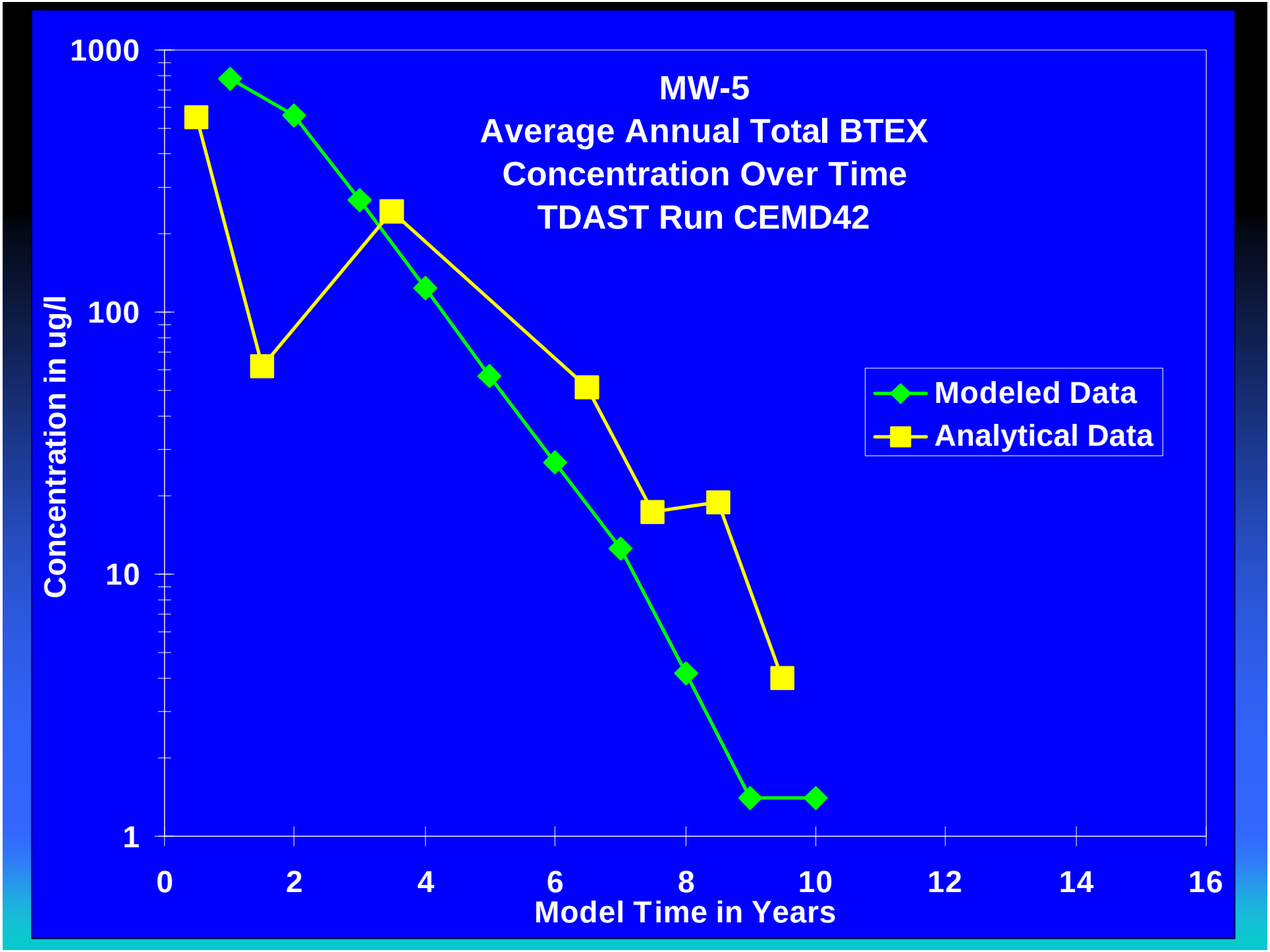
- Source size = 50 ft
- Source Concentrations =
  - Benzene: 40 mg/L
  - Ethylbenzene: 3 mg/L
  - Toluene: 80 mg/L
  - Xylene: 17 mg/L
- Source half-lives = 0 to 2 years
- BTEX half-lives = 0.5 to 1.0 years

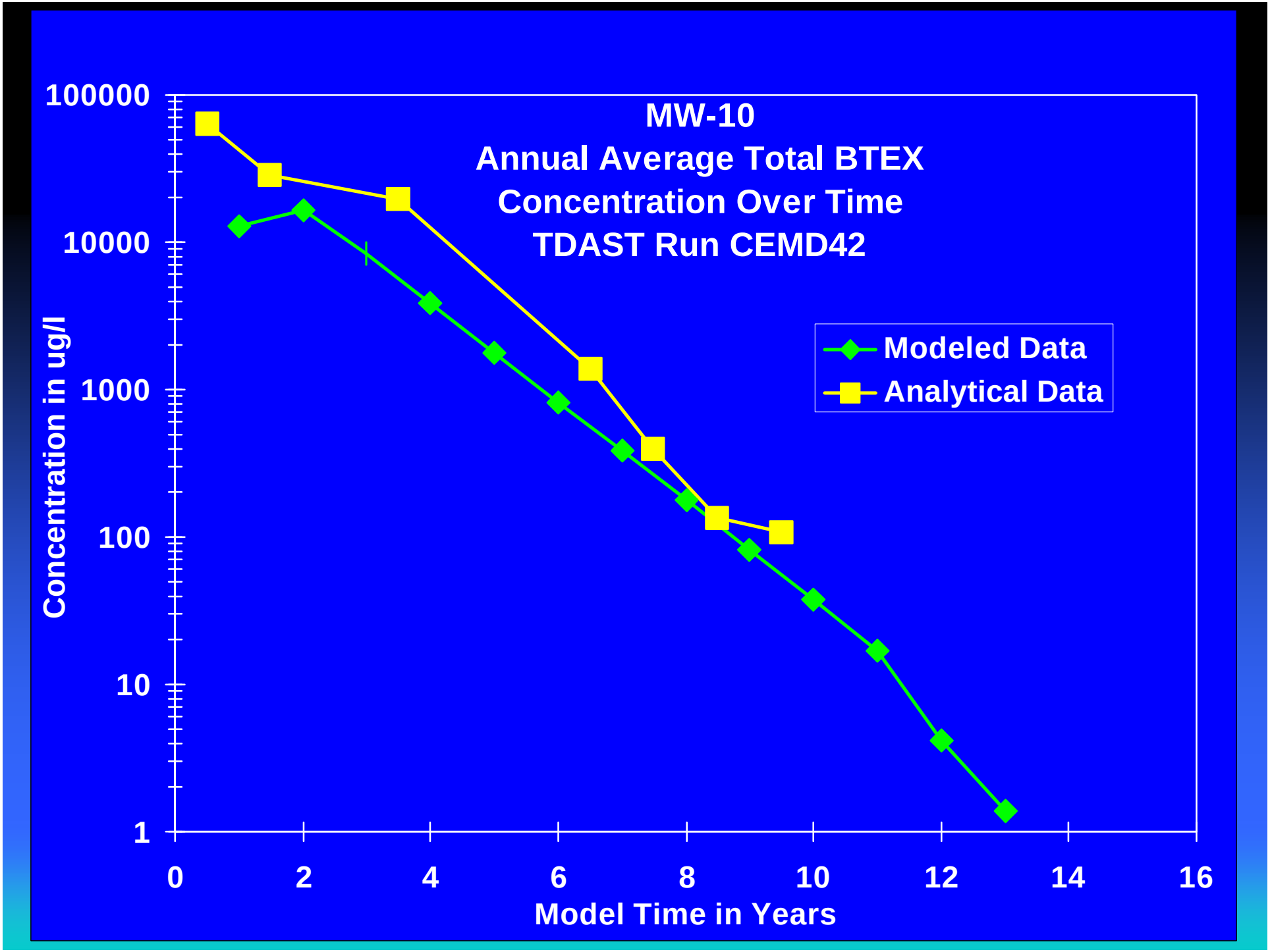

MW-8
Annual Average Benzene
Concentration Over Time
TDAST Run CEMD42
Modeled Data
Analytical Data
Concentration in mg/l
100
10
1
0.1
0.01
0.001
0
2
4
6
8
10
12
14
16
Model Time in Years


MW-5
Annual AverageBenzene
Concentration Over Time
TDAST Run CEMD42
Concentration in mg/l
1
0.1
0.01
0.001
0.0001
0
2
4
6
8
10
12
14
16
Model Time in Years
Modeled Data
Analytical Data


MW-10
Annual Average Benzene
Concentration Over Time
TDAST Run CEMD42
Concentration in mg/l
10
1
0.1
0.01
0.001
0.0001
0
2
4
6
8
10
12
14
16
Model Time in Years


MW-8
Annual Average Total BTEX
Concentration Over Time
TDAST Run CEMD42
Modeled Data
Analytical Data
Concentration in ug/l
100000
10000
1000
100
10
1
0
2
4
6
8
10
12
14
16
Model Time in Years


MW-5
Average Annual Total BTEX
Concentration Over Time
TDAST Run CEMD42
Concentration in ug/l
1000
100
10
1
0
2
4
6
8
10
12
14
16
Model Time in Years
Modeled Data
Analytical Data


MW-10
Annual Average Total BTEX
Concentration Over Time
TDAST Run CEMD42
Modeled Data
Analytical Data
Concentration in ug/l
100000
10000
1000
100
10
1
0
2
4
6
8
10
12
14
16
Model Time in Years

Conclusions

- Natural attenuation occurs for petroleum releases into outwash sand and gravel aquifer systems.
- Source removal is an effective means of controlling the spread of petroleum hydrocarbon plumes.
- Within the outwash system for this case history, maximum plume length was between 600 to 700 ft.

Conclusions

- Natural attenuation with monitoring saved substantial remediation costs and proved to be protective of human-health and the environment.
- Apparent degradation half-lives between 180 to 365 days were observed for the BTEX plume.