

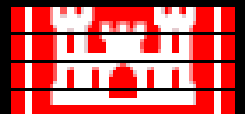
# **A Spill Management Information System for Freshwater Incidents**

**Edsel B. Daniel, James P. Dobbins, Paul H. Martin,  
Eugene J. LeBoeuf, Mark D. Abkowitz**

**Vanderbilt University  
Department of Civil and Environmental Engineering**

**in conjunction with**

**The Nashville District and the Engineering Research and Development  
Center, U.S. Army Corps of Engineers**



# Presentation Outline

- Background
- Project Objectives
- Conceptual Design and System Architecture
- Water and Air Quality Models
- Model Execution
- Spill Scenario Example
- Project Accomplishments
- Current and Future Work

# Background

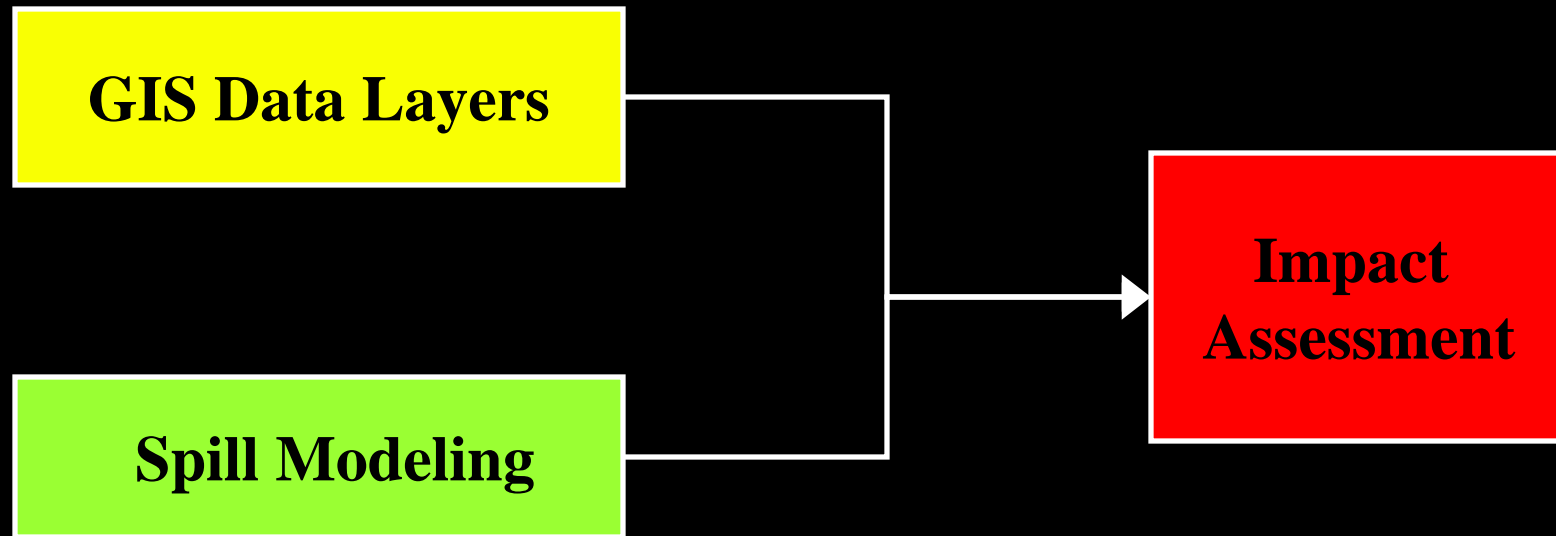
- **U.S. Army Corps of Engineers (USACE) maintains over 11,000 miles of navigable waterways which include numerous critical marine elements:**
  - **Water supply, recreation areas, and sensitive environmental areas**
- **Marine transportation is considered one of the nation's most efficient, safe, and economical modes of freight transport.**
- **Hazardous materials comprise a large portion of barge transported commodities, placing communities along navigable waterways at risk of exposure to toxic chemicals in the event of a collision, grounding, or terrorist action.**
- **Managing a navigable water body chemical spill response involves coordination and communication among numerous federal, state, and local entities posing challenges in the areas of:**
  - **Retrieving characteristic chemical data**
  - **Jurisdictional responsibility of responding agencies**
  - **Location of waterway access points**
  - **Community notification**

# **Project Objectives**

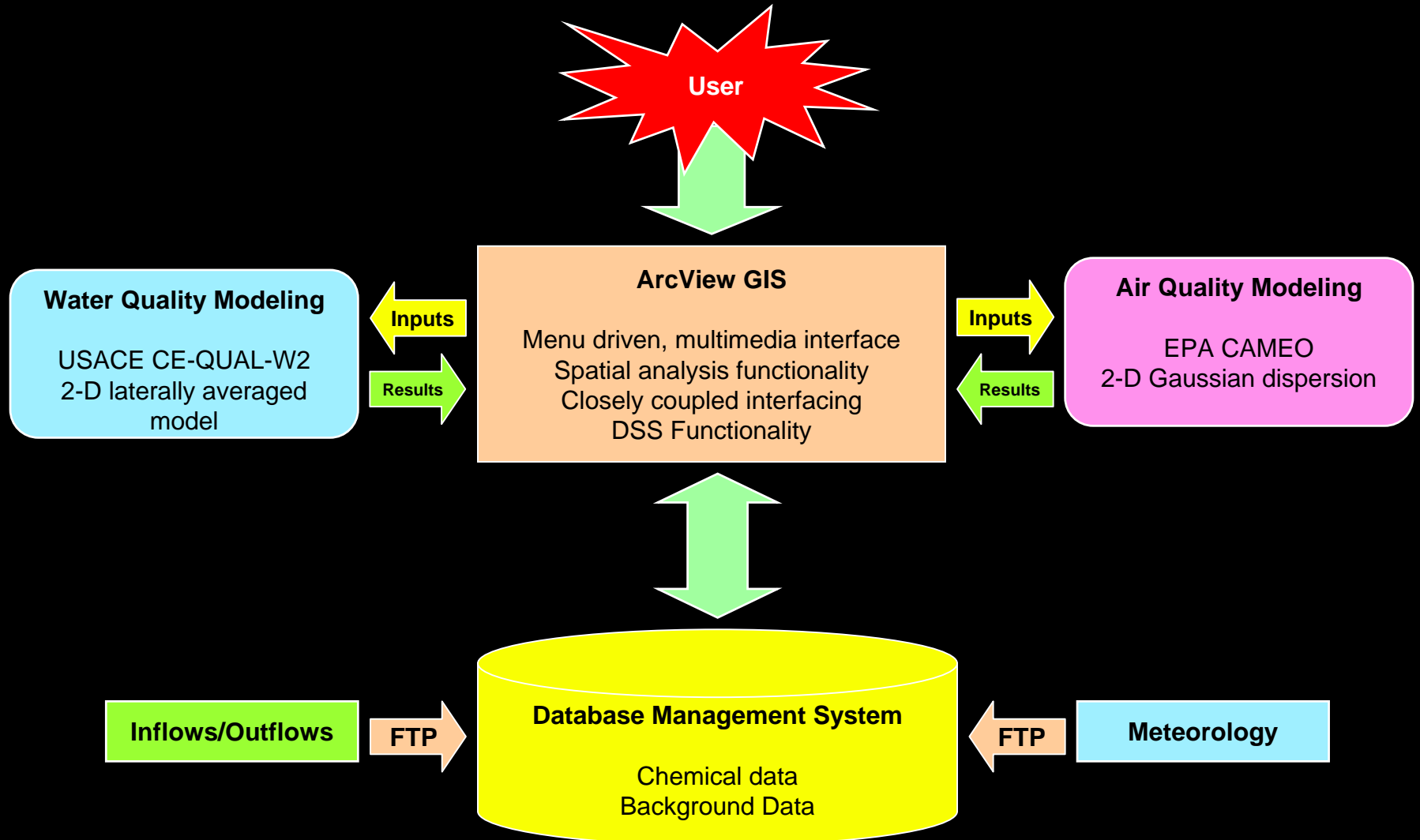
**Develop a spill management information system (SMIS) that:**

- **Addresses accidental releases and terrorist incidents**
- **Provides the capability to perform simulation training, contingency planning, and real-time incident management**
- **Utilizes advanced information technologies to deliver timely and accurate information in a spatial-based framework**

# Conceptual Design

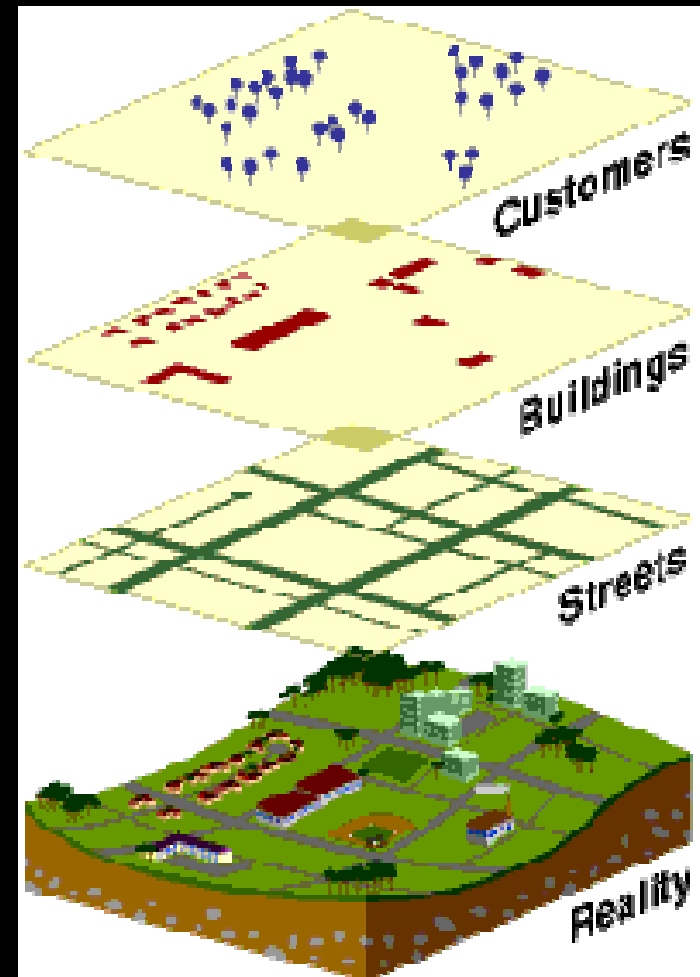


# System Architecture



# Geographic Information Systems

GIS is a system of computer software, hardware, and data to help manipulate, analyze, and present information that is tied to a spatial location.

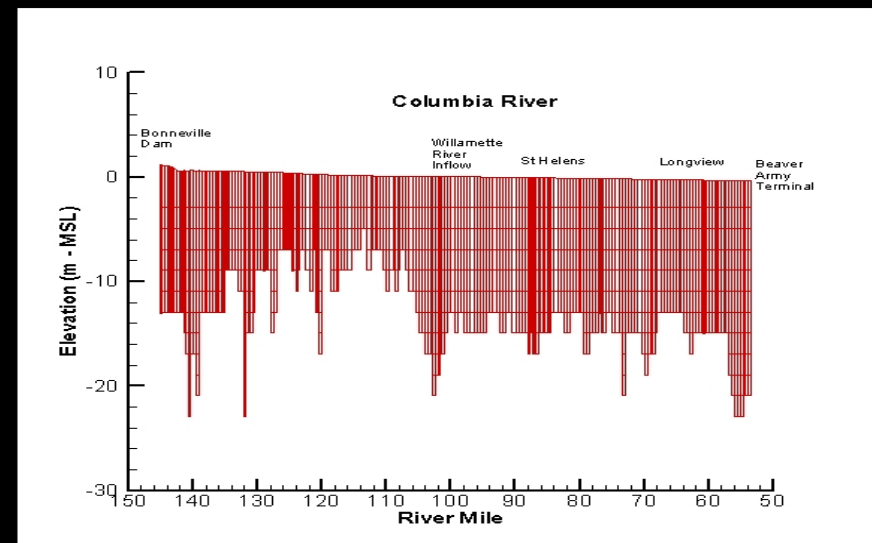
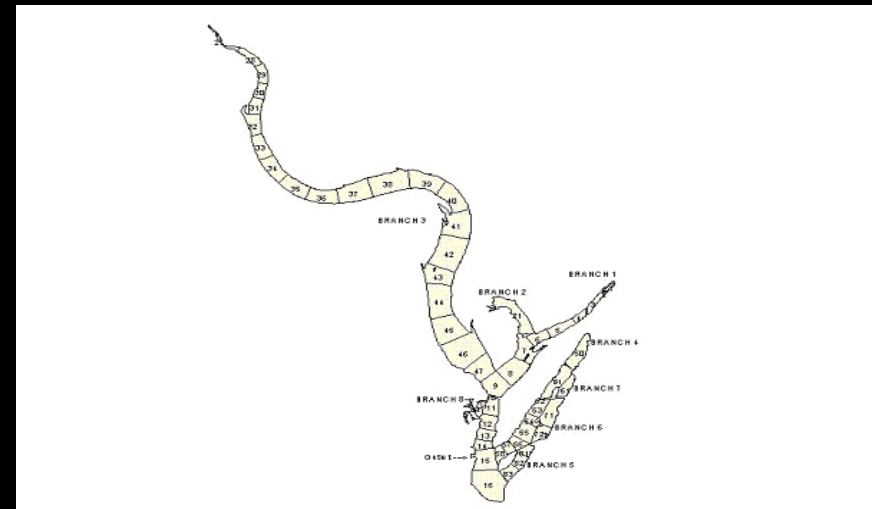


# CE QUAL W2

**2-D, longitudinal/vertical hydrodynamic and water quality model applicable to rivers, lakes, reservoirs, and estuaries.**

**Developed by Portland State University in conjunction with USACE Waterways Experiment Station (WES).**

**Version 3.1 developed for the Cheatham Reach of the Cumberland River.**





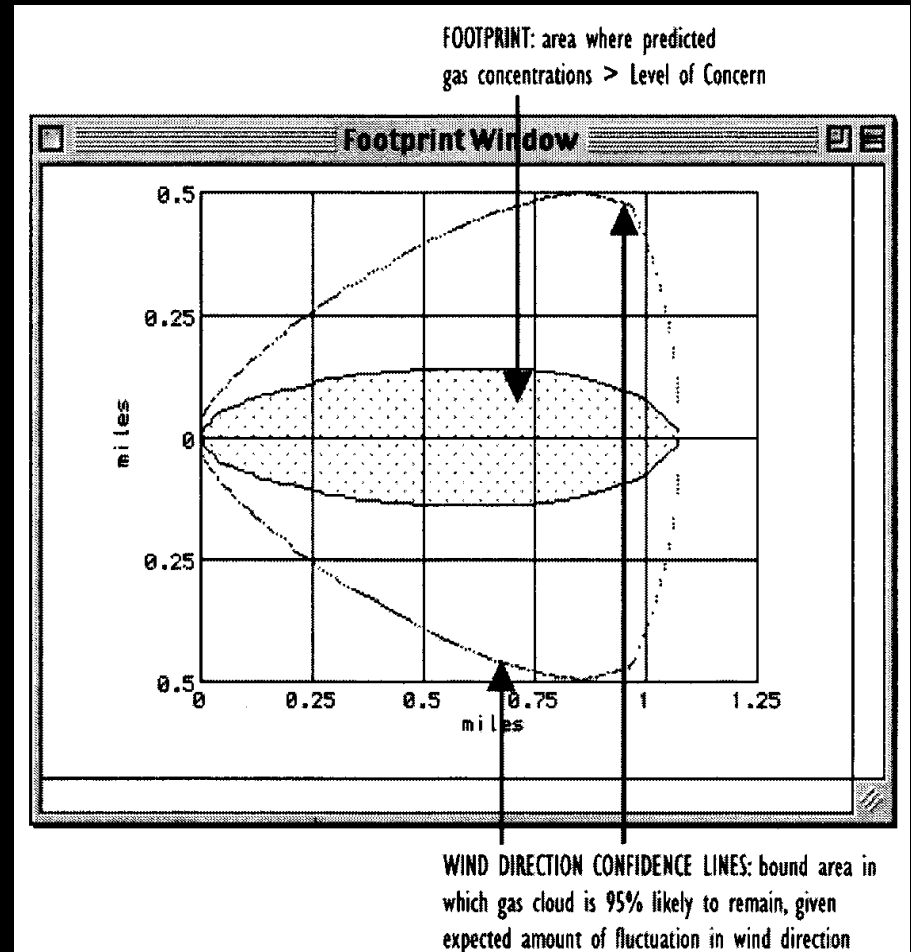
# CAMEO

**Computer Aided Management of Emergency Operations (CAMEO).**

**Suite of software programs used to plan for and respond to chemical emergencies developed by the USEPA and NOAA.**

**Includes a Chemical Library, Areal Location of Hazardous Atmospheres (ALOHA) and Mapping Applications for Response, Planning, and Operational Tasks (MARPLOT).**

**Generates a 'cloud footprint', encompassing the area where ground level concentration of a pollutant gas exceeds a pre-determined Level of Concern (LOC)**



# Database Management System

Database Management System stores chemical information and feeds meteorological data to the system.

The screenshot displays a database management interface with a table titled "Attributes of States.shp". The table contains 51 rows of data, each representing a state or district. The columns include State, Area, State\_name, State\_abbr, State\_abbrev, State\_abbr2, Pop1997, Pop1997, Pop1997, Area\_sqmi, Male, Female, White, Black, Asian, and A. The data is sorted by State.

State	Area	State_name	State_abbr	State_abbrev	State_abbr2	Pop1997	Pop1997	Pop1997	Area_sqmi	Male	Female	White	Black	Asian	A.
Polygon	67285.878	Washington	53	Pacific	WA	4566632	5504250	72	1872431	2413747	2452945	4308937	149803	814883	2
Polygon	147235.026	Montana	30	Mid	MT	795065	884723	5	305163	395761	403296	741111	2381	47675	
Polygon	32151.854	Maine	23	N Eng	ME	1227528	1244829	99	485012	597690	630079	1309360	5139	5999	
Polygon	78810.153	North Dakota	38	W N Cen	ND	638800	644782	9	240878	318201	320999	804142	3524	29817	
Polygon	77193.824	South Dakota	46	W N Cen	SD	686004	736549	9	264004	342499	353806	631515	3254	93875	
Polygon	97799.452	Wyoming	56	Mid	WY	453668	494519	5	188838	227091	226581	427061	1606	9479	
Polygon	56083.066	Wisconsin	55	E N Cen	WI	4891769	5189399	87	1822118	2352935	2498834	4512523	244529	35087	
Polygon	83340.898	Idaho	16	Mid	ID	1008748	1218819	12	380723	503896	589793	980481	3370	13780	
Polygon	9603.218	Vermont	50	N Eng	VT	562298	591859	59	210990	275492	287286	595088	1951	1696	
Polygon	94517.465	Minnesota	27	W N Cen	MN	4375099	4690417	52	1547850	2145190	2229916	4139395	90944	49086	
Polygon	97070.748	Illinois	41	Pacific	DR	2842321	3049429	29	1103313	1387073	1445248	2636787	46178	38486	
Polygon	9253.514	New Hampshire	33	N Eng	NH	1109252	1171443	130	411186	545544	585708	1007433	7198	2134	
Polygon	56257.220	Iowa	19	W N Cen	IA	2767955	2858263	45	1084325	1348002	1431953	2843000	40900	7343	
Polygon	8172.462	Massachusetts	25	N Eng	MA	6016425	6106904	796	2247110	2889745	3127880	5405394	300130	12241	1
Polygon	77328.337	Nebraska	31	W N Cen	NE	1528389	1680513	20	602363	769439	808846	1481828	57404	12410	
Polygon	48660.579	New York	36	Mid Atl	NY	17990465	18477299	370	6639322	8626701	9264782	13062355	2651055	62651	6
Polygon	45494.739	Pennsylvania	42	Mid Atl	PA	11981543	12651907	262	4409944	5946765	6187379	10510411	1080756	14732	1
Polygon	4375.434	Connecticut	09	N Eng	CT	3287116	3277113	661	1200479	1592873	1694243	2893353	274269	6854	
Polygon	1044.850	Rhode Island	44	N Eng	RI	1003464	998370	950	379377	481496	521968	917395	38861	4071	
Polygon	2507.302	New Jersey	34	Mid Atl	NJ	7730188	8018328	1030	2742711	3759085	3994503	6110465	1038825	14970	2
Polygon	36393.515	Indiana	18	E N Cen	IN	5644159	5874944	152	2085365	2690321	2859879	5203700	432052	12720	
Polygon	110667.293	Nevada	32	Mid	NV	1201833	1820383	11	486297	611880	588953	1012695	79771	19637	
Polygon	84870.185	Utah	49	Mid	UT	1722890	2034167	20	537273	665769	667091	1615945	11576	24283	
Polygon	15774.182	California	06	Pacific	CA	29780021	32197302	189	10381204	14876727	16342384	28524227	2208001	242164	28
Polygon	41192.852	Ohio	39	E N Cen	OH	10647119	11202691	263	4087546	5265340	5620775	9521795	1154826	20398	
Polygon	56297.954	Illinois	17	E N Cen	IL	11430602	11890919	203	4202240	5552231	5878369	8952578	1694273	21836	2
Polygon	66.063	District of Columbia	11	S Atl	DC	689900	539027	9187	269634	282970	323930	179667	399604	1466	
Polygon	2064.906	Delaware	10	S Atl	DE	686168	737219	324	247487	322098	342000	639004	112460	2019	
Polygon	24228.213	West Virginia	54	S Atl	WV	1793477	1828832	74	688267	861936	931941	1729523	56290	2498	
Polygon	9731.753	Maryland	24	S Atl	MD	4701948	5100819	491	1748361	2306771	2462197	3393344	1108169	12972	1
Polygon	104089.108	Colorado	08	Mid	CO	3284394	3886615	32	1262688	1671205	1643099	2905474	131146	27776	
Polygon	40018.777	Kentucky	21	E S Cen	KY	3606296	3906965	91	1399392	1785206	1900051	2916022	262007	5769	
Polygon	82195.436	Kansas	20	W N Cen	KS	2477974	2962933	30	944726	1214649	1262929	2231886	143076	21828	
Polygon	39813.194	Virginia	51	S Atl	VA	6187398	6726895	195	2291830	3033674	3183384	4791793	1162954	15282	1
Polygon	69831.624	Missouri	29	W N Cen	MO	5117073	5367763	73	1961206	2464315	2652780	4486228	542289	19036	
Polygon	11371.522	Arizona	04	Mid	AZ	3025220	4520066	32	1000043	1010091	1054537	2063102	110524	200527	
Polygon	70002.352	Oklahoma	40	W S Cen	OK	3145585	3318622	45	1281335	1530819	1614785	2503512	230801	252420	
Polygon	49046.813	North Carolina	37	S Atl	NC	6628637	7411219	135	2517026	3214920	3414347	5008491	1496323	80195	

# SMIS Data Input

## DATA INPUT

```
graph LR; A[DATA INPUT] --- B[Location of Spill Injection on Waterway]; A --- C[Selection of Spill Contaminant]; A --- D[Quantification of Spill]; A --- E[Time Interval Selection]; A --- F[Inflows/Outflows];
```

### Location of Spill Injection on Waterway

Select injection point by mouse click or river segment

### Selection of Spill Contaminant

Select contaminant from database of 1300+ common marine transported chemicals

### Quantification of Spill

Input spill volume in units of volume or mass

### Time Interval Selection

Select injection time of spill  
Select required overall simulation time

### Inflows/Outflows

'Current' flowrates (automatic transfer from FTP site)  
User-specified flowrates for scenario evaluation

# SMIS Data Input

**QUALW2- INPUT PARAMETERS** ✖

**CONSTITUENT**


Name: [Select Constituent] ▾

Volume [Enter Spill Volume] [Cu. Feet] ▾


Mass [Enter Spill Mass] [Kg] ▾

**SPILL DURATION**

Start Date(MM:DD)/Time(HR:MIN)

[ ] [ ] / [ ] [ ] 

End Date(MM:DD)/Time(HR:MIN)

[ ] [ ] / [ ] [ ] 


**LOCATION OF SPILL INCIDENT**

Waterway Name: [Cumberland River]

Segment ID: [86] Zoom to Segment

**SIMULATION**

Start Date(MM:DD)/Time(HR:MIN)

[ ] [ ] / [ ] [ ] 

Same as Spill Start Date/Time

Duration:  1  2  3  4  5 days

Run Map Output Close Help

# SMIS Data Input

**Dam Flow Settings** [Close]

Change Live Dam Flow and Weather File

**OLD HICKORY DAM FLOW**

Live Connection      FLOWRATE: 424.755      Cu. Meters/sec ▾

Enter Flow

DURATION:      Start(MM:DD:HR)      End(MM:DD:HR)

Same as Simulation Duration      1 1 0 [Calendar]      1 2 0 [Calendar]

**PERCY PRIEST DAM FLOW**

Live Connection      FLOWRATE: 0.28317      Cu. Meters/sec ▾

Enter Flow

DURATION:      Start(MM:DD:HR)      End(MM:DD:HR)

Same as Simulation Duration      1 1 0 [Calendar]      1 2 0 [Calendar]

**CHEATHAM DAM FLOW**

Live Connection      FLOWRATE: 396.438      Cu. Meters/sec ▾

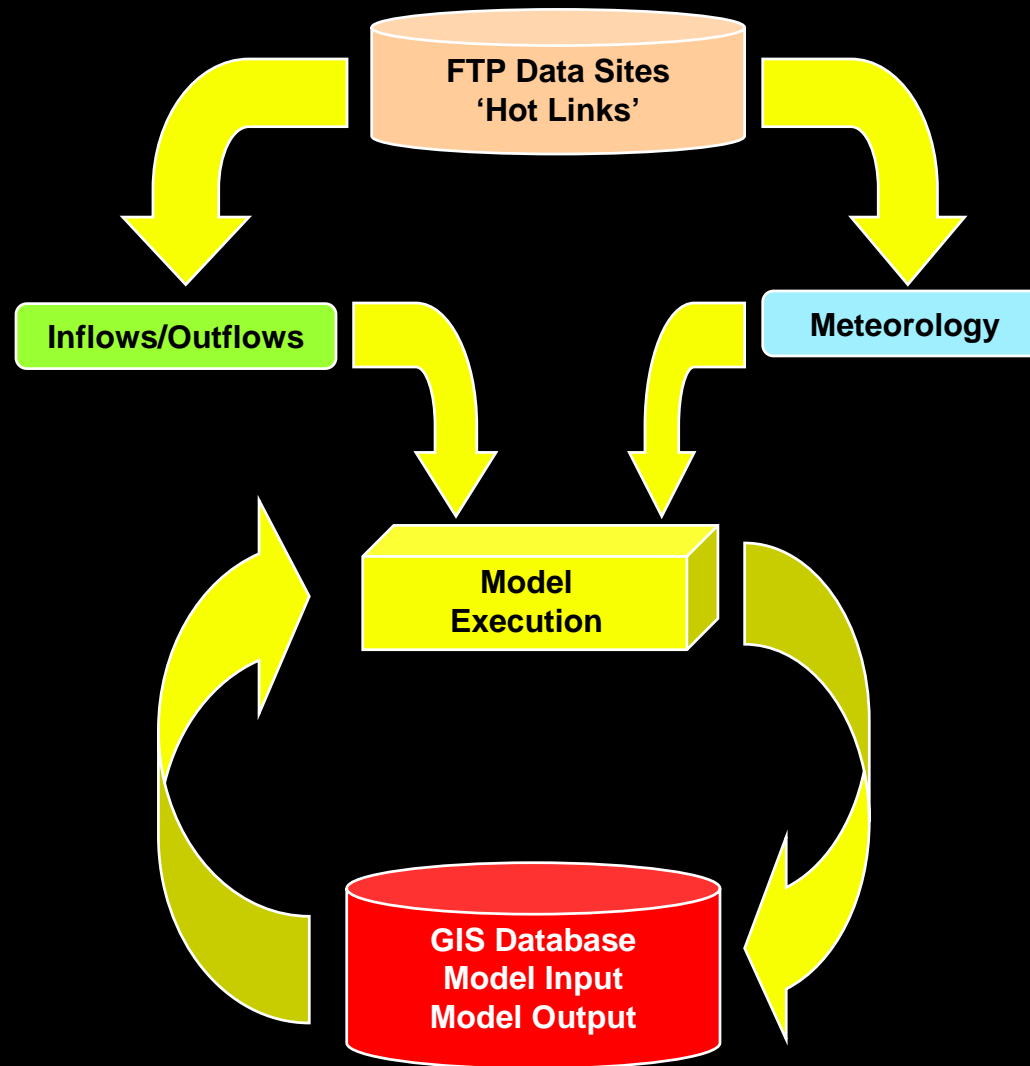
Enter Flow

DURATION:      Start(MM:DD:HR)      End(MM:DD:HR)

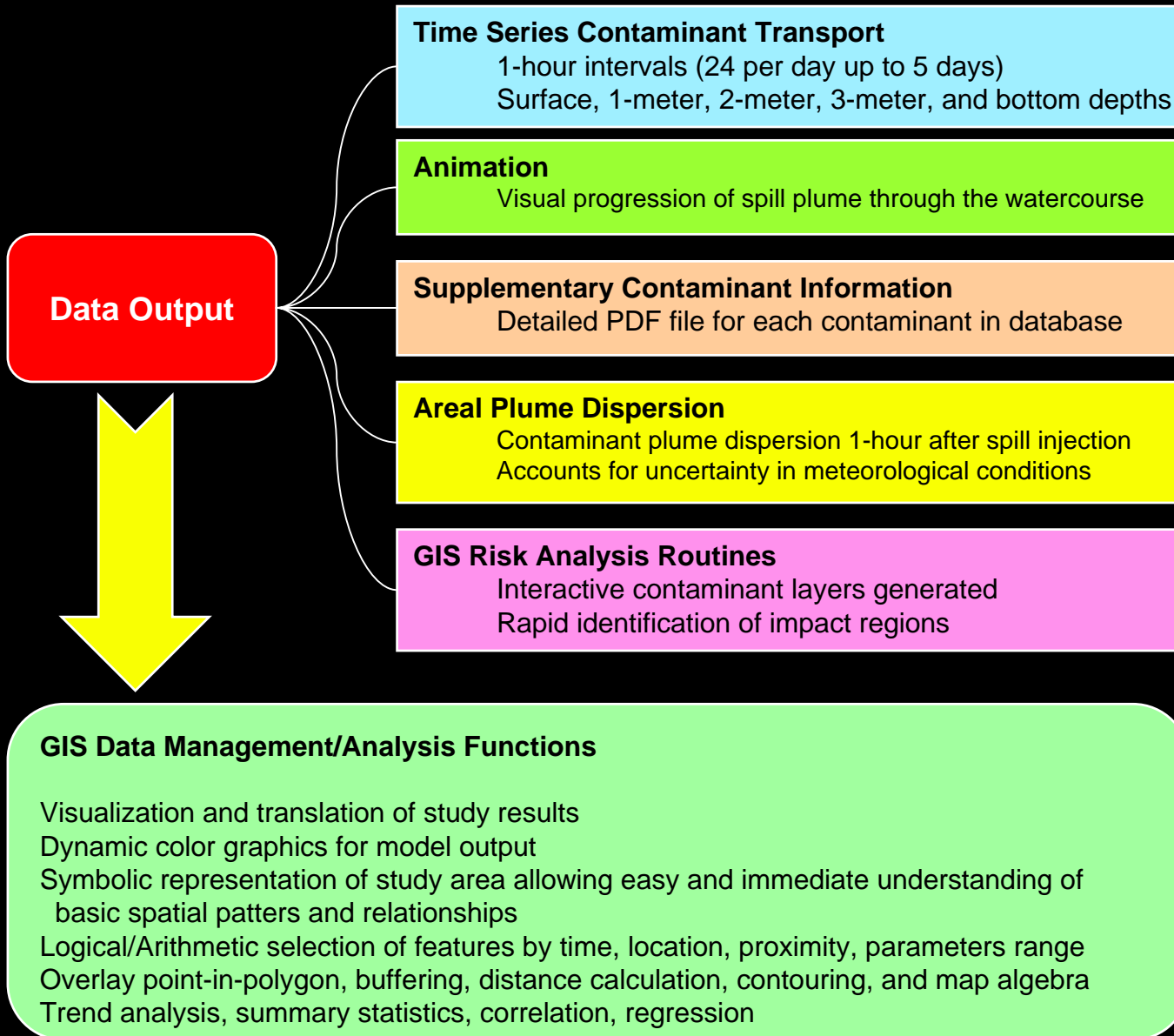
Same as Simulation Duration      1 1 0 [Calendar]      1 2 0 [Calendar]

Ok

# SMIS Model Execution



# SMIS Output



Prototype Spill Management Information System(SMIS)

File Edit View Insert Selection Tools Window Help

1:190,417 100%

Spill Modeling Constituent:

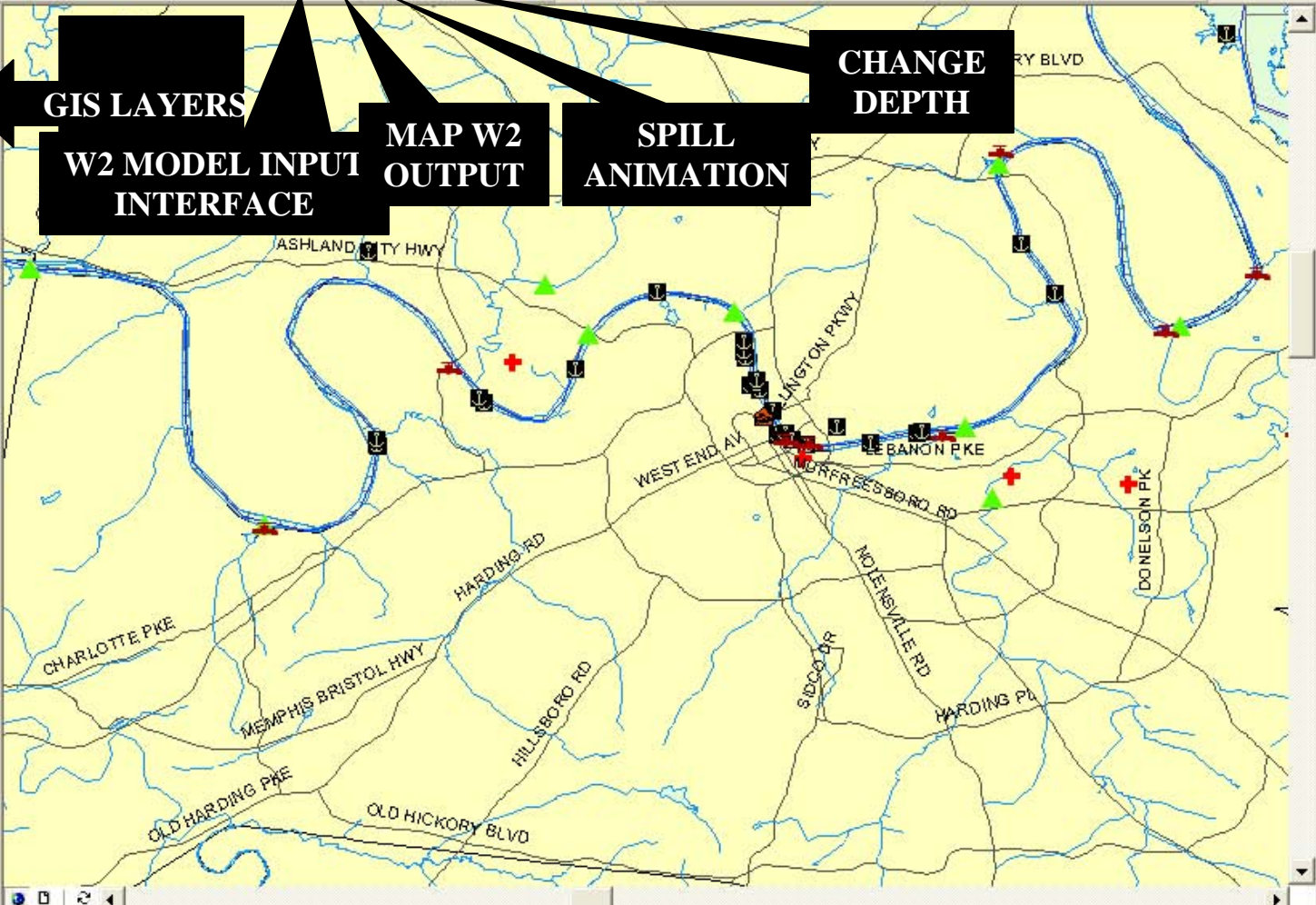
- Layers
  - CONCENTRATION
  - CAMEO P...
- EMS
- Fire Dept
- Dock Facilities
- Water Quality Stations
- Rare Species
- Gaging Stations
- Mile Markers
- Landmark Points
- Streets
- Railroad
- Waterway Network
- Tigerstreams

**GIS LAYERS**  
**W2 MODEL INPUT**  
**INTERFACE**

**MAP W2**  
**OUTPUT**

**SPILL**  
**ANIMATION**

**CHANGE**  
**DEPTH**



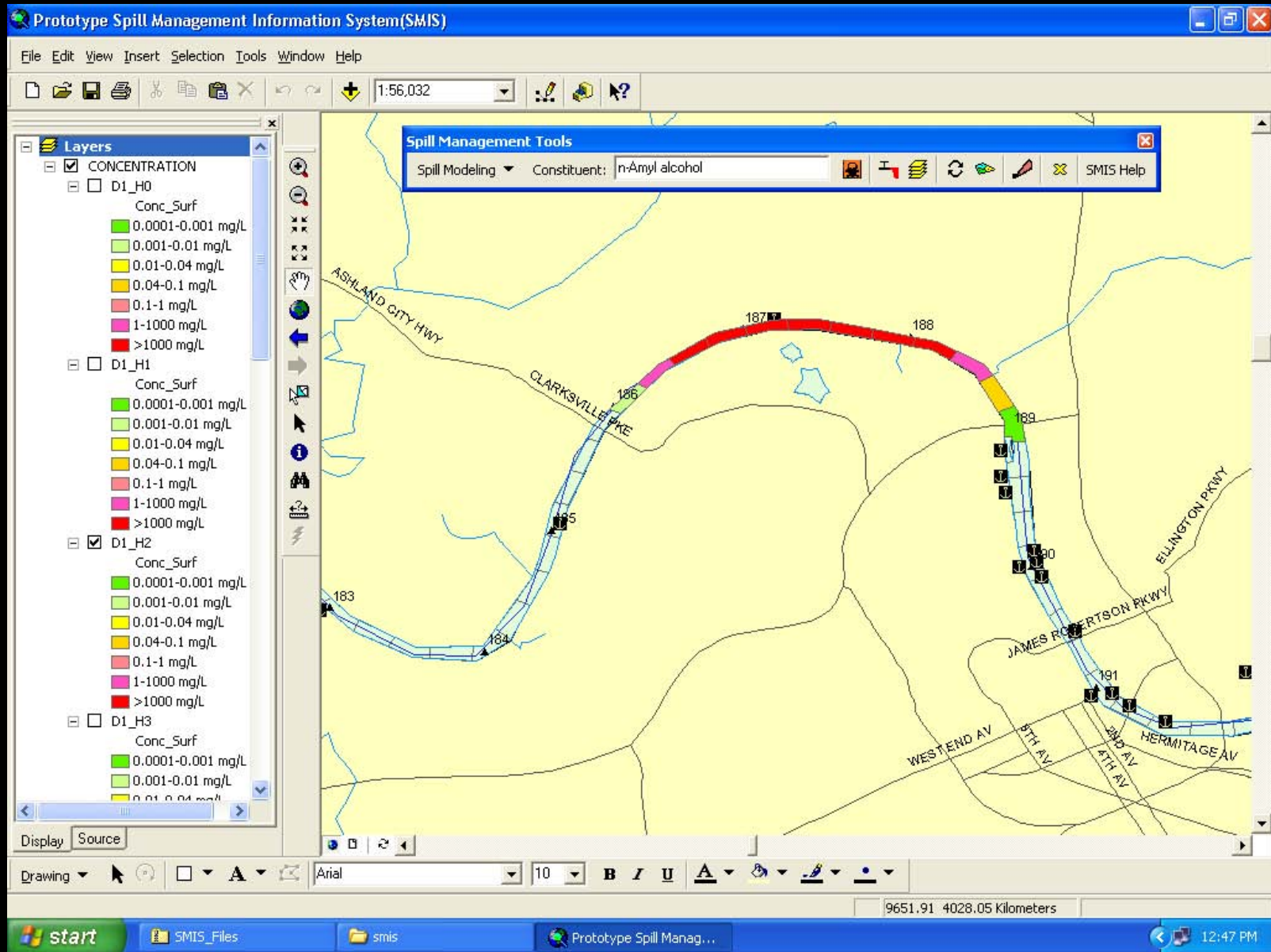
Display Source

Drawing Arial 10 B I U

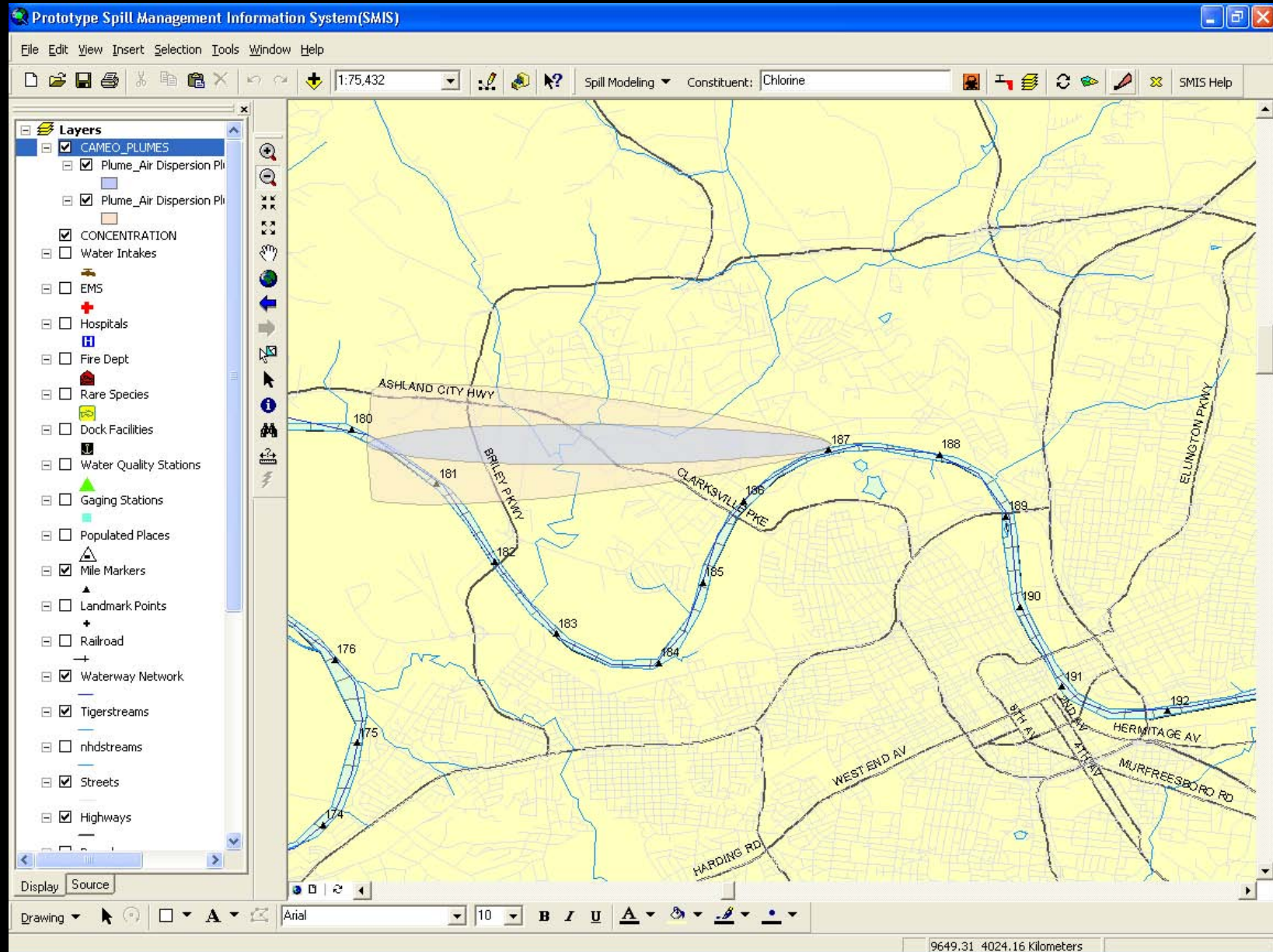
9673.19 4034.34 Kilometers



# Sample Output – Surface Water Contaminant Dispersion



# Sample Output – Air Dispersion



# Functionality Summary

## •Simulate Release

- Location by mouse click
- Select chemical (1300+)
- Enter quantity (mass or volume)
- Enter spill duration
- Specify simulation duration



## •Run Water/Air Quality Models

- CE-QUAL W2
- CAMEO
- Started from GIS interface
- Model fed from chemical database and weather data

## •Import and Display Model Results

- Multiple CE-QUALW2 model outputs
  - GIS layers depict stages of spill
  - Animate spill progression
  - Display output at surface, bottom, 1, 2, and 3 meter depths
- Detailed GIS layers for reference, routing, mitigation, and protection



## •Perform Mitigation

- Locate nearest responders and facilities (using GIS layer contact information)
- Predict where spill will be in future
- Estimate population and ecological exposure
- Perform “what-if” scenarios (e.g., increase/decrease water release from upstream/downstream flow control structures)

# **Scenario Demonstration**

# Scenario

- **Location:** Cheatham Reach - RM 194
- **Incident:** Barge Grounding
- **Release:** 25,000 barrels ( $1.05 \times 10^6$  gallons) over 30 minutes
- **Chemical:** ethylene glycol
- **Meteorology:** 10 mph easterly wind, 70° F, partly cloudy

# SMIS Input

**QUALW2- INPUT PARAMETERS**

**CONSTITUENT**

Name: Ethylene glycol

Volume 1050000 Gallons

Mass Enter Spill Mass Kg

**LOCATION OF SPILL INCIDENT**

Waterway Name: Cumberland River

Segment ID: 87 Zoom to Segment

**SIMULATION**

Start Date(MM:DD)/Time(HR:MIN)

12 / 1 / 12 / 0

Same as Spill Start Date/Time

Select constituent

Duration:  1  2  3  4  5 days

Run Map Output Close Help

# SMIS Flow Settings (Live)

**Dam Flow Settings** [X]

Change Live Dam Flow and Weather File

**OLD HICKORY DAM FLOW**

Live Connection      FLOWRATE: 12200      Cu, Feet/sec

Enter Flow

DURATION:      Start(MM:DD:HR)      End(MM:DD:HR)

Same as Simulation Duration      12   1   12      12   2   12

**PERCY PRIEST DAM FLOW**

Live Connection      FLOWRATE: 500      Cu, Feet/sec

Enter Flow

DURATION:      Start(MM:DD:HR)      End(MM:DD:HR)

Same as Simulation Duration      12   1   12      12   2   12

**CHEATHAM DAM FLOW**

Live Connection      FLOWRATE: 13800      Cu, Feet/sec

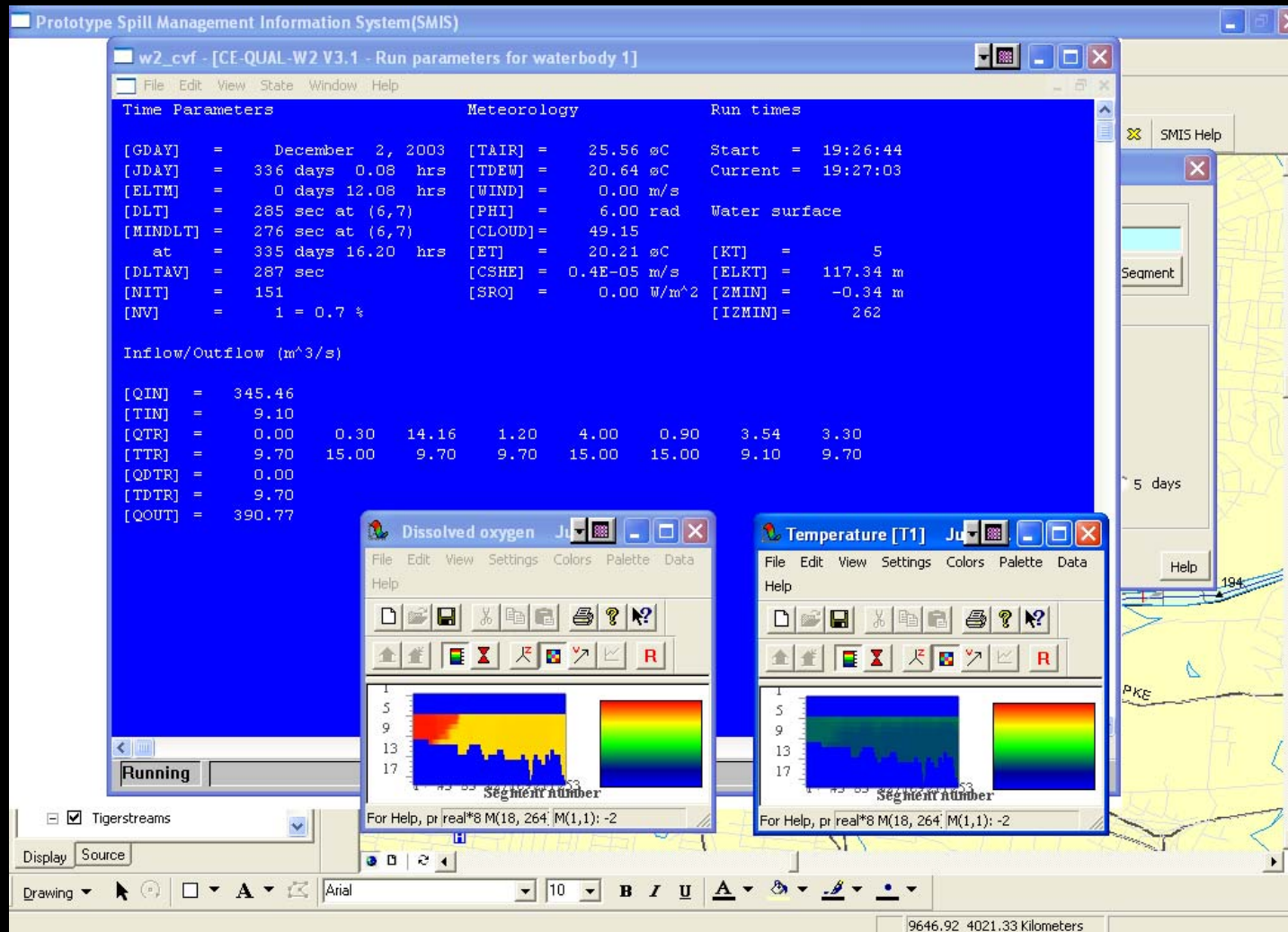
Enter Flow

DURATION:      Start(MM:DD:HR)      End(MM:DD:HR)

Same as Simulation Duration      12   1   12      12   2   12

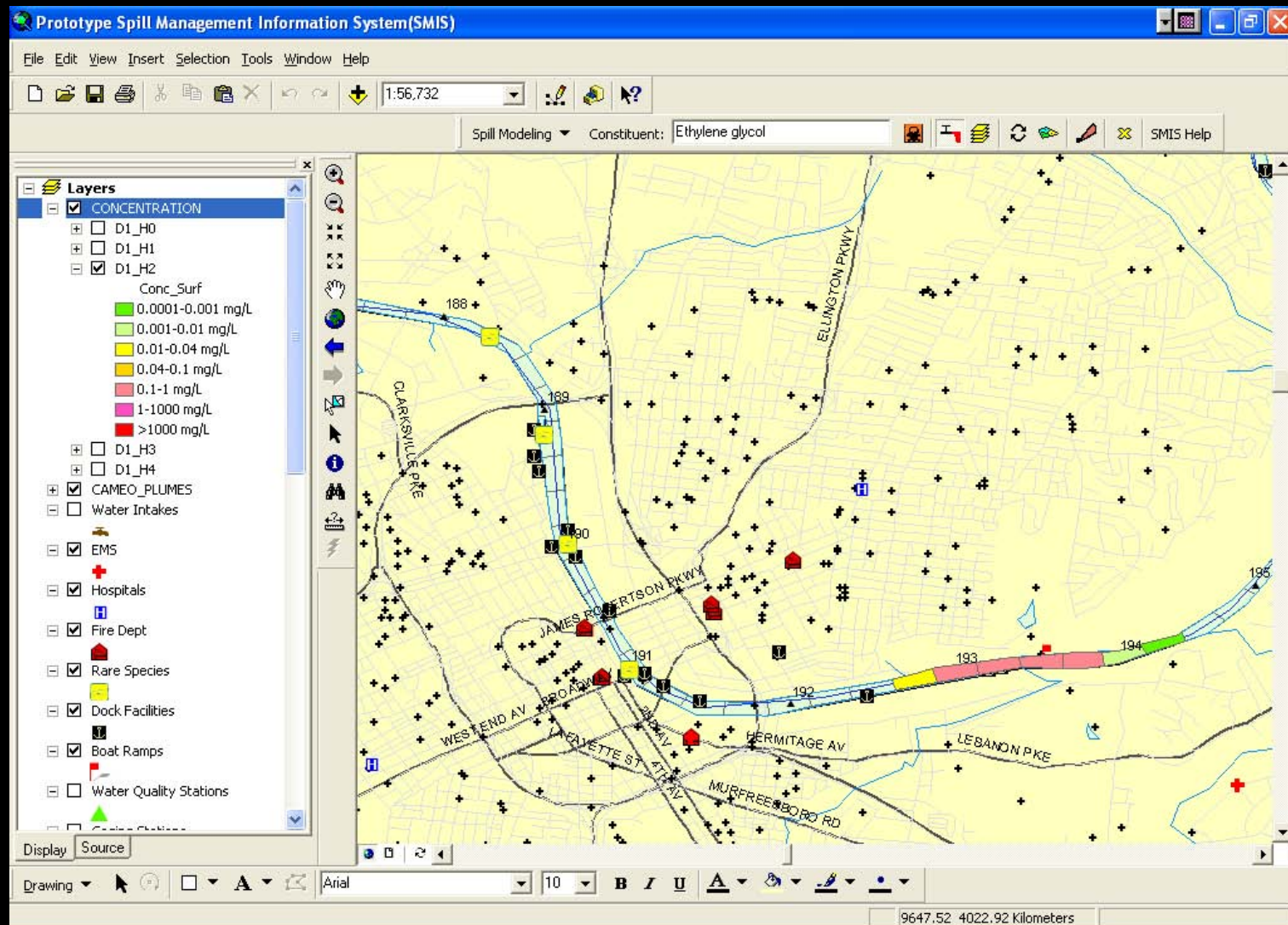
Ok

# CE-QUAL-W2 Model Execution

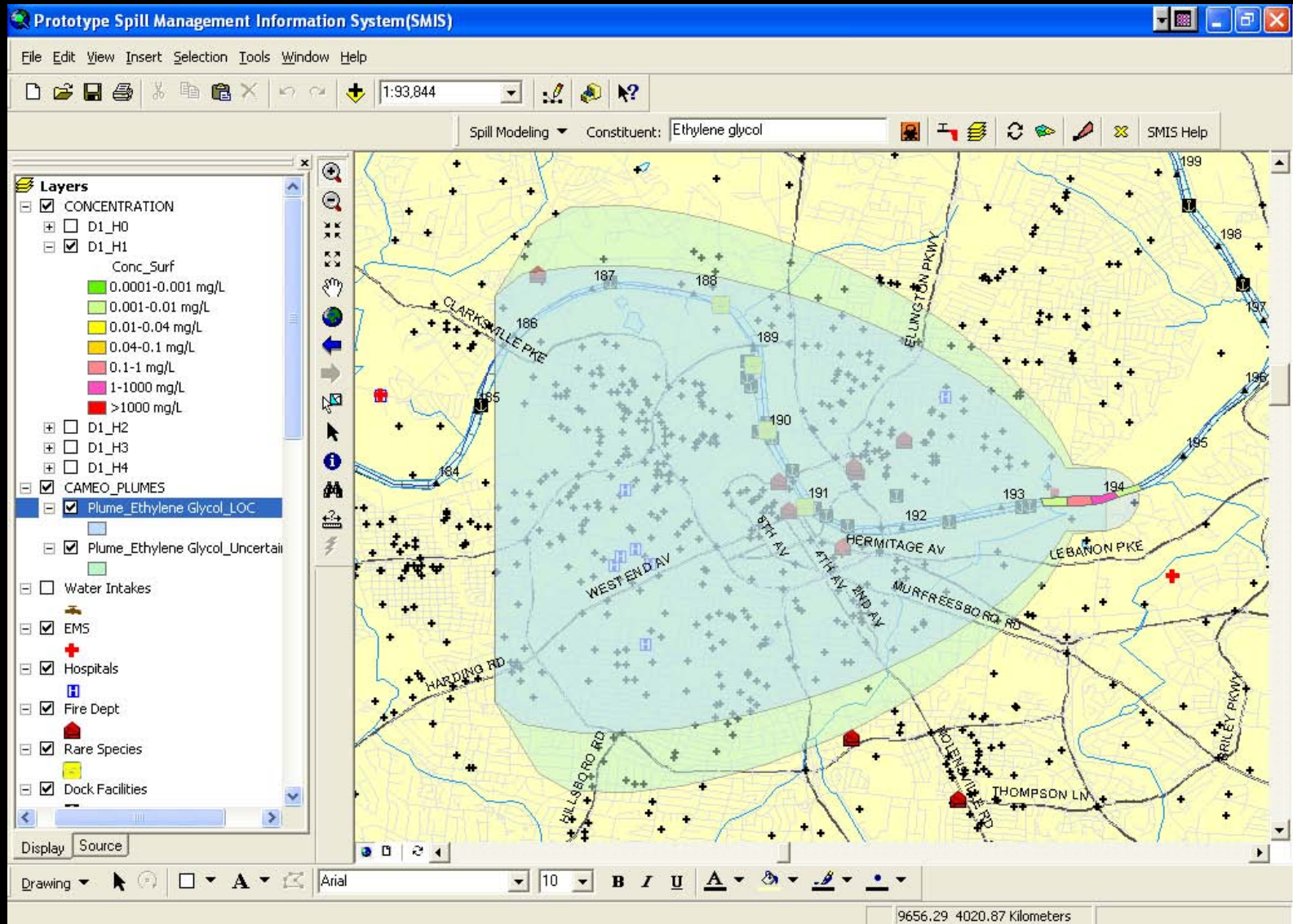




# Spill Progression – 2 hours



# Air Dispersion – 1 hour



# Analysis and Abatement Routines

- **Animation Tool** – toggles on/off layers in succession to create dynamic viewing of spill incident progression
- **GIS Risk Analysis Routines** – search for sensitive receptors within generated GIS layers (water intakes, endangered species, population centers) and associated attributes (contact numbers, responders, HAZMAT teams)
- **Locating Access Points** – boat launches, bridges, dock facilities, etc.

# **Key Project Accomplishments**

- **Completed information system design for managing spills on waterways**
- **Deployed state-of-the-art information model, data, and technologies**
- **Established proof of concept that a comprehensive Spill Management Information System is feasible**

# Current/Future Directions

- **Utilize existing system for spill management training, planning exercises, and operations**
  - **SMIS exercise with federal/state/local agencies conducted in October 2003**
- **Modular design allows for:**
  - **Application to different waterways**
  - **Use of different prediction models**
  - **Validation of existing models**
- **Development of additional interpretation tools:**
  - **Automate identification of proximate responders and endangered receptors**
  - **Locate vulnerable areas along the waterway**
  - **Rapid queries that identify key facilities & access points**
- **Provide remote Internet capability (with security)**

# Potential Applications and Developmental Options

## **Model enhancements to existing Cheatham Reach may include:**

- **Threat zone analysis queries to evaluate where a spill might occur that could threaten particular areas (e.g., endangered species areas, water intakes, schools, businesses, homes, etc.);**
- **Notification systems that can provide contact lists for facilities in affected areas, to include automated calling;**
- **Web-based SMIS to provide portability to first responders in the field (including employment of proper security measures to ensure access to SMIS is limited to authorized users);**
- **Resource analysis to help estimate the level of response needed to adequately address impacts of modeled spills, and the quantity of a particular resource that could be impacted by given spills (e.g., equipment required to isolate a specific endangered species area or water intake zone, such as length of boom, number of transport trucks, number of boats, number of personnel);**
- **Improved reactivity and transport capability within CE-QUAL-W2 to allow for inclusion of the effects of contaminant volatilization, reaction, and/or sorption; and**
- **Improved air dispersion model capabilities (nuclear, biological capability (HPAC))**

# Potential Applications and Developmental Options

## **Transferability of Cheatham Reach SMIS to Similar Waterway Systems:**

- **SMIS can be readily adapted to other waterways that can be effectively modeled with CE-QUAL-W2.**
- **Suggested prioritization of work includes other major population centers and/or large volume transportation sectors possessing similar water hydrodynamics to the Cheatham Reach of the Cumberland River.**
- **Required enhancements:**
  - **Incorporation of GIS layers representative of the geographic area of interest;**
  - **Development and calibration of CE-QUAL-W2 model to waterway of interest, to include:**
    - **Waterway bathymetry**
    - **Collection of appropriate flow and water quality data;**
  - **Establishment of ‘hot links’ to meteorological and water flow data; and**
  - **Installation and training.**

# Potential Applications and Developmental Options

## **Model enhancements for dissimilar waterway systems:**

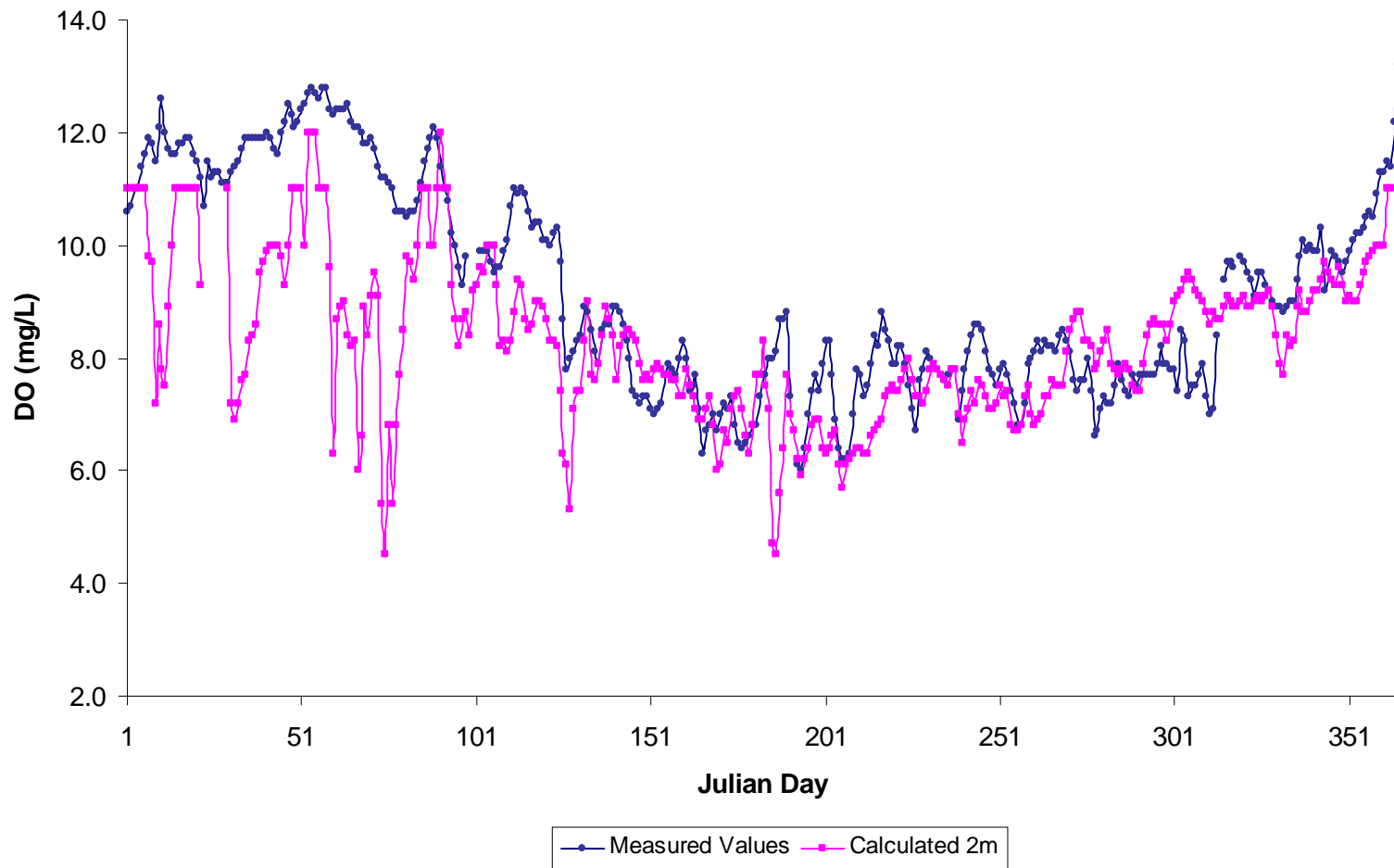
- **Modular framework of SMIS allows employment of additional water quality models to more appropriately model water bodies possessing hydrodynamics that are dissimilar to those modeled by CE-QUAL-W2.**
- **Such systems may include Resource Management Associates 2 (RMA-2) and Resource Management Associates 4 (RMA-4), and others.**
- **Required enhancements:**
  - **Evaluation of the waterway and needs of the client to determine the most appropriate hydrodynamic and contaminant transport models;**
  - **Incorporation of GIS layers representative of the geographic area of interest;**
  - **Development and calibration of the hydrodynamic and contaminant transport models of interest, to include:**
    - **Waterway bathymetry**
    - **Collection of appropriate flow and water quality data;**
  - **Design and implementation of applications module to activate and integrate model functionality within SMIS;**
  - **Establishment of ‘hot links’ to meteorological and water flow data; and**
  - **Installation and training.**



**Questions?**

# CE-QUAL-W2 Calibration

1999 Calibration Data - DO - Default Coefficients



# CE-QUAL-W2 Calibration

1999 Calibration Data - Temp - Default Coefficients

