Design of an Oil Spill Model Using Modern Software Design Principles & Associated Field Studies

Jim Weaver[1], Michel Boufadel[2], Bassem Naba[2], Karl Castleton[1,3]

[1]U.S. Environmental Protection Agency, Office of Research and Development, Athens, Georgia

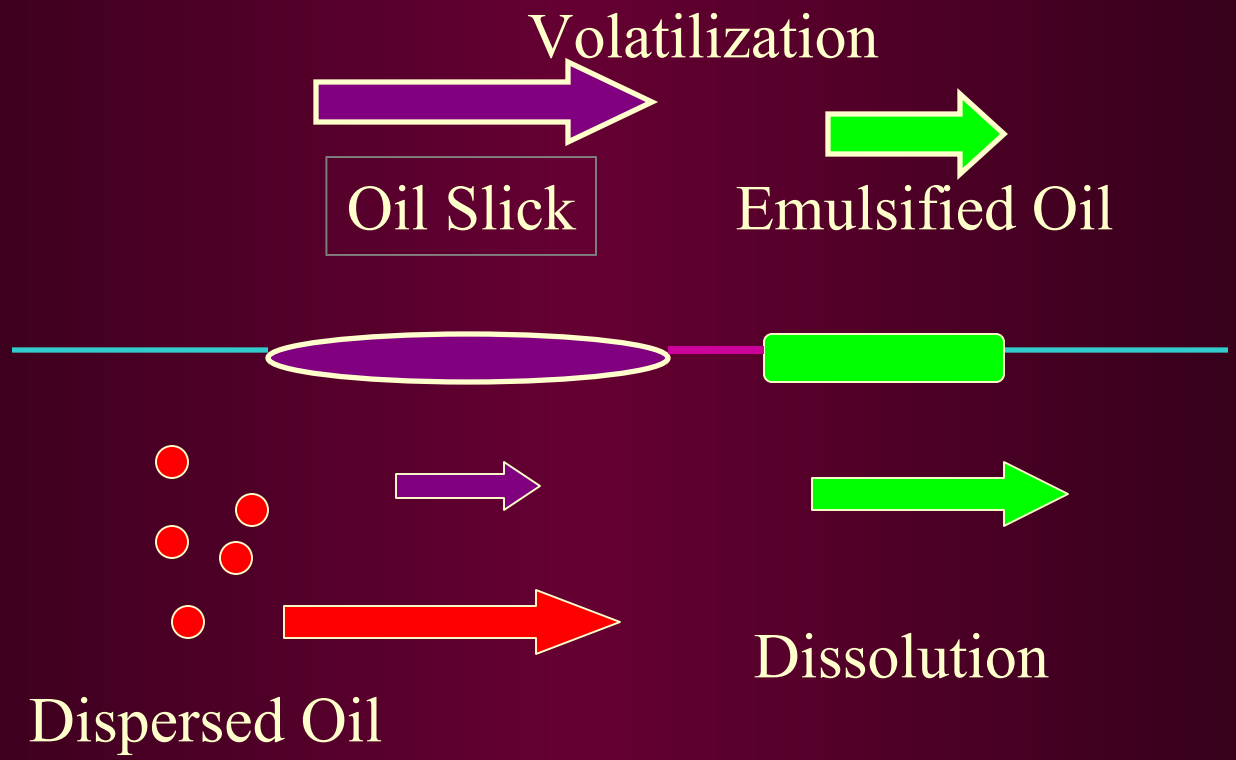
[2]Temple University, Philadelphia, Pennsylvania

[3]Now at Battelle Pacific Northwest Labs

Outline

- Model Design--Software Concepts
- 2001-2002 Field Studies at the Lock Lake tidal marsh
  - Significant Flow and Transport Features
  - Preliminary Simulations of Lock Lake
- Conclusions

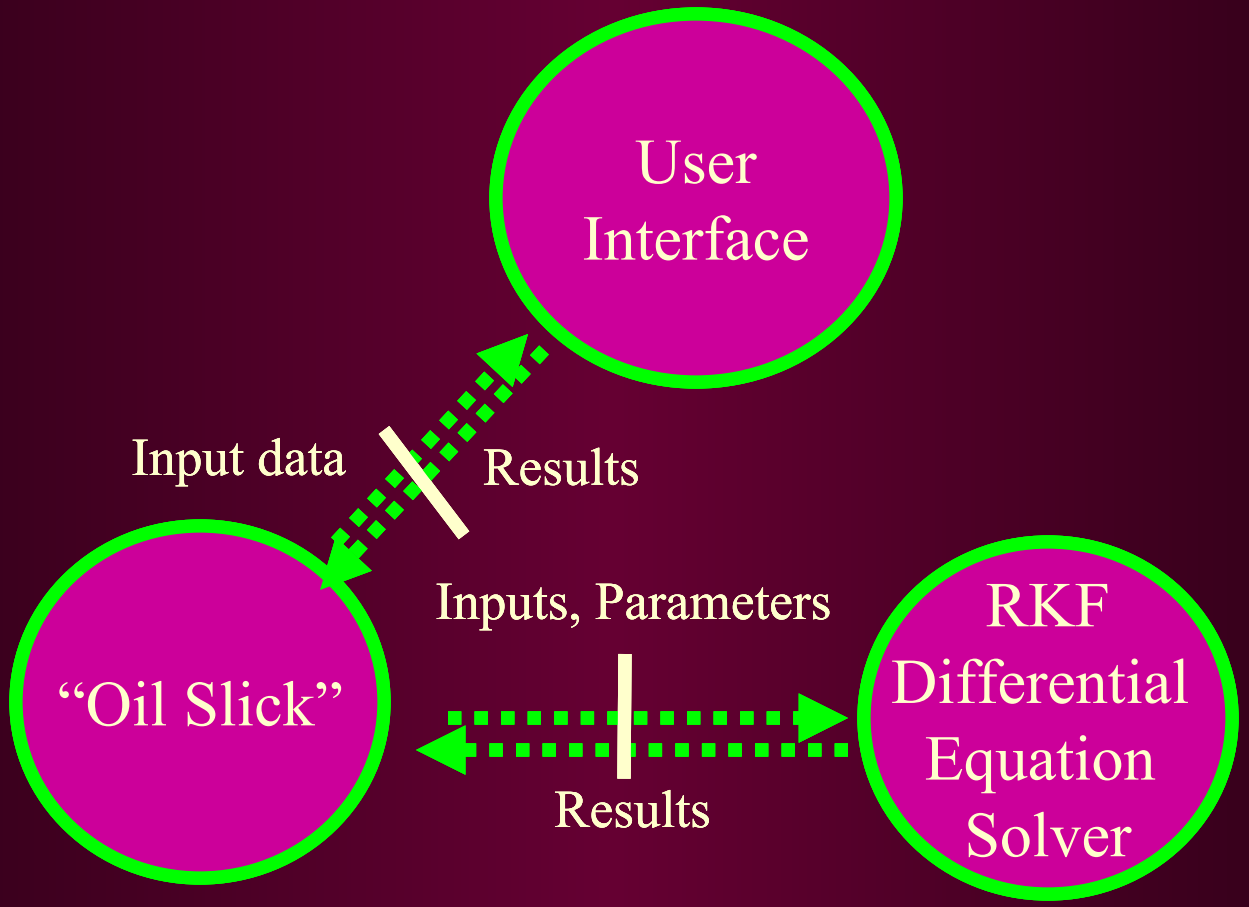
Oil Spill

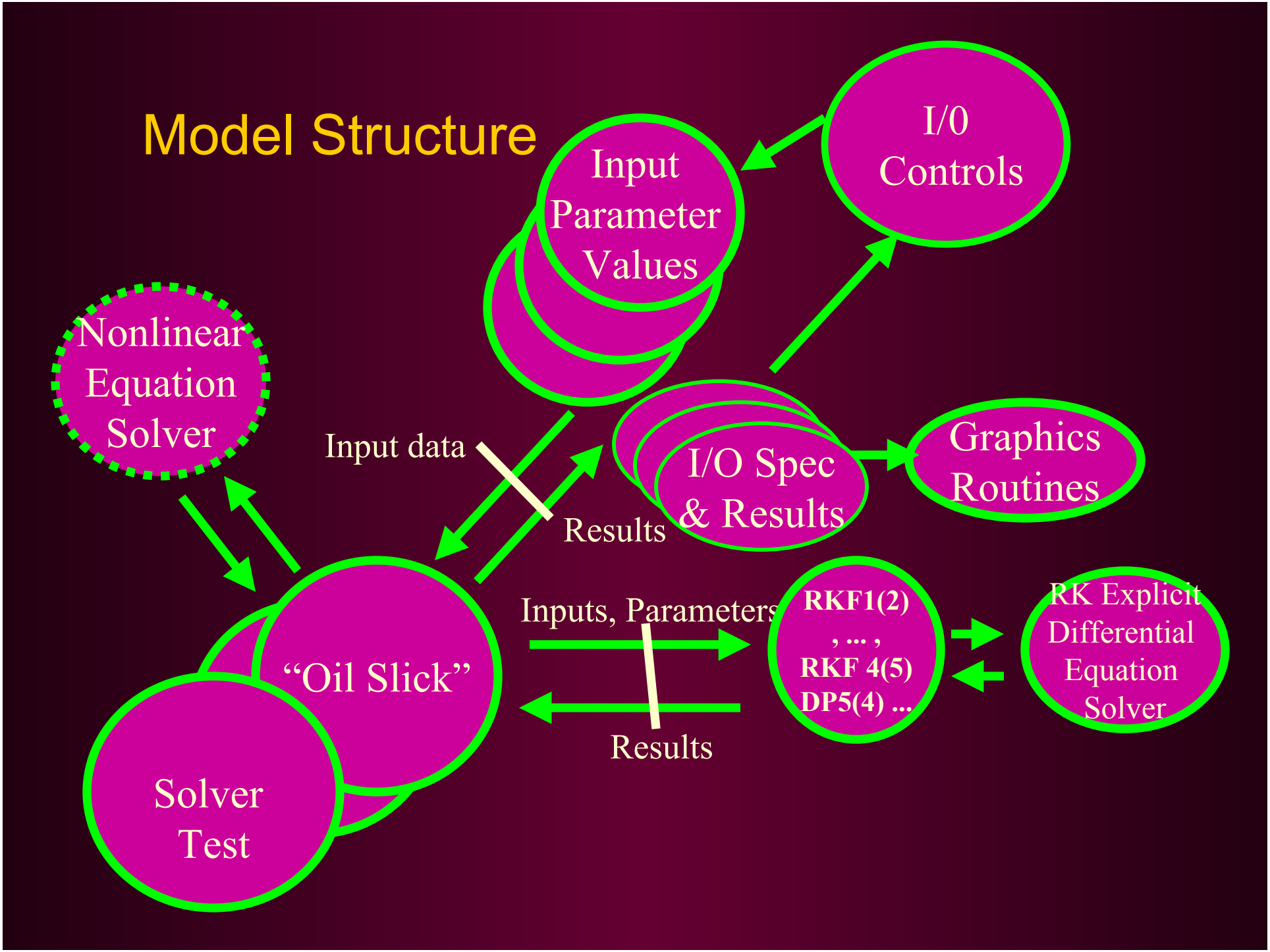

Volatilization
Oil Slick
Emulsified Oil
Dissolution
Dispersed Oil

Object Oriented Structure

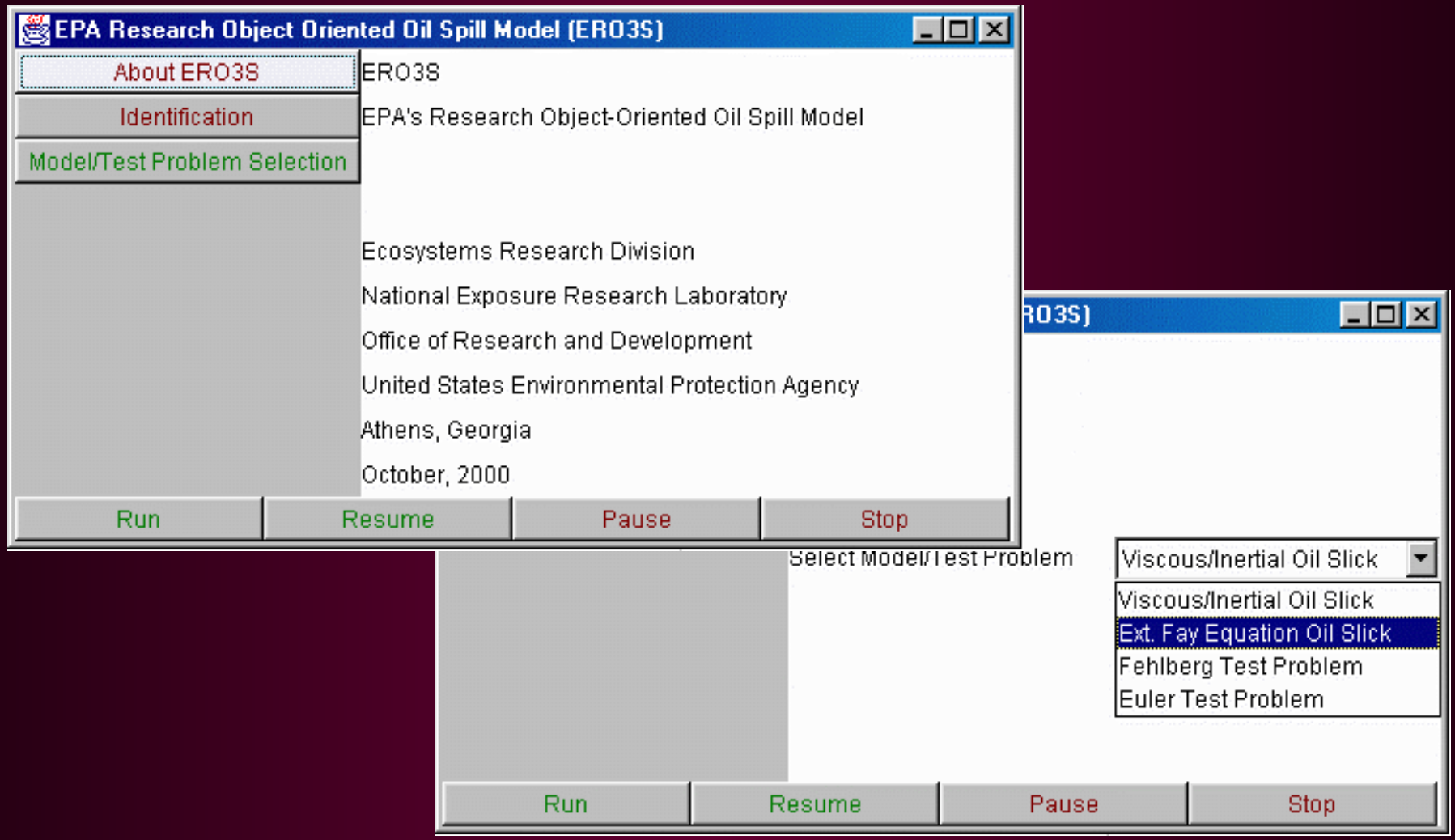
- Natural alignment with Problem Definition
  - Polymorphism: Slicks vs. droplets
  - Inheritance: Multiple droplets, e.g.
- *Vast* improvement over serial languages:
    - Flexibility
    - maintainability
    - testing
    - QA/QC
    - Cost is in Additional Design Time

EPA's Research Object-Oriented Oil Spill Model ----ERO^{3}S

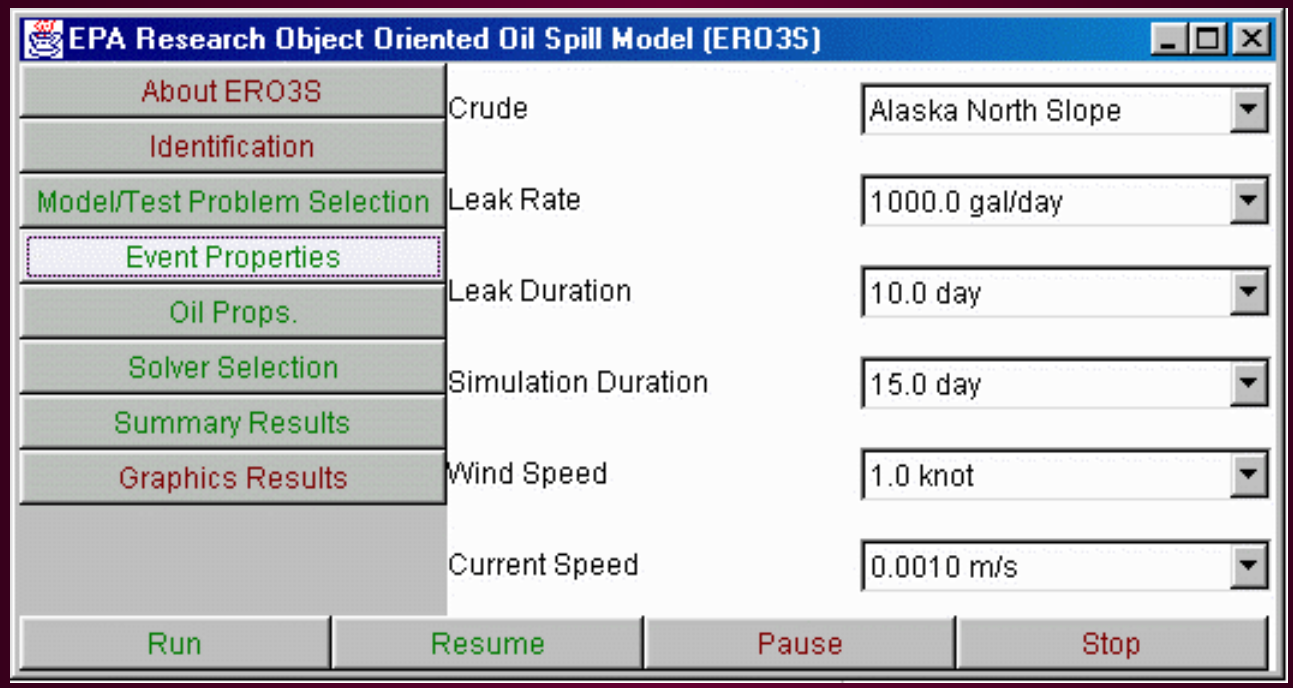



Model Structure
Input Parameter Values
I/0 Controls
Nonlinear Equation Solver
Input data
Results
I/O Spec & Results
Graphics Routines
"Oil Slick"
Inputs, Parameters
Results
RKF1(2) , ... , RKF 4(5) DP5(4) ...
RK Explicit Differential Equation Solver
Solver Test

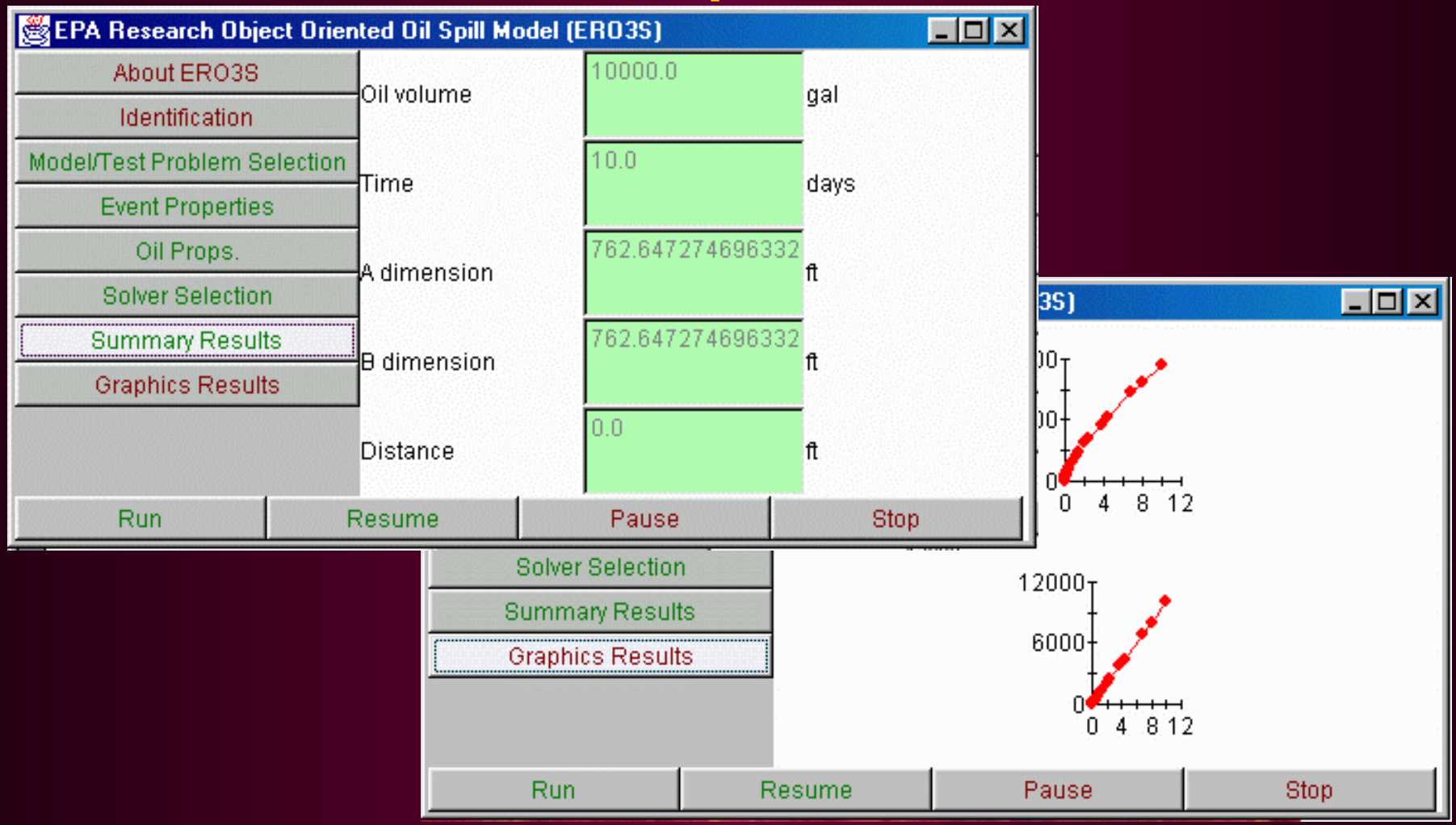
Main Screen


EPA Research Object Oriented Oil Spill Model (ERO3S)
About ERO3S
Identification
Model/Test Problem Selection
ERO3S
EPA's Research Object-Oriented Oil Spill Model
Ecosystems Research Division
National Exposure Research Laboratory
Office of Research and Development
United States Environmental Protection Agency
Athens, Georgia
October, 2000
Run
Resume
Pause
Stop
Select Model/Test Problem
Viscous/Inertial Oil Slick
Viscous/Inertial Oil Slick
Ext. Fay Equation Oil Slick
Fehlberg Test Problem
Euler Test Problem
Run
Resume
Pause
Stop

Input


EPA Research Object Oriented Oil Spill Model (ERO3S)
About ERO3S
Identification
Model/Test Problem Selection
Event Properties
Oil Props.
Solver Selection
Summary Results
Graphics Results
Crude
Alaska North Slope
Leak Rate
1000.0 gal/day
Leak Duration
10.0 day
Simulation Duration
15.0 day
Wind Speed
1.0 knot
Current Speed
0.0010 m/s
Run
Resume
Pause
Stop

Outputs


EPA Research Object Oriented Oil Spill Model (ERO3S)
About ERO3S
Identification
Model/Test Problem Selection
Event Properties
Oil Props.
Solver Selection
Summary Results
Graphics Results
Oil volume
10000.0
gal
Time
10.0
days
A dimension
762.647274696332
ft
B dimension
762.647274696332
ft
Distance
0.0
ft
Run
Resume
Pause
Stop
0
4
8
12
12000
6000

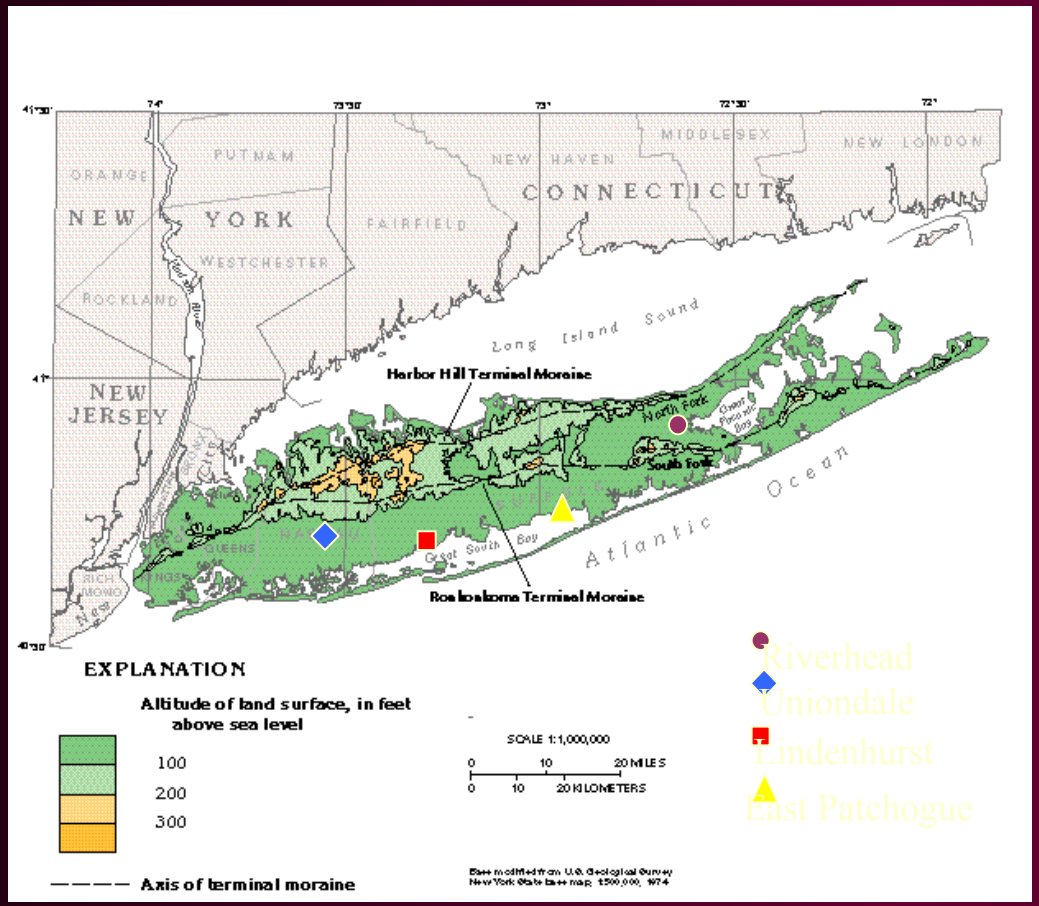
Lock Lake Tidal Marsh Study

- Gain understanding from studying field site
  - Component of model design
  - We have observed phenomena we could not have guessed
  - What data are critical for model-based studies?
- Test site for hypothesis testing
  - What would be the impact of an oil spill? Emulsified fuel spill?
- Parameter estimation from field studies
  - Measure dispersion coefficients

Lock Lake Tidal Marsh

- Small tidal marsh on south shore of Long Island
- Cooperative study between
  - US EPA, NYSDEC, Temple University
- Study transport in a setting influenced by
  - Tides, ground water discharge, freshwater inflows

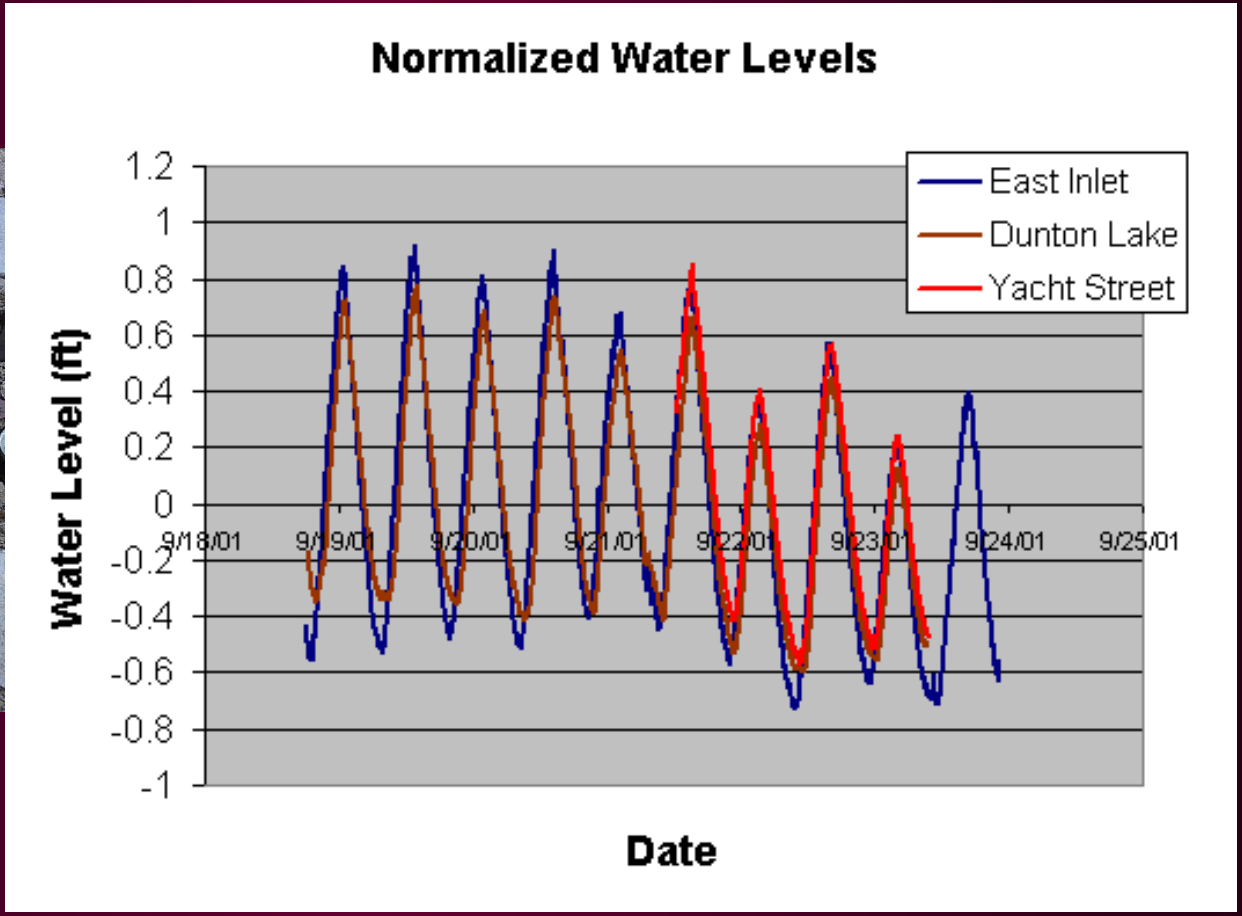
Lock Lake


NEW YORK
CONNECTICUT
NEW JERSEY
PUTNAM
ORANGE
ROCKLAND
WESTCHESTER
FAIRFIELD
NEW HAVEN
MIDDLESEX
NEW LONDON
Long Island Sound
Harbor Hill Terminal Moraine
Ronkonkoma Terminal Moraine
North Fork
South Fork
Great South Bay
Atlantic Ocean
Riverhead
Uniondale
Lindenhurst
East Patchogue
EXPLANATION
Altitude of land surface, in feet above sea level
100
200
300
Axis of terminal moraine
SCALE 1:1,000,000
0 10 20 MILES
0 10 20 KILOMETERS

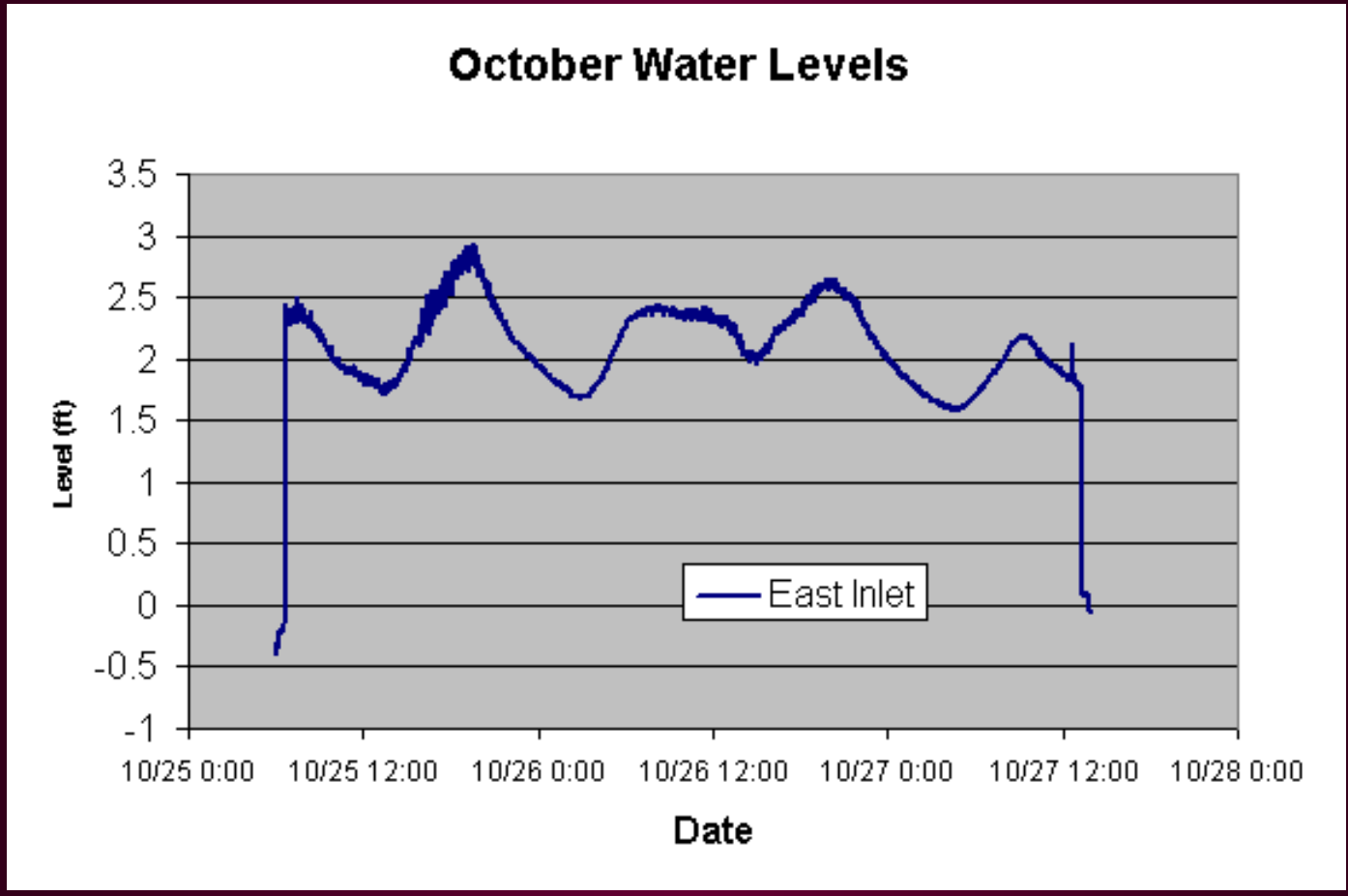
Stilling Well Data

- Do predicted and observed tides match?
  - (Sandy Hook, NJ or Montauk Point, NY + time lag and height correction?)
- How much does response lag in the marsh?
  - Approximately 20 minutes at Dunton Lake
  - Is this data reproduced by the model?

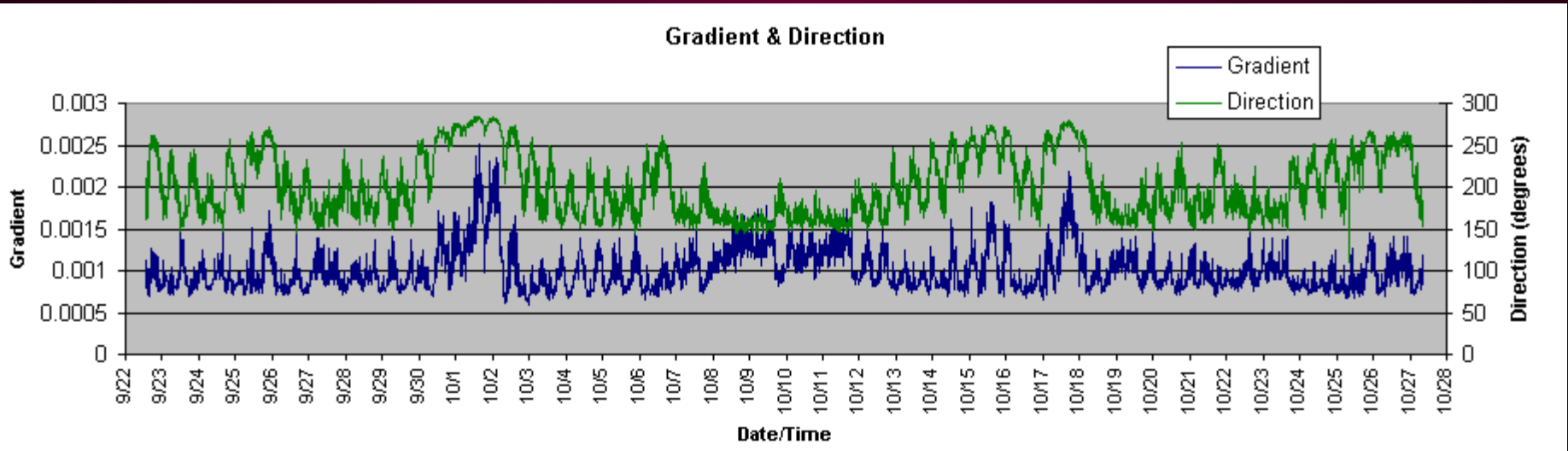
Marsh Water Levels (9-2001)

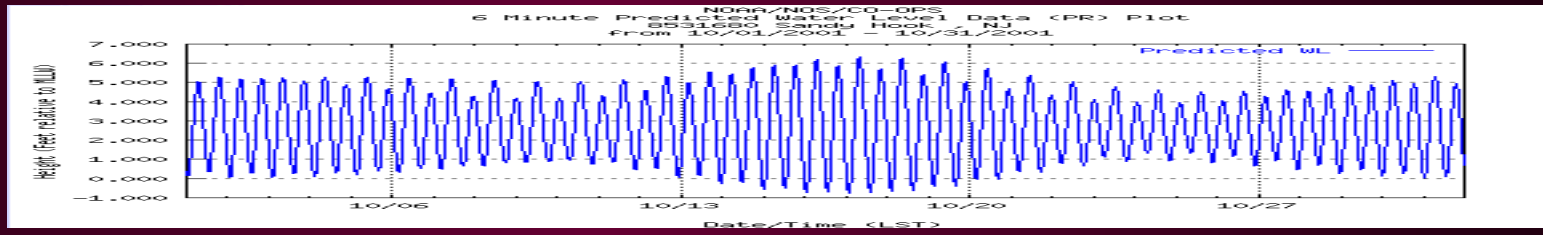


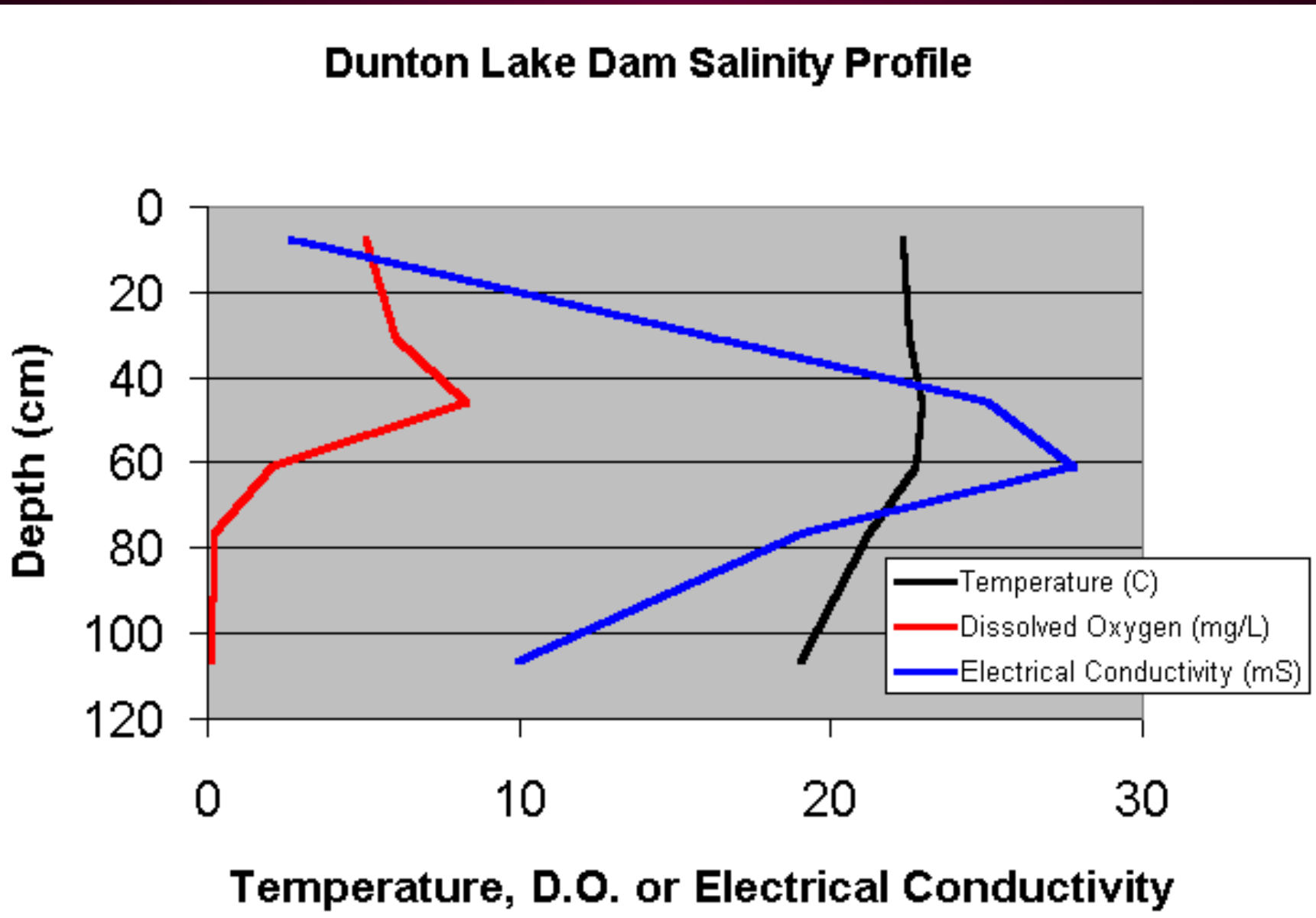
Marsh Water Levels (10-2001)

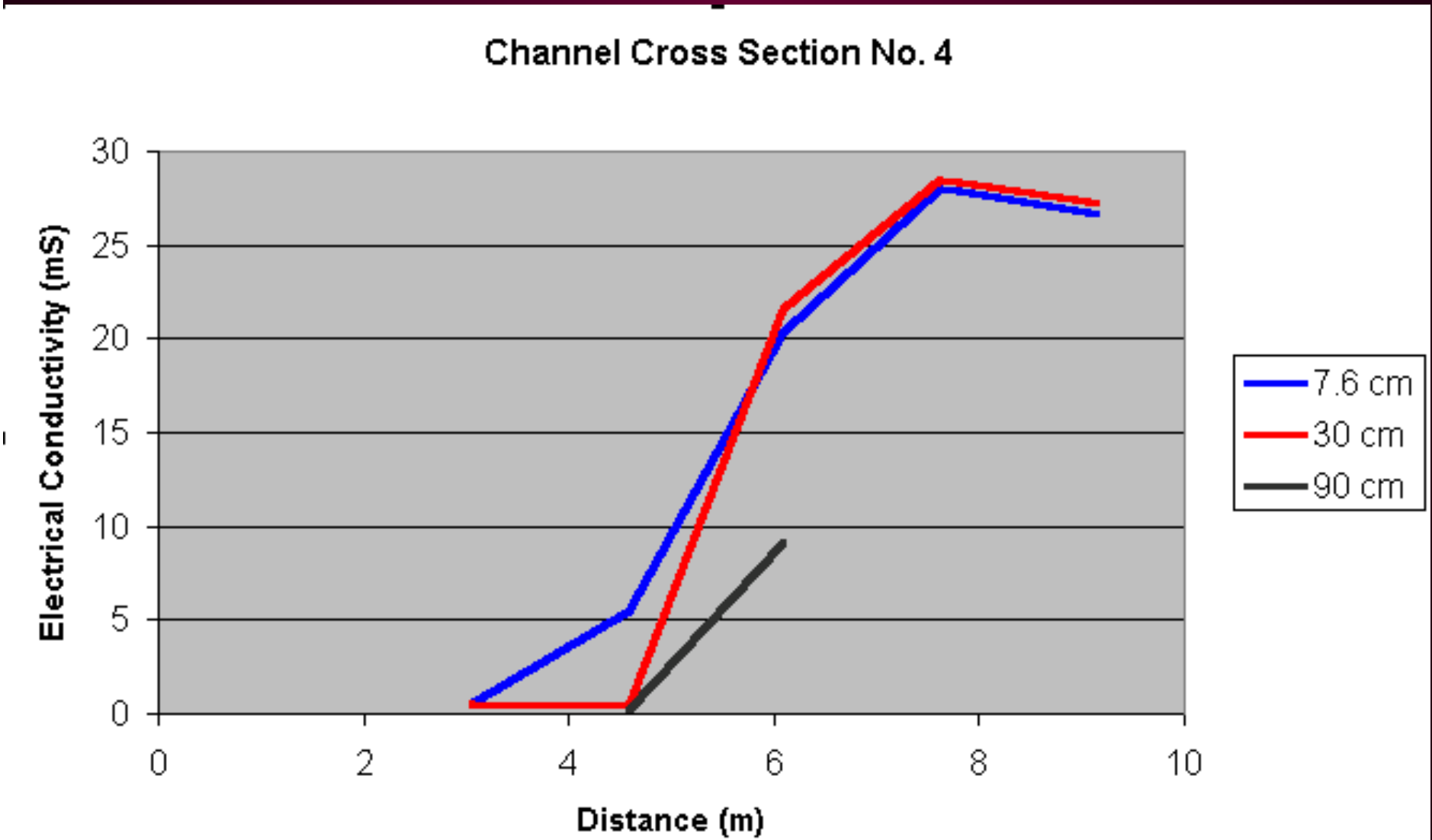


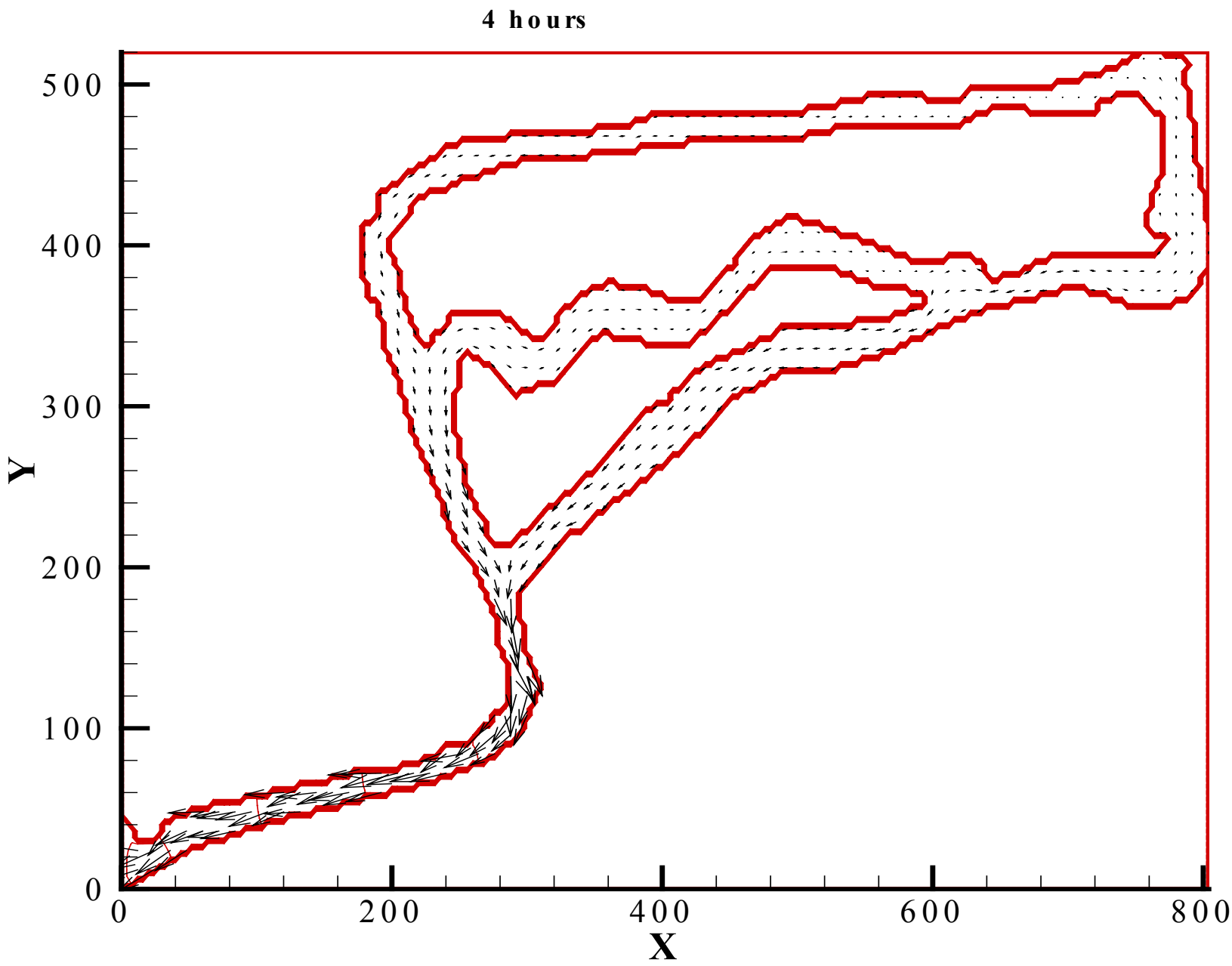
Aquifer Connection

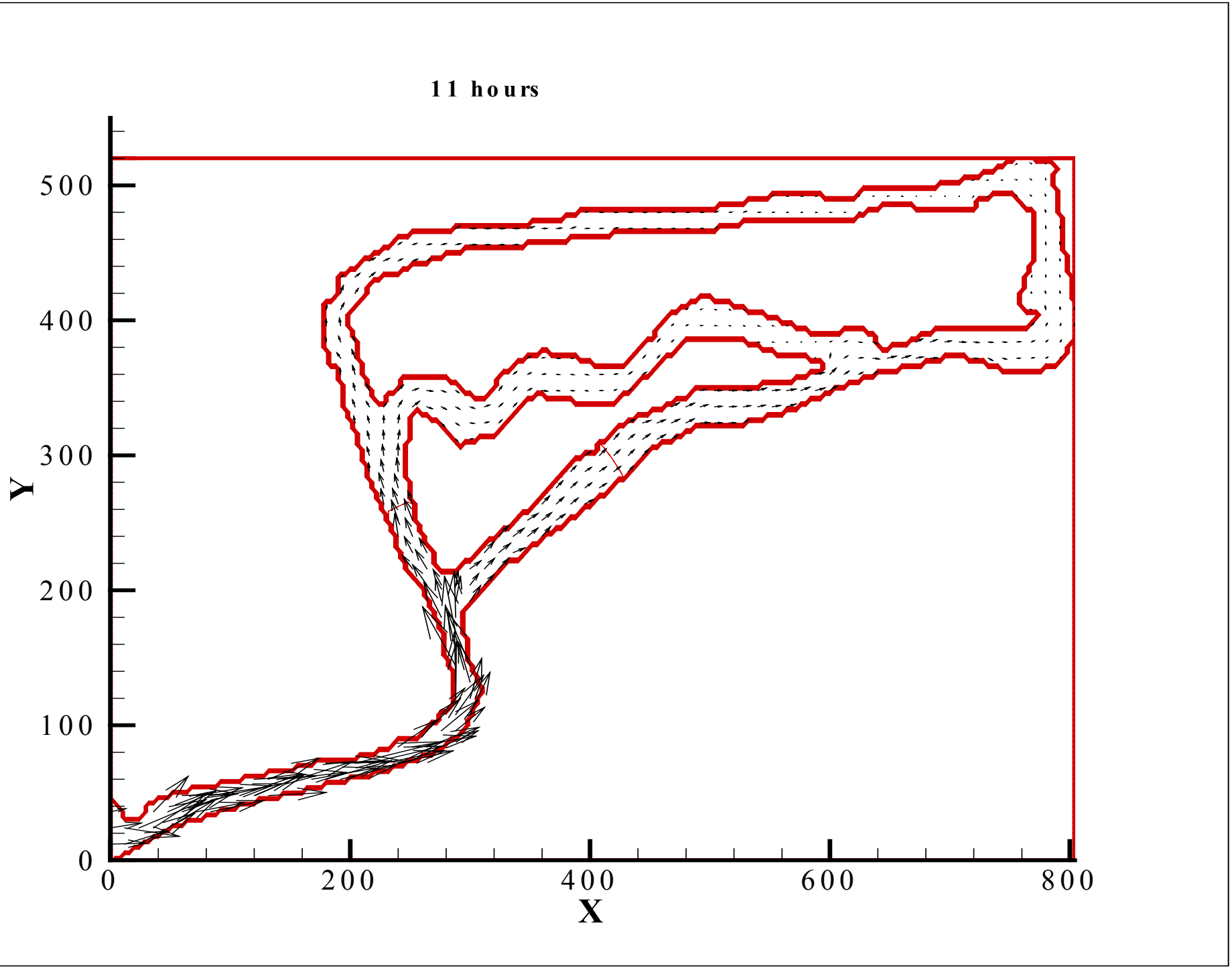




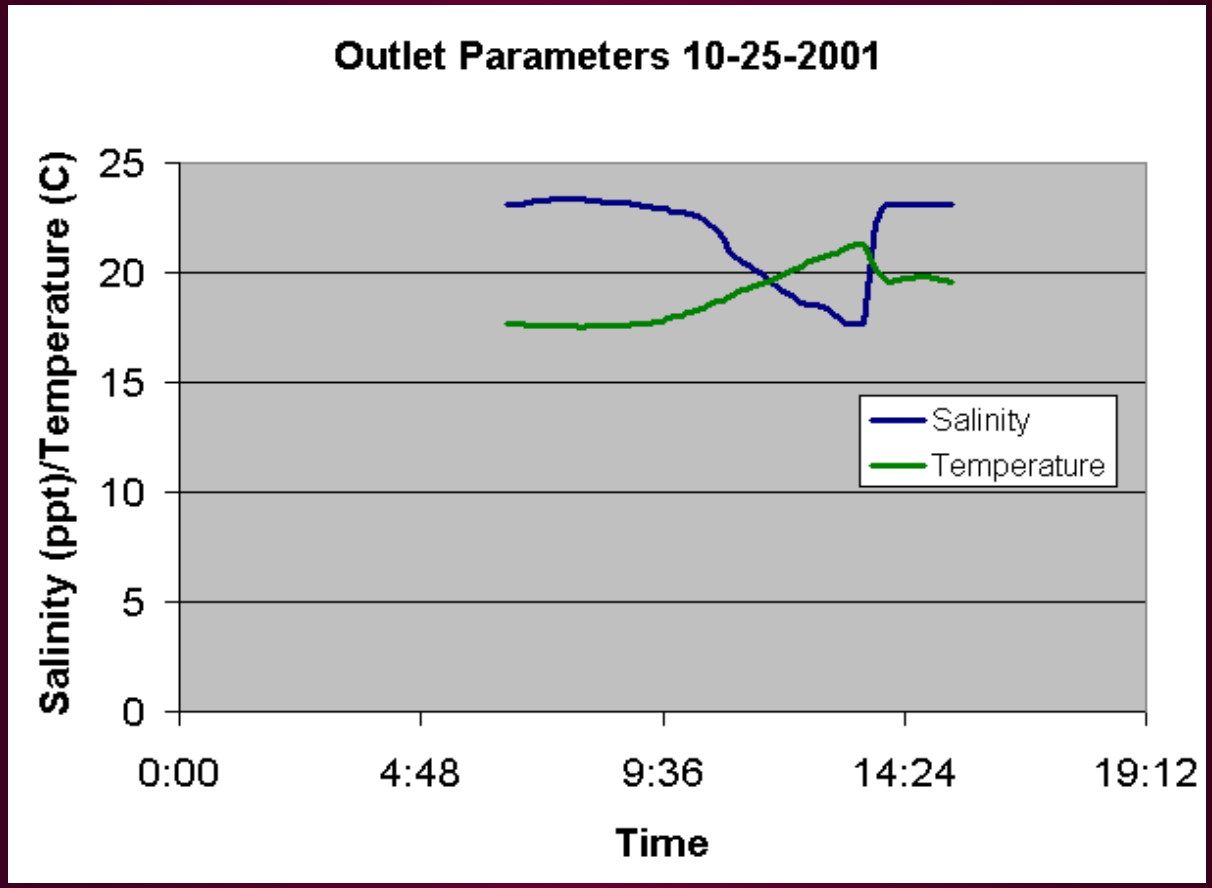

Dunton Lake Dam Salinity Profile
Depth (cm)
0
20
40
60
80
100
120
0
10
20
30
Temperature, D.O. or Electrical Conductivity
Temperature (C)
Dissolved Oxygen (mg/L)
Electrical Conductivity (mS)


Channel Cross Section No. 4
Electrical Conductivity (mS)
30
25
20
15
10
5
0
0
2
4
6
8
10
Distance (m)
7.6 cm
30 cm
90 cm


4 hours
500
400
300
200
100
0
Y
0
200
400
600
800
X


11 hours
500
400
300
200
100
0
Y
0
200
400
600
800
X

East Inlet Salinity & Temperature



Conclusions

- Lock Lake field study provides insight into transport behavior and contributes to model design
  - Preliminary Lock Lake data indicate
    - maximum propagation distance into marsh
    - mixing with fresh water
  - Inverted salinity profiles indicate fresh water inflows
  - Spring with abrupt salinity transition

Conclusions

- Preliminary model results correspond to observations
  - limited propagation distance into marsh
  - sensitivity analysis indicates topography controls flow
- Continuing work to link oil slick model to the flow model

2002 Field Work

- Long term logging of water levels, temperature and salinity in marsh
- Tracer study to generate testing data
  - Direct estimates of dispersion coefficients
  - Test data for water level model
  - Verification (or not) of transport hypothesis based on inlet data

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