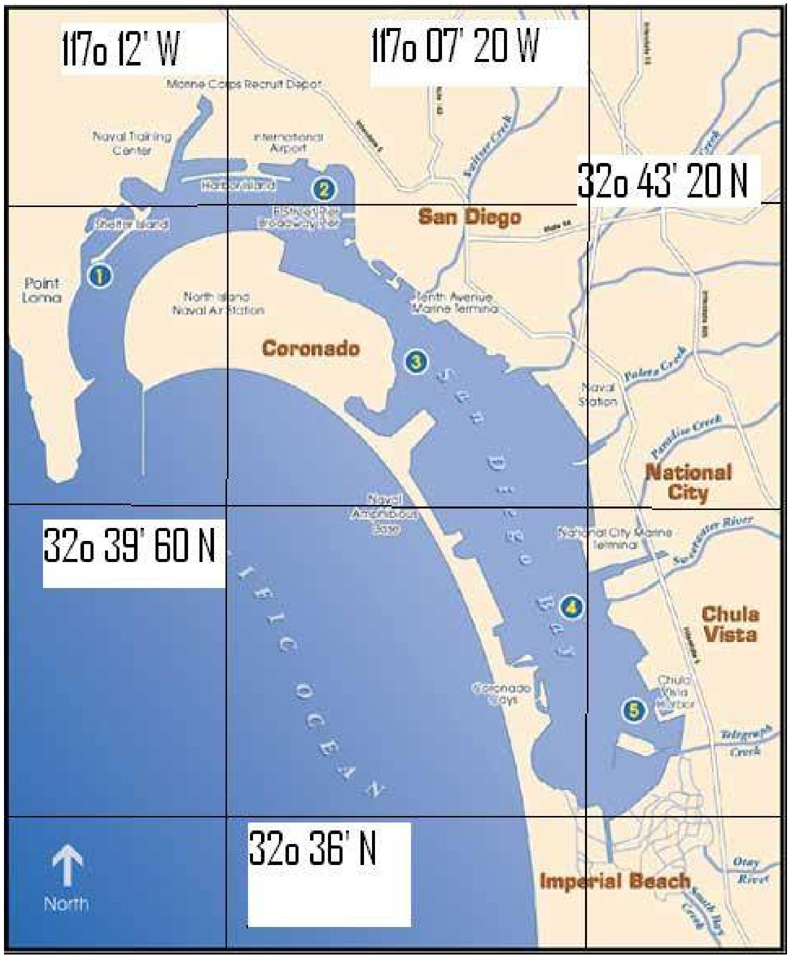
TWO CHEMICAL SPILL PATTERNS IN TIDALLY DOMINATED SAN DIEGO BAY

PETER C. CHU, KLEANTHIS KYRIAKIDIS
Naval Postgraduate School, Monterey, CA93943

STEVEN D. HAEGER
Naval Oceanographic Office, Stennis Space Center

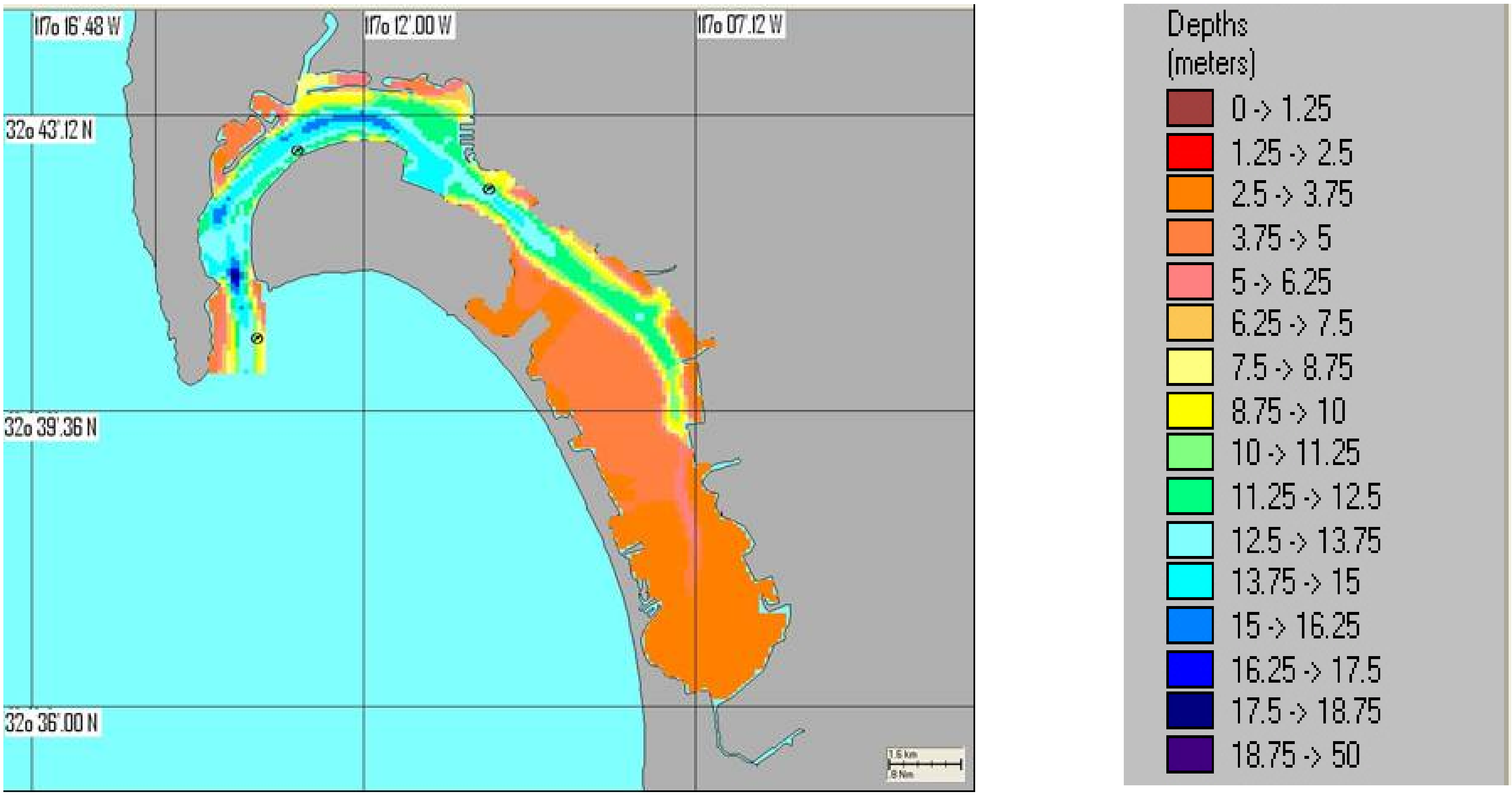
MATHEW WARD
Applied Science Associates, Inc.Narragansett, RI

San Diego Bay

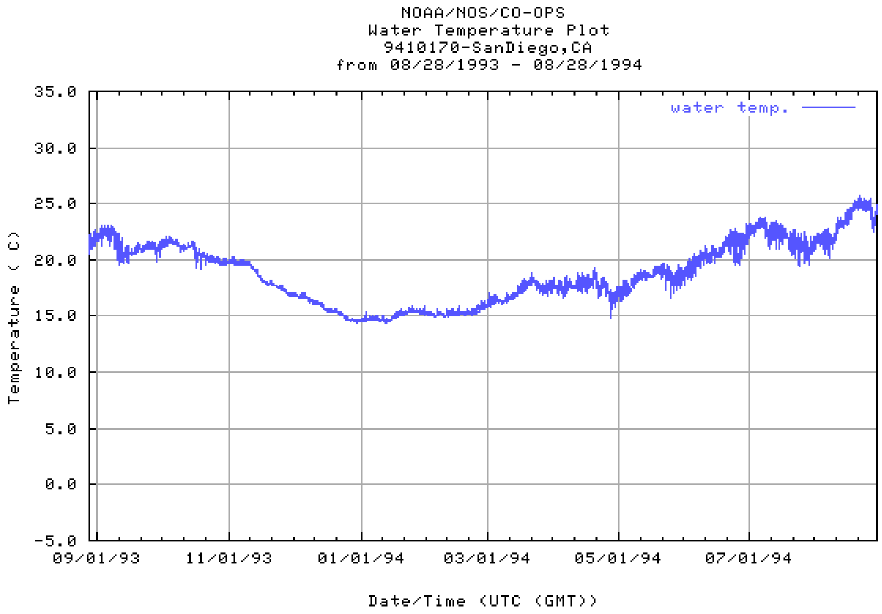


- Importance: Large City, Host of a significant part of US Navy, near the borders
- Hydrological Interest: Small Tidal Basin, Semi-Enclosed Bay
- Minor Wind Effect

Bottom Topography



Characteristics

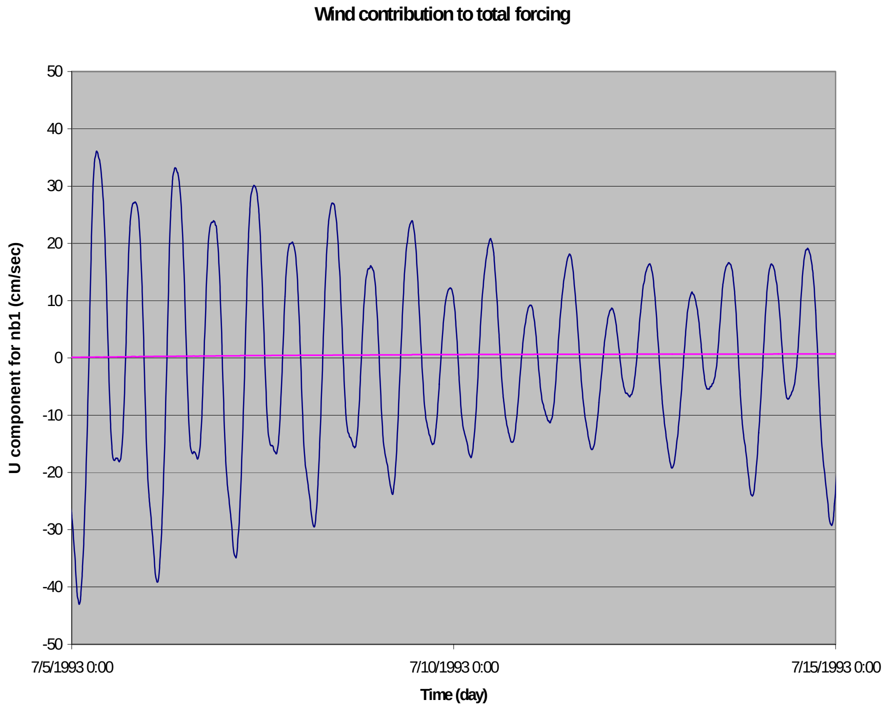


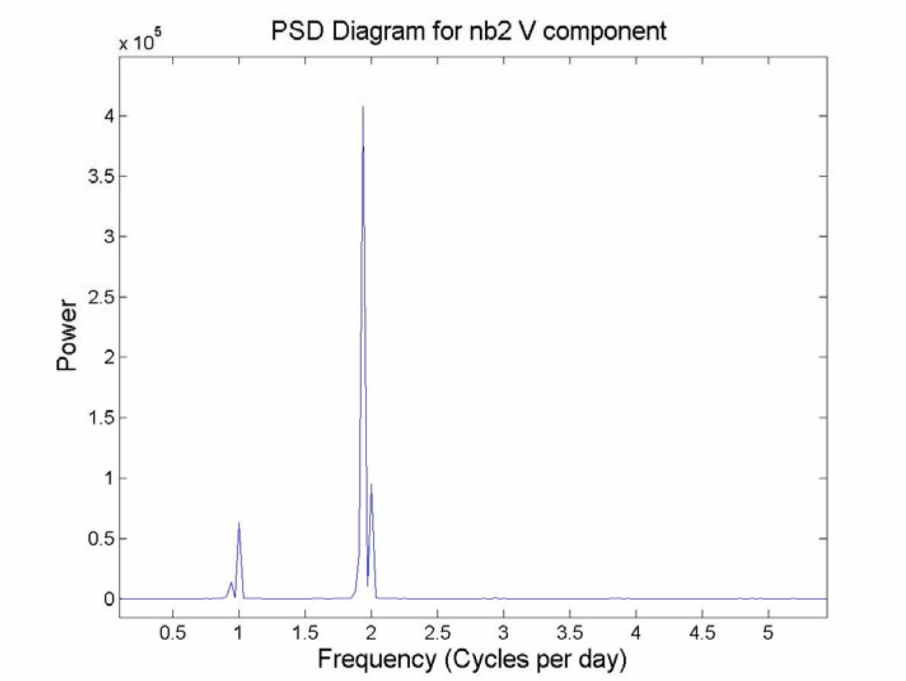
T ~ 21°C

(range 14° – 26°C).

S ~ 35 ppt

(range 32.5 - 37.5 ppt)



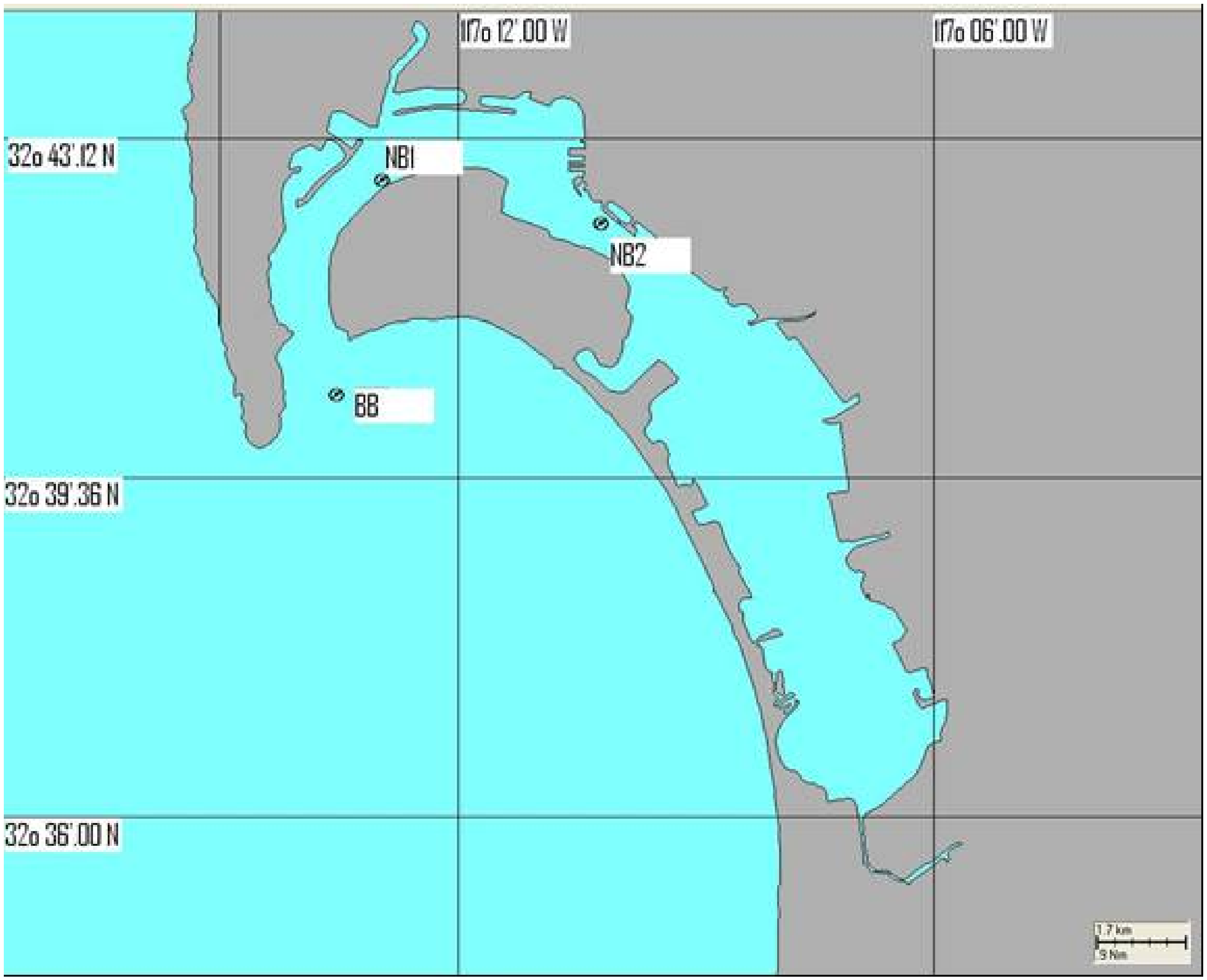


- *Currents produced by tides ("tidal pumping" caused by the flow difference between ebb and flood).*
- *Winds insignificant effect. Both westerly afternoon winds and easterly morning/ evening winds less than 5 m/sec*
- *Annual precipitation 0.26 m (in summer negligible – less than 0.005 m). No significant river inflow*

	Name	Amplitude (m)	Epoch (degrees)
1	M2	0.576	148.9
2	S2	0.233	145.9
3	N2	0.136	128.7
4	K1	0.352	210.5
5	O1	0223	195.6
6	NU2	0.027	134.3
7	MU2	0.010	109.7
8	2N2	0.018	108.7
9	OO1	0.010	225.4
10	LAM2	0.004	147.5
11	M1	0.011	194.2
12	J1	0.018	217.9
13	SSA	0.017	272.7
14	SA	0.063	182.0
15	RHO	0.008	189.2
16	Q1	0.041	188.7
17	T2	0.014	145.9
18	2Q1	0.006	180.7
19	P1	0.109	208.8
20	L2	0.013	121.7
21	K2	0.065	139.3

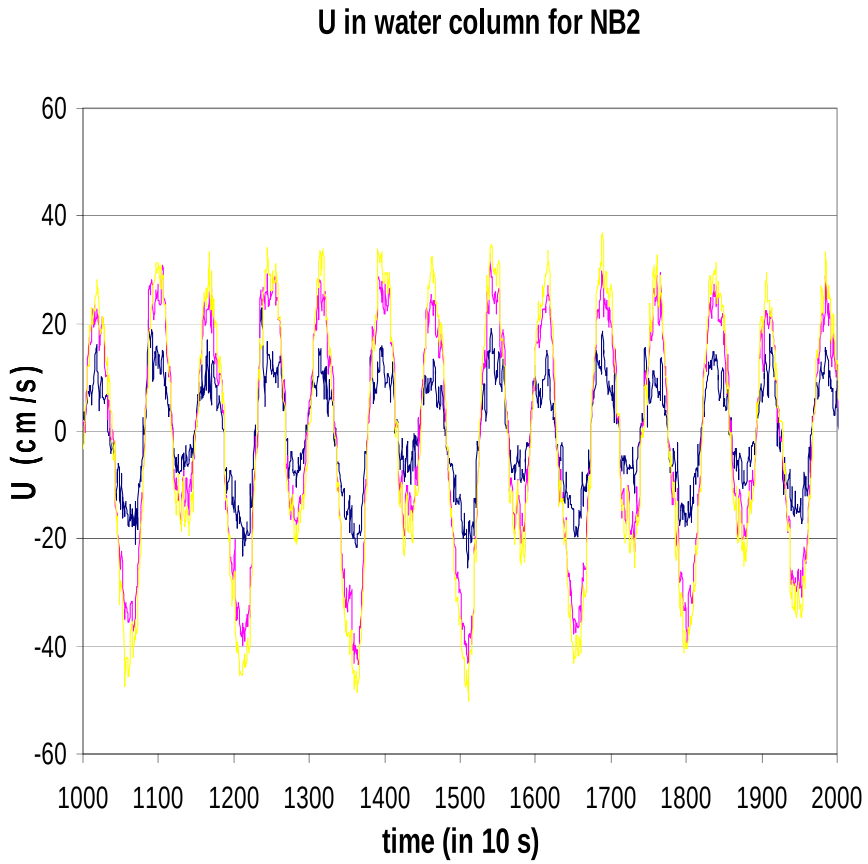
- Semi-diurnal and Diurnal Tides

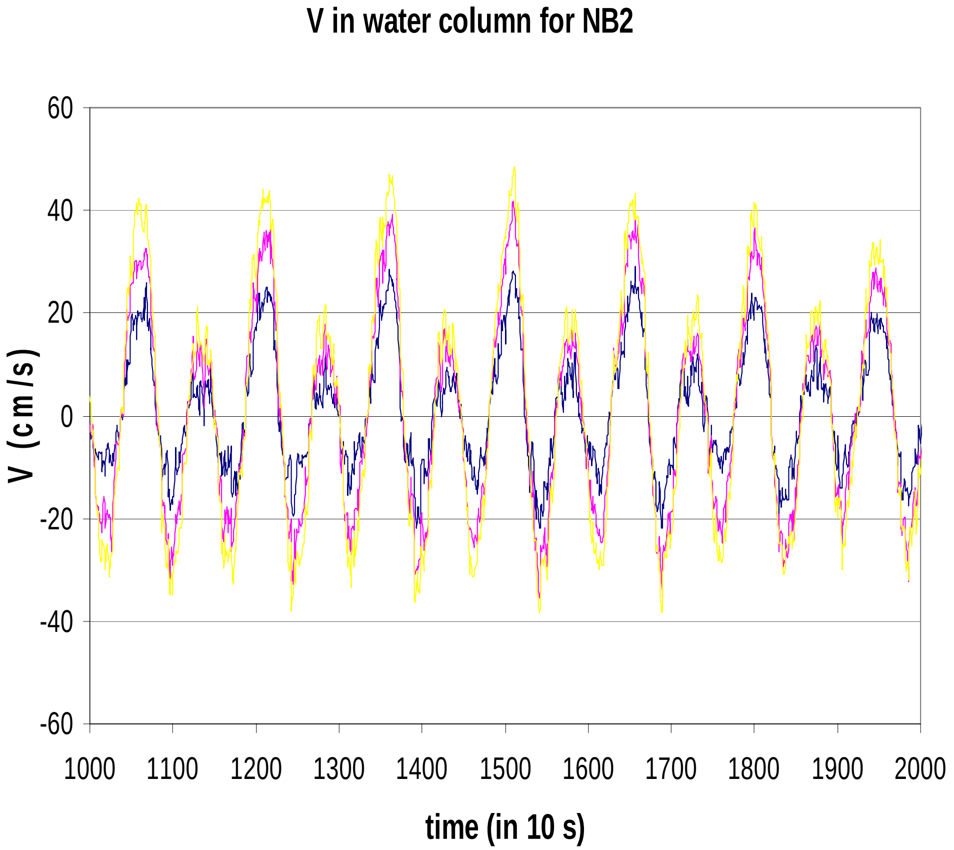
ADCP stations (SPAWAR) in June to August 1993.



Barotropic Tidal Currents

Currents at NB2 station for surface (yellow), middle depth (purple) and bottom (blue)





Water Quality Management and Analysis Package (WQMAP)

- **WQMAP** is an integrated modeling system designed to study surface water quality issues. The system allows the engineer or scientist to develop numerical grids, perform hydrodynamic simulations, conduct single constituent pollutant transport and multiple constituent eutrophication studies in a geographic context all from one application.

Features of WQMAP

- Integrated Geographic Information System
- Grid Generation
- Hydrodynamic Model
- Pollutant Transport Model
- Eutrophication Model
- All models use same computational grid
- Applicable within regions such as rivers, lakes, estuaries, bays and coastal seas.

Hydrodynamic Model

Continuity

$$R\sqrt{g_{11}g_{22}}\frac{\partial\zeta}{\partial t}+\frac{\partial\left(UD\sqrt{g_{22}}\right)}{\partial\xi}+\frac{\partial\left(VD\sqrt{g_{11}}\right)}{\partial\eta}=0$$

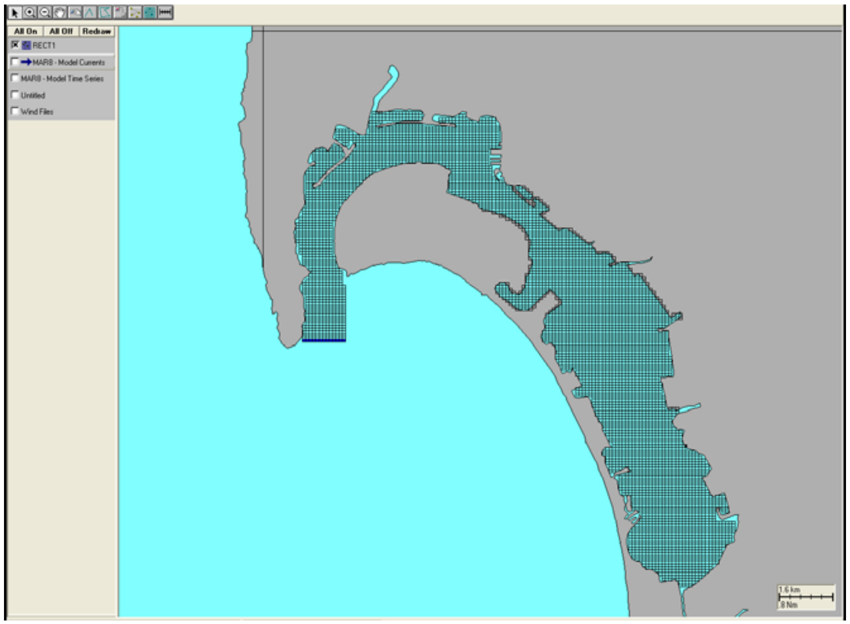
Momentum Equation in ξ-direction

$$\frac{\partial UD}{\partial t}+\frac{1}{\sqrt{g_{11}g_{22}}}\left[\frac{\partial\left(U^2D\sqrt{g_{22}}\right)}{\partial\xi}+\frac{\partial\left(UVD\sqrt{g_{11}}\right)}{\partial\eta}+UVD\frac{\partial\left(\sqrt{g_{11}}\right)}{\partial\eta}-V^2\frac{\partial\left(\sqrt{g_{22}}\right)}{\partial\xi}\right]-fDV$$
$$=-\frac{gD}{R\sqrt{g_{11}}}\left[\frac{\partial\zeta}{\partial\xi}+\frac{D}{\rho_0}\int_{-1}^{0}\int_{\sigma}^{0}\left(\frac{\partial\rho}{\partial\xi}-\frac{\sigma}{D}\frac{\partial D}{\partial\xi}\frac{\partial\rho}{\partial\sigma}\right)d\sigma\right]$$

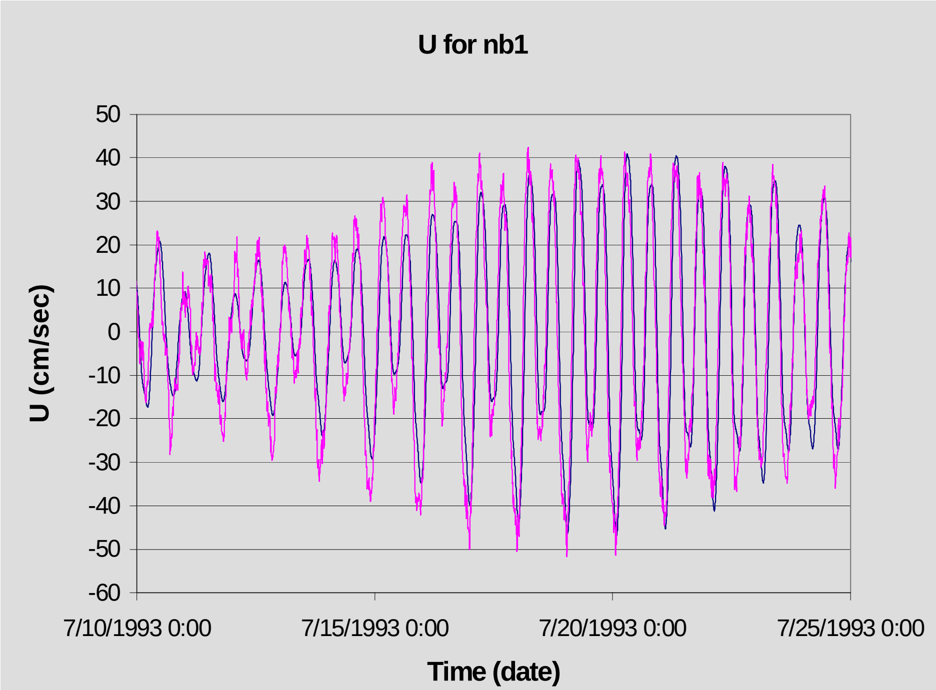
Momentum Equation in η-direction

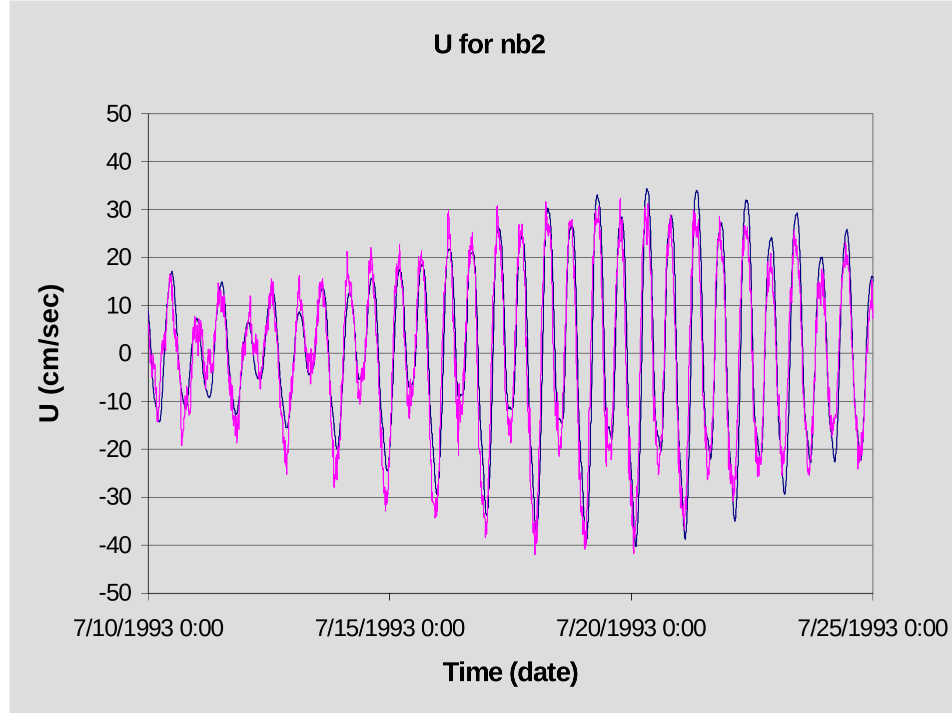
$$\frac{\partial VD}{\partial t}+\frac{1}{\sqrt{g_{11}g_{22}}}\left[\frac{\partial\left(UVD\sqrt{g_{22}}\right)}{\partial\xi}+\frac{\partial\left(V^2D\sqrt{g_{11}}\right)}{\partial\eta}+UVD\frac{\partial\left(\sqrt{g_{22}}\right)}{\partial\xi}-U^2\frac{\partial\left(\sqrt{g_{11}}\right)}{\partial\eta}\right]+fDV$$
$$=-\frac{gD}{R\sqrt{g_{22}}}\left[\frac{\partial\zeta}{\partial\eta}+\frac{D}{\rho_0}\int_{-1}^{0}\int_{\sigma}^{0}\left(\frac{\partial\rho}{\partial\eta}-\frac{\sigma}{D}\frac{\partial D}{\partial\eta}\frac{\partial\rho}{\partial\sigma}\right)d\sigma\right]$$

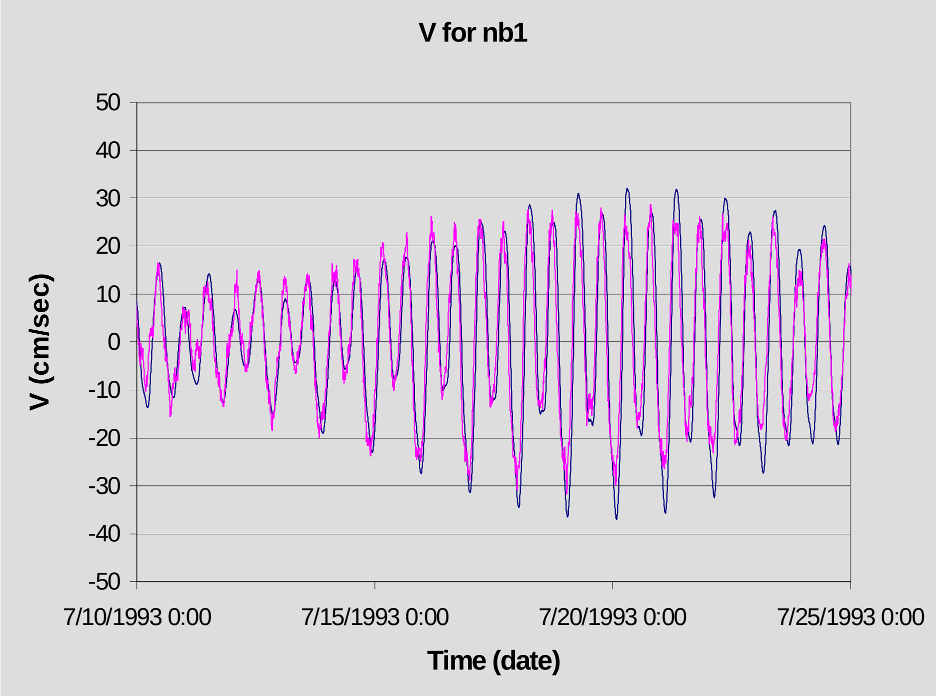
WQMAP MODEL - APPROXIMATIONS AND BOUNDARY CONDITIONS



- Hydrostatic
- Tidal forcing (tidal harmonic at the open boundary from NOAA)
- Land boundaries assumed impermeable (normal component of velocity set to zero).
- At closed boundaries transport of substance (i.e. salinity) is zero.
- At open boundaries, concentration specified during the inflow, using characteristic values.


U for nb1
U (cm/sec)
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
7/10/1993 0:00
7/15/1993 0:00
7/20/1993 0:00
7/25/1993 0:00
Time (date)


U for nb2
U (cm/sec)
50
40
30
20
10
0
-10
-20
-30
-40
-50
7/10/1993 0:00
7/15/1993 0:00
7/20/1993 0:00
7/25/1993 0:00
Time (date)


V for nb1
V (cm/sec)
50
40
30
20
10
0
-10
-20
-30
-40
-50
7/10/1993 0:00
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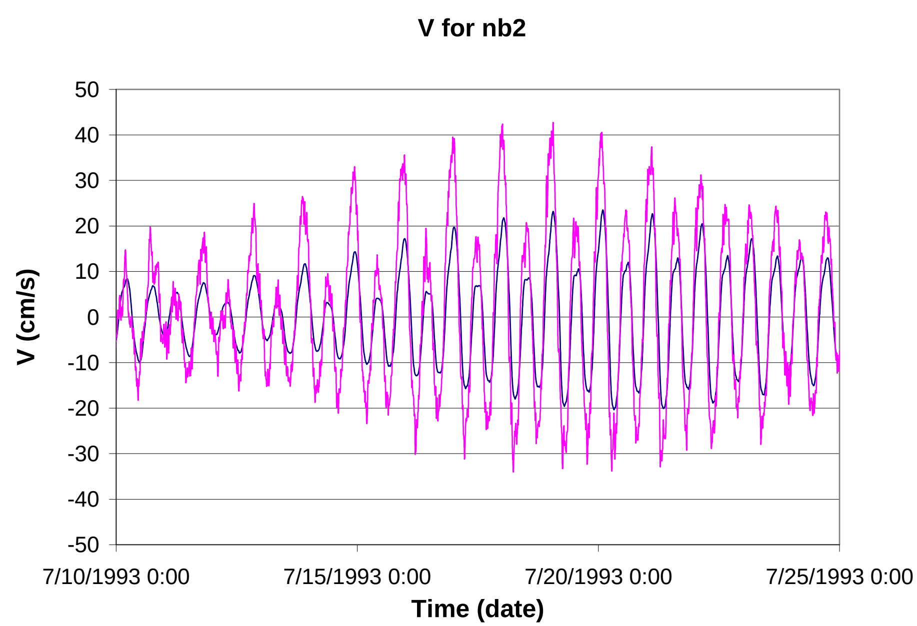
7/25/1993 0:00
Time (date)


V for nb2
V (cm/s)
50
40
30
20
10
0
-10
-20
-30
-40
-50
7/10/1993 0:00
7/15/1993 0:00
7/20/1993 0:00
7/25/1993 0:00
Time (date)

MODEL EVALUATION/ VELOCITY COMPONENTS

- Correlation Coefficient : 0.92
- Relative Root Mean Square Error: 0.09

MODEL EVALUATION/ ELEVATION

	NOAA	SPAWAR
M2 (ampl dif)	+ 2.51 cm	+ 3.83 cm
K1 (ampl dif)	- 0.94 cm	+ 3.73 cm
O1 (ampl dif)	- 0.84 cm	- 2.19 cm
S2 (ampl dif)	+ 0.71 cm	- 1.1 cm
M2 (ph dif)	+ 0.75º	- 1.71º

Chemical Discharge Model System (CHEMMAP)

- **CHEMMAP** is a chemical discharge model designed to predict the trajectory, fate, impacts and biological effects of a wide variety of chemical substances three-dimensionally.

Features of CHEMMAP

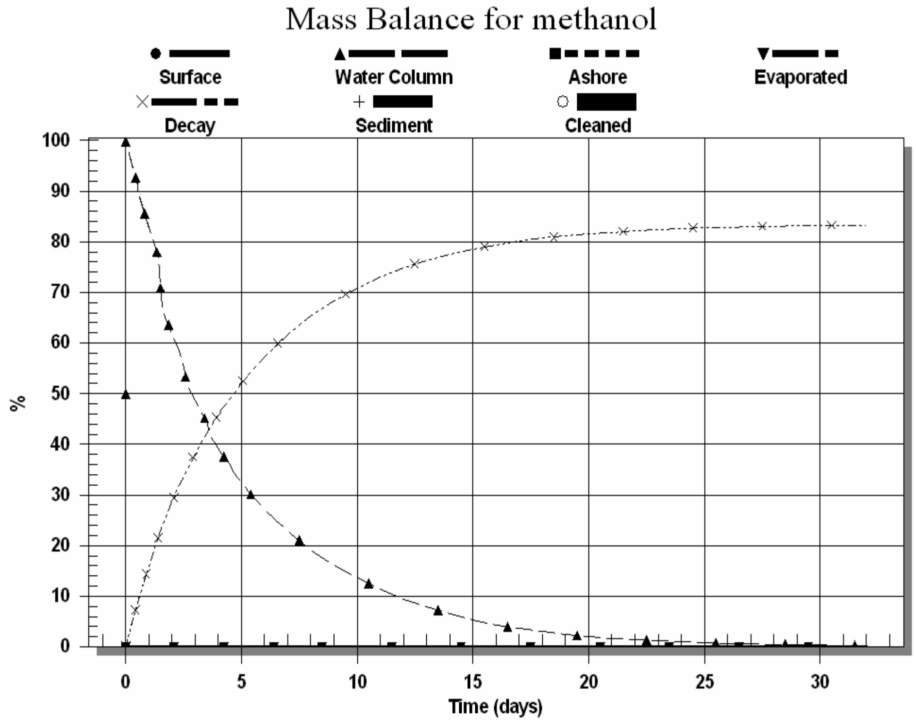
- Contains ASA's own GIS or can be used in other GIS software such as ArcView.
- Location specific environmental/ biological data applied to any fresh or salt aquatic environment in the world.
-
- Can utilize a variety of hydrodynamic file formats.
- Easily interpreted visual displays of concentrations over time.
- 3D Viewer capabilities.
- Biological exposure model to predict exposed fish and wildlife impacts.
- MSDS database linked to the physical-chemical database.
- Extensive chemical database providing physical-chemical data.

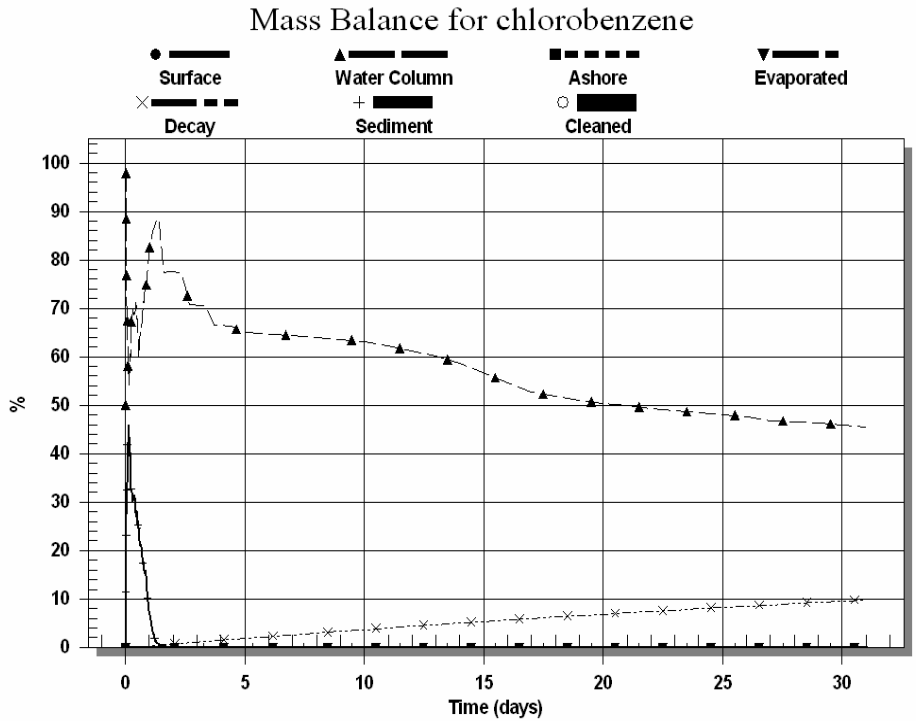
Chemical Fates Model

- Initial plume dynamics.
- Slick spreading, transport, and entrainment of floating materials.
- Evaporation and volatilization (to atmosphere).
- Transport and dispersion of dissolved and particulate materials in the water column and in the atmosphere.
- Dissolution and adsorption to suspended sediments.
- Sedimentation and resuspension.
- Natural degradation.
- Shoreline entrainment.
- Boom effectiveness.

Comparison of chemicals used in the chemical spill scenarios

	Methanol	Benzene	Ammonia	Chloro-benzene	TCE	Napthalene (gas)
Floatation	Floater	Floater	Floater	Sinker	Sinker	Sinker/ Air dispersed
Solubility	High	High	High	Normal	High	Semi
Volatility	High	High	High	Semi	Semi	None
Absorption	Dissolves	Moderate	Slight	Moderate	Moderate	Moderate
Flammability	High	High		High		High
Water/Air rapid interaction	No	No		No		No



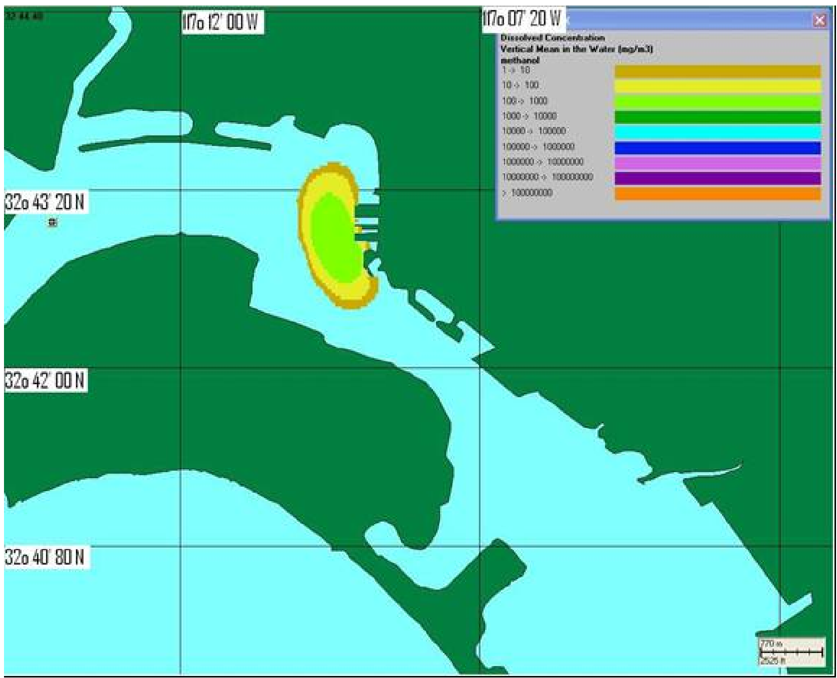


CHEMICAL Spill SCENARIOS

Released in North and South San Diego Bay)

- *Methanol (1 barrel released in depth 1m).*
- *Benzene (10 tons in depth 1m).*
- *Ammonia (200 tons in depth 3m).*
- *Chlorobenzene (200 tons in depth 3m).*
- *Trichloroethylene (200 tons in depth 3m).*
- *Naphthalene (200 tons in depth 3m).*

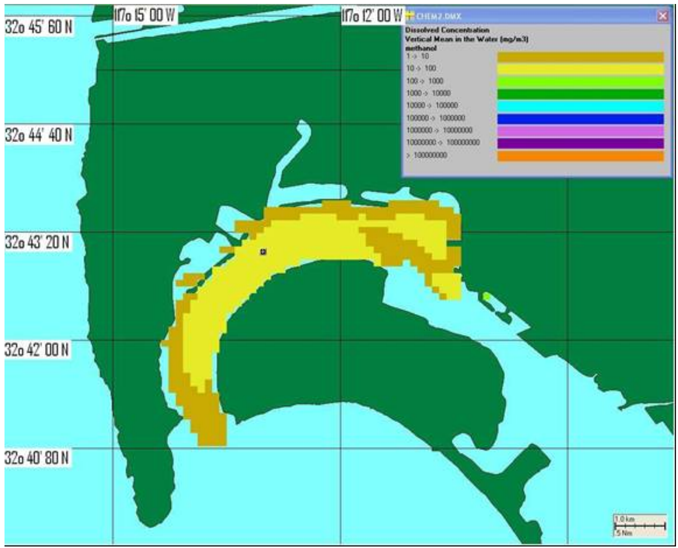
Pollutants Released at North San Diego Bay

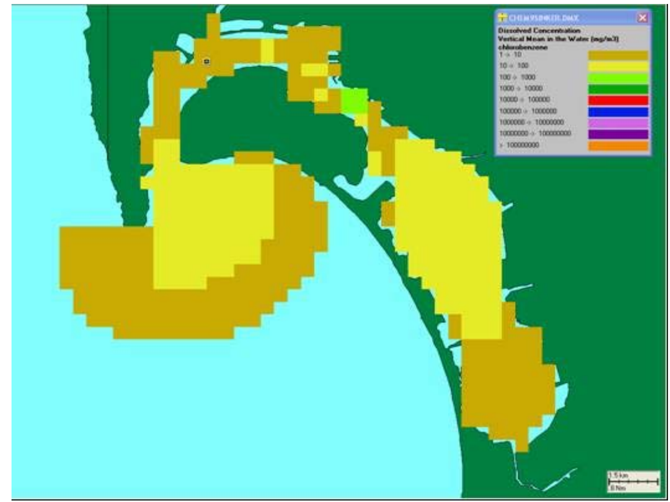


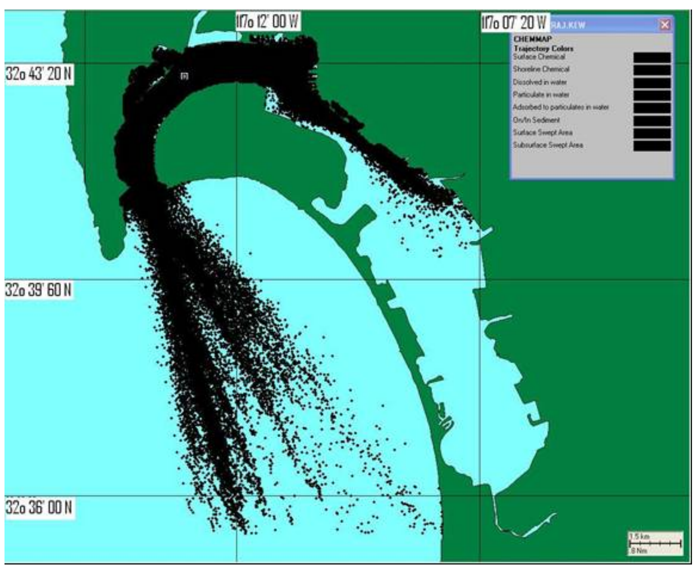
- After 3 hours

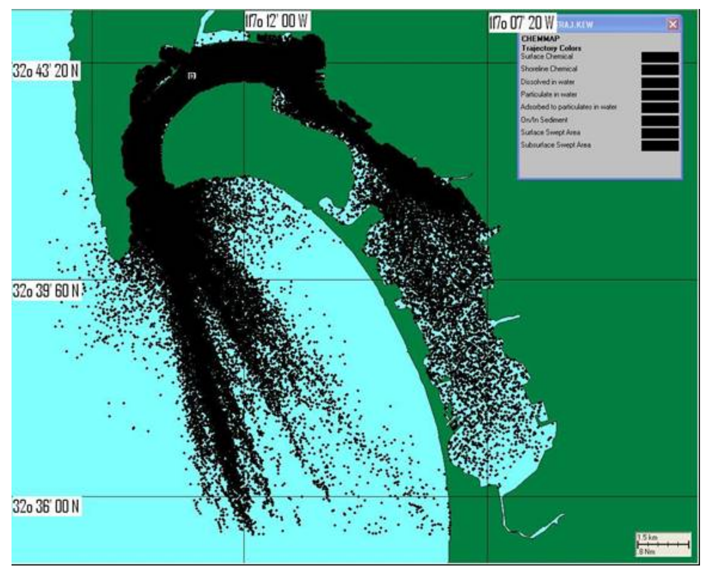
2 days

32 days

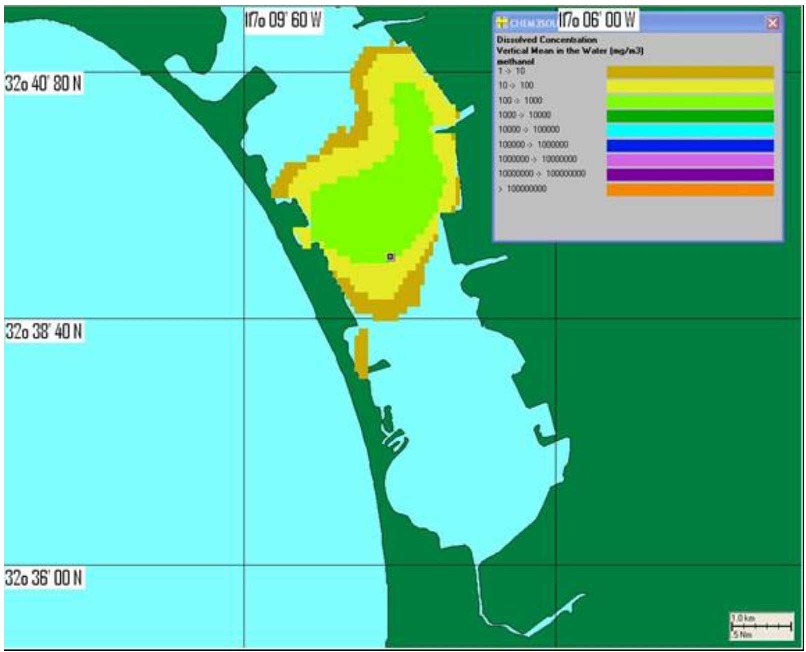






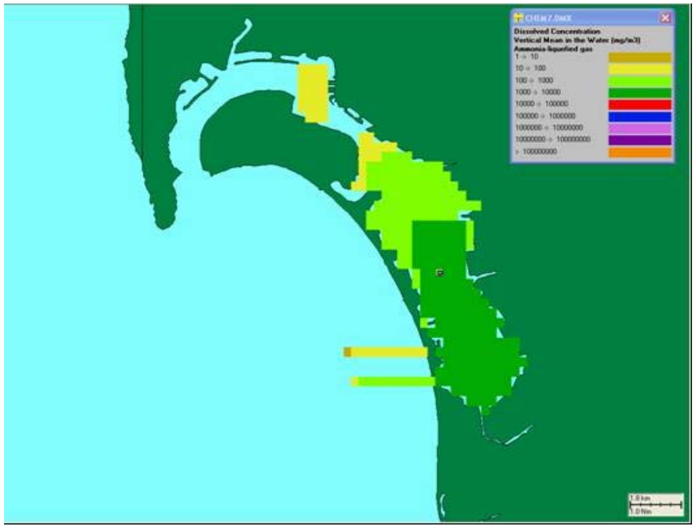


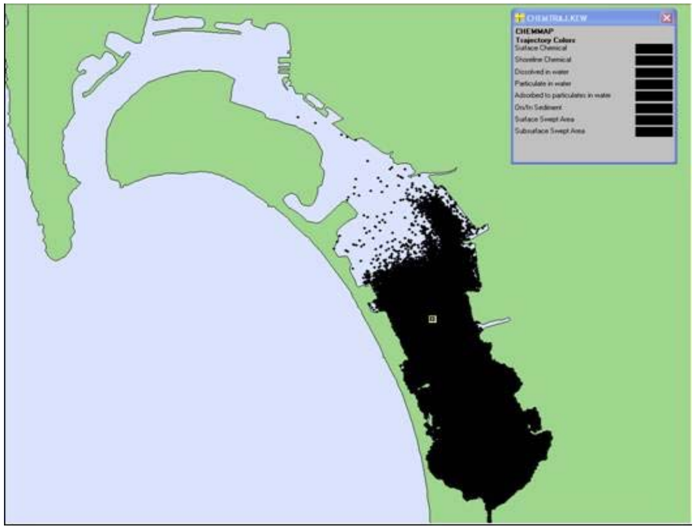
Pollutants Released at South San Diego Bay



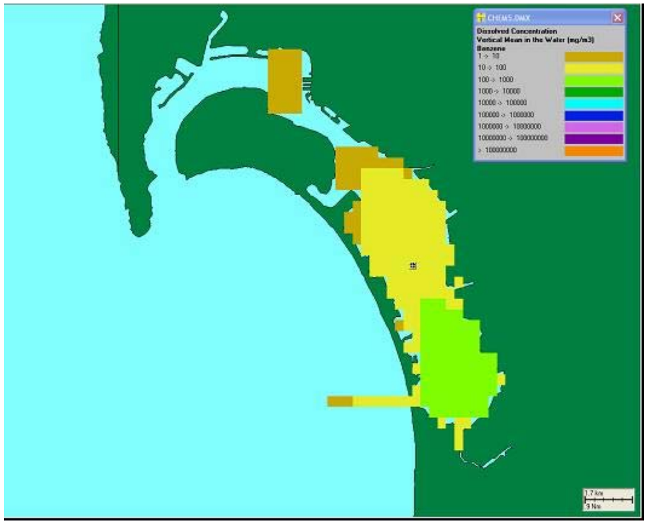
- After 12 hours

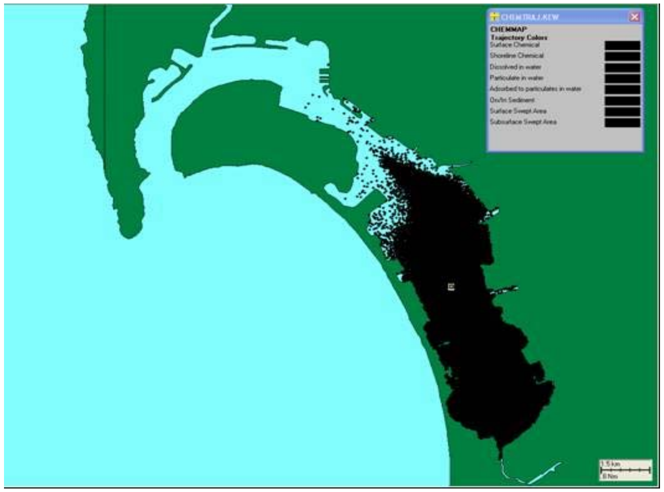
15 days





32 days





Conclusions

- Two Types of Chemical Dispersion in San Diego Bay
- Great danger/ vulnerability:
  - – In the North San Diego Bay, contamination of city/port, Bay – small reaction time.
  - – In the South San Diego Bay, contamination only of Southern part (including Naval Station).