Monitored Natural Attenuation in Aquatic Environments Physical Transport Considerations

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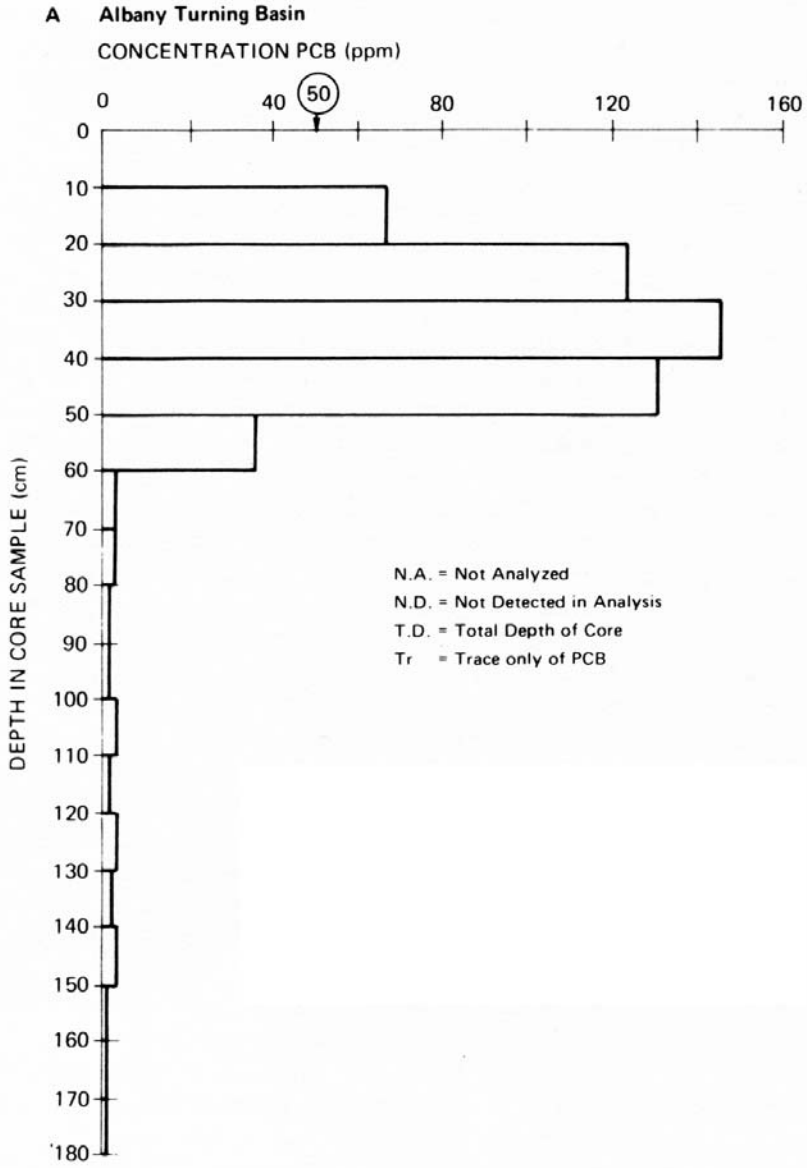
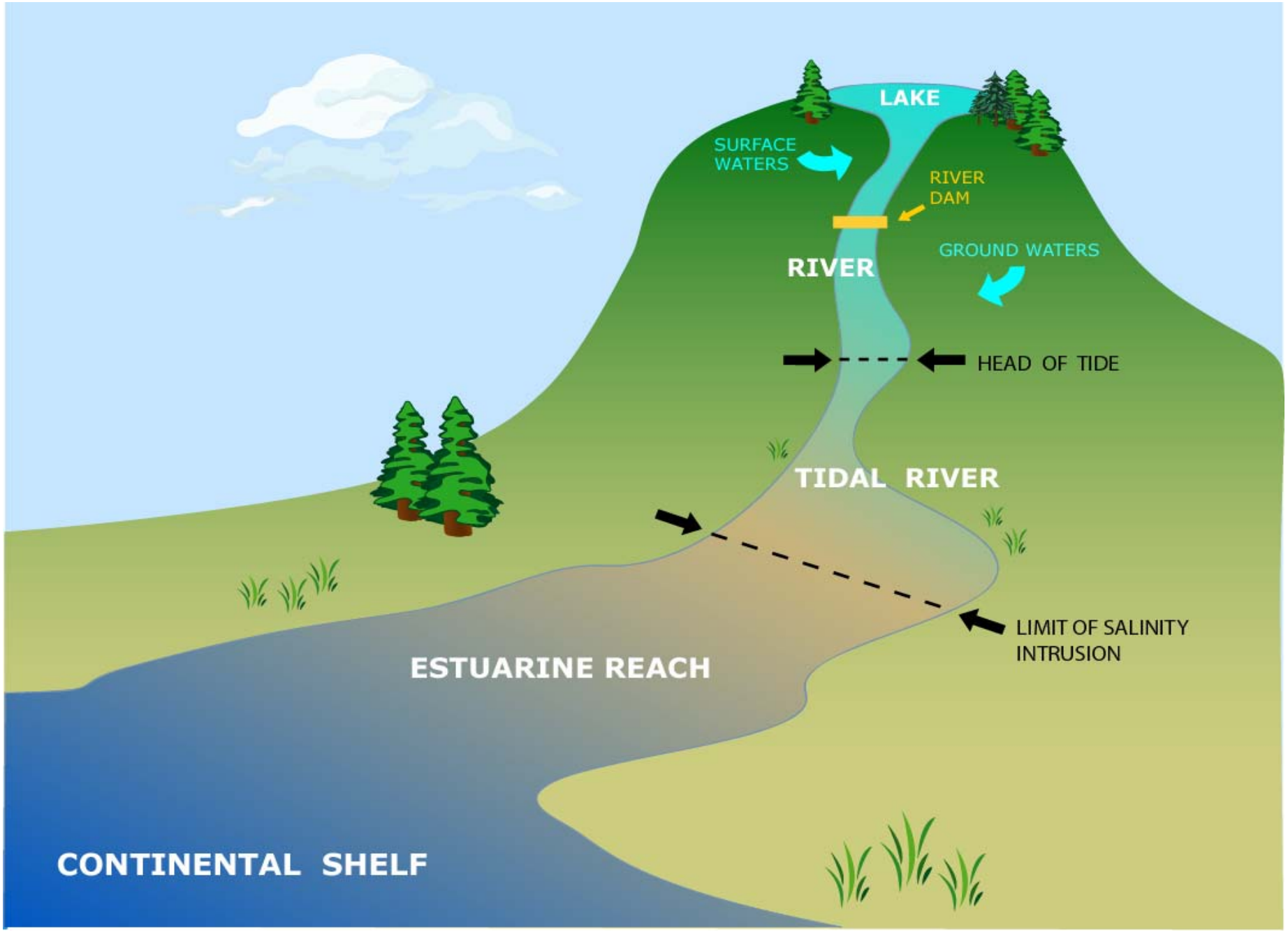
Department of Marine Sciences
Groton, Connecticut



SOURCE: Sanders (1979).


LAKE
SURFACE WATERS
RIVER DAM
GROUND WATERS
RIVER
HEAD OF TIDE
TIDAL RIVER
LIMIT OF SALINITY INTRUSION
ESTUARINE REACH
CONTINENTAL SHELF

Physical Setting : Transport Implications

Lake – Typically Depositional – Moderate to low Energy
Circulation- Wind Driven + Waves
Variable thermal stratification – Ice possible
Time Scales of Variability: Days to months

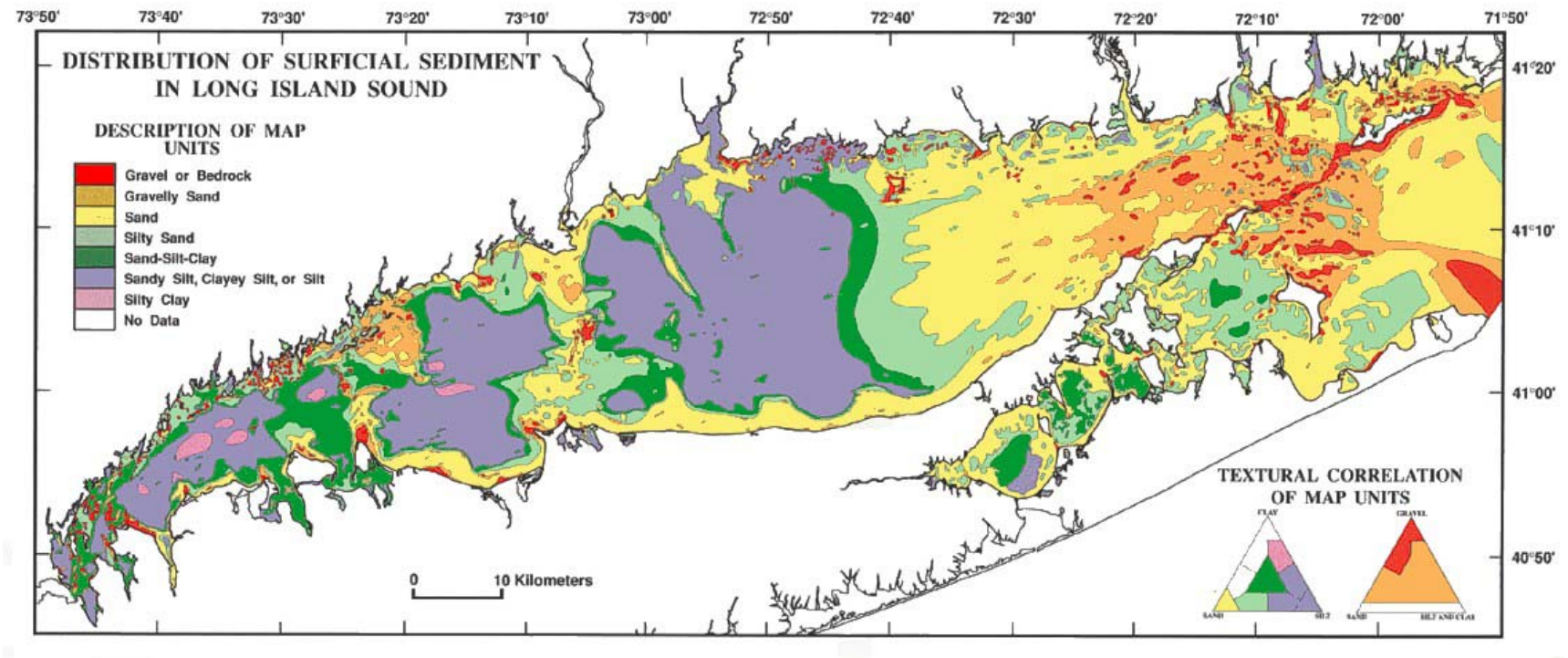
River – Variably Erosional/Depositional – Moderate to High Energy
Circulation – Gravitational – Unidirectional – Limited Wave Activity
Typically limited thermal stratification- Ice possible
Time Scales of Variability: Days to months

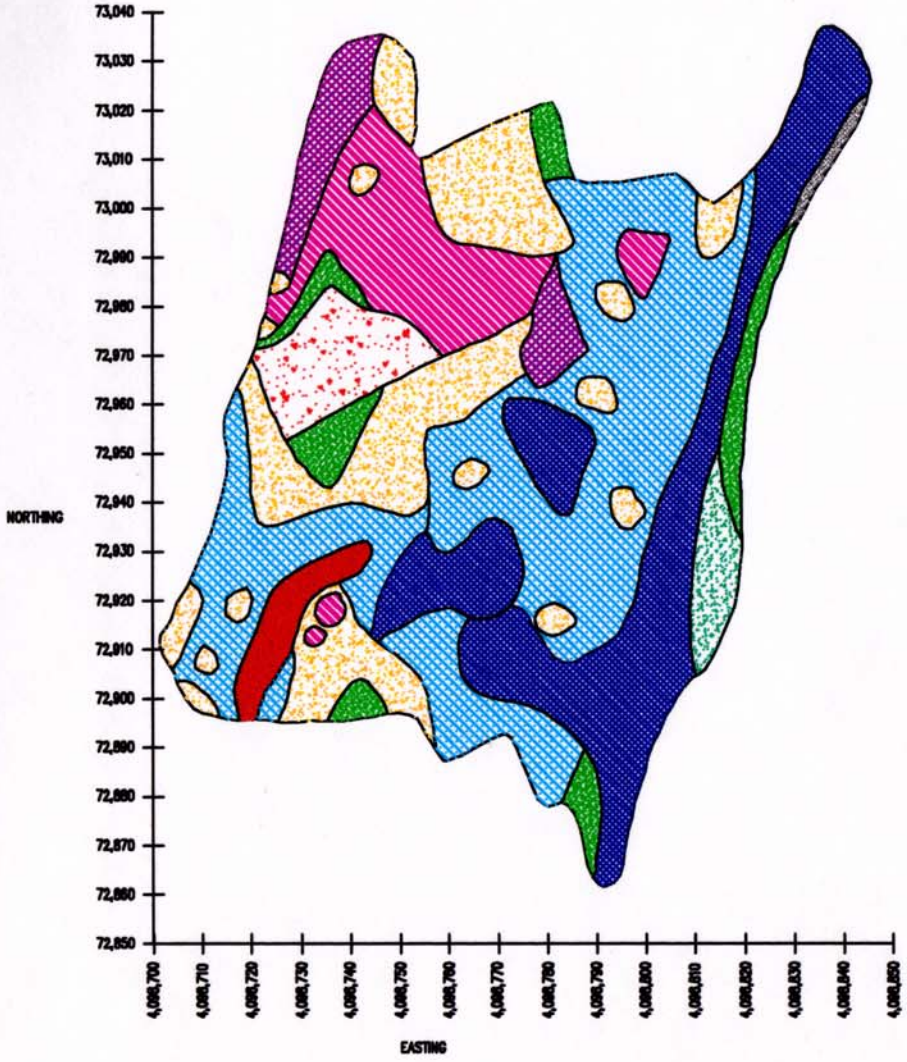
Tidal River – Variably Erosional/Depositional - Moderate to High Energy
Circulation – Gravitational – Oscillatory – Limited Wave Activity
Typically limited thermal stratification – Ice possible
Time Scales of Variability: hours to months

Physical Setting : Transport Implications cont.

Estuary - Variably Erosional/Depositional – Low to High Energy
Circulation – Tidal + Density Driven + Winds/Wind Waves
Oscillatory – T/S Density Stratification Significant
Limited Ice
Time Scales of Variability : hours to months

Continental Shelf – Variably Erosional/Depositional – Low to High Energy
Circulation – Tidal + Density Driven + Winds/Wind Waves
Oscillatory – T/S Density Stratification Significant
Limited to no ice
Time Scales of Variability : hours to months


DISTRIBUTION OF SURFICIAL SEDIMENT
IN LONG ISLAND SOUND
DESCRIPTION OF MAP UNITS
Gravel or Bedrock
Gravelly Sand
Sand
Silty Sand
Sand-Silt-Clay
Sandy Silt, Clayey Silt, or Silt
Silty Clay
No Data
0
10 Kilometers
TEXTURAL CORRELATION OF MAP UNITS
73°50'
73°40'
73°30'
73°20'
73°10'
73°00'
72°50'
72°40'
72°30'
72°20'
72°10'
72°00'
71°50'
41°20'
41°10'
41°00'
40°50'



LEGEND

NORMAL SEDIMENT	BASIC SOIL DESCRIPTION	POTENTIAL POLLUTED SEDIMENT
	FOAM/FLUFF	
	CLAY/SILTY CLAY	
	CLAY ON SILT/SILTY SAND	
	SILT	
	SILTY SAND TO SANDY SILT	
	SAND	
	HARD/COMPACT	
	SILTY SAND ON SILTY SAND	
	SURFACE ROCK	
	SAND ON SILTY SAND	

0 10 20m

LATERAL DISTANCE SCALE

CAULFIELD ENGINEERING

TITLE: BLACK LAGOON SEDIMENTS

DRN BY:	SCALE:	DATE:
HV	1:1000	15/1/97
JOB NO: 2117	DWG NO:	CADD FILE: color-map

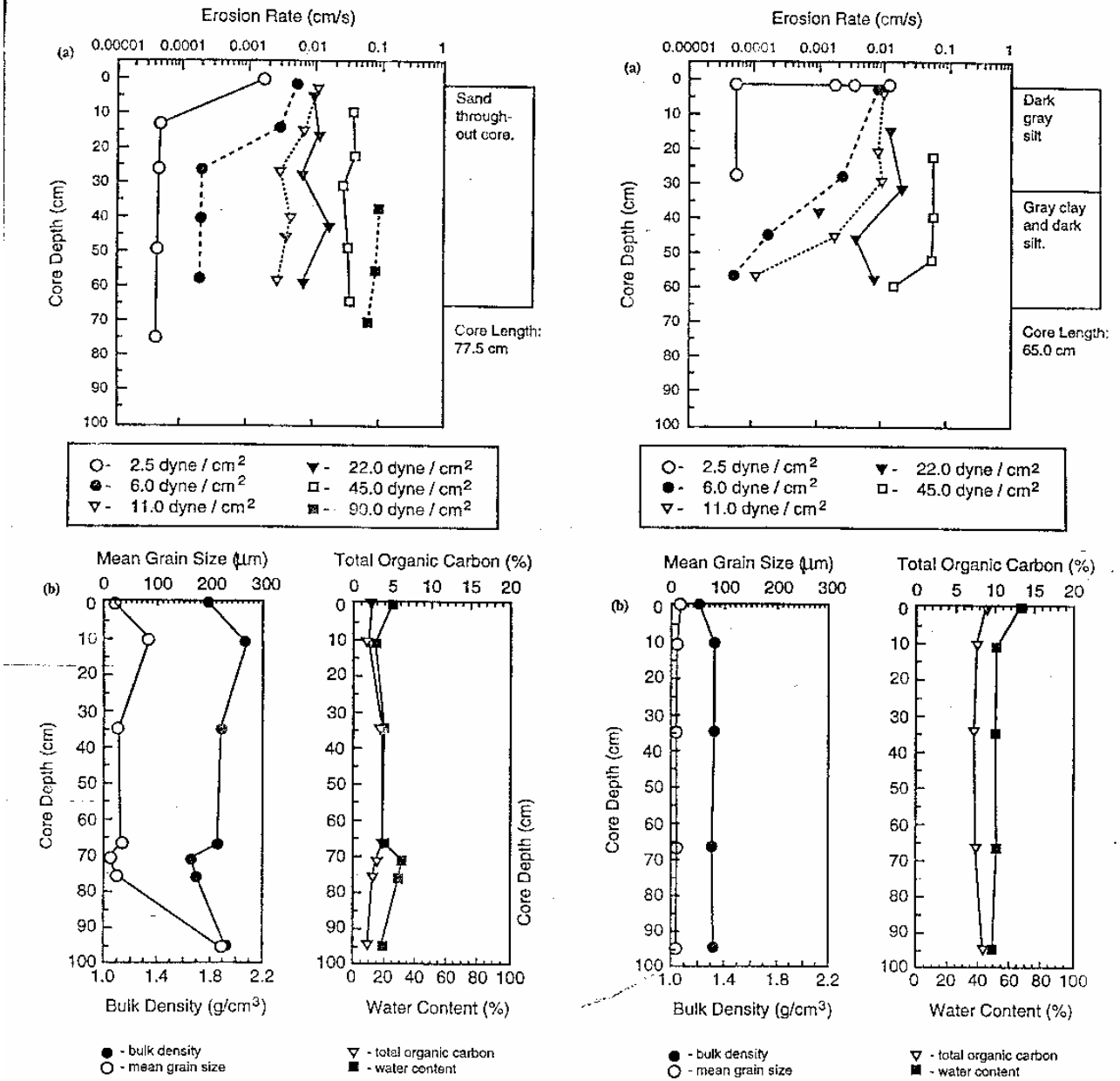
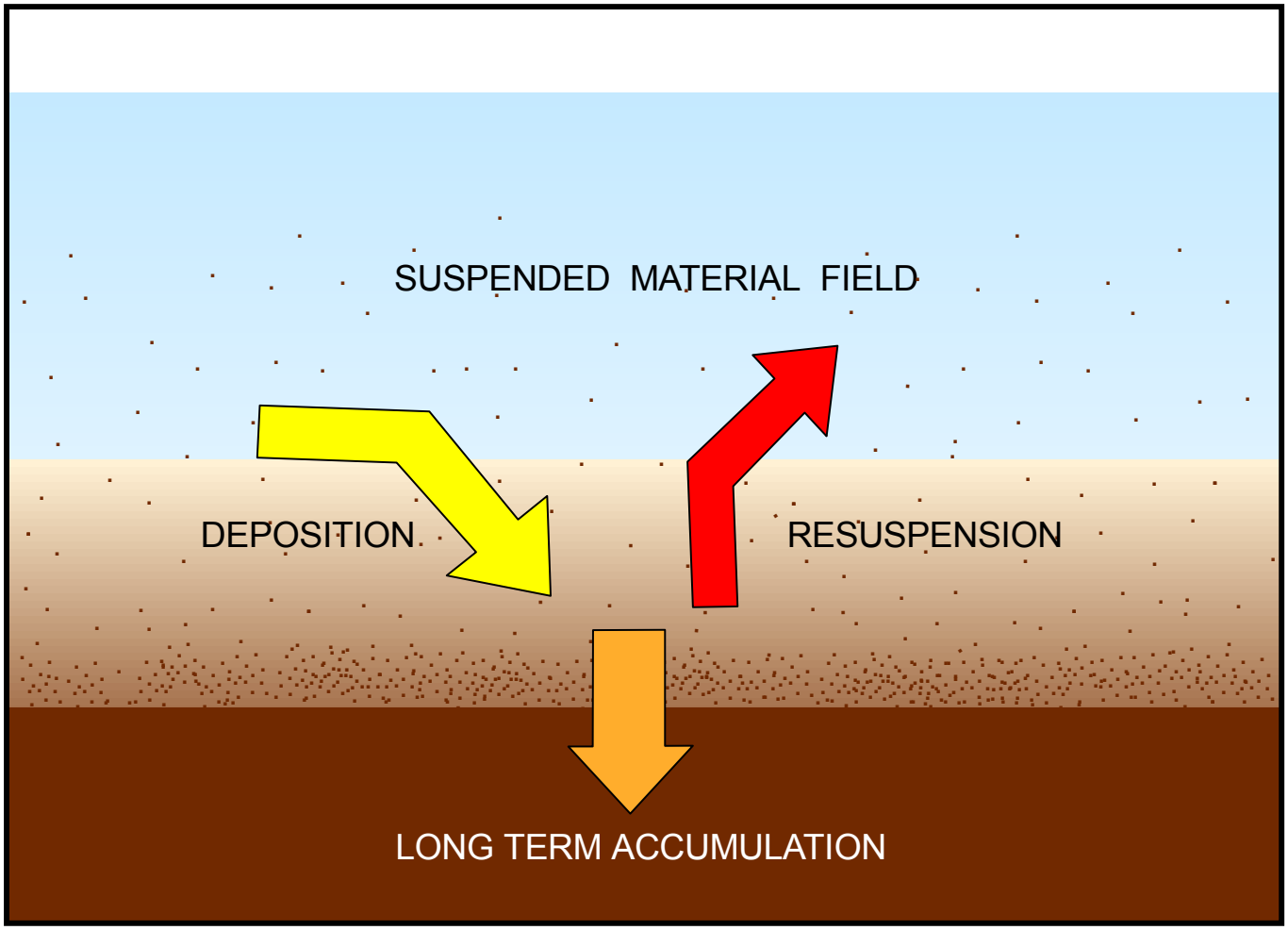
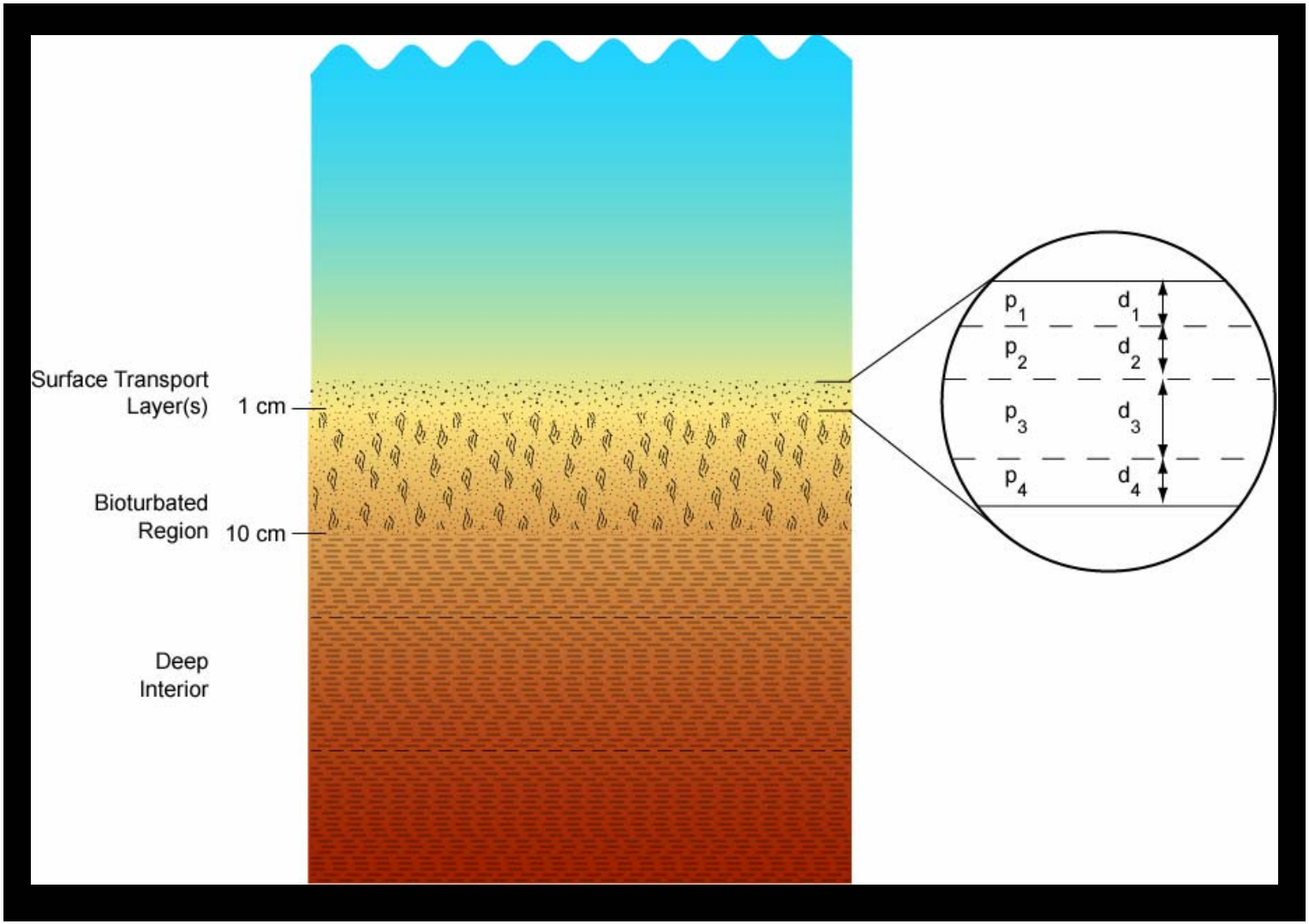


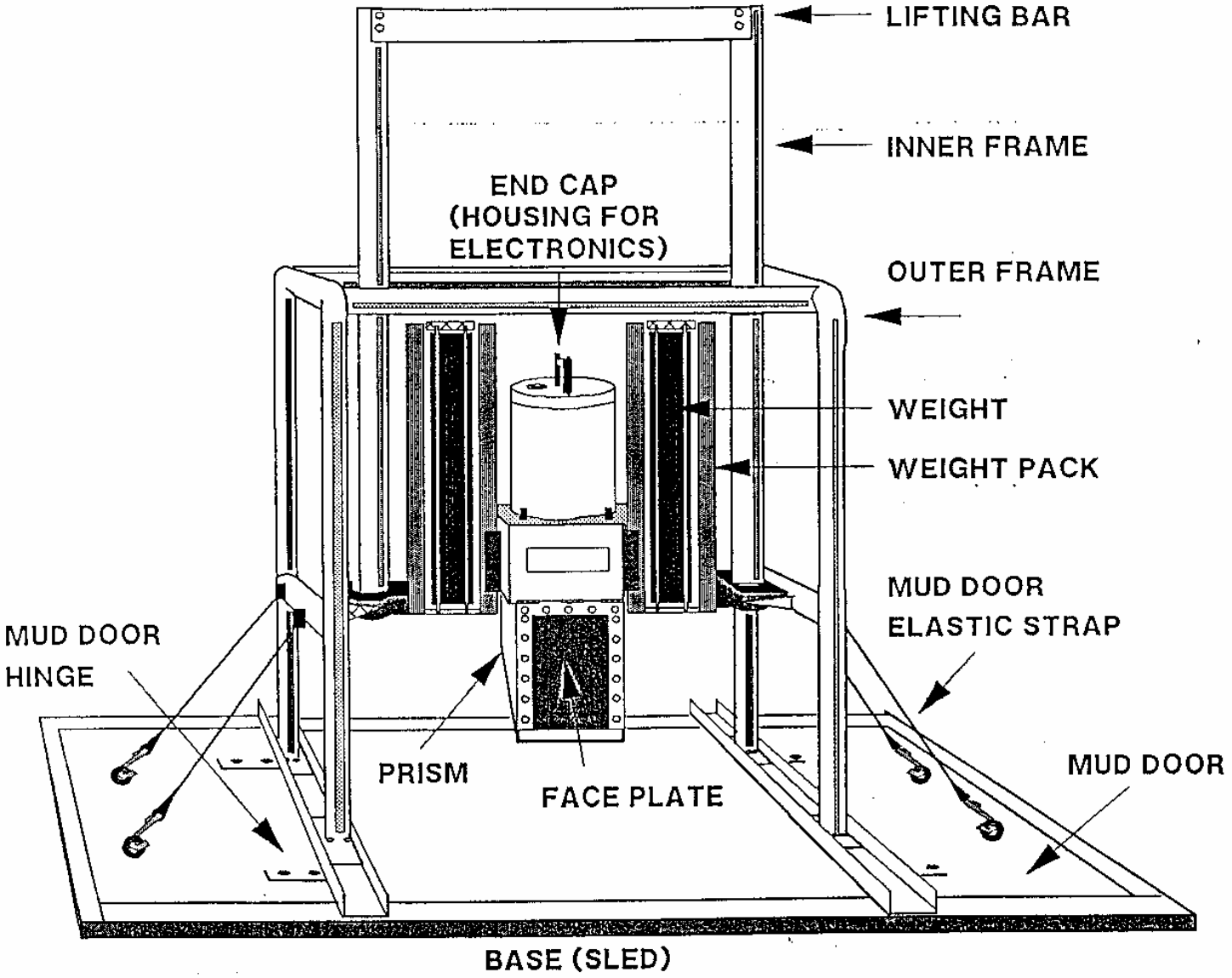
FIG. 4. Trenton Channel, Site 1, Water Depth of 2.3 m: (a) Erosion Rate as Function of Depth with Shear Stress as Parameter; (b) Bulk Properties as Function of Depth

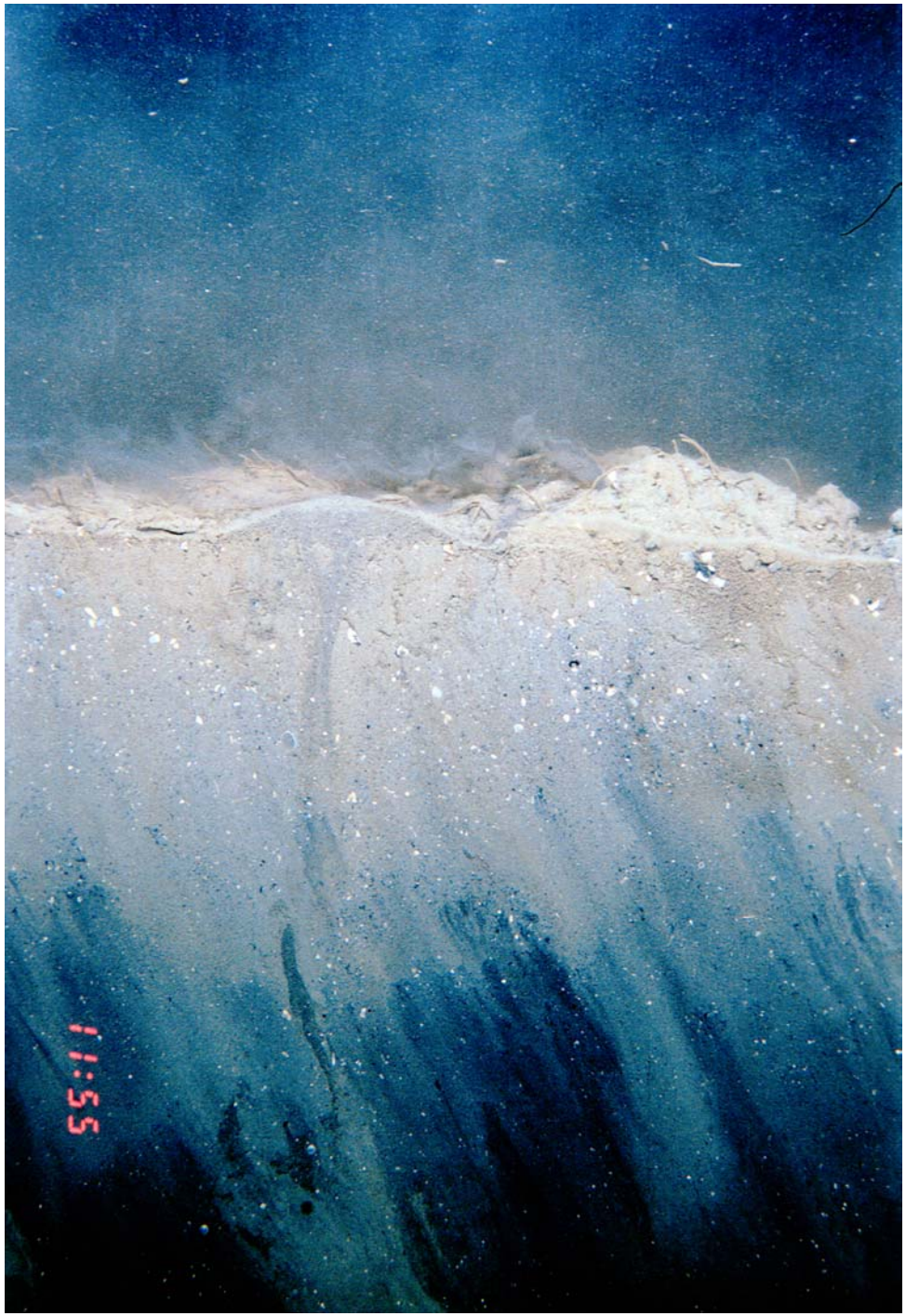
FIG. 5. Trenton Channel, Site 3, Water Depth of 5.9 m: (a) Erosion Rate as Function of Depth with Shear Stress as Parameter; (b) Bulk Properties as Function of Depth

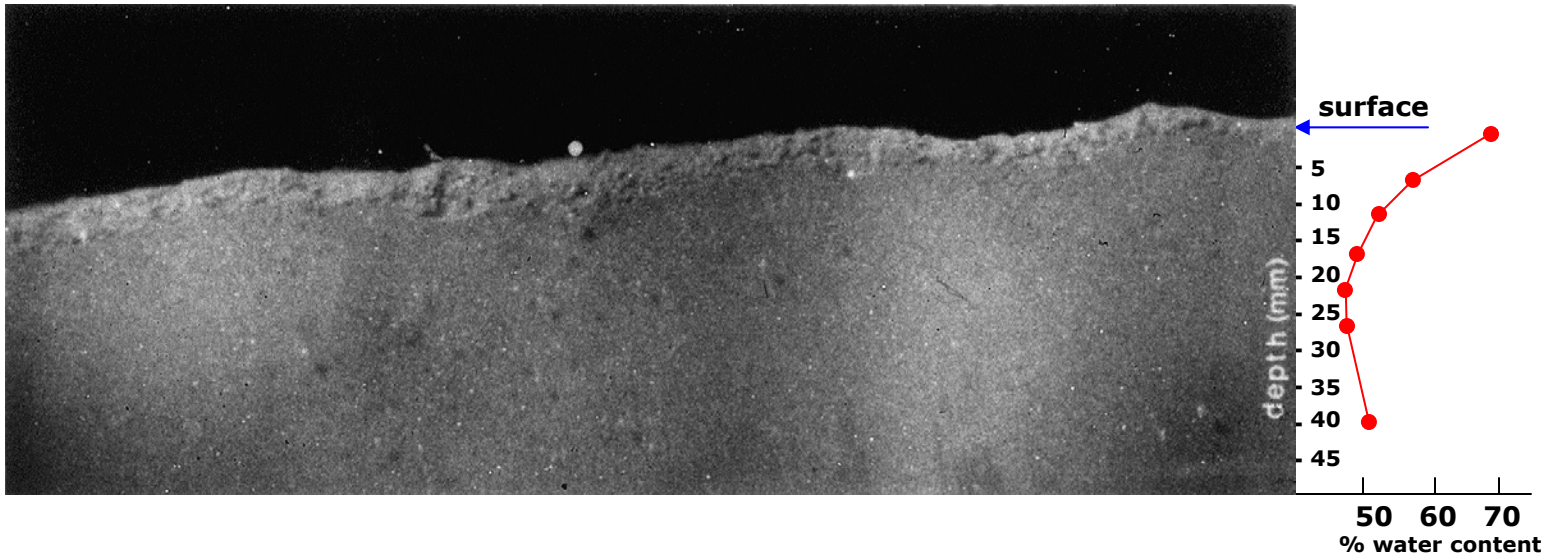
From: McNeil, Taylor and Lick , 1996

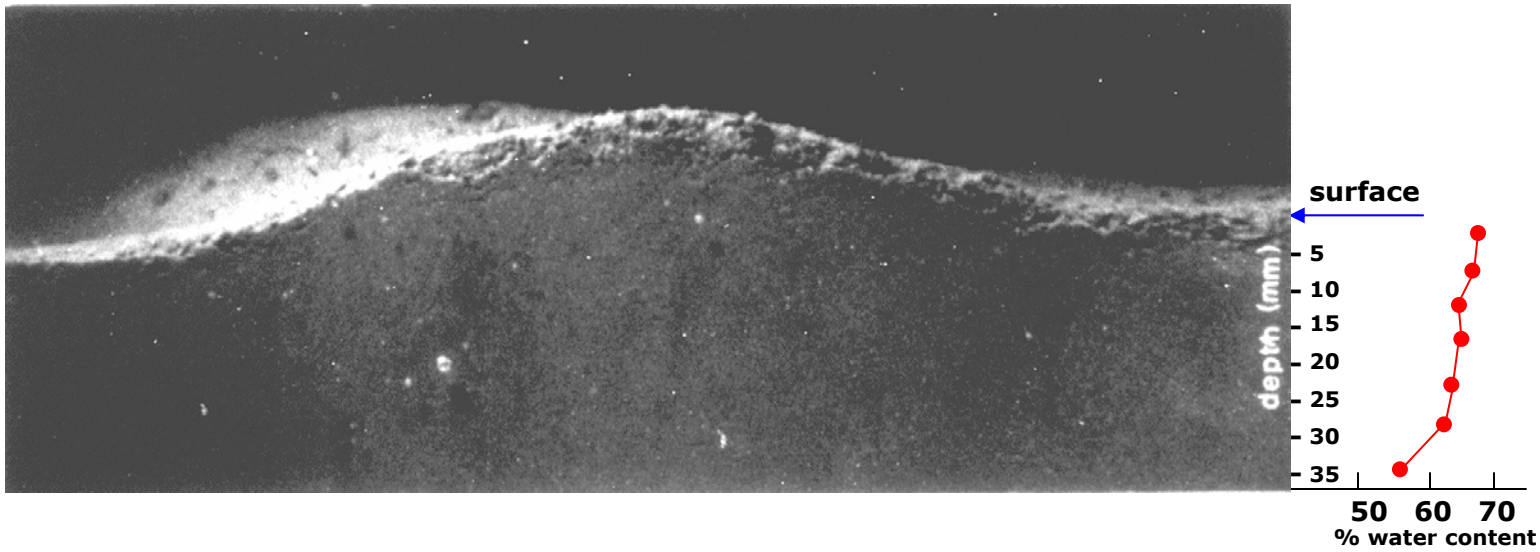

SUSPENDED MATERIAL FIELD
DEPOSITION
RESUSPENSION
LONG TERM ACCUMULATION

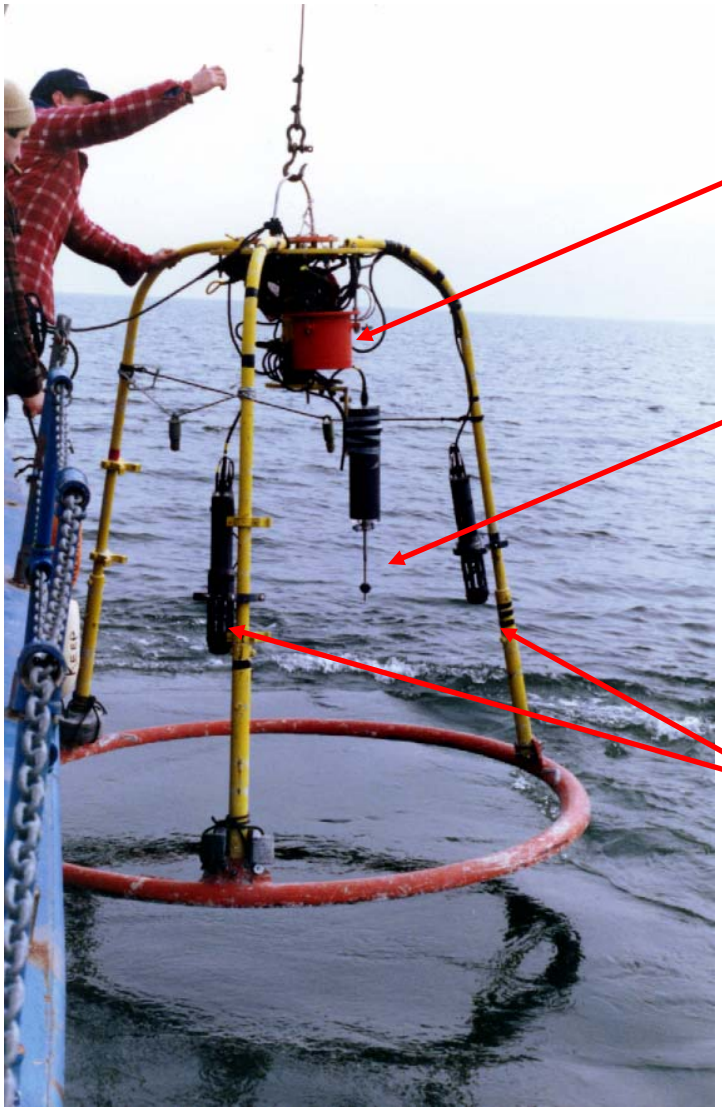

Surface Transport Layer(s)
1 cm
Bioturbated Region
10 cm
Deep Interior
p1
d1
p2
d2
p3
d3
p4
d4

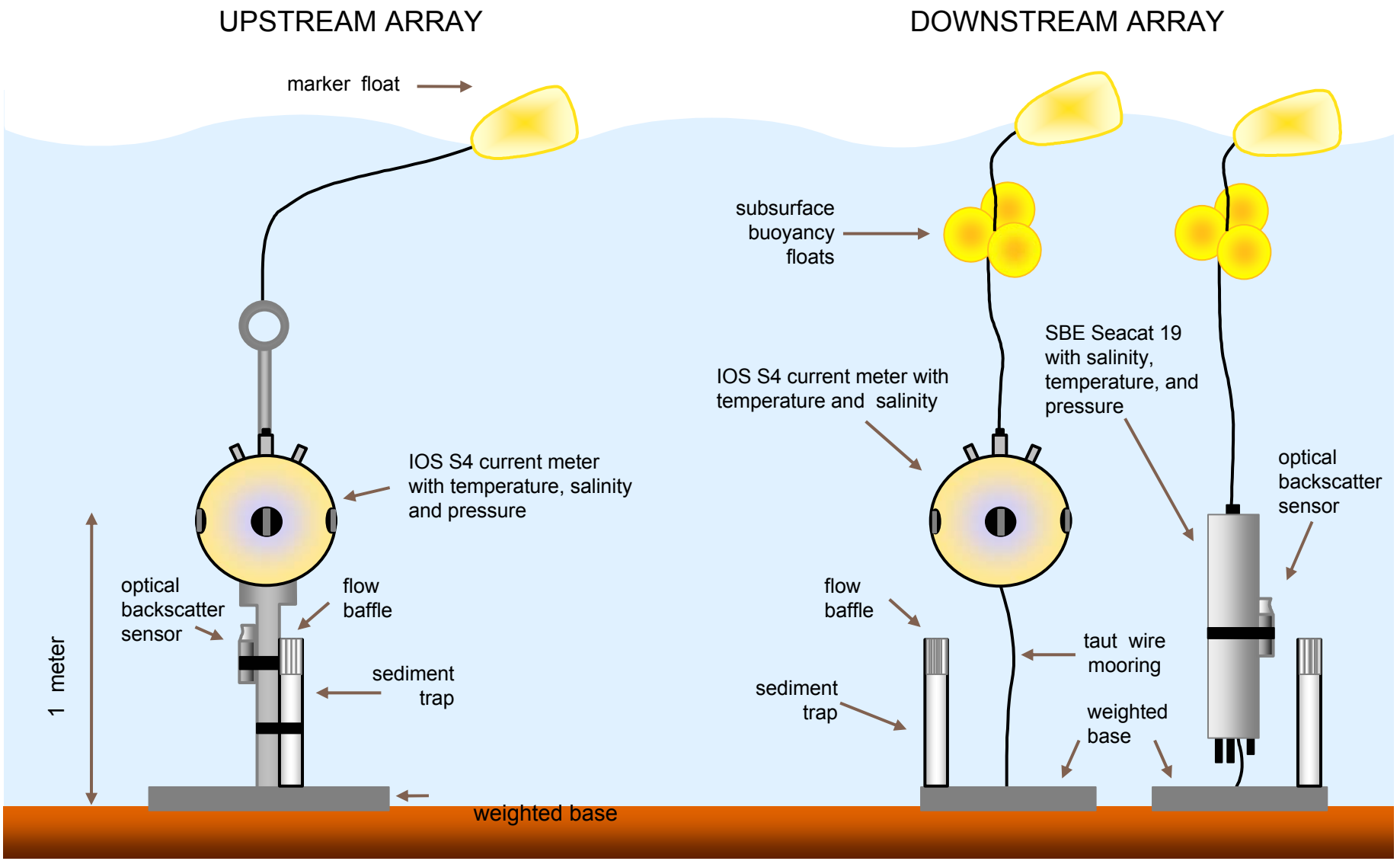

LIFTING BAR
INNER FRAME
END CAP
(HOUSING FOR
ELECTRONICS)
OUTER FRAME
WEIGHT
WEIGHT PACK
MUD DOOR
ELASTIC STRAP
MUD DOOR
HINGE
PRISM
FACE PLATE
MUD DOOR
BASE (SLED)

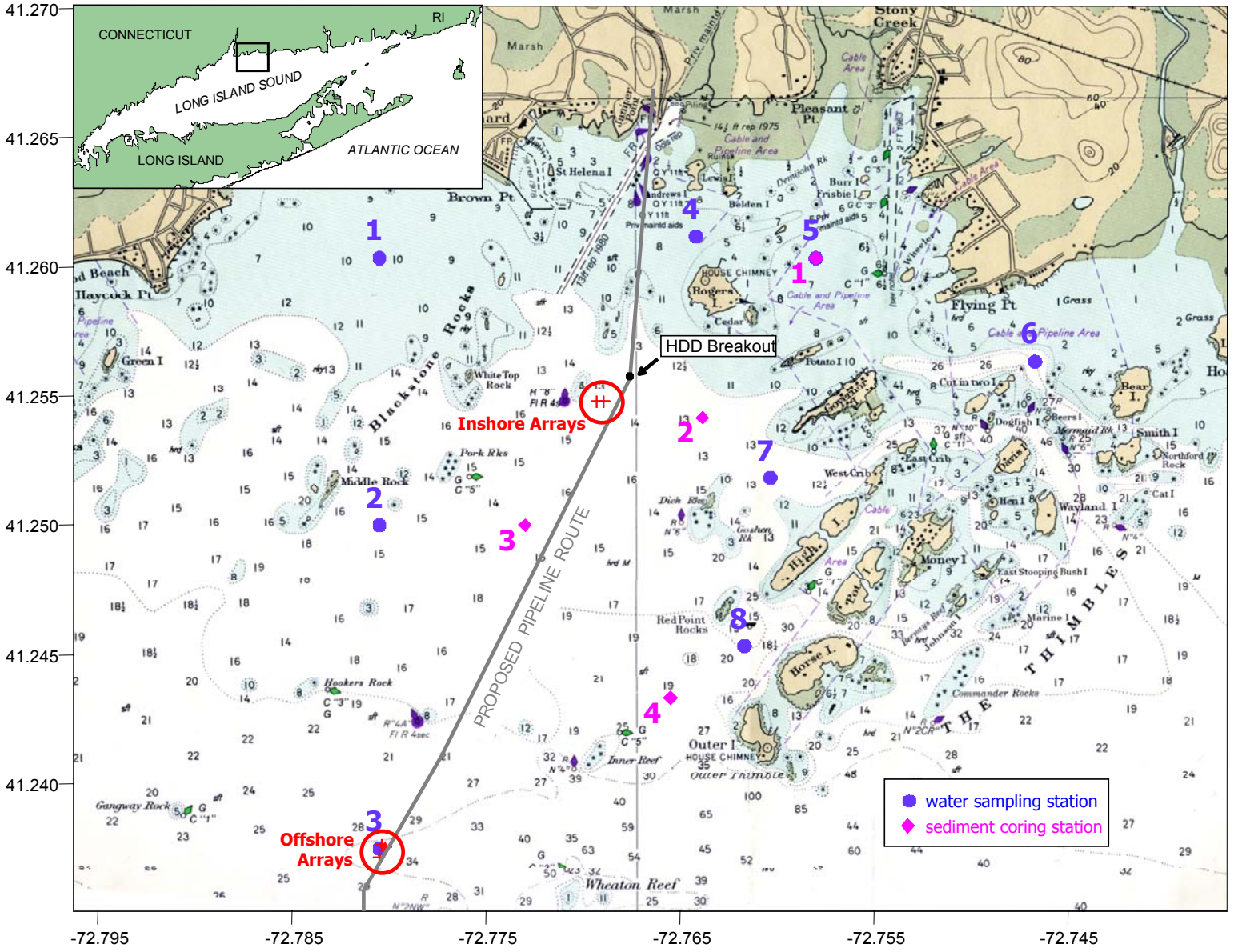

11:55


surface
depth (mm)
5
10
15
20
25
30
35
40
45
50
60
70
% water content


surface
depth (mm)
5
10
15
20
25
30
35
50
60
70
% water content


Datalogger
Marsh-McBirney
EM current meter
Red-light transmissometers


UPSTREAM ARRAY
DOWNSTREAM ARRAY
marker float
IOS S4 current meter with temperature, salinity and pressure
optical backscatter sensor
flow baffle
sediment trap
1 meter
weighted base
subsurface buoyancy floats
IOS S4 current meter with temperature and salinity
SBE Seacat 19 with salinity, temperature, and pressure
optical backscatter sensor
flow baffle
taut wire mooring
sediment trap
weighted base

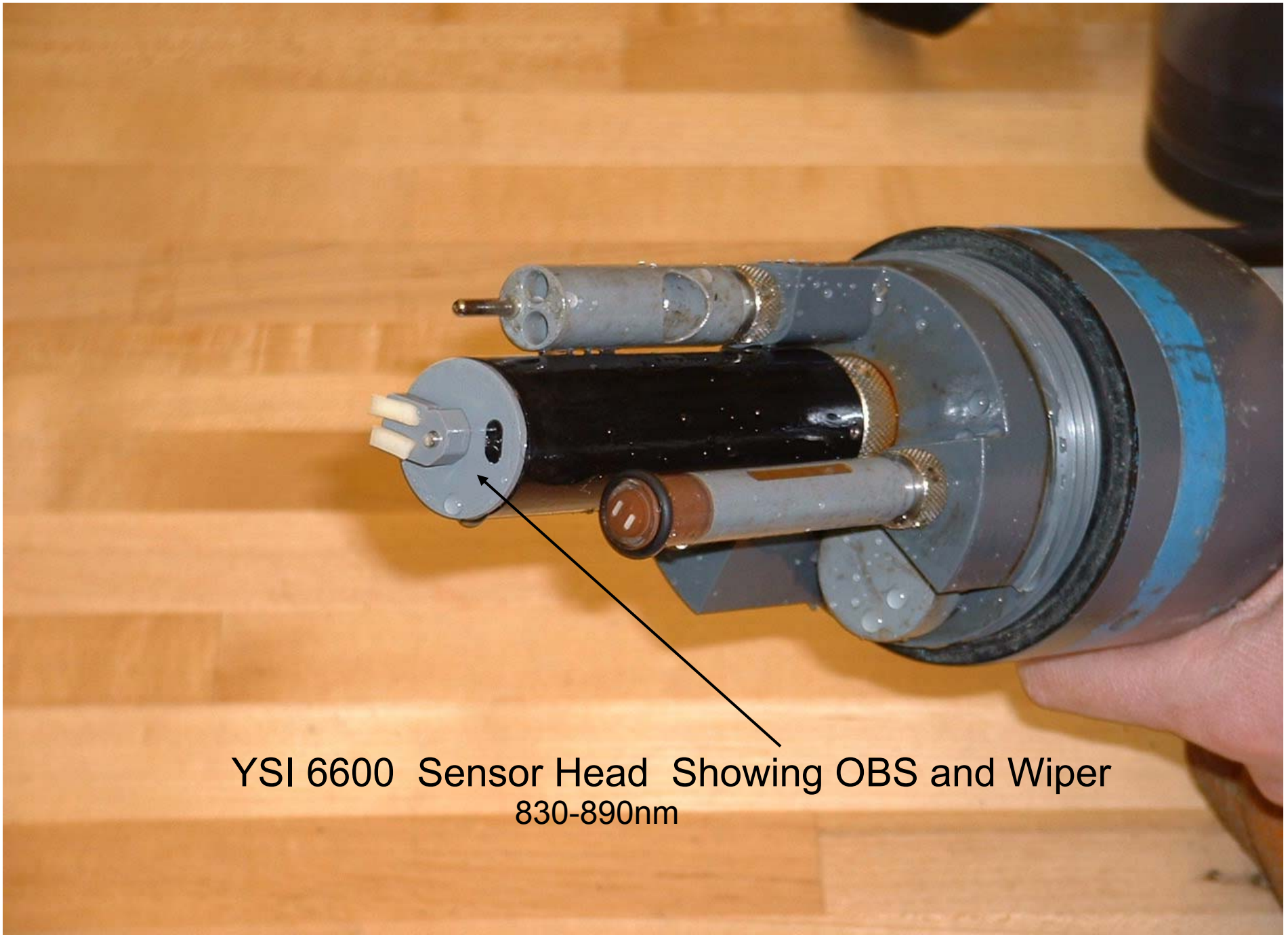


Connecticut Nearshore Study Area – Islander East Natural Gas Pipeline 2001-2002

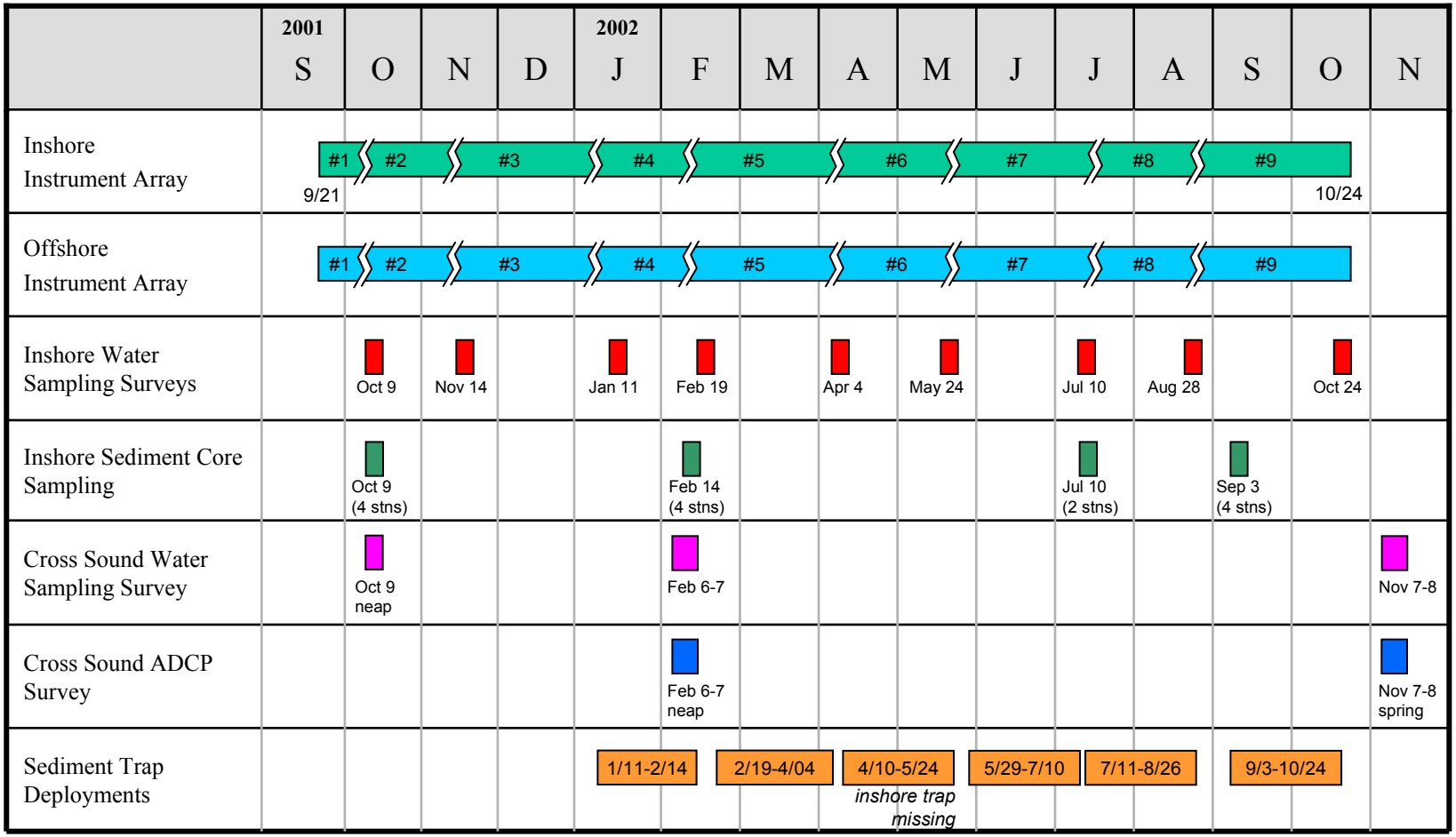
OFFSHORE BUOY

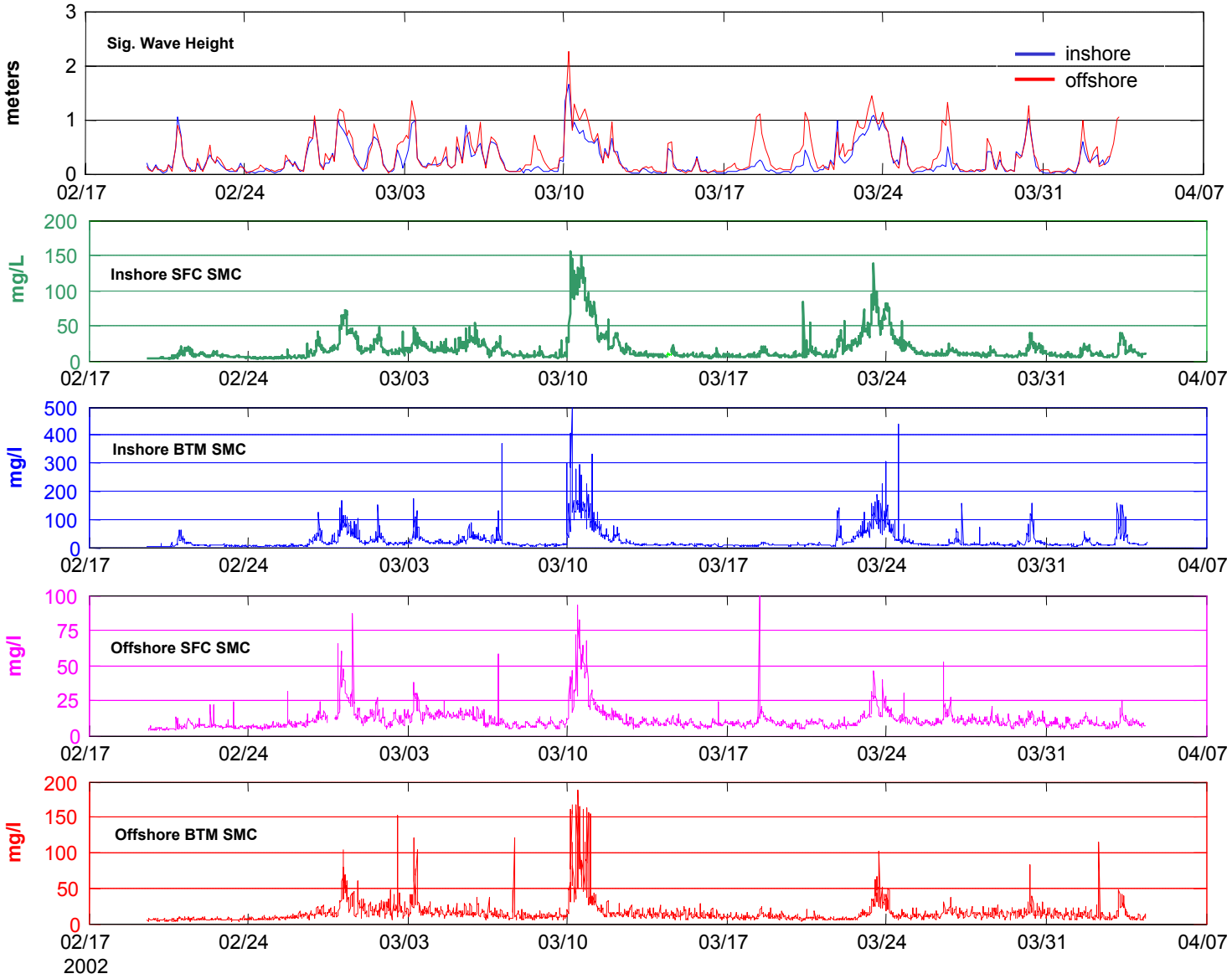
INSHORE BUOY

Branford, Connecticut Instrument Array Characteristics 2001-2002


YSI 6600 Sensor Head Showing OBS and Wiper
830-890nm

Islander East Data Collection Summary: Thimble Islands, Branford



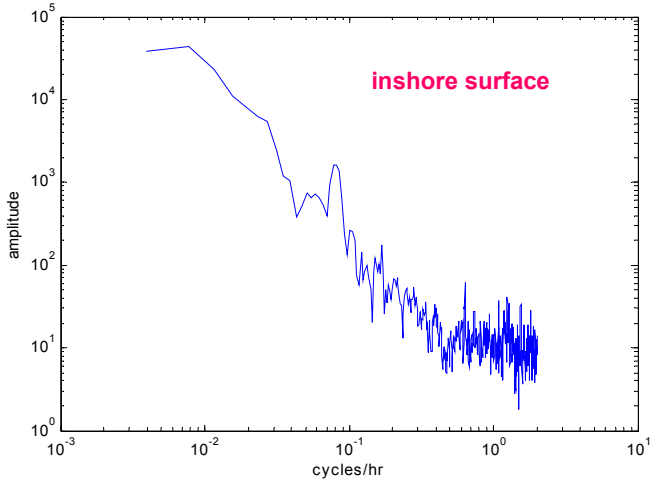


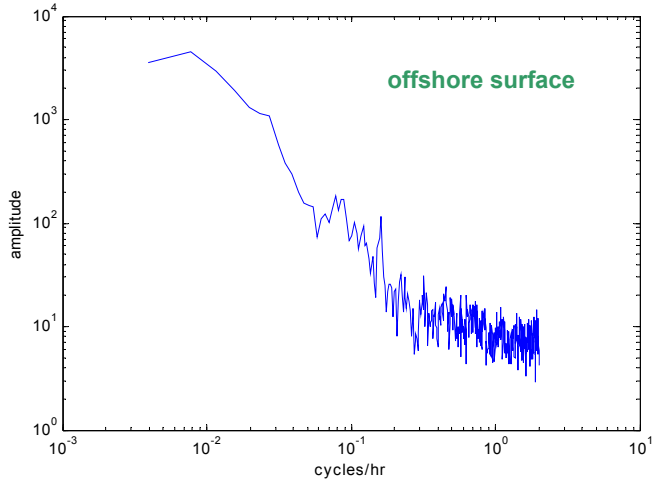
Branford, Connecticut Moored Array Data – February – April, 2002

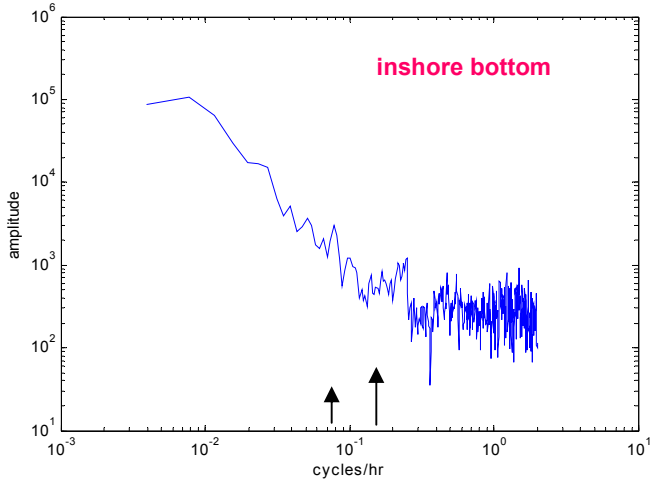
Branford, Connecticut - February – April,2002

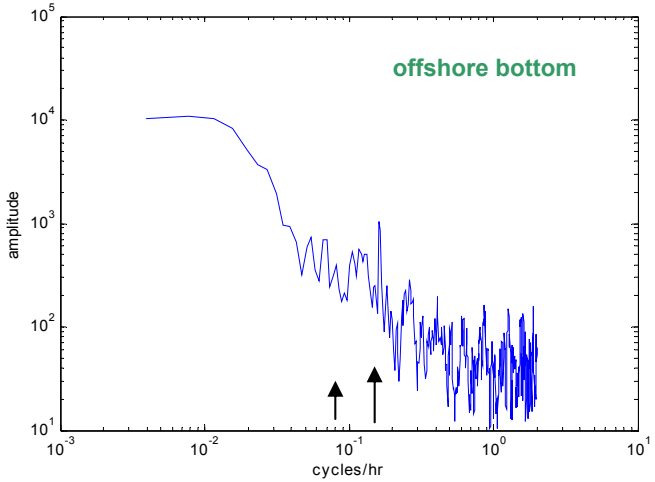
Moored Arrays

Power Spectra - Suspended Material Concentration



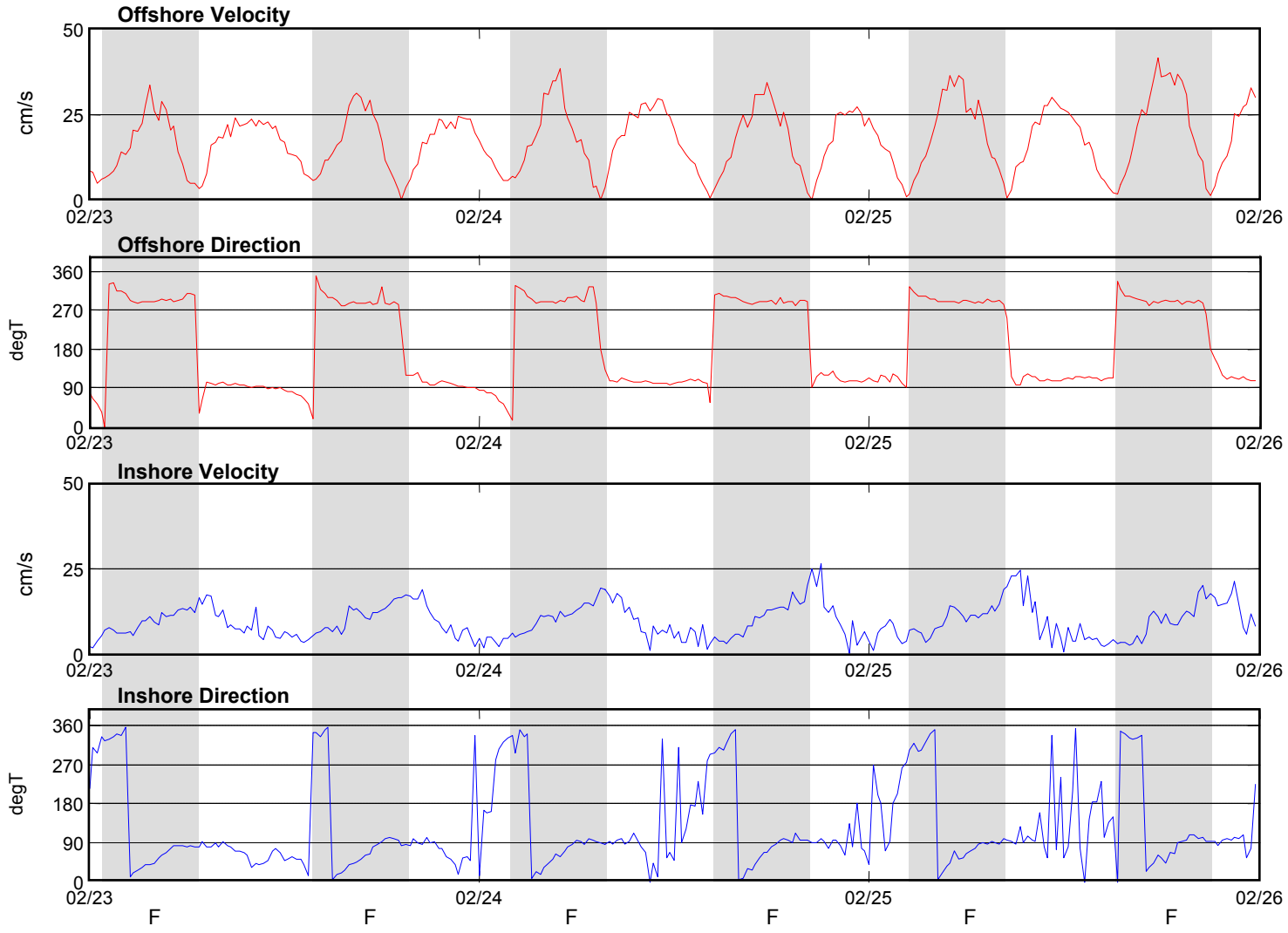


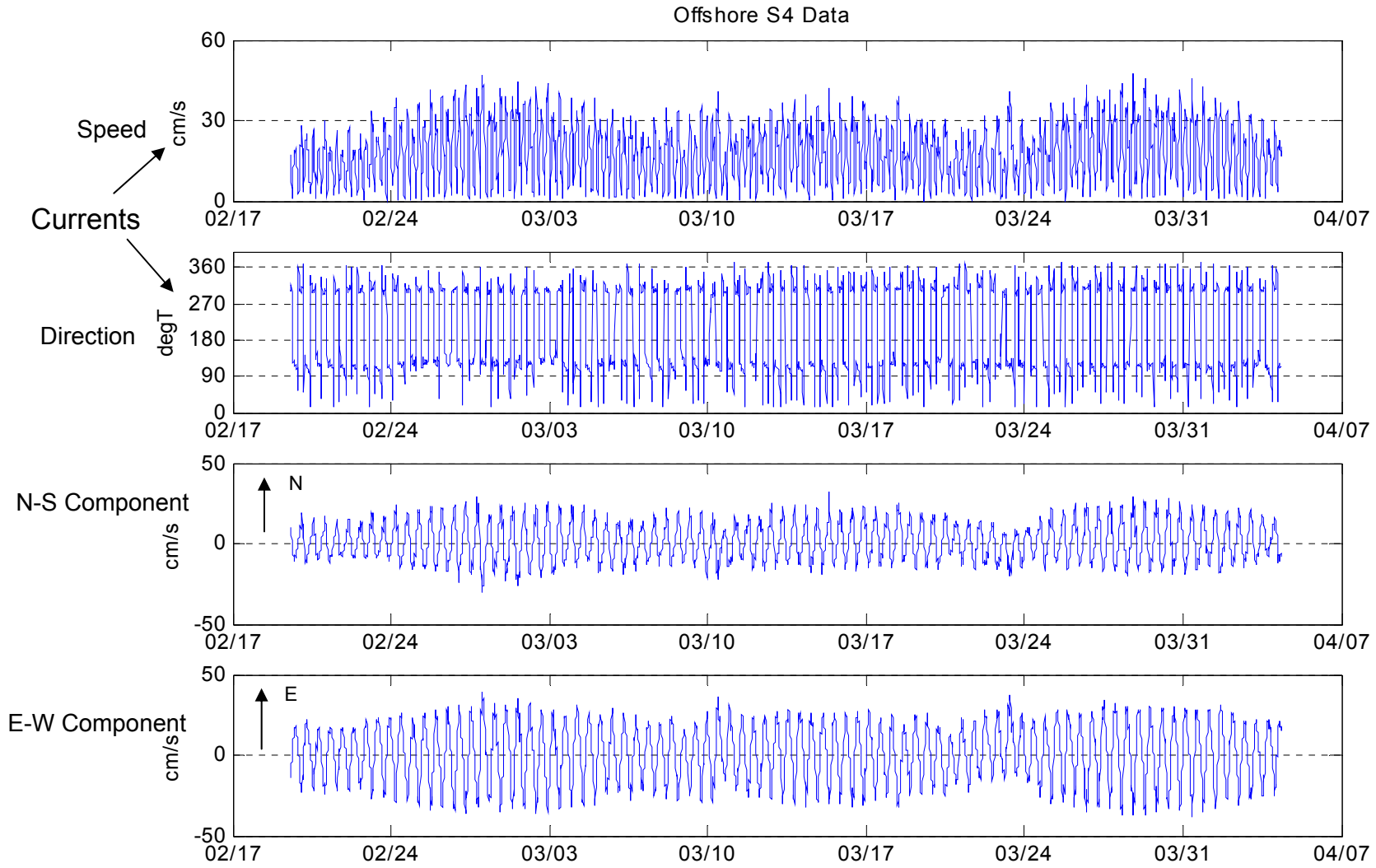




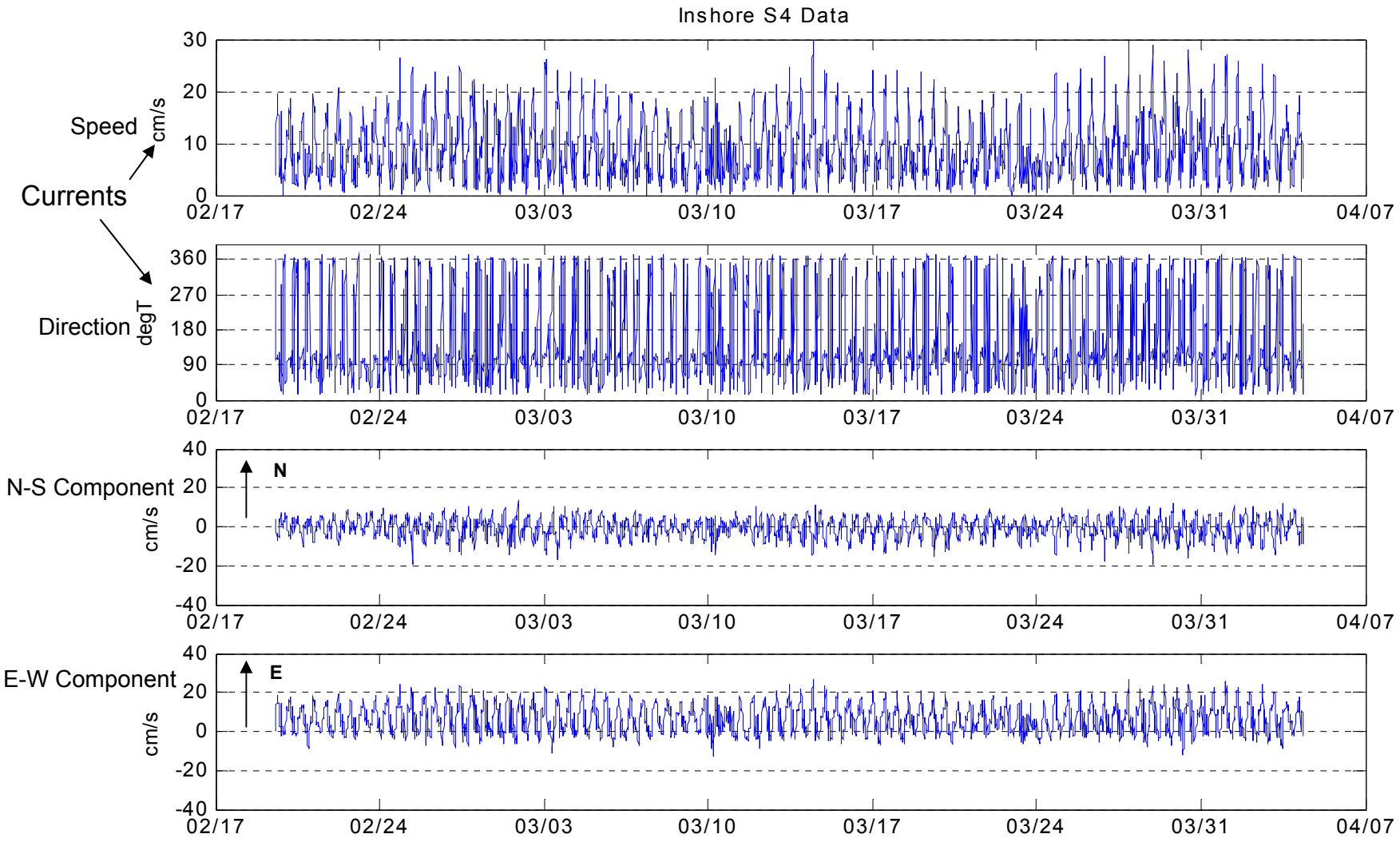
Branford, Connecticut – February,2002

AMBIENT CONDITIONS

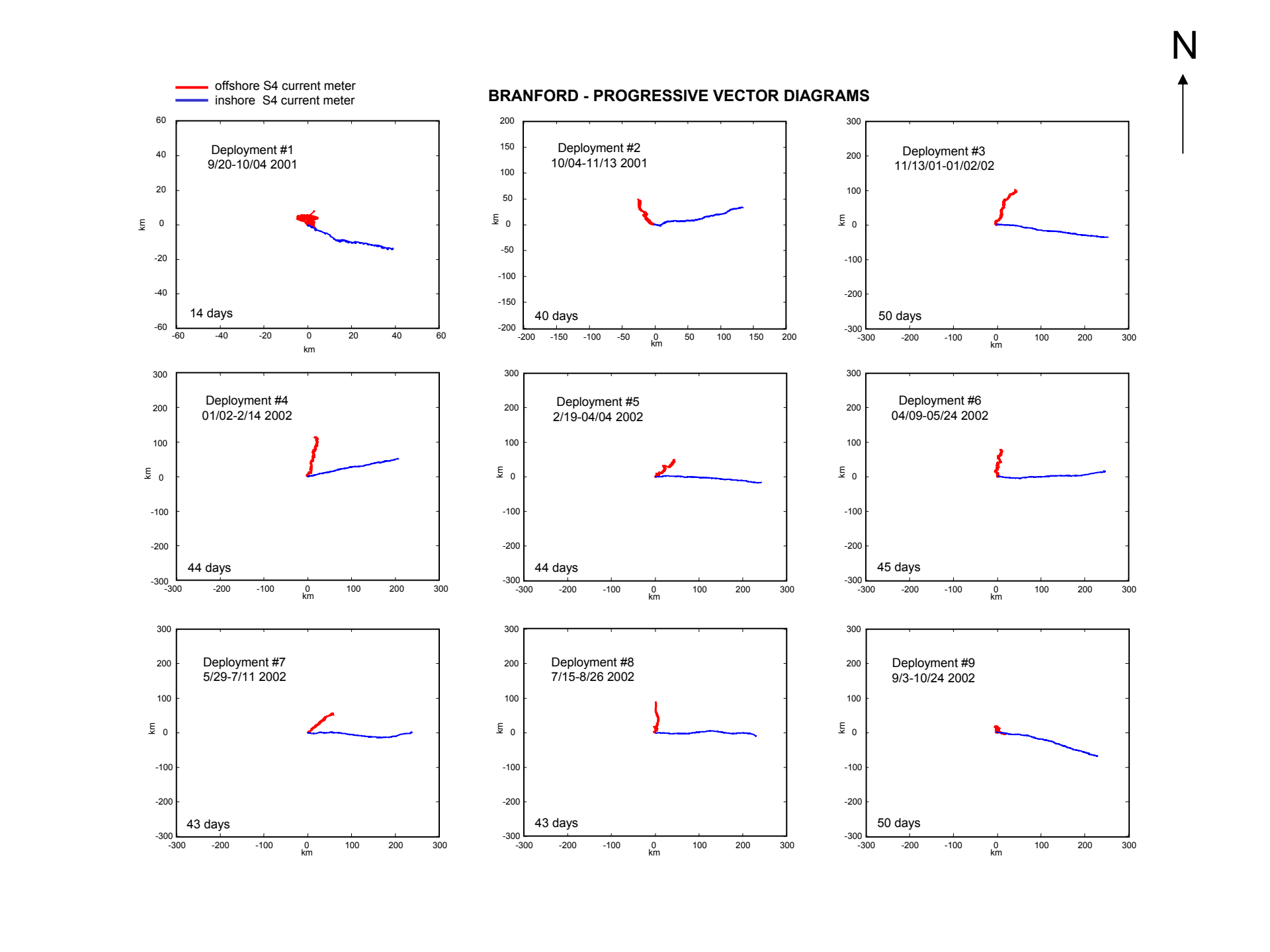


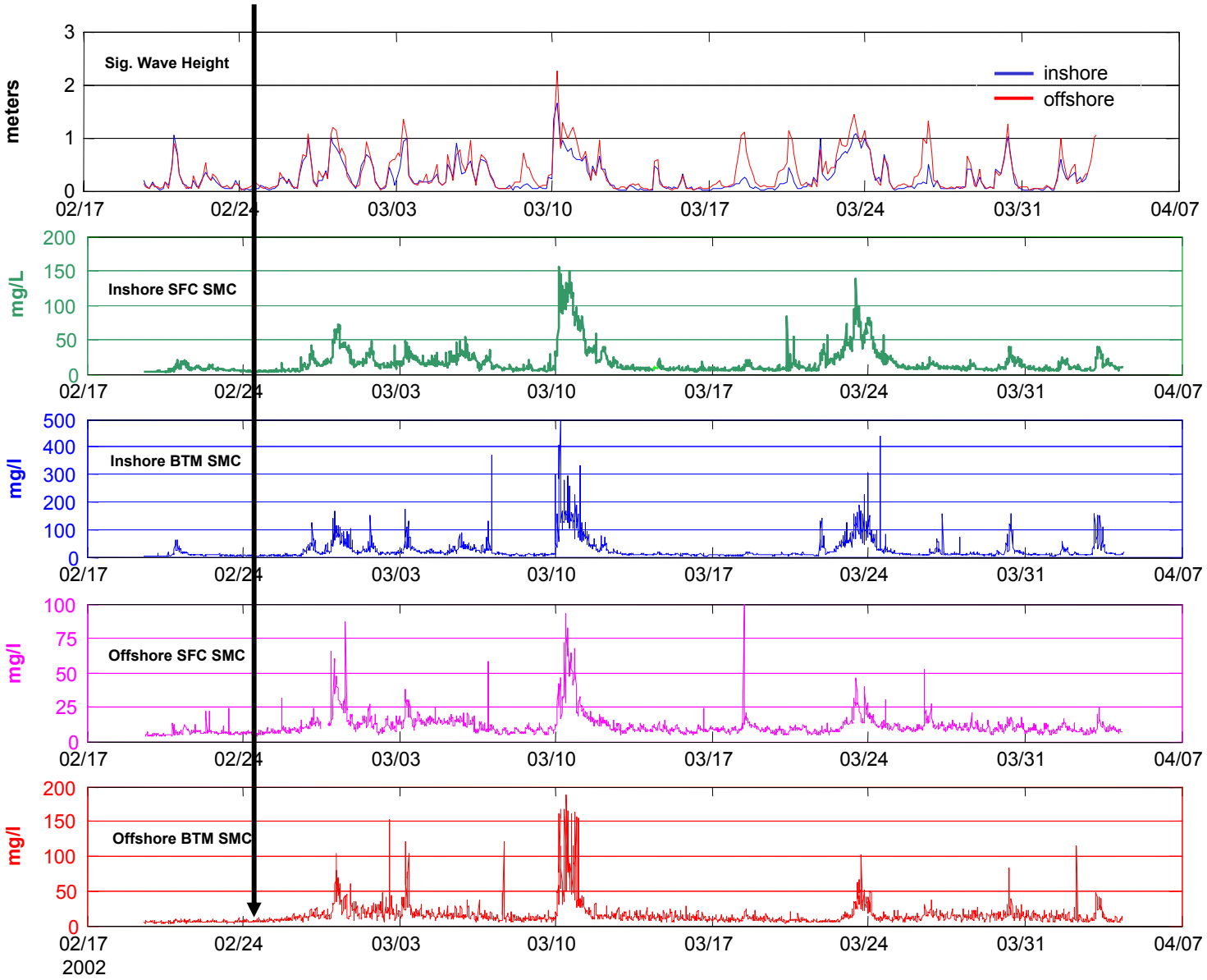


Branford, Connecticut Study Area February – April,2002



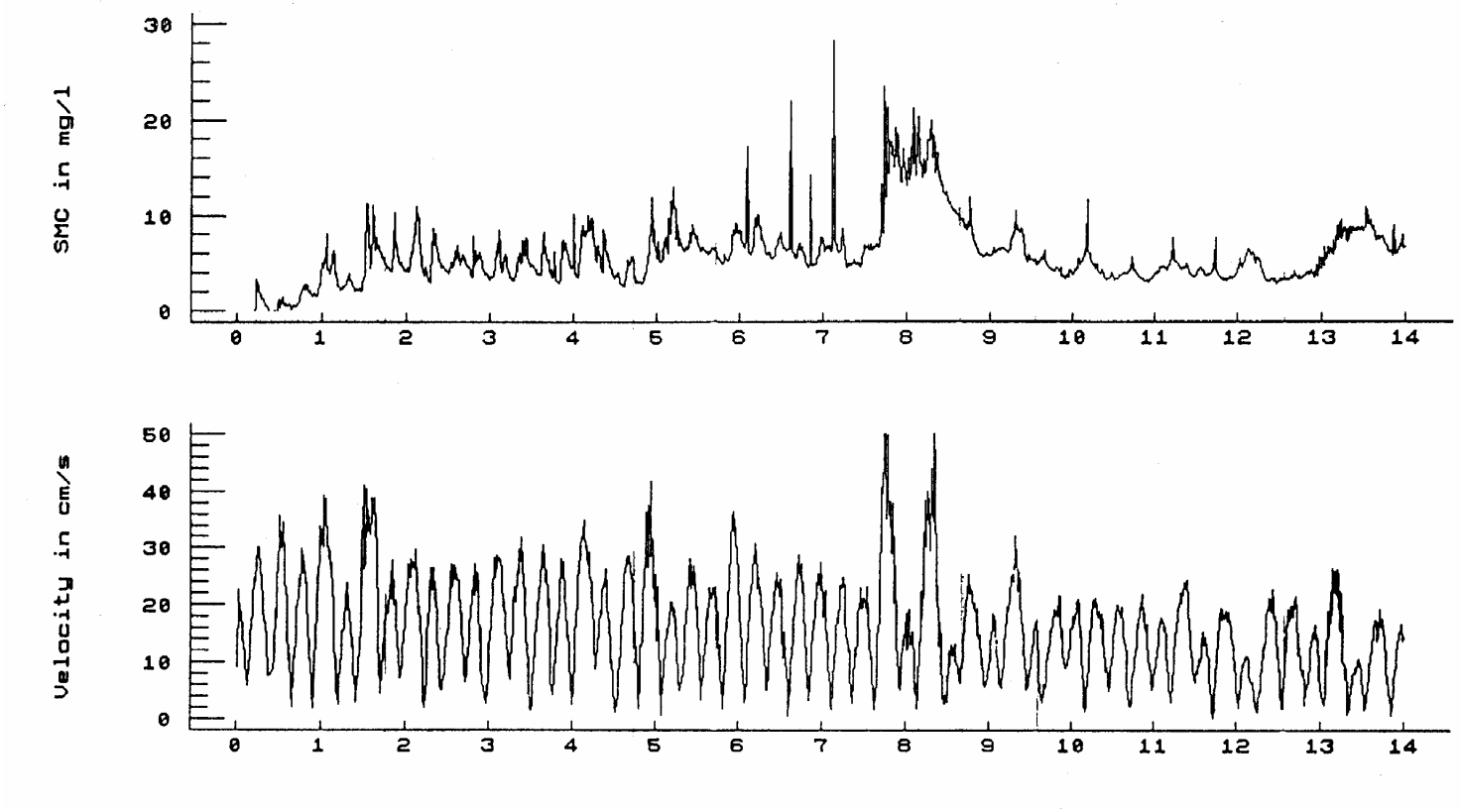
Branford, Connecticut Study Area February – April, 2002


offshore S4 current meter
inshore S4 current meter
BRANFORD - PROGRESSIVE VECTOR DIAGRAMS
N
Deployment #1
9/20-10/04 2001
14 days
Deployment #2
10/04-11/13 2001
40 days
Deployment #3
11/13/01-01/02/02
50 days
Deployment #4
01/02-2/14 2002
44 days
Deployment #5
2/19-04/04 2002
44 days
Deployment #6
04/09-05/24 2002
45 days
Deployment #7
5/29-7/11 2002
43 days
Deployment #8
7/15-8/26 2002
43 days
Deployment #9
9/3-10/24 2002
50 days
km

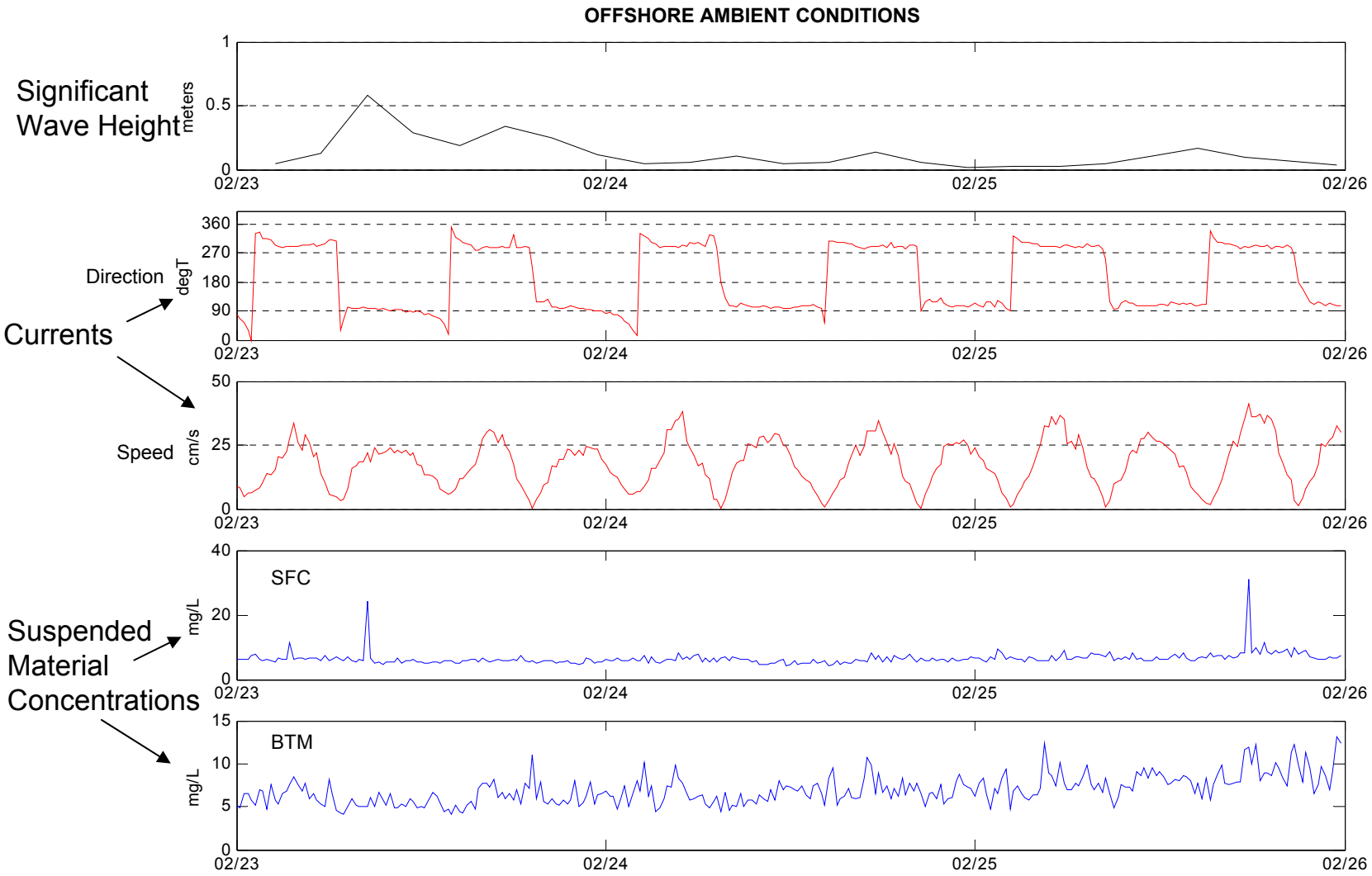


Branford, Connecticut Moored Array Data – February – April, 2002

NHD19: Nov 29 – Dec 12, 1983

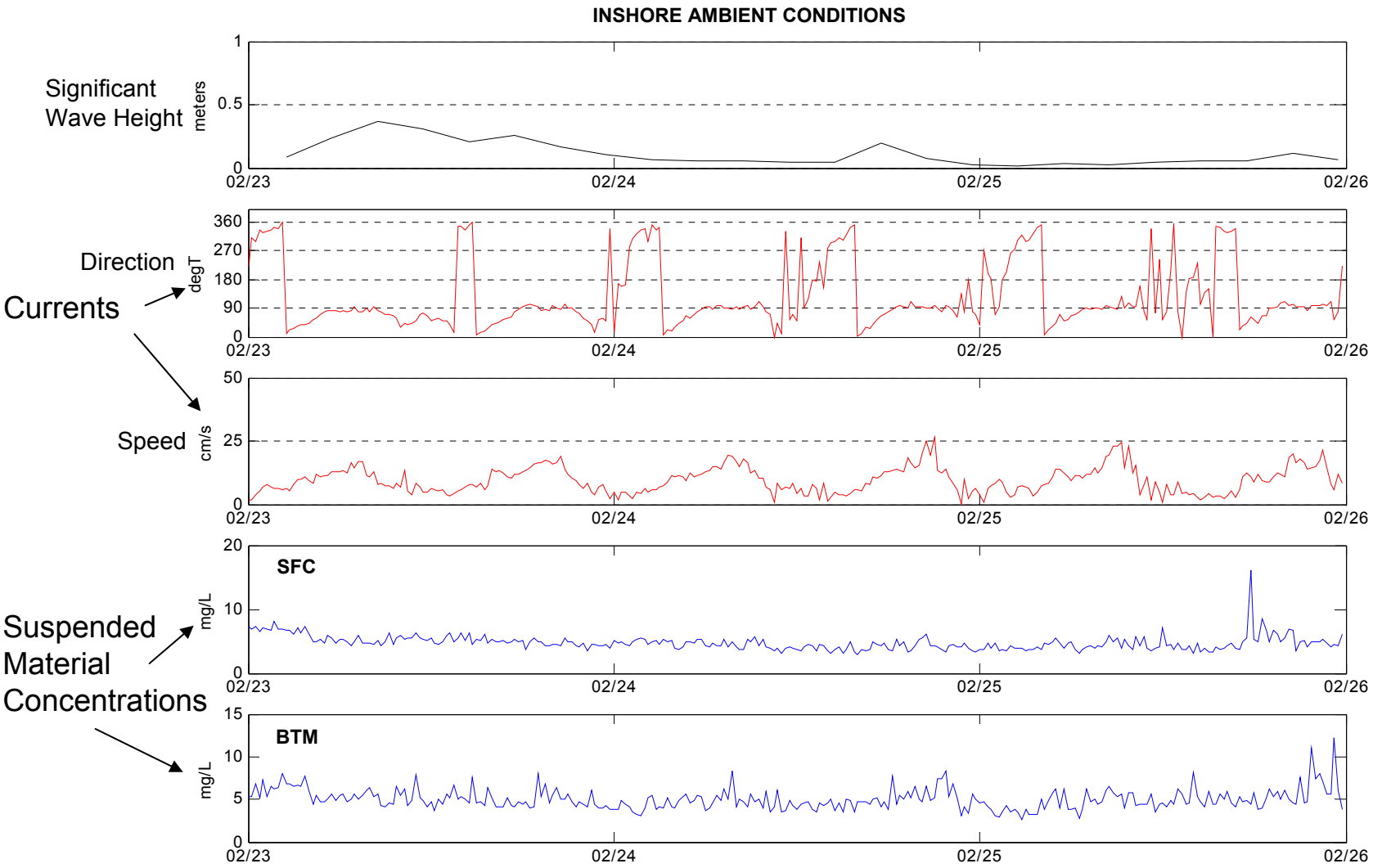


Nearbottom Time Series Data – Central Long Island Sound



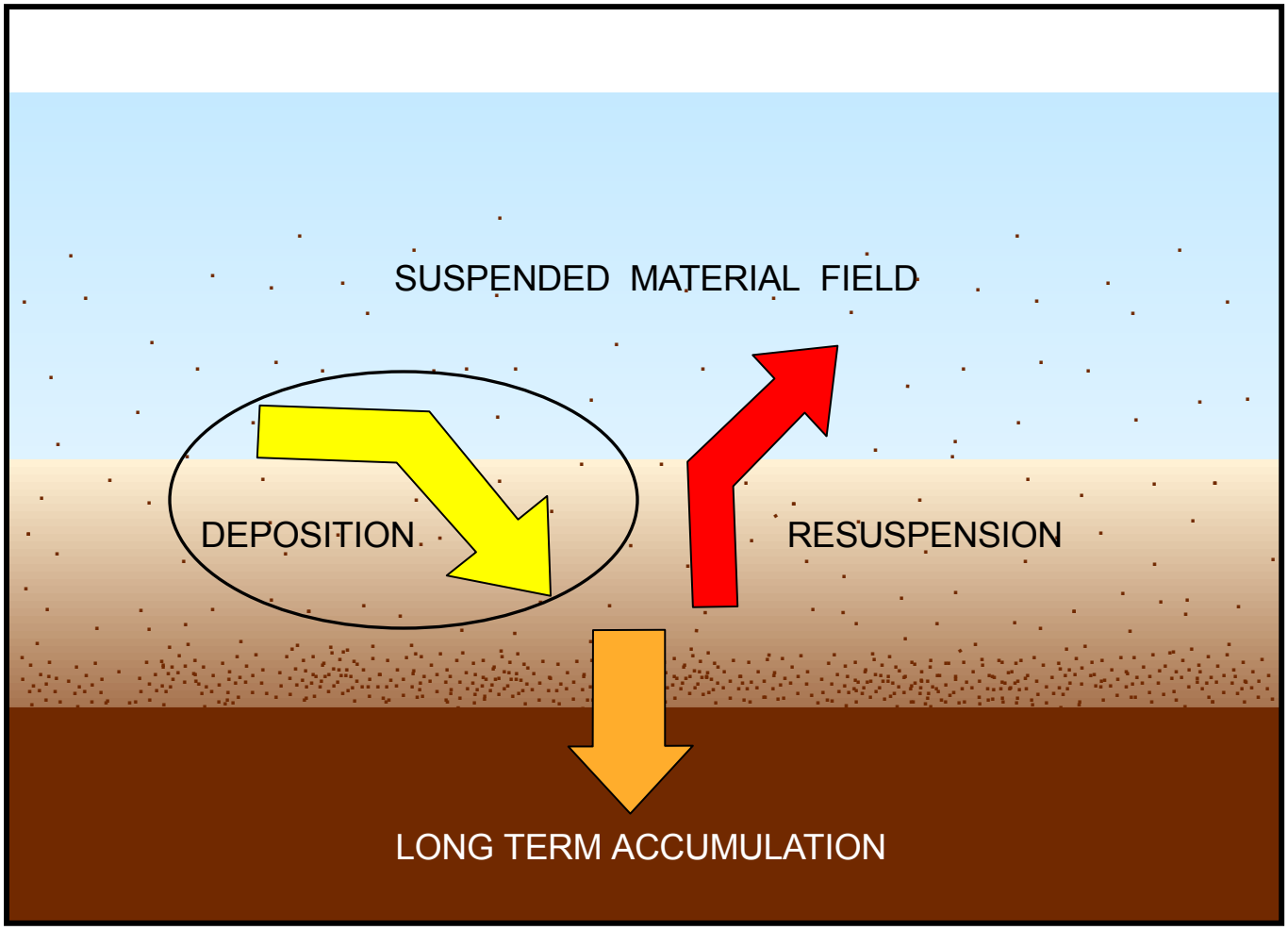
Selected Time Series Data - Branford Study Area

February , 2002



Selected Time Series Data – Branford Study Area

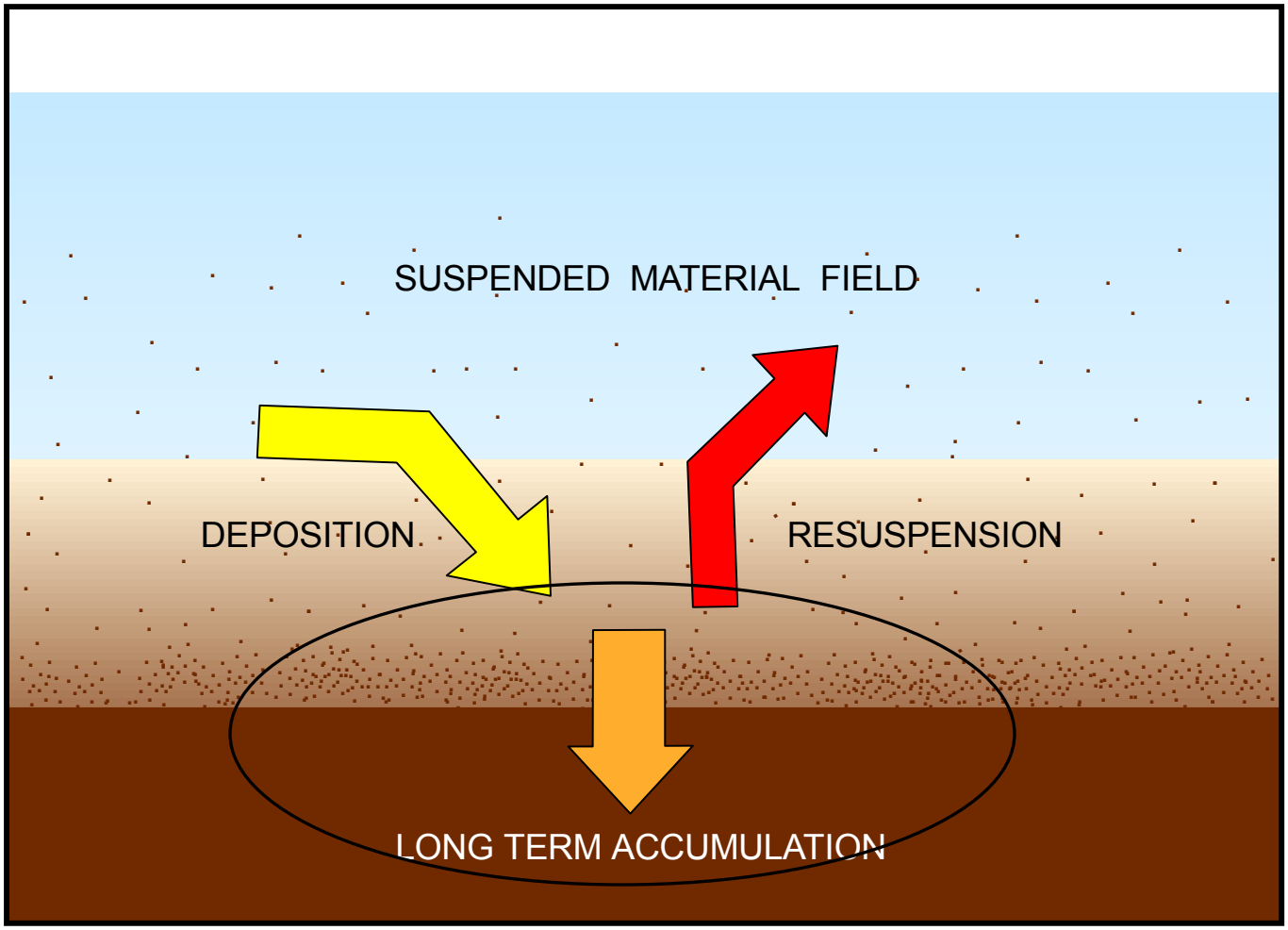
February, 2002

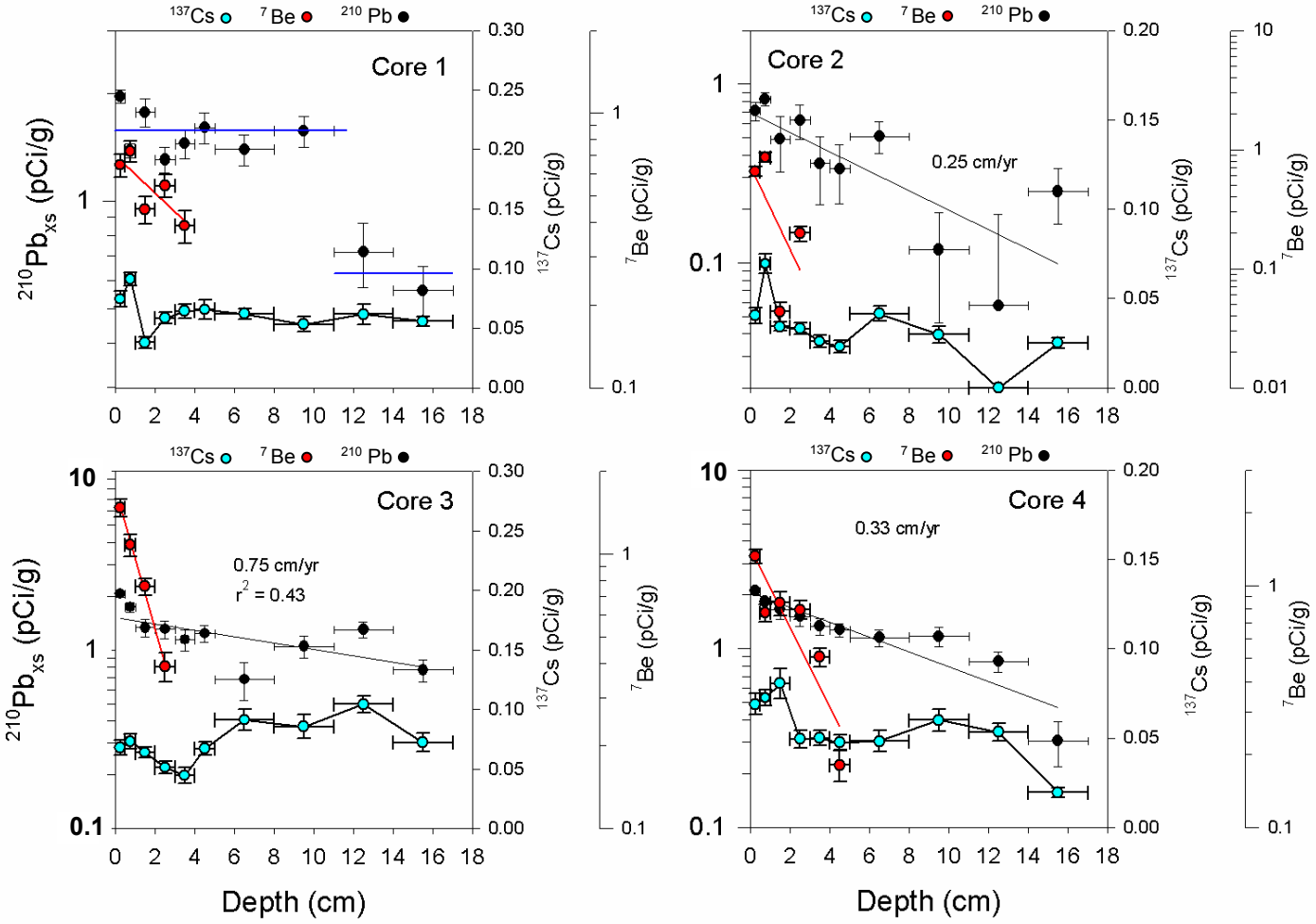

SUSPENDED MATERIAL FIELD
DEPOSITION
RESUSPENSION
LONG TERM ACCUMULATION

Sediment Trap Data - Islander East Study
Long Island Sound 2001/2002

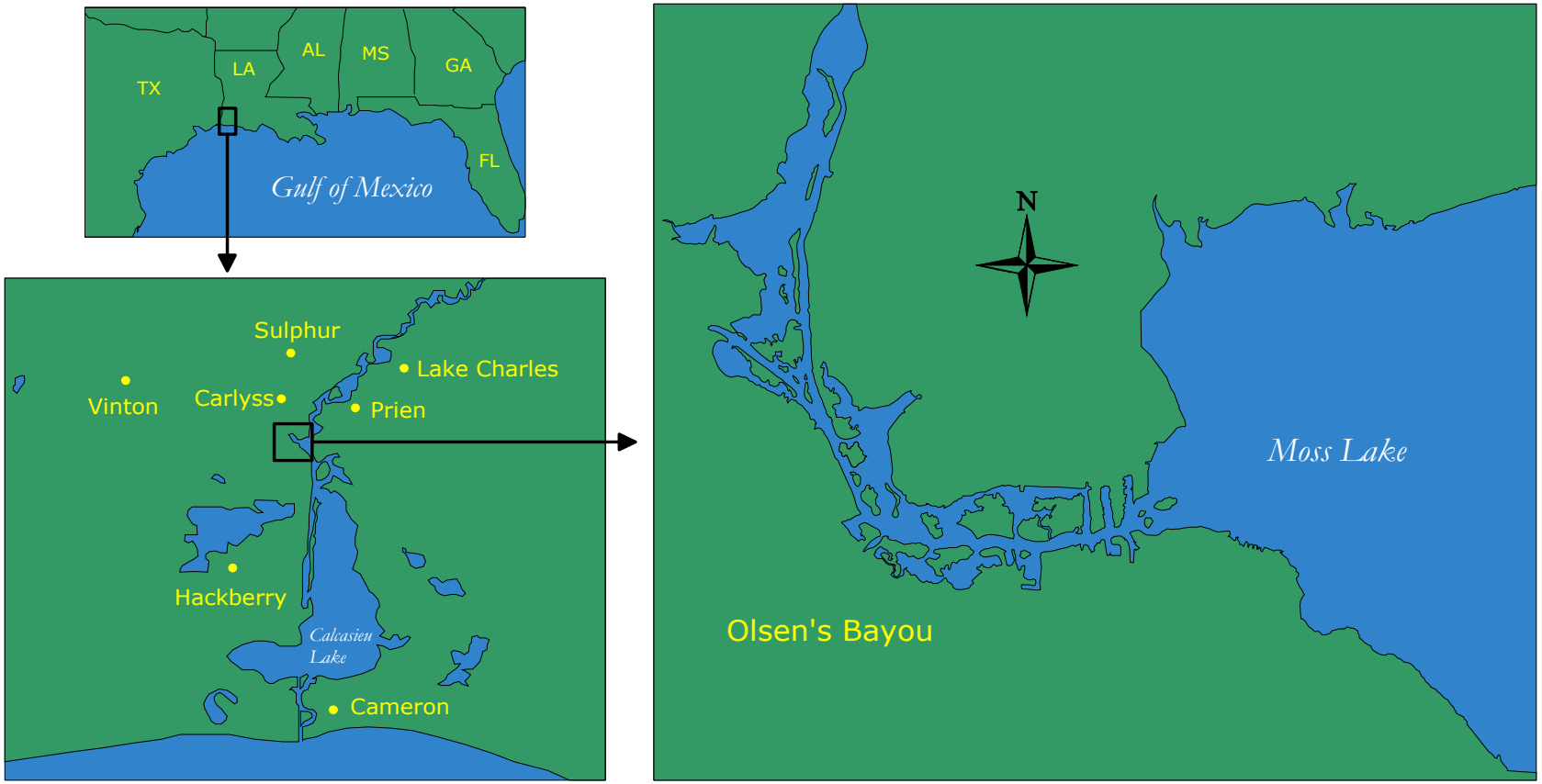
Deployed	Recovered	Site	Diameter of Tube	Height of Sediment	Volume of Sediment	Weight of Dish	Weight of Dish + Sediment (Dry)	Weight Sediment (Dry)	Duration (days)
1-11-02	2-14-02	inshore	6.7cm	10.5cm	370.19 cm^3	296.49g	502.93g	206.44g	34
1-11-02	2-14-02	offshore	6.7cm	3.9cm	137.50 cm^3	185.58g	241.97g	56.39g	34
2-14-02	4-04-02	offshore	6.7cm	9.0cm	317.31 cm^3	296.48g	414.51g	118.03g	49
4-04-02	5-24-02	inshore	6.7cm	10.5cm	370.19 cm^3	296.48g	442.90g	146.42g	50
4-04-02	5-24-02	offshore	6.7cm	7.5cm	264.42 cm^3	185.58g	294.27g	108.69g	50
5-29-02	7-10-02	inshore	6.7cm	11.0cm	387.82 cm^3	185.58g	332.53g	146.95g	42
5-29-02	7-10-02	offshore	6.7cm	12.5 m	440.71 cm^3	296.48g	499.50g	203.02g	42
7-10-02	8-26-02	inshore	6.7cm	3.0cm	105.77 cm^3	185.58g	289.12g	103.54g	47
7-10-02	8-26-02	offshore	6.7cm	4.25cm	149.84 cm^3	296.48g	461.53g	165.05g	47
9-03-02	10-24-02	inshore	6.7cm	39.72cm	1400.39 cm^3	28.2g	745.77g	717.57g	51
9-03-02	10-24-02	offshore	6.7cm	26.25cm	925.48 cm^3	28.3g	397.86g	369.56g	51

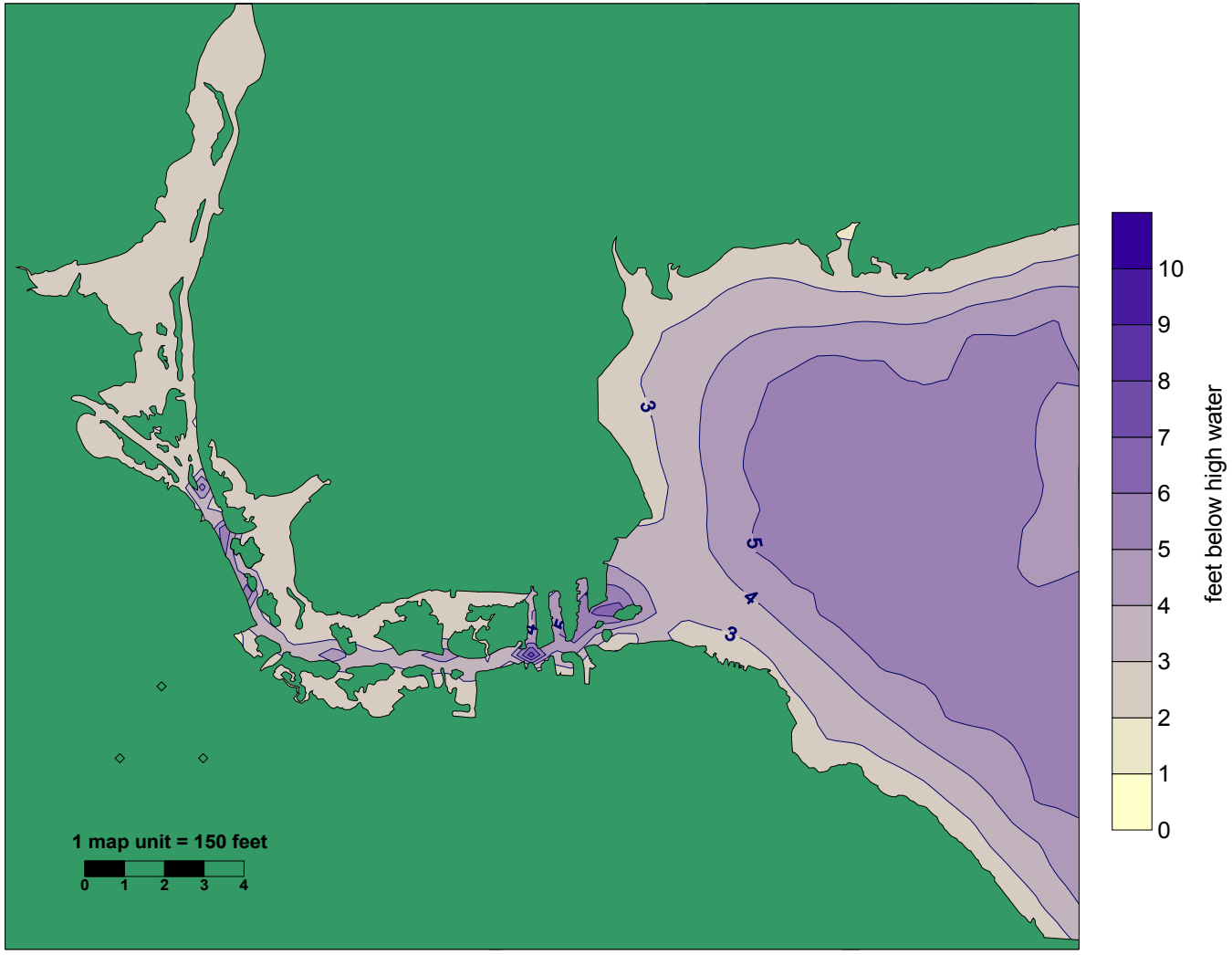
Sediments dried between 60 and 70°C for 24-72 hours.

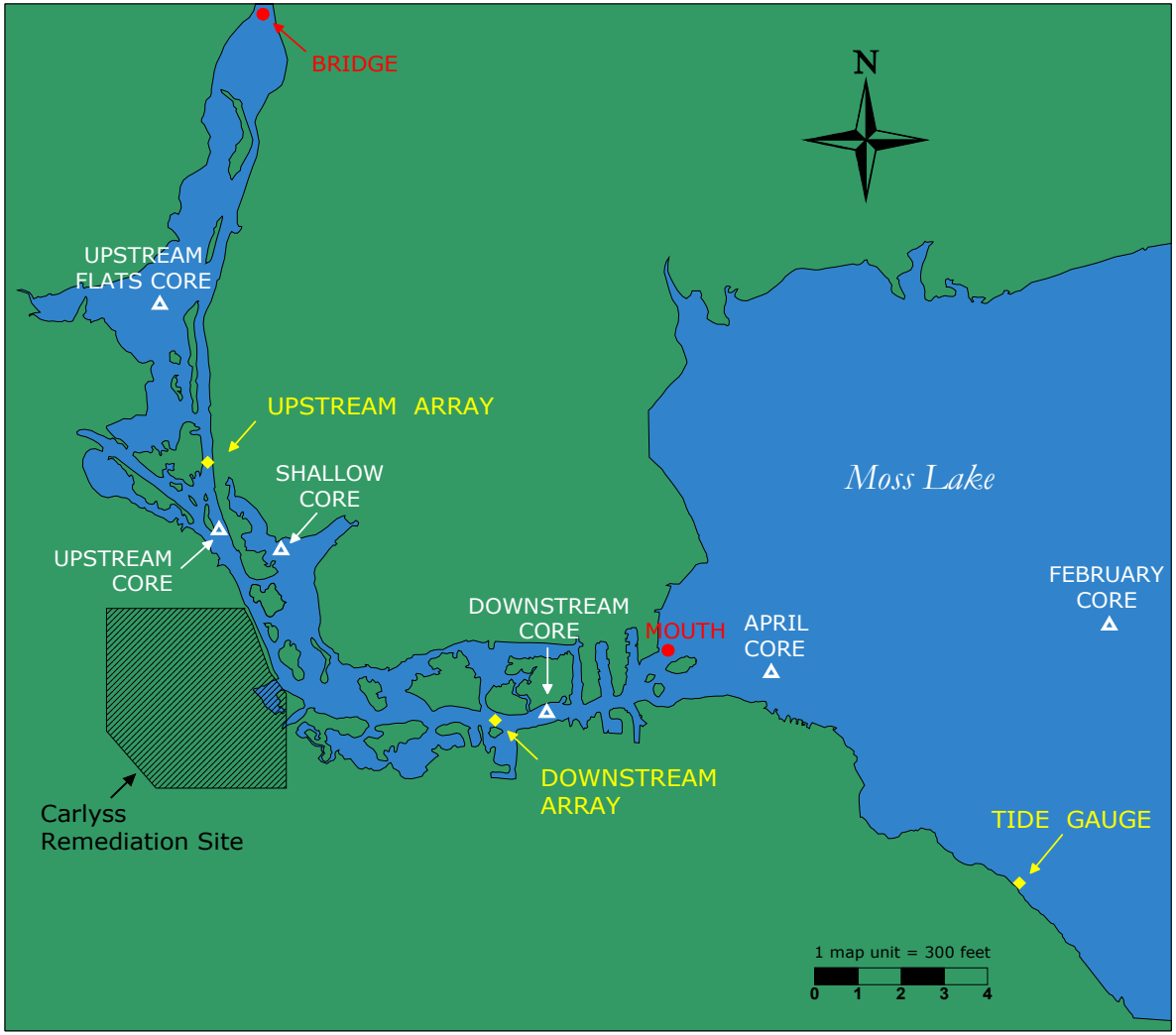

SUSPENDED MATERIAL FIELD
DEPOSITION
RESUSPENSION
LONG TERM ACCUMULATION

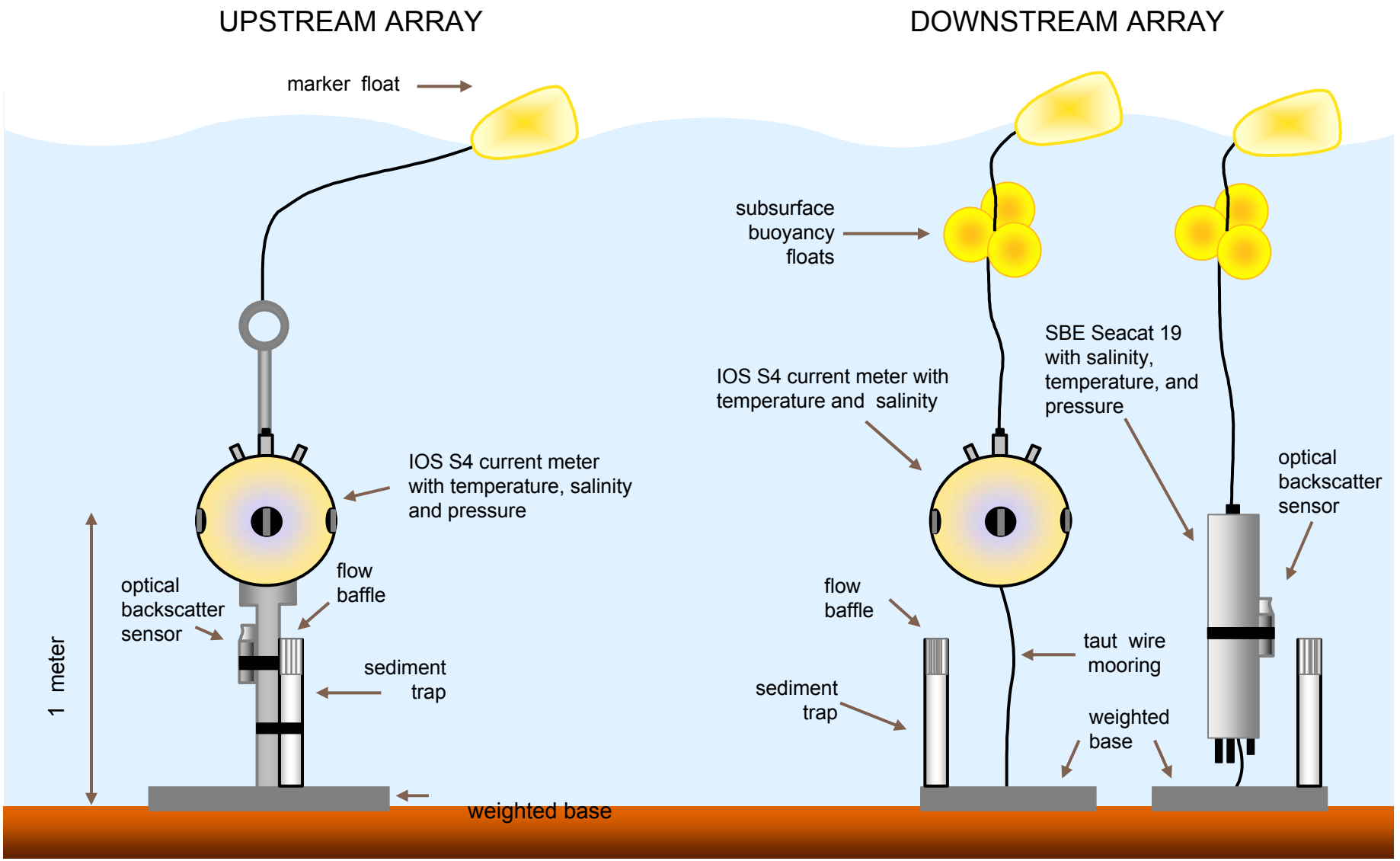


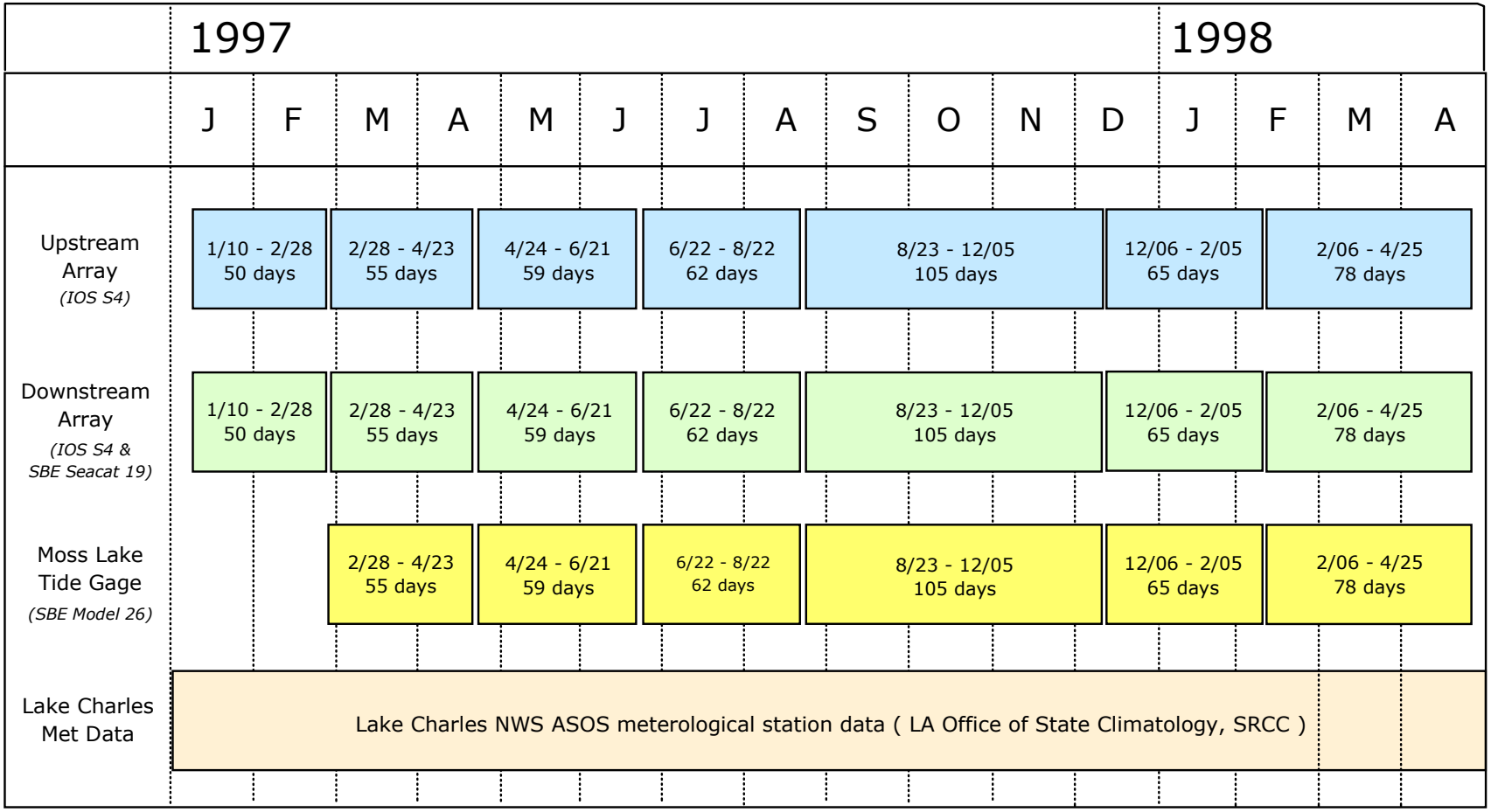
Sediment Core Radionuclide Profiles - September, 2002 Sampling
Islander East Study - Long Island Sound

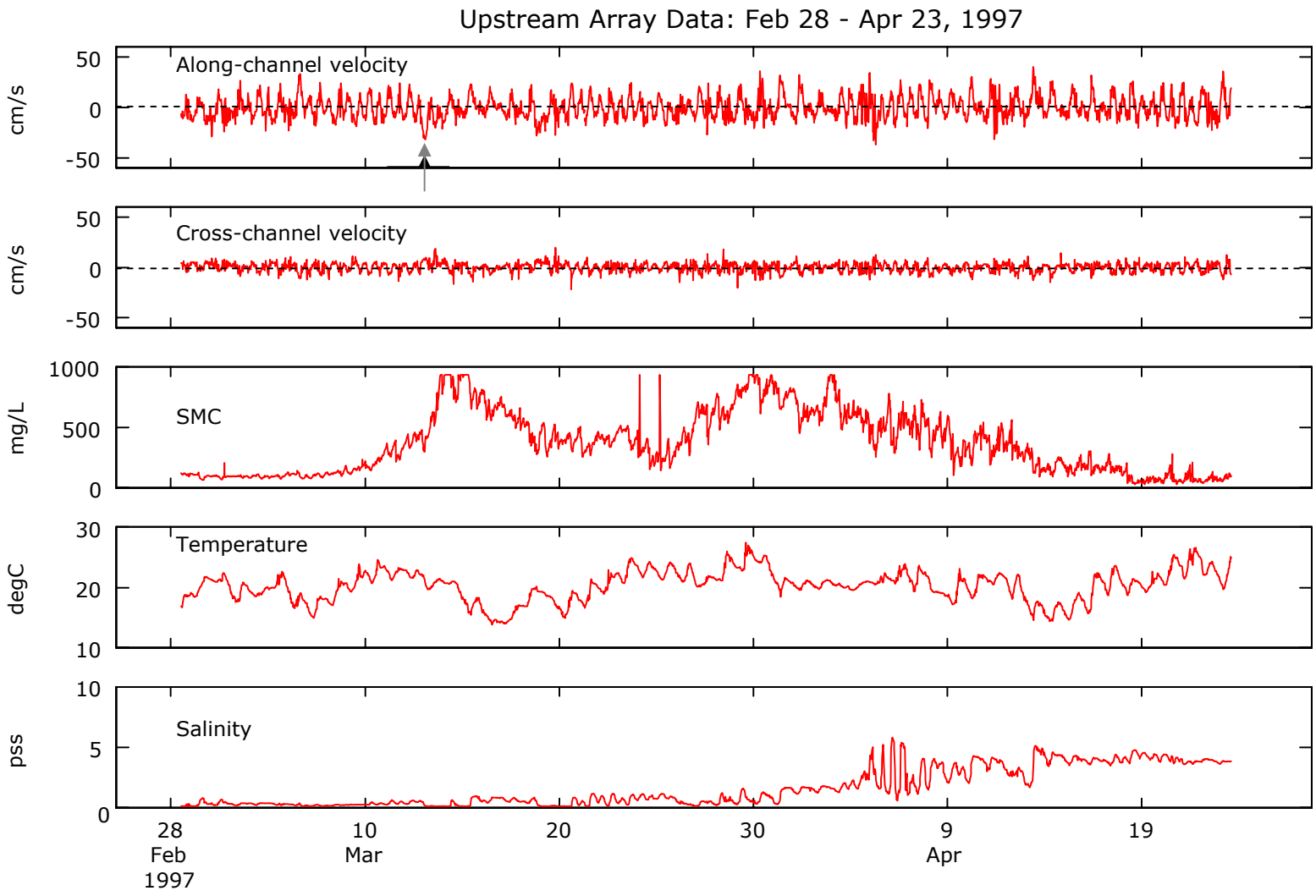

TX
LA
AL
MS
GA
FL
Gulf of Mexico
Sulphur
Lake Charles
Vinton
Carlyss
Prien
Hackberry
Calcasieu Lake
Cameron
N
Moss Lake
Olsen's Bayou

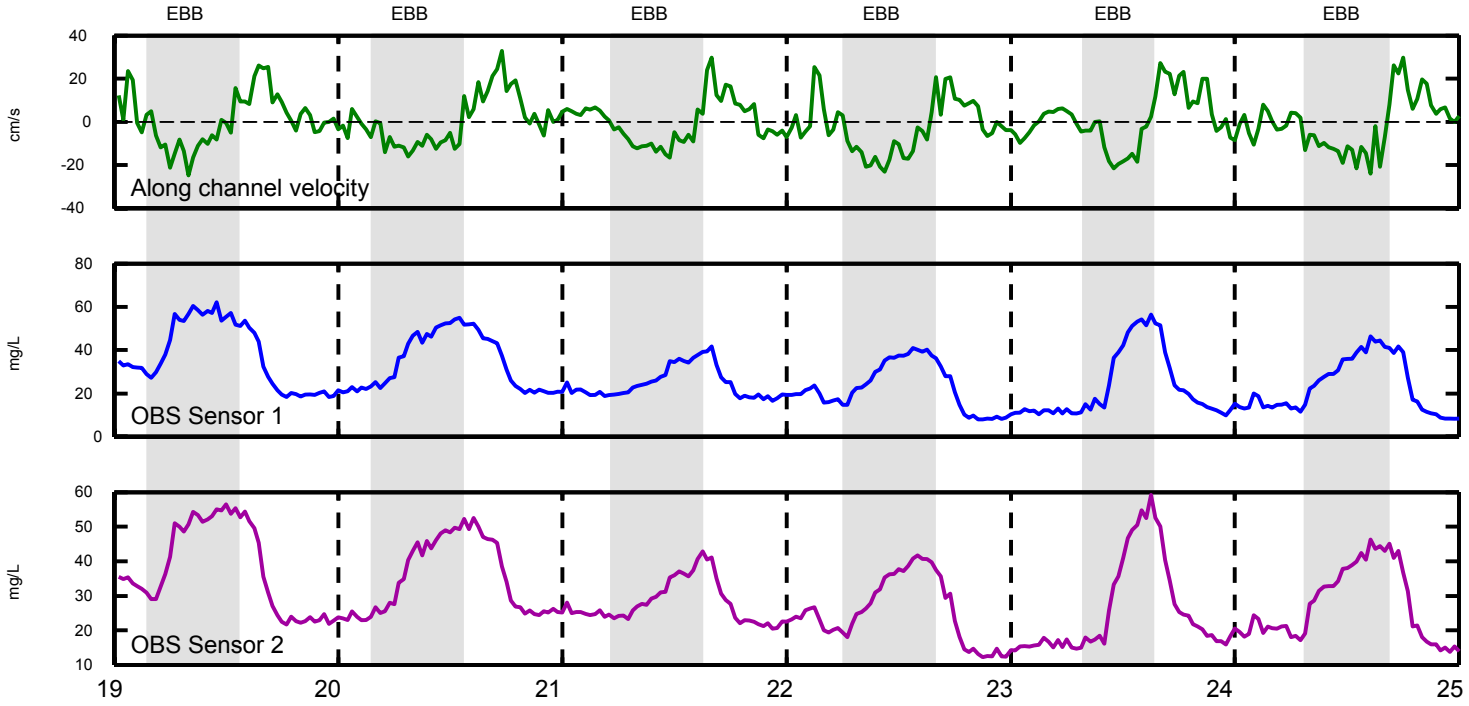

3
5
4
3
4
5
1 map unit = 150 feet
0 1 2 3 4
feet below high water
10
9
8
7
6
5
4
3
2
1
0


BRIDGE
N
UPSTREAM
FLATS CORE
UPSTREAM ARRAY
SHALLOW
CORE
UPSTREAM
CORE
Moss Lake
FEBRUARY
CORE
DOWNSTREAM
CORE
MOUTH
APRIL
CORE
DOWNSTREAM
ARRAY
TIDE GAUGE
Carlyss
Remediation Site
1 map unit = 300 feet
0 1 2 3 4

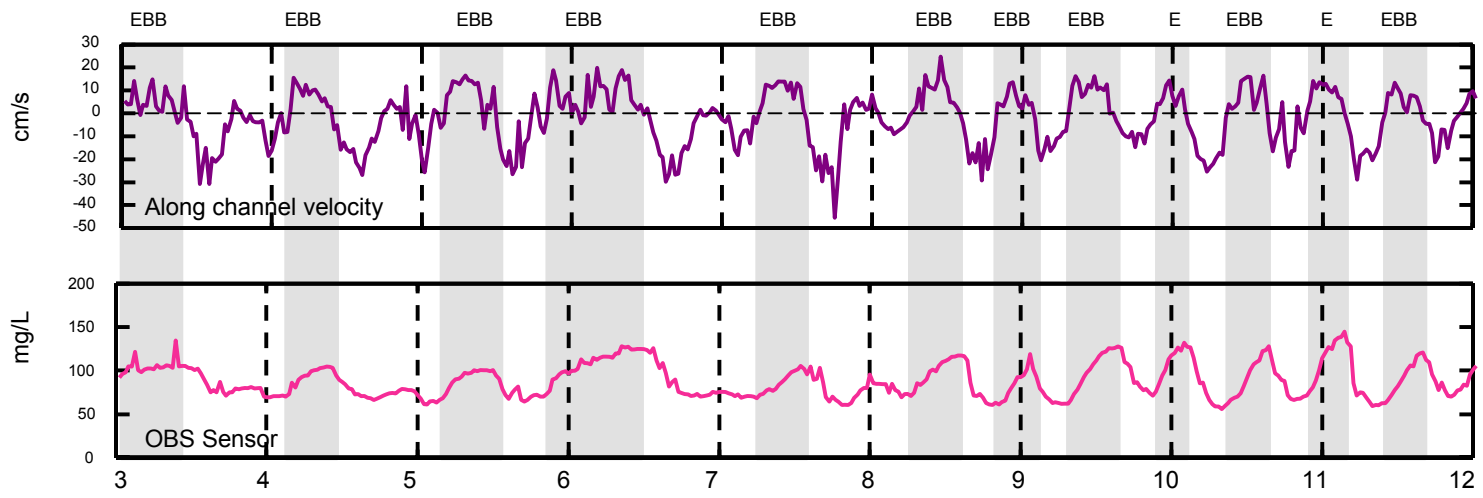

UPSTREAM ARRAY
DOWNSTREAM ARRAY
marker float
IOS S4 current meter with temperature, salinity and pressure
optical backscatter sensor
flow baffle
sediment trap
1 meter
weighted base
subsurface buoyancy floats
IOS S4 current meter with temperature and salinity
SBE Seacat 19 with salinity, temperature, and pressure
optical backscatter sensor
flow baffle
taut wire mooring
sediment trap
weighted base


1997
1998
J
F
M
A
M
J
J
A
S
O
N
D
J
F
M
A
Upstream Array (IOS S4)
1/10 - 2/28 50 days
2/28 - 4/23 55 days
4/24 - 6/21 59 days
6/22 - 8/22 62 days
8/23 - 12/05 105 days
12/06 - 2/05 65 days
2/06 - 4/25 78 days
Downstream Array (IOS S4 & SBE Seacat 19)
1/10 - 2/28 50 days
2/28 - 4/23 55 days
4/24 - 6/21 59 days
6/22 - 8/22 62 days
8/23 - 12/05 105 days
12/06 - 2/05 65 days
2/06 - 4/25 78 days
Moss Lake Tide Gage (SBE Model 26)
2/28 - 4/23 55 days
4/24 - 6/21 59 days
6/22 - 8/22 62 days
8/23 - 12/05 105 days
12/06 - 2/05 65 days
2/06 - 4/25 78 days
Lake Charles Met Data
Lake Charles NWS ASOS meterological station data (LA Office of State Climatology, SRCC)

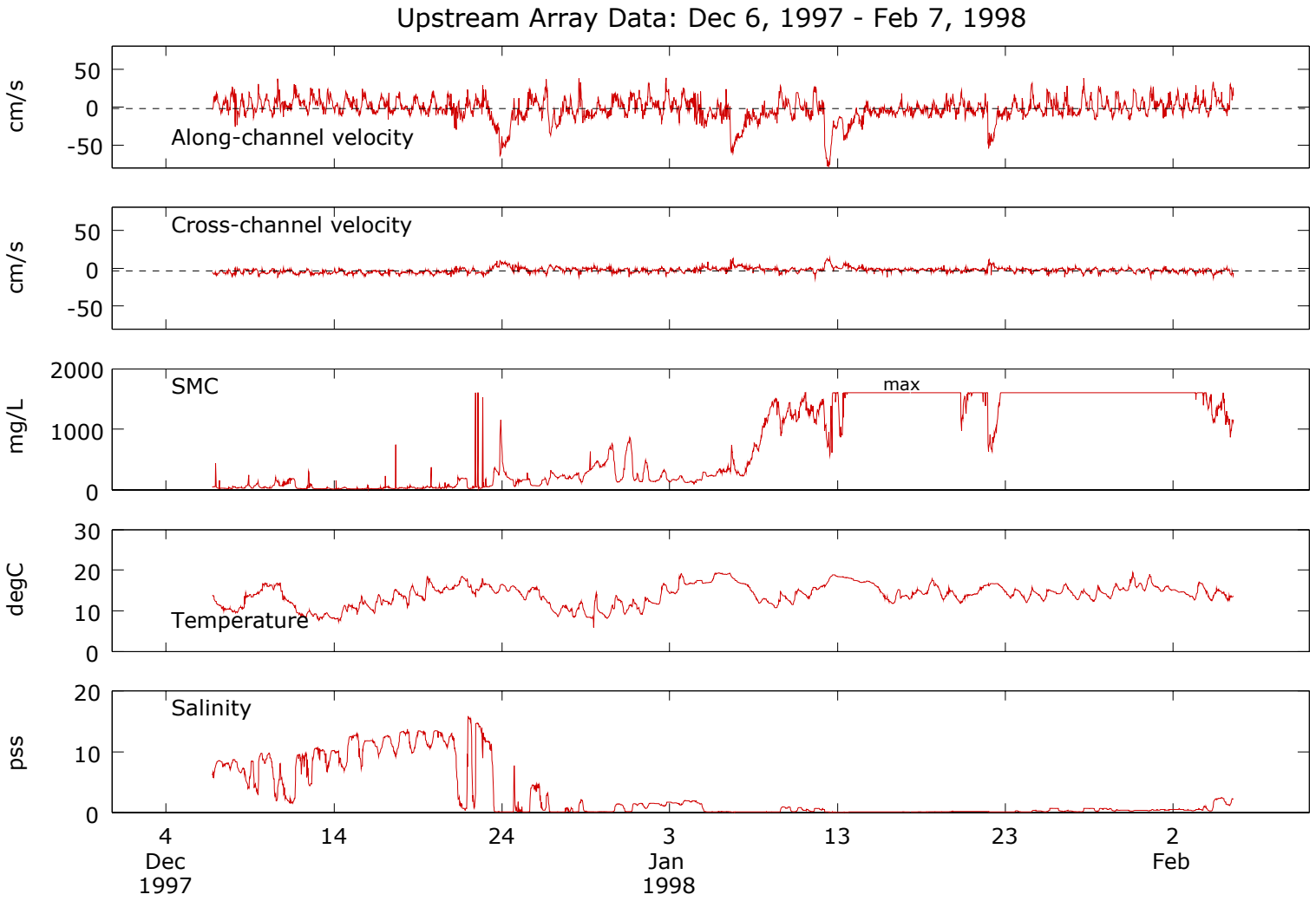

Upstream Array Data: Feb 28 - Apr 23, 1997
Along-channel velocity
cm/s
50
0
-50
Cross-channel velocity
cm/s
50
0
-50
SMC
mg/L
1000
500
0
Temperature
degC
30
20
10
Salinity
pss
10
5
0
28
Feb
1997
10
Mar
20
30
9
Apr
19



Olsen's Bayou - Ambient Conditions (Jan 19 - 24, 1997), upstream data.



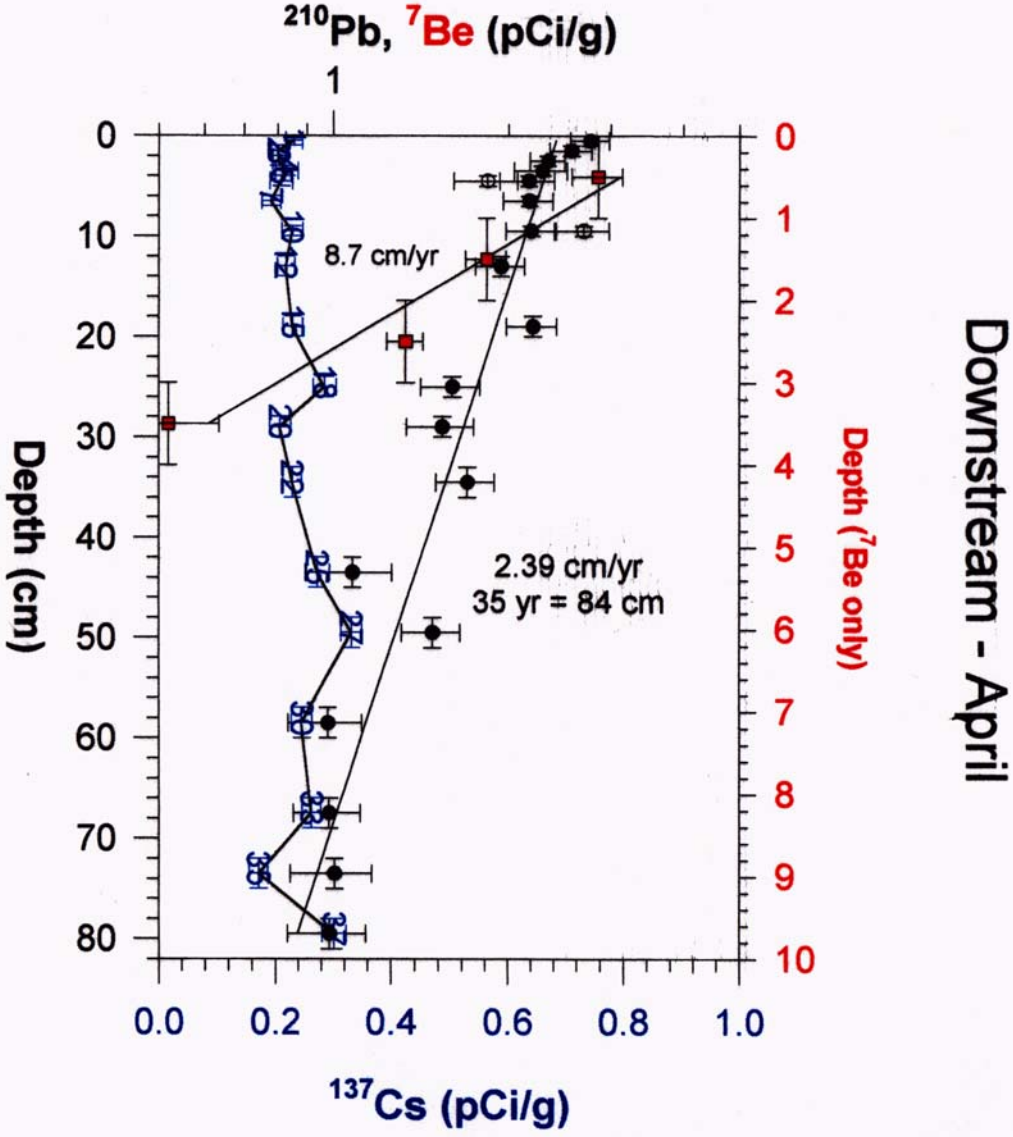
Olsen's Bayou - Ambient Conditions (March 3 -11, 1997), downstream data.

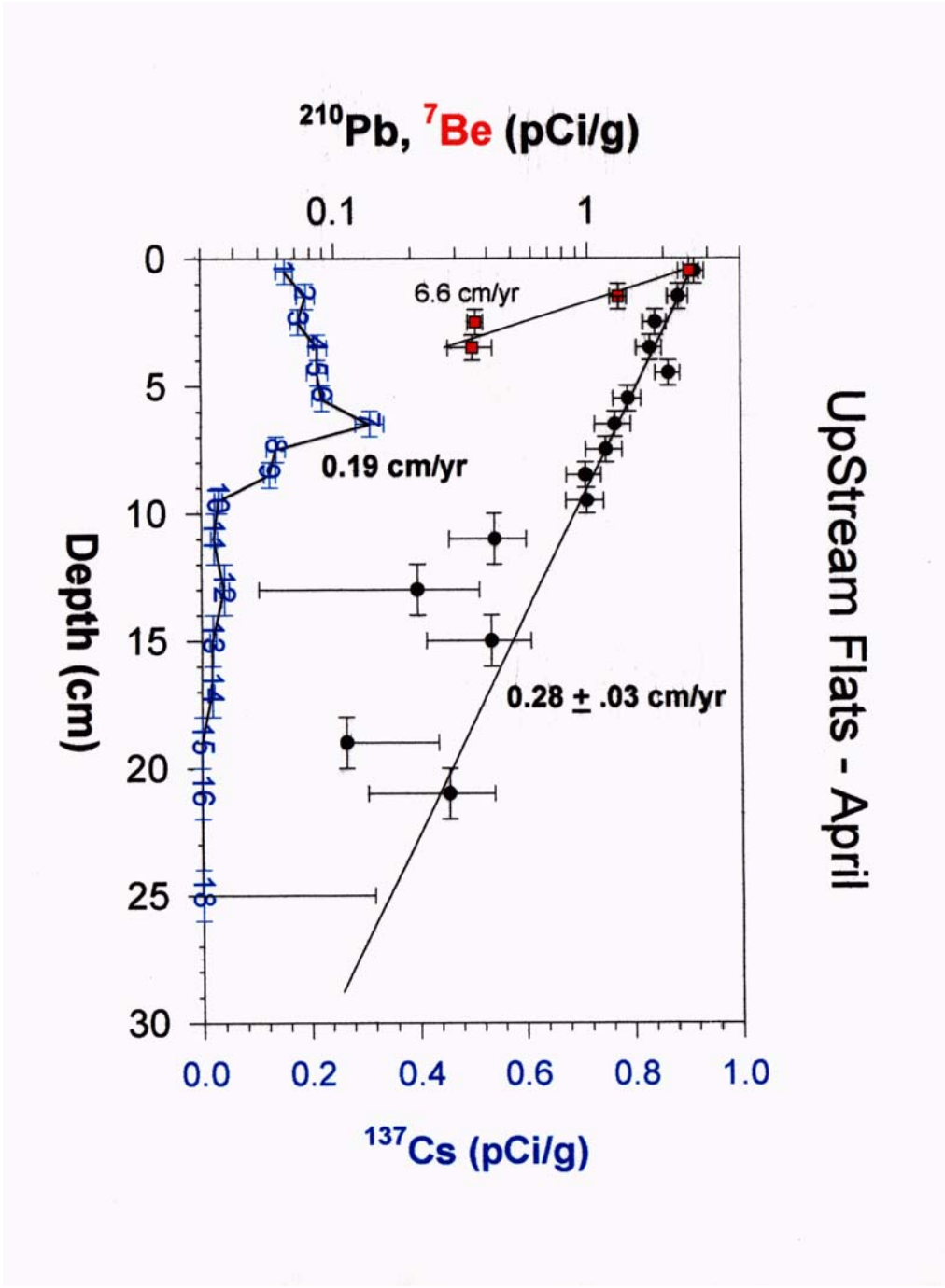

Upstream Array Data: Dec 6, 1997 - Feb 7, 1998
cm/s
50
0
-50
Along-channel velocity
cm/s
50
0
-50
Cross-channel velocity
mg/L
2000
1000
0
SMC
max
degC
30
20
10
0
Temperature
pss
20
10
0
Salinity
4
Dec
1997
14
24
3
Jan
1998
13
23
2
Feb

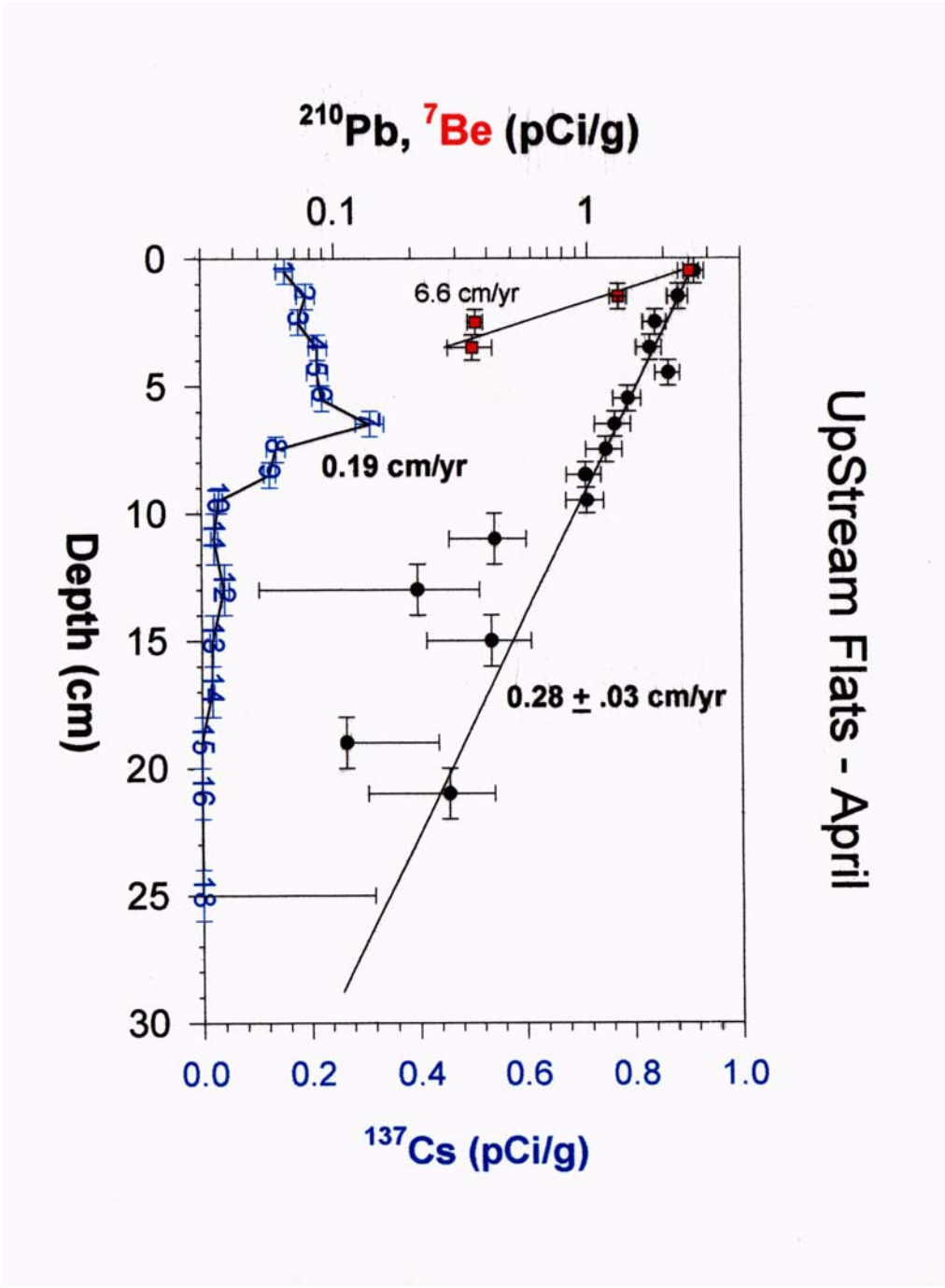
SEDIMENT TRAP DATA

	UPSTREAM ARRAY	DOWNSTREAM ARRAY
Dec-Feb, 1998	0.09 g/cm2/day	0.04 g/cm2 /day
Feb-Apr, 1998	0.05 g/cm2 /day	0.06 g/cm2 /day

reservoir of ~ 20 gm/cm2 is available annually


^{210}Pb, ^{7}Be (pCi/g)
1
0
10
20
30
40
50
60
70
80
Depth (cm)
8.7 cm/yr
2.39 cm/yr
35 yr = 84 cm
0.0
0.2
0.4
0.6
0.8
1.0
^{137}Cs (pCi/g)
0
1
2
3
4
5
6
7
8
9
10
Depth (^{7}Be only)
Downstream - April

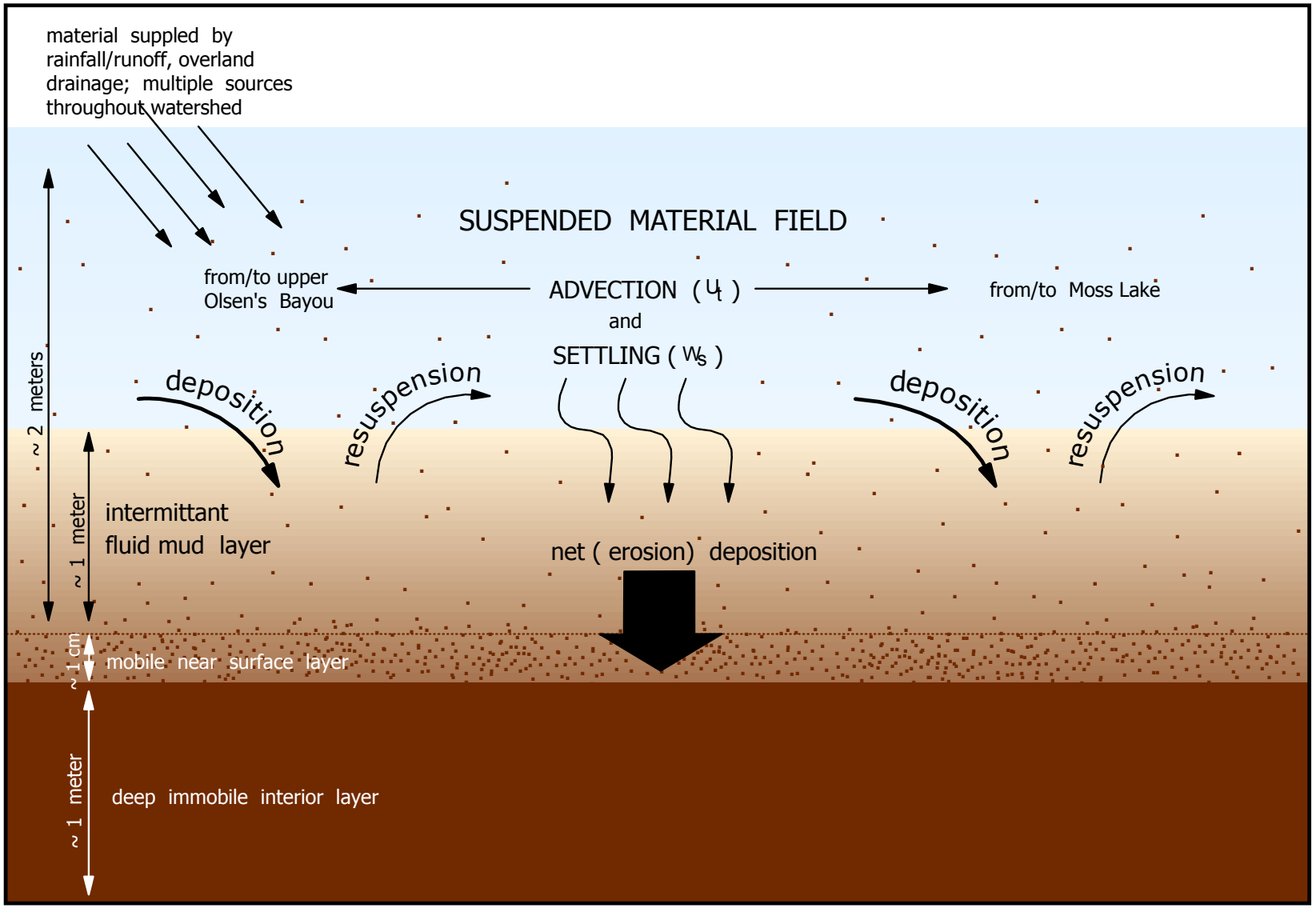

^{210}Pb, ^{7}Be (pCi/g)
0.1
1
0
5
10
15
20
25
30
Depth (cm)
6.6 cm/yr
0.19 cm/yr
0.28 ± .03 cm/yr
0.0
0.2
0.4
0.6
0.8
1.0
^{137}Cs (pCi/g)
UpStream Flats - April


^{210}Pb, ^{7}Be (pCi/g)
0.1
1
0
5
10
15
20
25
30
Depth (cm)
6.6 cm/yr
0.19 cm/yr
0.28 ± .03 cm/yr
0.0
0.2
0.4
0.6
0.8
1.0
^{137}Cs (pCi/g)
UpStream Flats - April

	Pb210 Core Data	Bulk Density	Estimated Flux
main channel	2-4 cm/yr	1.25 gm/cm3	0.5-1 gm/cm2/yr
shallows and flats	0.27 cm/yr		
Moss Lake (offshore)	0.40 cm/yr (post-dredging)		
Moss Lake (inshore)	0.03 cm/yr		

annual vertical flux rate of 20 gm/cm2

only 2.5-5% of suspended load cycled
to and through Olsen's Bayou will be retained


material suppled by rainfall/runoff, overland drainage; multiple sources throughout watershed
SUSPENDED MATERIAL FIELD
from/to upper Olsen's Bayou
ADVECTION (u_t)
from/to Moss Lake
and
SETTLING (w_s)
deposition
resuspension
deposition
resuspension
~ 2 meters
~ 1 meter
intermittant fluid mud layer
net (erosion) deposition
~ 1 cm
mobile near surface layer
~ 1 meter
deep immobile interior layer

Conclusions

- The sediment transport regime in the aquatic environment displays significant spatial and temporal variability

  -This affects the definition of setting and the formulation of conceptual models

- Specification of the Primary Transport Characteristics is best realized through the analysis of time series data

  - Requires careful consideration of the scales of variability

- Time Series Data complement the development, calibration, and verification of numerical models

  - Framework, governing factors, and skill