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REPORT

TO

GREAT LAKES NATIONAL PROGRAM OFFICE

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

MODELING THE BEHAVIOR AND FATE OF NUTRIENTS AND TRACE CONTAMINANTS IN THE UPPER GREAT LAKES CONNECTING CHANNELS

NOVEMBER 1986

INTERAGENCY AGREEMENT DW 13931213-01-0

BETWEEN

GREAT LAKES ENVIRONMENTAL RESEARCH LABORATORY

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

ANN ARBOR, MICHIGAN

AND

GREAT LAKES NATIONAL PROGRAM OFFICE

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

CHICAGO, ILLINOIS

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INTRODUCTION

The Upper Great Lakes Connecting Channels Study (UGLCCS) is a multi-agency, multi-national study of the St. Marys River, the St. Clair River, Lake St. Clair, and the Detroit River. The goals of the study include:

1. Determining the present environmental status of the study area;

2. Identifying and quantifying sources of ecosystem degradation in the study area;

3. Assessing the adequacy of existing or planned control programs;

4. Developing long-term monitoring programs for assessing the effectiveness of control programs;

5. Facilitating the development of remedial action plans by the the Province of Ontario and the State of Michigan.

Towards accomplishing these goals, the Great Lakes Environmental Research Laboratory (GLERL) of the National Oceanic and Atmospheric Administration (NOAA) has designed modeling, field, and laboratory studies of the connecting channels study area and processes therein. Through the Activities Integration Committee or other less formal avenues, GLERL's studies have been carefully coordinated with proposed or ongoing studies of other agencies in order to maximize scientific insights. A cross reference showing the correspondence between GLERL's studies and UGLCCS activity numbers is provided in Table 1. In some cases the GLERL studies are associated with more than one of the UGLCCS activities.

As part of the NOAA - EPA interagency agreement, GLERL will provide the Great Lakes National Program Office (GLNPO) with written quarterly reports describing progress towards meeting the goals of the study, oral presentations summarizing each year's work and a written report at the completion of the study. Scientists at GLERL will also submit the results of their work to professional scientific journals during the course of the study. Summarized in this document is research progress for the period September - November 1986.

Table 1. Correspondence of GLERL Activities with UGLCCS Activities.

GLERL Activity	UGLCCS Activity No.
Unsteady Flow Model of Entire St. Clair River	C.5
St. Clair and Detroit River Current Measurements	C.4
Development of a Shallow Water Numerical Wave Model for Lake St. Clair	C.4
The Currents of Lake St. Clair	C.4
Modeling Particle Transport in Lake St. Clair	C.2,C.4
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Sediment Transport and Resuspension in Lake St. Clair	G.3
Risk and Uncertainty Analysis of Contaminant and Phosphorus Models for the Connecting Channels and Lake St. Clair	C.3

QUARTERLY PROGRESS REPORT - NOVEMBER 1986

1. Title: Unsteady Flow Model of Entire St. Clair River

2. Principal Investigators: Jan A. Derecki

3. Organization: Great Lakes Environmental Research Laboratory - NOAA- 2300 Washtenaw Ave., Ann Arbor, MI 48104

4. Objectives: To develop an unsteady flow model of the St. Clair River from Lake St. Clair to Lake Huron including tributary stream inputs capable of simulating flows on hourly and daily time scales.

5. Progress Since Last Report: Continued work on calibration of the model for the entire river (from Lake Huron to Lake St. Clair) by incorporating the separation of river flow through the main delta channels.

6. Problems Encountered and Proposed Solutions: Encountered some problems in the extension of model through the delta region, which may affect planned completion (December 1986) of the entire river model.

7. Projected Activities for Next Quarter: Complete work on model development for the river delta.

QUARTERLY PROGRESS REPORT - NOVEMBER 1986

1. Title: St. Clair and Detroit River Current Measurements

2. Principal Investigators: Jan A. Derecki

3. Organization: Great Lakes Environmental Research Laboratory - NOAA-
2300 Washtenaw Ave., Ann Arbor, MI 48104

4. Objectives: (1) To determine the winter flow variability and characteristics of the St. Clair and Detroit Rivers; (2) To use the measured data to verify and/or recalibrate the existing St. Clair and Detroit River mathematical transient models.

5. Progress Since Last Report: Continued collection, analysis, and monitoring of current meter velocities in the Detroit and St. Clair Rivers. All three EM current meters in operation during summer (two in St. Clair and one in Detroit Rivers) indicated large reductions in the velocity readings (up to 50%) due to weed effects; this type of meter is not suitable for prolonged continuous operation in these rivers during heavy weed season. The acoustic profiler was deployed in the Detroit River on November 12, 1986, replacing one of the EM current meters. At the same time (November 12-14), the three EM meters were checked and cleaned by divers for the winter season.

6. Problems Encountered and Proposed Solutions: The EM current meters require frequent cleaning by divers during heavy weed season and are not practical for continuous operations during such periods.

7. Projected Activities for Next Quarter: Continue data collection and analysis, with monitoring of current meter results.

QUARTERLY PROGRESS REPORT - NOVEMBER 1986

1. Title: Development of a Shallow Water Numerical Wave Model for Lake St. Clair

2. Principal Investigators: D. J. Schwab and P. C. Liu

3. Organization: NOAA/GLERL

4. Objectives: (1) To modify the GLERL Wave Prediction Model to account for shallow bottom effects; (2) to relate the observed waves to sediment resuspension.

5. Progress Since Last Report: Wave energy spectra have been computed for all time series measured at the GLERL stations (hourly values for the months of September, October, and November 1985). The GLERL Wave Prediction Model was modified to take account of shallow water effects according to the theory of Kitaigorodskii. Tests of the model behavior for several ideal cases were compared to results from other shallow water ocean wave models in the literature. Both the deep and shallow water versions of the model were then run with observed winds for September, October, and November 1985. Even though observed wavelength to depth ratios are often as low as 0.2 - 0.3 in Lake St. Clair, the deep water model appears to perform quite acceptably. The shallow water modification systematically underestimates the highest waves.

6. Problems Encountered and Proposed Solutions: None

7. Projected Activities for Next Quarter: Specific cases of wave generation, growth, propagation and dissipation will be examined in detail in conjunction with CCIW data to determine more precisely the limits of deep water theory.

QUARTERLY PROGRESS REPORT - NOVEMBER 1986

1. Title: Modeling Particle Transport in Lake St. Clair

2. Principal Investigators: A. H. Clites, D. J. Schwab, and T. D. Fontaine

3. Organization: NOAA/GLERL

4. Objectives: (1) To use the GLERL Numerical Circulations Models to identify particulate transport pathways in Lake St. Clair; (2) to provide information on the physical environment in Lake St. Clair in terms of current distribution patterns.

5. Progress Since Last Report: Circulation patterns in Lake St. Clair at three hour intervals have been calculated for the period May-November, 1985, using winds observed at CCIW met buoys. Currents derived from these circulation patterns are being used for two purposes, (1) to drive the TOXIWASP pollution model and (2) to estimate the effect of wind-driven current on the dispersion of particles entering the Lake from tributaries. Tracer particles are released at the mouth of each tributary at 6 hour intervals and tracked until they leave the lake. Dispersion is estimated by plotting the position of all particles released from single tributary at a fixed time after release (one day after release, two days after release, etc.). This plot gives an indication of the probability that the water at a certain point in the lake originated from a certain tributary a certain time ago.

6. Problems Encountered and Proposed Solutions: None

7. Projected Activities for Next Quarter: Synthesize results into a scientific report.

QUARTERLY PROGRESS REPORT - NOVEMBER 1986

1. Title: Generic Contaminant Model for Lake St. Clair

2. Principal Investigators: T. D. Fontaine, G. A. Lang and S. J. Hull

3. Organization: Great Lakes Environmental Research Laboratory-NOAA
2300 Washtenaw Avenue, Ann Arbor, MI 48104

4. Objectives: (1) To develop a generic model that will aid in understanding contaminant transport, behavior, and fate in the study area; (2) to develop or obtain data which can be used to quantify the major inputs, losses and storages of contaminants in the connecting channels; (3) to test models of contaminant transport, behavior, and fate with whatever data become available, if adequate.

5. Progress Since Last Report:

A. One-Box Generic Contaminant Model.

The EPA Chemical Transport and Fate Model, TOXIWASP, is being used to simulate contaminant residence time, concentration, fate, exposure and environmental effects in the Lake St. Clair system for a range of physicochemical contaminant properties and loading scenarios. Loads are applied as variable duration, step input functions. The lake is modeled as a completely mixed, one-box system using average physical lake data. The results of these studies will be used to generate sets of graphs to aid in developing management strategies for an array of organic compounds. Initial investigations considered the effect of chemical partition coefficients, decay constants, diffusion coefficients and contaminant load duration and magnitude on the time to remove 90% of the added contaminant mass (Figure 1). These studies indicate the following:

1. for a given duration of loading the magnitude of the load does not affect the time to remove 90% of the added mass due to the linearity of the transformation terms,
2. the time to remove 90% of the added mass increases with increasing chemical partition coefficient,
3. the time to remove 90% of the added mass decreases with increasing chemical decay rate,
4. the time to remove 90% of the added mass decreases with increasing sediment-water exchange rate for medium to high partition coefficients,
5. the sediment-water exchange rate has little effect on the time to remove 90% of the added mass for low partition coefficients; i.e., the flux of chemical leaving the system via outflow dominates.

Currently, chemical concentration versus time plots are being generated for the water column and active sediment layer. In addition to the parameters identified above, the initial water column and sediment layer concentrations and the load magnitude are also expected to impact the predicted concentration time-series.

B. Multi-Segment Contaminant Model.

Much effort during the past quarter has been directed towards amassing and formatting Lake St. Clair physical data for the 126 segments (42 water column, 42 mixed layer, 42 deep layer). These data included segment depths and volumes, interfacial areas and mixing lengths, and suspended solids loading rates. In addition, the wind induced flow fields generated by D. Schwab's hydrodynamic model had to be re-formatted to conform to the space- and time-scales of our model.

Chloride was used as a conservative ion to verify the transport and diffusion components of the model. The model was driven by chloride loads estimated from data collected by G. Bell during a cruise in July, 1974. According to wind measurements made during the cruise, a northeasterly wind of 6 m/s was used to drive the flow field. Calculated concentrations from the model compare well with the depth-averaged, in-lake chloride data collected on the same cruise (Figure 2). Simulations generated using other wind speeds and directions were in less agreement with the observed values.

The model was also used to simulate the water column and sediment distributions of 137-Cesium in Lake St. Clair. Because Cesium partitions similarly to organic contaminants, it can be used to determine how well the model will predict temporal and spatial distributions of actual contaminants. Data were collected from sediment cores taken by J. Robbins. Two assumptions were made: 1) the solids flux into the active layer equals the solids flux out of the active layer, and 2) the chemical partition coefficient is represented as a function of the sediment type in the active layer. Initial results indicate very good agreement between calculated and observed 137-Cesium concentrations.

Current efforts include determining the effects of stochastic flows vs. steady flows on the fate and transport of contaminants in Lake St. Clair.

6. Problems Encountered and Proposed Solutions: Lack of available water column data for all three organic contaminants, lack of loading data for HCB and OCS, and lack of agreement between time of PCB measurements and loading data.

7. Projected Activities for Next Quarter: Work will continue with the one-box model in an effort to generate concentration profiles over time for several chemical and loading conditions. In addition, a simple biomass partitioning model will be incorporated to investigate bioaccumulation of contaminant by aquatic organisms. Work will continue using the 126-box model to simulate the fate and transport of three organochlorines (PCB, OCS, and HCB).

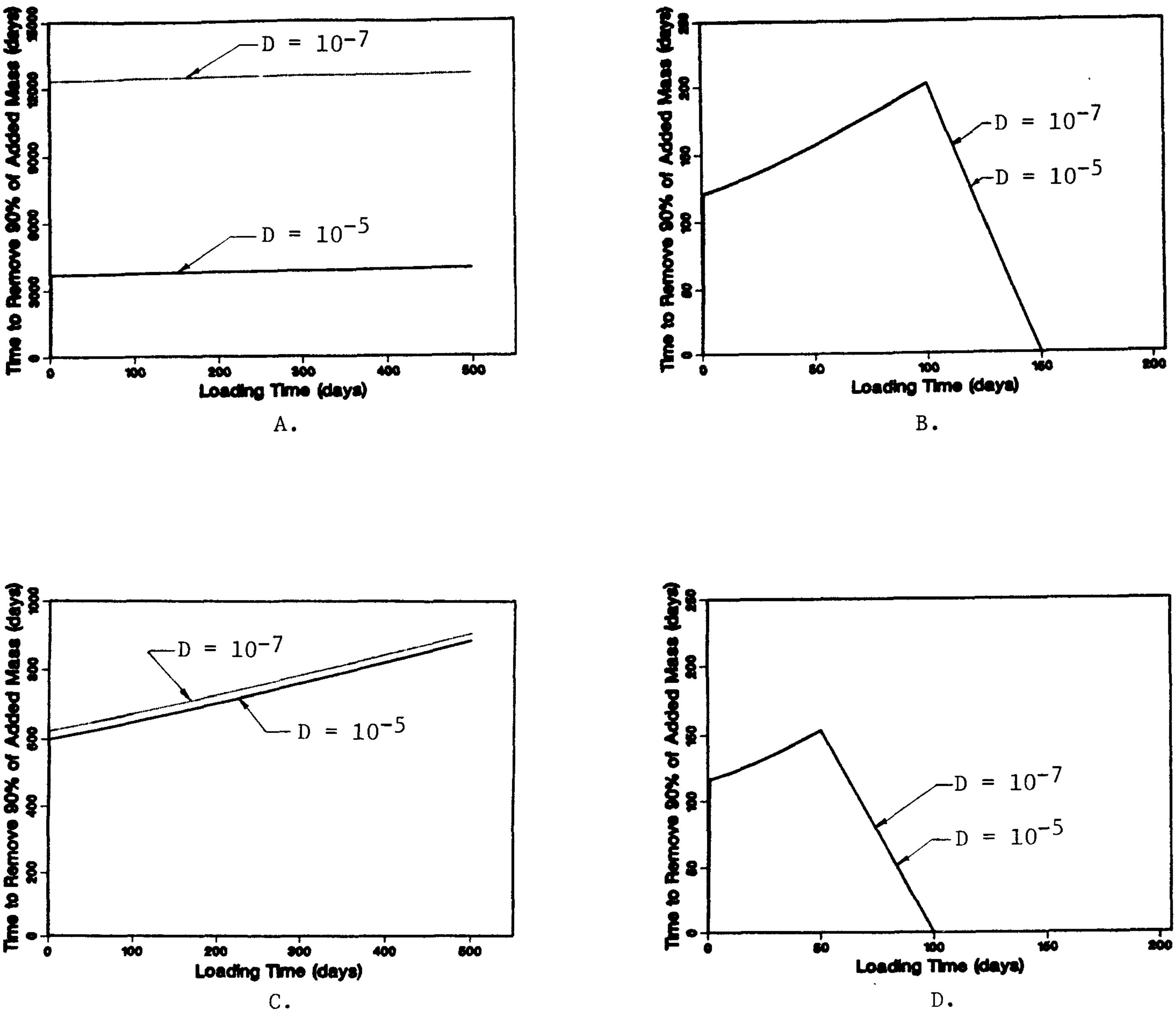


Figure 1. The effect of varying chemical partition coefficient (KP), decay rate, and diffusion rate (D) on the time to remove 90% of the added chemical mass. Diffusion coefficient units are cm^2/sec. a) KP = 10^5 L/kg, decay = 0.0 day^{-1}, representative of benzo[a]pyrene, b) KP = 10^3 L/kg, decay = 0.0 day^{-1}, representative of di-n-butyl-phthalate, c) KP = 10^5 L/kg, decay = 0.03 day^{-1}, representative of DDE, d) KP = 10^3 L/kg, decay = 0.03 day^{-1}, representative of benzo[a]anthracene.

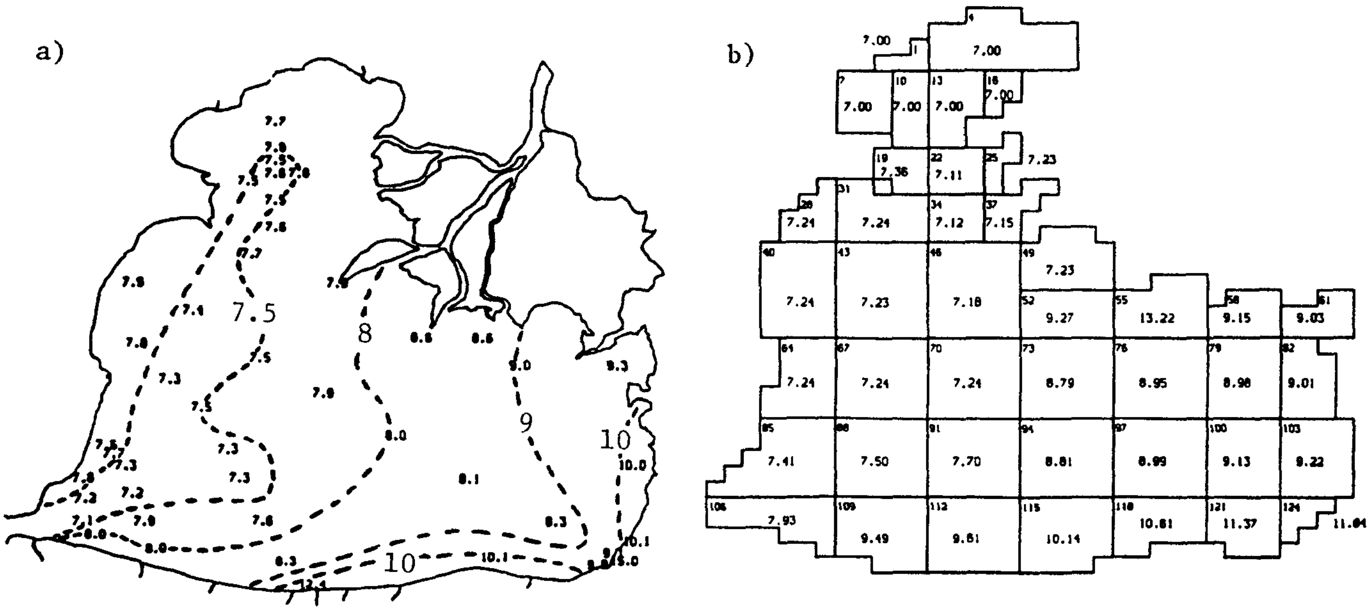


Figure 2. a) Lake St. Clair depth-averaged chloride concentrations (mg/l) observed during 15-24 July, 1974 cruise. Dashed lines represent approximate contours of data. b) Model-calculated chloride concentrations based on constant 6 m/s NE wind conditions.

QUARTERLY PROGRESS REPORT - NOVEMBER 1986

1. Title: Phosphorus Release from Sediments of Lake St. Clair

2. Principal Investigators: T. F. Nalepa and W. S. Gardner

3. Organization: Great Lakes Environmental Research Laboratory, NOAA, 2300 Washtenaw Ave., Ann Arbor, MI 48104

4. Objectives: (1) To quantify the release of phosphorus from sediments in Lake St. Clair. (2) To determine the importance of sediment phosphorus release relative to other sources. (3) To determine the role of benthic invertebrates in sediment phosphorus release.

5. Progress Since Last Report: Experiments to determine phosphorus excretion by the mussel *Lampsilis radiata siliquodea* were completed. Excretion rates were measured on individuals from two sampling sites on six sampling dates. Seasonal trends in excretion rates or consistent differences between the stations were not apparent (Table 1).

   A lake-wide quantitative survey of mussel populations in Lake St. Clair was conducted in September. Divers collected a total of 285 mussels at 30 stations. This data will be used to assess abundance, composition, biomass, and production.

   Preliminary work was conducted to determine the feasibility of measuring particle size selection and filtration rates of mussels using the Coulter Counter. The experiments were highly successful, and showed that mussels are capable of filtering 1,200 ml of water per hour and can select for particles less than 1 micron in size. A more detailed study is planned for 1987.

6. Problems Encountered and Proposed Solutions: None

7. Projected Activities for Next Quarter: Analyze data and begin writing papers.

Table 1. Mean (± S.E.) excretion rates of phosphorus (nmole p•gm•hr) by the mussel *Lampsilis radiata siliquodea* in 1986. The substrate at Station 1 consisted of sand, while the substrate at Station 24 was silt. The number of individual measurements on each date is given in parentheses.

Date	Station 1	Station 24
Apr 30	46.2 ± 13.9 (6)	18.3 ± 1.8 (3)
May 19	22.7 ± 3.7 (3)	-
Jul 15	15.7 ± 3.7 (4)	13.9 ± 2.7 (5)
Aug 4	45.1 ± 16.3 (5)	52.0 ± 12.2 (5)
Sept 16	65.4 ± 27.3 (5)	58.8 ± 11.9 (5)
Oct 15	54.8 ± 25.0 (5)	64.4 ± 13.5 (5)

QUARTERLY PROGRESS REPORT - NOVEMBER 1986

1. Title: Toxicokinetics of Organic Xenobiotics in the Mayfly Larvae, *Hexagenia*

2. Principle Investigators: P. F. Landrum and T. F. Nalepa

3. Organization: Great Lakes Environmental Research Laboratory, NOAA, 2300 Washtenaw Ave. Ann Arbor, MI 48104.

4. Objectives: (1) To assemble experimental systems for measurement of respiration and toxicokinetics. 2. To determine the toxicokinetics of selected PAH and PCB congeners in *Hexagenia*.

5. Progress Since Last Report: The monthly collections of *Hexagenia* have been completed for the field year. The last two collections were made at the end of September and the middle of November. The toxicokinetic experiments have been completed. The data analysis continues and is expected to be complete within the next quarter (Table 1). The uptake from water for Benzo(a)pyrene and hexachlorobiphenyl appear to be reasonably constant over the course of the season. Phenanthrene shows considerable variability. The reason for this variability is not clear. The depuration rate constants are highest in the late September collection for all compounds. These changes appear to be related to both temperature and season.

   In addition to the experiments with field collected organisms, a cooperative study with Dr. Mary Henry at the U. S. Fish and Wildlife Service is under way to examine the toxicokinetics of laboratory reared *Hexagenia*. This will permit studies of organisms that are the same age. Furthermore, this study will permit the examination of organisms at several instar levels. These data should help with the interpretation of the data from the field collected organisms. The first of the experiments in this series has been completed and the data is summarized in Table 2. In addition to the toxicokinetics, the respiration of the organisms is also being determined. This study will hopefully permit development of the relationship between the uptake from water and the rate of oxygen consumption. The oxygen and size relationships will hopefully be useful for determining the main variables affecting the variability in the accumulation data.

   The data collected from these experiments revealed that uptake rate constants are inversely proportional to the mass of the organisms. It is assumed that small animals have a large surface area to body ratio which accounts for the extremely large uptake observed. Estimates of uptake rate constants were based on initial rates and will need to be recalculated with a non-linear two compartment model because depuration is significant within the time frame of the experiments. Estimates of the uptake rate constants will increase when the two compartment model is used. Currently the uptake rate constants, as calculated with the model using initial rate assumptions, are 5 and 14 times greater than those determined previously for phenanthrene and benzo(a)pyrene respectively. A second experiment will be performed in late December.

6. Problems Encountered and Proposed Solutions: None

7. Projected Activities for Next Quarter: The remainder of the data from the kinetics studies will be analyzed and construction of the predictive simulation model will be initiated.

Table 1

Seasonal Uptake and Elimination Rate Constants for *Hexagenia limbata*

Month	Rate Constant	Benzo(a)pyrene	Phenanthrene	Hexachlorobiphenyl	Temp.
May	Ku[a]	68.5 ± 11.2	131.1 ± 46.8	47.5 ± 23.9	10[c]
	Kd[b]	0.011 ± 0.003	0.032 ± 0.004	0.007 ± 0.001	
June	Ku	67.0 ± 28.0	43.3 ± 12.0	44.2 ± 8.0	15
	Kd	0.006 ± 0.002	0.0076 ± 0.0016	0.005 ± 0.002	
July	Ku	101.9 ± 32.6	57.5 ± 5.0	40.8 ± 37.3	15
	Kd	0.013 ± 0.002	0.029 ± 0.002	0.005 ± 0.001	
Aug	Ku	65.1 ± 29.1	11.9 ± 4.0	40.8 ± 37.3	20
	Kd	lost	lost	0.007 ± 0.001	
Sept[d]	Ku	NC	NC	NC	20
	Kd	NC	NC	NC	
Sept[d]	Ku	76.3 ± 41.0	33.0 ± 8.0	95.0 ± 17.3	20
	Kd	0.028 ± 0.001	0.067 ± 0.008	0.017 ± 0.002	
Nov	Ku	40.9 ± 30.6	34.2 ± 7.2	45.5 ± 16.1	10
	Kd	0.010 ± 0.001	0.026 ± 0.002	0.004 ± 0.0006	

[a] Ku has been corrected for sorption to dissolved organic carbon and has units of mL g^{-1} h^{-1}.

[b] Kd has units of h^{-1}.

[c] Temperature is in degrees centigrade.

[d] The first collection in September was made during the first week of the month while the second collection was made at the end of the month.

NC = not calculated.

Table 2

Summary of Toxicokinetics Study with *Hexagenia*
Reared in the Laboratory
using Benzo(a)pyrene and Phenanthrene

Parameter	Benzo(a)pyrene	Phenanthrene
Ku (ml g^{-1} h^{-1})	633.6 ± 238.4	172.7 ± 69.7
Kd (h^{-1})	0.027 ± 0.008	0.094 ± 0.012
log BCF (Ku * Kd^{-1})	4.37	3.26
Half Life (h)	25.8	7.3

Mean animal size = 2.48 ± 1.35
Respiration = 0.51 ± 0.075 μg O_2 mg^{-1} h^{-1}
O_2 clearance = 90.3 ± 13.2 mL g^{-1} h^{-1}

QUARTERLY PROGRESS REPORT - NOVEMBER 1986

1. Title: Transport and Fate of Particle-Associated Tracers in Lake St. Clair and the Connecting Channels.

2. Principal Investigator: J. A. Robbins

3. Organization: Great Lakes Environmental Research Laboratory-NOAA 2300 Washtenaw Ave., Ann Arbor, MI 48104.

4. Objectives: (1) To determine levels of selected stable and radioactive tracers in sediments; (2) To determine patterns of accumulation and storage of tracers in the system; (3) To determine the extent and intensity of local integration processes; (4) To determine system response times and "trapping efficiency"; (5) to reconstruct where possible the history of contamination of the system by study of dated cores; (6) To provide an experimental basis for modeling the role of sediments in the regulation of contaminant levels; (7) to develop and apply mathematical models for the long-term transport and fate of tracers in the lake.

5. Progress Since Last Report: (1) All cores with the exception of the Johnson's Bay core (JB-85) have now been counted. All data are entered into computer files, (2) summary tables have been developed, (3) contouring programs have been developed and run to provide figures such as Fig. 1 which shows the activity of the radionuclide in surface sediments and the total storage, (4) two cores from Lake George have been collected and already analyzed for Cesium-137. Fig. 2. shows the distribution in core LG-86-1 along with the model distribution which yields a sedimentation rate of about 0.7 cm/yr. (5) Work has begun on a journal article by myself and Barry Oliver which will combine the results of radiometric measurements with the chlorinated organic data.

6. Problems Encountered and Proposed Solutions: Low activities of the radio nuclide require long counting times for adequate statistics. Analysis time is about 2 samples per day per counter. To facilitate turnaround, samples are counted on a second counter originally reserved for other research projects.

7. Projected Activities for Next Quarter: (1) I have received two additional sets of samples from Barry Oliver: sediment trap material from Lake St. Clair collected by Murray Charleton and surface sediment samples collected nine years earlier (1976) by CCIW from many of the same sites as the 1985 study. I will begin analyzing these samples on a reduced priority basis starting in this quarter. (2) I will continue work on the journal article and prepare visual and graphical materials for presentation of results at the forthcoming IAGLR meeting and UGLCCS workshops. (3) I will begin to coordinate the radionuclide and chlorinated organic data with the elemental analyses of R. Rossmann.

Concentration of Cesium-137 in surface (0-1 cm) sediments in 1985.

Vertically integrated activity of Cesium-137 (dpm/cm**2) in 1985.

Figure 1. Activity of Cs 137 in surface sediments and total accumulation of Cs-137.

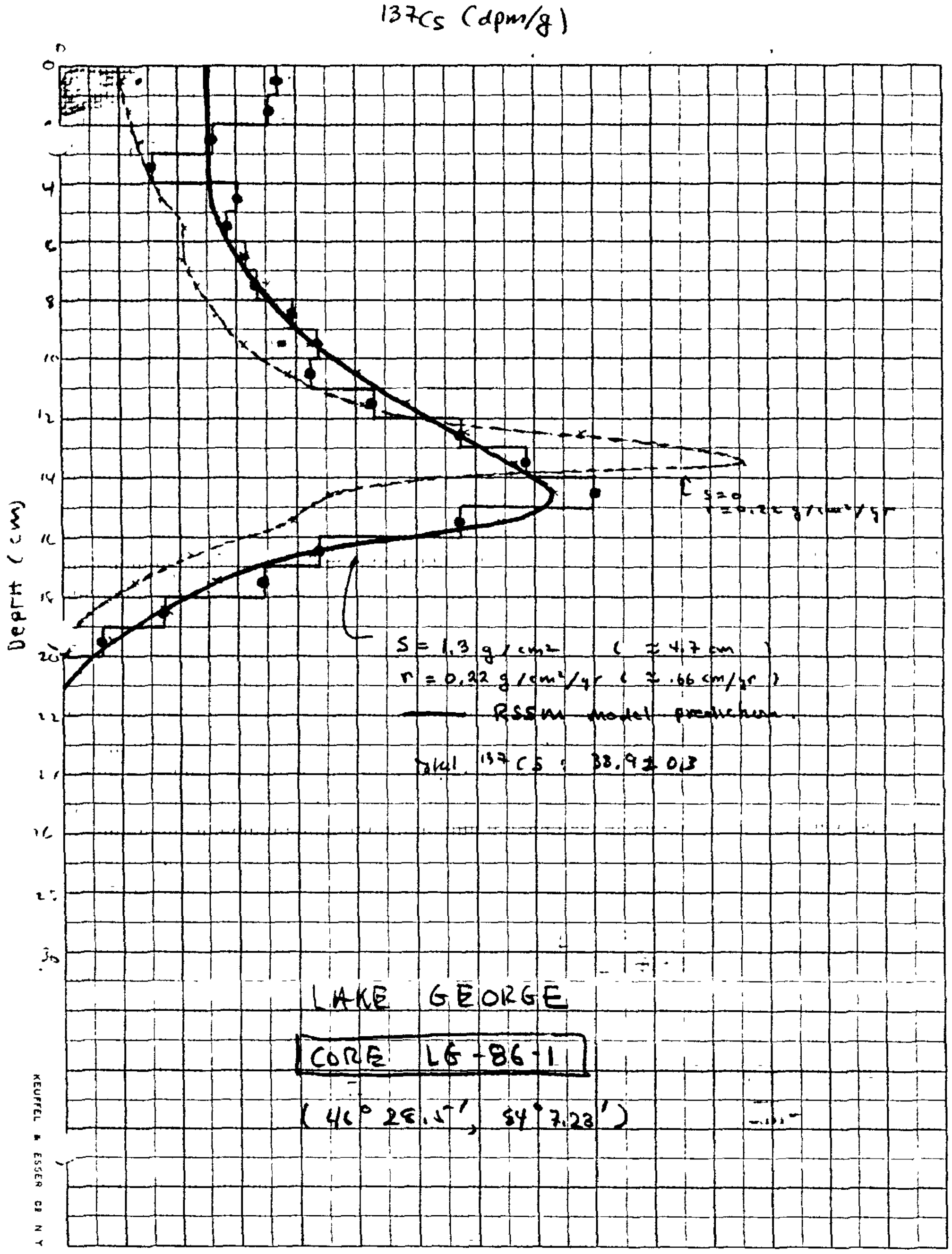


Figure 2. Vertical distribution of Cs-137 in a core from Lake George. The high sedimentation rate and excellent preservation of the fallout cesium record make this an excellent site for reconstruction of upstream contamination history.

QUARTERLY PROGRESS REPORT - NOVEMBER 1986

1. Title: Sediment Transport and Resuspension in Lake St. Clair

2. Principal Investigators: N. Hawley and B. Lesht

3. Organization: Great Lakes Environmental Research Laboratory - NOAA
2300 Washtenaw Avenue, Ann Arbor, MI 48104

4. Objectives: (1) To make observations of bottom currents, wave action, and sediment concentration in Lake St. Clair; (2) to experimentally determine erosion rates as a function of current velocity; (3) To use these data to determine sediment resuspension and transport in Lake St. Clair.

5. Progress since Last Report:

a) The three tripods deployed July 10 were retrieved on August 7; all worked successfully. The S4 current meters also provided data, but at this point we don't know how good it is.

b) The tripods were redeployed October 14; mine (stations 1 and 71) were retrieved October 29, Lesht's (station 75) on November 4.

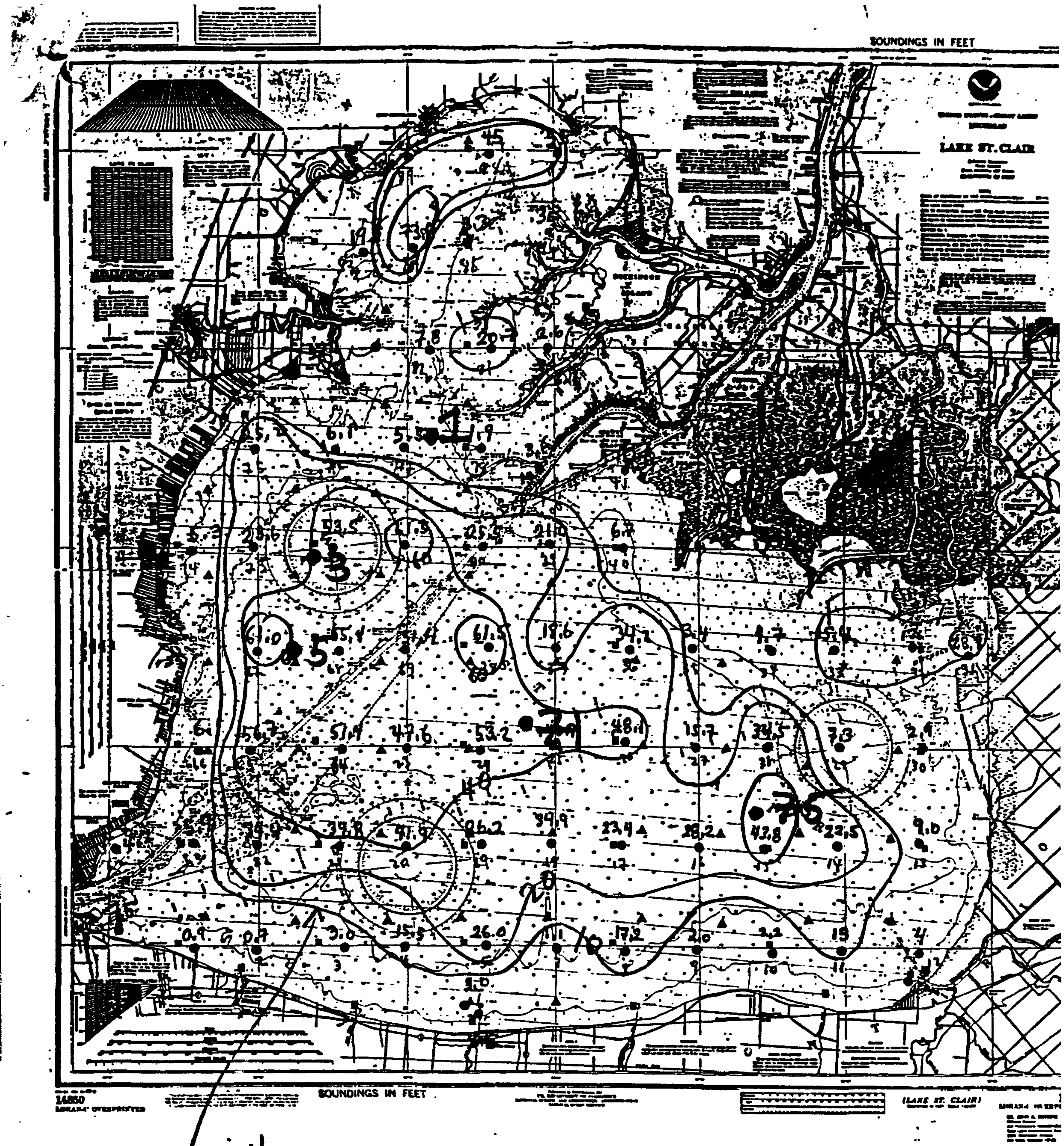
c) Results of the preliminary analysis of the spring deployments will be reported in two papers to be presented at the fall American Geophysical Union meeting.

6. Problems Encountered and Proposed Solutions:

The seaflume was not deployed because a suitable vessel was not available.

7. Projected Activities for Next Quarter:

Analyze data and begin writing report.



% clay/silt U of W particle size data.

Fig. 1 Very approximate locations of previous sediment sampling locations in Lake St. Clair.

▲ = CCIW (1970,1974); ■ =MOE (1983)
● = U. Windsor (1984)

QUARTERLY PROGRESS REPORT - NOVEMBER 1986

1. Title: Risk and Uncertainty Analysis of Contaminant and Phosphorus Models for the Connecting Channels and Lake St. Clair

2. Principal Investigator: T. D. Fontaine

3. Organization: Great Lakes Environmental Research Laboratory - NOAA-
2300 Washtenaw Ave., Ann Arbor, MI 48104

4. Objectives: (1) To use phosphorus models developed in other tasks for evaluating risks and uncertainties associated with phosphorus management strategies; (2) To use contaminant models developed in other tasks for evaluating risks and uncertainties associated with contaminant management strategies.

5. Progress Since Last Report: Work on this task will begin as soon as sufficient information can be gleaned from phosphorus and generic contaminant modeling tasks. Management alternatives that are generated as part of the Upper Great Lakes Connecting Channels Study will be evaluated as part of this task. Such alternatives might include changing the quantity, composition or timing of external pollutant inputs, altering ice breaking or shipping schedules, removal of in-place pollutant sources by dredging, or protection and enhancement of wetland areas. Uncertainty analyses will be conducted using Monte Carlo or related techniques. In the case of pollutant fate and transport models this would involve assigning probability distributions to loading rates, and then sampling repeatedly from this distribution over a large number of simulation runs to give a probable range of system behavior. Conducting this type of analysis will allow prediction of the probability distributions of toxicant concentrations to which an organism might be exposed. Combining this knowledge with information on the toxicity of a pollutant will allow calculations of risk to be made. Having defined exposure probabilities and toxicities, first-cut predictions of toxic effects, bioaccumulation etc., could be made by comparing modeled exposures with the results of laboratory and *in situ* exposure-toxicity tests.

6. Problems Encountered and Proposed Solutions: None

7. Projected Activities for Next Quarter: To continue work on phosphorus and generic contaminant models so that sufficient information will be available for testing management alternatives.