EVALUATING LAMPRICIDE TRANSPORT IN LAKE CHAMPLAIN

prepared for

Inland Fisheries Section
New York State
Department of Environmental Conservation
50 Wolf Road
Albany, New York 12233

by

Jeffrey P. Laible, P.E., Ph.D.
Civil Engineer
Holmes Road
Charlotte, Vermont 05445

and

William W. Walker, Jr., Ph.D.
Environmental Engineer
1127 Lowell Road
Concord, Massachusetts 01742

FINAL REPORT

APRIL 1987

EVALUATING LAMPRICIDE TRANSPORT IN LAKE CHAMPLAIN

prepared for

Inland Fisheries Section
New York State
Department of Environmental Conservation
50 Wolf Road
Albany, New York 12233

by

Jeffrey P. Laible, P.E., Ph.D.
Civil Engineer
Holmes Road
Charlotte, Vermont 05445

and

William W. Walker, Jr., Ph.D.
Environmental Engineer
1127 Lowell Road
Concord, Massachusetts 01742

FINAL REPORT

APRIL 1987

TABLE OF CONTENTS

1. INTRODUCTION

This report provides technical assistance to the New York State Department of Environmental Conservation (NYDEC) in projecting the transport of lampricides applied to Lake Champlain tributaries and bays. This information will be used by NYDEC to evaluate impacts on water supplies and on sensitive ecological areas and to design procedures for monitoring and mitigating impacts associated with the proposed lamprey control program.

Mathematical models are used to project the spatial and temporal histories of lampricide plumes resulting from specified treatment conditions (defined by applied concentration, duration, location, streamflow, wind regime, and season). Evaluations have been conducted at five sites and seven proposed treatments:

		Lampricide Treatment	
Site No.	**River/Creek**	**TFM**	**Bayer-73**
1	Great Chazy River	x	
2	Saranac River	x	x
3	Ausable River	x	x
4	Lewis Creek	x	
5	Putnam Creek	x	

Site locations are shown in Figure 1. For each site and treatment, the size and duration of the lampricide plume have been projected down to 50 and 20 ppb concentration levels.

2. TECHNICAL APPROACH

The projections are based upon mathematical models representing hydrodynamics and mass transport in the embayment and open lake waters associated with each application site. Two types of models are involved:

(1) **hydrodynamic model**, which predicts current speeds and directions in the lake surface layer as a function of wind speeds, wind directions, and topography (Laible, 1985a,1985b,1986); and

(2) **transport model**, which predicts concentration patterns as a function of current velocities, flows, applied concentrations, and topography (Walker,1985).

The models are tested against field data from Rhodamine dye studies conducted by the NYDEC between May and August, 1986 (Meyers,1986). The field data consist of river discharge rates, local wind conditions, dye concentrations and temperature recordings.

The tasks required for projecting the transport at each site are as follows:

(1) Based upon review of dye study results, define model regions.

(2) Develop finite element grid for hydrodynamic model.

(3) Run hydrodynamic model to generate lake circulation patterns for various wind conditions.

(4) Develop transport model grid.

(5) Using circulation patterns generated by the hydrodynamic model, simulate dye release experiments and test models by comparing observed and predicted dye concentrations.

(6) Use linked hydrodynamic and transport models to simulate lampricide plume under proposed treatment conditions (streamflow, applied concentration, duration) over a range of ambient wind conditions.

Results of preliminary simulations and sensitivity analyses are described in a previous report (Laible and Walker,1986). Initial sections of this report discuss basic concepts involved in the hydrodynamic analysis, mass transport analysis, and simulation of treatment conditions. Detailed results for each site are subsequently presented. A final section summarizes results and compares plume projections with those developed by Meyers (1986) based upon dye study results.

3. HYDRODYNAMIC ANALYSIS

Circulation patterns in the vicinities of the river mouths have been simulated using a steady-state finite element hydrodynamic model (FEM) which has been developed and applied elsewhere on Lake Champlain (Laible,1985a,1985b,1986). Lake circulation is driven by wind. The model first computes vertically averaged horizontal velocities of the fluid at discrete points (nodes) in the model region. Subsequently, the vertical distribution of the flow at each node is computed.

Wind-driven flows vary over depth owing to development of two types of currents: **drift currents** and **slope currents**. Drift currents are directly attributed to wind shear on the water surface. As water piles up or is drawn away from the shoreline, a surface elevation gradient develops. This gradient causes a pressure in the opposite direction of rising slope. This pressure drives fluid at the lower depths in a direction generally opposite to the direction of the wind (slope current).

The distribution of flow over depth generally starts with surface currents aligned with the wind, except in deeper regions, where they may deviate significantly due to Ekman frictional effects. With increased depth, the currents diminish and then reverse, pointing into the wind. In shallow regions, horizontal patterns are further complicated by effects of topography. Topographic flows interact with classical slope and drift currents to form relatively complex velocity distributions which can only be described by numerical models of the type employed in this study. For a detailed discussion of the finite element model, the reader is referred to Laible (1985a,1985b,1986).

From the complex flow distribution, it is possible to evaluate total flows in the mixed layer at each node in each of the orthogonal directions. This is done by integrating the vertical flow distribution over the mixed layer depth and keeping track of the total flow in each of four directions (north, south, east, and west). The vertically integrated flows are used in the two-dimensional mass transport model described below.

Circulation patterns have been generated at each site for eight different wind directions (N,NE,E,SE,S,SW,W,NW) under a standard wind speed (8.7 miles per hour). Flow patterns for other wind speeds have been generated by scaling (flow rates are roughly proportional to the square of the effective wind speed). These current fields have been used in modeling transport of dye and lampricide under appropriate wind conditions, as described below.

The hydrodynamic flow fields are presented as vector plots of vertically averaged flow at each node and total flux (velocity times depth) at each node. A total of 80 flow fields and their associated exchange and advective fields have been generated under this study. Examples for N and NE winds are presented for each site (e.g., Figures 17 and 18). Reversing the direction of the arrows on these figures yields circulation patterns under S and SW winds, respectively.

4. MASS TRANSPORT ANALYSIS

Mass transport simulations have been performed using S2D, a finite-difference model developed in previous studies on Lake Champlain (Walker,1985; Walker et al.,1986). As compared with the triangular, link/node grid used by the FEM, S2D simulations are performed on a grid of square cells. The model is two dimensional (latitude and longitude) and has been designed for application to the lake surface layer. Each cell is assumed to be completely mixed. Two basic modes of transport are considered:

(1) **advection** (based upon current velocities supplied by the hydrodynamic model), and

(2) **diffusion** (calculated from cell morphometry and an assumed diffusion or dispersion coefficient).

The advective circulation patterns supplied by the FEM reflect wind-driven currents in both directions across each cell interface. Exchange between adjacent cells can occur, for example, because of surface drift currents in one direction and bottom slope currents in the opposite direction. Currents supplied by the hydrodynamic model generally dominate flow and mass transport between cells; the diffusive component is relatively unimportant.

In a steady-state mode, S2D solves for concentration fields resulting from a fixed loading regime and flow field. In a dynamic mode, S2D solves for time-varying concentration fields resulting from transient loading regimes (e.g., 12-hour lampricide application). Flow fields are fixed for a given run, however. To simulate transient flow fields (e.g., resulting from shifting wind directions or varying tributary flows), a series of linked model runs must be performed; final concentrations for one run or time increment provide initial values for the next. Boundary conditions can be specified as fixed concentration or zero-gradient. The latter, more conservative boundary condition has been used in the simulations discussed below.

Consistent with previous model applications, a uniform cell size of 400 meters has been employed. Mean cell depths have been derived from Lake Champlain navigation charts, which refer to minimum lake elevations (28.4 meters msl). Under 1986 spring-summer conditions, lake elevations were near normal (1 to 1.2 meters above minimum). Accordingly, mean depths used in simulations have been increased by one meter relative to those displayed in cell grid maps (e.g., Figure 19). A maximum mixed-layer depth of 10 meters has been assumed in the hydrodynamic and transport simulations; accordingly, depths are truncated at 10 meters. As described below, shallower mixed layers are assumed in most simulations.

To permit use in transport simulations, flow fields generated by the hydrodynamic model must be interpolated and integrated along cell interfaces in the S2D grid. The resulting flows across each interface must also satisfy a water balance constraint on each cell. Considerable effort has been expended in refining the methodology used for these calculations, in order to minimize errors involved in linking the hydrodynamic and transport models. The resulting procedure consists of the following steps:

(1) read coordinates at FEM elements and nodes (x,y), corresponding velocities in each direction (+vx,-vx,+vy,-vy) and depths (z);

(2) translate FEM coordinates (x,y) to S2D grid coordinates (column,row);

(3) for each cell interface (excluding those bordering land masses):

  (a) divide interface into 3 segments of equal length;

  (b) interpolate products +vx*z, -vx*z, +vy*z, -vy*z at center of each segment, using weighted sum of values at nearest node or element in each quadrant (NE,SE,SW,NW); weight = squared inverse distance; maximum distance = 1 row/column width;

(c) sum interpolated values over 3 segments and multiply by cell width to get flows (m^3/day), positive and negative, across each segment;

(4) formulate water balance equations and calculate water balance error (total flow in - total flow out) for each cell;

(5) divide the grid into regions of approximately 30 cells;

(6) number regions in increasing order, so that highest numbered regions border on boundary conditions;

(7) for each region, in increasing order, correct water balance errors by adding a correction term for the net flow across each interface; exclude interfaces bordering cells in lower-numbered regions; select correction terms to minimize sum of squares of corrections, subject to water balance constraints; formulate problem using LaGrange Method of Undetermined Multipliers; solve resulting system of linear equations (containing roughly 3 x #cells unknowns) via Gauss Elimination;

(8) store resultant flow matrix for use in subsequent runs.

Prior to flow balance correction, median water balance errors for flow fields are on the order of 5%.

5. WIND VELOCITY DATA

Wind speed and direction partially determine circulation patterns predicted by the hydrodynamic model and the path of dye or lampricide released into the lake at a particular location and time. Wind velocity measurements taken during the dye release study at each site have been described previously (Laible and Walker,1986). The locations of wind measurements made in the field are critical; because of the sheltering effects of land masses, land-based measurements tend to under-predict effective wind speeds driving lake circulation. Wind speeds measured at the study sites were generally lower than speeds measured simultaneously at Burlington Airport. The latter provides a long term, quality wind record which has been shown to be more useful than onsite measurements for modeling purposes because of the factors discussed above (Laible and Walker,1987).

To provide perspectives on wind conditions, statistical analyses of the Burlington Airport wind record have been conducted for May through September of 1986 (3-hour observations). A cross-tabulation of wind speed and direction (Table 1) shows that there are two dominant wind events: South or Southeast (42.7% frequency) and North or Northwest (33.1% frequency). The frequency distribution for September only (the month proposed for lampricide application) is similar to that for May-

September. The distribution of total wind load (driving force for lake circulation, roughly proportional to square of wind speed) is also dominated by southerly and southeasterly winds (Table 2). Similar results have also been obtained for the May-September 1984 wind record from Burlington Airport (Laible and Walker,1987).

The wind load factor (calculated as shown in Table 2) is defined as the ratio of lake circulation rate at a given wind speed to the circulation rate at a standard wind speed of 8.7 mph. Flow fields have been generated by the FEM for each site and wind direction under a standard wind speed of 8.7 mph (load factor = 1.0). Figure 2 displays the three-day moving-average load factor vs. time for the May-September 1986 period. A three-day averaging period has been used because it is a reasonable time scale for evaluating lampricide plume duration (from TFM application to dilution below 50 or 20 ppb concentration levels). Moving average load factors range from .5 to 4. Figure 2 provides indications of the probabilities of encountering lake circulation rates which are higher or lower than those simulated. As discussed below, sensitivity analyses indicate that lampricide plume durations are strongly dependent upon circulation rates (wind load factors). Maximum plume areas and locations, however, are dependent primarily upon wind directions and mixed depths and are relatively insensitive to circulation rates.

6. MODEL TESTING

Table 3 summarizes dye study and lampricide treatment conditions at each site. The models are tested by simulating dye study conditions (flow, applied concentration, duration, wind) and comparing observed and estimated maximum dye concentrations in each model cell over the duration of the dye measurements. In these simulations, dye concentrations are rescaled to an applied concentration of 1000 ppb. Observed and predicted plumes are compared at 100 and 10 ppb, which correspond to 10-fold and 100-fold dilutions of the applied concentration, respectively. These comparisons are complicated by the following factors:

(1) variations in background fluorescence;

(2) potential errors in measurement coordinates;

(3) spatial data-reduction procedures;

(4) estimation of effective wind speeds and directions driving lake circulation during the study period.

These factors are discussed below.

Variations in background (natural) fluorescence limit the resolution of the dye studies, especially for detecting high dilution ratios. As indicated in Table 3, maximum detectable dilution ratios range from 93 to 470 for the various sites, based upon background fluorescence values ranging from .02-.03 assumed by Meyers(1986). The latter values are very conservative, however. Based upon review of dye measurements taken at locations distant from the application point and/or prior to the dye application, background fluorescence was highly variable and occasionally exceeded .1 units. A median value of .05 seems more representative; this reduces the resolution range to 56-236. Variations in background fluorescence likely account for some of the differences between observed and predicted concentration contours, particularly at the 100-fold dilution level.

As described by Meyers(1986), dye measurement locations were tracked using Loran-C units. Instrument drift and possible errors in the transformation to orthogonal coordinates (latitude and longitude) are additional potential sources of error in the dye data.

The model predicts the **mean** concentration in each cell and time step. The dye sampling strategy tended to exclude null samples (i.e., samples were more likely to be taken for laboratory analysis if the onboard fluorimeter indicated values which were significantly above background levels.). Because of this strategy, limited number of samples, and the complexities involved in spatial weighting, it is infeasible to calculate a mean dye concentration for each grid cell and time period for comparison with model simulations. Accordingly, the comparisons based upon the **maximum** dye concentration detected in each cell over the duration of the study. Both random and deterministic factors contribute to variability within model cells and partially explain differences between observed (maximum) and predicted (mean) dye concentrations.

For reasons discussed in Section 5, the selection of the appropriate wind regime (direction, speed) to drive the hydrodynamic model under dye study conditions is not straightforward. Each dye study has been simulated under three alternative sets of wind conditions:

(1) Burlington Airport directions and speeds (updated at 3-hour increments);

(2) Burlington Airport resultant direction and observed mean load factor, as defined in Table 2 (constant over entire simulation period); and

(3) Site directions and Burlington Airport speeds (updated at 3-hour increments).

Possibly because of sheltering effects, site measurements of wind speed are unrealistically low and have not been used in the simulations. The above wind cases provide a range of simulations for comparison with the observed dye plumes.

Based upon review of lake temperature profiles, the vertical distribution of dye with depth, and comparison of observed and predicted dye plumes, the maximum depth of the mixed layer is adjusted to represent dye study conditions. To reflect thermal buoyancy of the inflowing streams, shallower depths (1.5-2 meters) have been used in simulating spring dye studies at the Great Chazy and Saranac Rivers. Greater depths (5-10 meters) have been used in simulating the dye studies conducted during August at the remaining sites. Simulations of TFM and Bayer-73 applications (scheduled for September) assume maximum mixed layer depths of 5 meters. Subject to potential effects of inflow density currents (Section 10), the 5-meter mixed depth is conservative (likely causing over-estimation of plume areas) because the lake thermocline is likely to be found in the 15-20 meter range during September.

7. SIMULATION OF TFM APPLICATIONS

Once the hydrodynamic and mass transport models have been set up and tested for a given lake region, simulation of TFM applications to inflow streams is relatively straightforward. The application is represented as a square wave in stream concentration (12 or 16 hours in duration, depending upon site) at the prescribed treatment level. Hydrodynamic conditions (streamflow and lake circulation) are held fixed for a given run. Lake concentration levels respond to the transient input: concentrations near the river mouth increase during the application period and decrease thereafter, as the material is transported away from the mouth. The simulation is continued until all cell concentrations drop below 10 ppb.

To illustrate the methodology employed in simulations of river TFM applications, a "movie" of one treatment (Saranac River, North Wind) is shown in Figure 3. In this example, the simulation proceeds until all cell concentrations drop below 50 ppb (i.e., 90 hours). Results are summarized in the form of a plot of maximum TFM concentration in each model cell (last plot). Comparing this plot with the 50 ppb standard defines the spatial extent of the lampricide plume. Plume duration is defined as the time required (from start of lampricide loading to lake) for all cell concentrations to drop below the 50 ppb standard.

Simulations such as that shown in Figure 3 are conducted separately for each of eight wind directions and standard wind load. The resulting plume maps (cell-maximum concentrations for each wind direction) are subsequently overlayed and compared to produce a single, composite grid of cell-maximum concentrations. An example is shown in Figure 4. The grid is subsequently overlayed on a lake chart and contours are plotted for the 10, 20, and 50 ppb concentration levels. Derived in the way, the contours should surround the plume, regardless of wind speeds and directions which are present at the time of application. If the wind were from the south, for example, the plume would tend to fill the northern portions of the contours.

TFM simulations assume treatment conditions (streamflow, applied concentration, duration) specified in Table 3. Because the transport model is linear, simulation results can be rescaled to estimate maximum

TFM concentration contours for other sets of treatment conditions. This rescaling is performed based upon the total mass of lampricide applied:

$$C_o = C_t \; F$$

$$F = (Q_o \, Y_o \, T_o) \, / \, (Q_t \, Y_t \, T_t)$$

where,

F = scale factor

under proposed treatment conditions:

C_t = lake lampricide concentration (ppb)
Q_t = streamflow (cfs)
Y_t = applied lampricide concentration (ppb)
T_t = duration of application (hrs)

under simulated conditions (as defined in Table 3):

C_o = lake lampricide concentration (ppb)
Q_o = streamflow (cfs)
Y_o = applied lampricide concentration (ppb)
T_o = duration of application (hrs)

This rescaling is inaccurate for locations in the immediate vicinity of the river inflow, but is accurate for defining plume boundaries at 50 and 20 ppb concentration levels.

For example, the maximum concentration grid shown in Figure 4 is based upon a simulated streamflow of 600 cfs, applied TFM concentration of 1.5 ppm, and treatment duration of 12 hours. Since concentrations are displayed with a scale factor of 5, grid values greater then 10 would represent the 50 ppb plume under the simulated treatment conditions. Suppose that one wanted to use these results to predict the 50 ppb contours for treatment conducted at a streamflow of 800 cfs, applied TFM concentration of 2 ppm, and treatment duration of 12 hours. The first step is to calculate the scale factor:

$$F = (600 \text{ cfs} \times 1.5 \text{ ppm} \times 12 \text{ hrs}) \, / \, (800 \text{ cfs} \times 2 \text{ ppm} \times 12 \text{ hrs})$$

$$= .56$$

The grid cell value corresponding to 50 ppb would be 50 x .56 / 5 = 5.6. Thus, all cells in Figure 4 with scaled concentrations equal to or exceeding 5.6 would be inside the 50 ppb contour under the modified treatment conditions. Similar calculations can be performed to estimate other contour levels based upon the standard grid.

8. SIMULATION OF BAYER-73 APPLICATIONS

Simulation of Bayer-73 applications to delta areas is based upon the same principles, but is more complicated because the effective release period of the material must be considered. Bayer-73 is applied in a granular form (5% active ingredient bound to sand particles with a water-soluble adhesive). When the material hits the water, the some portion of the active ingredient is released immediately into the surface water. The sand particles sink and the remainder of the active ingredient is subject to slower release.

One laboratory study (Seeyle,1987) has shown that less than 35% of the active ingredient is released into the water, based upon a single overnight extraction in Lake Huron water (87 ppm alkalinity). Because of adsorption equilibria, however, multiple extractions may yield higher release percentages. Higher percentages may also be released into Lake Champlain waters because of differences in alkalinity.

Ho and Gloss (1987) describe results of a study of Bayer-73 levels following treatment in Seneca Lake, New York. A 101-acre plot in the vicinity of a lake inflow was treated at the prescribed rate of 100 lbs Bayer-73/acre (5% active ingredient). Concentrations of Bayer-73 were followed as a function of depth at nine stations over a 96-hour period and ranged from <10 to 573 ppb. All concentrations were below 50 ppb within 48 hours of treatment and below 10 ppb within 96 hours. Direct transfer of these results to other sites is impossible because concentration history is partially related to site-specific hydrodynamic factors (ambient lake currents, tributary inflow), as well as to water and sediment chemistry.

Of the nine stations monitored by Ho and Gloss, the shallow nearshore station (F) in the center of the treated region would be the least subject to hydrodynamic factors. Time series data from this station are plotted in Figure 5. Surface concentrations peaked at about 400 ppb between 4 and 6 hours after treatment. Mid-depth and near-bottom concentrations peaked at about 300 ppb between 2.5 and 5 hours after treatment. If the water in the vicinity of this station were completely isolated (no hydrodynamic exchange with surrounding regions) and if all of the applied active ingredient were dissolved in the water, a mass-balance calculation indicates that average Bayer-73 concentration in the region would peak at 550 ppb. Differences between the observed 300-400 ppb peak and the theoretical maximum value of 550 ppb are attributed to transport by lake currents flowing through the region, permanent binding of the active ingredient to the sand particles (lack of release), adsorption to lake bottom sediments, and decay in the water column.

Because effects of transport are potentially significant but were not quantitatively determined at the Seneca Lake site, the Ho and Gloss study does not show that less than 100% of the applied active ingredient was actually released into the water column. The difference between the observed and theoretical maximum concentrations is small enough to be explainable based upon hydrodynamic factors alone. Accordingly, 100% release is assumed in simulations of Lake Champlain Bayer-73 applications. Based upon the time series behavior observed by Ho and Gloss (Figure 5), an effective release period of 6 hours is assumed.

Sensitivity of Bayer-73 plume behavior to assumed release period is illustrated in Figure 6. In this simulation, Bayer-73 is applied at 100 lbs/acre to 175 acres near the mouth of the Saranac River under a north wind. Effects of alternative release periods (24, 12, 6, and 3 hours) on the simulated maximum concentrations and plume duration are shown. Plume duration is defined as the total length of time during which cell concentration exceeds the 50 ppb criterion. A longer release period increases dilution in ambient currents and decreases plume size and duration. As distance from the application area increases, the sensitivity of the simulated maximum concentrations to the assumed release period decreases. This reflects the fact that, over reasonable time scales for the release and under a given set of ambient conditions, the basic driving force for the creation of the lampricide plume in the surrounding lake waters is the total mass of active material applied (i.e., 5 lbs/acre), not its rate of application or rate of release (lbs/acre-hour).

Figure 6 indicates little difference between the 6-hour and 3-hour simulations. Accordingly, the 6-hour release period supported by the Ho and Gloss study is used in simulating Bayer-73 applications to Lake Champlain. Projections are conservative (i.e., under-predict cell-mean concentrations) because less than 100% of the active ingredient will be released into the water column and the dissolved material will be subject to various decay mechanisms (photolysis, adsorption, hydrolysis, uptake) as it is transported away from the application site.

9. SENSITIVITY ANALYSES

Sensitivity analyses indicate that, for a given site, applied concentration, and river flow, the most important factors determining the maximum area of the dye or lampricide plume are wind direction and the effective depth of the mixed layer. Figure 7 illustrates sensitivities of maximum plume area to wind load and mixed layer depth for the Saranac River TFM application under a north wind. Mixed depth and shoreline topography determine the availability of volume for dilution of the applied loading. Generally, plume areas will be greatest for wind directions which generate along-shore currents and hinder transport into deeper offshore regions. Wind speeds (which determine transport rates) generally have a strong influence on plume duration, but a weak influence on plume size and location, for a given wind direction.

Mechanisms responsible for decreasing lampricide or dye concentrations following application include:

(1) dilution in the lake volume contained within the simulation grid;

(2) transport out of the simulation grid via wind-driven currents;

(3) transport out of the simulation grid via river flow, as it moves through the lake towards the outlet;

(4) transport out of the simulation grid in the main lake flows to the north (driven by whole-lake water balance);

(5) decay due to various physical, chemical, biological mechanisms.

Generally, mechanism (1) is dominant for all simulations. Mass-balance calculations indicate that mechanisms (2) and (3) are relatively unimportant for the cases studied. Mechanisms (4) and (5) are potentially important over long time scales, but have not been considered in the simulations.

All simulations assume that lampricide behaves conservatively in the environment. Many studies have shown that TFM and, especially, Bayer-73 are subject to a number of physical, chemical, and biological processes which cause removal from the water column. Sediment adsorption and photolysis are considered to be important decay mechanisms; half-lives in the range of 2.5-10 days have been reported (NRCC,1985; Ho and Gloss,1987). Because these mechanisms are not accounted for, the simulations likely over-estimate the areas and durations of the lampricide plumes following treatment. Sensitivity analyses indicate that consideration of lampricide decay would generally have little effect on maximum plume areas (because these are generally achieved a within one or two days after treatment) but may have substantial effects on predicted plume duration.

10. DENSITY CURRENTS

The models assume that streams entering the lake are completely mixed into the lake epilimnion. Differences between inflowing stream temperature and lake surface temperature, as driven primarily by season, can create a potential for the inflowing stream to float or sink to lake layers of similar density. This phenomenon depends upon several factors, including temperature, flow velocities, stream and lake topographies (Fischer et al.,1979).

To provide regional perspectives on the driving forces for inflow density currents, stream and lake temperature records from the St. Albans Bay area of Lake Champlain have been analyzed. The data consist of weekly temperature measurements at two locations between 1982 and 1986, as derived from studies of St. Albans Bay being conducted by Water Resources Research Center of the University of Vermont. Figure 8 compares monthly-average stream and lake surface temperatures.

Average stream temperatures exceed the lake surface temperatures only during May. This creates a tendency for inflowing rivers to float on the lake surface for some distance, until the density gradient is dissipated by wind, other sources of turbulence, and thermal diffusion.

Stream temperatures average less than 1 deg-C below lake surface temperatures during June. As the season progresses from June through October, the stream becomes increasingly cool relative to the lake surface and a driving force for inflow plunging develops. During September, the month proposed for lampricide treatment, the average stream temperature (14 deg-C) is 5 degrees cooler than the lake surface (19 deg-C). Review of vertical temperature profiles from the Kingsland Bay area of Lake Champlain (Figure 9, from Smeltzer,1985) indicates that the 14-degree contour is found in a depth range of 15 to 25 meters during September. Thus, if no entrance mixing is involved, September streamflow would tend to plunge to the 15-25 meter level, spread laterally at that level and eventually dissipate. In reality, depending upon stream velocity and topography, some entrance mixing would tend to occur and cause entrainment of warm lake surface waters, until the "plunge point" is encountered (Fischer et al.,1979). With entrance mixing, the plunging inflow stream would seek a shallower depth range and be incorporated sooner into the mixed layer.

Effects of density currents are apparent in some of the dye study results. Mean and maximum dye concentrations are displayed by site and depth interval in Figure 10. Concentrations have been rescaled to an applied concentration of 1000, so that a value of 100 represents a 10-fold dilution of inflowing river water. As described by Meyers (1986), dye concentrated at the lake surface during May 1986 plume studies at the Great Chazy and Saranac Rivers (1 and 6 in Figure 10). This is attributed to stream temperatures which were 6-10 deg F warmer than lake surface temperatures (Table 3). During the August surveys, streams were slightly cooler than lake surface (1-3 deg F) and the dye was mixed to greater depths.

Seasonal variations may influence projections of lampricide behavior based either upon the dye studies (Meyers,1986) or upon the two-dimensional models discussed below. The dye studies were conducted during May and August, as compared with the proposed mid-to-late September lampricide treatment period. Because of differences in inflow plunging potential and mixed layer depths, the dye studies are limited analogues for plume behavior during the proposed treatment period. Additional interpretations of model results, given the potential for density currents, are presented in the Sections 13-18.

11. EMPIRICAL PLUME PROJECTIONS

To supplement TFM plume projections based upon the models and upon contour plotting (Meyers,1986), an alternative projection technique employing dye measurements has been developed and applied to each site. The technique is based upon two fundamental concepts which result from the linearity of mass transport:

(1) Under a given set of hydrodynamic conditions, plume response is related to the total mass of applied material (streamflow x applied concentration x duration).

(2) Once the material has been applied, maximum lake concentrations decay exponentially as a function of time and distance from the river inflow, at rates which reflect ambient hydrodynamics.

The first concept permits rescaling of dye concentrations measured in the lake to TFM concentrations under prescribed treatment conditions, based upon the ratio of TFM load to dye load. This rescaling is inaccurate at low travel distances and times (low dilution ratios for the inflowing river). The second concept permits approximate extrapolation of maximum plume concentration as a function of time and space on a semi-log scale. The exponential decay rate reflects the net influences of all transport processes operating during the study period. This is an approximation because effective dilution rates may vary with distance from the inflow.

The method is illustrated in Figure 11 using data from the May/June dye study at the Saranac site. Measured dye concentrations are rescaled to TFM concentrations based upon the TFM/dye load ratio. The logarithms of projected TFM concentrations are plotted as a function of time and distance from the river inflow. Time is measured relative to the start of plume entry to the lake. Distance is calculated from the latitude and longitude coordinates of the dye measurements relative to the river mouth. To illustrate vertical aspects of plume behavior, different symbols are used to represent surface (x) and subsurface samples (o).

Projections of time and distance required to reach 50 and 20 ppb maximum concentration levels are based upon extrapolations of straight lines defining the upper portions of the scatter plots. These are illustrated by the dashed lines in Figure 11. The linearity of these lines is consistent with the exponential decay discussed above ((2) above).

One advantage of this technique is that it is simple and easily implemented, given a data file containing dye measurements as a function of latitude, longitude, depth, and time. It avoids the complex spatial averaging and interpolation procedures required to generate contour diagrams. Spatial analysis is still required, however, to project directional aspects of the plume.

The major limitation of the technique is that the projections are valid only for the hydrodynamic conditions under which the dye study occurred. Projections may differ for wind speeds, wind directions, or lake mixed depths which are significantly different from those encountered during the dye study. Such variations can only be considered by conducting multiple dye studies or by using simulation models of the type described below.

At long distances and times (high dilution factors and low concentrations), the dye measurements are increasingly sensitive to variations in background fluorescence. As discussed above, very conservative (low) values for background fluorescence have been used; this may lead to underestimation of decay rates and overestimation of the plume durations and distances using this technique.

Despite limitations, this technique is useful for projecting and summarizing dye plume behavior as a function of time, distance, and depth. Based upon comparison of surface (x) and subsurface (o) samples, Figure 30 shows that the dye plume was initially concentrated at the surface (high concentrations at short times and distances from the river inflow). As time and distance increased, however, the dye became more evenly distributed with depth.

12. RESULTS

Table 3 summarizes treatment conditions for each site, as prescribed by NYDEC. The upper limit of the specified flow range has been used in the simulation of TFM and Bayer-73 treatments. Methodology for rescaling simulation results to project plumes resulting from other streamflows, concentrations, or durations is discussed above. Projected plume areas (maximum TFM or Bayer-73 concentration > 50 ppb), distances, and durations are displayed for each treatment and wind direction in Figures 12,13, and 14, respectively.

The following summary of figure numbers will assist readers in locating key results for each site:

	Chazy	Saranac	Ausable	Lewis	Putnam
Model Region	15	25	40	53	63
Finite Element Mesh	16	26	41	54	64
Circulation Patterns	17-18	27-28	42-43	55-56	65-66
Transport Model Grid	19	29	44	57	67
Empirical Projections	20	30-31	45	58	68
Dye Simulations	21	32-33	46	59	69
Plume Projections	22-24	34-39	47-52	60-62	70-72

Detailed results are discussed below.

13. SITE 1 - GREAT CHAZY RIVER

Model results for Site 1, Great Chazy River, are summarized in the following Figures:

15 Model Region
16 Finite Element Mesh
17 Circulation Patterns - North Wind
18 Circulation Patterns - Northeast Wind
19 Transport Model Grid
20 Empirical Projection of TFM Plume Based upon Dye Meas.

21 Observed and Predicted Maximum Dye Concentrations
22 Maximum TFM Concentrations vs. Wind Direction
23 Cell Maximum TFM Concentrations
24 Maximum TFM Concentration Contours

The hydrodynamic and mass transport models have been developed, tested, and applied to the Great Chazy site using methods described in the above sections. Results and unique features of this site are discussed below.

Plume areas and durations projected for the Great Chazy TFM treatment generally exceed those projected for other sites because of two primary factors: the relatively high quantity of TFM applied (1885 lbs, Table 3) and the shallow nature of this lake region. Depths range from <1 to 4 meters in King Bay and shoreline areas to the south within the projected plume area (Figures 15, 19, 24). Because of shallow depths, dye or lampricide applied to the river is potentially transported over relatively long distances before being diluted to 50 and 20 ppb concentration levels. Shallow depths would also increase exposure of TFM to bottom sediments and light, however; this would tend to increase losses due to adsorption and photolysis mechanisms and thereby reduce the spatial and temporal extent of the plume.

The Great Chazy dye study was conducted in late May of 1986. Because the dye was applied 5.5 miles above the river mouth, there was considerable delay (29 hrs) and dispersion of the plume in the river before it reached the lake. To account for this, the effective loading period used in the dye simulation has been increased from 12 to 36 hrs and the effective inflow concentration has been reduced by a factor of 3, based upon observed dispersion of the dye at the river mouth. In simulating TFM applications, the effective loading period has been increased from 16 to 48 hours and the concentration at the mouth of the river has been reduced from 3.5 to 1.16 ppb. This assumes that dispersion in the river during the TFM application will be similar to that observed during the dye study. Because they depend primarily upon the total mass of TFM applied, projections of maximum TFM plume areas are insensitive to a reasonable degree of dispersion in the river above the lake.

Because the inflowing river averaged about 10 degrees F warmer than the lake surface temperature, the plume was initially concentrated at the lake surface. Figure 20 shows that at short distances from the inflow, maximum surface dye concentrations (x) were much higher than maximum subsurface concentrations (o). Field observations indicate that the dye was initially mixed only to the 1-2 meter level (Meyers,1986). At long distances (> 3000 meters), however, maximum dye concentrations were similar in surface and subsurface samples. This indicates that vertical mixing increased as the plume proceeded south, driven by the northern winds which were dominant after the dye entered the lake. Northern winds generated high flow velocities along the lake shore (Figure 17).

Dye plume simulations under three wind conditions are compared with observed surface and subsurface concentrations in Figure 21. Based upon the observed dye distribution, simulations assume a maximum mixed layer depth of 1.5 meters. The simulation using the resultant wind (North, Load Factor = 1.16) agrees best with the observations and successfully predicts the southern extent of the plume.

The proposed Great Chazy TFM treatment will occur at a streamflow of 150 cfs, applied concentration of 3.5 ppm, and duration of 16 hours. Projected cell maximum TFM concentrations are displayed as a function of wind direction in Figure 22. Generally, N, NW, or NE winds would be most conducive to transport of the applied TFM. Based upon simulation of northern winds, the projected 50 ppb contour would extent south to the mouth of the Little Chazy and the 20 ppb contour would extend to Trembleau Point (Figure 24).

Under other wind conditions (including dominant southern winds), the Great Chazy TFM plume would tend to remain within the King Bay region. The long plume durations (200-300 hours) predicted for SE, S, and SW winds (Figure 14) reflect "trapping" of material in extreme northern portions of the King Bay. Actual plume durations would be lower because of decay mechanisms which are not considered in the simulations.

14. SITE 2 - SARANAC RIVER

Model results for Site 2, Saranac River, are summarized in the following Figures:

- 25 Model Region
- 26 Finite Element Mesh
- 27 Circulation Patterns - North Wind
- 28 Circulation Patterns - Northeast Wind
- 29 Transport Model Grid
- 30 Empirical Projection of TFM Plume (June)
- 31 Empirical Projection of TFM Plume (August)
- 32 Observed and Predicted Maximum Dye Concentrations (June)
- 33 Observed and Predicted Maximum Dye Concentrations (August)
- 34 Maximum TFM Concentrations vs. Wind Direction
- 35 Cell Maximum TFM Concentrations
- 36 Maximum TFM Concentration Contours
- 37 Maximum Bayer-73 Concentrations vs. Wind Direction
- 38 Cell Maximum Bayer-73 Concentrations
- 39 Maximum Bayer-73 Concentration Contours

The hydrodynamic and mass transport models have been developed, tested, and applied to the Saranac River site using methods described in the above sections. Results and unique features of this site are discussed below.

During the May 31-June 1 dye study, the inflowing river averaged 7-11 degrees F warmer than the lake surface temperature, the plume was initially concentrated at the lake surface. Figure 30 shows that at short distances from the inflow, maximum surface dye concentrations (x) were much higher than maximum subsurface concentrations (o). At long distances (> 3000 meters), however, maximum dye concentrations were similar in surface and subsurface samples. This indicates that vertical mixing increased as the plume traveled out into the lake. Generally, the pattern is similar to that observed at the Great Chazy, except transport distances were somewhat shorter at Saranac because of greater depths and different wind conditions.

During the August dye study, inflow and lake surface temperatures were similar and the appeared in subsurface samples at shorter times and distances from the inflow (Figure 31). A tendency for subsurface dye concentrations to exceed surface values developed as the plume progressed (e.g., times 15-20 hours, distances 500-1000 meters). This may have been caused by plunging of the river inflow; based upon surface temperature measurements at the mouth of the river, however, the river was only 0-2 degrees F cooler than the lake surface temperature and thus there was little driving force for development of density currents. Temperature measurements in the river above the lake would provide an improved basis for evaluating the potential for density currents.

Another possible explanation for the dye distributions observed during the August survey involves extraneous sources of fluorescence in the region, which would tend to interfere with the dye measurements. Surveys of the Cumberland Bay region conducted prior to dye applications indicated occasional "hot spots" of high fluorescence which could not be readily explained (Meyers,J.A., NYDEC, Pers. Comm., 1987).

As discussed above (Section 3), transport directions often vary vertically within the mixed layer owing to drift and slope currents. A third explanation for the observed vertical behavior of the dye during the August study involves initial mixing, followed by shearing and transport in different directions within the upper and lower portions of the mixed layer. Under the southern winds which were dominant during the dye study, predicted net flow velocities in the vicinity of the river mouth are towards the north and east (Figure 27). The surface plume would tend to follow this path. Reverse currents on the bottom of the mixed layer, may have transported dye towards the south, however. Contour plots of maximum surface and subsurface dye concentrations (Figure 33) suggest that maximum dye concentrations were greater in regions south of the river mouth.

Figure 31 reveals two outliers in the log(TFM) vs. distance plot. These were derived from a vertical profile taken south and east of the river inflow (Column 6, Row 16 of the transport grid, Figure 29) approximately 30 hours after the dye plume reached the lake and 2500 meters from the river mouth. Dye concentrations varied with depth as follows (samples SB108, SB109, SB110):

Depth (m)	0	1.5	3
Dye (ppb)	.07	.44	1.3

Other samples in the same general vicinity showed less variation with depth and maximum concentrations less than .5 ppb. The field log indicates that the maximum depth at this location was 3 meters. If this is true, entrainment of organic bottom sediments may explain the elevated fluorescence of the bottom sample. The recorded maximum depth is inconsistent with the lake navigational chart (Figure 25), which indicates maximum depths in the range of 8.5-11 meters in this region.

Dye plume simulations under three wind conditions are compared with observed surface and subsurface concentrations in Figures 32 and 33 for the June and August surveys, respectively. During the June survey, the dye apparently tracked further to the east (reaching Cumberland Head) than predicted by any of the simulations (Figure 32). It is possible that actual winds were more from the west or southwest than indicated by the airport or site measurements. Agreement between observed and predicted peak dye concentrations is generally good for all simulations of the August release (Figure 33). The exception to this is the anomalous profile discussed above.

The proposed Saranac River TFM treatment will occur at a streamflow of 600 cfs, applied concentration of 1.5 ppm, and duration of 12 hours. Projected cell maximum TFM concentrations are displayed as a function of wind direction in Figure 34. Generally, N or NW winds would be most conducive to transport of the applied TFM. Based upon simulation of northern winds, the projected 50 ppb contour would extent south to the oil terminals and the 20 ppb contour would extend to Bluff Point (Figure 36).

Under other wind conditions, the Saranac TFM plume would tend to remain within the Cumberland Bay region. The long plume durations (120-140 hours) predicted for SE, S, SW, and W winds (Figure 14) reflect "trapping" of material in extreme northern portions of the Cumberland Bay. Actual plume durations would be lower because of decay mechanisms which are not considered in the simulations.

The proposed Bayer-73 treatment of the Saranac River mouth will involve application of 100 lbs/acre of granular Bayer-73 to 175 acres. Plume projections are displayed in Figures 37-39. Because the total mass of active ingredient applied (875 lbs, Table 3) is less than the mass of TFM applied (2424 lbs), Bayer-73 plume projections fall within the TFM applications. Sensitivity to wind direction is qualitatively similar to that discussed above for TFM. Because Bayer-73 is less stable (more subject to adsorption and photolysis) than TFM, projected plume areas and durations are also more conservative.

15. SITE 3 - AUSABLE RIVER

Model results for Site 3, Ausable River, are summarized in the following Figures:

The hydrodynamic and mass transport models have been developed, tested, and applied to the Ausable River site using methods described in the above sections. Results and unique features of this site are discussed below.

In contrast to the other treatment sites, which discharge into sheltered bays, the Ausable River discharges into a region which is directly exposed to the open lake (Figure 40). Lake depths drop off rapidly about 600 meters east of Ausable Point. Material transported east from the mouth should be dispersed rapidly. Potential transport distances are greater, however, in the shallow shoreline regions extending from Prey's Marina on the north to Port Kent on the south. In simulating dye and TFM applications, flow is assumed to be split equally between the upper and lower mouths. Projections of 20 and 50 ppb plume contours are insensitive to this assumption.

The Ausable dye study was conducted in early August 1986 under south winds. A vertical profile taken near the river mouth 4 hours after the plume reached the lake indicated good initial mixing with depth, with dye concentrations ranging from 1.2 to 1.6 ppb over a 12 meters of depth. Stream temperatures were only about 1 degree F cooler than the lake surface, so there was little driving force for development of density currents.

Because of the exposed nature of Ausable Point and good initial mixing, dye concentrations dropped off rapidly as a function of time and distance (Figure 45). The dye data are limited, however, by the lack of observations during the initial loading period (0-10 hours). One outlier is evident at 24 hours after dye plume entry and distance of 1500 meters from the Upper Mouth. This observation was taken in shallow waters (Depth = 1 meter) northwest of Ausable Point. It is possible that this measurement reflected dye loadings from the Little Ausable River, which was studied simultaneously. The timing of the measurement coincided with the arrival of the trailing edge of the Little Ausable dye plume (Meyers,1986) and the measurement was taken approximately 500 meters from the river mouth. Agreement between observed and predicted 10-fold and 100-fold dilution plumes is reasonable for all simulated wind conditions (Figure 46).

Because the offshore open lake waters are deep at this site relative to the assumed 5-meter mixed depth, the projections of offshore transport, particularly the 20 and 10 ppb contours, are likely to be very conservative. While a potential for inflow plunging exists at this site under fall treatment conditions, this potential would be reduced by mixing which would occur as the plume travels across shallow shoreline regions with relatively high ambient current velocities (Figures 42,43) before reaching thermally stratified regions.

The proposed Ausable River TFM treatment will occur at a streamflow of 400 cfs, applied concentration of 1.6 ppm, and duration of 12 hours. Projected cell maximum TFM concentrations are displayed as a function of wind direction in Figure 47. The plume is driven south in shallow shoreline regions under N, NW, or W winds and is driven north under E, SE, or S winds. Other wind conditions are more conducive to transport east into the open lake. Over a range of wind conditions, the simulated 50 ppb TFM plume extends from Port Kent on the south to the mouth of the Little Ausable River on the north. Because of open lake exposure, projected plume durations are relatively short (less than 40 hours for all wind directions, Figure 14).

The proposed Bayer-73 treatment of the Ausable River mouth will involve application of 100 lbs/acre of granular Bayer-73 to 250 acres. Plume projections are displayed in Figures 37-39. Because the total mass of active ingredient applied (1250 lbs, Table 3) is less than the mass of TFM applied (1725 lbs), Bayer-73 plume projections fall within the TFM applications. Sensitivity to wind direction is qualitatively similar to that discussed above for TFM. Because Bayer-73 is less stable (more subject to adsorption and photolysis) than TFM, projected plume areas and durations are also more conservative.

16. SITE 4 - LEWIS CREEK

Model results for Site 4, Lewis Creek, are summarized in the following Figures:

53 Model Region
54 Finite Element Mesh
55 Circulation Patterns - North Wind
56 Circulation Patterns - Northeast Wind
57 Transport Model Grid
58 Empirical Projection of TFM Plume Based upon Dye Meas.
59 Observed and Predicted Maximum Dye Concentrations
60 Maximum TFM Concentrations vs. Wind Direction
61 Cell Maximum TFM Concentrations
62 Maximum TFM Concentration Contours

The hydrodynamic and mass transport models have been developed, tested, and applied to the Lewis Creek site using methods described in the above sections. Results and unique features of this site are discussed below.

Lewis Creek empties into Hawkins Bay, a shallow lake region inside McDonough Point and Long Point (Figure 53). Under dominant south or southeast winds, the hydrodynamic model predicts a counter-clockwise circulation pattern in Hawkins and Town Farm Bay region (east of Thompson's and McDonough Points, Figures 55-56).

Direct measurements of current velocities were taken on several occasions during August and September of 1986 in offshore regions of Hawkins Bay (west of Gardiner Island) (Laible and Walker, 1987). Comparison of measured and modeled current velocities indicate that the hydrodynamic model captures the general structure of circulation patterns in the region, but under-predicts current magnitudes, typically by a factor of two or more. Under-estimation of effective wind speeds driving lake circulation and/or the effective wind shear coefficient may contribute to differences between observed and predicted current speeds. The above field study results suggest that actual transport rates would be higher and plume durations would be shorter than those predicted at this site. Since the same methodology and wind shear coefficient have been used in all hydrodynamic simulations, this conclusion may hold for other sites as well.

Dense stands of aquatic weeds (water milfoil) are present in shallow regions of Hawkins Bay during the summer. These likely impede mixing of the creek inflows and alter the predicted circulation patterns shown in Figures 55 and 56. Because the hydrodynamic model does not account for the presence of these weeds, initial mixing of creek inflows is probably overestimated. This has minimal influence on simulation of 50 and 20 ppb plumes, however, because they generally extend beyond the weed-infested regions. Weed beds would have less influence under fall treatment conditions compared with summer dye study conditions.

The Lewis Creek dye study was conducted in mid August of 1986 under variable winds with a resultant direction from the west. Interpretation of dye study results at this site is complicated by the high storm flows which were present during the study and by variations in background fluorescence in the Hawkins and Town Farm Bays owing to turbid inflows from Lewis and Little Otter Creeks. Another limitation is lack of data from shallow regions of Hawkins Bay near the creek mouths.

The vertical distribution of fluorescence at this site was complex. At some locations and times, peak concentrations were found at depths of 7.6 meters. At others, the dye was well-mixed to depths of 15 meters. Still at others, the dye was concentrated at the surface (0-3 meters). Density currents attributed to cold storm inflows, variations in background fluorescence, entrainment of organic material in bottom samples, and shearing into surface and bottom currents likely contributed to the complex vertical distribution observed at this site. The stormy conditions provided a less than ideal data set for model testing and plume projection.

Decay of peak dye concentration as a function of time and distance was reasonably exponential (Figure 58). Concentration projections at long times and distances are probably over-estimated because actual background fluorescence levels were higher than the assumed value (.02 ppb). Model predictions for various wind conditions show the 10-fold and 100-fold dilution contours further to the east and south than the measurements indicate (Figure 59). This may be attributed to the presence of weed beds and other limitations in the dye data discussed above. The measured and predicted plume areas are in good agreement.

The proposed Lewis Creek TFM treatment will occur at a streamflow of 50 cfs, applied concentration of 6.5 ppm, and duration of 12 hours. Projected cell maximum TFM concentrations are displayed as a function of wind direction in Figure 60. Under dominant SE, S, or SW winds, the plume is transported north and east on counter-clockwise currents towards Town Farm Bay. North winds cause transport west towards McDonough Point. The projected maximum 50 ppb contour for all wind conditions (Figure 62) fills Hawkins Bay (inside McDonough and Long Points). The 20 ppb contour extends from the mouth of Kingsland Bay into Town Farm Bay at a point east of Point Bay Marina.

Under typical wind loads, projected plume duration for the Lewis Creek treatment ranges from 20 to 80 hours (Figure 60). Actual plume durations would be lower because of decay mechanisms which are not considered in the simulations and because observed current speeds are under-predicted by the hydrodynamic model.

17. SITE 5 - PUTNAM CREEK

Model results for Site 5, Putnam Creek, are summarized in the following Figures:

63 Model Region
64 Finite Element Mesh
65 Circulation Patterns - North Wind
66 Circulation Patterns - Northeast Wind
67 Transport Model Grid
68 Empirical Projection of TFM Plume Based upon Dye Meas.
69 Observed and Predicted Maximum Dye Concentrations
70 Maximum TFM Concentrations vs. Wind Direction
71 Cell Maximum TFM Concentrations
72 Maximum TFM Concentration Contours

The hydrodynamic and transport models have been developed, tested, and applied to the Putnam Creek site using methods described in the above sections. Results and unique features of this site are discussed below.

Putnam Creek discharges into a narrow portion of South Lake Champlain (Figure 63). The potential for transport of lampricide over long distances is limited by the relatively small quantity of TFM applied (686 lbs vs. 876-2424 lbs for other sites, Table 3) and by dilution in lake currents and advective flows. Moving east from the mouth, lake contours follow a shallow shelf and subsequently drop of sharply into the main channel (11-14 meters). Because of lake advection and dominant southern winds, plume transport would most likely occur towards the north. Moving north in the main channel, maximum depths decrease from 11-14 meters to 7-9 meters in the region north to Crown and Chimney Points. The likelihood that this region will be thermally stratified under fall treatment conditions is low.

Advection from south to north, as driven by inflows from the southern watersheds, is a potentially important source of dilution which has not been considered in the simulations discussed below. Based upon drainage area ratio (158 vs. 2900 km^2), lake advection would provide an initial dilution ratio of 18 for the applied TFM. This would reduce the applied TFM concentration from 8.5 to .47 ppm, once the streamflow is mixed with the lake advective flows. Further decreases would occur as a result of wind-driven currents and volume dilution considered in the simulations.

The Putnam Creek dye study was conducted in mid August of 1986 under light southern winds. Interpretation of dye study results at this site is complicated by the high storm flows which were present during the study and by variations in background fluorescence owing to the turbid character of the South Lake. Because of the cold storm flows, the river was roughly 3 degrees F cooler than the lake surface. Near the river inflow, the dye was sharply concentrated at a depth of 3 meters. As time and distance from the dye loading increased, a more uniform distribution with depth was achieved (Figure 68).

The observed 100-fold dilution contour was located near Yellow House Point, about 2000 meters north of the creek inflow (Figure 69). Variations in background fluorescence may cause over-statement of the observed dye plume. Model projections for a maximum mixed-layer depth of 5 meters put this contour about 1200 meters north of the inflow. Lack of complete mixing in the lake cross-section near the river inflow likely contributes to the under-estimation of the plume. Additional simulations assuming a maximum mixed-layer depth of 2 meters show better agreement with the observations. This does not physically describe the situation, however, because the dye was well mixed to depths up to 6 meters at the northern edge of the plume; i.e., lack of mixing occurred only near the river inflow.

The proposed Putnam Creek TFM treatment will occur at a streamflow of 30 cfs, applied concentration of 8.5 ppm, and duration of 12 hours. Projected cell maximum TFM concentrations are displayed as a function of wind direction in Figure 70. Consideration of lake advection would shift the plume directions towards the north and provide additional dilution. The predicted maximum 50 ppb contour extends from the town of Crown Point on the south to below Yellow House Point on the north (Figure 72). These simulations assume a maximum mixed layer depth of 5 meters under proposed treatment conditions. Assuming a more conservative maximum mixed-layer depth of 2 meters places the 50 ppb and 20 ppb contours at the 20 and 10 ppb contours, respectively, shown for the 5-meter mixed depth simulations in Figure 72.

Under typical wind loads, projected 50-ppb plume duration for the Putnam Creek treatment ranges from 50 to 120 hours (Figure 60). Actual plume durations would be lower because TFM decay mechanisms and dilution in lake advective flow are not considered in the simulations.

18. CONCLUSION

The plume projections described above are conservative estimates of transport resulting from lampricide applications under the prescribed treatment conditions. This section reviews important concepts that should be considered in interpreting the results. Plume projections are also compared with those developed by Meyers (1986) based directly upon dye measurements.

Assuming that significant density currents do not develop, plume area projections are conservative because a maximum mixed layer depth of 5 meters has been assumed, whereas actual mixed layer depths exceeding 12 meters are anticipated for September conditions. The assumed mixed layer depth has a greater influence on simulations of deeper lake areas (e.g., Ausable) than on simulations of shallower lake areas (e.g., Great Chazy).

Predicted contours refer to the **mean** concentration in the mixed layer at a given latitude and longitude. Individual samples taken within the mixed layer at given location will be higher or lower than the predicted mean value. Testing of the predicted **mean** dye concentrations against the observed **maximum** concentrations in each model cell considers this source of variability. Such comparisons are hindered by variations in background fluorescence, which influence the observed maximum concentrations, particularly at high dilution ratios (low dye concentrations).

Additional factors contributing to conservatism in the projections include:

(1) Lampricide decay mechanisms are not considered.

(2) Field studies have shown that current speeds predicted by the hydrodynamic model are lower than measured values, at least at the Lewis Creek site (Laible and Walker, 1987).

(3) Transport and dilution attributed to lake advective flow (as driven by the whole-lake water balance) are ignored.

Consideration of these factors would have more influence on predicted plume durations than on plume locations and maximum areas.

Figure 73 provides additional information on plume duration. For each treatment, the logarithm of the maximum TFM or Bayer-73 concentration (maximum of eight wind directions) is plotted against time in 50-hr increments. As discussed above, the long tails on the Great Chazy and Saranac decay curves reflect trapping of material in the extreme northern portions of King and Cumberland Bays, respectively, under south winds. The relatively slow decay of the Putnam TFM curve reflects lake morphometry; because dilution in the lake advective flow has been ignored, however, the Putnam decay curve over-estimates lake concentrations, particularly at long times which would facilitate mixing of the plume with the lake cross-section. Potential effects of lampricide decay are represented in Figure 73 by super-imposing decay rates of .07 and .23 day^{-1} on the simulated dilution curve for each treatment. These rates correspond to half-lives of 10 and 3 days, respectively, a reasonable range for decay of TFM or Bayer-73 attributed to photolysis and sediment adsorption (NRCC,1985; Ho and Gloss,1987).

One limitation of the maximum concentration grids (e.g., Figure 23) is that they may under-estimate maximum concentrations in the immediate vicinities of the river inflows because of possible incomplete mixing. This limitation should not influence peak concentrations in the vicinities of the projected 50 and 20 ppb contours, however.

Another, potentially more severe limitation is the possibility that density currents will develop under fall treatment conditions because of temperature differences between the inflowing river and lake surface. Such conditions would tend to increase the time and distance required for the plume to mix with the water column and reach 50 and 20 ppb concentration levels. To a degree, the shallow (5 meter) mixed depth assumption compensates for errors due to lack of complete mixing. Assuming a (very conservative) maximum 2-meter mixed depth shifts the maximum concentration contours for each treatment outward, but in each case the 20 ppb contour for a 2-meter mixed depth falls inside of the 10 ppb contour shown for a 5-meter mixed depth.

The significance of inflow plunging would depend upon site characteristics (in particular, stream velocity, shoreline and bottom topography) and upon the presence of deep water intakes in the lake region. Additional modeling studies could be done to evaluate potential dilution above and below the inflow plunge point. Because of extensive data requirements and limitations in the state-of-the-art, however, a full three-dimensional modeling effort would not necessarily yield results which are more accurate or reliable than those derived from the two-dimensional models. A fall dye study is recommended to provide a basis for testing model projections under conditions which are more representative of the proposed treatment conditions.

Model projections of maximum plume area are compared with results derived directly from the dye studies (Meyers,1986) in Figure 73. The sketched contours of dye concentration were developed by Meyers using a contour plotting program. The shaded areas represent the maximum 50 ppb TFM contour based upon simulation of eight wind directions.

To compare the projections, the dye or TFM concentrations have to be rescaled based upon the ratio of dye load to TFM load (see Table 3). Based upon the loading ratio, the dye concentration contour corresponding to the 50 ppb TFM contour can be calculated for each site.

As shown in Figure 73, these dye concentrations are .09 ppb for Great Chazy, .12 ppb for Saranac (August), .14 ppb for Ausable, .20 ppb for Lewis, and .15 ppb for Putnam.

Note that the dye projections reflect lake conditions (wind, mixed depth) which were present during the field study, whereas the model projections reflect maximum values for eight wind directions and a maximum mixed layer depth of 5 meters. When these differences are considered, the projections are generally consistent. Results for each site are described below.

For the Great Chazy, the 50 ppb TFM contour should correspond to the .09 ppb dye contour. As shown in Figure 73, however, the model projection more closely follows the .15 ppb contour. This difference is explained based upon differences in mixed layer depth between the dye study and the simulated fall treatment. As discussed above, the dye floated on the surface (< 2 meters) and did not mix vertically, except at long distances and times from the inflow. The model simulations are based upon a maximum 5 meter mixed depth. Thus, the simulated plume (shaded area) falls well inside the .09 ppb dye contour for the Great Chazy.

At the Saranac River site (August), the 50 ppb TFM contour should correspond to the .12 ppb dye contour. Results for the June survey are similar (not shown). Because of the effects of different wind directions, the model projections span a range of contours. The southern portion of the model plume reflects simulation of northern winds. For south winds representative of the dye study, model projections correspond roughly to the 0.20 ppb dye contour. Some of this inconsistency may be attributed to effects of variations in background fluorescence and the relatively low resolution of the Saranac dye study for detecting high dilutions of the river inflow. Because of the inconsistency between the projections, the Saranac site is a likely candidate for the fall dye study recommended above.

Agreement between the simulated Ausable TFM plume and the .14 ppb dye contour is good. The southern area of the model plume extends well beyond the .05 ppb dye contour because of effects of northern winds which were not present during the dye study.

Agreement between the simulated Lewis Creek TFM plume and the .20 ppb contour is also good. The dye study was conducted under shifting westerly winds. Simulation of southern and northern winds causes the plume to extend beyond .20 ppb contour to areas further west and north, but generally within Hawkins Bay.

The Putnam Creek results are also consistent. The shaded model plume coincides with the predicted .15 ppb dye contour. The dye study was conducted under prevailing southerly winds.

REFERENCES

Fischer, J.B., E.J. List, R.C.Y. Ho, J. Imberger, and N.H. Brooks, Mixing in Inland and Coastal Waters, Academic Press, New York, 1979.

Ho, K.T.Y. and S.P. Gloss, "Distribution and Persistence of the Lampricide Bayer 73 Following a Control Application", Canadian Journal of Fisheries and Aquatic Sciences, Vol. 44, No. 1, pp. 112-119, 1987.

Laible, J.P., "Phosphorus and Transport in Stevens Brook Wetland in SAB", Completion Report to University of Vermont Water Resources Research Center, June 1985a.

Laible, J.P., "Hydrodynamic Component of the Lake Champlain Offshore Hatchery Discharge Study", prepared for Vermont Department of Buildings, December 1985b.

Laible, J.P., "Coupled Finite Element and Boundary Model for Flow and Transport in Lakes", Draft Manuscript Submitted to Advances in Water Resources, 1986.

Laible, J.P. and W.W. Walker, "Evaluating Lampricide Transport in Lake Champlain", prepared for New York State Department of Environmental Conservation, Progress Report, December 1986.

Laible, J.P. and W.W. Walker, "Transport Studies in Hawkins and Town Farm Bays", prepared for Vermont Department of Buildings, January 1987.

Meyers, J.A., "Analysis of Rhodamine WT Dye Plume Studies on Lake Champlain, New York", Bureau of Monitoring and Assessment, New York State Department of Environmental Conservation, November 1986.

National Research Council Canada, "TFM and Bayer 73: Lampricides in the Aquatic Environment", NRCC Publication No. 22488, Associate Committee on Scientific Criteria for Environmental Quality, ISSN 0316-0114, 1985.

Seeley, J., Hammond Bay Laboratory, U.S. Fish and Wildlife Service, Unpublished Research on Bayer-73, Personal Communication, March 1987.

Smeltzer, E., "Lake Champlain Fish Hatchery Discharge Study", Vermont Department of Water Resources and Environmental Engineering, 1985.

Walker, W.W., "Documentation for P2D and S2D: Software for Analysis and Prediction of Water Quality Variations in Two Dimensions", prepared for Vermont Department of Buildings and Vermont Department of Water Resources and Environmental Engineering, April 1985.

Walker, W.W., J.P. Laible, E.M. Owens, and S.W. Effler, "Impact of an Offshore Hatchery Discharge on Phosphorus Concentrations in and Around Hawkins Bay, Lake Champlain", prepared for State of Vermont, Department of Fish and Wildlife, March 1986.

LIST OF FIGURES

LIST OF FIGURES (CT)

LIST OF FIGURES (CT)

LIST OF FIGURES (CT)

Figure 1
Lake Champlain Study Sites

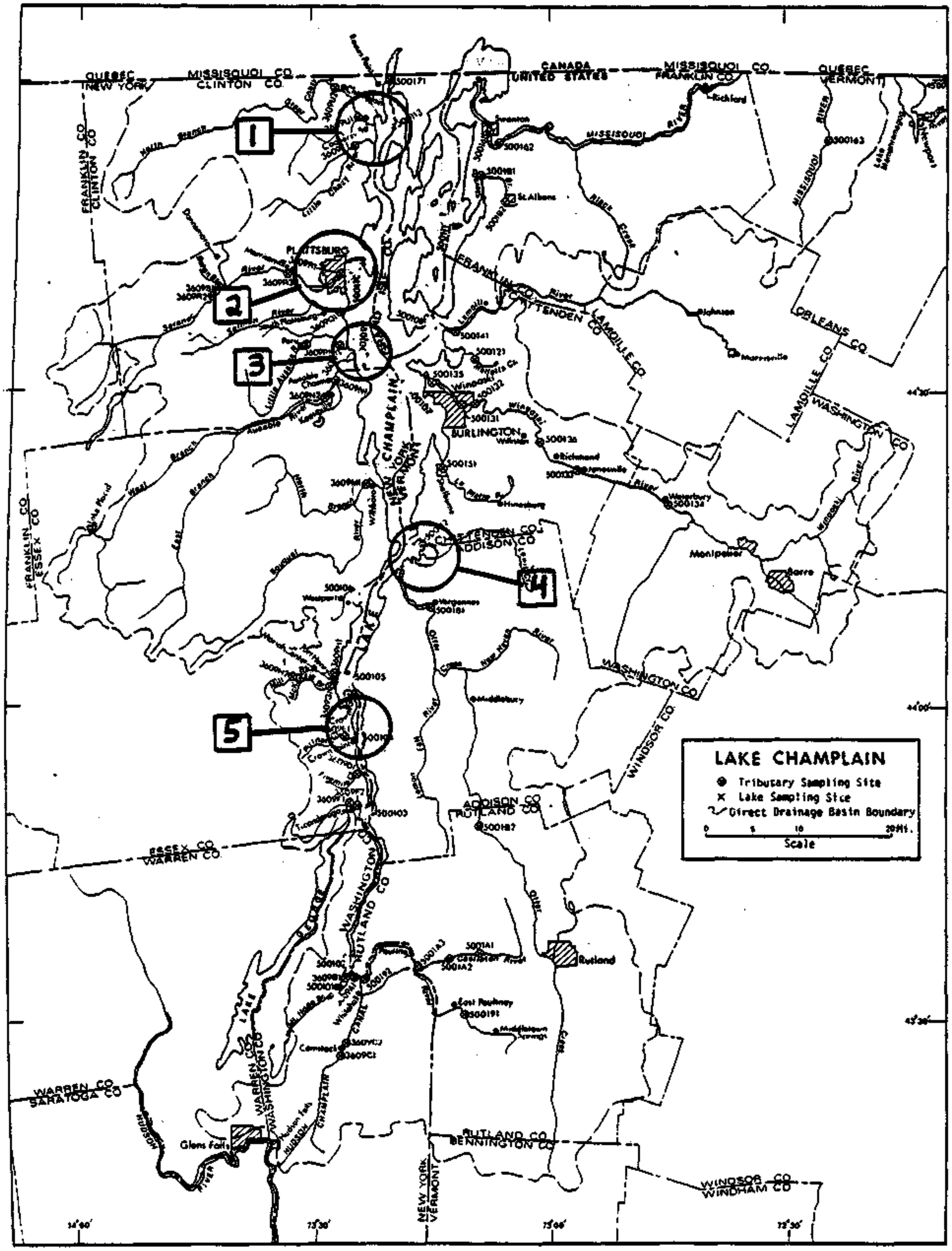


Figure 2
3-Day Moving-Average Wind Load Factor
Burlington Airport, 3-Hr Observations, May-September 1986

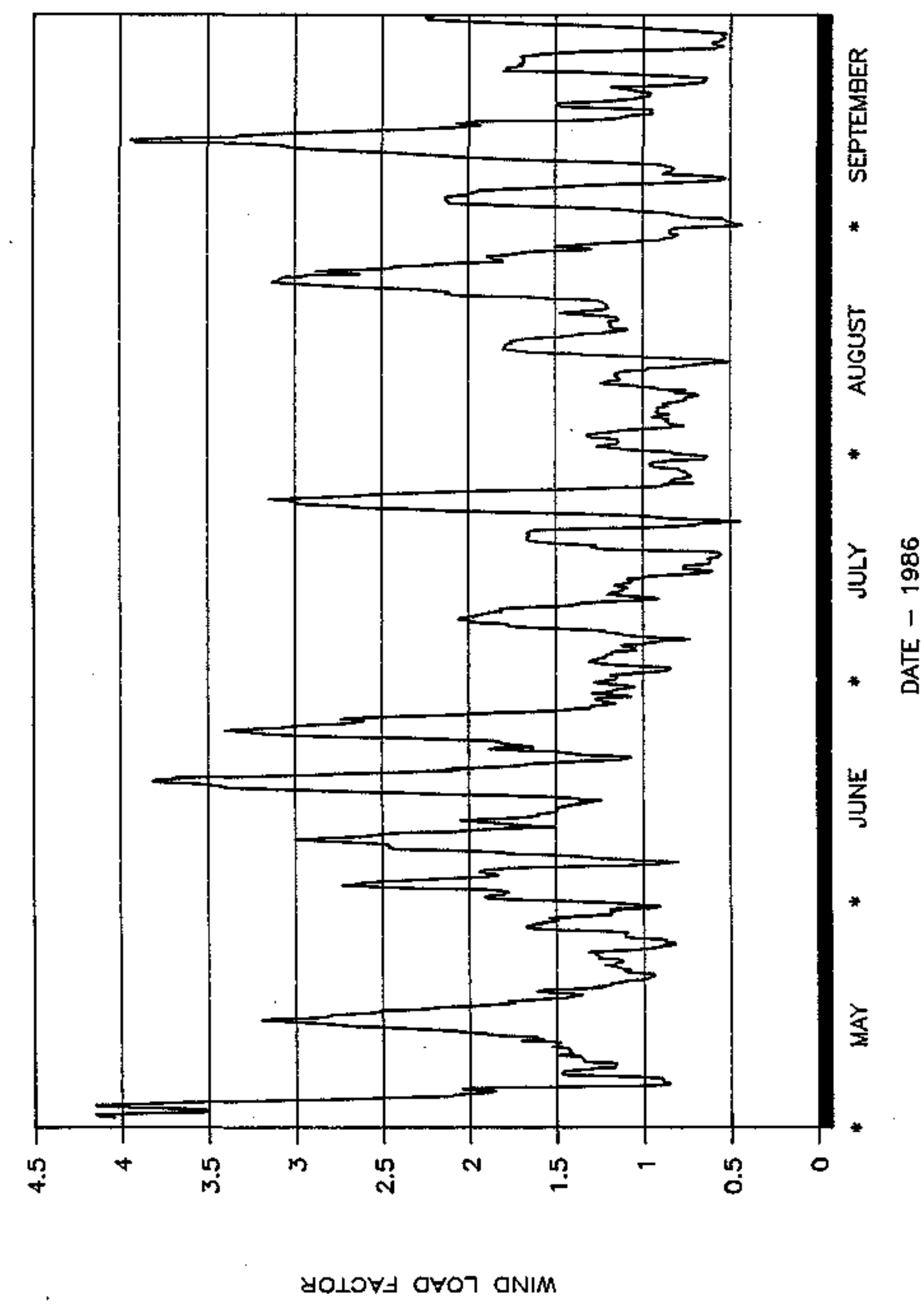


Figure 3

Simulated Response to Saranac TFM Treatment

North Wind, Grid Cell Size - 400 meters, Conc. Units - ppb/5

Model Region Shown in Figure 25

```
T = 0 HRS
     1  2  3  4  5  6  7  8  9 10 11 12 13 14 15
  +---------------------------------------------+
 4|xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx   |
 5|xxxxxxxxxxxxxxx            xxxxxxxxxxxxxxxxxx|
 6|xxxxxxxxx                  xxxxxxxxxxxxxxxxxx|
 7|xxxxxx                        xxxxxxxxxxxxxxx|
 8|xxxxxx                        xxxxxxxxxxxxxxx|
 9|xxxxxxxxx                        xxxxxxxxxxxx|
10|xxxxxx                           xxxxxxxxxxxx|
11|xxxxxx                              xxxxxxxxx|
12|xxxxxxxxx                              xxxxxx|
13|xxxxxxxxx                                    |
14|xxxxxxxxx                                    |
15|xxxxxxxxx                                    |
16|xxxxxxxxx                                    |
17|xxxxxxxxx                                    |
18|xxxxxxxxx                                    |
19|xxxxxxxxx                                    |
20|xxxxxxxxx                                    |
21|xxxxxxxxx                                    |
22|xxxxxxxxxxxx         xxx                     |
23|xxxxxxxxxxxx                                 |
24|xxxxxxxxxxxx                                 |
25|xxxxxxxxxxxx                                 |
  +---------------------------------------------+
```

```
T = 20 HRS
     1  2  3  4  5  6  7  8  9 10 11 12 13 14 15
  +---------------------------------------------+
 4|xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx   |
 5|xxxxxxxxxxxxxxx            xxxxxxxxxxxxxxxxxx|
 6|xxxxxxxxx                  xxxxxxxxxxxxxxxxxx|
 7|xxxxxx                        xxxxxxxxxxxxxxx|
 8|xxxxxx                        xxxxxxxxxxxxxxx|
 9|xxxxxxxxx                        xxxxxxxxxxxx|
10|xxxxxx 39  4  1                  xxxxxxxxxxxx|
11|xxxxxx 30 47 28  8  2               xxxxxxxxx|
12|xxxxxxxxx 50 24  6  1                  xxxxxx|
13|xxxxxxxxx 27 16  4                           |
14|xxxxxxxxx 12 10  3                           |
15|xxxxxxxxx  4  5  2                           |
16|xxxxxxxxx  1  3  1                           |
17|xxxxxxxxx     1  1                           |
18|xxxxxxxxx                                    |
19|xxxxxxxxx                                    |
20|xxxxxxxxx                                    |
21|xxxxxxxxx                                    |
22|xxxxxxxxxxxx         xxx                     |
23|xxxxxxxxxxxx                                 |
24|xxxxxxxxxxxx                                 |
25|xxxxxxxxxxxx                                 |
  +---------------------------------------------+
```

```
T = 40 HRS
     1  2  3  4  5  6  7  8  9 10 11 12 13 14 15
  +---------------------------------------------+
 4|xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx   |
 5|xxxxxxxxxxxxxxx            xxxxxxxxxxxxxxxxxx|
 6|xxxxxxxxx                  xxxxxxxxxxxxxxxxxx|
 7|xxxxxx                        xxxxxxxxxxxxxxx|
 8|xxxxxx                        xxxxxxxxxxxxxxx|
 9|xxxxxxxxx                        xxxxxxxxxxxx|
10|xxxxxx 13  1                     xxxxxxxxxxxx|
11|xxxxxx  3  4  3  1                  xxxxxxxxx|
12|xxxxxxxxx 15  5  1                     xxxxxx|
13|xxxxxxxxx 22  7  1                           |
14|xxxxxxxxx 23  8  2                           |
15|xxxxxxxxx 20 10  3  1  1                     |
16|xxxxxxxxx 13 10  4  2  1  1                  |
17|xxxxxxxxx  7  9  4  2  2  1                  |
18|xxxxxxxxx  4  7  4  3  2  1                  |
19|xxxxxxxxx  1  5  4  2  1  1                  |
20|xxxxxxxxx     3  2  2  1                     |
21|xxxxxxxxx     1  1  1                        |
22|xxxxxxxxxxxx         xxx                     |
23|xxxxxxxxxxxx                                 |
24|xxxxxxxxxxxx                                 |
25|xxxxxxxxxxxx                                 |
  +---------------------------------------------+
```

```
T = 90 HRS
     1  2  3  4  5  6  7  8  9 10 11 12 13 14 15
  +---------------------------------------------+
 4|xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx   |
 5|xxxxxxxxxxxxxxx            xxxxxxxxxxxxxxxxxx|
 6|xxxxxxxxx                  xxxxxxxxxxxxxxxxxx|
 7|xxxxxx                        xxxxxxxxxxxxxxx|
 8|xxxxxx                        xxxxxxxxxxxxxxx|
 9|xxxxxxxxx                        xxxxxxxxxxxx|
10|xxxxxx                           xxxxxxxxxxxx|
11|xxxxxx                              xxxxxxxxx|
12|xxxxxxxxx                              xxxxxx|
13|xxxxxxxxx  1                                 |
14|xxxxxxxxx  2                                 |
15|xxxxxxxxx  3                                 |
16|xxxxxxxxx  5  1           1                  |
17|xxxxxxxxx  8  1           1  1               |
18|xxxxxxxxx  9  2  1  1  1  1  1               |
19|xxxxxxxxx 10  3  1  1  1  1  1               |
20|xxxxxxxxx  9  4  2  2  2  2  1               |
21|xxxxxxxxx  7  5  3  3  2  2  1  1            |
22|xxxxxxxxxxxx  4  4  3xxx  2  1  1            |
23|xxxxxxxxxxxx  4  3  3  2  2  1               |
24|xxxxxxxxxxxx  3  3  3  2  1  1               |
25|xxxxxxxxxxxx  3  3  3  2  1  1               |
  +---------------------------------------------+
```

```
T = 10 HRS
     1  2  3  4  5  6  7  8  9 10 11 12 13 14 15
  +---------------------------------------------+
 4|xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx   |
 5|xxxxxxxxxxxxxxx            xxxxxxxxxxxxxxxxxx|
 6|xxxxxxxxx                  xxxxxxxxxxxxxxxxxx|
 7|xxxxxx                        xxxxxxxxxxxxxxx|
 8|xxxxxx                        xxxxxxxxxxxxxxx|
 9|xxxxxxxxx                        xxxxxxxxxxxx|
10|xxxxxx 33  2                     xxxxxxxxxxxx|
11|xxxxxx228 94 24  4                  xxxxxxxxx|
12|xxxxxxxxx 27  9  1                     xxxxxx|
13|xxxxxxxxx  6  3                              |
14|xxxxxxxxx  1  1                              |
15|xxxxxxxxx                                    |
16|xxxxxxxxx                                    |
17|xxxxxxxxx                                    |
18|xxxxxxxxx                                    |
19|xxxxxxxxx                                    |
20|xxxxxxxxx                                    |
21|xxxxxxxxx                                    |
22|xxxxxxxxxxxx         xxx                     |
23|xxxxxxxxxxxx                                 |
24|xxxxxxxxxxxx                                 |
25|xxxxxxxxxxxx                                 |
  +---------------------------------------------+
```

```
T = 30 HRS
     1  2  3  4  5  6  7  8  9 10 11 12 13 14 15
  +---------------------------------------------+
 4|xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx   |
 5|xxxxxxxxxxxxxxx            xxxxxxxxxxxxxxxxxx|
 6|xxxxxxxxx                  xxxxxxxxxxxxxxxxxx|
 7|xxxxxx                        xxxxxxxxxxxxxxx|
 8|xxxxxx                        xxxxxxxxxxxxxxx|
 9|xxxxxxxxx                        xxxxxxxxxxxx|
10|xxxxxx 23  2                     xxxxxxxxxxxx|
11|xxxxxx  7 11  9  4  1               xxxxxxxxx|
12|xxxxxxxxx 30 13  4                     xxxxxx|
13|xxxxxxxxx 31 14  4                           |
14|xxxxxxxxx 24 14  4  1                        |
15|xxxxxxxxx 14 11  4  1                        |
16|xxxxxxxxx  6  9  4  2  1                     |
17|xxxxxxxxx  2  6  4  2  1                     |
18|xxxxxxxxx  1  6  2  1                        |
19|xxxxxxxxx     2  1  1                        |
20|xxxxxxxxx                                    |
21|xxxxxxxxx                                    |
22|xxxxxxxxxxxx         xxx                     |
23|xxxxxxxxxxxx                                 |
24|xxxxxxxxxxxx                                 |
25|xxxxxxxxxxxx                                 |
  +---------------------------------------------+
```

```
T = 60 HRS
     1  2  3  4  5  6  7  8  9 10 11 12 13 14 15
  +---------------------------------------------+
 4|xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx   |
 5|xxxxxxxxxxxxxxx            xxxxxxxxxxxxxxxxxx|
 6|xxxxxxxxx                  xxxxxxxxxxxxxxxxxx|
 7|xxxxxx                        xxxxxxxxxxxxxxx|
 8|xxxxxx                        xxxxxxxxxxxxxxx|
 9|xxxxxxxxx                        xxxxxxxxxxxx|
10|xxxxxx  4                        xxxxxxxxxxxx|
11|xxxxxx  1  1                        xxxxxxxxx|
12|xxxxxxxxx  4                           xxxxxx|
13|xxxxxxxxx  7  1                              |
14|xxxxxxxxx 11  2                              |
15|xxxxxxxxx 15  3  1     1  1  1               |
16|xxxxxxxxx 15  4  1  1  1  1  1               |
17|xxxxxxxxx 13  5  2  1  1  1  1               |
18|xxxxxxxxx 11  6  3  2  2  2  1               |
19|xxxxxxxxx  7  6  4  3  3  2  1               |
20|xxxxxxxxx  4  6  4  3  3  2  1               |
21|xxxxxxxxx  1  4  4  3  3  2  1               |
22|xxxxxxxxxxxx  3  3  3xxx  1  1               |
23|xxxxxxxxxxxx  1  2  2  1  1                  |
24|xxxxxxxxxxxx     1  1                        |
25|xxxxxxxxxxxx     1  1                        |
  +---------------------------------------------+
```

```
MAXIMUM CONCENTRATIONS (ALL TIMES)
     1  2  3  4  5  6  7  8  9 10 11 12 13 14 15
  +---------------------------------------------+
 4|xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx   |
 5|xxxxxxxxxxxxxxx            xxxxxxxxxxxxxxxxxx|
 6|xxxxxxxxx                  xxxxxxxxxxxxxxxxxx|
 7|xxxxxx                        xxxxxxxxxxxxxxx|
 8|xxxxxx                        xxxxxxxxxxxxxxx|
 9|xxxxxxxxx                        xxxxxxxxxxxx|
10|xxxxxx 44  5  1                  xxxxxxxxxxxx|
11|xxxxxx235105 35  9  2               xxxxxxxxx|
12|xxxxxxxxx 51 24  6  1                  xxxxxx|
13|xxxxxxxxx 32 17  4                           |
14|xxxxxxxxx 25 14  4  1                        |
15|xxxxxxxxx 20 11  4  1  1  1  1               |
16|xxxxxxxxx 16 10  5  2  1  1  1               |
17|xxxxxxxxx 13  9  5  2  2  1  1               |
18|xxxxxxxxx 12  8  4  3  2  2  1               |
19|xxxxxxxxx 10  7  4  3  3  2  1               |
20|xxxxxxxxx  9  6  4  3  3  2  1               |
21|xxxxxxxxx  7  5  4  3  3  2  1  1            |
22|xxxxxxxxxxxx  4  4  3xxx  2  1  1            |
23|xxxxxxxxxxxx  4  3  3  2  2  1               |
24|xxxxxxxxxxxx  3  3  3  2  1  1               |
25|xxxxxxxxxxxx  3  3  3  2  1  1               |
  +---------------------------------------------+
```

Figure 4

Site: Saranac River (Example)

Cell Maximum TFM Concentrations

Composite Projections for Eight Wind Directions, Units = ppb/5

Flow = 600 cfs, Applied TFM Conc. = 1.5 ppm, Duration = 12 hrs

```
      1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18
   +------------------------------------------------------+
  3|xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx      MAX   |
  4|xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx            |
  5|xxxxxxxxxxxxxxx  9  8  7  6xxxxxxxxxxxxxxxxxxxxx      |
  6|xxxxxxxxx 16 14 11  9  7  6xxxxxxxxxxxxxxxxxxxxx      |
  7|xxxxxx 13 20 16 12  9  6  5  5xxxxxxxxxxxxxxxxxx      |
  8|xxxxxx 15 33 21 13  9  6  5  4xxxxxxxxxxxxxxx         |
  9|xxxxxxxxx 46 23 14  9  7  4  4  3xxxxxxxxxxxx         |
 10|xxxxxx107 66 28 15  9  7  4  3  3xxxxxxxxxxxx         |
 11|xxxxxx261138 62 28 15  5  3  3  2  2xxxxxxxxx         |
 12|xxxxxxxxx 51 28 12  9  5  3  3  2  2  2xxxxxx         |
 13|xxxxxxxxx 32 19 10  5  3  3  3  3  2  2  1  1         |
 14|xxxxxxxxx 25 14 10  6  5  4  3  3  2  2  2  1  1  1   |
 15|xxxxxxxxx 20 11  7  6  4  3  3  2  2  2  2  1  1  1  1|
 16|xxxxxxxxx 16 10  6  4  4  3  2  2  2  1  1  1  1  1  1|
 17|xxxxxxxxx 13  9  6  4  3  2  2  1  1  1  1  1  1  1  1|
 18|xxxxxxxxx 12  8  4  3  2  2  1  1  1  1  1  1     1  1|
 19|xxxxxxxxx 10  7  4  3  3  2  1     1  1  1            |
 20|xxxxxxxxx  9  6  4  3  3  2  1     1  1  1            |
 21|xxxxxxxxx  8  5  4  3  3  2  1  1  1  1  1            |
 22|xxxxxxxxxxxx  4  4  3xxx  2  1  1     1  1            |
 23|xxxxxxxxxxxx  4  4  3  2  2  1  1     1               |
 24|xxxxxxxxxxxx  4  3  3  2  1  1                        |
 25|xxxxxxxxxxxx  4  3  3  2  1  1                        |
   +------------------------------------------------------+
```

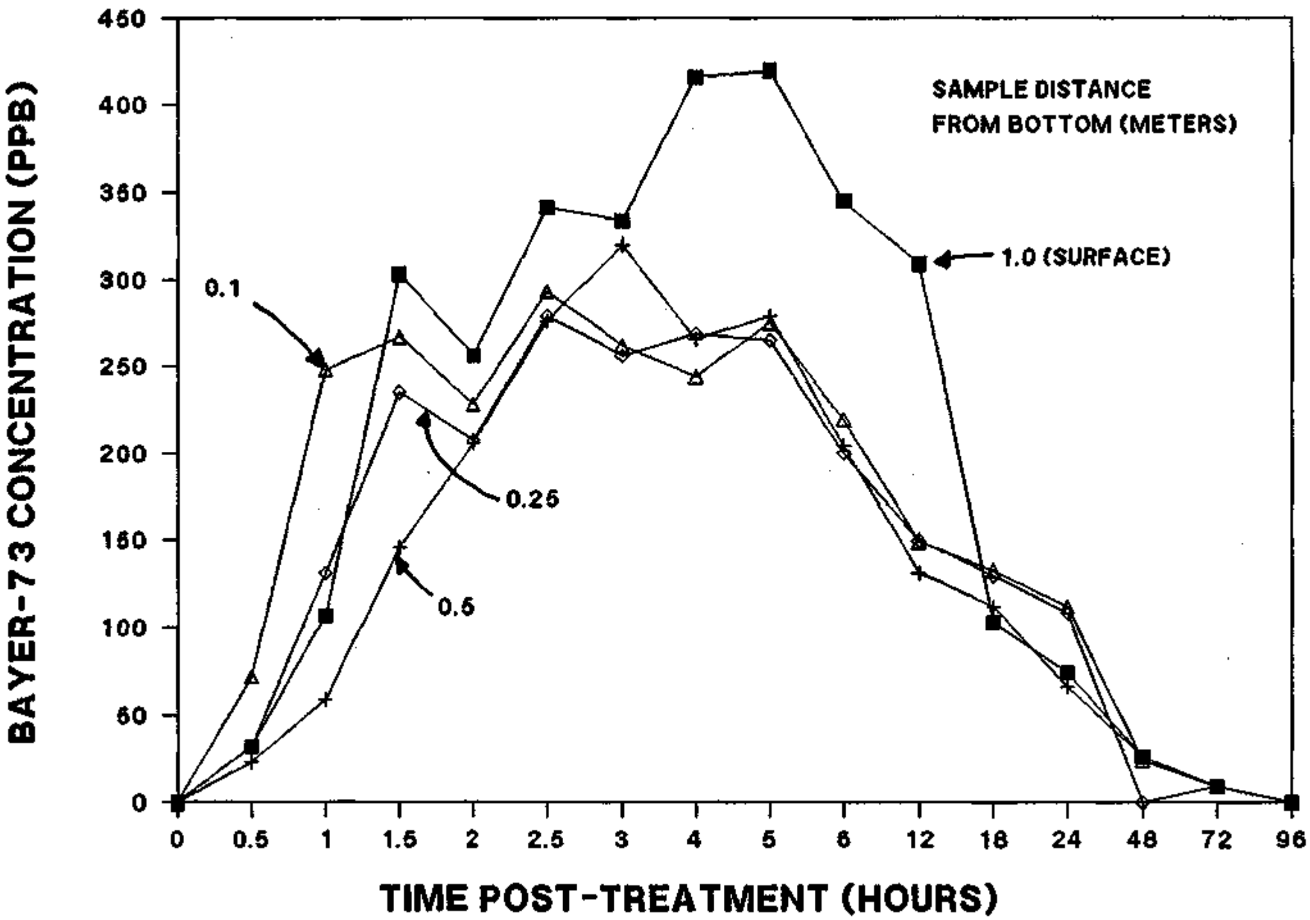


Figure 5
Observed Water Column Responses to Bayer-73 Treatment
Ho and Gloss (1987) Station F

Figure 6

Sensitivity of Simulated Lake Response to Bayer-73 Release Period
Saranac River Treatment, North Wind, Conc. Units - ppb/5

MAXIMUM BAYER-73 CONCENTRATION (PPB / 5) | PLUME DURATION (CONC. BAYER-73 > 50 PPB), HOURS

RELEASE PERIOD = 24 HOURS

```
     1  2  3  4  5  6  7  8  9 10 11 12 13 14 15
  +---------------------------------------------+
 4|xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx   |
 5|xxxxxxxxxxxxxxx            xxxxxxxxxxxxxxxxxx|
 6|xxxxxxxxx                  xxxxxxxxxxxxxxxxxx|
 7|xxxxxx                        xxxxxxxxxxxxxxx|
 8|xxxxxx                        xxxxxxxxxxxxxxx|
 9|xxxxxxxxx                        xxxxxxxxxxxx|
10|xxxxxx  5 12  7                  xxxxxxxxxxxx|
11|xxxxxx  1 12 11  3                  xxxxxxxxx|
12|xxxxxxxxx  8  8  2                     xxxxxx|
13|xxxxxxxxx  5  6  1                           |
14|xxxxxxxxx  3  4  1                           |
15|xxxxxxxxx  1  3  1                           |
16|xxxxxxxxx     2  1                           |
17|xxxxxxxxx     1  1                           |
18|xxxxxxxxx                                    |
  +---------------------------------------------+
```

```
     1  2  3  4  5  6  7  8  9 10 11 12 13 14 15
  +---------------------------------------------+
 4|xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx   |
 5|xxxxxxxxxxxxxxx            xxxxxxxxxxxxxxxxxx|
 6|xxxxxxxxx                  xxxxxxxxxxxxxxxxxx|
 7|xxxxxx                        xxxxxxxxxxxxxxx|
 8|xxxxxx                        xxxxxxxxxxxxxxx|
 9|xxxxxxxxx                        xxxxxxxxxxxx|
10|xxxxxx    15                     xxxxxxxxxxxx|
11|xxxxxx    12 12                     xxxxxxxxx|
12|xxxxxxxxx                              xxxxxx|
13|xxxxxxxxx                                    |
14|xxxxxxxxx                                    |
15|xxxxxxxxx                                    |
16|xxxxxxxxx                                    |
17|xxxxxxxxx                                    |
18|xxxxxxxxx                                    |
  +---------------------------------------------+
```

RELEASE PERIOD = 12 HOURS

```
     1  2  3  4  5  6  7  8  9 10 11 12 13 14 15
  +---------------------------------------------+
 4|xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx   |
 5|xxxxxxxxxxxxxxx            xxxxxxxxxxxxxxxxxx|
 6|xxxxxxxxx                  xxxxxxxxxxxxxxxxxx|
 7|xxxxxx                        xxxxxxxxxxxxxxx|
 8|xxxxxx                        xxxxxxxxxxxxxxx|
 9|xxxxxxxxx                        xxxxxxxxxxxx|
10|xxxxxx  6 20 12                  xxxxxxxxxxxx|
11|xxxxxx  1 18 18  4                  xxxxxxxxx|
12|xxxxxxxxx  9 11  2                     xxxxxx|
13|xxxxxxxxx  6  7  2                           |
14|xxxxxxxxx  3  5  1                           |
15|xxxxxxxxx  1  3  1                           |
16|xxxxxxxxx     2  1                           |
17|xxxxxxxxx     1                              |
18|xxxxxxxxx                                    |
  +---------------------------------------------+
```

```
     1  2  3  4  5  6  7  8  9 10 11 12 13 14 15
  +---------------------------------------------+
 4|xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx   |
 5|xxxxxxxxxxxxxxx            xxxxxxxxxxxxxxxxxx|
 6|xxxxxxxxx                  xxxxxxxxxxxxxxxxxx|
 7|xxxxxx                        xxxxxxxxxxxxxxx|
 8|xxxxxx                        xxxxxxxxxxxxxxx|
 9|xxxxxxxxx                        xxxxxxxxxxxx|
10|xxxxxx    14  6                  xxxxxxxxxxxx|
11|xxxxxx    13 13                     xxxxxxxxx|
12|xxxxxxxxx     8                        xxxxxx|
13|xxxxxxxxx                                    |
14|xxxxxxxxx                                    |
15|xxxxxxxxx                                    |
16|xxxxxxxxx                                    |
17|xxxxxxxxx                                    |
18|xxxxxxxxx                                    |
  +---------------------------------------------+
```

RELEASE PERIOD = 6 HOURS

```
     1  2  3  4  5  6  7  8  9 10 11 12 13 14 15
  +---------------------------------------------+
 4|xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx   |
 5|xxxxxxxxxxxxxxx            xxxxxxxxxxxxxxxxxx|
 6|xxxxxxxxx                  xxxxxxxxxxxxxxxxxx|
 7|xxxxxx                        xxxxxxxxxxxxxxx|
 8|xxxxxx                        xxxxxxxxxxxxxxx|
 9|xxxxxxxxx                        xxxxxxxxxxxx|
10|xxxxxx  6 26 17                  xxxxxxxxxxxx|
11|xxxxxx  1 25 22  4  1               xxxxxxxxx|
12|xxxxxxxxx 10 12  3                     xxxxxx|
13|xxxxxxxxx  6  8  2                           |
14|xxxxxxxxx  3  6  2                           |
15|xxxxxxxxx  1  3  1                           |
16|xxxxxxxxx     2  1                           |
17|xxxxxxxxx     1                              |
18|xxxxxxxxx                                    |
  +---------------------------------------------+
```

```
     1  2  3  4  5  6  7  8  9 10 11 12 13 14 15
  +---------------------------------------------+
 4|xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx   |
 5|xxxxxxxxxxxxxxx            xxxxxxxxxxxxxxxxxx|
 6|xxxxxxxxx                  xxxxxxxxxxxxxxxxxx|
 7|xxxxxx                        xxxxxxxxxxxxxxx|
 8|xxxxxx                        xxxxxxxxxxxxxxx|
 9|xxxxxxxxx                        xxxxxxxxxxxx|
10|xxxxxx    13  7                  xxxxxxxxxxxx|
11|xxxxxx    13 13                     xxxxxxxxx|
12|xxxxxxxxx  5  9                        xxxxxx|
13|xxxxxxxxx                                    |
14|xxxxxxxxx                                    |
15|xxxxxxxxx                                    |
16|xxxxxxxxx                                    |
17|xxxxxxxxx                                    |
18|xxxxxxxxx                                    |
  +---------------------------------------------+
```

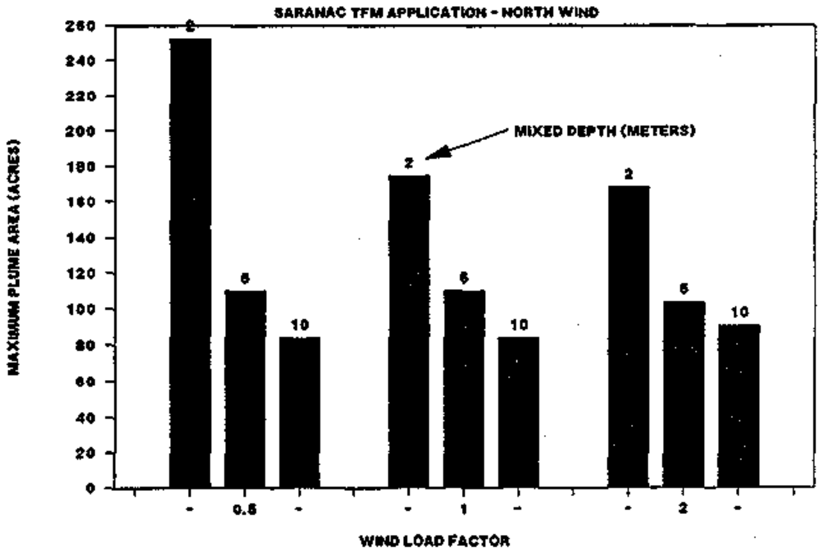
RELEASE PERIOD = 3 HOURS

```
     1  2  3  4  5  6  7  8  9 10 11 12 13 14 15
  +---------------------------------------------+
 4|xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx   |
 5|xxxxxxxxxxxxxxx            xxxxxxxxxxxxxxxxxx|
 6|xxxxxxxxx                  xxxxxxxxxxxxxxxxxx|
 7|xxxxxx                        xxxxxxxxxxxxxxx|
 8|xxxxxx                        xxxxxxxxxxxxxxx|
 9|xxxxxxxxx                        xxxxxxxxxxxx|
10|xxxxxx  6 30 21                  xxxxxxxxxxxx|
11|xxxxxx  1 29 24  5  1               xxxxxxxxx|
12|xxxxxxxxx 10 12  3                     xxxxxx|
13|xxxxxxxxx  6  8  2                           |
14|xxxxxxxxx  3  6  2                           |
15|xxxxxxxxx  1  4  1                           |
16|xxxxxxxxx     2  1                           |
17|xxxxxxxxx     1                              |
18|xxxxxxxxx                                    |
  +---------------------------------------------+
```

```
     1  2  3  4  5  6  7  8  9 10 11 12 13 14 15
  +---------------------------------------------+
 4|xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx   |
 5|xxxxxxxxxxxxxxx            xxxxxxxxxxxxxxxxxx|
 6|xxxxxxxxx                  xxxxxxxxxxxxxxxxxx|
 7|xxxxxx                        xxxxxxxxxxxxxxx|
 8|xxxxxx                        xxxxxxxxxxxxxxx|
 9|xxxxxxxxx                        xxxxxxxxxxxx|
10|xxxxxx    13  7                  xxxxxxxxxxxx|
11|xxxxxx    12 12                     xxxxxxxxx|
12|xxxxxxxxx  5 10                        xxxxxx|
13|xxxxxxxxx                                    |
14|xxxxxxxxx                                    |
15|xxxxxxxxx                                    |
16|xxxxxxxxx                                    |
17|xxxxxxxxx                                    |
18|xxxxxxxxx                                    |
  +---------------------------------------------+
```

Figure 7

Sensitivity of Plume Area and Duration to Wind Load and Mixed Depth
Saranac River TFM Treatment



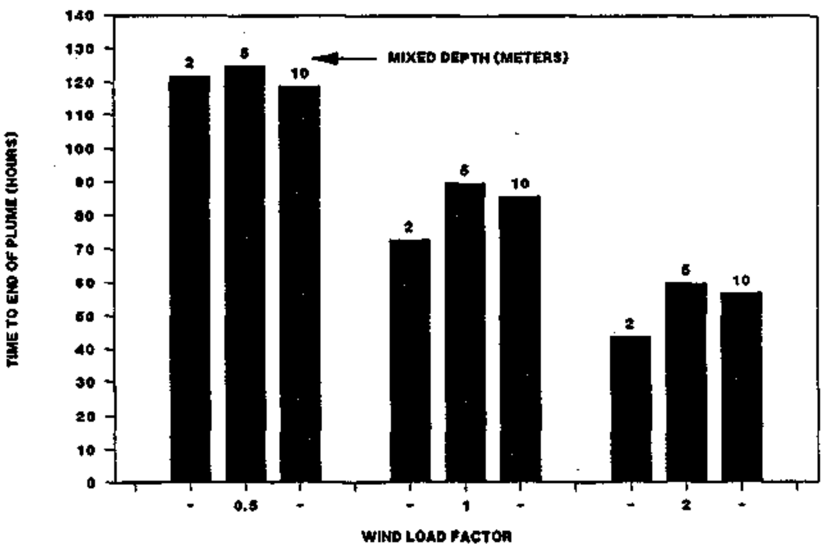


Figure 8
Seasonal Variations in Stream and Lake Surface Temperatures
St. Albans Bay, Lake Champlain, 1982-1986 Monthly Means

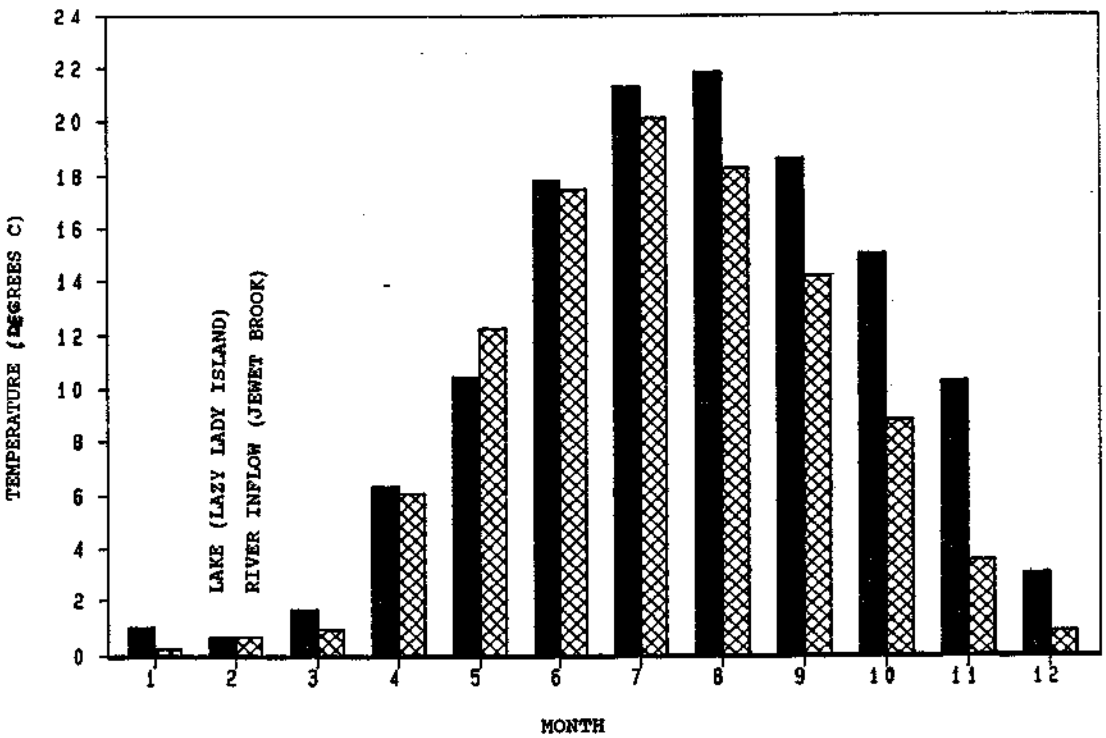


Figure 9
Lake Champlain Temperature vs. Depth and Season

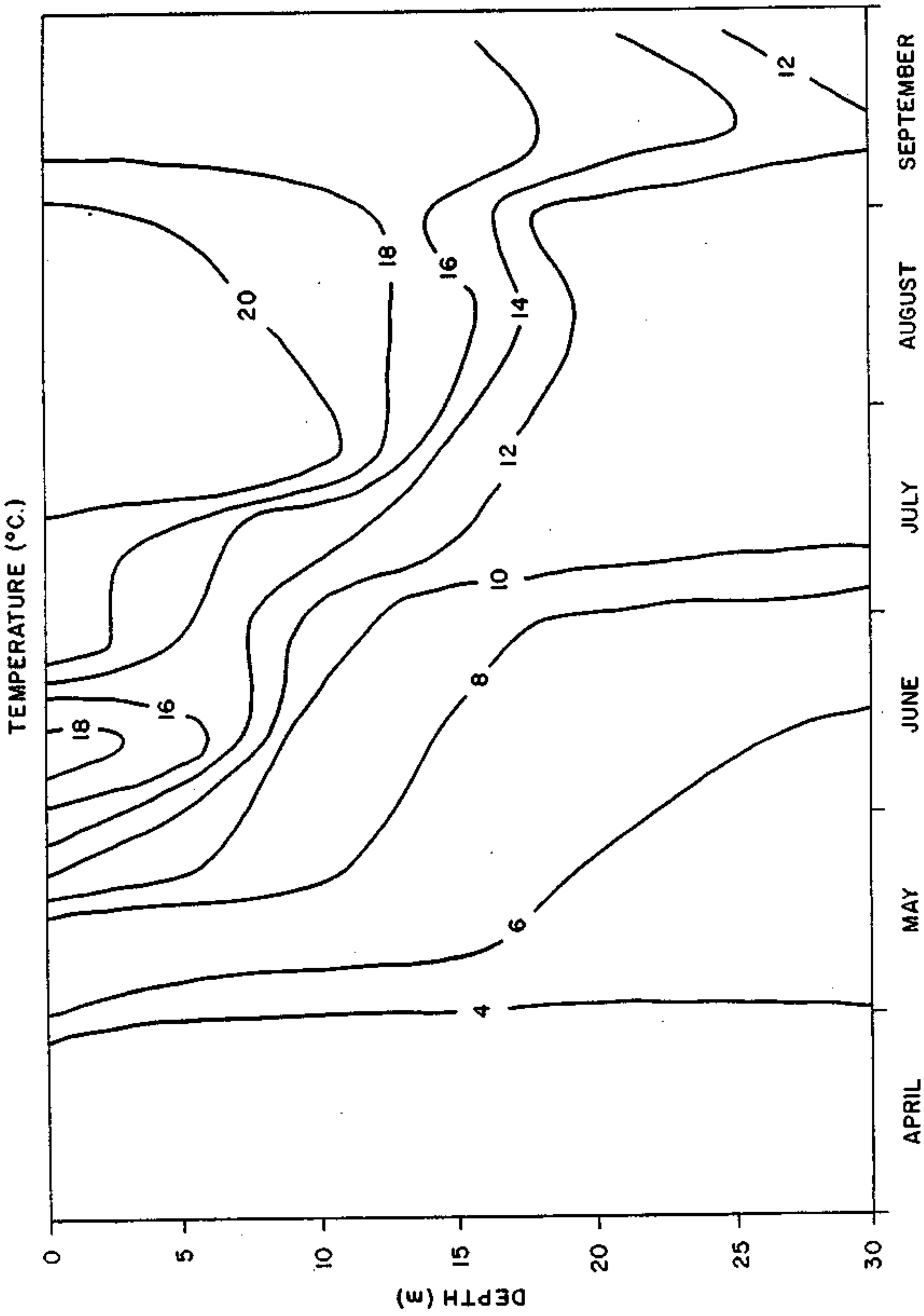


Figure 10
Mean and Maximum Scaled Dye Concentrations vs. Site and Depth Range
Concentration Units Scaled to River Application of 1000

Sites:
1-Great Chazy, 2-Saranac (August), 3-Ausable, 4-Lewis,
5-Putnam, 6-Saranac (June)

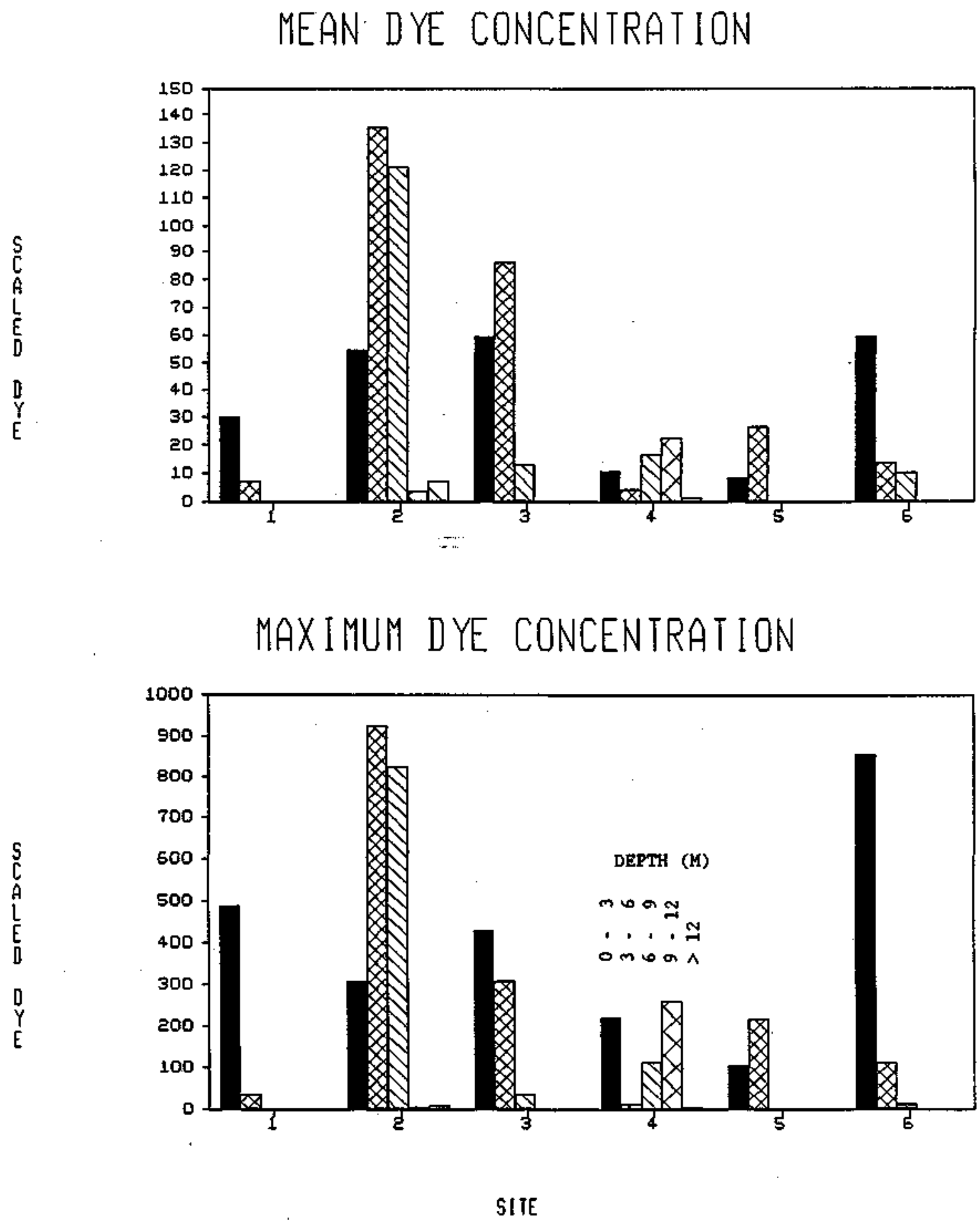
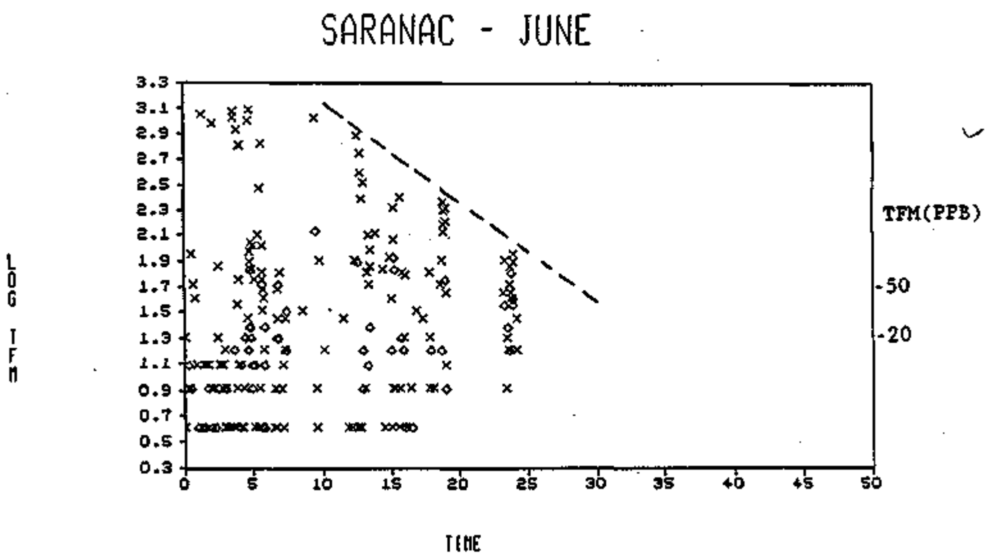
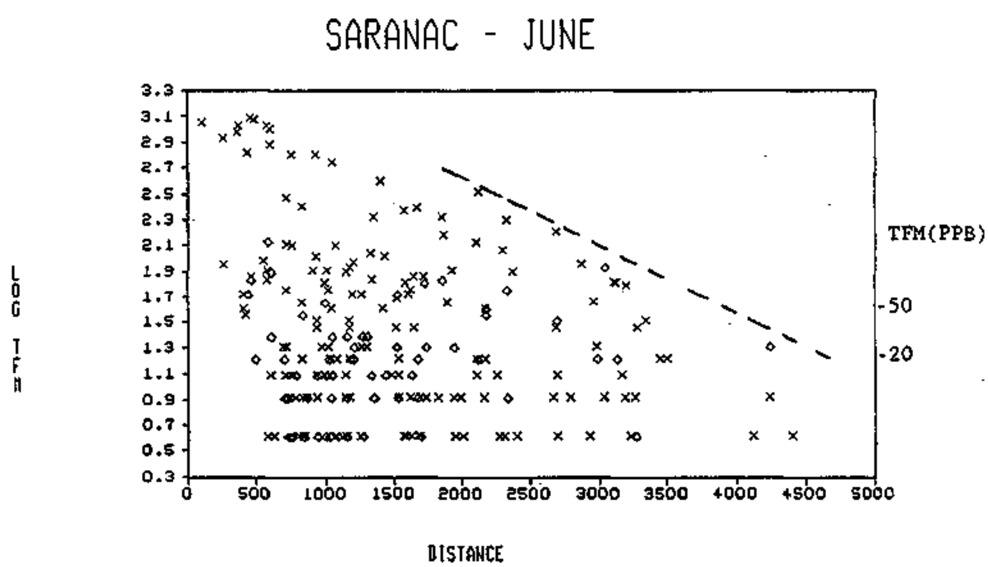


Figure 11
Site: Saranac-June (Example)
Empirical Projection of TFM Plume Based upon Dye Measurements

TIME - Hours from Entry of Lampricide Plume to Lake
DISTANCE - Distance from River Inflow (Meters)
LOG TFM - Log_{10} (Projected TFM Conc., ppb), Rescaled from Dye Data
TFM CONC - Measured Dye Conc. x TFM Load / Dye Load
LOAD - Streamflow x Applied Conc. x Treatment Duration

Symbols: x - surface samples, o - subsurface samples





TFM 750

Figure 12
Simulation Summary - Maximum Plume Areas

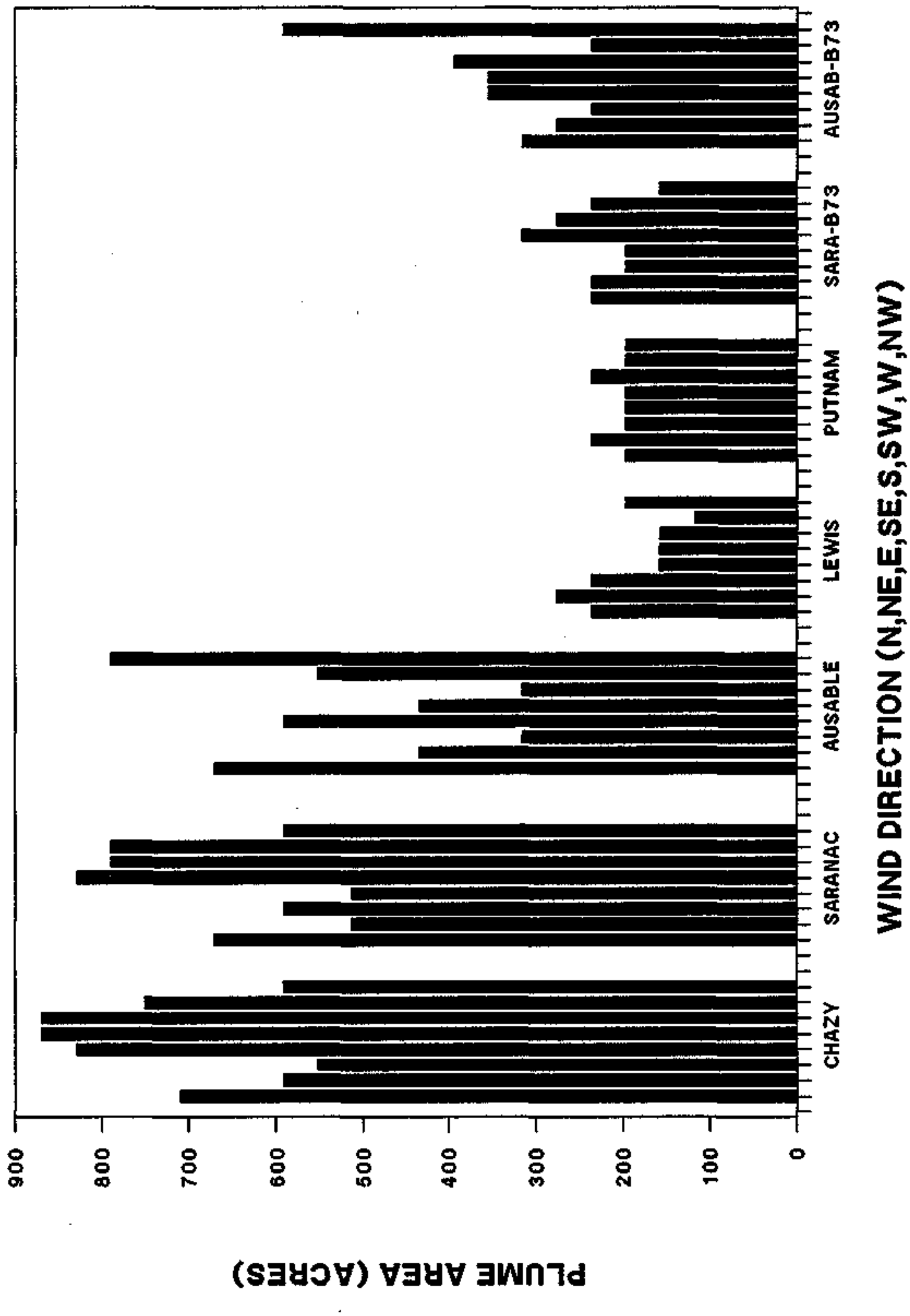
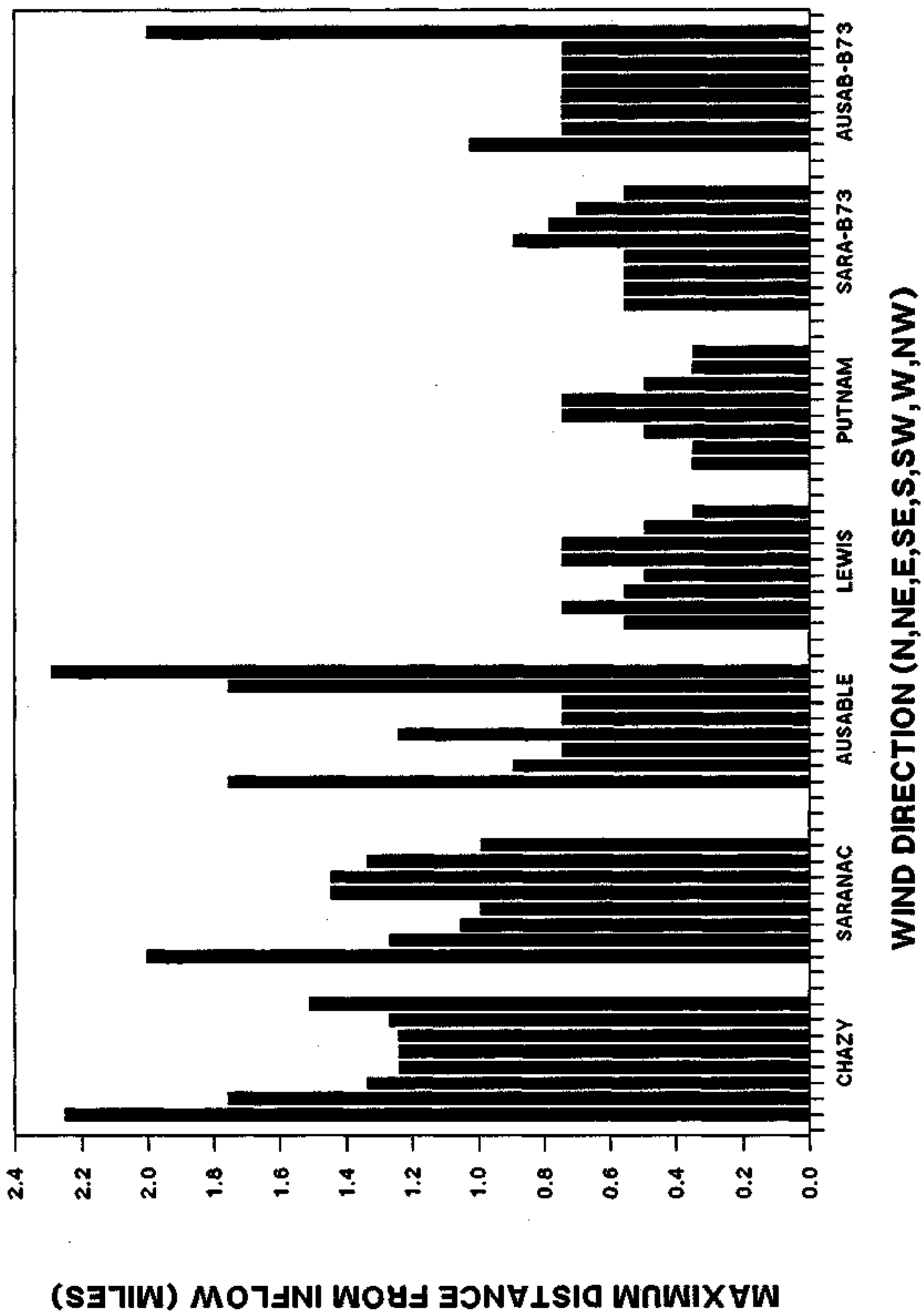


Figure 13
Simulation Summary - Maximum Plume Distance from Inflow



TFM7/10

Figure 14
Simulation Summary - Plume Duration

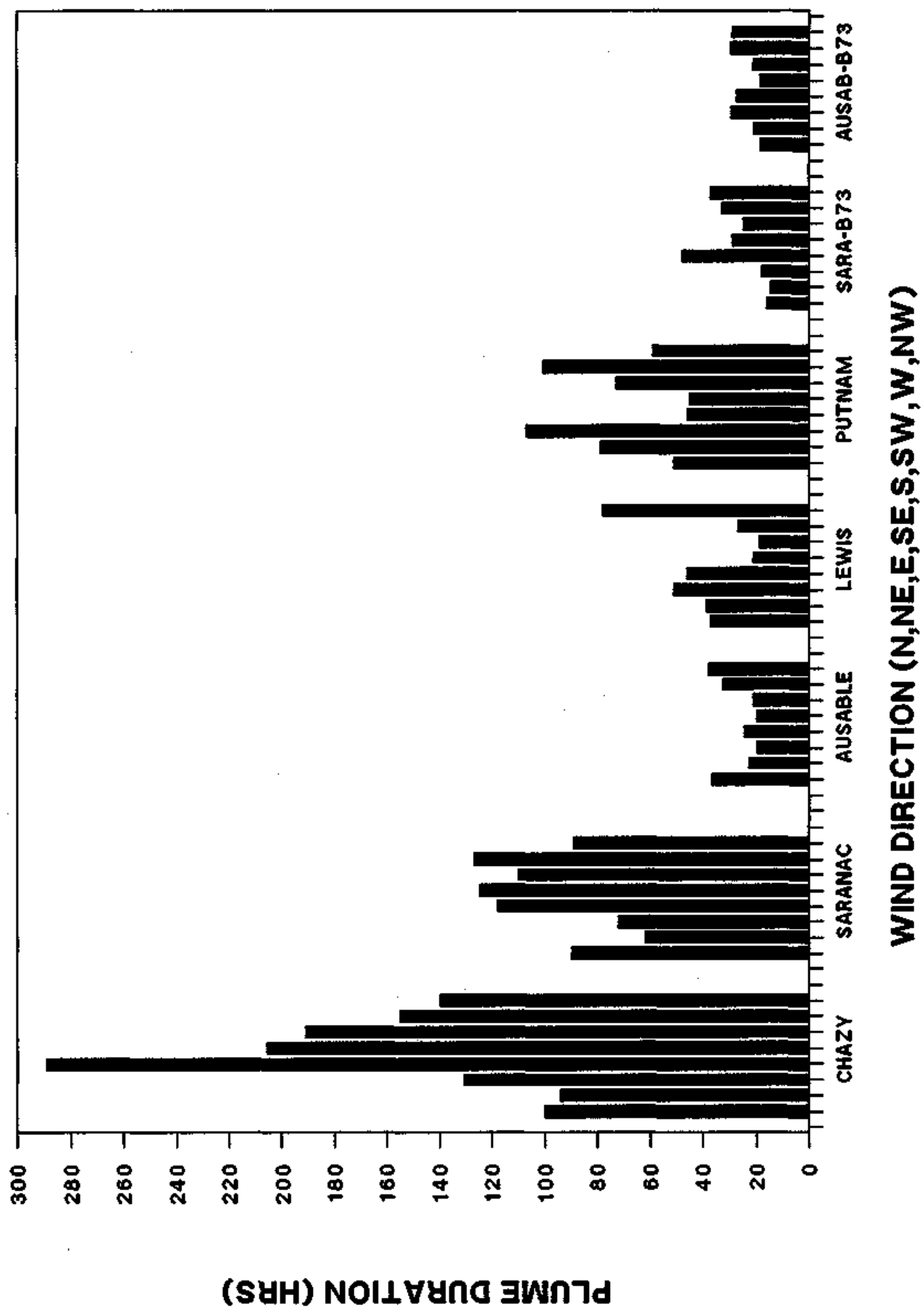


Figure 15
Site: Great Chazy River
Model Region

Map Scale = 1:88816,   1 Inch = 1.4 Miles

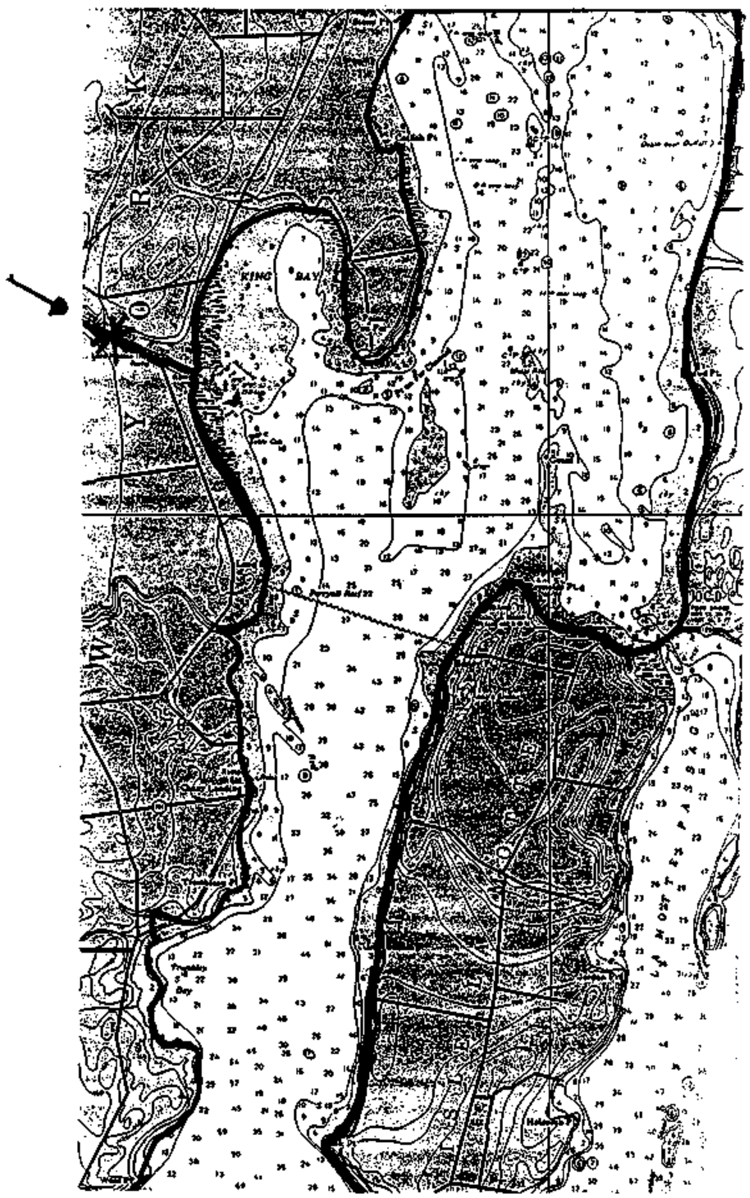


Figure 16
Site 1: Great Chazy River
Finite Element Mesh

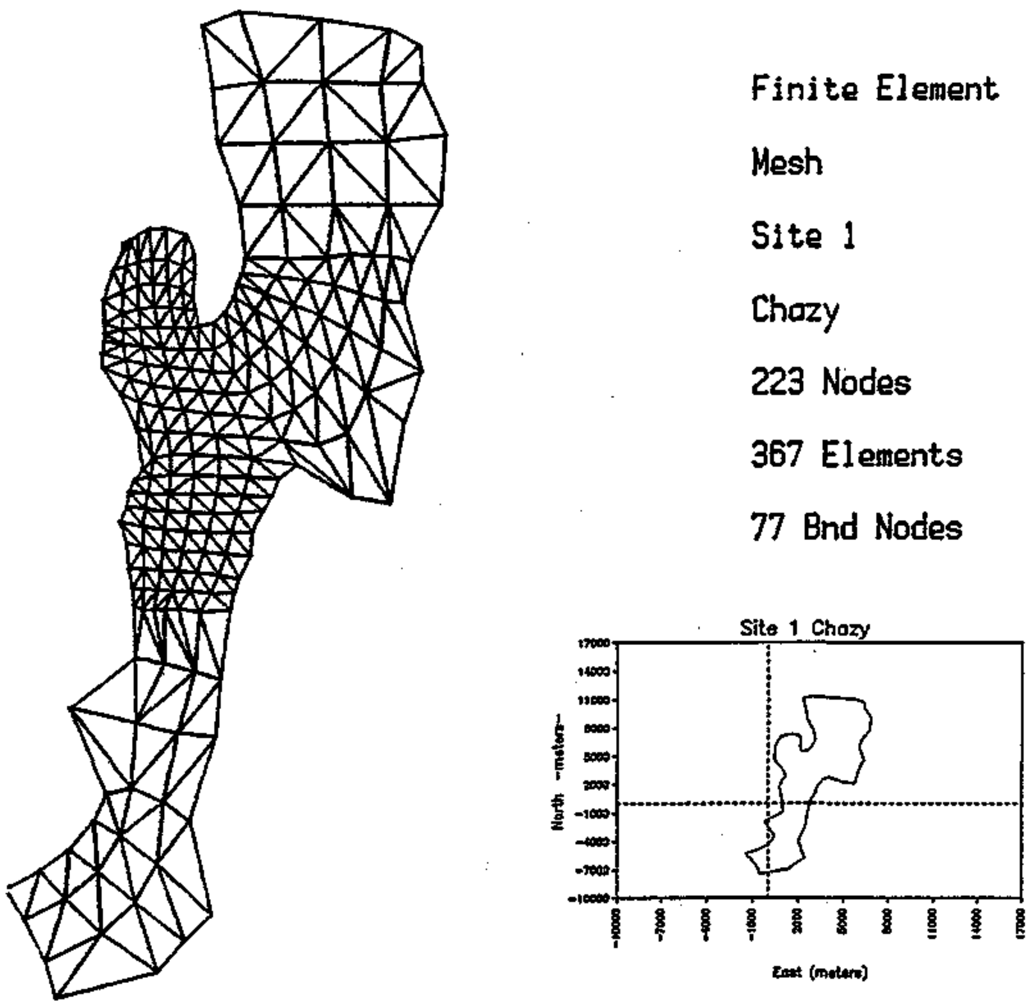


Figure 17
Site 1: Great Chazy River
Vertically Averaged Circulation Patterns - North Wind
(Directions Reversed for South Wind)

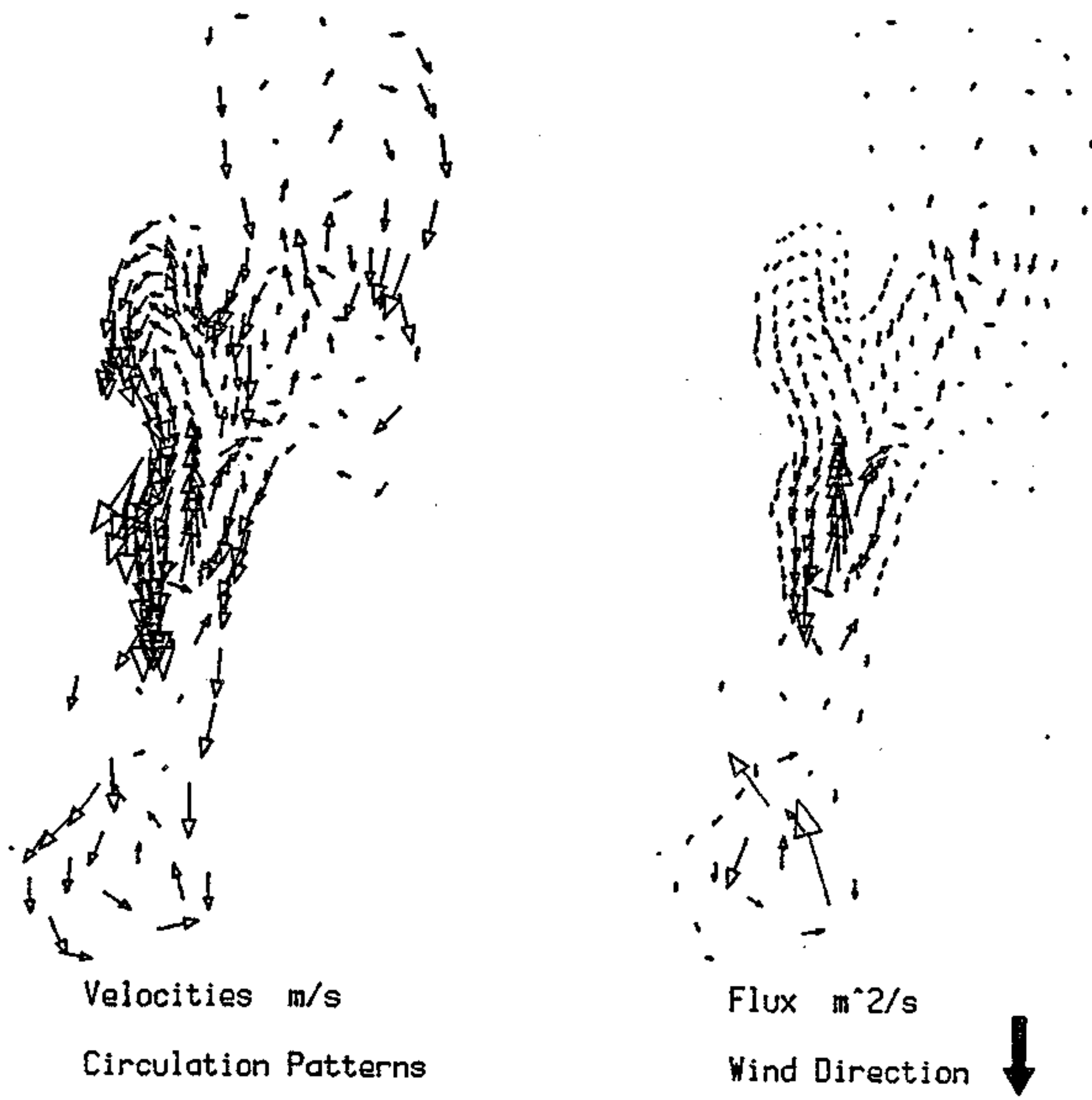


Figure 18
Site 1: Great Chazy River
Vertically Averaged Circulation Patterns - Northeast Wind
(Directions Reversed for Southwest Wind)

Figure 19
Site 1: Great Chazy River
Transport Model Grid

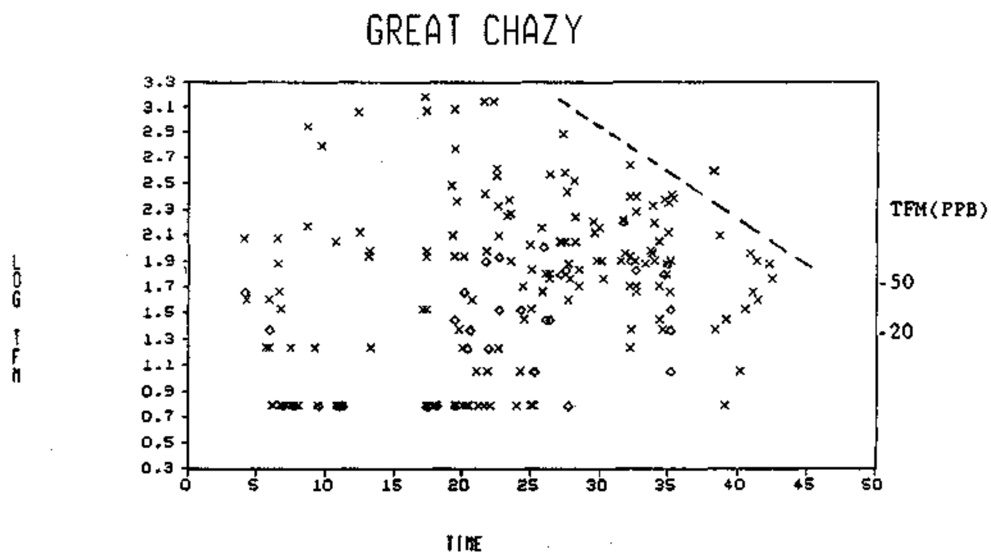
Cell Depths (Meters) at Minimum Lake Elevation (92.9 ft,msl)
xxx = Land Mass, Cell Dimension = 400 meters

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
1	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
2	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	3	4	3	xxx	xxx	0	0	0	0	xxx	xxx
3	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	1	4	4	3	0	3	3	3	3	1	xxx
4	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	1	2	4	3	3	2	3	3	3	1	xxx
5	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	2	5	3	3	3	4	3	3	1	0
6	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	2	3	6	3	3	4	3	3	2	2
7	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	1	3	4	6	2	3	3	3	3	2
8	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	1	3	4	6	2	3	3	3	3	1
9	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	1	3	4	6	2	3	3	3	3	1
10	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	3	4	5	3	3	2	2	2	1
11	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	3	4	5	4	4	2	2	2	1
12	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	1	3	6	4	5	2	2	2	1
13	xxx	xxx	xxx	xxx	xxx	xxx	xxx	0	0	0	xxx	xxx	1	3	6	6	5	3	2	2	xxx
14	xxx	xxx	xxx	xxx	xxx	xxx	0	1	2	0	xxx	xxx	1	3	6	6	5	3	3	2	xxx
15	xxx	xxx	xxx	xxx	xxx	xxx	0	1	2	1	xxx	xxx	2	3	6	6	5	3	3	2	xxx
16	xxx	xxx	xxx	xxx	xxx	xxx	0	0	1	1	xxx	0	2	4	6	5	5	3	3	2	xxx
17	xxx	xxx	xxx	xxx	xxx	xxx	0	1	1	1	0	1	2	4	7	1	5	4	3	2	xxx
18	xxx	xxx	xxx	xxx	xxx	xxx	0	1	2	3	3	3	1	4	7	3	3	5	3	2	0
19	xxx	xxx	xxx	xxx	xxx	xxx	0	2	3	4	4	3	0	3	7	6	3	4	3	2	0
20	xxx	xxx	xxx	xxx	xxx	xxx	0	2	3	5	4	3	0	3	7	6	2	4	3	2	0
21	xxx	xxx	xxx	xxx	xxx	xxx	xxx	1	3	4	5	3	1	3	6	6	2	4	2	1	xxx
22	xxx	xxx	xxx	xxx	xxx	xxx	xxx	0	3	4	5	3	3	3	7	3	2	3	3	2	xxx
23	xxx	xxx	xxx	xxx	xxx	xxx	xxx	0	2	3	6	4	4	8	4	1	1	3	2	1	xxx
24	xxx	xxx	xxx	xxx	xxx	xxx	xxx	0	2	4	7	7	9	4	0	0	1	2	2	1	xxx
25	xxx	xxx	xxx	xxx	xxx	xxx	xxx	0	2	7	9	8	6	1	xxx	xxx	0	0	1	1	xxx
26	xxx	xxx	xxx	xxx	xxx	xxx	xxx	1	4	7	10	7	1	0	xxx	xxx	xxx	xxx	1	1	xxx
27	xxx	xxx	xxx	xxx	xxx	xxx	xxx	1	4	9	10	10	1	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
28	xxx	xxx	xxx	xxx	xxx	xxx	xxx	1	4	9	10	6	1	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
29	xxx	xxx	xxx	xxx	xxx	xxx	xxx	1	4	8	10	6	0	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
30	xxx	xxx	xxx	xxx	xxx	xxx	xxx	1	5	9	10	4	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
31	xxx	xxx	xxx	xxx	xxx	xxx	xxx	1	6	10	8	1	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
32	xxx	xxx	xxx	xxx	xxx	xxx	xxx	1	7	10	7	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
33	xxx	xxx	xxx	xxx	xxx	xxx	0	1	7	10	4	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
34	xxx	xxx	xxx	xxx	xxx	xxx	6	8	10	10	3	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
35	xxx	xxx	xxx	xxx	3	7	8	9	10	10	1	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
36	xxx	xxx	xxx	xxx	3	6	9	10	10	8	1	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
37	xxx	xxx	xxx	xxx	3	6	9	10	10	7	1	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
38	xxx	xxx	xxx	xxx	xxx	3	9	10	7	6	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
39	xxx	xxx	xxx	xxx	xxx	1	10	6	6	6	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
40	xxx	xxx	xxx	xxx	xxx	7	10	9	9	1	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
41	xxx	xxx	xxx	xxx	2	10	10	10	9	0	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
42	xxx	xxx	xxx	xxx	7	10	10	10	10	7	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
43	xxx	0	3	4	7	9	10	10	10	9	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
44	xxx	2	4	5	6	10	10	10	10	10	9	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
45	xxx	0	3	3	4	6	10	10	10	10	10	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
46	xxx	xxx	3	4	5	5	8	10	10	10	10	10	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
47	xxx	xxx	0	4	4	4	7	7	10	10	10	10	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
48	xxx	xxx	xxx	3	3	4	4	5	5	6	10	10	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
49	xxx	xxx	xxx	1	2	3	3	xxx	xxx	4	10	10	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx
50	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	6	10	10	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx

Figure 20
Site 1: Great Chazy River
Empirical Projection of TFM Plume Based upon Dye Measurements

TIME = Hours from Entry of Lampricide Plume to Lake
DISTANCE = Distance from River Inflow (Meters)
LOG TFM = Log_{10} (Projected TFM Conc., ppb), Rescaled from Dye Data
TFM CONC = Measured Dye Conc. x TFM Load / Dye Load
LOAD = Streamflow x Applied Conc. x Treatment Duration

Symbols: x = surface samples, o = subsurface samples



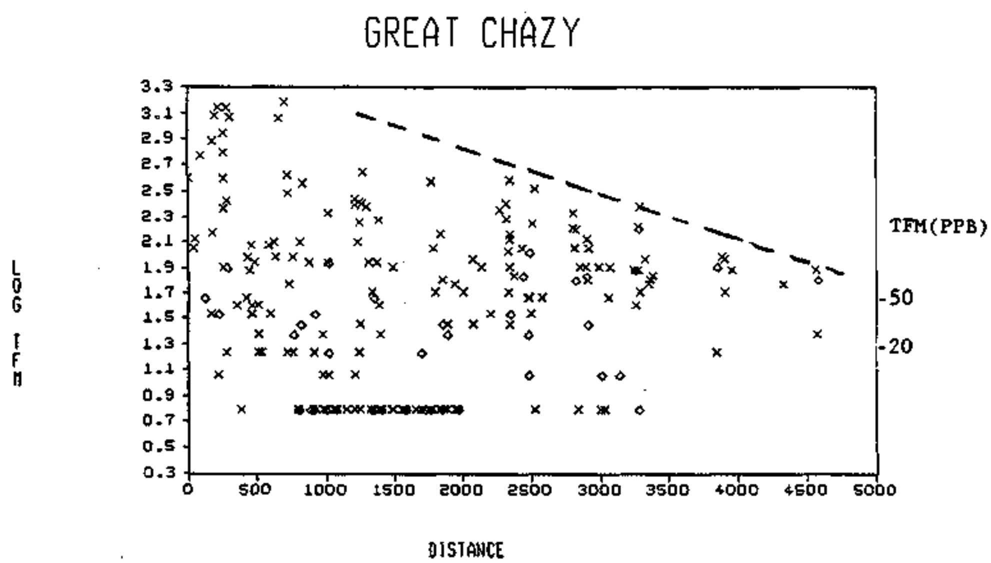


Figure 21
Site 1: Great Chazy River
Observed and Predicted Maximum Dye Concentrations
Rescaled to Applied Conc. of 1000, Contours = 100-Fold Dilution

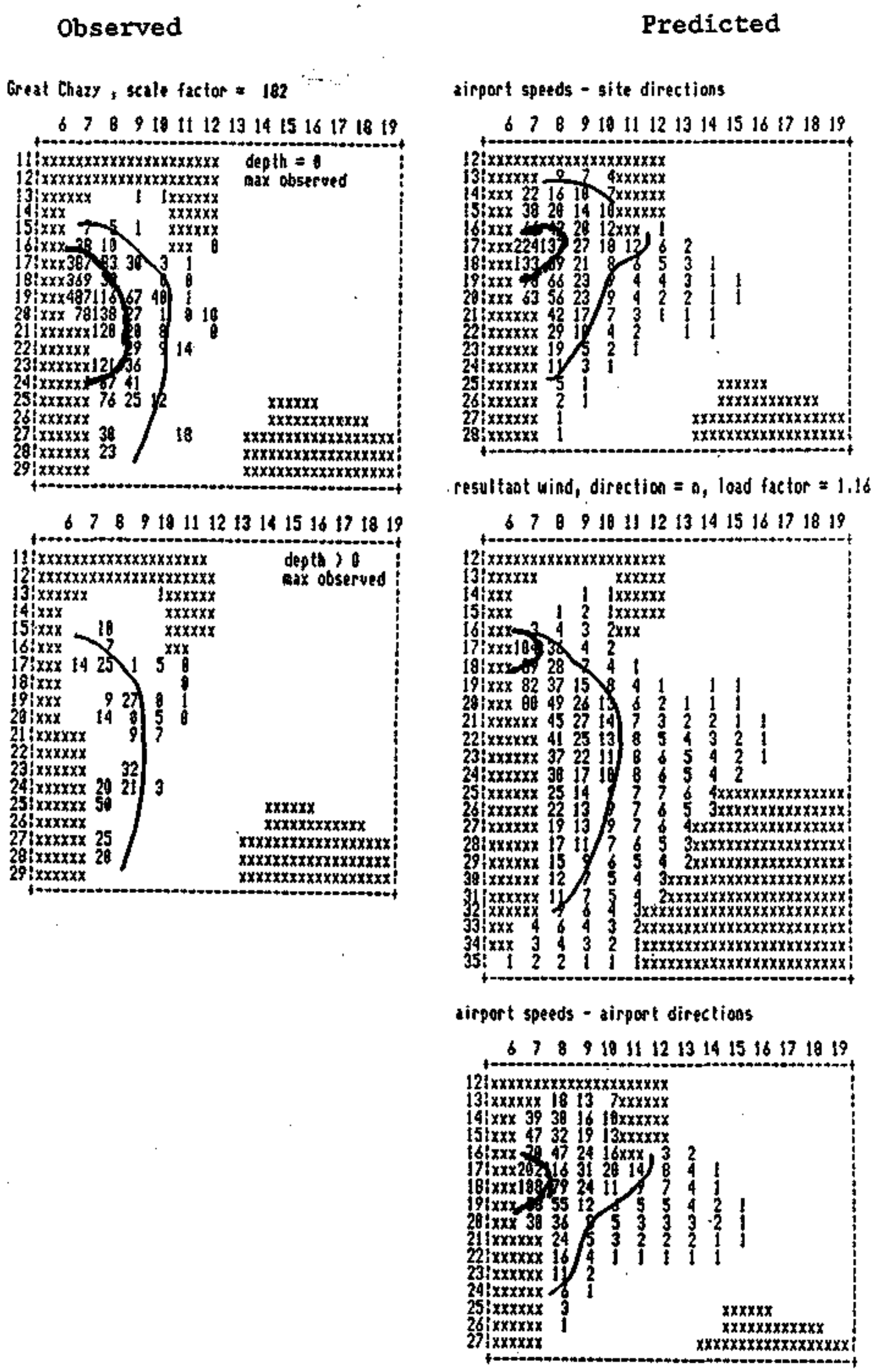


Figure 22
Site 1: Great Chazy River
Maximum TFM Concentrations vs. Wind Direction
Maximum Mixed Layer Depth = 5 Meters, Units = ppb/5

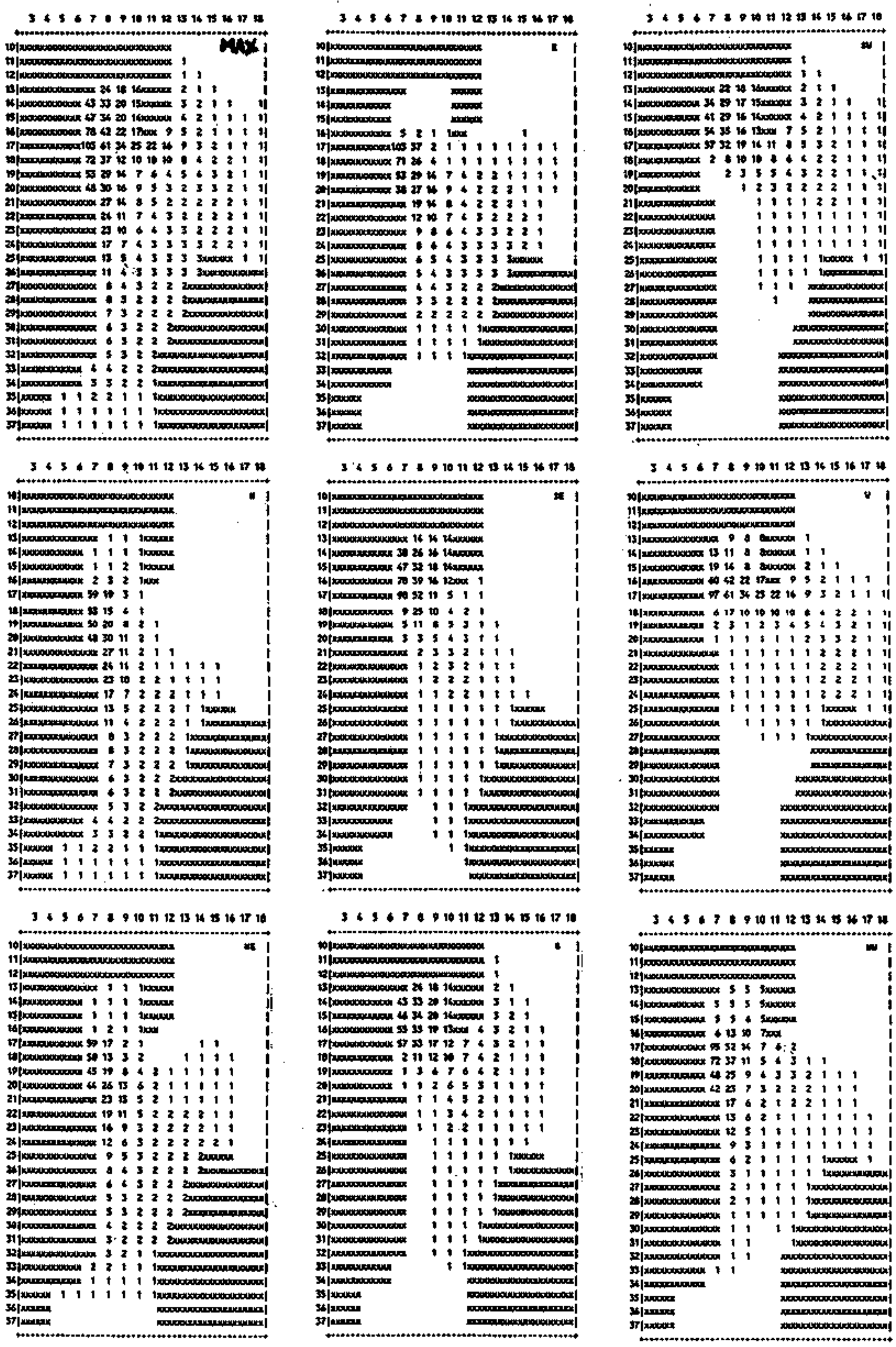


Figure 23
Site 1: Great Chazy River
Cell Maximum TFM Concentrations

Composite Projections for Eight Wind Directions, Units = ppb/5
Flow = 150 cfs, Applied TFM Conc.= 3.5 ppm, Duration = 16 hrs

	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
10	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx						
11	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	1					
12	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	1	1				
13	xxx	xxx	xxx	xxx	xxx	24	18	16	xxx	xxx	2	1	1			
14	xxx	xxx	xxx	xxx	43	33	20	15	xxx	xxx	3	2	1	1		1
15	xxx	xxx	xxx	xxx	47	34	20	14	xxx	xxx	4	2	1	1	1	1
16	xxx	xxx	xxx	xxx	78	42	22	17	xxx	9	5	2	1	1	1	1
17	xxx	xxx	xxx	xxx	103	61	34	25	22	16	9	3	2	1	1	1
18	xxx	xxx	xxx	xxx	72	37	12	10	10	10	8	4	2	2	1	1
19	xxx	xxx	xxx	xxx	53	29	14	7	6	4	5	4	3	2	1	1
20	xxx	xxx	xxx	xxx	48	30	16	9	5	3	2	3	3	2	1	1
21	xxx	xxx	xxx	xxx	xxx	27	14	8	5	2	2	2	2	2	1	1
22	xxx	xxx	xxx	xxx	xxx	24	11	7	4	3	2	2	2	2	1	1
23	xxx	xxx	xxx	xxx	xxx	23	10	6	4	3	3	2	2	2	1	1
24	xxx	xxx	xxx	xxx	xxx	17	7	4	3	3	3	3	2	2	1	1
25	xxx	xxx	xxx	xxx	xxx	13	5	4	3	3	3	3	xxx	xxx	1	1
26	xxx	xxx	xxx	xxx	xxx	11	4	3	3	3	3	3	xxx	xxx	xxx	xxx
27	xxx	xxx	xxx	xxx	xxx	8	4	3	2	2	2	xxx	xxx	xxx	xxx	xxx
28	xxx	xxx	xxx	xxx	xxx	8	3	2	2	2	2	xxx	xxx	xxx	xxx	xxx
29	xxx	xxx	xxx	xxx	xxx	7	3	2	2	2	2	xxx	xxx	xxx	xxx	xxx
30	xxx	xxx	xxx	xxx	xxx	6	3	2	2	2	xxx	xxx	xxx	xxx	xxx	xxx
31	xxx	xxx	xxx	xxx	xxx	6	3	2	2	2	xxx	xxx	xxx	xxx	xxx	xxx
32	xxx	xxx	xxx	xxx	xxx	5	3	2	2	xxx	xxx	xxx	xxx	xxx	xxx	xxx
33	xxx	xxx	xxx	xxx	4	4	2	2	2	xxx	xxx	xxx	xxx	xxx	xxx	xxx
34	xxx	xxx	xxx	xxx	3	3	2	2	1	xxx	xxx	xxx	xxx	xxx	xxx	xxx
35	xxx	xxx	1	1	2	2	1	1	1	xxx	xxx	xxx	xxx	xxx	xxx	xxx
36	xxx	xxx	1	1	1	1	1	1	1	xxx	xxx	xxx	xxx	xxx	xxx	xxx
37	xxx	xxx	1	1	1	1	1	1	1	xxx	xxx	xxx	xxx	xxx	xxx	xxx

Figure 24
Site 1: Great Chazy River
Maximum TFM Concentration Contours

Composite Projections for Eight Wind Directions, Units = ppb
Flow = 150 cfs, Applied TFM Conc.= 3.5 ppm, Duration = 16 hrs
Map Scale 1:59507, 1 Inch = .939 Miles

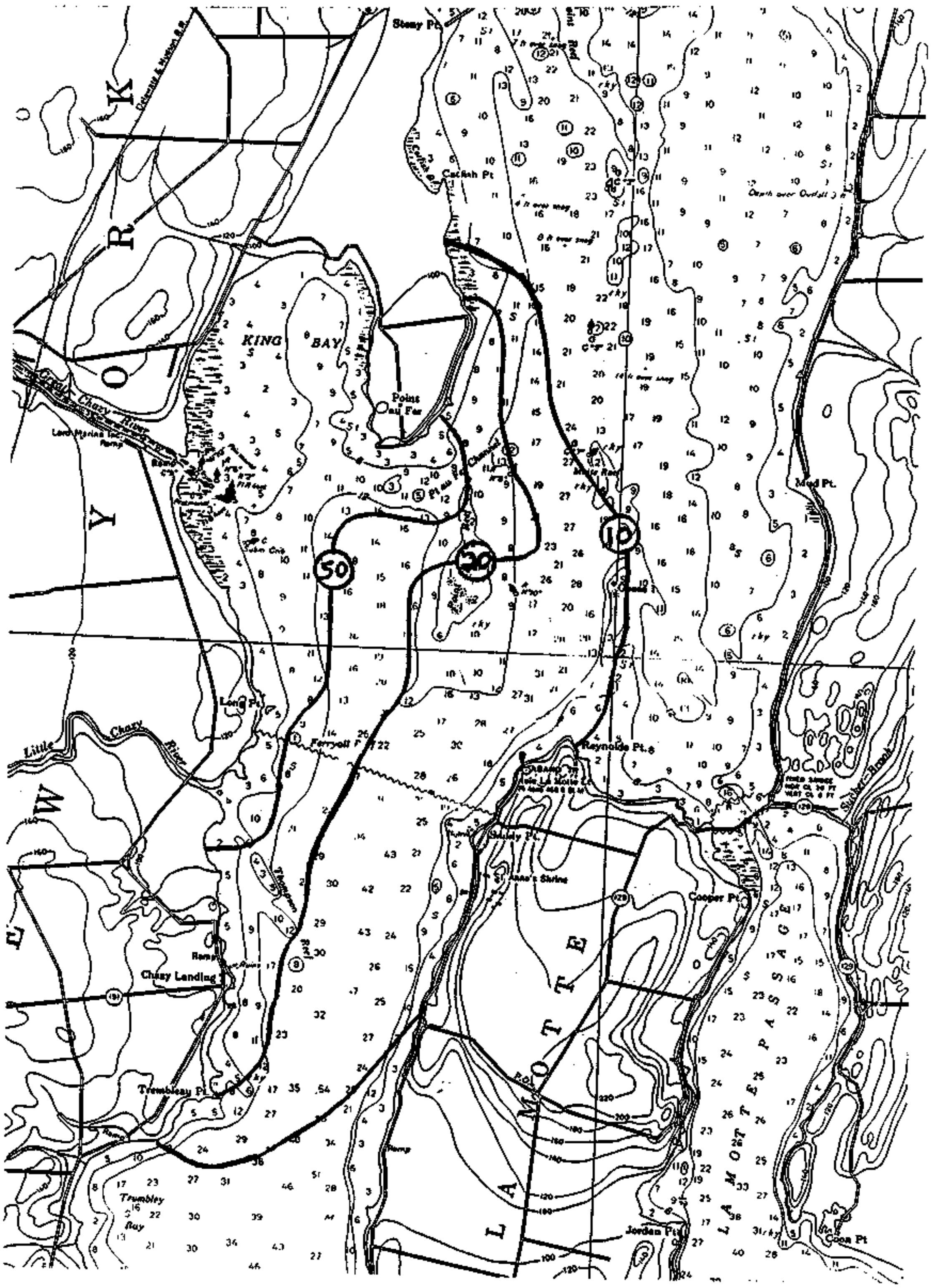


Figure 25
Site 2: Saranac River
Model Region

Map Scale = 1:88816,   1 Inch = 1.4 Miles

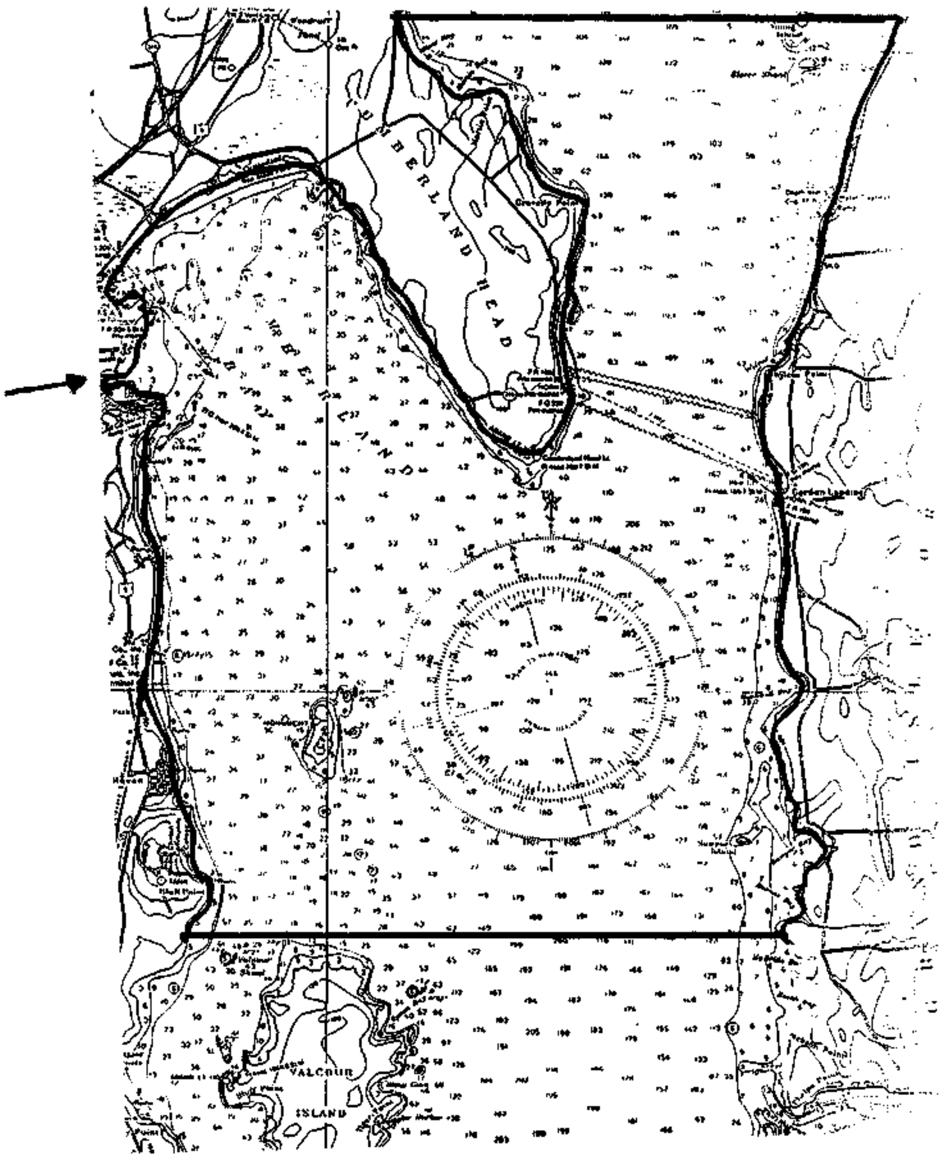


Figure 26
Site 2: Saranac River
Finite Element Mesh

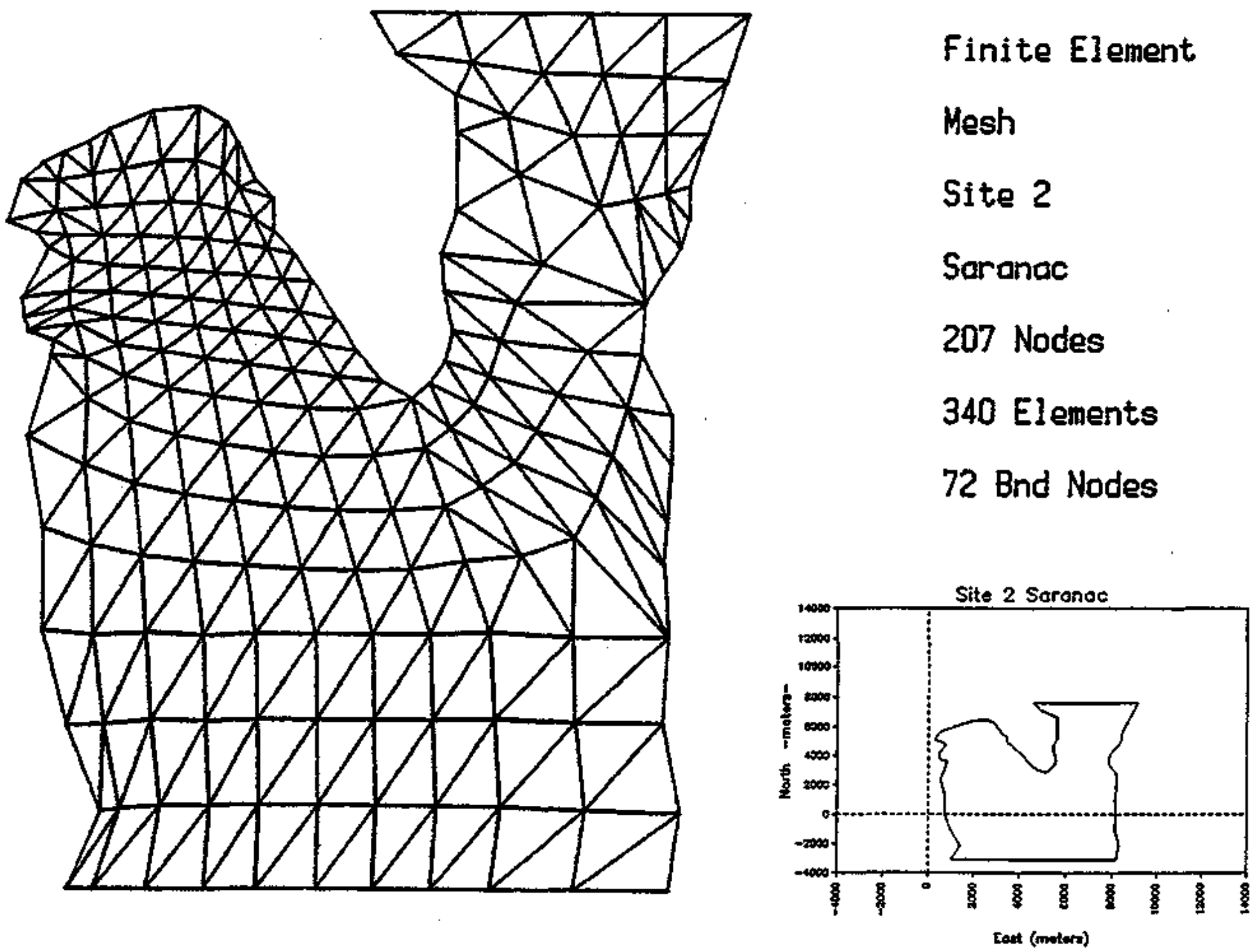


Figure 27
Site 2: Saranac River
Vertically Averaged Circulation Patterns - North Wind
(Directions Reversed for South Wind)

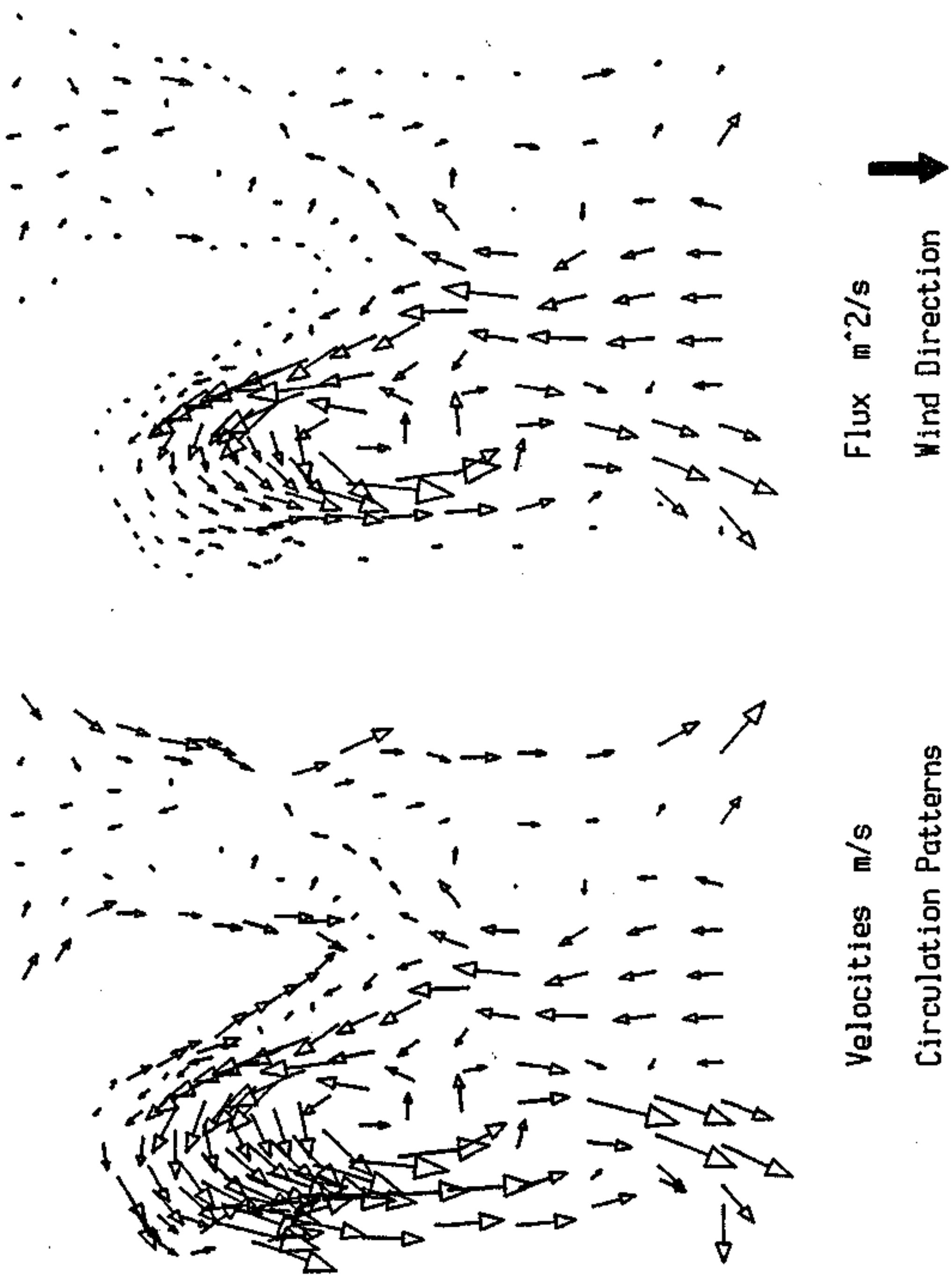


Figure 28
Site 2: Saranac River
Vertically Averaged Circulation Patterns - Northeast Wind
(Directions Reversed for Southwest Wind)

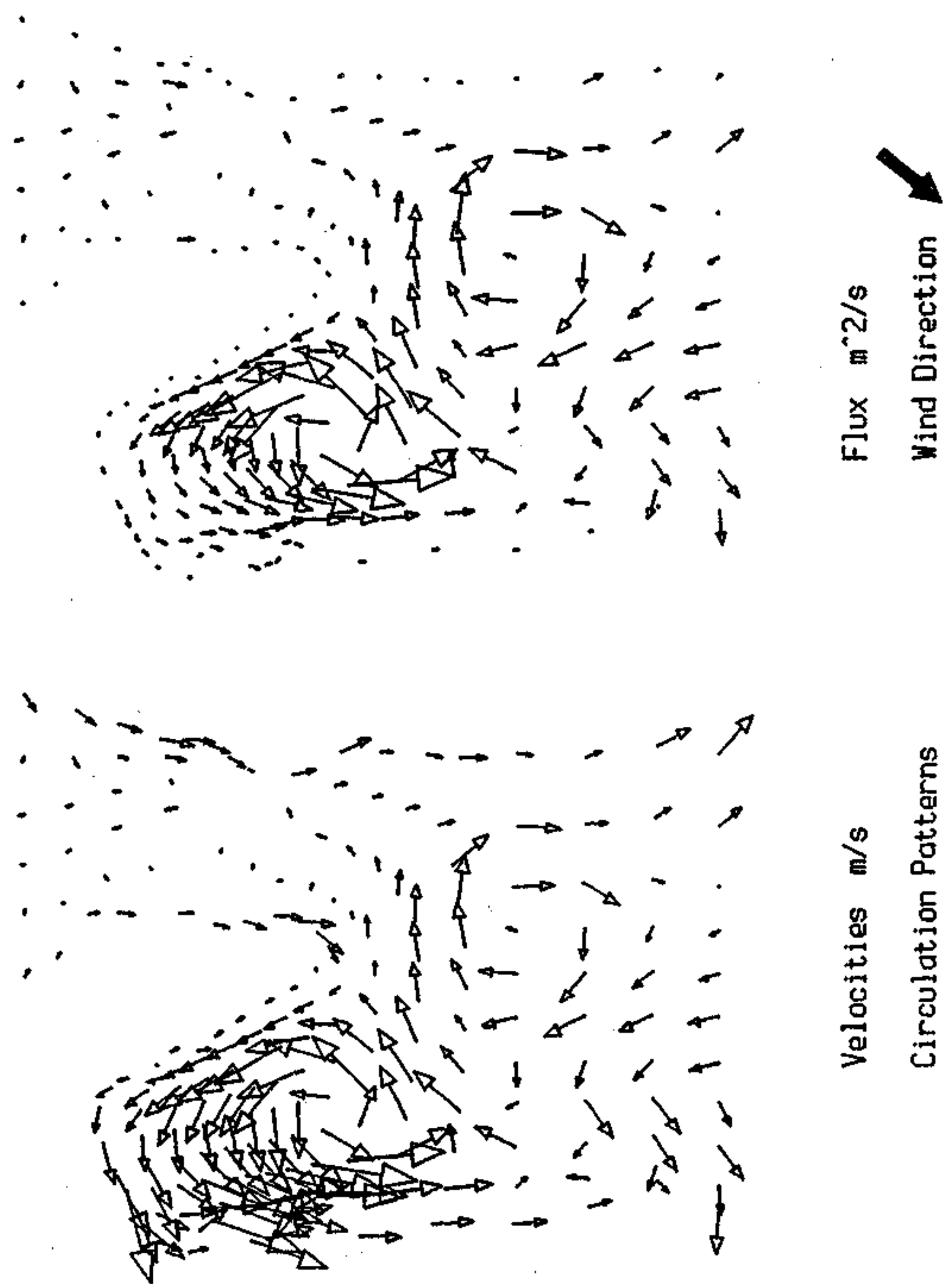


Figure 29
Site 2: Saranac River
Transport Model Grid

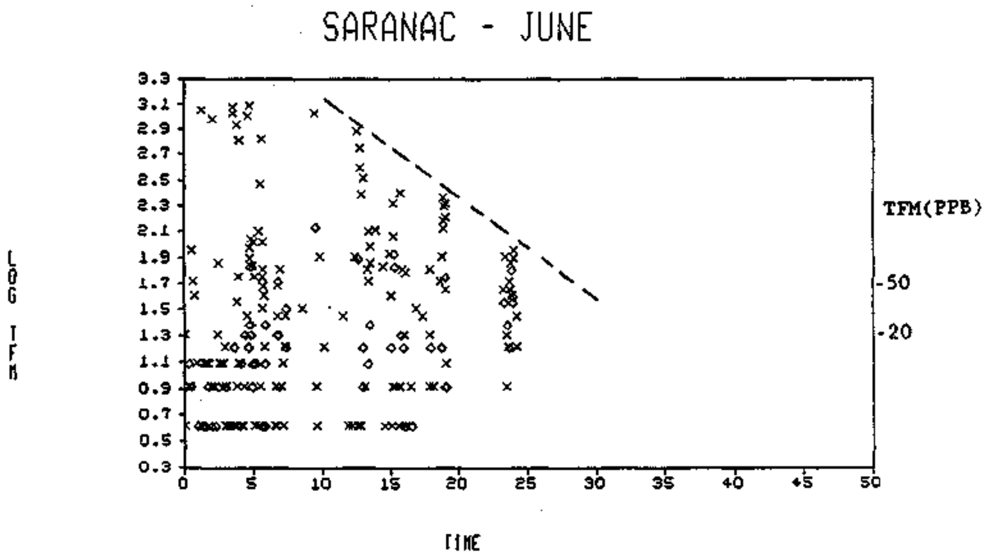
Cell Depths (Meters) at Minimum Lake Elevation (92.9 ft,msl)
xxx = Land Mass, Cell Dimension = 400 meters

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
1	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	2	3	4	10	10	10	10	10	10	10	10	10	6	3
2	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	3	10	10	10	10	10	10	10	10	7	6	xxx
3	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	6	10	10	10	10	10	10	10	8	6	xxx
4	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	3	10	10	10	10	10	10	10	9	3	xxx
5	xxx	xxx	xxx	xxx	xxx	1	3	3	1	xxx	xxx	xxx	xxx	xxx	xxx	xxx	10	10	10	10	10	10	7	xxx	xxx
6	xxx	xxx	xxx	1	1	3	3	4	4	xxx	xxx	xxx	xxx	xxx	xxx	xxx	10	10	10	10	10	10	4	xxx	xxx
7	xxx	xxx	0	2	2	3	5	6	7	3	xxx	xxx	xxx	xxx	xxx	xxx	10	10	10	10	10	10	3	xxx	xxx
8	xxx	xxx	1	2	2	4	5	7	8	4	xxx	xxx	xxx	xxx	xxx	3	10	10	10	10	10	8	xxx	xxx	xxx
9	xxx	xxx	xxx	2	3	4	6	9	8	6	3	xxx	xxx	xxx	xxx	6	10	10	10	10	10	7	xxx	xxx	xxx
10	xxx	xxx	0	2	3	5	8	9	10	9	6	xxx	xxx	xxx	xxx	9	10	10	10	10	10	2	xxx	xxx	xxx
11	xxx	xxx	0	2	4	9	9	10	10	10	8	4	xxx	xxx	xxx	3	10	10	10	10	10	xxx	xxx	xxx	xxx
12	xxx	xxx	xxx	3	5	9	10	10	10	10	10	9	4	xxx	xxx	4	10	10	10	10	10	xxx	xxx	xxx	xxx
13	xxx	xxx	xxx	6	5	9	10	10	10	10	10	10	6	2	2	10	10	10	10	10	9	xxx	xxx	xxx	xxx
14	xxx	xxx	xxx	6	7	10	10	10	10	10	10	10	10	10	2	10	10	10	10	10	10	1	xxx	xxx	xxx
15	xxx	xxx	xxx	5	6	9	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	2	xxx	xxx	xxx
16	xxx	xxx	xxx	4	7	9	9	10	10	10	10	10	10	10	10	10	10	10	10	10	10	2	xxx	xxx	xxx
17	xxx	xxx	xxx	4	7	7	9	10	10	10	10	10	10	10	10	10	10	10	10	10	10	2	xxx	xxx	xxx
18	xxx	xxx	xxx	4	6	7	7	9	10	10	10	10	10	10	10	10	10	10	10	10	10	2	xxx	xxx	xxx
19	xxx	xxx	xxx	3	4	7	8	9	10	10	10	10	10	10	10	10	10	10	10	10	10	2	xxx	xxx	xxx
20	xxx	xxx	xxx	4	5	7	9	8	10	10	10	10	10	10	10	10	10	10	10	10	10	2	xxx	xxx	xxx
21	xxx	xxx	xxx	4	6	10	9	6	2	10	10	10	10	10	10	10	10	10	10	10	10	2	xxx	xxx	xxx
22	xxx	xxx	xxx	xxx	6	9	9	xxx	6	10	10	10	10	10	10	10	10	10	10	10	10	2	xxx	xxx	xxx
23	xxx	xxx	xxx	xxx	4	10	10	4	10	10	10	10	10	10	10	10	10	10	10	10	10	2	xxx	xxx	xxx
24	xxx	xxx	xxx	xxx	6	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	2	xxx	xxx	xxx
25	xxx	xxx	xxx	xxx	6	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	2	1	xxx	xxx

Figure 30
Site 2: Saranac River (June)
Empirical Projection of TFM Plume Based upon Dye Measurements

TIME = Hours from Entry of Lampricide Plume to Lake
DISTANCE = Distance from River Inflow (Meters)
LOG TFM = Log_{10} (Projected TFM Conc., ppb), Rescaled from Dye Data
TFM CONC = Measured Dye Conc. x TFM Load / Dye Load
LOAD = Streamflow x Applied Conc. x Treatment Duration

Symbols: x = surface samples, o = subsurface samples



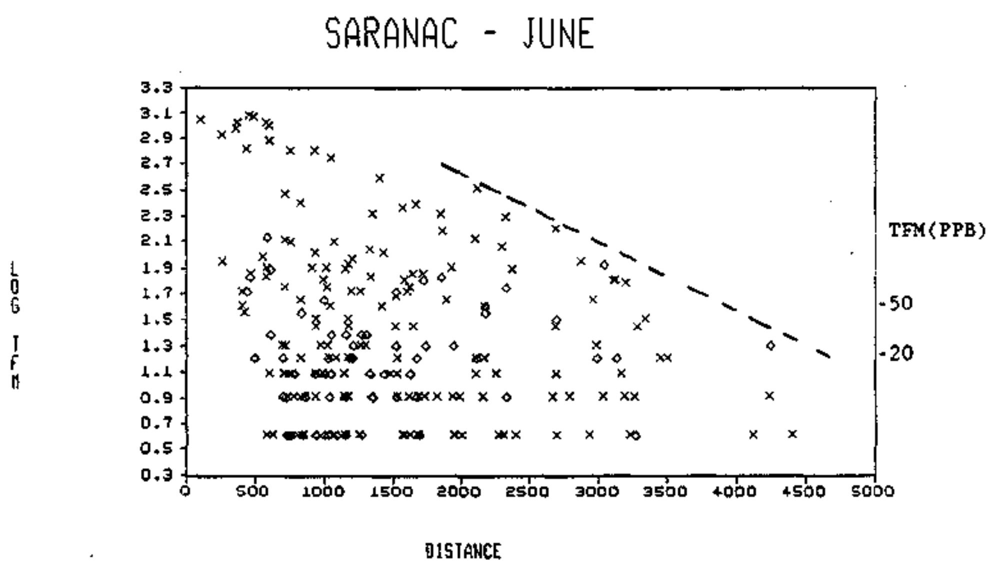
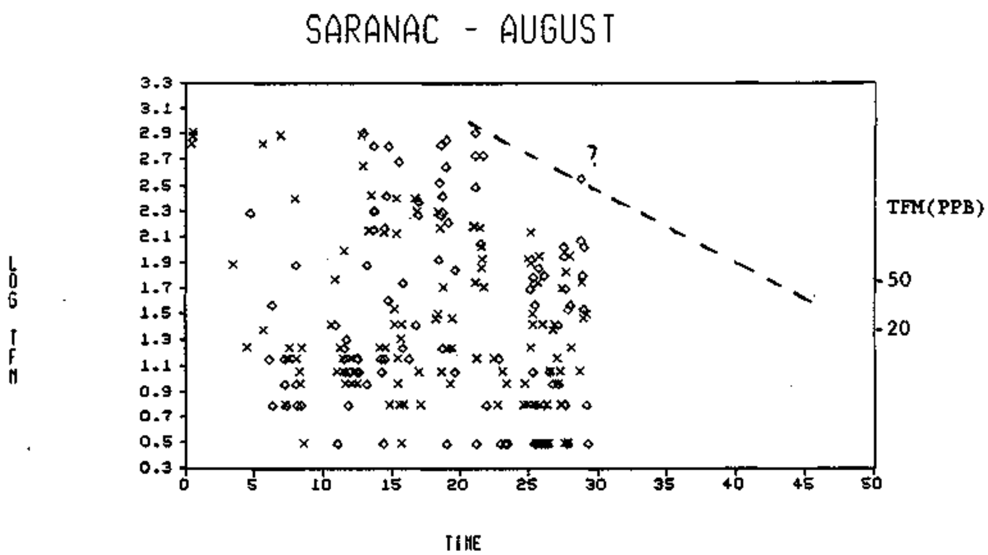


Figure 31
Site 2: Saranac River (August)
Empirical Projection of TFM Plume Based upon Dye Measurements

TIME = Hours from Entry of Lampricide Plume to Lake
DISTANCE = Distance from River Inflow (Meters)
LOG TFM = Log_{10} (Projected TFM Conc., ppb), Rescaled from Dye Data
TFM CONC = Measured Dye Conc. x TFM Load / Dye Load
LOAD = Streamflow x Applied Conc. x Treatment Duration

Symbols: x = surface samples, o = subsurface samples



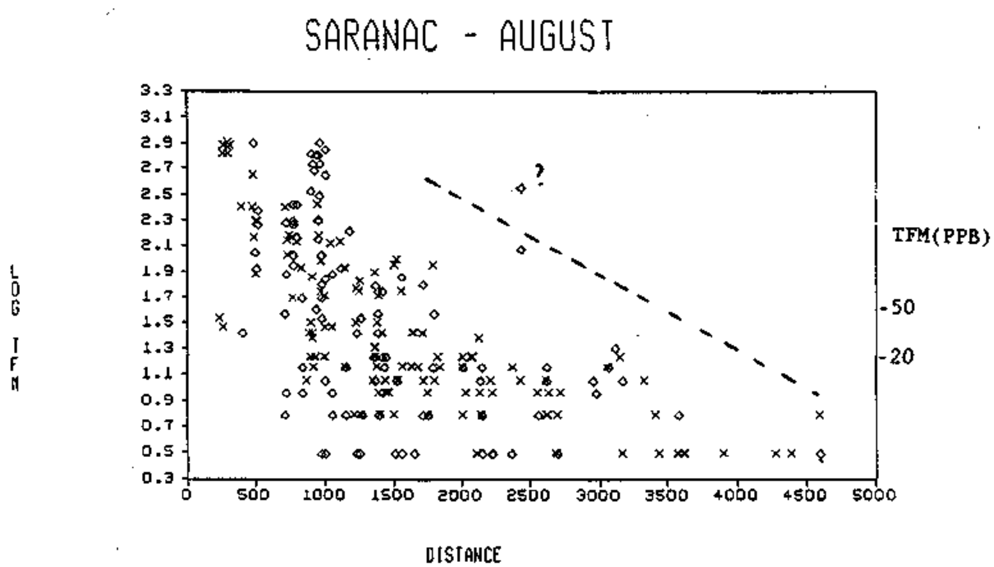


Figure 32

Site 2: Saranac River (June)

Observed and Predicted Maximum Dye Concentrations

Rescaled to Applied Conc. of 1000, Contours = 100-Fold Dilution

Observed | Predicted

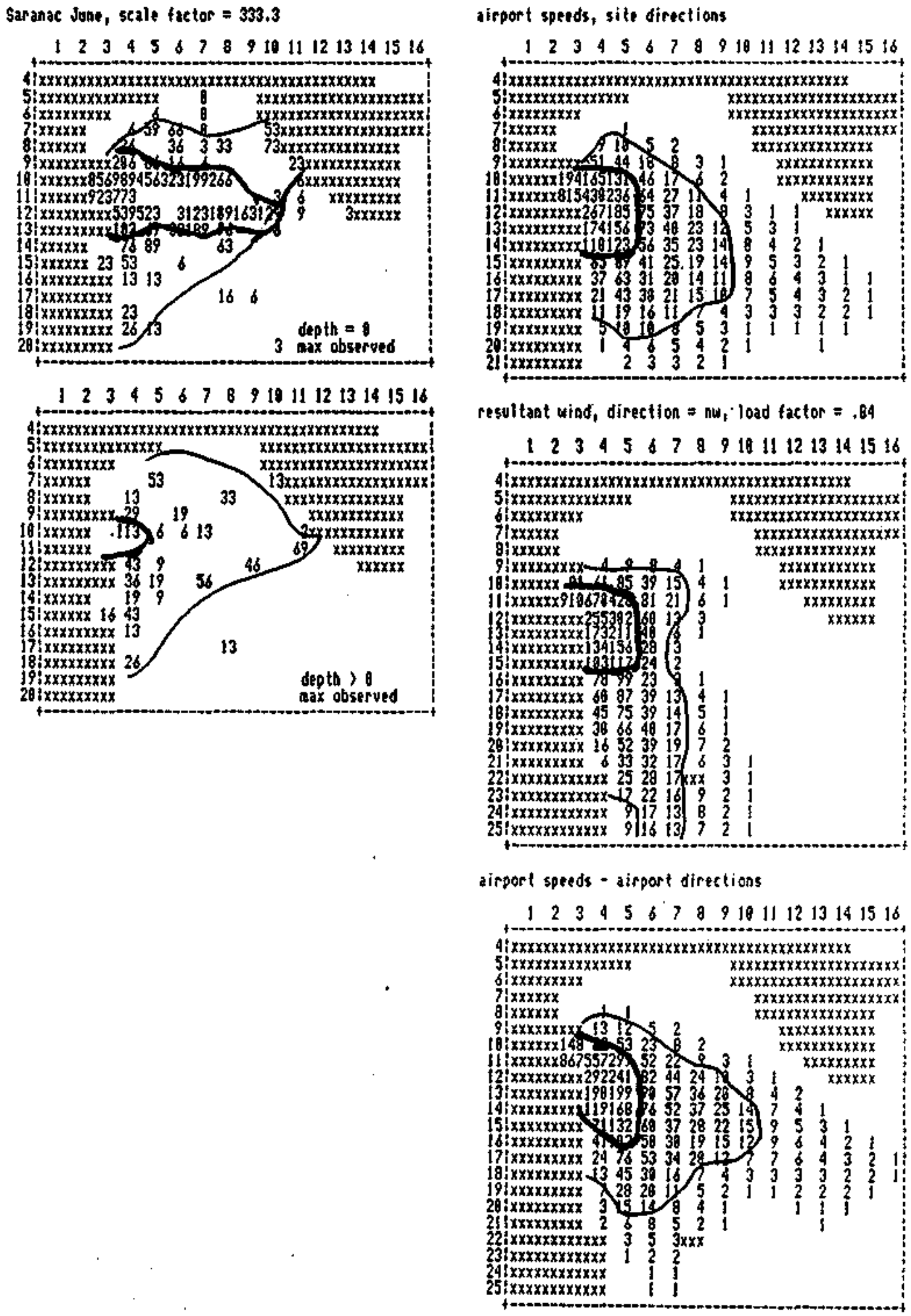


Figure 33
Site 2: Saranac River (August)
Observed and Predicted Maximum Dye Concentrations
Rescaled to Applied Conc. of 1000, Contours = 100-Fold Dilution

Observed | Predicted

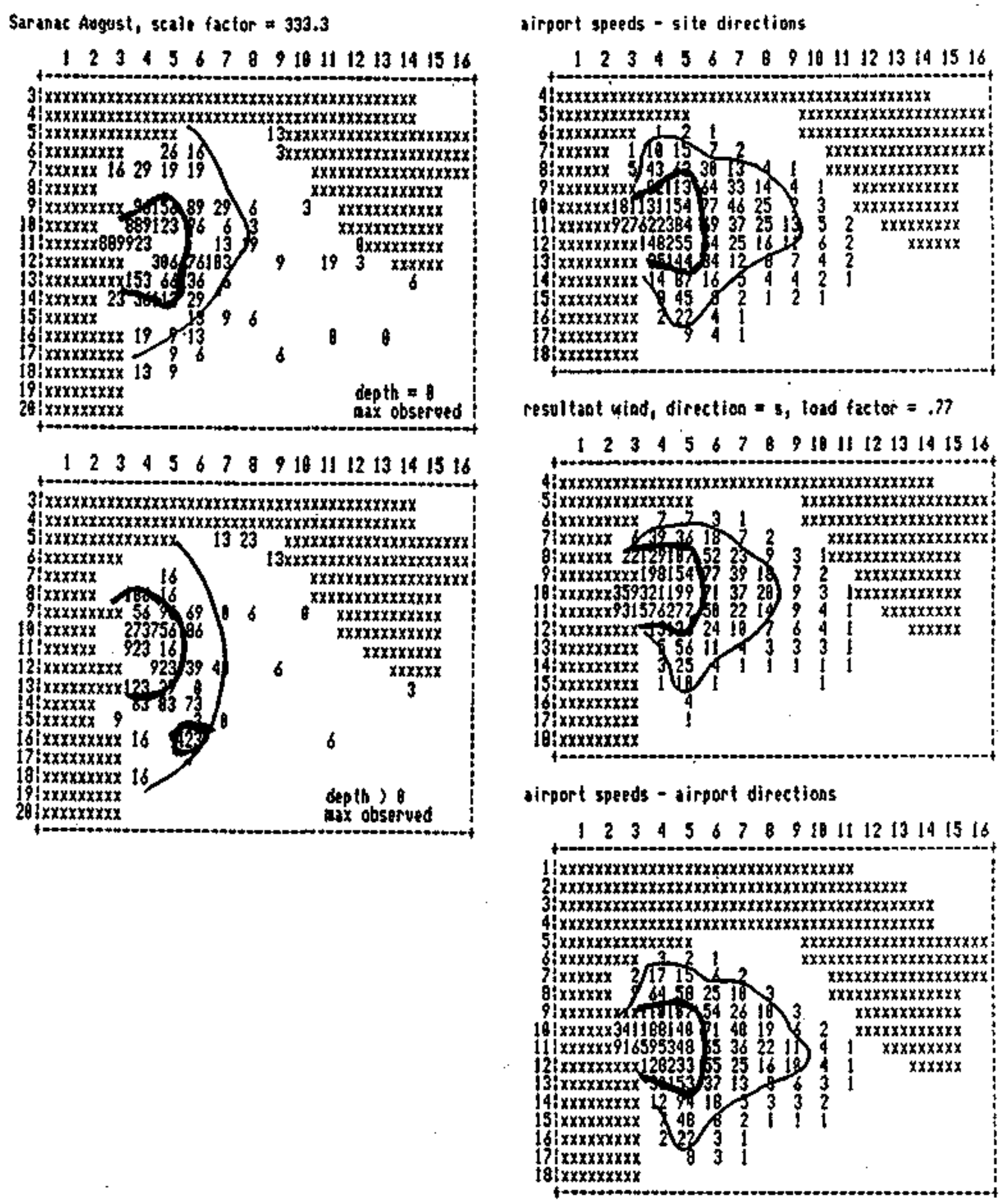


Figure 34
Site 2: Saranac River
Maximum TFM Concentrations vs. Wind Direction
Maximum Mixed Layer Depth = 5 Meters, Units = ppb/5

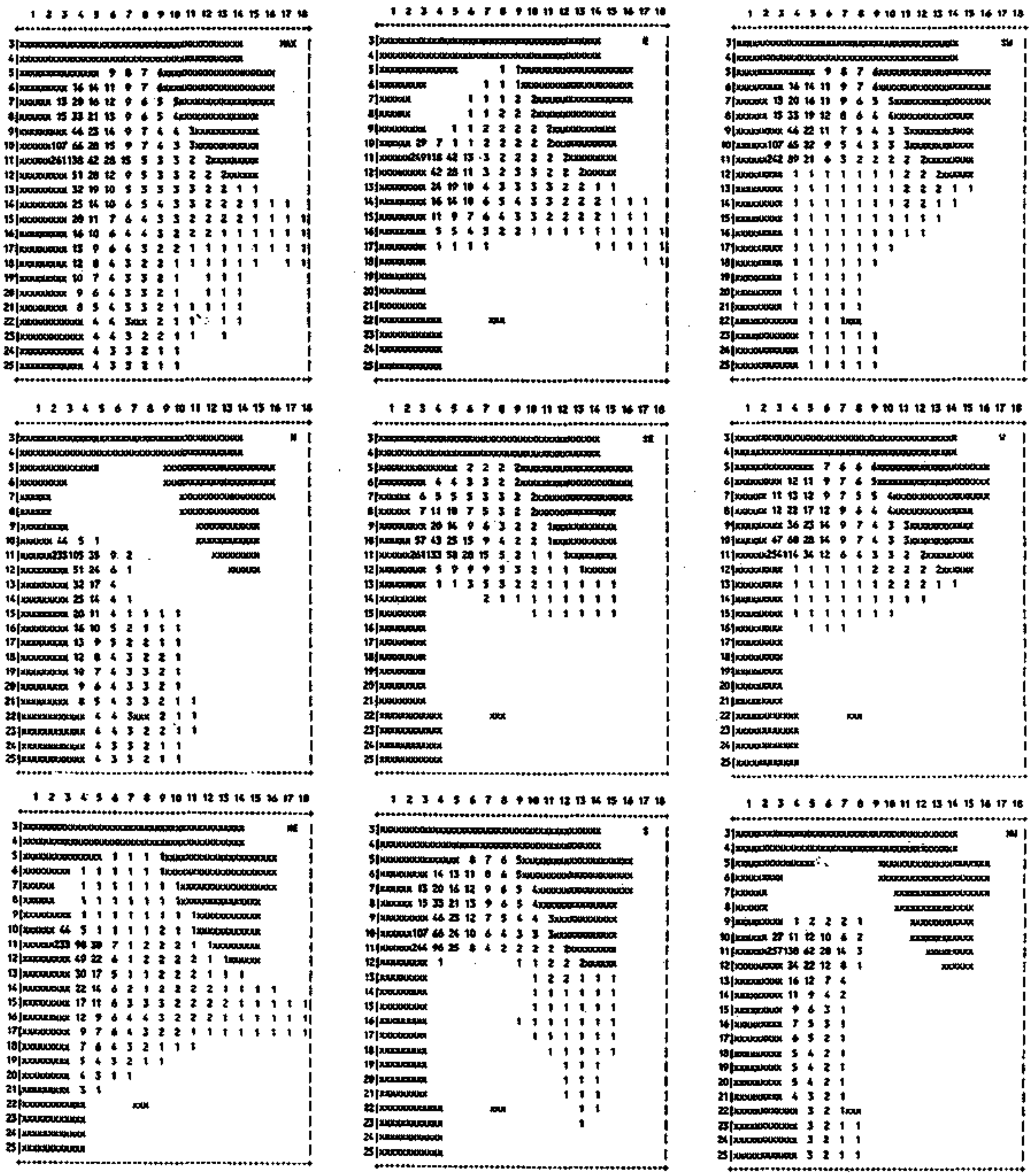


Figure 35
Site 2: Saranac River
Cell Maximum TFM Concentrations

Composite Projections for Eight Wind Directions, Units = ppb/5
Flow = 600 cfs, Applied TFM Conc.= 1.5 ppm, Duration = 12 hrs

```
     1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18
  +------------------------------------------------------+
 3|xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx      MAX   |
 4|xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx            |
 5|xxxxxxxxxxxxxxx  9  8  7  6xxxxxxxxxxxxxxxxxxxxx      |
 6|xxxxxxxxx 16 14 11  9  7  6xxxxxxxxxxxxxxxxxxxxx      |
 7|xxxxxx 13 20 16 12  9  6  5  5xxxxxxxxxxxxxxxxxx      |
 8|xxxxxx 15 33 21 13  9  6  5  4xxxxxxxxxxxxxxx         |
 9|xxxxxxxxx 46 23 14  9  7  4  4  3xxxxxxxxxxxx         |
10|xxxxxx107 66 28 15  9  7  4  3  3xxxxxxxxxxxx         |
11|xxxxxx261138 62 28 15  5  3  3  2  2xxxxxxxxx         |
12|xxxxxxxxx 51 28 12  9  5  3  3  2  2  2xxxxxx         |
13|xxxxxxxxx 32 19 10  5  3  3  3  3  2  2  1  1         |
14|xxxxxxxxx 25 14 10  6  5  4  3  3  2  2  2  1  1  1   |
15|xxxxxxxxx 20 11  7  6  4  3  3  2  2  2  2  1  1  1  1|
16|xxxxxxxxx 16 10  6  4  4  3  2  2  2  1  1  1  1  1  1|
17|xxxxxxxxx 13  9  6  4  3  2  2  1  1  1  1  1  1  1  1|
18|xxxxxxxxx 12  8  4  3  2  2  1  1  1  1  1  1     1  1|
19|xxxxxxxxx 10  7  4  3  3  2  1     1  1  1            |
20|xxxxxxxxx  9  6  4  3  3  2  1     1  1  1            |
21|xxxxxxxxx  8  5  4  3  3  2  1  1  1  1  1            |
22|xxxxxxxxxxxx  4  4  3xxx  2  1  1     1  1            |
23|xxxxxxxxxxxx  4  4  3  2  2  1  1     1               |
24|xxxxxxxxxxxx  4  3  3  2  1  1                        |
25|xxxxxxxxxxxx  4  3  3  2  1  1                        |
  +------------------------------------------------------+
```

Figure 36
Site 2: Saranac River
Maximum TFM Concentration Contours

Composite Projections for Eight Wind Directions, Units = ppb
Flow = 600 cfs, Applied TFM Conc. = 1.5 ppm, Duration = 12 hrs
Map Scale 1:59507, 1 Inch = .939 Miles

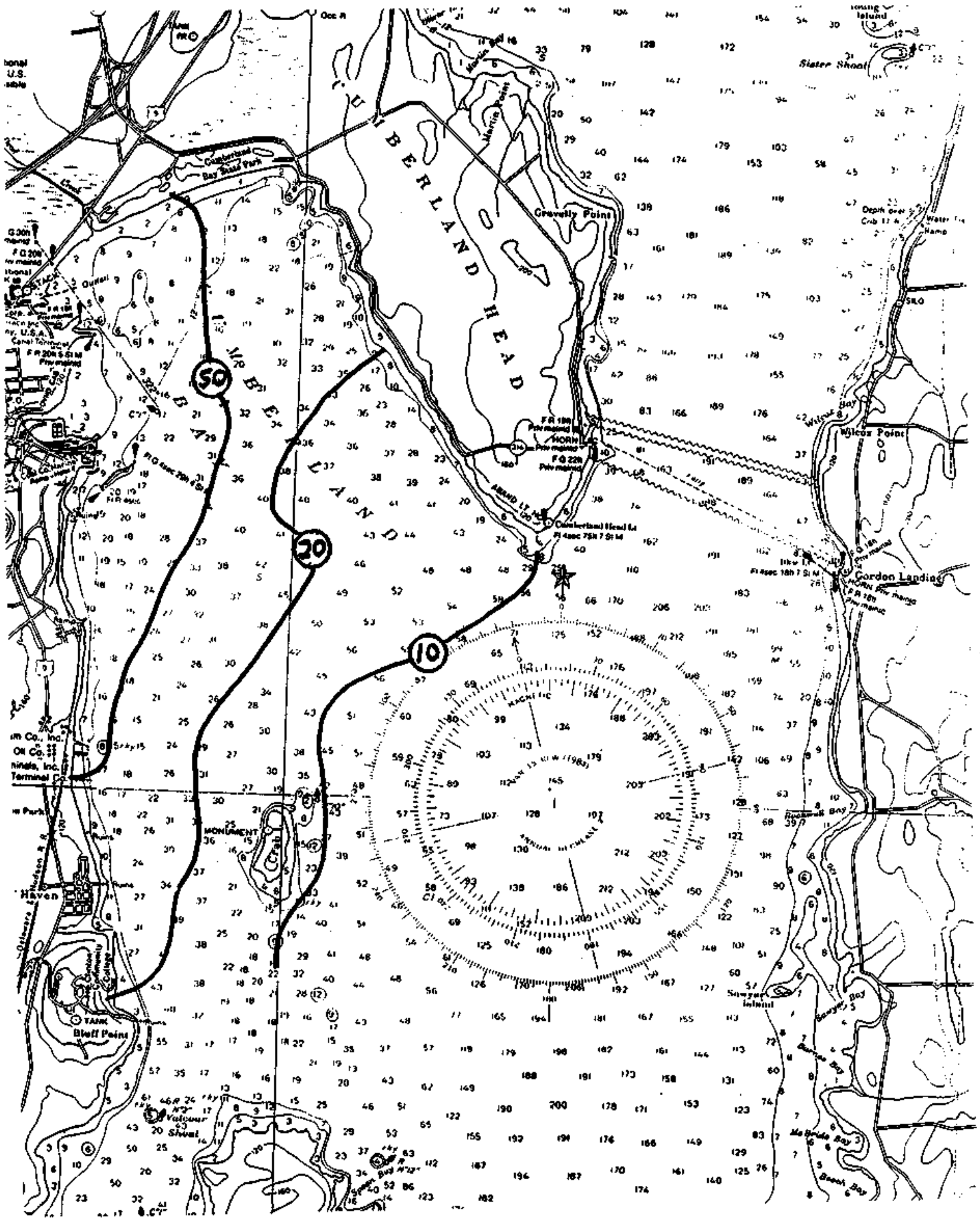


Figure 37
Site 2: Saranac River
Maximum Bayer-73 Concentrations vs. Wind Direction
Maximum Mixed Layer Depth = 5 Meters, Units = ppb/5

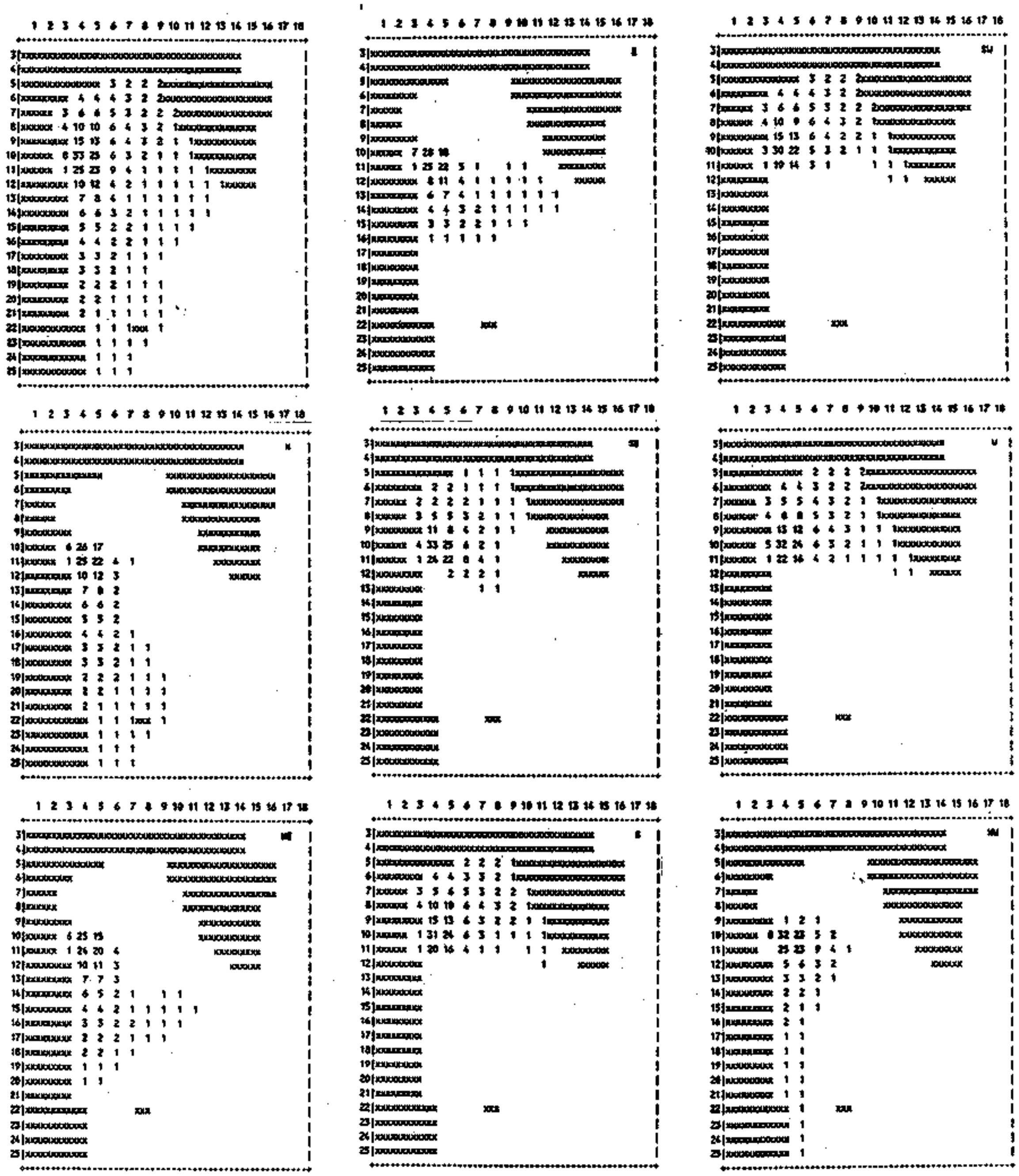


Figure 38
Site 2: Saranac River
Cell Maximum Bayer-73 Concentrations

Composite Projections for Eight Wind Directions, Units = ppb/5
Application Area = 175 Acres, Dose = 100 lbs/acre (5% Active Ingred.)

```
      1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18
   +------------------------------------------------------+
  3|xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx            |
  4|xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx            |
  5|xxxxxxxxxxxxxxx  3  2  2  2xxxxxxxxxxxxxxxxxxxxx      |
  6|xxxxxxxxx  4  4  4  3  2  2xxxxxxxxxxxxxxxxxxxxx      |
  7|xxxxxx  3  6  6  5  3  2  2  2xxxxxxxxxxxxxxxxxx      |
  8|xxxxxx  4 10 10  6  4  3  2  1xxxxxxxxxxxxxxx         |
  9|xxxxxxxxx 15 13  6  4  3  2  1  1xxxxxxxxxxxx         |
 10|xxxxxx  8 33 25  6  3  2  1  1  1xxxxxxxxxxxx         |
 11|xxxxxx  1 25 23  9  4  1  1  1  1  1xxxxxxxxx         |
 12|xxxxxxxxx 10 12  4  2  1  1  1  1  1  1xxxxxx         |
 13|xxxxxxxxx  7  8  4  1  1  1  1  1  1                  |
 14|xxxxxxxxx  6  6  3  2  1  1  1  1  1                  |
 15|xxxxxxxxx  5  5  2  2  1  1  1  1                     |
 16|xxxxxxxxx  4  4  2  2  1  1  1                        |
 17|xxxxxxxxx  3  3  2  1  1  1                           |
 18|xxxxxxxxx  3  3  2  1  1                              |
 19|xxxxxxxxx  2  2  2  1  1  1                           |
 20|xxxxxxxxx  2  2  1  1  1  1                           |
 21|xxxxxxxxx  2  1  1  1  1  1                           |
 22|xxxxxxxxxxxx  1  1  1xxx  1                           |
 23|xxxxxxxxxxxx  1  1  1  1                              |
 24|xxxxxxxxxxxx  1  1  1                                 |
 25|xxxxxxxxxxxx  1  1  1                                 |
   +------------------------------------------------------+
```

Figure 39
Site 2: Saranac River
Maximum Bayer-73 Concentration Contours

Composite Projections for Eight Wind Directions, Units = ppb
Application Area = 175 Acres, Dose = 100 lbs/acre (5% Active Ingred.)
Map Scale 1:59507, 1 Inch = .939 miles

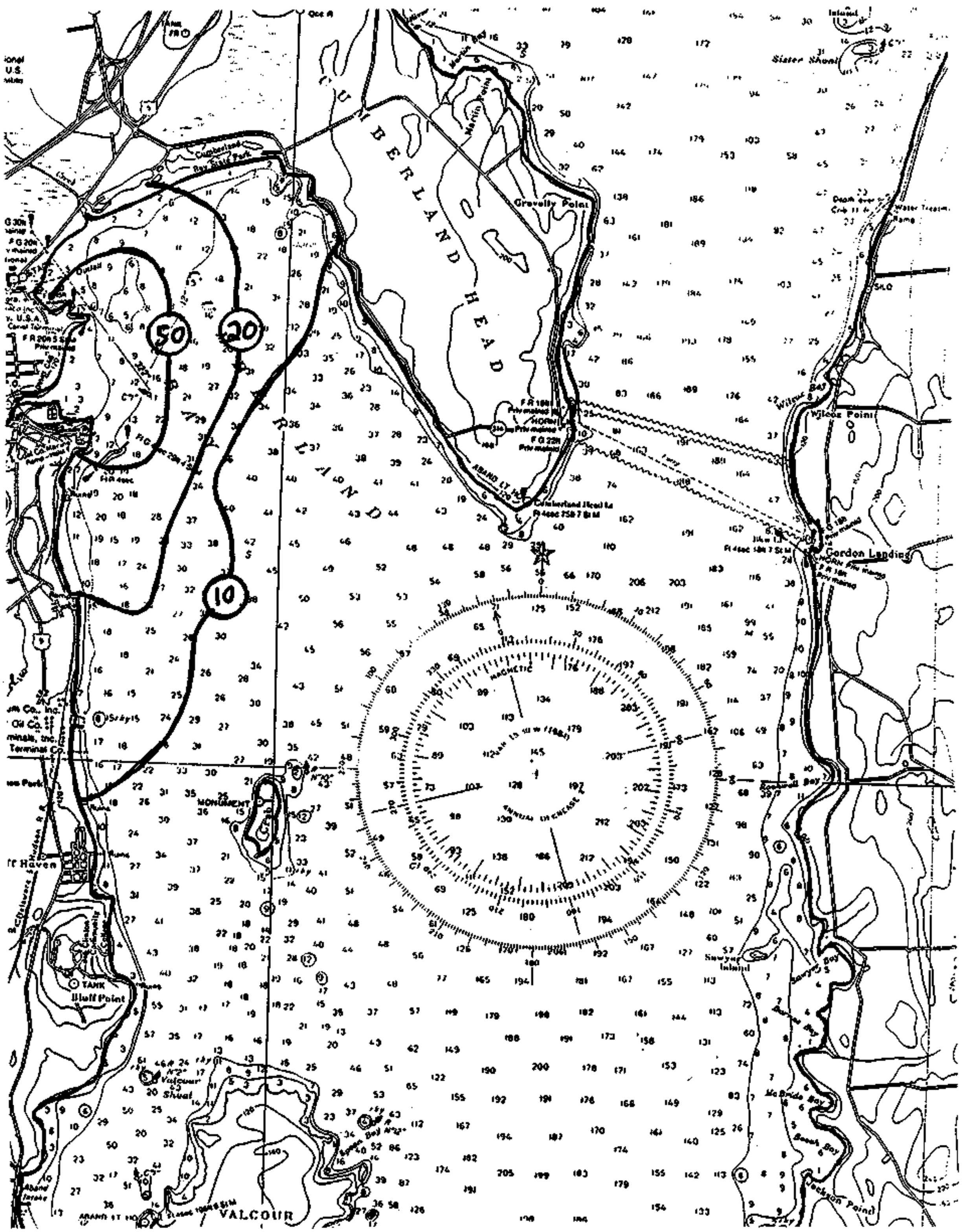
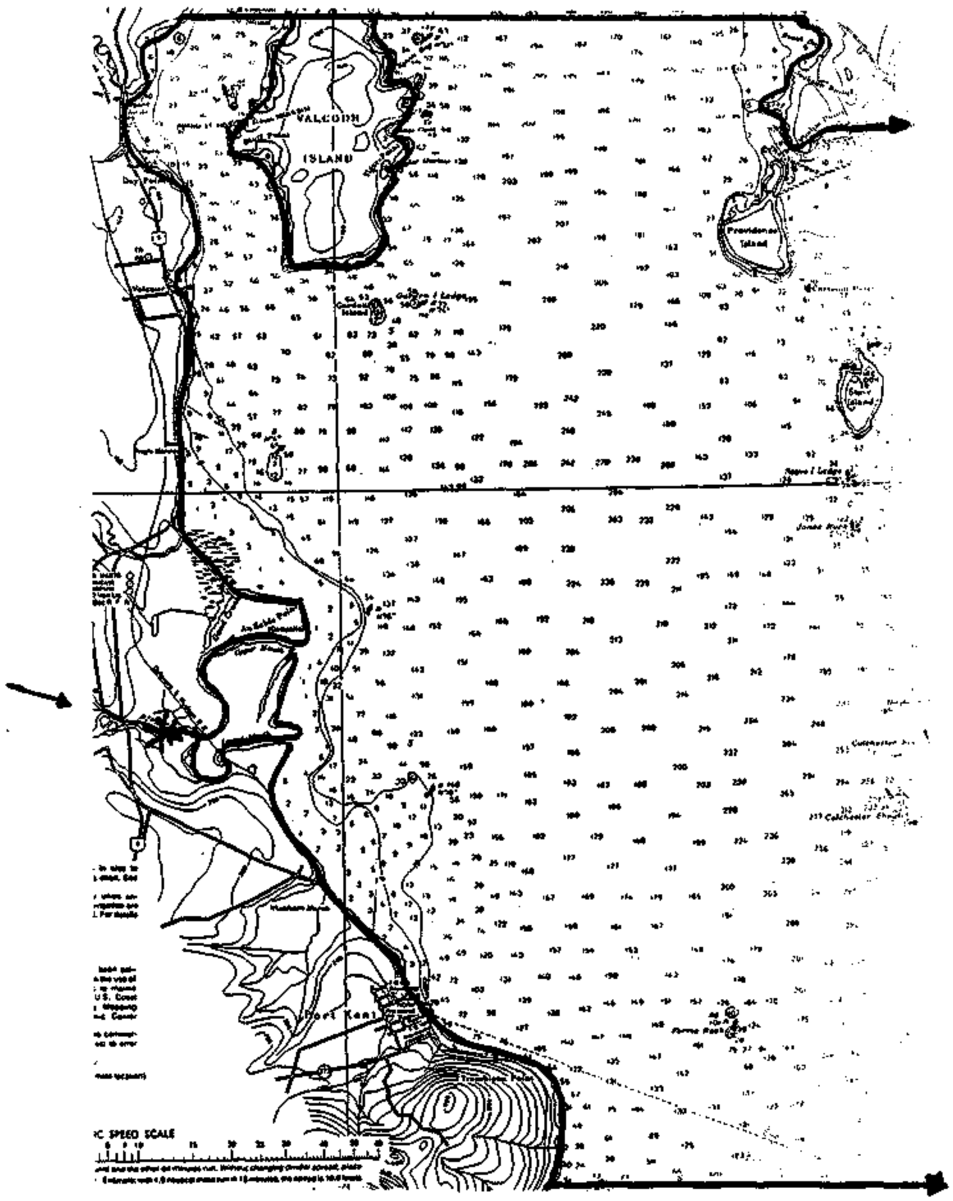
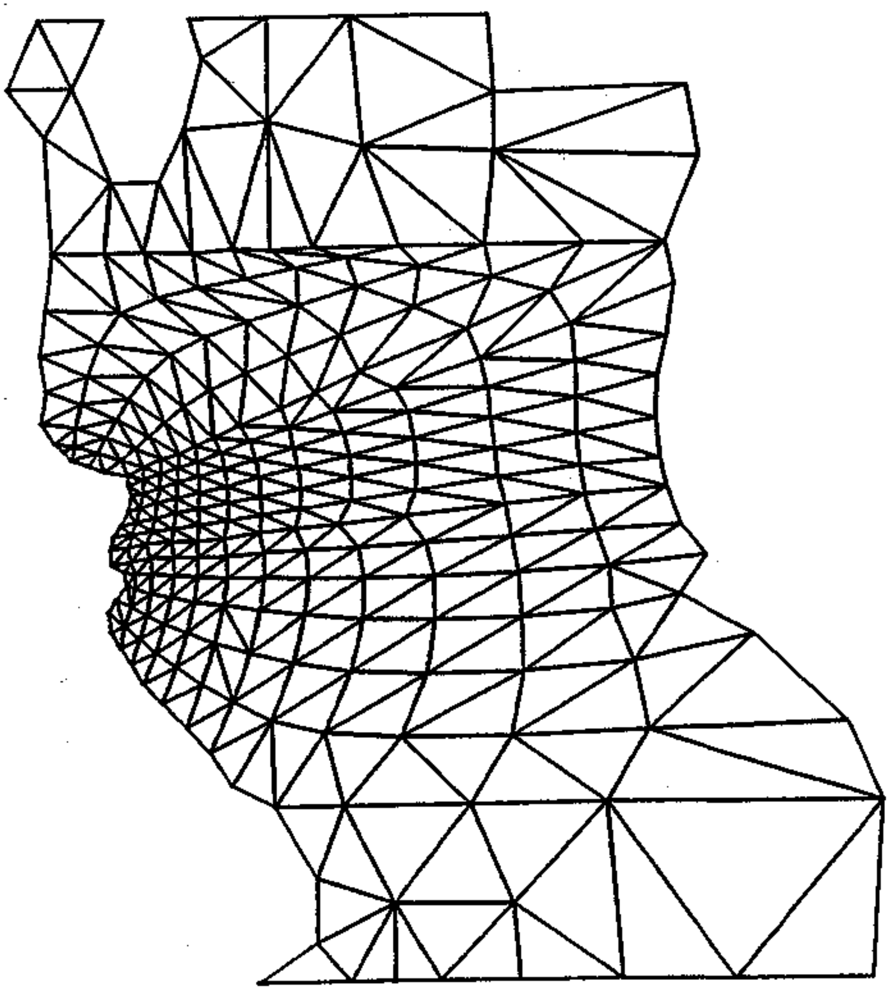


Figure 40
Site 3: Ausable River
Model Region
Map Scale - 1:88816,   1 Inch - 1.4 Miles





Finite Element

Mesh

Site 3

Aus able

252 Nodes

432 Elements

70 Bnd Nodes

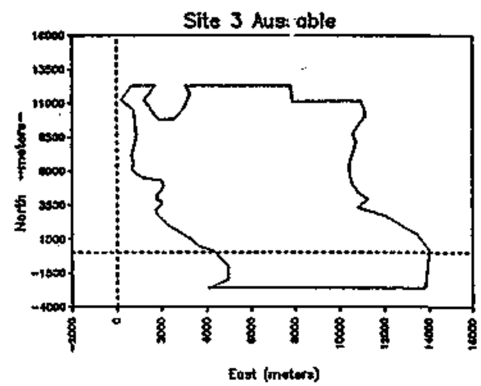


Figure 41
Site 3: Ausable River
Finite Element Mesh

Figure 42
Site 3: Ausable River
Vertically Averaged Circulation Patterns - North Wind
(Directions Reversed for South Wind)

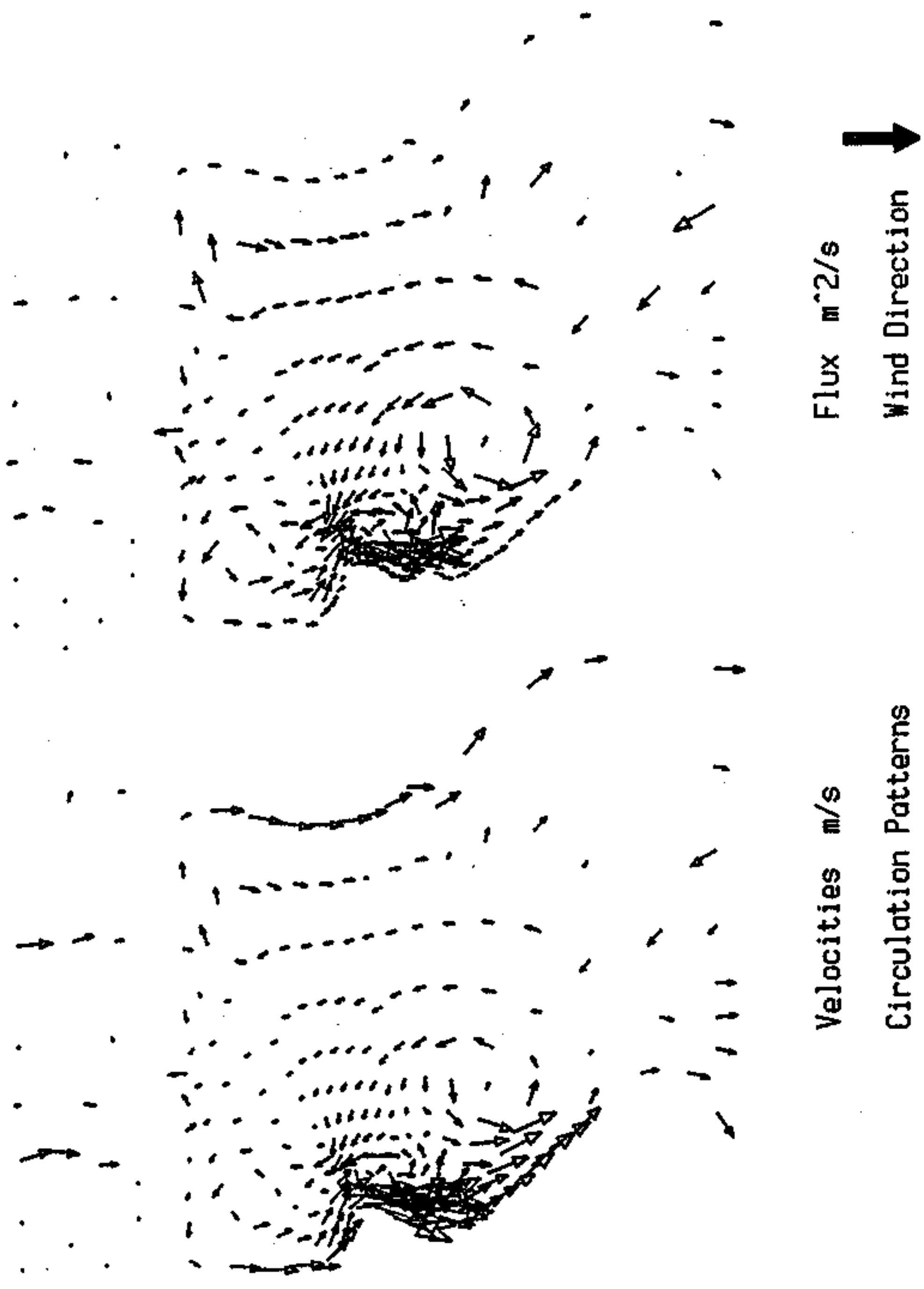


Figure 43
Site 3: Ausable River
Vertically Averaged Circulation Patterns - Northeast Wind
(Directions Reversed for Southwest Wind)

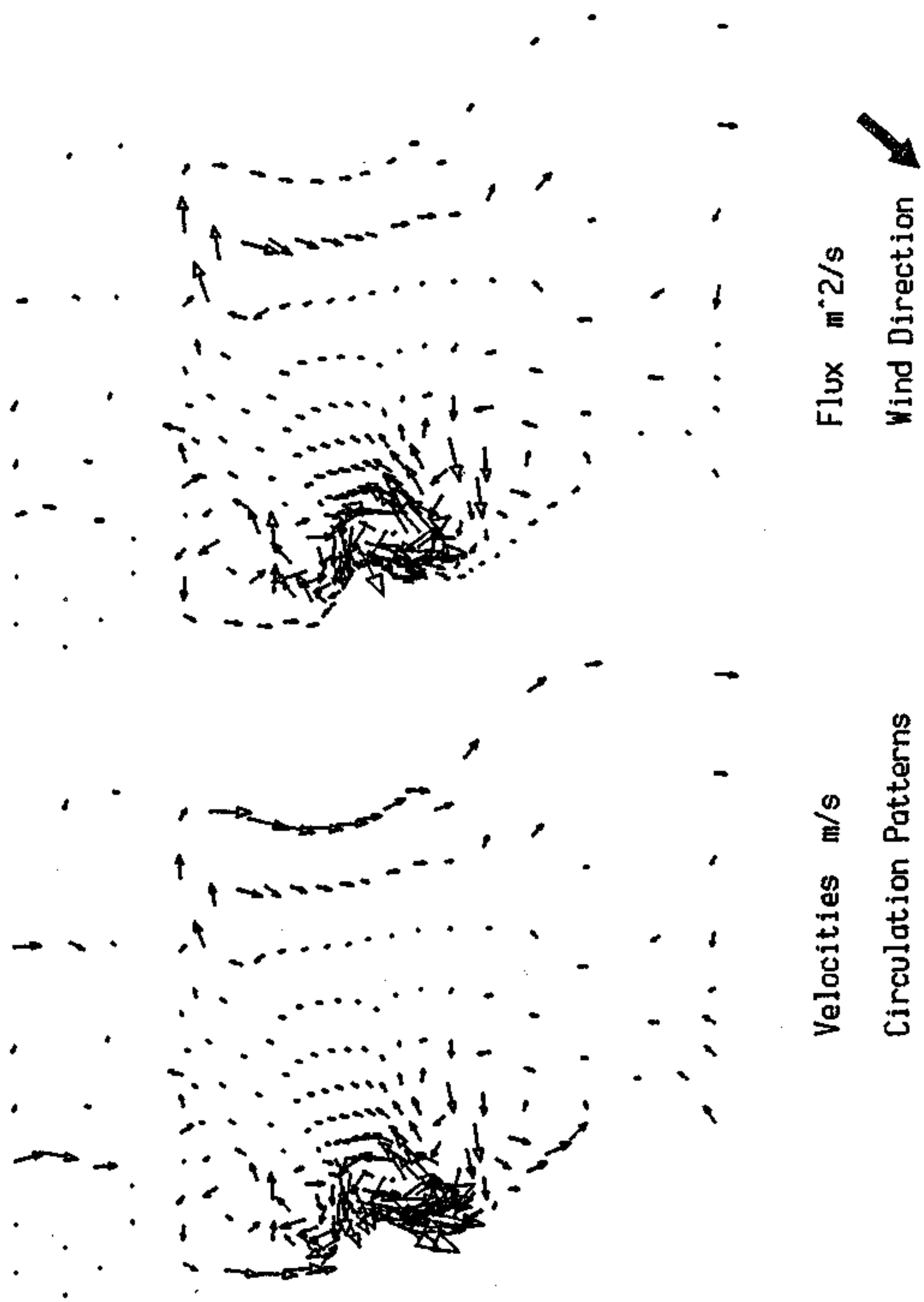


Figure 44
Site 3: Ausable River
Transport Model Grid

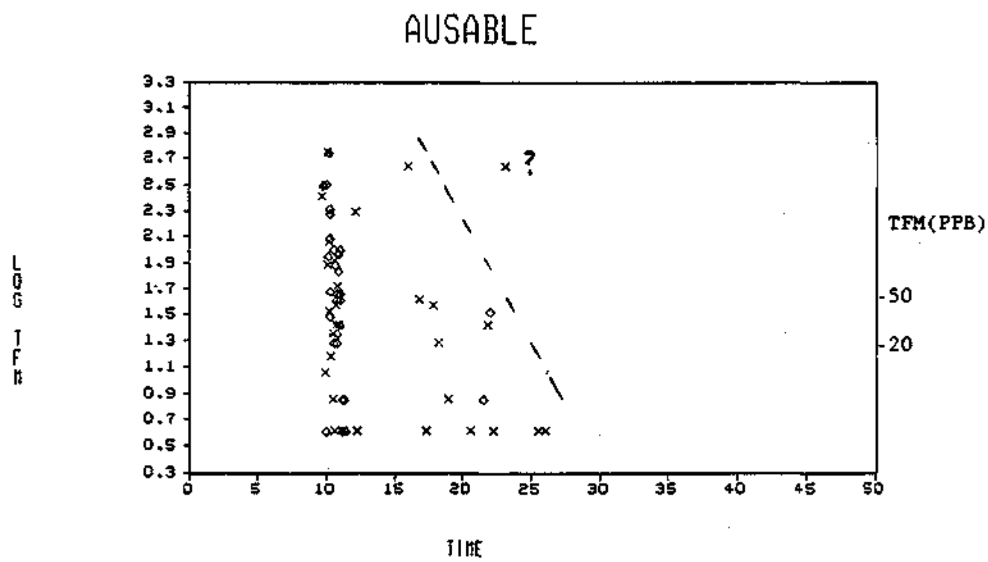
Cell Depths (Meters) at Minimum Lake Elevation (92.9 ft,msl)
xxx = Land Mass, Cell Dimension = 400 meters

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	xxx	2	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
2	xxx	2	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
3	xxx	2	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
4	xxx	1	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
5	xxx	1	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
6	xxx	1	6	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
7	xxx	1	3	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
8	xxx	1	2	4	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
9	xxx	0	0	1	6	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
10	xxx	xxx	0	0	5	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
11	xxx	xxx	0	0	1	1	10	10	10	10	10	10	10	10	10	10	10	10	10	10
12	xxx	xxx	xxx	xxx	xxx	0	3	10	10	10	10	10	10	10	10	10	10	10	10	10
13	xxx	xxx	xxx	xxx	xxx	1	6	10	10	10	10	10	10	10	10	10	10	10	10	10
14	xxx	xxx	xxx	xxx	0	5	10	10	10	10	10	10	10	10	10	10	10	10	10	10
15	xxx	xxx	xxx	xxx	0	7	10	10	10	10	10	10	10	10	10	10	10	10	10	10
16	xxx	xxx	xxx	xxx	xxx	3	10	10	10	10	10	10	10	10	10	10	10	10	10	10
17	xxx	xxx	xxx	xxx	1	3	8	10	10	10	10	10	10	10	10	10	10	10	10	10
18	xxx	xxx	xxx	xxx	0	1	2	3	3	10	10	10	10	10	10	10	10	10	10	10
19	xxx	xxx	xxx	xxx	xxx	0	1	2	3	6	10	10	10	10	10	10	10	10	10	10
20	xxx	xxx	xxx	xxx	xxx	0	0	3	3	5	9	10	10	10	10	10	10	10	10	10
21	xxx	xxx	xxx	xxx	xxx	xxx	0	2	3	9	10	10	10	10	10	10	10	10	10	10
22	xxx	xxx	xxx	xxx	xxx	xxx	xxx	0	6	10	10	10	10	10	10	10	10	10	10	10
23	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	9	10	10	10	10	10	10	10	10	10	10	10
24	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	9	10	10	10	10	10	10	10	10	10	10	10
25	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	9	10	10	10	10	10	10	10	10	10	10
26	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	9	10	10	10	10	10	10	10
27	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	9	10	10	10	10	10	10	10
28	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	9	10	10	10	10	10	10	10

Figure 45
Site 3: Ausable River
Empirical Projection of TFM Plume Based upon Dye Measurements

TIME = Hours from Entry of Lampricide Plume to Lake
DISTANCE = Distance from River Inflow (Meters)
LOG TFM = Log_{10} (Projected TFM Conc., ppb), Rescaled from Dye Data
TFM CONC = Measured Dye Conc. x TFM Load / Dye Load
LOAD = Streamflow x Applied Conc. x Treatment Duration

Symbols: x = surface samples, o = subsurface samples



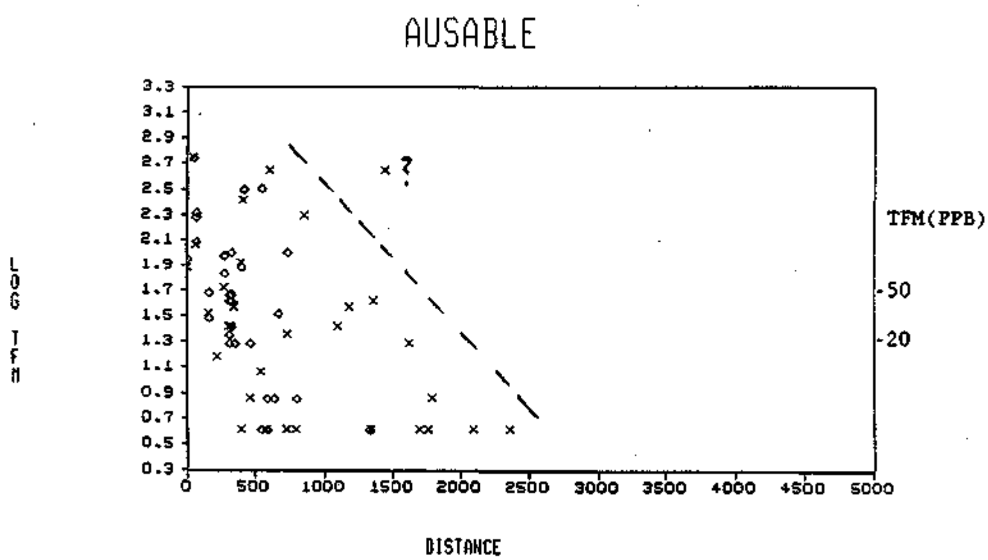


Figure 46
Site 3: Ausable River
Observed and Predicted Maximum Dye Concentrations
Rescaled to Applied Conc. of 1000, Contours = 100-Fold Dilution

Observed

```
ausable scale factor = 363.4
depth = 0, max observed

    1  2  3  4  5  6  7  8  9 10 11 12 13
  +---------------------------------------+
 7|xxx                                    |
 8|xxx                                    |
 9|xxx              0                     |
10|xxxxxx                                 |
11|xxxxxx      425    39     3            |
12|xxxxxxxxxxxxxxx   188 25     3         |
13|xxxxxxxxxxxxxxx   427                  |
14|xxxxxxxxxxxx   534 25  3               |
15|xxxxxxxxxxxx    78                     |
16|xxxxxxxxxxxxxxx 21  0    18            |
17|xxxxxxxxxxxx    36                     |
18|xxxxxxxxxxxx            7              |
19|xxxxxxxxxxxxxxx            0           |
20|xxxxxxxxxxxxxxx                        |
  +---------------------------------------+
```

```
depth > 0, max observed

    1  2  3  4  5  6  7  8  9 10 11 12 13
  +---------------------------------------+
 7|xxx                                    |
 8|xxx                                    |
 9|xxx                                    |
10|xxxxxx                                 |
11|xxxxxx                 0               |
12|xxxxxxxxxxxxxxx                        |
13|xxxxxxxxxxxxxxx   308                  |
14|xxxxxxxxxxxx   534 96  7               |
15|xxxxxxxxxxxx    94                     |
16|xxxxxxxxxxxxxxx 98                     |
17|xxxxxxxxxxxx                           |
18|xxxxxxxxxxxx                           |
19|xxxxxxxxxxxxxxx                        |
20|xxxxxxxxxxxxxxx                        |
  +---------------------------------------+
```

Predicted

```
airport speeds - site directions

    1  2  3  4  5  6  7  8  9 10 11 12 13
  +---------------------------------------+
 5|xxx  2  2  1                           |
 6|xxx  8  9  5  2  1                     |
 7|xxx 13 21 12  6  3  1                  |
 8|xxx 22 34 23 14  7  3  1               |
 9|xxx 28 41 28 21 13  7  3  1            |
10|xxxxxx 61 34 30 25 13  6  2  1         |
11|xxxxxx 47 51 61 84 24  9  4  2         |
12|xxxxxxxxxxxxxxx161 56 11  5  2         |
13|xxxxxxxxxxxxxxx276 52 11  5  2         |
14|xxxxxxxxxxxx 44 53 17  8  3  1         |
15|xxxxxxxxxxxx 49 78 15  5  1            |
16|xxxxxxxxxxxxxxx196 23  3  1            |
17|xxxxxxxxxxxx  1  4  3  1               |
18|xxxxxxxxxxxx     1  1                  |
19|xxxxxxxxxxxxxxx                        |
20|xxxxxxxxxxxxxxx                        |
  +---------------------------------------+
```

```
resultant wind, direction = s, load factor = .85

    1  2  3  4  5  6  7  8  9 10 11 12 13
  +---------------------------------------+
 5|xxx  2  1                              |
 6|xxx  6  4  2                           |
 7|xxx 12 11  6  2  1                     |
 8|xxx 20 19 13  7  3  1                  |
 9|xxx 26 34 21 14  9  5  2  1            |
10|xxxxxx 61 28 23 21 12  7  4  1         |
11|xxxxxx 36 35 45 88 29 15  9  4  1      |
12|xxxxxxxxxxxxxxx108 52 21 11  5  2      |
13|xxxxxxxxxxxxxxx119 40 17 10  5  2      |
14|xxxxxxxxxxxx 43 42 19 12  6  3  1      |
15|xxxxxxxxxxxx 46 59 14  8  3  1         |
16|xxxxxxxxxxxxxxx109 17  3  1            |
17|xxxxxxxxxxxx     3  3  1               |
18|xxxxxxxxxxxx                           |
19|xxxxxxxxxxxxxxx                        |
20|xxxxxxxxxxxxxxx                        |
  +---------------------------------------+
```

```
airport speeds - airport directions

    1  2  3  4  5  6  7  8  9 10 11 12 13
  +---------------------------------------+
 5|xxx  2  1  1                           |
 6|xxx  6  6  3  1                        |
 7|xxx 12 13  8  4  2                     |
 8|xxx 21 29 18 10  5  2                  |
 9|xxx 27 40 22 16 10  5  2  1            |
10|xxxxxx 54 26 23 21 12  8  4  2  1      |
11|xxxxxx 33 36 51 88 30 15  9  5  2      |
12|xxxxxxxxxxxxxxx162 64 21 11  6  2      |
13|xxxxxxxxxxxxxxx297 53 17 10  6  2  1   |
14|xxxxxxxxxxxx 46 46 20 11  6  3  1      |
15|xxxxxxxxxxxx 49 72 15  8  3  1         |
16|xxxxxxxxxxxxxxx203 24  3  1            |
17|xxxxxxxxxxxx     3  3  1               |
18|xxxxxxxxxxxx                           |
19|xxxxxxxxxxxxxxx                        |
20|xxxxxxxxxxxxxxx                        |
  +---------------------------------------+
```

Figure 47
Site 3: Ausable River
Maximum TFM Concentrations vs. Wind Direction
Maximum Mixed Layer Depth = 5 Meters, Units = ppb/5

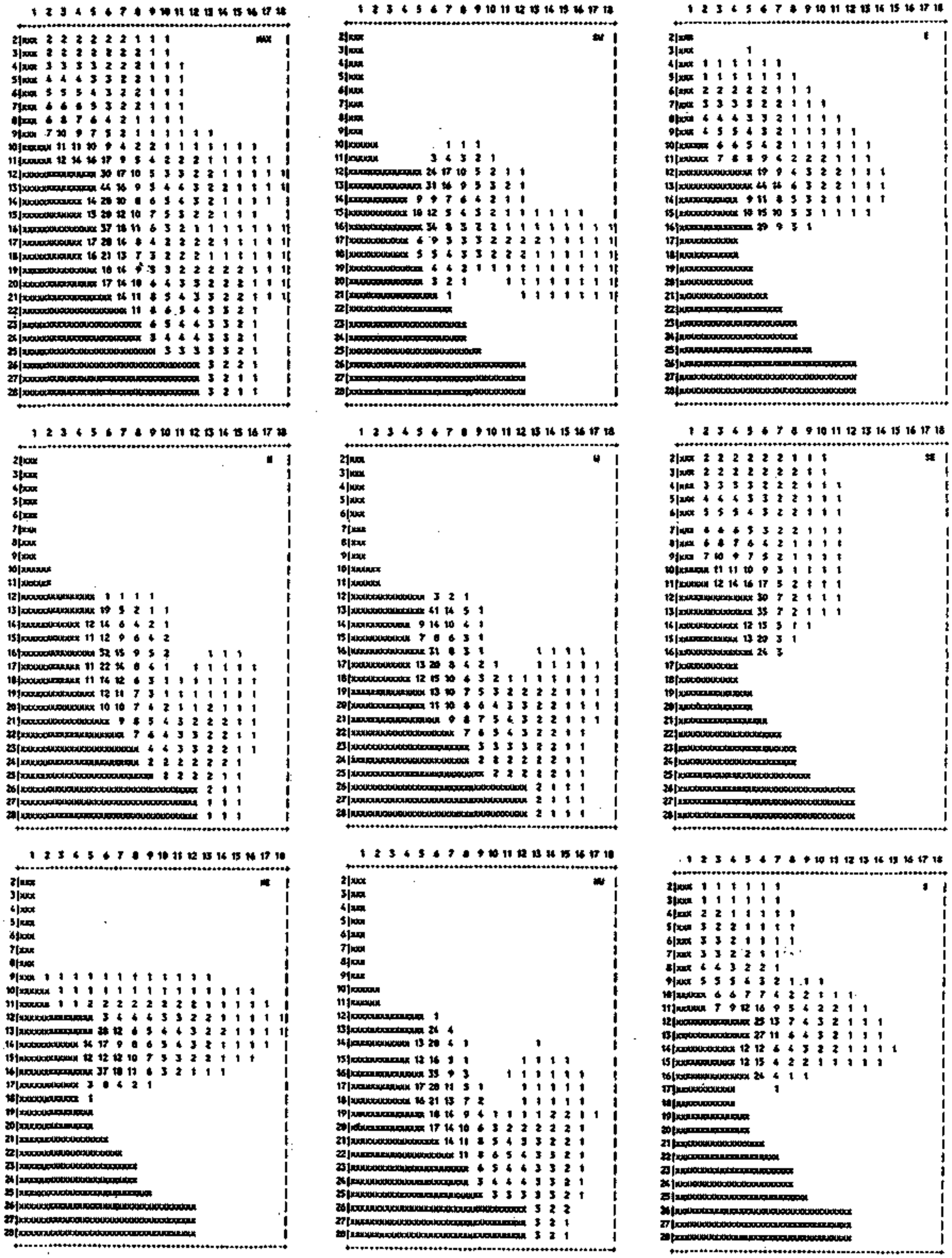


Figure 48
Site 3: Ausable River
Cell Maximum TFM Concentrations

Composite Projections for Eight Wind Directions, Units = ppb/5
Flow = 400 cfs, Applied TFM Conc.=1.6 ppm, Duration = 12 hrs

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
2	xxx	2	2	2	2	2	2	1	1	1							MAX	
3	xxx	2	2	2	2	2	2	2	1	1								
4	xxx	3	3	3	3	2	2	2	1	1	1							
5	xxx	4	4	4	3	3	2	2	1	1	1							
6	xxx	5	5	5	4	3	2	2	1	1	1							
7	xxx	6	6	6	5	3	2	2	1	1	1							
8	xxx	6	8	7	6	4	2	1	1	1	1							
9	xxx	7	10	9	7	5	2	1	1	1	1	1	1					
10	xxx	xxx	11	11	10	9	4	2	2	1	1	1	1	1	1	1		
11	xxx	xxx	12	14	16	17	9	5	4	2	2	2	1	1	1	1	1	
12	xxx	xxx	xxx	xxx	xxx	30	17	10	5	3	3	2	2	1	1	1	1	1
13	xxx	xxx	xxx	xxx	xxx	44	16	9	5	4	4	3	2	2	1	1	1	1
14	xxx	xxx	xxx	xxx	14	20	10	8	6	5	4	3	2	1	1	1	1	
15	xxx	xxx	xxx	xxx	13	20	12	10	7	5	3	2	2	1	1	1		
16	xxx	xxx	xxx	xxx	xxx	37	18	11	6	3	2	1	1	1	1	1	1	1
17	xxx	xxx	xxx	xxx	17	28	14	8	4	2	2	2	2	1	1	1	1	1
18	xxx	xxx	xxx	xxx	16	21	13	7	3	2	2	2	1	1	1	1	1	1
19	xxx	xxx	xxx	xxx	xxx	18	14	9	5	3	2	2	2	2	2	1	1	1
20	xxx	xxx	xxx	xxx	xxx	17	14	10	6	4	3	3	2	2	2	1	1	1
21	xxx	xxx	xxx	xxx	xxx	xxx	14	11	8	5	4	3	3	2	2	1	1	1
22	xxx	xxx	xxx	xxx	xxx	xxx	xxx	11	8	6	5	4	3	3	2	1		
23	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	6	5	4	4	3	3	2	1		
24	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	3	4	4	4	3	3	2	1		
25	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	3	3	3	3	3	2	1		
26	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	3	2	2	1		
27	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	3	2	1	1		
28	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	xxx	3	2	1	1		

Figure 49
Site 3: Ausable River
Maximum TFM Concentration Contours

Composite Projections for Eight Wind Directions, Units = ppb
Flow = 400 cfs, Applied TFM Conc.=1.6 ppm, Duration = 12 hrs
Map Scale 1:59507,   1 Inch = .939 Miles

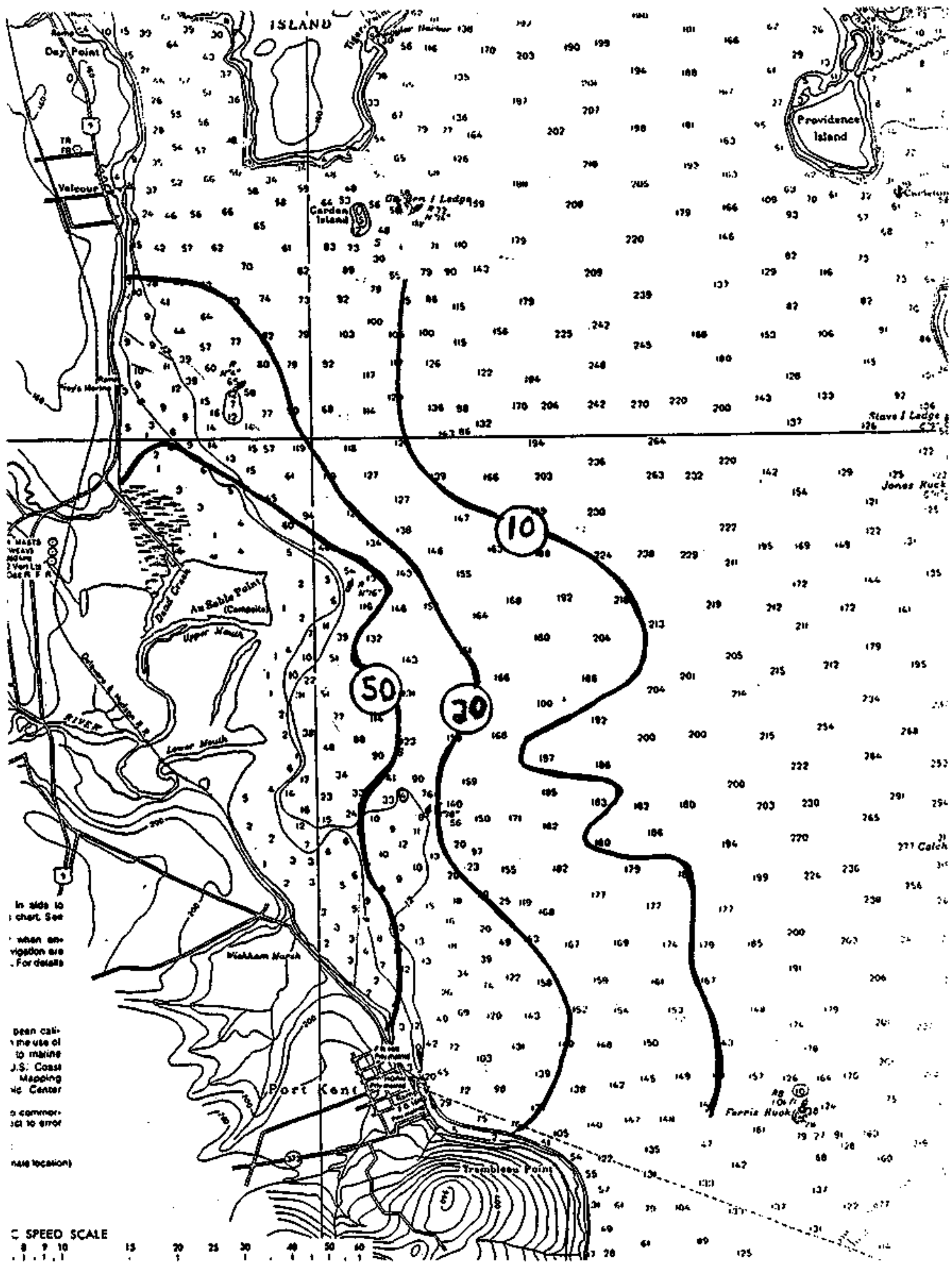


Figure 50
Site 3: Ausable River
Maximum Bayer-73 Concentrations vs. Wind Direction
Maximum Mixed Layer Depth = 5 Meters, Units = ppb/5

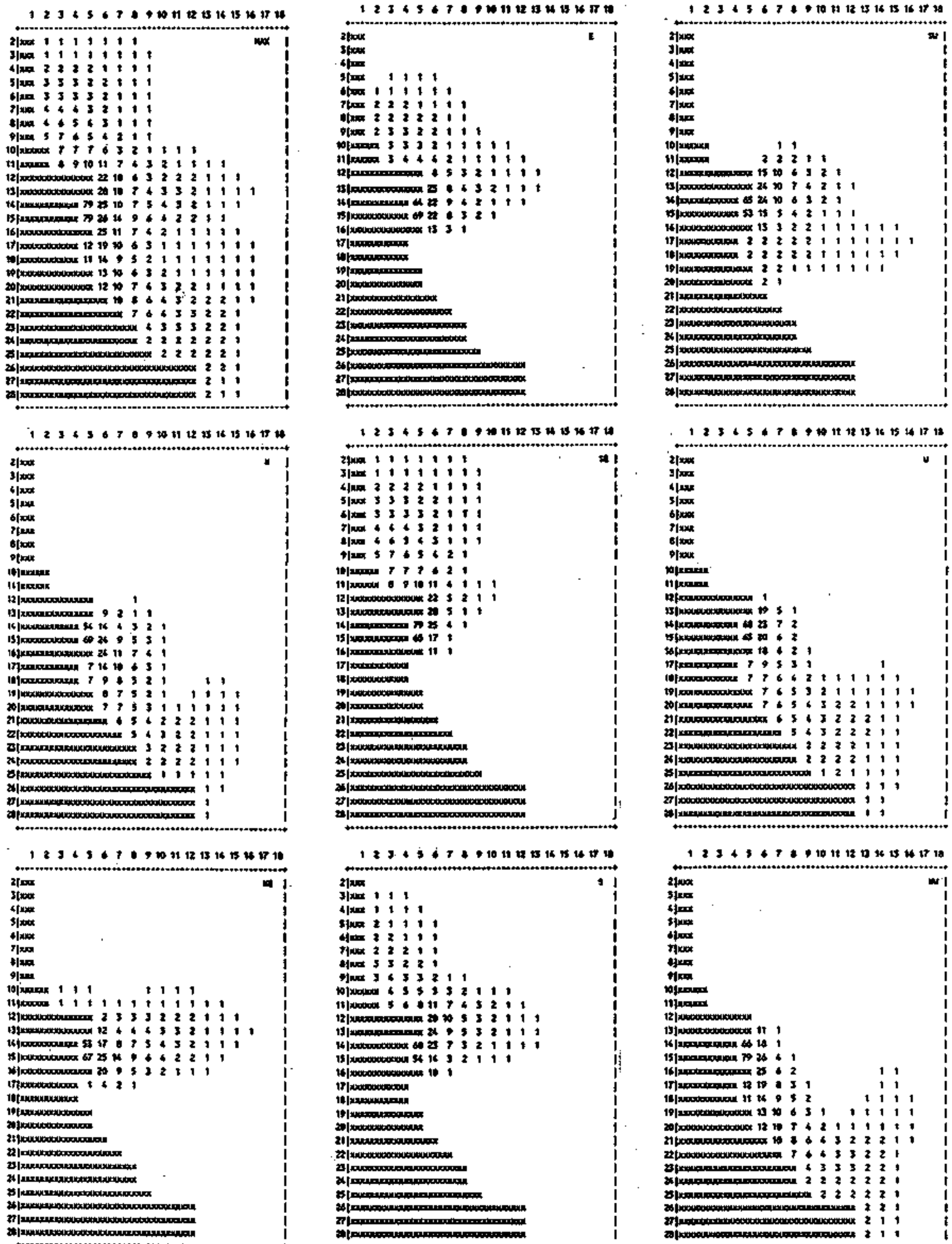


Figure 51
Site 3: Ausable River
Cell Maximum Bayer-73 Concentrations

Composite Projections for Eight Wind Directions, Units = ppb/5
Application Area = 250 Acres, Dose = 100 lbs/acre (5% Active Ingred.)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
2	xxx	1	1	1	1	1	1	1									MAX	
3	xxx	1	1	1	1	1	1	1	1									
4	xxx	2	2	2	2	1	1	1	1									
5	xxx	3	3	3	2	2	1	1	1									
6	xxx	3	3	3	3	2	1	1	1									
7	xxx	4	4	4	3	2	1	1	1									
8	xxx	4	6	5	4	3	1	1	1									
9	xxx	5	7	6	5	4	2	1	1									
10	xxxxxx		7	7	7	6	3	2	1	1	1	1						
11	xxxxxx		8	9	10	11	7	4	3	2	1	1	1	1				
12	xxxxxxxxxxxxxx					22	10	6	3	2	2	2	1	1	1			
13	xxxxxxxxxxxxxx					28	10	7	4	3	3	2	1	1	1	1		
14	xxxxxxxxxxxx				79	25	10	7	5	4	3	2	1	1	1			
15	xxxxxxxxxxxx				79	26	14	9	6	4	2	2	1	1				
16	xxxxxxxxxxxxxx					25	11	7	4	2	1	1	1	1	1			
17	xxxxxxxxxxxx				12	19	10	6	3	1	1	1	1	1	1	1		
18	xxxxxxxxxxxx				11	14	9	5	2	1	1	1	1	1	1	1		
19	xxxxxxxxxxxxxx					13	10	6	3	2	1	1	1	1	1	1		
20	xxxxxxxxxxxxxx					12	10	7	4	3	2	2	1	1	1	1		
21	xxxxxxxxxxxxxxxx						10	8	6	4	3	2	2	2	1	1		
22	xxxxxxxxxxxxxxxxxxxx							7	6	4	3	3	2	2	1			
23	xxxxxxxxxxxxxxxxxxxxxxx								4	3	3	3	2	2	1			
24	xxxxxxxxxxxxxxxxxxxxxxx								2	2	2	2	2	2	1			
25	xxxxxxxxxxxxxxxxxxxxxxxxxx									2	2	2	2	2	1			
26	xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx												2	2	1			
27	xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx												2	1	1			
28	xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx												2	1	1			

Figure 52
Site 3: Ausable River
Maximum Bayer-73 Concentration Contours

Composite Projections for Eight Wind Directions, Units = ppb
Application Area = 250 Acres, Dose = 100 lbs/acre (5% Active Ingred.)
Map Scale 1:59507, 1 Inch = .939 miles

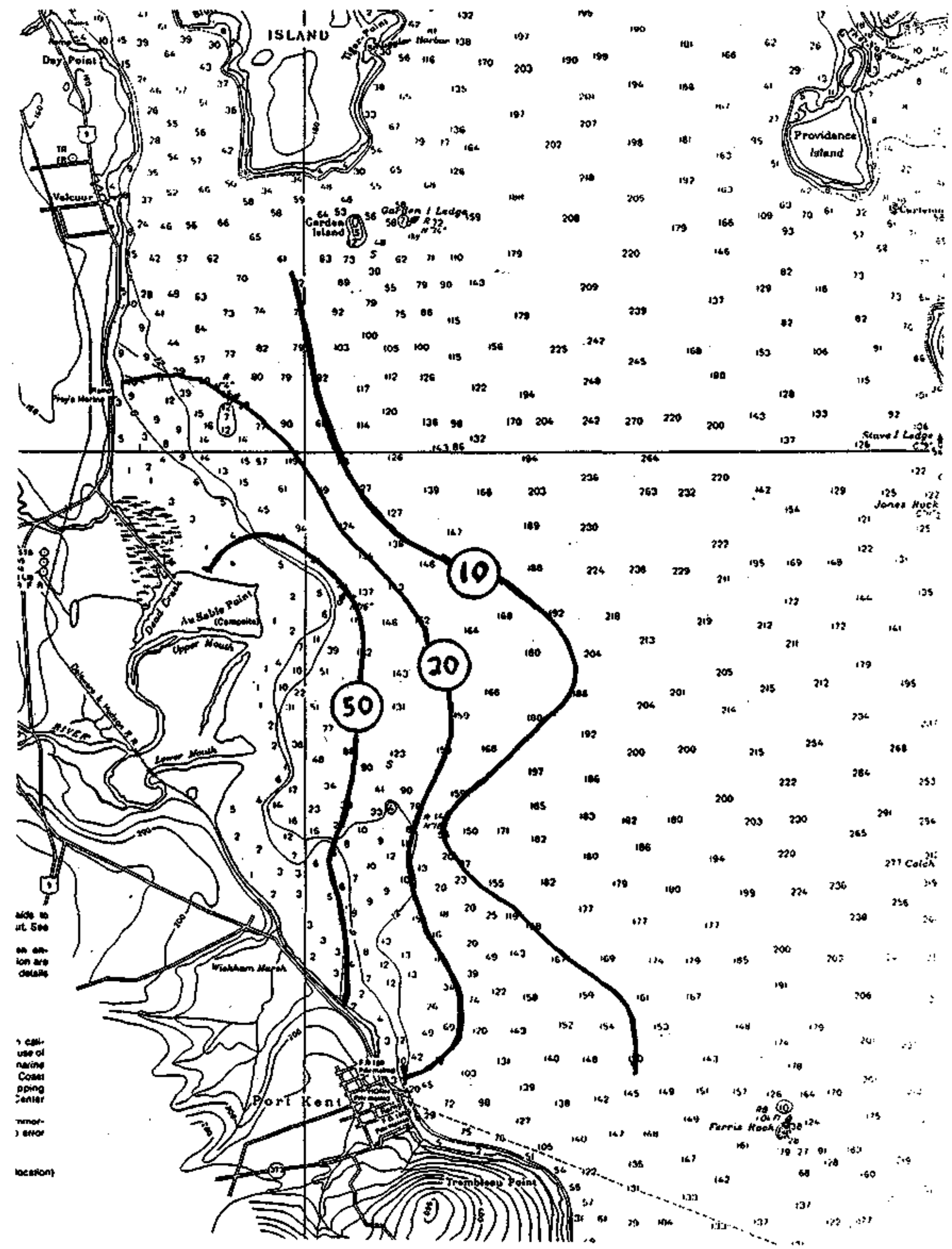
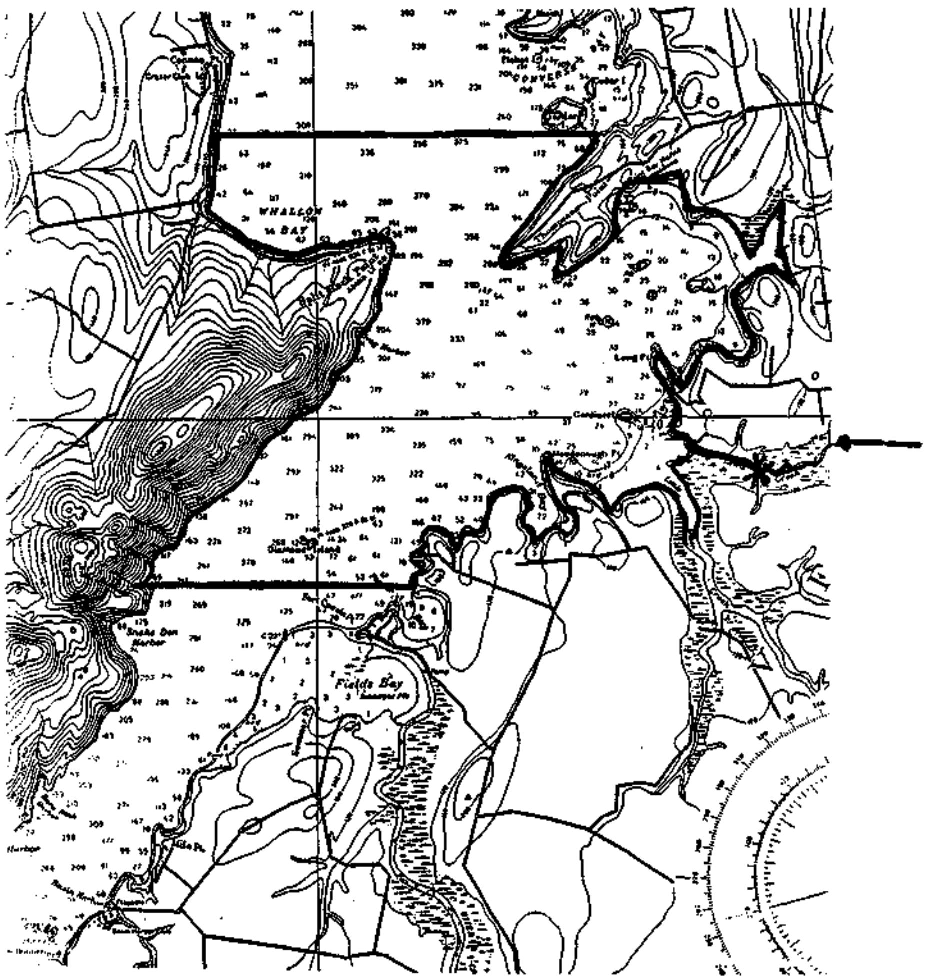
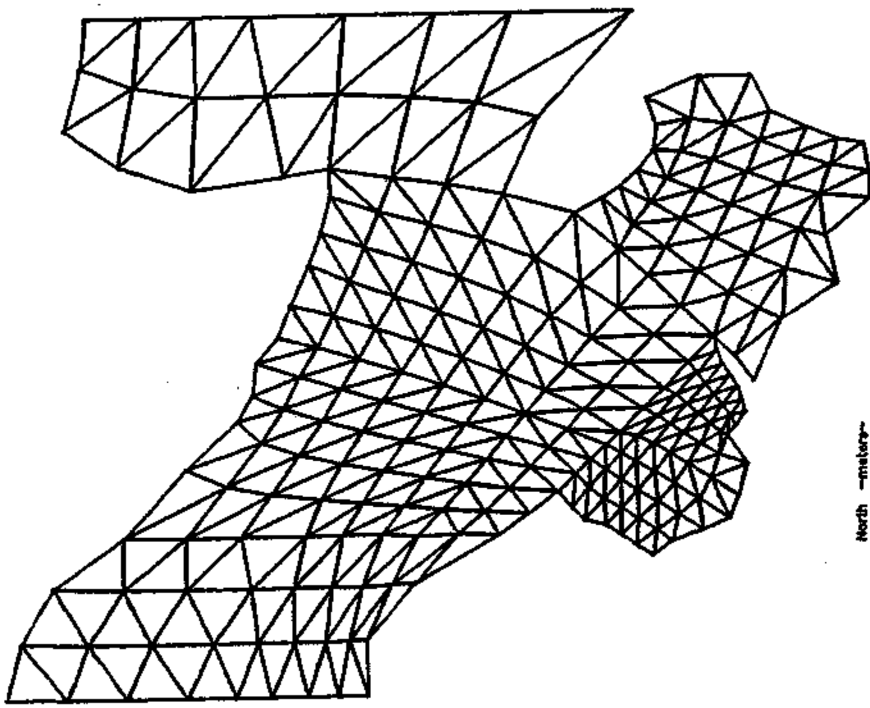


Figure 53
Site 4: Lewis Creek
Model Region
Map Scale = 1:88816,   1 Inch = 1.4 Miles





Finite Element

Mesh

Site 4

Lewis

244 Nodes

404 Elements

82 Bnd Nodes

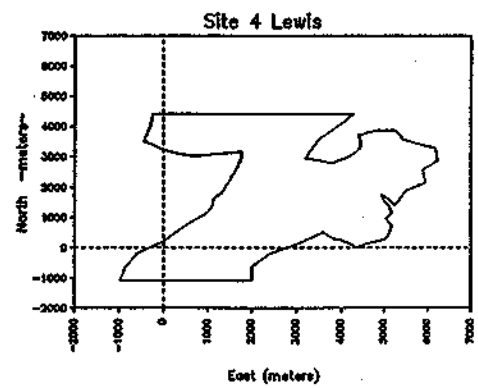


Figure 54
Site 4: Lewis Creek
Finite Element Mesh

Figure 55
Site 4: Lewis Creek
Vertically Averaged Circulation Patterns - North Wind
(Directions Reversed for South Wind)

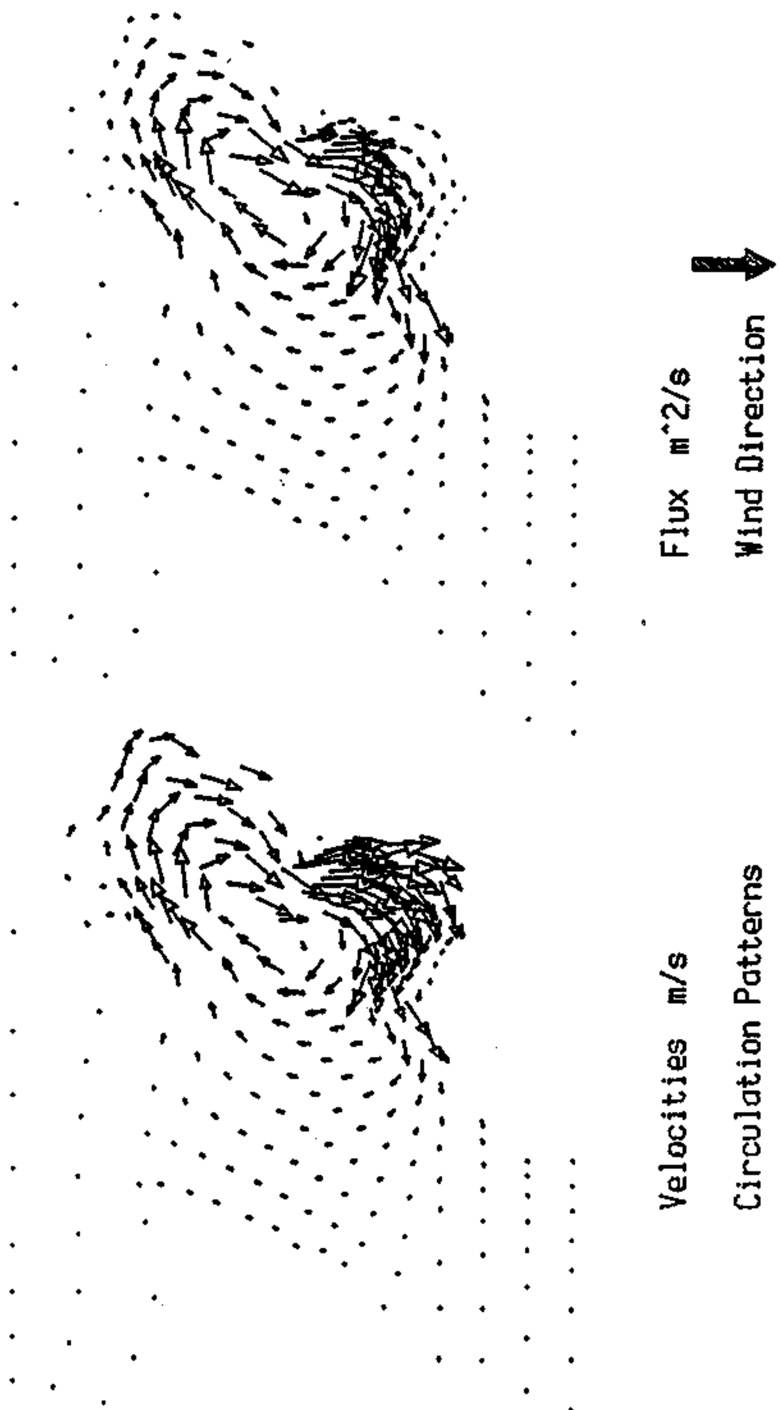


Figure 56
Site 4: Lewis Creek
Vertically Averaged Circulation Patterns - Northeast Wind
(Directions Reversed for Southwest Wind)

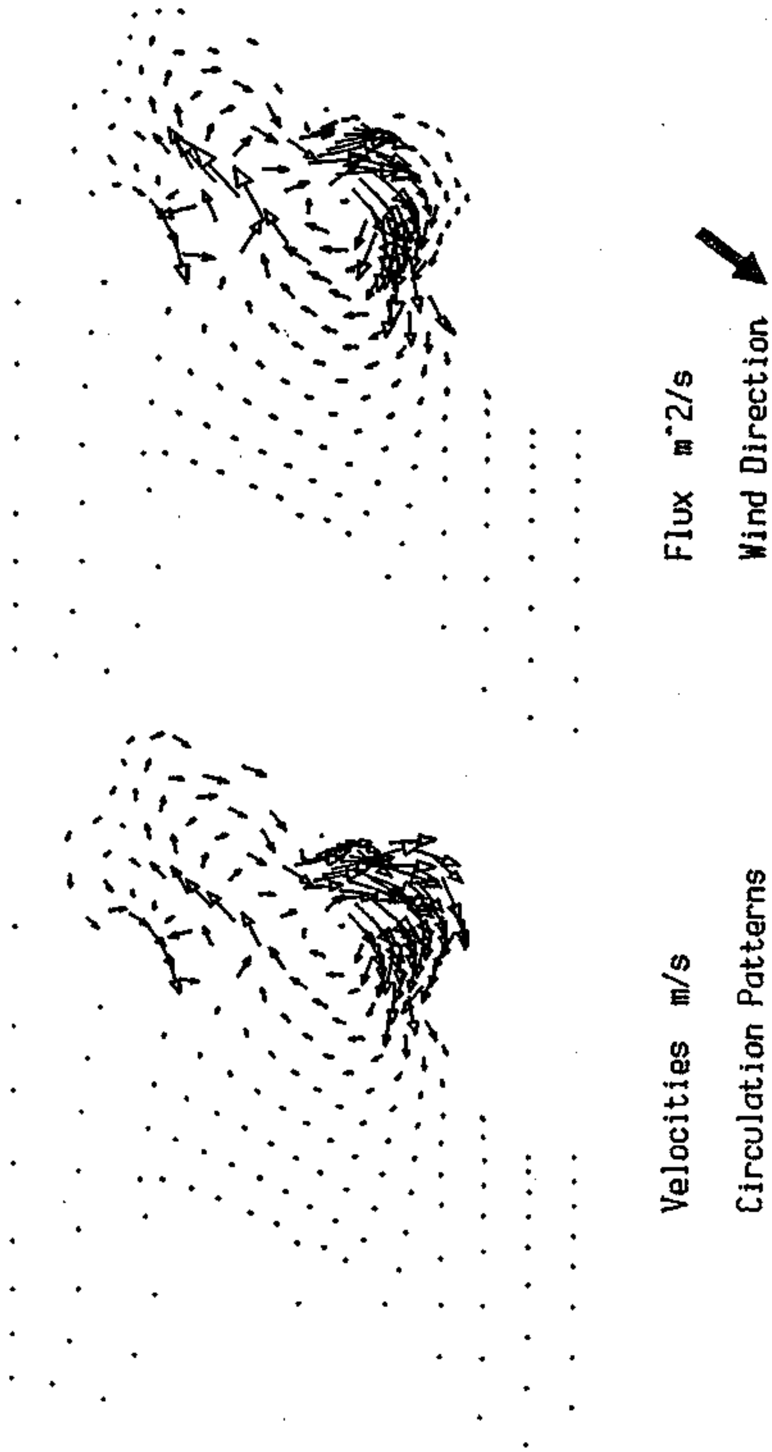


Figure 57
Site 4: Lewis Creek
Transport Model Grid

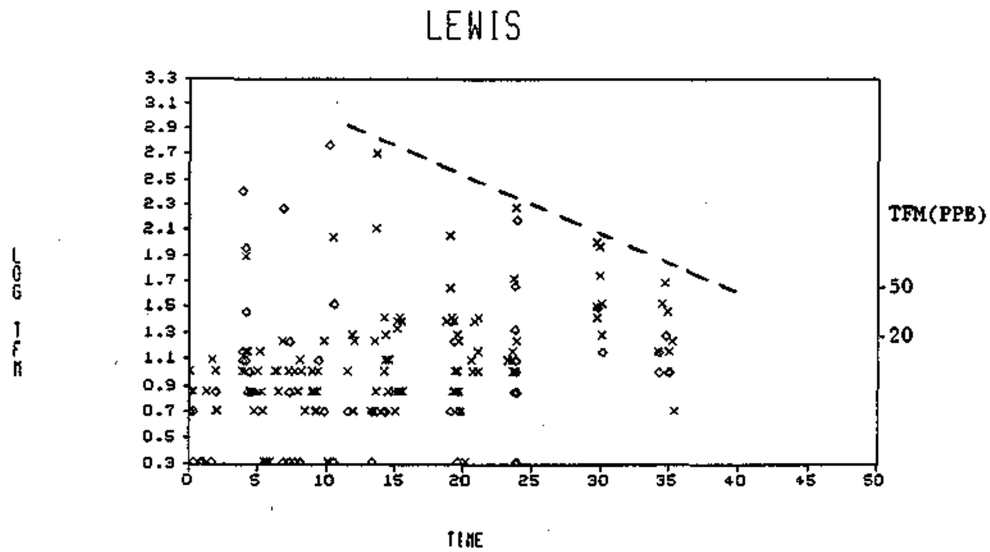
Cell Depths (Meters) at Minimum Lake Elevation (92.9 ft,msl)
xxx = Land Mass, Cell Dimension = 400 meters

```
     1  2  3  4  5  6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22
  +------------------------------------------------------------------+
 1|xxxxxxxxxxxxxxxxxx 10 10 10 10 10 10 10 10 10 10 10  4  2xxxxxxxxx|
 2|xxxxxxxxxxxxxxxxxx 10 10 10 10 10 10 10 10 10xxx  3xxxxxxxxxxxxxxx|
 3|xxxxxxxxxxxxxxx  7 10 10 10 10 10 10 10 10 10 10xxxxxxxxxxxxxxxxxx|
 4|xxxxxxxxxxxxxxx 10 10 10 10 10 10 10 10 10 10xxxxxx  0  0  0xxxxxx|
 5|xxxxxxxxxxxxxxxxxxxxx 10 10 10 10 10 10 10 10xxxxxx  2  3  2  1  0|
 6|xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 10 10 10xxxxxx  2  6  5  3  1  0|
 7|xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 10 10 10 10 10 10 10  7  6  3  1xxx|
 8|xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx 10 10 10 10 10 10 10  7  7  5  2xxx|
 9|xxxxxxxxxxxxxxxxxxxxxxxxxxx 10 10 10 10 10 10 10 10  7  6  3xxxxxx|
10|xxxxxxxxxxxxxxxxxxxxxxxxxxx 10 10 10 10 10 10 10 10  7  7xxxxxxxxx|
11|xxxxxxxxxxxxxxxxxxxxxxxx 10 10 10 10 10 10 10 10 10  6  2xxxxxxxxx|
12|xxxxxxxxxxxxxxxxxx 10 10 10 10 10 10 10 10 10  8  7  3  1xxxxxxxxx|
13|xxxxxxxxxxxxxxxxxx 10 10 10 10 10 10 10 10  8xxx  2  1  1xxxxxxxxx|
14|xxxxxxxxxxxxxxx 10 10 10 10 10 10 10 10xxx  6xxxxxxxxxxxxxxxxxxxxx|
15|xxxxxxxxxxxx 10 10 10 10 10 10 10  6xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx|
16|xxxxxxxxx 10 10 10 10 10 10 10 10  6xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx|
17|xxxxxxxxx 10 10 10 10 10 10  7xxx  2xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx|
18|xxxxxxxxx 10 10 10 10  3  3  1xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx|
19|xxxxxxxxx 10 10 10 10  0  0  0  0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx|
20|xxxxxx 10 10 10 10 10  3xxx  0xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx|
  +------------------------------------------------------------------+
```

Figure 58
Site 4: Lewis Creek
Empirical Projection of TFM Plume Based upon Dye Measurements

TIME = Hours from Entry of Lampricide Plume to Lake
DISTANCE = Distance from River Inflow (Meters)
LOG TFM = Log_{10} (Projected TFM Conc., ppb), Rescaled from Dye Data
TFM CONC = Measured Dye Conc. x TFM Load / Dye Load
LOAD = Streamflow x Applied Conc. x Treatment Duration

Symbols: x = surface samples, o = subsurface samples



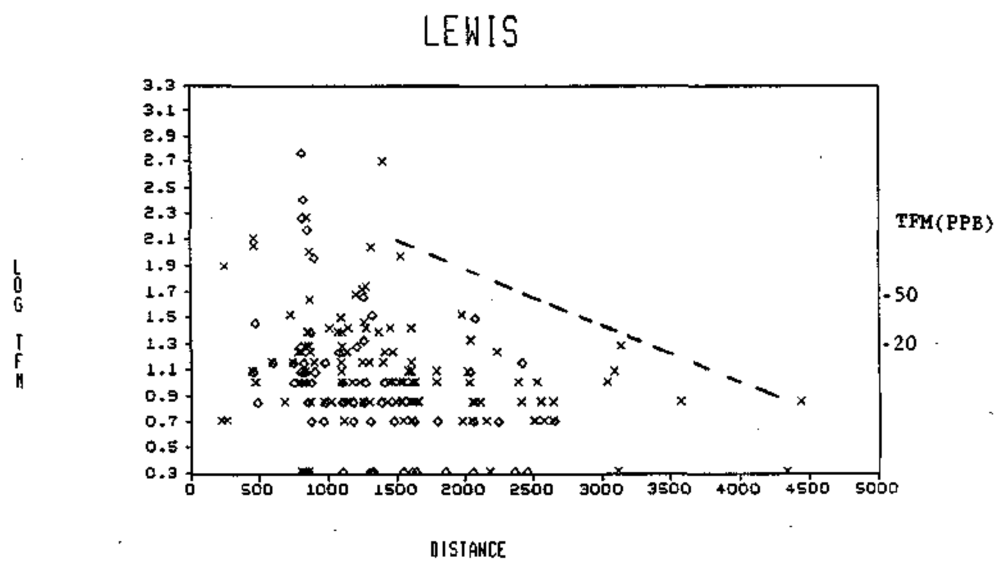


Figure 59
Site 4: Lewis Creek
Observed and Predicted Maximum Dye Concentrations
Rescaled to Applied Conc. of 1000, Contours = 100-Fold Dilution

Observed

```
Lewis, scale factor = 106.38

     9 10 11 12 13 14 15 16 17 18 19 20 21 22
   +------------------------------------------+
 1¦ depth = 0                       xxxxxxxxx¦
 2¦ max observed       3xxx    xxxxxxxxxxxxxx¦
 3¦                         xxxxxxxxxxxxxxxxx¦
 4¦                     xxxxxx         xxxxxx¦
 5¦        0           8xxxxxx               ¦
 6¦xxxxxxxxx         xxxxxx     2     3  4   ¦
 7¦xxxxxx                 2       14  3  4xxx¦
 8¦xxxxxx        1           2  3 41  4   xxx¦
 9¦xxx              7       11 24  6   xxxxxx¦
10¦xxx                 4  6  4 14   xxxxxxxxx¦
11¦                 1  7 48 82 57   xxxxxxxxx¦
12¦                 5 11  3  7  2 34xxxxxxxxx¦
13¦           3  4  9  5xxx         xxxxxxxxx¦
14¦        5  4  2xxx  3xxxxxxxxxxxxxxxxxxxxx¦
15¦     3      xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx¦
16¦            xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx¦
   +------------------------------------------+

     9 10 11 12 13 14 15 16 17 18 19 20 21 22
   +------------------------------------------+
 1¦ depth > 0                       xxxxxxxxx¦
 2¦ max observed        xxx    xxxxxxxxxxxxxx¦
 3¦                         xxxxxxxxxxxxxxxxx¦
 4¦                     xxxxxx         xxxxxx¦
 5¦                     xxxxxx               ¦
 6¦xxxxxxxxx         xxxxxx           6      ¦
 7¦xxxxxx                                5xxx¦
 8¦xxxxxx              0     1     4      xxx¦
 9¦xxx              2        3 20      xxxxxx¦
10¦xxx           0     0     7 14   xxxxxxxxx¦
11¦                    2 14 58 12   xxxxxxxxx¦
12¦                 2  2            xxxxxxxxx¦
13¦           2    13  xxx          xxxxxxxxx¦
14¦              xxx   xxxxxxxxxxxxxxxxxxxxxx¦
15¦            xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx¦
16¦            xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx¦
   +------------------------------------------+
```

Predicted

```
airport speeds - site directions

     9 10 11 12 13 14 15 16 17 18 19 20 21 22
   +------------------------------------------+
 3¦                         xxxxxxxxxxxxxxxxx¦
 4¦                     xxxxxx         xxxxxx¦
 5¦                     xxxxxx  2  2  2  2  1¦
 6¦xxxxxxxxx         xxxxxx  3  3  4  5  5  2¦
 7¦xxxxxx              1  2  3  5  7  8  7xxx¦
 8¦xxxxxx                 1  3  5 11 11  7xxx¦
 9¦xxx                    1  3  6 18 14xxxxxx¦
10¦xxx                    2  5 10 29xxxxxxxxx¦
11¦                       1  2  6 43xxxxxxxxx¦
12¦                          1  4 39xxxxxxxxx¦
13¦                     xxx  1  2 10xxxxxxxxx¦
14¦               xxx  xxxxxxxxxxxxxxxxxxxxxx¦
15¦            xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx¦
   +------------------------------------------+

resultant wind, direction = w, load factor = 1.23

     9 10 11 12 13 14 15 16 17 18 19 20 21 22
   +------------------------------------------+
 3¦                         xxxxxxxxxxxxxxxxx¦
 4¦                     xxxxxx         xxxxxx¦
 5¦                     xxxxxx  1            ¦
 6¦xxxxxxxxx         xxxxxx  2  1  1         ¦
 7¦xxxxxx              1  2  2  1         xxx¦
 8¦xxxxxx              2  3  2  2  2  1  1xxx¦
 9¦xxx              1  3  4  5  7 10  6xxxxxx¦
10¦xxx              1  3  6  9 17 34xxxxxxxxx¦
11¦                 1  2  4  5  8 56xxxxxxxxx¦
12¦                    1  2  2  5 47xxxxxxxxx¦
13¦                     xxx  1  2 12xxxxxxxxx¦
14¦               xxx  xxxxxxxxxxxxxxxxxxxxxx¦
15¦            xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx¦
   +------------------------------------------+

airport speeds - airport directions

     9 10 11 12 13 14 15 16 17 18 19 20 21 22
   +------------------------------------------+
 3¦                         xxxxxxxxxxxxxxxxx¦
 4¦                     xxxxxx         xxxxxx¦
 5¦                     xxxxxx  1            ¦
 6¦xxxxxxxxx         xxxxxx  1  1  1         ¦
 7¦xxxxxx                 1  1  1  1      xxx¦
 8¦xxxxxx              1  2  2  2  5  3  1xxx¦
 9¦xxx                 1  3  4  6 13  7xxxxxx¦
10¦xxx                 2  4  6 10 21xxxxxxxxx¦
11¦                    1  3  6 11 35xxxxxxxxx¦
12¦                       2  3 13 88xxxxxxxxx¦
13¦                     xxx  2  5 16xxxxxxxxx¦
14¦               xxx  xxxxxxxxxxxxxxxxxxxxxx¦
15¦            xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx¦
   +------------------------------------------+
```

Figure 60
Site 4: Lewis Creek
Maximum TFM Concentrations vs. Wind Direction
Maximum Mixed Layer Depth = 5 Meters, Units = ppb/5

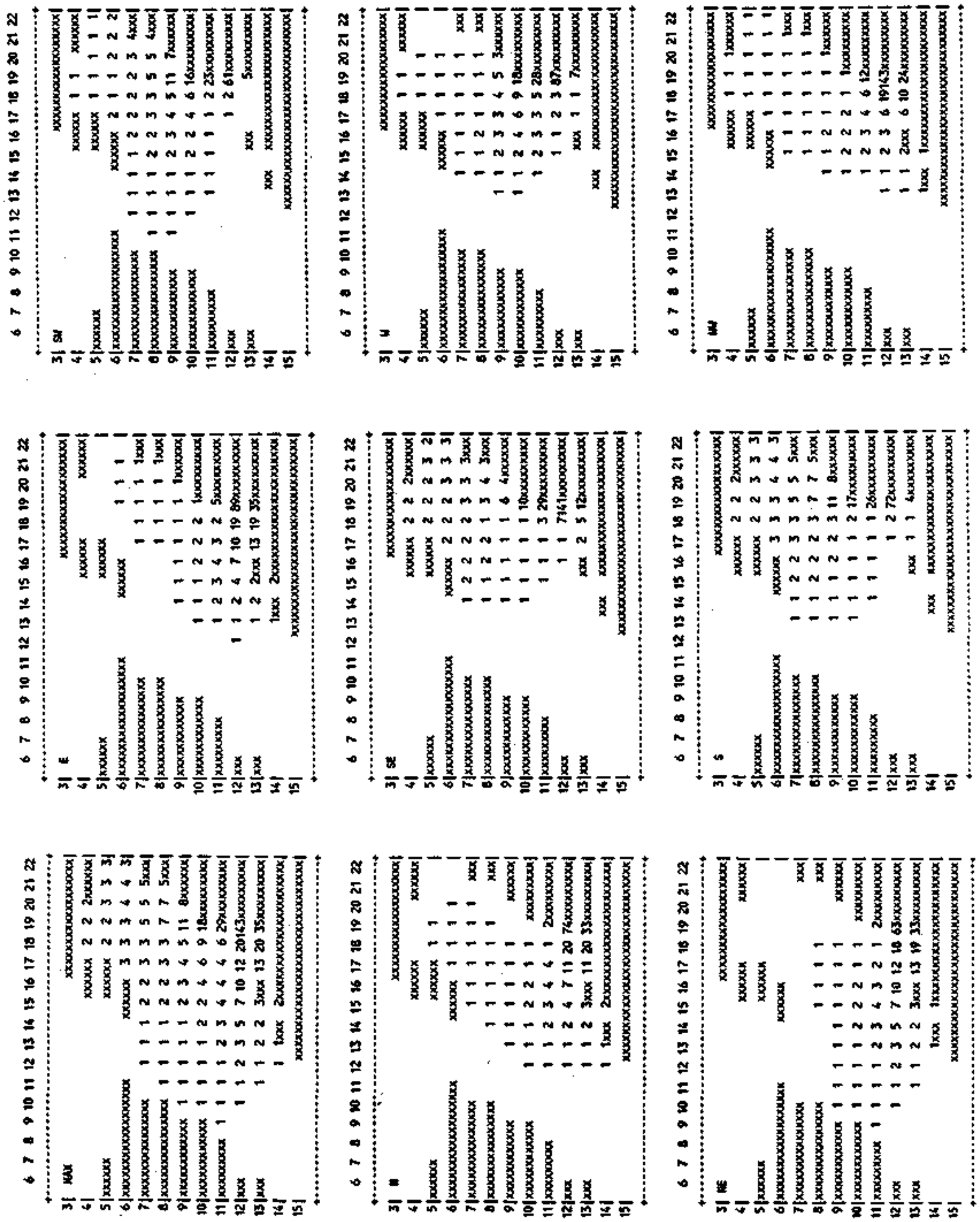


Figure 61
Site 4: Lewis Creek
Cell Maximum TFM Concentrations

Composite Projections for Eight Wind Directions, Units = ppb/5
Flow = 50 cfs, Applied TFM Conc.= 6.5 ppm, Duration = 12 hrs

```
      6  7  8  9 10 11 12 13 14 15 16 17 18 19 20 21 22
   +---------------------------------------------------+
  3| MAX                           xxxxxxxxxxxxxxxxxxxx|
  4|                              xxxxxx  2  2  2xxxxxx|
  5|xxxxxx                        xxxxxx  2  2  3  3  3|
  6|xxxxxxxxxxxxxxxxxx         xxxxxx  3  3  3  4  4  3|
  7|xxxxxxxxxxxxxxx     1  1  1  2  2  3  3  5  5  5xxx|
  8|xxxxxxxxxxxxxxx  1  1  1  1  2  2  3  3  7  7  5xxx|
  9|xxxxxxxxxxxx  1  1  1  1  1  2  3  4  5 11  8xxxxxx|
 10|xxxxxxxxxxxx  1  1  1  1  2  2  4  6  9 18xxxxxxxxx|
 11|xxxxxxxxx  1  1  1  1  2  3  4  4  4  6 29xxxxxxxxx|
 12|xxx           1  1  2  3  5  7 10 12 20143xxxxxxxxx|
 13|xxx              1  1  2  2  3xxx 13 20 35xxxxxxxxx|
 14|                    1  1xxx  2xxxxxxxxxxxxxxxxxxxxx|
 15|                     xxxxxxxxxxxxxxxxxxxxxxxxxxxxxx|
   +---------------------------------------------------+
```

Figure 62
Site 4: Lewis Creek
Maximum TFM Concentration Contours

Composite Projections for Eight Wind Directions, Units = ppb
Flow = 50 cfs, Applied TFM Conc.= 6.5 ppm, Duration = 12 hrs
Map Scale 1:59507, 1 Inch = .939 Miles

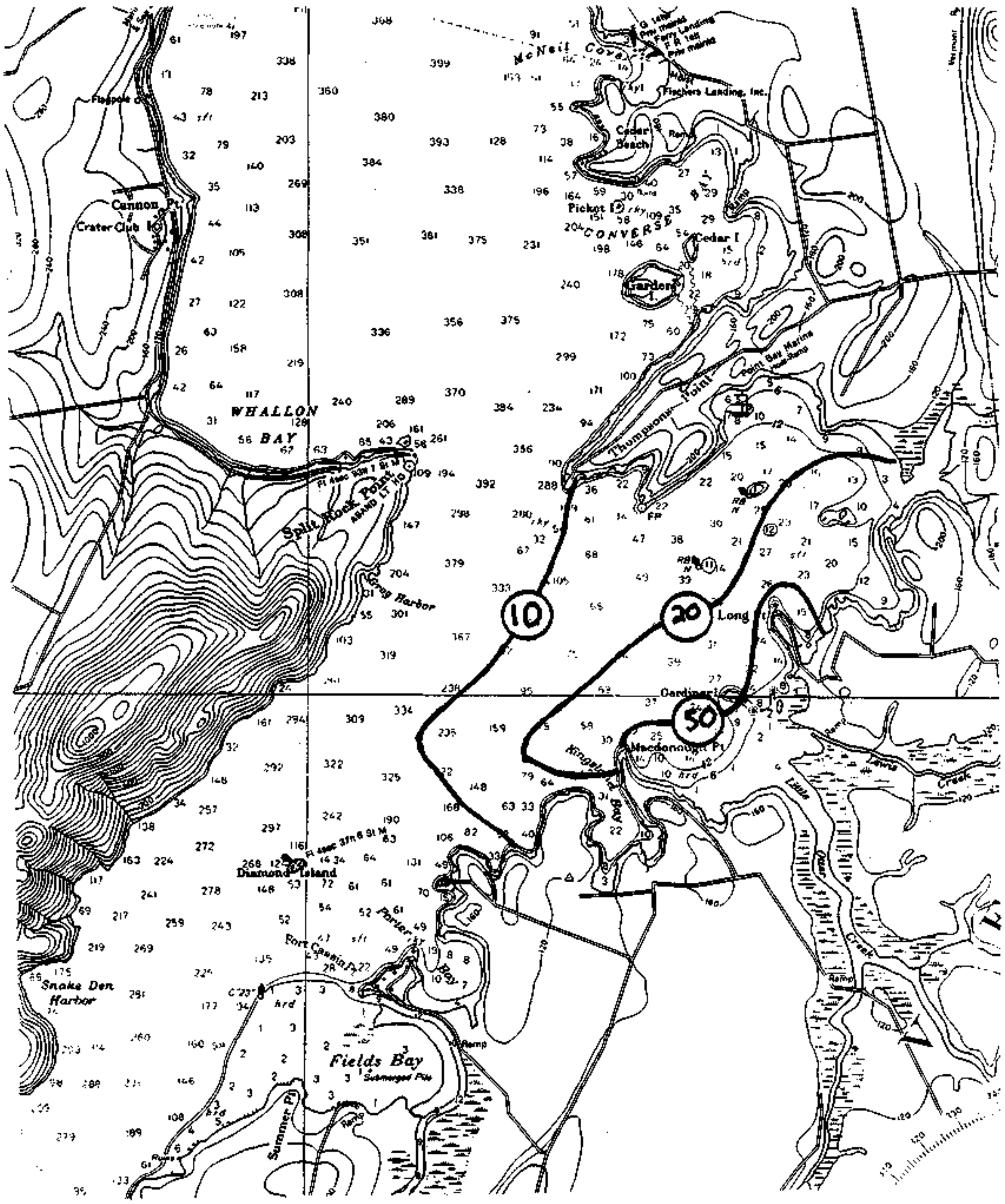


Figure 63
Site 5: Putnam Creek
Model Region
Map Scale = 1:88816, 1 Inch = 1.4 Miles

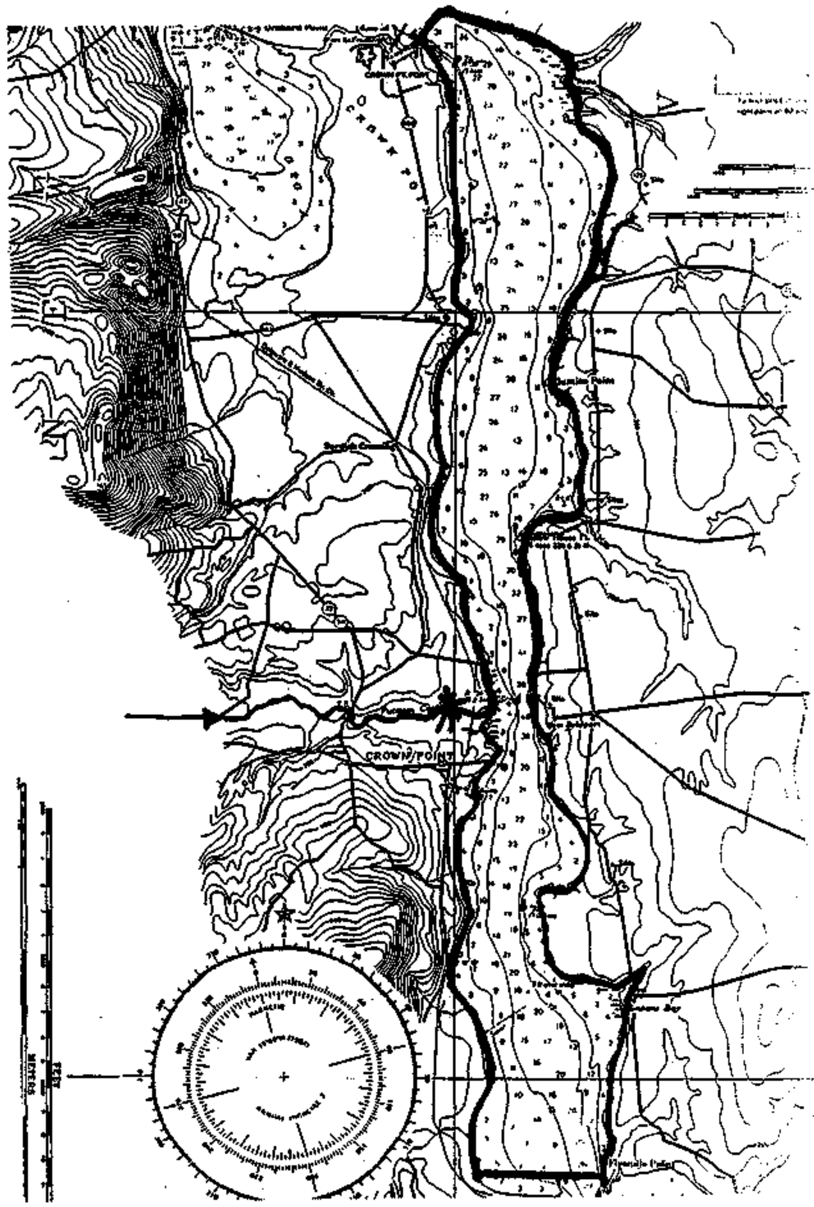


Figure 64
Site 5: Putnam Creek
Finite Element Mesh

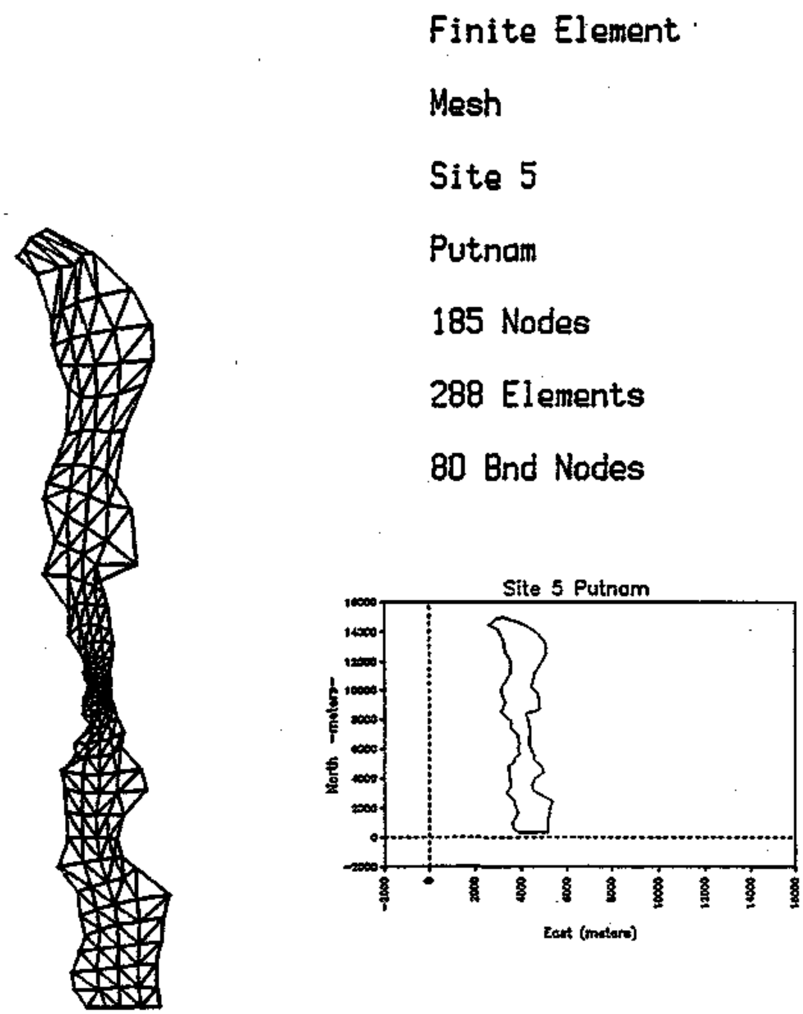


Figure 65
Site 5: Putnam Creek
Vertically Averaged Circulation Patterns - North Wind
(Directions Reversed for South Wind)

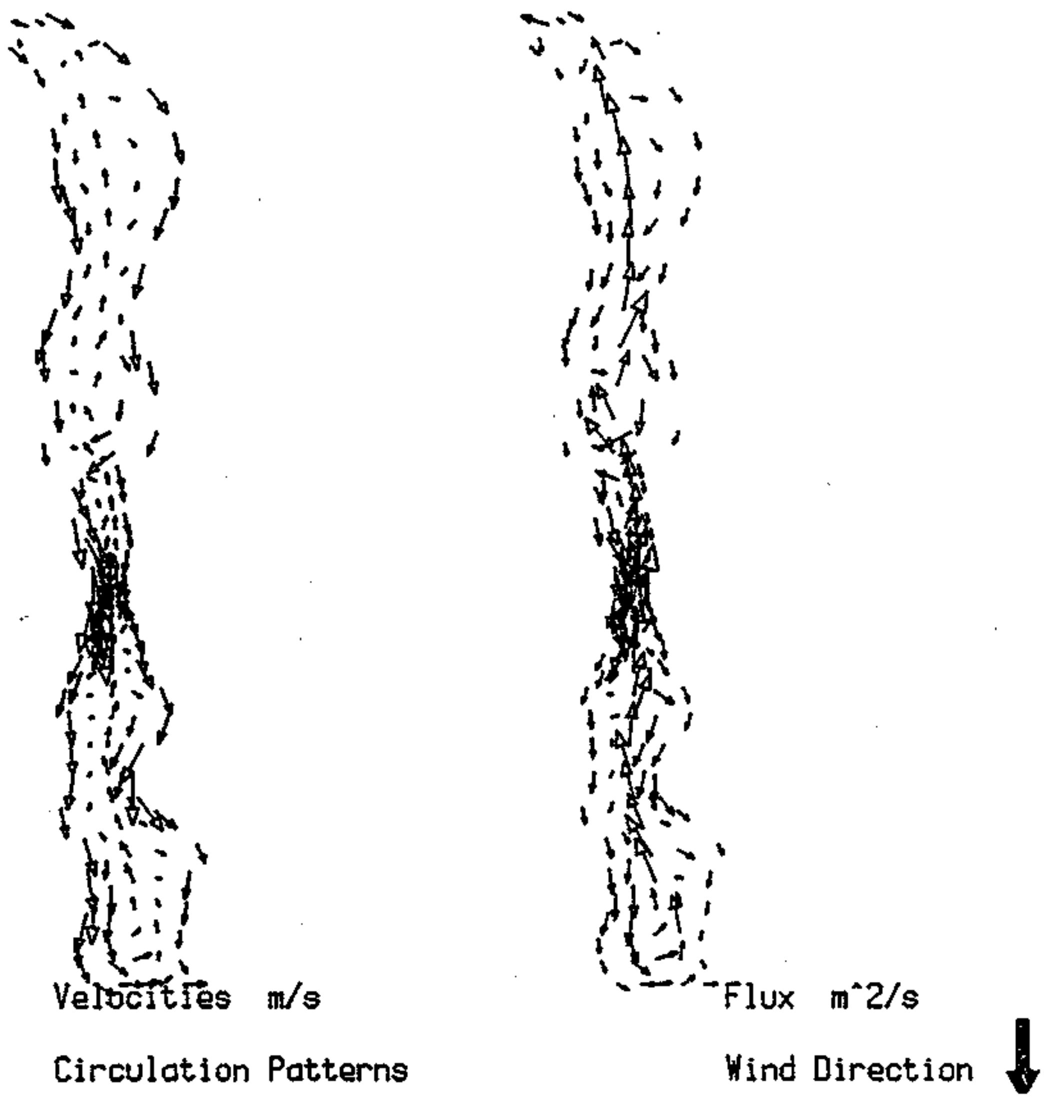


Figure 66
Site 5: Putnam Creek
Vertically Averaged Circulation Patterns - Northeast Wind
(Directions Reversed for Southwest Wind)

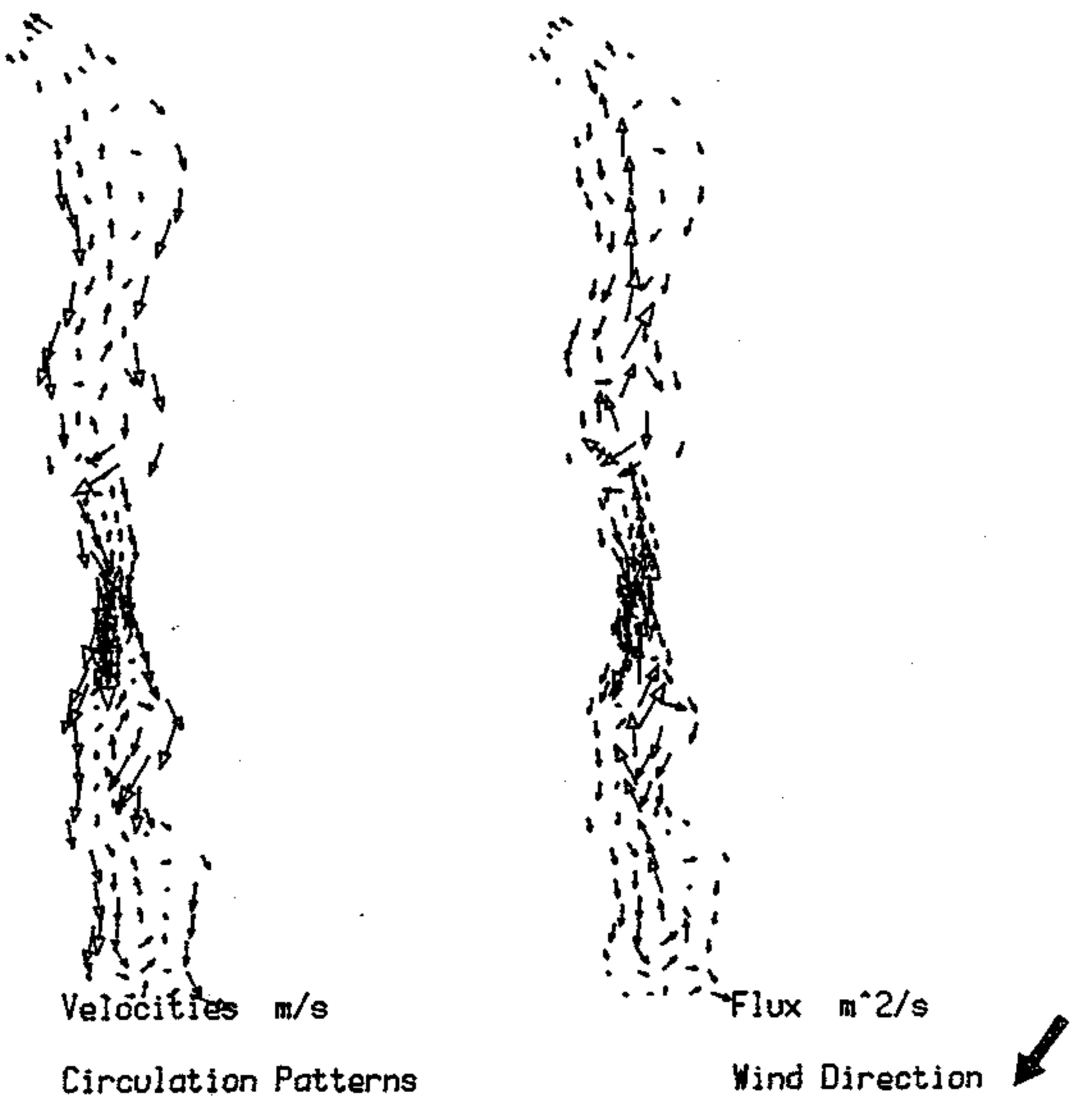


Figure 67
Site 5: Putnam Creek
Transport Model Grid

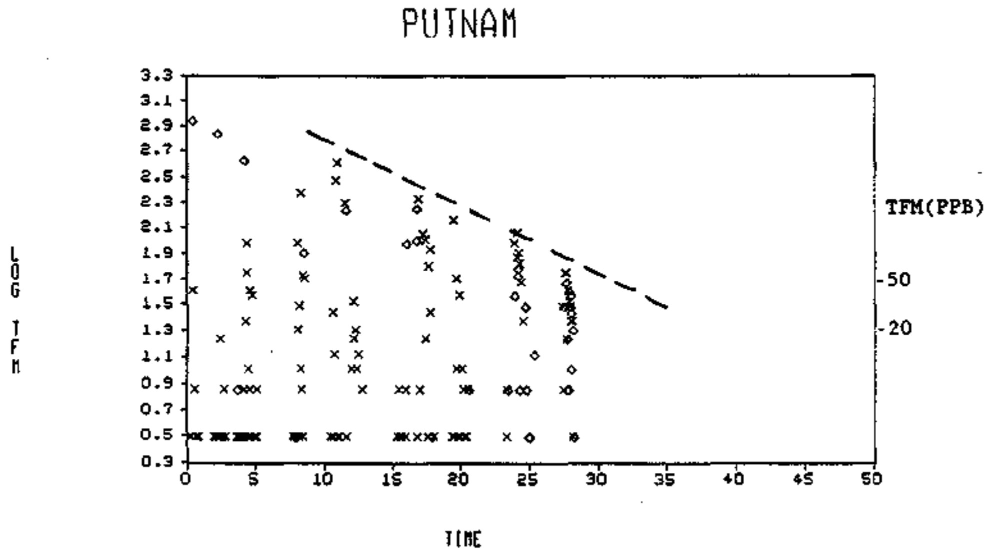
Cell Depths (Meters) at Minimum Lake Elevation (92.9 ft,msl)
xxx = Land Mass, Cell Dimension = 400 meters

```
     1  2  3  4  5  6  7  8
   +-----------------------+
  1|  7  5  5xxxxxxxxxxxxxx|
  2|  5  7  5  1xxxxxxxxxxx|
  3|xxx  3  7  3  0xxxxxxxx|
  4|xxxxxx  3  7  4  2xxxxx|
  5|xxxxxx  2  4  7  2xxxxx|
  6|xxxxxx  0  3  6  2  0xxx|
  7|xxxxxx  0  4  7  3  2xxx|
  8|xxxxxx  0  3  7  3  2xxx|
  9|xxxxxxxxx  3  6  3  0xxx|
 10|xxxxxxxxx  3  7  3xxxxx|
 11|xxxxxxxxx  1  6  3xxxxx|
 12|xxxxxxxxx  2  6  2xxxxx|
 13|xxxxxx  1  4  5xxxxxxxx|
 14|xxxxxx  1  6  5  1xxxxx|
 15|xxxxxx  1  7  3  2xxxxx|
 16|xxxxxx  1  7  4  3xxxxx|
 17|xxxxxx  2  7  3  0xxxxx|
 18|xxxxxx  2  7  3xxxxxxxx|
 19|xxxxxxxxx  2  7xxxxxxxx|
 20|xxxxxxxxx  2  7xxxxxxxx|
 21|xxxxxxxxx  0  8xxxxxxxx|
 22|xxxxxxxxx  0  9xxxxxxxx|
 23|xxxxxxxxx  0  9xxxxxxxx|
 24|xxxxxxxxx  0  9xxxxxxxx|
 25|xxxxxxxxxxxx  4  1xxxxx|
 26|xxxxxxxxx  0  5  2xxxxx|
 27|xxxxxxxxx  2  6  3xxxxx|
 28|xxxxxxxxx  3  7  1xxxxx|
 29|xxxxxxxxx  3  7  1xxxxx|
 30|xxxxxxxxx  3  6xxxxxxxx|
 31|xxxxxx  0  3  6xxxxxxxx|
 32|xxxxxx  0  3  6  3xxxxx|
 33|xxxxxxxxx  3  6  6  2  0|
 34|xxxxxxxxx  2  4  6  3  0|
 35|xxxxxxxxx  2  4  6  2xxx|
   +-----------------------+
```

Figure 68
Site 5: Putnam Creek
Empirical Projection of TFM Plume Based upon Dye Measurements

TIME - Hours from Entry of Lampricide Plume to Lake
DISTANCE - Distance from River Inflow (Meters)
LOG TFM - Log_{10} (Projected TFM Conc., ppb), Rescaled from Dye Data
TFM CONC - Measured Dye Conc. x TFM Load / Dye Load
LOAD - Streamflow x Applied Conc. x Treatment Duration

Symbols: x - surface samples, o - subsurface samples



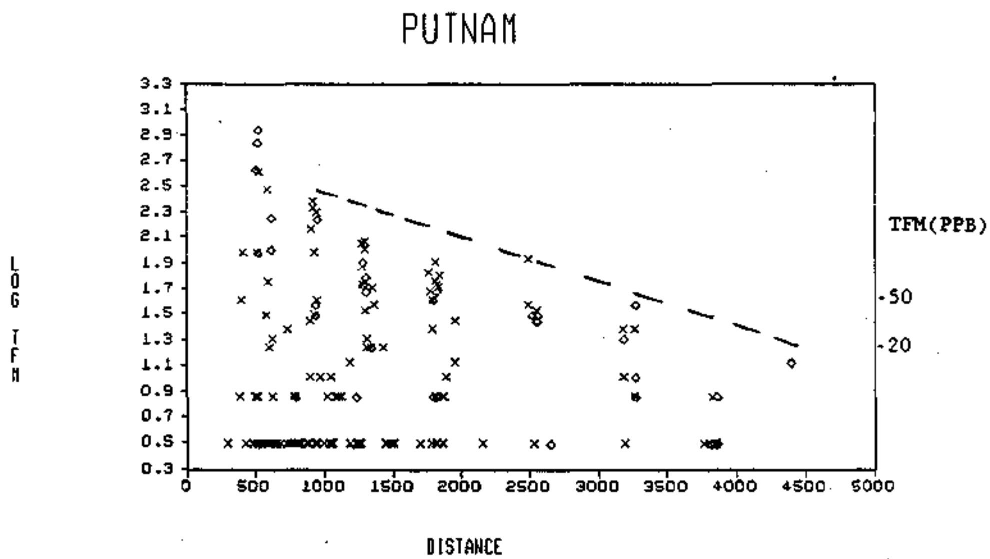


Figure 69
Site 5: Putnam Creek
Observed and Predicted Maximum Dye Concentrations
Rescaled to Applied Conc. of 1000, Contours = 100-Fold Dilution

Observed

depth = 0, max observed

```
    1  2  3  4  5  6  7  8
  +------------------------+
12|xxxxxxxxx         xxxxxx|
13|xxxxxx  0  0  1xxxxxxxxx|
14|xxxxxx     0      xxxxxx|
15|xxxxxx  5  5  2  1xxxxxx|
16|xxxxxx            xxxxxx|
17|xxxxxx  8  7 21   xxxxxx|
18|xxxxxx 20 16  6xxxxxxxxx|
19|xxxxxxxxx 16  5xxxxxxxxx|
20|xxxxxxxxx 29 12xxxxxxxxx|
21|xxxxxxxxx 60 50xxxxxxxxx|
22|xxxxxxxxx   103xxxxxxxxx|
23|xxxxxxxxx    24xxxxxxxxx|
24|xxxxxxxxx  0  1xxxxxxxxx|
25|xxxxxxxxxxxx  6  1xxxxxx|
26|xxxxxxxxx  0  3  0xxxxxx|
27|xxxxxxxxx  0      xxxxxx|
28|xxxxxxxxx  0      xxxxxx|
29|xxxxxxxxx         xxxxxx|
  +------------------------+
```

depth > 0, max observed

```
    1  2  3  4  5  6  7  8
  +------------------------+
12|xxxxxxxxx  3      xxxxxx|
13|xxxxxx  0  0   xxxxxxxxx|
14|xxxxxx            xxxxxx|
15|xxxxxx  9  5      xxxxxx|
16|xxxxxx     0      xxxxxx|
17|xxxxxx  7  7      xxxxxx|
18|xxxxxx 11 10   xxxxxxxxx|
19|xxxxxxxxx      xxxxxxxxx|
20|xxxxxxxxx 20   xxxxxxxxx|
21|xxxxxxxxx    43xxxxxxxxx|
22|xxxxxxxxx    44xxxxxxxxx|
23|xxxxxxxxx   217xxxxxxxxx|
24|xxxxxxxxx      xxxxxxxxx|
25|xxxxxxxxxxxx  1   xxxxxx|
26|xxxxxxxxx     1   xxxxxx|
27|xxxxxxxxx         xxxxxx|
28|xxxxxxxxx         xxxxxx|
29|xxxxxxxxx         xxxxxx|
  +------------------------+
```

Putnam, scale factor = 84.75

Predicted

airport speeds - site directions

```
    1  2  3  4  5  6  7  8
  +------------------------+
14|xxxxxx            xxxxxx|
15|xxxxxx            xxxxxx|
16|xxxxxx            xxxxxx|
17|xxxxxx            xxxxxx|
18|xxxxxx         xxxxxxxxx|
19|xxxxxxxxx  4  2xxxxxxxxx|
20|xxxxxxxxx 11  5xxxxxxxxx|
21|xxxxxxxxx 23  7xxxxxxxxx|
22|xxxxxxxxx 48 11xxxxxxxxx|
23|xxxxxxxxx130 19xxxxxxxxx|
24|xxxxxxxxx 29  7xxxxxxxxx|
25|xxxxxxxxxxxx  2   xxxxxx|
26|xxxxxxxxx         xxxxxx|
27|xxxxxxxxx         xxxxxx|
28|xxxxxxxxx         xxxxxx|
29|xxxxxxxxx         xxxxxx|
  +------------------------+
```

resultant wind, direction = s, load factor = 0.51

```
    1  2  3  4  5  6  7  8
  +------------------------+
14|xxxxxx            xxxxxx|
15|xxxxxx            xxxxxx|
16|xxxxxx            xxxxxx|
17|xxxxxx            xxxxxx|
18|xxxxxx         xxxxxxxxx|
19|xxxxxxxxx  4  2xxxxxxxxx|
20|xxxxxxxxx 13  6xxxxxxxxx|
21|xxxxxxxxx 31  7xxxxxxxxx|
22|xxxxxxxxx 54 10xxxxxxxxx|
23|xxxxxxxxx137 13xxxxxxxxx|
24|xxxxxxxxx 23  5xxxxxxxxx|
25|xxxxxxxxxxxx  1   xxxxxx|
26|xxxxxxxxx         xxxxxx|
27|xxxxxxxxx         xxxxxx|
28|xxxxxxxxx         xxxxxx|
29|xxxxxxxxx         xxxxxx|
  +------------------------+
```

airport speeds - airport directions

```
    1  2  3  4  5  6  7  8
  +------------------------+
13|xxxxxx         xxxxxxxxx|
14|xxxxxx            xxxxxx|
15|xxxxxx            xxxxxx|
16|xxxxxx            xxxxxx|
17|xxxxxx            xxxxxx|
18|xxxxxx         xxxxxxxxx|
19|xxxxxxxxx  4  2xxxxxxxxx|
20|xxxxxxxxx 11  5xxxxxxxxx|
21|xxxxxxxxx 24  7xxxxxxxxx|
22|xxxxxxxxx 53 11xxxxxxxxx|
23|xxxxxxxxx124 18xxxxxxxxx|
24|xxxxxxxxx 34  7xxxxxxxxx|
25|xxxxxxxxxxxx  2   xxxxxx|
26|xxxxxxxxx         xxxxxx|
27|xxxxxxxxx         xxxxxx|
28|xxxxxxxxx         xxxxxx|
29|xxxxxxxxx         xxxxxx|
  +------------------------+
```

Figure 70
Site 5: Putnam Creek
Maximum TFM Concentrations vs. Wind Direction
Maximum Mixed Layer Depth = 5 Meters, Units = ppb/5

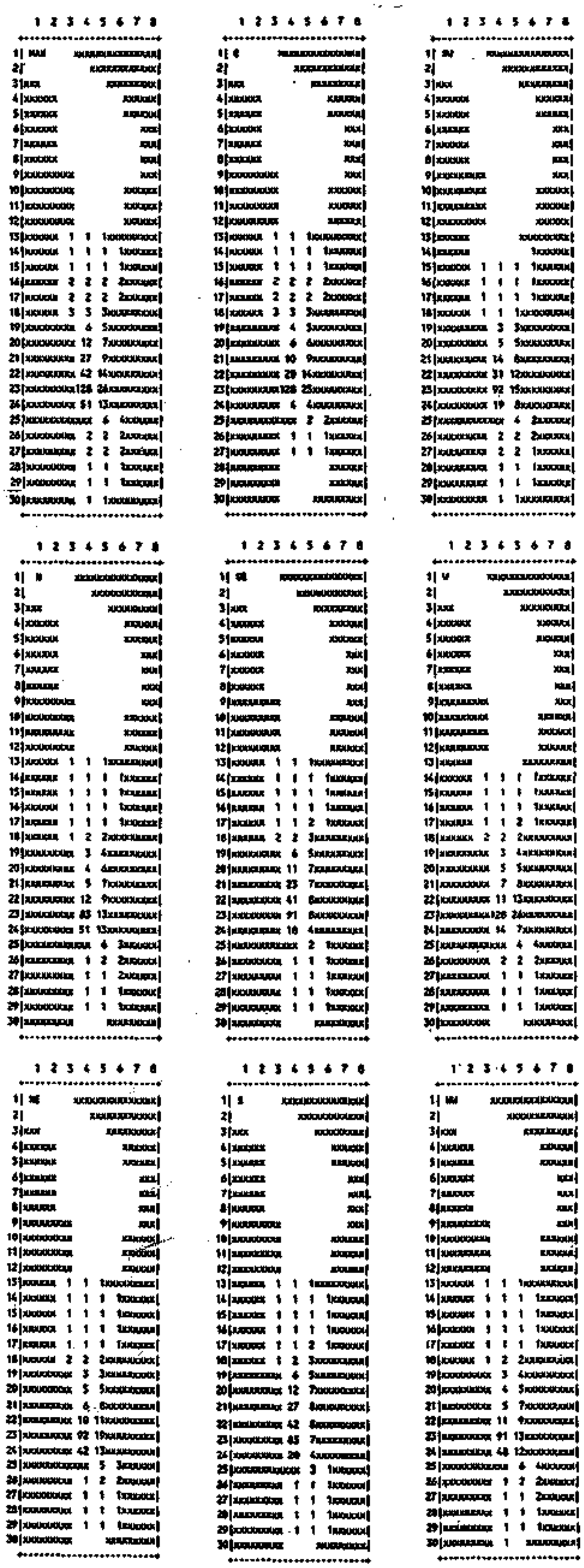


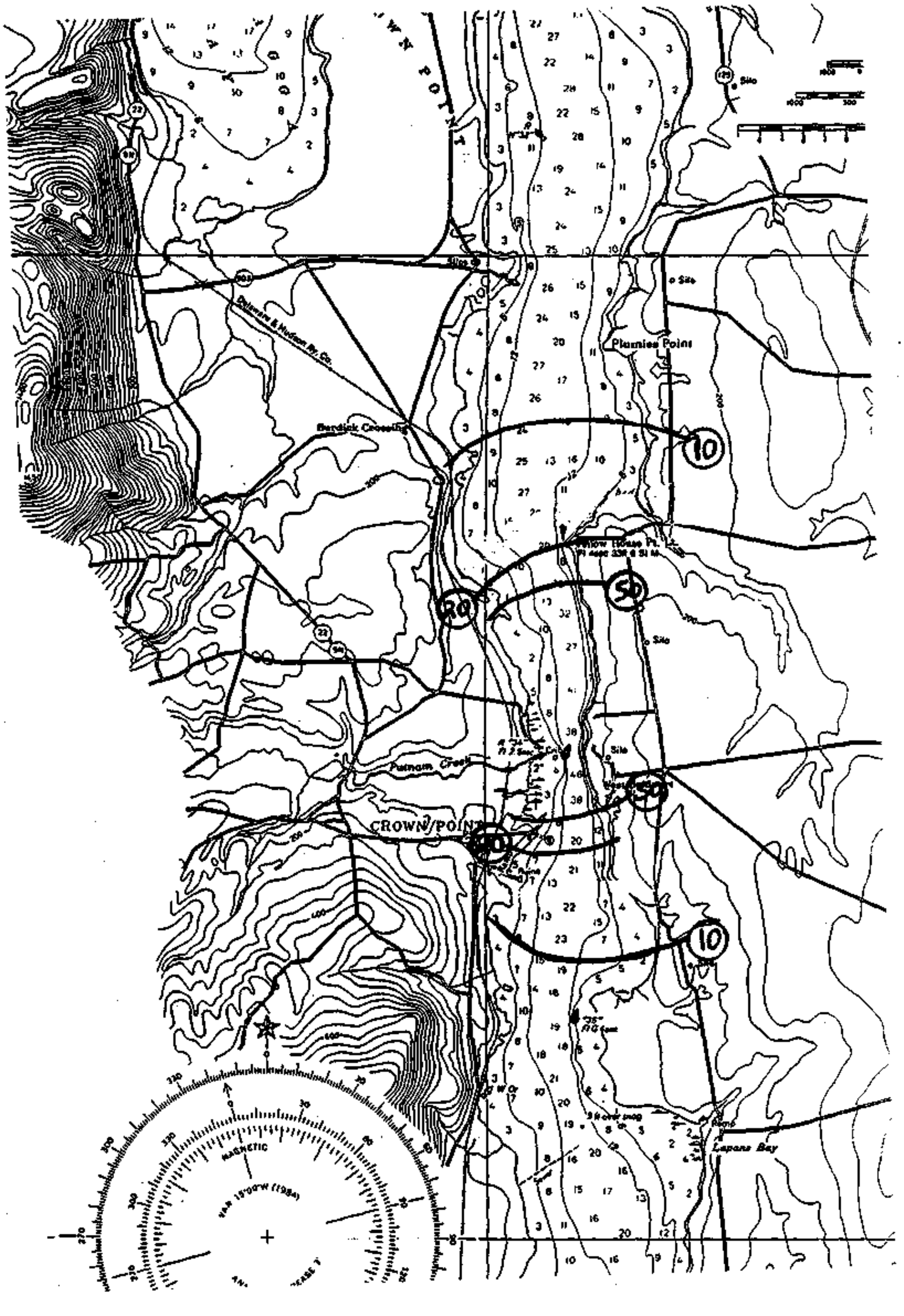
Figure 71
Site 5: Putnam Creek
Cell Maximum TFM Concentrations

Composite Projections for Eight Wind Directions, Units = ppb/5
Flow = 30 cfs, Applied TFM Conc.= 8.5 ppm, Duration = 12 hrs

```
     1  2  3  4  5  6  7  8
   +------------------------+
  1| MAX     xxxxxxxxxxxxxxx|
  2|            xxxxxxxxxxxx|
  3|xxx            xxxxxxxxx|
  4|xxxxxx            xxxxxx|
  5|xxxxxx            xxxxxx|
  6|xxxxxx               xxx|
  7|xxxxxx               xxx|
  8|xxxxxx               xxx|
  9|xxxxxxxxx            xxx|
 10|xxxxxxxxx         xxxxxx|
 11|xxxxxxxxx         xxxxxx|
 12|xxxxxxxxx         xxxxxx|
 13|xxxxxx  1  1  1xxxxxxxxx|
 14|xxxxxx  1  1  1  1xxxxxx|
 15|xxxxxx  1  1  1  1xxxxxx|
 16|xxxxxx  2  2  2  2xxxxxx|
 17|xxxxxx  2  2  2  2xxxxxx|
 18|xxxxxx  3  3  3xxxxxxxxx|
 19|xxxxxxxxx  6  5xxxxxxxxx|
 20|xxxxxxxxx 12  7xxxxxxxxx|
 21|xxxxxxxxx 27  9xxxxxxxxx|
 22|xxxxxxxxx 42 14xxxxxxxxx|
 23|xxxxxxxxx128 26xxxxxxxxx|
 24|xxxxxxxxx 51 13xxxxxxxxx|
 25|xxxxxxxxxxxx  6  4xxxxxx|
 26|xxxxxxxxx  2  2  2xxxxxx|
 27|xxxxxxxxx  2  2  2xxxxxx|
 28|xxxxxxxxx  1  1  1xxxxxx|
 29|xxxxxxxxx  1  1  1xxxxxx|
 30|xxxxxxxxx  1  1xxxxxxxxx|
   +------------------------+
```

Figure 72
Site 5: Putnam Creek
Maximum TFM Concentration Contours

Composite Projections for Eight Wind Directions, Units - ppb
Flow - 30 cfs, Applied TFM Conc.- 8.5 ppm, Duration - 12 hrs
Map Scale 1:59507, 1 Inch - .939 Miles



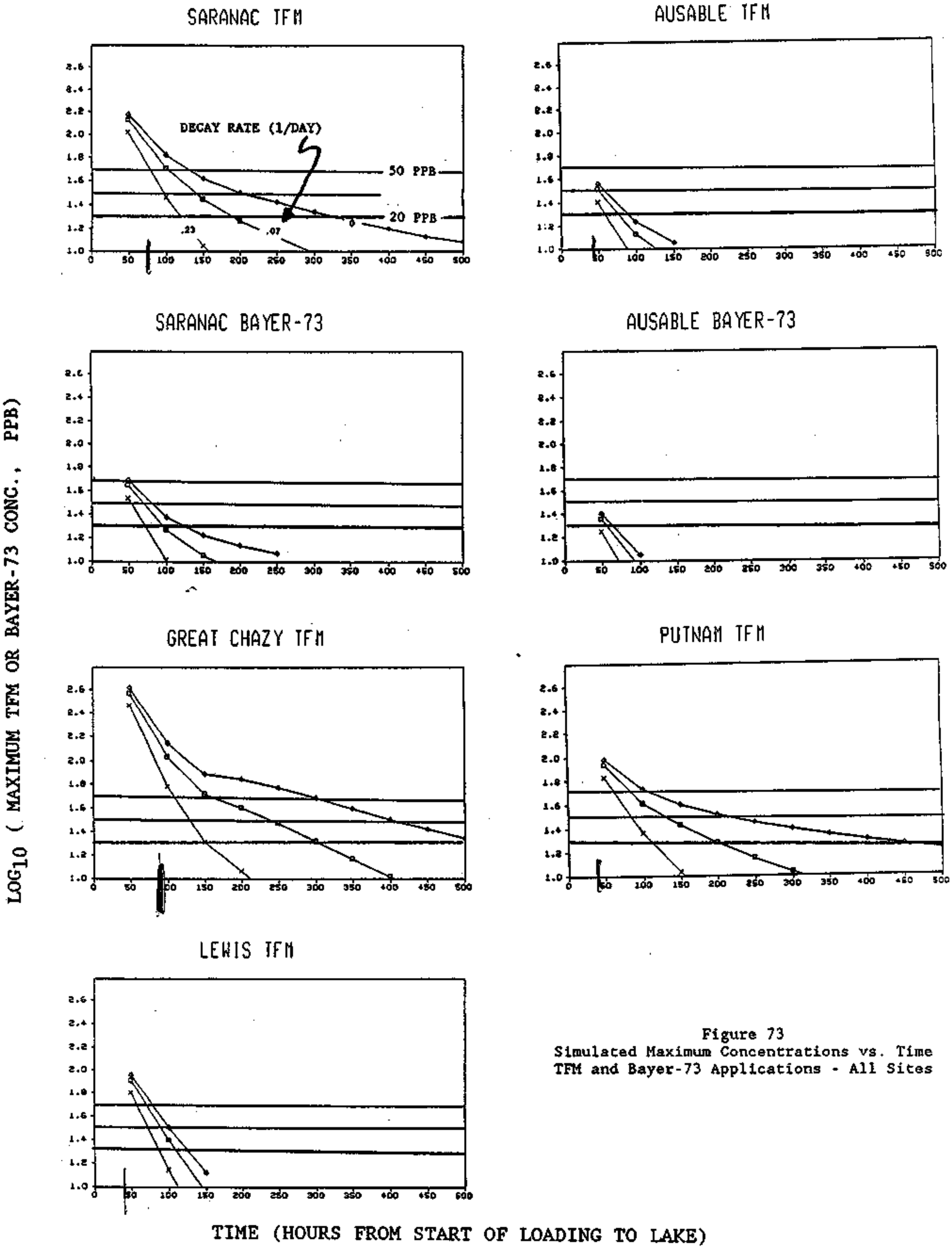
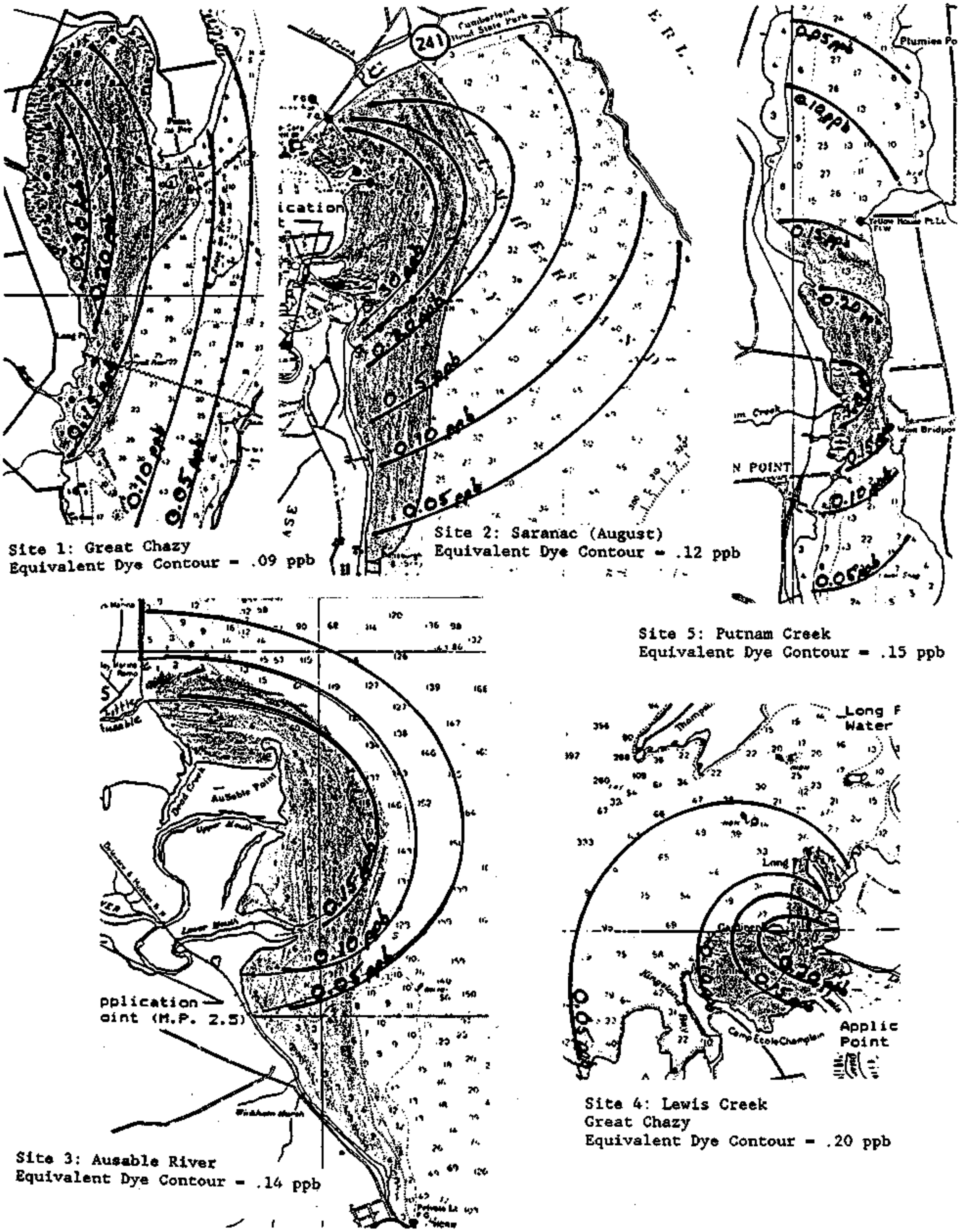


Figure 73
Simulated Maximum Concentrations vs. Time
TFM and Bayer-73 Applications - All Sites

Figure 74
Comparison of Plume Projections

Shaded Area = Projected 50 ppb TFM Plume
Contours = Maximum Dye Concentrations (Meyers,1986)



Site 1: Great Chazy
Equivalent Dye Contour = .09 ppb

Site 2: Saranac (August)
Equivalent Dye Contour = .12 ppb

Site 5: Putnam Creek
Equivalent Dye Contour = .15 ppb

Site 4: Lewis Creek
Great Chazy
Equivalent Dye Contour = .20 ppb

Site 3: Ausable River
Equivalent Dye Contour = .14 ppb

LIST OF TABLES

Table 1
Wind Speed and Direction Frequencies
Burlington Airport, 3-Hr Observations

May-September 1986

SPEED mph	WIND DIRECTION N	NE	E	SE	S	SW	W	NW	ALL
0	4.25	0.08	0.00	0.00	0.00	0.00	0.00	0.00	4.33
2	1.63	1.80	2.37	1.39	1.39	0.25	0.25	0.82	9.89
4	3.43	2.70	4.33	3.51	2.86	1.23	1.31	2.37	21.73
6	0.74	0.25	0.25	1.31	2.12	0.33	0.74	1.80	7.52
8	1.96	0.08	0.74	2.29	3.43	1.31	1.47	2.61	13.89
10	1.63	0.00	0.16	2.21	5.72	0.49	0.98	2.86	14.05
12	0.98	0.00	0.00	1.63	4.58	0.41	0.82	2.78	11.19
14	0.16	0.00	0.00	0.57	1.31	0.08	0.33	0.98	3.43
16	0.49	0.00	0.08	1.55	3.27	0.08	0.82	2.04	8.33
18	0.08	0.00	0.00	0.74	1.63	0.00	0.41	1.14	4.00
20	0.00	0.00	0.00	0.41	0.41	0.00	0.00	0.33	1.14
22	0.00	0.00	0.00	0.00	0.16	0.00	0.16	0.00	0.33
24	0.00	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.08
26	0.00	0.00	0.00	0.08	0.00	0.00	0.00	0.00	0.08
ALL	15.36	4.90	7.92	15.69	26.96	4.17	7.27	17.73	100.00
Mean Speed mph	5.7	4.5	5.1	10.0	11.3	8.0	10.6	11.0	9.2

September 1986

SPEED mph	WIND DIRECTION N	NE	E	SE	S	SW	W	NW	ALL
0	0.00								0.00
2	1.08	0.32	1.51	0.65	0.49	0.16		0.16	4.38
4	1.89	2.16	1.78	1.89	1.51	0.70	0.27	0.76	10.98
6	0.65	0.32		1.30	1.95		0.65	1.95	6.81
8	3.19		0.81	0.81	2.00	1.57	2.54	2.81	13.74
10	1.46			3.73	5.57	1.08	1.57	6.27	19.69
12				3.79	4.43	0.65		0.59	9.46
14				2.11	4.92			2.81	9.84
16			0.81	7.03	6.98		0.76		15.58
18				3.52	2.65				6.17
20				1.95					1.95
28				1.41					1.41
ALL	8.27	2.81	4.92	28.18	30.50	4.16	5.79	15.36	100.00
Mean Speed mph	4.2	5.0	5.0	12.0	11.4	8.1	9.5	9.6	8.9

Table Entries: Percent of Observations
Speed = minimum of interval

Table 2
Distribution of Wind Load by Direction and Speed Interval
Burlington Airport, 3-Hr Observations

May-September 1986

SPEED					WIND DIRECTION				
mph	N	NE	E	SE	S	SW	W	NW	ALL
0	0.00	0.00							0.00
2	0.14	0.16	0.20	0.12	0.12	0.02	0.02	0.07	0.85
4	0.72	0.53	0.82	0.73	0.62	0.24	0.29	0.53	4.48
6	0.28	0.09	0.09	0.50	0.81	0.13	0.28	0.69	2.88
8	1.17	0.04	0.42	1.41	2.09	0.75	0.97	1.60	8.45
10	1.65		0.17	2.43	5.93	0.51	1.06	3.13	14.88
12	1.45			2.53	7.32	0.63	1.29	4.31	17.53
14	0.34			1.18	2.71	0.17	0.68	2.03	7.10
16	1.23		0.23	4.03	8.43	0.20	2.03	5.30	21.47
18	0.27			2.56	5.70		1.43	4.07	14.03
20				1.77	1.87			1.47	5.11
22					0.91		0.91		1.81
24					0.57				0.57
26				0.84					0.84
ALL	7.26	0.83	1.94	18.11	37.07	2.65	8.96	23.19	100.00
Mean Load	0.75	0.27	0.39	1.83	2.18	1.01	1.96	2.08	1.59

57%

September 1986

SPEED					WIND DIRECTION				
mph	N	NE	E	SE	S	SW	W	NW	ALL
0	0.00								0.00
2	0.25	0.08	0.35	0.16	0.12	0.04		0.04	1.02
4	0.69	0.81	0.61	0.69	0.59	0.26	0.11	0.30	4.07
6	0.33	0.17		0.67	1.00		0.33	1.00	3.50
8	2.09		0.54	0.54	1.31	1.00	1.78	1.86	9.12
10	1.20			3.42	4.81	1.01	1.41	5.62	17.47
12				4.26	5.01	0.75		0.62	10.64
14				2.70	6.31			3.61	12.62
16			1.25	10.31	10.13		1.07		22.75
18				5.99	4.54				10.53
20				3.78					3.78
28				4.49					4.49
ALL	4.56	1.05	2.74	37.01	33.83	3.06	4.70	13.04	100.00
Mean Load	0.40	0.32	0.48	2.70	2.17	1.01	1.32	1.40	1.52

Table Entries: Percent of Total Wind Load Over Period of Observations
Load Factor = $(.22 S^2 + .004775 S^3)/19.8$
S = Mean Wind Speed (miles/hr)

37
34
71%

Table 3
Dye Study and Treatment Conditions

Site Number		1	2	2	3	4	5
River		Chazy	Saranac		Ausable	Lewis	Putnam
Dye Study Conditions (Meyers,1986)							
Date	1986	5/29	5/31	8/8	8/6	8/11	8/13
Mean Flow	cfs	225	750	1050	625	145	65
Applied Conc.	ppb	5.5	3.0	3.0	2.8	9.4	11.8
Applic. Duration	hrs	12	12	12	12	12	12
Background Fluor.	ppb	.02	.03	.03	.03	.02	.03
Resolution (a)		275	100	100	93	470	393
Resolution (Back.=.05)		110	60	60	56	188	236
Resultant Wind		N	NW	S	S	W	S
Wind Load Factor		1.16	.84	.77	.85	1.23	.51
Stream Temp. (b)	deg-F	67-72	67-68	71-72	70-72	?	69-70
Lake Surface Temp.	deg-F	57-63	56-61	72-73	71-73	72-73	73-74
Dye/TFM Load Factor (c)		1.77	3.50	2.50	2.73	4.19	3.00
Max. Mixed Depth	m	1.5	2.0	5.0	10.0	10.0	5.0
Prescribed TFM Treatment Conditions							
Streamflow							
Low	cfs	100	500		300	25	15
High	cfs	150	600		400	50	30
Assumed	cfs	150	600		400	50	30
Treatment Duration	hrs	16	12		12	12	12
Applied Conc.	ppm	3.5	1.5		1.6	6.5	8.5
Total TFM Load	lbs	1885	2424		1725	876	686
Spread Factor	-	3(d)	1		1	1	1
Dilution → 20 ppb		175	75		80	325	425 !
Bayer-73 Treatment Conditions							
Application Area	acres		175		250		
Total Dose	lbs/acre		100		100		
Active Fraction	-		.05		.05		
Duration of Release	hrs		6		6		
Active Load	lbs		875		1250		

a Resolution = Maximum detectable dilution factor = applied concentration / background fluorescence

b River inflow temperatures estimated from surface measurements in peak of dye plume at river mouth; lake surface temperatures estimated from surface measurments distant from river inflow.

c Dye Load / Prescribed TFM Load (lb/lb) x 1000

d Spread Factor accounts for dispersion of TFM in river above lake; conc. entering lake is divided by 3 and duration of loading is multiplied by 3 (based upon dye study results).