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The Application of a Segmented Tidal Mixing Model to the Great Bay Estuary, N.H.

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Wendell S. Brown
Edgar Arrelano M.

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Department of Earth Sciences
University of New Hampshire
Durham, New Hampshire 03824

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ABSTRACT

AN APPLICATION OF A SEGMENTED TIDAL PRISM MODEL TO THE GREAT BAY ESTUARINE SYSTEM

by

Wendell S. Brown

and

Edgar Arellano M.

Department of Earth Sciences
University of New Hampshire
Durham, NH 03824

The Great Bay Estuarine System has a very complex geometry with a high water volume of $230\times10^6 m^3$ and a tidal prism of $64\times10^6 m^3$. Tidal currents range from 150 cm/sec up to 300 cm/sec and river discharges range from $0.2\times10^6 m^3$ to $2\times10^6 m^3$ per tidal cycle. Measurements show that in general salt is vertically well-mixed everywhere in the estuary except near the river entrances at the head of the estuary.

Dyer and Taylor's (1973) modified version of Ketchum's segmented tidal prism model has been applied to the Great Bay Estuarine System in order to predict high and low water salinity distribution for a specified river flow. The theory has been modified here to account for the mixing which occurs at the junction of two branches of an estuary. The mixing parameter, which in this model is related to the tidal excursion of water in the estuary, has been determined for different segments in the estuary on the basis of a comparison between predictions and a comprehensive data set obtained for a low river flow period. Using a mixing parameter distribution based on the low river flow calibration procedure the salinity distribution has been predicted for high river flow. The result compares favorably with observed values for most of the estuary. The associated flushing time for water parcels entering at the head of the estuary during periods of low and high river flow is 58.0 and 48.5 tidal cycles respectively.

1. Introduction

A modified version of Ketchum's (1951) original segmented tidal prism mixing model has been developed by Dyer and Taylor (1973). This relatively simple model, which predicts salinity distribution at both high and low slack water, is based on the conservation of volume and salt and the assumption of thorough tidal mixing within each of its segments. The model has been applied successfully by Dyer and Taylor (1973) to the Raritan River (N.J.) and the Bay of Fundy. The predictability of the model is poor for estuaries such as the Severn and Thames Rivers where mixing is apparently less complete.

Based on these previous successes we have adapted the Dyer-Taylor model to mixing of salt within the Great Bay Estuary, New Hampshire (referred to hereafter as the Estuary). The Estuary, which is shown in figure 1, has a mean high water volume, V_H, of 230 x $10^6 m^3$ with a mean tidal prism, P, of 64 x $10^6 m^3$. Thus the currents, which range up to 300 cm/sec, are predominantly tidal because river discharge per tidal cycle, R, is generally less than 2% of the tidal prism. The turbulence associated with the tidal currents produces a vertically well-mixed water column throughout most of the Estuary. This is demonstrated in figure 2, which shows representative summertime salinity profiles along the Estuary (above) and averaged horizontal salinity distributions (below). Arellano (1978) has analyzed available river flow, current and salinity data from several locations with the Estuary in terms of the Hansen and Rattray (1966) estuarine classification scheme. With the exception of highest river discharge periods (which are limited to a few weeks in spring) most of the Estuary is found to be class 2a. This class is characterized by slight vertical salinity stratification and the fact that both advection and difusion processes are important in the upstream salt flux.

Therefore both observations and the Hansen-Rattray classification of the Estuary suggest that the Dyer-Taylor model may be appropriate for predicting

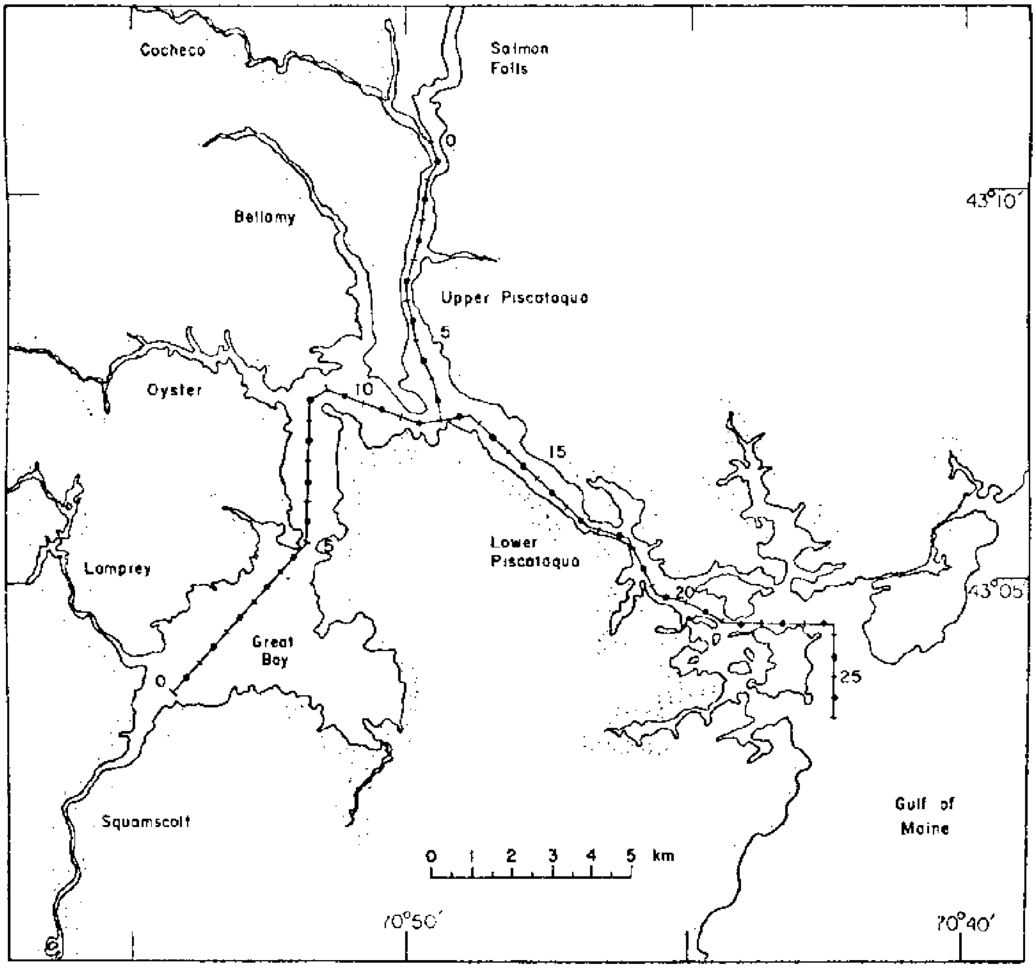

Figure 1. Location map of the Great Bay Estuary located in southeastern New Hampshire. The entry location of the important rivers are shown in relation to the downstream scale which is divided into units of kilometers.

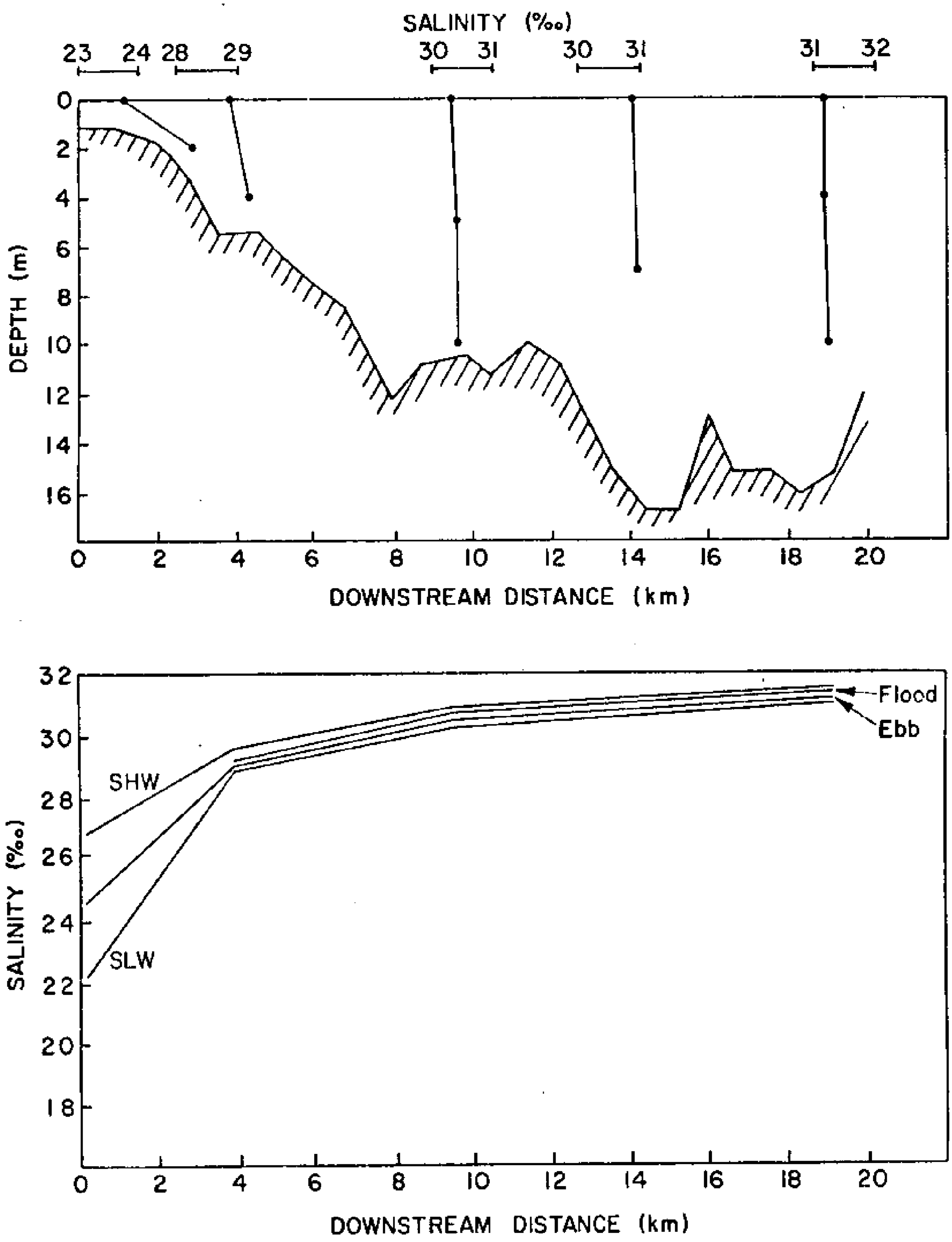

Figure 2. Typical summertime salinity distributions in the Great Bay Estuary. (above) Tidal averaged salinity profiles for several locations. (below) The depth averaged horizontal salinity distribution for slack high water (SHW), mid-ebb, slack low water (SLW), and mid flood.

salinities in this estuary. In Section 2 we present a summary of the essential elements of the model. In Section 3 the adaptation of the model to the Estuary for a low river discharge period is described. The results of a model prediction for a high river discharge period are presented in Section 4.

2. The Model

The Dyer-Taylor segmented tidal mixing model is one dimensional and predicts the salinity distribution at high and low tide in a well mixed estuary. This simple model is based on the conservation of salt and volume and provides for a crude spatial resolution of the salinity variability. We have adapted the original model described by Dyer and Taylor (1973) for a branching estuary. A schematic of the segment nomenclature for this version of the model is shown in figure 3. In general each segment, m, is subdivided into parts corresponding to the tidal prism P_m, the "mobil" low water volume, $\alpha_m V_m$, and the "stagnant" low water volume, $(1-\alpha_m)\ V_m$. The so called "mixing parameter", α_m, is chosen on the basis of the calibration procedure described in section 3 and has been interpreted in terms of the local tidal excursion of water parcels. The main branch of the Estuary is divided into M segments starting at the head where the river discharge per tidal cycle, R, enters. In the modified version a separate branch with its own river flow input is likewise segmented. In figure 3 the junction segment between the two branches occurs where segment ℓ of the second branch joints segment n of the main branch.

In general for each branch the volume relationships between segments are described by equations (1)-(3) below:

$$V_1 = R \tag{1}$$

$$\alpha_2 V_2 = P_1 \tag{2}$$

$$\alpha_{m+1}\ V_{m+1} = \alpha_m\ V_m + P_m \quad \text{for } m \geq 2 \tag{3}$$

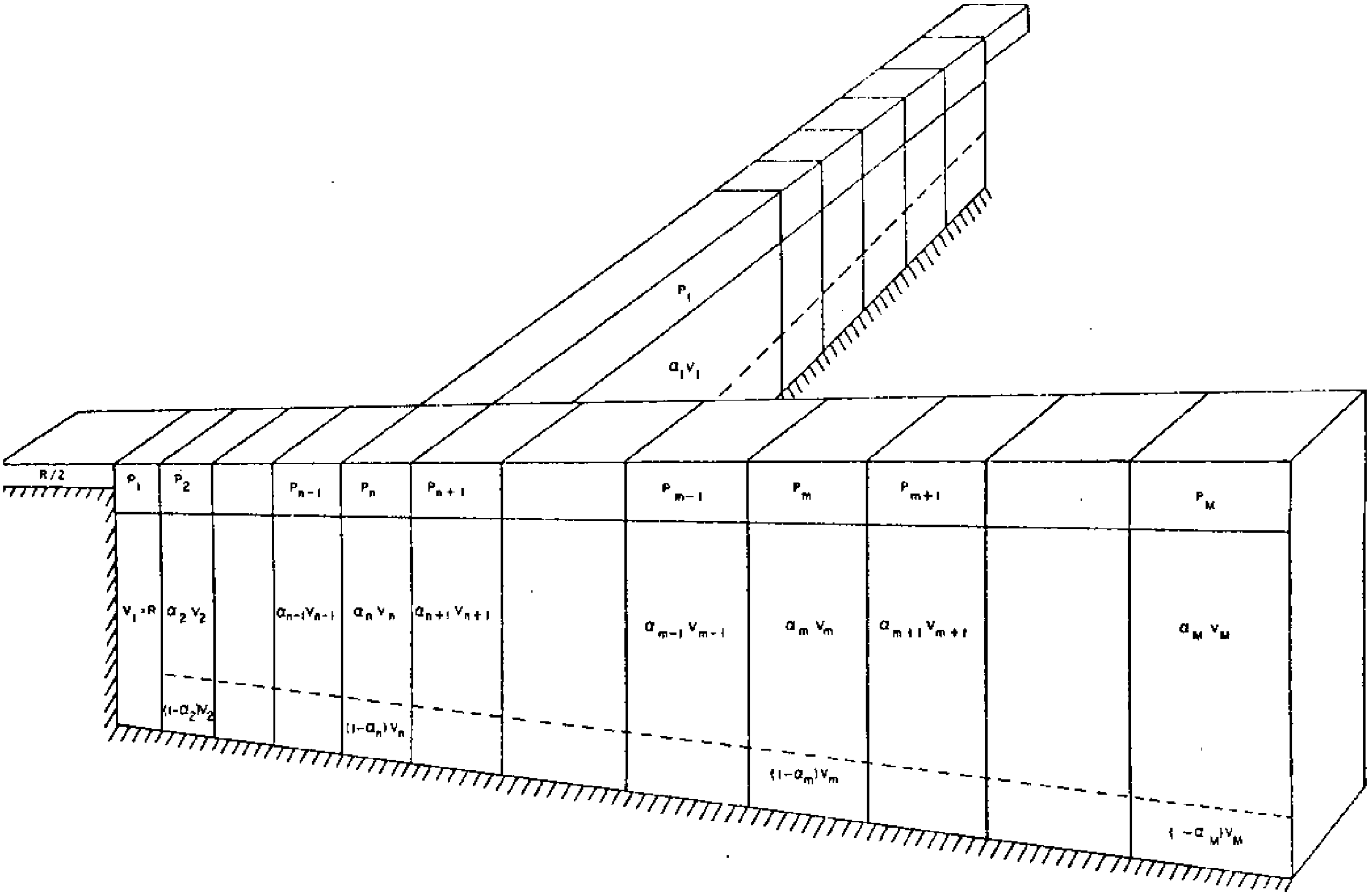

Figure 3. A schematic of segment nomenclature for the Dyer-Taylor mixing model applied to a branched estuary. The river discharge per tidal cycle R enters at the head of each of the branches of this model estuary. Each segment divided into a volume which contains (i) the tidal prism, P_m; (ii) a "mobil" portion of the low water; $\alpha_m V_m$, and (iii) a "stagnant" portion of the low water $(1-\alpha_m)V_m$ where α_m is a mixing parameter to be determined. In this particular representation the branch junction occurs at segment n.

where $0 < \alpha_m < 1$. These equations describe the process whereby on the flood tide the volume $\alpha_{m+1} V_{m+1}$ fills the portion of segment m which is designated by the sum of $\alpha_m V_m$ and P_m. If there is more than one branch to the estuary then the same volume relationships hold in a particular branch upstream of the junction between branches. For the branch junction segment n the volume is defined from the following

$$\alpha_n V_n = \alpha_{n-1} V_{n-1} + P_{n-1} + \alpha_\ell V_\ell + P_\ell \qquad \text{for } n \geq 2 \text{ and } \ell \geq 2 \tag{4}$$

where the subscript ℓ corresponds to the branch segment parameters.

The model assumes that at this high water stage that all the water in each segment m (including volume $(1 - \alpha_m)V_m$) mixes thoroughly. The following three expressions describe the conservation of fresh water for the branch junction segment n, the upstream segment n-1, and the upstream branch segment ℓ.

$$C^H_n \, (V_n + P_n) = (\alpha_n V_n + P_n) \, C^L_{n+1} + (1-\alpha_n) \, V_n \, C^L_n \tag{5a}$$

$$C^H_{n-1} \, (V_{n-1} + P_{n-1}) = (\alpha_{n-1} \, V_{n-1} + P_{n-1}) \, C^L_n + (1 - \alpha_{n-1}) \, V_{n-1} \, C^L_{n-1} \tag{5b}$$

$$C^H_\ell \, (V_\ell + P_\ell) = (\alpha_\ell V_\ell + P_\ell) \, C^L_n + (1 - \alpha_\ell) \, V_\ell C^L_\ell \quad , \tag{5c}$$

where C^L and C^H are the low and high water concentration of fresh water respectively.

At the low water stage thorough mixing is assumed such that the total volume of fresh water in segment n is

$$V_n C^L_n = (\alpha_{n-1} V_{n-1} + P_{n-1} + R_{n-1}) C^H_{n-1} + (\alpha_\ell V_\ell + P_\ell + R_\ell) C^H_\ell + [(1-\alpha_n) V_n - (R_{n-1} + R_\ell)] C^H_n , \tag{6}$$

where R_{n-1} and R_ℓ are the total river flow in the two branches respectively. Continuity of river water from both branches through segment n requires that

$$R_nC_{en} = R_{n-1}C_{n-1} + R_\ell C_\ell = (\alpha_{n-1}V_{n-1}+P_{n-1}+R_{n-1})C^H_{n-1} + (\alpha_\ell V_\ell+P_\ell+R_\ell)C^H_\ell - \alpha_n V_n\, C^L_n, \qquad (7)$$

where the accumulated river flow $R_n = R_\ell + R_{n-1}$ and the equivalent input concentration $C_{en} = (R_{n-1}\, C_{en-1} + R_\ell C_\ell)\, R_n$; C here is the input concentration of freshwater (normally=1).

(6) and (7) can be combined to form

$$R_n(C_{en} - C^H_n) = (1 - \alpha_n)V_n(C^L_n - C^H_n). \qquad (8)$$

For segments which are not branch junctions, such as segment m, (5), (6), (7) and (8) reduce to

$$C^H_m\,(V_m + P_m) = \alpha_{m+1}\, V_{m+1}\, C^L_{m+1} + (1 - \alpha_m)V_m + C^L_m \qquad (9)$$

$$V_mC^L_m = (\alpha_mV_m + R_{m-1})\, C^H_{m-1} + [(1-\alpha_m)V_m - R_{m-1}]C^H_m \qquad (10)$$

$$R_{m-1}C_{m-1} = (\alpha_mV_m + R_{m-1})C^H_{m-1} - \alpha_mV_mC^L_m \quad , \text{ and} \qquad (11)$$

$$R_{m-1}\,(C_{m-1} - C^H_m) = (1 - \alpha_m)V_m(C^L_m - C^H_m) \qquad (12)$$

(11) can be solved for C^H_{m-1} and rewritten for segment m as follows

$$C^H_m = (R_mC_m + \alpha_{m+1}\, V_{m+1}\, C^L_{m+1})/(\alpha_{m+1}V_{m+1} + R_m) \qquad (13)$$

and (12) can be solved for C^L_m as follows

$$C^L_m = R_{m-1}(C_{m-1} - C^H_m)/(1-\alpha_m)V_m + C^H_m. \qquad (14)$$

Therefore if C^L_{m+1} is known then (13) can be solved for C^H_m which in turn can be used with (14) to solve for C^L_m. In practice the high water fresh water concentration in the most seaward segment C^H_M is assumed to be zero. That is to say that only pure sea water is found in the most seaward segment at high water.

Thereafter (13) and (14) are used alternately to solve for C_m^H and C_m^L for the upstream segments which are not directly upstream from a branch junction.

Immediately upstream from the branch junction segment n, C_{n-1}^H can be determined from (7) as follows

$$C_{n-1}^H = (R_n C_{en} + \alpha_n V_n C_n^L - (\alpha_\ell V_\ell + P_\ell + R_\ell) C_\ell^H) / (\alpha_{n-1} V_{n-1} + P_{n-1} + R_{n-1}) \tag{15}$$

C_ℓ^H can be determined from the complementary relation. But this depends upon the value C_ℓ^H which is not known (and cannot be solved for). Therefore we will let $C_\ell^H = \beta\, C_n^L$, β represents the way in which the flood volumes split at the junction and will be chosen during the calibration of the model. In the described manner all C_n^H and C_n^L can be determined for upstream segments using (13) and (14) (or (15) where appropriate) in an alternating fashion.

Salinities S_m are determined from the fresh water concentration in accordance with $S_m = S_o (1 - C_m)$ where S_o is the specified oceanic salinity. In addition the flushing times for individual segments are found from the ratio of the high water fresh water volume in a particular segment to the accumulated river discharge rate appropriate for that segment.

3. Model Adaptation

The calibration of the model involves the choice of mixing parameters, α_m, for each section and the branch parameter β. These constants have been determined on the basis of the comparison of predictions with a comprehensive data set acquired for the Estuary during a relatively low river flow period of the year. The actual calibration process consists of the specification of the low water and tidal prism volume distributions, all river flow rates and the oceanic salinity. The α_m and β values are chosen so that the predicted and observed high and low slack water salinity distributions match as well as possible in a least square sense.

The low water volume distribution for the Great Bay-Lower Piscataqua section of the Estuary has been determined from existing nautical charts of the region and is shown above in figure 4. The cumulative volume distributions for mean low water, high water and tidal prism for the Great Bay-Lower Piscataqua and the Upper-Lower Piscataqua section are shown in the two panels below. The cumulative volume distributions have been fit with eighth order polynomials and are shown in figure 4 as dashed curves. The uncertainty in the data is greater than the difference between the fitted-curve and the data in most places. The measured volume data is compared with the results from the polynomials in table A-2 in appendix A.

Provisions have been made for the entry of three rivers into the model. The combined Lamprey-Squamscott, the Oyster-Bellamy and the Cocheco-Salmon Falls. The daily discharge from the Lamprey River is measured and the data are available in the form of U.S. Geological Survey Water Data Reports (1974, 1975, 1976, 1977). The model calibration was performed for a period of relatively low river flow during the summer of 1975 when extensive salinity distribution data was acquired. The flow rate for the Lamprey River is compared with that of the Salmon Falls River for 1975 in figure 5. In this case the flow rates are proportional to their respective drainage areas for most of the year. Therefore estimates of all river flows have been made by adjusting an appropriately averaged Lamprey flow rate by factors related to relative drainage basin areas of the others rivers shown in table 1. The factors are 1.6, 1.6 and 0.3 for the Lamprey - Squamscott, the Cocheco - Salmon Falls and the Oyster - Bellamy Rivers respectively. Preliminary calculations indicated that the flushing period for the entire estuary during a low river flow is about 50 tidal cycles or 26 days. Therefore average monthly discharges were determined for the calibration period and found to be 0.1, 0.1 and 0.025 x 10^6 m^3 per tidal cycle (TC) for the Lamprey - Squamscott, Cocheco - Salmon Falls and Oyster - Bellamy

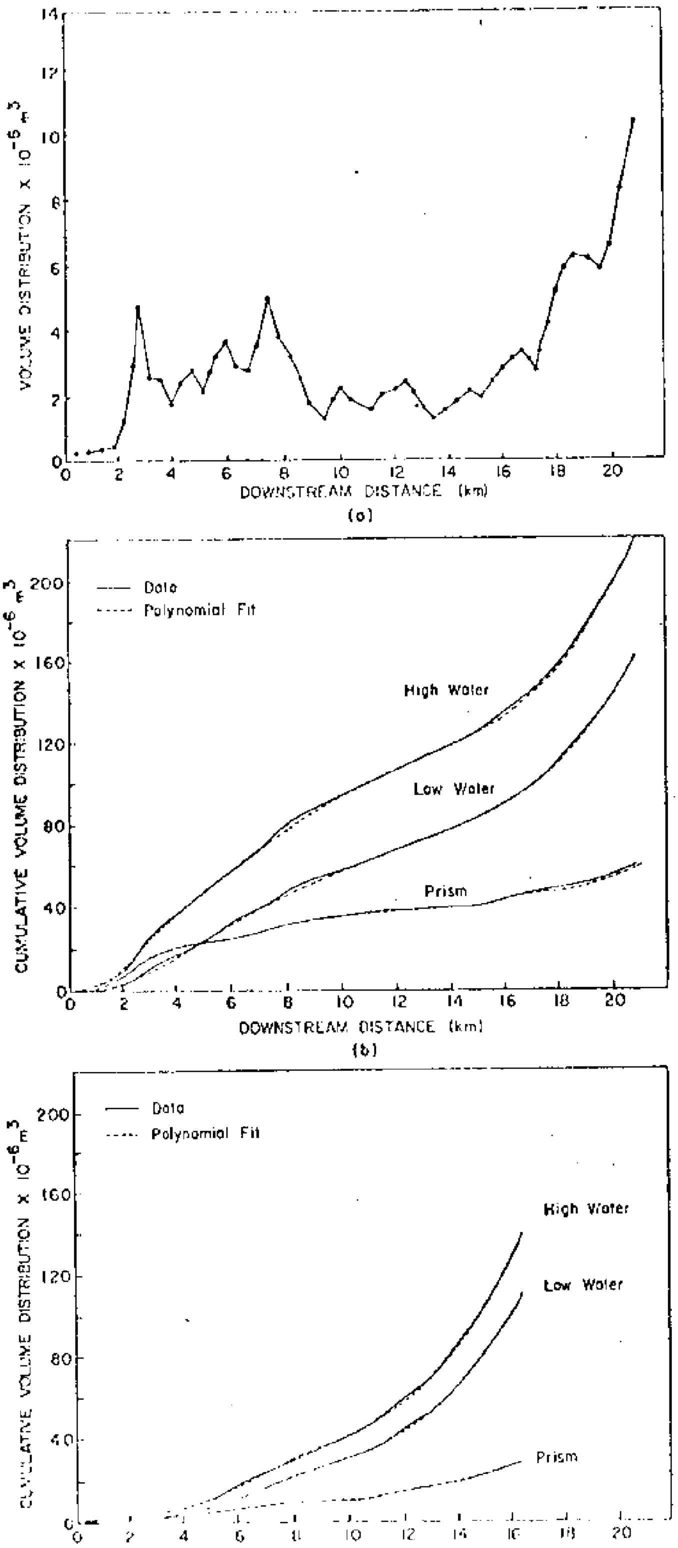

Figure 4. (a) The mean low water volume distribution for the Great Bay - Lower Piscataqua section of the Estuary is shown. In (b) and (c) below the mean cummulative distribution of high water, low water and tidal prisms for the Great Bay - Lower Piscataqua and Upper Piscataqua are shown as solid lines. Eighth order polynomial fits to the data (----) are presented for comparison.

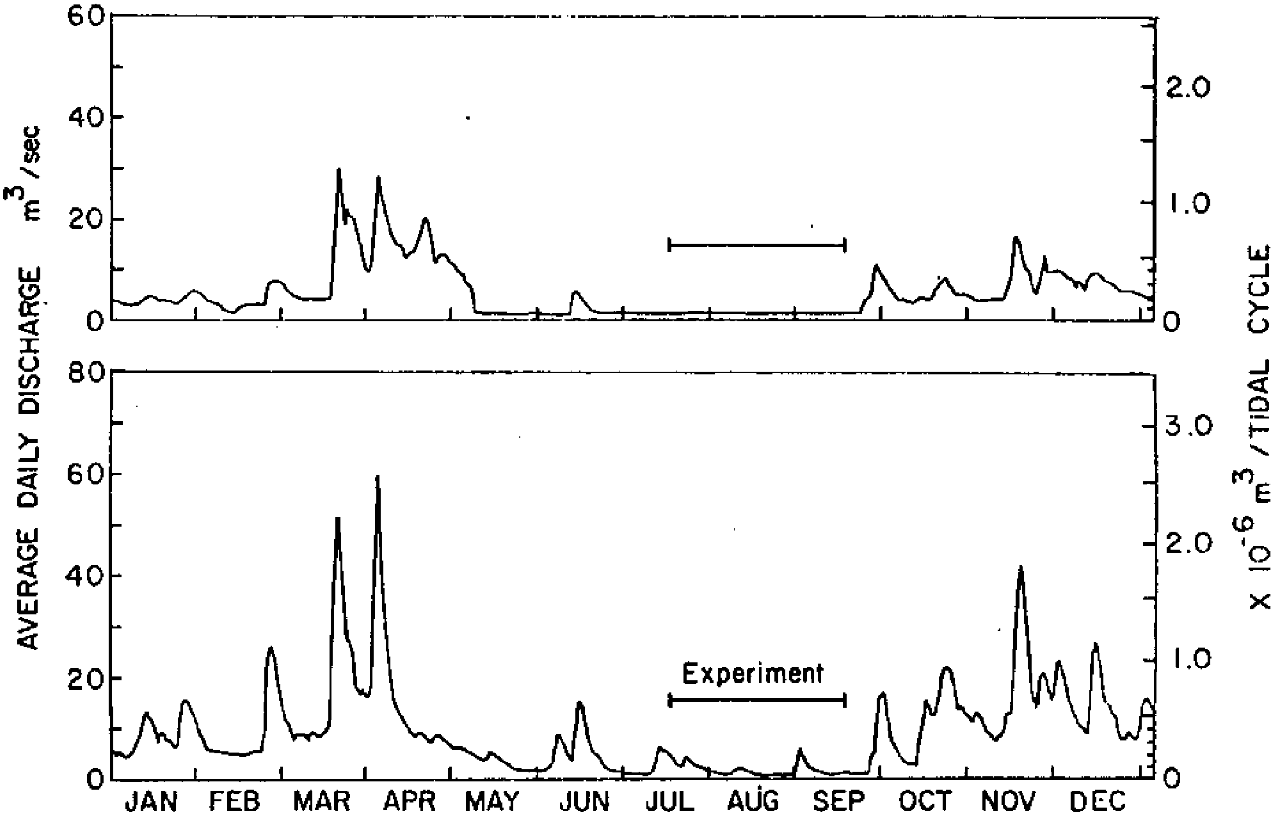

Figure 5. River discharge rates for the Salmon Falls (above) and Lamprey River (below) for 1975. The scale on the left is in units of m^3/sec and the right is in $10^6 m^3$ per semidaily tidal cycle. The Great Bay experiment was performed during the summer period indicated.

	Drainage Area (miles)^2			Fraction of Lamprey Drainage Area	
	Above Tidewater	Direct to Tidewater	Total		
Lamprey	207.5	2.0	209.5	1.00	1.61
Squamscott/Exeter	108.2	19.6	127.8	.61	
Oyster	19.6	10.5	30.1	.14	.30
Bellamy	27.7	5.1	32.8	.16	
Cocheco	173.5	8.6	182.1	.87	1.59
Salmon Falls	149.6	1.9	151.5	.72	
Piscataqua (est.)	---	160.0	160.0	.76	.76

Table 1 Drainage areas of the rivers entering the Great Bay Estuarine Systems. The areas have been normalized by the Lamprey River area since that river is gauged. (Data source: Robert Layton, Soil Conservation Service, U.S. Department of Agriculture, Durham, NH)

river pairs respectively. The value for the Oyster - Bellamy river pairs, which is an overestimate based on just drainage area, was chosen to compensate for a highly uncertain estimate of discharge into the Piscataqua (see table 1).

The salinity (freshwater concentration) distributions at high and low slack water were determined from synoptic salinity distribution maps (shown in figure B-1) for the Estuary. These composite maps were constructed on the basis of vertically averaged salinities collected during several multi-ship surveys of the Estuary during the summer 1975. (The detailed results of a program to measure the distribution of salinity and temperature in the Estuary are described by Brown and Silver (1979)). A summary of the salinity collection program associated directly with this modelling effort also appears in appendix B.

The calibration procedure involves the comparison of model predictions based on equations (1)-(15) with observed salinity distributions for the summer 1975 period. The details of this computation which have been coded in BASIC for use on the Tektronics 4051 Graphics System, are described in appendix C. An interative procedure has been used to determine the mixing coefficients α_m which will minimize the difference between model and observed freshwater concentration distribution in both branches of the Estuary. The best fit is shown in figure 6. The results from the calculation are presented in table 2 and a map of the segment boundaries is shown in figure 7. The distances of isohaline excursions (see figure B-1) in different parts of the estuary compare favorability with the sizes of the corresponding segments.

Because the relative volume contribution of the Upper Piscataqua branch is small (see table 2) the branch mixing coefficient β was chosen to be 1. This is equivalent to saying that the high water concentration, C_4^H; is the same as the low water concentration, C_6^H; a boundary condition which is equivalent to the oceanic boundary condition. Tests show for this case that the main branch conditions are not particularly sensitive to the choice of β.

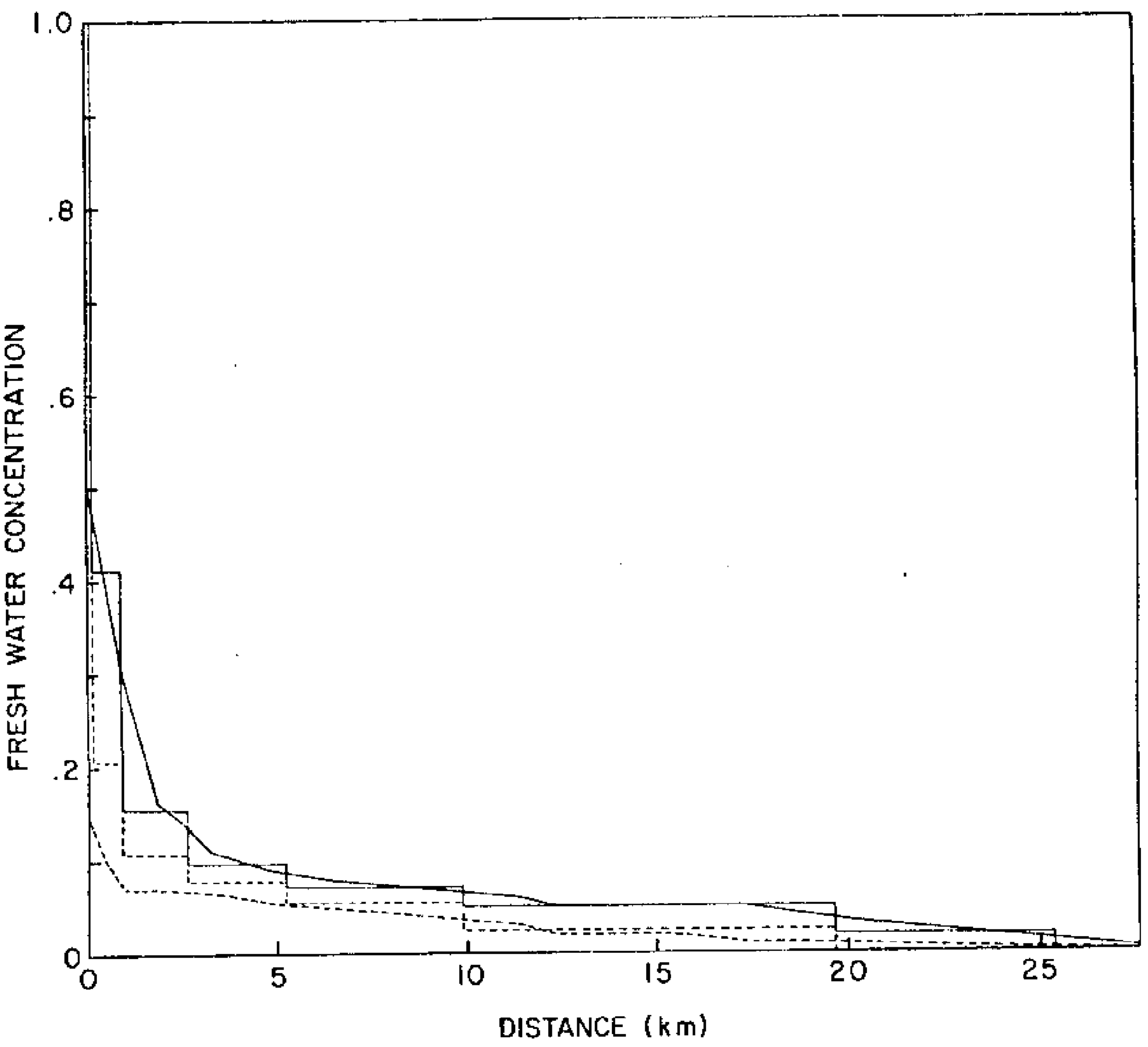

Figure 6. Comparison of model and observed fresh water concentration distribution for high (----) and low (——) slack water in the main branch of the Estuary. This fit has been achieved by choosing the mixing coefficients for a low river flow case in which the Lamprey-Squamscott, Oyster-Bellamy, and Cocheco-Salmon Falls flows are 0.1, 0.025 and 0.1 x $10^6 m^3$/TC, respectively. The ocean (Gulf of Maine) salinity to which the fresh water concentration is referred to as 31.5‰.

VOLUME AND SALINITY DISTRIBUTION

GREAT BAY AND LOWER PISCATAQUA

#m	Segment Boundary ES	km	α	(1-α)V	α*V	PRISM	α*V+P
1	1.3	0.2	0.00	0.000	0.100	0.167	0.267
2	7.4	0.9	0.30	0.388	0.166	1.386	1.552
3	21.1	2.6	0.45	1.897	1.552	7.128	8.688
4	41.9	5.2	0.65	4.674	8.680	12.082	20.762
5	79.2	9.9	0.75	6.921	20.762	10.075	30.837
6	157.3	19.7	0.80	8.678	34.711	12.461	47.172
7	203.0	25.4	0.80	11.793	47.172	13.090	60.261

UPPER PISCATAQUA

#m	Segment Boundary ES	km	α	(1-α)V	α*V	PRISM	α*V+P
1'	0.9	0.1	0.00	0.000	0.100	0.089	0.189
2'	6.2	0.8	0.20	0.357	0.089	0.380	0.469
3'	26.6	3.3	0.30	1.094	0.469	1.058	1.527
4'	45.8	5.7	0.50	1.527	1.527	2.348	3.874

FRESH WATER AND SALT DISTRIBUTIONS

GREAT BAY AND LOWER PISCATAQUA

#m	Segment Boundary ES	km	Fresh Conc. High	Low	Salinity (PPT) High	Low	F(TC)	R $10^6 m^3$/TC
1	1.3	0.2	0.26	1.00	23.45	0.00	0.68	0.100
2	7.4	0.9	0.21	0.41	25.03	18.57	3.99	0.100
3	21.1	2.6	0.11	0.15	28.12	26.64	11.35	0.100
4	41.9	5.2	0.08	0.10	29.07	28.44	19.65	0.100
5	79.2	9.9	0.05	0.07	29.78	29.24	16.47	0.125
6	157.3	19.7	0.02	0.05	30.75	29.95	5.89	0.225
7	203.0	25.4	0.00	0.02	31.50	30.90	0.00	0.225

UPPER PISCATAQUA

#m	Segment Boundary ES	km	Fresh Conc. High	Low	Salinity (PPT) High	Low	F(TC)	R $10^6 m^3$/TC
2'	6.2	0.8	0.38	0.55	14.17	19.68	3.10	0.100
3'	26.6	3.3	0.17	0.24	23.87	26.27	4.35	0.100
4'	45.8	5.7	0.05	0.11	27.99	29.95	2.65	0.100

Table 2. The results of model calibration procedure for the Estuary are listed. The α and volume distributions and downstream boundary are shown above for each segment m and m'. The two branches join in segment 6. The high and low water fresh water concentration and salinities for each section are listed along with the flushing period, F, and the accumulated river flow, R, for each segment. The ocean (Gulf of Maine) salinity for this calculation is 31.5% and the branch mixing coefficient β is 1. ES refers to Estuarine scale which is discussed in appendix A.

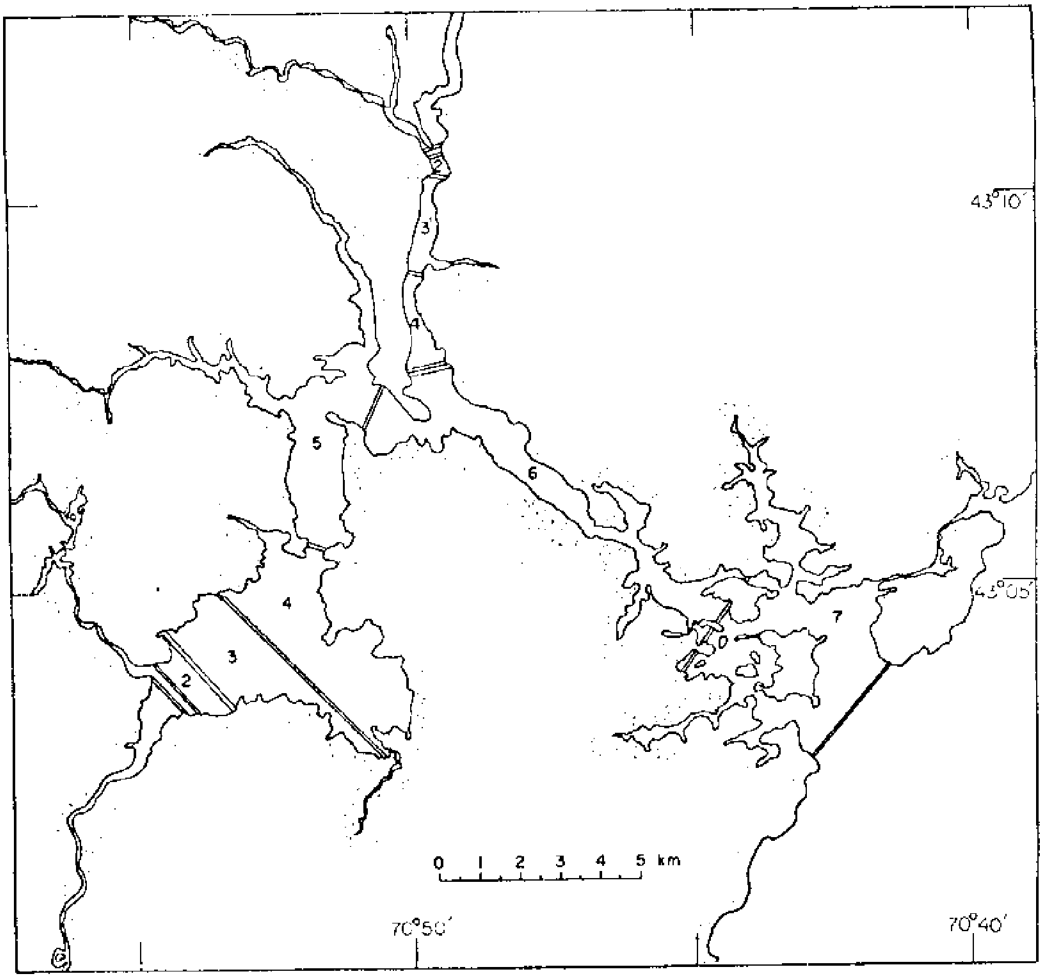

Figure 7. Segment boundaries for the low river flow calibration experiment. See table 2 for details.

4. Results

Using the α_m selected in the calibration process a prediction was made for a high river flow condition during the spring run off period of 1978. A set of salinity data acquired during this period was used to verify the model prediction.

The application of the model to high river flow is a bit subjective because the location of the segment boundaries are related to our variable river flow, R, (through equations (1)-(3)) and thus do not coincide with those used in the calibration phase. Our solution to the problem was to choose an α distribution which corresponds (approximately) geographically to the distribution found during calibration. The river flow was determined from the Lamprey gauge data averaged and adjusted in the same proportions as in the calibration phase. The segment boundaries for this flow condition are shown in figure 8 for Lamprey - Squamscott, Oyster - Bellamy and Cocheco - Salmon Falls river flows of .7, .175 and .7 x $10^6 m^3$/TC respectively. The α_2 and α_3 values were chosen slightly greater than the corresponding calibration values of α_3 and α_4 because segment 1(with $\alpha = 0$) is larger. Note that the Estuary is divided into one fewer segments. A comparison between predicted and observed salinities for an ocean salinity of 30.6‰ is shown in figure 9, while a summary of the full numerical results is presented in table 3.

A reasonable agreement between the prediction and the observations exists throughout all except the upper reaches of the Estuary; a region which was not well modelled at the outset (see figure 6). The excess of the model fresh water relative to observations in segments 3 and 4 is probably related to the extra fresh water input by the Oyster and Bellamy rivers as discussed in section 3. This could be corrected by representing the uncertain Piscataqua fresh water input more accurately. The consequences of such a correction to the overall flushing period of the estuary is probably small.

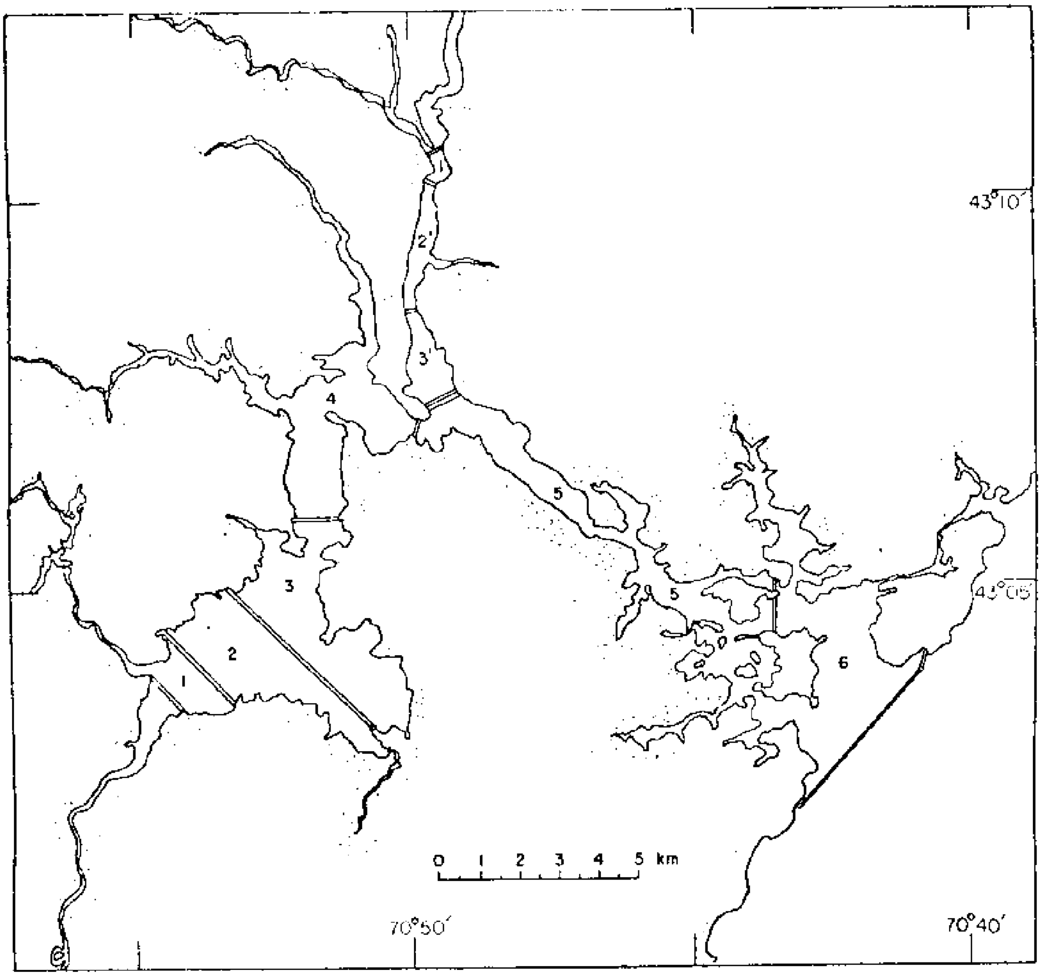

Figure 8. Segment boundaries for the high river flow prediction experiment. See table 3 for details.

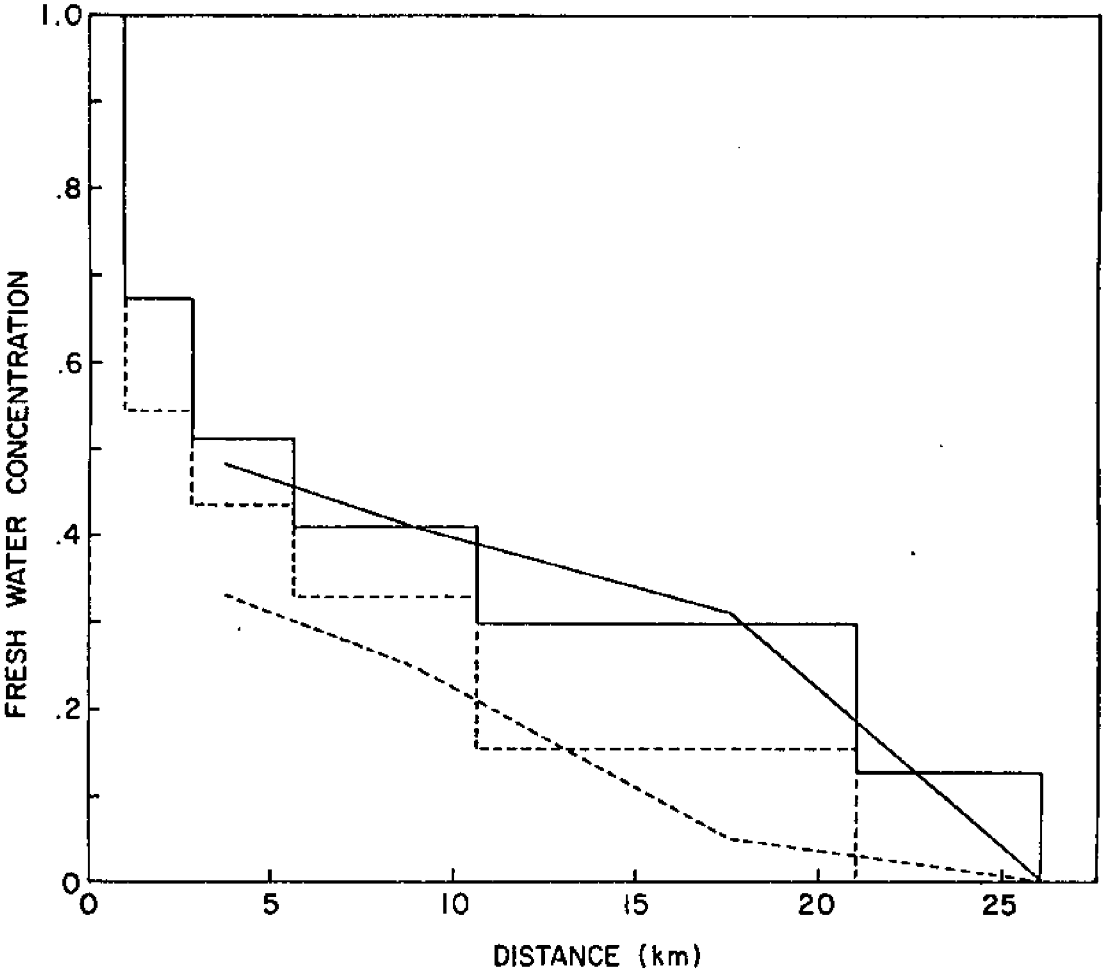

Figure 9. Comparison of model and observed fresh water concentration distribution for high (----) and low (——) slack water in the main branch of the Estuary. River flows of 0.7, 0.175 and 0.7 x $10^6 m^3$/TC have been input at the Lamprey-Squamscott, Oyster-Bellamy, and Cocheco-Salmon Falls respectively. The ocean (Gulf of Maine) salinity to which the fresh water concentration is referenced is 30.7%.

VOLUME AND SALINITY DISTRIBUTION

GREAT BAY AND LOWER PISCATAQUA

#m	Segment Boundary ES	km	α	(1-α)Vol	α*Vol	PRISM	α*V+P
1	7.8	1.0	0.00	0.000	0.700	1.654	2.354
2	22.6	2.8	0.40	2.480	1.654	8.100	9.754
3	45.1	5.6	0.65	5.252	9.754	12.179	21.933
4	85.2	10.7	0.75	7.311	21.933	10.431	32.364
5	168.2	21.0	0.80	9.273	37.090	12.769	49.868
6	208.3	26.0	0.80	12.465	49.860	14.125	63.985

UPPER PISCATAQUA

#m	Segment Boundary ES	km	α	(1-α)Vol	α*Vol	PRISM	α*V+P
1'	8.6	1.1	0.00	0.000	0.700	0.601	1.301
2'	33.5	4.2	0.30	1.403	0.601	1.499	2.100
3'	50.9	6.4	0.50	2.100	2.100	2.626	4.726

FRESH WATER AND SALT DISTRIBUTIONS

GREAT BAY AND LOWER PISCATAQUA

#m	Segment Boundary ES	km	Fresh Conc. High	Low	Salinity (PPT) High	Low	F(TC)	R $10^6 m^3$/TC
1	7.8	1.0	0.47	1.00	16.22	0.00	1.59	0.700
2	22.6	2.8	0.54	0.67	14.05	10.08	9.48	0.700
3	45.1	5.6	0.43	0.51	17.37	15.06	16.86	0.700
4	85.2	10.7	0.33	0.41	20.64	18.17	14.85	0.875
5	168.2	21.0	0.15	0.30	26.00	21.58	5.75	1.575
6	208.3	26.0	0.00	0.13	30.70	26.82	0.00	1.575

UPPER PISCATAQUA

#m	Segment Boundary ES	km	Fresh Conc. High	Low	Salinity (PPT) High	Low	F(TC)	R $10^6 m^3$/TC
1'	33.5	4.2	0.65	0.82	5.41	10.79	3.25	0.700
2'	50.9	6.4	0.30	0.53	14.39	2.158	2.90	0.700

Table 3. The results of the high river flow model prediction for the Estuary are listed. The α and volume distributions and the downstream boundary are shown above for each segment m and m. The two branches join segment 5. The high and low fresh water concnetration and salinities for each section are listed along with the flushing period, F, and the accumulated river flow, R, for each segment. The ocean (Gulf of Maine) salinity for the calculation is 30.7‰ and the branch mixing coefficient is $\beta = 1$. ES refers to Estuarine Scale, which is discussed in Appendix A.

The total flushing time for a parcel of water entering the model estuary at the head of the main branch during this high river flow period is found to be 48.5 M_2 tidal cycles or 25.1 days. This contrasts with 58.0 M_2 tidal cycles or 30.0 days flushing period for that same parcel of water entering the model estuary at the head during a low river flow period (such as our calibration period). The distribution of the segment flushing periods as listed in tables 2 and 3 suggest geographical locations where flushing is maximum and minimum.

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Appendix A - Volume Distributions

The mean high water and low water volume distribution has been determined for the Great Bay Estuary from the Coast and Geodetic Survey Chart 212. The bathymetry has been contoured and the Estuary has been subdivided into sections indicated by the longitudinal scale shown in figure A-1. A planimeter was used to determine mean low water volumes for each 4 unit subsection of the Estuary directly from the chart. A mean tidal range of 2m for the Estuary was determined on the basis of the sea level distribution shown in figure A-2. This was added to the mean low water and the chart areas were redetermined where necessary to find high water volume distribution. The tidal prism volume distribution was calculated from the difference between high and low water distributions.

In table A-1 the volumes of the major Estuary subsections are summarized. The uncertainties are calculated on the basis of a estimated random error of ± 7% for each 4 unit subsection. Cumulative volume distributions for all three sets of data were found and eighth order polynomial fits to the results were determined. A comparison of the measured cumulative volumes and the polynomial fits is presented in table A-2. The uncertainty of the cumulative volumes ranges from ± 7% near the head of the Estuary to ± 1% near the mouth.

A polynomial determined here can be generally specified as follows:

$$V(n) = q_o + \sum_{j=1}^{r} q_j n^j \qquad \text{where}$$

n is the estuarine scale shown in figure A-1 and r is the order for a particular polynomial. The coefficients for the polynomial fits are shown in table A-3. Separate fits where required for the distributions near the origin. The regions over which each is applied is shown in parentheses.

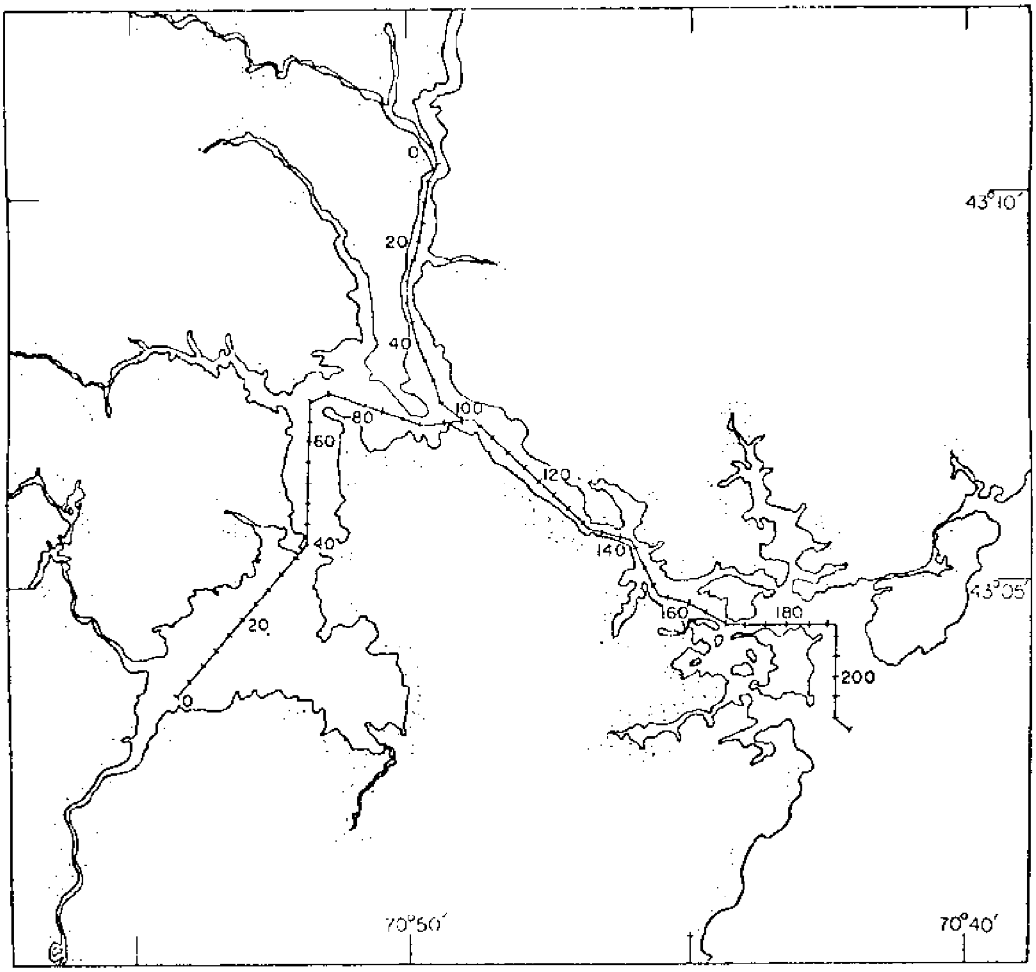

Figure A-1 The longitudinal estuarine scale, ES, for the Great Bay Estuarine System. The reference for the main branch begins at the junction of the Lamprey and Squamscott River and ends at the entrance to Portsmouth Harbor. The secondary branch begins at the junction of the Cocheco and Salmon Falls River and terminates at the junction between the Upper and Lower Piscataqua. The scale is 8 units per kilometer.

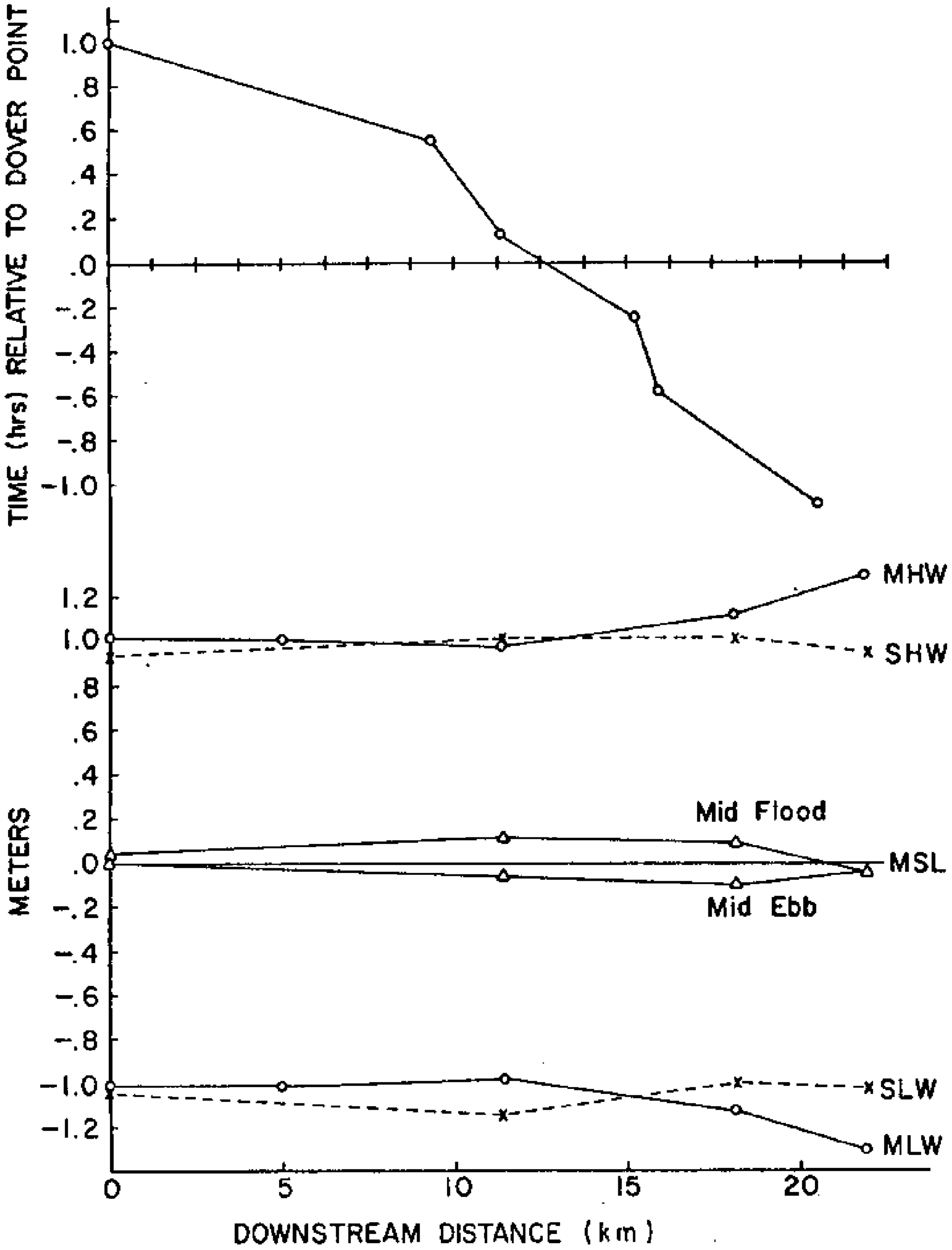

Figure A-2 Summary of tidal elevation distribution within the Great Bay Estuarine System. The distributions of 7-day mean high and low water (MHW,MLW) relative to a horizontal surface are shown below. These are compared with instantaneous sea level distributions shown for slack high and low water (SHW,SLW) and mid-ebb and flood at Dover Point for 15 July 1975. Above the phase distribution of high water relative to Dover Point is shown.

Section	Total	Total Prism	Low Water
Great Bay (0-38)	34.31 ± .82	18.81 ± .45	15.50 ± .37
Little Bay (38-95)	55.38 ± 1.05	15.84 ± .30	39.54 ± .76
Upper Piscataqua (0-52)	11.62 ± .23	4.55 ± .09	7.07 ± .14
Lower Piscataqua (95-217)	128.91 ± 1.66	24.44 ± .31	104.47 ± 1.34
Estuarine System	230.22 ± 2.43	63.64 ± .67	166.58 ± 1.78

Table A-1 Mean volume estimates of the major subsections of the Great Bay Estuarine System. The boundaries of each section are indicated in terms of the scale shown in figure A-1. Units are $10^6 m^3$.

Table A-2 Cumulative Volume Distributions for the Great Bay Estuarine System

Units are $10^6 m^3$.

GREAT BAY & LOWER PISCATAQUA

		HIGH WATER		LOW WATER		PRISM	
ES	km	Measured	Polynomial Fit	Measured	Polynomial Fit	Calculated	Polynomial Fit
0	0.0	0.0		0.0		0.0	
4	0.5	1.12	1.35	0.32	0.00	0.80	0.89
8	1.0	2.33	1.21	0.73	0.23	1.59	0.94
12	1.5	3.88	3.38	1.17	0.95	2.63	2.54
16	2.0	5.88	6.99	1.70	2.14	4.16	5.00
20	2.5	8.80	11.47	2.28	3.72	6.59	7.85
24	3.0	14.71	16.36	4.25	5.66	10.44	10.75
28	3.5	23.58	21.40	9.12	7.90	14.44	13.48
32	4.0	28.92	26.41	11.76	10.40	17.14	15.95
36	4.5	32.84	31.29	14.41	13.10	18.41	18.10
40	5.0	37.12	35.99	16.23	15.95	20.87	19.94
44	5.5	40.38	40.53	18.85	18.92	21.51	21.51
48	6.0	44.43	44.90	21.78	21.96	22.63	22.85
52	6.5	47.30	49.14	23.99	25.07	23.29	24.03
56	7.0	51.65	53.28	27.29	28.17	24.34	25.09
60	7.5	56.39	57.35	31.13	31.26	25.24	26.09
64	8.0	60.30	61.35	34.04	34.31	26.25	27.06
69	8.6	65.25	66.29	36.93	38.04	28.30	28.27
75	9.4	71.81	72.09	42.13	42.33	29.66	29.76
79	9.9	77.74	75.87	45.91	45.07	31.81	30.77
83	10.4	82.14	79.55	49.29	47.72	32.83	31.78
87	10.9	85.52	83.11	51.94	50.24	33.56	32.78
91	11.4	87.78	86.52	53.00	52.66	34.10	33.75
95	11.9	89.69	89.76	55.11	54.96	34.56	34.66
101	12.6	92.99	94.27	57.51	58.22	35.46	35.89
105	13.1	95.68	97.03	59.51	60.27	36.15	36.60
109	13.6	98.29	94.27	57.51	58.22	35.46	35.89
113	14.1	100.36	101.95	62.98	64.13	37.36	37.71
117	14.6	103.10	104.17	65.25	65.97	37.83	38.13
121	15.1	106.10	106.26	67.57	67.77	38.42	38.46
125	15.6	109.10	108.27	70.19	69.54	38.89	38.74
129	16.1	111.49	110.24	72.20	71.32	39.26	38.98
133	16.6	113.25	112.25	73.77	73.13	39.46	39.22
137	17.1	114.74	114.34	75.17	74.99	39.55	39.49
141	17.6	116.64	116.60	77.05	76.95	39.57	39.82
145	18.1	118.00	119.06	79.13	78.99	39.83	40.24
149	18.6	121.78	121.79	81.47	81.20	40.29	40.76
153	19.1	124.50	124.84	83.52	83.59	40.96	41.40
157	19.6	129.08	128.26	86.04	86.19	43.02	42.17
161	20.1	132.90	132.06	88.99	89.05	43.88	43.06
165	20.6	136.87	136.26	92.35	92.21	44.50	44.06
169	21.1	141.42	140.89	95.86	95.71	45.54	45.13
173	21.6	144.93	145.94	98.62	99.59	46.29	46.25
177	22.1	149.81	151.41	102.77	103.91	47.02	47.38
181	22.6	156.37	157.31	108.35	108.69	48.00	48.49
185	23.1	163.56	163.65	114.67	113.99	48.87	49.57
189	23.6	171.41	170.49	121.09	119.86	50.30	50.61
193	24.1	178.87	177.92	127.38	126.33	51.47	51.67
197	24.6	186.26	186.10	133.36	133.43	52.88	52.86
201	25.1	195.55	195.30	140.00	141.21	55.53	54.36
205	25.6	205.00	205.88	149.05	149.70	56.88	56.49
209	26.1	218.60	218.39	159.58	158.91	59.02	56.96

UPPER PISCATAQUA

		HIGH WATER		LOW WATER		PRISM	
ES	km	Measured	Polynomial Fit	Measured	Polynomial Fit	Calculated	Polynomial Fit
0	0.0	0.0		0.0		0.0	
4	0.5	0.74	0.58	0.38	0.49	0.36	0.09
8	1.0	1.22	1.34	0.66	0.49	0.55	0.85
12	1.5	1.74	2.00	0.91	0.64	0.83	1.16
16	2.0	2.43	2.52	1.24	1.26	1.19	1.26
20	2.5	3.13	2.93	1.57	1.63	1.55	1.31
24	3.0	3.45	3.33	1.77	1.92	1.68	1.41
28	3.5	3.91	3.80	2.03	2.20	1.88	1.61
32	4.0	4.55	4.47	2.64	2.54	1.90	1.94
36	4.5	5.57	5.39	3.28	3.00	2.29	2.39
40	5.0	6.90	6.63	3.96	3.69	2.94	2.95
44	5.5	8.13	8.20	4.59	4.63	3.54	3.57
48	6.0	9.30	10.10	5.27	5.85	4.02	4.24
52	6.5	11.62	12.26	7.07	7.34	4.54	4.92
56	7.0	14.92	14.67	9.47	9.09	5.45	5.58
60	7.5	17.61	17.23	11.47	11.03	6.14	6.20

Great Bay - Lower Piscataqua

	Low Water (0-13) "Poly 3"	Low Water (13-209) "Poly 1"	Tidal Prism (0-13)	Tidal Prism (13-209)
q_0	-1.0 E-3	1.38625673376	-.15666667	3.35174230102
q_1	0.0745706745621	-0.357906292049	.22875000	-1.02568322489
q_2	0.00195185208717	0.0310486461922		0.116527341976
q_3		-4.595897469 E-4		-0.0037091001160
q_4		4.479179641 E-6		6.056169163 E-5
q_5		-3.27715972 E-8		-5.586976425 E-7
q_6		1.575584494 E-10		2.930967282 E-9
q_7		-4.09031767677 E-13		-8.144640579 E-1
q_8		4.360196903 E-16		9.305260257 E-1

Upper Piscataqua

	Low Water (0-20) "Poly 5"	Low Water (20-164) "Poly 4"	Tidal Prism (0-20)	Tidal Prism (20-164)
q_0	-0.01	1.3678012724	1.806 E-4	-1.44398387302
q_1	0.11424903468	-0.391188559294	0.10316425592	0.514619161549
q_2	-0.00554757677474	0.0527167125734	-0.0062232366592	-0.377298761577
q_3	2.051552524 E-4	-0.00269081150333	2.78020052 E-4	0.00131618211388
q_4		6.956452472 E-5		-2.218964776 E-5
q_5		-9.424655932 E-7		1.967355402 E-7
q_6		6.8930207 E-9		-9.036148763 E-10
q_7		-2.581346736 E-11		1.86260282 E-12
q_8		3.892038236 E-14		-9.456139952 E-16

Table A-3 Polynomial coefficients for cumulative volume distribution for mean low water and tidal prism in the Great Bay - Lower Piscataqua and the Upper Piscataqua. The sections where these are applicable are indicated in parentheses. The volume units of the output of each polynomial is $10^6 m^3$.

Appendix B - Salinity Distributions

Salinities for the calibration of the model were obtained from water samples collected in the Estuary during July, August, and September 1975. The data set includes quasi-synoptic salinity data for several locations over a tidal cycle. The sample collection were done using the R/V Jere A. Chase, R/V Ferrel, R/V Explorer, the R/V Microboat and a Normandeau Associates, Inc., boat. Samples were obtained from several depths using either an on board 12-volt pump (Simer Model No. BW85) and hose or a standard sampling bottle such as Niskin, VanDorn or Nansen bottle.

Salinity profiles were also made within a couple hours of slack high and slack low water along the Estuary during high river flows period on March 22 and 28, 1978 respectively. Salinity samples were pumped on board using a submersible pump and plastic hose. Each station was sampled over 5 to 8 minute periods, and the calculated depth was approximated by the hose length.

All water samples were analyzed to obtain salinities using a Guildline Autosal Salinometer (Model 8400) which has a precision of $\pm$ .005%. The salinities in a single profile were averaged. A summary of the salinities and the fresh water concentrations found for the calibration and prediction experiments are shown in table B-1 and B-2 respectively.

The freshwater concentration, C, at a particular estuarine location is calculated according to $C = (S_0 - S)/S_0$ where S is the observed estuarine salinity and S_0 is the oceanic or reference salinity. The listed salinities for the calibration were determined from the 1975 composite salinity maps for high and low slack water shown in figure B-1. The salinities for the high river flow verification are vertically averaged values of salinities observed at the indicated locations.

	ES	km	S_L (o/oo)	S_H (o/oo)	C_L	C_H
Great Bay Lower Piscataqua	0	0.00	20.00	27.80	.367	.118
	10	1.25	23.00	29.10	.270	.077
	20	2.50	26.50	29.25	.159	.072
	30	3.75	28.20	29.55	.105	.062
	40	5.00	28.60	29.70	.093	.058
	50	6.25	29.00	29.90	.080	.051
	60	7.50	29.15	30.05	.075	.047
	70	8.75	29.30	30.10	.070	.045
	80	10.00	29.50	30.18	.064	.042
	90	11.25	29.70	30.50	.057	.032
	100	12.50	29.80	30.90	.055	.020
	110	13.75	29.90	31.10	.052	.013
	120	15.00	30.10	31.22	.045	.009
	130	16.25	30.20	31.25	.042	.008
	140	17.50	30.30	31.27	.039	.008
	150	18.75	30.50	31.30	.032	.007
	160	20.00	30.65	31.33	.028	.006
	170	21.26	30.75	31.36	.024	.005
	180	22.50	30.85	31.40	.021	.004
	190	23.75	31.00	31.42	.016	.003
	200	25.00	31.25	31.44	.008	.002
	210	26.25	31.35	31.46	.005	.002
Upper Piscataqua	0	0.00	20.00	26.20	.365	.168
	10	1.25	21.80	27.00	.308	.143
	20	2.50	23.00	28.20	.270	.105
	30	3.75	24.70	29.00	.216	.079
	40	5.00	26.20	30.00	.168	.048
	50	6.25	28.00	30.60	.111	.029

Table B-1 Composite high and low slack water salinity distributions in the Great Bay Estuary for the summer 1975. The salinities represent a mean (see text) vertically averaged values at the locations indicated in terms of the estuarine scale (ES) downstream and the distance downstream. The fresh water concentrations are calculated relative to an oceanic S_o = 31.5‰.

ES	(km)	S_L (o/oo)	S_H (o/oo)	C_L	C_H
17	2.13	13.25	20.93	0.470	0.316
24	3.00	11.93	20.19	0.523	0.340
29	3.63	13.07	20.50	0.477	0.330
33	4.13	13.70	20.19	0.452	0.340
38	4.75	13.68	20.50	0.453	0.330
44	5.50	13.63	20.81	0.455	0.320
47	5.88	14.05	21.42	0.438	0.300
50	6.25	14.13	22.03	0.435	0.280
58	7.25	14.25	26.24	0.430	0.260
64	8.00	14.05	22.95	0.438	0.250
68	8.50	15.50	22.80	0.380	0.225
70	8.75	15.50	23.62	0.380	0.228
75	9.38	15.70	24.97	0.372	0.184
80	10.00	15.48	24.79	0.381	0.190
85	10.63	15.05	25.09	0.398	0.180
95	11.88	15.38	26.68	0.385	0.128
107	13.38	15.93	27.29	0.363	0.108
118	14.75	16.38	29.80	0.345	0.026
125	15.63	17.15	29.65	0.314	0.031
141	17.63	17.48	30.51	0.301	0.030
160	20.00	17.63	30.36	0.295	0.008
165	20.63	18.30	30.55	0.268	0.002
170	21.25	18.90	30.50	0.244	0.003
190	23.75	22.63	30.62	0.175	0.000
200	25.00	25.10	30.60	0.000	0.000
210	26.25	27.48	30.70	0.000	0.000

Table B-2 High and low water salinity distributions based on measurements made on 22 and 28 March 1978 respectively in the Estuary. The salinities are vertically averaged values at the locations indicated in terms of the estuarine scale (ES) and the distance downstream. The fresh water concentration are calculated relative to an oceanic salinity of S_o = 30.7%.

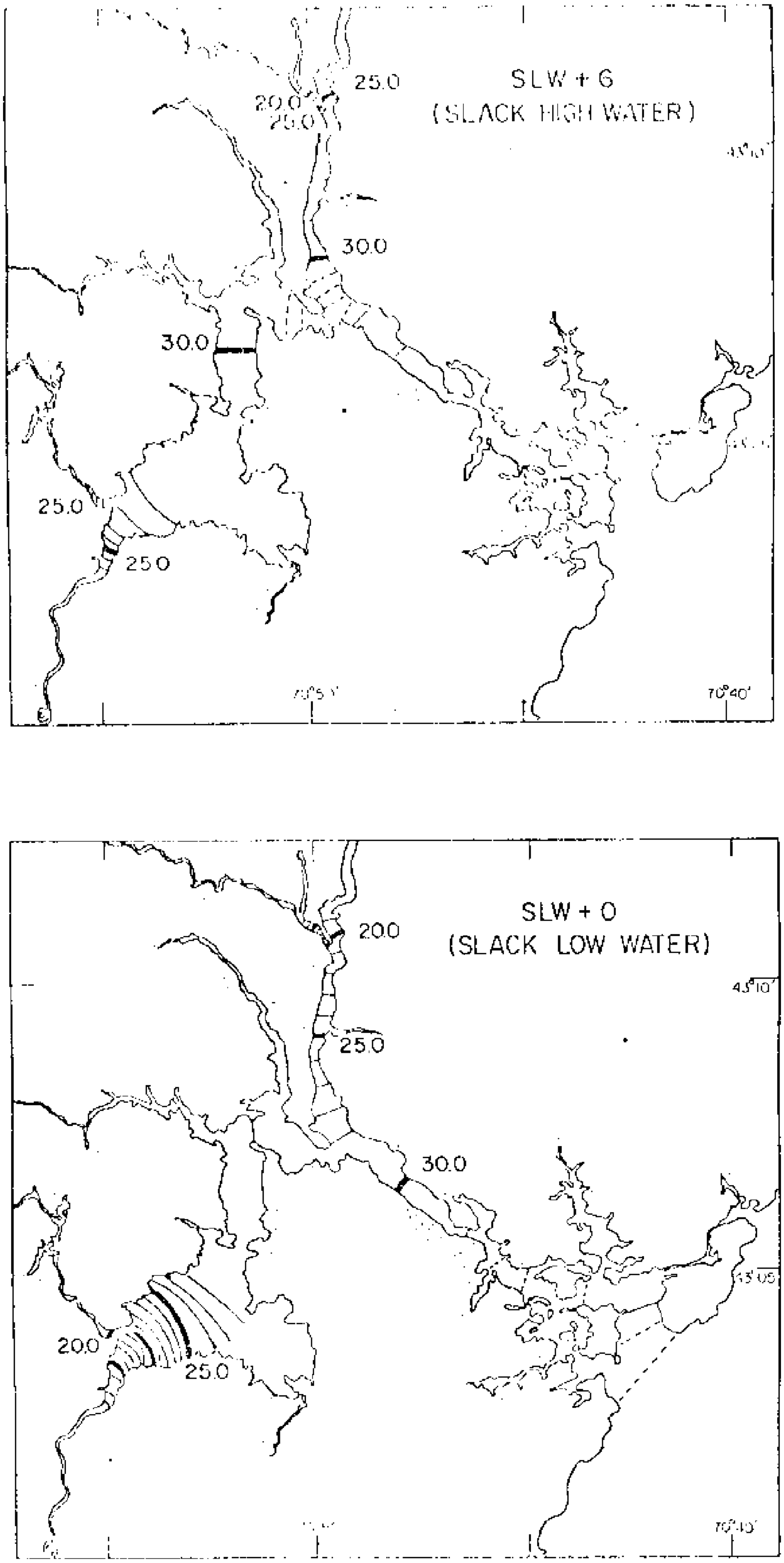

Figure B-1 Composite salinity distribution maps for July-September 1975 at slack high (above) and low water (below) the thick solid (——) isohalines have the indicated salinities (o/oo), the thin solid (——) are 1 o/oo increments and the dotted (----) are .2 o/oo increments.

Appendix C - Computations

This model has been adapted for calculations using the Tektronix 4051 Graphics System with 24K bytes of memory. Equations (1) through (4) in section 2 have been modified so that segment boundaries, x_n, can be expressed in terms of cumulative low water volume distributions:

$$v(x) = \sum_{i=0}^{8} q_i \, x^i \tag{C1}$$

and the tidal prism volume distribution,

$$p(x) = \sum_{i=0}^{8} r_i x^i \tag{C2}$$

where q_i and r_i are given in Table A-3. The following computation scheme was developed to calculate the segment boundaries x_n. For calculation of segment 1 boundary, x_1, (x_o = 0 the head of the model estuary) we know from equations (1)-(3) that:

$$V_1 = R \tag{C3-a}$$

$$\alpha_2 V_2 = P_1 \tag{C3-b}$$

$$\alpha_{n+1} V_{n+1} = \alpha_n V_n + P_n \qquad \text{for } n \geq 2 \tag{C3-c}$$

But also

$$V_1 = v(x_1) - v(x_o) = v(x_1) - v(x_o). \tag{C4}$$

Thus (C1), (C3-a) and (C4) yield

$$\sum_{i=0}^{8} q_i \, x_1^i + v(x_o) - R = 0$$

which in principal can be solved for x_1. Actually an iterative procedure (called Newton's iterations) is used on the computer to make this calculation.

Given x_1 we know from equation (C3-b) that

$$V_2 = P_1/\alpha_2.$$

Again $V_2 = v(x_2) - v(x_1)$ and $P_1 = p(x_1) - p(x_o) = p(x_1)$ so

$$v(x_2) = p(x_1)/\alpha_2 + v(x_1) = K_2(x_1) \ . \qquad \text{(C5)}$$

$K_2(x_1)$ can be calculated from (C1), (C2) and x_1. The following equation for x_2 can be found from (C1) and (C5)

$$\sum_{i=0}^{8} q_i \, x_2^i - K_2(x_1) = 0$$

This can be solved for x_2.

For $n > 2$ we know x_n and x_{n-1} from the previous segment boundary calculation and (C3-c) leads to the following for segment n+1.

$$V_{n+1} = (\alpha_n/\alpha_{n+1}) \, V_n + P_n/\alpha_{n+1}$$

But V_{n+1} and P_n can be found according to

$$V_{n+1} = v(x_{n+1}) - v(x_n) \text{ and } P_n = p(x_n) - p(x_{n-1})$$

so

$$v(x_{n+1}) = (\alpha_n/\alpha_{n+1})[v(x_n) - v(x_{n-1})] + [p(x_n) - p(x_{n-1})]/\alpha_{n+1} + v(x_n) \qquad \text{(C6)}$$

$$= K_{n+1} \, (x_{n-1}, x_n).$$

K_{n+1} can be calculated from x_{n-1}, x_n, (C1) and (C2) and the following equation in x_{n+1} can be found

$$\sum_{i=0}^{8} q_i \, x_{n+1}^i - K_{n+1} = 0.$$

Special provisions must be made for the input of additional branches into segments for which $n > 1$. The volumetric correction is made on the segment which coincides with the junction of the Estuary proper and the Upper Piscataqua.

Once the segment boundaries and volumes are calculated then high and low water fresh water concentrations are calculated using (13), (14), and (15) as outlined in section 2. The accumulated river flow due to multiple river input is accounted for during this step. The flushing time for each segment F_n is based on the amount of fresh water in a high water segment according to

$$F_n = \frac{C_n^H (V_n + P_n)}{R_n}$$

The total flushing time F_T for a water parcel entering the head of the Estuary is

$$F_T = \sum_{n=1}^{N} F_n$$

A BASIC program has been written to (i) perform the indicated computations, (ii) display the numerical results and (iii) make comparison plots of the predicted and observed fresh water concentrations. The listing of the program appears in Appendix D.

```
100 REM                      APPENDIX D
110 REM
120 REM
130 REM                    COMPUTER PROGRAM
140 REM
150 REM                    GENERAL COMMENTS
160 REM This program uses the Dyer Taylor's (1973) modified version of
170 REM ketchum's segmented tidal prism model and it is applied to the
180 REM Great Bay Estuarine System, in order to predict high and low
190 REM water salinity distribution based on the river flow, volume dist
200 REM ribution and geometry of the estuary for a variable river flow.
210 REM The mixing parameter, which in this case is related to the
220 REM tidal excursion of water in the estuary, has been determi-
230 REM mined for different segments on the basis of comparison
240 REM between avaliable data, the flushing time is also calculated
250 REM for individual segments and for the entire estuary.
260 REM REFERENCE;
270 REM A Simple, Segmented Prism model of tidal mixing in well mixed
280 REM Estuaries.
290 REM K.R. Dyer and P.A. Taylor
300 REM Estuarine and Coastal Marine Science (1973) I, 411-418.
310 PRINT
320 REM INPUT DATA
330 REM R1 = River discharge for the Lamprey/Squamscott rivers in
340 REM      cubic meters per tidal cycle.
350 REM R2 = River discharge for the Cacheco/Salmon Falls rivers in
360 REM      cubic meters per tidal cycle.
370 REM R3 = River discharge for the Oyster + Bellamy rivers in cubic
380 REM      meters per tidal cycle.
390 REM A  = Current value of mixing parameter.  If you want to
400 REM      change A delete lines 1180-1230 and print INPUT A in one
410 REM      of these lines .
430 REM PARAMETERS F,L,S, TO SEARCH FOR THE SOLUTION OF THE POLYNOMIAL
440 REM F  = First; Segment start.

450 REM L  = Last; segment end.
460 REM S  = Step; 0.1
470 REM I  = segment to be corrected.
580 REM
590 REM OUTPUT DATA
592 REM V=Current value of cum LW VOL at the segment boundary
594 REM D=Current value of cum PRISM VOL at the segment boundary
600 REM V2(I);(B2(I))=cum LW VOL at the ith seg boundary
605 REM V1(I);(V3(I))=LW VOL  of the ith segment
608 REM R(I);(P4(I))= cum PRISM VOL value at the ith seg boundary
610 REM P1(I);(P2(I))= PRISM VOL  of the ith segment
700 REM X(I)  = ith segment boundary for great bay/piscataqua
704 REM Y(I)  = ith segment boundary of upper piscataqua
710 REM B8(I);(B7(I))= (1-A)Volume
720 REM D8(I);(D7(I))= A*Volume
730 REM P1(I);(P2(I))= Prism.
740 REM U8(I);(U7(I))= A*Volume + Prism
741 REM N1=Great Bay segment # of UP/LP junction
742 REM O=UP segment # adjacent to UP/LP junction
743 REM W8=Prism volume in UP transition segment (x<52)
744 REM W1=Low water volume in UP transition segment (x<52)
745 REM O1=UP Segment number before transition segment
746 REM W2= A*H1 (x<52)
748 REM W3=Volume residual from UP added to LP segment(x>52)
750 REM FOR THE FRESH WATER CONCENTRATION CALCULATIONS
752 REM C8= EQUIVALENT RIVER WATER CONCENTRATION FOR A SEGMENT
760 REM C4(M);(C6(M))= Fresh water concentration for high water.
770 REM C5(M);(C7(M))= Fresh water concentration for low water.
780 REM S2(M);(S4(M))= Salinity in PPT for high water.
790 REM S1(M);(S3(M)= Salinity in PPT for low  water.
800 REM F7(M) = Tidal cycle for each segment.
810 REM R4(M) = River discharge through a particular segment
820 REM V7(I);(V8(I))= Mixing parameter of the ith   segment
830 REM F5     = Total Flushing time in tidal cycles.
840 REM F8     = Input any dummy number to plot your results (to stop
```

```
850 REM          your table results so you can make a copy).
860 PRINT
870 REM This program was developed using the 4051 GRAPHIC TERMINAL
880 REM (in basic language) by EDGAR ARELLANO.
890 REM AND REVISED BY W.S. BROWN DEC 12, 1978
900 REM BOTH OF THE DEPT OF EARTH SCIENCES;UNIV. OF NEW HAMPSHIRE
910 REM                DURHAM, N.H. 03824
940 PRINT
950 INIT
960 REM           Dimension of the different variables.
970 DIM X(10),X1(10),P(10),V1(10),P1(10),V2(10),P2(8),B2(8)
980 DIM R(10),P4(8),B8(10),D8(10),U8(10),R4(10),C8(10)
990 DIM Y(8),V8(8),C5(10),C4(10)
1000 DIM F7(10),F9(10),V7(10),C7(10),C6(10),V3(10),B7(8),D7(8),U7(8)
1010 REM              Input the different river discharge into the estuary
1020 REM          in units of 106 cubic meters per tidal cycle,and initial
1030 REM             ization of some variables.
1040 PRINT "RIVER DISCHARGE (106 M3/TIDE CY)for the"
1060 PRINT "LAMPREY+SQUAMSCOTT,UPPER PISCATAQUA AND OYSTER+BELLAMY = ";
1070 INPUT R1,R2,R3
1080 IMAGE 7(11A)
1090 E2=0
1098 D3=0
1100 D4=0
1102 F1=0
1104 F4=0
1106 F3=0
1108 N=0
1109 O=0
1110 J=1
1120 REM            Parameter J=1 to identify the Great Bay and Lower
1130 REM            Piscataqua System.
1140 J5=1
1150 J1=0
1160 J6=3
1170 K9=1
1180 GO TO 1270
1190 REM            Star the calculations for the Upper and Lower
1200 REM            Piscataqua in order to do a volumetric correction at
1210 REM            the section in DOVER POINT.
1220 PRINT
1222 PRINT "G UPPER PISCATAQUA G"
1230 REM            Parameter J=2 to identify calulatios for the Upper
1240 REM            Piscataqua System.
1250 J=2
1255 N1=I
1258 PRINT "THE UPPER PISCATAQUA ENTERS IN THE ";N1;"TH SEGMENT"
1260 REM CALCULATIONS FOR THE FIRST TWO SEGMENTS (LINES 1010-1960)
1270 REM
1280 A=1
1400 I=1
1410 V7(I)=1
1415 V8(I)=1
1418 REM SOLVE THE POLYNOMIAL EQUATION
1420 GOSUB 4960
1430 IF J=2 THEN 1470
1440 X2=X0
1450 X(I)=X2
1460 GO TO 1500
1470 X2=X0
1475 Y(I)=X2
1500 REM CALCULATE CUMULATIVE PRISM AND VOLUME DISTRIBUTION
1505 GOSUB 4130
1510 IF J=2 THEN 1700
1520 REM CALCULATE VOLUME PARAMETERS FOR FIRST GB SEGMENT
1530 P1(1)=D+0.0267981075204
1545 V2(1)=V
1550 V1(1)=V+1.0E-3
1570 B8(1)=(1-A)*V1(1)
1580 D8(1)=A*V1(1)
```

```
1590 U8(1)=P1(1)+D8(1)
1610 R(1)=D
1620 GO TO 1650
1630 PRINT
1640 PRINT
1650 I=2
1654 PRINT
1656 PRINT
1660 PRINT "INPUT MIXING PARAMETER A(";I;")=";
1670 INPUT A
1680 V7(2)=A
1685 V2(2)=P1(1)/A+V2(1)
1690 GO TO 1910
1700 REM CALCULATE VOLUME PARAMETERS FOR FIRST PISCATAQUA SEGMENT
1710 P4(1)=Z
1720 B2(1)=V
1730 P2(1)=Z-1.806E-4
1740 REM
1750 V3(1)=V+0.01
1752 B7(1)=0
1754 D7(1)=V3(1)
1756 U7(1)=D7(1)+P2(1)
1760 I=2
1764 PRINT
1765 PRINT
1770 PRINT "INPUT MIXING PARAMETER A(2)'= ";
1772 INPUT A
1774 V8(I)=A
1776 B2(2)=P2(1)/A+B2(1)
1780 GO TO 1860
1790 V2(1)=V
1800 P2(1)=Z
1860 REM
1900 REM SOLVE THE POLYNOMIAL EQUATION FOR 2ND SEGMENT OF GB AND UP
1910 GOSUB 4960
1920 IF J=2 THEN 1950
1930 X2=X0
1940 X(I)=X2
1945 GO TO 1979
1950 REM
1951 GO TO 1977
1952 X2=X0
1953 GOSUB 4960
1977 X2=X0
1978 Y(I)=X2
1979 REM CALCULATE CUMULATIVE PRISM AND VOLUMES
1980 GOSUB 4130
1990 IF J=2 THEN 2140
1995 REM CALCULATE VOLUME PARAMETERS FOR 2ND GREAT BAY SEGMENT
2000 V2(2)=V
2010 R(2)=D
2020 P1(2)=D-R(1)
2070 V1(2)=V-V2(1)
2100 B8(2)=(1-A)*V1(2)
2110 D8(2)=A*V1(2)
2120 U8(2)=P1(2)+D8(2)
2130 GO TO 2270
2140 REM CALCULATE VOLUME PARAMETERS FOR 2ND UP SEGMENT
2145 B2(2)=V
2150 P4(2)=Z
2160 P2(2)=Z-P4(1)
2170 V3(2)=V-B2(1)
2172 B7(2)=(1-A)*V3(2)
2174 D7(2)=A*V3(2)
2176 U7(2)=D7(2)+P2(2)
2180 GO TO 2270
2230 REM          Calculation for the segments greater than 3, after
2240 REM          the calibration the mixing parameters are known
2250 REM          so the prediction for any river flow situation can
2260 REM          be made.
```

```
2270 FOR I=3 TO 10 STEP 1
2274 IF J=2 THEN 2580
2276 PRINT
2278 PRINT
2280 PRINT "INPUT MIXING PARAMETER A(";I;")=";
2290 INPUT A
2420 K=I-1
2430 V7(I)=A
2450 REM
2470 V2(I)=V8(K)/A+V2(K)
2480 REM
2520 IF J=1 THEN 2550
2525 J=1
2530 J1=1
2535 PRINT "LAST UPPER PISCATAQUA SEGMENT IS #";01
2540 GO TO 2570
2550 REM
2570 GO TO 2620
2580 PRINT
2581 PRINT
2582 PRINT "INPUT MIXING PARAMETER A(";I;")'=";
2583 INPUT A
2584 V8(I)=A
2586 K=I-1
2587 01=I-1
2588 REM
2590 B2(I)=V7(K)/A+B2(K)
2600 REM
2620 REM SOLVE POLYNOMIAL EQUATION FOR SEGMENT=>3
2622 GOSUB 4960
2624 IF J1=1 THEN 2740
2629 IF J=2 THEN 2658
2630 REM
2640 X2=X0
2650 X(I)=X2
2652 GO TO 2740
2658 REM CHECK FOR POLYNOMIAL TRANSITION FOR UPPER PISCATAQUA
2659 REM
2660 IF X0>52 THEN 2670
2662 GO TO 2688
2670 X0=52
2677 GOSUB 4130
2678 A=V7(N1)
2679 W0=Z-P4(K)
2680 W1=V-B2(K)
2681 W2=A*W1
2682 W3=V7(K)-W2
2683 I=N1
2684 K=I-1
2685 V2(I)=(V8(K)+W3)/A+V2(K)
2686 GO TO 2520
2687 J1=1
2688 X2=X0
2689 Y(I)=X2
2690 GO TO 2740
2720 REM
2740 REM CALCULATE CUMULATIVE PRISM AND VOLUMES
2742 GOSUB 4130
2760 IF J=2 THEN 2870
2765 REM CALCULATE VOLUME PARAMETERS FOR GREAT BAY SEGMENTS=>3
2770 V2(I)=V
2780 R(I)=D
2790 IF J1=1 THEN 2792
2791 GO TO 2830
2792 REM CALCULATE VOLUME PARAMETERS FOR THE TRANSITION SEGMENT
2793 P1(I)=D-R(K)+W0
2794 V1(I)=V-V2(K)+W1
2796 X(I)=X2
2820 J1=2
2825 GO TO 2852
```

```
2830 P1(I)=D-R(K)
2850 V1(I)=V-V2(K)
2852 B8(I)=(1-A)*V1(I)
2854 D8(I)=A*V1(I)
2856 U8(I)=P1(I)+D8(I)
2858 IF J1=2 THEN 3030
2860 GO TO 2940
2870 REM CALCULATE VOLUME PARAMETERS FOR UPPER PISCATAQUA SEGMENTS=>3
2875 B2(I)=V
2880 P4(I)=Z
2890 P2(I)=Z-P4(K)
2900 V3(I)=V-B2(K)
2902 B7(I)=(1-A)*V3(I)
2904 D7(I)=A*V3(I)
2906 U7(I)=D7(I)+P2(I)
2910 GO TO 2980
2920 GO TO 2920
2930 GO TO 2920
2940 REM          To chech if a segment from the Upper and Lower
2950 REM          Piscataqua is in the Great and Lower Piscataqua
2960 REM          System, and if it does do the respective correction.
2970 GO TO 3000
2980 REM
2990 IF J=2 THEN 3230
3000 IF K9=2 THEN 3030
3010 IF X2<95 THEN 3230
3020 IF X2>95 THEN 1220
3030 IF X2>208 THEN 3240
3050 GO TO 3230
3060 GO TO 2700
3070 GO TO 3230
3230 NEXT I
3240 PRINT
3245 I1=I
3250 PRINT "THE MOST SEAWARD SEGMENT # IS ";I1

3252 REM THE CURRENT VALUE OF I IS THE MAXIMUM SEGMENT  #
3254 PRINT
3256 PRINT
3258 PRINT
3262 PRINT "DO YOU WANT TO DISPLAY VOLUME DISTRIBUTION?IF YES ENTER 1"
3264 INPUT A5
3266 IF A5=1 THEN 3480
3268 GO TO 3599
3320 PRINT
3480 PAGE
3490 REM          Output of the different parameters calculated.
3492 PRINT "           VOLUME AND SALINITY DISTRIBUTION "
3494 PRINT "                       FOR"
3500 PRINT "                 GREAT BAY AND LOWER PISCATAQUA "
3510 PRINT
3520 PRINT
3530 IMAGE 7A,11A,8A,14A,12A,11A,7A
3540 PRI USI 3530:"#M","BNDY","A","(1-A)*VOL","A*VOL","PRISM","A*V+P"
3550 PRINT
3560 FOR L=1 TO I1
3565 U=X(L)/8
3570 IMAGE 1(2D),1(4D.1D),1(3D.1D),1(5D.2D),4(8D.3D)
3580 PRINT USING 3570:L,X(L),U,V7(L),B8(L),D8(L),P1(L),U8(L)
3590 NEXT L
3591 PRINT
3592 PRINT "               UPPER PISCATAQUA"
3593 FOR L=1 TO O1 STEP 1
3594 W=Y(L)/8
3595 PRINT USING 3570:L,Y(L),W,V8(L),B7(L),D7(L),P2(L),U7(L)
3596 NEXT L
3597 PRINT "UPPER & LOWER PISCATAQUA JOIN IN SEGMENT";N1
3599 REM SALINITY BOUNDARY CONDITIONS
3600 F3=1
3602 REM          Input your salinity boundary condition at section
3604 REM          at the mouth of the estuary.
```

```
3606 PRINT "INPUT SALINITY (in ppt) AT THE MOUTH OF THE ESTUARY = ";
3608 INPUT S5
3610 PRINT "FRESHWATER CONCENTRATION(PPT) for the"
3612 PRINT "LAMPREY+SQUAMSCOTT,UPPER PISCATAQUA AND OYSTER+BELLAMY = ";
3614 INPUT C1,C2,C3
3620 REM             low water (all sea water).
3630 REM Highwater fresh water concentration of the seaward segment
3640 C4(I1)=0
3670 C=I1-1
3672 DELETE R4
3674 DIM R4(10)
3678 REM CALCULATION OF SALINITY DISTRIBUTION FOR GREAT BAY/LP
3680 FOR L=1 TO C STEP 1
3700 REM             To check the input of the different rivers discharge
3710 REM             at different segments.
3720 M=I1+1-L
3730 K=M+1
3740 IF X(M)>95 THEN 3770
3750 IF X(M)>64 THEN 3790
3760 IF X(M)<64 THEN 3810
3770 R4(M)=R1+R2+R3
3772 C8(M)=(R1*C1+R2*C2+R3*C3)/R4(M)
3780 GO TO 3813
3790 R4(M)=R3+R1
3792 C8(M)=(R1*C1+R3*C3)/R4(M)
3800 GO TO 3813
3810 R4(M)=R1
3812 C8(M)=C1
3813 REM
3814 IF F3=0 THEN 3820
3815 C4(M)=0
3816 F3=0
3817 K=I1
3818 C5(M)=R4(M)*(C8(M)-C4(M))/B8(M)+C4(M)
3819 GO TO 3890

3820 C4(M)=(R4(K)*C8(K)+D8(K)*C5(K))/(R4(M)+U8(M))
3821 IF M=N1-1 THEN 3823
3822 GO TO 3830
3823 REM
3824 C6(O1)=C5(K)
3826 C4(M)=(R4(K)*C8(K)+D8(K)*C5(K)-(C2+U7(O1))*C6(O1))/(R4(M)+U8(M))
3830 C5(M)=R4(M)*(C8(M)-C4(M))/B8(M)+C4(M)
3835 IF C4(M)>C1 THEN 3854
3840 IF C5(M)>C1 THEN 3860
3850 GO TO 3890
3854 C4(M)=C1
3860 C5(M)=C1
3890 REM
3900 A8=C4(M)*(U8(M)+B8(M))
3904 F7(M)=A8/R4(M)
3906 NEXT L
3908 C5(1)=C1
3914 C4(1)=C5(2)*D8(2)/U8(1)
3918 R4(1)=R1
3920 A8=C4(1)*(U8(1)+B8(1))
3922 F7(1)=A8/R4(1)
3925 REM CALULATION OF SALINITY DISTRIBUTION FOR UPPER PISCATAQUA
3927 O2=O1-1
3929 R5=R2
3931 C9=C2
3935 FOR L=1 TO O2
3937 IF L=1 THEN 3944
3939 O=O-1
3940 K=O+1
3942 GO TO 3951
3944 K=O1+1
3945 O=O1
3946 GO TO 3952
3951 C6(O)=(R5*C9+D7(K)*C7(K))/(R5+U7(O))
3952 C7(O)=R5*(C9-C6(O))/B7(O)+C6(O)
```

```
3953 IF C6(0)>C2 THEN 3956
3954 IF C7(0)>C2 THEN 3958
3955 GO TO 3962
3956 C6(0)=C2
3958 C7(0)=C2
3962 REM
3963 A9=C6(0)*(U7(0)+B7(0))
3965 F9(0)=A9/R5
3966 NEXT L
3968 PRINT "DO YOU WANT TO DISPLAY SALT DISTRIBUTIONS?IF YES ENTER 1"
3969 INPUT A4
3970 IF A4=1 THEN 3980
3971 GO TO 4070
3980 PAGE
3981 PRINT "FRESHWATER AND SALT DISTRIBUTIONS"
3982 PRINT "                    FOR"
3983 PRINT "GREAT BAY AND LOWER PISCATAQUA"
3984 PRI USI 3985:"#M","BNDY","FRESH CONC","SALINITY(PPT)","F(TC)","R"
3985 IMAGE  6A,14A,15A,20A,10A,8A
3986 PRINT USING 3987:" ","ES","KM","HIGH","LOW","HIGH","LOW"
3987 IMAGE  6A,5A,9A, 9A, 8A, 8A,12A
3990 FOR M=1 TO I1
3991 S1=S5*(1-C5(M))
3992 S2=S5*(1-C4(M))
3994 IMAGE 1(2D),2(4D.1D),5(6D.2D),1(4D.3D)
3995 U=X(M)/8
3996 PRINT USING 3994:M,X(M),U,C4(M),C5(M),S2,S1,F7(M),R4(M)
3998 NEXT M
4000 PRINT
4004 PRINT "UPPER PISCATAQUA"
4005 O2=O1-1
4006 FOR L=1 TO O2
4007 M=L+1
4008 S4=S5*(1-C7(M))
4010 S3=S5*(1-C6(M))

4015 W=Y(M)/8
4030 PRINT USING 3994:M,Y(M),W,C6(M),C7(M),S4,S3,F9(M),R5
4040 NEXT L
4070 PRINT "DO YOU WANT TO PLOT RESULTS?IF YES ENTER 1"
4074 INPUT A3
4076 IF A3=1 THEN 4082
4080 GO TO 4110
4082 GOSUB 6700
4084 PRINT "DO YOU WANT TO INPUT DIFFERENT BOUNDARY CONDITIONS?YES=1"
4086 INPUT A4
4088 IF A4=1 THEN 3599
4090 PRINT "DO YOU WANT A RERUN TO CHANGE MIXING PARAMETERS?YES=1"
4092 INPUT D4
4094 IF D4=3 THEN 950
4110 END
4120 REM CALCULATIONS OF VOLUME AND PRISM
4130 X2=X0
4140 REM GREAT BAY: CUMULATIVE VOLUME DISTRIBUTION AT LOW WATER
4144 IF J1=1 THEN 4170
4150 IF J=2 THEN 4420
4160 IF X2<=13 THEN 4260
4170 H=4.360196903E-16*X2↑8-4.690317677E-13*X2↑7+1.575584494E-10*X2↑6
4180 E=-3.27715972E-8*X2↑5+4.479179641E-6*X2↑4-4.595897469E-4*X2↑3
4190 Q=0.0310486461922*X2↑2-0.357906292049*X2+1.38625673376
4200 V=H+E+Q
4210 PRINT "POLY 1"
4220 GO TO 4350
4230 IF X2>13 THEN 4170
4240 IF X2<=13 THEN 4260
4250 GO TO 4350
4260 V=0.00195185208717*X2↑2+0.0745706745621*X2-1.0E-3
4270 PRINT "POLY 3"
4280 GO TO 4350
4350 PRINT "GREAT BAY"
4360 PRINT "SEGMENT ";I;" BOUNDARY=";X2
```

```
4380 PRINT
4390 PRINT
4400 GO TO 4630
4410 REM UPPER PISCATAQUA: CUMULATIVE VOLUME DISTRIBUTION AT LOW WATER
4420 IF I=1 THEN 4470
4421 IF X2<=20 THEN 4470
4422 IF X2>20 THEN 4520
4470 V=2.051552524E-4*X2↑3-0.00554757677474*X2↑2+0.114249039468*X2-0.01
4480 GO TO 4560
4490 REM
4500 V=H2+J2+G2
4510 GO TO 4560
4520 H2=3.892038236E-14*X2↑8-2.581346736E-11*X2↑7+6.8930207E-9*X2↑6
4530 J2=-9.424655932E-7*X2↑5+6.956452472E-5*X2↑4-0.00269081150333*X2↑3
4540 G2=0.0527167125734*X2↑2-0.391188559294*X2+1.36780127124
4550 V=H2+J2+G2
4560 PRINT "UPPER PISCATAQUA"
4570 PRINT "SEGMENT ";I;" BOUNDARY=";X2
4590 REM PRINT "CUMULATIVE VOLUME   = ";
4600 REM PRINT V
4610 GO TO 4790
4620 REM GREAT BAY : CUMULATIVE PRISM VOLUME DISTRIBUTION
4630 IF X2<=13 THEN 4700
4640 W=9.305260257E-15*X2↑8-8.144640579E-12*X2↑7+2.930967282E-9*X2↑6
4650 F1=-5.586976425E-7*X2↑5+6.056169163E-5*X2↑4-0.00370910011604*X2↑3
4660 G=0.116527341976*X2↑2-1.02568322489*X2+3.35174230102
4670 D=G+F1+W
4690 GO TO 4750
4700 REM
4730 D=-0.1566666667+0.22875*X2
4740 GO TO 4750
4750 REM PRINT "CUMULATIVE PRISM =  ";
4760 REM PRINT D
4770 GO TO 4940
4780 REM UPPER PISCATAQUA : CUMULATIVE PRISM VOLUME DISTRIBUTION

4790 IF I=1 THEN 4860
4792 IF X2<=20 THEN 4860
4795 IF X2>20 THEN 4880
4860 Z=2.78020952E-4*X2↑3-0.0062232366592*X2↑2+0.10316425592*X2+1.806E-4
4870 GO TO 4920
4880 M=-9.456139952E-16*X2↑8+1.86260202E-12*X2↑7-9.036148763E-10*X2↑6
4890 Q=1.967355402E-7*X2↑5-2.218964776E-5*X2↑4+0.00131618211388*X2↑3
4900 E=-0.0377298761577*X2↑2+0.514619161549*X2-1.44398487302
4910 Z=M+Q+E
4920 REM PRINT "CUMULATIVE PRISM   =  ";
4930 REM PRINT Z
4940 RETURN
4950 END
4960 PRINT
4970 PRINT "SOLVE POLYNOMIAL EQUATION"
4980 REM * THIS PROGRAM SEARCHES FOR A SIGN  CHANGE
4990 REM IN THE VALUE OF A POLINOMIAL FUNCTION
4995 IF J1=1 THEN 5120
5000 IF J=2 THEN 5060
5010 IF I=1 THEN 6120
5031 IF X2<=13 THEN 5036
5034 GO TO 5120
5036 F4=1
5037 GO TO 6120
5060 IF I=1 THEN 5530
5070 IF I=2 THEN 5081
5080 IF I=>3 THEN 5081
5081 IF X2<=20 THEN 5086
5083 GO TO 5850
5086 F1=1
5087 GO TO 5530
5090 REM
5100 REM GREAT BAY : CUMULATIVE VOLUME DISTRIBUTION AT LOW TIDE
5110 REM           Where N is the polynomial degree.
5120 N=8
```

```
5130 PRINT "POLY 1"
5140 P(9)=4.360196903E-16
5150 P(8)=-4.090317677E-13
5160 P(7)=1.575584494E-10
5170 P(6)=-3.27715972E-8
5180 P(5)=4.479179641E-6
5190 P(4)=-4.595897469E-4
5200 P(3)=0.0310486461922
5210 P(2)=-0.357906292049
5215 IF I=1 THEN 5250
5220 IF I=2 THEN 5270
5230 IF I=>3 THEN 5290
5250 P(1)=-R1
5260 GO TO 5300
5270 REM
5290 P(1)=1.38625673376-V2(I)
5300 REM
5310 GO TO 6210
5530 N=3
5535 PRINT "POLY 5"
5540 P(4)=2.051552524E-4
5550 P(3)=-0.00554757677474
5560 P(2)=0.114249039468
5565 IF I=1 THEN 5570
5567 GO TO 5650
5570 P(1)=-R2
5580 GO TO 6210
5650 P(1)=-0.01-B2(I)
5660 GO TO 6210
5850 N=8
5855 PRINT "POLY 4"
5860 P(9)=3.892038236E-14
5870 P(8)=-2.581346736E-11
5880 P(7)=6.8939207E-9
5890 P(6)=-9.424655932E-7

5900 P(5)=6.956452472E-5
5910 P(4)=-0.00269081150333
5920 P(3)=0.0527167125734
5930 P(2)=-0.391188559294
5940 P(1)=1.3678012724-B2(I)
5950 GO TO 6210
5960 IF X2>28 THEN 5120
5970 IF X2>12 THEN 5320
6100 P(1)=1.0E-3-V2(I)
6110 GO TO 6210
6120 N=2
6130 PRINT "POLY 3"
6140 P(3)=0.00195185208717
6150 P(2)=0.0745706745621
6154 IF I=1 THEN 6160
6156 GO TO 6100
6160 P(1)=-R1
6170 GO TO 6210
6180 REM            Input first,last,step in order to search for
6190 REM            a singh change in the polynomial equation to
6200 REM            give the segment lengh.
6210 PRINT "FIRST,LAST,STEP  ";
6220 INPUT F,L,S
6230 PRINT
6240 LET X5=F
6250 GOSUB 6530
6260 FOR T=F+S TO L STEP S
6270 LET Y1=P3
6280 LET X5=T
6290 GOSUB 6530
6295 REM CHECKS FOR SIGN CHANGE IN INTERVAL F+nS(n IS LOOP INDEX)
6300 IF Y1*P3>0 THEN 6350
6310 X4=T-S
6320 X2=S
6330 X5=(X4+X2)/2
```

```
6340 GO TO 6380
6350 NEXT T
6360 PRINT "NO SIGN CHANGE FOUND"
6370 GO TO 6210
6380 X1=T-S
6390 X2=T
6400 Y2=P3
6410 X5=(X4+X2)/2
6420 GOSUB 6530
6430 IF ABS(X4-X2)/(ABS(X4)+ABS(X2))>1.0E-6 THEN 6470
6440 PRINT
6450 X0=X5
6451 IF F4=1 THEN 6454
6452 IF F1=1 THEN 6458
6453 GO TO 6464
6454 IF X0>13 THEN 6460
6456 GO TO 6464
6458 IF X0>20 THEN 6462
6459 GO TO 6464
6460 F4=0
6461 GO TO 5120
6462 F1=0
6463 GO TO 5850
6464 REM
6465 F1=0
6466 F4=0
6468 RETURN
6470 IF Y1*P3>0 THEN 6500
6480 X2=X5
6490 GO TO 6400
6500 X4=X5
6510 Y1=P3
6520 GO TO 6410
6525 REM SUBROUTINE TO CALCULATE POLYNOMIAL FOR GUESSED VALUE
6530 P3=P(N+1)

6540 FOR H=N TO 1 STEP -1
6550 P3=P3*X5+P(H)
6560 NEXT H
6570 IF P3<>0 THEN 6610
6580 PRINT
6590 PRINT X5;"IS A ZERO "
6600 STOP
6610 RETURN
6620 END
6630 PRINT "INPUT SEGMENT (I) TO BE CORRECTED I =";
6640 INPUT I
6650 K=I-1
6660 V1(I)=B3(I)+V5
6670 K9=2
6680 RETURN
6690 REM          Initializing parameters for the plot subroutine.
6700 W1=0
6705 C=I1
6710 T5=32  -- ⊥
6720 W2=220
6730 T1=20
6740 W3=0
6750 IF E2>0 THEN 6770
6760 GO TO 6820
6770 W4=250
6780 T2=25
6790 X$="DISTANCE"
6800 Y$="CUM SALINITY*VOLUME"
6810 GO TO 6860
6820 W4=1
6830 T2=0.1
6840 X$="DISTANCE"
6850 Y$="FRESH WATER CONCENTRATION"
6860 P1=1
6870 T5=32  -- ⊥
```

```
6880 REM                 *** PLOT GRAPH AXES ***
6890 PAGE
6900 PRINT "G                            GREAT BAY AND LOWER PISCATAQUAG"
6910 WINDOW W1,W2,W3,W4
6920 VIEWPORT 15,125,15,97
6930 AXIS @T5:T1,T2,W1,W3
6940 AXIS @T5:T1,T2,W2,W4
6950 REM              *** HORIZ. TIC MARK LABELS ***
6960 MOVE @T5:W1,W3
6970 FOR I=W1 TO W2 STEP T1
6980 MOVE @T5:I,W3
6990 PRINT @T5:"JJH";I
7000 NEXT I
7010 REM              *** VERT. TIC MARK LABELS ***
7020 REM
7030 FOR I=W3 TO W4 STEP T2
7040 MOVE @T5:W1,I
7050 PRINT @T5:"HHHH";I
7060 NEXT I
7070 REM              *** HORIZ.AXIS LABEL ***
7080 MOVE @T5:(W1+W2)/2,W3
7090 PRINT @T5:"JJJ";
7100 FOR I=1 TO LEN(X$)/2
7110 T=T5
7120 PRINT @T:"H";
7130 NEXT I
7140 PRINT @T:X$
7150 REM              *** VERTICAL AXIS LABEL ***
7160 DIM Y$(25),P$(1)
7170 MOVE @T:W1,(W3+W4)/2
7180 PRINT @T:"HKKHHH";
7190 FOR I=1 TO LEN(Y$)/2
7200 PRINT @T:"K";
7210 NEXT I
7220 FOR I=1 TO LEN(Y$)

7230 P$=SEG(Y$,I,1)
7240 PRINT @T:P$;"HJ";
7250 NEXT I
7260 REM                *** Normal DATA PLOT ***
7270 PRINT
7280 GO TO 7350
7290 GOSUB 7530
7300 GO TO 6700
7310 END
7320 REM             To plot the fresh water concentration predicted
7330 REM             by the model at high and low water.
7340 MOVE @T:X(1),C5(1)
7350 MOVE @T:X(1),C5(1)
7360 FOR I=1 TO C-1
7370 K=I+1
7380 DRAW @T:X(I),C5(K)
7382 IF X(I)>220 THEN 7386
7384 GO TO 7390
7386 X(I)=220
7390 DRAW @T:X(I+1),C5(K)
7400 NEXT I
7402 IF X(C)>220 THEN 7406
7404 GO TO 7410
7406 X(C)=220
7410 DRAW X(C),C5(C)
7420 MOVE @T:X(1),C5(1)
7430 FOR I=1 TO C-1
7440 K=I+1
7450 DRAW @T:X(I),C4(K)
7460 DRAW @T:X(I+1),C4(K)
7470 NEXT I
7480 DRAW X(C),C5(K)
7490 REM             To plot the fresh water concentration at high and
7500 REM             low water calculated from the observed salinity
7510 REM             distribution in the estcary.
```

```
7520 GO TO 7620
7525 REM          HIGH RIVER FLOW SITUATION
7530 MOVE @T:30,0.48
7540 DRAW @T:70,0.41
7550 DRAW @T:140,0.31
7560 DRAW @T:209,0
7570 MOVE @T:30,0.33
7580 DRAW @T:70,0.25
7590 DRAW @T:140,0.05
7600 DRAW @T:209,0
7610 END
7615 REM          LOW RIVER FLOW SITUATION
7620 MOVE @T:0,0.51
7630 DRAW @T:8,0.29
7640 DRAW @T:15,0.16
7650 DRAW @T:20,0.14
7660 DRAW @T:26,0.11
7670 DRAW @T:32,0.1
7680 DRAW @T:38,0.09
7690 DRAW @T:50,0.08
7700 DRAW @T:70,0.07
7710 DRAW @T:90,0.06
7720 DRAW @T:99,0.05
7730 DRAW @T:120,0.05
7740 DRAW @T:138,0.05
7750 DRAW @T:150,0.04
7760 DRAW @T:165,0.03
7770 DRAW @T:185,0.02
7780 DRAW @T:220,0.003
7790 MOVE @T:0,0.15
7800 DRAW @T:4,0.1
7810 DRAW @T:8,0.07
7820 DRAW @T:15,0.07
7830 DRAW @T:26,0.065
7840 DRAW @T:32,0.06

7850 DRAW @T:38,0.055
7860 DRAW @T:50,0.05
7870 DRAW @T:70,0.04
7880 DRAW @T:90,0.03
7890 DRAW @T:99,0.02
7900 DRAW @T:120,0.02
7910 DRAW @T:138,0.01
7920 DRAW @T:150,0.01
7930 DRAW @T:220,0
7932 INPUT A9
7935 RETURN
7940 END
```