AN ANALYSIS OF THE DYNAMICS OF DDT AND ITS DERIVATIVES, DDD AND DDE, IN MARINE SEDIMENTS

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ABSTRACT

The concentration of the three chlorinated hydrocarbons, DDT, DDD, and DDE, were measured in sediments at 57 stations in Monterey Bay on the Central California coast during 1970 and 1971. Mean concentration in parts per billion was DDT 3.1, DDD 2.3, and DDE 5.4. Maximum concentrations were DDT 19.3, DDD 8.7, DDE, 20.5 parts per billion. The distribution of the three compounds within South Monterey Bay was charted. During 1973 nineteen of the original stations, representing locations that were low, intermediate, and high concentrations in the original survey, were resampled. The mean concentration approximately three years later were DDT 15.5, DDD 2.3, and DDE 5.4 parts per billion with maximum levels of DDT 83.1, DDD 11.4, and DDE 17.5 parts per billion. A chart of the concentrations in South Monterey Bay revealed essentially the same distribution of chlorinated hydrocarbons.

Two approaches to the estimation of annual system rates for input, I, output, O, decay, D, and internal translocation, T_I and T_O, expressed as decimal fractions of the existing concentration were developed, and Fortran programs that permit rapid estimations were written. The mean annual system rates obtained were for DDT, I+1.30, O-.059, D-.036, T_I and T_O ± .80 with a residence time of 11 years and life time of 29 years. An I of 1.30 means the amount of input is 130% of the existing concentration per year. The mean annual rates obtained for DDD were, I + 0.25, O - 0.11, D - 0.025, T_I and T_O ± 0.20 with residence time of 7 years and life time of 44 years. The rates for DDE were I + 0.28, O - 0.10, D - 0.027, T_O and T_I ± 0.22 with residence time of 8 years and life time of 39 years. The approaches to these estimates are dependent upon variability in net rates of change at the various stations and an approach to evaluation of the standard deviation of the estimated rates relative to distributions of net rates with minimal variance is presented.

Laboratory assays were developed to determine the relative rate of decomposition in sediment placed under conditions selective for various physiologically different kinds of microorganisms. ^{14}C ring labelled substrates were used in all assays. Decay of the three chlorinated hydrocarbons under aerobic conditions without additional nutrients was greater than decay under anaerobic conditions. The addition of accessory energy and carbon sources such as sodium acetate did not increase the rate of decay under anaerobic conditions. There was some decay under anaerobic conditions suggesting mechanisms of ring cleavage not involving incorporation or oxygen prior to ring split. Nitrate as an accessory electron acceptor increased the rate of decomposition under anaerobic conditions. Degradation products formed from the parent compounds included water soluble intermediates as well as carbon dioxide.

The Q_{10} for the decay process as determined by laboratory assays incubated at 10° and 20°C. is 2.5.

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A gift from the Forest Park Foundation permitted the acquisition of equipment essential to this project and other studies on chlorinated hydrocarbons in our laboratories. This support and interest in environmental problems has been greatly appreciated.

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SECTION I

CONCLUSIONS

Chlorinated hydrocarbons associated with sediment particles tend to concentrate in sedimentation basins which may be at some distance from the input source.

Although the use of chlorinated hydrocarbon pesticides has declined sharply the levels of three materials has continued to increase in marine sediments. The principal source of this additional pollutant load in this instance appears to be more related to translocation of these materials absorbed to sediments of adjacent land drainage systems.

The dynamics of chlorinated hydrocarbons in the coastal marine environment, although complex, are susceptible to study. Approaches to the estimation of rates of input, decay, and translocation can be developed and assessed by continued analysis of environmental samples.

The measurement of decay rate by laboratory assay appears to have its greatest utility in the determination of the effect of environmental conditions on the process of decay. Duplication of conditions existing *in situ* in the laboratory can only be approximated and then only for a limited time. The laboratory work, short term in its execution, serves only as a guide to what is happening in the environment.

SECTION II

RECOMMENDATIONS

The complexities of the dynamics of coastal pollution by chlorinated hydrocarbons necessitates an initial survey of the concentration of these environmental contaminants at a large number of stations. Once basins of accumulation are established and principal translocation paths established a much smaller number of stations require surveillance at later points in time. It doesn't appear to be essential to monitor exactly the same stations in any surveillance program as long as the set of surveillance stations includes established basins and positions along translocation pathways.

It is recommended that initial intensive surveys be carried out in the coastal marine environment adjacent to major agricultural and industrial areas which are known to produce or utilize poorly degraded environmental contaminants such as the chlorinated hydrocarbons.

Monterey Bay is a very useful model coastal marine environment for the establishment and testing of approaches to system rate estimation. Continued surveillance of this area is recommended.

It is also recommended that work be done on extending the approach to estimation of system rates explored with respect to sediments to other environmental systems including populations of organisms. It would appear desirable to concentrate initially upon abundant and useful indicator organisms rather than commercially desirable or affected species.

Finally, it is recommended that additional effort be expended on the study of laboratory assays of decay not only as approximations of the environment but as useful preparations for elucidating the conditions inhibitory and stimulatory to the decay process.

SECTION III

INTRODUCTION

Although the accumulation of chlorinated hydrocarbons in the marine ecosystem has been a matter of concern for some time, methods for assessing the rates of accumulation, decay, and translocation have been lacking. The problem is not unique to the marine environment, and methods for assessment of the dynamics of chemical pollutants in general are needed for meaningful analysis of the residue measurements tabulated in most investigations. Without an assessment of rates such tabulations generally permit only the detection of some general trend of increase or decrease in concentration during the period of study. In many cases, however, the amount of variability is so great that the number of samples required to show such general trends is prohibitive. Yet we have both the data available and a need to use these data for meaningful assessment. In addition, before any feasible monitoring activity geared to control and regulatory strategies are designed and implemented, a means of assessing any new tabulations is required as a determinant in the design of such activities. Whatever systems of assessment may be developed in the future it cannot be expected that they will overcome the variability that plagues environmental sampling. Rather, such systems should be expected to provide an estimate of this variability and a confidence interval for any derived parameter of environmental change.

Several models stressing one or another aspect of the dynamics of pesticides in the environment have been presented (Hamaker 1966, Robinson 1967, Woodwell 1967, Harrison et al. 1970, and Eberhardt et al. 1971), but there still appears to be a need for a general approach that provides a means of estimating rates of input, decay, and translocation from some minimal number of analyses. The study presented here is an attempt to fill this need.

The data used here for these estimations consists of analyses of marine sediment samples for 1,1,2-trichloro-2,2-bis (p-chlorophenyl) ethane, DDT; 1,1-dichloro-2,2-bis (p-chlorophenyl) ethane, DDD; and 1,1-dichloro-2,2-bis (p-chlorophenyl) ethylene, DDE. The rates of decay at a sampling site and translocation away from a sampling site are difficult to separate through the approach to estimation presented. Laboratory measurements of the rate of ^{14}C ring labelled DDT in marine sediments held under a variety of conditions are also presented. These measurements reflect decay to the point of $^{14}CO_2$ release rather than conversion to any one of a variety of other metabolites including DDD and DDE, but are useful in assessing the method of estimation based upon environmental samples alone.

The analysis of DDT residue levels in marine sediments reported herein is only a part of a larger study correlating the levels of pollutants with density and composition of benthic populations. Other results of this study will be reported elsewhere.

THE STUDY AREA

This study was carried out in Monterey Bay located in the central coastal region of California. Figure 1 shows the study area and the location of the forty-nine Stations from which sediment samples were obtained. The figure also shows several geographical features pertinent to this investigation. The bottom of Monterey Bay is divided by a major submarine canyon over 3800 meters in depth at its deepest point. The sampling effort was concentrated in the southern portion of the bay with no sampling beyond the 200 fathom, 365 meter, line. Residue levels of DDT, DDD, and DDE were first measured in samples from this southern portion of the bay during 1970 and nineteen of these stations were resampled in 1973. A small number of stations were sampled in the northern part of the bay during 1971.

Monterey Bay is the recipient of drainage from a major agricultural area, the Salinas Valley, where DDT was used in large amounts for a period of twenty years. Usage of this pesticide and DDD has decreased sharply since 1969. A tabulation of use was started in 1970 when 33,931 pounds was applied to 19,387 acres in Monterey County. This input level was further reduced in 1971 to 4,697 pounds, and in 1972 to 10 pounds on 20 acres (Calif. Dept. of Agriculture 1970, 1971, 1972). Final tabulations for 1973 will probably show levels of input similar to those of 1972. Although the use of DDT in the area adjacent to Monterey Bay has declined sharply since 1970, the level of DDT in marine sediments appears to be increasing as more of this pesticide finds its way to the sea via the drainage system of the neighboring agricultural area. The decrease in usage on adjacent land and apparent increase in concentration in the marine sediments of the area suggests that continued study of the Monterey area is of particular interest in determining the time lag between terrestrial input and marine accumulation of persistent chemical pollutants.

Although in the past, when DDT was being regularly applied on the adjacent lands, the atmosphere was an important source of input to the bay; at the present time the major source of input appears to be the Salinas River which drains the inland agricultural areas. This river flows directly into the bay only intermittently. Most of the time the mouth of the river is blocked by a bar of sand that is removed only at times of heavy rainfall to prevent flooding. During this investigation this event occurred Jan. 13, 1970, Nov. 30, 1970, Dec. 29, 1971, Nov. 16, 1972, Nov. 17, 1972, and Nov. 20, 1973. Input directly by the river has, therefore, not been continuous.

Analyses of the sediment samples from the river bed along its course in 1972 (State of California, 1974) showed considerable variation in the relative abundance and concentration of the three compounds. Table 1 gives the results of these analyses and the approximate location of the samples relative to the mouth of the river.

During the periods when the mouth of the river is blocked, there is a sluggish flow north to Elkhorn Slough which served as the mouth of the river until 1908. This flow is joined by drainage from Tembladero Slough which receives water and sediments from the Reclamation Canal that flows through the City of Salinas to the east and beyond the right-hand margin of the figures. The Reclamation Canal receives effluents from food processing plants and other industries, and analyses of its sediment in 1972 (State of Calif., 1974) revealed the levels also listed in Table 1.

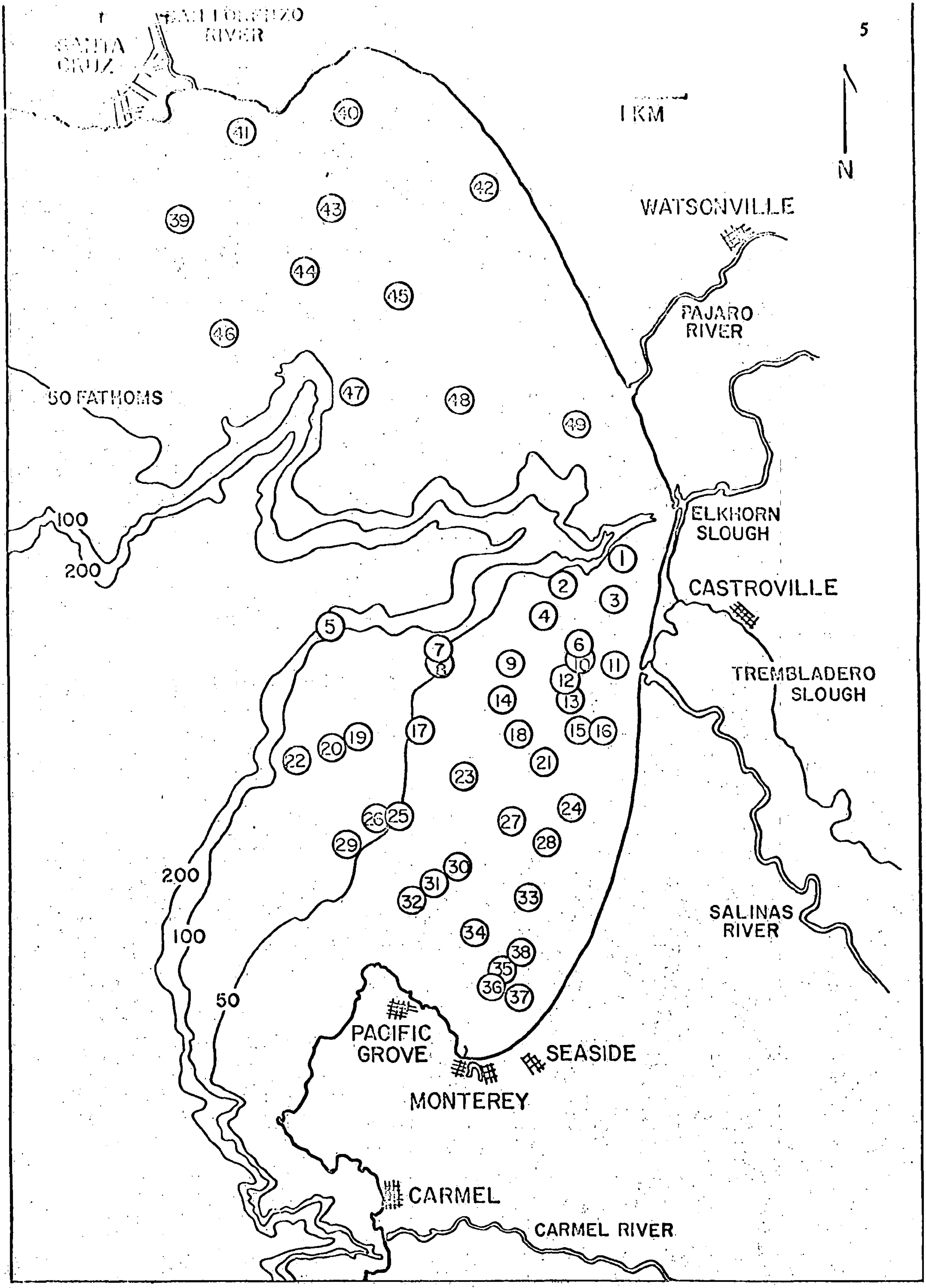


FIGURE 1. The study area, Monterey Bay. Sampling stations are indicated by number.

Table 1. CONCENTRATION OF DDT, DDD, AND DDE IN SEDIMENTS OF THE MONTEREY AREA LAND DRAINAGE SYSTEM IN 1972 (STATE OF CALIF., 1974)

Salinas River distance from mouth (kilometers)		(ppb)	
	DDT	DDD	DDE
42	1.0	1.3	
25	120.		20.
8	150.	1000.	360.
	16.	620.	
3	0.12	30.	
Reclamation Canal distance from mouth of Elkhorn Slough (kilometers)			
20	7,000.	45,000.	10,000.
	21,000.	150,000.	

RATIONALE OF DESCRIBED WORK

Selection of Study Site and Source of Marine Sediments for Decay Assays—For the estimation of rates governing the dynamics of a chlorinated hydrocarbon pollutant in marine sediments an area with the following characteristics appeared most desirable. (1) The marine area should be adjacent to a land area for which there exists an accounting of input to the environment through normal use. The use of DDT and DDD within the State of California has been subject to such accounting on a square mile section basis since 1970 (Calif. Dept. of Agriculture 1970). Such accounting is available only for normal agricultural and related uses. Therefore, areas which receive or have received less well determined inputs from chlorinated hydrocarbon manufacture, such as the ocean adjacent to Los Angeles, are less desirable for this type of study. (2) In order to assess translocation within the study area it would appear desirable to select a marine area with a limited number of point sources of input rather than one subject to diffuse input by way of the atmosphere. (3) The area should be one open to general oceanic influence rather than a closed system so that translocation of the pollutant out of the system by dilution or dissemination can be assessed. (4) As a source of materials for laboratory assays of decay the area should be one which has had a long exposure to the pollutant, thus insuring the establishment of microbial systems with the capacity for decomposition of the pollutant. (5) The area should be known to be contaminated with the pollutant. (6) The area should be accessible to sampling and close to the required analytical capability.

Monterey Bay, and in particular the southern portion of Monterey Bay, has these characteristics and was selected as the study site and source of materials for the development of laboratory assays for the rate of decay of DDT, DDD, and DDE.

Survey of Residue Levels in Monterey Bay Sediments—In order to assess the variability in concentration and distribution of the three compounds in the sediments of Monterey Bay thirty-seven sample sites were selected for analysis in the southern portion of the bay which receives water and sediments from the agricultural area of Monterey County by way of the Salinas River. An additional eleven sample sites in the northern portion of the bay were selected in order to assess any augmenting effect of additional river input sources such as the San Lorenzo and Pajaro Rivers that drain areas of Santa Cruz and San Benitio Counties lying adjacent to Monterey County and Monterey Bay.

Determination of the Amount of Change in Residue Levels with Time—In order to assess the magnitude of change in the concentration of DDT and related compounds a subset of the original survey sampling stations was resampled and analyzed after approximately three years. Nineteen of the original sample stations were selected as this subset. The selection was made on a basis of accessibility and representations of stations showing a broad range of residue concentrations as determined in the original survey.

Determination of the Variance of Sampling—One additional sample station, number 38, which had never before been sampled was added to the resampled subset and sampled three times on the same day. Three aliquots from each of these samples were analyzed for the three compounds to provide an estimate of the variability of sampling.

Approaches to the estimation of rates and Dynamics of the compounds in Sediments—Using the tabulated data obtained from the sampling programs various approaches to the estimation of the rates of input, translocation, and decay were developed for the system of sample sites. Considerable attention was directed to estimation of variance of these derived rates.

Development of Laboratory Assay Methods for the Determination of Decay Rate—Measurement of decay rate based on changes in residue level observed by repeated sampling from the environment are subject to error due to translocation to or away from the sample site. Therefore, a means of estimating decay rate in a closed system not susceptible to such error would be desirable. A variety of preparations using ^{14}C ring labelled compounds were established for such estimations.

Effect of Environmental Variables on Decay Rate—Any closed system preparation is by its very nature selective for one or another metabolic type of microorganism. The initial conditions and conditions which subsequently develop may have a marked effect upon the observed rate of decomposition through the election of particular microbial populations. Therefore, it was necessary to study the process of decay as influenced by a number of environmental variables chosen to encourage one or another of the major metabolic types of microorganisms.

SECTION IV

METHODS

ANALYSIS OF SEDIMENT SAMPLES

Samples of sediment were collected by Shipek grab or shallow dredge. Between 50 and 70 grams of wet sediment were placed in a 250 ml bottle and mixed with 30-50 grams of granular anhydrous sodium sulfate. The sediment was extracted with 50 ml of acetone:hexane, 1:1, by shaking for four hours. The acetone, hexane was decanted and filtered through a fritted glass filter or silicon-treated phase separation paper into a separatory funnel. Three additional 50 ml portions of hexane were used to wash the sediment and added to the original extractant.

The extract was washed with three 200 ml portions of water followed by dehydration of the extract by passage through a 2x5 cm column of anhydrous sodium sulfate and concentration in a Kuderna-Danish concentrator to less than 10 ml. The extract was then cleaned by shaking first with 1 ml of concentrated sulfuric acid and finally with approximately 0.1 ml of mercury. The analysis was performed in a Beckman GC-4 Gas Chromatograph with electron capture detector, using a mixed bed column of Chromosorb W, 80-100 mesh, DMCS treated, and acid washed, containing 5% DC-200 and 5% QF1.

Although the efficiency of extraction is difficult to assess, the effect of concentration and clean-up procedures can be measured by the use of ^{14}C labelled materials added just prior to extraction with acetone, hexane. Recovery was 73.9% for DDT, 94.4% for DDD, and 84.8% for DDE, and these figures were used to correct the results of analyses.

LABORATORY DECAY ASSAYS

A variety of preparations have been investigated for their applicability to decay assay preparations. These preparations have included sealed stationary aliquots of sediment and ^{14}C labelled substrate as well as ones in which the sediment with labelled substrate was subjected to continuous percolation or periodic gas flow. Maintenance of percolating systems for the length of time required to measure the very slow rates of decay is not feasible, and it is difficult to maintain a large number of preparations under conditions whereby they may be subjected to periodic gas flow and trapping of metabolic CO_2. Therefore, sealed stationary preparations have proved to be the only feasible type of preparation so far developed. The most convenient container for such preparations has been 125 ml Hypovials, Pierce, Rockford, Illinois, No. 12995, fitted with Teflon liners. The preparation of decay assays is as follows. Sediment is collected as for samples for residue analysis, packed in ice, and brought to the laboratory within a few hours. The sediment is rinsed through screen with 16 mesh to the inch to remove macroscopic infauna and refrigerated. Aliquots of the slurried sediment are removed for dry weight determination. A volume of the slurried sediment equivalent to 24 grams dry weight is delivered to a sterile Hypovial and seawater, with or without additional nutrients, is added to give a volume of 98 ml total. One ml each of ^{12}C and ^{14}C substrate adsorbed to sterile sediment is added giving a final volume of 100 ml. The preparation may be gassed with nitrogen to produce an anaerobic environment prior to sealing. All incubators are in the dark for periods of generally twelve weeks. All preparations are set up in quintuplicate. A typical protocol is presented in Table 2.

^{12}C Substrate Preparation—2.4 grams of either, 1,1-bis-(p-chlorophenyl)-2,2,2-trichloro ethane, p-p'DDT 99+% No. 10, 002-1; 2,2-bis-(p-chlorophenyl)-1,1-dichloro ethylene, No. 12, 289-7 (B 3964); or 2,2-bis-(p-chlorophenyl)-1,1-dichloroethane, puriss B 3959 Aldrich Chemical Co. Inc., Milwaukee, Wisconsin, were dissolved in 10 ml of acetone. To 10 grams of dried sterile sediment 1 ml of acetone solution was added and the sediment wet with an additional 3 ml of acetone. The acetone was evaporated off at room temperature and 96 ml of distilled water added to slurry the sediment and its adsorbed substrate. One ml contains 2.4×10^3 ug of substrate on 0.1 gram of sediment per ml. Similar preparations were made giving 2.4×10^2 ug and 21.6 ug of substrate on 0.1 gram of sediment per ml.

^{14}C-DDT Substrate Preparation—Uniformly ring labelled DDT, Amersham/Searle Corp., 63.9 u Ci/mg in benzene was used for preparation of the substrate. The original 250 u Ci preparation was diluted with acetone and 240 ug in 4 ml was added to 10 grams of dried sterile sediment. The acetone was removed by evaporation at room temperature and 96 ml of distilled water added to give 2.4 ug ^{14}C-DDT and 0.1 gram of sediment per ml. A similar preparation was made giving 0.24 ug ^{14}C-DDT and 0.1 gram of sediment per ml.

^{14}C-DDD Substrate Preparation—^{14}C-DDT was converted to ^{14}C-DDD by the method of Murphy (1970) and purity of the product confirmed by gas chromatography. The resulting material was used to prepare substrate as described above for ^{14}C-DDT.

^{14}C-DDE Substrate Preparation—^{14}C-DDT was converted to ^{14}C-DDE by the method of Gunther and Blinn (1950) and purity of the product confirmed by gas chromatography. The resulting material was used to prepare substrate as described above for ^{14}C-DDT.

Analysis of Decay Assays—After incubation for generally 12 weeks $^{14}CO_2$ was trapped by the addition of 1.5 ml of 5 N NaOH to the Hypovial. The base was introduced by syringe and the ampoule resealed with tape. Syringe delivered 5 ml aliquots of the basic slurried sediment were transfered to 25 ml Erlenmeyer flasks containing magnetic stirring bars. The flasks were stoppered with Top stoppers, K-882310, fitted with plastic center wells, K-882320, both from Kontes Glass Co., Vineland, N.J. The center wells contained an accordian pleated Whatman No. 1 filter paper wick, 2.5x5 cm. β-phenylethylamine, 0.15 ml, was delivered to the well and wick by syringe through the stopper. While the sediment in the flask was gently stirred on a magnetic stirrer 0.25 ml of 5 N H_2SO_4 was added to the sediment. The flasks were then held for 24 hours at room temperature after which time the wicks were removed to scintillation vials to which was added 15 ml of Toluene-omnifluror. Appropriate preparations for background

Table 2. TYPICAL DECAY ASSAY PROTOCOL.

Hypovial No.	Slurried (grams)	Sediment (ml)	Seawater plus nutrients (ml)	^{12}C Substrate (ug)	^{12}C Substrate (ml)	^{14}C Substrate (ug)	^{14}C Substrate (ml)	Total Substrate (ppm)	Total volume (ml)
1-5	24	59	39	2400	1	2.4	1	100	100
6-10	24	59	39	240	1	2.4	1	10	100
11-15	24	59	39	21.6	1	2.4	1	1	100
16-20	24	59	39	0	0	2.4	1	0.1	100
21-25	24	59	39	0	0	0.24	1	0.01	100

measurement were also made. The amount of $^{14}CO_2$ was determined in a Nuclear Chicago Corp. Unilux II. Diffusion time and trapping volume of β-phenylethylamine were established through tests using a standard preparation of Na $^{14}CO_3$.

DECAY AS AFFECTED BY ENVIRONMENTAL VARIABLES

The effect of temperature was determined by comparing the amount of decomposition at 10° and 20°C, and the effect of oxygen, nitrate, and sulfate as terminal electron acceptors in the presence and absence of cometabolizable sodium acetate and ethanol was determined by appropriate additions to the Hypovials.

SECTION V

RESULTS AND DISCUSSION

SURVEYS OF RESIDUE LEVELS IN MONTEREY BAY SEDIMENTS

The concentration in parts per billion of the three compounds, DDT, DDD, and DDE in sediment samples collected during the three sampling periods are presented in Table 3. Table 4 presents the same set of analyses in terms of the percent of total residues for each of the three compounds.

The variance of sampling at Station 38 can be assessed from the data presented in Table 5. The greatest variation in results can be observed with respect to DDT, the compound also showing the greatest loss during the extraction, concentration, and cleanup procedures as mentioned in the section on methods.

The data obtained in the 1970 and 1971 samplings is presented in Figures 2, 3, and 4, where the distribution of DDT and its two derivatives is displayed in terms of percent of the concentration of total DDT derivatives. Figures 5 and 6 show the distribution in terms of the total concentration of DDT and its two derivatives in parts per billion. Figure 5 shows the distribution in 1970 and 1971, and Figure 6 shows the distribution as indicated by the analyses of the smaller number of samples obtained in 1973.

The small number of sample stations in the northern portion of the bay did not reveal any unusual augmentation in concentrations of the three compounds due to input from the San Lorenzo and Pajaro Rivers although the percent composition of DDT derivatives does indicate differences between the northern and southern portions of the bay.

If particular attention is paid to the southern portion of the bay for which there is the greatest information, the distributions suggest a number of characteristics of the system. After input with sediments from the Salinas River, and perhaps also through Elkhorn Slough, these materials are subjected to considerable translocation due to the currents operating within the south bay. The highest concentration of DDT derivatives is to be found at a considerable distance from the mouth of the river. Close to the mouth of the river, however, the sediments show a high percentage of DDT which is characteristic of some of the sediments within the drainage system. These high DDT percentages are also found at the more distant points where the highest concentrations of derivatives are found as well. Over much of the area in terms of percent, however, DDE represents the major compound.

These plots of distribution reflect input over a considerable period of time. During this time the major routes of input may have changed considerably as has the relative concentrations of the three derivatives in these input sources. Nevertheless, the apparent constancy of location of major basins of deposition is remarkable. Areas with high concentrations in 1970 have become even more heavily contaminated in 1973.

Table 3. CONCENTRATIONS OF DDT, DDD, AND DDE IN MARINE SEDIMENT SAMPLES FROM MONTEREY BAY.

Station	LOCATION Latitude Longitude	Date	DDT (ppb)	DDD (ppb)	DDE (ppb)	TOTAL
1	36 47.25 121 48.90	8-23-70	8.36	3.67	5.76	17.79
2	36 46.85 121 53.50	11-15-70	1.63	6.76	14.70	23.09
3	36 46.35 121 49.00	2-20-70	5.71	0.71	1.02	7.44
4	36 46.05 121 51.00	11-15-70	4.28	6.61	10.70	21.59
5	36 46.00 121 57.00	5-29-70	2.14	0.93	4.00	7.07
6	36 45.45 121 50.00	11-15-70	2.04	1.17	1.80	5.01
7	36 45.30 121 54.00	5-29-70	0.0	2.50	4.51	7.01
8	36 45.20 121 54.00	5-29-70	2.65	4.26	6.51	13.42
9	36 45.10 121 52.00	5-29-70	4.48	5.14	4.51	14.13
10	36 45.10 121 50.00	5-29-70	6.42	8.67	7.01	22.10
11	36 45.00 121 49.00	2-20-70	3.67	0.40	0.45	4.52
12	36 44.60 121 50.50	2-20-70	0.52	0.18	0.28	0.98
13	36 44.25 121 50.35	11-15-70	0.26	0.19	0.45	0.90
14	36 44.20 121 52.25	8-23-70	5.20	7.50	15.50	28.20
15	36 44.00 121 50.00	5-29-70	0.0	0.19	0.35	0.54
16	36 44.00 121 49.50	2-20-70	0.69	0.14	2.75	3.58
17	36 43.75 121 54.45	11-15-70	1.02	0.38	0.70	2.10
18	36 43.50 121 51.80	2-20-70	1.73	2.64	2.40	6.77
19	36 43.35 121 56.25	8-23-70	1.12	0.25	0.65	2.02
20	36 43.18 121 57.00	2- 8-70	0.0	5.00	20.50	25.50
21	36 43.00 121 51.00	5-29-70	6.12	1.30	6.01	13.43
22	36 42.90 121 58.00	2-20-70	0.0	0.35	1.92	2.27
23	36 42.55 121 53.30	8-23-70	13.20	5.73	13.00	31.93
24	36 42.50 121 50.30	8-23-70	19.30	0.65	2.75	22.70
25	36 41.70 121 55.00	2-20-70	1.22	0.53	2.40	4.15
26	36 41.55 121 55.50	2- 8-70	0.0	2.35	7.01	9.36
27	36 41.50 121 52.00	5-29-70	2.85	2.50	8.01	13.36
28	36 41.00 121 51.00	11-15-70	0.0	1.61	4.26	5.87
29	36 40.90 121 56.40	2-20-70	1.32	1.61	9.02	11.95
30	36 40.50 121 53.50	5-29-70	2.55	1.76	6.76	11.07
31	36 40.08 121 54.05	2- 8-70	0.0	0.82	3.25	4.07
32	36 39.80 121 54.50	5-29-70	2.04	1.91	5.26	9.21
33	36 39.80 121 51.50	2- 9-70	0.0	1.42	8.52	9.94
34	36 39.10 121 53.08	2- 8-70	2.44	0.66	2.40	5.50
35	36 39.10 121 53.08	2- 8-70	8.67	0.66	3.00	12.33
36	36 37.95 121 52.50	2-20-70	2.65	2.79	10.00	15.44
37	36 37.77 121 51.83	2- 8-70	0.49	0.21	0.50	1.20

Cont'd...

Table 3. (continued) CONCENTRATIONS OF DDT, DDD, AND DDE IN MARINE SEDIMENT SAMPLES FROM MONTEREY BAY.

Station	LOCATION Latitude	Longitude	Date	DDT (ppb)	DDD (ppb)	DDE (ppb)	TOTAL
39	36 54.80	122 01.00	11-24-71	0.60	1.90	2.00	4.50
40	36 57.10	121 56.20	11-10-71	1.62	8.15	5.54	15.31
41	36 56.70	121 59.20	11-24-71	0.93	2.75	4.48	8.16
42	36 55.50	121 52.60	11-10-71	0.85	1.58	0.66	3.09
43	36 55.10	121 56.70	11-10-71	0.81	3.07	2.59	6.47
44	36 53.60	121 57.50	11-24-71	1.13	2.54	2.47	6.14
45	36 53.00	121 55.00	11-10-71	1.21	2.01	1.88	5.10
46	36 52.30	121 59.80	11-24-71	1.27	3.81	5.06	10.14
47	36 51.00	121 49.80	11-10-71	1.16	1.27	1.13	3.56
48	36 50.80	121 53.60	11-24-71	1.62	5.61	6.72	13.95
49	36 50.20	121 50.20	11-10-71	0.78	1.48	1.29	3.55
1	36 47.25	121 48.90	7- 9-73	1.06	0.53	0.56	2.15
2	36 46.85	121 53.50	7- 9-73	9.50	11.40	17.50	38.40
3	36 46.35	121 49.00	7- 9-73	1.10	0.53	0.63	2.26
4	36 46.05	121 51.00	7- 9-73	3.63	5.43	6.91	15.97
10	36 45.10	121 50.00	7- 2-73	0.92	0.39	0.52	1.83
11	36 45.00	121 49.00	7- 2-73	2.18	0.72	0.83	3.73
14	36 44.20	121 52.25	6-21-73	30.60	6.07	11.20	47.87
16	36 44.00	121 49.50	7- 2-73	0.96	0.06	0.23	1.25
17	36 43.75	121 54.45	8- 9-73	5.41	4.54	17.30	27.25
19	36 43.35	121 56.25	8- 9-73	72.70	3.19	12.00	87.89
20	36 43.18	121 57.00	6-21-73	63.10	0.79	3.48	67.37
22	36 42.90	121 58.00	8- 9-73	0.93	0.90	6.06	7.89
23	36 42.55	121 53.30	6-21-73	29.90	4.32	12.20	46.42
25	36 41.70	121 55.00	7-16-73	1.14	2.74	10.49	14.37
26	36 41.55	121 55.50	7-16-73	0.68	2.20	8.67	11.55
29	36 40.90	121 56.40	7-16-73	0.70	1.11	5.67	7.48
34	36 39.10	121 53.08	8- 9-73	1.18	0.42	2.44	4.04
36	36 37.95	121 52.50	6-21-73	83.10	0.95	3.34	87.39
37	36 37.77	121 51.83	7-16-73	0.54	0.20	0.40	1.14
38	36 38.47	121 51.68	9-21-73	0.62	0.38	2.72	3.72

Table 4. LEVELS OF DDT, DDD, AND DDE AS PERCENT OF TOTAL RESIDUES IN MARINE SEDIMENT SAMPLES FROM MONTEREY BAY.

Station	LOCATION Latitude Longitude	Date	DDT (%)	DDD (%)	DDE (%)
1	36 47.25 121 48.90	8-23-70	46.99	20.63	32.38
2	36 46.85 121 53.50	11-15-70	7.06	29.28	63.66
3	36 46.35 121 49.00	2-20-70	76.75	9.54	13.71
4	36 46.05 121 51.00	11-15-70	19.82	30.62	49.56
5	36 46.00 121 57.00	5-29-70	30.27	13.15	56.58
6	36 45.45 121 50.00	11-15-70	40.72	23.35	35.93
7	36 45.30 121 54.00	5-29-70	0.0	35.66	64.34
8	36 45.20 121 54.00	5-29-70	19.75	31.74	48.51
9	36 45.10 121 52.00	5-29-70	31.71	36.38	31.92
10	36 45.20 121 50.00	5-29-70	29.05	39.23	31.72
11	36 45.00 121 49.00	2-20-70	81.19	8.85	9.96
12	36 44.60 121 50.50	2-20-70	53.06	18.37	28.57
13	36 44.25 121 50.35	11-15-70	28.89	21.11	50.00
14	36 44.20 121 52.25	8-23-70	18.44	26.60	54.96
15	36 44.00 121 50.00	5-29-70	0.0	35.19	64.81
16	36 44.00 121 49.50	2-20-70	19.27	3.91	76.82
17	36 43.75 121 54.45	11-15-70	48.57	18.10	33.33
18	36 43.50 121 51.80	2-20-70	25.55	39.00	35.45
19	36 43.35 121 56.25	8-23-70	55.45	12.38	32.18
20	36 43.18 121 57.00	2- 8-70	0.0	19.61	80.39
21	36 43.00 121 51.00	5-29-70	45.57	9.68	44.75
22	36 42.90 121 58.00	2-20-70	0.0	15.42	84.58
23	36 42.55 121 53.30	8-23-70	41.34	17.95	40.71
24	36 42.50 121 50.30	8-23-70	85.02	2.86	12.11
25	36 41.70 121 55.00	2-20-70	29.40	12.77	57.83
26	36 41.55 121 55.50	2- 8-70	0.0	25.11	74.89
27	36 41.50 121 52.00	5-29-70	21.33	18.71	59.96
28	36 41.00 121 51.00	11-15-70	0.0	27.43	72.57
29	36 40.90 121 56.40	2-20-70	11.05	13.47	75.48
30	36 40.50 121 53.50	5-29-70	23.04	15.90	61.07
31	36 40.08 121 54.05	2- 8-70	0.0	20.15	79.85
32	36 39.80 121 54.50	5-29-70	22.15	20.74	57.11
33	36 39.80 121 51.50	2- 9-70	0.0	14.29	85.71
34	36 39.10 121 53.08	2- 8-70	44.36	12.00	43.64
35	36 39.10 121 53.08	2- 8-70	70.32	5.35	24.33
36	36 37.95 121 52.50	2-20-70	17.16	18.07	64.77
37	36 37.77 121 51.83	2- 8-70	40.83	17.50	41.67

Cont'd...

Table 4. (continued) LEVELS OF DDT, DDD, AND DDE AS PERCENT OF TOTAL RESIDUES IN MARINE SEDIMENT SAMPLES FROM MONTEREY BAY.

Station	LOCATION Latitude Longitude	Date	DDT (%)	DDD (%)	DDE (%)
39	36 54.80 122 01.00	11-24-71	13.33	42.22	44.44
40	36 57.10 121 56.20	11-10-71	10.58	53.23	36.19
41	36 56.70 121 59.20	11-24-71	11.40	33.70	54.90
42	36 55.50 121 52.60	11-10-71	27.51	51.13	21.36
43	36 55.10 121 56.70	11-10-71	12.52	47.45	40.03
44	36 53.60 121 57.50	11-24-71	18.40	41.37	40.23
45	36 53.00 121 55.00	11-10-71	23.73	39.41	36.86
46	36 52.30 121 59.80	11-24-71	12.52	37.57	49.90
47	36 51.00 121 49.80	11-10-71	32.58	35.67	31.74
48	36 50.80 121 53.60	11-24-71	11.61	40.22	48.17
49	36 50.20 121 50.20	11-10-71	21.97	41.69	36.34
1	36 47.25 121 48.90	7- 9-73	49.30	24.65	26.05
2	36 46.85 121 53.50	7- 9-73	24.74	29.69	45.57
3	36 46.35 121 49.00	7- 9-73	48.67	23.45	27.88
4	36 46.05 121 51.00	7- 9-73	22.73	34.00	43.27
10	36 45.10 121 50.00	7- 2-73	50.27	21.31	28.42
11	36 45.00 121 49.00	7- 2-73	58.45	19.30	22.25
14	36 44.20 121 52.25	6-21-73	63.92	12.68	23.40
16	36 44.00 121 49.50	7- 2-73	76.80	4.80	18.40
17	36 43.75 121 54.45	8- 9-73	19.85	16.66	63.49
19	36 43.35 121 56.25	8- 9-73	82.72	3.63	13.65
20	36 43.18 121 57.00	6-21-73	93.66	1.17	5.17
22	36 42.90 121 58.00	8- 9-73	11.79	11.41	76.81
23	36 42.55 121 53.30	6-21-73	64.41	9.31	26.28
25	36 41.70 121 55.00	7-16-73	7.93	19.07	73.00
26	36 41.55 121 55.50	7-16-73	5.89	19.05	75.06
29	36 40.90 121 56.40	7-16-73	9.36	14.84	75.80
34	36 39.10 121 53.08	8- 9-73	29.21	10.40	60.40
36	36 37.95 121 52.50	6-21-73	95.09	1.09	3.82
37	36 37.77 121 51.83	7-16-73	47.37	17.54	35.09
38	36 38.47 121 51.68	9-21-73	16.67	10.22	73.12

Table 5. VARIANCE OF SAMPLING MEASURED AT STATION 38.

Sample	Subsample	DDT ppb	DDD ppb	DDE ppb	TOTAL ppb
1	1	.687	.430	3.01	4.13
	2	.772	.470	2.90	4.14
	3	.550	.370	2.85	3.77
2	1	.561	.345	2.89	3.80
	2	.706	.333	2.38	3.42
	3	.801	.280	2.57	3.65
3	1	.663	.439	2.63	3.73
	2	.398	.315	2.96	3.67
	3	.405	.418	2.32	3.14
Mean		.6159	.3778	2.7233	3.7167
Variance		.02167	.00416	.06574	.09841
Standard Deviation		± .1472	± .0645	± .2564	± .3137
Standard Error		± .0491	± .0215	± .0855	± .1046
95% Confidence Limits		± .1131	± .0495	± .1971	± .2411

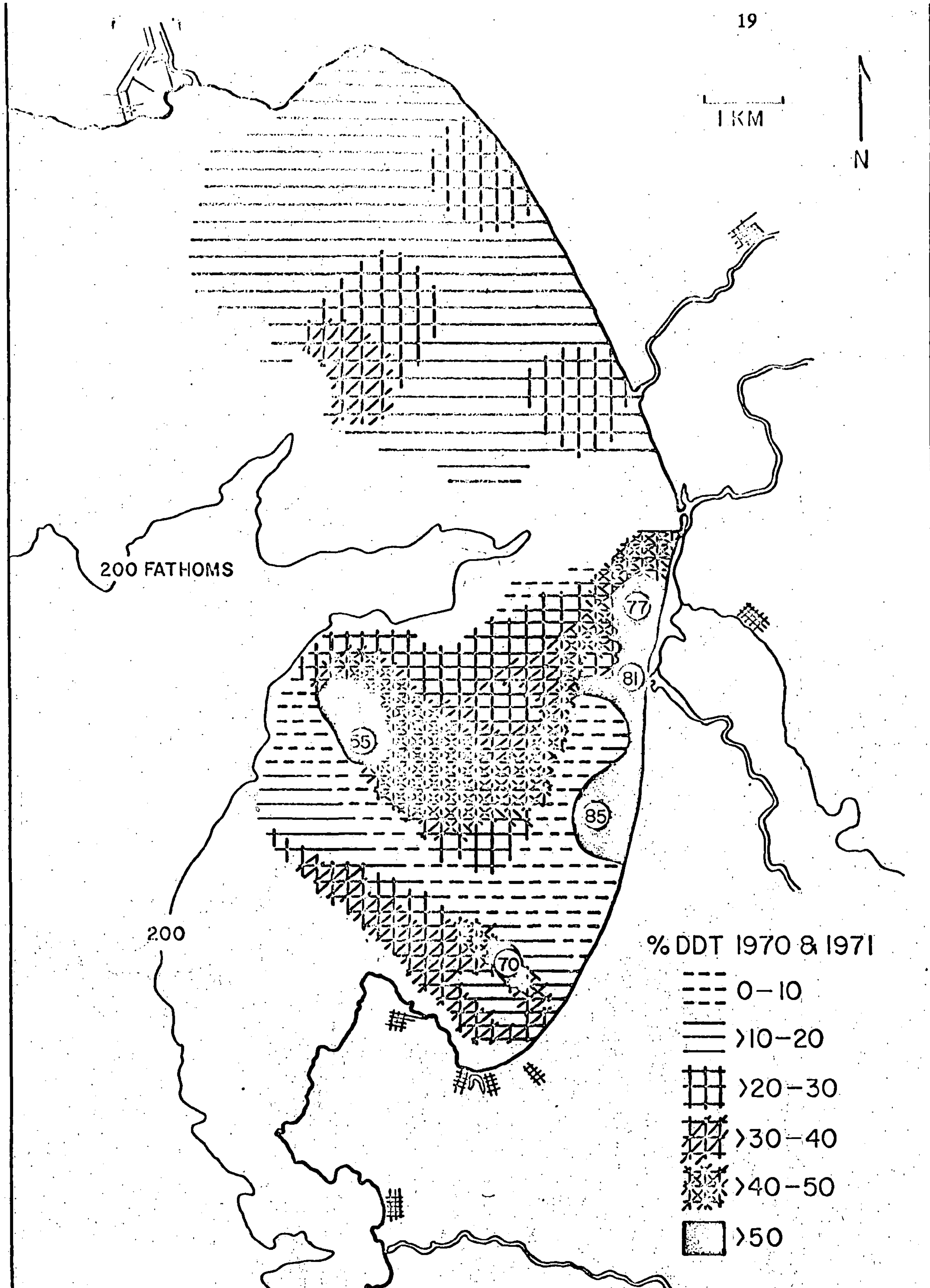


FIGURE 2. DDT as a percent of the total concentration of DDT, DDD, and DDE plotted for data obtained in 1970 and 1971. Circled numbers indicate actual percents in excess of 50%.

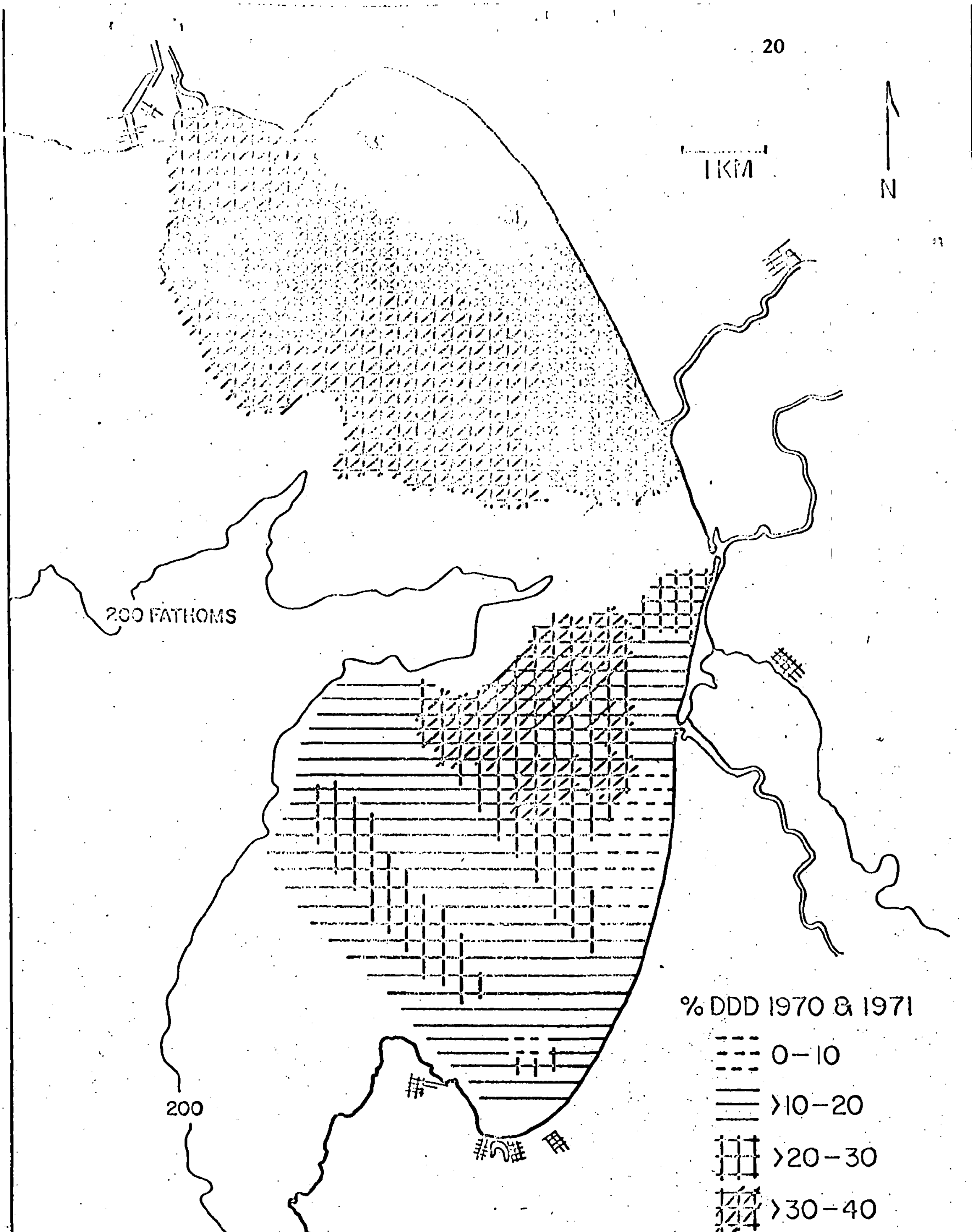


FIGURE 3. DDD as a percent of the total concentration of DDT, DDD, and DDE plotted for data obtained in 1970 and 1971. Circled numbers indicate actual percents in excess of 50%.

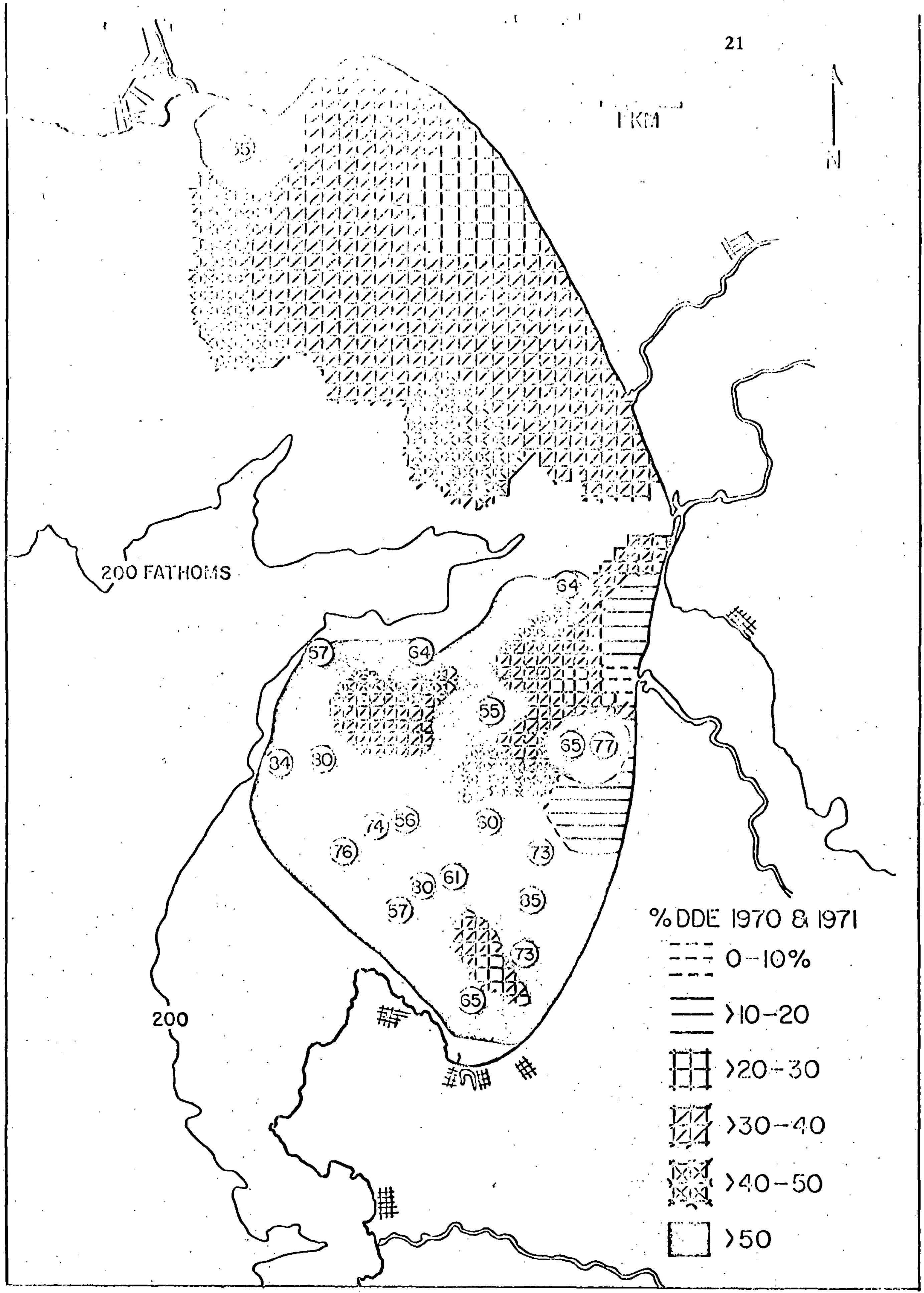


FIGURE 4. DDE as a percent of the total concentration of DDT, DDD, and DDE plotted for data obtained in 1970 and 1971. Circled numbers indicate actual percents in excess of 50%.

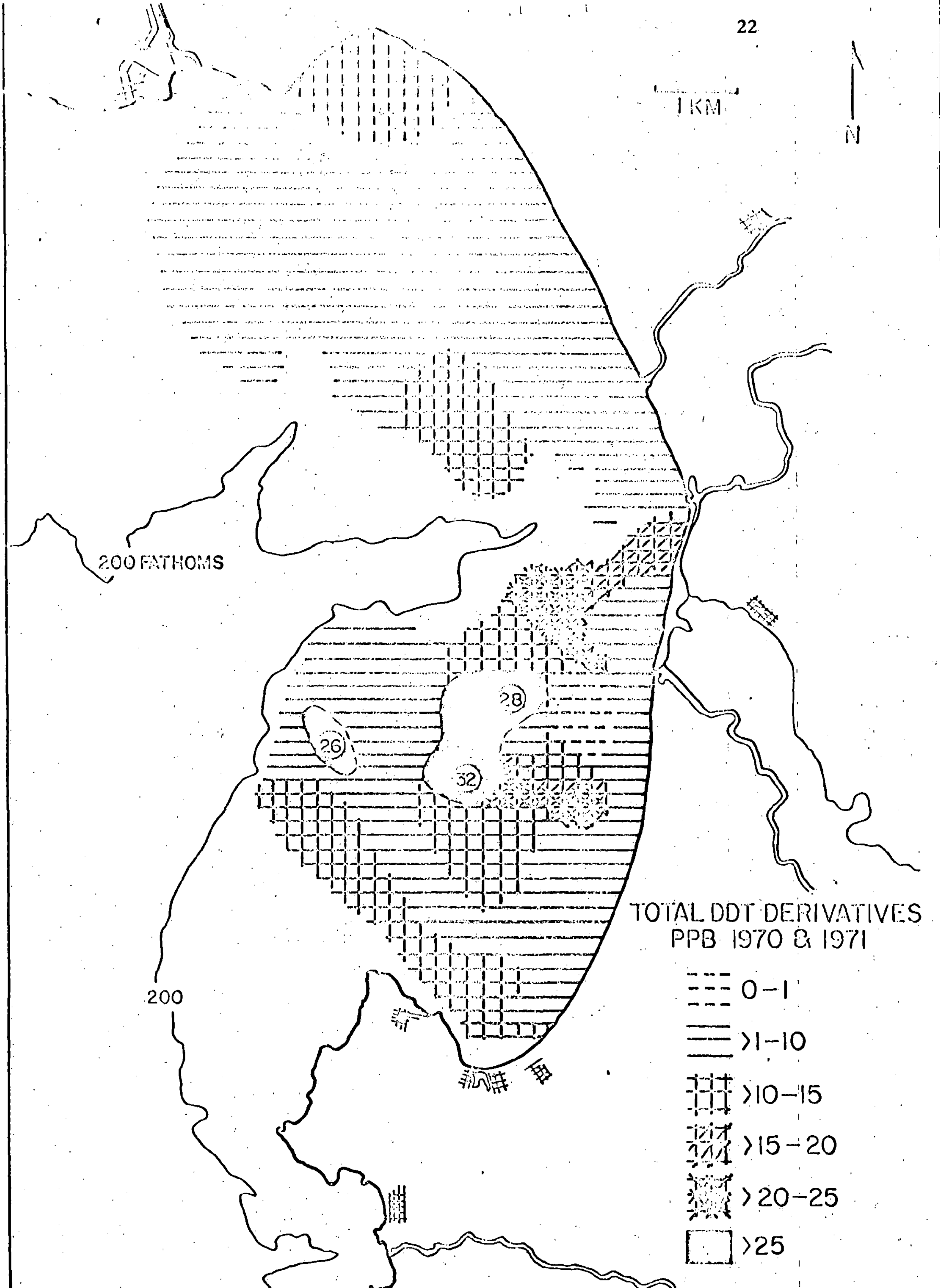


FIGURE 5. Total concentration in parts per billion of DDT, DDD, and DDE from data obtained in 1970 and 1971. Circled numbers indicate actual concentrations in excess of 50 ppb.

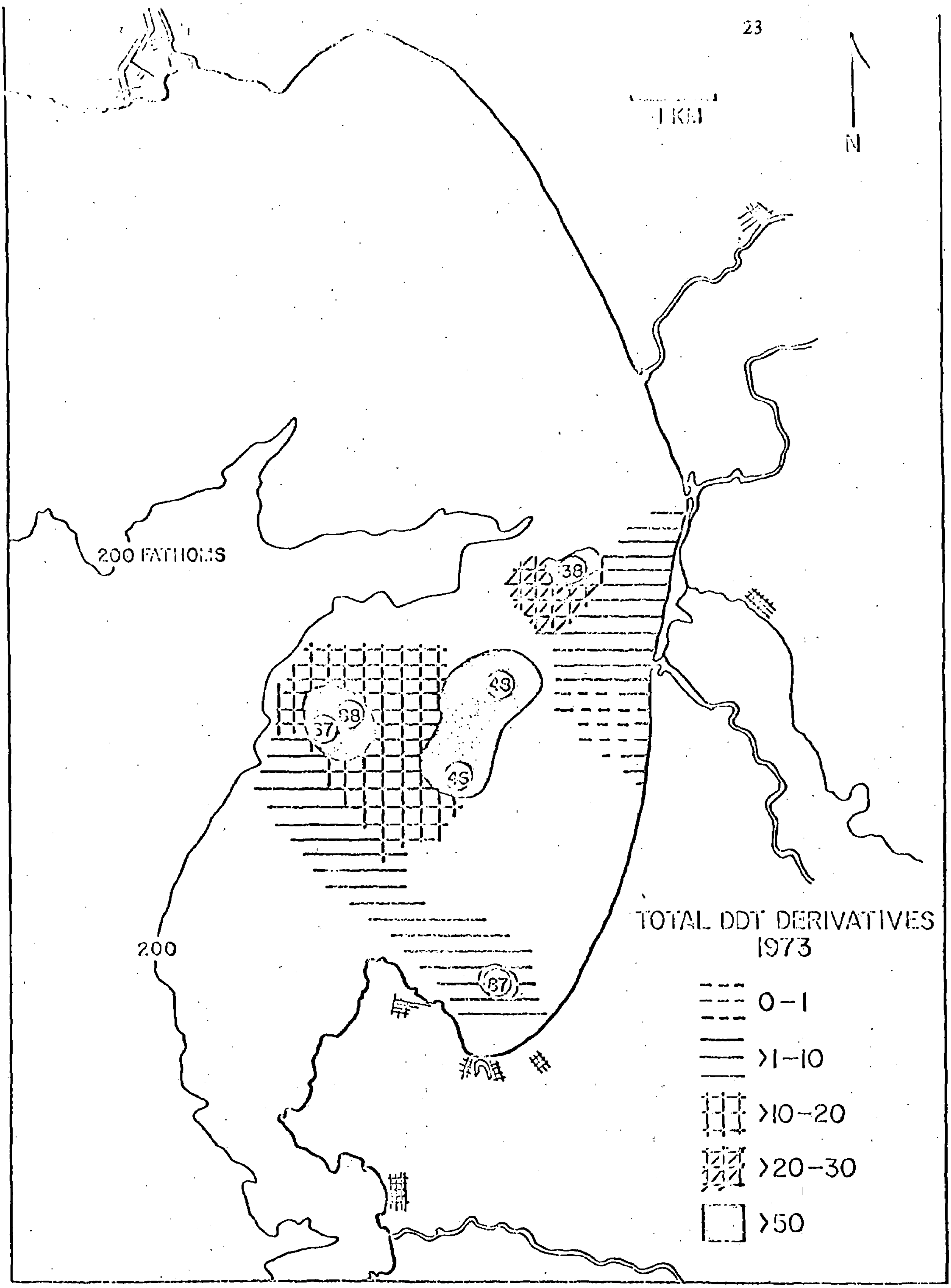


FIGURE 6. Total concentration in parts per billion of DDT, DDD, and DDE from data obtained in 1973. The blank portions of the area were not sampled. Circled numbers indicate actual concentrations in excess of 50 ppb.

ANALYSIS OF DYNAMICS

An approach to the analysis of the dynamics of sediment systems has been developed and has led to the development of Fortran programs permitting the rapid evaluation of data. The discussion of the approach to analysis will refer to output from these programs. The programs themselves with explanatory documentation are to be found in an appendix at the end of this report.

The first program requires sampling at the same set of stations at two points in time. The residue levels measured in sediments from the 19 stations sampled in both 1970 and 1973 constitute the data set used by this program. These data are presented as the first two pages of output, see Tables 6 and 7, followed by two pages showing the percent composition of total derivatives, see Tables 8 and 9. From the sums and means in Tables 6 and 7 it would appear that while DDT has shown an increase of several-fold the concentrations of DDD and DDE have changed very little. With respect to these latter two compounds input must be rather closely balanced with respect to output and decay. The changes in levels detected at individual stations must be a reflection of the rates of input of new material, output or removal both geographically and into other parts of the ecosystem, decay or decomposition within the sediment, and finally a shifting about of the material from sampling station to sampling station due primarily to the action of currents. The obvious complexity of the effect of these various rates has made the analysis of such a system extremely difficult. The approach presented here has necessitated the making of several simplifying assumptions. The utility of the method and the validity of the assumptions must await further evaluation, and the approach is intended more as a beginning than a final answer to the needs for methods of data analysis.

Figure 7 presents a diagram of the essential features of the system as it is envisaged. The individual stations where sediment samples were obtained are considered as compartments within the system of sediments in the southern portion of Monterey Bay. The diagram indicates that this system has a relationship to all other systems both geographical and of other kinds where the three compounds occur. Systems of different kinds would include the water above the sediment, the atmosphere above the water, organisms, etc. The effect of the rate of input, I, the rate of output, O, the rate of decay, D, and the rates of internal translocation, T_I and T_O, on the concentration within the system and within compartments is indicated.

A comparison of Figures 5 and 6 suggests that with continued input areas with the higher concentrations tend to increase in concentration due to the movement of the compounds within the system to these sinks or basins. Therefore, the amount of increase within any sediment compartment would appear to be related to the concentration already existing in that compartment. A similar relationship between the amount of decrease and concentration is less easily deduced from these Figures. However, the results of laboratory assays to be discussed in a later section have not revealed either a saturation of the decay process nor a stimulation by induction and selection of microbial populations that can be related to the concentration of these compounds. Instead the amount of decomposition appears to be a function of concentration. That the amount of translocation would be similarly related to concentration seems apparent.

Table 6. FIRST PAGE OF COMPUTER OUTPUT SHOWING CONCENTRATION OF POLLUTANT COMPOUNDS IN SEDIMENTS FROM SAMPLE STATIONS AT FIRST SAMPLING TIME. C_1 IDENTIFIES AS CONCENTRATIONS AT TIME ONE.

C_1

Station	LOCATION Latitude Longitude	Date	DDT (ppb)	DDD (ppb)	DDE (ppb)	TOTAL
1	36 47.25 121 48.90	8-23-70	8.36	3.67	5.76	17.79
2	36 46.85 121 53.50	11-15-70	1.63	6.76	14.70	23.09
3	36 46.35 121 49.00	2-20-70	5.71	0.71	1.02	7.44
4	36 46.05 121 51.00	11-15-70	4.28	6.61	10.70	21.59
10	36 45.10 121 50.00	5-29-70	6.42	8.67	7.01	22.10
11	36 45.00 121 49.00	2-20-70	3.67	0.40	0.45	4.52
14	36 44.20 121 52.25	8-23-70	5.20	7.50	15.50	28.20
16	36 44.00 121 49.50	2-20-70	0.69	0.14	2.75	3.58
17	36 43.75 121 54.45	11-15-70	1.02	0.38	0.70	2.10
19	36 43.35 121 56.25	8-23-70	1.12	0.25	0.65	2.02
20	36 43.18 121 57.00	2- 8-70	0.0	5.00	20.50	25.50
22	36 42.90 121 58.00	2-20-70	0.0	0.35	1.92	2.27
23	36 42.55 121 53.30	8-23-70	13.20	5.73	13.00	31.93
25	36 41.70 121 55.00	2-20-70	1.22	0.53	2.40	4.15
26	36 41.55 121 55.50	2- 8-70	0.0	2.35	7.01	9.36
29	36 40.90 121 56.40	2-20-70	1.32	1.61	9.02	11.95
34	36 39.10 121 53.08	2- 8-70	2.44	0.66	2.40	5.50
36	36 37.95 121 52.50	2-20-70	2.65	2.79	10.00	15.44
37	36 37.77 121 51.83	2- 8-70	0.49	0.21	0.50	1.20
	TOTALS		59.4199	54.3199	125.9899	239.7298
	Mean		3.1274	2.8589	6.6310	12.6174
	Standard Deviation		± 3.4385	± 2.9296	± 6.0673	± 10.1773
	Standard Error		± 0.7889	± 0.6721	± 1.3919	± 2.3348
	95% Confidence Limits		± 1.6574	± 1.4121	± 2.9245	± 4.9055

Table 7. SECOND PAGE OF COMPUTER OUTPUT SHOWING CONCENTRATION OF POLLUTANT COMPOUNDS IN SEDIMENT FROM SAMPLE STATIONS AT THE SECOND SAMPLING TIME. C_2 IDENTIFIES AS CONCENTRATIONS AT TIME TWO.

C_2

Station	LOCATION Latitude Longitude	Date	DDT (ppb)	DDD (ppb)	DDE (ppb)	TOTAL
1	36 47.25 121 48.90	7- 9-73	1.06	0.53	0.56	2.15
2	36 46.85 121 53.50	7- 9-73	9.50	11.40	17.50	38.40
3	36 46.35 121 49.00	7- 9-73	1.10	0.53	0.63	2.26
4	36 46.05 121 51.00	7- 9-73	3.63	5.43	6.91	15.97
10	36 45.10 121 50.00	7- 2-73	0.92	0.39	0.52	1.83
11	36 45.00 121 49.00	7- 2-73	2.18	0.72	0.83	3.73
14	36 44.20 121 52.25	6-21-73	30.60	6.07	11.20	47.87
16	36 44.00 121 49.50	7- 2-73	0.96	0.06	0.23	1.25
17	36 43.75 121 54.45	8- 9-73	5.41	4.54	17.30	27.25
19	36 43.35 121 56.25	8- 9-73	72.70	3.19	12.00	87.89
20	36 43.18 121 57.00	6-21-73	63.10	0.79	3.48	67.37
22	36 42.90 121 58.00	8- 9-73	0.93	0.90	6.06	7.89
23	36 42.55 121 53.30	6-21-73	29.90	4.32	12.20	46.42
25	36 41.70 121 55.00	7-16-73	1.14	2.74	10.49	14.37
26	36 41.55 121 55.50	7-16-73	0.68	2.20	8.67	11.55
29	36 40.90 121 56.40	7-16-73	0.70	1.11	5.67	7.48
34	36 39.10 121 53.08	8- 9-73	1.18	0.42	2.44	4.04
36	36 37.95 121 52.50	6-21-73	83.10	0.95	3.34	87.39
37	36 37.77 121 51.83	7-16-73	0.54	0.20	0.40	1.14
	TOTALS		309.3296	46.4899	120.4299	476.2488
	Mean		16.2805	2.4468	6.3384	25.0657
	Standard Deviation		± 26.9909	± 2.8805	± 5.7417	± 29.2362
	Standard Error		± 6.1921	± 0.6608	± 1.3172	± 6.7072
	95% Confidence Limits		± 13.0097	± 1.3884	± 2.7675	± 14.0919

Table 8. THIRD PAGE OF COMPUTER OUTPUT SHOWING PERCENT OF TOTAL OF EACH OF THE THREE COMPOUNDS IN SEDIMENTS FROM SAMPLE STATIONS AT THE FIRST SAMPLING TIME. C_1 IDENTIFIES AS DATA FOR TIME ONE.

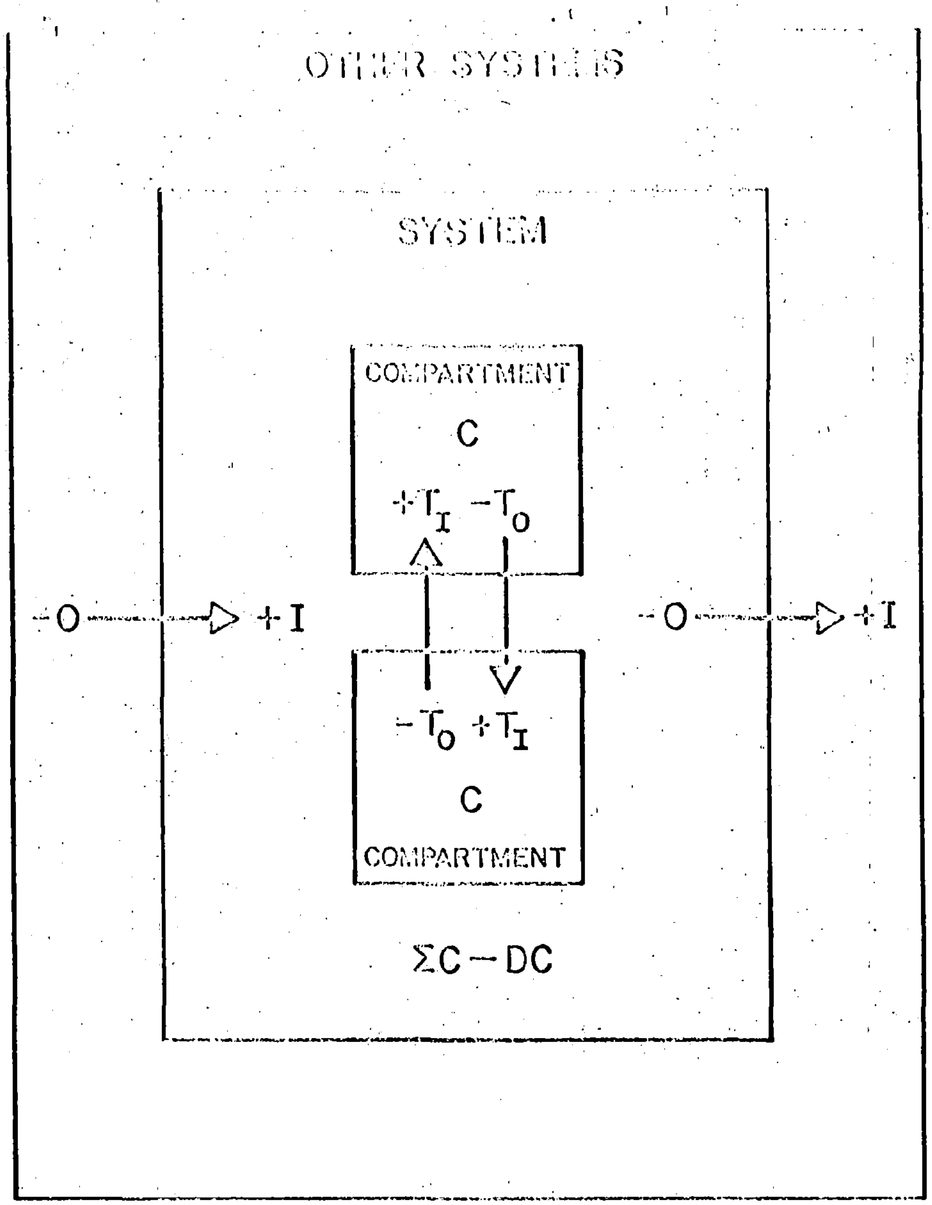
C_1

Station	LOCATION Latitude Longitude	Date	DDT (%)	DDD (%)	DDE (%)
1	36 47.25 121 48.90	8-23-70	46.99	20.63	32.38
2	36 46.85 121 53.50	11-15-70	7.06	29.28	63.66
3	36 46.35 121 49.00	2-20-70	76.75	9.54	13.71
4	36 46.05 121 51.00	11-15-70	19.82	30.62	49.56
10	36 45.10 121 50.00	5-29-70	29.05	39.23	31.72
11	36 45.00 121 49.00	2-20-70	81.19	8.85	9.96
14	36 44.20 121 52.25	8-23-70	18.44	26.60	54.96
16	36 44.00 121 49.50	2-20-70	19.27	3.91	76.82
17	36 43.75 121 54.45	11-15-70	48.57	18.10	33.33
19	36 43.35 121 56.25	8-23-70	55.45	12.38	32.18
20	36 43.18 121 57.00	2- 8-70	0.0	19.61	80.39
22	36 42.90 121 58.00	2-20-70	0.0	15.42	84.58
23	36 42.55 121 53.30	8-23-70	41.34	17.95	40.71
25	36 41.70 121 55.00	2-20-70	29.40	12.77	57.83
26	36 41.55 121 55.50	2- 8-70	0.0	25.11	74.89
29	36 40.90 121 56.40	2-20-70	11.05	13.47	75.48
34	36 39.10 121 53.08	2- 8-70	44.36	12.00	43.64
36	36 37.95 121 52.50	2-20-70	17.16	18.07	64.77
37	36 37.77 121 51.83	2- 8-70	40.83	17.50	41.67
	TOTALS		586.7412	351.0149	962.2397
	Mean		30.8811	18.4745	50.6442
	Standard Deviation		± 24.2998	± 8.6373	± 22.2953
	Standard Error		± 5.5748	± 1.9815	± 5.1149
	95% Confidence Limits		± 11.7126	± 4.1632	± 10.7464

Table 9. FOURTH PAGE OF COMPUTER OUTPUT SHOWING PERCENT OF TOTAL OF EACH OF THE THREE COMPOUNDS IN SEDIMENT FROM SAMPLE STATIONS AT THE SECOND SAMPLING TIME. C_2 IDENTIFIES AS DATA FOR TIME TWO.

C_2

Station	LOCATION Latitude Longitude	Date	DDT (%)	DDD (%)	DDE (%)
1	36 47.25 121 48.90	7- 9-73	49.30	24.65	26.05
2	36 46.85 121 53.50	7- 9-73	24.74	29.69	45.57
3	36 46.35 121 49.00	7- 9-73	48.67	23.45	27.88
4	36 46.05 121 51.00	7- 9-73	22.73	34.00	43.27
10	36 45.10 121 50.00	7- 2-73	50.27	21.31	28.42
11	36 45.00 121 49.00	7- 2-73	58.45	19.30	22.25
14	36 44.20 121 52.25	6-21-73	63.92	12.68	23.40
16	36 44.00 121 49.50	7- 2-73	76.80	4.80	18.40
17	36 43.75 121 54.45	8- 9-73	19.85	16.66	63.49
19	36 43.35 121 56.25	8- 9-73	82.72	3.63	13.65
20	36 43.18 121 57.00	6-21-73	93.66	1.17	5.17
22	36 42.90 121 58.00	8- 9-73	11.79	11.41	76.81
23	36 42.55 121 53.30	6-21-73	64.41	9.31	26.28
25	36 41.70 121 55.00	7-16-73	7.93	19.07	73.00
26	36 41.55 121 55.50	7-16-73	5.89	19.05	75.06
29	36 40.90 121 56.40	7-16-73	9.36	14.84	75.80
34	36 39.10 121 53.08	8- 9-73	29.21	10.40	60.40
36	36 37.95 121 52.50	6-21-73	95.09	1.09	3.82
37	36 37.77 121 51.83	7-16-73	47.37	17.54	35.09
	TOTALS		862.1616	294.0427	743.7920
	Mean		45.3769	15.4759	39.1469
	Standard Deviation		± 29.2068	± 9.2122	± 24.6220
	Standard Error		± 6.7005	± 2.1134	± 5.6487
	95% Confidence Limits		± 14.0777	± 4.4403	± 11.8679



SYSTEMS

$$C_2 = C_1(1 + I - O - D)^N \quad T_O = T_I$$

COMPARTMENTS

$$C_2 = C_1(1 + I + T_I - T_O - O - D)^N \quad T_O \neq T_I$$

C_1 = CONCENTRATION OF RESIDUE AT TIME 1

C_2 = CONCENTRATION OF RESIDUE AT TIME 2

I = RATE OF INPUT OF RESIDUE

O = RATE OF OUTPUT OF RESIDUE

D = RATE OF DECAY

T_O = RATE OF TRANSLOCATION OUT OF A COMPARTMENT

T_I = RATE OF TRANSLOCATION INTO A COMPARTMENT

FIGURE 7. Model of the system of sediment compartments and this system's relation to other systems.

Therefore, for the estimation of the overall rate of change in a compartment, i.e., the resultant of the various rates affecting concentration, the following expression was solved for K,

$$C_2 = C_1 e^{KN} \qquad 1.$$

C_1 and C_2 are the concentrations within the compartment at time one and time two, N is the length of the time interval in years, and e is the natural logarithm base. K is a nominal percentage rate in the form of a decimal fraction resulting in continuous compounding, and is converted to an annual rate for the expression,

$$C_2 = C_1 (1+K)^N \qquad 2.$$

The results of these calculations for the three compounds are presented as the fifth, sixth, and seventh pages of computer output in Tables 10, 11, and 12. In these tables the values of K are sorted into positive and negative values for purposes discussed below. Compartments which showed a zero concentration at time one were adjusted by substitution of 0.004 ppb, a value generally just below the level of detection in the analyses.

The standard deviation of these estimates was approximated through the use of the expression for the standard deviation of a function of two random variables (Papoulis, 1965),

$$\sigma^2_{K(C_1,C_2)} \simeq \left(\frac{\partial K}{\partial C_1}\right)^2 \sigma^2_{C_1} + \left(\frac{\partial K}{\partial C_2}\right)^2 \sigma^2_{C_2} + 2\frac{\partial K}{\partial C_1}\frac{\partial K}{\partial C_2}\sigma_{C_1C_2} \qquad 3.$$

For ease in computation only two variables at a time were used in developing this approximation to the standard deviation.

If we assume that the rate of change within the system can be approximated by the mean rate of change of its separate compartments, the mean of the K values becomes an estimate of the rate of net change of the system.

$$\text{Net rate of change} = I - (O+D) \qquad 4.$$

This net rate of change is unaffected by the rates of internal translocation, T_I and T_O, which are equal in magnitude and opposite in sign. The net rate of change is the sum of two other mean rates. One is the rate of input, I, which can be estimated by the mean of the positive K's, and the other is obtained as the mean of the negative K's and may be taken as an estimate of (O+D) in equation 4.

The mean of the differences between each K and the net rate of change, that is the mean deviation from the mean of K, becomes an estimate of T_O and T_I. The results of these calculations are included in Tables 10, 11, and 12.

The separation of the rate O and D is more difficult and several approaches have been attempted. The decimal fraction of the input rate that is translocated within the system, T_I/I, differs from compound to compound: DDT, 0.665; DDD, 0.882; and DDE, 0.860. One explanation for this difference is that they reflect differences in the rates of decomposition within the sediments. Based upon this assumption the rate O and D have been estimated by the following equations,

Table 10. FIFTH PAGE OF COMPUTER OUTPUT SHOWING THE RATE OF CHANGE, K, FOR DDT IN EACH SEDIMENT COMPARTMENT.

Station	C_2 DDT	C_1 DDT	N	+K	-K	+K + -K	+K - Net R	-K - Net R
1	1.06	8.36	2.8795	0.0	-0.5119	-0.5119	0.0	-2.0906
2	9.50	1.63	2.6493	0.9452	0.0	0.9452	0.0	-0.6336
3	1.10	5.71	3.3836	0.0	-0.3854	-0.3854	0.0	-1.9641
4	3.63	4.28	2.6493	0.0	-0.0603	-0.0603	0.0	-1.6390
10	0.92	6.42	3.0959	0.0	-0.4661	-0.4661	0.0	-2.0449
11	2.18	3.67	3.3644	0.0	-0.1434	-0.1434	0.0	-1.7222
14	30.60	5.20	2.8301	0.8706	0.0	0.8706	0.0	-0.7082
16	0.96	0.69	3.3644	0.1031	0.0	0.1031	0.0	-1.4756
17	5.41	1.02	2.7342	0.8408	0.0	0.8408	0.0	-0.7380
19	72.70	1.12	2.9644	3.0866	0.0	3.0866	1.5079	0.0
20	63.10	0.0	3.3671	16.6503	0.0	16.6503	15.0715	0.0
22	0.93	0.0	3.4685	3.8113	0.0	3.8113	2.2325	0.0
23	29.90	13.20	2.8301	0.3350	0.0	0.3350	0.0	-1.2438
25	1.14	1.22	3.4027	0.0	-0.0197	-0.0197	0.0	-1.5985
26	0.68	0.0	3.4356	3.4588	0.0	3.4588	1.8800	0.0
29	0.70	1.32	3.4027	0.0	-0.1701	-0.1701	0.0	-1.7488
34	1.18	2.44	3.5014	0.0	-0.1874	-0.1874	0.0	-1.7661
36	83.10	2.65	3.3342	1.8105	0.0	1.8105	0.2317	0.0
37	0.54	0.49	3.4356	0.0287	0.0	0.0287	0.0	-1.5501
Totals	309.3296	59.4199	60.0930	31.9407	-1.9442	29.9964	20.9236	-20.9235
Mean	16.2805	3.1274	3.1628	1.6811	-0.1023	1.5788	1.1012	-1.1012
S.D.	± 26.9909	± 3.4385	± 0.3100	± 0.9016	± 0.0984	± 1.0000	± 0.8738	± 0.1262
S.E.	± 6.1921	± 0.7889	± 0.0711	± 0.2068	± 0.0226	± 0.2294	± 0.2005	± 0.0289
95% C.L.	± 13.0097	± 1.6574	± 0.1494	± 0.4346	± 0.0474	± 0.4820	± 0.4212	± 0.0608

Table 11. SIXTH PAGE OF COMPUTER OUTPUT SHOWING THE RATE OF CHANGE, K, FOR DDD IN EACH SEDIMENT COMPARTMENT.

Station	C_2 DDD	C_1 DDD	N	+K	-K	+K + -K	+K - Net R	-K - Net R
1	0.53	3.67	2.8795	0.0	-0.4893	-0.4893	0.0	-0.5714
2	11.40	6.76	2.6493	0.2181	0.0	0.2181	0.1360	0.0
3	0.53	0.71	3.3836	0.0	-0.0828	-0.0828	0.0	-0.1648
4	5.43	6.61	2.6493	0.0	-0.0715	-0.0715	0.0	-0.1536
10	0.39	8.67	3.0959	0.0	-0.6328	-0.6328	0.0	-0.7148
11	0.72	0.40	3.3644	0.1909	0.0	0.1909	0.1089	0.0
14	6.07	7.50	2.8301	0.0	-0.0720	-0.0720	0.0	-0.1541
16	0.06	0.14	3.3644	0.0	-0.2226	-0.2226	0.0	-0.3047
17	4.54	0.38	2.7342	1.4774	0.0	1.4774	1.3953	0.0
19	3.19	0.25	2.9644	1.3607	0.0	1.3607	1.2787	0.0
20	0.79	5.00	3.3671	0.0	-0.4219	-0.4219	0.0	-0.5039
22	0.90	0.35	3.4685	0.3130	0.0	0.3130	0.2309	0.0
23	4.32	5.73	2.8301	0.0	-0.0950	-0.0950	0.0	-0.1770
25	2.74	0.53	3.4027	0.6206	0.0	0.6206	0.5386	0.0
26	2.20	2.35	3.4356	0.0	-0.0190	-0.0190	0.0	-0.1011
29	1.11	1.61	3.4027	0.0	-0.1035	-0.1035	0.0	-0.1856
34	0.42	0.66	3.5014	0.0	-0.1211	-0.1211	0.0	-0.2031
36	0.95	2.79	3.3342	0.0	-0.2761	-0.2761	0.0	-0.3582
37	0.20	0.21	3.4356	0.0	-0.0141	-0.0141	0.0	-0.0961
Totals	46.4899	54.3199	60.0930	4.1806	-2.6218	1.5588	3.6884	-3.6884
Mean	2.4468	2.8589	3.1628	0.2200	-0.1380	0.0820	0.1941	-0.1941
S.D.	± 2.8805	± 2.9296	± 0.3100	± 0.7233	± 0.2767	± 1.0000	± 0.7233	± 0.2767
S.E.	± 0.6608	± 0.6721	± 0.0711	± 0.1659	± 0.0635	± 0.2294	± 0.1659	± 0.0635
95% C.L.	± 1.3884	± 1.4121	± 0.1494	± 0.3486	± 0.1334	± 0.4820	± 0.3486	± 0.1334

Table 12. SEVENTH PAGE OF COMPUTER OUTPUT SHOWING THE RATE OF CHANGE, K, FOR DDE IN EACH SEDIMENT COMPARTMENT.

Station	C_2 DDE	C_1 DDE	N	+K	-K	+K + -K	+K - Net R	-K - Net R
1	0.56	5.76	2.8795	0.0	-0.5549	-0.5549	0.0	-0.6726
2	17.50	14.70	2.6493	0.0680	0.0	0.0680	0.0	-0.0497
3	0.63	1.02	3.3836	0.0	-0.1327	-0.1327	0.0	-0.2505
4	6.91	10.70	2.6493	0.0	-0.1522	-0.1522	0.0	-0.2699
10	0.52	7.01	3.0959	0.0	-0.5684	-0.5684	0.0	-0.6861
11	0.83	0.45	3.3644	0.1996	0.0	0.1996	0.0818	0.0
14	11.20	15.50	2.8301	0.0	-0.1085	-0.1085	0.0	-0.2262
16	0.23	2.75	3.3644	0.0	-0.5217	-0.5217	0.0	-0.6394
17	17.30	0.70	2.7342	2.2318	0.0	2.2318	2.1141	0.0
19	12.00	0.65	2.9644	1.6740	0.0	1.6740	1.5563	0.0
20	3.48	20.50	3.3671	0.0	-0.4094	-0.4094	0.0	-0.5272
22	6.06	1.92	3.4685	0.3929	0.0	0.3929	0.2752	0.0
23	12.20	13.00	2.8301	0.0	-0.0222	-0.0222	0.0	-0.1399
25	10.49	2.40	3.4027	0.5426	0.0	0.5426	0.4249	0.0
26	8.67	7.01	3.4356	0.0638	0.0	0.0638	0.0	-0.0539
29	5.67	9.02	3.4027	0.0	-0.1275	-0.1275	0.0	-0.2453
34	2.44	2.40	3.5014	0.0047	0.0	0.0047	0.0	-0.1130
36	3.34	10.00	3.3342	0.0	-0.2803	-0.2803	0.0	-0.3980
37	0.40	0.50	3.4356	0.0	-0.0629	-0.0629	0.0	-0.1806
Totals	120.4299	125.9899	60.0930	5.1774	-2.9407	2.2367	4.4522	-4.4522
Mean	6.3384	6.6310	3.1628	0.2725	-0.1548	0.1177	0.2343	-0.2343
S.D.	± 5.7417	± 6.0673	± 0.3100	± 0.7781	± 0.2243	± 1.0024	± 0.7761	± 0.2262
S.E.	± 1.3172	± 1.3919	± 0.0711	± 0.1785	± 0.0515	± 0.2300	± 0.1781	± 0.0519
95% C.L.	± 2.7675	± 2.9245	± 0.1494	± 0.3750	± 0.1081	± 0.4831	± 0.3741	± 0.1091

$$O = \frac{T_I}{I} (O+D)$$ 5.

$$D = (1.0 - \frac{T_I}{I}) (O+D) \text{ or } D = (O+D) - O$$ 6.

The residence time, T_R, and lifetime, T_L, in years, are calculated as the corresponding reciprocals.

$$T_R = 1.0/(O+D)$$ 7.

$$T_L = 1.0/D$$ 8.

The last three pages of computer output present a summary of these estimations and are presented in Tables 13, 14, and 15.

The effect of substitution of a minimal value for zero concentrations was investigated by reducing the set of sample stations to sixteen and elimination of all stations showing a zero concentration of DDT at time one. While there was some effect upon the estimates of rates as the system was reduced in size, only the estimates of T_O for DDT were significantly different when tested by the "test of equality of the means of two samples whose variances are assumed to be unequal" (Sokol and Rohlf, 1969). The difference between the other estimates was very small compared to the standard deviation of these estimates. Table 16 presents for comparison the set of rates for the nineteen and sixteen station data sets.

The approach to analysis of the data which provided these estimates of system rates requires sampling at the same stations at two different times. However, as presented in Table 3, there is additional data available with respect to the south bay system at time one. This additional data can not be used by the approach to analysis presented so far. More stations were sampled in the first sampling period than were sampled in the second, and the approach requires pairs of samples identical except for time of sampling. An additional program was written to permit analysis of a system where sampling does not meet the requirements of the first approach. This second program trêats all samples as unpaired and evaluates the rate of change, K, at the different sample locations by comparison of the actual measurement at that station at time one or time two with the mean concentrations of the system at either time one or time two. That is, a measurement at time one is paired with the mean concentration at time two and vice versa for the evaluation of K. Further the time interval, N, is evaluated as the interval between the time of actual sample of one sampling time and the mean time of the other sampling period. Equation 1 becomes,

$$\overline{C_2} = C_1 e^{KN}$$ 9.

with $N = \overline{T_2} - T_1$

Table 13. EIGHTH PAGE OF COMPUTER OUTPUT SHOWING A SUMMARY OF THE ANNUAL SYSTEM RATES EXPRESSED AS DECIMAL FRACTIONS OF THE MEAN CONCENTRATION OF DDT PRESENT IN THE SYSTEM.

System of Rates for DDT			S.D.	S.E.	95% Limit
Net rate of change	= Net = +	1.5788	± 1.0000	± 0.2294	± 0.4820
Translocation into compartments	= T_I = +	1.1012	± 0.8738	± 0.2005	± 0.4212
Translocation out of compartments	= T_O = -	1.1012	± 0.1262	± 0.0289	± 0.0608
Input	= I = +	1.6811	± 0.9016	± 0.2068	± 0.4346
Output and Decay	= O+D = -	0.1023	± 0.0984	± 0.0226	± 0.0474
Output from System	= O = -	0.0670	± 0.0644	± 0.0148	± 0.0311
Decay	= D = -	0.0353	± 0.0339	± 0.0078	± 0.0164
Lifetime in years	= T_L =	28.3322	± 27.2386	± 6.2490	± 13.1291
Residence time in years	= T_R =	9.7724	± 9.3952	± 2.1554	± 4.5285

Summary Equation for the System—

DDT — Mean C_2 = Mean C_1 (1.0 + I + T_I - T_O - O - D)^N

$$16.2805 = 3.1274\ (1.0 + 1.6811 + 1.1012 - 1.1012 - 0.0670 - 0.0353)^{3.1628}$$

Table 14. NINETH PAGE OF COMPUTER OUTPUT SHOWING A SUMMARY OF THE ANNUAL SYSTEM RATES EXPRESSED AS DECIMAL FRACTIONS OF THE MEAN CONCENTRATION OF DDD PRESENT IN THE SYSTEM.

System of Rates for DDD					S.D.		S.E.		95% Limit
Net rate of change	= Net	= +	0.0820	±	1.0000	±	0.2294	±	0.4820
Translocation into compartments	= T_I	= +	0.1941	±	0.7233	±	0.1659	±	0.3486
Translocation out of compartments	= T_O	= -	0.1941	±	0.2767	±	0.0635	±	0.1334
Input	= I	= +	0.2200	±	0.7233	±	0.1659	±	0.3486
Output and Decay	= O+D	= -	0.1380	±	0.2767	±	0.0635	±	0.1334
Output from System	= O	= -	0.1217	±	0.2441	±	0.0560	±	0.1177
Decay	= D	= -	0.0162	±	0.0326	±	0.0075	±	0.0157
Lifetime in years	= T_L	=	61.5459	±	123.4241	±	28.3154	±	59.4907
Residence time in years	= T_R	=	7.2469	±	14.5330	±	3.3341	±	7.0049

Summary Equation for the System—

DDD	Mean C_2		Mean C_1	I	T_I	T_O	O	D	N
	2.4468	=	2.8589						

$$2.4468 = 2.8589\,(1.0 + 0.2200 + 0.1941 - 0.1941 - 0.1217 - 0.0162)^{3.1628}$$

Table 15. TENTH PAGE OF COMPUTER OUTPUT SHOWING A SUMMARY OF THE ANNUAL SYSTEM RATES EXPRESSED AS DECIMAL FRACTIONS OF THE MEAN CONCENTRATION OF DDE PRESENT IN THE SYSTEM.

System of Rates for DDE					S.D.		S.E.		95% Limit
Net rate of change	= Net	= +	0.1177	±	1.0024	±	0.2300	±	0.4831
Translocation into compartments	= T_I	= +	0.2343	±	0.7761	±	0.1781	±	0.3741
Translocation out of compartments	= T_O	= -	0.2343	±	0.2262	±	0.0519	±	0.1091
Input	= I	= +	0.2725	±	0.7781	±	0.1785	±	0.3750
Output and Decay	= O+D	= -	0.1548	±	0.2243	±	0.0515	±	0.1081
Output from System	= O	= -	0.1331	±	0.1929	±	0.0442	±	0.0930
Decay	= D	= -	0.0217	±	0.0314	±	0.0072	±	0.0151
Lifetime in years	= T_L	=	46.1286	±	66.8453	±	15.3354	±	32.2196
Residence time in years	= T_R	=	6.4611	±	9.3629	±	2.1480	±	4.5129

Summary Equation for the System—

DDE	Mean C_2		Mean C_1	I	T_I	T_O	O	O_D	N
	6.3384	=	6.6310	(1.0 + 0.2725	+ 0.2343	- 0.2343	- 0.1331	- 0.0217)	3.1628

$$6.3384 = 6.6310\,(1.0 + 0.2725 + 0.2343 - 0.2343 - 0.1331 - 0.0217)^{3.1628}$$

Table 16. COMPARISON OF ESTIMATES OBTAINED FROM THE 16 AND 19 STATION DATA SETS AND USING ACTUAL PAIRED SAMPLE ANALYSES, STANDARD DEVIATIONS [S.D.] AND COEFFICIENTS OF VARIATIONS [C.V.] ARE INCLUDED.

	16 STATION DATA SET			19 STATION DATA SET		
	Estimate	S.D.	C.V. %	Estimate	S.D.	C.V. %
DDT						
$\bar{C}_1$ (ppb)	3.7137	± 3.4446	92.8	3.1274	± 3.4385	109.9
$\bar{C}_2$ (ppb)	15.2887	± 26.3645	172.4	16.2805	± 26.9909	165.8
Net	+ 0.3798	± 1.0000	263.3	+ 1.5788	± 1.0000	63.3
I	+ 0.5013	± 0.7556	150.7	+ 1.6811	± 0.9016	53.6
O + D	- 0.1215	± 0.2444	138.2	- 0.1023	± 0.0984	96.2
T_O	- 0.3534	± 0.2591	73.3	- 1.1012	± 0.1262	11.5
T_I	+ 0.3534	± 0.7409	209.6	+ 1.1012	± 0.8738	79.3
O	- 0.0857	± 0.1723	201.1	- 0.0670	± 0.0644	96.1
D	- 0.0358	± 0.0721	201.4	- 0.0353	± 0.0339	96.0
T_L (years)	27.9014	± 56.1105	201.1	28.3322	± 24.2386	96.1
T_R (years)	8.2294	± 16.5496	201.1	9.7724	± 9.3952	96.1
DDD						
$\bar{C}_1$ (ppb)	2.9137	± 3.0908	106.1	2.8589	± 2.9296	102.5
$\bar{C}_2$ (ppb)	2.6625	± 3.0921	116.1	2.4468	± 2.8805	117.7
Net	+ 0.1054	± 1.0000	948.8	+ 0.0820	± 1.0000	1219.5
I	+ 0.2417	± 0.7279	301.2	+ 0.2200	± 0.7233	328.8
O + D	- 0.1363	± 0.2721	199.6	- 0.1380	± 0.2767	200.5
T_O	- 0.2088	± 0.2721	130.3	- 0.1941	± 0.2767	142.6
T_I	+ 0.2088	± 0.7279	348.6	+ 0.1941	± 0.7233	5009.4
O	- 0.1177	± 0.2350	199.7	+ 0.1217	± 0.2441	200.6
D	- 0.0186	± 0.0371	199.5	- 0.0162	± 0.0326	201.2
T_L (years)	53.8306	± 107.4660	199.6	61.5459	± 123.4241	200.5
T_R (years)	7.3364	± 14.6462	199.6	7.2469	± 14.5330	200.5
DDE						
$\bar{C}_1$ (ppb)	6.0350	± 5.4299	90.0	6.6310	± 6.0673	91.5
$\bar{C}_2$ (ppb)	6.3887	± 6.2166	97.3	6.3384	± 5.7417	90.6
Net	+ 0.1368	± 1.0030	733.2	+ 0.1177	± 1.0024	851.7
I	+ 0.2950	± 0.7843	265.9	+ 0.2725	± 0.7781	285.5
O + D	- 0.1582	± 0.2186	138.2	- 0.1548	± 0.2243	144.9
T_O	- 0.2563	± 0.2211	86.3	- 0.2343	± 0.2262	96.5
T_I	+ 0.2563	± 0.7818	305.0	+ 0.2343	± 0.7761	332.1
O	- 0.1374	± 0.1899	138.2	- 0.1331	± 0.1929	144.9
D	- 0.0208	± 0.0287	138.0	- 0.0217	± 0.0314	144.7
T_L (years)	48.1189	± 66.4924	138.2	46.1286	± 66.8543	144.9
T_R (years)	6.3211	± 8.7347	138.2	6.4611	± 9.3629	144.9

$\bar{T}_2$ = mean time of second sampling period

T_1 = time of actual sampling in first sampling period

and $C_2 = \bar{C}_1 e^{KN}$ 10.

with $N = T_2 - \bar{T}_1$

T_2 = time of actual sampling in second sampling period

$\bar{T}_1$ = mean time of first sampling period.

Table 17 presents the estimates of the system obtained using this pairing with means approach. Once again the effect of substitution of a minimal value for zero concentrations was explored by eliminating stations with zero concentration thus providing the subset of 49 samples from the complete set of 57. Except for the estimates of T_O for DDT, there was no significant difference between the two sets of estimates once again, nor are these estimates significantly different from either of the sets of estimates based on the 16 and 19 station data sets. The principal effect of inclusion or exclusion of the zero level values with substitution of a minimal value is upon the estimates of the rates of input, I, translocation, T_I and T_O, and the net rate. The stations showing a zero concentration of DDT at time one show high positive rates of change, and therefore, have a particularly marked effect on the positive rate estimates as well as those based to at least some extent upon these positive rate estimates.

The second approach which uses sample values paired to mean values should find use in the analysis of systems where real paired values are impossible to obtain. Animals which are sacrificed at the time of sampling obviously can not be resampled at another point in time. The use of sample values at one sample time paired to the mean value of another permits estimation of system rates for the population. The comparison between the two approaches to these estimates that is presented here indicates that the use of mean values in pairing gives a close approximation of rate estimates obtained with real paired values.

Both of these approaches to the estimation of system rates are dependent upon variability in concentration level and rate of change within compartments. It is essential to these methods of analysis that individual compartments show the effect of the various processes to different degrees. If all the concentration levels and rates of change within compartments were the same, it would be possible to gain an estimate of net rate of change only. Therefore, these approaches to estimation of system rates are dependent upon variability in environmental samples of the system and make use of this variability for estimating the rates of the various processes.

Table 17. COMPARISON OF ESTIMATES OBTAINED FROM THE 49 AND 57 SAMPLE DATA SETS AND USING SAMPLE ANALYSES PAIRED TO MEAN CONCENTRATION LEVELS. STANDARD DEVIATIONS [S.D.] AND COEFFICIENTS OF VARIATIONS [C.V.] ARE INCLUDED.

	49 SAMPLE DATA SET			57 SAMPLE DATA SET		
	Estimate	S.D.	C.V. %	Estimate	S.D.	C.V. %
DDT						
$\bar{C}_1$ (ppb)	3.9576	± 4.1746	105.4	3.1019	± 4.0336	130.0
$\bar{C}_2$ (ppb)	15.4975	± 26.5034	171.0	15.4975	± 26.5034	171.0
Net	+ 0.5905	± 1.0000	169.3	+ 2.2567	± 1.0000	44.3
I	+ 0.6819	± 0.6374	93.5	+ 2.3233	± 0.9204	39.6
O + D	- 0.0913	± 0.3626	397.2	- 0.0667	± 0.0796	119.3
T_O	- 0.3234	± 0.3966	122.6	- 1.4256	± 0.1513	10.6
T_I	+ 0.3234	± 0.6034	186.6	+ 1.4256	± 0.8487	59.5
O	- 0.0433	± 0.1720	397.2	- 0.0409	± 0.0488	119.3
D	- 0.0480	± 0.1906	397.1	- 0.0258	± 0.0307	119.0
T_L (years)	20.8292	± 82.7111	397.1	38.8090	± 46.2947	119.3
T_R (years)	10.9502	± 43.4823	397.1	14.9951	± 17.8875	119.3
DDD						
$\bar{C}_1$ (ppb)	2.4107	± 2.5354	105.2	2.2743	± 2.3532	103.5
$\bar{C}_2$ (ppb)	2.3435	± 2.8415	121.3	2.3435	± 2.8415	121.3
Net	+ 0.1283	± 1.0000	779.4	+ 0.1587	± 1.0000	630.1
I	+ 0.2703	± 0.6357	235.2	+ 0.2813	± 0.6329	225.0
O + D	- 0.1420	± 0.3643	256.5	- 0.1226	± 0.3671	299.4
T_O	- 0.2095	± 0.3653	174.4	- 0.2039	± 0.3698	180.9
T_I	+ 0.2095	± 0.6347	303.0	+ 0.2039	± 0.6311	309.5
O	- 0.1101	± 0.2823	256.4	- 0.0889	± 0.2662	299.4
D	- 0.0319	± 0.0820	257.1	- 0.0337	± 0.1010	299.7
T_L (years)	31.3031	± 80.3119	256.6	29.6518	± 88.7883	299.4
T_R (years)	7.0424	± 18.0682	256.6	8.1558	± 24.4216	299.4
DDE						
$\bar{C}_1$ (ppb)	5.1138	± 4.4111	86.3	5.3681	± 4.8069	89.5
$\bar{C}_2$ (ppb)	6.1575	± 5.6469	91.7	6.1575	± 5.6469	91.7
Net	+ 0.1748	± 1.0010	572.7	+ 0.1793	± 1.0009	558.2
I	+ 0.2802	± 0.6628	236.5	+ 0.2785	± 0.6787	243.7
O + D	- 0.1054	± 0.3382	320.9	- 0.0993	± 0.3222	324.5
T_O	- 0.1946	± 0.3466	178.1	- 0.1906	± 0.3311	173.7
T_I	+ 0.1946	± 0.6544	336.3	+ 0.1906	± 0.6697	351.4
O	- 0.0732	± 0.2348	320.8	- 0.0679	± 0.2204	324.6
D	- 0.0322	± 0.1033	320.8	- 0.0314	± 0.1018	324.2
T_L (years)	31.0400	± 99.5728	320.8	31.8905	± 103.4957	324.5
T_R (years)	9.4853	± 30.4277	320.8	10.0735	± 32.6922	324.5

For any set of estimates of I, (O+D), T_I and T_O, based on a number of samples, n, there is a distribution of K's with a minimal variance. The members of the distribution can be determined through one of the following sets of equations:

Where the net rate of change, I + (O+D), is positive,

$$j = \frac{nI - nT_I}{I + (O+D)} \quad \text{and j is an integer obtained without rounding.} \qquad 11.$$

$$I + (O+D) + \frac{nT_I}{j} = K_1, K_2 \ldots K_j \qquad 12.$$

If $\sum_{1}^{j} K \angle nI$

$$nI - jK_1 = K_j + 1 \qquad 13.$$

$$\frac{n(O+D)}{n - j - 1} = K_j + 2, K_j + 3 \ldots K_n \qquad 14.$$

If $\sum_{1}^{j} K = nI$

$$\frac{n(O+D)}{n - j} = K_j + 1, K_j + 2 \ldots K_n \qquad 15.$$

Where the net rate of change, I + (O+D), is zero,

$$j = \frac{n}{2} \quad \text{and j is an integer obtained without rounding.} \qquad 16.$$

$$\frac{nT_I}{j} = K_1, K_2 \ldots K_j \qquad 17.$$

$$\frac{nT_O}{j} = K_j + 1, K_j + 2 \ldots K_{2j} \qquad 18.$$

If $2_j \angle n$,

$$K_n = 0.0 \qquad 19.$$

Where the net rate of change, I + (O+D), is negative,

$$j = \frac{n(O+D) - nT_O}{I + (O+D)} \qquad 20.$$

$$I + (O+D) + \frac{nT_O}{j} = K_1, K_2, \ldots K_j \qquad 21.$$

If $\sum_{1}^{j} K < n(O+D)$

$n(O+D) - jK_1 = K_j + 1$ 22.

$\frac{nI}{n-j-1} = K_{j+2}, K_{j+3} \ldots K_n$ 23.

If $\sum_{1}^{j} K = n(O+D)$

$\frac{n(I)}{n-j} = K_{j+1}, K_{j+2}, \ldots K_n$ 24.

The variances of such distributions are the minimal variances that will permit the estimations of I, T_I and T_O, and (O+D) with a given number of samples. This variance is less affected by the number of samples than it is by the difference between the values of I, T_I and T_O, and (O+D) as can be seen in Table 18. The lowest standard deviations are observed where T_I is low. Where I is increased relative to T_I, the standard deviation is reduced as well but not to the same extent. For example, I = 2.0, T_I = 1.2 has a ratio of 0.6 as does I = 1.5, T_I = 0.9, however, the latter has the lower standard deviation. The unavoidable variance related to any series of values of I, T_I and T_O, O+D, and n has significance to survey design. The greater the amount of internal translocation due to T_I and T_O the greater the unavoidable variance of the estimation of K. Increasing the number of sampling points has only a minor effect upon the variance although it has a marked effect upon the standard error and 95% confidence limits of the estimates.

The corrected standard deviations with associated standard errors and 95% confidence limits can be calculated using Subroutine FACTOR which will be found in the Appendix. The correction is imposed following the calculation of the standard deviation of K using equation 3, but only with respect to first moment as is true for the other estimations of standard deviations.

The variance is corrected as follows,

$$\left(\frac{s^2_{K\,calc.} - s^2_{Min.}}{s^2_{K\,calc.}}\right)^2 s^2_K = s^2_{K\,corr.} \qquad 25.$$

Where s^2_K is the variance calculated by equation 3, $s^2_{min.}$ is the variance of the distribution of K's with minimal variance, $s^2_{K\,calc.}$ is the variance of the distribution of K's calculated by equation 3, and $s^2_{K\,corr.}$ is the corrected variance of K. This correction appears to be justified because the variance of interest is that which is related to the variance of a system with particular characteristics as compared to a similar system with minimal unavoidable variance. Table 19 presents a comparison of uncorrected standard deviations from Tables 16 and 17 and the corresponding corrected values. The system estimates for

Table 18. STANDARD DEVIATIONS AND STANDARD ERRORS OF DISTRIBUTIONS OF K WITH MINIMAL VARIANCE FOR GIVEN VALUES OF I, T_I AND T_O, (O+D) AND n.

I	T_I	O+D	Net	n = 5 S.D.	n = 5 S.E.	n = 10 S.D.	n = 10 S.E.	n = 20 S.D.	n = 20 S.E.
2.00	1.20	-0.15	1.85	± 2.7524	± 1.2309	± 2.5965	± 0.8211	± 2.5338	± 0.5666
1.75	1.20	-0.15	1.60	± 3.4084	± 1.5243	± 2.7758	± 0.8778	± 2.7107	± 0.6061
1.50	1.20	-0.15	1.35	± 3.3586	± 1.5020	± 3.1663	± 1.0013	± 3.0831	± 0.6894
1.50	1.20	-0.30	1.20	± 3.3719	± 1.5080	± 3.1785	± 1.0051	± 2.8433	± 0.6358
1.50	1.20	-0.60	0.90	± 3.4249	± 1.5317	± 3.2267	± 1.0204	± 2.7077	± 0.6055
1.50	0.90	-0.15	1.35	± 2.0724	± 0.9268	± 1.9558	± 0.6185	± 1.9124	± 0.4276
1.50	0.60	-0.15	1.35	± 1.4335	± 0.6411	± 1.3528	± 0.4278	± 1.3063	± 0.2921

Table 19. COMPARISON OF UNCORRECTED AND CORRECTED STANDARD DEVIATIONS OF SYSTEM ESTIMATES

	16 Sample Set		19 Sample Set		49 Sample Set		57 Sample Set	
	Uncorrected	Corrected	Uncorrected	Corrected	Uncorrected	Corrected	Uncorrected	Corrected
DDT								
Net	± 1.0000	± 0.2751	± 1.0000	± 0.5986	± 1.0000	± 0.3366	± 1.0000	± 0.5379
I	± 0.7556	± 0.2806	± 0.9016	± 0.5397	± 0.6374	± 0.2145	± 0.9204	± 0.4951
O + D	± 0.2444	± 0.0907	± 0.0984	± 0.0589	± 0.3626	± 0.1221	± 0.0796	± 0.0428
T_O	± 0.2591	± 0.0962	± 0.1262	± 0.0755	± 0.3966	± 0.1335	± 0.1513	± 0.0814
T_I	± 0.7409	± 0.2751	± 0.8738	± 0.5231	± 0.6034	± 0.2031	± 0.8487	± 0.4565
O	± 0.1723	± 0.0640	± 0.0644	± 0.0386	± 0.1720	± 0.0579	± 0.0488	± 0.0263
D	± 0.0721	± 0.0268	± 0.0339	± 0.0203	± 0.1906	± 0.0642	± 0.0307	± 0.0165
T_L	± 56.1105	±20.8365	± 27.2386	±16.3047	±82.7111	±27.8380	± 46.2947	±24.9713
T_R	± 16.5496	± 6.1457	± 9.3952	± 5.6239	±43.4823	±14.6348	± 17.8875	± 9.6215
DDD								
Net	± 1.0000	± 0.3604	± 1.0000	± 0.3860	± 1.0000	± 0.3419	± 1.0000	± 0.3521
I	± 0.7279	± 0.2623	± 0.7233	± 0.2792	± 0.6357	± 0.2174	± 0.6329	± 0.2228
O + D	± 0.2721	± 0.0981	± 0.2767	± 0.1068	± 0.3643	± 0.1246	± 0.3671	± 0.1293
T_O	± 0.2721	± 0.0981	± 0.2767	± 0.1068	± 0.3653	± 0.1249	± 0.3689	± 0.1299
T_I	± 0.7279	± 0.2623	± 0.7233	± 0.2792	± 0.6347	± 0.2170	± 0.6311	± 0.2222
O	± 0.2350	± 0.0847	± 0.2441	± 0.0942	± 0.2823	± 0.0965	± 0.2662	± 0.0937
D	± 0.0371	± 0.0134	± 0.0326	± 0.0126	± 0.0820	± 0.0280	± 0.1010	± 0.0356
T_L	±107.4660	±38.7279	±123.4241	±47.6463	±80.3119	±27.4603	± 88.7883	±31.2619
T_R	± 14.6462	± 5.2781	± 14.5330	± 5.6103	±18.0682	± 6.1779	± 24.4216	± 8.5987
DDE								
Net	± 1.0030	± 0.3602	± 1.0024	± 0.4716	± 1.0010	± 0.4379	± 1.0009	± 0.4545
I	± 0.7843	± 0.2817	± 0.7781	± 0.3661	± 0.6628	± 0.2900	± 0.6787	± 0.3082
O + D	± 0.2186	± 0.0785	± 0.2243	± 0.1055	± 0.3382	± 0.1479	± 0.3222	± 0.1463
T_O	± 0.2211	± 0.0794	± 0.2262	± 0.1064	± 0.3466	± 0.1516	± 0.3311	± 0.1504
T_I	± 0.7818	± 0.2808	± 0.7761	± 0.3651	± 0.6544	± 0.2863	± 0.6697	± 0.3041
O	± 0.1899	± 0.0682	± 0.1929	± 0.0907	± 0.2348	± 0.1027	± 0.2204	± 0.1001
D	± 0.0287	± 0.0103	± 0.0314	± 0.0148	± 0.1033	± 0.0452	± 0.1018	± 0.0462
T_L	± 66.4924	±23.8815	± 66.8543	±31.4484	±99.5728	±43.5593	±103.4957	±46.9942
T_R	± 8.7347	± 3.1372	± 9.3629	± 4.4049	±30.4277	±13.3109	± 32.6922	±14.8445

DDT obtained from the four data sets did show some significant differences when compared using these corrected estimates of the standard deviation. The estimates obtained with the 49 and 57 sample sets were significantly different at the .05 level for Net, I, T_O, and T_I. The estimates obtained with the 16 and 57 sample sets were significantly different for Net, I, and T_O, and the estimates of T_O for the 19 and 57 data sets were also significantly different. These differences would appear to be primarily the result of inclusion or exclusion from the system of sites where there are major increases in the concentration of DDT rather than the effect of substitution of a minimal value for the concentration at time one. The estimation of T_O in systems showing a positive Net rate of change are particularly sensitive to significance testing due to their relatively low standard deviations that result from the distribution of variance between T_I and T_O.

If we keep in mind the limitations imposed by the variability of the data, the estimates can be used to gain a picture of the flux of these pollutants in the study area. The area of south Monterey Bay is approximately 280 square kilometers, or 69,190 acres in size. The density of the sediments on a dry weight basis averages 1.32 grams per cm^3. Table 20 gives the mean of the estimates for system concentrations and rates that were obtained by the two approaches to analysis and the four data sets. Standard deviations, standard errors, 95% confidence limits, and coefficients of variation for these means are included. These latter descriptive statistics refer only to the variation of the estimates and do not include the effect of compartment variability discussed above.

Table 21 uses the mean of the estimates and gives the total amounts of these chlorinated hydrocarbons in the area and the concentration in pounds per acre based upon the mean concentrations at the two times of sampling. These total amounts are estimated as being present in the top 10 cm of sediment, a depth generally sampled with the collecting gear used. Considering that the usual level of application on land is 2 pounds to the acre the total level of these compounds per acre has reached somewhat more than 1/100 of the land applications level.

The estimated annual rates of input, I, as seen in Table 20, average 130% for DDT, 25% for DDD, and 28% for DDE. The corresponding amounts of these materials expected in the next year are indicated in Table 21. Expected loss due to translocation, output, and decay based on the estimated annual rates, O+D, 10% for DDT, 13% for DDD, and 13% for DDE, are also shown. The resulting net effect for the year period following the last sample time in 1973 gives the expected values shown, Table 21. The expected change in the amount of the total chlorinated hydrocarbons derived from DDT amounts to an increase of 182%. The amounts translocated within the system are presented in Table 21 along with a separation of the expected loss into that expected from output and decay. All of the projections, of course, assume that the estimated rates reflecting flux of these materials in the past three years will persist for the next year period.

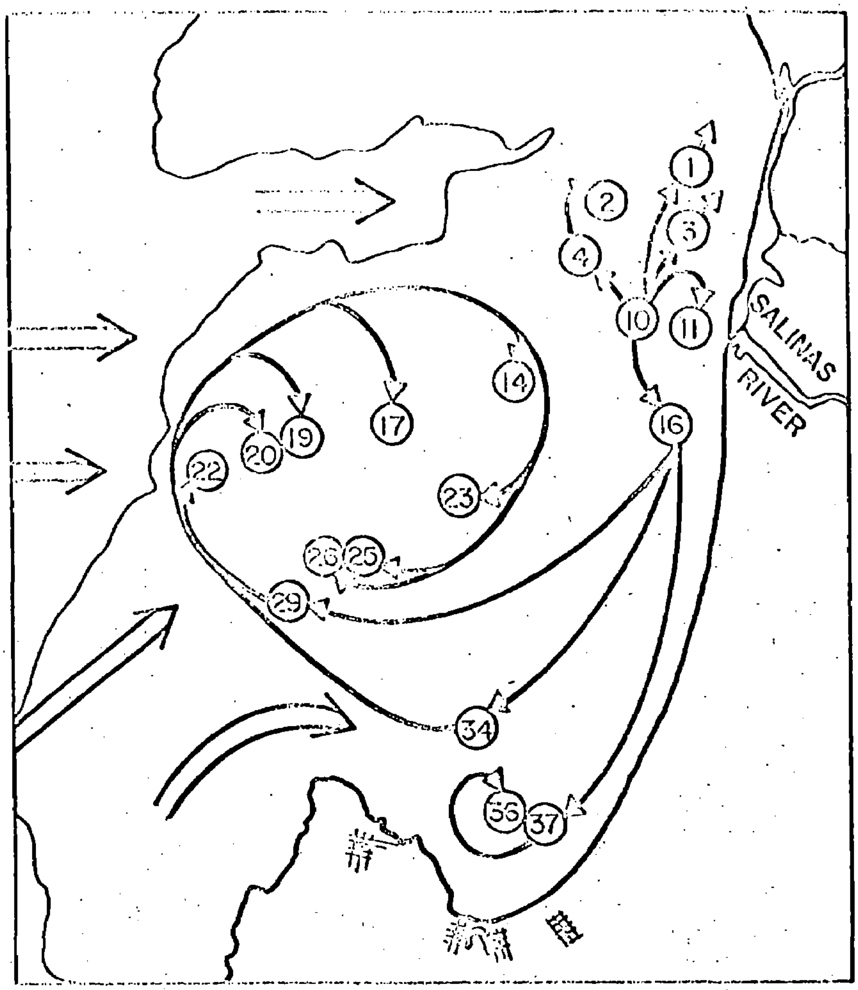
The K values for the individual compartments can also be used to present a composite view of the translocation of the three compounds within the system and principal points of geographical exit. The stations at their geographical location are connected with arrows pointing from more negative to less negative K values and ending in basins with positive K values. The result is a kinematic graph representing the movement of these materials within the system. It is composite with respect to the time interval under consideration and would appear to represent the result of several events of translocation. Figure 8 presents such a graph developed for the 19 station data set. The large double arrows indicate the main offshore forces that drive the inshore circulation and correlated with the kinematic expression of circulation within the system.

Table 20. MEAN OF THE ESTIMATES FOR THE SOUTH MONTEREY BAY SYSTEM AND ASSOCIATED DESCRIPTIVE STATISTICS.

			Mean	S.D.	S.E.	95% C.L.	C.V. %
C_1	DDT	(ppb)	3.4752	± 0.4281	± 0.2141	± 0.6812	12.3
	DDD	(ppb)	2.6144	± 0.3196	± 0.1598	± 0.5086	12.2
	DDE	(ppb)	5.7870	± 0.6837	± 0.3419	± 1.0878	11.8
C_2	DDT	(ppb)	15.6411	± 0.4375	± 0.2188	± 0.6961	2.8
	DDD	(ppb)	2.4491	± 0.1504	± 0.0752	± 0.2393	6.1
	DDE	(ppb)	6.2605	± 0.1207	± 0.0604	± 0.1921	1.9
Net	DDT		+ 1.2015	± 0.8764	± 0.4382	± 1.3944	72.9
	DDD		+ 0.1186	± 0.0327	± 0.0164	± 0.0521	27.6
	DDE		+ 0.1522	± 0.0298	± 0.0149	± 0.0475	19.6
I	DDT		+ 1.2969	± 0.8587	± 0.4294	± 1.3663	66.2
	DDD		+ 0.2533	± 0.0278	± 0.0139	± 0.0442	11.0
	DDE		+ 0.2816	± 0.0096	± 0.0048	± 0.0152	3.4
O + D	DDT		- 0.0955	± 0.0096	± 0.0114	± 0.0364	24.0
	DDD		- 0.1347	± 0.0229	± 0.0042	± 0.0134	6.2
	DDE		- 0.1294	± 0.0084	± 0.0157	± 0.0499	27.3
T_O & T_I	DDT		± 0.8009	± 0.5504	± 0.2752	± 0.8756	68.7
	DDD		± 0.2041	± 0.0071	± 0.0036	± 0.0113	3.5
	DDE		± 0.2190	± 0.0318	± 0.0159	± 0.0505	14.5
O	DDT		- 0.0592	± 0.0212	± 0.0106	± 0.0338	35.8
	DDD		- 0.1096	± 0.0146	± 0.0073	± 0.0233	13.3
	DDE		- 0.1029	± 0.0375	± 0.0187	± 0.0596	36.4
D	DDT		- 0.0362	± 0.0091	± 0.0045	± 0.0145	25.1
	DDD		- 0.0251	± 0.0090	± 0.0143	± 0.0143	35.9
	DDE		- 0.0265	± 0.0061	± 0.0031	± 0.0097	23.0
T_L	DDT	(years)	28.9680	± 7.4078	± 3.7039	± 11.7858	25.6
	DDD	(years)	44.0829	± 16.0370	± 8.0185	± 25.5148	36.4
	DDE	(years)	39.2945	± 9.0835	± 4.5418	± 14.4519	23.1
T_R	DDT	(years)	10.9868	± 2.8952	± 1.4476	± 4.6062	26.4
	DDD	(years)	7.4454	± 0.4893	± 0.2447	± 0.7785	6.6
	DDE	(years)	8.0853	± 1.9717	± 0.9859	± 3.1371	24.4

Table 21. TOTAL AMOUNTS OF DDT, DDD, AND DDE IN THE SOUTH MONTEREY BAY STUDY AREA BASED ON THE MEAN CONCENTRATIONS AT THE TWO SAMPLE TIMES, AND EXPECTED AMOUNTS AFFECTED BY THE MEAN OF THE ESTIMATES OF SYSTEM RATES.

		Kilograms	Pounds	Pounds/Acre
Amount at Sample Time 1	DDT	128	284	0.004
	DDD	97	213	0.003
	DDE	214	472	0.007
	TOTAL	439	969	0.014
Amount at Sample Time 2, 3 years later	DDT	579	1276	0.018
	DDD	91	200	0.003
	DDE	232	511	0.007
	TOTAL	932	1987	0.028
Expected input for next year interval	DDT	753	1659	0.024
	DDD	23	50	0.001
	DDE	65	143	0.002
	TOTAL	841	1852	0.027
Expected loss for next year interval	DDT	58	128	0.0018
	DDD	12	26	0.0004
	DDE	30	66	0.0010
	TOTAL	100	220	0.0032
Expected amounts due to Net change for next year interval	DDT	1274	2807	0.041
	DDD	102	224	0.003
	DDE	267	588	0.008
	TOTAL	1643	3619	0.052
Expected amount translocated within the system in next year interval	DDT	463	1020	0.015
	DDD	18	40	0.001
	DDE	51	112	0.002
	TOTAL	532	1172	0.018
Expected amount Output to other systems in next year interval	DDT	35	77	0.0011
	DDD	7	22	0.0003
	DDE	23	51	0.0007
	TOTAL	65	150	0.0021
Expected amount Decayed in next time interval	DDT	21	46	0.0007
	DDD	2	5	0.0001
	DDE	6	14	0.0002
	TOTAL	29	65	0.0010



CIRCULATION OF DDT DERIVATIVES

FIGURE 8. Composite chart of the translocation of DDT compounds based upon the rates of change, K, at individual stations in the southern portion of Monterey Bay.

DEVELOPMENT OF LABORATORY ASSAY METHODS FOR DETERMINATION OF DECAY RATE

Of the various preparations tested for the assay of decay rate, the sealed hypovial preparations described in the Methods section have best met the following desired criteria. (1) Preparations must be capable of being sealed to prevent loss of the chlorinated hydrocarbon and its degradation products including CO_2. (2) The containers must be readily sterilized and of materials that prevent contamination by other chlorinated hydrocarbons. (3) The preparations must be easily manipulated with respect to the establishment of aerobic and anaerobic conditions. (4) The preparation must be susceptible to replication both in terms of individual preparations and aliquots from the same preparation.

The most convenient estimate of decay can be obtained by measurement of the amount of $^{14}CO_2$ produced from ring labelled substrate after an interval of time. Knowing the initial concentrations of substrate the decay to carbon dioxide can be expressed as a decimal fraction of this initial concentration. The decimal fraction is the D_{CO_2}. Table 22 presents the results of an assay of DDT to CO_2 under aerobic conditions at 10°C. Two aliquots from each of five preparations at four concentrations of DDT were analysed for their $^{14}CO_2$ content. There is no significant difference between the D_{CO_2} measurements at the four concentrations of DDT. Therefore, over the range from 100 parts per billion to 100 parts per million there was neither a stimulation of the decay process nor a saturation of the decay process by substrate. Table 23 presents the results of assays for D_{CO_2} of DDT, DDD, and DDE. This Table also includes the results of assays in which the effect of environmental variables on the D_{CO_2} was determined.

The Q_{10} for D_{CO_2} of DDT calculated from the aerobic 10° and 20° assays is 2.50. The remaining assays where DDT is the substrate were designed to determine the participation of various physiologically different microbiol populations in the decay process. Aerobic conditions without additional nutrients gave the maximum D_{CO_2}. The decay process was inhibited by anaerobiosis, but a rate 27% of the aerobic rate remained. The addition of nitrate as an additional electron acceptor under anaerobic conditions permitted an increase in the anaerobic rate. The three highest concentrations of nitrate, 5 X 10^{-1}% to 5 X 10^{-3}% were inhibitory but below these concentrations the anaerobic rate becomes 68% of the aerobic rate at 5 X 10^{-5}% sodium nitrate.

The addition of a possible cometabolite, sodium acetate, somewhat removes the inhibitory effect of 5 X 10^{-1}% sodium nitrate probably by its lowering of the nitrate level through denitrification. However, at none of the levels of sodium acetate tested did the anaerobic rate reach the level with 5 X 10^{-5}% sodium nitrate alone. The effect of the addition of cometabolites on decay in the presence of nitrate reducing systems must be tested at lower concentrations of nitrate.

Sulfate, present in the seawater, was available as an electron acceptor under anaerobic conditions. Attempts to stimulate sulfate reduction systems by the addition of ethanol under anaerobic conditions were successful. However, the anaerobic decay of DDT was not increased over the rate observed with optimum nitrate concentrations and in the absence of added electron donors such as sodium acetate.

Table 22. RESULTS OF A LABORATORY ASSAY OF ANNUAL RATE OF DECAY OF DDT TO CO_2, D_{CO_2}, EXPRESSED AS A DECIMAL FRACTION OF THE INITIAL CONCENTRATION OF DDT MAINTAINED AT 10°C. UNDER AEROBIC CONDITIONS.

DDT	Prepar.	D_{CO_2}	Means	S.D.	Means	S.D.	Mean	S.D.
100 ppm	1	.0046						
	1	.0045	.00455	± .000071				
	2	.0048						
	2	.0042	.00450	± .000424				
	3	.0059						
	3	.0056	.00575	± .000212				
	4	.0050						
	4	.0045	.00475	± .000354				
	5	.0046						
	5	.0053	.00495	± .000495	.00490	± .000544		
10 ppm	1	.0050						
	1	.0052	.00510	± .000141				
	2	.0058						
	2	.0048	.00530	± .000707				
	3	.0045						
	3	.0056	.00505	± .000778				
	4	.0056						
	4	.0057	.00565	± .000071				
	5	.0051						
	5	.0056	.00535	± .000354	.00529	± .000436		
1 ppm	1	.0050						
	1	.0059	.00545	± .000636				
	2	.0045						
	2	.0046	.00455	± .000071				
	3	.0062						
	3	.0057	.00595	± .000354				
	4	.0058						
	4	.0052	.00550	± .000424				
	5	.0063						
	5	.0058	.00605	± .000354	.00550	± .000638		
100 ppb	1	.0057						
	1	.0057	.00570	± .0000				
	2	.0045						
	2	.0047	.00460	± .000141				
	3	.0051						
	3	.0051	.00510	± .0000				
	4	.0055						
	4	.0058	.00565	± .000212				
	5	.0063						
	5	.0053	.00580	± .000707	.00537	± .000542	.00527	± .000570

Table 23. RESULTS OF LABORATORY ASSAYS OF THE ANNUAL RATES OF DECAY TO CO_2, D_{CO_2}, AND THE EFFECT OF ENVIRONMENTAL VARIABLES ON THE PROCESS.

Conditions	Substrate	D_{CO_2}	Mean	S.D.
Aerobic, 10°C	DDT 100 ppm	.0050		
	10 ppm	.0053		
			.00529	± .00023
	1 ppm	.0055		
	100 ppb	.0054		
Aerobic, 20°C	DDT 100 ppm	.0100		
	10 ppm	.0111		
			.01320	± .00335
	1 ppm	.0167		
	100 ppb	.0154		
			Q_{10} 2.50	
Anaerobic, 10°C	DDT 100 ppm	.0012		
	10 ppm	.0013		
			.00145	± .00027
	1 ppm	.0015		
	100 ppb	.0018		
Anaerobic, 10°C	DDT 10 ppm	.0013		
5×10^{-1}% $NaNO_3$	1 ppm	.0016	.00150	± .00017
	100 ppb	.0016		
5×10^{-2}% $NaNO_3$	DDT 10 ppm	.0017		
	1 ppm	.0018	.00183	± .00015
	100 ppb	.0020		
5×10^{-3}% $NaNO_3$	DDT 10 ppm	.0024		
	1 ppm	.0024	.00250	± .00017
	100 ppb	.0027		
5×10^{-4}% $NaNO_3$	DDT 10 ppm	.0030		
	1 ppm	.0036	.00340	± .00035
	100 ppb	.0036		
5×10^{-5}% $NaNO_3$	DDT 10 ppm	.0037		
	1 ppm	.0034	.00360	± .00017
	100 ppb	.0037		
5×10^{-6}% $NaNO_3$	DDT 10 ppm	.0036		
	1 ppm	.0025	.00310	± .00056
	100 ppb	.0032		
5×10^{-7}% $NaNO_3$	DDT 10 ppm	.0031		
	1 ppm	.0032	.00313	± .00006
	100 ppb	.0031		

Table 23. CONTINUED (SECOND OF THREE PAGES)

Conditions	Concentration	D_{CO_2}	Mean	S.D.
Anaerobic, 10°C, 5×10^{-1}% Na NO_3				
5×10^{-1}% Na Acetate	DDT 10 ppm	.0011		
	1 ppm	.0008	.00090	± .00017
	100 ppb	.0008		
5×10^{-2}% Na Acetate	DDT 10 ppm	.0008		
	1 ppm	.0008	.00087	± .00012
	100 ppb	.0010		
5×10^{-3}% Na Acetate	DDT 10 ppm	.0022		
	1 ppm	.0022	.00223	± .00006
	100 ppb	.0023		
5×10^{-4}% Na Acetate	DDT 10 ppm	.0022		
	1 ppm	.0025	.00237	± .00015
	100 ppb	.0024		
5×10^{-5}% Na Acetate	DDT 10 ppm	.0022		
	1 ppm	.0023	.00227	± .00006
	100 ppb	.0023		
5×10^{-6}% Na Acetate	DDT 10 ppm	.0019		
	1 ppm	.0022	.00213	± .00021
	100 ppb	.0023		
5×10^{-7}% Na Acetate	DDT 10 ppm	.0024		
	1 ppm	.0024	.00240	± .00000
	100 ppb	.0024		
Aerobic, 10°C				
5×10^{-1}% Na Acetate	DDT 10 ppm	.0031		
	1 ppm	.0033	.00317	± .00012
	100 ppb	.0031		
5×10^{-2}% Na Acetate	DDT 10 ppm	.0034		
	1 ppm	.0031	.00307	± .00035
	100 ppb	.0027		
5×10^{-3}% Na Acetate	DDT 10 ppm	.0025		
	1 ppm	.0023	.00237	± .00012
	100 ppb	.0023		

Table 23. CONTINUED (THIRD OF THREE PAGES)

Conditions	Concentration	D_{CO_2}	Mean	S.D.
5 x 10^{-4}% Na Acetate	DDT 10 ppm	.0028		
	1 ppm	.0030	.00297	± .00015
	100 ppb	.0031		
5 x 10^{-5}% Na Acetate	DDT 10 ppm	.0027		
	1 ppm	.0030	.00287	± .00015
	100 ppb	.0029		
5 x 10^{-6}% Na Acetate	DDT 10 ppm	.0025		
	1 ppm	.0027	.00270	± .00020
	100 ppb	.0029		
5 x 10^{-7}% Na Acetate	DDT 10 ppm	.0028		
	1 ppm	.0030	.00277	± .00025
	100 ppb	.0025		
Anaerobic, 10°C				
5 x 10^{-1}% Ethanol	DDT 10 ppm	.0007		
	1 ppm	.0005	.00043	± .00031
	100 ppb	.0001		
5 x 10^{-2}% Ethanol	DDT 10 ppm	.0027		
	1 ppm	.0028	.00273	± .00006
	100 ppb	.0027		
5 x 10^{-3}% Ethanol	DDT 10 ppm	.0034		
	1 ppm	.0031	.00307	± .00035
	100 ppb	.0027		
5 x 10^{-4}% Ethanol	DDT 10 ppm	.0029		
	1 ppm	.0030	.00297	± .00006
	100 ppb	.0030		
5 x 10^{-5}% Ethanol	DDT 10 ppm	.0034		
	1 ppm	.0032	.00320	± .00020
	100 ppb	.0030		
5 x 10^{-6}% Ethanol	DDT 10 ppm	.0022		
	1 ppm	.0023	.00230	± .00010
	100 ppb	.0024		
5 x 10^{-7}% Ethanol	DDT 10 ppm	.0023		
	1 ppm	.0022	.00233	± .00015
	100 ppb	.0025		
Aerobic, 10°C	DDD 100 ppm	.0016		
	10 ppm	.0015	.00173	± .00000
	1 ppm	.0015		
	100 ppb	.0023		
Aerobic, 10°C	DDE 100 ppm	.0030		
	10 ppm	.0028	.00325	± .00058
	1 ppm	.0031		
	100 ppb	.0041		

Table 24. RATES OF DECAY TO WATER SOLUBLE COMPOUNDS AND CO_2 DETERMINED BY LABORATORY ASSAYS.

Laboratory Assays	DDT		DDD		DDE	
		S.D.		S.D.		S.D.
D_{CO_2}	.00529	± .00023	.00173	± .00036	.00325	± .00058
D_{WS}	.01539	± .000817	.00309	± .00052	.00459	± .00074
Laboratory Assays Corrected by Q_{10}						
D_{CO_2}	.00600	± .00026	.00196	± .00041	.00369	± .00066
D_{WS}	.01746	± .00093	.00351	± .00059	.00521	± .00084
Estimations from Field Data						
D	.0362		.0251		.0265	

The addition of sodium acetate as an extra electron donor under aerobic conditions was inhibitory to the aerobic decay process. However, since there was hydrogen sulfate produced in these preparations the inhibition may have been due to the competition for the available oxygen and the production of anaerobic conditions.

In summary, decay to CO_2 appears to be primarily due to the activity of aerobic microorganisms. The process attains the greatest rate where there is no unusual competition for oxygen. Since the known mechanisms for splitting aromatic rings involve the addition of oxygen to the aromatic nucleus prior to splitting, these observations are not unexpected. However, some considerable activity remains under anaerobic conditions even where an additional oxidizable substrate such as sodium acetate or ethanol is present to remove any traces of residual oxygen. The results also indicate that nitrate and sulfate may be acceptable electron acceptors in the oxidation of aromatic compounds under anaerobic conditions. The mechanisms for anaerobic ring split have not been elucidated. Finally, The Q_{10} for the decay process under aerobic conditions presents no surprise as to its magnitude.

A comparison of the D_{CO_2} for DDT, DDD, and DDE reveals a similar relationship to the total decay rates, D, estimated for South Monterey Bay in that $D_{DDT,CO_2} > D_{DDE,CO_2} > D_{DDD,CO_2}$ just as $D_{DDT} > D_{DDE} > D_{DDD}$. See Table 24.

For purposes of analysis the process of decay can be divided into a series of steps as follows,

$$\text{DDT} \xrightarrow{D_{LS}} \text{LS} \xrightarrow{D_{WS}} \text{WS} \xrightarrow{D_{CO_2}} CO_2$$

$$\text{DDD} \xrightarrow{D_{LS}} \text{LS} \xrightarrow{D_{WS}} \text{WS} \xrightarrow{D_{CO_2}} CO_2$$

$$\text{DDE} \xrightarrow{D_{LS}} \text{LS} \xrightarrow{D_{WS}} \text{WS} \xrightarrow{D_{CO_2}} CO_2$$

where LS represents lipid soluble degradation products of the starting compound and WS represents water soluble degradation products of the starting compound.

Water soluble degradation products were measured as water soluble ^{14}C after high speed centrifugation of samples from the initial preparations followed by acidification to remove $^{14}CO_2$.

D_{WS} values presented in Table 24 are based on the sum of the ^{14}C present in water soluble form plus that present as $^{14}CO_2$. Attempts at determining the amount of lipid soluble degradation products were unsuccessful. The high levels of the starting compound still present in the preparations made quantification by gas chromatography difficult. Thin layer chromatography was more successful but revealed that the sodium hydroxide added to stop further biological breakdown and to absorb $^{14}CO_2$ from the gas phase caused conversion of a considerable amount of the DDT to DDD.

While laboratory assays of decay rate have revealed rates compatible with the field estimation, it has not been possible to use this approach for full appraisal of the method of estimation of field rates. If we take the difference between the values of D_{WS} obtained from laboratory assays and D obtained from field estimations the rates of decay of the parent compounds to lipid soluble breakdown products, D_{LS}, are .0187 for DDT, .0216 for DDD, and .0213 for DDE under aerobic conditions at 11°C, the mean temperature of the sediments. It should be noted that although every precaution was taken to ensure purity of starting materials in laboratory assays, the amounts of decomposition in three month periods is extremely small and trace contaminants containing labell could have a large effect upon the results. In addition it must be emphasized that conditions in laboratory preparations poorly approximate conditions in the field. Therefore, their value is more in terms of results obtained by comparisons between preparations rather than comparisons between laboratory preparation and field observation.

SECTION VI

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APPENDIX

Program for estimating system rates based on real paired sample values.

This program for calculation of estimates of rates of input, output, translocation, and decay was written in Fortran IV level G, and was run on an IBM 360/67. In our experience 112k was used and the program required approximately 40 seconds per run. A maximum of 60 stations, 7 chemical compounds, and 2 sample times is permitted with the program as written.

The time interval is calculated in the subroutine, LEAPYR, through use of a calendar table described below. K values are calculated using double precision, and confidence intervals are estimated through use of a table of "t values."

There are eight cards which precede the data deck. Their formats and content are as follows:

First three cards, FORMAT (1X,13F6.3/13F6.3/4F6.3), contain the table of t values. The following numbers are punched using the indicated format:
First card, 12.706 4.303 3.182 2.776 2.571 2.447 2.365 2.306 2.262 2.228 2.201 2.179 2.160
Second card, 2.145 2.131 2.120 2.110 2.101 2.093 2.086 2.080 2.074 2.069 2.064 2.060 2.056
Third card, 2.052 2.048 2.045 2.042.

Fourth card, FORMAT (12I4), contains numbers for calculation of time intervals. The following numbers are punched using the indicated format:
0 31 59 90 120 151 181 212 243 273 304 334.

Fifth card, FORMAT (2I5), contains the number of stations followed by the number of chemical compounds in the data set.

Sixth through eighth cards, FORMAT (10A8), contain the names of the chemical compounds entered, left justified, followed by the word TOTAL, followed by the concentration level repeated once for each chemical compound. Any remaining portion of the three cards is left blank. The set of name cards used with the data analyzed in the present case was as follows:

First Card
DDT DDD DDE TOTAL PPB PPB PPB PPB PERCENT PERCENT

Second Card
PERCENT

The third card was left blank.

The data is organized using FORMAT (1X,I2,2(A4,A2),I2,2(1X,I2),7F7.2). The first variable is the station number. The next six fields store the location in terms of latitude and longitude. The next three variables store the month, day, and year, and the remaining fields store the measured concentrations of each chemical compound.

An optional subroutine FACTOR may be called by placing a card before the END card with CALL FACTOR.

```
      C     PROGRAM FOR ESTIMATING SYSTEM RATES BASED ON
      C     REAL PAIRED SAMPLE VALUES.
      C
0001        DIMENSION TABLE(30),MONTH(12),ALOC(2,60,6),TOT(10,8),STD(23,8)
           1, STE(23,8),CL95(23,8),VAR1(7),VAR2(7),VAR3(7),SUM1(7),SUM2(
           27),SUM3(7),SUM4(7),COV1(7),COV2(7)
0002        REAL *4MEAN,MR(7),M(17,8)
0003        REAL *8X(10,60,7),V2(60,7),NAME(23),V1(7)
0004        INTEGER CST(2,60),CDATE(2,60,3)
0005        COMMON X, TABLE,IA,I,K,KD,ID
0006        COMMON/BLK1/NAME,TOT,M,STD,STE,CL95,ALOC,YR,CST,CDATE,MONTH,L1,L
0006        COMMON/BLK2/MR
0007        READ (5,45) TABLE
0008        READ (5,46) MONTH
0009        READ (5,47) IA,ID
      C
      C     CALCULATE INDEXES.
      C     AI                 NUMBER OF STATIONS CONVERTED TO A REAL NUMBER
      C     IP1                ID + 1
      C     IP2                ID + 2
      C     I2TP2              2 * ID + 2
      C     I2TP3              2 * ID + 3
      C     I3TP2              3 * ID + 2
0010        AI=IA
0011        IP1=ID+1
0012        IP2=ID+2
0013        I2TP2=2*ID+2
0014        I2TP3=2*ID+3
0015        I3TP2=3*ID+2
      C
      C     CLEAR X ARRAY.
      C
0016        DO 1 I=1,10
      C
0017        DO 1 J=1,IA
      C
0018        DO 1 K=1,IP1
0019      1 X(I,J,K)=0.0
      C
0020        WRITE (6,50)
      C
      C     READ IN DERIVATIVE NAMES AND CONCENTRATION LEVEL ON UP TO 3 CARDS.
0021        READ (5,48) NAME
      C
      C     READ IN DATA.
      C
```

```
      DO 2 I=1,2
C
      DO 2 J=1,IA
    2 READ (5,49) CST(I,J),(ALOC(I,J,L),L=1,6),(CDATE(I,J,L),L=1,3),(X(I
     1,J,K),K=1,ID)
C
C
C     COMPUTE TOTAL OF EACH STATION.
C
      DO 3 I=1,2
C
      DO 3 J=1,IA
C
      DO 3 L=1,ID
    3 X(I,J,IP1)=X(I,J,L)+X(I,J,IP1)
C
C
C     WRITE HEADING OF FIRST TWO PAGES.
C
      DO 5 I=1,2
      L=I
      WRITE (6,51) I
      WRITE (6,53) (NAME(N),N=1,IP1)
      WRITE (6,52) (NAME(N),N=IP2,I2TP2)
      WRITE (6,54)
C
      DO 4 K=1,IP1
      CALL STDEV (TOTAL,MEAN,SD,SE,CL)
      TOT(I,K)=TOTAL
      M(I,K)=MEAN
      STD(I,K)=SD
      STE(I,K)=SE
    4 CL95(I,K)=CL
C
C     L1=NUMBER OF SETS COMPUTED.
C
C     WRITE FIRST TWO PAGES.
      L1=IP1
      CALL PRINT
      WRITE (6,53) (NAME(N),N=1,IP1)
      WRITE (6,52) (NAME(N),N=IP2,I2TP2)
      WRITE (6,54)
      CALL PRINT2
    5 CONTINUE
C
C
C     COMPUTE PERCENTS.
C
```

```
      DO 8 I=3,4
      L1=ID
      L=I-2
      WRITE (6,51) L
      WRITE (6,53) (NAME(N),N=1,ID)
      WRITE (6,52) (NAME(N),N=I2TP3,I3TP2)
      WRITE (6,54)
C
      DO 6 K=1,ID
C
      DO 6 J=1,IA
    6 X(I,J,K)=X(L,J,K)/X(L,J,IP1)*100.
C
C
      DO 7 K=1,3
      CALL STDEV (TOTAL,MEAN,SD,SE,CL)
      TOT(I,K)=TOTAL
      M(I,K)=MEAN
      STD(I,K)=SD
      STE(I,K)=SE
    7 CL95(I,K)=CL
C
      CALL PRINT
      WRITE (6,53) (NAME(N),N=1,ID)
      WRITE (6,52) (NAME(N),N=I2TP3,I3TP2)
      WRITE (6,54)
      CALL PRINT2
    8 CONTINUE
C
C
      DO 10 J=1,IA
C
      DO 10 L=1,IA
      IF (CST(1,J).EQ.CST(2,L)) GO TO 9
      GO TO 10
    9 CALL LEAPYR (J)
C
      DO 10 K=1,ID
      X(5,J,K)=YR
   10 CONTINUE
C
C
C     CALCULATE TOTAL AND MEAN OF N.
C
```

```
      DO 12 K=1,ID
      TOT(5,K)=0.
C
      DO 11 J=1,IA
   11 TOT(5,K)=TOT(5,K)+X(5,J,K)
C
   12 M(5,K)=TOT(5,K)/AI
C
C
      DO 14 K=1,ID
      V=0.0
C
      DO 13 J=1,IA
   13 V=(M(5,K)-X(5,J,K))**2+V
C
      STD(5,K)=SQRT(V/(AI-1.0))
   14 CALL STDEV2 (STD(5,K),STE(5,K),CL95(5,K))
C
C
C     CALCULATE K VALUES.
C
      DO 15 K=1,ID
      SUM1(K)=0.0
C
      DO 15 J=1,IA
      IF (X(1,J,K).EQ.0) X(1,J,K)=.004
      IF (X(2,J,K).EQ.0) X(2,J,K)=.004
      V=(DLOG10(X(2,J,K))–DLOG10(X(1,J,K)))/(X(5,J,K))
      V2(J,K)=10.**V–1.0
   15 SUM1(K)=SUM1(K)+V2(J,K)
C
C
C     SORT K VALUES
C
      DO 17 K=1,ID
C
      DO 17 J=1,IA
      IF (V2(J,K).GT.0) GO TO 16
      X(7,J,K)=V2(J,K)
      GO TO 17
   16 X(6,J,K)+V2(J,K)
   17 X(8,J,K)=X(7,J,K)+X(6,J,K)
C
C
C     CALCULATE K-NET.
C
```

```
      DO 19 K=1,ID
C
      DO 19 J=1,IA
      V=X(8,J,K)-SUM1(K)/AI
      IF (V.GT.0) GO TO 18
      X(10,J,K)=V
      GO TO 19
   18 X(9,J,K)=V
   19 CONTINUE
C
C
C
C     COMPUTE SUM AND MEAN FOR K VALUES.
C
C
      DO 21 K=1,ID
C
      DO 21 I=6,10
      V=0.0
C
C
      DO 20 J=1,IA
   20 V=V+X(I,J,K)
C
      TOT(I,K)=V
   21 M(I,K)=V/AI
C
C
C     CALCUALTE STANDARD DEVIATION, STANDARD ERROR, AND 95% CONFIDENCE
C     LIMITS OF K VALUES.
C
      DO 22 K=1,ID
      SUM 1 (K)=0.0
      SUM 2 (K)=0.0
      SUM 3 (K)=0.0
   22 SUM 4 (K)=0.0
      DO 23 J=1,IA
      V2(J,K)=DLOG(X(2,J,K))–DLOG(X(1,J,K))
      SUM2(K)=V2(J,K)+SUM2(K)
      SUM 3 (K)=(DLOG(X(1,J,K))–ALOG(M(1,K)))**2+SUM3(K)
```

```
      23 SUM 4 (K)=(DLOG(X(2,J,K))-ALOG(M(2,K)))**2+SUM4(K)
C
C
         DO 24 K=1,ID
         VAR 1(K)=(.43429/M(1,K))**2*SUM3(K)/(AI-1.0)+(-.43429/M(2,K))**2
        1*SUM4 (K)/(AI-1.0)
      24 V1(K)=SUM2(K)/AI
         DO 25 K=1,ID
         VAR2(K)=((1.0/M(5,K))**2*VAR1(K))+(-V1(K)/(M(5,K)**2))**2*STD(5,K)
        1**2
         VAR2(K)=10.0**VAR2(K)
         STD(8,K)=SQRT(VAR2(K))
      25 CALL STDEV2 (STD(8,K),STE(8,K),CL95(8,K))
C
C
C
C        CALCULATE THE DISTRIBUTION OF VARIANCE BETWEEN +K AND -K
C
         DO 30 K=1,ID
         V=0.0
C
         DO 27 J=1,IA
         IF (X(6,J,K)) 27,27,26
      26 V=(X(6,J,K)-M(8,K))**2+V
      27 CONTINUE
C
C
         V=V/(AI-1.0)
         W=0.0
C
C
         DO 29 J=1,IA
         IF (X(7,J,K)) 28,29,29
      28 W=(X(7,J,K)-M(8,K))**2+W
      29 CONTINUE
C
         W=W/(AI-1.0)
         U=V+W
         V=STD(8,K)**2*(V/U)**2
```

```
      STD(6,K)=SQRT(V)
      W=STD(8,K)**2*(W/U)**2
      STD(7,K)=SQRT(W)
      CALL STDEV2(STD(6,K),STE(6,K),CL95(6,K))
   30 CALL STDEV2 (STD(7,K),STE(7,K),CL95(7,K))
C
C
C     CALCULATION OF STANDARD DEVIATION K-NET AND ITS DISTRIBUTION.
C
C
C
      DO 35 K=1,ID
      V=0.0
      W=0.0
      DO 34 J=1,IA
      IF(X(9,J,K)) 32,32,31
   31 V=V+(X(9,J,K)**2)
   32 IF(X(10,J,K)) 33,34,34
   33 W=W+(X(10,J,K)**2)
   34 CONTINUE
C
C
      V=V/(AI-1.0)
      W=W/(AI-1.0)
      STD(9,K)=SQRT((V/(V+W))**2*(STD(8,K)**2))
      CALL STDEV2(STD(9,K),STE(9,K),CL95(9,K))
      STD(10,K)=SQRT((W/(V+W))**2*(STD(8,K)**2))
   35 CALL STDEV2(STD(10,K),STE(10,K),CL95(10,K))
C
C
C
      CALL PRINT3
C
      CALCULATE 0 AND ITS STANDARD DEVIATION
C
      DO 41 K=1,ID
      M(11,K)=(M(9,K)/M(6,K))*M(7,K)
      STD(11,K)=SQRT(STD(7,K)**2*((M(9,K)/M(6,K))**2))
      CALL STDEV2(STD(11,K),STE(11,K),CL95(11,K))
C
C
C
C
C     CALCULATION OF D
C
```

```
C
C
      M(12,K)=M(7,K)-M(11,K)
C
C
C     CALCULATION OF STANDARD DEVIATION OF D
C
      STD(12,K)=SQRT(STD(7,K)**2*(1.-M(9,K)/M(6,K))**2)
      CALL STDEV2 (STD(12,K),STE(12,K),CL95(12,K))
C
C
C     CALCULATE TL.
C
C
      M(13,K)=-1.0*(1.0/M(12,K))
      STD(13,K)=SQRT(STD(12,K)**2*(1.0/M(12,K)**2)**2)
   41 CALL STDEV2 (STD(13,K),STE(13,K),CL95(13,K))
C
C
C     CALCULATE TR.
C
      DO 42 K=1,ID
      M(14,K)=-1.0*(1.0/M(7,K))
      STD(14,K)=SQRT(STD(7,K)**2*(1.0/M(7,K)**2)**2)
   42 CALL STDEV2 (STD(14,K),STE(14,K),CL95(14,K))
C
C
      DO 44 K=1,ID
      WRITE (6,55) NAME (K)
      WRITE (6,56) NAME (K),M(8,K),STD(8,K),STE(8,K),CL95(8,K)
      WRITE (6,57) NAME (K),M(9,K),STD(9,K),STE(9,K),CL95(9,K)
      WRITE (6,58)
      WRITE (6,59) NAME (K),M(10,K),STD(10,K),STE(10,K),CL95(10,K)
      WRITE (6,60)
      WRITE (6,61) NAME (K),M(6,K),STD(6,K),STE(6,K),CL95(6,K)
      WRITE (6,62) NAME (K),M(7,K),STD(7,K),STE(7,K),CL95(7,K)
      WRITE (6,63) NAME (K),M(11,K),STD(11,K),STE(11,K),CL95(11,K)
      WRITE (6,64) NAME (K),M(12,K),STD(12,K),STE(12,K),CL95(12,K)
      WRITE (6,65) NAME (K),M(13,K),STD(13,K),STE(13,K),CL95(13,K)
      WRITE (6,66)
      WRITE (6,65) NAME (K),M(14,K),STD(14,K),STE(14,K),CL95(14,K)
      WRITE (6,67)
C
```

```
      DO 43 L=1,3
   43 WRITE (6,54)
C
      WRITE (6,68)
      WRITE (6,69) M(5,K)
      WRITE (6,70) NAME(K),M(2,K),M(1,K),M(6,K),M(9,K),M(10,K),M(11,K),M
     1(12,K)
   44 CONTINUE
C
      CALL FACTOR
      STOP
C
   45 FORMAT (1X,13F6.3/13F6.3/4F6.3)
   46 FORMAT (12I4)
   47 FORMAT (2I5)
   48 FORMAT (10A8)
   49 FORMAT (1X,I2,2(2A4,A2),I2,2(1X,I2),7F7.2)
   50 FORMAT('1')
   51 FORMAT('1','C'/2X,I1,/3X,'STATION',3X,'LATITUDE',3X,'LONGITUDE',
     -5X,'DATE')
   52 FORMAT(48X,8(3X,A8))
   53 FORMAT('+',47X,8(3X,A8))
   54 FORMAT(/)
   55 FORMAT('1',1X,'RATES OF CHANGE FOR ',A8,30X,'S.D.',7X,'S.E.',4X,
     -'95% LIMIT'//)
   56 FORMAT(2X,'MEAN OF K',13X,'= NET',3X,A8,'=',3X,4F11.4/)
   57 FORMAT(2X,'MEAN OF + ( K - NET ) = T',5X,A8,'=',3X,4F11.4)
   58 FORMAT(27X,'I'/)
   59 FORMAT(2X,'MEAN OF - ( K - NET ) = T',5X,A8,'=',3X,4F11.4)
   60 FORMAT(27X,'O'/)
   61 FORMAT(2X,'MEAN OF + K',11X,'= I',5X,A8,'=',3X,4F11.4//)
   62 FORMAT(2X,'MEAN OF - K',11X,'= O + D',1X,A8,'=',3X,4F11.4//)
   63 FORMAT(26X,'O',5X,A8,'=',3X,4F11.4/)
   64 FORMAT(26X,'D',5X,A8,'=',3X,4F11.4/)
   65 FORMAT(26X,'T',5X,A8,'=',3X,4F11.4)
   66 FORMAT(27X,'L'/)
   67 FORMAT(27X,'R')
   68 FORMAT(13X,'MEAN C',6X,'MEAN C',16X,'I',10X,'T',6X,'-',4X,'T',6X,
     -'-',5X,'O',5X,'-',5X,'D',9X,'N'/19X,'2',11X,'1,27X,'I',11X,'0'/)
   69 FORMAT(/97X,F11.4)
   70 FORMAT(2X,A8,F10.4,' =',F10.4,' ( 1.0 +',F10.4,' +',F10.4,3(F12.4)
     -,' ) ')
      END
C
C
```

```
      SUBROUTINE PRINT
      DIMENSION TABLE(30),MONTH(12),ALOC(2,60,6),TOT(10,8),STD(23,8)
     1, STE(23,8),CL95(23,8)
      REAL *4MEAN,M(17,8)
      REAL *8X(10,60,7),NAME(23)
      INTEGER CST(2,60),CDATE(2,60,3)
      COMMON X,TABLE,IA,I,K,KD,ID
      COMMON /BLK1/ NAME,TOT,M,STD,STE,CL95,ALOC,YR,CST,CDATE,MONTH,L1,L
C
      DO 1 J=1,IA
    1 WRITE (6,3) CST(L,J),(ALOC(L,J,K),K=1,6),(CDATE(L,J,K),K=1,3),(X(I
     1,J,K),K=1,L1)
C
C     SKIP TO BOTTOM OF PAGE
      N=(68-(IA+6))/2
C
      DO 2 J=1,N
    2 WRITE (6,4)
C
      RETURN
C
    3 FORMAT (5X,I2,5X,2A4,A2,2X,2A4,A2,2X,I2,2('-',I2),8F11.2)
    4 FORMAT (/)
      END
C
C
      SUBROUTINE PRINT2
      DIMENSION TABLE(30),MONTH(12),ALOC(2,60,6),TOT(10,8),STD(23,8)
     1, STE(23,8),CL95(23,8)
      REAL *4MEAN,M(17,8)
      REAL *8X(10,60,7),NAME(23)
      INTEGER CST(2,60),CDATE(2,60,3)
      COMMON X,TABLE,IA,I,K,KD,ID
      COMMON /BLK1/ NAME,TOT,M,STD,STE,CL95,ALOC,YR,CST,CDATE,MONTH,L1,L
      WRITE (6,1) (TOT(I,J),J=1,L1)
      WRITE (6,2) (M(I,J),J=1,L1)
      WRITE (6,3) (STD(I,J),J=1,L1)
      WRITE (6,4) (STE(I,J),J=1,L1)
      WRITE (6,5) (CL95(I,J),J=1,L1)
      RETURN
C
    1 FORMAT (34X,'TOTALS',6X,7F10.4)
    2 FORMAT (/34X,'MEAN',8X,7F10.4)
    3 FORMAT (/34X,'S.D.',8X,7F10.4)
    4 FORMAT (/34X,'S.E.',8X,7F10.4)
    5 FORMAT (/34X,'95% CL',6X,7F10.4)
      END
C
C
```

```
      SUBROUTINE PRINT3
      DIMENSION TABLE(30),MONTH(12),ALOC(2,60,6),TOT(10,8),STD(23,8)
     1, STE(23,8),CL95(23,8)
      REAL *8X(10,60,7)
      REAL *8NAME(23)
      REAL *4MEAN,M(17,8)
      INTEGER CST(2,60),CDATE(2,60,3)
      COMMON X,TABLE,IA,I,K,KD,ID
      COMMON /BLK1/ NAME,TOT,M,STD,STE,CL95,ALOC,YR,CST,CDATE,MONTH,L1,L
C
      DO 2 K=1,ID
      WRITE (6,3)
      WRITE (6,4)
      WRITE (6,5) NAME(K),NAME(K)
      WRITE (6,6)
      WRITE (6,8)
C
      DO 1 J=1,IA
    1 WRITE (6,7) CST(1,J),X(2,J,K),X(1,J,K),X(5,J,K),(X(IX,J,K),IX=6,10
     1).
C
      WRITE (6,8)
      WRITE (6,17) TOT(2,K),TOT(1,K),TOT(5,1),(TOT(L,K),L=6,10)
      WRITE (6,16)
      WRITE (6,14) NAME(K)
      WRITE (6,17) M(2,K),M(1,K),M(5,1),(M(L,K),L=6,10)
      WRITE (6,9)
      WRITE (6,14) NAME(K)
      WRITE (6,17) STD(2,K),STD(1,K),STD(5,1),(STD(L,K),L=6,10)
      WRITE (6,10)
      WRITE (6,13) NAME(K)
      WRITE (6,17) STE(2,K),STE(1,K),STE(5,1),(STE(L,K),L=6,10)
      WRITE (6,11)
      WRITE (6,13) NAME(K)
      WRITE (6,17) CL95(2,K),CL95(1,K),CL95(5,1),(CL95(L,K),L=6,10)
      WRITE (6,12)
      WRITE (6,15) NAME(K)
    2 CONTINUE
C
      RETURN
C
    3 FORMAT (‘1’,1X,‘STATION’)
    4 FORMAT (12X,‘C’,9X,‘C’,11X,‘N’,8X,‘+ K’,7X,‘- K’,6X,‘+K + -K’,
     1 4X,‘+K - NET’,3X,‘-K - NET’)
    5 FORMAT (‘+’,15X,A8,2X,A8)
    6 FORMAT (13X,‘2’,9X,‘1’,52X,‘R’,10X,‘R’/)
    7 FORMAT (4X,I2,1X,2F10.2,2X,3F10.4,3F11.4)
    8 FORMAT (/)
```

```
    9 FORMAT ('+',94X,'MEANS')
   10 FORMAT ('+',94X,'S.D.')
   11 FORMAT ('+',94X,'S.E.')
   12 FORMAT ('+',94X,'95% CONFIDENCE LIMITS')
   13 FORMAT ('+', 99X,A8)
   14 FORMAT ('+',102X,A8)
   15 FORMAT ('+',116X,A8)
   16 FORMAT ('+',94X,'TOTALS')
 17   FORMAT(/9X,5F10.4,3F11.4)
      END
C
C
      SUBROUTINE LEAPYR (J)
      DIMENSION TABLE(30), MONTH(12), ALOC(2,60,6), TOT(10,8), STD(23,8)
     1, STE(23,8),CL95(23,8)
      REAL *4MEAN,M(17,8)
      REAL *8X(10,60,7)
      REAL *8NAME(23)
      INTEGER TOT,YR1,YR2,DA1,DA2,DAYS
      INTEGER CST(2,60),CDATE(2,60,3)
      COMMON /BLK1/ NAME,TOT,M,STD,STE,CL95,ALOC,YR,CST,CDATE,MONTH,L1,L
      COMMON X,TABLE,IA,I,K,KD,ID
      DAYS=0
      NT=0
      MO1=CDATE(1,J,1)
      DA1=CDATE(1,J,2)
      YR1=CDATE(1,J,3)
      DA2=CDATE(2,L,2)
      YR2=CDATE(2,L,3)
      MO2=CDATE(2,L,1)
      AMO=MO1
C
      DO 4 I=YR1,YR2
      A=I
      LEAP=0
      IZ=A/4.
      Z=IZ
      Z=Z*4.
      IF (I.EQ.YR1) GO TO 1
      GO TO 2
    1 DAYS=365-(MONTH(MO1)+DA1)
      IF (Z.EQ.A.AND.AMO.LT.3.) LEAP=1
      GO TO 3
    2 IF (Z.EQ.A) LEAP=1
    3 NT=DAYS+LEAP+NT
    4 DAYS=365
C
```

```
      IF (LEAP.EQ.1) GO TO 5
      GO TO 6
    5 IF (MO2.LT.3) NT=NT-1
    6 YR=NT-365+MONTH(MO2)+DA2
      YR=YR/365.
      RETURN
      END
C
C
      SUBROUTINE TDIST (T)
      REAL *8X(10,60,7)
      DIMENSION TABLE(30)
      COMMON X,TABLE,IA,I,K,KD,ID
      11=IA-1
      AI=I1
      IF (I1) 1,1,2
    1 WRITE (6,11) I
      GO TO 10
    2 IF (I1.LT.31) GO TO 9
      IF (I1.LT.41) GO TO 3
      GO TO 4
    3 TINT=((2.042-2.021)/10.)*(AI-30.)
      T=TINT+2.042
      GO TO 10
    4 IF (I1.LT.61) GO TO 5
      GO TO 6
    5 TINT=((2.021-2.000)/20.)*(AI-40.)
      T=TINT+2.021
      GO TO 10
    6 IF (I1.LT.121) GO TO 7
      GO TO 8
    7 TINT=((2.000-1.980)/40.)*(AI-60.)
      T=TINT+2.000
      GO TO 10
    8 T=1.960
      GO TO 10
    9 T=TABLE(I1)
   10 RETURN
C
   11 FORMAT ('1','I IN T TABLE =',I3)
      END
C
C
```

```
      SUBROUTINE STDEV (SUMX,XBAR,STD,STE,CL$)
      REAL *8X(10,60,7)
      DIMENSION TABLE(30)
      COMMON X,TABLE,IA,I,K,KD,ID
      DEV=0.
      SUMX=0.
C
      DO 1 J=1,IA
    1 SUMX=SUMX+X(I,J,K)
C
      AI=IA
      XBAR=SUMX/AI
C
      DO 2 J=1,IA
      DEV=(XBAR-X(I,J,K))**2+DEV
    2 CONTINUE
C
      STD=SQRT(DEV/(AI-1.))
      STE=STD/SQRT(AI)
      CALL TDIST (T)
      CL$=T*STE
      END
C
C
      SUBROUTINE STDEV2 (STD,STE,CL$)
      REAL *8X(10,60,7)
      DIMENSION TABLE(30)
      COMMON X,TABLE,IA,I,K,KD,ID
      AI=IA
      STE=STD/SQRT(AI)
      CALL TDIST (T)
      CL$=T*STE
      RETURN
      END
```

```
C       SUBROUTINE FOR PROGRAM FOR ESTIMATING SYSTEM RATES
C       BASED ON REAL PAIRED SAMPLE VALUES.
        SUBROUTINE FACTOR
        DIMENSION TABLE (30), MONTH(12), ALOC(2,60,6), TOT(10,8), STD(23,8)
       1,STE(23,8), CL95(23,8), VAR1(7), VAR2(7), VAR3(7), SUM1(7), SUM2(
       27), SUM3(7), SUM4(7), COV1(7), COV2(7)
        REAL *4MEAN,M(17,8),MR(7)
        REAL *8X(10,60,7),V2(60,7),NAME(23),V1(7)
        INTEGER CST(2,60),CDATE(2,60,3)
        COMMON X,TABLE,IA,I,K,KD,ID
        COMMON /BLK1/ NAME,TOT,M,STD,STE,CL95,ALOC,YR,CST,CDATE,MONTH,L1,L
        COMMON /BLK2/ MR
C
C
C       CALCULATE CORRECTION FACTOR FOR STANDARD DEVIATION
C
        AI=IA
C
        DO 14 K=1,ID
C
        IF (M(8,K)) 1,4,5
      1 JX=(AI*M(7,K)-AI*M(10,K))/M(8,K)
        VJ=JX
        V=(((AI*M(10,K))/VJ)**2)*VJ
        IF ((M(8,K)+((AI*M(10,K))/VJ))*VJ-(AI*M(7,K))) 3,3,2
      2 V=V+(AI*M(7,K)-VJ*(M(8,K)+((AI*M(10,K))/VJ))-M(8,K))**2
        V=V+(((AI*M(6,K))/(AI-VJ-1.0))-M(8,K))**2*(AI-VJ-1.0)
        GO TO 8
      3 V=V+(((AI*M(6,K))/(AI-VJ))-M(8,K))**2*(AI-VJ)
        GO TO 8
      4 JX=AI/2.0
        VJ=JX
        V=((AI*M(6,K)/VJ)**2)*VJ
        V=V+((AI*M(7,K)/VJ)**2*VJ
        GO TO 8
      5 JX=(AI*M(6,K)-AI*M(9,K))/M(8,K)
        VJ=JX
        V=(((AI*M(9,K))/VJ)**2)*VJ
        IF ((M(8,K)+((AI*M(9,K))/VJ))*VJ-(AI*M(6,K))) 6,7,7
      6 V=V+(AI*M(6,K)-VJ*(M(8,K)+((AI*M(9,K))/VJ))-M(8,K))**2
        V=V+(((AI*M(7,K))/(AI-VJ-1.0))-M(8,K))**2*(AI-VJ-1.0)
        GO TO 8
      7 V=V+(((AI*M(7,K))/(AI-VJ))-M(8,K))**2*(AI-VJ)
      8 V=V/(AI-1.0)
        W=0.0
C
C
```

```
      DO 9 J=1,IA
    9 W=W+(X(8,J,K)-M(8,K))**2
C
C
      W=W/(AI-1.0)
      C=((W-V)/W)**2
C
C     CALCULATE CORRECTED STD,6,7,AND 8
C     STD(15,K) IS CORRECTED STD(6,K)
C
      STD(15,K)=SQRT(C*STD(6,K)**2)
      CALL STDEV2 (STD(15,K),STE(15,K),CL95(15,K))
C
C     STD(16,K)IS CORRECTED STE(7,K)
C
      STD(16,K)=SQRT(C*STD(7,K)**2)
      CALL STDEV2 (STD(16,K),STE(16,K),CL95(16,K))
C
C     STD(17,K)IS CORRECTED STD(8,K)
C
      STD(17,K)=SQRT(C*STD(8,K)**2)
      CALL STDEV2 (STD(17,K),STE(17,K),CL95(17,K))
C
C     CALCULATE CORRECTED STD(9,K) AND STD(10,K)
C
      V=0.0
C
C
      DO 11 J=1,IA
C
      IF (X(9,J,K)) 11,11,10
   10 V=V+X(9,J,K)**2
   11 CONTINUE
C
C
C
      V=V/(AI-1.0)
      W=0.0
C
C
      DO 13 J=1,IA
C
      IF (X(10,J,K)) 12,13,13
   12 W=W+(X(10,J,K))**2
   13 CONTINUE
C
C
C
```

```
      W=W/(AI-1.0)
C
C     STD(18,K) IS CORRECTED STD(9,K)
C
      STD(18,K)=SQRT((V/(V+W))**2*C*(STD(8,K)**2))
      CALL STDEV2 (STD(18,K),STE(18,K),CL95(18,K))
C
C
C     STD(19,K) IS CORRECTED STD(10,K)
C
      STD(19,K)=SQRT((W/(V+W))**2*C*(STD(8,K)**2))
      CALL STDEV2 (STD(19,K),STE(19,K),CL95(19,K))
C
C     CALCULATE CORRECTED STD(20,K) CORRECTED STD(11,K)
C
      STD(20,K)=SQRT(STD(16,K)**2*(M(9,K)/M(6,K))**2)
C
C
      CALL STDEV2 (STD(20,K),STE(20,K),CL95(20,K))
C     CALCULATE STD(21,K) CORRECTED STD(12,K)
      STD(21,K)=SQRT(STD(16,K)**2*(1.0-M(9,K)/M(6,K))**2)
      CALL STDEV2 (STD(21,K),STE(21,K),CL95(21,K))
C
C     CALCULATE STD(22,K) CORRECTED STD(13,K)
C
      STD(22,K)=SQRT(STD(21,K)**2*(1.0/M(12,K)**2)**2)
      CALL STDEV2 (STD(22,K),STE(22,K),CL95(22,K))
C
C     CALCULATE STD(23,K) CORRECTED STD(14,K)
C
      STD(23,K)=SQRT(STD(16,K)**2*(1.0/M(7,K)**2)**2)
      CALL STDEV2 (STD(23,K),STE(23,K),CL95(23,K))
C
C
   14 CONTINUE
C
C
      DO 15 K=1,ID
C
      WRITE (6,16) NAME(K)
      WRITE (6,17) NAME(K),M(8,K),STD(17,K),STE(17,K),CL95(17,K)
      WRITE (6,18) NAME(K),M(9,K),STD(18,K),STE(18,K),CL95(18,K)
      WRITE (6,19)
      WRITE (6,20) NAME(K),M(10,K),STD(19,K),STE(19,K),CL95(19,K)
```

```
      WRITE (6,21)
      WRITE (6,22) NAME(K),M(6,K),STD(15,K),STE(15,K),CL95(15,K)
      WRITE (6,23) NAME(K),M(7,K),STD(16,K),STE(16,K),CL95(16,K)
      WRITE (6,24) NAME(K),M(11,K),STD(20,K),STE(20,K),CL95(20,K)
      WRITE (6,25) NAME(K),M(12,K),STD(21,K),STE(21,K),CL95(21,K)
      WRITE (6,26) NAME(K),M(13,K),STD(22,K),STE(22,K),CL95(22,K)
      WRITE (6,27)
      WRITE (6,26) NAME(K),M(14,K),STD(23,K),STE(23,K),CL95(23,K)
      WRITE (6,28)
   15 CONTINUE
C
C
   16 FORMAT ('1',40X,'CORRECTED STANDARD DEVIATIONS'//,2X,'RATES OF CHA
     1NGE FOR ',A8,30X,'S.D.',7X,'S.E.',4X,'95% LIMIT'//)
   17 FORMAT (2X,'MEAN OF K',13X,'= NET',3X,A8,'=',3X,4F11.4/)
   18 FORMAT (2X,'MEAN OF + ( K - NET ) = T',5X,A8,'=',3X,4F11.4)
   19 FORMAT (27X,'I'/)
   20 FORMAT (2X,'MEAN OF - ( K - NET ) = T',5X,A8,'=',3X,4F11.4)
   21 FORMAT (27X,'O'/)
   22 FORMAT (2X,'MEAN OF + K',11X,'= I',5X,A8,'=',3X,4F11.4//)
   23 FORMAT (2X,'MEAN OF - K',11X,'= O + D',1X,A8,'=',3X,4F11.4//)
   24 FORMAT (26X,'O',5X,A8,'=',3X,4F11.4/)
   25 FORMAT (26X,'D',5X,A8,'=',3X,4F11.4/)
   26 FORMAT (26X,'T',5X,A8,'=',3X,4F11.4)
   27 FORMAT (27X,'L'/)
   28 FORMAT (27X,'R')
C
      RETURN
      END
```

APPENDIX

Program for estimating system rates based on sample values paired to mean values.

This program for calculation of estimates of input, output, translocation, and decay was written in Fortran IV level G, and was run on an IBM 360/67. In our experience 112k was used and the program required approximately 40 seconds per run. A maximum of 60 stations, 7 chemical compounds, and 2 sample times is permitted with the program as written.

The time interval is calculated in the subroutine, NCOMP, which calls the subroutine, LEAPYR. K values are calculated using double precision, and confidence intervals are estimated through use of a table of "t values."

There are eight cards which precede the data deck. Their formats and content are as follows:

First four cards, as in preceding program.
Fifth card, Format (3I5), contains the number of stations at time one, followed by the number of stations at time two, followed by the number of chemical compounds in the data set.
Sixth through eighth cards, Format (10A8), as in preceding program.

The data is organized as in the preceding program but is sorted chronologically.

An optional subroutine FACTOR may be called by placing a card before the END card with CALL FACTOR.

```
        C      PROGRAM FOR ESTIMATING SYSTEM RATES BASED ON
        C      SAMPLE VALUES PAIRED TO MEAN VALUES.
        C
        C
0001           DIMENSION TABLE(30),MONTH(12),ALOC(2,60,6),TOT(10,8),STD(23,8),
             1, STE(23,8),CL95(23,8),VAR1(7),VAR2(7),VAR3(7),SUM1(7),SUM 2(
             27), SUM3(7), SUM4(7), COV1(7), COV2(7), IA(2), AI(2)
0002           REAL *4MEAN,M(17,8),MR(7)
0003           REAL *8X(10,60,7),V2(60,7),NAME(23),V1(7).
0004           INTEGER CST(2,60),CDATE(2,60,3)
0005           COMMON X,TABLE,IA,IB,I,K,KD,ID
0006           COMMON /BLK1/ NAME,TOT,M,STD,STE,CL
0006           COMMON /BLK2/MR
0007         1 FORMAT (1X,13F6.3/13F6.3/4F6.3)
0008           READ (5,1) TABLE
0009         2 FORMAT (12I4)
0010           READ (5,2) MONTH
0011           READ (5,3) IA(1)'IA(2),ID
0012         3 FORMAT (3I5)
        C
```

```
C      CALCULATE INDEXES.
C      AI              NUMBER OF STATIONS CONVERTED TO A REAL NUMBER.
C      AI3             AI(1) + AI(2)
C      IA3             IA(1) + IA(2)
C      IP1             ID + 1
C      IP2             ID + 2
C      I2TP2           2 * ID + 2
C      I2TP3           2 * ID + 3
C      I3TP2           3 * ID + 2
C      J2T             IA(1) + IA(2)
       AI(1)=IA(1)
       AI(2)=IA(2)
       AI3=AI(1)+AI(2)
       IA3=IA(1)+IA(2)
       IP1=ID+1
       IP2=ID+2
       I2TP2=2*ID+2
       I2TP3=2*ID+3
       I3TP2=3*ID+2
       J2T=IA(1)+IA(2)
C
C      CLEAR X ARRAY.
C
       DO 4 I=1,10
C
       DO 4 J=1,J2T
C
       DO 4 K=1,IP1
     4 X(I,J,K)=0.0
C
       WRITE (6,9)
C
C      READ IN DERIVATIVE NAMES AND CONCENTRATION LEVEL ON UP TO 3 CARDS.
       READ (5,5) NAME
     5 FORMAT (10A8)
C
C      READ IN DATA.
     6 FORMAT (1X,I2,2(2A4,A2),I2,2(1X,I2),7F7.2)
C
       DO 7 I=1,2
       IB=IA(I)
C
       DO 7 J=1,IB
     7 READ (5,6) CST(I,J),(ALOC(I,J,L),L=1,6),(CDATE(I,J,L),L=1,3),(X(I,
      1J,K),K=1,ID)
C
C
C      COMPUTE TOTAL OF EACH STATION.
```

```
C
      DO 8 I=1,2
      IB=IA(I)
C
      DO 8 J=1,IB
C
      DO 8 L=1,ID
    8 X(I,J,IP1)=X(I,J,L)+X(I,J,IP1)
C
C
C     WRITE HEADING OF FIRST TWO PAGES.
C
      DO 15 I=1,2
      IB=IA(I)
      L=I
    9 FORMAT ('1')
   10 FORMAT ('1','C'/2X,I1,/3X,'STATION',3X,'LATITUDE',3X,'LONGITUDE',
     1 5X,'DATE')
      WRITE (6,10) I
   11 FORMAT (48X,8(3X,A8))
   12 FORMAT ('+',47X,8(3X,A8))
      WRITE (6,12) (NAME(N),N=1,IP1)
   13 FORMAT (/)
      WRITE (6,11) (NAME(N),N=IP2,I2TP2)
      WRITE (6,13)
C
      DO 14 K=1,IP1
      CALL STDEV (TOTAL,MEAN,SD,SE,CL)
      TOT(I,K)=TOTAL
      M(I,K)=MEAN
      STD(I,K)=SD
      STE(I,K)=SE
   14 CL95(I,K)=CL
C
C     L1=NUMBER OF SETS COMPUTED.
C
C     WRITE FIRST TWO PAGES.
      L1=IP1
      CALL PRINT
      WRITE (6,12) (NAME(N),N=1,IP1)
      WRITE (6,11) (NAME(N),N=IP2,I2TP2)
      WRITE (6,13)
      CALL PRINT2
   15 CONTINUE
C
C
C     COMPUTE PERCENTS.
```

```
C
      DO 18 I=3,4
      IB=IA(I-2)
      L1=ID
      L=I-2
      WRITE (6,10) L
      WRITE (6,12) (NAME(N),N=1,ID)
      WRITE (6,11) (NAME(N),N=I2TP3,I3TP2)
      WRITE (6,13)
C
      DO 16 K=1,ID
C
      DO 16 J=1,IB
   16 X(I,J,K)=X(L,J,K)/X(L,J,IP1)*100.
C
C
      DO 17 K=1,3
      CALL STDEV (TOTAL,MEAN,SD,SE,CL)
      TOT(I,K)=TOTAL
      M(I,K)=MEAN
      STD(I,K)=SD
      STE(I,K)=SE
   17 CL95(I,K)=CL
C
      CALL PRINT
      WRITE (6,12) (NAME(N),N=1,ID)
      WRITE (6,11) (NAME(N),N=I2TP3,I3TP2)
      WRITE (6,13)
      CALL PRINT2
   18 CONTINUE
C
      CALL NCOMP
C
C     CALCULATE TOTAL AND MEAN OF N.
C
      DO 20 K=1,ID
      TOT(5,K)=0.
C
      DO 19 J=1,IA3
   19 TOT(5,K)=TOT(5,K)+X(5,J,K)
C
   20 M(5,K)=TOT(5,K)/AI3
C
C
      DO 22 K=1,ID
      V=0.0
C
```

```
      DO 21 J=1,IA3
   21 V=(M(5,K)-X(5,J,K))**2+V
C
      STD(5,K)=SQRT(V/(AI3-1.0))
   22 CALL STDEV2 (STD(5,K),STE(5,K),CL95(5,K))
C
C
C     CALCULATE K VALUES.
C     DATA IN TWO SETS ARRANGED CHRONOLOGICALLY
C     CALCULATE K VALUES
C
      DO 24 K=1,ID
      SUM1(K)=0.0
      IB=IA(2)
C
      DO 23 J=1,IB
      IF (X(2,J,K).EQ.O.) X(2,J,K)=.004
      V=(DLOG10(X(2,J,K))−ALOG10(M(1,K)))/(X(5,J,K))
      V2(J,K)=10.**V−1.0
   23 SUM1(K)=SUM1(K)+V2(J,K)
C
      IB=IA(1)
C
      DO 24 J=1,IB
      IF (X(1,J,K).EQ.0.) X(1,J,K)=.004
      V=ALOG10(M(2,K))-DLOG10(X(1,J,K)))/X(5,J+IA(2),K)*.43429)
      V2(J+IA(2),K)=10.**(V*.43429)−1.0
   24 SUM1(K)=SUM1(K)+V2(J+IA(2),K)
C
C
C     SORT VALUES
C
      DO 26 K=1,ID
C
      DO 26 J=1,J2T
      IF (V2(J,K).GT.0.) GO TO 25
      X(7,J,K)=V2(J,K)
      GO TO 26
   25 X(6,J,K)=V2(J,K)
   26 X(8,J,K)=X(7,J,K)+X(6,J,K)
C
C     CALCULATE K-NET
C
      DO 28 K=1,ID
C
```

```
      DO 28 J=1,J2T
      V=X(8,J,K)-SUM1(K)/AI3
      IF (V.GT.0) GO TO 27
      X(10,J,K)=V
      GO TO 28
   27 X(9,J,K)=V
   28 CONTINUE
C
C     COMPUTE SUM & MEAN FOR K VALUES
C
      DO 30 K=1,ID
C
      DO 30 I=6,10
      V=0.0
C
      DO 29 J=1,J2T
   29 V=V+X(I,J,K)
C
      TOT(I,K)=V
   30 M(I,K)=V/AI3
C
      DO 31 I=6,10
C
      DO 31 K=1,7
      STD(I,K)=0.0
      STE(I,K)=0.0
   31 CL95(I,K)=0.0
C
C     CALCULATE STANDARD DEVIATION, STANDARD ERROR, AND 95% CONFIDENCE
C     LIMITS OF K VALUES.
      DO 32 K=1,ID
      SUM1(K)=0.0
      SUM2(K)=0.0
      SUM3(K)=0.0
   32 SUM4(K)=0.0
      IB=IA(2)
C
      DO 33 J=1,IB
      V2(J,K)=DLOG(X(2,J,K))-DLOG(X(1,J,K))
      SUM2(K)=V2(J,K)+SUM2(K)
      SUM3(K)=(DLOG(X(1,J,K))-ALOG(M(1,K)))**2+SUM3(K)
   33 SUM4(K)=(DLOG(X(2,J,K))-ALOG(M(2,K)))**2+SUM4(K)
C
      DO 34 K=1,ID
C
```

```
      VAR1(K)=(.43429/M(1,K))**2*SUM3(K)/(AI3-1.0)+(-.43429/M(2,K))**2
     1*SUM4(K)/(AI3-1.0)
   34 V1(K)=SUM2(K)/AI3
C
      DO 36 K=1,ID
      VAR2(K)=((1.0/M(5,K))**2*VAR1(K))+(-V1(K)/M(5,K)**2))**2*STD(5,K)
     1**2
      VAR2(K)=10.0**VAR2(K)
      STD(8,K)=SQRT(VAR2(K))
   36 CALL STDEV2(STD(8,K),STE(8,K),CL95(8,K))
C
C     CALCULATE THE DISTRIBUTION OF VARIANCE BETWEEN +K AND-K.
C
      DO 41 K=1,ID
      V=0.0
C
      DO 38 J=1,J2T
      IF (X(6,J,K))38,38,37
   37 V=(X(6,J,K)-M(8,K))**2+V
   38 CONTINUE
C
      V=V/AI3-1.0
      W=0.0
C
      DO 40 J=1,J2T
      IF (X(7,J,K)) 39,40,40
   39 W=(X(7,J,K)-M(8,K))**2+W
   40 CONTINUE
C
      W=W/AI3-1.0)
      U=V+W
      V=STD(8,K)**2*(V/U)**2
      STD(6,K)=SQRT(V)
      W=STD(8,K)**2*(W/U)**2
      STD(7,K)=SQRT(W)
      CALL STDEV2(STD(6,K),STE(6,K),CL95(6,K))
   41 CALL STDEV2(STD(7,K),STE(7,K),CL95(7,K))
C
C     CALCULATION OF STANDARD DEVIATION K-NET AND ITS DISTRIBUTION.
C
      DO 46 K=1,ID
      V=0.0
      W=0.0
C
      DO 45 J=1,J2T
      IF(X(9,J,K))43,43,42
   42 V=V+(X(9,J,K))**2)
   43 IF(X(10,J,K))44,45,45
   44 W=W+(X(10,J,K)**2)
   45 CONTINUE
```

```
C
      V=V/(AI3-1.0)
      W=W/(AI3-1.0)
      STD(9,K)=SQRT(((V/(V+W))**2*(STD(8,K)**2))
      CALL STDEV2(STD(9,K),STE(9,K),CL95(9,K))
      STD(10,K)=SQRT(((W/(V+W))**2*(STD(8,K)**2))
C
   46 CALL STDEV2(STD(10,K),STE(10,K),CL95(10,K))
      CALL PRINT3
C
C     CALCULATE O AND ITS STANDARD DEVIATION
C
      DO 52 K=1,ID
      M(11,K)=(M(9,K)/M(6,K))*M(7,K)
      STD(11,K)=SQRT(STD(7,K)**2*((M(9,K)/M(6,K))**2))
      CALL STDEV2 (STD(11,K),STE(11,K),CL95(11,K))
C
C
C     CALCULATION OF D
      M(12,K)=M(7,K)-M(11,K)
C
C     CALCULATION OF STANDARD DEVIATION OF D
C
      STD(12,K)=SQRT(STD(7,K)**2*(1.-M(9,K)/M(6,K))**2)
      CALL STDEV2 (STD(12,K),STE(12,K),CL95(12,K))
C
C     CALCULATE TL.
C
      M(13,K)=-1.0*(1.0/M(12,K))
      STD(13,K)=DSQRT(STD(12,K)**2*(1.0/M(12,K)**2)**2)
   52 CALL STDEV2(STD(13,K),STE(13,K),CL95(13,K))
C
C     CALCULATE TR.
C
      DO 53 K=1,ID
      M(14,K)=-1.0*(1.0/M(7,K))
      STD(14,K)=SQRT(STD(7,K)**2*(1.0/M(7,K)**2)**2)
   53 CALL STDEV2 (STD(14,K),STE(14,K),CL95(14,K))
C
      DO 71 K=1,ID
      WRITE (6,54) NAME(K)
   54 FORMAT ('1',1X,'RATES OF CHANGE FOR',A8,30X,'S.D.',7X,'S.E.',4X,
     1 '95%LIMIT'//)
      WRITE (6,55) NAME (K),M(8,K),STD(8,K),STE(8,K),CL95(8,K)
   55 FORMAT (2X,'MEAN OF K',13X,'=NET',3X,A8,'=',3X,4F11.4/)
      WRITE (6,56) NAME(K),M(9,K)STD(9,K),STE(9,K),CL95(9,K)
   56 FORMAT (2X, 'MEAN OF + ( K-NET ) = T' ,5X,A8,'=',3X,4F11.4)
      WRITE (6,57)
```

```
      57 FORMAT (27X,'I'/)
         WRITE (6,58) NAME(K),M(10,K),STD(10,K),STE(10,K),CL95(10,K)
      58 FORMAT (2X,'MEAN OF - ( K - NET ) = T',5X,A8,'=',3X,4F11.4)
         WRITE (6,59)
      59 FORMAT (27X,'O'/)
         WRITE (6,60) NAME(K),M(6,K),STD(6,K),STE(6,K),CL95(6,K)
      60 FORMAT (2X,'MEAN OF + K',11X,'= I',5X,A8,'=',3X,4F11.4//)
         WRITE (6,61) NAME(K),M(7,K),STD(7,K),STE(7,K),CL95(7,K)
      61 FORMAT (2X,'MEAN OF - K',11X,'= O + D',1X,A8,'=',3X,4F11.4//)
         WRITE (6,62) NAME(K),M(11,K),STD(11,K),STE(11,K),CL95(11,K)
      62 FORMAT (26X,'O',5X,A8,'=',3X,4F11.4/)
         WRITE (6,63) NAME(K),M(12,K),STD(12,K),STE(12,K),CL95(12,K)
      63 FORMAT (26X,'D',5X,A8,'=',3X,4F11.4/)
         WRITE (6,64) NAME(K),M(13,K),STD(13,K),STE(13,K),CL95(13,K)
      64 FORMAT (26X,'T',5X,A8,'=',3X,4F11.4)
         WRITE(6,65)
      65 FORMAT(27X,'L'/)
         WRITE(6,64) NAME(K),M(14,K),STD(14,K),STE(14,K),CL95(14,K)
         WRITE(6,66)
      66 FORMAT(27X,'R')
         DO 67 L=1,3
      67 WRITE(6,13)
         WRITE(6,68)
      68 FORMAT(13X,'MEAN C',6X,'MEAN C',16X,'I',10X,'T',6X,'-',4X,'T',6X,
        -'-',5X,'O',5X,'-',5X,'D',9X,'N'/19X,'2',11X,'1',27X,'I',11X,'0'/)
      69 FORMAT(/97X,F11.4)
         WRITE(6,69)  M(5,K)
         WRITE(6,70)  NAME(K),M(2,K),M(1,K),M(6,K),M(9,K),M(10,K),M(11,K),
        -M(12,K)
      70 FORMAT(2X,A8,F10.4,' =',F10.4,' ( 1.0 +',F10.4,' +',F10.4,3(F12.4)
        -,' )')
      71 CONTINUE
         CALL FACTOR
         STOP
         END
C
C
         SUBROUTINE PRINT
         DIMENSION TABLE(30),MONTH(12),ALOC(2,60,6),TOT(10,8),STD(23,8),
        1, STE (23,8),CL95(23,8),IA(2),AI(2)
         REAL *4MEAN,M(17,8)
         REAL *8X(10,60,7),V2(60,7),NAME(23),V1(7)
         INTEGER CST(2,60),CDATE(2,60,3)
         COMMON X,TABLE,IA,IB,I,K,KD,ID
         COMMON /BLK1/ NAME,TOT,M,STD,STE,CL95,ALOC,YR,CST,CDATE,MONTH,L1,L
C
```

```
      DO 1 J=1,IB
    1 WRITE (6,3) CST(L,J),(ALOC(L,J,K),K=1,6),(CDATE(L,J,K),K=1,3),(X(I
     1,J,K),K=1,L1)
C
C     SKIP TO BOTTOM OF PAGE
      N=(68-(IB+6))/2
C
      DO 2 J=1,N
    2 WRITE (6,4)
C
      RETURN
C
    3 FORMAT (5X,I2,5X,2A4,A2,2X,2A4,A2,2X,I2,2('-',I2),8F11.2)
    4 FORMAT (/)
      END
C
C
      SUBROUTINE PRINT2
      DIMENSION TABLE(30),MONTH(12),ALOC(2,60,6),TOT(10,8),STD(23,8)
     1, STE(23,8),CL95(23,8), IA(2),AI(2)
      REAL *MEAN,M(17,8)
      REAL *8X(10,60,7),V2(60,7),NAME(23),V1(7)
      INTEGER CST(2,60),CDATE(2,60,3)
      COMMON X,TABLE,IA,IB,I,K,KD,ID
      COMMON /BLK1/ NAME,TOT,M,STD,STE,CL95,ALOC,YR,CST,CDATE,MONTH,L1,L
      WRITE (6,1) (TOT(I,J),J=1,L1)
      WRITE (6,2) (M(I,J),J=1,L1)
      WRITE (6,3) (STD(I,J),J=1,L1)
      WRITE (6,4) (STE(I,J),J=1,L1)
      WRITE (6,5) (CL95(I,J),J=1,L1)
      RETURN
C
    1 FORMAT (34X,'TOTALS',6X,7F10.4)
    2 FORMAT (/34X,'MEAN',8X,7F10.4)
    3 FORMAT (/34X,'S.D.',8X,7F10.4)
    4 FORMAT (/34X,'S.E.',8X,7F10.4)
    5 FORMAT (/34X,'95% CL',6X,7F10.4)
      END
C
C
      SUBROUTINE PRINT3
      DIMENSION TABLE(30),MONTH(12),ALOC(2,60,6),TOT(10,8),STD(23,8)
     1, STE(23,8),CL95(23,8),IA(2),AI(2)
      REAL *4MEAN,M(17,8)
      REAL *8X(10,60,7),V2(60,7),NAME(23),V1(7)
      INTEGER CST(2,60),CDATE(2,60,3)
      COMMON X,TABLE,IA,IB,I,K,KD,ID
```

```
      COMMON /BLK1/ NAME,TOT,M,STD,STE,CL95,ALOC,YR,CST,CDATE,MONTH,L1,L
      DO 19 K=1,ID
      WRITE (6,3)
      WRITE (6,4)
      WRITE (6,5) NAME(K),NAME(K)
      WRITE (6,6)
      WRITE (6,7)
      IB=IA(2)
C
      DO 1 J=1,IB
    1 WRITE (6,17) CST(2,J),X(2,J,K),X(5,J,K),(X(IX,J,K),IX=6,10)
C
      JPIA=IA(2)
      IB=IA(1)
C
      DO 2 J=1,IB
      JPIA=JPIA+1
    2 WRITE (6,18) CST(1,J),X(1,J,K),X(5,JPIA,K),(X(IX,JPIA,K),IX=6,10)
C
      WRITE (6,7)
      WRITE (6,16) TOT(2,K),TOT(1,K),TOT(5,1),(TOT(N,K),N=6,10)
      WRITE (6,15)
      WRITE (6,13) NAME(K)
      WRITE (6,16) M(2,K),M(1,K),M(5,1),(M(N,K),N=6,10)
      WRITE (6,8)
      WRITE (6,13) NAME(K)
      WRITE (6,16) STD(2,K),STD(1,K),STD(5,1),(STD(N,K),N=6,10)
      WRITE (6,9)
      WRITE (6,12) NAME(K)
      WRITE (6,16) STE(2,K),STE(1,K),STE(5,1),(STE(N,K),N=6,10)
      WRITE (6,10)
      WRITE (6,12) NAME(K)
      WRITE (6,16) CL95(2,K),CL95(1,K),CL95(5,1),(CL95(N,K),N=6,10)
      WRITE (6,11)
   19 WRITE (6,14) NAME(K)
      RETURN
C
    3 FORMAT ('1',1X,'STATION')
    4 FORMAT (12X,'C',9X,'C',11X,'N',8X,'+ K',7X,'- K',6X,'+K + -K',
     1 4X,'+K - NET',3X,'-K - NET')
    5 FORMAT ('+',15X,A8,2X,A8)
    6 FORMAT (13X,'2',9X,'1',52X,'R',10X,'R'/)
    7 FORMAT (/)
    8 FORMAT ('+',94X,'MEANS')
    9 FORMAT ('+',94X,'S.D.')
   10 FORMAT ('+',94X,'S.E.')
```

```
      11 FORMAT ('+',94X,'95% CONFIDENCE LIMITS')
      12 FORMAT ('+', 99X,A8)
      13 FORMAT ('+',102X,A8)
      14 FORMAT ('+',116X,A8)
      15 FORMAT ('+',94X,'TOTALS')
      16 FORMAT (/9X,5F10.4,3F11.4)
      17 FORMAT (4X,I2,1X,F10.2,12X,3F10.4,3F11.4)
      18 FORMAT(4X,I2,1X,10X,F10.2,2X,3F10.4,3F11.4)
         END
C
C
         SUBROUTINE TDIST (KA,T)
         REAL *8X(10,60,7)
         DIMENSION TABLE(30), IA(2), AI(2)
         COMMON X,TABLE,IA,IB,I,K,KD,ID
         I1=KA-1
         AK=I1
         IF (I1) 1,1,2
       1 WRITE (6,11) I
         GO TO 10
       2 IF (I1.LT.31) GO TO 9
         IF (I1.LT.41) GO TO 3
         GO TO 4
       3 TINT=((2.042-2.021)/10.)*(AK-30.)
         T=TINT+2.042
         GO TO 10
       4 IF (I1.Lt.61) GO TO 5
         GO TO 6
       5 TINT=((2.021-2.000)/20.)*(AK-40.)
         T=TINT+2.021
         GO TO 10
       6 IF (I1.LT.121) GO TO 7
         GO TO 8
       7 TINT=((2.000-1.980)/40.)*(AK-60.)
         T=TINT+2.000
         GO TO 10
       8 T=1.960
         GO TO 10
       9 T=TABLE(I1)
      10 RETURN
C
      11 FORMAT ('1','I IN T TABLE =',I3)
         END
C
C
```

```
      SUBROUTINE STDEV (SUMX,XBAR,STD,STE,CL$)
      REAL *8X(10,60,7)
      DIMENSION TABLE(30), IA(2), AI(2)
      COMMON X,TABLE,IA,IB,I,K,KD,ID
      DEV=0.
      SUMX=0.
C
      DO 1 J=1,IB
    1 SUMX=SUMX+X(I,J,K)
C
      AI(I)=IA(I)
      XBAR=SUMX/AI(I)
C
      DO 2 J=1,IB
      DEV=(XBAR-X(I,J,K))**2+DEV
    2 CONTINUE
C
      STD=SQRT(DEV/(AI(I)-1.))
      STE=STD/SQRT(AI(I))
      KA=IB
      CALL TDIST (KA,T)
      CL$=T*STE
      END
C
C
      SUBROUTINE STDEV2 (STD,STE,CL$)
      REAL *8X(10,60,7)
      DIMENSION TABLE(30), IA(2), AI(2)
      COMMON X,TABLE,IA,IB,I,K,KD,ID
      AI3=IA(1)+IA(2)
      STE=STD/SQRT(AI3)
      KA=IA(1)+IA(2)
      CALL TDIST (KA,T)
      CL$=T*STE
      RETURN
      END
C
C
      SUBROUTINE NCOMP
      DIMENSION TABLE(30),MONTH(12),ALOC(2,60,6),TOT(10,8),STD(23,8)
     1, STE(23,8),CL95(23,8),IA(2), AI(2)
      DIMENSION IYRVAL(5),ITOTDA(5)
      REAL *4M(17,8)
      REAL *8X(10,60,7),NAME(23)
      INTEGER CST(2,60),CDATE(2,60,3)
      INTEGER SUMDA(2)
      COMMON X,TABLE,IA,IB,I,K,KD,ID
      COMMON /BLK1/ NAME,TOT,M,STD,STE,CL95,ALOC,YR,CST,CDATE,MONTH,L1,L
      IJ=0
```

```
C
      DO 13 I=1,2
      K=0
      SUMDA(I)=0
      ITOTDA(I)=0
C     STORE INITIAL TIME
      MO1=CDATE(I,1,1)
      IDA1=CDATE(I,1,2)
      IYR1=CDATE(I,1,3)
      IYRVAL(1)=365
      A=IYR1
      IZ=A/4.
      IF (IZ*4.EQ.IYR1.AND.MO1.GT.2) IYRVAL(1)=366
      INT1=MONTH(MO1)+IDA1
C     FIND TIME INTERVAL OF FIRST DATE TO END OF FIRST YEAR
      INT2=IYRVAL(1)-INT1
      IB=IA(I)
C
      DO 4 J=1,IB
      MO2=CDATE(I,J,1)
      IDA2=CDATE(I,J,2)
      IYR2=CDATE(I,J,3)
C     COMPUTE YEAR VALUES-365 OR 366
      IF (IYR1.EQ.IYR2) TO TO 3
C     K STORES NUMBER OF INTERVENING YEARS
      K=IYR2-IYR1
C
      DO 1 L=1,K
      IYRVAL(L+1)=365
      A-IYR1+L
      IZ=A/4.
      IF (IZ*4.EQ.IYR1+L) IYRVAL(L+1)=366
    1 CONTINUE
C
C     COMPUTE INTERVAL OF LAST YEAR
      LAST1=MONTH(MO2)+IDA2
C     CHECK FOR LEAPYR OF LAST YEAR
      IF (IYRVAL(K).EQ.366.AND.MO2.GT.2) LAST=LAST+1
      LAST2=IYRVAL(K)-LAST1
C     COMPUTE TOTAL DAYS OF DATA SET
C     INT=FIRST YEAR
      K=K+1
C     K= NUMBER OF YEARS
C
```

```
      DO 2 L=1,K
    2 ITOTDA(I)=ITOTDA(I)+IYRVAL(L)
C
C     SUM ALL DAYS OF YEARS INVOLVED
      ITOTDA(I)=ITOTDA(I)-INT1-LAST2
      SUMDA(I)=SUMDA(I)+ITOTDA(I)
      GO TO 4
    3 INT2=MONTH(MO2)+IDA2
      ITOTDA(I)=INT2-INT1
      SUMDA(I)-SUMDA(I)+ITOTDA(I)
    4 CONTINUE
C
C     COMPUTE MEAN OF TIME
      MEANT=SUMDA(I)/IA(I)
C     SUBTRACT FIRST YEAR
      IX=MEANT+INT1
      IF (K.EQ.0) GO TO 7
C
      DO 5 L=1,K
      IF (IX.LT.IYRVAL(L)) GO TO 6
      IF (IX.EQ.IYRVAL(L)) TO TO 6
      IX=IX-IYRVAL(L)
    5 CONTINUE
C
C     COMPUTE YEAR
    6 IYR=L-1+IYR1
      IF (IYRVAL(L).EQ.366.AND.IX.GT.59) IX=IX-1
      GO TO 8
    7 IF (IYRVAL(1).EQ.366.AND.IX.GT.59) IX=IX-1
      IYR=CDATE(I,1,3)
C
    8 DO 9 N=1,12
C     LOCATE MONTH
      IF (IX.LT.MONTH(N+1)) GO TO 10
      IF (IX.EQ.MONTH(N)) GO TO 10
    9 CONTINUE
C
   10 IMON=N
      IDAY=IX-MONTH(N)
      IF (I.EQ.1) IC=IA(2)
      IF (I.EQ.2) IC=IA(1)
C
      DO 12 J=1,IC
      IJ=IJ+1
      CALL LEAPYR (J,IMON,IDAY,IYR)
C
```

```
      DO 11 K=1,ID
      X(5,IJ,K)=YR
   11 CONTINUE
C
   12 CONTINUE
C
   13 CONTINUE
C
      RETURN
      END
C
C
      SUBROUTINE LEAPYR (J,IMON,IDAY,IYR)
      DIMENSION TABLE(30), MONTH(12), ALOC(2,60,6), TOT(10,8), STD(23,8)
     1,STE(23,8), CL95(23,8), IA(2), AI(2)
      REAL *4MEAN, M(17,8)
      REAL *8X(10,60,7),NAME(23)
      INTEGER YR1,YR2,DA1,DA2,DAYS
      INTEGER CST(2,60),CDATE(2,60,3)
      COMMON /BLK1/ NAME,TOT,M,STD,STE,CL95,ALOC,YR,CST,CDATE,MONTH,L1,L
      COMMON X,TABLE,IA,IB,I,K,KD,ID
      DAYS=0
      NT=0
      IF (I.EQ.2) GO TO 1
      MO1=IMON
      DA1=IDAY
      YR1=IYR
      MO2=CDATE(2,J,1)
      DA2=CDATE(2,J,2)
      YR2=CDATE(2,J,3)
      GO TO 2
    1 MO2=IMON
      DA2=IDAY
      YR2=IYR
      MO1=CDATE(1,J,1)
      DA1=CDATE(1,J,2)
      YR1=CDATE(1,J,3)
    2 AMO=MO1
C
      DO 6 IY=YR1,YR2
      A=IY
      LEAP=0
      IZ=A/4.
      Z=IZ
      Z=Z*4.
      IF (IY.EQ.YR1) GO TO 3
      GO TO 4
```

```
    3 DAYS=365-(MONTH(MO1)+DA1)
      IF (Z.EQ.A.AND.AMO.LT.3.) LEAP=1
      GO TO 5
    4 IF (Z.EQ.A) LEAP=1
    5 NT=DAYS+LEAP+NT
    6 DAYS=365
C
      IF (LEAP.EQ.1) GO TO 7
      GO TO 8
    7 IF (MO2.LT.3) NT=NT-1
    8 YR=NT-365+MONTH(MO2)+DA2
      YR=YR/365.
      RETURN
      END
```

```
C       SUBROUTINE FOR PROGRAM FOR ESTIMATING SYSTEM RATES
C       BASED ON SAMPLE VALUES PAIRED TO MEAN VALUES.
        SUBROUTINE FACTOR
        DIMENSION TABLE(30), MONTH(12), ALOC(2,60,6), TOT(10,8), STD(23,8)
       1, STE(23,8), CL95(23,8), VAR1(7), VAR2(7), VAR3(7), SUM1(7), SUM2(
       27), SUM3(7), SUM4(7), COV1(7), COV2(7), IA(2), AI(2)
        REAL *4MEAN,M(17,8),MR(7)
        REAL *8X(10,60,7),V2(60,7),NAME(23),V1(7)
        INTEGER CST(2,60),CDATE(2,60,3)
        COMMON X,TABLE,IA,IB,I,K,KD,ID
        COMMON /BLK1/ NAME,TOT,M,STD,STE,CL95,ALOC,YR,CST,CDATE,MONTH,LI,L
        COMMON /BLK2/ MR
C
C
C       CALCULATE CORRECTION FACTOR FOR STANDARD DEVIATION
C
        IA3=IA(1)+IA(2)
        AI3=IA3
C
        DO 14 K=1, ID
C
        IF (M(8,K)) 1,4,5
      1 JX=(AI3*M(7,K)-AI3*M(10,K))/M(8,K)
        VJ=JX
        V=( ((AI3*M(10,K) )/VJ)**2)*VJ
        IF ((M(8,K)+( (AI3*M(10,K))/VJ))*VJ-(AI3*M(7,K)) ) 3,3,2
      2 V=V+(AI3*M(7,K)-VJ*(M(8,K)+( (AI3*M(10,K) )/VJ))-M(8,K))**2
        V=V+( ((AI3*M(6,K))/AI3-VJ-1.0))-M(8,K))**2*(AI3-VJ-1.0)
        GO TO 8
      3 V=V+( ((AI3*M(6,K))/(AI3-VJ))-M(8,K))**2*(AI3-VJ)
        GO TO 8
      4 JX-AI3/2.0
        VJ=JX
        V=( (AI3*M(6,K)/VJ)**2)*VJ
        V=V+( (AI3*M(7,K)/VJ)**2)*VJ
        GO TO 8
      5 JX=(AI3*M(6,K)-AI3*M(9,K))/M(8,K)
        VJ=JX
        V=(((AI3*M(9,K))/VJ)**2)*VJ
        IF ((M(8,K)+((AI3*M(9,K))/VJ))*VJ-(AI3*M(6,K))) 6,7,7
      6 V=V+(AI3*M(6,K)-VJ*(M(8,K)+((AI3*M(9,K))/VJ))-M(8,K))**2
        V=V+(((AI3*M(7,K))/(AI3-VJ-1.0))-M(8,K))**2*(AI3-VJ-1.0)
        GO TO 8
      7 V=V+( ((AI3*M(7,K))/(AI3-VJ))-M(8,K))**2*(AI3-VJ)
      8 V=V/(AI3-1.0)
        W=0.0
C
C
```

```
          DO 9 J=1,IA3
        9 W=W+(X(8,J,K)-M(8,K))**2
C
C
          W=W/(AI3-1.0)
          C=( (W-V)/W)**2
C
C         CALCULATE CORRECTED STD,6,7,AND 8
C         STD(15,K) IS CORRECTED STD(6,K)
C
          STD(15,K)=SQRT(C*STD(6,K)**2)
          CALL STDEV2 (STD(15,K),STE(15,K),CL95(15,K))
C
C         STD(16,K)IS CORRECTED STE(7,K)
C
          STD(16,K)=SQRT(C*STD(7,K)**2)
          CALL STDEV2 (STD(16,K),STE(16,K),CL95(16,K))
C
C         STD(17,K) IS CORRECTED STD(8,K)
C
          STD(17,K)=SQRT(C*STD(8,K)**2)
          CALL STDEV2 (STD(17,K),STE(17,K),CL95(17,K))
C
C         CALCULATE CORRECTED STD(9,K) AND STD(10,K)
C
          V=0.0
C
C
          DO 11 J=1,IA3
C
          IF (X(9,J,K)) 11,11,10
       10 V=V+X(9,J,K)**2
       11 CONTINUE
C
C
C
          V=V/(AI3-1.0)
          W=0.0
C
C
          DO 13 J=1,IA3
C
          IF (X(10,J,K)) 12,13,13
       12 W=W+(X(10,J,K))**2
       13 CONTINUE
C
C
C
```

```
      W=W/(AI3-1.0)
C
C     STD(18,K) IS CORRECTED STD (9,K)
C
      STD(18,K)=SQRT((V/(V+W))**2*C*(STD(8,K)**2))
      CALL STDEV2 (STD(18,K),STE(18,K),CL95(18,K))
C
C
C     STD(19,K) IS CORRECTED STD(10,K)
C
      STD(19,K)=SQRT((W/(V+W))**2*C*(STD(8,K)**2))
      CALL STDEV2 (STD(19,K),STE(19,K),CL95(19,K))
C
C     CALCULATE CORRECTED STD(20,K) CORRECTED STD(11,K)
C
      STD(20,K)=SQRT(STD(16,K)**2*(M(9,K)/M(6,K))**2)
C
C
      CALL STDEV2 (STD(20,K),STE(20,K),CL95(20,K))
C     CALCULATE STD(21,K) CORRECTED STD(12,K)
      STD(21,K)=SQRT(STD(16,K)**2*(1.0-M(9,K)/M(6,K))**2)
      CALL STDEV2 (STD(21,K),STE(21,K),CL95(21,K))
C
C     CALCULATE STD(22,K) CORRECTED STD(13,K)
C
      STD(22,K)=SQRT(STD(21,K)**2*(1.0/M(12,K)**2)**2)
      CALL STDEV2 (STD(22,K),STE(22,K),CL95(22,K))
C
C     CALCULATE STD(23,K) CORRECTED STD(14,K)
C
      STD(23,K)=SQRT(STD(16,K)**2*(1.0/M(7,K)**2)**2)
      CALL STDEV2 (STD(23,K),STE(23,K),CL95(23,K))
C
C
   14 CONTINUE
C
C
      DO 15 K=1,ID
C
      WRITE (6,16) NAME(K)
      WRITE (6,17) NAME(K),M(8,K),STD(17,K),STE(17,K),CL95(17,K)
      WRITE (6,18) NAME(K),M(9,K),STD(18,K),STE(18,K),CL95(18,K)
      WRITE (6,19)
      WRITE (6,20) NAME(K),M(10,K),STD(19,K),STE(19,K),CL95(19,K)
      WRITE (6,21)
      WRITE (6,22) NAME(K),M(6,K),STD(15,K),STE(15,K),CL95(15,K)
      WRITE (6,23) NAME(K),M(7,K),STD(16,K),STE(16,K),CL95(16,K)
```

```
      WRITE (6,24) NAME(K),M(11,K),STD(20,K),STE(20,K),CL95(20,K)
      WRITE (6,25) NAME(K),M(12,K),STD(21,K),STE(21,K),CL95(21,K)
      WRITE (6,26) NAME(K),M(13,K),STD(22,K),STE(22,K),CL95(22,K)
      WRITE (6,27)
      WRITE (6,26) NAME(K),M(14,K),STD(23,K),STE(23,K),CL95(23,K)
      WRITE (6,28)
   15 CONTINUE
C
C
   16 FORMAT ('1',40X,'CORRECTED STANDARD DEVIATIONS'//,2X,'RATES OF CHA
     1NGE FOR',A8,30X,'S.D.',7X,'S.E.',4X,'95% LIMIT'//)
   17 FORMAT (2X,'MEAN OF K',13X,'=NET',3X,A8,'=',3X,4F11.4/)
   18 FORMAT (2X,'MEAN OF + ( K - NET ) = T',5X,A8,'=',3X,4F11.4)
   19 FORMAT (27X,'I'/)
   20 FORMAT  (2X,'MEAN  OF - ( K - NET ) = T',5X,A8,'=',3X,4F11.4)
   21 FORMAT (27X,'O'/)
   22 FORMAT (2X,'MEAN OF + K',11X,'= I',5X,A8,'=',3X,4F11.4//)
   23 FORMAT (2X,'MEAN OF - K',11X,'= 0+D',1X,A8,'=',3X,4F11.4//)
   24 FORMAT (26X,'O',5X,A8,'=',3X,4F11.4/)
   25 FORMAT (26X,'D',5X,A8,'=',3X,4F11.4/)
   26 FORMAT (26X,'T',5X,A8,'=',3X,4F11.4)
   27 FORMAT (27X,'L'/)
   28 FORMAT (27X,'R')
C
      RETURN
      END
```