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Socioeconomic Environmental Studies Series

The Integrated Multi-Media Pollution Model

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THE INTEGRATED MULTI-MEDIA POLLUTION MODEL

by

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Abstract

The primary objective of the project was to develop a prototype multi-pollution model for a typical metropolitan region. This report includes the basic design and some of the results of initial testing of the model. The Integrated Multi-Media Pollution Model, or IMMP, views environmental pollution as a set of interrelated problems -- the solution of which requires examination of all types of pollution jointly and simultaneously -- and attempts to seek an overall solution to environmental resource management. Specifically, the model embodies the trade-offs among different forms of residuals disposed finally in the environment that are effected by alternative land use policies, production processes, pollution control strategies and methods. Thus, the Land Use submodel relates various land use policies to the distribution of the sources of environmental pollution; the Residuals Management submodel relates alternative levels of pollution generating activities, input mixes, production processes of various activities, and the alternative treatment processes associated therewith to the magnitude, composition and distribution of pollutants; and Disposal-Dispersion submodel relates pollution emissions at source to (ambient) environmental quality at destination. The model provides a comprehensive framework in which to test and evaluate a wide range of strategies for planning, managing and controlling our environmental resources.

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CONTENTS

		Page
Abstract		ii
List of Figures		iv
Acknowledgments		v
Sections		
I	Overview	1
II	Alternative Strategies for Environmental Resource Management -- Land Use Submodel	33
III	Alternative Strategies for Environmental Resource Management -- Residual Management Submodel	40
IV	Alternative Strategies for Environmental Resource Management -- Dispersion Submodel	56
V	The Test of IMMP Model	77
VI	Instructions for Operation of IMMP	110
VII	The IMMP Program	140
VIII	Appendix	172
IX	Bibliography	256

FIGURES

No.		Page
1a	Interdependent Relationships Among Residuals From Air to Other Media	3
1b	Interdependent Relationships Among Residuals From Water to Other Media	4
1c	Interdependent Relationships Among Residuals From Land to Other Media	5
2	A Flow Diagram of IMMP Model	12
3	A Hypothetical Metropolitan Area	14
4	Alternative Controls of Land Use	39
5	A Flow Diagram of the Residuals Management Submodel	42
6	Residuals and Sources	45
7	Air Diffusion	60
8	Water Diffusion	70
9	Configuration of the Hypothetical Region	79
10	Gross Emissions of Pollutants from Six Alternative Specifications of the IMMP Model	85
11	Total Net Pollutant Levels (Water)	86
12	Ambient Pollution Levels (Water)	98

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This research was performed within the Economics Department, Georgetown University, Washington, D. C. Credit for the development of diffusion models goes to Professor F. W. McElroy; Dr. John Harrington, Jr. is responsible for programming the model. Inja Paik was director of the project, collected data, designed the overall model, and provided interface with EPA personnel.

SECTION I

OVERVIEW

The Integrated Multi-Media Pollution Model

The primary objective of the project has been to develop a prototype multi-pollution model for a typical metropolitan region. The Integrated Multi-Media Pollution Model or IMMP, embodies the trade-offs among different forms of residuals disposed finally in the environment that are effected by alternative production processes -- including possibilities of input substitution -- and alternative control strategies and methods. These trade-offs are ignored in most of the currently existing environmental pollution models but are clearly of critical importance for rational environmental quality management.

It is a well-known fact that abatement of one type of pollution results in another type of pollution. For example, the use of a wet scrubber to trap particulates that would otherwise be discharged into the air reduces the level of air pollution but increases that of water pollution. The dredging of a water body would make it cleaner, but would at the same time mean an increase in solid waste, which if burnt, would add to air pollution. Dumping solid wastes in a remote area would lessen "landscape" defacement in one area but aggravate the same in another area, and also, increase the level of air pollution and noise pollution in the process of their transportation. This phenomenon of trade-offs among different forms of wastes is evidently omnipresent and indeed no less than a logical consequence of the "law of conservation of mass." Figures 1a, 1b, 1c list possible trade-offs between air-, water-borne pollution and solid wastes.

While it is clear that the kind and quantity of residual wastes to be disposed eventually in the natural environment are dependent on these trade-offs, and therefore, no rational abatement program can be evaluated without including them in the analysis, traditionally, environmental pollution has been classified in terms of the "receiving medium," i.e., into air-, water-, solid waste- (or land-) pollution, with noise and thermal pollution treated as special cases, and accordingly, the formulation, planning and administration of policies and programs of environmental quality management, at both the federal and state levels, adhere closely to the same categorization.

The receiving-medium based organization of environmental management (for example, into "air program office," "water program office," etc.) may be necessary to take full advantage of the "administrative" and "operational" efficiency derived from grouping together the activities which require similar technical expertise, but cannot be considered a logical basis for determining overall optimal strategies for pollution control. To illustrate,

Figure 1a

Interdependent Relationships among Residuals

From Air to Other Media

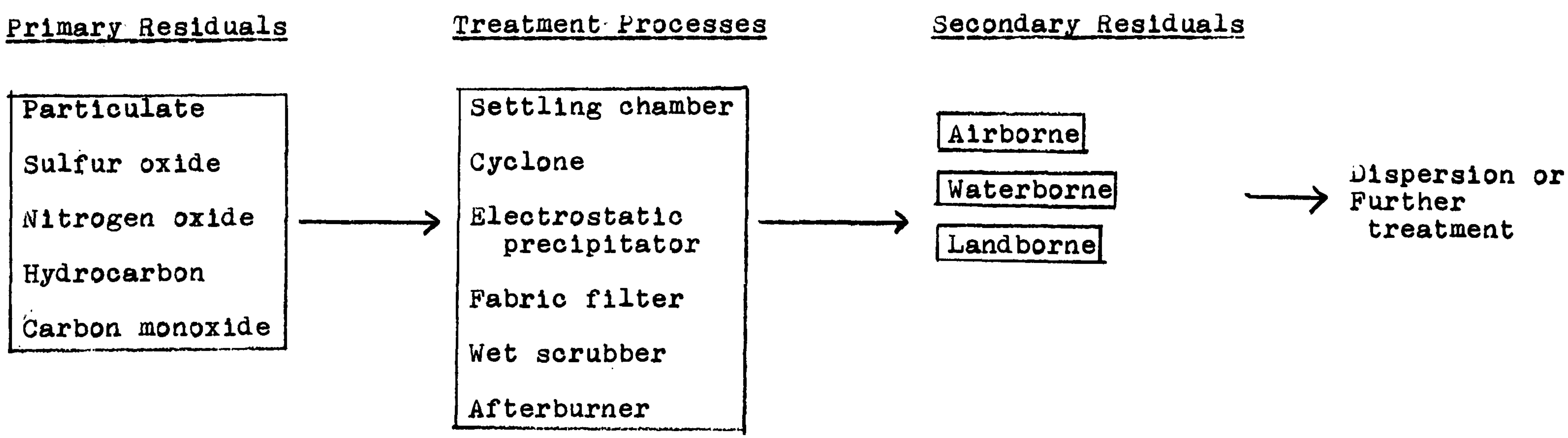


Figure 1b

Interdependent Relationships among Residuals

From Water to Other Media

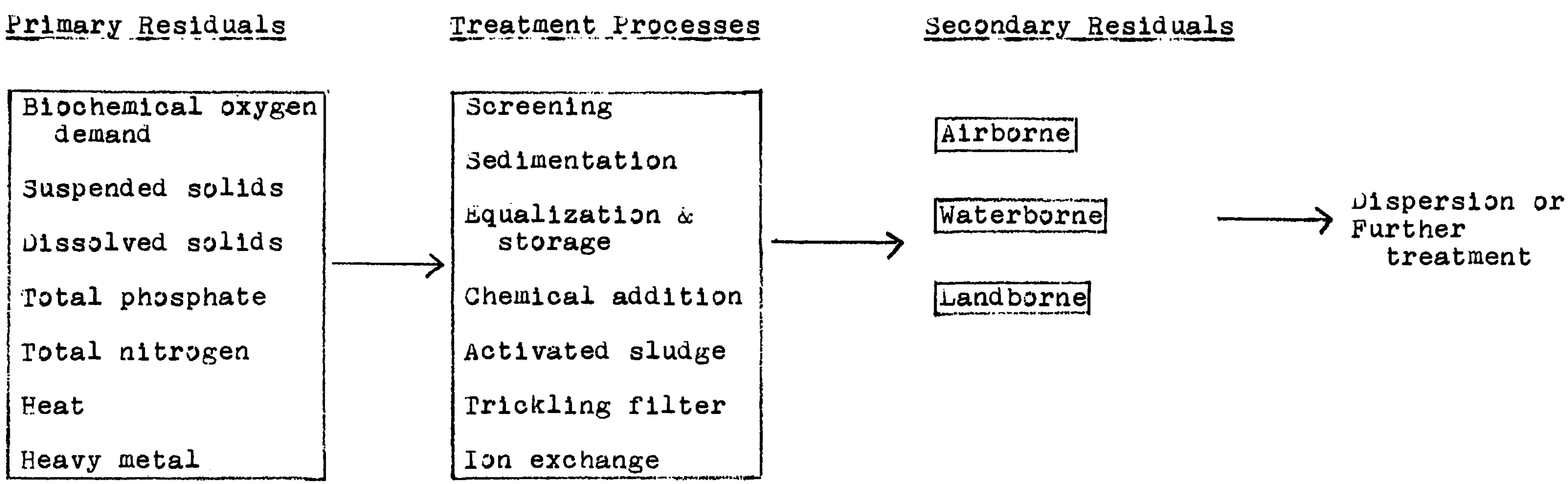
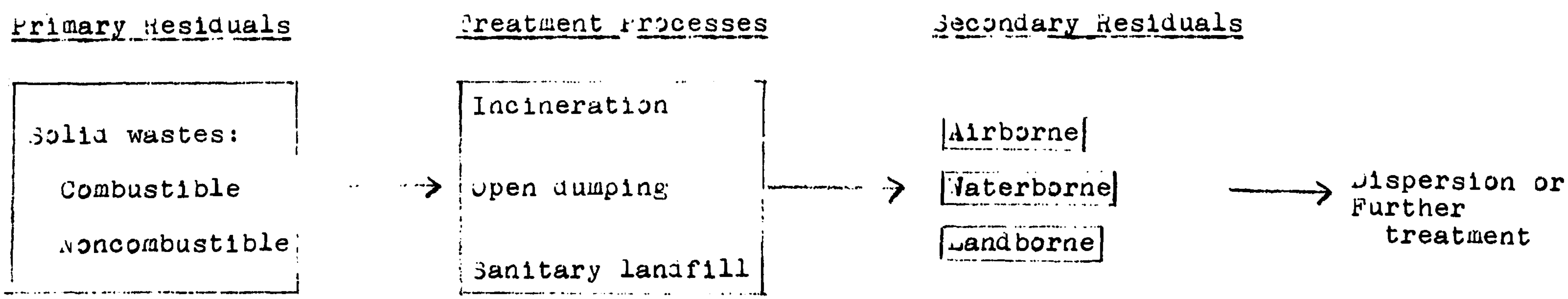


Figure 1c

Interdependent Relationships among Residuals

from Land to Other Media



consider a case of a "water program office" contemplating whether to permit the burning of the sludge that emerges from the water treatment plant. In the cost-benefit analysis of the program, the "direct" costs of incineration -- the costs of the initial investment and the operating costs -- will be included routinely, but the additional social costs entailing from the additional air pollution will not. At least not in commensurate terms. In short, there exists a divergence of social costs and parochial costs which nullifies the justification for partial analysis; the decision on one type of pollution cannot be made without recognizing its effects on other types of pollution.

A metropolitan area is a system of economic, political, social, demographic and environmental variables. Political-social institutions and forces, and the size and characteristics of the population in the area determine the kinds and levels of economic activities, i.e., production and consumption, and vice versa. Production and consumption inevitably generate residuals which, when disposed in the environment, result in its degradation. Given the quantities and locations of the residuals discharged, the particular hydrological, geophysical and meteorological characteristics of the area determine the type, location and degree of the environmental degradation, and these in turn bring aesthetic, health-, recreation-, and materials-related damages to the specific segments of the population. Efforts to abate the pollution and its damages entail changes in the mix and level of economic and noneconomic activities.

More specifically, if the population continues to hold to such traditional social and personal goals as economic growth and "high standard of living" -- especially through production and consumption of high-polluting goods (e.g., paper, electricity, automobiles) in contrast to low-polluting goods (e.g., services, bicycles), further depletion and deterioration of environmental resources are unavoidable. Alternatively, arrestment in population growth, demographic redistribution, change in land-use pattern and stabilization of the high standard of living may alleviate the problems of environmental pollution, but would have a profound effect on the pattern and level of economic activities, and therefore, prerequire a drastic revision in the social and personal values and way of thinking and living.

Obviously, the manager of environmental resources cannot ignore the permeating impact of his pollution control policies and programs on such economic and demographic-social variables as the pattern of economic growth, income, employment, health, migration, leisure-time allocation, etc., and in reverse, the effects on the environment of economic and noneconomic decisions and activities of individual households, businesses and governments that lie outside his control but amplify or attenuate the effectiveness of his own abatement efforts. Indeed, in order to examine the trade-offs among various types of pollution vis-a-vis the trade-offs among the competing goals of the region, it may be necessary to construct what may be called a total environmental resource management model that include all the relevant economic, political, social, demographic and environmental variables and their interactions. Building such a comprehensive model is envisioned, but is beyond the purview of present research effort.

A Brief Description of IMMP

The IMMP model is intended to be used either as a framework for analyzing the interdependent nature of environmental pollution, by focusing primarily on those variables that affect pollution levels directly, or as a submodel to other metropolitan system models thereby allowing the user of the model to observe the interactions between the environmental sector and other sectors within the metropolitan region.

The IMMP model differs from most of the currently existing environmental pollution models in several important respects. The distinguishing feature of the IMMP is its explicit recognition and representation of all of the significant elements of the metropolitan environmental pollution and their interrelationships. In contrast to other models which focus their attention on only a part of the total environmental pollution system, the IMMP views the environmental pollution as an integral set of interrelated problems -- the solution of which requires examination of all types of pollution jointly and simultaneously -- and attempts to seek an overall solution, while others offer partial solutions based on partial analyses.

The analysts and policy makers often find the existing models -- even when they are designed to deal with multiple pollutants and thus are quite comprehensive in scope -- do not render themselves readily as a practical tool for analyzing and evaluating alternative programs and policies in the real world. This is commonly due to the rigid structure the model is "locked in" as in the input-output models and linear programming models. Flexibility in addition to "comprehensiveness" and "integrality" is another distinguishing feature of IMMP. Specifically, the IMMP model is designed in modular form so that any part of the model -- e.g., an activity -- can be added or deleted freely with no structural change in the model. With such built-in flexibility, it can easily be adapted to different metropolitan regions faced with their own sets of environmental problems.

Finally, another main feature of the IMMP is a data bank developed and maintained to provide the user of the model with up-do-date information on alternative production processes of major industries, alternative abatement technologies, etc. which is necessary for the practical use to which the model is to be put.

In short, the IMMP is a multi-media pollution model which synthesizes the currently available information on all important aspects of the environmental degradation problem intended as a comprehensive, flexible and practical tool for analyzing and evaluating alternative strategies for managing the environmental resources of metropolitan areas.

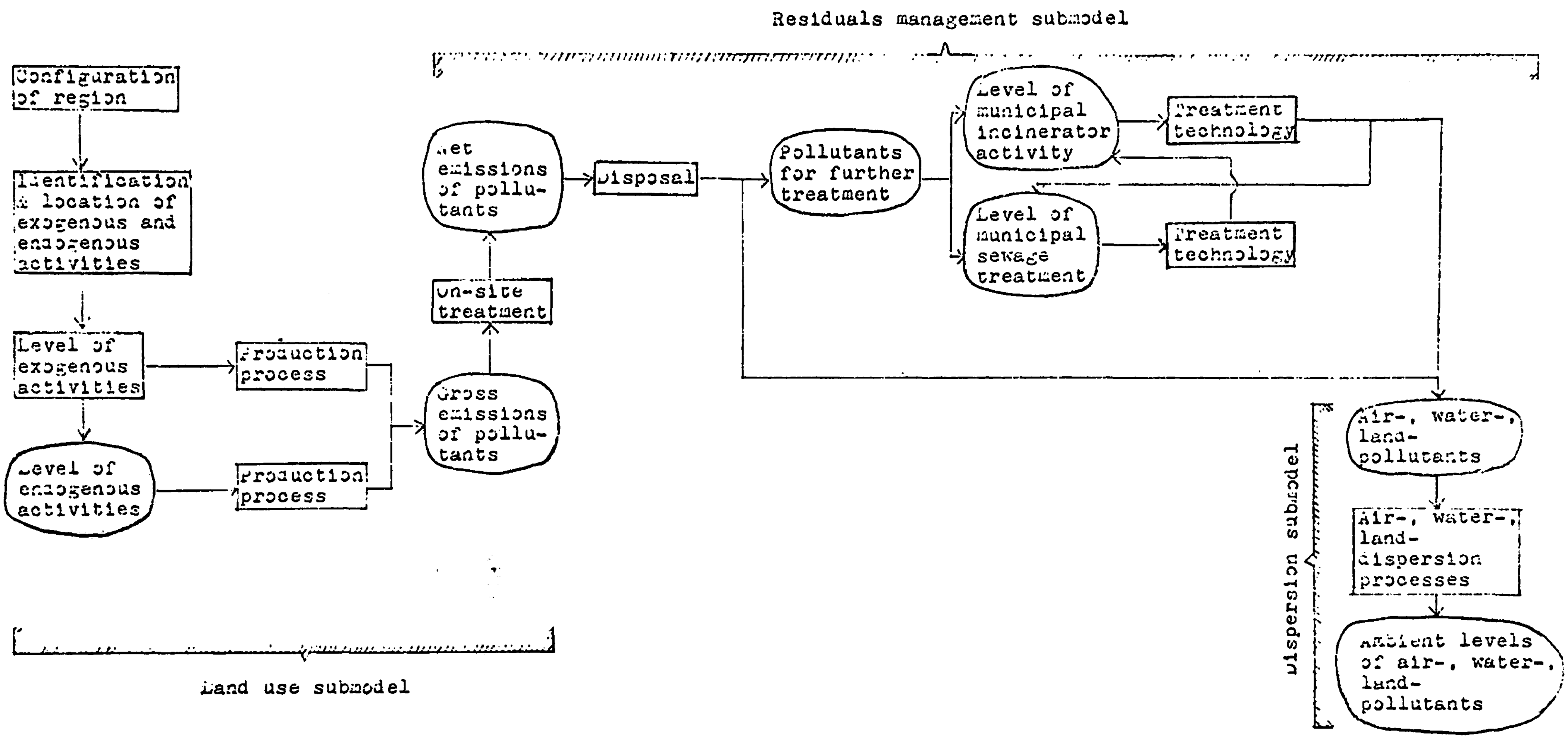
The IMMP is not an optimization model. The arguments for choosing a descriptive rather than optimizing framework are twofold: In general, the structure of an optimization model is more restrictive compared with that of a simulation model thus diminishing its adaptibility to various metropolitan areas with a varying set of environmental pollution problems. More importantly, because of the complex interrelationships that exist among various sectors within a metropolitan region, it is often difficult, if not impossible, to delineate a practical and meaningful single objective function for the model.
The IMMP as it stands is a steady-state model. This limitation is to be rectified in the next phase of the project.

The Structure of IMMP

Programs to protect environmental quality can be classified into three broad categories: (1) programs to regulate land-use pattern, (2) programs to regulate economic and non-economic activities which create the residuals initially, and programs to regulate on-site and central residuals treatment activities which alter the forms of residuals, and (3) programs to alter the residual dispersion processes. The model is structured along these categories. Specifically, the actions that affect the configuration of the metropolitan region and locations of pollutant generating and altering activities determine the distribution of pollutants within the region and belong to the first category. The actions determining the levels of pollution generating activities, production processes and pollution treatment processes all of which in turn determine the magnitudes and types of pollutants produced belong to the second categories. Finally, the actions which alter the disposal-dispersion of pollutants belong to the third category. These components of the model are shown in a flow-chart form in Figure 2.

Each rectangled entry represents a controllable variable or structural relation on which the user of the model is allowed to exercise his option, while each circled entry denotes a non-controllable variable or relation which is determined within the model given the specifications of the controllable variables and relations and the parameters.

With the aid of the data bank, the user of the model can test and make a wide range of decisions from those involving land-use to those concerning the choice of an appropriate set of activities (and locations thereof), through the knowledge of the quantities of pollutants generated therefrom and their ultimate impact on the ambient pollution levels throughout the region. Conversely,



A Flow Diagram of IMMP Model

Figure 2

the model provides a framework for evaluating the impact of alternative pollutant emission standards or ambient quality standards on various activities within the region.

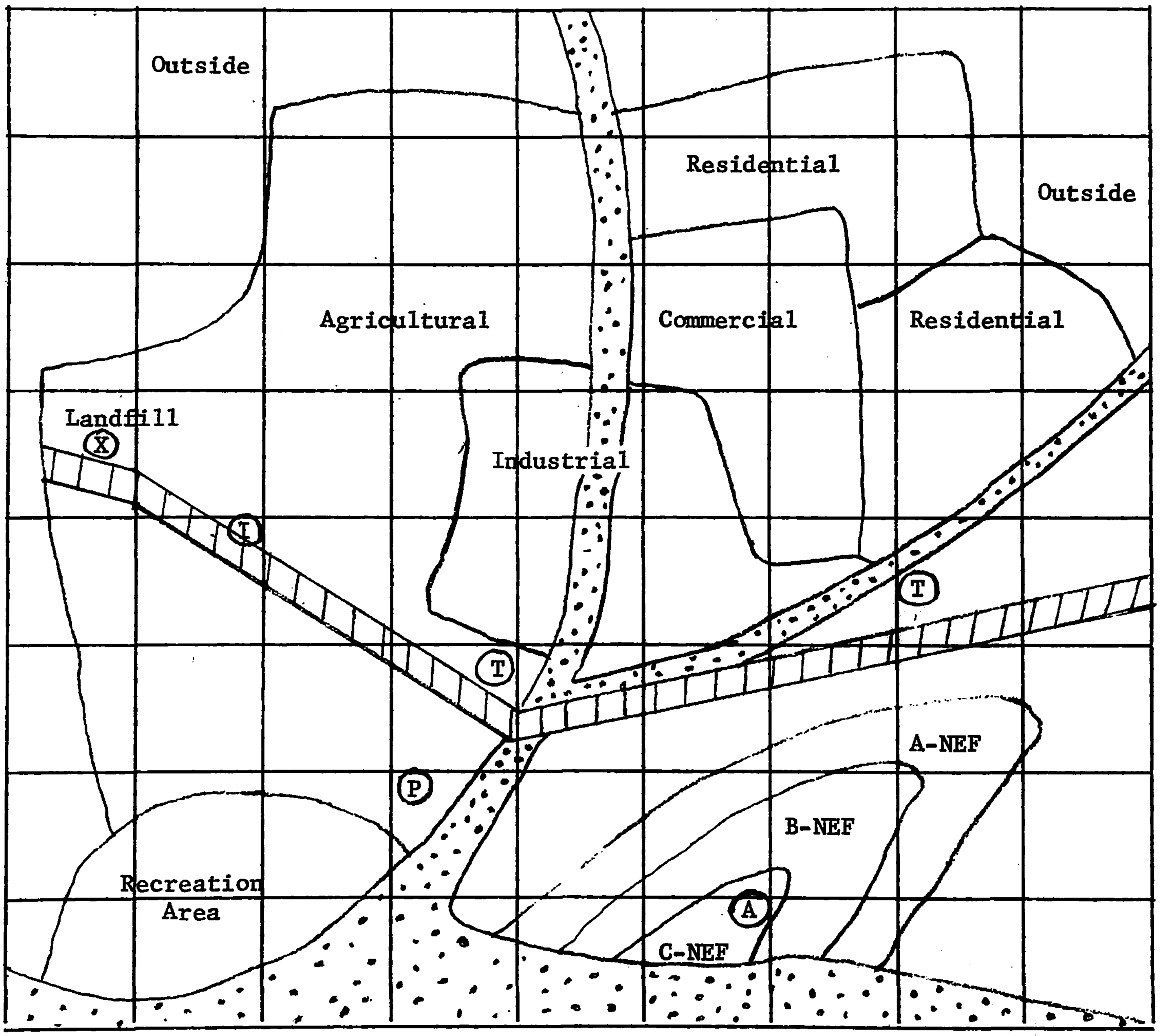
In anticipation of a more detailed discussion in the subsequent chapters, a brief overview of the basic nature and concepts of the model is given in the following with reference to the flow chart of Figure 2.

Configuration of the Region: For the model, a metropolitan region is considered a rectangular space with a number of rows and columns that divide the space into a set of square grids as illustrated in Figure 3. Political jurisdiction is not the main basis for defining the size of the region; the principal criterion is the degree or intensity of economic, social, political, demographic and environmental interaction that exists between activities carried out at different locations. The hypothetical metropolitan region of Figure 3 includes industrial, residential, commercial, agricultural and recreational areas as well as a landfill area, municipal incinerators, a municipal waste water treatment plant, a power plant, an airport and a river. Definition of the size of the region is accomplished by the user by specifying the number of rows and columns and the distance between two adjacent rows (or columns).

More important than defining the size of the region, the user can exercise a considerable degree of discretion in

Figure 3

A Hypothetical Metropolitan Area



Ⓐ Airport

Ⓘ Municipal Incinerator

Ⓟ Power Plant

Ⓣ Water Treatment Plant

NEF Noise Contours

Truck Route

River

specifying the land-use pattern. If a new city is being planned and designed from scratch, the option over the land-use available to the user of the model is rather complete, but even with an existing metropolitan region with more or less fixed spatial structure, the managers may be able to relocate activities, especially in the long run, through zoning classification, taxation and other means. Also, the direction of the flow of a river may be altered, or a new branch of a river may be opened for the exclusive use as the receptor of residual discharges. The model can evaluate the environmental impact of these alternative configurations of the region.

Identification and Location of Activities: The activities in the model as sources of pollution consist of a set of exogenous activities and a set of endogenous activities. Exogenous activities are those whose levels of operation are determined outside the model, i.e., by the user of the model. For IMMP, the agricultural, industrial, commercial, and residential activities are included as exogenous variables.[1] For endogenous activities, the levels of operation are determined within the model as the results of the exogenous activities. For the purpose of IMMP, the endogenous activities are classified into two categories: those representing residuals-treatment activities such as municipal incinerators and waste water treatment plants, and those other than treatment activities such as transportation and power plants.

[1]The model is however capable of treating any activity as endogenous.

Whether for a new or existing metropolitan region, the user of the model has the option of choosing which of these exogenous and endogenous activities are to be included in the model and of deciding where to locate them. Through exercise of this option, the managers can evaluate the environmental impact of alternative mixes of industries, etc. and of alternative land-uses.

Levels of Exogenous Activities and Nontreatment Endogenous Activities: Upon stipulating a set of activities, the user is required to specify for each exogenous activity its level of operation, e.g., output per day in dollars or tons for a steel mill. Once this is done, the levels of nontreatment endogenous activities, i.e., of transportation and power plant activities are determined automatically by applying transformation coefficients (or functions). Through varying the levels of various activities and evaluating the resulting variation in the levels of pollutant emissions and of ambient quality, the user enhances his understanding of the effect of economic (and other) policies on the environment and vice versa.

Production Processes: The magnitude and type of pollutants arising from an activity -- be it exogenous or endogenous -- are functions not only of the level of operation but also of production processes and inputs used. Thus, each of the alternative production processes can be represented by a matrix with an appropriate set of residual coefficients which transforms a vector of inputs into an output vector of pollutants.

The user of the model is allowed to evaluate the pollution effects of using alternative inputs, especially in reference to high-sulfur vs. low-sulfur fuels, as well as the effects of using alternative production process. The data bank contains pollution transformation coefficients for various production processes of each industry both in current use as well as in development, and the possibilities of input substitution.

Since different inputs and production processes involve different costs of investment and maintenance, the data bank includes data for these costs, enabling the user to compare the differential pollution effects of alternatives with their differential cost effects.

Gross Emissions of Pollutants: As shown in the flow chart, the result of the decisions made by the user of the model up to this point is the gross emissions of all pollutants in the various subareas of the region where the pollution-generating activities are located. In bare skeleton, the structural relations involved are as follows. Let:

X = a vector of exogenous activities, each element of which represents an activity in a particular subarea.

Y = a vector of endogenous activities such as transportation and power plants. Each element of Y represents an endogenous activity in a particular subarea.

E_g = a vector of gross pollutants emitted prior to any treatment, on-site or otherwise.

Then,

$$Y = F_1(X)$$

$$E_g = F_2(X) + F_3(Y) = F_2(X) + F_3\{F_1(X)\}$$

The decision maker can specify alternative levels of X as well as alternative residual transformations of X and Y into E_g, i.e., alternative relations, F_2 and F_3, in order to observe their effects on E_g. In reverse, the decision maker may stipulate alternative levels of E_g -- alternative emission standards -- and observe, through iteration, their effects on X and Y, the activities.

<u>On-site Treatment</u>: Prior to being dispersed into various environmental receptors, air, water and land, or being transported to other facilities for further treatment, the pollutants arising from the activities are often treated at the source.

In the model, a treatment process is represented by an array of coefficients whereby a given (untreated) residuals are transformed into a set of treated residuals. Simple treatment processes would be represented by such simple diagonal matrices as $T_1 = \begin{bmatrix} .5 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$. Assuming that there were only three pre-treatment pollutants $E_g = \begin{bmatrix} E_{g1} \\ E_{g2} \\ E_{g3} \end{bmatrix}$, the post-treatment vector of net pollutants would be $E_n = T_1 E_g = \begin{bmatrix} .5E_{g1} \\ E_{g2} \\ E_{g3} \end{bmatrix}$; that is, the treatment removes 50% of the first pollutant but leaves the other pollutants unchanged. A more complicated treatment may take the form, $T_2 = \begin{bmatrix} 1 & 0.3 & 0 \\ 0 & 0 & 0 \\ 0 & 1.5 & 1 \end{bmatrix}$ which removes the second pollutant entirely but, in the process, creates an additional 0.3 of the first pollutant and 1.5 of the third for every unit of the second pollutant removed.

The data bank supplies the user of the model a list of treatment technologies for each activity that correspond to known alternatives. If the user does not specify what treatment technology is applied in a given activity at a given location, the model will assume that no treatment is applied in that instance. In addition to the transformation matrix of coefficients, the data bank contains the information on the costs of investment and maintenance for alternative on-site treatments.

The quantities of net emissions after on-site treatment are the final emissions at the source and may serve as the basis for pollution regulation by standards; the user therefore is supplied with the printout of these net emissions.

Disposal: The next decision to be made by the user is what part of these initially treated pollutants is to be "shipped" to the municipal sewage treatment plants and incinerators, E_f, and to which environmental medium and at which location (subarea) the remainder of pollutants are to be disposed of, E_d. For each iteration, the user has complete freedom in specifying these proportions. Again the data bank supplies cost information on alternative disposal decisions.

Municipal Water Treatment and Incinerator Activities: Municipal waste water treatment and incinerator activities are endogenous in that the levels of these operations are determined as the result of exogenous activities. Thus, given the disposal decision and E_f, the resulting quantities of pollutants designated to be treated at the municipal facilities, the levels of these treatment activities are determined within the model. This is accomplished by solving a matrix equation reminiscent of the solution to an input-output problem.

The reason that E_f (the result of the disposal decision) cannot be directly used as the levels of these "central" or "collective" treatment operations is because of the interdependence that exist between the treatment activities themselves. Sludge and suspended solids produced by the water treatment plant may be shipped to the incinerator, and the residues from the incinerator may be discharged into the sewer or a river to end up as an added load to the water treatment plant. Thus, ultimately the levels of central treatment activities E_t are the sum of E_f, the pollutant loads from the disposal decision, and E_e, the increases in the loads of the treatment activities necessitated from the treatment activities themselves; that is, $E_t = E_f + E_e$.

Now, since E_e can be obtained as $E_e = SE_t$ where S is the matrix of coefficients each column of which represents the changes in the levels of all the treatment activities induced by a particular treatment activity, $E_t = E_f + SE_t$. Therefore,

$$E_t - SE_t = E_f$$

$$(I - S)E_t = E_f$$

$$E_t = (I - S)^{-1}E_f$$

In summary, the steps in determining the endogenous treatment activities are: (1) The user specifies a particular treatment technology for each and every treatment activity. This means in effect the specification of how much of what pollutant is discharged into air, water and land, and of how much of what pollutant is for further treatment at other treatment activities per unit activity of the treatment plant in question. (2) The computer forms a particular matrix based on the decision in the first step. Each column of this matrix pertains to a particular treatment activity. The (row) entries of a column are the changes in the levels of all the treatment activities induced by an additional unit of a particular treatment activity that is represented by the column. (3) The computer forms the matrix (I - S) and then inverts it. (4) When E_f, the pollutant loads resulting from the disposal decision, are read in, the ultimate levels of treatment activities E_t are computed by the matrix multiplication $(I - S)^{-1} E_f$.

Now that the levels of central treatment activities E_t have been computed, the next step is to determine E_m, the quantities of pollutants which are discharged from the treatment plants to the environmental media. In order to obtain E_m, another matrix multiplication, similar to the earlier transformation for production processes and on-site treatments, is performed on E_t. That is, $E_m = RE_t$, where the matrix R depends on the choice of treatment technologies made by the user in connection with the determination of the levels of treatment activities.

Again, the data bank stores descriptions of alternative treatment technologies together with the associated residual transformation matrices and costs so as to enable the user to evaluate their impact.

The sum of the quantities of pollutants discharged by the central treatment plants E_m and that part of pollutants emerging from on-site treatments which is discharged directly to the environmental media as the result of the disposal decision E_d, namely, $E = E_m + E_d$, gives the final quantities of emissions the environment receives initially at various subareas (i.e., grid squares). As a practical matter, these quantities often serve as the basis for pollution regulations, and accordingly, their printout is supplied to the user of the model.

Air-, Water-, and Land-Dispersion Processes: The part of IMMP described so far is sufficiently self-contained and, therefore, can be used by the environmental managers to test the impacts of changes in the kinds, levels and processes of various pollution-generating and pollution-abating or altering activities on the pollutants dumped in the environment, and in reverse, the impacts of alternative emission standards on various activities. But pollutants deposited in a water body or in the atmosphere do not remain there; they are diffused or dispersed to other parts of the region.[1] The environmental managers cannot limit their attention

[1]Solid wastes are assumed to remain where they are deposited initially. The user of the model can, however, decide to transport them to some other locations in the region, which could be viewed as a dispersion process. "Leaching" through land is totally ignored in the model.

only to the original emissions but must be concerned also with the ambient quality of the environment which results from such dispersion. Thus, IMMP adds another module relating the emissions E to the ambient pollution levels L.

Diffusion processes of pollutants whether via atmosphere or via water are extremely complex, and are functions of a larger number of variables and their interactions. The water diffusion process depends on water temperature, flow, velocity and other characteristics of the water body; the air diffusion process depends on wind speed and direction, emission rate, stack height and diameter, the stability of the atmosphere and other characteristics.

The complex diffusion processes can be modelled in a number of alternative forms: mathematical-analytical model, reduced-coefficient-matrix model, and simulation model. Although rather simple mathematical models are adopted for both air and water dispersion processes in the initial attempt, IMMP is flexible enough to permit later replacement by more refined mathematical models or by other kinds of model should they prove more reliable.[1] In brief, the water diffusion process used is a modified Streeter-Phelps model; the air diffusion process draws heavily on Turner's

[1]All diffusion processes take place over time. Since our model is a steady-state one, the temporal diffusion pattern is ignored at this stage.

model.[1] An added feature to these basic diffusion models is a provision for assigning different probabilities to the parameters. This would allow for shifts from season to season, month to month, or even day to day in the wind direction, air temperature, barometric pressure, river flow, velocity, water temperature, etc.

In the flow chart, the diffusion processes are given in a rectangle, denoting controllability by the user. Though certain parameters of the processes are geophysically, hydrologically and meteorologically fixed given a specific region, such other parameters as stack height and diameter in the case of air and water temperature, direction of flow (new tributaries can be opened), etc. are controllable by the user of the model. The model enables evaluation of the effects of variation in these controllable variables on the ambient quality level. Of course, even the geophysical and meteorological parameters can be considered controllable if the model is used for the purpose of planning a new metropolitan region.

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[1] D. Bruce Turner, Workbook of Atmospheric Dispersion Estimates, EPA, 1970.

The Human Link: The machine-part of the flow chart ends at the ambient quality of the environment. At that point, however, the man-part of the system, the user, takes over, evaluates the degree of desirability or undesirability of the system state, and decides to take various actions available to him; in other words, arrows could be drawn formally from the ambient quality to all the action points of the model -- all the rectangled entries including productive and treatment activities -- thus "forming loops" for these variables. As a matter of fact, the human participant can form direct or indirect loops between any two points in the model. It is the versatility of the model that the user can intervene almost at every stage of the flow chart and observe the system reaction -- both forward and backward, and often returning to the original point of intervention -- to the alternative programs he stipulates.

Rational Environmental Management

It has been seen in the above that the IMMP model provides its user with a tool to evaluate various mixes of all three major classes of strategies for the management of environmental resources, i.e., the land-use strategies, the residuals generating and altering strategies, and the residuals dispersion strategies, and that it recognizes and incorporates the interrelationships among various pollution and other variables of the metropolitan area. Yet there is no guarantee that the use of the model will yield more or less rational environmental management decisions. For while rationality presumes some preestablished objective function, the model does not offer one.

At the conceptual level, rationality requires comparison of <u>all</u> costs and <u>all</u> benefits -- economic or otherwise -- of an action. The costs and benefits of pollution abatement are many and diverse and difficult to measure: Besides the direct costs of investment and maintenance of abatement equipment and facilities, the costs include the net adverse effects on production, consumption, income and employment, and the effects on migration, welfare distribution, etc. The benefits include the general, subjective aesthetic benefits gained from the improved quality of the environment as well as the benefits in the form of reduced damages on health, plants, animals and inanimate materials.

Of all these benefits and costs, currently the IMMP model provides the user with only the direct costs of alternative strategies. Although the model is flexible enough to add other cost information and data on damages from pollution when and if they become available, it is doubtful that the time will ever come when the estimates of benefits and costs are inclusive and accurate enough to warrant an effort to define a single objective function for the purpose of environmental quality management in any metropolitan area. Incorporation of a partial and inaccurate objective function to maximize would run the danger of prejudicing the issues being analyzed. Furthermore, as stated earlier, optimiation models inevitably increase the rigidity of the model. For IMMP it has been decided that the human participant would make the subjective trade-offs among the multiple goals (and amenities) of the metropolitan area in order to arrive heuristically at a satisfactory solution to the environmental management problem.

Other Models

An extensive search of literature -- both published and unpublished -- has been made to determine what other researchers have done in developing models and tools of analysis for managing the environmental quality of metropolitan areas. Promising models have been built by Dorfman and Jacoby,[1] Isard et al,[2] Russell and Spofford,[3] Forrester,[4] and Ingram et al.[5] Some use input-

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[1]Robert Dorfman and Henry D. Jacoby, "A Model of Public Decisions Illustrated by a Water Pollution Problem," in U.S. Congress Joint Economic Committee, The Analysis and Evaluation of Public Expenditures: The PPB System, volume 1. GPO, Washington, D.C., 1969.

[2]Walter Isard et al, "On the Linkage of Secio-Economic and Ecological System," The Regional Science Association Papers, 21 (1968).

[3]Clifford S. Russell and Walter O. Spofford, Jr., "A Quantitative Framework for Residuals Management Decisions," in Environmental Quality Analysis: Theory and Method in the Social Sciences, edited by A.V. Kneese and B.T. Bower, Johns Hopkins Press, Baltimore, 1972.

[4]Jay W. Forrester, Urban Dynamics, MIT Press, Cambridge, 1970.

[5]Gregory K. Ingram, John F. Kain, J. Royce Ginn, The Detroit Prototype of the NBER Urban Simulation Model, National Bureau of Economic Research, New York, 1972.

output or linear programming models with a predominance of economic variables; some attempt to devise an explicit utility function for optimization -- mostly of economic efficiency; some include both economic and noneconomic variables besides pollution variables (but neglect to focus on the interrelationships among the latter); some allow participation by human decision makers through role playing.

When evaluated by the criteria we have imposed on ourselves -- comprehensiveness, integrality, flexibility, simplicity, man-machine interaction, none of the already developed models is directly suitable for our purpose. This does not mean, however, that we have not gained from these models; indeed, our model IMMP and TERM could be considered as the end product of improving, refining, expanding, and synthesizing the existing models.

Limitations of the Current IMMP

Despite our efforts to make the model as comprehensive and to obtain data as accurate as possible, due to the limitation on time and because the main objective of the current phase of the project is to determine the feasibility of such a model as described above, currently the IMMP is encumbered with a number of limitations that could be lifted in the coming phases of the research.

Data Bank, Transportation, Construction and Noise: The flexibility of the model is such that any number of pollution producing activities and any number of pollutants can be handled. The only limitation to the inclusion in the model of a particular activity or a particular pollutant is from nonavailability of relevant information. In general, a constant effort should be made to improve the quality and amount of information stored in the data bank; in particular, special attention shall be paid to noise and transportation.

While noise is receiving an increasing attention from the public and government agencies, no data on noise from trucks, aircrafts and construction activities have been collected during the current project period. Upon gathering of the information on alternative modes and processes of these activities, alternative noise abatement technologies, and their differential costs, the activities and the related noise can be included in the model.

Transportation (and construction) can be considered exogenous or endogenous as the case may be. Besides, transportation -- ground and air -- is a major source not only of noise but also of air pollution; the trade-off between noise and air pollution (and cost, of course), will have to be represented in the model.

Exogenous and Endogenous Variables: The levels of industrial, agricultural, household and commercial activities are treated in the current model as exogenous if the loops formed by the human user are ignored. These activities, however, may be formally linked to pollution control strategies through such intervening variables as income, employment, property values and others. An effort will be made to convert as many exogenous variables into endogenous variables as theoretically justifiable by formally drawing more loops between variables.

Nonlinearity: All relations in the current model are assumed linear. In some instances, however, the assumption may be unrealistic. For example, the level of an activity and the resulting levels of various pollutants discharged may not be in fixed proportion in reality. The assumed fixed efficiency rate of control technologies regardless of the quantity of the pollutant treated may also be unrealistic. In the model, nonlinearity need not necessarily be represented by formal mathematical functions, but could be represented by a set or "table" of transformation coefficient matrices which vary according to the variation in the level of activity.

Dynamic Model: The IMMP model as it stands is a timeless, steady-state model and has no provision to allow for the time lag in the system. This limitation can diminish the usefulness of the model materially, especially when the user of the model is interested in the changing levels of pollutants over a period of time. For example, both the carbonaceous and nitrogenous BOD's contribute to DOD, but the latter with a considerable time lag in comparison to the former. Thus, with a steady-state model, it may not be possible to distinguish between the behavior of the two pollutants within a specified time. In general, a dynamic model is needed to evaluate the system reaction pattern -- dampening or amplification -- over time. The necessity and feasibility of conversion to a dynamic model must be investigated in the next phase of the project.

The Organization of the Report

The ensuing chapters discuss the IMMP model in more detail. The discussion is organized in accordance with the flow chart, i.e., the classification of environmental management strategies into the land-use control strategies, the strategies to regulate pollutant generation and alteration, and the strategies affecting dispersion processes. Then, the last chapter demonstrates the feasibility of the model by actually exercising it for a hypothetical metropolitan region.

SECTION II

ALTERNATIVE STRATEGIES FOR ENVIRONMENTAL RESOURCE MANAGEMENT: LAND USE SUBMODEL

Once an airport, a power plant or a high rise building is sited and constructed at a given location, it stays there more or less permanently and restricts the area's options for spatial development for a long time. The spatial structure in combination with the prevailing geophysical, hydrological and meteorological conditions largely determines the levels of air, water, solid waste, noise and other pollution at various subareas. Thus it is a truism to say that the air pollution in Los Angeles today is a result of spatial decisions made many years ago. Land use decisions are obviously one of the most important elements of environmental resource management.

Traditionally the spatial structure of a metropolitan region has to a large extent been governed by economic motives of various decision making entities. Accessibility to the place of employment, i.e., the distance and the travel cost, has been a significant determinant of the household's decision on residential location. Once a cluster of homes form at a given location, such amenities as shopping centers, schools, parks and other municipal services follow in the vicinity, which in turn attracts more households to move into the area. Similarly, firms have also made their decision on the location of their plants primarily on the basis of accessibility to raw materials and labor, i.e., the costs of these inputs, and accessibility to the market for its output, i.e., the revenue. Then, the government in its turn, concerned with the maintenance of its tax base and to meet the needs of its constituents would build roads and highways and provide other services. Behind the rapid growth of the urban areas are these mutually amplifying interactions of the economically motivated forces, and the result has been one of the toughest problems of today -- the general decay of the inner-city, crimes, congestion and environmental degradation.

Though belatedly, in the last three or four years there has been an increasing awareness on the part of the public and the governments at different levels of the true nature of the urban problem, namely, an awareness that the economic goal is but one of many that a city strives to attain. The impacts of land-use policies are likely to permeate to all the economic, social, political, and environmental sectors within the metropolitan area. The IMMP model includes only the impact on the natural environment of land-use decisions.

The two rectangled entries right at the start of the flow chart of Figure 2; i.e., the "configuration of the region" and the "identification and location of exogenous and endogenous activities," refer to the land-use decisions by the human participants. The following alternatives for changing the land-use pattern have been identified as technically, economically, politically, and legally feasible. Basically, they are attempts to redistribute the sources of environmental pollution among subareas[1] in such a way as to improve the overall environmental quality of the metropolitan region.

Configuration of the Region

Diversion of Water Bodies: The model has the capability of testing the effects on pollution of alternative directions of the flow of rivers. This capability is useful not only in planning a new city but also in evaluating the effect of "rechanneling" an existing river of a given metropolitan area. Alternatively, the existing water bodies may be restricted to specified uses so that, for example, only the recreational use is permitted in one river while the other is used for the discharge of industrial wastes as was done in Ruhr, Germany.

Location of Activities

Zoning: Although under the Constitution, States apparently have the inherent power over land-use regulations, most States have delegated the authority to local governments. Local governments, with their narrower vision, have on many occasions yielded to economic pressures for development at the expense of environmental degradation. Recently, however, spurred by Federal legislative efforts and on their own accord, States have begun resuming control over local land use and have already enacted

[1] Or one alternative would be to "export" the pollutants to the outside of the region.

a number of laws under which the environmental and other broader interests can be protected. Thus, zoning is emerging as one of the potentially powerful means for locating and relocating various activity zones -- agricultural, industrial, commercial and residential areas -- within a metropolitan region. For the purpose of designing a new metropolis or for the purpose of relocation within an existing one, the IMMP model will enhance the planners' awareness of the environmental effects of alternative zoning classifications.

Power Plant Siting: A number of states have adopted potent power plant siting laws. For example, Maryland requires long-range planning by power companies and provides for early approval of the planned plant sites and for advance purchase by the State of plant sites for later sale to power companies. Inasmuch as power plants are one of the major sources of pollution, their alternative siting is a significant consideration in the overall management of the metropolitan environment.

Airport Siting: Aircrafts landing on and taking off from an airport are a major source of noise (and a source of air pollution). In addition, airports bring ground traffic congestion and unsightly sprouting of commercial activities -- motels, restaurants, etc. Thus, the possibility of alternative siting of airports and of controlling development in the vicinity of airports has been investigated in a number of metropolitan areas. For example, Minnesota has enacted an Airport Zoning Act which controls development around airports. The IMMP model does not allow evaluation of the desirability of alternative landscapes of the airport area but allows evaluation of the noise and air pollution effects of alternative siting of an airport.

<u>Housing, Highway and Transit System Construction Program</u>: Where homes are built, where highways are opened, and where and what kind of mass transit system is operated all affect at least three pollution-related variables: the levels of initial emissions at various subareas (because the industrial and residential location decisions by firms and households are dependent on these factors), the levels of ambient pollution at various subareas (when the initial emissions interact with the geophysical and meteorological conditions of the region), and the significance of the pollution problem to people (i.e., damages from pollution). What the last item means is simply that if people can be made to live and work away from the polluted area, a large part of the "pollution problem" will disappear. With the use of the model, the user can evaluate the effects on these variables of alternative housing, highway and transit system construction programs.

<u>Municipal Services Programs</u>: To the extent that availability at different locations of such amenities as parks, recreational areas, cultural centers, schools, sewage services, etc. influences the residential location decision by households, government agencies in charge of managing these municipal services affect the land-use pattern within the metropolitan area.

Tax Incentives: Differential tax treatments of different activities at different locations can be used to influence the location decisions by firms and households thereby affecting the land-use pattern. For example, the Federal Environmental Protection Tax Act purports to influence land use through differential taxes.

In summary, there are two classes of governmental actions that could be taken to affect the land-use decisions in a metropolitan area. Figure 4 summarizes them in tabular form.

Costs of Alternative Programs

One of the benefits of land-use alteration is the reduced damages from reduced pollution. The model provides variations in the level and pattern of pollution in response to alternative land uses and activity sitings, though not the damages per se. Costs -- both direct and secondary -- are the other side of the information input necessary for rational land-use policy decisions. Unlike the case with the alternative production processes and treatment technologies, no cost data are currently available for the case of land-use altering alternatives, and therefore, this aspect cannot be included in the model.

The next chapter discusses alternative production processes and alternative residuals treatment technologies as means of managing the level, composition and distribution of pollutants within the metropolitan region.

Figure 4

Alternative Controls of Land Use

By Regulations and Edicts

Zoning regulation
Area-specific emission standards
Power plant siting
Airport siting
Area-specific prohibition of specific activities

By Economic Incentives

Housing programs
Highway programs
Mass transit programs
Municipal services programs
  Parks, recreational areas, sewage, schools
  hospitals, cultural centers
Area- and activity-specific taxes and subsidies

SECTION III

ALTERNATIVE STRATEGIES FOR ENVIRONMENTAL RESOURCE MANAGEMENT -- RESIDUALS MANAGEMENT SUBMODEL

Section II discussed the land-use sub model which relates various land-use policies, e.g., zoning laws, tax incentives to relocate polluting activities, etc., to the distribution of the sources of environmental pollution within the metropolitan region. The present chapter discusses the residuals management submodel which relates alternative levels, input mixes, and production processes of various activities and the alternative treatment processes associated therewith to the magnitude, composition and distribution of pollutants within the region.

As stated earlier, the main objective of our study has been to develop a model that considers all forms of pollutants, i.e., air-borne, water-borne, land-borne simultaneously, and represents their interrelationships explicitly.

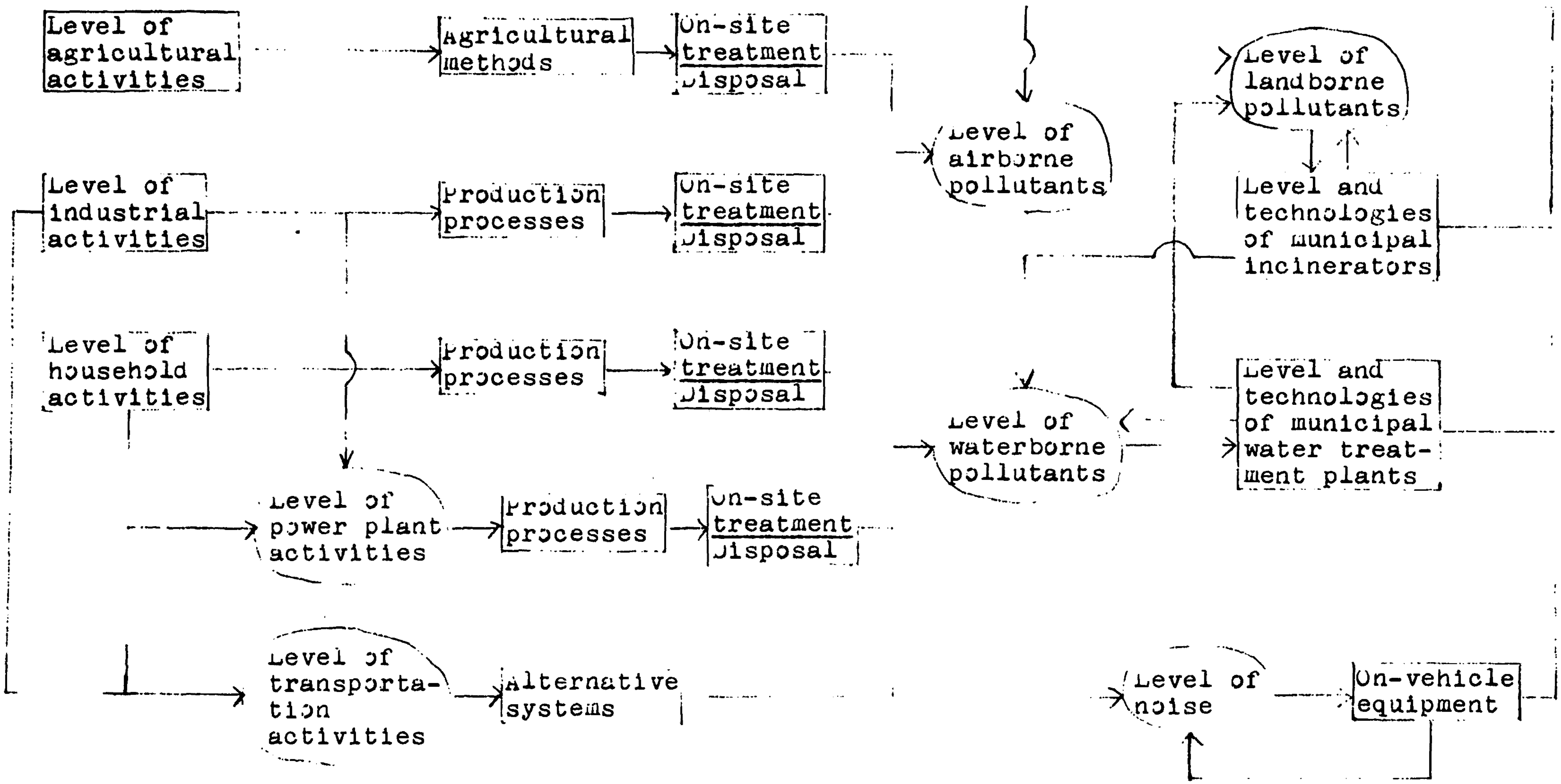
Of critical importance in planning, managing and controlling our environmental resources is to be aware that reduction in one form of residual does not eliminate it but merely changes its form. This interdependent nature of environmental pollution is largely ignored in most of the existing pollution abatement programs and models.

Figure 5 illustrates the structure of the residuals management submodel. It is simply an expansion of the relevant part of the overall IMMP flow chart given in Figure 2, and is presented in such a way as to highlight the interdependence among various forms of pollution. Without being linked to the diffusion processes, the residuals management submodel could very well serve as an independent tool of the environmental managers.

There are two alternative ways of regulating pollution through standards: (1) through setting and enforcing emission standards (at the sources), and (2) through setting and enforcing ambient quality standards. Although ultimately the ambient quality determines the level of pollution damages, and the damages must be taken into account in one form or another in making the environmental decisions, if the meteorology, geophysics and hydrology of the region are considered noncontrollable, what is controllable are the activities which emit pollutants. It is not surprising, therefore, that the regulatory bodies often favor the first approach, that is, the policies and programs regulating directly the levels of residuals emissions by households, industries and other activities and by central residuals and water treatment plants. Many believe that the control of residuals at the sources is the most direct and unambiguous approach; and the residuals management submodel standing alone is sufficient to accommodate the need for an analytical tool of such an approach.

Figure 5

A Flow Diagram of the Residuals Management Submodel



According to the diagram of Figure 5, the levels of various pollutants emitted or discharged into air, water and land within a metropolitan area depend not only on the size and nature of various activities -- agricultural, industrial, commercial, power plant, transportation, household, municipal incinerator, municipal water treatment, but also on the kinds of raw materials used, production processes, control processes applied to wastes, and the extent of recycling of the waste materials. Thus, these alternatives, individually and jointly, represent potential means for altering the forms and levels of pollutants ultimately discharged into the environment.

The following is a systematic and detailed presentation of the ways in which these alternatives can affect the forms and levels of various pollutants deposited in the environment.

Residuals and Sources

As an initial task in managing environmental quality one needs to identify both the pollutants that contribute to the environmental degradation and the sources from which these pollutants emanate. The forms in which this information might be gathered would depend largely on the purpose for which it is to be used and the availability of data.

As the potential sources of pollution in a metropolitan area a set of activities listed in Figure 6 are considered in the IMMP model. They are 2-digit SIC industries. Our decision to classify the sources into 2-digit SIC industries was based on two considerations. First, the available data do not permit the classification of sources on a more disaggregate level at present; but further disaggregation into 3-digit or 4-digit level can be achieved easily as such data become available in the future. Second, while the classification on this level of aggregation may not permit the user of the model to test the full range of alternative strategies, it would allow, as a minimum, the testing of the basic workings of the model and demonstrate the usefulness of the model.

Along with these pollution generating activities Figure 6 gives the list of pollutants generally considered to contribute significantly to the environmental pollution and the accompanying damages to the inhabitants. The lists of residuals and their sources are by no means exhaustive but would constitute the majority. At any rate, other items can be added readily if needed.

Exogenous and Endogenous Activities: All of the primary sources except the electrical power plant activity are considered exogenous in the IMMP model; and this exception and all of the secondary sources are considered endogenous. Thus, the levels of industrial, household and agricultural activities are determined outside the model, that

Figure 6

Residuals and Sources

Primary Sources of Residuals

Industrial Activities:

1. Food and Kindred
2. Tobacco
3. Textile Mill
4. Lumber and Wood
5. Apparel & Related Prod.
6. Furniture and Fixtures
7. Paper and Allied Prod.
8. Printing and PUblishing
9. Chemical and Allied Prod.
10. Petroleum and Coal
11. Rubber and Plastic
12. Leather and Leather Prod.
13. Stone, Clay and Glass
14. Primary Metal
15. Fabricated Metal
16. Machinery, Except Electrical
17. Electrical Machinery
18. Transportation Equipment
19. Instrument and Related Prod.

20. Houshold Activity

21. Agricultural Activity

22. Transportation Activity

23. Electric Power Plant

Secondary Sources of Residuals

24. Municipal Incinerator

25. Waste Water Treat. Plant

Primary Residuals

Airborne:

Particulates (P)
Hydrocarbon (HC)
Sulfur Oxide (SO_x)
Carbon Monoxide (CO)
Nitrogen Oxide (NO_x)

Waterborne:

Biochemical Oxygen Demand (BOD)
Suspended Solids (SS)
Dissolved Solids (DS)
Total Phosphate (TP)
Total Nitrogen (TN)
Heat (H)
Heavy Metal (HM)

Landborne:

Solid Waste (SW)
Combustible
Noncombustible

Others:

Noise
Radioactivity

is, are to be stipulated by the user of the model, while the levels of power plants, municipal incinerators and waste water treatment plants are determined within the model.

The distinction between the exogenous and endogenous activities is at best arbitrary. Strictly speaking, no economic activity is purely exogenous as all activities are to a greater or lesser extent interdependent. If a region under consideration is indeed "closed" -- in the sense that it is economically self-contained -- and a complete interdependency exists among the activities, the only correct specification would be to designate all of them as endogenous, that is, take into account their interrelationships. This is more or less the case with a national or a regional economy, and the input-output model is an excellent vehicle for illustrating the interdependent relationships within a closed economy.

But it is seldom that a relatively small geographic area such as a city or a metropolis can sustain economically on its own without sizable "importation" from and "exportation" to the outside of the area. In other words, a metropolitan area can be best characterized as an "open economy." This is, of course, not to imply that a strong interdependency cannot exist among certain activities even in a basically open economy.

A case in point is the dependency of the transportation activity on the industrial and household activities. On the other hand, the question of whether the level of the electric power plant activity is wholely endogenous is not so clear-cut. The ambiguity stems from the fact that at least in the short run, the amount of electricity generated in a power plant depends more on the capacity of the plant than on the area's demand for electricity. The IMMP model can treat the power plant activity as wholely or partially endogenous, or exogenous according to the degree of endogeneity or exogeneity being specified by the user. In general, the model possesses the capability to add any number of new endogenous activities if the need arises.

Finally, it is to be emphasized that in principle nothing prevents construction of a full-scale input-output table for a metropolitan region if the case warrants it, but it can be done only at the cost of considerably more work. The mix of activities and the extent of interdependency vary a great deal from one metropolitan region to another and to take this variation into account means the need to construct an entirely new input-output table for each different region. This vitiates the flexibility of the model, one of the distinguishing features of the IMMP.

Residuals: The list of residuals of Figure 6 includes heavy metals (toxic substances), noise and radioactivity. Data on these residuals are yet to be collected.

If the trade-off between coal-fired, oil-fired and nuclear power plants is adjudged real and significant within a relatively short span of time, data on radioactivity will also be collected in the next phase. At any rate, new data can be added, inadequate data supplemented, and inaccurate data corrected at any time better information becomes available.

One of the most harmful results of certain industrial activities and power plants is thermal pollution; heat, therefore, is included in the list under the heading of water-borne residuals. The effect of heat discharge into the atmosphere is not certain, and accordingly, it is not given under the air-borne category.

Residual Generation Coefficients

All productive activities produce some waste materials along with their intended output, i.e., useful products. The magnitudes of waste materials generated per unit level of activity are called residual generation coefficients or simply, residual coefficients. These coefficients are the formal link between the levels of activities and the initial emissions of pollutants at the sources. The nature, the assumptions and the limitations of the residual coefficients are discussed in the following.

A production process can be viewed under certain circumstances as a matrix of coefficients by which a set of raw materials (including fuels) is transformed into a set of (desired) outputs and a set of (undesired) waste materials. In matrix notation,

$$\begin{bmatrix} P \end{bmatrix} \begin{bmatrix} I \end{bmatrix} = \begin{bmatrix} O \\ \cdots \\ E \end{bmatrix}$$

where $\begin{bmatrix} P \end{bmatrix}$ is the production coefficients; $\begin{bmatrix} I \end{bmatrix}$ is the input vector; $\begin{bmatrix} O \\ \cdots \\ E \end{bmatrix}$ is the vector of outputs and residuals. If P is partitioned into P_O and P_E , the output production matrix and the residual production matrix, respectively, that is,

$\begin{bmatrix} P \end{bmatrix} = \begin{bmatrix} P_O \\ \cdots \\ P_E \end{bmatrix}$, then,

$$\begin{bmatrix} P_O \end{bmatrix} \begin{bmatrix} I \end{bmatrix} = \begin{bmatrix} O \end{bmatrix} \text{ and}$$

$$\begin{bmatrix} P_E \end{bmatrix} \begin{bmatrix} I \end{bmatrix} = \begin{bmatrix} E \end{bmatrix}$$

For a given activity, the selection of a productive process and the accompanying selection of a set of raw materials inputs would completely determine the levels of outputs and the levels of residuals produced. In symbols, once

$\begin{bmatrix} P \end{bmatrix} = \begin{bmatrix} P_O \\ \cdots \\ P_E \end{bmatrix}$ and $\begin{bmatrix} I \end{bmatrix}$ are specified, $\begin{bmatrix} O \end{bmatrix}$ and $\begin{bmatrix} E \end{bmatrix}$, the levels of outputs and the levels of residuals, respectively, are determined. If the vector [E], i.e., the levels of residuals, is divided by o_i , an element of the vector [0] or the level of one of the products produced, the result $\left[\frac{E}{o_i}\right]$ is the residual coefficients of that particular product. If it is assumed that a single output is produced from the production process, the output vector [0] is reduced to a scalar, [0] , and there is only one set of residual coefficients, i.e., $\left[\frac{E}{o}\right]$.

The fixed relationship between activity and residuals holds only to the extent that the inputs of production and production process are fixed. In general, as these factors vary, the residual coefficients vary. For example, use of oil instead of coal as fuel would change the levels of various air pollutants while replacing the sulfate method by the sulfite method in wood pulping would affect the levels of water pollutants. For each industry, therefore, it would be possible to develop a set of residual coefficients, each pertaining to a particular production process and a particular mix of raw materials.

In the present study, three alternative production processes (excluding fuels) and three alternative fuels are considered feasible for each of the industrial activities given in Figure 6

Thus, under the assumption that each industry produces only one product, nine (3 times 3) alternative residual production matrices are available to the user of the model for each industry. In evaluating the pollution effect of a particular industry, the user would invoke one of these. This, however, is not without a conceptual as well as practical difficulty when more than one heterogeneous product or subindustry are included in an industry. To understand the nature of the difficulty, suppose that the Food and Kindred Products industry consisted of meat packing and fruit canning. Insofar as an industry-wide residual production matrix is obtained on the basis of a particular meat packing process (including fuels) and a particular fruit canning process (including fuels) and the relative volumes of operations of the two sub-industries at a given point of time, it could yield distorted results when used in analyzing the residuals produced from either a fruit canning plant or a meat packing plant individually,[1] or at a different point of time. The industry-wide matrix presumes the existence of the industry-wide production process or technology, and the validity of the concept itself is suspect.

Ideally, therefore, given an activity, all its major heterogeneous products are identified first, and then a particular

[1]The use of the industry average residual matrix is justifiable if the fruit canning and the meat packing are the joint products, that is, two operations coexist in approximately the same proportion as that of the industry.

residual matrix are defined for each of the alternative production processes available for each of these products. The task would obviously entail a great deal of time and effort. An effort will be made along this line in the second phase of the project, perhaps by way of disaggregating the activity classification. But in the meantime, it must be noted that the problem is not as serious as it may appear: For managing a particular metropolitan area, the user of the model may obtain the particular residual coefficients applicable to the particular activities in the area and substitute them in lieu of what is in the data bank.

Another potential source of distortion that might arise from using the residual coefficients as described above is the underlying assumption of linearity, i.e., the assumption of a fixed relationship between the level of activity and the level of residuals generated. The fixed proportionality which may hold within a certain finite range of levels of a given activity, however, may not be valid beyond that range.

One way of handling the problem of nonlinearity would be to assume "piecewise" linearity, i.e., the varying linearity for different ranges of output, so that instead of one residual coefficient matrix, there would be a set of matrices for each production process alternative. This aspect will be pursued further in the next phase of the study.

The residual generation coefficients for the activities listed in Figure 6 are given in Tables P1 ~ P25, Appendix: Data Bank.[1]

Observe that for each of the industrial activities, different residual coefficients are given for three alternative production processes (other than fuel inputs) and for three alternative fuel inputs, i.e., coal, oil and gas. The unit of activity measure for industries is in millions of dollars. Dollars serve as the common denominator for the heterogeneous unit designations of heterogeneous products subsumed under an industry heading. For a more or less homogeneous industry such as paper products, the use of a physical measure (i.e., tons) may be more direct. Appropriate physical units of activity are employed for household, power plant and transportation activities.

Residual Transformation Coefficients

As in the above, a given level of a given activity can be translated into a set of pollutants. Prior to the discharge into the environment, these initially produced residuals or gross emissions may be treated by a control process to yield

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[1]The residual coefficients included in the Data Bank are developed from Environmental Implications of Technological and Economic Change for the United States, 1967-2000: An Input-Output Analysis, International Research and Technology, Washington, D.C., 1971. The mix of production processes and raw materials for 1967-1979 is used in our study as the production process 1, the mix for 1980-89 as the production process 2, and the mix for 1990-2000 as the production process 3.

a net set of pollutants. Analogous to the production process, the emission control process may be viewed as a matrix whereby a set of gross emissions are transformed into a set of treated residuals. The coefficients representing the transformation process are called the residual transformation coefficients or matrix. There are as many alternative matrices as there are alternative control technologies. Some of the more common control processes are given in Tables T1a, b,c ~ T25a, b, c, Appendix: Data Bank.[1] The coefficients reflecting the initial treatment of pollutants are referred to as primary residual transformation coefficients while the subsequent treatment coefficients are referred to as secondary and tertiary residual transformation coefficients.

Strictly speaking, the residual transformation coefficients are of two types: coefficients representing the magnitudes of pollutants removed -- or what is remaining of the pollutants -- by a treatment process, and coefficients representing the rates at which given pollutants are transformed into other types of pollutants. The distinction between the two can be seen in Table T1a, Appendix. When the high efficiency wet scrubber is installed, it reduces particulates by

[1]Data on air and solid waste treatment processes was obtained from Compilation of Air Pollutant Emission Factors, U.S. Environmental Protection Agency, 1972; data on water pollutant treatment processes came from The Economics of Clean Water, U.S. Environmental Protection Agency, 1972.

90%, SO_x by 90% and NO_x by 60%, or 10% of particulates, 10% of SO_x and 40% of NO_x would remain. At the same time, 90% of the particulates removed is "transformed" into bottom ash. Since it involves transformation of a pollutant from one medium (air) to another (solid waste), sometimes it is referred to as the intermedia residual transformation coefficient.

In compiling the above coefficients some simplifying assumptions were made: Regardless of the type of activity the efficiency of the treatment processes remains constant. Secondly, in the case of air, the total weight of particulates removed creates bottom ash in equal weight. Likewise, the total weights of BOD, SS, DS removed create dry sludge in equal weight. The magnitude of these coefficients is likely to vary from industry to industry. Further, the amount of sludge produced from various water treatment processes would vary considerably depending upon the concentration of waste materials and the amount of waste water treated. This variation is ignored here by relating the water pollutants removed directly to dry sludge.

SECTION IV

ALTERNATIVE STRATEGIES FOR ENVIRONMENTAL RESOURCE MANAGEMENT: DISPERSION SUBMODEL

Through the land-use submodel and the residuals management submodel as discussed in Sections II and III, the user of the IMMP model can, for given levels and locations of the exogenous and endogenous activities, determine the kinds, quantities and locations of pollutants discharged (initially) into the environment. Viewed in reverse, these two submodels are sufficient to test, through iteration, the compatibility of given sets of emission standards (at the sources) or given reductions in emission levels with the alternative mixes and locations of the residual-generating and residual-treating activities. Thus, by themselves, the land-use and residuals management submodels would be a practical tool of the metropolitan environmental management.

While the regulation of emission standards certainly is a direct and viable approach to the environmental resource management, it must be remembered that the approach runs the risk of neglecting one of the most important ingredients of rational environmental management, i.e., damages from pollution. For the pollution damages depend mostly on the ambient pollution, not on the emissions at the source. (If no one lives near the source of emission, there is no damage, no need for pollution abatement.) Thus, even if the emissions standard approach is chosen to take advantage of its direction and unambiguity, the ambient pollution and the accompanying damages cannot be totally ignored.

As stated earlier, no damage data are included in the current IMMP model, but it incorporates the dispersion process submodels which enable translation of the emissions at the sources into the ambient levels of pollution at the various subareas of the metropolitan area. With the dispersion submodels, the user of the model can evaluate the effects of alternative sets of emissions standards on the ambient quality at various subareas.

The model considers only the diffusion of pollutants through the atmosphere and water bodies. Once the transportation of solid wastes is regarded as part of disposal decisions within the residuals management submodel, the diffusion of pollutants through land such as leaching can probably be ignored as insignificant, or at least the process is too little known to be modeled at this time.

The mathematical form of the diffusion models has been adopted for both air and water in the IMMP. This does not imply, however, that the mathematical models are superior to other forms such as simulation models. Should the models of other forms prove more reliable, they can be easily substituted for the current models. Inasmuch the general applicability and the reliability of all existing models are suspect, there is room for constant testing and improvement no matter which models are in use.

As will be seen, some of the variables of the diffusion processes are controllable and others are not. Indeed, it may be said that the factors which are determined completely by the hydrology, geophysics and meteorology of the area are more predominant than the humanly controllable factors. But it is also true that with advance in weather-change technology, etc., more variables will become controllable -- at least partially -- in the future. In the case of the air diffusion process, the currently adjustable variables include stack height, stack diameter, emission rate; in the case of water, they include water temperature, reoxygenation rate. A detailed discussion of the diffusion model follows.

Air Diffusion Model

I Point Sources: The metropolitan area is covered with a grid as in Figure 7. Each square is referred to by the subscripts attached to its center; e.g., A_{13} is at the center of square 1,3.

Given the assumed meteorological conditions discussed in Sec. V, the user will specify a stability class (S = 1, 2, 3, 4, 5 or 6). When this is known, the effective height of release, h , of a point emission source is calculated as in Sec. VI and the depth of the mixing layer, L , is calculated as in Sec. VII.

With this information, χ(in gm^{-3}) , the pollutant concentration at (x, y) at ground level is given by

$$(1) \quad \chi(x,y,0;h) = \frac{Q}{\pi\sigma_y\sigma_z u} \exp\left[-1/2\left(\frac{y}{\sigma_y}\right)^2 - 1/2\left(\frac{h}{\sigma_z}\right)^2\right] \exp\left[-\frac{.693(x/u)}{3600T}\right]$$

where Q is the source strength ($gsec^{-1}$) , u is the mean wind speed ($msec^{-1}$) , T is the half-life of the pollutant in hours, and σ_y , σ_z are the horizontal and vertical standard deviations which like x , y and z are in meters.* The x-axis is in the direction of the mean wind; the y-axis, crosswind; the z-axis,

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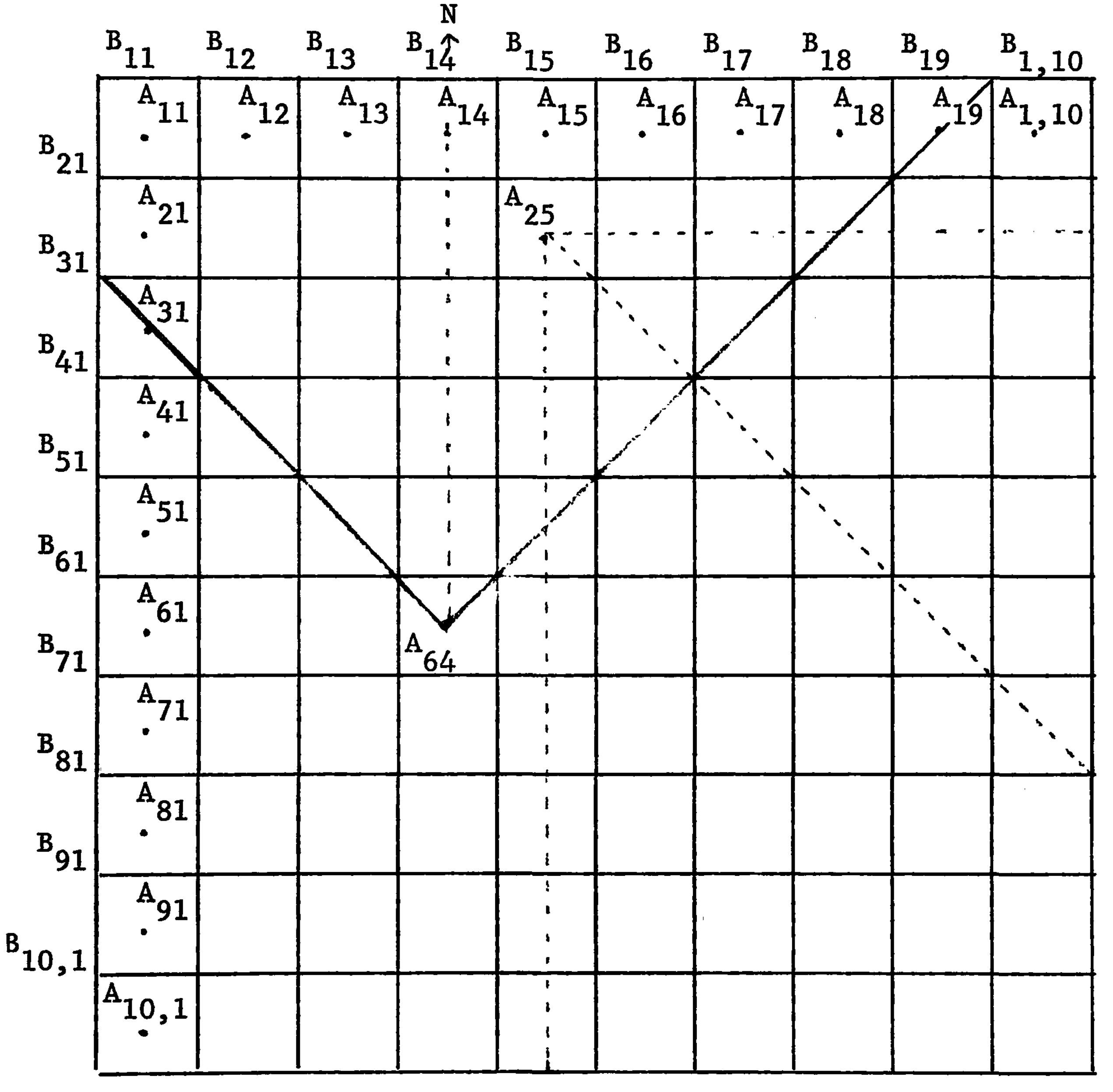
*For a discussion of the derivation of this formula see D. Bruce Turner, Workbook of Atmospheric Dispersion Estimates, Environmental Protection Agency, 1970, and TRW Air Quality Implementation Planning Program, Vol. 1, 1970.

Figure 7

Air Diffusion



For the square with center A_{ij}, NW corner is B_{ij}, NE Corner is B_{ij+1}, SE corner is $B_{i+1,j}$.

vertical; and the origin, at the base of the actual emission source. The formulas for calculating the standard deviations are

$$(2) \qquad \sigma_y = \alpha x^{\beta} \; ; \; \sigma_z = a x^b + c$$

where α , β , a , b , c are constants which vary with the stability class.[#]

Eq. (1) holds only for $x \leq x_L$ where x_L is such that $\sigma_z = 0.47$ L , i.e., x_L is the solution of $0.47 L = a x_L^{\;b} + c$ for $x \geq 2x_L$, the formula used is

$$(3) \quad \chi(x,y,0;h) = \frac{Q}{\sqrt{2\pi}\,\sigma_y LU} \exp\left[-1/2\left(\frac{y}{\sigma_y}\right)^2\right] \exp\left[-\frac{0.693(x/u)}{3600T}\right]$$

For $x = \theta x_L + (1 - \theta)2x_L$, $0 \leq \theta \leq 1$

$$(4) \quad \chi(x,y,0;h) = \theta[\chi(x_L,y,0;h)] + (1 - \theta)[\chi(x_{2L},y,0;h)]$$

where $\chi(x_L,y,0;h)$ is calculated from Eq. (1) and $\chi(x_{2L},y,0;h)$ is calculated from Eq. (3).[+]

[#]The actual values for these constants based on Figures 3-2 and 3-3 in Turner, _op. cit._ and on TRW, _op. cit._ are:

Constants for Stability Classes

	α	β	a	b	c
Class 1	.450	.889	.001	1.890	9.6
2	.285	.912	.048	1.110	2.0
3	.177	.924	.119	.915	0
4,5,6	.111	.928	2.610	.450	-25.5

[+]The rationale for using the different formulas is given in Turner, _op. cit._, p. 7.

The application of these formulas depends on which of 8 basic wind directions is involved, and is discussed below.

II <u>Area Sources*</u>: Area sources arise through such things as space heating in a residential area. To account for them, an average effective stack height (height of release), h , must be given. Given h , an area source is treated as though it were a point source with an initial standard deviation in the crosswind direction $\sigma_{y0} = s/4.3$, where s is the length of the side of the area (assumed square). This gives a virtual upwind distance x_{y0} as the solution of $\sigma_{y0} = s/4.3 = \alpha(x_{y0})^{\beta}$.

In applying the formulas (1) and (3), the distances x and y are measured from the square's center, but in calculating the appropriate σ_y , the distance $x + x_{y0}$ is used. (Note that in calculating σ_z , x itself is still used.)

Similarly, if σ_{z0} , the standard deviation of the initial vertical distribution of sources is known, a virtual distance x_{z0} given by solving $\sigma_{z0} = a(x_{z0})^b + c$ could be used to calculate σ_z.. at $x + x_{z0}$.

Calculation of the effects of area sources is then accomplished by the same procedure as for point sources, except that in (1) and (3), x and y are actual distances from the square's center point but σ_y is calculated at $x + x_{y0}$ (and, if σ_{z0} is known, σ_z is calculated at $x + x_{z0}$).

---

*The methods adopted here for treatment of area sources are suggested in Turner, *op. cit.*, pp. 39-40.

III <u>When Mean Wind Is from the South</u>: The squares affected by a point source at A_{64} in Exhibit 4-1 are assumed to be those within a 90^o sector*with vertex at A_{64}, the boundaries of which pass through A_{53}, A_{42}, A_{31} on the one hand and A_{55}, A_{46}, A_{37}, A_{28}, A_{19} on the other. In general, a point source at A_{ij} in a south wind will be assumed to affect squares within a 90^o sector bounded on one side by $A_{i-1,j-1}$, $A_{i-2,j-2}$, ... successively lowering each index by unity until one of them reaches unity and on the other, by $A_{i-1,j+1}$, $A_{i-2,j+2}$, ... successively augmenting the column index by unity and reducing the row index by unity until the row index hits unity or the column index hits its maximum.

For these squares, the concentration is calculated at the center point of each and also at the four corners, and these 5 numbers are averaged to obtain a single number for the square.

The computation for a south wind for a source at A_{64} thus involves 33 squares including A_{64} itself. The x-axis is taken along A_{64}, A_{54}, A_{44}. The cases of N, E and W winds are also treated analogously.

Similarly, when wind is from NW, Figure 7 shows the squares within a 90^o sector that would be affected by a source at A_{25}.

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*The 90^o sector was chosen since calculations showed that for each stability class the concentrations outside this sector would be very small proportions of the total, even if the grid step size were as small as 100 meters.

V Stability Classes: The classification of stability is based on the scheme in D. Bruce Turner, op. cit. The user will specify which of the six stability classes S = 1, 2, 3, 4, 5 or 6 is to be used in the calculations.* Class 1 refers to the most unstable and class 6 to the most stable condition.

However, for the purpose of calculating pollutants over longer-period averages, provision can be made to store all the items of information on which the stability classification is based, namely: day or night, wind speed in 5 classes, strength of incoming solar radiation in 4 classes for daytime, and degree of cloud cover in 3 classes.

---

*Stability classes 1, 2, 3, 4, 5, 6 correspond to Turner's A, B, C, D, E, F, respectively.

See TRW op. cit. for a justification for using the same values of α , β , a , b , c (discussed above) for classes 4, 5, and 6.

VI <u>Effective Height*</u>: To calculate the effective height of release h , use the formula

$$h = h^* + \Delta h(1.4 - 0.1S)$$

where $\Delta h = \frac{V_s d}{u} \left[1.5 + 2.68 \text{ X } 10^{-3} p \left(\frac{T_s - T_a}{T_s}\right) d\right]$.

h^* = actual height of release, m

Δh = rise of plume above the stack, m

V_2 = stack gas exit velocity, m sec^{-1}

u = wind speed, m sec^{-1}

p = atmospheric pressure, mb

T_s = stack gas temperature, c

T_a = air temperature, c

S = the index of the stability class and varies from 1 to 6

d = inside stack diameter, m .

---

* <u>cf</u>. Turner <u>op</u>. <u>cit</u>., Ch. 4 and TRW <u>op</u>. <u>cit</u>.

VII <u>Depth of Mixing Layer</u>*: The depth of the monthly mean afternoon mixing layer L_0 is taken as input.

The mixing layer depth L is taken to be

(1.5) L_0	for stability class		s = 1
(1.0) L_0	for	"	s = 2,3,4
100 m	for	"	s = 5,6

VIII <u>Average Concentration Levels</u>: The user may specify the proportion of the time each configuration of parameters (e.g., the wind direction, wind speed in several classes) occurs and the program will then calculate the average concentrations over the sets of different conditions corresponding to these different parameter configurations.+

*Based on TRW, op. cit.

+If the proportions specified do not add up to one, they are scaled up or down until they do, a message is printed, and the program continues.

X Limitations: The many assumptions on which this model is based are spelled out in the works by Turner and TRW cited above, and these should be consulted before the model is used for an actual problem.

As Turner points out (op. cit., pp. 37-38), the above formulas correspond to concentrations over short averaging times, and he includes an adjustment for longer periods which allows for the increased δ_y due to meander of wind direction. This adjustment was deliberately not applied since it reduces the concentrations from a given source everywhere and the concern here is to allow for the total effect of a given source. The use of a 90^o sector, as discussed above, is felt to go a long way towards allowing for a meandering wind direction.

Water Pollution Diffusion Model*

The model user must give a name to each river and specify the points through which it flows in their natural sequence as shown in Exhibit 4-2. The program then establishes a correspondence $P_1 = A_{11}$, $P_2 = A_{21}$, $P_3 = A_{32}$, ... to obtain a sequential ordering of the points through which the river flows. (Note that A_{31} could be P_3 , but the user is encouraged to take $P_3 = A_{32}$ in order that actual stream miles be better approximated.+)

It is also necessary to keep track of the distance in stream kilometers between successive points, P_1 , P_2 , P_3 , ..., from which a matrix (d_{ij}) of distances between any points P_i and P_j can be obtained.

The basic equation to describe the effects of a BOD load L_i discharged at P_i on stream conditions at a downstream point P_j , $j > i$, is#

$$(1) \qquad D_{ij} = \frac{kL_i}{r - k}\left[e^{-kt_{ij}} - e^{-rt_{ij}}\right] .$$

---

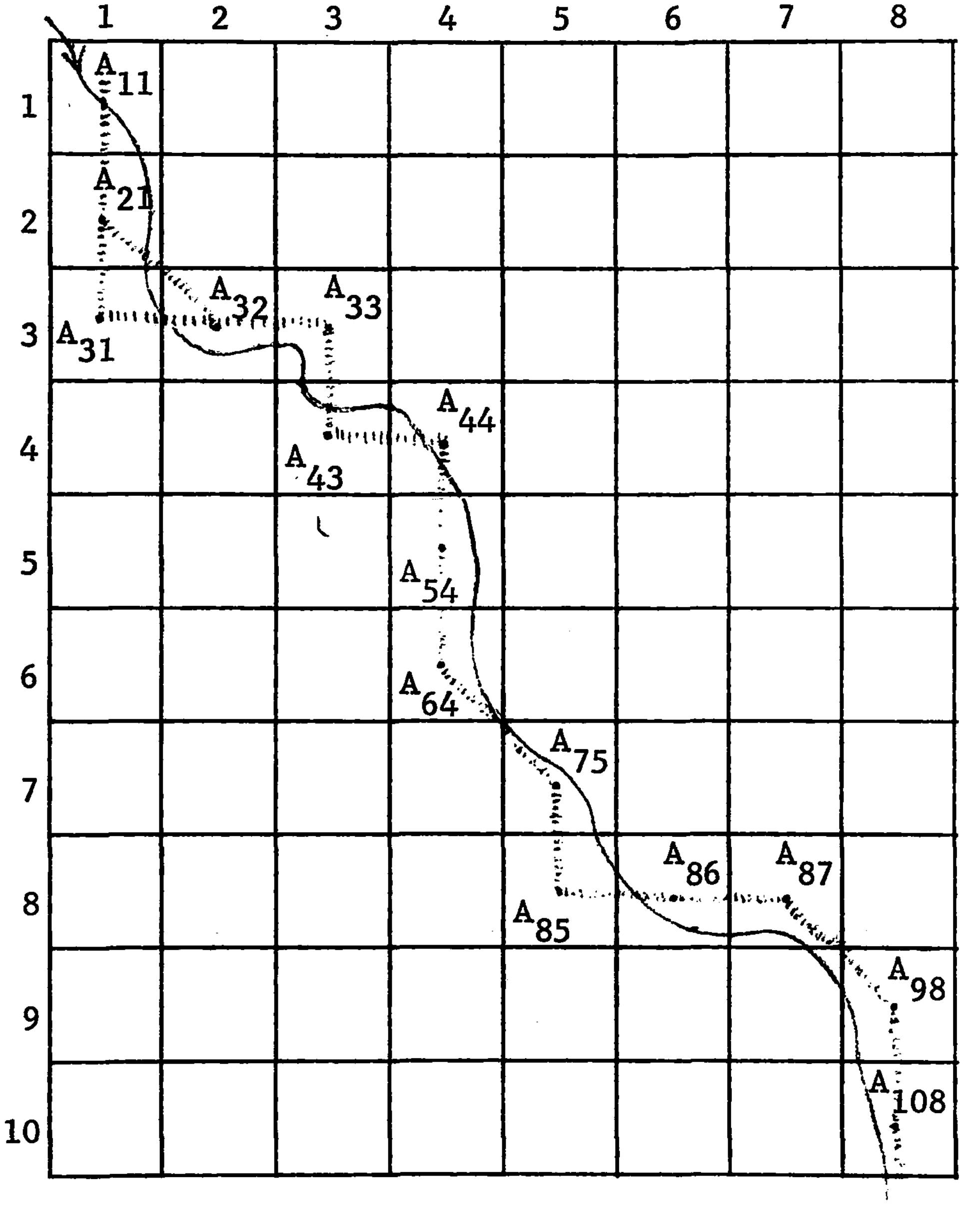
*In the present model version lakes and estuaries are not treated separately. Also, only (carbonaceous) BOD is considered.

+Similar remarks apply to the stretch from A_{75} to A_{86} .

#For a derivation of this formula, see Fair, G.M. Geyer, J.C., and Okun, D.A., Water and Wastewater Engineering, (New York: Wiley, 1968), Vol. 2, Ch. 33.

Figure 8

Water Diffusion



Direction of flow

Actual river path

Simulated path

Here t_{ij} is the average (stream) travel time (in days) between P_i and P_j, that is, $t_{ij} = \frac{d_{ij}}{v}$ where v is the average speed of the stream (in kilometers per day). D_{ij} is the contribution of the load at i to the dissolved oxygen deficit at j.* L_i is measured in mg/l (milligrams per liter), and might be calculated as X_i/F_i, where X_i is the discharge at P_i of BOD (in mg per day) and F_i is the river flow at P_i (in liters per day).

k and r are de- and re-oxygenation coefficients the calculation of which is described later. For simplicity of exposition v, r, k are here assumed constant for the whole river in question. The more general case is discussed below.

The total dissolved oxygen deficit at P_j is

$$D_j = \sum_{i<j} D_{ij} + D_1 e^{-rt_{1i}} \tag{2}$$

where D_1 is the (exogenously) given deficit at point P_1. The actual concentration of dissolved oxygen at P_j is given by

$$C_j = CS - D_j \tag{3}$$

where CS is the saturation value calculated as+

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*It is realized that there may be more than one source of BOD at P_i and a double subscript notation D_{ikj} might refer to the effect at P_j of the k-th source at P_i.

+*cf*. Fair *et al*., *op*. *cit*., Ch. 23, Sec. 6.

$$CS = \frac{P}{760}\,[14.652 - (4.1022 \times 10^{-1})T + (7.9910 \times 10^{-3})T^2$$
$$- (7.774 \times 10^{-5})T^3]$$

where T = temperature of the water in degrees centigrade

P = pressure (barometric) in mm of mercury.

Calculation of k*

$$k = k_0 \theta_k^{(T-T_0)}$$

where, if k_0 and T_0 are not specified by the user, $k_0 = 0.39$ and $T_0 = 20^oC$.

If $0^oC < T < 7.5^oC$ $\theta_k = 1.15$

if $7.5^oC \le T < 15^oC$ $\theta_k = 1.11$

if $15^oC \le T \le 30C$ $\theta_k = 1.05$

if $30^oC < T$ $\theta_k = 0.97$

k is in units of $days^{-1}$

T is the water temperature in degrees of centigrade.

Calculation of r+

$$r = r_0 e^{0.024(T-T_0)}$$

If r_0 and T_0 are not specified by the user, $T_0 = 20^oC$, and calculations of r_0 is as follows:

The user will be asked to designate the class of the receiving water as one of the following:

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*cf. ibid., Ch. 33, Sec. 7.

+Based on Fair et al., op. cit., Ch. 33, Sec. 13.

Class	Description
1	Sluggish streams and large lakes or impoundments
2	Large streams of low velocity
3	Large streams of moderate velocity
4	Swift streams

The value of r_0 is then taken from the following table:*

Class	1	2	3	4
r_0	0.5	0.7	1.0	1.6

r is also in units of $days^{-1}$.

General Case

Because of many factors, the basic user-supplier parameters such as water temperature, flow, etc., may well change from stretch to stretch of the river. The user must specify these new values at any change points.

The way the program actually operates is to take a given initial load from a particular source and compute its contribution to the dissolved oxygen deficit at each successive point downstream in an iterative fashion allowing for the changes in conditions from

*This table is based on Table 33-4 of Fair *et al.*, *op. cit.*, and the r_0 values are obtained by multiplying by the default value of k_0 (.39) the mid-points of the ranges of values given for the r/k ratio of the corresponding classes in that table.

stretch to stretch. The BOD load (from this particular source) remaining at the beginning of each stretch is taken as the load remaining at the beginning of the previous stretch multiplied by e^{-kt}, where t is the time required to traverse the previous stretch and k has the value appropriate for the previous stretch.* Then Eq. (1) above is applied with this value of L_i and the current-stretch values for r and k.

The program goes through this computation for each load source and then cumulates the contributions to obtain a total dissolved oxygen deficit at each point (including the effects of any initial deficits in the system). Subtraction of the total deficit from the DO saturation value at each point then yields the DO concentration at each point.

Treatment of Tributaries

Since the model user gives each river a name, specifies the sequence of points through which it flows, and can terminate it by indicating that it flows into another river, the junction of two rivers can be handled by making either river a tributary of the other, or else forming a new river where they meet. In

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*For a justification of this procedure, see Fair *et al.*, *op. cit.*, Ch. 33, Sec. 7. When the flow changes between successive stretches, the load is also adjusted by multiplication by F_p/F_c where F_p and F_c are the flows in the previous and current stretches, respectively, and $F_p < F_c$. If $F_p > F_c$, the load is not adjusted.

According to the diagram of Figure 5, the levels of various pollutants emitted or discharged into air, water and land within a metropolitan area depend not only on the size and nature of various activities -- agricultural, industrial, commercial, power plant, transportation, household, municipal incinerator, municipal water treatment, but also on the kinds of raw materials used, production processes, control processes applied to wastes, and the extent of recycling of the waste materials. Thus, these alternatives, individually and jointly, represent potential means for altering the forms and levels of pollutants ultimately discharged into the environment.

The following is a systematic and detailed presentation of the ways in which these alternatives can affect the forms and levels of various pollutants deposited in the environment.

Residuals and Sources

As an initial task in managing environmental quality one needs to identify both the pollutants that contribute to the environmental degradation and the sources from which these pollutants emanate. The forms in which this information might be gathered would depend largely on the purpose for which it is to be used and the availability of data.

As the potential sources of pollution in a metropolitan area a set of activities listed in Figure 6 are considered in the IMMP model. They are 2-digit SIC industries. Our decision to classify the sources into 2-digit SIC industries was based on two considerations. First, the available data do not permit the classification of sources on a more disaggregate level at present; but further disaggregation into 3-digit or 4-digit level can be achieved easily as such data become available in the future. Second, while the classification on this level of aggregation may not permit the user of the model to test the full range of alternative strategies, it would allow, as a minimum, the testing of the basic workings of the model and demonstrate the usefulness of the model.

Along with these pollution generating activities Figure 6 gives the list of pollutants generally considered to contribute significantly to the environmental pollution and the accompanying damages to the inhabitants. The lists of residuals and their sources are by no means exhaustive but would constitute the majority. At any rate, other items can be added readily if needed.

Exogenous and Endogenous Activities: All of the primary sources except the electrical power plant activity are considered exogenous in the IMMP model; and this exception and all of the secondary sources are considered endogenous. Thus, the levels of industrial, household and agricultural activities are determined outside the model, that

Figure 6

Residuals and Sources

Primary Sources of Residuals

Industrial Activities:

1. Food and Kindred
2. Tobacco
3. Textile Mill
4. Lumber and Wood
5. Apparel & Related Prod.
6. Furniture and Fixtures
7. Paper and Allied Prod.
8. Printing and PUblishing
9. Chemical and Allied Prod.
10. Petroleum and Coal
11. Rubber and Plastic
12. Leather and Leather Prod.
13. Stone, Clay and Glass
14. Primary Metal
15. Fabricated Metal
16. Machinery, Except Electrical
17. Electrical Machinery
18. Transportation Equipment
19. Instrument and Related Prod.

20. Houshold Activity

21. Agricultural Activity

22. Transportation Activity

23. Electric Power Plant

Secondary Sources of Residuals

24. Municipal Incinerator

25. Waste Water Treat. Plant

Primary Residuals

Airborne:

Particulates (P)
Hydrocarbon (HC)
Sulfur Oxide (SO_x)
Carbon Monoxide (CO)
Nitrogen Oxide (NO_x)

Waterborne:

Biochemical Oxygen Demand (BOD)
Suspended Solids (SS)
Dissolved Solids (DS)
Total Phosphate (TP)
Total Nitrogen (TN)
Heat (H)
Heavy Metal (HM)

Landborne:

Solid Waste (SW)
- Combustible
- Noncombustible

Others:

Noise
Radioactivity

is, are to be stipulated by the user of the model, while the levels of power plants, municipal incinerators and waste water treatment plants are determined within the model.

The distinction between the exogenous and endogenous activities is at best arbitrary. Strictly speaking, no economic activity is purely exogenous as all activities are to a greater or lesser extent interdependent. If a region under consideration is indeed "closed" -- in the sense that it is economically self-contained -- and a complete interdependency exists among the activities, the only correct specification would be to designate all of them as endogenous, that is, take into account their interrelationships. This is more or less the case with a national or a regional economy, and the input-output model is an excellent vehicle for illustrating the interdependent relationships within a closed economy.

But it is seldom that a relatively small geographic area such as a city or a metropolis can sustain economically on its own without sizable "importation" from and "exportation" to the outside of the area. In other words, a metropolitan area can be best characterized as an "open economy." This is, of course, not to imply that a strong interdependency cannot exist among certain activities even in a basically open economy.

A case in point is the dependency of the transportation activity on the industrial and household activities. On the other hand, the question of whether the level of the electric power plant activity is wholely endogenous is not so clear-cut. The ambiguity stems from the fact that at least in the short run, the amount of electricity generated in a power plant depends more on the capacity of the plant than on the area's demand for electricity. The IMMP model can treat the power plant activity as wholely or partially endogenous, or exogenous according to the degree of endogeneity or exogeneity being specified by the user. In general, the model possesses the capability to add any number of new endogenous activities if the need arises.

Finally, it is to be emphasized that in principle nothing prevents construction of a full-scale input-output table for a metropolitan region if the case warrants it, but it can be done only at the cost of considerably more work. The mix of activities and the extent of interdependency vary a great deal from one metropolitan region to another and to take this variation into account means the need to construct an entirely new input-output table for each different region. This vitiates the flexibility of the model, one of the distinguishing features of the IMMP.

Residuals: The list of residuals of Figure 6 includes heavy metals (toxic substances), noise and radioactivity. Data on these residuals are yet to be collected.

If the trade-off between coal-fired, oil-fired and nuclear power plants is adjudged real and significant within a relatively short span of time, data on radioactivity will also be collected in the next phase. At any rate, new data can be added, inadequate data supplemented, and inaccurate data corrected at any time better information becomes available.

One of the most harmful results of certain industrial activities and power plants is thermal pollution; heat, therefore, is included in the list under the heading of water-borne residuals. The effect of heat discharge into the atmosphere is not certain, and accordingly, it is not given under the air-borne category.

Residual Generation Coefficients

All productive activities produce some waste materials along with their intended output, i.e., useful products. The magnitudes of waste materials generated per unit level of activity are called residual generation coefficients or simply, residual coefficients. These coefficients are the formal link between the levels of activities and the initial emissions of pollutants at the sources. The nature, the assumptions and the limitations of the residual coefficients are discussed in the following.

A production process can be viewed under certain circumstances as a matrix of coefficients by which a set of raw materials (including fuels) is transformed into a set of (desired) outputs and a set of (undesired) waste materials. In matrix notation,

$$\begin{bmatrix} P \end{bmatrix} \begin{bmatrix} I \end{bmatrix} = \begin{bmatrix} O \\ \cdots \\ E \end{bmatrix}$$

where $\begin{bmatrix} P \end{bmatrix}$ is the production coefficients; $\begin{bmatrix} I \end{bmatrix}$ is the input vector; $\begin{bmatrix} O \\ \cdots \\ E \end{bmatrix}$ is the vector of outputs and residuals. If P is partitioned into P_O and P_E, the output production matrix and the residual production matrix, respectively, that is,

$\begin{bmatrix} P \end{bmatrix} = \begin{bmatrix} P_O \\ \cdots \\ P_E \end{bmatrix}$, then,

$$\begin{bmatrix} P_O \end{bmatrix} \begin{bmatrix} I \end{bmatrix} = \begin{bmatrix} O \end{bmatrix} \quad \text{and}$$

$$\begin{bmatrix} P_E \end{bmatrix} \begin{bmatrix} I \end{bmatrix} = \begin{bmatrix} E \end{bmatrix}$$

For a given activity, the selection of a productive process and the accompanying selection of a set of raw materials inputs would completely determine the levels of outputs and the levels of residuals produced. In symbols, once

$\begin{bmatrix} P \end{bmatrix} = \begin{bmatrix} P_O \\ \cdots \\ P_E \end{bmatrix}$ and $\begin{bmatrix} I \end{bmatrix}$ are specified, $\begin{bmatrix} O \end{bmatrix}$ and $\begin{bmatrix} E \end{bmatrix}$, the levels of outputs and the levels of residuals, respectively, are determined. If the vector [E], i.e., the levels of residuals, is divided by o_i , an element of the vector [0] or the level of one of the products produced, the result $\left[\frac{E}{o_i}\right]$ is the residual coefficients of that particular product. If it is assumed that a single output is produced from the production process, the output vector [0] is reduced to a scalar, [0] , and there is only one set of residual coefficients, i.e., $\left[\frac{E}{o}\right]$.

The fixed relationship between activity and residuals holds only to the extent that the inputs of production and production process are fixed. In general, as these factors vary, the residual coefficients vary. For example, use of oil instead of coal as fuel would change the levels of various air pollutants while replacing the sulfate method by the sulfite method in wood pulping would affect the levels of water pollutants. For each industry, therefore, it would be possible to develop a set of residual coefficients, each pertaining to a particular production process and a particular mix of raw materials.

In the present study, three alternative production processes (excluding fuels) and three alternative fuels are considered feasible for each of the industrial activities given in Figure 6

Thus, under the assumption that each industry produces only one product, nine (3 times 3) alternative residual production matrices are available to the user of the model for each industry. In evaluating the pollution effect of a particular industry, the user would invoke one of these. This, however, is not without a conceptual as well as practical difficulty when more than one heterogeneous product or subindustry are included in an industry. To understand the nature of the difficulty, suppose that the Food and Kindred Products industry consisted of meat packing and fruit canning. Insofar as an industry-wide residual production matrix is obtained on the basis of a particular meat packing process (including fuels) and a particular fruit canning process (including fuels) and the relative volumes of operations of the two subindustries at a given point of time, it could yield distorted results when used in analyzing the residuals produced from either a fruit canning plant or a meat packing plant individually,[1] or at a different point of time. The industry-wide matrix presumes the existence of the industry-wide production process or technology, and the validity of the concept itself is suspect.

Ideally, therefore, given an activity, all its major heterogeneous products are identified first, and then a particular

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[1]The use of the industry average residual matrix is justifiable if the fruit canning and the meat packing are the joint products, that is, two operations coexist in approximately the same proportion as that of the industry.

residual matrix are defined for each of the alternative production processes available for each of these products. The task would obviously entail a great deal of time and effort. An effort will be made along this line in the second phase of the project, perhaps by way of disaggregating the activity classification. But in the meantime, it must be noted that the problem is not as serious as it may appear: For managing a particular metropolitan area, the user of the model may obtain the particular residual coefficients applicable to the particular activities in the area and substitute them in lieu of what is in the data bank.

Another potential source of distortion that might arise from using the residual coefficients as described above is the underlying assumption of linearity, i.e., the assumption of a fixed relationship between the level of activity and the level of residuals generated. The fixed proportionality which may hold within a certain finite range of levels of a given activity, however, may not be valid beyond that range.

One way of handling the problem of nonlinearity would be to assume "piecewise" linearity, i.e., the varying linearity for different ranges of output, so that instead of one residual coefficient matrix, there would be a set of matrices for each production process alternative. This aspect will be pursued further in the next phase of the study.

The residual generation coefficients for the activities listed in Figure 6 are given in Tables P1 ~ P25, Appendix: Data Bank.[1]

Observe that for each of the industrial activities, different residual coefficients are given for three alternative production processes (other than fuel inputs) and for three alternative fuel inputs, i.e., coal, oil and gas. The unit of activity measure for industries is in millions of dollars. Dollars serve as the common denominator for the heterogeneous unit designations of heterogeneous products subsumed under an industry heading. For a more or less homogeneous industry such as paper products, the use of a physical measure (i.e., tons) may be more direct. Appropriate physical units of activity are employed for household, power plant and transportation activities.

Residual Transformation Coefficients

As in the above, a given level of a given activity can be translated into a set of pollutants. Prior to the discharge into the environment, these initially produced residuals or gross emissions may be treated by a control process to yield

[1]The residual coefficients included in the Data Bank are developed from Environmental Implications of Technological and Economic Change for the United States, 1967-2000: An Input-Output Analysis, International Research and Technology, Washington, D.C., 1971. The mix of production processes and raw materials for 1967-1979 is used in our study as the production process 1, the mix for 1980-89 as the production process 2, and the mix for 1990-2000 as the production process 3.

a net set of pollutants. Analogous to the production process, the emission control process may be viewed as a matrix whereby a set of gross emissions are transformed into a set of treated residuals. The coefficients representing the transformation process are called the residual transformation coefficients or matrix. There are as many alternative matrices as there are alternative control technologies. Some of the more common control processes are given in Tables T1a, b,c ~ T25a, b, c, Appendix: Data Bank.[1] The coefficients reflecting the initial treatment of pollutants are referred to as primary residual transformation coefficients while the subsequent treatment coefficients are referred to as secondary and tertiary residual transformation coefficients.

Strictly speaking, the residual transformation coefficients are of two types: coefficients representing the magnitudes of pollutants removed -- or what is remaining of the pollutants -- by a treatment process, and coefficients representing the rates at which given pollutants are transformed into other types of pollutants. The distinction between the two can be seen in Table T1a, Appendix. When the high efficiency wet scrubber is installed, it reduces particulates by

[1]Data on air and solid waste treatment processes was obtained from Compilation of Air Pollutant Emission Factors, U.S. Environmental Protection Agency, 1972; data on water pollutant treatment processes came from The Economics of Clean Water, U.S. Environmental Protection Agency, 1972.

90%, SO_x by 90% and NO_x by 60%, or 10% of particulates, 10% of SO_x and 40% of NO_x would remain. At the same time, 90% of the particulates removed is "transformed" into bottom ash. Since it involves transformation of a pollutant from one medium (air) to another (solid waste), sometimes it is referred to as the intermedia residual transformation coefficient.

In compiling the above coefficients some simplifying assumptions were made: Regardless of the type of activity the efficiency of the treatment processes remains constant. Secondly, in the case of air, the total weight of particulates removed creates bottom ash in equal weight. Likewise, the total weights of BOD, SS, DS removed create dry sludge in equal weight. The magnitude of these coefficients is likely to vary from industry to industry. Further, the amount of sludge produced from various water treatment processes would vary considerably depending upon the concentration of waste materials and the amount of waste water treated. This variation is ignored here by relating the water pollutants removed directly to dry sludge.

SECTION IV

ALTERNATIVE STRATEGIES FOR ENVIRONMENTAL RESOURCE MANAGEMENT: DISPERSION SUBMODEL

Through the land-use submodel and the residuals management submodel as discussed in Sections II and III, the user of the IMMP model can, for given levels and locations of the exogenous and endogenous activities, determine the kinds, quantities and locations of pollutants discharged (initially) into the environment. Viewed in reverse, these two submodels are sufficient to test, through iteration, the compatibility of given sets of emission standards (at the sources) or given reductions in emission levels with the alternative mixes and locations of the residual-generating and residual-treating activities. Thus, by themselves, the land-use and residuals management submodels would be a practical tool of the metropolitan environmental management.

While the regulation of emission standards certainly is a direct and viable approach to the environmental resource management, it must be remembered that the approach runs the risk of neglecting one of the most important ingredients of rational environmental management, i.e., damages from pollution. For the pollution damages depend mostly on the ambient pollution, not on the emissions at the source. (If no one lives near the source of emission, there is no damage, no need for pollution abatement.) Thus, even if the emissions standard approach is chosen to take advantage of its direction and unambiguity, the ambient pollution and the accompanying damages cannot be totally ignored.

As stated earlier, no damage data are included in the current IMMP model, but it incorporates the dispersion process submodels which enable translation of the emissions at the sources into the ambient levels of pollution at the various subareas of the metropolitan area. With the dispersion submodels, the user of the model can evaluate the effects of alternative sets of emissions standards on the ambient quality at various subareas.

The model considers only the diffusion of pollutants through the atmosphere and water bodies. Once the transportation of solid wastes is regarded as part of disposal decisions within the residuals management submodel, the diffusion of pollutants through land such as leaching can probably be ignored as insignificant, or at least the process is too little known to be modeled at this time.

The mathematical form of the diffusion models has been adopted for both air and water in the IMMP. This does not imply, however, that the mathematical models are superior to other forms such as simulation models. Should the models of other forms prove more reliable, they can be easily substituted for the current models. Inasmuch the general applicability and the reliability of all existing models are suspect, there is room for constant testing and improvement no matter which models are in use.

As will be seen, some of the variables of the diffusion processes are controllable and others are not. Indeed, it may be said that the factors which are determined completely by the hydrology, geophysics and meteorology of the area are more predominant than the humanly controllable factors. But it is also true that with advance in weather-change technology, etc., more variables will become controllable -- at least partially -- in the future. In the case of the air diffusion process, the currently adjustable variables include stack height, stack diameter, emission rate; in the case of water, they include water temperature, reoxygenation rate. A detailed discussion of the diffusion model follows.

Air Diffusion Model

I Point Sources: The metropolitan area is covered with a grid as in Figure 7. Each square is referred to by the subscripts attached to its center; e.g., A_{13} is at the center of square 1,3.

Given the assumed meteorological conditions discussed in Sec. V, the user will specify a stability class (S = 1, 2, 3, 4, 5 or 6). When this is known, the effective height of release, h , of a point emission source is calculated as in Sec. VI and the depth of the mixing layer, L , is calculated as in Sec. VII.

With this information, $\chi(\text{in } gm^{-3})$, the pollutant concentration at (x, y) at ground level is given by

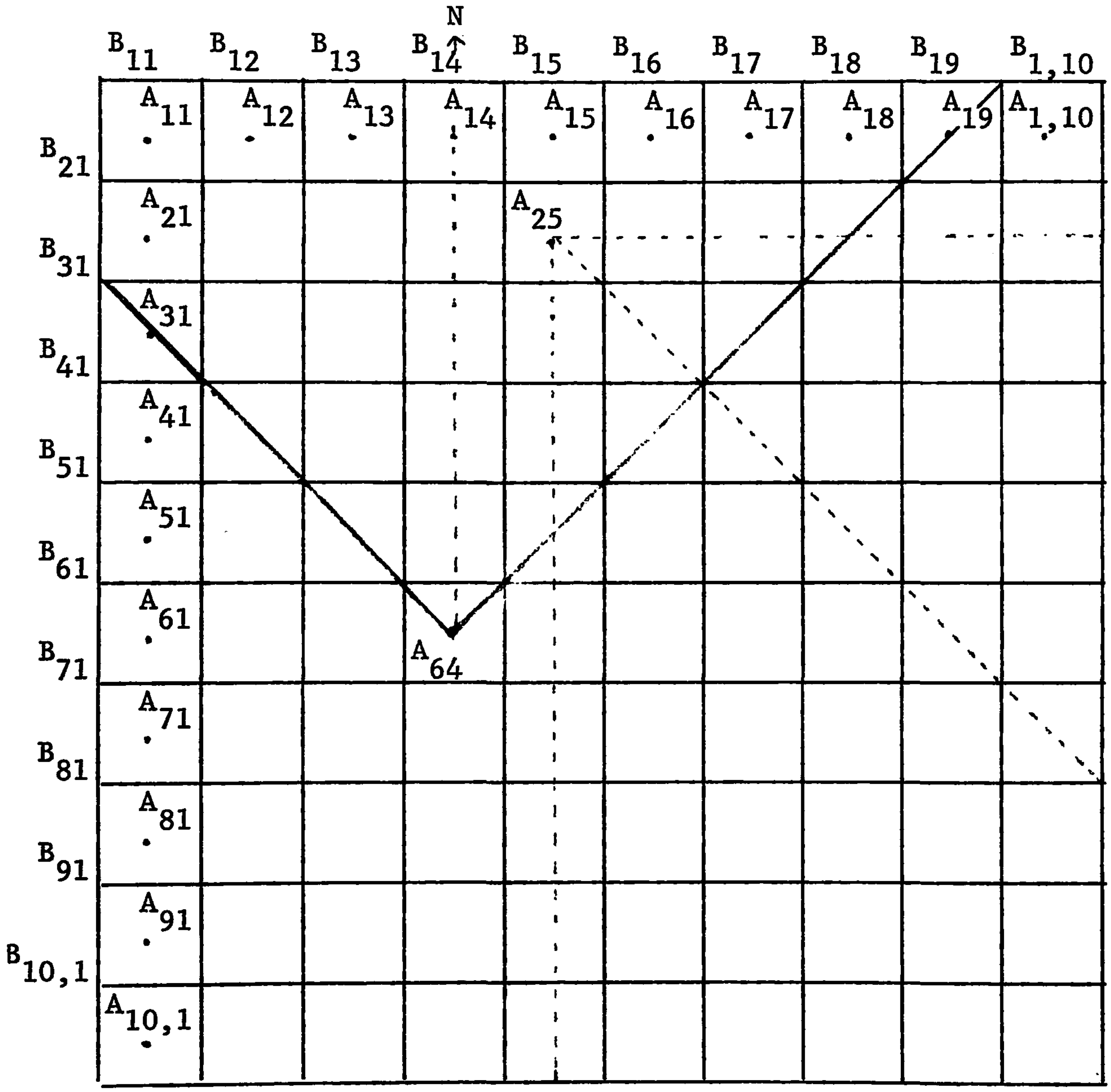
$$(1) \quad \chi(x,y,0;h) = \frac{Q}{\pi\sigma_y\sigma_z u} \exp\left[-1/2\left(\frac{y}{\sigma_y}\right)^2 - 1/2\left(\frac{h}{\sigma_z}\right)^2\right] \exp\left[-\frac{.693(x/u)}{3600T}\right]$$

where Q is the source strength $(gsec^{-1})$, u is the mean wind speed $(msec^{-1})$, T is the half-life of the pollutant in hours, and σ_y , σ_z are the horizontal and vertical standard deviations which like x , y and z are in meters.* The x-axis is in the direction of the mean wind; the y-axis, crosswind; the z-axis,

*For a discussion of the derivation of this formula see D. Bruce Turner, Workbook of Atmospheric Dispersion Estimates, Environmental Protection Agency, 1970, and TRW Air Quality Implementation Planning Program, Vol. 1, 1970.

Figure 7

Air Diffusion



For the square with center, A_{ij}, NW corner is B_{ij}, NE Corner is B_{ij+1}, SE corner is $B_{i+1,j}$.

vertical; and the origin, at the base of the actual emission source. The formulas for calculating the standard deviations are

$$(2) \qquad \sigma_y = \alpha x^{\beta} \; ; \; \sigma_z = a x^b + c$$

where α , β , a , b , c are constants which vary with the stability class.#

Eq. (1) holds only for $x \le x_L$ where x_L is such that $\sigma_z = 0.47\ L$, i.e., x_L is the solution of $0.47\ L = a x_L{}^b + c$ for $x \ge 2x_L$, the formula used is

$$(3) \quad \chi(x,y,0;h) = \frac{Q}{\sqrt{2\pi}\,\sigma_y L U} \exp\left[-1/2\left(\frac{y}{\sigma_y}\right)^2\right] \exp\left[-\frac{0.693(x/u)}{3600T}\right]$$

For $x = \theta x_L + (1 - \theta)2x_L$, $0 \le \theta \le 1$

$$(4) \quad \chi(x,y,0;h) = \theta[\chi(x_L,y,0;h)] + (1 - \theta)[\chi(x_{2L},y,0;h)]$$

where $\chi(x_L,y,0;h)$ is calculated from Eq. (1) and $\chi(x_{2L},y,0;h)$ is calculated from Eq. (3).+

#The actual values for these constants based on Figures 3-2 and 3-3 in Turner, op. cit. and on TRW, op. cit. are:

Constants for Stability Classes

	α	β	a	b	c
Class 1	.450	.889	.001	1.890	9.6
2	.285	.912	.048	1.110	2.0
3	.177	.924	.119	.915	0
4,5,6	.111	.928	2.610	.450	-25.5

+The rationale for using the different formulas is given in Turner, op. cit., p. 7.

The application of these formulas depends on which of 8 basic wind directions is involved, and is discussed below.

II <u>Area Sources*</u>: Area sources arise through such things as space heating in a residential area. To account for them, an average effective stack height (height of release), h , must be given. Given h , an area source is treated as though it were a point source with an initial standard deviation in the crosswind direction $\sigma_{y0} = s/4.3$, where s is the length of the side of the area (assumed square). This gives a virtual upwind distance x_{y0} as the solution of $\sigma_{y0} = s/4.3 = \alpha(x_{y0})^{\beta}$.

In applying the formulas (1) and (3), the distances x and y are measured from the square's center, but in calculating the appropriate σ_y , the distance $x + x_{y0}$ is used. (Note that in calculating σ_z , x itself is still used.)

Similarly, if σ_{z0} , the standard deviation of the initial vertical distribution of sources is known, a virtual distance x_{z0} given by solving $\sigma_{z0} = a(x_{z0})^b + c$ could be used to calculate σ_z at $x + x_{z0}$.

Calculation of the effects of area sources is then accomplished by the same procedure as for point sources, except that in (1) and (3), x and y are actual distances from the square's center point but σ_y is calculated at $x + x_{y0}$ (and, if σ_{z0} is known, σ_z is calculated at $x + x_{z0}$).

---

*The methods adopted here for treatment of area sources are suggested in Turner, *op. cit.*, pp. 39-40.

III <u>When Mean Wind Is from the South</u>: The squares affected by a point source at A_{64} in Exhibit 4-1 are assumed to be those within a 90° sector* with vertex at A_{64}, the boundaries of which pass through A_{53}, A_{42}, A_{31} on the one hand and A_{55}, A_{46}, A_{37}, A_{28}, A_{19} on the other. In general, a point source at A_{ij} in a south wind will be assumed to affect squares within a 90° sector bounded on one side by $A_{i-1,j-1}$, $A_{i-2,j-2}$, ... successively lowering each index by unity until one of them reaches unity and on the other, by $A_{i-1,j+1}$, $A_{i-2,j+2}$, ... successively augmenting the column index by unity and reducing the row index by unity until the row index hits unity or the column index hits its maximum.

For these squares, the concentration is calculated at the center point of each and also at the four corners, and these 5 numbers are averaged to obtain a single number for the square.

The computation for a south wind for a source at A_{64} thus involves 33 squares including A_{64} itself. The x-axis is taken along A_{64}, A_{54}, A_{44}. The cases of N, E and W winds are also treated analogously.

Similarly, when wind is from NW, Figure 7 shows the squares within a 90° sector that would be affected by a source at A_{25}.

---

*The 90° sector was chosen since calculations showed that for each stability class the concentrations outside this sector would be very small proportions of the total, even if the grid step size were as small as 100 meters.

V Stability Classes: The classification of stability is based on the scheme in D. Bruce Turner, op. cit. The user will specify which of the six stability classes S = 1, 2, 3, 4, 5 or 6 is to be used in the calculations.* Class 1 refers to the most unstable and class 6 to the most stable condition.

However, for the purpose of calculating pollutants over longer-period averages, provision can be made to store all the items of information on which the stability classification is based, namely: day or night, wind speed in 5 classes, strength of incoming solar radiation in 4 classes for daytime, and degree of cloud cover in 3 classes.

---

*Stability classes 1, 2, 3, 4, 5, 6 correspond to Turner's A, B, C, D, E, F, respectively.

See TRW op. cit. for a justification for using the same values of α , β , a , b , c (discussed above) for classes 4, 5, and 6.

VI <u>Effective Height*</u>: To calculate the effective height of release h , use the formula

$$h = h^* + \Delta h(1.4 - 0.1S)$$

where $\Delta h = \frac{V_s d}{u} \left[1.5 + 2.68 \times 10^{-3} p \left(\frac{T_s - T_a}{T_s}\right) d\right]$.

h^* = actual height of release, m

Δh = rise of plume above the stack, m

V_2 = stack gas exit velocity, m sec^{-1}

u = wind speed, m sec^{-1}

p = atmospheric pressure, mb

T_s = stack gas temperature, c

T_a = air temperature, c

S = the index of the stability class and varies from 1 to 6

d = inside stack diameter, m .

---

*<u>cf</u>. Turner <u>op</u>. <u>cit</u>., Ch. 4 and TRW <u>op</u>. <u>cit</u>.

VII Depth of Mixing Layer*: The depth of the monthly mean afternoon mixing layer L_0 is taken as input.

The mixing layer depth L is taken to be

(1.5) L_0	for stability class		$s = 1$
(1.0) L_0	for	"	$s = 2,3,4$
100 m	for	"	$s = 5,6$

VIII Average Concentration Levels: The user may specify the proportion of the time each configuration of parameters (e.g., the wind direction, wind speed in several classes) occurs and the program will then calculate the average concentrations over the sets of different conditions corresponding to these different parameter configurations.+

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*Based on TRW, op. cit.

+If the proportions specified do not add up to one, they are scaled up or down until they do, a message is printed, and the program continues.

X <u>Limitations</u>: The many assumptions on which this model is based are spelled out in the works by Turner and TRW cited above, and these should be consulted before the model is used for an actual problem.

As Turner points out (*op. cit.*, pp. 37-38), the above formulas correspond to concentrations over short averaging times, and he includes an adjustment for longer periods which allows for the increased δ_y due to meander of wind direction. This adjustment was deliberately not applied since it reduces the concentrations from a given source *everywhere* and the concern here is to allow for the total effect of a given source. The use of a 90^o sector, as discussed above, is felt to go a long way towards allowing for a meandering wind direction.

Water Pollution Diffusion Model*

The model user must give a name to each river and specify the points through which it flows in their natural sequence as shown in Exhibit 4-2. The program then establishes a correspondence $P_1 = A_{11}$, $P_2 = A_{21}$, $P_3 = A_{32}$, ... to obtain a sequential ordering of the points through which the river flows. (Note that A_{31} could be P_3 , but the user is encouraged to take $P_3 = A_{32}$ in order that actual stream miles be better approximated.+)

It is also necessary to keep track of the distance in stream kilometers between successive points, P_1 , P_2 , P_3 , ..., from which a matrix (d_{ij}) of distances between any points P_i and P_j can be obtained.

The basic equation to describe the effects of a BOD load L_i discharged at P_i on stream conditions at a downstream point P_j , $j > i$, is#

$$(1) \qquad D_{ij} = \frac{kL_i}{r - k} \left[e^{-kt_{ij}} - e^{-rt_{ij}} \right] .$$

---

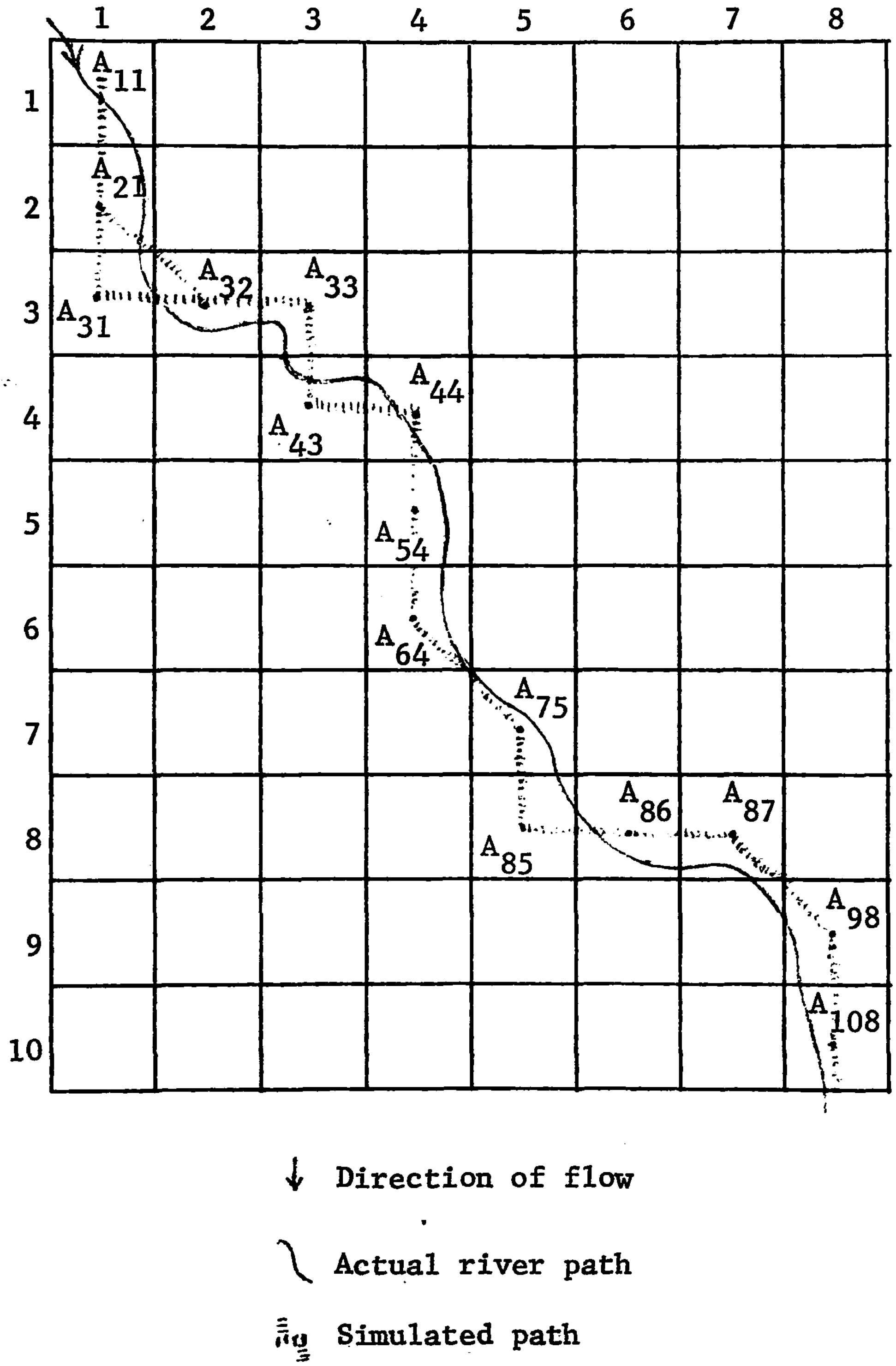
*In the present model version lakes and estuaries are not treated separately. Also, only (carbonaceous) BOD is considered.

+Similar remarks apply to the stretch from A_{75} to A_{86} .

#For a derivation of this formula, see Fair, G.M. Geyer, J.C., and Okun, D.A., Water and Wastewater Engineering, (New York: Wiley, 1968), Vol. 2, Ch. 33.

Figure 8

Water Diffusion



Here t_{ij} is the average (stream) travel time (in days) between P_i and P_j, that is, $t_{ij} = \frac{d_{ij}}{v}$ where v is the average speed of the stream (in kilometers per day). D_{ij} is the contribution of the load at i to the dissolved oxygen deficit at j.* L_i is measured in mg/l (milligrams per liter), and might be calculated as X_i/F_i, where X_i is the discharge at P_i of BOD (in mg per day) and F_i is the river flow at P_i (in liters per day).

k and r are de- and re-oxygenation coefficients the calculation of which is described later. For simplicity of exposition v, r, k are here assumed constant for the whole river in question. The more general case is discussed below.

The total dissolved oxygen deficit at P_j is

$$D_j = \sum_{i<j} D_{ij} + D_1 e^{-rt_{1i}} \tag{2}$$

where D_1 is the (exogenously) given deficit at point P_1. The actual concentration of dissolved oxygen at P_j is given by

$$C_j = CS - D_j \tag{3}$$

where CS is the saturation value calculated as[+]

---

*It is realized that there may be more than one source of BOD at P_i and a double subscript notation D_{ikj} might refer to the effect at P_j of the k-th source at P_i.

+*cf*. Fair *et al*., *op*. *cit*., Ch. 23, Sec. 6.

$$CS = \frac{P}{760}\,[14.652 - (4.1022 \times 10^{-1})T + (7.9910 \times 10^{-3})T^2 - (7.774 \times 10^{-5})T^3]$$

where T = temperature of the water in degrees centigrade

P = pressure (barometric) in mm of mercury.

Calculation of k*

$$k = k_0 \theta_k^{(T-T_0)}$$

where, if k_0 and T_0 are not specified by the user, $k_0 = 0.39$ and $T_0 = 20^{o}C$.

If $0^{o}C < T < 7.5^{o}C$ $\theta_k = 1.15$

if $7.5^{o}C \leq T < 15^{o}C$ $\theta_k = 1.11$

if $15^{o}C \leq T \leq 30C$ $\theta_k = 1.05$

if $30^{o}C < T$ $\theta_k = 0.97$

k is in units of $days^{-1}$

T is the water temperature in degrees of centigrade.

Calculation of r+

$$r = r_0 e^{0.024(T-T_0)}$$

If r_0 and T_0 are not specified by the user, $T_0 = 20^{o}C$, and calculations of r_0 is as follows:

The user will be asked to designate the class of the receiving water as one of the following:

---

*cf. ibid., Ch. 33, Sec. 7.

+Based on Fair et al., op. cit., Ch. 33, Sec. 13.

Class	Description
1	Sluggish streams and large lakes or impoundments
2	Large streams of low velocity
3	Large streams of moderate velocity
4	Swift streams

The value of r_0 is then taken from the following table:*

Class	1	2	3	4
r_0	0.5	0.7	1.0	1.6

r is also in units of $days^{-1}$.

General Case

Because of many factors, the basic user-supplier parameters such as water temperature, flow, etc., may well change from stretch to stretch of the river. The user must specify these new values at any change points.

The way the program actually operates is to take a given initial load from a particular source and compute its contribution to the dissolved oxygen deficit at each successive point downstream in an iterative fashion allowing for the changes in conditions from

*This table is based on Table 33-4 of Fair et al., op. cit., and the r_0 values are obtained by multiplying by the default value of k_0 (.39) the mid-points of the ranges of values given for the r/k ratio of the corresponding classes in that table.

stretch to stretch. The BOD load (from this particular source) remaining at the beginning of each stretch is taken as the load remaining at the beginning of the previous stretch multiplied by e^{-kt}, where t is the time required to traverse the previous stretch and k has the value appropriate for the previous stretch.* Then Eq. (1) above is applied with this value of L_i and the current-stretch values for r and k.

The program goes through this computation for each load source and then cumulates the contributions to obtain a total dissolved oxygen deficit at each point (including the effects of any initial deficits in the system). Subtraction of the total deficit from the DO saturation value at each point then yields the DO concentration at each point.

Treatment of Tributaries

Since the model user gives each river a name, specifies the sequence of points through which it flows, and can terminate it by indicating that it flows into another river, the junction of two rivers can be handled by making either river a tributary of the other, or else forming a new river where they meet. In

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*For a justification of this procedure, see Fair *et al.*, *op. cit.*, Ch. 33, Sec. 7. When the flow changes between successive stretches, the load is also adjusted by multiplication by F_p/F_c where F_p and F_c are the flows in the previous and current stretches, respectively, and $F_p < F_c$. If $F_p > F_c$, the load is not adjusted.

AMBIENT AIR POLLUTANTS (G PER CUBIC METER) Run E

POLLUTANT : PARTICUL

COLUMN	1	2	3	4	5	6	7
ROW 1	6.259692E-04	6.467055E-04	6.717835E-04	7.593043E-04	5.906502E-04	9.285223E-04	4.808165E-03
ROW 2	4.106565E-04	3.274623E-04	2.112150E-04	1.427985E-04	3.417023E-04	2.415232E-03	1.571959E-02
ROW 3	7.149451E-04	6.733462E-04	6.107532E-04	5.943887E-04	1.686650E-03	1.507535E-02	3.111662E-02
ROW 4	2.221566E-04	1.873031E-04	1.502541E-04	4.284980E-04	1.505245E-02	3.630134E-02	1.492098E-02
ROW 5	1.707084E-05	3.760352E-05	5.926243E-05	1.784514E-02	4.533529E-02	1.498276E-02	1.259450E-03
ROW 6	7.013077E-05	8.077688E-05	9.520043E-03	4.336081E-02	1.785098E-02	5.620834E-04	1.549566E-03
ROW 7	1.743752E-04	2.148356E-04	1.146757E-02	1.510472E-02	7.550001E-03	8.694477E-03	9.940010E-03
ROW 8	5.670092E-04	4.282692E-04	2.743166E-02	2.529638E-02	3.198287E-02	3.257292E-02	1.350606E-02
ROW 9	6.054491E-03	2.167583E-03	4.922245E-03	1.606188E-02	2.003782E-02	2.716660E-02	7.438824E-03
ROW 10	2.389006E-03	1.266489E-04	2.753604E-04	2.518520E-03	1.790713E-03	3.834746E-04	9.133972E-04

COLUMN	8
ROW 1	1.391092E-02
ROW 2	2.977698E-02
ROW 3	1.731859E-02
ROW 4	2.771493E-03
ROW 5	9.7[illegible]0615E-04
ROW 6	3.613699E-03
ROW 7	6.049676E-03
ROW 8	8.571744E-03
ROW 9	5.977288E-03
ROW 10	1.226611E-03

POLLUTANT : SOX

COLUMN	1	2	3	4	5	6	7
ROW 1	1.775077E-03	1.841668E-03	1.908614E-03	2.089231E-03	2.607236E-03	2.544402E-03	5.002405E-03
ROW 2	6.479881E-04	5.524026E-04	4.063882E-04	3.274779E-04	7.133740E-04	7.100347E-04	2.340408E-03
ROW 3	2.904764E-04	2.688146E-04	2.808108E-04	4.015167E-04	4.279425E-04	1.257681E-03	1.782130E-03
ROW 4	9.277772E-05	1.065419E-04	1.544568E-04	1.786188E-04	1.030577E-03	2.053062E-03	7.655365E-04
ROW 5	3.585577E-05	8.404092E-05	1.234073E-04	1.069795E-03	2.430853E-03	7.979299E-04	2.290914E-04
ROW 6	6.62[illegible]13E-04	5.666043E-04	8.883455E-04	2.373405E-03	9.374472E-04	3.281573E-05	8.828897E-03
ROW 7	2.029477E-03	1.980535E-03	7.346542E-03	2.266416E-03	1.643825E-03	1.607228E-02	3.736410E-02
ROW 8	2.676241E-03	1.452400E-03	1.901061E-03	1.352699E-03	9.158564E-02	1.448956E-01	2.162029E-02
ROW 9	1.377657E-02	1.595783E-02	2.649633E-02	8.815563E-02	1.057606E-01	1.302079E-01	1.637108E-02
ROW 10	2.307939E-03	9.027317E-04	2.334172E-03	2.119385E-02	1.464972E-02	1.384645E-03	3.574130E-03

COLUMN	8
ROW 1	3.132704E-03
ROW 2	2.693771E-03
ROW 3	1.557462E-03
ROW 4	1.454054E-04
ROW 5	8.426799E-03
ROW 6	2.499019E-02
ROW 7	1.540496E-02
ROW 8	4.771698E-03
ROW 9	1.182596E-02
ROW 10	4.139062E-03

Figure 12 (Cont)

Ambient Pollution Levels (Water)

Run F

RIVER	ROW	COLUMN	DISSOLVED OXYGEN (MG/L)	SATURATION (MG/L)	DEFICIT (MG/L)
POTOMAC	1	6	6.94728E 00	1.06473E 01	3.70000E 00
PCTOMAC	2	6	6.90363E 00	1.06473E 01	3.74364E 00
POTOMAC	3	6	6.86157E 00	1.06473E 01	3.78571E 00
PCTOMAC	4	6	6.46544E CC	1.C6473E 01	4.18183E 00
POTOMAC	5	5	6.25308E CO	1.06473E 01	4.39419E 00
POTOMAC	6	4	5.77641E 00	1.06473E 01	4.87087E 00
POTOMAC	7	5	5.31741E CC	1.C6473E 01	5.32987E 00
POTOMAC	8	6	4.87560E 00	1.06473E 01	5.77167E 00
PCTCMAC	7	7	4.45053E CO	1.06473E 01	6.19675E 00
POTOMAC	8	7	4.15980E CO	1.C6473E 01	6.48747E 00
POTOMAC	9	7	3.87705E 00	1.06473E 01	6.77022E 00
PCTOMAC	9	6	3.60213E 00	1.06473E 01	7.04515E 00
PCTCMAC	10	6	3.33487E CO	1.06473E 01	7.31240E 00
ROCK CRK	3	1	9.32192E 00	1.03219E 01	1.CCC00E 00
ROCK CRK	3	2	9.31149E CC	1.03219E 01	1.01043E 00
ROCK CRK	4	3	9.29727E CO	1.03219E 01	1.02465E 00
ROCK CRK	4	4	9.28758E 00	1.03219E 01	1.03434E 00

AMBIENT AIR POLLUTANTS (G PER CUBIC METER) Run F

POLLUTANT = PARTICUL

COLUMN	1	2	3	4	5	6	7
ROW 1	3.864546E-04	3.565052E-04	3.092692E-04	2.382266E-04	1.586509E-04	1.652139E-04	3.551786E-03
ROW 2	1.724057E-04	1.214049E-04	7.184003E-05	6.620584E-05	1.130239E-04	2.237006E-03	1.540752E-02
ROW 3	1.724939E-04	1.207267E-04	8.525063E-05	1.001489E-04	1.298136E-03	1.491858E-02	3.058767E-02
ROW 4	5.636735E-05	4.857873E-05	6.031140E-05	3.930160E-04	1.495658E-02	3.592950E-02	1.461042E-02
ROW 5	1.625153E-05	3.567571E-05	5.442195E-05	1.781575E-02	4.518550E-02	1.489601E-02	1.257858E-03
ROW 6	3.922795E-05	5.226162E-05	8.877642E-03	4.224841E-02	1.781425E-02	5.330238E-04	1.507517E-03
ROW 7	7.451217E-05	1.053502E-04	9.370826E-03	1.178863E-02	5.444687E-03	7.659990E-03	9.402961E-03
ROW 8	3.407688E-04	7.057984E-04	1.983161E-03	1.294531E-02	2.636816E-02	3.020867E-02	1.245849E-02
ROW 9	2.025985E-03	1.974832E-03	3.655971E-03	1.346155E-02	1.799409E-02	2.116047E-02	6.931644E-03
ROW 10	5.856040E-04	1.253810E-04	2.732778E-04	2.510806E-03	1.777143E-03	3.556060E-04	8.718122E-04

COLUMN	8
ROW 1	1.328584E-02
ROW 2	2.421738E-02
ROW 3	1.574985E-02
ROW 4	2.223420E-03
ROW 5	9.308495E-04
ROW 6	3.476260E-03
ROW 7	5.461428E-03
ROW 8	8.062944E-03
ROW 9	5.695049E-03
ROW 10	1.164186E-03

POLLUTANT = SOX

COLUMN	1	2	3	4	5	6	7
ROW 1	1.112251E-03	1.045994E-03	9.259288E-04	7.353770E-04	5.199286E-04	3.345038E-04	1.256805E-03
ROW 2	3.770423E-04	2.970609E-04	2.015930E-04	1.729904E-04	2.267191E-04	3.156725E-04	1.263703E-03
ROW 3	6.827478E-05	5.179025E-05	6.953134E-05	1.735714E-04	2.409059E-04	1.099078E-03	1.674334E-03
ROW 4	2.793428E-05	5.007657E-05	1.110118E-04	1.543374E-04	9.721476E-04	1.892514E-03	7.247480E-04
ROW 5	3.415125E-05	7.994588E-05	1.169228E-04	1.050395E-03	2.365038E-03	7.624652E-04	2.290612E-04
ROW 6	2.191668E-04	1.894847E-04	6.085280E-04	2.214216E-03	9.167297E-04	3.088824E-05	8.819912E-03
ROW 7	5.828820E-04	4.675630E-04	7.639518E-04	6.996153E-04	2.779269E-04	1.736984E-02	3.668925E-02
ROW 8	2.422748E-03	1.063439E-03	2.977280E-04	6.554374E-04	9.107763E-02	1.436265E-01	2.112792E-02
ROW 9	1.357582E-02	1.594672E-02	2.642721E-02	8.796215E-02	1.052814E-01	1.299340E-01	1.634675E-02
ROW 10	2.217592E-03	9.020190E-04	2.306445E-03	2.108674E-02	1.458345E-02	1.379716E-03	3.572138E-03

COLUMN	8
ROW 1	1.541335E-03
ROW 2	1.755367E-03
ROW 3	9.363806E-04
ROW 4	1.764686E-04
ROW 5	7.814933E-03
ROW 6	2.357787E-02
ROW 7	1.040518E-02
ROW 8	4.626215E-03
ROW 9	1.181255E-02
ROW 10	4.136998E-03

SECTION VI

INSTRUCTIONS FOR OPERATION OF IMMP

I Introduction

This program has been designed to make it as easy as possible for the user to specify the required information. In all cases items such as activities, rivers, pollutants, etc., are given names of up to 8 characters for ease in identifying them elsewhere. The program recognizes the end of groups of cards by the use of an END card. This relieves the user from the task of identifying how many of each type of card will be specified. Every card supplied to the program by the user will be printed exactly as it is read. This print will be preceeded and followed by five asterisks (*****).

This manual will follow with an outline of the input cards. This will be followed by a discussion of each type of group of data required for a run of the program. Detailed format of the 14 different types of cards will be found in the format section of this manual. The last section will contain some technical notes on the computer program.

II <u>Outline</u>

A. Header Card

B. Economic Input and Pollutant Names Card

C. Activity Technology Cards

End Card

D. On-Site Pollution Treatment Activity Technology Cards

End Card

E. General Parameter List Card

F. Background Air Pollutant Levels Card

G. Air Pollutant Half Life Card

H. Air Diffusion Characteristics with Probabilities Card

End Card

I. River Characteristic Probability Card

J. For Each River Position

a. River Position Identification Card

b. River Point Characteristic Cards (optional except for first river point in each river)

End Card

K. Endogenous Activity Descriptions

a. Endogenous Activity Specification Card

b. Stack Parameter Card

c. Move Pollutants to Endogenous Activities Card (optional)

End Card

L. Exogenous Activity Descriptions

a. Exogenous Activity Specification Card

b. Stack Parameter Card (optional)

c. Move Pollutants to Endogenous Activity Card (optional)

End Card

III. Detailed Description of Each Card or Card Group

A. Header Card

Format of Header Card will be found in IV A. This card requires the user to specify the number of various categories which will be used subsequently in the program. On this card is specified the number of each different type of pollutant and the number of rows and columns on the grid which will comprise the region under consideration. One option which the user must specify on this card is the number of hours in the analysis. This refers to the number of hours per day that the activities are presumed to run. This is important as the meteorological data is presumed to be valid over the period of time that the pollutants are being generated. This number affects the air pollution diffusion model as the pollutants are presumed to be emitted in the units of mg/sec. Thus the total number of KG of pollutants generated per period must be converted to mg/sec. In the case of water pollutants this number adjusts the river flow (given in millions of gallons per day) to the number of millions of gallons per period.

The print option refers to the print of the final emitted and ambient levels of air and solid pollutants. Option 1 gives for each air and solid pollutant a matrix location. The emitted levels on the grid are for each air pollutant a matrix of the ambient levels at each point on the grid. Option 2 gives these values by row/column point on the grid.

By specifying a logical unit (other than 5) for reading the Activity Descriptions, the program could read the Activity Technology Cards and (if separated by an END card) the On-Site Pollution Treatment Activity Technology Cards from a tape or disk (any sequential file).

B. Economic Input and Pollutant Name Cards

Format of Economic Input and Pollutant Name Card will be found in IV B. On this card the user will give names of up to eight (8) characters to the economic inputs, the actual pollutants, and to any dummy pollutants. If the names are less than eight (8) characters they should be punched left adjusted in the field. These names will be used in the print out to refer to the pollutants and will be used in the card "Move Pollutants to Endogenous Variables" to refer to the pollutants to be sent to the appropriate Endogenous activity.

C. Activity Technology Cards

Format of Activity Technology Cards will be found in IV C. These cards give the Economic input data values and the residual pollutants per unit of output for an activity. All pollutants will be measured in kilograms (KG). What is considered unit output for an activity is optional. It is probably a good idea to keep the levels of the residual pollutants in the same order of magnitude among the various activities. The unit output levels can be adjusted to achieve this goal.

D. <u>On-Site Pollution Treatment Activity Technology Cards</u>

Format of On-Site Pollution Treatment Activity Cards will be found in IV D. An on-site pollution treatment activity is represented by a square matrix of order equal to the number of actual pollutants in the model. The jth column represents the per unit effect of reducing the jth pollutant (the value of the jth row will be less than or equal to one). The other rows will contain the resultant increases (if any) in the other pollutants. As indicated in IV D the economic input values are punched first and then the matrix. The matrix is punched by column, i.e., all the elements of the first column are punched before any elements of the second column are punched and so on.

As a matrix does not have a unit level of operation, the economic input variable values should reflect the fact that they will be multiplied by the level of operation of the associated activity to reflect the total impact of this on-site treatment activity.

E. General Parameter List

Format of General Parameter List Card will be found in IV E. This card is designed to supply those values which will be used in various subroutines, particularly those involved with diffusion processes. Currently two numbers must be supplied in this card: the length of the side of a grid square and the mean afternoon mixing layer depth.

F. Background Air Pollution Levels Card

Format of Background Air Pollution Levels Card will be found in IV F. This card provides the assumed ambient levels of air pollutants coming from outside of the region measured in grams per cubic meter. The level punched on this card for each air pollutant is added to the final ambient levels determined from the activities in the region (hence the final print of ambient levels includes these values).

G. Air Pollutant Half Life Card

Format of Air Pollutant Half Life Card will be found in IV G. This card contains the half life of each air pollutant which is used in the air diffusion model. These half lives are measured in hours.

H. Air Diffusion Characteristics with Probabilities Card

Format of an Air Diffusion Characteristic with Probabilities Card will be found in IV H. These cards describe the atmospheric conditions which will be used in the air diffusion model. On each card with the atmospheric conditions is a probability. This number is used to weight the ambient levels generated by the corresponding atmospheric conditions. The probabilities on these cards must sum up to one. One or more of these cards may be submitted. There is no limit to the number of cards of this type which may be used. If only one card is submitted, then the analysis would study a region under a single atmospheric situation. The set of these cards must be followed by an END card, i.e., a card with END punched in Columns 1-3 and the rest of the card blank.

I. River Characteristic Probability Card

Format of a River Characteristic Probability Card will be found in IV I. This card describes the number of River Point Characteristic Cards which may follow each River Position Identification Card. Each River Point Characteristic

Card will describe a set of river characteristics which will determine the diffusion of the water pollutants. The probabilities specified on this card are used to weight the resultant ambient levels of the water pollutants generated by the corresponding River Point Characteristic Card. The number of probabilities on this card must be the number as specified in Columns 8-10.

J. <u>For Each River Position</u>

Each river position is specified by a River Position Identification Card. The format of a River Position Identification Card will be found in IV J. This card gives a name to the river, the sequence this river point appears in the river, and the row, column position on the grid which the river is passing through.

The first position of each river must have a set of River Point Characteristic Cards, i.e., a set of cards must immediately follow the first River Position Identification Card for each river. The format of a River Point Characteristic Card will be found in IV K. The river characteristics (such as flow, temperature, etc.) defined for a river point are assumed to continue to subsequent river points on the same river unless a new set of River Point Characteristic Cards follow a River Position Identification Card for a down river point. This subsequent specification will assume to hold for further down river points until superseded by another set of River Point Characteristic Cards for some subsequent river point. It should be noted that the order of the River Point Characteristic Cards is very important as they must be associated with the probabilities specified on the River Characteristic Probability Card.

The exogenous load and exogenous deficit will be diffused through the remaining points in the river system. They need not only be specified for the first river point (i.e., coming from outside the region). If a small stream or sewer outlet appear at some point on the river and an activity does not seem appropriate (because say, the water already has an oxygen deficit) then an exogenous load and/or an exogenous deficit can be specified.

If more than one river flows through the region, the program can have one river flow into another. This is accomplished by following the last River Position Identification Card (or the associated set of River Point Characteristic Cards if it has one) with a card with a -1 (minus one) in the field called "Position Sequence for this Point". The name of the river into which the river is to flow should be punched in the "River Name" field of this card. The row/column of this river into which it will flow should be punched appropriately in the fields marked "River Point Location". In this way pollutants flowing down one river may flow into another river. One should note that the order that the rivers are specified does not make any difference to the program. However the print out of the pollutants at the river points will be in the order that the rivers are specified and consequently it is a good idea to put the rivers in a logical flow sequence when arranging the deck.

After the last river point has been described, the next card should be an END card (i.e., END punched in Columns 1-3 and blank for the rest of the card).

K. Endogenous Activity Descriptions

Endogenous Activities are those whose levels of operation are determined by the level of the pollutants "sent to" them. Each Endogenous activity is assigned a name on the Activity Specification Card. The format of this card will be found in IV L. This name will be used on the Move Pollutants to Endogenous Activities Card (the format of this card will be found in IV N).

When the Endogenous Activity Cards are read, the level of operation has not yet been determined. The level of operation is not determined until all the exogenous activities have been processed. What is generated is a "per unit" output of pollutants and this information is stored. The actual processing of Endogenous Activities follows the processing of the exogenous activities. Except that their level of operation is not specified, all the other information that must be supplied about exogenous activities must be specified also for endogenous activities. As this is so, the detailed description of this information will be provided in the next subsection on Exogenous Activities.

After the last Endogenous activity has been specified, the next card must be an END card (END in Columns 1-3, blank elsewhere). This END card indicates the division between the Endogenous and Exogenous activities.

L. Exogenous Activity Description

Exogenous Activities are those whose levels of operation are specified by the user. The format of the Activity Specification Card will be found in IV L. The activity called will be referred to by the name given it in Activity Technology Cards. The actual pre on-site treatment pollution residuals are determined by multiplying the vector of pre-unit residuals given in the Activity Technology Card by the specified level of operation. This vector is then multiplied by the on-site treatment technology matrix (if any) to obtain the effective residual pollutants which is printed out. Some or all of these pollutants may be "moved" to an Endogenous activity by the use of the Move Pollutants to Endogenous Activities Card. This card associates the name of a pollutant with the name of the Endogenous activity. If any water pollutants remain they will be dumped into the river specified at the location specified. The diffusion process is seen immediately and if a P is punched in column 69 of the Activity Specification Card, the user will see a print out of the diffused water pollutants. If any air pollutants remain, these will be diffused. The Activity Specification Card contains a field to specify the stack height for the air diffusion model. The user has the option of specifying the effective stack height or by punching an * in column 56, the actual stack height. If an * is punched in column 56 then the Stack Parameters Card (format will be found in IV M) must <u>immediately</u> follow the Activity Specification Card. The parameters specified here are used to calculate the effective stack height for the diffusion model. Again, if a P is punched in column 69 of the Activity Specification Card, the user will see a print out of the ambient levels of the pollutants determined by this activity alone.

A

HEADER CARD

Note: No decimal points should be punched in this card. Each number should be right adjusted in its field.

H
1

	Field (end column)	Description
1.	5	Number of Economic Input Variables (>0)
2.	10	Number of Water Pollutants
3.	15	Number of Air Pollutants
4.	20	Number of Solid Pollutants
5.	25	Number of Dummy Pollutants
6.	30	Number of Rows in Grid
7.	35	Number of Columns in Grid
8.	40	Number of Hours in the Analysis (24 assumed if left blank)
9.	45	Number of General Parameters
10.	50	Logical Unit Containing Activity Descriptions (card reader assumed if this is left blank)
11.	55	Print Option - Leave blank for both types of final print. Punch 1 for matrix print. Punch 2 for print by position.

Maximums built into program (can be easily changed)

1.	Maximum number of activities	100
2.	Maximum number of On-site transformation activities	50
3.	Maximum number of rivers parameters	20
4.	Maximum number of river points	200
5.	Maximum number of endogenous activities	20

B

ECONOMIC INPUT AND POLLUTANT NAMES

List Economic Input and Pollutant Names in the same order as data appears on Activity Technology cards. All names should begin at left most position of field.

Start	End
1	8
11	18
21	28
31	38
41	48
51	58
61	68
71	78

Use subsequent cards in the same format as required.

C

ACTIVITY TECHNOLOGY

A
1

|___|___|___|___|___|___|___| Activity Technology Name
2 ... 9

List for unit output Economic Inputs and Pollutant Residuals in the following order

1. Economic Inputs
2. Water Pollutants
3. Air Pollutants
4. Solid Pollutants

Each number should be punched either

a. with a decimal point
b. right adjusted in field only if it is a whole number

|__________|
11

|__________|
21

|__________|
31

|__________|
41

|__________|
51

|__________|
61

|__________|
71

Continue with Column 11 for subsequent cards as needed.

D

ON-SITE POLLUTION TREATMENT ACTIVITY TECHNOLOGY

T
1

|_|_|_|_|_|_|_| On-site Pollution Treatment Technology Name
2 9

List 1)Economic Input Variables
2)Pollution Treatment Matrix by Column
Each number should be punched either
a)with a decimal point
b)right adjusted in field only if it is a whole number

|______|
11

|______|
16

|______|
21

|______|
26

|______|
31

|______|
36

|______|
41

|______|
46

|______|
51

|______|
56

|______|
61

|______|
66

|______|
71

|______|
76

E

GENERAL PARAMETER LIST

| G |
1

Note: Each number should be punched either
a) with a decimal point
b) right adjusted in field only if it is a whole number

Grid Size - Distance between rows and columns, in meters

Depth of the monthly mean afternoon mixing layer (L_0)

|______________| Parameter 1
11

|______________| Parameter 2
21

|______________| Parameter 3
31

|______________| Parameter 4
41

|______________| Parameter 5
51

|______________| Parameter 6
61

|______________| Parameter 7
71

F

BACKGROUND AIR POLLUTANT LEVELS

List background air pollution levels in G per cubic meter in the order that the air pollutants appear in the Activity Description Cards.

Each number should be punched either
a)with a decimal point
b)right adjusted in field only if it is a whole number

|——————| 1 ... 10

|——————| 11 ... 20

|——————| 21 ... 30

|——————| 31 ... 40

|——————| 41 ... 50

|——————| 51 ... 60

|——————| 61 ... 70

|——————| 71 ... 80

Use subsequent cards in the same format as required.

G

AIR POLLUTANT HALF LIFE

| HALF LIFE |
1

Each number should be punched either
a)with a decimal point
b)right adjusted in field only if it is a whole number

Columns	Contents
11–20	Half life of 1st air pollutant
21–30	2nd
31–40	3rd
41–50	4th
51–60	5th
61–70	6th
71–80	7th

H

AIR DIFFUSION CHARACTERISTICS WITH PROBABILITIES

| P |
1

Each number in a field of length ten should be punched either
a)with a decimal point
b)right adjusted in field only if it is a whole number

11–20	Probability
25	Stability Class - 1 to 6 (1=unstable, 6=verystable)
30	(N,S,E,W in column 30 or NE,NW,SE,SW in column 29-30)
31–40	Mean Wind Speed (meters per second)
* 41–50	Atmospheric Pressure (mm of mercury)
* 51–60	Air Temperature (C° or K°: consistent with degree used with Stark Parameter Card)

*Used to calculate effective stack height. If effective stack heights are given in all activity specifications, then this parameter may be left blank.

I

RIVER CHARACTERISTIC PROBABILITY CARD

Each number in a field of length ten should be punched either
a)with a decimal point
b)right adjusted in field only if it is a whole number

Columns	Content
1–4	PROB
–10	Number of River Point Characteristic Cards which may follow a River Point Identification Card. This will be the number of probabilities which will follow. Punch this number right adjusted in field.
11–20	Probability associated with 1st River Point Characteristic Card
21–30	...2nd
31–40	...3rd
41–50	...4th
51–60	...5th
61–70	...6th
71–80	...7th

If needed probabilities may be continued starting in column 11 of subsequent cards.

J

RIVER POSITION IDENTIFICATION CARD

R
1

Punch fields in length three right adjusted with no decimal.

|____|____|____|____|____|____| River Name (punch left adjusted)
2

|____|____|____| Position Sequence for this point
11

|____|____|____| |____|____|____| River Point Location
15 19
Row Column

K

RIVER POINT CHARACTERISTIC CARD

Punch all fields (except River Class) either
a)with a decimal point
b)right adjusted in field only if it is a whole number

Columns	Field
# (1)	Identifies card as River Characteristic Card
10	Any information, such as season
11–20	Flow (millions of liters per day)
21–30	Average speed (kilometers per day) (1 m/sec=86.4 km per day=2.24 miles/hr)
31–40	Water temperature (C°)
41–50	Barometric Pressure (mm of mercury)
51–55	K_0 (calculated if blank)
56–60	r_0 (calculated if blank)
61	River class (1 to 4) - 1=sluggish stream, 4=swift stream
62–70	Exogenous Load (mg/l)
71–80	Exogenous Deficit (mg/l)

L

ACTIVITY SPECIFICATION

Punch all names left adjusted.
Punch all three position fields with a number right adjusted without a decimal point.
On other fields follow specific instructions.

ENDOGENOUS	EXOGENOUS
Column 1: N	Column 1: X
Columns 2–9: Specify the name which will be used to refer to this endogenous activity.	Columns 2–9: Activity Technology Name
Columns 11–18: Activity Technology Name	Columns 11–18: Level of operation of this activity (punch with a decimal).

Columns 20–23: Row; Columns 24–27: Column — Activity Location

Columns 28–35: On-site Pollution Treatment Technology Name

Columns 37–44: If the water pollutants are to be moved directly into a river, specify to the left the river name and the location to which the pollutants will be moved.

Columns 46–49: Row; Columns 50–53: Column

Column 54: For dispersion of air pollutants is this to be considered a point or area source. Leave blank or punch zero for point source. Punch a one for area source.

Columns 56–63: Specify to the left the effective stack height for the dispersion of air pollutants (punch with a decimal point). If the effective stark height is to be calculated, punch an asterisk in column 56 and follow with the actual stack height. The card following this must contain the relevant parameter values.

[continued]

ACTIVITY SPECIFICATION [continued]

|________| 65	Specify the number of endogenous activities which will be specified on subsequent cards.
|___| 69	Punch a P to print the effects of this activity in all points.

M

STACK PARAMETERS

| STACK PARM |
1 — 10

This card will immediately follow an Activity Specification Card if an X is punched in column 56 of the Activity Specification Card.

Each number should be punched either
a)with a decimal point
b)right adjusted in field only if it is a whole number

1. | 11 — 20 | Escape velocity of the gas (m/sec)

2. | 21 — 30 | Diameter of Stack (meters)

3. | 31 — 40 | Temperature of particles emmitted from stack (degree used must be consistent with temperature specified on Air Diffusion Characteristics Card)

N

MOVE POLLUTANTS TO ENDOGENOUS ACTIVITIES

Name of Pollutant to be Moved	Name of Endogenous Activity to which it will be moved
1. |________| 1 – 8	|________| 11 – 18
2. |________| 21 – 28	|________| 31 – 38
3. |________| 41 – 48	|________| 51 – 58
4. |________| 61 – 68	|________| 71 – 78

Note: If an asterisk is placed in the first column of the Name of the Pollutant to be moved, then the associated Endogenous Activity will be run based on the level of operation of the activity itself (rather than on the basis of the level of some pollutant output).

Technical Notes on the Computer Program IMMP

1. Maximums built into the program

All maximums built into the program can be easily changed. Their specifications will all be found in the main routine.

a.	Maximum number of Activity Technology Descriptives	100
b.	Maximum number of On-Site Pollution Treatment Activity Matrices	50
c.	Maximum number of River Point Characteristic Cards in a set	20
d.	Maximum number of river points	200
e.	Maximum number of endogenous activities	20

2. Matrix Storage

All matrices are stored as required for the IBM Scientific Subroutine Package for use as general matrices. This program utilizes many of the matrix subroutines of the IBM Scientific Subroutine Package. Space for these matrices is dynamically allocated using the technique of defining a single large vector. This vector is then partitioned into the required matrices based on the length of card one. In this way only one number on a dimension card need be changed to increase the size of the problem that this program can handle (also change the specification on NMAX in the main routine). The program prints out how much of this large vector is being used up in any run of this program.

3. Overlay Structure

As the program is large, an overlay structure is used to cut down the memory requirements for the program. This is clearly optional if the computer being used has a memory large enough to handle the program. Listed below are all the routines used in the program IMMP with the overlay structure specified:

MAIN
ITEST
ZERORY
SMPY
LOC
FREAD
FNUMBR
ERROR
ADD

```
  SEQ
  ZEROI2
  MADD
  MXOUT
  GMPRD
  MOVE
  KOMP
  NUMBER
OVERLAY ALPHA
  SIMPOL
OVERLAY BETA
  NAMEP
OVERLAY BETA
  AIRCHR
OVERLAY BETA
  WRCH
OVERLAY BETA
  EFAC
OVERLAY BETA
  MINV
OVERLAY BETA
  ASREAD
OVERLAY BETA
  PMOVE
OVERLAY GAMMA
  WATER1
  LOADP
  FLOW
  DEOXK
  REOXR
  STPH
  WPADD
OVERLAY GAMMA
  ESH
  AIRPRB
  AIRDIF
  SIG
  CHI1
  CHI2
  DML
  CALT
  AVG
OVERLAY BETA
  DGMPRD
OVERLAY ALPHA
  PRINTP
  CS
```

SECTION VII

THE IMMP MODEL PROGRAM

```
C --- ARRAYS                                                            SIMP0005
C --- P STORES FOR EACH POINT THE LEVEL OF AIR AND SOLID POLLUTANTS     SIMP0006
C ---         COL 1 - INITIAL LEVEL OUTPUTTED BY ACTIVITIES             SIMP0007
C ---         COL 2 - MODIFIED AND SUMMED BY DISPERSION PROCESS         SIMP0008
C --- W STORES FOR EACH WATER POINT THE LEVEL OF WATER POLLUTION        SIMP0009
C ---         COL 1 - INITIAL LEVEL OUTPUTTED BY ACTIVITEES             SIMP0010
C ---         COL 2 - MODIFIED AND SUMMED BY DISPERSION PROCESS         SIMP0011
C ---                                                                   SIMP0012
C --- RP EACH COL REPRESENTS A RIVER POINT AND THE COL SEQUENCE NUMBER WSIMP0013
C ---    BE THE RANDOM ACCESS SEQUENCE NUMBER                           SIMP0014
C ---         ROW 1 - RIVER I.D. NUMBER                                 SIMP0015
C ---         ROW 2 - ROW                                               SIMP0016
C ---         ROW 3 - COLUMN                                            SIMP0017
C ---         ROW 4 - SEQUENCE NUMBER INDICATING RIVER PARAMETER GROUP  SIMP0018
C ---                                                                   SIMP0019
C --- E EACH COLUMN REPRESENTS AN ENDOGINOUS ACTIVITY.  EACH ROW REPRESTSIMP0020
C ---    DIRECT EFFECT OF THAT ACTIVITY ON THE ASSOCIATED ENDOGINOUS ACTSIMP0021
C ---                                                                   SIMP0022
C --- EL ENDOGINOUS ACTIVITIES LEVEL DUE TO EXOGINOUTS ACTIVITESS       SIMP0023
C ---                                                                   SIMP0024
C --- FL ENDOGINOUS ACTIVITEES LEVEL DUE TO EXOGINOUS AND ENDOGINOUS ACTSIMP0025
C ---                                                                   SIMP0026
C --- A STORES THE POLLUTANT LEVELS FOR UNIT OUTPUT FOR ANY ACTIVITY    SIMP0027
C ---                                                                   SIMP0028
C --- T STORES POLLUTION TRANSFORMATION MATRICEES BY COLUMN             SIMP0029
C ---                                                                   SIMP0030
C --- MTOT - STORES ECONOMIC INPUT VARIABLE LEVELS                      SIMP0031
C ---      COL 1 - DUE TO ACTIVITY TECHNOLOGY                           SIMP0032
C ---      COL 2 - DUE TO ON SITE TREATMENT                             SIMP0033
C ---      COL 3 - TOTAL                                                SIMP0034
C ---                                                                   SIMP0035
C --- IEND STORES THE ENDOGENOUS ACTIVITIES AND THE ASSOCIATED POLLUTANTSIMP0036
C --- NUMBER GENERATED BY EACH ACTIVITY.  EACH COLUMN IS EACH ENDOGENOUSSIMP0037
C ---         ROW 1 - ENDOGENOUS ACTIVITY IDENTIFICATION NUMBER         SIMP0038
C ---         ROW 2 - POLLUTANT SEQUENCE NUMBER DETERMENING LEVEL OF ACTSIMP0039
C ---                                                                   SIMP0040
C --- WPRB - ONE ENTRY, A PROBABILITY, FOR EACH RIVEER CONDITION ENCOUNTSIMP0041
C ---                                                                   SIMP0042
C --- DAV - MAXIMUM LENGTH IS MAXIMUM NUMBER OF RIVER POINTS.  STORES THSIMP0043
C --- AVERAGE DEFICIT FOR EACH LOAD L                                   SIMP0044
C ---                                                                   SIMP0045
C --- DPP - SAME AS DAV EXCEPT FOR A PARTICULAR PROBABILITY             SIMP0046
C ---                                                                   SIMP0047
C --- TBL1 STORES ACTIVITY NAMES                                        SIMP0048
C ---                                                                   SIMP0049
C --- TBL2 STORES TRANSFORMATION ACTIVITY NAMES                         SIMP0050
C ---                                                                   SIMP0051
C --- TBL3 STORES RIVER NAMES                                           SIMP0052
C ---                                                                   SIMP0053
C --- TBL4 STORES ENDOGENOUS ACTIVITY NAMES                             SIMP0054
C ---                                                                   SIMP0055
C --- TBL5 STORES ECONOMIC INPUT NAMES FOLLOWED BY POLLUTANT NAMES      SIMP0056
C ---                                                                   SIMP0057
C --- LOGICAL UNITS USES IN THIS PROGRAM                                SIMP0058
C ---     N5 - CARD READER                                              SIMP0059
C ---     N6 - PRINTER                                                  SIMP0060
C ---    N10 - SEQUENTIAL FILE WHICH CONTAINS ACTIVITEES                SIMP0061
C ---     20 - RANDOM ACCESS FILE TO STOREE ACTIVITIES                  SIMP0062
C ---     21 - RANDOM ACCESS FILE TO STORE TRANSFORMATION MATRICIES     SIMP0063
C ---     22 - RANDOM ACCESS FILE TO STORE ENDOGINOUS ACTIVITIES        SIMP0064
C ---     23 - RANDOM ACCESS FILE TO STORE WATER POLLUTANTS AT EACH RIVERSIMP0065
C ---     24 - RANDOM ACCESS FILE TO STORE AIR AND SOLID POLLUTANTS AT EASIMP0066
C ---             ON THE GRID.                                          SIMP0067
C ---                                                                   SIMP0068
      REAL*4 X( 8000)                                                   SIMP0069
      COMMON NE,NA,NEND,NT,NIA,NIA1,NTR,NAS,NR,NC,NPR,NG,NW1,NW2,NAS2,  SIMP0070
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     * NM,NTM,NTRM,NM1,NRA,NCA,NARP,NH,NOP                              SIMP0071
       COMMON /MAX/ MAXA,MAXT,NRIV,NRPTS,NNV,MXA,MXT,MXR,MXE,MXN         SIMP0072
       COMMON /UNIT/ K5,K6,K10,K30                                        SIMP0073
       COMMON /SPACE/ X                                                   SIMP0074
C ---  THIS RANDOM ACCESS FILE DEFINES A MAXIMUM OF  100 POSSIBLE ACTIVITISIMP0075
C ---     A MAXIMUM OF  10 ACTUAL POLLUTANT OUTPUTS,  2 DUMMY POLLUTANT CSIMP0076
C ---  AND  4 MACRO VARIABLES (OR A TOTAL NOT TO EXCEED  16)             SIMP0077
C ---  (10)(4)+( 2)(4)+( 4)(4)=64                                         SIMP0078
       DEFINE FILE 20(100,64,L,I0)                                        SIMP0079
C ---  THIS RANDOM ACCESS FILE DEFINES A MAXIMUM OF  50 POSSIBLE TRANSFORSIMP0080
C ---     MATRICIES WITH A MAXIMUM OF  10 POLLUTANT OUTPUTS AND 4 MACRO VSIMP0081
C ---  ( 10)( 10)(4)+( 4)(4)=416                                          SIMP0082
       DEFINE FILE 21( 50,416,L,I1)                                       SIMP0083
C ---  THIS RANDOM ACCESS FILE DEFINES A MAXIMUM OF   20 ENDOGINOUS ACTIVSIMP0084
C ---  AND 10 ACTUAL POLLUTANT OUTPUTS,  2 DUMMY POLLUTANT OUTPUTS, AND 4SIMP0085
C ---  VARIABLES (12)(4)+(10)(4)+( 2)(4)+( 4)(4)+( 4)(4)=128              SIMP0086
       DEFINE FILE 22( 20,128,L,I2)                                       SIMP0087
C ---  THIS RANDOM ACCESS FILE DEFINES A MAXIMUM OF  200 RIVER POINTS     SIMP0088
C ---  AND 5 WATER POLLUTANTS       ( 5)(2)(4)=40                         SIMP0089
       DEFINE FILE 23( 200, 40,L,I3)                                      SIMP0090
C ---  THIS RANDOM ACCESS FILE DEFINES A MAXIMUM OF  400 GRID POINTS AND SIMP0091
C ---     AND AIR POLLUTANTS           ( 8)(2)(4)=64                      SIMP0092
       DEFINE FILE 24( 400,64,L,I3)                                       SIMP0093
C ---  THIS RANDOM ACCESS FILE DEFINES A MAXIMUM OF 4 PROBABILITY SITUATISIMP0094
C ---  FOR EACH 200 RIVER POINTS       (9)(4)=36                          SIMP0095
       DEFINE FILE 25( 800,36,L,I5)                                       SIMP0096
C ---  INITIALIZE LOGICAL UNIT FOR CARD READER AND PRINTER                SIMP0097
       K5=5                                                               SIMP0098
       K6=6                                                               SIMP0099
       K30=30                                                             SIMP0100
C ---  MAXA - MAXIMUM NUMBER OF ACTIVITEES.  SEE R.A. FILE #20            SIMP0101
       MAXA=100                                                           SIMP0102
C ---  MAXT - MAXIMUM NUMBER OF TRANSFORMATION ACTIVITIES.  SEE R.A. FILESIMP0103
       MAXT=50                                                            SIMP0104
C ---  NRIV - MAXIMIM NUMBER OF RIVERS                                    SIMP0105
       NRIV=10                                                            SIMP0106
C ---  NRPTS - MAXIMUM NUMBER OF RIVER POINTS.  SEE R.A. FILE #23         SIMP0107
       NRPTS=200                                                          SIMP0108
C ---  NNV - MAXIMUM NUMBER OF ENDOGENOUS ACTIVITIES.  SEE R.A. FILE #22 SIMP0109
       NNV=20                                                             SIMP0110
C ---  MXPR - MAXIMUM NUMBER OF RIVER PARAMETER SETS AT EACH RIVER POINT SIMP0111
       MXPR=20                                                            SIMP0112
C ---  INITIALIZE COUNTERS FOR TABLE NAMES TO ZERO.                       SIMP0113
       MXA=0                                                              SIMP0114
       MXT=0                                                              SIMP0115
       MXR=0                                                              SIMP0116
       MXE=0                                                              SIMP0117
       MXN=0                                                              SIMP0118
C ---  READ ACTIVITY HEADER                                               SIMP0119
       READ(K5,11) HD,NM,NW,NA,NS,ND,NR,NC, NH,NG,K10,NOP                 SIMP0120
    11 FORMAT(A1,I4,12I5)                                                 SIMP0121
       WRITE(K6,12) HD,NM,NW,NA,NS,ND,NR,NC,NH,NG,K10,NOP                 SIMP0122
    12 FORMAT('1*****',A1,I4,12I5,'*****')                                SIMP0123
       IF(NH.EQ.0) NH=24                                                  SIMP0124
       IF(K10.EQ.0) K10=K5                                                SIMP0125
       NT=NW+NA+NS+NC                                                     SIMP0126
       NTA=NT-ND                                                          SIMP0127
       NTA1=NTA+1                                                         SIMP0128
       NTM=NT+NM                                                          SIMP0129
       NM1=NM+1                                                           SIMP0130
       NTR=NTA*NTA                                                        SIMP0131
       NTRM=NTR+NM                                                        SIMP0132
       NW1=NW+1                                                           SIMP0133
       NW2=NW*2                                                           SIMP0134
       NAS=NA+NS                                                          SIMP0135
       NAS2=NAS*2                                                         SIMP0136
       NRA=NR*2+1                                                         SIMP0137
       NCA=NC*2+1                                                         SIMP0138
       NMAX= 8000                                                         SIMP0139
       I1=1                                                               SIMP0140
C ---  L                                                                  SIMP0141
       I2=I1+NNV+NNV*2                                                    SIMP0142
C ---  A                                                                  SIMP0143
       I3=I2+NTM                                                          SIMP0144
       I3=(I3/2)*2+1                                                      SIMP0145
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```
C --- T
      I4=I3+NTRM
      I4=(I4/2)*2+1
C --- G
      I5=I4+NG
      I5=(I5/2)*2+1
C --- W
      I6=I5+2*NW
C --- P
      I7=I6+2*NAS
C --- EA
      I8=I7+NT
      I8=(I8/2)*2+1
C --- EL
      I9=I8+NNV
      I9=(I9/2)*2+1
C --- FL
      I10=I9+NNV
      I10=(I10/2)*2+1
C --- WPRB
      I11=I10+MXPR
      I11=(I11/2)*2+1
C --- W1
      I12=I11+NNV
      I12=(I12/2)*2+1
C --- W2
      I13=I12+NNV
      I13=(I13/2)*2+1
C --- RP
      I14=I13+(NRPTS*4)/2+1
      I14=(I14/2)*2+1
C --- DAV
      I15=I14+NRPTS
      I15=(I15/2)*2+1
C --- IEND
      I16=I15+2*NNV
C --- MA
      I17=I16+NM
      I17=(I17/2)*2+1
C --- MT
      I18=I17+NM
      I18=(I18/2)*2+1
C --- MTOT
      I19=I18+NM*3
      I19=(I19/2)*2+1
C --- TBL1
      I20=I19+2*MAXA
C --- TBL2
      I21=I20+2*MAXT
C --- TBL3
      I22=I21+2*NRIV
C --- TBL4
      I23=I22+2*NNV
C --- TBL5
      I24=I23+2*NTM
C --- A1
      I25=I24+NR*NC
      I25=(I25/2)*2+1
C --- A2
      I26=I25+NR*NC
      I26=(I26/2)*2+1
C --- B
      I27=I26+NRA*NCA
      I27=(I27/2)*2+1
C --- HL
      I28=I27+NA
      I28=(I28/2)*2+1
C --- DPP
      I29=I28+NRPTS
      I29=(I29/2)*2+1
      IF(I29.GT.NMAX) GO TO 100
      WRITE(K6,91) I29,NMAX
   91 FORMAT('0THE ARRAYS IN THIS RUN ARE USING ',I6,' OF THE ',I6,' WOR
     *DS OF SPACE AVAILABLE.')
      CALL SIMPCL(X(I1),X(I2),X(I3),X(I4),X(I5),X(I6),X(I7),X(I8),X(I9),
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```
     * X(I10),X(I11),X(I12),X(I13),X(I14),X(I15),X(I16),X(I17),X(I18),
     * X(I19),X(I20),X(I21),X(I22),X(I23),X(I24),X(I25),X(I26),X(I27),
     * X(I28))
      CALL PRINIP(X(I1),X(I2),X(I3),X(I4),X(I5),X(I6),X(I7),X(I8),X(I9),
     * X(I10),X(I11),X(I12),X(I13),X(I14),X(I15),X(I16),X(I17),X(I18),
     * X(I19),X(I20),X(I21),X(I22),X(I23),X(I24),X(I25),X(I26),X(I27),
     * X(I28))
      GO TO 200
  100 WRITE(K6,101) I29,NMAX
  101 FORMAT('0YOU HAVE ATTEMPTED TO ALLOCATE SPACE FOR ',I10,' WORDS.
     *THE MAXIMUM ALLOWABLE IS ',I10)
  200 WRITE(K6,201)
  201 FORMAT('0END OF SIMULATION RUN')
      STOP
      END
      SUBROUTINE SIMPOL(E,A,T,G,W,P,EA,EL,FL,WPRB,W1,W2,RP,CAV,IEND,MA,
     * MT,MTOT,TBL1,TBL2,TBL3,TBL4,TBL5,A1,A2,B,HL,DPP)
      REAL*8 E(1),DET,S(10),TBL1(1),TBL2(1),TBL3(1),TBL4(1),TBL5(1)
      REAL*4 A(1),T(1),G(1),W(1),P(1),EA(1),EL(1),FL(1),WPRB(1),CAV(1),
     * W1(1),W2(1),MA(1),MT(1),MTOT(1),A1(1),A2(1),B(1),HL(1),DPP(1)
      INTEGER*2 RP(1),IEND(1)
      COMMON NW,NA,NS,ND,NT,NTA,NTA1,NTR,NAS,NR,NC,NPR,NG,NW1,NW2,NAS2,
     * NM,NTM,NTRM,NM1,NRA,NCA,NARP,NH,NCP
      COMMON /MAX/ MAXA,MAXT,NRIV,NRPTS,NNV,MXA,MXT,MXR,MXE,MXN
      COMMON /UNIT/ K5,K6,K10,K30
      DATA END,STAR,EXC/'END','*','#'/
      DATA BLANK/'      '/
C --- READ AND PRINT ECONOMIC INPUT AND POLLUTANT NAMES
    5 IC=0
    6 IC=IC+1
      READ(K5,1,END=140)(S(I),I=1,10)
      WRITE(K6,2)(S(I),I=1,10)
      L=NTM-(IC-1)*8
      ISET=0
      IF(L.LE.8) GO TO 7
      ISET=1
      L=8
    7 IPOS=-9
        DO 8 I=1,L
      IPOS=IPOS+10
      CALL ADD(TBL5,S,IPOS,8,NTM,MXN)
    8 CONTINUE
      IF(ISET.EQ.1) GO TO 6
      K=0
      WRITE(K6,11)
   11 FORMAT('0ECONOMIC INPUT VARIABLES'/)
      CALL NAMEP(TBL5,K,NM)
      WRITE(K6,12)
   12 FORMAT('0WATER POLLUTANTS'/)
      CALL NAMEP(TBL5,K,NW)
      WRITE(K6,13)
   13 FORMAT('0AIR POLLUTANTS'/)
      CALL NAMEP(TBL5,K,NA)
      WRITE(K6,14)
   14 FORMAT('0SOLID POLLUTANTS'/)
      CALL NAMEP(TBL5,K,NS)
      WRITE(K6,15)
   15 FORMAT('0DUMMY POLLUTANTS'/)
      CALL NAMEP(TBL5,K,ND)
      WRITE(K6,17)
   17 FORMAT(//)
      WRITE(K6,18)
   18 FORMAT('0AVAILABLE ACTIVITY TECHNOLOGIES'/)
      WRITE(K6,19)(TBL5(I),I=1,NTM)
   19 FORMAT(14X,7(2X,A8))
      WRITE(K6,17)
C --- READ ACTIVITY DESCRIPTION
   20 IC=0
   21 READ(K10,1 ,END=40)(S(I),I=1,10)
    1 FORMAT(10A8)
      WRITE(K6,2)(S(I),I=1,10)
    2 FORMAT(' *****',10A8,'*****')
      IF(KOMP(S,1,3,END,1).EQ.0) GO TO 28
      IF(IC.EQ.0) CALL ADD(TBL1,S,2,8,MAXA,MXA)
      IF(MXA.LT.0) CALL ERROR(1,1,MAXA,S,2,8)
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```
      CALL FREAD(S,A,11,10,7,NTM,IC)
      IF(IC) 25,21,21
   25 WRITE(20'MXA)(A(I),I=1,NTM)
      GO TO 20
   28 WRITE(K6,29)
   29 FORMAT('OAVAILABLE ON-SITE POLLUTION ABATEMENT TECHNOLOGY MATRICIE
     *S'/)
C --- READ POLLUTION TREATMENT MATRICIES - BY COLUMNS
   30 IC=0
   31 READ(K10,1,END=50)(S(I),I=1,10)
      WRITE(K6,2)(S(I),I=1,10)
      IF(KOMP(S,1,3,END,1).EQ.0) GO TO 48
      IF(IC.EQ.0) CALL ADD(TBL2,S,2,8,MAXT,MXT)
      IF(MXT.LT.0) CALL ERROR(1,2,MAXT,S,2,8)
      CALL FREAD(S,T,11,5,14,NTRM,IC)
      IF(IC) 35,31,31
   35 WRITE(21'MXT)(T(I),I=1,NTRM)
      CALL MXOUT(0,T(NM1),NTA,NTA,0,60,132,1)
      GO TO 30
   40 K10=K5
      GO TO 28
C --- READ GENERAL PARAMETER LIST
   48 WRITE(K6,49)
   49 FORMAT('OGENERAL PARAMETER LIST'/)
   50 IC=0
   51 READ(K5,1,END=140)(S(I),I=1,10)
      WRITE(K6,2)(S(I),I=1,10)
      CALL FREAD(S,G,11,10,7,NG,IC)
      IF(IC) 55,51,51
C --- INITIALIZE AIR AND SOLID POLLUTANT ARRAYS AND RANDOM ACCESS AREAS
   55 CALL ZEROR4(P,NAS,2)
      WRITE(K6,56)
   56 FORMAT('OBACKGROUND AIR POLLUTION LEVELS'/)
      IC=0
   57 READ(K5,1,END=140)(S(I),I=1,10)
      WRITE(K6,2)(S(I),I=1,10)
      CALL FREAD(S,A,11,10,7,NA,IC)
      IF(IC) 58,57,57
C --- INITILIZE ORIGINAL LEVEL OF AIR POLLUTANTS
   58 CALL LOC(1,2,L,NAS,2,0)
        DO 59 I=1,NA
      K=L+I-1
      P(K)=A(I)
   59 CONTINUE
      WRITE(K6,60)
   60 FORMAT('OHALF LIFE OF AIR POLLUTANTS (IN HOURS)'/)
      IC=0
   61 READ(K5,1,END=140)(S(I),I=1,10)
      WRITE(K6,2)(S(I),I=1,10)
      CALL FREAD(S,HL,11,10,7,NA,IC)
      IF(IC) 65,61,61
   65 WRITE(K6,69)
   69 FORMAT('OAIR POLLUTION  DIFFUSION CHARACTERISTICS WITH PROBABILITI
     *ES'/)
      SUM=0
   70 READ(K5,1,END=140)(S(I),I=1,10)
      WRITE(K6,2)(S(I),I=1,10)
      IF(KOMP(S,1,3,END,1).EQ.0) GO TO 75
      CALL AIRCHR(S,PROB,ISTAB,WIND,U,PRES,TA,IER)
      IF(IER.EQ.1) GO TO 70
      WRITE(K30) PROB,ISTAB,WIND,U,PRES,TA
      SUM=SUM+PROB
      GO TO 70
   75 WRITE(K6,76) SUM
   76 FORMAT('OPROBABILITIES SUM TO ',F10.3/)
      IF(SUM.EQ.0.0) SUM=1.
      PSUM=SUM
        DO 80 I=1,NR
        DO 80 J=1,NC
      CALL LOC(I,J,L,NR,NC,0)
      WRITE(24'L) (P(K),K=1,NAS2)
   80 CONTINUE
C --- INITILIZE TOTAL ECONOMIC VARIABLE ARRAY TO ZERO
      CALL ZEROR4(ETOT,NM,3)
C --- READ IN RIVER DESCRIPTIONS
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C --- FIRST INITIALIZE WATER ARRAYS TO ZERO
  100 CALL ZEROR4(W,NW,2)
      CALL ZEROI2(RP,4,NRPTS)
        DO 105 I=1,NRPTS
      WRITE(23'I)(W(J),J=1,NW2)
  105 CONTINUE
      IN=0
      JP=0
      IPR=0
      NPR=0
      LD=1
      IRP=0
      WRITE(K6,119)
  119 FORMAT('ORIVER SPECIFICATIONS'/)
  120 IC=0
  121 READ(K5,1,END=140)(S(I),I=1,10)
      WRITE(K6,2)(S(I),I=1,10)
      IF(IC.EQ.0) NPR=NUMBER(S,8,3)
      CALL FREAD(S,WPRB,11,10,7,NPR,IC)
      IF(IC) 123,121,121
  123 ASUM=0
        DO 124 I=1,NPR
      ASUM=ASUM+WPRB(I)
  124 CONTINUE
      WRITE(K6,76) ASUM
  125 READ(K5,1,END=140)(S(I),I=1,10)
      WRITE(K6,2)(S(I),I=1,10)
      IF(KOMP(S,1,3,END,1).EQ.0) GO TO 150
      IF(KOMP(S,1,1,EXC,1).EQ.0) GO TO 142
      IF((IPR.NE.0).AND.(IPR.NE.NPR)) GO TO 144
  126 IPR=0
      IN=IN+1
      CALL LOC(1,IN,L,4,NRPTS,0)
      CALL SEQ(TBL3,S,2,8,MXR,ID)
      IF(ID.GT.0) GO TO 127
      CALL ADD(TBL3,S,2,8,NRIV,MXR)
      IF(MXR.LT.0) CALL ERROR(1,3,NRIV,S,2,8)
      ID=MXR
  127 IPS=NUMBER(S,11,3)
      IF(IPS.LT.0) GO TO 130
      IF(ID.EQ.LD) GO TO 128
      IRP=0
      IN=IN+1
      CALL LOC(1,IN,L,4,NRPTS,0)
  128 IRP=IRP+1
C --- CHECK FOR CORRECT RIVER SEQUENCE
      IF(IPS.EQ.IRP) GO TO 132
      WRITE(K6,129)
  129 FORMAT('OWARNING, LAST CARD PRINTED HAS AN INVALID SEQUENCE NUMBER
     * OR IS OUT OF SEQUENCE.  IT WILL BE PROCESSED IN THE SEQUENCE READ
     *.'/)
      GO TO 132
  130 ID=-ID
  132 RP(L)=ID
      IROW=NUMBER(S,15,3)
      ICOL=NUMBER(S,19,3)
      IF(ITEST(IROW,ICOL,NR,NC).EQ.1) GO TO 134
      WRITE(K6,133)
  133 FORMAT('ORIVER POINT IS OUT OF REGION.  IT WILL BE PROCESSED AS SP
     *ESIFIED.'/)
  134 RP(L+1)=IROW
      RP(L+2)=ICOL
      IF(IRP.EQ.1) GO TO 136
      IDR=IABS(IROW-LROW)
      IDC=IABS(ICOL-LCOL)
      IF((IDR.EQ.0).AND.(IDC.EQ.0)) GO TO 137
      IF((IDR.GT.1).OR.(IDC.GT.1)) GO TO 137
  136 LD=ID
      LROW=IROW
      LCOL=ICOL
      GO TO 125
  137 WRITE(K6,138)
  138 FORMAT('OWARNING, LAST CARD PRINTED IS NOT ADJACENT TO PRIOR CARD.
     *  RIVER DISTANCE WILL BE STRAIGHT LINE DISTANCE BETWEEN POINTS.'/)
      GO TO 136
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  140 WRITE(K6,141)
  141 FORMAT('ONO MORE CARDS WERE FOUND AFTER LAST CARD PRINTED.  MORE W
     *ERE EXPECTED.'/)
      STOP
  142 IF(IPR.NE.0) GO TO 143
      JP=JP+1
      CALL LOC(1,IN,L,4,NRPTS,0)
      RP(L+3)=JP
  143 IPR=IPR+1
      IF(IPR.GT.NPR) GO TO 148
      CALL WRCH(S,FX,VL,TM,PR,FKO,TO,ICLASS,EXL,EXD)
C --- ADJUST FLOW FOR RUN PERIOD LESS THAN ONE DAY
      FX=FX*(NH/24.)
      IP=(JP-1)*NPR+IPR
      WRITE(25'IP) FX,VL,TM,PR,FKO,TO,ICLASS,EXL,EXD
      GO TO 125
  144 WRITE(K6,145) IPR,NPR
  145 FORMAT('OONLY ',I5,' RIVER CONDITION CARDS WERE READ PROIR TO THE
     *LAST CARD PRINTED.  THERE WERE ',I5,' EXPECTED.')
      N=NPR-IPR
      WRITE(K6,146) N
  146 FORMAT(' THE LAST RIVER CONDITION CARD READ WILL BE DUPLICATED ',
     * I5,' TIMES')
  147 IPR=IPR+1
      IP=JP+IPR-1
      WRITE(25'IP) FL,VL,TM,PR,FKO,TO,ICLASS,EXL,EXD
      IF(IPR.GE.NPR) GO TO 126
      GO TO 147
  148 WRITE(K6,149) NPR
  149 FORMAT('OTHE LAST RIVER CONDITION CARD PRINTED EXCEEDS THE ',I5,
     * ' EXPECTED.  IT WILL BE IGNORED.'/)
      IPR=NPR
      GO TO 125
  150 NARP=IN
C --- CALCULATE RIVER TRANSITIONS
      DO 160 I=1,NARP
      CALL LOC(1,I,L,4,NRPTS,0)
C --- IF RIVER PARAMETERS ARE NOT SPECIFIED FOR A POINT, THEN PRIOR POIN
C --- PARAMETERS WILL BE SPECIFIED.
      IF(RP(L+3).EQ.0) RP(L+3)=RP(L-1)
      IF(RP(L).GE.0) GO TO 160
      RP(L)=-RP(L)
      DO 155 J=1,NARP
      IF(I.EQ.J) GO TO 155
      CALL LOC(1,J,M,4,NRPTS,0)
      IF((RP(L).EQ.RP(M)).AND.(RP(L+1).EQ.RP(M+1)).AND.(RP(L+2).EQ.RP(M+
     * 2))) GO TO 158
  155 CONTINUE
      ID=RP(L)
      WRITE(K6,156) TBL3(ID),RP(L+1),RP(L+2)
  156 FORMAT('OA RIVER WAS TO FLOW INTO RIVER : ',A8,' AT ROW : ',I5,
     * ' AND COLUMN : ',I5,'.  THIS RIVER POSITION WAS NOT FOUND AND THE
     * RIVER WILL BE'/' ASSUMED TO TERMINATE.'/)
      RP(L)=0
      GO TO 159
  158 RP(L)=J
  159 RP(L+1)=0
      RP(L+2)=0
  160 CONTINUE
C --- RUN DIFFUSION FOR ANY EXOGENOUS LOADS AND/OR DEFICITS
      JPP=-1
      CALL ZERO R4(DAV,NRPTS,1)
      DO 175 I=1,NARP
      CALL LOC(1,I,L,4,NRPTS,0)
      JP=RP(L+3)
      IF(JP.EQ.JPP) GO TO 175
      IRIV=RP(L)
      IROW=RP(L+1)
      ICOL=RP(L+2)
      CALL LOADP(IL,0.0,IRIV,IROW,ICOL,RP,C,1,IER)
      DO 172 J=1,NPR
      IP=(JP-1)*NPR+J
      READ(25'IP) FL,VL,TM,PR,FKO,TO,ICLASS,EXL,EXD
      IF((EXL.EQ.0.0).AND.(EXD.EQ.0.0)) GO TO 172
      CALL ZEROR4(DPP,NRPTS,1)
```

```
      CALL FLOW(DPP,EXL,EXD,G(1),J,IL,RP,1)
      CALL SMPY(DPP,WPRB(J),DPP,NRPTS,1,0)
      CALL MADD(DPP,DAV,DAV,NRPTS,1,0,0)
  172 CONTINUE
      JPP=JP
  175 CONTINUE
      CALL WPADD(DAV,RP,TBL3,W,BLANK,1)
C --- INITIALIZE ARRAY E TO ZERO
        DO 195 I=1,NNV
      EL(I)=0.0
        DO 195 J=1,NNV
      CALL LOC(I,J,IJ,NNV,NNV,0)
      E(IJ)=0.0
  195 CONTINUE
C --- READ IN ENDOGENOUS ACTIVITIES
      WRITE(K6,199)
  199 FORMAT('0ENDOGENOUS ACTIVITIES'/)
  200 IC=0
      ISET=0
      IERROR=0
  201 READ(K5,1,END=240)(S(I),I=1,10)
      WRITE(K6,2)(S(I),I=1,10)
      IF(KOMP(S,1,3,END,1).EQ.0) GO TO 250
      CALL        ASREAD(S,TBL1,TBL2,TBL3,TBL4,TBL5,IE,IA,IROW,ICOL,XL,
     * IT,IRV,IRR,IRC,H,VS,D,TS,IPOINT,NEA,PRNT,IEND,IC,C,ISET,IERROR)
      IF(IC) 205,201,201
  205 IF(IERROR.EQ.1) GO TO 200
      CALL EFAC(EA,A,T,MA,MT,IA,IT,1.)
      WRITE(K6,203)
  203 FORMAT('0EFFECTIVE (AFTER ON-SITE TREATMENT) POLLUTANT FACTORS GEN
     *ERATED BY THIS ACTIVITY'/)
      WRITE(K6,204)(TBL5(I),I=NM1,NTM)
  204 FORMAT(' ',9(3X,A8,3X))
  999 FORMAT('0',9(1PE12.6,2X))
      WRITE(6,999)(EA(J),J=1,NT)
      IF(NEA.EQ.0) GO TO 220
        DO 210 I=1,NEA
      CALL LOC(1,I,IJ,2,NNV,0)
      M=IEND(IJ)
      CALL LOC(M,IE,L,NNV,NNV,0)
      K=IEND(IJ+1)
C --- POLLUTANT NAME ERROR CONDITION
      IF(K.EQ.0) GO TO 210
      IF(K.LT.0) GO TO 207
      E(L)=E(L)+EA(K)
      EA(K)=0.0
      GO TO 210
  207 E(L)=E(L)+1.
  210 CONTINUE
      IF(NEA.EQ.0) GO TO 200
  220 WRITE(22'IE) IA,IROW,ICOL,IRV,IRR,IRC,H,VS,D,TS,IPOINT,PRNT,
     * (EA(J),J=1,NT),(MA(J),J=1,NM),(MT(J),J=1,NM)
      WRITE(K6,221)
  221 FORMAT('0EFFECTIVE POLLUTANT FACTORS AFTER SELECTIVE POLLUTANT DIS
     *POSAL THROUGH ENDOGENOUS ACTIVITIES'/)
      WRITE(K6,204)(TBL5(I),I=NM1,NTM)
      WRITE(6,999)(EA(J),J=1,NT)
      WRITE(K6,226)
  226 FORMAT(//)
      GO TO 200
  240 WRITE(K6,241)
  241 FORMAT('0NO MORE CARDS WERE FOUND WHEN READING ENDOGENOUS ACTIVITY
     * DESCRIPTIONS')
      STOP
C --- FORM (I-E) MATRIX
  250   DO 260 I=1,NNV
        DO 260 J=1,NNV
      CALL LOC(I,J,L,NNV,NNV,0)
      IF(I.EQ.J) GO TO 255
      E(L)=-E(L)
      GO TO 260
  255 E(L)=1-E(L)
  260 CONTINUE
      CALL MINV(E,NNV,DET,W1,W2)
C --- READ EXOGENOUS ACTIVITIES
```

```
      WRITE(K6,299)
  299 FORMAT('OEXOGENOUS ACTIVITIES'/)
  300 IC=0
      ISET=0
      IERROR=0
  301 READ(K5,1,END=500)(S(I),I=1,10)
      WRITE(K6,2)(S(I),I=1,10)
      IF(KOMP(S,1,3,END,1).EQ.0) GO TO 500
      CALL      ASREAD(S,TBL1,TBL2,TBL3,TBL4,TBL5,IE,IA,IROW,ICOL,XL,
     * IT,IRV,IRR,IRC,H,VS,D,TS,IPOINT,NEA,PRNT,IEND,IC,1,ISET,IERROR)
      IF(IC) 305,301,301
  305 IF(IERROR.EQ.1) GO TO 300
      CALL EFAC(EA,A,T,MA,MT,IA,IT,XL)
      WRITE(K6,303)
  303 FORMAT('OEFFECTIVE (AFTER ON-SITE TREATMENT) POLLUTANT LEVELS GENE
     *RATED BY THIS ACTIVITY'/)
      WRITE(K6,204)(TBL5(J),J=NM1,NTM)
      WRITE(6,999)(EA(J),J=1,NT)
C --- STORE ECONOMIC INPUT VARIABLES
        DO 310 J=1,NM
      MTOT(J)=MTOT(J)+MA(J)
      CALL LOC(J,2,L,NM,3,0)
      MTOT(L)=MTOT(L)+MT(J)
  310 CONTINUE
C --- MOVE POLLUTANT TO ENDOGINOUS ACTIVITEES
      IF(NEA.EQ.0) GO TO 325
        DO 320 I=1,NEA
      CALL LOC(1,I,IJ,2,NNV,0)
      K=IEND(IJ)
      L=IEND(IJ+1)
C --- POLLUTANT NAME ERROR CONDITION
      IF(L.EQ.0) GO TO 320
      IF(L.LT.0) GO TO 315
      EL(K)=EL(K)+EA(L)
      EA(L)=0.0
      GO TO 320
  315 EL(K)=EL(K)+XL
  320 CONTINUE
      WRITE(K6,321)
  321 FORMAT('OEFFECTIVE POLLUTANT LEVELS AFTER SELECTIVE POLLUTANT DISP
     *OSAL THROUGH ENDOGENOUS ACTIVITIES'/)
      WRITE(K6,204)(TBL5(J),J=NM1,NTM)
      WRITE(K6,999)(EA(J),J=1,NT)
      WRITE(K6,226)
  325 CALL PMOVE(IA,IROW,ICOL,EA,IRV,IRR,IRC,RP,W,P,WPRB,DAV,DPP,
     * TBL1,TBL3,TBL4,TBL5,A1,A2,B,G,HL,H,VS,D,TS,IPOINT,PSUM,PRNT)
      GO TO 300
C --- CALCULATE ENDUGINOUS ACTIVITY FINAL LEVEL
C --- DGMPRD IS A DOUBLE PRECISION (FOR SECOND MATRIX) VERSION OF GMPRD
  500 CALL DGMPRD(E,EL,FL,NNV,NNV,1)
      WRITE(K6,501)
  501 FORMAT('OENDOGENOUS ACTIVITY LEVELS DUE TO EXOGENOUS ACTIVITIES ON
     *LY'/)
      WRITE(K6,204)(TBL4(J),J=1,MXE)
      WRITE(6,999)(EL(J),J=1,MXE)
      WRITE(K6,503)
  503 FORMAT('OFINAL ENDOGENOUS ACTIVITY LEVELS'/)
      WRITE(K6,204)(TBL4(J),J=1,MXE)
      WRITE(6,999)(FL(J),J=1,MXE)
        DO 550 I=1,MXE
      XL=FL(I)
      IF(XL.LE.0.0) GO TO 550
      READ(22'I) IA,IROW,ICOL,IRV,IRR,IRC,H,VS,D,TS,IPOINT,PRNT,
     * (EA(J),J=1,NT),(MA(J),J=1,NM),(MT(J),J=1,NM)
      CALL SMPY(EA,XL,EA,NT,1,0)
      CALL SMPY(MA,XL,MA,NM,1,0)
      CALL SMPY(MT,XL,MT,NM,1,0)
C --- STORE ECONOMIC INPUT VARIABLES FOR ENDOGENOUS ACTIVITIES
        DO 520 J=1,NM
      MTOT(J)=MTOT(J)+MA(J)
      CALL LOC(J,2,L,NM,3,0)
      MTOT(L)=MTOT(L)+MT(J)
  520 CONTINUE
      CALL PMOVE(IA,IROW,ICOL,EA,IRV,IRR,IRC,RP,W,P,WPRB,DAV,DPP,
     * TPL1,TPL3,TPL4,TBL5,A1,A2,B,G,HL,H,VS,C,TS,IPOINT,PSUM,PRNT)
```

```
550 CONTINUE
    RETURN
    END
    SUBROUTINE PRINTP(E,A,T,G,W,P,EA,EL,FL,WPRB,W1,W2,RP,DAV,IEND,MA,
   * MT,MTOT,TBL1,TBL2,TBL3,TBL4,TBL5,A1,A2,B,HL,DPP)
    REAL*8 E(1),DET,S(10),TBL1(1),TBL2(1),TBL3(1),TBL4(1),TBL5(1)
    REAL*4 A(1),T(1),G(1),W(1),P(1),EA(1),EL(1),FL(1),WPRB(1),DAV(1),
   * W1(1),W2(1),MA(1),MT(1),MTOT(1),A1(1),A2(1),B(1),HL(1),DPP(1)
    INTEGER*2 RP(1),IEND(1)
    COMMON NW,NA,NS,ND,NT,NTA,NTA1,NTR,NAS,NR,NC,NPR,NG,NW1,NW2,NAS2,
   * NM,NTM,NTRM,NM1,NRA,NCA,NARP,NH,NOP
    COMMON /MAX/ MAXA,MAXT,NRIV,NRPTS,NNV,MXA,MXT,MXR,MXE,MXN
    COMMON /UNIT/ K5,K6,K10,K30
    WRITE(K6,101)
101 FORMAT('1FINAL REGIONAL POLLUTION LEVELS'//)
      DO 400 K=1,NW
200 JPP=-1
    WRITE(K6,201)
201 FORMAT('ORIVER        ROW COLUMN  DISCHARGE            DISSCLVED OXYGE
   *N       SATURATION              DEFICIT'/
   *        '                           (KG/DAY)                 (MG/L)
   *          (MG/L)              (MG/L)'//)
      DO 300 I=1,NARP
    CALL LOC(1,I,L,4,NRPTS,0)
    IF(RP(L+1).EQ.0) GO TO 300
    IRIV=RP(L)
    JP=RP(L+3)
    IF(JP.EQ.JPP) GO TO 250
    SUM=0.0
      DO 240 J=1,NPR
    IP=(JP-1)*NPR+J
    READ(25'IP) FL,VL,TM,PR
    SUM=SUM+WPRB(J)*CS(TM,PR)
240 CONTINUE
250 READ(23'I)(W(J),J=1,NW2)
    CALL LOC(K,2,M,NW,2,0)
    DOX=SUM-W(M)
    CALL LOC(K,1,MM,NW,2,0)
    WRITE(K6,251) TBL3(IRIV),RP(L+1),RP(L+2),W(MM),DOX,SUM,W(M)
251 FORMAT(' ',A8,2(2X,I3),4(3X,1PE16.5))
300 CONTINUE
400 CONTINUE
    IF(NOP.EQ.1) GO TO 755
700 WRITE(K6,701)
701 FORMAT('0AIR AND SOLID POLLUTANTS'/)
      DO 750 I=1,NR
      DO 750 J=1,NC
    CALL LOC(I,J,L ,NR,NC,0)
    READ(24'L) (P(JJ),JJ=1,NAS2)
    WRITE(K6,25) I,J
 25 FORMAT('0ROW ',I5,'  COLUMN ',I5)
    WRITE(K6,26)
 26 FORMAT('0POLLUTANT NAME       EMITTED (KG)       AMBIENT (G PER CUBI
   *C METER)'/)
      DO 50 II=1,NAS
    K=NM+NW+II
    CALL LOC(II,1,L1,NAS,2,0)
    CALL LOC(II,2,L2,NAS,2,0)
    WRITE(K6,30) TBL5(K),P(L1),P(L2)
 30 FORMAT(' ',A8,2(5X,1PE15.6))
 50 CONTINUE
750 CONTINUE
755 IF(NOP.EQ.2) GO TO 805
      DO 800 K=1,2
    IF(K.EQ.1) WRITE(K6,761)
    IF(K.EQ.2) WRITE(K6,762)
761 FORMAT('0EMITTED AIR AND SOLID POLLUTANTS (KG)'/)
762 FORMAT('0AMBIENT AIR POLLUTANTS (G PER CUBIC METER)'/)
      DO 800 I=1,NAS
    IF((K.EQ.2).AND.(I.GT.NA)) GO TO 800
      DO 790 II=1,NR
      DO 790 JJ=1,NC
    CALL LOC(II,JJ,L,NR,NC,0)
    READ(24'L)(P(J),J=1,NAS2)
    CALL LOC(I,K,LL,NAS,2,0)
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      AI(L)=P(LL)
  790 CONTINUE
      KK=I+NM+NW
      WRITE(K6,795) TBL5(KK)
  795 FORMAT('OPOLLUTANT : ',A8)
      CALL MXOUT(I,AI,NR,NC,0,60,132,1)
  800 CONTINUE
  805 WRITE(K6,890)
  890 FORMAT('OECONOMIC INPUT VARIABLES - FINAL REGIONAL LEVELS'/)
      WRITE(K6,899)(TBL5(I),I=1,NM)
  899 FORMAT(26X,7(3X,A8,3X))
        DO 891 I=1,NM
      CALL LOC(I,1,L1,NM,3,0)
      CALL LOC(I,2,L2,NM,3,0)
      CALL LOC(I,3,L3,NM,3,0)
      MTOT(L3)=MTOT(L1)+MTOT(L2)
  891 CONTINUE
      WRITE(K6,892)(MTOT(I),I=1,NM)
  892 FORMAT('ODUE TO ACTIVITIES',8X,7(1PE12.6,2X)/(26X,7(1PE12.6,2X)))
        DO 893 I=1,NM
      CALL LOC(I,2,L2,NM,3,0)
      MTOT(I)=MTOT(L2)
  893 CONTINUE
      WRITE(K6,894)(MTOT(I),I=1,NM)
  894 FORMAT('ODUE TO ON-SITE TREATMENT ',7(1PE12.6,2X)/(26X,7(1PE12.6,
     * 2X)))
        DO 895 I=1,NM
      CALL LOC(I,3,L3,NM,3,0)
      MTOT(I)=MTOT(L3)
  895 CONTINUE
      WRITE(K6,896)(MTOT(I),I=1,NM)
  896 FORMAT('OTOTAL',20X,7(1PE12.6,2X)/(26X,7(1PE12.6,2X)))
      RETURN
      END
      SUBROUTINE ASREAD(S,TBL1,TBL2,TBL3,TBL4,TBL5,IE,IA,IROW,ICOL,XL,
     * IT,IRV,IRR,IRC,H,VS,D,TS,IPOINT,NEA,PRNT,IEND,IC,IP,ISET,IERROR)
C --- THIS SUBROUTINE READS IN ACTIVITY SPECIFICATION
C ---          IP=0 ENDOGENOUS ACTIVITY
C ---          IP=1 EXOGENOUS ACTIVITY
      REAL*8 S(1),FNUMBR,TBL1(1),TBL2(1),TBL3(1),TBL4(1),TBL5(1),STAR
      COMMON NW,NA,NS,ND,NT,NTA,NTA1,NTR,NAS,NR,NC,NPR,NG,NW1,NW2,NAS2,
     * NM,NTM,NTRM,NM1,NRA,NCA,NARP,NH,NOP
      COMMON /MAX/ MAXA,MAXT,NRIV,NRPTS,NNV,MXA,MXT,MXR,MXE,MXN
      COMMON /UNIT/ K5,K6,K10,K30
      INTEGER*2 IEND(1)
      DATA STAR/'*       '/
      IF(IC.GT.0) GO TO 35
      IF(IP.EQ.1) GO TO 20
      CALL SEQ(TBL1,S,11,8,MXA,IA)
      IF(IA.GT.0) GO TO 10
      IPOS=11
   11 CALL ERROR(2,1,MAXA,S,IPOS,8)
      WRITE(K6,12)
   12 FORMAT('OTHIS ACTIVITY WILL BE IGNORED')
      IERROR=1
      GO TO 30
   10 CALL SEQ(TBL4,S,2,8,MXE,IE)
      IF(IE.GT.0) GO TO 30
      CALL ADD(TBL4,S,2,8,NNV,MXE)
      IF(MXE.LT.0) CALL ERROR(1,4,NNV,S,2,8)
      IE=MXE
      GO TO 30
   20 CALL SEQ(TBL1,S,2,8,MXA,IA)
      IF(IA.GT.0) GO TO 25
      IPOS=2
      GO TO 11
   25 XL=FNUMBR(S,11,8)
   30 IROW=NUMBER(S,20,3)
      ICOL=NUMBER(S,24,3)
      CALL SEQ(TBL2,S,28,8,MXT,IT)
      IF(IT.GE.0) GO TO 32
      CALL ERROR(2,2,MAXT,S,28,8)
      WRITE(K6,31)
   31 FORMAT('OTRANSFORMATION ACTIVITY ATTEMPTED WILL BE IGNORED')
      II=0
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   32 CALL SEQ(TBL3,S,37,8,MXR,IRV)                                      SIMP0821
      IF(IRV.GE.0) GO TO 34                                              SIMP0822
      CALL ERROR(2,3,NRIV,S,37,8)                                        SIMP0823
   33 FORMAT('OIF WATER POLLUTANTS WERE TO BE MOVED INTO THIS RIVER, THESIMP0824
     *Y WILL BE IGNORED.')                                               SIMP0825
      IRV=0                                                              SIMP0826
   34 IRR=NUMBER(S,46,3)                                                 SIMP0827
      IRC=NUMBER(S,50,3)                                                 SIMP0828
      IPOINT=NUMBER(S,54,1)                                              SIMP0829
      NEA=NUMBER(S,65,3)                                                 SIMP0830
C C --- PRINT OPTION                                                      SIMP0831
      CALL MOVE(S,69,1,PRNT,1)                                           SIMP0832
      IF(KOMP(S,56,1,STAR,1).EQ.0) GO TO 150                             SIMP0833
      H=FNUMBR(S,56,8)                                                   SIMP0834
      D=-1.0                                                             SIMP0835
      IF(NEA.EQ.0) GO TO 100                                             SIMP0836
   36 IC=IC+1                                                            SIMP0837
      RETURN                                                             SIMP0838
   35 IF(ISET.EQ.1) GO TO 200                                            SIMP0839
      LNEA=NEA-(IC-1)*6                                                  SIMP0840
      ISET=0                                                             SIMP0841
      IF(LNEA.LE.6) GO TO 45                                             SIMP0842
      ISET=1                                                             SIMP0843
      LNEA=6                                                             SIMP0844
   45 IPOS=-9                                                            SIMP0845
      K=2*(IC-1)*6                                                       SIMP0846
       DO 60 I=1,LNEA                                                    SIMP0847
      K=K+2                                                              SIMP0848
      IPOS=IPOS+10                                                       SIMP0849
      IF(KOMP(S,IPOS,8,STAR,1).EQ.0) GO TO 49                            SIMP0850
      CALL SEQ(TBL5,S,IPOS,8,MXN,ISEQ)                                   SIMP0851
      IEND(K)=ISEQ-NM                                                    SIMP0852
      IF(IEND(K).GT.0) GO TO 46                                          SIMP0853
      CALL ERROR(2,5,NTM,IPOS,8)                                         SIMP0854
      WRITE(K6,44)                                                       SIMP0855
   44 FORMAT('OTHIS EFFECT ON THE ENDOGENOUS ACTIVITY WILL BE IGNORED.')SIMP0856
      IEND(K)=0                                                          SIMP0857
      GO TO 46                                                           SIMP0858
   49 IEND(K)=-1                                                         SIMP0859
   46 K=K-1                                                              SIMP0860
      IPOS=IPOS+10                                                       SIMP0861
      CALL SEQ(TBL4,S,IPOS,8,MXE,ISEQ)                                   SIMP0862
      IF(ISEQ.GT.0) GO TO 48                                             SIMP0863
      IF(ISEQ.LT.0) GO TO 47                                             SIMP0864
      CALL ERROR(2,4,NNV,S,IPOS,8)                                       SIMP0865
   47 CALL ADD(TBL4,S,IPOS,8,NNV,MXE)                                    SIMP0866
      IF(MXE.LT.0) CALL ERROR(1,4,NNV,S,2,8)                             SIMP0867
      ISEQ=MXE                                                           SIMP0868
   48 IEND(K)=ISEQ                                                       SIMP0869
      K=K+1                                                              SIMP0870
   60 CONTINUE                                                           SIMP0871
      IF(ISET.EQ.0) GO TO 100                                            SIMP0872
      IC=IC+1                                                            SIMP0873
      RETURN                                                             SIMP0874
  100 IC=-1                                                              SIMP0875
      RETURN                                                             SIMP0876
  150 ISET=1                                                             SIMP0877
      H=FNUMBR(S,57,7)                                                   SIMP0878
      GO TO 36                                                           SIMP0879
  200 VS=FNUMBR(S,11,10)                                                 SIMP0880
      D=FNUMBR(S,21,10)                                                  SIMP0881
      TS=FNUMBR(S,31,10)                                                 SIMP0882
      ISET=0                                                             SIMP0883
      IF(NEA.EQ.0) GO TO 100                                             SIMP0884
      RETURN                                                             SIMP0885
      END                                                                SIMP0886
      SUBROUTINE PMOVE(IA,IRCW,ICOL,EA,IRV,IRR,IRC,RP,W,P,WPRB,DAV,DPP,  SIMP0887
     * TBL1,TBL3,TBL4,TBL5,A1,A2,B,G,HL,H,VS,D,TS,IPOINT,PSUM,PRNT)     SIMP0888
      REAL*8 TBL1(1),TBL3(1),TBL4(1),TBL5(1)                             SIMP0889
      REAL*4 EA(1),WPRB(1),W(1),P(1),A1(1),A2(1),B(1),G(1),HL(1),DAV(1),SIMP0890
     * DPP(1)                                                            SIMP0891
      INTEGER*2 RP(1)                                                    SIMP0892
      COMMON NW,NA,NS,ND,NT,NTA,NTA1,NTR,NAS,NR,NC,NPR,NG,NW1,NW2,NAS2,  SIMP0893
     * NM,NTM,NTRM,NM1,NRA,NCA,NARP,NH,NCP                               SIMP0894
      COMMON /MAX/ MAXA,MAXT,NRIV,NRPTS,NNV,MXA,MXT,MXR,MXE,MXN          SIMP0895
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      COMMON /UNIT/ K5,K6,K10,K30
      DATA PP /'P'/
      IF(KOMP(PRNT,1,1,PP,1).NE.0) GO TO 300
      WRITE(K6,251) TBL1(IA),IROW,ICOL
  251 FORMAT('0PRINT OF DISPERSED WATER AND AIR POLLUTANTS FOR ACTIVITY
     *',A8,' LOCATED AT ROW ',I3,' AND COLUMN ',I3//)
  300   DO 380 I=1,NW
      IF(EA(I).EQ.0.0) GO TO 380
      CALL WATERI(I,EA(I),IRV,IRR,IRC,PRNT,RP,WPRB,DAV,DPP,W,G,TBL3,IER)
      IF(IER.EQ.0) GO TO 380
  341 WRITE(K6,342) TBL1(IA),IROW,ICOL,TBL3(IRV),IRR,IRC
  342 FORMAT('0INVALID RIVER SPECIFICATION FOR ACTIVITY : ',A8,' LOCATED
     * AT ROW ',I3,' AND COLUMN ',I3,'.  THE RIVER : ',A8,' AT ROW ',
     * I3,' AND'/' COLUMN ',I3,' NOT FOUND.  WATER POLLUTANT OUTPUTS IGN
     *ORED.'//)
      GO TO 400
  380 CONTINUE
C --- CHECK TO SEE IF ANY REMAINING AIR OR SOLID POLLUTANTS
  400 SUM=0
        DO 410 I=1,NAS
      K=I+NW
      SUM=SUM+EA(K)
  410 CONTINUE
      IF(SUM.EQ.0) GO TO 500
      CALL LOC(IROW,ICOL,L,NR,NC,0)
      READ(24'L) (P(J),J=1,NAS2)
        DO 420 J=1,NAS
      K=J+NW
      P(J)=P(J)+EA(K)
  420 CONTINUE
      WRITE(24'L) (P(J),J=1,NAS2)
C --- CALL AIR DIFFUSION FOR THIS ACTIVITY
  500   DO 600 I=1,NA
      K=I+NW
      IF(EA(K).EQ.0.0) GO TO 600
      CALL AIRPRB(A1,A2,B,G(1),EA(K),IROW,ICOL,G(2),HL(I),H,VS,D,TS,
     * IPOINT,PSUM)
      IF(KOMP(PRNT,1,1,PP,1).NE.0) GO TO 540
      KK=I+NM+NW
      WRITE(K6,506) TBL5(KK)
  506 FORMAT('0POLLUTANT : ',A8)
      CALL MXOUT(I,A1,NR,NC,0,60,132,1)
  540   DO 550 II=1,NR
        DO 550 JJ=1,NC
      CALL LOC(II,JJ,L,NR,NC,0)
      READ(24'L)(P(J),J=1,NAS2)
      CALL LOC(I,2,LL,NAS,2,0)
      P(LL)=P(LL)+A1(L)
      WRITE(24'L)(P(J),J=1,NAS2)
  550 CONTINUE
  600 CONTINUE
      END
      SUBROUTINE EFAC(EA,A,T,MA,MT,IA,IT,XL)
C --- SUBROUTINE TO CALCULATE EFFECTIVE ACTIVITY BY COMBINING PRIMARY AC
C --- AND TRATMENT MATRIX WITH LEVEL OF OPERATION
      COMMON NW,NA,NS,ND,NT,NTA,NTA1,NTR,NAS,NR,NC,NRP,NG,NW1,NW2,NAS2,
     * NM,NTM,NTRM,NM1,NRA,NCA,NARP,NH
      REAL*4 A(1),T(1),EA(1),MA(1),MT(1)
      IF(IT.EQ.0) GO TO 10
      READ(20'IA)(MA(I),I=1,NM),(A(I),I=1,NT)
      READ(21'IT)(MT(I),I=1,NM),(T(I),I=1,NTR)
      CALL GMPRD(T,A,EA,NTA,NTA,1)
      IF(ND.EQ.0) GO TO 20
        DO 5 I=NTA1,NT
      EA(I)=A(I)
    5 CONTINUE
      GO TO 20
   10 READ(20'IA)(MA(I),I=1,NM),(EA(I),I=1,NT)
        DO 15 I=1,NM
      MT(I)=0
   15 CONTINUE
   20 CALL SMPY(EA,XL,EA,NT,1,0)
      CALL SMPY(MA,XL,MA,NM,1,0)
      CALL SMPY(MT,XL,MT,NM,1,0)
      RETURN
```

```
      END
      SUBROUTINE WATER1(IPOL,XLOAD,IRIV,IROW,ICOL,PRNT,RP,WPRB,
     * DAV,DPP,W,G,TBL3,IER)
C --- XLOAD IS BOD (KG PER DAY)
      REAL*8 TBL3(1)
      REAL*4 WPRB(1),DAV(1),DPP(1),W(1),G(1)
      INTEGER*2 RP(1)
      COMMON NW,NA,NS,ND,NT,NTA,NTA1,NTR,NAS,NR,NC,NPR,NG,NW1,NW2,NAS2,
     * NM,NTM,NTRM,NM1,NRA,NCA,NARP,NH,NCP
      COMMON /MAX/ MAXA,MAXT,NRIV,NRPTS,NNV,MXA,MXT,MXR,MXE,MXN
      COMMON /UNIT/ K5,K6,K10,K30
      CALL LOADP(IL,XLOAD,IRIV,IROW,ICOL,RP,IPOL,0,IER)
      IF(IER.EQ.1) GO TO 200
      CALL ZEROR4(DAV,NRPTS,1)
        DO 100 I=1,NPR
      CALL ZEROR4(DPP,NRPTS,1)
      CALL FLOW(DPP,XLOAD,0.0   ,G(1),I,IL,RP,0)
   90 CALL SMPY(DPP,WPRB(I),DPP,NRPTS,1,0)
      CALL MADD(DPP,DAV,DAV,NRPTS,1,0,0)
  100 CONTINUE
      CALL WPADD(DAV,RP,TBL3,W,PRNT,IPOL)
  200 RETURN
      END
      REAL FUNCTION DEOXK(FKO,TO,T)
      IF(FKO.EQ.0) FKO=.39
      IF(TO.EQ.0) TO=20.
      IF((T.GE.0).AND.(T.LT.7.5)) THETAK=1.15
      IF((T.GE.7.5).AND.(T.LT.15.0)) THETAK=1.11
      IF((T.GE.15.0).AND.(T.LE.30.0)) THETAK=1.05
      IF(T.GT.30.0) THETAK=.97
      DEOXK=FKO*THETAK**(T-TO)
      RETURN
      END
      REAL FUNCTION REOXR(RO,TO,T,ICLASS)
      IF(TO.EQ.0) TO=20.
      IF(ICLASS.EQ.1) RO=.5
      IF(ICLASS.EQ.2) RO=.7
      IF(ICLASS.EQ.3) RO=1.0
      IF(ICLASS.EQ.4) RO=1.6
      REOXR=RO*EXP(.024*(T-TO))
      RETURN
      END
      REAL FUNCTION CS(T,P)
      CS=(P/760.)*(14.652-4.1022E-1*T+7.9910E-3*T**2-7.7774E-5*T**3)
      RETURN
      END
      SUBROUTINE STPH(DOD,XLN,XL,DOX,FK,FR,DIST,V)
C --- STREETER-PHELPS MODEL
C --- DOD IS DISSOLVED OXYGEN DIFICIT AT NEXT POINT
C --- XLN IS EFFECTIVE RESIDUAL LOAD AT NEXT POINT (MG/L)
C --- XL IS INITIAL LOAD
C --- DOX IS INITIAL DEFICIT
C --- FK IS DIOXYGENATION CONSTANT
C --- FR IS REOXYGENATION CONSTANT
C --- DIST IS DISTANCE BETWEEN POINTS
C --- V IS RIVER VELOCITY
C --- T IS TIME
      T=DIST/V
      DOD=((FK*XL)/(FR-FK))*(EXP(-FK*T)-EXP(-FR*T))+DOX*EXP(-FR*T)
      XLN=XL*EXP(-FK*T)
      RETURN
      END
      SUBROUTINE FLOW(DPP,XLOAD,EXOGD,SIDE,IP,IL,RP,ITYPE)
C --- ITYPE=1 -- EXOGENOUS LOAD
C --- ITYPE=0 -- BOD CONTRIBUTION (KG PER DAY)
      REAL*4 DPP(1)
      INTEGER*2 RP(1)
      COMMON NW,NA,NS,ND,NT,NTA,NTA1,NTR,NAS,NR,NC,NPR,NG,NW1,NW2,NAS2,
     * NM,NTM,NTRM,NM1,NRA,NCA,NARP,NH,NCP
      COMMON /MAX/ MAXA,MAXT,NRIV,NRPTS,NNV,MXA,MXT,MXR,MXE,MXN
C --- SET I TO LOAD POINT
      I=IL
      CALL LOC(1,I,L,4,NRPTS,0)
      ISET=0
   15 XL=XLOAD
```

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      DOX=EXOGD
      LROW=RP(L+1)
      LCOL=RP(L+2)
      IRAP=-1
C --- CALCULATE RANDOM ACCESS SEQ FOR RIVER CHARACTERISTICS
   16 IRA=(RP(L+3)-1)*NPR+IP
C --- IF SAME AS PREVIOUS RIVER STRETCH, DO NOT REREAD SAME NUMBERS
      IF(IRA.EQ.IRAP) GO TO 20
      READ(25'IRA) FL,VL,TM,PR,FKO,TO,ICLASS
      FK=DECXK(FKO,TO,TM)
      FR=REOXR(RO,TO,TM,ICLASS)
      IF(ISET.EQ.0) GO TO 21
   20 ADJ=1.
      IF(FL.GT.PFL) ADJ=PFL/FL
      XL=XLN*ADJ
      DCX=DOD*ADJ
C --- STORE CONTRIBUTION TO DISSOLVED OXYGEN DEFICIT AFTER FLOW ADJUSTME
   19 DPP(I)=DOX
      GO TO 22
   21 ISET=1
      IF(ITYPE.EQ.1) GO TO 19
      XL=XL/FL
C --- FIND NEXT POINT
   22 I=I+1
      CALL LOC(1,I,L,4,NRPTS,0)
C --- A POSITIVE RIVER ROW INDICATES SAME RIVER
      IF(RP(L+1).GT.0) GO TO 30
C --- A ZERO RIVER SEC INDICATES THAT RIVER DOES NOT EMPTY INTO ANY OTHE
      IF(RP(L).EQ.0) RETURN
C --- POLLUTANTS NOW FLOW INTO A NEW RIVER
      I=RP(L)
      CALL LOC(1,I,L,4,NRPTS,0)
   30 NROW=RP(L+1)
      NCOL=RP(L+2)
      X=(IABS(LROW-NROW))*SIDE
      Y=(IABS(LCOL-NCOL))*SIDE
      DIST=SQRT(X**2+Y**2)
C --- CHECK TO AVOID OVERFLOW
      IF(DOX.LE.1.0E-20) DCX=0.0
      IF(XL.LE.1.0E-20) XL=0.0
      IF((DOX.EQ.0.0).AND.(XL.EQ.0.0)) RETURN
      CALL STPH(DOD,XLN,XL,DCX,FK,FR,DIST,VL)
      PFL=FL
      LROW=NROW
      LCOL=NCOL
      GO TO 16
      END
      SUBROUTINE LOADP(IL,BOD,IRIV,IROW,ICOL,RP,IPOL,ITYPE,IER)
      REAL*4 W(1)
      INTEGER*2 RP(2)
      COMMON NW,NA,NS,ND,NT,NTA,NTA1,NTR,NAS,NR,NC,NPR,NG,NW1,NW2,NAS2,
     * NM,NTM,NTRM,NM1,NRA,NCA,NARP,NF,NCP
      COMMON /MAX/ MAXA,MAXT,NRIV,NRPTS,NNV,MXA,MXT,MXR,MXE,MXN
      IER=0
C --- FIND LOAD POINT
        DO 10 I=1,NRPTS
      CALL LOC(1,I,L,4,NRPTS,0)
      IF((IRIV.EQ.RP(L)).AND.(IROW.EQ.RP(L+1)).AND.(ICOL.EQ.RP(L+2)))
     * GO TO 15
   10 CONTINUE
      IER=1
      RETURN
   15 IL=I
      IF(ITYPE.EQ.1) GO TO 100
C --- STORE BOD CONTRIBUTION (KG)
      READ(23'IL)(W(J),J=1,NW2)
      CALL LOC(IPOL,1,L,NRPTS,2,0)
      W(L)=W(L)+BOD
      WRITE(23'IL)(W(J),J=1,NW2)
  100 RETURN
      END
      SUBROUTINE WPACL(DAV,RP,TBL3,W,PRNT,IPCL)
      REAL*8 TBL3(1)
      REAL*4 DAV(1),W(1)
      INTEGER*2 RP(1)
```

```
      COMMON NW,NA,NS,ND,NT,NTA,NTA1,NTR,NAS,NR,NC,NPR,NG,NW1,NW2,NAS2,
     * NM,NTM,NTRM,NM1,NRA,NCA,NARP,NH,NOP
      COMMON /MAX/ MAXA,MAXT,NRIV,NRPTS,NNV,MXA,MXT,MXR,MXE,MXN
      COMMON /UNIT/ K5,K6,K10,K30
      DATA PP/'P'/
      IF(KOMP(PRNT,1,1,PP,1).NE.0) GO TO 102
      WRITE(K6,101)
  101 FORMAT('ORIVER     ROW COLUMN  CONTRIBUTION TO DISSOLVED OXYGEN DE
     *FICIT'/)
  102  DO 150 I=1,NARP
      IF(DAV(I).EQ.0.0) GO TO 150
      CALL LOC(1,I,L,4,NRPTS,0)
      IF(KOMP(PRNT,1,1,PP,1).NE.0) GO TO 105
      K=RP(L)
      WRITE(K6,103) TBL3(K),RP(L+1),RP(L+2),DAV(I)
  103 FORMAT(' ',A8,2(2X,I3),5X,1PE15.6)
  105 READ(23'I)(W(J),J=1,NW2)
      CALL LOC(IPOL,2,L,NW,2,0)
      W(L)=W(L)+DAV(I)
      WRITE(23'I)(W(J),J=1,NW2)
  150 CONTINUE
      RETURN
      END
      SUBROUTINE WRCH(S,FL,VL,TM,PR,FKO,TO,ICLASS,EXL,EXD)
      REAL*8 S(1)
C C --- FL IS FLOW(LITERS PER DAY)
      FL=FNUMBR(S,11,10)
C C --- VL IS VELOCITY (KM PER DAY) - CONVERT TO METERS PER DAY
      VL=FNUMBR(S,21,10)
      VL=VL*1000.
C C --- TM IS WATER TEMPERATUE (DEGREES CENT)
      TM=FNUMBR(S,31,10)
C C --- PR IS BARAMETRIC PRESSURE (MM OF MERCURY)
      PR=FNUMBR(S,41,10)
      FKO=FNUMBR(S,51,5)
      TO=FNUMBR(S,56,5)
C C --- ICLASS IS RIVER TYPE (1 IS SLOW MOVING RIVER ; 4 IS RAPIDS)
      ICLASS=NUMBER(S,61,1)
C C --- EXL IS EXOGENOUS LOAD AT A POINT
      EXL=FNUMBR(S,62,9)
C C --- EXD IS EXOGENOUS CONRIBUTION TO DEFICIT
      EXD=FNUMBR(S,71,10)
      RETURN
      END
      SUBROUTINE AIRPRB (A1,A2,B,S,C,IROW,ICOL,LO,T,H,VS,D,TS,IPOINT,
     * SUM)
      REAL*4 A1(1),A2(1),B(1)
      COMMON NW,NA,NS,ND,NT,NTA,NTA1,NTR,NAS,NR,NC,NPR,NG,NW1,NW2,NAS2,
     * NM,NTM,NTRM,NM1,NRA,NCA,NARP,NH,NOP
      COMMON /UNIT/ K5,K6,K10,K30
      CALL ZERO R4(A1,NR,NC)
      IROW2=IROW*2
      ICOL2=ICOL*2
C C --- Q IS ENTERED AS KG - IT MUST BE CONVERTED TO MG/SEC BASED ON # HRS
      Q=(C*500.)/(9.*NH)
      REWIND K30
   10 CALL ZEROR4(B,NRA,NCA)
      READ(K30,END=50) PROB,ISTAB,WIND,U,P,TA
      CALL AIRDIF(B,NRA,NCA,S,C,IROW2,ICOL2,WIND,IPOINT,ISTAB,U,P,TA,
     * LO,T,H,VS,D,TS,IER)
      IF(IER.EQ.1) GO TO 10
      PROB=PROB/SUM
      CALL AVG(A2,B,NR,NC,NRA,NCA)
      CALL SMPY(A2,PROB,A2,NR,NC,0)
      CALL MADD(A2,A1,A1,NR,NC,0,0)
      GO TO 10
   50 RETURN
      END
      SUBROUTINE AIRDIF(B,NRA,NCA,S,C,IROW2,ICOL2,WIND,IPOINT,ISTAB,U,
     * P,TA,LO,T,H,VS,D,TS,IER)
      REAL*4 B(1),WD(8)
      INTEGER*4 INDEX(32)
      COMMON /UNIT/ K5,K6,K10,K30
      DATA WD/' N',' S',' E',' W','NE','NW','SE','SW'/
      DATA INDEX/1,0,0,1,-1,0,0,1,0,-1,1,0,0,1,1,0,1,-1,1,1,1,1,-1,1,-1,
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     * -1,-1,1,-1,1,1,1/
    1 HE=ESH(H,ISTAB,VS,D,U,P,TS,TA)
      FL=DML(LO,ISTAB)
      CALL SIG(SIGY,SIGZ,S,XL,ISTAB,IPOINT,FL,1)
      IER=0
        DO 5 I=1,8
      IF(WIND.EQ.WD(I)) GO TO 9
    5 CONTINUE
      IER=1
      RETURN
    9 CALL LOC(1,I,L,4,8,0)
      IX=INDEX(L)
      JX=INDEX(L+1)
      IY=INDEX(L+2)
      JY=INDEX(L+3)
      DIST=S/2
      IF(I.GT.4) DIST=S/SQRT(2.)
      I=0
   10 I=I+1
      IR=IROW2+I*IX
      IC=ICOL2+I*JX
      IF(ITEST(IR,IC,NRA,NCA)) 200,15,15
   15 X=DIST*I
      CALL SIG(SIGY,SIGZ,S,X,ISTAB,IPOINT,FL,0)
      CALL CALT(ICAL,X,XL,THETA)
      ISET=0
      JSET=0
C --- FOR THE WIND DIRECTIONS NE,NW,SE,AND SW, THE FOLLOWING ALGORTHM DO
C --- NOT CALCULATE VALUES FOR ALL THE B VALUES.  IT CALCULATES ONLY
C --- THOSE SUBSEQUENTLY USED IN THE SUBROUTINE AVG.
      J=-1
   20 J=J+1
      IF(J.GT.I) GO TO 10
      IF((ISET.EQ.1).AND.(JSET.EQ.1)) GO TO 10
      Y=DIST*J
      GO TO (30,40,50),ICAL
   30 APD=CHI1(X,Y,Q,SIGY,SIGZ,U,HE,T)
      GO TO 60
   40 APD=CHI2(X,Y,Q,SIGY,SIGZ,U,FL,T)
      GO TO 60
   50 APD=THETA*CHI1(X,Y,Q,SIGY,SIGZ,U,HE,T)+(1-THETA)*CHI2(X,Y,Q,SIGY,
     * SIGZ,U,FL,T)
   60 IR1=IR+J*IY
      IC1=IC+J*JY
      IF(ITEST(IR1,IC1,NRA,NCA)) 90,70,70
   70 CALL LOC(IR1,IC1,L,NRA,NCA,0)
      B(L)=APD
   75 IR1=IR-J*IY
      IC1=IC-J*JY
      IF(ITEST(IR1,IC1,NRA,NCA)) 100,80,80
   80 CALL LOC(IR1,IC1,L,NRA,NCA,0)
      B(L)=APD
      GO TO 20
   90 ISET=1
      GO TO 75
  100 JSET=1
      GO TO 20
  200 RETURN
      END
      SUBROUTINE AIRCHR(S,PROB,ISTAB,WIND,U,PRES,TA,IER)
      REAL*8 S(1),FNUMBR
      REAL*4 WD(8)
      COMMON /UNIT/ K5,K6,K10,K30
      DATA WD/' N',' S',' E',' W','NE','NW','SE','SW'/
      DATA BLANK/'    '/
      IER=0
      PROB=FNUMBR(S,11,10)
      ISTAB=NUMBER(S,25,1)
      CALL MOVE(BLANK,1,4,WIND,1)
      CALL MOVE(S,29,2,WIND,1)
      U=FNUMBR(S,31,10)
      PRES=FNUMBR(S,41,10)
      TA=FNUMBR(S,51,10)
        DO 5 I=1,8
      IF(WIND.EQ.WD(I)) GO TO 9
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    5 CONTINUE
      WRITE(K6,6) WIND
    6 FORMAT('0',A2,' IS AN INVALID WIND DIRECTION.')
    7 WRITE(K6,8)
    8 FORMAT(' AIR DIFFUSION FOR THIS PROBABILITY NOT CALCULATED.')
      IER=1
    9 IF(ITEST(ISTAB,ISTAB,6,6)) 110,200,200
  110 CALL MOVE(S,25,1,X,1)
      WRITE(K6,111) X
  111 FORMAT('0STABILITY CLASS ',A1 ,' NOT DEFINED.')
      WRITE(K6,8)
      IER=1
  200 RETURN
      END
      REAL FUNCTION   ESH(H,ISTAB,VS,D,U,P,TS,TA)
      IF(D.EQ.-1.) GO TO 10
      ESH=H+(1.4-0.1*ISTAB)*(((VS*D)/U)*(1.5+2.68E-3*P*((TS-TA)/TS)*D))
      RETURN
   10 ESH=H
      RETURN
      END
      SUBROUTINE SIG(SIGY,SIGZ,S,X,ISTAB,IPOINT,FL,ICALL)
C --- ICALL=0   CALCULATES STANDARD DEVEATIONS BASED ON X
C --- ICALL=1   CALCULATES XL, CRITICAL MIXING LAYER DEPTH - PLACES RESU
      REAL*4 STAB(30)
C ---                ALPHA      BETA       A          B          C
      DATA STAB/     .450,      .889,      .001,      1.890,     9.6,
     *               .285,      .912,      .048,      1.110,     2.0,
     *               .177,      .924,      .119,      .915,      0.0,
     *               .111,      .928,      2.610,     .450,      -25.5,
     *               .111,      .928,      2.610,     .450,      -25.5,
     *               .111,      .928,      2.610,     .450,      -25.5/
      L=(ISTAB-1)*5+1
      IF(ICALL.EQ.1) GO TO 10
      IF(IPOINT.EQ.1) GO TO 5
      SIGY=STAB(L)*X**STAB(L+1)
      GO TO 8
    5 SIGY=STAB(L)*(X+((S/(4.3*STAB(L)))**(1./STAB(L+1)))**STAB(L+1))
    8 SIGZ=STAB(L+2)*X**STAB(L+3)+STAB(L+4)
      RETURN
   10 X=((.47*FL-STAB(L+4))/STAB(L+2))**(1./STAB(L+3))
      RETURN
      END
      REAL FUNCTION CHI1(X,Y,Q,SIGY,SIGZ,U,HE,T)
C --- X=DISTANCE IN X(WIND) DIRECTION
C --- Y=DISTANCE IN PERPENDICULAR WIND DIRECTION
C --- Q=SOURCE STRENGTH (G PER SEC)
C --- U=MEAN WIND SPEED
C --- HE=EFFECTIVE HEIGHT OF RELEASE
C --- T=HALF LIFE OF THE POLLUTANT IN HOURS
      CHI1=(Q/(3.14159*SIGY*SIGZ*U))*EXP(-.5*(Y/SIGY)**2
     *     -.5*(HE/SIGZ)**2)*EXP ((-.693*(X/U))/(3600*T))
      RETURN
      END
      REAL FUNCTION CHI2(X,Y,Q,SIGY,SIGZ,U,FL,T)
C --- X=DISTANCE IN X(WIND) DIRECTION
C --- Y=DISTANCE IN PERPENDICULAR WIND DIRECTION
C --- Q=SOURCE STRENGTH (G PER SEC)
C --- U=MEAN WIND SPEED
C --- FL=MIXLING LAYER DEPTH
C --- T=HALF LIFE OF THE POLLUTANT IN HOURS
      CHI2=(Q/(SQRT(2.*3.14159)*SIGY*FL*U))*
     *     EXP(-.5*(Y/SIGY)**2)*EXP((-.693*(X/U))/(3600*T))
      RETURN
      END
      REAL FUNCTION DML(LO,ISTAB)
      IF(ISTAB.LT.2) GO TO 20
      IF(ISTAB.GT.4) GO TO 30
      DML=LO
      RETURN
   20 DML=1.5*LO
      RETURN
   30 DML=100
      RETURN
      END
```

```
      SUBROUTINE CALT(ICAL,XDIST,XL,THETA)
      IF(XDIST.LE.XL) GO TO 10
      XL2=2*XL
      IF(XDIST.GE.XL2) GO TO 20
      ICAL=3
      THETA=(XDIST-XL2)/(XL-XL2)
      RETURN
   10 ICAL=1
      RETURN
   20 ICAL=2
      RETURN
      END
      INTEGER FUNCTION ITEST(IR,IC,NRA,NCA)
      ITEST=1
      IF((IR.LT.1).OR.(IR.GT.NRA)) GO TO 10
      IF((IC.LT.1).OR.(IC.GT.NCA)) GO TO 10
      RETURN
   10 ITEST=-1
      RETURN
      END
      SUBROUTINE AVG(R,B,NR,NC,NRA,NCA)
      REAL*4 R(1),B(1)
        DO 50 I=1,NR
        DO 50 J=1,NC
      CALL LOC(I,J,L,NR,NC,0)
      CALL LOC(2*I-1,2*J-1,L1,NRA,NCA,0)
      CALL LOC(2*I-1,2*J+1,L2,NRA,NCA,0)
      CALL LOC(2*I,2*J,L3,NRA,NCA,0)
      R(L)=B(L1)+B(L2)+B(L3)+B(L1+2)+B(L2+2)
      R(L)=R(L)/5.
   50 CONTINUE
      RETURN
      END
      SUBROUTINE SEQ(TABLE,S,IPOS,ILNG,N,ISEQ)
      REAL*8 TABLE(1),S(1),BLANK
      DATA BLANK/'        '/
      IF(KOMP(S,IPOS,ILNG,BLANK,1).EQ.0) GO TO 15
      IF(N.LE.0) GO TO 12
        DO 10 I=1,N
      IPS=(I-1)*ILNG+1
      IF(KOMP(S,IPOS,ILNG,TABLE,IPS).EQ.0) GO TO 20
   10 CONTINUE
   12 ISEQ=-1
      RETURN
   15 ISEQ=0
      RETURN
   20 ISEQ=I
      RETURN
      END
      SUBROUTINE ADD(TABLE,S,IPOS,ILNG,MAX,N)
      REAL*8 TABLE(1),S(1)
      N=N+1
      IF(N.GT.MAX) GO TO 20
      IPS=(N-1)*ILNG+1
      CALL MOVE(S,IPOS,ILNG,TABLE,IPS)
      RETURN
   20 N=-1
      RETURN
      END
      SUBROUTINE ZEROR4(S,NR,NC)
      REAL*4 S(1)
        DO 20 I=1,NR
        DO 20 J=1,NC
      CALL LOC(I,J,IJ,NR,NC,0)
      S(IJ)=0.0
   20 CONTINUE
      RETURN
      END
      SUBROUTINE ZEROI2(S,NR,NC)
      INTEGER*2 S(1)
        DO 20 I=1,NR
        DO 20 J=1,NC
      CALL LOC(I,J,IJ,NR,NC,0)
      S(IJ)=0
   20 CONTINUE
```

```
      RETURN
      END
      SUBROUTINE NAMEP(TBL,K,N)
      REAL*8 TBL(1)
      COMMON /UNIT/ K5,K6,K10
      IF(N.EQ.0) GO TO 20
        DO 10 I=1,N
      K=K+1
      WRITE(K6,6) TBL(K)
    6 FORMAT(5X,A8)
   10 CONTINUE
   20 RETURN
      END
      SUBROUTINE ERROR(ITYPE,ITBLE,MAX,S,IPOS,ILNG)
C --- ITYPE
C ---      1 = ADD - EXCEEDS MAXIMUM ALLOWED
C ---      2 = SEQ - NOT FOUND
C --- ITBLE
C ---      1 = ACTIVITY
C ---      2 = TRANSFORATION ACTIVITY
C ---      3 = RIVER
C ---      4 = ENDOGENOUS ACTIVITY
C ---      5 = POLLUTANT NAMES
      REAL*8 S(1),NAME,TYPE(5)
      COMMON /UNIT/ K5,K6,K10
      DATA NAME/'        '/
      DATA TYPE/'ACTIVITY','TRMATRIX','RIVER','ENDOG-AC','POLLUTNT'/
      CALL MOVE(S,IPOS,ILNG,NAME,1)
      GO TO(10,50),ITYPE
   10 WRITE(K6,11) NAME,TYPE(ITBLE),MAX
   11 FORMAT('0WHILE READING ',A8,' A ',A8,' YOU HAVE EXCEEDED THE MAXIM
     *UM (',I5,') SET FOR THE PROGRAM - CHECK YOUR SET UP THEN HAVE MAXI
     *MUM'/' INCREASED IN PROGRAM.  THIS RUN IS NOW TERMINATED.')
      STOP
   50 WRITE(K6,51) NAME,TYPE(ITBLE)
   51 FORMAT('0',A8,' A ',A8,', NOT PREVIOUSLY DEFINED AS REQUIRED.')
      RETURN
      END
      SUBROUTINE MATPD(E,NR,NC,MAXR,MAXC)
      REAL*8 E(1)
      COMMON /UNIT/ K5,K6,K10,K30
        DO 10 J=1,NC
      CALL LOC(1,J,IJ,MAXR,MAXC,0)
      IJE=IJ+NR-1
      WRITE(K6,1)(E(I),I=IJ,IJE)
    1 FORMAT('0',10F10.3)
   10 CONTINUE
      RETURN
      END
      SUBROUTINE FREAD(S,T,IS,IL,N,NT,IC)
C --- S IS CHARACTER STRING OF LENGTH 80
C --- T IS RESULTANT VECTOR OF FLOATING POINT NUMBERS
C --- IS IS STARTING POSITION OF FIRST NUMBER
C --- IL IS LENGTH OF EACH NUMBER
C --- N IS NUMBER OF NUMBERS TO READ PER CARD
C --- NT IS TOTAL NUMBER OF NUMBERS TO READ INTO THE VECTOR
C --- IC IS COUNTER FOR NUMBER OF CARDS READ - THIS MUST BE SET TO ZERO
C --- FIRST READ.  THE PROGRAM WILL SET IC TO -1 WHEN ALL IS READ INTO T
C --- VECTOR
      REAL*8 S(1),FNUMBR
      REAL*4 T(1)
        DO 50 I=1,N
      K=N*IC+I
      IPOS=(I-1)*IL+IS
      T(K)=FNUMBR(S,IPOS,IL)
      IF(K.GE.NT) GO TO 60
   50 CONTINUE
      IC=IC+1
      RETURN
   60 IC=-1
      RETURN
      END
      REAL FUNCTION FNUMBR*8(S,IPOS,ILNG)
      REAL*8 S(1),F,FR
      DATA ALPHA/'.- '/
```

```
      IPOS1=IPOS+ILNG-1
      ISET=0
        DO 20 I=IPOS,IPOS1
      IF(KOMP(S,I,1,ALPHA,2).EQ.0) GO TO 15
      IF(KOMP(S,I,1,ALPHA,1).EQ.0) GO TO 30
      GO TO 20
   15 ISET=1
      CALL MOVE(ALPHA,3,1,S,I)
   20 CONTINUE
      ID=NUMBER(S,IPOS,ILNG)
      FNUMBR=ID
      GO TO 50
   30 IPOS2=I+1
      ILNG1=I-IPOS
      ILNG2=ILNG-ILNG1-1
      IF(ILNG1.LE.0) GO TO 60
      ID=NUMBER(S,IPOS,ILNG1)
      FNUMBR=ID
      F=FNUMBR
   40 IF(ILNG2.LE.0) GO TO 50
      ID=NUMBER(S,IPOS2,ILNG2)
      FR=ID
      FR=FR/10**ILNG2
      IF(ISET.EQ.1) FR=-FR
      FNUMBR=F+FR
   50 IF(ISET.EQ.1) FNUMBR=-FNUMBR
      RETURN
   60 F=0.0
      GO TO 40
      END
C
C     ...............................................................
C
C        SUBROUTINE LOC
C
C        PURPOSE
C           COMPUTE A VECTOR SUBSCRIPT FOR AN ELEMENT IN A MATRIX OF
C           SPECIFIED STORAGE MODE
C
C        USAGE
C           CALL LOC (I,J,IR,N,M,MS)
C
C        DESCRIPTION OF PARAMETERS
C           I    - ROW NUMBER OF ELEMENT
C           J    - COLUMN NUMBER  OF ELEMENT
C           IR   - RESULTANT VECTOR SUBSCRIPT
C           N    - NUMBER OF ROWS IN MATRIX
C           M    - NUMBER OF COLUMNS IN MATRIX
C           MS   - ONE DIGIT NUMBER FOR STORAGE MODE OF MATRIX
C                   0 - GENERAL
C                   1 - SYMMETRIC
C                   2 - DIAGONAL
C
C        REMARKS
C           NONE
C
C        SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED
C           NONE
C
C        METHOD
C           MS=0   SUBSCRIPT IS COMPUTED FOR A MATRIX WITH N*M ELEMENTS
C                  IN STORAGE (GENERAL MATRIX)
C           MS=1   SUBSCRIPT IS COMPUTED FOR A MATRIX WITH N*(N+1)/2 IN
C                  STORAGE (UPPER TRIANGLE OF SYMMETRIC MATRIX). IF
C                  ELEMENT IS IN LOWER TRIANGULAR PORTION, SUBSCRIPT IS
C                  CORRESPONDING ELEMENT IN UPPER TRIANGLE.
C           MS=2   SUBSCRIPT IS COMPUTED FOR A MATRIX WITH N ELEMENTS
C                  IN STORAGE (DIAGONAL ELEMENTS OF DIAGONAL MATRIX).
C                  IF ELEMENT IS NOT ON DIAGONAL (AND THEREFORE NOT IN
C                  STORAGE), IR IS SET TO ZERO.
C
C     ...............................................................
C
      SUBROUTINE LOC(I,J,IR,N,M,MS)
C
```

```
      IX=I
      JX=J
      IF(MS-1) 10,20,30
   10 IRX=N*(JX-1)+IX
      GO TO 36
   20 IF(IX-JX) 22,24,24
   22 IRX=IX+(JX*JX-JX)/2
      GO TO 36
   24 IRX=JX+(IX*IX-IX)/2
      GO TO 36
   30 IRX=0
      IF(IX-JX) 36,32,36
   32 IRX=IX
   36 IR=IRX
      RETURN
      END
C
C     ..................................................................
C
C        SUBROUTINE DGMPRD
C
C        PURPOSE
C           MULTIPLY TWO GENERAL MATRICES TO FORM A RESULTANT GENERAL
C           MATRIX WHERE FIRST  MATRIX IS DOUBLE PRECISION
C
C        USAGE
C           CALL DGMPRD(A,B,R,N,M,L)
C
C        DESCRIPTION OF PARAMETERS
C           A - NAME OF FIRST INPUT DOUBLE PRECISION MATRIX
C           B - NAME OF SECOND INPUT MATRIX
C           R - NAME OF OUTPUT MATRIX
C           N - NUMBER OF ROWS IN A
C           M - NUMBER OF COLUMNS IN A AND ROWS IN B
C           L - NUMBER OF COLUMNS IN B
C
C        REMARKS
C           ALL MATRICES MUST BE STORED AS GENERAL MATRICES
C           MATRIX R CANNOT BE IN THE SAME LOCATION AS MATRIX A
C           MATRIX R CANNOT BE IN THE SAME LOCATION AS MATRIX B
C           NUMBER OF COLUMNS OF MATRIX A MUST BE EQUAL TO NUMBER OF ROW
C           OF MATRIX B
C
C        SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED
C           NONE
C
C        METHOD
C           THE M BY L MATRIX B IS PREMULTIPLIED BY THE N BY M MATRIX A
C           AND THE RESULT IS STORED IN THE N BY L MATRIX R.
C
C     ..................................................................
C
      SUBROUTINE DGMPRD(A,B,R,N,M,L)
      DOUBLE PRECISION A
      DIMENSION A(1),B(1),R(1)
C
      IR=0
      IK=-M
      DO 10 K=1,L
      IK=IK+M
      DO 10 J=1,N
      IR=IR+1
      JI=J-N
      IB=IK
      R(IR)=0
      DO 10 I=1,M
      JI=JI+N
      IB=IB+1
   10 R(IR)=R(IR)+A(JI)*B(IB)
      RETURN
      END
C
C     ..................................................................
C
C        SUBROUTINE GMPRD
```

```
C
C        PURPOSE
C           MULTIPLY TWO GENERAL MATRICES TO FORM A RESULTANT GENERAL
C           MATRIX
C
C        USAGE
C           CALL GMPRD(A,B,R,N,M,L)
C
C        DESCRIPTION OF PARAMETERS
C           A - NAME OF FIRST INPUT MATRIX
C           B - NAME OF SECOND INPUT MATRIX
C           R - NAME OF OUTPUT MATRIX
C           N - NUMBER OF ROWS IN A
C           M - NUMBER OF COLUMNS IN A AND ROWS IN B
C           L - NUMBER OF COLUMNS IN B
C
C        REMARKS
C           ALL MATRICES MUST BE STORED AS GENERAL MATRICES
C           MATRIX R CANNOT BE IN THE SAME LOCATION AS MATRIX A
C           MATRIX R CANNOT BE IN THE SAME LOCATION AS MATRIX B
C           NUMBER OF COLUMNS OF MATRIX A MUST BE EQUAL TO NUMBER OF ROW
C           OF MATRIX B
C
C        SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED
C           NONE
C
C        METHOD
C           THE M BY L MATRIX B IS PREMULTIPLIED BY THE N BY M MATRIX A
C           AND THE RESULT IS STORED IN THE N BY L MATRIX R.
C
C     ..................................................................
C
      SUBROUTINE GMPRD(A,B,R,N,M,L)
      DIMENSION A(1),B(1),R(1)
C
      IR=0
      IK=-M
      DO 10 K=1,L
      IK=IK+M
      DO 10 J=1,N
      IR=IR+1
      JI=J-N
      IB=IK
      R(IR)=0
      DO 10 I=1,M
      JI=JI+N
      IB=IB+1
   10 R(IR)=R(IR)+A(JI)*B(IB)
      RETURN
      END
C
C     ..................................................................
C
C        SUBROUTINE MINV
C
C        PURPOSE
C           INVERT A MATRIX
C
C        USAGE
C           CALL MINV(A,N,D,L,M)
C
C        DESCRIPTION OF PARAMETERS
C           A - INPUT MATRIX, DESTROYED IN COMPUTATION AND REPLACED BY
C               RESULTANT INVERSE.
C           N - ORDER OF MATRIX A
C           D - RESULTANT DETERMINANT
C           L - WORK VECTOR OF LENGTH N
C           M - WORK VECTOR OF LENGTH N
C
C        REMARKS
C           MATRIX A MUST BE A GENERAL MATRIX
C
C        SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED
C           NONE
C
```

```
C        METHOD
C           THE STANDARD GAUSS-JORDAN METHOD IS USED. THE DETERMINANT
C           IS ALSO CALCULATED. A DETERMINANT OF ZERO INDICATES THAT
C           THE MATRIX IS SINGULAR.
C
C     ..................................................................
C
      SUBROUTINE MINV(A,N,D,L,M)
      DIMENSION A(1),L(1),M(1)
C
C        ...............................................................
C
C        IF A DOUBLE PRECISION VERSION OF THIS ROUTINE IS DESIRED, THE
C        C IN COLUMN 1 SHOULD BE REMOVED FROM THE DOUBLE PRECISION
C        STATEMENT WHICH FOLLOWS.
C
      DOUBLE PRECISION A,D,BIGA,HOLD
C
C        THE C MUST ALSO BE REMOVED FROM DOUBLE PRECISION STATEMENTS
C        APPEARING IN OTHER ROUTINES USED IN CONJUNCTION WITH THIS
C        ROUTINE.
C
C        THE DOUBLE PRECISION VERSION OF THIS SUBROUTINE MUST ALSO
C        CONTAIN DOUBLE PRECISION FORTRAN FUNCTIONS.  ABS IN STATEMENT
C        10 MUST BE CHANGED TO DABS.
C
C        ...............................................................
C
C        SEARCH FOR LARGEST ELEMENT
C
      D=1.0
      NK=-N
      DO 80 K=1,N
      NK=NK+N
      L(K)=K
      M(K)=K
      KK=NK+K
      BIGA=A(KK)
      DO 20 J=K,N
      IZ=N*(J-1)
      DO 20 I=K,N
      IJ=IZ+I
   10 IF(DABS(BIGA)-DABS(A(IJ))) 15,20,20
   15 BIGA=A(IJ)
      L(K)=I
      M(K)=J
   20 CONTINUE
C
C        INTERCHANGE ROWS
C
      J=L(K)
      IF(J-K) 35,35,25
   25 KI=K-N
      DO 30 I=1,N
      KI=KI+N
      HOLD=-A(KI)
      JI=KI-K+J
      A(KI)=A(JI)
   30 A(JI) =HOLD
C
C        INTERCHANGE COLUMNS
C
   35 I=M(K)
      IF(I-K) 45,45,38
   38 JP=N*(I-1)
      DO 40 J=1,N
      JK=NK+J
      JI=JP+J
      HOLD=-A(JK)
      A(JK)=A(JI)
   40 A(JI) =HOLD
C
C        DIVIDE COLUMN BY MINUS PIVOT (VALUE OF PIVOT ELEMENT IS
C        CONTAINED IN BIGA)
C
```

```
   45 IF(BIGA) 48,46,48
   46 D=0.0
      RETURN
   48 DO 55 I=1,N
      IF(I-K) 50,55,50
   50 IK=NK+I
      A(IK)=A(IK)/(-BIGA)
   55 CONTINUE
C
C        REDUCE MATRIX
C
      DO 65 I=1,N
      IK=NK+I
      HOLD=A(IK)
      IJ=I-N
      DO 65 J=1,N
      IJ=IJ+N
      IF(I-K) 60,65,60
   60 IF(J-K) 62,65,62
   62 KJ=IJ-I+K
      A(IJ)=HOLD*A(KJ)+A(IJ)
   65 CONTINUE
C
C        DIVIDE ROW BY PIVOT
C
      KJ=K-N
      DO 75 J=1,N
      KJ=KJ+N
      IF(J-K) 70,75,70
   70 A(KJ)=A(KJ)/BIGA
   75 CONTINUE
C
C        PRODUCT OF PIVOTS
C
      D=D*BIGA
C
C        REPLACE PIVOT BY RECIPROCAL
C
      A(KK)=1.0/BIGA
   80 CONTINUE
C
C        FINAL ROW AND COLUMN INTERCHANGE
C
      K=N
  100 K=(K-1)
      IF(K) 150,150,105
  105 I=L(K)
      IF(I-K) 120,120,108
  108 JQ=N*(K-1)
      JR=N*(I-1)
      DO 110 J=1,N
      JK=JQ+J
      HOLD=A(JK)
      JI=JR+J
      A(JK)=-A(JI)
  110 A(JI) =HOLD
  120 J=M(K)
      IF(J-K) 100,100,125
  125 KI=K-N
      DO 130 I=1,N
      KI=KI+N
      HOLD=A(KI)
      JI=KI-K+J
      A(KI)=-A(JI)
  130 A(JI) =HOLD
      GO TO 100
  150 RETURN
      END
C
C     ...............................................................
C
C        SUBROUTINE SMPY
C
C        PURPOSE
C           MULTIPLY EACH ELEMENT OF A MATRIX BY A SCALAR TO FORM A
```

```
C           RESULTANT MATRIX
C
C        USAGE
C           CALL SMPY(A,C,R,N,M,MS)
C
C        DESCRIPTION OF PARAMETERS
C           A - NAME OF INPUT MATRIX
C           C - SCALAR
C           R - NAME OF OUTPUT MATRIX
C           N - NUMBER OF ROWS IN MATRIX A AND R
C           M - NUMBER OF COLUMNS IN MATRIX A AND R
C           MS  - ONE DIGIT NUMBER FOR STORAGE MODE OF MATRIX A (AND R)
C                  0 - GENERAL
C                  1 - SYMMETRIC
C                  2 - DIAGONAL
C
C        REMARKS
C           NONE
C
C        SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED
C           LOC
C
C        METHOD
C           SCALAR IS MULTIPLIED BY EACH ELEMENT OF MATRIX
C
C     ..................................................................
C
      SUBROUTINE SMPY(A,C,R,N,M,MS)
      DIMENSION A(1),R(1)
C
C        COMPUTE VECTOR LENGTH, IT
C
      CALL LOC(N,M,IT,N,M,MS)
C
C        MULTIPLY BY SCALAR
C
      DO 1 I=1,IT
    1 R(I)=A(I)*C
      RETURN
      END
C
C     ..................................................................
C
C        SUBROUTINE MXOUT
C
C        PURPOSE
C           PRODUCES AN OUTPUT LISTING OF ANY SIZED ARRAY ON
C           LOGICAL UNIT 6
C
C        USAGE
C           CALL MXOUT(ICODE,A,N,M,MS,LINS,IPOS,ISP)
C
C        DESCRIPTION OF PARAMETERS
C           ICODE- INPUT CODE NUMBER TO BE PRINTED ON EACH OUTPUT PAGE
C           A-NAME OF OUTPUT MATRIX
C           N-NUMBER OF ROWS IN A
C           M-NUMBER OF COLUMNS IN A
C           MS-STORAGE MODE OF A WHERE MS=
C                  0-GENERAL
C                  1-SYMMETRIC
C                  2-DIAGONAL
C           LINS-NUMBER OF PRINT LINES ON THE PAGE (USUALLY 60)
C           IPOS-NUMBER OF PRINT POSITIONS ACROSS THE PAGE (USUALLY 132)
C           ISP-LINE SPACING CODE, 1 FOR SINGLE SPACE, 2 FOR DOUBLE
C               SPACE
C
C        REMARKS
C           NONE
C
C        SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED
C           LOC
C
C        METHOD
C           THIS SUBROUTINE CREATES A STANDARD OUTPUT LISTING OF ANY
C           SIZED ARRAY WITH ANY STORAGE MODE. EACH PAGE IS HEADED WITH
```

```
C           RESULTANT MATRIX
C
C        USAGE
C           CALL SMPY(A,C,R,N,M,MS)
C
C        DESCRIPTION OF PARAMETERS
C           A - NAME OF INPUT MATRIX
C           C - SCALAR
C           R - NAME OF OUTPUT MATRIX
C           N - NUMBER OF ROWS IN MATRIX A AND R
C           M - NUMBER OF COLUMNS IN MATRIX A AND R
C           MS  - ONE DIGIT NUMBER FOR STORAGE MODE OF MATRIX A (AND R)
C                  0 - GENERAL
C                  1 - SYMMETRIC
C                  2 - DIAGONAL
C
C        REMARKS
C           NONE
C
C        SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED
C           LOC
C
C        METHOD
C           SCALAR IS MULTIPLIED BY EACH ELEMENT OF MATRIX
C
C     ..................................................................
C
      SUBROUTINE SMPY(A,C,R,N,M,MS)
      DIMENSION A(1),R(1)
C
C        COMPUTE VECTOR LENGTH, IT
C
      CALL LOC(N,M,IT,N,M,MS)
C
C        MULTIPLY BY SCALAR
C
      DO 1 I=1,IT
    1 R(I)=A(I)*C
      RETURN
      END
C
C     ..................................................................
C
C        SUBROUTINE MXOUT
C
C        PURPOSE
C           PRODUCES AN OUTPUT LISTING OF ANY SIZED ARRAY ON
C           LOGICAL UNIT 6
C
C        USAGE
C           CALL MXOUT(ICODE,A,N,M,MS,LINS,IPOS,ISP)
C
C        DESCRIPTION OF PARAMETERS
C           ICODE- INPUT CODE NUMBER TO BE PRINTED ON EACH OUTPUT PAGE
C           A-NAME OF OUTPUT MATRIX
C           N-NUMBER OF ROWS IN A
C           M-NUMBER OF COLUMNS IN A
C           MS-STORAGE MODE OF A WHERE MS=
C                  0-GENERAL
C                  1-SYMMETRIC
C                  2-DIAGONAL
C           LINS-NUMBER OF PRINT LINES ON THE PAGE (USUALLY 60)
C           IPOS-NUMBER OF PRINT POSITIONS ACROSS THE PAGE (USUALLY 132)
C           ISP-LINE SPACING CODE, 1 FOR SINGLE SPACE, 2 FOR DOUBLE
C               SPACE
C
C        REMARKS
C           NONE
C
C        SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED
C           LOC
C
C        METHOD
C           THIS SUBROUTINE CREATES A STANDARD OUTPUT LISTING OF ANY
C           SIZED ARRAY WITH ANY STORAGE MODE. EACH PAGE IS HEADED WITH
```

```
C           THE CODE NUMBER,DIMENSIONS AND STORAGE MODE OF THE ARRAY.
C           EACH COLUMN AND ROW IS ALSO HEADED WITH ITS RESPECTIVE
C           NUMBER.
C
C     ...............................................................
C
      SUBROUTINE MXOUT (ICODE,A,N,M,MS,LINS,IPOS,ISP)
      DIMENSION A(1),B(8)
C   1 FORMAT(1H1,5X, 7HMATRIX ,I5,6X,I3,5H ROWS,6X,I3,8H COLUMNS,
C    18X,13HSTORAGE MODE ,I1,8X,5HPAGE ,I2,/)
    1 FORMAT(//)
    2 FORMAT(12X,8HCOLUMN  ,7(3X,I3,10X))
    3 FORMAT(1H )
C   4 FORMAT(1H ,7X,4HROW ,I3,7(E16.6))
    4 FORMAT(1H ,7X,4HROW ,I3,7(1PE16.6))
C   5 FORMAT(1H0,7X,4HROW ,I3,7(E16.6))
    5 FORMAT(1H0,7X,4HROW ,I3,7(1PE16.6))
C
      J=1
C
C        WRITE HEADING
C
      NEND=IPOS/16-1
      LEND=(LINS/ISP)-2
      IPAGE=1
   10 LSTRT=1
C  20 WRITE(6,1)ICODE,N,M,MS,IPAGE
   20 WRITE(6,1)
      JNT=J+NEND-1
      IPAGE=IPAGE+1
   31 IF(JNT-M)33,33,32
   32 JNT=M
   33 CONTINUE
      WRITE(6,2)(JCUR,JCUR=J,JNT)
      IF(ISP-1) 35,35,40
   35 WRITE(6,3)
   40 LTEND=LSTRT+LEND-1
      DO 80 L=LSTRT,LTEND
C
C        FORM OUTPUT ROW LINE
C
      DO 55 K=1,NEND
      KK=K
      JT = J+K-1
      CALL LOC(L,JT,IJNT,N,M,MS)
      B(K)=0.0
      IF(IJNT)50,50,45
   45 B(K)=A(IJNT)
   50 CONTINUE
C
C        CHECK IF LAST COLUMN.  IF YES GO TO 60
C
      IF(JT-M) 55,60,60
   55 CONTINUE
C
C        END OF LINE, NOW WRITE
C
   60 IF(ISP-1)65,65,70
   65 WRITE(6,4)L,(B(JW),JW=1,KK)
      GO TO 75
   70 WRITE(6,5)L,(B(JW),JW=1,KK)
C
C        IF END OF ROWS,GO CHECK COLUMNS
C
   75 IF(N-L)85,85,80
   80 CONTINUE
C
C        END OF PAGE, NOW CHECK FOR MORE OUTPUT
C
      LSTRT=LSTRT+LEND
      GO TO 20
C
C        END OF COLUMNS, THEN RETURN
C
   85 IF(JT-M)90,95,95
```

```
   90 J=JI+1
      GO TO 10
   95 RETURN
      END
C
C     ...............................................................
C
C        SUBROUTINE MADD
C
C        PURPOSE
C           ADD TWO MATRICES ELEMENT BY ELEMENT TO FORM RESULTANT
C           MATRIX
C
C        USAGE
C           CALL MADD(A,B,R,N,M,MSA,MSB)
C
C        DESCRIPTION OF PARAMETERS
C           A - NAME OF INPUT MATRIX
C           B - NAME OF INPUT MATRIX
C           R - NAME OF OUTPUT MATRIX
C           N - NUMBER OF ROWS IN A,B,R
C           M - NUMBER OF COLUMNS IN A,B,R
C           MSA - ONE DIGIT NUMBER FOR STORAGE MODE OF MATRIX A
C                  0 - GENERAL
C                  1 - SYMMETRIC
C                  2 - DIAGONAL
C           MSB - SAME AS MSA EXCEPT FOR MATRIX B
C
C        REMARKS
C           NONE
C
C        SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED
C           LOC
C
C        METHOD
C           STORAGE MODE OF OUTPUT MATRIX IS FIRST DETERMINED. ADDITION
C           OF CORRESPONDING ELEMENTS IS THEN PERFORMED.
C           THE FOLLOWING TABLE SHOWS THE STORAGE MODE OF THE OUTPUT
C           MATRIX FOR ALL COMBINATIONS OF INPUT MATRICES
C                             A                B                R
C                       GENERAL          GENERAL          GENERAL
C                       GENERAL          SYMMETRIC        GENERAL
C                       GENERAL          DIAGONAL         GENERAL
C                       SYMMETRIC        GENERAL          GENERAL
C                       SYMMETRIC        SYMMETRIC        SYMMETRIC
C                       SYMMETRIC        DIAGONAL         SYMMETRIC
C                       DIAGONAL         GENERAL          GENERAL
C                       DIAGONAL         SYMMETRIC        SYMMETRIC
C                       DIAGONAL         DIAGONAL         DIAGONAL
C
C     ...............................................................
C
      SUBROUTINE MADD(A,B,R,N,M,MSA,MSB)
      DIMENSION A(1),B(1),R(1)
C
C        DETERMINE STORAGE MODE OF OUTPUT MATRIX
C
      IF(MSA-MSB) 7,5,7
    5 CALL LOC(N,M,NM,N,M,MSA)
      GO TO 100
    7 MTEST=MSA*MSB
      MSR=0
      IF(MTEST) 20,20,10
   10 MSR=1
   20 IF(MTEST-2) 35,35,30
   30 MSR=2
C
C        LOCATE ELEMENTS AND PERFORM ADDITION
C
   35 DO 90 J=1,M
      DO 90 I=1,N
      CALL LOC(I,J,IJR,N,M,MSR)
      IF(IJR) 40,90,40
   40 CALL LOC(I,J,IJA,N,M,MSA)
      AIJ=0.0
```

```
      IF(IJA) 50,60,50
   50 AEL=A(IJA)
   60 CALL LOC(I,J,IJB,N,M,MSB)
      BEL=0.0
      IF(IJB) 70,80,70
   70 BEL=B(IJB)
   80 R(IJR)=AEL+BEL
   90 CONTINUE
      RETURN
C
C        ADD MATRICES FOR OTHER CASES
C
  100 DO 110 I=1,NM
  110 R(I)=A(I)+B(I)
      RETURN
      END
NUMBER START 0
 BC 15,12(15)
 DC X'7'
 DC CL7'NUMBER'
 STM 14,12,12(13)
 BALR 10,0
 USING *,10
*
*
* N=NUMBER(A,IPOS,ILNG)
*  ILNG MAY NOT EXCEED 15
*
*
 LM 2,4,0(1)
 L 3,0(3)
 L 4,0(4)
 LR 5,4
 BCTR 5,0
 LR 6,3
 BCTR 6,0
 AR 2,6
 STC 4,MM+1
MM MVC WORK(0),0(2)
 LA 2,WORK
 LR 9,2
 LR 7,4
 LA 8,1
LOOP CLI 0(9),C'-'
 BNE NXT1
 MVI 0(9),C'0'
 LNR 8,8
 B TST
NXT1 CLI 0(9),C'+'
 BNE TST
 MVI 0(9),C'0'
TST CLI 0(9),C' '
 BNE TST3
 MVI  0(9),C'0'
TST3 A 9,=F'1'
 BCT 7,LOOP
 BCTR 9,0
 LTR 8,8
 BP BYBY
 LR 9,2
 AR 9,5
 OI 0(9),X'D0'
 B CYCY
BYBY OI 0(9),X'C0'
CYCY L 9,=F'15'
 SLA 9,4(0)
 AR 9,5
 STC 9,PCK+1
PCK PACK DBL,0(0,2)
 CVB 0,DBL+8
 LTR 8,8
 BP ARND
 LNR 0,0
ARND LM  2,12,28(13)
 LM 2,12,28(13)
```

```
 MVI 12(13),X'FF'
 BCR 15,14
DBL DS 2D
WORK DS CL16
 END NUMBER
KOMP START 0
 BC 15,10(15)
 DC X'5'
 DC CL5'KOMP'
 STM 14,8,12(13)
 BALR 8,0
 USING *,8
*****************************************************************
*
* FORTRAN SUBROUTINE FOR CHARACTER COMPARISON
*
*  USAGE GIVEN BY
*         K=KOMP(A1,IPOS1,ILNG1,A2,IPOS2)
*
* THE ILNG1 CHARS(BYTES) STARTING AT ADDRESS A1+(IPOS1-1)
* ARE COMPARED AGAINST THE ILNG1 CHARS(BYTES) STARTING AT ADDRESS
* A2+(IPOS2-1)
*
* RESULT:
*   K=-1 IF LESS THAN
*   K=0 IF EQUAL
*   K=1 IF GREATER THAN
*
*
* A1 AND A2 MAY BE DIMENSIONED OR UNDIMENSIONED
*
*****************************************************************
 SR 0,0
 LM 2,6,0(1)
 L 3,0(3)
 L 4,0(4)
 L 6,0(6)
 LA 7,1
 SR 3,7
 SR 6,7
 AR 2,3
 AR 5,6
 SR 4,7
 STC 4,MVC+1
MVC CLC 0(0,2),0(5)
 BE FINE
 BL NEG
 LR 0,7
 B FINE
NEG SR 0,7
FINE LM 2,8,28(13)
 MVI 12(13),X'FF'
 BCR 15,14
 END KOMP
MOVE START 0
 BC 15,12(15)
 DC X'7'
 DC CL7'MOVE'
 STM 14,8,12(13)
 BALR 8,0
 USING *,8
*
*
*   FORTRAN
*   USAGE:
*     CALL MOVE(A1,IPOS1,LNG1,A2,IPOA2)
*
*    MOVES THE LNG1 CHARACTERS AT A1+(IPOS1-1) INTO
*      A2+(IPOS2-1)
*
*  RESULTS UNPREDICTABLE IF FIELDS OVERLAP
*
*
 LM 2,6,0(1)
```

```
 L 4,0(4)                                                              SIMP2246
 L 6,0(6)                                                              SIMP2247
 LA 7,1                                                                SIMP2248
 SR 4,7                                                                SIMP2249
 STC 4,MVC+1                                                           SIMP2250
 AR 2,3                                                                SIMP2251
 SR 2,7                                                                SIMP2252
 AR 5,6                                                                SIMP2253
  SR 5,7                                                               SIMP2254
MVC MVC 0(0,5),0(2)                                                    SIMP2255
 LM 2,8,28(13)                                                         SIMP2256
 MVI 12(13),X'FF'                                                      SIMP2257
 BCR 15,14                                                             SIMP2258
 END MOVE                                                              SIMP2259
```

SECTION VIII

APPENDICES

Appendix : Data Bank

Table P1

Residual Generation Coefficients

Food and Kindred Products

Unit of activity: Million dollars of output
Level of pollutants: Kilograms
Level of waste water: Million liters

Air Pollutant Emissions from Alternative Production Processes Other than Heat and Power Generation

	P	HC	SO_x	CO	NO_x
Process 1	12,066	--	--	--	--
Process 2	9,653	--	--	--	--
Process 3	7,239	--	--	--	--

Air Pollutant Emissions from Alternative Production Processes -- Heat and Power Generation

	P	HC	SO_x	CO	NO_x
Process 1	9,420	66	5,974	175	1,928
Process 2	7,065	50	4,481	131	1,446
Process 3	2,355	33	2,987	86	964

Water Pollutant Discharges from Alternative Production Processes

	BOD	SS	DS	WW
Process 1	25,780	39,569	7,218	22.0
Process 2	19,335	29,677	5,053	20.9
Process 3	12,890	19,785	3,609	16.5

Solid Waste Generation from Alternative Production Processes

	Combustible	Noncombustible	Total
Process 1			74,239
Process 2			51,968
Process 3			44,546

Table [illegible]1a

Residual Transformation Coefficients: Air

Air Pollutant Transformation Factors for Alternative Treatment Processes -- Primary Residual Transformation Coefficients

	P		SO_x		NO_x		HC		CO		Solid Waste (Bottom Ash)	
	H*	L*	H	L	H	L	H	L	H	L		
Settling Chamber	.30	.80									.7 (P)	.2 (P)
Cyclone	.20	.70									.8 (P)	.3 (P)
Electrostatic Precipitator	.05	.10									.95 (P)	.9 (P)
Fabric Filter	.01	.05									.99 (P)	.95 (P)
Wet Scrubber	.10	.20	.10	.20	.40	.60					.9 (P)	.8 (P)
Afterburner							0		0			

Secondary Residual Transformation Coefficients From Solid Waste (Bottom Ash) to Other Media

	P	SO_x	NO_x	HC	CO	SS	SW
Open Dumping							
Sanitary Landfill							
Discharge to Water Bodies							

*H: High Efficiency
L: Low Efficiency

Table T1b

Residual Transformation Coefficients: Water

Water Pollutant Transformation Factors for Alternative Treatment Processes -- Primary Residual Transformation Coefficients

	BOD	SS	DS	Sludge
Primary Treatment Screening Sedimentation Neutralization & Storage Chemical Addition	.65	.1	0	.35(BOD)+.9 (SS)+1(DS)
Secondary Treatment Activated Sludge Trickling Filter	.1	.05	.95	.9 (BOD)+.95(SS)+.5(DS)
Tertiary Treatment Activated Carbon Iron Exchange	.01	.01	.5	.99(BOD)+.99(SS)+.5(DS)

Intermedia Residual Transformation Coefficients From Sludge to Other Media

	P*	SO_x	NO_x	HC	CO	SW*
Incinerator Open Dumping Sanitary Landfill						

* For further treatment of P and SW , see 3-Ta.

Table T1c

Residual Transformation Coefficients: Solid Waste (Combustible)

Solid Waste Transformation Factors for Alternative Control Technologies -- Primary Residual Transformation Coefficients from Solid Waste to Other Media

Incinerator Incinerator	P KG/MT	HC KG/MT	SO_x KG/MT	CO KG/MT	NO_x KG/MT	SW KG/MT
Multiple Chamber	15	.75	.75	17.5	1	
Multiple Chamber With Water Spray	7	.75	.75	17.5	1	

Intermedia Residual Transformation Coefficients From Particulate to Other Media

	P	SO_x	NO_x	HC	CO	SW
Settling Chamber	.30 .80				.7 (P)	.2 (P)
Cyclone	.20 .70				.8 (P)	.3 (P)
Electrostatic Precipitator	.05 .10				.95 (P)	.9 (P)
Fabric Filter	.01 .05				.99 (P)	.95 (P)
Wet Scrubber	.10 .20	.10 .20	.40 .60		.9 (P)	.8 (P)
Afterburner				0	0	

Intermedia Residual Transformation Coefficients From Bottom Ash to Other Media

	P	SO_x	NO_x	HC	CO	SW
Open Dumping						
Sanitary Landfill						
Discharge to Water Bodies						

Table P2

Residual Generation Coefficients

Tobacco

Unit of activity: Million dollars of output
Level of pollutants: Kilograms
Level of waste water: Million liters

Air Pollutant Emissions from Alternative Production Processes Other than Heat and Power Generation

	P	HC	SO_x	CO	NO_x
Process 1	--	--	--	--	--
Process 2	--	--	--	--	--
Process 3	--	--	--	--	--

Air Pollutant Emissions from Alternative Production Processes -- Heat and Power Generation

	P	HC	SO_x	CO	NO_x
Process 1	4,609	30	2,494	84	673
Process 2	3,457	23	1,871	63	505
Process 3	1,152	15	1,247	42	337

Water Pollutant Discharges from Alternative Production Processes

	BOD	SS	DS	WW
Process 1	1,381	3,294	--	7.88
Process 2	1,312	2,635	--	6.31
Process 3	1,243	2,470	--	6.31

Solid Waste Generation from Alternative Production Processes

	Combustible	Noncombustible	Total
Process 1			--
Process 2			--
Process 3			--

Table T2a

Residual Transformation Coefficients: Air

Air Pollutant Transformation Factors for Alternative Treatment Processes -- Primary Residual Transformation Coefficients

	P		SO_x		NO_x		HC		CO		Solid Waste (Bottom Ash)	
	H*	L*	H	L	H	L	H	L	H	L		
Settling Chamber	.30	.80									.7 (P)	.2 (P)
Cyclone	.20	.70									.8 (P)	.3 (P)
Electrostatic Precipitator	.05	.10									.95 (P)	.9 (P)
Fabric Filter	.01	.05									.99 (P)	.95 (P)
Wet Scrubber	.10	.20	.10	.20	.40	.60					.9 (P)	.8 (P)
Afterburner							0		0			

Intermedia Residual Transformation Coefficients From Solid Waste (Bottom Ash) to Other Media

	P	SO_x	NO_x	HC	CO	SS	SW
Open Dumping							
Sanitary Landfill							
Discharge to Water Bodies							

*H: High Efficiency
L: Low Efficiency

Table T2b

Residual Transformation Coefficients: Water

Water Pollutant Transformation Factors for Alternative Treatment Processes -- Primary Residual Transformation Coefficients

	BOD	SS	DS	Sludge
Primary Treatment Screening Sedimentation Neutralization & Storage Chemical Addition	.65	.1	0	.35(BOD)+.9 (SS)+1(DS)
Secondary Treatment Activated Sludge Trickling Filter	.1	.05	.95	.9 (BOD)+.95(SS)+.5(DS)
Tertiary Treatment Activated Carbon Iron Exchange	.01	.01	.5	.99(BOD)+.99(SS)+.5(DS)

Intermedia Residual Transformation Coefficients From Sludge to Other Media

	P*	SO_x	NO_x	HC	CO	SW*
Incinerator Open Dumping Sanitary Landfill						

* For further treatment of P and SW , see 3-Ta.

Table T2c

Residual Transformation Coefficients: Solid Waste (Combustible)

Solid Waste Transformation Factors for Alternative Control Technologies -- Primary Residual Transformation Coefficients from Solid Waste to Other Media

Incinerator Incinerator	P KG/MT	HC KG/MT	SO_x KG/MT	CO KG/MT	NO_x KG/MT	SW KG/MT
Multiple Chamber	15	.75	.75	17.5	1	
Multiple Chamber With Water Spray	7	.75	.75	17.5	1	

Intermedia Residual Transformation Coefficients From Particulate to Other Media

	P	SO_x	NO_x	HC	CO	SW
Settling Chamber	.30 .80					.7 (P) .2 (P)
Cyclone	.20 .70					.8 (P) .3 (P)
Electrostatic Precipitator	.05 .10					.95 (P) .9 (P)
Fabric Filter	.01 .05					.99 (P) .95 (P)
Wet Scrubber	.10 .20	.10 .20	.40 .60			.9 (P) .8 (P)
Afterburner				0	0	

Intermedia Residual Transformation Coefficients From Bottom Ash to Other Media

	P	SO_x	NO_x	HC	CO	SW
Open Dumping						
Sanitary Landfill						
Discharge to Water Bodies						

Table P3

Residual Generation Coefficients

Textile Mill Products

Unit of activity: Million dollars of output
Level of pollutants: Kilograms
Level of waste water: Million liters

Air Pollutant Emissions from Alternative Production Processes Other than Heat and Power Generation

	P	HC	SO_x	CO	NO_x
Process 1	--	--	--	--	--
Process 2	--	--	--	--	--
Process 3	--	--	--	--	--

Air Pollutant Emissions from Alternative Production Processes -- Heat and Power Generation

	P	HC	SO_x	CO	NO_x
Process 1	13,745	101	347,482	261	2,667
Process 2	10,309	76	260,612	196	2,000
Process 3	3,436	51	173,741	131	1,334

Water Pollutant Discharges from Alternative Production Processes

	BOD	SS	DS	WW
Process 1	21,400	--	24,502	39.43
Process 2	21,400	--	22,052	37.46
Process 3	19,260	--	20,827	35.49

Solid Waste Generation from Alternative Production Processes

	Combustible	Noncombustible	Total
Process 1			--
Process 2			--
Process 3			--

Table T3a

Residual Transformation Coefficients: Air

Air Pollutant Transformation Factors for Alternative Treatment Processes -- Primary Residual Transformation Coefficients

	P		SO_x		NO_x		HC		CO		Solid Waste (Bottom Ash)	
	H*	L*	H	L	H	L	H	L	H	L		
Settling Chamber	.30	.80									.7 (P)	.2 (P)
Cyclone	.20	.70									.8 (P)	.3 (P)
Electrostatic Precipitator	.05	.10									.95 (P)	.9 (P)
Fabric Filter	.01	.05									.99 (P)	.95 (P)
Wet Scrubber	.10	.20	.10	.20	.40	.60					.9 (P)	.8 (P)
Afterburner							0		0			

Intermedia Residual Transformation Coefficients From Solid Waste (Bottom Ash) to Other Media

	P	SO_x	NO_x	HC	CO	SS	SW
Open Dumping							
Sanitary Landfill							
Discharge to Water Bodies							

*H: High Efficiency
L: Low Efficiency

Table T3b

Residual Transformation Coefficients: Water

Water Pollutant Transformation Factors for Alternative Treatment Processes -- Primary Residual Transformation Coefficients

	BOD	SS	DS	Sludge
Primary Treatment	.65	.1	0	.35(BOD)+.9 (SS)+1(DS)
Screening				
Sedimentation				
Neutralization & Storage				
Chemical Addition				
Secondary Treatment	.1	.05	.95	.9 (BOD)+.95(SS)+.5(DS)
Activated Sludge				
Trickling Filter				
Tertiary Treatment	.01	.01	.5	.99(BOD)+.99(SS)+.5(DS)
Activated Carbon				
Iron Exchange				

Intermedia Residual Transformation Coefficients From Sludge to Other Media

	P*	SO_x	NO_x	HC	CO	SW*
Incinerator						
Open Dumping						
Sanitary Landfill						

* For further treatment of P and SW , see 3-Ta.

Table T3c

Residual Transformation Coefficients: Solid Waste (Combustible)

Solid Waste Transformation Factors for Alternative Control Technologies -- Primary Residual Transformation Coefficients from Solid Waste to Other Media

Incinerator	P KG/MT	HC KG/MT	SO_x KG/MT	CO KG/MT	NO_x KG/MT	SW KG/MT
Multiple Chamber	15	.75	.75	17.5	1	
Multiple Chamber With Water Spray	7	.75	.75	17.5	1	

Intermedia Residual Transformation Coefficients From Particulate to Other Media

	P	SO_x	NO_x	HC	CO	SW
Settling Chamber	.30 .80				.7 (P)	.2 (P)
Cyclone	.20 .70				.8 (P)	.3 (P)
Electrostatic Precipitator	.05 .10				.95 (P)	.9 (P)
Fabric Filter	.01 .05				.99 (P)	.95 (P)
Wet Scrubber	.10 .20	.10 .20	.40 .60		.9 (P)	.8 (P)
Afterburner				0	0	

Intermedia Residual Transformation Coefficients From Bottom Ash to Other Media

	P	SO_x	NO_x	HC	CO	SW
Open Dumping						
Sanitary Landfill						
Discharge to Water Bodies						

Table P4

Residual Generation Coefficients

Apparel and Related Products

Unit of activity: Million dollars of output
Level of pollutants: Kilograms
Level of waste water: Million liters

Air Pollutant Emissions from Alternative Production Processes Other than Heat and Power Generation

	P	HC	SO_x	CO	NO_x
Process 1	--	--	--	--	--
Process 2	--	--	--	--	--
Process 3	--	--	--	--	--

Air Pollutant Emissions from Alternative Production Processes -- Heat and Power Generation

	P	HC	SO_x	CO	NO_x
Process 1	715	6	668	1	200
Process 2	536	5	501	0.8	150
Process 3	179	3	334	0.5	100

Water Pollutant Discharges from Alternative Production Processes

	BOD	SS	DS	WW
Process 1	1,381	3,294	--	7.88
Process 2	1,312	2,635	--	6.31
Process 3	1,243	2,470	--	6.31

Solid Waste Generation from Alternative Production Processes

	Combustible	Noncombustible	Total
Process 1			--
Process 2			--
Process 3			--

Table T4a

Residual Transformation Coefficients: Air

Air Pollutant Transformation Factors for Alternative Treatment Processes -- Primary Residual Transformation Coefficients

	P		SO_x		NO_x		HC		CO		Solid Waste (Bottom Ash)	
	H*	L*	H	L	H	L	H	L	H	L		
Settling Chamber	.30	.80									.7 (P)	.2 (P)
Cyclone	.20	.70									.8 (P)	.3 (P)
Electrostatic Precipitator	.05	.10									.95 (P)	.9 (P)
Fabric Filter	.01	.05									.99 (P)	.95 (P)
Wet Scrubber	.10	.20	.10	.20	.40	.60					.9 (P)	.8 (P)
Afterburner							0		0			

Intermedia Residual Transformation Coefficients From Solid Waste (Bottom Ash) to Other Media

	P	SO_x	NO_x	HC	CO	SS	SW
Open Dumping							
Sanitary Landfill							
Discharge to Water Bodies							

*H: High Efficiency
L: Low Efficiency

Table T4b

Residual Transformation Coefficients: Water

Water Pollutant Transformation Factors for Alternative Treatment Processes -- Primary Residual Transformation Coefficients

	BOD	SS	DS	Sludge
Primary Treatment Screening Sedimentation Neutralization & Storage Chemical Addition	.65	.1	0	.35(BOD)+.9 (SS)+1(DS)
Secondary Treatment Activated Sludge Trickling Filter	.1	.05	.95	.9 (BOD)+.95(SS)+.5(DS)
Tertiary Treatment Activated Carbon Iron Exchange	.01	.01	.5	.99(BOD)+.99(SS)+.5(DS)

Intermedia Residual Transformation Coefficients From Sludge to Other Media

	P*	SO_x	NO_x	HC	CO	SW*
Incinerator Open Dumping Sanitary Landfill						

* For further treatment of P and SW , see 3-Ta.

Table T4c

Residual Transformation Coefficients: Solid Waste (Combustible)

Solid Waste Transformation Factors for Alternative Control Technologies -- Primary Residual Transformation Coefficients from Solid Waste to Other Media

Incinerator Incinerator	P KG/MT	HC KG/MT	SO_x KG/MT	CO KG/MT	NO_x KG/MT	SW KG/MT
Multiple Chamber	15	.75	.75	17.5	1	
Multiple Chamber With Water Spray	7	.75	.75	17.5	1	

Intermedia Residual Transformation Coefficients From Particulate to Other Media

	P	SO_x	NO_x	HC	CO	SW
Settling Chamber	.30 .80				.7 (P)	.2 (P)
Cyclone	.20 .70				.8 (P)	.3 (P)
Electrostatic Precipitator	.05 .10				.95 (P)	.9 (P)
Fabric Filter	.01 .05				.99 (P)	.95 (P)
Wet Scrubber	.10 .20	.10 .20	.40 .60		.9 (P)	.8 (P)
Afterburner				0	0	

Intermedia Residual Transformation Coefficients From Bottom Ash to Other Media

	P	SO_x	NO_x	HC	CO	SW
Open Dumping						
Sanitary Landfill						
Discharge to Water Bodies						

Table P5

Residual Generation Coefficients

Lumber and Wood Products

Unit of activity: Million dollars of output
Level of pollutants: Kilograms
Level of waste water: Million liters

Air Pollutant Emissions from Alternative Production Processes Other than Heat and Power Generation

	P	HC	SO_x	CO	NO_x
Process 1	--	--	--	--	--
Process 2	--	--	--	--	--
Process 3	--	--	--	--	--

Air Pollutant Emissions from Alternative Production Processes -- Heat and Power Generation

	P	HC	SO_x	CO	NO_x
Process 1	2,617	29	3,355	58	1,039
Process 2	1,963	22	2,516	44	779
Process 3	654	15	1,678	29	520

Water Pollutant Discharges from Alternative Production Processes

	BOD	SS	DS	WW
Process 1	1,381	3,294	--	7.88
Process 2	1,312	2,635	--	6.31
Process 3	1,243	2,470	--	6.31

Solid Waste Generation from Alternative Production Processes

	Combustible	Noncombustible	Total
Process 1			2,518,295
Process 2			2,014,636
Process 3			1,762,807

Table T5a

Residual Transformation Coefficients: Air

Air Pollutant Transformation Factors for Alternative Treatment Processes -- Primary Residual Transformation Coefficients

	P		SO_x		NO_x		HC		CO		Solid Waste (Bottom Ash)	
	H*	L*	H	L	H	L	H	L	H	L		
Settling Chamber	.30	.80									.7 (P)	.2 (P)
Cyclone	.20	.70									.8 (P)	.3 (P)
Electrostatic Precipitator	.05	.10									.95 (P)	.9 (P)
Fabric Filter	.01	.05									.99 (P)	.95 (P)
Wet Scrubber	.10	.20	.10	.20	.40	.60					.9 (P)	.8 (P)
Afterburner							0		0			

Intermedia Residual Transformation Coefficients From Solid Waste (Bottom Ash) to Other Media

	P	SO_x	NO_x	HC	CO	SS	SW
Open Dumping							
Sanitary Landfill							
Discharge to Water Bodies							

*H: High Efficiency
L: Low Efficiency

Table T5b

Residual Transformation Coefficients: Water

Water Pollutant Transformation Factors for Alternative Treatment Processes -- Primary Residual Transformation Coefficients

	BOD	SS	DS	Sludge
Primary Treatment Screening Sedimentation Neutralization & Storage Chemical Addition	.65	.1	0	.35(BOD)+.9 (SS)+1(DS)
Secondary Treatment Activated Sludge Trickling Filter	.1	.05	.95	.9 (BOD)+.95(SS)+.5(DS)
Tertiary Treatment Activated Carbon Iron Exchange	.01	.01	.5	.99(BOD)+.99(SS)+.5(DS)

Intermedia Residual Transformation Coefficients From Sludge to Other Media

	P*	SO_x	NO_x	HC	CO	SW*
Incinerator Open Dumping Sanitary Landfill						

* For further treatment of P and SW , see 3-Ta'.

Table T5c

Residual Transformation Coefficients: Solid Waste (Combustible)

Solid Waste Transformation Factors for Alternative Control Technologies -- Primary Residual Transformation Coefficients from Solid Waste to Other Media

Incinerator Incinerator	P KG/MT	HC KG/MT	SO_x KG/MT	CO KG/MT	NO_x KG/MT	SW KG/MT
Multiple Chamber	15	.75	.75	17.5	1	
Multiple Chamber With Water Spray	7	.75	.75	17.5	1	

Intermedia Residual Transformation Coefficients From Particulate to Other Media

	P	SO_x	NO_x	HC	CO	SW
Settling Chamber	.30 .80				.7 (P)	.2 (P)
Cyclone	.20 .70				.8 (P)	.3 (P)
Electrostatic Precipitator	.05 .10				.95 (P)	.9 (P)
Fabric Filter	.01 .05				.99 (P)	.95 (P)
Wet Scrubber	.10 .20	.10 .20	.40 .60		.9 (P)	.8 (P)
Afterburner				0	0	

Intermedia Residual Transformation Coefficients From Bottom Ash to Other Media

	P	SO_x	NO_x	HC	CO	SW
Open Dumping						
Sanitary Landfill						
Discharge to Water Bodies						

Table P6

Residual Generation Coefficients

Furniture and Fixtures

Unit of activity: Million dollars of output
Level of pollutants: Kilograms
Level of waste water: Million liters

Air Pollutant Emissions from Alternative Production Processes Other than Heat and Power Generation

	P	HC	SO_x	CO	NO_x
Process 1	--	--	--	--	--
Process 2	--	--	--	--	--
Process 3	--	--	--	--	--

Air Pollutant Emissions from Alternative Production Processes -- Heat and Power Generation

	P	HC	SO_x	CO	NO_x
Process 1	5,675	38	3,319	104	976
Process 2	4,256	29	2,489	78	732
Process 3	1,419	19	1,660	52	488

Water Pollutant Discharges from Alternative Production Processes

	BOD	SS	DS	WW
Process 1	1,381	3,294	--	7.88
Process 2	1,312	2,635	--	6.31
Process 3	1,243	2,470	--	6.31

Solid Waste Generation from Alternative Production Processes

	Combustible	Noncombustible	Total
Process 1			254,861
Process 2			203,889
Process 3			178,403

Table T6a

Residual Transformation Coefficients: Air

Air Pollutant Transformation Factors for Alternative Treatment Processes -- Primary Residual Transformation Coefficients

	P		SO_x		NO_x		HC		CO		Solid Waste (Bottom Ash)	
	H*	L*	H	L	H	L	H	L	H	L		
Settling Chamber	.30	.80									.7 (P)	.2 (P)
Cyclone	.20	.70									.8 (P)	.3 (P)
Electrostatic Precipitator	.05	.10									.95 (P)	.9 (P)
Fabric Filter	.01	.05									.99 (P)	.95 (P)
Wet Scrubber	.10	.20	.10	.20	.40	.60					.9 (P)	.8 (P)
Afterburner							0		0			

Intermedia Residual Transformation Coefficients From Solid Waste (Bottom Ash) to Other Media

	P	SO_x	NO_x	HC	CO	SS	SW
Open Dumping							
Sanitary Landfill							
Discharge to Water Bodies							

*H: High Efficiency
L: Low Efficiency

Table T6b

Residual Transformation Coefficients: Water

Water Pollutant Transformation Factors for Alternative Treatment Processes -- Primary Residual Transformation Coefficients

	BOD	SS	DS	Sludge
Primary Treatment Screening Sedimentation Neutralization & Storage Chemical Addition	.65	.1	0	.35(BOD)+.9 (SS)+1(DS)
Secondary Treatment Activated Sludge Trickling Filter	.1	.05	.95	.9 (BOD)+.95(SS)+.5(DS)
Tertiary Treatment Activated Carbon Iron Exchange	.01	.01	.5	.99(BOD)+.99(SS)+.5(DS)

Intermedia Residual Transformation Coefficients From Sludge to Other Media

	P*	SO_x	NO_x	HC	CO	SW*
Incinerator Open Dumping Sanitary Landfill						

* For further treatment of P and SW , see 3-Ta.

Table T6c

Residual Transformation Coefficients: Solid Waste (Combustible)

Solid Waste Transformation Factors for Alternative Control Technologies -- Primary Residual Transformation Coefficients from Solid Waste to Other Media

Incinerator Incinerator	P KG/MT	HC KG/MT	SO_x KG/MT	CO KG/MT	NO_x KG/MT	SW KG/MT
Multiple Chamber	15	.75	.75	17.5	1	
Multiple Chamber With Water Spray	7	.75	.75	17.5	1	

Intermedia Residual Transformation Coefficients From Particulate to Other Media

	P	SO_x	NO_x	HC	CO	SW
Settling Chamber	.30 .80				.7 (P)	.2 (P)
Cyclone	.20 .70				.8 (P)	.3 (P)
Electrostatic Precipitator	.05 .10				.95 (P)	.9 (P)
Fabric Filter	.01 .05				.99 (P)	.95 (P)
Wet Scrubber	.10 .20	.10 .20	.40 .60		.9 (P)	.8 (P)
Afterburner				0	0	

Intermedia Residual Transformation Coefficients From Bottom Ash to Other Media

	P	SO_x	NO_x	HC	CO	SW
Open Dumping						
Sanitary Landfill						
Discharge to Water Bodies						

Table P7

Residual Generation Coefficients

Paper and Allied Products

Unit of activity: Million dollars of output
Level of pollutants: Kilograms
Level of waste water: Million liters

Air Pollutant Emissions from Alternative Production Processes Other than Heat and Power Generation

	P	HC	SO_x	CO	NO_x
Process 1	29,882	--	--	34,500	--
Process 2	31,376	--	--	36,224	--
Process 3	32,870	--	--	37,949	--

Air Pollutant Emissions from Alternative Production Processes -- Heat and Power Generation

	P	HC	SO_x	CO	NO_x
Process 1	65,275	445	39,115	1,206	11,366
Process 2	48,956	334	29,336	905	8,525
Process 3	16,319	223	19,558	603	5,683

Water Pollutant Discharges from Alternative Production Processes

	BOD	SS	DS	WW
Process 1	144,708	73,582	315,784	374.73
Process 2	166,414	73,582	299,995	412.20
Process 3	180,885	77,261	299,995	449.67

Solid Waste Generation from Alternative Production Processes

	Combustible	Noncombustible	Total
Process 1			254,861
Process 2			263,329
Process 3			274,778

Table T7a

Residual Transformation Coefficients: Air

Air Pollutant Transformation Factors for Alternative Treatment Processes -- Primary Residual Transformation Coefficients

	P		SO_x		NO_x		HC		CO		Solid Waste (Bottom Ash)	
	H*	L*	H	L	H	L	H	L	H	L		
Settling Chamber	.30	.80									.7 (P)	.2 (P)
Cyclone	.20	.70									.8 (P)	.3 (P)
Electrostatic Precipitator	.05	.10									.95 (P)	.9 (P)
Fabric Filter	.01	.05									.99 (P)	.95 (P)
Wet Scrubber	.10	.20	.10	.20	.40	.60					.9 (P)	.8 (P)
Afterburner							0		0			

Intermedia Residual Transformation Coefficients From Solid Waste (Bottom Ash) to Other Media

	P	SO_x	NO_x	HC	CO	SS	SW
Open Dumping							
Sanitary Landfill							
Discharge to Water Bodies							

*H: High Efficiency
L: Low Efficiency

Table T7b

Residual Transformation Coefficients: Water

Water Pollutant Transformation Factors for Alternative Treatment Processes -- Primary Residual Transformation Coefficients

	BOD	SS	DS	Sludge
Primary Treatment Screening Sedimentation Neutralization & Storage Chemical Addition	.65	.1	0	.35(BOD)+.9 (SS)+1(DS)
Secondary Treatment Activated Sludge Trickling Filter	.1	.05	.95	.9 (BOD)+.95(SS)+.5(DS)
Tertiary Treatment Activated Carbon Iron Exchange	.01	.01	.5	.99(BOD)+.99(SS)+.5(DS)

Intermedia Residual Transformation Coefficients From Sludge to Other Media

	P*	SO_x	NO_x	HC	CO	SW*
Incinerator Open Dumping Sanitary Landfill						

* For further treatment of P and SW , see 3-Ta.

Table T7c

Residual Transformation Coefficients: Solid Waste (Combustible)

Solid Waste Transformation Factors for Alternative Control Technologies -- Primary Residual Transformation Coefficients from Solid Waste to Other Media

Incinerator Incinerator	P KG/MT	HC KG/MT	SO_x KG/MT	CO KG/MT	NO_x KG/MT	SW KG/MT
Multiple Chamber	15	.75	.75	17.5	1	
Multiple Chamber With Water Spray	7	.75	.75	17.5	1	

Intermedia Residual Transformation Coefficients From Particulate to Other Media

	P	SO_x	NO_x	HC	CO	SW
Settling Chamber	.30 .80				.7 (P)	.2 (P)
Cyclone	.20 .70				.8 (P)	.3 (P)
Electrostatic Precipitator	.05 .10				.95(P)	.9 (P)
Fabric Filter	.01 .05				.99(P)	.95(P)
Wet Scrubber	.10 .20	.10 .20	.40 .60		.9 (P)	.8 (P)
Afterburner				0	0	

Intermedia Residual Transformation Coefficients From Bottom Ash to Other Media

	P	SO_x	NO_x	HC	CO	SW
Open Dumping						
Sanitary Landfill						
Discharge to Water Bodies						

Table P8

Residual Generation Coefficients

Printing and Publishing

Unit of activity: Million dollars of output
Level of pollutants: Kilograms
Level of waste water: Million liters

Air Pollutant Emissions from Alternative Production Processes Other than Heat and Power Generation

	P	HC	SO_x	CO	NO_x
Process 1	--	--	--	--	--
Process 2	--	--	--	--	--
Process 3	--	--	--	--	--

Air Pollutant Emissions from Alternative Production Processes -- Heat and Power Generation

	P	HC	SO_x	CO	NO_x
Process 1	582	6	724	13	271
Process 2	437	5	543	10	203
Process 3	145	3	362	7	136

Water Pollutant Discharges from Alternative Production Processes

	BOD	SS	DS	WW
Process 1	1,381	3,294	--	7.88
Process 2	1,312	2,635	--	6.31
Process 3	1,243	2,470	--	6.31

Solid Waste Generation from Alternative Production Processes

	Combustible	Noncombustible	Total
Process 1			388,181
Process 2			349,363
Process 3			329,953

Table T8a

Residual Transformation Coefficients: Air

Air Pollutant Transformation Factors for Alternative Treatment Processes -- Primary Residual Transformation Coefficients

	P		SO_x		NO_x		HC		CO		Solid Waste (Bottom Ash)	
	H*	L*	H	L	H	L	H	L	H	L		
Settling Chamber	.30	.80									.7 (P)	.2 (P)
Cyclone	.20	.70									.8 (P)	.3 (P)
Electrostatic Precipitator	.05	.10									.95 (P)	.9 (P)
Fabric Filter	.01	.05									.99 (P)	.95 (P)
Wet Scrubber	.10	.20	.10	.20	.40	.60					.9 (P)	.8 (P)
Afterburner							0		0			

Intermedia Residual Transformation Coefficients From Solid Waste (Bottom Ash) to Other Media

	P	SO_x	NO_x	HC	CO	SS	SW
Open Dumping							
Sanitary Landfill							
Discharge to Water Bodies							

*H: High Efficiency
L: Low Efficiency

Table T8b

Residual Transformation Coefficients: Water

Water Pollutant Transformation Factors for Alternative Treatment Processes -- Primary Residual Transformation Coefficients

	BOD	SS	DS	Sludge
Primary Treatment Screening Sedimentation Neutralization & Storage Chemical Addition	.65	.1	0	.35(BOD)+.9 (SS)+1(DS)
Secondary Treatment Activated Sludge Trickling Filter	.1	.05	.95	.9 (BOD)+.95(SS)+.5(DS)
Tertiary Treatment Activated Carbon Iron Exchange	.01	.01	.5	.99(BOD)+.99(SS)+.5(DS)

Intermedia Residual Transformation Coefficients From Sludge to Other Media

	P*	SO_x	NO_x	HC	CO	SW*
Incinerator Open Dumping Sanitary Landfill						

* For further treatment of P and SW , see 3-Ta.

Table T8c

Residual Transformation Coefficients: Solid Waste (Combustible)

Solid Waste Transformation Factors for Alternative Control Technologies -- Primary Residual Transformation Coefficients from Solid Waste to Other Media

Incinerator Incinerator	P KG/MT	HC KG/MT	SO_x KG/MT	CO KG/MT	NO_x KG/MT	SW KG/MT
Multiple Chamber	15	.75	.75	17.5	1	
Multiple Chamber With Water Spray	7	.75	.75	17.5	1	

Intermedia Residual Transformation Coefficients From Particulate to Other Media

	P	SO_x	NO_x	HC	CO	SW
Settling Chamber	.30 .80				.7 (P)	.2 (P)
Cyclone	.20 .70				.8 (P)	.3 (P)
Electrostatic Precipitator	.05 .10				.95 (P)	.9 (P)
Fabric Filter	.01 .05				.99 (P)	.95 (P)
Wet Scrubber	.10 .20	.10 .20	.40 .60		.9 (P)	.8 (P)
Afterburner				0	0	

Intermedia Residual Transformation Coefficients From Bottom Ash to Other Media

	P	SO_x	NO_x	HC	CO	SW
Open Dumping						
Sanitary Landfill						
Discharge to Water Bodies						

Table P9

Residual Generation Coefficients

Chemical and Allied Products

Unit of activity: Million dollars of output
Level of pollutants: Kilograms
Level of waste water: Million liters

Air Pollutant Emissions from Alternative Production Processes Other than Heat and Power Generation

	P	HC	SO_x	CO	NO_x
Process 1	4,717	17,237	12,882	10,886	3,629
Process 2	5,715	15,513	11,594	9,798	3,266
Process 3	5,398	15,558	11,594	9,798	3,266

Air Pollutant Emissions from Alternative Production Processes -- Heat and Power Generation

	P	HC	SO_x	CO	NO_x
Process 1	51,615	324	26,371	937	9,127
Process 2	38,710	243	19,778	701	6,835
Process 3	12,905	162	13,186	469	4,564

Water Pollutant Discharges from Alternative Production Processes

	BOD	SS	DS	WW
Process 1	121,470	23,792	647,832	101.73
Process 2	97,175	20,224	485,850	111.90
Process 3	91,101	19,034	453,400	116.98

Solid Waste Generation from Alternative Production Processes

	Combustible	Noncombustible	Total
Process 1			74,281
Process 2			81,712
Process 3			85,422

Table T9a

Residual Transformation Coefficients: Air

Air Pollutant Transformation Factors for Alternative Treatment Processes -- Primary Residual Transformation Coefficients

	P		SO_x		NO_x		HC		CO		Solid Waste (Bottom Ash)	
	H*	L*	H	L	H	L	H	L	H	L		
Settling Chamber	.30	.80									.7 (P)	.2 (P)
Cyclone	.20	.70									.8 (P)	.3 (P)
Electrostatic Precipitator	.05	.10									.95(P)	.9 (P)
Fabric Filter	.01	.05									.99(P)	.95(P)
Wet Scrubber	.10	.20	.10	.20	.40	.60					.9 (P)	.8 (P)
Afterburner							0		0			

Intermedia Residual Transformation Coefficients From Solid Waste (Bottom Ash) to Other Media

	P	SO_x	NO_x	HC	CO	SS	SW
Open Dumping							
Sanitary Landfill							
Discharge to Water Bodies							

*H: High Efficiency
L: Low Efficiency

Table T9b

Residual Transformation Coefficients: Water

Water Pollutant Transformation Factors for Alternative Treatment Processes -- Primary Residual Transformation Coefficients

	BOD	SS	DS	Sludge
Primary Treatment Screening Sedimentation Neutralization & Storage Chemical Addition	.65	.1	0	.35(BOD)+.9 (SS)+1(DS)
Secondary Treatment Activated Sludge Trickling Filter	.1	.05	.95	.9 (BOD)+.95(SS)+.5(DS)
Tertiary Treatment Activated Carbon Iron Exchange	.01	.01	.5	.99(BOD)+.99(SS)+.5(DS)

Intermedia Residual Transformation Coefficients From Sludge to Other Media

	P*	SO_x	NO_x	HC	CO	SW*
Incinerator Open Dumping Sanitary Landfill						

* For further treatment of P and SW , see 3-Ta.

Table T9c

Residual Transformation Coefficients: Solid Waste (Combustible)

Solid Waste Transformation Factors for Alternative Control Technologies -- Primary Residual Transformation Coefficients from Solid Waste to Other Media

Incinerator Incinerator	P KG/MT	HC KG/MT	SO_x KG/MT	CO KG/MT	NO_x KG/MT	SW KG/MT
Multiple Chamber	15	.75	.75	17.5	1	
Multiple Chamber With Water Spray	7	.75	.75	17.5	1	

Intermedia Residual Transformation Coefficients From Particulate to Other Media

	P	SO_x	NO_x	HC	CO	SW
Settling Chamber	.30 .80				.7 (P)	.2 (P)
Cyclone	.20 .70				.8 (P)	.3 (P)
Electrostatic Precipitator	.05 .10				.95 (P)	.9 (P)
Fabric Filter	.01 .05				.99 (P)	.95 (P)
Wet Scrubber	.10 .20	.10 .20	.40 .60		.9 (P)	.8 (P)
Afterburner				0	0	

Intermedia Residual Transformation Coefficients From Bottom Ash to Other Media

	P	SO_x	NO_x	HC	CO	SW
Open Dumping						
Sanitary Landfill						
Discharge to Water Bodies						

Table P10

Residual Generation Coefficients

Petroleum and Coal Products

Unit of activity: Million dollars of output
Level of pollutants: Kilograms
Level of waste water: Million liters

Air Pollutant Emissions from Alternative Production Processes Other than Heat and Power Generation

	P	HC	SO_x	CO	NO_x
Process 1	32,583	150,195	106,722	94,874	1,307
Process 2	34,212	165,214	117,394	104,361	1,437
Process 3	30,954	135,175	96,050	85,386	1,176

Air Pollutant Emissions from Alternative Production Processes -- Heat and Power Generation

	P	HC	SO_x	CO	NO_x
Process 1	4,197	40	4,576	91	7,090
Process 2	3,148	30	3,432	68	5,318
Process 3	1,049	20	2,288	46	3,545

Water Pollutant Discharges from Alternative Production Processes

	BOD	SS	DS	WW
Process 1	10,560	9,716	15,397	43.76
Process 2	11,088	9,716	16,937	48.13
Process 3	8,448	8,258	12,317	37.19

Solid Waste Generation from Alternative Production Processes

	Combustible	Noncombustible	Total
Process 1			--
Process 2			--
Process 3			--

Table T10a

Residual Transformation Coefficients: Air

Air Pollutant Transformation Factors for Alternative Treatment Processes -- Primary Residual Transformation Coefficients

	P		SO_x		NO_x		HC		CO		Solid Waste (Bottom Ash)	
	H*	L*	H	L	H	L	H	L	H	L		
Settling Chamber	.30	.80									.7 (P)	.2 (P)
Cyclone	.20	.70									.8 (P)	.3 (P)
Electrostatic Precipitator	.05	.10									.95 (P)	.9 (P)
Fabric Filter	.01	.05									.99 (P)	.95 (P)
Wet Scrubber	.10	.20	.10	.20	.40	.60					.9 (P)	.8 (P)
Afterburner							0		0			

Intermedia Residual Transformation Coefficients From Solid Waste (Bottom Ash) to Other Media

	P	SO_x	NO_x	HC	CO	SS	SW
Open Dumping							
Sanitary Landfill							
Discharge to Water Bodies							

*H: High Efficiency
L: Low Efficiency

Table T10b

Residual Transformation Coefficients: Water

Water Pollutant Transformation Factors for Alternative Treatment Processes -- Primary Residual Transformation Coefficients

	BOD	SS	DS	Sludge
Primary Treatment Screening Sedimentation Neutralization .& Storage Chemical Addition	.65	.1	0	.35(BOD)+.9 (SS)+1(DS)
Secondary Treatment Activated Sludge Trickling Filter	.1	.05	.95	.9 (BOD)+.95(SS)+.5(DS)
Tertiary Treatment Activated Carbon Iron Exchange	.01	.01	.5	.99(BOD)+.99(SS)+.5(DS)

Intermedia Residual Transformation Coefficients From Sludge to Other Media

	P*	SO_x	NO_x	HC	CO	SW*
Incinerator Open Dumping Sanitary Landfill						

* For further treatment of P and SW , see 3-Ta.

Table T10c

Residual Transformation Coefficients: Solid Waste (Combustible)

Solid Waste Transformation Factors for Alternative Control Technologies -- Primary Residual Transformation Coefficients from Solid Waste to Other Media

Incinerator Incinerator	P KG/MT	HC KG/MT	SO_x KG/MT	CO KG/MT	NO_x KG/MT	SW KG/MT
Multiple Chamber	15	.75	.75	17.5	1	
Multiple Chamber With Water Spray	7	.75	.75	17.5	1	

Intermedia Residual Transformation Coefficients From Particulate to Other Media

	P	SO_x	NO_x	HC	CO	SW
Settling Chamber	.30 .80				.7 (P)	.2 (P)
Cyclone	.20 .70				.8 (P)	.3 (P)
Electrostatic Precipitator	.05 .10				.95 (P)	.9 (P)
Fabric Filter	.01 .05				.99 (P)	.95 (P)
Wet Scrubber	.10 .20	.10 .20	.40 .60		.9 (P)	.8 (P)
Afterburner				0	0	

Intermedia Residual Transformation Coefficients From Bottom Ash to Other Media

	P	SO_x	NO_x	HC	CO	SW
Open Dumping						
Sanitary Landfill						
Discharge to Water Bodies						

Residual Generation Coefficients

Rubber and Plastic Products

Unit of activity: Million dollars of output
Level of pollutants: Kilograms
Level of waste water: Million liters

Air Pollutant Emissions from Alternative Production Processes Other than Heat and Power Generation

	P	HC	SO_x	CO	NO_x
Process 1	--	--	--	--	--
Process 2	--	--	--	--	--
Process 3	--	--	--	--	--

Air Pollutant Emissions from Alternative Production Processes -- Heat and Power Generation

	P	HC	SO_x	CO	NO_x
Process 1	18,044	120	10,264	330	2,922
Process 2	13,533	90	7,698	248	2,192
Process 3	4,511	60	5,132	165	1,961

Water Pollutant Discharges from Alternative Production Processes

	BOD	SS	DS	WW
Process 1	1,637	2,046	--	6.73
Process 2	1,637	2,046	--	6.73
Process 3	1,637	2,046	--	6.73

Solid Waste Generation from Alternative Production Processes

	Combustible	Noncombustible	Total
Process 1			202,214
Process 2			222,436
Process 3			232,546

Table T11a

Residual Transformation Coefficients: Air

Air Pollutant Transformation Factors for Alternative Treatment Processes -- Primary Residual Transformation Coefficients

	P		SO_x		NO_x		HC		CO		Solid Waste (Bottom Ash)	
	H*	L*	H	L	H	L	H	L	H	L		
Settling Chamber	.30	.80									.7 (P)	.2 (P)
Cyclone	.20	.70									.8 (P)	.3 (P)
Electrostatic Precipitator	.05	.10									.95 (P)	.9 (P)
Fabric Filter	.01	.05									.99 (P)	.95 (P)
Wet Scrubber	.10	.20	.10	.20	.40	.60					.9 (P)	.8 (P)
Afterburner							0		0			

Intermedia Residual Transformation Coefficients From Solid Waste (Bottom Ash) to Other Media

	P	SO_x	NO_x	HC	CO	SS	SW
Open Dumping							
Sanitary Landfill							
Discharge to Water Bodies							

*H: High Efficiency
L: Low Efficiency

Table T11b

Residual Transformation Coefficients: Water

Water Pollutant Transformation Factors for Alternative Treatment Processes -- Primary Residual Transformation Coefficients

	BOD	SS	DS	Sludge
Primary Treatment Screening Sedimentation Neutralization & Storage Chemical Addition	.65	.1	0	.35(BOD)+.9 (SS)+1(DS)
Secondary Treatment Activated Sludge Trickling Filter	.1	.05	.95	.9 (BOD)+.95(SS)+.5(DS)
Tertiary Treatment Activated Carbon Iron Exchange	.01	.01	.5	.99(BOD)+.99(SS)+.5(DS)

Intermedia Residual Transformation Coefficients From Sludge to Other Media

	P*	SO_x	NO_x	HC	CO	SW*
Incinerator Open Dumping Sanitary Landfill						

* For further treatment of P and SW, see 3-Ta.

Table T11c

Residual Transformation Coefficients: Solid Waste (Combustible)

Solid Waste Transformation Factors for Alternative Control Technologies -- Primary Residual Transformation Coefficients from Solid Waste to Other Media

Incinerator Incinerator	P KG/MT	HC KG/MT	SO_x KG/MT	CO KG/MT	NO_x KG/MT	SW KG/MT
Multiple Chamber	15	.75	.75	17.5	1	
Multiple Chamber With Water Spray	7	.75	.75	17.5	1	

Intermedia Residual Transformation Coefficients From Particulate to Other Media

	P	SO_x	NO_x	HC	CO	SW
Settling Chamber	.30 .80				.7 (P)	.2 (P)
Cyclone	.20 .70				.8 (P)	.3 (P)
Electrostatic Precipitator	.05 .10				.95 (P)	.9 (P)
Fabric Filter	.01 .05				.99 (P)	.95 (P)
Wet Scrubber	.10 .20	.10 .20	.40 .60		.9 (P)	.8 (P)
Afterburner				0	0	

Intermedia Residual Transformation Coefficients From Bottom Ash to Other Media

	P	SO_x	NO_x	HC	CO	SW
Open Dumping						
Sanitary Landfill						
Discharge to Water Bodies						

Table P12

Residual Generation Coefficients

Leather and Leather Products

Unit of activity: Million dollars of output
Level of pollutants: Kilograms
Level of waste water: Million liters

Air Pollutant Emissions from Alternative Production Processes Other than Heat and Power Generation

	P	HC	SO_x	CO	NO_x
Process 1	--	--	--	--	--
Process 2	--	--	--	--	--
Process 3	--	--	--	--	--

Air Pollutant Emissions from Alternative Production Processes -- Heat and Power Generation

	P	HC	SO_x	CO	NO_x
Process 1	6,817	51	4,866	130	4,928
Process 2	5,113	38	3,650	98	3,696
Process 3	1,704	26	2,433	65	2,464

Water Pollutant Discharges from Alternative Production Processes

	BOD	SS	DS	WW
Process 1	1,381	3,294	--	7.88
Process 2	1,312	2,635	--	6.31
Process 3	1,243	2,470	--	6.31

Solid Waste Generation from Alternative Production Processes

	Combustible	Noncombustible	Total
Process 1			--
Process 2			--
Process 3			--

Table T12a

Residual Transformation Coefficients: Air

Air Pollutant Transformation Factors for Alternative Treatment Processes -- Primary Residual Transformation Coefficients

	P		SO_x		NO_x		HC		CO		Solid Waste (Bottom Ash)	
	H*	L*	H	L	H	L	H	L	H	L		
Settling Chamber	.30	.80									.7 (P)	.2 (P)
Cyclone	.20	.70									.8 (P)	.3 (P)
Electrostatic Precipitator	.05	.10									.95 (P)	.9 (P)
Fabric Filter	.01	.05									.99 (P)	.95 (P)
Wet Scrubber	.10	.20	.10	.20	.40	.60					.9 (P)	.8 (P)
Afterburner							0		0			

Intermedia Residual Transformation Coefficients From Solid Waste (Bottom Ash) to Other Media

	P	SO_x	NO_x	HC	CO	SS	SW
Open Dumping							
Sanitary Landfill							
Discharge to Water Bodies							

*H: High Efficiency
L: Low Efficiency

Table T12b

Residual Transformation Coefficients: Water

Water Pollutant Transformation Factors for Alternative Treatment Processes -- Primary Residual Transformation Coefficients

	BOD	SS	DS	Sludge
Primary Treatment Screening Sedimentation Neutralization & Storage Chemical Addition	.65	.1	0	.35(BOD)+.9 (SS)+1(DS)
Secondary Treatment Activated Sludge Trickling Filter	.1	.05	.95	.9 (BOD)+.95(SS)+.5(DS)
Tertiary Treatment Activated Carbon Iron Exchange	.01	.01	.5	.99(BOD)+.99(SS)+.5(DS)

Intermedia Residual Transformation Coefficients From Sludge to Other Media

	P*	SO_x	NO_x	HC	CO	SW*
Incinerator Open Dumping Sanitary Landfill						

* For further treatment of P and SW , see 3-Ta.

Table T12c

Residual Transformation Coefficients: Solid Waste (Combustible)

Solid Waste Transformation Factors for Alternative Control Technologies -- Primary Residual Transformation Coefficients from Solid Waste to Other Media

Incinerator Incinerator	P KG/MT	HC KG/MT	SO_x KG/MT	CO KG/MT	NO_x KG/MT	SW KG/MT
Multiple Chamber	15	.75	.75	17.5	1	
Multiple Chamber With Water Spray	7	.75	.75	17.5	1	

Intermedia Residual Transformation Coefficients From Particulate to Other Media

	P	SO_x	NO_x	HC	CO	SW
Settling Chamber	.30 .80				.7 (P)	.2 (P)
Cyclone	.20 .70				.8 (P)	.3 (P)
Electrostatic Precipitator	.05 .10				.95 (P)	.9 (P)
Fabric Filter	.01 .05				.99 (P)	.95 (P)
Wet Scrubber	.10 .20	.10 .20	.40 .60		.9 (P)	.8 (P)
Afterburner				0	0	

Intermedia Residual Transformation Coefficients From Bottom Ash to Other Media

	P	SO_x	NO_x	HC	CO	SW
Open Dumping						
Sanitary Landfill						
Discharge to Water Bodies						

Table P13

Residual Generation Coefficients

Stone, Clay and Glass Products

Unit of activity: Million dollars of output
Level of pollutants: Kilograms
Level of waste water: Million liters

Air Pollutant Emissions from Alternative Production Processes Other than Heat and Power Generation

	P	HC	SO_x	CO	NO_x
Process 1	132,074	--	--	--	--
Process 2	118,867	--	--	--	--
Process 3	118,867	--	--	--	--

Air Pollutant Emissions from Alternative Production Processes -- Heat and Power Generation

	P	HC	SO_x	CO	NO_x
Process 1	22,216	421	35,102	1,195	13,025
Process 2	16,662	316	26,327	896	9,769
Process 3	5,554	211	17,551	598	6,513

Water Pollutant Discharges from Alternative Production Processes

	BOD	SS	DS	WW
Process 1	1,381	3,294	--	7.88
Process 2	1,312	2,635	--	6.31
Process 3	1,243	2,470	--	6.31

Solid Waste Generation from Alternative Production Processes

	Combustible	Noncombustible	Total
Process 1			158,524
Process 2			174,376
Process 3			190,227

Table T13a

Residual Transformation Coefficients: Air

Air Pollutant Transformation Factors for Alternative Treatment Processes -- Primary Residual Transformation Coefficients

	P		SO_x		NO_x		HC		CO		Solid Waste (Bottom Ash)	
	H*	L*	H	L	H	L	H	L	H	L		
Settling Chamber	.30	.80									.7 (P)	.2 (P)
Cyclone	.20	.70									.8 (P)	.3 (P)
Electrostatic Precipitator	.05	.10									.95 (P)	.9 (P)
Fabric Filter	.01	.05									.99 (P)	.95 (P)
Wet Scrubber	.10	.20	.10	.20	.40	.60					.9 (P)	.8 (P)
Afterburner							0		0			

Intermedia Residual Transformation Coefficients From Solid Waste (Bottom Ash) to Other Media

	P	SO_x	NO_x	HC	CO	SS	SW
Open Dumping							
Sanitary Landfill							
Discharge to Water Bodies							

*H: High Efficiency
L: Low Efficiency

Table T13b

Residual Transformation Coefficients: Water

Water Pollutant Transformation Factors for Alternative Treatment Processes -- Primary Residual Transformation Coefficients

	BOD	SS	DS	Sludge
Primary Treatment Screening Sedimentation Neutralization & Storage Chemical Addition	.65	.1	0	.35(BOD)+.9 (SS)+1(DS)
Secondary Treatment Activated Sludge Trickling Filter	.1	.05	.95	.9 (BOD)+.95(SS)+.5(DS)
Tertiary Treatment Activated Carbon Iron Exchange	.01	.01	.5	.99(BOD)+.99(SS)+.5(DS)

Intermedia Residual Transformation Coefficients From Sludge to Other Media

	P*	SO_x	NO_x	HC	CO	SW*
Incinerator Open Dumping Sanitary Landfill						

* For further treatment of P and SW, see 3-Ta.

Table T13c

Residual Transformation Coefficients: Solid Waste (Combustible)

Solid Waste Transformation Factors for Alternative Control Technologies -- Primary Residual Transformation Coefficients from Solid Waste to Other Media

Incinerator Incinerator	P KG/MT	HC KG/MT	SO_x KG/MT	CO KG/MT	NO_x KG/MT	SW KG/MT
Multiple Chamber	15	.75	.75	17.5	1	
Multiple Chamber With Water Spray	7	.75	.75	17.5	1	

Intermedia Residual Transformation Coefficients From Particulate to Other Media

	P		SO_x		NO_x		HC		CO		SW	
Settling Chamber	.30	.80									.7 (P)	.2 (P)
Cyclone	.20	.70									.8 (P)	.3 (P)
Electrostatic Precipitator	.05	.10									.95 (P)	.9 (P)
Fabric Filter	.01	.05									.99 (P)	.95 (P)
Wet Scrubber	.10	.20	.10	.20	.40	.60					.9 (P)	.8 (P)
Afterburner							0		0			

Intermedia Residual Transformation Coefficients From Bottom Ash to Other Media

	P	SO_x	NO_x	HC	CO	SW
Open Dumping						
Sanitary Landfill						
Discharge to Water Bodies						

Table P14

Residual Generation Coefficients

Primary Metal Industries

Unit of activity: Million dollars of output
Level of pollutants: Kilograms
Level of waste water: Million liters

Air Pollutant Emissions from Alternative Production Processes Other than Heat and Power Generation

	P	HC	SO_x	CO	NO_x
Process 1	40,337	--	72,745	11,151	--
Process 2	46,387	--	83,657	12,824	--
Process 3	50,421	--	90,932	13,939	--

Air Pollutant Emissions from Alternative Production Processes -- Heat and Power Generation

	P	HC	SO_x	CO	NO_x
Process 1	27,063	200	18,823	515	7,023
Process 2	20,297	150	14,117	386	5,267
Process 3	6,766	100	9,912	258	3,512

Water Pollutant Discharges from Alternative Production Processes

	BOD	SS	DS	WW
Process 1	6,267	61,358	81,593	157.76
Process 2	6,267	55,222	81,593	173.54
Process 3	6,267	52,154	81,593	189.32

Solid Waste Generation from Alternative Production Processes

	Combustible	Noncombustible	Total
Process 1			37,279
Process 2			41,007
Process 3			44,734

Table T14a

Residual Transformation Coefficients: Air

Air Pollutant Transformation Factors for Alternative Treatment Processes -- Primary Residual Transformation Coefficients

	P		SO_x		NO_x		HC		CO		Solid Waste (Bottom Ash)	
	H*	L*	H	L	H	L	H	L	H	L		
Settling Chamber	.30	.80									.7 (P)	.2 (P)
Cyclone	.20	.70									.8 (P)	.3 (P)
Electrostatic Precipitator	.05	.10									.95(P)	.9 (P)
Fabric Filter	.01	.05									.99(P)	.95(P)
Wet Scrubber	.10	.20	.10	.20	.40	.60					.9 (P)	.8 (P)
Afterburner							0		0			

Intermedia Residual Transformation Coefficients From Solid Waste (Bottom Ash) to Other Media

	P	SO_x	NO_x	HC	CO	SS	SW
Open Dumping							
Sanitary Landfill							
Discharge to Water Bodies							

*H: High Efficiency
L: Low Efficiency

Table T14b

Residual Transformation Coefficients: Water

Water Pollutant Transformation Factors for Alternative Treatment Processes -- Primary Residual Transformation Coefficients

	BOD	SS	DS	Sludge
Primary Treatment Screening Sedimentation Neutralization & Storage Chemical Addition	.65	.1	0	.35(BOD)+.9 (SS)+1(DS)
Secondary Treatment Activated Sludge Trickling Filter	.1	.05	.95	.9 (BOD)+.95(SS)+.5(DS)
Tertiary Treatment Activated Carbon Iron Exchange	.01	.01	.5	.99(BOD)+.99(SS)+.5(DS)

Intermedia Residual Transformation Coefficients From Sludge to Other Media

	P*	SO_x	NO_x	HC	CO	SW*
Incinerator Open Dumping Sanitary Landfill						

* For further treatment of P and SW , see 3-Ta.

Table T14c

Residual Transformation Coefficients: Solid Waste (Combustible)

Solid Waste Transformation Factors for Alternative Control Technologies -- Primary Residual Transformation Coefficients from Solid Waste to Other Media

Incinerator Incinerator	P KG/MT	HC KG/MT	SO_x KG/MT	CO KG/MT	NO_x KG/MT	SW KG/MT
Multiple Chamber	15	.75	.75	17.5	1	
Multiple Chamber With Water Spray	7	.75	.75	17.5	1	

Intermedia Residual Transformation Coefficients From Particulate to Other Media

	P	SO_x	NO_x	HC	CO	SW
Settling Chamber	.30 .80				.7 (P)	.2 (P)
Cyclone	.20 .70				.8 (P)	.3 (P)
Electrostatic Precipitator	.05 .10				.95 (P)	.9 (P)
Fabric Filter	.01 .05				.99 (P)	.95 (P)
Wet Scrubber	.10 .20	.10 .20	.40 .60		.9 (P)	.8 (P)
Afterburner				0	0	

Intermedia Residual Transformation Coefficients From Bottom Ash to Other Media

	P	SO_x	NO_x	HC	CO	SW
Open Dumping						
Sanitary Landfill						
Discharge to Water Bodies						

Table P15

Residual Generation Coefficients

Fabricated Metal Products

Unit of activity: Million dollars of output
Level of pollutants: Kilograms
Level of waste water: Million liters

Air Pollutant Emissions from Alternative Production Processes Other than Heat and Power Generation

	P	HC	SO_x	CO	NO_x
Process 1	--	--	--	--	--
Process 2	--	--	--	--	--
Process 3	--	--	--	--	--

Air Pollutant Emissions from Alternative Production Processes -- Heat and Power Generation

	P	HC	SO_x	CO	NO_x
Process 1	3,292	29	3,076	67	1,105
Process 2	2,469	22	2,307	50	829
Process 3	823	15	1,538	34	553

Water Pollutant Discharges from Alternative Production Processes

	BOD	SS	DS	WW
Process 1	1,381	3,294	--	7.88
Process 2	1,312	2,635	--	6.31
Process 3	1,243	2,470	--	6.31

Solid Waste Generation from Alternative Production Processes

	Combustible	Noncombustible	Total
Process 1			--
Process 2			--
Process 3			--

Table T15a

Residual Transformation Coefficients: Air

Air Pollutant Transformation Factors for Alternative Treatment Processes -- Primary Residual Transformation Coefficients

	P		SO_x		NO_x		HC		CO		Solid Waste (Bottom Ash)	
	H*	L*	H	L	H	L	H	L	H	L		
Settling Chamber	.30	.80									.7 (P)	.2 (P)
Cyclone	.20	.70									.8 (P)	.3 (P)
Electrostatic Precipitator	.05	.10									.95 (P)	.9 (P)
Fabric Filter	.01	.05									.99 (P)	.95 (P)
Wet Scrubber	.10	.20	.10	.20	.40	.60					.9 (P)	.8 (P)
Afterburner							0		0			

Intermedia Residual Transformation Coefficients From Solid Waste (Bottom Ash) to Other Media

	P	SO_x	NO_x	HC	CO	SS	SW
Open Dumping							
Sanitary Landfill							
Discharge to Water Bodies							

*H: High Efficiency
L: Low Efficiency

Table T15b

Residual Transformation Coefficients: Water

Water Pollutant Transformation Factors for Alternative Treatment Processes -- Primary Residual Transformation Coefficients

	BOD	SS	DS	Sludge
Primary Treatment Screening Sedimentation Neutralization & Storage Chemical Addition	.65	.1	0	.35(BOD)+.9 (SS)+1(DS)
Secondary Treatment Activated Sludge Trickling Filter	.1	.05	.95	.9 (BOD)+.95(SS)+.5(DS)
Tertiary Treatment Activated Carbon Iron Exchange	.01	.01	.5	.99(BOD)+.99(SS)+.5(DS)

Intermedia Residual Transformation Coefficients From Sludge to Other Media

	P*	SO_x	NO_x	HC	CO	SW*
Incinerator Open Dumping Sanitary Landfill						

* For further treatment of P and SW , see 3-Ta..

Table T15c

Residual Transformation Coefficients: Solid Waste (Combustible)

Solid Waste Transformation Factors for Alternative Control Technologies -- Primary Residual Transformation Coefficients from Solid Waste to Other Media

Incinerator Incinerator	P KG/MT	HC KG/MT	SO_x KG/MT	CO KG/MT	NO_x KG/MT	SW KG/MT
Multiple Chamber	15	.75	.75	17.5	1	
Multiple Chamber With Water Spray	7	.75	.75	17.5	1	

Intermedia Residual Transformation Coefficients From Particulate to Other Media

	P	SO_x	NO_x	HC	CO	SW
Settling Chamber	.30 .80				.7 (P)	.2 (P)
Cyclone	.20 .70				.8 (P)	.3 (P)
Electrostatic Precipitator	.05 .10				.95(P)	.9 (P)
Fabric Filter	.01 .05				.99(P)	.95(P)
Wet Scrubber	.10 .20	.10 .20	.40 .60		.9 (P)	.8 (P)
Afterburner				0	0	

Intermedia Residual Transformation Coefficients From Bottom Ash to Other Media

	P	SO_x	NO_x	HC	CO	SW
Open Dumping						
Sanitary Landfill						
Discharge to Water Bodies						

Table P16

Residual Generation Coefficients

Machinery, Except Electrical

Unit of activity: Million dollars of output
Level of pollutants: Kilograms
Level of waste water: Million liters

Air Pollutant Emissions from Alternative Production Processes Other than Heat and Power Generation

	P	HC	SO_x	CO	NO_x
Process 1	--	--	--	--	--
Process 2	--	--	--	--	--
Process 3	--	--	--	--	--

Air Pollutant Emissions from Alternative Production Processes -- Heat and Power Generation

	P	HC	SO_x	CO	NO_x
Process 1	5,344	40	3,713	102	1,149
Process 2	4,008	30	2,785	77	862
Process 3	1,336	20	1,857	51	575

Water Pollutant Discharges from Alternative Production Processes

	BOD	SS	DS	WW
Process 1	643	536	--	2.87
Process 2	611	429	--	2.29
Process 3	578	402	--	2.29

Solid Waste Generation from Alternative Production Processes

	Combustible	Noncombustible	Total
Process 1			--
Process 2			--
Process 3			--

Table T16b

Residual Transformation Coefficients: Air

Air Pollutant Transformation Factors for Alternative Treatment Processes -- Primary Residual Transformation Coefficients

	P		SO_x		NO_x		HC		CO		Solid Waste (Bottom Ash)	
	H*	L*	H	L	H	L	H	L	H	L		
Settling Chamber	.30	.80									.7 (P)	.2 (P)
Cyclone	.20	.70									.8 (P)	.3 (P)
Electrostatic Precipitator	.05	.10									.95 (P)	.9 (P)
Fabric Filter	.01	.05									.99 (P)	.95 (P)
Wet Scrubber	.10	.20	.10	.20	.40	.60					.9 (P)	.8 (P)
Afterburner							0		0			

Intermedia Residual Transformation Coefficients From Solid Waste (Bottom Ash) to Other Media

	P	SO_x	NO_x	HC	CO	SS	SW
Open Dumping							
Sanitary Landfill							
Discharge to Water Bodies							

*H: High Efficiency
L: Low Efficiency

Table T16b

Residual Transformation Coefficients: Water

Water Pollutant Transformation Factors for Alternative Treatment Processes -- Primary Residual Transformation Coefficients

	BOD	SS	DS	Sludge
Primary Treatment Screening Sedimentation Neutralization & Storage Chemical Addition	.65	.1	0	.35(BOD)+.9 (SS)+1(DS)
Secondary Treatment Activated Sludge Trickling Filter	.1	.05	.95	.9 (BOD)+.95(SS)+.5(DS)
Tertiary Treatment Activated Carbon Iron Exchange	.01	.01	.5	.99(BOD)+.99(SS)+.5(DS)

Intermedia Residual Transformation Coefficients From Sludge to Other Media

	P*	SO_x	NO_x	HC	CO	SW*
Incinerator Open Dumping Sanitary Landfill						

* For further treatment of P and SW , see 3-Ta.

Table T16c

Residual Transformation Coefficients: Solid Waste (Combustible)

Solid Waste Transformation Factors for Alternative Control Technologies -- Primary Residual Transformation Coefficients from Solid Waste to Other Media

Incinerator Incinerator	P KG/MT	HC KG/MT	SO_x KG/MT	CO KG/MT	NO_x KG/MT	SW KG/MT
Multiple Chamber	15	.75	.75	17.5	1	
Multiple Chamber With Water Spray	7	.75	.75	17.5	1	

Intermedia Residual Transformation Coefficients From Particulate to Other Media

	P	SO_x	NO_x	HC	CO	SW
Settling Chamber	.30 .80				.7 (P)	.2 (P)
Cyclone	.20 .70				.8 (P)	.3 (P)
Electrostatic Precipitator	.05 .10				.95 (P)	.9 (P)
Fabric Filter	.01 .05				.99 (P)	.95 (P)
Wet Scrubber	.10 .20	.10 .20	.40 .60		.9 (P)	.8 (P)
Afterburner				0	0	

Intermedia Residual Transformation Coefficients From Bottom Ash to Other Media

	P	SO_x	NO_x	HC	CO	SW
Open Dumping						
Sanitary Landfill	/					
Discharge to Water Bodies						

Table P17

Residual Generation Coefficients

Electrical Machinery

Unit of activity: Million dollars of output
Level of pollutants: Kilograms
Level of waste water: Million liters

Air Pollutant Emissions from Alternative Production Processes Other than Heat and Power Generation

	P	HC	SO_x	CO	NO_x
Process 1	--	--	--	--	--
Process 2	--	--	--	--	--
Process 3	--	--	--	--	--

Air Pollutant Emissions from Alternative Production Processes -- Heat and Power Generation

	P	HC	SO_x	CO	NO_x
Process 1	3,488	26	2,460	67	774
Process 2	2,616	20	1,845	50	581
Process 3	872	13	1,230	34	387

Water Pollutant Discharges from Alternative Production Processes

	BOD	SS	DS	WW
Process 1	941	269	--	4.52
Process 2	894	215	--	3.62
Process 3	847	202	--	3.62

Solid Waste Generation from Alternative Production Processes

	Combustible	Noncombustible	Total
Process 1			--
Process 2			--
Process 3			--

Table T17a

Residual Transformation Coefficients: Air

Electrical Machinery

Air Pollutant Transformation Factors for Alternative Treatment Processes -- Primary Residual Transformation Coefficients

	P		SO_x		NO_x		HC		CO		Solid Waste (Bottom Ash)	
	H*	L*	H	L	H	L	H	L	H	L		
Settling Chamber	.30	.80									.7 (P)	.2 (P)
Cyclone	.20	.70									.8 (P)	.3 (P)
Electrostatic Precipitator	.05	.10									.95 (P)	.9 (P)
Fabric Filter	.01	.05									.99 (P)	.95 (P)
Wet Scrubber	.10	.20	.10	.20	.40	.60					.9 (P)	.8 (P)
Afterburner							0		0			

Intermedia Residual Transformation Coefficients From Solid Waste (Bottom Ash) to Other Media

	P	SO_x	NO_x	HC	CO	SS	SW
Open Dumping							
Sanitary Landfill							
Discharge to Water Bodies							

*H: High Efficiency
L: Low Efficiency

Table T17b

Residual Transformation Coefficients: Water

Water Pollutant Transformation Factors for Alternative Treatment Processes -- Primary Residual Transformation Coefficients

	BOD	SS	DS	Sludge
Primary Treatment Screening Sedimentation Neutralization & Storage Chemical Addition	.65	.1	0	.35(BOD)+.9 (SS)+1(DS)
Secondary Treatment Activated Sludge Trickling Filter	.1	.05	.95	.9 (BOD)+.95(SS)+.5(DS)
Tertiary Treatment Activated Carbon Iron Exchange	.01	.01	.5	.99(BOD)+.99(SS)+.5(DS)

Intermedia Residual Transformation Coefficients From Sludge to Other Media

	P*	SO_x	NO_x	HC	CO	SW*
Incinerator Open Dumping Sanitary Landfill						

* For further treatment of P and SW, see 3-Ta.

Table T17c

Residual Transformation Coefficients: Solid Waste (Combustible)

Solid Waste Transformation Factors for Alternative Control Technologies -- Primary Residual Transformation Coefficients from Solid Waste to Other Media

Incinerator Incinerator	P KG/MT	HC KG/MT	SO_x KG/MT	CO KG/MT	NO_x KG/MT	SW KG/MT
Multiple Chamber	15	.75	.75	17.5	1	
Multiple Chamber With Water Spray	7	.75	.75	17.5	1	

Intermedia Residual Transformation Coefficients From Particulate to Other Media

	P	SO_x	NO_x	HC	CO	SW
Settling Chamber	.30 .80				.7 (P)	.2 (P)
Cyclone	.20 .70				.8 (P)	.3 (P)
Electrostatic Precipitator	.05 .10				.95 (P)	.9 (P)
Fabric Filter	.01 .05				.99 (P)	.95 (P)
Wet Scrubber	.10 .20	.10 .20	.40 .60		.9 (P)	.8 (P)
Afterburner				0	0	

Intermedia Residual Transformation Coefficients From Bottom Ash to Other Media

	P	SO_x	NO_x	HC	CO	SW
Open Dumping						
Sanitary Landfill						
Discharge to Water Bodies						

Table P18

Residual Generation Coefficients

Transportation Equipment

Unit of activity: Million dollars of output
Level of pollutants: Kilograms
Level of waste water: Million liters

Air Pollutant Emissions from Alternative Production Processes Other than Heat and Power Generation

	P	HC	SO_x	CO	NO_x
Process 1	--	--	--	--	--
Process 2	--	--	--	--	--
Process 3	--	--	--	--	--

Air Pollutant Emissions from Alternative Production Processes -- Heat and Power Generation

	P	HC	SO_x	CO	NO_x
Process 1	4,908	33	2,854	90	844
Process 2	3,681	25	2,141	68	633
Process 3	1,227	17	1,427	45	422

Water Pollutant Discharges from Alternative Production Processes

	BOD	SS	DS	WW
Process 1	891	--	--	4.55
Process 2	846	--	--	3.64
Process 3	802	--	--	3.64

Solid Waste Generation from Alternative Production Processes

	Combustible	Noncombustible	Total
Process 1			--
Process 2			--
Process 3			--

Table T18a

Residual Transformation Coefficients: Air

Air Pollutant Transformation Factors for Alternative Treatment Processes -- Primary Residual Transformation Coefficients

	P		SO_x		NO_x		HC		CO		Solid Waste (Bottom Ash)	
	H*	L*	H	L	H	L	H	L	H	L		
Settling Chamber	.30	.80									.7 (P)	.2 (P)
Cyclone	.20	.70									.8 (P)	.3 (P)
Electrostatic Precipitator	.05	.10									.95 (P)	.9 (P)
Fabric Filter	.01	.05									.99 (P)	.95 (P)
Wet Scrubber	.10	.20	.10	.20	.40	.60					.9 (P)	.8 (P)
Afterburner							0		0			

Intermedia Residual Transformation Coefficients From Solid Waste (Bottom Ash) to Other Media

	P	SO_x	NO_x	HC	CO	SS	SW
Open Dumping							
Sanitary Landfill							
Discharge to Water Bodies							

*H: High Efficiency
L: Low Efficiency

Table T18b

Residual Transformation Coefficients: Water

Water Pollutant Transformation Factors for Alternative Treatment Processes -- Primary Residual Transformation Coefficients

	BOD	SS	DS	Sludge
Primary Treatment Screening Sedimentation Neutralization & Storage Chemical Addition	.65	.1	0	.35(BOD)+.9 (SS)+1(DS)
Secondary Treatment Activated Sludge Trickling Filter	.1	.05	.95	.9 (BOD)+.95(SS)+.5(DS)
Tertiary Treatment Activated Carbon Iron Exchange	.01	.01	.5	.99(BOD)+.99(SS)+.5(DS)

Intermedia Residual Transformation Coefficients From Sludge to Other Media

	P*	SO_x	NO_x	HC	CO	SW*
Incinerator Open Dumping Sanitary Landfill						

* For further treatment of P and SW , see 3-Ta.

Table T18c

Residual Transformation Coefficients: Solid Waste (Combustible)

Solid Waste Transformation Factors for Alternative Control Technologies -- Primary Residual Transformation Coefficients from Solid Waste to Other Media

Incinerator Incinerator	P KG/MT	HC KG/MT	SO_x KG/MT	CO KG/MT	NO_x KG/MT	SW KG/MT
Multiple Chamber	15	.75	.75	17.5	1	
Multiple Chamber With Water Spray	7	.75	.75	17.5	1	

Intermedia Residual Transformation Coefficients From Particulate to Other Media

	P	SO_x	NO_x	HC	CO	SW
Settling Chamber	.30 .80				.7 (P)	.2 (P)
Cyclone	.20 .70				.8 (P)	.3 (P)
Electrostatic Precipitator	.05 .10				.95 (P)	.9 (P)
Fabric Filter	.01 .05				.99 (P)	.95 (P)
Wet Scrubber	.10 .20	.10 .20	.40 .60		.9 (P)	.8 (P)
Afterburner				0	0	

Intermedia Residual Transformation Coefficients From Bottom Ash to Other Media

	P	SO_x	NO_x	HC	CO	SW
Open Dumping						
Sanitary Landfill						
Discharge to Water Bodies						

Table P19

Residual Generation Coefficients

Instruments and Related Products

Unit of activity: Million dollars of output
Level of pollutants: Kilograms
Level of waste water: Million liters

Air Pollutant Emissions from Alternative Production Processes Other than Heat and Power Generation

	P	HC	SO_x	CO	NO_x
Process 1	--	--	--	--	--
Process 2	--	--	--	--	--
Process 3	--	--	--	--	--

Air Pollutant Emissions from Alternative Production Processes -- Heat and Power Generation

	P	HC	SO_x	CO	NO_x
Process 1	6,596	47	4,211	123	1,194
Process 2	4,947	35	3,158	92	896
Process 3	1,649	24	2,206	62	597

Water Pollutant Discharges from Alternative Production Processes

	BOD	SS	DS	WW
Process 1	1,381	3,294	--	7.88
Process 2	1,312	2,635	--	6.31
Process 3	1,243	2,470	--	6.31

Solid Waste Generation from Alternative Production Processes

	Combustible	Noncombustible	Total
Process 1			--
Process 2			--
Process 3			--

Table T19a

Residual Transformation Coefficients: Air

Air Pollutant Transformation Factors for Alternative Treatment Processes -- Primary Residual Transformation Coefficients

	P		SO_x		NO_x		HC		CO		Solid Waste (Bottom Ash)	
	H*	L*	H	L	H	L	H	L	H	L		
Settling Chamber	.30	.80									.7 (P)	.2 (P)
Cyclone	.20	.70									.8 (P)	.3 (P)
Electrostatic Precipitator	.05	.10									.95 (P)	.9 (P)
Fabric Filter	.01	.05									.99 (P)	.95 (P)
Wet Scrubber	.10	.20	.10	.20	.40	.60					.9 (P)	.8 (P)
Afterburner							0		0			

Intermedia Residual Transformation Coefficients From Solid Waste (Bottom Ash) to Other Media

	P	SO_x	NO_x	HC	CO	SS	SW
Open Dumping							
Sanitary Landfill							
Discharge to Water Bodies							

*H: High Efficiency
L: Low Efficiency

Table T19b

Residual Transformation Coefficients: Water

Water Pollutant Transformation Factors for Alternative Treatment Processes -- Primary Residual Transformation Coefficients

	BOD	SS	DS	Sludge
Primary Treatment Screening Sedimentation Neutralization & Storage Chemical Addition	.65	.1	0	.35(BOD)+.9 (SS)+1(DS)
Secondary Treatment Activated Sludge Trickling Filter	.1	.05	.95	.9 (BOD)+.95(SS)+.5(DS)
Tertiary Treatment Activated Carbon Iron Exchange	.01	.01	.5	.99(BOD)+.99(SS)+.5(DS)

Intermedia Residual Transformation Coefficients From Sludge to Other Media

	P*	SO_x	NO_x	HC	CO	SW*
Incinerator Open Dumping Sanitary Landfill						

* For further treatment of P and SW , see 3-Ta.

Table T19c

Residual Transformation Coefficients: Solid Waste (Combustible)

Solid Waste Transformation Factors for Alternative Control Technologies -- Primary Residual Transformation Coefficients from Solid Waste to Other Media

Incinerator Incinerator	P KG/MT	HC KG/MT	SO_x KG/MT	CO KG/MT	NO_x KG/MT	SW KG/MT
Multiple Chamber	15	.75	.75	17.5	1	
Multiple Chamber With Water Spray	7	.75	.75	17.5	1	

Intermedia Residual Transformation Coefficients From Particulate to Other Media

	P	SO_x	NO_x	HC	CO	SW
Settling Chamber	.30 .80				.7 (P)	.2 (P)
Cyclone	.20 .70				.8 (P)	.3 (P)
Electrostatic Precipitator	.05 .10				.95 (P)	.9 (P)
Fabric Filter	.01 .05				.99 (P)	.95 (P)
Wet Scrubber	.10 .20	.10 .20	.40 .60		.9 (P)	.8 (P)
Afterburner				0	0	

Intermedia Residual Transformation Coefficients From Bottom Ash to Other Media

	P	SO_x	NO_x	HC	CO	SW
Open Dumping						
Sanitary Landfill						
Discharge to Water Bodies						

Table P20

Residual Generation Coefficients

Household

Level of activity: Number of housing units
Level of pollutants: Kilograms
Level of waste water: Million liters

Air Pollutant Emission Factors for Single and Multiple Housing Units

	P	HC	SO_x	CO	NO_x
Single Dwelling Units					
Multiple Dwelling Units					

Water Pollutant Discharge Factors for High, Middle, Low Income Housing Units

Units	BOD	SS	DS	WW
High Income Housing				
Middle Income Housing				
Low Income Housing				

Solid Waste Generation Factors for High, Middle, Low Income Housing Units

Units	Combustible	Noncombustible	Total
High Income Housing			
Middle Income Housing			
Low Income Housing			

Table P21

Residual Generation Coefficients

Agriculture

Unit of activity: Million dollars of output
Level of pollutants: Kilograms
Level of waste water: Million liters

Air Pollutant Emissions from Alternative Production Processes

	P	HC	SO_x	CO	NO_x
Process 1					
Process 2					
Process 3					

Water Pollutant Discharges from Alternative Production Processes

	BOD	SS	DS	WW
Process 1				
Process 2				
Process 3				

Solid Waste Generation from Alternative Production Processes

	Combustible	Noncombustible	Total
Process 1			
Process 2			
Process 3			

Table P22

Residual Generation Coefficients

Transportation

Unit of activity: Number of vehicles
Level of pollutants: Kilograms

Air Pollutant Emission Factors for Different Vehicle Types

	P	SO_x	NO_x	HC	CO
Passenger Car					
Passenger Bus					
Truck					
Aircraft					

Table P23

Residual Generation Coefficients

Electric Power Plant

Unit of activity: BBU
Level of pollutants: Kilograms except heat
Level of waste water: Million liters
Heat:

Air Pollutant Emission Factors for Alternative Fuel Types

	P	SO_x	NO_x	HC	CO
Coal:					
High sulfur content					
Average sulfur content					
Low sulfur content					
Oil					
Gas					
Nuclear Power					

Water Pollutant Discharge Factors

	Heat	SS	DS	WW
Fossil fuel				
Nuclear power				

Solid Waste Generation Factors

	Combustible	Noncombustible
Fossil fuel		
Nuclear power		

Table P24

Residual Generation Coefficients

Municipal Incinerator

Unit of activity: Metric tons
Level of pollutants: Kilograms

Air Pollutant Generation Factors for Alternative Incinerator Types

Incinerator Type	P KG/MT	HC KG/MT	SO_x KG/MT	CO KG/MT	NO_x KG/MT	SW KG/MT
Multiple Chamber	15	.75	.75	17.5	1	
Multiple Chamber With Water Spray	7	.75	.75	17.5	1	

Table T24a

Residual Transformation Coefficients

Municipal Incinerator

Air Pollutant Transformation Factors for Alternative Treatment Processes -- Primary Residual Transformation Coefficients

	P		SO_x		NO_x		HC		CO		Solid Waste (Bottom Ash)	
	H*	L*	H	L	H	L	H	L	H	L		
Settling Chamber	.30	.80									.7 (P)	.2 (P)
Cyclone	.20	.70									.8 (P)	.3 (P)
Electrostatic Precipitator	.05	.10									.95(P)	.9 (P)
Fabric Filter	.01	.05									.99(P)	.95(P)
Wet Scrubber	.10	.20	.10	.20	.40	.60					.9 (P)	.8 (P)
Afterburner							0		0			

Intermedia Residual Transformation Coefficients From Solid Waste (Bottom Ash) to Other Media

	P	SO_x	NO_x	HC	CO	SS	SW
Open Dumping							
Sanitary Landfill							
Discharge to Water Bodies							

Table P25

Residual Generation Coefficients

Municipal Waste Water Treatment Plant

Unit of Activity: Million liters of Waste Water
Level of pollutants: Kilograms

Water Pollutant Factors for Different Levels of Concentration of Waste Materials

	BOD	SS	DS
High concentration			
Average concentration	140		
Low concentration			

Table T25b

Residual Transformation Coefficients

Municipal Waste Water Treatment Plant

Water Pollutant Transformation Factors for Alternative Treatment Processes -- Primary Residual Transformation Coefficients

	BOD	SS	DS	Sludge
Primary Treatment	.65	.1	0	.35(BOD)+.9 (SS)+1(DS)
Screening				
Sedimentation				
Neutralization & Storage				
Chemical Addition				
Secondary Treatment	.1	.05	.95	.9 (BOD)+.95(SS)+.5(DS)
Activated Sludge				
Trickling Filter				
Tertiary Treatment	.01	.01	.5	.99(BOD)+.99(SS)+.5(DS)
Activated Carbon				
Iron Exchange				

Intermedia Residual Transformation Coefficients From Sludge to Other Media

	P*	SO_x	NO_x	HC	CO	SW*
Fluidized Bed Incinerator	.47	.01	.006			.514(Sludge)
Multiple Hearth						
Atomized Suspension and Firing						
Wet Air Oxidization						
Open Dumping						
Sanitary Landfill						

*For further treatment of P and SW, see 3-Ta.

SECTION IX

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16. Abstract

The primary objective of the project was to develop a prototype multi-pollution model for a typical metropolitan region. This report includes the basic design and some of the results of initial testing of the model. The Integrated Multi-Media Pollution Model, or IMMP, views environmental pollution as a set of interrelated problems -- the solution of which requires examination of all types of pollution jointly and simultaneously-- and attempts to seek an overall solution to environmental resource management. The model embodies the trade-offs among different forms of residuals disposed finally in the environment that are effected by alternative land use policies, production processes, pollution control strategies and methods. Thus, the Land Use submodel relates various land use policies to the distribution of the sources of environmental pollution; the Residuals submodel relates alternative levels of pollution generating activities, input mixes, production processes of various activities and the alternative treatment processes associated therewith to the magnitude, composition and distribution of pollutants; and Disposal-Dispersion submodel relates pollution emissions at source to (ambient) environmental quality at destination. The model provides a comprehensive framework in which to test and evaluate a wide range of strategies for planning, managing and controlling our environmental resources.

17a. Descriptors

Environmental Resource Management; Land Use Submodel; Residual Management Submodel; Dispersion Submodel; Integrated Multi-Media Pollution Model.

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