DP-MS-75-75
CONF-750706--8

ENVIRONMENTAL SCIENCES AND COMPUTATIONS:
A MODULAR DATA-BASED SYSTEMS APPROACH

by

T. V. Crawford and C. E. Bailey

Savannah River Laboratory
E. I. du Pont de Nemours & Co.
Aiken, South Carolina 29801

A Paper Proposed for Presentation at the
Conference on Computer Support of Environmental Science and Analysis
Albuquerque, New Mexico
July 9-11, 1975

This paper was prepared in connection with work under Contract No. AT(07-2)-1 with the U. S. Energy Research and Development Administration.

ABSTRACT

A major computer code for environmental calculations is under development at the Savannah River Laboratory. The primary aim is to develop a flexible, efficient capability to calculate, for all significant pathways, the dose to man resulting from releases of radionuclides from the Savannah River Plant and from other existing and potential radioactive sources in the southeastern United States.

The environmental sciences programs at SRP are described, with emphasis on the development of the calculational system. It is being developed as a modular data-based system within the framework of the larger JOSHUA Computer System, which provides data management, terminal, and job execution facilities.

ENVIRONMENTAL SCIENCES AND COMPUTATIONS: A MODULAR DATA-BASED SYSTEMS APPROACH*

T. V. Crawford, Research Manager
C. E. Bailey, Staff Chemist

Savannah River Laboratory
E. I. du Pont de Nemours & Co.
Aiken, South Carolina 29801

INTRODUCTION

A modular data-based systems approach is being undertaken to facilitate the use of various computational models being developed by the environmental research programs to help answer environmental questions associated with the operation of the Savannah River Plant (SRP).

The Plant Site

The 300-square-mile Savannah River Plant site is owned by the Energy Research and Development Administration (ERDA) and is located in South Carolina, alongside the Savannah River, south of Aiken, South Carolina and Augusta, Georgia. The Savannah River Plant employs about 5,000 people and has as its main purpose the production of various nuclear materials of interest to the U.S. Government. It is operated by E. I. du Pont de Nemours and Company and consists of three large operating production reactors (there are also two that have been shut down), a nuclear fuel fabrication facility, two large chemical reprocessing plants, a heavy water production plant, and various waste management facilities. This site contains all of the components of the nuclear fuel cycle with the exception of mining and enrichment; however, the nuclear facilities are not used to produce electrical power. The reactors, reprocessing plants, and waste management facilities are located near the middle of the 300-square-mile site. Their locations are indicated on Figure 1. Most of the land on the site not used by specific operating areas or by roads has been planted with pine trees and operated as a pine plantation. The reactors are cooled and moderated by heavy water that is pumped in a closed loop through the core and heat exchangers. In two of the currently operating reactors, the heavy water is cooled by Savannah River water that is discharged to two of the on-site streams. The water flows through the Savannah River swamp before returning to the Savannah River. The third reactor uses water from the Par Pond reservoir, and returns to the reservoir, with makeup water being added from the Savannah River.

* The information contained in this article was developed during the course of work under Contract No. AT(07-2)-1 with the U. S. Energy Research and Development Administration.

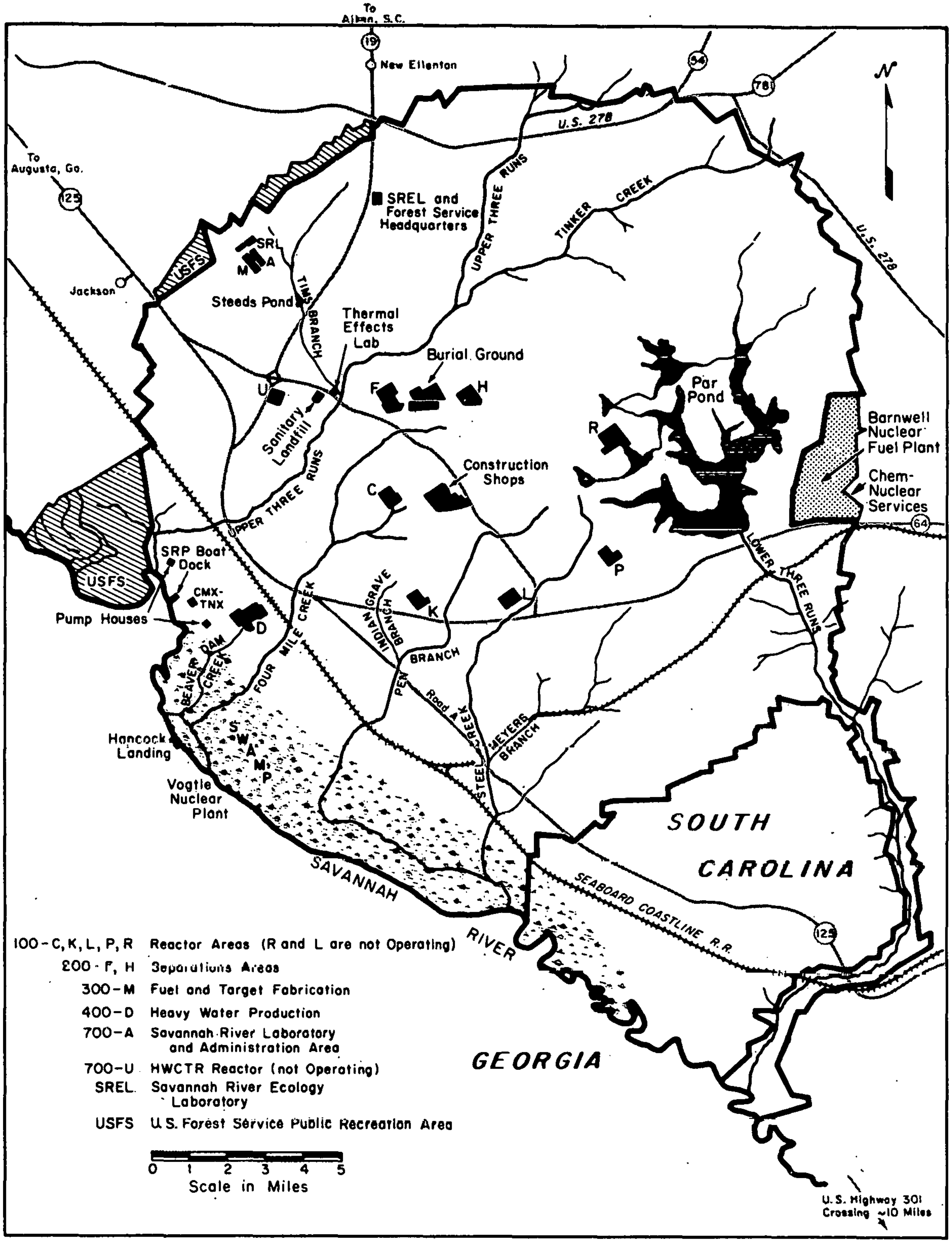

FIGURE 1. The Savannah River Plant Site

The Savannah River Laboratory (SRL) is also located on the SRP site. It has about 900 employees, and its primary objective is the performance of the necessary research and development to support the Savannah River Plant operations. A second objective is the performance of research of general applicability to the nuclear community.

Environmental Studies

Environmental studies commenced at the Savannah River Plant before the start of operations in the early 1950's and have continued on through today. The early studies were largely focused on environmental monitoring (biological, physical, and chemical). Measurements have been and are still being made of radionuclide concentrations in environmental systems and of the effects of thermal discharges, particularly into the Savannah River swamp. The current off-site monitoring network for air, water, and precipitation is shown on Figure 2.

In the last several years, additional emphasis in the environmental programs has been aimed at developing a greater understanding of transport and dispersion processes of materials as they move through environmental systems. Routinely available monitoring data are used as much as possible in these studies, but, in addition, many specialized measurement programs are conducted in order to test the various computational models being developed for transport and dispersion. Part of the reason for this new emphasis has been the rapid development of other nuclear facilities in the southeastern United States (Figure 3), both power reactors and fuel cycle facilities. For instance, a commercial fuel reprocessing plant is currently under construction near Barnwell, South Carolina, on the eastern border of the Savannah River Plant site.

A large environmental monitoring effort is carried out by the Savannah River Plant organization. The transport, dispersion, and effects studies are research programs conducted within the Savannah River Laboratory. Those research efforts which lead to developing and understanding data that are of general applicability to the ERDA are funded by the Division of Biomedical and Environmental Research (ERDA). Those research programs which have specific applicability to the operation of the Savannah River Plant are funded by the Division of Production and Materials Management of ERDA.

In addition to the Du Pont organization at the Savannah River Plant site, the Savannah River Ecology Laboratory (SREL) of the University of Georgia performs basic ecology studies on the site. Also, the U.S. Forest Service manages the timberlands and wildlife preserves. In 1972, the Savannah River Plant site was declared the Nation's first environmental research park. This declaration has facilitated the use of the site by university researchers who wish to perform ecology studies.

Computer Facilities and Personnal

From the very beginning of plant operation, it was realized that a large digital computing facility was necessary to support the reactor physics and engineering calculations. This support now extends to most site operations.

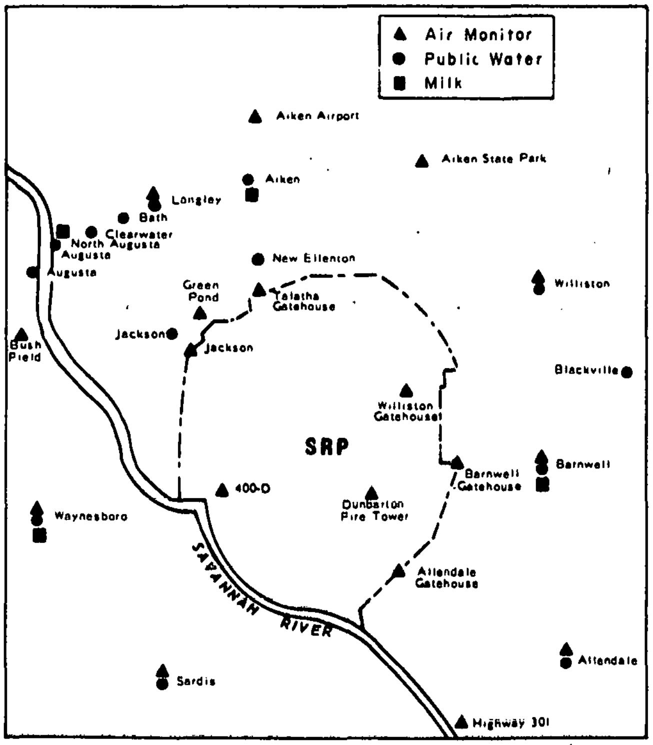

FIGURE 2. Continuous Air Monitoring Stations and Public Water Sample Locations

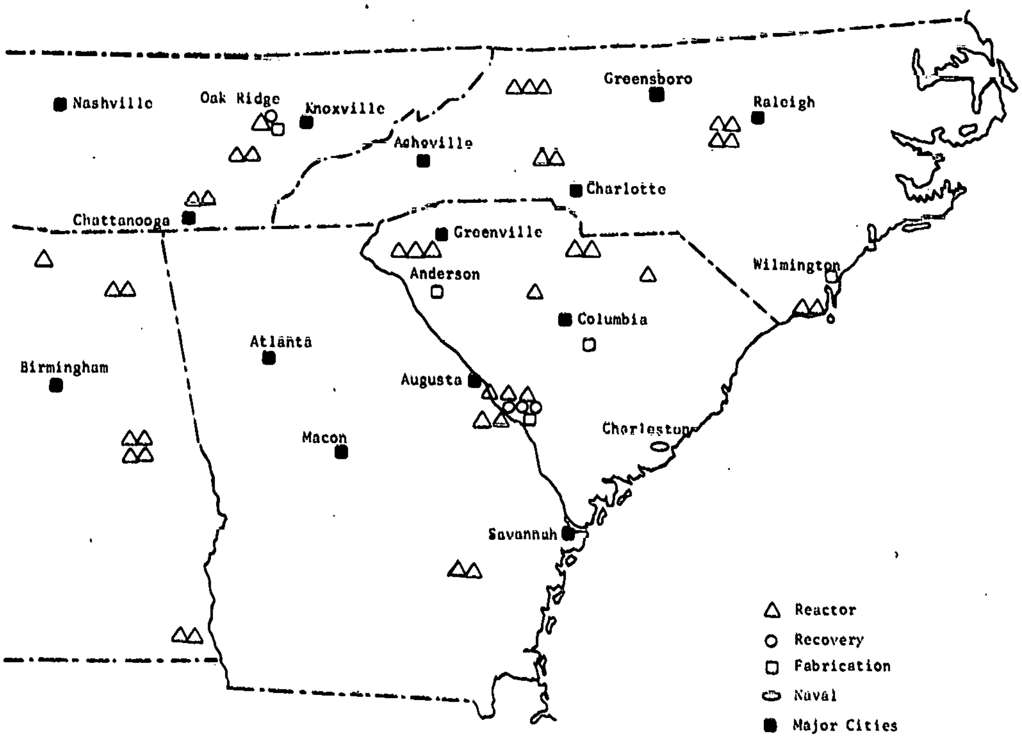

FIGURE 3. Nuclear Facilities in the Southeastern United States

The current computational facilities are listed in Table 1. The IBM 360/195 computing system serves the entire site. As the table indicates, there are a number of remote cathode ray tube terminals from which jobs may be entered, jobs may be executed, and programs may be debugged. There is also a new unit for preparing graphical output. Several minicomputers are used in the environmental research programs. In addition, many other minicomputers are dedicated to operating systems. Particularly with the use of minicomputer data collecting systems, the environmental programs can collect large amounts of data, which must be processed and presented in easily interpretable forms for the scientists. Many of the computer programs executed on the large central computing system take minicomputer-generated data and prepare summarized results. Figure 4 summarizes the use of the IBM 360/195 computer system in environmental programs for FY-1974 and most of FY-1975, month by month. The units are central processing unit hours, and the usage is divided into that for environmental programs of SRP, environmental programs in support of SRP but done by SRL, environmental research programs of general applicability, and environmental programs of SREL. The usage has increased significantly in recent months and is expected to continue increasing for the next several years.

The Savannah River Laboratory is organized into 14 divisions, with 10 to 40 professional people assigned to each. Most of the environmental research activities are focused in the Environmental Transport and Environmental Effects Divisions of the Savannah River Laboratory. These two divisions call heavily on other divisions for collaborative efforts (utilizing complementary equipment and personnel) and for support. The Computer Applications Division provides computer systems software and assists in applications programming; The Computer Operations Division is responsible for operating the central computing complex serving the whole site.

The rest of this paper will discuss the details of the principal environmental programs which make use of the central computing facilities and will discuss a modular data-based system that is being applied to integrate the various computational modules and data bases in order to shorten the time between development and application of computational capability.

ENVIRONMENTAL PROGRAMS AND COMPUTATION NEEDS

A few years ago, the primary environmental calculations that were done with the digital computing facilities were statistical in nature. This is still an important activity, and the Savannah River Ecology Laboratory of the University of Georgia uses several basic statistics programs to analyze a variety of biological data.

In the late 1960's, SRL instrumented a nearby commercial television tower in order to collect a two-year meteorological data base. This data base consisted of samples of wind speed, wind direction, and temperature at seven heights taken every three minutes for a period of two years. Many computer codes were developed to analyze these data statistically and to calculate relative concentrations around the Savannah River Plant by sector (16 sectors) and by distance out to 80 km from assumed unit curie releases

TABLE I

COMPUTATIONAL FACILITIES

CENTRAL PROCESSOR:	IBM 360/195 (2KK Bytes) IBM 360/30 (32K Bytes)
DISK STORAGE:	IBM 3330 (16 Packs) IBM 2314 (16 Packs) IBM 2305-1 (1) IBM 2305-2 (2) IBM 2311 (2)
TAPES:	IBM 2402 (15)
UNIT RECORD:	IBM 2540 (2) IBM 1403 (3)
TERMINALS:	IBM 2260 (28) VG 11 (2), PDP 11/45
MICROFILM:	FR-80
ENVIRONMENTAL SUPPORT	
MINICOMPUTERS:	PDP 15 PDP 11
TERMINALS:	TEKTRONIX 4010 (3)

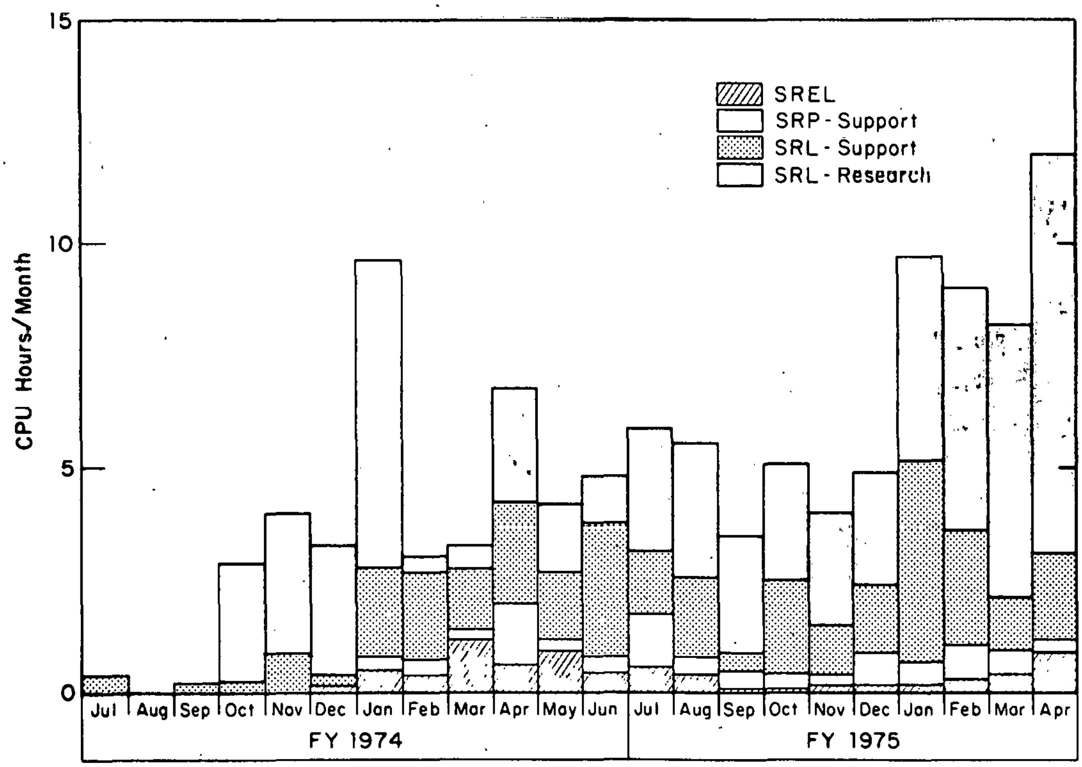

FIGURE 4. CPU Usage for Environmental Programs (IBM 360/195)

of various isotopes. These data, grouped in 15-minute periods, are used to estimate annual average exposure to off-site population from external sources and from inhalation and are used to statistically determine the frequency of occurrence of particular meteorological conditions.

Development of an expanded program in environmental sciences was begun in 1973. A major objective of the new effort is the development, adaptation, testing, and use of computational models for the transport and dispersion of various materials through environmental systems. The ultimate objective is to evaluate the effects from releases, routine or accidental, through a number of pathways to man. The focus in these applied programs is on releases from the Savannah River Plant site.

Atmospheric Studies

The atmospheric pathway is the principal pathway for material to move off-site in the shortest amount of time and is the pathway for the main contribution to off-site doses to the surrounding population. The research program includes distances ranging from a few kilometers to a few hundred kilometers. This is a greater distance than that of most atmospheric dispersion studies which have focused on distances of 1 to 10 km.

The developing research programs make use of the reinstrumented TV tower northwest of the site and seven new 200-ft towers, one in each operating area at the site (Figure 5). In addition, National Weather Service (NWS) data are received in a Weather Center-Analysis Laboratory at the Savannah River Laboratory.

The site data and the TV tower data are also focused into this Weather Center-Analysis Laboratory, and recently a minicomputer has been installed for data collection, translation of raw data to checked data in meteorological units, the archiving of turbulence intensity data for research studies, and the use of real-time meteorological data for upgrading the Savannah River Plant site's own capabilities in case of an accidental release. These data flow connections are indicated on Figure 6. Figure 6 also indicates a planned connection from the minicomputer to the IBM 360/195 in FY-1976 to facilitate the integration of the real-time meteorological data with the other environmental programs and to permit the use of more complex models to support the Emergency Operating Center activities. A cathode ray tube and hard copy unit are being installed in the site's Emergency Operating Center, and data hookup is available to the Lawrence Livermore Laboratory (LLL) as a result of our participation with LLL in the evaluation of the Atmospheric Release Advisory Capability concept.

The basic questions to be answered are: where is the material going, what will be its concentrations, and what will be deposited? The Savannah River Laboratory has developed a number of codes of varying degrees to sophistication to answer the above questions; these codes are applicable both to routine releases and to postulated accidental releases. SRL has developed codes for quality control of the meteorological data, for preparing straight-line persistent trajectories, for preparing single-station time-dependent

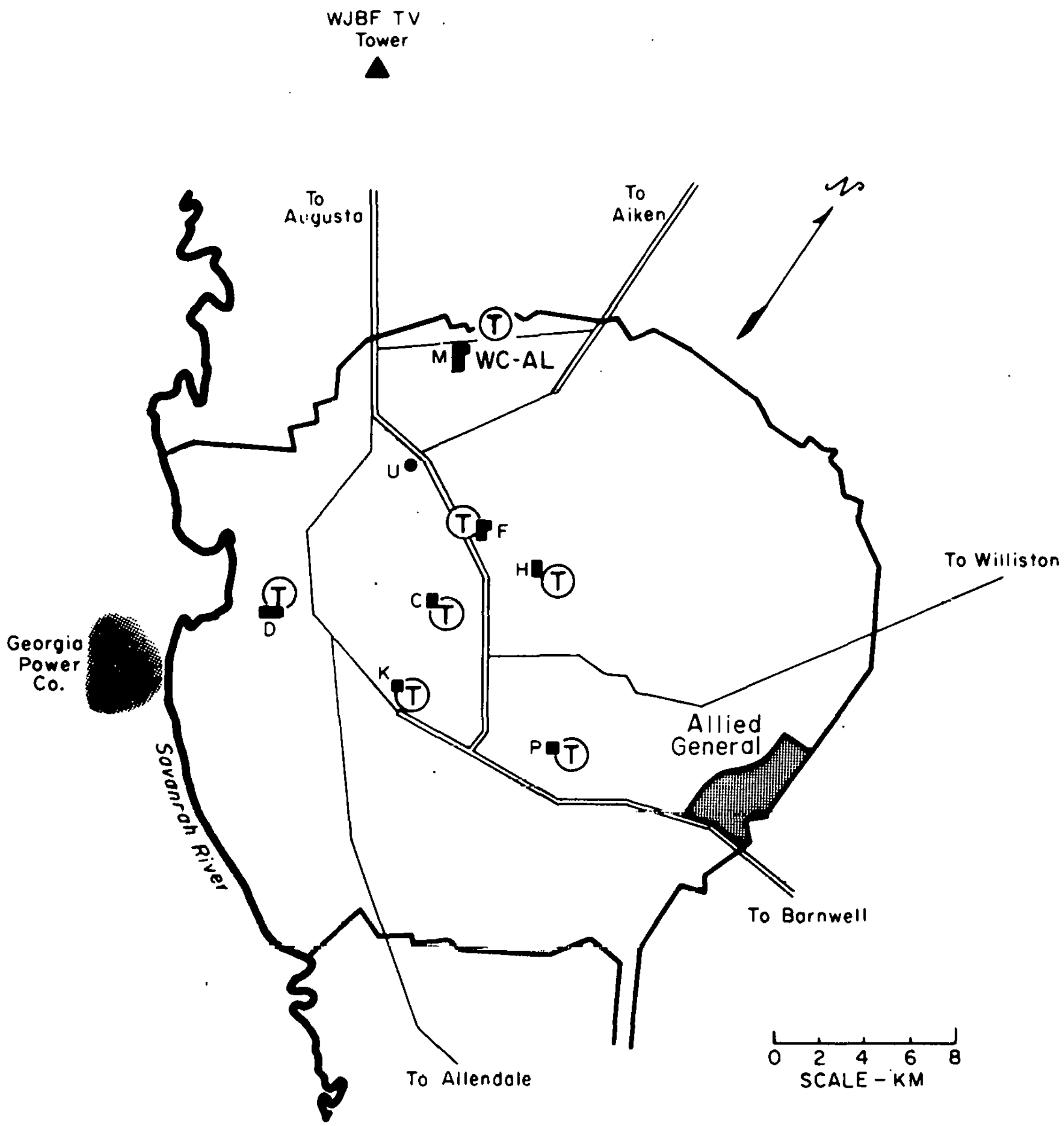

FIGURE 5. Locations of the Seven Area Meteorological Towers, the WJBF-TV Tower, the Weather Center-Analysis Laboratory (WC-AL), and the Wind Tunnel(U)

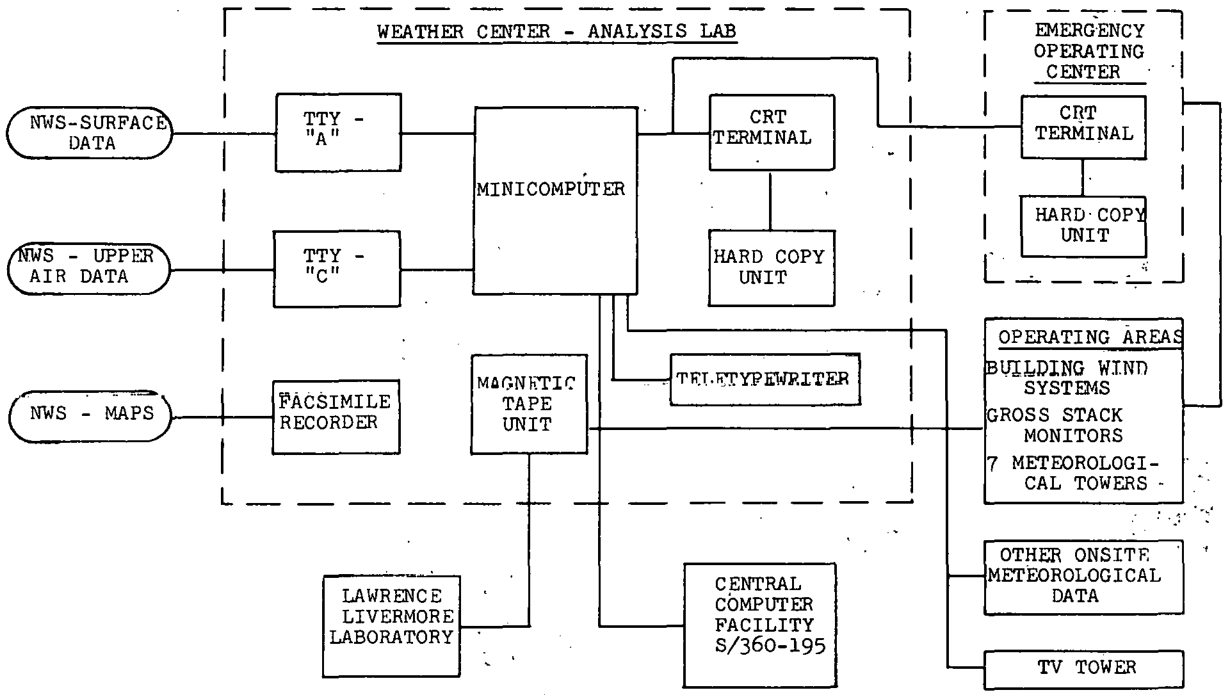

FIGURE 6. Data Flow in Weather Center - Analysis Laboratory

trajectories, for preparing two-dimensional objective analysis of wind fields as input to two-dimensional trajectory calculations, and for preparing two-dimensional time-dependent trajectory calculations.

Many diffusion calculational models are also available, such as the Gaussian instantaneous point source solutions using similarity theories of turbulence and the continuous point source solutions using different formulations for the standard deviations of the plume width and depth as a function of distance and stability; many models are also available for displaying the results of these calculations on two-dimensional grids of the Southeast. In addition, work is being done on the use of implicit techniques (alternating direction and strongly implicit) for the solution of the advection diffusion equation on a grid encompassing the southeastern United States.

A marker and cell code has been obtained and is operational at the Savannah River Laboratory for calculating two-dimensional flow and concentrations, and the Savannah River Laboratory has used results from the Lawrence Livermore Laboratory ADPIC (Atmospheric Diffusion by Particle-in-Cell) code.

A computer code has also been developed for calculating the flux of gases in the vertical direction, including the physiological aspects of the forest.

The above modules all assume that the basic meteorological field (winds, temperatures, etc.) is known. Work is under way to develop predictive boundary layer models. A two and one-half dimensional solution of the wave equation has been used for calculating mesoscale boundary layer flows, and one-, two-, and three-dimensional fine mesh-prediction models are being developed in collaboration with the Techniques Development Laboratory of NOAA.

A number of these codes have been adapted or developed at the Savannah River Laboratory within the last two years, and it is highly desirable to link them within a computing system that permits use of common data bases, that permits the substitution of improved computational modules as they become available, and that facilitates use of these codes in operational programs. Such a basic scheme is indicated on Figure 7. The use of common data bases will also facilitate the implementation of the programs by the research personnel. For instance, meteorological inputs, such as roughness length and albedo, and dose inputs, such as population distributions and agricultural crops, need to be on a common grid system so that they can be used by many of the programs. Once such a common data base is established and thoroughly checked, the individual researcher will be relieved of the responsibility and effort to generate a new data base to operate his particular program. The common data base will also facilitate the use of improved computational modules in applied problems as these new modules become available. For instance, such a framework would permit the monthly calculation of the doses from routine releases, because these release rates are now being tabulated for each major source on the site. Such a framework would also facilitate the evaluation of effects of following an accidental release.

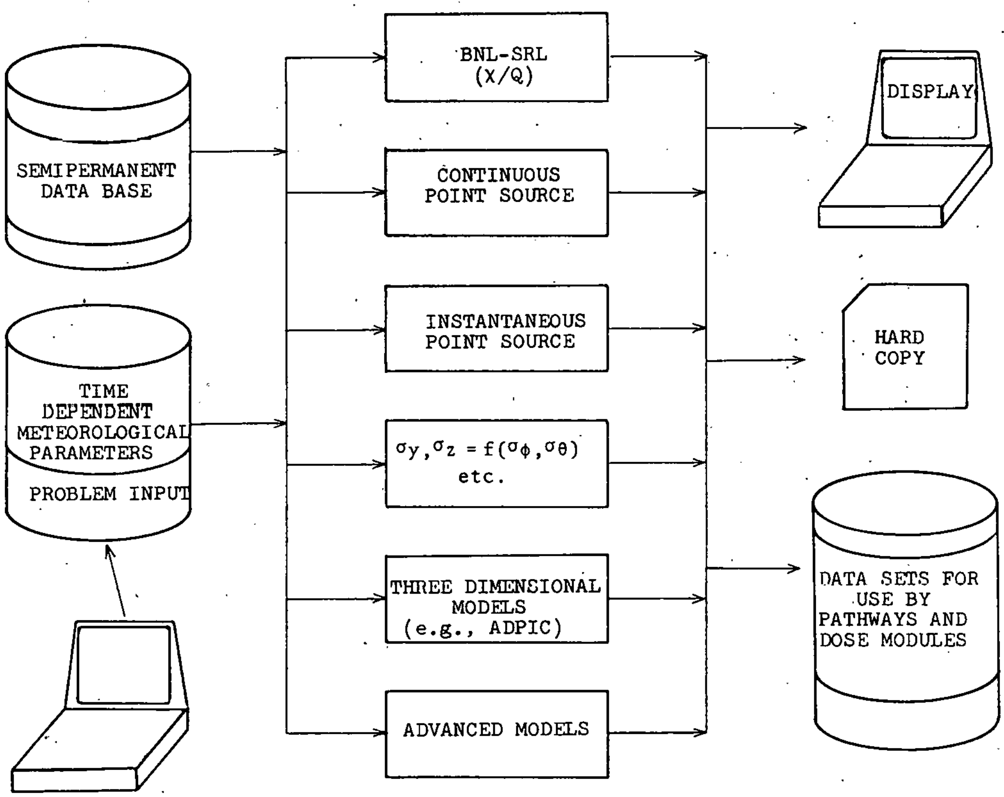

FIGURE 7. Summary of Input and Output for Atmospheric Dispersion Calculational Modules

Aqueous Systems Studies

A similar philosophy is being applied to the stream systems of the Savannah River Plant site. As noted on Figure 1, there are a number of streams on the site which eventually drain into the Savannah River. Most of the streams receive some effluent from various production areas. They are well monitored at various points along the stream, and USGS-operated stream gauges determine the flow rates. For those streams in which a reactor discharges cooling water, the stream flow varies greatly, depending on whether the reactor is operating or not.

Codes have been developed for calculating the transport and dispersion of pollutants within the stream systems. Tracer tests using rhodamine dye have been performed on all of the Savannah River Plant streams in order to obtain transport and dispersion coefficients for nonreacting pollutants. It is now possible, given a source term as a function of time at a point, to calculate the concentration as a function of time at any downstream site point for a nonreacting pollutant.

Current research programs are extending these efforts from nonreacting to reacting pollutants, and will link effects calculational modules to the concentration calculational modules. Once this latter link is made, it will be possible to calculate the dose effects at a downstream point from a particular release at an upstream point on the site.

The same stream transport and dispersion modules are also applicable to the Savannah River, and some tracer test data exist to enable transport and dispersion coefficients to be determined. The Savannah River empties into the Savannah River estuary near Savannah, Georgia. The Savannah River Laboratory is currently conducting research programs within the estuary focused on the cycling of tritiated water and plutonium. Low concentrations of tritiated water in the estuary as a result of Savannah River Plant operation can be measured. This tracer provides a basis for developing simple estuary flushing models, and perhaps later more-sophisticated computational models for transport and dispersion of material within the estuary system. Current research is focused heavily on the measurement of tritium, plutonium, and various plutonium isotopes in the Savannah River estuary water, sediments, grasses, and various foodstuffs.

The Savannah River Laboratory, in association with other oceanographic groups in the southeastern United States, is developing new programs focused on the South Atlantic bight area. The South Atlantic bight extends from Miami to Cape Hatteras and from the shoreline out to the continental shelf. These research programs make use of existing data bases of physical, chemical, and biological parameters from this area and will be developing new data. These data will also become part of the computerized data base. Computational modules will be developed for calculating the transport and dispersion of materials released from hypothetical points in this oceanographic area. The Savannah River Plant tritium flux through the Savannah River estuary will be used as a plume with which to develop dispersion parameters for the ocean area. It is possible that special tests will also be performed. A framework will be developed which will allow calculation of the effects of operating various offshore power-producing or energy-related facilities (offshore nuclear power plants, offshore oil drilling, etc.).

The same transport and dispersion philosophy is being carried over to the ground water systems under the waste tank farm and reprocessing areas of the Savannah River Plant (Figure 1). A computer model has been developed for calculating two-dimensional water flux in ground water systems. A three-dimensional model is under development. Upon completion of the water flux models, a transport and dispersion model will be developed for various chemical species which could be released into the ground water systems. These dispersion models will be three dimensional and will have to consider chemical interactions. This research, both computational and experimental, will provide the basis for calculating long-term effects of actual or postulated releases of material into ground water systems under the waste tank farm and reprocessing areas of the Savannah River Plant.

In summary, there is a heavy focus, primarily within the Environmental Transport Division of the Savannah River Laboratory, on developing computational modules for calculating transport and dispersion of various materials in environmental systems.[1,2] The ultimate objective is to improve the calculation of the effects of any release. Many of the efforts will use common data bases (i.e., dose calculational parameters) and will need to be able to use these data bases and computational models in a most expeditious way in order to make assessments. Simple interpretable summaries will be prepared from these data that will eventually provide the bases for cost benefit studies. Many of the data bases may well be prepared by minicomputers. Therefore, it is absolutely essential that a software system exist which can handle the large amounts of digital data the minicomputers can provide and which can integrate these data into assessment programs using the latest tested computational modules.

MODULAR DATA-BASED SYSTEMS

The introduction of third-generation computers in the mid-1960's greatly expanded the capability for large-scale scientific calculations. The high-speed central processing units with large cores, the large quantities of direct access storage, and the availability of alphanumeric and graphic display terminals provided a means not only to do large-scale computations, but also to develop modular data-based systems with remote terminal capability to enable such calculations to be made quickly and easily. Two such systems, the ARC System[3] at Argonne National Laboratory and the NOVA System[4] at the Knolls Atomic Power Laboratory, were developed shortly after the introduction of the third-generation computers. These systems did not have a remote terminal capability. In 1968, development of the JOSHUA System[5-7] was begun at the Savannah River Laboratory. Development of the JOSHUA Operating System has been accompanied by the development of a very wide range of reactor physics and engineering computational modules along with significant development in other areas. Currently about 75% of the computer workload at SRL is performed under the JOSHUA System.

The JOSHUA System

The JOSHUA Operating System provides the capability to develop modular data-based computational systems for large-scale multistep iterative calculations oriented toward the use of remote terminals. Because the operating system provided by IBM in 1968 for the 360 series of computers was not adequate for this purpose, the operating system capabilities was extended to provide the following capabilities:

- A random access data management system usable from both computational modules and remote terminals.
- A terminal monitor system to provide terminal access to the data base and to initiate the execution of modules.
- A flexible dynamic linking facility allowing one module to call one or more other modules into execution.

The JOSHUA Operating System has been in production use since 1970. The relationship of the JOSHUA System to the computing system is shown in Figure 8.

The use of a large semi-permanent data base residing on disk and the development of modular computational programs are key features of the JOSHUA System. The capability of storing large amounts of basic data for input to computational modules and of storing output from computational modules for use by other computational modules provides a powerful and flexible capability for doing large-scale multistep calculations.

Under JOSHUA System operation, data are stored on disk as named data records. Because IBM FORTRAN required specification of a record location in order to read or write the record to disk, an extension was made to allow reading and writing of such records by specifying the record name along with the input/output list in the FORTRAN coding. A precompiler was developed to convert these statements to IBM-FORTRAN-compatible statements. The precompiler inserts statements to call a Data Manager which takes the record name, looks up the record location, and catalogs and supplies the record location to the IBM FORTRAN direct access statement. However, from the user's standpoint, no consideration of the location of the record is required.

The data records are stored in binary form on disk and can be retrieved and displayed on terminal screens by use of the Data Manager. They must be converted to alphanumeric form before they can be displayed on a terminal screen. A display program performs this function using templates that are stored like the data records on disk storage. The template defines the structure of the record, the conversion from binary to alphanumeric, and the placement of data on the screen along with explanatory text headings. The templates are created dynamically at a terminal by creating on the terminal screen the display exactly as it is to appear when data are to be displayed. A template is created for each type of data record to be displayed.

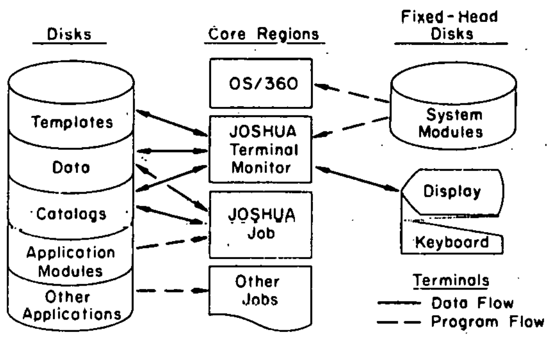

FIGURE 8. Relationship of JOSHUA to the Computing System

Programs are being developed in modular fashion because many programs may be developed to carry out similar calculations. An example is shown in Figure 7, where many of the calculational procedures that can be used to carry out atmospheric dispersion calculations are indicated. Calculational modules can be developed for these various calculational procedures such that all use the same basic input data. Careful definition of the named data records within the data base is required to provide the input for all of these various computational modules. Furthermore, the results of these computational modules may be used by other calculational modules to determine dose-to-man, and the output records from these calculational modules should be so structured that they likewise may be used by a variety of pathways and dose calculational modules.

The use of terminals with the JOSHUA System has been very successful. The terminals provide the capability to enter data directly into the data base, inspect results in the data base, modify data in the data base, and execute modules. Terminals are located in a number of areas in the Savannah River Laboratory and the Savannah River Plant. Currently, the JOSHUA workload makes up about 75% of the total workload on the IBM 360/195, and 97% of the JOSHUA jobs is submitted from terminals.

Future Development

The JOSHUA System was developed for use on an IBM 360/195, and has been successfully operated on IBM 360/65 and 360/75 computers. The system should also be operable on any large IBM 360 or 370 series computer with at least one megabyte of core and several disk packs. If terminals are not available, the system can be operated in the batch mode.

Conversion of the JOSHUA System to non-IBM computers appears feasible, but rather costly. It has been estimated that 8-10 man-years would be required to convert the system to operate on a CDC-7600 computer. This large effort would be required because many features supported by IBM FORTRAN, but not by CDC FORTRAN, have been used throughout the operating system and applications modules.

Continued development of the JOSHUA Operating System is being carried out to incorporate interactive graphics, to adapt to new hardware, and to provide for future needs. Through 1974, thirty-one man-years of development effort have been devoted to development of the Operating System. In the applications area, by far the largest effort has been devoted to the development of reactor analysis subsystems. Seventy-two man-years have been devoted to this effort. The level of effort devoted to this JOSHUA development is shown in Figure 9 for the years 1968 through 1974.

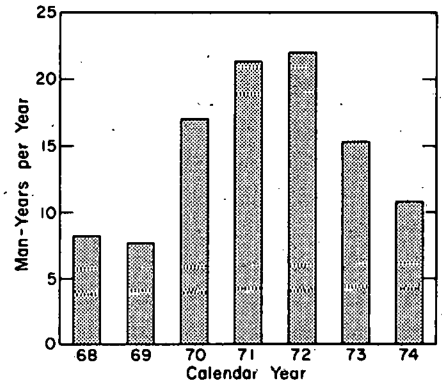

FIGURE 9. Level of Effort in JOSHUA Development

DEVELOPMENT OF ENVIRONMENTAL COMPUTATIONAL CAPABILITY

When the JOSHUA Operating System became available in 1970, several groups of existing codes, primarily in the reactor analysis area, were modified to run under this system. The necessary modifications could be done quickly to provide special-purpose capabilities at modest cost. This was followed by a major effort in the development of new computational modules for reactor analysis. This same procedure is being followed in the environmental computation area.

As described earlier, many codes have been developed at SRL to calculate atmospheric transport and dispersion as well as to calculate transport and dispersion in streams and in the ground water systems under the waste tank farm and reprocessing areas. These codes are being converted to operate under the JOSHUA System. The major effort in the future will be devoted to definition of a generalized data base for the environmental computational system and the development of new computational modules for calculating transport and dispersion of materials, for evaluating the exposure to man through the various pathways, and for calculating the resulting dose to man from materials released from the Savannah River Plant and from other sites. The methods that will be developed are expected to be generally applicable over a large portion of southeastern United States.

The calculation of dose to man due to release of both radioactive and other pollutants involves three distinct calculational steps: the transport and dispersion calculations, the pathways calculations, and the dose calculations. The relationship between these steps is shown in Figure 10. The dispersion calculations provide the time- and space-dependent concentrations of pollutants in air and water and the quantities of pollutants deposited on ground, sediment, and vegetation. These concentrations provide input to the pathways calculations that determine the concentration of pollutants in materials that man will consume or to which he will be exposed. The dose calculations use results both from the dispersion calculations (for external exposure and inhalation doses) and from the pathways calculations (for ingested doses and possibly for external exposure doses), as shown in Figure 11.

Grid Structure

Because of the very large amount of data that will be required to define the geographical area of interest, as well as the large amount of data necessary to define atmospheric parameters and aqueous systems, it is important to define these data in terms of a basic grid structure so that the proper information can be provided to computational modules using different grid structures. This approach has two significant advantages. First, placing as much site or region-dependent information as possible in the data base rather than including it in the programs will make the system much more adaptable for use for other geographic regions. Second, great flexibility can be provided by developing calculational modules that do not have a rigid grid structure built in, but rather have the capability to use various size grids of one or more types.

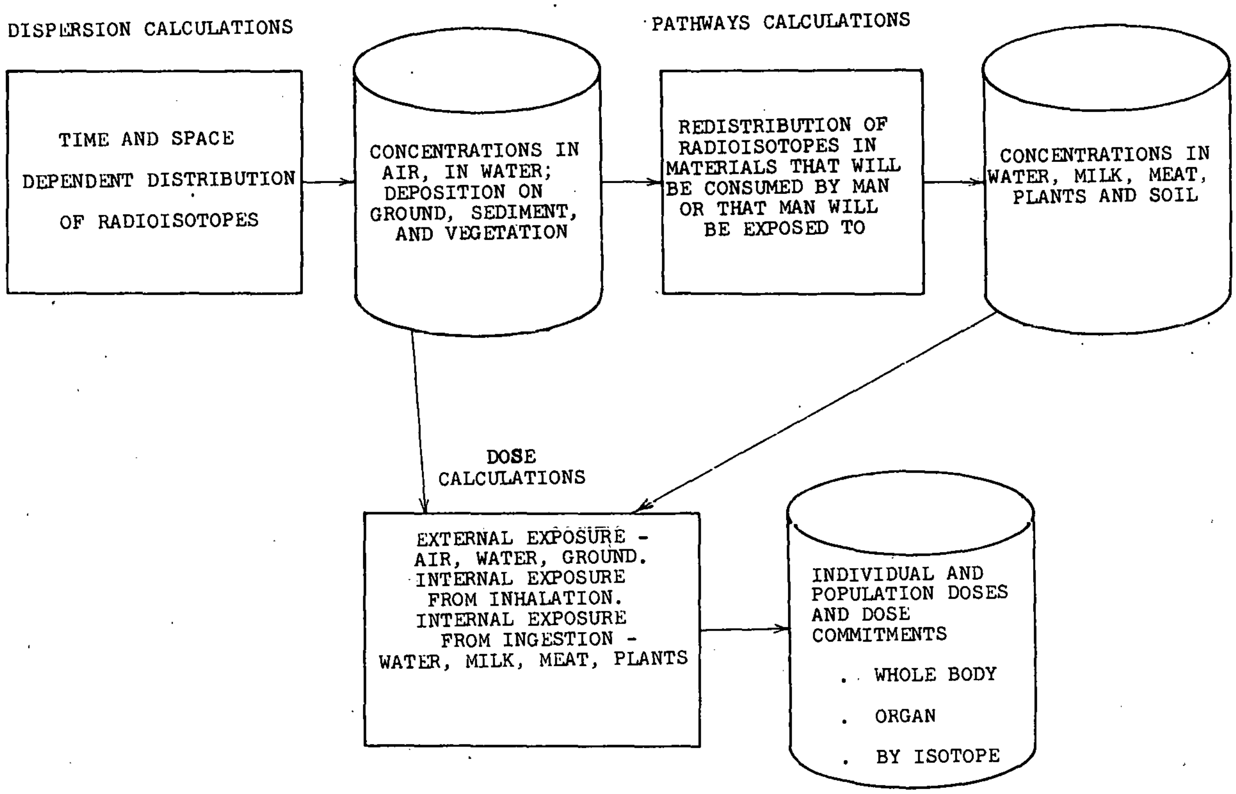

FIGURE 10. Dose-to-Man Calculational System

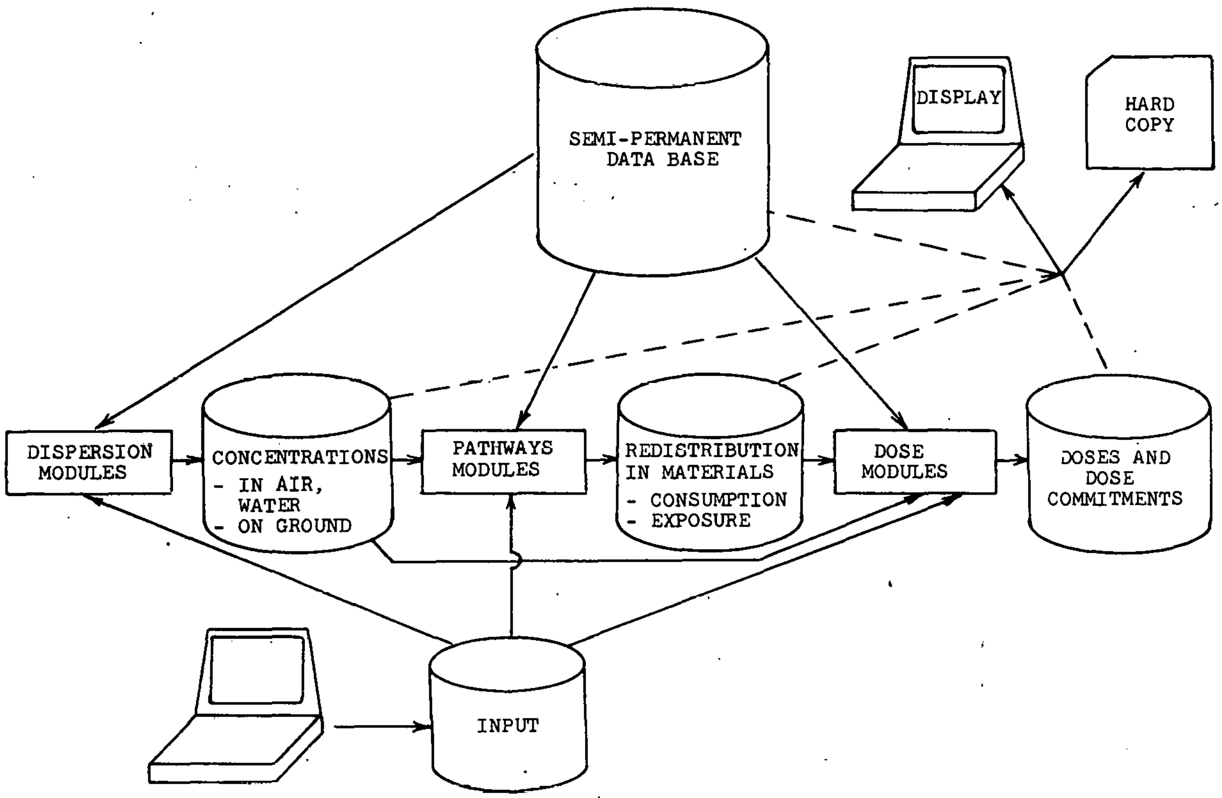

FIGURE 11. Overall System Representation

A square grid covering the southeastern United States covers about 2.5 million square kilometers (a significant part of this total is made up of Atlantic Ocean and the Gulf of Mexico). Consideration of region census sizes and of computer storage requirements suggests that a grid point spacing of about 15 km would be adequate for the basic grid structure, resulting in approximately 10,000 areas. If a base grid point spacing of 15 km does not provide the desired resolution in the vicinity of source locations, a sub-grid with smaller spacing between the grid points can be defined around such source locations. This sub-grid could be used for close-in studies where high resolution is desired.

Calculational Modules and Data Base Requirements

The calculational modules that have been and are being developed for atmospheric and aqueous transport and dispersion calculations cover a wide range of complexity, and the quantity of data required varies from small to very large as the model complexity increases. The large amount of atmospheric data that will be continuously recorded will require efficient processing to make current data available in cases of accidental releases and to provide long-term historical records.

The pathways for released pollutants reaching man are illustrated for releases to the atmosphere and releases to surface or ground water in Figures 12 and 13. As indicated in the figures, mechanisms considered are external exposure, inhalation and transpiration, and ingestion of foodstuffs and water. The models that may be used to describe the pathways are computationally simple, but the degree of detail of the models will have a large effect on the data base requirements. For example, in determining the dose to man from routine releases of radioisotopes over a year-long period, conversion factors may be derived and used to go directly from integrated air concentrations to dose to man, and only a small amount of information will be required in the data base. On the other hand, the model used by Booth[8] to describe the transfer of iodine through the deposition-cow-milk chain, shown in Figure 14, illustrates the detail that can be used in pathways descriptions. When this detail is used, the data base required for pathways calculations is very large.

The data-base requirements for the dose-to-man calculations can likewise range from relatively small to very large. Except for the calculation of gamma dose from a passing cloud, the computational models are not complex, but the data requirements vary widely depending on the level of detail incorporated in the models. Figure 15 shows the various contributions to the total dose to man.

Output data sets from the transport and dispersion calculational modules provide input to the pathways and dose calculational modules, and output data sets from the pathways modules also provide input to the dose modules. Because of the wide range of detail that will be provided by the various computational modules and the large amounts of data involved, development as a modular data-based system is the key element to ensure that the system will be efficient and flexible.

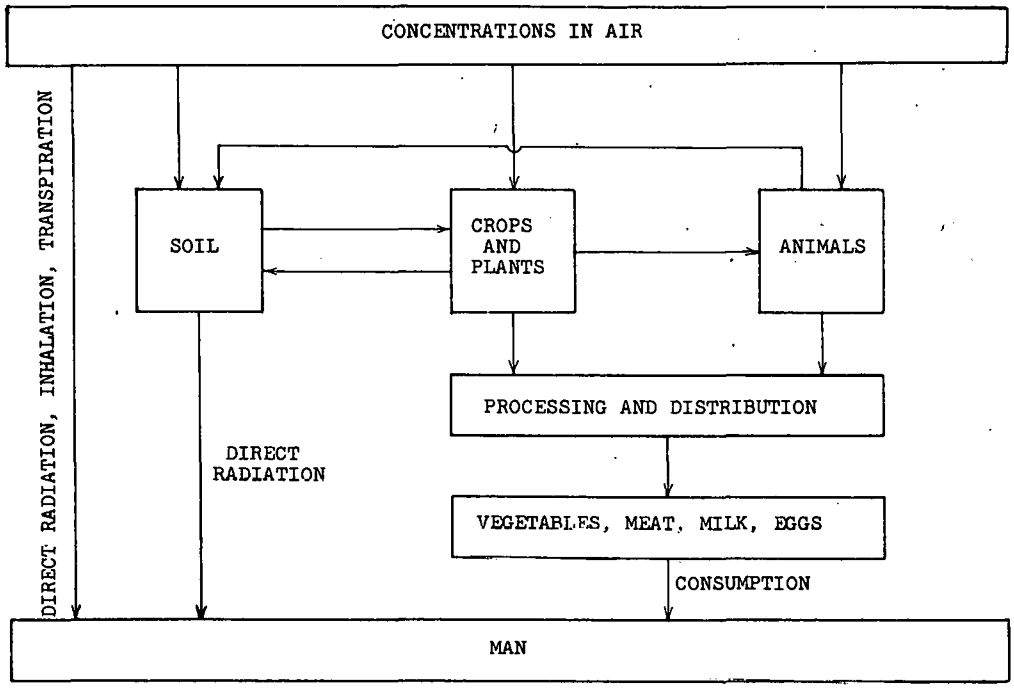

FIGURE 12. Pathways to Man From Releases to Atmosphere

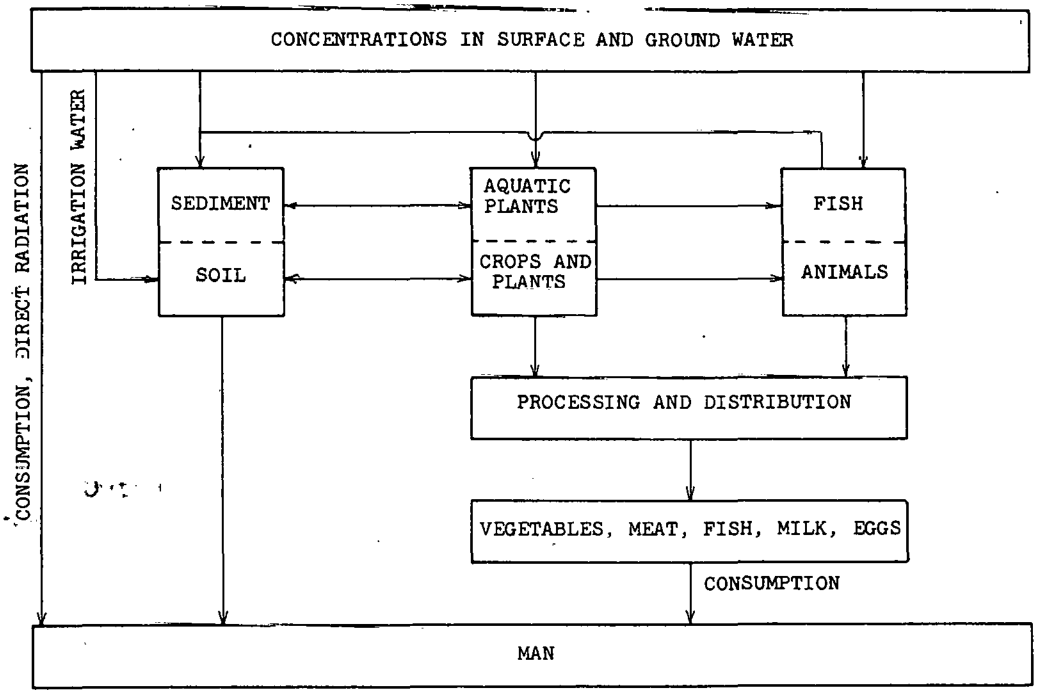

FIGURE 13. Pathways to Man From Releases to Aqueous Systems

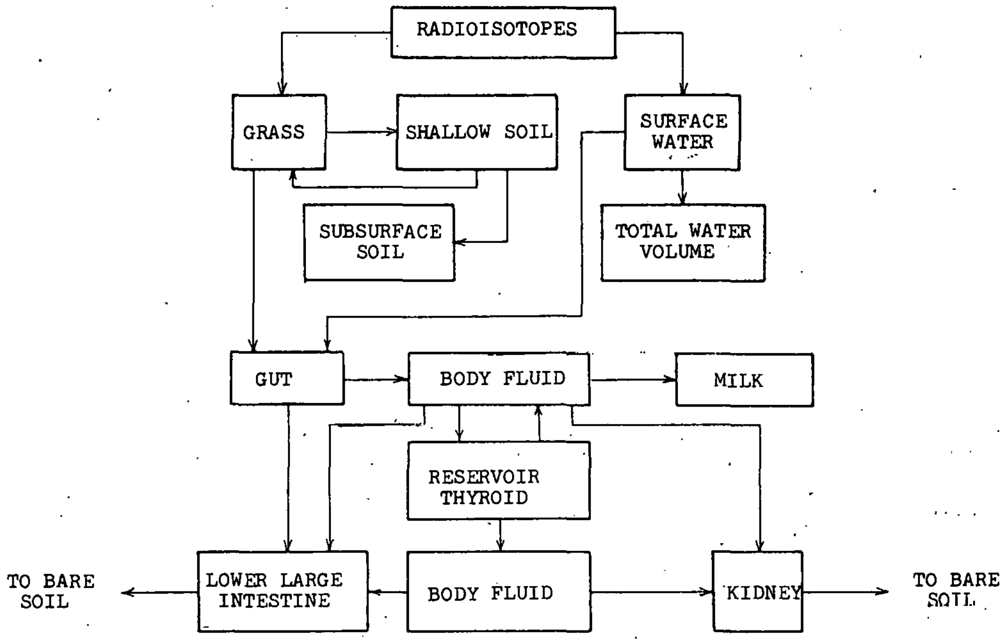

FIGURE 14. Block Diagram of the Forage-Cow-Milk-Man Pathway for Radioiodine

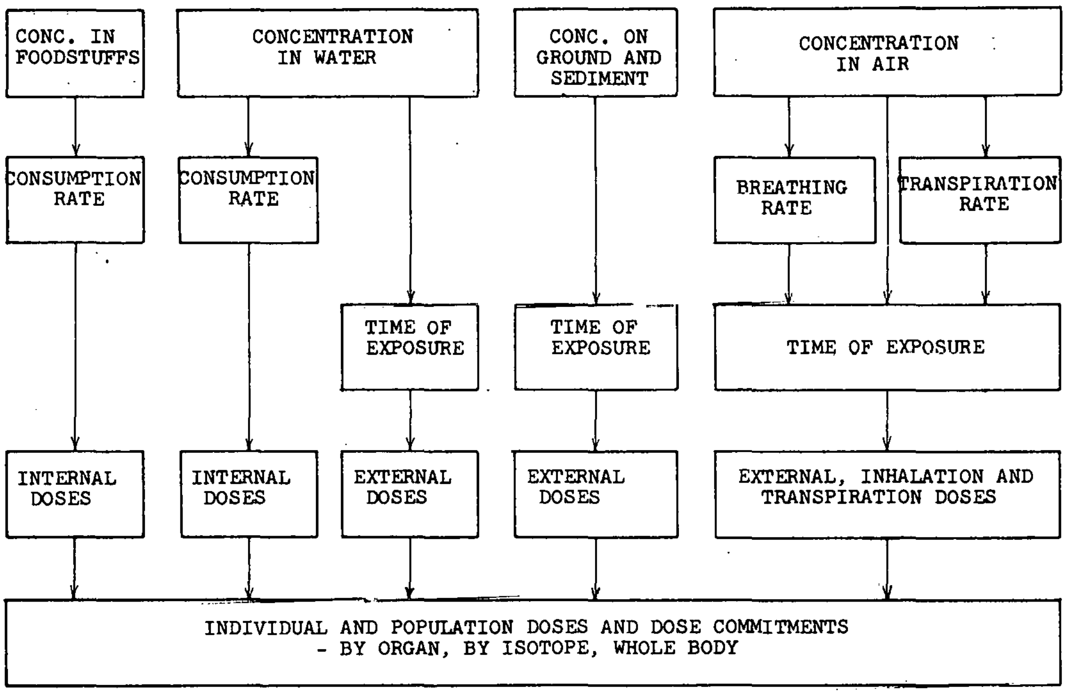

FIGURE 15. Dose Calculation Model

CONCLUSIONS

A comprehensive environmental computational system is under development at SRL within the framework of the JOSHUA System. A basic objective of this program is to calculate the dose to man resulting from the release of pollutants from multiple sources in the southeastern United States. Development within the modular, data-based JOSHUA System framework will:

- Provide efficient data management of large volumes of data.
- Provide the flexibility to perform calculations over a wide range of complexity.
- Shorten the turnaround time between research and development and its application.
- Assure that all calculational modules use a consistent, documented data base.
- Provide the means for doing the integrated calculations necessary for environmental assessments and cost-benefit studies.

REFERENCES

1. T. V. Crawford. *Progress Report, Dose-to-Man Program, FY-1973.* USAEC Report DP-1341, E. I. du Pont de Nemours and Company, Inc., Savannah River Laboratory, Aiken, South Carolina (1974).

2. T. V. Crawford. *Savannah River Laboratory Environmental Transport and Effects Research Annual Report - 1974.* USERDA Report DP-1374, E. I. du Pont de Nemours and Company, Inc., Savannah River Laboratory, Aiken, South Carolina (1975).

3. C. N. Kelber, G. Jensen, L. Just, and B. J. Toppel, "The Argonne Reactor Computation System, ARC," *Proc. Intern. Conf. Utilization of Research Reactors and Reactor Mathematics and Computation,* Mexico City, May 2-4, 1967, Report CNM-R-2, Vol. III, pp 1428-45 (1967).

4. E. D. Reilly and W. H. Turner. "The Automation of Reactor Design Calculations at the Knolls Atomic Power Laboratory." *Proc. Conf. Application of Computing Methods to Reactor Problems,* Argonne, Ill., May 27-29, 1965, USAEC Report ANL-7050, pp 251-63 (1965).

5. H. C. Honeck, J. E. Suich, J. C. Jensen, C. E. Bailey, and J. W. Stewart. "JOSHUA - A Reactor Physics Computational System," *Proc. Conf. Effective Use of Computers in the Nuclear Industry,* Knoxville, Tenn., April 21-23, 1969, USAEC Report CONF-690401, pp 324-36 (1969).

6. J. E. Suich, J. C. Jensen, and H. C. Honeck, "Data Management for Multiaccess Computational Systems." *Proc. Conf. Effective Use of Computers in the Nuclear Industry,* Knoxville, Tenn., April 21-23, 1969, USAEC Report CONF-690401, pp 471-81 (1969).

7. H. C. Honeck. *The JOSHUA System.* USERDA Report DP-1380, E. I. du Pont de Nemours and Company, Inc., Savannah River Laboratory, Aiken, South Carolina (1975).

8. R. S. Booth, O. W. Burke, and S. V. Kaye. "Dynamics of the Forage-Cow-Milk Pathway for Transfer of Radioactive Iodine, Strontium, and Cesium to Man." *Proc. Amer. Nucl. Soc. Topical Meeting Nuclear Methods in Environmental Research,* J. R. Vogt, T. F. Parkinson and R. L. Carter (eds.) pp 127-143, University of Missouri-Columbia, Columbia, Missouri (1971).