Simulation of Surface-Water Integrated Flow and Transport in Two Dimensions: SWIFT2D User's Manual

By Raymond W. Schaffranek

Chapter 1 of
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Conversion Factors, Symbols, and Units

Multiply	By	To obtain
centimeter (cm)	0.3937	inch (in.)
cubic centimeter (cm^3)	0.06102	cubic inch (in^3)
cubic meter (m^3)	35.31	cubic foot (ft^3)
	8.107×10^{-4}	acre-foot (acre-ft)
cubic meter per second (m^3/s)	35.31	cubic foot per second (ft^3/s)
	1.585×10^4	gallons per minute (gal/min)
gram per cubic centimeter (g/cm^3)	6.243×10^{-5}	pound per cubic foot (lb/ft^3)
kilogram per cubic meter (kg/m^3)	0.06243	pound per cubic foot (lb/ft^3)
meter (m)	3.281	foot (ft)
meter per second (m/s)	3.281	foot per second (ft/s)
kilometer (km)	0.6214	mile (mi)
square centimeter (cm^2)	0.1550	square inch (in^2)
square meter (m^2)	10.76	square foot (ft^2)
square kilometer (km^2)	0.3861	square mile (mi^2)

Temperature: Degree Celsius (°C) = (degree Fahrenheit -32)/1.8 (°F).

B	=	relative width of a barrier	L
c_d	=	coefficient relating longitudinal dispersion to local mean velocity	---
C	=	Chezy resistance coefficient	$L^{1/2}T^{-1}$
dz	=	distance increment in vertical z direction	L
D_x, D_y	=	diffusion coefficients of dissolved substances	L^2T^{-1}
f	=	Coriolis parameter	---
g	=	acceleration due to gravity	LT^{-2}
h	=	distance from horizontal reference plane to channel bottom	L
H	=	temporal flow depth $(h + \zeta)$	L
h_1	=	vertical distance between upstream water level and sill level	L
H_0	=	height of a gate above the top of a barrier sill	L
H_1	=	upstream water level relative to the top of a barrier sill	L
H_2	=	downstream water level relative to the top of a barrier sill	L
k	=	horizontal exchange coefficient	L^2T^{-1}
n	=	Manning's resistance coefficient	$TL^{-1/3}$
p_i	=	concentration of i-th constituent at a point	---
P	=	vector of vertically averaged dissolved constituent concentrations	---
Q	=	flow rate	L^3T^{-1}
s	=	salinity at a point	---
S	=	source of fluid with dissolved substances	---
T	=	water temperature in °C	(deg)
$\bar{u}$	=	local mean velocity	LT^{-1}
u	=	x-component of flow velocity at a point	LT^{-1}
U	=	vertically averaged velocity component in x direction	LT^{-1}
v	=	y-component of flow velocity at a point	LT^{-1}
V	=	vertically averaged velocity component in y direction	LT^{-1}
v_1	=	upstream velocity at a barrier	LT^{-1}
W	=	wind speed	LT^{-1}
α_1	=	empirical coefficient defining salinity-gradient correction to Chezy coefficient	---

ζ	=	water-surface elevation relative to horizontal reference plane	L
λ	=	units conversion factor for friction coefficient (1 for metric or 1.49 for inch-pound)	---
$\mu_{1,2}$	=	barrier coefficient for free-surface subcritical flow	---
$\mu_{2,3}$	=	barrier coefficient for transitional flow	---
$\mu_{3,4}$	=	barrier coefficient for free-surface supercritical flow	---
$\mu_{5,6}$	=	barrier coefficient for gate-restricted flow	---
ρ	=	density of water	ML^{-3}
ρ_a	=	density of air	ML^{-3}
Δt	=	time increment	T
Δx	=	distance increment in x direction	L
Δy	=	distance increment in y direction	L
θ	=	wind stress coefficient	---
ψ	=	angle between wind direction and the positive y direction	(deg)

Simulation of Surface-Water Integrated Flow and Transport in Two Dimensions: SWIFT2D User's Manual

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Abstract

A numerical model for simulation of surface-water integrated flow and transport in two (horizontal-space) dimensions is documented. The model solves vertically integrated forms of the equations of mass and momentum conservation and solute transport equations for heat, salt, and constituent fluxes. An equation of state for salt balance directly couples solution of the hydrodynamic and transport equations to account for the horizontal density gradient effects of salt concentrations on flow. The model can be used to simulate the hydrodynamics, transport, and water quality of well-mixed bodies of water, such as estuaries, coastal seas, harbors, lakes, rivers, and inland waterways. The finite-difference model can be applied to geographical areas bounded by any combination of closed land or open water boundaries. The simulation program accounts for sources of internal discharges (such as tributary rivers or hydraulic outfalls), tidal flats, islands, dams, and movable flow barriers or sluices. Water-quality computations can treat reactive and (or) conservative constituents simultaneously. Input requirements include bathymetric and topographic data defining land-surface elevations, time-varying water level or flow conditions at open boundaries, and hydraulic coefficients. Optional input includes the geometry of hydraulic barriers and constituent concentrations at open boundaries. Time-dependent water level, flow, and constituent-concentration data are required for model calibration and verification. Model output consists of printed reports and digital files of numerical results in forms suitable for postprocessing by graphical software programs and (or) scientific visualization packages. The model is compatible with most mainframe, workstation, mini- and micro-computer operating systems and FORTRAN compilers. This report defines the mathematical formulation and computational features of the model, explains the solution technique and related model constraints, describes the model framework, documents the type and format of inputs required, and identifies the type and format of output available.

Introduction

The Surface-Water Integrated Flow and Transport two-dimensional model, SWIFT2D, was designed and developed specifically for simulation of flow and constituent transport in vertically well-mixed estuaries, tidal embayments, and inland waterways. By well mixed, it is assumed that velocity accelerations in the vertical direction are negligible thereby permitting a two-dimensional numerical approximation of the governing equations in the horizontal plane. The model numerically solves finite-difference forms of the governing, vertically integrated equations of mass and momentum conservation, in conjunction with transport equations for heat, salt, and constituent fluxes. Momentum conservation accounts for local, convective, and Coriolis accelerations; pressure differentials due to water-level and density gradients; shear-stress effects of the bottom and winds on the surface; and the internal effects of horizontal momentum diffusion. The convection-diffusion form of the mass-balance transport equation includes terms accounting for the generation, decay, and interaction of constituents. An equation of state for salt balance is included to account for pressure-gradient effects in the momentum equation; thus, the hydrodynamic and transport computations are directly coupled.

SWIFT2D can simulate hydrodynamics and transport in any nonrectangular geographical area and in any area bounded by any combination of closed land and open water boundaries. The model can be used to investigate tidal influences, residual circulations, and the fate of discharged substances in water bodies. It can be used to analyze flow through bridge openings, over highway embankments, around causeways, and through culverts at highway crossings of riverine floodplains and estuarine wetlands. Circulation in lakes and enclosed embayments under the influence of wind; storm surges in coastal areas, bays, and estuaries; and harbor oscillations can be investigated. The model can be driven by steady-state conditions or dynamic (tides, floods, etc.) fluxes at open boundaries (in the form of water levels, velocities, or transport rates) specified as time-varying data or harmonic components (in the form of Fourier functions of phase and amplitude at specified tidal frequencies). The model accounts for discharge sources and controls (such as tributary rivers or sewage outfalls), tidal flats, islands, and dams. The computation algorithm is capable of treating the flow effects of hydraulic barriers such as a partially or fully submerged weir, an adjustable gate structure, or a series of bridge piers. The model simulates the flooding and dewatering of tidal flats and marshes and the depth-dependent variations of frictional resistance. The transport of multiple constituents can be simulated simultaneously and each constituent can decay or grow at a fixed rate or in linear relation to the concentration of any other constituent.

The model is a mathematical representation of the governing hydrodynamic and transport equations in the framework of an adaptable computer program. By means of a number of variables defining the inputs, outputs, and internal flow conditions and data describing the bathymetry and physical characteristics of the water body, the model computes water levels and flow velocities, as well as (optionally) the concentration and dispersion of constituents, in response to internal and external forcing functions. Dynamic forcing can result from the time-varying effects of tides, winds, inflow and outflow discharges, boundary-constituent fluxes, and hydraulic-barrier controls. For input, SWIFT2D requires bathymetric and topographic data defining land-surface elevations, time-varying flow conditions and constituent concentrations at open boundaries, definition of internal resistance coefficients, specification of initial conditions, and (optionally) the geometry of hydraulic barriers. Discrete sets of time-dependent flow and constituent-concentration data are required for model calibration and verification.

SWIFT2D provides varied forms of output printed at selected time intervals and (or) filed in History, Map, and Coarse-Grid files. The History file contains time series of computed results at selected cells at a user-specified time frequency whereas the Map file contains simulation results over the entire grid at a specified frequency. The optional Coarse-Grid file contains output at intermediate grid cells to facilitate the simulation of constituent transport at a coarse-grid resolution. A Run Log file is written that shows the status of a completed simulation and catalogs data sets created during model runs. The Run Log file contains user comments supplied in the model input that identify the purpose of the simulation. A master file is created by the model that retains the names of all input and output files used in the most recent simulation run.

FORTRAN 77 coding makes the model compatible with most mainframe, workstation, mini- and microcomputer systems and host compilers. Implementation-dependent constants such as file-unit numbers, input as defined in Appendix 1, are isolated in the model code so that the program can be adapted more easily to different computer systems. Array-dimensioning information also is isolated to enable easy modification for efficient computer memory utilization. A companion Input Data Processor program, SWIFT_IDP, developed to interpret and quality-check model input and to generate the time-sequential file of input needed by SWIFT2D, is described in Appendix 2.

This report provides documentation for the U.S. Geological Survey (USGS) SWIFT2D model and its input data processor SWIFT_IDP. Some content of this report was derived from reports and unpublished technical notes provided by The Rand Corporation to describe the original two-dimensional simulation model, referred to as SIM2D, and its supporting simulation system, SIMSYS2D, contractually developed for the USGS.

Model Applications

SWIFT2D has been used to simulate the hydrodynamics and transport of a wide variety of water bodies. The model was used to design the Dutch Delta Works (Leendertse and others, 1981) and to predict barrier effects on salinity and water quality in the Oosterschelde Estuary, The Netherlands (Dronkers and others, 1981). Leendertse (1988) investigated the effects of the advection term in the hydrodynamic equations on residual tidal circulations in the Oosterschelde Estuary using the model. In a study of the tidal Potomac River, Schaffranek (1986) and Schaffranek and Baltzer (1990) used the Lagrangian particle-

tracking feature of the model to evaluate the effects of horizontal density gradients on estuarine flushing and circulation and to examine the effects of grid resolution on numerical results and flow behavior. Schaffranek and Baltzer (1988) demonstrated use of the model to evaluate hydrodynamic effects resulting from modifications to wetlands in Port Royal Sound, South Carolina, and floodplains in the Pearl River Basin, Louisiana. Using a nested series of SWIFT2D model implementations built with successively finer grid resolution, Lee and others (1989, 1994) demonstrated how highway crossings and road embankments can impede circulation and flow in an estuarine system. SWIFT2D model applications to the Pamlico (Bales and Robbins, 1995) and Neuse (Robbins and Bales, 1995) River Estuaries in North Carolina were developed to conduct studies of flow, circulation, and solute transport. Dredging and spoil placement designs were investigated in Tampa Bay, Florida (Goodwin, 1987) and Hillsborough Bay, Florida (Goodwin, 1977; 1991) to determine residual flow, circulation, and flushing behavior. SWIFT2D applications to Charlotte Harbor, Florida (Goodwin, 1996) and the Loxahatchee River Estuary, Florida (Russell and Goodwin, 1987) provided insight into the response of tidal flow and mixing characteristics to proposed causeway and bridge alterations. Modifications have been made to the model to facilitate applications in the southern Florida Everglades (Schaffranek, 2001; Schaffranek and others, 2002; Swain, 1999). An extension of the model also has been developed to account for the exchange of surface-water flows and solutes with surficial aquifers in the southern Everglades (Langevin and others, 2002).

Purpose and Scope

The purpose of this report is to provide a user's manual for the SWIFT2D model. Functional aspects, computational features, input requirements, and limitations of the SWIFT2D model are described to aid in model design and setup, identification and assignment of input parameters, program execution, and interpretation of simulation results. Model limitations are identified both in the description of SWIFT2D computational features and in the context of defining the input required to invoke a particular numerical function. An overview of the governing equations and their numerical solution is given, the SWIFT2D simulation process is defined, computational features of the model are described, controls on numerical output are discussed, and instructions for preparing model input based on the selective computational features are provided.

This report does not document the mathematical formulation or finite-difference techniques of the SWIFT2D model. Refer to Leendertse (1987) and preceding publications by Leendertse (1970) and Leendertse and Gritton (1971), for details on the finite-difference formulation and related numerical aspects. Background knowledge of the SWIFT2D model gained by reading the precursor technical reports, although helpful, is not a prerequisite to use of this report to successfully setup and conduct a numerical simulation. Knowledge of fundamental hydrodynamic concepts and numerical modeling principles, however, is required to understand and correctly interpret related topics in this report. Prior knowledge or experience in either or both is greatly beneficial to the setup and conduct of a successful SWIFT2D simulation.

Operational details for SWIFT2D model design, setup, and use, which are not formally published elsewhere, are provided in this report. Use of SWIFT_IDP, the input data processor program, to generate the time-sequential input file required to execute a SWIFT2D simulation is documented. Detailed instructions for formatting and preparing all control and input files needed to execute the SWIFT2D model and SWIFT_IDP program are presented in Appendixes 1 and 2. Interactive program-execution and file-designation procedures for SWIFT2D and SWIFT_IDP are described to facilitate use of the model on window-based personal computer (PC) systems.

This report is subdivided into six fundamental sections:

- **SWIFT2D Model Overview** provides an overview of technical aspects of the model

- **Model Implementation Process** discusses general model implementation approaches and practices

- **SWIFT2D Simulation Process** identifies setup and execution procedures for the model and its input data processor

- **SWIFT2D Input** describes model input requirements

- **SWIFT2D Numerical Aspects and Computational Features** defines numerical aspects and special capabilities of the model

- **SWIFT2D Output** identifies the type and format of available model output

SWIFT2D Model Overview

The SWIFT2D model is specifically formulated to compute time-dependent variable-density fluid flows in bodies of water whose depths, though varying, are shallow compared with their horizontal dimensions. This two-dimensional model numerically integrates finite-difference forms of the governing equations of mass and momentum conservation developed by neglecting vertical accelerations and replacing horizontal velocity components by their respective vertically averaged values. The equations of mass and momentum conservation are solved implicitly in alternating direction fashion in conjunction with vertically integrated transport equations for heat, salt, and dissolved constituents. In addition to accounting for local and convective accelerations, differential pressure gradients, horizontal density variations, and forces due to bed and friction slopes, the model rigorously accounts for factors of importance in broad bodies of water such as Coriolis acceleration, wind stress effect, and horizontal momentum diffusion. Alternative treatments and formulations of specific terms in the governing equations are available in the model. In this overview, the most typical representations of terms in the governing equations are presented; other optional expressions can be found in Leendertse (1987).

Governing Equations

The partial-differential equations used in the SWIFT2D model to express horizontal mass and momentum, as well as constituent, conservation as defined in Leendertse (1987), are

$$\frac{\partial \zeta}{\partial t} + \frac{\partial (HU)}{\partial x} + \frac{\partial (HV)}{\partial y} = 0, \tag{1}$$

$$\frac{\partial U}{\partial t} + U\frac{\partial U}{\partial x} + V\frac{\partial U}{\partial y} - fV + g\frac{\partial \zeta}{\partial x} + \frac{gH}{2\rho}\frac{\partial \rho}{\partial x} + gU\frac{(U^2+V^2)^{1/2}}{C^2 H} - \frac{\theta \rho_a W^2 \sin\psi}{\rho H} - k\left(\frac{\partial^2 U}{\partial x^2} + \frac{\partial^2 U}{\partial y^2}\right) = 0, \tag{2}$$

$$\frac{\partial V}{\partial t} + U\frac{\partial V}{\partial x} + V\frac{\partial V}{\partial y} + fU + g\frac{\partial \zeta}{\partial y} + \frac{gH}{2\rho}\frac{\partial \rho}{\partial y} + gV\frac{(U^2+V^2)^{1/2}}{C^2 H} - \frac{\theta \rho_a W^2 \cos\psi}{\rho H} - k\left(\frac{\partial^2 V}{\partial x^2} + \frac{\partial^2 V}{\partial y^2}\right) = 0, \text{ and} \tag{3}$$

$$\frac{\partial (HP)}{\partial t} + \frac{\partial (HUP)}{\partial x} + \frac{\partial (HVP)}{\partial y} - \frac{\partial (HD_x \partial P/\partial x)}{\partial x} - \frac{\partial (HD_y \partial P/\partial y)}{\partial y} + HS = 0, \tag{4}$$

where

C = Chezy resistance coefficient;
Dx, Dy = diffusion coefficients of dissolved substances;
f = Coriolis parameter;
g = acceleration due to gravity;
h = distance from horizontal reference plane to channel bottom (positive downward);
H = temporal flow depth ($h + \zeta$);
k = horizontal exchange coefficient;
P = vector of vertically averaged dissolved constituent concentrations;
S = source of fluid with dissolved substances;
U = vertically averaged velocity component in x direction;
V = vertically averaged velocity component in y direction;
W = wind speed;
ζ = water-surface elevation relative to horizontal reference plane;
θ = wind stress coefficient;
ρ = density of water;
ρ_a = density of air; and
ψ = angle between wind direction and the positive y direction.

In these equations, x and y are Cartesian coordinates in the horizontal plane and t represents time. Equation 1 expresses mass conservation; equations 2 and 3 express momentum conservation in the x and y coordinate directions, respectively; and equation 4 represents the mass-balance of dissolved constituents. In equation 2 and 3, bottom stress is shown in the conventional velocity form; an optional turbulent energy form also is available. The variables U and V represent the vertically averaged velocity components in the x and y horizontal coordinate directions, respectively, defined as

$$U = \frac{1}{H}\int_{-h}^{\zeta} u \, dz \text{ and} \tag{5}$$

$$V = \frac{1}{H}\int_{-h}^{\zeta} v \, dz, \tag{6}$$

where dz is the differential increment in the vertical direction by which the u and v point flow velocities are integrated over the temporal depth H. Similarly, P is the vertically averaged concentration of a constituent defined by

$$P = \frac{1}{H}\int_{-h}^{\zeta} p_i \, dz, \tag{7}$$

where p_i is the point concentration of the i-th constituent.

In the solution, the Chezy (C) coefficient is treated as a dependent variable of the temporal flow depth and the bottom roughness, expressed by the Manning coefficient (n). The Chezy coefficient is related to the Manning coefficient according to

$$C = \frac{\lambda}{n}H^{1/6}, \tag{8}$$

where $\lambda = 1$ or 1.49 for metric or inch-pound units, respectively (Leendertse, 1987).

For bodies of water in which a considerable horizontal density gradient exists, the Chezy coefficient also depends on the direction of flow and can be treated as a linear function of the salinity gradient

$$C = \lambda\frac{H^{1/6}}{n}\left[1 + \alpha_1 \frac{\left(U\frac{\partial s}{\partial x} + V\frac{\partial s}{\partial y}\right)}{(U^2 + V^2)^{1/2}}\right], \tag{9}$$

where s = salinity in g/kg and α_1 is an empirical coefficient.

The momentum equations 2 and 3 contain pressure terms representing forces due to salinity-dependent density gradients. Weakly variable temperature effects on densities are neglected. For bodies of water in which a horizontal density gradient exists these terms can be evaluated during the simulation. In the simulation, an equation of state is solved for every point in the computational field at every time step to define the relationship between salinities and densities. The salinity field is determined by solution of the transport equation 4, given initial- and boundary-condition salt concentrations. The equation of state for salt balance is expressed in a form of the Tumlirz equation in which pressure and specific volume are related by empirical expressions that are combined quadratic functions of temperature and linear functions of salinity derived by Eckert (1958):

$$\rho = \frac{5890 + 38T - 0.375T^2 + 3s}{(1779.5 + 11.25T - 0.0745T^2) - (3.8 + 0.01T)s + 0.698(5890 + 38T - 0.375T^2 + 3s)}, \tag{10}$$

where T is temperature in °C. Because density varies only weakly with temperature, temporal and spatial variations in temperature are not computed and a constant temperature is used for the entire water body.

Finite-Difference Approximations

Spatial approximations of equations 1 through 4 over a water body area yield a large number of finite-difference expressions. Each finite-difference equation is similar in form to the governing partial differential equation but is applicable at only one point in space and time and is separated from all other points by finite space and time increments. The chosen finite-space increment ($\Delta x = \Delta y$ square cell) must be of adequate size to capture the important physical properties of the water body being simulated. The finite-time increment (Δt) is determined based on the prototype wave celerity and the chosen space increment. By applying this finite-difference approximation, the governing partial differential equations are reduced to multiple interrelated algebraic equations containing known and unknown quantities. The computation proceeds in stepwise fashion throughout time with computational elements defined at both whole (Δt) and half ($\Delta t/2$) time intervals. Leendertse and Gritton (1971) give a complete description of how equations 1 through 4 are structured in finite-difference form at each (x, y, t) point.

Solution Technique

The SWIFT2D numerical solution technique is based on an alternating-direction implicit (ADI) method in which the horizontal velocity components U and V are computed at alternating half time steps. A thorough treatment of the stability and accuracy requirements of the ADI technique is given by Stelling and others (1986). The SWIFT2D solution technique includes an extensive set of options for approximation of the more complex terms of the non-linear equations and other unique computational-control features (Leendertse, 1970; Leendertse and Gritton, 1971; Leendertse, 1987). In addition to optional treatment of the bottom stress term in SWIFT2D, various integration methods are available for approximating and handling the convective terms of the governing equations. Integration options allow the user to specify the time level at which the approximation of certain terms is made and the spatial representation of certain terms. The various integration methods are summarized in the Integration Options section. A thorough treatment of the solution technique, integration methods, and stability aspects of the SWIFT2D numerical scheme is given in Leendertse (1987).

Special Computational Features

In addition to numerical capabilities allowing for varied integration methods and optional formulations of the bottom-stress and convective acceleration terms, SWIFT2D includes special computational features to treat horizontal momentum diffusion, Fourier tide openings, space-varying wind and pressure, drying and flooding of cells, permanently dry cells or dams, sluices or barriers, and hydraulic pumps or effluent outfalls. Coarse-grid computational capability and particle-tracking techniques are available to aid in transport simulation and analyses. Use of these features and instructions for assignment of appropriate parameters are discussed in the context of the preparation of model input in the **SWIFT2D Numerical Aspects and Computational Features** section.

Model Implementation Process

SWIFT2D is a general-purpose model that must be particularized to water body being investigated. This process, termed model implementation, includes parameterization of the model to uniquely represent the physical characteristics of the prototype water body, preparation of model input to conduct the numerical simulations, as well as calibration of the model to accurately reproduce the hydrodynamic and transport properties of the water body. Parameterization involves delineating the water body area of coverage, generating a bathymetric grid, assigning frictional-resistance (water-surface and channel-bottom stress) coefficients, defining external boundary conditions at water body openings, specifying initial conditions at the start of the simulation, and determining appropriate computation-control parameter values. Parameterization includes the processes by which prototype data constituting initial-value and (or) time-varying boundary-value data—water depths, water levels, flow velocities, wind conditions, structure discharges, salinities, constituent concentrations, and so forth—are incorporated into the model. Calibration is the process by which the model parameterization is adjusted and refined to achieve as close agreement as possible between simulation results and prototype observations of water levels, flows, constituent concentrations, and other measurable quantities. Calibration also includes a verification step in which model results are evaluated using independent sets of conditions within the calibration range.

Model implementation frequently entails a vast amount of data compilation, processing, and analyses. Software database systems and (or) graphical programs can be used to undertake most aspects of the implementation process, including model setup, input data preparation, simulation design, calibration and verification, and postprocessing of simulation results. Commercially available software packages can be readily adapted and used in the model implementation and simulation processes. A geographic information system (GIS) in conjunction with topographic maps and (or) satellite images can be effective aides in the setup phase of model implementation. A GIS can be used with hypsographic and hydrographic data to develop a model grid and to assign spatially variable energy dissipation coefficients from land cover information and satellite imagery (Schaffranek and Baltzer, 1988). A GIS also can be used to display simulation results, to analyze model behavior, to evaluate model and prototype comparisons, and to investigate flow and transport conditions using model results.

Simulation Data Requirements

Three broad categories of input data and prototype information are needed to conduct a hydrodynamic/transport simulation using SWIFT2D:

- geometry of spatially variable boundaries within the model domain,

- intrinsic properties and initial states of time-dependent variables, and

- time-varying functions at open boundaries of the model domain.

The first category of input includes information on the physical attributes, size, and dimensions of the water body. The water body geometry must be defined by overlaying a rectangular grid on a map of the model domain, determining an appropriate size to subdivide the grid into square cells, and specifying a mean water depth or land elevation for every potential flow-conveying cell. Every cell must be assigned a coefficient representing its flow resistance. If the transport of a constituent is being simulated, a coefficient representing its spatially variable dispersion can be assigned to every cell within the computational domain. Additional attributes might need to be defined to account for varied forcing functions, hydraulic structures or flow barriers, and special characteristics unique to the water body being simulated.

The second category of input includes the initial water-surface elevation, flow condition, and concentration of any transported constituents for every active cell that is initially wetted or potentially wetted within the model domain.

The third category of input includes information that defines time-varying conditions. Time sequences of water level, velocity, or flow discharge data must be defined at the open boundaries of the water body being simulated. Rates of freshwater and constituent inflows must be defined at appropriate locations to account for tributary discharges, effluent outfalls, hydraulic structure releases, point-source inputs, and so forth.

Determination and assignment of some model input values requires considerable judgment. Inputs, such as diffusion coefficients, sometimes need to be assigned trial values, frequently obtained from the literature that are subsequently evaluated and adjusted through numerical experimentation. Sensitivity tests should be conducted to determine the effects of varied input parameter assignments on model results (Bales and Robbins, 1995; Lee and others, 1989; Leendertse, 1988) and model results always should be verified using measured data (Goodwin, 1987; Lee and others, 1994; Robbins and Bales, 1995; Schaffranek, 1986). Varied methods and approaches to model calibration and verification are discussed in these reports.

Model Limitations and Program Considerations

Knowledge of numerical solution techniques and modeling principles is required to undertake and conduct implementation of a hydrodynamic/transport model, such as SWIFT2D, and to properly analyze and interpret simulation results. SWIFT2D is designed so that only minimal familiarity with and skill in computer use is required for its execution. However, limitations of the simulation model, its numerical solution scheme, and the computer program need to be understood in order to eliminate simulation errors and to obtain credible model results. Some of the major limitations and considerations are described below; others are identified and discussed at appropriate sections in the report. Limitations on data input are described in subsequent sections and in Appendixes 1 and 2. Some fundamental model limitations and application considerations include:

- The water body should be well mixed for vertically integrated two-dimensional flow and transport simulation.

- The model grid size must be chosen such that waves of importance in the water body are not short relative to the chosen cell size, especially whenever eddies are likely. Any wavelength shorter than two cell sizes cannot be resolved by the model. Cell dimensions are typically determined based on the minimum resolution required to adequately represent major hydraulic features in the water body. Sensitivity testing with finer grid resolution is an effective means to establish and demonstrate the credibility of the chosen cell size.

- Although the ADI scheme permits running a simulation using a large time step, there are practical limits on the time-step size. The time step should be chosen with considerable care and tested for sensitivity, particularly in applications to water bodies with irregular boundaries and complex bathymetries (Benque and others, 1982; Weare, 1979). The Courant number of the chosen cell size and time step should be evaluated against the celerity of waves in the water body and propagation properties of the ADI scheme as identified by Stelling and others (1986).

- Long open-water boundaries should be placed on the edge of the rectangular grid that defines the model domain. In this situation, advection terms in the momentum equations are set to zero and gradients across the open boundaries are better represented, which results in more accurate and stable computations. Closed boundaries within the computational domain should be non-reflective.

- There are no rigid upper limits on the numbers of grid points, boundary openings, sources, dams, barriers, islands, stations, or cross sections, or on the complexity of the shape of the computational grid within the rectangular model domain. There are practical code limits for some parameters, such as the number of discharge sources and number of simulated constituents; however, these can be extended by modification of the program code.

SWIFT2D Simulation Process

Processes and techniques associated with designing and developing a SWIFT2D numerical simulation, structuring and coding model input, setting up and executing the model, and interpreting model output are documented in this and subsequent report sections. In this report section, the structure of the SWIFT2D model program is described, an overview of the SWIFT2D simulation setup process is provided, execution-specific information about the SWIFT2D model and its input data processor SWIFT_IDP is given, an interactive file-designation and program-execution procedure developed to facilitate use of SWIFT_IDP and SWIFT2D on window-based PC systems is described, and the computer resources needed to conduct a numerical simulation are identified. Model input is described in the **SWIFT2D Input** section, inputs and variables required by various simulation options are discussed in the **SWIFT2D Numerical Aspects and Computational Features** section, and model output is described in the **SWIFT2D Output** section.

The design and setup of a simulation using SWIFT2D is similar to the approach used for the two-dimensional simulation model SIM2D, as originally designed, developed, and described for the SIMSYS2D modeling system (Leendertse, 1987). Although much of the code for supporting programs in the original SIMSYS2D modeling system remains intact, some of these programs, previously operational on both UNIX and PC systems, are presently either non-functional or only partially functional because their operational status has not kept pace with the rapidly changing computer environment. In the present-day SWIFT2D simulation process only the core components of the original SIMSYS2D modeling system are used. These are the simulation model, now called SWIFT2D, and its companion input data processor, SWIFT_IDP, as depicted in the system flowchart in figure 1.

Figure 1 identifies the major functional steps in the SWIFT2D simulation process. The order of these steps is:

1. Build the SWIFT_IDP executable.

2. Create the SWIFT_IDP input (*.idp) file using a text editor following coding instructions in Appendix 2.

3. Run SWIFT_IDP using the input (*.idp) file to create the SWIFT2D program dimension (idpdim.cmn) and model input (*.inp) files.

4. Build the SWIFT2D executable using the program dimension (idpdim.cmn) file.

5. Create the SWIFT2D control (*.ctl) file using a text editor following coding instructions in Appendix 1.

6. Run SWIFT2D using the prepared control (*.ctl) and input (*.inp) files.

7. Postprocess and analyze simulation results in the map (*.map) and history (*.hst) output files using available software programs.

SWIFT2D Program Structure

The SWIFT2D computer program was designed and written using modular programming practices for both its computational procedures and code structure. Any special numerical or computational feature other than the fundamental hydrodynamic simulation is not activated during a model run unless specified by the data input stream. For example, transport simulation is only active when constituent inputs are defined. This also is true for time-varying boundary openings, Fourier-driven tide openings, flow barriers, particle tracking, discharge outfalls, or constituent sources. The output of grid maps, time histories, and other results for postprocessing also is optionally controlled by input computational-control variables.

The modular design of the SWIFT2D source code permits the size of its executable program, in terms of computer memory usage, to be controlled directly and easily by dynamically dimensioned parameters. Dimension parameters control the size of model-dependent arrays in a FORTRAN include file called IDPDIM.CMN (fig. 1). The SWIFT_IDP program generates the IDPDIM.CMN file with parameter values taken directly from the in-stream input data defining the model dimensions and identifying the computational features chosen for the simulation (See Appendix 2). SWIFT_IDP also annotates the IDPDIM.CMN file with comments identifying the simulation and title of the model setup. Thus, various IDPDIM.CMN files can be easily identified and archived.

After the SWIFT2D code is compiled and loaded with the proper IDPDIM.CMN file, an executable program sized to the exact dimensions of the prototype water body and simulation setup is created (fig. 1). Modification or re-creation of the IDPDIM.CMN file (consisting of about 20 lines of code) and recompilation and loading of the SWIFT2D program is required to change the dimensions of the executable program to match those of a new model or simulation setup. A SWIFT2D executable program must be created using a new IDPDIM.CMN file when: (1) a new model is implemented; (2) new computational features are selected for a simulation; (3) key model dimension parameters are changed; or (4) any array dimension becomes larger than its size in the IDPDIM.CMN in the present executable.

Figure 1.   Flowchart showing the processing of data and files associated with SWIFT2D. (Asterisk preceding the suffix in filenames represents a text string identifying the model setup.)

Simulation Setup

The first step in preparing to execute the SWIFT2D program is to generate the input computational-control, model-parameter, and data-definition records. This must be done according to the formats specified in Appendixes 1 and 2. The model program expects this input to be in 80-character text format. The number, content, and extent of required input and output files are dependent upon specific parameter assignments as defined principally on the computational-control records input to the model. Strict time order of input is required since SWIFT2D sequentially processes time-varying data during a simulation run, that is, alternately computing new dependent variables and reading new boundary-value data. A flowchart of the steps for using SWIFT2D is shown in figure 1.

Three basic types of input are required: (1) grid data (depths, Manning resistance coefficients, initial flow conditions and constituent concentrations, and so forth); (2) time-series data (water levels, discharges, concentrations, and so forth); and (3) computational-control variables (grid size, output options, integration scheme, and so forth). All input can be generated using a text editor or any other program or software that generates text-formatted records. After all input records are generated (coded in the required format as defined in Appendixes 1 and 2), they are preprocessed by the Input Data Processor program SWIFT_IDP to generate the array dimension (IDPDIM.CMN) and simulation input files for the model. Interactive procedures developed to facilitate SWIFT_IDP and SWIFT2D execution in the DOS (disk operating system) window of a PC are described in the following report section.

Interactive File-Designation Procedure

All input and output filenames must be defined to subsequently execute the SWIFT_IDP and SWIFT2D programs. Interactive window-based procedures have been developed to facilitate filename definitions and perform all file-opening operations for SWIFT_IDP and SWIFT2D execution. The number of SWIFT_IDP input and output files is fixed. The number of input and output files required for SWIFT2D execution is dependent upon specific parameter assignments as defined principally on simulation-control input records (See Appendix 2). SWIFT_IDP and SWIFT2D automatically store input and output filenames in master files called SWIFT_IDP.MTR and SWIFT2D.MTR, respectively, for subsequent retrieval. Master files are stored in the current simulation directory and a master file is automatically created if

one does not exist. The purpose of the master file is to retain the filenames used in the most recent program execution. During the interactive file-designation process, the current filenames in the master file are displayed in the DOS window. It is then possible to execute the program using the displayed files by responding to a single interactive prompt. Master files can be renamed or copied to another file to save for subsequent reuse. (To re-activate a saved master file, it must be renamed SWIFT2D.MTR or SWIFT_IDP.MTR, as appropriate.)

Interactive prompts are issued in the DOS window for all required files if the master file does not exist or if the filenames in the master file are to be changed. In the prompt for each file, the current name, as given in the master file or a default program-generated filename, is displayed. If the displayed filename is acceptable, a carriage return is a sufficient response to the prompt; otherwise, a filename must be entered. All output filenames can be automatically generated based on the name of the *.idp input file for SWIFT_IDP (of the *.inp input file for SWIFT2D) by response to a single prompt, thus eliminating the need to answer individual prompts for output filenames. (Asterisk preceding the suffix represents a text string identifying the model setup.) The master file is recreated using the specified or chosen filenames and the program execution is initiated after all filenames have been assigned. An existing version of the master file is not updated if the program is terminated during the file-designation procedure. The SWIFT2D and SWIFT_IDP interactive-execution programs can be terminated during the file-designation process by typing 'q' and issuing a carriage return.

The SWIFT_IDP and SWIFT2D programs generate a default name if a required filename is not defined in the master file. The default filename is created as follows. A "base" name is determined from the input *.idp and *.inp filenames for SWIFT_IDP and SWIFT2D, respectively, by removing any three letter suffix. If no such suffix ends the filename, the full name is used as the base name. The default, program-generated filename is then the base name plus a unique program-assigned suffix. Table 1 presents the contents of a typical SWIFT2D.MTR file and gives the suffixes used for each filename. In this example, "potomac200" represents the base name. Table 2 presents the contents of a typical SWIFT_IDP.MTR file and identifies the suffixes used for all filenames. In this example (as in table 1), "potomac200" represents the base name. SWIFT_IDP uses six temporary files that are opened with filenames defined in the master file. Prompts are not issued for these temporary files and viewing them is not necessary. (All temporary files are deleted upon normal program termination.)

Table 1.   Typical contents of the SWIFT2D.MTR file.

IN-STREAM-CONTROL INPUT	: potomac200.ctl
IDP-CREATED INPUT (SIMINP)	: potomac200.inp
TIME-VARYING WIND INPUT	: potomac200.wnd
SIMULATION PRINTOUT	: potomac200.prt
RUN STATISTICS PRINTOUT	: potomac200.log
PARTICLE-TRACKING PRINTOUT	: potomac200.par
STAGE & TRANSPORT PRINTOUT	: potomac200.wlt
MODEL OUTPUT (SIMMOT)	: potomac200.map
HISTORY OUTPUT (SIMHST)	: potomac200.hst
RESTART OUTPUT (SIMRST)	: potomac200.rst
COARSE-GRID OUTPUT (CGDATA)	: potomac200.cgd
EMERGENCY RESTART 1 (EMRST1)	: potomac200.er1
EMERGENCY RESTART 2 (EMRST2)	: potomac200.er2
MINIMUM VELOCITY OUTPUT	: potomac200.mnv

Table 2.   Typical contents of the SWIFT_IDP.MTR file.

IDP INPUT DATA (IDPIN)	potomac200.idp
SIMINP OUTPUT FILE	potomac200.inp
DIMENSION PARAMETER FILE	idpdim.pot200.cmn
SIMULATION INPUT REPORT	potomac200.rpt
RUN STATISTICS PRINTOUT	potomac200.log
SCRATCH FILE UNIT 16	t$in12.dat
SCRATCH FILE UNIT 17	t$in2a3.dat
SCRATCH FILE UNIT 18	t$new2a3.dat
SCRATCH FILE UNIT 19	t$itpcom.dat
SCRATCH FILE UNIT 50	t$ifmtfl.dat
SCRATCH FILE UNIT 55	t$nupr55.dat

SWIFT_IDP Execution

SWIFT_IDP performs consistency checks on SWIFT2D input data, interprets grid enclosures used to define the computational domain and solution sequence, combines various time-varying input data into sequential order for concurrent processing during the simulation, generates the IDPDIM.CMN file used to dimension the SWIFT2D model arrays, and prints an input report on the status of the model setup and simulation design. Limitations, considerations, input format, and data structure for SWIFT_IDP are defined in Appendix 2.

SWIFT_IDP reads the model-setup input file (*.idp), reads and writes two program files (IDPRUN.LOG and SWIFT_IDP.MTR), and writes four output files (*.inp, *.rpt, *.log, and IDPDIM.CMN) as shown in figure 2. The type and format of information in the SWIFT_IDP input (*.idp) file is described in detail in Appendix 2 and a sample file is shown in Appendix 3. The IDPRUN.LOG output file retains a chrono-logical history of past SWIFT_IDP executions using input files within the current simulation directory. Information about the simulation, the SWIFT_IDP program version, and the program execution date and time are appended to this file after each SWIFT_IDP execution. Typical contents of the IDPRUN.LOG file are presented in table 3. The SWIFT_IDP.MTR file is the "master" file that contains the filenames referenced in the SWIFT_IDP execution. Contents of this file, described previously in the **Interactive File-Designation Procedure** section, are illustrated in table 2.

The four SWIFT_IDP output files are the: (1) SIMulation INPut (SIMINP) file, (2) array dimension (IDPDIM.CMN) file, (3) simulation report (*.rpt), and (4) run statistics file (*.log). The SIMINP file (*.inp) is the input file of computational-control, grid, and time-series data in the format required by SWIFT2D. The IDPDIM.CMN file is the FORTRAN include file used to generate the SWIFT2D executable. The simulation report (*.rpt) is the SWIFT_IDP processing report that can be used to verify the simulation design and model setup before conducting the simulation. The run statistics file (*.log) contains any error and warning messages generated by SWIFT_IDP that are listed separately from the simulation report.

SWIFT2D Execution

The SWIFT2D executable and an in-stream control file (*.ctl) must be created after the SIMINP (*.inp) and IDPDIM.CMN files have been generated by SWIFT_IDP in order to run the model. A flowchart of the processes and files associated with SWIFT2D execution is shown in figure 3. A summary of SWIFT2D files is presented in table 4. A UNIX "MAKE" procedure, or equivalent facility typically available in FORTRAN compiler packages for PC systems, can be used to create the SWIFT2D executable. After this is accomplished, the SWIFT2D in-stream control file (*.ctl in fig. 3) must be created using a text editor and coded according to the format described in Appendix 1 and illustrated in Appendix 3.
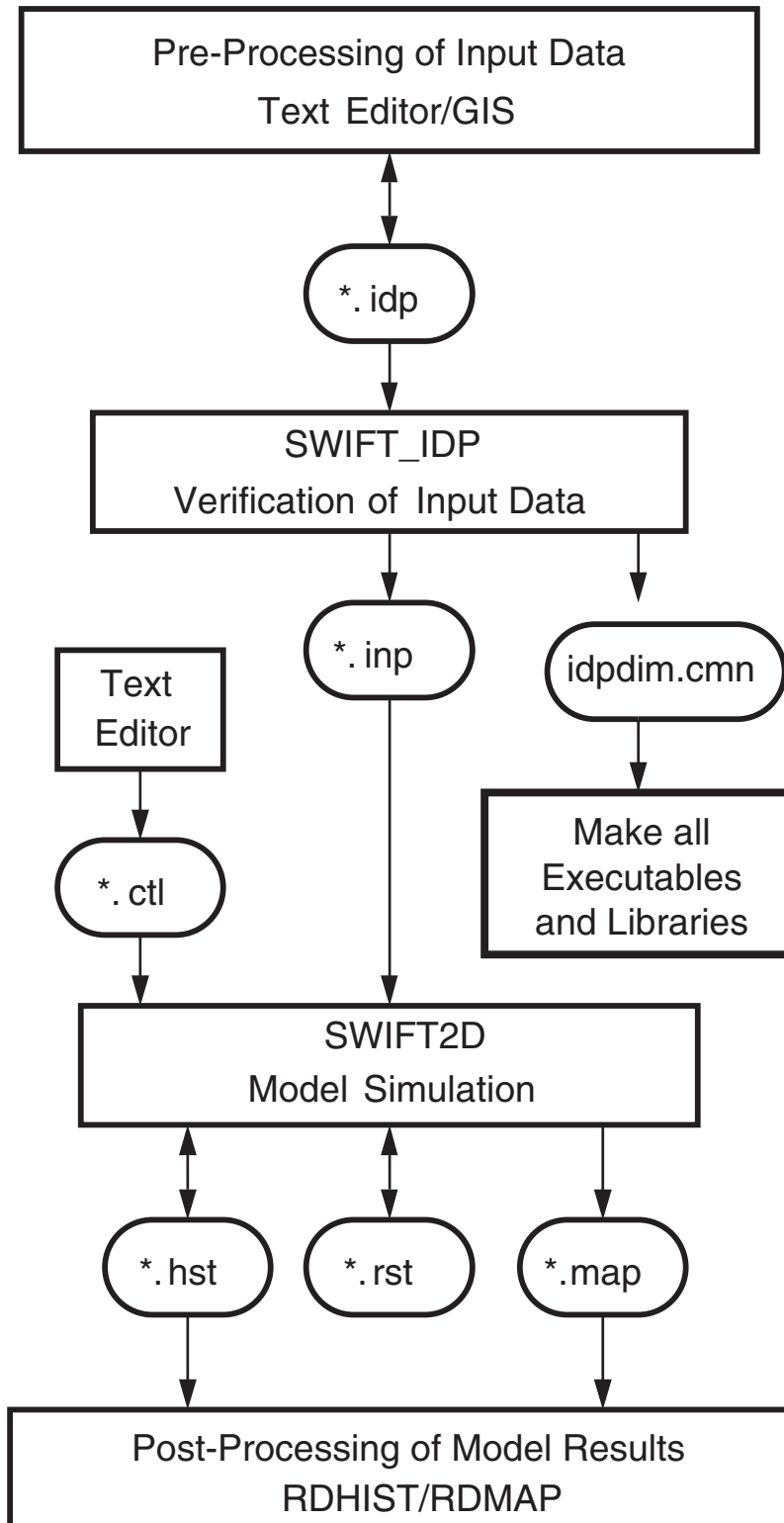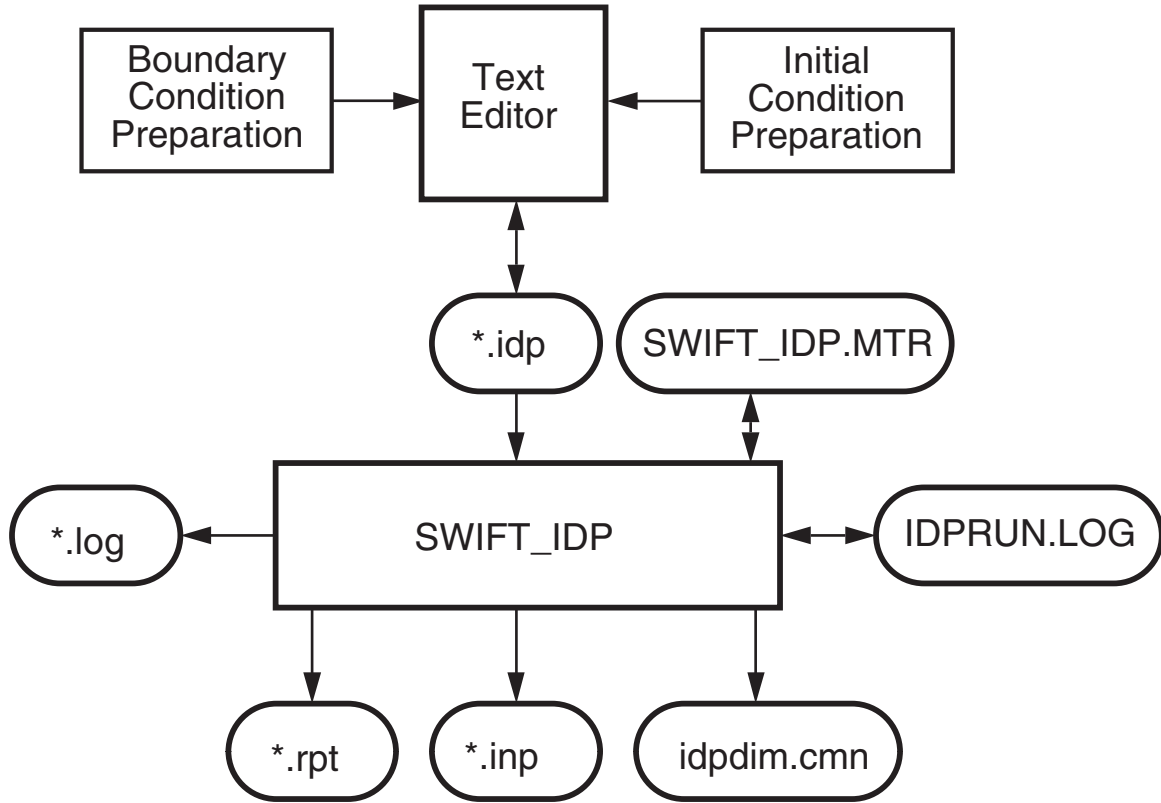
Figure 2.   Flowchart showing the preprocessing of data and files associated with SWIFT_IDP. (Asterisk preceding the suffix in filenames represents a text string identifying the model setup.)

Table 3.   Typical contents of the IDPRUN.LOG file.

```
            NOTES:
            LSEPA=1,LHDIV=0,LINP=60,NCO=133,LFICH=0,NOPLU=0,MCKOUT=00000
            INDIAN HD TO MORGANTOWN MODEL
            200M-GRID, SIM RUN #06 USING SIMSYS2D V514
IDP         STARTED AT 92/10/31 15:16:10 FOR POTOMAC RIVER
       *    PO200MTZ/IDP...R01
            INDIAN HEAD TO MORGANTOWN : 200 M GRID : SIM RUN #06
            NOTES:
            LSEPA=1,LHDIV=0,LINP=60,NCO=133,LFICH=0,NOPLU=0,MCKOUT=00000
            INDIAN HD TO MORGANTOWN MODEL
            200M-GRID, SIM RUN #06 USING SIMSYS2D V514
IDP         STARTED AT 92/11/ 1 12:11:47 FOR POTOMAC RIVER
       *    PO200MTZ/IDP...R02
            INDIAN HEAD TO MORGANTOWN : 200 M GRID : SIM RUN #06
            NOTES:
            LSEPA=1,LHDIV=0,LINP=60,NCO=133,LFICH=0,NOPLU=0,MCKOUT=00000
            INDIAN HD TO MORGANTOWN MODEL
            200M-GRID, SIM RUN #06 USING SIMSYS2D V514
IDP         STARTED AT 92/11/ 3 15:19:54 FOR POTOMAC RIVER
       *    PO200MTZ/IDP...R03
            INDIAN HEAD TO MORGANTOWN : 200 M GRID : SIM RUN #06
```
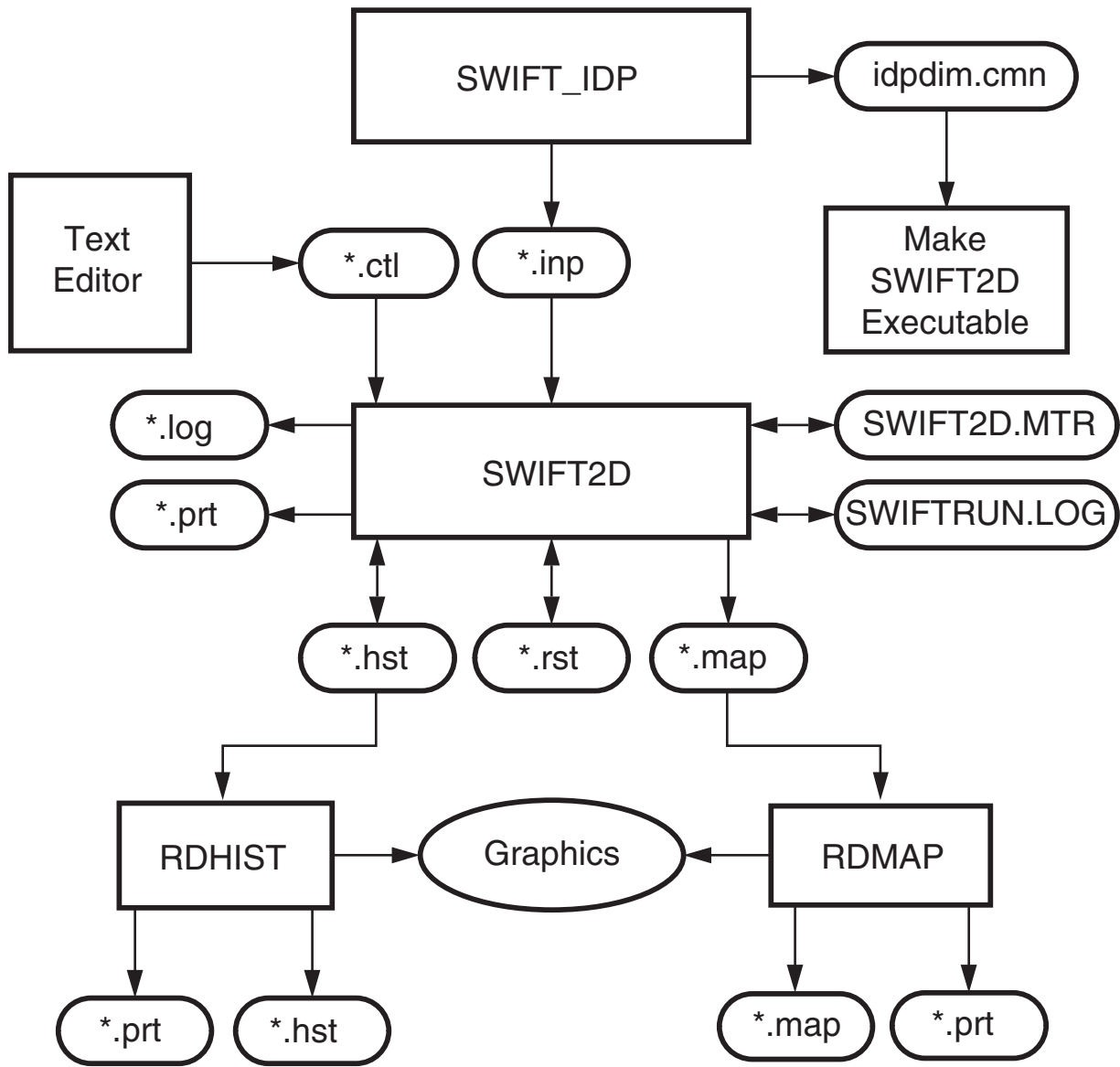
Figure 3.   Flowchart showing files associated with SWIFT2D execution. (Asterisk preceding the suffix in filenames represents a text string identifying the model setup.)

SWIFT2D reads two input files (*.inp and *.ctl), reads and writes to four files (SWIFTRUN.LOG, SWIFT2D.MTR, *.hst, and *.rst), and writes three files (*.prt, *.log, and *.map) as shown in figure 3. The main SWIFT2D input is the *.inp file, which is generated by SWIFT_IDP, and contains Part 1 (simulation control), Part 2 (initial condition), and Part 3 (time-varying) data records described in the **SWIFT2D Input** section and documented in Appendix 2. The *.ctl file consists of annotation, Part 0 (model identification), and optional Part 1 override records documented in Appendix 1. The SWIFTRUN.LOG file is described below. The SWIFT2D.MTR file described in the **Interactive File-Designation Procedure** section and presented in table 2 is the "master" file that contains the file names referenced in the execution of SWIFT2D. The History file (*.hst), described in the **SWIFT2D Output** section, is an output file used in post-processing that normally contains time-series output from a single simulation run. If desired, however, SWIFT2D can append to an existing History file to combine results of successive simulations in a single file. The Restart (*.rst) file, described below, contains all information that SWIFT2D needs to restart a simulation at an intermediate time step within the present simulation setup. Two additional read/write files, not shown in figure 3 but described below, are the Emergency Restart files. These files contain essentially the same information as the Restart file, but serve a different purpose, which is explained below.

Table 4. SWIFT2D files.

Unit number	Variable name	Default file name	File identifier	Type	Description
8	LUREST	swift2d.rst	SIMRST	in/out	Permanent-Restart binary
9	LUHIST	swift2d.hst	SIMHST	output	Time-History binary
10	LU2	swift2d.inp	SIMINP	input	Part 1, 2 and 3 records, IDP-created input
12	LUCG	swift2d.cgd	CGDATA	output	Coarse-Grid-Data binary
13	NUPRIN	swift2d.prt	Printer	output	Bulk of printed output
13	NUPRTC	swift2d.par	Printer	output	Particle-tracking printout
13	NUWLTR	swift2d.wlt	Printer	output	Stage and transport printout
14	LUWPT	swift2d.wnd	Wind	input	Part 4 input records, time-varying wind & pressure
15	LUMAP	swift2d.map	SIMNAP	output	Map binary
16	LUSPAN	swift2d.mnv		output	Minimum velocity binary
41	NUERS1	swift2d.er1	EMRST41	in/out	Emergency-Restart binary 1
42	NUERS2	swift2d.er2	EMRST42	in/out	Emergency-Restart binary 2
47	NUTLOG	swiftrun.log	RUNLOG	in/out	Run Log
55	SCRUNT		IPRT55	temporary	Temporary bulk of printout
65	MASTR	SWIFT2D.MTR		in/out	Master file containing the file names last used
66	MDIAG	swift2d.log	Printer	output	Run statistics and messages
72	LUCHK	T$CHKFIL.DAT	Scratch	temporary	Temporary file used by CHECKOUT program
75	LU1	swift2d.ctl	In-stream	input	Computer ID, unit numbers, Part 0 and override records

   The principal model output files are the printed output file (*.prt), the run statistics file (*.log), the simulation Map file (*.map), and the simulation History file (*.hst). The printed output file can be divided into three separate files by assigning non-zero values to the unit-number variables *NUPRTC* and *NUWLTR* on the file-units record of the in-stream-input file (see Appendix 1). Printed output can be divided into water-level and transport results (*.wlt), particle tracking computations (*.par), and the remainder of printed output (*.prt). The run statistics print file contains error and warning messages generated by SWIFT2D. Error and warning messages described in the **SWIFT2D Output** section are separated from the simulation printout to enable quick and easy recognition of any problems encountered by the model during the simulation. The simulation Map and History files contain grids and time histories of model results, respectively, for output postprocessing. Two programs were developed in the original SIMSYS2D modeling system to postprocess simulation results written by SWIFT2D to the binary Map and History files. RDMAP is an interactive program that allows selective viewing and manipulation of model results in the Map file as graphic images or printed tables. RDHIST performs similar functions for model results in the History file. These programs can be updated, modified, and used to postprocess results for analysis or graphical display or to re-format model output for input to commercially available statistical or graphical programs and (or) software.

   Because SWIFT2D can generate large amounts of output, some restraint should be exercised in specifying the frequencies to write to the Restart, Map, and History files. Printed output also can become excessively large if all computational features are activated and the printout of simulation results is requested frequently. Postprocessing is an essential part of the model simulation process because SWIFT2D produces large quantities of computational results that are not easily scrutinized and analyzed.

Run Log File

   The Run Log file (SWIFTRUN.LOG) contains a history of all past SWIFT2D executions in the current simulation directory. During each execution, SWIFT2D appends run information to the current SWIFTRUN.LOG file if one exists in the current directory; otherwise, it creates a new file. Run information includes identification of SWIFT_IDP and SWIFT2D program versions, program execution dates and times, the times of restart file writes, any simulation error or warning messages, and any annotation information given by the user to describe the purpose of the simulation run. Therefore, the Run Log file is not only a history of runs, but also a status report on the model development. A text line of asterisks separates each simulation entry in the Run Log file. Typical entries in a SWIFTRUN.LOG file are illustrated in table 5.

Table 5.   Typical contents of the SWIFTRUN.LOG file.

NOTES:
POTOMAC 200M MODEL
SWIFT2D STARTED AT 93/01/31 15:12:32 FOR POTOMAC RIVER
* PO200MTZ/IDP...R03_POTOMAC02
INDIAN HEAD TO MORGANTOWN : 200 M GRID : SIM RUN #06
SWIFT2D WAS RUN AT 93/01/31 12: 5:18 POTOMAC RIVER
INDIAN HEAD TO MORGANTOWN : 200 M GRID : SIM RUN #06
* SWIFT2D RESTART FILE WRITTEN AT 300.00 MINUTES (STEP 300)
* SWIFT2D RESTART FILE WRITTEN AT 600.00 MINUTES (STEP 600)
* SWIFT2D RESTART FILE WRITTEN AT 900.00 MINUTES (STEP 900)
* SWIFT2D RESTART FILE WRITTEN AT 1200.00 MINUTES (STEP 1200)
* SWIFT2D RESTART FILE WRITTEN AT 1500.00 MINUTES (STEP 1500)
* SWIFT2D RESTART FILE WRITTEN AT 1800.00 MINUTES (STEP 1800)
* SWIFT2D RESTART FILE WRITTEN AT 1816.00 MINUTES (STEP 1816)
SWIFT2D COMPLETED WITH 0 ERRORS, 0 WARNINGS, AT 93/01/31 16:28:41
LAST TIME IS 1816.00 MINUTES (STEP 1816)************

Restart File

The Restart file (*.rst) allows a SWIFT2D simulation to begin at a specified time step using results computed and stored during the prior simulation run. This allows a simulation to continue from any time when restart information was written to the Restart file. The main uses of this capability are to: (1) allow a long simulation to be split into several executions, (2) begin a simulation at some specified time beyond the computational "warm-up" time required by the model, or (3) allow a simulation to be restarted after a computer failure. The Restart file is a sequential-access binary file. The time to restart (read initial conditions from the Restart file) is controlled by the input variable *TRST*. If *TRST* is zero, SWIFT2D does not write or attempt to read a Restart file and starts the simulation at the time specified by *TSTART*. If *TRST* is not zero, SWIFT2D reads the Restart file and begins the simulation using the first set of restart results encountered in the file for a time equal to or greater than *TRST*. If all times on the Restart file are less than *TRST*, SWIFT2D uses the last set of restart results in the file. If no restart results are found, the simulation starts at *TSTART* using the input data read in Parts 1 and 2 input, that is, as if *TRST* were zero. Variables controlling model restart are specified on record 4 of Part 1 SWIFT_IDP input (see Appendix 2).

SWIFT2D writes simulation results to the Restart file at intervals of *TIRST*. The last integration time step *TSTOP* also is written if SWIFT2D terminates normally. For example, if *TIRST* is greater than *TSTOP*, only the last step is written upon normal model termination. Because the same file is used to read and write restart information, results from the current simulation are written after the results used for the restart. This process overwrites any results previously saved for time steps beyond the restart time. Therefore, care must be taken that the re-written Restart file is from the same model setup, simulation design, and program versions as the original model run to avoid compatibility problems.

Emergency Restart Files

Emergency Restart files 1 and 2 are alternately written and used primarily to allow restart of a model run when a computer failure occurs during a simulation by continuing from the last time either file was written. Developed primarily for original batch-oriented model execution, these files were established to allow a computer operator executing the model at a remote computer facility to restart the simulation without intervention by the modeler. The Emergency Restart files (EMRST41 and EMRST42) are direct-access files that contain essentially the same information as the Restart file. SWIFT2D writes to EMRST41 and EMRST42 at alternating intervals of *TIERST*. These files are written at alternating intervals to avoid destroying the restart information if the computer system fails during a file write. In light of modern computer advances, the value of this emergency restart capability is significantly reduced and possibly only of benefit if a computer failure were to occur in an exceedingly long model run. In general, it is not recommended that these files be used (thus, specify *TIERST* = 0.0). However, if the files are used, note that the Map and Coarse-Grid files are overwritten at restart if their file names are not changed prior to executing the emergency restart. In addition, the History file is overwritten unless *NHST* is not zero. The time interval to write the Emergency Restart files, *TIERST*, is specified on record 5 of Part 1 input (see Appendix 2).

Hardware and Software Requirements

The only mandatory software requirement of the SWIFT2D model is availability of a FORTRAN compiler. Other software and hardware requirements identified here are model and simulation dependent:

- A FORTRAN 77, 90, or 95 compiler (backward compatible with earlier versions) is needed to generate the computer-system-dependent executable programs.

- A computer system clock accessible by a FORTRAN subroutine is required to have simulation output annotated with the run date and time.

- A computer with sufficient main memory; in general, about 2 mB (megabytes) is required for a model having 10,000 grid cells.

- A computer with on-line disk space; typically, about 50 mB is required for a small model or short simulation.

Computer Memory

The SWIFT2D code can vary in computer memory requirements depending on the physical dimensions of the water body being simulated and the computational features of the model being used. The SWIFT2D code requires about 350 kB (kilobytes) of memory for the solution code and other computational features in addition to the amount of memory needed for data-dependent arrays as dimensioned by IDPDIM.CMN parameters. The amount of memory required for data-dependent arrays is printed by SWIFT_IDP and stored in the IDPDIM.CMN file as the *NOBYTV* parameter. The amount of memory, in bytes, for array dimensions can be estimated by the formula $4*(17+4*LMAX)*MMAX*NMAX$. For a model with grid dimensions 100 x 100 (*NMAX* by *MMAX*) and 3 (*LMAX*) constituents, the arrays would require at least 1.1 mB of memory. Therefore, the model would require about 1.5 mB of memory for execution.

Run Time

The amount of time required for a SWIFT2D model run varies greatly depending on the simulation design and the Central Processor Unit (CPU) and input/output (I/O) speeds of the computer. Run times depend mainly on the size and complexity of the water body (number of cells within the rectangular grid), the length of time being simulated (number of time steps), the numerical solution options being used (first or second order integration with or without iteration), the computational features being invoked, and the number and type of constituents being simulated. Other factors that affect the run time, to a lesser extent, include the number of Fourier components, the frequency of checking for flooding and drying, and amount of output requested.

Table 6 is presented to identify the relative speed of various computers in executing a SWIFT2D simulation. The last column in table 6 gives the ratio of the length of time simulated to the CPU time required to complete the simulation. The example simulation is of the upper tidal-river segment of the Potomac Estuary between Indian Head and Morgantown, Maryland. The model used a 173 by 180 rectangular grid of 200-m-square cells with about 18,000 active computational cells representing the tidal river and its tributaries (Schaffranek, 1986). A 1-minute time step was used to conduct the 26-hour 45-minute simulation. The simulation used second-order integration, second-order advection, coupled salinity, particle tracking, and transport of an interactive constituent. The size of the executable program was about 1.1 mB. Output consisted of over 8 mB of text and 19.5 mB of binary data. Times shown in table 6 are for optimized compilations (compiler options are shown in parentheses under the software heading) and are given as CPU time when available; otherwise, they are given as clock time. The simulations were conducted when the computers were in single-user mode or when only computer operating system processes were active. All disk I/O involved local disk drives.

Table 6.   Relative speed of various computers executing SWIFT2D.

Hardware (memory)	Software (OS/compiler)	CPU Time (hr:mn:sec)	Ratio (SIM/CPU)
SUN SPARCstation 2 40 MHz SPARC Processor 32 MB memory	SunOS 4.1.1 SC1.0 Fortran V1.4 1 (O3)	1:48:06	15
Data General AViiON 530 33 MHz Motorola 88000 32 MB memory @ 39 MIPS	DG/UX 5.4.1 Green Hills Fortran-88000 1.8.6 VERSION (OM)	1:30:43	18
IBM RISC 6000 Model 560 50MHz RISC processor 128MB memory, 31.3 MFLOPS 97.6 SPECfp92	AIX Version 3.2 XLF Version 2.2 (O)	0:22:11	72
Silicon Graphics 540 Pentium III 550 MHz 478 MB RAM	MS Windows NT V4.0 Compaq Visual Fortran Professional Edition 6.6A	0:05:32	240
Micron Pentium III 933 MHz 512 MB RAM	MS Windows NT V4.0 Compaq Visual Fortran Professional Edition 6.6A	0:04:23	366
Dell Pentium 4 3.2 GHz 2.0 GB RAM	MS Windows XP Compaq Visual Fortran Professional Edition 6.6A	0:01:02	1,553

SWIFT2D Input

Input to SWIFT2D is divided into 5 parts (numbered 0 to 4 in Appendixes 1 and 2). This input is separated into three files: a processing-control file (in-stream input file described in the following **In-stream Input** section) containing Part 0 and optionally Part 1 override records, a simulation input file (SIMINP) that contains data processed by SWIFT_IDP (Parts 1–3 input discussed in the **Simulation Input File** section), and an optional Part 4 input file that contains time- and space-varying wind and pressure data (discussed in the **Part 4 Input** section). Records in these input files are required to be in 80-character text format. Coding specifications for the in-stream input file are given in Appendix 1. Coding specifications for the SIMINP file are not given directly for input to SWIFT2D although the formats of most input are unchanged in pre-processing by SWIFT_IDP. The SWIFT_IDP program generates the information and data in the SIMINP file in the format and sequential order required by SWIFT2D. Coding specifications for the SWIFT_IDP input file (*.idp), from which the SWIFT2D input file (*.inp) is generated, are given in Appendix 2. Format specifications and input order for Part 1 and Part 2 input are similar (except for the computational grid enclosure) for both SWIFT_IDP and SWIFT2D, therefore, instructions in Appendix 2 can be used to manually generate, edit, or modify the majority of a SIMINP file directly. However, additional input is derived from the computational grid enclosure that must be manually prepared and formatted in the SIMINP file if not preprocessed and prepared by SWIFT_IDP. The format of Part 3 input is significantly different between SWIFT_IDP and SWIFT2D.

If minor changes to an existing SIMINP file are needed, such as type or frequency of output, time step, type of advection computation, number of iterations, and so forth, records defining these new variable assignments can be input to SWIFT2D as "override" records in the in-stream input file described in the **In-Stream Input** section. Major changes such as grid size, particle-tracking options, number of water-level stations, discharge sources, transport cross sections, and so forth, require re-execution of SWIFT_IDP to recreate the SIMINP file since such changes usually affect the IDPDIM.CMN file generated by SWIFT_IDP to build the SWIFT2D executable.

In-stream Input

The SWIFT2D in-stream input control file (*.ctl) consists of up to 10 record types, identified by order of input in table 7. These include the computer and program identification records, file-units record, Part 0 records, and optional Part 1 override records. Coding specifications and restrictions on parameters of the in-stream-input records are defined in Appendix 1. Record types that can have multiple input (Heading, Note, and Override records) are delimited by END records that signal SWIFT2D to read the next record type.

Input on the computer and program identification records is used to build the *RUNID*, which is used to catalog simulation results stored in various output files.

Variables on the file-units record allow specification of alternate unit numbers for SWIFT2D input and output files. A primary use of this record is to divide the printed output file into smaller, more manageable parts. If desired, the particle-tracking results can be written to a separate file and (or) the water level and transport results can be written to a separate file by assigning unique nonzero file-unit numbers to the *NUPRTC* and *NUWLTR* variables, respectively. The file-units record also can be used to resolve unit number conflicts that might arise with the computer operating system being used to run the model.

Part 0 input consists of parameters that control the appearance of printed output and user notes that describe the purpose of the simulation. These are defined by record types 4 through 9. Parameters defined on the Heading records are used to label each page of printed output. The Print record specifies the appearance of the printed output, including whether or not to separate error and warning messages from printed output. These records are written to the Run Log file, described in the **Run Log File** section, and to the printed output, described in the **Printed Output** section.

Optional override records complete the SWIFT2D in-stream input control file. Override records specify replacement values for Part 1 input as given in the SIMINP file described in the **Simulation Input File** section. The override process is used in SWIFT2D to allow modification of specific Part 1 input parameters controlling the simulation without requiring manual

Table 7.   In-stream-input record order.

Record	Description
1	Computer Identification Record*
2	Program Identification Record
3	File Units Record
4	Head Record(s) (0 to 3)*
5	End-Head Record*
6	Print Record*
7	Note Record(s) (0 to n)*
8	End-Note Record*
9	Override Record(s) (0 to 183)
10	End-Override Record

*Part 0 records.

edit or regeneration of the SIMINP file through re-execution of SWIFT_IDP. Most values for Part 1 variables as generated by SWIFT_IDP can be overridden in SWIFT2D. The exceptions (fatal errors and warnings) are listed in tables 8 and 9. The variables shown in table 8, in general, cannot be overridden because other input in Parts 2 and 3 and (or) program array dimensions in the IDPDIM.CMN file generated by SWIFT_IDP depend on these values. The variables identified in table 9 should be avoided or only overridden with caution, as possible conflicts with other variables can occur. Override variables should be ordered by record number. Table 10 gives a list and identifies the FORTRAN coding format of all Part 1 variables specified on each record in order of input, with the most likely variables to be overridden identified in bold letters.

The variable *GOVER*, defined on the "END OVER" record (see Appendix 1), is a flag provided to control SWIFT2D treatment of errors in the specification of override records. An error message is printed, and the simulation terminates if *GOVER* is set to 0.0 and an attempt is made to override a variable shown in table 8. The maximum number of override records is equal to the number of input variables defined in Part 1. If more are found, the model assumes that the "END OVER" record is missing. If the same variable is specified to be over-ridden more than once, the last override value specified is used.

A sample in-stream input (*.ctl) file for the SWIFT2D model of the tidal Potomac River, identified and used in the **Run Time** section, is shown in Appendix 3 to aid in model setup. A sample output from the simulation is shown in the **Particle Tracking** section.

Simulation Input File

The SIMINP file for SWIFT2D is generated by SWIFT_IDP from the *.idp file coded according to the format specifications identified in Appendix 2. This file contains user notes, model dimensions, and Parts 1 (simulation-control), 2 (initial-condition), and 3 (time-varying) input information. User notes describe the purpose of the SWIFT2D simulation. Dimension information passed to SWIFT2D is used to verify that the dimensions of input model data are compatible with the dimensions of model-dependent arrays in the IDPDIM.CMN file used during the compilation and build of the SWIFT2D executable. (This compatibility check is required to ensure that the SWIFT2D executable was not generated for another model setup or set of simulation data.) Part 1 input specifies computational-control parameters. Part 2 input specifies initial values, values related to geometry, and locations where data are input or model results are output. Part 3 input specifies time-varying data to be used during the simulation, such as water levels, discharges, velocities, or constituent concentrations at open boundaries. To aid in model setup, a sample SWIFT_IDP input (*.idp) file for the SWIFT2D model of the tidal Potomac River, identified and used in the **Run Time** section, is shown in Appendix 3. (Only the first and last three records defining the depth grid, input on record set 27 of Part 2, and the initial constituent-concentration grid, input on record set 36 of Part 2, are shown in Appendix 3 to conserve space.)

Table 8.   Part 1 variables that cannot be overridden.

Name	Record number	Description
AL	18	Grid size (feet or meters)
ICOFMT	6	Flag for coefficient formats
ICORR[1]	6	Flag: integration correction method (<4 to >3)
IDKFMT	6	Flag for depth & concentration formats
IPAR	6	Flag for particle movement: 0=No,1=Yes
IPM	16	Number of M grid points in pressure input
IWM	16	Number of M grid points in wind input
JPM	16	Number of N grid points in pressure input
JWM	16	Number of N grid points in wind input
KC	15	Number of Fourier or harmonic components
KPOL	15	Number of constituent stations or checkpoints
LBOD	17	Constituent number used for benthic demand
LERG[2]	17	Constituent number used for energy (0 to not 0)
LMAX	15	Number of types of constituents
LOX	17	Constituent number used for dissolved oxygen
LTEMP	17	Constituent number used for temperature
MCGM	25	Number of coarse grid points in the M-direction
MET	6	Flag: 0 means No, feet; 1 means Yes, meters
MMAX	15	Number of M grid points
NCGM	25	Number of coarse grid points in the N-direction
NMAX	15	Number of N grid points
NOCUR	15	Number of current stations or checkpoints
NOLAN	6	Flag for land boundary outline: 1=SIM,2=IDP omit
NOWL	15	Number of water level stations or checkpoints
NSLU	16	Number of barrier points with U-velocity
NSLV	16	Number of barrier points with V-velocity
NSRC	15	Number of discharge sources
NTOF	15	Number of tide openings with Fourier functions
NTOT	15	Number of tide openings with time-varying data
NTRA	15	Number of U-transport cross sections
NTRAV	15	Number of V-transport cross sections
TITIDE	4	Time interval to read tidal records

[1]ICORR cannot be changed from less than or equal to 3 to greater than 3 after SWIFT_IDP.

[2]LERG cannot be changed from zero after SWIFT_IDP, but can be changed otherwise, for example, from 3 to 2.

Table 9.   Part 1 variables that produce a warning message if overridden.

Name	Record number	Description
HALFDT	4	Half time step (minutes)
LINX	25	Number of M grid spaces in first coarse grid space
LINY	25	Number of N grid spaces in first coarse grid space
MCG	25	Number of M grid spaces per coarse grid space
MPF	16	M grid ratio for pressure
MWF	16	M grid ratio for wind
NCG	25	Number of N grid spaces per coarse grid space
NPF	16	N grid ratio for pressure
NWF	16	N grid ratio for wind
SEINV	18	Initial water level (feet or meters)
TSTART	4	Time to start simulation
TSTOP	4	Time to stop simulation

A brief summary of the contents of the SIMINP file is presented below. SWIFT_IDP generates the SIMINP file by: (1) copying input user notes and writing computed model dimensions to the file; (2) copying Part 1 through most of Part 2 input, after performing data consistency checks and translating the computational grid enclosures into rows and columns; and (3) grouping all time-varying inputs in time sequence to generate the Part 3 input.

Part 1 Input

Part 1 input consists of 27 records numbered 1–27 (the particle-parameters record is optional). Part 1 is a collection of several types of computational-control parameters. Table 10 gives the order of variables and format for Part 1 input by record number. Table 11 describes the type of information on Part 1 input records. Table 12 gives an alphabetized list of all Part 1 input variables, their definitions, and a code identifying the type of use and whether or not the variable can be overridden. Tables 10, 11, and 12 should be used in conjunction with one another to assign any required changes or overrides to Part 1 input.

Part 1 parameters include the following, not listed in order of input:

1. The model identification, simulation title, map title, SWIFT_IDP run date and time, and simulation start date identifying the model.

2. Times and time intervals to read input, compute, smooth, print, and write files.

3. Flags specifying optional input, such as space-varying wind and pressure in Part 4, optional output, English or metric units, and so forth.

4. Number of cells in the grid, check stations, boundary openings, constituents, and so forth. These values are used to verify that model-dependant arrays of the SWIFT2D executable can accommodate the dimensions of the model and simulation setup.

5. Specifications that distinguish between salinity, temperature, dissolved oxygen and biochemical oxygen demand in reactions.

6. Physical characteristics, coefficients, and constants such as the angle of latitude for evaluation of the Coriolis force, the initial water level in the interior of the model domain, the gravitational acceleration constant, and atmospheric pressure.

7. Arrangement of displays, including the size and position of the basic grid on maps to be plotted (optional).

8. Contents of displays (maps) such as the interval of grid points at which to draw vectors representing velocity and transport, as well as the scales determining vector lengths, and arrowheads on vectors (optional).

9. Coarse grid parameters (optional).

10. Parameters that relate the wind and pressure macro grid to the computational grid.

Table 10.   Part 1 variables input order and override checklist.

[**Variable list:** Variables highlighted as **bold** are the most likely variables to be overridden]

Record	Format	Variable list
1	A28	RUNID
2	A72	TITL
3	A16,I2,A4,A2, 5I2,2X,4A4,4X,A2	HTITL, ITDAY, ITDATE, ITYR, IDPDAT, VERIDP
4	12E6.0	**HALFDT,** TITIDE, TSTART, **TRST, TSTOP, TIRST, TIHISP, TIHIST, TIMAPC, TIMAPV, TIMAPM, TIMAPL**
5	12E6.0	**TICG, TFCG, TLCG, TITSMO, TICVAL, TIFLOD, TIFLUX, TLFSMO, TIMAPF, TFMAPF, TLMAPF, TIERST**
6	12I6	NEXAN, **NHST,** NOLAN, MET, ISVWP, **ICORR, NCORR, MAPMOT,** IDKFMT, ICOFMT, **IADVEC,** IPAR
7	12I6	**NPRLAN, NPRDEP, NPRVIS, NPRDIF, NPRMAN,** NPRBEN
8	12I6	NPRCON(1...7)
9	12I6	NPRSE, NPRSEP, NPRVCU, NPRVCV, NPRVML, NPRVMD, NPRVMU, NPRVMV, NPRC
10	12I6	NPRR(1...7)
11	12E6.0	TPRINT(1...12)
12	12E6.0	TPRINT(13...24)
13	12E6.0	TPRINT(25...36)
14	12E6.0	TPRINT(37...42)
15	12I6	MMAX, NMAX, LMAX, NOWL, NOCUR, NSRC, KPOL, NTRA, NTRAV, NTOT, NOTF, KC
16	12I6	NSLU, NSLV, IWM, JWM, IPM, JPM, MWF, NWF, MPF, NPF
17	3E6.0,9I6	AKTP, SOX, GAMM, LRMX, LOX, LTEMP, LBOD, LCG, **LSAL, LERG**
18	12F6.0	ANGLAT, GRDANG, AL, SEINV, DEPDEF, **VAR, DCO, DML, SPA, VIVOR, CSET, CCOR**
19	9E8.0	AG, WSTR, DAIR, DWAT, WCONV, CDCON, PRES, ABSF, CMASTR
20	A4,2X,I6,A4,8X, 2F6.0,I6	PLOTER, IFILM, CAMERA, ROTCAM, ROTGRI, ISAVEG
21	2I6,4F6.0,A4,2X, F6.0,I6	NCTITL, ISOCOL, FMTISO, CLKRAD, ARRLEN, VECTW, PWUNIT, SIZISO, ISONUM
22	12F6.0	HX(1), HY(1), HZ(1), HX(2), HY(2), HZ(2), HX(3), HY(3), HZ(3), HX(4), HY(4), HZ(4)
23	12F6.0	DXPDY, XLEFT, YBOT, XRIGHT, YTOP, XDELT, YDELT, VECWDR, VECWDV
24	3I6,7F6.0,2I6	IPLC, IPLV, IWLDP, VECT, VECTM, ARRR, ARRV, TANG, DOR, DOV, MAPX, MAPO
25	12I6	LINX, LINY, MCG, NCG, MCGM, NCGM
26	9E8.0	TEMPW, RHOM, ALPH0, **ERGC1, ERGC2,** ERGC3
27	I6,4E6.0	INRAND, TIPARP, **PAR1, PAR2,** PAR3

Table 11. Part 1 input record order.

Record	Description	Record	Description
1	Model-Identification Record	16	Data-Array Dimensions Record B
2	Run-Title Record	17	Constituents Record
3	Titles and Dates Record	18	Physical-Characteristics Record
4	Times Record A	19	Coefficients and Constants Record A
5	Times Record B	20	Displays - Plotter-Specifications Record
6	Flags Record	21	Displays - Title-Block Record A
7	Input Print-Flags Record	22	Displays - Title-Block Record B
8	Concentration Input Print-Flags Record	23	Displays - Grid Record A
9	Output Print-Flags Record	24	Displays - Grid Record B
10	Concentration Output Print-Flags Record	25	Coarse-Grid Parameters Record
11–14	Print-Times Records	26	Coefficients and Constants Record B
15	Data-Array Dimensions Record A	27	Particle-Parameters Record (Optional)

Table 12. Definition of Part 1 input variables.

[**Code:** I, important variable, due to interrelationships; E, error if override is attempted; W, warning if override is attempted; S, not input to SWIFT_IDP but contained in the SIMINP file; N, not used by SWIFT2D (most are stored in output files for postprocessing purposes)]

Name	Code	Record	Description
ABSF		19	Absorption factor (emissivity)
AG		19	Gravity (feet-or-meters/sec/sec)
AKTP	I	17	Re-aeration coefficient (overrides AKK for D.O.)
AL	E	18	Grid size (feet or meters)
ALPH0		26	Constant in equation of state
ANGLAT		18	Latitude (degrees)
ARRLEN	N	21	Length of north direction arrow in M grid units
ARRR	N	24	Ratio of arrowhead to current vector length with constituent isolines
ARRV	N	24	Ratio of arrowhead to current vector length all other isolines
CAMERA	N	20	Type of camera (default is "UNSP" rocketed)
CCOR		18	C-value correction coefficient for salinity gradient
CDCON		19	Coefficient relating diffusion coefficient and Chezy coefficient
CLKRAD	N	21	Radius of clock in M grid units (default is 0.5 inch)
CMASTR		19	Mass transfer coefficient (In/MB-Day) (Hrs/Mile)
COEF	S	19	Computed coefficient
CSET	I	18	Chezy coefficient if depth less than "VAR"
DAIR		19	Air density
DCO	I	18	Depth threshold (feet or meters)
DEPDEF	I	18	Default depth value (feet or meters)
DML	I	18	Multiplier for depth greater than "DCO"
DOR	N	24	Flag: 0 means no dots in constituent displays
DOV	N	24	Flag: 0 means no dots in other displays
DWAT		19	Water density
DXPDY		23	DX/DY (Ratio of displayed grid width/height)
ERCG1		26	Fraction of energy height upstream of barrier
ERGC2		26	Turbulent energy coefficient times the depth/length scale
ERGC3	N	26	Energy coefficient 3
FMTISO	N	21	Code for format of isoline values in legend
GAMM		17	Weighting factor for pollutant smoothing
GRDANG		18	Angle between Y-axis and north (degrees)

Table 12. Definition of Part 1 input variables.—Continued

[**Code:** I, important variable, due to interrelationships; E, error if override is attempted; W, warning if override is attempted; S, not input to SWIFT_IDP but contained in the SIMINP file; N, not used by SWIFT2D (most are stored in output files for postprocessing purposes)]

Name	Code	Record	Description
HALFDT	W	4	Half time step (minutes)
HTITL		3	Title for displays (16 characters)
HX(1)	N	22	"HTITL" sub-block: M position on grid
HX(2)	N	22	Legend sub-block: M position on grid
HX(3)	N	22	Clock sub-block: M position on grid of clock center
HX(4)	N	22	North & wind sub-block: M position on grid of center of north arrow
HY(1)	N	22	"HTITL" sub-block: N position on grid
HY(2)	N	22	Legend sub-block: N position on grid
HY(3)	N	22	Clock sub-block: N position on grid of center
HY(4)	N	22	North & wind sub-block: N position on grid of center of north arrow
HZ(1)	N	22	"HTITL" sub-block: character size (default is 1.5)
HZ(2)	N	22	Legend sub-block: character size (default is 1.0)
HZ(3)	N	22	Clock sub-block: character size (default is 0.75)
HZ(4)	N	22	North & wind sub-block: character size (default=0.75)
IADVEC		6	Flag for advection comp.: 0=Arakawa, 1=Leendertse 70, 2=none
ICOFMT	E	6	Flag for coefficients: 0=Old formats E5.0 & 3I5,10F5.0; 1=New formats E8.0 & 3I5,7E8.0
ICORR	E	6	Option: integration correction method (codes 0 TO 6) (May not increase from 3 or less to greater than 3)
IDKFMT	E	6	Flag for depth & concentrations: 0=old format 16F4.1; 1=new format 10E6.1
IDPDAT	E	3	Date and time of SWIFT_IDP computer run
IFILM	N	20	Film size in millimeters (default is 35)
INRAND		27	Random number initializer for particle movement
IPAR	E	6	Flag: (0=No, 1=Yes) for particle movement
IPLC	N	24	Interval of vectors in constituent displays
IPLV	N	24	Interval of vectors in all other displays
IPM	E	16	Number of M grid points in pressure input
ISAVEG	N	20	Map flag: (0=No, 1=Yes) CALL SAVEG/MERGEG
ISOCOL	N	21	Number columns of isoline values in legend (default=3)
ISONUM	N	20	Grid interval for display of isoline sequence numbers
ISVWP		6	Flag: (0=No, 1=Yes) space-varying wind & pressure
ITDATE		3	Simulation start date (DD MM 'YY)
IWLDP	N	24	Flag: vectors at water level and/or depth points
IWM	E	16	Number of M grid points in wind input
JPM	E	16	Number of N grid points in pressure input
JWM	E	16	Number of N grid points in wind input
KC	E	15	Number of Fourier or harmonic components
KPOL	E	15	Number of constituent stations or checkpoints
LBOD	E	17	Constituent number used for benthic demand
LCG		17	Constituent number used for coarse grid computation
LERG	E	17	Constituent number used for energy (LERG may not be overridden from 0 to greater than 0)
LINX	W	25	Number of M grid spaces in first coarse grid space
LINY	W	25	Number of N grid spaces in first coarse grid space
LMAX	E	15	Number of types of constituents
LOX	E	17	Constituent number used for dissolved oxygen
LRMX	I	17	Number of interactive constituents
LSAL		17	Constituent number used for salinity gradient

Table 12. Definition of Part 1 input variables.—Continued

[**Code:** I, important variable, due to interrelationships; E, error if override is attempted; W, warning if override is attempted; S, not input to SWIFT_IDP but contained in the SIMINP file; N, not used by SWIFT2D (most are stored in output files for postprocessing purposes)]

Name	Code	Record	Description
LTEMP	E	17	Constituent number used for temperature
MAPMOT	I	6	Option: draw maps, write Map File/File and/or write Map file
MAPO	N	24	Flag: (0=No, 1=Yes) to omit outfalls and numbers on maps
MAPX	N	24	Flag: (0=No, 1=Yes) to omit "X" at constituent checkpoints on maps
MCG	W	25	Number of M grid spaces per coarse grid space (after the first)
MCGM	E	25	Number of coarse grid points in the M-direction
MET	E	6	Flag: 0=feet; 1=meters
MMAX	E	15	Number of M grid points
MPF	W	16	M grid ratio for pressure
MWF	W	16	M grid ratio for wind
NCG	W	25	Number of N grid spaces per coarse grid space (after the first)
NCGM	E	25	Number of coarse grid points in the N-direction
NCORR		6	Number of iterations in integration correction
NCTITL	N	21	Number of characters of "TITL" to display (default=32)
NEXAN	I	6	Flag: (0=No, 1=Yes) to put extended computations in History File
NHST		6	Flag: (0=No, 1=Yes) to continue same History File on restart
NMAX	E	15	Number of N grid points
NOCUR	E	15	Number of current stations or checkpoints
NOLAN	E	6	Flag for land boundary outline: 1=SIM omit, 2=IDP omit
NOWL	E	15	Number of water level stations or checkpoints
NPF	W	16	N grid ratio for pressure
NPRBEN		7	Benthic demand input print option (codes 0-7)
NPRC		9	Flag: (0=No, 1=Yes) C-values output print flag
NPRCON		8	Array of constituent input print option (codes 0-7)
NPRDEP		7	Depth values input print option (codes 0-7)
NPRDIF		7	Diffusion input print option (codes 0-7)
NPRLAN		7	Land outline input print option (codes 0-7)
NPRMAN		7	Manning's input (and initial computed C-values) print option (codes 0-7)
NPRR		10	Array of constituent output print flags (0/1)
NPRSE		9	Water level (SE array at wet points, SEN array at dry points) output print flag (0/1)
NPRSEP		9	Water level (SEP array) output print flag (0/1)
NPRVCU		9	Velocity U components output print flag (0/1)
NPRVCV		9	Velocity V components output print flag (0/1)
NPRVIS		7	Viscosity coefficient input print option (codes 0-7)
NPRVMD		9	Velocity magnitude at depth points output print flag (0/1)
NPRVML		9	Velocity magnitude at WL points output print flag (0/1)
NPRVMU		9	Velocity magnitude at U-velocity points output print flag (0/1)
NPRVMV		9	Velocity magnitude at V-velocity points output print flag (0/1)
NSLU	E	16	Number of barrier points with U-velocity
NSLUV	E S	16	Number of barrier points
NSLV	E	16	Number of barrier points with V-velocity
NSRC	E	15	Number of discharge sources
NTO	E S	15	Total number of tide openings
NTOF	E	15	Number of tide openings with Fourier functions
NTOT	E	15	Number of tide openings with time-varying data

Table 12.   Definition of Part 1 input variables.—Continued

[**Code:** I, important variable, due to interrelationships; E, error if override is attempted; W, warning if override is attempted; S, not input to SWIFT_IDP but contained in the SIMINP file; N, not used by SWIFT2D (most are stored in output files for postprocessing purposes)]

Name	Code	Record	Description
NTRA	E	15	Number of U-transport cross sections
NTRAV	E	15	Number of V-transport cross sections
NWF	W	16	N grid ratio for wind
PLOTER	N	20	Plotter used for displays (default is "FR80")
PRES		19	Atmospheric pressure in MBS
PWUNIT	N	21	Name of wind speed unit to display (see WCONV)
RHOM		26	Reference density
ROTCAM	N	20	Camera rotation code, 1.0 or 2.0 (default is 1.0)
ROTGRI	N	20	Grid rotation code, 1.0 or 2.0 (default is 1.0)
RUNID	S	1	Run identification
SEINV	W	18	Initial water level (feet or meters)
SIZISO	N	20	Character size of isoline sequence numbers (default=0.75)
SOX		17	Saturation value for dissolved oxygen
SPA		18	Weighting factor for surface smoothing
TANG		24	Tangent of angle of vector arrow heads
TEMPW		26	Water temperature in equation of state
TFCG		5	Time first of coarse grid computation
TFMAPF		5	Time first to write Map File/File and/or Model Output File
TICG		5	Time interval of coarse grid computation
TICVAL		5	Time interval to compute C values
TIERST		5	Time interval to write Emergency Restart File
TIFLOD		5	Time interval to check boundary changes (flooding)
TIFLUX		5	Time interval to calculate heat flux
TIHISP		4	Time interval to print water level, current and transport history data
TIHIST		4	Time interval to write History File
TIMAPC	N	4	Time interval to display constituent isolines (and velocity vectors)
TIMAPF		5	Time interval to write Map File/File and/or Model Output File
TIMAPL	N	4	Time interval to display water level isolines (and velocity vectors)
TIMAPM	N	4	Time interval to display mass-transport isolines and vectors
TIMAPV	N	4	Time interval to display velocity isolines (and velocity vectors)
TIPARP		27	Time interval to print particle positions
TIRST	I	4	Time interval to write Restart File
TITIDE	E	4	Time interval to read tidal records
TITL	I	2	Name of the simulation (72 characters)
TITSMO	I	5	Time interval for time smoothing
TLCG		5	Time last of coarse grid computation
TLFSMO		5	Time last to smooth Fourier functions
TLMAPF		5	Time last to write Map File/File and/or Model Output File
TPRINT		5	Times to print constituent, water level and velocity arrays
TRST	I	4	Time to restart simulation
TSTART	W	4	Time to start simulation
TSTOP	W	4	Time to stop simulation
VAR	I	18	Marginal depths in tidal flats (feet or meters)
VECT	N	24	Current speed (feet-or-meters/sec) equal to length DX
VECTM	N	24	Transport per unit width (CFS/F or CMS/M) equal to length DX

Table 12. Definition of Part 1 input variables.—Continued

[**Code:** I, important variable, due to interrelationships; E, error if override is attempted; W, warning if override is attempted; S, not input to SWIFT_IDP but contained in the SIMINP file; N, not used by SWIFT2D (most are stored in output files for postprocessing purposes)]

Name	Code	Record	Description
VECTW	N	21	Units of wind per M grid space unit on displays
VECWDR	N	23	Normal line width of vectors on constituent maps
VECWDV	N	23	Normal line width of vectors on all other maps
VERIDP	E	3	Version of SWIFT_IDP
VIVOR		18	Vorticity-related viscosity factor
WCONV	I	19	Wind conversion coefficient
WSTR		19	Wind stress coefficient
XDELT	I	23	X adjustment to boundary outlines (in grid spaces)
XLEFT	N	23	Number of grid spaces margin to left of grid on display
XRIGHT	N	23	Minimum number of grid spaces margin to right of grid on display
YBOT	N	23	Number of grid spaces margin below grid on display
YDELT	I	23	Y adjustment to boundary outlines (in grid spaces)
YTOP	N	23	Minimum number of grid spaces margin above grid on display

Part 2 Input

Part 2 input consists of 39 sets of records numbered 1–39. Record sets 1–6 and 9–22 consist of a variable number of records as specified on data array-dimension records 15 and 16 of Part 1 input. Record sets 8, 23, 24, 25, 28, 30, 32, and 34 consist of a single record. Record sets 7, 29, 31, 33, 35, 36, 37, and 39 have a variable number of records with a blank record signaling the end of each set. Optional record set 26 has a variable number of records with a "999999999." record signaling the end. The number of records in the depth record set 27 is determined by the rectangular gird dimensions (*NMAX*, *MMAX*) and the number of values per record as defined by the input format variable *IDKFMT* (See definition in Appendix 2.). The keyword delimiter record, "END PART," is used to signal the end of the optional particle-tracking record set 38. Table 13 gives the input order of Part 2 record sets and identifies the number of records in each set.

Part 2 input specifies the static (geometry) and initial-condition data. Initial conditions given in Part 2 are those that can be varied in time in Part 3 including flow and constituent conditions at open boundaries plus constituent concentration(s) in the interior of the model grid. Not given in Part 2 input, but assumed zero, are the initial discharge rate and constituent concentration at outfall sources. Part 2 input controls the diagnostics of the computations; that is, it defines stations at which computations are saved for later generation of time history plots. It defines the open boundaries or water-level openings, including Fourier tide components, and describes the discharge sources and barrier properties (time-varying data for these are specified in Part 3).

Part 2 input includes the following static and initial conditions, not listed in input order:

Static Conditions—

1. Station definitions designating grid cells for input source discharges and water level, velocity, constituent, and transport cross-section checkpoints where model output results are saved for postprocessing.

2. Dam points, or permanently dry points at designated grid cells.

3. Barrier definitions at grid cells including the direction of flow that is restricted and applicable contraction coefficients.

4. Open-boundary definitions, specified by location on the grid, data type (such as water level or discharge), and whether data are input as time-varying values or defined by phase and amplitude functions.

5. Fourier functions, phase and amplitude of tide input for given frequencies, for applicable tide openings.

6. Constituent descriptions, units of concentration, and coefficients of interaction rates between constituents.

7. Isoline values for map displays (no longer used).

8. Land boundary outlines for map displays (no longer used).

9. Depth values to define the bathymetry.

10. Viscosity, diffusion, Manning's n coefficients and benthic demand values, where each can be given a uniform value and overriding values at specified grid cells.

11. Permanent titles to be displayed on maps (no longer used).

12. Optional particle group descriptions for simulation of particle movement.

13. Computational grid definition, which is the result of the boundary enclosures, open boundaries, and barrier points, as determined by SWIFT_IDP.

Initial Conditions—

1. Initial global wind speed and direction, global radiation flux at the surface, and three types of measured temperatures.

2. Initial barrier conditions: sill depth, gate height and effective width.

3. Initial water level and constituent concentration at all boundary openings.

4. Initial concentrations of constituents in the grid interior. For each constituent, a single global value can be given or discrete values can be assigned to each cell throughout the computational domain.

Table 13.   Part 2 input record order.

Set	Number	Description
1	NOWL	Water-Level Stations
2	NOCUR	Current Stations
3	NSRC	Discharge Sources
4	KPOL	Constituent Stations
5	NTRA	U-Transport Cross Sections
6	NTRAV	V-Transport Cross Sections
7	1-n to blank record	Dams or Permanently Dry Points
8	1	Initial Wind and Temperatures
9	NSLU+NSLV	Barrier or Sluice Description
10	NSLU+NSLV	Barrier Coefficients
11	NSLU+NSLV	Barrier Initial Input
12	NTOT+NTOF	Tide Opening Description
13	NTOT+NTOF	Tide Opening Initial Values at End A
14	NTOM	Tide Opening Initial Values at End B
15	INT(KC+7)/8	Fourier Frequencies or Harmonic Tidal Components
16	NTOF	Amplitude Components at End A of Tide Openings
17	NTOF	Amplitude Components at End B of Tide Openings
18	NTOF	Phase Components at End A of Tide Openings
19	NTOF	Phase Components at End B of Tide Openings
20	LMAX	Constituent Description
21	LMAX	Constituents - Interaction Rates
22	LMAX	Constituent Isolines
23	1	Velocity Isolines
24	1	Mass-Transport Isolines
25	1	Water-Level Isolines
26	1-n to 999999999.	Land-Boundary Outlines (Optional)
27	MMAX*INT(NMAX+15)/16	Depth Values
28	1	Default Value - Viscosity Coefficient
29	1-n to blank record	Viscosity Coefficients
30	1	Default Value - Diffusion Coefficient
31	1-n to blank record	Diffusion Coefficients
32	1	Default Value - Manning's Coefficient
33	1-n to blank record	Manning's Coefficients
34	1	Default Value - Benthic Demand
35	1-n to blank record	Benthic Demand Values
36	1-n to blank record	Initial Concentration
37	1-n to blank record	Permanent Titles
38	1-n to END PART	Particle Group Description (Optional)
39	1-n to blank record	Computational Grid Enclosures

Part 3 Input

Part 3 input consists of 15 sets of records. These are referred to as record types A–N and Z. Record type Z has a variable number of records, with a blank record at the end. All other record types consist of a specified number of records, as defined in the **Part 1 Input** section. If Z records are input, a blank record is input to signal the end of record types A–N. Table 14 gives the input order and defines the records for Part 3 input.

Part 3 input specifies the time-varying data (except for time- and space-varying wind and pressure which are given in Part 4, see **Part 4 Input** section). Part 3 input includes the following, not listed in order of input:

1. Forcing functions of water levels, velocities, and transport rates at open boundaries.

2. Constituent concentrations at open boundaries.

3. Discharge rates at outfall sources.

4. Constituent concentrations at outfall sources.

5. Global wind speed and direction.

6. Radiation flux.

7. Three types of measured temperature.

8. Barrier sill depths, widths, and gate heights.

All time-varying data are optional. Water-level data are given only if the number of time-varying tidal boundary openings *NTOT* (in Part 1) is greater than zero. Discharge data are given only if the number of outfalls (*NSRC*) is greater than zero. Concentration data are input only if the number of constituents (*LMAX*) is greater than zero. Global wind speed and direction can be unused if space-varying wind is specified (see *ISVWP* in Part 1). Barrier data should not be input if *NSLU* and *NSLV* in Part 1 are zero.

Part 3 input is processed by SWIFT_IDP, which arranges all time-varying data into concurrent order so that it can be read sequentially by SWIFT2D throughout simulated time. If *NTOT* is nonzero, time-varying data are input at the time interval (*TITIDE*) specified for water-level (tide) data at every interval after *TSTART* through *TSTOP*. All other time-varying data can be given at irregular intervals at any multiple of *TITIDE*. The maximum duration covered by time-varying input is 99 days. This limitation is based on the input format for reading the variable *CDDAY* and can be readily increased by changing the program source code. All time-varying data are identified by the day, hour, and minute relative to midnight at the beginning of the simulation start date (*ITYR, ITDATE, ITDAY*), which is considered day 1, hour 0, minute 0. Midnight ending the first day is designated day 1, hour 24, minute 0.

Table 14.   Part 3 input record order.

Type	Description
A	Tide at end A (KB1) of all time-varying tide openings, at all time intervals
B	Tide at end B (KB2) of all time-varying tide openings for which LVSAME is non-zero, at all time intervals
C	Concentration at both ends of a tide opening
D	Discharge rate
E	Concentration at discharge source
F	Wind speed (global)
G	Wind direction (global)
H	Radiation flux from surface (Q1)
I	Dry bulb temperature (Q2)
J	Wet bulb temperature (Q3)
K	Temperature at measuring station (Q4)
L	Barrier sill depth
M	Barrier gate height
N	Barrier effective width
(blank)	Signals the end of record types A-N
Z	Temporary titles
(blank)	Signals the end of record type Z

Time-varying data input in Part 3 are interpolated in time to provide values at each computational time step. For water-level data, linear interpolation to the computational time step is performed between input values given every *TITIDE* minutes. Water-level interpolation begins with the initial values at the ends of the boundary opening *TIDA* and *TIDB*, which are specified in the **Part 2 Input** section. The effective time of these initial values is always *TITIDE* minutes before the first time-varying value input. Interpolation of all other time-varying values (concentrations, discharge rate, global wind speed and direction, temperatures, and barrier input) to the computational time step is done during the *TITIDE* minutes preceding the time specified on the input records. If time-varying values are not given every *TITIDE* minutes, then the previous values persist until *TITIDE* minutes before new values are given. This is also true of initial values, whether they are given in the **Part 2 Input** section or set automatically. The exception is for input concentrations at boundary openings, which are set automatically by SWIFT2D.

Spatial interpolation is performed at water-level boundary openings for both water levels and constituent concentrations prior to interpolation over time. Values at grid points along an opening are the result of linear interpolation between values specified at the ends.

Part 4 Input

Optional Part 4 input contains time and space varying wind and atmospheric pressure data. Wind and pressure data are input as grids at regular or irregular time intervals that typically are less frequent than Part 3 input. SWIFT2D interpolates across time steps, beginning as soon as the data are read; there is no given time interval or interpolation period for Part 4 input data. SWIFT2D also spatially interpolates to the model grid from the input wind and pressure grids, which typically provide less resolution than the computational grid. Part 4 input data are input directly to SWIFT2D and not preprocessed by SWIFT_IDP. The format of Part 4 input data is defined in Appendix 2.

SWIFT2D Numerical Aspects and Computational Features

Familiarity with the numerical aspects and varied computational features of SWIFT2D is needed to design an effective model and setup a successful simulation. Important numerical aspects and computational features include the sequence of numerical computations, spatial grid configuration, computational grid enclosure, time-step procedure, time and space interpolation methods, integration options, time smoothing process, drying and flooding cells, permanently dry cells or dams, Chezy computation technique, Fourier tide openings, space-varying wind and pressure, constituent concentrations at open boundaries, sluice or barrier descriptions, particle tracking, and transport and water-quality simulation.

Input parameters directly affect each numerical aspect and computational feature. In this section, information is presented to aid in assigning values to these input parameters to create the SIMINP file. Numerical aspects and computational features are identified and discussed in the context of their implementation in the SWIFT2D program code. Key input parameters invoking these capabilities in the model are identified in italics and definitions of these input parameters are given in tables in following report sections and in Appendixes 1 and 2.

Sequence of Operations

Knowledge of the sequential order of numerical operations in SWIFT2D can prevent difficulties from arising during the simulation. The computational flow of SWIFT2D is shown in figure 4. An alphabetical list of the primary SWIFT2D computational routines is given in table 15 and definitions of important arrays are provided in table 16.

Computational considerations require that some numerical operations not occur simultaneously. In such cases, SWIFT2D automatically delays conflicting operations and produces appropriate warning messages in the Run Log file. For instance, re-computation of depth-dependent Chezy coefficients (time interval specified by *TICVAL*) is delayed when the flooding and drying of cells (time interval specified by *TIFLOD*) is being checked during the same time step. Time smoothing of computed variables (time interval specified by *TITSMO*) is delayed under several conditions. If flood checking, Chezy computation, and time smoothing are requested at the same time, Chezy coefficient computations are delayed one time step, and time smoothing is delayed at least two time steps or until no other conflicting operations are requested. Therefore, the parameter variables *TICVAL* and *TIFLOD* should not be equal or multiples of each other and *TITSMO* should be a non-multiple frequency of both. Time intervals for numerical operations and simulation output control are specified on records 4 and 5 of Part 1 input. *TITSMO, TICVAL*, and *TIFLOD* are specified on record 5. See Appendix 2.

Rectangular Grid Layout

A rectangular grid that minimizes the amount of permanently dry (land) areas in the model domain is typically laid out to delineate the water body being investigated. Wherever feasible, consideration should be given to aligning the rectangular grid so that long open water boundaries coincide with a principal grid axis, either x or y, in order that flows through the boundary are approximately normal to the opening. The alignment of the grid does not need to correspond with a geodetic map coordinate system. The angle between the y axis of the rectangular grid and the north coordinate direction of the geodetic system in use can be specified by the *GRDANG* variable input to SWIFT2D to have the model geodetically reference output results, for instance, for subsequent analysis or visualization in a GIS system.

Routine MAIN

READ1 (Read Parts 0 and 1 data)
SETUP (Initialize data, call SETUPS)
Read or Initialize Restart File
Position or Initialize History File
MAMOST (Initialize Map File)
WRIV (Print initial array values)

Advance Time (NST=NST+1)
First Half of TIme Step

Time smoothing now?
    yes
    no

Compute First Half Data
Remove Effect of Discharges
FLO (Flooding)
Shift Data
CVAL (C values)

TIMSMO (Time Smoothing)

Second Half of Time Step
Compute Second Half Data
Remove Effect of Discharges
PARTIC (Compute Particle Locations)
WRMOT3 (Write Map File)
OUT (Print array data)
Shift Data
Write Restart Files and Runlog

Figure 4.   Computational procedure in SWIFT2D.

Table 15.   Primary computational routines in SWIFT2D.

Subroutine name	Function
CVAL	Computes Chezy coefficients and tests for drying at intervals of TICVAL (execution of CVAL is delayed one integration step if tests for flooding, in FLO, are done during the step that CVAL is scheduled)
DIFU	Computes concentrations (RP) from U velocities
DIFV	Computes concentrations (R) from V velocities
FLO	Tests for flooding and drying at intervals of TIFLOD
FLOW	Computes values for History Tape after SEPU and DIFU, it also prints values at water level and current stations and transport cross sections at intervals of TIHISP
FLOWV	Computes values for History Tape after SEPV and DIFV
MAIN	Controls SWIFT2D
OUT	Prints computed grid array data and values at constituent measuring stations at times specified in TPRINT
READ1	Checks dimensions, reads Part 0, Part 1, Part 1 overrides
SEPU	Computes new values for UP and SEP arrays and tests for drying
SEPV	Computes new values for VP and SEP arrays and tests for drying
SETUP	Reads some Part 2 data and does initial interpolation at open boundaries
SETUP2	Reads some Part 2 data and initializes arrays
SINVAL	Initializes water levels
SLOSHU	Computes concentrations at open boundaries for U flow.
SLOSHV	Computes concentrations at open boundaries for V flow.
SLUCEU	Computes C values and velocities at U barriers
SLUCEV	Computes C values and velocities at V barriers
SMOOT	Smoothes velocities in time and water levels in time and space
TIDAL	Reads time-varying data when needed, does time and space interpolation, computes Fourier values at openings, sets time-varying water levels, velocities, concentrations, discharge rates, barriers, titles, and wind
TIMSMO	Acts as a counterpart to MAIN to control time smoothing at intervals of TITSMO
TRANWL	Performs Fourier transformations and interpolations

Cell Size

After the rectangular grid is delineated and positioned, a cell size (AL) is chosen to subdivide the grid into square cells. Grid cells overlaying land within the model domain defined by the rectangular grid are assigned negative depth values to represent their land-surface elevations. The cell size should be chosen so that important hydrodynamic features of the water body (such as tributary creeks, canals, and so forth) are adequately represented. In selecting a cell size, consideration should be given to the total size of the grid and the amount of computer time required to run a simulation, as governed principally by the time and space discretizations. The chosen cell size fixes the grid dimension in each coordinate direction, $MMAX$ is the number of cells in the x-coordinate direction and $NMAX$ is the number in the y-coordinate direction. Variables pertinent to the grid layout and model array dimensions are defined on records 15, 16, and 18 of Part 1 input. Array dimensions, including $MMAX$ and $NMAX$, are specified on records 15 and 16 and physical characteristics such as the model cell size AL are defined on record 18. See Appendix 2.

Location of Variables

Finite-difference approximations in SWIFT2D are made on a space-staggered grid. Four properties define flow conditions in a SWIFT2D grid cell: depth (land-surface elevation relative to a horizontal datum plane), stage (water-surface elevation relative to the depth datum), and U- and V-components of velocity. Figure 5 shows the staggered grid layout. Flow depth (determined from the input land-surface elevations of the cell and the simulated water level in the cell) is specified at the center of each cell, water level is computed at the lower left corner, and directional velocity components are computed along the sides, U-velocity component along the x-axis and V-velocity component along the y-axis. The columns of the grid (1 to $MMAX$) correspond to U-velocity components and are referenced as m-grid subscripts in the model. Rows of the grid (1 to $NMAX$) correspond to V-velocity components and are referenced as n-grid subscripts.

Table 16.   Important arrays in SWIFT2D.

[All arrays are dimensioned NMAX by MMAX, except for the concentration arrays (R and RP) which are dimensioned NMAX by MMAX by LMAX. The times associated with array variables in this list are relative to t=2n(HALFDT) and are effective immediately after execution of DIFU and before shifting the velocity and water level arrays]

Array name	Description
C	Chezy coefficients (computed in CVAL, may be changed in FLO, SEPU, or SEPV)
H	Depth array (modified input, unchanged during integration)
R	Concentration at time t (computed in DIFV), also used for the predicted values of V-velocity in SEPV
RP	Concentration at time t+HALFDT (computed in DIFU), also used for the predicted values of U-velocity in SEPU
SE	Water level at time t (shifted from SEP in MAIN)
SEN	Water level at time t-HALFDT (shifted from SE in MAIN)
SEP	Water level at time t+HALFDT (computed in SEPU and SEPV)
SES	Residual water level (set in SINVAL, CVAL, FLO, SEPU, or SEPV)
U	Velocity in X direction at time t-HALFDT (shifted from UP in MAIN)
UP	Velocity in X direction at time t+HALFDT (computed in SEPU)
V	Velocity in Y direction at time-t (shifted from VP in MAIN, the value was at time t-2*HALFDT before shifting after SEPV)
VMAN	Manning's n (input, unchanged during integration)
VP	Velocity in Y direction at time t (computed in SEPV)
XXX	Temporary computational array used for time smoothing and data averaging for Map and model output files
YYY	Semi-temporary array used for the predicted values of water level in SEPU and SEPV
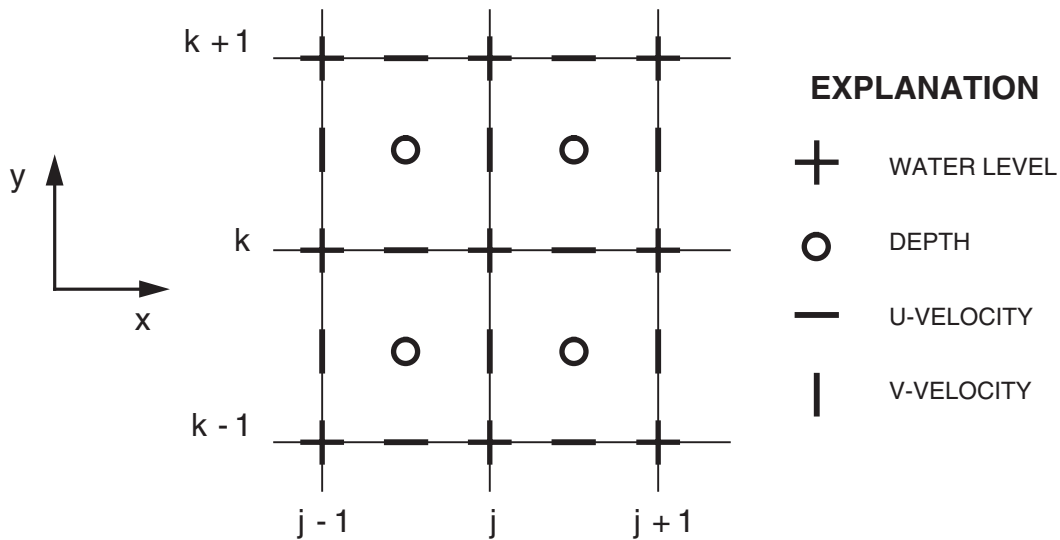
Figure 5.   Location of variables on SWIFT2D staggered grid.

Each computational cell is a control volume centered on a computed (n, m) water level point. U-velocity components are computed at the left and right sides of the control-volume cell and V-velocities are computed at the top and bottom. Constituent concentrations are computed at the center of the cell. Water-surface elevation (ζ) and constituent concentration (P) are defined at integer values of m and n. Water depth (h) is defined at the point midway between successive integer values of m and n. The U-velocity component is defined at a point midway between successive integer values of m and at an integer value of n. The V-velocity component is defined at a point midway between successive integer values of n and at an integer value of m. The total number of points for each physical property as well as the number of columns and rows of points in the grid is shown below:

Physical property	Number of columns	Number of rows	Total number of points
Stage	MMAX	NMAX	(MMAX)(NMAX)
Depth	MMAX-1	NMAX-1	(MMAX-1)(NMAX-1)
U-velocity	MMAX-1	NMAX	(MMAX-1)(NMAX)
V-velocity	MMAX	NMAX-1	(MMAX)(NMAX-1)

Computational Grid Enclosure

SWIFT2D performs computations on a subset of the full rectangular grid defined by *MMAX* and *NMAX*. This subset of grid cells is called the computational grid. The set of cells enclosing the computational grid is called the computational grid enclosure. SWIFT_IDP translates the input computational grid enclosure into computational row and column delimiters used by SWIFT2D to define recursion limits and specify boundary conditions for the ADI solution process.

Default Enclosure

A default computational grid with arbitrary water-level boundary openings is depicted in figure 6. SWIFT2D requires that open boundaries, where measured water-level data are typically specified to drive the simulation, be on the "outside" edge of the computational grid (on the computational grid enclosure). It is desirable to place long open boundaries on an "outside" edge of the computation grid so that model cells along the boundary are just "inside" the grid where the advection terms in the momentum equations are omitted. If the open

boundary is not along an edge, then the advection terms are used, which can introduce boundary instabilities, especially along long open boundaries. The boundary of the computational grid enclosure itself is not part of the computational field. The default computational grid extends from columns $m = 2$ through *MMAX*-1 and rows $n = 2$ through *NMAX*-1. The default computational grid enclosure is bounded by cells (1, 1), (*NMAX*, 1), (1, *MMAX*), and (*NMAX, MMAX*)—the outer cells of the rectangular grid. Therefore, water-level openings are either located along one or more of the following: columns $m = 1$ and *MMAX* and rows $n = 1$ and *NMAX*. However, velocity and transport rate boundary conditions on the top and right of the computational grid are specified on the m = *MMAX*-1 column or n = *NMAX*-1 row because the velocity points are above and to the right of the water-level grid point with the same (n, m) index (see fig. 6). Thus, this grid scheme results in effectively one fewer row and column of velocities than water levels.

Complex Enclosure

If geographic locations of water body openings or boundary-value data-collection sites are not conveniently aligned along the boundaries of the rectangular grid, a more complex computational grid can be specified. Also, where the outline of the water body is quite irregular, a computational grid that more precisely fits the water body shape can be defined to exclude large areas of permanently dry cells from the simulation, thus increasing computational efficiency and decreasing run time. In such cases, a rectangular grid is still chosen to cover the entire geographic area and boundary openings are still related to (n, m) points on the grid, but a nonrectangular computational grid boundary is drawn as a sequence of line segments aligned along interior columns or rows, or along diagonals.

A nonrectangular computational grid is defined by one or more enclosures of arbitrary shape. Each enclosure is a closed figure or polygon that defines either an outer edge around the computational domain or an inner edge defining an area, such as an island, to be excluded from the computation grid. Enclosure definitions pass through (n, m) grid points and fall outside the computational grid. An enclosure is specified as a set of (n, m) grid points where successive points define straight-line segments, with the first and last points defining an enclosure being identical to close the polygon. Grid coordinate points defining the computational enclosure are input to SWIFT_IDP on record set 39 of Part 2 input.
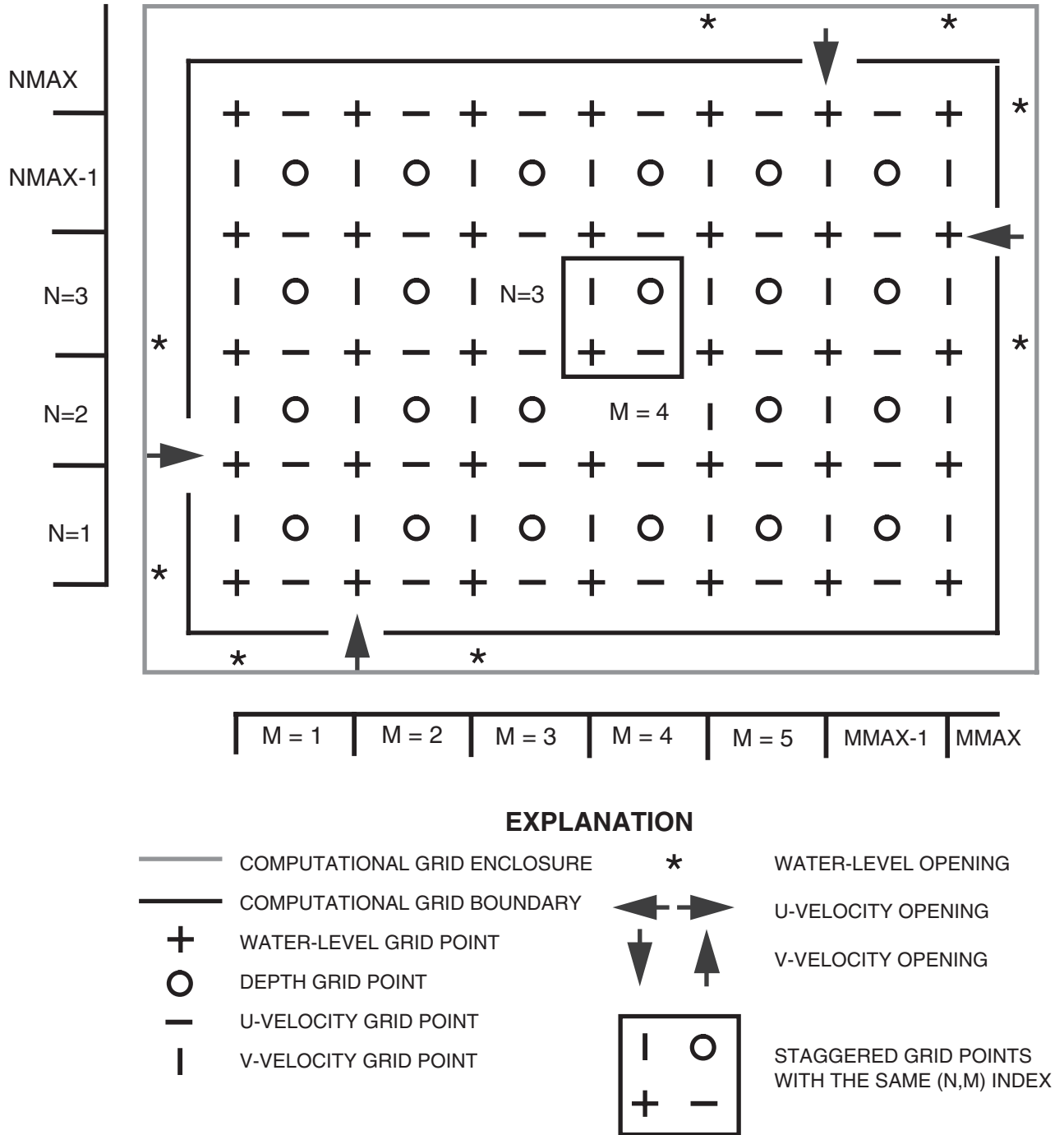
Figure 6.   Default computational grid with arbitrary openings.

Certain guidelines and restrictions apply to the definition of a computational grid enclosure. Every grid point specified to define the computational grid should be a "corner" of the enclosure where each grid point defines a line segment that is not a straight-line continuation of the previous line segment. Line segments can be horizontal along grid rows or vertical along grid columns with respect to the rectangular grid, or they can be oriented as diagonals at multiples of 45 degrees. All inner and outer angles formed by consecutive line segments must be at least 90 degrees. Correct and incorrect grid enclosure angles are defined and illustrated in figure 7. Parallel line segments cannot be adjacent; that is, at least one row or column must fall between parallel line segments if the area between them is "inside" the computational grid. A line segment must be at least two grid spaces long if the next segment reverses the direction of the previous segment. Correct and incorrect line segment lengths are illustrated in figure 8. Although an enclosure defining an island can be wholly contained within another enclosure polygon, their boundary lines should not cross or coincide. Correct and incorrect enclosure polygons are illustrated in figure 9.

Boundary Openings

Water-level openings can be defined along rows, columns, or diagonals. Velocity or mass transport openings are permitted at velocity grid points. These velocity-point openings are single points, rows, or columns on the grid. Velocity-point openings cannot be defined along diagonals because velocity-point openings are associated with either the horizontal or vertical component of velocity, not both. Velocity-point openings are positioned just outside the computational grid, but within the defined grid enclosure and between water-level points (fig. 6). For a given (n, m) water-level point, its velocity components are located to the right and above. This means that velocity-point openings on the left or bottom of the computational grid have the same (n, m) indices are as those included in the enclosure. However, on the right of the computational grid, U-velocity-point openings are assigned one m-column to the left of the enclosure, and V-velocity-point openings at the top of the computational grid are assigned one n-row below the enclosure. Open boundary locations are defined on record set 12 of Part 2 input in Appendix 2.

Time Step

The basic time unit for SWIFT2D is the duration (specified in minutes) between successive computations of U and V velocity components. SWIFT2D performs velocity computations every half time step, *HALFDT*, and the computation proceeds in increments of *HALFDT*. Water levels (initially equal to *SEINV*) and concentrations are computed each *HALFDT*. U and V velocity components (initially zero) are computed at alternate half time steps. For example, U-velocity components are computed in the first half of the time step and V-velocity components are computed in the second half. Each velocity component is re-computed every other half time step; therefore, computed U and V velocity components are never coincident in time as is evident in table 17. Caution, therefore, should be exercised in the selection of an appropriate computational time step, especially in simulations involving rapidly varying transient flows. In selecting a computational time step, accuracy and stability aspects of the ADI solution technique should be considered (see Leendertse, 1987; Stelling and others, 1986; and Weare, 1979). The half time step for the simulation, *HALFDT*, is the first variable specified on record 4 of Part 1 input, other times and time intervals for various computational features of the simulation are defined on record 4 as well.

Time and Space Interpolation

SWIFT2D assumes that input time-varying data are instantaneous field-collected values, not values averaged over a given time interval. Time-series data defining dynamic conditions at open boundaries do not need to be input at the *HALFDT* time-step frequency; linear interpolation is used to obtain values at *HALFDT* time steps during the simulation. However, time-series water-level or velocity data used to drive the model must be input at an integer multiple frequency of 2*HALFDT time steps as defined by the variable *TITIDE*. Other time-varying data (flow rates, constituent concentrations, wind speed, and barrier conditions) are input at the same times as water-level or velocity data, but not necessarily at every *TITIDE* interval. The exception is constituent concentrations at openings that are not interpolated. If constituent concentrations are not specified at every time interval, the last value input persists (constant value) until the time *TITIDE* minutes before a new concentration is specified.

Time interpolation occurs during the *TITIDE* number of minutes preceding the specified time of a time-varying value. The value at the beginning of the interpolation time interval is the initial value assigned to start the simulation, the previous input boundary value, or a user-specified default water-surface elevation (*SEINV*). The time for all initially specified time-varying data is *TITIDE* minutes before the simulation begins, which is *TSTART* or *TRST*, that is, the start or restart time of the simulation, respectively. The time interval for boundary-value data, *TITIDE*, is defined on record 4 of Part 1 input. Initial values for boundary openings are specified on records 13 and 14 of Part 2 input. The default initial-value, water-surface elevation, *SEINV*, assigned throughout the grid at the simulation start, is defined on record 18 of Part 1 input. *TSTART* and *TRST* are input on record 4 of Part 1. See Appendix 2.
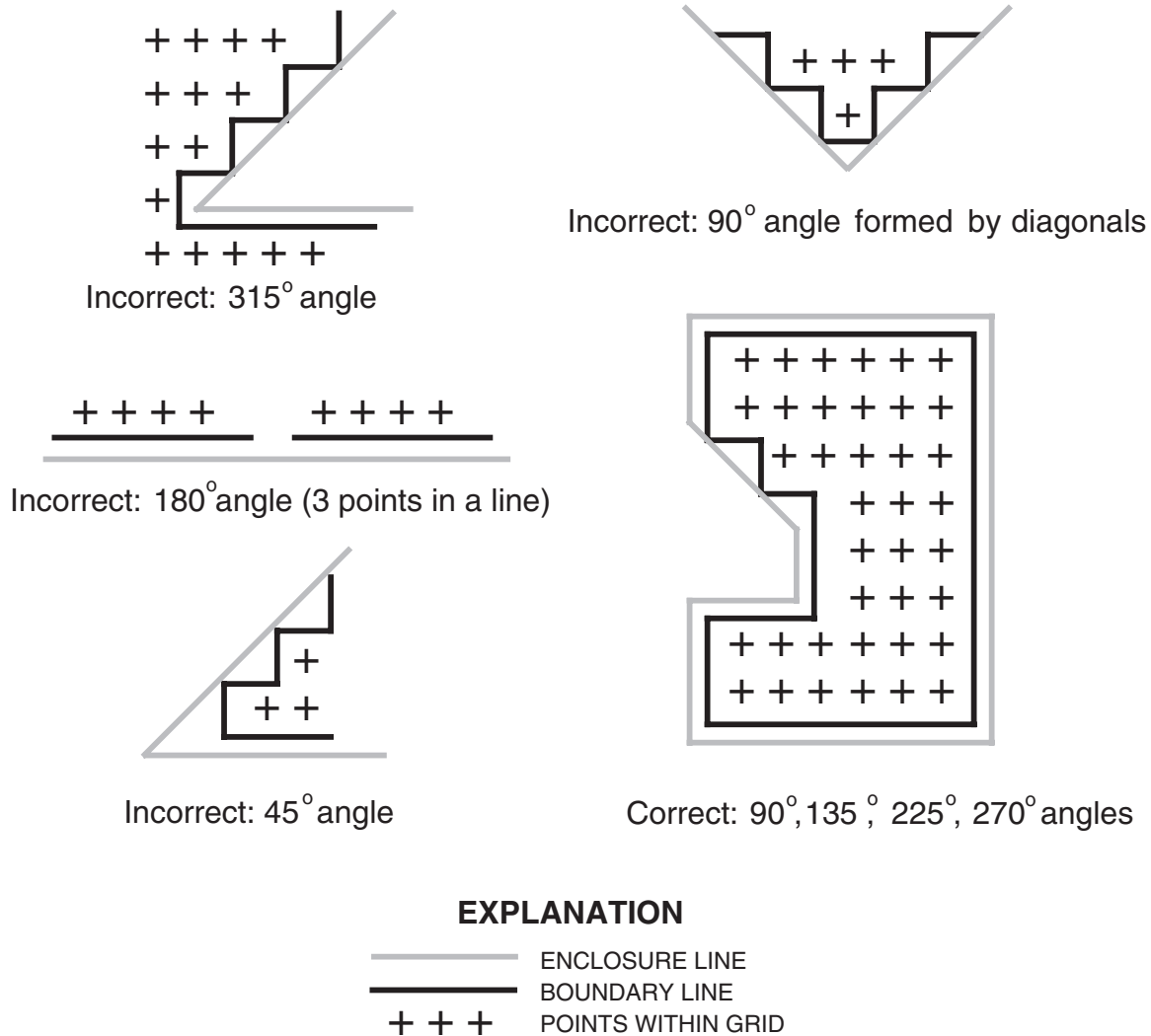
Figure 7.   Computational grid enclosure angles.

Spatial interpolation is performed at boundary openings consisting of more than two grid cells for water-surface elevations specified as time-series data or Fourier functions, constituent concentrations, and constituent return times, which are explained in the **Constituent Concentrations at Open Boundaries** section. Values at interior grid cells along an open boundary are the result of linear interpolation between the input values specified at each end of the opening. If both space and time interpolations are required at a boundary cell, spatial interpolation is performed first.

Integration Options

User specified options define the time level at which approximations of certain terms in the governing equations are made, the finite-difference representation of the convective acceleration and frictional-resistance terms, and the number of iterations per solution time step.

Numerical integrations of the governing equations are performed with two different operations at each computational time step. In one operation, the new velocity components and water levels are computed at time step $t + 0.5$ by use of the continuity equation 1 and the momentum equation 2 in the x-direction. In the second operation, the new velocity components and water levels are computed at time step $t + 1$ from information available at time step $t + 0.5$ and t by use of the continuity equation 1 and the momentum equation 3 in the y-direction. The relation of variables in the seven available integration options, specified by the input variable *ICORR*, are summarized in table 18 and explained in detail in Leendertse (1987). Option 0 (*ICORR* = 0) should be used only when the flow velocities are very low. This method is potentially unstable because of negative viscosity, which is introduced by the advection terms as shown by Vreugdenhil (1983). Option 5 (*ICORR* = 5) approaches a second-order accuracy after a few iterations because the convective acceleration terms become centered in time. This integration option has proven to be the most accurate method (Leendertse, 1987).
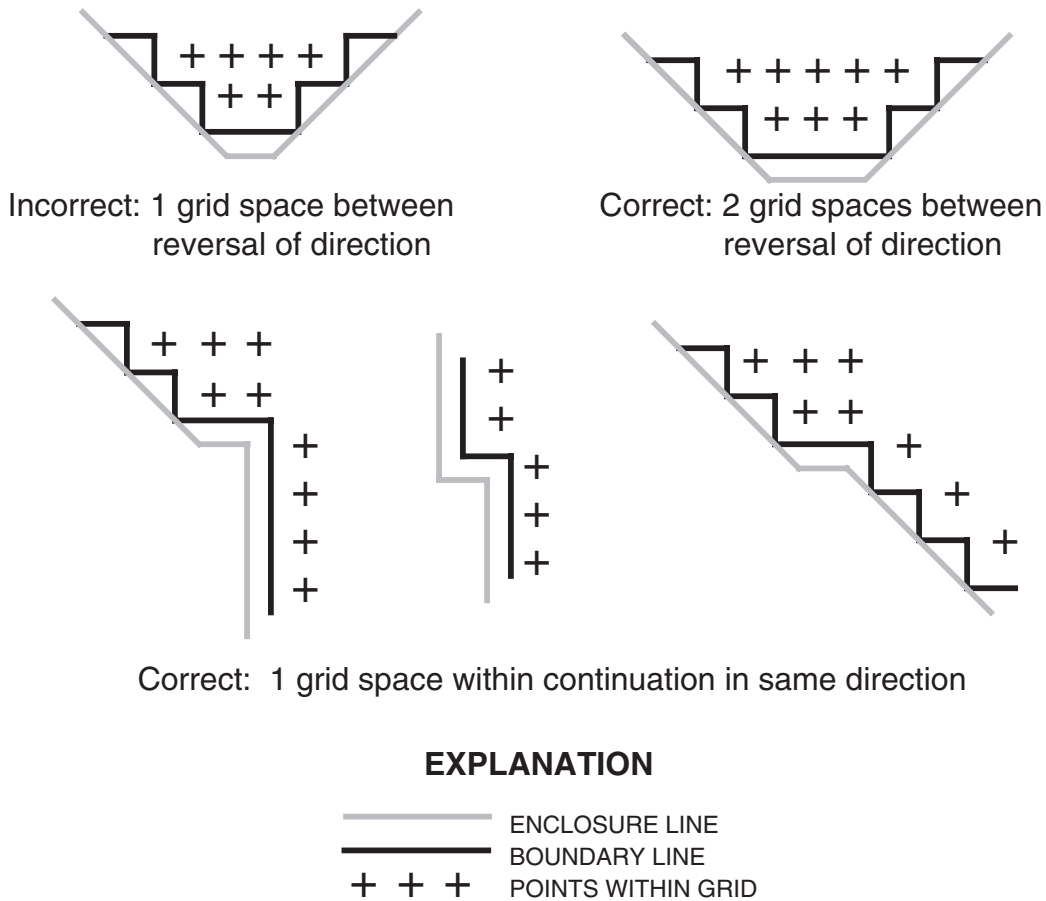
Figure 8.   Computational grid enclosure lines.

The convective acceleration terms, second and third terms in equations 2 and 3, can be approximated in three different ways as defined by the input variable *IADVEC*. The terms can be omitted (*IADVEC* = 2) or approximated by the Arakawa (1966) representation which conserves vorticity (*IADVEC* = 0) or the lower order Leendertse (1987) formulation (*IADVEC* = 1).

In addition to the conventional velocity form of the frictional-resistance term shown in equation 2 and 3, bottom stress can be approximated by an optional turbulent energy form. This form (Leendertse, 1987) requires the transport of energy as a constituent and is rarely used.

Iterations also can be performed to improve intermediate estimators used in the integration operation by specifying a value for *NCORR*. Experience has shown that more than one iteration is rarely justified.

Experimentation with the various integration options is easy to perform and should be conducted in every model application. The integration option, *ICORR*, advection option, *IADVEC*, and number of iterations, *NCORR*, are specified on record 6 of Part 1 input.

Time Smoothing

An optional time smoothing feature is available in the model to permit intermediate conditioning of the computed dependent variables, water-surface elevation and velocity. Smoothing introduces artificial viscosity into the solution; therefore, it should be used only with considerable caution and not as a way to overcome or mask computational instabilities. Other computational features including the time step, integration options, and solution iterations should be thoroughly analyzed and evaluated in numerical sensitivity tests prior to exercising the time smoothing option.

Incorrect: not closed

Correct: closed polygon

Incorrect: overlapping polygons

Correct: polygons separated by one line

Incorrect: polygons touching

Correct: one polygon inside another

EXPLANATION

ENCLOSURE LINE
BOUNDARY LINE
+ + +   POINTS WITHIN GRID
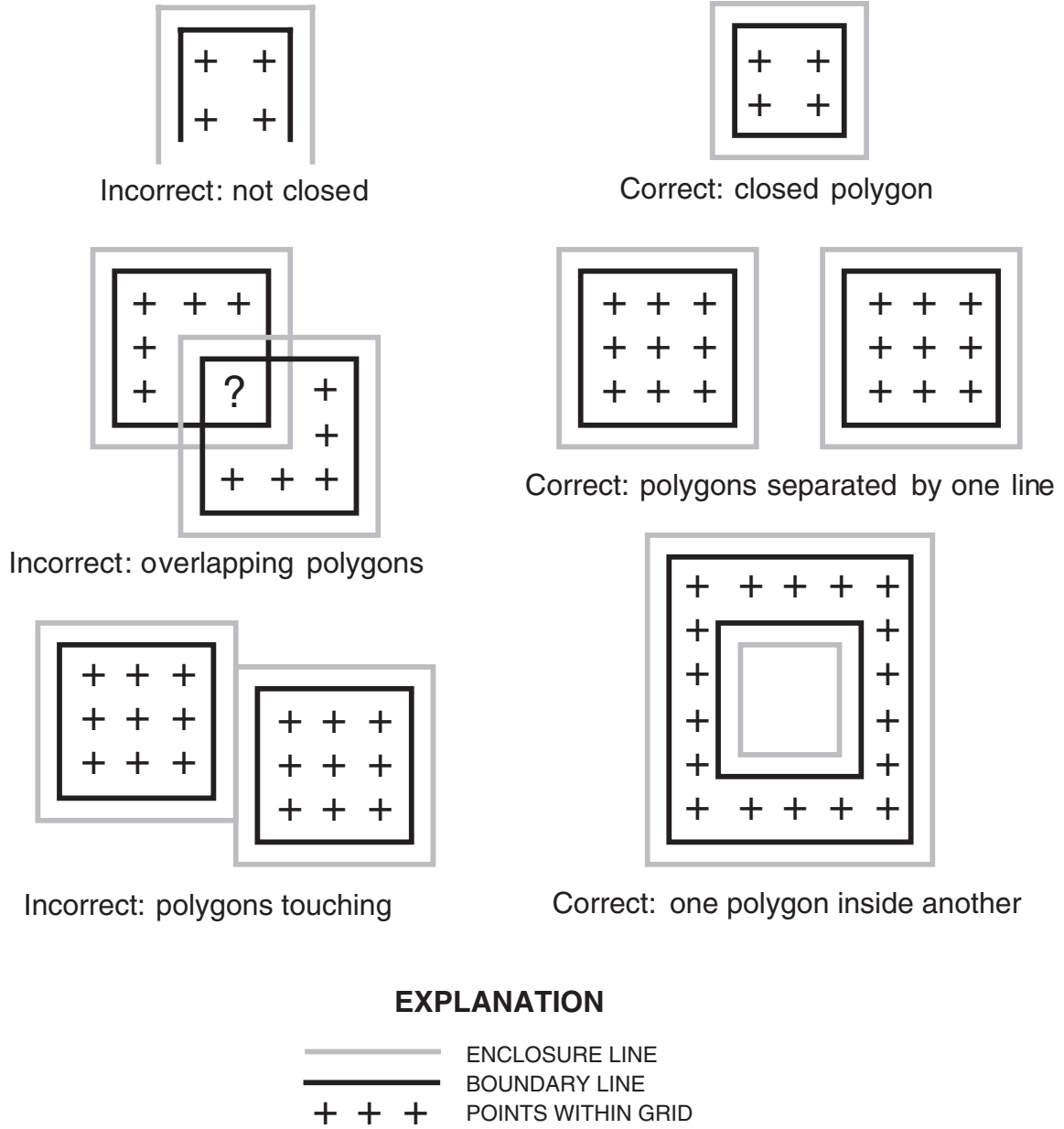
Figure 9.   Computational grid enclosure polygons.

Table 17. Time step of variable computation.

Integration time	Time of latest computation of:			
	Water level	Concen- tration	U-velocity	V-velocity
t	t	t	t - 0.5	t
t + 0.5	t + 0.5	t + 0.5	t + 0.5	t
t + 1	t + 1	t + 1	t + 0.5	t + 1
t + 1.5	t + 1.5	t + 1.5	t + 1.5	t + 1

Table 18. Relation of variables in integration options.

ICORR	Velocity in the advection term		Water level in continuity equation	
	Timestep (t + 0.5)	Timestep (t + 1)	Timestep (t + 0.5)	Timestep (t + 1)
0	Previous	Previous	Previous	Previous
1	Predicted	Predicted	Previous	Previous
2	Average	Average	Previous	Previous
3	Previous	Predicted	Previous	Previous
4	Predicted	Predicted	Predicted	Predicted
5	Average	Average	Predicted	Predicted
6	Previous	Predicted	Previous	Predicted

Time smoothing is done at intervals specified by the variable *TITSMO* in the routine *SMOOT*. In effect, this procedure creates a pause in the integration process; therefore, other operations (saving Map or Restart files, computing flooding or Chezy coefficients, or printing output) are given priority over time smoothing. Writing the History file (*TIHIST*), printing history data (*TIHISP*), and writing the Coarse-Grid file (*TICG* and *TFCG*) do not cause a delay in time smoothing. The frequency for time smoothing, *TITSMO*, and time intervals of various computational functions that need to be correlated with time smoothing are defined on record 5 of Part 1 input. Time smoothing is delayed one or more time steps until none of the following conflicting activities occur:

1. Writing the Restart file (see *TIRST*),
2. Computing C-values (see *TICVAL*),
3. Checking for flooding (see *TIFLOD*),
4. Computing heat flux (see *TIFLUX*),
5. Writing the Map file (see *TIMAPF* and *TFMAPF*),
6. Writing the Emergency Restart files (see *TIERST*),
7. Printing computations (see *TPRINT*), or
8. Printing particle positions (see *TIPARP*).

Time smoothing of velocities begins with the normal computation of U at t + 0.5 and V at t + 1. The average of U at t - 0.5 and U at t + 0.5 results in a value for U at time t. Similarly, averaging V at t and V at t + 1 results in a value for V at time t + 0.5. Then, using the selected integration scheme and the time averaged values, U at t + 1 and V at t + 1.5, are computed. A second averaging of U and V at successive steps (U at t and t + 1, V at t + 0.5 and t + 1.5) returns them to their normal points in time (that is, U at t + 0.5 and V at t + 1). The integration then proceeds using the smoothed values.

The values of water level are averaged in both time and space. The time average of water level at t - 0.5 and t + 0.5 replaces the computed value at time t. Similar averaging is done to compute values for t + 0.5 and t + 1. Spatial smoothing of water levels uses a user-specified weighting factor for surface smoothing (0<*SPA*<1) and the four adjacent water levels. *SPA* is defined on record 18 of Part 1 input. Time and space averaging of water levels is of the form

$$S_{n,m} = (1 - SPA)SBT2_{n,m} + (SPA)SBBT2_{n,m}, \qquad (11)$$

where

$S_{n,m}$ is the water level at grid point (n, m) at time t;

SPA is the weighting factor for surface smoothing;

$SBT2_{n,m}$ is the full integration step, time-average water level at $S_{n,m}$, that is, $(S_{n,m}(t + 0.5) + S_{n,m}(t - 0.5))/2$; and

$SBBT2_{n,m}$ is the full integration step, time-average water level of points adjacent to $S_{n,m}$, $SBB_{n,m}$, that is, $(SBB_{n,m}(t + 0.5) + SBB_{n,m}(t - 0.5))/2$.

Variable definitions used in equation 11 and also common to following equations 13–15 are compiled in table 19.

Drying and Flooding

The SWIFT2D model accounts for tidal flats and other alternately drying and flooding areas by considering grid points dry at depths less than a specified small marginal value *VAR*. When a point becomes dry (depth < *VAR*/2), it is taken out of the computation of velocities and water levels. A check is made for re-flooding (changing from dry to wet, if necessary) again at a specified time interval *TIFLOD*. These checks are made in routines *SINVAL, CVAL, FLO, SEPU*, and *SEPV*. After the initial determination of its wet or dry status in *SINVAL*, a point can re-flood only in routine *FLO*. The criteria for assigning Chezy coefficients for drying and flooding in applicable routines are presented in table 20 and discussed in the **Chezy Coefficients** section. In table 20, *CSET* is a Chezy coefficient user-specified for shallow-depth cells; its assignment and use is explained in the **Marginal Depth Values** section. Also in table 20, HBM + STM is an effective minimum water depth used for drying and flood checking that is the average minimum water depth plus the minimum water level during the last two consecutive half time steps at the (*n, m*) point, SES is the residual water level in the (*n, m*) dry cell, and HBadj, Sadj, and SBTMadj represent the average depth, water level, and minimum average water level during consecutive half time steps adjacent to the water level point (*n, m*) under consideration. See table 19 for a complete definition of variables in table 20. The marginal depth value for cell drying, *VAR*, is input on record 18 of Part 1 and the time interval for flood checking, *TIFLOD*, is specified on record 5 of Part 1 input. See Appendix 2. The drying and flooding process is further described in the **Marginal Depth Values** section.

Table 19.   Variable definitions common to equations 11–15.

Symbol	Definition
B	Average (as in *HB* = average depth)
BX	Average of variable in X direction
BY	Average of variable in Y direction
BT	Half time step average of variable
BT2	Full time step average of variable
H	Depth
HBn,m	Average depth at n,m
HBadj	Average depth adjacent to Sn,m
HBMn,m	Minimum average depth adjacent to n,m
HBXYn,m	Average depth at Sn,m $(Hn,m + Hn-1,m + Hn,m-1 + Hn-1,m-1)/4$
R	Concentration
Rn,m	Concentration at n,m
S	Water level (ζ in equations 1–3)
Sn,m	Water level at *n,m*
SBBn,m	Average water level adjacent to *n,m* $(Sn,m+1 + Sn,m-1 + Sn+1,m + Sn-1,m)/4$
SBTn,m	Time average of water level at Sn,m $(Sn,m(t) + Sn,m(t-0.5))/2$
SBBT2n,m	Full integration step time average of *SBB* at Sn,m $(SBBn,m(t+0.5) + SBBn,m(t-0.5))/2$
SBT2n,m	Full integration step time average of water level at Sn,m $(Sn,m(t+0.5) + Sn,m(t-0.5))/2$
SBTMadj	Minimum average water level at any non-dry points adjacent to Sn,m during consecutive half time steps
STMn,m	Minimum water level during consecutive half time steps
Sadj	Water level adjacent to *Sn,m*
U	Velocity in the X direction
Un,m	Velocity in the X direction at *n,m*
V	Velocity in the Y direction
Vn,m	Velocity in the Y direction at *n,m*
m	Grid point location in the X direction
n	Grid point location in the Y direction
t	Time
t - 0.5	One half time step before *t*
t + 0.5	One half time step after *t*

Table 20.   Criteria for Chezy coefficient computation, drying, and flooding.

[All references to computational arrays apply only to the (n, m) point under consideration]

Computation	Criterion		
	SINVAL	**CVAL**	**FLO**
C=CSET/2	None	VAR>HBM+STM>VAR/2	VAR>HBM+STM>VAR/2
C=CSET	None	None	When point floods
Drying	VAR/2>HBM+SEINV	VAR/2>HBM+STM	VAR/2>HBM+STM
Flooding	HBM+SEINV>VAR/2	None	2*HBadj+SES+Sadj>0 and SBTMadj>SES

Permanently Dry Points or Dams

Any grid point within the computational domain can be specified as permanently dry even if the depths of surrounding cells would normally cause it to be flooded. This capability provides a means to simulate a dam, causeway, or other flow-blocking structure in the water body accommodating flow on either side of the constriction. Dam points can be configured in any alignment, along rows, columns, or diagonals. Grid coordinates (n, m) defining dam locations or permanently dry points are defined on record set 7 of Part 2 input.

Chezy Coefficients

Chezy coefficients are periodically re-computed for use in the conservation of momentum equations 2 and 3 as a function of depth and optionally as a function of the salinity gradient if salt is a transported constituent. However, computed Chezy coefficients can be reset in other routines dependent on drying and flooding conditions as explained in the following section on **Marginal Depth Values**. Depth-dependent Chezy (C) coefficients are computed according to equation 8 in the routine CVAL at the start of the simulation and at time intervals of *TICVAL*, specified on record 5 of Part 1 input, from Manning coefficients specified on record sets 32 and 33 of Part 2 input. Solution considerations require that re-computation of Chezy coefficients be delayed a *HALFDT* time step if the current simulation time is a multiple of both *TICVAL* and *TIFLOD*, that is, if the computation of Chezy values and flood checking are coincident in time. Salinity-dependent Chezy computations are discussed in the **Functions of Salinity Gradient** section.

Marginal Depth Values

Chezy coefficients are uniquely set for cells having a user-specified marginal depth indicating they are dry, about to become dry, or have re-flooded according to the simulated water level. A point becomes dry if its effective minimum water depth is less than half of the user-specified marginal water depth *VAR*, specified on record 18 of Part 1 input. The effective

minimum water depth at a grid point is the minimum average depth of the four bordering grid cells plus the minimum water level during the last two consecutive half time steps. When a cell becomes dry, the residual water level ($SES_{n,m}$) is set equal to the water level at time t ($SE_{n,m}$), after which the Chezy coefficient ($C_{n,m}$), water level at time $t + 0.5$ ($SEP_{n,m}$), water level at time $t - 0.5$ ($SEN_{n,m}$), water level at time t ($SE_{n,m}$), and velocities adjacent to the (n, m) grid point are set to zero. At a point where the water depth becomes shallow (that is, the effective minimum water depth is between *VAR*/2 and *VAR*), the Chezy coefficient is set to *CSET*/2, where *CSET* is a Chezy coefficient for shallow-depth cells specified on record 18 of Part 1 input. When a point becomes dry (that is, the effective minimum water depth is less than *VAR*/2), the Chezy coefficient is set to zero, the residual water level is saved, and the point is removed from the computation. When a dry point re-floods (that is, when the average water level of surrounding points is greater than the residual water level saved when the cell became dry), the Chezy coefficient is set to *CSET*, the water level is set to the residual water level saved when the point became dry, and the point is returned to the computation. When the simulated water depth exceeds the marginal depth *VAR*, the point returns to the normal computation with the Chezy coefficient computed by the depth-dependent equation 8, optionally corrected for the salinity gradient as shown in equation 9.

Functions of Salinity Gradient

A correction is made to the Chezy coefficient in the routine CVAL to account for the salinity gradient if a non-zero Chezy correction value is specified and salt is a transported constituent. The salinity-gradient form of the Chezy coefficient is shown in equation 9, in which α_1 represents the correction coefficient. In tidal flow situations, the effect of the salinity correction is to increase flow resistance during flood tide and decrease it during ebb. The salinity-gradient correction coefficient, *CCOR*, is specified on record 18 of Part 1 input and the constituent number assigned to salt, *LSAL*, is defined on record 17 of Part 1 input. The correction coefficient *CCOR* is limited to the range 0.5 to 1.5.

Forcing Functions

The forcing functions that drive SWIFT2D simulations are input water-surface elevations (stages), velocities, mass transport rates, or constituent concentrations at open boundaries, along with wind conditions, source discharges, and constituents input within the computational domain. Open-boundary conditions can be prescribed by time-varying input data (given in Part 3) or by Fourier components of tidal amplitude and phase (given in Part 2). Time-varying water-level, velocity, or transport data at open boundaries (number of openings *NTOT* identified on record 15 Part 1 input) are specified (or implied) for both ends of the openings at intervals of *TITIDE*. The values at each point along a boundary opening are linearly interpolated spatially and temporally to obtain intermediate values at the *HALFDT* time-step frequency. Initial values for boundary conditions at openings are specified on record sets 13 and 14 of Part 2 of SWIFT_IDP input. The format requirements of all time-varying input are defined in Part 3 of Appendix 2. The position, orientation, and type of boundary openings are defined by the *KBO* codes illustrated in figure 10 and presented in table 21. *KBO* codes for boundary openings are defined on record set 12 of Part 1 input. See Appendix 2.

Fourier Tide Openings

The primary hydrodynamic forcing functions are observed time-varying water-surface elevations at open boundaries or tide openings. However, other types of time-varying input are acceptable, such as Fourier functions. Fourier functions have any number of angular frequency components with corresponding phase and amplitude values. The Fourier equation used in the SWIFT2D code is of the form

$$X = AZERO + SOM, \tag{12}$$

where

X	is	the water level or velocity at the open boundary;
AZERO	is	the amplitude at zero frequency;
SOM	is	the sum of (*AMPL*)cos[*t*(*OMEGA*)-*PHASE*] for all Fourier components; and
t	is	elapsed time in seconds at *HALFDT*, 2(*HALFDT*), 3(*HALFDT*),..., n(*HALFDT*).

SWIFT2D spatially interpolates phase and amplitude across the open boundary before interpolating over time. Linear interpolation over time is used at openings specified by Fourier functions to obtain tide values during the interval that simulated time is less than the last time specified to smooth the Fourier function, *TLFSMO*. The interpolation for water levels is between the initial value (interpolated across the opening using *TIDA* and *TIDB*) and the computed value *X* from equation 12. The interpolation for velocities is between *AZERO* (interpolated across the opening using input end values *AZEROA* and *AZEROB*) and the computed value *X*.
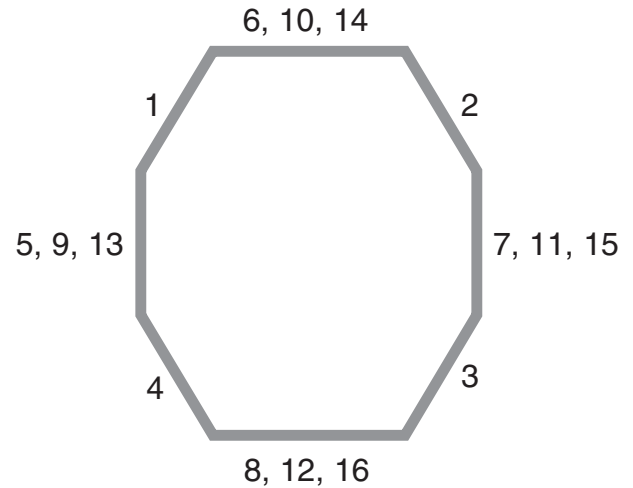
Figure 10. KBO codes defining type, location, and orientation of boundary opening.

Transformations and interpolations for Fourier functions are performed in the *TRANWL* routine. The numbers of tide openings defined by Fourier functions, *NTOF*, and components specified for the Fourier functions, *KC*, are defined on record 15 of Part 1 input. Amplitude, phase, and frequency of Fourier components (*AZERO*, *AMPL*, *PHASE*, and *OMEGA*) are specified on record sets 15 through 19 in Part 2 of SWIFT_IDP input. *OMEGA* must be input in radians/sec and *PHASE* in radians.

Space-Varying Wind and Pressure

SWIFT2D accepts constant or time-varying global wind speed and direction as well as spatial-varying wind speed, wind direction, and atmospheric pressure as forcing functions. Wind conditions can be defined as constant throughout time and over the whole model domain by speed and direction values *WIND* and *WINDA* assigned on record set 8 of Part 2 input; they can assume time-varying global values assigned on record types F and G of Part 3 input; or they can be input as spatial-varying values from a binary file of grid data as specified in Part 4 input. In the later case, SWIFT2D reads time-varying grid inputs from a file independent of the SIMINP file and interpolates values across time steps and over model grid cells.

The variable *ISVWP* on record 6 of Part 1 input defines whether or not spatial-varying wind and pressure grids are input in Part 4. The time interval for space varying wind and pressure inputs need not be regular. The grid for spatial-varying wind and pressure input is typically a grid of less resolution than the computational grid. Variables on the array dimensions record 16 of Part 1 input define the input wind and pressure grid dimensions and their correlations to the computational model grid.

Table 21. KBO codes for defining boundary conditions.

KBO code	Type of opening	Line type	Position relative to computational grid
1	water level	diagonal	left & above
2	water level	diagonal	right & above
3	water level	diagonal	right & below
4	water level	diagonal	left & below
5	water level	vertical	left
6	water level	horizontal	above
7	water level	vertical	right
8	water level	horizontal	below
9	u-velocity	vertical	left
10	v-velocity	horizontal	above
11	u-velocity	vertical	right
12	v-velocity	horizontal	below
13	u-transport rate	vertical	left
14	v-transport rate	horizontal	above
15	u-transport rate	vertical	right
16	v-transport rate	horizontal	below

The wind stress coefficient (θ) in momentum equations 2 and 3 is specified as the variable *WSTR* on record 19 of Part 1 input and applies to the whole computational domain. Suggested values for the wind stress coefficient range from 0.0015 for light winds to 0.0026 for strong winds (Wilson, 1960). Air and water densities, *DAIR* and *DWAT*, specified on record 19 of Part 1 input, are used to complete definition of the wind stress term in equations 2 and 3.

Constituent Concentrations at Open Boundaries

The concentrations of constituents at open boundaries are computed in routines SLOSHU and SLOSHV. These routines are called from DIFU and DIFV with different arguments representing the appropriate values of velocities and concentrations. The computation is dependent upon the direction of flow relative to each point on the boundary opening and on the type of opening as defined by *KBO* codes illustrated in figure 10 and presented in table 21. Concentrations at boundary openings are automatically varied during the simulation using ambient concentrations at each end of the opening (*RBNDA* and *RBNDB*), specified constituent return times at the opening (*TCRETA* and *TCRETB*), and the concentration in the interior of the computational domain. See record sets 13, 14, 20, 21, and 36 of Part 2 SWIFT_IDP input.

A *KBO* code defines the orientation, position, and type of each boundary opening, as illustrated in figure 10 and presented in table 21. The direction of flow at a

constituent open boundary is determined as specified in table 22 for various boundary locations. During outflow, concentrations are computed from inside the computational field. If the flow reverses to inward flow (such as at a tide opening) at points on the boundary, the concentrations return over the specified return period to the concentrations specified in Part 3 input. If no value is given in Part 3, the initial concentration at the boundary is used. The Part 3 specifications, thus, permit time-varying concentrations at the open boundary during and after the return period. Measured time-varying constituent concentrations at open boundaries are specified on record type C of Part 3 input. Constituent concentrations are input at the same times as water-level or velocity data, but they do not need to be input at every *TITIDE* time interval. However, if constituent concentrations are not input at every *TITIDE* interval, the last value input persists (constant value) until the time *TITIDE* minutes before a new concentration is specified.

The concentration at each point is computed as follows, with equation 13 representing outflow, equation 14 representing mixed flow, and equation 15 representing inflow:

$$Rnew = Rold - \frac{Vel(Radj - Rold)AT}{AL}, \tag{13}$$

$$Rnew = Rold, \text{ and} \tag{14}$$

$$Rnew = RBND - 0.5[\cos(Ret*PI) - 1](DFL - RBND) \tag{15}$$

if Ret>0, or *Rnew = RBND* if Ret<0,

where

- *Rnew* is the new concentration to be computed;
- *Rold* is the previous concentration (computed at last half time step);
- *Radj* is the concentration at the adjacent inward point used for outflow;
- *AT* is half time step (*HALFDT*) in seconds;
- *AL* is the grid cell size;
- *RBND* is the ambient concentration at the point;
- *Ret* is the ratio of the time remaining in the return cycle to the maximum time in the return cycle (*TCRET*); and
- *DFL* is the concentration at the time that flow starts inward.

The function cos(*Ret*PI*)-1 varies from -2 to 0 as *Ret* varies from 1 to 0 and is primarily intended for tidal boundary openings. The cosine variant can be changed in the program code if another functional relationship is deemed more appropriate. The return cycle counter is set equal to the maximum time in the cycle (*TCRET*) when flow is outward or mixed. Therefore, each time that inward flow is interrupted, even briefly, the counter is reset to *TCRET*. *DFL* is set equal to the concentration at the point when the flow turns inward. The concentration at the point reverts to *RBND* during the interval *TCRET* if inward flow is uninterrupted.

Table 22. Flow direction of concentration computations at open boundaries.

[Where: Radj, the concentration at the adjacent inward point used for outward flow; Vel, the velocity component used to determine direction]

KBO	Radj	U-Velocity	V-Velocity	Outward	Inward	Mixed
			Diagonal boundary; call from DIFU routine:			
1	R right	U here	V below	U neg	U pos, V neg	U pos, V pos
2	R left	U left	V below	U pos	U neg, V neg	U neg, V pos
3	R left	U left	V here	U pos	U neg, V pos	U neg, V neg
4	R right	U here	V here	U neg	U pos, V pos	U pos, V neg
			Diagonal boundary; call from DIFV routine:			
1	R below	U here	V below	V pos	U pos, V neg	U neg, V neg
2	R below	U left	V below	V pos	U neg, V neg	U pos, V neg
3	R above	U here	V here	V neg	U pos, V pos	U neg, V pos
4	R above	U here	V here	V neg	U pos, V pos	U neg, V pos
			Horizontal and vertical boundaries; call from both DIFU and DIFV routines			
5,9,13	R right	U here	----	U neg	U pos	----
6,10,14	R below	----	V below	V pos	V neg	----
7,11,15	R left	U left	----	U pos	U neg	----
8,12,16	R above	----	V here	V neg	V pos	----

If the initial concentration of a constituent along an open boundary is non-uniform, then the concentration at all grid points on the boundary must be specified. Values specified as zero or left blank on initial concentration input records (record set 36 in Part 2 input) are set to the value specified for the initial concentration in the interior of the grid, *RINT*, input on record set 20 in Part 2. At open boundaries, initial constituent concentrations specified with water level openings on record sets 13 and 14 of Part 2 input override other input values.

Barriers

Grid cells can be specified to be flow barriers, which are time-varying constrictions on flow in the *U* or *V* velocity direction, or both. A barrier can be a weir, a hydraulic gate, or a bridge pier. Each barrier occupies one grid cell, is located at a water-level grid point, and must be specified as either a *U* or *V* flow constriction. Typically a barrier is located between dam points and (or) other barriers.

At a barrier, flow is restricted in some form and a special computation is made to allow for energy loss at the constriction that results in differences in water levels on either side of the barrier. If a *U*-barrier is at water-level point (*n, m*), the computation takes water out of cell (*n, m*-1) and discharges it into cell (*n, m*+1) if the water level in cell (*n, m*-1) is higher than in cell (*n, m*+1). The adjacent points for a *V*-barrier at water-level point (*n, m*) are (*n*+1, *m*) and (*n*-1, *m*).

Certain restrictions apply to the location and arrangement of barriers. Barrier points should be located at least three grid points apart in the direction of the flow and three grid points away from the computational grid boundary. Barrier points can be side by side, forming a row or column to simulate a storm-surge barrier. Typically, a barrier is located between dam points and (or) other barrier points as shown in figure 11. A *U* and *V* flow barrier can be inserted at the same grid point, even though each works independently of the other. An example of a barrier with two flow directions is shown in figure 12.

For the example U-barrier shown designated at water-level point (*n, m*) in figure 11, the points (*n, m*-1) and (*n, m*+1) should be normal computation points. These adjacent water-level points are checked during the simulation to ensure that all cross sections through two depth points surrounding these water-level points are always flooded, otherwise the solution is aborted. Modifications can be made to the model barrier code to allow adjacent water-level points to become dry without the simulation aborting, however, the suitability of any such modification should be verified in every model application.

A flow constriction can be imposed vertically by raising and lowering either the elevation of the barrier sill (*SILL*) above the bottom or the height of a gate (*GATE*) above the water surface, or both. In the horizontal, the effective width of a barrier (*BRAT*) can be increased or decreased for more or less constriction. The gate height, the sill elevation, and the relative width of the barrier (width/grid size) can be varied in time, which makes it possible to create a time-varying operational constriction. The gate height is described as positive upward and the sill elevation as positive downward. Thus, if the sill is located at a depth of 5.0, then the barrier is completely closed when the gate height is -5.0. Barrier descriptions *SILL, GATE*, and *BRAT* are specified on record set 11 of Part 2 input. See Appendix 2.
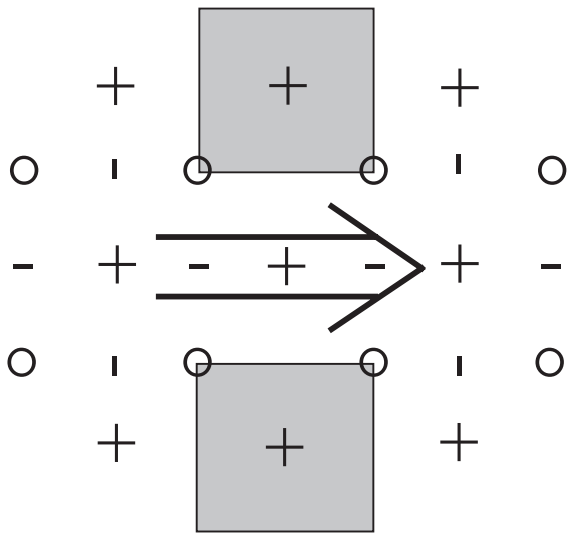
EXPLANATION

O	DEPTH GRID POINT
+	WATER-LEVEL GRID POINT
▬	U-VELOCITY GRID POINT
▮	V-VELOCITY GRID POINT

Figure 11.   Typical barrier between two dam points.

EXPLANATION

O	DEPTH GRID POINT
+	WATER-LEVEL GRID POINT
▬	U-VELOCITY GRID POINT
▮	V-VELOCITY GRID POINT

Figure 12.   Barrier in two flow directions at a single grid point.

Hydraulic equations are used for the computation of the flow through a barrier, which are determined by the upstream and downstream water levels in relation to the sill elevation and height of the gate. The upstream water level relative to the top of the sill (H_1), the downstream water level relative to the top of the sill (H_2), and the height of the gate above the top of the sill (H_0) are used to define flow conditions at a barrier. The five basic flow conditions (1, 3, 4, 7, and 8) are shown in figure 13. Transitions between these five basic flow conditions also are treated in SWIFT2D; namely, conditions 0, 2, 5, and 6.

Condition 0

In the computations, the gate can be closed or the sill is above the highest water level and no flow occurs (not shown in fig. 13). Thus, if $H_0 = 0$, $B = 0$, or $H_1 < 0$, then $Q = 0$.

Condition 1

Flow is restrained by the gate, but not influenced by the downstream water level. This condition occurs when $H_1 > 3/2(H_0)$ and $0 < H_2 < H_0$. For these conditions, the flow is supercritical and the discharge is

$$Q = \mu_{5,6} B H_0 [2g(H_1 - H_0)]^{1/2}. \qquad (16)$$

$H_1 > 3/2(H_0)$

$H_2 < H_0$

Condition 1

$H_1 < H_0$

$H_2 < 2/3(H_1)$

Condition 3

$H_1 < H_0$

$H_2 > 2/3(H_1)$

Condition 4

$H_1 > 3/2(H_0)$

$H_2 > H_0$

Condition 7

$H_1 > H_0$

$H_2 < 0$
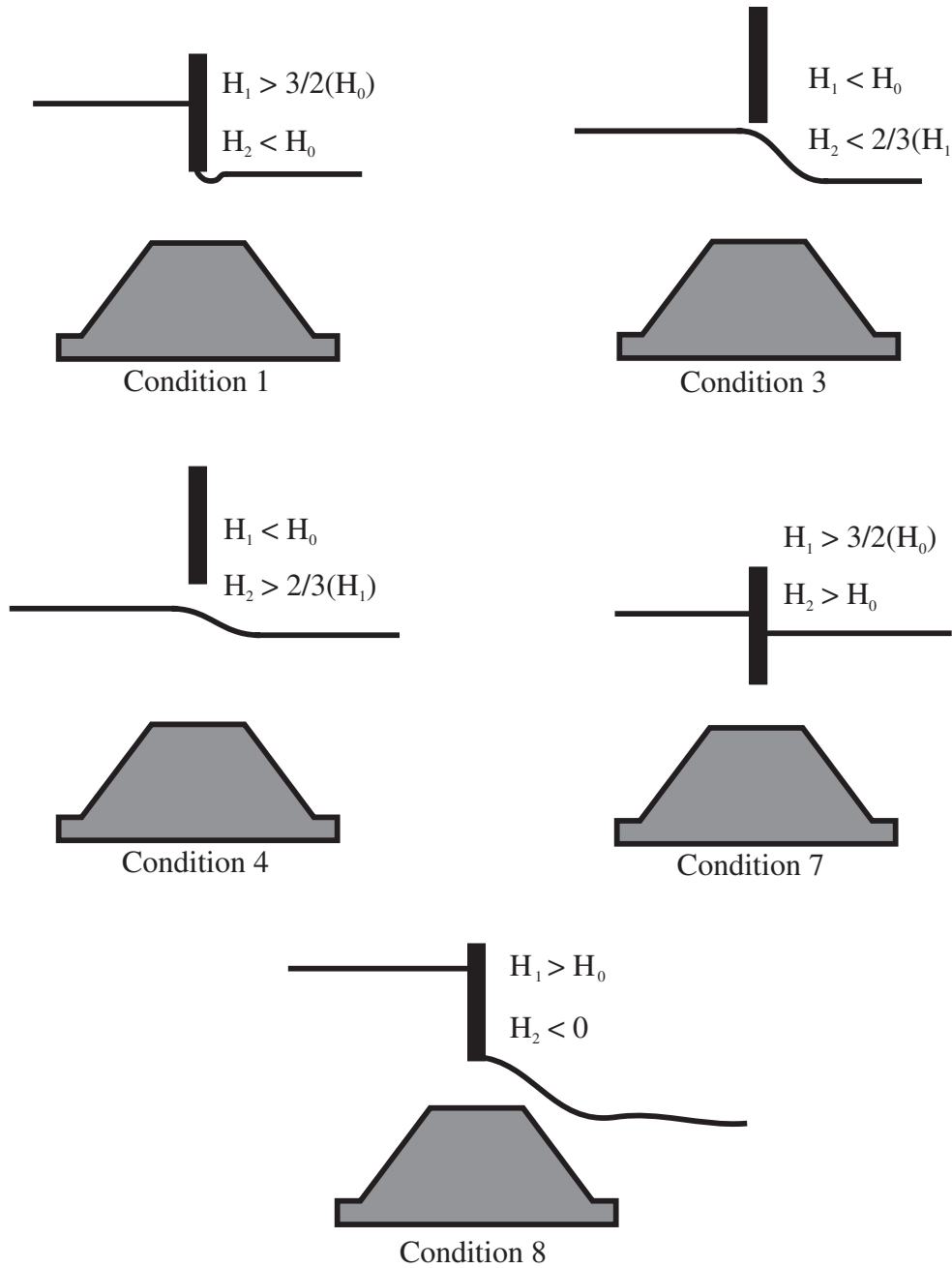
Condition 8

Figure 13.   Five basic flow conditions for a barrier. (Transitions between these basic flow conditions represented by conditions 0, 2, 5, and 6 also are treated in SWIFT2D.)

Condition 2

Condition 2 is the transition between supercritical gate flow (condition 1) and free-surface subcritical flow (condition 3). This condition is encountered in condition 3 with free-surface supercritical flow when the gate is lowered and touches the water surface; the flow is suddenly much more restricted and it becomes discontinuous. This condition ocurs for $H_2 < 2/3(H_1)$ and $H_1 < H_0 < 3/2(H_1)$. The discharge is computed as

$$Q = \left\{ 1 + 2\left[\frac{H_1}{H_0} - 1\right]\left[\frac{\mu_{5,6}H_0(H_1 - H_0)^{1/2} - \frac{2}{3}\mu_{3,4}H_1(H_1/3)^{1/2}}{\frac{2}{3}\mu_{2,3}H_1(H_1/3)^{1/2}}\right]\right\}\left[\frac{2}{3}\mu_{2,3}H_1B(2H_1/3)^{1/2}\right]. \tag{17}$$

Condition 3

Flow does not touch the gate, and the sill is so high that the downstream water level has no influence on the flow rate. This condition occurs when $H_1 < H_0$ and when $H_2 < 2/3(H_1)$. The flow is supercritical and the flow rate is expressed by

$$Q = \mu_{3,4}\frac{2}{3}BH_1\left(\frac{2}{3}gH_1\right)^{1/2}. \tag{18}$$

Condition 4

In this case, the flow does not touch the gate, but the downstream water level is high enough to influence the flow rate. This condition occurs when $H_1 < H_0$ and $H_2 > 2/3(H_1)$. The flow is subcritical and can be expressed by

$$Q = \mu_{1,2}BH_2[2g(H_1 - H_2)]^{1/2}. \tag{19}$$

Conditions 5 and 6

These conditions are for the gradual transition between free-surface subcritical flow (condition 4) and subcritical gate flow (condition 7).

Condition 5, which is valid for $H_0 > H_2 > 2/3(H_1)$ and $H_1 > H_0$, yields

$$Q = \left\{ 1 + 2\left[\frac{H_1}{H_0} - 1\right]\left[\frac{\mu_{5,6}H_0 - \mu_{1,2}H_2}{\mu_{1,2}H_2}\right]\right\}\mu_{1,2}H_1B[2g(H_1 - H_2)]^{1/2}. \tag{20}$$

Condition 6, which is valid for $H_2 > H_0$ and $H_1 < 3/2(H_0)$, yields

$$Q = \left\{ 1 + 2\left[\frac{H_1}{H_0} - 1\right]\left[\frac{\mu_{5,6}H_0 - \mu_{1,2}H_2}{\mu_{1,2}H_2}\right]\right\}\mu_{5,6}H_0B[2g(H_1 - H_2)]^{1/2}. \tag{21}$$

Condition 7

Both the upstream and downstream water levels are higher than the gate and the flow is subcritical, thus $H_1 > 3/2(H_0)$ and $H_2 > H_0$. The flow is expressed by

$$Q = \mu_{5,6} B H_0 [2g(H_1 - H_2)]^{1/2}. \tag{22}$$

Condition 8

In this case, the upstream water level is higher than the gate and the downstream water is below the top of the sill, thus $H_1 > H_0$ and $H_2 < 0$. The flow rate is expressed by

$$Q = \mu_{5,6} B H_0 \left[2g\left(H_1 - \frac{H_0}{2} \right) \right]^{1/2}, \tag{23}$$

where

- Q is   flow rate;
- B is   relative width of the barrier;
- H_0 is   vertical distance from sill to the bottom of the gate;
- H_1 is   vertical distance from the sill to the upstream water level;
- H_2 is   vertical distance from the sill to the downstream water level;
- g is   acceleration of gravity;
- $\mu_{1,2}$ is   barrier flow coefficient for free-surface subcritical flow;
- $\mu_{3,4}$ is   barrier flow coefficient for free-surface supercritical flow; and
- $\mu_{5,6}$ is   barrier flow coefficient for gate-restricted flow.

Because the constriction can cause critical flow, coefficients of critical and subcritical flow must be specified. Flow across the barrier depends on contraction coefficients, μ_1 through μ_6 (specified as *BARMU* on record set 10 of Part 2 SWIFT_IDP input), in the barrier equations for different flow conditions, such as subcritical and supercritical flow. Separate coefficients are used for each flow direction because the flow characteristics of the structure can be flow-direction dependent. The model automatically selects the appropriate contraction coefficient for the computed flow condition. Barrier coefficients are generally obtained from laboratory or field measurements.

In most cases, the barrier coefficients are determined with H_1 being the vertical distance between the sill level and the upstream water level, but in some cases the energy height is used and H_1 is taken as

$$H_1 = h_1 + \frac{v_1}{2g}, \tag{24}$$

where

- h_1 is   vertical distance between upstream water level and sill level; and
- v_1 is   upstream velocity.

When the latter definition is used, the velocity head can be taken into account by setting the fraction of energy to be used (*ERGC1*) (on record 26 of Part 1 input) equal to 1.0. However, use of the energy head can result in instabilities in the computation and this must be carefully monitored. A thorough treatment of finite-difference approximations for barrier computations and considerations governing the use of barriers is given in Leendertse (1987).

Barrier descriptions and initial gate and sill heights are input in Part 2 of SWIFT_IDP input on record sets 9, 10, and 11. Time-varying gate, sill, and width conditions are defined in Part 3 input on type L, M, and N records. Since water levels on each side of a barrier and the flow rates and velocities are typically of practical interest, these variables are always printed when water levels, velocities, and flows through cross sections are requested. Barrier flow results also are written to the History file. Thus, there is no need to insert water level and velocity check stations near the barrier to obtain these computed flows.

Particle Tracking

Particles, representing conservative substances or parcels of water, can be injected into a water body at any location within the computational grid at any time during a simulation and the model tracks their paths of travel. Particles are assumed to represent some quantity or substance that moves with the water, but does not influence water movement. Particle tracking is an effective means of investigating the flow-induced transport of suspended material, a conservative substance, or a dye concentration. Leendertse and others (1981) demonstrated the use of tracer particles to delineate tidal excursions and examine dispersion in the Oosterschelde Estuary, The Netherlands. Lee and others (1994) used particle tracking to illustrate the effects of highway crossings on tidal flushing and circulation in Port Royal Sound, South Carolina. Schaffranek (1986) illustrated the effects of channel alignment and bathymetry on tidal excursions in the Potomac Estuary using particle tracking. The tidal excursions of 17 particles, injected along four cross-sectional transects, simulated by the Potomac Estuary model are shown in the sample plot in figure 14. Tidal boundary conditions used to conduct the simulation are shown in the insert.

Particles move according to the magnitude and direction of the flow velocity at the particle location. The velocity of a particle is determined by interpolating the velocity components at the particle location at the beginning of the time step. The distance a particle travels is computed as the product of the velocity magnitude and time step. Particle movements also can be computed using velocity and energy. The energy equation is used to simulate the intensity of random movement where a random number generator is used to determine the random displacement. The intensity of random movement in the direction of flow and in the transverse direction can be scaled differently.
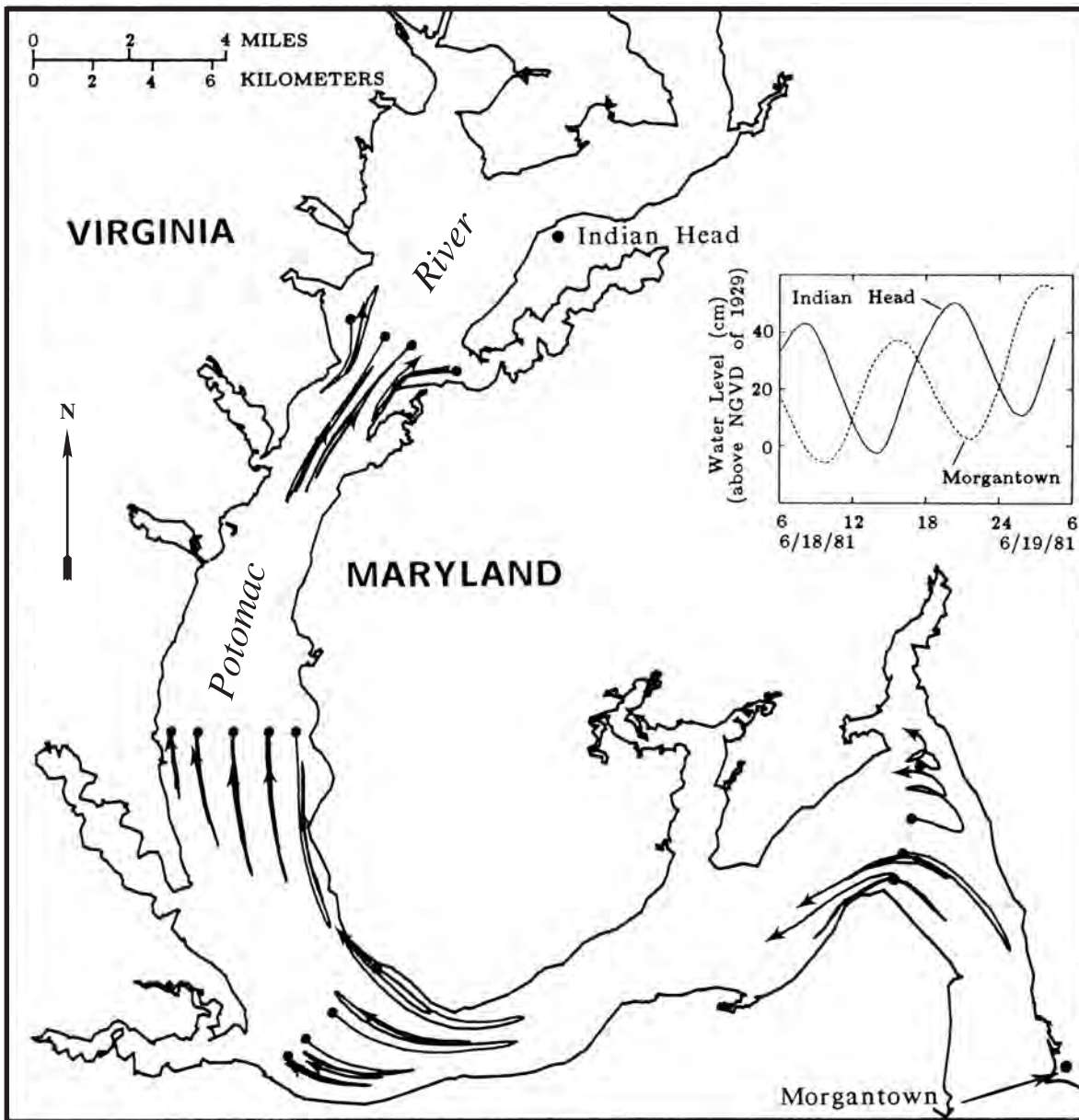
Figure 14.   Sample plot of SWIFT2D simulated particle excursions in the Potomac Estuary.

Particles can be grouped and given particle groups can have any number of particles, each randomly affected by energy. Any number of particle groups can be introduced at various times and places and withdrawn at various times. For example, a group of particles can be introduced at a particular time and location to simulate the dispersion of a dye cloud.

Particle positions (Xp, Yp) are computed throughout time as

$$Xp(t+1) = Xp(t) + UpDT$$

$$+(Rn_1 PAR_1 \cos\varphi - Rn_2 PAR_2 \sin\varphi)DT\sqrt{E} \text{ and} \qquad (25)$$

$$Yp(t+1) = Yp(t) + VpDT$$

$$+(Rn_1 PAR_1 \sin\varphi + Rn_2 PAR_2 \cos\varphi)DT\sqrt{E}, \qquad (26)$$

where

Up and Vp	are	the components of velocity at the particle location;
Rn_1 and Rn_2	are	0 if $IPARG = 1$;
	are	uniformly distributed random numbers if $IPARG = 2$;
	are	pseudo-Gaussian random numbers if $IPARG = 3$;
PAR_1 and PAR_2	are	directional energy-related dispersion coefficients;
φ	is	the angle between the x coordinate and the flow direction at the particle location;
DT	is	the integration time-step size in seconds; and
E	is	the energy at the particle location.

The values of U, V, and energy closest to the particle are bi-linearly interpolated to obtain values of Up, Vp, and E. Rn_1 and Rn_2 are in the range -1 to 1 if $IPARG = 2$ and -6 to 6 if $IPARG = 3$.

Graphical presentation of particle tracks is conducted in postprocessing after the simulation. In postprocessing, maps can be drawn showing particle positions along with other computed variables appropriate to analyze the effects of interest. See figure 14.

Particle group descriptions are specified in Part 2 input on record set 38 in Appendix 2. Variables *TFPAR* and *TLPAR* delimit the injection times, *XPAR* and *YPAR* define the injection locations, *IPARG* identifies the type of movement, and *NPARI* defines the number of particles in the group. Appendix 3 illustrates the definition of 17 particles for the Potomac Estuary simulation output shown in figure 14.

Transport and Water-Quality Simulation

The SWIFT2D transport simulation uses time-varying concentrations of constituents specified at open boundaries and internal outfall sources to compute the advection, dispersion, and resultant concentrations of constituents throughout the computational domain. Salinity, chloride, temperature, dissolved oxygen (DO), biochemical oxygen demand (BOD), energy, and dye are constituents that have been simulated. Distributions of salinity, DO, BOD, coliform bacteria and BOD–DO reactions were simulated in Jamaica Bay, NY, using the transport component of the model (Leendertse and Gritton, 1971).

For the computation of dispersion in the transport equation 4, both the effects of lateral mixing and longitudinal dispersion in the direction of flow are considered. Diffusion coefficients representing lateral mixing effects at water-level points are defined on record sets 30 and 31 in Part 2 input. A uniform diffusion coefficient can be specified by *DIFDEF* on record 30 or spatially varied coefficients can be assigned throughout the model domain using record set 31.

The longitudinal dispersion coefficient is computed at each cell according to a relation established by Elder (1959) between the local flow conditions, depth and velocity, and the Chezy resistance coefficient

$$D_l = c_d H \bar{u} \sqrt{(2g)}/C, \tag{27}$$

where
  c_d is a coefficient relating longitudinal dispersion to the local velocity;
  $\bar{u}$ = local velocity;
  H = temporal flow depth;
  g = acceleration due to gravity; and
  C = Chezy resistance coefficient.

A representative value of 14.3 has been determined for the coefficient relating the longitudinal dispersion and Chezy coefficients (Harleman, 1966). The effective dispersion used in transport equation 4 is the sum of the lateral mixing and longitudinal dispersion components.

Input parameters and coefficients for transport of constituents are specified on records 17, 19, and 26 of Part 1 input. The coefficient relating the longitudinal dispersion and Chezy coefficients, *CDCON*, in equation 27 is input on record 19 of Part 1 input. Constituent descriptions are given in record set 20 of Part 2 input. Time-varying constituent concentrations at boundary openings are specified on type C records of Part 3 input. See Appendix 2.

Several constituents can be simulated simultaneously and their interactions can be treated. For reactive constituents a reaction term with a matrix of interaction coefficients is added to the vertically integrated transport equation 4. Coefficients of interaction rates must be specified for reactive constituents. Constituents can grow or decay at a fixed rate and grow or decay in linear relation (first order reactions) to another constituent. The interaction between BOD and DO is specifically treated in the SWIFT2D reactive transport algorithm. Interaction rates between constituents are defined in record set 21 of Part 2 input.

Constituents discharged by outfalls into the interior of the water body also are treated by the model. In the hydrodynamics computation, the flow volume at the outfall is added to the volume of the grid cell designated as the outfall site and the new constituent concentration is computed. The model assumes that the outfall discharge enters the cell with negligible momentum and that instantaneous mixing occurs. On input, both the discharge rate and constituent concentration of the outfall can be time varying. Discharges and concentrations at outfall sources are specified on type D and E records of Part 3 input, respectively.

SWIFT2D Output

This section describes SWIFT2D printed output and simulation results saved to the History, Map and Coarse-Grid files for subsequent postprocessing. SWIFT2D also writes to several temporary files for various operations. These files are deleted upon normal termination of a simulation; however, they might be retained on the computer system if SWIFT2D terminates abnormally. The functions of these temporary files include formatting printout with carriage control, pre-formatting printout lines, and formatting error, warning, and run messages.

Printed Output

Four types of SWIFT2D printed output exist:
- **Type A output:** This printed output includes a listing of user notes, Part 1 input before and after overrides, plot parameters in Part 1 after defaults are set, Part 1 overrides, initial values resulting from Part 2 input, and specified data (depth, Chezy, Manning, benthic demand, and constituent concentrations) in arrays and at selected grid locations. Barrier conditions at specified points are printed at intervals of *TIHISP*; for example: *QUL* and *QUR* = transport at a U-barrier at the left and right, respectively; *QVB* and *QVT* = transport at a V-barrier at the bottom and top, respectively; *SEG* = water level at t; and *SEGP* = water level at $t + HALFDT$. Data arrays are printed at the times given in *TPRINT*. Flags given to control the selection of variables to be printed are found in Output Print-Flags records in Part 1 input described in Appendix 2. Table 23 defines the symbols used in the printout of barrier data.

- **Type B output:** This printout includes run messages such as simulation time, time-varying data read from Part 3, tasks being performed, as well as error or warning messages.

- **Type C output:** This printout includes particle locations at each time step.

- **Type D output:** This printout includes water levels, velocities, and transports at specified points printed at intervals of *TIHISP*.

The following rules apply to SWIFT2D printed output:
- If the file unit *NUPRTC* (on the Units record of the In-stream Input file) does not equal *NUPRIN*, Type C output is contained in the "*.par" output file; otherwise, it is part of the Type A output.

Table 23. Symbols used in barrier history printout.

[**Definition:** The terms "left" and "right" in definitions refer to the negative X and positive X directions. Terms "below" and "above" refer to the negative Y and positive Y directions]

Symbol	Definition
SILL, GATE, BRAT	Latest values of sill depth, gate height, and effective width of the barrier from time varying input data.
FLOW	Flow condition at the barrier.
QUL and **QUR**	Discharges of water to the left and right of a U-barrier (in volume/second).
QVB and **QVT**	Discharges of water below and above a V-barrier (in volume/second).
RBAR	Concentration of energy at a V-barrier (if energy is not a constituent, **RBAR** is the concentration of the first constituent defined).
RBARP	Concentration of energy at a U-barrier (if energy is not a constituent, **RBARP** is the concentration of the first constituent defined).
SEGP and **SEG**	Water levels at the barrier now and at the previous **HALFDT**. (**SEGP** indicates "Plus **HALFDT**".)
SEP(M-1) and **SEP(M+1)**	Water levels now at points to the left and right of a U barrier.
SEP(N-1) and **SEP(N+1)**	Water levels now at points below and above a V barrier.
UP(M-1) and **UP(M)**	U-velocities now between a U-barrier and points to the left and right.
V(N-1) and **V(N)**	V-velocities now between a V-barrier and points below and above it.

- If the file unit *NUWLTR* does not equal *NUPRIN*, Type D output is contained in the "*.wlt" output file; otherwise, it is part of the Type A output.
- If *LSEPAR* = 0, Types A and B output are intermixed in the "*.prt" file.
- If *LSEPAR* = 1, Type A output is in the "*.prt" output file and Type B output in the "*.log" output file.

Error, Warning, and Run Messages

FORTRAN and computer system error or warning messages are displayed when necessary (for example, data set not defined, computed numbers out of range, and so forth). Example error and warning messages issued by SWIFT2D are given below. An "xxxxx" character string in an example message indicates that an integer value is printed in the field. An "xxxx.xx" string with a decimal place in a message indicates that a floating-point value is printed in the field. Similarly, an "AAAAA" character string indicates that a character string is printed.

Override Messages

Messages are printed if Part 1 variables are overridden. An error condition prevents SWIFT2D from continuing if *GOVER* = 0.0, and the user must correct the override record as appropriate. Warning messages should be examined to verify that the override is correct. The following are examples of override messages:

*** ERROR--"ICOFMT" MAY NOT BE CHANGED FROM xxxxxxxx TO xxxxxxxx ***

*** WARNING--"SEINV" IS CHANGED FROM xxxxx.xx TO xxxxx.xx ***

*** "ABSF" IS CHANGED FROM xxxxx.xx TO xxxxx.xx ***

*** ARRAY "HTITL" IS CHANGED FROM: AAAAAAAAAAAAAAAA TO: AAAAAAAAAAAAAAAA ***

*** ERROR--INPUT TIME "TITIDE"=xxxxxx.xxxxx IS NOT A MULTIPLE OF THE TIME STEP LENGTH OF xxxxx.xxxxx MINUTES ***

*** ERROR--INPUT TIME "TITIDE"=xxxxxx.xxxxx IS NOT A WHOLE NUMBER OF MINUTES ***

*** WARNING--INPUT TIME "TSTART", GIVEN AS xxxxx.xxxxx IS CHANGED TO xxxxx.xxxxx, WHICH EQUALS xxxxx TIMESTEPS ***

Dimension Messages

Among other messages that might be printed at SWIFT2D initialization are those caused by a difference between the generated IDPDIM.CMN dimensioning parameters and the dimensioning data from the SIMINP file (note, an error condition prevents SWIFT2D from continuing). The most likely causes for these error conditions are using a SWIFT2D executable compiled with an IDPDIM.CMN file generated for a different model or simulation or specifying an incorrect SIMINP file name. Each IDPDIM.CMN file contains internal identification information based on the *RUNID, TITL*, and *HTITL* taken from the SWIFT_IDP input file. Note that each time the IDPDIM.CMN file is altered a new SWIFT2D executable must be generated. Warning messages should be examined carefully to detect any differences between the generated IDPDIM.CMN dimensioning parameters and the dimensioning data from the SIMINP file. The following are examples of conflicting dimensioning messages:

*** ERROR--NOTI = xxxxxxxxx IN COMMON, BUT = xxxxxxxxx IN DATA--1+ TITLES, PERMANENT PLUS TEMPORARY ***

*** WARNING--NOWLD = xxxxxxxxx IN COMMON, BUT = xxxxxxxxx IN DATA--WATER LEVEL STATIONS (SEE NOWL IN PART 1) ***

Restart Messages

The following messages pertain to the use of the Restart file. The first seven are for informational purposes and usually can be ignored. The eighth message shows that the designated restart time is beyond the last time available on the file, in which case the restart data for the last time in the file are used to begin the simulation. The last three messages are error messages usually indicating that the wrong Restart file has been designated.

COUNTS FROM RESTART=(15 six digit integers)

DIMENSIONS FROM RESTART=(13 six digit integers) TRST=(NTAPE)=xxxxxx.x TIERST= (NRDA)=xxxx.x RESTART IF TRST AND TIERST ARE NOT BOTH ZERO

****** RESTART FILE IS VRFLR, FLTYR= xx.xx, AAAA IT SHOULD BE xx.xx, AAAA

PREVIOUS RESTART AT:xxxxxxx HALFDT= xxx.xxxx DATE= xx/xx/xx xx:xx:xx (VRFLIN,FLTYIN)= (xx.xx,AAAA)

(13 six-digit integers)

RESTART DATA WILL BE READ. TIME xxxxx.xx MINUTES FOUND ON RESTART FILE. STEP xxxxxxx

RESTART DATA SUCCESSFULLY READ. RESTART AT TIME xxxxx.xx MINUTES. STEP NOW (WITH INPUT HALFDT)= xxxxxxx

* SWIFT2D RESTART FILE WRITTEN AT xxxxx.xx MINUTES (STEP xxxxxx)

****

RESTART FILE REWOUND. BEWARE.

RESTART WILL BE AT xxxxx.xx MINUTES, xxxxxxx STEPS

****

DIMENSIONS WRONG ON RESTART FILE.

**RESTART FILE INCORRECT. PROBABLY WRONG VERSION

***** ERROR ON RESTART FILE *****

Emergency Restart Messages

The following messages pertain to the Emergency Restart files and are separated from the previous restart messages because the emergency restart capability is not frequently used:

EMERGENCY RESTART TIMES: NST(TIMR41)= xxxxxx(xxxxx.xx MIN), NTT(TIMR42)= xxxxxx(xxxxx.xx MIN) OLD HALFDT= xxx.xxxx

PERMANENT RESTART READ AT TIME xxxxx.xx TO POSITION FOR CONTINUATION AT EMERGENCY RESTART

PERMANENT RESTART FILE WILL BE CONTINUED FOLLOWING TIME xxxxx.xx

* EMERGENCY RESTART WRITTEN AT STEP xxxxxx (xxxxx.xx MIN)

END OF FILE OR ERROR ENCOUNTERED WHILE ATTEMPTING TO POSITION PERMANENT RESTART FILE FOR EMERGENCY RESTART AT

TIME xxxxx.xx. PERMANENT RESTART FILE WILL BE REWRITTEN.

History File Messages

The following messages pertain to a continuation of the History file at restart (*NHST*=1). The first two messages provide general information and are followed by three error messages usually indicating that the wrong Restart file has been designated.

HISTORY FILE BEING CONTINUED FROM xxxxxxx.xx MINUTES (STEP xxxxxxx)

HISTORY FILE HAS NO PREVIOUS DATA -- INITIALIZE

HISTORY FILE VERSION IS xx.xx NOT GREATER THAN OR EQUAL TO xx.xx -- CANNOT CONTINUE

TIHIST ON HISTORY FILE= xxx.xxxx, NOT EQUAL TO xxx.xxxx CANNOT CONTINUE

RUN TERMINATING. HISTORY FILE DOES NOT HAVE STEP xxxxxxx -- LAST STEP ON HISTORY IS xxxxxxx

Run Messages

The following messages provide a simulation history and can be ignored unless an unexplained failure occurs.

FLAGS I1 THRU I13 ARE ONE IF THE TASK CONTROLLED BY THE FLAG IS SCHEDULED FOR THE GIVEN TIME.

I1 THRU I13 CONTROL: 1-CONST. PLOT; 2-VEL. PLOT; 3-MT. PLOT; 4-WL. PLOT; 5- FLOODING; 6-TIMSMO; 7-PRINT; 8-CVAL; 9-HEAT; 10-EMER. REST; 11-MAP FILE; 12-PERM. REST; 13-PARTICLE PRINT

TIME xxxxx.xx: I1 THRU I13= x x x x x x x x x x x x x

TIME SMOOTHING DELAYED AT TIME xxxxx.xx MINUTES

TIME SMOOTHING APPLIED AT TIME xxxxx.xx MINUTES (STEP xxxxxx)

**BEGIN FIRST HALF OS STEP xxxxxx (xxxxx.xx MIN) HOUR=xxxxx DATE=xxx AAAA 'xx WIND(SP,ANG)=(xxx.xxxx,xxx.xxxx)

BEGIN SECOND HALF OF STEP xxxxxx (xxxxx.xx MIN) WIND(SP,ANG)= (xxx.xxxx,xxx.xxxx)

*TIME-VARYING DATA READ. VALUES WILL BE EFFECTIVE AT TIME xxxxxxxxxx.xxx MIN: NF=xxx ND= xxx NS=xxx LTITL=xxx

WIND, WINDA= xxxxxx.xxx xxxxxx.xxx HEAT(Q)= xxxxxx.xxx xxxxxx.xxx xxxxxx.xxx xxxxxx.xxx

TIDE AND CONC. AT END X OF OPENING xx= xxxxx.xxxx x.xxxxE xx xxxxE xx x.xxxxE xx x.xxxxE xx xxxxE xx x.xxxxE xx

x.xxxxE xx

FLOOD IN FLO AT NST=xxxxx M=xxx N=xxx SES= xx.xxxx

DRY IN FLO AT NST=xxxxx M=xxx N=xxx SES= xx.xxxx

DRY IN CVAL AT NST=xxxxx M=xxx N=xxx SES= xx.xxxx SET=xx.xxxx

POINT (N,M) = (xxx,xxx) HAS BECOME DRY IN CALCULATION OF U AND W. L. -- SEN,SE,SEP = xxxxx.xxx xxxxx.xxx xxxxx.xxx

POINT (N,M) = (xxx,xxx) HAS BECOME DRY IN CALCULATION OF V AND W. L. -- SEN,SE,SEP = xxxxx.xxx xxxxx.xxx xxxxx.xxx

Data Messages

The following warning and error messages usually indicate that some conditions (probably initial depths) are not suitable for the model:

*** WARNING: POINT DRY NEXT TO VELOCITY OPENING. N,M= xxx xxx VELOCITY= xxxxx.xx

**C=0,STEMP NOT ZERO AT SECTION xxxxx N,M= xxxx xxxx

These messages indicate fatal errors that terminate the simulation run. Examine the input carefully, correct it, and rerun SWIFT_IDP:

DRY POINT IN SEPU NEXT TO BARRIER NO. xxxx (N,M)= xxx xxx

DRY POINT IN SEPV NEXT TO BARRIER NO. xxxx (N,M)= xxx xxx

The following warning and error messages are caused by requesting a stop time beyond the last time of time-varying input. If the second message occurs, the user must either change *TSTOP* or rerun SWIFT_IDP with sufficient time-varying data:

END OF DATA ON SIMINP AT NST=xxxxx. RUN WILL CONTINUE FOR xxx HALFDT

END OF FILE OR TOO FAR PAST END OF DATA ON SIMINP

The following messages pertain to disordered data in Part 2; typically, they should never occur because SWIFT_IDP provides ordered data.

*** FATAL ERROR: TIME-VARYING DATA OUT OF ORDER. RECORD TYPE xx IS WRONG. RUN TERMINATING.

RECORDS OUT OF ORDER

OPEN BOUNDARY DEFINITION RECORDS OUT OF ORDER

POLLUTANT NAMES OUT OF ORDER

Final Messages

The following message is printed when a run fails:
*** CANNOT CONTINUE ***

The following message is displayed when the simulation is completed:

SWIFT2D COMPLETED AT xx/xx/xx XX:XX:xx FOR AAAAAAAAAAAAAAAA LAST TIME IS xxxxxxx.xx MINUTES (STEP xxxxx) WITH xxxxxx ERRORS, xxxxxx WARNINGS, xxxxxx PLOTS

History File

A History file (SIMHST) is an optional sequential binary file written by giving the time-interval variable, *TIHIST*, a value greater than zero. The History file contains time series of simulation results at the specified time frequency at identified stations (grid cells) and (or) cross-section transects (grid row or column segments). The History file contains computed water levels, U- and V-directional velocity components, constituent concentrations, and (or) U- and V-components of mass, advective, diffusive, and total constituent transport. Values at selected points or stations (specified in Part 2 input) can be saved at intervals of *TIHIST* for postprocessing, such as creating graphical displays, reformatted sequential files, and (or) printouts. Time-history results can be written to an existing History file beginning at the specified Restart time *TRST*. If the append flag, *NHST*, is not zero, the SIMHST file is appended to the History file from the previous simulation. If *NHST* is zero, the SIMHST file is overwritten at restart. If the flag to write additional information, *NEXAN*, equals one, the History file also includes the following computations: (1) acceleration, advection, kinetic and potential energy, friction, gradient, and vorticity at velocity stations; and (2) kinetic and potential energy at U- and V-transport cross-sections. The advection term stored in the extended diagnostics output written to the History file (if *NEXAN* = 1) is computed using the Arakawa method (Arakawa, 1966) regardless of what method is used in the simulation (that is, it is not controlled by the value of *IADVEC*). *TIHIST* is specified on record 4 of Part 1 input; *NHST* and *NEXAN* are specified on record 6 of Part 1 input of Appendix 2.

Map File

The Map file (SIMMAP) is an optional sequential binary file containing snapshot grids of simulation results at a specified time frequency. The Map file contains computed water levels, U- and V-directional velocity components, Chezy coefficients, particle tracks, and constituent concentrations. Map file results can be used to produce graphs, extract histories, and plot particle paths or to print or reformat simulation output for generating computer animations. The Map file is written at intervals of *TIMAPF* beginning at time *TFMAPF* and ending at time *TLMAPF* only if the map option flag *MAPMOT* is 4, 5, 6, or 7. The SIMMAP file is overwritten if an emergency restart is performed. *TIMAPF* , *TFMAPF*, and *TLMAPF* are assigned on record 5 in Part 1 input of Appendix 2.

Coarse-Grid File

The Coarse-Grid file is written at intervals of *TICG* beginning at time *TFCG* and ending at time *TLCG*. The Coarse-Grid file can be used by postprocessing programs to obtain plots of transport, vorticity, and so forth. The Coarse-Grid file is overwritten if an emergency restart is performed. Useful in the past to reduce simulation run times, the Coarse-Grid file is seldom used.

Summary

A computer model for simulation of surface-water integrated flow and transport in two (horizontal-space) dimensions is documented. The finite-difference model solves vertically integrated forms of the equations of mass and momentum conservation and solute transport equations for heat, salt, and constituent fluxes. An equation of state for salt balance directly couples solution of the hydrodynamic and transport equations to account for the density gradient effects of salt concentrations on flow. The mathematical formulation and computational features of the model are identified and discussed to facilitate its application to well-mixed bodies of water. The types and format of input required by the model are explained and described in the context of defining the model configuration and setup, designing and preparing a numerical simulation, and executing the computer model and its supporting input data processor. The types and format of output produced by the model, which are user controlled, are identified to aid in the analysis of simulation results. The format of input computational control variables and data required to setup and execute the model are described in report Appendixes.

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Appendix 1. SWIFT2D IN-STREAM-INPUT RECORD FORMAT

Primary SWIFT2D input consists of the SIMulation INPut (SIMINP) file created by SWIFT_IDP according to specifications identified in Appendix 2 and an In-stream input file. The In-stream input file is an 80-character, ASCII text file that consists of a Computer-Identification record, a Program-Identification record, a File-Units record, Part 0 records, and optional Part 1 Override records. Part 0 records consist of operational parameters that control the appearance of printed output and user notes that describe the purpose of the simulation. Override records specify replacement values for Part 1 variables as given in the SIMINP file. The following table gives the format of records contained in the In-stream input file.

==

Variable Position Format   Default   Definition

==

<div align="center">

Computer-Identification record (one required per execution)
</div>

CMPUTR   1-4   A4   "IBM"   Name of the hardware platform used for the
                                           simulation, used for annotation purposes
                                           only.

<div align="center">

Program-Identification record (one required per execution)
</div>

DPGMID   1-8   A8   SW921021   Model code identification to distinguish
                                           between run id's for different code versions.
                                           Note, the default value will be updated as
                                           the code is updated, but will be of this
                                           form SWYRMODY.

<div align="center">

File-Units record (one required per execution)
</div>

Note: Fortran unit numbers for most files and data sets. This record may be used to override the default unit numbers as specified
in the BLSWIFT routine. In general, this record should be left blank. Unit numbers may range from 1 to 98. However, it is
recommended that units 1–6 not be used as many operating systems use these as standard input and output units. The
following units should not be used as they are used for other miscellaneous files: 13 (temporary print file), 16 (Luspan), 41
(emergency restart file 1), 42 (emergency restart file 2), 43 (run log), 65 (master file), 66 (printed output file), 70 (scratch
file), and 75 (default in-stream input file). Note, that NULOC through NUTIDE allow the user to split the SIMINP file into
functional data sets.

Variable	Position	Format	Default	Definition
NU1	1-3	I3	75	In-stream input file unit
NU2	4-6	I3	10	Simulation input (SIMINP) file unit
NUREST	7-9	I3	8	Restart input/output file unit
NUHIST	10-12	I3	9	History file output file unit
NUWPT	13-15	I3	14	Wind and Pressure data input file unit
NULOC	16-18	I3	10	Station Locations (data sets 1-7)
NUWP	19-21	I3	10	Wind and Temperatures (data set 8)
NUSLU	22-24	I3	10	Barrier or Sluice (data sets 9-11)
NUBND	25-27	I3	10	Tide Opening--BC (data sets 12-19)
NUPOL	28-30	I3	10	Constituents (data sets 20-25)
NUOUT	31-33	I3	10	Water-body outline (data set 26)
NUDEP	34-36	I3	10	Depth Values (data set 27)
NUDAT1	37-39	I3	10	Coefficient Input (data sets 28-35)
NUPOLD	40-42	I3	10	Initial Concentration (data set 36)
NUTIT	43-45	I3	10	Permanent Titles (data set 37)
NUCOMP	46-48	I3	10	Computation grid (data set 39)
NUTIDE	49-51	I3	10	Time-varying data (Part 3)
NUCG	52-54	I3	12	Coarse-Grid output file unit
NUMAP	55-57	I3	73	Map output file unit (no longer used)
NUMOT	58-60	I3	15	Map output file unit
NUPRTC	61-63	I3	13	Particle Locations output file unit
NUWLTR	64-66	I3	13	Water levels and currents output unit

==

Variable	Position	Format	Default	Definition

==

Part 0 records: Administrative Data

_____

Head record(s) (up to three per execution)

Variable	Position	Format	Default	Definition
FORM	1-72	A72	blanks	Text printed in page headings. It is recommended that these records specify the user's name and address.
DCDID	73-80	A8	blanks	Record identifier(annotation only).

_____

End-Head record (one required per execution)

Variable	Position	Format	Default	Definition
ENDHED	1-8	A8	blanks	This record marks the end or absence of the Head records and must have the value: "END HEAD"
DCDID	73-80	A8	blanks	Record identifier (annotation only).

_____

Print record (one required per execution)

The Print record should be coded according to the following example (note that variable names are given in the unused columns, they are not read.

```
PRINT LSEPA=1,LHDIV=0,LINP=60,NCO=133,LFICH=0,NOPLU=0,MCKOUT=00000000
```

Variable	Position	Format	Default	Definition
KEYWRD	1-8	A8	blanks	Should have the value: "PRINT".
LSEPAR	16	I1	0	Flag to separate run messages from requested print (0=no, 1=yes).
LHDIV	24	I1	0	Flag to print additional heading, including the heading text given above (0=no,1=yes).
LINP	31-32	I3	60	The number of lines to print per page(max=60).
NCOLP	38-40	I3	132	The number of columns per print line, including carriage control (max=133).
LFICHE	48	I1	0	Flag to write microfiche plot file (no longer used).
NOPLUS	56	I1	0	Not applicable to SWIFT2D.
MCKOUT	65-72	I8	1	Flag to allow special checkout print (no longer used).
DCDID	73-80	A8	blanks	Record identifier (annotation only).

_____

Note record(s) (as many as desired per execution)

Variable	Position	Format	Default	Definition
DNOTE	9-72	A64	blanks	Used to indicate the purpose of the run, thus distinguishing this run from other runs. Notes are written to the run log file and also printed
DCDID	73-80	A8	blanks	Record identifier (annotation only).

_____

End-Note record (one required per execution)

Variable	Position	Format	Default	Definition
ENDNOT	1-8	A8	blanks	This record marks the end or absence of the Note records and must have the value: "END NOTE"
DCDID	73-80	A8	blanks	Record identifier (annotation only).

==
Variable Position Format   Default   Definition
==

Override record(s) (up to 183 per execution)

| VARNAM | 1-6 | A6 | blanks | The variable name as shown in Table 10 of a scalar or array to override, i.e., to change its value from that specified in the SIMINP file. |

If VARNAM is a scalar variable:

VAL	10-17	F8.0	0.0	The new value if VARNAM is a floating-point scalar, otherwise it is ignored.
IVAL	19-26	I8	0	The new value if VARNAM is an integer scalar, otherwise it is ignored.
AVAL	30-33	A4	blanks	The new value if VARNAM is an alphanumeric scalar, otherwise it is ignored.
DCDID	73-80	A8	blanks	Record identifier for annotation purposes only.

Note: If VARNAM is an array, then its new values are given in one or more records following the Override record, in the same format as it is input to SWIFT_IDP except that the field of the array is leftmost on the record. The elements of arrays HX, HY, and HZ are overridden individually, as if they were scalars. For example, the first element of array HX is overridden using "HX(1)" as VARNAM with the new value given in the VAL field of that record.

End-Override record (one required per execution)

AKEYWD	1-8	A8	blanks	This record marks the end or absence of the Override records and must have the value: "END OVER".
GOVER	10-17	F8.0	0.0	Flag controlling error termination (0.0=do not continue if override errors, 1.0=continue even if override errors). It is recommended that GOVER always be specified as 0.0.
DCDID	73-80	A8	blanks	Record identifier (annotation only).

Appendix 2. SWIFT_IDP PROGRAM AND INPUT DESCRIPTION

SWIFT_IDP, the Input Data Processor program for SWIFT2D, is the creator of the SWIFT2D SIMulation INPut (SIMINP) file. SWIFT_IDP generates the IDPDIM.CMN Fortran include file used to set the dimensions of SWIFT2D arrays, performs consistency checks on input data, interprets the computational grid enclosures, combines the various time-varying input data into sequential order for concurrent use during the simulation, prints an Input Report describing the simulation setup, and writes the SIMINP file. The Input Report serves as a record of the simulation setup, as a visual check on the accuracy of input data, and as a guide to data insertion for subsequent simulations.

Limitations:

SWIFT_IDP has a number of limitations, which are identified below.

Zero Values

SWIFT_IDP does not check data input as zero, except for the following:

- CSET, IPLC, and IPLV cannot be zero.

- ERGC2 cannot be zero when LERG is non-zero for an energy constituent.

- Manning's N coefficients in Part 2 data cannot be zero.

- Time-varying concentrations at openings (CTOA and CTOB in record type C in Part 3) cannot be zero.

- TIERST must be zero, that is, the Emergency Restart capability is not fully functional.

Time Specifications

Time smoothing (set **TITSMO** on Times record B in Part 1) will be delayed until none of these conflicting activities occur at a time step:

- writing the Restart File (see TIRST on Times record A in Part 1)

- computing C-values (see TICVAL on Times record B, and note that computing C-values itself may be delayed)

- testing for flooding (see TIFLOD on Times record B)

- computing heat flux (see TIFLUX on Times record B)

- writing the Map file (see TIMAPF and TFMAPF on Times record B)

- writing the Emergency Restart Files (see TIERST on Times record B)

- printing computations (see TPRINT on the Print Times records)

- printing particle positions (see TIPARP on the Particle Parameters record in Part 1)

- drawing maps (see TIMAPC, TIMAPV, TIMAPM, and TIMAPL on Times record A)

However, time smoothing can coincide with writing the History file, printing history data, and writing Coarse-Grid data (see **TIHIST, TIHISP** on Times record A and **TICG** and **TFCG** on Times record B).

Time-varying water-level (e.g., tide) data, if given, must be input at a regular time interval (see **TITIDE** in Part 1), which is a whole number of minutes, and also a multiple of the time step **HALFDT***2. A simulation can span only the time period for which time-varying data are specified. Other time-varying input can be specified at any time interval within the time-span of time-varying water-level data.

Maximum Dimensions

- The maximum duration of a simulation is 999999 minutes (about 20 months); the maximum duration of time-varying input is 99 days. Code changes can be made to increase these values.

- The maximum number of constituents is 7 (see **LMAX** in Part 1); this is a limitation that easily can be increased by modifying the source code.

- There are limits of 99 sources and 99 barriers, as these values are read in as a two-digit fields in Part 3 input. This limitation can be increased by a minor code change.

Physical Characteristics

- Constituents designated as oxygen and biochemical oxygen demand (BOD) should be interactive, that is **LOX** and **BOD** should be no greater than **LRMX** in the Part 1 Constituents record.

- Discharge cannot be negative if constituents are computed.

- The computation of temperature in the reaction matrix is implemented for foot-pound units only; that is, if **LTEMP** in Part 1 is non-zero, then flag **MET** in Part 1 must be zero.

Grid Placement

- Open boundaries lie just outside the computational grid. Long open boundaries should be at the edge of the rectangular grid as well.

- Water-level stations can be inside the computational grid or on a water-level open boundary.

- The following must lie inside the computational grid: sources of discharge, constituent checkpoints, barriers or sluices, permanently dry points or dams (ineffective if outside).

- Sources must be at least 2 grid spaces in the U- and V-directions away from: 1) other sources, 2) dams, 3) barriers, 4) computational grid enclosures, and 5) points that dry and flood. However, sources can be diagonally adjacent to any of these.

- Barriers must be at least 2 grid spaces in the constricted direction away from: 1) sources, 2) dams, 3) other barriers, 4) computational grid enclosures, and 5) points that dry and flood. However, sources may be diagonally adjacent to the above. Also, U-barrier and V-barrier can be at the same grid point.

- Definition and arrangement of computational grid enclosures must follow a number of rules, so that an appropriate computational boundary outline can be determined. For details on these rules, refer to the **Computational Grid Enclosure** section and figures 7–9 in the body of the report.

Reminders

- **SEINV** in Part 1 or assumed zero velocity should correspond to **TLVL1** and **TLVL2** in record types A and B for time **TSTART**, for level and velocity time-varying openings, respectively.

- Initial values in Part 2 have no effect when **TSTART** is later than the first time-varying values in Part 3.

- When a simulation is being restarted and the time simulated will be longer, the user should recheck times and time intervals specified for printing and writing files. Also, flags **MAPMOT, NEXAN,** and **NHST** should be rechecked, and possibly other Part 1 variables.

- In Part 2, any record set not controlled by a dimension in Part 1 must end with a blank record (except for land-boundary outlines and particle group description).

- U- and V-barriers are separately sequentially numbered beginning with 1 in Part 2 and Part 3.

- There must be a constituent number record in front of each set of initial concentrations.

- Computational grid enclosures lie just outside the computational grid.

- All records in Part 3 must be given in order: first by record type; then by constituent number (for concentrations only) or U- or V-type (for barriers only); then by place number such as tide opening or outfall or barrier number, and lastly by time in day, hour, minute. Any sequence error in Part 3 causes SWIFT_IDP to discontinue processing.

- Although SWIFT_IDP prints zero errors and zero warnings indicating a valid SIMINP file has been created, the Input Report should be carefully reviewed and verified before running the simulation. It is best to eliminate warning messages by rerunning SWIFT_IDP, so that any pertinent new messages are not overlooked.

Input

SWIFT_IDP input specifications are similar to input specifications for SWIFT2D. SWIFT_IDP input consists of a Computer Identifications record and Parts 0 through 3 input, specified on 80-character data records. Part 0 gives administrative input, generally related to printout control in SWIFT_IDP and SWIFT2D. Part 1 gives program control parameters, for computation in SWIFT2D and output in both programs. Part 2 gives initial values, as well as, values related to geometry and locations where data are abstracted or inserted. Part 3 gives time-varying inputs to be used during the simulation, for example, time-varying tides at boundary openings.

The order in which inputs are given to SWIFT_IDP is not the order in which decisions have to be made when a model is being defined. First of all, the availability of tide data will often determine the number and length of tide openings, which along with actual land-water boundaries will determine the computational grid, which will determine the rectangular grid and its dimensions **MMAX** and **NMAX**. Most of the input in Part 0 and Part 1 can be changed after IDP is run. The SWIFT_IDP input is described in tabular form below. Most input records include a record identifier in columns 73–80. These are used as a means of identifying records quickly. For example, all Part 1 records could be labeled RECORD01 to RECORD27, but these label formats are optional.

```
===============================================================================
```
Variable Position Format   Default   Definition
```
===============================================================================
```
PART 0 RECORDS: ADMINISTRATIVE DATA

Part 0 is given separately to SWIFT_IDP and SWIFT2D

Computer-Identification record (one required per execution)

Variable	Position	Format	Default	Definition
CMPUTR	1-4	A4	"IBM"	Name of the hardware platform used for the simulation, used for annotation purposes only.

Head record(s) (up to three per execution)

Variable	Position	Format	Default	Definition
FORM	1-72	A72	blanks	Text printed in page headings. It is recommended that these records be used to specify the user's name and address.
DCDID	73-80	A8	blanks	Record identifier (annotation only).

End-Head record (one required per execution)

Variable	Position	Format	Default	Definition
ENDHED	1-8	A8	blanks	This record marks the end or absence of the Head records and must have the value: "END HEAD"
DCDID	73-80	A8	blanks	Record identifier (annotation only).

Print record (one required per execution)

The Print record should be coded according to the following example (note that variable names are given in the unused columns, they are not read).

```
PRINT    LSEPA=1,LHDIV=0,LINP=60,NCO=133,LFICH=0,NOPLU=0,MCKOUT=00000000
```

Variable	Position	Format	Default	Definition
KEYWRD	1-8	A8	blanks	Should have the value: "PRINT".
LSEPAR	16	I1	0	Flag to separate error, warning, and run messages from the requested print of simulation results (0=no, 1=yes).
LHDIV	24	I1	0	Flag to print additional heading, including the heading text given above (0=no, 1=yes).
LINP	31-32	I3	60	The number of lines to print per page (max=60).
NCOLP	38-40	I3	132	The number of columns per print line, including carriage control (max=133). This variable is not used as SWIFT_IDP prints results in a fixed format requiring as many as 132 columns.
LFICHE	48	I1	0	Flag to write microfiche plot file (no longer used).
NOPLUS	56	I1	0	Remove "+" carriage control from print (0=no, 1=yes--not recommended).
MCKOUT	65-72	I8	1	Flag to allow special checkout print, normally 0. 0=no checkout print, 3=DADI checkout print, 5=IGS-related checkout print, 7=Shared routine checkout print,11=each program's checkout print, 15=3 and 5, etc.
DCDID	73-80	A8	blanks	Record identifier (annotation only).

===
Variable	**Position**	**Format**	**Default**	**Definition**
===

Note record(s) (as many as desired per execution)

| DNOTE | 9-72 | A64 | blanks | Used to indicate the purpose of this run, thus distinguishing the run from other runs. The notes are written to the run log file and also printed |
| DCDID | 73-80 | A8 | blanks | Record identifier (annotation only). |

End-Note record (one required per execution)

| ENDNOT | 1-8 | A8 | blanks | This record marks the end or absence of the Note records and must have the value: "END NOTE". |
| DCDID | 73-80 | A8 | blanks | Record identifier (annotation only). |

==
Variable Position Format   Default   Definition
==

PART 1 RECORDS: CONTROL PARAMETERS

Part 1 consists of 26 or 27 records (27th record is optional)

_____

RECORD 1: Model Identification (one required per execution)

Variable	Position	Format	Default	Definition
MODID	1-8	A8	blanks	Model identification, that is used in the generation of run identifications. Normally, MODID does not contain a run number.
DCDID	73-80	A8	blanks	Record identifier (annotation only).

_____

RECORD 2: Run Title (one required per execution)

Variable	Position	Format	Default	Definition
TITL	1-72	A72	blanks	The full run title. This title appears in the Run Log file and is carried in the History and Map files.
DCDID	73-80	A8	blanks	Record identifier (annotation only).

_____

RECORD 3: Titles and Dates (one required per execution)

Variable	Position	Format	Default	Definition
HTITL	1-16	A16	blanks	The title for displays. This is generally the name of the geographical area being modeled. This title is also written on the Run Log and printed.
ITDAY	17-18	I2	1	The simulation start day (1-31). This and the next three variables define the start of the simulation in the form "DDMMM 'YY" (for example, 01 JAN '93). All specified times, such as TSTART on Times Record A, are specified as elapsed minutes from midnight of the simulation start date. The simulation date is printed and displayed in the form YY/MM/DD (for example, 93/01/01).
ITDATE(1)	19-22	A4	" JAN"	The simulation start month abbreviation ("JAN", "FEB", "MAR", "APR", "MAY", "JUN", "JUL", "AUG", "SEP", "OCT","NOV", "DEC")
ITDATE(2)	23-24	A2	" '"	The string " '" (space and apostrophe).
ITYR	25-26	I2	0	The simulation start year in the century (0-99)
DCDID	73-80	A8	blanks	Record identifier (annotation only).

_____

RECORD 4: Times A (one required per execution)

Note: This and the next record specify times and time intervals for computations and output for SWIFT2D. All times are specified in minutes. Times are given as the elapsed time from midnight of the simulation begin date (specified on record 3 above). All times must be multiples of HALFDT*2. Therefore, all times except TITIDE will be set to the nearest multiple of HALFDT*2 that is greater than zero, if a non-zero value was given.

==
Variable Position Format   Default   Definition
==

HALFDT   1-6   E6.0   0.5   The half time step duration. Each of the multi-
                                      operation steps is advanced forward every HALFDT
                                      minutes. Thus, the same type of operation occurs
                                      at steps HALFDT*2 minutes apart.

Limitation: HALFDT can have 3 decimal places, or 4 if the last digit is 5, for example, HALFDT= 0.3125.

TITIDE   7-12   E6.0   15.0   The time interval to read time-varying data
                                      in Part 3. Time-varying tide levels or velocities
                                      are read at every TITIDE number of simulated
                                      minutes, starting just after TSTART (or after
                                      TRST, if TRST is greater than zero). Other time-
                                      varying data may be read at any of the same
                                      times, but not necessarily at every interval.
                                      Time-varying tide may begin earlier than TSTART
                                      (or TRST), however the other time-varying data
                                      may not begin earlier than time-varying tide
                                      begins.

Limitation: TITIDE must be an exact multiple of HALFDT*2, and it also must be an integer number of minutes.

TSTART   13-18 E6.0   0.0   The time to start the simulation. TSTART is
                                      chosen based on the availability of input data,
                                      particularly of time-varying tide in Part 3 and
                                      of the hydrodynamics of the model system. SWIFT2D
                                      is started with the same water level and velocity
                                      equal zero for the entire computational grid. For
                                      small model areas, TSTART should be chosen near
                                      high or low-water slack. For large model areas,
                                      this may not be advisable as long duration
                                      oscillations may be generated.

Limitation: TSTART may be no earlier than the first time of time-varying tide minus TITIDE, if the number of time-varying
           openings, NTOT, is greater than zero.

TRST   19-24 E6.0   0.0   The time to restart the simulation. The
                                      simulation will restart at the first time
                                      available on the Restart File that is equal to or
                                      greater than TRST (see TIRST below). If all
                                      available times on the Restart File are earlier
                                      than TRST, the last time available is used. A
                                      value of zero implies that no restart is being
                                      made. If TRST is non-zero, then special care
                                      should be taken in changing any other data since
                                      the previous simulation run was made. Most
                                      important are the dimensions MMAX and NMAX and
                                      the number of constituents LMAX which can not
                                      change (see Data Array Dimensions Record A).

Note: It is a good practice to test a new model by making a short simulation run, and then use the restart facility to start a long
        simulation if the results of the short run were successful. Restarting may also be used to make comparative simulations
        using different inputs.

===
Variable Position Format   Default   Definition
===
```
TSTOP      25-30  E6.0    0.0          The time to stop the simulation.
```

Limitation: The maximum value of time to stop is 999999 minutes, however, the maximum time of time-varying input is 99 days (142560 minutes). TSTOP may be no greater than the last time of time-varying tide if the number of time-varying openings, NTOT, is greater than zero.

```
TIRST      31-36  E6.0    0.0          The time interval to write to the Restart
                                       file. In addition to this interval, the Restart
                                       File is written at the time the simulation
                                       terminates successfully at TSTOP, except as noted
                                       below. If TIRST is zero, the Restart File is not
                                       written to. If TIRST is greater than TSTOP, the
                                       Restart file is written once, at TSTOP
```

Note: In successive runs, the simulation can be restarted at any time when the Restart file was written. The Restart file can also be used as a protection against computer failure during a long simulation, although the Emergency Restart files could be used for this purpose. A long interval TIRST should be used to conserve disk space, as all computational arrays are written to the Restart file.

```
TIHISP     37-42  E6.0    0.0          The time interval to print computations for water
                                       level, current, and transport at stations chosen
                                       for the output of history data. These stations
                                       are defined at the beginning of Part 2. Also,
                                       computations at barriers or sluices are printed.
TIHIST     43-48  E6.0    0.0          The time interval at which to write computation
                                       results for water level, current, and transport
                                       at specified stations, barriers or sluices,
                                       weighted values of constituents, and other
                                       optional computations to the History file. (See
                                       also the flags NEXAN and NHST, on the Flags
                                       record, below.)
TIMAPC     49-54  E6.0    0.0          The time interval to draw maps for constituent
                                       concentration (not used).
TIMAPV     55-60  E6.0    0.0          The time interval to draw maps for velocity (not
                                       used).
TIMAPM     61-66  E6.0    0.0          The time interval to draw maps for mass transport
                                       (not used).
TIMAPL     67-72  E6.0    0.0          The time interval to draw maps for water levels
                                       (not used).
DCDID      73-80  A8      blanks       Record identifier (annotation only).
```

RECORD 5: Times B (one required per execution)

```
TICG       1-6    E6.0    0.0          The time interval to write a Coarse-Grid file.
TFCG       7-12   E6.0    0.0          The first time to write to the Coarse-Grid file.
TLCG       13-18  E6.0    0.0          The last time to write to the Coarse-Grid file.
TITSMO     19-24  E6.0    0.0          The time interval for time smoothing, used to
                                       obtain more stable computations.
```

Note: If only minor changes in the boundary occur, the value of TITSMO can be large. This value has to be determined by experimentations. (See the **Time Smoothing** section in the body of the report for a description of the time smoothing process.)

===
Variable	Position	Format	Default	Definition
===
| TICVAL | 25-30 | E6.0 | 0.0 | The time interval at which to compute Chezy values from given Manning's n values. |

Note: When a large tidal range exists, this interval should be smaller than for simulations with a very small variation in tide level; typically Chezy values have been recomputed every 15 to 20 minutes of simulated time. This computation is rather time consuming, because it involves fractional exponents. Limitation: TICVAL and TIFLOD next should not be multiples of each other. When their requests coincide, computing Chezy values will be delayed.

Variable	Position	Format	Default	Definition
TIFLOD	31-36	E6.0	0.0	The time interval to check for flooding and drying at all points in the computational grid. (See also VAR, the marginal depth in tidal flats, on the Physical Characteristics record).
TIFLUX	37-42	E6.0	0.0	The time interval to compute heat flux.
TLFSMO	43-48	E6.0	0.0	The last time for interpolation from initial values at open boundaries driven by Fourier or harmonic functions. That is, during the initial period TLFSMO, the initial water levels and velocities, and the Fourier-generated levels or velocities are interpolated to obtain a "smooth start-up" of the simulation.
TIMAPF	49-54	E6.0	0.0	The time interval to write to the Map file.

Note: The Map file can be used to display the standard simulation maps after the simulation has been run.

Variable	Position	Format	Default	Definition
TFMAPF	55-60	E6.0	0.0	The first time to write to the Map file.
TLMAPF	61-66	E6.0	0.0	The last time to write to the Map file.
TIERST	67-72	E6.0	0.0	The time interval to write the Emergency Restart files. If TIERST is non-zero, then the two files must pre-exist.

Note: The Emergency Restart files retain only the latest data written for restart. In case of a computer failure during a simulation, SWIFT2D can be restarted. However, it is recommended that the Restart File be used for all restarts. This functionality is not fully implemented, therefore, TIERST should always be zero.

Variable	Position	Format	Default	Definition
DCDID	73-80	A8	blanks	Record identifier (annotation only).

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RECORD 6: Flags (one required per execution)

Variable	Position	Format	Default	Definition
NEXAN	1-6	I6	0	Flag to write to the History file additional computations (acceleration, advection, kinetic and potential energy, friction, gradient and vorticity) at current stations and the energies also computed at transport cross-sections (0=no, 1=yes).
NHST	7-12	I6	0	Flag to append to existing History file on restart (0=no, 1=yes).

Note: The advantage of turning this flag on is to create continuous history of results. However, the History file header (Title, Runid, and Simulation Date) is not updated, thus, all labeling information comes from the first simulation, which may be misleading.

===
Variable	Position	Format	Default	Definition

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Variable	Position	Format	Default	Definition
NOLAN	13-18	I6	0	Land boundary option. (0=read the land boundary outlines in SWIFT_IDP and write them to the SIMINP file, 1=read the outlines but do not write them in the SIMINP file. 2=the outlines are not present). See also NPRLAN, on the Input Print-Flags record, below.
MET	19-24	I6	0	Units flag (0=English, 1=metric). This flag applies to both input and output data. Velocities are computed as either feet per second or meters per second.
ISVWP	25-30	I6	0	Flag to input space-varying wind and pressure-gradient in Part 4 (0=no,1=yes).
ICORR	31-36	I6	0	Integration method option used in the simulation (0-6).

    0 = no integration correction (prediction only)

    1 = correct the velocity in the advection terms using the predicted value

    2 = correct the velocity in the advection terms using the average of the previous and predicted values

    3 = correct the velocity in the advection terms at every other time step, using the predicted value

    4 = correct the velocity in the advection terms and water level in the continuity equation, using the predicted value

    5 = correct the velocity in the advection terms using the average of the previous and predicted values, and correct the water level in the continuity equation using the predicted value only

    6 = correct the velocity and water level at every other time step, using the predicted value

Variable	Position	Format	Default	Definition
NCORR	37-42	I6	0	The number of corrective iterations to make in the chosen integration correction method (ICORR) above. Ordinarily, a value of 1 is adequate. Increasing this value will greatly increase execution time.
MAPMOT	43-48	I6	0	Map output option. (0=no map, 1=draw map during simulation--not available, 2=write a Map file in alternate format--not available, 3=1 and 2, 4=write Map file, 5=1 & 4, 6=2 & 4, and 7=1 & 2 & 4.)

Note: This flag overrides the times TIMAPC, TIMAPV, TIMAPM, TIMAPL and TIMAPF, TFMAPF, TLMAPF on Times records A and B above. For example, TIMAPC is the time interval to write to the Map file only if MAPMOT >3.

Variable	Position	Format	Default	Definition
IDKFMT	49-54	I6	0	Depth and initial constituent concentrations values format flag (0=old format 16F4.1, 1=new format 10E6.1)

Note: The old format allows 16 values per record versus 10. The new format is more flexible, allowing two more places of accuracy, and allowing an exponent for constituent concentrations.

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Variable	Position	Format	Default	Definition
ICOFMT	55-60	I6	0	Viscosity, diffusion, Manning's n, and benthic demand values format flag (0=old formats--F5.0 for the default coefficient and 3I5, 10F5.0 for the override coefficients, 10 per record; 1=new format--E8.0 for the default coefficient and 3I5, 7E8.0 for the override coefficients, 7 per record.)
IADVEC	61-66	I6	0	Advection option (0=Arakawa 1966 method; 1=Leendertse 1970 method, 2=None, no advection term)
IPAR	67-72	I6	0	Particle movement input flag (0=no,1=yes). Only if IPAR is non-zero are the particle movement input records given at the end of Part 1 (record 27) and near the end of Part 2.
DCDID	73-80	A8	blanks	Record identifier (annotation only).

RECORD 7: Input Print-Flags (one required per execution)

Note: The purpose of this and the next record is to reduce the volume of print, especially where that print will be redundant in SWIFT_IDP and SWIFT2D or repetitive in successive runs of both programs. However, some care needs to be taken that the print is not lost entirely, if a record of the input defining a model is to be kept for the future. All of the flags on this and record 8 have the same codes and meanings, as follows:

0 = print the pertinent input in IDP'S Listing of All Input records in SWIFT_IDP's Input Report and in the SWIFT2D print;

1 = omit in SWIFT_IDP listing of all Input records,

2 = omit in SWIFT_IDP Input report;

3 = 1 + 2 (print only in the SWIFT2D print);

4 = omit in the SWIFT2D print;

5 = 1 + 4 (print only in SWIFT_IDP Input report);

6 = 2 + 4 (print only in IDP's Listing of All Input Records);

7 = 1 + 2 + 4 (do not print this input at all)

Variable	Position	Format	Default	Definition
NPRLAN	1-6	I6	0	The input print flag for the land boundary outlines (See also NOLAN on the Flags record, above.)
NPRDEP	7-12	I6	0	The input print flag for depth values.

Note: If these are likely to be changed, then their print should not be suppressed in the listing of all input records, because it is the only accurate reflection of the actual values read.

NPRVIS	13-18	I6	0	The input print flag for viscosity coefficient overrides and the resulting viscosity throughout the computational grid.
NPRDIF	19-24	I6	0	The input print flag for diffusion coefficient overrides and the resulting diffusion throughout the computational grid.
NPRMAN	25-30	I6	0	The input print flag for Manning's n overrides and the resulting Manning's n throughout the computational grid. (Also, the SWIFT2D print includes the initial Chezy values computed from Manning's n; see NPRC in the Output Print-Flags record, below).

===
Variable	Position	Format	Default	Definition

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| NPRBEN | 31-36 | I6 | 0 | The input print flag for Benthic demand overrides and the resulting Benthic demand throughout the computational grid. |
| DCDID | 73-80 | A8 | blanks | Record identifier (annotation only). |

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RECORD 8: Input Print-Flags (one required per execution)

Note: The code values for these flags are the same as in the previous record.

| NPRCON | 1-42 | 7I6 | 0 | Array of input print flags for initial constituent concentration throughout the computational grid. Entries 1-7 correspond to constituents 1-7. The printing only applies to constituents that initial constituent concentrations were specified (near end of Part 2). |
| DCDID | 73-80 | A8 | blanks | Record identifier (annotation only). |

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RECORD 9: Output Print-Flags (one required per execution)

Note: In this and the next record, all defined code values are the same (0=no, 1=yes--print the pertinent output (computational results) in SWIFT2D at times indicated in the array TPRINT (See the Print Times records below.).

NPRSE	1-6	I6	0	The output print flag for water levels and the residual water level on tidal flats. At wet points, the water level is printed for the previous half time step; at dry points the residual water is printed, preceded by a "P" or "N" for positive or negative.
NPRSEP	7-12	I6	0	The output print flag for water levels. At all points, the water level value is printed for the latest time step. At dry points, the value is zero.
NPRVCU	13-18	I6	0	The output print flag for U-velocity components.
NPRVCV	19-24	I6	0	The output print flag for V-velocity components.
NPRVML	25-30	I6	0	The output print flag for velocity magnitude, computed at water level grid points. This computation is not made unless the print is requested.
NPRVMD	31-36	I6	0	The output print flag for velocity magnitude at depth points. This computation is not made unless the print is requested.
NPRVMU	37-42	I6	0	The output print flag for velocity magnitude at U-velocity grid points. This computation is not made unless the print is requested.
NPRVMV	43-48	I6	0	The output print flag for velocity magnitude at V-velocity grid points. This computation is not made unless the print is requested.
NPRC	49-54	I6	0	The output print flags for Chezy values. (Separately controlled by input print flag NPRMAN above is the print of the initial Chezy values determined from the given Manning's n values.)
DCDID	73-80	A8	blanks	Record identifier (annotation only).

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Variable	Position	Format	Default	Definition

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RECORD 10: Concentration Output Print Flags (one required per execution)

Note: The code values for these flags are the same as in record 9.

NPRR	1-42	7I6	0	An array of 7 output print flags for computed constituent concentration throughout the grid. Entries 1-7 correspond to constituents 1-7, such that print is produced only for those constituents that were defined in the input (see LMAX on Dimensions record A, below).
DCDID	73-80	A8	blanks	Record identifier (annotation only).

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RECORD 11-14: Print Times (four required per execution)

Note: All times are in minutes. Twelve values coded on the first 3 records and six on the fourth one.

TPRINT	1-72	12F6.0	0.0	An array of times to print computations.

Note: These computed values are selected by the output print flags on the previous two records, and might include constituent concentrations, water levels, velocities and Chezy values. As many as 42 print times may be selected. The times are given in ascending order, and the first zero value ends the effective list of times. However, all four records must be input.

Limitation: TPRINT times should not be multiples of TITSMO (see Times B record) because time smoothing delays by one time step the printing of computations.

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RECORD 15: Data Array Dimension A (one required per execution)

Note: In SWIFT2D, data arrays may vary in size, depending on the complexity of the model being run. Parameters on this and the next record indicate the size of the grid, the number of locations on the grid selected for the insertion or abstraction of data, and similar numbers related to the model setup.

MMAX	1-6	I6	0	The number of grid points in the U direction (see Space-staggered grid description in the body of the report).
NMAX	7-12	I6	0	The number of grid points in the V direction.
LMAX	13-18	I6	0	The number of constituents. LMAX can range from 0 to 7.
NOWL	19-24	I6	0	The number of water-level checkpoints.
NOCUR	25-30	I6	0	The number of current checkpoints.
NSRC	31-36	I6	0	The number of discharge sources.
KPOL	37-42	I6	0	The number of constituent checkpoints. KPOL may be zero, or it may be non-zero even though LMAX is zero, because constituent checkpoints are retained in Map files, and may be associated with computed values other than concentrations.
NTRA	43-48	I6	0	The number of transport cross sections in the U direction. This means where GRDANG (on the Physical Characteristics record) is zero, there are NTRA number of cross sections running north-south and NTRAV number running east-west.
NTRAV	49-54	I6	0	The number of transport cross section in the V direction.

==
Variable Position Format   Default   Definition
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Variable	Position	Format	Default	Definition
NTOT	55-60	I6	0	The number of tide openings or open boundaries where time-varying tide input will be given in Part 3 (see also TITIDE on the Times A record, above). NTOT may be zero; however, in that case, NTOF (given next) should not be zero.
NTOF	61-66	I6	0	The number of tide openings or open boundaries where Fourier functions of tide will be given in Part 2 (see also KC, next). NTOF may be zero, if so, then NTOT above should not also be zero; else there is no tide to drive the model.
KC	67-72	I6	0	The number of Fourier or harmonic components given for the Fourier-driven open boundaries. KC should be zero if NTOF above is zero, but not otherwise.
DCDID	73-80	A8	blanks	Record identifier (annotation only).

RECORD 16: Data Array Dimension B (one required per execution)

Variable	Position	Format	Default	Definition
NSLU	1-6	I6	0	The number of sluices or time-varying barriers in the U direction. The related sill depth, gate height and effective width of the barriers are given in Part 3.
NSLV	7-12	I6	0	The number of sluices or time-varying barriers in the V direction.

Note: The remaining variables on the record pertain to space-varying wind and air pressure gradient. There may be separately defined grids for wind and for air pressure gradient, and these will probably be coarser than the grid defined above by MMAX and NMAX.

Variable	Position	Format	Default	Definition
IWM	13-18	I6	0	The number of grid points in the U direction for the space-varying wind input grid. IWM should be zero if ISVWP=0 (see the Flags record, above).
JWM	19-24	I6	0	The number of grid points in the V direction for the space-varying wind input grid. JWM should be zero if ISVWP=0 (see the Flags record, above).
IPM	25-30	I6	0	The number of grid points in the U direction for the space-varying air-pressure gradient input grid. IPM should be zero if ISVWP=0.
JPM	31-36	I6	0	The number of grid points in the V direction for the space-varying air-pressure gradient input grid. JPM should be zero if ISVWP=0.
MWF	37-42	I6	0	The grid ratio for wind in the U direction. For example, MWF is the number of grid spaces per space-varying wind input grid space in the U direction, unused if ISVWP=0.
NWF	43-48	I6	0	The grid ratio for wind in the V direction, unused if ISVWP=0.
MPF	49-54	I6	0	The grid ratio for air pressure gradient in the U direction, unused if ISVWP=0.
NPF	55-60	I6	0	The grid ratio for air pressure gradient in the V direction, unused if ISVWP=0.
DCDID	73-80	A8	blanks	Record identifier (annotation only).

===
Variable	Position	Format	Default	Definition

===

RECORD 17: Constituents (one required per execution)

Variable	Position	Format	Default	Definition
AKTP	1-6	E6.0	0.0	The re-aeration coefficient for dissolved oxygen. This value overrides the constituent interaction rate for dissolved oxygen, within the array AKK given in Part 2 for constituent interaction rates.
SOX	7-12	E6.0	0.0	The saturation value for dissolved oxygen.
GAMM	13-18	E6.0	0.0	The weighting factor for concentration Smoothing

Note: Discontinuities may occur in the concentrations. This discontinuity may even be so large that negative values are present in the computational field. This occurs very rarely, but experience shows that it does occur. In such cases the isolines on constituent concentration maps would show many contours between two grid points. To prevent this, a smoothing operation is used upon the computational array before plotting (the actual data in the simulation is not smoothed, only the data to be plotted). GAMM is that fraction of the value for concentration at grid point n,m which is to be replaced by the average value of the surrounding points. Thus, for GAMM=0.4, 60 percent of the value at location n,m is used, plus 10 percent of the values for each of the 4 surrounding points. This smoothing operation is also applied to concentrations written on the History file. GAMM should be > 0.0 and < 1.0.

Variable	Position	Format	Default	Definition
LRMX	19-24	I6	0	The number of interactive constituents.

Note: LRMX should be less than or equal to LMAX, and may be zero. It is advisable to give the constituents which interact the lowest constituent numbers, then LRMX is as small as possible, so the computation is as fast as possible. LRMX should be equal to or greater than LOX and LBOD (see below).

Variable	Position	Format	Default	Definition
LOX	25-30	I6	0	The constituent number used for dissolved oxygen. If LOX=0, then none of the constituents are dissolved oxygen.

Limitation: LOX should be greater than LRMX, that is dissolved oxygen should be an interactive constituent.

Variable	Position	Format	Default	Definition
LTEMP	31-36	I6	0	The constituent number used for temperature. If LTEMP=0, temperature is not computed.

Limitation: LTEMP can be non-zero only if Part 1 flag MET is zero, (using English units).

Variable	Position	Format	Default	Definition
LBOD	37-42	I6	0	The constituent number used for Benthic oxygen demand. If LBOD=0, Benthic demand is not computed, if LOX also is zero.

Limitation: LBOD should be greater than LRMX, that is Benthic oxygen demand should be an interactive constituent.

Variable	Position	Format	Default	Definition
LCG	43-48	I6	0	The constituent number used for coarse grid computation (see TICG on Times record). LCG may be zero unless coarse grid data are being saved, or it may be the same number as LTERM, LBOD, LSAL, or LERG, or any other constituent.
LSAL	49-54	I6	0	The constituent number used for salinity when the salinity pressure gradient is included in the equation of motion. Thus, the use of LSAL not equal to zero couples the advective and diffusive transport computation to the hydrodynamic computation. To compute the pressure gradient from the salinity, an equation of state is used.
LERG	55-60	I6	0	The constituent number used for energy.
DCDID	73-80	A8	blanks	Record identifier (annotation only).

==
Variable Position Format   Default   Definition
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RECORD 18: Physical Characteristics (one required per execution)

ANGLAT   1-6   F6.0   0.0   The angle of latitude at the middle of the
                                      computational field, in degrees.
GRDANG   7-12   F6.0   0.0   The angle between the V direction and north, in
                                      degrees. For example, if the upward direction of
                                      V is west, then GRDANG is 90 degrees. In general,
                                      GRDANG is the angle from the upward direction
                                      rotating clockwise to the direction of the north
                                      direction arrow.
AL   13-18 F6.0   0.0   The distance between grid points, in feet
                                      or meters. (See MET on the Flags record) The
                                      total geographical area represented by the grid
                                      is MMAX*AL by NMAX*AL.
SEINV   19-24 F6.0   0.0   The initial water level throughout the
                                      grid at which the simulation is started. SEINV
                                      may be zero.

Note: This value must be closely correlated with the levels at tide openings (not necessarily TIDA and TIDB in the tide opening initial values in Part 2). These in turn must be well chosen considering the Fourier-computed amplitude at start time of any Fourier-driven openings (see record sets 14-16 in Part 2), as well as, the first time-varying levels used for any time-varying openings in Part 3(see TLVL1 and TLVL2 on the A and B records). Correlating all of these inputs is often a difficult task. It is recommended that the input tides be examined graphically, prior to their use in SWIFT2D.

DEPDEF   25-30 F6.0   0.0   The default depth value, interpreted as the
                                      negative of the value specified.

Note: If a depth value (given in Part 2) is zero, then that value is replaced by the negative of DEPDEF, so that the result is a point that is above high tide and always dry. DEPDEF is in feet or meters (see MET on FLAGS record), although the depth values are given in tenths of feet or in decimeters. DEPDEF should have a positive value, slightly greater than the difference between high tide and the reference level, because then the DEPDEF value has a limited effect in taking points out of the computation by means of the flooding routines. (The reference level is typically either mean sea level or mean low water, an implicit zero level from which other levels and depths are determined.)

VAR   31-36 F6.0   0.0   The marginal depth in tidal flats, in
                                      feet or meters.

Note: VAR should have a value at least twice the maximum rate of rise of the tide times TIFLOD*2.0*HALFDT (see Time A and B records). This will avoid repeated backtracking in the simulation through the grid when flooding and drying occur, and thereby avoid increased computation time. When the water level at a cross-section between two grid points becomes half the value of VAR, then the two points are taken out of the computation (see also CSET, below).

DCO   37-42 F6.0   0.0   DCO is a depth threshold, in feet or
                                      meters, under which the multiplier DML
                                      (next) is not applied. DCO and DML can be used to
                                      investigate the sensitivity of the computations
                                      to a small variation in depth.
DML   43-48 F6.0   0.0   Experimental multiplier for depths greater
                                      than DCO. The normal value for DML is one.

==

Variable	Position	Format	Default	Definition
SPA	49-54	F6.0	0.0	Weighting factor for surface smoothing, that is, smoothing of water levels only at times when time smoothing is done (see TITSMO in Times B record).

Note: SPA is a weighting factor similar to GAMM (on Constituents record); it is the fraction of the value at grid point n,m to replace by the average of values at surrounding points. SPA is surface filter and its use has influence on the computational results.

Variable	Position	Format	Default	Definition
VIVOR	55-60	F6.0	0.0	Vorticity-related viscosity factor.
CSET	61-66	F6.0	0.0	Chezy value, used where the depth is less than VAR, above. The intention is to use a small Chezy value for these shallow depths so that when the water becomes shallow the friction increases considerably, and thus the currents decrease.
CCOR	67-72	F6.0	0.0	Correction coefficient for Chezy values due to salinity gradient.
DCDID	73-80	A8	blanks	Record identifier (annotation only).

RECORD 19: Coefficients and Constants A (one required per execution)

See also Coefficients and Constants B record (record 26)

Variable	Position	Format	Default	Definition
AG	1-8	E8.0	0.0	Acceleration due to gravity, in feet per second squared, or meters per second squared (set MET on Flags record).
WSTR	9-16	E8.0	0.0	Wind stress coefficient
DAIR	17-24	E8.0	0.0	Air density.
DWAT	25-32	E8.0	0.0	Water density.

Note: WSTR, DAIR, and DWAT are the coefficients used in the computation of the force due to wind.

Variable	Position	Format	Default	Definition
WCONV	33-40	E8.0	0.0	Wind conversion factor. WCONV is a multiplier that will be applied to the input wind speeds to convert the data to units used in the simulation. For example, if wind speed is given in knots and the simulation is in metric units, set WCONV=0.5144. (see MET on Flags record).
CDCON	41-48	E8.0	0.0	Coefficient relating diffusion coefficients and Chezy values. It is used in the computation of the dispersion coefficient from the local velocity and Chezy.
PRES	49-56	E8.0	0.0	Atmospheric pressure, in millibars, used in temperature computations.
ABSF	57-64	E8.0	0.0	Absorption factor (emissivity), used in temperature computations.
CMASTR	65-72	E8.0	0.0	Mass transfer coefficient, used in temperature computations.
DCDID	73-80	A8	blanks	Record identifier (annotation only).

===
Variable Position Format   Default   Definition
===

RECORD 20: Displays - Plotter Specifications (one blank record required per execution)

Graphics are no longer supported during a simulation. All graphical operations should be performed in postprocessing operations. Data specified on records 20 through 24 are saved in the Map file and printed, otherwise they are not used. The 5 Display records (20-24) define the display arrangement of maps.

Variable	Position	Format	Default	Definition
PLOTER	1-4	A4	"FR80"	Plot device name.
IFILM	7-12	I6	35	Film size in millimeters.
CAMERA	13-16	A4	"UNSP"	UNSProcketed or SPROcketed camera flag, valid values are "UNSP" and "SPRO".
ROTCAM	25-30	F6.0	1.0	Camera rotation flag. (1.0=comic mode, 2.0=movie mode-rotated 90 degrees counter-clockwise from comic mod).
ROTGRI	31-36	F6.0	1.0	Grid rotation flag. (1.0=no rotation-V direction upward, 2.0=90 degree rotation counter-clockwise-U direction upward).
ISAVEG	37-42	I6	0	Flag to call FR80 graphics routines SAVEG and MERGEG.
DCDID	73-80	A8	blanks	Record identifier (annotation only).

RECORD 21: Displays - Title Block A (one blank record required per execution)

Graphics are no longer supported during a simulation.

Variable	Position	Format	Default	Definition
NCTITL	1.6	I6	32	The number of characters of TITL (on Run-Title record) to display on maps.
ISOCOL	7-12	I6	3	The number of columns of isoline values to display in the map legend.
FMTISO	13-18	F6.0	0.0	The code for the format of isoline values in the legend on maps (0.0=exponential format, e.g. -12.3 displayed as 0.123E-04, 1.0=scientific format, e.g.0.123x10-4.

Note: In general, the fractional part of FMTISO is the number of decimal places to display, and the integer part is the total number of character positions in which to display the isoline values. The minus sign indicates exponential format. If a positive number (greater than the code 1.0) were given, e.g., if FMTISO = 8.3, the resulting display would be floating point, like "1234.678". In general notation, a display format of the form -w.d corresponds to a Fortran format Ew.d, and a display format w.d corresponds to a Fortran format Fw.d.

Variable	Position	Format	Default	Definition
CLKRAD	19-24	F6.0	5	Radius of the clock in the map title block, in grid space units.
ARRLEN	25-30	F6.0	2*CLKRAD	Length of the North direction arrow in the map title block.
VECTW	31-36	F6.0	0.0	Number of units of wind speed corresponding to a vector as long as the width of a grid space unit, on displays.
PWUNIT	37-42	F6.0	blanks	Name of the wind speed unit to display. For example if MET=0, PWUNIT="MPH".

Note: If VECTW=10.0 and PWUNIT="MPH", then a wind speed of 10 mph would be represented by a vector as long as one M grid space unit.

Variable	Position	Format	Default	Definition
SIZISO	43-48	F6.0	0.75	Character size for displaying isoline sequence numbers within certain contours.

==

Variable	Position	Format	Default	Definition

==

| ISONUM | 49-54 | I6 | 0 | Interval of opportunities to use for displaying isoline sequence numbers within certain contours. |

Note: An "opportunity" is a grid space where the contour segment is long (where the segment would reach from left to right or from bottom to top). Larger values of ISONUM cause fewer numbers to be displayed. If ISONUM=0, then no numbers are displayed within contours.

| DCDID | 73-80 | A8 | blanks | Record identifier (annotation only). |

_____

RECORD 22: Displays - Title Block B (one blank record required per execution)

Graphics are no longer supported during a simulation. Assigns variables to specify the position on maps of, and the character size of, four sub-blocks of the title block. The HZ array gives the character size of the first line of sub-blocks where lines below these may be in correspondingly smaller character sizes. Only the first two, HX(1) and HY(1), must be given; all the other have defaults.

HX(1)	1-6	F6.0	0.0	Position of sub-block 1 (HTITL block) in terms of M grid units.
HY(1)	7-12	F6.0	0.0	Position of sub-block 1 (HTITLE block) in terms of N grid units.
HZ(1)	13-18	F6.0	1.5	Character size of the first line of sub-block 1.
HX(2)	19-24	F6.0	HX(1)	Position of sub-block 2 (legend block) in terms of M grid units.
HY(2)	25-30	F6.0	HX(1)	Position of sub-block 2 (legend block) in terms of N grid units.
HZ(2)	31-36	F6.0	1.0	Character size of the first line of sub-block 2.
HX(3)	37-42	F6.0	***	Position of sub-block 3 (clock block) in terms of M grid units. The default is to the right of and above sub-block 1.
HY(3)	43-48	F6.0	***	Position of sub-block 3 (clock block) in terms of N grid units. The default is to the right of and above sub-block 1.
HZ(3)	49-54	F6.0	0.75	Character size of sub-block 3.
HX(4)	55-60	F6.0	***	Position of sub-block 4 (north direction arrow and wind) in terms of M grid units of the center of the north direction arrow. The default is to the right of the clock block.
HX(4)	61-66	F6.0	***	Position of sub-block 4 (north direction arrow and wind) in terms of N grid units of the center of the north direction arrow. The default is to the right of the clock block.
HZ(4)	67-72	F6.0	0.75	Character size of sub-block 4.
DCDID	73-80	A8	blanks	Record identifier (annotation only).

_____

RECORD 23: Displays - Grid A (one blank record required per execution)

Graphs are no longer created during a simulation.

| DXPDY | 1-6 | F6.0 | 0.0 | The ratio of DX and DY, that is, the ratio between the width and height of a grid space on displays. Normally DXPDY=1.0, since the grid space represents a square in geographic space. |

===
Variable	**Position**	**Format**	**Default**	**Definition**

===
XLEFT	7-12	F6.0	0.0	Left-hand margin in terms of grid units.
YBOT	13-18	F6.0	0.0	Bottom margin in terms of grid units.
XRIGHT	19-24	F6.0	0.0	Right-hand margin in terms of grid units.
YTOP	25-30	F6.0	0.0	Top margin in terms of grid space units.
XDELT	31-36	F6.0	0.0	The X adjustment of position of all land boundary outlines, in grid units.
YDELT	37-42	F6.0	0.0	The Y adjustment of position of all land boundary outlines, in grid units.
VECWDR	43-48	F6.0	0.5	The normal line width of vectors on constituent concentration maps(maximum=1.0).
VECWDV	49-54	F6.0	0.5	The normal line width of vectors on all other maps (maximum=1.0).
DCDID	73-80	A8	blanks	Record identifier (annotation only).

RECORD 24: Displays - Grid B (one blank record required per execution)

Graphs are no longer created during a simulation

IPLC	1-6	I6	0	Interval of vectors on constituent maps. If IPLC=1, vectors are drawn at every grid point; if IPLC=2, vectors are drawn at every other grid point, etc. IPLC should not be zero.
IPLV	7-12	I6	0	Interval of vectors in all other maps. If IPLV=1, vectors are drawn at every grid point, as in IPLC. IPLV should not be zero.
IWLDP	13-18	I6	0	Flag for vectors on all maps (1=draw vectors at water-level grid points; 2=draw vectors at depth points; 3=draw vectors at both water level and depth points).
VECT	19-24	F6.0	0.0	Current speed (in units of feet per second or meters per second) to represent by a vector of length DX or the width of a grid space. VECT is similar in purpose to VECTW in Displays - Title Block A.
VECTM	25-30	F6.0	0.0	Transport per unit width. That is, VECTM is the number of units of transport to represent by a vector of length DX. VECTM is similar in purpose to VECT. The units of mass transport are cfs/foot or cms/meter.
ARRR	31-36	F6.0	0.0	Ratio of arrowhead to vector length in concentration maps. If negative, a full arrowhead is drawn, if positive, a half arrowhead is drawn.
ARRV	37-42	F6.0	0.0	Ratio of arrowhead to vector length in all other maps. If negative, a full arrowhead is drawn, if positive, a half arrowhead is drawn.
TANG	43-48	F6.0	0.0	Tangent of the angle of arrowheads to vectors.
DOR	49-54	F6.0	0.0	Flag for displaying dots at flooded grid points (0.0=no, 1.0=yes) on concentration maps.
DOV	55-60	F6.0	0.0	Flag for displaying dots at flooded grid points (0.0=no, 1.0=yes) on all other maps.

===

Variable	Position	Format	Default	Definition
MAPX	61-66	I6	0	Flag to omit display of checkpoint location and computed values. For concentration maps the computed values are concentration and water level, for mass-transport maps: mass transport and water level; for velocity and water-level maps: velocity magnitude and water level. (0=include checkpoint data, 1=omit).
MAPO	67-72	I6	0	Flag for omitting marker at outfall or sources locations on maps (0=no, 1=yes).
DCDID	73-80	A8	blanks	Record identifier (annotation only).

_____

RECORD 25: Coarse-Grid Parameters (one required per execution)

Variable	Position	Format	Default	Definition
LINX	1-6	I6	0	Number of grid spaces in the first coarse grid space on the left. LINX must be > 0.
LINY	7-12	I6	0	Number of grid spaces in the first coarse grid space on the right. LINY must be >0.
MCG	13-18	I6	0	Number of grid spaces per coarse grid space other than the first and last in the M direction. MCG must be > 0.
NCG	19-24	I6	0	Number of grid spaces per coarse grid space other than the first and last in the N direction. NCG must be > 0.
MCGM	25-30	I6	0	Number of coarse grid points in the M direction.
NCGM	31-36	I6	0	Number of coarse grid points in the N direction.

Note: The combination of LINX, MCG and MCGM determine the number of grid spaces in the rightmost grid space, which must be at least 1. Similarly, LINY, NCG and NCGM determine the number of fine grid spaces in the topmost grid space, which must be at least 1.

Variable	Position	Format	Default	Definition
DCDID	73-80	A8	blanks	Record identifier (annotation only).

_____

RECORD 26: Coefficients and Constants B (one required per execution)

See also the Coefficients and Constants A record (record 19).

Variable	Position	Format	Default	Definition
TEMPW	1-8	F8.0	0.0	Water temperature in the equation of state, in Fahrenheit or centigrade degrees.
RHOM	9-16	F8.0	0.0	Reference density used in the computation of the effect of the pressure gradient caused by the salinity (see LSAL on Constituents record, above). In other works, RHOM is the ambient density of the sea water surrounding the model. The normal density of water is 1.0.
ALPH0	17-24	F8.0	0.0	Constant in the equation of state.
ERGC1	25-32	F8.0	0.0	Fraction of energy height upstream of a barrier that is to be used in computation.
ERGC2	33-40	F8.0	0.0	Turbulent energy coefficient times the depth/length scale. ERGC2 may not be zero when LERG is non-zero, because it is a divisor in energy calculations.
ERGC3	41-48	F8.0	0.0	Energy coefficient 3 (not used).

===

Variable	Position	Format	Default	Definition
DCDID	73-80	A8	blanks	Record identifier (annotation only).

===

RECORD 27: Particle Parameters (one required if IPAR<0 of Flags record)

Variable	Position	Format	Default	Definition
INRAND	1-6	I6	0	Random number initializer for particle movement due to energy (0=use computer clock for randomness, other=initializing number for random numbers (the number will be set to the next highest odd integer).
TIPARP	7-12	F6.0	0.0	Time interval to print particle positions, in minutes. TIPARP should be a multiple of HALFDT*2.
PAR1	13-18	E6.0	0.0	Coefficient for random movement of particles due to energy in the same direction as the current.
PAR2	19-24	E6.0	0.0	Coefficient for random movement of particles due to energy in the direction normal to the current direction.
PAR3	25-30	E6.0	0.0	Coefficient 3 for random movement (not used).
DCDID	73-80	A8	blanks	Record identifier (annotation only).

==
Variable Position Format   Default   Definition
==
PART 2 RECORDS: INITIAL ARRAY DATA

   Part 2 input defines stations at which computations are saved in the History file, Fourier components of tide are assigned, and initial values in computational control arrays and constituents are specified. Part 2 consists of 38 or 39 (1 is optional) input record sets. All records in Part 2 must be given in order: first by record set; then by sequence number of the data type, for example 1, 2, 3,.NOCUR (number of current stations) within the record sets that have multiple records. Eight record sets consist of a single record. Five other record sets have a variable number of records, delimited by a blank record or 999999. The optional record set (Particle Group Description) is delimited by an "END PART" record. The other record sets have a number of records based on input dimensions defined in Part 1, such as number of tide openings, number of discharge sources, grid size (NMAX and MMAX), etc. Refer to Table 13 in the body of the report for a concise list of the 39 record sets of Part 2 input.

Stations and Cross-Sections (Record sets 1-6)

   Only outfalls or discharge sources are input stations; all other stations and cross-sections are locations at which computations are printed (see TIHISP), and saved on the History file for subsequent postprocessing (see TIHIST). Some of these stations (or checkpoints) will normally correspond to points for which field measurements are available, because model results can be directly compared to the field measurements for model calibration and verification.

   The constituent checkpoints may not lie on the computational grid boundary, because a spatial smoothing operation is performed before data are written to the History file. If the station were taken on the boundary, erroneous data would be introduced by the smoothing operation. The transport cross-sections may not include open boundaries, because no flow computations are made there. Other locations may lie on the computational grid boundary, but not normally outside of it. The recommended convention for naming stations and cross-sections is: "STATION AT XXXXX (n,m)", where XXXXX is the geographic location and n,m is the grid-point location.

RECORD SET 1: Water-Level Stations (NOWL number of records)

```
I          1-5    I5      0              Sequence number (1,2,3,...,NOWL)
MWL        6-10   I5      0              M grid-point location.
NWL        11-15  I5      0              N grid-point location.
```

Limitation: Water-level stations should be placed within the computational grid or on water-level open boundaries just outside the computational grid.

```
NAMWL      16-35  A20     blanks         Station name.
DCDID      73-80  A8      blanks         Record identifier (annotation only).
```

RECORD SET 2: Current Stations (NOCUR number of records)

   Current stations are selected grid points at which current magnitude is printed, and U- and V-components are saved on the History file. Also, saved (depending on the value of NEXAN in Part 1) are acceleration, advection, kinetic and potential energy, friction, gradient, and vorticity.

```
I          1-5    I5      0              Sequence number (1,2,3,...,NOCUR)
MC         6-10   I5      0              M grid-point location.
NC         11-15  I50     N grid-point location.
```

Limitation: Current is always zero outside the computational grid.

```
NAMC       16-35  A20     blanks         Station name.
DCDID      73-80  A8      blanks         Record identifier (annotation only).
```

RECORD SET 3: Discharge Sources (NSRC number of records)

```
I          1-5    I5      0              Sequence number (1,2,3,...,NSRC)
MINT       6-10   I5      0              M grid-point location.
```

===
Variable	**Position**	**Format**	**Default**	**Definition**

===
| NINT | 11-15 | I5 | 0 | N grid-point location. |

Limitation: Discharge sources have considerable limitations on their placement, see body of report for more detail.

| NAMINT | 16-35 | A20 | blanks | Station name. |
| DCDID | 73-80 | A8 | blanks | Record identifier (annotation only). |

RECORD SET 4: Constituent Stations (KPOL number of records)

I	1-5	I5	0	Sequence number (1,2,3,...,KPOL)
MPOL	6-10	I5	0	M grid-point location.
NPOL	11-15	I5	0	N grid-point location.

Limitation: Constituent stations should be placed within the computational grid.

| NAMPOL | 16-35 | A20 | blanks | Station name. |
| DCDID | 73-80 | A8 | blanks | Record identifier (annotation only). |

RECORD SET 5: U-Transport Stations (NTRA number of records)

U-transport cross-sections are selected segments of grid columns at which mass transport and advective, diffusive, and total constituent transport are printed and saved to the History file. Optionally written to the History file are kinetic and potential energy based on the value of NEXAN in Part 1.

I	1-5	I5	0	Sequence number (1,2,3,...,NTRA)
MIT	6-10	I5	0	M grid-point location of cross section.
NIT1	11-15	I5	0	First N grid-point location of cross section.
NIT2	16-20	I5	0	Last N grid-point location of cross section.

Limitation: If cross section extends beyond the computational grid, then there will be zero contribution to transport from the grid points outside the computational grid.

| NAMTRA | 21-40 | A20 | blanks | Cross section name. |
| DCDID | 73-80 | A8 | blanks | Record identifier (annotation only). |

RECORD SET 6: V-Transport Stations (NTRAV number of records)

V-transport cross-sections are selected segments of grid columns at which mass transport and advective, diffusive, and total constituent transport are printed and saved to the History file. Optionally written to the History file are kinetic and potential energy based on the value of NEXAN in Part 1.

I	1-5	I5	0	Sequence number (1,2,3,...,NTRAV)
NIT	6-10	I5	0	N grid-point location of cross section.
MIT1	11-15	I5	0	First M grid-point location of cross section.
MIT2	16-20	I5	0	Last M grid-point location of cross section.

Limitation: If cross section extends beyond the computational grid, then there will be zero contribution to transport from the grid points outside the computational grid.

| NAMTRV | 21-40 | A20 | blanks | Cross section name. |
| DCDID | 73-80 | A8 | blanks | Record identifier (annotation only). |

===
Variable Position Format   Default   Definition
===

RECORD SET 7: Dams or Dry Points (0 to any number of records, delimited by a blank record)

These records give the locations of permanently dry points, even though the depth surrounding this point would normally cause this point to be flooded. This provides a means to make a dam or causeway through the water body with considerable depth on either side.

```
MDAM      1-5    I5       0             M grid-point location of a dam point.
NDAM      6-10   I5       0             N grid-point location of a dam point.
DCDID     73-80  A8       blanks        Record identifier (annotation only).
```

RECORD TYPE ' ': Blank Record Delimiter

A blank record is given after all Dam or Dry points are input.

```
CDTYPE    1-72   A72      blanks        Blank record.
DCDID     73-80  A8       blanks        Record identifier (annotation only).
```

RECORD SET 8: Initial Wind and Temperatures (one required per execution)

This record gives the initial conditions pertaining to the entire grid.

```
WIND      1-8    E8.0     0.0           Initial wind speed, in units indicated by
                                        WCONV and PWUNIT in Part 1. If ISVWP=1, then
                                        space-varying wind is given, which overrides this
                                        value.
WINDA     9-16   E8.0     0.0           Initial wind direction, in degrees. Wind
                                        direction is measured from North, where North
                                        equals 0 degrees, east equals 90 degrees, and so
                                        on, clockwise, WINDA is not used if ISVWP=1.
                                        (e.g., set WINDA = 0 Degrees for wind blowing to
                                        the north.)
QNRFL     17-24  E8.0     0.0           Radiation flux from the surface, in cal/cm²day.
                                        This and the following temperatures are not
                                        effective unless LTEMP is set equal to a
                                        constituent number. At present, these variables
                                        are only valid when using English units in the
                                        simulation.
TDRYB     25-32  E8.0     0.0           Dry bulb air temperature, in degrees centigrade.
TWETB     33-40  E8.0     0.0           Wet bulb air temperature, in degrees centigrade.
TWMS      41-48  E8.0     0.0           Water temperature at measuring station, in
                                        degrees centigrade.
DCDID     73-80  A8       blanks        Record identifier (annotation only).
```

RECORD SET 9: Barrier or Sluice Description (NSLU+NSLUV number of records)

The barrier computation in the simulation program permits computation through an opening in a dam. The flow can be in the U- or V-direction or both. If a U barrier is at point n,m, then the computation takes water out of m-1 and discharges it at m+1, if the water level is higher than at m+1. If U- and V-barriers are placed at the same grid point, the flow in each direction is independent of the other.

The History file contains the following computations at barriers: barrier flow condition, gate height, sill depth, effective width or ratio; water level, current, and transport rate at left or bottom and at right or top of barrier; and concentrations of constituents.

==
Variable Position Format   Default   Definition
==

U-barriers may be no closer than three grid spaces to one another in the m direction, and must be similarly spaced away from the computational grid enclosure. Likewise, V-barriers must be spaced by at least three grid points in the n direction and from the computational grid enclosure.

Variable	Position	Format	Default	Definition
IBUV	1-5	I5	0	Barrier flag (1=U-barrier, 2=V-barrier).
I	6-10	I5	0	Sequence number (1, 2, 3,...,NSLU-if IBUV=1 and 1, 2, 3,...,NSLV-if IBUV=2). Note: Input all U-barriers and then all V-barriers with I starting at 1 for each set.
MBAR	11-15	I5	0	M grid-point location of barrier.
NBAR	16-20	I5	0	N grid-point location of barrier.

Limitation: See body of report for limitation on placement of barriers.

Variable	Position	Format	Default	Definition
NAMBAR	16-35	A20	blanks	Cross section name.
DCDID	73-80	A8	blanks	Record identifier (annotation only).

RECORD SET 10: Barrier Coefficients (NSLU+NSLUV number of records)

Variable	Position	Format	Default	Definition
IBUV	1-5	I5	0	Barrier flag (1=U-barrier, 2=V-barrier).
I	6-10	I5	0	Sequence number (1, 2, 3,...,NSLU-if IBUV=1 and 1, 2, 3,...,NSLV-if IBUV=2).

Note: Input all U-barrier coefficients and then all V-barrier coefficients with I starting at 1 for each set.

Variable	Position	Format	Default	Definition
BARMU	11-58	6E8.0	0.0	Array of six coefficients. The first four are contraction coefficients, two for subcritical flow (positive and negative), and two for supercritical flow (positive and negative). Coefficients 5 and 6 are for gate restricting flow (positive and negative flow).
DCDID	73-80	A8	blanks	Record identifier (annotation only).

RECORD SET 11: Barrier Initial Input (NSLU+NSLUV number of records)

Variable	Position	Format	Default	Definition
IBUV	1-5	I5	0	Barrier flag (1=U-barrier, 2=V-barrier).
I	6-10	I5	0	Sequence number (1, 2, 3,...,NSLU-if IBUV=1 and 1, 2, 3,...,NSLV-if IBUV=2).

Note: Input all U-barrier coefficients and then all V-barrier coefficients with I starting at 1 for each set.

Variable	Position	Format	Default	Definition
SILL	11-20	E10.0	0.0	Initial sill depth, in feet or meters. SILL is positive downwards.
GATE	21-30	E10.0	0.0	Initial gate height, in feet or meters. GATE is positive upwards.
BRAT	31-40	E10.0	0.0	Initial effective width or ratio (barrier width divided by the grid size AL). BRAT is the fraction of the grid space that is open (BRAT=0.0 means the grid is entirely closed to flow).
DCDID	73-80	A8	blanks	Record identifier (annotation only).

===

Variable	Position	Format	Default	Definition

===

Tide Openings (Record sets 12-19)

At each open boundary, water levels or velocities or transport rates are to be given. These can be described by time-varying data (given in Part 3), or by Fourier components of amplitude and phase (given in Part 2). The inputs are given or implied at both ends of the opening. Linear interpolation between these inputs is used for time-varying data. If Fourier components are used, then the amplitude and phase of each component are linearly interpolated between the inputs at the two ends. If an open boundary is long (greater than 10 percent of the shortest grid dimension), it should be placed on the edge of the rectangular grid (and the computational grid chosen to correspond).

If the data are the same at each side of the opening, then the flag LVSAME is set to one and the inputs at end B are not given (these values are automatically set in the program). The initial tide levels given here override the initial level (SEINV in Part 1) at the openings.

Concentrations and constituent return times are also described at both ends of openings. Constituent return time is the time interval after outflow changes to inflow during which the concentration returns to the value of the inflow. Concentrations and return times are also interpolated linearly across the opening, and the results override at the opening the concentrations given by RINT and R in Part 2.

RECORD SET 12: Tide Opening Description (NTO=NTOT+NTOF number of records)

Open boundaries may be defined in any order regardless of their position on the grid. However, the NTOT number of time-varying tide openings are input first, followed by the NTOF number of Fourier-related tide openings. Also, the ends of a tide opening need not be defined in any specific order. The convention is that ends are defined in a clockwise direction.

ISQ	1-2	I2	0	Sequence number (1,2,3,...,NTO). Fourier-related tide openings are numbered NTOT+1 to NTOF.
KBO	3-4	I2	0	Type of opening option as to water level or velocity or transport rate input, and position relative to the computational grid. KB0 range is 1-16.

Note: For water-level openings there are 8 possibilities: 4 diagonals at 45-degree multiples and 2 vertical and 2 horizontal sides of the grid. For velocity and transport rate openings, there are 4 possibilities each: the 2 vertical and 2 horizontal sides of the grid. Table 21 and Figure 10 in the **Forcing Functions** section describe the assignment of KB0 values.

KB1M	5-7	I3	0	M grid-point location of end A of the opening.
KB1N	8-10	I3	0	N grid-point location of end A of the opening.
KB2M	11-13	I3	0	M grid-point location of end B of the opening.
KB2N	14-16	I3	0	N grid-point location of end B of the opening.

Note: The two coordinates are the same values if the opening consists of a single grid point. Otherwise they define a diagonal, vertical, or horizontal line as indicated by KB0.

Limitation: Tide openings must be positioned just outside the computational grid. The default computational grid, if none is explicitly specified, extends from m=1 through m=MMAX-1 and from n=2 through n=NMAX-1. In this case, tide openings are located on one of the four lines m=1, m=MMAX, n=1, or n=NMAX, except for velocity and transport rate openings which are located on m=1, m=MMAX-1, n=1, or n=NMAX-1. The reason for these exceptions is that in the space-staggered grid the velocity points are already above and to the right of the water level grid point with the same n,m index.

LVSAME	17-18	I2	0	Flag to indicate that the values at both ends of the opening are the same. (0=no, 1=yes).
CBND	19-26	E8.0	0.0	Chezy value along the opening. These Chezy values are not computed from Manning's n input, although Chezy values in the interior are.
NAMT1	27-46	A20	blanks	Name of end A

===

Variable	Position	Format	Default	Definition

===

| NAMT2 | 47-66 | A20 | blanks | Name of end B |
| DCDID | 73-80 | A8 | blanks | Record identifier (annotation only). |

RECORD SET 13: Tide Opening Initial Values at End A (NTO number of records)

NSQ	1-2	I2	0	Sequence number (1, 2, 3,...,NTO). Fourier-related tide openings are numbered NTOT+1 to NTOF.
TID1	3-10	E8.0	0.0	Initial water level, velocity, or transport rate at end A of the opening, depending on the KB0 code. For Fourier-related openings, TID1 is also used in the initial interpolation through time TLFSMO as given in Part 1.
TCRETA	11-16	F6.0	0.0	Constituent return time at end A after the current reverses to inward flow, in minutes. This value will be set to the nearest non-zero multiple of HALFDT*2.
TRBNDA	17-72	7E8.0	0.0	Array of 7 entries, for the initial concentration at end A of the tide opening for as many as 7 constituents.

Note: TRBNDA is also the ambient concentration in the waterbody outside this end of the boundary; the computation automatically returns to this concentration over the given period of time (TCRETA), after the current reverses to inward flow. TRBNDA as the ambient concentration can be varied with time (see record type C in Part 3).

| DCDID | 73-80 | A8 | blanks | Record identifier (annotation only). |

RECORD SET 14: Tide Opening Initial Values at End B (NTOM number of records)
NTOM equals NTO less the number of openings where LVSAME=1.

NSQ	1-2	I2	0	Sequence number (1, 2, 3,...,NTO). Fourier-related tide openings are numbered NTOT+1 to NTOF. No records are input for those openings where LVSAME was specified as 1.
TID2	3-10	E8.0	0.0	Initial water level, velocity, or transport rate at end B of the opening, depending on the KB0 code. For Fourier-related openings, TID2 is also used in the initial interpolation through time TLFSMO as given in Part 1.
TCRETB	11-16	F6.0	0.0	Constituent return time at end B after the current reverses to inward flow, in minutes. This value will be set to the nearest non-zero multiple of HALFDT*2.
TRBNDB	17-72	7E8.0	0.0	Array of 7 entries, for the initial concentration at end B of the tide opening for as many as 7 constituents.

Note: An interpolation between TRBNDA and TRBNDB overrides at the opening the initial concentration, as given below. TRBNDB is also the ambient concentration in the waterbody outside this end of the boundary; the computation automatically returns to this concentration over the given period of time (TCRETB), after the current reverses to inward flow. TRBNDB as the ambient concentration can be varied with time (see record type C in Part 3).

| DCDID | 73-80 | A8 | blanks | Record identifier (annotation only). |

===

Variable	Position	Format	Default	Definition

===

RECORD SET 15: Frequencies of Fourier or Harmonic Components (NOFC=INT(KC+7)/8 number of records)

This set consists of 1 record per 8 components. For example, if KC=10, then there are 8 components defined on record 1 and 2 components defined on record 2.

Variable	Position	Format	Default	Definition
OMEGA	11-66	8E7.0	0.0	Array of angular frequencies, in 0.0001 radians per second.
DCDID	73-80	A8	blanks	Record identifier (annotation only).

RECORD SET 16: Amplitude Components at End A (NTOF number of record groups with each group consisting of NOFC=INT(KC+7)/8 number of records)

This and the next three record sets define the Fourier components of amplitude and phase at both ends of relevant tide openings. Amplitudes pertain to water level or velocity or transport rate, depending on the value of KB0. The form is identical in these four record sets, except that amplitude is given at the initial zero frequency, and phase is not.

Variable	Position	Format	Default	Definition
CDTYPE	1	A1	blank	The value "A" for end A of each opening.
NSQ	2-3	I2	0	Sequence number (NTOT+1,NTOT+2,...,NTO). The same NSQ value is repeated in continuation records with a record group.
AZEROA	4-10	E7.0	0.0	Amplitude at end A for zero frequency, given only on the first record of group.
AMPLA	11-66	8E7.0	0.0	Array of amplitudes at end A of the opening for the KC number of frequencies, 8 per record.
DCDID	73-80	A8	blanks	Record identifier (annotation only).

RECORD SET 17: Amplitude Components at End B (NTOFM number of record groups with each group consisting of NOFC=INT(KC+7)/8 number of records)

NTOFM is NTOF less the number of Fourier-related openings where the flag LVSAME=1. In other words, the amplitude at end B is only given for openings where the values differ at each end.

Variable	Position	Format	Default	Definition
CDTYPE	1	A1	blank	The value "B" for end B of each opening.
NSQ	2-3	I2	0	Sequence number (NTOT+1,NTOT+2,...,NTO). The same NSQ value is repeated in continuation records with a record group. No records appear for tide opening numbers whose flag LVSAME=1.
AZEROB	4-10	E7.0	0.0	Amplitude at end B for zero frequency, given only on the first record of group.
AMPLB	11-66	8E7.0	0.0	Array of amplitudes at end B of the opening for the KC number of frequencies, 8 per record.
DCDID	73-80	A8	blanks	Record identifier (annotation only).

RECORD SET 18: Phase Components at End A (NTOF number of record groups with each group consisting of NOFC=INT(KC+7)/8 number of records)

Variable	Position	Format	Default	Definition
CDTYPE	1	A1	blank	The value "A" for end A of each opening.
NSQ	2-3	I2	0	Sequence number (NTOT+1,NTOT+2,...,NTO) The same NSQ value is repeated in continuation records with a record group.

===
Variable	Position	Format	Default	Definition
===
| PHASEA | 11-66 | 8E7.0 | 0.0 | Array of phases at end A of the opening for the KC number of frequencies, 8 per record. |
| DCDID | 73-80 | A8 | blanks | Record identifier (annotation only). |

RECORD SET 19: Phase Components at End B (NTOFM number of record groups with each group consisting of NOFC=INT(KC+7)/8 number of records)

NTOFM is NTOF less the number of Fourier-related openings where the flag LVSAME=1. In other words, the phase at end B is only given for openings where the values differ at each end.

CDTYPE	1	A1	blank	The value "B" for end B of each opening.
NSQ	2-3	I2	0	Sequence number (NTOT+1,NTOT+2,...,NTO). The same NSQ value is repeated in continuation records with a record group. No records appear for tide opening numbers whose flag LVSAME=1.
PHASEB	11-66	8E7.0	0.0	Array of phases at end B of the opening for the KC number of frequencies, 8 per record.
DCDID	73-80	A8	blanks	Record identifier (annotation only).

RECORD SET 20: Constituent Description (LMAX number of records)

The constituents should be ordered so that interacting constituents come first (see LMRX on the Constituents record in Part 1).

NSQ	1-2	I2	0	Constituent number (1,2,...,LMAX) maximum=7.
RINT	3-10	E8.0	0.0	Initial concentration in the interior. This value is overridden if concentrations are given in record set 36 below, except that this value replaces any zero values given in record set 36.
POLT	11-30	A20	blanks	Constituent name, used for annotation and saved in History file for display on graphics.
POLTUN	31-50	A20	blanks	Units of the concentration data for this particular constituent, used for annotation and saved in History file.
KPFLAG	51	I1	0	Axis type for graphics (not currently used) (0=linear axis, 1=log axis).
DCDID	73-80	A8	blanks	Record identifier (annotation only).

RECORD SET 21: Constituents - Interaction Rates (LMAX number of records)

| NSQ | 1-2 | I2 | 0 | Constituent number (1,2,...,LMAX) |
| AKK | 3-50 | 6E8.0 | 0.0 | Array of 6 entries defining the interaction rates between constituent NSQ and constituent 1 through 6. |

Note: Non-zero interaction rates are given for the first LRMX number of interactive constituents, and decay (action upon itself) is possible for all constituents, regardless of LRMX. If LOX is not zero (on Constituents record in Part 1), then the interaction rate given here for constituent LOX will be overridden by AKTP (in Part 1).

| DCDID | 73-80 | A8 | blanks | Record identifier (annotation only). |

RECORD SET 22: Constituents Isolines (LMAX number of records)

| NSQ | 1-2 | I2 | 0 | Constituent number (1,2,...,LMAX) |

==

Variable	Position	Format	Default	Definition
PLEC	3-74	9E8.0	0.0	Isoline values for drawing maps for this constituent (not currently used). The first zero isoline value ends the list, so that if a zero isoline is intended, a number very close to zero should be given.
DCDID	75-80	A6	blanks	Record identifier (annotation only).

RECORD SET 23: Velocity Isolines (1 record required per execution)

Variable	Position	Format	Default	Definition
PLEV	3-74	9E8.0	0.0	Isoline values for drawing velocity maps (not currently used). The first zero isoline value ends the list, so that if a zero isoline is intended, a number very close to zero should be given.
DCDID	75-80	A6	blanks	Record identifier (annotation only).

RECORD SET 24: Mass-Transport Isolines (1 record required per execution)

Variable	Position	Format	Default	Definition
PLEM	3-74	9E8.0	0.0	Isoline values for drawing mass-transport maps (not currently used). The first zero isoline value ends the list, so that if a zero isoline is intended, a number very close to zero should be given.
DCDID	75-80	A6	blanks	Record identifier (annotation only).

RECORD SET 25: Water-Level Isolines (1 record required per execution)

Variable	Position	Format	Default	Definition
PLEW	3-74	9E8.0	0.0	Isoline values for drawing water-level maps (not currently used). The first zero isoline value ends the list, so that if a zero isoline is intended, a number very close to zero should be given.
DCDID	75-80	A6	blanks	Record identifier (annotation only).

RECORD SET 26: Land-Boundary Outlines (Not presently used, but one boundary-outline end record required, see below.)

The geography of the land boundaries can be digitized by tracing the outlines on a position-sensitive device. The results are connected by straight-line segments approximating the land boundary (represented by the end points defining the lines). A record is input for each point giving the m and n grid coordinate values. Multiple sets of continuous lines can be input. A continuous outline group consists of an outline header record, a variable number (at least two) of point records, and a blank record to indicate the end of the group. After all outline groups are input a Land-Boundary End record is input.

==

Variable Position Format   Default   Definition

==

Outline Header record (1 per outline group)

Variable	Position	Format	Default	Definition
BMOD	1-6	F6.0	0.0	Line width to use for this group (not currently used).
BLIN	7-12	F6.0	0.0	Dash length, in grid space units (not currently used).
BSPC	13-18	F6.0	0.0	Space between dashes. If BSPC=0.0 then the line will be solid (not currently used).
DCDID	73-80	A8	blanks	Record identifier (annotation only).

Outline End-Point records (2 to any number per outline group)

Variable	Position	Format	Default	Definition
XLAND	1-12	E12.0	0.0	Location in the grid in terms of M for this end point on the outline segment.
YLAND	13-24	E12.0	0.0	Location in the grid in terms of N for this end point on the outline segment.
DCDID	73-80	A8	blanks	Record identifier (annotation only).

Blank Record Delimiter (1 per outline group)

A blank record is given to signal the end of an outline segment.

Variable	Position	Format	Default	Definition
CDTYPE	1-72	A72	blanks	Blank record.
DCDID	73-80	A8	blanks	Record identifier (annotation only).

Note: The above three record types are repeated until the land-boundary is completely specified.

Land-Boundary End record (1 required per execution)

Variable	Position	Format	Default	Definition
RFLAG	1-10	F10.0	0.0	The value "999999999." must be coded to signal the end of record set 26.

RECORD SET 27: Depth Values (1 set of depth records required per execution)

This record set specifies the depth values for all points on the grid. However, for grid points on dry land, depth values should be left blank or set to zero, and they will be reset to the negative of the default depth value DEPDEF. Depth values greater than the depth threshold DCO will be multiplied by the experimental depth multiplier DML (DEPDEF, DCO, and DML are on the Physical Characteristics record in Part 1). The only print of the depth values as originally coded is therefore in the SWIFT_IDP Listing of All Input Records. The depth point (n,m) is actually located in the grid at (n+.5, m+.5) (See staggered grid description in **Rectangular Grid Layout** section.)

If depth values are specified as integers (no decimal point), then one decimal point is assumed, so that the units of these integer values are tenths of feet or decimeters. If a decimal point is explicitly given, then the units are feet or meters. Depth values (and concentrations--record set 35 below) can be input as either 16 values per record with a field width of 4 or 10 values per record with a field width of 6, depending on the value of IDKFMT in Part 1.

If IDKFMT=0:

Variable	Position	Format	Default	Definition
H	1-64	16F4.1	DEPDEF	Array of 16 depth values. On the first MMAX number of records are the values for columns n=1 to 16. On the second MMAX number of records are the depth values for grid columns n=17 to 32, and so, for a total of MMAX*INT((NMAX+15)/16) number of records.

```
================================================================================
```
Variable	Position	Format	Default	Definition
```
================================================================================
```
```
If IDKFMT=1:
H         1-60   10F6.1  DEPDEF      Array of 10 depth values. On the first
                                     MMAX number of records are the values for columns
                                     n=1 to 10. On the second MMAX number of records
                                     are the depth values for grid columns n=11 to 20,
                                     and so, for a total of MMAX*INT((NMAX+9)/10)
                                     number of records.
DCDID     73-80  A8      blanks      Record identifier (annotation only).
```

Coefficient Input (Record sets 28-35)

Viscosity coefficients, diffusion coefficients, Manning's n, and benthic demand are all input in the same manner. First, a default coefficient is input, then a variable number of overrides to that default are given for particular sections of the grid, then a blank record ends the set.

RECORD SET 28: Default Value - Viscosity Coefficient (1 required per execution)

```
If ICOFMT=0:
VISDEF    1-5    F5.0    0.0         Default viscosity coefficient.
If IDKFMT=1:
VISDEF    1-8    E8.0    0.0         Default viscosity coefficient.
DCDID     73-80  A8      blanks      Record identifier (annotation only).
```

RECORD SET 29: Viscosity Coefficients (any number per execution)

```
If ICOFMT=0:
MVIS      1-5    F5.0    0.0         The M row in the grid at which to override.
N1VIS     6-10   I5      0           The first N grid point to override.
N2VIS     11-15  I5      0           The last N grid point to override.
                                     N1VIS+9 is the maximum value for N2VIS, as
                                     only 10 viscosity values can be input per record.
CDVIS     16-65  10F5.0  0.0         Viscosity coefficients for grid points
                                     (MVIS,N1VIS) through (MVIS,N2VIS)
If IDKFMT=1:
MVIS      1-5    F5.0    0.0         The M row in the grid at which to override.
N1VIS     6-10   I5      0           The first N grid point to override.
N2VIS     11-15  I5      0           The last N grid point to override.
                                     N1VIS+6 is the maximum value for N2VIS, as only
                                     7 viscosity values can be input per record.
CDVIS     16-71  7E8.0   0.0         Viscosity coefficients for grid points
                                     (MVIS,N1VIS) through (MVIS,N2VIS)
DCDID     73-80  A8      blanks      Record identifier (annotation only).
```

Blank Record Delimiter (1 required per execution)

A blank record is given to signal the end of record set 29.

```
CDTYPE    1-72   A72     blanks      Blank record.
DCDID     73-80  A8      blanks      Record identifier (annotation only).
```

===
Variable Position Format   Default   Definition
===

RECORD SET 30: Default Value - Diffusion Coefficient (1 required per execution)

```
If ICOFMT=0:
DIFDEF   1-5   F5.0   0.0           Default diffusion coefficient.
If IDKFMT=1:
DIFDEF   1-8   E8.0   0.0           Default diffusion coefficient.
DCDID    73-80 A8     blanks        Record identifier (annotation only).
```

RECORD SET 31: Diffusion Coefficients (any number per execution)

```
If ICOFMT=0:
MDIF     1-5    F5.0   0.0    The M row in the grid at which to override.
N1DIF    6-10   I5     0      The first N grid point to override.
N2DIF    11-15  I5     0      The last N grid point to override.
                              N1DIF+9 is the maximum value for N2DIF,
                              as only 10 diffusion values can be input per
                              record.
CDDIF    16-65  10F5.0 0.0    Diffusion coefficients for grid points
                                (MDIF,N1DIF) through (MDIF,N2DIF).
If IDKFMT=1:
MDIF     1-5    F5.0   0.0    The M row in the grid at which to override.
N1DIF    6-10   I5     0      The first N grid point to override.
N2DIF    11-15  I5     0      The last N grid point to override.
                              N1DIF+6 is the maximum value for N2DIF, as only 7
                              diffusion values can be input per record.
CDDIF    16-71  7E8.0  0.0    Diffusion coefficients for grid points
                                (MDIF,N1DIF) through (MDIF,N2DIF).
DCDID    73-80  A8     blanks Record identifier (annotation only).
```

Blank Record Delimiter (1 required per execution)

A blank record is given to signal the end of record set 31.

```
CDTYPE   1-72   A72    blanks        Blank record.
DCDID    73-80  A8     blanks        Record identifier (annotation only).
```

RECORD SET 32: Default Value - Manning's Coefficient (1 required per execution)

```
If ICOFMT=0:
VMDEF    1-5   F5.0   0.0            Default Manning's coefficient.
If IDKFMT=1:
VMDEF    1-8   E8.0   0.0            Default Manning's coefficient.
DCDID    73-80 A8     blanks         Record identifier (annotation only).
```

RECORD SET 33: Manning's Coefficients (any number per execution)

```
If ICOFMT=0:
MMAN     1-5    F5.0   0.0    The M row in the grid at which to override.
N1MAN    6-10   I5     0      The first N grid point to override.
```

==

Variable	Position	Format	Default	Definition
N2MAN	11-15	I5	0	The last N grid point to override. N1MAN+9 is the maximum value for N2MAN, as only 10 Manning's values can be input per record.
CDMAN	16-65	10F5.0	0.0	Manning's coefficients for grid points (MMAN,N1MAN) through (MMAN,N2MAN).

If IDKFMT=1:

Variable	Position	Format	Default	Definition
MMAN	1-5	F5.0	0.0	The M row in the grid at which to override.
N1MAN	6-10	I5	0	The first N grid point to override.
N2MAN	11-15	I5	0	The last N grid point to override. N1MAN+6 is the maximum value for N2MAN, as only 7 Manning's values can be input per record.
CDMAN	16-71	7E8.0	0.0	Manning's coefficients for grid points (MMAN,N1MAN) through (MMAN,N2MAN).
DCDID	73-80	A8	blanks	Record identifier (annotation only).

Blank Record Delimiter (1 required per execution)

A blank record is given to signal the end of record set 33.

Variable	Position	Format	Default	Definition
CDTYPE	1-72	A72	blanks	Blank record.
DCDID	73-80	A8	blanks	Record identifier (annotation only).

RECORD SET 34: Default Value - Benthic Demand (1 required per execution, if either LBOD or LOX are not zero)

Benthic demand is not used if LBOD and LOX are both zero (see the Constituents record in Part 1). However, at least the blank delimiter must be input.

If ICOFMT=0:

Variable	Position	Format	Default	Definition
BENDEF	1-5	F5.0	0.0	Default Benthic demand value.

If IDKFMT=1:

Variable	Position	Format	Default	Definition
BENDEF	1-8	E8.0	0.0	Default Benthic demand value.
DCDID	73-80	A8	blanks	Record identifier (annotation only).

RECORD SET 35: Benthic demand values (any number per execution, if either LBOD or LOX are not zero)

If ICOFMT=0:

Variable	Position	Format	Default	Definition
MBEN	1-5	F5.0	0.0	The M row in the grid at which to override.
N1BEN	6-10	I5	0	The first N grid point to override.
N2BEN	11-15	I5	0	The last N grid point to override. N1BEN+9 is the maximum value for N2BEN, as only 10 Manning's values can be input per record.
CDBEN	16-65	10F5.0	0.0	Benthic demand values for grid points (MBEN,N1BEN) through (MBEN,N2BEN)

If IDKFMT=1:

Variable	Position	Format	Default	Definition
MBEN	1-5	F5.0	0.0	The M row in the grid at which to override.
N1BEN	6-10	I5	0	The first N grid point to override.
N2BEN	11-15	I5	0	The last N grid point to override. N1BEN+6 is the maximum value for N2BEN, as only 7 Benthic values can be input per record.
CDBEN	16-71	7E8.0	0.0	Benthic demand values for grid points (MBEN,N1BEN) through (MBEN,N2BEN)
DCDID	73-80	A8	blanks	Record identifier (annotation only).

==

Variable Position Format   Default   Definition

==

_____

Blank Record Delimiter (1 required per execution)

A blank record is given to signal the end of record set 35.

CDTYPE   1-72   A72   blanks   Blank record.
DCDID   73-80 A8   blanks   Record identifier (annotation only).

_____

RECORD SET 36: Initial Concentration (optional, at least a blank record required)

If initial concentration for a constituent is non-uniform, then concentration at all grid points is given here for that constituent. The units of concentration are given in POLTUN. Where concentration values are left blank or set to zero, they will be reset to RINT for that constituent (see POLTUN and RINT on Constituent Description record set 20). Also, at open boundaries, values given in the tide opening initial values override values given here at the same grid points (see RBNDA and RBNDB in record sets 12 and 13). Preceding each concentration set is a record indicating which constituent those values pertain to. Ending each concentration set is a blank record delimiter. The concentration set is specified in the same format as initial depth values based on the value of IDKFMT. If integer values (no decimal point specified), then one decimal place is assumed, e.g. 100=10.0.

Initial Concentration Header (1 required for each concentration set input)

L   1-5   I5   0   Constituent number to which the following
                                      concentration set pertains.

Concentration Set (1 set required for each concentration set input)

If IDKFMT=0:
R   1-64   16F4.1 RINT   Array of 16 initial concentration values for
                                      constituent L. On the first MMAX number of
                                      records are the values for columns n=1 to 16. On
                                      the second MMAX number of records are the
                                      concentration values for grid columns n=17 to 32,
                                      and so on, for a total of MMAX*INT((NMAX+15)/16)
                                      number of records.
If IDKFMT=1:
R   1-60   10F6.1 RINT   Array of 10 initial concentration values for
                                      constituent L. On the first MMAX number of
                                      records are the values for columns n=1 to 10. On
                                      the second MMAX number of records are the
                                      concentration values for grid columns n=11 to 20,
                                      and so on, for a total of MMAX*INT((NMAX+9)/10)
                                      number of records.
DCDID   73-80 A8   blanks   Record identifier (annotation only).

Note: These two record types are repeated for any constituents with non-uniform initial concentration.

_____

Blank Record Delimiter (1 required per execution)

A blank record is given to signal the end of record set 36.

CDTYPE   1-72   A72   blanks   Blank record.
DCDID   73-80 A8   blanks   Record identifier (annotation only).

Note: A blank record delimiter is required, whether or not there are any constituents (even though LMAX=0).

==
Variable	Position	Format	Default		Definition

==

RECORD SET 37: Permanent Titles (optional, at least a blank record required)

Permanent titles may be given, to be written to the Map file for later use in labeling map displays. Usually these will label geographical areas and features, for orientation of generated graphics. In a similar way, titles may be input in Part 3 to be displayed for a given time during the simulation (not currently supported).

Variable	Position	Format	Default	Definition
TITLM	18-23	F6.0	0.0	The M grid position of the center of the first character in the title.
TITLN	24-29	F6.0	0.0	The N grid position of the center of the first character in the title.
ITICV	30	I1	0	Flag for character font (0=hardware font, 1=stroke font) (not currently supported).
TITSZ	31-34	F4.0	0.0	Character size. The normal size is 1.0 with a maximum of 2.7 (not currently supported).
TITLW	35-38	F4.0	0.0	Line width for characters in title. TITLW=0.0 allows software to choose a value, maximum value is 2.0 (not currently supported).
TITOR	39-42	F4.0	0.0	Orientation of the title line, in degrees. (0.0=horizontal, 90.0=vertical).
TTITL	43-70	A28	blanks	Title
DCDID	73-80	A8	blanks	Record identifier (annotation only).

Blank Record Delimiter (1 required per execution)

A blank record is given to signal the end of record set 37.

Variable	Position	Format	Default	Definition
CDTYPE	1-72	A72	blanks	Blank record.
DCDID	73-80	A8	blanks	Record identifier (annotation only).

Note: A blank record delimiter is required, whether or not there are any permanent titles.

RECORD SET 38: Particle Group Description (optional, any number of records if IPAR > 0)

This record set is delimited by an END PART record and is only input if IPAR is greater than 0.

Variable	Position	Format	Default	Definition
TFPAR	9-16	E8.0	0.0	The first time for particles in this particle group to appear, in minutes. TFPAR must be a multiple of HALFDT*2, if not it is reset and a warning is issued.
TLPAR	17-24	E8.0	0.0	The last time for particles in this particle group to appear, in minutes. TLPAR must be a multiple of HALFDT*2, if not it is reset and a warning is issued.
XPAR	25-32	E8.0	0.0	The M grid position where the particle group begins.
YPAR	33-40	E8.0	0.0	The N grid position where the particle group begins.
IPARG	41-48	I8	0	Option for type of particle movement (1=by current only, 2=by current and a uniform random function of energy, 3=by current and a Gaussian random function of energy). IPARG may be 2 or 3 only when Part 1 flag LERG is non-zero.

Variable	Position	Format	Default	Definition
NPARI	49-56	I8	0	Number of particles in this particle group. NPARI must be set to 1 if IPARG=1)
DCDID	73-80	A8	blanks	Record identifier (annotation only).

End Particle Record Delimiter (1 required if IPAR>0 per execution)

This record is given to signal the end of record set 38.

Variable	Position	Format	Default	Definition
CDTYPE	1-72	A72	blanks	Blank record.
DCDID	73-80	A8	blanks	Record identifier (annotation only).

RECORD SET 39: Computational Grid Enclosure (optional, any number of records)

This record set is delimited by a blank record. A computational grid may be defined within the rectangular grid defined by MMAX and NMAX. The purpose of the computational grid is to limit the computation to those grid points which are potentially flooded. If the full grid rectangle is to be computed in the simulation, then only a blank record is given here. In this case, the effective computation rows and columns are m=1 to MMAX-1 and n=2 to NMAX-1. In effect, SWIFT_IDP has generated a default computational grid enclosure through the grid points (1,1), (1,NMAX), (MMAX,NMAX), (MMAX,1), and back to (1,1). See the **Computational Grid Enclosure** section for a more complete description of the computation grid. The computational grid enclosure itself is not included in the computations. As it is just outside the computation field, tide openings are located along the computational grid enclosure. Considerable computer time can be saved by defining a computational grid that fits the shape of the waterbody as compared to the default rectangular enclosure.

Limitations: The computational grid may be defined by one or several computational grid enclosures of arbitrary shape. Each enclosure is a closed figure or polygon, which defines an outer edge, or an inner edge around an island. An enclosure is given as a set of (n,m) grid points where adjacent points define straight line segments, and the first point equals the last point. No redundant points are given; rather every point given is a "corner" where the next line segment is not a straight-line continuation of the previous line segment. Line segments may be horizontal or vertical with respect to the grid, or they may be diagonals at multiples of 45 degrees.

Limitations: Although an enclosure polygon defining an island may be wholly contained within another enclosure polygon, they should not cross or coincide. Parallel line segments may not be adjacent; that is, at least on M row or N column must fall between them. Similarly, all inner and outer angles formed by consecutive line segments must be at least 90 degrees. A line segment must be at least two grid spaces long, if the following line segment reverses the direction of the previous segment. See Figures 7–9 for illustrations of correct and incorrect grid enclosures. The last point of a given polygon is identified by setting the flag MNLAST=1; points for the next polygon follow immediately after that record. After all enclosures are defined a blank record signals the end of record set 39.

Variable	Position	Format	Default	Definition
MBE	1-5	I5	0	The M grid-point location of a "corner".
NBE	6-10	I5	0	The N grid-point location of a "corner".
NMLAST	11-15	I5	0	Flag to signal the end of a polygon (0=no,1=yes).
DCDID	73-80	A8	blanks	Record identifier (annotation only).

Blank Record Delimiter (1 required per execution)

This record is given to signal the end of record set 39.

Variable	Position	Format	Default	Definition
CDTYPE	1-72	A72	blanks	Blank record.
DCDID	73-80	A8	blanks	Record identifier (annotation only).

===
| **Variable** | **Position** | **Format** | **Default** | **Definition** |

===

PART 3 RECORDS: TIME-VARYING DATA

Part 3 consists of record types A-N and Z. All time-varying data are optional. If time-varying tide is given, it must be specified at every interval TITIDE after TSTART through TSTOP. Other time-varying data can be given at irregular intervals as long as the time is a multiple of TITIDE and linear interpolation is valid over the time interval. The maximum duration allowed by time-varying inputs is 99 days. All time-varying data are identified by a time as the day, hour, and minute, relative to midnight at the beginning of the simulation start date (ITDATE) which is day 1, hour 0, minute 0. Midnight ending the first day of simulation is called day 1, hour 24, minute 0. All records in Part 3 must be given in order: first by record type; then by constituent number (for concentrations only) or U- or V-type (for barriers only); then by place number such as tide opening or outfall or barrier number, and lastly by time in day, hour, and minute. Any sequence error causes SWIFT_IDP to abort. There may be tide values for 6 time intervals on a type A or B record. In the other record types, only one value is given per record, or two values in the case of concentration at the ends of a tide opening.

RECORD TYPE A: Tide at End A (required if NTOT > 0)

Tide values at grid points across the opening are the result of linear interpolation between the given tide at end A and the result of linear interpolation between the given tide at end A and at end B (interpolation across space), as with the initial values in Part 2. Tide values at each half time step (HALFDT) are the result of linear interpolation between values at two given times (interpolation across time), for all grid points in the opening.

Variable	Position	Format	Default	Definition
CDTYPE	1	A1	blank	Code "A".
ITO	4-5	I2	0	Time-varying tide opening number (the same number as NSQ in the Tide Opening Description record set in Part 2).
CDDAY	6-7	I2	0	Day of first tide value on this record.
CDHOUR	8-9	I2	0	Hour of first tide value on this record.
CDMIN	10-11	I2	0	Minute of first tide value on this record.
KDNUMS	12-13	I2	6	The number of tide values given on this record (maximum=6).
TLVL1(6)	16-63	6E8.0	0.0	Array of KDNUMS tide values at end A of tide opening ITO.

Note: Input values are water level, velocity, or transport rate, depending on the code KB0 in the tide opening description of Part 2, for the corresponding NSQ. The units of water levels are feet or meters. The KDNUMS values pertain to times starting at CDDAY, CDHOUR, and CDMIN with an interval of TITIDE number of minutes. The first value of TLVL1 on the first type "A" record should be considered when choosing the value of TIDA in the tide opening initial values in Part 2. If water levels are given here, then see global initial level SEINV in Part 1 for the default. If velocities or transport rates are given, the default value is zero.

Variable	Position	Format	Default	Definition
DCDID	73-80	A8	blanks	Record identifier (annotation only).

RECORD TYPE B: Tide at End B (required if NTOT > 0 and LVSAME is non-zero for at least one time-varying tide opening)

Variable	Position	Format	Default	Definition
CDTYPE	1	A1	blank	Code "B".
ITO	4-5	I2	0	Time-varying tide opening number (the same number as NSQ in the Tide Opening Description record set in Part 2).If, associated with NSQ, the flag LVSAME=1, then no type "B" records are given for that opening.
CDDAY	6-7	I2	0	Day of first tide value on this record.
CDHOUR	8-9	I2	0	Hour of first tide value on this record.
CDMIN	10-11	I2	0	Minute of first tide value on this record.

===

Variable	Position	Format	Default	Definition

===

Variable	Position	Format	Default	Definition
KDNUMS	12-13	I2	6	The number of tide values given on this record (maximum=6).
TLVL1(6)	16-63	6E8.0	0.0	Array of KDNUMS tide values at end B of tide opening ITO.

Note: Input values are water level, velocity, or transport rate, depending on the code KB0 in the tide opening description of Part 2, for the corresponding NSQ.

Variable	Position	Format	Default	Definition
DCDID	73-80	A8	blanks	Record identifier (annotation only).

RECORD TYPE C: Concentrations at Tide Openings (LMAX > 0)

Concentrations at grid points across the opening are the result of a linear interpolation between concentrations at end A and at end B (interpolation across space), as with initial water levels in Part 2. Concentrations at tide openings are automatically varied during the simulation, the constituent return times at the opening (TCRETA and TCRETB), and the concentration in the interior. During outgoing flow, the concentrations are computed from inside the field. After current reverses to inward flow at points on the boundary, the concentrations return over the return period, to the concentrations given as input here. If no value has been presented here, the initial concentrations at the boundary are used. The data in this section thus permit time-varying concentrations at the boundary during and after the return period.

Variable	Position	Format	Default	Definition
CDTYPE	1	A1	blank	Code "C".
ICON	2-3	I2	0	The constituent number (the same as NSQ in the Part 2 constituent description, varying from 1 to LMAX).
ITO	4-5	I2	0	Time-varying tide opening number (the same number as NSQ in the Tide Opening Description record set in Part 2.
CDDAY	6-7	I2	0	Day of the values on this record.
CDHOUR	8-9	I2	0	Hour of the values on this record.
CDMIN	10-11	I2	0	Minute of the values on this record.
KDEXPO	14-15	I2	0	The exponent to apply to values on the record.
CTOA	16-23	E8.0	0.0	The concentration of constituent ICON at end A of tide opening ITO
CTOB	24-31	E8.0	0.0	The concentration of constituent ICON at end B of tide opening ITO

Note: If LVSAME=1 for ITO, then only the value CTOA need be given, and the concentration at end B will be set equal to the concentration at end A. If a zero concentration is intended, then a value very near zero should be given, i.e., 1.0E-10.

Variable	Position	Format	Default	Definition
DCDID	73-80	A8	blanks	Record identifier (annotation only).

RECORD TYPE D: Discharges (NSRC > 0)

All discharge rates are automatically set to zero at simulation time zero. Any discharge rates are given here in Part 3, and a particular rate persists until interpolation to a new rate at the same discharge source. Thus, if a discharge is to be "turned off", a zero discharge rate must be given. The discharge rate cannot be negative.

Variable	Position	Format	Default	Definition
CDTYPE	1	A1	blank	Code "D".
ISRC	4-5	I2	0	Source number (the same number as ISRC in the Discharge sources record set in Part 2, varies from 1 to NSRC).
CDDAY	6-7	I2	0	Day of the value on this record.
CDHOUR	8-9	I2	0	Hour of the value on this record.
CDMIN	10-11	I2	0	Minute of the value on this record.
KDEXPO	14-15	I2	0	The exponent to apply to value on this record.

Variable	Position	Format	Default	Definition
DISCHG	16-23	E8.0	0.0	Discharge rate at outfall (discharge source) ISRC. Discharge is given in cubic feet per second or cubic meters per second.
DCDID	73-80	A8	blanks	Record identifier (annotation only).

RECORD TYPE E: Concentration at Discharge Sources (NSRC > 0 and LMAX > 0)

All concentrations at discharge sources are automatically set to zero at simulation time zero. Any change in concentration at sources is given here in Part 3, and a particular concentration persists for the same constituent at the same source. This means if a discharge is "turned off" and restarted, then the associated concentrations resume at the latest value given as input here for each constituent.

Variable	Position	Format	Default	Definition
CDTYPE	1	A1	blank	Code "E".
ICON	2-3	I2	0	The constituent number (the same as NSQ in the part 2 constituent description, varying from 1 to LMAX).
ISRC	4-5	I2	0	Source number (the same number as I in the Discharge sources record set in Part 2, varies from 1 to NSRC).
CDDAY	6-7	I2	0	Day of the value on this record.
CDHOUR	8-9	I2	0	Hour of the value on this record.
CDMIN	10-11	I2	0	Minute of the value on this record.
KDEXPO	14-15	I2	0	The exponent to apply to value on this record.
COF	16-23	E8.0	0.0	Concentration of constituent ICON at source ISRC.
DCDID	73-80	A8	blanks	Record identifier (annotation only).

RECORD TYPE F: Wind Speed (ISVWP=0)

Values specified on record types F-K are initially given in Part 2. Global wind is not used if input and space-varying wind is also input (Part 4). Radiation flux and the three temperatures have no effect unless one of the constituents is temperature (that is, unless LTEMP is non-zero in the Constituents record in Part 1). Any change in any one condition is given by a record here with the new value, and a record type to indicate which condition is changing. As with the initial values, a new value persists until interpolation to a new value given here at a later time interval.

Variable	Position	Format	Default	Definition
CDTYPE	1	A1	blank	Code "F".
CDDAY	6-7	I2	0	Day of the value on this record.
CDHOUR	8-9	I2	0	Hour of the value on this record.
CDMIN	10-11	I2	0	Minute of the value on this record.
WIND	16-23	E8.0	0.0	Global wind speed.
DCDID	73-80	A8	blanks	Record identifier (annotation only).

RECORD TYPE G: Wind Direction (ISVWP=0)

See general description under record type F.

Variable	Position	Format	Default	Definition
CDTYPE	1	A1	blank	Code "G".
CDDAY	6-7	I2	0	Day of the value on this record.
CDHOUR	8-9	I2	0	Hour of the value on this record.
CDMIN	10-11	I2	0	Minute of the value on this record.
WINDA	16-23	E8.0	0.0	Global wind direction, in degrees. Wind direction is measured from North, where North equals 0.0 degrees, east equals 90.0 degrees, and so on, clockwise.

```
================================================================================
Variable Position Format    Default         Definition
================================================================================
DCDID     73-80  A8         blanks          Record identifier (annotation only).
```

RECORD TYPE H: Radiation Flux from Surface (ISVWP=0)

> See general description under record type F.

```
--------------------------------------------------------------------------------
CDTYPE    1      A1         blank           Code "H".
CDDAY     6-7    I2         0               Day of the value on this record.
CDHOUR    8-9    I2         0               Hour of the value on this record.
CDMIN     10-11  I2         0               Minute of the value on this record.
KDEXPO    14-15  I2         0               The exponent to apply to value on this record.
QNRFL     16-23  E8.0       0.0             Radiation flux from surface. The E format allows
                                            an exponent; however, more significance can be
                                            attained if the exponent KDEXPO is specified.
DCDID     73-80  A8         blanks          Record identifier (annotation only).
```

RECORD TYPE I: Dry Bulb Air Temperature (ISVWP=0)

> See general description under record type F.

```
--------------------------------------------------------------------------------
CDTYPE    1      A1         blank           Code "I".
CDDAY     6-7    I2         0               Day of the value on this record.
CDHOUR    8-9    I2         0               Hour of the value on this record.
CDMIN     10-11  I2         0               Minute of the value on this record.
TDRYB     16-23  E8.0       0.0             Dry-bulb air temperature.
DCDID     73-80  A8         blanks          Record identifier (annotation only).
```

RECORD TYPE J: Wet Bulb Air Temperature

> See general description under record type F.

```
--------------------------------------------------------------------------------
CDTYPE    1      A1         blank           Code "J".
CDDAY     6-7    I2         0               Day of the value on this record.
CDHOUR    8-9    I2         0               Hour of the value on this record.
CDMIN     10-11  I2         0               Minute of the value on this record.
TWETB     16-23  E8.0       0.0             Wet-bulb air temperature.
DCDID     73-80  A8         blanks          Record identifier (annotation only).
```

RECORD TYPE K: Temperature at Measuring Station

> See general description under record type F.

```
--------------------------------------------------------------------------------
CDTYPE    1      A1         blank           Code "K".
CDDAY     6-7    I2         0               Day of the value on this record.
CDHOUR    8-9    I2         0               Hour of the value on this record.
CDMIN     10-11  I2         0               Minute of the value on this record.
TWMS      16-23  E8.0       0.0             Water temperature at measuring station.
DCDID     73-80  A8         blanks          Record identifier (annotation only).
```

===
Variable Position Format   Default   Definition
===

RECORD TYPE L: Barrier Sill Depth

The initial value of barrier sill depth is given in Part 2. This value persists until interpolation to a new value given here; then that value persists until interpolation to a new value given at a later time for the same barrier.

```
CDTYPE     1      A1      blank          Code "L".
IBUV       2-3    I2      0              Barrier sequence number (the same as IBUV in the
                                         Barrier Initial Input record set in Part 2).
I          4-5    I2      0              Barrier sequence number (the same as I in the
                                         Barrier Initial Input record set in Part 2).
```

Note: I begins at 1 again, for V-barriers.

```
CDDAY      6-7    I2      0              Day of the value on this record.
CDHOUR     8-9    I2      0              Hour of the value on this record.
CDMIN      10-11  I2      0              Minute of the value on this record.
KDEXPO     14-15  I2      0              The exponent to apply to value on this record.
SILL       16-23  E8.0    0.0            Barrier sill depth, in feet or meters.
                                         SILL is positive downwards.
DCDID      73-80  A8      blanks         Record identifier (annotation only).
```

RECORD TYPE M: Barrier Gate Height

The initial value of barrier gate height is given in Part 2. This value persists until interpolation to a new value given here; then that value persists until interpolation to a new value given at a later time for the same barrier.

```
CDTYPE     1      A1      blank          Code "M".
IBUV       2-3    I2      0              Barrier sequence number (the same as IBUV in the
                                         Barrier Initial Input record set in Part 2).
I          4-5    I2      0              Barrier sequence number (the same as I in the
                                         Barrier Initial Input record set in Part 2).
```

Note: I begins at 1 again, for V-barriers.

```
CDDAY      6-7    I2      0              Day of the value on this record.
CDHOUR     8-9    I2      0              Hour of the value on this record.
CDMIN      10-11  I2      0              Minute of the value on this record.
KDEXPO     14-15  I2      0              The exponent to apply to value on this record.
GATE       16-23  E8.0    0.0            Barrier gate height, in feet or meters.
                                         GATE is positive upwards.
DCDID      73-80  A8      blanks         Record identifier (annotation only).
```

RECORD TYPE N: Barrier Effective Width

The initial value of barrier effective width is given in Part 2. This value persists until interpolation to a new value given here; then that value persists until interpolation to a new value given at a later time for the same barrier.

```
CDTYPE     1      A1      blank          Code "N".
IBUV       2-3    I2      0              Barrier sequence number (the same as IBUV in the
                                         Barrier Initial Input record set in Part 2).
I          4-5    I2      0              Barrier sequence number (the same as I in the
                                         Barrier Initial Input record set in Part 2).
```

Note: I begins at 1 again, for V-barriers.

==

Variable	Position	Format	Default	Definition
CDDAY	6-7	I2	0	Day of the value on this record.
CDHOUR	8-9	I2	0	Hour of the value on this record.
CDMIN	10-11	I2	0	Minute of the value on this record.
KDEXPO	14-15	I2	0	The exponent to apply to value on this record.
BRAT	16-23	E8.0	0.0	Barrier effective width or ratio (the fraction of the grid space that is open to flow)
DCDID	73-80	A8	blanks	Record identifier (annotation only).

RECORD TYPE ' ': Blank Record Delimiter

A blank record is given after all of the above card types A to N.

Variable	Position	Format	Default	Definition
CDTYPE	1-72	A72	blanks	Blank record.
DCDID	73-80	A8	blanks	Record identifier (annotation only).

RECORD TYPE Z: Temporary Titles (no longer used)

Temporary titles can be introduced for a given time span, during which they will be displayed on maps, in addition to the permanent titles given in Part 2.

Variable	Position	Format	Default	Definition
CDTYPE	1	A1	blank	Code "Z".
CDDAY	6-7	I2	0	Initial Day to display this title.
CDHOUR	8-9	I2	0	Initial Hour to display this title.
CDMIN	10-11	I2	0	Initial Minute to display this title.
ENDDAY	12-13	I2	0	Day to stop displaying this title.
ENHOUR	14-15	I2	0	Hour to stop displaying this title.
ENDMIN	16-17	I2	0	Minute to stop displaying this title.
TITLM	18-23	F6.0	0.0	The M grid position of the center of the first character in the title.
TITLN	24-29	F6.0	0.0	The N grid position of the center of the first character in the title.
ITICV	30	I1	0	Character font flag.
TITSZ	31-34	F4.0	0.0	Character size. Normal range 1.0-3.0.
TITLW	35-38	F4.0	0.0	Line width of characters in title (0.0=software determined based on character size, maximum=2.0).
TITOR	39-42	F4.0	0.0	Orientation of the title line, in degrees. (0.0=horizontal, 90.0=vertical).
TITLE	43-70	A28	blanks	Temporary title.
DCDID	73-80	A8	blanks	Record identifier (annotation only).

RECORD TYPE ' ': Blank Record Delimiter

A blank record is given to signal the end of record type Z input. This record should be present whether record type Z input is present or not.

Variable	Position	Format	Default	Definition
CDTYPE	1-72	A72	blanks	Blank record.
DCDID	73-80	A8	blanks	Record identifier (annotation only).

===
Variable **Position** **Format** **Default** **Definition**
===

PART 4 RECORDS: TIME- AND SPACE-VARYING WIND AND PRESSURE DATA

Optional Part 4 data are input directly to SWIFT2D in binary format that is not preprocessed by SWIFT_IDP. Part 4 data contains gridded time- and space-varying wind and atmospheric pressure data, input only if the space-varying wind input flag ISVWP is assigned a value of 1 (see ISVWP flag on Record 6 of Part 1 input). Grids of wind and pressure data throughout the computational model domain can be input at regular or irregular time intervals (usually longer intervals than time-varying data in Part 3 because of their greater volume). SWIFT2D interpolates these gridded data across time steps; there is no given time interval or interpolation period for Part 4 input. At least two time steps are needed for interpolation. SWIFT2D spatially interpolates the typically coarser wind and pressure data grids to the computational model grid using wind and pressure grid dimension (IWM, JWM, IPM, and JPM) and ratio (MWF, NWF, MPF, and NPF) variables assigned on Record 16 of Part 1 input. Sets of successive wind and air pressure grids dimensioned (JWM, IWM) and (JPM, IPM), respectively, are input in the following format and order:

Nstw	Binary		Time step at which values apply
Wvel(jwm,iwm)	Binary		Wind speed
Wdir(jwm,iwm)	Binary		Wind direction
Dpdx(jpm,ipm)	Binary		U direction pressure gradient
Dpdy(jpm,ipm)	Binary		V direction pressure gradient

Appendix 3. Sample SWIFT2D In-Stream-Input (*.ctl) and SWIFT_IDP Input (*.idp) Files

Sample In-Stream-Input (*ctl) and Input (*.idp) files are presented for SWIFT2D and SWIFT_IDP, respectively. These sample files for a SWIFT2D model of the Potomac River between Indian Head and Morgantown, Maryland, can be used as guides in defining input parameters and preparing model input to develop other SWIFT2D model applications.

Sample SWIFT2D In-Stream Input (*.ctl) File

```
IBM
/SIM2D-R
 75 10  8  9  0  0  0  0  0  0  0  0  0  0  0  0  0 12 40 15 17 18
POTOMAC 200M MODEL
END HEAD
PRINT     LSEPA=1,LHDIV=0,LINP=60,NCO=133,LFICH=0,NOPLU=0,MCKOUT=00000000
          POTOMAC 200M MODEL
END NOTE
TFMAPF   850.0
TLMAPF   1800.0
MAPMOT                    4
END OVER      0.0        0
```

Sample SWIFT_IDP Input (*.idp) File for the SWIFT2D Model

```
IBM                                                              COMPID
PO200MTZ                                                         HEAD 1
POTOMAC-INDIAN HEAD TO MORGANTOWN MODEL                          HEAD 2
POTOMAC 200M-GRID, SIM RUN #06 USING SIMSYS2D V514               HEAD 3
END HEAD                                                         ENDHEAD
PRINT     LSEPA=1,LHDIV=0,LINP=60,NCO=133,LFICH=0,NOPLU=0,MCKOUT=00000  PRINT
          INDIAN HD TO MORGANTOWN MODEL                          NOTE 1
          200M-GRID, SIM RUN #06 USING SIMSYS2D V514             NOTE 2
END NOTE                                                         ENDNOTE
PO200MTZ                                                         MODELID
INDIAN HEAD TO MORGANTOWN : 200 M GRID : SIM RUN #06              TITLE
POTOMAC RIVER   18 JUN '81                                        DATES
   0.5  15.0 210.0     1815.0 300.0  15.0  15.0 180.0  30.0  60.0  90.0 TIMES A
99999.99999.99999.    75.   30.   15.99999.    0.   30.  360. 1800.    0. TIMES B
      0       0       2       1       0       5       1       4       0       0       1       1 RECRD 6
      7       1       4       4       0       4                                 RECRD 7
      1                                                           RECRD 8
      1       0       0       0       1       0       0       0       0         RECRD 9
      1       0       0       0       0       0       0                         RECRD10
    480     585     765     945    1125    1290    1470    1665    1800          RECRD11
                                                                 RECRD12
                                                                 RECRD13
                                                                 RECRD14
    180     173       1       3       3       0       3       4       3       2       0       0 DIMENSA
                                                                 DIMENSB
              0.4       0                               1         RECRD17
38.375   0.0 200.0 0.230   1.0 0.061   0.3  1.00   0.5   1.0  25.0 300.0 RECRD18
    9.81  0.0026 0.00237  1.9362  1.4667      14.3  1000.0      0.97  0.0023 RECRD19
FR80      35SPRO          1.0   1.0                              RECRD20
     25       1   0.0  13.0  20.0  14.0K/HR               5      RECRD21
    4.0 170.0  2.00 121.0 163.0  1.25  74.0  89.0  1.00 122.0 103.0  1.00 RECRD22
    1.0   2.0   2.0   2.0   2.0                                  RECRD23
      1       1       2   0.5   1.0 -0.40 -0.40  0.25   1.0   0.0       1       1 RECRD24
  99999 99999                                                    RECRD25
```

```
   25.0  1.0000   0.698                                              RECRD26
       15.0                                                          RECRD27
   1   85  151 INDIAN HEAD                                           WLSTN 1
   2   70  157 OCCOQUAN BAY                                          WLSTN 2
   3   85  130 MATTAWOMAN CREEK                                      WLSTN 3
   1   85  151 INDIAN HEAD                                           CURNT 1
   2   70  157 OCCOQUAN BAY                                          CURNT 2
   3   85  130 MATTAWOMAN CREEK                                      CURNT 3
   1   85  151 INDIAN HEAD                                           CONST 1
   2   70  157 OCCOQUAN BAY                                          CONST 2
   3   85  130 MATTAWOMAN CREEK                                      CONST 3
   1   82  139  160INDIAN HEAD                                       UTRAN 1
   2   71    5   17MARYLAND PT                                       UTRAN 2
   3  101   17   31STUART WHARF                                      UTRAN 3
   4  145   38   61MATHIAS PT                                        UTRAN 4
   1  109   43   56QUANTICO                                          VTRAN 1
   2   14  158  175MORGANTOWN                                        VTRAN 2
   3   47   26   50SMITH PT                                          VTRAN 3
                                                                     ENDDAM
                                                                     WINDSD
 1 6110173121173 1    70.0 HALLOWING PT - WEST HALLOWING PT - EAST   OPEN 1
 2 8158  1179  1 1    70.0 MORGANTOWN - WEST   MORGANTOWN - EAST     OPEN 2
 1    0.23 372.0    0.0                                              INIT 1
 2    0.23 372.0   12.0                                              INIT 2
 1     0.0SALINITY          PPT                  0                   CONST 1
 1                                                                   CONST 1
 1    1.0     2.0     3.0     4.0     5.0                            C LINE
      0.05    0.10    0.20    0.5     1.0     2.0     5.0            V LINE
      1.0     2.0     5.     10.     50.    100.    200.    500. 1000.  T LINE
     -0.5    -0.2    -0.1   -0.05   0.001    0.1     0.2     0.5   1.0  Z LINE
   0   0   0   0   0   0   0   0   0   0 -15 -11  -9  -8 -11 -15     DEEP   1
   0   0   0   0   0   0   0   0   0   0  -9  -9  -1  -2  -2 -11     DEEP   2
   0   0   0   0   0   0   0   0   0   0  -9  -9  -1  -2  -2 -11     DEEP   3
.........................................................................
.........................................................................
.........................................................................
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0     DEEP1978
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0     DEEP1979
   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0     DEEP1980
0.005                                                               VISC
                                                                    END VIS
20.00                                                               DIFF
                                                                    END DIF
0.018                                                               MANN
                                                                    END MAN
  0.0                                                               BENT
                                                                    END BEN
   1                                                                CONST 1
   0   0   0   0   0   0   0   0   0   0  20  20  20  20  20  20     CONC   1
   0   0   0   0   0   0   0   0   0   0  20  20  20  20  20  20     CONC   2
   0   0   0   0   0   0   0   0   0   0  20  20  20  20  20  20     CONC   3
.........................................................................
.........................................................................
.........................................................................
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 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0       CONC1978
 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0       CONC1979
 0   0   0   0   0   0   0   0   0   0   0   0   0   0   0   0       CONC1980
                                                                    END CON
                                                                    END TIT
           315.0 99999.0    56.0    136.0       1       1           PART  1
           315.0 99999.0    62.0    133.0       1       1           PART  2
           315.0 99999.0    68.0    130.0       1       1           PART  3
           315.0 99999.0    74.0    127.0       1       1           PART  4
           315.0 99999.0    26.0     65.0       1       1           PART  5
           315.0 99999.0    31.0     65.0       1       1           PART  6
           315.0 99999.0    37.0     65.0       1       1           PART  7
           315.0 99999.0    43.0     65.0       1       1           PART  8
           315.0 99999.0    47.0     65.0       1       1           PART  9
           315.0 99999.0    46.0     10.0       1       1           PART 10
           315.0 99999.0    49.0     13.0       1       1           PART 11
           315.0 99999.0    53.0     17.0       1       1           PART 12
           315.0 99999.0    61.0     25.0       1       1           PART 13
           315.0 99999.0   148.0     40.0       1       1           PART 14
           315.0 99999.0   149.0     44.0       1       1           PART 15
           315.0 99999.0   151.0     50.0       1       1           PART 16
           315.0 99999.0   153.0     65.0       1       1           PART 17
END PART                                                            ENDPART
  156    1                                                          COMP  1
  156   20                                                          COMP  2
  152   20                                                          COMP  3
  152   29                                                          COMP  4
  139   29                                                          COMP  5
  136   26                                                          COMP  6
  136   23                                                          COMP  7
  125   12                                                          COMP  8
  101   12                                                          COMP  9
   94    5                                                          COMP 10
   76    5                                                          COMP 11
   72    1                                                          COMP 12
   45    1                                                          COMP 13
   42    4                                                          COMP 14
    1    4                                                          COMP 15
    1   17                                                          COMP 16
   17   17                                                          COMP 17
   17   37                                                          COMP 18
    1   53                                                          COMP 19
    1   67                                                          COMP 20
   22   67                                                          COMP 21
   22   97                                                          COMP 22
   16   97                                                          COMP 23
   16  106                                                          COMP 24
   26  106                                                          COMP 25
   26  134                                                          COMP 26
   43  134                                                          COMP 27
   43  173                                                          COMP 28
  136  173                                                          COMP 29
  136  163                                                          COMP 30
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 122  149                                                                   COMP 31
 122  139                                                                   COMP 32
 100  139                                                                   COMP 33
 100  122                                                                   COMP 34
  74  122                                                                   COMP 35
  74  109                                                                   COMP 36
  58  109                                                                   COMP 37
  58   35                                                                   COMP 38
  70   23                                                                   COMP 39
  76   23                                                                   COMP 40
  88   35                                                                   COMP 41
 104   35                                                                   COMP 42
 104   59                                                                   COMP 43
 101   59                                                                   COMP 44
  92   50                                                                   COMP 45
  82   50                                                                   COMP 46
  82   61                                                                   COMP 47
  88   61                                                                   COMP 48
 109   82                                                                   COMP 49
 146   82                                                                   COMP 50
 146  101                                                                   COMP 51
 160  101                                                                   COMP 52
 160   62                                                                   COMP 53
 170   62                                                                   COMP 54
 170   38                                                                   COMP 55
 180   38                                                                   COMP 56
 180    1                                                                   COMP 57
 156    1     1                                                             COMP 58
                                                                           ENDCOMP
A   1 1 330 6      .2300    .2300    .2302    .2304    .2308    .2316       BC1    1
A   1 1 5 0 6      .2328    .2378    .2428    .2500    .2600    .2700       BC1    2
A   1 1 630 6      .2900    .3100    .3300    .3450    .3575    .3668       BC1    3
A   1 1 8 0 6      .3683    .3706    .3679    .3600    .3470    .3334       BC1    4
A   1 1 930 6      .3064    .2852    .2508    .2082    .1779    .1412       BC1    5
A   1 111 0 6      .1075    .0723    .0427    .0125   -.0098   -.0327       BC1    6
A   1 11230 6     -.0468   -.0662   -.0775   -.0900   -.1000   -.1067       BC1    7
A   1 114 0 6     -.1103   -.1043   -.0940   -.0853   -.0719   -.0493       BC1    8
A   1 11530 6     -.0170    .0052    .0430    .0686    .1037    .1446       BC1    9
A   1 117 0 6      .1733    .1974    .2280    .2545    .2769    .2988       BC1   10
A   1 11830 6      .3191    .3361    .3630    .3846    .3948    .4160       BC1   11
A   1 120 0 6      .4315    .4459    .4495    .4527    .4491    .4422       BC1   12
A   1 12130 6      .4281    .4099    .3884    .3588    .3245    .3012       BC1   13
A   1 123 0 6      .2751    .2401    .2092    .1819    .1473    .1242       BC1   14
A   1 2 030 6      .0959    .0707    .0512    .0390    .0270    .0200       BC1   15
A   1 2 2 0 6      .0180    .0195    .0313    .0453    .0661    .0928       BC1   16
A   1 2 330 6      .1191    .1503    .1849    .2109    .2463    .2844       BC1   17
A   1 2 5 0 6      .3201    .3599    .3930    .4235    .4463    .4794       BC1   18
A   2 1 330 6      .2300    .2300    .2298    .2296    .2292    .2284       BC2    1
A   2 1 5 0 6      .2253    .2172    .2083    .1935    .1704    .1456       BC2    2
A   2 1 630 6      .1271    .1057    .0808    .0582    .0344    .0133       BC2    3
A   2 1 8 0 6     -.0105   -.0229   -.0370   -.0489   -.0573   -.0609       BC2    4
A   2 1 930 6     -.0645   -.0632   -.0591   -.0493   -.0309   -.0189       BC2    5
A   2 111 0 6     -.0020    .0208    .0485    .0834    .1167    .1507       BC2    6
A   2 11230 6      .1775    .2050    .2361    .2666    .2946    .3130       BC2    7
A   2 114 0 6      .3288    .3423    .3520    .3635    .3751    .3809       BC2    8
```

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A   2 11530 6      .3825   .3799   .3779   .3705   .3593   .3458      BC2   9
A   2 117 0 6      .3289   .3064   .2857   .2638   .2435   .2193      BC2   10
A   2 11830 6      .1914   .1718   .1494   .1298   .1107   .0962      BC2   11
A   2 120 0 6      .0723   .0605   .0457   .0338   .0268   .0212      BC2   12
A   2 12130 6      .0208   .0262   .0335   .0463   .0616   .0856      BC2   13
A   2 123 0 6      .1086   .1380   .1660   .1938   .2262   .2605      BC2   14
A   2 2 030 6      .2991   .3451   .3855   .4222   .4561   .4831      BC2   15
A   2 2 2 0 6      .5110   .5303   .5441   .5578   .5700   .5761      BC2   16
A   2 2 330 6      .5768   .5728   .5681   .5562   .5471   .5380      BC2   17
A   2 2 5 0 6      .5241   .5084   .4842   .4595   .4346   .4182      BC2   18
                                                                     END  IDP
```