

CDFATE User's Manual

(This user's manual was developed for the DOS version of CDFATE (DROPMIX). In general, the Windows and Dos versions are the same, but questions about differences are addressed in the Windows version online help messages.)

DRAFT

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PART 1: INTRODUCTION

Background

Each year several hundred million cubic yards of sediment are removed from rivers, waterways, ports, and harbors within the United States. The primary purpose of these dredging activities is to maintain inland and coastal navigation and coastal defense readiness. Given the nature of dredging operations, the processes involved in removing, transporting, storing, and disposing dredged material must be carefully managed to insure that dredging projects are completed in a cost-effective and environmentally safe manner.

Of central concern in dredging operations is the impact of discharges on the receiving water environment. As such, the creation, migration, and dilution of a discharge plume is of considerable interest as is the size of a required mixing zone for adequate dilution. A mixing zone is a limited volume of water that serves as a zone of initial dilution in the immediate vicinity of the point where material is discharged into the receiving waters. Within this zone, the quality of the receiving waters, once mixed with the discharged effluent, may not meet water quality criteria or standards otherwise applicable to the receiving water. Most states limit the size of the mixing zone, and hence the area where water quality standards may be violated, to as small a size as practical. For example, 17 states restrict the size of the mixing zone in streams to 25% or less of the stream's cross-sectional area (USEPA, 1990).

Several mathematical models are available for estimating the growth and movement of discharge plumes caused by subaqueous emissions. One of these models, the Cornell Mixing Zone Expert System (CORMIX), was specifically developed to provide a predictive tool for conventional or toxic pollutant discharges into waterways. The CORMIX model focuses on the geometry and dilution characteristics of the initial or near-field mixing zone. The CORMIX system consists of three separate modules: 1) CORMIX1, 2) CORMIX2, and 3) CORMIX3. The CORMIX1 module is used to examine submerged single port discharges, the CORMIX2 model is used to address submerged multiport diffuser discharges, and the CORMIX3 program is used to analyze surface discharges from channels.

The CORMIX model was originally developed to address bottom discharges with low suspended solids concentrations. Such discharges are typically associated with municipal wastewater or industrial waste outfalls. Dredged disposal operations, on the other hand, typically involve surface or near-surface discharges with high suspended solids concentrations. Consequently the existing CORMIX package is not directly applicable. However, CORMIX may be used if surface discharges from dredge disposal operations are made equivalent to the mirror image of bottom discharges. This fundamental assumption is the foundation for the Dredging Operations Mixing Zone Model (DROPMIX).

Instead of modifying the existing set of CORMIX programs to analyze surface or near-surface discharges, a separate computer program was developed (Havis, 1994). This preprocessor program takes data describing typical dredge discharge activities and transforms the information into an equivalent mirror-image, bottom-discharge scenario with sedimentation. As a result, the existing CORMIX models are used. However, some slight modifications to the CORMIX output routines is necessary so that results can be referenced back to the original geometry of the surface or near-surface discharge.

Purpose

To address the processes inherent in removal, transport, disposal, storage, and general management of dredged material; the U.S. Army Corps of Engineers, Waterways Experiment Station (USAEWES) has developed a computer package that assists engineers, planners, and dredging operations managers in predicting the fate and behavior of dredged material. The personal computer-based package is called ADDAMS - The Automated Dredging and Disposal Alternatives Management System (Schroeder and Palermo, 1990). ADDAMS consists of a number of individual computer programs, each of which performs a unique function related to dredge material disposal or management. One of the ADDAMS modules is the CDFATE (DROPMIX) computer program.

This document serves as the User's Manual for the CDFATE (DROPMIX) computer program. This manual will provide the necessary guidance so that data files describing various dredge disposal operations can be created, executed, and interpreted. Specifically the program is used to predict the fate and transport of dredged material discharges into a receiving water environment. Results from the CDFATE (DROPMIX) program typically consist of the physical limits of the mixing zone and the concentration of pollutants within the zone. It is assumed that users of the ADDAMS family of programs are already familiar with dredging operations.

Scope

This document is subdivided into four parts. Part 1 provides a brief introduction to the CDFATE (DROPMIX) computer program. Part 2 gives a more thorough discussion of dredged material disposal operations within the context of the CDFATE (DROPMIX) program. Part 3 provides a summary of the data requirements and Part 4 addresses the particular data format required by the CDFATE (DROPMIX) program.

PART 2: DREDGE DISCHARGE OPERATIONS AND THE MIXING ZONE

Dredging Overview

Dredging is the act of removing or excavating sediments from the bottom of bodies of water and is typically performed in order to maintain navigable channels in inland and coastal waterways. Maintaining such channels helps to promote commerce and national defense readiness. The *dredging process* typically refers to the removal, transport, storage, and placement or disposal of dredged material. For any dredging project, each element of the dredging process must be properly analyzed and designed and the various components which comprise the project must be carefully coordinated to insure a successful, cost-effective, and environmentally safe completion of the project.

Sediment can be removed from the bottom of a waterway either through hydraulic or mechanical means. Hydraulic dredges remove sediment in a liquid slurry form through use of a suction pump. The sediment is then pumped from the dredging site to a disposal site or to a transportation vessel such as a hopper barge. Hydraulic dredges are generally used for loosely compacted materials that are easily disturbed. As might be expected, hydraulic dredges also transport large volumes of water through the slurry pipeline.

Because of the high water content associated with hydraulic dredging methods, hopper dredges and scows used in these operations are occasionally filled past their rated volume and are allowed to overflow. In such cases, the heavy material will quickly settle to the bottom of the hopper while fine-grained material is held in suspension. The liquid that is allowed to overflow will typically have a specific gravity very close to water, but may also have a high turbidity (cloudy) and possibly high concentrations of pollutants if the dredged sediment is contaminated. Consequently, environmental concerns may preclude the use of hopper overflow to increase sediment loads.

Mechanical dredges remove bottom material through mechanical or physical means. The material is excavated using backhoes, buckets, draglines, etc., lifted out of the water, and typically placed into a temporary storage facility. Alternately, dredge material may be placed directly into a permanent disposal facility if a suitable site can be found in close proximity to the dredge site. Mechanical dredging activities exhibit the desirable characteristic of removing very little water with the excavated material. Consequently, excavated densities are very close to in-situ densities.

Regardless of how the dredge material is excavated, once the dredged material is removed it must be disposed of in some fashion. There are three major alternatives for dredged material disposal: 1) Open-water disposal, 2) Confined disposal, and 3) Beneficial use. With regard to environmental impacts of disposal on receiving waters, the open-water and confined disposal alternatives pose the greatest risk. As a result, they are described in greater detail in the following paragraphs.

Open Water Disposal. Open-water disposal is the act of placing dredged sediments within water bodies such as rivers, lakes, estuaries, or oceans as shown in Figure 2-1. The dredged material may either be transported directly to the disposal site via a pipeline or the material may be shipped to the site and released from hopper dredges or barges. The discarded material is discharged at or very near the surface of the receiving waters.

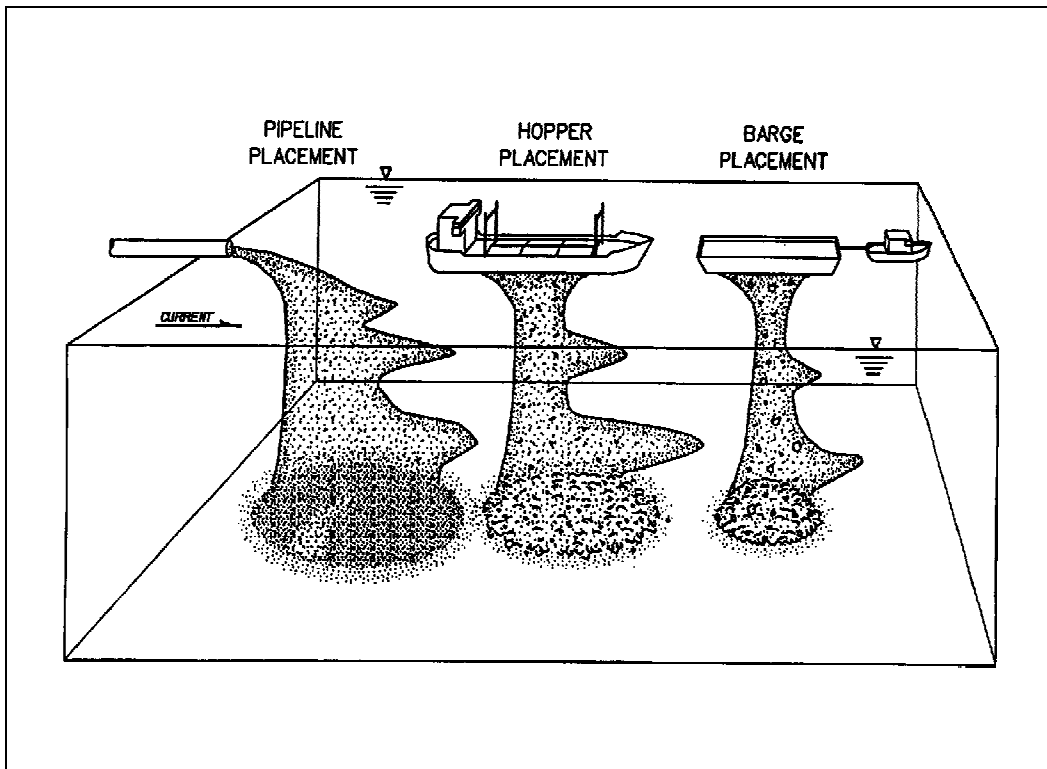


Figure 2-1 Open-Water Dredge Disposal Methods

Because dredged material is generally heavier than water, sediment that is disposed of through open-water means will usually sink to the bottom. Material more dense than the receiving water is said to be *negative buoyant*. Of course the material will not settle to the bottom directly below the point of discharge. As shown in Figure 2-1, receiving water currents may transport the material some distance away from the original discharge point. In addition, the density of the receiving water can also influence the movement of discharged material. Finally, the initial velocity associated with the effluent itself may play a role in the final resting place for disposed sediments. The CDFATE (DROPMIX) computer program can be used to identify the extent over which material discharged into

open waters will migrate due to the receiving water environment and the nature of the open-water disposal method.

Confined Disposal. In some situations open-water disposal of dredged material may not be feasible and the material must be stored in a confined disposal facility (CDF). Generally a confined disposal facility is a man-made structure consisting of dikes which enclose a specific disposal area. As shown in Figure 2-2, CDF's may either be located entirely on the shore (upland), adjacent to the shore (nearshore), or located away from the shore (island). Several very large man-made islands are actually confined disposal facilities for dredged material.

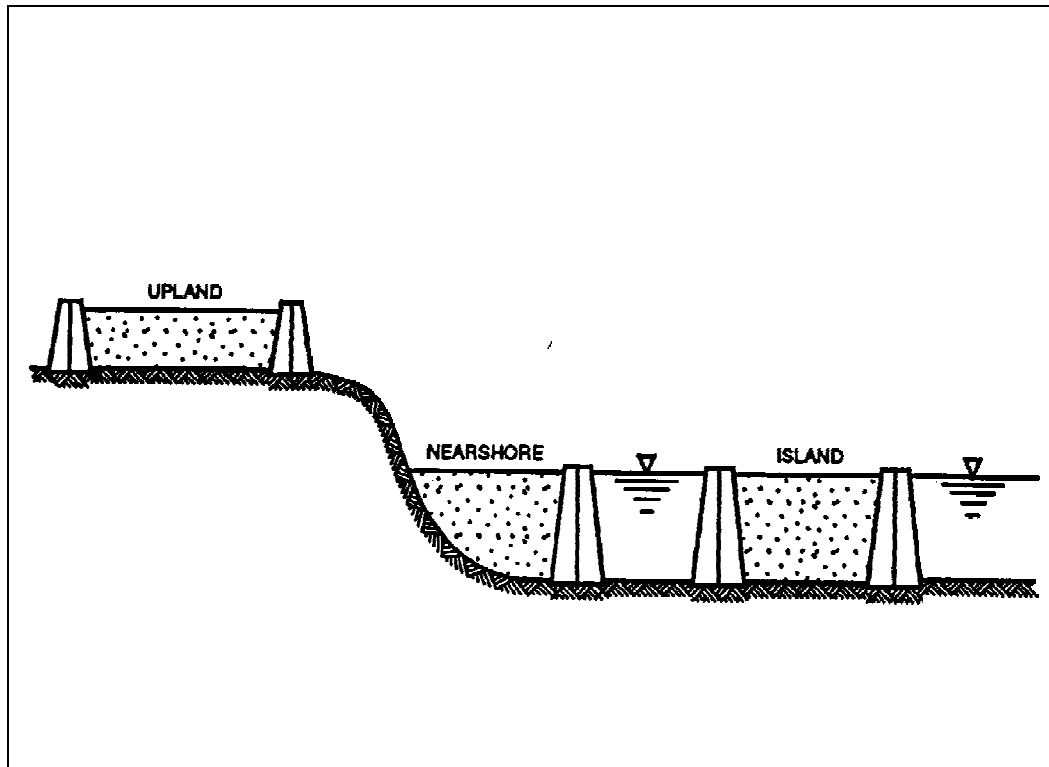


Figure 2-2 Examples Of Confined Disposal Facilities

Dredged material removed by hydraulic or mechanical means can be stored in a CDF. However, because of the high water content associated with hydraulic dredging methods, storage volumes will be greater than if material were excavated using mechanical dredging methods.

Effect Of Disposal On The Environment

Depending upon the means by which dredged material is disposed, there can be varying degrees of impact on the receiving water environment. For example, if a hopper barge is allowed to overflow, then effluent - possibly contaminated, probably highly turbid - will enter the receiving water causing a degradation of water quality in the vicinity of the discharge point. If, on the other hand, a pipeline is used in an open-water disposal project then the quality of the receiving water in the vicinity of the discharge location and possibly at points further downstream will be affected, perhaps more than in the hopper overflow case. Albeit small, even seepage from confined disposal facilities can impact the quality of the receiving waters.

When discharges into a receiving body are made, a pollutant cloud or plume will form. The discharge need not be toxic or highly polluted as suspended solids also degrade water quality. The size, location, and movement of the plume, and hence the impact on the receiving water, can be estimated using the CDFATE (DROPMIX) model. In addition, the program can be used to determine the extent of the mixing zone, that is, that area in the immediate vicinity of the discharge point where water quality parameters may exceed established criteria. Information describing the receiving water environment, the dredged material disposal method, and the mixing zone is provided to the model. The model will use this data in concert with numerical computations to generate information describing the plume location, plume geometry, and pollutant concentration within the plume as a function of time.

Overview Of Hydrodynamic Mixing

Consider a subaqueous outfall from a municipal wastewater treatment plant which discharges into a water body as shown in Figure 2-3. A number of questions regarding the discharge case can be asked. How far will the plume of significant concentration move in the downstream direction? How far will the plume exceeding water quality standards move laterally across the river's cross-section? What is the concentration of a specific pollutant 5, 50, or even 500 meters downstream of the discharge point? If the stream is only 15 meters wide and the mixing zone is restricted to 25% of the stream's width, is this discharge case in compliance? Clearly a myriad of questions regarding the geometric and pollutant characteristics of the discharge scenario can be asked not only by design engineers but by regulating agencies as well.

Fortunately such questions can be answered with the assistance of mathematical models, such as CORMIX, that have been specifically developed to address aqueous discharges of this sort. The major variables needed to quantify the impact of the discharge on the receiving water include:

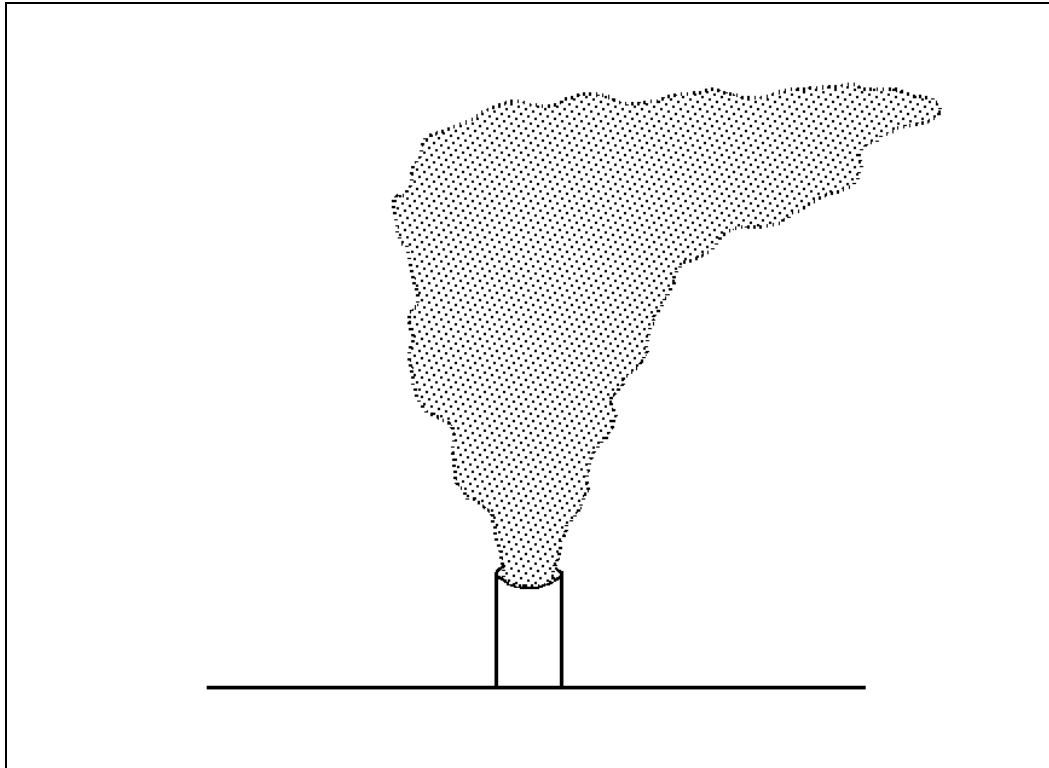


Figure 2-3 Sewage Outfall Discharging Into A River

- The velocity of the receiving water,
- The velocity of the effluent,
- The density of the receiving water,
- The density of the effluent,
- The geometry of the receiving body of water,
- The geometry of the effluent discharge mechanism.

Discharges into a receiving stream may be subdivided into two fundamental classes: a *pure jet* and a *pure plume* (Fischer, et al., 1979, Holley and Jirka, 1986). A pure jet occurs when the discharge into the receiving environment is caused solely by the momentum or velocity associated with the effluent. A pure plume, on the other hand, has NO momentum affiliated with it. Rather the movement into the receiving environment is due entirely to a difference in densities between the effluent and the receiving fluid, i.e. one fluid is lighter than the other. A large number of discharges are a combination of a pure jet and a pure plume. Discharges where both momentum and buoyancy play a role in the shape and movement of the discharge plume are called *buoyant jets* or *forced plumes*. Regardless of the mechanism by which effluent is introduced into the receiving environment, the effluent will generally surge into the receiving fluid thereby forming a cloud or plume.

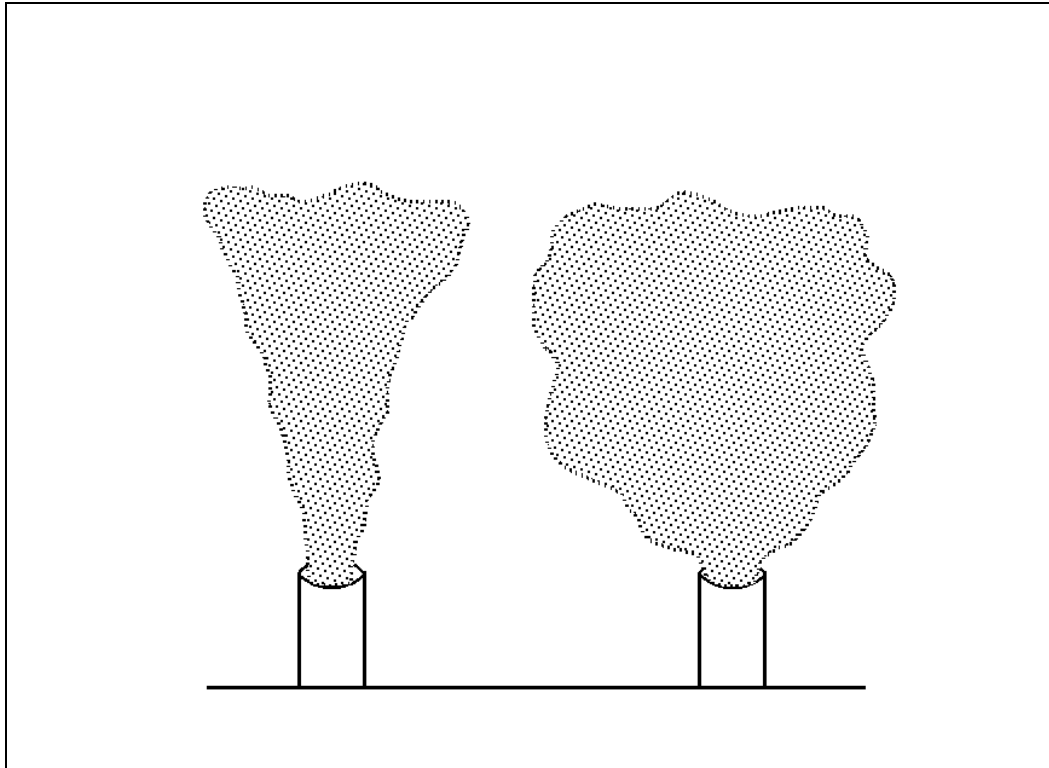


Figure 2-4 Example of a Pure Jet and a Pure Plume

When effluent is released from a discharge mechanism (pipe, diffuser, etc.) the momentum (velocity) affiliated with the effluent will typically dominate over the receiving water velocity. Likewise, the distance the effluent column travels before succumbing to the effects of the receiving water is also dependent upon the buoyancy (density) of the effluent. Discharges that are lighter than water and hence move upwards through the water column are said to be *positively buoyant*. The mixing that occurs in the immediate vicinity of the outfall is dependent upon the characteristics of the effluent and its discharge mechanism. The area where the momentum, buoyancy, and outfall geometry control the shape and size of the discharge plume is termed the *near field*.

As the effluent plume rises, the initial momentum and buoyancy is dissipated and the effects of the receiving water velocity and density become more pronounced. In fact, the plume may begin to bend and will eventually start to disperse due to turbulence associated with the receiving water. The region where the characteristics of the effluent plume are governed by the receiving water environment is called the *far field*.

Once the far field region is encountered, the velocity of the receiving water dominates and the effluent will, in most cases, begin to travel in a downstream direction. In other words, the receiving water current will begin to carry the effluent away. For

most practical problems, the extent of the far field is much larger than that of the near field. Of course the relative sizes of each field is dependent upon the particular discharge and receiving water characteristics, but it is not uncommon for the limits of the near field to be five percent or less of the far field. The CORMIX set of programs will identify where the transition from the near field to the far field occurs.

Near Field Mixing. A very short distance from the outfall mechanism the effluent will begin to mix with the receiving water. As the effluent mixes with the receiving water, the concentration of any pollutants present within the effluent will begin to decrease. In other words, the effluent will become *diluted*. As might be expected, the concentration of any pollutant will generally decrease as the distance from the mouth of the discharge mechanism increases. In fact, the dilution for a pure jet is linearly proportional to the distance from the discharge point. For a pure plume, the dilution varies with the distance squared. Thus for a buoyant jet, that is, a discharge case that has both initial momentum and buoyancy, the pollutant concentration will decrease with distance at a rate that varies between the rate for a pure jet and a pure plume.

Within the near field not only does the pollutant concentration decrease along the plume trajectory, but the pollutant concentration also radiates outward perpendicular to the trajectory as illustrated in Figure 2-5. Generally the concentration profile exhibits a Gaussian or Normal probability distribution as it radiates outward from the trajectory centerline. Regardless of the distance from the discharge point, the maximum concentration can be found at the centerline of the plume trajectory and lower concentrations normally exist at radial distances from the centerline.

Far Field Mixing. Once the effluent momentum has sufficiently dissipated, then the effluent is said to be in the far field and far field mixing processes further dilute the effluent pollutant concentration. There are two mixing processes at work in the far field 1) buoyant spreading and 2) passive diffusion. Buoyant spreading precedes diffusion and is caused by the relative density differences of the now-mixed effluent and the receiving waters. Doneker and Jirka (1990) indicate that four types of spreading may occur, an example of which is shown in Figure 2-6.

- 1) Spreading at the water surface,
- 2) Spreading at the bottom,
- 3) Spreading at a sharp internal density interface (pycnocline or thermocline),
- 4) Spreading at the terminal level

However, if the effluent is nonbuoyant or weakly buoyant, or there are no pronounced density differences within the receiving water, then buoyant spreading will not occur and any additional mixing beyond the near field will be due entirely to passive diffusion. In other words, the turbulence associated with the receiving waters will cause

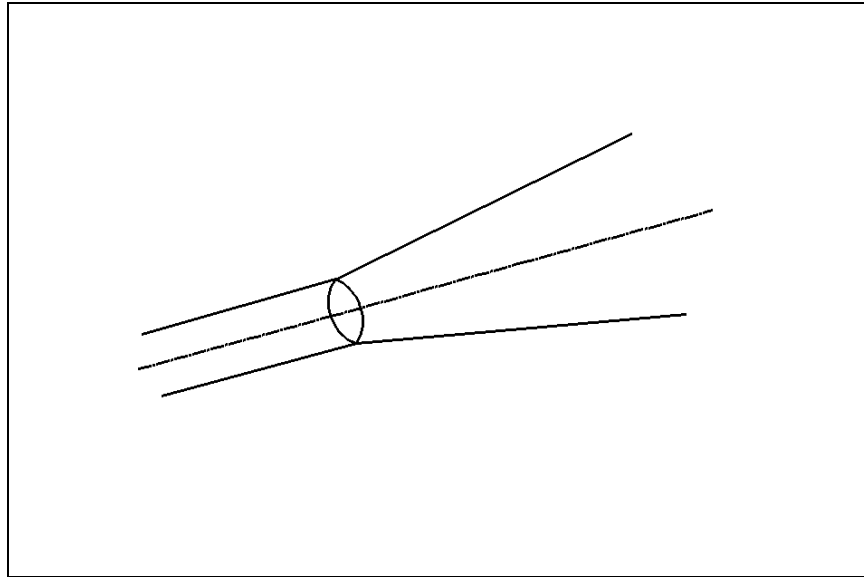


Figure 2-5 Velocity and Concentration Profile In The Near-Field

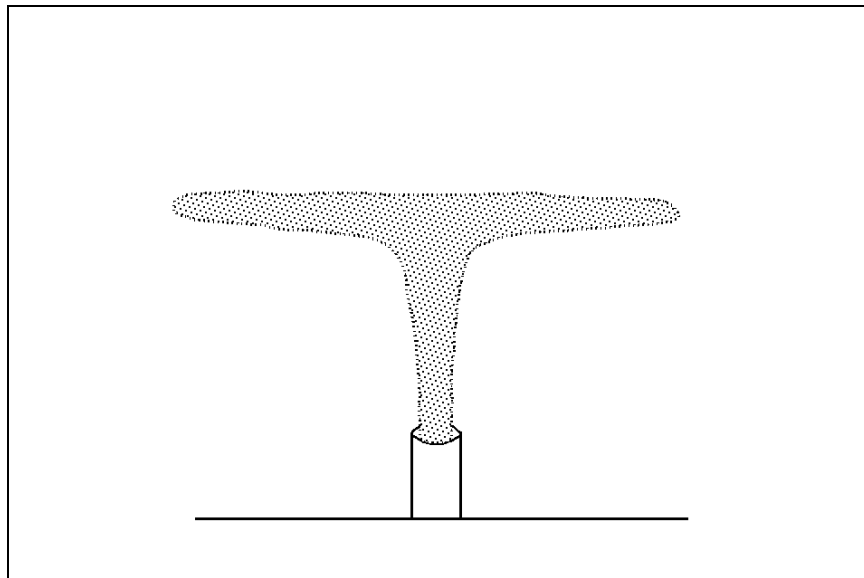


Figure 2-6 Example Of Buoyant Spreading

further dilution of the effluent.

Like near field mixing, mixing within the far field will occur in a longitudinal direction parallel to the receiving water current and in a direction perpendicular to the current. It is extremely important to point out that the geometry of the receiving water plays a major role in far field mixing since it is possible that the effluent may come in contact with and attach itself to the bank or receiving water bottom.

Application To Dredging Operations

The description of hydrodynamic mixing presented above is valid for subaqueous bottom discharges that are commonly associated with point source emissions from industry or municipalities. Dredging operations, on the other hand, involve discharges that occur at or very near the receiving water surface. Fortunately the mixing behavior of *negatively buoyant surface discharges* can be fully described by the physics of *positively buoyant bottom discharges*. The fundamental assumption which allows bottom discharges to be used to model surface discharges can be stated as follows.

Negatively-Buoyant Surface Discharges = The *Mirror Image* of
Positively-Buoyant Bottom Discharges

In order for results to be meaningful, however, the boundary conditions of the surface discharge problem must be transformed to remain consistent with the equivalent boundary conditions for the bottom discharge problem.

This is the approach taken in the CDFATE (DROPMIX) computer model. The mixing characteristics of surface or near-surface dredge-related discharges into receiving waters are modeled by transforming the problem into an equivalent bottom discharge problem. This is accomplished by creating a mirror image of the surface discharge problem using a preprocessor program (Havis, 1994). The preprocessor program generates a data file representing the equivalent bottom discharge case for the CORMIX model. CORMIX analyzes the bottom discharge case to generate information on the mixing zone and pollutant plume. This information includes the location and concentrations of effluent within the receiving waters.

The majority of effort required to transform a surface discharge case into an equivalent mirror image bottom discharge scenario is affiliated with the effluent and receiving water densities. For the CORMIX routines, receiving water density profiles are referenced to the receiving water bottom. However for dredged material disposal, density differences are referenced to the water surface. Also the CORMIX programs reference step density changes to the bottom. Once again a transformation must be made to reference any step changes to the surface.

Dredge Discharge Mechanisms

Six types of surface or near-surface discharges are accommodated by the CDFATE (DROPMIX) program. Each discharge case is described in greater detail in the following paragraphs.

- 1) Pipeline Slurry Discharges
- 2) Hopper Overflow Discharge - Single Port
- 3) Hopper Overflow Discharge - Weir Flow
- 4) CDF Effluent Discharge Via Channel/Side Stream
- 5) CDF Effluent Discharge Via Pipe
- 6) Containment Dike Leakage

Pipeline Slurry Discharges. A common disposal method, particularly for open-water disposal operations, is to discharge dredged material through a pipeline. Pipeline discharges of this sort are most commonly used in concert with hydraulic dredging operations. The pipeline transports the dredged slurry a reasonable distance from the dredging site to a location where its deposition will not interfere with navigation or other uses of the water body. Effluent from a pipeline will typically have a much higher concentration of suspended solids than the receiving water. The effluent could also contain heavy metals, toxins, or other pollutants that have previously settled to the bottom of the dredged channel and adsorbed to the sediment.

When effluent discharges from a pipeline, it will typically find its way to the bottom of the receiving water. This may be accomplished by directing the outlet of the effluent pipe downwards towards the bottom of the receiving waters. More likely, however, the nature of the negatively buoyant effluent will cause the material to sink to the bottom. Regardless of the bottom-forcing mechanism, when the effluent plume strikes the bottom, it will begin to disperse or fan-out. Furthermore, the momentum associated with the sinking effluent could disturb dredged material which has previously settled to the bottom thus increasing the size of the dispersion plume.

The approach used to model pipeline discharges and subsequent bottom collapse-induced mixing involves use of both the CORMIX1 and CORMIX2 modules. That portion of the mixing from the mouth of the pipeline to the receiving water bottom is modeled using the CORMIX1 program within a mirror image framework. Any subsequent mixing that occurs after the plume strikes the bottom is modeled assuming that the flow resembles flow through a multi-port diffuser. Thus the CORMIX2 module is used; however, in this case there is no mirror image transformation since the discharge originates at the bottom of the receiving water.

Hopper Overflow Discharges. As mentioned previously, a hopper barge may be allowed to overflow in order to increase the sediment load carried by the vessel. This has proven to be an effective method for coarse-grained sediments although for fine-grained material the effectiveness of this approach is questionable (USACE and USEPA, 1992). When the barge overflows, sediment-laden water leaves the vessel and enters the receiving water. Not only is the effluent likely to have a higher turbidity than the receiving water, but because it has been in contact with the dredged material it may also have trace concentrations of heavy metals, toxins, or other pollutants.

Hopper barges typically overflow in an uncontrolled manner. The flow may be over one or more sides of the vessel and generally resembles flow over a weir. In some cases, the flow over the sides is collected and routed to a common point where it is discharged through a single pipe. When a hopper is used in conjunction with hydraulic dredge operations a steady-state condition may assume to exist. In other words, the flow rate over the sides of the barge is equal to the rate at which sediment is pumped to the vessel. The assumption of steady-state conditions is made in the CDFATE (DROPMIX) program for the hopper overflow case. For the single port discharge, hopper overflow is modeled using the CORMIX1 program; whereas, CORMIX2 is used for uncontrolled weir-type discharges. In both instances, however, a mirror image transformation is made.

CDF Effluent Discharges. Confined disposal facilities are engineered structures, and as such, they are typically equipped with outlet devices that decant excess water generated by the hydraulic dredging process. An example of such an outlet structure would be a culvert passing through the dike face. Because the excess water comes in contact with the disposed material, it is possible that the effluent has higher concentrations of suspended solids or other pollutants than the receiving water. Usually the outlet structure represents a single point discharge and as a result the CORMIX1 module may be used. For effluent discharges from confined disposal facilities via a single pipe, CDFATE (DROPMIX) uses the CORMIX1 module with a mirror-image transformation.

For upland CDF's, that is, those structures that are not located adjacent to open waters; the effluent is usually discharged into a receiving stream having little or no continuous flow. In fact, the discharge from the CDF may represent the greatest fraction of flow within the stream. The stream, in turn, typically discharges into a much larger body of water such as a river, estuary, or ocean. Like pipeline discharges, hopper overflows, and direct CDF discharges, channel discharges can also degrade receiving water quality. The CORMIX3 module is used to analyze channel or side stream discharges from upland containment facilities. CORMIX3 was developed specifically to evaluate aqueous mixing of surface discharges and, as a result, no modifications of the discharge scenario is necessary.

Seepage From Confined Disposal Facilities. When a confined disposal facility is used to store dredged material, the material may initially have a high water content especially if used in hydraulic dredging operations. Although the sediment may eventually dewater (dry out), a combination of factors including hydraulic gradients, weight of the sediment, and porosity of the dike will cause effluent to leak from the containment facility. In addition, infiltrated precipitation will recharge the zone of saturation such that leakage from the facility may continue long after the initial sediment moisture content has decreased.

Admittedly the flow or velocity through the CDF's porous dikes will be small and occur over very large distances compared to the other disposal cases described above. Nonetheless, the flow through the CDF can degrade water quality and as a result merits examination. In CDFATE (DROPMIX), flow through a porous dike is modeled assuming that the dike acts as a multi-port diffuser. Consequently, the CORMIX2 module is used to predict pollutant concentrations within the receiving water.

PART 3: DATA REQUIREMENTS AND PROGRAM OUTPUT

Program Limitations and Assumptions

In order for CORMIX to accurately simulate subaqueous discharges, the effluent must represent a continuous steady-state discharge. In addition, steady-state flow within the receiving water must exist. Of course the condition of continuous flow is relative to the time over which mixing occurs. For example, a hopper overflow will not be "truly continuous". Operations - and hence discharges into the receiving water - will cease after the hoppers have filled. However, the duration over which overflow occurs, on the order of hours, is typically much larger than the duration over which initial dilution occurs, on the order of minutes or even seconds. Moreover, the travel time within the regulatory mixing zone is typically less than one hour. Furthermore, a second barge may begin to overflow relatively shortly after the first barge thus preserving the assumption of continuous flow. Consequently the assumption of continuous discharge is assumed to be valid.

With regard to the assumption of steady-state flow, flow through a pipeline or over a weir will not be "truly steady" due to minor variances in the flow rate. However, the time over which these variances occur is generally small compared to the time over which mixing occurs. Thus the assumption of steady-state flow is assumed to hold. Not only is the flow presumed to be steady, but the receiving water velocity is assumed to be uniform, that is, the velocity exhibits the same magnitude everywhere over its entire cross-section.

Changes in receiving water velocities associated with tidal effects may be ignored since these occur over much longer periods of time than mixing occurs (hours vs. minutes). Alternatively, if long-term mixing results are desired, then it is possible to conduct a quasi-steady analysis. Typically in these cases the results from prior steady-state analyses are used as boundary or initial conditions for subsequent analyses.

Mixing within the receiving water is assumed to be due solely to hydrodynamic processes. In other words, dilution of the effluent concentrations is assumed to be the result of the interactions between effluent and receiving water velocities, densities, and geometries. The original CORMIX modules assume that the pollutant is a conservative species and that any physical, chemical, or biological reactions or decay processes do not exist. However, modifications to the program have incorporated first-order reaction processes (Havis, 1994). Field studies suggest that results of CORMIX simulations accurately predict the mixing and the subsequent migration of contaminant plumes (Doneker and Jirka, 1990).

CORMIX assumes that regardless of its natural cross-section, the receiving water body can be modeled as a rectangular channel as shown in Figure 3-1. For many artificial waterways and well-channelized natural streams, this assumption is clearly valid and hence selection of receiving water geometry (channel width and depth) is rather straightforward. However for natural streams having irregular cross-sectional geometry, selection of this data is not as apparent. Consequently, engineering judgement plays a major role in identifying channel geometry. The astute program user will conduct multiple simulations varying channel geometry to obtain an intuitive feel for the sensitivity between model input and output.

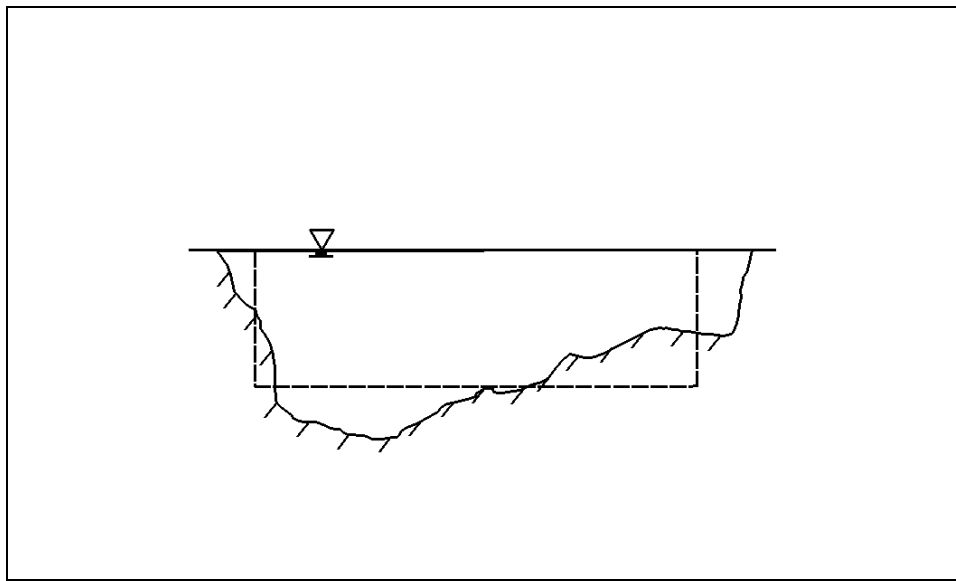


Figure 3-1 CORMIX Representation of a Natural Channel Cross-Section

Input Data Requirements

The primary function of CDFATE (DROPMIX) is to analyze mixing of effluent from dredging operations discharging into inland and coastal waterways and at ocean dumping sites. The model can accommodate six discharge scenarios:

- 1) Pipeline Slurry Discharges
- 2) Hopper Overflow Discharge - Single Port
- 3) Hopper Overflow Discharge - Weir Flow
- 4) CDF Effluent Discharge Via Channel/Side Stream
- 5) CDF Effluent Discharge Via Pipe
- 6) Containment Dike Leakage

Given information describing the receiving water conditions, the characteristics of the effluent and the manner in which it is disposed, and general information on initial pollutant concentrations; CDFATE (DROPMIX) will determine the dilution characteristics of the effluent-receiving water environment. Program output includes the centerline concentration of a pollutant along the trajectory of the contaminant plume and the degree of lateral dispersion perpendicular to the plume trajectory.

CDFATE (DROPMIX) utilizes the CORMIX suite of computer programs to analyze mixing. Since discharges associated with dredging operations typically occur at or very near the surface, a mirror image transformation is made. Using a numerical preprocessing program, a negatively-buoyant surface discharge is converted to an equivalent positively-buoyant bottom discharge. This mirror image discharge is then analyzed by the CORMIX modules. Modifications to the output routines in the CORMIX programs have been made so that program output is referenced to the surface.

The data required to perform a complete mixing zone simulation can essentially be subdivided into three categories:

- 1) Data describing the receiving water environment,
- 2) Data describing the effluent and its discharge mechanism,
- 3) Data describing the mixing zone.

Each of the individual data requirements are described in greater detail in the following paragraphs.

All data supplied to the CDFATE (DROPMIX) program must be given in *METRIC* units.

Receiving Water Data

There are three major data items which fully describe the receiving water environment: 1) density, 2) velocity, and 3) geometry. CORMIX will determine if an effluent plume comes in contact with or attaches to a boundary such as the bank of a river or the bottom of a lake. Consequently information describing the presence of boundaries, receiving water depths, bottom roughnesses, and degree of channel meandering are required. Also required are the mean channel velocity and mean wind speed. Finally data describing the receiving water density profile must be provided.

The receiving water may exhibit one of three density profiles: 1) Uniform, 2) Linearly varying, or 3) a Two-Layer or Pycnocline profile. For the uniform profile, the receiving water density is assumed to remain constant throughout its depth. With the

linear profile, on the other hand, density is assumed to vary linearly from the surface density to the bottom density as illustrated in Figure 3-2. The final density profile assumes a uniform two-layer density separated by a step located a specified distance from the receiving water bottom. Density information may be specified directly or computed by the program based on user-specified depth, salinity, and temperature.

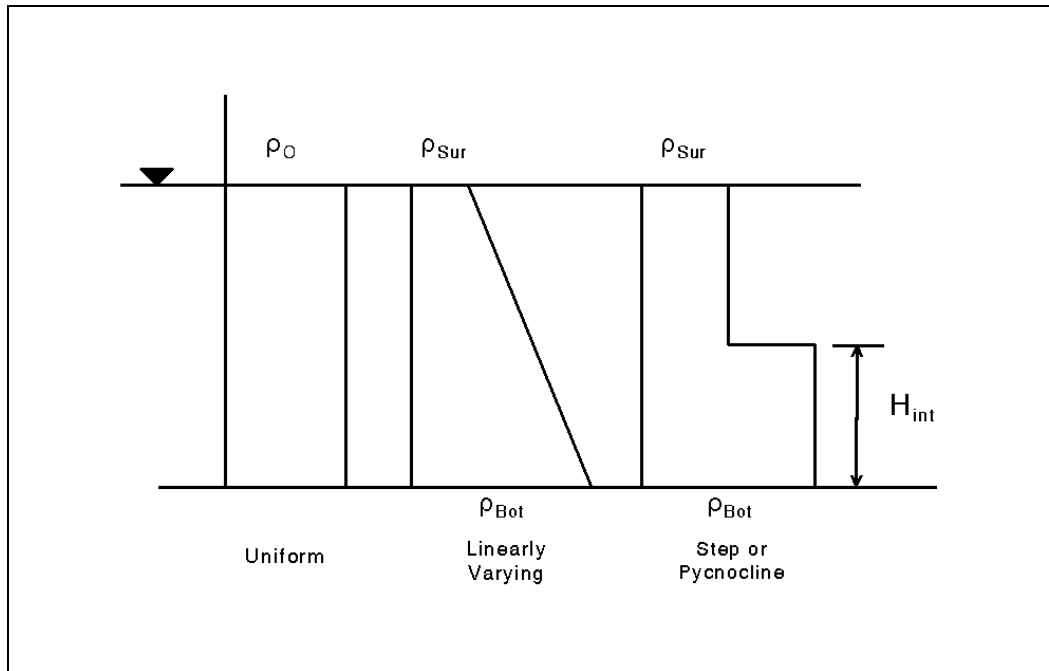


Figure 3-2 Possible Receiving Water Density Profiles

Receiving water velocity is specified directly by the program user. It is assumed that information on channel velocities would be more readily available than data describing receiving water discharges. The specified velocity represents the mean velocity acting uniformly over the width and depth of the receiving water body. In addition, the velocity is assumed to be constant over the duration of the simulation. The mean wind speed must also be specified to account for mixing effects from wind-induced turbulence. CDFATE (DROPMIX) allows users to indicate if the wind speed is low, medium, or high. Depending upon the wind conditions specified by the program user, CDFATE (DROPMIX) will assign a value of 0 m/s, 2 m/s, or 15 m/s respectively to the wind speed.

CORMIX has the ability to indicate if the effluent plume comes in contact with and attach to the receiving water banks or bottom. Obviously the potential for bank contact and attachment is higher for narrow channels, such as rivers and streams, than for wider bodies of water, e.g. lakes, bays, and coastal areas. In addition, diffusivity

coefficients - which control far-field mixing - differ for narrow and wide water courses. Thus CORMIX requires information on whether the receiving water is *bounded*. As the name implies, a bounded channel is one where the receiving water channel is bounded on both sides by banks. Examples of bounded channels include rivers, streams, or even narrow harbors. Examples of unbounded channels include wide lakes, estuaries, and coastal areas. In some cases it may not be clear whether the receiving water is bounded or unbounded. Under these circumstances the program-user should perform multiple simulations assuming bounded and unbounded conditions and make appropriate engineering decisions accordingly.

Receiving water geometry is also described by the average or mean depth and the bottom roughness. As mentioned previously, CORMIX assumes that the receiving water body can be characterized as a rectangular channel. Thus the depth specified by the program user represents the depth of the rectangular section. Bottom roughness values may be specified either in terms of Manning's "n" value or a Darcy-Weisbach friction factor "f". Table 3-1 lists receiving water variable names and a brief description of their meaning.

Table 3-1 Description of Receiving Water Variables

Variable Name	Description	Notes
CBOUND	Indicates if receiving body of water is bounded	
ICHREG	Indicates degree of channel meandering	1
BS	Width of rectangular channel cross-section	1
HA	Mean depth of rectangular channel cross-section	
MANN	Manning's "n" for bottom roughness	2
F	Darcy-Weisbach friction factor "f" for bottom roughness	2
UA	Mean velocity of receiving water	
UW	Mean wind speed	
STRCND	Indicates type of density profile	3
RHOA	Density for Uniform density profile	
RHOAS	Surface density for Linear or Two-Layer density profile	
RHOAB	Bottom density for Linear or Two-Layer density profile	
HINT	Distance from bottom of water body where density step occurs	4

Notes:

1) If the receiving water body is unbounded, then the degree of channel meandering and the width of the channel does not have to be specified. These variables are only applicable to for bounded channels.

2) The user must specify either Manning's roughness "n" or Darcy-Weisbach friction factor "f". If Manning's "n" is given, then the preprocessor will convert it to an equivalent Darcy-Weisbach friction factor.

3) The following convention is adopted for density profiles:

U - Uniform Density Profile

A - Linearly-Varying Density Profile

B - Two-Layer or Pycnocline Density Profile

4) The distance above the receiving water bottom where the pycnocline occurs must only be specified for a Two-Layer or Pycnocline Density Profile.

Dredged Material Disposal Operations Data

Dredged material disposal data generally refers to the physical characteristics of the discharged effluent and its discharge mechanism. As mentioned earlier, six dredged material disposal mechanisms can be analyzed with CDFATE (DROPMIX). Although there is certain data that is unique to each discharge case, the information required to describe the dredging operations environment is very similar to that of the receiving water. Information needed to fully describe the disposal operations are: 1) effluent density, 2) effluent velocity, 3) geometry of the effluent discharge device, and 4) orientation of the effluent discharge mechanism with respect to the receiving water current.

Unlike the receiving water, the dredge effluent is not allowed to have multiple densities. The density of the effluent is initially assumed to be greater than the surface density of the receiving water so as to preserve negatively buoyant conditions. This will typically result in the effluent continuing to sink to the receiving water bottom even after the initial effluent momentum is dissipated. However, it is possible that as the effluent plume migrates towards the bottom, the density of the diluted effluent and the density of the surrounding water will converge. Under these circumstances it is possible that the effluent plume will cease to move downward and will begin to disperse laterally in a direction parallel to the channel bottom as shown in Figure 3-3. CORMIX will model lateral spreading of this sort. Within the CDFATE (DROPMIX) program, effluent density may be specified directly, or computed based on user-supplied data describing the effluent fluid density and the concentration and density of solids within the effluent.

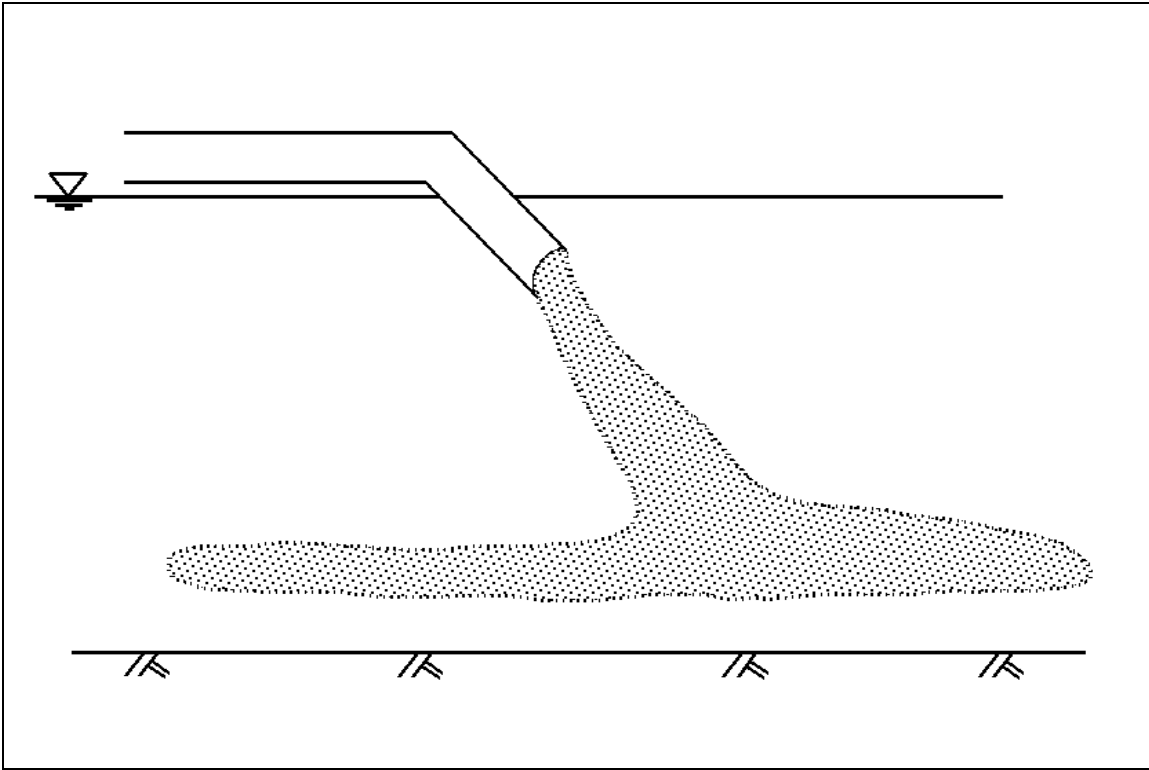


Figure 3-3 Lateral Spreading Caused By Density Differences

In addition to the effluent density, CDFATE (DROPMIX) requires the user to supply the velocity of the effluent exiting from the discharge mechanism. In a practical sense the velocity of flow over the sides of a barge or through a dike, pipeline, or channel is rarely known. What is typically known, however, is the effluent flow rate. Consequently, CDFATE (DROPMIX) does not allow entry of effluent velocities. Rather an effluent discharge rate is required and the program will convert the user-provided flow rate into an equivalent velocity using the continuity equation shown below:

$$U_0 = \frac{Q_0}{A_0} \quad (1)$$

where: U_0 = Effluent Velocity (m/s)
 Q_0 = Effluent Discharge (m^3/s)
 A_0 = Area Over Which Discharge Occurs (m^2)

Pipeline Slurry Discharge. Concerning effluent velocities, the pipeline slurry discharge case requires data that quite possibly is the easiest of the six discharge cases to obtain. The user must specify the flow rate through the pipeline. Since pipeline

discharges are most frequently used in hydraulic dredging operations, the pipeline flow rate may assumed to be equal to the hydraulic dredge pumping rate. The program user must also specify the diameter of the pipe. The effluent velocity is then easily found by employing the continuity equation.

The pipeline slurry discharge case is simulated in CDFATE (DROPMIX) as a combination of a single port discharge followed by a multi-port diffuser discharge. Consequently, information describing the physical characteristics of the multi-port diffuser must be provided. Diffuser information includes the length of the diffuser, the number of diffuser ports, and the diameter of each port.

Hopper Overflow Discharges. For the hopper overflow case, the rate at which effluent leaves the barge is assumed to be equal to the pumping rate of the hydraulic dredge. Hopper overflows resulting from mechanical dredging operations should not be simulated with the CDFATE (DROPMIX) model. Receiving water effects from barge, scow, or other vessel overflows are found assuming that effluent leaves the vessel as: 1) weir flow or 2) flow through a single pipe or port.

As mentioned previously, hoppers are frequently allowed to overflow in order to increase the sediment load carried by the vessel. Usually the overflow is uncontrolled, that is, flow is allowed to spill over one or more sides of the vessel. In some cases, however, the overflow is captured and routed to a common point on the vessel where it is then discharged, generally through a pipeline, into the receiving waters. For overflow discharged through a single port, the velocity of the effluent is found using the continuity equation assuming that the port is a circular pipe. As a result, the user must supply the overflow rate and the diameter of the pipe.

CDFATE (DROPMIX) can also simulate uncontrolled overflows assuming that the flow acts as weir flow. Once again the continuity equation may be used to determine the effluent velocity; however, the unknown in this case is the area over which flow occurs. If the overflow rate and the length over which flow occurs is known, then the height or head above the "weir" can be found by the weir equation:

$$H_w = \left(\frac{Q_0}{C_w L_0} \right)^{2/3} \quad (2)$$

where: H_w = Height of Effluent Above the Weir (m)
 Q_0 = Effluent Discharge (m^3/s)
 L_0 = Hopper Overflow Length (m)
 C_w = Weir Coefficient ≈ 1.88

Once the height above the weir is known, then the flow area is simply the product of the overflow length, L_0 , and the weir height as shown below:

$$A_0 = L_0 H_w \quad (3)$$

CDF Effluent Discharges. CDFATE (DROPMIX) assumes that direct effluent discharges, not seepage, from confined disposal facilities is either routed immediately to the receiving water through a single pipeline or is transported through a channel or side stream for ultimate disposal into the receiving waters. In either case, the velocity of the effluent is required in order to perform the mixing zone simulation.

For the case of CDF effluent disposal via a pipeline, CDFATE (DROPMIX) requires the program user to supply data on the discharge from the CDF and the diameter of the pipeline. This information is used with the continuity equation to determine effluent velocity. Discharge from a CDF will primarily be due to displacement of supernatant by the dredged discharge and can generally be assumed to be equal to the rate at which material is discharged into the CDF, i.e. steady-state conditions. Use of the continuity equation shown in Eq. (1) implies that the pipeline is flowing full during discharge events.

The velocity within a stream or open channel can also be found using the continuity equation. The program user must supply the channel discharge and geometry. For the case of a side stream, the discharge within the waterway can be found from a hydrologic analysis of the CDF and any surrounding areas which contribute flow to the channel.

Two types of open channels are supported by the CDFATE (DROPMIX) program: 1) rectangular channels and 2) circular pipes. For the rectangular channel, the channel width and depth of flow must be provided. The product of these two quantities is the flow area which is used in the continuity equation to obtain the effluent velocity. For circular pipes, the pipe diameter and depth of flow are specified by the program user.

CDFATE (DROPMIX) treats circular pipes flowing partially full as rectangular channels with comparable depths and cross-sectional areas. For a set of given pipe characteristics (diameter and depth of flow), one may determine a congruent rectangular channel by equating the area of both sections and solving for the depth of flow in the rectangular channel. For a given discharge, the equation below provides an expression for the flow depth in a rectangular channel which will have the same area and velocity as a pipe flowing partially full.

$$y_{ch} = \frac{D^2(\theta - \cos\theta \sin\theta)}{4B} \quad (4)$$

where:

- y_{ch} = Depth of Flow in a Rectangular Channel (m)
- B = Width of Rectangular Channel (m)
- D = Pipe Diameter (m)
- θ = Central Angle (rad) = $\cos^{-1}(1-2y_p/D)$
- y_p = Depth of Flow in a Circular Pipe (m)

Eq. (4) will allow an equivalent depth in a rectangular channel, y_{ch} , to be computed based on a pipeline that is flowing partially full at a depth of y_p . However, in order to compute y_{ch} , the width of the rectangular channel, B , - which is not known - must be supplied. Consequently the program user must supply an assumed value for the rectangular channel bottom width and compute the depth of flow accordingly. The approach outlined above will insure that the velocity in the rectangular section is the same as the velocity in the circular pipe for the same effluent discharge rate. This is key since effluent velocity and not effluent discharge is the critical parameter in evaluating receiving water quality effects.

Channels used to transport releases from upland CDF's to receiving waters may be natural or man-made. In either case, it is quite possible that the channel will not exhibit a true rectangular shape. Under these circumstances, an equivalent rectangular cross-section must be provided. An analysis similar to the one described above can be used. The cross-sectional area of the actual channel and a rectangular channel are equated and solved assuming a fixed bottom width. The solution will provide the flow depth such that both channels have the same velocity.

Seepage From Confined Disposal Facilities. For the case of leakage from a confined disposal facility, the user must specify the total discharge through all porous dikes which contribute flow to the receiving waters. However, this may not include each and every side of the facility. At present, CORMIX is unable to model counter-flowing discharges, that is, discharges where the effluent direction is opposite the receiving water direction. Figure 3-4 shows a three-sided nearshore CDF used to store dredged material. Of the three sides, side A opposes the current; whereas, sides B and C do not. Consequently, the discharge supplied to the CDFATE (DROPMIX) model must reflect the seepage through sides B and C. It is the responsibility of the program user to supply accurate estimates of flow through the porous dike. One possibility is to employ Darcy's Law or use flow nets to estimate leakage through the contributing sides of the facility.

Leakage through a porous dike is modeled with the CORMIX2 module assuming that flow through the dike behaves similarly to flow through a multi-port diffuser. As a result, information describing the multi-port diffuser must be provided - namely the

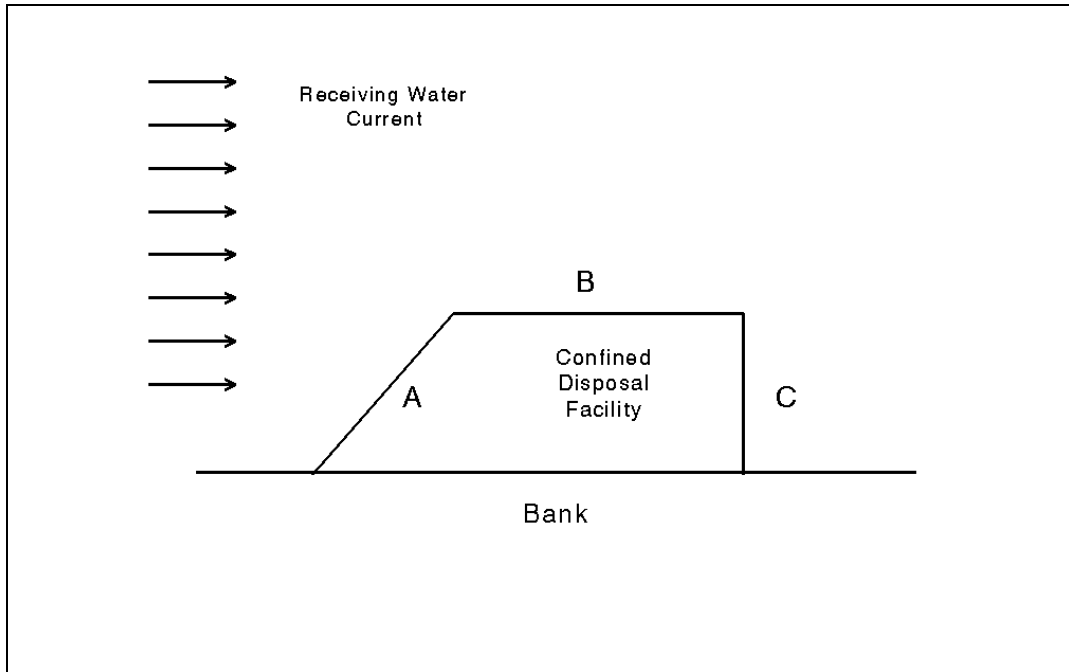


Figure 3-4 Dike Leakage Case

number of diffuser ports, the diameter of the individual ports, and the length of the diffuser. It is assumed that each port has the same diameter.

Because of the wide variability in potential diffuser characterization and the somewhat unwieldy data requirements associated with diffuser depiction, CDFATE (DROPMIX) takes a simplistic approach when describing diffusers used to simulate dike leakage. First, the number of diffuser ports is assumed to be 10,000. Secondly, the velocity of the effluent seeping from a CDF is assumed to be 0.02 m/s. Using this information with the total leakage rate, the diameter of the individual diffuser ports can be found from the equation below. The length of the diffuser may be specified directly or can be determined automatically by the program. The next section provides details on diffuser lengths.

$$D_0 = \sqrt{\frac{4Q_T}{N_p \pi U_0}} \quad (5)$$

where:

- D_0 = Diffuser Port Diameter (m)
- Q_T = Cumulative Discharge Through Porous Dikes (m^3/s)
- U_0 = Effluent Velocity = 0.02 m/s
- N_p = Number of Diffuser Ports = 10,000

Dredge Discharge Orientation Data

The final component of dredged material disposal data is the orientation of the discharge mechanism. CORMIX requires information describing the positioning of the discharge mechanism in relation to the receiving water current. Although the particular data which must be supplied is dependent upon the particular discharge case, each of the six cases requires information describing the vertical and horizontal discharge angles.

The vertical discharge angle, Θ , is the angle in the X-Z plane the effluent device centerline makes with the receiving water surface. An angle of 0° reflects a discharge case where flow is parallel to the water surface. A value of 90° indicates that flow is oriented vertically downwards; whereas, a value of -45° refers to the case where discharge is occurring upwards at an angle of 45° with the water surface. The horizontal angle, σ , is the angle in the X-Y plane measured with respect to the receiving water current. Thus an angle of 0° indicates a co-flowing case where flow is parallel to the current, while a value of 180° describes a counter-flowing case, i.e. flow directly opposes the prevailing current. Horizontal angles of 90° and 270° reflect cross-flow conditions where the effluent is discharged perpendicular to the receiving water current. Figure 3-5 illustrates the vertical and horizontal discharge angles used in the CDFATE (DROPMIX) program.

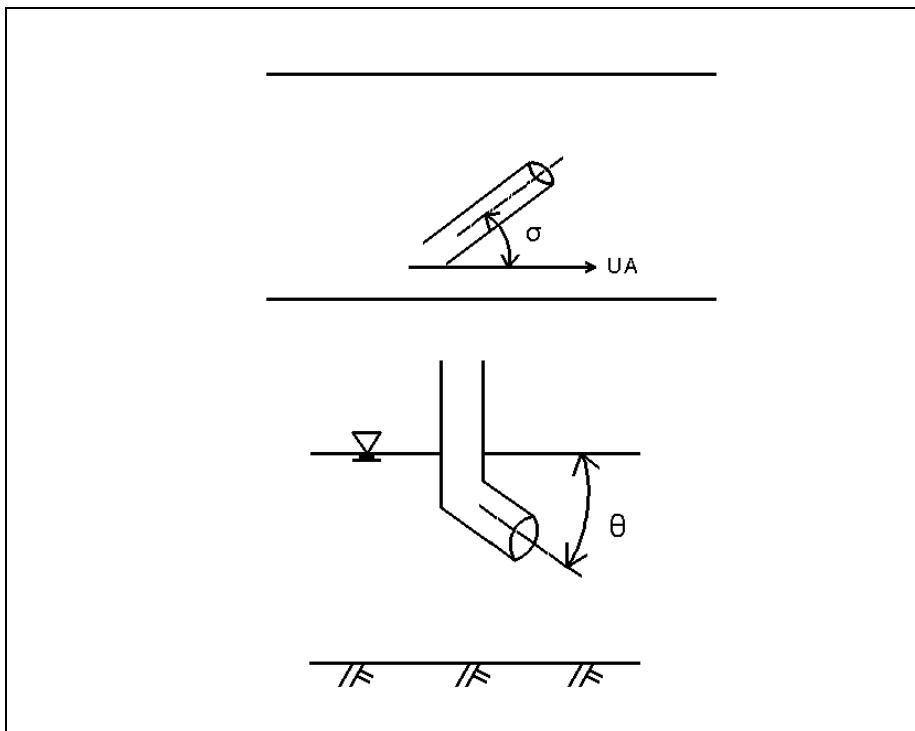


Figure 3-5 Examples of Horizontal and Vertical Discharge Angles

Pipeline Slurry Discharge. The pipeline discharge case is simulated assuming a single port discharge followed by a multi-port diffuser discharge. Consequently, the information needed to describe the orientation of the discharge mechanisms are the vertical and horizontal discharge angles of the pipeline, and the vertical, horizontal, and diffuser axis angles describing the diffuser. Figure 3-6 depicts the angles necessary to fully describe the orientation of the pipeline discharge case.

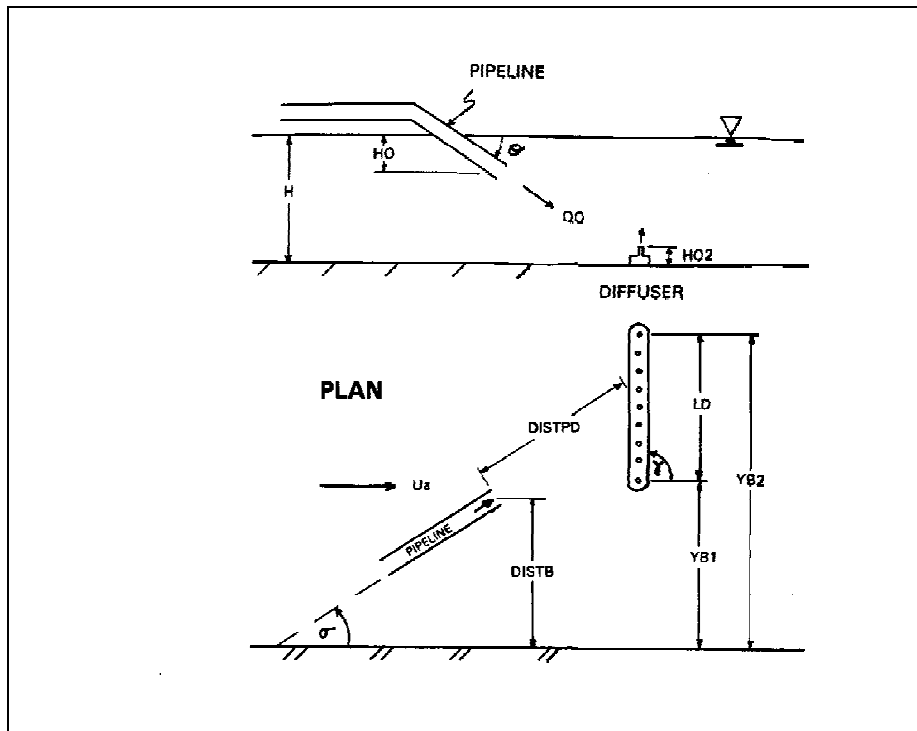


Figure 3-6 Pipeline Slurry Discharge Case

Note in Figure 3-6, that the distance between the pipeline outlet and the diffuser, DISTPD, is needed. This length represents the horizontal distance the effluent will travel before it strikes the bottom of the receiving water channel. This distance may be found using vector analysis. The composite velocity in the same direction as the effluent stream is a function of the effluent velocity, the receiving water velocity, and the horizontal and vertical discharge angles. The expression below can be used to compute this velocity.

$$U_{DISTPD} = U_A \cos(\sigma) + U_0 \cos(\Theta) \tag{6}$$

where:

- U_{DISTPD} = Horizontal Effluent Velocity (m/s)
- U_A = Receiving Water Velocity (m/s)
- U_0 = Effluent Velocity (m/s)
- Θ = Vertical Discharge Angle (rad)
- σ = Horizontal Discharge Angle (rad)

The time required for the effluent plume to travel from the pipeline to the receiving water bottom is found from Eq. (7). Once the travel time is known, it is multiplied by the composite velocity, U_{DISTPD} , to find the distance traveled, DISTPD.

$$t = U_0 \sin \Theta * H_d \quad (7)$$

where:

- t = Time For Effluent To Travel From Pipeline To Channel Bottom (sec)
- U_0 = Effluent Velocity (m/s)
- Θ = Vertical Discharge Angle (rad)
- H_d = Mean Receiving Water Depth at Discharge Location (m)

Hopper Overflow. For the hopper overflow case, the only geometric information needed to fully describe the discharge orientation are the vertical and horizontal discharge angles and the distance below the water surface where effluent enters the receiving water. If overflow is through a single port, then the vertical angle is the angle the pipe makes with the water surface and the horizontal angle is the angle the pipeline makes with the receiving water current as shown in Figure 3-5. If, on the other hand, overflow is simulated as weir flow then the user must specify the vertical discharge angle and the angle the *vessel* makes with the receiving water current. Typically for weir flow the vertical angle will be 90°. Based on the angle the vessel makes with the current, CDFATE (DROPMIX) automatically computes the remaining necessary discharge angles.

In certain discharge cases, the barge may be moving as it releases dredged material. This factor is considered by using vector analysis. Using the horizontal discharge angle, the vessel velocity can be decomposed into two components - one component acting in the same direction as the receiving water and another component which is orthogonal to the receiving water direction. A composite velocity, acting in the same direction as the receiving water current, is then found by adding the receiving water current to the velocity component acting in the same direction as the receiving water.

CDF Effluent Discharges. The geometric information needed for direct discharges from a CDF are dependent upon how discharge from a confined disposal facility is modeled. If flow is assumed to enter the receiving water from a single pipeline, then only the vertical and horizontal discharge angles are needed. Figure 3-5 portrays this information.

If CDF discharge is modeled as a channel or side stream discharge, then three variables are needed to fully describe the orientation of the channel with respect to the receiving water. The first variable is a horizontal angle that the channel centerline makes with the receiving water current. The second variable is the slope of the receiving water bottom. This quantity represents the change in receiving water bottom elevation from the point where the channel discharges to the point where the average receiving water depth is reached. Finally, the distance the channel protrudes out into the receiving water must be supplied. Each of the geometric variables described above are shown in Figure 3-7.

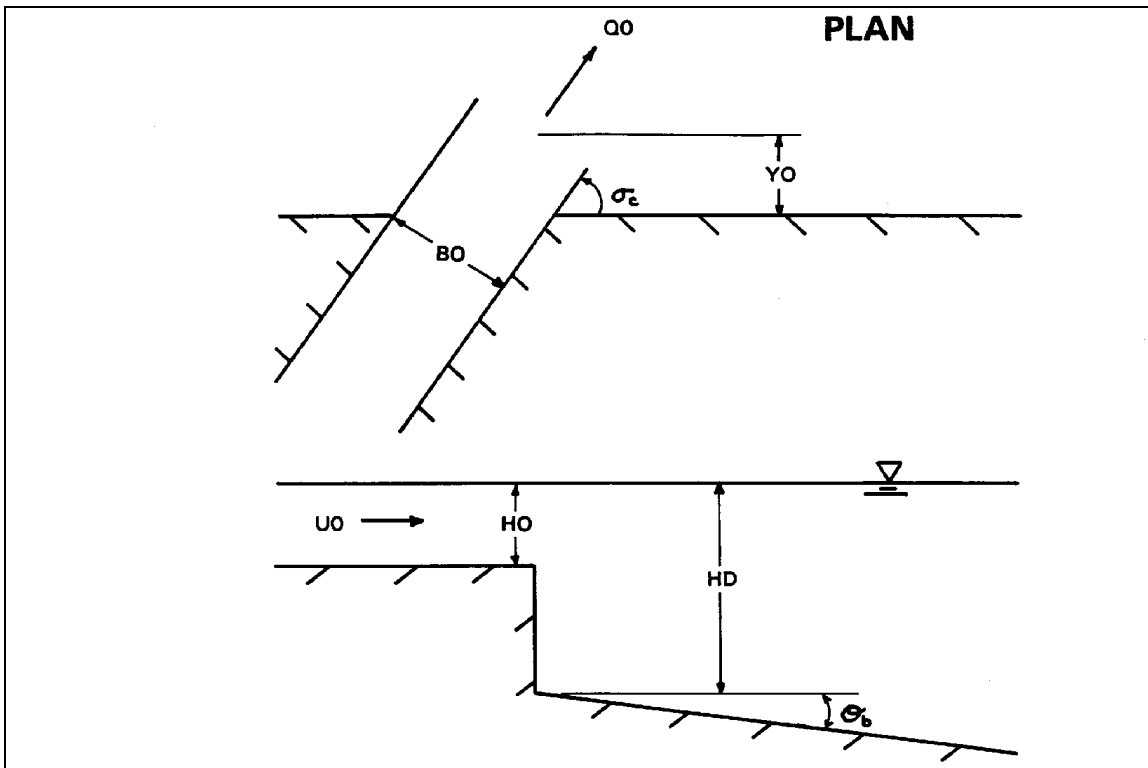


Figure 3-7 Channel Discharge Case.

Seepage From Confined Disposal Facilities. The geometric description of the dike leakage case is somewhat more involved than the hopper overflow or CDF discharge cases due to the presence of multiple diffuser ports. As before, the vertical and horizontal discharge angles for the diffuser ports must be specified. In addition, the orientation of the dike itself in relation to the receiving water current must be provided. Assuming that the individual discharge ports are perpendicular to the dike axis, a relationship between the port discharge direction and dike axis angles exists as shown below:

$$\gamma = 90^{\circ} + \sigma \quad (8)$$

where: σ = Horizontal Discharge Angle (deg)
 γ = Dike Axis Angle (deg)

For confined disposal facilities with multiple faces, a single equivalent dike face is assumed to discharge effluent. The user is required to supply the maximum distance the CDF extends out into the receiving water and the width of the facility. CDFATE (DROPMIX) will then compute the dike axis angle, γ , using the following equation:

$$\gamma = \tan^{-1}\left(\frac{YB1}{Width}\right) \quad (9)$$

where YB1 is the maximum distance the CDF extends out into the receiving water (m) and **width** is the maximum width of the disposal facility. The equivalent dike length is found from:

$$L_{dike} = \sqrt{YB1^2 + width^2} \quad (10)$$

Recall that dike faces which oppose the flow should not be included in the analysis. A list of the variables required to completely describe the dredged material disposal environment are provided in Table 3-2.

Table 3-2 Description of Dredged Disposal Variables

Variable Name	Description	Notes
CBANK	Bank closes to point of discharge	
DISTB	Distance from CBANK to point of discharge	
DISTPD	Distance between pipeline discharge and diffuser	
Data Required For Hopper Overflow, Dike Leakage, and Pipeline Discharge Case		
THETA	Horizontal angle between effluent trajectory and receiving water current	
SIGMA	Vertical angle between effluent trajectory and receiving water current	
H0	Depth from surface to point of discharge	
HD	Depth of receiving water at discharge location	
Diffuser Data For Dike Leakage and Pipeline Discharge Cases		
DITYPE	Type of diffuser	
BETA	Angle between diffuser discharge direction and diffuser axis	
GAMMA A	Angle between diffuser axis and receiving water current	
THETA2	Horizontal angle between diffuser effluent trajectory and receiving water current	
SIGMA2	Vertical angle between diffuser effluent trajectory and receiving water current	
H02	Depth from surface to point of discharge for diffuser	
SPAC	Spacing of diffuser ports for dike leakage case	
PORTN	Number of diffuser ports in dike leakage case	
D02	Diameter of diffuser ports in dike leakage case	
LD	Dike Length	
YB1	Maximum distance dike extends out into receiving water	

Table 3-2 (Cont.)

Variable Name	Description	Notes
Channel Data For Open Channel Flow Case		
CHNTY P	Type of open channel: Rectangular or Pipe	
BO	Width of rectangular channel	
HO	Depth of flow in open channel	
YO	Distance channel protrudes into waterway	
THETA B	Slope of receiving water bottom	
SIGMAC	Horizontal angle of discharge	
Hydraulic Data Required For All Four Cases		
Q0	Effluent discharge rate	
A0	Area over which effluent is discharge	
D0	Diameter of single port discharge pipe	
RHO0	Effluent density	
RE2D	Reynolds number	
Q0T2D	Total flow through dikes	

Mixing Zone Data

The final bit of information required before CDFATE (DROPMIX) can conduct a mixing zone simulation is data on initial pollutant concentrations and data on the mixing zone itself. For the most part, this data is not used in the mixing zone calculations. Rather the information is used for information purposes in terms of indicating the limits of the mixing zone and other regulatory zones. For example, two pieces of mixing zone information required by CDFATE (DROPMIX) are the criterion maximum concentration (CMC) and the criterion continuous concentration (CCC).

The criterion maximum concentration (CMC) indicates the level of pollutant concentrations, above which, acute or lethal effects may occur. To prevent potentially lethal concentrations of toxins, the CMC must be met a short distance from the effluent discharge mechanism. The limits of the zone where the pollutant concentration is higher than the CMC is termed the *toxic dilution zone*.

The U.S. Environmental Protection Agency provides guidance on the limits of the toxic dilution zone - if one exists (USEPA, 1985). A minimum effluent velocity of 3 m/s is required to insure rapid near-field so that toxic exposure to receiving water organisms is minimized. Likewise, EPA has specified three geometric criteria (shown below) which must also be met if a toxic dilution zone is specified (CMC > 0). Table 3-3 lists the mixing zone variables which must be supplied by the program user.

- 1) The CMC must be met within 10% of the distance from the effluent outfall structure to the edge of the regulatory mixing zone in any spatial direction.
- 2) The diluted concentration must be less than the CMC at a distance no more than 50 times the discharge length scale in any direction. The discharge length scale is defined as the square root of the cross-sectional area of the effluent discharge port.
- 3) The CMC must be met within a distance of 5 times the local water depth in any horizontal direction. For design purposes, the local water depth may be defined as the depth which occurs under low flow conditions.

Table 3-3 Description of Mixing Zone Variables

Variable Name	Description	Notes
C0	The initial pollutant concentration in the effluent	
CUNITS	Units of concentration or name of pollutant	1
KS	First-order reaction coefficient	
KD	Surface heat exchange coefficient	
CTOX	Indicates presence of a toxic dilution zone (CMC)	2
CMC	Concentration of criterion maximum concentration	
CCC	Concentration of criterion continuous concentration	
CLEGMZ	Indicates presence of regulatory mixing zone	3
CLEGSP	Specifies how regulatory mixing zone is defined	
REGVAL	Dimension of the regulatory mixing zone	
WQSTD	Indicates presence of a water quality standard (CCC)	4

Notes:

- 1) CUNITS is a simple string variable and its contents have no bearing on the computations.
- 2) CTOX is automatically set to 'yes' if $CMC > 0$, otherwise $CTOX = 'no'$
- 3) CLEGMZ is automatically set to 'yes' if $REGVAL > 0$, otherwise $CLEGMZ = 'no'$
- 4) WQSTD is automatically set to 'yes' if $CCC > 0$, otherwise $WQSTD = 'no'$

Program Output

The output provided by CDFATE (DROPMIX) is currently given in text form and is essentially the output produced by the CORMIX routines. Selected output reflecting a hopper overflow discharge case is shown in Table 3-4. CORIMX1 will supply more output than is shown below, but most of this additional output is simply an echo of input data.

Table 3-4 (Cont.)

BEGIN MOD132: LAYER BOUNDARY IMPINGEMENT/UPSTREAM SPREADING

Vertical angle of layer/boundary impingement = 49.80 deg
 Horizontal angle of layer/boundary impingement = 0.00 deg

UPSTREAM INTRUSION PROPERTIES:

Upstream intrusion length = 5.93 m
 X-position of upstream stagnation point = -0.52 m
 Thickness in intrusion region = 1.60 m
 Half-width at downstream end = 15.56 m
 Thickness at downstream end = 1.60 m

Plume width as a function of position:

X:	-0.52	1.44	3.40	5.36	7.32	9.28	11.24	13.20
BH:	0.00	5.88	8.32	10.19	11.76	13.15	14.41	15.56

Profile definitions:

BV = top-hat thickness, measured vertically
 BH = top-hat half-width, measured horizontally in Y-direction
 ZU = lower plume boundary (Z-coordinate)
 ZL = upper plume boundary (Z-coordinate)
 S = hydrodynamic average (bulk) dilution
 C = average (bulk) concentration (includes reaction effects, if any)

Control volume inflow:

X	Y	Z	S	C	B
5.42	0.00	8.20	14.7	0.170E+01	1.23

Control volume outflow:

X	Y	Z	S	C	BV	BH	ZU	ZL
13.20	0.00	10.00	25.0	0.100E+01	1.60	15.56	10.00	8.40

Cumulative travel time = 17. sec

END OF MOD132: LAYER BOUNDARY IMPINGEMENT/UPSTREAM SPREADING

 ** End of NEAR-FIELD REGION (NFR) **

BEGIN MOD141: BUOYANT AMBIENT SPREADING

Profile definitions:

BV = top-hat thickness, measured vertically
 BH = top-hat half-width, measured horizontally in Y-direction
 ZU = lower plume boundary (Z-coordinate)
 ZL = upper plume boundary (Z-coordinate)
 S = hydrodynamic average (bulk) dilution
 C = average (bulk) concentration (includes reaction effects, if any)

Plume Stage 1 (not bank attached):

X	Y	Z	S	C	BV	BH	ZU	ZL
13.20	0.00	10.00	25.0	0.100E+01	1.60	15.56	10.00	8.40

** REGULATORY MIXING ZONE BOUNDARY **

In this prediction interval the plume distance meets or exceeds
 the regulatory value = 1000.00 m.

Table 3-4 (Concluded)

This is the extent of the REGULATORY MIXING ZONE.

1010.56	0.00	10.00	69.9	0.357E+00	0.43	161.44	10.00	9.57
2007.92	0.00	10.00	166.8	0.150E+00	0.67	249.84	10.00	9.33
3005.28	0.00	10.00	345.7	0.723E-01	1.06	325.47	10.00	8.94
4002.64	0.00	10.00	621.5	0.402E-01	1.58	394.26	10.00	8.42
5000.00	0.00	10.00	1005.9	0.249E-01	2.19	458.33	10.00	7.81
Cumulative travel time =		9990. sec						

Simulation limit based on maximum specified distance = 5000.00 m.

This is the REGION OF INTEREST limitation.

END OF MOD141: BUOYANT AMBIENT SPREADING

```

-----
CORMIX1: Submerged Single Port Discharges                End of Prediction File
111111111111111111111111111111111111111111111111111111111111111111111111111111111111111

```

As seen from the given output, the majority of the CDFATE (DROPMIX) output is contained in a series of tables that describe the changes in dilution (S) and concentration (C) over an X-Y-Z coordinate system. In addition, the horizontal widths (BH) and vertical thicknesses (BV) of the contaminant plume are provided. A detailed description of the coordinate system and output variables are provided in the following paragraphs.

All CDFATE (DROPMIX) output is referenced to an origin in a three-dimensional Cartesian coordinate system. As shown in Figure 3-8, the positive X-direction points downstream in a direction parallel to the receiving water current, the positive Y-direction points towards to left bank (looking downstream), and the positive Z-direction is oriented downwards. The location of the origin is described in the CORMIX output and generally corresponds to the location of the effluent discharge mechanism.

For each coordinate point (X,Y,Z) a dilution and concentration is given. The dilution at any point is simply the ratio of the initial concentration of effluent pollutant to the concentration at the point as shown in Eq. (13). The location of the (X,Y,Z) point in the CDFATE (DROPMIX) output corresponds to the centerline of the effluent trajectory.

$$S_{x,y,z} = \frac{C_0}{C_{x,y,z}} \tag{11}$$

- where:
- $S_{x,y,z}$ = The Dilution At Any Point P(x,y,z)
 - $C_{x,y,z}$ = The Concentration At Any Point P(x,y,z)
 - C_0 = The Initial Pollutant Concentration

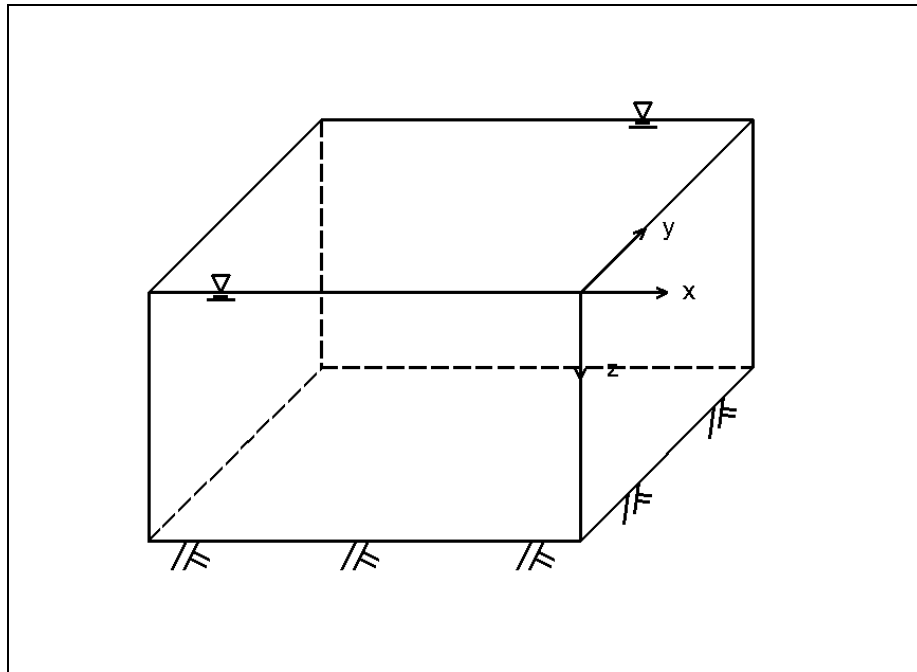


Figure 3-8 Example of CORMIX X-Y-Z Coordinate System

In addition, if a toxic dilution zone or zone of initial dilution defined by the acute toxicity standard (CMC) or a mixing or chronic toxicity standard (CCC) is specified, the CDFATE (DROPMIX) program will indicate if the criterion has been met by printing messages shown below. In this particular case, the CMC value was 5.0 and the CCC value was 2.0. The concentration units are specified by the program user.

**** CMC HAS BEEN FOUND ****

The pollutant concentration in the plume falls below CMC value of 0.500E+01
in the current prediction interval.
This is the extent of the TOXIC DILUTION ZONE.

**** WATER QUALITY STANDARD OR CCC HAS BEEN FOUND ****

The pollutant concentration in the plume falls below water quality standard
or CCC value of 0.200E+01 in the current prediction interval.
This is the spatial extent of concentrations exceeding the water quality
standard or CCC value.

The point where the criterion maximum concentration (CMC) is met defines the limits of the toxic dilution zone. For example in the output shown in Table 3-4, the pollutant concentration falls below the CMC somewhere between 1.95 to 3.04 meters downstream of the origin and 3.88 to 5.32 meters below the water surface. Likewise, the location where the criterion continuous concentration (CCC) has been satisfied defines the limits a water quality standard. Again referring to Table 3-4, the water quality

standard is met somewhere between 4.20 to 5.42 meters downstream of the discharge point and 6.76 to 8.20 meters below the receiving water surface. The final zone is the regulatory mixing zone - the limits of which the user identifies. CDFATE (DROPMIX) will also indicate the dilution and concentration at the limits of the regulatory mixing zone.

Not only will CDFATE (DROPMIX) indicate the effluent trajectory centerline concentrations, but it will also supply information describing the size of the effluent plume along its trajectory. The quantity BV refers to the thickness of the contaminant plume while BH represents the half-width of plume measured normal to the effluent centerline trajectory. Figure 3-9 illustrates the usefulness of BV and BH in constructing a three-dimensional representation of the contaminant plume.

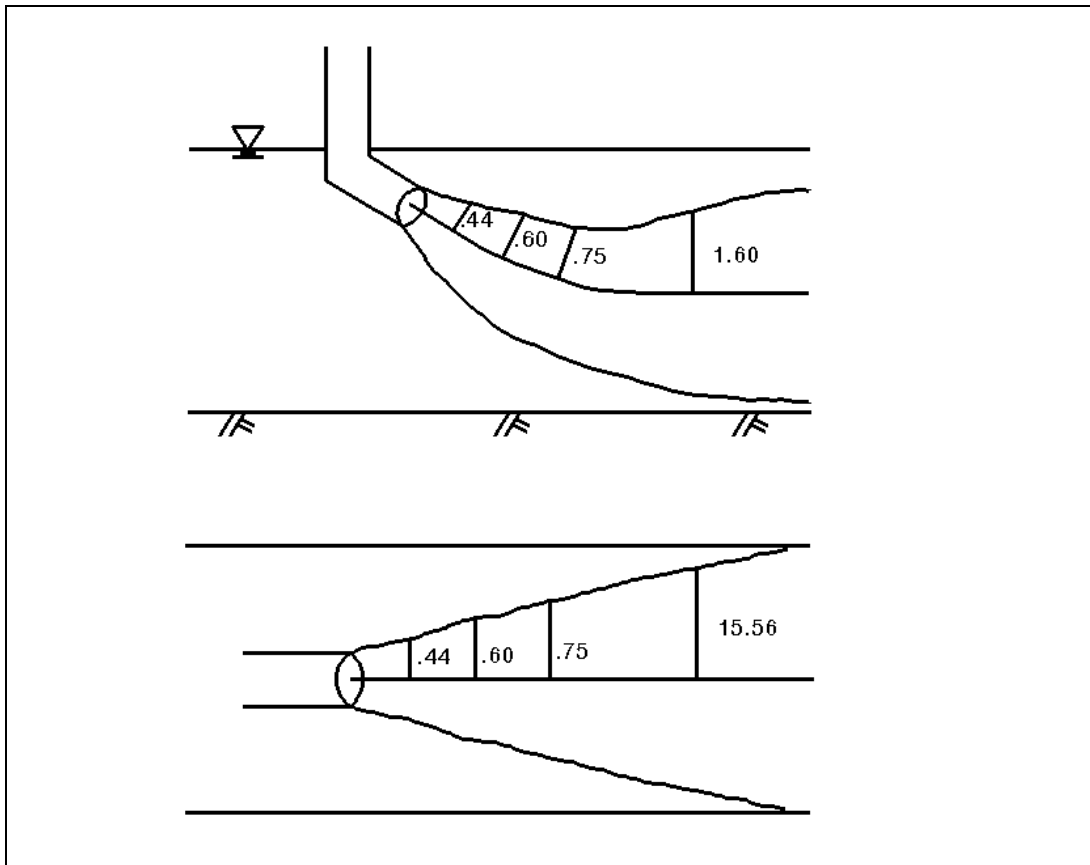


Figure 3-9 Three-Dimensional Representation of Contaminant Plume

PART 4: USER'S MANUAL

Getting Started

The CDFATE (DROPMIX) component of ADDAMS is designed to run in the DOS environment on an IBM or compatible personal computer with 640 KB of RAM and a hard disk. The program does not run in extended memory. As a result, approximately 510 KB of RAM must be free or available for the program to successfully load and begin executing. The amount of available memory can be determined by running the **CHKDSK** DOS utility (DOS Version 4.0 and earlier) or the **MEM** DOS utility (DOS Version 5.0 and higher). Consult a DOS manual for instructions on running the **CHKDSK** or **MEM** utilities.

There are no special hardware requirements so the program can be run on basically any personal computer with a hard disk regardless of the type of video card (CGA, EGA, VGA, SVGA), amount of extended memory (higher than 640 KB), or presence of any other peripheral devices (mouse, printer, CD-ROM, etc.). The total amount of hard disk space required by CDFATE (DROPMIX) is approximately 1.5 MB. At present the program *does not* support mouse usage.

The CDFATE (DROPMIX) package can be installed by running the **INSTALL** program found on the floppy disk which contains the package. This installation program will create a subdirectory on a user-specified drive (C:, D:, etc.) named **CDFATE** and copy all pertinent files to the subdirectory. All files supplied on the floppy disk have been compressed. Consequently, the installation routine must be run in order to uncompress the files. A list and brief description of all files contained on the CDFATE (DROPMIX) diskette is given in Appendix A.

The CDFATE (DROPMIX) Environment

The CDFATE (DROPMIX) package actually consists of a number of individual computer programs including a user interface, a numerical preprocessor, several numerical engines, and a numerical postprocessor. The flowchart shown in Figure 4-1 depicts the interrelationship between the various CDFATE (DROPMIX) components. All of the programs which make up the CDFATE (DROPMIX) package are written in FORTRAN 77. Due to the limited screen functions associated with standard FORTRAN, most of the screen control operations are performed through the use of an Assembly language routine. In addition, because of FORTRAN's inability to communicate with DOS within a run-time environment, a number of DOS interactions and system calls are accomplished through use of a third-party library.

The interface program is responsible for file management, data entry, preprocessor file generation, program execution, and results presentation. Generally

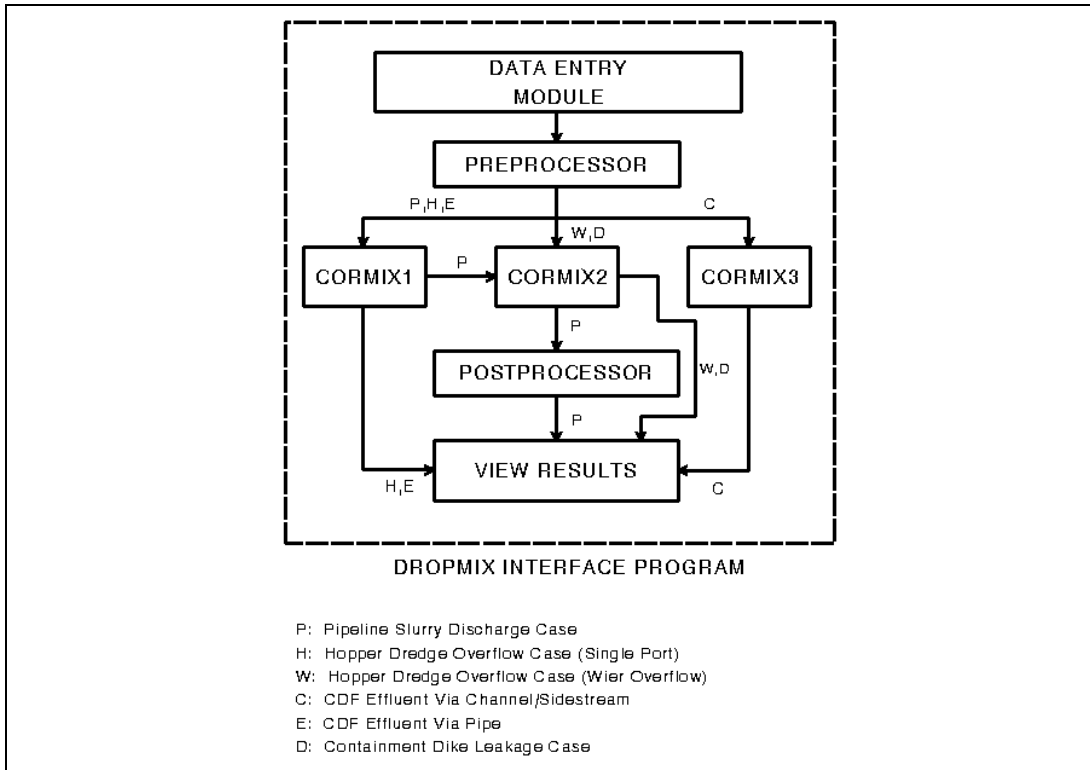


Figure 4-1 Interrelationship Between DROPMIX Modules

speaking, the interface program is the only component of the CDFATE (DROPMIX) package that most users will run. The interface program is a user-friendly menu-driven, cursor-controlled program that accepts all input necessary to conduct a complete mixing zone simulation. The interface program consists of a series of screens each representing a different program option. An example of the Activity Selection Menu is shown in Figure 4-2.

Once all data has been supplied and the file is saved, then the interface program will generate a data file compatible with the numerical preprocessor. When a CDFATE (DROPMIX) simulation is requested, the interface program will execute the preprocessor. The preprocessor will take the data describing a surface or near-surface discharge and transform it into an equivalent mirror-image bottom discharge problem. The preprocessor will then create a data file that will be read by the appropriate CORMIX model, i.e. CORMIX1, CORMIX2, or CORMIX3.

At this point control is transferred back to the interface program where the next step is to initiate execution of the appropriate CORMIX model. Table 4-1 indicates which CORMIX modules are executed. For the hopper overflow, channel/side stream discharge, and containment facility leakage cases, the simulation is complete after the

```

Automated Dredging and Disposal Alternatives Management System

      DROPMIX - Dredging Operations Mixing Zone Model

      DROPMIX Activity Selection Menu

      F1 - Build or edit input data file.
      F2 - Execute DROPMIX.
      F3 - Print or view output.
      F4 - Generate graphics.
      F5 - Perform hardware configuration for graphics.
      Esc - Quit.

ACTIVE FILE:  C:\DROPMIX\TEST
              TEST.DAT - A SAMPLE FILE

Use ↑ and ↓ keys to highlight option and then ENTER to select,
or press the selection key of the desired option.
    
```

Figure 4-2 DROPMIX Activity Selection Menu

Table 4-1 Discharge Cases and Appropriate CORMIX Module

Discharge Case	CORMIX Module
Pipeline Slurry Discharges	CORMIX1 & CORMIX2
Hopper Overflow Discharge - Single Port	CORMIX1
Hopper Overflow Discharge - Weir Flow	CORMIX2
CDF Effluent Discharge Via Channel/Side Stream	CORMIX3
CDF Effluent Discharge Via Pipe	CORMIX1
Containment Dike Leakage	CORMIX2

appropriate CORMIX module has executed. At this point the user may examine program output to determine the characteristics of the mixing zone. However, if the pipeline discharge case is selected, then the interface program will automatically initiate execution of a postprocessor that combines CORMIX1 and CORMIX2 output into a single output file. Once this has been accomplished, then this simulation is complete.

Selection Menus

There are a total of five menus in the CDFATE (DROPMIX) program. Each of the menus are listed below and are described in greater detail in subsequent paragraphs. For each of the selection menus, the up and down arrow keys and the function keys are used to invoke various program options and features. For example, referring to Figure 4-2, the F1 key is used to edit an existing data file or to create a new file, the F2 key is used to initiate execution of the preprocessor and CORMIX modules, the F3 key allows program output to be viewed, and so on. For each individual selection menu, the ESC key can be used to exit the menu move to the next higher level menu. Note that near the bottom of each selection menu the current data file name is displayed. Also presented is a character string describing the currently loaded data file.

- 1) Activity Selection Menu
- 2) Input Data File Selection Menu
- 3) Data Selection Menu
- 4) Input File Saving Menu
- 5) Execution Data File Selection Menu

Activity Selection Menu. The Activity Selection Menu, shown in Figure 4-2, is the main CDFATE (DROPMIX) menu where major program functions are initiated. The first option (F1) allows existing data files to be edited or new files to be created. The second option (F2) launches execution of the CDFATE (DROPMIX) preprocessor immediately followed by the appropriate CORMIX module. F3 will invoke the view or print output option. This option will allow the CORMIX output file or any other ASCII file to be viewed through the LIST.COM viewer. The fourth option is to generate graphics which will allow a pictorial examination of the CDFATE (DROPMIX) output. Graphics for the CDFATE (DROPMIX) program are unavailable at this time. The fifth option is to configure hardware for graphics - namely the monitor and printer. Finally, pressing the ESC key will terminate execution of the CDFATE (DROPMIX) program. Any of the program options may be initiated by pressing the appropriate function key or using the up or down arrow keys to highlight the option and then pressing ENTER key.

Input Data File Selection Menu. Pressing the F1 key - "Build or edit input data file" - will summon the Input Data File Selection Menu as shown in Figure 4-3. As before, the various program options can be invoked by pressing the pertinent function key or using the arrow keys to highlight the option and then pressing the ENTER key. Pressing ESC key will return control the CDFATE (DROPMIX) Activity Selection Menu.

```
Automated Dredging and Disposal Alternatives Management System

      DROPMIX - Dredging Operations Mixing Zone Model

      DROPMIX Input Data File Selection Menu

F1 - Enter name of input data file to be built or edited.
F2 - Enter DOS path to data file storage location. (Optional)
F3 - Display directory of input data files.
F4 - Build or edit input data file.
Esc - Return to DROPMIX Activity Selection Menu.

ACTIVE FILE:  C:\DROPMIX\channel
Sample Data File To Test Channel Velocity Computations

Use ↑ and ↓ keys to highlight option and then ENTER to select,
or press the selection key of the desired option.
```

Figure 4-3 DROPMIX Input Data File Selection Menu

The first option allows the name of the active data file to be entered. Active files may either be existing files or new files that have yet to be created. When this feature is used, the line displaying the active or current data file will be highlighted and the program user will be able to type in any valid filename. CDFATE (DROPMIX) assumes that all data files end with a .DRI extension. As a result, file extensions should not be provided. If the file name supplied to CDFATE (DROPMIX) is the name of a file that does not exist, then the user will be given the option to create the file.

All data files are assumed to reside in the same directory as the CDFATE (DROPMIX) subdirectory. In order to manage the location of data files more effectively, the current directory may be changed to a user-supplied name. This can be accomplished through the section menu option - "Enter DOS path to data file storage location". If this option is used, then a line near the bottom of the menu will be highlighted and the program user may type the name of any existing subdirectory.

The third menu option - "Display directory of input data files" - is a very convenient option that will display the eight-letter DOS filename of *every file ending in a .DRI extension*. Figure 4-4 shows an example of the screen that will be presented if this menu item is selected. It is possible that files displayed with this option may not be CDFATE (DROPMIX) data files since every file ending with a .DRI extension, regardless of its origin or purpose, will be displayed. CDFATE (DROPMIX) data files can be selected by using the up and down arrow keys to highlight the file of interest and then pressing the ENTER key. This procedure will cause the selected file to become the active or current file and, as such, it may be edited or used in program execution.

File Name	Data Set Title
BARGE	- SITE DESCRIPTION - Hopper Overflow Case
CHANNEL	- Sample Data File To Test Channel Velocity Computations
D-1	- Craney Island
INPUT	- Sample Data File To Test Channel Velocity Computations
JUNK	- JUNK.DRI - a SAMPLE FILE
OUTPUT	-
T-1	- DATA FILE: T-1 - SITE DESCRIPTION
TEST	- Sample Data File

Figure 4-4 Display Directory of Input Data Files Screen

Option four - "Build or edit input data file" - is the feature that must be selected in order to edit an existing or create a new CDFATE (DROPMIX) data file. Selecting this option will cause control to transfer to the Data Selection Menu which will be discussed in greater detail in following paragraphs. Pressing the ESC key will transfer control back to the CDFATE (DROPMIX) Activity Selection Menu.

Data Selection Menu. Selecting option four - "Build or edit input data file" - from the CDFATE (DROPMIX) Input Data File Selection Menu will cause the CDFATE (DROPMIX) Data Selection Menu to be displayed. This menu is shown in Figure 4-5. Note that this menu provides the only avenue for saving data files. Also note, that as with the other menus, the name and a brief description of the active file is displayed at the bottom of the screen. Each of the menu items will be briefly discussed below. The particular format for each of the individual data items which make up the CDFATE (DROPMIX) data file can be found later in this chapter.

The first data item which is supplied by the program user is narrative information describing the dredging site and the project in general. CDFATE (DROPMIX) provides a total of six (6) 60 character lines where specific information unique to the dredging project may be placed. The first line of narrative information is displayed with the active file name at the bottom of every CDFATE (DROPMIX) selection menu.

The second data item is information describing the receiving water environment. Essential data which is entered here includes receiving water density, velocity, and geometry. Part 3 of this manual provides a general description of the input data requirements for the receiving water. Similarly, selection of the third data item - "Disposal Operations Data" - will cause a series of screens to be displayed where data characterizing dredge disposal operations is provided. Data of this type includes the dredge discharge effluent density and velocity, and information on the type of disposal

```
Automated Dredging and Disposal Alternatives Management System

DROPMIX - Dredging Operations Mixing Zone Model

DROPMIX Data Selection Menu

F1 - Project Title and Site Description.
F2 - Receiving Water Data.
F3 - Disposal Operations Data.
F4 - Mixing Zone Data.
F5 - Save data file to disk.
Esc - Return to DROPMIX Activity Selection Menu.

ACTIVE FILE: C:\DROPMIX\channel
Sample Data File To Test Channel Velocity Computations

Use ↑ and ↓ keys to highlight option and then ENTER to select,
or press the selection key of the desired option.
```

Figure 4-5 DROPMIX Data Selection Menu

mechanism and the orientation of the dredged disposal device with respect to the receiving waters. Finally, the user must supply information representing the mixing zone. Specifically initial pollutant concentrations must be supplied. In addition, the presence and sizes of regulatory mixing zones must be provided.

After the program user has supplied all necessary information on the dredge disposal operations, the data file may be saved to disk for subsequent analysis or future reference. This is accomplished by selecting the fifth data selection menu item - "Save data file to disk". If this item is selected then CDFATE (DROPMIX) will transfer control to the Input File Saving Menu. Finally, the user may return to the Input Data File Selection Menu by pressing the ESC key.

If the Active File is an existing file, then the "-" symbol located between the function keys and the major data items will be replaced with a "*" symbol thereby indicating that data for those items has been furnished. Similarly if a new file is constructed, the dash will be replaced by an asterisk once the individual data screens have been accessed and data supplied. Figure 4-6 illustrates the case where Receiving Water Data and Disposal Operations Data have been supplied. Note that information on the Project Title and Site Description and Mixing Zone Data has yet to be provided.

Input File Saving Menu. The Input File Saving Menu is displayed if the user selects the "Save data file to disk" option from the Data Selection Menu. This menu is nearly identical to the Input Data File Selection Menu as can be seen from Figure 4-7. In fact, options 1-3 in the file saving menu operate identically to options 1-3 in the file selection menu. The only difference between the two menus is the fourth option.

```
Automated Dredging and Disposal Alternatives Management System

DROPMIX - Dredging Operations Mixing Zone Model

DROPMIX Data Selection Menu

F1 - Project Title and Site Description.
F2 * Receiving Water Data.
F3 * Disposal Operations Data.
F4 - Mixing Zone Data.
F5 - Save data file to disk.
Esc - Return to DROPMIX Activity Selection Menu.

ACTIVE FILE: C:\DROPMIX\channel
Sample Data File To Test Channel Velocity Computations

Use ↑ and ↓ keys to highlight option and then ENTER to select,
or press the selection key of the desired option.
```

Figure 4-6 Example of Existing Data

Selecting this option will cause the active data file to be saved to disk. If the file already exists and the file saving option is selected, CDFATE (DROPMIX) will indicate that the file exists and provides the program user the choice of saving the data file. ***Any existing file that is saved to disk will be overwritten.***

```
Automated Dredging and Disposal Alternatives Management System

DROPMIX - Dredging Operations Mixing Zone Model

DROPMIX Input File Saving Menu

F1 - Enter name of file to be saved.
F2 - Enter DOS path for data file. (Optional)
F3 - Display directory of input data files.
F4 - Save data in (or to) the active file.
Esc - Return to DROPMIX data selection menu.

ACTIVE FILE: C:\DROPMIX\channel
Sample Data File To Test Channel Velocity Computations

Use ↑ and ↓ keys to highlight option and then ENTER to select,
or press the selection key of the desired option.
```

Figure 4-7 DROPMIX Input File Saving Menu

CDFATE (DROPMIX) provides some error detection before the data file is written to disk. Under these circumstances, the CDFATE (DROPMIX) will notify the program user that an error has been discovered and will then transfer control back to the Data Selection Menu. If no errors have been found then the current file will be written to the current directory. At this point the ESC key may be pressed and program control will be transferred back to the Data Selection Menu.

Execution Data File Selection Menu. Once the data file has been saved to disk, the CDFATE (DROPMIX) numerical engines may be executed. As mentioned before, this is a two-step process. The first step is to execute the preprocessor which converts the data describing surface or near surface discharge conditions into an equivalent bottom discharge problem. The second step is to run the appropriate CORMIX model using a separate data file created by the preprocessor which depicts bottom discharge conditions. Once the CDFATE (DROPMIX) modules have run to completion, the output produced by CORMIX may be viewed.

```

Automated Dredging and Disposal Alternatives Management System

      DROPMIX - Dredging Operations Mixing Zone Model

      DROPMIX Execution Data File Selection Menu

F1 - Enter name of data file to be used during execution.
F2 - Enter DOS path to data file storage location. (Optional)
F3 - Display directory of execution data files.
F4 - Execute DROPMIX with selected file.
Esc - Return to DROPMIX Activity Selection Menu.

ACTIVE FILE:  C:\DROPMIX\channel
Sample Data File To Test Channel Velocity Computations

Use ↑ and ↓ keys to highlight option and then ENTER to select,
or press the selection key of the desired option.

```

Figure 4-8 DROPMIX Execution Data File Selection Menu

The format of the Execution Data File Selection Menu is the same as the Input Data File Selection Menu and the Input File Saving Menu. The first three options operate identically for all three menus. Thus if one wishes to analyze a file different from the active file displayed at the bottom of the menu, then the data filename can be directly specified by using option 1 - "Enter name of data file to be used during execution". Alternately, option 3 can be selected causing all files ending in a .DRI extension to be displayed on the screen. The up and down arrow keys may then be used to highlight a particular file. Pressing the ENTER key will select the file and make it active. Selecting option four - "Execute CDFATE (DROPMIX) with selected file", will initiate the two-step program execution process. The active file, displayed at the bottom of the screen, will be the file used in the mixing zone analysis.

CDFATE (DROPMIX) Data Entry

Data is entered into the active file in a spreadsheet fashion. A series of screens, each containing a series of major data items, is displayed and specific information is requested as shown in Figure 4-9. The up and down arrow keys and the TAB key may be used to move between the individual data items. Once data for a particular item has been supplied, the ENTER key must be pressed to "lock" the data into memory. After the ENTER key is pressed the cursor automatically moves to the next data item.

```

      ▶ RECEIVING WATER DATA - SCREEN 1 OF 3 ◀
ENTER THE MEAN DEPTH OF THE RECEIVING WATER (m)                20.00

IS THE RECEIVING BODY OF WATER NARROW OR IS THE DISCHARGE     Y
LOCATION CLOSE TO A BOUNDARY? (Y) or (N)
  Examples of narrow waters are rivers and streams.
  Lakes and coastal areas are not considered narrow.

INDICATE THE TYPE OF CHANNEL GEOMETRY:                          S
(S) - STRAIGHT UNIFORM CHANNEL
(M) - MODERATELY MEANDERING, NONUNIFORM CHANNEL
(I) - STRONGLY WINDING, IRREGULAR CHANNEL
  Far field dispersion can be affected by the shape
  of the channel containing the receiving waters.

ENTER THE WIDTH OF THE RECEIVING WATER (m)                      0.00
  The width of the receiving water is used to
  determine if the disposal material adheres to
  the bank for waters which are bounded.

<Esc> Exit <Home> Main Menu <Pg Up> Previous Menu <Pg Dn>NEXTMenu

```

Figure 4-9 Sample DROPMIX Spreadsheet For Data Entry

CDFATE (DROPMIX) data may either be numeric or text-based. Referring to Figure 4-9, an example of a text-based variable is CBOUND, which is used to indicate whether or not the body of receiving water is bounded. Possible values for CBOUND are "yes" or "no". All valid entries for text-based data are shown on the spreadsheet as illustrated by the "INDICATE THE TYPE OF CHANNEL GEOMETRY:" data item. However, most of the CDFATE (DROPMIX) data is numeric. An example of a numeric data item is HA, the mean depth of the receiving water (assuming a rectangular channel). Although in some cases typical values are provided, valid entries for numerical data are not shown on the screen. Instead, each variable typically has a range over which it is acceptable. If numeric data supplied by the program user falls outside the valid range, then CDFATE (DROPMIX) will display a warning message indicating such.

Each of the spreadsheet screens respond to the four keys listed at the bottom of the display: ESC, HOME, PG UP, and PG DN. The ESC key returns control to the previous menu without any loss of data. The HOME key permits the user to exit from the current data entry screen and return to the most recent menu, again with no loss of data. The PG UP (Page Up) key returns control to the most recent data entry screen while the PG DN (Page Down) key advances to the next data screen. Generally speaking, there are about two to three data screens for each major data item, i.e. receiving water data, disposal data, mixing zone data. The PG UP and PG DN keys can be used to navigate among the individual data screens. As shown in Figure 4-9, descriptive information for the current screen is displayed at the top of each screen. If the PG DN key is pressed while the last screen is displayed, control will be transferred to the CDFATE (DROPMIX) Data Selection Menu.

CDFATE (DROPMIX) Data Requirements

Each of the individual data items will be addressed in the following paragraphs. However, before proceeding to a description of the data items, the general format of the CDFATE (DROPMIX) data file will be discussed. Table 4-3 shows the general format of the CDFATE (DROPMIX) data file. A constant pattern is maintained throughout the file. As shown below, a line of text/numeric data is preceded by two lines of descriptive information. The first line provides general information indicating the general use of the variables. The next line of information contains the variable names of the individual data items. The third and final line contains the values of the variables. Each three-line segment of data is separated by a blank line. Definitions of the individual variables were given in Tables 3-1 through 3-3. Tables 4-4 through 4-6 provide information on the format and possible range of values for each data item.

```

AMBIENT WATER VARIABLES (GEOMETRIC)
  CBOUND      ICHREG      BS      HA
no           0.100E+01  0.000E+00  0.100E+02

AMBIENT WATER VARIABLES (HYDRAULIC)
  MANN      F      UA      QA      UW
0.150E-01  0.000E+00  0.300E+01  0.000E+00  0.500E+01

```

The format of the CDFATE (DROPMIX) data file is the same regardless of the discharge case analyzed. Although all data is read, certain data which is applicable to a given discharge case is not used at all. For example, the two-dimensional effluent discharge variables (GAMMA, SIGMA2, THETA2, etc.) are not used in any computations if a single port discharge case is analyzed. Such an approach allows a consistent data file structure to be maintained regardless of the actual discharge case described by the data file.

Table 4-3 Typical DROPMIX Data File

```

SITE DESCRIPTION - Hopper Overflow Case
SITNAM
Example Problem, Hopper Dredge Overflow
DESCRIPTION OF THE DISCHARGE CASE FOR CONSIDERATION
CASE
Hopper Dredge Overflowing into Estuary

RUN CONTROL P - pipeline; B - pipe2d; C - channel; H - hoppe
  EFFTYP      ROI      NSTEP
P            0.100E+04 0.500E+01

AMBIENT WATER VARIABLES (GEOMETRIC)
  CBOUND      ICHREG      BS      HA
no           0.100E+01 0.000E+00 0.100E+02

AMBIENT WATER VARIABLES (HYDRAULIC)
  MANN      F      UA      QA      UW
0.150E-01 0.000E+00 0.300E+01 0.000E+00 0.500E+01

AMBIENT WATER VARIABLES (WATER COLUMN)
  STRCND      RHOA      HINT      RHOAS      RHOAB
B            0.9900E+03 0.200E+01 0.1002E+04 0.1003E+04

AMBIENT WATER VARIABLES (WATER COLUMN) CONTINUED
  FRESHA      TA      TAS      TAB
F            0.000E+00 0.000E+00 0.000E+00

EFFLUENT DISCHARGE VARIABLES (GEOMETRIC)
  CBANK      DISTB      DISTPD      THETA      SIGMA      H0      HD
LEFT        0.100E+04 0.207E+02 0.900E+02 0.000E+00 0.100E+01 0.100E+02

EFFLUENT DISCHARGE VARIABLES (2D GEOMETRY)
  DITYPE      BETA      GAMMA      THETA2      SIGMA2      H02
AAP          0.900E+02 0.000E+00 0.900E+02 0.900E+02 0.100E+00

EFFLUENT DISCHARGE VARIABLES (2D GEOMETRY) CONTINUED
  SPAC      PORTN      D02      LD      YB1      YB2
0.100E+00 0.171E+03 0.200E+00 0.343E+02 0.983E+03 0.102E+04

EFFLUENT DISCHARGE VARIABLES (CHANNEL)
  CHNTYP      BO      HO      YO      THETAB      SIGMAC
CHAN          0.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00

EFFLUENT DISCHARGE VARIABLES (HYDRAULIC)
  Q0      U0      A0      D0      RHO0      RE2D      Q0T2D
0.100E+01 0.318E+00 0.314E+01 0.200E+01 0.1004E+04 0.000E+00 0.10E+01

EFFLUENT DISCHARGE VARIABLES (HYDRAULIC) CONTINUED
  FRESH0      T0      C0      CUNITS      KS      KD
F            0.000E+00 0.250E+02 ppm      0.000E+00 0.000E+00

MIXING ZONE DATA
  CTOX      CMC      CCC      CLEGMZ      CLEGSP      REGVAL      WQS
yes          0.500E+01 0.200E+01 yes      width      0.140E+01 yes

DIKE LEAKAGE CASE DATA
  IDKTYP      IAUTO      DWIDTH      WLENGTH
0            0            0.2000E+03 0.3434E+02
    
```

Project Title and Site Description. The first data item which will typically be entered is information describing the project title and site description. Figure 4-10 shows the screen where narrative information identifying the particular dredge disposal project is provided. A total of six lines, each 60 characters long, are supplied for narrative input. The up and down arrow keys can be used to move among the six character lines. Once narrative information has been typed, the user should press the ENTER key to lock the data into memory.

```
▶ TITLE INFORMATION - SCREEN 1 OF1 ◀  
  
Sample Data File To Test Channel Velocity Computations  
Title #1:  Site Name  
  
Joe Engineer - July 18, 1994  
Title #2:  Site Description  
  
Title #3:  Site Description  
  
Title #4:  Description of the Discharge Case  
  
Title #5:  Description of the Discharge Case  
  
Title #6:  Description of the Discharge Case  
  
◀Esc> Exit  ◀Home> Main Menu  ◀Pg Up> Previous Menu  ◀Pg Dn> NEXT Menu
```

Figure 4-10 Project Title and Site Description Screen

Receiving Water Data. The next major data item is the receiving water data. Receiving water data utilizes three separate screens. On the first screen the program user indicates the mean depth of the receiving waters and whether or not the receiving water body is bounded. If the body of water is bounded, then the user must supply the degree of channel meandering and the width of the channel. Recall that CORMIX idealizes a natural channel as a rectangular section. Thus the mean depth and channel width supplied from this screen represents values for the rectangular channel section.

The second receiving water data screen accepts input describing the bottom roughness of the channel. Manning's "n" value or Darcy-Weisbach friction factor "f" may be supplied to the program. If Manning's "n" is provided, then CDFATE (DROPMIX) will convert the roughness to an equivalent Darcy-Weisbach friction factor. Typical values of Manning's "n" and Darcy-Weisbach "f" are shown on the screen. Also supplied through this screen is the mean receiving water velocity and the average wind speed.

The third and final receiving water screen allows the user to supply information on the density of the receiving water environment. Three density profiles are possible: 1) Uniform Density Profile (U), 2) Linearly Varying Profile (A), and 3) Step or Pycnocline Profile (B). Densities may be specified directly or they may be computed based on user-specified salinity and temperature data. If densities are input directly and the Linearly Varying or Step profile is selected, then the densities must refer to the surface and bottom densities. In addition, if the Step or Pycnocline profile is selected, the user must indicate the distance from the bottom of the receiving water body to the location of the pycnocline. If densities are computed, the program user must supply the salinity in ppt and the temperature. Specified and computed densities are in kg/m^3 .

Disposal Operations Data. Disposal Operations Data refers to information which describes the density and velocity characteristics of the effluent and the geometry and orientation of the effluent discharge device. Entering dredge disposal data is actually a two-step process although the process appears seamless to the program user. The first step is to supply *general* information describing the dredge disposal operation with the second step involving presenting data on the *particular* disposal case, i.e. pipeline slurry, hopper overflow, etc.

There are two screens associated with the general disposal operations data. The first screen requests input describing the particular discharge case, the maximum distance over which the mixing simulation is modeled, and the number of reporting intervals used in generating program output. The dredged disposal discharge case may be one of six possible cases as shown below. The maximum distance over which the plume is modeled represents the horizontal distance (X-direction) over which computations will be carried out. Finally, the number of reporting intervals represents the number of locations where the plume centerline position will be determined and the pollutant concentration will be computed.

- (P) - Pipeline Slurry Discharges
- (H) - Hopper Overflow Discharge (Single Port)
- (W) - Hopper Overflow Discharge (Weir Flow)
- (C) - CDF Effluent Discharge Via Channel/Side Stream
- (E) - CDF Effluent Discharge Via Pipe
- (D) - Containment Dike Leakage

The second general disposal operations screen allows information on the effluent density to be supplied. Like the receiving water density, the effluent density may either be specified directly or it can be computed based on user-supplied data. There is no density stratification allowed for the discharged effluent. If the user wishes to compute effluent density, then the salinity and temperature of the fluid portion of the effluent must be provided. In addition, the specific gravity and concentration of solids within the effluent must be furnished. CDFATE (DROPMIX) will then compute the overall effluent density with units in kg/m^3 .

Once the general disposal operations data has been supplied, then specific information for the selected dredge disposal case may be supplied. The particular information required for each discharge case is a function of the case itself, but typically this data includes a description of the hydraulic and geometric characteristics of the discharge mechanism.

With regards to the geometric properties of the discharge mechanism, CDFATE (DROPMIX) requires the user to specify which bank (LEFT or RIGHT) is closest to the point of discharge. In addition, the distance from the bank to the discharge location must be furnished. Finally, the depth below the surface where the effluent enters the receiving water must also be provided. These three items are used, in part, to establish the origin of the discharge scenario. The depth to the bottom of the receiving water body at the point of discharge is also used in the CDFATE (DROPMIX) computations and, as such, must be supplied by the program user.

The orientation of the discharge mechanism with respect to the receiving water current must also be supplied by the program user. With the exception of the CDF seepage case, this will only involve the vertical and horizontal discharge angles. Any additional angles needed in the hydrodynamic computations are automatically determined by the CDFATE (DROPMIX) program. For the case of leakage through porous dikes, the angle the dike axis makes with the receiving water current must also be supplied. However, in lieu of directly supplying this information, the program user may wish to enable automatic computation of the dike axis angle.

Hydraulic variables which must be supplied to the CDFATE (DROPMIX) program include the rate at which effluent is discharged and the area of over which it is discharged. For the pipeline slurry and single port hopper overflow or CDF discharge cases, flow is routed through a single pipe. For seepage through a porous dike, conceptually flow is assumed to pass through a multi-port diffuser where each port is assumed to have the same diameter. Hence, for these cases the diameter of the port must be supplied by the program user. In the case of seepage through a CDF, port diameters are automatically computed. For hopper overflow cases where uncontrolled spillage over the sides occurs, the flow length must be supplied. The flow area is then found using weir formulas. Finally for the side stream discharge case, the flow area is determined based on user-supplied channel geometry.

Mixing Zone Data

Mixing zone data is furnished to CDFATE (DROPMIX) through two data screens. The first screen allows the user to enter a nine (9) character string which is used to specify the concentration units or, if the user wishes, the name of the pollutant. The next data item supplied is the concentration of pollutant in the user-specified units if units are provided. A first order reaction constant and a surface heat exchange coefficient is also supplied from this screen.

The second screen allows the user to specify if a toxic dilution zone or a water quality standard exist. This is accomplished by supplying a positive value for the Criterium Maximum Concentration (CMC) in which case a toxic dilution zone is assumed to exist. In fact, the limits of the toxic dilution zone are those areas where the pollutant concentration is higher than the CMC. Similarly if the user supplies a positive value for the Criterium Continuous Concentration (CCC), then a water quality standard is assumed to apply. At those locations where the pollutant concentration is higher than the CCC, the water quality standard is violated. Finally, the limits of a regulatory mixing zone may be defined using distance, width, or area to indicate the extend of the zone.

Example Input Session

Table 4-4 Receiving Water Data

Variable Name	Minimum Value	Maximum Value	Units	Default Value	Format	Notes/Possible Values
HA	0	1,000	meters	0.00	F10.2	
CBOUND	N/A	N/A	N/A	Y	A1	Yes, No
ICHREG	N/A	N/A	N/A	S	A1	S,M,I; Not Required if CBOUND=No
BS	0.01	10,000	meters	0.01	F10.2	Not Required if CBOUND=No
MANN	0.1	0.2			F10.5	
F	0.0				F10.5	
UA	0	10	m/s		F10.2	
UW	0	15.0	m/s	0.0	F10.2	Low=0.0 m/s; Medium=2.0 m/s; High=15 m/s
RHOA	900	1,200	kg/m ³		F10.2	
RHOAS	900	1,200	kg/m ³		F10.2	
RHOAB	900	1,200	kg/m ³		F10.2	

Table 4-5 Dredge Disposal Operations Data

Variable Name	Minimum Value	Maximum Value	Units	Default Value	Format	Notes/Possible Values
CBANK	N/A	N/A	N/A	Left	A10	Left, Right
DISTB	0	N/A	Meters	0	F10.5	
DISTPD	0	N/A	meters	0	F10.5	
Data Required For Hopper Overflow, Dike Leakage, and Pipeline Slurry Discharge Case						
THETA	-45.0	90.0	degrees	0.0	F10.5	Horizontal Discharge Angle
SIGMA	0.0	360.0	degrees	0.0	F10.5	Vertical Discharge Angle
H0	0.0	0.33HD	meters	0.0	F10.5	
HD	0.0	1,0000	meters	0.0	F10.2	
Diffuser Data For Dike Leakage and Pipeline Slurry Discharge Case						
DITYPE	N/A	N/A	N/A	N/A	A3	UAP: Dike Leakage Case AAP: Pipeline Slurry Case
BETA	0.0	90.	degrees	0.0	F10.5	
GAMMA	0.0	360.0	degrees	0.0	F10.5	Avoid Counter Flowing Discharges
THETA2	-45.0	90.0	degrees	0.0	F10.5	90° Recommended
SIGMA2	0.0	360.0	degrees	0.0	F10.5	

Table 4-6 Mixing Zone Data

Variable Name	Minimum Value	Maximum Value	Units	Default Value	Format	Notes/Possible Values
CUNITS	N/A	N/A	N/A		A9	
C0					F10.2	
KS			sec ⁻¹		F10.5	
KD			W/m ² /C		F10.2	
CMC	0.0				F10.2	
CCC	0.0				F10.2	
CLEGSP	N/A	N/A	N/A		A1	D - Distance W - Width A - Area
REGVAL			m,m ²		F10.2	

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Appendix A

Table A-1 List of CDFATE (DROPMIX) Files

Program Name	Type of File	Description
DROPMIX	Executable	DROPMIX interface program.
PREPRO	Executable	Preprocessor which converts surface discharge into mirror-image bottom discharge.
HYDRO1	Executable	CORMIX1 - Single port bottom discharge model
HYDRO2	Executable	CORMIX2 - Multi-port bottom discharge model
HYDRO3	Executable	CORMIX3 - Surface discharge model
POSTPRO	Executable	Postprocessor for pipeline discharge case