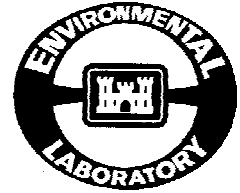# Environmental Effects of Dredging
Technical Notes

Documentation of the DYECON Module for ADDAMS: Determining the Hydraulic Retention and Efficiency of Confined Disposal Facilities

Purpose

This technical note describes procedures for determining mean hydraulic retention time and efficiency of a confined disposal facility (CDF) from a dye tracer slug test. These parameters are required to properly design a CDF for solids retention and for effluent quality considerations. Detailed information on conduct and analysis of dye tracer studies can be found in Engineer Manual 1110-2-5027, "Confined Dredged Material Disposal" (Office, Chief of Engineers (OCE), U.S. Army 1987). This technical note documents the DYECON computer program which facilitates the analysis of dye tracer concentration data and computes the hydraulic efficiency of a CDF as part of the Automated Dredging and Disposal Alternatives Management System (ADDAMS).

Background

Confined disposal facilities detain and store sediment dredged from navigation channels, estuaries, lakes, and other waterways. Conventional hydraulic dredging processes add large volumes of water to facilitate pipeline transport, resulting in a liquid slurry mixture being discharged into the CDF. This disposal process requires that the CDF provide sufficient hydraulic retention time for removal of suspended solids to meet local and state effluent quality standards.

Solids retention depends heavily on the hydraulic retention time within the CDF. Thus, accurately determining the mean hydraulic retention time is an important aspect of CDF design. Hydraulic efficiency is a convenient parameter for describing the hydraulic characteristics of a CDF since mean hydraulic retention time varies with inflow rate and volume of ponded surface water. Hydraulic efficiency, defined as the ratio of the mean hydraulic retention time to the theoretical hydraulic reten-

tion time, remains reasonably constant over a wide range of inflow rates and ponded volumes. Once the hydraulic efficiency of a CDF is determined, it can be used to evaluate the effects of flow and ponded volume variations during future disposal activities.

Additional Information

This technical note was written by Dr. Donald F. Hayes, University of Nebraska-Lincoln, and Dr. Paul R. Schroeder, U.S. Army Engineer Waterways Experiment Station. Questions regarding this technical note should be directed to Dr. Schroeder, (601) 634-3709, the manager of the Environmental Effects of Dredging Programs, Dr. Robert M. Engler, (601) 634-3624, or the manager of the Dredging Operations Technical Support Program (DOTS), Mr. Thomas R. Patin, (601) 634-3444.

DYECON Application of ADDAMS

Introduction

Slug dye tracer studies are commonly used to determine the mean hydraulic retention time for ponds, lakes, rivers, and other water bodies. Procedures for performing slug dye tracer studies are very similar and are described in detail in EM 1110-2-50-27 (OCE 1987). One can compute the theoretical hydraulic retention time for a CDF using the equation

$$T = \frac{V_p}{\overline{Q}} \qquad (1)$$

where

T = theoretical hydraulic retention time, sec
V_p = ponded water volume in CDF, cu ft
$\overline{Q}$ = average inflow rate into CDF, cu ft/sec

Unfortunately, the actual hydraulic retention is often much smaller than the theoretical hydraulic retention time due to the nonideal dispersion resulting from short-circuiting and dead zones. Actual mean hydraulic retention time can be determined for a CDF, or any other water body, by instantaneously injecting a known mass of dye at the inflow point, then measuring the dye concentration in the outflow. The mean hydraulic retention time occurs when 50 percent, by mass, of the dye has exited. Since some dye is always lost to unknown sources, the mean hydraulic retention time is normally taken as the time when 50 percent of the total mass of dye recorded at the outflow has exited the water body. Figure 1 shows an idealized plot of the retention time distribution for a CDF.
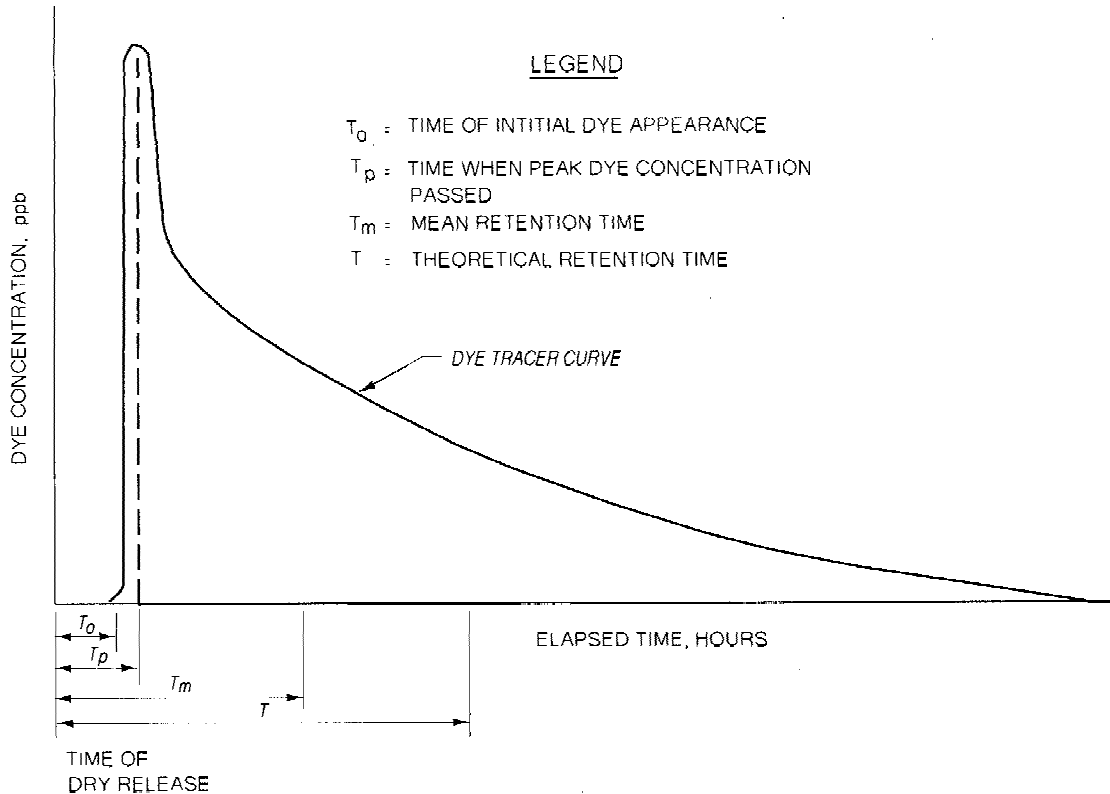
LEGEND

T_o = TIME OF INITIAL DYE APPEARANCE

T_p = TIME WHEN PEAK DYE CONCENTRATION PASSED

T_m = MEAN RETENTION TIME

T = THEORETICAL RETENTION TIME

DYE TRACER CURVE

ELAPSED TIME, HOURS

TIME OF DRY RELEASE

Figure 1. An idealized plot of the retention time distribution for a CDF

Slug dye tracer studies are an effective means for determining the mean hydraulic retention time and hydraulic efficiency only for an existing CDF during an operating disposal project. However, hydraulic retention time and efficiency are also necessary to perform design calculations for constructing new CDFs; similarly, these parameters may be required for an existing CDF at times when it is not in operation. Fortunately, hydraulic efficiency can also be estimated based upon the geometric configuration of a water body or, in this case, a CDF. These methods are not routinely as reliable as direct measurement, but they do facilitate design calculations which would otherwise be impossible.

Capabilities

DYECON is a computer program and module of the Automated Dredging and Disposal Alternatives Management System (ADDAMS). The general goal of ADDAMS, an interactive computer-based design and analysis system for dredged material management, is to provide state-of-the-art computer-based tools that will increase the accuracy, reliability, and cost-effectiveness of dredged material management activities in a timely manner. *Environmental Effects of Dredging Technical Notes* EEDP-06-12 (Schroeder and Palermo 1990) describes ADDAMS in more detail.

The DYECON module of ADDAMS has the following specific capabilities:

- Analyze and reduce slug dye tracer data.

- Calculate the hydraulic efficiency of an existing CDF based upon test data.

- Estimate hydraulic efficiency of a CDF based upon geometric characteristics.

Availability

DYECON as well as the other modules of ADDAMS is available through the Information Technology Laboratory of the U.S. Army Engineer Waterways Experiment Station. See Appendix A for an order form.

Using DYECON

DYECON may be started from the ADDAMS executive shell by selecting the DYECON program (option 2) or started separately by typing DYECON at the DOS prompt. The preferable method for starting DYECON depends upon your familiarity with the DOS operating system, available RAM, system configuration, and the existence of other ADDAMS modules. It is primarily a matter of personal preference, however, since DYECON operates the same regardless of how it is initiated.

General Operation

DYECON operates in a user-friendly, menu-driven environment and facilitates data entry and editing by using a full-screen editor approach. A central menu called the *DYECON Activity Selection Menu* allows the user to select the desired operation such as enter/edit slug dye tracer data, perform hydraulic efficiency calculations, perform file management operations, and set the hardware configuration for the DYECON graphics. All menu selections are numbered and the user may select an option by pressing the number of the desired option. The user may also choose to cycle through the menu options using the up arrow (↑) or down arrow (↓) key and then select the highlighted option by pressing the ENTER key.

Each selection from the *DYECON Activity Selection Menu* provides the user with a full-screen editor for data entry and editing. Most editing screens describe several required data items with the current value for the data item displayed. Editing focuses on the highlighted data item or question. A description of the data item and options are usually located to the left of the cell; units are displayed to the right of the cell. The user may enter a new value in the cell or modify the value in the cell. Moving to another data item on the current screen requires pressing either the ENTER key, the TAB key, or one of the vertical arrow keys. Page Down and Page Up keys display the next and previous screens, respectively. DYECON presents the results of design computations on descriptive screens similar to the full-screen data editor. DYECON will also print the results to ASCII output files or directly to the printer.

Getting Started

The user should establish the proper hardware configuration prior to any other use of DYECON. Hardware configuration can be established or modified by selecting menu item 5, perform hardware configuration for graphics. DYECON uses the stored configuration to display and print graphics. Modifications to the hardware configuration are not required after the initial setup unless the available hardware changes or the configuration data file is lost.

After the initial hardware configuration, later uses of DYECON should begin by selecting (or making "active") the desired data file. DYECON recalls the data file from the previous session and initially makes it the "active" data file. A new or different existing data file can be activated by using the ADDAMS File Manager. The File Manager is initiated by selecting menu item 4, perform data file selection and operation; the ADDAMS File Manager and its operation are discussed in detail by Schroeder and Palermo (1990). When the File Manager returns control to DYECON, it reads the active data file, if it exists, and assigns values to variables as appropriate. If the file does not exist, the File Manager will initialize the active data file. Note that DYECON does not offer an option to change the name of the active data file after it has been read. Thus to modify an existing data file and retain the original file, the user must change the active file name to the desired name for the modified file before saving the data. This operation is performed using the ADDAMS File Manager, but must be done before modifications are saved to prevent loss of the original data.

On-line Help

On-line comprehensive help messages are available to DYECON users by pressing F1 or Alt-F1. Pressing the F1 key provides general assistance on the current menu and information regarding choices the user needs to make. Detailed assistance for the currently highlighted data item is available on-line by simultaneously pressing the Alt and F1 keys. These context-sensitive messages provide detailed information about the user's options at the current position and/or describe data to be entered or edited at the current cursor position. Help messages may also provide default values or typical ranges.

Hardware Requirements

DYECON requires a MS-DOS based personal computer with at least 640 kilobytes of RAM, a hard disk with 2 megabytes of free space, and a CGA, EGA or higher resolution color video card and compatible monitor.

Determining Mean Hydraulic Retention Time and Efficiency

Mean hydraulic retention time and hydraulic efficiency are required for proper CDF design. DYECON computes the mean hydraulic retention time from dye

concentration or fluorescence in the CDF effluent as a function of elapsed time and background concentration or fluorescence in the effluent. DYECON requires the theoretical hydraulic retention time of the CDF to compute the hydraulic efficiency. DYECON assumes that the flow is nearly constant during the conduct of the test; therefore, flow measurements are not required. Calculations for mean hydraulic retention time and efficiency are based upon procedures described in EM 1110-2-5027 (OCE 1987).

Entering/Editing Dye Tracer Data

Option 1 of the *DYECON Activity Selection Menu*, Enter/edit dye concentration data, initiates a series of screens for data entry and edit. These screens allow the user to enter or edit the data required to compute the mean hydraulic retention time and efficiency; these data are described in Table 1.

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Table 1. Summary of DYECON Input Parameters

Parameters	Units
Background dye concentration	Fluorescence readings or ppb
Theoretical retention time	Hours
Elapsed time of sample	Hours
Dye concentration of sample	Fluorescence readings or ppb

_____

The first screen under this option requests the background dye concentration, in parts per billion or fluorescence readings, and theoretical retention time in hours. The second screen allows the user to enter the elapsed time in hours and the measured dye concentration in the effluent, in parts per billion or fluorescence. Control returns to the original menu after the concentration versus time data are entered. Actually, any consistent set of units for concentration or time can be used. The user would only have to substitute his units of concentration for parts per billion in the results and his units of time for hours.

Analyzing Dye Tracer Data

Selecting Option 2, Analyze dye tracer data, prompts DYECON to compute the statistical parameters associated with the effluent slug dye tracer data. The calculations occur quickly, and a screen summarizing the results is displayed. Table 2 lists the parameters displayed on this screen. DYECON also provides an option for generating a plot of dye concentration versus elapsed time. The graph may be displayed on the screen or printed on an attached printer or plotter.

Table 2. Summary of DYECON Output Parameters

Parameter	Units
Theoretical retention time, T	hr
Hydraulic efficiency	percent
Mean retention time, T_m	hr
Background concentration (fluorescence)	ppb
Mean concentration (fluorescence)	ppb
Maximum concentration (fluorescence)	ppb
Time of initial dye appearance, T_0	hr
Time to when 10 percent of the dye has passed, T_{10}	hr
Time to when 50 percent of the dye has passed, T_{50}	hr
Time to when 90 percent of the dye has passed, T_{90}	hr
Time of last observation when dye concentration was greater than 10 percent of the maximum observed concentration	hr
Time when peak dye concentration passed, T_p	hr
Morrill index, T_{90}/T_{10}	hr

Estimating Hydraulic Efficiency from Site Geometry

Proper CDF design for solids removal requires an estimate of the hydraulic efficiency of the proposed site. DYECON can estimate hydraulic efficiency for a given site geometry based upon the relative length along the flow path to the width normal to the flow path. Selecting option 3 displays a screen describing how these lengths should be determined and allows the user to enter values for both lengths. When both lengths are entered, DYECON calculates the estimated hydraulic efficiency and displays it in the lower portion of the screen. Hydraulic efficiency is displayed as a percent corresponding to the size of mean retention time relative to the theoretical hydraulic retention time.

Hardware Setup for Graphics

Graphics are an integral part of the design process using DYECON. Displaying, printing, and plotting the graphics require the user to specify the hardware configuration. Selecting option 5, perform hardware configuration for graphics, from the *DYECON Activity Selection Menu* provides the user with a screen for selecting the plotter, printer, and video hardware from a list of available choices. The user will also need to specify the desired resolution for each hardware device.

Computational Procedures

The computational procedures employed by DYECON are essentially those described in EM 1110-2-5027 (OCE 1987) for determining the mean hydraulic retention time and hydraulic efficiency of a CDF. The procedures are described below.

Hydraulic Retention Time

DYECON calculates the mean hydraulic retention time (sometimes referred to as the average residence time), Morrill Index, and other statistical parameters used to evaluate CDF performance with regards to hydraulic efficiency (Deaner 1970, Rebhun and Argaman 1965, and Morrill 1932). DYECON first calculates the centroid of the area under the dye concentration versus time curve from the data entered by the user. The mean retention time is the first moment of this area about the origin and is equal to the x-coordinate of the calculated centroid (Rich 1973, and Beer and Johnston 1977). The y-coordinate of the centroid is the mean dye concentration and can be used to estimate the effective dye recovery if the effluent discharge rate remained constant during the test.

Hydraulic Efficiency

DYECON calculates hydraulic efficiency using Equation 1 based upon the results of the slug dye tracer data and the theoretical retention time entered by the user. This method is preferable but requires an existing site which is operating to conduct the field test.

DYECON also provides a method for estimating hydraulic efficiency of a CDF based upon site geometry. The method is described in EM 1110-2-5027 and based upon the equation:

$$e_h = \frac{T}{T_d} = 0.9 \left[1 - e^{-0.3 \frac{L}{W}} \right] \tag{2}$$

where
e_h = hydraulic efficiency, dimensionless
T = mean hydraulic retention time, sec
T_d = theoretical hydraulic retention time, sec
L = length of the flow path, ft
W = width of CDF normal to flow path, ft

The length of the flow path is the distance travelled from the inflow point to the discharge point. This is the straight line distance between the discharge pipe and effluent weir if flow diversions or obstructions do not exist. Flow diversion or spur dikes can significantly reduce dead zones and increase the length of the flow path by

forcing the flow path to change directions. The flow path then is the sum of the flow path lengths along the direction of flow.

The width, W, should reflect the average width along the flow path. This width should reflect flow restrictions imposed by flow diversions or obstructions. For example, in a long, rectangular CDF with equally spaced and equal length spur dikes in the longitudinal direction, the width specified should be the distance between spur dikes. Alternatively, the width could be estimated to be the result of the ponded area divided by the length of the flow path.

Summary

DYECON is an effective and efficient means of analyzing slug dye tracer results and calculating the hydraulic efficiency of a CDF. DYECON is easy to use and its procedures provide a consistent means for CDF analysis and design. It is an ADDAMS tool which facilitates proper dredged material management by encouraging the evaluation of an array of design alternatives.

References

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APPENDIX A: REQUEST FORM FOR ADDAMS

Please send the ADDAMS diskettes to:

Name and Title   _____

Mailing Address   _____

  and Office Symbol   _____

                        _____

Telephone Number   _____

Anticipated uses of ADDAMS _____

_____

Date   _____

Requests for ADDAMS must be sent with *formatted* floppy disks.

Please circle the applications desired and the number of diskettes enclosed.

Requested Modules	Number of diskettes (3.5-in., 1.44-MB)
ADDAMS (all modules)	16
ADDAMS DEMO	2
SETTLE	1
DYECON	1
PSDDF	1
D2M2	1
STFATE	3
EFQUAL	1
RUNQUAL	1
HELPQ	2
LTFATE	1
PUP	1
RECOVERY	1

MAIL THE COMPLETED REQUEST FORM AND FORMATTED DISKETTES TO:

U.S. Army Engineer Waterways Experiment Station
ATTN: CEWES-EE-A (Paul R. Schroeder)
3909 Halls Ferry Road
Vicksburg, MS 39180-6199