Environmental Effects of Dredging
Technical Notes

INTERIM GUIDANCE FOR PREDICTING QUALITY OF EFFLUENT DISCHARGED
FROM CONFINED DREDGED MATERIAL DISPOSAL AREAS--APPLICATION

PURPOSE: The following series of technical notes describe the functions necessary for predicting the quality of effluent discharged from confined dredged material disposal areas during disposal operations.*

EEDP-04-1   General

EEDP-04-2   Test Procedures

EEDP-04-3   Data Analysis

EEDP-04-4   Application

The guidance was developed as a part of on-going research conducted under the Long-Term Effects of Dredging Operation (LEDO) Program. Procedures for such predictions are being refined and verified under LEDO through comparative evaluation of predictions and field measurement of effluent water quality.

BACKGROUND: Confined dredged material disposal has increased because of constraints on open-water disposal. The quality of water discharged from confined disposal areas during disposal operations (effluent) is a major environmental concern associated with such disposal.

Dredged material placed in a disposal area undergoes sedimentation that results in a thickened deposit of material overlaid by clarified water (called supernatant), which is discharged as effluent from the site during disposal operations. The concentrations of suspended solids in the effluent can be determined by column settling tests.

The effluent may contain both dissolved and particle-associated contaminants. A large portion of the total contaminant content is particle

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*   The modified elutriate test does not account for long-term geochemical changes that may occur following disposal and subsequent drying of the dredged material and therefore should not be used to evaluate quality of surface runoff from the disposal sites.

associated. The modified elutriate test was developed for use in predicting both the dissolved and particle-associated concentrations of contaminants in the effluent from confined disposal areas.

REGULATORY ASPECTS: Guidelines have been published to reflect the 1977 Amendments of Section 404 of the Clean Water Act (EPA 1980). Proposed testing requirements define dredged material according to four categories. Category 3 includes potentially contaminated material proposed for confined disposal that has "potential for contamination of the receiving water column only." The proposed testing requirements call for evaluation of the short-term water column impacts of disposal area effluents. Predicted contaminant levels based on results of modified elutriate and column settling tests along with operational considerations can be used with appropriate water-quality standards to determine the mixing zone required to dilute the effluent to an acceptable level (Environmental Effects Laboratory 1976, EPA/CE 1977).

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<u>Example 1: Evaluation of Effluent Water Quality
for an Existing Disposal Area</u>

Project information

Dredged material from a maintenance project will be placed in an existing disposal site. The site will be ponded over an area of approximately 35 acres. The design indicated that the surface area was adequate for effective sedimentation if a minimum ponding depth D_{pw} of 2 ft was maintained. The dredging equipment and anticipated pumping conditions will result in a flowrate of approximately 30 cfs. A field mean retention time of 20 hr was determined from a dye tracer test run during earlier disposal operations at this site under similar operational conditions. Previous sampling of inflow from the dredged pipe under similar conditions indicated an influent solids concentrations of approximately 150 g/ℓ.

The quality of effluent must be predicted and compared to applicable water quality standards so that the acceptability of the proposed discharge can be evaluated. A mixing evaluation was conducted, and a dilution factor of 38 was determined for the allowable mixing zone. The water quality standard for copper at the perimeter of the mixing zone was set at 0.004 mg/ℓ (whole water). The concentration of copper in the effluent at the point of discharge must, therefore, be less than 0.15 mg/ℓ.

Modified elutriate test

Modified elutriate tests were conducted on samples of sediment and

water from three stations at the proposed dredging site. Modified elutriate tests were run at the anticipated influent solids concentration C_{slurry} of 150 g/ℓ. Sediment samples from each sampling station were homogenized.

For one of the homogenized samples, a sediment solids concentration $C_{sediment}$ of 450 g/ℓ was determined by oven drying a sample of known volume. The volumes of sediment and water to be mixed to obtain 3-3/4 ℓ of slurry with 150 g of solids per liter was determined as follows:

$$V_{sediment} = 3.75 \frac{C_{slurry}}{C_{sediment}} = 3.75 \frac{150}{450} = 1.25 \tag{1}$$

$$V_{water} = 3.75 - V_{sediment} = 3.75 - 1.25 = 2.50 \tag{2}$$

The modified elutriate tests were completed as described in Technical Note EEDP-04-2. A settling time of 20 hr was used since that was the estimated field retention for this case. Samples were extracted for the replicate tests and analyzed for total suspended solids and both dissolved and total concentration of contaminants of concern.

The total suspended solids concentration SS in one of the extracted samples was 40 mg/ℓ. The dissolved concentration C_{diss} of copper in this sample was 0.06 mg/ℓ, while the total concentration C_{total} of copper was 0.08 mg/ℓ. The fraction of copper in the total suspended solids F_{SS} for this sample was determined as follows:

$$F_{SS} = 1 \times 10^6 \left(\frac{C_{total} - C_{diss}}{SS} \right)$$

$$= 1 \times 10^6 \left(\frac{0.08 - 0.06}{40} \right) \text{ or } 500 \text{ mg/kg SS} \tag{3}$$

These calculations were repeated for other replicate tests, and the average dissolved and particulate copper concentrations were found to be 0.06 mg/ℓ and 510 mg/kg SS , respectively.

Column settling test

Samples from all stations were homogenized into a composite for column settling tests. The test used for prediction of effluent suspended solids was run at a slurry concentration of 150 g/ℓ , which was equal to the anticipated influent slurry concentration.

The interface was formed early in the test. Samples were extracted from

all ports above the interface at 3, 7, 14, 24, and 48 hr. The recorded observation and the subsequent computations are shown in Figure 1.

Since an interface formed in the test, the slurry mass was undergoing zone settling. Therefore, the initial supernatant solids concentration SS_0 was assumed equal to the highest concentration of the first port samples taken, 169 mg/ℓ. In computing ϕ and constructing the concentration profile diagram (Figure 2), 169 mg/ℓ was used as ϕ = 100 percent .

The concentration profile diagram (Figure 2) was used for graphical determination of R , the percentage of solids removed, for the various time intervals at z = 1, 2, and 3 ft, which was the range of anticipated depths of withdrawal influence at the weir. This was done by using a planimeter to measure the area to the right of each concentration profile (defined by circled numbers in the figure) and computing its ratio to the total area above 1, 2, and 3 ft.

An example calculation of removal percentage for the concentration profile at T = 14 hr and a depth of influence of 2 ft is as follows:

$$R_{14} = \frac{\text{Area Right of Profile}}{\text{Total Area}} \, 100 = \frac{\text{Area 1-2-3-0}}{\text{Area 1-2-4-0}} \, 100 \text{ or 78 percent} \qquad (4)$$

The percentage of solids remaining at T = 14 hr was found as follows:

$$P_{14} = 100 - R_{14} = 100 - 78 \text{ or 22 percent} \qquad (5)$$

The value for the suspended solids remaining at T = 14 hr was determined as follows:

$$SS_{14} = \frac{P_{14}}{100} \times SS_0 = 0.22 \times 169 \text{ or 37 mg/}\ell \qquad (6)$$

Values at other times were determined in a similar manner. The data for the 2-ft depth of influence were compiled as shown in the following tabulation.

Sample Extraction Time t , hr	Removal Percentage R_t	Remaining Percentage P_t	Suspended Solids SS, mg/ℓ
3	14	86	145
7	47	53	90
14	78	22	37
24	90	10	17
48	94	6	10

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COLUMN SETTLING DATA				
(1) TIME t HR	(2) SAMPLE DEPTH z FT	(3) TOTAL SUSPENDED SOLIDS SS mg/ℓ	(4) PERCENT OF INITIAL CONCENTRATION ϕ	
3	0.2	93		
	1.0	169	100	
7	1.0	100	59	
	2.0	105	62	
14	1.0	45	27	
	2.0	43	25	
	3.0	50	30	
24	1.0	19	11	
	2.0	18	11	
	3.0	20	12	
48	1.0	15	9	
	2.0	7	4	
	3.0	14	8	

NOTES: COLUMNS 1 AND 2 - RECORD FOR EACH PORT SAMPLE.
COLUMN 3 - COMPLETE FROM TEST RESULTS.
COLUMN 4 - COMPUTE USING THE HIGHEST SUSPENDED SOLIDS CONCENTRATION OF
THE FIRST PORT SAMPLE AS THE INITIAL CONCENTRATION SS_0.

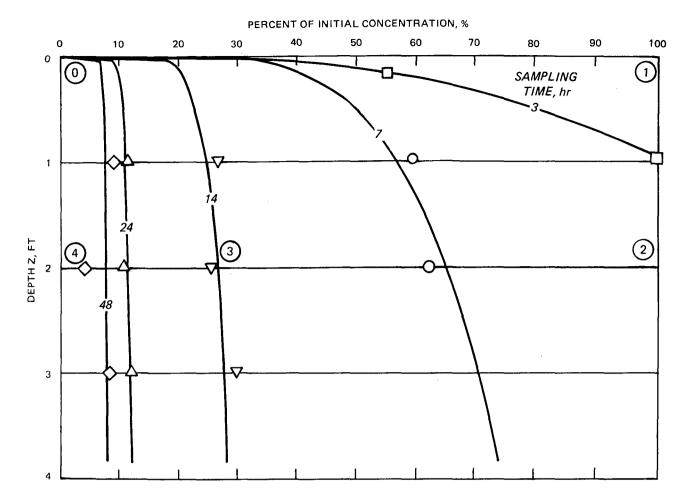Figure 1

PERCENT OF INITIAL CONCENTRATION, %

Figure 2. Concentration profile diagram

Similar calculations for other depths of influence were made. Curves were fitted to the total suspended solids versus retention time for depths of influence of 1, 2, and 3 ft, as shown in Figure 3.

Prediction of effluent
suspended solids concentration

A value for effluent suspended solids can be determined for quiescent settling conditions using the column test relationships. In this case, the field mean retention time of 20 hr corresponds to a suspended solids concentration SS_{col} of 24 mg/ℓ, as shown in Figure 3. This value should be adjusted for anticipated resuspension using the resuspension factors as given in Technical Note EEDP-04-3:

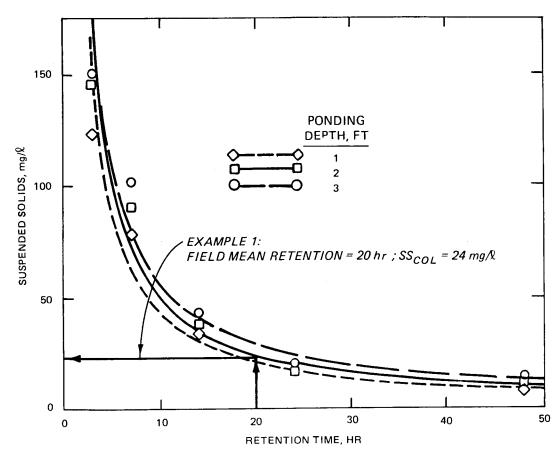| Anticipated Ponded Area acres	Resuspension Factor- Average Ponded Depth	
	Less than 2 ft	2 ft or Greater
Less than 100	2.0	1.5
Greater than 100	2.5	2.0

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Figure 3. Suspended solids concentration estimated
from column settling test

In this case, for a surface area less than 100 acres and average ponding depth
of 2 ft, the resuspension factor RF is 1.5. The predicted total suspended
solids concentration SS_{eff} in the effluent is calculated as follows:

$$SS_{eff} = SS_{col} \times RF = 24 \text{ mg/}\ell \times 1.5 \text{ or } 36 \text{ mg/}\ell \tag{7}$$

Prediction of contaminant concentrations

The modified elutriate test results indicated that the concentration of
dissolved copper C_{diss} would be 0.06 mg/ℓ and that the fraction of copper in
the total suspended solids F_{SS} would be 510 mg/kg. The predicted total
suspended solids concentration in the effluent SS_{eff} is 36 mg/ℓ . The pre-
dicted concentration of total copper in the effluent C_{total} is calculated as
follows:

$$C_{total} = C_{diss} + \frac{F_{SS} \times SS_{eff}}{1 \times 10^6} = 0.06 + \frac{510 \times 36}{1 \times 10^6} = 0.078 \text{ or } 0.08 \text{ mg/}\ell \tag{8}$$

The estimated concentrations of other contaminants in the disposal area

effluent can be determined in a similar manner. The acceptability of the proposed discharge can be evaluated by comparing the estimated effluent concentrations with applicable water-quality standards, considering an appropriate mixing zone. For total copper, the predicted concentration of 0.08 mg/ℓ at the point of discharge is less than the maximum of 0.15 mg/ℓ specified in the water-quality standards. The discharge would therefore be acceptable.

Example 2: Determination of Disposal Area Requirements to Meet a Given Effluent Quality Standard

Project information

A disposal area is planned for contaminated sediment from a small maintenance dredging project. Dredging plant traditionally used in the project area is capable of flowrates up to 15 cfs. Available real estate in the project vicinity is scarce with the maximum available area limited to 60 acres. The minimum disposal area requirements to meet applicable water-quality standards must be determined.

The design using procedures described by Montgomery (1978) and Palermo, Montgomery, and Poindexter (1978) indicated that a minimum ponded surface of 20 acres was required for effective sedimentation, assuming a flow rate of 15 cfs and a minimum ponding depth of 2 ft. A mixing evaluation was conducted and a dilution factor of 60 was determined for the allowable mixing zone. The water-quality standard for PCB at the perimeter of the mixing zone was set at 0.00003 mg/ℓ. The concentrations of PCB in the effluent (at the point of discharge) must therefore be less than 0.0018 mg/ℓ to meet the standards, considering an appropriate mixing zone.

Modified elutriate test

Modified elutriate tests were conducted and calculations made as described for Example 1. For this example, the mean field retention time for the proposed disposal area was not known, so the maximum laboratory retention of 24 hr was used for the tests. Since the inflow concentration was not known, the tests were run at a slurry concentration of 150 g/ℓ. Results for replicate tests for this example were 0.001 mg/ℓ for the concentration of dissolved PCB C_{diss} and 44 mg/kg for the fraction of PCB in the total suspended solids F_{SS}.

Column settling test

Column settling tests were run at a slurry concentration of 150 g/ℓ,

and the resulting concentration profile was developed as in Example 1 (Figure 2). For simplicity, the results of the column settling tests used in Example 1 will also be used for this example.

Determination of required effluent suspended solids concentration

Since this requires determination of disposal site characteristics to meet a given water-quality standard, the calculations proceeded in a manner similar to Example 1, but in a reverse sequence. The concentration of effluent suspended solids SS_{eff} required to meet water-quality standards must first be determined. For total PCB C_{total}, the standard at the point of discharge is 0.0018 mg/ℓ. The suspended solids concentration required to meet this standard is calculated as follows:

$$C_{total} = C_{diss} + \frac{F_{SS} \times SS_{eff}}{1 \times 10^6} \qquad (9)$$

or transposed,

$$SS_{eff} = \frac{1 \times 10^6}{F_{SS}} \left(C_{total} - C_{diss} \right)$$

$$= \frac{1 \times 10^6}{44.0} (0.0018 - 0.001) \text{ or } 18 \text{ mg/}\ell$$

Based on this calculation, the effluent suspended solids concentration cannot exceed 18 mg/ℓ without exceeding the standard for PCB. Similar determinations should be made for other contaminants being considered in order to define the limiting value for the required effluent suspended solids concentration. For this example, 18 mg/ℓ was used as the limiting value.

Since the final site configuration is not known, a conservative resuspension factor RF should be selected from the tabulation given in Example 1. The minimum ponding depth of 2 ft required by the site design is used. A resuspension factor of 1.5 was selected corresponding to an area less than 100 acres and ponding depth of 2 ft.

The value of 18 mg/ℓ suspended solids (including resuspended particles) must be met at the point of discharge. The corresponding value for total suspended solids concentration under quiescent settling condition is determined by transposing Equation 7 ($SS_{eff} = SS_{col} \times RF$) as follows:

$$SS_{col} = \frac{SS_{eff}}{RF} = \frac{18 \text{ mg/}\ell}{1.5} \text{ or } 12 \text{ mg/}\ell$$

The required configuration of the disposal area must correspond to a retention time that will allow the necessary sedimentation. The required retention time to achieve 12 mg/ℓ under quiescent settling conditions can be determined from the laboratory column relationship for suspended solids versus retention time.

Using the concentration profile data and the assumed depth of ponding at the weir of 2 ft, the relationship for suspended solids versus field mean retention was developed as shown in Figure 4. Using Figure 4, 12 mg/ℓ corresponds to a field mean retention time T_d of 36 hr. To determine the required disposal site geometry, the theoretical retention time T should be used. Since no other data were available, the hydraulic efficiency factor HEF was assumed as 2.25. The theoretical retention time T was calculated as follows:
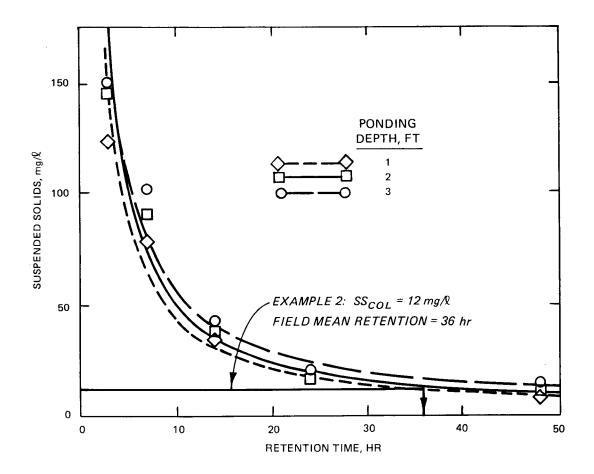

Figure 4. Field mean retention time estimated from column settling test

$$t_d = \frac{T}{(HEF)} \tag{10}$$

transposed to

$$T = T_d \ (HEF) = 36 \ (2.25) \ or \ 81 \ hr$$

Determination of disposal area configuration

The disposal area configuration can now be determined using data on anticipated flowrate and the required retention time. Since the dredging equipment available in the project area is capable of flowrates up to 15 cfs, the high value should be assumed.

The pond volume required is calculated as follows:

$$T = \frac{V_p}{Q_i} \ (12.1) \tag{11}$$

transposed to

$$V_p = \frac{T \ Q_i}{12.1} = \frac{81 \ hr \times 15 \ cfs}{12.1} \ or \ 100 \ acre\text{-}ft$$

A ponding depth of 2 ft is the minimum required. This same depth should be maintained over the entire ponded surface area and at the weir. The disposal site should, therefore, encompass approximately 50 acres of ponded surface area if the dredge selected for the project has an effective flowrate not greater than 15 cfs. The surface area of 50 acres required to meet the water-quality standard controls over the design surface area of 20 acres required for effective sedimentation.

References

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Environmental Protection Agency/Corps of Engineers. 1977. "Ecological Evaluation of Proposed Discharge of Dredged Material into Ocean Water, Implementation Manual for Section 103 of Public Law 95-532 (Marine Protection, Research, and Sanctuaries Act of 1972), US Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

Montgomery, R. L. 1978. "Methodology for Design of Fine-Grained Dredged Material Containment Areas for Solids Retention," Technical Report D-78-56, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

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