

## Planning Level Cost-Benefit Analysis for Physical Separation at Confined Disposal Facilities

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**PURPOSE:** This technical note is the fourth in a series providing guidance on evaluating the potential for recovery of dredged material from confined disposal facilities (CDFs) for beneficial use (BU). Olin-Estes and Palermo (2000a, 2000b) and Olin-Estes (2000) discuss physical separation concepts as they apply to dredged material recovery, mathematical relationships for estimating recoverable material, and methods for developing sampling plans for CDFs to support these evaluations. This technical note describes a conceptual approach to estimating the comparative cost benefit for separation as a volume reduction method, based on recoverable volume, processing cost, and disposal facility life and replacement cost.

**BACKGROUND:** The technical feasibility of separation as a management approach is dependent upon several factors, including the ability to identify and separate distinct fractions within the material that meet BU criteria. The economic feasibility of separation is dependent on the complexity of the separation treatment train, disposal and BU alternatives and costs, site-specific logistical considerations, and project scale.

The principal motivation for BU recovery of dredged material is the growing shortage of storage capacity in CDFs, coupled with the high cost to replace this capacity. The fundamental purpose of these technical notes is to assist in determining when material recovery is technically and economically feasible. Olin-Estes and Palermo (2000a, 2000b) and Olin-Estes (2000) provide strategies for obtaining and interpreting physical and chemical information necessary for this evaluation at the least possible cost. This technical note develops an approach for screening-level economic analysis of separation alternatives, together with methods for quantifying potential volume reduction for different processes, which can be used in planning-level decision making and in support of a detailed cost-benefit analysis. It presents the basic economic principles and approach utilized, followed by simple separation concepts and volume reduction calculations. Examples are developed for one-time and long-term dredging projects to illustrate the relative importance of the different variables involved.

**INTRODUCTION:** Although physical separation has been successfully demonstrated technically, the economic viability of full-scale implementation is difficult to determine based on overall project volumes and unit costs reported in the literature. Part of the difficulty can be attributed to the fact that costs associated with small volume demonstrations are typically high on a per-unit basis. In part, this is because mobilization and demobilization costs are relatively insensitive to the volume being processed: a larger project will distribute these costs over a larger volume, resulting in lower unit costs. For the most part, representative full-scale costs are difficult to extract from the literature or from other projects because they are heavily influenced by site-specific factors such as local labor cost, equipment availability, site accessibility, distance to water, terrain, weather and climate, material characteristics, disposal requirements and costs, and differences in what is included in

reported costs. Some examples of total project costs and cost estimating sheets for soil remediation projects, however, can be found in U.S. Environmental Protection Agency (USEPA) (1999).

This technical note introduces a planning level approach to making cost comparisons between disposal and process alternatives and quantifying volume reduction, or volume recovery, potential. Site-specific cost information should be used when possible; cost ranges reported herein should be used primarily as a "reality check." Cost estimates falling significantly outside the cost ranges reported for similar projects should be closely scrutinized to determine the basis for the difference. Detailed costs should be developed for potentially viable alternatives based on the planning level cost-benefit analysis. These costs should be used in conducting a detailed economic analysis for the project.

**ECONOMIC ANALYSIS:** The benefits of physical separation and mechanical dewatering of dredged material are based on the next least cost dredged material disposal alternative. In the absence of separation and dewatering processing, the analyst must identify the most likely future dredged material disposal alternative (the base condition). Potential quantitative benefits of physical separation are reductions in cost and increases in revenue from the base condition to the physical separation alternative. The analysis assumes the in situ volume of sediment to be dredged will be the same for all alternatives.

### **Identifying the Base Condition**

**Step 1: Determine the period of analysis.** Corps planning studies typically use either a 50- or 100-year planning horizon; however, a shorter period may be appropriate for the analysis of physical separation projects. The period of analysis should be of sufficient length to allow a life-cycle analysis of the benefits and cost of all alternatives.

**Step 2: Define the project scope.** Estimate the quantity and timing of dredged material to be disposed over the life cycle of the project planning horizon.

**Step 3: Define the dredging and disposal alternatives.** Disposal alternatives may include CDF disposal, a combination of CDF disposal and offsite disposal, or offsite disposal.

**Step 4: Determine the base condition.** From the available alternatives, determine the least-cost method of dredging and disposal without physical separation. This will establish the Base Condition from which to measure benefits of physical separation.

1. This analysis compares the cost of alternative dredging and disposal scenarios. The scenarios may assume different dredging technologies, different transportation methods and offloading costs at an offsite disposal area or CDF, and/or the cost of developing a disposal site. For example, when available CDF capacity is limited, material may be disposed offsite, dredging may be done with a smaller dredge (requiring less settling freeboard), or CDF capacity may be increased. The combinations of offsite disposal and CDF facilities (existing and developed) must be of sufficient size to receive the quantity estimated in Step 2. New CDF sites will incur site acquisition, permitting, and design cost and may require additional transportation cost. The

analysis should assume that the costs incurred for the new facilities are expended such that the new facility becomes available just as the existing facilities reach their capacity.

2. Calculate the average annual cost of dredging and disposal for each scenario. Correlate the cost of each action required (dredging, transportation, CDF construction, offsite disposal, etc.) with the timing of the action. This is illustrated in Figure 1. Discount the cost from the time incurred to its present value using the Federal discount rate<sup>1</sup>. Sum all the present values and amortize over the period of analysis. The least-cost method will have the lowest present value and lowest average annual cost. This method is the base condition and will be used to measure the cost and benefits of physical separation. A conceptual example of the base condition is depicted in Figure 1. It shows the existing CDF being expanded by raising the berms and then later being replaced by construction of a new CDF of sufficient capacity to last the remainder of the period of analysis.

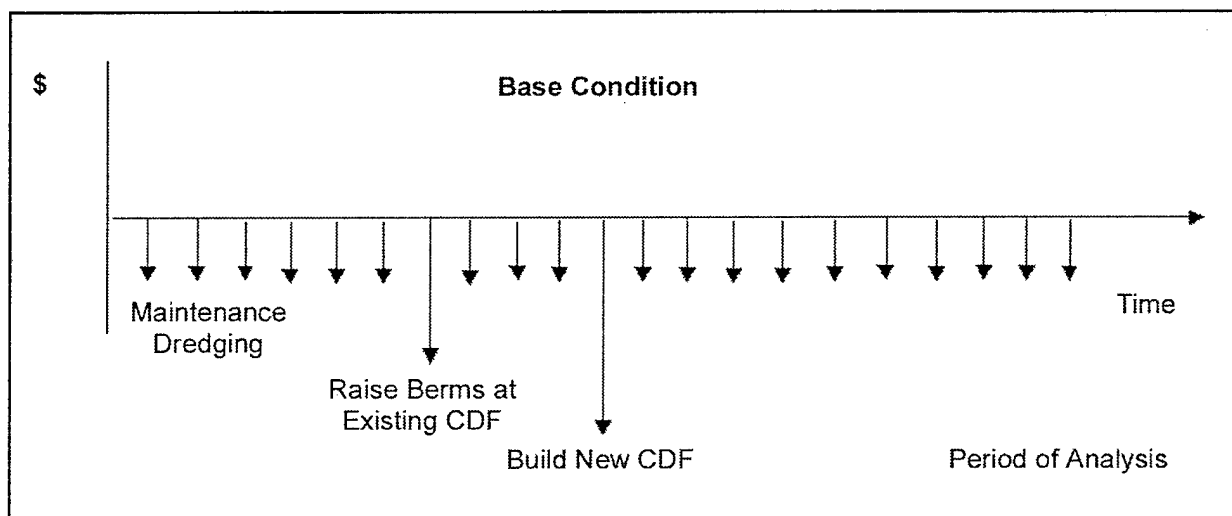


Figure 1. Base condition

## Formulating Physical Separation Alternatives

There are three general separation scenarios that could be formulated to extend the life of an existing CDF:

- 1) Volume reduction of incoming material.
- 2) Capacity recovery, i.e., removal of materials previously placed.
- 3) Capacity recovery and volume reduction of incoming material.

<sup>1</sup> Section 1.4.11 of the Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies requires discounting of future monetary values to present values. The discount rate is established each year and published in an Economics Guidance Memorandum by the Planning and Policy Division of the Directorate of Civil Works.

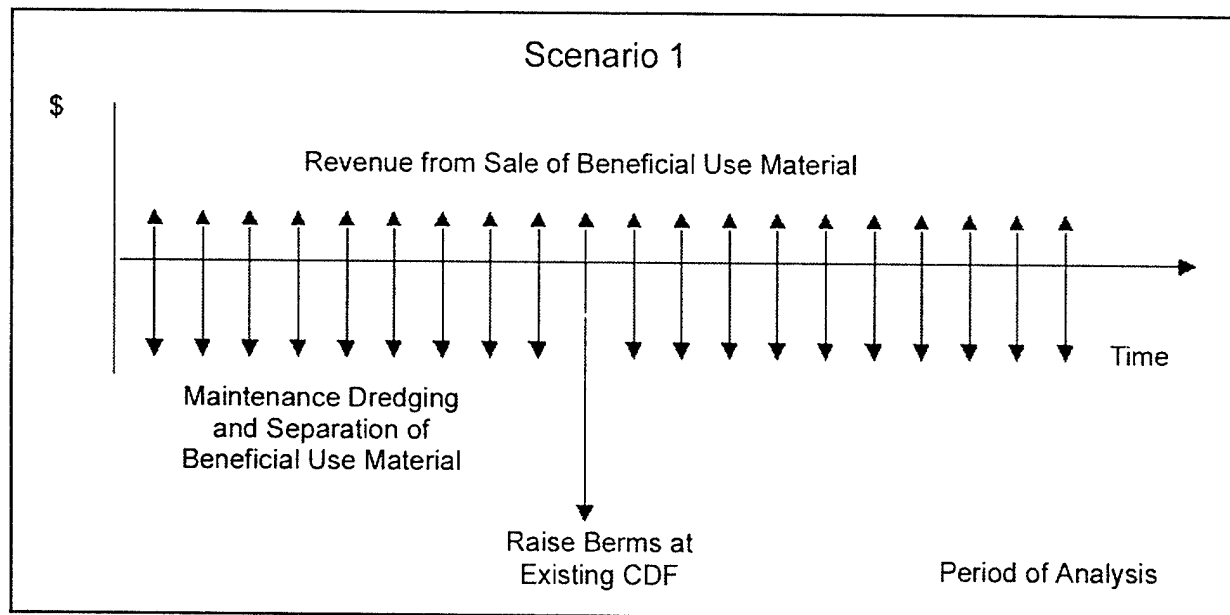


Figure 2. Scenario 1, separation of incoming material

Where CDF capacity is diminishing, volume reduction of incoming material might seem to be indicated in all cases (Figure 2). However, the benefit will be dependent upon the nature of the incoming material and the amount of volume reduction to be derived compared to the processing cost incurred. In cases where the incoming material is not suited to volume reduction, then removal of previously placed materials to recover in-CDF capacity might be another option, depending upon the nature of the materials previously placed (Figure 3). Where both incoming and previously placed materials lend themselves to volume reduction, the third alternative could be implemented (Figure 4).

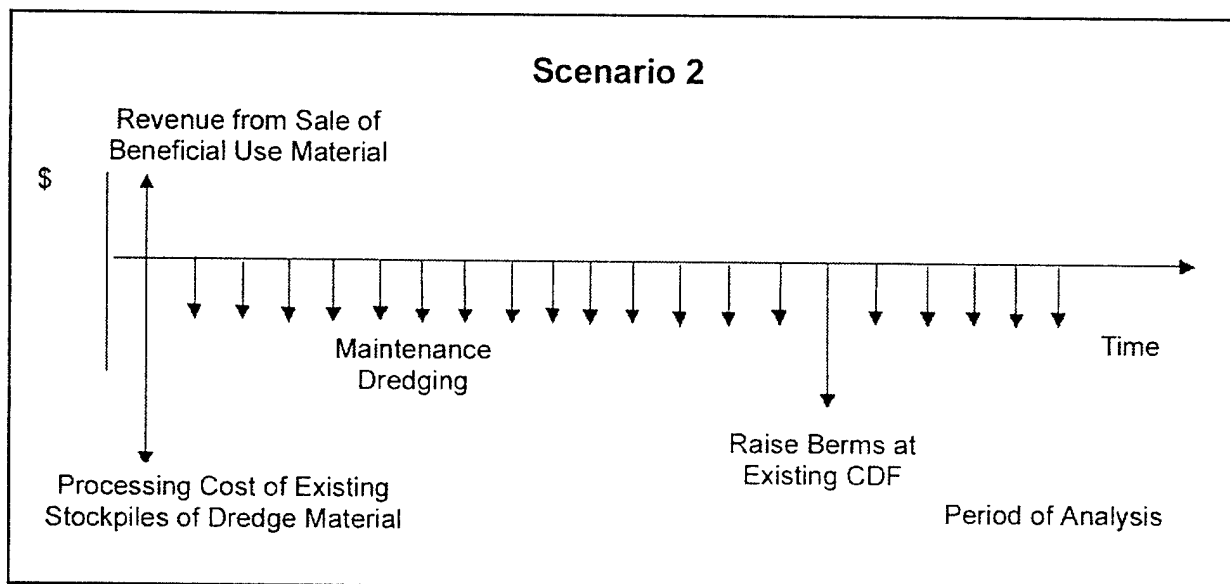


Figure 3. Scenario 2, processing material removed from CDF

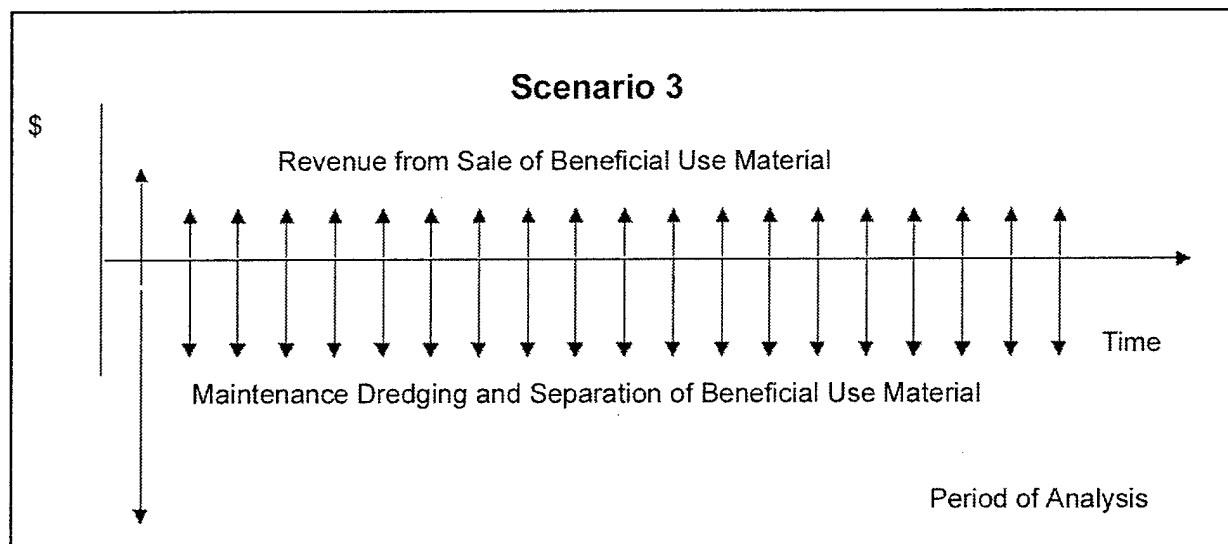


Figure 4. Scenario 3, processing incoming material and material removed from CDF

In the first scenario, volume reduction of incoming material (Figure 2), expansion of the CDF is deferred relative to the baseline condition depicted in Figure 1. This is indicated here by a downward arrow for raising the berms of the existing CDF. Revenues from the sale of BU material produced by processing incoming materials are represented by the upward arrow at the time of dredging and processing. This revenue is assumed to be realized with every dredging and processing event for purposes of illustration, but is not guaranteed. Regulatory restrictions on use of the material, public acceptance, and market demand will determine whether the material will be revenue producing.

Comparing the base condition (Figure 1) to scenario 2 (Figure 3), the processing of material removed from the CDF also postpones the need to expand the capacity of the CDF. In this example, the need for a new facility is completely eliminated during the period of analysis. Revenues from the sale of BU material produced by processing previously placed materials are represented in Figure 3 by the upward arrow at the time of the excavation and processing. The relative rates of material processing and maintenance dredging will determine how far into the future the need for additional capacity is postponed.

Figure 4 represents the third scenario, in which incoming material is separated and in-place material is processed to recover usable material. In this conceptual example, both the expansion of the existing CDF and the construction of a new CDF are eliminated for the period of analysis. The downward arrows are longer than in the base condition, reflecting the added cost of processing incoming material.

## Evaluating and Comparing Alternatives

**Step 1: Evaluate the alternatives.** Calculate the average annual cost of each alternative and compare to the base condition. The net benefits of the alternative are equal to the average annual cost of the base condition less the average annual cost of the alternative. The benefit-to-cost ratio is equal to the average annual cost of the base condition divided by the average annual cost of the

alternative. Alternatives with positive net benefits (a.k.a. BCR 1) are economically efficient alternatives. The alternative with the greatest net benefits maximizes benefits.

**Step 2: Calculate average annual cost.** Although specifics will vary between sites and the alternatives being evaluated, the economic analysis essentially follows the same series of steps. These are described in the following paragraphs. The analysis can be readily incorporated into a spreadsheet, facilitating comparison of several alternatives. This has been done for two examples, which are included as Appendix C.

I. Project Assumptions. This might include type of work, available disposal capacity, and base condition, for example:

- a. Type of dredging: new channel construction followed by maintenance dredging over the period of analysis.
- b. Disposal alternatives: no existing CDF.
- c. Base condition: CDF disposal, without separation or mechanical dewatering (no material will go offsite).

II. Calculate Base Condition

- a. Develop initial construction/dredging costs. These will be engineering costs, including all items that will impact the total project costs. Such items include mobilization/demobilization, dredging, dewatering, transportation, and placement. Any associated costs, such as CDF construction or expansion required to accommodate the initial (new-work construction) dredged material, must also be included in the construction costs. (Existing capacity is treated as a sunk cost, and is not factored into the evaluation.) Establish a construction period, annual quantity dredged, and total annual construction cost.
- b. Calculate interest during construction (IDC). IDC is the value adjustment of pre-base year construction costs, and is an economic cost that will not actually be paid by any party involved with the project. (In economic analyses, the base year refers to the first full year the project is operational.) IDC should be applied to all construction costs, including all costs associated with channel dredging as well as any placement costs, such as CDF construction or expansion. (Sunk construction costs for an existing CDF are not considered pre-base construction costs. Costs for a CDF constructed specifically for the project defined for the period of analysis are considered pre-base construction costs.) The calculation is done to bring all construction costs to the base year and make them equivalent in their time value. IDC should be calculated using the formula:

$$IDC = P * (1 + i)^t - P \quad (1)$$

where

$P$  = Annual construction amount

$i$  = Federal discount rate

$t$  = Time (years from construction year to base year)

- c. Calculate initial investment. The initial construction cost will equal the sum of all construction costs and IDC for each construction year.
- d. Develop maintenance dredging cycle and associated costs, including mobilization/demobilization, dredging, dewatering, transportation, and placement. Sufficient placement capacity must be available to accommodate all maintenance material for the entire period of analysis. All associated placement costs, such as CDF construction or expansion, as well as facility maintenance costs, must be developed and included. Timing for future costs must be established.
- e. Calculate net present value (NPV). Determine NPV of all costs, including construction costs, IDC, and anticipated future expenditures. Summing the present value for each project year, beginning with the base year (project year 1) and continuing throughout the period of analysis, results in the present worth of all project costs. NPV is given by

$$NPV = \sum P [1 / (1+i)^t] \quad (2)$$

where

$P$  = Annual cost  
 $i$  = Federal discount rate  
 $t$  = Time (project year)

- f. Compute average annual equivalent values (AAEV). Through amortization the previously calculated present worth can be converted to an average annual equivalent. This calculation results in representation of the total project costs spread uniformly across the period of analysis. Average annual equivalent values have a common price level and base year, making it simple to calculate potential benefits. AAEV is given by

$$AAEV = (NPV) * (i) * [(1 + i)^n / (1 + i)^{n-1}] \quad (3)$$

where

$NPV$  = Net present value (all costs)  
 $i$  = Federal discount rate  
 $n$  = Project life

- g. Determine the base condition. If more than one alternative is being considered for the base condition, these steps must be completed for each alternative. The least costly alternative, including initial investment, IDC, and future maintenance costs, is the base condition. The selected alternative will have the lowest average annual equivalent value.

### III. Calculate Separation Alternatives

- a. Develop construction/dredging costs. These will be engineering costs, including all items that will impact the total project costs. Such items include, but are not limited to, mobilization/demobilization, dredging, dewatering, separation, transportation, and placement. Separation alternatives must also consider the value of the coarse material as a negative cost, or profit, from the process. Establish a construction period, annual quantity dredged (in situ basis), annual quantity residuals requiring placement or offsite

disposal, and quantity suitable for beneficial use. Methods for estimating recoverable and residual volumes follow in the section titled "Volume Reduction Estimating."

- b. Calculate interest during construction (IDC). IDC must be calculated for each construction (new work) year using Equation 1.
- c. Calculate initial investment. The initial construction cost will equal the sum of all construction costs and IDC for each construction year.
- d. Develop maintenance dredging cycle and associated costs, including mobilization/demobilization, dredging, dewatering, separation, transportation, and placement. Sufficient placement capacity (either CDF or offsite) must be available to accommodate all residual maintenance material for the entire period of analysis. All associated placement costs for the disposal alternative, such as CDF construction or expansion, facility maintenance costs, and transportation and unit disposal costs, must be developed and included. Timing for future costs must be established.
- e. Calculate net present value (NPV). Determine NPV of all costs, including construction costs, IDC, and anticipated future expenditures. These calculations are completed using Equation 2.
- f. Compute the AAEV for each alternative using Equation 3.
- g. Select the separation alternative. If more than one separation alternative is being considered, these steps must be completed for each alternative. The least costly alternative that accommodates all future maintenance material, including initial investment, IDC, and future maintenance costs, is the selected separation option. The selected plan will have the lowest AAEV.

IV. Calculate Benefits from Separation. The benefit to separation is the savings between the annualized base condition costs and the annualized selected separation alternative costs. If separation is not more efficient than the base plan, the benefits from separation will be negative. Among separation alternatives with comparable benefits, intangible benefits, such as reduced contaminant emissions or habitat creation, may be factored into the final selection.

**VOLUME REDUCTION ESTIMATING:** Economic analysis requires estimation of in situ sediment volumes and relative volumes of recoverable materials and residuals requiring disposal. Procedures for estimating the percent material by mass meeting BU specifications (recoverable materials) were presented in Olin-Estes and Palermo (2000a). Mass and volume percentages are not equivalent, however, and this is central to the concept of volume reduction. The volume represented by a given mass percent of sand, for example, is a function of the specific gravity of the relative sediment fractions and the void ratio of the material. The relative proportions and specific gravity of the principal sediment fractions (sand, fines, organics) and in situ void ratio can be determined from bench-scale characterization of the material to be processed. Nomographs were developed for a hypothetical material to illustrate the variation in percent sand by volume versus percent sand by mass (Figure 5). Similar nomographs can be developed using site-specific information and the mathematical and geotechnical relationships describing the sediment fractions for a unit mass of sediment. By bounding the analysis within a range of values representative of

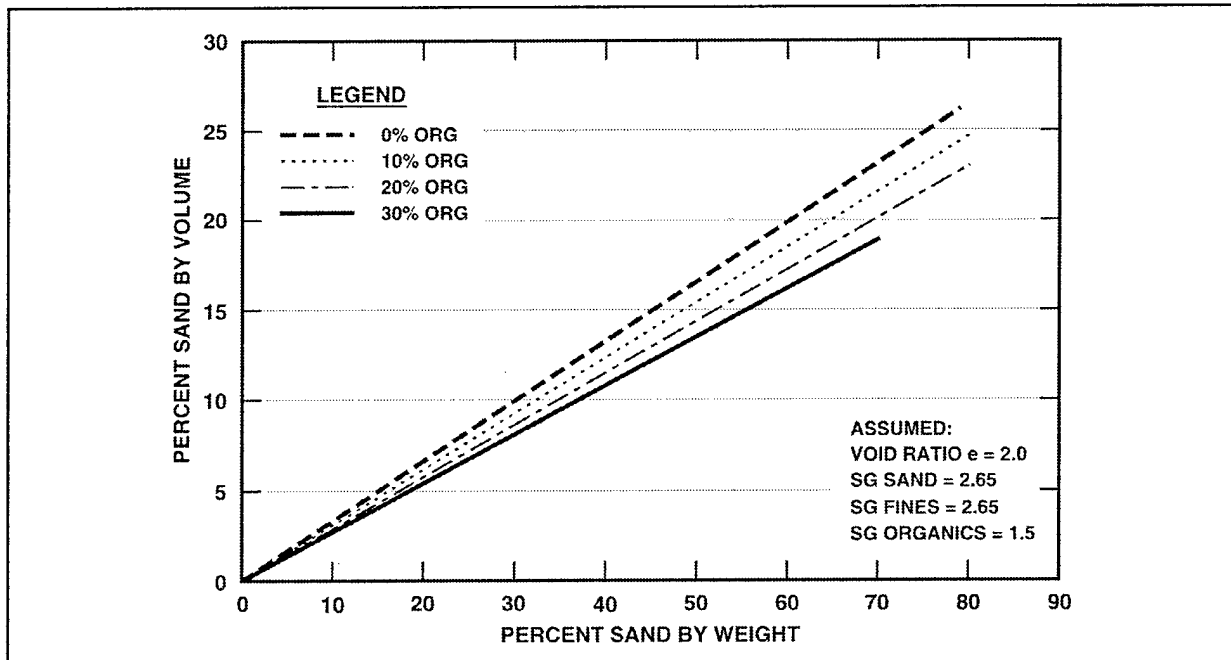


Figure 5. Percent sand by volume versus percent sand by weight, for void ratio 2.0 and organic specific gravity of 1.5

the entire deposit, coupled with proportional bulk sediment volumes, the best- and worst-case volume reduction potential for the total project volume can be roughly estimated.

In the recovery of a specified fraction from the bulk material, the material is slurried and separated around a “cut size” using equipment best suited to make the specified separation. Where a coarse/fine separation is desired, the cut is typically made at about 75  $\mu\text{m}$ . The material does not separate sharply at this cut size, however. A percentage of the material below the cut size will report with the coarse material. Similarly, a percentage of the material above the cut size will report with the fines. These proportions will vary depending upon the type and efficiency of the selected process. The major products will typically include a coarse fraction, a fine fraction, and a wastewater stream. These concepts are illustrated in Figures 6 and 7.

**Solids Mass Balance** - Although the sediment or dredged material will be slurried with water in the course of dredging and processing, conceptually it is helpful to look at the solid and water balances separately. Figure 6 is a simplification of the actual distribution of solids.

$M_T$  is the solids mass flow rate ( $M/T$ ) from a dredge or CDF excavation process, and is represented by the following equation:

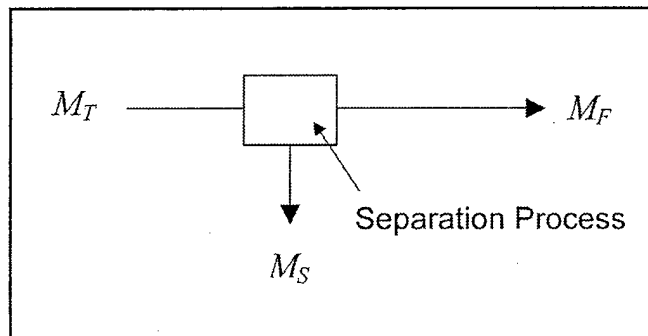


Figure 6. Solids mass balance diagram

$$M_T = Qs\rho_s \quad (4)$$

where

$Q$  = the volumetric flow rate to the separation process,  $V/T$

$s$  = percent solids by volume, as decimal, unitless

$\rho_s$  = particle density,  $M/V$

$M_S$  is the solids mass flow rate of the coarse material from the separation process, and is given by

$$M_S = x_m M_T c \quad (5)$$

where

$x_m$  = efficiency of coarse solids separation on a mass basis, unitless (decimal)

$c$  = percent coarse (specified cut size) by mass in bulk material, unitless (decimal)

$M_F$  is the solids mass flow rate of the fines from the separation process, and is given by the following, assuming 100 percent of the fines reports with the process overflow. The first term represents the coarse material that reports to the fine fraction as a result of process inefficiency:

$$M_F = M_T c (1 - x_m) + M_T (1 - c) \quad (6)$$

**Volumetric Water Balance** –  $Q_X$  is the volumetric flow rate of water to the separation process (Figure 7).  $Q_F$  is the flow rate reporting with the fines, typically the bulk of the processing water.  $Q_S$  is the flow rate reporting with the coarse fraction. Some of this water will be free draining ( $Q_{Free}$ ), and will be captured and returned to the process or released as effluent. The residual pore water makes up the remainder ( $Q_{Pore}$ ).

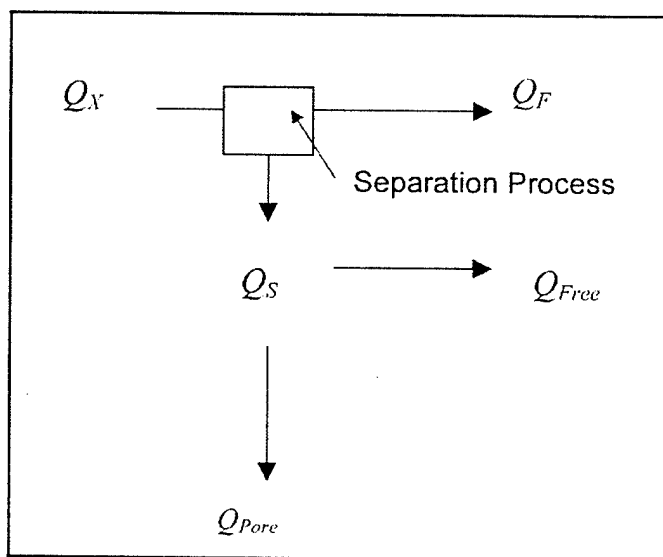


Figure 7. Water balance diagram

$Q_F$  and  $Q_{Free}$  represent volumetric flows that must be managed. Following a settling or dewatering process to remove solids, they may be recirculated through the process, or treated and released as effluent. Process slurries are typically fairly dilute, with 10 to 15 percent solids by volume being representative. Process water volumes are therefore relatively high. Volumes reported in the literature ranged from approximately 1,000 gallons to 1,700 gallons process water per cubic yard processed and dewatered sediment.

The coarse solids fraction is typically targeted for beneficial use and the fine fraction

for onsite or offsite disposal. The disposal volume of the fine fraction relative to the disposal volume for the bulk material represents the volume savings to be realized. Where material is to be transported offsite, weight reduction may be the controlling parameter. Volume reduction estimates can be refined with bench- or pilot-scale process testing. A fractional bulking factor was developed to facilitate quantitative estimation of volume reduction potential based on initial and final material properties derived from such testing. This is potentially useful in comparative process evaluations, such as different dewatering techniques, and may form the basis for cost justification of one process over another.

Define in situ volume  $V_{T_i}$  as follows:

$$V_{T_i} = V_{s_i} + V_{F_i} + V_{V_i} \quad (7)$$

where

$V_{T_i}$  = volume total, in situ or initial

$V_{s_i}$  = volume sand, in situ or initial

$V_{F_i}$  = volume fines, in situ or initial

$V_{V_i}$  = volume voids, in situ or initial

Define dewatered sediment volume  $V_{T_f}$  (final total volume) as follows:

$$V_{T_f} = (1 - x_v) V_{s_i} + V_{F_i} + V_{V_f} \quad (8)$$

where

$x_v$  = efficiency of sand removal, by volume

$V_{V_f}$  = volume voids, final

Define the overall bulking factor as

$$b = \frac{V_{T_f}}{V_{T_i}} \quad (9)$$

Expressing material volumes in terms of mass and density, the bulking factor can be expressed in terms of initial and final material properties, which are readily measured before and after processing. The derivation of this factor is described in Appendix A, and yields the following expression:

$$b = \frac{(1 + w_f)[(1 - x_m)M_{S_i} + M_{F_i}]\rho_{t_i}}{(1 + w_i)(M_{S_i} + M_{F_i})\rho_{t_f}} \quad (10)$$

where

$w_i$  and  $w_f$  = water content, as a decimal

$M_{S_i}$  = mass sand, in situ or initial

$M_{F_i}$  = mass fines, in situ or initial

$\rho_{t_i}$  = total or wet density, in situ or initial

$\rho_{t_f}$  = total or wet density, final

An estimate of the disposal volume following processing can therefore be obtained based on the hydrographic survey and projected dredging depths  $V_{T_i}$ , and the bulking factor derived by measuring the initial and final water content, sand and fine mass, and wet density of representative samples, thus:

$$V_{T_f} = b V_{T_i} \quad (11)$$

The net volume recovery is then

$$\Delta V = V_{T_i} - V_{T_f} \quad (12)$$

Conceptually, it is valuable to consider potential volume reduction in the context of the processes being utilized. Depending upon the process under consideration, this may be a time-dependent value. For example, hydraulically dredged and placed materials require additional disposal volume to provide adequate freeboard and settling depth for effective solids capture. The initial disposal capacity required for hydraulic placement will therefore be much larger than for mechanically dredged, or mechanically dewatered, materials. Figure 8 illustrates the time-dependent nature of volume recovery, which determines

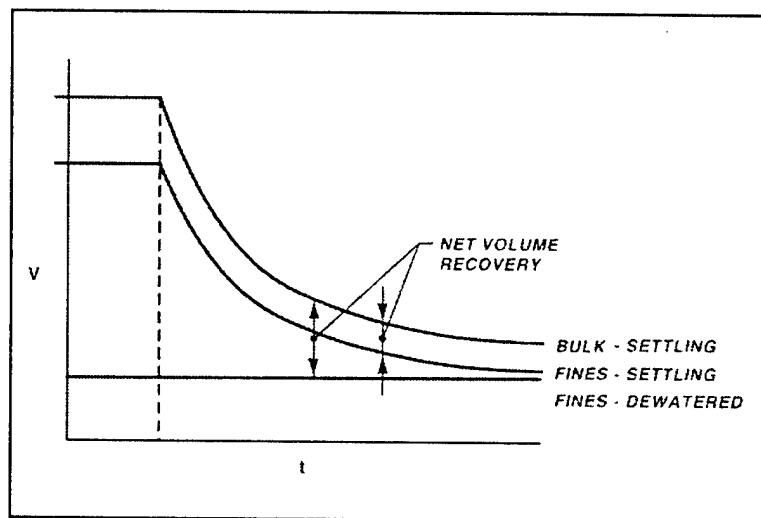


Figure 8. Relative disposal volumes as a function of time for bulk and separated, hydraulically placed material, and separated, mechanically dewatered material

the initial disposal volume for hydraulically placed sediments versus disposal volume requirements for mechanically dewatered sediments.

The necessary volume and cost comparisons will be site specific depending upon excavation method (mechanical or hydraulic), use of separation for BU material recovery, and dewatering method employed.

**DESIGN VALUES:** Some cost information is available for the following cost components. These would form the basis of a detailed economic analysis, applying the unit costs to the relative volume estimates as developed in the preceding section.

- CDF construction.
- Dredging.
- Excavation.
- Separation/dewatering.
- Offsite transportation and disposal.

The cost ranges reported in this document are intended to serve primarily to provide a frame of reference in the cost evaluation process. It is incumbent upon the planner to obtain site-specific cost information for detailed decision level planning and economic analysis.

**CDF Construction.** Reported CDF construction costs for the Great Lakes area were obtained and updated<sup>1</sup> (Table 1). The complete listing is included as Appendix B. The least costly alternative for expanding CDF capacity is typically to raise the dikes of an existing facility. Lateral expansion of an existing CDF is likely the next least cost alternative, provided space is available and public and environmental issues do not preclude construction. New CDF construction is expected to be the most expensive alternative. Note that the estimated \$20-\$50/cubic yard new construction cost may be comparable to that of transporting to and disposal at a commercial landfill, depending upon the nature of the material (whether covered by the Toxic Substances Control Act (TSCA) or not) and transportation costs. However, for a landfill to be a viable alternative to CDF disposal, the landfill must be suitably permitted to accept the material and have the necessary capacity.

**Table 1**  
**CDF Construction/Expansion Cost Estimates for Great Lakes Area**

| Alternative                                                                                                                                                                                                                                                                                                                  | Unit Cost                                |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------|
| Raise dikes of existing facility                                                                                                                                                                                                                                                                                             | Typically <\$2/cubic yard capacity added |
| Lateral expansion of existing facility                                                                                                                                                                                                                                                                                       | \$5-\$10/cubic yard                      |
| New CDF/New site                                                                                                                                                                                                                                                                                                             | Estimated at \$20-\$50/cubic yard*       |
| * Costs as high as \$86-\$195/cubic yard were estimated for construction of a new shoreline CDF to receive sediments from a Superfund site in the northeast United States, where foundation materials would first have to be excavated and replaced with competent fill (Personal communication, Rose Schmidt, 10 Dec 2001). |                                          |

<sup>1</sup> Personal communication, Jan Miller, USACE, July 24, 2000.

**Dredging.** Dredging costs are included as part of the economic analysis. Where physical separation is employed, the type of dredge or processing rates may be determined by separation plant capacity and slurry feed requirements. Dredging costs may be impacted by this factor. These costs typically include a substantial mobilization/demobilization cost, and unit costs incremented based on the volume to be dredged. Costs may differ substantially between regions, and be strongly influenced by the distance the contractor has to travel to the site. The level of contamination of the sediment will typically influence unit costs as well.

Reported costs for mechanical dredging of clean sediment in the north-central region of the United States range from \$3.53 to \$10.46/m<sup>3</sup> (\$2.70/yd<sup>3</sup> to \$8/yd<sup>3</sup>), with costs incremented downward above a specified volume threshold that varies from 11,475 to 114,750 m<sup>3</sup> (15,000 to 150,000 yd<sup>3</sup>). Mobilization/demobilization and bond costs for this region ranged from 2 to 38 percent of the total contract cost. Mobilization/demobilization costs in excess of \$1 million are not uncommon. McCorquodale, Selvidge, and Bennett (2000) provide a useful summary comparison of cost and suitability of dredging equipment developed for the Great Lakes area. Based on that report, clamshell, conventional excavation, portable hydraulic, and plain suction dredges all fall within a low cost range. Cutterhead and airlift dredges are classified as moderate in cost, and cable-arm dredges as high cost. Cost ranges of approximately \$15-\$40/m<sup>3</sup> (\$12-\$31/yd<sup>3</sup>) were cited, with lower unit costs associated with high-volume projects (over 50,000 m<sup>3</sup> (65,400 yd<sup>3</sup>)).

**Excavation.** Cost estimates for hydraulic excavation of existing dredged material stockpiles were obtained for a site in the north-central region (U.S. Fiscal Year (FY) 2000). Costs included redredging, transferring, and disposing of uncontaminated dredged material from two dredged material stockpile areas. Mobilization, demobilization, and bond costs were additional. Costs ranged from \$2.10 to \$8.00 per cubic yard for a 60,000-yd<sup>3</sup> (45,873-m<sup>3</sup>) site and \$1.62 to \$11.00 for a 500,000-yd<sup>3</sup> (382,277-m<sup>3</sup>) site. The effort was completed over a period of 2 years.

A small volume of dredged material (approximately 382 m<sup>3</sup> (500 yd<sup>3</sup>)) was mechanically excavated from a Great Lakes CDF using a large backhoe. Unit costs for this effort were approximately \$2.25/yd<sup>3</sup>. The effort required approximately one-half day in the field to complete.

**Separation/Dewatering.** Overall project costs expressed on a unit basis ranged from \$18 to \$410/yd<sup>3</sup> for 10 case studies reported in the literature, utilizing separation and mechanical dewatering (Wisconsin Department of Natural Resources 2002; Severson Environmental Services 2002a, 2002b, 2002c; USEPA 2002a, 2002b, 2002c; USEPA 1992). Project costs appear to have been influenced by level of contamination, total project volume, offsite transportation and disposal costs, real estate and permitting costs, water treatment requirements, and public relations efforts. A range of \$18 to \$60/yd<sup>3</sup> appears to be representative of the separation and dewatering cost component, when isolated from other project costs, for project volumes of 191,139-573,416 m<sup>3</sup> (250,000-750,000 yd<sup>3</sup>). The lowest unit cost is exclusive of a mobilization/demobilization cost. Unit costs for smaller volume projects would likely be higher.

**Transportation/Off-site Disposal.** Transportation and offsite disposal costs may be on a unit volume distance or a unit weight distance basis. River transportation costs reported in the northeastern region ranged from \$0.65/cubic yard mile to \$1.00/cubic yard mile, with the higher costs reflecting distances greater than 8 river miles. Overland transport over distances up to

1,067 m (3,500 ft) ranged from \$1.25 to \$2.50/cubic yard mile, with the lower cost reflecting volumes greater than 7,646 m<sup>3</sup> (10,000 yd<sup>3</sup>). Transport by truck, or truck/rail combination, ranged from \$80- \$110/ton, with direct rail costs being lowest, but access dependent. Offsite disposal costs ranged from \$50 to \$150/ton (U.S. FY 2000), with the highest disposal costs including the transportation costs.

**SUMMARY:** The economic viability of separation as a dredged material management alternative is largely dependent upon the benefits to be derived by reducing the volume or the weight of material requiring onsite or offsite disposal. Preliminary estimates of recoverable volume can be made on the basis of bench-scale sediment characterization data. More quantitative estimates of potential volume recovery can be obtained by calculating a fractional bulking factor based on material properties in situ and following bench- or pilot-scale process testing. The benefit of this volume reduction can be determined by calculating an average annual cost for the base condition, and comparing the average annual cost for the selected separation alternative. This information will be useful in making planning level decisions, and determining what alternatives merit detailed cost analysis. Among cost-comparable alternatives, intangible benefits may also be factored in.

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## APPENDIX A BULKING FACTOR DERIVATION

Define in situ volume  $V_{T_i}$  as follows:

$$V_{T_i} = V_{s_i} + V_{F_i} + V_{V_i} \quad (A1)$$

where

$V_{s_i}$  = volume sand, in situ or initial

$V_{F_i}$  = volume fines, in situ or initial

$V_{V_i}$  = volume voids, in situ or initial

Define dewatered sediment volume  $V_{T_f}$  (final total volume) as follows:

$$V_{T_f} = (1 - x_v) V_{s_i} + V_{F_i} + V_{V_f} \quad (A2)$$

where

$x_v$  = efficiency of sand removal, by volume

$V_{V_f}$  = volume voids, final

Define the overall bulking factor as

$$b = \frac{V_{T_f}}{V_{T_i}} \quad (A3)$$

By definition, total or wet density is

$$\rho_t = \frac{M_T}{V_T} \quad (A4)$$

where

$M_T$  = total mass of water and solids

$V_T$  = total volume of voids and solids

= total volume of water and solids, at 100 percent saturation ( $V_{voids} = V_{water}$ )

Then:

$$b = \frac{V_{Tf}}{V_{Ti}} = \frac{\frac{M_{Tf}}{\rho_{Tf}}}{\frac{M_{Ti}}{\rho_{Ti}}} = \frac{\frac{(1-x_m)M_{Si} + M_{Fi} + M_{wf}}{\rho_{Tf}}}{\frac{M_{Si} + M_{Fi} + M_{wi}}{\rho_{Ti}}} \quad (A5)$$

where

$M_{Tf}$  = total mass of water and solids, final or dewatered condition

$\rho_{Tf}$  = total density, final or dewatered condition

$M_{Ti}$  = total mass of water and solids, in situ or initial

$\rho_{Ti}$  = total density, in situ or initial

$x_m$  = sand removal efficiency by mass

$M_{Si}$  = mass sand, in situ or initial

$M_{Fi}$  = mass fines, in situ or initial

$M_{wf}$  = mass of water, final or dewatered condition

$M_{wi}$  = mass water, in situ or initial

Percent water content  $w$  is defined as

$$w = \frac{M_w}{M_{solids}} (100) \quad (A6)$$

$M_{wi}$  can therefore be described as

$$M_{wi} = \frac{w_i}{100} M_{solids_i} = \frac{w_i}{100} (M_{Si} + M_{Fi}) \quad (A7)$$

where  $w_i$  is water content as a decimal.

$M_{wf}$  can be described as:

$$M_{wf} = \frac{w_f}{100} M_{solids_f} = \frac{w_f}{100} [(1-x_m)M_{Si} + M_{Fi}] \quad (A8)$$

where  $w_f$  is water content as a decimal.

Substituting:

$$b = \frac{\frac{(1-x_m)M_{S_i} + M_{F_i} + \frac{w_f}{100} [(1-x_m)M_{S_i} + M_{F_i}]}{\rho_{t_f}}}{\frac{M_{S_i} + M_{F_i} + \frac{w_i}{100} (M_{S_i} + M_{F_i})}{\rho_{t_i}}} \quad (A9)$$

Simplifying yields:

$$b = \frac{(1+w_f)[(1-x_m)M_{S_i} + M_{F_i}]\rho_{t_i}}{(1+w_i)(M_{S_i} + M_{F_i})\rho_{t_f}} \quad (A10)$$

Recall that

$$b = \frac{V_{T_f}}{V_{T_i}} \quad (A11)$$

An estimate of the disposal volume following processing can therefore be obtained based on the hydrographic survey and projected dredging depths  $V_{T_i}$ , and the bulking factor derived by measuring the initial and final water content, sand and fine mass, and wet density, of representative samples, thus:

$$V_{T_f} = b V_{T_i} \quad (A12)$$

The net volume recovery is then

$$\Delta V = V_{T_i} - V_{T_f} \quad (A13)$$

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## APPENDIX B

### CDF CONSTRUCTION COSTS

Great Lakes Confined Disposal Facilities Constructed under Section 123, PL 91-611

| Name/Location                 | State | Type* | Year Built | CCl <sub>yr</sub> /CCl <sub>2000</sub> | CCl <sub>2000</sub> /CCl <sub>yr</sub> | Capacity, yd <sup>3</sup> | Planned Uses        | Const. Cost  | Present \$<br>Const. Cost | Present \$<br>cost/yr <sup>3</sup> |
|-------------------------------|-------|-------|------------|----------------------------------------|----------------------------------------|---------------------------|---------------------|--------------|---------------------------|------------------------------------|
| Cleveland Harbor Dike 12      | OH    | L     | 1974       | 0.3238                                 | 3.088                                  | 2760000                   | Waterfront Dev.     | \$6,800,000  | \$20,999,208              | \$7.61                             |
| Huron Harbor                  | OH    | L     | 1975       | 0.3546                                 | 2.820                                  | 2600000                   | Small Boat Harbor   | \$6,400,000  | \$18,048,463              | \$6.94                             |
| Toledo Harbor site 3          | OH    | L     | 1976       | 0.3849                                 | 2.598                                  | 11100000                  | Port Development    | \$18,400,000 | \$47,804,748              | \$4.31                             |
| Buffalo harbor Dike 4         | NY    | L     | 1977       | 0.4130                                 | 2.422                                  | 6900000                   | Wildlife Area       | \$15,400,000 | \$37,292,391              | \$5.40                             |
| Lorain Harbor                 | OH    | L     | 1977       | 0.4130                                 | 2.422                                  | 1850000                   | Small Boat Harbor   | \$7,900,000  | \$19,130,512              | \$10.34                            |
| Erie Harbor                   | PA    | L     | 1979       | 0.4814                                 | 2.077                                  | 420000                    | Industrial Dev.     | \$400,000    | \$830,902                 | \$1.98                             |
| Cleveland harbor Dike 14      | OH    | L     | 1979       | 0.4814                                 | 2.077                                  | 6130000                   | Recreation/Park     | \$28,300,000 | \$58,786,347              | \$9.59                             |
| Michigan City                 | IN    | U     | 1978       | 0.4450                                 | 2.247                                  | 50000                     | Recreation/Park     | \$300,000    | \$674,135                 | \$13.48                            |
| Chicago Area                  | IL    | L     | 1984       | 0.6646                                 | 1.505                                  | 1300000                   | Marina Expansion    | \$7,800,000  | \$11,735,745              | \$9.03                             |
| Grand haven Harbor            | MI    | U     | 1974       | 0.3238                                 | 3.088                                  | 310000                    | Public Use          | \$433,000    | \$1,337,155               | \$4.31                             |
| Milwaukee Harbor              | WI    | L     | 1975       | 0.3546                                 | 2.820                                  | 1600000                   | Expansion           | \$5,963,000  | \$16,816,091              | \$10.51                            |
| Dickinson Island              | MI    | I     | 1975       | 0.3546                                 | 2.820                                  | 2000000                   | Wildlife Area       | \$5,072,000  | \$14,303,407              | \$7.15                             |
| Manitowoc Harbor              | WI    | L     | 1975       | 0.3546                                 | 2.820                                  | 800000                    | Land Use Dev        | \$4,147,000  | \$11,694,840              | \$14.62                            |
| Kenosha Harbor                | WI    | L     | 1975       | 0.3546                                 | 2.820                                  | 750000                    | Public Use          | \$8,270,000  | \$23,321,998              | \$31.10                            |
| Boiles Harbor                 | MI    | L     | 1978       | 0.4450                                 | 2.247                                  | 335000                    | marina expansion    | \$972,000    | \$2,164,199               | \$6.52                             |
| Saginaw Bay                   | MI    | I     | 1978       | 0.4450                                 | 2.247                                  | 10000000                  | Wildlife Area       | \$14,844,000 | \$33,356,222              | \$3.34                             |
| Holland Bbr-Riverview Site    | MI    | L     | 1978       | 0.4450                                 | 2.247                                  | 120000                    | Recreation/Park     | \$1,583,000  | \$3,557,188               | \$29.64                            |
| Holland Bbr-Windmill Site     | MI    | I     | 1978       | 0.4450                                 | 2.247                                  | 160000                    | Recreation/Park     | \$1,654,000  | \$3,716,733               | \$23.23                            |
| Sebewaing Harbor              | MI    | U     | 1979       | 0.4814                                 | 2.077                                  | 84000                     | Airport Expansion   | \$1,300,000  | \$2,700,433               | \$32.15                            |
| Duluth Harbor Erie Pier       | MN    | L     | 1979       | 0.4814                                 | 2.077                                  | 1000000                   | Recreational Area   | \$1,558,000  | \$3,236,365               | \$3.24                             |
| Pte Mouille                   | MI    | I     | 1981       | 0.5667                                 | 1.765                                  | 18000000                  | Wildlife Area/Marsh | \$55,856,000 | \$98,565,694              | \$5.48                             |
| Green Bay Harbor              | WI    | I     | 1979       | 0.4814                                 | 2.077                                  | 1200000                   | Recreational        | \$5,565,000  | \$11,559,930              | \$9.63                             |
| Kewaunee Harbor               | WI    | L     | 1982       | 0.6132                                 | 1.631                                  | 500000                    | Recreational        | \$2,017,000  | \$3,289,424               | \$6.58                             |
| Frankfort Harbor              | MI    | U     | 1982       | 0.6132                                 | 1.631                                  | 74000                     |                     | \$800,000    | \$1,304,680               | \$17.63                            |
| Inland Route                  | MI    | U     | 1982       | 0.6132                                 | 1.631                                  | 195000                    | Wildlife Area       | \$176,000    | \$287,030                 | \$1.47                             |
| Monroe Harbor                 | MI    | L     | 1983       | 0.6518                                 | 1.534                                  | 4300000                   | State Park          | \$38,380,000 | \$58,882,056              | \$13.69                            |
| Keweenaw Waterway             | MI    | U     | 1987       | 0.7063                                 | 1.416                                  | 308000                    |                     | \$941,000    | \$1,332,265               | \$4.33                             |
| Clinton River                 | MI    | U     | 1989       | 0.7398                                 | 1.352                                  | 370000                    | Recreational Area   | \$2,618,000  | \$3,538,696               | \$9.56                             |
| Cleveland Harbor Dike 10      | OH    | L     | 1970       | 0.2214                                 | 4.517                                  | 1000000                   | Waterfront Dev.     |              |                           |                                    |
| Cleveland Harbor Dike 10B     | OH    | L     | 1998       | 0.9490                                 | 1.054                                  | 3840000                   | Airport             | \$32,900,000 | \$34,667,264              | \$9.03                             |
| Small Boat Harbor/Bufalo      | NY    | L     | 1968       | 0.1852                                 | 5.401                                  | 1500000                   | Small Boat Harbor   | \$500,000    | \$2,700,433               | \$1.80                             |
| Times Beach/Bufalo            | NY    | L     | 1972       | 0.2810                                 | 3.558                                  | 1500000                   | Wildlife Area       | \$500,000    | \$1,779,236               | \$1.19                             |
| Grassy Island (Isl 18)/Toledo | OH    | I     | 1977       | 0.4130                                 | 2.422                                  | 5000000                   | None                | \$5,000,000  | \$12,107,919              | \$2.42                             |
| Toledo Harbor Site 3 Ext      | OH    | L     | 1994       | 0.8669                                 | 1.153                                  | 5300000                   |                     | \$4,800,000  | \$5,536,686               | \$1.04                             |
| Bayport/Green Bay             | WI    | L     | 1965       | 0.1557                                 | 6.424                                  | 650000                    | City Landfill       |              |                           |                                    |
| Clinton River/Fisheries Site  | MI    | L     | 1979       | 0.4814                                 | 2.077                                  | 21000                     | Recreational Area   |              |                           |                                    |
| Grassy Island/Detroit River   | MI    | I     | 1960       | 0.1321                                 | 7.570                                  | 4320000                   | Wildlife Area       | \$747,150    | \$5,656,216               | \$1.31                             |
| Harsen's Island/St Clair nv.  | MI    | U     | 1975       | 0.3546                                 | 2.820                                  | 100000                    | Wildlife Area       |              |                           |                                    |
| Kawkaulin River               | MI    | U     |            |                                        |                                        |                           |                     |              |                           |                                    |
| Monroe Edison                 | MI    | U     |            |                                        |                                        |                           | Detroit Edison      |              |                           |                                    |
| Port Sanilac                  | MI    | U     | 1979       | 0.4814                                 | 2.077                                  | 143300                    | Municipal Landfill  |              |                           |                                    |
| Verplank/Grand Haven Harbor   | MI    | U     | 1974       | 0.3238                                 | 3.088                                  | 134000                    | Parking Lot         |              |                           |                                    |
| Whirlpool/St. Joseph Harbor   | MI    | U     | 1978       | 0.4450                                 | 2.247                                  | 25000                     | Transfer Site       | \$638,076    | 1,433,832.16              | \$57.35                            |
| Malleable/St. Joseph Harbor   | MI    | U     | 1978       | 0.4450                                 | 2.247                                  | 35000                     |                     |              |                           |                                    |
| Middleground/Saginaw River    | MI    | L     | 1978       | 0.4450                                 | 2.247                                  | 150000                    | Recreation Area     |              |                           |                                    |

\* U - Upland, I - In water, Island, L - In water, Adjacent to land or breakwater

Construction Cost Index from ENR (website)

| ANNUAL AVERAGE |     |      |     |      |      |      |             |
|----------------|-----|------|-----|------|------|------|-------------|
| 1908           | 97  | 1931 | 181 | 1954 | 628  | 1977 | 2576        |
| 1909           | 91  | 1932 | 157 | 1955 | 660  | 1978 | 2776        |
| 1910           | 96  | 1933 | 170 | 1956 | 692  | 1979 | 3003        |
| 1911           | 93  | 1934 | 199 | 1957 | 724  | 1980 | 3237        |
| 1912           | 91  | 1935 | 196 | 1958 | 759  | 1981 | 3535        |
| 1913           | 100 | 1936 | 206 | 1959 | 797  | 1982 | 3825        |
| 1914           | 89  | 1937 | 235 | 1960 | 824  | 1983 | 4066        |
| 1915           | 93  | 1938 | 236 | 1961 | 847  | 1984 | 4146        |
| 1916           | 130 | 1939 | 236 | 1962 | 872  | 1985 | 4195        |
| 1917           | 181 | 1940 | 242 | 1963 | 901  | 1986 | 4295        |
| 1918           | 189 | 1941 | 259 | 1964 | 936  | 1987 | 4406        |
| 1919           | 198 | 1942 | 276 | 1965 | 971  | 1988 | 4519        |
| 1920           | 251 | 1943 | 290 | 1966 | 1019 | 1989 | 4615        |
| 1921           | 202 | 1944 | 299 | 1967 | 1074 | 1990 | 4732        |
| 1922           | 174 | 1945 | 300 | 1968 | 1155 | 1991 | 4835        |
| 1923           | 214 | 1946 | 346 | 1969 | 1269 | 1992 | 4985        |
| 1924           | 215 | 1947 | 413 | 1970 | 1381 | 1993 | 5210        |
| 1925           | 207 | 1948 | 461 | 1971 | 1581 | 1994 | 5400        |
| 1926           | 208 | 1949 | 477 | 1972 | 1753 | 1995 | 5471        |
| 1927           | 206 | 1950 | 510 | 1973 | 1895 | 1996 | 5620        |
| 1928           | 207 | 1951 | 543 | 1974 | 2020 | 1997 | 5825        |
| 1929           | 207 | 1952 | 569 | 1975 | 2212 | 1998 | 5920        |
| 1930           | 203 | 1953 | 600 | 1976 | 2401 | 1999 | 6060        |
|                |     |      |     |      |      | 2000 | 6238 (June) |

## APPENDIX C PROJECT EXAMPLES<sup>1</sup>

### Example 1

The first example compares costs for the following six dredging and disposal alternatives for a one-time project, such as a remediation action, with a 2-year period of analysis:

1. Hydraulic dredging, CDF disposal
2. Hydraulic dredging, sand separation, CDF disposal of fines
3. Hydraulic dredging, sand separation, CDF placement of dewatered fines
4. Hydraulic dredging, sand separation, dewatering and offsite disposal of fines
5. Mechanical dredging, CDF disposal
6. Mechanical dredging, offsite disposal

Dredging costs are applied to in situ project volume. Separation, dewatering, and transportation costs are applied to processed volumes or weights. Unit CDF construction costs are based on sediment storage requirements, and are adjusted upward for alternatives requiring higher dikes to provide freeboard and ponding volume. For each alternative, a total project cost is calculated, including dredging, processing, transport, and disposal costs. These costs are then converted to a project cost/year, based on the duration of the dredging (Tables C1, C3, C5,...C11). Costs for CDF construction and closure capping are also calculated. Interest during construction is then calculated for each alternative and applied to the annual project costs, plus CDF construction and capping costs, which are added to the annual project costs in the respective years in which they occur (Tables C2, C4,...C12). This gives a Total Financial Investment cost for each alternative, which is the basis for the economic comparison of each alternative. The least-cost CDF disposal alternative without separation (mechanical dredging, CDF disposal) is the base condition. The results of this analysis indicate that, for the assumptions made, a negative benefit is derived from the use of separation, where mechanical dredging and CDF disposal is an alternative (Table C13). A positive benefit is seen where offsite disposal is required. For separation alternatives, beneficial use of sand with no associated transport or disposal costs is assumed. No real estate acquisition is included in CDF construction costs, as the site is normally provided by the sponsor and is not a government expense.

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<sup>1</sup> To convert measurements given in tons in these examples to kilograms, multiply by 907. To convert measurements given in cubic yards to cubic meters, multiply by 0.7645.

**Table C1**  
**Alternative 1: Hydraulic Dredging, CDF Disposal, Engineering Costs**

| Cost Item                          | Engineering Costs, Alternative 1 |       |            |         |          |          |                    |                  |
|------------------------------------|----------------------------------|-------|------------|---------|----------|----------|--------------------|------------------|
|                                    | \$/ton                           | \$/cy | Total Tons | tons/yr | Total cy | cy/yr    | Total \$           | \$/yr            |
| Hyd Dredging Cost <sup>1</sup>     |                                  | \$4   |            | 0       | 225,000  | 112,500  | 900,000            | \$450,000        |
| Mech Dredging Cost <sup>1</sup>    |                                  | \$7   |            | 0       |          | 0        |                    | \$0              |
| Mobilization/demobilization        |                                  |       |            | 0       |          | 0        | 1,000,000          | \$500,000        |
| Separation <sup>1</sup>            |                                  | \$15  |            | 0       |          | 0        |                    | \$0              |
| Separation/Dewatering <sup>1</sup> |                                  | \$60  |            | 0       |          | 0        |                    | \$0              |
| Transportation <sup>2</sup>        | \$110                            |       |            | 0       |          | 0        |                    | \$0              |
| Disposal <sup>2</sup>              | \$50                             |       |            | 0       |          | 0        |                    | \$0              |
| Revenues from sale                 |                                  | 1     |            | 0       |          | 0        |                    | 0                |
| <b>Total:</b>                      |                                  |       |            |         |          | <b>0</b> | <b>\$1,900,000</b> | <b>\$950,000</b> |
| CDF Construction <sup>3</sup>      |                                  | \$4   |            |         | 602,165  |          |                    | \$2,408,660      |
| Capping                            |                                  | \$2   |            |         | 172,888  |          |                    | \$345,776        |

<sup>1</sup> Based on in situ volumes or weights.

<sup>2</sup> Based on processed volumes or weights.

<sup>3</sup> Based on sediment storage volume. Estimated unit costs are based on literature values for similar size CDFs, with upward adjustments made where freeboard and ponding are required.

**Table C2**  
**Alternative 1: Hydraulic Dredging, CDF Disposal, Financial Costs**  
**(Interest Rate = 0.06375)**

|                                                                                      | 2001               | 2002        | 2003               |
|--------------------------------------------------------------------------------------|--------------------|-------------|--------------------|
| Cubic Yards                                                                          | 0                  | 112,500     | 112,500            |
| \$/yr                                                                                | <b>\$2,408,660</b> | \$950,000   | \$1,295,776        |
| IDC (interest during construction)                                                   | \$490,647          | \$124,986   | \$82,606           |
| Cost/Year                                                                            | \$2,899,307        | \$1,074,986 | \$1,378,382        |
| <b>Total Financial Investment:</b>                                                   |                    |             | <b>\$5,352,675</b> |
| CDF Construction included here if completely precedes dredging.                      |                    |             |                    |
| CDF and first-year dredging included here if they will both occur in the first year. |                    |             |                    |
| Includes final-year capping costs.                                                   |                    |             |                    |

**Table C3**  
**Alternative 2: Hydraulic Dredging, Sand Separation, CDF Disposal of Fines, Engineering Costs**

| Cost Item                          | Engineering Costs, Alternative 2 |       |            |         |          |         |                    |                    |
|------------------------------------|----------------------------------|-------|------------|---------|----------|---------|--------------------|--------------------|
|                                    | \$/ton                           | \$/cy | Total Tons | tons/yr | Total cy | cy/yr   | Total \$           | \$/yr              |
| Hyd Dredging Cost <sup>1</sup>     |                                  | \$4   |            | 0       | 225,000  | 112,500 | 900,000            | \$450,000          |
| Mech Dredging Cost <sup>1</sup>    |                                  | \$7   |            | 0       |          | 0       |                    | \$0                |
| Mobilization/demobilization        |                                  |       |            | 0       |          | 0       | 1,000,000          | \$500,000          |
| Separation <sup>1</sup>            |                                  | \$15  |            | 0       | 225,000  | 112,500 | 3,375,000          | \$1,687,500        |
| Separation/Dewatering <sup>1</sup> |                                  | \$60  |            | 0       |          | 0       |                    | \$0                |
| Transportation <sup>2</sup>        | \$110                            |       |            | 0       |          | 0       |                    | \$0                |
| Disposal <sup>2</sup>              | \$50                             |       |            | 0       |          | 0       |                    | \$0                |
| Revenues from sale                 |                                  | -1    |            | 0       | 33,613   | 16,807  | -33,613            | -16,806.5          |
| <b>Total:</b>                      |                                  |       |            |         |          |         | <b>\$5,241,387</b> | <b>\$2,620,694</b> |
| CDF Construction <sup>3</sup>      |                                  | \$4   |            |         | 538,753  |         |                    | \$2,155,012        |
| Capping                            |                                  | \$2   |            |         | 153,244  |         |                    | \$306,488          |

<sup>1</sup> Based on in situ volumes or weights.  
<sup>2</sup> Based on processed volumes or weights.  
<sup>3</sup> Based on sediment storage volume. Estimated unit costs are based on literature values for similar size CDFs, with upward adjustments made where freeboard and ponding are required.

**Table C4**  
**Alternative 2: Hydraulic Dredging, Sand Separation, CDF Disposal of Fines, Financial Costs (Interest Rate = 0.06375)**

|                                                                                      | 2001        | 2002        | 2003               |
|--------------------------------------------------------------------------------------|-------------|-------------|--------------------|
| Cubic Yards                                                                          | 0           | 112,500     | 112,500            |
| \$/yr                                                                                | \$2,155,012 | \$2,620,694 | \$2,927,182        |
| IDC (interest during construction)                                                   | \$438,979   | \$344,789   | \$186,608          |
| Cost/Year                                                                            | \$2,593,991 | \$2,965,483 | \$3,113,789        |
| <b>Total Financial Investment:</b>                                                   |             |             | <b>\$8,673,263</b> |
| CDF Construction included here if completely precedes dredging.                      |             |             |                    |
| CDF and first-year dredging included here if they will both occur in the first year. |             |             |                    |
| Includes final-year capping costs.                                                   |             |             |                    |

**Table C5**  
**Alternative 3: Hydraulic Dredging, Sand Separation, Dewatering and CDF Fines Disposal, Engineering Costs**

| Cost Item                          | Engineering Costs, Alternative 3 |       |            |                                |          |         |                     |                    |
|------------------------------------|----------------------------------|-------|------------|--------------------------------|----------|---------|---------------------|--------------------|
|                                    | \$/ton                           | \$/cy | Total Tons | tons/yr                        | Total cy | cy/yr   | Total \$            | \$/yr              |
| Hyd Dredging Cost <sup>1</sup>     |                                  | \$4   |            | 0                              | 225,000  | 112,500 | 900,000             | \$450,000          |
| Mech Dredging Cost <sup>1</sup>    |                                  | \$7   |            | 0                              |          | 0       |                     | \$0                |
| Mobilization/demobilization        |                                  |       |            | 0                              |          | 0       | 1,000,000           | \$500,000          |
| Separation <sup>1</sup>            |                                  | \$15  |            | 0                              |          | 0       |                     | \$0                |
| Separation/Dewatering <sup>1</sup> |                                  | \$60  |            | 0                              | 225,000  | 112,500 | 13,500,000          | \$6,750,000        |
| Transportation <sup>2</sup>        | \$110                            |       |            | 0                              |          | 0       |                     | \$0                |
| Disposal <sup>2</sup>              | \$50                             |       |            | 0                              |          | 0       |                     | \$0                |
| Revenues from sale                 |                                  | -1    |            | 0                              | 33,613   | -16,807 | -33,613             | -16,805.5          |
| <b>Total:</b>                      |                                  |       |            |                                |          |         | <b>\$15,366,387</b> | <b>\$7,683,194</b> |
| CDF Construction <sup>3</sup>      |                                  | \$6   |            |                                | 100,158  |         |                     | \$600,948          |
| Capping                            |                                  |       |            | no freeboard or ponding volume |          |         |                     | \$306,488          |

<sup>1</sup> Based on in situ volumes or weights.  
<sup>2</sup> Based on processed volumes or weights.  
<sup>3</sup> Based on sediment storage volume. Estimated unit costs are based on literature values for similar size CDFs, with upward adjustments made where freeboard and ponding are required.

**Table C6**  
**Alternative 3: Hydraulic Dredging, Sand Separation, Dewatering and CDF Fines Disposal, Financial Costs (Interest Rate = 0.06375)**

|                                                                                                                                                                                                                              | 2001      | 2002        | 2003                |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|-------------|---------------------|
| Cubic Yards                                                                                                                                                                                                                  | 0         | 112,500     | 112,500             |
| \$/yr                                                                                                                                                                                                                        | \$600,948 | \$7,683,194 | \$7,989,682         |
| IDC (interest during construction)                                                                                                                                                                                           | \$122,414 | \$1,010,832 | \$509,342           |
| Cost/Year                                                                                                                                                                                                                    | \$723,362 | \$8,694,026 | \$8,499,024         |
| <b>Total Financial Investment:</b>                                                                                                                                                                                           |           |             | <b>\$17,916,411</b> |
| CDF Construction included here if completely precedes dredging.                                                                                                                                                              |           |             |                     |
| CDF and first-year dredging included here if they will both occur in the first year.                                                                                                                                         |           |             |                     |
| Although there is no freeboard or ponding volume that must be filled, it was assumed that some form of cap would be required at closure, and a representative value was included based on amount calculated for other sites. |           |             |                     |

**Table C7**  
**Alternative 4: Hydraulic Dredging, Sand Separation, Dewatering and Offsite Disposal of Fines, Engineering Costs**

| Cost Item                          | Engineering Costs, Alternative 4 |       |            |         |          |         |                     |                     |
|------------------------------------|----------------------------------|-------|------------|---------|----------|---------|---------------------|---------------------|
|                                    | \$/ton                           | \$/cy | Total Tons | tons/yr | Total cy | cy/yr   | Total \$            | \$/yr               |
| Hyd Dredging Cost <sup>1</sup>     |                                  | \$4   |            | 0       | 225,000  | 112,500 | 900,000             | \$450,000           |
| Mech Dredging Cost <sup>1</sup>    |                                  | \$7   |            | 0       |          | 0       |                     | \$0                 |
| Mobilization/demobilization        |                                  |       |            | 0       |          | 0       | 1,000,000           | \$500,000           |
| Separation <sup>1</sup>            |                                  | \$15  |            | 0       |          | 0       |                     | \$0                 |
| Separation/Dewatering <sup>1</sup> |                                  | \$60  |            | 0       | 225,000  | 112,500 | 13,500,000          | \$6,750,000         |
| Transportation <sup>2</sup>        | \$110                            |       | 137,392    | 68,696  |          | 0       | 15,113,120          | \$7,556,560         |
| Disposal <sup>2</sup>              | \$50                             |       | 137,392    | 68,696  |          | 0       | 6,869,600           | \$3,434,800         |
| Revenues from sale                 |                                  | -1    |            |         | 33,613   | 16,807  | -33,613             | -16,806.5           |
| <b>Total:</b>                      |                                  |       |            |         |          |         | <b>\$37,349,107</b> | <b>\$18,674,554</b> |
| CDF Construction <sup>3</sup>      |                                  | \$6   |            |         | 0        |         |                     | \$0                 |
| Capping                            |                                  | \$2   |            |         | 0        |         |                     | \$0                 |

<sup>1</sup> Based on in situ volumes or weights.

<sup>2</sup> Based on processed volumes or weights.

<sup>3</sup> Based on sediment storage volume. Estimated unit costs are based on literature values for similar size CDFs, with upward adjustments made where freeboard and ponding are required.

**Table C8**  
**Alternative 4: Hydraulic Dredging, Sand Separation, Dewatering and Offsite Disposal of Fines, Financial Costs (Interest Rate = 0.06375)**

|                                                                                      | 2001 | 2002         | 2003                |
|--------------------------------------------------------------------------------------|------|--------------|---------------------|
| Cubic Yards                                                                          | 0    | 112,500      | 112,500             |
| \$/yr                                                                                | \$0  | \$18,674,554 | \$18,674,554        |
| IDC (interest during construction)                                                   | \$0  | \$2,456,900  | \$1,190,503         |
| Cost/Year                                                                            | \$0  | \$21,131,454 | \$19,865,056        |
| <b>Total Financial Investment:</b>                                                   |      |              | <b>\$40,996,510</b> |
| CDF Construction included here if completely precedes dredging.                      |      |              |                     |
| CDF and first-year dredging included here if they will both occur in the first year. |      |              |                     |

**Table C9**

**Alternative 5: Mechanical Dredging, CDF Disposal, Engineering Costs**

| Cost Item                          | Engineering Costs, Alternative 5 |       |            |         |          |         |             |                    |
|------------------------------------|----------------------------------|-------|------------|---------|----------|---------|-------------|--------------------|
|                                    | \$/ton                           | \$/cy | Total Tons | tons/yr | Total cy | cy/yr   | Total \$    | \$/yr              |
| Hyd Dredging Cost <sup>1</sup>     |                                  | \$4   |            | 0       |          | 0       | 0           | \$0                |
| Mech Dredging Cost <sup>1</sup>    |                                  | \$7   |            | 0       | 225,000  | 112,500 |             | \$787,500          |
| Mobilization/demobilization        |                                  |       |            | 0       |          | 0       | 1,000,000   | \$500,000          |
| Separation <sup>1</sup>            |                                  | \$15  |            | 0       |          | 0       |             | \$0                |
| Separation/Dewatering <sup>1</sup> |                                  | \$60  |            | 0       |          | 0       |             | \$0                |
| Transportation <sup>2</sup>        | \$110                            |       |            | 0       |          | 0       |             | \$0                |
| Disposal <sup>2</sup>              | \$50                             |       |            | 0       |          | 0       |             | \$0                |
| Revenues from sale                 |                                  | 1     |            | 0       |          | 0       |             | \$0                |
| <b>Total:</b>                      |                                  |       |            |         |          |         | \$1,000,000 | <b>\$1,287,500</b> |
| CDF Construction <sup>3</sup>      |                                  | \$5   |            |         | 317,673  |         |             | \$1,588,367        |
| Capping                            |                                  | \$2   |            |         | 70,173   |         |             | \$140,347          |

<sup>1</sup> Based on in situ volumes or weights.  
<sup>2</sup> Based on processed volumes or weights.  
<sup>3</sup> Based on sediment storage volume. Estimated unit costs are based on literature values for similar size CDFs, with upward adjustments made where freeboard and ponding are required.

**Table C10**

**Alternative 5: Mechanical Dredging, CDF Disposal, Financial Costs**  
(Interest Rate = 0.06375)

|                                                                                      | 2001               | 2002        | 2003               |
|--------------------------------------------------------------------------------------|--------------------|-------------|--------------------|
| Cubic Yards                                                                          | 0                  | 112,500     | 112,500            |
| \$/yr                                                                                | <b>\$1,588,367</b> | \$1,287,500 | <b>\$1,427,847</b> |
| IDC (interest during construction)                                                   | \$323,552          | \$169,389   | \$91,025           |
| Cost/Year                                                                            | \$1,911,920        | \$1,456,889 | \$1,518,872        |
| <b>Total Financial Investment:</b>                                                   |                    |             | <b>\$4,887,681</b> |
| CDF Construction included here if completely precedes dredging.                      |                    |             |                    |
| CDF and first-year dredging included here if they will both occur in the first year. |                    |             |                    |
| Includes final-year capping costs.                                                   |                    |             |                    |

**Table C11**  
**Alternative 6: Mechanical Dredging, Offsite Disposal, Engineering Costs**

| Cost Item                          | Engineering Costs, Alternative 6 |       |            |         |          |         |                     |                     |
|------------------------------------|----------------------------------|-------|------------|---------|----------|---------|---------------------|---------------------|
|                                    | \$/ton                           | \$/cy | Total Tons | tons/yr | Total cy | cy/yr   | Total \$            | \$/yr               |
| Hyd Dredging Cost <sup>1</sup>     |                                  | \$4   |            | 0       |          | 0       | 0                   | \$0                 |
| Mech Dredging Cost <sup>1</sup>    |                                  | \$7   |            | 0       | 225,000  | 112,500 |                     | \$787,500           |
| Mobilization/demobilization        |                                  |       |            | 0       |          | 0       | 1,000,000           | \$500,000           |
| Separation <sup>1</sup>            |                                  | \$15  |            | 0       |          | 0       |                     | \$0                 |
| Separation/Dewatering <sup>1</sup> |                                  | \$60  |            | 0       |          | 0       |                     | \$0                 |
| Transportation <sup>2</sup>        | \$110                            |       | 287,943    | 143,972 |          | 0       | 31,673,730          | \$15,836,865        |
| Disposal <sup>2</sup>              | \$50                             |       | 287,943    | 143,972 |          | 0       | 14,397,150          | \$7,198,575         |
| Revenues from sale                 |                                  | 1     |            | 0       |          | 0       |                     | 0                   |
| <b>Total:</b>                      |                                  |       |            |         |          |         | <b>\$47,070,880</b> | <b>\$24,322,940</b> |
| CDF Construction <sup>3</sup>      |                                  | \$5   |            |         | 0        |         |                     | \$0                 |
| Capping                            |                                  | \$2   |            |         | 0        |         |                     | \$30                |

<sup>1</sup> Based on in situ volumes or weights.  
<sup>2</sup> Based on processed volumes or weights.  
<sup>3</sup> Based on sediment storage volume. Estimated unit costs are based on literature values for similar size CDFs, with upward adjustments made where freeboard and ponding are required.

**Table C12**  
**Alternative 6: Mechanical Dredging, Offsite Disposal, Financial Costs**  
(Interest Rate = 0.06375)

|                                                                                      | 2001 | 2002         | 2003                |
|--------------------------------------------------------------------------------------|------|--------------|---------------------|
| Cubic Yards                                                                          | 0    | 112,500      | 112,500             |
| \$/yr                                                                                | \$0  | \$24,322,940 | \$24,322,940        |
| IDC (interest during construction)                                                   | \$0  | \$3,200,025  | \$1,550,587         |
| Cost/Year                                                                            | \$0  | \$27,522,965 | \$25,873,527        |
| <b>Total Financial Investment:</b>                                                   |      |              | <b>\$53,396,492</b> |
| CDF Construction included here if completely precedes dredging.                      |      |              |                     |
| CDF and first-year dredging included here if they will both occur in the first year. |      |              |                     |

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**Table C13****Identification of Base Plan and Calculation of Separation Benefit**

| <b>Compare Alternatives</b>                    |                           |                                                                                         |
|------------------------------------------------|---------------------------|-----------------------------------------------------------------------------------------|
| <b>Alternative</b>                             | <b>Initial Investment</b> | <b>Alternative Description</b>                                                          |
| <b>Initial Construction &amp; Maintenance</b>  |                           |                                                                                         |
| 1                                              | \$5,352,675               | Hydraulic dredging, CDF disposal                                                        |
| 2                                              | \$8,673,263               | Hydraulic dredging, sand separation, CDF disposal of fines                              |
| 3                                              | \$17,916,411              | Hydraulic dredging, sand separation, dewatering of fines and placement in CDF           |
| 4                                              | \$40,996,510              | Hydraulic dredging, sand separation, dewatering of fines, and offsite disposal of fines |
| 5                                              | \$4,887,681               | Mechanical dredging and placement in a CDF                                              |
| 6                                              | \$53,396,492              | Mechanical dredging and offsite disposal                                                |
| <b>Assuming all alternatives are available</b> |                           |                                                                                         |
| Base plan                                      | \$4,887,681               | Least-cost alternative without separation is base plan                                  |
| Separation                                     | \$8,673,263               | Least-cost separation alternative is selected for comparison                            |
| <b>Benefit to separation</b>                   | <b>-\$3,785,582</b>       |                                                                                         |
| <b>Assuming offsite disposal is required</b>   |                           |                                                                                         |
| Base plan                                      | \$53,396,492              | Mechanical dredging with offsite disposal is base plan                                  |
| Separation                                     | \$40,996,510              | Least-cost separation alternative with offsite disposal is selected for comparison      |
| <b>Benefit to separation</b>                   | <b>\$12,399,982</b>       |                                                                                         |

## Example 2

The second example assumes a 30-year period of analysis and available CDF storage capacity of 1,800,000 yd<sup>3</sup> at the inception of the period of analysis. Capacity of the CDF constructed in the out years of the project is assumed to accommodate the material produced from the time of filling of the old CDF to the end of the period of analysis. Rate of capacity consumption is based on solids volume at the end of each disposal operation, neglecting consolidation. Capping material volume is assumed to equal freeboard and ponding volume. (Neglecting material consolidation results in a conservative overestimate of storage capacity required and an underestimate of capping material required. Programs are available to estimate time-dependent consolidation of dredged material and fill, but these simplifying assumptions facilitate planning level cost comparisons. A more rigorous evaluation of consolidation and effect on the CDF life cycle would be required for detailed cost estimating.) In situ sediment volume for the construction phase was assumed to be 775,000 yd<sup>3</sup> with 40 percent fines by weight. Maintenance dredging was assumed to take place every 3 years, with an in situ volume of 75,000 yd<sup>3</sup>. A 16-in. (0.4-m) hydraulic dredge is assumed for hydraulic dredging scenarios, and calculation of sediment storage requirements using SETTLE. A bulking factor of 1.1 (applied to in situ volume) was used to estimate sediment storage requirements for mechanical dredging alternatives. An annual cost to maintain the CDF (facility maintenance) of \$20,000 was assumed for all alternatives. The following alternatives were considered:

1. Hydraulic dredging, CDF disposal (Tables C14-C16).
2. Hydraulic dredging, sand separation, CDF disposal of fine residuals (Tables C17-C19).
3. Hydraulic dredging, sand separation, CDF disposal of dewatered fine residuals (Tables C20-C22).

As for the first example, no cost was assumed to be incurred for disposal or transportation of sand produced for beneficial use. No real estate acquisition costs are considered.

Comparison of average annual costs for the three alternatives reveals that Alternative 1 (Table C23) has the lowest average annual cost (\$1,785,100), with the CDF being replaced after two maintenance dredging cycles. Alternative 2 (Table C24) is next at \$1,898,300, with the CDF being replaced after 14 maintenance dredging cycles (beyond the end of the period of analysis). Alternative 3 (Table C25) has the highest annual cost (\$2,776,000), but the CDF does not need to be replaced for 49 maintenance dredging cycles (beyond the end of the period of analysis). The base alternative may therefore be different (Alternative 2 or 3, rather than Alternative 1) for a longer period of analysis that captures the life extension of the CDF (Table C26). As the period of analysis increases, however, the effect of consolidation on rate of capacity consumption becomes more important and should be factored into the analysis.

**Table C14****Alternative 1: Hydraulic Dredging and Conventional Disposal in an Existing CDF, Engineering Costs**

| Cost Item                          | Engineering Costs, Alternative 1 |       |            |         |          |             |         |                    |                    |
|------------------------------------|----------------------------------|-------|------------|---------|----------|-------------|---------|--------------------|--------------------|
|                                    | \$/ton                           | \$/cy | Total tons | tons/yr | Total cy | Duration yr | cy/yr   | Total \$           | \$/yr              |
| Hyd Dredging Cost <sup>1</sup>     |                                  | \$4   |            | 0       | 775,000  | 2           | 387,500 | \$3,100,000        | \$1,550,000        |
| Mech Dredging Cost <sup>1</sup>    |                                  | \$7   |            | 0       |          |             | 0       |                    | \$0                |
| Mob/Demob                          |                                  |       |            | 0       |          | 2           | 0       | \$1,000,000        | \$500,000          |
| Separation <sup>1</sup>            |                                  | \$15  |            | 0       |          |             | 0       |                    | \$0                |
| Separation/Dewatering <sup>1</sup> |                                  | \$25  |            | 0       |          |             | 0       |                    | \$0                |
| Transportation <sup>2</sup>        | \$110                            |       |            | 0       |          |             | 0       |                    | \$0                |
| Disposal <sup>2</sup>              | \$50                             |       |            | 0       |          |             | 0       |                    | \$0                |
| Revenues from sale                 |                                  | 1     |            | 0       |          |             | 0       |                    | \$0                |
| <b>Total:</b>                      |                                  |       |            |         |          |             |         | <b>\$4,100,000</b> | <b>\$2,050,000</b> |
| CDF Construction                   |                                  | \$6   |            |         | 0        |             |         |                    | \$0                |
| Capping                            |                                  | \$2   |            |         | 619,830  |             |         |                    | \$1,239,660        |
|                                    |                                  |       |            |         |          |             |         |                    | 1,800,000          |

<sup>1</sup> Based on in situ volumes or weights.  
<sup>2</sup> Based on processed volumes or weights.

Available Storage Capacity (cy) 1,800,000  
Storage Capacity Consumed (cy) 1,399,016  
Remaining Storage Capacity (cy) 400,984

**Table C15****Alternative 1: Hydraulic Dredging and Conventional Disposal in an Existing CDF, Financial Costs (Interest Rate = 0.06375)**

|                                                                                      | 2001 | 2002        | 2003               |
|--------------------------------------------------------------------------------------|------|-------------|--------------------|
| Cubic Yards                                                                          | 0    | 112,500     | 112,500            |
| \$/yr                                                                                |      | \$2,050,000 | \$2,050,000        |
| IDC (interest during construction)                                                   | \$0  | \$269,706   | \$130,688          |
| Cost/Year                                                                            | \$0  | \$2,319,706 | \$2,180,688        |
| <b>Total Financial Investment:</b>                                                   |      |             | <b>\$4,500,394</b> |
| CDF Construction included here if completely precedes dredging.                      |      |             |                    |
| CDF and first-year dredging included here if they will both occur in the first year. |      |             |                    |

**Table C16**  
**Alternative 1: Hydraulic Dredging and Conventional Disposal in an Existing CDF, Maintenance Dredging Engineering Costs**

| Cost Item                                                                                                   | Maintenance Dredging Engineering Costs, Alternative 1 |       |            |           |                              |
|-------------------------------------------------------------------------------------------------------------|-------------------------------------------------------|-------|------------|-----------|------------------------------|
|                                                                                                             | \$/ton                                                | \$/cy | tons/yr    | cy/3 yr   | \$/yr                        |
| Hyd Dredging Cost <sup>1</sup>                                                                              |                                                       | \$4   | 0          | 75,000    | \$350,000                    |
| Mech Dredging Cost <sup>1</sup>                                                                             |                                                       | \$7   | 0          | 0         | \$0                          |
| Mob/Demob                                                                                                   |                                                       |       | 0          | 0         | \$500,000                    |
| Separation <sup>1</sup>                                                                                     |                                                       | \$15  | 0          | 0         | \$0                          |
| Separation/Dewatering <sup>1</sup>                                                                          |                                                       | \$25  | 0          | 0         | \$0                          |
| Transportation <sup>2</sup>                                                                                 | \$110                                                 |       | 0          | 0         | \$0                          |
| Disposal <sup>2</sup>                                                                                       | \$50                                                  |       | 0          | 0         | \$0                          |
| Revenues from sale                                                                                          |                                                       | 1     | 0          | 0         | \$0                          |
| <b>Total:</b>                                                                                               |                                                       |       |            |           | <b>\$800,000</b>             |
| Additional Cost Items:                                                                                      |                                                       |       |            |           |                              |
| Annual Facility Maintenance                                                                                 |                                                       |       |            |           | \$20,000                     |
| Storage capacity consumed cy/3 yr                                                                           |                                                       |       |            | 143,087   |                              |
| Available storage capacity at first cycle                                                                   |                                                       |       |            | 400,984   |                              |
| Cycles to replacement of existing CDF yr                                                                    |                                                       |       |            | 2.80      |                              |
| Number of maintenance cycles completed                                                                      |                                                       |       |            | 2         |                              |
| Number of maintenance cycles remaining                                                                      |                                                       |       |            | 8         |                              |
| Volume CDF required to accommodate remainder of dredging for period of analysis, plus freeboard and ponding |                                                       |       |            |           |                              |
| In situ sediment volume total cy                                                                            |                                                       |       |            | 600,000   |                              |
| Freeboard and ponding (1 cycle requirement) cy                                                              |                                                       |       |            | 704,218   |                              |
| Total volume cy                                                                                             |                                                       |       |            | 1,304,218 |                              |
|                                                                                                             |                                                       |       |            | <b>cy</b> | <b>Total Estimated Costs</b> |
| CDF Construction cost                                                                                       |                                                       | \$18  |            |           | \$23,475,924                 |
| Capping Old CDF (after 2 cycles)                                                                            |                                                       | \$2   | cap volume | 800,000   | \$1,600,000                  |
| Capping New CDF                                                                                             |                                                       | \$2   |            |           | 1,408,436                    |
| <sup>1</sup> Based on in situ volumes or weights.                                                           |                                                       |       |            |           |                              |
| <sup>2</sup> Based on processed volumes or weights.                                                         |                                                       |       |            |           |                              |

**Table C17****Alternative 2: Hydraulic Dredging, Sand Separation, CDF Disposal of Fines, Engineering Costs**

| Cost Item                          | Engineering Costs, Alternative 2 |       |            |         |          |             |         |                     |                    |
|------------------------------------|----------------------------------|-------|------------|---------|----------|-------------|---------|---------------------|--------------------|
|                                    | \$/ton                           | \$/cy | Total tons | tons/yr | Total cy | Duration yr | cy/yr   | Total \$            | \$/yr              |
| Hyd Dredging Cost <sup>1</sup>     |                                  | \$4   |            | 0       | 775,000  | 2           | 387,500 | \$3,100,000         | \$1,550,000        |
| Mech Dredging Cost <sup>1</sup>    |                                  | \$7   |            | 0       |          |             | 0       |                     | \$0                |
| Mob/Demob                          |                                  |       |            | 0       |          | 2           | 0       | \$1,000,000         | \$500,000          |
| Separation <sup>1</sup>            |                                  | \$15  |            | 0       | 775,000  |             | 387,500 | \$11,625,000        | \$5,812,500        |
| Separation/Dewatering <sup>1</sup> |                                  | \$25  |            | 0       |          |             | 0       |                     | \$0                |
| Transportation <sup>2</sup>        | \$110                            |       |            | 0       |          |             | 0       |                     | \$0                |
| Disposal <sup>2</sup>              | \$50                             |       |            | 0       |          |             | 0       |                     | \$0                |
| Revenues from sale                 |                                  | -1    |            | 0       | 254,700  |             | 127,350 |                     | -127,350           |
| <b>Total:</b>                      |                                  |       |            |         |          |             |         | <b>\$15,725,000</b> | <b>\$7,735,150</b> |
| CDF Construction                   |                                  | \$6   |            |         | 0        |             |         |                     | \$0                |
| Capping                            |                                  | \$2   |            |         | 0        |             |         |                     | \$0                |

<sup>1</sup> Based on in situ volumes or weights.  
<sup>2</sup> Based on processed volumes or weights.

|                                 |           |
|---------------------------------|-----------|
| Available Storage Capacity (cy) | 1,800,000 |
| Storage Capacity Consumed (cy)  | 759,255   |
| Remaining Storage Capacity (cy) | 1,040,745 |

**Table C18****Alternative 2: Hydraulic Dredging, Sand Separation, CDF Disposal of Fines, Financial Costs (Interest Rate = 0.06375)**

|                                                                                      | 2001 | 2002        | 2003                |
|--------------------------------------------------------------------------------------|------|-------------|---------------------|
| Cubic Yards                                                                          | 0    | 387,500     | 387,500             |
| \$/yr                                                                                |      | \$7,735,150 | \$7,735,150         |
| IDC (interest during construction)                                                   | \$0  | \$1,017,668 | \$493,116           |
| Cost/Year                                                                            | \$0  | \$8,752,818 | \$8,228,266         |
| <b>Total Financial Investment:</b>                                                   |      |             | <b>\$16,981,084</b> |
| CDF Construction included here if completely precedes dredging.                      |      |             |                     |
| CDF and first-year dredging included here if they will both occur in the first year. |      |             |                     |

**Table C19**  
**Alternative 2: Hydraulic Dredging, Sand Separation, CDF Disposal of Fines,**  
**Maintenance Dredging Engineering Costs**

| Cost Item                                                                                                   | Maintenance Dredging Engineering Costs, Alternative 2 |       |         |           |                       |
|-------------------------------------------------------------------------------------------------------------|-------------------------------------------------------|-------|---------|-----------|-----------------------|
|                                                                                                             | \$/ton                                                | \$/cy | tons/yr | cy/3 yr   | \$/yr                 |
| Hyd Dredging Cost <sup>1</sup>                                                                              |                                                       | \$4   | 0       | 75,000    | \$300,000             |
| Mech Dredging Cost <sup>1</sup>                                                                             |                                                       | \$7   | 0       | 0         | \$0                   |
| Mob/Demob                                                                                                   |                                                       |       | 0       | 0         | \$500,000             |
| Separation <sup>1</sup>                                                                                     |                                                       | \$15  | 0       | 75,000    | \$1,125,000           |
| Separation/Dewatering <sup>1</sup>                                                                          |                                                       | \$25  | 0       | 0         | \$0                   |
| Transportation <sup>2</sup>                                                                                 | \$110                                                 |       | 0       | 0         | \$0                   |
| Disposal <sup>2</sup>                                                                                       | \$50                                                  |       | 0       | 0         | \$0                   |
| Revenues from sale                                                                                          |                                                       | -1    | 0       | 24,648    | -24,648               |
| <b>Total:</b>                                                                                               |                                                       |       |         |           | <b>\$1,900,352</b>    |
| Additional Cost Items:                                                                                      |                                                       |       |         |           |                       |
| Annual Facility Maintenance                                                                                 |                                                       |       |         |           | \$20,000              |
| Storage capacity consumed cy/3 yr                                                                           |                                                       |       |         | 73,477    |                       |
| Available storage capacity at first cycle                                                                   |                                                       |       |         | 1,040,745 |                       |
| Cycles to replacement of existing CDF yr                                                                    |                                                       |       |         | 14.16     |                       |
| Number of maintenance cycles completed                                                                      |                                                       |       |         | 10        |                       |
| (There are only 10 cycles in period of analysis)                                                            |                                                       |       |         |           |                       |
| Number of maintenance cycles remaining                                                                      |                                                       |       |         | 0         |                       |
| Volume CDF required to accommodate remainder of dredging for period of analysis, plus freeboard and ponding |                                                       |       |         |           |                       |
| In situ sediment volume total cy                                                                            |                                                       |       |         | 0         |                       |
| Freeboard and ponding (1 cycle requirement) cy                                                              |                                                       |       |         | 0         |                       |
| Total volume cy                                                                                             |                                                       |       |         | 0         |                       |
|                                                                                                             |                                                       | \$/cy |         |           | Total Estimated Costs |
| CDF Construction Cost                                                                                       |                                                       | \$18  |         |           | \$0                   |
| Capping Old CDF<br>(after 14 cycles)                                                                        |                                                       | \$2   |         |           | \$0 <sup>3</sup>      |
| Capping New CDF                                                                                             |                                                       | \$2   |         |           | \$0                   |
| <sup>1</sup> Based on in situ volumes or weights.                                                           |                                                       |       |         |           |                       |
| <sup>2</sup> Based on processed volumes or weights.                                                         |                                                       |       |         |           |                       |
| <sup>3</sup> Closure of existing CDF falls outside period of analysis.                                      |                                                       |       |         |           |                       |

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**Table C20****Alternative 3: Hydraulic Dredging, Sand Separation, Dewatering and CDF Placement of Fines, Engineering Costs**

| Cost Item                          | Engineering Costs, Alternative 3 |       |            |         |          |             |         |                    |                     |
|------------------------------------|----------------------------------|-------|------------|---------|----------|-------------|---------|--------------------|---------------------|
|                                    | \$/ton                           | \$/cy | Total tons | tons/yr | Total cy | Duration yr | cy/yr   | Total \$           | \$/yr               |
| Hyd Dredging Cost <sup>1</sup>     |                                  | \$4   |            | 0       | 775,000  | 2           | 387,500 | \$3,100,000        | \$1,550,000         |
| Mech Dredging Cost <sup>1</sup>    |                                  | \$7   |            | 0       |          |             | 0       |                    | \$0                 |
| Mob/Demob                          |                                  |       |            | 0       |          | 2           | 0       | \$1,000,000        | \$500,000           |
| Separation <sup>1</sup>            |                                  | \$15  |            | 0       |          |             | 0       |                    | \$0                 |
| Separation/Dewatering <sup>1</sup> |                                  | \$25  |            | 0       | 775,000  |             | 387,500 |                    | \$9,687,500         |
| Transportation <sup>2</sup>        | \$110                            |       |            | 0       |          |             | 0       |                    | \$0                 |
| Disposal <sup>2</sup>              | \$50                             |       |            | 0       |          |             | 0       |                    | \$0                 |
| Revenues from sale                 |                                  | -1    |            | 0       | 254,700  |             | 127,350 |                    | -127,350            |
| <b>Total:</b>                      |                                  |       |            |         |          |             |         | <b>\$4,100,000</b> | <b>\$11,610,150</b> |
| CDF Construction                   |                                  | \$6   |            |         | 0        |             |         |                    | \$0                 |
| Capping                            |                                  | \$2   |            |         | 0        |             |         |                    | \$0                 |

<sup>1</sup> Based on in situ volumes or weights.  
<sup>2</sup> Based on processed volumes or weights.

|                                 |           |
|---------------------------------|-----------|
| Available Storage Capacity (cy) | 1,800,000 |
| Storage Capacity Consumed (cy)  | 309,863   |
| Remaining Storage Capacity (cy) | 1,490,137 |

**Table C21****Alternative 3: Hydraulic Dredging, Sand Separation, Dewatering and CDF Placement of Fines, Financial Costs (Interest Rate = 0.06375)**

|                                                                                      | 2001 | 2002         | 2003                |
|--------------------------------------------------------------------------------------|------|--------------|---------------------|
| Cubic Yards                                                                          | 0    | 387,500      | 387,500             |
| \$/yr                                                                                |      | \$11,610,150 | \$11,610,150        |
| IDC (interest during construction)                                                   | \$0  | \$1,527,479  | \$740,147           |
| Cost/Year                                                                            | \$0  | \$13,137,629 | \$12,350,297        |
| <b>Total Financial Investment:</b>                                                   |      |              | <b>\$25,487,926</b> |
| CDF Construction included here if completely precedes dredging.                      |      |              |                     |
| CDF and first-year dredging included here if they will both occur in the first year. |      |              |                     |

**Table C22**

**Alternative 3: Hydraulic Dredging, Sand Separation, Dewatering and CDF Placement of Fines, Maintenance Dredging Engineering Costs**

| Cost Item                                                                                                   | Maintenance Dredging Engineering Costs, Alternative 3 |       |            |           |                       |
|-------------------------------------------------------------------------------------------------------------|-------------------------------------------------------|-------|------------|-----------|-----------------------|
|                                                                                                             | \$/ton                                                | \$/cy | tons/yr    | cy/3 yr   | \$/yr                 |
| Hyd Dredging Cost <sup>1</sup>                                                                              |                                                       | \$4   | 0          | 75,000    | \$300,000             |
| Mech Dredging Cost <sup>1</sup>                                                                             |                                                       | \$7   | 0          | 0         | \$0                   |
| Mob/Demob                                                                                                   |                                                       |       | 0          | 0         | \$500,000             |
| Separation <sup>1</sup>                                                                                     |                                                       | \$15  | 0          | 0         | \$0                   |
| Separation/Dewatering <sup>1</sup>                                                                          |                                                       | \$25  | 0          | 75,000    | \$1,875,000           |
| Transportation <sup>2</sup>                                                                                 | \$110                                                 |       | 0          | 0         | \$0                   |
| Disposal <sup>2</sup>                                                                                       | \$50                                                  |       | 0          | 0         | \$0                   |
| Revenues from sale                                                                                          |                                                       | -1    | 0          | 24,648    | -24,648               |
| <b>Total:</b>                                                                                               |                                                       |       |            |           | <b>\$2,650,352</b>    |
| Additional Cost Items:                                                                                      |                                                       |       |            |           |                       |
| Annual Facility Maintenance                                                                                 |                                                       |       |            |           | \$20,000              |
| Storage capacity consumed cy/3 yr                                                                           |                                                       |       |            | 29,987    |                       |
| Available storage capacity at first cycle                                                                   |                                                       |       |            | 1,490,137 |                       |
| Cycles to replacement of existing CDF yr                                                                    |                                                       |       |            | 49.69     |                       |
| Number of maintenance cycles completed                                                                      |                                                       |       |            | 10        |                       |
| (There are only 10 cycles in period of analysis)                                                            |                                                       |       |            |           |                       |
| Number of maintenance cycles remaining                                                                      |                                                       |       |            | 0         |                       |
| Volume CDF required to accommodate remainder of dredging for period of analysis, plus freeboard and ponding |                                                       |       |            |           |                       |
| In situ sediment volume total cy                                                                            |                                                       |       |            | 0         |                       |
| Freeboard and ponding (1 cycle requirement) cy                                                              |                                                       |       |            | 0         |                       |
| Total volume cy                                                                                             |                                                       |       |            | 0         |                       |
|                                                                                                             |                                                       |       |            | cy        | Total Estimated Costs |
| CDF Construction Cost                                                                                       |                                                       | \$18  |            |           | \$0                   |
| Capping Old CDF                                                                                             |                                                       | \$2   | cap volume | 0         | \$0 <sup>3</sup>      |
| Capping New CDF                                                                                             |                                                       | \$2   |            |           | \$0                   |
| <sup>1</sup> Based on in situ volumes or weights.                                                           |                                                       |       |            |           |                       |
| <sup>2</sup> Based on processed volumes or weights.                                                         |                                                       |       |            |           |                       |
| <sup>3</sup> Old CDF is not replaced during period of analysis.                                             |                                                       |       |            |           |                       |

**Table C23**  
**Alternative 1 Annual Cost (Interest Rate = 0.0638)**

| Project Year               | Contract Cost (2000 \$) | Present Value Factor | Present Value          | Present Worth         | Cost Item                                   |
|----------------------------|-------------------------|----------------------|------------------------|-----------------------|---------------------------------------------|
| 0                          | \$4,500,394             | 1                    | \$4,500,394            | \$4,500,394           | Initial dredging- sum of 2 years plus IDC   |
| 1                          | \$20,000                | 0.940071             | \$18,801               | \$18,801              | Facility maintenance                        |
| 2                          | \$20,000                | 0.883733             | \$17,675               | \$17,675              | Facility maintenance                        |
| 3                          | \$820,000               | 0.830771             | \$681,232              | \$681,232             | Maintenance dredging + facility maintenance |
| 4                          | \$20,000                | 0.780983             | \$15,620               | \$15,620              | Facility maintenance                        |
| 5                          | \$20,000                | 0.734179             | \$14,684               | \$14,684              | Facility maintenance                        |
| 6                          | \$820,000               | 0.69018              | \$565,947.85           | \$565,947             | Maintenance dredging + facility maintenance |
| 7                          | \$1,600,000             | 0.648818             | \$1,038,109.04         | \$1,038,109           | Capping of old facility                     |
| 8                          | \$23,475,924            | 0.609935             | \$14,318,783.09        | \$14,318,783          | Construction of new facility                |
| 9                          | \$820,000               | 0.573382             | \$470,173.01           | \$470,173             | Maintenance dredging + facility maintenance |
| 10                         | \$20,000                | 0.539019             | \$10,780.38            | \$10,780              | Facility maintenance                        |
| 11                         | \$20,000                | 0.506716             | \$10,134.32            | \$10,134              | Facility maintenance                        |
| 12                         | \$820,000               | 0.476349             | \$390,606.06           | \$390,606             | Maintenance dredging + facility maintenance |
| 13                         | \$20,000                | 0.447802             | \$8,956.03             | \$8,956               | Facility maintenance                        |
| 14                         | \$20,000                | 0.420965             | \$8,419.30             | \$8,419               | Facility maintenance                        |
| 15                         | \$820,000               | 0.395737             | \$324,504.15           | \$324,504             | Maintenance dredging + facility maintenance |
| 16                         | \$20,000                | 0.37202              | \$7,440.41             | \$7,440               | Capping of old facility                     |
| 17                         | \$20,000                | 0.349725             | \$6,994.51             | \$6,995               | Capping of old facility                     |
| 18                         | \$820,000               | 0.328767             | \$269,588.61           | \$269,589             | Maintenance dredging + facility maintenance |
| 19                         | \$20,000                | 0.309064             | \$6,181.28             | \$6,181               | Facility maintenance                        |
| 20                         | \$20,000                | 0.290542             | \$5,810.83             | \$5,811               | Facility maintenance                        |
| 21                         | \$820,000               | 0.27313              | \$223,966.37           | \$223,966             | Maintenance dredging + facility maintenance |
| 22                         | \$20,000                | 0.256761             | \$5,135.22             | \$5,135               | Facility maintenance                        |
| 23                         | \$20,000                | 0.241374             | \$4,827.47             | \$4,827               | Facility maintenance                        |
| 24                         | \$820,000               | 0.226908             | \$186,064.75           | \$186,064             | Maintenance dredging + facility maintenance |
| 25                         | \$20,000                | 0.21331              | \$4,266.19             | \$4,266               | Capping of old facility                     |
| 26                         | \$20,000                | 0.200526             | \$4,010.52             | \$4,011               | Capping of old facility                     |
| 27                         | \$820,000               | 0.188509             | \$154,577.18           | \$154,577             | Maintenance dredging + facility maintenance |
| 28                         | \$20,000                | 0.177212             | \$3,544.23             | \$3,544               | Facility maintenance                        |
| 29                         | \$20,000                | 0.166591             | \$3,331.83             | \$3,332               | Facility maintenance                        |
| 30                         | \$820,000               | 0.156608             | \$128,418.22           | \$128,418             | Maintenance dredging + facility maintenance |
| 31                         | \$1,408,436             | 0.147222             | \$207,353.01           | \$207,353             | Capping                                     |
|                            | <b>\$33,635,924</b>     |                      | <b>\$19,115,935.33</b> |                       |                                             |
| <b>Total</b>               |                         |                      |                        | <b>\$23,616,329</b>   |                                             |
| Capital Recovery Factor    |                         |                      |                        | 0.07558759            | \$1,785,101.42                              |
| <b>Average Annual Cost</b> |                         |                      |                        | <b>\$1,785,101.42</b> |                                             |
|                            |                         |                      |                        | <b>\$1,785,100</b>    |                                             |

**Table C24**  
**Alternative 2 Annual Cost (Interest Rate = 0.0638)**

| Project Year               | Contract Cost (2000 \$) | Present Value Factor | Present Value         | Present Worth                             | Cost Item                                   |
|----------------------------|-------------------------|----------------------|-----------------------|-------------------------------------------|---------------------------------------------|
| 0                          | \$16,981,084            | 1                    | \$16,981,084          | \$16,981,084                              | Initial dredging- sum of 2 years plus IDC   |
| 1                          | \$20,000                | 0.940071             | \$18,801              | \$18,801                                  | Facility maintenance                        |
| 2                          | \$20,000                | 0.883733             | \$17,675              | \$17,675                                  | Facility maintenance                        |
| 3                          | \$1,920,352             | 0.830771             | \$1,595,373           | \$1,595,373                               | Maintenance dredging + facility maintenance |
| 4                          | \$20,000                | 0.780983             | \$15,620              | \$15,620                                  | Facility maintenance                        |
| 5                          | \$20,000                | 0.734179             | \$14,684              | \$14,684                                  | Facility maintenance                        |
| 6                          | \$1,920,352             | 0.69018              | \$1,325,389.13        | \$1,325,389                               | Maintenance dredging + facility maintenance |
| 7                          | \$20,000                | 0.648818             | \$12,976.36           | \$12,976                                  | Facility maintenance                        |
| 8                          | \$20,000                | 0.609935             | \$12,198.70           | \$12,199                                  | Facility maintenance                        |
| 9                          | \$1,920,352             | 0.573382             | \$1,101,094.73        | \$1,101,095                               | Maintenance dredging + facility maintenance |
| 10                         | \$20,000                | 0.539019             | \$10,780.38           | \$10,780                                  | Facility maintenance                        |
| 11                         | \$20,000                | 0.506716             | \$10,134.32           | \$10,134                                  | Facility maintenance                        |
| 12                         | \$1,920,352             | 0.476349             | \$914,757.47          | \$914,757                                 | Maintenance dredging + facility maintenance |
| 13                         | \$20,000                | 0.447802             | \$8,956.03            | \$8,956                                   | Facility maintenance                        |
| 14                         | \$20,000                | 0.420965             | \$8,419.30            | \$8,419                                   | Facility maintenance                        |
| 15                         | \$1,920,352             | 0.395737             | \$759,953.90          | \$759,954                                 | Maintenance dredging + facility maintenance |
| 16                         | \$20,000                | 0.37202              | \$7,440.41            | \$7,440                                   | Facility maintenance                        |
| 17                         | \$20,000                | 0.349725             | \$6,994.51            | \$6,995                                   | Facility maintenance                        |
| 18                         | \$1,920,352             | 0.328767             | \$631,347.59          | \$631,348                                 | Maintenance dredging + facility maintenance |
| 19                         | \$20,000                | 0.309064             | \$6,181.28            | \$6,181                                   | Facility maintenance                        |
| 20                         | \$20,000                | 0.290542             | \$5,810.83            | \$5,811                                   | Facility maintenance                        |
| 21                         | \$1,920,352             | 0.27313              | \$524,505.21          | \$524,505                                 | Maintenance dredging + facility maintenance |
| 22                         | \$20,000                | 0.256761             | \$5,135.22            | \$5,135                                   | Facility maintenance                        |
| 23                         | \$20,000                | 0.241374             | \$4,827.47            | \$4,827                                   | Facility maintenance                        |
| 24                         | \$1,920,352             | 0.226908             | \$435,743.67          | \$435,744                                 | Maintenance dredging + facility maintenance |
| 25                         | \$20,000                | 0.21331              | \$4,266.19            | \$4,266                                   | Facility maintenance                        |
| 26                         | \$20,000                | 0.200526             | \$4,010.52            | \$4,011                                   | Facility maintenance                        |
| 27                         | \$1,920,352             | 0.188509             | \$362,003.17          | \$362,003                                 | Maintenance dredging + facility maintenance |
| 28                         | \$20,000                | 0.177212             | \$3,544.23            | \$3,544                                   | Facility maintenance                        |
| 29                         | \$20,000                | 0.166591             | \$3,331.83            | \$3,332                                   | Facility maintenance                        |
| 30                         | \$1,920,352             | 0.156608             | \$300,741.70          | \$300,742                                 | Maintenance dredging + facility maintenance |
|                            | <b>\$19,603,520</b>     |                      | <b>\$8,132,695.05</b> |                                           |                                             |
| <b>Total</b>               |                         |                      |                       | <b>\$25,113,780</b>                       |                                             |
| Capital Recovery Factor    |                         |                      |                       | 0.07558759                                | \$1,898,290.09                              |
| <b>Average Annual Cost</b> |                         |                      |                       | <b>\$1,898,290.09</b><br><b>1,898,300</b> |                                             |

**Table C25**  
**Alternative 3 Annual Cost (Interest Rate = 0.0638)**

| Project Year               | Contract Cost (2000 \$) | Present Value Factor | Present Value          | Present Worth         | Cost Item                                   |
|----------------------------|-------------------------|----------------------|------------------------|-----------------------|---------------------------------------------|
| 0                          | \$25,487,926            | 1                    | \$25,487,926           | \$25,487,926          | Initial dredging- sum of 2 years plus IDC   |
| 1                          | \$20,000                | 0.940071             | \$18,801               | \$18,801              | Facility maintenance                        |
| 2                          | \$20,000                | 0.883733             | \$17,675               | \$17,675              | Facility maintenance                        |
| 3                          | \$2,670,352             | 0.830771             | \$2,218,451            | \$2,218,451           | Maintenance dredging + facility maintenance |
| 4                          | \$20,000                | 0.780983             | \$15,620               | \$15,620              | Facility maintenance                        |
| 5                          | \$20,000                | 0.734179             | \$14,684               | \$14,684              | Facility maintenance                        |
| 6                          | \$2,670,352             | 0.69018              | \$1,843,024.36         | \$1,843,024           | Maintenance dredging + facility maintenance |
| 7                          | \$20,000                | 0.648818             | \$12,976.36            | \$12,976              | Facility maintenance                        |
| 8                          | \$20,000                | 0.609935             | \$12,198.70            | \$12,199              | Facility maintenance                        |
| 9                          | \$2,670,352             | 0.573382             | \$1,531,131.02         | \$1,531,131           | Maintenance dredging + facility maintenance |
| 10                         | \$20,000                | 0.539019             | \$10,780.38            | \$10,780              | Facility maintenance                        |
| 11                         | \$20,000                | 0.506716             | \$10,134.32            | \$10,134              | Facility maintenance                        |
| 12                         | \$2,670,352             | 0.476349             | \$1,272,019.11         | \$1,272,019           | Maintenance dredging + facility maintenance |
| 13                         | \$20,000                | 0.447802             | \$8,956.03             | \$8,956               | Facility maintenance                        |
| 14                         | \$20,000                | 0.420965             | \$8,419.30             | \$8,419               | Facility maintenance                        |
| 15                         | \$2,670,352             | 0.395737             | \$1,056,756.47         | \$1,056,756           | Maintenance dredging + facility maintenance |
| 16                         | \$20,000                | 0.37202              | \$7,440.41             | \$7,440               | Facility maintenance                        |
| 17                         | \$20,000                | 0.349725             | \$6,994.51             | \$6,995               | Facility maintenance                        |
| 18                         | \$2,670,352             | 0.328767             | \$877,922.54           | \$877,923             | Maintenance dredging + facility maintenance |
| 19                         | \$20,000                | 0.309064             | \$6,181.28             | \$6,181               | Facility maintenance                        |
| 20                         | \$20,000                | 0.290542             | \$5,810.83             | \$5,811               | Facility maintenance                        |
| 21                         | \$2,670,352             | 0.27313              | \$729,352.50           | \$729,353             | Maintenance dredging + facility maintenance |
| 22                         | \$20,000                | 0.256761             | \$5,135.22             | \$5,135               | Facility maintenance                        |
| 23                         | \$20,000                | 0.241374             | \$4,827.47             | \$4,827               | Facility maintenance                        |
| 24                         | \$2,670,352             | 0.226908             | \$605,924.84           | \$605,925             | Maintenance dredging + facility maintenance |
| 25                         | \$20,000                | 0.21331              | \$4,266.19             | \$4,266               | Facility maintenance                        |
| 26                         | \$20,000                | 0.200526             | \$4,010.52             | \$4,011               | Facility maintenance                        |
| 27                         | \$2,670,352             | 0.188509             | \$503,384.73           | \$503,385             | Maintenance dredging + facility maintenance |
| 28                         | \$20,000                | 0.177212             | \$3,544.23             | \$3,544               | Facility maintenance                        |
| 29                         | \$20,000                | 0.166591             | \$3,331.83             | \$3,332               | Facility maintenance                        |
| 30                         | \$2,670,352             | 0.156608             | \$418,197.39           | \$418,197             | Maintenance dredging + facility maintenance |
|                            | <b>\$27,103,520</b>     |                      | <b>\$11,237,950.63</b> |                       |                                             |
| <b>Total</b>               |                         |                      |                        | <b>\$36,725,876</b>   |                                             |
| Capital Recovery Factor    |                         |                      |                        | 0.07558759            | \$2,776,020.49                              |
| <b>Average Annual Cost</b> |                         |                      |                        | <b>\$2,776,020.49</b> |                                             |
|                            |                         |                      |                        | <b>\$2,776,000</b>    |                                             |

**Table C26**  
**Identification of Base Condition and Comparison of Annualized Amounts**

| Alternative | Initial Investment | Present Value | Annualized Amount |                                                                |
|-------------|--------------------|---------------|-------------------|----------------------------------------------------------------|
| 1           | \$4,500,394        | \$23,616,329  | \$1,785,100       | CDF must be replaced after 2 maintenance dredging cycles       |
| 2           | \$16,981,084       | \$25,113,780  | \$1,898,300       | Life of CDF is extended through 14 maintenance dredging cycles |
| 3           | \$25,487,926       | \$36,725,876  | \$2,776,000       | Life of CDF is extended through 49 maintenance dredging cycles |