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The Sediment Budget Calculator: A Webtool to Develop a Family of Viable Inlet and Adjacent Beach Sediment Budget Solutions

by Julie Dean Rosati, Charles A. Sumner, and Derek A. Wilson

PURPOSE: This Coastal and Hydraulics Engineering Technical Note (CHETN) describes the Sediment Budget Calculator (SBC), an online webtool that calculates a family of viable solutions for an inlet and adjacent beach sediment budget given site-specific parameters as defined by the user. Data required include the following: (a) ranges of likely longshore sand transport rates; (b) characterization of inlet processes, bypassing, and jetty performance; and (c) known volume change rates from adjacent beaches, engineering activities (dredging and placement), river influx or other upland sources of littoral sediment, and gross change in the inlet system (channel infilling plus shoal growth). The SBC applies the Bodge Method (Bodge 1999) as described in the Coastal Engineering Manual (CEM) Part V-6 (USACE 2003).

BACKGROUND: The Bodge Method solves for all viable sediment budget solutions given user-defined constraints and known site conditions, using sediment transport pathways shown in Figure 1 for an idealized inlet.

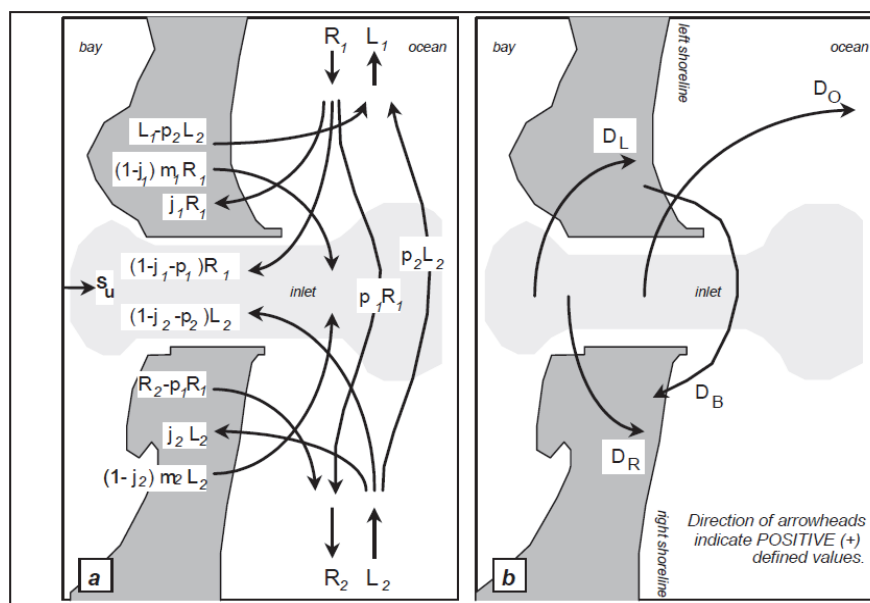


Figure 1. Sediment transport pathways for the Bodge Method.

Right- and left-directed transport paths are based upon a seaward-looking observer: right-directed transport is positive and left-directed transport is negative, except as noted. The boundaries of the study area are set to be outside the influence of the inlet. Variables are defined as follows:

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- R, L = rightward- and leftward-directed incident transport values at the study area's boundaries, where a subscript of 1 or 2 indicates the right or left boundaries, respectively
- j_1, j_2 = fraction of incident transport (R or L) impounded by the inlet's jetties (j_1 = left jetty; j_2 = right jetty; 0.0 = transparent jetty; 1.0 = impermeable jetty)
- p_1, p_2 = fraction of incident transport (R or L) naturally bypassed across the inlet (p_1 = from the left; p_2 = from the right; 0.0 = no bypassing; 1.0 = perfect bypassing)
- m_1 = local inlet-induced transport from the left shoreline into the inlet (expressed as a fraction or multiple of the right-directed incident transport, R_1)
- m_2 = local inlet-induced transport from the right shoreline into the inlet (expressed as a fraction or multiple of the left-directed incident transport, L_2)
- S_u = transport of littoral sediments into the inlet from sources other than the coast (e.g., river influx of sediment, bank erosion along inner bay; positive value)
- D_L, D_R = mechanical transfer of sand from the inlet to the left and right shorelines, respectively
- D_B = mechanical transfer of sand from the left shoreline to the right shoreline (defined as positive from left to right; negative from right to left)
- D_O = maintenance dredging and out-of-system disposal from the inlet (positive-valued; includes only sediment deposited by coastal processes (e.g., not to include river influx nor bank erosion in bay); includes deepwater (offshore) and upland disposal; excludes new work)
- Q_{net1}, Q_{net2} = net longshore transport rates at right (1) and left (2) study area boundaries
- $\Delta V_L, \Delta V_R$ = net volume change on the left and right beaches, respectively
- ΔV_G = gross volume of sand entering the inlet prior to maintenance dredging

The transport terms ($R, L, Q_{net}, S_u, D_L, D_R, D_O, \Delta V_L, \Delta V_R, \Delta V_G$) can be expressed as volumetric quantities or rates. Only a brief review is given here; for a full discussion of this method and associated equations, the reader is directed to the CEM-V-6 (USACE 2003).

APPLICATION: A fictitious dataset is used to illustrate operation of the SBC. To access the SBC, go to the CIRP website¹. Under **Products**, click on **Sediment Budget Tools** and choose the **Sediment Budget Calculator** (webtool) tab.

¹ <http://cirp.usace.army.mil/>

DATA INPUT TAB

Step 1. To run the SBC webtool, the user begins at the **Data Input** tab and enters the range of likely right- and left-directed transport rates and the increment between values, then clicks **Populate** (Figure 2). Selecting **Populate Sample** will automatically fill the entries with example values. In this example, right- and left-transport rates are set to range between 100,000 and 500,000 cu yd/year in increments of 50,000 cu yd/year, resulting in 9 values each for R_1 , R_2 , L_1 , and L_2 for $9 \times 9 \times 9 \times 9 = 6,561$ potential solutions. Note that large calculations may not be able to be displayed in the SBC; the user can still calculate and save results using the SBC-lite version, discussed later.

Auto-populate R's and L's

Enter minimum, maximum, and increment for the Right- and Left-directed longshore sand transport rates at the Right and Left boundaries of the budget region (see figure above). By clicking "Populate" these values will be entered into the input table below. To populate an example data set, click on Populate Sample.

Min: Max: Increment:

Which shoreline is downdrift OR of less certain volume change? Units:

R1 minimum	<input type="text" value="100000"/>	R1 maximum	<input type="text" value="500000"/>	increment	<input type="text" value="50000"/>
R2 minimum	<input type="text" value="100000"/>	R2 maximum	<input type="text" value="500000"/>	increment	<input type="text" value="50000"/>
L1 minimum	<input type="text" value="-100000"/>	L1 maximum	<input type="text" value="-500000"/>	increment	<input type="text" value="-50000"/>
L2 minimum	<input type="text" value="-100000"/>	L2 maximum	<input type="text" value="-500000"/>	increment	<input type="text" value="-50000"/>
V change, Left	<input type="text" value="-100000"/>	Right	<input type="text" value="-300000"/>	gross	<input type="text" value="250000"/>

Figure 2. Defining ranges of transport rates and volumetric change in SBC interface.

In Figure 2, the right shoreline was chosen as being downdrift with volume change on the left and right beaches of $\Delta V_L = -100,000$ cu yd/year and $\Delta V_R = -300,000$ cu yd/year, respectively, and the inlet system (ebb and flood shoals, navigation channel, and all inlet-influenced morphology) gross inlet volume change prior to dredging of $\Delta V_G = 250,000$ cu yd/year. Note that when the left-directed transport rates are populated, they show negative values which is the convention for transport towards the left for a seaward-facing observer.

Step 2. The remaining values in the form are filled out next (Figure 3). In the example below, $j_1 = j_2 = 0$ because there are no jetties (or very degraded jetties); inlet-induced transport is greater from the right beach into the inlet ($m_2 = 0.4$) as compared to the left beach ($m_1 = 0.2$); and there was no mechanical transport of sand ($D_L = D_R = D_B = D_o = 0$) and no sources of sand other than from the coast ($S_u = 0$).

Fraction of incident transport impounded at left (j1) and right (j2) jetties (0= transparent jetty; 1= impermeable jetty)

J1 J2

Local inlet-induced transport from left (m1) and right (m2) shorelines (expressed as a percentage of R1 and L2, respectively):

M1 M2

Mechanical transfer of sand from the inlet to the left (DL) and right (DR) shorelines, respectively:

DL DR

Mechanical transport of sand from left shoreline to right shoreline (DB; positive if left to right, negative if right to left) or placement offshore (Do):

DB DO

Transport of sand into inlet from upland sources

SU

Calculate
(scroll down to view calculated chart)

Figure 3. Entering remaining parameters in SBC interface.

Step 3. Once all values have been populated, clicking **Calculate** will plot all viable solutions for the given data, as shown in Figure 4. Note that all *potential* solutions (6,561 for the example) may not be *viable* (and are not plotted), and some solutions may overlay each other.

Hovering the cursor over a data point will show values associated with that point, with Q_{net} representing the updrift boundary of the study area, or Q_{net1} for this example. In Figure 4, solutions for shoaling from the left and right beaches are shown in orange and blue, respectively. The data point highlighted has a net natural bypassing of 170,000 cu yd/year, indicating that this particular solution has natural bypassing around the inlet from the left beach to the right; shoaling from the right beach (because it is a blue point) into the inlet is 120,000 cu yd/year; and the net longshore transport rate is 200,000 cu yd/year. The user can also zoom in and out by highlighting areas of the chart and deactivating a data set by clicking on the name of the data set in the legend below. Doing so will toggle the data on and off.

For a large number of potential solutions, a different warning box will indicate that the data set is too large for the web-based chart to plot. A *lite* SBC is available at the top toolbar that doesn't plot the solutions on a chart but saves the results for the user to inspect in Excel.

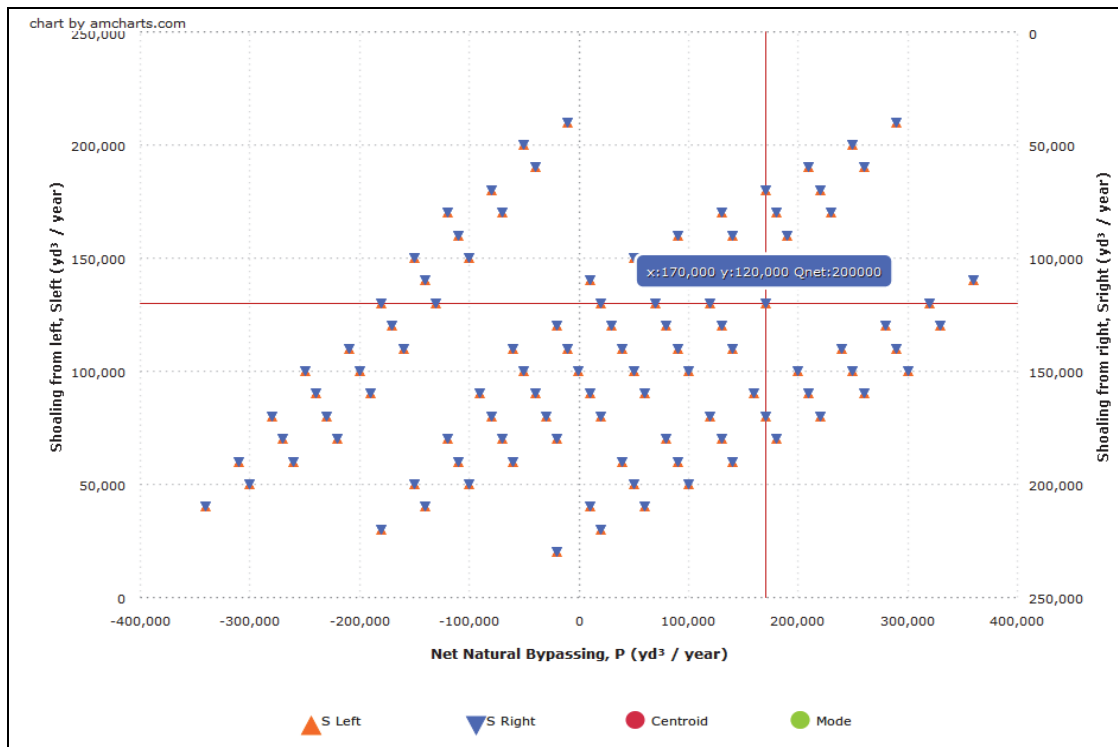


Figure 4. Example solutions.

Step 4. The **Settings** button at the top of the page can be accessed from any tab and allows changes to labels on the chart, colors of the data points, and symbols. To apply new settings, the user must scroll down and click **Apply** (Figure 5).

Step 5. The user may export the narrowed family of solutions to Excel by clicking on **Export Data** at the bottom of the page.

FAMILY OF SOLUTIONS TAB

Step 6. The solutions can be narrowed by clicking on the **Family of Solutions** tab in the upper portion of the page. Use the check boxes to the left of each constraint to toggle them off or on and enter values (Figure 6). In Figure 6, natural bypassing (P) has been constrained to be in the same direction as the net longshore transport (Q_{net}). The ranges of reasonable values for shoaling from the left and net longshore transport can also be specified to narrow the solutions. Clicking **Update Chart** will plot the narrowed solutions. Clicking **Calculate Modal** and **Calculate Centroid** will plot these values on the chart for the narrowed family of solutions (Figure 7). Removing constrained values and clicking **Update Chart** will restore the original solution set.

Data Time Series Chart Settings

X Axis Label:

Y Axis Label:

Y Axis2 Label:

Color for S Left data:

Color for S Right data:

Color for Mode:

Color for Centroid:

S Left Bullet Type:

Figure 5. Changing plot settings.

Data Input
Family Of Solutions
Formulate Traditional Sediment Budget

Narrow Family of Solutions

How do you want to narrow your family of solutions? (check the constraints that apply)

☒ P must be in the same direction as Qnet

☐ Minimum Sleft = 0 Maximum Sleft = 0

☐ Qnet between 0 and 0

Update Chart »

Calculate Modal on Current Data

Calculate Centroid on Current Data

Modal: p: 210000, s: 90000

Centroid: p: 168943.7, s: 122253.

Figure 6. Narrow family of solutions in the **Family of Solutions** tab.

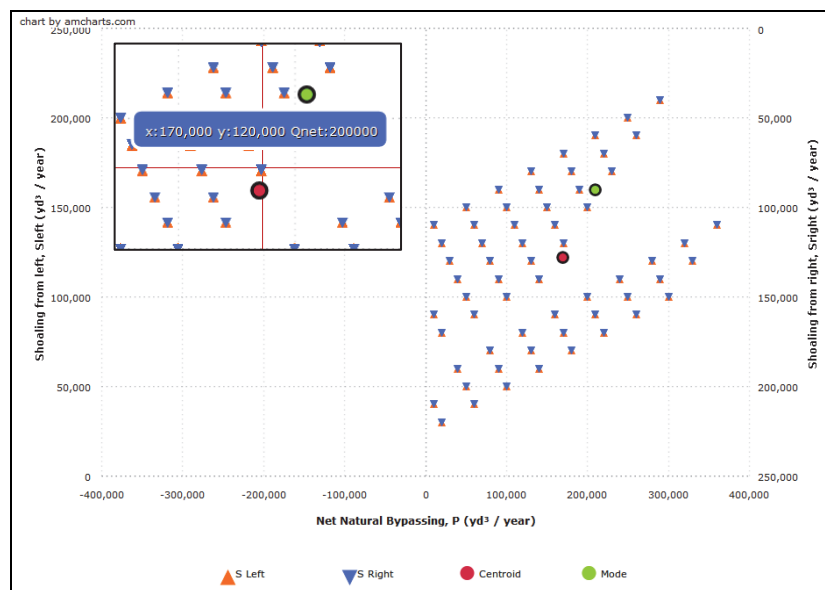


Figure 7. Example with narrowed solutions; natural bypassing is constrained to be in the same direction as net longshore transport. The centroid and modal values are shown for the narrowed solutions, and the inset shows the solution selected to formulate a traditional sediment budget.

The CEM discusses using the modal solution as a representative budget, but the centroid solution may also be a reasonable characterization of processes at the site. The user may choose to select several plausible calculations to demonstrate a range of potential solutions.

Step 7. Click on any data point in the **Data Input** tab (Figure 4) or the **Family of Solutions** tab (Figure 7) to proceed in developing a traditional sediment budget with cells and fluxes. Here we clicked on a data point close to the centroid solution, as shown in Figure 7 inset.

FORMULATE TRADITIONAL SEDIMENT BUDGET TAB

Step 8. By clicking on the **Formulate Traditional Sediment Budget** tab at the top of the page, a plot is generated which shows the fluxes and volume changes associated with the selected solution, as shown in Figure 8 for this example (net natural bypassing = 170,000 cu yd/year; shoaling from the right beach = 120,000 cu yd/year; and the net longshore transport rate = 200,000 cu yd/year). Shoaling from the right beach is the total of $q_6 = 0$ and $q_9 = 120,000$ cu yd/year.

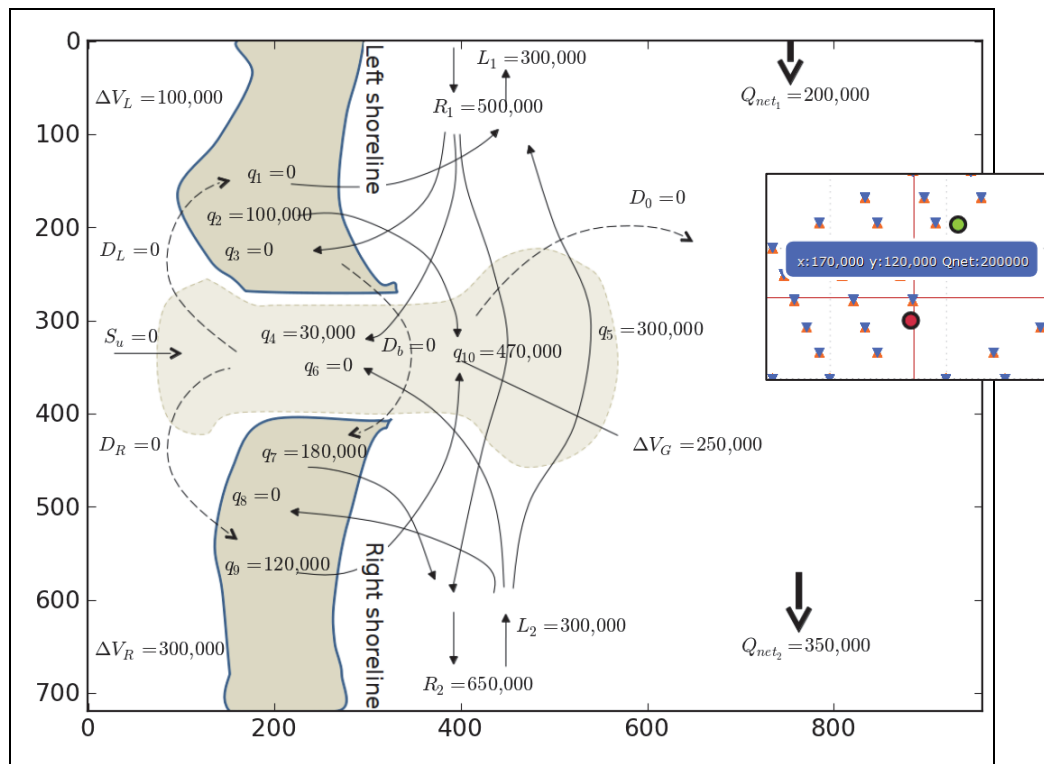


Figure 8. Traditional sediment budget formulated for solution near centroid.

From the **Formulate a Traditional Sediment Budget** tab, a solution near the modal value can also be selected to formulate another representative budget for consideration, as shown in Figure 9. For this example, we selected a data point representing shoaling from the left beach (orange data point) as indicated in Figure 9 inset (net natural bypassing = 190,000 cu yd/year; shoaling from the left beach = 160,000 cu yd/year; and the net longshore transport rate = 250,000 cu yd/year). Shoaling from the left beach is the total of $q_2 = 90,000$ and $q_4 = 70,000$ cu yd/year.

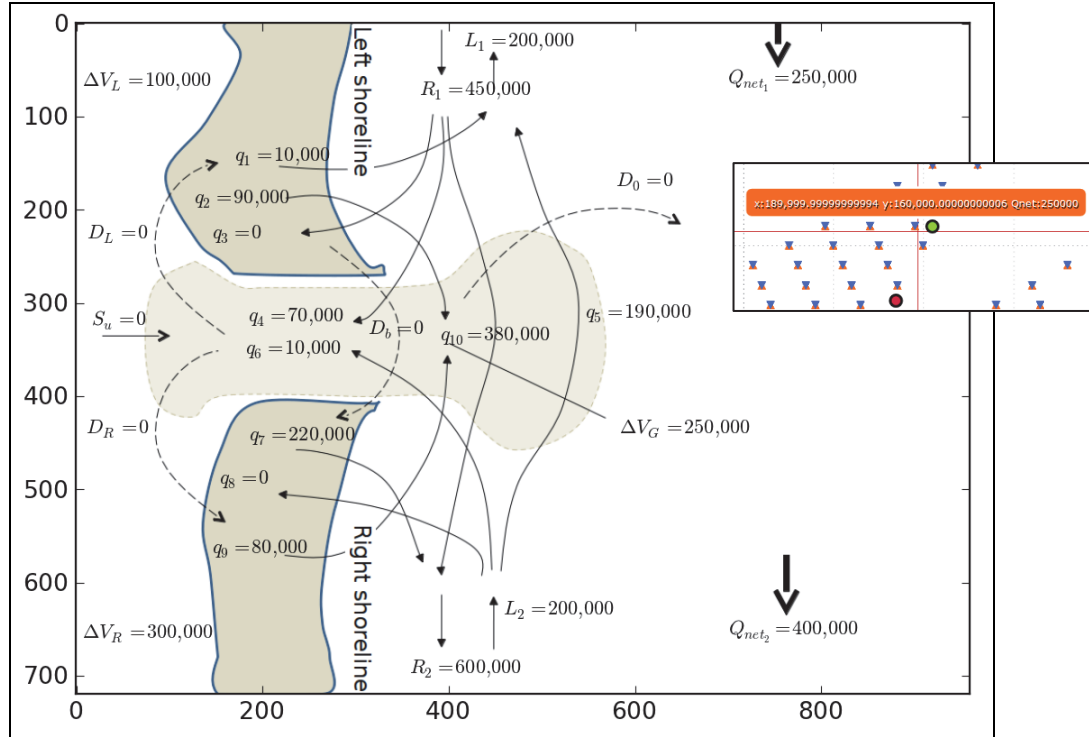


Figure 9. Traditional sediment budget formulated for solution near modal.

When communicating how sediment is transported along beaches, it is useful to present a range of sediment budget solutions such as shown here or present a solution with uncertainty values so that the variability in coastal processes and the resulting volume changes within the littoral system can be realized by partners and stakeholders.

The SBC solves equations presented in the CEM-V-6 (USACE 2003) to calculate the traditional sediment budgets (equation numbers are referenced from CEM-V-6 (USACE 2003)):

$$\Delta V_L = (j_1 + j_1 m_1 - m_1) R_1 + L_1 - p_2 L_2 - D_B + D_L \quad (\text{V-6-50})$$

$$\Delta V_R = (m_2 - j_2 m_2 - j_2) L_2 - R_2 + p_1 R_1 + D_B + D_R \quad (\text{V-6-51})$$

$$Q_{net1} = R_1 + L_1; Q_{net2} = R_2 + L_2 \quad (\text{V-6-61a, b})$$

$$S_{left} = (1 - j_1 - p_1 + m_1 - j_1 m_1) R_1 \quad (\text{V-6-62b})$$

$$S_{right} = - (1 - j_2 - p_2 + m_2 - j_2 m_2) L_2 \quad (\text{V-6-62c})$$

CONCLUSIONS: This CHETN describes application of a new webtool, the Sediment Budget Calculator (SBC), which automates the Family of Solutions method presented by Bodge (1999), and documented in the CEM Part V-6 (USACE 2003).

POINTS OF CONTACT: This CHETN was prepared as part of the Coastal Inlets Research Program (CIRP) and was written by Dr. Julie Dean Rosati (Julie.D.Rosati@usace.army.mil), Charles Sumner, formerly at the Mobile District of the USACE, and Dr. Derek Wilson (Derek.A.Wilson@erdc.dren.mil). Mitchell Brown is gratefully acknowledged for providing website updates for the SBC. For more information about CIRP, please contact the CIRP Program Manager, Julie Rosati (tel: 202-761-1850) or by email (Julie.D.Rosati@usace.army.mil).

This technical note should be referenced as follows:

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