Methodology for Flow and Salinity Estimates in the Sacramento-San Joaquin Delta and Suisun Marsh

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Chapter 2
Improved Geometry Interpolation in DSM2-Hydro

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2 Improved Geometry Interpolation in DSM2-Hydro

2.1 Introduction

This chapter documents modifications to the DSM2 program source code that improve the model's internal representation of bathymetry under conditions typical of the Sacramento-San Joaquin River Delta (the Delta). In DSM2, geometry is input by means of *cross sections* specified by the user at selected points along a channel. The cross section input represents a lookup table of width, area, and wetted perimeter versus elevation. The geometry is then interpolated along the channel from locations chosen by the user to locations where geometry is needed for computations. This interpolation requires some assumption about the vertical structure of the cross section, and whether properties at upstream and downstream locations should be compared based on "similar height from the bed" or "similar absolute elevation."

The original methods used in DSM2 were based on height from the bed and were suited to long river reaches with consistent slopes. The authors found this assumption to be less accurate in the Delta, which has an undulating bottom due to local scour, channel dredging, berms, and other local geometric features. In the present project, the authors implemented a more accurate scheme based on absolute elevation and also increased the density of geometry samples (number of quadrature points) used when calculating integral quantities such as volume.

2.2 Hydro Geometry Setup and Channel Cross Section Interpolation Methods

DSM2-Hydro uses an adapted version of the FourPt program (DeLong, Thompson, & Lee, 1997), which divides the Delta into discrete computation points along its channels. A contrived example for a single channel is shown in Figure 2-1. Two nodes are shown connected by a channel, and a network of nodes and channels represent the "user" view of the channel network. Additionally, the user must specify a nominal spatial grid size ΔX (usually 5,000 feet in DSM2 practice in the Delta) and some cross section geometry (possible locations of which are shown by thick violet arrows).

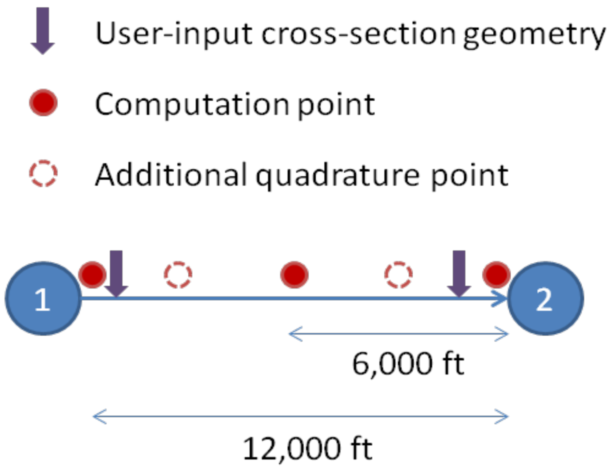

Figure note: The user cross section locations are indicated using thick violet arrows. The computation points and quadrature points where geometry is used in calculations are shown as small (closed and opened) red circles.

Figure 2-1 Computational Grid for a Fictional Channel Connecting Nodes '1' and '2'

The model calculations are based on computational points, which are more densely spaced than channels and nodes. When the computational mesh is constructed internally, channels may be further subdivided to conform better to the requested grid size. Specifically, a channel is subdivided into uniform computational sections no smaller than the requested ∆X. If in the example ∆X is assumed to be 5,000 ft, and the channel is 12,000 ft, the channel will be divided in two computational sections of 6,000 ft.

Finally, Hydro generates *virtual cross sections* not only at the computational point locations but also at quadrature points between the computation points that are used for calculating integral quantities such as volume. The computation and potential quadrature points are indicated with closed and open red circles in Figure 2-1; advanced users can discover their location, but they are not exposed in standard usage.

The basis for assigning values at virtual cross sections is *bilinear interpolation.* User-input cross sections are located downstream and upstream, and a value is obtained by assuming geometry at similar heights is comparable and can be interpolated in the streamwise direction based on distance. Wetted perimeter is similarly interpolated. Area is integrated vertically from width for consistency rather than independently interpolated.

The crux of the interpolation geometry is deciding what a “similar height” is. The original DSM2 geometry module compared the geometry based on height from the bed. In other words, the width of a virtual cross section 10 ft from the lowest point in the cross section was assumed to be comparable to the width of upstream and downstream user cross sections 10 ft from their respective beds. This assumption is clearly problematic when adjacent user cross sections used in interpolation are dramatically different in bottom elevation due to local irregularities.

An applied example that illustrates the issue is given by DSM2 channel 445 (connecting nodes 329 and 366) in Suisun Bay. Figure 2-2 shows user input cross sections in this channel at fractional lengths[1] 0.211, 0.551, and 0.819. The cross sections look symmetrical because they are inverted from width and area, which are the only data used by the model but are insufficient to infer exact geometry.

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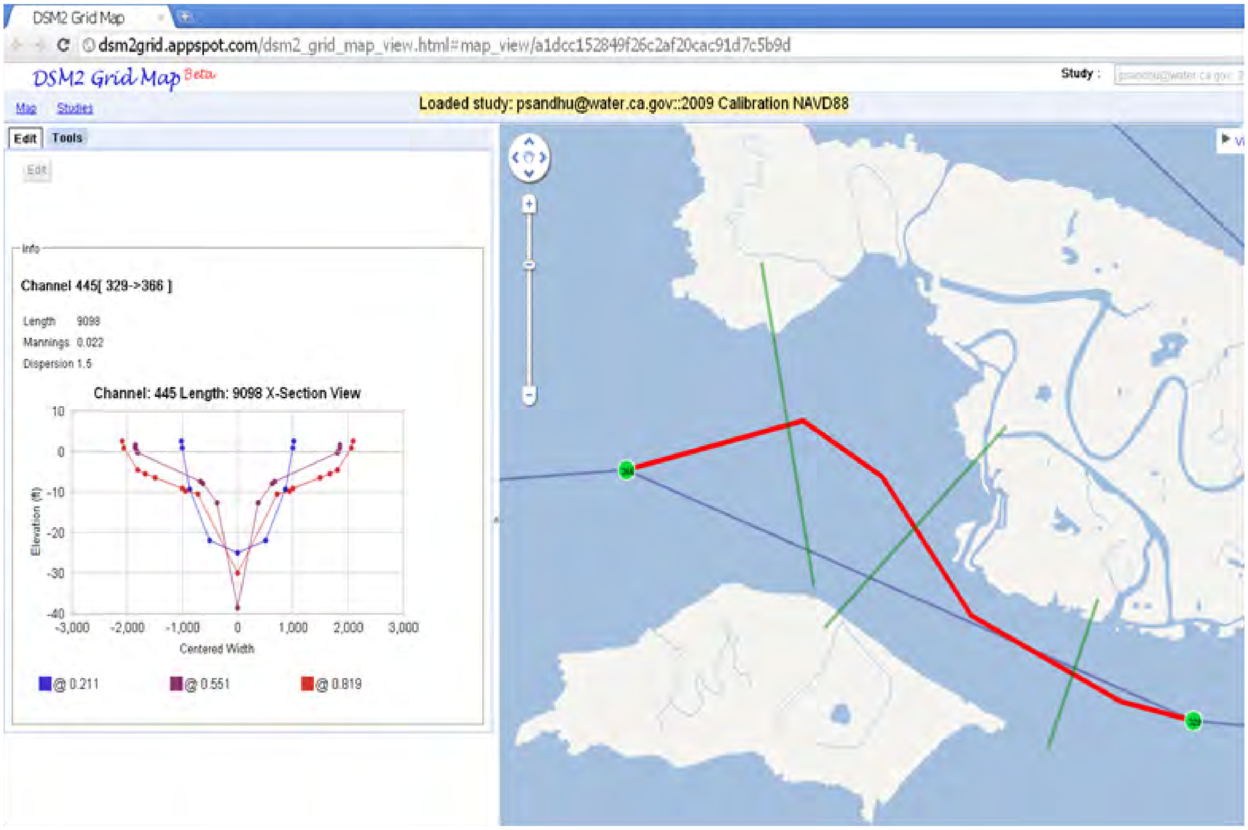
[1] The relative locations multiplied by the length of the channel will give the distance from the upstream node to the user-input cross sections.



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Channel 445[329->366]

Length 9098
Mannings 0.022
Dispersion 1.5

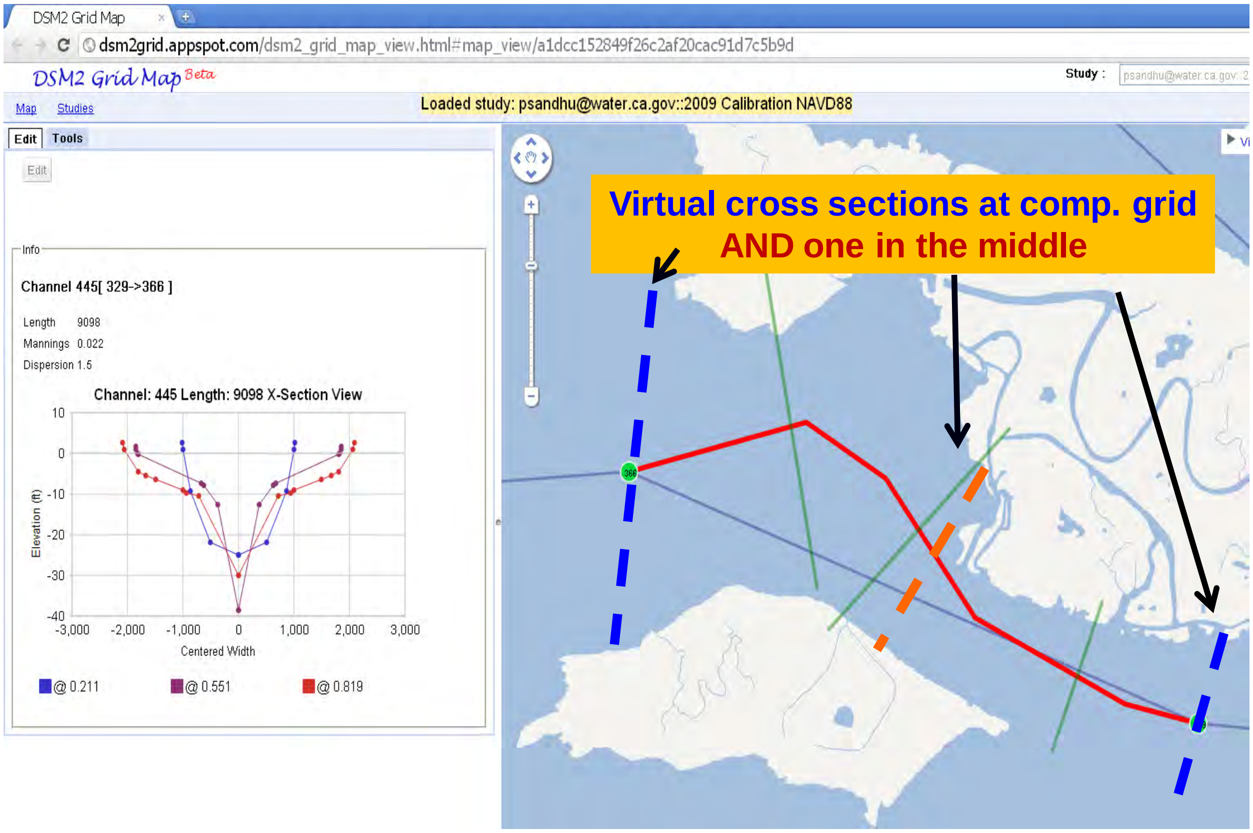
Channel: 445 Length: 9098 X-Section View

Figure note: Cross sections are shown as symmetric because they are inverted from area and width and do not determine the exact shape of the cross section. Distances are in feet.

Figure 2-2 A Map of User Input Cross Sections of Channel 445 in Suisun Marsh

Figure 2-3 shows the virtual cross sections used in DSM2-Hydro. Because the channel length is 9,098 ft, with a ∆X of 5,000 ft, the channel has only one computational reach. Computational points are located at both ends of the channel. Virtual cross sections at the ends are generated by interpolation with cross sections in channel 445 and adjacent channels. The virtual cross section at the midpoint is interpolated from the cross sections at fractional lengths 0.211 and 0.551.

Figure 2-4 illustrates height-based interpolation. Due to the big difference in bottom elevation, the interpolation layers have a large slope. The interpolation is not accurate. The method assumes that the change in bottom elevation is due to a slope in the channel that is also reflected in the slope of the water surface. For the Delta, this large change in bottom elevation is not a sloping bottom as much as it is an irregularity in the depth.



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Channel 445[329->366]

Length 9098

Mannings 0.022

Dispersion 1.5

Virtual cross sections at comp. grid AND one in the middle

Figure 2-3 Virtual Cross Section Locations at Computational Points and Midpoint

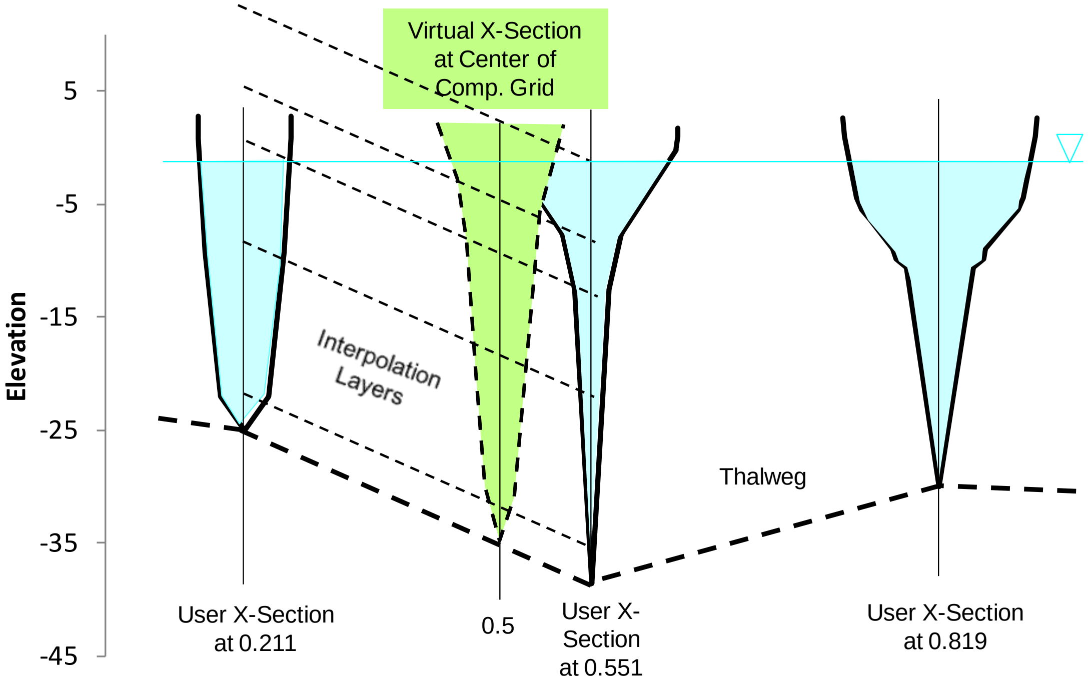

Figure 2-4 Illustration of Height-based Cross Section Interpolation

We have changed the interpolation to an elevation-based method, which is more appropriate for the Delta where the water surface is mostly flat, as shown in Figure 2-5 . Test runs showed this modification changed electrical conductivity (EC) results by only around 1% in most Delta stations. The effect of this modification is not significant.

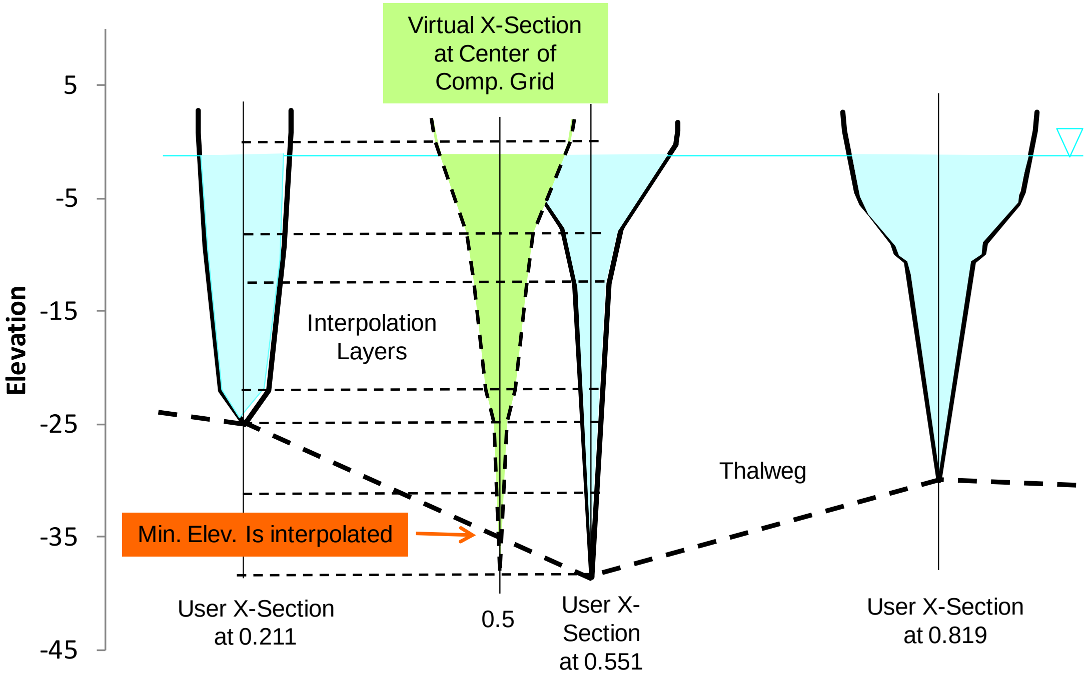

Figure 2-5 Illustration of Elevation-based Cross Section Interpolation

2.3 Improvement in Spatial Integration

Numerical integration in space is accomplished in the model through the use of a general quadrature. For a typical variable, φ, it is expressed by

$$\int_{x1}^{x2} \varphi \, dx \cong \Delta x \sum_{k=1}^{n} \omega_k \, \varphi_{\xi_k}$$

where ω is a weighting function. The number of points n, location ξ_k, and corresponding weight ω_k, in general determine accuracy of the approximation. Weights ω_k must sum to 1.

DSM2-Hydro has been using n = 1 for the simplicity and speed, a decision that was made at a time when relatively little detailed geometry was available. In this case, integrated properties such as the volume of a channel are calculated entirely from one cross section at the middle of the computational reach. When n = 2, a channel is represented by average of two cross sections at computational points. When n = 3, a channel is represented by average of all 3 virtual cross sections in a computational reach.

Results should be more accurate and reliable using n = 3, especially when one cross section is quite different from the others.

2.4 Model State at the Midpoint of a Computational Reach

At some quadrature points, we need to calculate a geometry parameter such as area at a location where there is no model state representing water surface. In this case, the model must interpolate an elevation to use as the basis for the geometry lookup. And an analogous issue arises to the one discussed above, i.e., whether to interpolate height (from bed to surface) or absolute surface relative to a datum.

As an example, DSM2 uses a file called a tidefile to pass data from Hydro to Qual. In the tidefile, average channel area was not calculated accurately in some channels. Because a single quadrature point was being used, average channel area was being calculated as average of areas at the middle of computational reaches. As shown in Figure 2-6, height (same as water depth) was interpolated first to the middle of the computational grid, and then area was calculated based on this interpolated depth. When the bottom elevation of the virtual cross section in the middle is quite different from those on the ends, the true depth is quite different from the interpolated depth; and calculated area is not correct. The problem is that depth is not a good variable to interpolate. Water surface elevation can be safely assumed to change linearly and slowly within a computational reach and should be used in the interpolation. This error affected Qual results because average channel area is used to initialize the volume of the channel. The error also affected Hydro because the same algorithm is used in Hydro to calculate some terms involving channel area. Test runs showed this modification has significant effects on both Hydro and Qual results. Recalibration will be needed for both Hydro and Qual before the change is formally released.

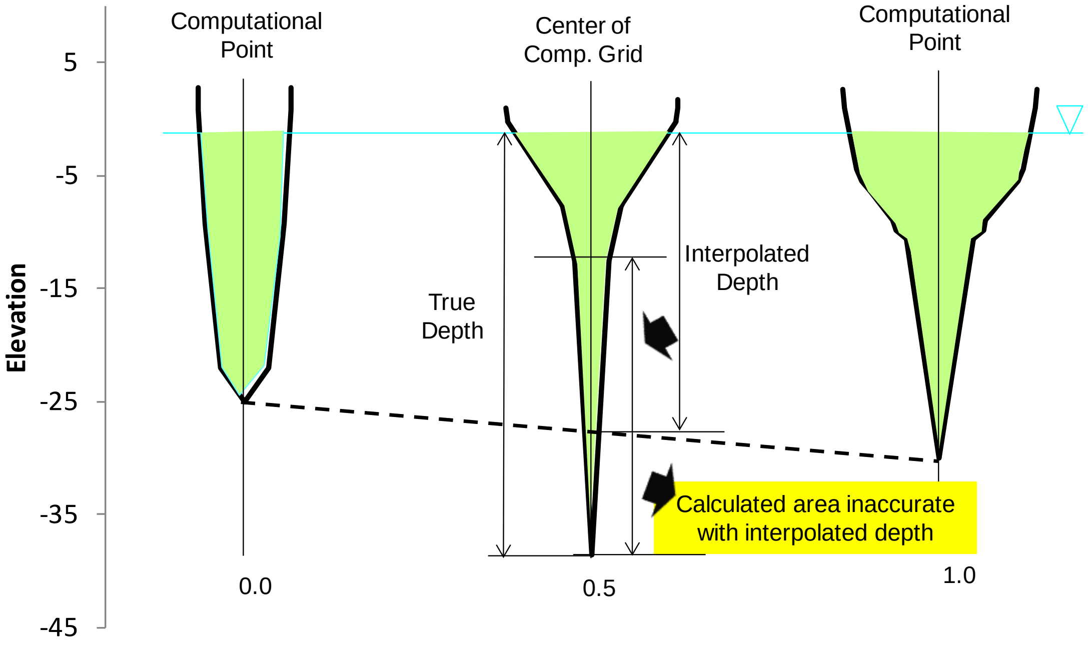

Figure 2-6 Illustration of a Poor Area Calculation

2.5 Summary of Modifications

- Virtual cross sections are generated based on elevation instead of height.
- Interpolated water surface instead of depth for midpoint geometry calculation.
- Quadrature points changed to 3. Results should be more accurate.
- Re-calibration is needed as a result of modifications.

2.6 References

DeLong, L. L., Thompson, D. B., & Lee, J. K. (1997). *The computer program FourPt (Version 95.01)--a model for simulating one-dimensional, unsteady, open-channel flow.* U.S. Geological Survey.

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