1. Working with Bathymetry

The CMS setup for Shark River Inlet provides a succinct example for illustrating a number of methods and SMS tools that can be applied to most engineering projects. The area is heavily structured, with a jettied inlet (and a jetty spur), developed bay shoreline (seawalls and riprap), and densely spaced groins, some of which on the south (up-drift) side have been notched. The overall goal of this guided example is to allow the user to work with real datasets, many of which were provided by the U.S. Army Corps of Engineers, New York District (NAN).

The original datasets for creating the Shark River Inlet grid are provided in sub-folders described throughout this document. Bathymetry can come from various sources and often is given in various horizontal and vertical projections. Before bathymetry datasets can be used to build a CMS grid, they must all reside in the same horizontal plane and have the same datum reference and units. This section explains how to convert all loaded data over to the same reference.

The following files, located in the "**Workshop\Bathymetry**" folder will be used for this tutorial on working with bathymetry:

- Channel_Survey_NJ-DEP_0609_ft_MLW.xyz
- Coastal_Relief_Model_ll_m_msl.xyz
- 3364_0409_ft_MLW.xyz
- LIDAR_ft_NAVD.xyz
- Field_Team_Measurements_0809_m_NAVD.xyz
- 0.75m_Contour.xyz

1.1. Horizontal Projections

In the SMS 13.1 and later, the term "projection" refers to a map projection such as "State Plane" or "Geographic". Within the software, a display projection can be associated with a project. Individual datasets also have their own projections. Previous versions of the SMS (11.2 and before) software have referred to projections as "coordinate systems" and reprojection as "coordinate conversion".

The present projection for the project can be specified from the *Display | Display Projection* pull-down menu command. Changing the projection does not alter the XYZ coordinates of the project data. The CMS models operate in a Cartesian coordinate system such as State Plane or UTM and units must always be specified in **meters**. Therefore, despite the display projection in the viewer, all datasets must be changed to metric values in a relevant Cartesian coordinate system. Also, note that the vertical projection is relative to your project and presently does not convert to/from common datums (e.g., NAVD) as these are site and timeframe specific.

1.1.1. Set initial project projection.

- Choose *Display | Projection* from the pull-down menu. The resulting dialog is shown in Figure 1.
- Click "Global Projection" and find the correct projection you wish to use. In our case, we will be using "State Plane New Jersey, NAD 1983, (meters).

- The easiest way to search through all the entries is to type some characters into the "Filter Strings:" box to show matching projections in the top selection box.
- Once you find the right Horizontal Projections, select it by left clicking it in the list. The bottom (gray) box will update with the information. Click OK (Figure 1).
- As you add projections, they are added to "Recent Projections" for future use.
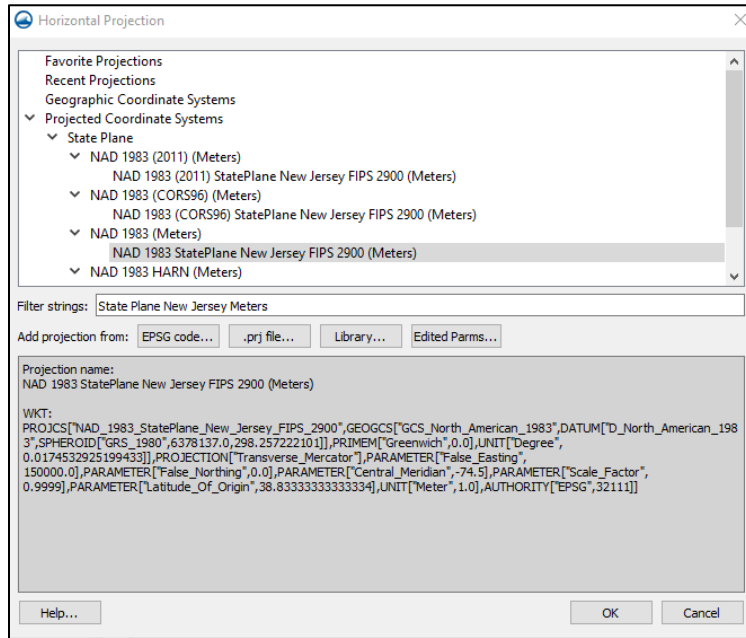

Figure 1. Selecting Horizontal Projection

- Set the Vertical datum to *Local* projection and units in *Meters*.
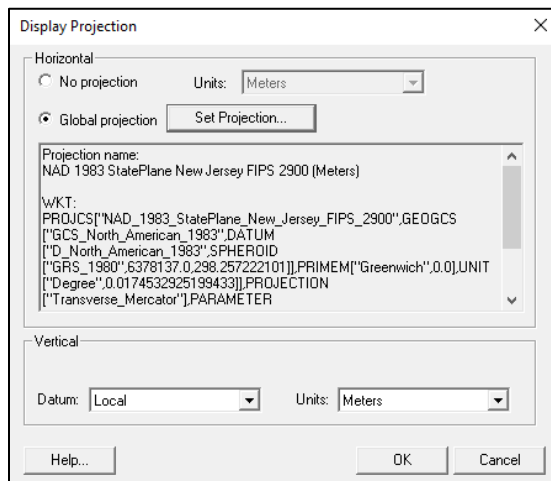- Click Ok to exit back to the interface (Figure 2).

Figure 2. Display Projection dialog

1.1.2. Open XYZ files.

- Open the "Workshop\Bathymetry" folder and observe the various data files.
- Select the six files with your mouse and drag them into the SMS graphical window. SMS will attempt to open each file in the format as defined by their extension (such as .xyz or .pts for columnar data).
  - o During the import process, there are several screens that appear for each dataset

(Figure 3). On Step 1, click the box next to "Space" so that spaces are used for delimiters. Simply hit *Next* or *Finish* through each.
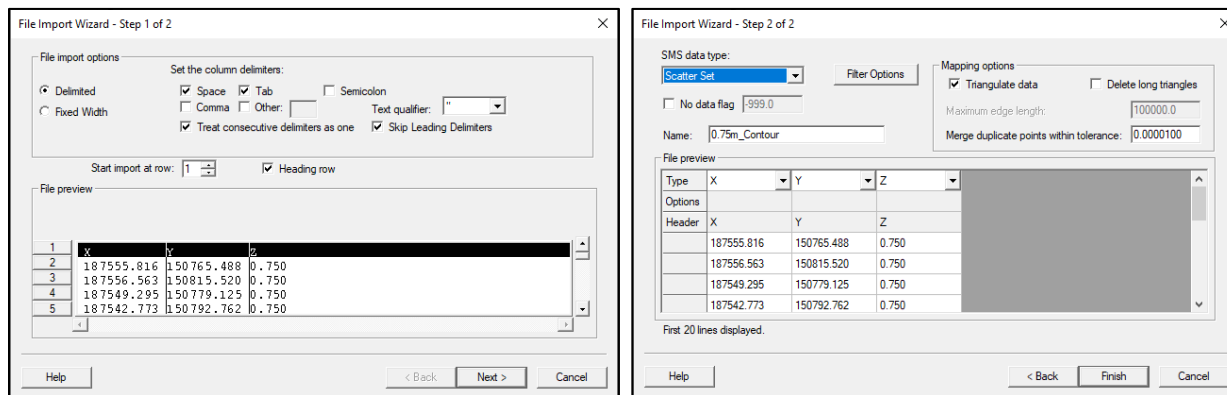

Figure 3. File Import Wizard

- o For each of the 6 imported datasets, SMS will ask you to define the projection for the imported data. Simply click OK and assign the projections as defined in the Table 1.

Table 1. Survey list with Horizontal Projection Information

Filename	Horizontal Projection information
Channel_Survey_NJ- DEP_0609_ft_MLW.xyz	State Plane, New Jersey, U.S. Feet, NAD83
Coastal_Relief_Model_ll_m_msl	Geographic (Lat/Long), Arc Degrees, NAD83
3364_0409_ft_MLW.xyz	State Plane, New Jersey, U.S. Feet, NAD83
LIDAR_ft_NAVD	State Plane, New Jersey, U.S. Feet, NAD83
Field_Team_Measurements_0809_ m_NAVD.xyz	State Plane, New Jersey, Meters, NAD83
0.75m_Contour	State Plane, New Jersey, Meters, NAD83

- • Make sure that the Vertical units match the Horizontal Units.
- • For the Coastal Relief Model, there are several "NAD 1983" options that come up. Choose the one that is under "Geographic Coordinate Systems | North America | NAD 1983" and choose meters for the vertical units.
- o Also, there is a default tolerance that is assigned. When loading certain very dense datasets or datasets that are relative to degrees (Latitude and Longitude), there may be a message that appears stating that a certain number of points have been removed due to the tolerance factor (Figure 4).
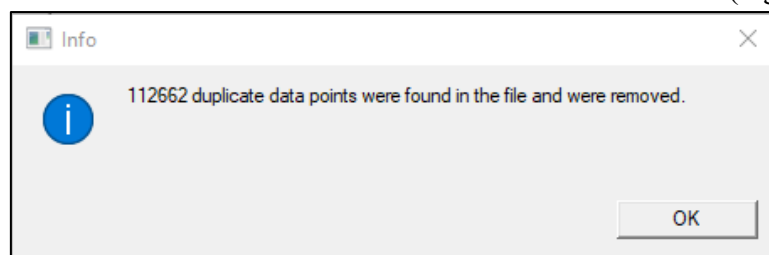

Figure 4. Duplicate data points

- • For convenience, the file names have been altered to give a description of a) the data contained, and b) the projection and units associated with the data. For example, the file "Channel Survey NJ-DEP 0609_ft_MLW.xyz" contains channel survey data obtained in

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June 2009 and the values are in feet relative to mean lower water (MLW).

- Since the projection for each of the 6 datasets was defined on import, all should line up nicely (Figure 5). If this doesn't happen, try to find the datasets that do not line up, right click on them in the data tree and set the Projection.
  - o Note, depending on which datasets is selected (bold) in the data tree, that object will be red in the resulting display and may not exactly match this image.
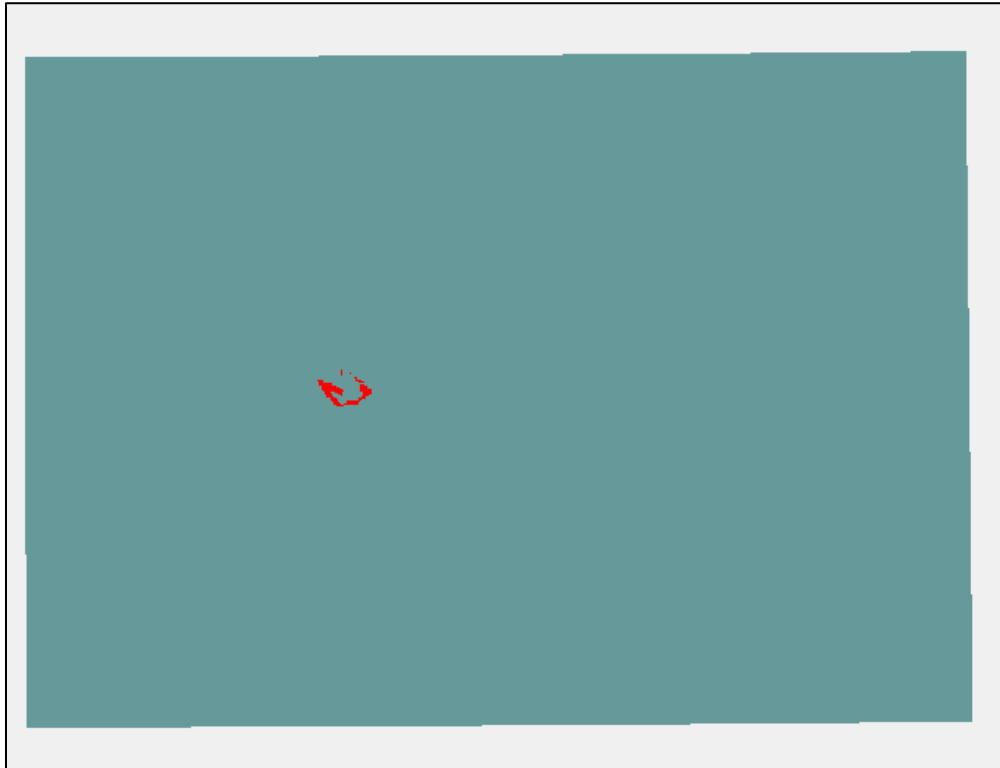

Figure 5. After loading 6 datasets

1.2. Saving your progress

Working with bathymetry files can be a lengthy process. This tutorial loads only six surveys, but some projects may have many more. To be on the safe side and to keep from having to duplicate effort because of a SMS bug, computer glitch, or user mistake, it is a wise idea to save your project frequently during this stage.

1.2.1. Saving the Project in SMS

There are few different ways to save your progress. One of the most useful in the early stages of grid development in the SMS is to save the entire project. This saves everything that is listed in the data tree under a project name. Images are handled differently due to their possible size and only a link to the files is stored.

- Under the *File* pull-down menu, choose the "Save New Project" option (Figure 6).
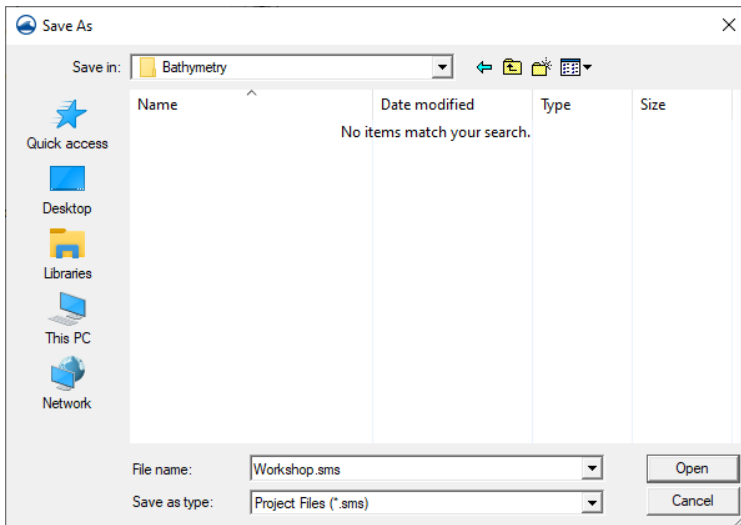
Figure 6. File | Save New Project dialog

- Choose the directory (or create a new one) where you wish to save the project and enter "Workshop" as the filename.
    - Just choose the present directory as the location.
    - The filename that you choose should be descriptive in a manner that you are able to understand.
    - Note that all datasets loaded in the data tree will have the filename chosen as a prefix.
    - This means that the entire filename for each dataset can be long.
    - For this example, I have used the name Workshop as the project filename. Figure 7 shows the list of files after the project has been saved so far. Notice that the original files still exist.

The next time you start SMS, you can simply load the file "Workshop.sms" to load all associated files with this project. Also, after a project has been saved or loaded, the *File* menu changes to "Save Project" and simply resaves all the data under the previously saved filename.

Periodically through the following sections, it is good to save the project to save your progress. I will mark this step with the word SAVE.

Figure 7. List of files after project saved

1.3. Vertical Datums

In preparing the vertical reference for the survey datasets, one must consider the various datum references and the sign and units of the data values. The Coastal Modeling System suite of models (CMS-Flow and CMS-Wave) requires that all bathymetries be oriented so that the values are positive as the water gets deeper and that the data are in metric units.

Beginning with SMS 13.1, the GUI now depicts all values consistently positive **UP** regardless of the desired model depth orientation. This contradicts who CMS expects the data values. The issue is addressed when the model files are exported to disk. For those of us who have used SMS before, this may be hard to remember, but it is vital.

1.3.1. Convert Elevations to Depths

The files that are obtained from various sources may be in positive depths rather than positive elevations. This information for each survey should accompany the data by means of a metadata file. If there are datasets which have vertical references that are positive depths, these must be converted from positive to negative. **For this exercise, all the survey data are already in the proper value reference (negative down) and no change is needed.**

An easy way to convert from elevations to depths is to use the *Data | Transform* from the SMS pull-down menu for each applicable survey dataset in the data tree. Below are instructions to make this change, however we will be addressing this in another manner later in this tutorial since there are multiple operations that may need to be performed.

- Choose the dataset from the data tree, you wish to switch the sign.
- On the dialog, shown in Figure 8, select "Depths ←→ Elevations" and enter a water surface elevation (WSE) value of zero.
- When OK is clicked, the signs of all values in that dataset will be reversed.
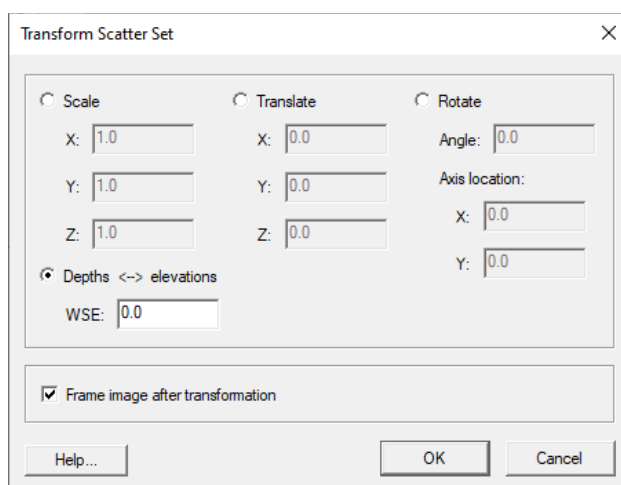- Repeat for all applicable survey datasets.
- SAVE project.

Figure 8. Transform dialog box

1.3.2. Local and Regional Datums

There are two types of vertical datums. Some use local references (such as mean low water or mean higher-high water) and others use national or regional references (such as the North Atlantic Vertical Datum, NAVD88). NOAA maintains a list of many locations and offers a benchmark sheet that explains the relationship between the available datums for a given location. Not all references are available at each location. A sample benchmark sheet for Long Branch Fishing Pier, NJ, NOAA station 8531991, is shown in Figure 9. These datum relationships are needed to convert from one to another. For example, for NOAA station 8531991, the value for mean lower-low water (MLLW) is 0.00 m and the value for mean sea level (MSL) is 0.744 m. To convert from MLLW to MSL, the user must subtract desired vertical datum from the individual datum. So, to convert MLLW to MSL, the following expression must be evaluated - MSL – MLLW = 0.744 – 0.00 = 0.744 m. This is generally easy to figure out for local datums. Be aware that regional or national datums in some locations may be higher than MSL and in other locations be lower than MSL.
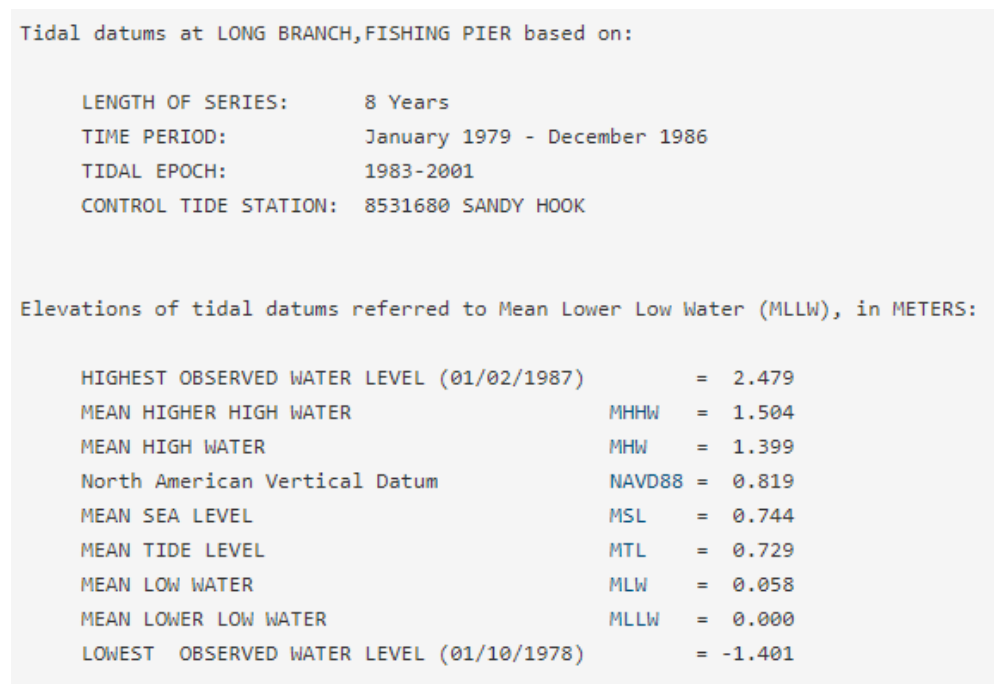
```
Tidal datums at LONG BRANCH,FISHING PIER based on:


    LENGTH OF SERIES:      8 Years
    TIME PERIOD:           January 1979 - December 1986
    TIDAL EPOCH:           1983-2001
    CONTROL TIDE STATION:  8531680 SANDY HOOK



Elevations of tidal datums referred to Mean Lower Low Water (MLLW), in METERS:


    HIGHEST OBSERVED WATER LEVEL (01/02/1987)        =  2.479
    MEAN HIGHER HIGH WATER                    MHHW   =  1.504
    MEAN HIGH WATER                           MHW    =  1.399
    North American Vertical Datum             NAVD88 =  0.819
    MEAN SEA LEVEL                            MSL     =  0.744
    MEAN TIDE LEVEL                           MTL     =  0.729
    MEAN LOW WATER                            MLW     =  0.058
    MEAN LOWER LOW WATER                      MLLW    =  0.000
    LOWEST  OBSERVED WATER LEVEL (01/10/1978)        = -1.401
```

Figure 9. NOAA Benchmark sheet for Long Branch Fishing Pier, NJ

Additionally, there may be additional benchmark information from where the survey was obtained that gives relationships for datums in the area. It is sometimes good to draw the relationships of the datums on a graph. One such diagram is shown in Figure 10.

Using these datasets with CMS, all datasets must have both units and datums converted. Optimally, MSL is closest to the ambient mean water level along a coastline. Initialization of a new hydrodynamic simulation may require near-MSL water levels for stability. MSL in meters is the preferred datum for bathymetry and forcing files in CMS. The following process is used to switch from one datum (and unit) to another.
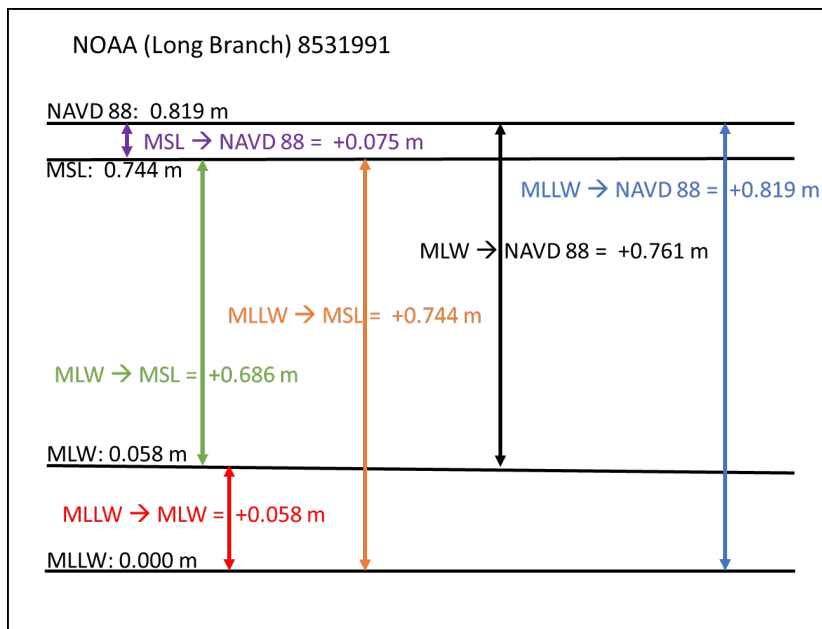
NOAA (Long Branch) 8531991

NAVD 88: 0.819 m

MSL → NAVD 88 = +0.075 m

MSL: 0.744 m

MLLW → NAVD 88 = +0.819 m

MLW → NAVD 88 = +0.761 m

MLLW → MSL = +0.744 m

MLW → MSL = +0.686 m

MLW: 0.058 m

MLLW → MLW = +0.058 m

MLLW: 0.000 m

Figure 10. Graphical representation of datum relationships from NOAA

1.3.2.1. Datum conversion

Obtain necessary information about the data.

- Known projection information has been gathered and Table 2 has been created to assist in converting datums. The datum for this file is MLW in feet.

- From Figure 10, the information can be derived to get the conversion from MLW to MSL.
    - From the NOAA Benchmarks (in green), the distance from MLW to MSL is 2.25 ft (0.686 m).
    - Two columns in Table 2 have been updated to reflect the conversion values to MSL for each survey.

- Make sure you get the conversion value for the appropriate units (feet or meters) to change the datum reference. The next section covers changing the units from feet to meters, where necessary.

Table 2. Survey list with Horizontal Projection and Vertical Datum information.

Dataset name	Horizontal Projection	Horizontal Units	Vertical Datum	Vertical Units	Convert to MSL (ft)	Convert to MSL (m)	Depth or Elevation
0.75m_Contour.xyz	SP NJ	m	MSL	m	--	--	Elevation
3364_0409_ft_MLW.xyz	SP NJ	ft	MLW	ft	2.25	0.686	Elevation
Channel_Survey_NJ-DEP_0609_ft_MLW.xyz	SP NJ	ft	MLW	ft	2.25	0.686	Elevation
Coastal_Relief_Model_ll_m_msl.pts	Geographic	deg.	MSL	m	--	--	Elevation
Field_Team_Measurements_0809_m_NAVD.xyz	SP NJ	m	NAVD88	m	-0.246	-0.075	Elevation
LIDAR_ft_NAVD.xyz	SP NJ	ft	NAVD88	ft	-0.246	-0.075	Elevation

Working with datums can be confusing. Moving from a lower to higher datum (MLW to MSL), means you need to end up with a larger value at the end. Moving from a higher to lower datum (NAVD88 to MSL), means you need to end up with a smaller value at the end. The expression you use will entirely depend on whether you are dealing with Depths (positive down) or Elevations (negative down). If you need to draw a diagram to help figure it out. See

an example of this in Figure 11. Make sure the expression used to obtain the final values is correct ahead of time.
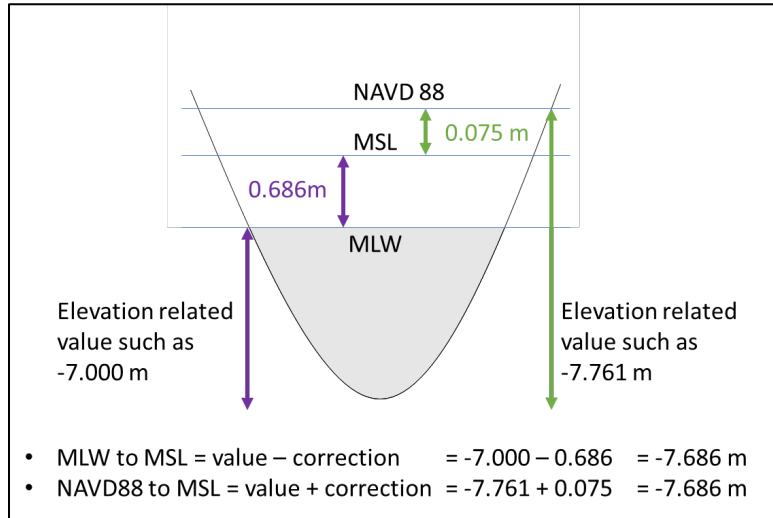

Figure 11. Diagram of datum changes.

- Select the "Channel_Survey…" dataset from the data tree.
- Choose *Data | Dataset Toolbox* from the SMS pull-down menu, shown in Figure 12.
- Select "Data Calculator" and note the item assignment for the Z dataset. It may be different on your computer than in this figure. In the figure, the item is assigned "d1". Select the Z dataset and choose "Add to expression".

Remember we are using Elevations (negative down).

- For the expression in the "Calculator" blank, add the conversion information so that the expression reads "<u>d1 - 2.25</u>".
- Give a new dataset name (bottom of middle pane) such as "MSL, ft" and click the "Compute" button. Do not hit Enter because we want to stay in this dialog for the next step.
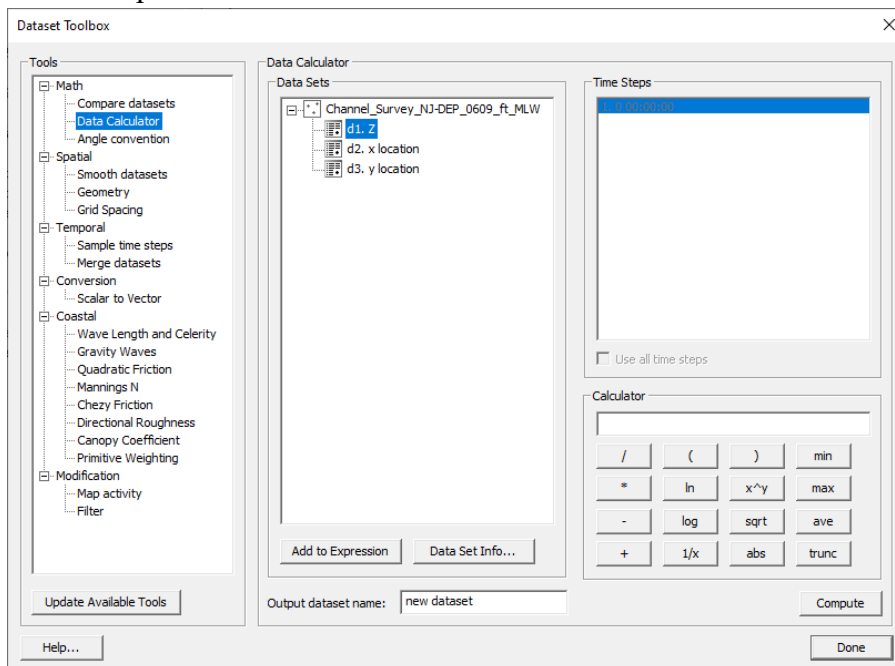

Figure 12. Dataset Toolbox Dialog

1.3.2.2. Unit Conversion

- From the dataset toolbox, you now see that there is a new entry listed and its assigned number is "d4". Now we want to convert this new dataset from feet to meters.
- Select the new dataset and then hit "Add to Expression".
- Enter the conversion from feet to meters in the calculator expression blank, "<u>d4 * 0.3048</u>".
- Enter a new name for the converted units, such as "MSL, m" and hit "Compute".

1.3.2.3. Sign Change

If any of the survey datasets we are working with were using a positive value as they go deeper, then we would need to change the sign. This is a simple calculation to perform with the data calculator. The user would just need to:

- Select the last created dataset value from the data calculator (most likely MSL, m) and multiply that by -1 or even easier, place a minus sign in front of the dataset designator (i.e., d5.), give it a new name, and hit Calculate.
- Note: we do not need to do this for any of the surveys as they are already Elevation related datasets.

Repeat sections 1.3.2.1 through 1.3.2.3 where appropriate for the remaining datasets loaded into SMS. The datasets "0.75m Contour" and "Coastal_Relief_Model_ll_m_msl" need no datum or unit conversion, since those datasets are already in MSL, m.

SAVE your progress before continuing.

1.3.3. Merging Data from Surveys

When generating a CMS-Flow grid, one bathymetry set is needed to provide depth values for each cell. So far in this tutorial, we have shown how to bring in several surveys, set object projections and perform datum corrections on them. The next step is to merge all surveys together into one full dataset.

There are two options for merging scattersets, a) merge ALL points from all selected scattersets and b) merge points from each selected scatterset based on its assigned priority. When merging all points, special care must be taken to ensure correct results because some scattersets may overlap others. Overlapping areas of scattersets should either be deleted or use the second method of merging by prioritization covered in section 1.3.3.2.

1.3.3.1. Merge All Scatter Points

The first option will integrate all points for the selected scattersets. Figure 13 shows the SMS dialog for merging scattersets. Because the Coastal Relief Model does not have accurate bathymetric data in the near shore, we will merge that one dataset later with priority.

- From the pull-down menu, select *Scatter | Merge Sets*.
- Select all datasets except the "Coastal_Relief_Model…" by clicking the Merge check box next to each dataset, or by choosing the "Select All" button and then deselecting the

one we do not want to merge all points.

- For each dataset, select the appropriate dataset value to use for the merge (MSL, m).
- Choose a name for the merged scatter set. The default is "Merged".
- Choose "Merge all scatter points" and click OK.

Once the merge has been completed and you are satisfied with the results, you can delete the old datasets from the SMS data tree since they are no longer needed. Removing from the data tree will not erase the actual file saved in the folder; it is only deleted from local memory in SMS. When the next Save of the project is made, these datasets will no longer be included in the project file structure. Go ahead and SAVE your project now.
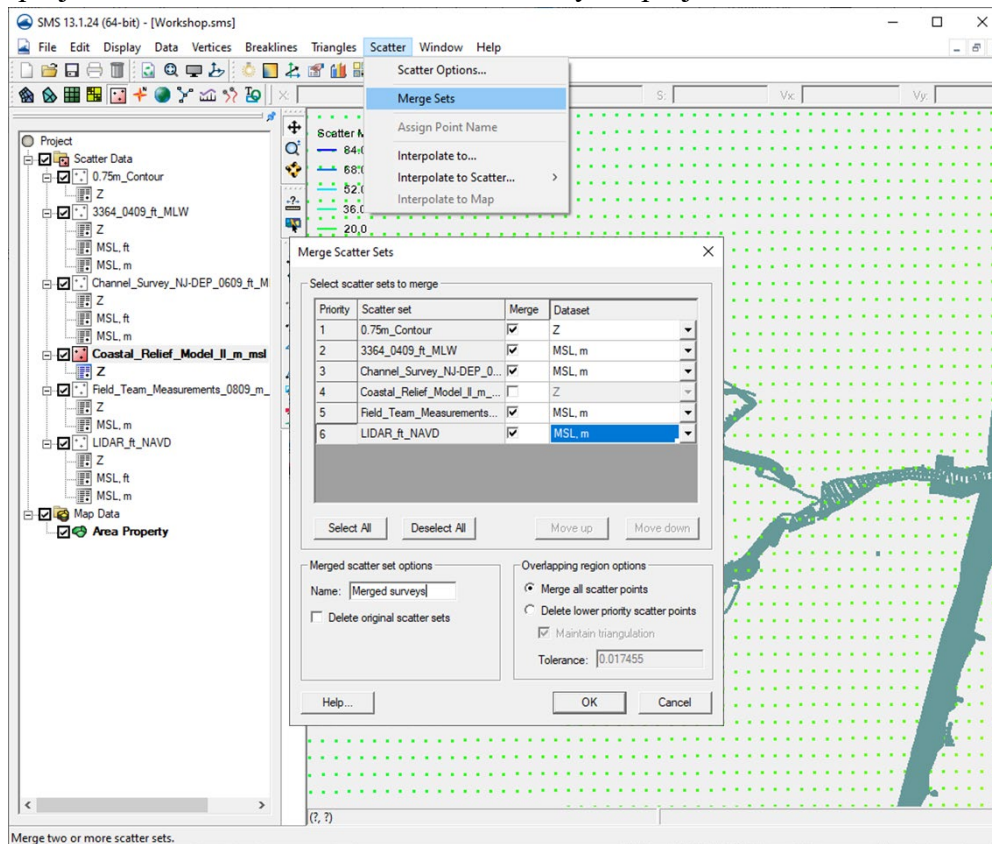

Figure 13. Merge scatter points dialog

Now we have one scatterset that contains all surveys except the data from the Coastal Relief Model. We will use a different method to combine these two datasets so that points from the Coastal Relief Model, which are very coarse with poor nearshore elevation accuracy, are only used in areas where we do not have better data.

This option uses the triangulated area of the scattersets to decide where to keep given points from a higher priority dataset. In Figure 14 we see the loaded scattersets with triangles on (Display Options | Triangles [checked]), and we can see the total triangulated area. If this scatterset is used as a higher priority than another, no points from a lower priority dataset will be kept in the merged set of points where any of the triangles exist. The user may use or remove triangles as needed for prioritizing merged datasets as is discussed in the next section.
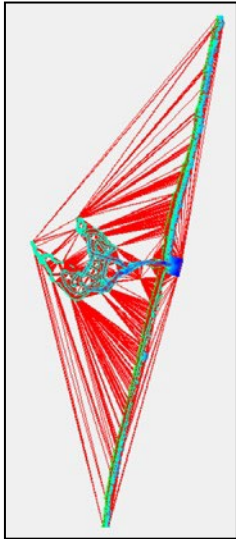
Figure 14. Triangulated elements for merged scatterset

1.3.3.2. Removing Triangulated Elements

Due to the nature of triangulation, there can be large areas where no points exist that lie inside of a triangulated area. If needed, there is a tool in the SMS that can assist in finding these empty areas.

- To set a threshold of the maximum edge length of a triangle, click *Scatter | Scatter Options*, then set a value. Note: the units of the value are determined by the horizontal projection units (degrees, feet, meters, etc).
- Enter a value of 500. This will allow SMS to select triangles that have edges 500 m or longer.
- Click the box to *Select long triangles*. This will allow the user to see what will be deleted first.
- To select the affected triangles, click *Triangles | Select Long Triangles*. All triangles that exceed the given threshold will be selected and can be deleted, if desired.

Another way to remove triangles, is to manually select them with the mouse.

- Click the *Select triangle* tool, .
- Click and hold down the "Ctrl" key, then use the mouse to left-click and drag a line.
  - o An arrow will appear as the user drags the mouse.
  - o Any triangle that is touching the arrow when the user lifts from a left-click will be selected.
  - o If multiple selections are desired, add the "Shift" after the "Ctrl" is depressed and each new clicked triangle will be added to the previous selected triangles.
- Once a set of cells are selected, the "Delete" key can be used to delete the cells.
- Repeat as needed to remove triangular elements.

1.3.3.3. Merging scattersets with priority

- In the merged scatterset dialog, change the selection in the "Overlapping region options"

from *Merge all scatter points* to *Delete lower priority scatter points*.

- o This will enable the list of scattersets to be reordered using the "Move up" and "Move down" buttons.
- Select and reorder the scattersets that are to be merged together.
    - o In our case this is the "Merged" and "Coastal_Relief_Model…" scattersets.
    - o Make sure that the "Merged" scatterset is a higher priority than the other.
    - o One resulting list of scattersets is shown in Figure 15.
- Make sure the dataset values to be merged are the one containing the desired datum and units, i.e., "m MSL".
- Provide a new name for the resulting dataset, such as "Merged_all".
- Click OK.
- SAVE project.

When the resulting scatterset is viewed with points and contours visible, the "Merged_all" scatterset should look like Figure 16. In the image for Figure 16, I zoomed nearer the inlet and changed a few things in the Display Options:

- Main scatter tab

    - o Scatterpoint point size – 2

    - o Contours – checked

- Contours tab

    - o Contour method – Color Fill

    - o Specify a range – Min: -20, Max 5

    - o Specify precision – 2

    - o Color Ramp – Reverse colors (bluer is deeper or more negative)

In the next section, we will be loading a different set of files where all the conversions and merging has already been completed.
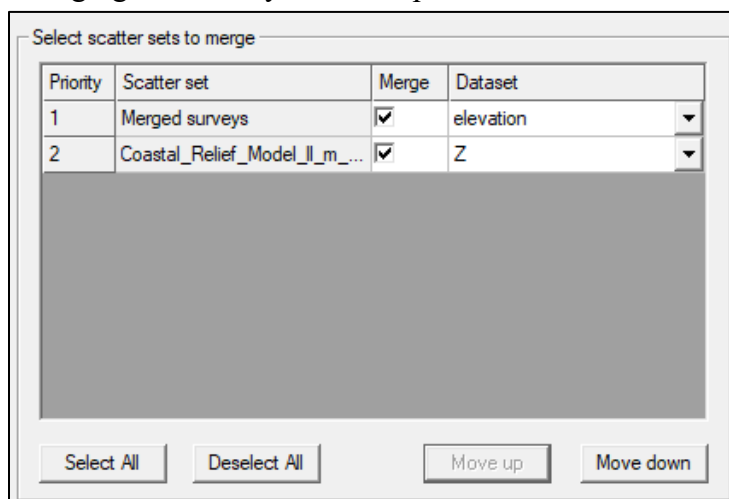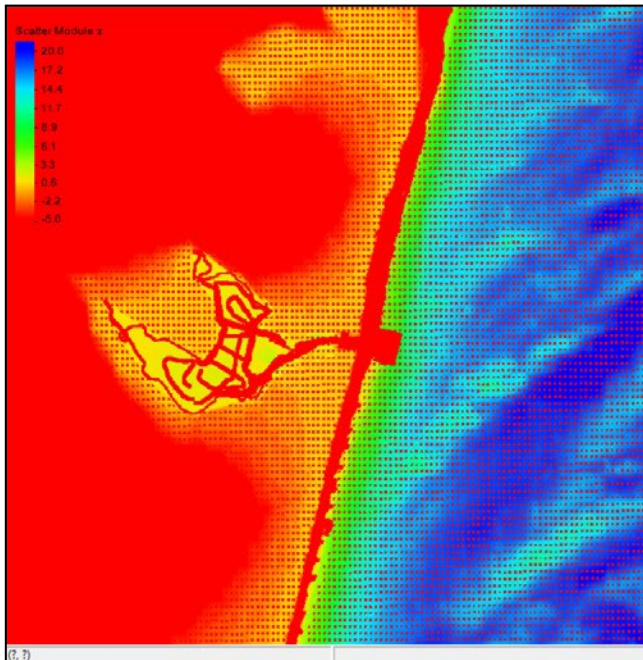

Figure 15. Reordered list of scattersets to be merged

Figure 16. Scatter points and contours for the final Merged scatterset