APPENDIX E: HOW HABITAT AND SEDIMENT INJURY INFORMATION IS MAPPED VIA A GEOGRAPHIC INFORMATION SYSTEM (SPATIAL ANALYSIS OF SEDIMENT CHEMISTRY DATA)

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Prepared for:

The Commencement Bay Natural Resource Co-Trustees

By

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Purpose and Overview

The Hylebos Habitat Equivalency Analysis (HEA) evaluates and quantifies natural resource injuries in areas of contaminated sediment and expresses those injuries with a standard metric across a variety of habitats over time for all resources. "Injured" habitat (sediment) is defined as areas containing concentrations of a substance of concern (SOCs) at amounts higher than that indicated in scientific studies as causing the onset of an adverse effect to any invertebrate, fish, or bird. (Development of injury thresholds is discussed in Appendix B).

A Geographic Information System (GIS) was used to develop a picture that combines the injury footprints for all SOCs with data layers that define all habitats in Hylebos Waterway. The functional value of each habitat is based on its relational value to a standard, and that value is adjusted if a habitat has been physically altered (see Nick Iadanza's habitat appendix for examples). Total injury is determined by incorporating time that the habitat is contaminated, including the period into the future until the contamination level is remediated or naturally attenuated (see HEA Appendix).

Names for all data layers are listed in Table 1, along with a description of each layer.

Data and Software Used in Our Spatial Analysis

In this section we describe the data layers, files, and GIS software used in our spatial analysis. Layers and files are presented in the procedural sequence of the spatial analysis. We define "layers" as GIS maps or covers created and used by GIS software. In this GIS analysis, we use vector data as much as possible because of software limitations using raster (gridded) data. Most layers are polygon files, including those used in the overlay procedure. The interpolation procedure produces grid files, which are immediately reclassified and converted to non-generalized polygons, i.e., taking all identical-value, adjacent grid cells and combining them into a polygon whose perimeter is comprised of the outer cell edges rounded into a continuous line.

All layers are identified as original, intermediate, or final, and are described as follows:

- Original layers are unmodified versions of data needed for the spatial analysis. Original layers come from a variety of sources, including some that are developed with our digitizing board. In all cases, original layers needed to be modified. Modifications usually involved adjustments to match outlines, or preparation for the interpolation procedure.
- Intermediate layers are all layers we created in the spatial analysis but did not use in the intersection procedure. Most of the intermediate layers are created as part of the interpolation procedure, to automate tasks, and to verify input parameters
- Final layers are those layers or themes that are used in the intersection procedure to create the final overlay dataset.

This section also describes files that are not layers. These files include data (both .dbf and .xls files) used to create or modify layers, Avenue script files for ArcView™ functions not available in the default Graphics User Interface, and other ArcView™ features that define parameters for specific operations. Data files are also typed as original or intermediate.

All GIS work was accomplished using ArcView™ 3.2, Spatial Analyst 1.1, and the freeware extension Xtools from the Oregon State Department of Forestry. All data layers were projected to *Washington State Plane South 1983 Coordinate System*, *NAD 1983*. Prior to analysis, some layers were converted from other projections using PC Arc/Info™ 3.5.2 or the extension Washington State Projection utility [1]for ArcView™. Certain analyses, such as converting a gridded layer into a non-generalized polygonal layer, are not features within the default Graphics

[1] Developed by Eugene Martin and is used with permission of .CommEn Space (The Community and Environment Spatial Center, *www.commenspace.org*.)

User Interface. For these type analyses, ArcView™ Avenue scripts (or macros) are used. Map and distance units for all layers are in feet.

Other Details About Our Spatial Analysis

There are several terms used in this document that should be defined.

Projects, Views and Themes—Use of a Geographic Information System requires the manipulation of different forms of spatial data files and groups of files.

A **Project** is a file in which work performed in ArcView™ is stored. It contains all the views, tables, charts, layouts, and scripts used for a particular Arcview™ application or set of related applications. Project file names have an ".apr" extension. The project window is used to initiate new views, tables, etc. or to move between or open existing files.

A **view** is a screen that serves as an interactive map that lets you display, explore, query, and/or analyze geographic data. Multiple data layers may be displayed or overlapped at one time. The view displays these layers in the geographic coordinates systems in which they were created.

These layers are called **themes.** They can be polygons, lines, or points such as remedial areas, transects, or sample points, respectively. All themes in a view are listed to the left of the map in the view's Table of Contents. This table (legend) also shows the symbols (and colors) used to draw the features in each theme. The checkbox next to each theme indicates which theme is turned on or off in the map, i.e, whether it is current drawn on the map or not. Analyses, manipulations, and other applications may be applied to a theme when they are selected. A theme is selected when its position in the Table of Contents has been "activated" (curser is placed over theme and left mouse button is pushed.) When selected, a theme appears as a raised object.

Why IDW (Inverse Distance Weighting) is used for mapping injury footprints—Mapping injury footprints for each SOC (Substance of Concern) requires the interpolation of SOC concentration isopleths (contours) throughout Hylebos Waterway. This is accomplished through establishing known values (reported SOC concentrations at each sediment sampling station) at precise coordinates, and then determining an interpolated concentration value for each pixel within the analytical area, based on relationships between adjacent or nearby sampling station data. The interpolated values are obtained through the simplest interpolation method: inverse distance weighting.

IDW or inverse distance weighting is a technique in which interpolated estimates are based on values of nearby known values that are weighted by their distance from the interpolation location. This technique makes a basic assumption that nearby points ought to be more closely related than distant points to the value at the interpolation location. The neighborhood around the interpolated point is identified and a weighted average is taken of the observation values within this neighborhood. The weighting function used is inverse power.

$$W(d) = 1/d^p$$

Where: W = the weight of a nearest neighbor

d = distance of nearest neighbor from point of interest; and

p = the power (p>0, and < ∞ in ArcView Spatial Analyst; however, values 8 or less are recommended.)

We chose a power of 6, and 8 nearest neighbors to perform the interpolation. This combination assures that all nearest neighbors are within about 1000 ft of each interpolated point and the power function is the least value that eliminates splinter contours when wide ranging concentrations are present in an SOC's data base. This last point was determined through test evaluations with the SOC, DDT.

This information is based on direction within ArcView™ Spatial Analyst and from the National Center for Geographic Information and Analysis at their UCSB web site (www.ncgic.pubs/spherekit/inverse.html).

Data Transformation—To further aid in eliminating splinter contours and aberrant spikes resulting from extreme differences in reported concentrations at neighboring sediment sampling stations, all reported values have undergone a log normal transformation. This is a standard statistical technique for reducing variability within a data set, without biasing the relationships between individual values in that set.

Step 1—Creating the Initial Analysis Universe.

In this step, an initial outline of the analytical area is combined with two additional data layers to establish the initial baseline perimeter of the analytical area.

The initial outline of the analytical area, **MHHWout**, is defined by the mean higher high-water shoreline of Hylebos Waterway and an artificial seaward boundary established bayward of the outermost sediment sampling stations used in the analysis. **MHHWout** is derived from U.S. Army Corps of Engineers CAD-file bathymetry data for Commencement Bay and shoreline information from digitized shoreline data of the *NOAA Coast and Geodetic Survey Nautical Chart No. 18453*. **MHHWout** is the base outline of the Hylebos Waterway from which all other shoreline outlines are created, and is used to create the intermediate layer, **ExpMHHWout** (i.e., expanded mean higher high water outline).

To create **ExpMHHWout**, two data layers are used to modify the initial layer, **MHHWout.** These are:

1) a layer that identifies areas where physical structures (e.g., log rafts, certain docks, etc.) occur both within the waterway and overlap the shoreline (**DimHabOver**), and
2) a layer that contains all areas of the waterway that are proposed for remediation (**RemedAreas**), including some high-intertidal locations that extend outside (above) the mean higher high-water shoreline.

The combination of these three initial data layers is performed by the Arc Tools command, "UNION". This creates the intermediate output data layer (**ExpMHHWout**) that incorporates the two modifying layers or themes, expanding the analytical area perimeter to include areas under docks and high intertidal areas that are incorporated into the waterway's proposed marine sediment remediation. This initial activity is displayed in Figure 1-1.

Following the unioning of the three data layers, the output file **ExpMHHWout** is cleaned (i.e., all internal polygon lines are removed) via the edit mode within ArcView™. All interior polygons are selected, and the "union features" command in the drop-down menu is applied. This command breaks down the boundaries between adjacent polygons and creates a new intermediate layer, **HEAout 1** (Habitat Equivalency Area outline No. 1), that represents an outline of the expanded analytical area (Figure 1-2).

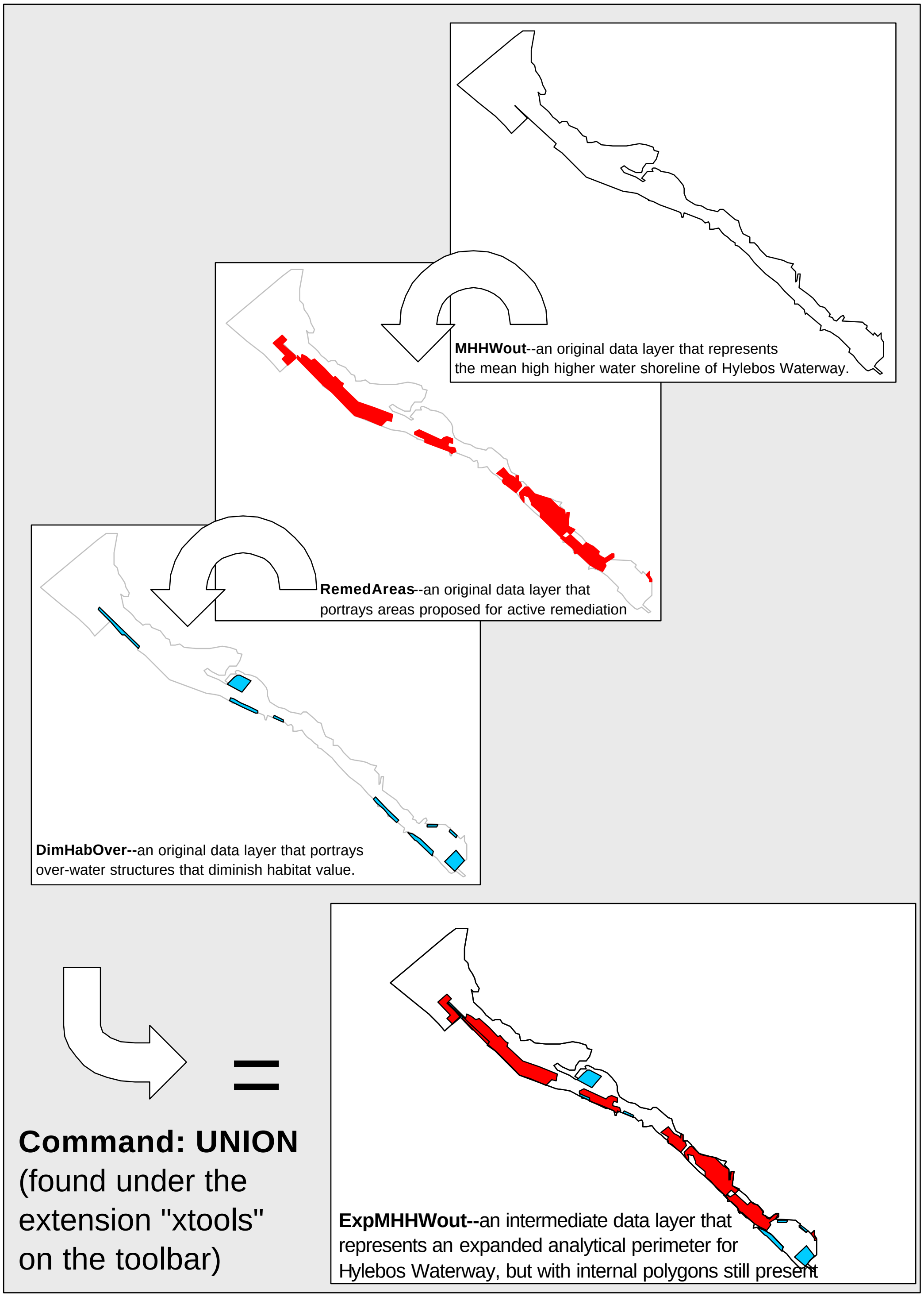


Figure 1-1. Establishing the initial outline or perimeter for the Hylebos Waterway analytical area. This initial step is accomplished via the “UNION” command.

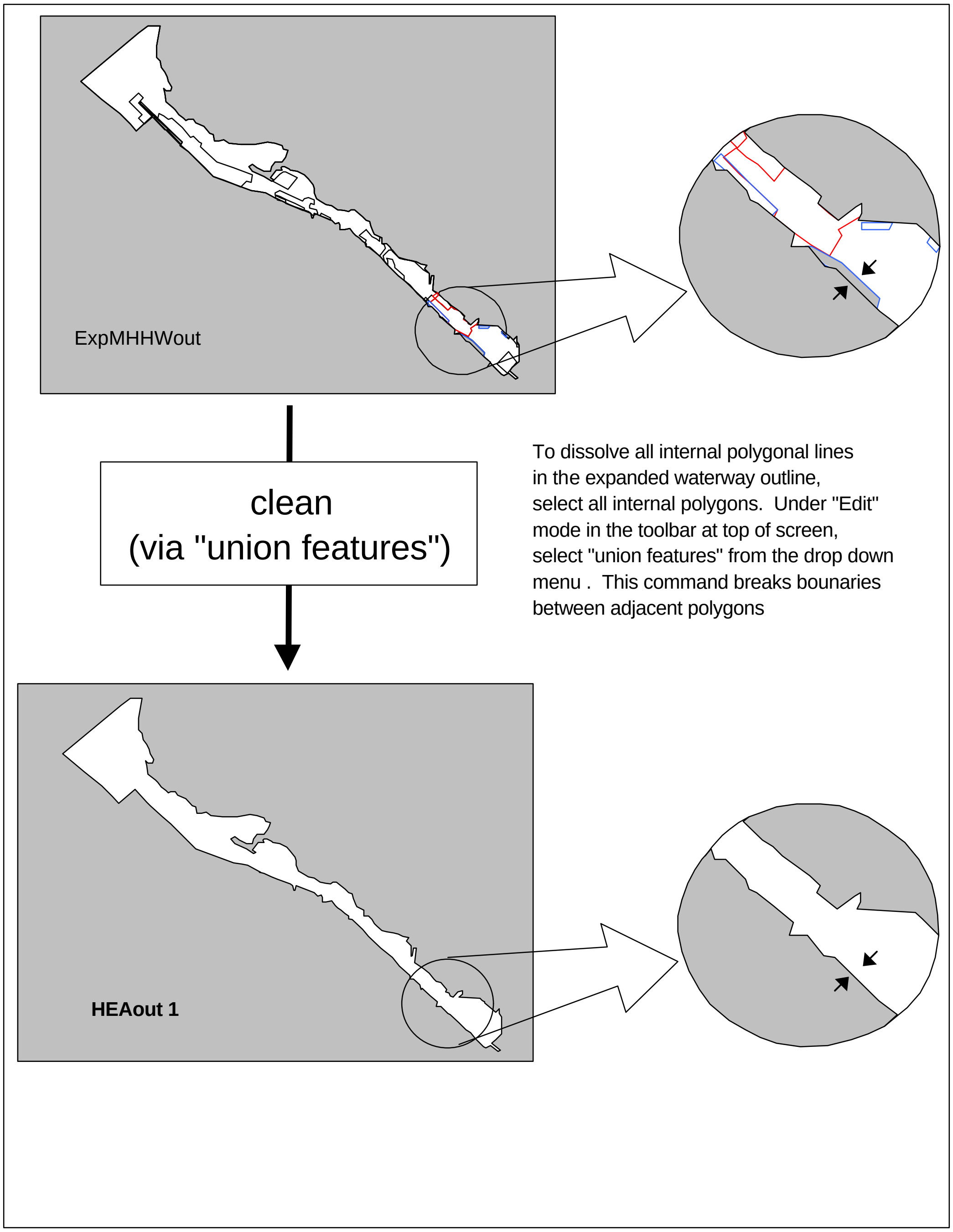


Figure 1-2. The intermediate layer, **HEAout 1**, is created by removing internal polygon lines and establishing a revised analytical perimeter that is somewhat expanded over the previous analytical perimeter layer, **ExpMHHWout.**

Step 2—Further Preparation of the Analysis Universe—Reducing the Analytical Area.

The intermediate layer, **HEAout 1**, is modified to eliminate waterway areas deemed inappropriate for interpolating chemical footprints. These inappropriate areas are either beyond 1000 ft of a sampling station or are locations known to be free of chemical contamination. The distance of 1000 ft was determined the maximum distance to extrapolate SOC contours using "nearest neighbors" and inverse distance weighting (IDW) features of ArcView™ spatial analysis.

Sediment sampling stations are attached to the waterway outline **HEAout 1** by adding information from a "dbf" file to the project. A previously created database of georeferenced sampling stations, **StnData.dbf**, is added as a table via the "Add Event Table" feature. To do this, highlight the "tables" icon on the vertical menu, select "project/add table" from the drop-down menu, navigate to **StnData.dbf** and select. This puts the dbf into the project. Return to the view, go to "Add Event Table", choose **StnData.dbf**, and assign X and Y coordinates. This turns the dbf coordinate data into georeferenced spatial points (Figure 2-1.)

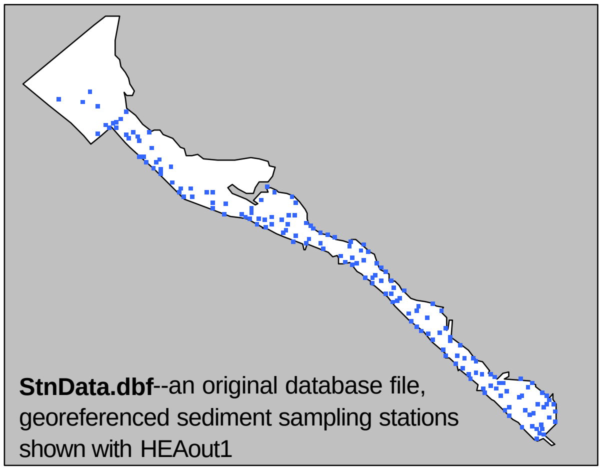


Figure 2-1. Station sampling stations included in the databases used to develop spatial analyses.

Next, highlight the new points/ coordinates theme. Select all station points, and buffer them to 1000 ft (select contiguous). This generates a 1000 ft buffer (Figure 2-2) around each sampling station (important later when various spatial analysis features are selected to perform contaminant foot-print contouring.) This intermediate file is named **Stn_Influence**, and incorporates the command BUFFER to create the areas of influence for each station. To do this, in "xtools" select:
<u>Map units</u> = feet
<u>In theme</u> = Station points (StnData.dbf)
Assign name and location of new file
<u>Buffer Input</u> = Buffer Distance
<u>Buffer Distance</u> = 1000
<u>Output Structure</u> = contiguous
<u>Intersect</u> = buffer with outline

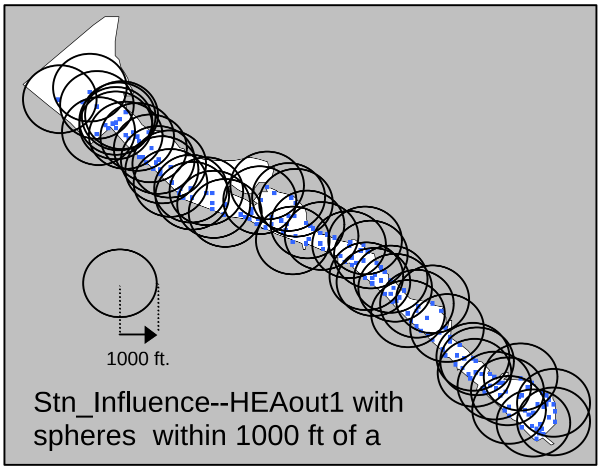


Figure 2-2. The intermediate data theme, **Stn_Influence** is shown with spheres representing 1,000 ft radii of influence from every sampling station.

HEAout 1 and the buffer file **Stn_influence** are intersected. All portions of the waterway within 1000 ft of any sediment sampling station are maintained. Areas outside the waterway outline and/or beyond 1000 ft of any station are eliminated. The output file is **Stn_InfluenceCLIP** (Figure 2-3).

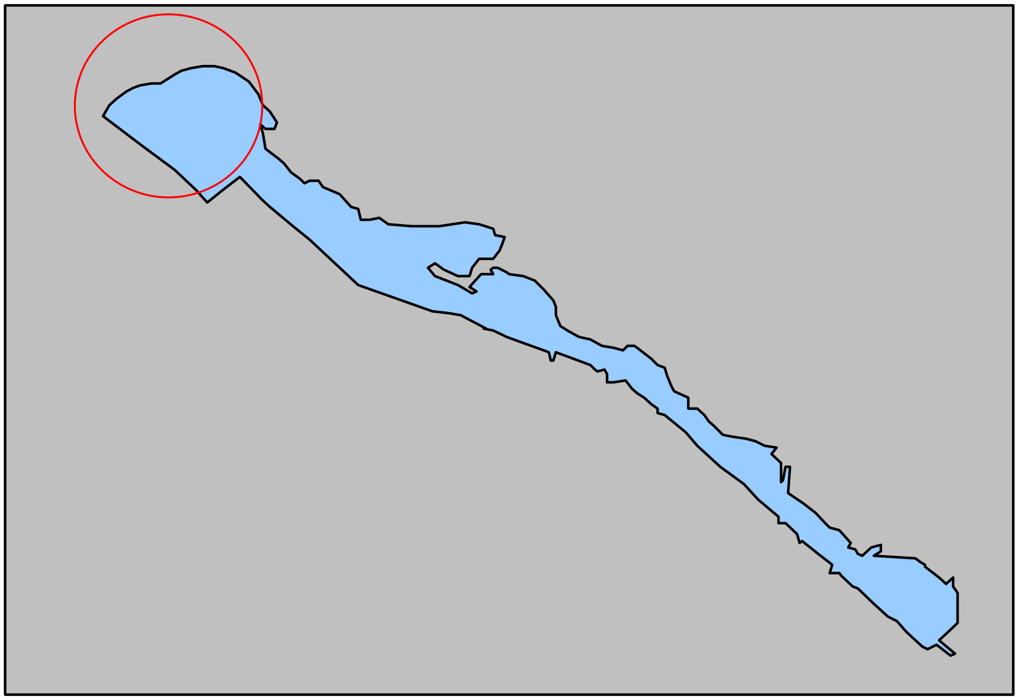


Figure 2-3. The intermediate layer **Stn_InfluenceCLIP,** represents all areas in Hylebos Waterway that are within 1000 ft of any sampling station. The only portion of **HEAout 1** that is not included in this layer is the area outside the mouth of the waterway (see red circle)

Another sequence is performed to create an intermediate clip layer that eliminates the Puyallup Tribe intertidal property from the analysis. This step was taken to assure that SOC injury footprints developed during this spatial analysis do not extend onto the tribal intertidal area. The tribal intertidal area was transferred by the Port of Tacoma pursuant to a land claims settlement agreement that contains terms addressing potential sediment contamination. Hence no sediment samples from this area are included in the database used for this analysis. To eliminate the tribal intertidal property from the analysis, a shapefile of 1983 pro-perty boundaries (**Prop83.shp)** is used to erase the tribal tidelands part of the waterway on the layer, **Stn_InfluenceCLIP** (Figure 2-4). The output file of this step is **HEAout 2** (Figure 2-5).

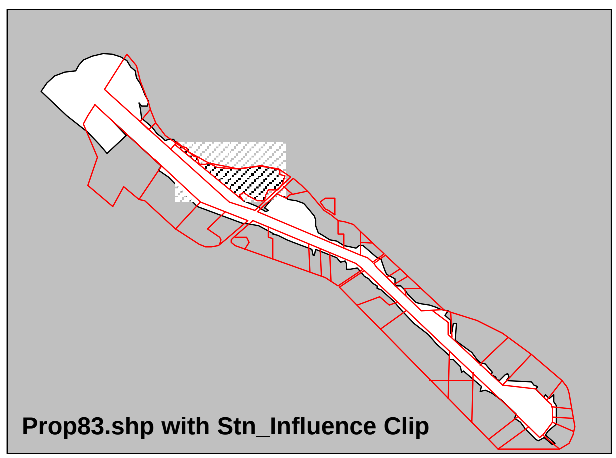


Figure 2-4. 1983 Pierce County property boundaries are overlaid on a map of Hylebos Wateway. The Puyallup tribal lands are shaded.

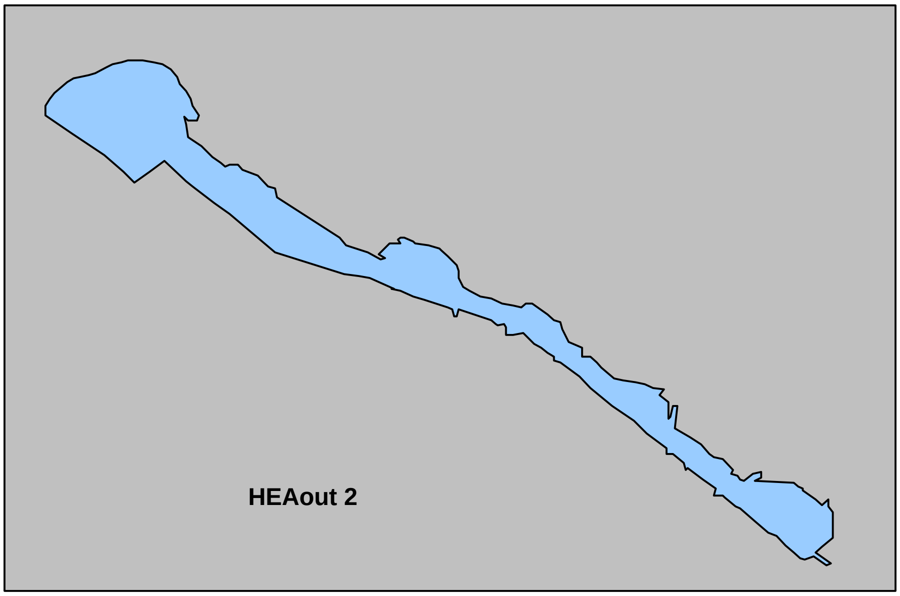


Figure 2-5. The intermediate file **HEAout 2** represents an intermediate step in developing boundaries for spatial analysis of Hylebos Waterway. It omits areas beyond 1000 ft of any sediment sampling location and a large intertidal area on the north shore of the waterway.

Step 3.—Assuring Appropriate Treatment of Intertidal Data During Interpolation of Injury Footprints.

Some sediment sampling stations lie in the upper intertidal zone. When using "Spatial Analyst", we want to be sure that all data points to be included in the analysis for SOC concentration contouring lie within the analytical area. Some intertidal stations may fall outside our defined boundary. To make sure all intertidal stations are included, a 100 ft. buffer is added to the perimeter of our analytical area, **HEAout 2** (Figure 3-1). This is accomplished using the BUFFER command in "xtools". We select "100 ft"--this provides an output with an area expanded on all sides by 100 ft. This is the final size of the analytical area we will use to map sediment chemistry data. This intermediate file is named, **IDWout** (Inverse Distance Weighting outline). Following the determination of contaminant footprints (contours), the buffered area will be removed.

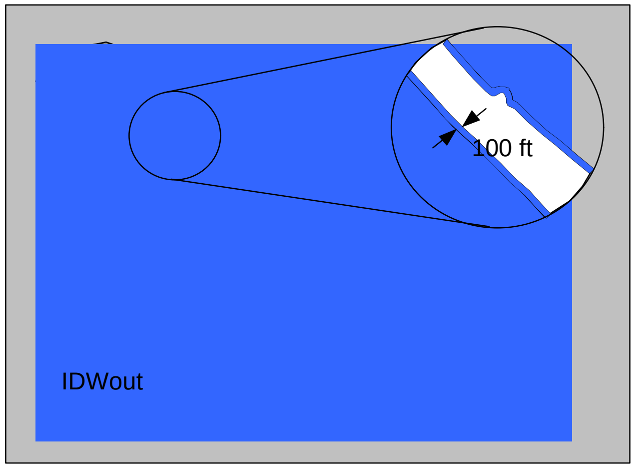


Figure 3-1. The intermediate layer, **IDWout**, is a combination of the waterway outline (**HEAout 2**) and a 100 ft border added shoreward of the outline. (Buffer is not to scale).

Step 4.—Transforming Polygonal Data to Grids.

The buffered outline is now transformed from a polygon into a grid layer. This step establishes a baseline grid layer from which all subsequent grids will maintain a common set of parameters: common extent, origin, and cell size. Use of the same grid extent and cell size is essential to assure that all subsequently created layers overlap each other precisely after the re-conversion from a grid format to a polygon format. To begin this step, set the initial display extent by highlighting the “IDW” theme and using the “Zoom to Active Theme” button (Figure 4-1). The command for this polygon transformation is “Convert to Grid”, found under the “Theme” drop-down menu. Inputs are as follows:

- *Name the grid version of the “IDWout”layer is **IDWmask;***
- *For “Output Grid Extent”, use “Same as Display” (or “Same as IDWout” if the display has not been set to the “IDWout” extent already);*
- *Set “Output Grid Cell Size” to 10 ft.*

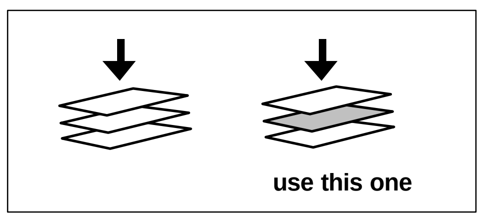


Figure 4-1. The “extent of themes” icon in the toolbar.

Again, the grid version of **IDWout** is named **IDWMask**. This is an intermediate analytical layer that defines the area within which any interpolation analysis will occur, not the whole extent of the theme (Figure 4-2).

All other grids used in our spatial analysis are created using the origin, extent, and cell size of **IDWMask** to ensure an exact match of cell corners during the intersection procedure. This will be used to create all SOC grid layers. This is the first time we will use “Theme Effect” as a way to establish the initial grid for the mask.

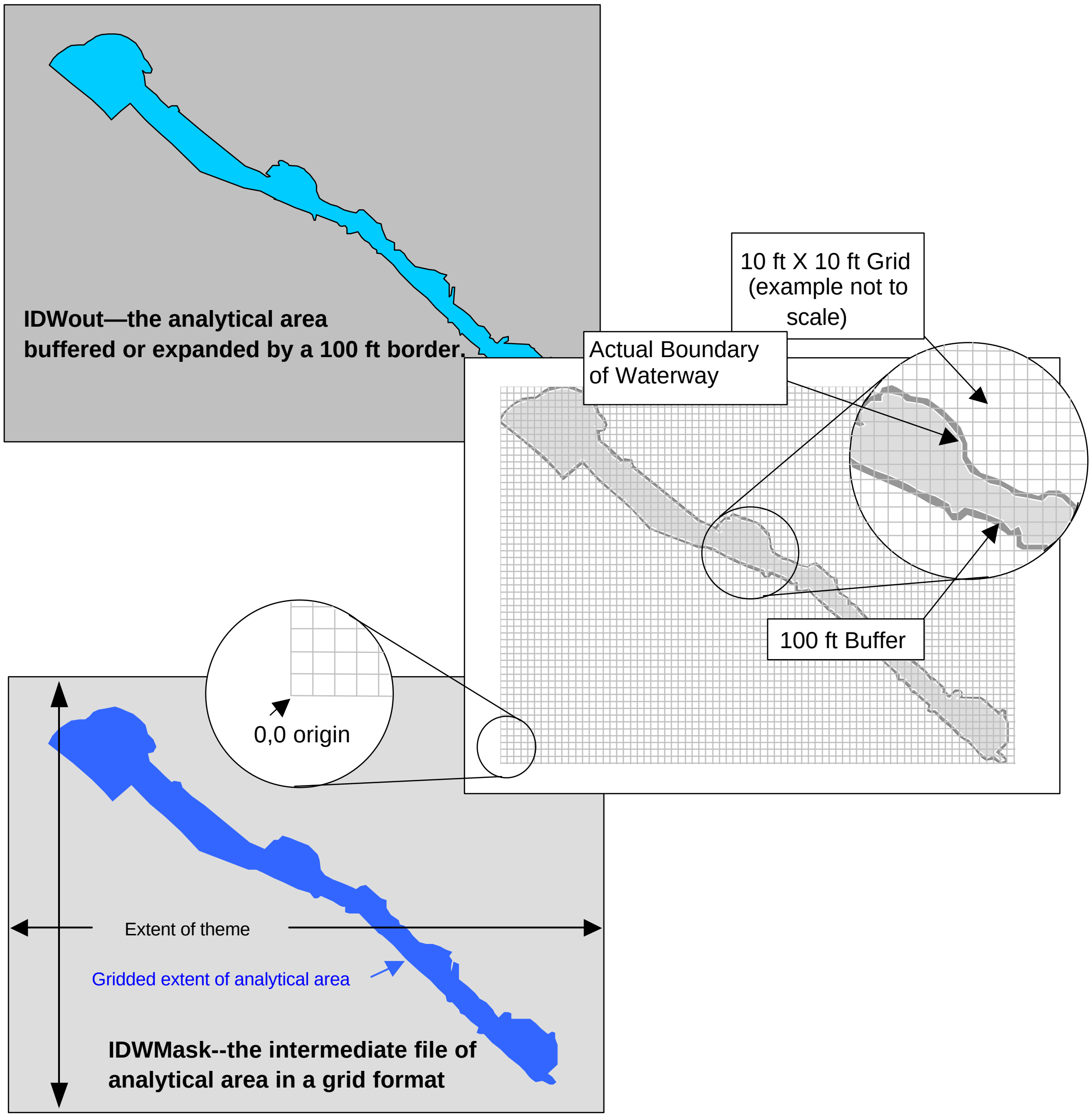


Figure 4-2. Transforming a polygon layer into a grid layer with defined coordinates for precise multiple theme overlapping or overlayering.

Step 5.—Creating a "cookie cutter" to Clip Off Areas Outside Analytical Boundaries.

All spatial analyses of the geographic extent of SOC injury footprints are performed in a raster or gridded environment. Following creation of the SOC footprints, the 100 ft buffers on these data layers must be clipped off so that the footprints extend only to the shoreline of the waterway (i.e., mean higher high water). This clipping exercise will occur after the SOC gridded layers have been converted into a non-generalized polygon form. However, to create the "cookie cutter" layer, **HEAout 2** is converted into a gridded layer similar to the way **IDWout** was. The baseline grid (**IDWMask**) must be in the view when this and all subsequent grids are produced because it must be referenced in their production. With these grid themes in the view, set "extent area" under "Analysis/Properties" as follows:

Analysis Extent = "Same as IDWMask";
Analysis Cell Size = Same as IDWMask";
Analysis Mask = "No Mask Set"

The analysis mask will always be set to "Same as IDWMask" when the SOC injury footprint layers are generated.

With the Analysis Extent set, convert **HEAout 2** into a grid layer called **ClipMask** (Figure 5-1). To clip polygons, **ClipMask** must be converted into a non-generalized polygon that will maintain the same grid cell size and orientation as polygons created later from the SOC injury footprints. To do this, open a script and add the ArcView™ Avenue Script "g2poly-no-gen.ave", compile it (checkmark), highlight **ClipMask** theme, run "g2poly-no-gen.ave" script, and name the new file,

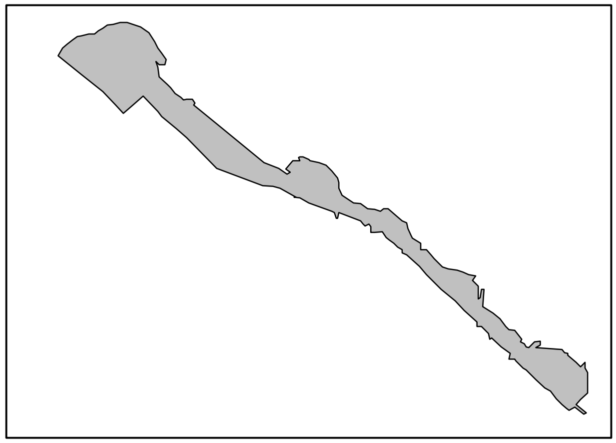


Figure 5-1. The intermediate layer or theme, **ClipMask,** is used to lay over all analytical grid layers and cut off (remove) all grid cells that are beyond our defined analytical boundary of the waterway. The analytical area is shadded.

Step 6.—Setting up Data For Spatial Analyses (in the analytical areas).

This step involves inputting data into the analytical area for spatial analyses. We will work with "dbf" files for this procedure. Go back to the initial screen of the "apr" (i.e., analytical project) and go to the "Tables" portion. Highlight "Tables". In the project drop-down menu select "Add Table". This will open a new window that lists all folders/files in the ArcView™ data section of the hard drive. Select a dbf and click "ok". An example is METSTNOO1--a file containing concentrations of metals at each sampling station with associated geographic coordinates (Table 2). Once selected, METSTNOO1 will open as a table in the project. Return to the initial screen of the "apr", select "VIEW" and open a new or listed view. Open the "View" and select "Add Event Theme". Now we have an "Add Event Theme" dialog box. If the coordinates in the "dbf" are named "x" and "y", or "Latitude" and "Longitude", they will be detected automatically. If not, navigate the "x field" and "y field" boxes to the appropriate x and y coordinates.

Table 2. A portion of METSNOO1, input file for metals concentrations and station coordinates.

ID	STA	SOURCE	SURVEY	PTS	ASMD	LN_ ASMD	CDBD	LN_ CDBD	…	ZNMD	LN_ ZNMD	X_COORD	Y_COORD
26	5209	HCC-1BI	HCC-1B	99	16.94	2.83	198.00	5.29	…	264.00	5.58	1168129.625	715417.250
219	1101	HCC-1AG	HCC-1A	1	41.39	3.72	1457.50	7.28	…	159.09	5.07	1176461.250	710173.000
232	1117	HCC-1C	HCC-1C	1	140.80	4.95	715.00	6.57	…	436.70	6.08	1176424.250	710141.000
331	28	DAC	Trustee	1	38.40	3.65	1500.00	7.31	…	263.00	5.57	1178348.250	708977.000

Step 7.—Special Cases: Adding Barriers to Assure Appropriate "Nearest Neighbors" Are Used for IDW Interpolation.

SOC injury footprints are determined by interpolating gradients of SOC chemical concentrations around a data point (sediment sampling station) by comparing the data point's reported concentration to amounts reported for nearby data points, or nearest neighbors. A mathematical formula is used to interpolate how concentrations are estimated between data points. The influence of an adjacent data point or nearest neighbor is inversely related to the distance it is from the map pixel being analyzed, i.e., greater the distance, lesser the influence: This is inverse distance weighting or IDW. The number of nearest neighbors used in our analyses is "8": the minimum amount found to eliminate splinter contours from spatial analyses of SOC data sets with wide ranging concentrations in our data base (see Introduction for further details).

In the interpolation of concentration isopleths with calculations between "nearest neighbor" data points, nearest neighbors are sometimes on opposite sides of natural and human geographic impediments (e.g., peninsulas and piers). A "spatial analysis barrier" is required to disassociate inappropriate nearby data points. Barriers are required for several contaminants' spatial analysis areas. Examples are provided for Arsenic (Figure 7-1) and PAHs (Figure 7-2).

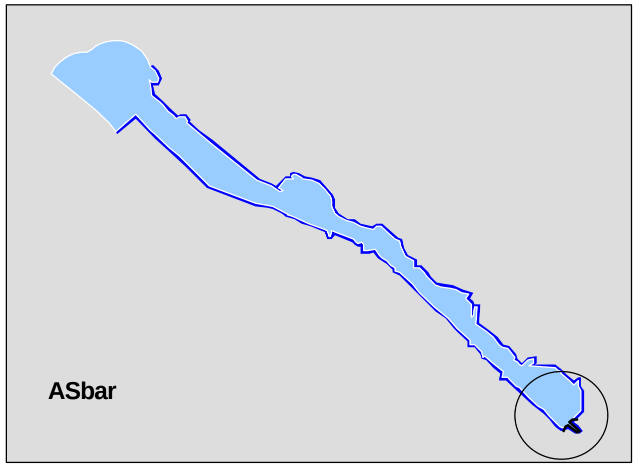


Figure 7-1. ASbar, the intermediate layer used as a spatial analysis barrier when interpolating concentration ispoleths for Arsenic. Shown in this figure are the analytical area (light blue, outlined in white), the 100 ft. buffer (dark blue) and the analytical barrier that extends across the buffer in the circled area.

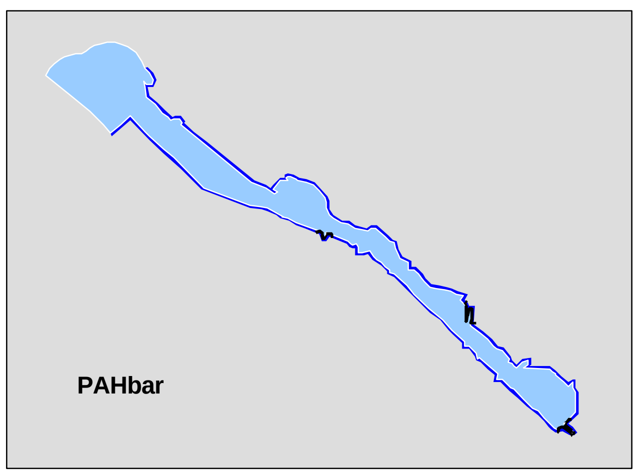


Figure 7-2. The intermediate layer **PAHbar**, the spatial analysis barrier for PAHs. Shown in this figure are the analytical area (light blue, outlined in white), the 100 ft. barrier (dark blue), and the analytical barriers the extend across the buffer at three locations in the waterway.

Step 8.--Establishing Data Points for Transect Data.

A complicating factor in developing maps of sediment chemistry contours is interpreting intertidal transect data and relating those data to the subtidal data points. Intertidal samples were obtained during the HCC sampling effort (See Appendix A). Each sample was a composite of several sub-samples acquired along a transect located at the outermost edge of upland properties on the waterway, or in high intertidal areas adjacent to the upland properties (Figure 8-1). Sediment chemistry was determined from a split of the homogenized composite; consequently, only one chemistry concentration per SOC was reported per transect by the analytical laboratory. As a result, transects represent two dimensions, whereas subtidal sediment sampling stations are only one dimensional.

The two-dimensional transect samples are converted to series of finite sampling points by the following method.

- First, the minimum distance is calculated between each of the subtidal samples (Figure 8-2), and a mean minimum distance determined--about 150 ft.;
- Second, the distance between the beginning and end of each transect was determined--initial transect data had x and y co-ordinates reported for the initial and end subsample for each transect; and
- Third, the length of each tran-sect was divided by 150, and the resulting quotient rounded down to a whole number. This is done so that the density of stations associated with the revised transect data is not greater than the subtidal station density. Nevertheless, minimum data points per transect is two.

On each transect, the number of data points resulting from our methodology are situated equidistant from each other. The result is a set of transect data similar to that presented in Figure 8-3.)

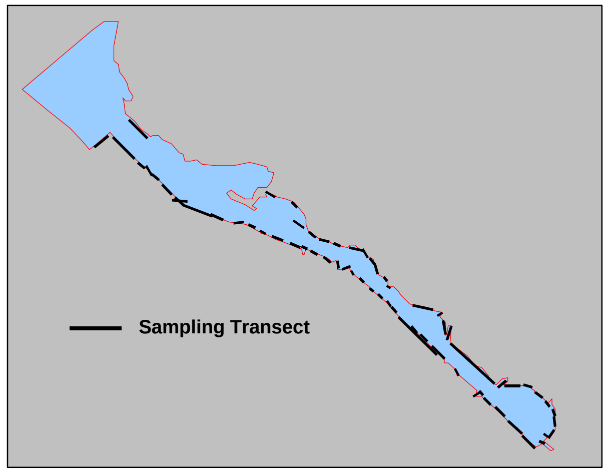


Figure 8-1. Sediment sampling transects in high intertidal areas of Hylebos Waterway (shown on the intermediate layer, **HEAout_1**).

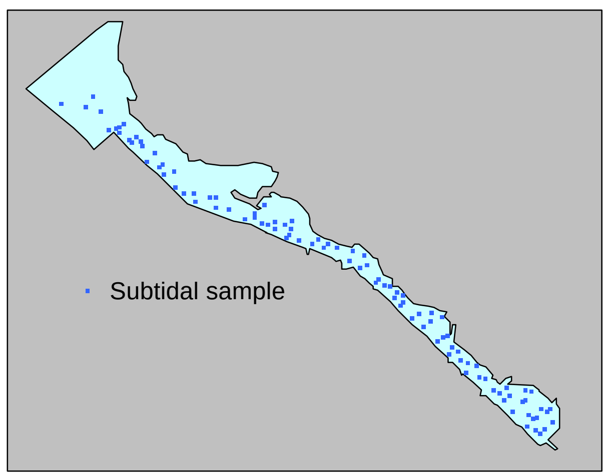


Figure 8-2. Subtidal sediment sampling stations (shown in the intermediate layer **HEAout_1**). Mean distance to nearest neighbor for all stations is about 150 ft.

There is more than one way to create the new intertidal data points along the transects and merging them with the existing subtidal data set. One way is to bring both intertidal and subtidal data sets into the project ("add table"), and then into the view ("add event theme"). Under "xtools", select "merge themes" and then select the two data sets—one for the "Input Theme" dialog box, and the other for the "Theme to Merge With" dialog box, and name the merge file. Another way to merge the intertidal and subtidal data sets would be to take the dbf files of each set, bring them into Excel™, and then add one set to the end of the other and bring them back into ArcView™. Whatever way used, the result is a combined data set that will be used to calculate the injury footprints of each SOC. A spatial representation of the combined sediment chemistry data points is shown in Figure 8-4

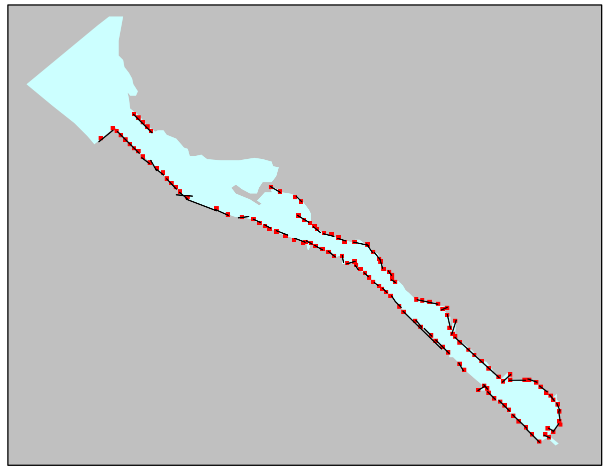


Figure 8-3. Intertidal sediment sampling transects with interpolated data points (shown on the intermediate layer **HEAout_1**)

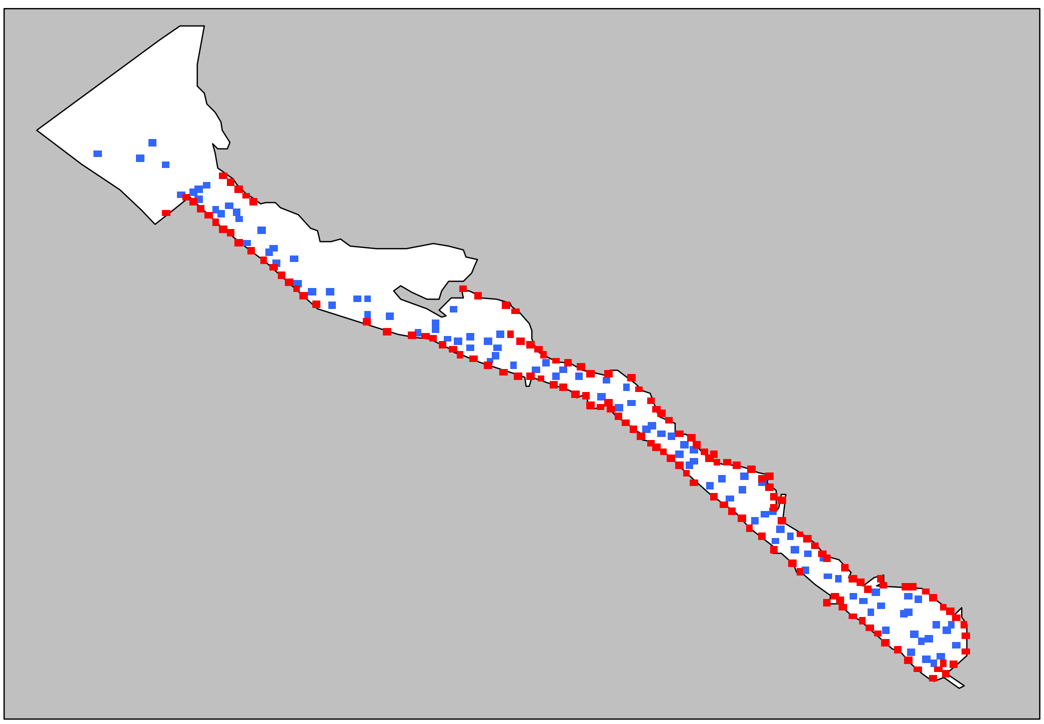
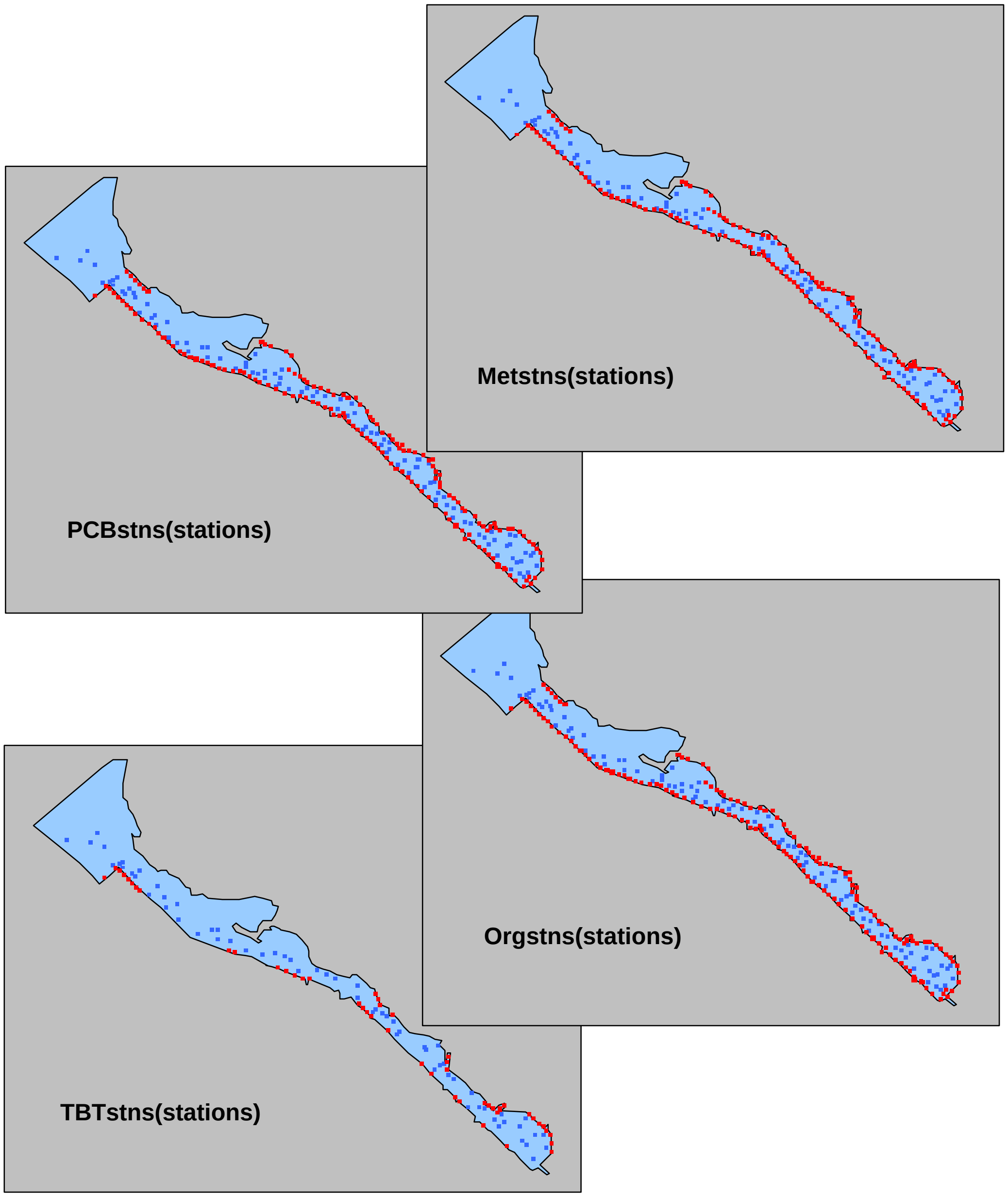


Figure 8-4. The data base **AllStns.dbf** displayed on the intermediate layer **HEAout 1**.

Step 9.--Creating a master list of spatial data points by contaminant group for spatial analyses

A separate set of sediment sampling stations is established for each of four major contaminant groups: PCBs, Organic compounds, metals, and Tributyl-tin. This is done because of the amount of time needed to create each injury footprint--streamline analyses for those substances that have many "no reported concentration" stations—i.e., eliminate those stations from the spatial analysis. An illustration of quantity and location of data points for each of the four major contaminant groups is shown below.



Step 10.-- Preparing Habitat Layers for Analysis.

Our Habitat Equivalency Analysis (HEA) evaluates injuries to sediment and identifies levels or amounts of restoration needed to compensate for the injuries. In addition to evaluating the effects of varying concentrations of SOCs, the quality or type of habitat associated with the injured sediment is equally important. Natural resource habitats in Hylebos Waterway are described in Appendix D. Water depth and substrate are the physical parameters used to help define habitat value. Also used to define habitat value are information on over-water structures and underwater alterations to the sediment that are separate from contamination from SOCs. Examples of the former are shore-fast docks and log rafts, and an example of the latter is high concentrations of wood waste. Further, information is needed on whether contaminated areas are proposed for remediation or are assumed to become naturally attenuated over time. All these "habitat evaluators" are included in our spatial analyses.

a. Depth--The original depth interval data from CAD files associated with proposed remediation options are converted into shape files along with digitized data from appropriate navigation charts. Five depth contours are assigned (Figure 10-1) based on habitat parameters defined in the appendix describing habitat valuation. An intermediate layer, **HEAdepth,** is formed by overlaying **HEAout 2**, the analytical area clip file, onto the original depth information, **HylDepth**. Using the INTERSECT command, the extent of the depth layer is limited to the analytical area (Figure 10-2) (IDWMask is not used since the 100 ft buffer is not required to establish the habitat depth layer),

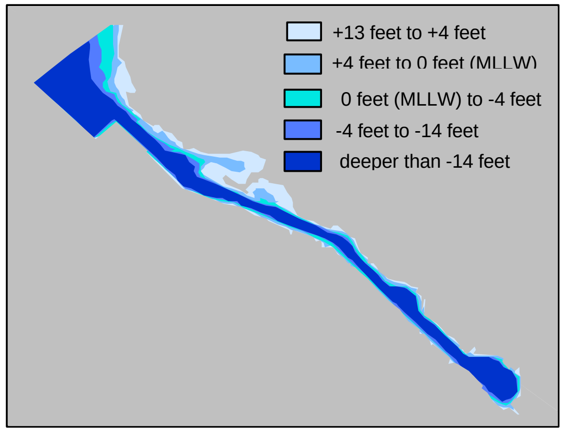


Figure 10-1. **HylDepth,** an original data layer with the five depth intervals within Hylebos Waterway (shown with HEAout_1)

The generalized polygonal layer, **HEAdepth**, is transformed into a final spatial analysis layer by gridding it and then converting it back into a non-generalized polygonal form for final intersection with other data layers. This procedure is necessary to assure that this habitat layer conforms to the precise overlaying grid topology of the **<SOCcode>ID** layers used in the INTERSECTION procedure (see Step 6). In this procedure the depth layer is converted to a grid configuration, using parameters determined for **IDWMask** (See Step 4)**.** After grid configuration, this theme is reconfigured into a non-generalized polygonal data layer using **g2poly-no-gen.ave**, an Arcview™ Avenue script[2]. Again, this procedure is used to ensure that the origin, extent, cell

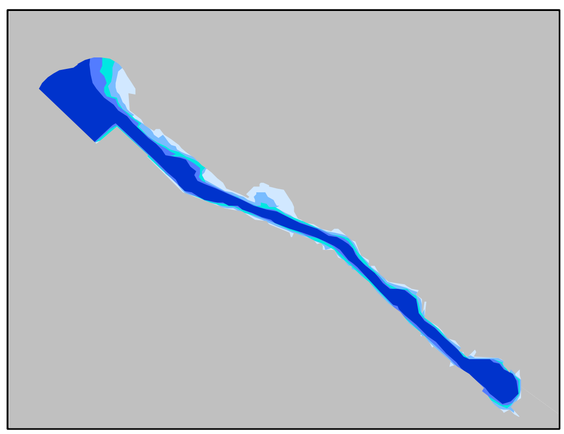


Figure 10-2. **HEAdepth**, the intermediate data layer representing a generalized polygon layer for depth, displayed with **HEAout 2** as a clip file

[2] G2poly-no-gen.ave is a script or macro developed by Eugene Martin of CommEn Space, The Community and Environmental Spatial Analysis Center, and is used with his permission.

size, and cell nodes of this data layer are identical to all other final data layers. This allows an exact overlay of the layers and eliminates sliver polygons as well as software performance problems.

The result of converting the gridded depth habitat layer into a non-generalized polygonal form for final data intersection is **NGDepth** (Figure 10-3)

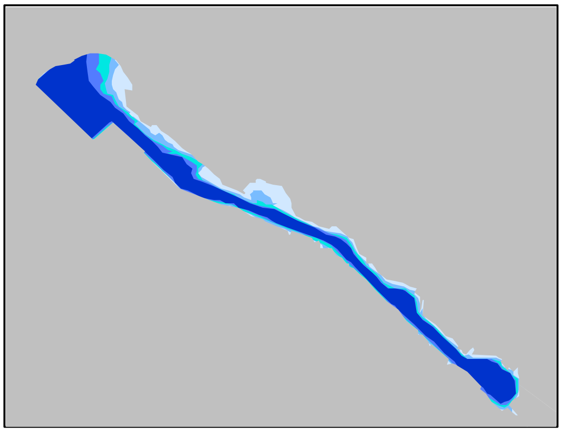


Figure 10-3. **NGDepth** is a final data layer representing a non-generalized polygon version of **HEAdepth**. It is shown with **HEAout 2** as the clip file.

b. Substrate—Habitat substrate in Hylebos Waterway is determined through the spatial analysis of grain size data from both the HCC and Trustee sediment surveys (See Appendix A). Based on substrate preferences for certain species (Appendix D), substrate is classified by the amount of sediment with grain sizes greater than 2 mm in diameter; five categories of substrate are identified (Figure 10-4). Grain-size contours are interpolated using nearly-identical procedures to those used for mapping the injury footprints for the SOCs (Step 11). The only differences are: (1) there is no log transformation of the original point data, and (2) the limit of the resultant footprint is bounded by the non-buffered analytical area (**HEAout 2**). Procedures for proceeding from the original depth file (**HylSed)** (Figure 10-4) to the intermediate grid layer (**HEASed)** and to the non-generalized polygonal form for final data intersection (**NGsed** in Figure 10-5) are identical to those followed in the previous subsection..

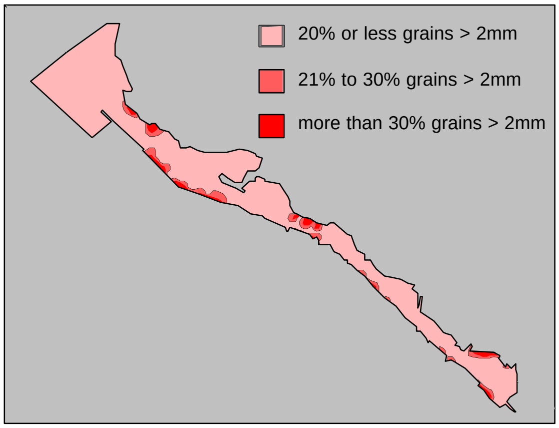


Figure 10-4. **HylSed**, an original layer with five levels of sediment grain size outlined by **HEAout 1**. Only three size levels are displayed. Large grained sediments are found in very limited amounts in Hylebos Waterway.

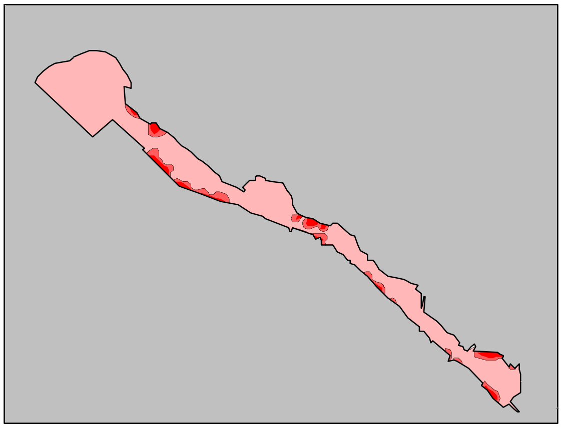


Figure 10-5. **NGsed** is the final non-generalized polygon sediment data layer. It is shown with **HEAout 2** as the clip file.

c. Diminished-value Habitat Layers—The three other habitat-related layers incorporated into our spatial analysis deal with modifying habitat values. These modifications are due to either additional physical alterations or the likelihood of active remediation. These layers are important because they often represent locations where the baseline value of habitats must be identified as diminished prior to evaluation of additional impacts from the presence of SOCs. Examples are areas under shore-fast docks and log rafts as well as areas with extensive woodwaste. Shore-fast docks eliminate daylight in intertidal/shallow subtidal areas beneath them, inhibiting use of these areas by juvenile salmonids. Log rafts not only ground out in intertidal areas during low tides (eliminating forage habitat for fishes), but they can also scour and disturb the surficial sediment. Woodwaste can accumulate on the seabed in quantities sufficient to inhibit colonization by epibenthic organisms and prohibit foraging by others. These habitat alterations result in lower-valued habitats even in the absence of chemical contamination. They must be considered prior to evaluating injuries from SOCs. Appendix B provides a more detailed discussion of these details.

Proposed areas of remediation represent locations that are evaluated differently. They must be examined to determine how soon the injury will be eliminated. Remediation allows more rapid achievement of full habitat function versus areas with injury-level concentrations of SOCs that are left to natural attenuation. Natural attenuation is defined in our analyses as the time an area needs to reduce surficial sediment contamination to a level that no longer injures living natural resources. This can occur through settling out of suspended clean sediment that is carried into the area from streams and rivers. Another possible (though unlikely) method for natural attenuation is from weathering of SOCs and chemical degredation into non-injurious substances. Further discussion of natural attenuation is presented in Appendix C.

The diminished-habitat value data layers are based on digitized shapefiles. They are derived from a variety of sources: the review of nautical charts (for docks), 1960-2000 aerial photos (for usual locations of log rafts), the HCC Pre-remedial Design Evaluation Report and remediation proposed by the Port of Tacoma and Occidental Chemical Co.(for areas of remediation); and reports from the Cleanup Study Work Plan for the Head of the Hylebos Waterway Wood Debris Program (for the location of significant wood waste).

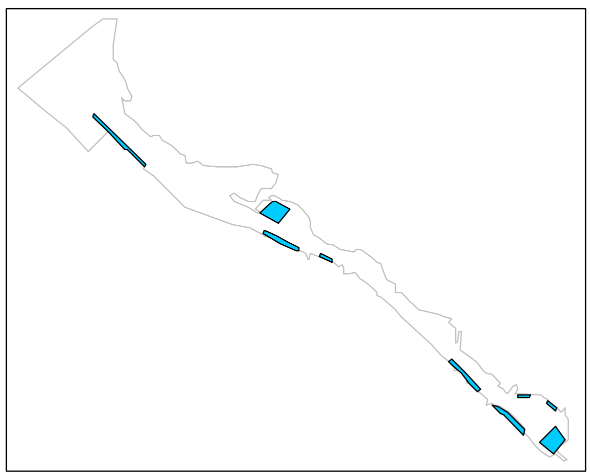


Figure 10-6 **DimHabOver** is the original data layer with diminished habitat areas outlined by **HEAout_1**.

c-1 Overwater Areas That Diminish Habitat Value—
DimHabOver is the original layer created from nautical charts and aerial photographs showing locations of shore-fast docks and consistent or frequent log rafts (Figure 10-6). This layer is converted into a generalized polygon version, **003genodim**, and then transformed into the non-generalized polygon layer **003grdnodim** (Figure 10-7) for a later INTERSECTION procedure with all other data layers at the end of our spatial analysis.

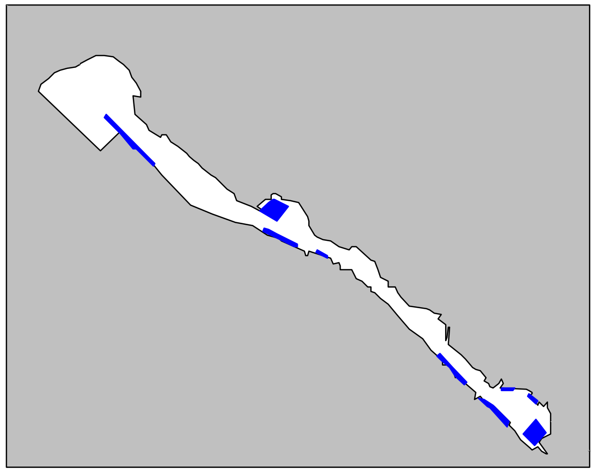


Figure 10-7. **003grdnodim** is the final layer representing a non-generalized polygon version of **003genodim,** areas with diminished-value habitat due to man-made structures.

c-2 Underwater Areas That Diminish Habitat Value-- DimHabUnder is an original layer digitized from mapped surficial wood debris coverage contours obtained from the Hylebos Wood Debris Group (Pentec, 1998). It portrays areas where there is significant accumulation of wood waste (Figure 10-8). For our purposes, significant accumulation is 50% or more coverage of the seabed surface by wood debris. This layer was converted into a generalized polygon version, **003genudim**, ----fix---------------- and then transformed into the non-generalized polygon layer **003grdudim** (Figure 10-9) for the later INTERSECTION procedure with all other data layers at the end of our spatial analysis.

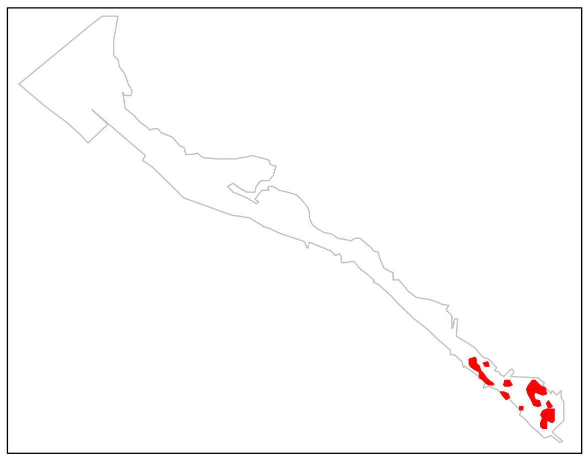


Figure 10-8. **DimHabUnder** is an original data layer with diminished habitat areas that are due to underwater accumulations of debris such as bark and other woodwaste (outlined by **HEAout_1**). Areas in red represent locations where woodwaste covers 50% or more of the surface.

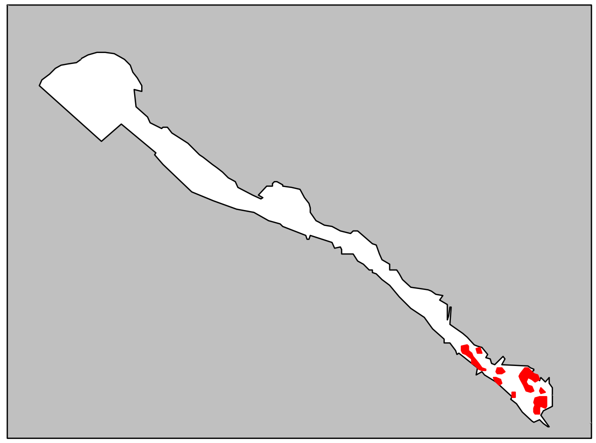


Figure 10-9**.** **003grdudim** is a final data layer showing underwater areas of diminished habitat. It represents a non-generalized polygon version of **003genudim,** ready for INTERSECTION procedures**.**

c-3 Potential Areas of Active Remediation—003rem_gen (formerly known as **RemedAreas**) is an original layer digitized from mapped potential remediation areas identified in the HCC's Pre-Remedial Design Evaluation Report (Appendix B by Hartman Consulting Corp. 1999) and in a later document prepared for Occidental Chemical Corp (Anchor Environmental, 2000). These areas will be dredged and back-filled or capped with non-injurious sediment. **003rem_gen** (Figure 10-10) is transformed into a gridded layer **003rem_grd**, which is then transformed into the non-generalized polygon layer, **003rem.ng** (Figure 10-11) for the later INTERSECTION procedure with all other data layers at the end of our spatial analysis.

Figure 10-10. **003rem_gen** is an original layer showing proposed areas for active remediation (clean up) (outlined by **HEAout 1**)

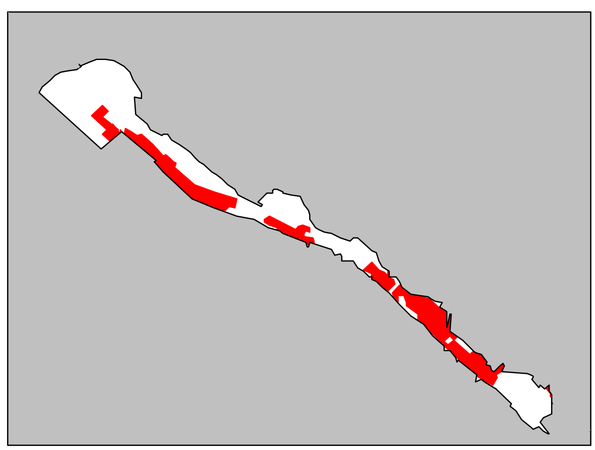


Figure 10-11. **003rem_ng** is a final data layer showing proposed areas for active remediation . It represents a non-generalized polygon version of **003rem_grd**, and is ready for INTERSECTION procedures. It is displayed with **HEAout 2** as the clip file.

Step 11.—Developing Injury Footprints for Each SOC.

We are now ready to develop injury footprints for each Substance of Concern (SOC). To accomplish this step we utilize procedures discussed in Step 6 and perform the following sequence of operations:

- Select the database file for an SOC (point data) and perform a natural log transformation of the reported SOC concentration;
- Execute a spatial analysis (in a raster environment) to establish the interpolated pattern of the distribution of concentrations of the SOC;
- Reclassify the 10 default ranges of concentration on the IDW (Inverse Distance Weighting) grid surface into a series of five values (no injury, low injury, medium injury, high injury; and very high injury), based on injury threshold information presented in Appendix C;
- Convert the gridded layer (surface) into a non-generalized polygon version of the grid data;
- Clip off the 100 ft buffer used to interpolate the injury footprints; and
- Attach a unique number to each injury footprint (polygon) for future allocation of damages associated with each footprint (please see Appendix E for explanation).

An example of all sequences is provided for the metal, Arsenic (As).

<u>Step 11a. Spatial Analysis</u>—An **<SOCcode>grid** layer is produced by the interpolation of log-transformed point data (see Station Data, Step 6). In our analyses, grid surfaces are produced for 28 SOCs[3]. Figure 11-1 shows the result of IDW analyses for Arsenic. The grid layer **IDWMask**

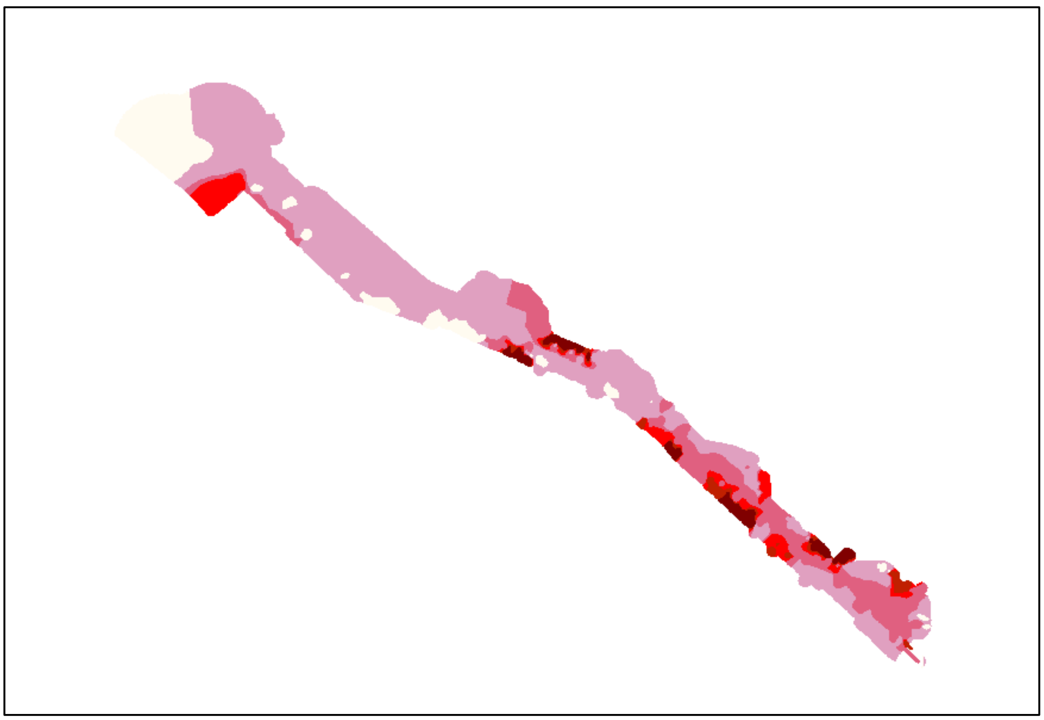


Figure 11-1 The Inverse Distance Weighting (IDW) interpolation of the distribution of Arsenic in the Hylebos Waterway analytical area. The darker the color, the higher the concentration. Limits of the analytical area are defined by a "mask (**IDWmask**) that eliminates concentration isopleths beyond a defined boundary.

is used to define the interpolated grid origin, extent, cell size, and analysis area. Limits of the resultant footprints are bounded by the defined analytical area, **IDWout** (i.e. the study area with a 100 foot buffer added upland to the shoreline +13 ft above mean lower low tide). The buffered area is shown in Figure 11-2 as the peripheral area outside by the grey line. The parameters used to create each grid are: *Analysis Extent = Same as IDWMask; Analysis Cell Size = Same as IDWMask; Analysis Mask Method = IDW; Z value = <SOCcode>* log transformed concentration (from the Station Data Tables); *Number Nearest Neighbors = 8; Power = 6; Barriers = no barriers* (except for As and PAHs, where barriers are **Asbar** and **PAHbar,** respectively; see Step 7.)

Step 11b. Establishing injury footprints via reclassification of the default display concentrations--The standard output from Inverse Distance Weighting spatial analyses is a grid layer or theme with ten concentration ranges displayed (Figure 11-2). This default output is determined by taking the range of values shown in the "concentration" column of the database file and dividing that range into 10 equal segments, regardless of the extent of the range.

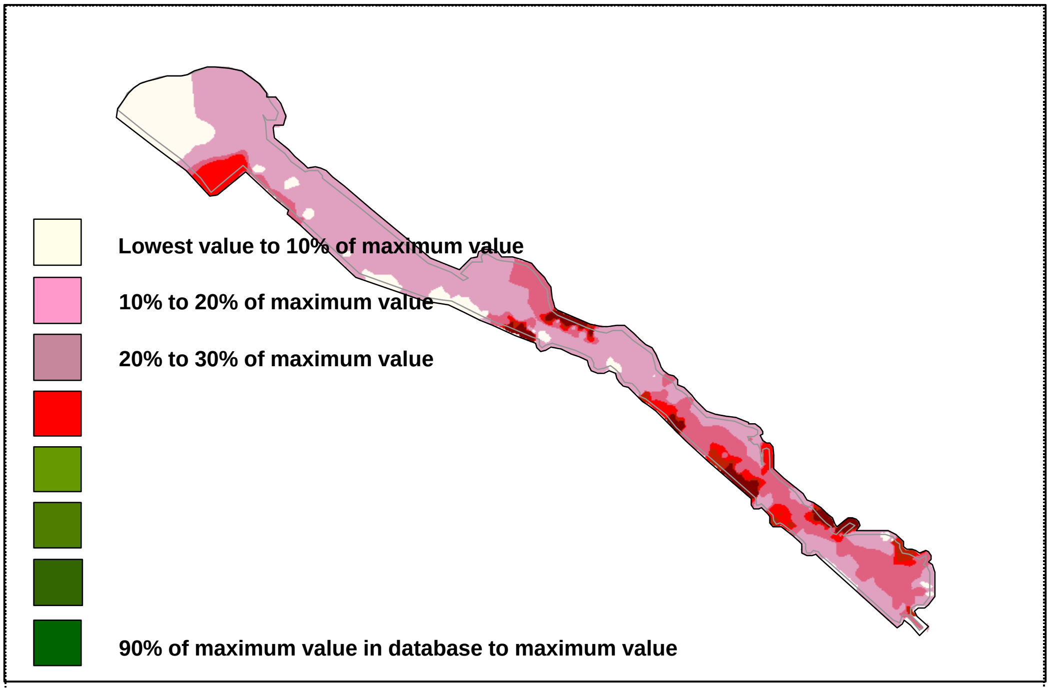


Figure 11-2. IDW interpolation of Arsenic in Hylebos Waterway with default concentrations expressed in 10 percent segments of the range of concentrations found in the interpolated data base. The 100-ft analytical buffer added to the analytical area is outside the grey line. (Only 8 segments shown in this example.)

In many instances, several of the initial default segments are all less than the value determined as the injury threshold value. Consequently, the display ranges have to be reclassified to reflect relevant information. Five concentration ranges were established, based on information determined from Appendix C. In most instances (i.e. for most SOCs), not all reclassified ranges are displayed on the revised data layer because the higher injury level(s) exceed values for any sample in the analytical database. For Arsenic, only four of the five levels are present (Figure 11-3a); concentrations exceeding the level associated with the threshold of "very high injury" were not present in the Arsenic data base. For most SOCs, only three levels were displayed: no injury, low injury, and medium injury.

[3] An SOC was analyzed if at least one station in its database had a concentration that exceeded the minimum threshold injury level for that SOC. All SOCs and their codes are listed in Table 3.

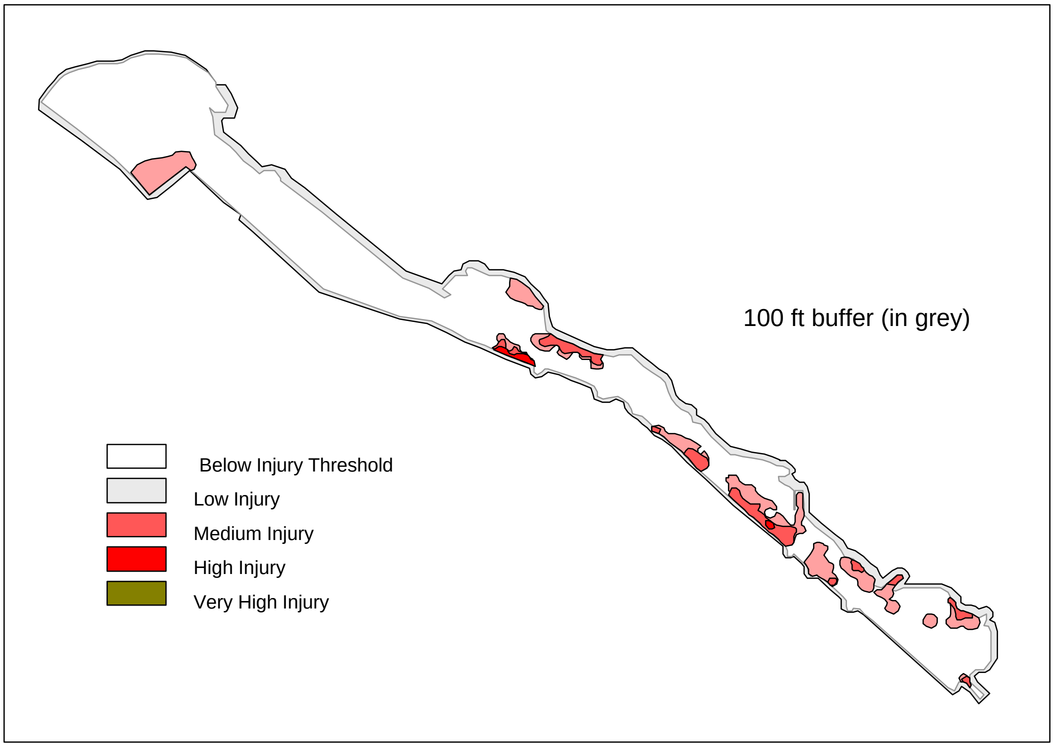


Figure 11-3a. Reclassified range of Arsenic concentrations isopleths based on levels of injury. The 100-ft buffer area was clipped from the IDW analytical area to display the actual analytical area only (i.e., the +13 ft above MLLW shoreline as defined by HEAout 2 in Step 5).

To perform this reclassification, select "Analysis" on the menu bar and then "Properties" in the pull-down menu to set the "Analysis Extent". Set the extent of the map to baseline (a defined parameter to establish the same exact origins). Go to analysis cell size and select "_____baseline". You don't need to select a mask (it already has one due to creating the grid). Click "OK". Then go back up to "Analysis" on the menu bar and select "reclassify" in the drop-down menu. You will see the 10 default range segments, and will rewrite these segments based on your data range. Always use three decimal places and set your highest value well above the maximum value in your database (e.g. "99.000", since we are dealing with log transformed data). After writing over the interval ranges with the actual values based on injury thresholds, delete the remaining default intervals that have not been written-over, except for "no data". Before implementing this reclassification, go to the bottom of the dialog box to the two buttons labeled "load" and "save", and save your reclassification ranges. (Note: if this is not the first time you reclassified, you can directly load). This reclassified range of concentrations is saved as an "avc" file--a file extension. At this point you are bounced back to the original dialog box with three buttons: "OK", "Save", and "Load". Hit "OK". The "avc" file **AS.avc** is the saved macro for reclassifying the **ASgrid** layer. These **<SOCcode>.avc** files were saved to maintain a record of reclassification input parameters for future verification.

Step 11c. Converting Grid Layers to Non-Generalized Polygon Layers--During initial development of our GIS analyses, we were limited by the number of data layers that could be joined together to develop an input data file for the Habitat Equivalency Analysis (Appendix D). Default parameters within the standard ArcView™ software limited us to about two dozen possible data layers. The data detail resulting from joining numerous polygonal layers overwhelmed the software capability. This was likely due to the extensive number of "sliver" polygons resulting from overlaying numerous themes with fairly similar, but not identical polygonal perimeters. Joining (overlaying) 15-20 (data) themes often created thousands of sliver polygons, many less than a few sq. ft. in area. Since we had 27 separate SOC layers and several additional habitat layers, the standard software limitations were problematic. An initial solution was determined by performing the spatial analyses in a raster (grid) environment rather than a polygonal one. (See the Introduction for a discussion of why raster is better than vector analyses.) However, other idiosyncrasices in ArcView™ complicated the joining together of grid layers. The final solution to our dilemma was to convert the grid layer into a non-generalized polygon form where cell edges are smoothed into a curved line. In other words, convert the grid layer into a non-generalized polygon where the exact (coordinate) edges are maintained --this is absolutely essential to perform an exact overlay of all data layers for an accurate database to perform an HEA.

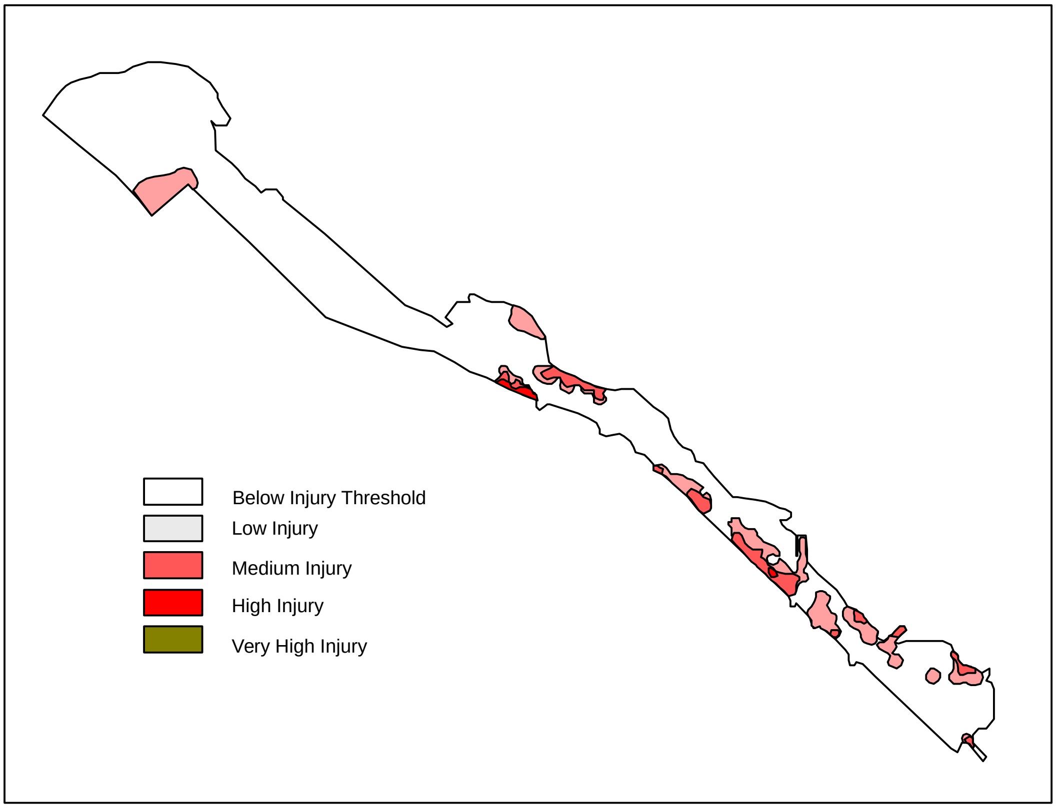


Figure 11-3b Injury footprints for Arsenic in Hylebos Waterway with the 100 ft buffer area clipped. The outline shown is **HEAout 2**, the area used for our analyses.

Asgrid was the intermediate layer used to create the **Aspoly** layer (Figure 11-3b) using **ClipMask, As.avc**, and the Avenue script, **g2poly-no-gen.ave**[4]. Clipping allows us to reduce the grid area to the initially defined HEA analytical area (i.e., **HEAout 2** in Step 5.) To clip after creating a polygon-grid layer, use the "clip" function in the "xtools" in the menu bar. The dialog box will ask, "What file do you want to clip?", "What do you want to clip with?", and it will give you a chance to save it where you want and with what name.

[4] The Avenue script, **g2poly-no-gen.ave**, a macro for converting grids to non-generalized polygons, is not a feature within the ArcView default Graphic User Interface. This macro was created by Eugene Martin and was used with the permission of Eugene Martin of CommEn Space (The Community and Environment Spatial Analysis Center, *www.commenspace.org.)*

Step 11d. Attach identifiers to injury footprints for further analysis.--The ultimate purpose of this spatial analysis is to create a datafile with injury footprints for each SOC and associated information on habitat types and habitat conditions so that a Habitat Equivalency Analysis can be determined. The layers discussed up to this point provide sufficient data to determine overall injury and amount of injury by SOC. Further actions are needed to identify HEA input for the determination of injury by geographic site and ultimately to allocate injuries to responsible parties.

One additional action is the unique identification of each SOC footprint. **<SOCcode>ID** layers are the final contaminant layers needed to perform the final intersection of all habitat and SOC themes. Each **<SOCcode>ID** layer is spatially identical to its respective **<SOCcode>poly** layer, but with two changes to its attribute table: (1) the *Gridcode* column heading is changed to *<SOCcode>conc* for uniqueness, and (2) a *<SOCcode>ID* column with footprint ID is manually added. Footprints for each SOC are numbered to agree with the footprint allocation database

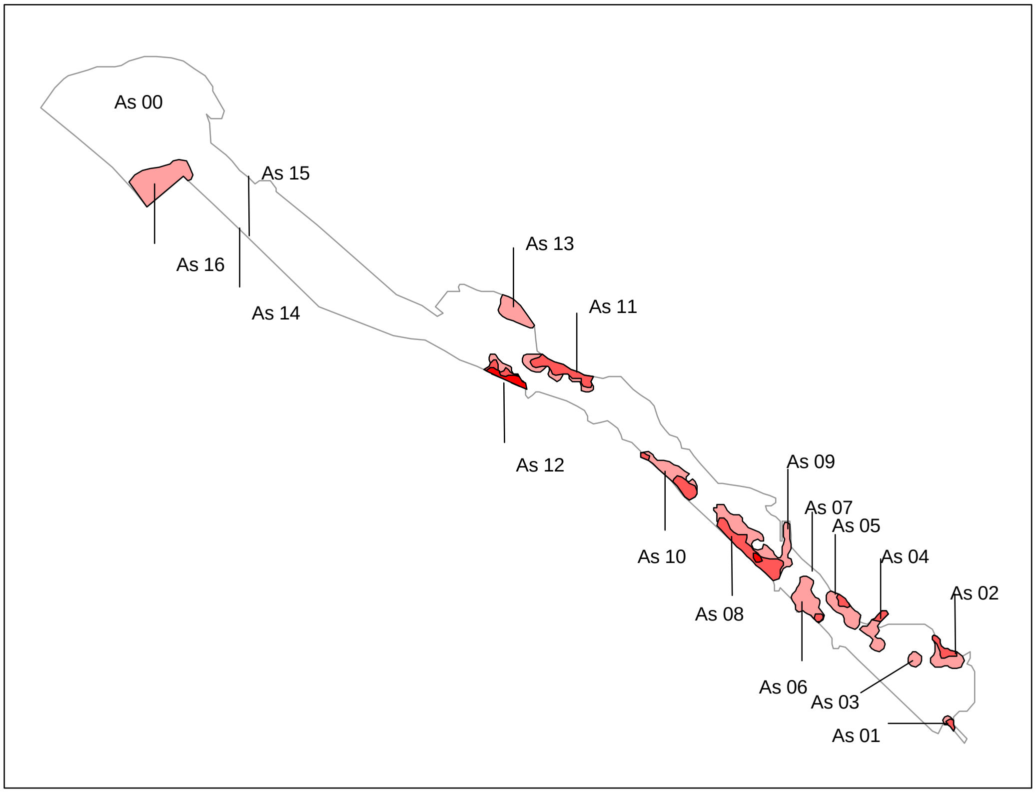


Figure 11-4. Each Arsenic injury footprint is labeled. Some footprints are so small they cannot be seen on this figure.

(See Appendix E: Injury Allocation). All polygons within a footprint are given the same footprint ID code (i.e., each injury level--low, medium, etc.--have the same footprint ID number). Up to 18 footprints were enumerated for each SOC (except PAHs and PCBs, which were allocated differently). The example for Arsenic is shown in Figure 11-4, with footprints numbered AS1 through AS16. All areas where there is no injury from Arsenic are labeled As 00 (AS zero).

Infrequently, an injury footprint will extend across the waterway (Figure 11-5a) and be adjacent to two or more sites, each with triggers (See Appendix E) for that SOC's release. In these special cases, the footprints were manually divided midway across the waterway (Figure 11-5b), and the initial footprint assigned separate numbers for the two resulting polygonal portions. This exercise requires selecting “Theme/start editing” in the Edit mode, and selecting “Draw line to split polygon” button in the drop-down menu under the “Draw Rectangle” icon.

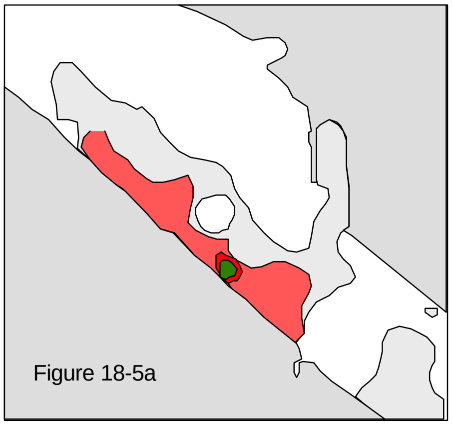


Figure 18-5a

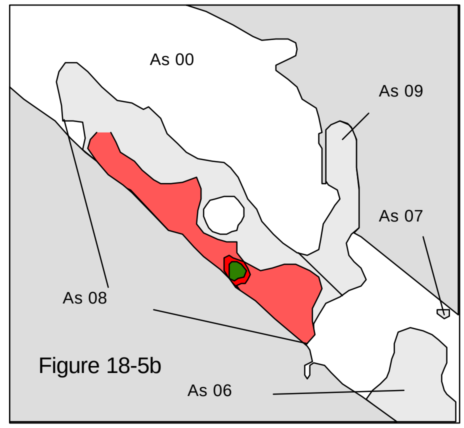


Figure 18-5b

Another footprint allocation step is the development of a file with names of each Hylebos Waterway industrial site for attachment to the final overlay dataset used in performing the HEA**.** **FootprintID.xls** is an original file that is a spreadsheet for attaching industrial site names to SOC footprints. (Decision criteria for allocating footprints are discussed in Appendix E.) **Footprint ID.xls** is used to create the SOC-specific .dbf files that list all footprints by ID code with names of all industrial sites associated with each footprint. **<SOCcode>fp.dbf** files are extracted from **FootprintID.xls** and used to attach industrial site names to all polygons in their allocated footprints for completing the final overly data set, **HEAoverlay,** using the "spatial join" procedure via Intersection. This information is needed to allocate Service Acre Years (the metric used for injury) to specific industrial sites via the HEA. A total of 25 separate **<SOCcode>fp.dbf** files are created for all Substances of Concern in our analysis except PAHs and PCBs. Injuries from these two groups of compounds are allocated differently than the other SOCs (again, see Appendix E). This final data is not used directly in the Habitat Equivalency Analysis, i.e., it is not part of any calculations of injury; however, it does remain attached to all SOC footprints so that when injuries per footprint are calculated, responsible sites are attached.

Step 12—Final Assembly of the HEA Input Database

As mentioned previously, the non-generalized polygonal data layers are all overlayed with the INTERSECTION command that combines all data layers into a single theme, called **hylhea2000_3** (it is the HEAoverlay mentioned in the previous step). All layers have identical origins, theme extents, and cell sizes. Visually, this theme is very complex, due to overlaying of 27 SOC layers and 5 habitat layers. Actually, you can have up to 27,000 possible combinations of the data layers: 27 SOCs x 5 injury levels x 5 depth intervals x 5 sediment types x two remediation options (yes or no) x two over-water diminished habitat options (yes or no) x two underwater diminished habitat options. The .dbf file associated with the final data layering combination is also saved as an Excel™ spreadsheet. This spreadsheet is the endpoint of the spatial analyses and forms the input data for the Habitat Equivalency Analysis (Appendix D).

Information on IDW

Inverse distance weighting is the simplest interpolation method.

It is an interpolation technique in which interpolated estimates are based on values at nearby locations weighted by distance from the interpolation location. It makes to basic assumption that nearby points ought to be more closely related than distant points to the value at the interpolation location.

The neighborhood about the interpolated point is identified and a weighted average is taken of the observation values within this neighborhood.

The weights are a decreasing function of distance.

The user has control over the mathematical form of the weighting function, the size of the neighborhood (expressed as a radius or a number of points), in addition to other options

The simplest weighting function is the inverse power:

$W(d) = 1/d^p$

Where: W = the weight of a nearest neighbor
d = distance of nearest neighbor from point of interest; and
p = the power (p>0, and in ArcView Spatial Analyst, its maximum value = __)

neighborhood size determines how many points are included in the inverse distance weighting, and its size can be specified in terms of its radius (distance), the number of points, or a combination of the two.---I think we used just number of points.

This information is from The National Center for Geographic Informatioin and Analysis at their University of California at Santa Barbara web site (www.ncgic.pubs/spherekit/inverse.html).

The neighborhood about the interpolated point is identified by looking at the values of known points (i.e., sediment dampling stations) that are near the pixel and a weighted average is taken.

Z_x = value at pixel of interest.
Z_p= value at a known point "p".
d_p= distance from point to point "p".
n = "friction of distance"; usually between 1 and 6.

Z_x = ______________

Table 1.--Data Layers Used in the Spatial Analysis of Natural Resource Injury Footprints by Substances of Concern

Which Step	File Name	Command	Type Layer	Type	Remarks
Step 1--Creating the Initial Analysis Universe					
	MHHWout		Original	Polygon	Initial waterway outline
	RemedAreas		Original	Polygon	MHHWout with planned remediation areas
	DimHabOver		Original	Polygon	MHHWout with overwater structures that diminish habitat.
		UNION			
	Exp(anded)MHHWout		Intermediate	Polygon	MHHWout with expanded areas due to remedial areas and diminished habitat areas
		CLEAN (via union features)			
	HEAout 1		Intermediate	Polygon	ExpMHHWout with internal polygons removed
Step 2.--Further Preparation of the Analysis Universe--Reducing the Analytical Area					
	HEAout 1				
	StnData.dbf		Original	database/ polygon	HEAout1 with sampling stations
		ft)			
		UNION			
	Stn_Influence		Intermediate	Polygon	station
	StnInfluence_CLIP		Intermediate	Polygon	HEAout 1 without areas > 1000 ft fm stations
	HEAout 1				
	Prop83.shp		Intermediate	Polygon	HEAout 1 with property boundaries; specifically, tribal properties
		UNION (or			
	HEAout 2		Intermediate	Polygon	HEAout1 with both Tribal Tidelands and outer areas removed
Step 3.--Assuring Appropriate Treatment of Intertidal Data During Interpolation of Injury Footprints					
	HEAout 2				
		ft)			
	IDWout		intermediate	polygon	HEAout 2 expanded by a 100-ft buffer at shoreline
Step 4.--Transforming Polygonal Data to Grids					
		Convert to Grid			

Table 1.--Data Layers Used in the Spatial Analysis of Natural Resource Injury Footprints by Substances of Concern

Which Step	File Name	Command	Type Layer	Type	Remarks
	IDWmask		intermediate	grid	creates raster (grid)-based analytical area
Step 5.--Creating a "cookie cutter" to Clip Off Areas Outside Analytical Boundaries					
	HEAout 2				
	ClipMask	g2poly-no-gen.ave	intermediate	non-generalized polygon	The file used to remove the 100 ft buffer are from the interpolated injury footprint area defined by IDWmask
Step 7.--Special Cases: Adding Barriers to Assure Appropriate "Nearest Neighbors" are Used for IDW Interpolation.					
	IDWmask				
		Barrier			
	ASbar (barrier)		intermediate	grid	adding analytical barriers to assure appropriate "nearest neighbors" are used in SOC countour interpolation
	PAHbar		intermediate	grid	same as above
Step 8.--Establishing Data Points for Transect Data					
	AllStns.dbf		intermediate		This is shown on HEAout 1. It is a combination of subtidal data points (from dbf) and a set of intertidal data points defined by length of intertidal sampling transect and concentrations reported in the chemical analysis of the transect's composite sample.
Step 9.--Creating a Master List of Spatial Data Points by Contaminant Group for Spatial Analysis					
	PCBstns		intermediate		all shown on HEAout 1
	Orgstns		intermediate		Organic chemistry stations
	Metstns		intermediate		Metals chemistry stations
	TBTstns		intermediate		Tributyl-tin stations

Table 1.--Data Layers Used in the Spatial Analysis of Natural Resource Injury Footprints by Substances of Concern

Which Step	File Name	Command	Type Layer	Type	Remarks
Step 10.--Preparing Habitat Layers for Analysis					
Step 10 a.--depth intervals					
	HylDepth		original	polygon	The original depth interval data converted from the HCC CAD files and other sources--shown on HEAout 1
	HEAdepth	INTERSECT	intermediate	polygon	a generalized polygonal layer for depth in our spatial analysis. It is a modified version of HylDepth because some areas with depth info are extended beyond perimeter of HEAout 2. Additionally…..
	NGDepth	g2poly-no-gen.ave	Final	non-generalized polygon	A non-generalized polygon version of HEAdepth created to provide a habitat layer that conforms to the grid topology of the <SOCcode>ID layers used in the INTERSECTION procedure. In this procedure, each habitat layer (each analytical layer) is converted into grid configuration using parameters determined for IDWMask (see Step 7). After configured as a grid, this file is converted into non-generalized polygons using the Avenue script g2poly-no0gen.ave. This step is used to insure that the origins, extents, cell sizes, and cell nodes of all layers used in the intersection pr9cedure are identical. This procedure allows an exact overlay of all layers in the INTERSECT procedure. It eliminates the sliver polygons as well as software performance problems.
Step10 b.--sediment types					Preparing habitat layers…: sediment types
	HylSed		Original	polygon	This original sediment layer is created from______ where grain size data from each co-trustee and HCC sediment sample is spatially analyzed and contours developed. It is presented on HEAout 1.
	HEAsed	INTERSECT	intermediate	polygon	a generalized polygonal layer for sediment, presented on HEAout 2.
	NGSed	g2poly-no-gen.ave	final	non-generalized polygon	The non-generalized polygon version of HEAsed, created for/via the INTERSECT procedure, along with the Avenue script as in previous step.
Step 10 c-1.--Preparing habitat layers…: diminished habitat areas on or above the water.					
	DimHabOver		original	polygon	Derived from analysis of aerial photos for 1960-2000 showing docks and areas of frequent or consistently present lografts. This information was digitized by DARC NW staff.
	003genodim	INTERSECT	intermediate	polygon	Diminished habitat areas shown on HEAout 2

Table 1.--Data Layers Used in the Spatial Analysis of Natural Resource Injury Footprints by Substances of Concern

Which Step		File Name	Command	Type Layer		Type		Remarks
		003grdnodim	g2poly-no-gen.ave	final		generalized polygon		The non-generalized version…as in previous step
Step 10 c-2.--Preparing habitat layers…: underwater diminished habitat areas								
		DimHabUnder		original		polygon		Preparing habitat layers: underwater diminished habitat areas.
		003genudim	INTERSECT	intermediate		polygon		Preparing habitat layers: areas proposed for active remediation.
		003grdudim	g2poly-no-gen.ave	final		generalized polygon		
Step 10 c-3.--Preparing habitat layers…: potential areas of active remediation								
		RemedAreas		original		polygon		
		003rem_gen	renamed	original		polygon		
		003rem_grd	INTERSECT	intermediate		grid		
		003rem.ng	g2poly-no-gen.ave	final		generalized polygon		
Step 11.--Developing Injury Footprints for Each SOC								
Step 11		ASgrid	IDW	intermediate		grid		number of concentration ranges--10. These are 10 equal interval ranges.
		IDWMask	DEFINE	intermediate		grid		defines the origin, extent and____ of the interpolated concentration isopleths of arsenic
		ASbar	barrier	intermediate		polygon		limits the selection of nearest neighbors for the Inverse Distance Weighting interpolation
		IDWout						Limits the resultant fooprints to the study area and the 100 ft buffer added upland
Step 11 b		AS.avc	Analysis Extent	macro				contour ranges specifically associated with identified injury levels for Arsenic
Step 11 c		ASpoly	g2poly-no-gen.ave	final		generalized polygon		the final layer for the Arsenic injury footprint, developed from Asgrid, ClipMask, AS.avc, and clipped via HEAout 2.
Step 11d		ASID		final		non-generalized polygon		the final injury footprint layer for Arsenic, but with two columns in its attribute table changed to create a unique file that identifies areas by concentration by individual footprints--the ID for the individual footprints is entered manually.
		FootprintID.xls		original		Spreadsheet		A spreadsheet that attaches names of all industrial sites associated with each identified footprint

Table 1.--Data Layers Used in the Spatial Analysis of Natural Resource Injury Footprints by Substances of Concern

Which Step		File Name	Command	Type Layer		Type		Remarks
Step 12.--Final Assembly of the HEA Input Database								
		hylhea2000_3	INTERSECT	final		generalized polygon		The final theme that contains the intersection of all SOC data layers, along with all habitat layers and remediation option layers
		ASfp.dbf		final		database file		separate polygon associated with each Arsenic injury footprint created via hylhea2000_3. This type of file is created for each Substance of Concern