

**GISHydro Nutrient Loading Interpolator
for the Chesapeake Bay Program Model**

FINAL REPORT

Submitted to:

Maryland Department of the Environment

By:

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Overview

This project was comprised of a series of six tasks as outlined below. Appendices generated over the course of the project are now used as documentation for the completion of each item. The tasks are summarized here and refer the reader to the appropriate appendix for further details.

- **Task 1: Development of Beta-version GIS-Based Tool to Produce Nutrient Loading Estimates based on Chesapeake Bay Model Land Cover and Loading Rates.** – see Appendix A (attached)
- **Task 2: Development of a GIS-Based Tool Allowing User to Modify and/or Update Land Cover over an Area for the Performance of Before/After Loading Analyses.** – see Appendix B (attached)
- **Task 3: Development of a GIS-Based Tool for Allowing the User to Indicate BMPs over an area.** – see Appendix C (attached)
- **Task 4: Development of a Beta-version GIS-Based Tool to Produce Nutrient Loading Estimates based on User-Supplied Land Use.** – see Appendix B (attached)
- **Task 5: Hold 1-Day Training Workshop** – This workshop was held on Thursday, January 11, 2007 at the University of Maryland, Department of Civil and Environmental Engineering computer design lab. There were attendees from the Maryland Department of the Environment, Maryland Department of Natural Resources, and the US EPA Chesapeake Bay Program. Workshop exercises were presented and worked through by all attendees. A copy of these exercises is attached as Appendix D.
- **Task 6: Write Final Report and User Documentation** – this entire document
- **Other:**
 - **Memoranda:** Under Task 1 several memoranda were produced. They are attached here as a group under Appendix E:
 - Memorandum 1: Meeting held at MDE on June 9, 2006
 - Memorandum 2: Meeting held at MDE on August 29, 2006
 - Memorandum 3: Meeting held at DNR on November 20, 2006
 - Memorandum 4: Meeting held at DNR on February 1, 2007
 - **Septics:** Nitrogen loading is modeled differently from the methods and values reported by the Chesapeake Bay program. Methods for this item are presented in Appendix F.

- ***GISHydro Software:*** A deliverable of this project was a working copy of the software as described in this final report. The reader may go to: <http://www.gishydro.umd.edu> to download a standalone version of this software or to access the GISHydro webserver for use directly through a web-browser interface. The most recent changes to this software were posted for the webserver version on May 2, 2007.

Appendix A: General Presentation of a Nutrient Loading Analysis

The presentation below discusses and illustrates the use of a tool that determines the unique loading contributions of Nitrogen, Phosphorus, and Total Sediment that are associated with a user defined polygon or set of polygons covering area within the State of Maryland. Loadings are calculated by using GIS techniques to use the Chesapeake Bay Program Office's (CBPO) own electronic land cover data, converting this land cover to land use using the CBPO conversion rules, assigning spatially varied loading rates defined at the county segment resolution and again determined by the CBPO, to finally determine current overall loads for the above three nutrients within the user defined polygon(s). Finally, there is an option for the user to define future land use for each of their specified polygons to determine estimates of the future loads that would result from these same polygons. The code also calculates the difference between current and future loads to quantitatively determine the impact on loading that would result from the proposed development.

File Preparation

To use the Nutrient Loading Interpolator, you must create a polygon shapefile. This shapefile should have the following properties:

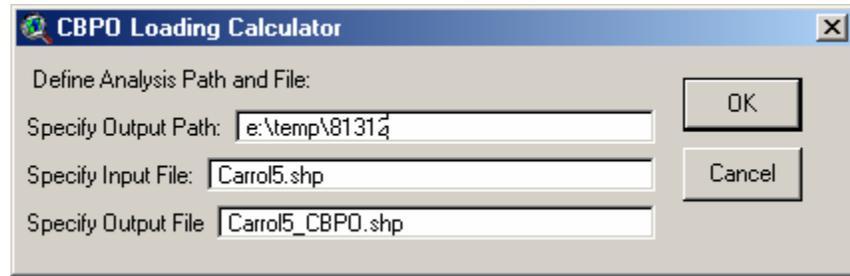
1. The file should be in the Maryland Stateplane projection, NAD 1983, in horizontal units of meters.
2. The file should contain one or more polygons that indicate boundaries over which current (and possibly future) nutrient load calculations are desired. If future nutrient loads are desired, each polygon should represent a single future land use.
3. In the attribute table:
 - a. There should be a field called "ID" with unique values for each record in the table.
 - b. (optional) If future nutrient loads are desired, there should be a field called "LU_New" that contains text descriptions of the land use that will appear in that polygon under post development conditions. (Please note: at this time there are only two valid future land uses that can appear here: "pervious urban" or "impervious urban". Spelling, capitalization, and spaces count!)

Using the CBPO Menu

To use the tool, you must have shapefile in the format described above loaded into the view window of GISHydro. By default, GISHydro will use the first shapefile (the topmost theme that ends with the name extension "*.shp") that is loaded into the active view, although you can specify a different file from the view from the dialog box that is provided.

Setting the Development File: From the "CBPO Loading" menu, choose "Set Development File". (Please note that this option will be grayed out unless you have loaded the development shapefile described under the "File Preparation" section above.) After selecting this menu choice you will see dialog box shown at right. GISHydro will generate a suggested output path (e.g. "e:\temp\81312" in the above dialog) but you can modify to whatever you like so long as you retain

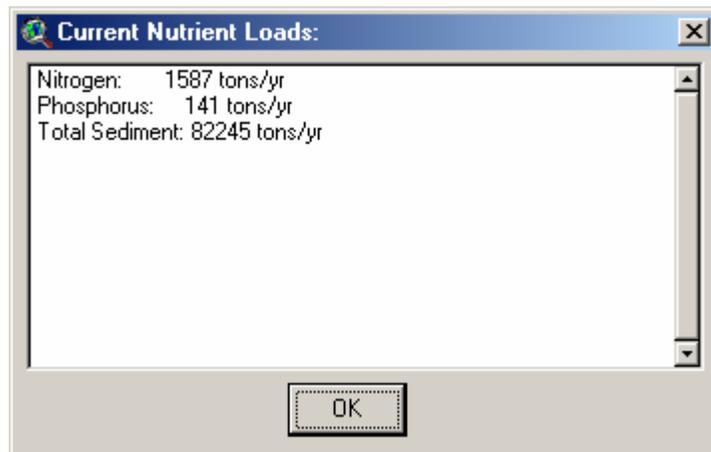
the
“e:\temp\
portion of the
path. In the
above
example,
GISHydro
has detected



the first shapefile called, “Carrol5.shp”. If you wish to use a different input shapefile, you can modify the this entry, but the changed entry must precisely match the name of another shapefile that is already loaded into the view. The last entry is a suggested output file shapefile name (in this case “Carrol5_CBPO.shp”). You can change this entry to anything you like. The output file will be written to the output directory path indicated in the top entry of the dialog box. Once all entries are satisfactory, click the “OK” button.

Once the “OK” button is clicked, GISHydro will generate an initial version of the specified output file. The output file will contain the same polygons as the input file, except they will be split along any differing CBPO county segments. If you examine the attribute table, you will find a listing of the acreage of each polygon, the county segment (“coseg”) it is located in, and initially zero entries for all remaining attributes.

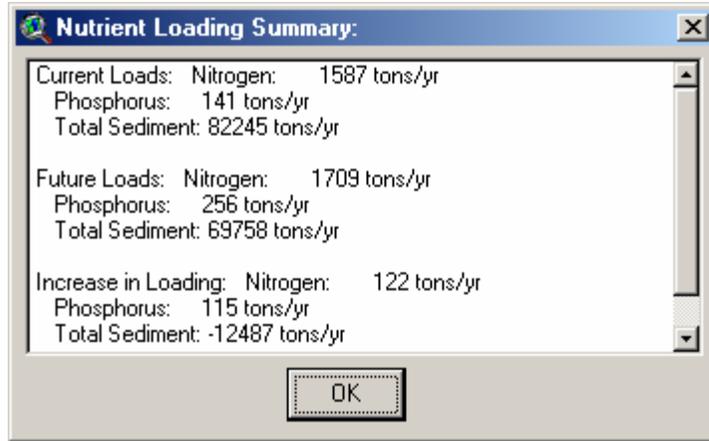
Calculating Current Nutrient Loads: After the development file has been set, you will find that the “Calculate Current Load” menu choice is selectable. Choose this item. GISHydro will now determine the nutrient loads (Nitrogen, Phosphorus, and Total Sediment) over all the polygons indicated in the development file. Depending on the number and size of polygons selected, this step may take just a few seconds or many minutes. In the example shown below, calculations performed at the web server required about 20



seconds. When calculations are completed, a dialog box will be displayed indicated the overall loads determined. A sample is shown above. (This is a very preliminary output box. We need to discuss what format and content is appropriate.) For more detailed analysis of the results, you will need to examine the attribute table of the output shapefile. This will provide individual nutrient loading values for each polygon in the original development shapefile.

Calculating Future Nutrient Loads:

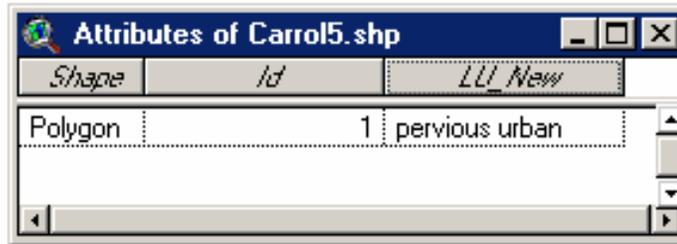
Assuming an attributed field called “LU_New” appears in the original development shapefile, the “Calculate Future Load” menu choice will become selectable after the current loads have been calculated as described above. A



similar dialog box to the one under “Calculate Current Load” will appear as shown above. The output repeats the current loading values, presents the future loading estimates, and indicates the calculated increase in loading in moving from current to future conditions. (A negative value such as for Total Sediment above, indicates a projected decrease in loading resulting over the development area.)

An Example

Let’s consider a hypothetical nutrient loading analysis over all of Carroll county, Maryland. To do this, we prepared a shapefile with a single polygon representing the outline of Carroll county in the Maryland Stateplane projection, NAD 1983, horizontal units of meters. The attribute table looks as shown to the right. This represents a minimalist attribute table with only a single record and with only the fields “ID” and “LU_New” indicated. It is fine to have additional fields or multiple records in the input shapefile.

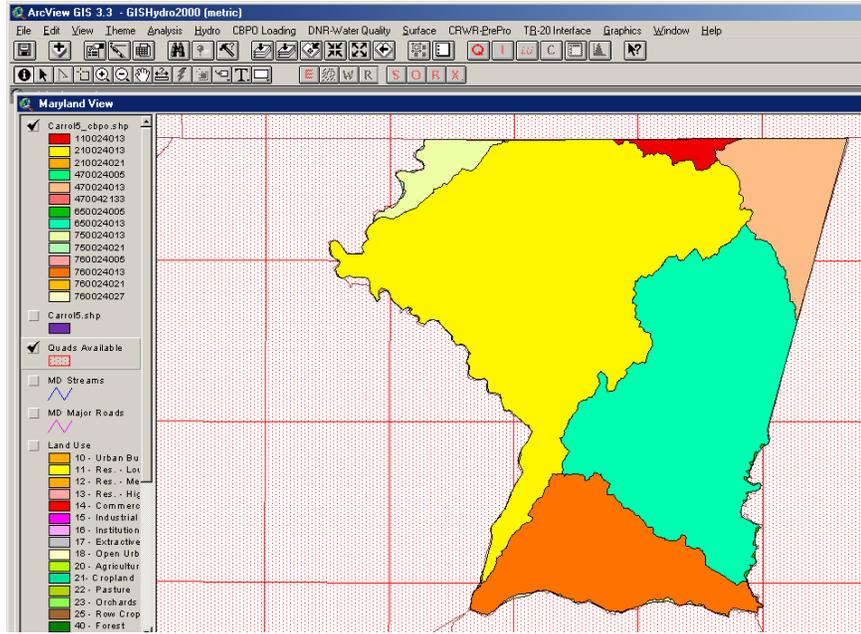


After setting the development

Shape	ID	coseg	LU_new	acres	lc17	lc12	lc13	lc14
Polygon	1	110024013	pervious urban	3362.66	0	0	0	0
Polygon	1	210024013	pervious urban	130252.55	0	0	0	0
Polygon	1	210024021	pervious urban	324.29	0	0	0	0
Polygon	1	470024005	pervious urban	0.09	0	0	0	0
Polygon	1	470024013	pervious urban	21379.53	0	0	0	0
Polygon	1	470042133	pervious urban	7.79	0	0	0	0
Polygon	1	650024005	pervious urban	332.60	0	0	0	0
Polygon	1	650024013	pervious urban	86886.36	0	0	0	0
Polygon	1	750024013	pervious urban	6740.35	0	0	0	0
Polygon	1	750024021	pervious urban	135.16	0	0	0	0
Polygon	1	760024005	pervious urban	44.41	0	0	0	0
Polygon	1	760024013	pervious urban	38913.63	0	0	0	0
Polygon	1	760024021	pervious urban	0.02	0	0	0	0
Polygon	1	760024027	pervious urban	450.77	0	0	0	0

shapefile, the resulting output shapefile looks as shown at the bottom of the previous page. Notice that one specified polygon has become 14 analysis polygons. This is because there are 14 unique county segments (“cosegs”) that intersect some portion of Carroll county. (There are numerous other fields appearing to the right of the attribute

table shown above, but they are omitted here for sake of presentation.) The actual intersected county appears as shown to the right. Although there are 14 unique intersections, the figure clearly shows that there are only about 6 intersections of any substantial size. A closer examination of the attribute table shows that only 6 of the polygons have area in excess of 640 acres (or 1 square mile). Viewed at the scale of the entire county, it is not possible to make out the remaining smaller polygons.



When the “Calculate Current Load” menu choice is selected the resulting dialog box is as shown under the “Calculating Current Nutrient Loads” sub-section above. Let’s look a little more closely at the changes to the attribute table of the output shapefile:

<i>h₁ till</i>	<i>h₂ till</i>	<i>h₃</i>	<i>pasture</i>	<i>manure</i>	<i>forest</i>	<i>mix open</i>	<i>p_urb</i>	<i>i_urb</i>	<i>water</i>	<i>TN</i>	<i>TP</i>	<i>TSed</i>
432.6440	528.5808	280.1767	319.3767	1.0316	1273.4329	501.5535	18.1474	4.3145	0.0000	33594.20	1822.66	1133.8
19667.6413	24030.9300	12742.6798	14534.9124	56.3005	32266.1558	22801.7025	2716.4418	1342.7089	111.1974	1726580.18	176863.42	41852.9
2.2618	37.8294	19.6252	23.0279	0.1201	148.7821	17.2034	31.5912	16.6685	25.3530	2824.48	253.78	34.5
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.0
2865.0804	3500.7017	1856.2878	2117.3710	8.2016	6888.6803	3321.6342	604.8361	219.5815	0.0000	122971.04	7560.87	3064.1
0.9477	1.8440	0.6673	0.5273	0.0040	2.0016	1.7919	0.0000	0.0000	0.0000	54.50	3.73	1.1
0.0213	0.0569	0.0197	0.0411	0.0001	40.9207	0.0833	1.3344	0.8896	288.8909	2989.47	167.52	3.5
9960.5174	12170.2696	6453.4268	7361.0885	28.5129	31502.2295	11547.7372	4406.5537	2079.8143	1379.7376	821010.90	59644.18	23165.7
1101.9540	1345.8980	713.9568	814.8992	3.1544	1322.5821	1278.0774	44.4345	12.2762	106.7495	101078.49	9497.76	2137.6
1.2009	20.1810	10.4668	12.2869	0.0640	50.9284	9.1805	4.8037	1.2009	24.2410	1384.77	115.58	15.3
0.0000	0.0000	0.0000	0.0000	0.0000	44.2566	0.0000	0.1668	0.9452	0.0000	73.79	1.75	3.3
4426.6946	5406.6499	2868.0588	3271.4456	12.6718	14097.8315	5132.0935	2401.2638	998.7085	298.2315	359743.91	26284.39	10989.4
0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.00	0.00	0.00	0.0
1.0268	4.5096	1.7104	2.6541	0.0030	363.1708	5.2204	45.8689	25.5198	0.0000	1431.49	116.42	43.2

The leftmost 10 fields in the above attribute table show the calculated acreage in different land uses across each of the 14 individual county segments. The final 3 fields at the right of the table show the determine loadings of Total Nitrogen, Total Phosphorus, and Total Sediment, from left to right, respectively. Loadings are in pound/year for Nitrogen and Phosphorus and tons/year for Sediment. If needed for reporting purposes, the associated “Carroll5_cbpo.df” file part of the overall shapefile, can be read directly by Excel for subsequent spreadsheet manipulations or calculations.

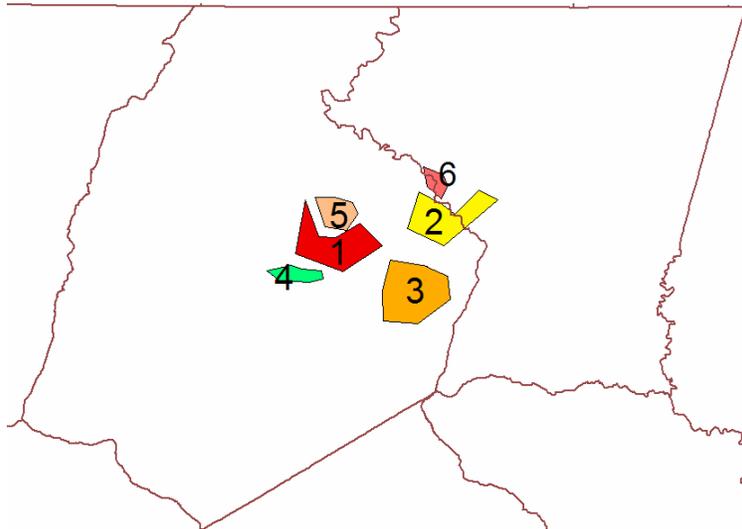
When the “Calculate Future Load” menu choice is selected, the resulting dialog box is as shown under the “Calculating Future Nutrient Loads” sub-section above. This example illustrates the case of defining all of the Carroll county as “pervious urban” under future conditions. This is obviously an extreme and unrealistic example. Nevertheless, it is useful to examine the remainder of the attribute table after this menu choice is selected:

TN	TP	TSed	TN_after	TP_after	TSed_after	TN_diff	TP_diff	TSed_diff
33594.20	1822.66	1133.81	50252.94	3736.25	934.15	16658.74	1913.59	-199.66
1726580.18	176863.42	41652.98	1734182.45	254174.83	32276.58	7602.27	77311.41	-9376.40
2824.48	253.78	34.56	4317.60	632.82	80.36	1493.12	379.04	45.80
0.00	0.00	0.00	0.60	0.08	0.01	0.60	0.08	0.01
122971.04	7560.87	3064.12	142821.67	18350.05	2304.71	19850.63	10789.18	-759.41
54.50	3.73	1.12	52.14	6.72	0.82	-2.36	2.99	-0.30
2989.47	167.52	3.51	3653.94	582.55	86.18	664.47	415.03	82.67
821010.90	59644.18	23165.78	954533.55	152181.46	22512.26	133522.65	92537.28	-653.52
101078.49	9497.76	2137.67	98565.49	15141.52	1758.56	-2513.00	5643.76	-379.11
1384.77	115.58	15.33	1976.47	303.62	35.26	591.70	188.04	19.93
73.79	1.75	3.39	480.82	76.24	11.01	407.03	74.49	7.62
359743.91	26284.39	10989.47	421310.09	66803.03	9646.69	61566.18	40518.64	-1342.78
0.00	0.00	0.00	0.22	0.03	0.00	0.22	0.03	0.00
1431.49	116.42	43.22	4880.40	773.84	111.75	3448.91	657.42	68.53

Above, the middle 3 fields with “xx_after” show the after development loadings in pounds/year (for Nitrogen and Phosphorus” and tons/year (for sediment). The rightmost 3 fields present the loading difference (future minus current). Positive values indicate increases in nutrient loading, while negative values indicate reductions in nutrient loading. Based on the unique land uses found within Carroll county and the CBPO nutrient loading model output for the county segments within this county, we see that changing all of this county from it’s current land use to the “pervious urban” land use defined by the CBPO results in increases to both Nitrogen and Phosphorus (substantial increases, in percent change, for Phosphorus) loading, but an actual decrease in Sediment loading taken across the entire county.

A Worked Example

Consider the following hypothetical development shapefile located partially in Frederick and Carroll counties of Maryland. After setting the development file for this shapefile, we find that polygons 2 and 6 are split because each resides partially in Frederick and Carroll counties. The split takes place along the county lines. We will focus on polygon 2.



Total Acreage

The GIS calculates that the total acreage of polygon 2 is distributed as

follows: in Carroll county (1951.3 acres), in Frederick county (4799.5 acres).

Land Cover Distribution

Using the CBPO Phase 4 land cover, the GIS determines the number of 30m pixels in each of 9 land cover classes fall within the polygon 2 area as follows:

Land Cover ID	Description	Carroll County (number of 30m pixels)	Frederick County (number of 30m pixels)
11	CBPLU High Intensity Urban	0	0
12	CBPLU Low Intensity Urban	117	24
13	CBPLU Herbaceous Urban	63	0
14	CBPLU Woody Urban	0	0
20	CBPLU Herbaceous	7444	18338
30	CBPLU Woody	1145	3220
40	CBPLU Exposed	0	0
60	CBPLU Water	5	0
70	CBPLU Herbaceous Wetlands	0	1

Land Use Distribution

Land Cover is converted to Land Use using rules set out in the document, “Chesapeake Bay Watershed Model Land Use and Model Linkages to the Airshed and Estuarine Models” (January, 2000). The rules for this conversion were applied as follows:

- Agricultural Land:** The land cover CBPLU Herbaceous (20) was divided into six land uses: hi till, low till, pasture, hay, manure, and non-agricultural herbaceous. The CBPO used agricultural census data to determine these proportions. We did not use the census data directly, but rather we simply used the reported values from the table: “1990 Phase 4.2 Watershed Model Land Use Sorted by Major Tributary Basin”. This table provides the acreage in each land use division. The acres in each of the above categories were summed and then the relative fraction of each specific land use was calculated. This fraction was then used to apportion the herbaceous land cover into the appropriate fractions of land use. Thus, we are treating all herbaceous land [CBPLU Herbaceous (20)] as being uniformly constituted of these six fractions of land use within each county segment. For example, consider the two county segments intersected by polygon 2. The table below shows the acreage and area fractions for these two county segments (cosegs).

Land Use	Coseg 210024013 (acres)	Fraction in coseg 210024013	Coseg 210024021 (acres)	Fraction in coseg 210024021
Hi Till	20038	0.2096	3823	0.0226
Lo Till	24475	0.2561	63997	0.3780
Pasture	14808	0.1549	38959	0.2301
Hay	12982	0.1358	33208	0.1961

Manure	53	0.0006	206	0.0012
Non-Ag Herbaceous	23226	0.2430	29110	0.1719
Sum	95582	1.0000	169303	1.0000

Land use in each of these agricultural categories is then determined by the product of the acreage in CBPLU Herbaceous and the fractions indicated in the above table. For instance, we have 7,444 pixels CBPLU Herbaceous (1,655.5 acres) in polygon 2 of Carroll county. Likewise we have 18,448 pixels (4,078.0 acres) in polygon 2 of Frederick county. To single out Hi Till land use in Carroll county this is (1655.5 acres) * (0.2096) = 347.0 acres. The remaining values are tabulated below:

Land Use	Coseg 210024013 (acres)	Coseg 210024021 (acres)
Hi Till	347.0	92.2
Lo Till	424.0	1541.6
Pasture	256.4	938.4
Hay	224.8	799.8
Manure	1.0	4.9
Non-Ag Herbaceous	402.3	701.1
Sum	1655.5	4078.0

- All remaining land use conversions are simpler to calculate and do not vary in proportion from one county segment to another:
 - **Impervious Urban Land:** this quantity is calculated as a weighted function of 5 different categories of CBPLU land cover as follows:
$$U_{impervious} = 0.85 \cdot (HIU) + 0.40 \cdot (LIU) + 0.10 \cdot (HU) + 0.10 \cdot (WU) + 0.40 \cdot (E)$$
where $U_{impervious}$ is the amount of impervious urban land, HIU is CBPLU High Intensity Urban (code 11), LIU is CBPLU Low Intensity Urban (code 12), HU is CBPLU Herbaceous Urban (code 13), WU is CBPLU Woody Urban (code 14) and E is CBPLU Exposed (code 40).
 - **Pervious Urban Land:** this quantity is the complement of impervious urban land and is calculated as follows:
$$U_{pervious} = 0.15 \cdot (HIU) + 0.60 \cdot (LIU) + 0.90 \cdot (HU) + 0.90 \cdot (WU) + 0.60 \cdot (E)$$
where $U_{pervious}$ is the amount of pervious urban land.
 - **Forest:** this quantity is calculated as a function of 2 CBPLU land cover categories as follows:
$$F = 1.00 \cdot (W) + 1.00 \cdot (HW)$$
where F is the amount of forested land, W is CBPLU Woody (code 30) and HW is CBPLU Herbaceous Wetlands (code 70).
 - **Water:** is simply taken as the acreage in CBPLU Water (code 60).

Applying these rules to the remaining (non-agricultural) land uses we determine the following land use distributions in polygon 2 across the two counties:

Land Use	Coseg 210024013 (acres)	Coseg 210024021 (acres)
Impervious Urban	11.8	2.1
Pervious Urban	28.2	3.2
Forest	254.6	716.3
Water	1.1	0.0

Calculating Nutrient Loads

Nutrient loads are determined as a function of land use, area, and spatial location. The primary output of the Chesapeake Bay Program model are estimates of nutrient loads. In Phase 4 modeling, these estimates are reported from two perspectives: edge of stream and as delivered to the Bay. Because the perspective of our modeling seeks to treat all lands equitably and because loadings imposed on local streams, not just the Bay, are a concern, our modeling assumes the edge of stream perspective for determining loads and changes in loads. Loads are calculated using the following general equation:

$$L_{i,j} = \sum_k c_{i,j,k} \cdot A_{j,k}$$

Where $L_{i,j}$ is the nutrient load for nutrient, i , from location, j ; $c_{i,j,k}$ is the loading coefficient for nutrient, i , from location, j , for land use, k ; and $A_{j,k}$ is the area of location, j in land use, k . The loading coefficients for nutrients: Total Nitrogen, Total Phosphorus, and Total Sediment were determined by dividing the modeled total loading for each of these nutrients for each state segment and land use by the area of that land use within the state segment. The table used to derive these loadings was provided by Gary Shenk of the Chesapeake Bay Program in the file “sseosallcall.prn” (state segment edge of stream all land uses calibrated). The mechanics of calculating nutrient loads then becomes a straightforward bookkeeping exercise in which the areas of land uses identified in the previous step are then multiplied with the appropriate loading coefficients and then summed across all locations of interest. Considering the case of polygon 2 we can develop the following table for the nutrient, Total Nitrogen:

Land Use	Coseg 210024013			Coseg 210024021		
	Area (acres)	Loading Coef. (lbs/acre)	Product (lbs)	Area (acres)	Loading Coef. (lbs/acre)	Product (lbs)
Hi Till	347.0	27.86	9667.7	92.2	27.86	2568.0
Lo Till	424.0	22.20	9413.4	1541.6	22.20	34227.4
Pasture	256.4	11.39	2921.5	938.4	11.39	10691.0
Hay	224.8	7.83	1759.9	799.8	7.83	6260.5
Manure	1.0	1985.31	1972.0	4.9	1985.31	9715.9
Non-Ag	402.3	6.66	2678.1	701.1	6.66	4667.1

Herbaceous						
Impervious						
Urban	11.8	9.90	116.9	2.1	9.90	21.1
Pervious Urban	28.2	13.31	375.7	3.2	13.31	42.6
Forest	254.6	2.03	517.1	716.3	2.03	1454.7
Water	1.1	10.44	11.6	0.0	10.44	0.0
Sum	1951.3		29,434.1	4799.5		69,648.4

Similar tables can be developed for Total Phosphorus and Total Sediment. The above table shows that the total loading of Nitrogen for current land use conditions in polygon 2 is $29,434.1 + 69,648.4 = 99,085.5$ lbs or 49.54 tons of Nitrogen.

Assuming a fictitious future land use of “pervious urban” for Polygon 2 the future loading for this pixel is simply the product of Polygon 2’s area (1951.3 acres in coseg 210024013) and (4799.5 acres in 210024021) and the pervious urban loading rate of 13.31 lbs/acre. Thus the future loading is 89,853.1 lbs or 44.92 tons of Nitrogen. The change in loading (future land use – current land use) is $44.92 - 49.54 = -4.62$ tons. Thus, for this particular polygon, the fictitious future loading actually produces 4.62 tons of nitrogen *less* than current conditions. We should note that overall (across all 6 polygons shown at the beginning of the example, the modeled future land use (pervious urban everywhere) produces 8.75 tons of Nitrogen *more* than the current land use.

Appendix B: Preparing a File for Nutrient Loading Analysis

File Preparation

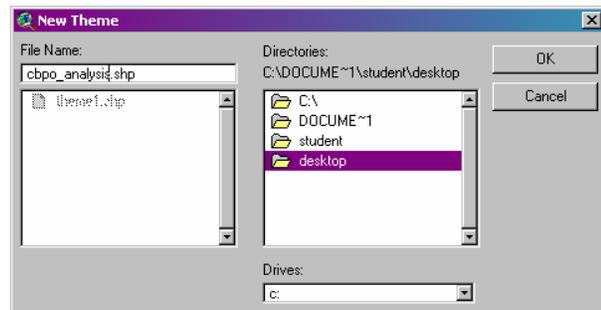
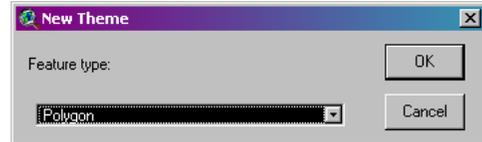
General Information/Rules

To use the Nutrient Loading Interpolator, you must create a polygon shapefile. This shapefile should have the following properties:

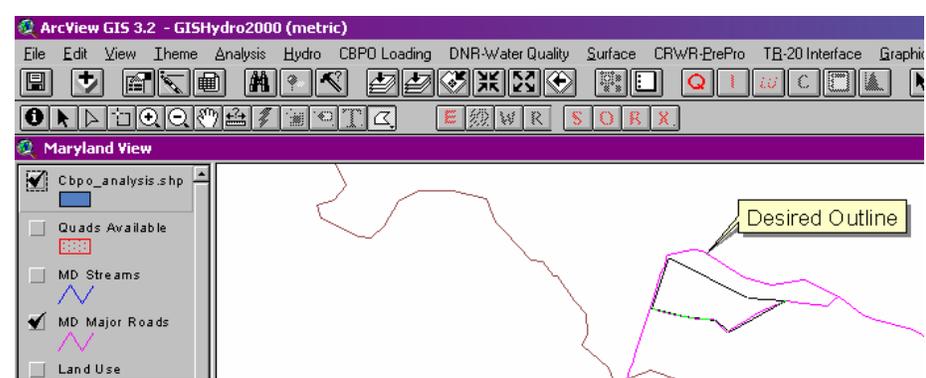
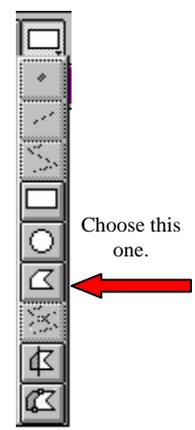
4. The file should be in the Maryland Stateplane projection, NAD 1983, in horizontal units of meters.
5. The file should contain one or more polygons that indicate boundaries over which current (and possibly future) nutrient load calculations are desired. If future nutrient loads are desired, each polygon should represent a single future land use.
6. In the attribute table:
 - a. There should be a field called "ID" with unique values for each record in the table.
 - b. (optional) If future nutrient loads are desired, there should be a field called "LU_New" that contains text descriptions of the land use that will appear in that polygon under post development conditions. (Spelling, capitalization, and spaces count!) A tool within GISHydro (illustrated below) will aide you in setting up this field and populating the table entries with allowable land uses.

Mechanics of GIS Preparation for Analysis

1. From the "Maryland View" of GISHydro2000, choose "View: New Theme...". You will be prompted with the dialog box shown at right. Click the down arrow and choose "Polygon" as shown. Click the OK button.
2. You will now be prompted to specify a path and name for the GIS theme you are creating. A sample dialog box is shown at right with the filename, "cbpo_analysis.shp" indicated. Click "OK" once you have specified your desired filename and path.

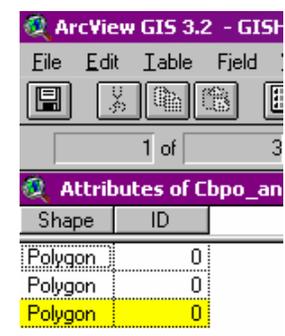


3. You will now see the theme you have indicated at the top of the table of contents of the "Maryland View" window. You are now ready to begin digitizing the polygons that cover your area of interest. You might find it helpful to zoom in to the scale of your study area using the navigation tools in ArcView, or you might want to load in additional GIS themes that will be helpful for placing your polygons. The default polygon to digitize is a rectangle, but more likely you will want to digitize an irregular polygon. Click *carefully* at the bottom right of the rectangle tool (you will see a small triangle there indicating a drop-down menu). When you click there the dropdown menu shown at right will appear. Select the irregular polygon tool from this list as indicated.
4. You are now ready to begin digitizing. A sample of the digitizing process

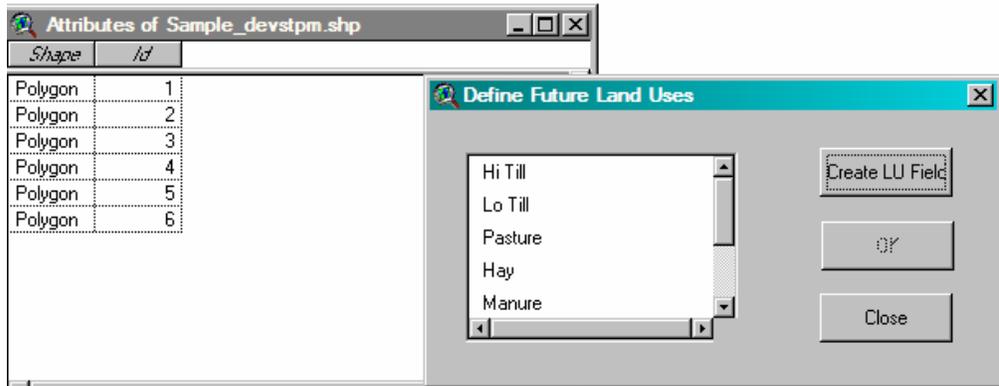


in action is shown above. When the entire polygon has been digitized as desired, double-click quickly on the last point to finish that polygon. Repeat as needed for all analysis areas.

5. With the polygon theme active, choose, "Theme: Table..." to open the attribute table of the polygon theme you have digitized. The last polygon you have digitized will be shown selected (in yellow highlight) as shown in the screen capture at right (I have digitized 3 polygons, though the process for doing this was only shown once). By default, all polygons are given ID=0. You can number you polygons using the data entry tool . Be sure to press the "Enter" key after your last entry to apply it. It is advisable to give each polygon area a unique ID (I will use 1, 2, and 3).

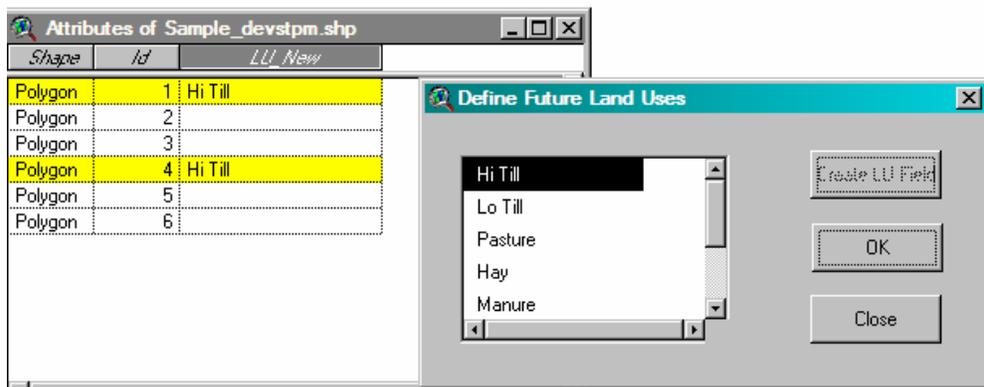


6. If you do not require calculations of future loadings, skip to Step 11.
7. (optional: to calculate future loadings) As indicated in the "General Information" section above, if you wish to specify new (future) land uses, you will need to add a field to the attribute table and specify these land uses. To do this, there is a GISHydro dialog tool to help you. With your polygon theme's table the active document, choose: "CBPO Loading: Define Land Uses" (*repeat*: the table *must* be active, not the view).



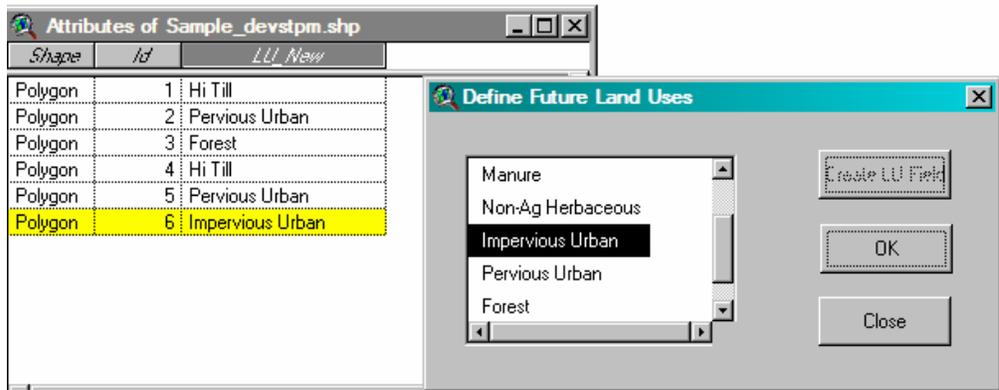
The “Create LU Field” button should be active (not grayed out) if you have not yet created an “LU_New” field. To create this field, simply click the “Create LU Field” button.

8. (optional: to calculate future loadings) With the “LU_New” field, created, you now must populate all records of the polygon attribute table with CBPO recognized land uses. To do this, select one or more records from the polygon attribute table using the select tool . To simultaneously select more than one record, hold down the shift key and click all records that you want to select. The “selected” property toggles, so clicking a



selected record unselects it if you accidentally select a record you don’t want to include. Once you’ve selected all the records in the table you want to assign a given land use, click the entry from the scrolling menu choices at the left of the dialog box (“Hi Till” is shown as selected in the figure above). Click the “OK” button to assign the selected land use to the selected records in the attribute table.

9. (optional: to calculate future loadings) Repeat step 8 until all records in the attribute table are populated such as shown in the figure at the top of the next page. If one or more records are not assigned a future land use, these records will not contribute to the calculated future loadings.



10. (optional: to calculate future loadings) When you are satisfied with all of your entries, click the "Close" button. You are now ready to begin a nutrient loading analysis with the file you have just created.
11. (continuing from Step 6) When you are satisfied with all of your entries, both to the spatial representation of all polygons and to the attribute table numbering, choose "Table: Stop Editing", then click on "Yes" to the "Save Edits?" question. You will see the field headings in your attribute table shift from regular to italics, indicating that the table is now closed to editing. *Note: You can always return to editing the table using "Table: Start Editing" if your attribute table is the active document or return to adding new polygons from the "Theme: Start Editing" if the view window is the active document.* You are now ready to begin a nutrient loading analysis with the file you have just created.

Appendix C: Defining BMPs in the Nutrient Loading Tool

This appendix presents a new GIS-based tool added to the GISHydro2000 program for working with BMPs in nutrient loading calculations. This tool works with the list of BMPs developed by the Department of Natural Resources (DNR) and the Maryland Department of the Environment (MDE) in cooperation with the US EPA's Chesapeake Bay Program Office (CBPO). Further, this tool is consistent with these agencies in its modeling approach to the application of BMPs as either additive or multiplicative in their performance. The details of this approach are defined in the next section.

How BMPs are modeled

Nutrient loading is modeled in GISHydro2000 in a manner consistent with and based upon the land uses and loading rates defined by the CBPO. Annual nutrient loads are calculated according the equation:

$$L_{i,j,k} = A_i \cdot R_{i,j,k} \quad (1)$$

Where L is the nutrient load (in lbs/year), A is the area of land in land use, i (in acres), and R is the loading rate [in lbs/(acre-year)]. The subscripts in the equation are i (denoting land use), j (denoting the spatial county segment, referred to as a "cosegment"), and k (denoting the specific nutrient: nitrogen, phosphorus, or sediment). Calculations in GISHydro2000 are organized such that any unique polygon being analyzed resides in only one cosegment, j , but may include multiple land uses, i . Calculations are performed for all three nutrients. If a user has specified a polygon that resides in more than one cosegment, that polygon will be split into two or more polygons, each of which resides in only a single cosegment.

BMPs act to reduce nutrient loading according to the following general equation:

$$\gamma_{i,k} = \alpha_{i,k} \cdot \beta_{i,k} \quad (2)$$

where γ is the total BMP reduction multiplier, α is the aggregate additive BMP factor and β is the aggregate multiplicative BMP factor. As with nutrient loading rates, BMP factors, and thus the overall BMP reduction factor, are a function of land use category and nutrient type.

The new loading achieved with the BMPs in place is simply the product of the BMP reduction multiplier and the loading calculated in equation 1:

$$(BL)_{i,j,k} = L_{i,j,k} \cdot \gamma_{i,k} \quad (3)$$

where BL is the BMP mediated loading and the other terms are as defined earlier. It is necessary to define how the aggregate additive and multiplicative factors are determined. The additive factor, α , is calculated as:

$$\alpha_{i,k} = 1 - \sum_{m=1}^n \frac{(A_{B,i})_m}{A_i} \cdot (\varepsilon_{i,k})_m \quad (4)$$

where $(A_{B,i})_m$ is the area of the m^{th} BMP applied to land use, i , (in acres), $(\varepsilon_{i,k})_m$ is the efficiency of the m^{th} BMP applied to land use, i , for nutrient, k (as a decimal fraction between 0 and 1), and n is the total number of additive BMPs applying to the particular land use. Similarly, the multiplicative factor, β , is calculated as:

$$\beta_{i,k} = \prod_{m=1}^n \left(1 - \frac{(A_{B,i})_m}{A_i} \cdot (\varepsilon_{i,k})_m \right) \quad (5)$$

where n is now the total number of multiplicative BMPs applying to the particular land use.

List of Available BMPs

GISHydro2000 has a default list of available BMPs from which the user can choose. This list is based on the set developed by DNR in consultation with the CBPO. This list is shown in Table 1.

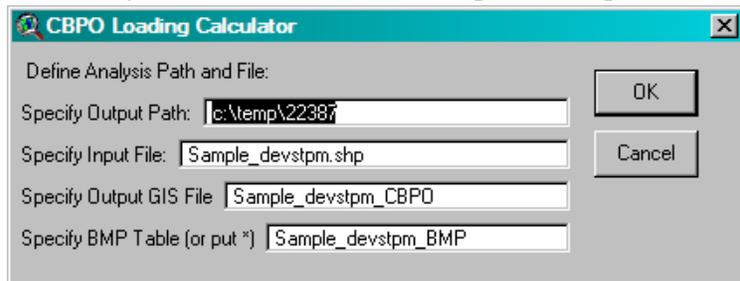
Table 1. List of default BMPs built into GISHydro2000.

Land Use	Name	Symbol	Add. or Mult.	BMP Efficiency		
				Nitrogen	Phosphorus	Sediment
Impervious Urban	Stormwater Management - New	SWM-New	+	40	60	0
Impervious Urban	Stormwater Management - Recent	SWM - Recent	+	33	46	0
Impervious Urban	Stormwater Management - Retrofits	SWM Retrofits	+	33	46	0
Impervious Urban	Erosion and Sedimentation Control	E&S Control	+	33	50	0
Pervious Urban	Stormwater Management - New	SWM-New	+	40	60	0
Pervious Urban	Stormwater Management - Recent	SWM - Recent	+	33	46	0
Pervious Urban	Stormwater Management - Retrofits	SWM Retrofits	+	33	46	0
Pervious Urban	Erosion and Sedimentation Control	E&S Control	+	33	50	0
Manure	Animal Waste Management Systems (livestock)	AWMSL	+	75	75	0
Manure	Animal Waste Management Systems (poultry)	AWMSP	+	30	30	0
Pasture	Stream Protection with fencing	SPWF	+	75	75	0
Pasture	Stream Protection without fencing	SPWOF	+	38	38	0
Pasture	Soil Conservation and Water Quality Plan Implementation	SCWQPI	x	12	17	0
Hi Till	Nutrient Management Plan Implementation	NMPI	x	30	20	0
Hi Till	Yield Reserve / Precision Agriculture	YR	x	26	17	0
Hi Till	Cover Crop	CC	x	58	0	0
Hi Till	Soil Conservation and Water Quality Plan Implementation	SCWQPI	x	12	17	0
Hi Till	Buffer Forested	BF	x	57	70	0
Hi Till	Buffer Grassed	BG	x	43	53	0
Hi Till	Retirement of Highly Erodible Land	RHEL	x	20	59	0
Lo Till	Nutrient Management Plan Implementation	NMPI	x	30	20	0
Lo Till	Yield Reserve / Precision Agriculture	YR	x	26	17	0
Lo Till	Cover Crop	CC	x	58	0	0
Lo Till	Soil Conservation and Water Quality Plan Implementation	SCWQPI	x	12	17	0
Lo Till	Buffer Forested	BF	x	57	70	0
Lo Till	Buffer Grassed	BG	x	43	53	0
Lo Till	Retirement of Highly Erodible Land	RHEL	x	20	59	0
Hay	Nutrient Management Plan Implementation	NMPI	x	30	20	0
Hay	Yield Reserve / Precision Agriculture	YR	x	26	17	0
Hay	Soil Conservation and Water Quality Plan Implementation	SCWQPI	x	12	17	0

Setting up a Loading Analysis

To use the CBPO loading tool, you must have shapefile in the format developed in Exercise 3 (from the January 2007 workshop – included here as Appendix D) loaded into the view window of GISHydro. By default, GISHydro will use the first shapefile (the topmost theme that ends with the name extension “*.shp”) that is loaded into the active view, although you can specify a different file from the view from the dialog box that is provided.

From the “CBPO Loading” menu, choose “Set Development File”. (Please note that this option will be grayed out unless you have loaded the development shapefile as described above.) After selecting this menu choice you will see dialog box shown at right.



The Entries:

- **Specify Output Path:** GISHydro will generate a suggested output path (e.g. “c:\temp\22387” as shown in the dialog) but you can modify to whatever you like so long as you retain the “c:\temp\” portion of the path.
- **Specify Input File:** In this example, GISHydro has detected the first shapefile called, “Sample_devstpm.shp”. If you wish to use a different input shapefile, you can modify this entry, but the changed entry must precisely match the name of another shapefile that is already loaded into the view.
- **Specify Output GIS File:** The next entry is the output shapefile *root* name (in this case “Sample_devstpm_CBPO”).
 - If you wish to have a different output root file name, you can modify this entry as you like.
 - If GISHydro detects the field “Lu_new” in the specified input file, GISHydro will create both a “current” and “future” output GIS shapefile with the root name indicated, otherwise only a “current” output GIS shapefile will be created.
 - The output file(s) will be written to the output directory path indicated in the top entry of the dialog box.

Specify BMP Table (or put *): The final entry specifies the name of a table that GISHydro will build interactively as you define the BMPs that will be applied to your analysis. The contents of this table will be described and illustrated in the next section. If you have an existing BMP table that you wish to apply to this analysis simply enter a “*” for this entry and you will be able to import the BMP table as a separate step. This import feature will be described and more fully in the “Importing a Pre-defined BMP scenario” section.

Once all entries are satisfactory, click the “OK” button. Once the “OK” button is clicked, GISHydro will generate an initial version of the specified output file. The output file will contain the same polygons as the input file, except they will be split along any differing CBPO county segments (cosegments). If you examine the attribute table, you will find a listing of the total acreage of each polygon, the county segment (“coseg”) it is located in, and the existing (or future) land uses that are present in that polygon.

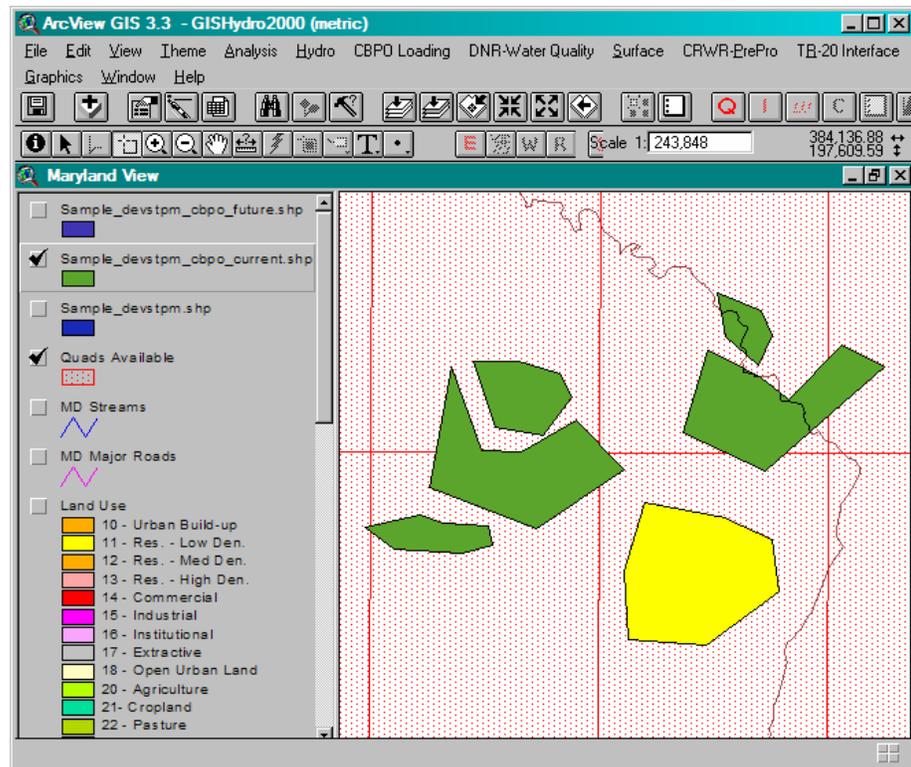
Using the Define BMP dialog

Before demonstrating how the BMP dialog works, it's important to understand the way in which BMPs are assumed to apply. The following assumptions apply to all BMPs that a user can specify:

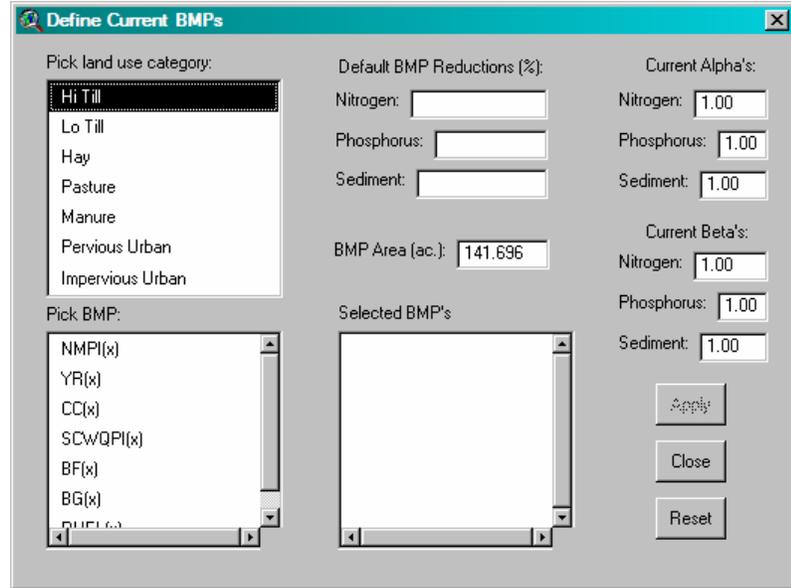
- BMPs are defined and applied one-by-one by individual land use categories and individual polygon areas.
- Users can only interactively specify BMPs that appear in Table 1. If users wish to apply other BMPs, they must be manually entered into an appropriately formatted BMP table and imported into GISHydro.
- The area that a BMP is applied to must be between 0 and A_i as defined in equation 1. If the user specifies an area smaller than 0, then 0 will be assumed. If the user specifies an area greater than A_i , then A_i will be assumed.

To begin defining BMPs, one (of the possibly two) output GIS file must be active (popped up) in the legend. Further, one (and only one) polygon from this active GIS file must be selected. The selected polygon will be the one for which the user is initially defining BMPs. An example of this condition is shown in the screen capture below. In this example the current condition shapefile called "Sample_devstpm_cbpo_current.shp" is shown active

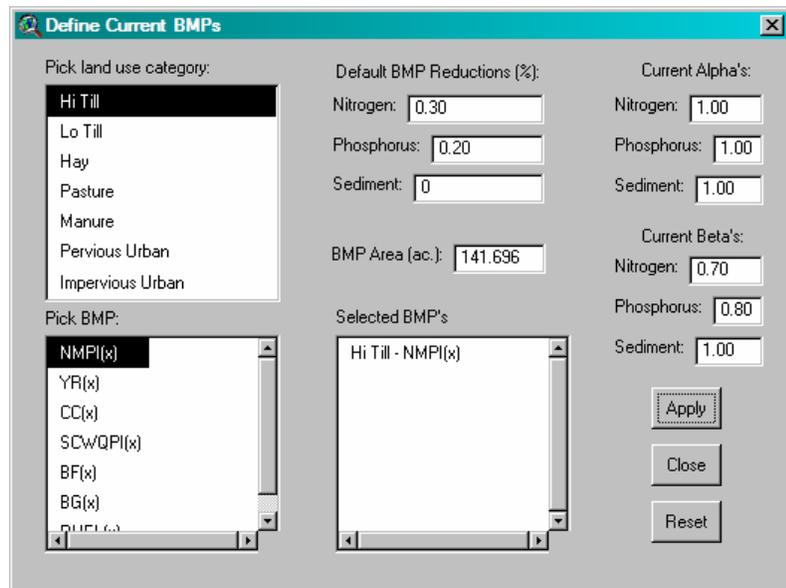
with one polygon selected (appearing in yellow). To select a polygon, set either the current or future development shapefile active (popped up) and then click on the "select feature" tool () and then click on the polygon you wish to select – it will turn yellow when it is selected.



To open the Define Current BMPs dialog choose: “CBPO Loading: Define BMPs”. The following dialog box will appear at right. The upper left box displays a list of detected land uses within the selected polygon to which a BMP can be applied. If you click on a land use category you will see that the lower left box will refresh and list the BMPs that can be applied to that land use. The item in parentheses – either “(+)” or “(x)” indicates whether that BMP is additive or multiplicative, respectively. When you select a land use, you will also note that the BMP Area entry updates. The area that appears will be the area in acres for the selected land use and polygon. You can modify this number as needed to reflect that area that will be managed by the BMP you are specifying. (Please be sure that the entry you leave in this box is a valid number – no text is allowed.)



In the dialog box at right, the “NMPI(x)” BMP (Nutrient Management Plan Implementation) has been selected and applied. Selecting a BMP will cause the Nitrogen, Phosphorus, and Sediment reduction efficiencies to update in the upper center of the dialog box. When the “Apply” button is pressed, you will see that the selected BMP is added to the lower center box of the dialog which lists all selected BMPs for the currently selected polygon. You will also note the α 's and β 's that are currently active for the land use indicated in the land use box.



Multiple BMPs can be applied to a single land use type. The dialog below shows the application of a second multiplicative BMP – “RHEL(x)” to the Hi Till land use. It’s reduction efficiencies are now shown in the upper center of the dialog and you should

note that the β values have updated at the right center of the dialog box to reflect the overall β values that apply to the Hi Till land use based on the application of these two BMPs to the entire Hi Till land use area within this polygon and the entry of the two different reduction efficiencies to equation 5.

The dialog box shown below illustrates the application of one more BMP to this

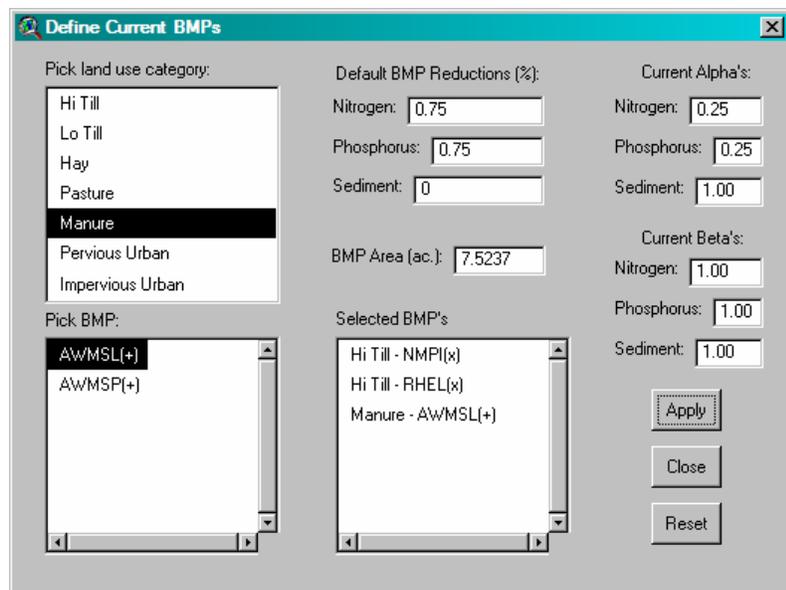
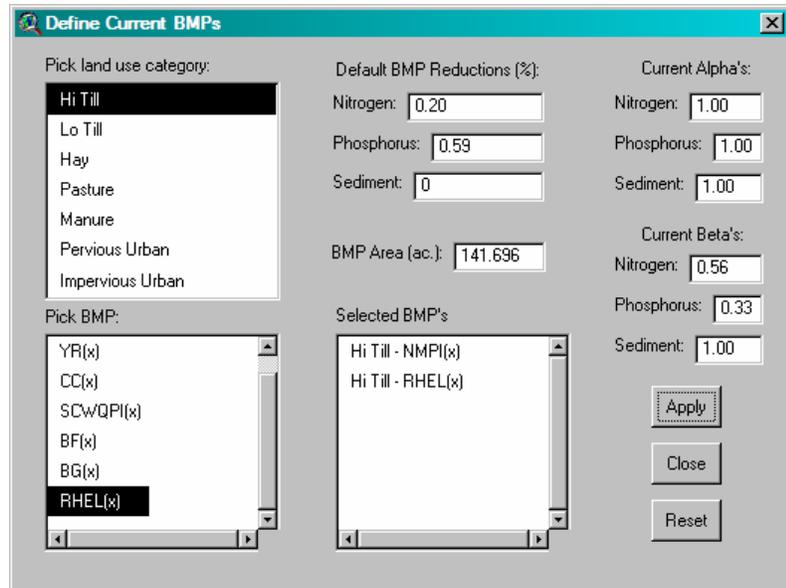
polygon. In this screen capture, the BMP, “AWMSL(+)” has been applied to the Manure land use. Note that the lower center box now reflects that three BMPs have been

specified overall to the selected polygon. The α 's and β 's, however, reflect only the current aggregate α 's and β 's that apply to the selected (Manure) land use.

To apply further BMPs to other polygons in the output GIS shapefile you can either press the “Close” button in the dialog box and then repeat the above process after selecting a new polygon in the output GIS shapefile, or just use the

“select feature” tool to select the new polygon directly (without closing the dialog) and then proceed as before. When you have defined all the BMPs for your analysis, you should press the “Close” button to exit the dialog.

It is now possible to review the BMP table that has been built interactively by the user in the example shown above. Goto the project window and click on the “Tables” icon to get a list of tables that are loaded into the GIS. The above example has involved developing BMPs for the “current” land use conditions so let’s examine the table called, “User-Defined Current BMP Table”. (Had we been working with the future land use shapefile, we would want to examine the table called, “User-Defined Future BMP Table”.) The “current” table is shown in the screen capture appearing below:



Poly_ID	Land_Use	BMP	tot_area	bmp_area	add_mult	nit_alpha	nit_beta	phos_alpha	phos_beta	sed_alpha	sed_beta
4	Hi Till	NMPI(x)	141.696	141.696	x	0.00	0.30	0.00	0.20	0.00	0.00
4	Hi Till	RHEL(x)	141.696	141.696	x	0.00	0.20	0.00	0.59	0.00	0.00
4	Manure	AWMSL(+)	7.524	7.524	+	0.75	0.00	0.75	0.00	0.00	0.00

The contents of the fields are as follows:

- Poly_ID: polygon identifier that corresponds to the polygon in the GIS shapefile called simply, "ID".
- Land_Use: this is the CBPO land use to which the BMP is being applied.
- BMP: this is the name of the BMP that is being applied.
- tot_area: this is the total area of the land use type listed earlier in the indicated polygon. This corresponds to A_i in equations 1, 4, and 5.
- bmp_area: this is the total area of the land use type listed earlier in the indicated polygon. This corresponds to $A_{B,i}$ in equations 4 and 5.
- add_mult: contains either a "+" indicating an additive BMP or a "x" indicating a multiplicative BMP
- nit_alpha: indicates the additive nutrient reduction efficiency (ε) for the specified BMP for nitrogen. This is set to 0 if the BMP is multiplicative.
- nit_beta: indicates the multiplicative nutrient reduction efficiency (ε) for the specified BMP for nitrogen. This is set to 0 if the BMP is additive.
- phos_alpha: indicates the additive nutrient reduction efficiency (ε) for the specified BMP for phosphorus. This is set to 0 if the BMP is multiplicative.
- phos_beta: indicates the multiplicative nutrient reduction efficiency (ε) for the specified BMP for phosphorus. This is set to 0 if the BMP is additive.
- sed_alpha: indicates the additive nutrient reduction efficiency (ε) for the specified BMP for sediment. This is set to 0 if the BMP is multiplicative.
- sed_beta: indicates the multiplicative nutrient reduction efficiency (ε) for the specified BMP for sediment. This is set to 0 if the BMP is additive.

Notice that in the above table the tot_areas and the bmp_areas are the same, this indicates that in all cases the specified BMP applies to the entire area of the land use. Also notice that only Poly_ID=4 has any specified BMPs. All other polygons in the development file are unmitigated.

Limitations of BMPs

Depending on the BMP areas and efficiencies selected, it is possible for the user to select multiple additive BMPs for a single polygon and land use and have the application of equation 4 yield α values that are less than zero. If this situation is encountered by the program, GISHydro will update the α value to zero. Because of the mathematical structure of equation 5, this equation cannot produce a negative β value.

If the user tries to specify a polygon – land use – BMP combination that has already been specified the dialog will allow this, but the new specified BMP will overwrite the previously specified settings.

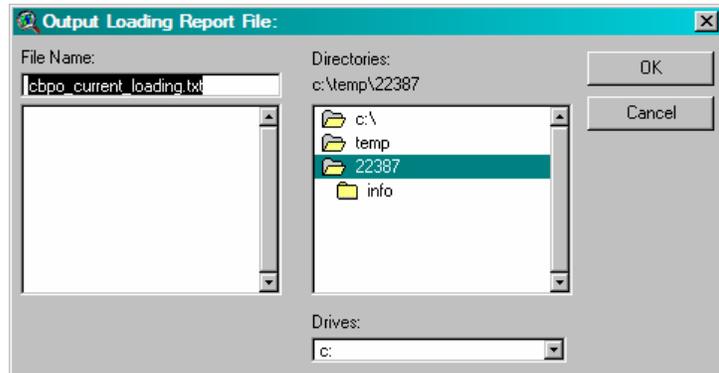
Finally, as stated earlier, the area that a BMP is applied to must be between 0 and A_i as defined in equation 1. If the user specifies an area smaller than 0, then 0 will be assumed. If the user specifies an area greater than A_i , then A_i will be assumed.

Nutrient Loading Reports and BMPs

Once all BMPs have been specified, the next step is to determine the corresponding nutrient loads. In the example being shown this document, we are working with current loads. Choose, “CBPO Loading: Calculate Current Load”. You will be prompted with a file

browser to specify the path and name of an output loading report file as shown at right. Indicate the desired file name and file path and click the “OK” button. A terse nutrient loading dialog summary will appear indicating only the non-BMP mitigated aggregate loads for the current analysis (not shown). Click the “OK”

button. The program will then output the nutrient loading file specified in the above file dialog. Let’s examine the contents of parts of that file as shown on the next page:



Defined BMPs



Unmitigated Loads



Nitrogen α 's



Nitrogen β 's



Mitigated Loads



cbpo_current_loading.txt - Notepad

File Edit Format View Help

Specified BMPs for current conditions

ID	COSEG	Land Use	BMP	Total Area	141.696	141.696	x	0	Add or Mult	0	Nitrogen Add	0
3	210024021	Hi Till	NMPI(x)	141.696	141.696	x	0	0.3	0	0	0.2	0
3	210024021	Hi Till	RHEL(x)	141.696	141.696	x	0	0.2	0	0	0.59	0
3	210024021	Manure	AwMSL(+)	7.524	7.524	+	0.75	0	0.75	0	0.75	0

Nitrogen Loading Rate Table in lbs/(acre-year)

COSEG	STSEG	hi_till	lo_till	hay	pasture	manure	forest	mixed_open	pervious_urban	imperv	
210024021	4210	27.9	22.2	7.8	11.4	1985.3	2.0	6.7	13.3	9.9	10.4
210024013	4210	27.9	22.2	7.8	11.4	1985.3	2.0	6.7	13.3	9.9	10.4

Nitrogen Loading Table in tons/year

ID	COSEG	hi_till	lo_till	hay	pasture	manure	forest	mixed_open	pervious_urban	imperv		
1	210024021	1.5	19.6	3.6	6.1	5.6	2.3	2.7	1.7	0.6	0	
2	210024013	4.8	4.7	0.9	1.5	1.0	0.3	1.3	0.2	0.1	0.0	
3	210024021	1.3	17.1	3.1	5.3	4.9	0.7	2.3	0.0	0.0	0	
4	210024021	2.0	26.3	4.8	8.2	7.5	3.0	3.6	0.0	0.0	0	
5	210024021	0.4	5.1	0.9	1.6	1.4	0.3	0.7	1.0	0.5	0	
6	210024021	0.5	6.4	1.2	2.0	1.8	0.9	0.9	1.3	0.6	0	
7	210024013	1.8	1.8	0.3	0.5	0.4	0.1	0.5	0.6	0.2	0	
8	210024021	0.0	0.5	0.1	0.2	0.2	0.0	0.1	0.6	0.3	0	
		12.3	81.6	14.9	25.5	22.7	7.7	12.1	5.4	2.3	0.1	184.5

Nitrogen aggregate alpha BMP values

ID	COSEG	hi_till	lo_till	hay	pasture	manure	forest	mixed_open	pervious_urban	imperv
1	210024021	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2	210024013	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
3	210024021	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
4	210024021	1.00	1.00	1.00	1.00	0.25	1.00	1.00	1.00	1.00
5	210024021	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
6	210024021	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
7	210024013	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
8	210024021	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Nitrogen aggregate beta BMP values

ID	COSEG	hi_till	lo_till	hay	pasture	manure	forest	mixed_open	pervious_urban	imperv
1	210024021	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
2	210024013	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
3	210024021	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
4	210024021	0.56	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
5	210024021	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
6	210024021	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
7	210024013	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
8	210024021	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00

Nitrogen Loading Table (with BMPs active) in tons/year

ID	COSEG	hi_till	lo_till	hay	pasture	manure	forest	mixed_open	pervious_urban	imperv		
1	210024021	1.5	19.6	3.6	6.1	5.6	2.3	2.7	1.7	0.6	0.0	
2	210024013	4.8	4.7	0.9	1.5	1.0	0.3	1.3	0.2	0.1	0.0	
3	210024021	1.3	17.1	3.1	5.3	4.9	0.7	2.3	0.0	0.0	0.0	
4	210024021	1.1	26.3	4.8	8.2	1.9	3.0	3.6	0.0	0.0	0.0	
5	210024021	0.4	5.1	0.9	1.6	1.4	0.3	0.7	1.0	0.5	0.0	
6	210024021	0.5	6.4	1.2	2.0	1.8	0.9	0.9	1.3	0.6	0.0	
7	210024013	1.8	1.8	0.3	0.5	0.4	0.1	0.5	0.6	0.2	0.0	
8	210024021	0.0	0.5	0.1	0.2	0.2	0.0	0.1	0.6	0.3	0.0	
		11.4	81.6	14.9	25.5	17.1	7.7	12.1	5.4	2.3	0.1	178.0

The circled items (from top to bottom) correspond to:

- The unmitigated total nitrogen load in tons/year
- The nitrogen a value for the manure land use (the column looks like it's forest, but this is a tab delimited file which is difficult to read in a simple text editor, but will orient fine if imported into an Excel spreadsheet.)
- The nitrogen b value for the hi_till land use.
- The mitigated total nitrogen load in tons/year (note that the specified BMPs have reduced the loading from 184.5 to 178.0 tons/year).

Importing a Pre-defined BMP scenario

If BMPs have been previously defined and are to be used again in subsequent analyses, then the user can simply import this file (or these files if future conditions are to be modeled) into the analysis without having to redefine BMPs. To do this, first indicate an "*" for the BMP Table name in the initial dialogue. Once you've passed this dialog, choose: "CBPO Loading: Import BMP File(s)". You will be prompted to input one or two *.dbf files that correspond to the same development file(s) you are already working

with. Continue normally as before. You may use the dialog to define additional BMPs not included in the original imported *.dbf file.

Note that since the BMP tables are just *.dbf files, these files can be edited manually in Microsoft Excel and then re-imported into ArcView. Be sure to adhere to the formatting style of these files and that all entries are correctly filled out. I suggest that you build examples files (*.dbf) of all possible BMPs using the tool and then follow the entries in these example files if you plan to do substantial manual editing of your BMP tables.

Appendix E. Exercises for the CBPO Nutrient Loading Interpolator Workshop Held January 11, 2007 (revised January 16, 2007)

Exercise 1: Navigating and File Basics in ArcView

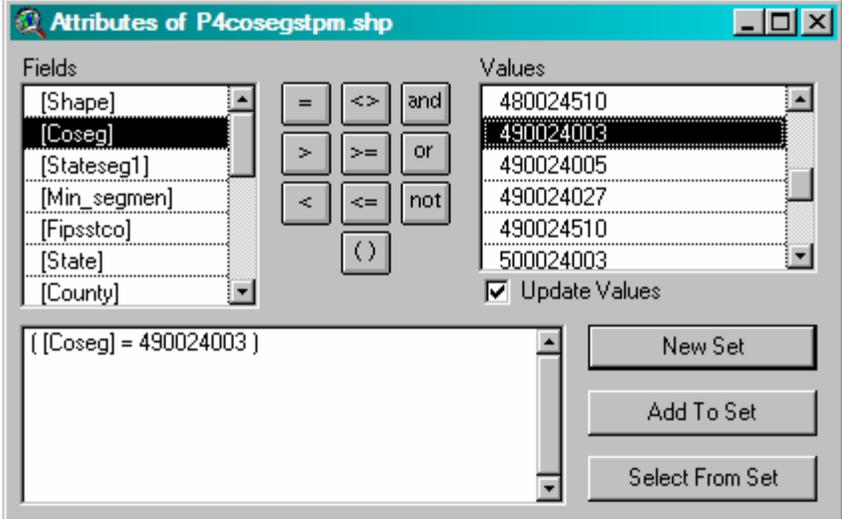
1. Start up GISHydro. You can either click on the GISHydro2000 icon on the computer desktop or open the file from
c:\umdgism\mdinterface\gishydrometric.apr
2. Review ArcView Basics at end of this document for information on using the basic tools provided by the GIS for navigating.
 - a. Play with the navigation tools to zoom in, zoom out, pan, etc.
 - b. Practice clicking on several theme legends to control which themes are visible, active, and the order of theme appearance on the screen.
 - c. For practice, set the “MD Counties” theme active. Use the “select feature” tool  to select a county of your choice. Now click on the “zoom to selected” button  and see how the view zooms to the extents of the county you have selected.
3. Loading themes: there are two directories within GISHydro that contain many GIS themes relevant to the State of Maryland. Please look at the contents of the c:\umdgism\maryland directory and the c:\umdgism\cbpo directory. To load a theme you can either choose: “View: Add theme...” or click on the add theme button . You can examine any of the themes in either directory, but here are a few specific suggestions:
 - a. Load in one or more vector data themes. Vector data themes contain information that is composed of points, lines, or polygons. The following themes are good examples of each:
 - i. Point: c:\umdgism\maryland\usgsgagesm.shp: this theme contains the point locations and attributes of all USGS stream gages in and around the state of Maryland.
 - ii. Line: c:\umdgism\maryland\nhd_streams.shp: this theme contains the 1:100,000 scale USGS digitized blue lines from the National Hydrography Dataset (NHD).
 - iii. Polygon: c:\umdgism\cbpo\P4cosegstpm.shp: this theme shows all the CBPO Phase 4 modeling cosegments that intersect with the State of Maryland.
 - b. Load in Raster Data: Raster (or “grid”) data is information that is represented by a set of pixels (generally 30m by 30m within GISHydro). Common examples of raster data include topography (DEMs: digital elevation maps), and land use.
 - i. As an example, click on the add theme button. In the lower left hand corner of the “Add Theme” dialog box under “Data Source Type:” choose: “Grid Data Source”.
 - ii. Use the dialog box to navigate/select the land use from year 2000: c:\umdgism\maryland\lu2000stpm

4. Examine a theme table: every theme that you can look at in a view (spatial representation) can also be examined for its attribute data (tabular representation).
 - a. In the legend, click on any theme's legend entry to make it active, then either choose: "Theme: Table..." or click on the "open table" button . This will open the table for that theme.
 - b. Repeat for several themes. Note differences in how each theme contains varying tabular information. Note the style and content differences between vector and raster data tables.
 - c. Click on a specific row (record) of the table. The GIS indicates a record is selected by turning it yellow.
 - d. Experience the spatial/table linkage of GIS themes:
 - i. Make only one theme visible (for example, the P4cosegstpm.shp theme). Zoom to the full extents of that theme by clicking on the "zoom to active theme" button . Open the table for this theme. Choose, "Window: Tile" to simultaneously have both the View and the Table visible.
 - e. Click on a record in the table to select that record. Notice that somewhere in the view, a cosegment will be selected (turn yellow). Click on different records and see how the selected cosegment changes in the view.
 - f. Now use the select feature tool (see step 2c of this exercise) to select different cosegments in the view. Notice that the table record for each selected segment turns on/off as you click in the view.

Exercise 2: Examining CBPO Land Cover, Land Area Segmentation, Land Use Disaggregation

1. Load in the Phase 4 cosegment theme: c:\umdgism\cbpo\p4cosegstpm.shp. See Exercise 1, Step 3a(iii) for details.
2. Open the table associated with this theme. See Exercise 1, Step 4a for details.
3. Locate the record associated with cosegment = 490024003. This can be done quickly by building a query. With the theme table active, click on the “Query

Builder” button . This will bring up the Query Builder dialog box shown below. Build the following query, “[Coseg]=490024003” as shown in the dialog below. You can either type this query string in manually or use the controls at the top of the dialog box to do the whole thing. After you’ve built the query, click on the “New Set”



- button to select all records that satisfy this query (there will be one such record located in northern Anne Arundel county).
4. Use the horizontal scroll bar at the bottom of the table. Scroll over to the right hand end of the table. The records from “Phi_till” to “Pmanure” provide the decimal fraction of all agricultural census disaggregation coefficients for converting the herbaceous land *cover* into the land *use*.
 5. Now select all Anne Arundel county cosegments. This will be any cosegment with Fipsstco = “24003” or County = “Anne Arundel”. Build either query and click “New Set”. There should be 7 such records. You can quickly group and bring all these selected records to the top of the table using the “Promote” button .
 6. Examine the “Phi_till” through “Pmanure” records. You should see that all selected records have the same land use disaggregation (to the nearest thousandth). This is because the ag census data is provided at the county-level of detail, so all cosegments in the same county are disaggregated the same way.
 7. Select a different county and note how the disaggregation coefficients vary.

Exercise 3: Preparing a File for Nutrient Loading Analysis

File Preparation

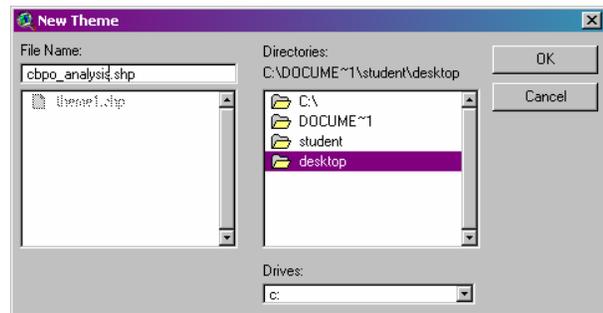
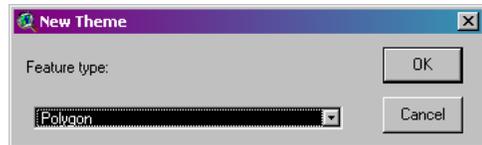
General Information/Rules

To use the Nutrient Loading Interpolator, you must create a polygon shapefile. This shapefile should have the following properties:

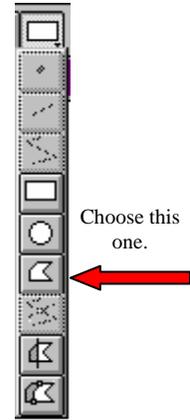
7. The file should be in the Maryland Stateplane projection, NAD 1983, in horizontal units of meters.
8. The file should contain one or more polygons that indicate boundaries over which current (and possibly future) nutrient load calculations are desired. If future nutrient loads are desired, each polygon should represent a single future land use.
9. In the attribute table:
 - a. There should be a field called "ID" with unique values for each record in the table.
 - b. (optional) If future nutrient loads are desired, there should be a field called "LU_New" that contains text descriptions of the land use that will appear in that polygon under post development conditions. (Spelling, capitalization, and spaces count!) A tool within GISHydro (illustrated below) will aide you in setting up this field and populating the table entries with allowable land uses.

Mechanics of GIS Preparation for Analysis

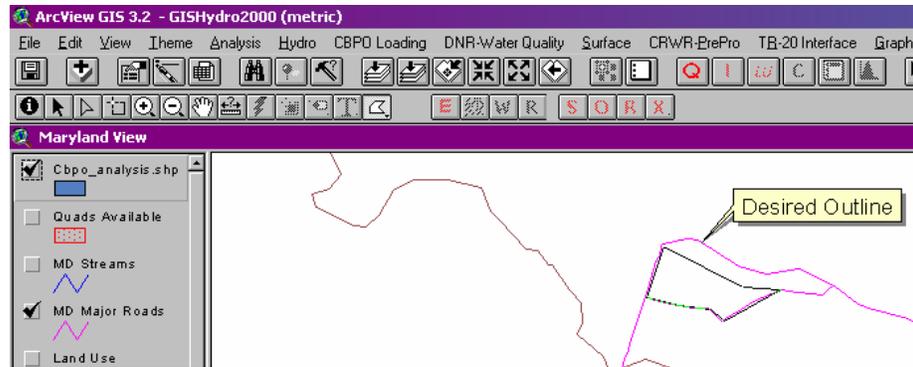
8. From the "Maryland View" of GISHydro2000, choose "View: New Theme...". You will be prompted with the dialog box shown at right. Click the down arrow and choose "Polygon" as shown. Click the OK button.
9. You will now be prompted to specify a path and name for the GIS theme you are creating. A sample dialog box is shown at right with the filename, "cbpo_analysis.shp" indicated. Click "OK" once you have specified your desired filename and path.



10. You will now see the theme you have indicated at the top of the table of contents of the "Maryland View" window. You are now ready to begin digitizing the polygons that cover your area of interest. You might find it helpful to zoom in to the scale of your study area using the navigation tools in ArcView, or you might want to load in additional GIS themes that will be helpful for placing your polygons. The default polygon to digitize is a rectangle, but more likely you will want to digitize an irregular polygon. Click *carefully* at the bottom right of the rectangle tool (you will see a small triangle there indicating a drop-down menu). When you click there the dropdown menu shown at right will appear. Select the irregular polygon tool from this list as indicated.

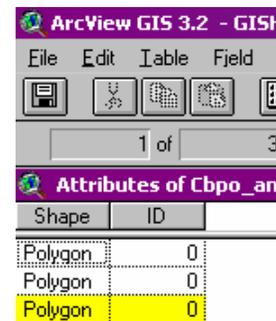


11. You are now ready to begin digitizing. A sample of the digitizing process



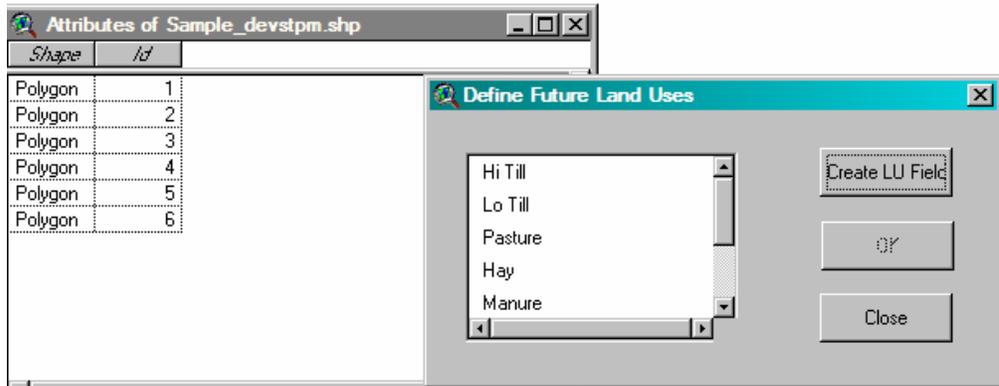
in action is shown above. When the entire polygon has been digitized as desired, double-click quickly on the last point to finish that polygon. Repeat as needed for all analysis areas.

12. With the polygon theme active, choose, "Theme: Table..." to open the attribute table of the polygon theme you have digitized. The last polygon you have digitized will be shown selected (in yellow highlight) as shown in the screen capture at right (I have digitized 3 polygons, though the process for doing this was only shown once). By default, all polygons are given ID=0. You can number you polygons using the data entry tool . Be sure to press the "Enter" key after your last entry to apply it. It is advisable to give each polygon area a unique ID (I will use 1, 2, and 3).



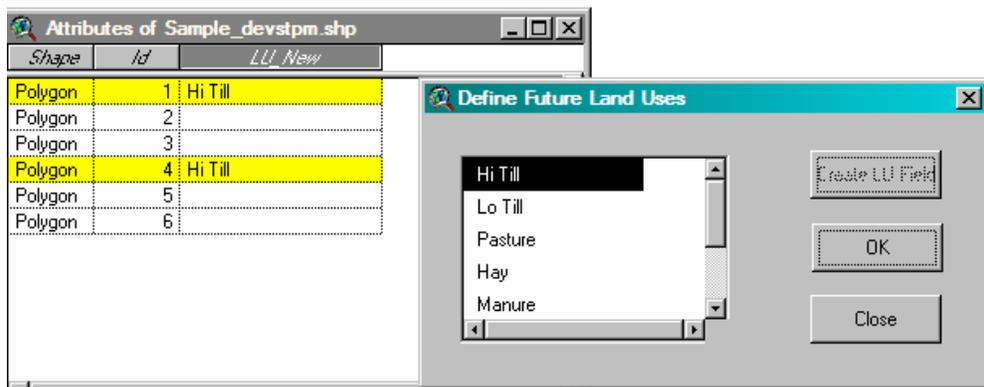
13. If you do not require calculations of future loadings, skip to Step 11.

14. (optional: to calculate future loadings) As indicated in the "General Information" section above, if you wish to specify new (future) land uses, you will need to add a field to the attribute table and specify these land uses. To do this, there is a GISHydro dialog tool to help you. With your polygon theme's table the active document, choose: "CBPO Loading: Define Land Uses" (*repeat*: the table *must* be active, not the view).



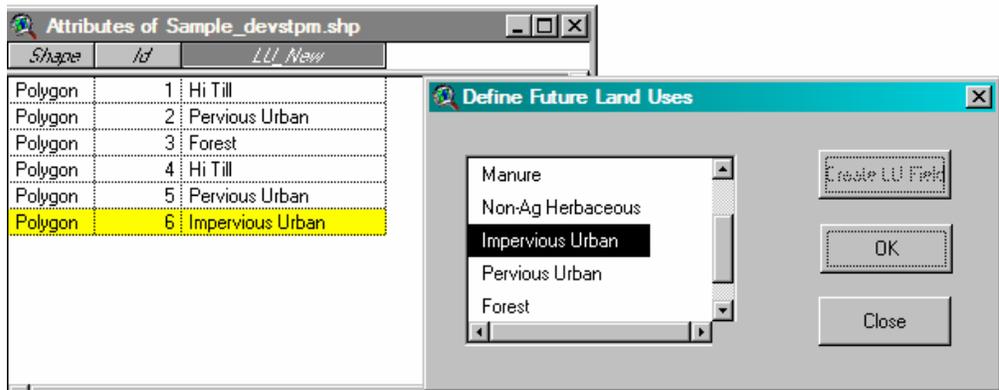
The “Create LU Field” button should be active (not grayed out) if you have not yet created an “LU_New” field. To create this field, simply click the “Create LU Field” button.

12. (optional: to calculate future loadings) With the “LU_New” field, created, you now must populate all records of the polygon attribute table with CBPO recognized land uses. To do this, select one or more records from the polygon attribute table using the select tool . To simultaneously select more than one record, hold down the shift key and click all records that you want to select. The “selected” property toggles, so clicking a



selected record unselects it if you accidentally select a record you don’t want to include. Once you’ve selected all the records in the table you want to assign a given land use, click the entry from the scrolling menu choices at the left of the dialog box (“Hi Till” is shown as selected in the figure above). Click the “OK” button to assign the selected land use to the selected records in the attribute table.

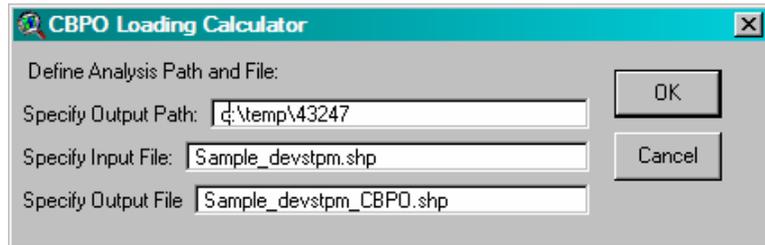
13. (optional: to calculate future loadings) Repeat step 8 until all records in the attribute table are populated such as shown in the figure at the top of the next page. If one or more records are not assigned a future land use, these records will not contribute to the calculated future loadings.



14. (optional: to calculate future loadings) When you are satisfied with all of your entries, click the "Close" button. You are now ready to begin a nutrient loading analysis with the file you have just created or with one provided with the workshop. ***Skip to Exercise 4.***
15. (continuing from Step 6) When you are satisfied with all of your entries, both to the spatial representation of all polygons and to the attribute table numbering, choose "Table: Stop Editing", then click on "Yes" to the "Save Edits?" question. You will see the field headings in your attribute table shift from regular to italics, indicating that the table is now closed to editing. *Note: You can always return to editing the table using "Table: Start Editing" if your attribute table is the active document or return to adding new polygons from the "Theme: Start Editing" if the view window is the active document.* You are now ready to begin a nutrient loading analysis with the file you have just created or with one provided with the workshop. ***Continue to Exercise 4.***

Exercise 4: Performing a Nutrient Loading Analysis

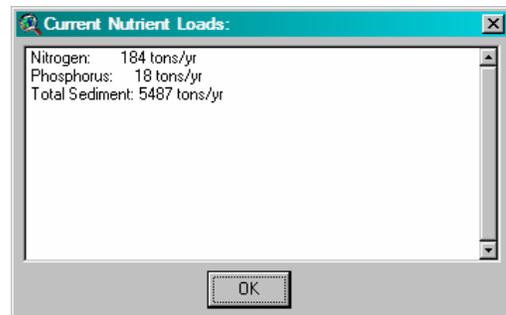
1. **Before doing the analysis:** To use the tool, you must have shapefile in the format developed in Exercise 3 loaded into the view window of GISHydro. By default, GISHydro will use the first shapefile (the topmost theme that ends with the name extension “*.shp”) that is loaded into the active view, although you can specify a different file from the view from the dialog box that is provided. You can use either your own shapefile developed in Exercise 3 or you can download a sample shapefile (sample_devstpm.shp) for analysis from the workshop webpage.
2. **Setting the Development File:** From the “CBPO Loading” menu, choose “Set Development File”. (Please note that this option will be grayed out unless you have loaded the development shapefile from Step 1 above.) After selecting this menu choice you will see dialog box shown at



right. GISHydro will generate a suggested output path (e.g. “c:\temp\43247” in the above dialog) but you can modify to whatever you like so long as you retain the “c:\temp\” portion of the path. In the above example, GISHydro has detected the first shapefile called, “Sample_devstpm.shp”. If you wish to use a different input shapefile, you can modify this entry, but the changed entry must precisely match the name of another shapefile that is already loaded into the view. The last entry is a suggested output file shapefile name (in this case “Sample_devstpm_CBPO.shp”). You can change this entry to anything you like. The output file will be written to the output directory path indicated in the top entry of the dialog box. Once all entries are satisfactory, click the “OK” button.

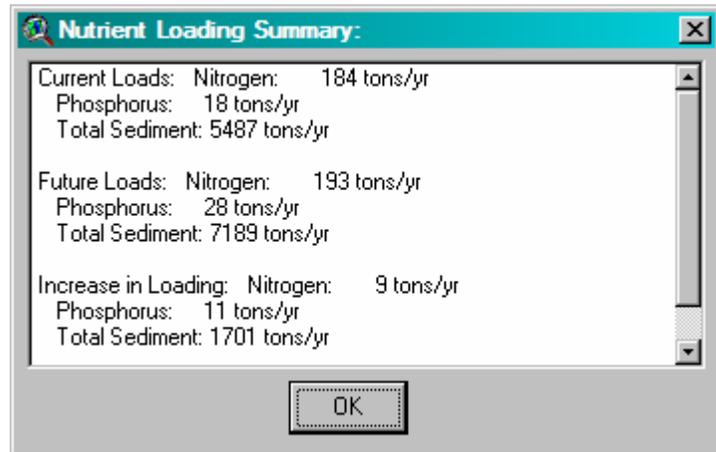
Once the “OK” button is clicked, GISHydro will generate an initial version of the specified output file. The output file will contain the same polygons as the input file, except they will be split along any differing CBPO county segments (cosegments). If you examine the attribute table, you will find a listing of the acreage of each polygon, the county segment (“coseg”) it is located in, and initially zero entries for all remaining attributes.

3. **Calculating Current Nutrient Loads:** After the development file has been set, you will find that the “Calculate Current Load” menu choice is selectable. Choose this item. GISHydro will now determine the nutrient loads (Nitrogen, Phosphorus, and Total Sediment) over all the polygons indicated in the development file. Depending on the number and size of polygons selected,



this step may take just a few seconds or several minutes. When calculations are completed, a dialog box will be displayed indicating the overall loads determined. A sample output dialog is shown on the previous page. This is a very plain, general output box. For more detailed analysis of the results, you will need to examine the attribute table of the output shapefile or (better yet) use the report file that is also output with this step. This report file provides individual nutrient loading values for each polygon in the original development shapefile. You will be prompted by the GIS to specify a report file name. The report file can then be opened using a text editor (e.g. Word or Notepad) but it is probably best to open this file from within Excel (this is the subject of Exercise 5, below).

4. **Calculating Future Nutrient Loads:** Assuming an attribute field called "LU_New" appears in the original development shapefile, the "Calculate Future Load" menu choice will become selectable after the current loads have been calculated as described above. A similar dialog box to the one under "Calculate Current Load" will appear as shown to the right. The output repeats the current loading values, presents the future loading



estimates, and indicates the calculated increase (if values are positive as they are here) in loading in moving from current to future conditions. (A negative value would indicate a projected decrease in loading resulting over the development area.). As above for the current loads, you will be prompted for the name of an output report file for the future loads.

Exercise 5: Report Writing: Examining Analysis Output

The output files created by the “CBPO Loading: Calculate Current Load” or “CBPO Loading: Calculate Future Load” menu choices can be opened in Excel. Tools within Excel can be used for subsequent calculations, graphing, etc.

1. Open Excel.
2. Within Excel, choose: “File: Open...”. You will get a browser dialog. Provide the correct path and filename to the output file created earlier in this step (remember that *.txt files will not be visible by default). Once the file is correctly selected, click on the “Open” button.
3. A text import wizard dialog will appear. All defaults should work fine for this file. Simply click the “Finish” button.
4. If examining the current loading file, the content of the file is as follows:
 - a. Detected current land cover distribution (by polygon ID) in acres.
 - b. Derived current land use distribution (by polygon ID) in acres.
 - c. For nutrients Nitrogen, Phosphorus, and Sediment, respectively
 - i. Nutrient loading rates in lbs/(acre-yr) for each land use (by cosegment).
 - ii. Nutrient loads in tons/year for each land use (by polygon ID).
5. If examining the future loading file, the content of the file is as follows:
 - a. User-defined future land use distribution (by polygon ID) in acres.
 - b. For nutrients Nitrogen, Phosphorus, and Sediment, respectively
 - i. Nutrient loading rates in lbs/(acre-yr) for each land use (by cosegment).
 - ii. Nutrient loads in tons/year for each land use (by polygon ID).
6. Because of the size of the cosegment identification numbers, you should resize columns A and B of the excel file to have a width of 9 or greater. You can now use Excel to manipulate or perform subsequent calculations based on the nutrient loading data.
7. Graphing and other analysis tools within Excel can also be used to graphically visualize the derived nutrient loading output.

Exercise 6: File Upload/Download within the GISHydro Web Server

GISHydro2000 functionality can be obtained in stand-alone form by downloading the GISHydro program from the download page at:

http://www.gishydro.umd.edu/download_sign_in.asp

The stand-alone program is available for download at no cost but you must have your own version of ArcView (version 3.2 or greater with the Spatial Analyst v1.1 extension) in order to use the program.

Alternatively, you can access the GISHydro2000 through a Web Server version at no cost. To do this, you must contact Glenn Moglen (moglen@umd.edu) for an account and a small (free) plug in program must be installed on each machine from which you plan to access the web server. More information on how to obtain web server access is available at:

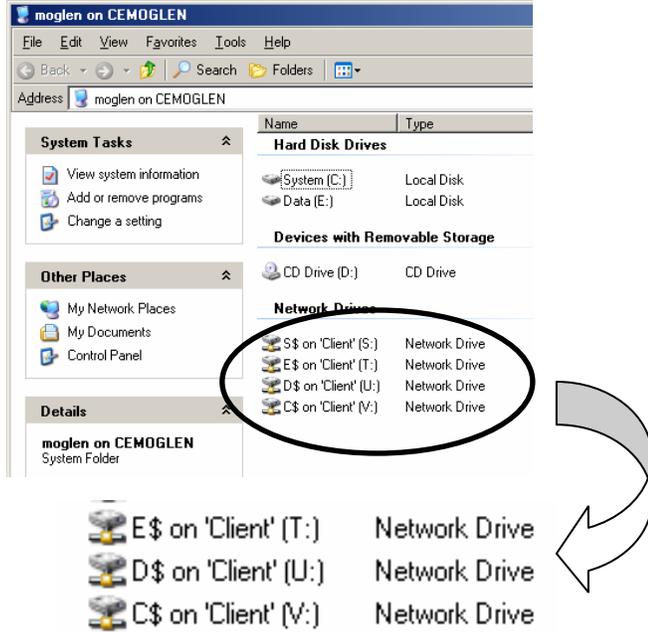
<http://www.gishydro.umd.edu/web.htm>

The following is short exercise showing how you can upload/download files to/from the GISHydro web server.



1. Log into the web server.
2. Click on the “Windows Explorer” icon shown circled above.
3. You will then get the Citrix “Client File Security” Dialog shown at left. Under the question, “What access do you want to grant?”, choose “Full Access” as shown. Then click “OK”.

4. You will see the windows explorer application appear as shown at right.
5. When working on the server, you should confine your activities to the “e:\temp\” directory, for example setting up a directory with your last name. In my case that would be: “e:\temp\moglen”.
6. Notice that the lower part of the windows explorer application shows “Network Drives” (circled and blown up at right). These are the drives on your local machine



(the machine you are accessing the web server from). For instance, the drive labeled “D\$ on ‘Client’ (U:)” is physically the “d:” drive on my laptop, but windows explorer, from the perspective of the web server, sees it as the “u:” drive. Using the windows explorer application shown above. If I had a file (or files) on my laptop’s “d:” drive that I wanted to upload to the web server, I could simply use windows explorer to cut/paste them. Here’s how.

- a. From the web server’s windows explorer application, navigate to the laptop “d:”drive (seen by the server as network drive “u:”).
- b. Select the file (or files) to be copied. Type <Ctrl>-c to copy.
- c. From the web server’s windows explorer application, navigate to “e:\temp\moglen”. Type <Ctrl>-v to paste. The files are now uploaded to the server.
- d. Reverse the operation to download files created by the GISHydro web server to your local machine.

*Hint: close **all** other windows explorer applications that might be running on your local machine before starting. The copy/paste processes must be done **only** using windows explorer running on the web server.*

Using this approach, you can upload GIS shapefiles (such as those created in Exercise 3) from your local machine to the server for analysis. Also, you can download files created by GISHydro2000 web server (such as the modified GIS shapefile created during Exercise 4 or the Nutrient Loading Report File also created in Exercise 4 (Step 4) and used in Exercise 5).

Appendix E: Memoranda

Memorandum 1: Summary Meeting held at Maryland Department of the Environment Glenn E. Moglen - June 9, 2006 (revised August 29, 2006)

Attending: Kevin Coyne (DNR), Richard Eskin, Jim George, David Guignet, Glenn Moglen, Key Pensyl, Marya Levelev, Steve Luckman, Yen-Der Cheng and Mary Dela Dewa.

The meeting began with brief introductions. Glenn Moglen (the PI) then provided a summary of the GISHydro program's history:

- GISHydro was originally developed by Bob Ragan at the University of Maryland under funding from SHA.
- Glenn Moglen took over the GISHydro project in 1996 and converted the program to the current ArcView GIS platform.
- Major recent developments in the program and funding history include
 - In 2005 MDE funding allowed for the purchase of software and hardware to support a web-based version of this program which is available to anybody requesting access at no charge. Please see: <http://www.gishydro.umd.edu/web.htm>
 - In 2005 DNR (Coastal Zone) funded a project undertaken by Glenn Moglen and Michael Paul (a sub-contractor at Tetra-Tech) to add the EPA PLOAD tool and stream biodiversity tools into GISHydro.
 - In 2006 conversations between Glenn Moglen, Jim George (MDE), and Helen Stewart (DNR) have led to follow-on projects to the 2005 DNR project to expand the tools developed. The emphases of these follow-on projects are:
 - Compatibility/consistency with the EPA Bay Program modeling
 - Development of a tool that produces nutrient loads for the Maryland 8-digit and 12-digit watersheds
 - Development of a tool that produces nutrient loads for political boundaries (Maryland counties)
 - Development of a tool that produces nutrient loads for user-delineated watersheds
 - Development of enhanced tools for defining BMPs.

After the summary, a general discussion followed. Two important points about what the tool is and is not:

- The tool *is* an objective, consistent, reproducible method for assessing land use change based nutrient loadings in Maryland. Above all, it is an “accounting system” that generates estimates of changes in nutrient loading that the entity proposing the land use change is responsible for. This accounting system is consistent with predictions from the EPA Chesapeake Bay program loadings and

will include pre-determined loading rates for all types of planned land development.

- The tool *does not* make predictions of actual loadings or concentrations that can be observed in the field. The loadings it predicts are on an annual basis and are oriented towards helping MDE achieve its regulatory objective of improving water quality, especially in impaired streams/rivers.

Glenn Moglen then reviewed a small handout provided for this meeting (attached as an appendix to this document). The review included a demonstration of the GISHydro software executing the EPA PLOAD program to estimate nutrient loading. The demonstration focused on the same location as in the handout but also included a brief demonstration of the existing BMP tools.

Planned Changes to GISHydro Program for this MDE Project

Coming out of the demonstration, several changes are needed to make the tool developed in GISHydro meet the specifications identified earlier in the meeting:

1. The EPA Phase 5 land cover database will need to be integrated into GISHydro. The example demonstration used the Maryland Office of Planning database for illustrative purposes.
2. The PI will need to codify the EPA Bay program approach for converting land *cover* to land *use* (since loading coefficients are based on land use, not land cover).
3. The PI will need to determine loading coefficients for all land use types. The PI's current plan is to develop coefficients that vary spatially according to the "state-segments" defined by the Bay program. This will result in a tool that produces loading estimates that are consistent with the Bay Model at the land-river segment scale (this is generally smaller than the scale of individual counties). At present, the plan is to develop coefficients for total nitrogen, total phosphorus, and total sediment.
4. The PI will need to develop a list of pre-determined loading rates for a suite of possible land use choices. For instance residential land uses of various densities, commercial, and industrial land uses. The PI can develop a preliminary list for tool development, but the finalized list and associated loading coefficients will represent policy developed by MDE. Changes to land use can be indicated two ways:
 - a. Changed land use polygons can be digitized on-screen with the new land use selected from a drop-down menu choice in the "modify land use" tool so that users will be constrained to specify simply a land use type. This will then determine the associated loading coefficients.
 - b. An alternative method to manually digitizing changed land use polygons will be for the user to provide a GIS shapefile with polygons indicating locations of changed land use and having attribute information that indicates the new land use. The PI will need to specify the precise format of this shapefile.

Input from MDE on this item is helpful.

5. Similar to item 4, the PI will need to develop a pre-determined list of BMPs, or levels of urban stormwater treatment associated with meeting the minimum required level of stormwater management. Again, the PI can develop a preliminary list, but the finalized list and associated nutrient reduction efficiencies will represent policy developed by MDE. Again, users will be constrained to specify a BMP type from a drop-down menu list, which will then determine the associated nutrient reduction characteristics. *Input from MDE on this item is helpful.*

Related to item 3 above, there was some discussion at the meeting about which EPA model run would be used to develop the nutrient loading coefficients. The Bay program has produced many different scenarios, each with their own unique output (and resulting loading coefficients). For example there is a “calibration” run and a “no-BMP” run. The preliminary decision was made to use the “calibration” run for generating nutrient loading coefficients. This issue must be re-visited relative to the intended use of the tool.

Data MDE needs to supply to Glenn Moglen

- A GIS file of the 12-digit watersheds in Maryland (Note: this has been done.)
- Information concerning the following for a large scale planned development (Terrapin Run) in Maryland to be used as a test case:
 - Spatial extent (a shapefile of the spatial extent would be best)
 - Planned new land use(s)(Note: this information was conveyed to the PI at technical meeting 2.)

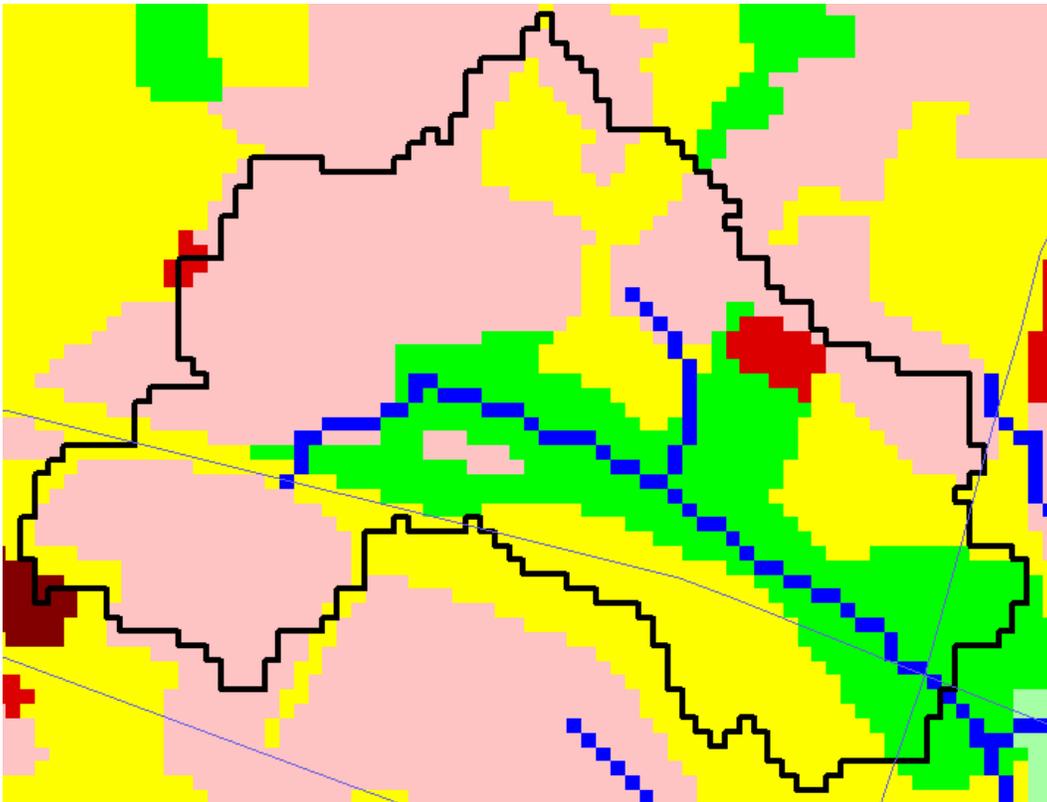
Outstanding Issues:

- **What values are to be used for developing loading coefficients for item 3?** Jim George wrote, “Glenn: That later statement isn’t accurate. If the model was calibrated using 1999 & 2000 data, then it would reflect observed data in 1999 & 2000, which wouldn’t be reasonable/defensible if the tool is used to compute the best estimate of “current” loads. It isn’t even clear that using “current” loads is appropriate, for reasons I could explain. We need to discuss this further.”
- **What test case data would be both useful (and possible) to examine?** Jim George wrote, “Glenn: I’ve been told that we can’t use Blackwater for this. We might, however, approach Worcester County if you and the County are interested.” Data from Terrapin Run has not been obtained.

Appendix
An Example Nutrient Loading Analysis for a Small Commercial Development
Glenn E. Moglen – June 8, 2006

This brief example shows a preliminary land use change/nutrient loading example for a small watershed in the Woodbine quadrangle of Howard County, Maryland.

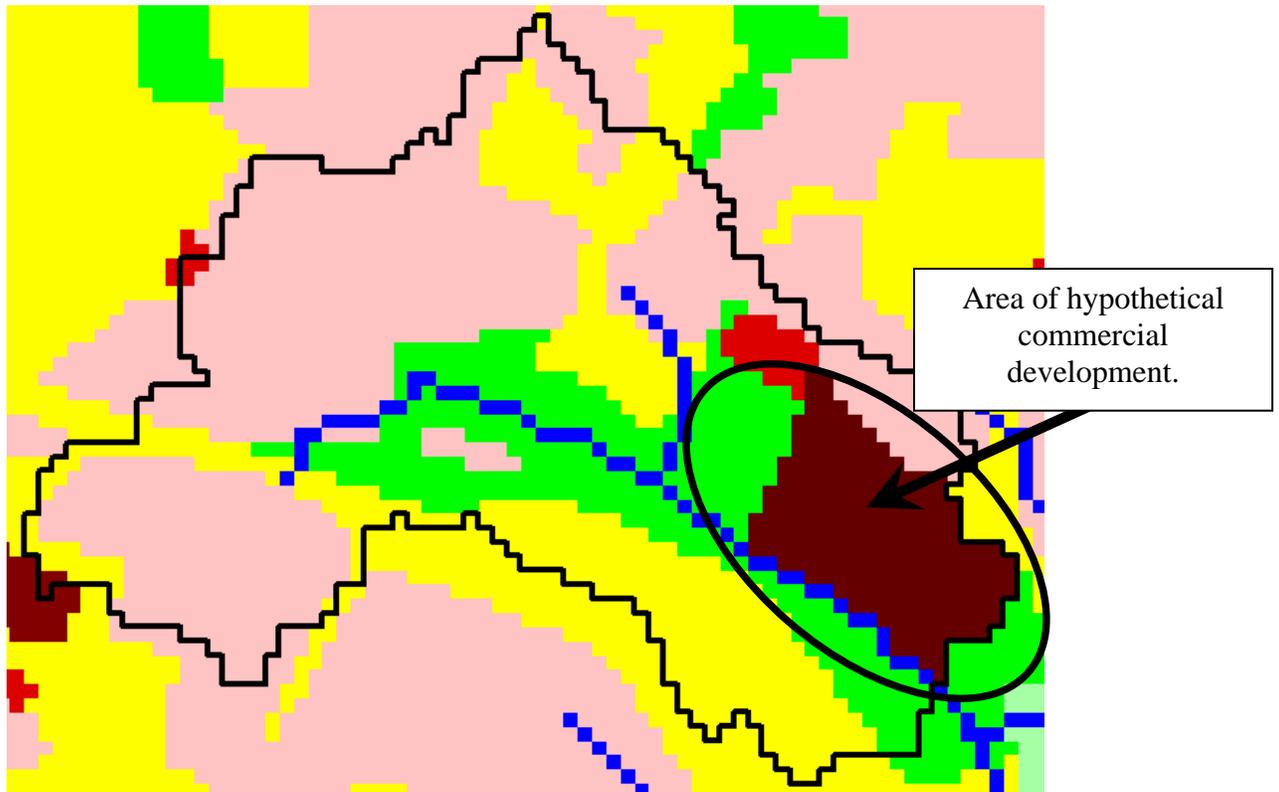
Shown below is the watershed outline and drainage network (shown by blue pixels). The overall color scheme shows current land use with shades of red indicating urban land uses, yellow indicating agricultural land uses, and green indicating forested land uses. Based on Maryland Department of Planning data as of 2002 this watershed



was 44 percent low density residential, about 2 percent other urban land uses, 29 percent agricultural land uses (mostly cropland), and 25 percent deciduous forest. (FYI – all modeling is being done based on a raster (pixel-based) approach at a resolution of 30 meters.)

Using the land use change tool in GISHydro we digitized a hypothetical commercial development in the northeastern corner of the watershed just north of the stream. The hypothetical development is shown on the next page as the dark red patch and is 44.9 acres in area and approximately 1900 feet long measured along the axis from northwest to southeast. This development replaced only forest and agricultural land. The changes in land use include: 11 percent commercial (gain of 11 percent), 23 percent agriculture (loss of 6 percent), and 20 percent forest (loss of 5 percent).

Shown at right is the dialog box which is used to indicate the land use change to GISHydro. These conditions were imposed to the dark red shaded area in the northeastern corner of the watershed shown in the figure below. Please note that the values shown in the dialog correspond well with commercial land use nutrient and sediment loadings.



Using the nutrient loading tools in GISHydro we can calculate the annual loadings at the *overall* outlet of the watershed. The calculated loadings were:

Condition	Nitrogen (tons/yr)	Phosphorus (tons/yr)	TSS (tons/yr)
Before	0.4	0.1	6.9
After	0.9	0.1	15.7

This analysis illustrates the lower end of the scales at which I believe GISHydro can be applied in a meaningful way. My general rule of thumb is to not go below 0.5 square miles in overall watershed area west of the Bay and not below 1.0 square mile east of the Bay. Individual development areas might be smaller than these thresholds as in this example, but it should be recognized that their contribution to nutrient loads is felt downstream of their location at the first stream location that incorporates all the flow running locally off the development. In this case, the overall watershed location coincides with that location.

Memorandum 2
Summary
Meeting held at Maryland Department of the Environment
Glenn E. Moglen – August 29, 2006

Attending: Jim George, Stephanie Martins, Megan Rhodes, Dan Baldwin, Ken Pensyl, Jim Reilly, Robin Pellicano, Shan Abeywickrama, Simin Rezai, Steve Luckman, Glenn Moglen, Helen Stewart, Yen-Der Cheng

Suggested Agenda Items for Next Meeting:

- Calculation of Loading Rates
 - [Not directly relevant]Helen Stewart: We should work with and be consistent with Phase 5, not Phase 4. <See Thoughts below>
 - Glenn Moglen: We all collectively have to come to agreement on how to develop a table of loading rates. For now we move forward with a straw-man table, and switch in a finalized table at a later time. <It is conceivable that we'll need more than one table of loading rates, or the ability to upload CBP coefficients from different model scenarios. Alternatively, if we could have the "no BMP" scenario as the baseline, and the ability to automatically upload the Trib Strategy BMPs, that should give us the Trib Strategy loads, right?>
- Land Use/Land Cover Data Source
 - Stephanie Martins: Concern at MDP that Phase 5 land cover data are used and not MDP's land use. There is particular concern that low density residential is being mis-categorized as forest
 - Glenn Moglen: Land use from MDP vs. Land Cover from Phase 5. There will be a need for two different sets of loading tables. It's not correct to mix/match between the two. <MDE has established TMDLs using MDP land use data, and Bay Program annual loading rates. Furthermore, Maryland's TMDL implementation guidance allows for using any available land use data with CBP loading rates. I'm not aware of any other way to do the calculations, thus as regulators, we have to make the best decision we can based on the data available.>
- BMPs
 - Discussion from many attendees: similar to the loading rates, we need to collectively come to an agreement on what BMPs will be recognized, what their rules are for application, and what removal efficiencies they realize

Discussion of PLOAD model:

- Glenn discussed EMCs in PLOAD model and general level of sensitivity of this model to EMCs used. Answers can easily range by 1-2 orders of magnitude depending on EMC values that are chosen for a given land use.
- In this project our plan is to back-calculate EMC values that are consistent with the EPA Bay Program Phase 5 modeling. (What are the benefits of calculating EMCs versus just using the CBP loading rates?)

New Discussion:

- DNR is developing 10 tributary strategy plans for across the state
- House Bill 1141: Local governments will need to consider pollutant loads in the water resource elements of their comprehensive plans by October 2009. There would logically be a 1-year review/adoption process in advance of this. It is possible that GISHydro will play a role in this. (If it doesn't, I'd consider this project to be something of a failure)
- Jim George: how are we going to use this tool? Example 1: Currently, we take tributary strategy loading rate, multiply by amount of land area and compare that to the NPS allocation for corresponding TMDL to see if the Trib Strategy level of implementation will achieve the TMDL. Example 2: Start off with some baseline loading practice, (e.g. no BMPs), now introduce BMPs and see how loadings change. This is much more data intensive (a BMP inventory and estimate of available land for the application of additional BMPs is necessary), and tools do not presently exist for doing this kind of analysis properly.
- DNR: wants to move forward with Phase 5 modeling (not Phase 4). Wants to look at both the 8-digit watershed scale and look at individual development scale. <See thoughts below.>
- DNR: interested in benthic and fish communities. DNR likes the visual nature of the GISHydro model as opposed to a tabular spreadsheet approach.
- Jim Reilly: concerned about the science of the modeling approach. Can we refine our estimates to be sensitive to soil type, slopes, etc? This comment led to a debate among the whole group of whether to develop a predictive model of actual observed loads or to develop an accounting model that can be used in a planning or regulatory sense. Similarly, are BMPs to be applied with an emphasis on the physics of the system or on consistency with the modeling approach used by the EPA Bay Program? The dominant view of the group was to focus on an accounting tool that would be objective, reproducible, and fair to all jurisdictions across the state

Main Discussion Items:

- **Land Use Loading Rates:** There was considerable discussion on what loading rates to use. Should they be from Phase 4 or Phase 5? Should the rates reflect any assumed BMPs? After considerable debate the group agreed that the loading rates to be used would (I'm not sure the "group" can make this decision. It's really MDE and DNR's decision):
 - Correspond to Phase 5 modeling
 - Assume no BMPs

<If we use Phase 5, at what point in the future will the GISHydro tool have any applicability? Will local governments be able to begin using it in 2007 as part of the HB1141 process? Should we do a quick comparison of Phase 5 and Phase 4 loads before committing? E.g., Phase 4 No BMP and Phase 5 No BMP, or some other suitable comparison?>

- **BMPs (Age and Scale):**
 - **Age of Urban BMPs:** Urban stormwater BMPs have been installed since the mid-1980s and with newer regulation coming into play in 2000 with the

publication of the stormwater manual. So land development can have either no BMPs, old BMPs, or new BMPs depending on the age of the development. How should our modeling/accounting reflect this?

- **Scale of Modeling:** At larger scales (12-digit, 8-digit, county-level) we have fairly reliable information about the BMPs that are in place. At much smaller scales (1 mi² or less) the general larger scale understanding of BMPs is not valid. It's possible at this smaller scale for considerable deviation in the details of BMP application from the general prevailing BMP characteristics.
- Glenn: It might be most effective to model BMPs similar to the proposed changes in land use. The mechanics of this modeling would have the user prepare a GIS shapefile that would convey the BMPs that are in play in a given area. This would have the advantage that the file could be augmented over time to reflect newly installed BMPs. This approach would also aid in the documentation of exactly how and to what degree BMP modeling was performed.
- No concrete conclusions/decisions have been made with regards to these issues.

Next Steps/Action Items:

- Glenn to finalize Technical Memorandum 1 and send invoice to MDE
- Glenn to create a straw-man GIS tool to calculate loadings and changes in loadings based on Phase 5 targets (Glenn to also determine with Bay Program what the Phase 5 target loading rates represent. Example, do they represent the case of “no bmps,” do they represent a particular time period, if so, what time period? If they do not represent a “no bmp” scenario, when will EPA have a Phase 5 “no bmp” scenario for our use?) <I raise these questions, because MDE needs a tool it can use in the near future, or we risk missing significant opportunities (some could be effectively irreversible). I'm still approaching the commitment to Phase 5 with some caution. I need to be educated on this some more>.
- Helen Stewart to obtain Bay Program recognized BMP list from Rob Burgholzer.
- Next meeting to be held in approximately 1 month.

Thoughts:

MDE is presently making regulatory decisions based on loading rates from Phase 4. Trib Strategies are expressed in terms of Phase 4 output. Can we use the Phase 5 baseline load, apply the Trib Strategy BMPs and call that the Trib Strategy for present purposes?

Maryland might need a tool before the Phase 5 model is completed. We need to understand the near-term needs for a tool.

Memorandum 3
Summary
Meeting held at Maryland Department Natural Resources
Glenn E. Moglen – November 20, 2006
(last revised January 16, 2007)

Attending: Kevin Coyne, Helen Stewart, Robin Pellicano, Diana Reynolds, Jim George, Glenn Moglen

Reviewed November 2006 draft document, “Using the Nutrient Loading Interpolator Tool in GISHydro.” (see attached)

- Low Till and High Till: Discussed reflecting Hi Till and Low Till as the single land use “Cropland,” given that we don’t have geographic locations these two types of cropland. The loading rate would be the weighted average of the other two land uses. However, it might be necessary for the user to be able to access information on the percentages of Hi Till and Low Till. This subject should be re-visited in the context of discussing BMPs. For now, Glenn Moglen as constructed GISHydro to treat the two land uses as distinct.
- Planned Future Land Development: Discussed pros and cons of reflecting a planned developed land parcel as a single polygon, supplemented by ratios of impervious cover, versus including multiple polygons that explicitly represent separate types of land cover. In the end, it was decided to try to offer both options. This approach was based on a recognition that, 1) Some BMPs are represented as land uses (e.g., forest land), 2) Some we want the option of reflecting BMPs both as a percentage coverage of a broad geographic area or as an explicit geographic location of the BMP and land area that it treats.
 - Additional comment: Glenn Moglen thinks each land polygon should be represented as a single land use. This structures the calculations to be made in GISHydro in a much more straightforward manner. This “single polygon – single land use” mentality is how the tools in GISHydro have been organized.
- Septic Systems: Discussed options for incorporating septic systems. Jim George expressed an interest in reflecting them as point data rather than as loads-per-acre. Robin Pellicano outlined a method of developing a GIS coverage using MDP Property View and sanitary sewer GIS coverages. Discussed ways for GISHydro to use updated septic information in the future without intervention by Glenn, i.e., user-provided septic layer that the GISHydro tool could read.
 - Additional comment: This would be good. Glenn Moglen needs to be provided this septic layer from MDE, DNR, of the Bay Program in order to incorporate this. Does such a layer exist now? Can somebody provide it to me?
- Manure Acres: Discussed manure acres and agreed to keep it as-is, and be conscious of explaining it to the user.

Actions:

- DNR to provide phase 4 scenario output spreadsheets for 2005 Progress, Tributary Strategies, other?
 - Additional comment: Helen provided (I think) a file on November 27, 2006 which contained tributary strategies data. The title of the file is: “2004_Inputs-Outputs_110105.xls”. I need to meet with Helen and Jim to discuss this file and see how it might be incorporated as an additional scenario. I’m not sure I understand the interpretation of this file versus the numbers that were given to me directly by Gary Shenk at the Bay Program Office.
- Glenn to extend model cosegments in Garrett and Cecil counties so that all Maryland land area is covered by some model cosegment.
 - Additional comment: I have not extended these cosegments because the underlying land cover for these areas is not necessary. While extending the cosegment land use distribution in these two counties is easy, knowing the appropriate underlying land cover to convert to those land uses is not possible since the Phase 4 land cover data is unavailable outside of the Chesapeake Bay watershed.
- Glenn to incorporate sample BMPs, both explicit and percent-coverage types, into the next draft of the Beta-version tool.
 - Additional Comment: No progress on this item as of January 16, 2007. We need to meet to discuss this further so that Glenn fully understands what this means and how it would work.

Memorandum 4
Summary
Meeting held at Maryland Department Natural Resources
Glenn E. Moglen – February 1, 2007
(last revised February 5, 2007)

Attending: Helen Stewart, Robin Pellicano, Diana Reynolds, Jim George, Danielle Lucid, Glenn Moglen

Reviewed: “**Development of a GIS-Based Tool for BMP Definition**” document written by Glenn in preparation for this meeting

Items Discussed:

- Discussed that 5 different BMP types outlined in the Moglen proposal document for the current MDE project. There was general agreement that, for this project, Glenn would focus on a BMP structure according to type 1b “reduced loadings from all areas within the delineated watershed corresponding to a particular land use”. Glenn pointed out that although the proposal says, “delineated watershed” the tool he is developing would work for any polygon whether it corresponds to a watershed outline or to any generalized land area.
 - Jim pointed out that in the cases of BMP types 1d and 1e the user could still use the tool Glenn is building to work out the loading reductions according to these BMP types, they’d just need to independently determine the areas that would be treated by a forest buffer or detention pond through other means and then enter these areas into the tool manually.
- Discussed the prototype “Define BMPs” dialog Glenn provided in his write-up. There was general acceptance of this dialog, but with the following improvements:
 - Dialog needs to reflect the areas being treated by a given BMP. Glenn will revise the dialog to show the current total area in the selected land use and the user will be able to indicate the treated area with any number up to the total area in the selected land use class. Robin asked about what if the user tries to specify a BMP for a land use that doesn’t exist in the selected polygon. Glenn responded that the tool will be “smart” and not list any land use in Box A that isn’t found in the selected polygon.
 - BMP “Import/Export” feature: Jim suggested and everyone agreed that it would be important for there to be some way to retrieve and update BMP scenarios that a user had defined at some earlier time. Such a tool would allow users to return to old analyses, make small changes and update results quickly without the need to tediously go through the re-definition of BMPs with the dialog. Glenn agreed to build in a feature so that this could be done.
- Glenn indicated that he needed a list of all acceptable BMPs that could be defined by the user. This list needed to indicate the land use, additive or multiplicative nature, and the removal rates for nitrogen, phosphorus, and sediment. Dianna supplied Glenn with materials from which he could develop this list. Glenn will circulate the “master list” he develops for this tool by the time of the next meeting. Dianna’s materials

covered nitrogen and phosphorus, but were not as good at characterizing sediment BMPs.

- Jim indicated that removal efficiencies for sediment were not of as great a concern as nitrogen and phosphorus. For the near term, sediment removal could be calculated according to a relationship with phosphorus.
- It was pointed out that removal efficiencies (and possibly other BMP characteristics) vary spatially (i.e. removal efficiencies in the Piedmont may be different than in the Coastal Plain). For now Glenn is going to code these efficiencies as spatially uniform but these spatial dependencies can be revisited later once the tool is more fully-constructed.
- There was some discussion of where the current land cover, land use, and loading information built into GISHydro comes from. Here are the answers:
 - **Land Cover:** Obtained from the Chesapeake Bay Program Office Data Hub at: <http://www.chesapeakebay.net/data/index.htm>. The specific grid obtained corresponds to year 2000 land use, called: "cbplugurb_new.zip". It includes 9 distinct land cover classes.
 - **Land Use:** based on conversion from land cover according to the conversion rules outlined in the document entitled: "CHESAPEAKE BAY WATERSHED MODEL LAND USES AND LINKAGES TO THE AIRSHED AND ESTUARINE MODELS: A Report of the Modeling Subcommittee Chesapeake Bay Program Office, Annapolis, MD, January 2000". This document also contains the total acreage in each land use type which Glenn used to disaggregate the agricultural land cover across multiple agricultural land uses.
 - **Loadings:** based on a file supplied to Glenn by Gary Shenk (sseosalcal.prn). Name is interpreted to mean: state segments edge of stream all areas calibration run. Gary's email transmission message confirmed that this was for Phase 4.

Action Items:

- Glenn to continue building "Define BMPs" dialog according to the plan presented at the meeting and the suggestions/understandings indicated in this memorandum.
- Glenn to develop master BMP list for nitrogen and phosphorus based on the materials supplied by Dianna.

Development of a GIS-Based Tool for BMP Definition
Glenn Moglen
January 31, 2007

Background

In my proposal description for the currently funded project with MDE, I specified the following for Task 3:

Task 3: Development of a GIS-Based Tool for Allowing the User to Indicate BMPs over an area. (20% of effort)

1. The PI will develop an interactive GIS-based dialog/tool that enables the user to define BMPs that are applicable within the delineated watershed. We envision these BMPs to be of five possible general types <<<are others needed?>>>:
 - a. BMP reduces loadings produced by user-digitized polygon area. (Corresponds to a BMP that applies to a specified location of possibly varied land use.)
 - b. BMP reduces loadings from all areas within the delineated watershed corresponding to a particular land use. (Corresponds to a BMP that is assumed to apply globally to all land area in a particular land use within the watershed.)
 - c. BMP changes loading rates associated with all areas within the delineated watershed that correspond to a particular land use. (Corresponds to a BMP that is assumed to apply globally to all land area in a particular land use. This is not a percent reduction as in #1b above, but instead allows user to indicate specific loading rates that apply. This might be used in the case of globally assumed LID practices such as rain gardens, green rooftops, etc to be applied to urban land use categories.)
 - d. BMP reduces loadings from a user-defined “buffer area” which moderates the nutrient contributions of all land use of type x (e.g. agricultural land) that flows directly through the buffer area from an upstream location. (Corresponds to a BMP of forested or grassed buffer strips adjacent to a stream.)
 - e. BMP reduces loadings from all locations upstream of a user specified point. (Corresponds to the condition of a detention pond.)
2. Once the user has indicated the BMP type in #1a-e above, the user will be able to indicate the reduction percentage (or loading rate in the case of #1c) realized by this BMP. The values that apply to this BMP can be either uniquely defined by the user or selected from a drop-down list based on the BMP type that has been selected.
3. Once the user has defined all BMPs, these BMPs will be “applied” and new (“BMP moderated”) nutrient loadings for the user’s watershed will be determined. These moderated loadings can then be compared to the “before” (Task 1, item 7) or “after” (Task 2, item 2) loadings so that the effects of the proposed BMPs can be assessed.

Further, Helen Stewart (DNR) has shared the following information on methods for determining loading reductions brought on by multiple BMPs acting within a single land use:

Method of Calculating Nutrient Loads from Landuses with Multiple Best Management Practices (BMPs)

LU = landuse

LR = landuse nutrient loading rate

BMP = BMP acres

E% = BMP nutrient reduction efficiency

Additive BMPs Nutrient Load

$$LU[ac] * LR[lb/ac] * \left[1 - \left(\frac{\left[BMP1[ac] * \left(\frac{E_{BMP1} \%}{100} \right) \right] + \left[BMP2[ac] * \left(\frac{E_{BMP2} \%}{100} \right) \right]}{LU[ac]} \right) \right]$$

Multiplicative BMPs Nutrient Load

$$LU[ac] * LR[lb/ac] * \left[\left(1 - \left[\frac{BMP1[ac]}{LU[ac]} \left(\frac{E_{BMP1} \%}{100} \right) \right] \right) * \left(1 - \left[\frac{BMP2[ac]}{LU[ac]} \left(\frac{E_{BMP2} \%}{100} \right) \right] \right) \right]$$

Combination of Multiplicative and Additive BMPs Nutrient Load

$$LU[ac] * LR[lb/ac] * \alpha * \beta$$

where,

$$\alpha = \left[1 - \left(\frac{\left[BMP1[ac] * \left(\frac{E_{BMP1} \%}{100} \right) \right] + \left[BMP2[ac] * \left(\frac{E_{BMP2} \%}{100} \right) \right]}{LU[ac]} \right) \right]$$

and

$$\beta = \left[\left(1 - \left[\frac{BMP3[ac]}{LU[ac]} \left(\frac{E_{BMP3} \%}{100} \right) \right] \right) * \left(1 - \left[\frac{BMP4[ac]}{LU[ac]} \left(\frac{E_{BMP4} \%}{100} \right) \right] \right) \right]$$

Sample Calculation for Nitrogen Load from Pasture Acres:

Pasture Land = 1,000 acres
 Stream Protection with fencing (SPWF) = 100 acres (additive)
 Stream Protection without fencing (SPWOF) = 175 acres (additive)
 Soil Conservation & Water Quality Plan Implementation (SCWQPI) = 350 acres (multiplicative)

Using, *Combination of Multiplicative and Additive BMPs* equation:

$$\text{Nutrient Load} = (1,000 \text{ ac}) * (1.05 \text{ lbs/ac}) * \alpha * \beta$$

$$\alpha = \left[1 - \left(\frac{\left[100 \text{ ac} * \left(\frac{75\%}{100} \right) \right] + \left[175 \text{ ac} * \left(\frac{38\%}{100} \right) \right]}{1,000 \text{ ac}} \right) \right] = 0.859$$

$$\beta = \left[\left(1 - \left[\frac{350 \text{ ac}}{1,000 \text{ ac}} \left(\frac{17\%}{100} \right) \right] \right) \right] = 0.941$$

$$\text{Nutrient Load} = (1,000 \text{ ac}) * (1.05 \text{ lbs/ac}) * 0.859 * 0.941$$

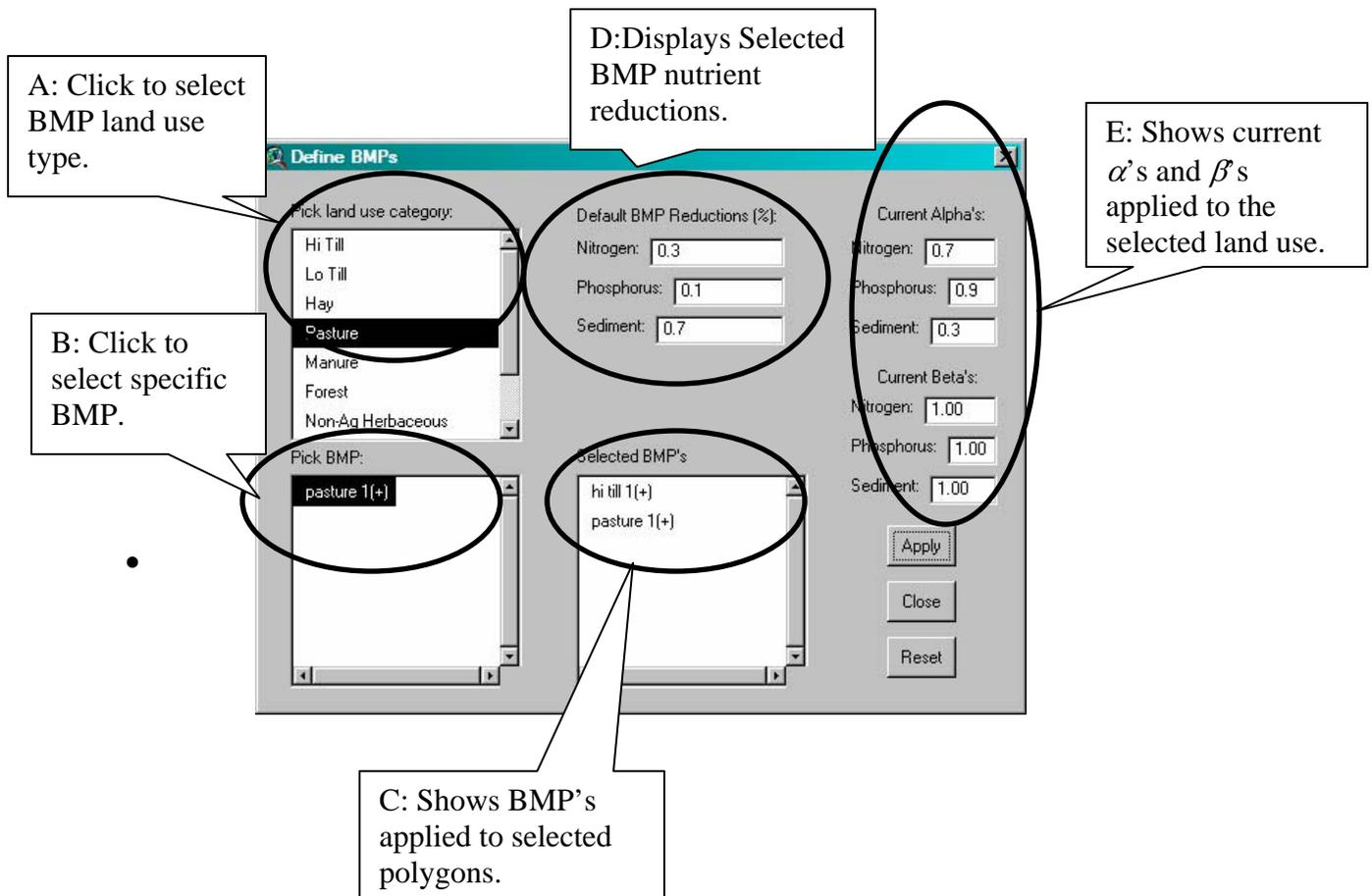
Nutrient Load = 848 pounds of nitrogen

My Plan

At the time of writing this proposal I had a naïve view of how BMPs were specified and methods for their accounting. I am focusing on the BMP type indicated in item 1b since this is the format that most closely approximates BMP calculation/accounting in Maryland. The only major difference between what I wrote and what I am now interpreting is that task 1b speaks of a “delineated watershed”. This may be the case, but the tool I am developing would work for any polygon area whether it corresponds to a watershed outline or not.

Item 2 corresponds to the development of a tool/dialog that I have already started to develop. A screen capture of a prototype of this tool is shown on the next page along with brief descriptions of each item in the dialog’s function.

Item 3 corresponds to managing how BMPs will be implemented/reported once they have been specified. I plan on adding “ α ” and “ β ” tables to the existing output in the report text file that you previously saw during the training workshop earlier this month. There will be one “ α ” and “ β ” table for each of the three nutrients: nitrogen, phosphorus, and sediment output to this text file. I plan to output both the non-BMP and BMP mediated runs for both the current and, if applicable, future land use loading analyses.



Explanation of “Define BMP” Dialog Box

- **Box A:** BMPs are defined for specific land use types. The user first clicks in this box on general type of land use to which one or more BMPs will be applied. Shown selected is the “Pasture” land use type.
- **Box B:** Once a land use type is selected, the specific available BMPs that can be applied to the selected land use are listed. Shown selected is the “pasture 1(+)” BMP. This is just a generic place holder for a BMP that would be applied to pasture land use. The “+” indicates that it acts as an additive BMP. A “*” would indicate a multiplicative BMP.
- **Box C:** Once a BMP has been selected, the “Apply” button will become active. Click on the “Apply” button to invoke the use of this specific BMP. Shown are the selected BMPs for the active polygon (not just the selected land use). The “hi till 1(+)” BMP was selected and applied at an earlier (not illustrated) step.
- **Box D:** This box shows the loading reductions (as a fraction of 1.0) that are realized by the application of the selected BMP. For example, the Nitrogen loading shown is 0.3, corresponding to a loading reduction of 30% if this BMP is used.
- **Box E:** This box shows the running cumulative α 's and β 's for the current selected land use and polygon. In this case, since the selected land use is “Pasture” and the

“pasture 1(+)” BMP has been applied, the α values are all simply 1 minus the indicated reductions in Box D. The β values remain at 1 because no multiplicative BMPs for this land use type have been applied.

- **Apply Button:** Press this button to apply the current selected BMP shown in Box B.
- **Close Button:** Press this button after all BMPs have been specified for the current selected polygon.
- **Reset Button:** This button “clears” any selected BMP’s for the current selected polygon (i.e. α and β will be reset to 1.00).

Work Remaining:

The prototype is just roughed out as it appears in this document. I will illustrate the dialog box at tomorrow’s meeting. I would estimate that roughly 1/3rd of the programming to get the BMP implementation fully functional has been accomplished at this time (i.e. now is a good time for feedback!).

- **Dialog Box Appearance:**
 - The dialog needs a listbox that makes it clear which polygon(s) have been selected for BMP definition somewhere in the dialog box.
 - The dialog needs an textline that shows the acres available for the selected polygon and land use category. The user should be able to modify this number from 0 up to the indicated value before applying the BMP. This is still missing.
- **Dialog Box Functionality:**
 - The dialog box currently does edit the α table but not the β table for a given land use. Obviously this needs extending.
 - Currently α ’s are calculated but not used in loading calculations
 - Currently none of the BMP reductions are recorded to the report file.
 - I need to develop a logical way to store/report selected BMPs to the report file. The “ α ” and “ β ” values will be reported as aggregate values, but the specific BMPs selected to result in these values is not stored beyond the dialog box echo feature.
 - I need to

Information Needed:

- I need a listing of all approved BMPs that the user can define. This listing should have the following information:
 - BMP name
 - applicable to what land use(s)?
 - additive or multiplicative?
 - reduction efficiencies for:
 - nitrogen
 - phosphorus
 - sediment
- Are we agreed on this plan for a BMP tool?
- My view is that this tool does a good job of covering all BMP definition needs. Are others in agreement on this?

Appendix F: Modeling Septics in the GISHydro Nutrient Loading Tool

Approach:

- In GISHydro, user's development file will indicate (by polygon) the location of analysis and will therefore select all existing septic systems within the user-indicated polygons. Each detected septic system in the point file will have a known land use type, acreage, and census tract average household size. This will result in a number of people using these septic systems. Rules for calculating people served vary depending on land use type as described below.
- In GISHydro, user's development file will indicate projected future number of persons served by a septic system within their future development polygon. This number should include current persons served plus any new persons served by new development. This will be a required input for future analysis just as the "LU_new" field in the development file is required so that the proposed new land use for the polygon is understood. (Please Note: This feature is planned, but not implemented until the MDE and the PI have discussed this item more fully.)
- With population on septic known, load is calculated as $9.5 \text{ lbs}/(\text{person-year}) * \text{number of people} * \text{factor}$ (factor currently is set as 0.4).

$$L = 9.5 \cdot n \cdot f$$

where L is the nitrogen load in lbs/year for the single septic system being studied, n is the number of people being served by the septic system, and f is the transport factor that represents the fraction of the nitrogen load that actually makes it to the stream (default, $f=0.4$)

Land Uses indicated in Point File

The sample point file provided by MDE (originating from the Maryland Department of Planning "Property View" dataset) shows 11 potential land uses:

- A: agricultural
- C: commercial
- CR: commercial property with small residential space
- E: tax exempt
- EC: tax exempt commercial
- I: industrial
- M: apartments
- MA: marshland
- R: residential
- RC: residential property with small commercial space
- TH: townhomes

To manage these land uses, we need to determine a rule as to which land uses to employ census determined household densities to define, and which land uses to fix number of users by other means. The following rules were adopted:

"Residential Rule" (based on census data)

- One septic system serves one household (point file)*
- Persons served by each septic system determined by the average household size reported from census data: A (agricultural), M* (apartments), MA (marshland), R (residential), RC (residential/commercial), TH (townhomes).
- * I propose handling apartments based on a modified residential rule. For all of the above categories, the assumption is that one septic system serves one household. In the case of apartments, I suspect that one septic system serves multiple households. I assumed 8 dwelling units/apartment so for all properties indicated by a single point in Shan’s point file that were marked by an “M” (for apartment), I multiply the load computed load by 8.

“Non-Residential Rule” (based on Raleigh, NC approach)

- One septic system serves one point in Shan’s point file. The population using this one point is described below.
- Persons served by each septic system is determined as the product of “equivalent persons/acre” times the acreage of the land parcel in question. This is consistent with the City of Raleigh, North Carolina approach
- The number in parenthesis for each land use category is the “equivalent person/acre” suggested for use in GISHydro application:
 - C: (commercial – 25)
 - CR: (commercial/residential – 25)
 - E: (tax exempt – 25)
 - EC: (tax exempt/commercial – 25)
 - I: (industrial – 50)

Table 2. Average Wastewater Flow and Equivalent People per Acre of Non-Residential Land Use

Zoning	Equivalent Person/Acre	Average Flow (gal/acre/day)
Shopping Center	18	1800
Business/Commercial	25	2500
O&I (light)	13	1300
O&I (heavy)	30	3000
Industrial	50	5000

Source: Orange County, NC, adapted from City of Raleigh Public Utilities Handbook

* Please note: The current point file implemented in GISHydro contains *only* data for Caroline county for methods/program development purposes. The PI awaits point data for all other remaining counties (and Baltimore City) so that septic calculations can be made in these areas.