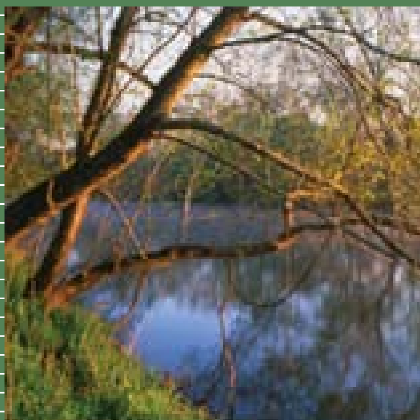

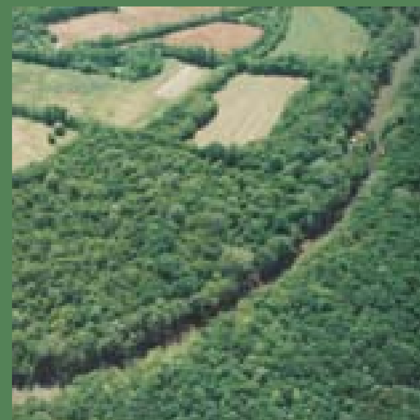

Big Darby Accord
Watershed Master Plan

Appendix

Prepared for

City of Columbus
City of Hilliard
Grove City
Brown Township
Norwich Township
Pleasant Township
Prairie Township
Washington Township
Village of Harrisburg
Franklin County

EDAW

FINAL / JUNE 2006

Prepared by
EDAW Inc

In Collaboration With:
MSI Design
EMH&T
Ohio State University Extension
Squire, Sanders & Dempsey LLP
Schottenstein Zox & Dunn
Trans Associates

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- Final Pilot Study Model

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Big Darby Accord
Water Quality Modeling Summary Report

EMH&T, Inc.
June 2006

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A. Purpose

The purpose of the water quality modeling was to determine the impact on water quality, measured in terms of pollutant loading, related to projected land use changes within the Big Darby Accord planning area. Using the Soil and Water Assessment Tool (SWAT) software, a baseline condition model was created similar to the Generalized Watershed Loading Functions (GWLF) model established by the Ohio EPA for the Big Darby Creek TMDL analysis and draft report. The SWAT baseline model was calibrated for flow to the USGS gage along Hellbranch Run; the model was then calibrated to the EPA's GWLF model results for Total Nitrogen (TN), Total Phosphorous (TP), and Total Suspended Solids (TSS). Although the Ohio EPA did not publish calculated TN loadings in the TMDL report, we were provided detailed and summary model results by the Ohio EPA that included those values for the Hellbranch Run watershed and the 14-digit HUC's that are at least partially within the Big Darby Accord planning area.

The final calibration model's parameters were then used to analyze the effects of the final land use plan, comparing the resultant pollutant loadings predicted by the SWAT model to the target water quality goals published in the OEPA draft TMDL report. The model results were also used to evaluate the requirements for stormwater best management practices (BMPs), in an effort to mitigate the impact of development on pollutant loadings.

B. Pollutant Loading Considerations

The pollutant constituents chosen for this analysis, Total Nitrogen (TN), Total Phosphorous (TP), and Total Suspended Solids (TSS), are those that are commonly considered and are most likely to be affected by changing land use conditions. Heavy metals, especially within the Big Darby Accord planning area, did not appear to be a significant consideration in the Big Darby Creek TMDL. Furthermore, there are no anticipated future industrial land uses within the Big Darby Accord area that would be a significant contributor of those pollutants.

C. Initial Model Set-Up

1. Digital Elevation Model (DEM)

The first step in the modeling process was to create a Digital Elevation Model (DEM). Using the Arc/INFO "TOPOGRID" command, a 15-ft DEM was created from the following data inputs:

- Franklin County Auditor's spot elevation data
- Franklin County Auditor's 2-ft contours
- Madison County Auditor's 5-ft contours
- 1:24,000 scale USGS Digital Line Graph (DLG) contours (for Pickaway County)
- Blue line streams from Franklin County Soil and Water Conservation District's (FSWCD) hydrography layer
- Blue line streams from USGS Digital Line Graph (DLG) hydrography, manually edited to include only stream centerlines and to better correspond to contour data (for areas outside of Franklin County)

2. Spatial Extent

The Big Darby Accord planning area consists of the portion of the Big Darby Creek watershed located within Franklin County. To restrict the automated sub-basin delineation to Franklin

County, a mask was used. However, instead of simply using a mask equivalent to the Franklin County boundary, small portions of Madison County and Pickaway County were also required for SWAT to correctly delineate the portion of Big Darby Creek that forms the Madison County/Franklin County boundary and the stream network at the southern part of the Big Darby Accord planning area.

Therefore the mask used during the sub-basin delineation only limited the extent of the sub-basins along the eastern, western, and northern sides. Along the eastern and western sides, the mask extent was for the most part identical to the initial boundary of the Big Darby Accord planning area, which consisted of the Madison County/Franklin County boundary on the west and the HUC 14 Big Darby Creek watershed boundary on the east. (Note: the Accord planning area's eastern boundary was later revised; this is discussed below in the section "Revision of Sub-basin Areas".) However, for Big Darby Creek to be correctly delineated along the Madison County/Franklin County boundary, the mask actually extended 100 feet west of the Big Darby Creek centerline into Madison County. Along the northern side, the mask extent was equivalent to the Franklin County boundary and the Hellbranch Watershed Forum (HWF) boundary for the Hellbranch sub-watershed.

3. Delineation of Sub-basins, Hydrologic Response Units (HRUs)

Sub-basin outlets were selected according to the following criteria:

- Within the Hellbranch Run sub-watershed, sub-basin outlets corresponded to those utilized by the Hellbranch Watershed Forum (HWF) to maintain general agreement with the HWF for potential comparison of model results. The SWAT sub-basin boundaries delineated using the DEM were in general agreement with the HWF sub-basin boundaries.

- For areas outside of the Hellbranch Run sub-watershed, a sub-basin outlet was placed at each blue line stream's confluence with Big Darby Creek. Additional sub-basin outlets along Big Darby Creek were selected such that an average sub-basin size of approximately 1,000 acres was maintained.

- Sub-basin outlets were created at the outlets of each of the 14-digit HUC's contained or at least partially contained within the study area, to allow for potential pollutant calibration with EPA data. However, with the exception of the Hellbranch sub-watershed outlet, these outlets were not used as calibration points since the majority of the area within each 14-digit HUC was actually located outside of the modeling study area and would therefore not provide for an accurate calibration.

- A watershed inlet was created at the confluence of Little Darby Creek with Big Darby Creek, which corresponds to a 14-digit HUC outlet, to better allow for OEPA/GWLF point source pollutant loadings for areas outside of Franklin County to be added to the model. After the establishment and calibration of the baseline SWAT model, however, a decision was made not to include point source loadings for areas outside of Franklin County since these values were unable to be accurately projected for the time period corresponding to the final land use scenario. The resultant exclusion of the Little Darby Creek tributary area from the SWAT model was determined to have little to no impact on the model results, since the majority of the land in this region is currently

MetroPark forested land and continues to be designated as forested land in the future land use scenario.

The result of the SWAT sub-basin delineation process was a 53,068-acre watershed comprised of 51 sub-basins (average of 1,041 acres per sub-basin). The SWAT sub-basins along with the Big Darby Accord planning area can be seen in Figure 1. The modeling study area is essentially comprised of two large sub-watersheds: the Hellbranch Run sub-watershed (25,154 acres) and all other areas within Franklin County that are directly tributary to Big Darby Creek. It should be noted that a small area in the southwest corner and the very northernmost tip of the Big Darby Accord planning area are actually located outside of the Big Darby watershed boundary, so these regions were not included in the modeling efforts. The 51 sub-basins initially created for the SWAT calibration model were also utilized for the final land use scenario model so results from the two models could be readily compared.

To adequately capture the diversity of land uses and soils present within each sub-basin, the SWAT model then divides each sub-basin into even smaller units, referring to unique combinations of land use and soil type as Hydrologic Response Units (HRUs). HRUs allow for increased accuracy in the model since loadings from each HRU are calculated independently, based on specific parameters that correspond to land use/management operations and soil type (i.e., percent impervious, plant species, fertilizer application rates, soil hydrologic group, etc.). Although the sub-basin boundaries were consistent for the baseline/calibration model and the final land use scenario model, since the land use coverages for the two models varied significantly, the total number of Hydrologic Response Units (HRUs) analyzed in each model differed. On average each SWAT model contained at least 10 HRUs per sub-basin; a further discussion of the HRU delineation process for each model is included in the "Land Use Data" section below.

4. Revision of Sub-basin Areas

For some sub-basins along the eastern boundary of the study area, the sub-basin areas were manually revised in SWAT to include additional drainage area. This revision was due to a change in the eastern boundary of the Big Darby Accord planning area that occurred after the sub-basin delineation process had already been completed and work on the calibration model was underway. The revised boundary corresponds to either the Hellbranch Watershed Forum boundary or the HUC 14 Big Darby Creek watershed boundary, whichever is "greatest". Where the boundary was changed, a larger total drainage area is reflected in the SWAT model. For the majority of the sub-basins with revised areas, the additional drainage area was simply distributed proportionally amongst the various HRUs already established. However, where significant differences were observed in terms of land use percentages within a sub-basin, HRUs were added, revised or deleted as necessary to maintain accuracy in the model.

5. Revision of Main Channel Widths/Depths, Channel Lengths

The default SWAT values for main channel widths and depths were overwritten; instead, the main channel widths and depths were calculated using the following regional curve equations provided by The Ohio State University (OSU):

$$\text{Width (meters)} = 0.477 \times (\text{Drainage area in ha})^{0.4032}$$

$$\text{Depth (meters)} = 0.0474 \times (\text{Drainage area in ha})^{0.3167}$$

Based on a GIS analysis of the river shapefile delineated by SWAT, some main and tributary channel lengths were also manually revised, since the SWAT program had incorrectly clipped or merged some river segments.

6. Study Period

The designated modeling study period was selected to match that used by the OEPA in its TMDL analysis: April 1, 1994 through March 31, 2004.

D. Data Inputs

A summary of the data inputs used in the SWAT water quality modeling process is shown as Table 1. This data (with the exception of the baseline land use data) was used for both the baseline/calibration model and the future land use scenario model.

1. Weather/Climate Data

Precipitation and temperature data for April 1994 through March 2004 were provided by the OEPA from its Big Darby Creek TMDL efforts. This data was collected from eight gages, none of which were located within the Big Darby Accord planning area. Of these, the Columbus, London, Marysville, and Delaware gages were in closest proximity to the planning area; however, when comparing the relative magnitude and timing of precipitation events to the observed flows at the U.S. Geological Survey's (USGS) Hellbranch Run gage, none of the gages had data that was consistent with the Hellbranch sub-watershed over the entire span of the study period.

Various combinations of gages and individual gages were then tested in the model: the average of the nearest four gages, the average of all eight gages, and individual data from the Columbus and London gages. However, all yielded poor calibration results. As a result, additional precipitation data sources were explored. Data from the three nearest City of Columbus gages were incomplete and inaccurate for large portions of the ten-year study period. Finally, after evaluating precipitation data from a variety of sources, the National Weather Service (NWS) gage at the Port Columbus International Airport was determined to most accurately represent the conditions within the Hellbranch Run sub-watershed. The precipitation events recorded at the NWS gage best corresponded to the flow data from the USGS Hellbranch Run gage in terms of both relative magnitude and the timing of events.

For consistency, temperature data from the same NWS gage was then also selected for use in the SWAT model. However, NWS precipitation and temperature data were only available for the duration July 1996 through March 2004, which does not include the beginning of the designated ten-year study period (April 1994 through March 2004). Therefore, for the time period ranging from April 1994 through June 1996, precipitation data from the Ohio Agricultural Research and Development Center (OARDC) Columbus Station gage and temperature data from the OARDC Delaware Station gage were utilized. This substitution did not have a significant effect on the accuracy of the SWAT model or the interpretation of its results, since these gages are located in close proximity to the study area and are also considered to be adequately representative of the weather/climate in this region. Also, since the SWAT model requires one to two years for initial conditions to equilibrate, the calibration period was set as study years three through 10 (April 1996 through March 2004), during which the majority of the precipitation and temperature data consisted of the NWS gage data.

All other weather/climate data (solar radiation, wind speed, relative humidity, and potential evapotranspiration) were simulated by SWAT, which uses a database of national weather information to create approximations customized to a specific geographical area.

Table 1
SWAT Data Input Summary

Data Input	Applies to SWAT Land Use(s)	Data Source(s)
Precipitation data	All land uses	OARDC Columbus Station gage (Apr 1994-Jun 1996); NWS Port Columbus Airport gage (Jul 1996-Mar 2004)
Temperature data	All land uses	OARDC Delaware Station gage (Apr 1994-Jun 1996); NWS Port Columbus Airport gage (Jul 1996-Mar 2004)
All other weather/climate data	All land uses	Approximated within SWAT using national weather/climate database
Soil data	All land uses	NRCS Soil Survey Geographic Database (SSURGO)
Baseline land use data	NA	OEPA Hybrid Land Use Coverage
Initial groundwater concentrations of nitrate and soluble phosphorus	All land uses	OEPA
Agricultural operations including crop types/rotations, tillage practices, fertilizer application rates	Agricultural Land - Row Crops (AGRR)	NRCS, research conducted by OSU, OSU Extension Bulletin E-2567 (http://ohioline.osu.edu/e2567)
Manure application from livestock	Pasture (PAST)	OEPA
Lawn fertilizer application	Pervious portions of all urban land uses	OSU Extension FactSheet HYG-4006 (http://ohioline.osu.edu/hyg-fact/4000/4006.html)
Recreational field fertilizer application	Parks (PARK)	OSU Extension FactSheet SRT-2-05 (http://ohioline.osu.edu/srt-fact/0002.html), Purdue University's Turfgrass Science report AY-325-W (http://www.agry.purdue.edu/turf/pubs/AY-325-W.pdf)
Golf course fertilizer application	Golf Courses (GOLF)	Virginia Cooperative Extension Publication Number 430-399 (http://www.ext.vt.edu/pubs/turf/430-399/430-399.html), Delaware Department of Natural Resources and Environmental Control "Turf Nutrient Management" report (http://www.dnrec.state.de.us/water2000/Sections/Watershed/WS/fact_appo_turf_nutrient.pdf)
Build-up/wash-off parameters	Impervious portions of all urban land uses	SWAT, OEPA
Runoff curve numbers and percent impervious values	All urban land uses	SWAT, NRCS TR-55 documentation

2. Soil Data

NRCS SSURGO data was utilized due to its more detailed determination of the soil types. Additionally, this soil data was utilized by the OEPA for the TMDL. To minimize the number of HRUs created while still maintaining the distinct data attributes used by SWAT, the SSURGO soil types were reclassified into soil series. Figure 2 displays the predominant soil series within the modeling study area (those soil series comprising at least 1% of the overall watershed area).

3. Land Use Data

a) Baseline Conditions

The land use coverage used to represent baseline conditions in the calibration model was provided by the OEPA and is identical to that used in the OEPA's TMDL analysis. This hybrid land use dataset includes data from the USGS National Land Cover Dataset (NLCD - 1992), OEPA's analysis of forested land cover using 1997 Landsat 5 satellite imagery, an OEPA-funded land use study based on 2000-2001 Landsat 7 satellite imagery conducted by the University of Cincinnati, and land use data based on 1997 Landsat Thematic Mapper data provided by Dr. Steve Gordon at The Ohio State University (OSU). To verify that this hybrid land use information reflected the most current land use within the Accord planning area, a parcel-based MORPC land use coverage representing 2003 conditions was revised using 2005 Franklin County Auditor's land use codes, taking into account any changes from agricultural land or open space to other land uses. This revised MORPC dataset (showing urban land uses/zoning type categories only) was then merged with the natural land cover data from the hybrid land use coverage to create an updated 2005 existing land use layer.

After comparing the updated 2005 existing land use dataset to the original OEPA hybrid land use dataset, it was determined that the differences between the two land use coverages would likely have very little impact on the SWAT modeling results. Therefore, for consistency with the OEPA TMDL analysis, the hybrid land use dataset was selected to represent baseline conditions in the baseline/calibration model.

Based on the land use descriptions for each category, a "look-up" table (Table 2) was created to convert the hybrid land use categories to the appropriate SWAT land use categories. Since a significant part of the hybrid land use dataset was from the USGS 1992 National Land Cover Dataset (NLCD), the majority of this lookup table was derived from a lookup table that had previously been created to convert NLCD classes to SWAT land use classes, based on research and trial runs in SWAT. A map showing the hybrid land use coverage (converted to SWAT land use categories/codes is included as Figure 3.

The SWAT land use data was then used in conjunction with SSURGO soil data from the NRCS to create HRUs. A 10% threshold value for land use and a 10% threshold value for soil type were utilized to limit the total number of HRUs created, so that in subsequent modeling steps the HRUs could be effectively managed. This meant that if a particular land use or soil type was not did not comprise at least 10% of a sub-basin, an HRU was not created. Many of the land uses in the hybrid land use coverage represented only a very small portion of the entire modeling area (less than 1% in most cases) and less than 10% of each sub-basin; thus, only the following SWAT land use categories remained in the calibration model after the HRU delineation: AGRR, FRSD, PAST, URLD, and URMD.

After the initial creation of 464 HRUs, some additional HRUs were then manually added to the model to assure the accurate representation of parks and golf courses in the study area and to account for the land uses outside of the sub-basin boundaries but yet still inside the Accord planning area (due to the revision in the eastern boundary of the Accord planning area), for a total of 505 HRUs. The management files for park and golf course HRUs were created by starting with the default PAST management file (no grazing operations or manure application), and adding fertilizer application rates appropriate for the land use type based on various research. See section “Fertilizer Application Data” below for more detail.

Table 2
Hybrid Land Use to SWAT Land Use Look-up Table

Hybrid Land Use Value	Hybrid Land Use Description	SWAT Code	SWAT Description
1	20% - 39% (pct forest canopy)	RNGB	Range-brush
2	40% - 59% (pct forest canopy)	FRSD	Forest-deciduous
3	60% - 79% (pct forest canopy)	FRSD	Forest-deciduous
4	80% - 100% (pct forest canopy)	FRSD	Forest-deciduous
5	Residential (2000)	URMD	Residential-Medium Density
11	Open Water	WATR	Water
21	Low Intensity Residential	URLD	Residential-Low Density
22	High Intensity Residential	URHD	Residential-High Density
23	Commercial / Industrial / Transportation	UCOM	Commercial
32	Quarries / Strip Mines / Gravel Pits	RNGE	Range-grasses
41	Deciduous Forest	FRSD	Forest-deciduous
42	Evergreen Forest	FRSE	Forest-evergreen
43	Mixed Forest	FRST	Forest-mixed
81	Pasture / Hay	PAST	Pasture
82	Row Crops	AGRR	Agricultural Land - Row Crops
85	Urban / Recreational Grasses	URLD	Residential-Low Density
91	Woody Wetlands	WETF	Wetlands-forested
92	Emergent Herbaceous Wetlands	WETL	Wetlands

b) Final Land Use Scenario

A map showing the final land use scenario for the Big Darby Accord Planning area is included as Figure 4. Based on the land use descriptions for each category, a “look-up” table (Table 3) was created to convert the final land use scenario categories to the appropriate SWAT land use categories. To account for conservation development areas in SWAT, instead of creating entirely new SWAT land use categories, a revised GIS land use coverage was created to divide these conservation development areas into separate areas of range-brush and the appropriate residential land use category. The areas for the new range-brush regions were calculated cumulatively by sub-basin. Since the exact location of the open space (range-brush land use) within each conservation development area was unknown, the location of the open space areas were randomly selected within the conservation development areas and were simply drawn as circles of the correct size. A map showing this revised final land use scenario (converted to SWAT land use categories/codes) is included as Figure 5.

The addition of the following land use codes/categories in SWAT was required to accurately model the final land use scenario: URR2, URM2, PARK, and GOLF. The two new urban land use codes were created by copying existing land use categories in the urban.dat SWAT database and making revisions to the urban land use parameters as necessary (see section "Urban Land Use Parameters"). The PARK and GOLF categories were simply created by copying and renaming the PAST category from the crop.dat SWAT database.

Table 3
Final Land Use to SWAT Land Use Look-up Table

Final Land Use Scenario Land Use Description	SWAT Code	SWAT Description
Agricultural Use	AGRR	Agricultural Land - Row Crops
Riparian Corridor	FRSD	Forest-deciduous
Forest/Wooded Land	FRSD	Forest-deciduous
Active Recreation Park Land	PARK[1]	Park
Open Space	RNGB	Range-brush
Golf Course	GOLF[1]	Golf Course
Public/Institutional	URM2*	Suburban High Density
Commercial	UCOM	Commercial
Mixed Use	UCOM	Commercial
Industrial	UIDU[2]	Industrial
Transportation	UTRN	Transportation
Water Body	WATR	Water
Rural Estate (< 0.2 DU/ac)	PAST	Pasture
Rural (0.2-0.5 DU/ac)	URR2[1]	Rural residential
Residential Conservation Development 50% (0.2-0.4 DU/ac)	URR2[1] (+RNGB)	Rural residential
Residential Conservation Development 50% (1 DU/ac)	URLD (+RNGB)	Residential-Low Density
Suburban Low Density (0.5-3 DUs/ac)	URLD	Residential-Low Density
Suburban Medium Density (3 DUs/ac)	URMD	Residential-Medium Density
Suburban Medium-High Density (5 DUs/ac)	URM2[1]	Suburban High Density
Urban Medium Density (8 DUs/ac)	URM2[1]	Suburban High Density
Urban High Density (>8 DU/ac)	URHD	Residential-High Density
Special Residential LEEDS	URMD	Residential-Medium Density

[1] New SWAT land use category created

[2] UIDU land use code was not actually used in the final land use scenario model, due to the very small area of UIDU included in the final land use coverage and the land use thresholds used during the HRU delineation process

After the final land use scenario had been converted to the correct SWAT land use codes, the data was then used in conjunction with SSURGO soil data from the NRCS to create HRUs. A 3% threshold value for land use and a 12% threshold value for soil type were utilized to ensure that the land use scenario was represented effectively in the model while still limiting the total number of HRUs created. These threshold values resulted in a total of 684 HRUs being delineated for the entire modeling area.

4. Initial Groundwater Pollutant Concentrations

Initial concentrations of nitrate and soluble phosphorus in the shallow aquifer for each 14-digit HUC were entered into SWAT using data provided by the OEPA from the Big Darby Creek TMDL study. A summary of these values is shown in Table 4.

Table 4
SWAT Initial Groundwater Pollutant Concentrations

14-digit HUC	Nitrate (mg N/L or ppm)	Soluble Phosphorus (mg P/L or ppm)
Hellbranch Run (220-010)	0.5351	0.0574
BDC 4 (200-010)	0.5537	0.0601
BDC 5 (200-020)	0.4635	0.0467
BDC 6 (220-020)	0.4451	0.0440
BDC 7 (220-030)	0.4888	0.0505

5. Agricultural Data

Input parameters regarding agricultural operations were generated in collaboration with OSU and the local NRCS office. Ten different agricultural management scenarios were created within the SWAT model, consisting of various three-year crop rotations of corn, soybeans, and/or winter wheat. For each of the three years in the rotation, approximately 30% to 40% of the crops grown are corn, 50% to 60% are soybeans, and 10% are winter wheat. The total number of heat units for each plant type to reach maturity was either the SWAT default value of 1,800 heat units or that recommended by the SWAT Potential Heat Unit Program, which estimates the heat units for crops based on local weather/climate conditions:

- Corn – 1,800 heat units
- Soybeans – 1,360 heat units
- Winter wheat – 1,506 heat units

The selected values were chosen based on the ability of the calibrated model to predict crop yields that were relatively close to historical crop yield statistics for Ohio (see Table 15).

The SWAT agricultural management scenarios also included tillage practices appropriate for the modeling area, based on information provided by the NRCS. For each of the three years in the rotation, approximately 30% of the crops grown utilize fall tillage, while about 70% use conservation tillage. The ten agricultural management scenarios were applied randomly to agricultural HRUs, such that each scenario was applied to a total of approximately 10% of the area within each 14-digit HUC (or partial HUC).

6. Fertilizer Application Data

a) Crops

The fertilizer application rates for agricultural lands were based on guidelines from the report "Tri-State Fertilizer Recommendations for Corn, Soybeans, Wheat and Alfalfa" (OSU Extension Bulletin E-2567). Values were then adjusted by about +/- 20% during the calibration process, to better correlate with the results from the OEPA GWLF model. The final values used in the model are still within an acceptable range and generally correspond to the range of application rates observed within the local area. All fertilizer was applied as elemental nitrogen and phosphorus; Application dates were selected to correspond to the dates used by OSU in its Olentangy TMDL agricultural management files/scenarios A summary of the annual fertilizer application rates is shown in Table 5.

Table 5
SWAT Annual Fertilizer Application Rates - Crops

Crop Type	Elemental Nitrogen (kg/ha)	Elemental Phosphorus (kg/ha)
Corn	185	22
Soybean	20	15
Winter wheat	99	22

b) Livestock Manure Application

Using data provided from the OEPA for each 14-digit HUC, manure application from livestock was applied to pasture lands via both grazing operations and direct fertilizer application (manure collected from non-grazing animals year-round and from grazing animals during non-grazing seasons). All manure was applied to pasture/PAST land (versus agricultural/AGRR land), so that the amount of manure applied per unit area of pasture could remain constant for the final land use scenario model, according to the assumption that the number of livestock would increase/decrease in proportion to any increases/decreases in pasture. Grazing operation data is summarized in Table 6, while livestock manure application data is summarized in Table 7.

Table 6
Grazing Operations Data

14-digit HUC (portion within Franklin County)	Livestock Type	Number of Livestock[1]	Number of Grazing Days (Start Date)[1]	Animal Weight (kg)[1]	Dry Mass Intake/Day (% of body weight)	Total Dry Mass Intake (kg/ha/day)[5]
Hellbranch Run (220-010)	Cattle	142	244 (Apr 1)	363	2.25%[2]	1.096
	Horses	172	232 (Apr 1)	454	1.75%[3]	1.291
	Sheep	976	365 (Jan 1)	27	2.00%[4]	0.502
BDC 4 (200-010)	Cattle	40	244 (Apr 1)	363	2.25%[2]	0.920
	Horses	35	232 (Apr 1)	454	1.75%[3]	0.782
	Sheep	282	365 (Jan 1)	27	2.00%[4]	0.432
BDC 5 (200-020)	Cattle	34	244 (Apr 1)	363	2.25%[2]	0.648
	Horses	30	232 (Apr 1)	454	1.75%[3]	0.556
	Sheep	241	365 (Jan 1)	27	2.00%[4]	0.306
BDC 6 (220-020)	Cattle	68	244 (Apr 1)	363	2.25%[2]	1.717
	Horses	59	232 (Apr 1)	454	1.75%[3]	1.448
	Sheep	479	365 (Jan 1)	27	2.00%[4]	0.806
BDC 7 (220-030)	Cattle	19	244 (Apr 1)	363	2.25%[2]	0.751
	Horses	16	232 (Apr 1)	454	1.75%[3]	0.615
	Sheep	133	365 (Jan 1)	27	2.00%[4]	0.350

[1] Source: OEPA (from TMDL analysis)
[2] Source: http://ohioline.osu.edu/anr-fact/0002.html
[3] Source: http://ohioline.osu.edu/b762/b762_12.html
[4] Estimated value
[5] Calculated value: Total Dry Mass Intake = (Number of Livestock x Animal Weight x Dry Mass Intake/Day) / Total Pasture area within 14-digit HUC

Table 7
Livestock Manure Application Data

14-digit HUC (portion within Franklin County)	Livestock Type	Number of Livestock[1]	Dry Weight of Manure Produced (kg/ animal/day)[2]	Total Manure Produced (kg/ha/day)[3]	Non-grazing Days/Yr[1]	Annual Non-grazing Loading (kg/ha)[4]
Hellbranch Run (220-010)	Cattle	142	6.27	0.840	121	101.7
	Horses	172	4.75	0.771	121	93.3
	Sheep	976	0.27	0.251	0	0
	Hogs	312	1.25	0.368	365	134.3
BDC 4 (200-010)	Cattle	40	6.27	0.705	121	85.3
	Horses	35	4.75	0.467	121	56.5
	Sheep	282	0.27	0.216	0	0
	Hogs	88	1.25	0.309	365	112.8
BDC 5 (200-020)	Cattle	34	6.27	0.497	121	60.1
	Horses	30	4.75	0.332	121	40.2
	Sheep	241	0.27	0.153	0	0
	Hogs	76	1.25	0.221	365	80.8
BDC 6 (220-020)	Cattle	68	6.27	1.316	121	159.3
	Horses	59	4.75	0.865	121	104.7
	Sheep	479	0.27	0.403	0	0
	Hogs	150	1.25	0.579	365	211.2
BDC 7 (220-030)	Cattle	19	6.27	0.576	121	69.7
	Horses	16	4.75	0.367	121	44.4
	Sheep	133	0.27	0.175	0	0
	Hogs	42	1.25	0.254	365	92.6

[1] Source: OEPA (from TMDL analysis)
[2] Source: Wet weights (lb/animal/day) from OEPA TMDL analysis; Converted to dry weights using conversion rates from http://www.metrokc.gov/dchs/csd/wsu-ce/agriculture/PDFs/ManureGuide.pdf
[3] Calculated value: Total Manure Produced = (Number of livestock x Dry Weight of Manure Produced) / Total Pasture area within 14-digit HUC; These values were used for the SWAT grazing operations as required; they were also then used to calculate the annual non-grazing loadings.
[4] Calculated value: Annual Non-grazing Loading = (Total Manure Produced x Non-grazing Days/Yr); These annual loadings were then separated into four separate manure application dates according to the dates and percentages used in the OEPA TMDL analysis. These dates (and corresponding percent of annual loadings) were: for cattle, Apr 1 (20%), May 1(20%), Oct 1(30%), and Nov 1(30%); for hogs, 1 (10%), May 1(10%), Oct 1(40%), and Nov 1(40%); and for horses, Jan 1 (25%), Feb 1 (25%), Mar 1 (25%), Dec 1 (25%).

c) Lawns

For the pervious parts of all urban land uses, fertilizer type, application dates, and amounts were set according to an OSU Extension Fact Sheet discussing recommended lawn fertilizer application specific to the state of Ohio. Selecting a fertilizer with an approximate 5:1:2 ratio, the 25-5-0 fertilizer from the default SWAT fertilizer database was chosen (disregarding K, since this pollutant was not specifically studied in the model). The application recommendations for similar fertilizers (24-4-8 and 24-4-12) were then utilized. The final lawn fertilizer application information used in the SWAT model is summarized in Table 8.

Table 8
SWAT Fertilizer Application Rates - Lawns

Date	25-5-0 Application (kg/ha)
May 1	98
July 1	146
Sept 1	195
Nov 1	293

d) Recreational Fields/Parks

For active recreational park lands, the fertilizer type, application dates, and amounts were based on recommendations for recreational/sports fields published by the OSU Extension and by Purdue University. First, the 24-6-0 fertilizer was selected from the SWAT database, since this most closely matched the 4:1:2 and 4:1:3 ratios recommended by the OSU Extension (disregarding K, since this pollutant was not specifically studied in the model). The dates and application rates used in the SWAT model are shown in Table 9.

Table 9
SWAT Fertilizer Application Rates - Recreational Fields/Parks

Date	24-6-0 Application (kg/ha)
Jun 1	203
Aug 20	203
Sept 20	203
Nov 20	305

e) Golf Courses

For active golf courses, the fertilizer type, application dates, and amounts were based on recommendations published by the Virginia Cooperative Extension and by the Delaware Department of Natural Resources and Environmental Control. First, the 28-10-10 fertilizer was selected from the SWAT database, since this is between the recommended 4:1:2 and 4:2:4 ratios from the Virginia report (disregarding K, since this pollutant was not specifically studied in the model). The recommended total nitrogen application rates for greens, tees, fairways, and rough areas are summarized in Table 10.

Using estimated percentages of these areas within each golf course (derived using Franklin County orthophotos), a composite annual fertilizer application rate for golf courses was then estimated as: Total Annual 28-10-10 Loading (lb/1000 sq ft/yr) = (0.05)(35) + (0.03)(14.29) + (0.70)(10.71) + (0.22)(3.57) = 10.46. Converted to kg/ha, this composite value was then divided into five equal applications of 102.1 kg/ha on May 1, May 15, June 1, June 15, and July 1.

Table 10
Recommended Annual Fertilizer Application Rates - Golf Courses

Golf Course Area	Recommended Total N (lb/1000 sq ft/yr)	Annual 28-10-10 Application (lb/1000 sq ft/yr)[1]	Estimated Percentage of Total Golf Course Area[2]
Greens	9.8	35.00	5%
Tees	4	14.29	3%
Fairways	3	10.71	70%
Rough	1	3.57	22%

[1] Calculated as Total N/0.28
[2] Estimated using Franklin County orthophotos

7. Urban Land Use Parameters

   a) Build-up/Wash-off Parameters

For the impervious portions of urban lands, the build-up/wash-off algorithms within SWAT were used; however, the default values for nutrient concentrations and time to reach one-half of the maximum build-up were adjusted in order to better correspond with values used by the GWLF model. Thus, the build-up/wash-off calculations from the SWAT model more closely matched those predicted in the Big Darby TMDL analysis. Table 11 summarizes the build-up/wash-off parameters from the SWAT urban.dat file that were revised.

Table 11
Revised SWAT Build-up/Wash-off Parameters

SWAT Land Use Code	TN (ppm)	TP (ppm)	Time to Reach 1/2 Maximum Build-up (days)
URR2	1,076	136	5
URLD	2,466	312	5
URMD	3,408	431	5
URM2	4,664	590	5
URHD	5,830	738	5
UCOM	12,944	1,443	5
UTRN	14,793	1,650	5

   b) Runoff Curve Numbers and Percent Impervious Values

Curve numbers and percent impervious values for various land uses within SWAT were determined based on documentation for the Natural Resources Conservation Service (NRCS) TR-55 program, which performs hydrologic calculations for small, urban watersheds. The revised percent impervious values were implemented within SWAT by actually overwriting the CN2 values in the management files for each HRU. The revised percent impervious values were implemented by editing the default values in the urban.dat file. The CN2 and percent impervious values used are shown in Table 12.

Table 12
Revised SWAT Runoff Curve Numbers and Percent Impervious Values

SWAT Land Use Code	Description	Runoff Curve Number (CN2) by Soil Hydrologic Group				Total Impervious (%)	Directly Connected Impervious (%)
		A	B	C	D		
AGRR	Agricultural Land-Row Crops	62	71	78	81	NA	NA
FRSD	Forest-deciduous	36	60	73	79	NA	NA
PAST	Pasture	39	61	74	80	NA	NA
GOLF	Golf Course	39	61	74	80	NA	NA
PARK	Park	39	61	74	80	NA	NA
RNGB	Range-brush	35	56	70	77	NA	NA
URR2	Rural Residential	47	66	77	81	12	10
URLD	Residential-Low Density	56	71	80	85	27.5	24
URMD	Residential-Medium Density	61	75	83	87	38	30
URM2	Suburban High Density	69	80	87	90	52	48
URHD	Residential-High Density	77	85	90	92	65	49
UCOM	Commercial	89	92	94	95	85	80
UTRN	Transportation	98	98	98	98	98	95

E. Calibration/Baseline Model

The SWAT baseline model was first calibrated for flow to the USGS gage along Hellbranch Run. The calibrated model flow volumes were within 1.5 % of the USGS Hellbranch gage's values and produced R^2 values of approximately 0.7 and 0.6 for average annual and average monthly flows, respectively. The R^2 values can, in part, be attributed to several instances in the dataset where measured precipitation did not coincide with observed flow at the HB gage and vice versa.

Pollutant loads in the stream (phosphorous, nitrogen, and total suspended solids) were calculated in SWAT based on the volume of runoff and groundwater flow entering the stream in conjunction with the following inputs: fertilizer application on agricultural land, parks, golf courses and pervious portions of urban land; manure application on pasture; build-up/wash-off pollutants from impervious portions of urban land; and initial concentrations of nitrates and soluble phosphorus in the shallow aquifer. Point source pollutant loadings from OEPA's TMDL model were not entered into the model. The model was then calibrated to the EPA's GWLF model results for Total Nitrogen (TN), Total Phosphorous (TP), and Total Suspended Solids (TSS). All calibration operations were performed using data for the Hellbranch Run sub-watershed.

The parameters and values used to calibrate the baseline model are summarized in Table 13. Results of the calibration are presented in Table 14 (pollutant values are average annual loadings for the calibration period).

Table 13
Calibration Parameters

Category	Variable Name	Input File	Description	Value Used	SWAT Default Value	Minimum	Maximum	Comments	Reference for Value Used
Water Balance									
	ESCO	hru	Soil evaporation compensation factor	0.95	0.95	0.01	1.0	As ESCO is reduced, more evaporation occurs due to effect of capillary action, crusting and cracks in soil	SWAT ET for entire modeling area (study yrs 1-10) was compared to GWLF results for Hellbranch subwatershed (study yrs 2-10); SWAT = 53.47 cm, GWLF = 53.94 cm
	IPET	hru	Potential evapotranspiration method (PET)	Priestley-Taylor	NA	NA	NA	Available methods: - Priestley-Taylor method (uses solar radiation, air temperature, relative humidity) - Penman/Monteith method (uses solar radiation, air temperature, relative humidity, wind speed) - Hargreaves method (uses air temperature only)	
	SFTMP	hru	Snowfall temperature (degrees C)	2.5	1.0	-5	5	Mean temperature at which precipitation is equally likely to be rain as snow/freezing rain	Value used was determined by comparing annual snowfall predicted by SWAT to ODOT average annual snowfall map, which shows 30 to 40 in/yr for Franklin County (using a 1:10 rain to snow depth ratio, SWAT model yielded 34.9 in of equivalent snowfall). See http://www.dot.state.oh.us/snowmap.htm
	SMFMX	hru	Melt factor for snow on June 21 (mm H2O/degree C - day)	3.0	4.5	NA	NA	Varies depending on land use; for rural areas, can vary from 1.4 to 6.9; for urban areas, 3.0 to 8.0; for asphalt, 1.7 to 6.5 (from SWAT manual)	
	SMFMN	hru	Melt factor for snow on Dec 21 (mm H2O/degree C - day)	3.0	4.5	NA	NA	Varies depending on land use; for rural areas, can vary from 1.4 to 6.9; for urban areas, 3.0 to 8.0; for asphalt, 1.7 to 6.5 (from SWAT manual)	
Surface Runoff									
	CN2	mgt	Initial SCS runoff curve number for moisture condition II	Varies by land use type, soil hydrologic group (see Table 12)					Values used are within SWAT recommended ranges for specific land use types and soil hydrologic groups. Also utilized TR-55 as reference to set urban CNs
	SURLAG	hru	Surface runoff lag coefficient	1.0	4.0	NA	NA	Allows for surface runoff storage, to lag a portion of the surface runoff release to the main channel; as SURLAG decreases in value, more water is held in storage	
Baseflow Groundwater Flow									
	ALPHA_BF	gw	Baseflow alpha factor (days)	0.1	0.048	NA	NA	Baseflow recession constant, is a direct index of groundwater flow response to changes in recharge. Values vary from 0.1-0.3 for land with slow response to recharge to 0.9-1.0 for land with rapid response	Value obtained from SWAT baseflow separation program was 0.0135, but value calculated from equation in SWAT manual using baseflow days (BFD) was equal to 2.3/BFD = 2.3/29.88 = 0.077
	GWQMN	gw	Threshold depth of water in the shallow aquifer required for return flow to occur (mm H2O)	150	0	NA	No maximum value	Groundwater flow to the reach is allowed only if the depth of water in the shallow aquifer is equal to or greater than GWQMN	
	GW_REVAP	gw	Groundwater "revap" coefficient	0.175	0.02	0.02	0.2	As GW_REVAP increases, increased transfer of water from shallow aquifer to root zone occurs, allowing more water loss due to plant uptake and evaporation	
	RCHRG_DP	gw	Deep aquifer percolation fraction	0.05	0.05	0.0	1.0	Fraction of percolation from the root zone that recharges the deep aquifer	
	REVAPMN	gw	Threshold depth of water in shallow aquifer for "revap" or percolation to the deep aquifer to occur (mm H2O)	0.0	1.0	NA	NA		

Table 13 (continued)
Calibration Parameters

Category	Variable Name	Input File	Description	Value Used	SWAT Default Value	Minimum	Maximum	Comments	Reference for Value Used
Nutrients									
	FRT_KG	mgt	Amount of fertilizer applied to agricultural HRUs (kg/ha)	Varies by crop type, fertilizer type	0.30	NA	NA	All fertilizer applied as elemental N, P. Recommended fertilizer application rates were altered +/- 20% to calibrate to GWLF (see Table 5 for final values used)	Fertilizer application dates based on Olentangy TMDL management files/scenarios; Application rates based on "Tri-State Fertilizer Recommendations for Corn, Soybeans, Wheat and Alfalfa" (http://ohioline.osu.edu/e2567)
	GW_NO3	gw	Initial concentration of nitrate in shallow aquifer (mg N/L or ppm)	Varies by HUC14	0.30	NA	NA		Values from TMDL study used for each HUC14 subwatershed
	GWSOLP	gw	Initial concentration of soluble phosphorus in shallow aquifer (mg P/L or ppm)	Varies by HUC14	0.30	NA	NA		Values from TMDL study used for each HUC14 subwatershed
	NPERCO	bsn	Nitrate percolation coefficient	1.0	0.20	0.01	1.0	Controls amount of nitrate removed from surface layer in runoff relative to amount removed via percolation; as NPERCO approaches 1.0, surface runoff has the same concentration of nitrate as the percolate	
	PPERCO	bsn	Phosphorus percolation coefficient (10 m3/Mg)	10.0	10.0	10.0	17.5	Ratio of solution phosphorus concentration in the surface 10 mm of soil to the concentration of phosphorus in percolate	
	PHOSKD	bsn	Phosphorus soil partitioning coefficient (m3/Mg)	175	175	NA	NA	Controls amount of phosphorus removed from surface layer in runoff via diffusion; is the ratio of soluble phosphorus concentration in the surface 10 mm of soil to that in surface runoff	
	HRU_SLP	hru	Average slope steepness (m/m)	0.5 * SWAT default value	Varies by sub-basin	NA	NA	This value is calculated automatically by SWAT during the sub-basin delineation process, using the DEM. Since a relatively small DEM grid cell size of 15 ft was utilized, based on other research studies, the slope calculated for each sub-basin is likely greater than that actually observed.	SWAT recommendations for a calibration range for sediment indicate +/- 50% of the default slope value.
Reaches									
	ALPHA_BNK	rte	Baseflow alpha factor for bank storage (days)	0.1	ALPHA_BF	0.0	1.0	Recession constant that characterizes bank storage recession curve; Value approaches 1.0 for flat recessions; value approaches 0.0 for steep recessions	
	CH_K1	sub	Effective hydraulic conductivity in tributary channel alluvium (mm/hr)	11.3	0.30	NA	NA	Controls transmission losses from surface runoff as it flows to the main channel in the subbasin	Value set at 11.3 mm/hr, which is equivalent to the predominant hydraulic conductivity within the modeling area as shown in the DRASTIC dataset
	CH_K2	rte	Effective hydraulic conductivity in main channel alluvium (mm/hr)	11.3	0.30	NA	NA	Perennial streams that simultaneously receive and lose groundwater have an effective hydraulic conductivity of zero	For all subbasins with Big Darby Creek as the main channel, CH_K2 was set to zero; For all other subbasins (tributaries of Big Darby Creek), CH_K2 was set to 11.3 mm/hr, which is equivalent to the predominant hydraulic conductivity within the modeling area as shown in the DRASTIC dataset
	CH_N1	sub	Manning's "n" value for tributary channels	0.03	0.014	NA	NA		
	CH_N2	rte	Manning's "n" value for main channels	0.045	0.014	NA	NA		

Table 14
Calibration Model Results

Description	Volume (mm)	Q (cfs)	SF/BF (%)	TN (kg)	TP (kg)	TSS (kg)
USGS Hellbranch Run gage	348.7	39.8	52/48 to 70/30[1]	NA	NA	NA
OEPA's GWLF model	NA	NA	59/41[2]	212,320[3]	15,297[3]	3,085,230[3]
SWAT Baseline model	344.4	39.3	54/46	190,200	14,706	3,439,721
Percent Error	-1.2%[4]	-1.3%[4]	NA	-10.4%[5]	-3.9%[5]	11.5%[5]

mm – millimeters cfs – cubic feet per second SF/BF – surface flow/baseflow

[1] Range derived using SWAT Baseflow Separation program

[2] Published value in draft Big Darby Creek TMDL report for Hellbranch Run sub-watershed (220-010)

[3] Does not include point source data that was added outside of GWLF to yield published TMDL "Existing" pollutant loadings; GWLF data corresponds to the SWAT model's calibration period (study years 3-10, Apr 1996 through Mar 2004)

[4] Compared to USGS Hellbranch Run gage data

[5] Compared to OEPA GWLF values

In addition to the calibration results shown in Table 14, as a check to determine the relative accuracy of the parameters associated with agricultural row crops, crop yields predicted by the model were compared to crop yield statistics for Franklin County. Table 15 demonstrates that crop yields, and therefore crop parameters, are relatively accurate since the SWAT yields are generally within 10% of the historical yields for each crop type.

Table 15
SWAT Crop Yields Compared to Historical Data

Crop	Average Crop Yields for Ohio, 1997-2003 (bu/ac)[1]	Average Crop Yields for Ohio, 1997-2003 (kg/ha)[2]	SWAT Crop Yields (kg/ha), Calibrated Model
Corn	125	7,822	6,892
Soybeans	39	2,587	2,308
Winter Wheat	69	4,668	3,299

[1] Source: USDA National Agricultural Statistics Service (http://www.nass.usda.gov/Statistics_by_State/Ohio/index.asp)

[2] Conversion from bu/ac to kg/ha, assuming 56 lb/bu for corn, 60 lb/bu for soybeans and winter wheat

The results of the calibration modeling serve as the basis for comparison with the results of the final land use scenario modeling, described below. This comparison allows for a determination of the changes in pollutant loading within the study area corresponding with only the changes in land use associated with the final land use plan associated with the Big Darby Accord.

F. Final Land Use Scenario Model

The final land use scenario model was established from the baseline (calibration) model by changing the land use coverage to reflect projected build-out conditions within the Accord planning area, considering various development types and housing densities along with their location. The fundamental changes related to the final land use scenario are described below.

1. Converting existing agricultural land uses to a variety of urbanized land uses, varying from a low density (rural) residential to a commercial level of development.
2. Converting existing agricultural land uses to preserved open space (conservation areas).

For areas outside of the Accord planning area, the baseline land use data was used, since build-out conditions were not projected for these regions.

The results of the final land use scenario model along with results from the calibration model are summarized in Table 16. Data is categorized by each 14-digit HUC (or portion of) within the modeling study area. For the Hellbranch sub-watershed only, published values from the Big Darby Creek draft TMDL report are also included. To be able to compare the SWAT results to these TMDL values, additional TN and TP point source loadings that were added to the GWLF results to yield the published "Existing" pollutant loadings in the TMDL report were also added to the SWAT results. The TSS values reported in the TMDL are cumulative values that account for both sediment yield from overland runoff (predicted by the GWLF model) and a larger amount of sediment from channel degradation and construction activities (estimated by the OEPA outside of GWLF). The SWAT model, similar to GWLF, accounts only for sediment related to overland runoff. The parameters that dictate bank erosion are site specific, and this information did not exist at the time of calibration. Therefore, sediment produced by channel degradation and construction runoff was not estimated as a part of these water quality modeling efforts. TSS from construction/channel erosion is assumed to be the same as that estimated for the TMDL analysis.

TMDL allowable values for the other 14-digit sub-watersheds are not provided in the table below because the Accord planning area and, therefore, the area modeled within the SWAT analysis, does not include the entire extent of those 14-digit HUCs. As such, it is not logical to report the allowable values from the TMDL report for those areas, nor is it feasible to estimate the proportion of the published allowable values that are attributed to only a portion of the 14-digit HUC.

Table 16
Comparison of Pollutant Loading Values

Hellbranch Run (220-010)

Description	Volume (mm)	Q (cfs)	SF/BF (%)	TN (kg)	TP (kg)	Overland Runoff TSS (kg)	Construction/ Channel Erosion TSS (kg)
TMDL Existing	NA	NA	59/41	NA	16,359	3,051,200	17,594,074
TMDL Allowable	NA	NA	NA	NA	3,175	1,086,249	
SWAT Baseline model + PS	344.4	39.3	54/46	190,885	15,944	3,439,721	17,594,074
SWAT Future Land Use Scenario model + PS	369.8	42.2	62/38	113,617	4,517	1,023,087	17,594,074

PS – Point Source Loading (additional TN and TP loadings calculated by OEPA that were added to GWLF results to yield TMDL Existing values)

BDC 4 (200-010)

Description	Volume (mm)	Q (cfs)	SF/BF (%)	TN (kg)	TP (kg)	Overland Runoff TSS (kg)
SWAT Baseline model	351.7	11.0	46/54	47,985	3,938	454,960
SWAT Future Land Use Scenario model	346.6	10.8	44/56	20,019	582	184,825

BDC 5 (200-020)

Description	Volume (mm)	Q (cfs)	SF/BF (%)	TN (kg)	TP (kg)	Overland Runoff TSS (kg)
SWAT Baseline model	341.6	20.0	48/52	83,537	7,038	1,903,448
SWAT Future Land Use Scenario model	344.5	20.1	49/51	36,393	1,175	427,247

BDC 6 (220-020)

Description	Volume (mm)	Q (cfs)	SF/BF (%)	TN (kg)	TP (kg)	Overland Runoff TSS (kg)
SWAT Baseline model	331.1	37.1	50/50	163,813	16,230	8,548,723
SWAT Future Land Use Scenario model	335.1	37.6	50/50	93,456	6,840	6,858,007

Entire SWAT Modeling Area

Description	Volume (mm)	Q (cfs)	SF/BF (%)	TN (kg)	TP (kg)	Overland Runoff TSS (kg)
SWAT Baseline model	338.2	81.3	64/36	382,681	34,148	18,462,134
SWAT Future Land Use Scenario model	354.6	85.3	68/32	228,523	11,882	10,283,179

G. Conclusions

The modeling provided has been successful in duplicating the results from the TMDL study, at least for the Hellbranch Run sub-watershed. With that modeling serving as a baseline for comparison, it has been determined that the proposed land use plan for the Big Darby Accord will ultimately reduce the level of pollutants that are contained in stormwater runoff and discharged to Hellbranch Run or directly to the Big Darby Creek main stem. The percent reduction in the various pollutants for Hellbranch Run and for the larger study area is contained in Table 17, below. As expected, the increase in impervious area associated with the urbanizing land uses contained within the final land use plan will increase the calculated average annual flow rate and cause a re-distribution of the surface flow/baseflow relationship within the study area.

Table 17
Comparison of Baseline Condition to Final Land Use Plan

Pollutant	Percent Loading Reduction[1]	
	Hellbranch Run Watershed	Entire Study Area[2]
TSS[3]	70%	44%
TP	72%	65%
TN	41%	40%

[1]Compared to SWAT Baseline model
[2]Includes areas directly tributary to Big Darby Creek
[3]Pertains only to the overland runoff component of TSS

The percent reductions noted in Table 17 for the Hellbranch Run watershed are less than those specified in the TMDL to obtain the target levels for those pollutants. [Note: TN is not presented in the TMDL.] Furthermore, the comparison of TSS only pertains to the overland runoff component of that pollutant. Table 16 contains additional information relating the additional loading associated with construction activities and channel bank erosion. Considerations to reduce these individual components include comprehensive erosion and sediment control criteria and incentives to promote stream bank stabilization and/or restoration activities within the watershed.

It is important to note that the results represented by the SWAT modeling and summarized within this document represent only an analysis of land use changes within the Accord planning area and do not account for stormwater best management practices or specific site planning practices, such as low-impact design, that would further reduce pollutant loading or increase infiltration from urbanizing land uses. Other important observations regarding the modeling and the accompanying results are described below.

- The significant reduction in pollutants when comparing the final land use plan to the baseline condition can be attributed not only to the replacement of agriculture with urbanizing land uses, but also the representation of conservation open space that is part of the plan and also replaces a considerable amount of land currently being used for agriculture.

- The analysis performed for this study did not represent the presence of field tile that exists in conjunction with agricultural land uses throughout the study area. Eliminating field tile in conjunction with changing land uses would likely reduce the change in flow rate and the surface flow/baseflow relationship.
- Stream restoration activities can have a beneficial impact on multiple facets of the modeling provided for this study. Stream restoration to add floodplain storage can mitigate the impact of increased flow associated with urbanizing areas. It can also increase the assimilative capacity of pollutants conveyed within the stream channel, particularly TSS.

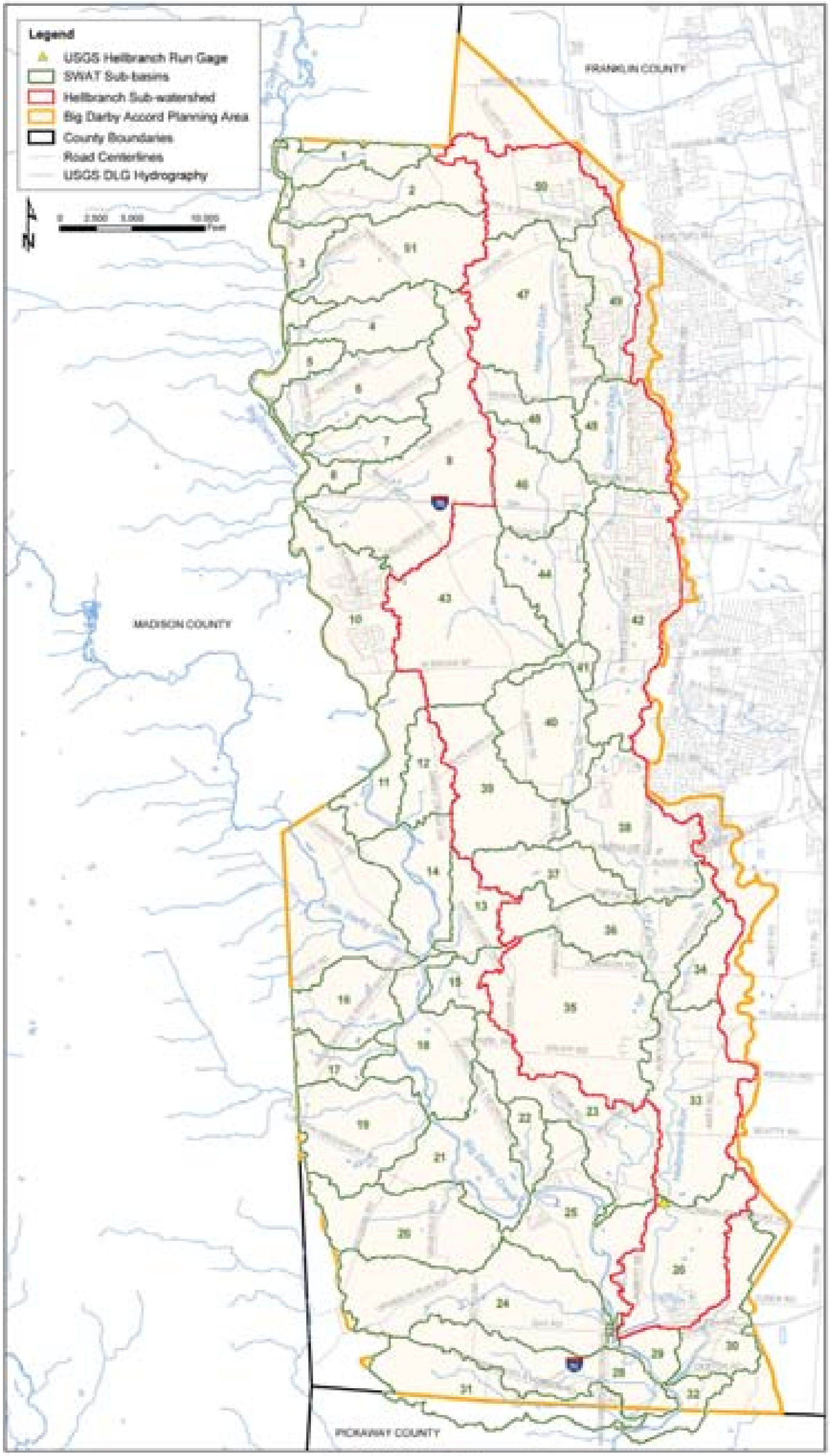


Figure 1: Modeling Study Area

Figure 2: Soils Series (NRCS SSURGO Data)

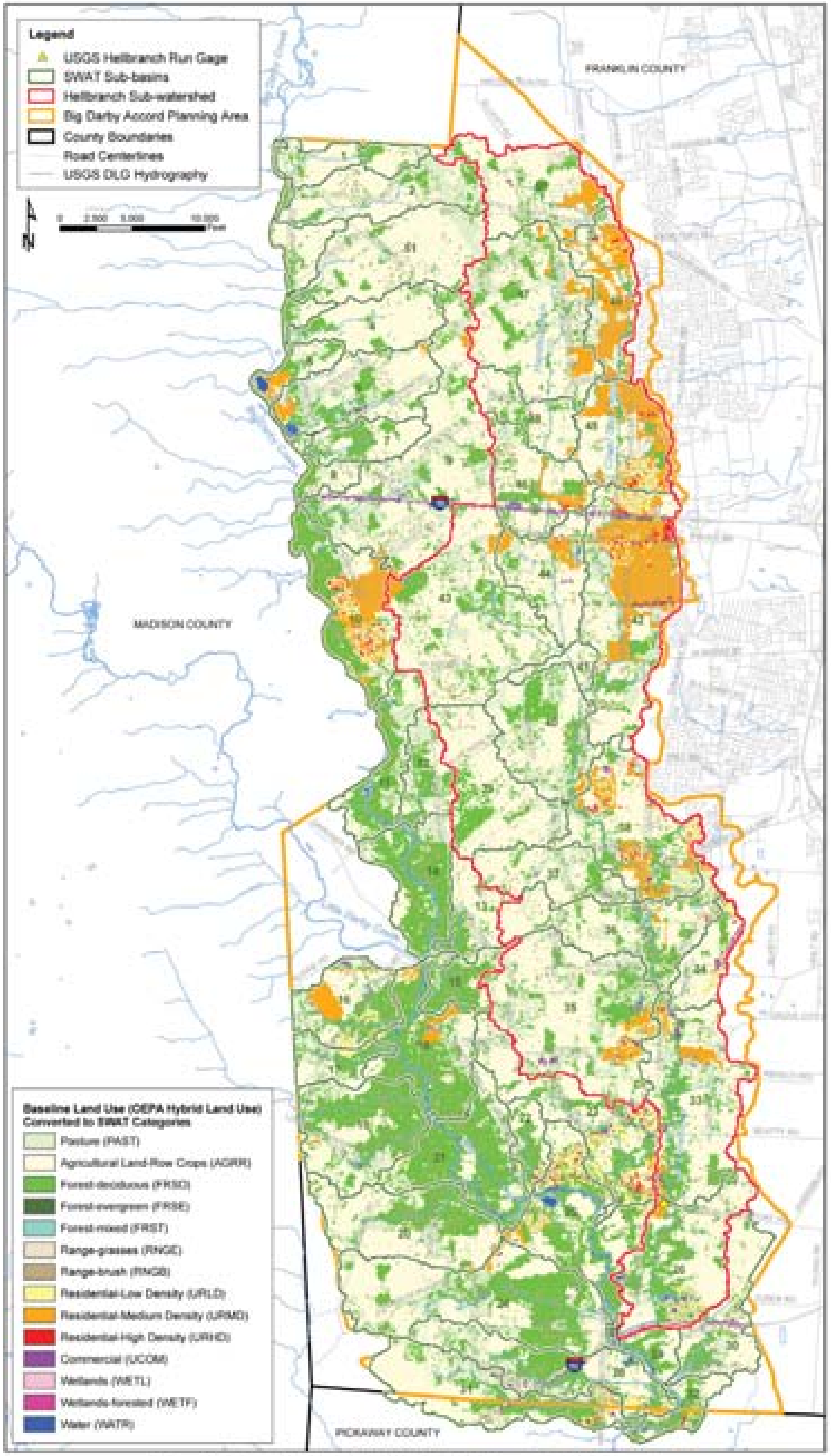


Figure 3: Baseline Land Use (OEPA Hybrid Land Use) Converted to SWAT Categories

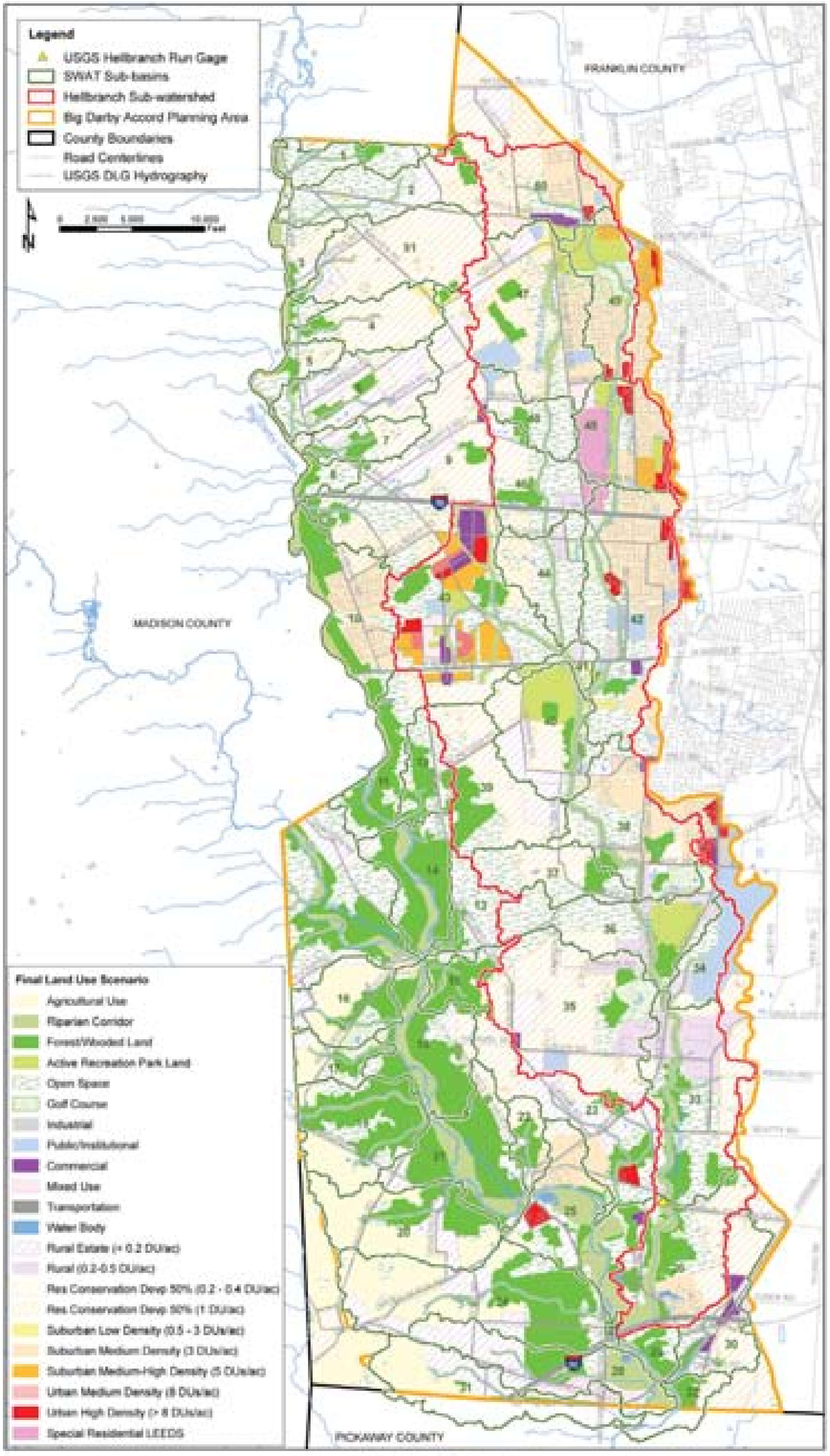


Figure 4: Final Land Use Scenario

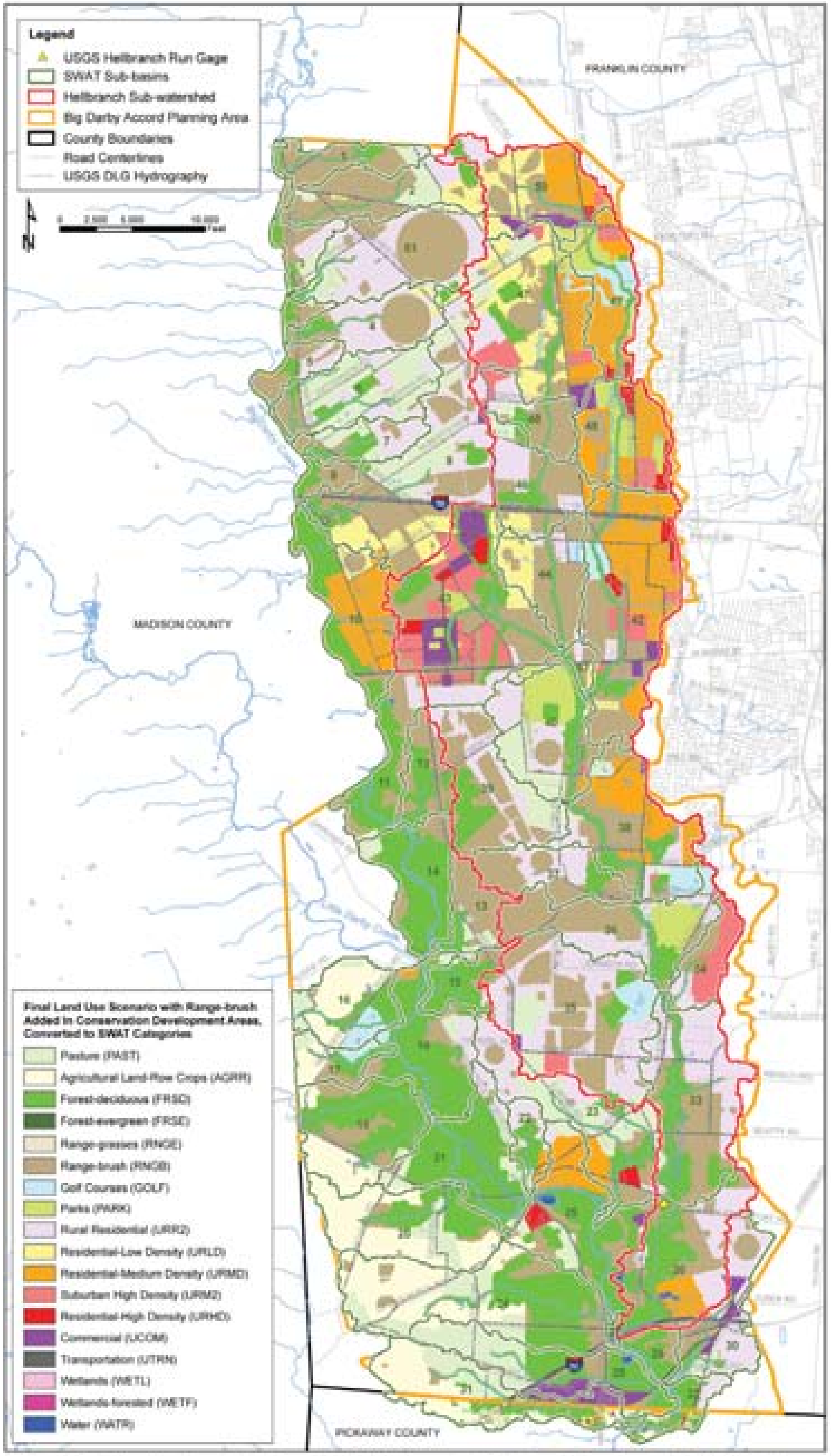


Figure 5: Final Land Use Scenario With Range-brush Added In Conservation Development Areas, Converted to SWAT Categories

Big Darby Accord
Best Management Practice Pilot Study Report

EMH&T, Inc.
June 2006

Table of Contents

A. Introduction

The SWAT model that was prepared for the final land-use plan did not include a representation of any stormwater BMPs, and the results of the modeling were compared to similar locations within the OEPA Total Maximum Daily Load (TMDL) report. For example, SWAT model results were compared to the TMDL results for the entire Hellbranch Run watershed. A pilot study was undertaken in an effort to more closely review the results of the SWAT modeling of one sub-watershed within the Hellbranch Run watershed and to provide an analysis of stormwater BMPs for the pilot study area, in this way, the pilot study analysis would examine a possible template for meeting the proposed water quality performance goals for the planning area.

The BMP pilot study was focused on the Town Center area of the most recent Darby Accord land use plan. The Town Center is located within sub-basin 43 of the overall SWAT model and is tributary to McCoy Ditch, within the Hellbranch Run watershed. Refer to Figure 1 for a representation of the pilot study area.

B. SWAT Analysis of Pilot Study Development Area

The structural BMPs that are part of the BMP Toolkit in the land use plan cannot be modeled within the SWAT model platform. Two of the non-structural BMPs that are part of the Low Impact Development parameters can be directly analyzed within SWAT: 1) a reduction in directly connected impervious area (DCIA), and 2) the use of filter strips (vegetated buffers along streams). A reduction of DCIA is indicative of a development that has less downspout to gutter to storm sewer connections and the filter strips are representative of a storm water conveyance system discharging into a dedicated stream side riparian area prior to entering a stream channel.

DCIA is represented by a percentage of the total impervious surface that is considered directly connected, for example, if a site is 20% impervious cover and the DCIA is 90%, then 90% of the 20% impervious cover is directly connected and is defined within the "urban.dat" file of the SWAT program. The SWAT manual includes information on a range of values for DCIA for different land use types based on research done on several sites in Wisconsin and Michigan (page 477 of the Input/Output File Documentation manual). The calibrated model utilizes numbers for DCIA that are close to the averages listed in the SWAT manual. For the purposes of the pilot study, the DCIA percentage was lowered to the lowest value listed in the SWAT manual for each of the urban land-use types in the pilot study area. The lowest limit for DCIA takes into account practical limitations on disconnecting impervious surfaces, for example, it is not practical to disconnect sidewalk runoff from driveway runoff, and to disconnect driveway runoff from street runoff.

The results of the reduction in DCIA, and the impact on each of the pollutants of concern, are summarized in Table No. 1. In comparing the results of the DCIA reduction modeling to the final land use plan modeling, an increase in TSS, phosphorous, and nitrogen is present. Upon further study of the modeling output, this increase is present only from the commercial areas, which is likely due to the manner in which pollutants buildup on paved surfaces before being washed off during a rain event. In general, a decrease in pollutants is realized by disconnecting impervious surfaces on all land uses except for commercial development, however, it is not enough to eliminate the need for other BMPs on the site that would have a larger impact on pollutant removal rates.

In addition to DCIA, the impact of filter strips on the pollutant loads was analyzed in SWAT. Within SWAT, a filter strip width is defined within the management file for each HRU. SWAT utilizes a simple equation to determine the pollutant removal efficiency for a filter strip which it applies equally to total suspended solids (TSS) and nutrients (phosphorous and nitrogen). The equation is:

$$trap_{ef} = 0.367*(width_{filstrip})^{0.2967}$$

Where $trap_{ef}$ is the fraction of the pollutant loading trapped by the filter strip, and $width_{filstrip}$ is the width of the filter strip in meters

Two different widths were analyzed, 10 meters and 20 meters, and the results of this analysis are also summarized in Table No. 1 below. It should be noted that by utilizing the equation in the SWAT theory manual (pg. 325) for the removal efficiency of filter strips, a 25 meter (82 feet) wide filter strip would meet the 95% removal target for TSS, with no other BMP application. After reviewing the results of the filter strip modeling it is possible that the model is over-simplifying the processes that occur within a filter strip and, therefore, over-estimating the removal efficiency that can be achieved through their use.

Table No. 1
Summary of SWAT Modeling for Pilot Study

Scenario	TSS (kg)	% Reduction from Existing	Total P (kg)	% Reduction from Existing	Total N (kg)	% Reduction from Existing
Existing	2,302,169.14	NA	1,602.19	NA	18,260.50	NA
Final Plan	301,310.34	86.9	483.66	69.8	9,641.87	47.2
10 Meter Filter Strip	116,091.96	95.0	239.22	85.1	5,791.58	68.3
20 Meter Filter Strip	73,798.50	96.8	183.45	88.6	4,703.69	74.2
Reduced DCIA	310,159.67	86.5	516.07	67.8	9,897.37	45.8
Reduced DCIA & 20 meter filter strip	74,763.70	96.8	187.72	88.3	4,839.30	73.5

The analysis of the SWAT model output from the pilot study area is based on pollutant loading numbers from each individual HRU before they are routed and transported downstream, and should not be compared to the Hellbranch Run output that was used for calibration purposes. As runoff is routed downstream in the SWAT model attenuation of pollutant loads and runoff peak flows are accounted for, the results summarized above are prior to any of that attenuation occurring. The results presented above are useful for comparative purposes for the pilot study area, and specifically for the BMPs analyzed within the SWAT model.

C. Post-SWAT Analysis of BMPs

In order to determine which BMPs will be necessary to meet the target pollutant removal rates from the TMDL report, analysis outside of the SWAT model was performed. In 2004 the State of Georgia developed the *Georgia Stormwater Management Manual Stormwater Quality Site Development Review Tool* as a method for both designers and reviewers to determine whether or not a proposed BMP or combination of BMPs would meet the requirements for removal of TSS that the State of Georgia requires. The State of Georgia has an 80% TSS removal as their primary pollutant removal goal, and other pollutants are secondary. As part of this tool, it is possible to link multiple BMPs in sequence and determine the cumulative benefit of the “treatment train” of BMPs. As part of the tool, Georgia includes an instruction manual which includes the equations used to determine the diminishing benefit of BMPs in series. For example, if two BMPs are in series, and individually they can remove 80% of the TSS load, when placed in series the first will remove 80% of the TSS, but the second will not remove 80% of the final 20% of the TSS, which would be a total removal efficiency of 96%. The calculator determines that two combined BMPs will remove approximately 88% of the total TSS load. The diminishing affect of the treatment train concept is attributed mostly to the finer (smaller) particles that are not captured in the initial BMP and less likely to be captured by the second. Information contained within the Georgia tool references previously determined removal efficiencies of the various BMPs, and the removal efficiencies have no correlation to land use. For example, if a Stormwater Wetland is the selected BMP, an 80% removal of TSS can be achieved regardless of the land use type that provides runoff to that feature. TSS and phosphorus (P) removal efficiencies for certain individual BMPs used within the tool are summarized in Table No. 2, below.

Table No. 2
BMP Removal Efficiencies

Structural Control	TSS Removal (%)	Total P Removal (%)
Stormwater Pond	80	50
Stormwater Wetland	80	40
Bioretention Area	80	60
Infiltration Trench	80	60
Enhanced Swales	80	50
Filter Strip	50	20
Grass Channel	50	25

The Georgia tool was used to determine which BMPs used in conjunction with one another would be able to reach the Big Darby Creek TMDL target goal of 95% removal of TSS. TSS removal was the focus for the pilot study analysis as it is the primary pollutant targeted by the design tool being used, and has the highest standard for removal in the TMDL.

Two different scenarios were considered, one utilizing BMPs that would be more likely within a residential development, and one that would be more typical of a commercial development. Both scenarios are built on the concept of a treatment train, assessing multiple BMPs applied in combination. The scenarios below are shown with multiple different removal efficiencies, starting at 80% (which is a common goal in other stormwater management guidelines), and proceeding up to the 95% goal of the TMDL. These different efficiencies require different numbers of BMPs to meet the goal, and are therefore listed in order of which BMPs are the most likely to be implemented to meet a specific goal. For example, on a residential development, if the goal were to meet 80% removal of TSS only a stormwater wetland would be needed, but if 85% were required a stormwater wetland and an enhanced swale would be necessary. This method was utilized due to ongoing discussion regarding the target for water quality protection. There is a possibility that due to the large conservation areas required in the final land use plan that a 95% removal of TSS would not be required, and that a different removal rate would become the goal for the BMPs to achieve. It is recommended that a minimum removal efficiency of 80% be used on all development sites.

The results of the treatment train analysis are presented below.

Residential Land Use Area:

- To meet 80% removal: Stormwater Wetland
- To meet 85% removal: 80% + Enhanced Swale (which reaches 88%)
- To meet 90% removal: 85% + Enhanced Swale
- To meet 95% removal: 90% + either Bioretention or an Infiltration Trench

This listing above does not take the order of the BMPs into account, which would likely be:

Bioretention to Enhanced Swale to Stormwater Wetland to Enhanced Swale

Commercial Land Use Area:

- To meet 80% removal: Bioretention
- To meet 85% removal: 80% + Infiltration Trench (which reaches 88%)
- To meet 90% removal: 85% + Filter Strip
- To meet 95% removal: 90% + Stormwater Wetland *and* an Enhanced Swale (which reaches 96%)

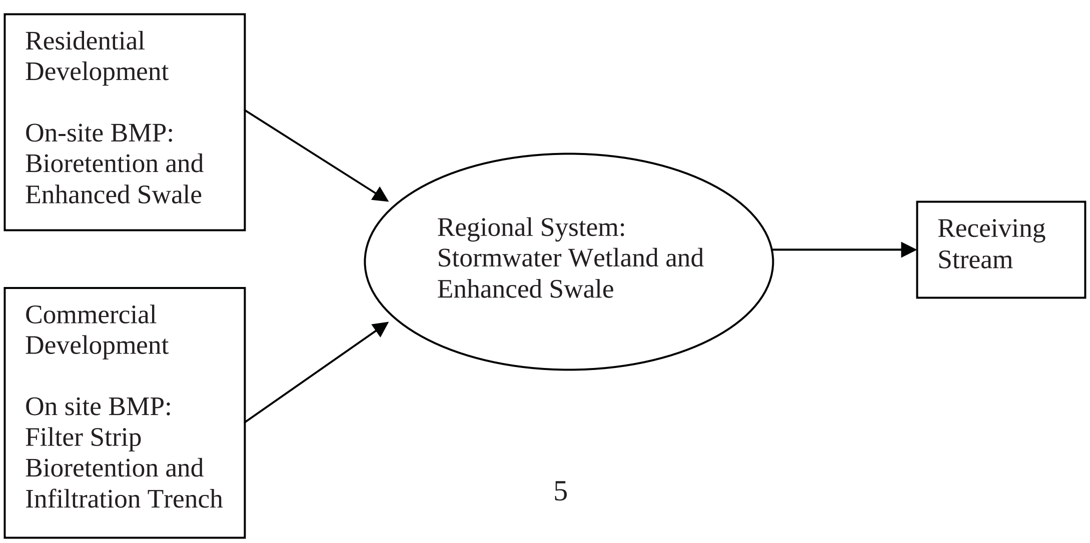
The more likely order would be:
Filter Strip to Bioretention to Infiltration Trench to Stormwater Wetland to Enhanced Swale.

D. Application of Results

As part of the final land use plan, the Town Center area is expected to be an area of high population density and a mix of different housing types and commercial uses. Projections were made about the composition and arrangement of development within the Town Center area in order to facilitate the modeling of the area for both the final land use plan model and the pilot study modeling. Figure 1 has been prepared to show the configuration of proposed land use within the Town Center area that has been used to perform the SWAT analysis of that condition. Figure 2 has been prepared to show a more detailed depiction of that proposed land use with a conceptual representation of stormwater management applications.

After comparing the results of the analysis to determine which BMPs would be necessary to meet the TMDL goal of 95% removal of TSS and the proposed conceptual configuration of the Town Center, it became apparent that it may be impractical for certain development types to incorporate all of the BMPs that would be necessary to meet the TMDL target. For example, a small commercial development site would be unlikely to have enough space to incorporate 5 separate BMPs without compromising the ability to feasibly develop the site. Furthermore, the proliferation of numerous smaller BMP applications presents a concern regarding long term maintenance and viability. These realizations, coupled with the projected development composition of the Town Center area led to the development of a more regionalized BMP implementation process. In the regional system, the stormwater BMPs that are physically larger and occupy more land area would be considered the regional BMPs that would provide for a portion of the water quality control, and much of the quantity control for a development area.

Using the BMP treatment train concept outlined above for commercial and residential development, the regional system would likely be the last two or three BMPs in the train, while the initial BMPs would be included within individual development sites, as illustrated in the diagram below.



In an effort to determine what some of these BMPs could potentially change in the appearance of different types of development, Figures 3 through 6 were created using existing developed areas within Franklin County. None of these developments is located within the planning area, nor are any retrofit projects expected from these Figures. The Figures were created for illustrative purposes only to show how development would have to be altered to incorporate a treatment train of stormwater BMPs. As development density increases it requires more creativity on the part of the site designer to incorporate some of the required BMPs, but as shown on the Figures is possible. Figures 3 through 6 show BMPs that are not primary BMPs for a site, like pervious pavement, that have the possibility to reduce the overall size of required runoff quantity control by increasing the portion of the post development runoff that is allowed to infiltrate into the soil. These secondary BMPs are shown for illustrative purposes only and will not be required, but may be encouraged, for any development.

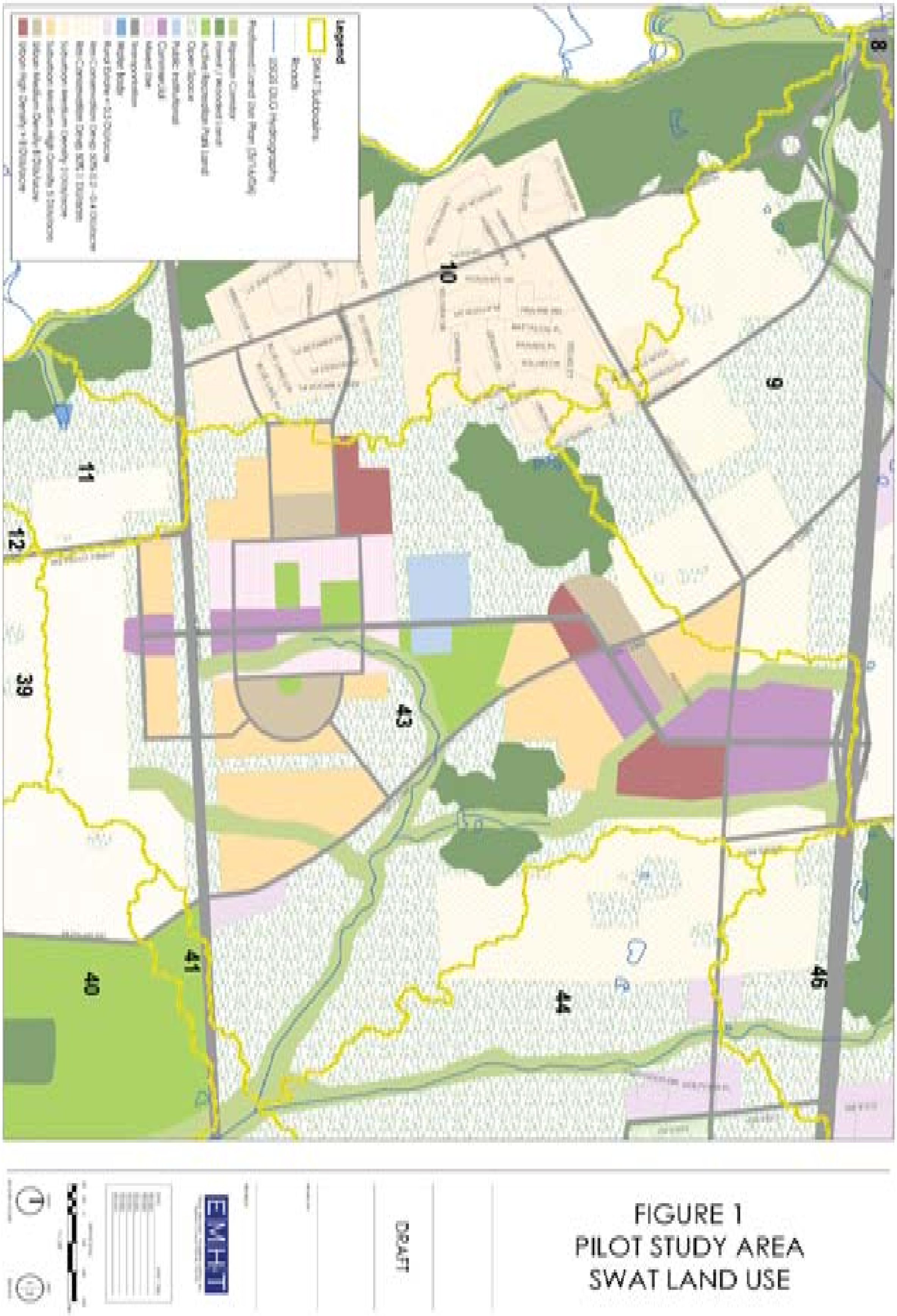
E. Conclusions

The pilot study was undertaken to allow for a greater understanding of the impact of stormwater BMPs on the pollutant loads that are produced by urban runoff. This was done through two different methods, by analyzing results from the SWAT modeling performed for the final land use plan, and through the use of a tool developed for use in the State of Georgia to determine the BMPs necessary on a site to meet a TSS removal requirement. Based on the analysis performed, a treatment train of BMPs will likely be required to meet the current pollutant targets for the Darby Accord planning area. The information gathered regarding this treatment train method of controlling water quality led to the realization that regional stormwater BMPs have the ability to allow for a higher density development in the area tributary to the BMPs by minimizing the area required for BMPs on individual development sites.

The final land use plan indicated, and the pilot study model reinforces, that by enabling land use change, a significant reduction in pollutant loads can be achieved. This would indicate that any post-development stormwater BMPs implemented in the developed condition may not have to meet the removal efficiency shown in the TMDL. The pollutant removal requirements (for TSS and phosphorous) listed in the TMDL are from the existing condition for the planning area, and the implementation of the land use plan will likely account for a portion of the removal requirement for those pollutants. Certain land use types reduce TSS, but may increase phosphorous, and other land use types may do the opposite. The final removal efficiency required for post-development BMPs will likely vary somewhat by land use type, with sites that have a higher pollutant loading potential requiring a removal efficiency closer to the 95% required by the TMDL.

Based on the pilot study analysis, minimizing directly connected impervious areas does provide a benefit to water quality and should be encouraged, it does not eliminate the necessity for other BMPs for a site. While filter strips were shown to provide a marked decrease in the pollutant load to the streams, the results may exaggerate the actual benefit provided. So, like minimizing DCIA, it is a practice that should be encouraged, but will not eliminate the need for additional BMPs as part of the development.

Details regarding the implementation of a regional stormwater system and the related BMP treatment train must be resolved, including who constructs the regional portions of the system and the timing of the construction of the regional system in relation to the rest of the development that will be tributary to it. These issues and others will need to be addressed before any regional stormwater system is implemented within the planning area. Furthermore, more specific allowable pollutant load rates are being developed at this time to provide additional design guidance for site-specific or regional-based stormwater BMPs. .


Legend
11
12
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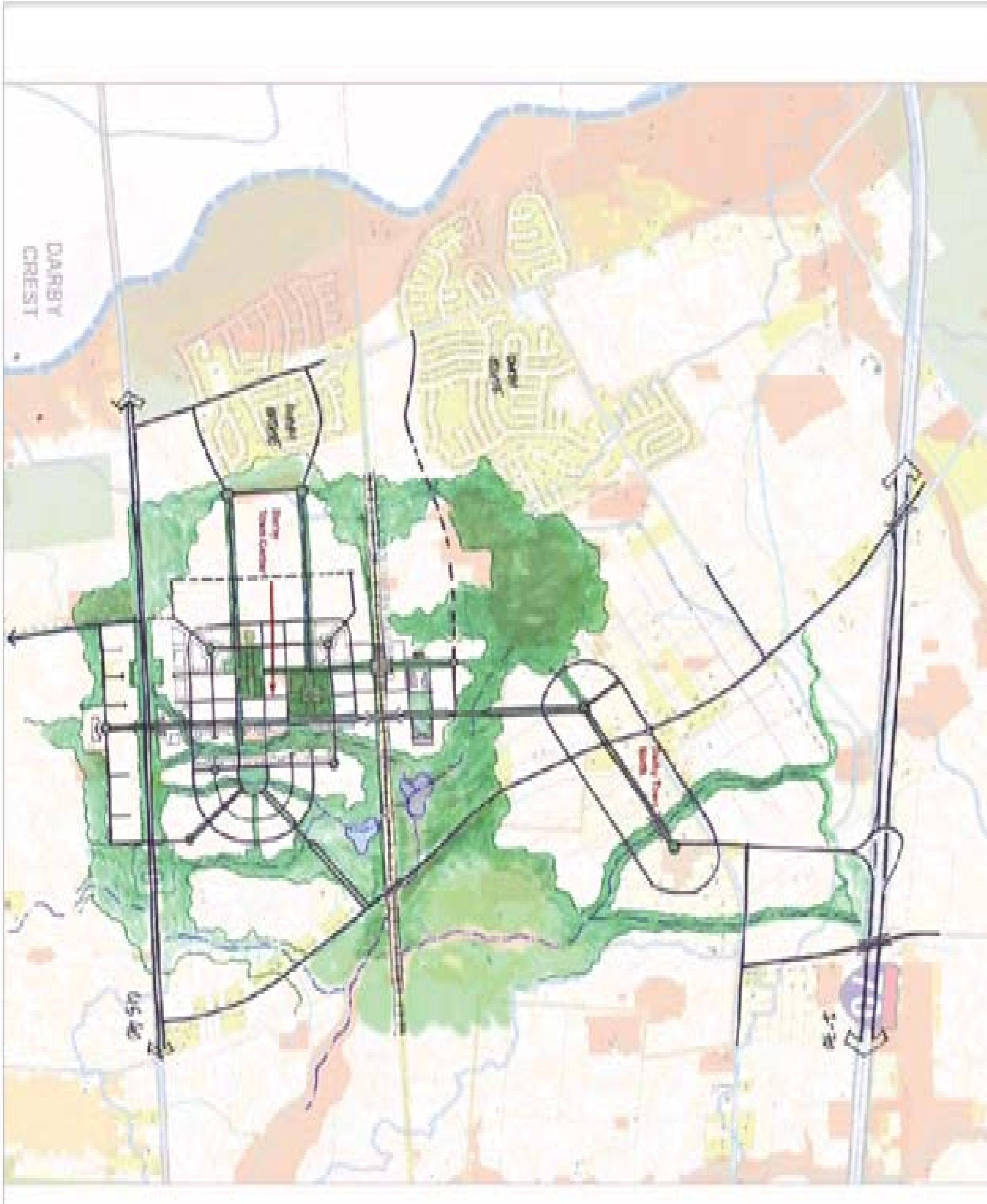
DRAFT
EMH&T
FIGURE 1
PILOT STUDY AREA
SWAT LAND USE



EDAW

DRAFT

FIGURE 2
TOWN CENTER DESIGN

DRAFT

MEDIUM DENSITY AND
MULTI-FAMILY HOUSING

DRAFT

LOW DENSITY SINGLE FAMILY RESIDENTIAL

Figure 5

DRAFT

HIGH DENSITY SINGLE FAMILY RESIDENTIAL AND BIG BOX RETAIL

RETAIL CENTER
PLANTED BIO-RETENTION / INFILTRATION AREA
MANUFACTURED INLET
FLOW DIRECTION
GRASSED SWALE / BIO-RETENTION MEDIAN
PERVIOUS PAVEMENT
EMHT
DRAFT
NEIGHBORHOOD RETAIL

Organization / Agency and Grant or Program	Website/Contact	Resource Management					Development					Recreation						Other	
		Land Acquisition/Open Space/Resource Protection	Conservation Corridors	Wildlife Habitat (Rehabilitation/ Restoration)	Pollution Control/ Water Quality/Stormwater/Flood Prevention	Farmland Protection	Community and Economic Development	Facility and Service Improvements	Streetscaping	Neighborhood Revitilization / Rehabilitation	Future Planning and Ordinances	Trails	Recreational Areas or Fields	Facilities/ Amenities	Management and Maintenance	Restoration and Rehabilitation of Existing Sites	Future Planning	Education / Interpretation	General Operating Budget
Federal Agencies and Programs																			
Federal Emergency Management Agency	http://www.fema.gov/fima/planning.shtm	✔	✔	✔	✔														
National Park Service																			
Rivers, Trails, and Conservation Assistance Program	http://www.ncrc.nps.gov/rtca/	✔	✔																
North American Wetlands Conservation Act Grants Program	http://www.nature.nps.gov/water/NorthAmWetlands ConsActGrantsProgram.doc	✔	✔	✔		✔													
US Army Corp of Engineers	http://www.usace.army.mil/public.html	✔		✔	✔	✔													
US Department of Agriculture/Natural Resources Conservation Service																			
Conservation Reserve Program	http://www.fsa.usda.gov/dafp/cepd/crp.htm	✔	✔	✔	✔	✔													
Conservation Security Program	http://www.oh.nrcs.usda.gov/programs/csp_06/csp_home_2006.html		✔	✔															
Conservation Innovation Grants (CIG)	http://www.oh.nrcs.usda.gov/programs/CIG/cig2006.html																		
Emergency Conservation Program	http://www.fsa.usda.gov/pas/publications/facts/html/ecp04.htm	✔				✔													
Farmland Protection Program	http://www.info.usda.gov/nrcs/fpcp/fpp.htm	✔	✔			✔													
Grassland Reserve Program	http://www.oh.nrcs.usda.gov/programs/grp/grassland_res_2003.html	✔	✔	✔		✔													
Wetlands Reserve Program and Wetlands Reserve Enhancement Program	http://www.nrcs.usda.gov/programs/wrp	✔	✔	✔															
Wildlife Habitat Incentives Program (WHIP)	http://www.oh.nrcs.usda.gov/programs/whip/whip_2006.html	✔		✔															
Cooperative Conservation Partnership Initiative (CCPI)	http://www.oh.nrcs.usda.gov/programs/eqip/eqip2006.html																		
Environmental Quality Incentives Program (EQIP) - National	http://www.oh.nrcs.usda.gov/programs/eqip/eqip2006.html		✔		✔														
Resource Conservation and Development (RC&D) Program	http://www.oh.nrcs.usda.gov/programs/RCD/index.html	✔	✔	✔	✔														
US Department of Housing and Urban Development	http://www.hud.gov/offices/adm/grants/fundsavail.cfm#grants						✔	✔	✔	✔	✔								
US Department of the Interior	http://www.nbc.gov/cci/matrix.cfm	✔		✔						✔	✔	✔	✔	✔		✔	✔		
US Department of Transportation	http://www.fhwa.dot.gov/reauthorization/safetea.htm	✔										✔		✔	✔	✔	✔		
US Environmental Protection Agency	http://www.epa.gov/epahome/grants.htm	✔	✔	✔	✔						✔								
Water Resource Restoration Sponsor Program	www.epa.state.oh.us/defa	✔	✔	✔	✔														
Non source Program and Grants	http://www.epa.gov/owow/nps/cwact.html				✔														
US Fish and Wildlife	http://www.fws.gov/grants																		
Private Stewardship Grants	http://endangered.fws.gov/grants/private_stewardship.html	✔		✔															
State Agencies and Programs																			
Ohio Department of Natural Resources (ODNR)	http://www.dnr.state.oh.us/grants.htm																		
Division of Real Estate and Land Management																			
Natureworks	614-265-6646	✔										✔	✔			✔	✔		
Land and Water Conservation Fund	614-265-6646	✔	✔									✔	✔	✔	✔	✔	✔		
Clean Ohio Trails Fund	614-265-6477	✔										✔							
Recreational Trails Program	614-265-6477	✔	✔									✔	✔	✔	✔	✔	✔		
Division of Forestry																			
Greenworks	614-265-6657	✔	✔			✔												✔	
Recycle Ohio	614-265-6333				✔														
Division of Soil and Water Conservation																			
Agriculture Pollution Abatement Cost Sharing	Local Soil and Water Conservation District Office				✔	✔													
Pollution Abatement Toolbox	614-265-6684				✔	✔													
Non Point Source Pollution Grants	614-265-6682																	✔	
Conservation Reserve Enhancement Program (CREP)	(614) 255-2441		✔		✔														
Watershed Coordinators	614-265-6647		✔		✔														✔
Urban Streams Program	614-265-6685	✔			✔			✔			✔								✔
Division of Wildlife																			
Grassland Restoration: Pastures to Prairies	614-265-6907			✔										✔					
Wetland Restoration	614-265-6907	✔	✔		✔														
Ohio Department of Development																			
DoD website	http://www.odod.state.oh.us/																		
Community Services Block Grant	http://www.odod.state.oh.us/cdd/ocs/csbg.htm						✔	✔	✔	✔	✔								

		Resource Management					Development					Recreation						Other	
Organization / Agency and Grant or Program	**Website/Contact**	Land Acquisition/Open Space/Resource Protection	Conservation Corridors	Wildlife Habitat (Rehabilitation/ Restoration)	Pollution Control/ Water Quality/Stormwater/Flood Prevention	Farmland Protection	Community and Economic Development	Facility and Service Improvements	Streetscaping	Neighborhood Revitilization / Rehabilitation	Future Planning and Ordinances	Trails	Recreational Areas or Fields	Facilities/ Amenities	Management and Maintenance	Restoration and Rehabilitation of Existing Sites	Future Planning	Education / Interpretation	General Operating Budget
Office of Housing and Community Partnerships (grants and loans)	http://www.odod.state.oh.us/cdd/ohcp/	✓	✓	✓	✓		✓	✓	✓	✓	✓								
Ohio Environmental Protection Agency	http://www.epa.state.oh.us/cleanohio.html	✓	✓	✓	✓	✓													
Clean Ohio Fund	http://www.epa.state.oh.us/cleanohio.html	✓	✓	✓	✓	✓													
Clean Ohio Green Space Conservation Program	http://www.pwc.state.oh.us/clean_ohio.htm	✓	✓		✓		✓	✓	✓	✓	✓								
Clean Ohio Agricultural Easement Purchase Program	http://www.ohioagriculture.gov/pubs/divs/farm/farm-index.stm	✓				✓													
Clean Ohio Trails Fund	http://www.dnr.state.oh.us/cleanohiofund/admin.htm											✓	✓	✓	✓	✓	✓		
Clean Ohio Revitilization Fund	http://www.odod.state.oh.us/ud/CORF.htm	✓	✓	✓	✓		✓	✓				✓	✓	✓	✓	✓	✓		
Ohio Department of Transportation (Ohio DOT)	http://www.dot.state.oh.us/programresource/	✓	✓		✓		✓	✓	✓	✓	✓	✓			✓		✓	✓	
Ohio Emergency Management Agency (PEMA)	http://www.ema.ohio.gov/ema.asp																		
Ohio Water Development Authority	http://www.owda.org/																		
Research and Development Grant Program	http://www.owda.org/ProgramInfo/rdgrants/rdgrants.asp				✓			✓											
Private Sources and Programs/Foundations																			
Altria Group, Inc.	http://www.altria.com/responsibility/4_9_1_1_whatwefund.asp																	✓	
Balance Bar	http://mountainbike.about.com/od/bikenewsevents/a/Bgrants_comm.htm																		
Kraft Food	http://www.kraft.com/profile/cares.html#Anchor-Focus-49575																		
Captain Planet Foundation	http://www.captainplanetfdn.org/aboutUs.html																		✓
Cherokee Investment Partners	http://www.cherokeefund.com						✓	✓		✓	✓								
Doris Duke Charitable Foundation	http://www.ddcf.org/page.asp?pageId=1	✓	✓	✓	✓													✓	
Local Initiatives Support Corporation (LISC)	http://www.lisc.org										✓								
North American Association for Environmental Education	http://eelink.net/pages/Grants+-+General+Information																		
The George Gund Foundation	http://www.gundfdn.org/	✓	✓	✓	✓		✓											✓	
The Joyce Foundation	http://www.joycefdn.org/seekingagrant/seekingmain-fs.html				✓														
The John Merck Fund	http://www.jmfund.org/	✓	✓	✓	✓													✓	
Surdna Foundation	http://www.surdna.org/	✓	✓	✓	✓		✓			✓									
The Kenneth A. Scott Charitable Trust	http://www.vetmed.wsu.edu/depts-pppp/Scott.asp			✓															
The Columbus Foundation	http://www.columbusfoundation.org																		
Clean Air Task Force	http://www.catf.us/																		
The Energy Foundation	http://www.ef.org/home.cfm																		
Kodak American Greenways Awards Program	http://www.conservationfund.org						✓					✓						✓	
Environmental Support Center	http://www.envsc.org/														✓			✓	
Great Lakes Aquatic Habitat Fund	http://www.glhabitat.org/grants.html																		
Project Grants	http://www.glhabitat.org/grant1.html	✓	✓																
Technical Assistance Grants	http://www.glhabitat.org/grant1.html																		
Special Opportunity Grants	http://www.glhabitat.org/Special.html																		
Theme Grants	http://www.glhabitat.org/grant2.html																		
Invasive Species Grants	http://www.glhabitat.org/nuisance.html			✓															
Great Lakes National Program Office of the National Fish and Wildlife Foundation	http://www.epa.gov/glnpo/fund/glf.html																		
Institute for Conservation Leadership	http://www.icl.org/																		
National Wildlife Federation	http://www.nwf.org/																		
River Network	http://www.rivernetwork.org/library/index.cfm?doc_id=114	✓	✓																
State Environmental Leadership Program (SELP)	http://www.selp.org/	✓	✓																
The Wege Foundation	http://www.healingourwaters.org/																		
Rural Action	http://www.ruralaction.org/																		
Smart Growth America (SGA)	http://www.smartgrowthamerica.org	✓									✓								

Reference Information

American Journal of Agricultural Economics, 86 (Number 5, 2004): 1196-1202, American Agricultural Economics Association, 2004.

Arendt, Randall. *Rural By Design*, American Planning Association, Chicago, IL, 1994.

Bannerman, R. 1994. *Sources of Pollutants in Wisconsin Stormwater*. Wisconsin Dept. of Natural Resources. Milwaukee, WI.

Benedict, Mark and Edward T. McMahon. Renewable Resource Journal, *Green Infrastructure: Smart Conservation for the 21st Century*, Autumn 2002.

Center for Earth and Environmental Science, Indiana University- Purdue University (http://www.cees.iupui.edu/Education/floodplains.htm).

Central Ohio Transit Authority, *Vision 2020 Transportation for a Great Community*, Mid Ohio Regional Planning Commission, 1999

City of Columbus, Division of Sewerage and Drainage, *Stormwater Drainage Manual*, March 2006.

Clark, J., et al. *Growth and Change at the Urban Rural Interface*, An Overview of Ohio's Changing Population and Land Use. The Exurban Change Project Summary Report, The Ohio State University, 2003.

DiLuzio, M., et al. *ArcView Interface for SWAT 2000: User's Guide*. Blackland Research and Extension Center, Texas Agricultural Experiment Station; Grassland, Soil and Water Research Laboratory, USDA Agricultural Research Service, 2002.

Duaney, Andres, William Wright, and Sandy Sorlien, *Smart Code and Manual Version 8.0*. New Urban Publications Inc.

Federal Emergency Management Agency(FEMA). *Flood Insurance Study, Franklin County and Incorporated Areas, Number 39049C.* March 16, 2004.

Federal Emergency Management Agency(FEMA). *Flood Insurance Rate Map, Franklin County and Incorporated Areas, Number 39049C; panels* 0115, 0116, 0205, 0210, 0215, 0220, 0305 and 0310 *G.* August 2, 1995.

Fuller, Mossbarger, Scott & May; Center for Watershed Protection; *Darby Creek Watershed Stormwater Management Strategies and Standards for New Development, Volume 1;* January 2001.

Georgia Stormwater Management Manual (Stormwater Quality Site Development Review Tool), August 2001.

Hellbranch Watershed Forum, Inventory and Policy Papers, 2005 through 2006.

U.S. Green Building Council. *Foundations of the Leadership in Energy and Environmental Design Environmental Rating System, A Tool for Market Transformation*. LEED Policy Manual, January 2006.

Metro Parks Community Update, 2004

Miller, Economic Benefits of Open Space, 1992.

McQueen, Mike and Ed McMahon. *Land Conservation Financing*. The Conservation Fund, Island Press, 2003.

Mid Ohio Regional Planning Commission *2030 Transportation Plan Summary (and Supplement)*, 2004

Mid Ohio Regional Fact Book, Regional Growth Strategy for Central Ohio. Mid Ohio Regional Planning Commission and ACP - Visioning and Planning, LTD.

Minnesota Stormwater Steering Committee. *The Minnesota Stormwater Manual*, Version 1.0, November 2005

Neitsch, S.L., et al. *Soil and Water Assessment Tool: Input/Output File Documentation, Version 2005*. Blackland Research and Extension Center, Texas Agricultural Experiment Station; Grassland, Soil and Water Research Laboratory, USDA Agricultural Research Service, September, 2004.

Neitsch, S.L., et al. *Soil and Water Assessment Tool: Theoretical Documentation, Version 2000*. Blackland Research and Extension Center, Texas Agricultural Experiment Station; Grassland, Soil and Water Research Laboratory, USDA Agricultural Research Service, 2002.

Northern Virginia Regional Planning Commission and Engineers Surveyors Institute. *Northern Virginia Best Management Practices Handbook*, November 6, 1992.

Northern Virginia Planning District Commission, Division of Environmental Services. Maintaining Your BMP, February 2000.

Ohio Department of Development, Ohio Office of Strategic Research, *Franklin County Population Projections by Age and Sex*: 2005-2030.

Ohio Department of Natural Resources. *Fact Sheet 93-18 – The Hydrologic Cycle.* Updated September 2, 1993

Ohio Department of Natural Resources. *Geographic Information System (GIMS).* Available URL: “http://www.dnr.state.oh.us/gims/”

Ohio Department of Natural Resources, revised *Rainwater and Land Development Manual (Draft),* May 2005

Ohio Department of Natural Resources. *Report No. 40 - Ground Water Pollution Potential of Franklin County.* Michael P. Angle. 1995

Ohio EPA and City of Columbus Public Utilities. *Environmentally Sensitive Development Area, External Advisory Group Recommendations*, November 2004.

Ohio EPA. *NPDES Permit NO. OHC100001*. Fact Sheet and Draft Permit. December 2005.

Ohio EPA. Division of Surface Water. *Biological and Water Quality Study of the Big Darby Creek Watershed, 2001/2002,* June 28, 2004.

Ohio EPA. Division of Surface Water. *Darby at the Crossroads.* June 30, 2004.

Ohio EPA. Division of Surface Water. *State Water Quality Management Plan*, Final Draft, February 2006.

Ohio EPA. Division of Surface Water. *Total Maximum Daily Loads for the Big Darby Creek Watershed*, Final Report, January 6, 2006.

Rhoads, Bruce L., David Wilson, Michael Urban, Edwin E. Herricks. *Interaction Between Scientists and Nonscientists in Community-Based Watershed Management: Emergence of the Concept of Stream Naturalization*, 1999.

Schueler, T.R. *The Importance of Imperviousness, Watershed Protection Techniques* 1 (3): 100-111. 1994.

Sohngen, Brent. *An Investigation to the Potential to Link Voluntary Incentives Payments to Water Quality Performance.* Ohio State University Department of Agriculture, Environment and Development Economics, March 2005. (In association with Taylor, Department of Political Science, Seton Hall University).

Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Soil Survey Geographic (SSURGO) Database for Survey Area, State [Online WWW]. Available URL: "http://soildatamart.nrcs.usda.gov" [Accessed 5/18/05].

Steur, stormwater center.net, better site design fact sheets

The President’s Council on Sustainable Development, *Towards a Sustainable America – Advancing Prosperity, Opportunity, and a Healthy Environment for the 21st Century*, US. Government Printing Office, 1999.

US Army Engineer Research and Development Center, Environmental Laboratory, Design Recommendations for Riparian Corridors and Vegetated Buffer Strips, April 2000.

USDA-SCS. United States Department of Agriculture-Natural Resources Conservation Service. 2004. *Soil Survey of Franklin County, Ohio.*

USDA-SCS. 1985. Hydric Soils of the United States. USDA-SCS National Bulletin No. 430-5-9. Washington, D.C.

US EPA. Office of Wetlands, Oceans and Watershed. *National Management Measure to Control Non-point Source Pollution from Urban Areas,* Draft July 2002,

U.S. Geological Survey. *Floodprone Quadrangles. 1978.*

Webb, Ben. *Darby Creek Watershed Inventory (Final Draft).* Produced in partnership with the Darby Creek Watershed Joint Board of Supervisors and the Darby Creek Watershed Planning Group. March 21, 2005.

Williams, Lance R., Ph. D. and Marsha G. Williams, M.S. *Evaluation of Stream and Riparian Enhancement Opportunities for the Hellbranch Watershed in Central Ohio.* School of Natural Resources, The Ohio State University. January 16, 2004, revised March 12, 2004.

US Census Bureau, *Summary Table 1 Population*, 1990 and 2000.

Prairie Township Comprehensive Plan, 2003
Brown Township Comprehensive Plan, 2005
Franklin County Zoning Resolution, March 2004
Hilliard Economic Development Master Plan
City of Hilliard Thoroughfare Plan, 2001
Pleasant Township Comprehensive Plan
Franklin County Greenways Plan
Columbus Comprehensive Plan, 1993

The Darby Accord recognizes the following organizations for contributing photos for the Big Darby Accord Plan:
The Darby Creek Association
The Nature Conservancy
Metro Parks

Inventory of GIS Data for Darby Creek Watershed

Category	Data Layer	Spatial Extent	Data Type	Feature Type	Date of Material	Data Source
Aerial photography	Orthophotos (b/w)	Western part of Franklin County	.sid image	N/A	2000	Franklin County Auditor
	USGS Orthophotos (color)	Darby watershed	GeoTIFF	N/A	May 2002	USGS website
Base Map	Address ranges	Franklin County	shapefile	Line	2005	Franklin County Auditor
	Addresses of parcel owners	Franklin County	shapefile	Point	2005	Franklin County Auditor
	Buildings (only roofed structures)	Franklin County	shapefile	Line	2005	Franklin County Auditor
	Parcels	Franklin County	shapefile	Polygon	2005	Franklin County Auditor
	Airport parcels	Franklin County	shapefile	Polygon	2005	Franklin County Auditor
	Cemetery parcels	Franklin County	shapefile	Polygon	2005	Franklin County Auditor
	Condo parcels	Franklin County	shapefile	Polygon	2005	Franklin County Auditor
	Golf course parcels	Franklin County	shapefile	Polygon	2005	Franklin County Auditor
	Health services parcels	Franklin County	shapefile	Polygon	2005	Franklin County Auditor
	Hopsital parcels	Franklin County	shapefile	Polygon	2005	Franklin County Auditor
	Misc. parcels	Franklin County	shapefile	Polygon	2005	Franklin County Auditor
	Notable building parcels	Franklin County	shapefile	Polygon	2005	Franklin County Auditor
	Parks and recreation center parcels	Franklin County	shapefile	Polygon	2005	Franklin County Auditor
	Police and fire departments parcels	Franklin County	shapefile	Polygon	2005	Franklin County Auditor
	Service-related parcels	Franklin County	shapefile	Polygon	2005	Franklin County Auditor
	Retirement center parcels	Franklin County	shapefile	Polygon	2005	Franklin County Auditor
	School parcels	Franklin County	shapefile	Polygon	2005	Franklin County Auditor
	Shopping center parcels	Franklin County	shapefile	Polygon	2005	Franklin County Auditor
	Subdivision parcels	Franklin County	shapefile	Polygon	2005	Franklin County Auditor
	Tall building parcels	Franklin County	shapefile	Polygon	2005	Franklin County Auditor
	Venue parcels	Franklin County	shapefile	Polygon	2005	Franklin County Auditor
	Worship center parcels	Franklin County	shapefile	Polygon	2005	Franklin County Auditor
	Railroads	Franklin County	shapefile	Line	2005	Franklin County Auditor
	Road centerlines	Franklin County	shapefile	Line	2005	Franklin County Auditor
	Roads	Franklin County	shapefile	Line	2005	Franklin County Auditor
	School districts	Franklin County	shapefile	Polygon	2005	Franklin County Auditor
	Structures (all man-made feaures/structures as seen in orthophotos)	Franklin County	shapefile	Line	2005	Franklin County Auditor
	Subdivisions (points)	Franklin County	shapefile	Point	2005	Franklin County Auditor
	Tax districts	Franklin County	shapefile	Polygon	2005	Franklin County Auditor
	Zipcodes	Franklin County	shapefile	Polygon	2005	Franklin County Auditor

Inventory of GIS Data for Darby Creek Watershed

Category	Data Layer	Spatial Extent	Data Type	Feature Type	Date of Material	Data Source
	Bikeways	MORPC	shapefile	Line	Unknown	MORPC
	Parks, Golf Courses, Cemeteries	MORPC	shapefile	Polygon	Unknown	MORPC
	School districts	MORPC	shapefile	Polygon	Unknown	MORPC
	ODOT Road centerlines - interstates, US highways, state routes	Ohio	shapefile	Line	2004	ODOT
	ODOT Road centerlines - county & township roads	Ohio	shapefile	Line	2004	ODOT
	ODOT Road centerlines - municipal roads	Ohio	shapefile	Line	2004	ODOT
	City of Columbus parks	City of Columbus	shapefile	Polygon	Unknown	City of Columbus, Parks & Recreation
	City of Columbus recreation centers	City of Columbus	shapefile	Point	Unknown	City of Columbus, Parks & Recreation
	City of Columbus senior centers	City of Columbus	shapefile	Point	Unknown	City of Columbus, Parks & Recreation
	City of Columbus hospitals	City of Columbus	shapefile	Point	2005	City of Columbus
	City of Columbus neighborhood health centers	City of Columbus	shapefile	Point	2005	City of Columbus
	City of Columbus urgent care centers	City of Columbus	shapefile	Point	2005	City of Columbus
	City of Columbus police stations	City of Columbus	shapefile	Point	2005	City of Columbus
	City of Columbus fire stations	City of Columbus	shapefile	Point	2005	City of Columbus
	Parcels (DUPLICATE DATA)	Townships within Franklin County	shapefile	Polygon	Unknown	Franklin County
Cultural Resources	National Register sites	Study area	shapefile	Point	2005	Ohio Historical Preservation Office (OHPO)
	Ohio Archaeological Inventory (OAI) sites	Study area	shapefile	Point	2005	Ohio Historical Preservation Office (OHPO)
	Ohio Historical Inventory (OHI) sites	Study area	shapefile	Point	2005	Ohio Historical Preservation Office (OHPO)
	Previously Surveyed Areas (PSA)	Study area	shapefile	Polygon	2005	Ohio Historical Preservation Office (OHPO)
Demographics	Population change - 1990 to 2000	Darby watershed	shapefile	Polygon	2000	Benjamin Webb, Darby Creek Watershed Coordinator
	US Census 2000 Data	Franklin (39049), Madison (39097), and Pickaway (39129) Counties	shapefiles, tables	Polygon	2000	ESRI Geography Network
Environmental Resources	Agency & non-profit preserved land	Darby watershed	shapefile	Polygon	2004	ODNR, Division of Natural Areas and Preserves
	Franklin County easements	Franklin County	shapefile	Polygon	Unknown	MORPC
	Environmental Conservation District (ECD) grid	N/A	shapefile	Polygon	Unknown	MORPC
	Environmentally Sensitive Development Area (ESDA) boundary	N/A	shapefile	Polygon	Unknown	OEPA
	Environmentally Sensitive Development Area (ESDA) boundary	N/A	shapefile	Polygon	Unknown	City of Columbus
	Environmentally Sensitive Development Area (ESDA) grid	N/A	shapefile	Polygon	Unknown	MORPC
	Historic vegetation	Darby watershed	.jpg image	N/A	Unknown	ODNR

Inventory of GIS Data for Darby Creek Watershed

Category	Data Layer	Spatial Extent	Data Type	Feature Type	Date of Material	Data Source
	Biological Water Quality Indices - Bugs	Darby watershed	shapefile	Point	2004	Benjamin Webb, Darby Creek Watershed Coordinator (created using OEPA Sampling Data, 1977-2002)
	Biological Water Quality Indices - Fish	Darby watershed	shapefile	Point	2004	Benjamin Webb, Darby Creek Watershed Coordinator (created using OEPA Sampling Data, 1979-2003)
	Biological Water Quality Indices - Sampling Trends	Darby watershed	shapefile	Point	2004	Benjamin Webb, Darby Creek Watershed Coordinator (created using OEPA Sampling Data, 1979-2003)
	Water quality attainment, Aquatic life use designations	Darby watershed	shapefile	Line	2004	Benjamin Webb, Darby Creek Watershed Coordinator (created using OEPA Sampling Data, 2001-2002)
	Public water supplies	Franklin County portion of Darby	shapefile	Point	2004	OEPA
	National Wetland Inventory (NWI)	Study area	scanned images (.tif)	N/A	1985	US Fish & Wildlife Service
	Ohio Wetland Inventory (OWI)	Franklin County	shapefile	Polygon	1987	ODNR website
	NPDES Point Sources	Darby watershed	shapefile	Point	2004	OEPA
	Riparian cover	Darby watershed	shapefile	Line	2004	Benjamin Webb, Darby Creek Watershed Coordinator
	Natural Heritage Database	Study area	shapefile	Polygon	2005	ODNR, Division of Natural Areas and Preserves
	Managed Areas	Study area	shapefile	Polygon	2005	ODNR, Division of Natural Areas and Preserves
	Scenic Rivers	Study area	shapefile	Line	2005	ODNR, Division of Natural Areas and Preserves
	Metro Parks land holdings	Western part of Franklin County	shapefiles (derived from AutoCAD)	Polygon, Line	2005	Metro Parks
Floodplains	FEMA 100-yr boundary	Franklin County	shapefile	Polygon	1978	ODNR website
	FEMA floodway	Franklin County	shapefile	Polygon	1978	ODNR website
	FEMA other flood hazard areas	Franklin County	shapefile	Polygon	1978	ODNR website
	Flooding potential (USGS & NRCS)	Franklin County	shapefile	Polygon	1978-79	ODNR website
	Inventory of structures at risk of flooding	Franklin County	shapefile	Point	1995	ODNR website
	USGS flood prone areas	Franklin County	shapefile	Polygon	1978	ODNR website
Geology	Bedrock geology	Franklin County	shapefile	Polygon	1958	ODNR website
	Depth to bedrock	Franklin County	shapefile	Polygon	1979	ODNR website
	Glacial geology	Franklin County	shapefile	Polygon	1958	ODNR website
	Ground water pollution potential	Franklin County	shapefile	Polygon	1995	ODNR website
	Ground water resources	Franklin County	shapefile	Polygon	1993	ODNR website
	Limitations for large scale development	Franklin County	shapefile	Polygon	1958-79	ODNR website
	Oil and gas well location database	Franklin County	.dbf	N/A	2004-05	ODNR website

Inventory of GIS Data for Darby Creek Watershed

Category	Data Layer	Spatial Extent	Data Type	Feature Type	Date of Material	Data Source
Hydrography	Lakes	Ohio	shapefile	Polygon	Unknown	ODOT
	Rivers	Ohio	shapefile	Line	Unknown	ODOT
	Lakes, rivers, streams	Franklin County	shapefile	Line	2005	Franklin County Auditor
	National Hydrography Dataset (NHD)	Scioto River watershed	GDB	N/A	2005	USGS NHD website
	USGS Digital Line Graphs (DLGs)	Franklin County	shapefile	N/A	(as per USGS topo maps)	USGS
Land Use	1976 Land Use/Land Cover	Franklin County	shapefile	Polygon	1976	ODNR website
	1992 National Land Cover Dataset (NLCD) - USGS	Darby watershed	grid	N/A	1992	USGS NLCD website
	1994 Land Cover	Franklin County	shapefile	Polygon	1994	ODNR website
	1998 Land Use/Land Cover	Franklin County	shapefile	Polygon	1998	ODNR website
	2005 Existing Land Use (auditor's parcel data)	Franklin County	shapefile	Polygon	2005	Franklin County Auditor
	Hybrid Land Use Data	Darby watershed	ARC/INFO Coverage, Raster (with corresponding layer file)	N/A	Various	Benjamin Webb, Darby Creek Watershed Coordinator
	Existing and Future land use	Franklin County	shapefile	Polygon	Unknown	MORPC
	Existing and Future land use	Madison County	shapefile	Polygon	Unknown	MORPC
	Existing land use	Pickaway County	shapefile	Polygon	Unknown	MORPC
	Future land use	Pickaway County	shapefile	Polygon	Unknown	MORPC
	Existing and Future land use	Union County	shapefile	Polygon	Unknown	MORPC
	Prime farmland	Franklin County	shapefile	Polygon	1979	ODNR website
	Development - Commercial (through May 2005)	Franklin & Delaware Counties	shapefile	Point	2005	MORPC
	Development - Residential (through May 2005)	Franklin & Delaware Counties	shapefile	Point	2005	MORPC
Planning Data	Airport noise levels	City of Columbus	shapefile	Polygon	2005	City of Columbus
	Hellbranch planning overlay	City of Columbus	shapefile	Polygon	2005	City of Columbus
	Hellbranch planning overlay (DUPLICATE DATA)	City of Columbus	shapefile	Polygon	2005	City of Columbus
	Northwest corridor boundary	City of Columbus	shapefile	Polygon	2005	City of Columbus
	Westland area plan - adopted 1994	City of Columbus	shapefile	Polygon	2005	City of Columbus
	West Columbus Interim Development Concept - adopted 1991	City of Columbus	shapefile	Polygon	2005	City of Columbus
Political Boundaries	City boundaries	Franklin County	shapefile	Polygon	2005	Franklin County Auditor
	Township boundaries	Franklin County	shapefile	Polygon	2005	Franklin County Auditor
	Corporate Boundaries	Franklin County	shapefile	Polygon	Unknown	Franklin County
	County boundaries	Ohio	shapefile	Polygon	Unknown	ODOT
	Historical township boundaries	Franklin County	shapefile	Polygon	2005	Franklin County Auditor

Inventory of GIS Data for Darby Creek Watershed

Category	Data Layer	Spatial Extent	Data Type	Feature Type	Date of Material	Data Source
	Neighborhood boundaries	Franklin County	shapefile	Polygon	2005	Franklin County Auditor
Soils Data	SSURGO	Franklin County	shapefile	Polygon	1980	NRCS website
	Hydric soils	Study area	shapefile	Polygon	1980	EMHT created from SSURGO data
Topography	2-ft contours - Franklin County	Study area	shapefile	Line	2005	Franklin County Auditor
	5-ft contours - Madison County	Madison County	shapefile	Line	Unknown	Madison County GIS website
	National Elevation Dataset (NED) 1-arc second resolution	Darby watershed	grid	N/A	Created 1999	USGS website
	National Elevation Dataset (NED) 1/3-arc second resolution	Western part of Franklin County	grid	N/A	Created Oct 2003	USGS website
	Spot elevations	Franklin County	shapefile	Point	2005	Franklin County Auditor
Transportation	Franklin County 2020 Thoroughfare Plan - Draft	Franklin & Delaware Counties +	shapefile	Line	2005	MORPC
	City of Columbus Thoroughfare Plan	City of Columbus	shapefile	Line	2005	City of Columbus
	Transportation Improvement Plan (TIP), FY 2006-2009 (July 1, 2005 to June 30, 2009)	Franklin & Delaware Counties +	shapefiles	Various	Unknown	MORPC
	Transportation Plan - 2030 (TPLAN)	Franklin & Delaware Counties +	shapefiles	Various	Unknown	MORPC
	ODOT Road centerlines - interstates, US highways, state routes (contains some ADT data)	Ohio	shapefile	Line	2004	ODOT
	Traffic Analysis Zones (TAZ) with incremental 30-yr forecast data	Franklin County +	shapefile	Polygon	2000	MORPC
Utilities	Sewer service areas	Darby watershed	shapefile	Polygon	2004	Benjamin Webb, Darby Creek Watershed Coordinator
	Proposed Facility Planning Area (FPA) for City of Columbus	N/A	shapefile	Polygon	Unknown	MORPC
	Community Planning Areas	Franklin County +	shapefile	Polygon	Unknown	City of Columbus
	Marysville existing sewer area	N/A	shapefile	Polygon	Unknown	MORPC
	Pickaway future sewer area	N/A	shapefile	Polygon	Unknown	MORPC
	Union sewer service area	N/A	shapefile	Polygon	Unknown	MORPC
	Water and Wastewater Treatment Plants - DATA INCORRECT	MORPC	shapefile	Point	Unknown	MORPC
	City of Columbus Sewer Lines (DOSD)	Study area	shapefile	Line	Unknown	City of Columbus
	City of Columbus Sewer Nodes (DOSD)	Study area	shapefile	Point	Unknown	City of Columbus
	City of Columbus utility data (SECAP project) - sewer lines (sanitary, storm, combined)	City of Columbus	shapefiles	Line	2005	EMHT
	SECAP - sanitary sewers (including combined) 18" and larger	City of Columbus	shapefile	Line	2005	EMHT
	SECAP - sanitary sewers (including combined) main trunk lines only	City of Columbus	shapefile	Line	2005	EMHT
	SECAP - service boundary area	City of Columbus	shapefile	Polygon	2005	EMHT
	SECAP - sewersheds	City of Columbus	shapefile	Polygon	2005	EMHT
	SECAP - pump stations	City of Columbus	shapefile	Point	2005	EMHT

Inventory of GIS Data for Darby Creek Watershed

Category	Data Layer	Spatial Extent	Data Type	Feature Type	Date of Material	Data Source
	SECAP - contract entities	City of Columbus	shapefile	Polygon	2005	EMHT
	City of Hilliard water lines	City of Hilliard	shapefile	Line	2005	City of Hilliard
	City of Hilliard sanitary sewer lines	City of Hilliard	shapefile	Line	2005	City of Hilliard
	City of Hilliard storm sewer lines	City of Hilliard	shapefile	Line	2005	City of Hilliard
Watersheds	8-digit watersheds, USGS	Ohio	shapefile	Polygon	1996	Created from Detailed Ohio watersheds file
	11-digit watersheds, NRCS	Ohio	shapefile	Polygon	2005	Ohio NRCS website
	14-digit watersheds, NRCS	Ohio	shapefile	Polygon	2005	Ohio NRCS website
	Detailed Ohio watersheds, USGS	Ohio	shapefile	Polygon	1996	ODNR website
	Darby Creek watershed	Darby watershed	shapefile	Polygon	1997-99	Created by Ben Webb using NRCS 14-digit watersheds
	Darby Creek watershed (DUPLICATE DATA)	Darby watershed	shapefile	Polygon	1997-99?	Unknown - created using NRCS 14-digit watersheds
	Darby Creek watershed, with 14-digit subwatersheds	Darby watershed	shapefile	Polygon	1997-99?	Unknown - created using NRCS 14-digit watersheds
Zoning	Township zoning map	Townships within Franklin County	shapefile	Polygon	2005	Franklin County
	Prairie Township zoning map	Prairie Twp	shapefile	Polygon	2005	Franklin County
	Washington Township zoning map	Washington Twp	shapefile	Polygon	2005	Franklin County
	City of Columbus zoning map	City of Columbus	shapefile	Polygon	2005	City of Columbus
	City of Hilliard zoning map	City of Hilliard	shapefile	Polygon	2005	City of Hilliard

Big Darby Accord Advisory Panel
Development Review Checklist - Concept

Project Information

Location	(Requested) Zoning	Use(s)	Acreage	Sq Ft or Number of Units	Proposed Density	Permitted Density	Open Space Required	Public Parkland Provided	Public Parkland Required

Water Quality / Conservation	yes	no		Details / Comments
Incorporates BMPs in Site Plan to achieve TMDL Requirements				
Protects Tier 1 Land				
Protects Tier 2 Land				
Protects Tier 3 Land				
Protects Stream Corridor Protection Zone				
Incorporates Stream Restoration				
Incorporates Site Monitoring of Water Quality				
Incorporates Low Impact Development Techniques				
Provides Open Space that Links with Adjacent Open Space Areas				
Incorportes Permanent Easements to Protect Open Space Land				
Meets and Complies with all Ohio EPA Requirements				
Meets Sewage System requirements				
Provides Necessary Performance Bond for Monitoring and Open Space Areas				
Provides Necessary Measures for Site-level Monitoring				
Development	**yes**	**no**		**Details / Comments**
Incorporates Principles of Conservation Development				
Incorporates Principles of Town Center Development				
Incorporates Principles of LEED ND				
Land use is Consisitent with Darby Accord Plan				
Proposed Density is Consistent with Darby Accord Plan				
Incorporates Required Public Facilities				
Provides Trail Linkages				
Provides Revenue Toward achieving the Darby Accord Plan				
Provides Required Transportation Improvements				

Stormwater Utility

A stormwater utility is a special assessment set up to generate funding specifically for stormwater management. Users within the utility pay a stormwater fee and the revenue generated from the fee is used to support maintenance and upgrades to the existing storm drain system, the development of drainage plans, water quality programs, and to cover administrative costs. Communities in Ohio are increasingly examining the option of stormwater utilities for use in funding stormwater management and water quality programs in order to keep up with the requirements of the NPDES Phase II program. The shift towards stormwater utility funding addresses the need for a consistent source of revenue. The Accord should consider a stormwater utility as another funding option for implementing the Plan.

Stormwater utilities are often a preferred funding method due to limited resources available to cities and counties to meet the general government needs related to implementation of the NPDES Phase II program. The utility generates additional funds directly targeted to address the increasing requirements of stormwater management programs. The revenues generated by the utility are constant, gradually increasing with the community's growth and rate structure. The constant income directed toward the stormwater program allows for programmatic stability, supports the stormwater staff, and provides for continued maintenance and monitoring operations. Bonds for capital improvements can also be issued to facilitate construction of stormwater management infrastructure, using the revenues generated by the utility to pay back those bonds.

Establishing the Utility Fee Structure

The utility fee is related to the amount of runoff that a parcel of land contributes to the overall stormwater condition. The fee structure includes an option for credits through stormwater quantity reduction or water quality improvement, providing an incentive for developers of commercial (and industrial) properties to consider methods for reducing pervious area.

Most stormwater utilities base the user fees at least in part on the percentage of impervious cover of the parcels of developed land within the community. For simplicity, many utilities charge a flat rate for residential properties and then assess commercial and industrial properties based upon the actual impervious area within their parcel. The stormwater fee is frequently included as a line item within the water and sewer bill.

The revenue that could be generated by a stormwater utility would be dependant upon the number of parcels and the stormwater rate fee. Residential users are typically charged a base rate per equivalent residential unit (ERU), representing an "average" amount of imperviousness for a residential lot. This base fee typically ranges from $2 to $5 per month, per ERU. Non-residential users are typically charged per square footage of impervious area. A rate of 2.5 ERU per commercial parcel is an average that can be used for revenue approximation.

The first step in creating a stormwater utility is the evaluation of the number of equivalent residential units and the delineation of the impervious area. A comprehensive rate study may be completed to determine the revenue needs to support the community's stormwater programs and initiatives and justify the amount of the utility fee assessed on an ERU basis. The study should account for costs related to the items listed below.

- Operation and maintenance of stormwater infrastructure, including personnel and equipment costs.
- Development and promulgation of stormwater programs, including ordinances, policies and regulations, and initiatives related to public outreach and education.
- Compilation of technical documentation related to the public stormwater infrastructure, including mapping and capacity analysis (where appropriate).
- Development and implementation of a Capital Improvement Program (CIP) to replace or upgrade components of the stormwater infrastructure.

Once the stormwater utility rate is established, the community must prepare an ordinance that will adopt the utility, establish its rules and regulations and also stipulate the system of rates and charges. It is important to note that even with a user fee system in place the cost of a comprehensive stormwater program, especially related to large capital projects, will often exceed the revenues that a utility can generate. A utility is part of the revenue stream but it is not all of it.

Application to the Accord Planning Area

The City of Columbus already has an established stormwater utility program that funds a comprehensive program related to maintenance of and improvements to their public stormwater infrastructure. The City of Hilliard has considered implementing a similar program. Within the remainder of the Accord planning area, a stormwater utility could be established and implemented by the Franklin County Drainage Engineer. The authority for such a program outside of an incorporated community is provided within the Ohio Revised Code, Chapter 6117. This utility would then be administered through the office of the County Drainage Engineer or other governmental body, such as the Franklin County Soil and Water Conservation District.

The mechanism for billing the stormwater utility within the unincorporated areas may have to be examined in consideration of the fact that there would not be a consistent system of sanitary and/or water utility billing throughout the county.

Darby Alternative Wastewater Treatment Technical Advisory Committee

Date: Friday, June 23, 2006

Committee Members:
Paul Rosile, FCBH
Karen Mancl, OSU Extension
Tom Shockley, FCSE
Mike Gallaway, OEPA
Cathy Alexander, OEPA
Jean Caudill, ODH
Mike Rowan, OSU FABE
Timothy Lawrence, Ohio NEMO (Chair)
Gary Young, FCBH

Ex-Officio:
Dave Parkinson, EMH&T
Kevin Kershner, Zande & Associates

Draft Recommendations:

This committee was formed independent of the Darby Accord to provide guidance and recommendations for landowners and jurisdictions within Franklin County portion of the Darby regarding their options for wastewater treatment. The Franklin County portion of the Darby Watershed is likely to experience major development within the next 20 to 30 years as outlined in the Darby Accord Plan (DAP), developed by the 10 political jurisdictions involved. Currently there are approximately 12,500 units in the area, the majority being on non-centralized sewer. The DAP calls for that number to grow to 32,500 units, with approximately 7,000 of the new units on centralized sewer. This leaves approximately 13,000 new units, within the Accord planning area needing to find onsite or an acceptable regional approach to wastewater treatment. The Ohio Legislature has recently enacted new legislation for household sewage treatment systems (HSTS). Scheduled to go into effect January 1st, 2007. These new regulations were crafted to assure the highest level of wastewater treatment and the protection of public health and environmental quality from individual households and other similar and ancillary uses. The regulations also require local boards of health to establish nutrient reduction standards in areas “when there is a significant risk of nutrient contamination to surface or ground water…or risk due to proximity to local, state, or federally recognized nutrient sensitive environments.” Residents and jurisdictions are encouraged to review those regulations and consult with the Franklin County Board of Health for restrictions that apply to property within this area.

The committee’s recommendations, presented in this document, are limited to land application (drip, spray, or other timed and pressure dosed effluent distribution) systems for household (one home connected to its own system), and community (a group of homes on one treatment system, but not connected to the main sewer trunk from Columbus, i.e., centralized sewer). The use of community type systems supports the application of “conservation” developments, or developments with significant open space. The committee recognizes that household sewage treatment systems, such as the Wisconsin mound system and a drip distribution system (possibly with nutrient reduction components) may be necessary to overcome specific site conditions and to meet new state regulations. This document contains general concerns, limitations, and recommendations to protect human health and the biological and ecological integrity of the Darby Creek system.

The two areas targeted for non-centralized sewer in the DAP are Brown and Pleasant Township. There is also a smaller area within Prairie Township that may have some units not on centralized sewer. The single biggest limiting factor to non-centralized alternative wastewater treatment in this area is the soil types. Brown Township is predominately a Kokomo-Crosby-Lewisburg (KCL) soil association that is great for farming but has conditions that limit the use of household sewage treatment systems such as leach fields, Wisconsin mounds, or other land application systems. Pleasant Township also has a large percentage of KCL soil association. However, they also have some areas of Miamian and Celina intermixed with Lewisburg and Crosby, all of which may support HSTS. The committee stressed the importance of site specificity and cautioned about making blanket statements regarding Crosby or Lewisburg in regard to their suitability for household sewage treatment systems. There is consensus among the members of the committee that HSTS should continue to not be permitted on Kokomo soils. Kokomo soils are not permitted for HSTS for new development in any part of Franklin County.

Another important limiting factor is the depth to the seasonally high water table or other limiting conditions. The KCL soil association is seasonally saturated with a water table that will need to be professionally evaluated on each site being considered for development. In addition to the depth to seasonal water table, the type of water table – apparent or perched – is also an area of concern. An apparent water table is connected with the ground water system. The new state rules places additional restrictions on the use of apparent seasonal high water tables for HSTS. Perched water tables may have fewer restrictions, but still have significant limitations. Thus the committee recommends that HSTS only be permitted in areas where the perched water table is at least 12 inches below the surface where the treated effluent is being applied. This recommendation would ensure a strict application of the new sewage rules with no variances to accommodate more severe soil limitations, and no gradient drainage around the HSTS to remove excess groundwater from around the system.

Seasonal application of drip or spray community (see above definition) land application systems on Kokomo is an option that the committee does support. However, this would require the onsite storage of large amounts of wastewater during times when the soil is saturated (generally the winter months but can begin in the fall and extend well into the spring). Other soil types found in the area are also suitable for land application systems, but they too are limited during saturated conditions. Land application should not be made strictly by the calendar and the operator of any system should carefully monitor the soil water conditions to ensure there is at least 12 inches of soil above the water table before making application.

The placement of any community land application system must first contain a component of a documented investigation into the tiling structure on the proposed spray field. If a tile does exist in the spray field, then efforts to collect and divert the tile away from the spray field must be done. This effort will include interception of the tile before it reaches the spray field, collection of all subterranean streams prior to the proposed spray field, and diversion into a new tile or existing tiling system which must show evidence of the continuum of the streams downstream. The committee recommends adherence to the Franklin County Sanitary Engineer’s "Rules and Regulations for the Construction & Operation of Land Application Wastewater Treatment Systems,” for spray field placement which is referenced under "Hydrogeologic Site Investigation/Soils Report of the Application Site." The hydrogolgic site investigation/soils report includes the location of the tiles and the feasibility of rerouting the drainage system from the spray field. This report should be presented to both the Franklin County Sanitary and Drainage Engineer for approval.

The committee recommends that the multi-unit community or “cluster development” permitted in the DAP which is not on a centralized sewer system be serviced by either a regional (more than one small community) or one community system for each group of homes, be managed under the direct supervision and maintenance of the Franklin County Sanitary Engineer. Where feasible, regional treatment systems are strongly encouraged. However, the committee also recognizes that there may be developments where it is cost prohibitive to run sewer lines to a regional facility. The committee supports the idea of using sewage treatment technology other than the traditional aeration treatment plant for community systems prior to land application, such as fixed film bio-reactors (re-circulating sand filters and synthetic or peat filter systems) however, these systems should also be under the direct supervision and maintenance of the Franklin County Sanitary Engineer. The committee is also aware that properties with existing HSTS will be in close proximity to new regional or community developments; therefore it will be necessary to connect all of those properties that are contiguous (i.e., accessible/available) into the community or regional treatment system.

The committee supports the Ohio EPA Draft Rules for Land Application of Treated Sewage dated Oct 2003 monitoring frequency requirements. In addition it is recommended that monitoring wells in all land application fields be installed to ensure the depth to water table is at least 12 inches before effluent is applied. The committee also supports the requirement for obtaining an NPDES permit on any system that discharges directly into the Darby or any of it tributaries regardless of their size. There was also support for Land Application Management Plans for any system that is a non-discharging and the requirement for a five year renewal of those plans. The committee made these recommendations prior to the release of a more current version of the draft rules that will eventually be adopted by the state of Ohio after comment and further review. Thus the recommendations put forth in this document may change to reflect these new rules, which will set the standard for governance.

When there is less than 12 inches of unsaturated soil above the water table the treated effluent should be diverted to a holding pond which has a minimum storage capacity of 6 months based on 300 gal/unit/day. These ponds are for storage only and should not be a part of the treatment process, however the committee does not object to the use of aeration if deemed appropriate by the operator to minimize algae growth. These ponds should not be placed within the "streamway" as defined in the DAP or within the 100-year flood plain, however, they should be permitted within designated open space areas. Similar restrictions should also apply to aeration treatment plants or bio-reactor systems.

In all areas under consideration, with exception to the spray fields outline above, the existing field tile system should be maintained to ensure adequate drainage of the water table from areas that have or may have a HSTS, single community or regional wastewater treatment system. It is suggested that these existing field tile systems be placed under the ditch petition process or other maintenance assessment programs through Franklin County.

These recommends are intended for the protection of both human health and the Darby ecological system from pathogens and pollutants. The committee recognizes that it will need to continue to meet with regulators and other interested parties to further refine and implement a final set of recommendations.