Watershed Modeling Report

Trenton Area Storm Water Management Project
Butler County, Ohio

Prepared for:
Butler County Storm Water District
Hamilton. Ohio

July 10, 2006

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Mr. Gregory Wilkens, PE, PS
Butler County Storm Water District
1921 Fairgrove Avenue
Hamilton, Ohio 4501

Re: Watershed Modeling Report
Trenton Area Storm Water
Management Project
Butler County, Ohio

Dear Mr. Wilkens:

The consultant team of Fuller, Mossbarger, Scott and May Engineers, Inc. (FMSM); XCG Consultants, Inc. (XCG); and Eagon and Associates is continuing work on the watershed study and storm water management plan for the Jackson Ditch watershed located west of the City of Trenton, in Butler County, Ohio. The data gathering phase of the project was completed in July 2005. Since that time, the project team has developed hydrologic, hydraulic, and water quality models for the watershed. These modeling efforts constitute the second phase of the project and help identify potential flooding and water quality problems in the watershed and support evaluation of planning policies and potential mitigation options for the watershed master plan that is being developed in the third and final phase of the project. Preliminary model results were presented to your office and subsequently to project stakeholders during review meetings in December 2005.

Enclosed is a report describing the technical approach and findings from the modeling efforts. The findings include a summary of potential problem areas identified during the modeling efforts along with potential mitigation options to help alleviate those issues that are being explored in more detail during phase three. Based on the modeling results and review meetings the mitigation options that are being evaluated during phase three efforts include a regional detentionlretention facility, hydraulic structure improvements along Jackson Ditch, and a collection of other non-structural best management practices (BMPs) applied throughout the watershed. In addition, this report reflects the final results of the modeling efforts after incorporating comments received during the review meetings.

On behalf of the FMSM Project Team, we appreciate the opportunity to work with the Butler County Storm Water District on this project and to assist with storm water management efforts in the area. Please review the enclosed report and contact FMSM with any questions or comments.

Sincerely,

FULLER, MOSSBARGER, SCOTT AND MAY
ENGINEERS, INC.

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/sj

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Watershed Modeling Report

Trenton Area Storm Water Management Project
Butler County, Ohio

I. Introduction

The Butler County Engineer's Office retained the consultant team of Fuller, Mossbarger, Scott and May Engineers, Inc. (FMSM), XCG Consultants (XCG), and Eagon and Associates (EAGON) to perform a watershed study and prepare a storm water management plan for a developing watershed located on the west side of the City of Trenton in Wayne and St. Clair Townships of Butler County, Ohio.

The majority of the study area is underlain by the Lower Great Miami Valley Aquifer system, which serves as the primary potable water source for industrial and residential users in the area. The primary purpose for the study is to address concerns that storm water runoff from future development might adversely impact flooding conditions along Jackson Ditch and increase pollutant loading, through infiltration throughout the watershed, into the aquifer. The goal of the study is to evaluate the potential storm water impacts and develop a watershed storm water management plan that includes Best Management Practices (BMPs) to help abate these impacts.

The principle drainage pathway for the study watershed is a partially man-made channel named Jackson Ditch. For the purposes of this report the watershed is referred to as the Jackson Ditch watershed, although surface drainage for much of the watershed infiltrates into the groundwater aquifer before it reaches the channel itself, due largely to the high sand and gravel content of the aquifer's soils. The Jackson Ditch watershed is approximately 10.2 square miles in area, and the net contributing drainage area for the Jackson Ditch channel is approximately 5.2 square miles. At the downstream end of Jackson Ditch, the man-made channel degrades to overland flow before it empties into a large pond west of Wehr Road near Morganthaler Road. The pond was previously part of a gravel mining operation and has no formal outlet structure. For modeling purposes the pond was assumed to serve as a sink and direct connection to the aquifer.

The Jackson Ditch watershed study is being performed in three-phases. The first phase consisted of a data gathering effort to characterize the current conditions in the watershed. A report describing that phase of work was submitted by FMSM on July 27, 2005 (Reference 1). The second phase of the project was to develop water quantity and quality models to simulate current and future conditions in the watershed. The models are being used during the third phase of the project to evaluate changes in the watershed due to development and the effectiveness of proposed storm water BMPs as a storm water management plan is prepared for the watershed.

This report documents the work performed by the project team during the modeling phase of the project. Included in this report is an overview of the technical approach used in developing the models, a summary of modeling results, a description of current or potential problem areas predicted by the modeling, and a preliminary evaluation of potential mitigation options. The mitigation options along with other BMPs are being explored in more detail in phase three of the project.

2. Watershed Modeling

The watershed modeling efforts performed for the project included developing hydrologic and hydraulic (H&H) models for Jackson Ditch, as well as a HSPF water quality model for the watershed.

A hydrologic model of the Jackson Ditch watershed and a hydraulic model for the channel portion of Jackson Ditch were developed to characterize the in-stream response to major storm events and identify potential flooding effects. Processes that govern storm water runoff associated with flood events often relate to intense rainfall that occurs over a short period of time, while processes associated with storm water quality usually take place over a longer time period. Therefore, a separate modeling effort was required for water quality to better distinguish between the long-term water quality processes and the shorter-term more extreme storm runoff events.

A detailed project geographic information system (GIS) was assembled during the data gathering phase of the project that facilitated model development. Common to both water quantity and quality modeling efforts was the simulation of future conditions in the watershed. Based on observations in the watershed and input from local stakeholders, a hypothetical land use / land cover GIS theme was developed to hydrologically characterize the watershed for a simulation that assumed 20-years of future development beyond the present state. A fully developed watershed scenario was also simulated in order to determine the sensitivity of the models to land use changes and to simulate a hypothetical "highly impacted" hydrologic condition from a development/runoff perspective. The land use themes developed for these modeling are depicted on the maps included as Appendix A.

FMSM coordinated and met with officials from ST. Clair and Wayne Townships as well as the Butler County Transportation Improvement District while developing the future and fully developed land use maps shown in Appendix A. The maps are adequate for the hydrologic and water quality analyses performed for this study, but should not be considered as a comprehensive land use planning tool or as a recommendation for future activities in the watershed. These future land use themes should be considered as one of many possible outcomes in the watershed, and are being used along with the other elements of the project GIS to support development of the watershed storm water management plan. Schematic maps of the land use themes are also included digitally on the CD in Appendix E.

2.1. HEC-HMS Hydrologic Model

To simulate storm water runoff in the watershed during more intense short term storm events a hydrologic model was developed using the U.S. Army Corps of Engineers Hydraulic Engineering Center Hydrologic Modeling System (HEC-HMS, v. 2.2.2) computer application. Extreme storm events of this type are more often those associated with significant flooding of streams and structures.

The project GIS contains digital orthorectified aerial photography, detailed 2-foot contour topographic mapping, and soil characteristic data that were critical to the development of the hydrologic, hydraulic, and water quality models. GIS data processing and model pre-/post-processing was accomplished using the ESRI ArcMap software package. For modeling purposes, the watershed was subdivided into smaller distinct units based on land use and hydrologic characteristics. Delineation of these subbasins was performed by manual

digitization using the 2-foot contour topographic data provided by the Butler County GIS Department. Subbasin parameters were determined in the GIS environment using the ArcMap software's computational capabilities.

Standard engineering methods were used to determine the discharge rates for flood events with recurrence intervals (return periods) of 2-, 5-, 10-, 25-, 50-, and 100-years. These events have a 50-, 20-, 10-, 4-, 2-, and I-percent chance, respectively, of being equaled or exceeded during any given year. Precipitation intensities and synthetic rainfall distributions (hyetographs) for the HEC-HMS model were taken from NOAA Atlas 14 (Reference 3). Historically, NOAA's Bulletin 71 (Reference 4) has been typically applied in this region of the country, but the recently published NOAA Atlas 14 updates and supersedes that document. Applicable reference materials from NOAA Atlas 14 and other historic storm data sets are included in the precipitation data section of Appendix B of this report.

Although a storm event can be related by its return period, it also has an associated rainfall intensity and duration. For example, a storm event with a 100-year return period might take the form of 5.5 inches of rain over a 24-hour time frame or 4.12 inches of rain over a 6 hour time frame, but both events are described as 100-year storm events. Conceptually, the most significant flooding is expected to occur when the storm duration closely approximates the total time of concentration for the watershed. For the Jackson Ditch watershed study, a storm duration of 6-hours was used based on the computed time of concentration for the watershed. If it takes a minimum of 6 hours for storm water runoff to travel through the watershed from the most distant point to the outlet, the most intense flooding will occur when the storm lasts at least 6 hours.

A schematic of the HEC-HMS model that illustrates the watershed, subbasins, and reach connectivity along with other hydrologic model data and results is presented in Appendix B. Note that low lying areas near the Miller Brewing Company facility and downstream of the railroad near Riverside Drive and Wehr Road have been modeled as detention basins. Though these areas are not formal detention facilities and do not have a fixed outlet control structure, they do have significant storage capacities that greatly attenuate peak flood flows during storm events. In fact, the low lying area on the Miller Brewing Company's property, referred herein as the Miller Sink, is large enough to completely contain runoff from smaller volume flood events. The channel portion of Jackson Ditch that continues downstream towards Gephardt Road is typically dry except during large floods where the Miller Sink fills to capacity or the depth of inflow from Jackson Ditch is great enough to promote flow to both the Miller Sink and the downstream channel.

Another important hydrologic feature occurs at the area upstream of the railroad culvert near the previous crossing of Riverside Drive just south of Hamilton-Trenton Road. In this area, the railroad embankment functions much like a dam or levee restricting downstream flow in Jackson Ditch to the capacity of the dual 6' span x 5' rise concrete box culvert at the location. The geometry of the railroad bed appears to be at an elevation that is high enough to prevent significant overtopping during flood events. Instead, flood waters flow laterally out of the channel as overland flow. For modeling consideration the area was modeled as a diversion and results in a nearly constant downstream flow for Jackson Ditch during floods larger than the capacity of the culvert. To illustrate the magnitude of this phenomenon for an event with a peak flow of 1000 cfs at Hamilton-Trenton Road, the peak flow downstream of the railroad culvert is on the order of 500 cfs with the remainder flowing overland or ponding north of the culvert entrance.

To simulate the infiltration and runoff relationships from each of the subbasins, standard Soil Conservation Service (SCS) Curve Number methodology was used. The SCS Curve Number classification depends on land use and soil group. A dataset describing generalized land use for the existing conditions was created specifically for the modeling effort using the zoning for the area and the aerial photography. Soil data was obtained digitally from the Natural Resources Conservation Service (NRCS, formerly the SCS) in the form of SSURGO data. These two datasets were overlaid using GIS spatial analysis tools and a unique curve number was assigned to each specific combination of land use and soil group. The curve number dataset was then overlaid onto the delineated subbasins to derive a composite curve number value for each of the watersheds. To simulate hydrologic conditions for the 20-year future and fully developed watershed scenarios, the SCS Curve Numbers for each subbasin were recalculated using the hypothetical land use GIS theme described above. More information pertaining to application of SCS curve numbers can be found in the NRCS document "Urban Hydrology for Small Watersheds, TR-55" (Reference 5). The values and correlations used to develop the composite curve numbers are presented in tabular format in Appendix B.

The time of concentration for each subbasin was determined using standard TR-55 methodology. To simulate the hydrograph generation and transformation, the SCS Lag Time method was used. The SCS Lag Time is generally defined as 60-percent of the calculated time of concentration. Development in a watershed tends to increase the rate of runoff and decrease the time of concentration. For the 20-year future and fully developed watershed scenarios the times of concentration for each subbasin were reduced by 5-percent and 10-percent respectively. These reduction values were selected based on engineering judgment and appear reasonable for this analysis.

Since the hydrologic modeling being performed here was associated with extreme storm events and not for long-term water balance, baseflow within the watershed and subbasins was not included in the calculations.

To simulate the hydrograph attenuation that occurs over longer stream reaches and where the channel provides storm water storage, reach routing was applied to the larger reaches. The standard lag time reach routing method was selected based on the channel length, slope, and an assumed velocity, which was later compared to the HEC-RAS hydraulic results.

Detailed descriptions for each of the hydrologic modeling techniques described above can be found in hydrology texts and in the "Hydrologic Modeling System HEC-HMS Technical Reference Manual" (Reference 6). Appendix B contains summary information for the hydrologic model parameters described for each of the subbasins and reaches modeled in the Jackson Ditch watershed HEC-HMS model. The actual HEC-HMS model is found digitally on the CD included in Appendix E.

Table 1 summarizes the determined discharge values at select locations in the watershed for the existing conditions scenario. Detailed results at other locations and for other scenarios are included in Appendix B.

Table 2.1. HEC-HMS Modeling Results (Existing Conditions)

Location	Hydrologic Element	Drainage Area (sq mi)	Discharge Peak (cfs) – 6 Hour Duration					
			100-Yr	50-Yr	25-Yr	10-Yr	5-Yr	2-Yr
West Trib. Upstream of Howe Road	Howe_Rd_1	0.122	34	28	23	17	12	7
West Trib. Upstream of Oxford Road (SR73)	SR73_West	1.226	343	285	233	169	125	73
East Trib - West Fork Upstream of Howe Road	Howe_Rd_2	0.232	63	52	43	31	22	13
East Trib - East Fork Upstream of Howe Road	Howe_Rd_3	0.522	115	93	73	49	34	17
Junction of 2 forks of East Trib.	J17-19	0.930	218	178	142	98	68	36
East Trib Upstream of Oxford Road (SR73)	SR73_East	1.857	492	408	331	237	174	100
Junction of West and East Tribs	J_East_West	3.337	907	755	614	443	327	191
Upstream of Hamilton-Trenton Road	Hamilton_Trenton_Rd2	3.374	918	764	622	448	331	193
Upstream of RR Culvert, Downstream of Previous Riverside Drive Crossing	Railroad_2	3.391	596	596	596	450	332	194
Inflow to Low Area on Miller Brewing Property	J_8	3.576	190	183	177	169	163	148
Upstream of Gephart Road	Gephart_Rd	3.846	200	174	154	123	83	1
Upstream of Hamilton-Trenton Road Southwest of Gephart Intersection	Hamilton_Trenton_Rd1	4.519	289	218	162	124	88	55
Upstream of Riverside Drive	RR_Riverside_Drive	4.701	163	141	118	90	68	46
Upstream of Wehr Drive	Wehr_Road	5.030	222	195	170	133	103	69
Outlet of Jackson Ditch Watershed at Gravel Pit	Outfall	5.131	250	218	190	145	113	76

As previously described, the structures south of Hamilton-Trenton Road and the Miller Sink significantly alter and attenuate peak flood flows in the downstream portion of the watershed because they provide channel storage capacity and promote shallow overland flow. Peak flow values in that portion of the watershed do not necessarily increase in the downstream direction as typically would be expected, and delayed timing effects are exhibited in the streamflow hydrographs. Stream segments located upstream of those storage locations yield more typical results as indicated by the graphical hydrographs included in Appendix B.

The timing and attenuation effects at the south end of the watershed are also apparent in the 20-year future and fully developed watershed scenario results. Appendix B includes a comparison of the existing, 20-year future, and fully developed watershed simulations at the outlet of Jackson Ditch and just downstream of Hamilton-Trenton Road. Peak flood flows and hydrographs at the outlet of Jackson Ditch are relatively small and similar for each of the scenarios, but at the Hamilton-Trenton Road location the hydrographs exhibit greater deviation and the peak flows are larger. This effect is due to the storage and attenuation effects of downstream structures, as well as the insufficient channel capacity described in the hydraulic analyses below.

2.1.1. Hydrologic Model Verification

Calibration and verification of a HEC-HMS model is best accomplished using data from a flow gage located in the watershed being studied and a specific storm event. Unfortunately, sufficient gage data was not available to perform such a calibration in this watershed. Instead, the model results were compared to results obtained by examining a stream gage from a similar watershed and by using generalized regression equations to predict discharge values.

In order to compare the ungaged Jackson Ditch watershed to a similar gaged watershed, a flow frequency analysis of available stream flow gage data had to be performed and the results scaled based on areas to perform a comparison. Little Williams Creek at Connersville, Indiana was the closest gaged stream (USGS Gage # 03274950, Reference 7) with comparable drainage area and statistically sufficient data available to perform a frequency analysis. The gage is located approximately 40 miles from the Jackson Ditch watershed, has a drainage area of 9.2 square miles (compared to the 5.2 square miles of direct drainage area for the Jackson Ditch watershed), and has peak flow data available for a period of record of 24 years.

The peak flow values from each year were used to perform a flow frequency analysis using the USGS Peak-FQ computer application. This application uses Bulletin 17B (Reference 8) procedures. Given the results of the frequency analysis, a comparison was made to the Jackson Ditch watershed using a unit area weighting approach. Theoretical gage-predicted flow values were derived for the Jackson Ditch watershed by proportioning the flow based on upstream drainage area. Table 2 lists the results of the gage comparison at the Hamilton-Trenton Road stream crossing, which is upstream of the significant storage and overland flow effects.

Table 2.2. Bulletin 17B (Peak FQ) Gage Analysis Comparison

Value	Discharge Peak (cfs)					
	100-Yr	50-Yr	25-Yr	10-Yr	5-Yr	2-Yr
Gage 03274950	3139	2633	2176	1634	1262	790
Unit Basis[1] (cfs/sq-mi)	343	287	238	178	138	86
Scaled Peak[1] (cfs)	1156	970	801	602	465	291
HEC-HMS Prediction	915	765	620	450	330	195
Percent Difference	26%	27%	29%	34%	41%	49%

[1] Based on a contributing area of 9.16 square miles at the gage and 3.37 square miles at Hamilton-Trenton Road.

The results of this analysis support the model predicted flow rates within a reasonable level of accuracy. A detailed calibration was not performed to these values and the HEC-HMS model parameters were not directly adjusted as a result because of differences between the locations of the available gage and the Jackson Ditch watershed, the hydrologic setting of the Jackson Ditch watershed, the limited amount of historic data, and degree of uncertainty involved in the input parameters for the gage analysis and the linkage between the results of that gage and the Jackson Ditch watershed. Instead, these results provide validity to the HEC-HMS model output data.

As an additional comparison, regional regression equations were used as specified in the USGS Water Resources Investigation Report 03-4164, "Techniques for Estimating Flood-Peak Discharges of Rural, Unregulated Streams in Ohio, Second Edition" (G.F. Koltun, August 2003) (Reference 9). That document provides guidance on estimating flow values for the 2-, 5-, 10-, 25-, 50-, and 100-year events by regression equations that use contributing drainage area and location as variables. Again, the comparison is more applicable upstream of Hamilton-Trenton Road due to the storage and overland flow effects. The values from those calculations are included in Table 3.

Table 2.3. Regression Equation Flow Comparison

Value	Discharge Peak (cfs)					
	100-Yr	50-Yr	25-Yr	10-Yr	5-Yr	2-Yr
Regression Equation Calculated Value[1]	941	837	725	573	451	278
HEC-HMS Prediction	915	765	620	450	330	195
Percent Difference	3%	9%	17%	27%	37%	43%

[1] Based on a contributing area of 3.374 square miles, an average channel slope of 50 ft/mile, and an assumed 5% of the watershed as storage at Hamilton-Trenton Road.

The published error range for the regression equation approach is in the range of 40-50%. The HEC-HMS results are within that range and well supported by the results of the regression equation analyses. Again, an actual detailed calibration is not applicable due to the degree of uncertainty, but the data does provide validity to the model results. Peak discharge values selected for the hydraulic analyses were based directly on the HEC-HMS model output and are summarized in Table 1 and Appendix B.

2.2. HEC-RAS Hydraulic Model

For the detailed hydraulic modeling portion of the watershed study, only the most significant drainage pathways of Jackson Ditch were studied. The goal of the hydraulic modeling was to predict water surface elevations and profiles along the stream to determine flood inundation limits. The detailed study reach extends from the pond/gravel pit west of Wehr Road at Morganthaler Road, upstream approximately 5 miles along the mainstem and three tributaries before terminating just upstream of Howe Road near the headwaters of the watershed. The detailed study reaches include a total of 17 structures of hydraulic significance and approximately 79 channel cross sections.

Hydraulic analyses were performed using the US Army Corps of Engineers HEC-RAS (v.3.1.3) computer program. Data entry and manipulation for the HEC-RAS model were performed largely using GIS techniques and the HEC-GeoRAS software extension for ESRI's ArcMap software package. To support the model development, a field survey was performed to accurately measure structures along the reach and the channel characteristics at various locations along the studied reaches.

Cross sections for the hydraulic analyses were obtained by combining field surveyed channel and overbank data with 2-foot topographic contour mapping obtained from the Butler County GIS Department. Survey data was used for the channel portion of the cross section and where additional data was needed, primarily in the overbank areas, it was extracted from the contour information. The typical procedure for a flood study of this nature is to extend cross sections across the entire floodplain. Due to the braided nature of overland flow in this area and the varying flow paths during extremely large events, the cross sections were limited to an extent that characterized flow attributable only to the Jackson Ditch channel. Ineffective flow areas were used as needed to distinguish these boundaries within the HEC-RAS model.

Cross section locations are shown in plan view on the inundation mapping included in Appendix C. A digital version of the HEC-RAS model, which includes a background map and facilitates viewing of the cross sections in both plan view and profile view, is included on the CD in Appendix E. The digital HEC-RAS model also includes links to digital photos of each of the structures.

Geometric information for culvert and bridge structures for the HEC-RAS model was also obtained during the field survey. The normal procedure for hydraulic analyses is to assume unobstructed flow at the structures and assume that they remain unobstructed, operate properly, and do not fail. Due to the variety of ways that structures may become clogged by debris and the uncertainty involved in modeling partially obstructed flow paths, the structures along Jackson Ditch have been modeled as if they were unobstructed at the time of the flood event. Significant debris accumulation upstream of many of the structures along Jackson Ditch, particularly at the railroad culvert south of Hamilton-Trenton Road, can greatly magnify flood potential in the area, but it has not been explicitly accounted for.

As mentioned above, there is potential for overland flow upstream of the railroad culvert south of Hamilton-Trenton Road caused by the geometry of the railroad embankment and the low lying west bank of the Jackson Ditch channel. The diversion modeled in the hydrologic (HEC-HMS) model was used to simulate the overland flow rates and a separate reach was added to the HEC-RAS model to simulate flood depths along this overland flow path. Cross sections and model geometry along this reach were based only on the available

topographic data as overland flooding is expected to be shallow in nature and occur on a less frequent basis associated with the hydraulic performance of the railroad culvert. The flood inundation limits and depths determined in this area are useful from a flood risk perspective but should be considered approximate in the overall scope of these analyses.

Channel and overbank roughness factors (Manning's "n" values) used in the HEC-RAS model were chosen based on engineering judgment and field observations of the stream and floodplain areas. The selected channel "n" values ranged from 0.030 to 0.055, while overbank "n" values ranged from 0.040 to 0.080. In some cases, the Manning's "n" values for the channel portion of the cross section are greater than the overbank portions. This may appear atypical, but in this watershed it is appropriate as much of the area immediately adjacent to the channel remains brushy and wooded while portions of the overbank areas have been cleared for agricultural type uses.

Other model parameters such as cross section stream stations, channel and overbank reach lengths, and ineffective flow areas were derived from the 2-foot contour topographic mapping. Flow values were obtained from the hydrologic analysis described in Section 2.1 and flow change locations were selected based on cross section proximity to tributary and subbasin inflow locations. Starting water surface elevations at the downstream end of the model were obtained by assuming normal depth for the given flow and channel slope.

During several flood events, most recently in 2001 and 2004, flooding has occurred in the southern portion of the watershed along Hamilton-Trenton Road and Riverside Drive. The right descending bank of the channel portion of Jackson Ditch in this area is slightly built up to prevent flooding during smaller storm events, but it is not sufficient to completely contain larger flood flows. In those events, the water breaks out of the channel and flows overland in a generally southwestward direction. The overland flow in this area was modeled in a similar manner to the channel, but is based only on the data available from the project GIS. Determined flood depths in this area are shallow (less than three feet) and should be considered approximate.

In order to accurately calibrate a HEC-RAS model, historic storm data is required that characterizes the water surface elevations at various points along the stream along with accurate hydrologic data that characterizes the precipitation event and runoff that produced the flooding. Only a limited amount of calibration data was available for Jackson Ditch associated with storms that occurred in 2001 and 2004. Most of the flooding from those events is thought to be attributable to problems with debris at structures along the reach and not as much with the storm runoff, therefore a detailed calibration was not performed. Model parameters, such as Manning's "n" values and contraction/expansion coefficients were slightly adjusted during model development to achieve reasonable hydraulic profiles for the stream reaches.

For illustration purposes, graphical flood profiles have been prepared illustrating the 2-, 10-, 50-, and 100-year flood events along the Jackson Ditch channel and are included in Appendix C. Flood inundation limits were also delineated using the 2-foot topographic mapping and elevations based on the profile results. These inundation limits are illustrated on the maps included in Appendix C.

The typical modeling procedure is to extend the cross sections across the entire floodplain, but for this model the cross sections were limited to flow attributable only to the Jackson Ditch channel. A similar process was used to delineate the floodplain inundation limits for

the area. Floodplain limits were terminated at a point where flooding was no longer believed to be attributable to Jackson Ditch. In the areas beyond that boundary, flooding may still be possible. However, it is anticipated that the flooding in these areas would be shallow in nature and highly variable. There are statistical based methods to better quantify the shallow overbank flooding throughout the watershed, but those calculations are beyond the scope of this planning level watershed study.

As previously described, the watershed was analyzed for existing, future (20-years of development), and fully developed conditions. Because of the similar peak flood flows values and the overland flow that occurs when water spills out of the channel in the southern end of the watershed, the hydraulic results for the future and fully developed scenarios do not vary significantly from the existing conditions in that portion of the watershed. A fully developed condition may cause overland flow to occur and adjacent areas to become inundated on a more frequent basis, but the magnitude or depth of that overland flow does not change significantly.

In the northern portion of the watershed, upstream of Hamilton-Trenton Road, increased peak flood flows do cause a slight change in the flood profile elevations, but in that area, the channel is well defined and more deeply entrenched. Flooding is generally contained within the top-of-embankment geometry of the channel and flood inundation limits do not change significantly for the 20-year future or fully developed scenarios.

Graphical flood profiles are included for each of the 20-year future and fully developed watershed scenarios in Appendix C. Flood inundation mapping was not prepared solely for the scenarios as the inundation limits did not change significantly from the existing conditions. Instead, for comparison a dashed line is shown on the existing condition flood inundation map that indicates the model predicted inundation limit for the fully developed watershed scenario.

2.3. HSPF Water Quality Model

The consulting firm of XCG Consultants, Inc., assisted with the modeling efforts for this study by preparing a water quality model for the watershed. XCG provided the narrative description of their methodology and results to FMSM. That data was formatted for consistency and has been included herein as Sections 2.3 – 2.34 and Appendix D.

Hydrologic and water quality modeling was performed using the US EPA Hydrological Simulation Program – FORTRAN (HSPF) software. The HSPF software is capable of simulating the entire hydrologic cycle including rainfall, snowfall, evapotranspiration, surface and subsurface runoff, and percolation to an aquifer. During the duration of a simulation, HSPF keeps track of the water stored on the ground surface and in the soil.

The impervious and pervious areas in HSPF are modeled as depths without areas. Runoff, evaporation, etc. are reported as depth per time unit (inches per hour, etc.). The Trenton watershed was modeled as inches per 5 minute time step. For the impervious runoff onto the pervious area, the runoff in inches per time step was multiplied by the area of the impervious area and divided by the pervious area. This depth in inches is the runoff from the impervious area spread evenly across the entire pervious area. This methodology works well in areas where the impervious areas flow out onto the adjacent pervious areas such as roof downspouts and driveways onto yards. The urban areas in the City of Trenton have the

only extensive network of storm sewers. The storm sewers carry storm water to infiltration basins or to dry wells instead of directing runoff to streams. This method of storm water management directs all storm water to the aquifer.

For impervious surfaces, HSPF models runoff the same way as most hydrologic models. Precipitation is first stored in interception storage (vegetation and other surfaces) and depression storage (puddles and low points). The remaining water becomes surface runoff with the flow rates determined by surface roughness, surface slope and the length of the slope to the stream. HSPF is different from other models in adjusting available storage by evaporating water as time passes.

For pervious surfaces, HSPF includes subsurface storage in modeling surface runoff. Water is stored in interflow storage (horizontal flow through upper soil layers), upper storage, lower storage, and active groundwater (baseflow) layers. As these layers approach capacity, the infiltration rates are reduced, which increases surface runoff from the sub-basin. The model allows water to flow to the stream from the surface, the interflow layer and from the active groundwater. Below these storage layers is the aquifer which is assumed to have infinite capacity to absorb water and is too deep for water to flow to streams or evapotranspire.

A third modeling feature of HSPF used in the Trenton watershed model is the reach reservoir (RCHRES). RCHRES is a simple stream model that is a storage volume with one or more outflows. The outflows may be time series or flow curves based on the storage volume (or depth) in the stream. While capable of use in a variety of ways, RCHRES was used for two purposes in the Trenton model. The first is as a storage area to attenuate the flow hydrograph by storing runoff and limiting the outflow rate. The second is as a method to simulate the sinks used to infiltrate storm water.

2.3.1. HSPF Model Data

Climatic data for the model was downloaded from the National Oceanic and Atmospheric Administration (NOAA) National Climatic Data Center (NCDC) website and from the Ohio State University (OSU) Agricultural Research and Development Center website. The OSU data were used to calculate potential evapotranspiration using the methodology described in ASCE-EWRI Task Committee Report, January, 2005. The evapotranspiration data were calculated since measured data were not of sufficient quality for modeling. The measured data were from distant sites, contained a number of missing data points, or were only available as daily totals.

For the climatic base of the HSPF model, the calendar year 2004 was selected. Of the past seven years (1998 to 2004 inclusive), 2004 had the annual rainfall closest to regional normal rainfall as shown in Table 4 and in Figure 1. A third factor for choosing 2004 was the reported flooding on January 4, 2004. The ability to recreate high flows during that time period would indicate that the HSPF hydrology reflected observed events. The time period modeled was from November 1, 2003 through December 31, 2004. The initial two months were intended to allow the model to adjust soil water storage values to appropriate levels for the observed conditions.

Table 2.4 Historical Annual Rainfall

Time Period	Annual Rainfall (inches)
NOAA Ohio Region 8 Southwest 1931-2000 Average	40.76
1971-2000 Average	42.25
Observed Rainfall	
2004	40.33
2003	45.47
2002	45.68
2001	44.37
2000	35.00
1999	23.85
1998	33.00

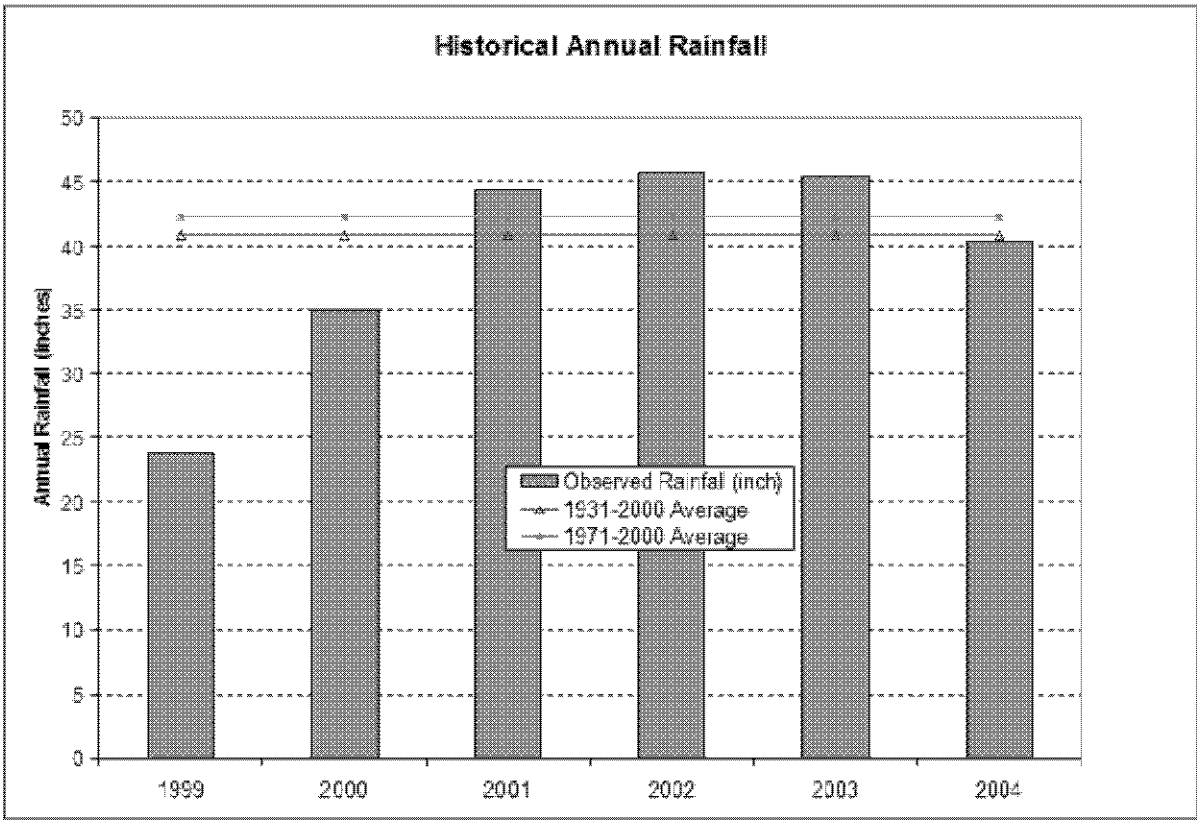


Figure 2.1. Historical Annual Rainfaill

The Trenton watershed was divided into 7 basins for comparing different land use conditions. The basins which were further subdivided into 53 sub-basins based on topography, soil type, land use, and drainage patterns. The sub-basins were used to develop parameters for modeling small, reasonably homogeneous areas.

Soil mapping and data reports were downloaded from the US Department of Agriculture, Natural Resources Conservation Service, Soil Data Mart website. The mapping is from the 1980 Butler County soil survey. Generally the soils on the slopes to the north, west and south of the watershed were clay soils with shallow bedrock. These soils and slopes have high runoff rates. The flatter areas in the east and central portions of the watershed have loamy soils. These areas have high to very high infiltration rates to the Great Miami Aquifer. One change in the watershed since the soil mapping was completed was the construction of the Miller Brewery. The area of what is now the brewery and the Miller Sink was farmland. The surface soil properties for these two areas were kept in the soil mapping given the lack of alternative data sources.

The land use for the watershed was developed based on consultation with various local agencies, aerial photography, and site visits as previously described and illustrated in Appendix A. The 20-year future and fully developed scenarios were also applied to the HSPF model.

Miller Sink was partially incorporated into the flow analysis of Jackson Ditch as follows. During periods of low flow, water in Jackson Ditch flows into Miller Sink and infiltrates along with water from the Miller basin. During periods of higher flow, the combined flows from Jackson Ditch and the Miller basin exceed the infiltration capacity. Flows in excess of the Miller Sink capacity pass under Gephardt Road and further down Jackson Ditch toward the former quarry.

2.3.2. HSPF Future Conditions Models

During the development of the Storm Water Management Plan for the watershed, various mitigation options are being explored. Structural mitigation options such as regional detention facilities and channel improvements are being evaluated using the HEC-HMS and HEC-RAS models. Land use practices and other storm water Best Management Practices (BMPs) are modeled as separate conditions in the HSPF model.

The No-BMP and With-BMP conditions models were developed using presumed future land use development. The land use was suggested by planning efforts of local agencies but is generally more urbanized in an effort to capture the worst case scenario.

The No-BMP conditions assume that the Urban Development areas outside the City of Trenton basin have storm sewers discharging directly to Jackson Ditch. Some runoff from these sub-basins was considered as having entered storm sewers or ditches leading directly to Jackson Ditch. This water would reach Jackson Ditch faster and without the opportunity to infiltrate to the soil or have pollutant loading reduced while flowing across pervious areas when compared to the Existing conditions.

With-BMP conditions assume that the Urban Development areas are using various BMPs by directing all impervious runoff to the pervious areas. The With-BMP conditions do not assume the maximum use of all possible BMPs. The BMPs envisioned as part of this effort include grassed swales and ditches to allow some infiltration and pollutant reduction. The effects of more intensive BMPs such as bioretention areas, infiltration basins, and grit chambers were not estimated at this time.

The HSPF models were run using the 2004 observed meteorological data.

The No-BMP and With-BMP conditions increased impervious area and reduced the evaporation compared to the Existing conditions. For the With-BMP conditions, the increased runoff from impervious areas allowed more water to percolate into the groundwater based on the assumption that impervious areas discharge to the pervious areas rather than Jackson Ditch.

For the No-BMP and With-BMP conditions, the increased impervious runoff to pervious areas caused the pervious soils to become saturated more often, causing increased volume of runoff to Jackson Ditch.

The increased impervious area for the future land use leads to increased runoff. For the area of Trenton Watershed outside of the City of Trenton, this increased volume of runoff means increased volume of flow in Jackson Ditch.

Flows to Jackson Ditch were summed without routing or storage effects to examine the flow to Miller Sink from the basins upstream of Gephardt Road. Flows up to the infiltration capacity of Miller Sink were subtracted from the total flow. The remaining flow was assumed to flow downstream past Gephardt Road. This remaining flow with the addition of local runoff is the estimated flow in Jackson Ditch towards the former quarry. The flow from Jackson Ditch overland to the quarry was beyond the ability of the summation process and was not modeled.

2.3.3. HSPF Hydrology Results

The summation of results for the HSPF hydrology model is shown in Table 5.

Table 2.5 2004 Annual Water Budget

Description	2004 Depth Over Watershed (Inch)			Change From Existing	
	Existing	No-BMP	With-BMP	No-BMP	With-BMP
Inflows					
Total Precipitation	40.33	40.33	40.33	0%	0%
Change in Soil Water	0.15	0.36	0.36	145%	154%
Outflows					
Evapotranspiration	23.60	17.81	18.23	-25%	-23%
Runoff to Jackson Ditch	4.90	9.03	8.89	84%	81%
Groundwater Recharge	12.06	14.22	14.33	18%	19%
Pervious Infiltration	8.71	7.98	8.10	-8%	-7%
City of Trenton Runoff	2.82	5.32	5.32	89%	88%
Sink Infiltration	0.53	0.91	0.91	72%	71%

For the year 2004, total flow volume into Jackson Ditch increased 84% for No-BMP conditions and 81% for With-BMP conditions compared to the Existing conditions. The additional water, compared to Existing conditions, is from reductions in evaporation and in increases in runoff. With the exception of the sinks, local infiltration to the aquifer decreases due to increased impervious areas. The increase in flow to Jackson Ditch means that water that had infiltrated to the aquifer in the northern portions of the watershed would flow south and infiltrate in the southern portions of the aquifer.

The increased volume of flows to Jackson Ditch downstream of Gephardt Road is likely to aggravate any tendencies to flood this area. The inclusion of BMPs to increase infiltration and retard runoff is expected to reduce the total flow volumes and peak flows in Jackson Ditch. A secondary benefit of attenuating the flood flows is to allow more time for infiltration at Miller Sink and other areas, which in turn reduce flood flows further.

With development, percolation decreased with increased impervious area. Percolation increased overall due to the large increase in percolation in the sinks offsetting the decreased percolation due to development in the rest of the basin. The Miller Sink was estimated to allow one-third more percolation due to the increased availability of water from Jackson Ditch. The additional runoff volume entering Jackson Ditch due to urbanization is modeled as reaching Jackson Ditch below Gephardt Road and the quarry. The additional water is assumed to percolate to the aquifer along Jackson Ditch or at the quarry.

Percolation in the City of Trenton is projected to increase with the addition of impervious areas draining to sinks and dry wells. The increased impervious area caused decreased evapotranspiration which in turn increased the volume of water available for percolation.

The largest water withdrawal wells in the Trenton Watershed are Southwest Regional Water District, City of Trenton, Miller Brewing, and Cincinnati Gas & Electric (CG&E). All of these wells are located near Hamilton Trenton Road in the southern half of the watershed. The change in percolation was examined for patterns that might impact the water levels and flow patterns in the aquifer. The primary concern was that the changes in runoff volume to Jackson Ditch would transfer percolation to the area of Miller Sink and the quarry. This transfer, combined with continuing and possibly increased withdrawals, could lower the aquifer water surface, especially for the City of Trenton and CG&E which are furthest from the Miller Sink and quarry.

The percolation north of Route 73 increased from the Existing conditions to the No-BMP and With-BMP conditions. The primary source of this additional percolation north of Route 73 was the increase in Trenton percolation due to the increased impervious areas draining to sinks and dry wells. Without using a groundwater model, the effects of the additional percolation on the water levels at the City of Trenton and CG&E wells cannot be estimated. At least some of the additional percolation within the City of Trenton may flow southeast to the Great Miami River instead of south to the wells.

The large increase in percolation at the Miller Sink caused by development would increase the water surface elevation of the aquifer in that area of the watershed. Much of the additional percolation would be expected to flow west to the Great Miami River, but some water would be expected to flow toward the Miller Brewery and the Southwest Regional Water District wells. Water percolating from Jackson Ditch below Gephardt Road and the quarry would enter the aquifer west of the Miller Brewing and Southwest Regional wells. The effects of increased percolation from this area on the water levels at the wells may be small due to the distance to the wells and the location of the percolation in the aquifer flow pattern.

Overall, urbanization should not decrease the availability of water from the aquifer at the City of Trenton and CG&E wells. The large increase in percolation at the Miller Sink should increase the availability of water at the Miller Brewing and Southwest Regional Water District wells. The actual extent of the changes is currently unknown.

2.3.4. HSPF Water Quality Results

The results of the hydrologic modeling were used to estimate current and future loading of water quality. A literature search was conducted to find Event Mean Concentrations (EMC) for the parameters of concern. An Event Mean Concentration is the average of the parameter concentrations measured during a rainfall runoff event.

As a measure of the magnitude of estimated contamination, the modeling results were compared to the drinking water standards. The US and Ohio EPA have identical standards for the maximum levels of contaminants in the drinking water supply. A pollutant may be regulated under one or more of a number of different standards. The most stringent standard is the Maximum Contaminant Level Goal (MCLG) which is the concentration below which no health risks are known or expected. This level is a goal but not an enforcement standard. The Maximum Contaminant Level (MCL) is the enforcement standard and is based on the MCLG. An MCL is set as close as possible to the MCLG considering the available technology and cost. When determining the contaminant level in the drinking water is either technically or economically not feasible, a specific Treatment Technique is required as a means to guarantee that the contaminant is removed. A Secondary Standard is a non-enforceable guideline for contaminants that based on aesthetics (water color, odor, or taste), cosmetics (staining of skin or teeth), or equipment (staining, corrosion, or sedimentation and scaling).

The model results were also compared with water quality targets intended to improve water quality in the streams and lakes. These standards developed by Ohio EPA are determined based on water samples taken in streams and lakes around Ohio. The target levels for pollutants were set to minimize the negative effects on aquatic life based on the number and variety of sensitive species.

Water quality was examined for six parameters; nitrate, dissolved phosphorus, copper, zinc, chloride, and suspended sediment. The loading for each was based on EMCs for each land use. Nitrate and dissolved phosphorus concentrations for water percolating into the ground were reduced by 30% to account for biological activity within the soil.

Nitrate loading in the watershed is expected to decrease with the development of farmland into residential and urban areas. Nitrates are currently below drinking water standards and surface water targets and are expected to drop further.

Phosphorus loading is expected to increase in both total load and in concentration due to the increase in lawn fertilization with development. No drinking water standard currently exists for phosphorus. The expected future concentrations will be above the surface water targets intended to prevent eutrophication. The expected increase in concentration can be reduced with the use of BMPs targeted at phosphorus reduction such as grassed swales.

Copper and zinc will increase in total loading and in concentration. Both metals are expected to be far below drinking water standards. Using both metals as indicators of metal pollutants in general, urbanization is not expected to create drinking water problems due to increased metal pollution. Copper is estimated to be currently at and is expected to exceed the target concentrations for the protection of aquatic life. The concentration of copper can be reduced by BMPs that remove sediment such as grit pits and grassed swales.

Chloride concentrations will increase in total loading and in concentration with the increase in road surface and resulting increase in road salt use. Uncertainty in the estimation is due to the greatly varying road salt application rates for county roads, residential streets, and parking lots. Chloride concentrations are estimated to be below drinking water standards currently and in the future.

Suspended sediment loading is expected to change with development. The conversion of cropland to urban development will reduce the average suspended sediment concentration. The storm sewers of the No-BMP conditions will carry much higher surface runoff with a higher total sediment load to Jackson Ditch than the Existing conditions. Sediment buildup on the paved areas will be washed directly to Jackson Ditch through the sewers. The With-BMP conditions will reduce the total sediment load to Jackson Ditch compared to both Existing and No-BMP conditions. The With-BMP conditions assume the capture of sediment through the use of practices such as grit chambers or grassed swales before it can enter Jackson Ditch.

3. Potential Problems and Mitigation Options

The hydrologic and hydraulic modeling predicts some flooding in the southern portion of the Jackson Ditch watershed. Several factors apparently contribute to these flooding issues including: insufficient capacity of the channel and hydraulic structures along the reach, accumulation of debris upstream of the structures, and a channel geometry that promotes overland flow into adjacent areas during large events. Excess debris appears to clog the channel and structures frequently and removing this debris to maintain positive drainage continues to be a maintenance burden. In the future as the upstream watershed develops, it is likely that more storm water runoff will be contributed to Jackson Ditch. This increased flow will increase both the magnitude and frequency of the flooding problems already recognized.

Based on the water quality modeling, the overall water quality associated with the storm water runoff appears to be good from a drinking water source perspective, but surface water quality may be slightly impacted biologically or ecologically. The watershed is expected to become increasingly stressed for flood risk and threats to surface water quality as future development occurs. This underlines the need for smart development practices and BMPs in the watershed.

Although the flooding problems in the Jackson Ditch watershed are relatively minor, the watershed still could be improved and needs protection by controlling future development. There are several potential mitigation options to reduce flooding impacts along Jackson Ditch, especially near the location of the Old Riverside Drive crossing just south of Hamilton-Trenton Road in the central portion of the watershed. One option that seems to fit this particular location is a regional detention/retention basin. The basin would not only provide flood control benefits, but it could also serve to enhance water quality and promote infiltration into the aquifer. As much of this watershed drains to an aquifer that is an important source of drinking water, maintaining water quality is critical. There is an existing tract of land situated between two branches of Jackson Ditch near the middle of the watershed south of S.R. 73 that appears to be a good potential location for a basin of this nature. The negative side of a regional basin is the cost of construction and on-going maintenance.

Another potential flood mitigation option for Jackson Ditch is to improve the channel and culverts along the reach to provide more flow capacity. This would reduce flooding in the area and decrease maintenance requirements, but like the regional basin, these types of structural options would be costly to implement. Improving the channel and structures may also cause negative effects long-term as it displaces the storm water downstream. This would pose a flooding threat to downstream areas, but more importantly would decrease the amount of storm water available to recharge the aquifer.

During the initial research phase of the project, much of the research data indicated a continuing pattern of reduced groundwater levels in the upper portion of the aquifer. Many of the area residents with shallow wells have had water supply problems in the last few years. The Miami Conservancy report, "Groundwater Elevation Trends in the Buried Valley Aquifer near Trenton, Ohio" (Reference 10) explored the issue. The report concluded that the effect is caused by a combination of increased withdraw from the aquifer by major facilities and a cycle of reduced groundwater recharge associated with intermittent drought periods. Reduced storm water recharge in the upper reaches of the aquifer and the Jackson Ditch Watershed as discussed herein may also be a contributing factor.

It would promote aquifer recharge if more of the storm water runoff were captured on site throughout the upper reaches of the watershed. This would not only promote groundwater recharge, but it would also prevent excess runoff from reaching Jackson Ditch, where it could worsen flooding problems. Capturing storm water runoff near its source also is a good practice from a water quality perspective. It prevents potential surface water contaminants generated from a large area from becoming concentrated and forming a point source of pollution, thus reducing the potential for groundwater impacts. There are a host of non-structural best management practices (BMPs) that can be applied throughout the watershed to promote this concept. Those BMPs that focus on the interface between the surface water runoff, vegetation, and the near-surface soils will be more effective for this watershed due to the pervious nature of the soils. These types of BMPs are also effective because they can filter and capture potential solid and particulate pollution such as chlorides, sediment, and metals. The vegetation is also effective for absorption of any excess nutrients that may be present.

4. Conclusion and Recommendations

The modeling efforts performed for this study indicate two potential quantity problems for the watershed: flooding along Jackson Ditch and decreased infiltration/recharge of storm water in the upper portion of the watershed. The flooding predicted by this study is expected to be relatively minor and more of a nuisance rather than a permanent threat to life or property. Structural mitigation options such as a regional detention/retention basin and channel/structural improvements will be further investigated and conceptual costs will be developed during the watershed master plan development phase of the project to help address these minor flooding issues.

The transfer and concentration of storm water infiltration to recharge the aquifer from the upper portions of the watershed to a few low lying areas at the southern end of the watershed is a larger potential problems predicted by the modeling efforts. The solution to this problem could be linked to the regional detention/retention basin, but non-structural BMPs throughout the watershed may be a better alternative. Practices such as vegetated filter strips, grassy swales, and low-impact development fit well with this approach. Maintaining and promoting good water quality is also an ongoing concern and these types of

BMPs also work well for those efforts. The watershed storm water management plan will include descriptions and evaluation of a suite of BMPs and will include decision criteria for their selection and application.

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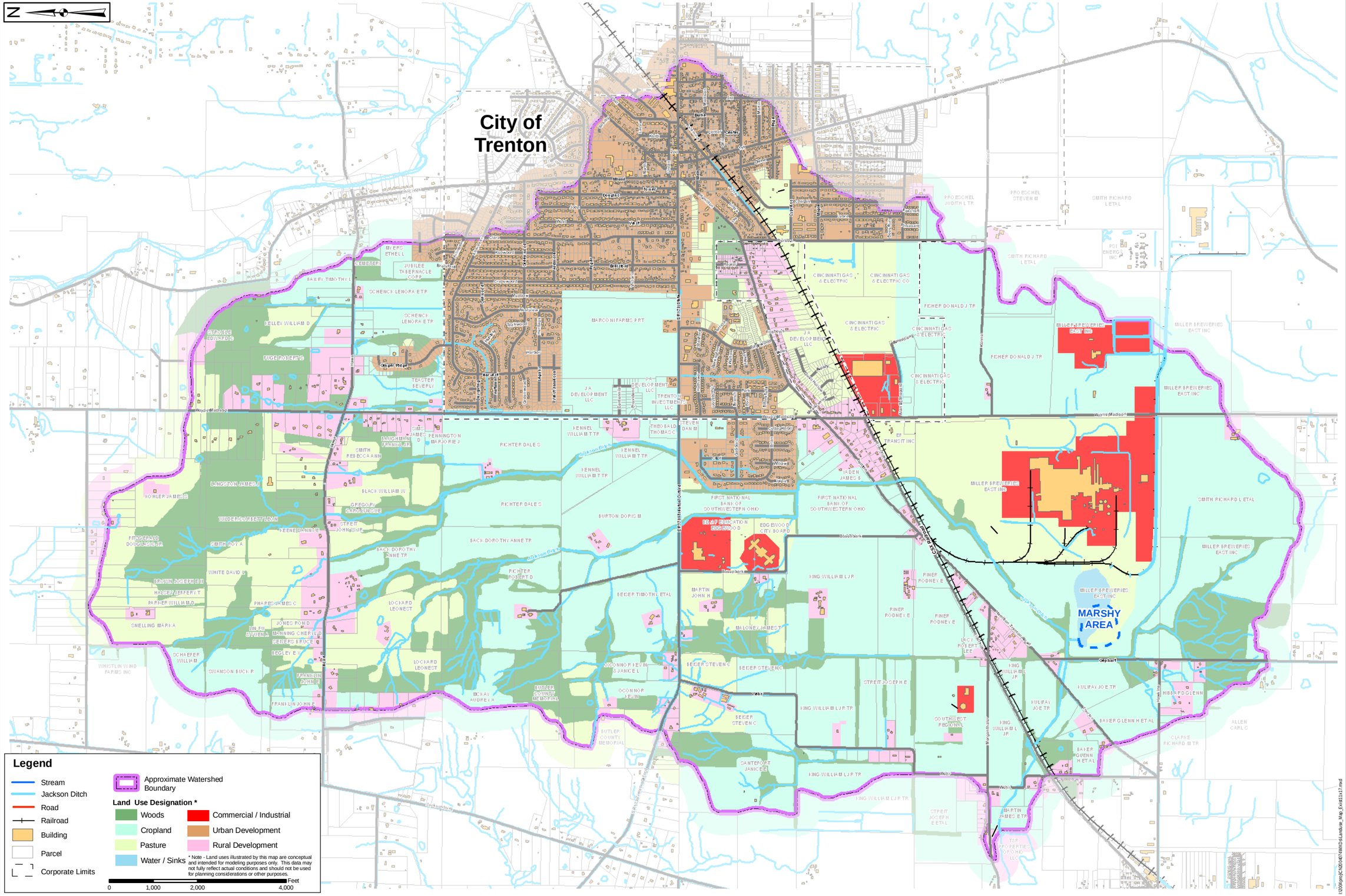
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Appendix A

Land Use Maps



FULLER MOSSBARGER SCOTT AND MAY ENGINEERS, INC.
11687 Lebanon Road
Cincinnati, Ohio 45241
513-842-8200

Fuller Mossbarger Scott & May

FMSM ENGINEERS

LEXINGTON LOUISVILLE CINCINNATI COLUMBUS ST. LOUIS

EXISTING LANDUSE

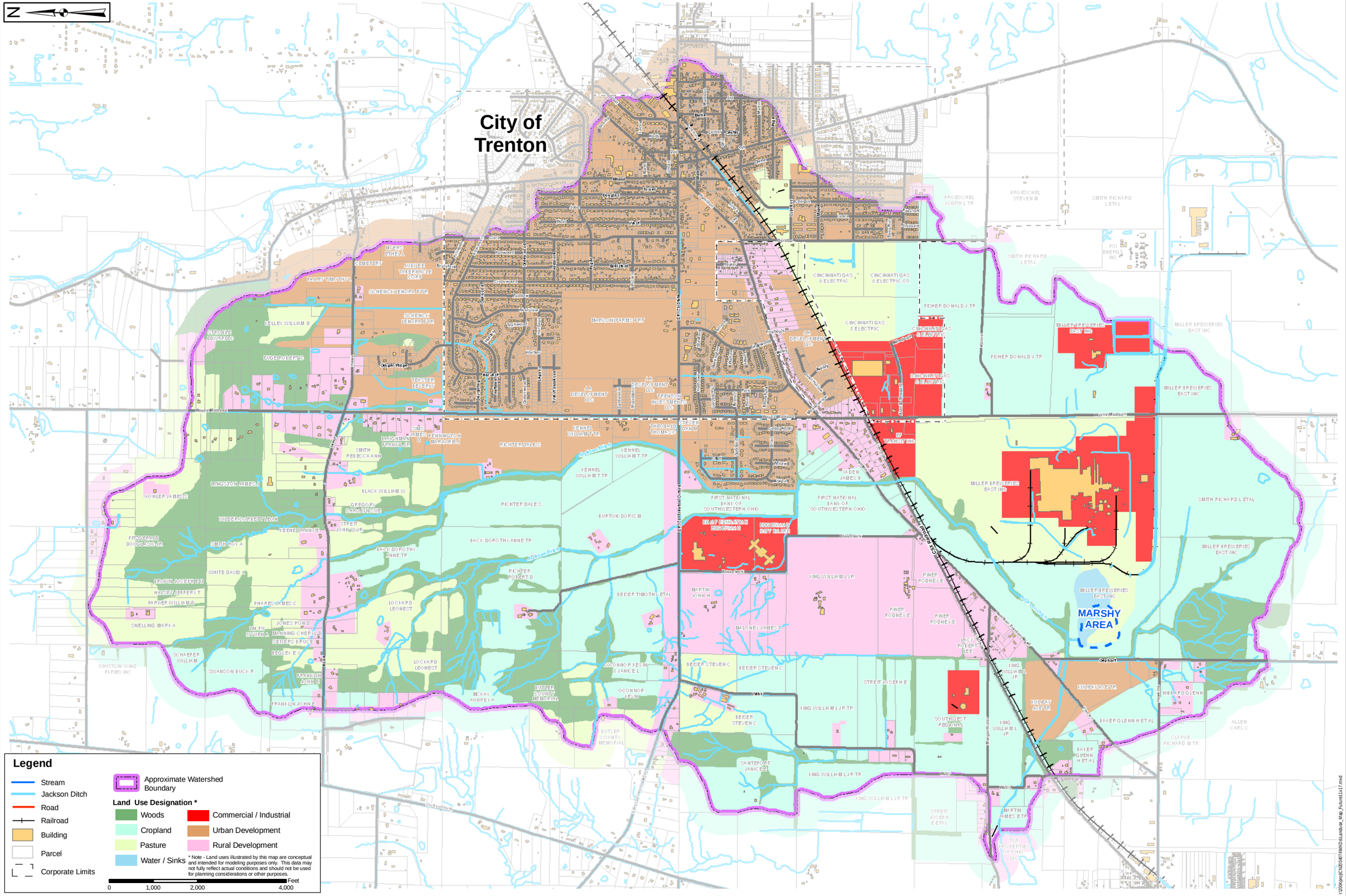
Watershed Study and Master Plan
Butler County Storm Water District
Butler County, Ohio

PROJECT NO.	CN2004074
DATE	MAY, 2006
DRAWN BY	ELC
CHECKED BY	JR
CHECKED BY	
SCALE	1" = 2000'
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1 OF 3

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FSM ENGINEERS

Fuller Mossbarger Scott & May

LEXINGTON LOUISVILLE CINCINNATI COLUMBUS ST. LOUIS

FUTURE LANDUSE

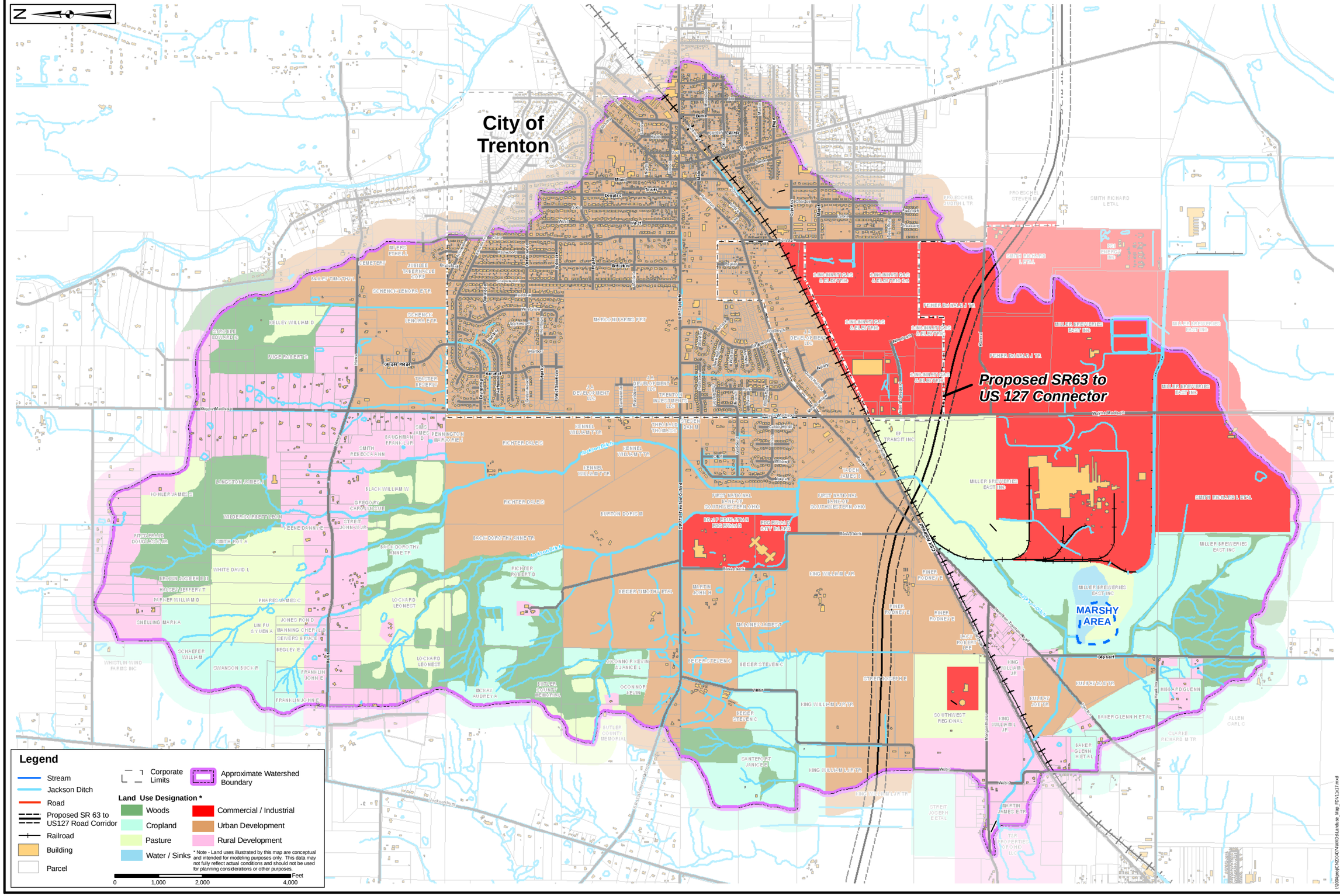
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LEXINGTON LOUISVILLE CINCINNATI COLUMBUS ST. LOUIS

FULLY DEVELOPED LANDUSE

Watershed Study and Master Plan
Butler County Storm Water District
Butler County, Ohio

PROJECT NO.	CN2004074
DATE	MAY, 2006
DRAWN BY	ELC
CHECKED BY	JR
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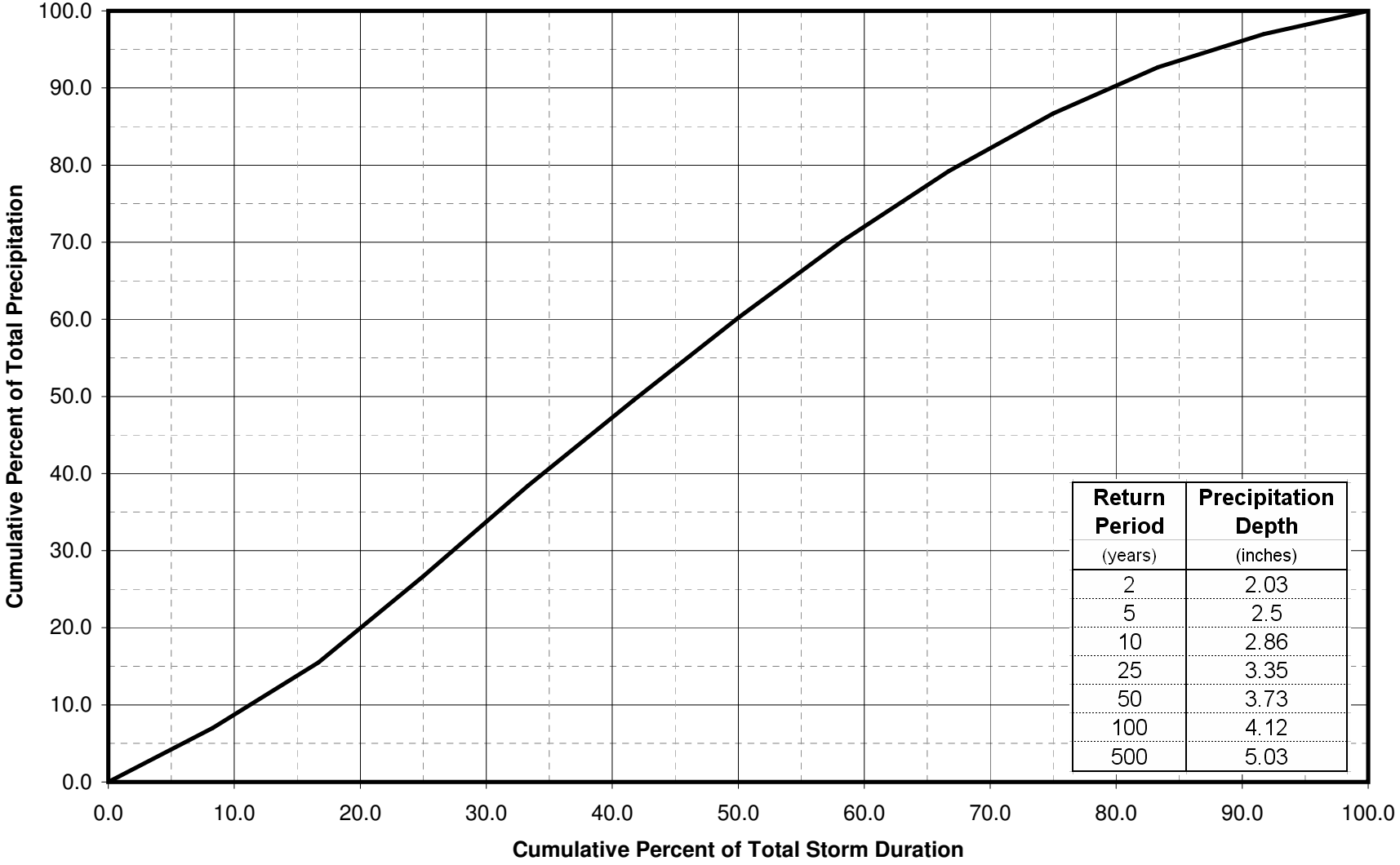
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Appendix B

HEC-HMS Model Data and Results

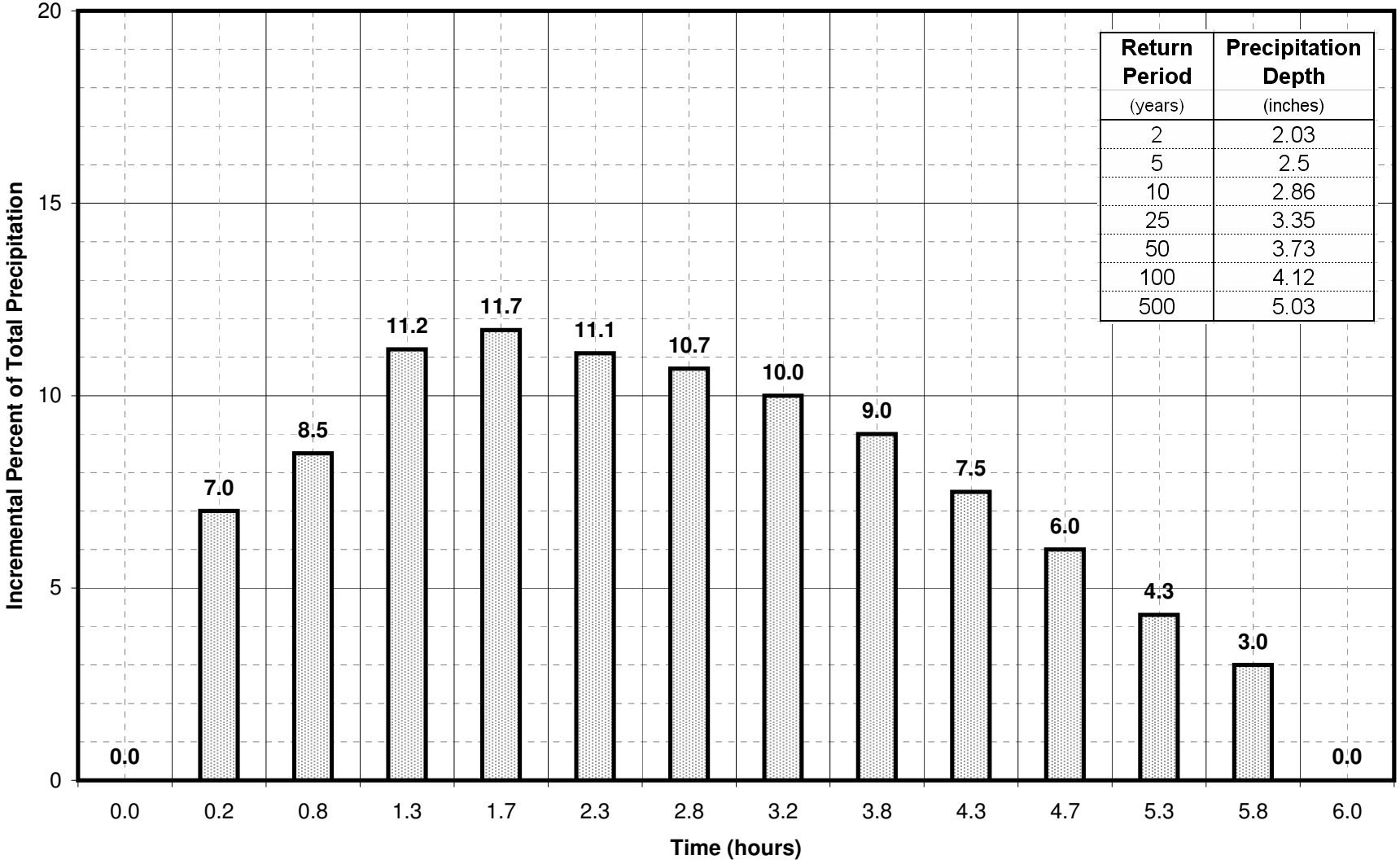
Precipitation Data

NOAA Atlas 14 Storm Distribution
(6-Hour Duration - Dimensionless Curve)



Return Period (years)	Precipitation Depth (inches)
2	2.03
5	2.5
10	2.86
25	3.35
50	3.73
100	4.12
500	5.03

NOAA Atlas 14 Storm Hyetograph
(6-Hour Duration - Dimensionless Curve)



Return Period (years)	Precipitation Depth (inches)
2	2.03
5	2.5
10	2.86
25	3.35
50	3.73
100	4.12
500	5.03

HEC-HMS
Schematic/Subbasin Map

N

City of Trenton

Elk Creek

Wayne Madison

Busenbark

Jacksonburg

CSX Railroad

MARSHY AREA

Legend

Stream
Jackson Ditch
Road
Railroad

Contours
2' Intermediate
10' Index

Building
Parcel
Corporate Limits
Flood Model Area
Approximate Watershed Boundary

Hydraulic Structure
Ohio DNR Observation Well
USGS Monitoring Site
Other Monitoring Well in Approximate Location
Production Well
HEC-HMS Subbasin ID #

0 1,000 2,000 4,000 Feet

FULLER MOSSBARGER SCOTT AND MAY ENGINEERS, INC.
11687 Lebanon Road
Cincinnati, Ohio 45241
513-842-8200

Fuller Mossbarger Scott & May

FMSM ENGINEERS
LEXINGTON LOUISVILLE CINCINNATI COLUMBUS ST. LOUIS

HEC-HMS Subbasin Schematic

Watershed Study and Master Plan
Butler County Storm Water District
Butler County, Ohio

PROJECT NO.	CN2004074
DATE	FEBRUARY, 2006
DRAWN BY	MAE/ELC
CHECKED BY	
CHECKED BY	
SCALE	1" = 2000'
REVISED	
1.	
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SHEET

1 OF 1

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HEC-HMS Parameters

HEC-HMS Model Data
Land Use - SCS Curve Number Correlation

Assumed Land Use	Characterization
Commercial / Industrial	Larger facilities such as Miller, Cinergy, and SW Water District.
Cropland	Primarily farmlands.
Pasture	Includes grazing areas and large open spaces.
Rural Development	Homes, farmsteads, buildings, etc. in areas away from City of Trenton
Urban Development	City of Trenton and tract homes.
Woods	Areas with distinguishable tree cover.

Assumed Land Use	TR-55 Equivalent[1]	Hydrologic Soil Group	SCS Curve Number
Commercial / Industrial	.	B	88
Commercial / Industrial	Urban District, Industrial	C	91
Pasture	Urban Areas, Open Space, Good Condition, Grass Cover > 75%	A	39
Pasture	Urban Areas, Open Space, Good Condition, Grass Cover > 75%	B	61
Pasture	Urban Areas, Open Space, Good Condition, Grass Cover > 75%	C	74
Pasture	Urban Areas, Open Space, Good Condition, Grass Cover > 75%	D	80
Cropland	Cultivated Agriculture, Small Grain, Straight Row, Good Condition	A	63
Cropland	Cultivated Agriculture, Small Grain, Straight Row, Good Condition	B	75
Cropland	Cultivated Agriculture, Small Grain, Straight Row, Good Condition	C	83
Cropland	Cultivated Agriculture, Small Grain, Straight Row, Good Condition	D	87
Rural Development	Residential Districts by Average Lot Size, 2 acres	A	46
Rural Development	Residential Districts by Average Lot Size, 2 acres	B	65
Rural Development	Residential Districts by Average Lot Size, 2 acres	C	77
Rural Development	Residential Districts by Average Lot Size, 2 acres	D	82
Urban Development	Residential Districts by Average Lot Size, 1/4 acres	A	61
Urban Development	Residential Districts by Average Lot Size, 1/4 acres	B	75
Urban Development	Residential Districts by Average Lot Size, 1/4 acres	C	83
Urban Development	Residential Districts by Average Lot Size, 1/4 acres	D	87
Woods	Woods-grass Combination (Orchard or tree farm), Good Condition	A	32
Woods	Woods-grass Combination (Orchard or tree farm), Good Condition	B	58
Woods	Woods-grass Combination (Orchard or tree farm), Good Condition	C	72
Woods	Woods-grass Combination (Orchard or tree farm), Good Condition	D	79

1. Reference: "Urban Hydrology for Small Watersheds, Technical Release 55 (TR-55)", June 1986, U.S. Dpartment of Agriculture, Natural Resources Conservation Service, Conservation Engineering Division

HEC-HMS Model Data
Subbasin Parameters

Subbasin ID #	Subbasin Name	Drainage Area (sq-mi)	Composite SCS Curve Number (Listed by Scenario)			Percentage of Impervious Area[1] (Listed by Scenario)			SCS Lag Time[2] (Listed in Minutes by Scenario)		
			Existing	Future	Fully Developed	Existing	Future	Fully Developed	Existing	Future	Fully Developed
1	Watershed-1	0.10119	72	72	72	4	9	14	18	17	16
2	Watershed-2	0.28951	73	73	73	4	9	14	30	28	27
3	Watershed-3	0.03878	73	73	73	13	18	23	15	14	13
4	Watershed-4	0.13885	71	71	71	4	9	14	42	40	38
5	Watershed-5	0.04339	73	75	75	7	12	17	13	12	11
6	Watershed-6	0.08928	76	77	77	3	8	13	13	13	12
7	Watershed-7	0.01369	73	74	74	7	12	17	8	8	7
8	Watershed-8	0.08461	76	76	76	2	7	12	22	20	19
9	Watershed-9	0.03587	77	77	77	4	9	14	17	16	15
10	Watershed-10	0.03643	75	75	75	0	5	10	23	22	21
11	Watershed-11	0.02851	68	72	72	0	5	10	25	24	23
12	Watershed-12	0.01652	65	67	75	16	21	26	8	8	7
13	Watershed-13	0.03790	72	72	75	1	6	11	18	17	16
14	Watershed-14	0.06499	71	71	75	3	8	13	17	16	16
15	Watershed-15	0.28767	74	74	76	1	6	11	22	21	20
16	Watershed-16	0.02647	68	68	73	0	5	10	5	5	5
17	Watershed-17	0.09756	61	61	62	2	7	12	10	9	9
18	Watershed-18	0.52244	62	62	64	1	6	11	18	17	16
19	Watershed-19	0.07769	67	67	67	1	6	11	11	10	10
20	Watershed-20	0.23230	67	67	69	1	6	11	11	10	10
21	Watershed-21	0.18827	72	80	84	7	12	17	17	17	16
22	Watershed-22	0.19875	71	71	75	3	8	13	13	12	12
23	Watershed-23	0.32835	70	70	71	1	6	11	12	11	10
24	Watershed-24	0.23120	70	70	71	0	5	10	15	14	13
25	Watershed-25	0.14230	66	66	66	2	7	12	14	13	12
26	Watershed-26	0.12155	67	67	69	2	7	12	6	6	6
27	Watershed-27	0.07670	73	75	75	5	10	15	8	8	8
28	Watershed-28	0.50687	72	72	77	1	6	11	29	28	26
29	Watershed-29	0.25623	79	79	84	4	9	14	49	46	44

HEC-HMS Model Data
Subbasin Parameters

Subbasin ID #	Subbasin Name	Drainage Area (sq-mi)	Composite SCS Curve Number (Listed by Scenario)			Percentage of Impervious Area[1] (Listed by Scenario)			SCS Lag Time[2] (Listed in Minutes by Scenario)		
			Existing	Future	Fully Developed	Existing	Future	Fully Developed	Existing	Future	Fully Developed
30	Watershed-30	0.19634	72	73	73	4	9	14	24	23	22
31	Watershed-31	0.28742	67	67	70	7	12	17	26	25	24
32	Watershed-32	0.12890	65	65	66	1	6	11	12	12	11
33	Watershed-33	0.20434	62	62	62	1	6	11	11	10	10
100	Watershed-100	0.43433	72	72	74	2	7	12	15	14	13
101	Watershed-101	0.53878	72	72	76	3	8	13	14	14	13
102	Watershed-102	0.07911	70	70	76	2	7	12	8	7	7
103	Watershed-103	0.27420	68	68	68	1	6	11	9	9	8
104	Watershed-104	0.44473	74	75	75	15	20	25	28	26	25
105	Watershed-105	0.18846	75	75	83	12	17	22	22	20	19
106	Watershed-106	0.28334	68	71	74	7	12	17	29	27	26
107	Watershed-107	0.22465	73	73	75	14	19	24	21	20	19
108	Watershed-108	2.66113	73	75	80	13	18	23	83	79	75

[1] - Existing percent impervious values were calculated using GIS data, Future and Fully Developed percent impervious values assumed existing conditions plus 5% and 10% respectively.
[2] - SCS Lag Time calculated as 60% of Time of Concentration. Time of Concentration determined using the Kirpich Equation, where L = flowpath length, and H = change in elevation.

$$T_C = 0.0078 L^{0.77} \left(\frac{L}{H} \right)^{0.385}$$

HEC-HMS Model Data
Storage and Overflow Parameters

Channel Overflow - South of Hamilton Trenton Road at the previous location of Riverside Drive

Elevation (feet)	Hydraulic Head (feet)	Discharge Rating Curve [1] Dual 5'x6' RCBCs (cfs)	Comments
638.0	0.0	0	
639.0	1.0	34	
640.0	2.0	94	
641.0	3.0	172	
642.0	4.0	264	
643.0	5.0	368	
644.0	6.0	484	
645.0	7.0	596	
645.1	7.1	606	< Spill over to adjacent basins.

[1] - Controlling structure is the Railroad Culvert Downstream

Storage Area - Upstream of the Railroad Spur on Miller Brewing Company's Property

Elevation (feet)	Cumulative Channel Storage (ac-ft)	Discharge Rating Curve Dual 48" CMPs (cfs)	Comments
634.0	0.0	0	
636.0	1.8	44	
638.0	14.6	142	
638.1	14.7	142	< Spill over to adjacent basins.

Storage Area - Low Lying Area of Miller Brewing Company's Property

Elevation (feet)	Cumulative Channel Storage (ac-ft)	Discharge Rating Curve Weir Overflow [2] (cfs)	Comments
625.0	0.0	0	
626.0	0.5	0	
627.0	18.8	0	
628.0	60.6	0	
630.0	160.8	2619	< Spill over towards Gephart Road.
632.0	273.3	7409	

[2] - Assumed overflow width of 300'.

HEC-HMS Model Data
Storage and Overflow Parameters

Storage Area - Upstream of the Railroad and Southern Crossing of Hamilton-Trenton Road

Elevation (feet)	Cumulative Channel Storage (ac-ft)	Discharge Rating Curve 60" RCP (cfs)	Comments
626.0	0.0	0	
628.0	1.0	28	
630.0	16.2	91	
632.0	51.2	158	
634.0	91.8	213	
636.0	132.4	254	
638.0	173.0	290	< Spill over to adjacent basins.

Storage Area - Low Area Downstream of Hamilton-Trenton Road near Wehr Road

Elevation (feet)	Cumulative Channel Storage (ac-ft)	Discharge Rating Curve Weir Overflow [3] (cfs)	Comments
625.0	0.0	0	
625.5	0.0	0	
626.0	0.1	0	
628.0	1.9	1746	< Spill over to overland flow.
629.0	4.0	3208	
630.0	7.8	4939	

[3] - Assumed overflow width of 200'.

Peak Flow Results

HEC-HMS Model Data
Predicted Peak Flow Values

Location	Hydrologic Element	Drainage Area (sq mi)	Existing Condition Scenario					
			Discharge Peak (cfs) – 6 Hour Duration					
			100-Yr	50-Yr	25-Yr	10-Yr	5-Yr	2-Yr
West Trib. Upstream of Howe Road	Howe_Rd_1	33.883	34	28	23	17	12	7
West Trib. Upstream of Oxford Road (SR73)	SR73_West	342.950	343	285	233	169	125	73
East Trib - West Fork Upstream of Howe Road	Howe_Rd_2	62.968	63	52	43	31	22	13
East Trib - East Fork Upstream of Howe Road	Howe_Rd_3	114.630	115	93	73	49	34	17
Junction of 2 forks of East Trib.	J17-19	217.840	218	178	142	98	68	36
East Trib Upstream of Oxford Road (SR73)	SR73_East	491.540	492	408	331	237	174	100
Junction of West and East Tribs	J_East_West	906.630	907	755	614	443	327	191
Upstream of Hamilton-Trenton Road	Hamilton_Trenton_Rd2	917.580	918	764	622	448	331	193
Upstream of RR Culvert, Downstream of Previous Riverside Drive Crossing	Railroad_2	596.080	596	596	596	450	332	194
Inflow to Low Area on Miller Brewing Property	J_8	189.610	190	183	177	169	163	148
Upstream of Gephart Road	Gephart_Rd	199.760	200	174	154	123	83	1
Upstream of Hamilton-Trenton Road Southwest of Gephart Intersection	Hamilton_Trenton_Rd1	288.690	289	218	162	124	88	55
Upstream of Riverside Drive	RR_Riverside_Drive	163.210	163	141	118	90	68	46
Upstream of Wehr Drive	Wehr_Road	222.230	222	195	170	133	103	69
Outlet of Jackson Ditch Watershed at Gravel Pit	Outfall	249.910	250	218	190	145	113	76

HEC-HMS Model Data
Predicted Peak Flow Values

Location	Hydrologic Element	Drainage Area (sq mi)	20-Year Future Condition Scenario					
			Discharge Peak (cfs) – 6 Hour Duration					
			100-Yr	50-Yr	25-Yr	10-Yr	5-Yr	2-Yr
West Trib. Upstream of Howe Road	Howe_Rd_1	33.883	36	30	24	18	14	8
West Trib. Upstream of Oxford Road (SR73)	SR73_West	342.950	360	301	246	182	138	85
East Trib - West Fork Upstream of Howe Road	Howe_Rd_2	62.968	67	55	45	33	25	15
East Trib - East Fork Upstream of Howe Road	Howe_Rd_3	114.630	122	101	80	56	40	22
Junction of 2 forks of East Trib.	J17-19	217.840	231	191	154	109	79	44
East Trib Upstream of Oxford Road (SR73)	SR73_East	491.540	520	434	355	260	195	119
Junction of West and East Tribs	J_East_West	906.630	968	811	666	491	371	230
Upstream of Hamilton-Trenton Road	Hamilton_Trenton_Rd2	917.580	980	821	674	497	376	233
Upstream of RR Culvert, Downstream of Previous Riverside Drive Crossing	Railroad_2	596.080	596	596	596	499	377	234
Inflow to Low Area on Miller Brewing Property	J_8	189.610	191	184	178	171	165	156
Upstream of Gephart Road	Gephart_Rd	199.760	220	195	172	147	125	67
Upstream of Hamilton-Trenton Road Southwest of Gephart Intersection	Hamilton_Trenton_Rd1	288.690	347	279	214	152	126	67
Upstream of Riverside Drive	RR_Riverside_Drive	163.210	176	157	134	106	87	51
Upstream of Wehr Drive	Wehr_Road	222.230	231	203	177	144	113	77
Outlet of Jackson Ditch Watershed at Gravel Pit	Outfall	249.910	260	228	198	157	124	84

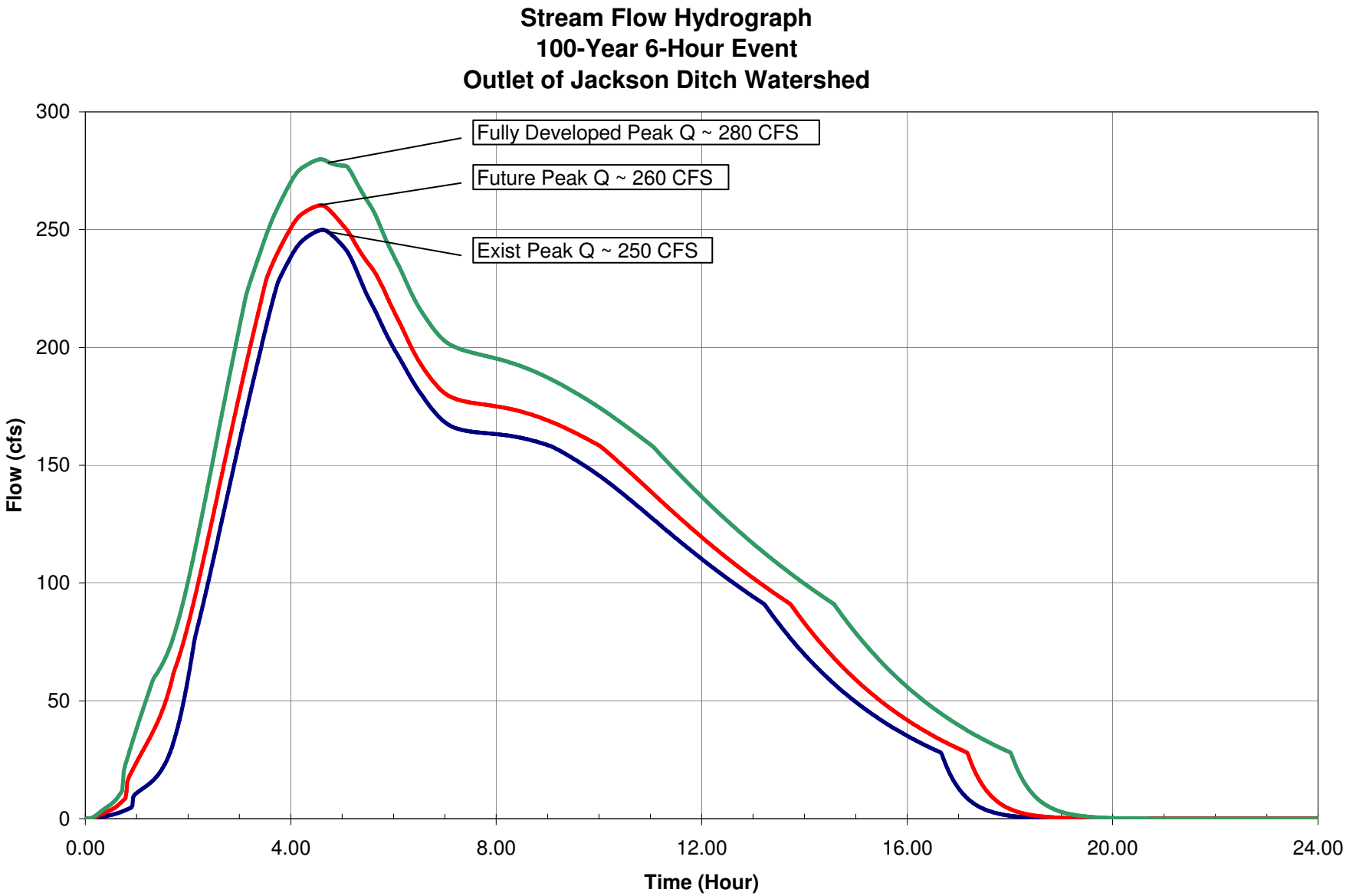
HEC-HMS Model Data
Predicted Peak Flow Values

Location	Hydrologic Element	Drainage Area (sq mi)	Fully Developed Future Condition Scenario					
			Discharge Peak (cfs) – 6 Hour Duration					
			100-Yr	50-Yr	25-Yr	10-Yr	5-Yr	2-Yr
West Trib. Upstream of Howe Road	Howe_Rd_1	33.883	40	34	28	21	16	11
West Trib. Upstream of Oxford Road (SR73)	SR73_West	342.950	393	332	275	206	160	104
East Trib - West Fork Upstream of Howe Road	Howe_Rd_2	62.968	75	63	52	39	30	19
East Trib - East Fork Upstream of Howe Road	Howe_Rd_3	114.630	139	117	95	69	52	31
Junction of 2 forks of East Trib.	J17-19	217.840	260	217	178	131	99	61
East Trib Upstream of Oxford Road (SR73)	SR73_East	491.540	578	489	406	304	234	152
Junction of West and East Tribs	J_East_West	906.630	1070	908	755	568	441	290
Upstream of Hamilton-Trenton Road	Hamilton_Trenton_Rd2	917.580	1082	919	764	575	447	293
Upstream of RR Culvert, Downstream of Previous Riverside Drive Crossing	Railroad_2	596.080	596	596	596	578	449	295
Inflow to Low Area on Miller Brewing Property	J_8	189.610	192	186	179	172	166	160
Upstream of Gephart Road	Gephart_Rd	199.760	250	224	200	170	152	121
Upstream of Hamilton-Trenton Road Southwest of Gephart Intersection	Hamilton_Trenton_Rd1	288.690	429	362	292	211	162	121
Upstream of Riverside Drive	RR_Riverside_Drive	163.210	198	178	159	130	109	81
Upstream of Wehr Drive	Wehr_Road	222.230	255	221	193	159	134	93
Outlet of Jackson Ditch Watershed at Gravel Pit	Outfall	249.910	280	246	214	176	144	101

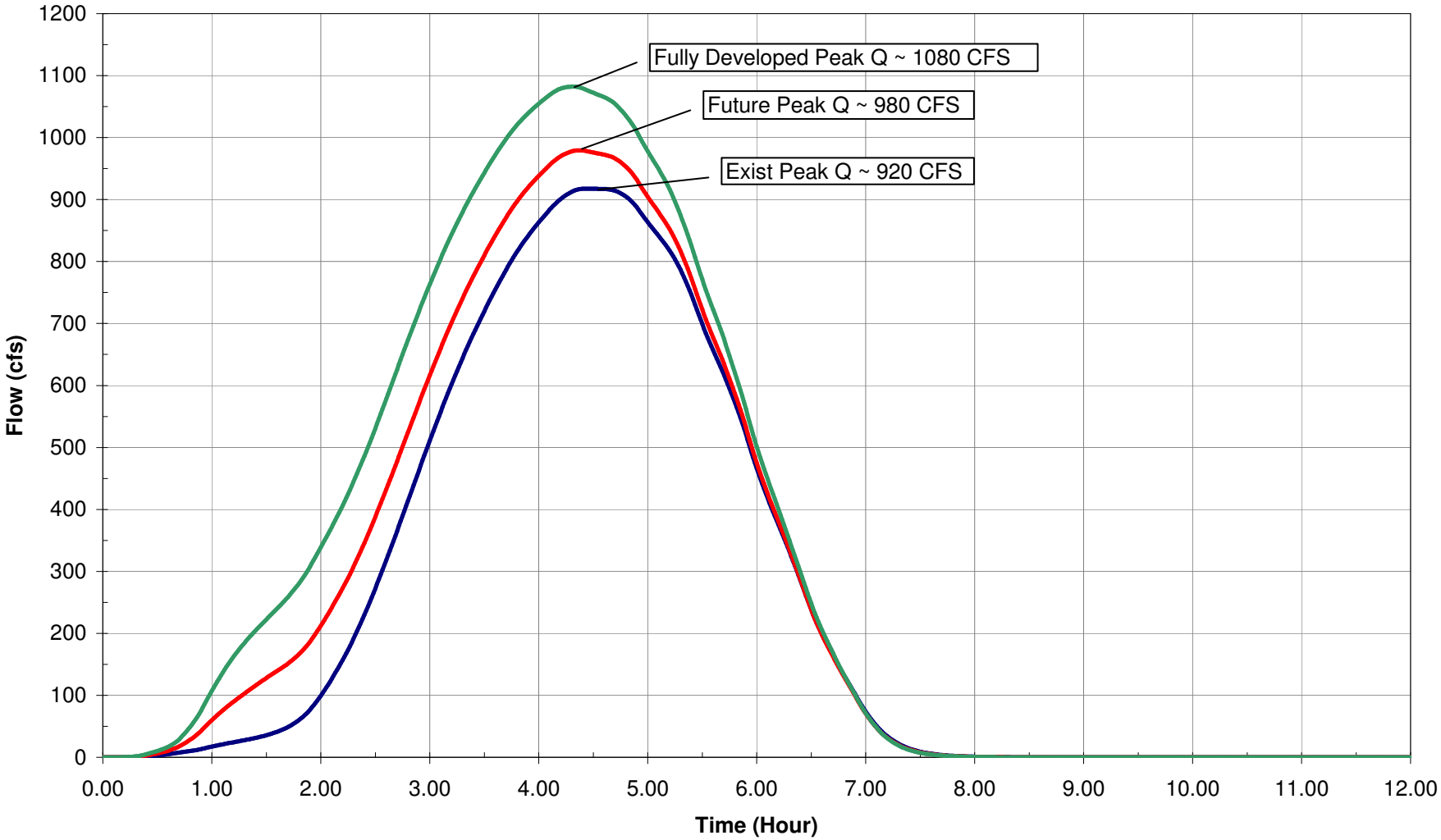
HEC-HMS Model Data
Predicted Peak Flow Values

Location	Hydrologic Element	Drainage Area (sq-mi)	100-Year Storm Event 6 Hour Duration Peak Discharge (cfs) - Listed by Scenario		
			Existing Conditions	Future Conditions	Fully Developed Conditions
West Trib. Upstream of Howe Road	Howe_Rd_1	33.883	34	36	40
West Trib. Upstream of Oxford Road (SR73)	SR73_West	342.950	343	360	393
East Trib - West Fork Upstream of Howe Road	Howe_Rd_2	62.968	63	67	75
East Trib - East Fork Upstream of Howe Road	Howe_Rd_3	114.630	115	122	139
Junction of 2 forks of East Trib.	J17-19	217.840	218	231	260
East Trib Upstream of Oxford Road (SR73)	SR73_East	491.540	492	520	578
Junction of West and East Tribs	J_East_West	906.630	907	968	1070
Upstream of Hamilton-Trenton Road	Hamilton_Trenton_Rd2	917.580	918	980	1082
Upstream of RR Culvert, Downstream of Previous Riverside Drive Crossing	Railroad_2	596.080	596	596	596
Inflow to Low Area on Miller Brewing Property	J_8	189.610	190	191	192
Upstream of Gephart Road	Gephart_Rd	199.760	200	220	250
Upstream of Hamilton-Trenton Road Southwest of Gephart Intersection	Hamilton_Trenton_Rd1	288.690	289	347	429
Upstream of Riverside Drive	RR_Riverside_Drive	163.210	163	176	198
Upstream of Wehr Drive	Wehr_Road	222.230	222	231	255
Outlet of Jackson Ditch Watershed at Gravel Pit	Outfall	249.910	250	260	280

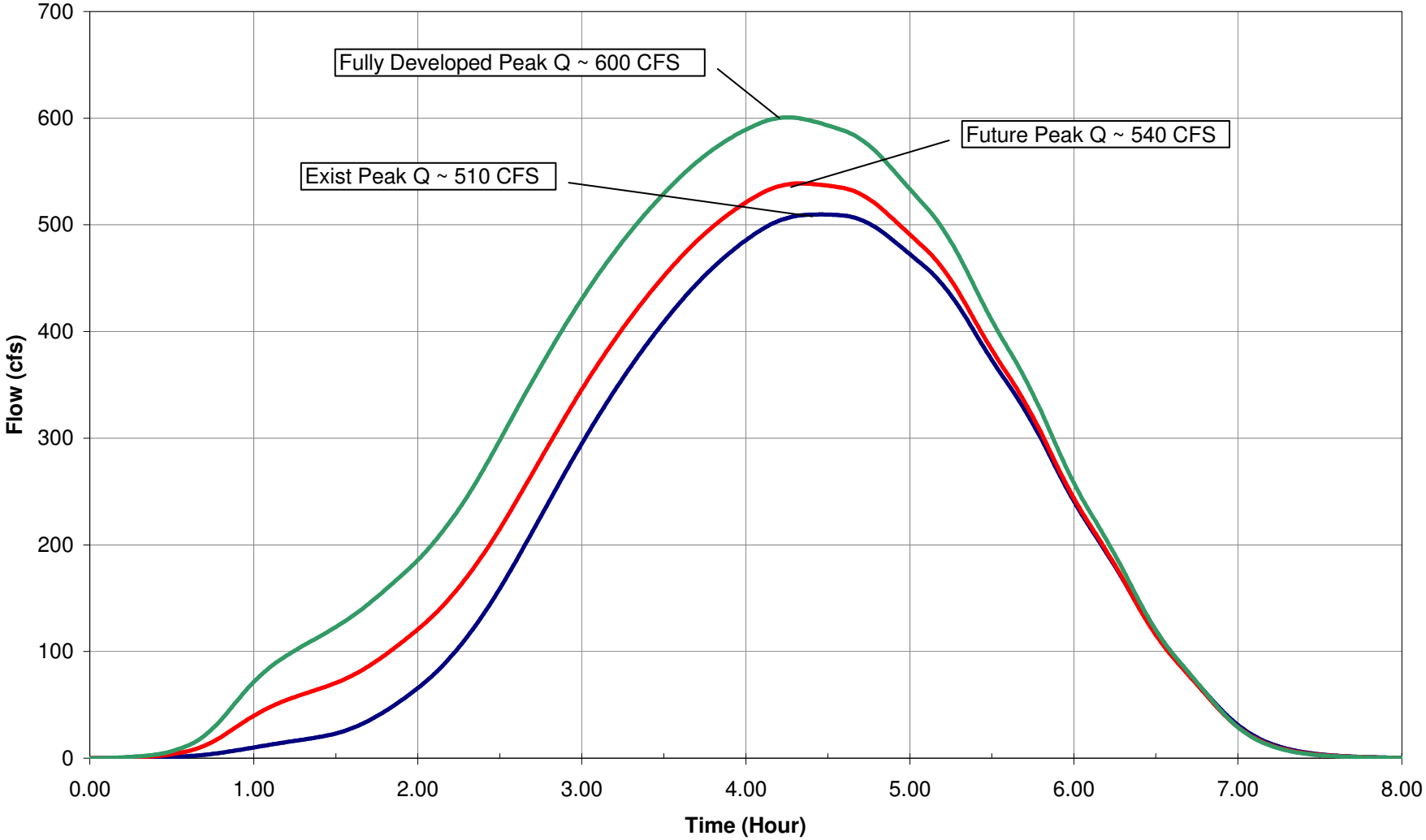
Runoff Hydrographs


Stream Flow Hydrograph
100-Year 6-Hour Event
Outlet of Jackson Ditch Watershed
Fully Developed Peak Q ~ 280 CFS
Future Peak Q ~ 260 CFS
Exist Peak Q ~ 250 CFS
Flow (cfs)
300
250
200
150
100
50
0
0.00
4.00
8.00
12.00
16.00
20.00
24.00
Time (Hour)

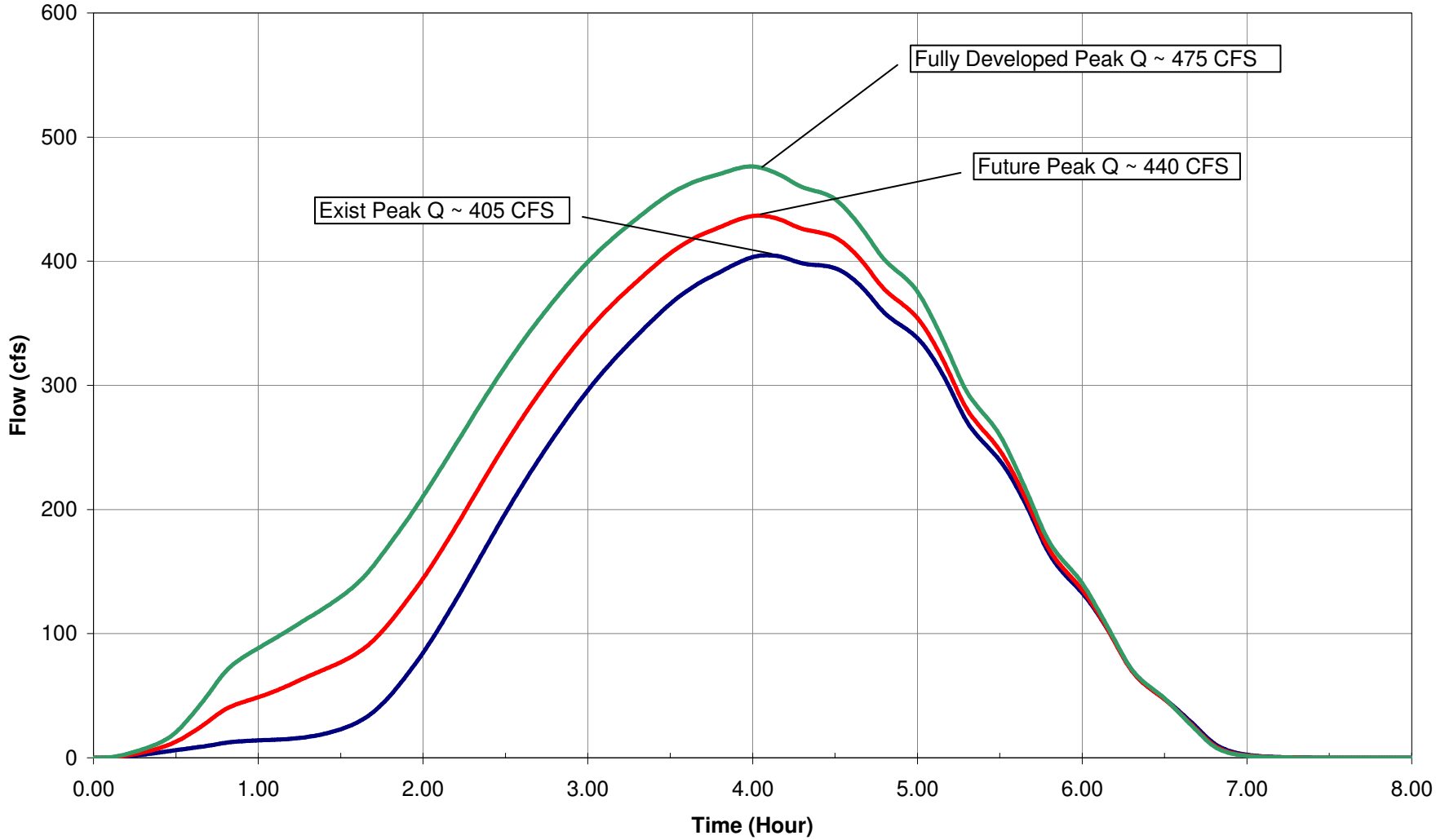
Streamflow Hydrograph
100-Year 6-Hour Event
Upstream of Hamilton-Trenton Road



Stream Flow Hydrograph
100-Year 6-Hour Event
East Tributary of Jackson Ditch at S.R. 73



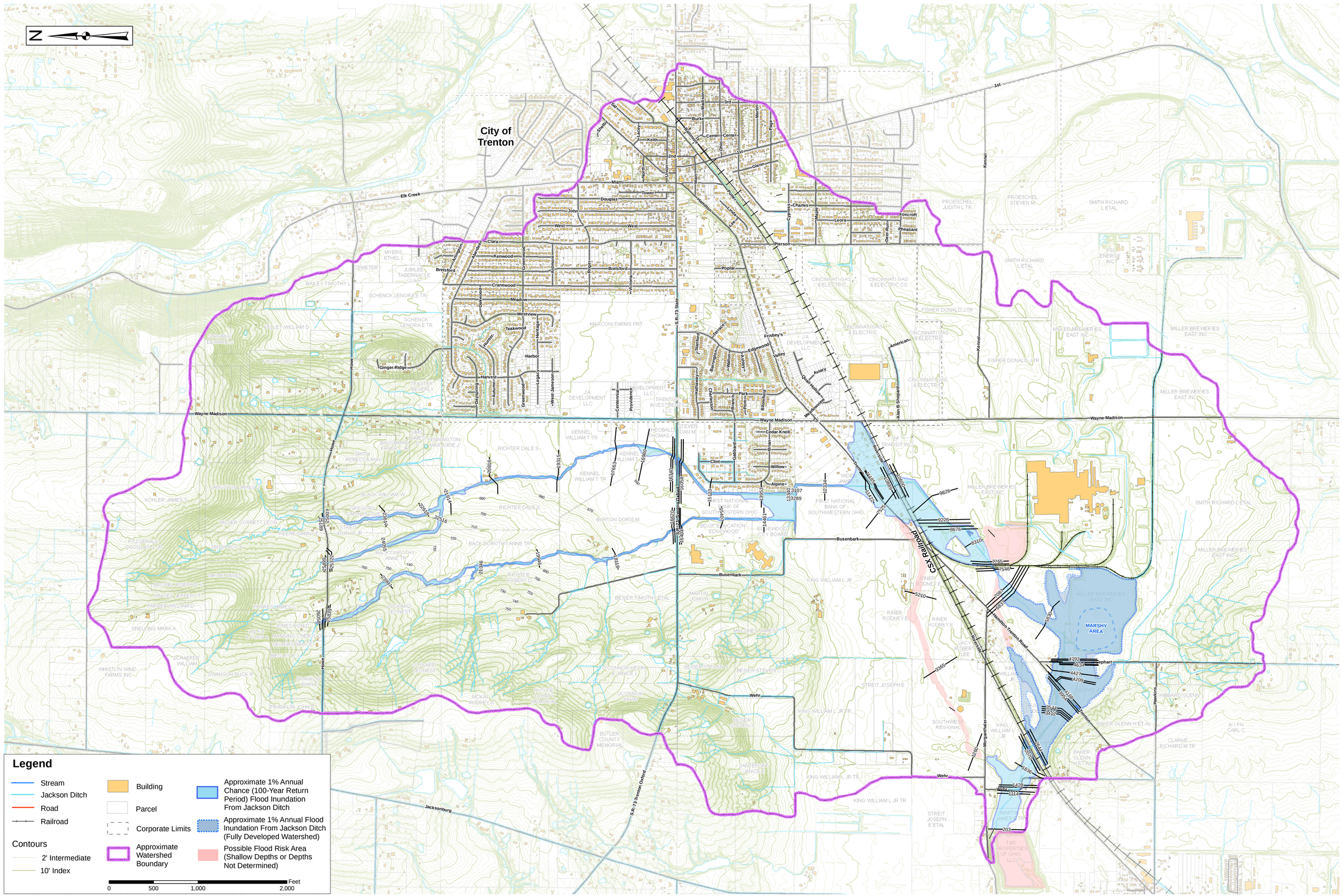
Stream Flow Hydrograph
100-Year 6-Hour Event
West Tributary of Jackson Ditch at S.R. 73



Appendix C

HEC-RAS Model Data and Results

Flood Inundation Map



FULLER MOSSBARGER SCOTT AND MAY ENGINEERS, INC.
11687 Lebanon Road
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Fuller Mossbarger Scott & May

FMSM ENGINEERS

LEXINGTON LOUISVILLE CINCINNATI COLUMBUS ST. LOUIS

Jackson Ditch Flood Hazards

Watershed Study and Master Plan

Butler County Storm Water District
Butler County, Ohio

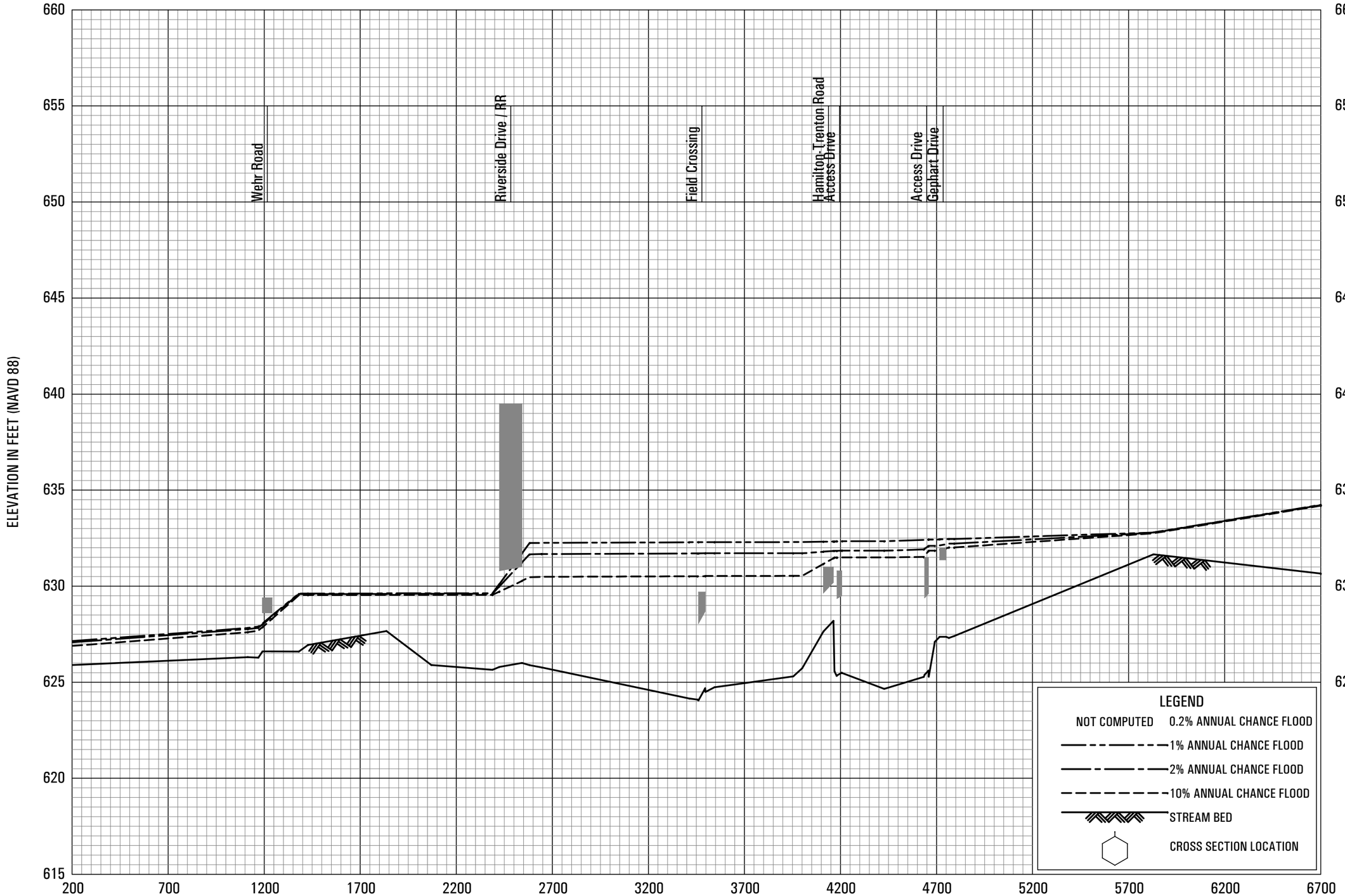
PROJECT NO.	CN2004074
DATE	MAY, 2006
DRAWN BY	MAE/ELC
CHECKED BY	JR
CHECKED BY	
SCALE	1" = 1000'
REVISED	
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Graphical Flood Profiles



FLOOD PROFILES - EXISTING CONDITIONS

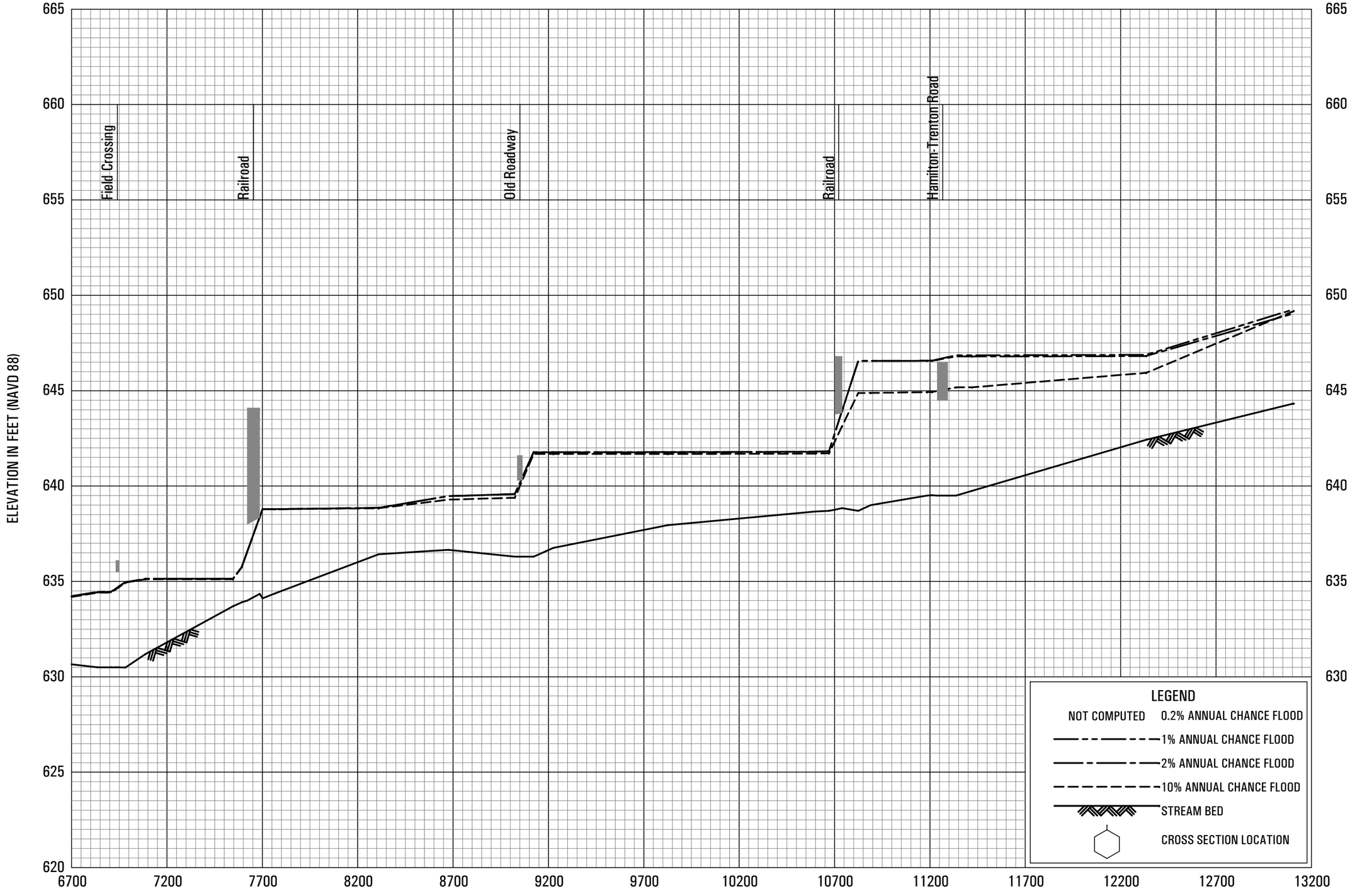
JACKSON DITCH - DOWNSTREAM REACH

BUTLER COUNTY ENGINEERS' OFFICE

TRENTON WATERSHED STUDY

BUTLER COUNTY OHIO

01P



FLOOD PROFILES - EXISTING CONDITIONS

JACKSON DITCH - DOWNSTREAM REACH

BUTLER COUNTY ENGINEERS' OFFICE

TRENTON WATERSHED STUDY

BUTLER COUNTY OHIO

02P

ELEVATION IN FEET (NAVD 88)

710
700
690
680
670
660
650
640
630
620

13200 13600 14000 14400 14800 15200 15600 16000 16400 16800 17200 17600 18000 18400

STREAM DISTANCE IN FEET IN FEET ABOVE GRAVEL PIT WEST OF WEHR RD.

Oxford Road (SR 73)

LEGEND

- NOT COMPUTED
- 0.2% ANNUAL CHANCE FLOOD
- 1% ANNUAL CHANCE FLOOD
- 2% ANNUAL CHANCE FLOOD
- 10% ANNUAL CHANCE FLOOD
- STREAM BED
- CROSS SECTION LOCATION

FLOOD PROFILES - EXISTING CONDITIONS

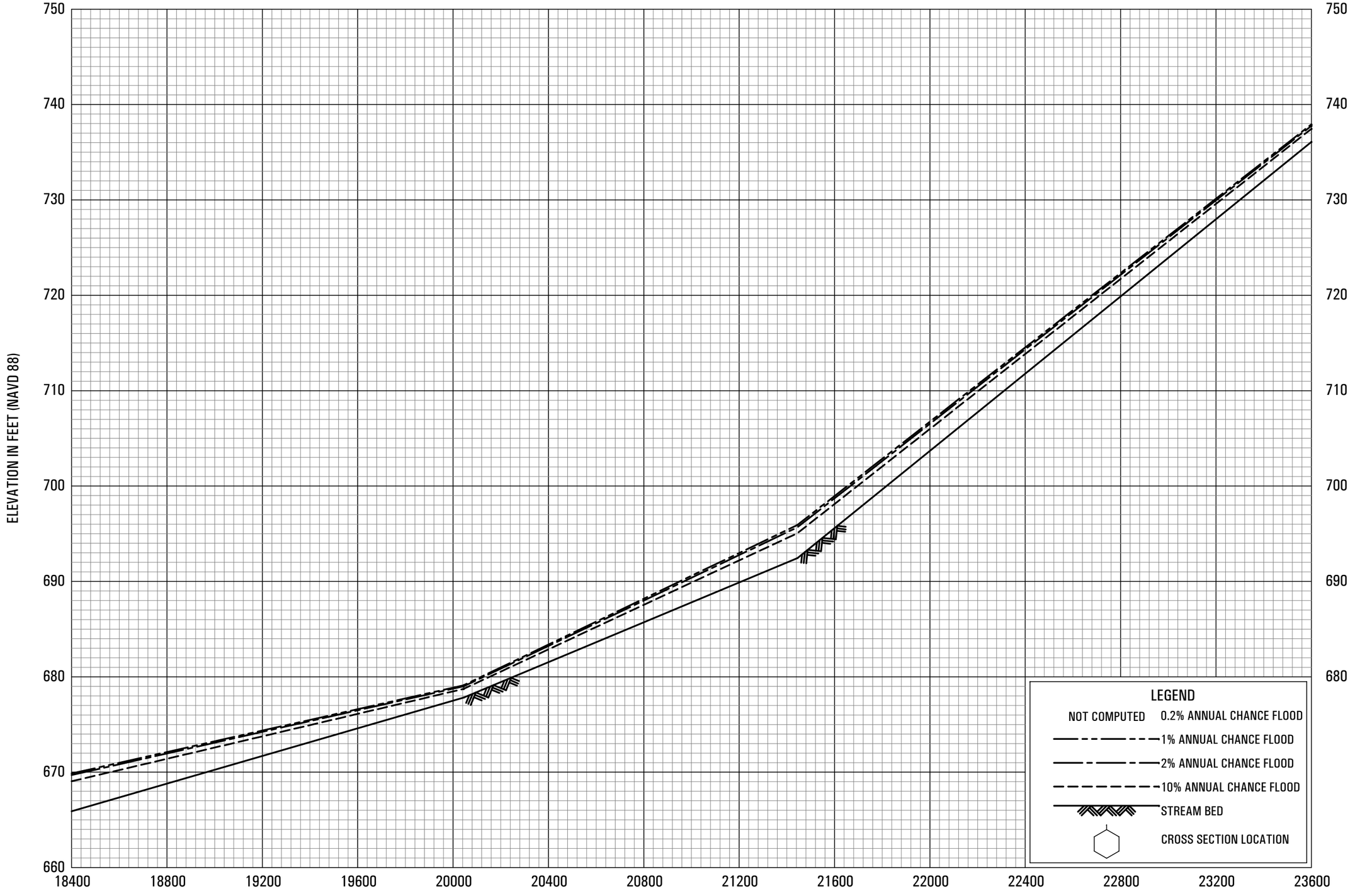
JACKSON DITCH - WEST FORK

BUTLER COUNTY ENGINEERS' OFFICE

TRENTON WATERSHED STUDY

BUTLER COUNTY, OHIO

03P



FLOOD PROFILES - EXISTING CONDITIONS

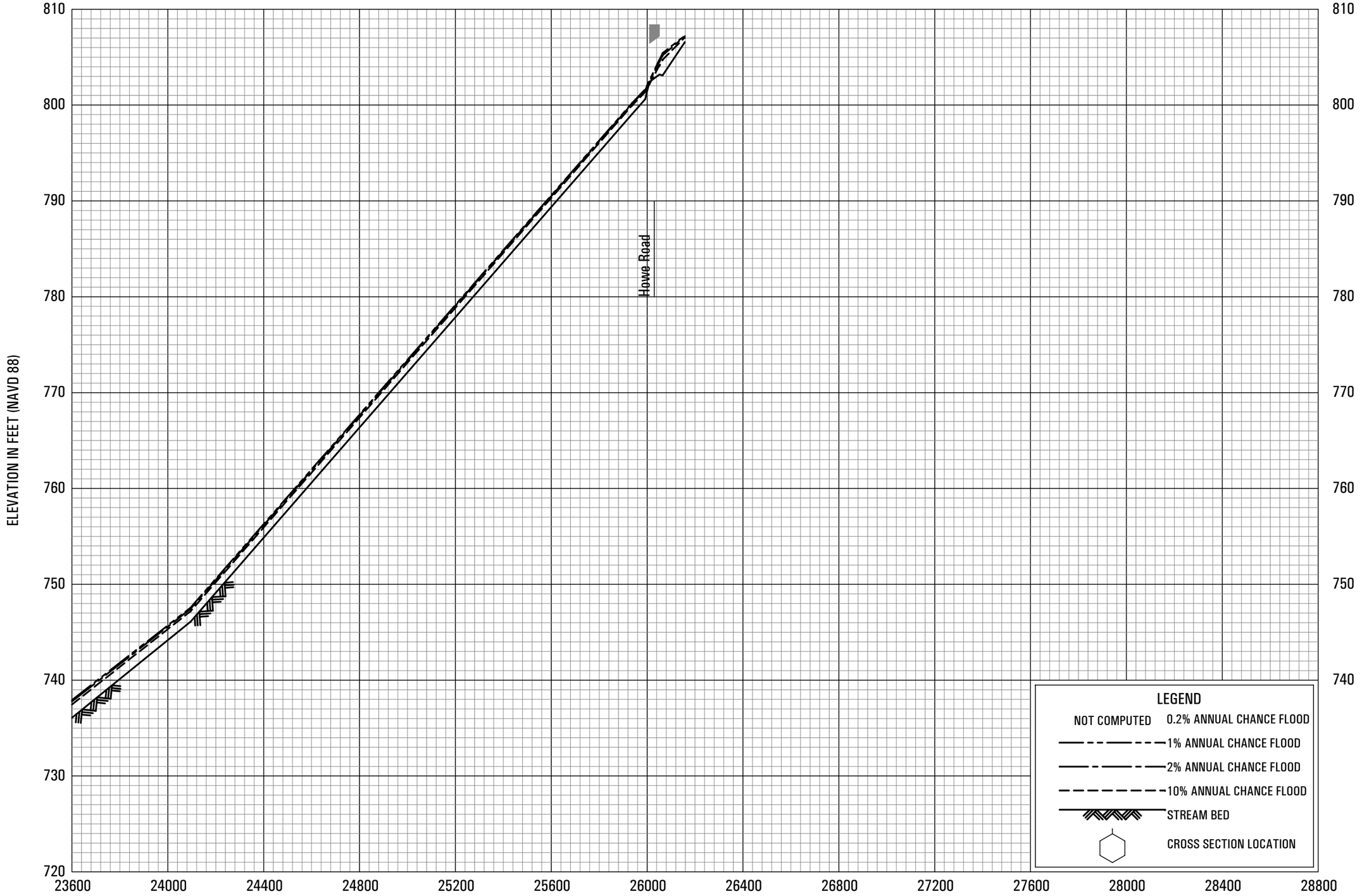
JACKSON DITCH - WEST FORK

BUTLER COUNTY ENGINEERS' OFFICE

TRENTON WATERSHED STUDY

BUTLER COUNTY, OHIO

04P



FLOOD PROFILES - EXISTING CONDITIONS

JACKSON DITCH - WEST FORK

BUTLER COUNTY ENGINEERS' OFFICE

TRENTON WATERSHED STUDY

BUTLER COUNTY, OHIO

05P

ELEVATION IN FEET (NAVD 88)

710
700
690
680
670
660
650
640
630
620

Oxford Road (SR73)

13200 13600 14000 14400 14800 15200 15600 16000 16400 16800 17200 17600 18000 18400

STREAM DISTANCE IN FEET IN FEET ABOVE GRAVEL PIT WEST OF WEHR RD.

LEGEND

NOT COMPUTED
0.2% ANNUAL CHANCE FLOOD
1% ANNUAL CHANCE FLOOD
2% ANNUAL CHANCE FLOOD
10% ANNUAL CHANCE FLOOD
STREAM BED
CROSS SECTION LOCATION

FLOOD PROFILES - EXISTING CONDITIONS

JACKSON DITCH - EAST FORK

BUTLER COUNTY ENGINEERS' OFFICE

TRENTON WATERSHED STUDY

BUTLER COUNTY, OHIO

06P

730
720
710
700
690
680
670
660
650
640

ELEVATION IN FEET (NAVD 88)

18400 18800 19200 19600 20000 20400 20800 21200 21600 22000 22400 22800 23200 23600

STREAM DISTANCE IN FEET IN FEET ABOVE GRAVEL PIT WEST OF WEHR RD.

LEGEND

- NOT COMPUTED
- 0.2% ANNUAL CHANCE FLOOD
- 1% ANNUAL CHANCE FLOOD
- 2% ANNUAL CHANCE FLOOD
- 10% ANNUAL CHANCE FLOOD
- STREAM BED
- CROSS SECTION LOCATION

FLOOD PROFILES - EXISTING CONDITIONS

JACKSON DITCH - EAST FORK

BUTLER COUNTY ENGINEERS' OFFICE

TRENTON WATERSHED STUDY

BUTLER COUNTY, OHIO

07P

780
770
760
750
740
730
720
710
700
690

ELEVATION IN FEET (NAVD 88)

Howe Road

23600 24000 24400 24800 25200 25600 26000 26400 26800 27200 27600 28000 28400 28800

STREAM DISTANCE IN FEET IN FEET ABOVE GRAVEL PIT WEST OF WEHR RD.

LEGEND

NOT COMPUTED
0.2% ANNUAL CHANCE FLOOD
1% ANNUAL CHANCE FLOOD
2% ANNUAL CHANCE FLOOD
10% ANNUAL CHANCE FLOOD
STREAM BED
CROSS SECTION LOCATION

FLOOD PROFILES - EXISTING CONDITIONS

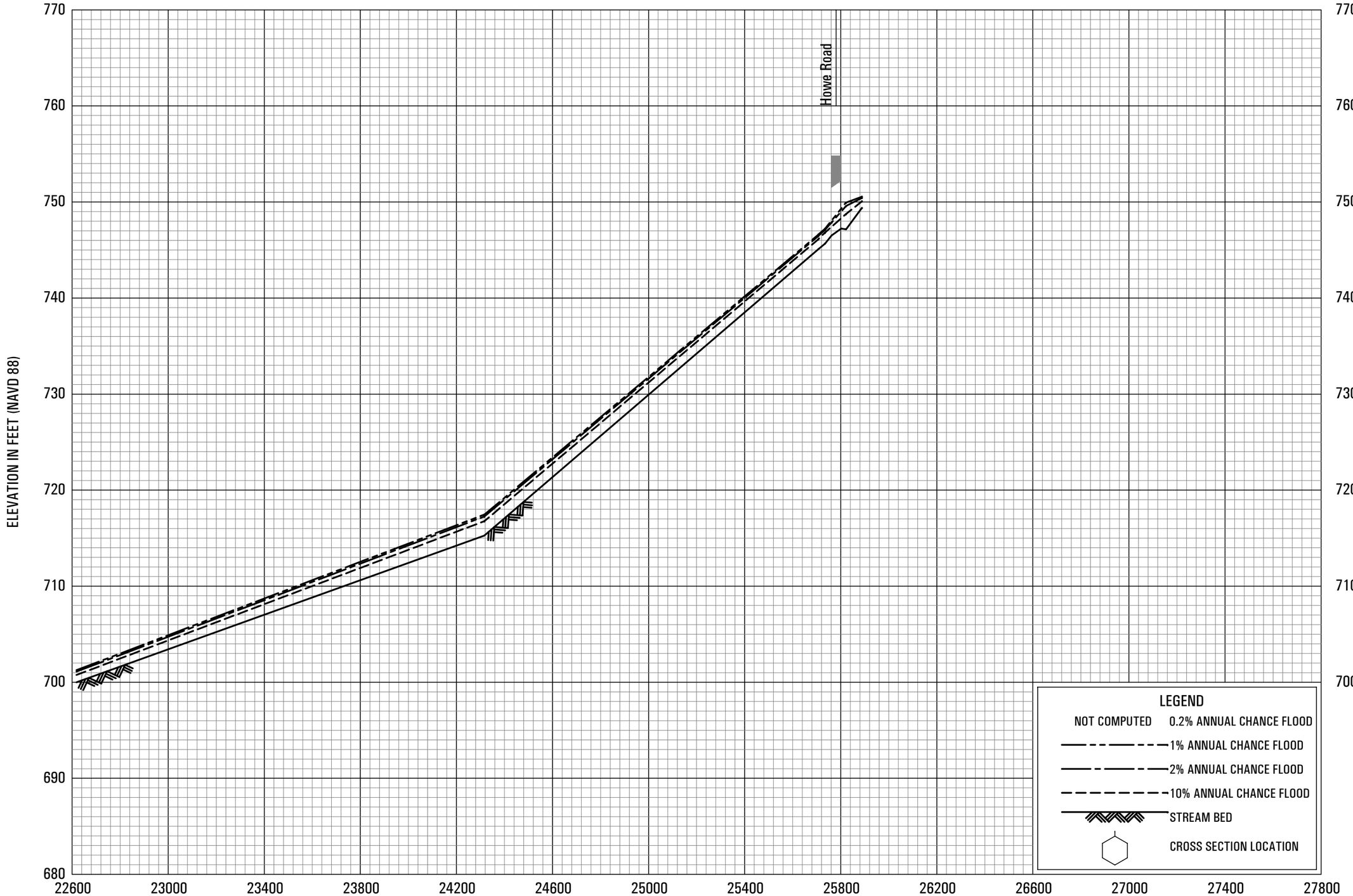
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BUTLER COUNTY, OHIO

08P



FLOOD PROFILES - EXISTING CONDITIONS

JACKSON DITCH - EAST TRIB OF EAST FORK

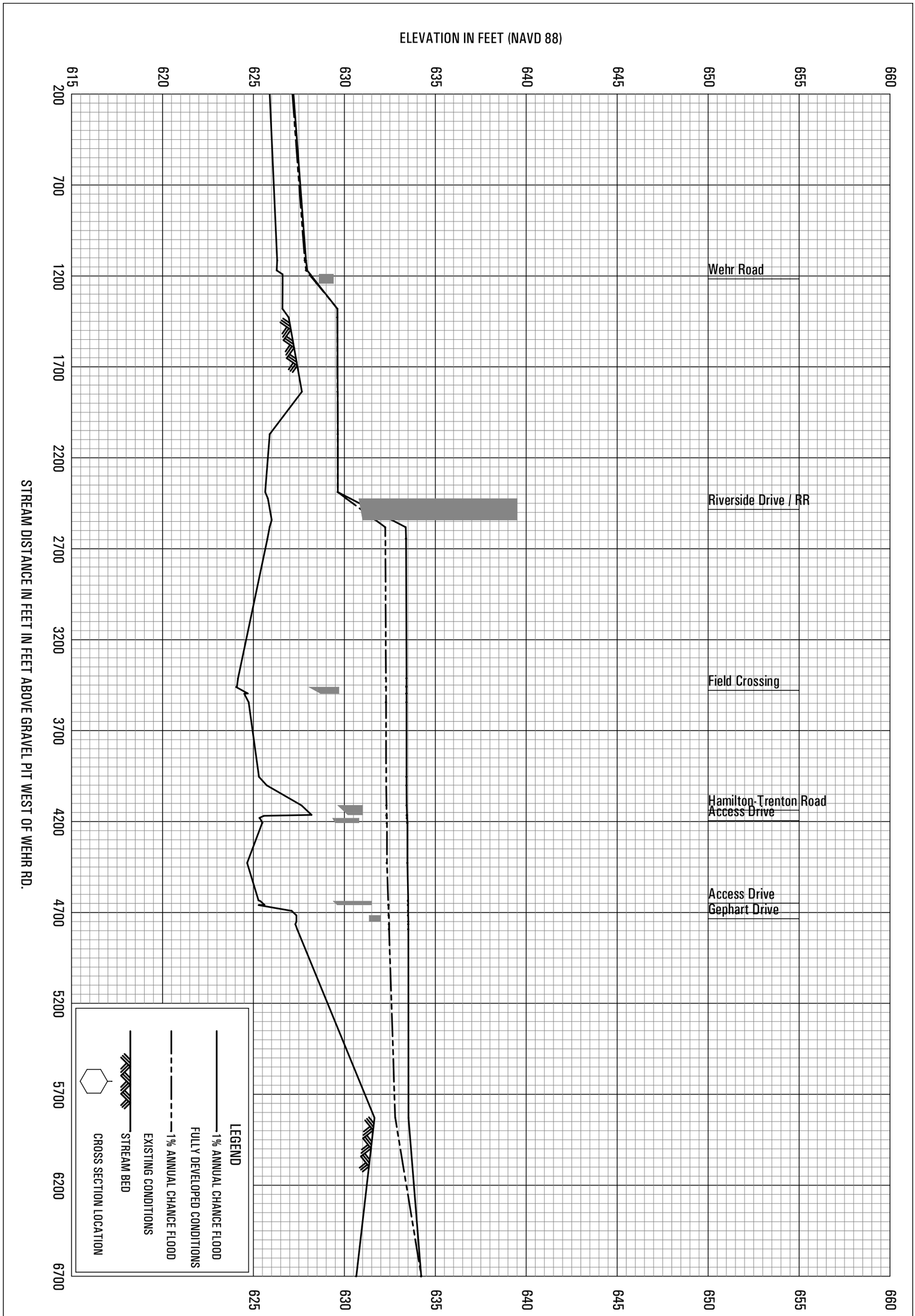
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BUTLER COUNTY, OHIO

09P

Future Development
Graphical Flood Profiles



01P

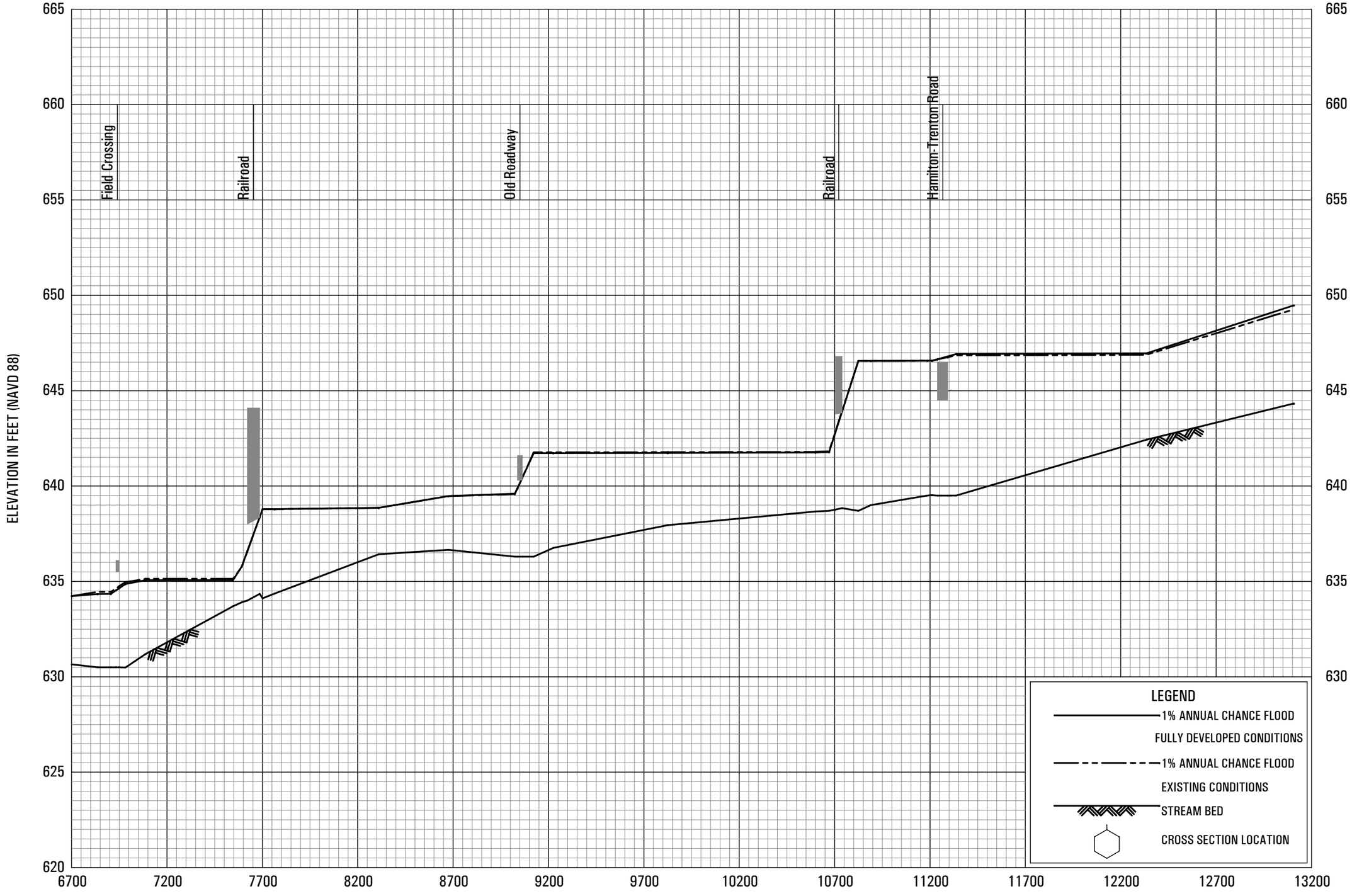
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TRENTON WATERSHED STUDY

BUTLER COUNTY, OHIO

FLOOD PROFILES - EXISTING & FULLY DEVELOPED

JACKSON DITCH - DOWNSTREAM REACH



FLOOD PROFILES - EXISTING & FULLY DEVELOPED

JACKSON DITCH - DOWNSTREAM REACH

BUTLER COUNTY ENGINEERS' OFFICE

TRENTON WATERSHED STUDY

BUTLER COUNTY, OHIO

02P

Appendix D

HSPF Model Data and Results



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Watershed Modeling Report
Appendix D HSPF Model Data and Results

Trenton Area Storm Water Management Project
Butler County, Ohio

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HSPF Water Quality Model

1. Background for Water Quality Model

The Trenton watershed is primarily a rural area that is beginning to be developed into residential and urban areas. The flat central portion of the watershed is currently cultivated with corn and soy bean fields. The high ground surrounding the watershed is generally woods and pasture with some rural residential development. The eastern portion of the watershed is the City of Trenton which contains some undeveloped areas that are currently or are expected to be developed into urban residential and commercial areas. The primary industrial area is the Miller Brewery in the southern portion of the watershed.

Generally runoff from the highlands of the watershed flows down to the central portion of the watershed. The high infiltration rates of the streambed and surrounding farmland in the central portion allows the storm runoff to percolate to the local portion of the Great Miami Aquifer. Additionally, a number of sinks and dry wells have been excavated down to the very high infiltration rate sub-soils. These sinks allow for the storage and percolation of large volumes of water to the aquifer.

The aquifer is the water source for the Southwest Regional Water District, the City of Trenton, Miller Brewing, and Cincinnati Gas and Electric. These large users are dependent of the volume and quality of the water in the aquifer. Variations in rainfall have caused large fluctuations in the aquifer water surface elevation. For the period of 1994 through 2005, the aquifer has varied 4 to 16 feet during the course of a single year with a total range of 24 feet during the entire period.

This section describes the model investigation into three concerns in the Trenton watershed due to development of rural land into residential and urban areas.

The first concern is the possible increase in flooding in the flat central portion of the watershed. This problem was investigated in other portions of this report.

The second concern is the possible change in volume of the aquifer recharge. Two aspects of aquifer recharge could be impacted by development. The first aspect is the rate of recharge for the watershed generally. Converting pervious areas to impervious areas decreases the surface area available for recharge to the aquifer. Reduced pervious area may lead to reduced aquifer recharge. The second aspect is the location of the aquifer recharge. With development, water that would have percolated locally may now flow to Jackson Ditch and percolate at other areas further downstream in the watershed. Depending on where the percolation occurs, the water may enter the aquifer downstream of the water supply wells. This change in percolation location may reduce the volume of water available from the aquifer.

The third concern is the possible degradation of water quality in the surface water and in the aquifer. The conversion of rural land to residential and urban uses impacts the water quality by changing how pollutants are added and removed from the runoff. Generally cropland runoff has higher values for nitrogen and sediment compared to other land uses. Industrial

runoff contains higher metal concentrations. Residential land has high phosphorus concentration in the runoff. The primary concern with water quality is that increased development will degrade the water quality entering the aquifer to the point the water is unsuitable as a drinking water supply without additional treatment.

2. HSPF Model Description

Hydrologic and water quality modeling was performed using the US EPA Hydrology Simulation Program – FORTRAN (HSPF) software. The HSPF software is capable of simulating the entire hydrologic cycle including rainfall, snowfall, evapotranspiration, surface and subsurface runoff, and percolation to an aquifer. During the duration of a simulation, HSPF keeps track of the water stored on the ground surface and in the soil.

The impervious and pervious areas in HSPF are modeled as depths without areas. Runoff, evaporation, etc. are reported as depth per time unit (inches per hour, etc.). Conversion to flow rates such as cubic feet per second (cfs) is through math functions. The Trenton watershed was modeled as inches per 5 minute time step. The runoff was multiplied by 300 seconds per time step and the area in square feet, and then divided by 12 inches per foot to calculate the runoff in cfs. For the impervious runoff onto the pervious area, the runoff in inches per time step was multiplied by the area of the impervious area and divided by the pervious area. This depth in inches is the runoff from the impervious area spread evenly across the entire pervious area. This methodology works well in areas where the impervious areas flow out onto the adjacent pervious areas such as roof downspouts and driveways onto yards. The urban areas in the City of Trenton have the only extensive network of storm sewers. The storm sewers carry storm water to infiltration basins or to dry wells instead of directing runoff to streams. This method of storm water management directs all storm water to the aquifer so the model methodology was deemed appropriate.

For impervious surfaces, HSPF models runoff the same way as most hydrologic models. Precipitation is first stored in interception storage (vegetation and other surfaces) and depression storage (puddles and low points). The remaining water becomes surface runoff with the flow rates determined by surface roughness, surface slope and the length of the slope to the stream. HSPF is different from other models in adjusting available storage by evaporating water as time passes. For the Trenton watershed model, impervious area runoff is evenly distributed onto the surface of the adjoining pervious area.

For pervious surfaces, HSPF includes subsurface storage in modeling surface runoff. Water is stored in interflow storage (horizontal flow through upper soil layers), upper storage, lower storage, and active groundwater (baseflow) layers. As these layers approach capacity, the infiltration rates are reduced, which increases surface runoff from the sub-basin. The model allows water to flow to the stream from the surface, the interflow layer and from the active groundwater. Below these storage layers is the aquifer which is assumed to have infinite capacity to absorb water and is too deep for water to flow to streams or evapotranspire.

A third modeling feature of HSPF used in the Trenton watershed model is the reach reservoir (RCHRES). RCHRES is a simple stream model that is a storage volume with one or more outflows. The outflows may be time series or flow curves based on the storage volume (or

depth) in the stream. While capable of use in a variety of ways, RCHRES was used for two purposes in the Trenton model. The first is as a storage area to attenuate the flow hydrograph by storing runoff and limiting the outflow rate. The second is as a method to simulate the sinks used to infiltrate storm water. Based on soil characteristics and available infiltration area, a fixed outflow curve is used to remove water from the storage in the RCHRES. If the inflow exceeds the available storage in the RCHRES, a second outflow curve was developed to model the flow out of the sink onto the surrounding land surface.

3. HSPF Model Development

3.1. Historical Data

Climatic data for the model was downloaded from the National Oceanic and Atmospheric Administration (NOAA) National Climatic Data Center (NCDC) website and from the Ohio State University (OSU) Agricultural Research and Development Center website. The data from the NCDC were hourly precipitation, temperature and dew point at Butler County Regional Airport, Hamilton Ohio, and Dayton Wright Brothers Airport, Montgomery County Ohio. The primary site was Butler County Airport with missing data filled in using Dayton Wright Brothers Airport and interpolated points. The OSU data were used to calculate potential evapotranspiration using the methodology described in ASCE-EWRI Task Committee Report, January, 2005. Hourly data at Miami University, Oxford Ohio, for the evapotranspiration calculation included temperature, observed solar radiation, humidity and wind movement. The evapotranspiration data were calculated since measured data were from distant sites, contained a number of missing data points, and were only available as daily totals.

The small size of the watershed produced short times of concentration. The hourly climatic data was interpolated into 5 minute increments. Air temperature and dew point were linearly interpolated between the hourly observations. Precipitation and evapotranspiration values were divided into 12 equal 5 minute increments.

For the climatic base of the HSPF model, the calendar year 2004 was selected. Of the past seven years (1998 to 2004 inclusive), 2004 had the annual rainfall closest to regional normal rainfall as shown in Tables 3.1 and 3.2 and Figure 3.1. Additionally the calculated evapotranspiration was close to the pan evaporation from the Hydrologic Atlas for Ohio as shown in Table 3.3. The Atlas reports pan evaporation which is roughly converted to evapotranspiration by a factor of 0.7. A third factor for choosing 2004 was the reported flooding on January 4, 2004. The ability to recreate high flows during that time period would indicate that the HSPF hydrology reflected observed events. The time period modeled was from November 1, 2003 through December 31, 2004. The initial two months were intended to allow the model to adjust soil water storage values to appropriate levels for the observed conditions. The twelve months of calendar year 2004 were then used for the comparisons between existing and fully developed conditions. The model was run several times to check the final soil water storage values at the end of the simulation. The initial values were adjusted until the final values were approximately constant for subsequent runs.

Table 3.1 Historical Annual Rainfall	
Time Period	**Annual Rainfall (inches)**
NOAA Ohio Region 8 Southwest 1931-2000 Average	40.76
1971-2000 Average	42.25
Observed Rainfall	
2004	40.33
2003	45.47
2002	45.68
2001	44.37
2000	35.00
1999	23.85
1998	33.00

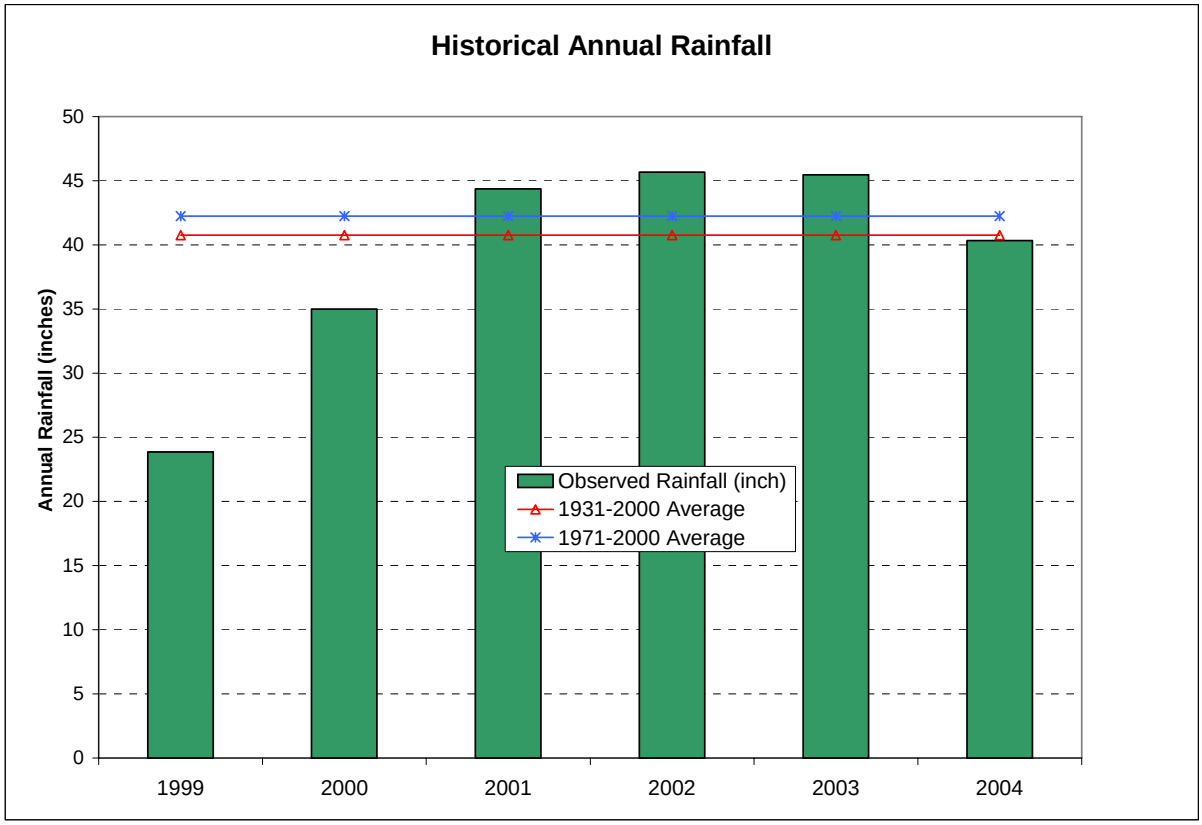


Figure 3.1 Historical Annual Rainfall

Table 3.2 2004 Monthly Rainfall					
Month	Hamilton Observed Rain (inch)	NOAA Average (1931-2000) (inch)	Observed Percent of Normal	NOAA Average (1971-2000) (inch)	Observed Percent of Normal
January	5.10	3.10	165%	2.83	180%
February	1.29	2.65	49%	2.60	50%
March	3.12	3.84	81%	3.58	87%
April	4.68	3.92	119%	4.00	117%
May	4.65	4.28	109%	4.74	98%
June	3.15	4.02	78%	4.20	75%
July	5.51	4.00	138%	4.09	135%
August	2.40	3.41	70%	3.76	64%
September	0.55	2.95	19%	2.94	19%
October	3.60	2.52	143%	2.90	124%
November	4.14	3.14	132%	3.42	121%
December	2.14	2.93	73%	3.19	67%
Annual	40.33	40.76	101%	42.25	95%

Table 3.3 2004 Monthly Evaporation				
Month	Dayton Pan Evaporation 1937 -1969 (inch)	Dayton Pan Evaporation * 0.7 (inch)	2004 Calculated Potential Evaporation (inch)	2004 Calculated as Percent of 0.7 Dayton
April	4.04	2.83	3.05	108%
May	5.65	3.96	3.96	100%
June	6.77	4.74	4.72	100%
July	7.06	4.94	4.43	90%
August	6.20	4.34	4.15	96%
September	4.63	3.24	3.43	106%
October	2.86	2.00	1.99	99%
Total		26.05	25.71	99%

The Trenton watershed was divided into 7 basins for comparing different land use conditions as shown in Figure 3.2. The basins were further subdivided into 53 sub-basins as shown in Figure 3.3 based on topography, soil type, land use, and drainage patterns. The sub-basins were used to develop parameters for modeling small, reasonably homogeneous areas. Sub-basin properties included area, flow surface slope, and flow surface length.

Soil mapping and data reports were downloaded from the US Department of Agriculture, Natural Resources Conservation Service, Soil Data Mart website. The mapping is from the 1980 Butler County soil survey. Forty-seven soils were found within the Trenton watershed

as shown in Figure 3.4. Soil properties included infiltration rates, soil moisture storage capacities, and parameters for percolation to aquifers. Generally the soils on the slopes to the north, west and south of the watershed were clay soils with shallow bedrock. These soils and slopes have high runoff rates. The flatter areas in the east and central portions of the watershed have loamy soils. These areas have high to very high infiltration rates to the Great Miami Aquifer. Figure 3.5 highlights the area of very high infiltration rates for aquifer recharge. One change in the watershed since the soil mapping was completed was the construction of the Miller Brewery. The area of what is now the brewery and the Miller Sink was farmland. The surface soil properties for these two areas were kept in the soil mapping given the lack of alternative data sources.

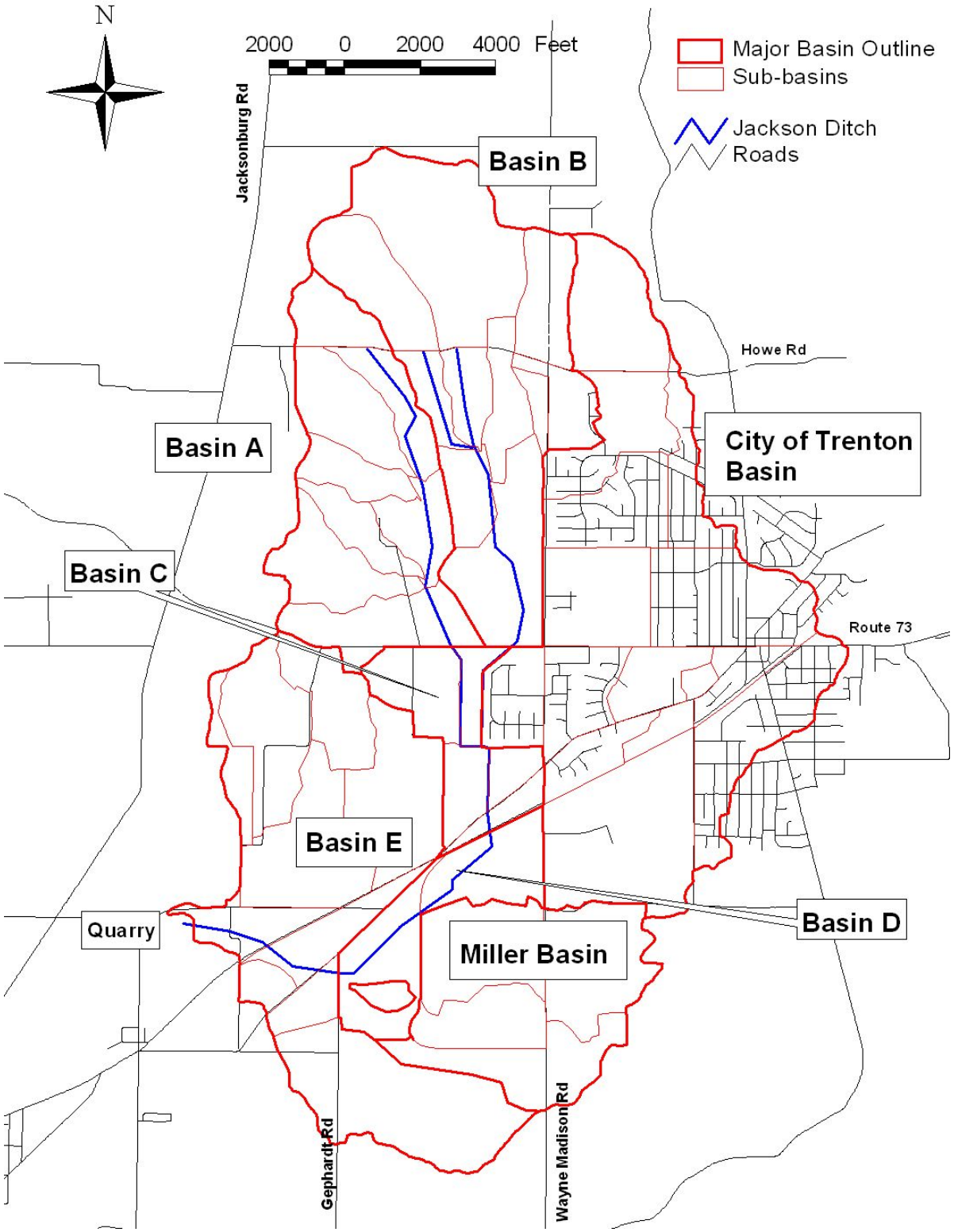


Figure 3.2 HSPF Watershed Basins

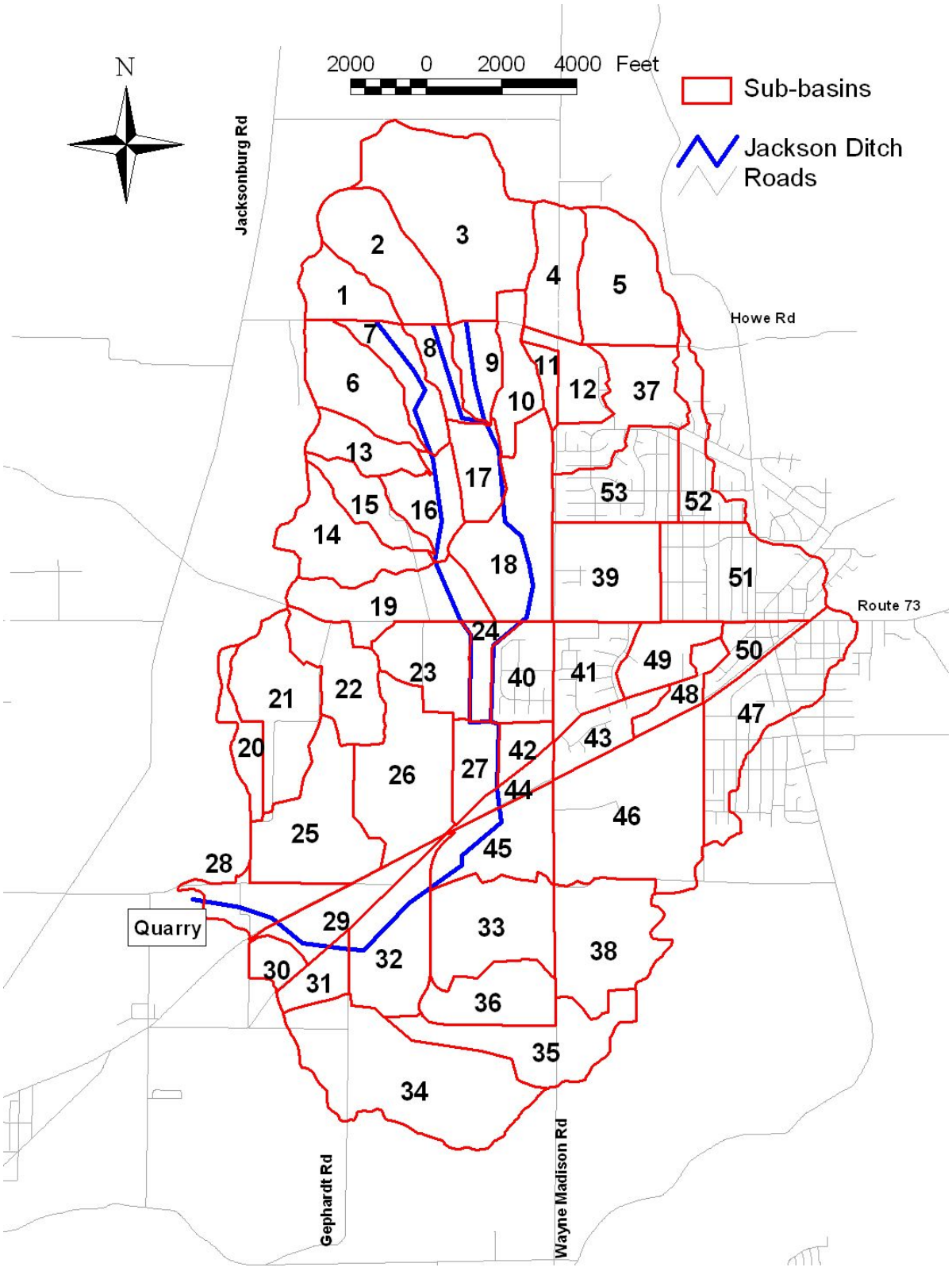


Figure 3.3 HSPF Sub-basins

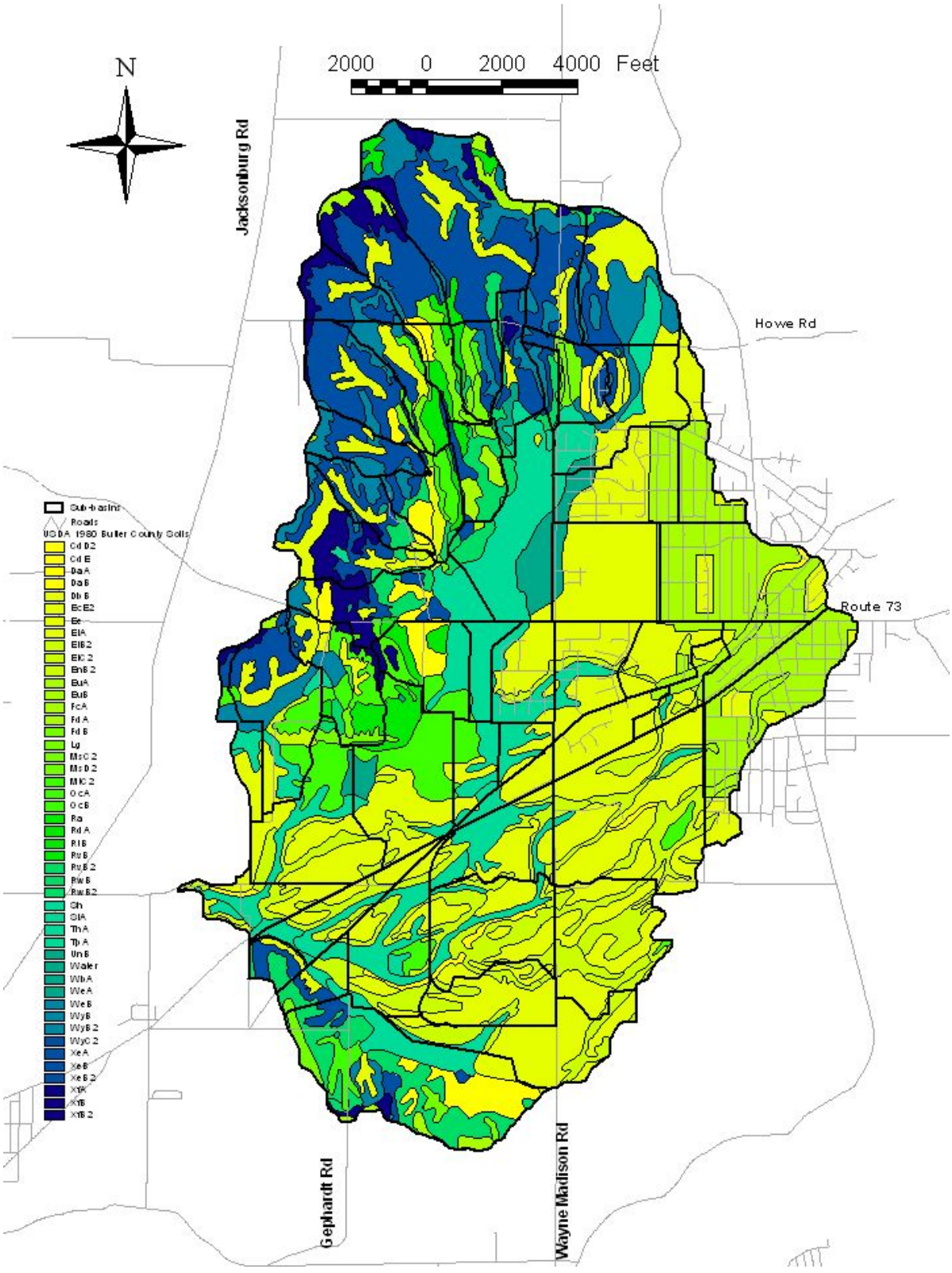


Figure 3.4 Soil Mapping

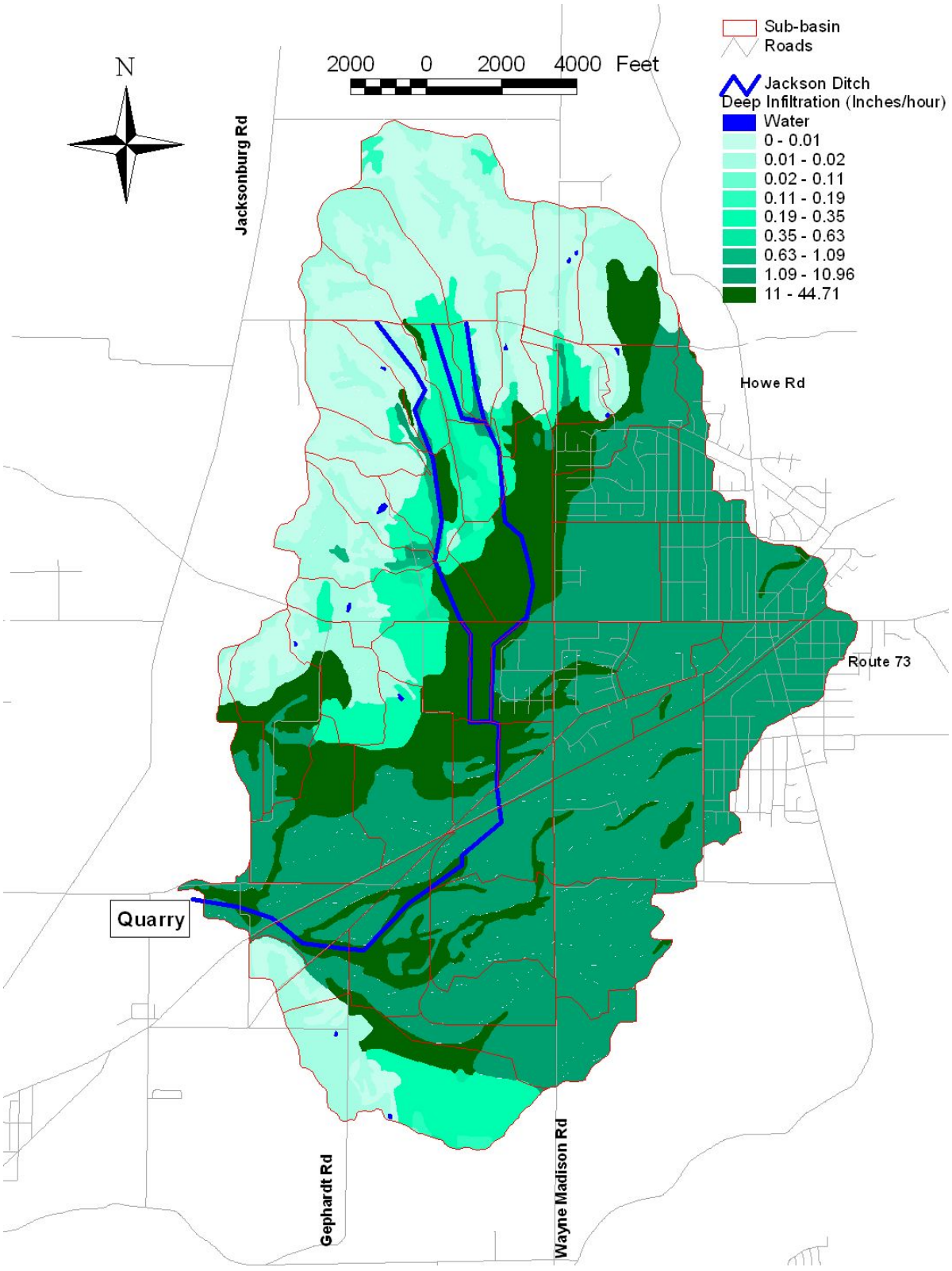


Figure 3.5 Infiltration Rates to Aquifer

The land use for the watershed was developed based on consultation with various local agencies, air photos, and site visits. Seven land use categories were selected: Commercial/Industrial, Cropland, Pasture, Rural Development, Sink, Urban Development, and Woods. Land use properties included percent impervious area, surface roughness, interception storage, and soil evaporation parameters. Values for these parameters are shown in Table 3.4.

Table 3.4 Runoff Parameters by Land Use

Land Use	% Impervious	Surface Roughness	% Coniferous Forest	Interception Storage
Commercial / Industrial	95	0.05	0	0.1
Cropland	0	0.30	0	0.3
Pasture	0	0.40	0	0.3
Rural Development	25	0.20	0	0.2
Sink	0	0.01	0	0
Urban Development	50	0.15	0	0.1
Woods	0	0.40	10	0.5

Sub-basin, soil, and land use mapping were overlaid to produce 1,716 unique combination areas. The properties for the combinations were aggregated into the 53 sub-basins using area weighting.

The combined properties were used to create a model of the watershed. Impervious areas in each sub-basin were modeled as flowing evenly onto the pervious area for each sub-basin.

3.2. Infiltration Sink Modeling

The 53 HSPF sub-basins can be grouped in three broad categories based on the destination of surface runoff.

The first category is the 27 sub-basins which flow directly into some segment of Jackson Ditch. For these sub-basins, the outflow consists of the surface, interflow, and active groundwater flows.

The second category is the sub-basins of the City of Trenton which are assumed to flow entirely to dry wells and infiltration basins. All precipitation that falls on these 14 sub-basins and does not evaporate is assumed to infiltrate to the aquifer. Sub-basin 5 is outside the City of Trenton but flows into the drainage system within the city, and is considered to be part of the City of Trenton basin.

The third category is the sub-basins that are not directly tributary to Jackson Ditch. The category contains three groups of sub-basins; the Route 73 Sink group, the Miller Sink group, and the Riner and Streit Sinks group. These groups are highlighted in Figure 3.6.

The Route 73 Sink group is the three sub-basins 4, 11, and 12 along Wayne Madison Road north of the City of Trenton. These sub-basins flow into a ditch along Wayne Madison Road to Route 73. This ditch is a wide, flat bottomed channel designed to store storm water and allow infiltration. The surface, interflow, and active groundwater outflows from these three sub-basins are routed through two reservoir reaches to attenuate flows and allow infiltration before entering Jackson Ditch.

The Miller Sink group is the four sub-basins 33, 35, 36, and 38 which flow into the Miller Sink before flowing to Jackson Ditch. Sub-basin 38 surface flows pass through a culvert under Wayne Madison Road and are distributed onto sub-basin 33. Sub-basins 33, 35 and 36 surface and interflow outflows flow into the Miller Sink. The active groundwater for these sub-basins and the interflow for sub-basin 38 are assumed to flow to the aquifer.

The six sub-basins 20, 21, 22, 25, 26 and 28 of the Riner and Streit Sinks group flow across farmland before entering Jackson Ditch as shown in Figure 3.7. Sub-basins 21 and 22 discharge through ditches into the Streit Sink and the Riner Sink (named for land owners), respectively. The Riner Sink overflows onto sub-basin 26. Runoff from the Streit Sink, and sub-basins 20 and 26 flows onto sub-basin 25. Runoff from sub-basin 25 flows onto sub-basin 28. From sub-basin 28, water flows into the Jackson Ditch near the quarry. For these sub-basins, surface and interflow outflow are distributed onto the downstream sub-basin. Active groundwater flows are assumed to flow to the aquifer.

These sinks are modeled as reservoir reaches with two outflows. The first outflow is estimated infiltration to the aquifer. The second outflow is overflow from the reservoir onto the downstream sub-basin.

The infiltration capacity for each sink was estimated based on soil type and surface area. The soil survey data includes a table of estimated soil properties including a range of saturated soil permeability. The sinks were assumed to be excavated down to the lowest layer of the soil with some restriction on the infiltration rate due to vegetation, settled fine material and surface compaction. The estimated infiltration rate was assumed to be one-quarter of the low end of the estimated rate. The infiltration from the sinks was assumed to enter a deep layer of highly permeable soil so all water infiltrating at the sinks entered the aquifer. The area for infiltration was estimated based on the area of the sink overlying soils with high infiltration rates. The peak infiltration rates are shown in Table 3.5

Table 3.5 Estimated Sink Infiltration Rate	
Sink	Infiltration Rate (cubic feet per second)
Miller Sink	50
Riner Sink	21
Route 73 Sink	9
Streit Sink	4

The dry wells and infiltration basins for the City of Trenton include storage for the runoff awaiting infiltration. As these storages would not have overflowed during the moderate storms of 2004, and all the water would have infiltrated regardless of the infiltration rate, the infiltration rates for the City of Trenton were not estimated.

3.3. Jackson Ditch Modeling

Miller Sink was partially incorporated into the flow analysis of Jackson Ditch as follows. During periods of low flow, water in Jackson Ditch flows into Miller Sink and infiltrates along with water from the Miller basin. During periods of higher flow, the combined flows from Jackson Ditch and the Miller basin exceed the infiltration capacity. Flows in excess of the Miller Sink capacity pass under Gephardt Road and further down Jackson Ditch toward the former quarry.

The HSPF model developed for the Trenton watershed does not include stream hydraulics modeling. HSPF RCHRES modeling is intended for water quality modeling and depends on the development of outflow curves by other methods. Additionally, RCHRES would not properly handle the backwater conditions in the flat central part of the Trenton watershed. Examination of the flows in Jackson Ditch was done with simple summation of inflows which does not account for storage, routing times, or attenuation of the flood wave.

Examination of flows in Jackson Ditch is this section of the report is intended to highlight changes in aquifer recharge and water quality. Flows in Jackson Ditch in this section of the report do not account for attenuation and storage effects of the channel. For a discussion of flows and water surface elevations, refer to other sections of this report.

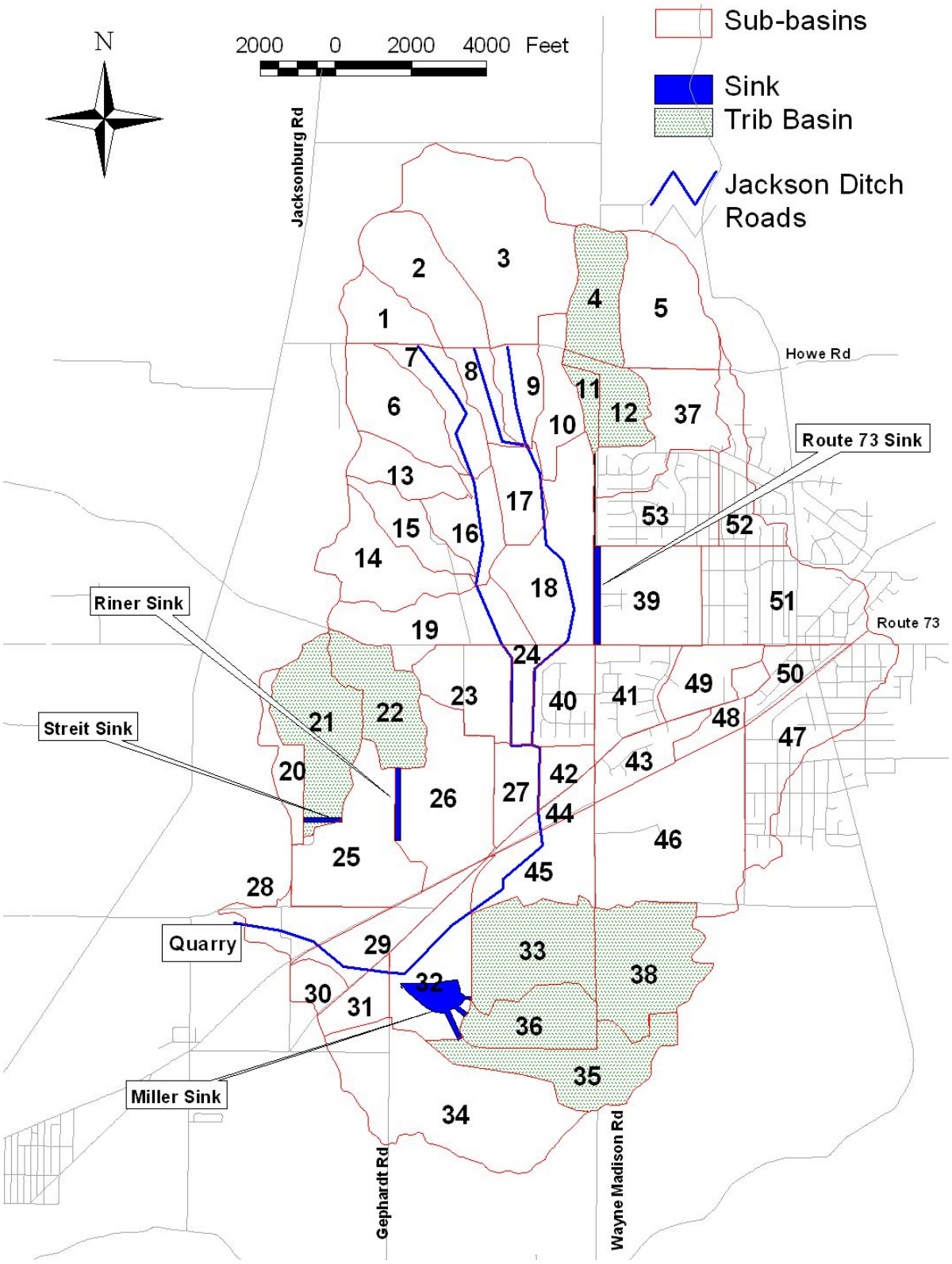


Figure 3.6 Infiltration Sinks

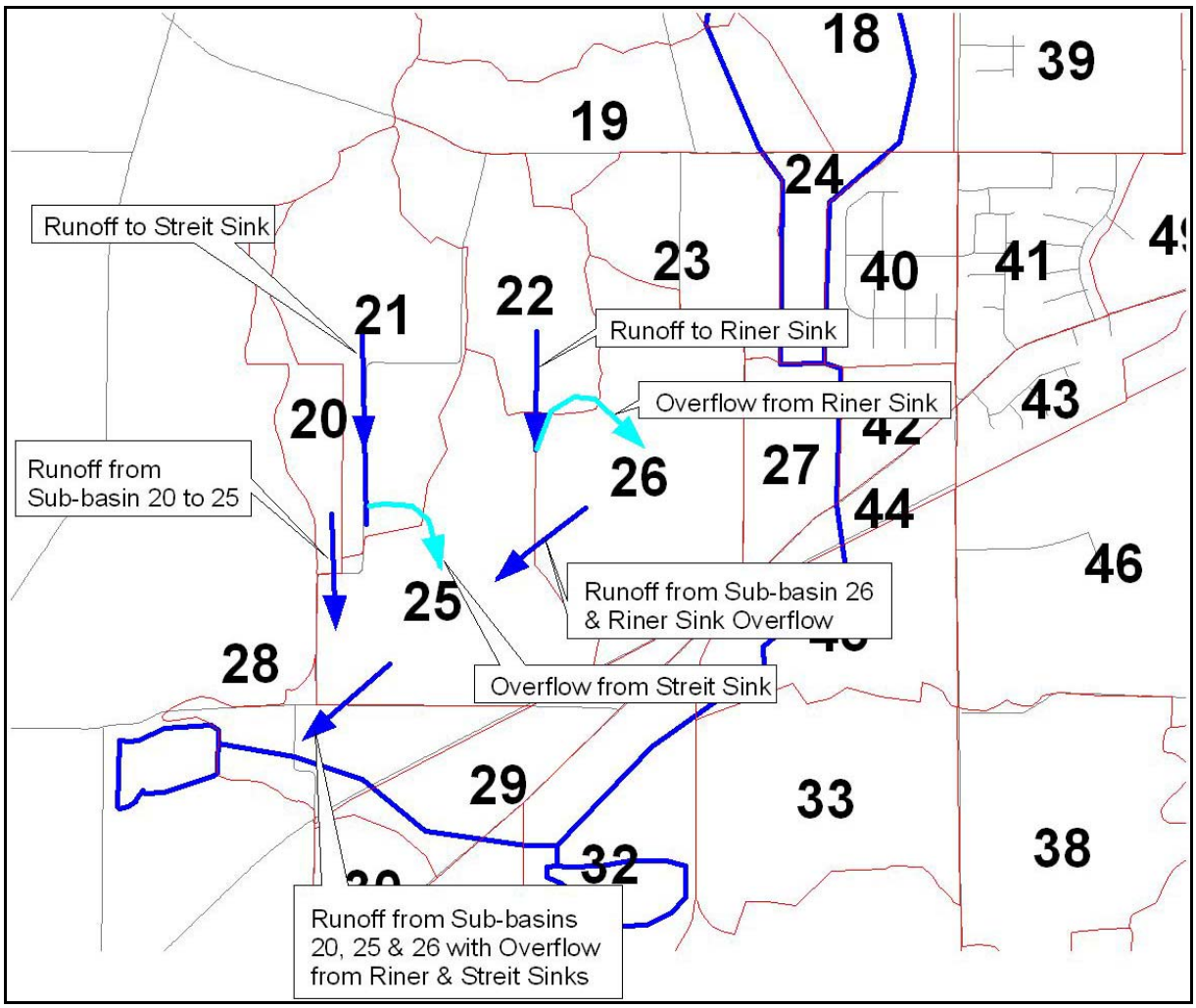


Figure 3.7 Flow Pattern for Riner and Streit Sink Group

3.4. Best Management Practices

Best Management Practices (BMPs) are methods found by experience and experiment to be the most effective and practical for coping with problems. Some BMPs are retention structures such as a constructed wetland. Some are design guidelines such as reducing runoff by requiring downspouts discharge to lawns instead of connecting to storm sewers. Others are management operations such as scheduling street sweeping to remove sediment and debris before they enter the storm water system.

An individual BMP is limited in its impacts and effectiveness. A BMP is typically selected to perform specific functions within a particular situation. For example, a grassed swale for reducing sediment and nutrient discharge will allow only limited infiltration to groundwater because the required sod has low infiltration rates.

Two basic water quality BMP structures are the buffer strip and the grassed swale. A buffer strip is a section of vegetation, usually grass, between an impervious area and a stream or

other water conveyance. A grassed swale is a wide grassed channel with gentle slopes both along and across the flow path. Both of these structures are intended to slow the velocity of runoff which in turn allows the sediment and nutrients to settle out and be absorbed within the grass and soil. For the grassed swale, the lower velocities allow for some storage of storm water for later discharge or infiltration. A ditch, in contrast, is designed to move storm water to streams as quickly as possible. Storage, infiltration, and sediment and nutrient removal are very limited in a ditch due to relatively high velocities and lack of dense vegetation.

3.5. Future Land Use Models

The No-BMP and With-BMP conditions models were developed the same way as the Existing conditions model using presumed future land use development. The land use was suggested by planning efforts of local agencies but is generally more urbanized in an effort to capture the worst case scenario. Table 3.6 and Figure 3.8 show the total areas for each land use for current and future conditions.

The No-BMP conditions assume that the Urban Development areas outside the City of Trenton basin have storm sewers discharging directly to Jackson Ditch (sub-basins 14, 16, 17, 18, 19, 23, 24, 27, 42, and 44). The sewered sub-basins are highlighted in Figure 3.9. Some runoff from these sub-basins was considered as having entered storm sewers or ditches leading directly to Jackson Ditch. This water would reached Jackson Ditch faster and without the opportunity to infiltrate to the soil or have pollutant loading reduced while flowing across pervious areas when compared to the Existing conditions. One-fourth of the Urban Development area was assigned as impervious surface flowing to Jackson Ditch. One fourth of the area is impervious surface flowing to the pervious half of the Urban Development.

With-BMP conditions assume that the Urban Development areas are using various BMPs by directing all impervious runoff to the pervious areas. The With-BMP conditions do not assume the maximum use of all possible BMPs. The BMPs envisioned as part of this effort include grassed swales and ditches to allow some infiltration and pollutant reduction. The effects of more intensive BMPs such as bioretention areas, infiltration basins, and grit chambers were not estimated at this time. With additional effort, the effects of more intensive BMPs could be examined for their impacts on Jackson Ditch flows, percolation and overall water quality.

Table 3.6 Changes in Land Use Areas					
Land Use	Existing Land Use (acre)	Percent of Watershed	No-BMP With-BMP (acre)	Percent of Watershed	Percent change with time
Commercial / Industrial	291	4.4%	1,110	17.0%	281.4%
Cropland	2,632	40.3	649	9.9	-75.3
Pasture	1,142	17.5	550	8.4	-51.8
Rural Development	475	7.3	750	11.5	57.9
Sink	23	0.3	23	0.3	0.0
Urban Development	953	14.6	2,871	43.9	201.3
Woods	1,018	15.6	580	8.9	-43.0
Undeveloped Land	4,815	73.7	1,801	27.6	-62.6
Developed Land	1,719	26.3	4,732	72.4	175.3
Road (subset of above)	148	2.3	436	6.7	194.6

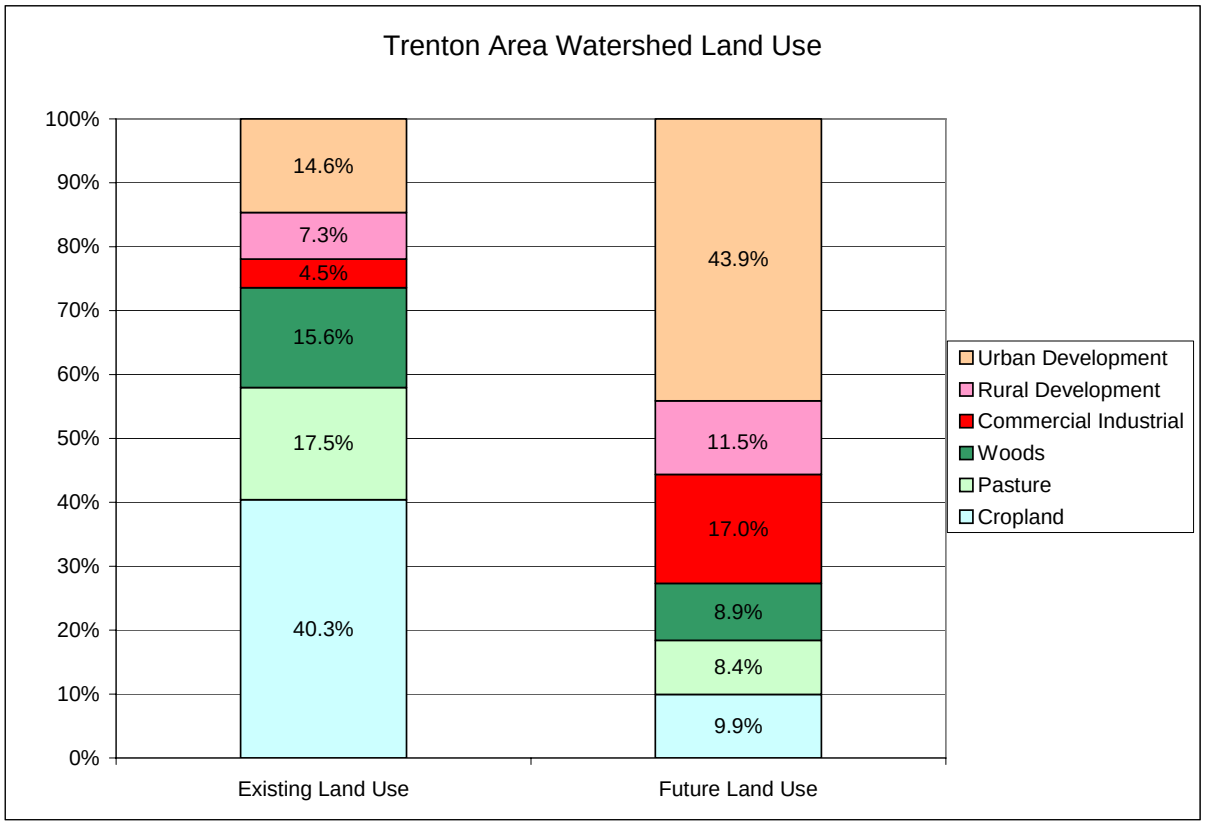


Figure 3.8 Land Use Distribution

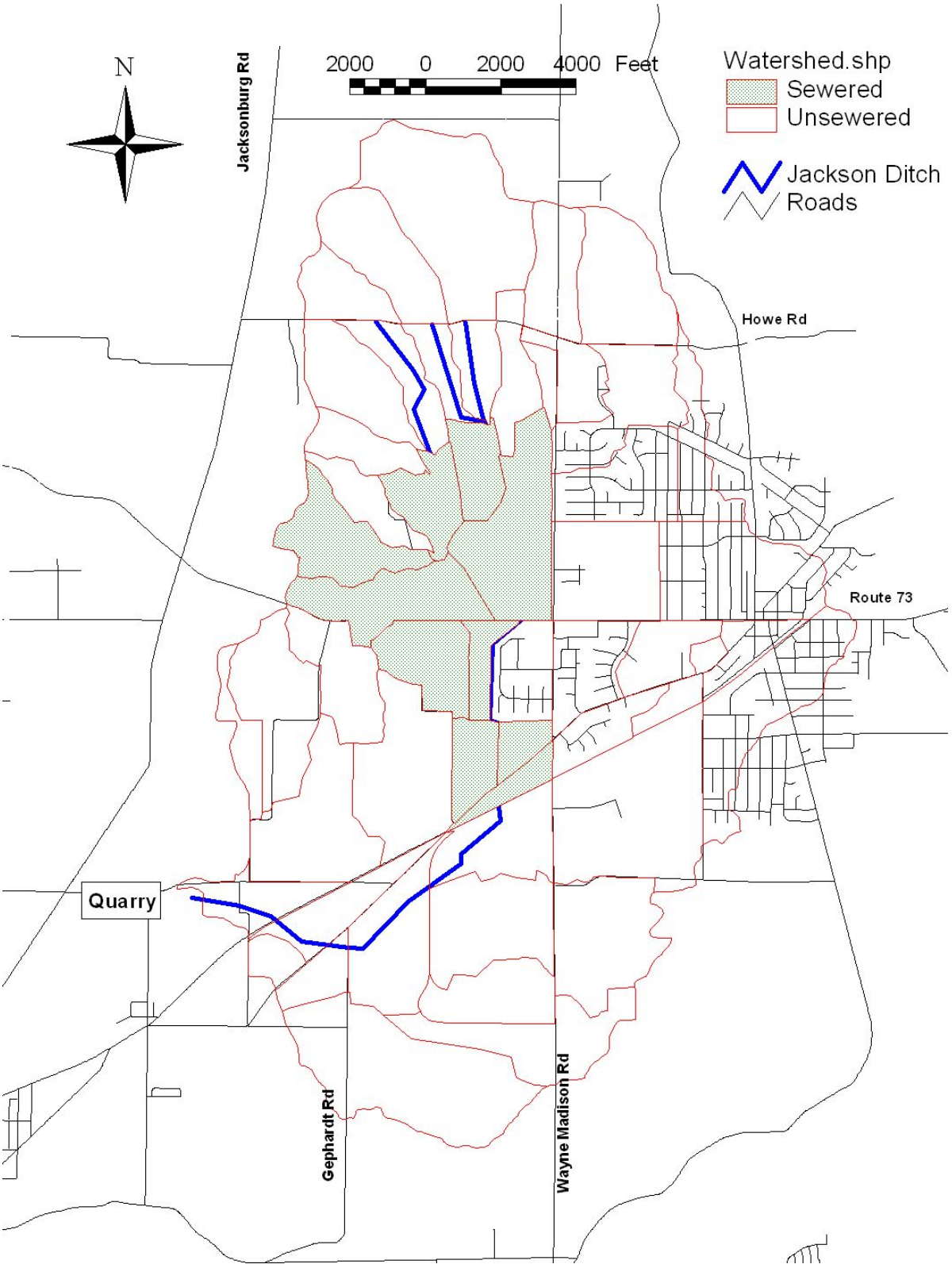


Figure 3.9 Sub-basins With Storm Sewers to Jackson Ditch

4. HSPF Hydrology Results

In the discussions of the hydrology results, only two destinations are assumed to exist in the Trenton Watershed, evapotranspiration to the atmosphere and percolation to the aquifer. Surface runoff within the watershed flows directly to sinks or into Jackson Ditch. Water flowing into Jackson Ditch may percolate to the aquifer through the streambed, through Miller Sink, or at the former quarry. No surface runoff flows out of the Trenton watershed.

The HSPF models were run using the 2004 observed meteorological data. Table 4.1 summarizes the distribution of the water entering the watershed. The total evapotranspiration in this table is less than in Table 3.3 because the runoff from impervious areas flows to Jackson Ditch or is infiltrated on the pervious areas instead of being available for evapotranspiration. In Table 4.1, the row heading Change in the Soil Water is the change in the soil water storage that will vary from year-to-year depending on the amount and timing of rainfall and evapotranspiration.

Based on a review of groundwater studies in the area, the aquifer flows to the Great Miami River southeast from the City of Trenton and west from the quarry. These reports do not discuss the size of the flows. Based on available data and from observed water level data from 2003, the flow southeast from the City of Trenton was very roughly estimated at 1 cfs and the flow west from the quarry at 5 cfs. The annual groundwater flow at these rates would be 31,500,000 ft^3 and 158,000,000 ft^3 respectively. The annual depth over the watershed would be 1.33 inches and 6.65 inches respectively. The combined volume of groundwater flow leaving the watershed is close to half the combined groundwater recharge and percolation of Jackson Ditch flows currently entering the aquifer.

Table 4.1 summarizes the annual water budget for the Existing, No-BMP, and With-BMP conditions modeling for 2004. The No-BMP and With-BMP conditions increased impervious area and reduced the evaporation compared to the Existing conditions. For the With-BMP conditions, the increased runoff from impervious areas allowed more water to percolate into the groundwater based on the assumption that impervious areas discharge to the pervious areas rather than Jackson Ditch.

For the No-BMP and With-BMP conditions, the increased impervious runoff to pervious areas caused the pervious soils to become saturated more often, causing increased volume of runoff to Jackson Ditch.

Under the Groundwater Recharge heading, City of Trenton Runoff and Sink Infiltration (specifically the Route 73 Sink) both increased significantly due to development within the City of Trenton. The future conditions land use assumes that undeveloped and less developed areas within the city are urbanized. The increase in impervious areas and decrease in vegetation cause increased flows to the various sinks and dry wells in the city, leading to 20% more groundwater recharge within the city limits.

Runoff, percolation, and contaminant loadings by sub-basin are tabulated and mapped in Appendix D-1.

Table 4.1 2004 Annual Water Budget									
	2004 Volume (1,000,000 ft3)			2004 Depth Over Watershed (Inch)			Change From Existing		Change
Description	Existing	No-BMP	With-BMP	Existing	No-BMP	With-BMP	No-BMP	With-BMP	From No-BMP
Inflows									
Total Precipitation	956.4	956.4	956.4	40.33	40.33	40.33	0%	0%	0%
Change in Soil Water	3.0	7.4	7.7	0.15	0.36	0.36	145%	154%	3%
Outflows									
Evapotranspiration	559.7	422.3	432.3	23.60	17.81	18.23	-25%	-23%	2%
Runoff to Jackson Ditch	116.1	214.1	210.8	4.90	9.03	8.89	84%	82%	-2%
Groundwater Recharge	286.0	337.2	339.8	12.06	14.22	14.33	35%	36%	1%
Pervious Infiltration	206.5	189.3	192.2	8.71	7.98	8.10	-8%	-7%	1%
City of Trenton Runoff	67.0	126.2	126.2	2.82	5.32	5.32	89%	88%	0%
Sink Infiltration	12.6	21.7	21.5	0.53	0.91	0.91	72%	71%	-1%

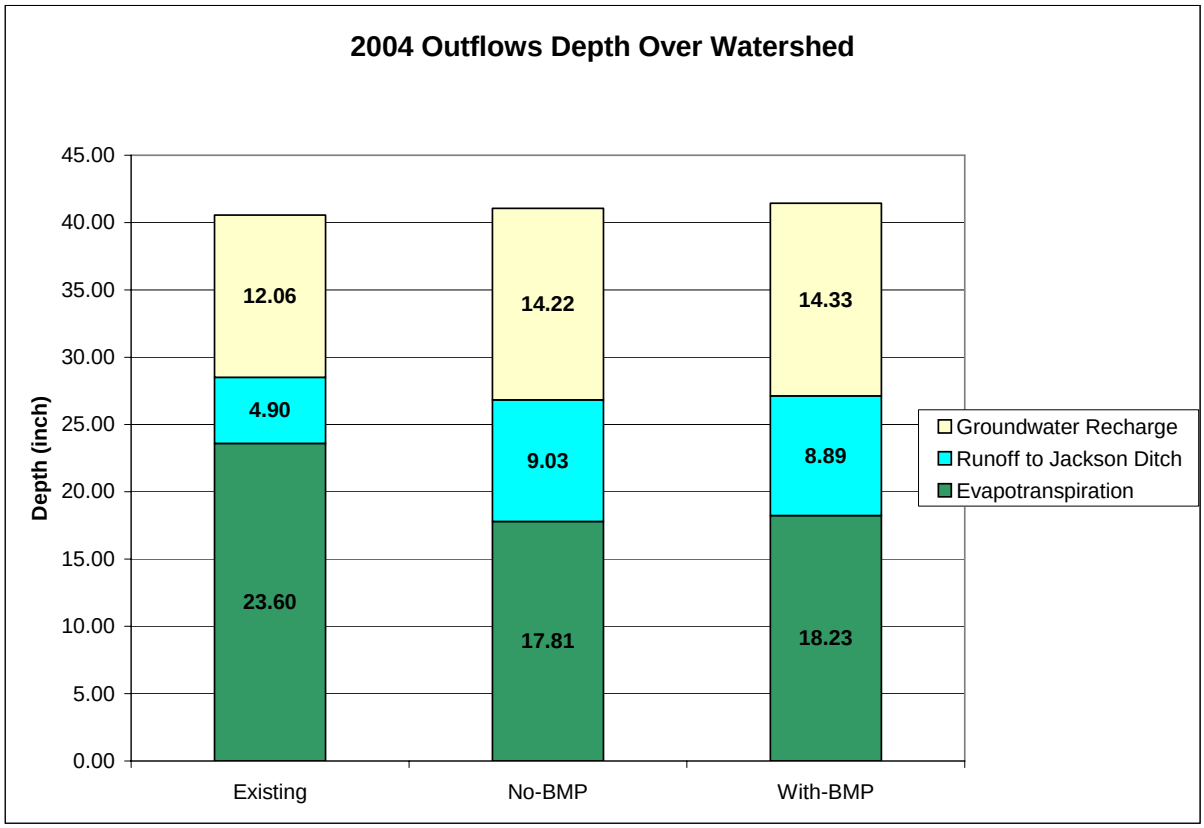


Figure 4.1 Outflow Depth Over Watershed

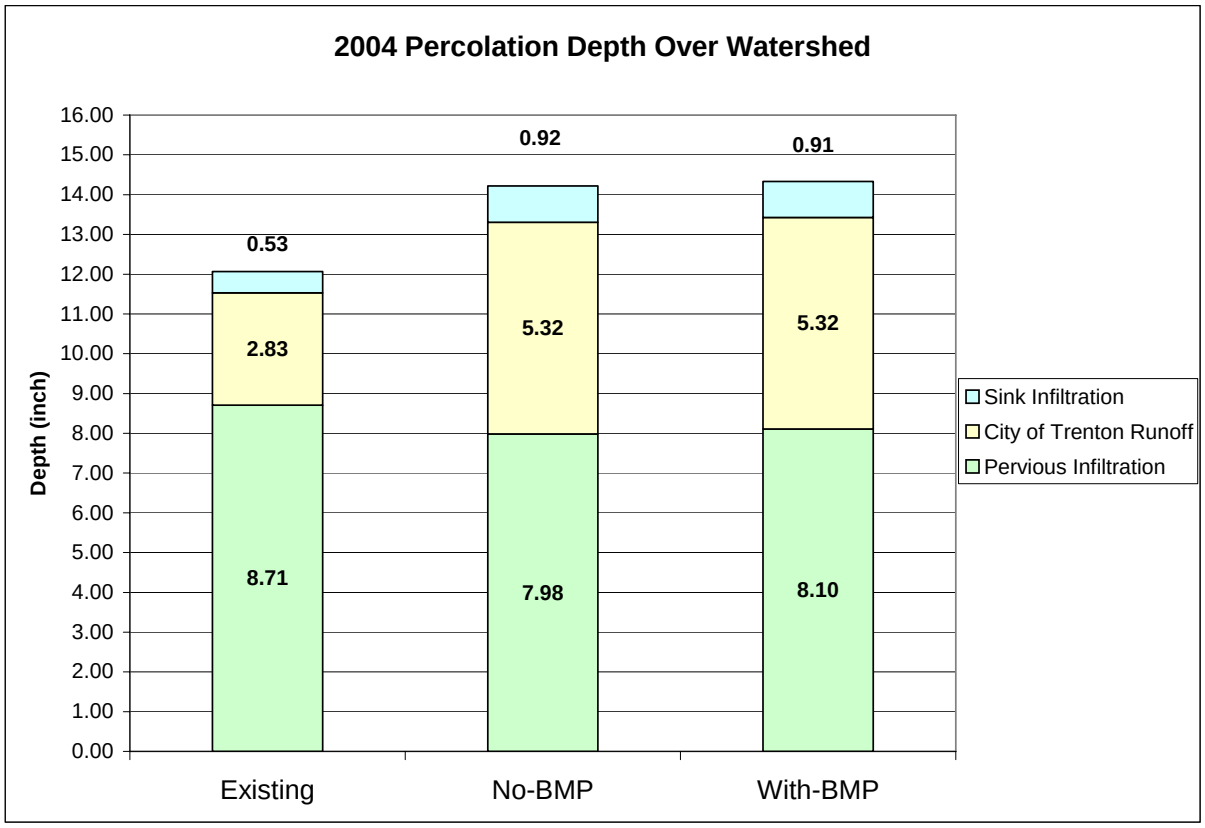


Figure 4.2 Groundwater Recharge Depth Over Watershed

4.1. Runoff to Jackson Ditch

The increased impervious area for the future land use leads to increased runoff. For the area of Trenton Watershed outside of the City of Trenton, this increased volume of runoff means increased volume of flow in Jackson Ditch.

Table 4.2 lists flows to Jackson Ditch for basins shown in Figure 4.3. Since HSPF RCHRES modeling of streams is unable to properly model the flat slopes and backwater conditions of Jackson Ditch, a simple summation of flows was used to examine flows to the stream.

Hourly average flows to Jackson Ditch were summed without routing or storage effects to examine the flow to Miller Sink from the basins upstream of Gephardt Road (basins A, B, C, D, and Miller). Flows up to the 50 cfs infiltration capacity of Miller Sink were subtracted from the total flow. The remaining flow was assumed to flow downstream past Gephardt Road. This remaining flow with the addition of runoff from Basin E is the estimated flow in Jackson Ditch towards the former quarry. The flow from Jackson Ditch overland to the quarry was beyond the ability of the summation process and was not modeled.

Table 4.2 Annual Flow to Jackson Ditch						
Basin	Existing (1,000,000 ft3)	No-BMP (1,000,000 ft3)	% Change	With-BMP (1,000,000 ft3)	% Change	% BMP Reduction
A	34.8	46.0	32%	45.1	30%	2%
B	36.7	53.4	46	51.9	41	3
C	7.7	20.6	166	19.7	155	4
D	3.7	4.3	17	4.3	17	0
Miller	14.9	57.7	286	57.7	286	0
E	18.3	32.0	75	32.0	75	0
A+B+C	79.2	120.0	52	116.7	47	3
A+B+C+D +Miller	97.8	182.0	86	178.7	83	2
All	116.1	214.0	84	210.7	82	2
Miller Sink Infiltration	96.8	154.7	60	158.6	64	-3
Flow Past Gephardt Road	0.9	27.0	3,027	19.2	2,124	29
Between Gephardt & Quarry	19.1	59.0	209	51.2	168	13

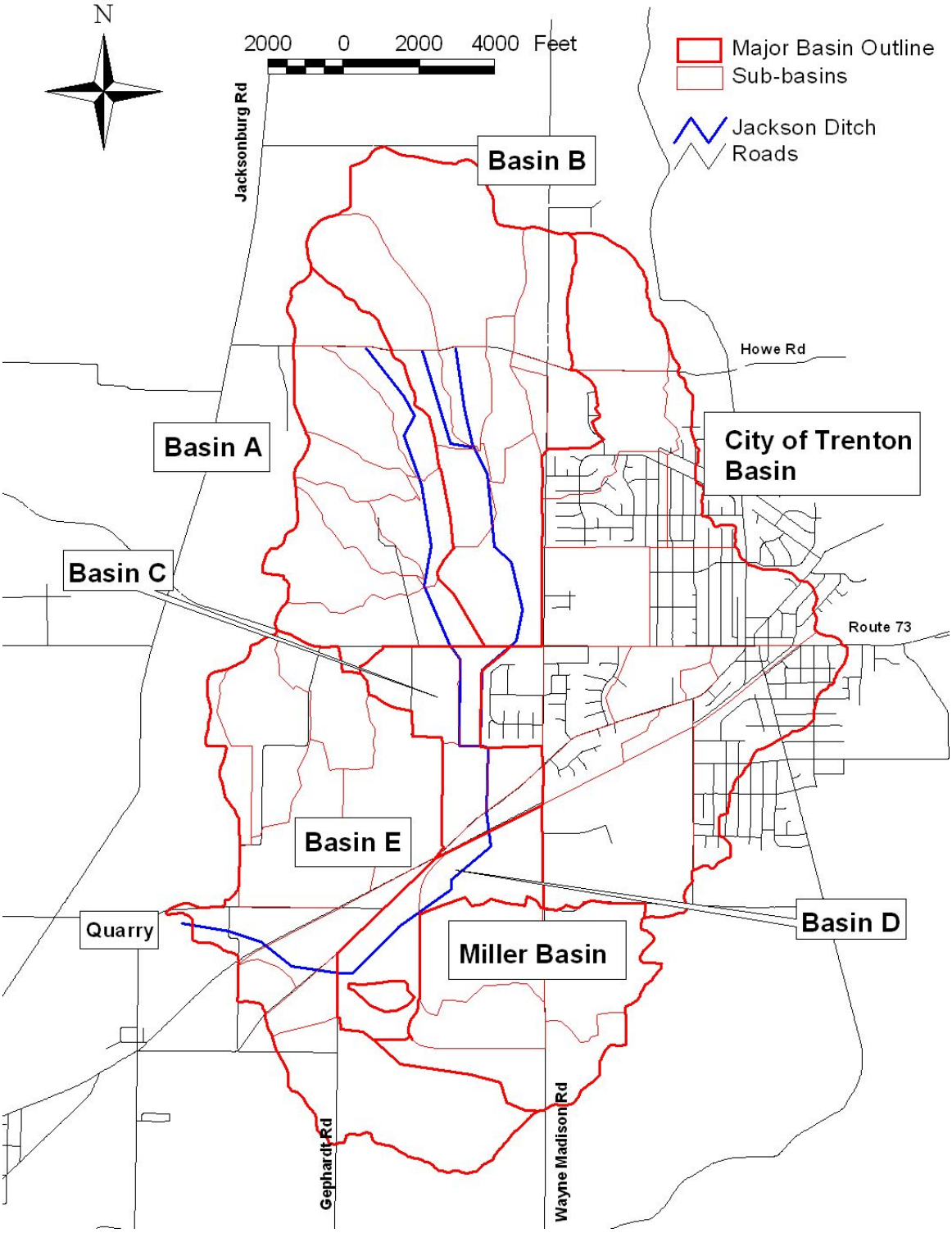


Figure 4.3 Trenton Watershed Basins

As this summation process was intended to look at annual volumes, the method does not properly account for flood flows. Hydraulic modeling of Jackson Ditch is examined in other sections of this report.

For the year 2004, Table 4.2 shows total flow volume into Jackson Ditch increased 84% for No-BMP conditions and 82% for With-BMP conditions compared to the Existing conditions. The additional water, compared to Existing conditions, is from reductions in evaporation and in increases in runoff. With the exception of the sinks, local infiltration to the aquifer decreases due to increased impervious areas. The increase in flow to Jackson Ditch means that water that had infiltrated to the aquifer in the northern portions of the watershed would flow south and infiltrate in the southern portions of the aquifer.

When the effects of infiltration at Miller Sink are included, the increase in flow volumes to Jackson Ditch downstream of Gephardt Road was 3,000% for No-BMP conditions and 2,000% for With-BMP conditions. Peak flows (without storage or routing) increased from the Existing conditions to the No-BMP conditions and the With-BMP conditions as shown in Table 4.3. The increased volume of flows to Jackson Ditch downstream of Gephardt Road is likely to aggravate any tendencies to flood this area. The inclusion of BMPs to increase infiltration and retard runoff is expected to reduce the total flow volumes and peak flows in Jackson Ditch. A secondary benefit of attenuating the flood flows is to allow more time for infiltration at Miller Sink and other areas which in turn reduce flood flows further.

Increased flows to Jackson Ditch, especially increased peak flows, are expected to change Jackson Ditch. Increased flows with accompanying increased velocities may erode the stream banks. Trees along the wooded banks could be under cut and collapse into the stream. Falling trees would take soil from the bank in their root balls. Additional soil may wash into the stream as the bank, without the support of tree roots, slumps into a flatter slope. The trees and branches as well as the eroded soils would be washed downstream to debris jams or will settle out in low velocity reaches downstream. Debris jams and sediment buildup will likely aggravate any existing local tendencies to flood.

Table 4.3 Peak Flow in Jackson Ditch

Basin	Existing (ft^3/s)	No-BMP (ft^3/s)	% Change	With-BMP (ft^3/s)	% Change	% BMP Reduction
Flow to Miller Sink	94	1,105	1,081	985	953	11
Flow Past Gephardt Road	44	1,055	3,027	935	2,124	29

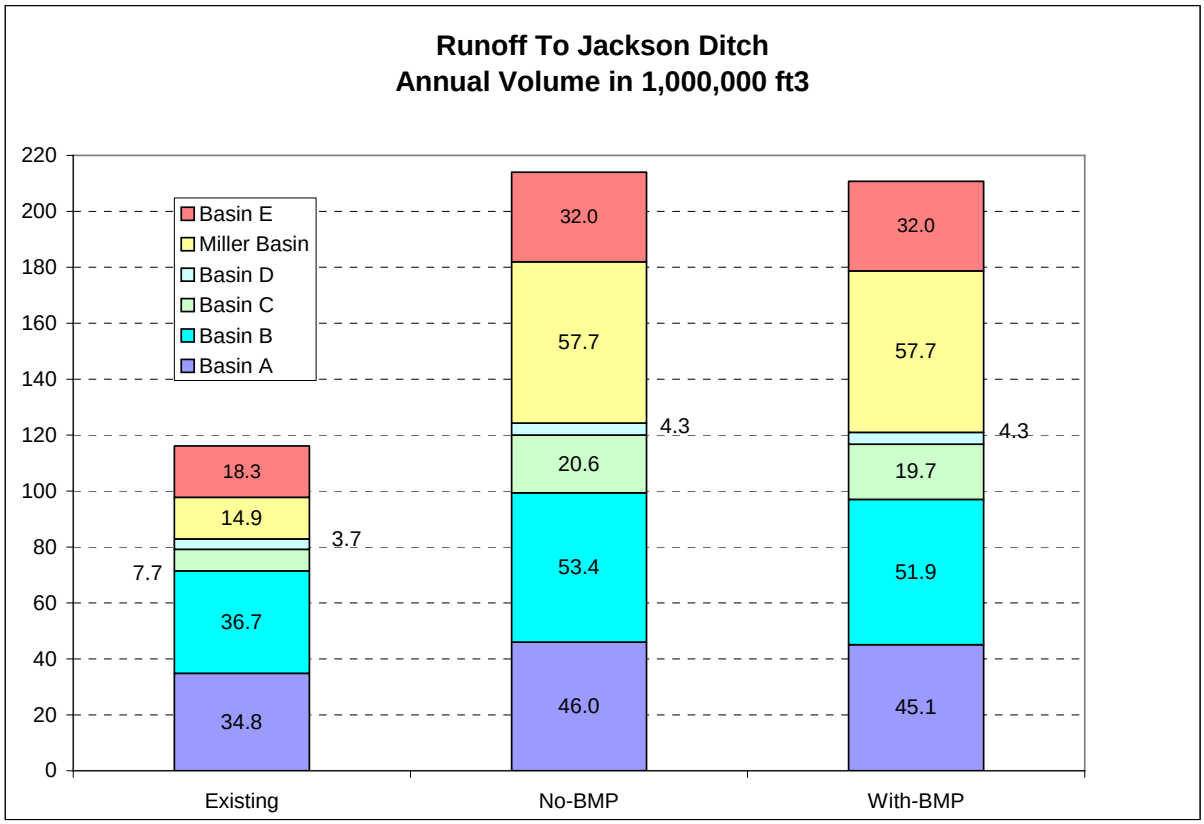


Figure 4.4 Annual Runoff to Jackson Ditch

On January 4, 2004, 3.03 inches of rain fell during the course of the day. This storm was approximately a 2.5 year storm. Local flooding was observed in the area near the intersection of Trenton and Gephardt Roads. For 2004, this storm had the peak flow into the Jackson Ditch for the Existing conditions. This storm fell on moist but not frozen soils. The No-BMP peak flow was over three times the peak flow for Existing conditions as seen in Figure 4.5. The effects of the BMPs can be seen in the elimination of peaks in the beginning of the runoff event. After the peak of the flood, the With-BMP flows are higher than the No-BMP flows due to runoff that infiltrates into the soils and flows to the stream as groundwater.

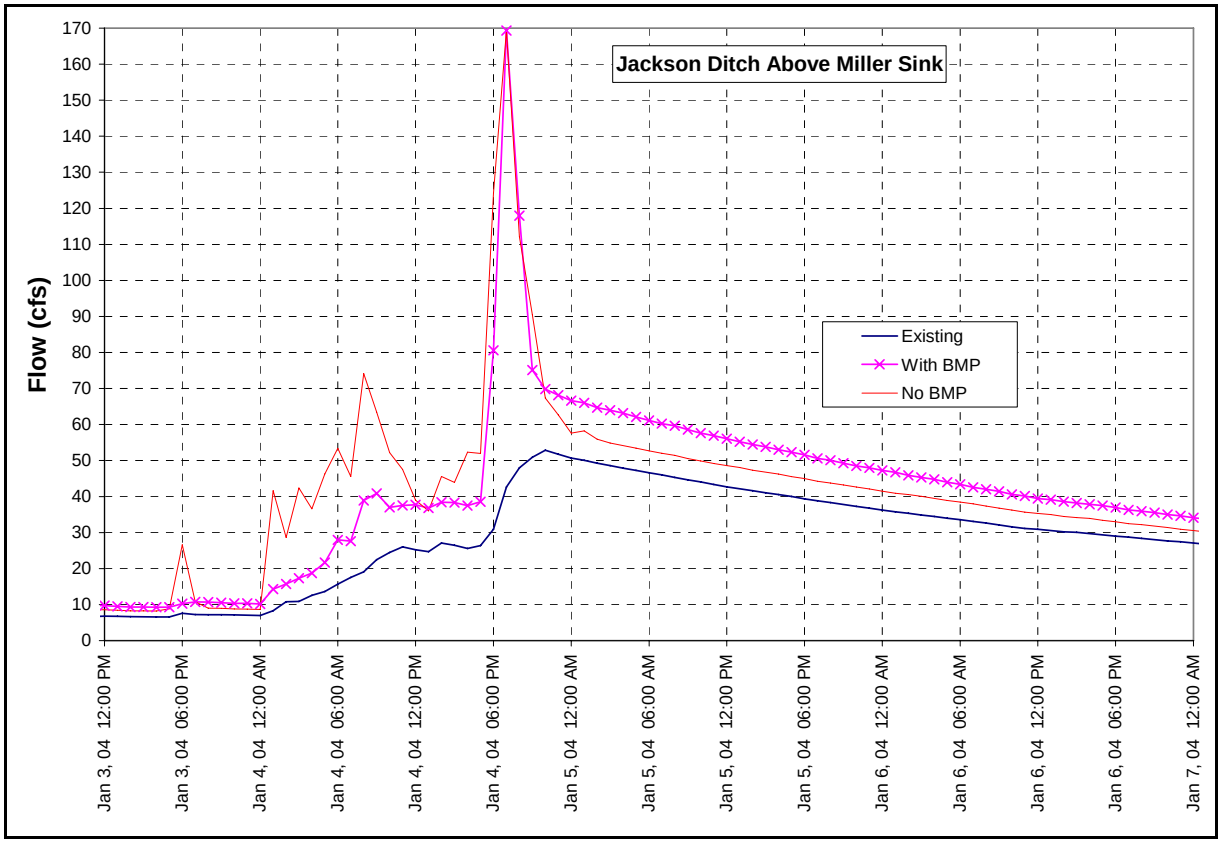


Figure 4.5 Jackson Ditch Flow January 2004

During the July 22, 2004, storm, 1.56 inches of rain fell in one hour which is approximately a 3 year rainfall. The soils at this time were dry after a week in warm summer temperatures without rain. The hourly flows in Jackson Ditch are shown in Figure 4.6. The peak flow into Jackson Ditch for the No-BMP conditions at 413 cfs was over 43 times the peak flow of 9 cfs for the Existing conditions. The changes from No-BMP to With-BMP conditions decreased the peak flow by 29% due to increased infiltration.

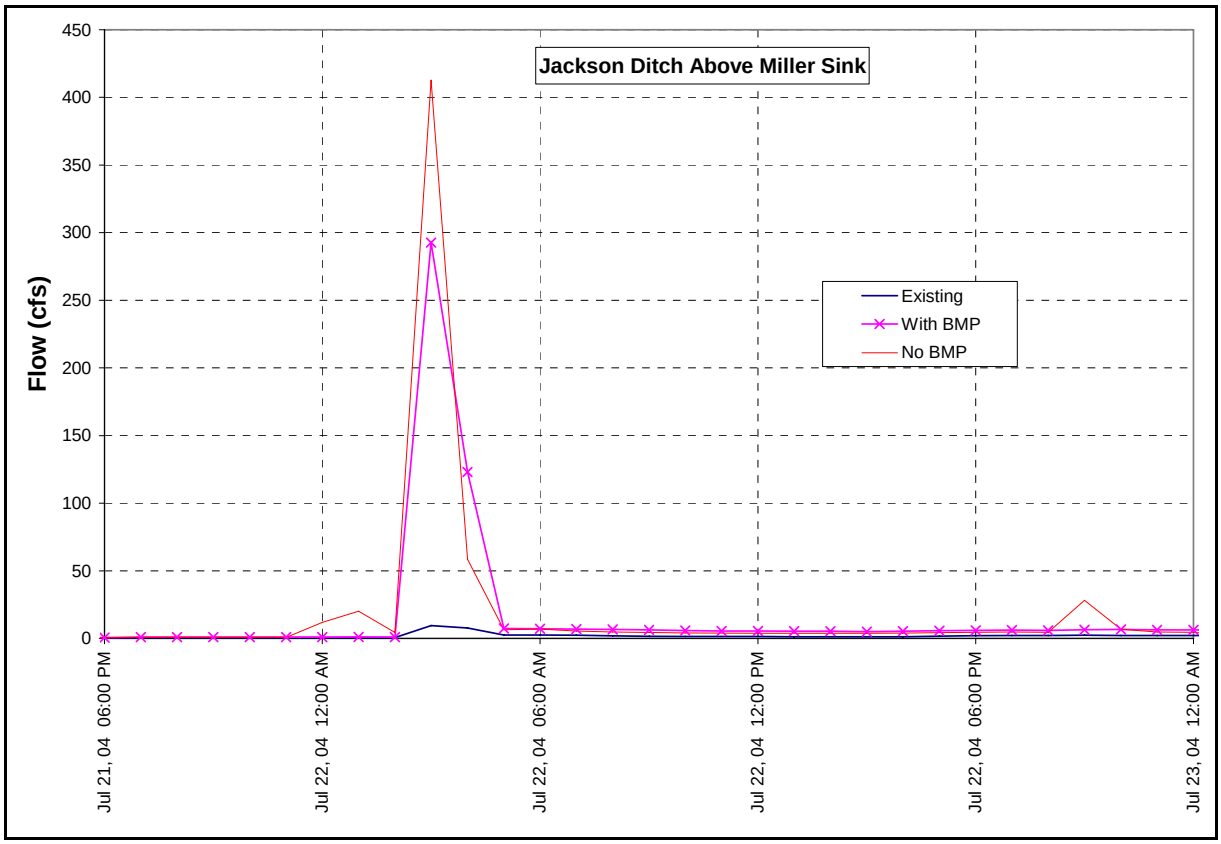


Figure 4.6 Jackson Ditch Flow July 2004

4.2. Percolation

Percolation to the aquifer is the dispersed in which the aquifer is recharged as opposed to the concentrated manner via the sinks. Changes in percolation patterns could impact aquifer water surface elevations, flow patterns in the aquifer and the volume of water in the aquifer. The changes in land use impact percolation in several ways. Increased impervious area increases the volume of runoff to Jackson Ditch which may decrease the volume of water available for percolation. Reductions in vegetation may reduce evapotranspiration which would increase water available for percolation. Trees transpire much more water than grass so the conversion of forest to grass would increase water available for percolation. The cumulative effects of land use on percolation will depend on the amount of impervious area added, the degree to which vegetation (before and after development) is grass instead of trees, how much of the impervious area has sewers to streams, the amount of runoff stored in detention and infiltration facilities, and other factors.

The annual percolation is summarized by basin in Table 4.4 and Figure 4.7. With development, percolation in Basins A and C decreased with increased impervious area. Basin B percolation increased due to the large increase in percolation in the Route 73 Sink (35% increase) offsetting the decreased percolation due to development in the rest of the basin. For

Basin E, the percolation increased primarily in the Riner and Streit Sinks, and on the flat area of sub-basin 28. Basin D and the Miller Basin had small changes in percolation due to limited changes in land use. The Miller Sink was estimated to allow 60% more percolation due to the increased availability of water from Jackson Ditch. The additional runoff volume entering Jackson Ditch due to urbanization is modeled as reaching Jackson Ditch below Gephardt Road and the quarry. The additional water is assumed to percolate to the aquifer along Jackson Ditch or at the quarry.

Percolation in the City of Trenton is projected to increase with the addition of impervious areas draining to sinks and dry wells. The increased impervious area caused decreased evapotranspiration which in turn increased the volume of water available for percolation.

The largest water withdrawal wells in the Trenton Watershed are Southwest Regional Water District, City of Trenton, Miller Brewing, and Cincinnati Gas & Electric (CG&E). All of these wells are located near Hamilton Trenton Road in the southern half of the watershed as shown in Figure 4.8. The change in percolation was examined for patterns that might impact the water levels and flow patterns in the aquifer. The primary concern was that the changes in runoff volume to Jackson Ditch would transfer percolation to the area of Miller Sink and the quarry. This transfer combined with continuing, and possibly increased, withdrawals could lower the aquifer water surface, especially for the City of Trenton and CG&E which are furthest from the Miller Sink and quarry.

Future development within the City of Trenton is assumed to continue the current practices using dry wells and infiltration basins to manage stormwater through infiltration. Total infiltration in the City of Trenton is predicted to increase 30% as the increased impervious area reduces evapotranspiration. The additional groundwater should raise the aquifer level at the City of Trenton and CG & E wells.

The large (60%) increase in percolation at the Miller Sink caused by development would increase the water surface elevation of the aquifer in that area of the watershed. Much of the additional percolation would be expected to flow west to the Great Miami River but some water would be expected to flow toward the Miller Brewery and the Southwest Regional Water District wells. Water percolating from Jackson Ditch below Gephardt Road and the quarry would enter the aquifer west of the Miller Brewing and Southwest Regional wells. The effects of increased percolation from this area on the water levels at the wells may be small due to the distance to the wells and the location of the percolation in the aquifer flow pattern.

Overall, the increase in percolation should increase the availability of water from the aquifer at the City of Trenton and CG&E wells. The large increase in percolation at the Miller Sink should increase the availability of water at the Miller Brewing and Southwest Regional Water District wells. The actual extent of the changes is currently unknown.

Table 4.4 Annual Percolation to Aquifer						
Basin	**Existing (1,000,000 ft3)**	**No-BMP (1,000,000 ft3)**	**% Change**	**With-BMP (1,000,000 ft3)**	**% Change**	**% BMP Increase**
A	8.1	7.2	-10%	7.8	- 3%	9%
B	24.4	26.8	10	27.8	14	4
C	10.3	7.2	-30	8.2	-20	15
D	12.1	12.0	-1	12.0	-1	0
Miller Basin	34.5	27.2	-21	27.2	-21	0
Miller Sink	96.8	154.7	60	158.6	64	3
E	52.5	69.3	32	69.3	32	0
Between Gephardt & Quarry	19.1	59.0	209	51.2	168	-13
A+B+C	42.7	41.2	-3	43.9	3	6
A+B+C+ D+Miller	89.2	80.4	-10	83.1	-7	3
All	257.7	363.5	41	362.2	41	0
Trenton Runoff Infiltrated	67.0	126.2	88	126.2	88	0
Trenton Direct Infiltrated	75.3	59.3	-21	59.3	-21	0
Trenton Total	142.3	185.5	30	185.5	30	0

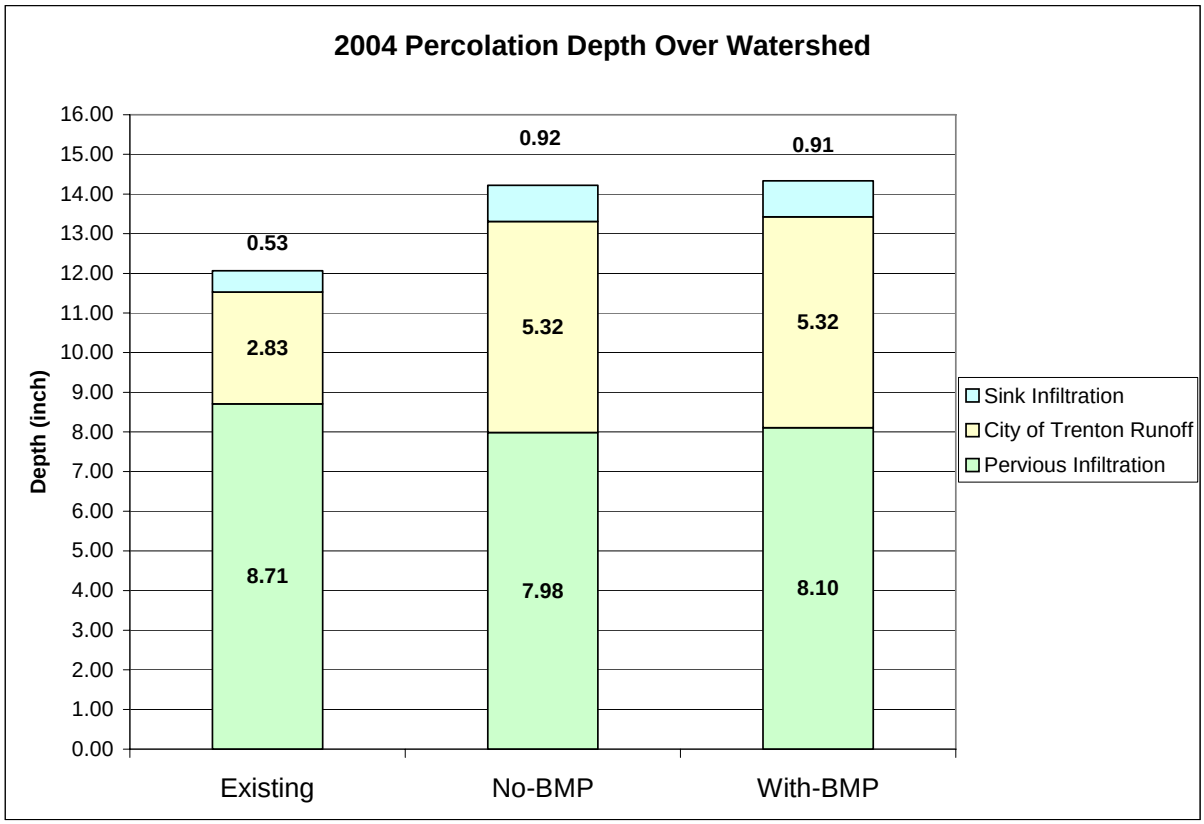


Figure 4.7 Percolation Depth Over Watershed

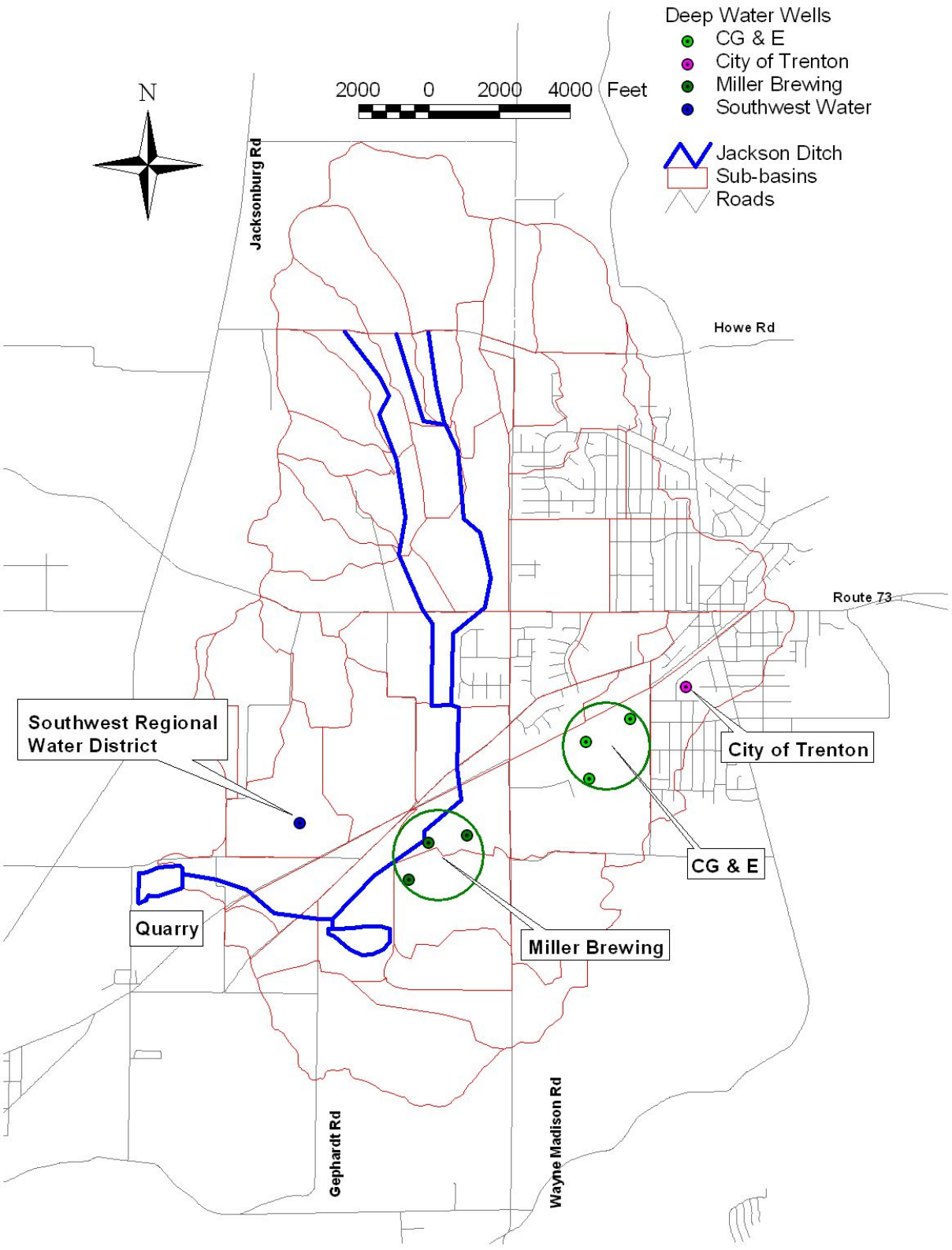


Figure 4.8 Deep Well Locations

5. Water Quality Results

5.1. Water Quality Parameters

The results of the hydrologic modeling were used to estimate current and future loading of water quality. A literature search was conducted to find Event Mean Concentrations (EMC) for the parameters of concern. An Event Mean Concentration is the average of the parameter concentrations measured during a rainfall runoff event. The concentration of a substance in the runoff may vary for several reasons. The substance may have an immediate peak concentration if it is on the ground surface and is easily dissolved. If the substance requires time to travel to the stream, time to dissolve, or stored in below ground, the peak concentration will be delayed. The peak concentration is also impacted by the length of time since the last rainfall, temperature, time of year, and any other factor that impacts the production and destruction of the substance.

An EMC is based on a number of water samples. Several water samples are taken during a single rainfall runoff event to determine the average concentration of a pollutant which may vary during the duration of the event. Ideally the sample results from several events and several locations are combined to find the Event Mean Concentration for each land use.

For the Trenton Watershed study, the EMCs were assigned based on land use as shown in Table 5.1. The sub-basin EMC for a parameter was calculated from the various land uses using area weighting.

Table 5.1 Contaminant EMC by Land Use

Land Use	Nitrate mg/L	Soluble Phosphorus mg/L	Total Copper mg/L	Total Zinc mg/L
Commercial / Industrial	0.42	0.11	0.025	0.160
Cropland	1.70	0.30	0.010	0.050
Pasture	0.60	0.55	0.005	0.025
Rural Development	0.35	0.55	0.015	0.090
Sink	0.00	0.00	0.000	0.000
Urban Development	0.45	0.33	0.020	0.125
Woods	0.25	0.05	0.005	0.025

As a measure of the magnitude of estimated contamination, the modeling results were compared to the drinking water standards. The US and Ohio EPA have identical standards for the maximum levels of contaminants in the drinking water supply. A pollutant may be regulated under one or more of a number of different standards. The most stringent standard is the Maximum Contaminant Level Goal (MCLG) which is the concentration below which no health risks are known or expected. This level is a goal, but not an enforcement standard. The Maximum Contaminant Level (MCL) is the enforcement standard and is based on the

MCLG. An MCL is set as close as possible to the MCLG considering the available technology and cost. When determining the contaminant level in the drinking water is either technically or economically not feasible, a specific Treatment Technique is required as a means to guarantee that the contaminant is removed. A Secondary Standard is a non-enforceable guideline for contaminants that based on aesthetics (water color, odor, or taste), cosmetics (staining of skin or teeth), or equipment (staining, corrosion, or sedimentation and scaling). The standards for specific contaminants will be discussed individually below.

The model results were also compared with water quality targets intended to improve water quality in the streams and lakes. These standards developed by Ohio EPA are determined based on water samples taken in streams and lakes around Ohio. These water sample results were compared with measures of the health and diversity of aquatic life at the sample sites. The target levels for pollutants were set to minimize the negative effects on aquatic life based on the number and variety of sensitive species. The targets vary according to region of the state and by habitat classification.

A habitat classification is determined based on the diversity and overall quality of the biological community living in the stream. Of the various habitat classifications available, the two most appropriate for the Trenton watershed are Warmwater and Modified Warmwater. A Warmwater Habitat is capable of supporting a balanced community of warmwater aquatic species. A Modified Warmwater Habitat has lower diversity and overall quality but is unlikely to improve to the Warmwater Habitat designation due to human modification such as channelization, mining runoff, or installation of impoundments. Determination of the existing habitat designation would require a biological assessment. Jackson Ditch could be classified as a Modified Warmwater Habitat due to the deeply embedded channel which limits habitat diversity and flow regime variety.

5.2. Nitrate Results

Nitrate is a contaminant that may impact human health and a nutrient that may impact water quality.

Nitrate in drinking water is converted by intestinal bacteria to nitrite. Nitrite in the blood oxidizes some of the hemoglobin which in turn reduces the oxygen carrying capacity of the blood. Most frequently found in infants (and some rare adults), this situation causes a blue or lavender tinge to the skin more commonly known as blue baby syndrome.

Nitrate in surface water acts as a fertilizer to encourage the growth of aquatic vegetation, especially algae and floating plants. The decomposition of the vegetation and the nocturnal oxygen use of the plants reduce the dissolved oxygen in the effected water. The low oxygen levels and clogging of the stream by the vegetation adversely impact many fish, amphibians, and invertebrates.

Nitrate concentrations were estimated based on the percent of a sub-basin assigned to each land use. The nitrate concentration for water infiltrating into the soil was reduced by 30% to account for biological activity.

The largest source of nitrates is farm fertilizer for crops. As the cropland area of the Trenton Area watershed decreases, the total load of nitrates decreases. Additional major sources of nitrates are residential fertilizer, pet and livestock waste, malfunctioning septic tanks, and leaking sanitary or combined sewers.

As shown in Table 5.2 and Figure 5.1, nitrate loads in surface runoff increase with the increased runoff due to urbanization. The percolation numbers include the City of Trenton surface runoff percolating from infiltration basins and dry wells. The nitrate loads in the percolation water significantly decrease due to the presumed development of cropland to urban land uses. The cropland converted generally coincides with the soils having the highest infiltration rates.

The annual average concentration in runoff and percolation is shown in comparison to the EPA MCL standard. The average concentration for the existing conditions is a fraction of the EPA standard and decreases with development. The change in concentration is greater than the change in load since the decreased evapotranspiration and increased runoff and percolation diluted the nitrate concentration.

Ohio EPA has statewide targets for nitrate and nitrite in streams based on watershed size and ecological quality of the stream. For the small watershed of Jackson Ditch, the target for nitrate and nitrite combined is 1.0 mg/L. The expected future annual average concentration of nitrate is far below the target. No surface water quality problems are expected due to nitrate.

Table 5.2 Annual Nitrate Loading

	Existing (kg)	**No-BMP (kg)**	**% change**	**With-BMP (kg)**	**% change**	**% BMP Improvement**
Surface Runoff	2,510	2,630	5%	2,600	4%	1%
Percolation	5,040	3,920	-22	3,960	-21	-1
Total	7,550	6,550	-13	6,560	-13	0
Average Concentration	0.66 mg/L	0.41	-38%	0.41	-38%	
Maximum Concentration	1.66 mg/L	1.13	-32%	1.13	-32%	
EPA MCL standard 10 mg/L						

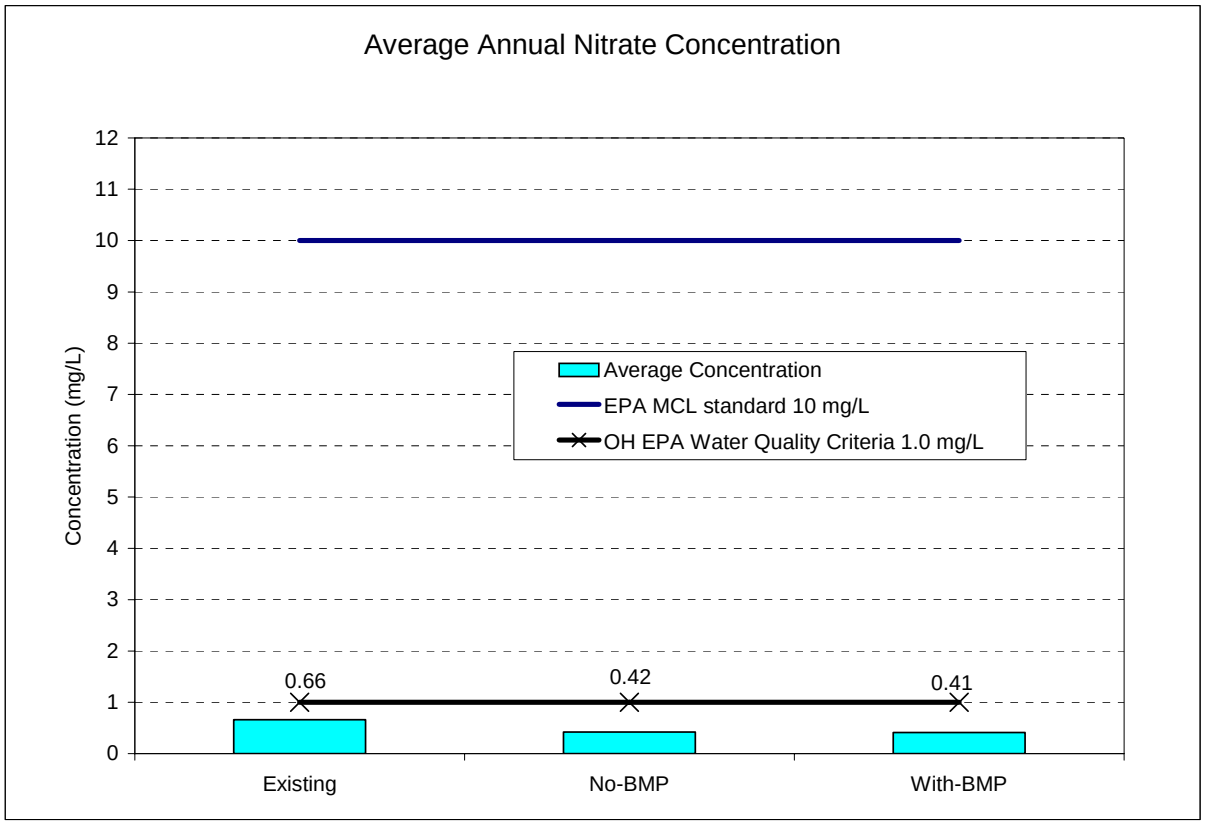


Figure 5.1 Average Annual Nitrate Concentration

5.3. Phosphorus Results

Phosphorus in surface water acts as a fertilizer to encourage the growth of aquatic vegetation, especially algae and floating plants. The decomposition of the vegetation and the nocturnal oxygen use of the plants reduce the dissolved oxygen in the effected water. The low oxygen levels and clogging of the stream by the vegetation adversely impact many fish, amphibians, and invertebrates. In the eastern United States, phosphorus is generally the limiting nutrient for algae and floating vegetation growth.

Currently no drinking water standard exists for phosphorus.

Phosphorus concentrations were estimated based on the percent of a sub-basin assigned to each land use. The phosphorus concentration for water infiltrating into the soil was reduced by 30% to account for biological activity.

The largest source of phosphorus is fertilizer for pastures and lawns. As the cropland area of the Trenton watershed is converted to lawns, the total phosphorus load increases. Additional major sources of nitrates are pet and livestock waste, malfunctioning septic tanks, and leaking sanitary or combined sewers.

As shown in Table 5.3 and Figure 5.2, phosphorus loads increased due to urbanization with increased lawn fertilization. The percolation numbers include the City of Trenton surface

runoff percolating from infiltration basins and dry wells. Increased runoff and percolation with development did moderate the increase in total load.

Ohio EPA has statewide targets for total phosphorus in streams based on watershed size and ecological quality of the stream. For the small watershed of Jackson Ditch, the target for total phosphorus is 0.08 mg/L for a Warmwater Habitat or 0.34 mg/L for a Modified Warmwater Habitat. The expected future annual average concentration of dissolved phosphorus is near the target for the Modified Warmwater Habitat and far above the target for the Warmwater Habitat. Based on Existing Conditions results, Jackson Ditch is likely supporting the less diverse aquatic life of a Modified Warmwater Habitat.

The increased total load concentration for phosphorus indicates a possible future problem with eutrophication. The most likely locations for this problem are pools where aeration is low and sunlight is available for heat and photosynthesis. These conditions encourage eutrophication. Small pools tend to form above and below constrictions such as culverts and road crossings. The major areas where eutrophication may be a problem are the Miller Sink and the quarry. The eutrophication may impact the taste and odor of groundwater infiltrating in the aquifer from the Miller Sink and the quarry. The eutrophic water in the sink and the quarry would suffer from visual and odor problems, would have lower biodiversity, and may lead to increased insect populations. The severity of these problems would depend on a variety of factors.

The phosphorus concentration can be lowered by the intentional design of storm water systems that increase the removal of phosphorus before discharge to the stream. In stream measures to reduce water temperature (preservation of trees on stream banks) and increase dissolved oxygen (man made riffles or weirs) may reduce the effects of eutrophication.

Table 5.3 Annual Phosphorus Loading

	Existing (kg)	**No-BMP (kg)**	**% Change**	**With-BMP (kg)**	**% Change**	**% BMP Improvement**
Surface Runoff	890	1,340	52%	1,450	64%	-7%
Percolation	1,850	2,760	49	2,790	50	-1
Total	2,740	4,110	50	4,240	55	-3
Average Concentration	0.24 mg/L	0.26	8%	0.27	13%	
Maximum Concentration	0.55 mg/L	0.55	0	0.55	0	
No EPA Standard						

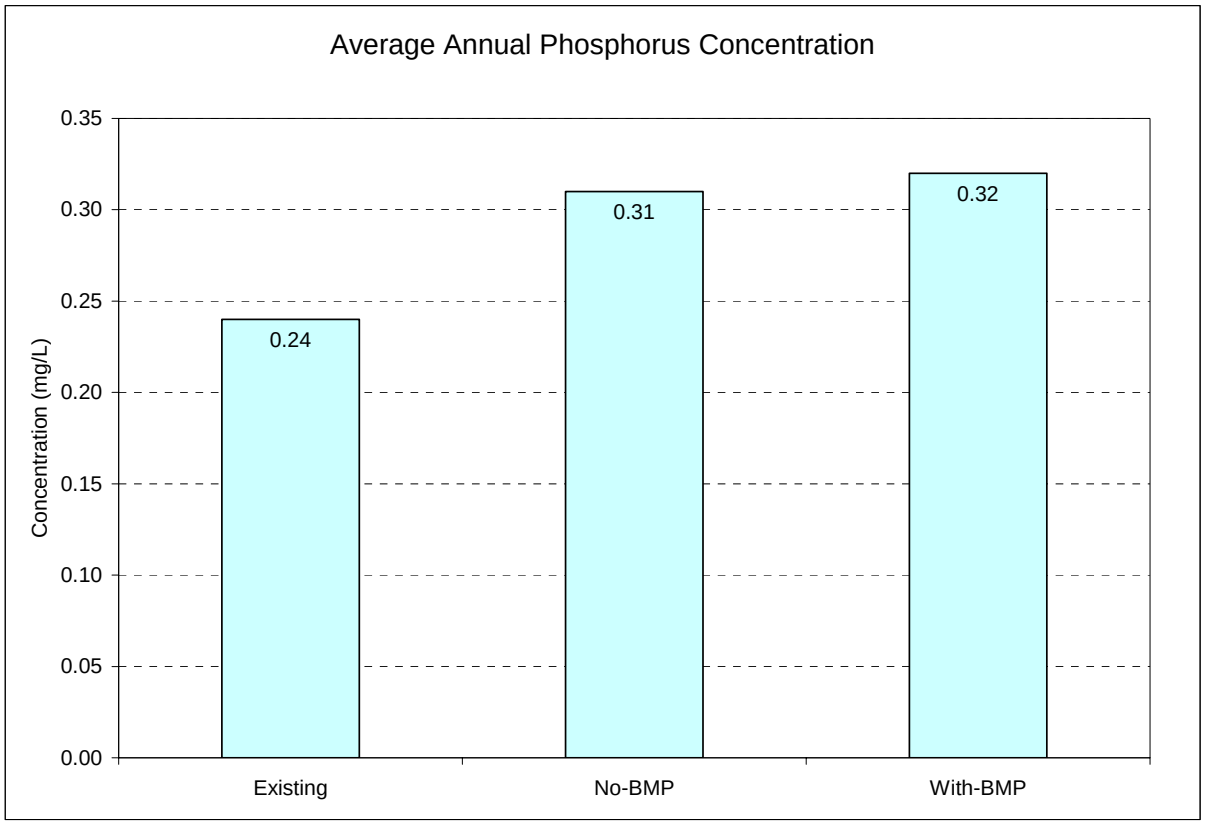


Figure 5.2 Annual Average Phosphorus Concentration

5.4. Copper Results

Copper at high levels is a health concern due to short term gastrointestinal distress and long term liver and kidney damage. Additionally, copper is a threat to people with Wilson's Disease, a genetic disorder that causes the accumulation of excessive copper in the liver or brain.

The sources of copper include brake pads, bearings and wear surfaces, and some insecticides and fungicides.

In addition to the US and Ohio EPA Secondary Standard for taste, odor and corrosion, copper is also regulated under a Treatment Technique Standard. If the treated water is too corrosive, copper and lead may be leached out of household plumbing. When testing at households indicates the water is too corrosive as shown by the copper and lead concentrations, treatment techniques are used to limit the leaching of metals from plumbing fixtures. The Secondary Standard is set at 1.0 mg/L to limit metallic taste and blue-green staining. The Treatment Technique Action Level is set to 1.3 mg/L to protect against health hazards.

As shown in Table 5.4 and Figure 5.3, copper loads increased due to urbanization and increased vehicle traffic. The percolation numbers include the City of Trenton surface runoff percolating from infiltration basins and dry wells. Increased runoff and percolation with development did dilute the increase in total load. The annual average concentration is and is

expected to continue to be far below the Secondary Standard and the Treatment Technique Action Level.

Ohio EPA has a water quality target for copper intended to protect aquatic life. Assuming a hardness of 100 mg/L $CaCO_3$ (moderately hard water and the lowest in the criteria), the target is 0.009 mg/L of copper. Currently, the copper concentration is estimated as above the target with the future concentrations significantly exceeding the target. Reduction of the copper in the runoff can be achieved by using BMPs that focus on capturing runoff from streets and paved areas, and removing suspended sediment.

Table 5.4 Annual Copper Loading

	Existing (kg)	**No-BMP (kg)**	**% Change**	**With-BMP (kg)**	**% Change**	**% BMP Improvement**
Surface Runoff	24	72	201%	66	176%	9%
Percolation	102	200	99	200	99	-1
Total	126	272	120	266	115	2
Average Concentration	0.011 mg/L	0.018	59%	0.017	57%	
Maximum Concentration	0.020 mg/L	0.025	25	0.025	25	
No MCL Secondary Standard 1 mg/L Treatment Technique Action Level 1.3 mg/L						

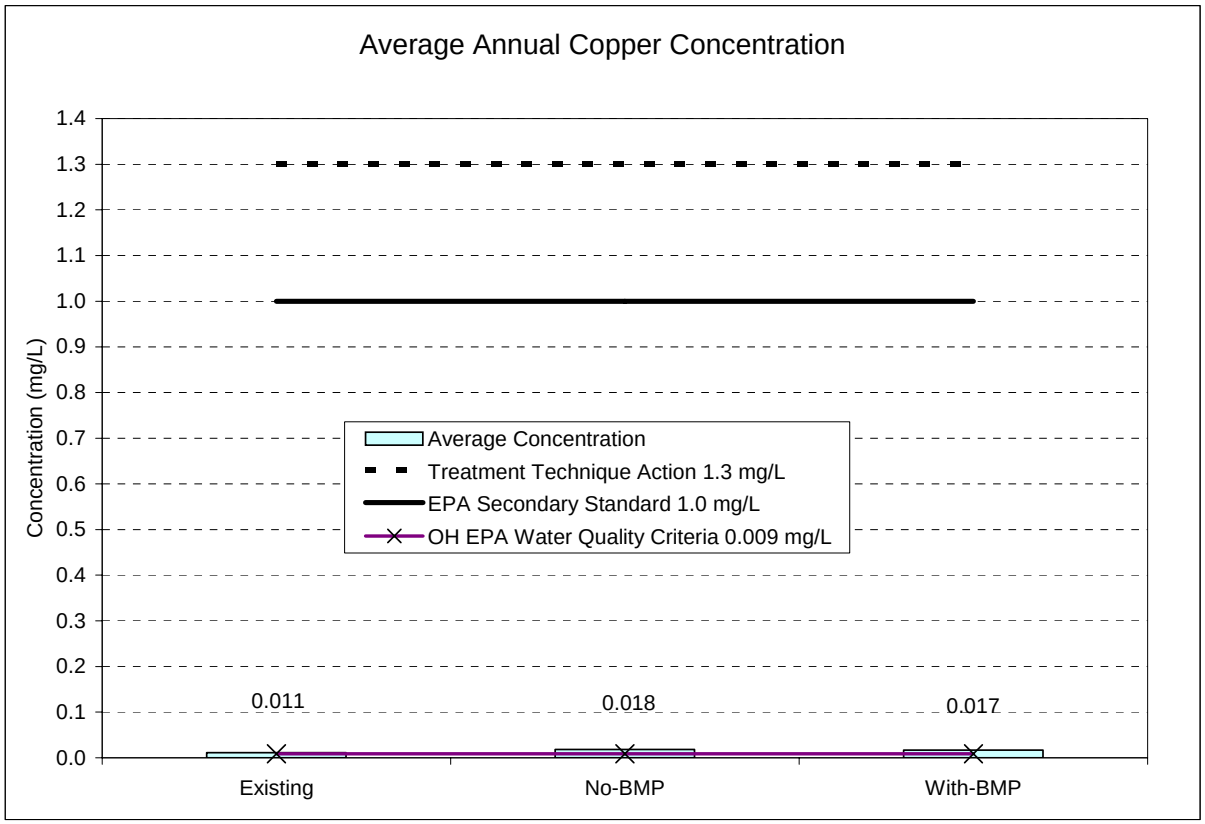


Figure 5.3 Average Annual Copper Concentration

5.5. Zinc Results

Zinc has limits due to its aesthetic effects. The sources of zinc include tires, oil and grease, and galvanized metal surfaces. The loading estimates are for total zinc.

The Secondary Standard is set at 5 mg/L to limit metallic taste and staining.

As shown in Table 5.5 and Figure 5.4, zinc loads increased due to urbanization with increased vehicle traffic and industrialization. The percolation numbers include the City of Trenton surface runoff percolating from infiltration basins and dry wells. Increased runoff and percolation with development did dilute the increase in total load. The annual average concentration is and is expected to continue to be far below the Secondary Standard.

Ohio EPA has a water quality target for zinc intended to protect aquatic life. Assuming a hardness of 100 mg/L $CaCO_3$ (moderately hard water and the lowest in the criteria), the target is 0.12 mg/L of zinc. Currently, the zinc concentration is estimated as well below the target with the future concentrations approaching but not exceeding the target. Reduction of the zinc in the runoff can be achieved by using BMPs that focus on capturing runoff from streets and paved areas, and removing suspended sediment.

Table 5.5 Annual Zinc Loading						
	Existing (kg)	**No-BMP (kg)**	**% Change**	**With-BMP (kg)**	**% Change**	**% BMP Improvement**
Surface Runoff	130	400	216%	390	215%	0%
Percolation	590	1,260	115	1,270	117	-1
Total	710	1,660	133	1,670	134	0
Average Concentration	0.063 mg/L	0.094	50	0.094	50	
Maximum Concentration	0.127 mg/L	0.160	26	0.160	26	
No MCL Secondary Standard 5 mg/L						

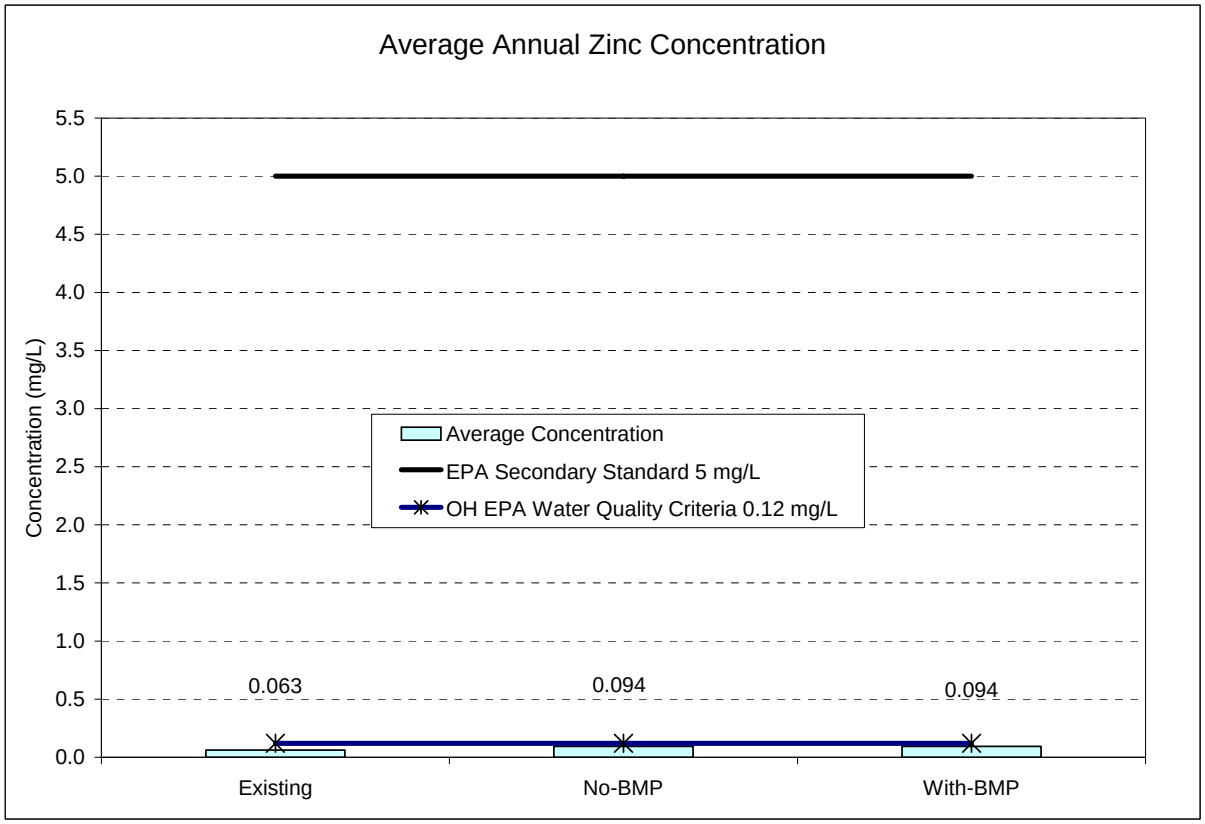


Figure 5.4 Average Annual Zinc Concentration

5.6. Chloride Results

Road salt used to melt snow and ice on roadways and parking lots enters the water cycle with the melting of the snow and ice and with washoff by runoff. When dissolved in snow melt and rainwater, the salt disassociates into sodium and chloride ions. The chloride dissolved in melt water generally is neither used in biological activity nor absorbed by the soil. The chloride passes through the water cycle diluted but not reduced.

Currently, no MCL exists for chloride. The EPA Secondary Standard of 250 mg/L for chloride is based on taste.

For this study the chloride loading was based on the loading rates reported by Butler County Engineer's Office. Butler County, in an average year, spreads 4,500 tons of salt on 623 lane miles throughout the county. Assuming 12 foot wide lanes, the annual loading rate is 0.62 kilograms of chloride per square foot (Cl^{-} kg/ft^2). This loading rate is the estimate for heavily traveled main roads. Lesser roads, residential streets and parking lots would have lower loading rates that are reflected in the estimation of road surface area.

The road surface salted was estimated from the land use as shown in Table 5.6. Industrial areas were estimated as 10% road surface and 95% impervious area. The low fraction of road surface is due to assumptions of large areas of roof, paved storage areas, and lightly or unsalted parking lots for this land use. Urban Development and Rural Development were assumed to have 10% and 5% road surface respectively.

Table 5.6 Impervious and Road Surface Area by Land Use

Land Use	% Impervious	% Road Surface
Commercial / Industrial	95	10
Cropland	0	0
Pasture	0	0
Rural Development	25	5
Sink	0	0
Urban Development	50	10
Woods	0	0

Annual loadings were used rather than trying to estimate continuous concentrations and loadings given the approximate nature of the road surface area estimate. The method of estimation of road salt loading was checked in two ways. The first used available center of road data in the GIS to estimate the road existing road surface assuming 12-foot wide lanes. This road surface area was approximately the same as the road surface estimated from land use information. The second check was against the reported peak chloride concentration in the raw water at the Southwest Regional Water District wells. The reported peak of 31.8 mg/L compares favorably to the Existing conditions estimate of 35 mg/L.

The increase in chloride load and concentration shown in Table 5.7 and Figure 5.6 are strictly functions of increased road surface and road salt use. The large increase in road salt loading was partial offset by the increased runoff and percolation.

Given the conservative nature of chloride, land development BMPs do not impact the annual average concentration of chloride in runoff. Operational BMPs will reduce the effects of chloride both for the entire watershed and for specific locations. Possible BMPs include reducing road salt use through brine spraying or other techniques,

Table 5.7 Annual Chloride Loading

	Existing	**No-BMP**	**% Change**	**With-BMP**	**% Change**	**% BMP Improvement**
Total Load (1000 kg)	400	1,200	194%	1,200	194%	0%
Average Concentration mg/L	35	75	115%	75	115%	
Maximum Concentration mg/L	104	232	123%	232	123%	
	No MCL Secondary Standard 250 mg/L					

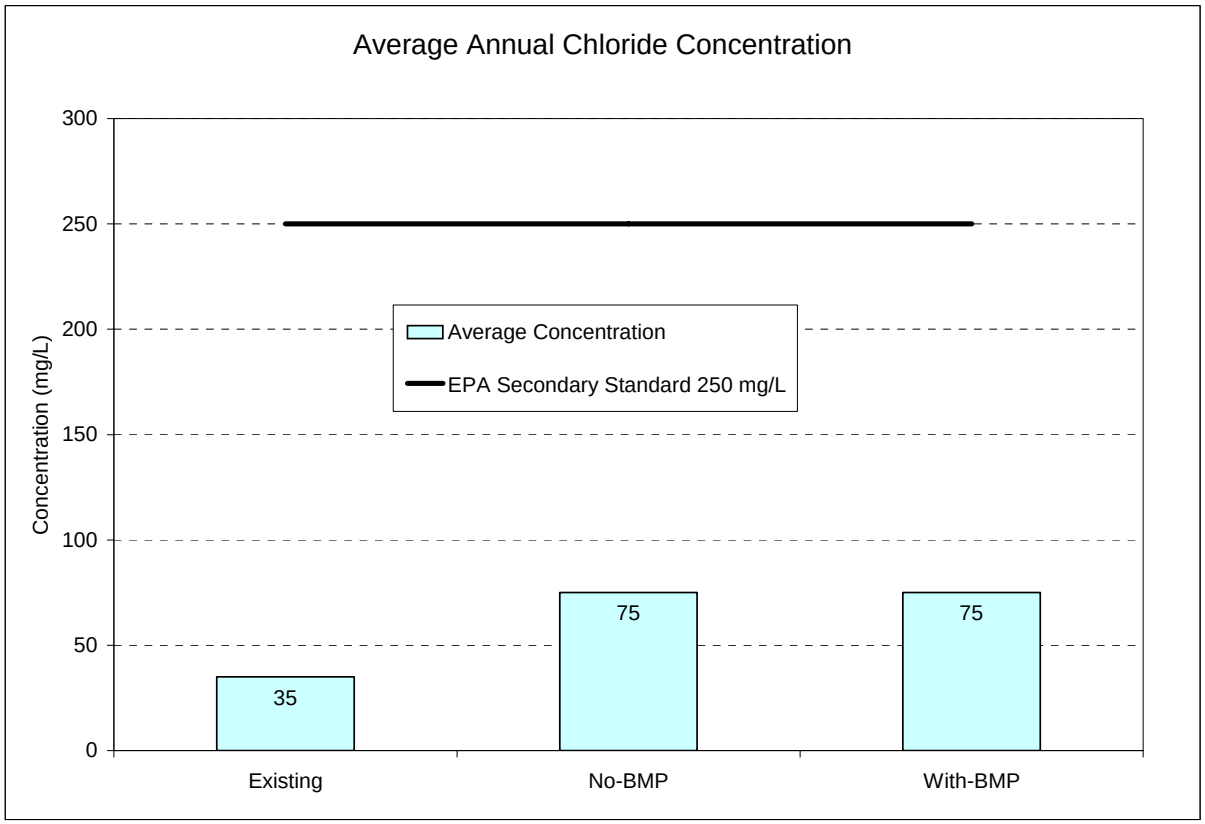


Figure 5.5 Average Annual Chloride Concentration

5.7. Suspended Sediment Results

Suspended sediments are small pieces of soil or debris washed into water courses. Suspended sediment may be a water quality problem from two processes. The physical existence of the sediment can block sunlight from aquatic vegetation, fill streambeds, and clog openings in gravel beds and other substrate. Clogging the substrates buries the habitat for invertebrates and small fish that populate the stream. Clogging the substrate will also reduce the infiltration capacity of the streambed. Sediment may also serve as a carrier for phosphates, petroleum products, and other pollutants. Additionally the sediment itself may be composed of particles of pollutants such as zinc, copper, lead, and other metals.

Cropland, as shown in Table 5.8, has very high suspended sediment concentrations compared to other land uses due to the length of time that the soil is bare and due to exposed soil between rows of crops.

Table 5.8 Suspended Sediment Concentration by Land Use	
Land Use	Suspended Sediment (mg/L)
Commercial / Industrial	110
Cropland	6,000
Pasture	160
Rural Development	160
Sink	0
Urban Development	110
Woods	30

Suspended sediment is washed into streams by surface runoff. Interflow and groundwater flows do not carry sediment to the streams. The urbanization of the Trenton watershed leads to increased surface runoff to Jackson Ditch as shown in Table 5.9. This change is most apparent for the No-BMP conditions where storm sewers carry impervious area runoff directly to the Jackson Ditch. Almost one-third of the surface runoff for the No-BMP conditions is from the storm sewers. Sediment washed off of impervious surfaces in the No-BMP conditions has less chance of depositing on pervious surfaces compared to the With-BMP conditions. For the With-BMP conditions, the suspended sediment loading decreases while the runoff increases as cropland is developed. Both changes are due to the conversion of cropland to urban development.

Table 5.9 Annual Suspended Sediment Loading to Jackson Ditch						
	Existing	**No-BMP**	**% Change**	**With-BMP**	**% Change**	**% BMP Improvement**
Total Sediment Load (1000 kg)	116	273	136%	204	55%	25%
Surface Runoff (1,000,000 ft3)	2.8	95.6	3,400%	45.9	1,600%	52%
Sediment Concentration mg/L	1,434	101	-93%	157	-89%	-55%

6. Summary

The Trenton watershed is expected to experience significant development as farmland is converted to residential and urban areas. Changes are foreseen in the volume, timing, and quality of the water flowing through the surface channels and into the aquifer. The aquifer under the Trenton watershed is the source of water for two public water supplies (Southwest Regional Water District and City of Trenton), Miller Brewing, and the Cincinnati Gas & Electric power plant. Reductions in the volume of water available or declines in the water quality would have adverse economic impacts on the community.

A model using the US EPA HSPF software was developed to examine the Trenton watershed for changes in aquifer recharge and water quality with development. Watershed data in the model included areas, slopes, and flow channels. Land use information was developed for existing and future conditions. Weather data was developed for 2004 as a typical weather year. Water quality parameters were estimated based on literature values.

Three scenarios were examined using the HSPF model results. The first was Existing conditions as a basis for comparison. The No-BMP conditions assume the installation of storm sewers in some urbanized areas. These sewers drained directly to Jackson Ditch. The With-BMP conditions assumed the use of some BMPs to reduce runoff and pollution.

As no calibration data was available, the results should not be viewed as absolute numbers but rather as a method for estimating the degree of changes in water volumes and water quality that can be expected with development.

6.1. Hydrology Summary

Identical weather conditions for 2004 were used for each of the three scenarios. The results of the model were examined as described below.

6.1.1. Runoff to Jackson Ditch

Due to limitations of the HSPF model, the flows in Jackson Ditch could not be modeled accurately. The flows were examined using hourly average runoff flows summed together. No attempt was made to account for storage and attenuation due to the channel length and geometry. The results for flows in Jackson Ditch are intended for relative comparison between the scenarios rather than as realistic representation of how the stream would act.

The runoff to Jackson Ditch increased with development as would be expected with the increase in impervious area. The No-BMP conditions increased runoff volume to Jackson Ditch by 80% and peak flows by up to 10 times compare to the Existing conditions. The With-BMP conditions increase runoff volume by 80% and peaks by a factor of 9.5. Inclusion of BMPs reduced the volume of runoff to Jackson Ditch by only 2% but reduced the peak flow by 11% compared to the No-BMP conditions. The increase in flows is expected to aggravate flooding and erosion issues in Jackson Ditch.

Increased peak flows and total runoff volume in Jackson Ditch will more often exceed the infiltration capacity of Miller Sink in the future compared to the current conditions. The volume of water and peak flows passing Gephardt Road are expected to increase by 30 times for the No-BMP conditions compared with the Existing conditions. For the With-BMP conditions, the volume and peak flows are expected to increase over 20 times. Installing basic BMPs during development reduces the volume and peak flows past Gephardt Road by roughly 30% compared to the No-BMP conditions.

6.1.2. Percolation

The development of rural land to residential and urban areas decreases the pervious areas and reduces the percolation to the aquifer. The overall decrease in percolation was offset by the increased percolation at the Route 73, Riner and Streit Sinks as well as infiltration basins and dry wells in the City of Trenton. Aquifer recharge at the Miller Sink is expected to increase 60% with development as water volumes in Jackson Ditch increase. Runoff volumes between Gephardt Road and the quarry increase 210% for the No-BMP conditions and 170% for the With-BMP conditions. All water in this area of the watershed is assumed to percolate to the aquifer from the streambed, the floodplains or at the quarry.

For the wells of the City of Trenton and Cincinnati Gas & Electric, the aquifer level and capacity should rise with the 30% increase in infiltration with development. The changes for the Southwest Regional Water District and Miller Brewery may be larger due to their proximity to the large increase in Miller Sink percolation. For both the No-BMP and With-BMP conditions, a significant volume of water flows past Gephardt Road before percolating to the aquifer. This water may percolate into the aquifer too far from the Southwest and Miller wells to have a significant effect on the wells.

6.2. Water Quality Summary

Water quality was examined for six parameters; nitrate, dissolved phosphorus, copper, zinc, chloride, and suspended sediment. The loading for each was based on EMCs for each land use. Nitrate and dissolved phosphorus concentrations for water percolating into the ground were reduced by 30% to account for biological activity within the soil.

Nitrate loading in the watershed is expected to decrease with the development of farmland into residential and urban areas. Nitrates are currently below drinking water standards and surface water targets and are expected to drop further.

Phosphorus loading is expected to increase in both total load and in concentration due to the increase in lawn fertilization with development. No drinking water standard currently exists for phosphorus. The expected future concentrations will be above the surface water targets intended to prevent eutrophication. The expected increase in concentration can be reduced with the use of BMPs targeted at phosphorus reduction such as grassed swales.

Copper and zinc will increase in total loading and in concentration. Both metals are expected to be far below drinking water standards. Using both metals as indicators of metal pollutants in general, urbanization is not expected to create drinking water problems due to increased

metal pollution. Copper is estimated to be at and is expected to exceed the target concentrations for the protection of aquatic life. The concentration of copper can be reduced by BMPs that remove sediment such as grit pits and grassed swales.

Chloride concentrations will increase in total loading and in concentration with the increase in road surface and resulting increase in road salt use. Uncertainty in the estimation is due to the greatly varying road salt application rates for county roads, residential streets, and parking lots. Chloride concentrations are estimated to be below drinking water standards currently and in the future.

Suspended sediment loading is expected to change with development. The conversion of cropland to urban development will reduce the average suspended sediment concentration. The storm sewers of the No-BMP conditions will carry much higher surface runoff with a higher total sediment load to Jackson Ditch than the Existing conditions. Sediment buildup on the paved areas will be washed directly to Jackson Ditch through the sewers. The With-BMP conditions will reduce the total sediment load to Jackson Ditch compared to both Existing and No-BMP conditions. The With-BMP conditions assume the capture of sediment through the use of practices such as grit chambers or grassed swales before it can enter Jackson Ditch.

Appendix D-1 HSPF Model Results by Sub-basin

	Runoff Depth (Inch)			Percolation Depth (Inch)		
Sub-basin	Existing	No-BMP	With-BMP	Existing	No-BMP	With-BMP
1	14.04	15.06	15.06	1.48	1.56	1.56
2	13.42	13.79	13.79	1.48	1.54	1.54
3	13.58	14.92	14.92	1.21	1.35	1.35
4	15.38	18.87	18.87	1.09	1.32	1.32
5	8.81	11.63	11.63	5.12	4.82	4.83
6	13.77	14.08	14.08	1.97	2.08	2.08
7	12.26	13.54	13.54	3.46	3.73	3.73
8	10.45	12.3	12.3	4.29	4.32	4.32
9	11.95	13.29	13.29	3.85	4.05	4.06
10	11.71	16.08	16.08	2.95	2.86	2.86
11	15.4	18.35	18.35	2.19	2.24	2.23
12	10.82	19.13	19.13	5.59	5.04	5.04
13	13.69	13.61	13.61	1.06	1.12	1.12
14	12.37	15.87	15.35	1.64	1.44	1.59
15	13.23	15.79	15.79	1.4	1.31	1.31
16	8.43	15.12	13.79	5.08	4.23	4.98
17	10.46	22.09	20.93	3.57	3.2	3.73
18	2.18	15.23	13.3	11.29	9.43	10.76
19	9.1	19.87	19.44	4.78	3.68	4.24
20	1.78	4.73	4.73	12.16	13.34	13.34
21	2.17	4.22	4.21	11.51	12.13	12.13
22	2.72	9.38	9.38	11.41	12.37	12.37
23	13.98	27.29	28.42	6.66	1.81	2.06
24	0.84	13.95	11.78	12.3	10.87	12.5
25	2.83	11.59	11.59	14.47	23.36	23.36
26	1.81	12.63	12.63	12.34	12.21	12.21
27	1.98	14.83	12.82	11.87	10.25	11.78
28	7.25	20.65	20.66	15.73	28.61	28.61
29	4.19	10.45	10.44	11.22	11.67	11.66
30	13.45	15.29	15.29	2.2	2.09	2.09
31	7.57	14.42	14.42	6.8	5.79	5.79
32	2.72	3.57	3.57	12.05	11.86	11.86
33	7.63	45.15	45.15	21.1	32.74	32.73
34	9.49	14.62	14.62	4.16	4.33	4.32
35	3.42	25.32	25.32	13.27	5.92	5.92
36	19.39	32.24	32.24	9.13	1.97	1.97
37	6.68	15.09	15.09	10.34	9.44	9.43
38	9.34	9.34	9.34	13.14	1.98	1.98
39	4.43	14.81	14.81	10.73	10.29	10.29

	Runoff Depth (Inch)			Percolation Depth (Inch)		
Sub-basin	Existing	No-BMP	With-BMP	Existing	No-BMP	With-BMP
40	10.37	13.74	13.74	12.22	10.99	11
41	12.39	14.65	14.65	11.28	10.4	10.4
42	3.18	15.12	13.08	12.52	9.94	11.4
43	7.78	15.27	15.27	10.43	10.1	10.1
44	8.87	16.78	14.71	10.2	8.55	9.77
45	4.36	4.63	4.63	10.68	10.76	10.76
46	5.44	32.16	32.16	11.11	1.89	1.89
47	11.98	15.31	15.3	11.2	10.07	10.07
48	6.12	14.98	14.98	11.17	10.22	10.22
49	7.51	15.21	15.21	11.52	10.13	10.13
50	13.59	15.33	15.33	10.79	10.03	10.03
51	14.4	15.01	15.01	10.83	10.36	10.36
52	10.94	15.3	15.3	11.32	10.06	10.06
53	13.09	14.71	14.71	11.05	10.3	10.3

	Nitrate EMC (mg/L)			Nitrate Load (kg/yr)		
Sub-basin	Existing	No-BMP	With-BMP	Existing	No-BMP	With-BMP
1	0.81	0.94	0.94	92.00	114.44	114.44
2	0.75	0.97	0.97	155.83	207.60	207.60
3	0.42	0.39	0.39	200.27	203.61	203.58
4	0.38	0.35	0.35	64.63	72.51	72.51
5	0.65	0.35	0.35	70.86	50.02	50.04
6	0.52	0.44	0.44	98.07	84.86	84.86
7	0.76	0.59	0.59	78.43	67.06	67.06
8	0.79	0.63	0.63	42.95	40.13	40.12
9	0.45	0.41	0.41	35.00	35.42	35.43
10	0.68	0.38	0.38	64.36	49.74	49.74
11	0.43	0.36	0.36	16.37	16.27	16.27
12	1.01	0.44	0.44	77.79	59.41	59.42
13	0.80	0.80	0.80	79.22	78.76	78.76
14	0.85	0.58	0.58	142.93	120.12	102.45
15	1.04	0.75	0.75	99.49	84.91	84.91
16	1.34	0.78	0.78	99.00	94.57	71.79
17	1.52	0.45	0.45	114.35	67.64	43.24
18	1.53	0.45	0.45	72.57	130.02	64.44
19	1.28	0.49	0.49	184.49	150.82	95.94
20	1.52	1.06	1.06	14.53	26.97	26.99
21	1.20	1.03	1.03	47.23	77.98	78.06
22	0.73	0.74	0.74	25.46	89.05	89.05

	Nitrate EMC (mg/L)			Nitrate Load (kg/yr)		
Sub-basin	Existing	No-BMP	With-BMP	Existing	No-BMP	With-BMP
23	0.48	0.43	0.43	75.29	137.89	80.72
24	1.19	0.45	0.45	4.36	23.06	10.52
25	1.46	0.54	0.54	86.90	129.98	129.98
26	1.49	0.45	0.45	59.39	125.05	125.01
27	1.58	0.45	0.45	19.86	36.62	17.51
28	1.41	0.35	0.35	78.07	112.39	112.35
29	1.17	0.39	0.39	44.38	36.72	36.72
30	1.09	1.06	1.06	50.90	56.41	56.41
31	1.59	0.90	0.90	60.69	65.28	65.28
32	0.94	1.13	1.13	41.71	66.23	66.25
33	0.53	0.46	0.46	75.30	385.36	385.36
34	1.22	0.86	0.86	406.24	444.35	444.35
35	1.38	0.58	0.58	78.01	242.11	242.11
36	0.48	0.42	0.42	106.73	156.47	156.47
37	1.06	0.45	0.45	75.65	72.30	72.30
38	1.53	0.42	0.42	281.37	77.15	77.15
39	1.66	0.45	0.45	90.90	82.39	82.39
40	0.61	0.45	0.45	42.87	41.95	41.95
41	0.46	0.45	0.45	45.27	51.83	51.83
42	1.11	0.45	0.45	13.44	22.55	11.18
43	0.49	0.45	0.45	18.96	34.37	34.37
44	0.58	0.45	0.45	19.29	25.01	13.75
45	0.79	0.60	0.60	46.58	37.51	37.52
46	1.17	0.42	0.42	155.94	332.40	332.40
47	0.52	0.45	0.45	96.54	106.68	106.73
48	0.41	0.45	0.45	8.13	21.93	21.93
49	0.47	0.45	0.45	20.35	39.12	39.12
50	0.46	0.45	0.45	24.87	27.48	27.48
51	0.45	0.45	0.45	108.41	112.39	112.41
52	0.66	0.45	0.45	47.65	45.75	45.75
53	0.51	0.45	0.45	69.29	69.24	69.24

	Phosphorus EMC (mg/L)			Phosphorus Load (kg/yr)		
Sub-basin	Existing	No-BMP	With-BMP	Existing	No-BMP	With-BMP
1	0.33	0.45	0.45	37.07	54.48	54.48
2	0.36	0.46	0.46	74.60	97.74	97.74
3	0.30	0.35	0.35	145.80	183.86	183.83
4	0.37	0.55	0.55	63.18	113.95	113.95
5	0.26	0.30	0.30	28.58	43.57	43.59

	Phosphorus EMC (mg/L)			Phosphorus Load (kg/yr)		
Sub-basin	Existing	No-BMP	With-BMP	Existing	No-BMP	With-BMP
6	0.39	0.41	0.41	73.03	79.60	79.60
7	0.35	0.36	0.36	36.68	41.02	41.02
8	0.28	0.35	0.35	15.29	22.18	22.18
9	0.38	0.42	0.42	29.48	36.42	36.43
10	0.37	0.47	0.47	34.82	61.52	61.52
11	0.42	0.54	0.54	16.19	24.41	24.41
12	0.32	0.36	0.36	24.61	48.38	48.38
13	0.15	0.15	0.15	14.99	14.90	14.90
14	0.24	0.26	0.26	39.64	55.04	46.80
15	0.19	0.21	0.21	18.47	24.41	24.41
16	0.26	0.28	0.28	19.22	34.10	25.86
17	0.27	0.33	0.33	20.28	49.57	31.53
18	0.30	0.33	0.33	14.40	96.50	47.22
19	0.30	0.32	0.32	43.56	98.85	62.23
20	0.28	0.31	0.31	2.63	7.80	7.80
21	0.27	0.26	0.26	10.40	19.49	19.51
22	0.35	0.32	0.32	12.06	38.70	38.70
23	0.30	0.19	0.19	47.82	60.73	34.01
24	0.27	0.33	0.33	0.98	16.81	7.44
25	0.28	0.40	0.40	16.55	97.84	97.84
26	0.30	0.33	0.33	12.16	91.95	91.93
27	0.29	0.33	0.33	3.63	26.63	12.51
28	0.32	0.55	0.55	17.71	59.70	59.68
29	0.33	0.46	0.46	12.37	43.77	43.77
30	0.32	0.41	0.41	14.82	21.71	21.71
31	0.30	0.33	0.33	11.43	23.80	23.80
32	0.33	0.28	0.28	14.49	16.08	16.09
33	0.37	0.20	0.20	53.29	169.08	169.08
34	0.24	0.20	0.20	80.90	101.12	101.12
35	0.31	0.13	0.13	17.42	55.88	55.88
36	0.22	0.11	0.11	48.52	40.96	40.96
37	0.30	0.33	0.33	21.16	53.07	53.07
38	0.28	0.11	0.11	51.04	20.25	20.25
39	0.30	0.33	0.33	16.59	60.42	60.42
40	0.32	0.33	0.33	22.62	30.76	30.76
41	0.35	0.33	0.33	34.49	38.01	38.01
42	0.39	0.33	0.33	4.78	16.54	8.04
43	0.55	0.33	0.33	21.32	25.17	25.17

	Phosphorus EMC (mg/L)			Phosphorus Load (kg/yr)		
Sub-basin	Existing	No-BMP	With-BMP	Existing	No-BMP	With-BMP
44	0.48	0.33	0.33	15.96	18.40	9.98
45	0.45	0.55	0.55	26.35	34.17	34.18
46	0.37	0.11	0.11	49.21	89.53	89.53
47	0.36	0.33	0.33	66.37	78.23	78.27
48	0.43	0.33	0.33	8.51	16.08	16.08
49	0.42	0.33	0.33	17.95	28.69	28.69
50	0.34	0.33	0.33	18.66	20.15	20.15
51	0.33	0.33	0.33	79.05	82.42	82.43
52	0.31	0.33	0.33	22.58	33.55	33.55
53	0.33	0.33	0.33	44.99	50.78	50.78

	Copper EMC (microg/L)			Copper Load (kg/yr)		
Sub-basin	Existing	No-BMP	With-BMP	Existing	No-BMP	With-BMP
1	8.76	10.86	10.86	0.99	1.32	1.32
2	7.16	8.10	8.10	1.49	1.73	1.73
3	5.49	9.22	9.22	2.64	4.87	4.87
4	8.77	15.00	15.00	1.48	3.11	3.11
5	8.06	10.55	10.55	1.26	2.17	2.17
6	6.61	7.55	7.55	1.25	1.45	1.45
7	8.52	10.56	10.56	0.88	1.20	1.20
8	7.54	10.40	10.40	0.41	0.66	0.66
9	6.20	9.07	9.07	0.48	0.78	0.78
10	7.54	13.48	13.48	0.72	1.76	1.76
11	11.66	15.34	15.34	0.45	0.70	0.70
12	11.41	19.40	19.40	0.88	2.63	2.63
13	6.92	6.92	6.92	0.68	0.68	0.68
14	7.14	10.64	10.64	1.20	2.22	1.92
15	7.87	11.05	11.05	0.75	1.26	1.26
16	9.21	14.52	14.52	0.68	1.75	1.34
17	9.39	19.98	19.98	0.71	3.00	1.93
18	10.06	19.93	19.93	0.48	5.78	2.88
19	9.40	19.32	19.32	1.35	5.94	3.81
20	9.51	14.58	14.58	0.09	0.37	0.37
21	8.84	11.91	11.91	0.35	0.91	0.91
22	7.20	17.65	17.65	0.25	2.12	2.12
23	13.59	23.19	23.19	2.14	7.42	4.39
24	8.81	20.05	20.05	0.03	1.03	0.48
25	10.05	15.13	15.13	0.60	3.67	3.67

	Copper EMC (microg/L)			Copper Load (kg/yr)		
Sub-basin	Existing	No-BMP	With-BMP	Existing	No-BMP	With-BMP
26	9.85	19.99	19.99	0.39	5.56	5.56
27	9.72	20.07	20.07	0.12	1.63	0.79
28	10.50	15.00	15.00	0.56	2.73	2.72
29	10.53	16.96	16.96	0.40	1.60	1.60
30	10.32	12.69	12.69	0.48	0.68	0.68
31	9.99	16.19	16.19	0.38	1.18	1.18
32	6.51	7.71	7.71	0.29	0.45	0.45
33	12.99	20.89	20.89	1.85	17.61	17.61
34	8.81	13.39	13.39	2.95	6.90	6.90
35	11.42	23.14	23.14	0.65	9.68	9.68
36	20.08	24.99	24.99	4.49	9.30	9.30
37	13.45	19.99	19.99	1.37	4.59	4.59
38	11.89	24.99	24.99	2.18	4.59	4.59
39	10.28	20.00	20.00	0.80	5.23	5.23
40	18.43	20.00	20.00	1.85	2.66	2.66
41	18.46	20.00	20.00	2.57	3.29	3.29
42	11.86	20.00	20.00	0.14	1.00	0.50
43	9.58	20.01	20.01	0.53	2.18	2.18
44	13.35	19.83	19.83	0.45	1.10	0.61
45	6.03	5.16	5.16	0.36	0.32	0.32
46	9.89	24.88	24.88	1.89	28.07	28.07
47	17.67	20.00	20.00	4.69	6.77	6.78
48	10.02	20.00	20.00	0.29	1.39	1.39
49	12.00	20.00	20.00	0.74	2.48	2.48
50	18.99	20.00	20.00	1.47	1.74	1.74
51	19.98	20.00	20.00	6.84	7.14	7.14
52	17.51	20.00	20.00	1.82	2.90	2.90
53	19.55	20.00	20.00	3.82	4.40	4.40

	Zinc EMC (microg/L)			Zinc Load (kg/yr)		
Sub-basin	Existing	No-BMP	With-BMP	Existing	No-BMP	With-BMP
1	46.95	60.10	60.10	5.30	7.28	7.28
2	37.25	42.42	42.42	7.73	9.05	9.05
3	28.17	52.27	52.27	13.54	27.59	27.59
4	49.50	90.00	90.00	8.36	18.65	18.65
5	43.15	61.44	61.44	6.73	12.65	12.66
6	35.08	41.56	41.56	6.61	8.01	8.01
7	45.82	60.26	60.26	4.74	6.88	6.88

	Zinc EMC (microg/L)			Zinc Load (kg/yr)		
Sub-basin	Existing	No-BMP	With-BMP	Existing	No-BMP	With-BMP
8	39.13	58.61	58.61	2.12	3.73	3.73
9	32.83	51.48	51.48	2.55	4.45	4.45
10	40.04	80.43	80.43	3.80	10.48	10.48
11	67.83	92.35	92.35	2.60	4.21	4.21
12	63.51	120.77	120.77	4.87	16.38	16.39
13	34.60	34.60	34.60	3.41	3.39	3.39
14	36.11	61.38	61.38	6.07	12.81	11.04
15	39.58	62.79	62.79	3.77	7.15	7.15
16	46.73	85.95	85.95	3.45	10.38	7.93
17	46.98	124.84	124.84	3.53	18.77	12.00
18	51.32	124.53	124.53	2.44	36.09	17.87
19	48.44	120.17	120.17	6.97	36.95	23.53
20	47.72	84.71	84.71	0.46	2.15	2.15
21	45.16	66.93	66.93	1.77	5.09	5.10
22	37.53	107.39	107.39	1.31	12.87	12.87
23	82.88	147.31	147.31	13.05	47.14	26.91
24	45.05	125.34	125.34	0.17	6.43	2.92
25	51.71	92.00	92.00	3.07	22.35	22.35
26	50.19	124.92	124.92	2.00	34.76	34.75
27	48.82	125.49	125.49	0.61	10.22	4.88
28	54.83	90.00	90.00	2.86	16.47	16.46
29	56.33	103.71	103.71	2.13	9.79	9.79
30	55.40	71.20	71.20	2.60	3.80	3.80
31	50.51	96.53	96.53	1.93	7.01	7.01
32	32.79	39.26	39.26	1.46	2.29	2.29
33	78.93	132.23	132.23	11.24	111.49	111.49
34	44.83	78.11	78.11	14.99	40.23	40.23
35	61.95	146.35	146.35	3.51	61.25	61.25
36	126.67	159.95	159.95	28.35	59.51	59.51
37	77.07	124.96	124.96	7.83	28.69	28.69
38	63.89	159.92	159.92	11.73	29.37	29.37
39	52.09	125.00	125.00	4.08	32.69	32.69
40	113.43	125.00	125.00	11.40	16.65	16.65
41	114.73	125.00	125.00	15.97	20.57	20.57
42	65.37	125.00	125.00	0.79	6.26	3.10
43	54.80	125.08	125.08	3.05	13.65	13.65
44	78.03	123.89	123.89	2.61	6.86	3.77
45	30.15	26.02	26.02	1.78	1.62	1.62

	Zinc EMC (microg/L)			Zinc Load (kg/yr)		
Sub-basin	Existing	No-BMP	With-BMP	Existing	No-BMP	With-BMP
46	53.32	159.20	159.20	10.18	179.59	179.59
47	109.13	125.00	125.00	28.94	42.33	42.35
48	57.79	125.00	125.00	1.64	8.70	8.70
49	71.41	125.00	125.00	4.38	15.52	15.53
50	118.29	125.00	125.00	9.15	10.90	10.90
51	124.84	125.00	125.00	42.73	44.60	44.61
52	106.97	125.00	125.00	11.11	18.16	18.16
53	121.63	125.00	125.00	23.79	27.48	27.48

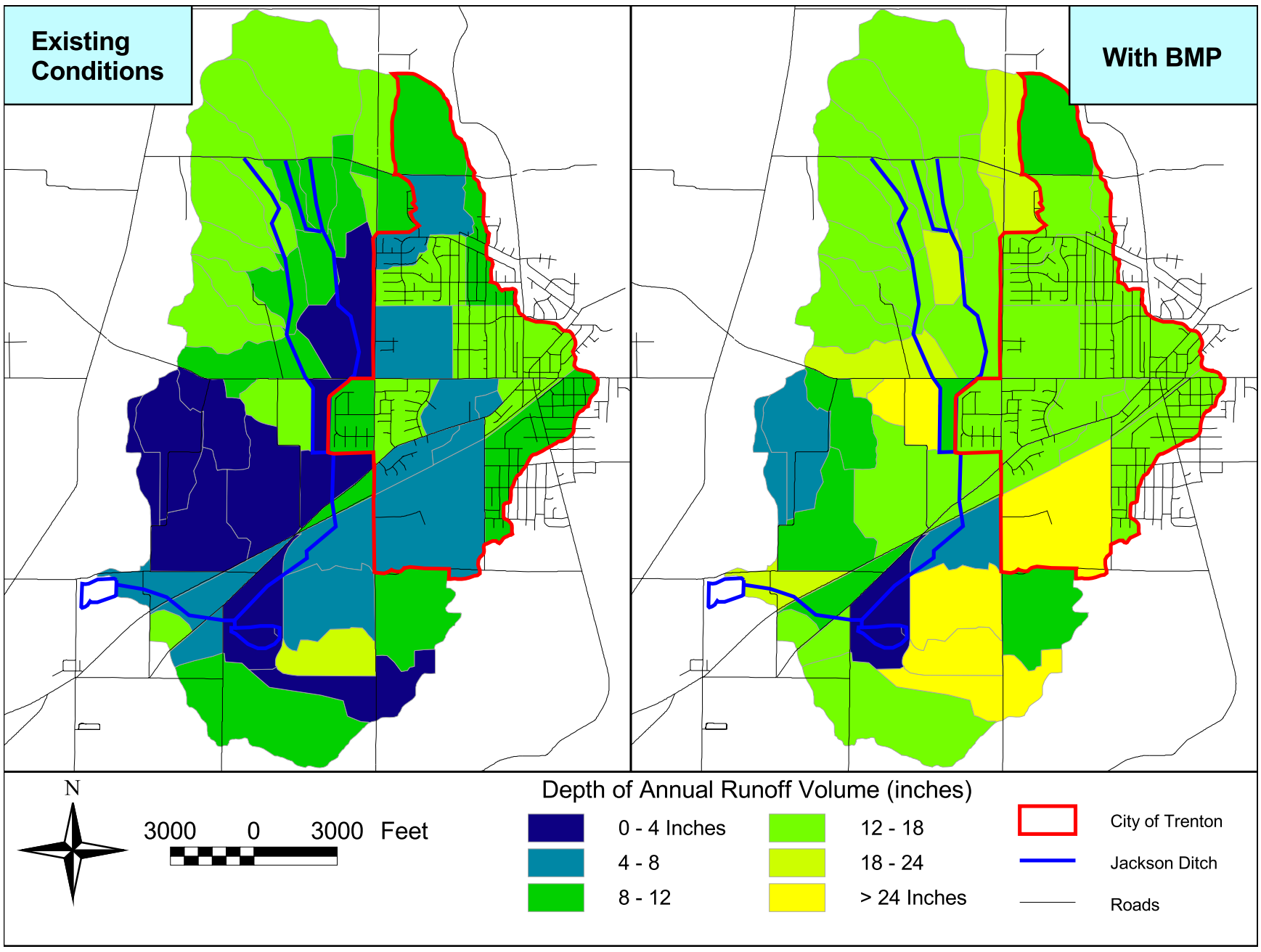
	Chloride EMC (mg/L)			Chloride Load (kg/yr)		
Sub-basin	Existing	No-BMP	With-BMP	Existing	No-BMP	With-BMP
1	17.8	30.5	30.5	2,222	4,076	4,076
2	8.4	10.8	10.8	1,941	2,573	2,573
3	4.3	33.1	33.1	2,248	19,083	19,083
4	30.1	65.1	65.1	5,436	14,425	14,425
5	17.9	50.5	50.5	4,404	14,718	14,718
6	11.2	20.7	20.7	2,422	4,581	4,581
7	18.0	40.8	40.8	2,381	5,934	5,934
8	8.5	35.7	35.7	647	3,071	3,071
9	10.0	31.0	31.0	1,028	3,496	3,496
10	14.1	63.2	63.2	1,675	9,701	9,701
11	47.5	68.1	68.1	2,077	3,485	3,485
12	39.0	102.2	102.2	4,538	17,510	17,510
13	0.2	0.2	0.2	17	17	17
14	2.5	49.2	50.3	486	11,580	11,580
15	1.3	46.2	46.2	135	5,692	5,692
16	4.5	72.2	74.4	529	12,229	12,229
17	0.1	103.7	106.4	10	18,846	18,846
18	6.7	105.8	108.5	1,954	56,859	56,859
19	9.0	105.0	104.4	1,982	39,115	39,115
20	1.2	68.8	68.8	91	6,675	6,675
21	6.1	47.6	47.6	1,495	14,039	14,039
22	9.5	92.5	92.5	1,720	25,701	25,701
23	54.5	90.3	86.2	12,680	29,590	29,590
24	6.8	105.9	108.2	388	11,434	11,434
25	6.8	45.7	45.7	2,462	33,493	33,493
26	5.9	105.5	105.5	1,837	57,730	57,730
27	1.5	104.7	106.8	128	16,692	16,692

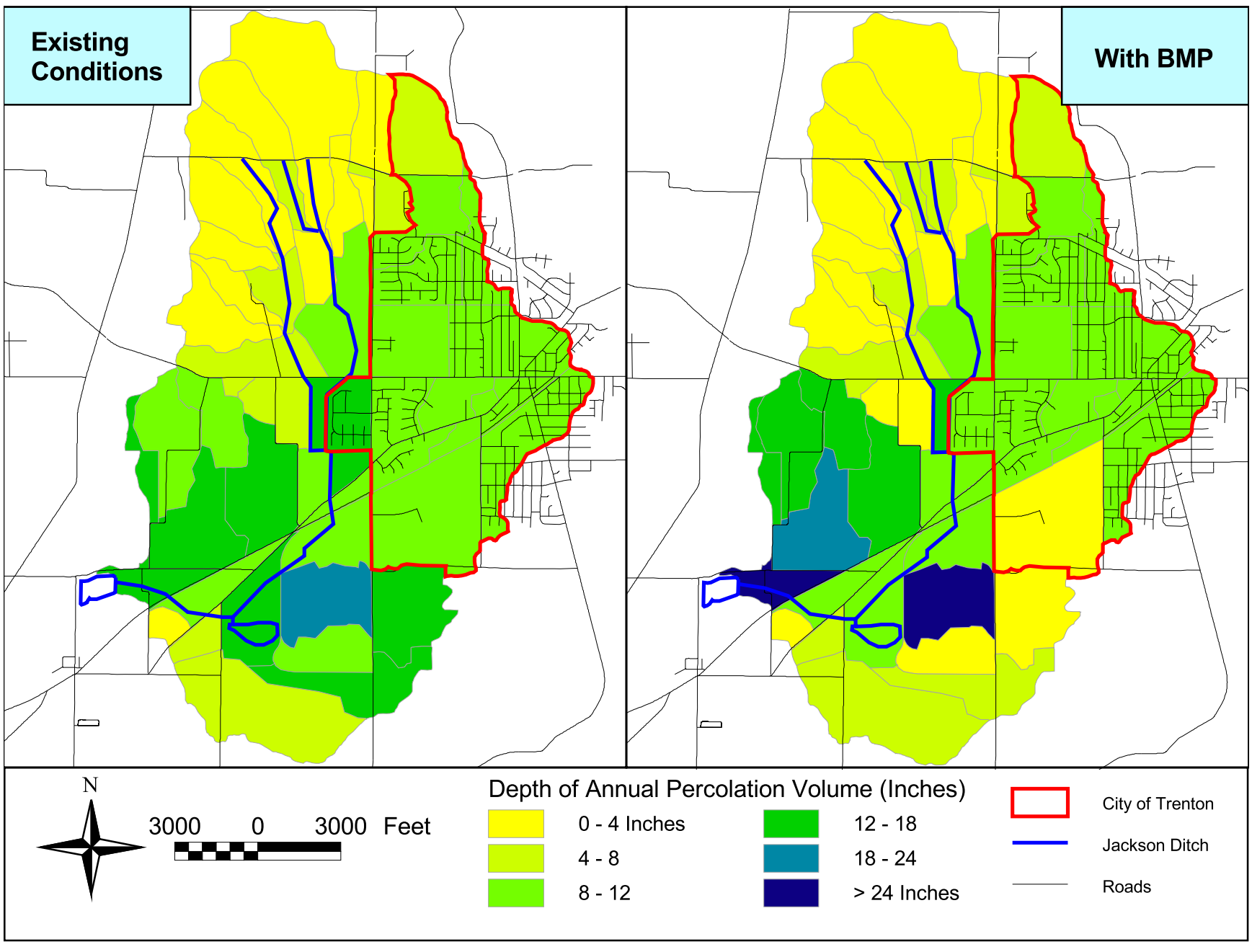
	Chloride EMC (mg/L)			Chloride Load (kg/yr)		
Sub-basin	Existing	No-BMP	With-BMP	Existing	No-BMP	With-BMP
28	8.9	26.7	26.7	1,689	10,828	10,828
29	20.8	82.7	82.7	2,895	16,531	16,531
30	21.2	40.6	40.6	1,157	2,460	2,460
31	3.5	80.5	80.5	251	8,196	8,196
32	1.4	3.9	3.9	335	985	985
33	36.5	26.8	26.8	19,597	38,975	38,975
34	4.9	46.0	46.0	2,344	30,688	30,688
35	21.8	73.7	73.7	6,011	38,042	38,042
36	69.2	76.8	76.8	22,775	30,309	30,309
37	60.3	107.1	107.1	15,614	39,950	39,950
38	14.9	232.0	232.0	6,573	51,624	51,624
39	4.8	104.7	104.7	1,280	46,399	46,399
40	99.1	106.3	106.2	21,691	25,473	25,473
41	99.4	104.9	104.9	26,421	29,508	29,508
42	33.9	31.0	107.3	2,037	10,063	10,063
43	33.3	103.6	103.6	4,327	18,780	18,780
44	51.7	124.7	106.2	3,713	9,781	9,781
45	0.0	1.7	1.7	0	343	343
46	17.6	76.8	76.8	10,237	91,797	91,797
47	94.1	103.6	103.6	48,289	58,159	58,159
48	40.2	104.3	104.3	3,228	12,212	12,212
49	61.2	103.7	103.7	9,505	21,452	21,452
50	100.5	103.6	103.6	13,940	14,949	14,949
51	103.9	103.6	103.6	62,333	62,465	62,465
52	91.7	103.6	103.6	19,373	24,948	24,948
53	103.9	105.1	105.1	37,496	39,259	39,259

	Sediment EMC (mg/L)			Sediment Load (kg/yr)		
Sub-basin	Existing	No-BMP	With-BMP	Existing	No-BMP	With-BMP
1	2,058	2,502	2,502	1,767	2,339	2,335
2	1,536	2,308	2,308	2,442	3,520	3,521
3	102	244	244	370	907	909
4	114	160	160	140	279	278
5	1,465	97	97	2,764	181	181
6	432	124	124	578	165	165
7	1,726	1,025	1,025	1,025	742	741
8	1,967	1,347	1,347	734	603	604
9	116	127	127	49	58	58

	Sediment EMC (mg/L)			Sediment Load (kg/yr)		
Sub-basin	Existing	No-BMP	With-BMP	Existing	No-BMP	With-BMP
10	1,250	141	141	1,028	176	176
11	478	157	157	135	87	87
12	2,928	116	116	1,415	367	367
13	2,297	2,297	2,297	1,777	1,784	1,784
14	2,286	928	928	3,663	5,836	2,252
15	3,292	1,850	1,850	2,676	2,338	2,338
16	4,511	1,832	1,832	2,761	5,888	1,624
17	5,263	110	110	1,952	7,063	358
18	5,265	111	111	8,335	21,342	1,724
19	4,167	321	321	5,648	14,685	5,052
20	5,257	3,023	3,023	2,189	1,860	1,859
21	3,881	3,002	3,002	6,202	5,975	5,984
22	1,494	1,491	1,491	1,988	13,962	13,962
23	148	110	110	407	17,658	9,150
24	3,796	110	110	979	4,359	571
25	4,996	422	422	10,617	6,849	6,849
26	5,070	110	110	8,290	2,492	2,492
27	5,483	110	110	2,313	6,317	573
28	4,754	160	160	5,715	2,009	2,009
29	3,756	140	140	3,364	455	454
30	3,400	3,195	3,195	1,247	1,319	1,319
31	5,539	2,242	2,242	2,698	1,699	1,702
32	2,543	3,607	3,607	3,227	4,855	4,849
33	143	120	120	648	46,280	46,280
34	3,986	2,345	2,345	12,748	10,377	10,381
35	4,424	110	839	6,999	13,812	13,812
36	186	112	112	6,735	29,513	29,513
37	3,084	110	110	4,969	1,809	1,809
38	5,228	110	110	9,804	48,915	48,915
39	5,813	110	110	9,454	1,658	1,658
40	876	110	110	5,922	1,636	1,636
41	121	110	110	1,270	1,985	1,985
42	3,437	110	110	1,249	3,803	388
43	160	110	110	136	944	944
44	1,140	111	111	490	3,753	329
45	1,351	172	172	1,649	223	223
46	3,272	110	110	10,252	79,386	79,386
47	359	110	110	6,231	4,052	4,051

	Sediment EMC (mg/L)			Sediment Load (kg/yr)		
Sub-basin	Existing	No-BMP	With-BMP	Existing	No-BMP	With-BMP
48	128	110	110	59	531	532
49	128	110	110	116	864	864
50	113	110	110	794	1,120	1,120
51	122	110	110	3,959	4,118	4,117
52	1,123	110	110	6,473	1,740	1,739
53	364	110	110	6,161	2,620	2,620





XCG

Butler County Storm Water District
Trenton Area Storm Water Management Project

Figure D.1 Depth of Runoff and Percolation

Existing Conditions

With BMP

N

3000 0 3000 Feet

Estimated Annual Nitrate Concentration

- 0.0 - 0.5 mg/l
- 0.5 - 1.0 Ohio Water Quality Standard
- 1.0 - 2.0
- 2.0 - 4.0
- 10.0 US & OH EPA Maximum Contaminant Level

City of Trenton

Jackson Ditch

Roads

Existing Conditions

With BMP

N

3000 0 3000 Feet

Estimated Annual Nitrate Load

- 0 - 25 kg/yr
- 25 - 50
- 50 - 75
- 75 - 100
- 100 - 200
- > 200 kg/yr

City of Trenton

Jackson Ditch

Roads

XCG

Butler County Storm Water District
Trenton Area Storm Water Management Project

Figure D.2 Nitrate Concentrations and Loads

Existing Conditions

With BMP

N

3000 0 3000 Feet

Estimated Annual Phosphorus Concentration

0.0 - 0.1 mg/L
0.1 - 0.2
0.2 - 0.3
0.3 - 0.5
> 0.5 mg/L

City of Trenton
Jackson Ditch
Roads

Existing Conditions

With BMP

N

3000 0 3000 Feet

Estimated Annual Phosphorus Load

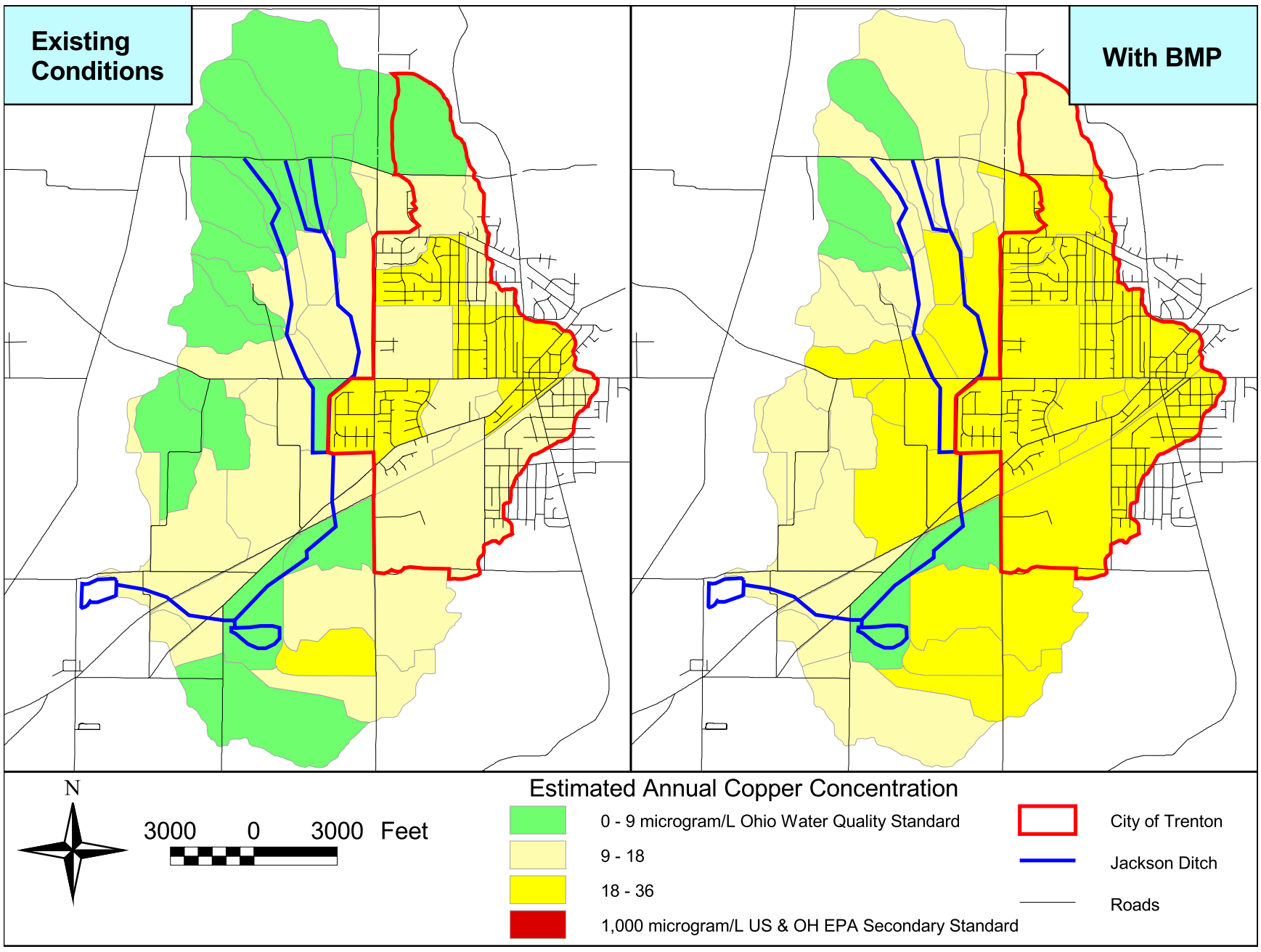
0 - 10 kg/yr
10 - 20
20 - 30
30 - 50
50 - 70
> 70 kg/yr

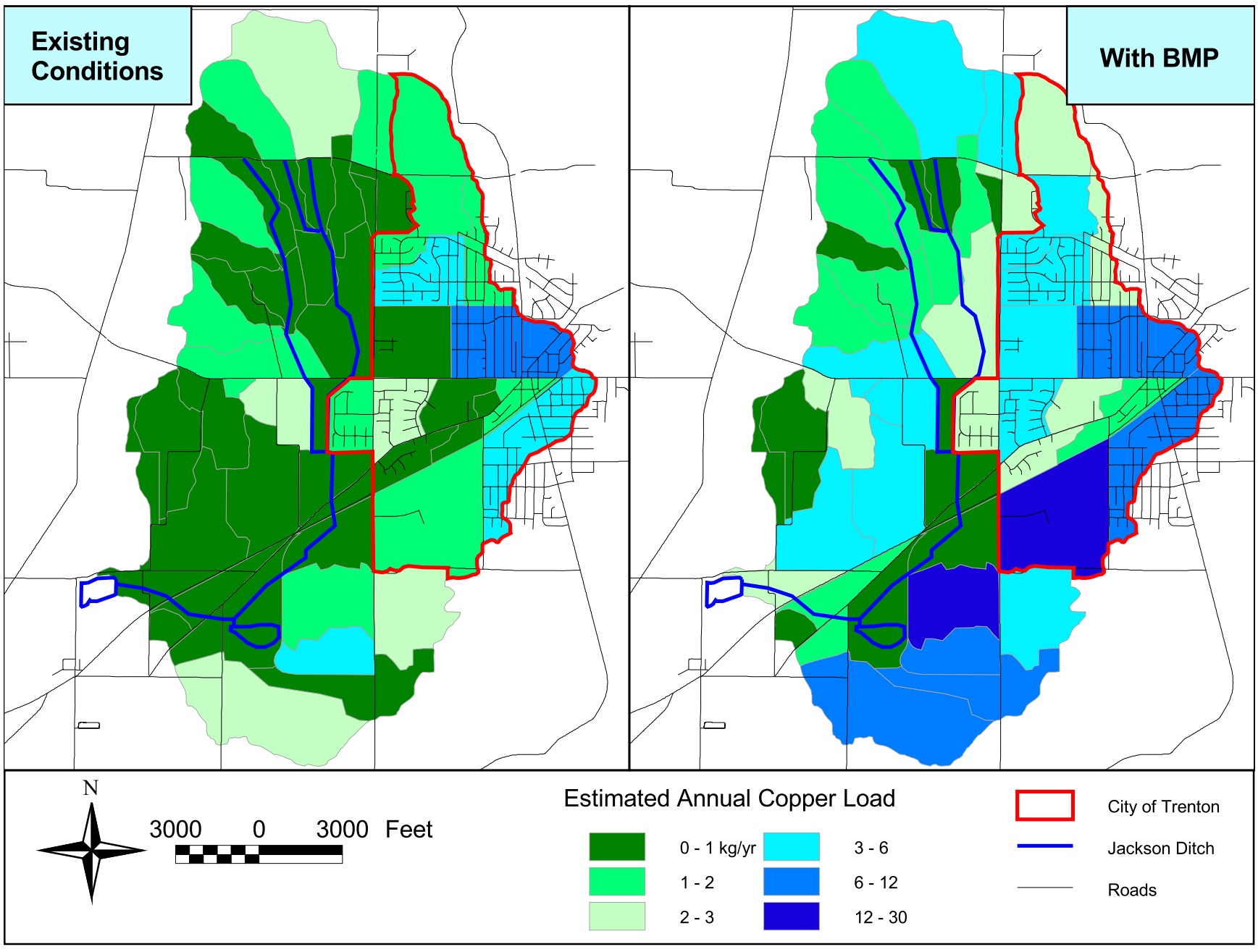
City of Trenton
Jackson Ditch
Roads

XCG

Butler County Storm Water District
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Figure D.3 Phosphorus Concentrations and Loads

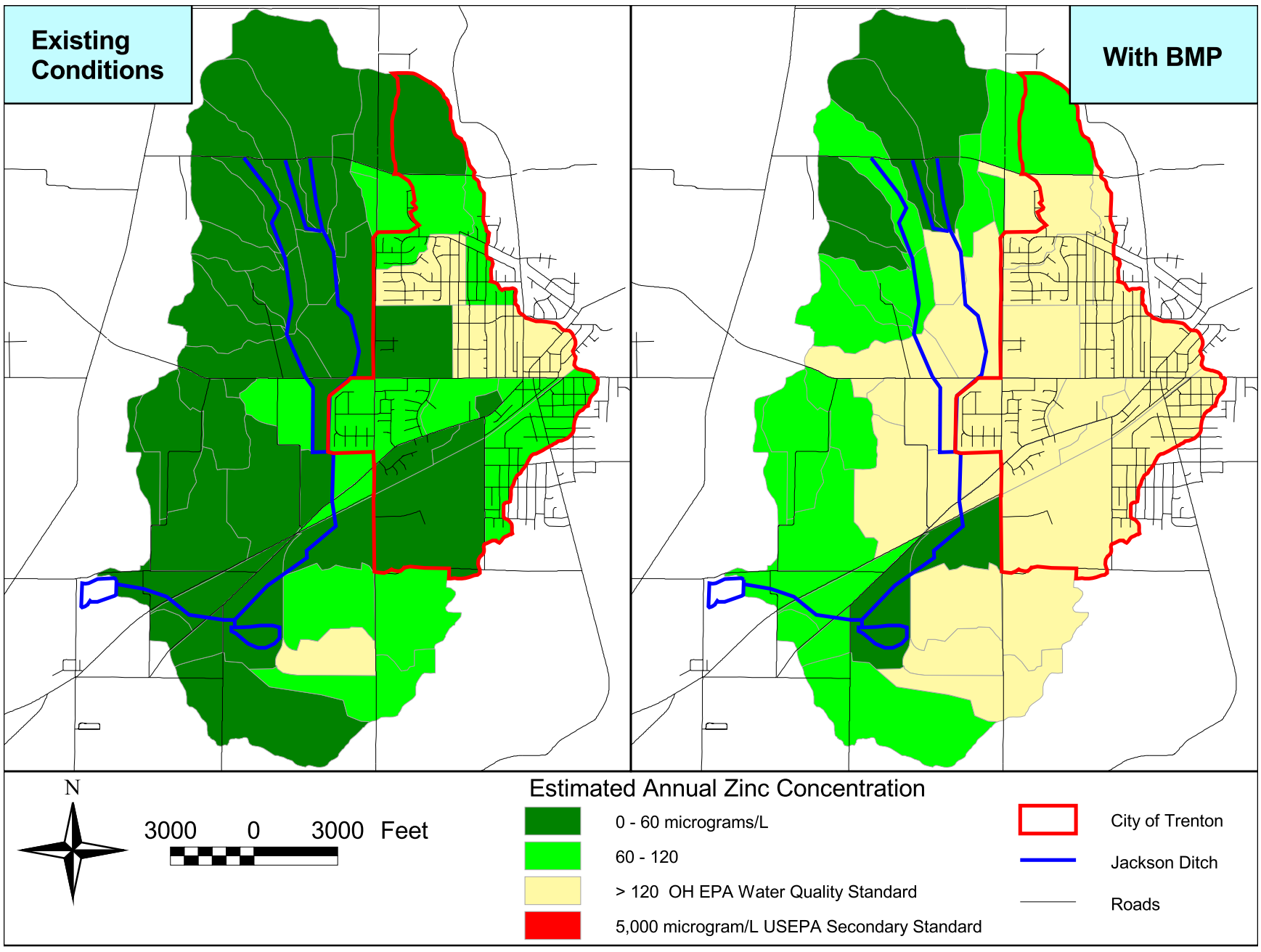


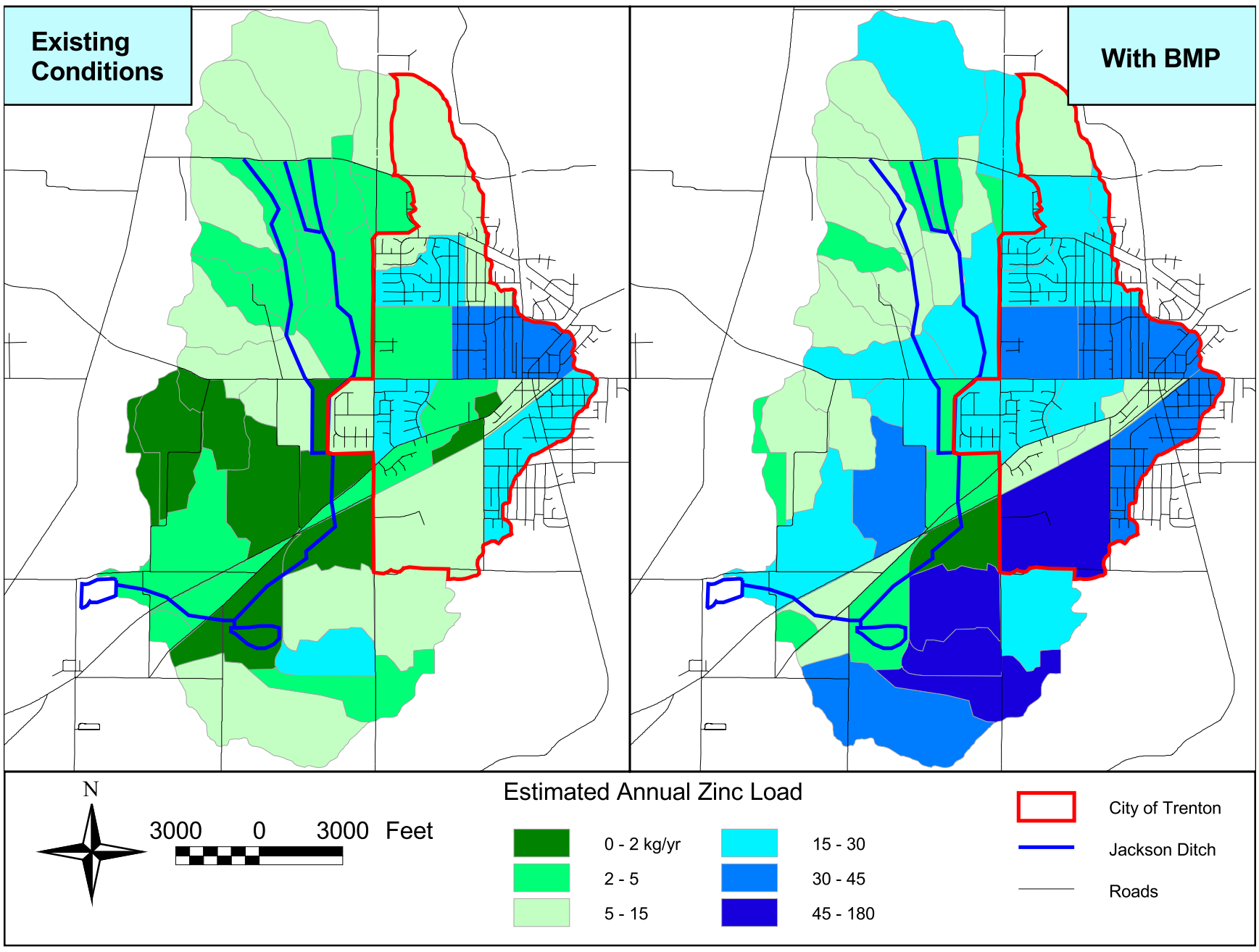


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Butler County Storm Water District
Trenton Area Storm Water Management Project

Figure D.4 Copper Concentrations and Loads

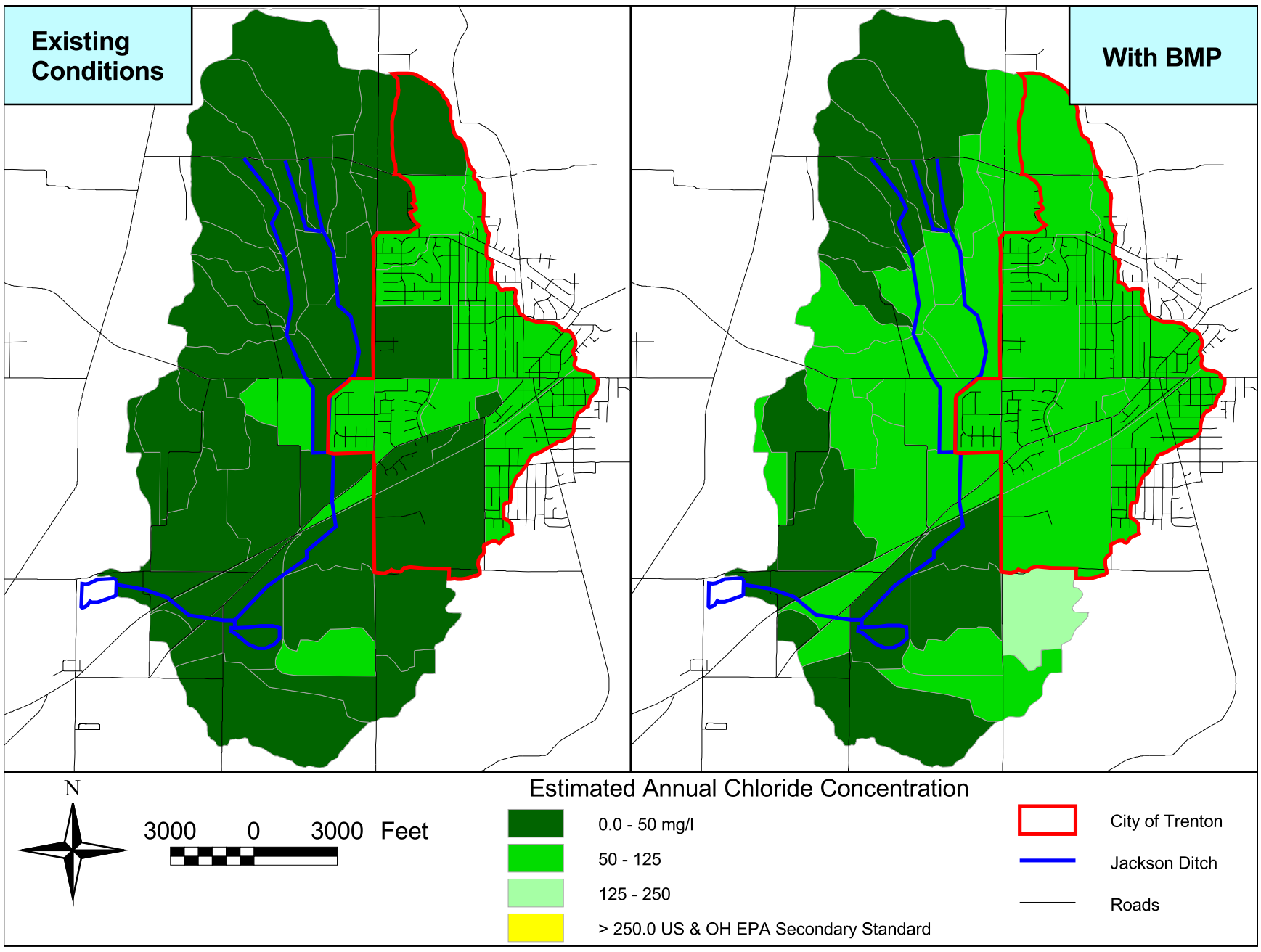


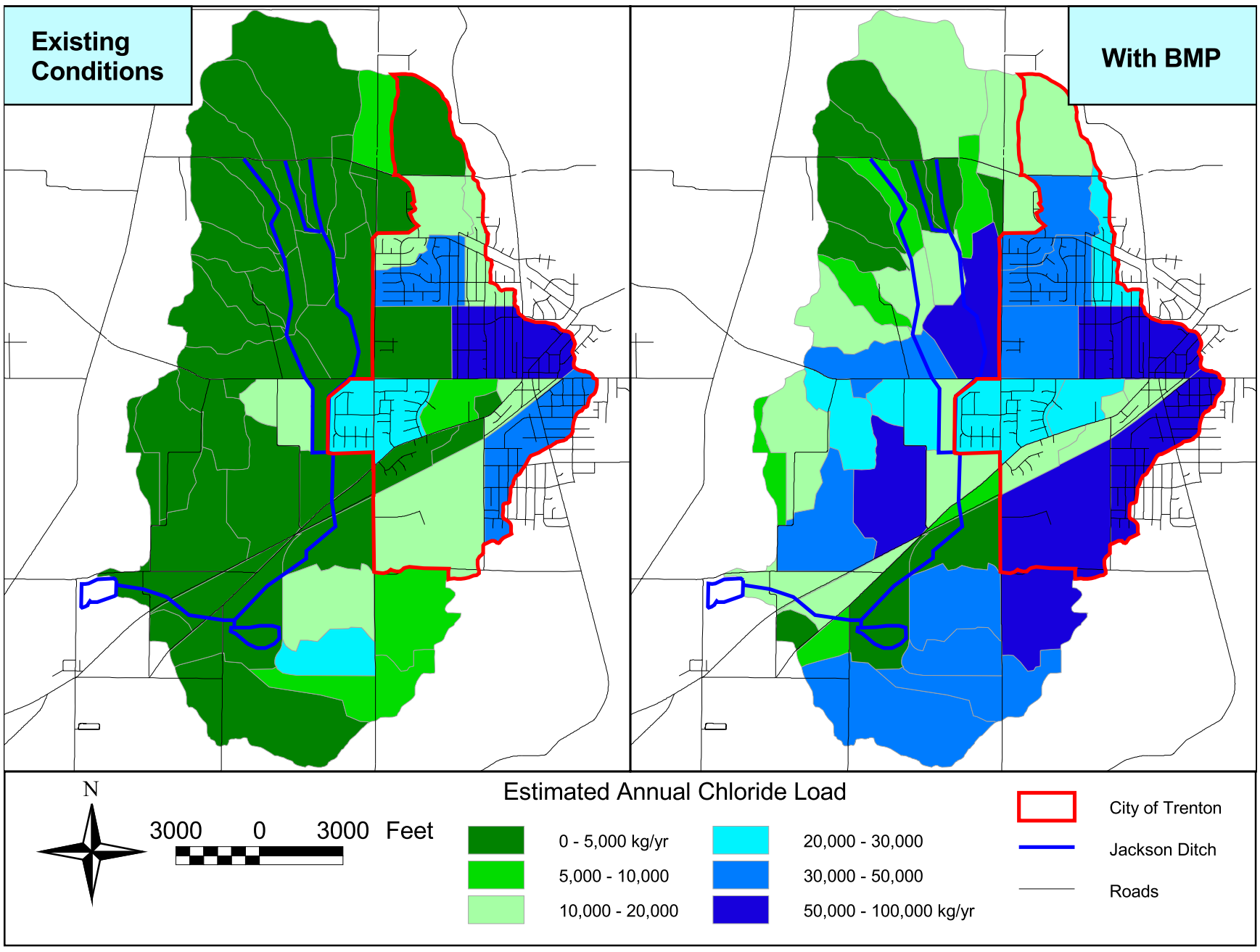


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Butler County Storm Water District
Trenton Area Storm Water Management Project

Figure D.5 Zinc Concentrations and Loads

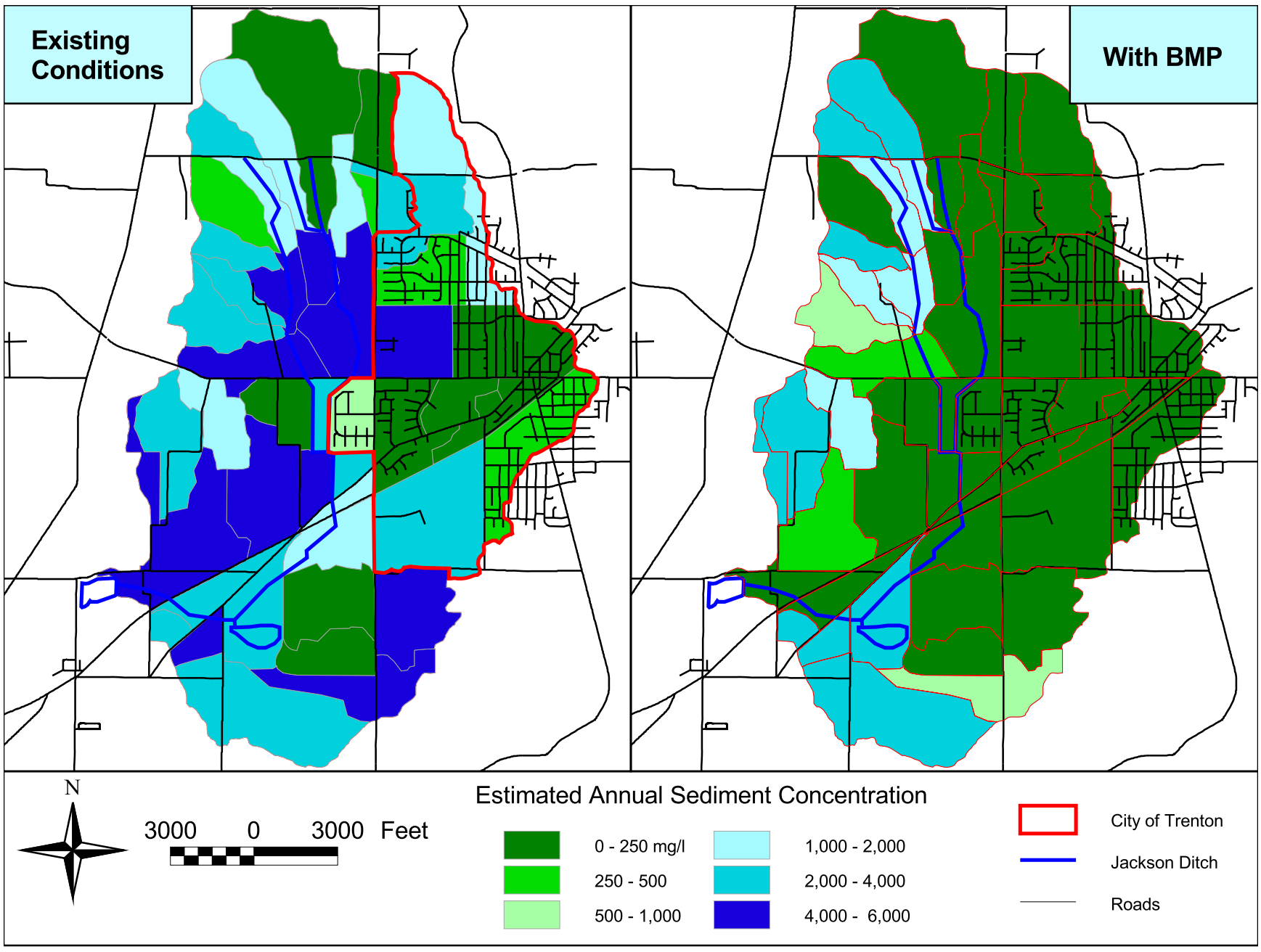


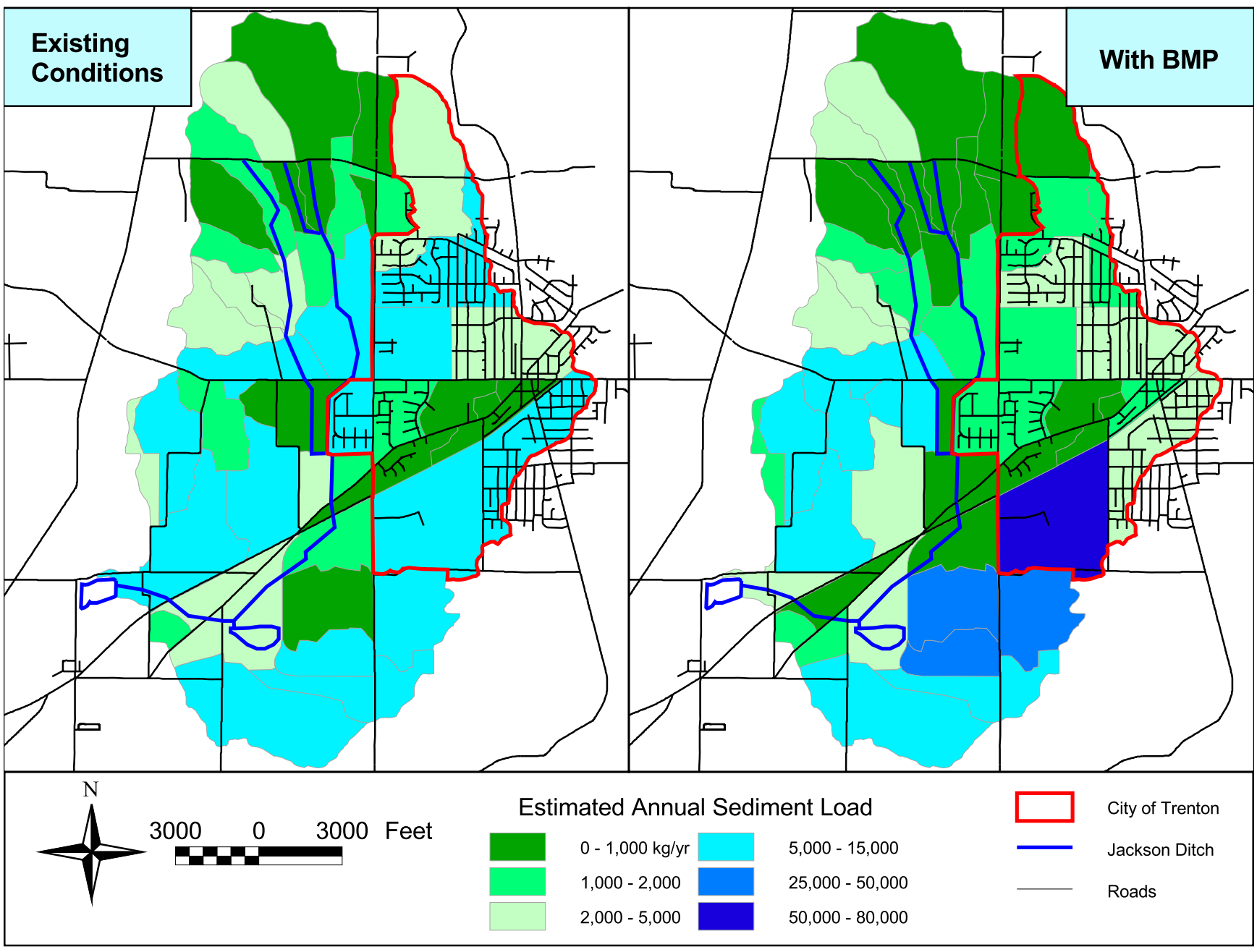


XCG

Butler County Storm Water District
Trenton Area Storm Water Management Project

Figure D.6 Chloride Concentrations and Loads





XCG

Butler County Storm Water District
Trenton Area Storm Water Management Project

Figure D.7 Sediment Concentrations and Loads

Watershed Modeling Report
Trenton Area Storm Water Management Project
Butler County, Ohio

Appendix
Swale Modeling Results

Watershed Modeling Report
Appendix Swale Modeling Results

Trenton Area Storm Water Management Project
Butler County, Ohio

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Modeling Impacts of Recommended Best Management Practices

1. Water Quality Model Changes

The water quality model developed for the future development with some best management practices installed (WithBMP) was used as the starting point for studying more in depth BMP uses.

1.1. Hydrologic and Hydraulic Modeling

To model the effects large scale use of water quality BMP's would have on Trenton area runoff, fifteen sub-basins were selected. The sub-basins were selected as those to be primarily or completely developed to residential, urban, or industrial land uses in the future. The selected sub-basins are highlighted in Figure 1.1.

The modeled BMP combination was a grassed swale flowing to a dry detention basin. Each 1,000-foot long swale and its basin were assumed to serve a 20-acre parcel having the average properties of the sub-basin. No infiltration was assumed to occur in the swales to prevent double counting infiltration, as the swales will be contained in the pervious areas of the sub-basins. The basins were assumed to have infiltration as the runoff would pool there longer than would have occurred on the original pervious surface.

A grassed swale improves runoff water quality by providing a habitat for microorganisms that feed on dissolved nutrients. Additionally, the grass captures suspended sediment. Finally, the swale slows the runoff to reduce peak flows downstream. The grassed swale was modeled as a trapezoidal channel with a 5-feet wide flat bottom with side slopes of 1 vertical on 4 horizontal. The flow entering the swale was modeled as being from the pervious portions of the 20-acre parcel. That is, the percentage of the sub-basin that was pervious was multiplied by 20-acres and the depth of runoff to calculate the runoff to the swale. The swale was modeled as having either a 2% or a 0.5% slope depending on the sub-basin topography.

The dry detention basin improves water quality by storing water for an extended time. Detention basins are normally designed to hold runoff for 24 to 48-hours. While runoff is held in the basin, suspended sediment is able to settle to the bottom and some biological activity occurs. Given sufficient time, the majority of suspended sediment will settle out and the dissolved nutrients will decrease. Each swale empties into a dry storm water basin. The basin bottom was set to 40-feet wide and 240-feet long. The side slopes of the basin were 1 vertical on 4 horizontal. A 5-inch or 6-inch pipe at the basin bottom and an overflow weir 4-feet above the bottom drain the basin. The pipe diameter was chosen to limit outflow so that the runoff of the largest event modeled was detained for at least one day but less than four days. The overflow weir was set to contain the water quality runoff volume of 0.75 inches of rain on an industrial/ commercial area (runoff coefficient 0.8) from the contributing 20 acres. This method for sizing ponds was determined by the Ohio EPA based on research into rainfall events and polluted runoff. The water quality volume is estimated to capture and allow treatment of the total runoff volume for 85% of the storms during an average year. Treatment of the runoff, in this case, being filtration, infiltration, settling, and biological activity due to the BMP's installed.

The swales and basins for Sub-basins 22, 25, and 26 discharges into a large swale flowing to Jackson Ditch. The swale was modeled as having a 10-foot wide base and a slope of 0.5%. The swale discharges to Jackson Ditch near the quarry. As runoff would slowly flow through this swale, infiltration was assumed to occur in this swale.

Sub-basin 38 land use changed from primarily cropland in the existing conditions to completely commercial/industrial in the future conditions. For Sub-basin 38, a single large dry detention pond was assumed. Outflow from Sub-basin 38 passes through a culvert under Wayne Madison Road. The outflow from the dry detention basin was limited to the flow through a 24-inch pipe. This restriction causes deep ponding (up to 10-feet) in the detention basin.

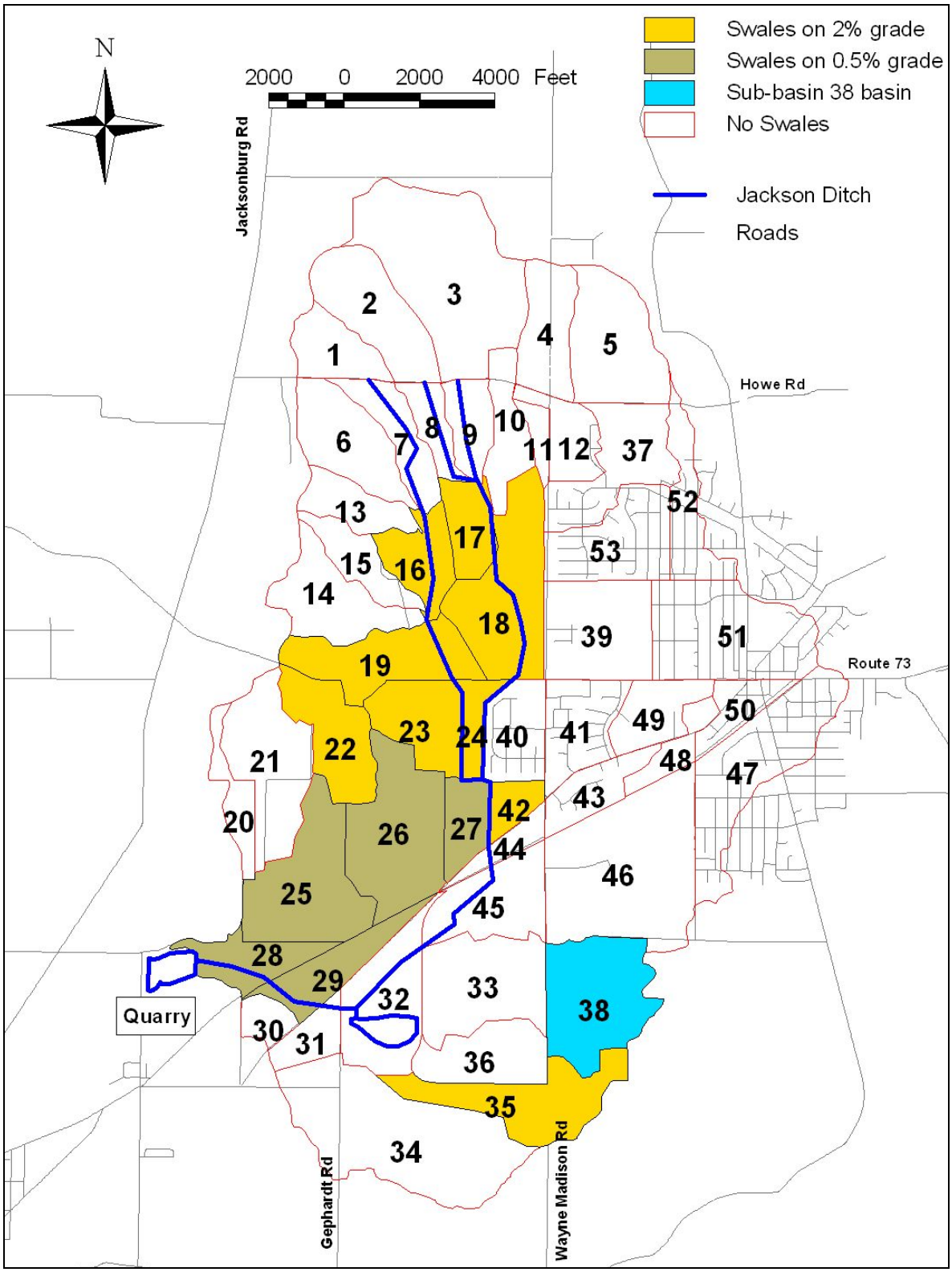


Figure 1.1 Sub-Basins with Swales

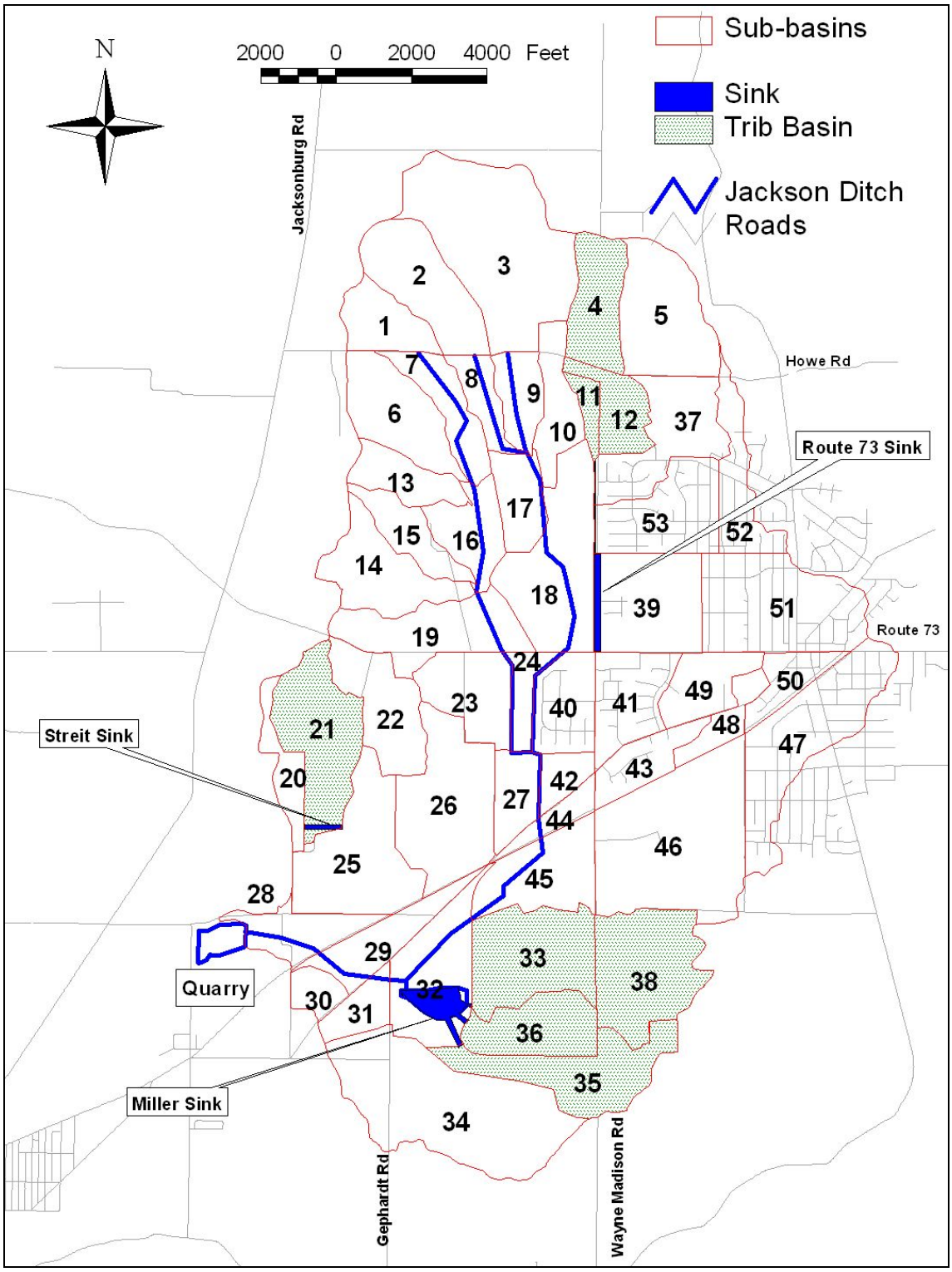


Figure 1.2 Infiltration Sinks

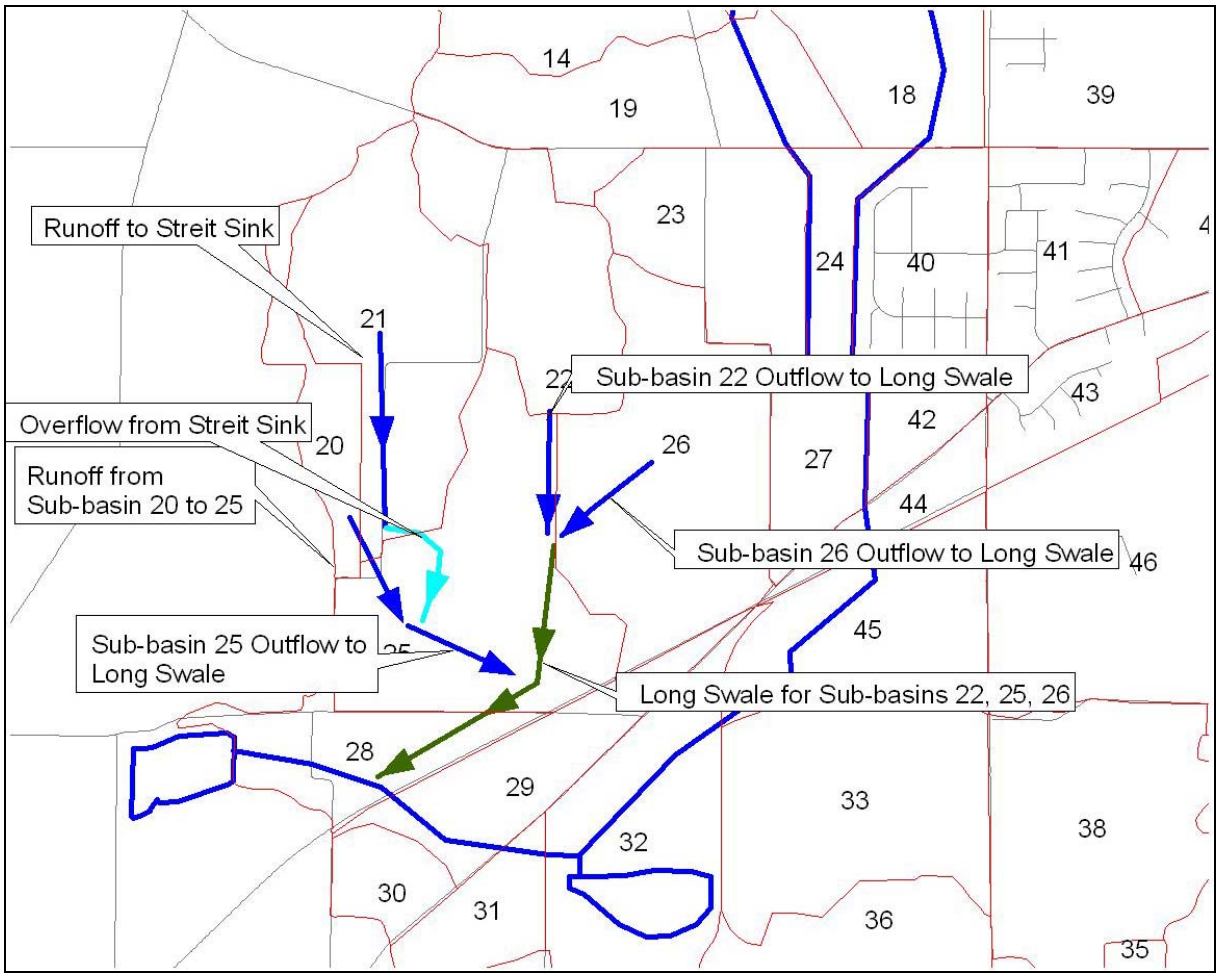


Figure 1.3 Flow Pattern for the Swale Network and Streit Sink

Table 1.1 Sub-basin Swale Information		
Sub-basin Number	Slope of Swale	Number of Swales in Sub-basin
16	2%	4.3
17	2%	3.5
18	2%	10.6
19	2%	7.7
22	2%	1.0
23	2%	5.5
24	2%	2.1
25	0.5%	10.2
26	0.5%	10.7
27	0.5%	3.1
28	0.5%	4.0
29	0.5%	4.4
35	2%	8.0
38	---	1
42	2%	1.9

1.2. Water Quality Modeling

The contaminant removal rates of various BMP's are generally given as a range of values. A number of factors influence the removal rates of any BMP for a particular storm. For instance, a swale would be more effective for runoff from a gentle shower producing steady shallow flows compared to runoff from a sudden downpour with short intense flows. A conservative assumption was made for this report. The peak removal rate for a BMP, for a particular contaminant, was selected as a mid-range value from a literature review as shown in Table 2. The peak removal rate was reduced based on hourly average conditions within the

BMP. For example, in a swale, the contaminants are removed largely by physical processes during flow through the grass lining of the swale. For this report, the peak removal rate was assumed to occur up to water depth of 0.33-feet (4-inches). As the depth of flow increased, the removal rate was reduced as more water flowed above the grass. The removal rate calculation assumed that the bottom 0.33-feet of flow had the peak removal rate while the flow above 0.33-feet had no contaminant removal. The calculated removal rate was the depth weighted average of the two layers of flow. For the dry detention basins, the removal rate was based on the duration of time water was deeper than 0.33-feet. Dry detention ponds remove contaminants by allowing time for settling and for some biological activity. The removal rate was linearly interpolated from zero to the peak rate as the time of ponding increased from zero to 24-hours. After 24-hours, the removal rate was the peak rate.

Table 1.2 Peak Contaminant Removal Rates

BMP	Nitrate	Phosphorus	Copper	Zinc	Sediment
Swale	50%	65%	80%	80%	80%
Pond	30%	30%	30%	30%	50%
Combined	65%	75.5%	86%	86%	90%

To calculate the contaminant loading for a sub-basin, first the pervious surface loading was determined from land use as was done in previous versions of the model. Next, the effective removal rate for the sub-basin swale was determined from the hourly average depth of flow. The hourly effective removal rate, the hourly average flow, and the sub-basin contaminant concentration were combined to find the hourly average contaminant discharge for the swale. Finally, the hourly average depth of the detention basin was used find the duration of ponding and the effective removal rate for the basin. The hourly average contaminant loading from the swale, the hourly effective removal rate, the hourly basin percolation rate, and the basin discharge rate were combined to find the hourly contaminant discharge for the basin.

For the long swale carrying flow from Sub-basins 22, 25, and 26, the incoming contaminant concentration was the flow weighted average of the three sub-basins. The contaminant removal rate for this swale was calculated the same way as other swales.

2. HSPF Hydrology Results

In the discussions of the hydrology results, only two destinations are assumed to exist in the Trenton Watershed, evapotranspiration to the atmosphere and percolation to the aquifer. Surface runoff within the watershed flows directly to sinks or into Jackson Ditch. Water flowing into Jackson Ditch may percolate to the aquifer through the streambed, through Miller Sink, or at the former quarry. No surface runoff flows out of the Trenton watershed.

The HSPF models were run using the 2004 observed meteorological data.

Table 2.1 summarizes the annual water budget for the Existing, No-BMP, and Swale conditions modeling for 2004. As discussed in the previous report, increased development from the Existing conditions to the future conditions in the No-BMP and Swale models increased the impervious surface in the watershed. The increased impervious area decreased the evapotranspiration when pavement and buildings replaced cropland, forest, and pasture. Additionally, the increased impervious area increased runoff with the decrease in surface storage and infiltration.

The inclusion of swales and basins had a marked impact on the volume of water flowing to Jackson Ditch and the volume of water infiltration to the aquifer. The first cause of changes is the swales slowing the runoff from a sub-basin. This attenuated runoff is then detained in the basins. The delay in leaving the sub-basin allows some water to infiltrate into the aquifer from the basin. The second cause is the detention basin slowly releasing the runoff to Jackson Ditch. The Miller Sink is hydraulically connected to Jackson Ditch. By delaying the runoff to Jackson Ditch, including the detention basins more effectively uses the infiltration capacity of Miller Sink.

Runoff, percolation, and contaminant loadings by sub-basin are tabulated and mapped in Appendix D-1.

Table 2.1 2004 Annual Water Budget									
	2004 Volume (1,000,000 ft3)			2004 Depth Over Watershed (Inch)			Change From Existing		Change
Description	Existing	No-BMP	Swales	Existing	No-BMP	Swales	No-BMP	Swales	From No-BMP
Inflows									
Total Precipitation	956.4	956.4	956.4	40.33	40.33	40.33	0%	0%	0%
Change in Soil Water	3.0	7.4	7.5	0.15	0.36	0.36	145%	154%	0%
Outflows									
Evapotranspiration	559.7	422.3	423.5	23.60	17.81	17.86	-25%	-24%	0%
Runoff to Jackson Ditch	116.1	214.1	155.1	4.90	9.02	6.54	84%	34%	-28%
Groundwater Recharge	286.0	337.2	392.3	12.06	14.22	16.54	18%	37%	16%
Pervious Infiltration	206.5	189.3	190.9	8.71	7.98	8.05	-8%	-8%	1%
City of Trenton Runoff	67.0	126.2	126.2	2.82	5.32	5.32	89%	88%	0%
Sink & Basin Infiltration	12.6	21.7	75.2	0.53	0.91	3.17	72%	498%	247%

2.1. Runoff to Jackson Ditch

The increased impervious area for the future land use leads to increased runoff. For the area of Trenton Watershed outside of the City of Trenton, this increased volume of runoff means increased volume of flow in Jackson Ditch.

Table 2.2 lists flows to Jackson Ditch for basins shown in Figure 2.1. Figure 2.2 compares the volume of water entering Jackson Ditch from the various basins. Since HSPF RCHRES modeling of streams is unable to properly model the flat slopes and backwater conditions of Jackson Ditch, a simple summation of flows was used to examine flows to the stream.

Hourly average flows to Jackson Ditch were summed without routing or storage effects to examine the flow to Miller Sink from the basins upstream of Gephardt Road (basins A, B, C, D, and Miller). Flows up to the 50 cfs infiltration capacity of Miller Sink were subtracted from the total flow. The remaining flow was assumed to flow downstream past Gephardt Road. This remaining flow with the addition of runoff from Basin E is the estimated flow in Jackson Ditch towards the former quarry. The flow from Jackson Ditch overland to the quarry was beyond the ability of the summation process and was not modeled.

For the year 2004, Table 2.2 shows total flow volume into Jackson Ditch increased 84% for No-BMP conditions and 35% for Swale conditions compared to the Existing conditions. The additional water, compared to Existing conditions, is from reductions in evaporation and in increases in runoff.

The use of swales and basins greatly reduces the runoff to Jackson Ditch. For areas above Miller Sink, the swales and basins reduce flow volumes compared to No-BMP conditions but do not reduce them to the Existing conditions. Additionally, peak flows from the sub-basins will increase from the Existing conditions to the Swale conditions. These higher peaks will aggravate flooding in areas adjacent to Jackson Ditch with existing problems. One area of concern is the farmland east of the quarry. Without a defined channel, the greatly increased flow (123% increase from Existing to Swale conditions) is expected to cause wide, shallow ponding in this area.

Table 2.2 Annual Flow to Jackson Ditch						
	2004 Volume (1,000,000 ft3)			% Change From Existing		Swale % Change from No-BMP
Basin	Existing	No-BMP	Swale	No-BMP	Swale	
A	34.8	46.0	32.5	32%	-7%	-29%
B	36.7	53.4	39.2	46	7	-27
C	7.7	20.6	2.8	166	-64	-87
D	3.7	4.3	4.3	17	15	-1
Miller	14.9	57.7	43.4	286	191	-25
E	18.3	32.0	34.2	75	87	7
A+B+C	79.2	120.0	74.5	52	-6	-38
A+B+C+D +Miller	97.8	182.0	122.2	86	25	-33
All	116.1	214.0	156.3	84	35	-27
Miller Sink Infiltration	96.8	154.7	125.7	60	30	-19
Flow Past Gephardt Road	0.9	27.0	8.4	3,027	830	-69
Between Gephardt & Quarry	19.1	59.0	42.5	209	123	-28

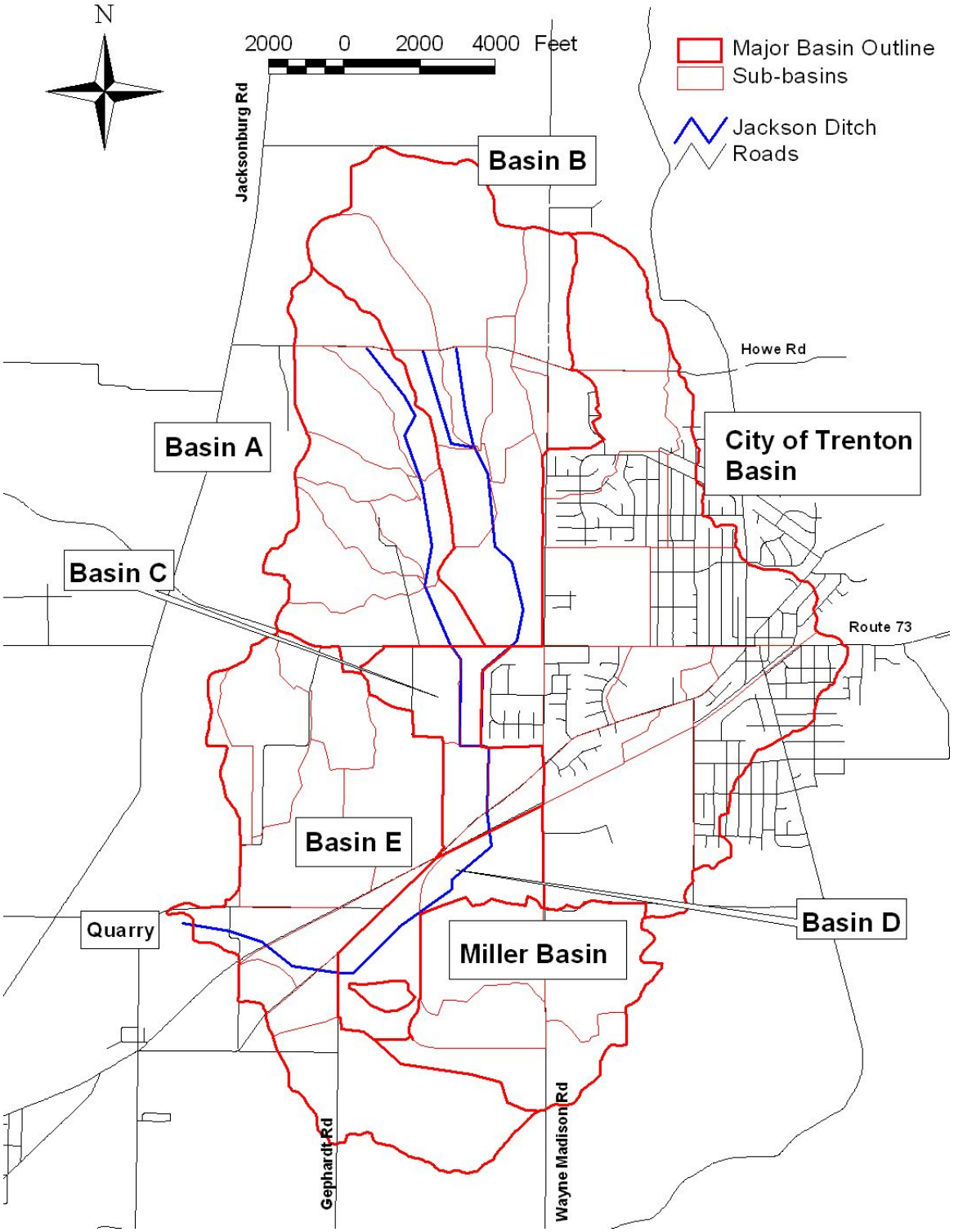


Figure 2.1 Trenton Watershed Basins

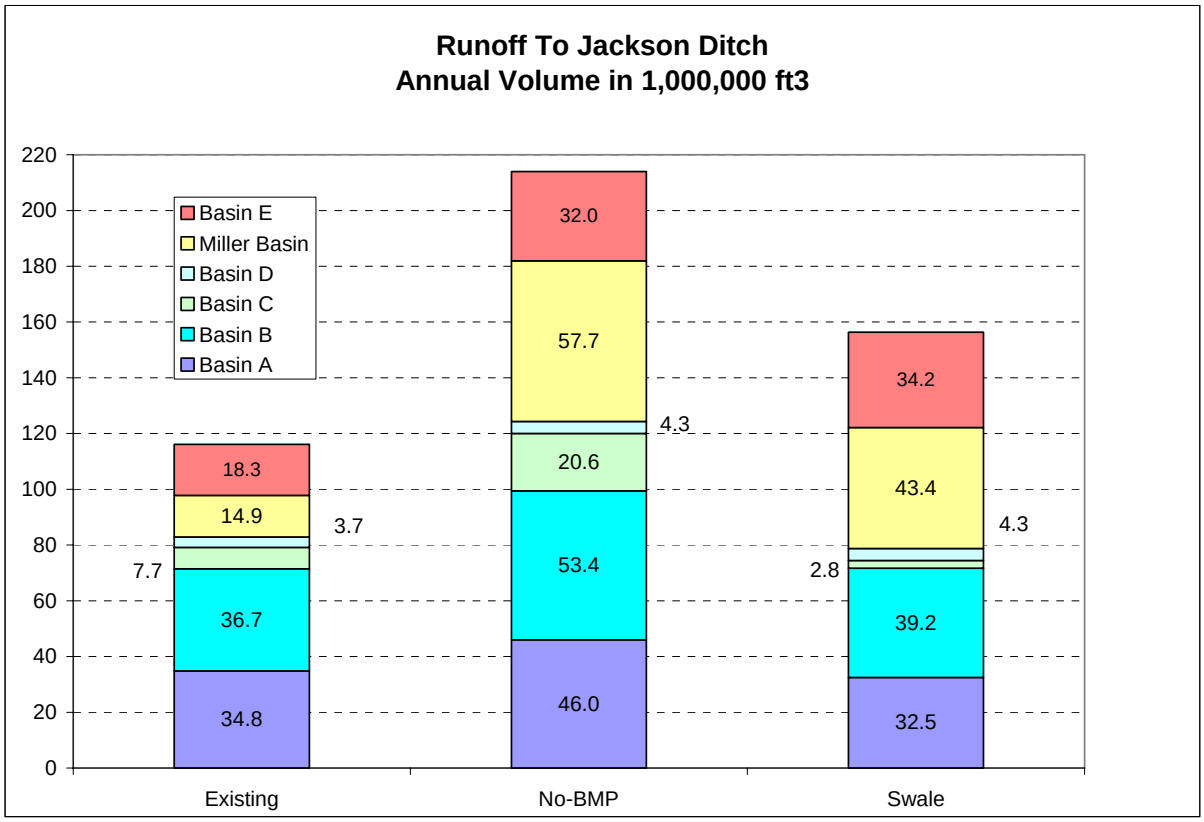


Figure 2.2 Annual Runoff to Jackson Ditch

When the effects of infiltration at Miller Sink are included, the increase in flow volumes to Jackson Ditch downstream of Gephardt Road was 3,000% for No-BMP conditions and 900% for Swale conditions. Peak flows (without storage or routing) increased from the Existing conditions to the No-BMP conditions and the Swale conditions as shown in Table 2.3. The increased volume of flows to Jackson Ditch downstream of Gephardt Road is likely to aggravate any tendencies to flood this area. The inclusion of BMPs to increase infiltration and retard runoff in Swale reduced both the total flow volumes and the peak flows to Jackson Ditch. A secondary benefit of attenuating the flood flows is to allow more time for infiltration at Miller Sink and other areas, which in turn reduce flood flows further.

Table 2.3 Peak Flow to Jackson Ditch

	2004 Peak Flow (ft3/s)			% Change From Existing		Swale % Change from No-BMP
Basin	Existing	No-BMP	Swale	No-BMP	Swale	
Flow to Miller Sink	94	1,105	401	1,081%	328%	-64%
Flow Past Gephardt Road	44	1,055	350	3,027%	868%	-69%

On January 4, 2004, 3.03 inches of rain fell during the course of the day. This storm was approximately a 2.5-year storm. Local flooding was observed in the area near the intersection of Trenton and Gephardt Roads. For 2004, this storm had the peak flow into the Jackson Ditch for the Existing conditions. This storm fell on moist but not frozen soils. The No-BMP peak flow was over three times the peak flow for Existing conditions as seen in Figure 2.3. The effects of the swales can be seen in the elimination of peaks in the beginning of the runoff event. After the peak of the flood, the Swale flows are higher than the No-BMP flows due to release of runoff stored in the various basins.

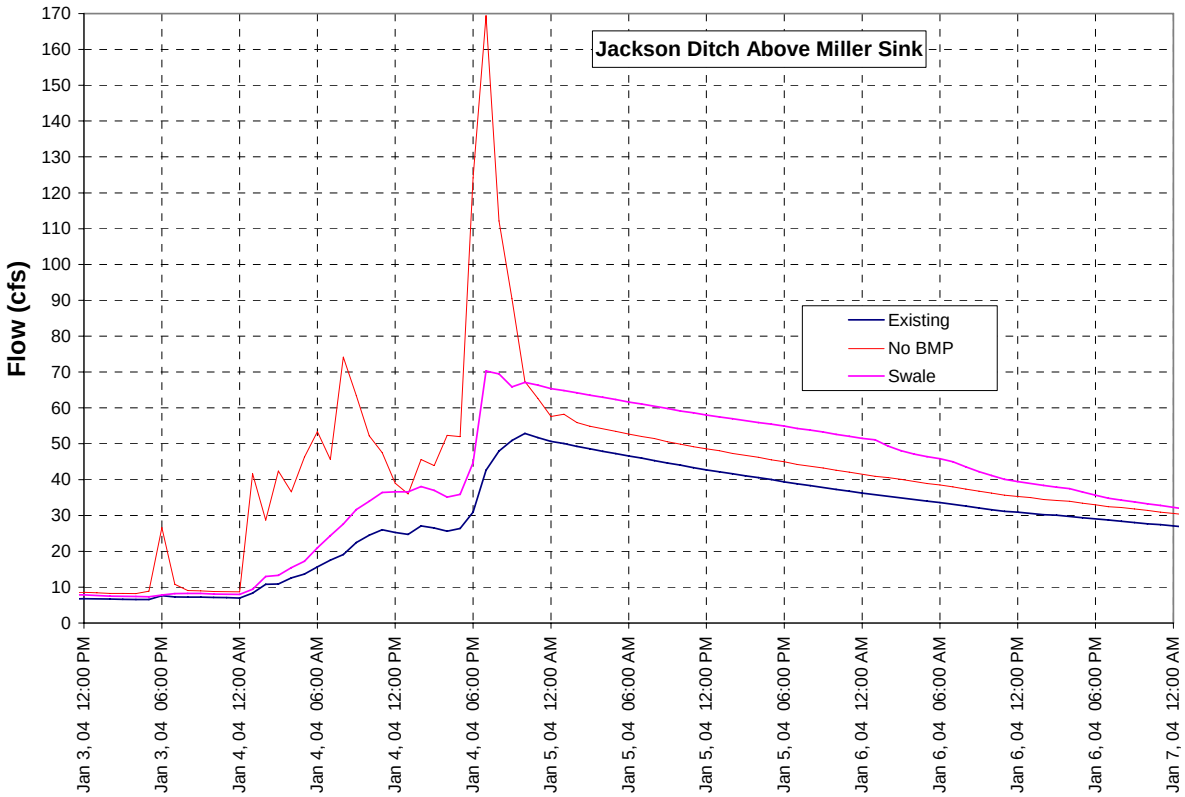


Figure 2.3 Jackson Ditch Flow January 2004

During the July 22, 2004, storm, 1.56 inches of rain fell in one hour which is approximately a 3-year rainfall. The soils at this time were dry after a week in warm summer temperatures without rain. The hourly flows in Jackson Ditch are shown in Figure 2.4. The peak flow into Jackson Ditch for the No-BMP conditions at 413 cfs was over 43 times the peak flow of 9 cfs for the Existing conditions. The changes from No-BMP to Swale conditions decreased the peak flow by 80% due to storage in the detention basins.

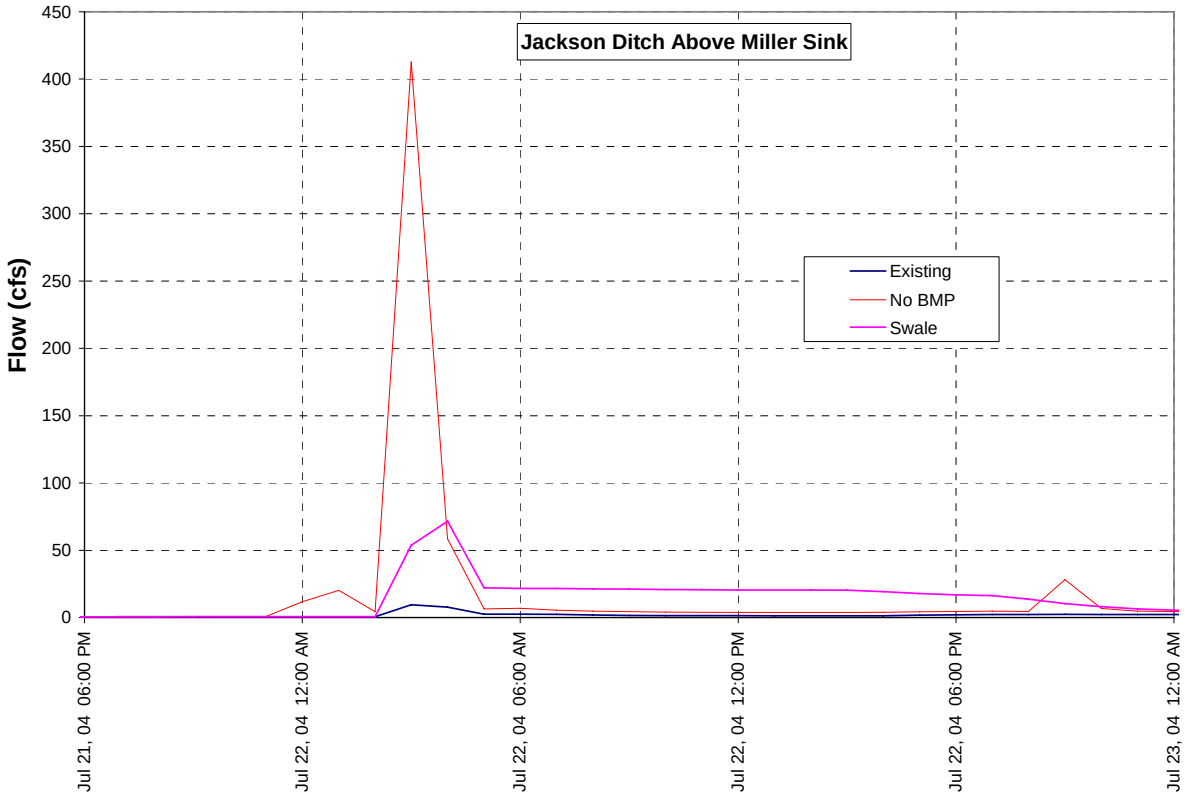


Figure 2.4 Jackson Ditch Flow July 2004

2.2. Percolation

Percolation to the aquifer is the dispersed way in which the aquifer is recharged as opposed to the concentrated manner via the sinks. Changes in percolation patterns could impact aquifer water surface elevations, flow patterns in the aquifer and the volume of water in the aquifer. The changes in land use impact percolation in several ways. Increased impervious area increases the volume of runoff to Jackson Ditch which may decrease the volume of water available for percolation. Reductions in vegetation may reduce evapotranspiration which would increase water available for percolation. Trees transpire much more water than grass so the conversion of forest to grass would increase water available for percolation. The cumulative effects of land use on percolation will depend on the amount of impervious area added, the degree to which vegetation (before and after development) is grass instead of trees, how much of the impervious area has sewers to streams, the amount of runoff stored in detention and infiltration facilities, and other factors.

The annual percolation is summarized by basin in Table 2.4 and Figure 2.5. The Swale model shows large increases in the percolation for Basins A, B, and C due to the basins detaining water and allowing infiltration.

The largest water withdrawal wells in the Trenton Watershed are Southwest Regional Water District, City of Trenton, Miller Brewing, and Cincinnati Gas & Electric (CG&E). All of these wells are located near Hamilton Trenton Road in the southern half of the watershed as shown in Figure 2.6.

For the Swale conditions, percolation in Basins A, B, and C will increase the water reaching the aquifer.

Overall, the increase in percolation should increase the availability of water from the aquifer at the City of Trenton and CG&E wells. The large increase in percolation at the Miller Sink should increase the availability of water at the Miller Brewing and Southwest Regional Water District wells. The actual extent of the changes is currently unknown.

Table 2.4 Annual Percolation to Aquifer

	2004 Volume (1,000,000 ft3)			% Change From Existing		Swale % Change from No-BMP
Basin	Existing	No-BMP	Swale	No-BMP	Swale	
A	8.1	7.2	20.5	-10%	152%	184%
B	24.4	26.8	40.4	10	66	51
C	10.3	7.2	17.5	-30	70	143
D	12.1	12.0	12.0	-1	-1	0
Miller Basin	34.5	27.2	53.6	-21	55	97
Miller Sink	96.8	154.7	125.7	60	30	-19
E	52.5	69.3	69.1	32	32	0
Between Gephardt & Quarry	19.1	59.0	42.5	209	123	-28
A+B+C	42.7	41.2	72.3	-3	79	85
A+B+C+ D+Miller	89.2	80.4	136.3	-10	53	69
All	257.7	363.5	368.6	41	43	1
Trenton Runoff Infiltrated	67.0	126.2	126.2	88	88	0
Trenton Direct Infiltrated	75.3	59.3	59.3	-21	-21	0
Trenton Total	142.3	185.5	185.5	30	30	0

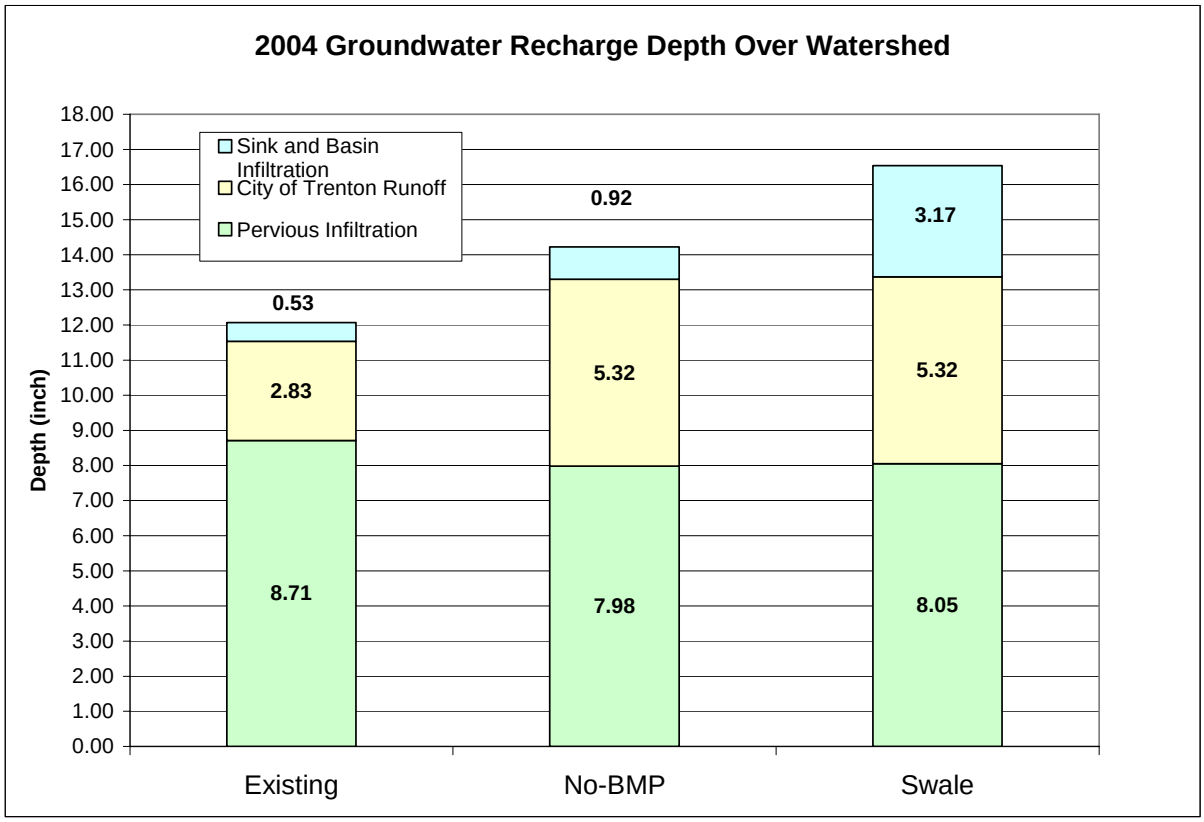


Figure 2.5 Percolation Depth Over Watershed

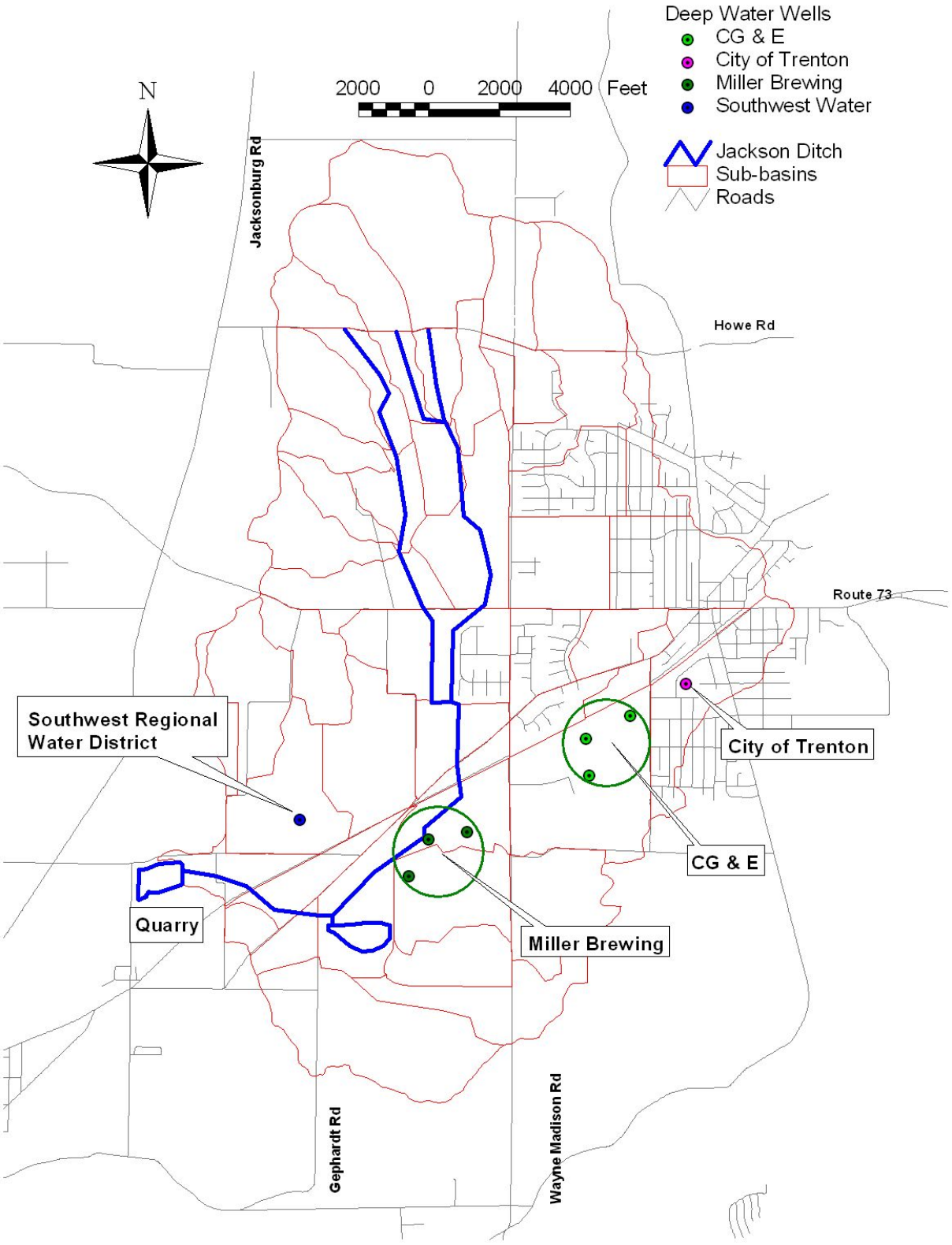


Figure 2.6 Deep Well Locations

3. Water Quality Results

3.1. Water Quality Parameters

The results of the hydrologic modeling were used to estimate current and future loading of water quality.

For the Trenton Watershed study, the EMCs were assigned based on land use as shown in Table 3.1. The sub-basin EMC for a parameter was calculated from the various land uses using area weighting.

Table 3.1 Contaminant EMC by Land Use

Land Use	Nitrate mg/L	Soluble Phosphorus mg/L	Total Copper mg/L	Total Zinc mg/L
Commercial / Industrial	0.42	0.11	0.025	0.160
Cropland	1.70	0.30	0.010	0.050
Pasture	0.60	0.55	0.005	0.025
Rural Development	0.35	0.55	0.015	0.090
Sink	0.00	0.00	0.000	0.000
Urban Development	0.45	0.33	0.020	0.125
Woods	0.25	0.05	0.005	0.025

3.2. Nitrate Results

Nitrate is a contaminant that may impact human health and a nutrient that may impact water quality.

As shown in Table 3.2 and Figure 3.1, nitrate loads in surface runoff increase with the increased runoff due to urbanization. The percolation numbers include the City of Trenton surface runoff percolating from infiltration basins and dry wells. The nitrate loads in the percolation water significantly decrease due to the presumed development of cropland to urban land uses. The cropland converted generally coincides with the soils having the highest infiltration rates. Inclusion of swales and basins reduces the watershed nitrate load and average concentration by approximately 10%. Table 3.3 shows the effectiveness of the swales and basins in reducing nitrate loads. The reductions include the removal rate reductions due to depth of flow and duration of ponding described above.

The annual average concentration in runoff and percolation is shown in comparison to the EPA MCL standard. Ohio EPA has statewide targets for nitrate and nitrite in streams based on watershed size and ecological quality of the stream. For the small watershed of Jackson Ditch, the target for nitrate and nitrite combined is 1.0 mg/L. The expected future annual average concentration of nitrate is far below the target. No surface water quality problems are expected due to nitrate.

Table 3.2 Annual Nitrate Loading						
	2004 Load (kg)			% Change From Existing		Swale % Change from No-BMP
Category	Existing	No-BMP	Swale	No-BMP	Swale	
Surface Runoff	2,510	2,630	2,150	5%	-14%	-18%
Percolation	5,040	3,920	3,620	-22	-28	-8
Total	7,550	6,550	5,770	-13	-24	-12
Average Concentration	0.66 mg/L	0.41	0.37	-38%	-44%	-11
Maximum Concentration	1.66 mg/L	1.13	1.13	-32%	-32%	
EPA MCL standard 10 mg/L						

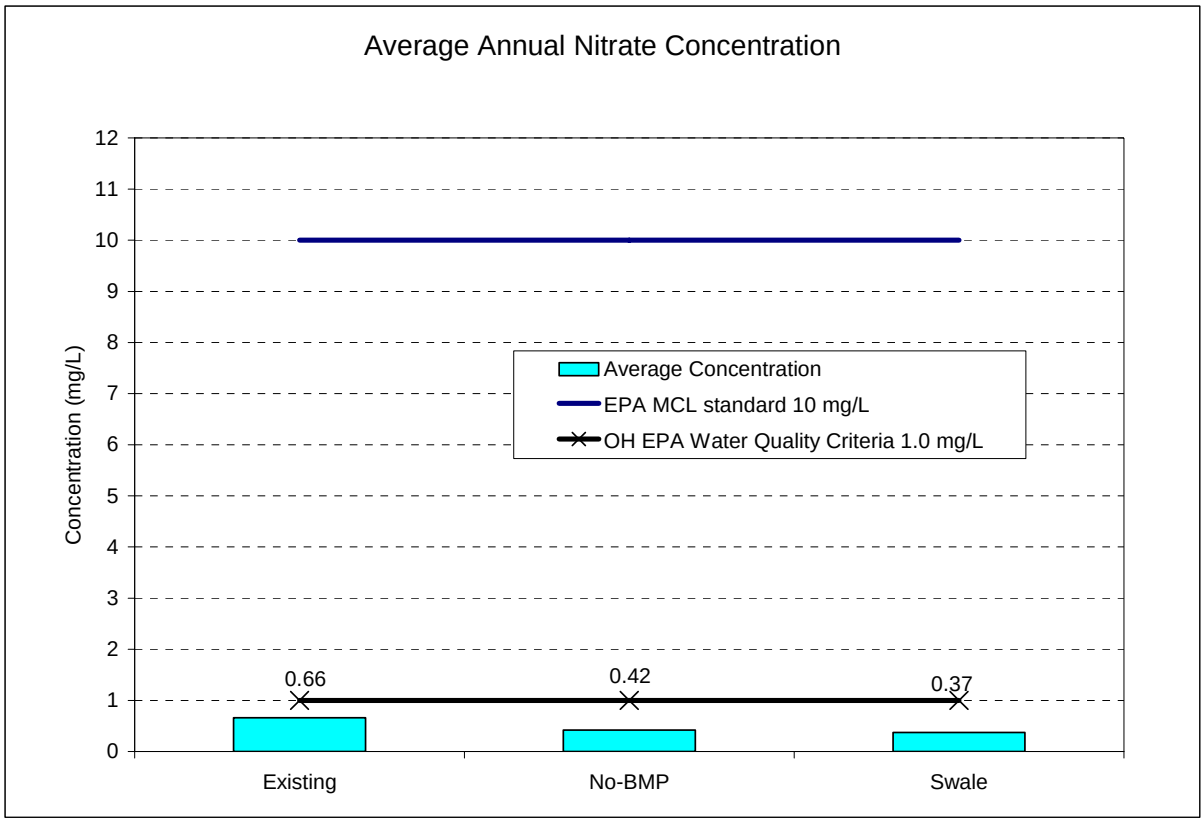


Figure 3.1 Average Annual Nitrate Concentration

Table 3.3 Annual Nitrate Load for Swale Sub-Basins						
Sub-Basin	2004 Total Load (kg)		% Change	Concentration mg/L		% Change
	No-BMP	Swale		No-BMP	Swale	
16	121	90	-35%	0.78	0.38	-52%
17	79	59	-34%	0.45	0.22	-52%
18	215	172	-25%	0.45	0.21	-53%
19	182	136	-33%	0.49	0.23	-53%
22	239	185	-29%	0.74	0.35	-54%
23	158	123	-29%	0.43	0.21	-52%
24	43	35	-23%	0.45	0.21	-53%
25	214	181	-19%	0.54	0.25	-53%
26	222	181	-23%	0.45	0.22	-51%
27	64	51	-24%	0.45	0.21	-53%
28	52	42	-23%	0.35	0.16	-53%
29	69	56	-23%	0.39	0.18	-53%
35	459	339	-35%	0.58	0.26	-54%
38	433	378	-14%	0.42	0.34	-19%
42	39	32	-23%	0.45	0.25	-44%

3.3. Phosphorus Results

Phosphorus in surface water acts as a fertilizer to encourage the growth of aquatic vegetation, especially algae and floating plants. The decomposition of the vegetation and the nocturnal oxygen use of the plants reduce the dissolved oxygen in the effected water. The low oxygen levels and clogging of the stream by the vegetation adversely impact many fish, amphibians, and invertebrates. In the eastern United States, phosphorus is generally the limiting nutrient for algae and floating vegetation growth.

Currently no drinking water standard exists for phosphorus.

Phosphorus concentrations were estimated based on the percent of a sub-basin assigned to each land use. The phosphorus concentration for water infiltrating into the soil was reduced by 30% to account for biological activity.

The largest source of phosphorus is fertilizer for pastures and lawns. As the cropland area of the Trenton watershed is converted to lawns, the total phosphorus load increases. Additional major sources of nitrates are pet and livestock waste, malfunctioning septic tanks, and leaking sanitary or combined sewers.

As shown in Table 3.4 and Figure 3.2, phosphorus loads increased due to urbanization with increased lawn fertilization. The percolation numbers include the City of Trenton surface runoff percolating from infiltration basins and dry wells. Increased runoff and percolation with development did moderate the increase in total load. Table 3.5 shows the effectiveness of the swales and basins in reducing phosphorus loads. The reductions include the removal rate reductions due to depth of flow and duration of ponding described above.

Ohio EPA has statewide targets for total phosphorus in streams based on watershed size and ecological quality of the stream. For the small watershed of Jackson Ditch, the target for total phosphorus is 0.08 mg/L for a Warmwater Habitat or 0.34 mg/L for a Modified Warmwater Habitat. The expected future annual average concentration of dissolved phosphorus is near the target for the Modified Warmwater Habitat and far above the target for the Warmwater Habitat. Based on Existing Conditions results, Jackson Ditch is likely supporting the less diverse aquatic life of a Modified Warmwater Habitat.

Table 3.5 shows that inclusion of BMP's, such as swales and basins, greatly reduce the phosphorus load entering Jackson Ditch. The results modeled would greatly reduce the likelihood of water quality problems due to phosphorus.

The increased total load concentration for phosphorus indicates a possible future problem with eutrophication. The most likely locations for this problem are pools where aeration is low and sunlight is available for heat and photosynthesis. These conditions encourage eutrophication. Small pools tend to form above and below constrictions such as culverts and road crossings. The major areas where eutrophication may be a problem are the Miller Sink and the quarry. The eutrophication may impact the taste and odor of groundwater infiltrating in the aquifer from the Miller Sink and the quarry. The eutrophic water in the sink and the quarry would suffer from visual and odor problems, would have lower biodiversity, and may lead to increased insect populations. The severity of these problems would depend on a variety of factors.

The phosphorus concentration can be lowered by the intentional design of storm water systems that increase the removal of phosphorus before discharge to the stream. In stream measures to reduce water temperature (preservation of trees on stream banks) and increase dissolved oxygen (man made riffles or weirs) may reduce the effects of eutrophication.

Table 3.4 Annual Phosphorus Loading						
	2004 Load (kg)			% Change From Existing		Swale % Change from No-BMP
Category	Existing	No-BMP	Swale	No-BMP	Swale	
Surface Runoff	890	1,340	1,170	52%	31%	-12%
Percolation	1,850	2,760	2,610	49	41	-5
Total	2,740	4,110	3,780	50	38	-8
Average Concentration	0.24 mg/L	0.26	0.25	8%	5%	-19%
Maximum Concentration	0.55 mg/L	0.55	0.55	0	0	
No EPA Standard						

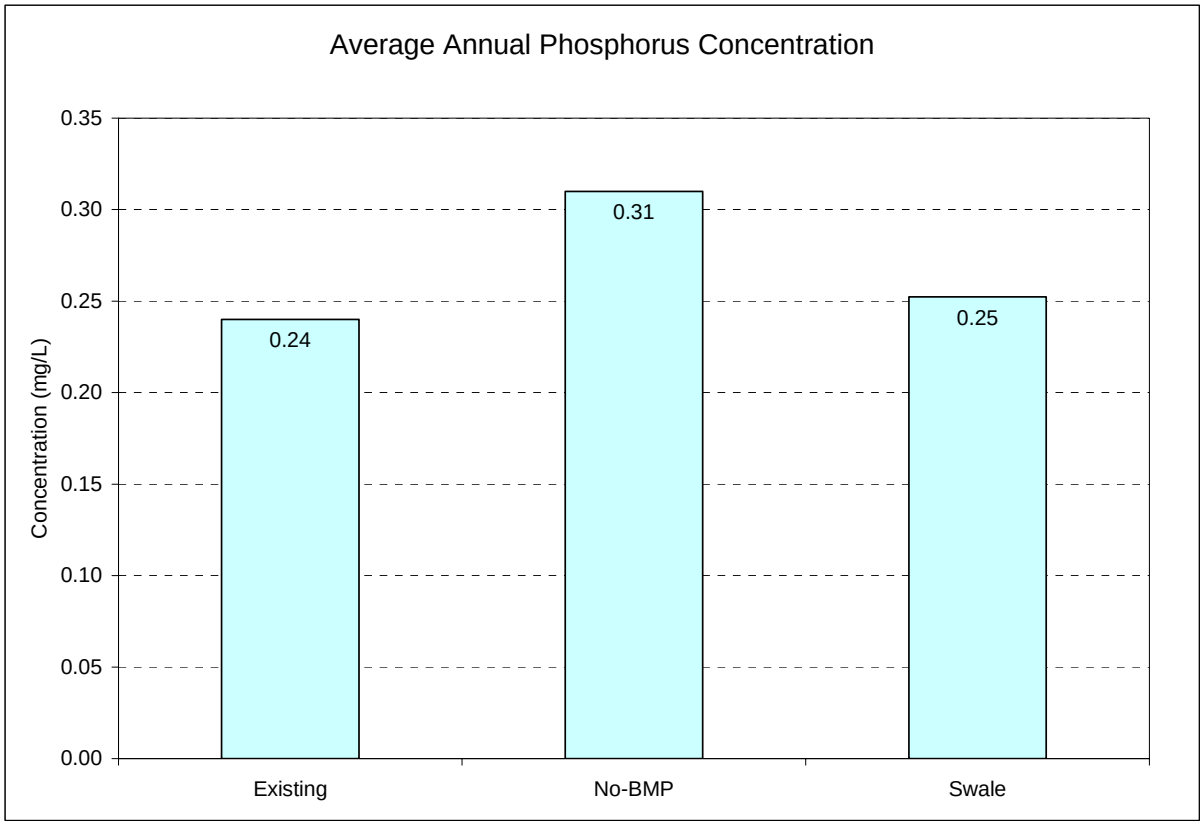


Figure 3.2 Annual Average Phosphorus Concentration

Table 3.5 Annual Phosphorus Load for Swale Sub-Basins						
Sub-Basin	2004 Total Load (kg)		% Change	Concentration mg/L		% Change
	No-BMP	Swale		No-BMP	Swale	
16	63	45	-38%	0.28	0.10	-66%
17	82	58	-40%	0.33	0.11	-66%
18	229	175	-30%	0.33	0.11	-67%
19	169	121	-39%	0.32	0.11	-67%
22	117	90	-30%	0.32	0.11	-67%
23	96	69	-39%	0.19	0.06	-66%
24	44	35	-27%	0.33	0.11	-67%
25	229	183	-25%	0.40	0.13	-67%
26	227	172	-32%	0.33	0.11	-66%
27	66	51	-29%	0.33	0.11	-67%
28	117	93	-26%	0.55	0.18	-67%
29	118	93	-27%	0.46	0.15	-67%
35	107	78	-37%	0.13	0.04	-68%
38	121	105	-15%	0.11	0.09	-23%
42	40	30	-32%	0.33	0.06	-83%

3.4. Copper Results

Copper at high levels is a health concern due to short-term gastrointestinal distress and long-term liver and kidney damage. Additionally, copper is a threat to people with Wilson's Disease, a genetic disorder that causes the accumulation of excessive copper in the liver or brain.

The sources of copper include brake pads, bearings and wear surfaces, and some insecticides and fungicides.

In addition to the US and Ohio EPA Secondary Standard for taste, odor, and corrosion, copper is also regulated under a Treatment Technique Standard. If the treated water is too corrosive, copper and lead may be leached out of household plumbing. When testing at households indicates the water is too corrosive as shown by the copper and lead concentrations, treatment techniques are used to limit the leaching of metals from plumbing fixtures. The Secondary Standard is set at 1.0 mg/L to limit metallic taste and blue-green staining. The Treatment Technique Action Level is set to 1.3 mg/L to protect against health hazards.

As shown in Table 3.6 and Figure 3.3, copper loads increased due to urbanization and increased vehicle traffic. The percolation numbers include the City of Trenton surface runoff percolating from infiltration basins and dry wells. Increased runoff and percolation with development did dilute the increase in total load. The annual average concentration is and is expected to continue to be far below the Secondary Standard and the Treatment Technique Action Level. Table 3.7 shows the effectiveness of the swales and basins in reducing copper

loads. The reductions include the removal rate reductions due to depth of flow and duration of ponding described above.

Ohio EPA has a water quality target for copper intended to protect aquatic life. Assuming a hardness of 100 mg/L $CaCO_3$ (moderately hard water and the lowest in the criteria), the target is 0.009 mg/L of copper. Currently, the copper concentration is estimated as above the target with the future concentrations significantly exceeding the target. Reduction of the copper in the runoff can be achieved by using BMPs that focus on capturing runoff from streets and paved areas, and removing suspended sediment. The use of swale and basin as modeled is not expected to reduce copper sediments sufficiently. Specific measures targeting suspended sediment would need to be added to the train of BMPs for areas exporting copper and other metals.

Table 3.6 Annual Copper Loading

	2004 Load (kg)			% Change From Existing		Swale % Change from No-BMP
Category	Existing	No-BMP	Swale	No-BMP	Swale	
Surface Runoff	24	72	49	201%	103%	-32%
Percolation	102	200	201	99	97	1
Total	126	272	250	120	98	-7
Average Concentration	0.011 mg/L	0.018	0.017	59%	51%	-8%
Maximum Concentration	0.020 mg/L	0.025	0.025	25	25	
No MCL Secondary Standard 1 mg/L Treatment Technique Action Level 1.3 mg/L						

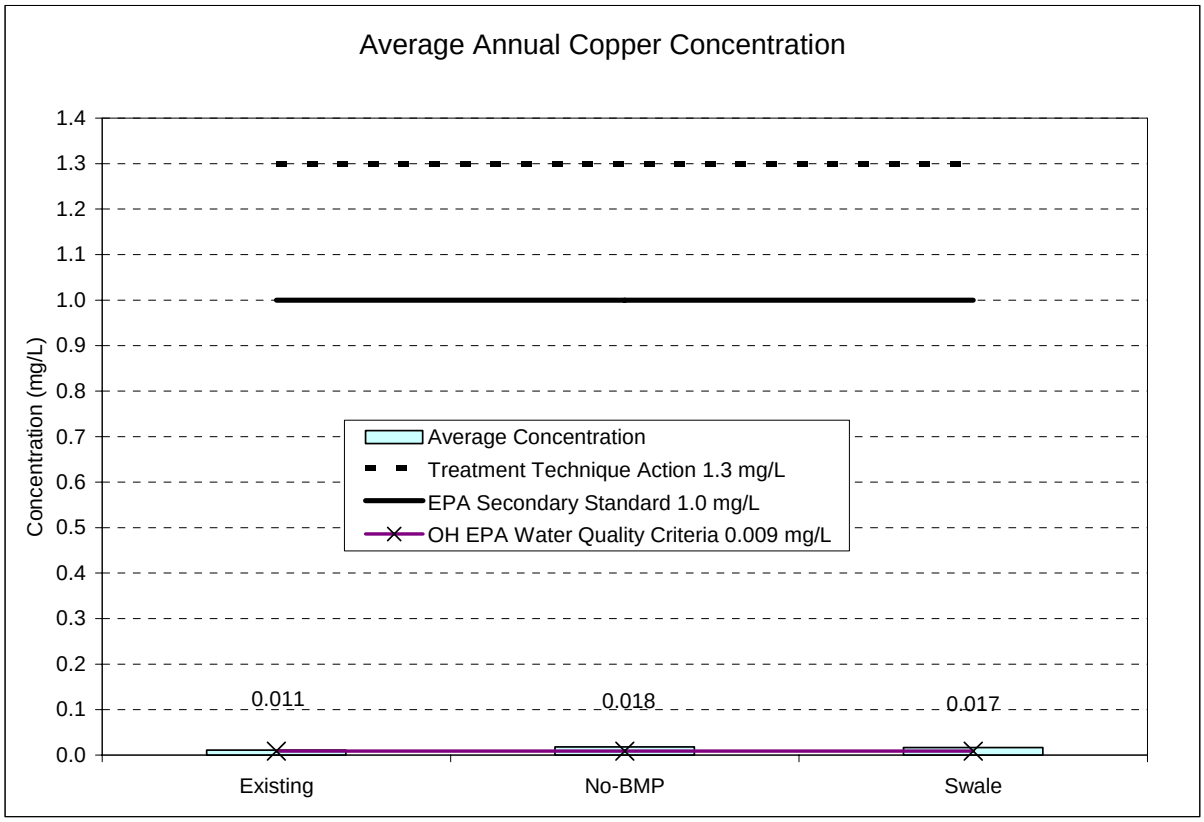


Figure 3.3 Average Annual Copper Concentration

Table 3.7 Annual Copper Load for Swale Sub-Basins

Sub-Basin	2004 Total Load (kg)		% Change	Concentration mg/L		% Change
	No-BMP	Swale		No-BMP	Swale	
16	3	2	-41%	0.086	0.017	-81%
17	5	4	-43%	0.125	0.024	-81%
18	14	11	-33%	0.125	0.023	-81%
19	11	8	-42%	0.120	0.023	-81%
22	6	5	-30%	0.107	0.020	-81%
23	6	5	-36%	0.147	0.029	-80%
24	2	2	-20%	0.125	0.023	-81%
25	7	6	-17%	0.092	0.017	-81%
26	10	8	-24%	0.125	0.024	-80%
27	3	2	-21%	0.125	0.024	-81%
28	2	2	-19%	0.090	0.017	-81%
29	3	3	-20%	0.104	0.020	-81%
35	18	13	-40%	0.146	0.027	-82%
38	27	24	-16%	0.160	0.119	-26%
42	2	1	-16%	0.125	0.065	-49%

3.5. Zinc Results

Zinc has limits due to its aesthetic effects. The sources of zinc include tires, oil, grease, and galvanized metal surfaces. The loading estimates are for total zinc.

The Secondary Standard is set at 5 mg/L to limit metallic taste and staining.

As shown in Table 3.6 and Figure 3.4, zinc loads increased due to urbanization with increased vehicle traffic and industrialization. The percolation numbers include the City of Trenton surface runoff percolating from infiltration basins and dry wells. Increased runoff and percolation with development did dilute the increase in total load. The annual average concentration is and is expected to continue to be far below the Secondary Standard.

Ohio EPA has a water quality target for zinc intended to protect aquatic life. Assuming a hardness of 100 mg/L $CaCO_3$ (moderately hard water and the lowest in the criteria), the target is 0.12 mg/L of zinc. Currently, the zinc concentration is estimated as well below the target with the future concentrations approaching but not exceeding the target. Reduction of the zinc in the runoff can be achieved by using BMPs that focus on capturing runoff from streets and paved areas, and removing suspended sediment. The use of swale and basin as modeled is expected to reduce zinc sediments sufficiently to prevent problems due to zinc.

Table 3.8 Annual Zinc Loading

	2004 Load (kg)			% Change From Existing		Swale % Change from No-BMP
Category	Existing	No-BMP	Swale	No-BMP	Swale	
Surface Runoff	130	400	291	216%	133%	-27%
Percolation	590	1,260	1,250	115	114	-1
Total	710	1,660	1,540	133	117	-7
Average Concentration	0.063 mg/L	0.106	0.103	71	64	-3
Maximum Concentration	0.127 mg/L	0.160	0.160	26	26	
No MCL Secondary Standard 5 mg/L						

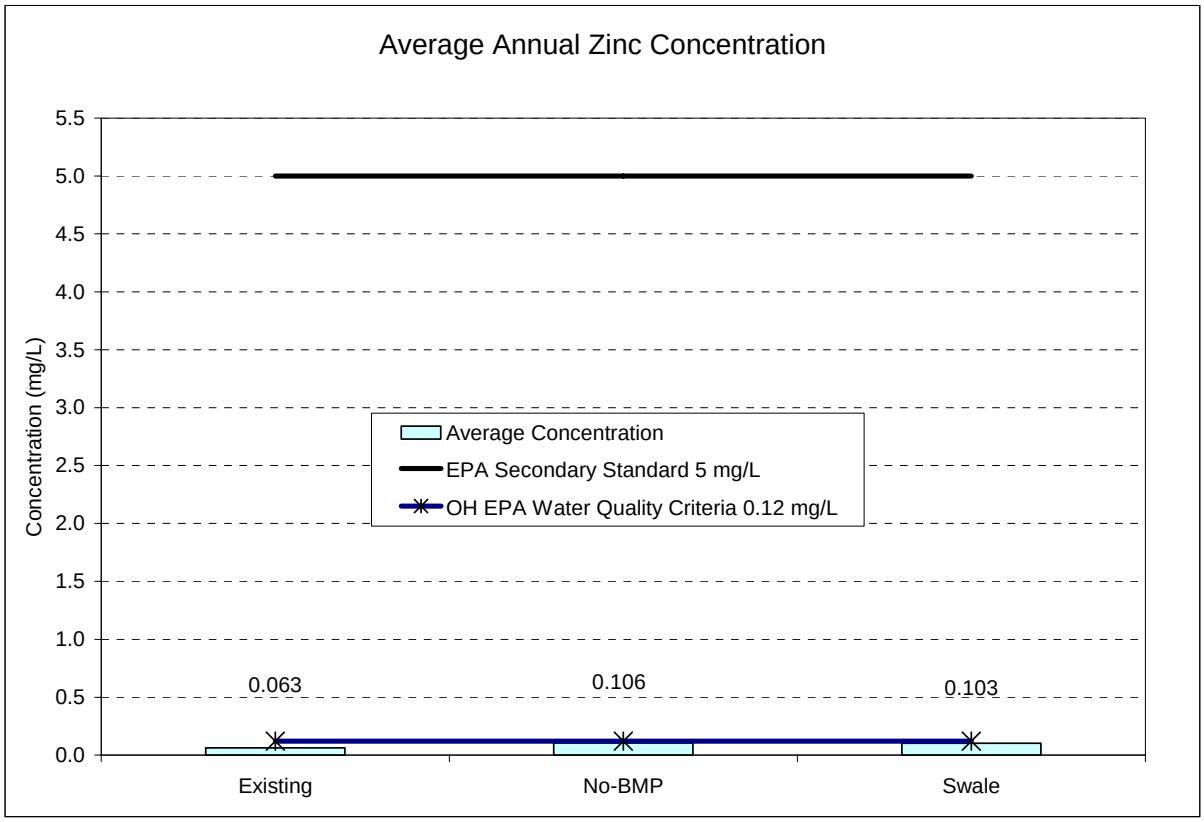


Figure 3.4 Average Annual Zinc Concentration

Table 3.9 Annual Zinc Load for Swale Sub-Basins

Sub-Basin	2004 Total Load (kg)		% Change	Concentration mg/L		% Change
	No-BMP	Swale		No-BMP	Swale	
16	12	9	-33%	0.086	0.017	-81%
17	18	13	-36%	0.125	0.024	-81%
18	58	48	-23%	0.125	0.023	-81%
19	36	27	-35%	0.120	0.023	-81%
22	39	30	-30%	0.107	0.020	-81%
23	40	29	-36%	0.147	0.029	-80%
24	12	10	-20%	0.125	0.023	-81%
25	40	35	-17%	0.092	0.017	-81%
26	61	49	-24%	0.125	0.024	-80%
27	18	15	-21%	0.125	0.024	-81%
28	15	12	-19%	0.090	0.017	-81%
29	19	16	-20%	0.104	0.020	-81%
35	114	81	-40%	0.146	0.027	-82%
38	175	151	-16%	0.160	0.119	-26%
42	11	9	-16%	0.125	0.065	-48%

3.6. Chloride Results

Road salt used to melt snow and ice on roadways and parking lots enters the water cycle with the melting of the snow, ice and with washoff by runoff. When dissolved in snow melt and rainwater, the salt disassociates into sodium and chloride ions. The chloride dissolved in melt water generally is neither used in biological activity nor absorbed by the soil. The chloride passes through the water cycle diluted but not reduced.

Currently, no MCL exists for chloride. The EPA Secondary Standard of 250 mg/L for chloride is based on taste.

For this study the chloride loading was based on the loading rates reported by the Butler County Engineer's Office. Butler County, in an average year, spreads 4,500 tons of salt on 623 lane miles throughout the county. Assuming 12-foot wide lanes, the annual loading rate is 0.62 kilograms of chloride per square foot (Cl^{-} kg/ft^2). This loading rate is the estimate for heavily traveled main roads. Lesser roads, residential streets and parking lots would have lower loading rates that are reflected in the estimation of road surface area.

The road surface salted was estimated from the land use as shown in Table 3.10. Industrial areas were estimated as 10% road surface and 95% impervious area. The low fraction of road surface is due to assumptions of large areas of roof, paved storage areas, and lightly or unsalted parking lots for this land use. Urban Development and Rural Development were assumed to have 10% and 5% road surface respectively.

Table 3.10 Impervious and Road Surface Area by Land Use

Land Use	% Impervious	% Road Surface
Commercial / Industrial	95	10
Cropland	0	0
Pasture	0	0
Rural Development	25	5
Sink	0	0
Urban Development	50	10
Woods	0	0

Annual loadings were used rather than trying to estimate continuous concentrations and loadings given the approximate nature of the road surface area estimate. The method of estimation of road salt loading was checked in two ways. The first used available center of road data in the GIS to estimate the road existing road surface assuming 12-foot wide lanes. This road surface area was approximately the same as the road surface estimated from land use information. The second check was against the reported peak chloride concentration in the raw water at the Southwest Regional Water District wells. The reported peak of 31.8 mg/L compares favorably to the Existing conditions estimate of 35 mg/L.

The increase in chloride load and concentration shown in Table 3.11 and Figure 3.5 are strictly functions of increased road surface and road salt use. The large increase in road salt loading was partial offset by the increased runoff and percolation.

Given the conservative nature of chloride, land development BMPs such as swales and basins do not impact the annual average concentration of chloride in runoff. Operational BMPs will reduce the effects of chloride both for the entire watershed and for specific locations. Possible BMPs include reducing road salt use through brine spraying or other techniques,

Table 3.11 Annual Chloride Loading

	2004 Load			% Change From Existing		Swale % Change from No-BMP
Category	Existing	No-BMP	Swale	No-BMP	Swale	
Total Load (1000 kg)	400	1,200	1,200	194%	194%	0%
Average Concentration	35 mg/L	75	99	115%	183%	32%
Maximum Concentration	104 mg/L	232	232	123%	123%	
	No MCL Secondary Standard 250 mg/L					

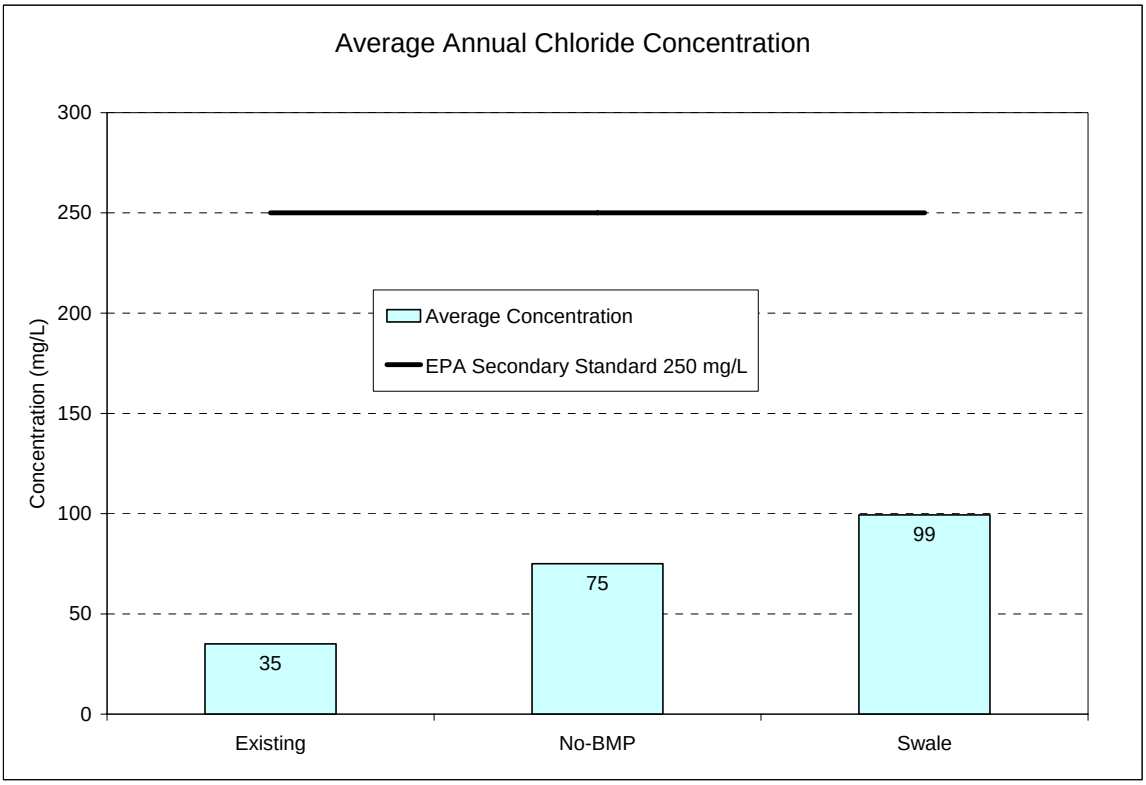


Figure 3.5 Average Annual Chloride Concentration

3.7. Suspended Sediment Results

Suspended sediments are small pieces of soil or debris washed into water courses. Suspended sediment may be a water quality problem from two processes. The physical existence of the sediment can block sunlight from aquatic vegetation, fill streambeds, and clog openings in gravel beds and other substrate. Clogging the substrates buries the habitat for invertebrates and small fish that populate the stream. Clogging the substrate will also reduce the infiltration capacity of the streambed. Sediment may also serve as a carrier for phosphates, petroleum products, and other pollutants. Additionally the sediment itself may be composed of particles of pollutants such as zinc, copper, lead, and other metals.

Cropland, as shown in Table 3.12, has very high suspended sediment concentrations compared to other land uses due to the length of time that the soil is bare and due to exposed soil between rows of crops.

Table 3.12 Suspended Sediment Concentration by Land Use	
Land Use	Suspended Sediment (mg/L)
Commercial / Industrial	110
Cropland	6,000
Pasture	160
Rural Development	160
Sink	0
Urban Development	110
Woods	30

Suspended sediment is washed into streams by surface runoff. Interflow and groundwater flows do not carry sediment to the streams. The urbanization of the Trenton watershed leads to increased surface runoff to Jackson Ditch as shown in Table 3.13. This change is most apparent for the No-BMP conditions where storm sewers carry impervious area runoff directly to the Jackson Ditch. Almost one-third of the surface runoff for the No-BMP conditions is from the storm sewers. Sediment washed off of impervious surfaces in the No-BMP conditions has less chance of depositing on pervious surfaces compared to the With-BMP conditions. For the With-BMP conditions, the suspended sediment loading decreases while the runoff increases as cropland is developed. Both changes are due to the conversion of cropland to urban development.

Table 3.13 Annual Suspended Sediment Loading to Jackson Ditch						
	2004 Load			% Change From Existing		Swale % Change from No-BMP
Category	Existing	No-BMP	Swale	No-BMP	Swale	
Total Sediment Load (1000 kg)	116	273	90	136%	-22%	-67%
Surface Runoff (1,000,000 ft3)	2.8	95.6	38.1	3,400%	1,236%	-60%
Sediment Concentration mg/L	1,434	101	84	-93%	-94%	-17%

Table 3.14 Annual Sediment Load for Swale Sub-Basins						
Sub-Basin	2004 Total Load (kg)		% Change	Concentration mg/L		% Change
	No-BMP	Swale		No-BMP	Swale	
16	551	304	-81%	77.6	14.5	-81%
17	121	67	-81%	8.8	1.6	-81%
18	565	311	-82%	19.7	3.5	-82%
19	1,657	911	-82%	55.9	10.1	-82%
22	4,491	2,463	-82%	371.8	65.6	-82%
23	3,180	1,759	-81%	59.2	11.4	-81%
24	184	101	-82%	34.4	6.1	-82%
25	2,053	1,127	-82%	122.1	21.8	-82%
26	869	481	-81%	27.0	5.2	-81%
27	187	103	-82%	22.4	4.0	-82%
28	535	293	-82%	88.1	15.7	-82%
29	150	83	-82%	17.8	3.2	-82%
35	4,388	2,403	-83%	66.1	11.5	-83%
38	44,356	33,982	-31%	134.5	93.4	-31%
42	207	123	-68%	24.5	7.8	-68%

4. Summary

The Trenton watershed is expected to experience significant development as farmland is converted to residential and urban areas. Changes are foreseen in the volume, timing, and quality of the water flowing through the surface channels and into the aquifer. The aquifer under the Trenton watershed is the source of water for two public water supplies (Southwest Regional Water District and City of Trenton), Miller Brewing, and the Cincinnati Gas & Electric power plant. Reductions in the volume of water available or declines in the water quality would have adverse economic impacts on the community.

A model using the US EPA HSPF software was developed to examine the Trenton watershed for changes in aquifer recharge and water quality with development. Watershed data in the model included areas, slopes, and flow channels. Land use information was developed for existing and future conditions. Weather data was developed for 2004 as a typical weather year. Water quality parameters were estimated based on literature values.

Three scenarios were examined; Existing, No-BMP, and Swale. Existing conditions used information on the land use and flow patterns as they currently exist. No-BMP conditions used future land uses and assumed standard storm water practices. Swale conditions used future land uses and modeled storm water swales and detention basins in certain areas of the watershed. The scenarios were selected to examine the effects of development on the watershed and possible solutions to negative impacts.

As no calibration data was available, the results should not be viewed as absolute numbers, but rather as a method for estimating the degree of changes in water volumes and water quality that can be expected with development.

4.1. Hydrology Summary

Identical weather conditions for 2004 were used for each of the three scenarios. The results of the model were examined as described below.

4.1.1. Runoff to Jackson Ditch

Due to limitations of the HSPF model, the flows in Jackson Ditch could not be modeled accurately. The flows were examined using hourly average runoff flows summed together. No attempt was made to account for storage and attenuation due to the channel length and geometry. The results for flows in Jackson Ditch are intended for relative comparison between the scenarios. rather than as realistic representation of how the stream would act.

The runoff to Jackson Ditch increased with development as would be expected with the increase in impervious area. The No-BMP conditions increased runoff volume to Jackson Ditch by 80% and peak flows by up to 10 times compare to the Existing conditions. The Swale conditions increase runoff volume by 35% and peaks by a factor of 3.3. Inclusion of BMPs reduced the volume of runoff to Jackson Ditch by 27% and reduced the peak flow by 64% compared to the No-BMP conditions. The increase in flows is expected to aggravate flooding and erosion issues in Jackson Ditch.

Increased peak flows and total runoff volume in Jackson Ditch will more often exceed the infiltration capacity of Miller Sink in the future compared to the current conditions. The volume of water and peak flows passing Gephardt Road are expected to increase by 30 times for the No-BMP conditions compared with the Existing conditions. For the Swale conditions, the volume and peak flows are expected to increase over 8 times. Installing BMPs during development reduces the volume and peak flows past Gephardt Road by roughly 70% compared to the No-BMP conditions.

4.1.2. Percolation

The development of rural land to residential and urban areas decreases the pervious areas and reduces the percolation to the aquifer. The overall decrease in percolation was offset by the increased percolation at the Route 73, and Streit Sinks as well as infiltration basins and dry wells in the City of Trenton. Aquifer recharge at the Miller Sink is expected to increase with development as water volumes in Jackson Ditch increase. Runoff volumes between Gephardt Road and the quarry increase 210% for the No-BMP conditions and 120% for the Swale conditions. All water in this area of the watershed is assumed to percolate to the aquifer from the streambed, the floodplains or at the quarry.

For the wells of the City of Trenton and Cincinnati Gas & Electric, the aquifer level and capacity should rise with the 30% increase in infiltration with development in the City of Trenton. The changes for the Southwest Regional Water District and Miller Brewery may be

larger due to their proximity to the large increase in Miller Sink percolation. The large increase in percolation due to storm water basins in the Swale conditions is expected to increase the available water for all of the water supply wells. For both the No-BMP and Swale conditions, a significant volume of water flows past Gephardt Road before percolating to the aquifer. This water may percolate into the aquifer too far from the Southwest and Miller wells to have a significant effect on the wells.

4.2. Water Quality Summary

Water quality was examined for six parameters; nitrate, dissolved phosphorus, copper, zinc, chloride, and suspended sediment. The loading for each was based on EMCs for each land use. Nitrate and dissolved phosphorus concentrations for water percolating into the ground were reduced by 30% to account for biological activity within the soil.

Nitrate loading in the watershed is expected to decrease with the development of farmland into residential and urban areas. Nitrates are currently below drinking water standards and surface water targets and are expected to drop further.

Phosphorus loading is expected to increase in both total load and in concentration due to the increase in lawn fertilization with development. No drinking water standard currently exists for phosphorus. The expected future concentrations will be above the surface water targets intended to prevent eutrophication. The use of swales, basins, and other BMPs is expected to significantly reduce phosphorus loads and concentrations where used. These practices may not reduce concentrations below the surface water targets.

Copper and zinc will increase in total loading and in concentration. Both metals are expected to be far below drinking water standards. Using both metals as indicators of metal pollutants in general, urbanization is not expected to create drinking water problems due to increased metal pollution. Copper is estimated to be at and is expected to exceed the target concentrations for the protection of aquatic life.

Chloride concentrations will increase in total loading and in concentration with the increase in road surface and resulting increase in road salt use. Uncertainty in the estimation is due to the greatly varying road salt application rates for county roads, residential streets, and parking lots. Chloride concentrations are estimated to be below drinking water standards currently and in the future.

Suspended sediment loading is expected to change with development. The conversion of cropland to urban development will reduce the average suspended sediment concentration. The storm sewers of the No-BMP conditions will carry much higher surface runoff with a higher total sediment load to Jackson Ditch than the Existing conditions. Sediment buildup on the paved areas will be washed directly to Jackson Ditch through the sewers. The With-BMP conditions will reduce the total sediment load to Jackson Ditch compared to both Existing and No-BMP conditions. The With-BMP conditions assume the capture of sediment through the use of practices such as grit chambers or grassed swales before it can enter Jackson Ditch.

Appendix D-1 HSPF Model Results by Sub-Basin

	Runoff Depth (Inch)			Percolation Depth (Inch)		
Sub-Basin	Existing	No-BMP	Swale	Existing	No-BMP	Swale
1	14.04	15.06	13.79	1.48	1.56	1.54
2	13.42	13.79	14.92	1.48	1.54	1.35
3	13.58	14.92	11.63	1.21	1.35	4.83
4	15.38	18.87	15.06	1.09	1.32	1.56
5	8.81	11.63	14.08	5.12	4.82	2.08
6	13.77	14.08	13.54	1.97	2.08	3.73
7	12.26	13.54	12.30	3.46	3.73	4.32
8	10.45	12.3	18.87	4.29	4.32	1.32
9	11.95	13.29	13.61	3.85	4.05	1.12
10	11.71	16.08	15.79	2.95	2.86	1.31
11	15.4	18.35	15.35	2.19	2.24	1.59
12	10.82	19.13	14.62	5.59	5.04	4.32
13	13.69	13.61	14.42	1.06	1.12	5.79
14	12.37	15.87	15.29	1.64	1.44	2.09
15	13.23	15.79	32.24	1.4	1.31	1.97
16	8.43	15.12	2.39	5.08	4.23	16.40
17	10.46	22.09	5.69	3.57	3.2	18.98
18	2.18	15.23	4.03	11.29	9.43	20.03
19	9.1	19.87	5.72	4.78	3.68	17.96
20	1.78	4.73	2.39	12.16	13.34	16.40
21	2.17	4.22	5.69	11.51	12.13	18.98
22	2.72	9.38	2.94	11.41	12.37	18.81
23	13.98	27.29	13.75	6.66	1.81	16.72
24	0.84	13.95	3.82	12.3	10.87	20.46
25	2.83	11.59	2.47	14.47	23.36	19.91
26	1.81	12.63	4.19	12.34	12.21	17.65
27	1.98	14.83	4.03	11.87	10.25	20.56
28	7.25	20.65	2.27	15.73	28.61	20.13
29	4.19	10.45	2.83	11.22	11.67	19.28
30	13.45	15.29	6.96	2.2	2.09	26.82
31	7.57	14.42	4.73	6.8	5.79	13.34
32	2.72	3.57	7.72	12.05	11.86	22.83
33	7.63	45.15	4.21	21.1	32.74	12.13
34	9.49	14.62	13.29	4.16	4.33	4.06
35	3.42	25.32	12.69	13.27	5.92	18.55
36	19.39	32.24	14.81	9.13	1.97	10.29
37	6.68	15.09	13.74	10.34	9.44	11.00
38	9.34	9.34	18.51	13.14	1.98	15.71
39	4.43	14.81	4.13	10.73	10.29	20.35

	Runoff Depth (Inch)			Percolation Depth (Inch)		
Sub-Basin	Existing	No-BMP	Swale	Existing	No-BMP	Swale
40	10.37	13.74	14.71	12.22	10.99	9.77
41	12.39	14.65	15.27	11.28	10.4	10.10
42	3.18	15.12	4.13	12.52	9.94	20.35
43	7.78	15.27	32.16	10.43	10.1	1.89
44	8.87	16.78	15.30	10.2	8.55	10.07
45	4.36	4.63	3.57	10.68	10.76	11.86
46	5.44	32.16	15.21	11.11	1.89	10.13
47	11.98	15.31	14.98	11.2	10.07	10.22
48	6.12	14.98	15.33	11.17	10.22	10.03
49	7.51	15.21	14.71	11.52	10.13	10.30
50	13.59	15.33	15.01	10.79	10.03	10.36
51	14.4	15.01	15.30	10.83	10.36	10.06
52	10.94	15.3	45.15	11.32	10.06	32.73
53	13.09	14.71	18.51	11.05	10.3	15.71

	Nitrate Concentration (mg/L)			Nitrate Load (kg/yr)		
Sub-Basin	Existing	No-BMP	Swale	Existing	No-BMP	Swale
1	0.81	0.94	0.94	92.00	114.44	114.44
2	0.75	0.97	0.97	155.83	207.60	207.60
3	0.42	0.39	0.39	200.27	203.61	203.58
4	0.38	0.35	0.35	64.63	72.51	72.51
5	0.65	0.35	0.35	70.86	50.02	50.04
6	0.52	0.44	0.44	98.07	84.86	84.86
7	0.76	0.59	0.59	78.43	67.06	67.06
8	0.79	0.63	0.63	42.95	40.13	40.12
9	0.45	0.41	0.41	35.00	35.42	35.43
10	0.68	0.38	0.38	64.36	49.74	49.74
11	0.43	0.36	0.36	16.37	16.27	16.27
12	1.01	0.44	0.44	77.79	59.41	59.42
13	0.80	0.80	0.80	79.22	78.76	78.76
14	0.85	0.58	0.58	142.93	120.12	102.45
15	1.04	0.75	0.75	99.49	84.91	84.91
16	1.34	0.78	0.55	99.00	94.57	89.88
17	1.52	0.45	0.33	114.35	67.64	58.71
18	1.53	0.45	0.33	72.57	130.02	171.70
19	1.28	0.49	0.36	184.49	150.82	136.27
20	1.52	1.06	1.06	14.53	26.97	26.99
21	1.20	1.03	1.03	47.23	77.98	78.06
22	0.73	0.74	0.67	25.46	89.05	185.31

	Nitrate Concentration (mg/L)			Nitrate Load (kg/yr)		
Sub-Basin	Existing	No-BMP	Swale	Existing	No-BMP	Swale
23	0.48	0.43	0.36	75.29	137.89	123.06
24	1.19	0.45	0.33	4.36	23.06	34.71
25	1.46	0.54	0.39	86.90	129.98	180.73
26	1.49	0.45	0.38	59.39	125.05	180.94
27	1.58	0.45	0.33	19.86	36.62	51.37
28	1.41	0.35	0.27	78.07	112.39	42.33
29	1.17	0.39	0.28	44.38	36.72	55.95
30	1.09	1.06	1.06	50.90	56.41	56.41
31	1.59	0.90	0.90	60.69	65.28	65.28
32	0.94	1.13	1.13	41.71	66.23	66.25
33	0.53	0.46	0.46	75.30	385.36	385.36
34	1.22	0.86	0.86	406.24	444.35	444.35
35	1.38	0.58	0.66	78.01	242.11	339.34
36	0.48	0.42	0.42	106.73	156.47	156.47
37	1.06	0.45	0.45	75.65	72.30	72.30
38	1.53	0.42	0.56	281.37	77.15	378.11
39	1.66	0.45	0.45	90.90	82.39	82.39
40	0.61	0.45	0.45	42.87	41.95	41.95
41	0.46	0.45	0.45	45.27	51.83	51.83
42	1.11	0.45	0.34	13.44	22.55	31.57
43	0.49	0.45	0.45	18.96	34.37	34.37
44	0.58	0.45	0.45	19.29	25.01	13.75
45	0.79	0.60	0.60	46.58	37.51	37.52
46	1.17	0.42	0.42	155.94	332.40	332.40
47	0.52	0.45	0.45	96.54	106.68	106.73
48	0.41	0.45	0.45	8.13	21.93	21.93
49	0.47	0.45	0.45	20.35	39.12	39.12
50	0.46	0.45	0.45	24.87	27.48	27.48
51	0.45	0.45	0.45	108.41	112.39	112.41
52	0.66	0.45	0.45	47.65	45.75	45.75
53	0.51	0.45	0.45	69.29	69.24	69.24

	Phosphorus Concentration (mg/L)			Phosphorus Load (kg/yr)		
Sub-Basin	Existing	No-BMP	Swale	Existing	No-BMP	Swale
1	0.33	0.45	0.45	37.07	54.48	54.48
2	0.36	0.46	0.46	74.60	97.74	97.74
3	0.30	0.35	0.35	145.80	183.86	183.83
4	0.37	0.55	0.55	63.18	113.95	113.95
5	0.26	0.30	0.30	28.58	43.57	43.59

	Phosphorus Concentration (mg/L)			Phosphorus Load (kg/yr)		
Sub-Basin	Existing	No-BMP	Swale	Existing	No-BMP	Swale
6	0.39	0.41	0.41	73.03	79.60	79.60
7	0.35	0.36	0.36	36.68	41.02	41.02
8	0.28	0.35	0.35	15.29	22.18	22.18
9	0.38	0.42	0.42	29.48	36.42	36.43
10	0.37	0.47	0.47	34.82	61.52	61.52
11	0.42	0.54	0.54	16.19	24.41	24.41
12	0.32	0.36	0.36	24.61	48.38	48.38
13	0.15	0.15	0.15	14.99	14.90	14.90
14	0.24	0.26	0.26	39.64	55.04	46.80
15	0.19	0.21	0.21	18.47	24.41	24.41
16	0.26	0.28	0.28	19.22	34.10	45.33
17	0.27	0.33	0.33	20.28	49.57	58.43
18	0.30	0.33	0.33	14.40	96.50	175.32
19	0.30	0.32	0.32	43.56	98.85	120.97
20	0.28	0.31	0.31	2.63	7.80	7.80
21	0.27	0.26	0.26	10.40	19.49	19.51
22	0.35	0.32	0.32	12.06	38.70	90.07
23	0.30	0.19	0.20	47.82	60.73	69.41
24	0.27	0.33	0.33	0.98	16.81	34.88
25	0.28	0.40	0.39	16.55	97.84	182.76
26	0.30	0.33	0.36	12.16	91.95	171.87
27	0.29	0.33	0.33	3.63	26.63	51.41
28	0.32	0.55	0.59	17.71	59.70	92.98
29	0.33	0.46	0.46	12.37	43.77	92.63
30	0.32	0.41	0.41	14.82	21.71	21.71
31	0.30	0.33	0.33	11.43	23.80	23.80
32	0.33	0.28	0.28	14.49	16.08	16.09
33	0.37	0.20	0.20	53.29	169.08	169.08
34	0.24	0.20	0.20	80.90	101.12	101.12
35	0.31	0.13	0.15	17.42	55.88	78.28
36	0.22	0.11	0.11	48.52	40.96	40.96
37	0.30	0.33	0.33	21.16	53.07	53.07
38	0.28	0.11	0.16	51.04	20.25	105.38
39	0.30	0.33	0.33	16.59	60.42	60.42
40	0.32	0.33	0.33	22.62	30.76	30.76
41	0.35	0.33	0.33	34.49	38.01	38.01
42	0.39	0.33	0.32	4.78	16.54	30.22
43	0.55	0.33	0.33	21.32	25.17	25.17

	Phosphorus Concentration (mg/L)			Phosphorus Load (kg/yr)		
Sub-Basin	Existing	No-BMP	Swale	Existing	No-BMP	Swale
44	0.48	0.33	0.33	15.96	18.40	9.98
45	0.45	0.55	0.55	26.35	34.17	34.18
46	0.37	0.11	0.11	49.21	89.53	89.53
47	0.36	0.33	0.33	66.37	78.23	78.27
48	0.43	0.33	0.33	8.51	16.08	16.08
49	0.42	0.33	0.33	17.95	28.69	28.69
50	0.34	0.33	0.33	18.66	20.15	20.15
51	0.33	0.33	0.33	79.05	82.42	82.43
52	0.31	0.33	0.33	22.58	33.55	33.55
53	0.33	0.33	0.33	44.99	50.78	50.78

	Copper Concentration (microg/L)			Copper Load (kg/yr)		
Sub-Basin	Existing	No-BMP	Swale	Existing	No-BMP	Swale
1	8.76	10.86	10.86	0.99	1.32	1.32
2	7.16	8.10	8.10	1.49	1.73	1.73
3	5.49	9.22	9.22	2.64	4.87	4.87
4	8.77	15.00	15.00	1.48	3.11	3.11
5	8.06	10.55	10.55	1.26	2.17	2.17
6	6.61	7.55	7.55	1.25	1.45	1.45
7	8.52	10.56	10.56	0.88	1.20	1.20
8	7.54	10.40	10.40	0.41	0.66	0.66
9	6.20	9.07	9.07	0.48	0.78	0.78
10	7.54	13.48	13.48	0.72	1.76	1.76
11	11.66	15.34	15.34	0.45	0.70	0.70
12	11.41	19.40	19.40	0.88	2.63	2.63
13	6.92	6.92	6.92	0.68	0.68	0.68
14	7.14	10.64	10.64	1.20	2.22	1.92
15	7.87	11.05	11.05	0.75	1.26	1.26
16	9.21	14.52	14.93	0.68	1.75	2.45
17	9.39	19.98	20.94	0.71	3.00	3.71
18	10.06	19.93	20.61	0.48	5.78	10.80
19	9.40	19.32	20.28	1.35	5.94	7.60
20	9.51	14.58	14.58	0.09	0.37	0.37
21	8.84	11.91	11.91	0.35	0.91	0.91
22	7.20	17.65	17.69	0.25	2.12	4.92
23	13.59	23.19	13.45	2.14	7.42	4.61
24	8.81	20.05	15.33	0.03	1.03	1.62
25	10.05	15.13	12.12	0.60	3.67	5.69

	Copper Concentration (microg/L)			Copper Load (kg/yr)		
Sub-Basin	Existing	No-BMP	Swale	Existing	No-BMP	Swale
26	9.85	19.99	16.40	0.39	5.56	7.89
27	9.72	20.07	14.99	0.12	1.63	2.34
28	10.50	15.00	12.83	0.56	2.73	2.02
29	10.53	16.96	13.00	0.40	1.60	2.60
30	10.32	12.69	12.69	0.48	0.68	0.68
31	9.99	16.19	16.19	0.38	1.18	1.18
32	6.51	7.71	7.71	0.29	0.45	0.45
33	12.99	20.89	20.89	1.85	17.61	17.61
34	8.81	13.39	13.39	2.95	6.90	6.90
35	11.42	23.14	24.94	0.65	9.68	12.88
36	20.08	24.99	24.99	4.49	9.30	9.30
37	13.45	19.99	19.99	1.37	4.59	4.59
38	11.89	24.99	35.05	2.18	4.59	23.58
39	10.28	20.00	20.00	0.80	5.23	5.23
40	18.43	20.00	20.00	1.85	2.66	2.66
41	18.46	20.00	20.00	2.57	3.29	3.29
42	11.86	20.00	15.92	0.14	1.00	1.49
43	9.58	20.01	20.01	0.53	2.18	2.18
44	13.35	19.83	19.83	0.45	1.10	0.61
45	6.03	5.16	5.16	0.36	0.32	0.32
46	9.89	24.88	24.88	1.89	28.07	28.07
47	17.67	20.00	20.00	4.69	6.77	6.78
48	10.02	20.00	20.00	0.29	1.39	1.39
49	12.00	20.00	20.00	0.74	2.48	2.48
50	18.99	20.00	20.00	1.47	1.74	1.74
51	19.98	20.00	20.00	6.84	7.14	7.14
52	17.51	20.00	20.00	1.82	2.90	2.90
53	19.55	20.00	20.00	3.82	4.40	4.40

	Zinc Concentration (microg/L)			Zinc Load (kg/yr)		
Sub-Basin	Existing	No-BMP	Swale	Existing	No-BMP	Swale
1	46.95	60.10	60.10	5.30	7.28	7.28
2	37.25	42.42	42.42	7.73	9.05	9.05
3	28.17	52.27	52.27	13.54	27.59	27.59
4	49.50	90.00	90.00	8.36	18.65	18.65
5	43.15	61.44	61.44	6.73	12.65	12.66
6	35.08	41.56	41.56	6.61	8.01	8.01
7	45.82	60.26	60.26	4.74	6.88	6.88

	Zinc Concentration (microg/L)			Zinc Load (kg/yr)		
Sub-Basin	Existing	No-BMP	Swale	Existing	No-BMP	Swale
8	39.13	58.61	58.61	2.12	3.73	3.73
9	32.83	51.48	51.48	2.55	4.45	4.45
10	40.04	80.43	80.43	3.80	10.48	10.48
11	67.83	92.35	92.35	2.60	4.21	4.21
12	63.51	120.77	120.77	4.87	16.38	16.39
13	34.60	34.60	34.60	3.41	3.39	3.39
14	36.11	61.38	61.38	6.07	12.81	11.04
15	39.58	62.79	62.79	3.77	7.15	7.15
16	46.73	85.95	53.67	3.45	10.38	8.82
17	46.98	124.84	72.60	3.53	18.77	12.87
18	51.32	124.53	90.93	2.44	36.09	47.66
19	48.44	120.17	71.87	6.97	36.95	26.92
20	47.72	84.71	84.71	0.46	2.15	2.15
21	45.16	66.93	66.93	1.77	5.09	5.10
22	37.53	107.39	107.60	1.31	12.87	29.91
23	82.88	147.31	85.43	13.05	47.14	29.31
24	45.05	125.34	95.83	0.17	6.43	10.13
25	51.71	92.00	73.70	3.07	22.35	34.58
26	50.19	124.92	102.49	2.00	34.76	49.29
27	48.82	125.49	93.74	0.61	10.22	14.65
28	54.83	90.00	77.13	2.86	16.47	12.16
29	56.33	103.71	79.48	2.13	9.79	15.89
30	55.40	71.20	71.20	2.60	3.80	3.80
31	50.51	96.53	96.53	1.93	7.01	7.01
32	32.79	39.26	39.26	1.46	2.29	2.29
33	78.93	132.23	132.23	11.24	111.49	111.49
34	44.83	78.11	78.11	14.99	40.23	40.23
35	61.95	146.35	157.76	3.51	61.25	81.46
36	126.67	159.95	159.95	28.35	59.51	59.51
37	77.07	124.96	124.96	7.83	28.69	28.69
38	63.89	159.92	224.33	11.73	29.37	150.91
39	52.09	125.00	125.00	4.08	32.69	32.69
40	113.43	125.00	125.00	11.40	16.65	16.65
41	114.73	125.00	125.00	15.97	20.57	20.57
42	65.37	125.00	99.79	0.79	6.26	9.36
43	54.80	125.08	125.08	3.05	13.65	13.65
44	78.03	123.89	123.89	2.61	6.86	3.77
45	30.15	26.02	26.02	1.78	1.62	1.62

	Zinc Concentration (microg/L)			Zinc Load (kg/yr)		
Sub-Basin	Existing	No-BMP	Swale	Existing	No-BMP	Swale
46	53.32	159.20	159.20	10.18	179.59	179.59
47	109.13	125.00	125.00	28.94	42.33	42.35
48	57.79	125.00	125.00	1.64	8.70	8.70
49	71.41	125.00	125.00	4.38	15.52	15.53
50	118.29	125.00	125.00	9.15	10.90	10.90
51	124.84	125.00	125.00	42.73	44.60	44.61
52	106.97	125.00	125.00	11.11	18.16	18.16
53	121.63	125.00	125.00	23.79	27.48	27.48

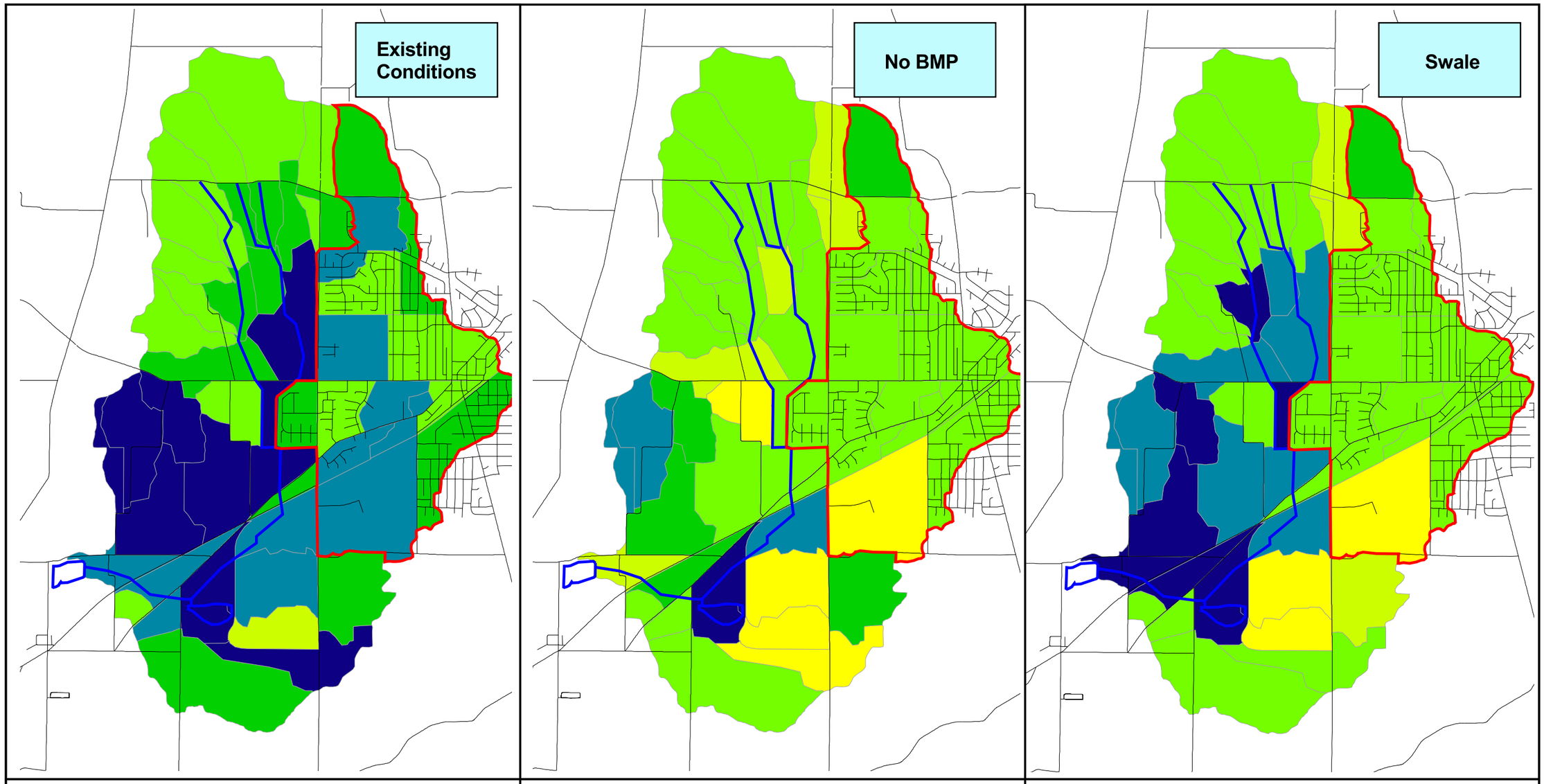
	Chloride Concentration (mg/L)			Chloride Load (kg/yr)		
Sub-Basin	Existing	No-BMP	Swale	Existing	No-BMP	Swale
1	17.8	30.5	30.5	2,222	4,076	4,076
2	8.4	10.8	10.8	1,941	2,573	2,573
3	4.3	33.1	33.1	2,248	19,083	19,083
4	30.1	65.1	65.1	5,436	14,425	14,425
5	17.9	50.5	50.5	4,404	14,718	14,718
6	11.2	20.7	20.7	2,422	4,581	4,581
7	18.0	40.8	40.8	2,381	5,934	5,934
8	8.5	35.7	35.7	647	3,071	3,071
9	10.0	31.0	31.0	1,028	3,496	3,496
10	14.1	63.2	63.2	1,675	9,701	9,701
11	47.5	68.1	68.1	2,077	3,485	3,485
12	39.0	102.2	102.2	4,538	17,510	17,510
13	0.2	0.2	0.2	17	17	17
14	2.5	49.2	50.3	486	11,580	11,580
15	1.3	46.2	46.2	135	5,692	5,692
16	4.5	72.2	74.4	529	12,229	12,229
17	0.1	103.7	106.4	10	18,846	18,846
18	6.7	105.8	108.5	1,954	56,859	56,859
19	9.0	105.0	104.4	1,982	39,115	39,115
20	1.2	68.8	68.8	91	6,675	6,675
21	6.1	47.6	47.6	1,495	14,039	14,039
22	9.5	92.5	92.5	1,720	25,701	25,701
23	54.5	90.3	86.2	12,680	29,590	29,590
24	6.8	105.9	108.2	388	11,434	11,434
25	6.8	45.7	45.7	2,462	33,493	33,493
26	5.9	105.5	105.5	1,837	57,730	57,730
27	1.5	104.7	106.8	128	16,692	16,692

	Chloride Concentration (mg/L)			Chloride Load (kg/yr)		
Sub-Basin	Existing	No-BMP	Swale	Existing	No-BMP	Swale
28	8.9	26.7	26.7	1,689	10,828	10,828
29	20.8	82.7	82.7	2,895	16,531	16,531
30	21.2	40.6	40.6	1,157	2,460	2,460
31	3.5	80.5	80.5	251	8,196	8,196
32	1.4	3.9	3.9	335	985	985
33	36.5	26.8	26.8	19,597	38,975	38,975
34	4.9	46.0	46.0	2,344	30,688	30,688
35	21.8	73.7	73.7	6,011	38,042	38,042
36	69.2	76.8	76.8	22,775	30,309	30,309
37	60.3	107.1	107.1	15,614	39,950	39,950
38	14.9	232.0	232.0	6,573	51,624	51,624
39	4.8	104.7	104.7	1,280	46,399	46,399
40	99.1	106.3	106.2	21,691	25,473	25,473
41	99.4	104.9	104.9	26,421	29,508	29,508
42	33.9	31.0	107.3	2,037	10,063	10,063
43	33.3	103.6	103.6	4,327	18,780	18,780
44	51.7	124.7	106.2	3,713	9,781	9,781
45	0.0	1.7	1.7	0	343	343
46	17.6	76.8	76.8	10,237	91,797	91,797
47	94.1	103.6	103.6	48,289	58,159	58,159
48	40.2	104.3	104.3	3,228	12,212	12,212
49	61.2	103.7	103.7	9,505	21,452	21,452
50	100.5	103.6	103.6	13,940	14,949	14,949
51	103.9	103.6	103.6	62,333	62,465	62,465
52	91.7	103.6	103.6	19,373	24,948	24,948
53	103.9	105.1	105.1	37,496	39,259	39,259

	Sediment Concentration (mg/L)			Sediment Load (kg/yr)		
Sub-Basin	Existing	No-BMP	Swale	Existing	No-BMP	Swale
1	2,058	2,502	2,502	1,767	2,339	2,335
2	1,536	2,308	2,308	2,442	3,520	3,521
3	102	244	244	370	907	909
4	114	160	160	140	279	278
5	1,465	97	97	2,764	181	181
6	432	124	124	578	165	165
7	1,726	1,025	1,025	1,025	742	741
8	1,967	1,347	1,347	734	603	604
9	116	127	127	49	58	58

	Sediment Concentration (mg/L)			Sediment Load (kg/yr)		
Sub-Basin	Existing	No-BMP	Swale	Existing	No-BMP	Swale
10	1,250	141	141	1,028	176	176
11	478	157	157	135	87	87
12	2,928	116	116	1,415	367	367
13	2,297	2,297	2,297	1,777	1,784	1,784
14	2,286	928	928	3,663	5,836	2,252
15	3,292	1,850	1,850	2,676	2,338	2,338
16	4,511	1,832	15	2,761	5,888	304
17	5,263	110	2	1,952	7,063	67
18	5,265	111	4	8,335	21,342	311
19	4,167	321	10	5,648	14,685	911
20	5,257	3,023	3,023	2,189	1,860	1,859
21	3,881	3,002	3,002	6,202	5,975	5,984
22	1,494	1,491	66	1,988	13,962	2,463
23	148	110	11	407	17,658	1,759
24	3,796	110	6	979	4,359	101
25	4,996	422	22	10,617	6,849	1,127
26	5,070	110	5	8,290	2,492	481
27	5,483	110	4	2,313	6,317	103
28	4,754	160	16	5,715	2,009	293
29	3,756	140	3	3,364	455	83
30	3,400	3,195	3,195	1,247	1,319	1,319
31	5,539	2,242	2,242	2,698	1,699	1,702
32	2,543	3,607	3,607	3,227	4,855	4,849
33	143	120	120	648	46,280	46,280
34	3,986	2,345	2,345	12,748	10,377	10,381
35	4,424	110	12	6,999	13,812	2,403
36	186	112	112	6,735	29,513	29,513
37	3,084	110	110	4,969	1,809	1,809
38	5,228	110	93	9,804	48,915	33,982
39	5,813	110	110	9,454	1,658	1,658
40	876	110	110	5,922	1,636	1,636
41	121	110	110	1,270	1,985	1,985
42	3,437	110	8	1,249	3,803	123
43	160	110	110	136	944	944
44	1,140	111	111	490	3,753	329
45	1,351	172	172	1,649	223	223
46	3,272	110	110	10,252	79,386	79,386
47	359	110	110	6,231	4,052	4,051

	Sediment Concentration (mg/L)			Sediment Load (kg/yr)		
Sub-Basin	Existing	No-BMP	Swale	Existing	No-BMP	Swale
48	128	110	110	59	531	532
49	128	110	110	116	864	864
50	113	110	110	794	1,120	1,120
51	122	110	110	3,959	4,118	4,117
52	1,123	110	110	6,473	1,740	1,739
53	364	110	110	6,161	2,620	2,620



Surface Runoff Depth (inches)

0 - 4 Inches
4 - 8
8 - 12
12 - 18
18 - 24
> 24 Inches

City of Trenton
Jackson Ditch
Roads

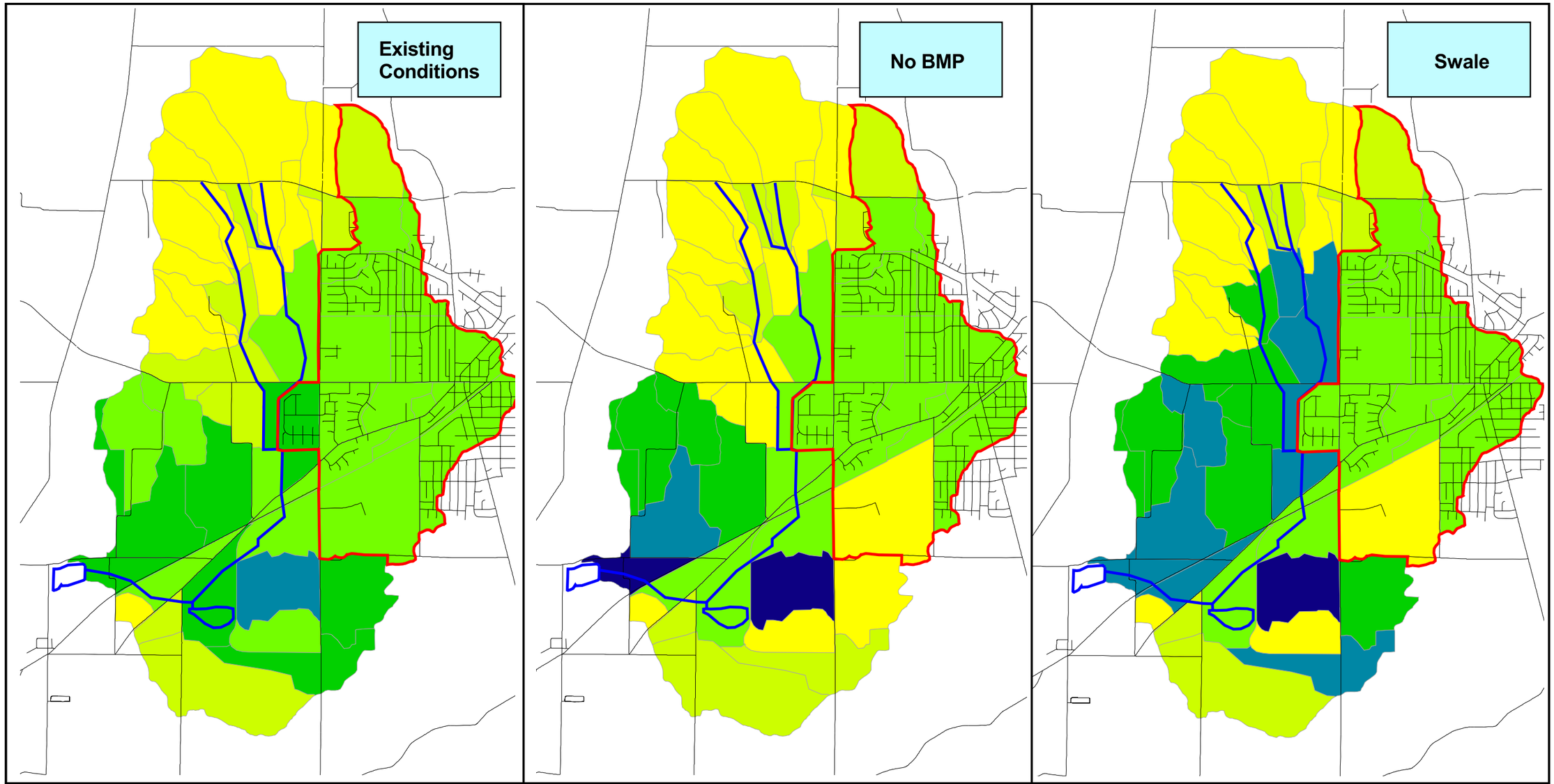
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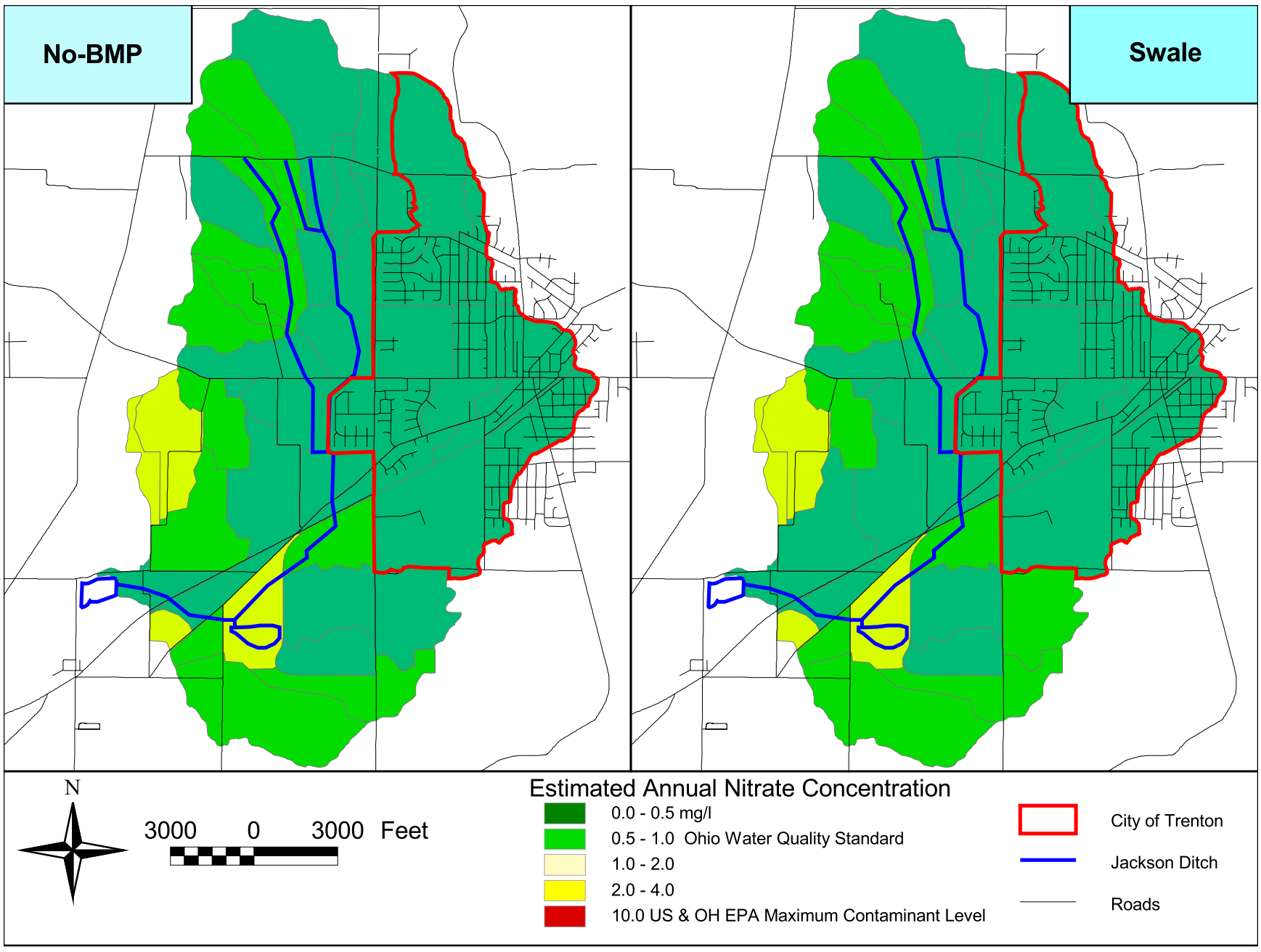
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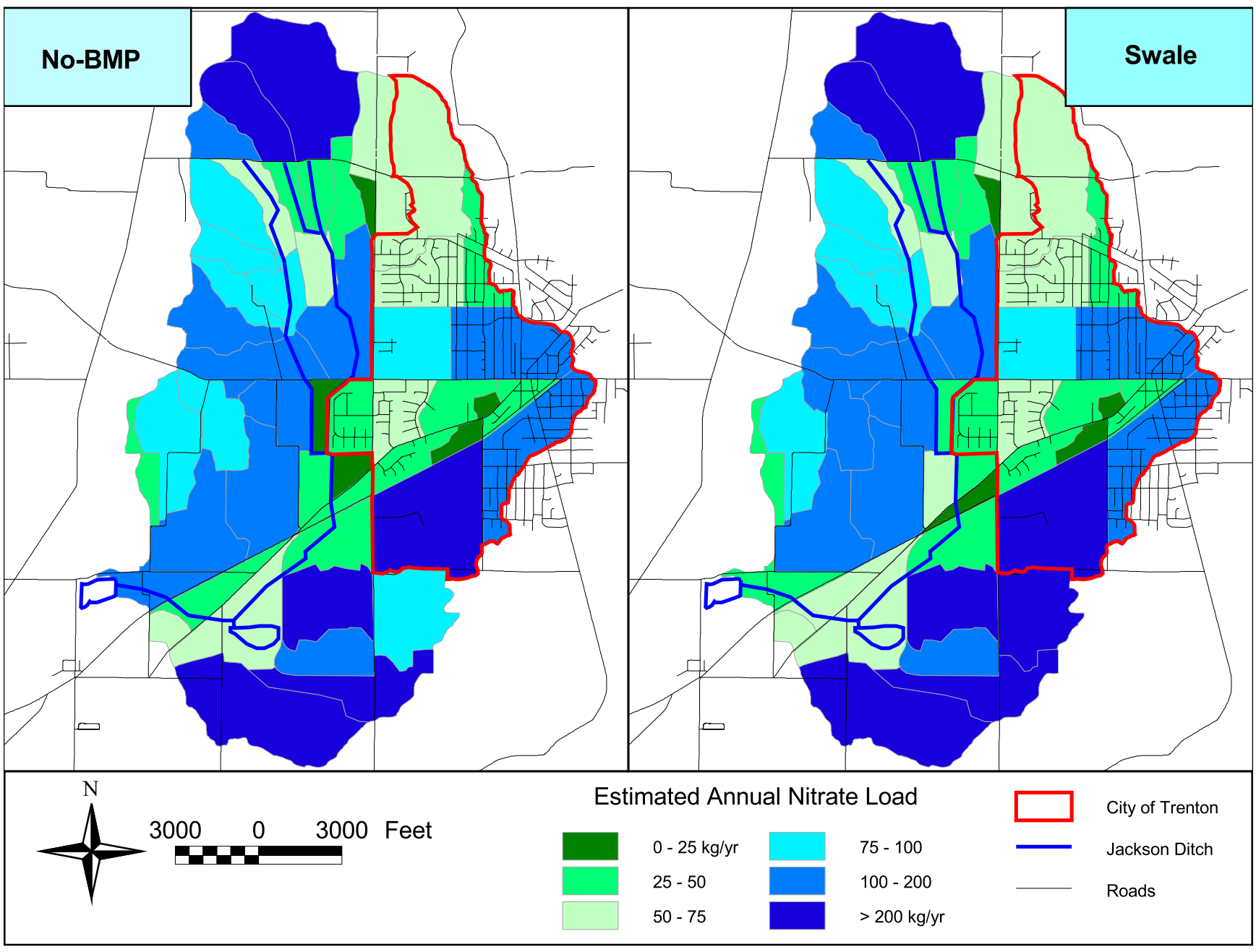
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Butler County Engineer's Office
Trenton Area Storm Water Management Project

Figure D.1
Annual Runoff Depth


Existing Conditions
No BMP
Swale
Annual Percolation Depth (Inches)
0 - 4 Inches
4 - 8
8 - 12
12 - 18
18 - 24
> 24 Inches
Jackson Ditch
Roads
N
2000 0 2000 4000 6000 Feet
XCG
Butler County Engineer's Office Trenton Area Storm Water Management Project
Figure D.2 Annual Percolation Depth

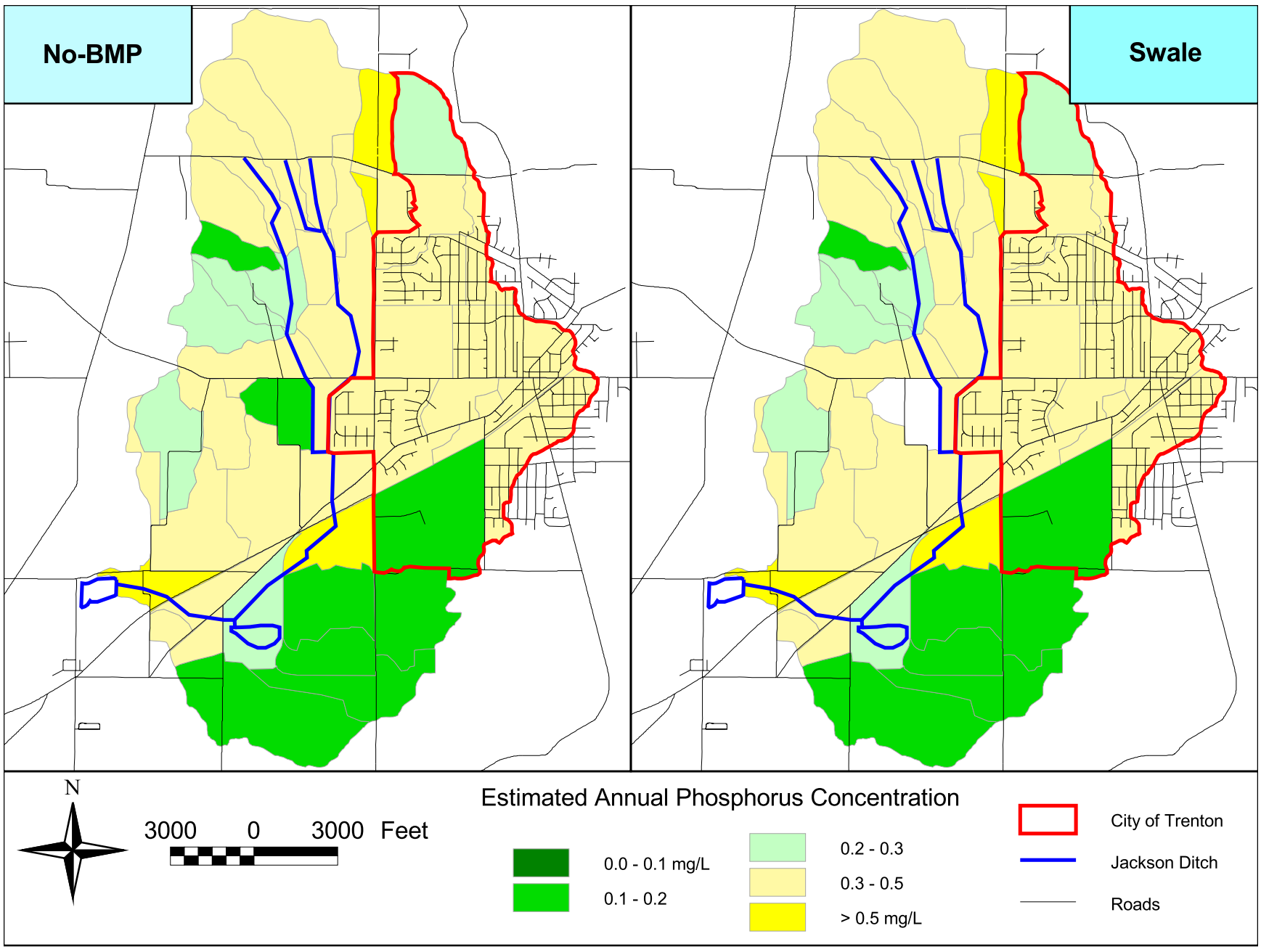


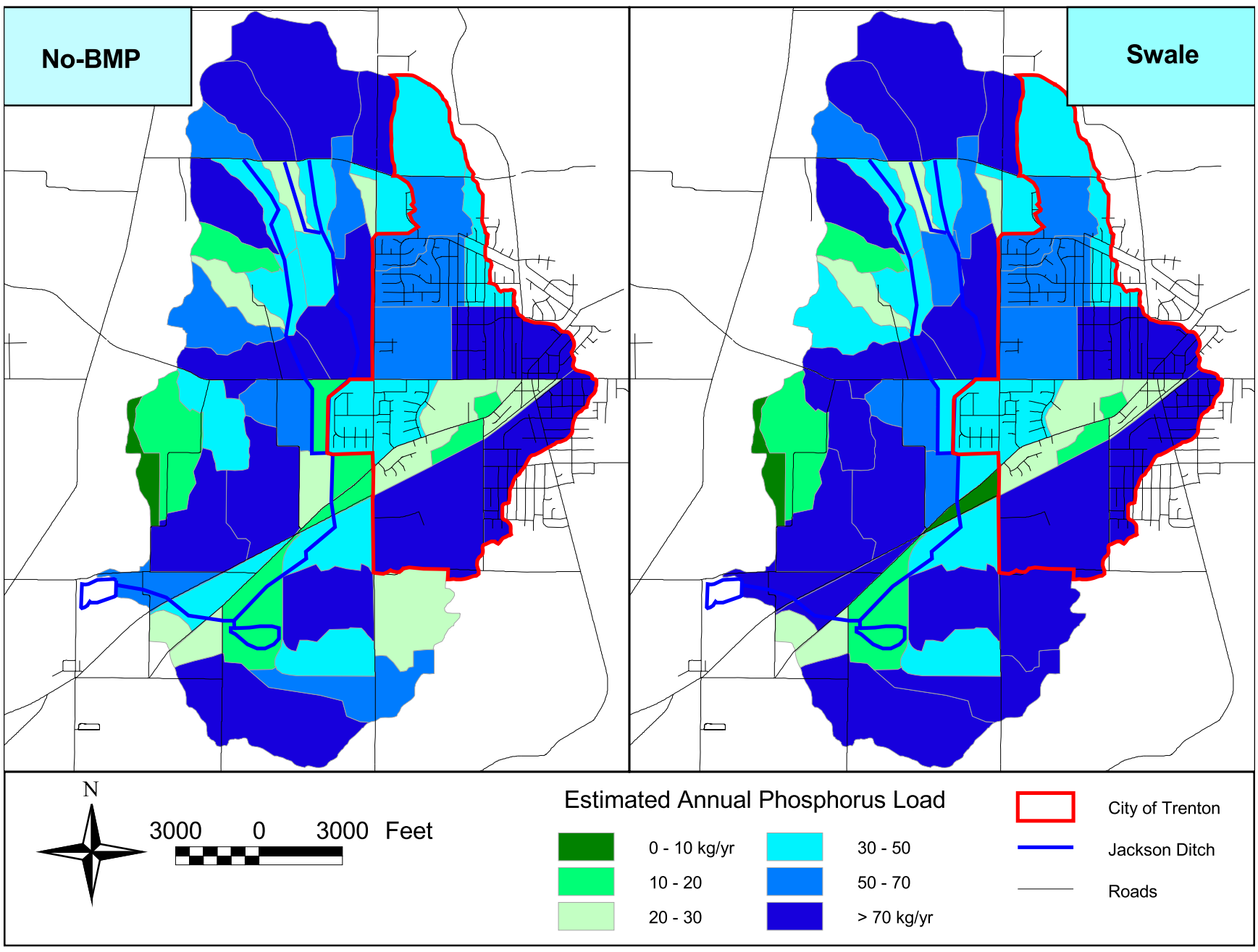


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Figure D.3 Nitrate Concentrations and Loads

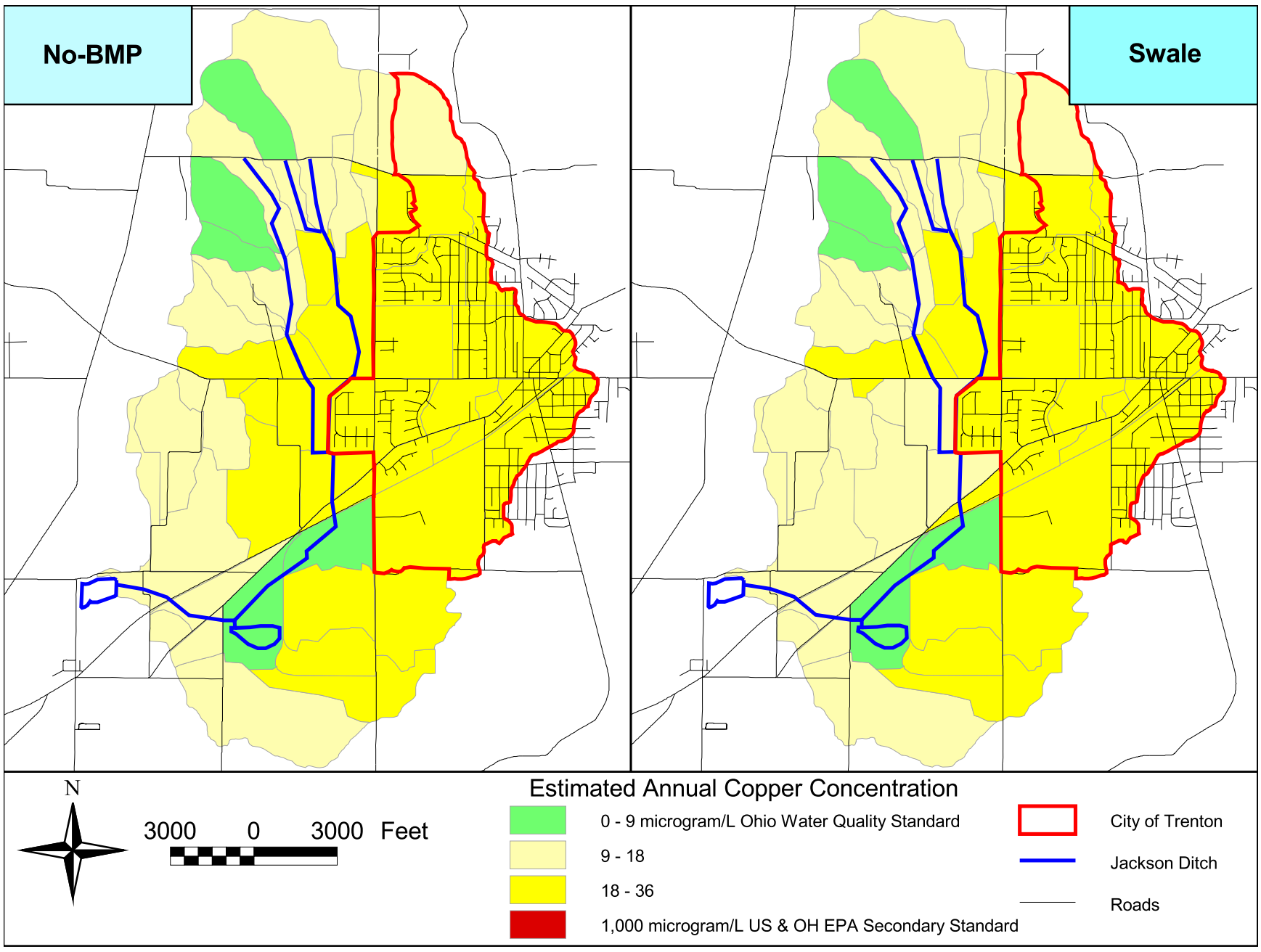


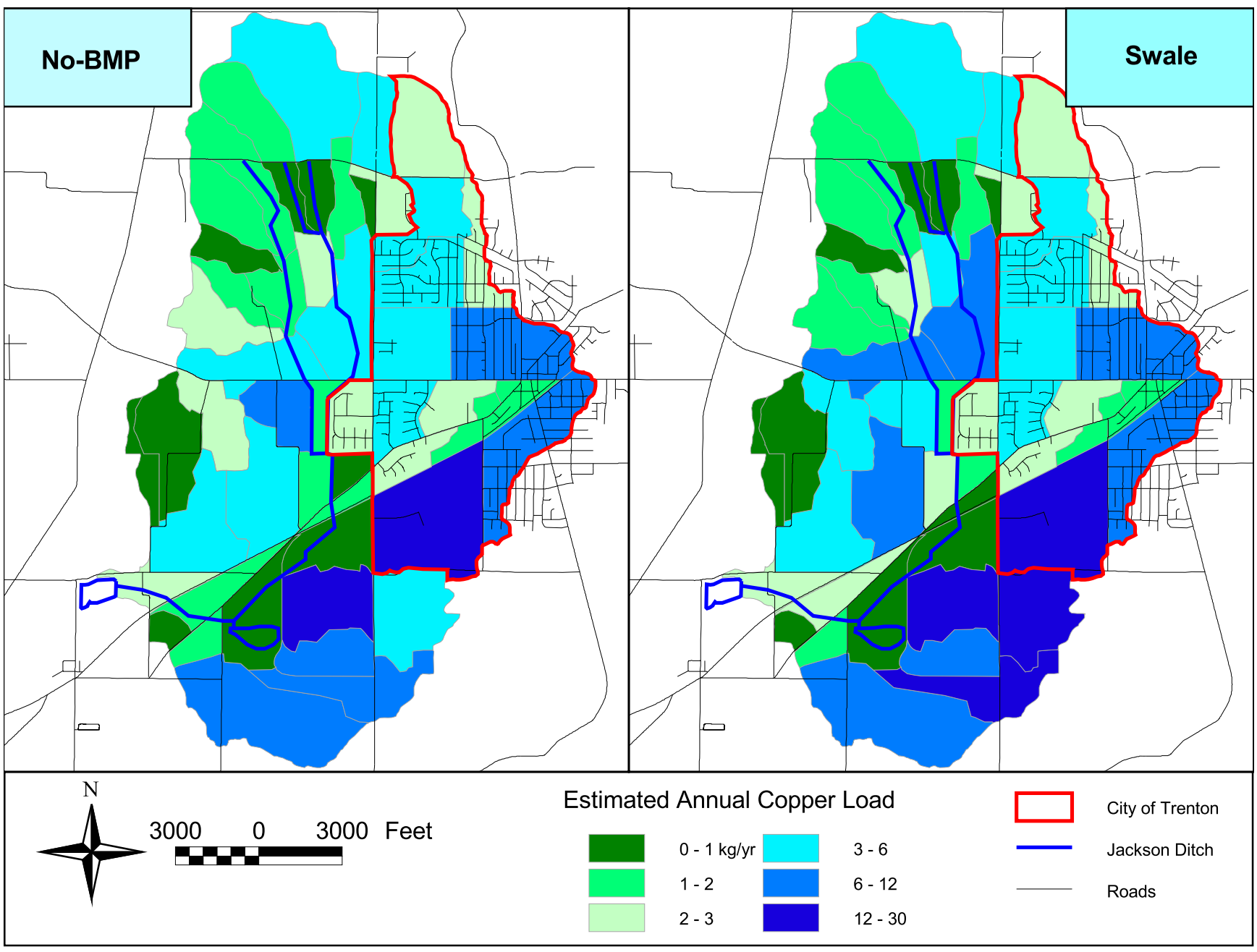


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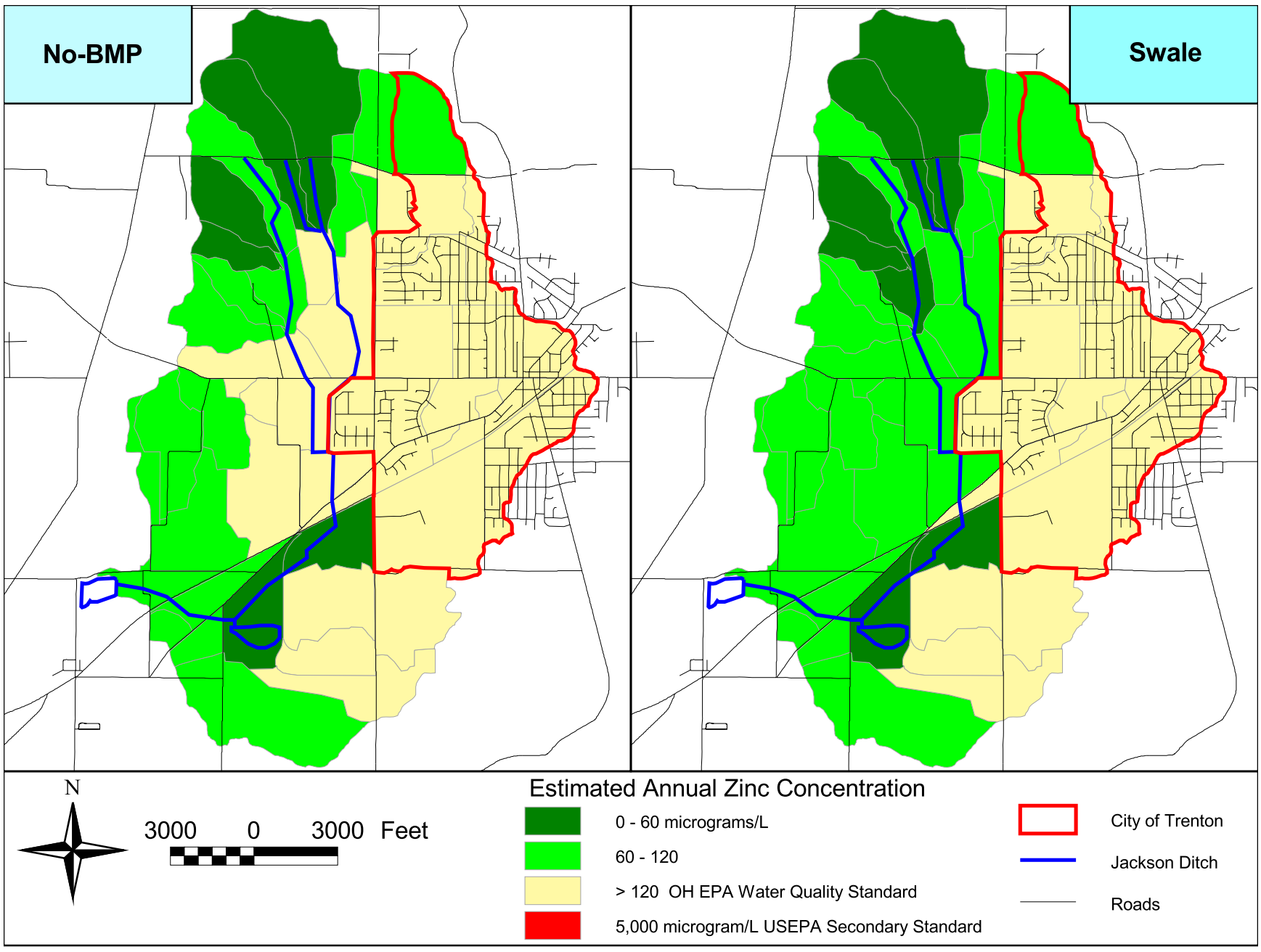
Figure D.4 Phosphorus Concentrations and Loads

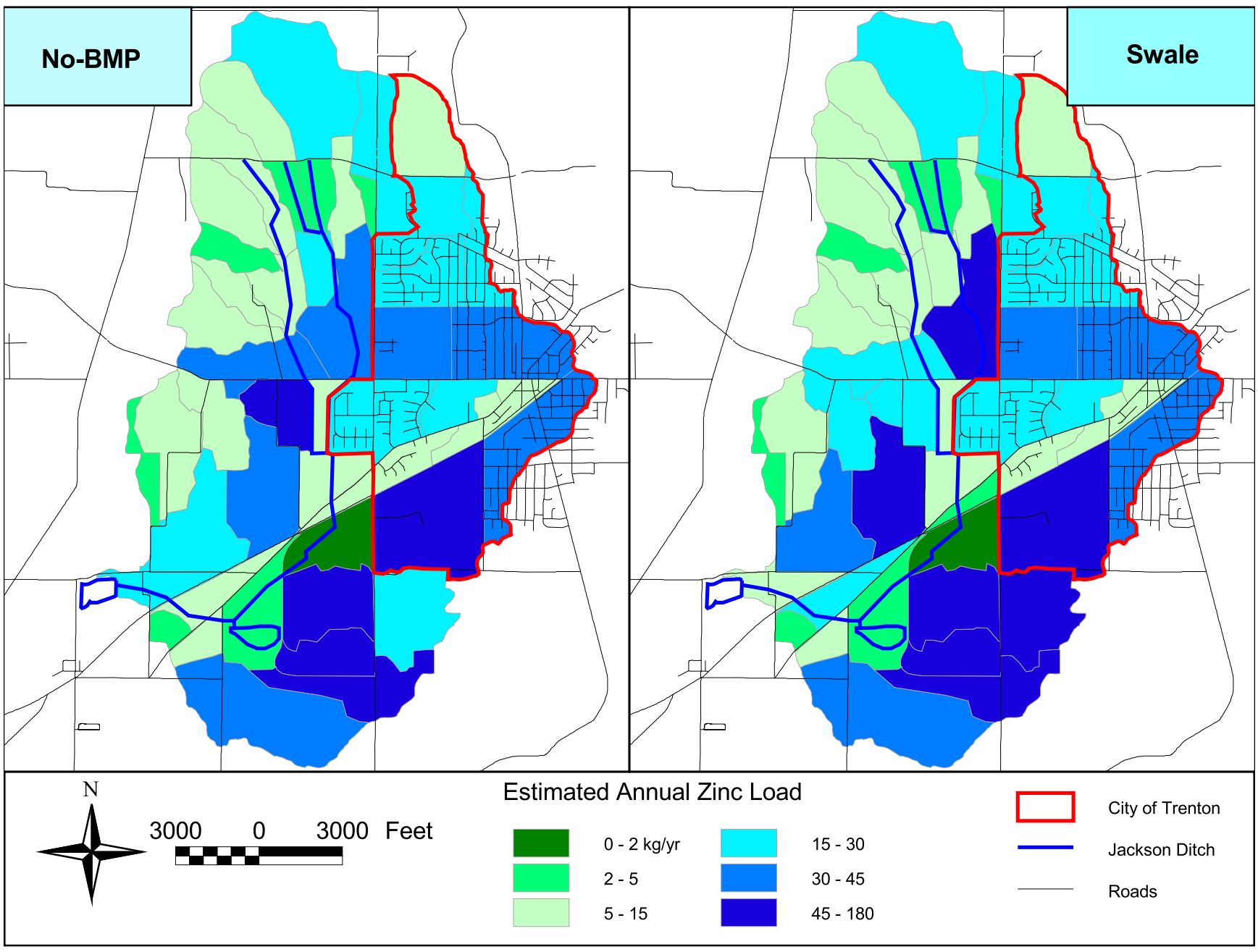




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Figure D.5 Copper Concentrations and Loads

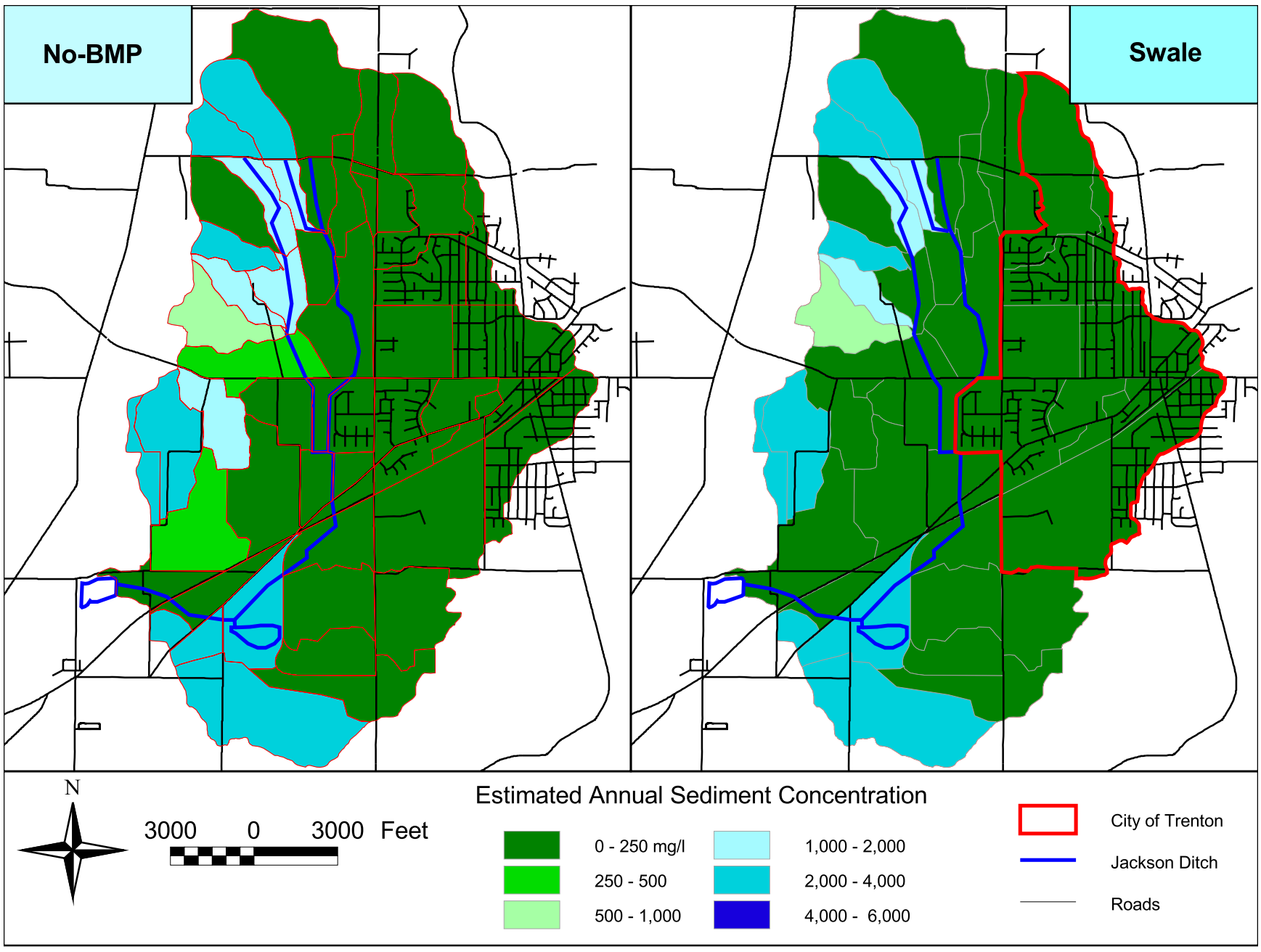


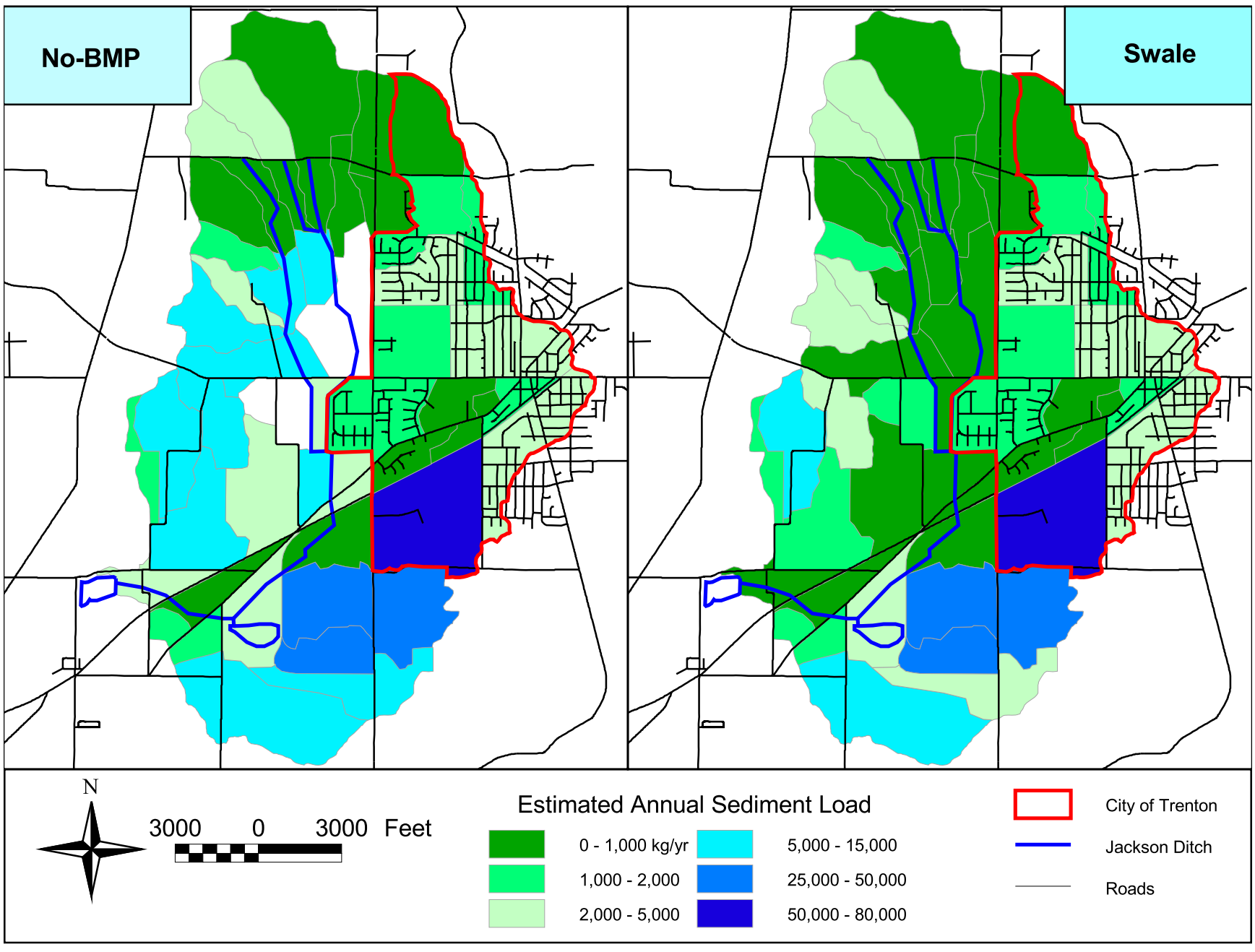


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Trenton Area Storm Water Management Project

Figure D.6 Zinc Concentrations and Loads





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Trenton Area Storm Water Management Project

Figure D.7 Sediment Concentrations and Loads

Appendix E

Digital Data CD