# Analysis of Potential Flood Magnitude and Severity for Land Surrounding the Consent Decree Area, Robert Brace Farm, Waterford, Erie County, Pennsylvania

## Expert Report Prepared For

## United States Department of Justice

## In Regard to Case

## United States v. Robert Brace and Robert Brace Farms, Inc., Civ. No. 90-229, W.D. Pa.

## Prepared By

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**Lexington, Kentucky**

**December 18, 2017**

EXHIBIT
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# I. Introduction

1. The United States of America engaged me to conduct a flood analysis of the area immediately upstream (south) of the Lane Road Culvert (near Waterford Township in Erie County, Pennsylvania; culvert location 41° 58’ 44.17” N, 80° 2’ 35.7” W) through which the stream referred to hereafter as “Elk Creek” passes. More specifically, I was engaged to analyze flooding (peak discharges and corresponding inundated land areas), and the physical impact thereof, that might reasonably be expected in this area and to assess the circumstances and degree to which inundation due to flooding might expand outside the wetland region known as the Consent Decree Area (“CDA”) and into the adjoining uplands areas. Based on information I was provided and that I subsequently verified, I judged that flooding upstream of the Lane Road Culvert might be influenced by a downstream culvert (referred to as the Sharp Road Culvert, located roughly 2000 ft NNE of the Lane Road Culvert at 41° 58’ 59.5” N, 80° 2’ 49.2” W). As a result, the presence of the Sharp Road Culvert was incorporated into subsequent assessments of flooding upstream of the Lane Road Culvert. Both culverts and the CDA are shown in Fig. 1.

# II. Qualifications

2. I hold a B.S. in Agricultural Engineering from the University of Arkansas (1984); a M.S. in Agricultural Engineering from the University of Arkansas (1986); a M.S. in Strategic Studies from the United States Army War College (2005);[1] and, a Ph.D. in Agricultural Engineering from Oklahoma State University (1988).

3. I am currently a professor in the Biosystems and Agricultural Engineering Department at the University of Kentucky, and have held a professorship and associate professorship there since 1994. From 1988 to 1994, I was an associate and assistant professor in the Biological and Agricultural Engineering Department at the University of Arkansas.

4. I hold a professional engineer license from the Arkansas State Board of Licensure for Professional Engineers and Professional Surveyors.

5. Over the course of my professional career, I have (a) conceived and conducted original research, (b) reported on my findings in peer-reviewed scientific journal and other venues, (c) served as editor of a scientific journal and thus as arbiter of scientific merit in papers submitted to that journal, and (d) provided service as a professional expert/consultant in multiple cases, with each of these activities falling within the field of knowledge referred to as “surface water resources engineering.” During each of my 23 years at the University of Kentucky, I have taught graduate-level courses in surface hydrology and statistical hydrology as well as a senior-level course on water resources engineering. The subject matter of these courses includes each of the tools, methods,

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[1] In September 2014, I retired from the United States Army Reserve at the rank of Brigadier General.

models and approaches used in this report. Finally, I have served as thesis advisor and dissertation advisor to graduate students whose success depended on mastery of the techniques used in this report, as well as my own ability to guide them in this endeavor. Based on these experiences, I consider myself qualified to have performed the analysis and drawn the conclusions contained in this report.

6. My curriculum vitae, including a list of all publications I have within the last 10 years follow the main body of this report in Appendix A. The description of the information I considered in forming my opinions is contained in Appendix B. My statement of compensation and testimony history for the last four years is contained in Appendix C.

# III. Standards

7. All methodologies utilized, assumptions made, and actions described herein conform to generally-accepted hydrologic and water resources engineering industry standards for flood modeling and analysis.

# IV. Summary of Opinions.

8. On the basis of data and methods described in succeeding portions of the report, my opinions can be summarized as follows:

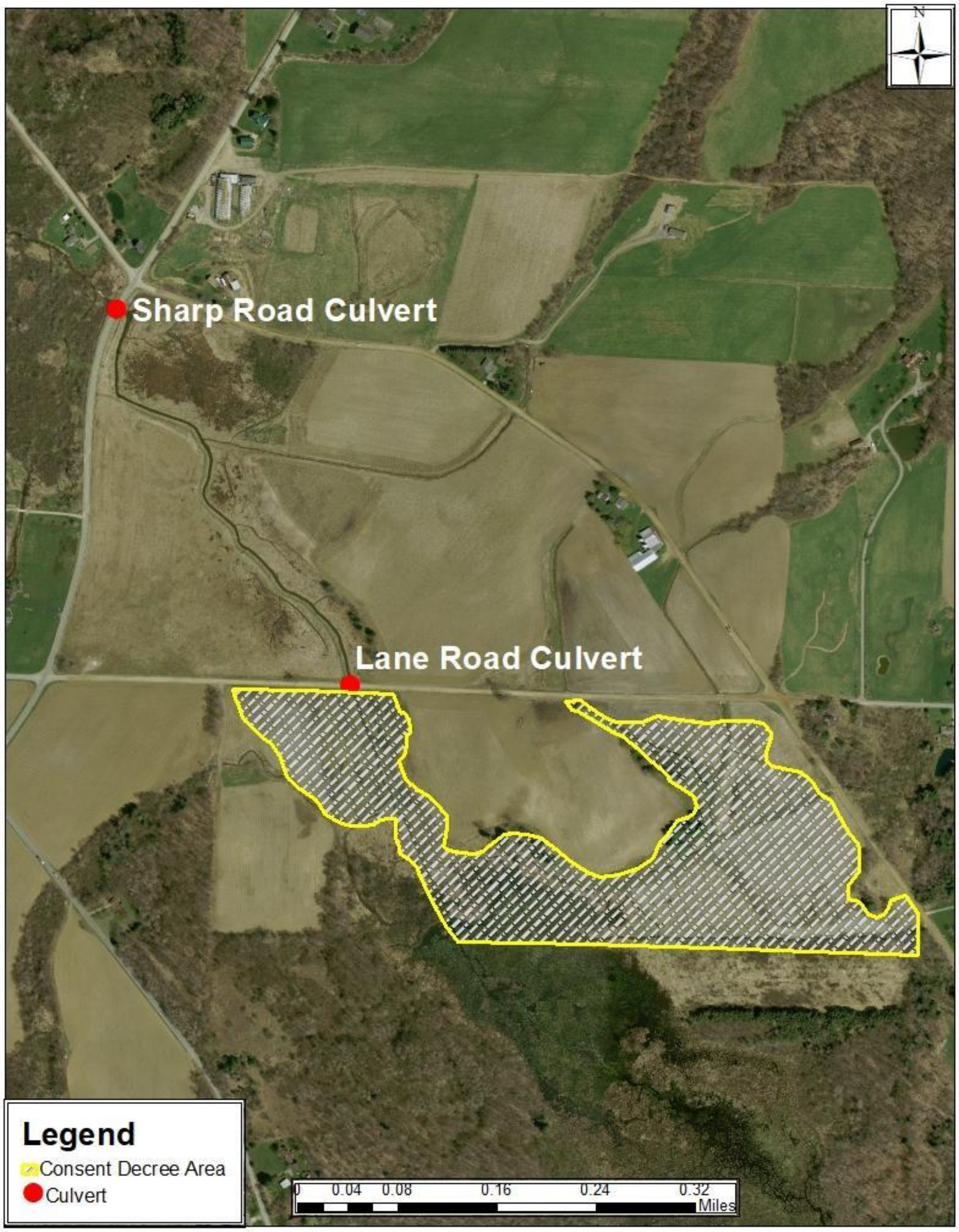
   a. Very little farmed land adjoining the CDA, if any, floods under any conditions considered. Even under severe conditions, flooding will extend outside the CDA and into adjoining uplands to an extent of 0.0636 acres or less (roughly one-quarter of one percent of the total upland acreage adjoining the CDA). This can be visualized as a roughly 50 ft x 50 ft plot of land or, alternatively, a “buffer” of 3.5 inches extending outside and along the entire (including the southern boundary) perimeter of the CDA.

   b. Depth of flooding in adjoining uplands is low (less than 2 ft at maximum) as is the duration of flooding (less than five hours for flooding anywhere, at any depth, in the adjoining uplands). Furthermore, these measures of flooding magnitude are conservative (i.e., worse than expected in reality) as a result of study area characteristics and methods used in the analysis.

   c. Based upon the extent, depth, and duration of the predicted flooding, the flooding itself would likely have no significant impact on the adjoining uplands or any activities conducted therein.

9. All conclusions and opinions described herein are offered to a reasonable degree of scientific and engineering certainty based upon industry standards, best available methods, and best available data.

**Fig. 1. Immediate context of work.**



Data sources: (1) 2015 orthoimagery, (2) Client-provided documents.

# V. Methodology

## A. Primary Datasets

10. Except as noted, physical characteristics of the study area (watershed area, slopes, soils, land use) were analyzed on a geographic information system ("GIS") using publicly-available information. The GIS software application was ArcMap for Desktop (v. 10.3.1.4959; Environmental Systems Research Institute, Redlands, California), the industry standard application that is widely, if not almost exclusively, used in hydrologic and water resources engineering. Datasets used in initial analysis were:

    a. Digital Elevation Model ("DEM") Data. Data collected through Light Detection and Ranging ("LiDAR") methods to provide location and elevation (X,Y,Z) information averaged for 2.5 ft x 2.5 ft "cells." Data collection date was April 29, 2015, and the data were downloaded from http://www.pasda.psu.edu/uci/DataSummary.aspx?dataset=3204.

    b. Orthoimagery. Color photography data that permit the identification of key features and attributes (roads, highways, ponds, culverts, land use, etc.), georeferencing of historical and other non-georeferenced materials, and other functions. Resolution is 2.5 ft by 2.5 ft. Data collection date was April 29, 2015, and the data were downloaded from http://www.pasda.psu.edu/uci/DataSummary.aspx?dataset=3201.

    c. Soils Data. Coded data that indicate the soil associated with a location as well as the properties of that soil. These data were used primarily to determine locations' potential for runoff generation as captured by the Hydrologic Soil Group ("HSG") property. Soils classified as HSG A are considered as having the lowest runoff potential, whereas HSG D has the highest. Some soils are jointly classified to reflect that their hydrologic behavior can vary with soil moisture condition. Data are aggregated within irregular boundaries rather than grids. The data are archived in the Soil Survey Geographic ("SSURGO") database of the Natural Resources Conservation Service ("NRCS"), U.S. Department of Agriculture and were downloaded from https://datagateway.nrcs.usda.gov/GDGOrder.aspx.

    d. Land Use Data. Coded data that indicate the dominant (as of 2011, the most current available) land use at a 30m x 30m resolution. The data are archived in the National Land Cover Database ("NLCD") of the U.S. Geological Survey, U.S. Department of the Interior, and were downloaded from http://www.pasda.psu.edu/uci/DataSummary.aspx?dataset=3141.

    e. Historical Imagery. Images, both georeferenced and non-georeferenced, of multiple spectra (e.g., black and white, color, color infrared) that serve the same basic purposes as the orthoimagery described earlier. Images irregularly spanning the period 1939 – 2015 are available and were downloaded from http://maps.psiee.psu.edu/ImageryNavigator/ Additional imagery of the same character and irregularly spanning the period 1993 – 2016 was available through the Google Earth Pro software application v. 7.3.0.3832 (Google, Inc., Mountain View, CA). Non-georeferenced images were georeferenced using the georeferencing tools available in ArcMap and the April 2015 orthoimagery as the standard.

f. Wetlands Boundaries. Coded data, aggregated within irregular boundaries, indicating presence and nature of wetlands. These data were used in conjunction with published information to estimate flood peak flows for various return periods. The data were published by the U.S. Fish and Wildlife Service, U.S. Department of the Interior, in 2009 and were downloaded from http://www.pasda.psu.edu/uci/DataSummary.aspx?dataset=1457.

g. Stream network. Irregular lines that representing the drainage network (i.e., streams and rivers). The data, known as the National Hydrograph Dataset ("NHD"), were published in 2009 by the U.S. Geological Survey, Department of the Interior, and download from http://www.pasda.psu.edu/uci/DataSummary.aspx?dataset=770.

h. Legal Boundaries. Irregular lines that indicate the areal extent of property parcels and the CDA. These data were derived by georeferencing and digitizing images provided by the Client.

i. All other data used and/or referenced in this report are derivative of one or more of these primary datasets. Projected data were used in all analyses, and the coordinate system was the North American Datum ("NAD") 1983 High Accuracy Reference Network ("HARN") State Plane Pennsylvania North Federal Information Processing System ("FIPS") 3701.

## B. Hydrologic Model Parameterization

11. Flood analysis was performed using the Hydrologic Engineering Center Hydrological Modeling System ("HEC-HMS") software application, v. 4.1, developed by the Hydrologic Engineering Center, U.S. Army Corps of Engineers, and available at http://www.hec.usace.army.mil/software/hec-hms/downloads.aspx. There is a more current version (4.2) available as of March 2017; however, it does not vary from v. 4.1 in any way that is relevant to this analysis, and the older version was assessed to be more stable from the perspective of code error detection and repair. HEC-HMS has been used worldwide in hydrology and water resources research, analysis and design; it is considered an industry standard, certified for use in Federal Emergency Management Agency studies and adopted by multiple U.S. agencies.

12. ***Basic Model Elements:***

    a. The process of acquiring the HEC-HMS data required to parameterize (mathematically describe) a watershed is facilitated by GIS-based tools developed by the U.S. Army Corps of Engineers for use with ArcMap. The software package of these tools, which are based on tailored sequences of ArcMap's native tools and capabilities, is referred to as HEC-GeoHMS. Version 10.2 (most current) of HEC-GeoHMS was used in this work to automate the process of generating GIS-based inputs to HEC-HMS. The major secondary datasets (layers) generated by HEC-GeoHMS and used for HEC-HMS parameterization included:

        i. Reconditioned DEM Layer. A dataset resulting from alteration of the original DEM to ensure that automatically-defined streams will retain their approximately original locations. This layer is derived from the original DEM and a stream layer (in this instance, the NHD dataset, edited to include increased stream network resolution and verified by site visit on October 16-17, 2017).

        ii. Filled DEM Layer. An alteration of the reconditioned DEM to remove any depressions which, in this context, are considered to be the result of small and random errors in the original LiDAR data.

        iii. Stream Layer. Cells of the filled DEM identified as receiving the drainage from a specified minimum number of contributing cells. This layer should be very similar to that used in creating the reconditioned DEM layer (in this case, the modified NHD dataset).

        iv. Catchment/Subwatershed Layer. Upstream areas draining to streams. Subwatersheds are defined just upstream of each junction in the stream layer and are based on the filled DEM layer.

v. Watershed Boundary Layer. Also known as area of interest ("AOI") layer. A subset of the study area that consists of the outline of all subwatersheds draining to a user-defined point of interest (in this case, the entrance to the Sharp Road Culvert).

vi. Slope Layer. A dataset based on the original DEM that indicates the "flatness" or "steepness" of the land surface.

vii. Curve Number ("CN") Layer. A dataset derived, on the basis of NRCS guidance, from NLCD and SSURGO data that quantifies potential for runoff generation. The CN is used in NRCS methods to convert rainfall depth to runoff depth and ranges from 0 (no runoff is possible) to 100 (impervious surface).

b. These secondary datasets are used with HEC-GeoHMS tools to parameterize the basic hydrologic model elements (i.e., subwatersheds, stream segments and their connectivity, but not more specialized model elements such as detention basins and diversions).

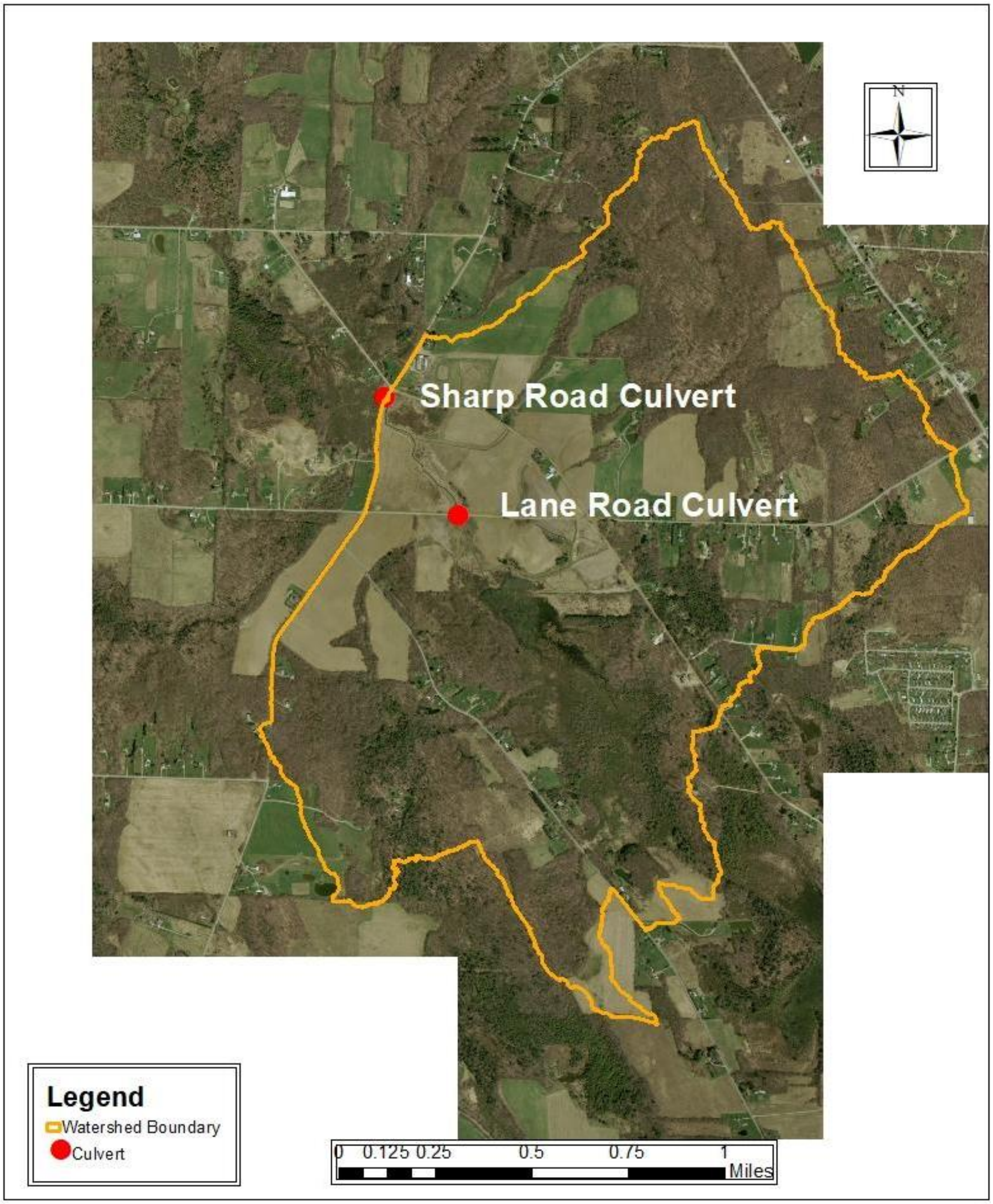
c. The AOI (watershed relative to the Sharp Road Culvert inlet) is given in Fig. 2. The watershed covers an extent of roughly 10,000 ft (southwest to northeast axis) by 6,000 ft (northeast to southwest axis) with a total area of 2.13 mi$^2$. Elevations within the watershed range from 1216.4 ft to 1516.9 ft (generally highest along the northeast boundary) with an average of 1319.8 ft. Slopes range from 0.0 to 210.5% with an average slope of 10.1%. The lowest slopes generally correspond to the valley of the Elk Creek, whereas the highest slopes are of a localized extent and primarily associated with steep stream bank slopes in the northeastern portion of the watershed.

d. Land use in the AOI as determined by the NLCD data consisted primarily of deciduous forest (37.2%), cultivated crops (24.9%), pasture/hay (15.1%) and woody wetlands (12.5%). All other identified land uses (developed – open space, developed – low intensity, developed – medium intensity, evergreen forest, mixed forest, shrub/scrub and emergent herbaceous wetlands) accounted for the balance (10.3%) of land uses within the AOI (Fig. 3).

e. Based on SSURGO data, 42.1% of the AOI is classified as having a soil belong to HSG D (highest runoff potential), while HSG A (lowest runoff potential) accounted for 11.5% of the AOI. Roughly 0.2% of the watershed consisted of HSG B soils, whereas no pure HSG C soils were identified. Jointly-classified HSG A/D soils accounted for 15.4% of the AOI, B/D soils made up 12.4% of the AOI, and the balance (18.4%) consisted of HSG C/D soils (Fig. 4).

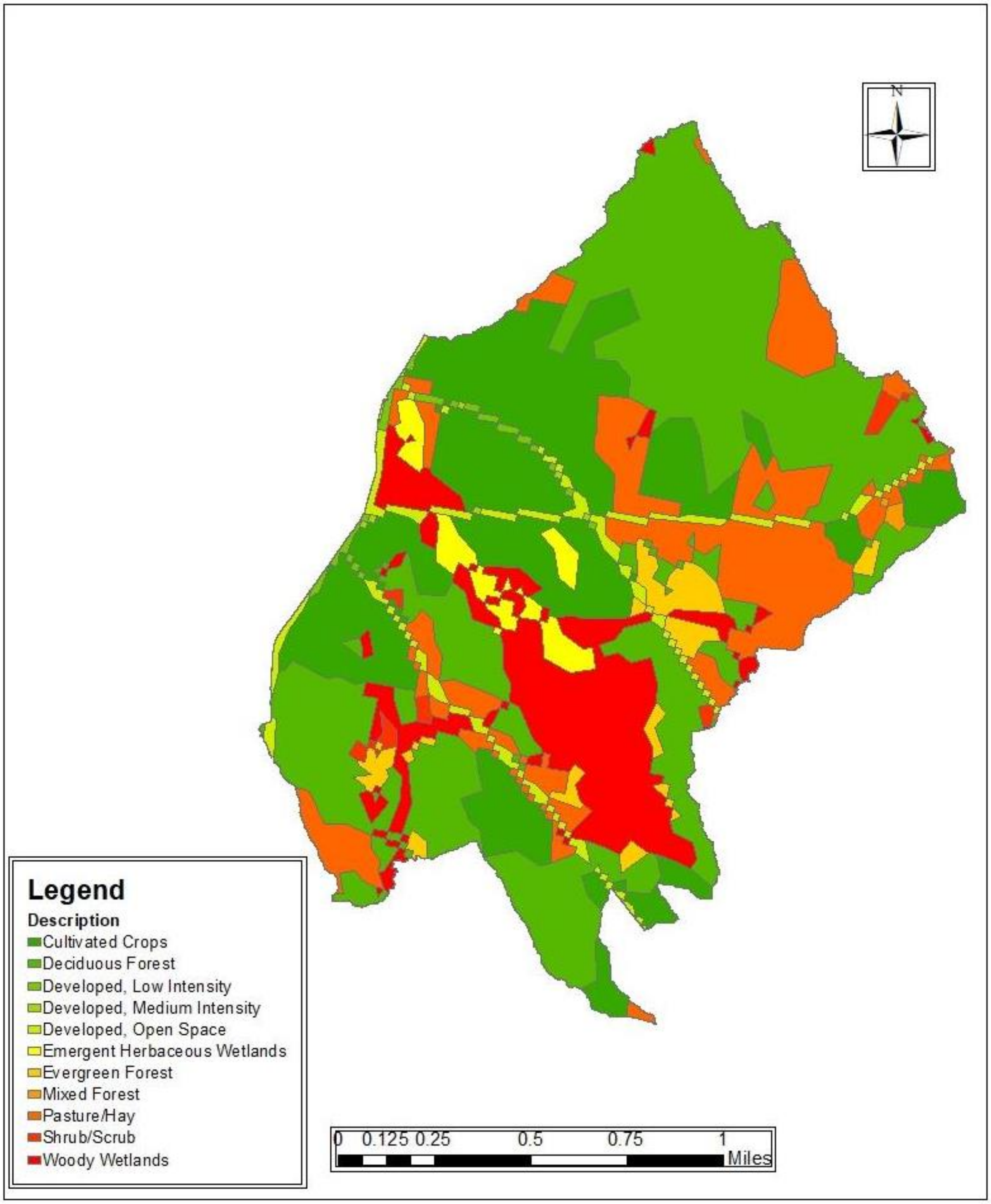
f. The CN layer is given in Fig. 5. The average over the AOI is 77.8, ranging from a low of 36 to a high of 98 along the Elk Creek valley. These CN values reflect average soil moisture conditions as defined by NRCS.

**Fig. 2. Area of interest, defined as the watershed relative to the Sharp Road Culvert.**



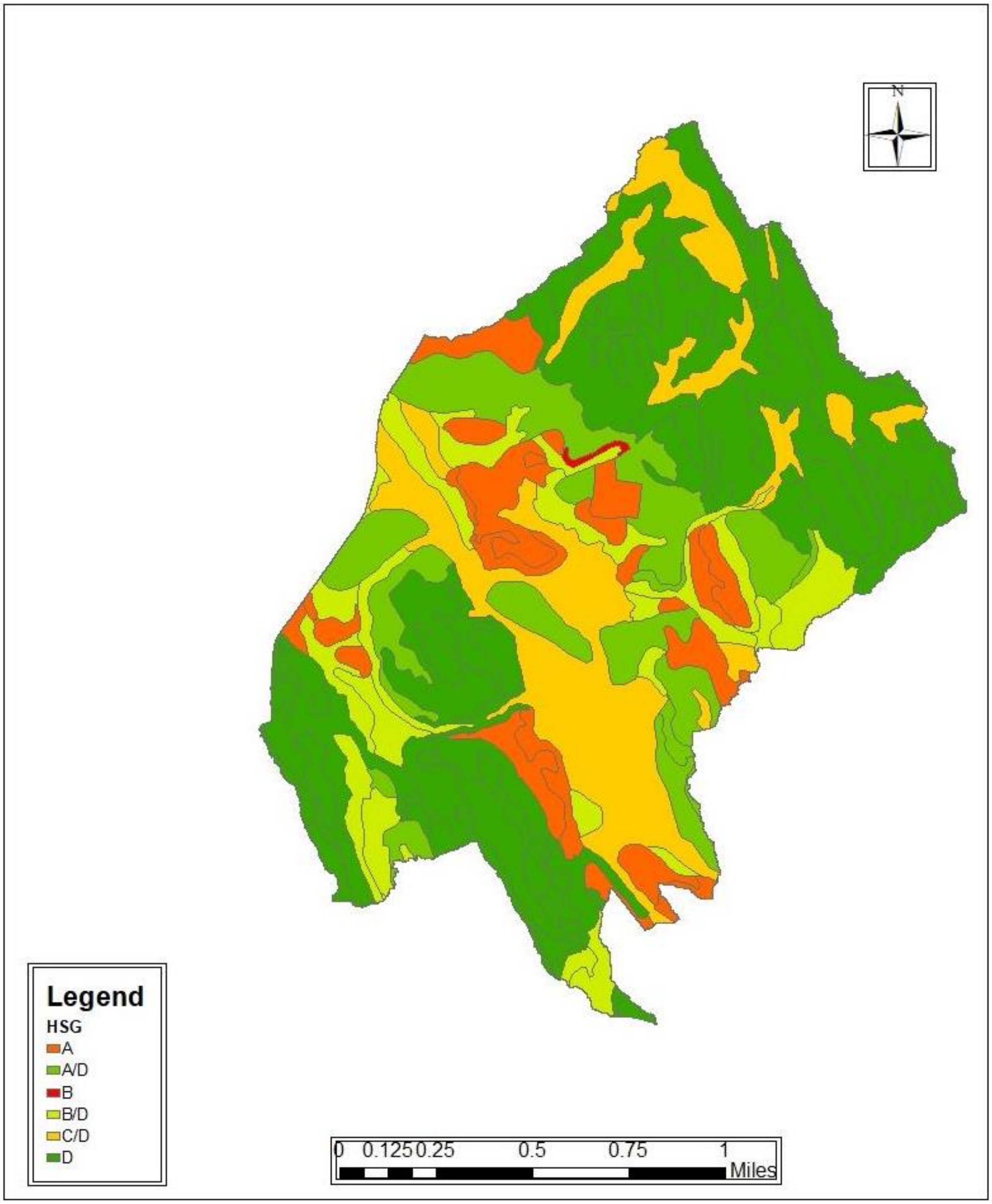
Data sources: (1) 2015 orthoimagery, (2) 2015 DEM.

**Fig. 3. Land uses within area of interest.**



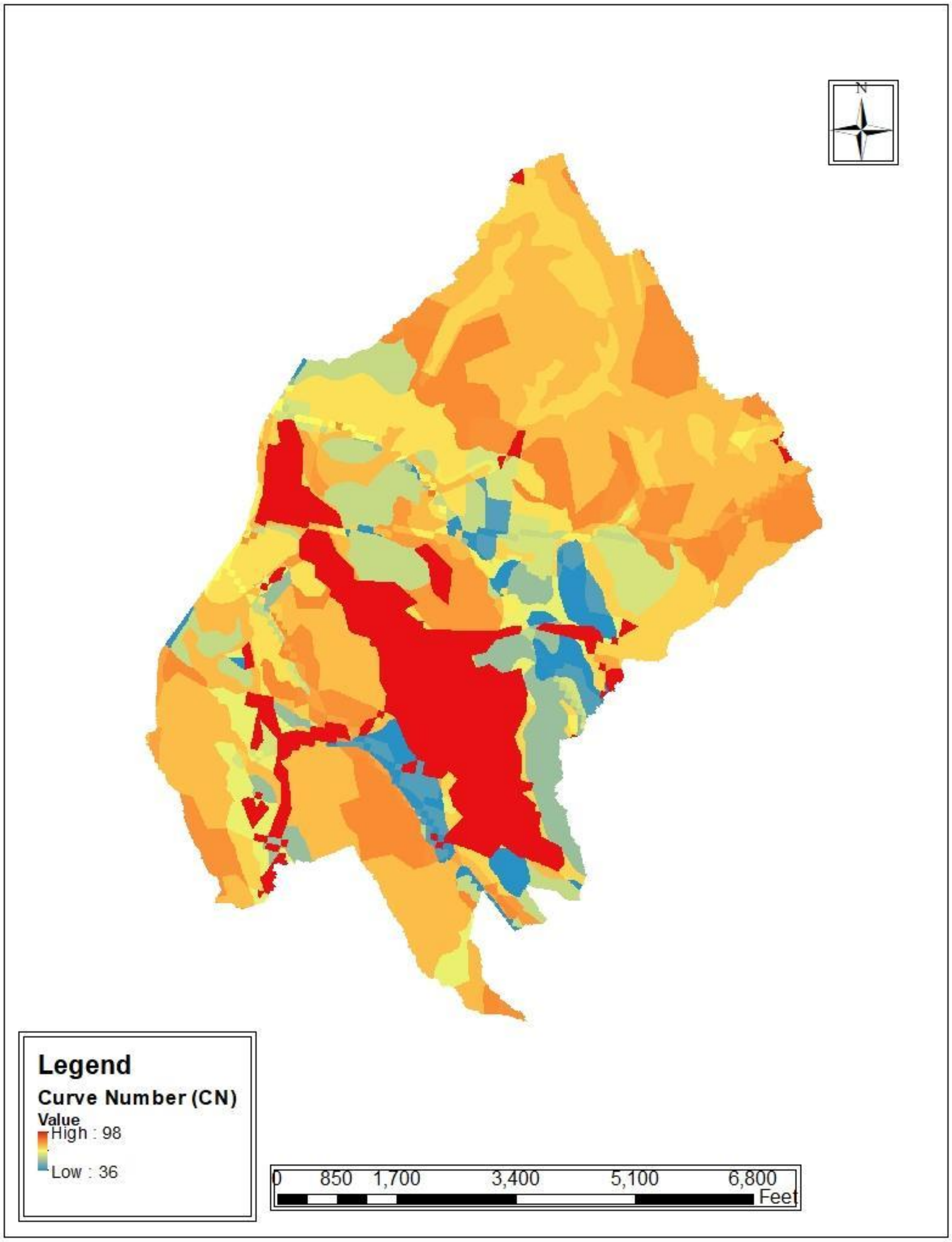
Data sources: (1) 2015 orthoimagery, (2) 2015 DEM, (3) 2011 NLCD.

Fig. 4. Hydrologic soil groups (HSG) within area of interest.



Data sources: (1) 2015 orthoimagery, (2) 2015 DEM, (3) USDA NRCS SSURGO database.

**Fig. 5. Curve Number (CN) values within area of interest.**



Data sources: (1) 2015 orthoimagery, (2) 2015 DEM, (3) USDA NRCS SSURGO database, (4) 2011 NLCD.

g. The stream layer and subwatersheds identified by HEC-GeoHMS, both labeled according to HEC-GeoHMS convention, are given in Figs. 6 and 7, respectively. Streams were defined as cells draining 1% or more (the HEC-GeoHMS default threshold; can be adjusted to provide the desired level of subwatershed resolution) of the total watershed area. Characteristics of stream reaches (which can include both streams and segments of streams as needed to describe the connectivity of the subwatersheds) identified by HEC-GeoHMS are given in Table 1. Lengths, elevations and bed slopes are based on original DEM data, with the exception that bed slopes calculated as negative (for stream segments R10, R240, R270, R280 and R300, which were calculated as slightly negative) were corrected to zero.[2] Stream segments used to connect subwatersheds required estimates of travel time within the stream segment. For those segments, travel time was calculated as segment distance divided by the sum of celerity and segment velocity. Segment velocities were based on Manning's Equation (the classical industry standard) with channel properties estimated from orthoimagery and Manning's roughness coefficient taken as 0.025 (from best judgment based on October 16-17, 2017 site visit) to reflect a natural streambed composed primarily of silt. Subwatershed characteristics appear in Table 2. Lag values, which are a measure of how quickly subwatershed runoff flows respond to rainfall, are estimated internally within HEC-GeoHMS using industry-standard methods that are based on NRCS guidance; all other parameters (e.g., lengths, areas, slopes, CN values) are derived from previously-discussed data, but disaggregated and averaged over individual subwatersheds.

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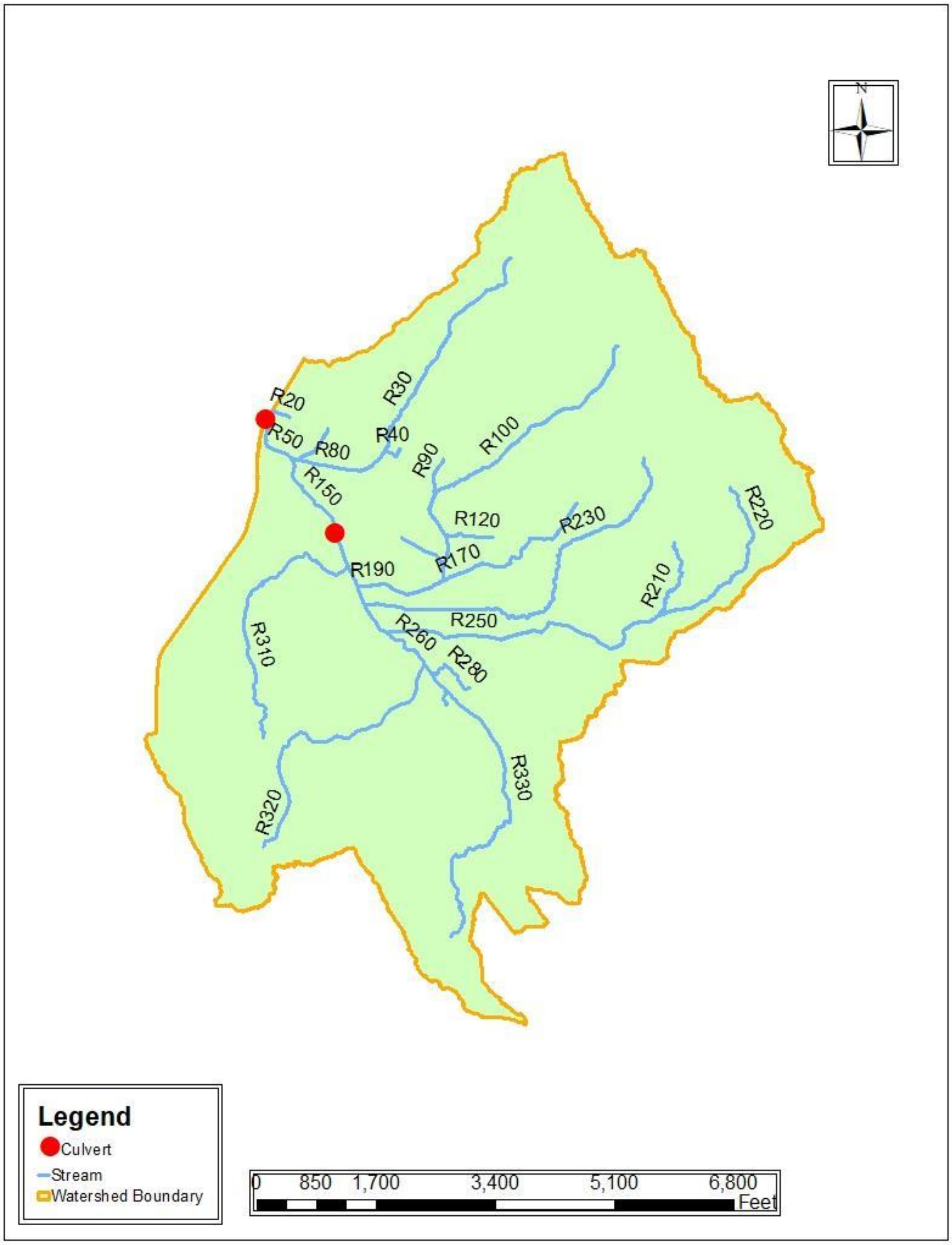
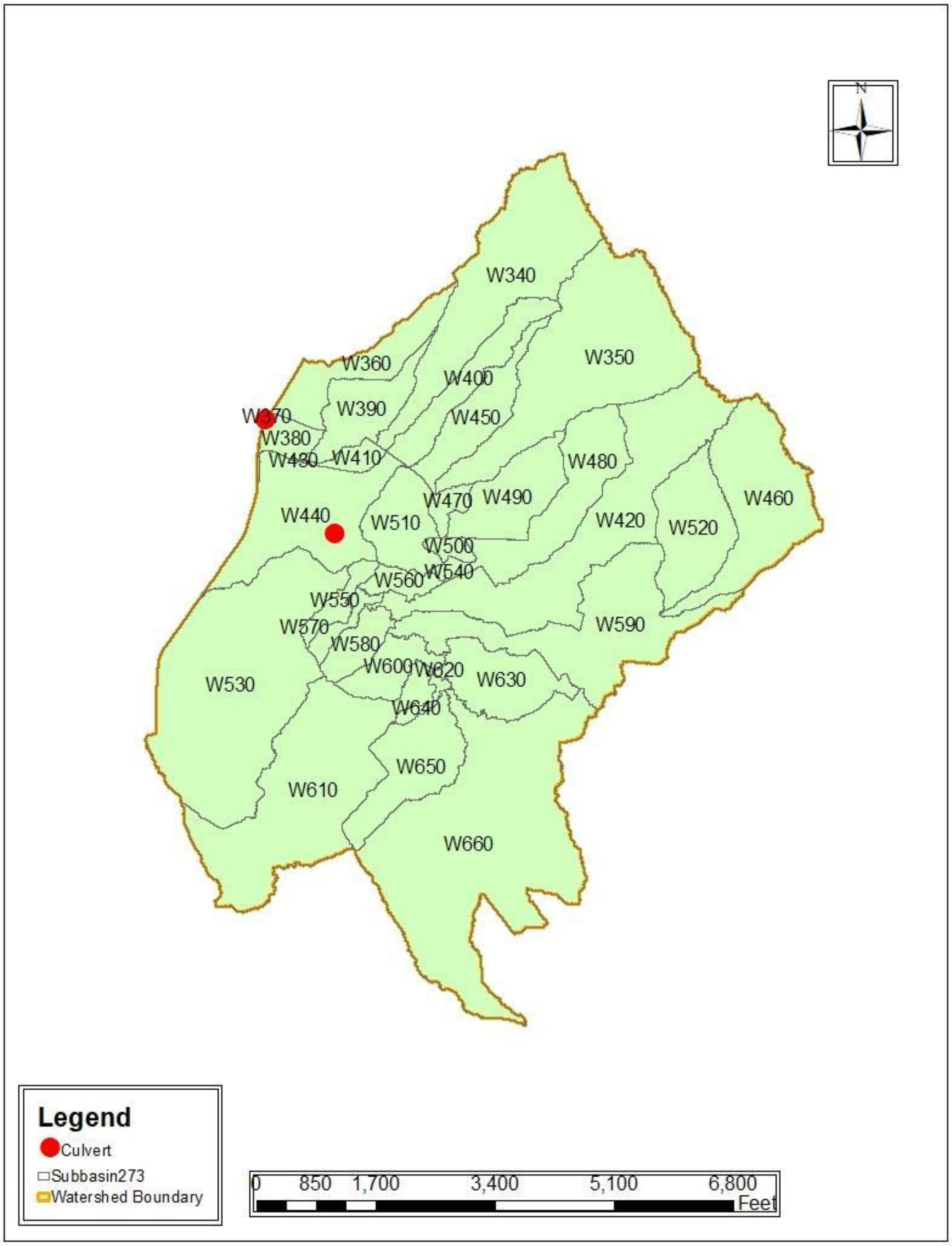
[2] Bed slopes can be identified as negative due to small and random errors in the DEM, relatively flat terrain, short segment lengths, or a combination of these factors. A negative bed slope would indicate that, under steady conditions, the water in the segment is flowing in the opposite direction than indicated on the map. Given that the true overall direction of flow is well-established by other data (e.g., hydrography, orthoimagery), corrections under these circumstances are appropriate.

**Fig. 6. Stream layer for area of interest.**



Data sources: (1) 2015 orthoimagery, (2) 2015 DEM, (3) 2009 NHD.

**Fig. 7. Subwatersheds within area of interest.**



Data sources: (1) 2015 orthoimagery, (2) 2015 DEM, (3) 2009 NHD.

**Table 1. Characteristics of stream reaches in the area of interest.**

| Label | Length (ft) | Upstream Elevation (ft) | Downstream Elevation (ft) | Slope | Travel Time[3] (minutes) |
|---|---|---|---|---|---|
| R10[4] | 5 | 1217.40 | 1217.52 | 0.0000 | 0.0 |
| R20 | 441 | 1221.61 | 1217.40 | 0.0095 | |
| R30 | 3785 | 1422.30 | 1249.25 | 0.0457 | |
| R40 | 338 | 1254.33 | 1249.25 | 0.0151 | |
| R50[4] | 814 | 1217.61 | 1217.40 | 0.0003 | 1.4 |
| R60 | 126 | 1218.58 | 1217.61 | 0.0077 | 0.2 |
| R70 | 674 | 1232.46 | 1218.58 | 0.0206 | |
| R80 | 1459 | 1249.25 | 1218.58 | 0.0210 | 1.0 |
| R90 | 570 | 1262.62 | 1241.20 | 0.0375 | |
| R100 | 3782 | 1433.76 | 1241.20 | 0.0509 | |
| R110 | 736 | 1241.20 | 1230.46 | 0.0146 | 0.6 |
| R120 | 752 | 1255.80 | 1230.46 | 0.0337 | |
| R130 | 769 | 1229.56 | 1223.43 | 0.0080 | |
| R140 | 449 | 1230.46 | 1223.43 | 0.0157 | 0.4 |
| R150[4] | 1950 | 1217.61 | 1217.61 | 0.0000 | 3.3 |
| R160 | 265 | 1223.43 | 1221.96 | 0.0055 | 0.5 |
| R170 | 2678 | 1305.72 | 1221.96 | 0.0313 | |
| R180[4] | 326 | 1218.93 | 1217.61 | 0.0040 | 0.6 |
| R190 | 1388 | 1221.96 | 1218.93 | 0.0022 | 2.0 |
| R200[4] | 302 | 1224.15 | 1218.93 | 0.0173 | 0.5 |
| R210 | 1440 | 1341.28 | 1291.75 | 0.0344 | |
| R220 | 2937 | 1446.83 | 1291.75 | 0.0528 | |
| R230 | 6227 | 1386.41 | 1224.15 | 0.0261 | |
| R240[4] | 557 | 1224.01 | 1224.15 | 0.0000 | 0.9 |
| R250 | 4625 | 1291.75 | 1224.01 | 0.0146 | 6.8 |
| R260[4] | 797 | 1224.58 | 1224.01 | 0.0007 | 1.7 |
| R270[4] | 208 | 1224.23 | 1224.58 | 0.0000 | 0.5 |
| R280 | 861 | 1224.08 | 1224.23 | 0.0000 | |
| R290[4] | 314 | 1224.59 | 1224.23 | 0.0011 | 0.9 |
| R300 | 305 | 1224.12 | 1224.59 | 0.0000 | |
| R310 | 4481 | 1280.30 | 1217.61 | 0.0140 | |
| R320 | 4679 | 1308.86 | 1224.58 | 0.0180 | |
| R330 | 5191 | 1290.02 | 1224.59 | 0.0126 | |

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[3] Reaches without travel times are first-order reaches; travel time computations were unnecessary and are incorporated into subwatershed lag values.

[4] Elk Creek main stem.

**Table 2. Characteristics of subwatersheds in the area of interest.**

| Name | Area ($mi^2$) | Average Slope | Average CN | Lag (minutes) |
|---|---|---|---|---|
| W340 | 0.14 | 12.2 | 78.7 | 24.7 |
| W350 | 0.18 | 12.0 | 79.2 | 23.8 |
| W360 | 0.05 | 8.0 | 71.9 | 27.5 |
| W370 | 0.00 | 18.8 | 79.0 | 0.2 |
| W380 | 0.01 | 6.7 | 85.0 | 7.9 |
| W390 | 0.04 | 6.9 | 73.4 | 23.4 |
| W400 | 0.04 | 10.3 | 79.1 | 19.6 |
| W410 | 0.01 | 7.5 | 69.6 | 13.0 |
| W420 | 0.16 | 10.1 | 74.1 | 38.9 |
| W430 | 0.00 | 15.5 | 98.0 | 0.5 |
| W440 | 0.10 | 4.8 | 81.8 | 24.9 |
| W450 | 0.04 | 10.0 | 79.6 | 17.8 |
| W460 | 0.10 | 11.3 | 80.6 | 20.3 |
| W470 | 0.01 | 6.8 | 73.2 | 13.5 |
| W480 | 0.07 | 10.9 | 74.5 | 23.9 |
| W490 | 0.05 | 7.5 | 69.6 | 23.7 |
| W500 | 0.01 | 6.4 | 78.5 | 6.2 |
| W510 | 0.04 | 7.0 | 71.8 | 17.0 |
| W520 | 0.06 | 12.6 | 80.1 | 14.8 |
| W530 | 0.23 | 10.6 | 77.4 | 30.8 |
| W540 | 0.00 | 11.3 | 97.7 | 1.5 |
| W550 | 0.01 | 11.7 | 81.5 | 8.3 |
| W560 | 0.01 | 11.1 | 76.0 | 9.5 |
| W570 | 0.01 | 12.0 | 87.4 | 6.3 |
| W580 | 0.02 | 12.2 | 86.7 | 7.3 |
| W590 | 0.13 | 6.9 | 71.3 | 42.6 |
| W600 | 0.03 | 9.8 | 91.7 | 7.9 |
| W610 | 0.17 | 12.1 | 81.2 | 23.6 |
| W620 | 0.00 | 3.4 | 98.0 | 1.5 |
| W630 | 0.05 | 7.1 | 82.6 | 20.7 |
| W640 | 0.01 | 6.4 | 97.4 | 5.2 |
| W650 | 0.06 | 9.3 | 78.9 | 19.9 |
| W660 | 0.28 | 10.9 | 77.6 | 31.3 |

13. ***Special Model Elements:***

a. Beaver Dams. Orthoimagery indicated the presence of beaver dams along Elk Creek south of Lane Road. The dams and their impacts on upstream water surface elevations ("WSE") are indicated in Fig. 8, in which the orthoimagery was created roughly 12 years ago. Historical orthoimagery indicates that the dams have not been continuously present, but rather that one or more have been removed on occasion. Present orthoimagery and my site visit on October 16-17, 2017, however, indicate the presence of two major dams (dams that raise the upstream WSE by approximately 3 ft each) as indicated in Fig. 8, as well as at least two minor dams (that increase upstream WSE by approximately 1 ft; not shown).

i. The effects of the major dams on downstream flooding were accounted for by adding reservoir elements to HEC-HMS to reflect the dams' connectivity to other elements, their WSE vs. discharge characteristics, and their WSE vs. storage characteristics. This is the method by which HEC-HMS represents confined (by dams, embankments, topography or other methods) regions that attenuate inflows by physically restricting outflows.

ii. The smaller of the two dams impounds water at an elevation of approximately 1221.5 ft (as determined from DEM). At greater WSE, water exits the impounded area across the dam and the connected terrain at the same elevation, at which point the dam and connected terrain function as a weir crest having measured crest length of approximately 320 ft. Required elevation-storage-discharge information were derived using these data along with the broad-crested weir equation and ArcMap's Surface Volume tool (the classical, industry-standard method). The process of deriving required information was the same for the larger of the two dams, which was found to impound water at an elevation of approximately 1224.5 ft, above which the dam and connected terrain function as a weir crest having total length of approximately 400 ft. Elevation vs. discharge and elevation vs. storage curves for the two dams are given in Figs. 9 and 10, respectively and were used in HEC-HMS to parameterize these two elements.

**Fig. 8. Major beaver dam locations.**

**Dams are situated to the immediate right of corresponding text labels, inside the circles.**

Data sources: (1) 2005 orthoimagery.

**Fig. 9. Elevation vs. discharge curves for major beaver dams.**

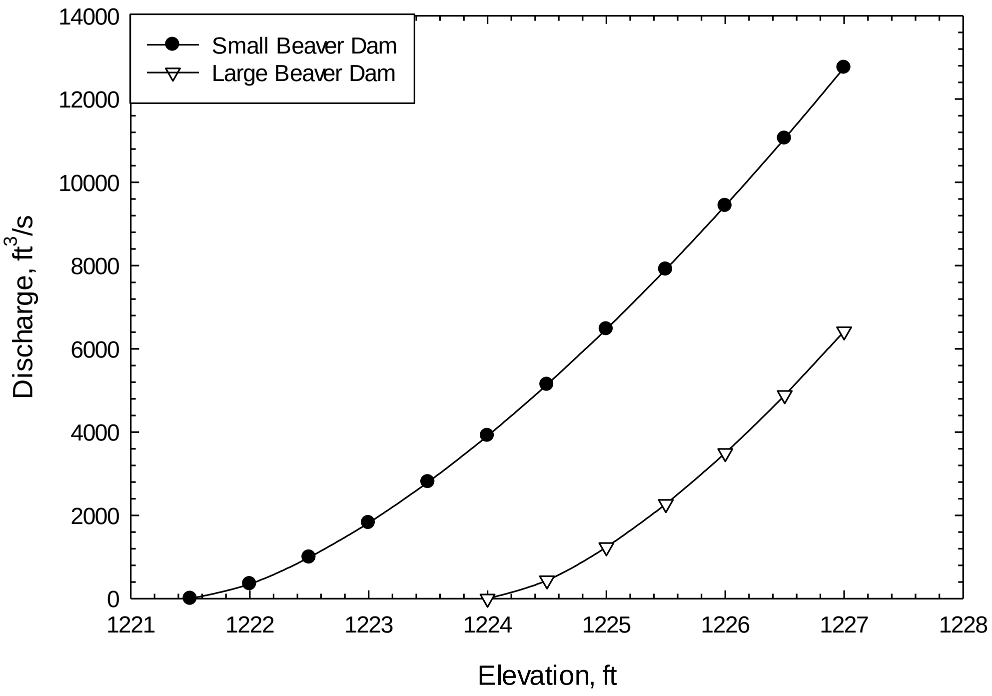
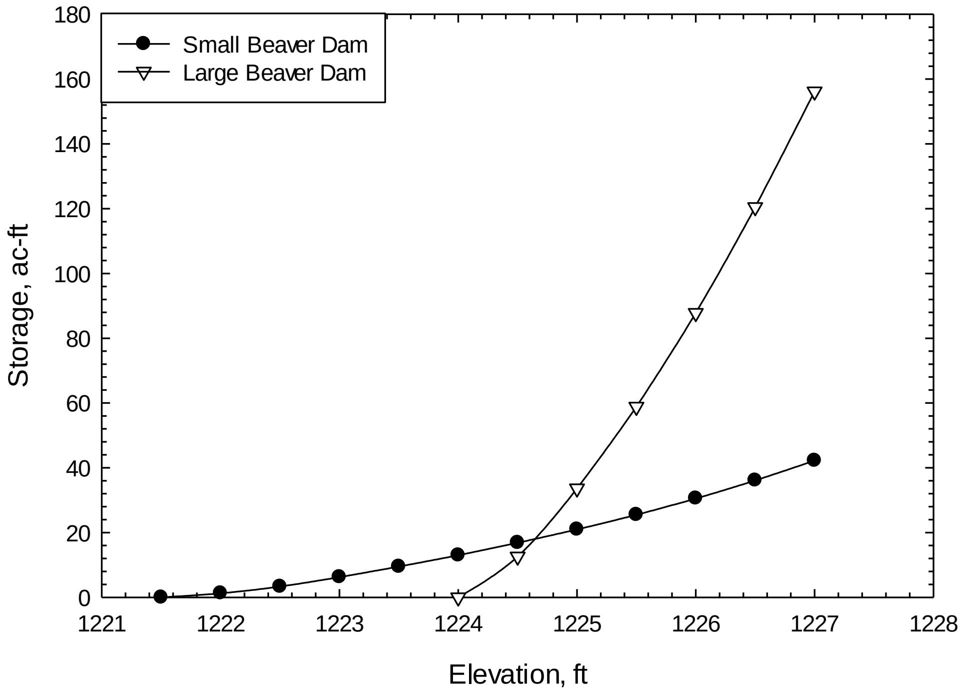


**Fig. 10. Elevation vs. storage curves for major beaver dams.**



b. Culverts. Reservoir elements representing the Lane Road and Sharp Road Culverts were added to HEC-HMS to assess impacts on flooding because, similar to the beaver dams, they act to restrict flow and impound water upstream. As with the beaver dam elements, HEC-HMS requires elevation vs. discharge and elevation vs. storage information at each culvert inlet location. Elevation vs. storage data were derived as described earlier (using the ArcMap Surface Volume tool in connection with the DEM). Elevation vs. discharge data were generated using the industry standard HY-8, v. 7.5 (most current as of time of report preparation) software application. This application was developed by the Federal Highway Administration, US Department of Transportation, and is available at https://www.fhwa.dot.gov/engineering/hydraulics/software/hy8/

i. Culvert data required by HY-8 were collected during the 16-17 October 2017 site visit and are as indicated below in Table 3. The span and rise used for the Sharp Road Culvert were the nearest standard match to on-site measurements (115 and 69 inches, respectively), which were affected by the presence of concrete paving at the bottom of the culvert. Manning's n values represent best professional judgment given the culvert materials (aged metal for Lane Road, corrugated metal for Sharp Road). Inlet configurations as given are best matches, in professional judgment, to non-standard on-site conditions.

**Table 3. Evaluated culvert properties.**

| | Lane Road | Sharp Road |
|---|---|---|
| Shape | Circular | Pipe Arch |
| Diameter (ft) | 6 | --- |
| Span (in) | N/A | 117 |
| Rise (in) | N/A | 79 |
| Manning's n | 0.016 | 0.028 |
| Inlet Configuration | Square Edge With Headwall | Mitered |
| Inlet elevation | 1215.94 | 1217.3 |
| Outlet Elevation | 1215.60 | 1217.3 |

ii. HY-8 requires roadway data (distance vs. elevation profile, roadway top width, weir coefficient) to calculate overtopping discharges during high flow conditions. Roadway profile data were taken from the DEM using ArcMap's Interpolate Line tool. The weir coefficient was based on a paved crest for the Sharp Road Culvert and a gravel crest for the Lane

Road Culvert. Roadway top widths were estimated from orthoimagery using ArcMap's linear measurement tool (25 ft for Lane Road and 22 ft for Sharp Road).

iii. HY-8 additionally requires information on the downstream channel to account for any outlet limitations on culvert discharge. Channel cross-sections for both downstream channels were determined using ArcMap's Interpolate Line tool with the DEM. For the Lane Road Culvert, the downstream channel slope was estimated as 0.001. The in-channel Manning's n was estimated as 0.025, and the out-of-bank Manning's n was estimated as 0.045 (based on best judgment following October 16-17, 2017 site visit). For the Sharp Road Culvert, the downstream channel slope was estimated as 0.0024. Manning's n was estimated as 0.03 in the channel, and the out-of-bank Manning's n was estimated as 0.045 based on best judgment following the October 16-17, 2017 site visit. Elevation vs. discharge curves for both downstream channels were developed using the sum of segments approach in HY-8 and are given in Fig. 11. The curves are of a very similar nature, having an apparent horizontal offset due to the Sharp Road Culvert downstream channel being situated at a lower elevation than the Lane Road Culvert downstream channel.

iv. It should be noted that the inlet to the Sharp Road Culvert is higher (approximately 1.7 ft) than the outlet of the Lane Road Culvert. This can create a backwater condition that extends upstream for 2500 ft or more and decreases the discharge capacity of the Lane Road Culvert. This potential backwater condition was incorporated into the analysis by correcting the elevation of the channel bed downstream of Lane Road Culvert to 1217.3 ft in HY-8, the same elevation as the Sharp Road Culvert inlet invert.

v. The resulting elevation vs. discharge and elevation vs. storage curves for the two culverts are indicated in Figs. 12 and 13, respectively, and were used in HEC-HMS to parameterize the reservoir elements. The rating curves for the culverts are again very similar in nature; the horizontal offset is due to flow overtopping Sharp Road (minimum crest elevation is 1222.09 ft) before Lane Road (minimum crest elevation is 1222.75 ft).

c. Split Subwatershed. It was noted that, as a result of the automatic subwatershed delineation procedures in HEC-GeoHMS, the entirety of one of the subwatersheds (W440) was routed downstream of the Lane Road Culvert when, in reality, an approximately 20-ac portion of this subwatershed (as measured within ArcGIS) drains through the Lane Road Culvert. This situation was corrected by manually subdividing W440 to create a new subwatershed element

(W440A), having the same slope and CN value as W440 but one-third the area and lag, and directing it to drain through the Lane Road Culvert in HEC-HMS. The area and lag of the original subwatershed W440 were adjusted downward to two-thirds of the respective original values.

**Fig. 11. Elevation vs. discharge curves for the Lane Road Culvert and Sharp Road Culvert downstream channels.**

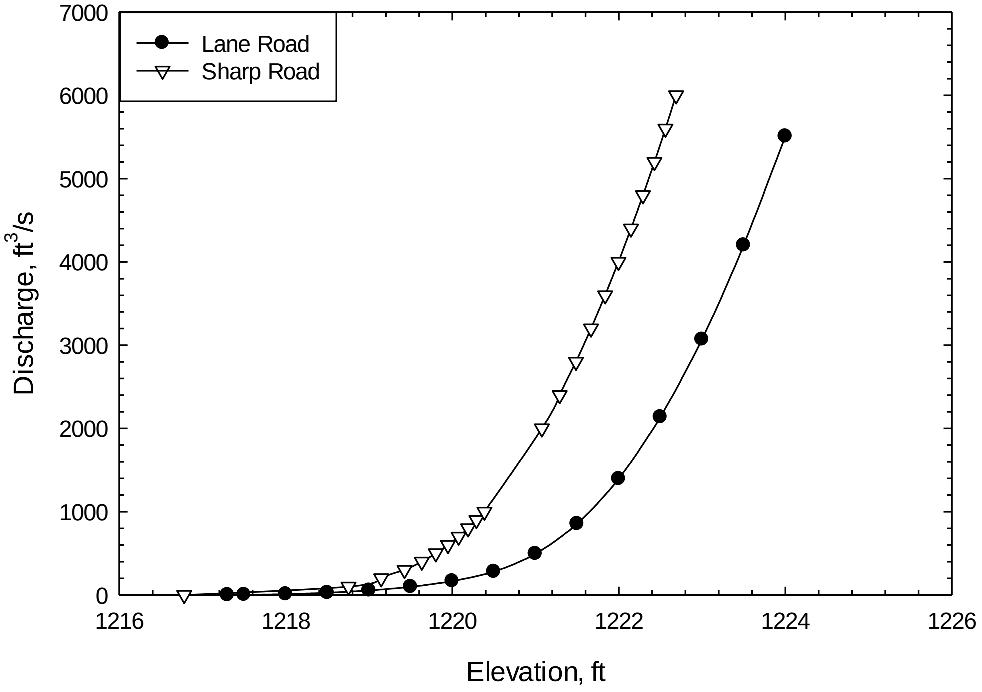


**Fig. 12. Elevation vs. discharge curves for the Lane Road Culvert and Sharp Road Culvert.**

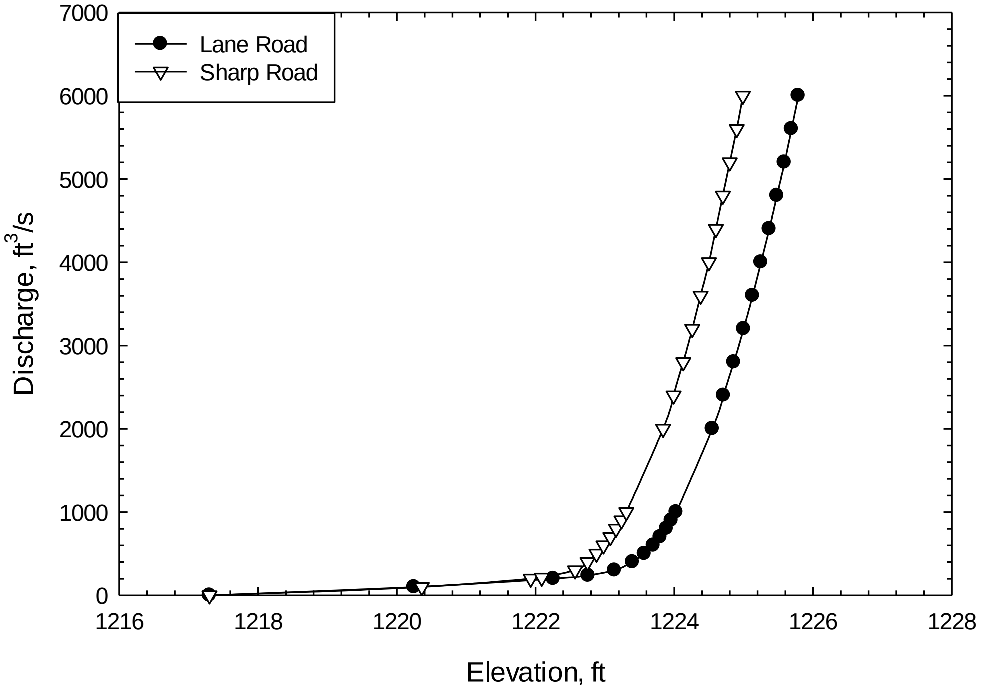
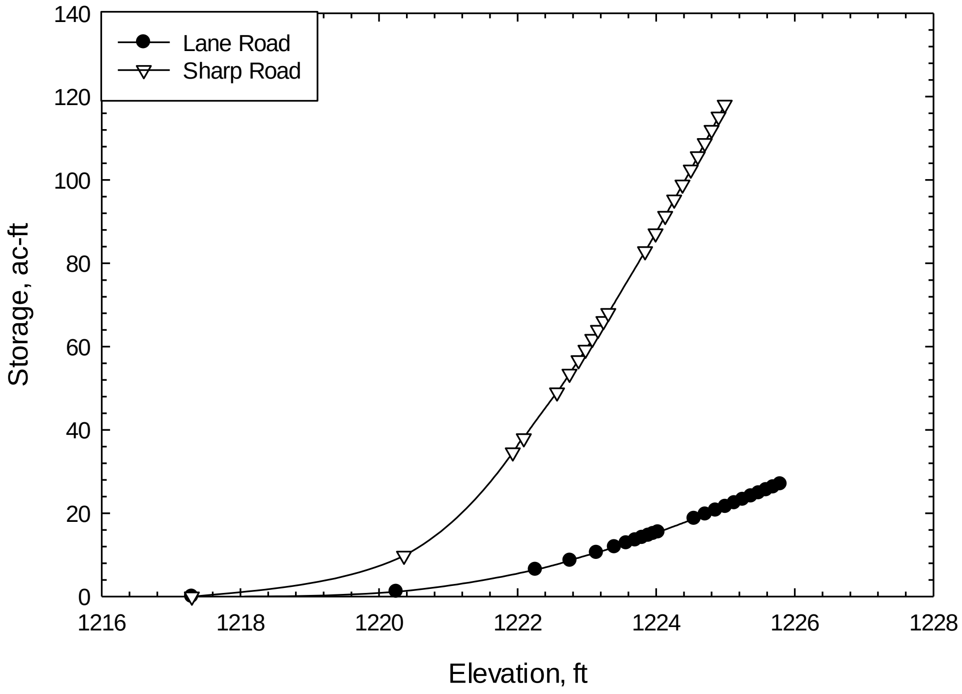


**Fig. 13. Elevation vs. storage curves for the Lane Road Culvert and Sharp Road Culvert.**



## C. Consent Decree Area

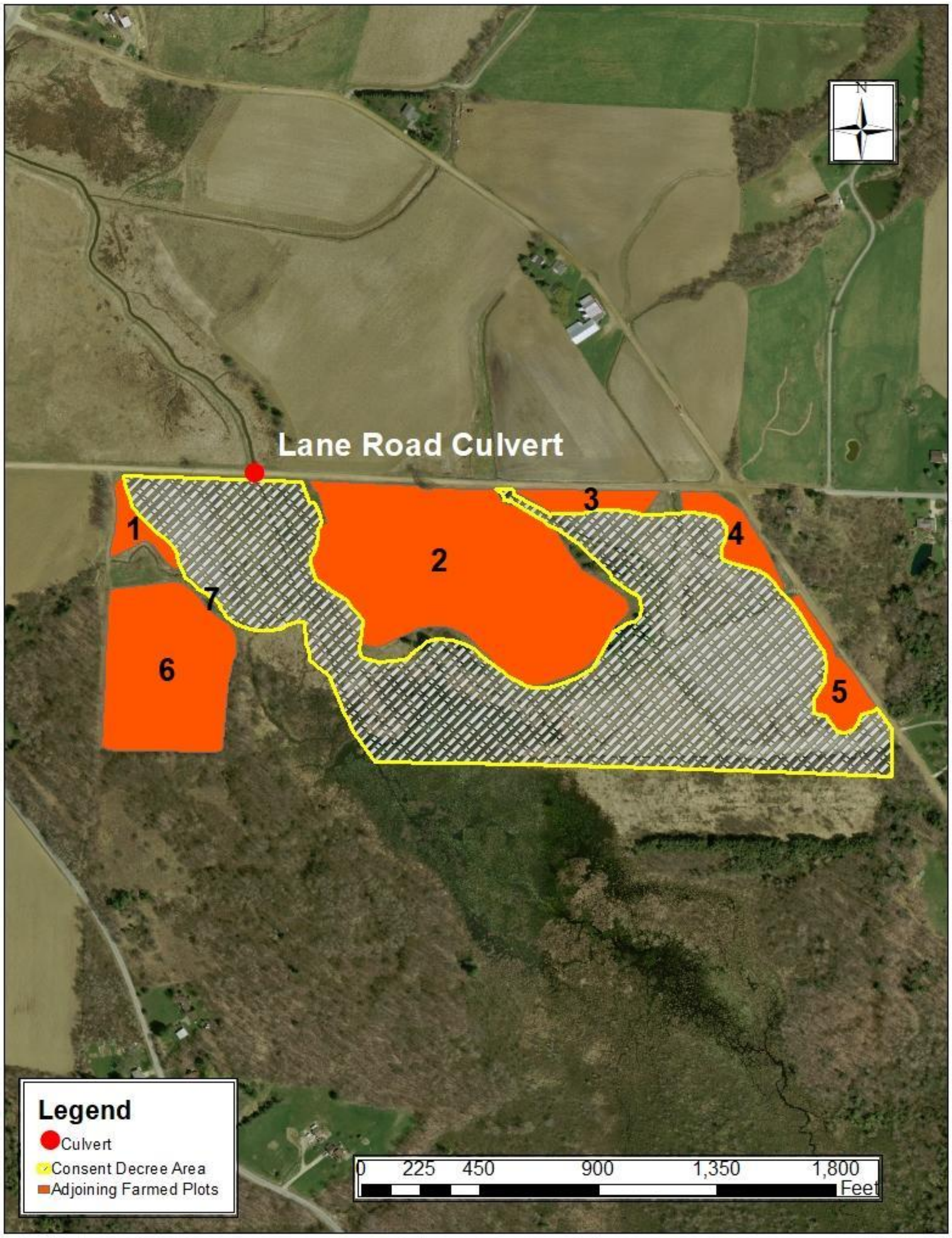
14. Characteristics of the CDA and immediately surrounding land were not used as direct inputs to HEC-HMS. However, given that this region is the context of the study, some of its relevant attributes are described.

15. As was apparent from Fig. 1, the CDA is an irregular "U-shaped" area enclosing approximately 33.9 acres as measured within ArcGIS. Elevations within the CDA range from 1216.77 ft to 1238.77 ft, averaging 1225.71 ft, with the lowest elevations near the Lane Road Culvert inlet and the highest along the eastern edge of the CDA. The CDA is surrounded by seven adjoining plots (each continuous but separated from the others by streams) that, based on interpretation of 2015 orthoimagery, have been used for farming at some point in the past. These adjoining plots lie to the west, north and east of the CDA. Characteristics of the adjoining plots are given in Table 4. As indicated, flood waters begin to encroach on the adjoining plots at a WSE of 1223.08 ft (i.e., when water is overtopping Lane Road by approximately 1.3 ft at its lowest point).

**Table 4. Characteristics of plots adjoining the Consent Decree Area**

| Plot | Area (ac) | Minimum Elevation (ft) | Maximum Elevation (ft) | Average Elevation (ft) |
|---|---|---|---|---|
| 1 | 0.74 | 1223.62 | 1235.38 | 1229.61 |
| 2 | 13.67 | 1224.68 | 1253.43 | 1239.14 |
| 3 | 0.89 | 1226.35 | 1235.22 | 1231.45 |
| 4 | 1.08 | 1229.02 | 1236.97 | 1233.06 |
| 5 | 1.18 | 1228.65 | 1242.49 | 1236.26 |
| 6 | 6.49 | 1223.08 | 1276.53 | 1243.93 |
| 7 | 0.01 | 1223.50 | 1224.06 | 1223.79 |
| Total | 24.1 | | | |

**Fig. 14. Upland plots adjoining the Consent Decree Area.**



Data sources: (1) 2015 orthoimagery, (2) Client-provided documents.

## D. Rainfall Data

16. Rainfall data to be input to HEC-HMS were selected to represent a range of average frequencies, ranging from a 2-year return period (equaled or exceeded every other year, on average) to a 1000-year return period (equaled or exceeded once in a thousand years, on average). These data were obtained from the Precipitation Frequency Data Server (https://hdsc.nws.noaa.gov/hdsc/pfds/), hosted by the Hydrometeorological Design Studies Center, National Weather Service, National Oceanic and Atmospheric Administration. The location was set to the Lane Road Culvert, and the rainfall duration was taken as 24 hours in each case, consistent with common engineering design practice. The method of analysis option within the Precipitation Frequency Data Server (time series type) was selected as annual maximum. The annual maximum series analysis is common for locations having substantial record lengths, as is the case for the nearby Erie weather station (75 years of rainfall data). Analyses based on annual maximum series and the alternative partial duration series are generally very similar for return periods of greater than 20 years. The rainfall depths are as given in Table 5 below.

**Table 5. Rainfall depths at selected return periods for the area of interest.**

| Return Period (years) | Rainfall Depth (inches) |
|---|---|
| 2 | 2.36 |
| 5 | 3.10 |
| 10 | 3.63 |
| 25 | 4.37 |
| 50 | 4.97 |
| 100 | 5.62 |
| 500 | 7.32 |
| 1000 | 8.16 |

## E. HEC-HMS Model Calibration

17. No observed data for Elk Creek were available to calibrate HEC-HMS model parameters, which is ideally done to produce an acceptable match between model predictions and observations. Therefore, as is common when no site-specific observations are available, independent estimates of peak flow rates were derived using the methods and data of Roland and Stuckey (2008) and the characteristics of the AOI as previously reported and compared to HEC-HMS predictions of peak flows entering the Sharp Road Culvert. For the calibration process, the HEC-HMS model of the AOI did not include the two culverts or beaver dams since (a) stream gaging stations as used in the Roland and Stuckey (2008) study are normally not situated upstream of culverts due to their mitigating influence on peak flows, and (b) as discussed earlier, the beaver dams have not been continuously present in the AOI. Neglecting the beaver dams for this portion of the work has the additional effect of producing conservative (higher than would be expected in reality) calibrated HEC-HMS peak flow estimates, since the presence of beaver dams generally reduces downstream peak flows.

18. The CN model parameter in the HEC-HMS model was calibrated by varying each subwatershed's CN by a fixed proportion relative to the original CN until peak flow at the Sharp Road Culvert matched as closely as possible to the Roland and Stuckey (2008) estimates of peak flow at the same location. This occured when original CN values were adjusted downward to 0.79 (identified by trial-and-error) of their respective original values.

19. As may be inferred from Table 6, there was no single CN adjustment that produced a perfect fit to the Roland and Stuckey (2008) estimates for the investigated return periods (Roland and Stuckey (2008) estimates were not available for the 1000-year return period). The CN calibration factor of 0.79 was evaluated as acceptable in this context because it (a) produced HEC-HMS peak flow estimates that varied from Roland and Stuckey (2008) estimates by 17% or less for return periods of 5-10 years and (b) HEC-HMS peak flow estimates for the larger, rarer storms will be even more conservative. HEC-HMS underestimation of peak flows at the 2-year return period is proportionately substantial but will prove to have little, if any, bearing on the major findings of this report. Table 7 indicates calibrated CN values and updated lag values for each of the subwatersheds.

**Table 6. Peak flows at the Sharp Road Culvert inlet estimated from Roland and Stuckey (2008) methods (Target), HEC-HMS in uncalibrated mode (Uncalibrated) and HEC-HMS after setting CN values to 0.79 of original (Calibrated).**

| Return Period (years) | Target ($ft^3/s$) | Uncalibrated ($ft^3/s$) | Calibrated ($ft^3/s$) |
|---|---|---|---|
| 2 | 124 | 531 | 48 |
| 5 | 213 | 961 | 176 |
| 10 | 284 | 1305 | 311 |
| 50 | 465 | 2242 | 770 |
| 100 | 552 | 2718 | 1035 |
| 500 | 789 | 3997 | 1813 |

**Table 7. Corrected Curve Number (CN) and lag values from HEC-HMS model calibration.**

| Name | Area ($mi^2$) | Average Slope | Average CN | Lag (minutes) |
|---|---|---|---|---|
| W340 | 0.14 | 12.2 | 62.2 | 38.9 |
| W350 | 0.18 | 12.0 | 62.6 | 37.6 |
| W360 | 0.05 | 8.0 | 56.8 | 40.8 |
| W370 | 0.00 | 18.8 | 62.4 | 0.3 |
| W380 | 0.01 | 6.7 | 67.2 | 13.3 |
| W390 | 0.04 | 6.9 | 58.0 | 35.1 |
| W400 | 0.04 | 10.3 | 62.5 | 30.9 |
| W410 | 0.01 | 7.5 | 55.0 | 18.9 |
| W420 | 0.16 | 10.1 | 58.5 | 58.7 |
| W430 | 0.00 | 15.5 | 77.4 | 1.1 |
| W440 | 0.06 | 4.8 | 64.7 | 27.0 |
| W440A | 0.03 | 4.8 | 64.7 | 13.5 |
| W450 | 0.04 | 10.0 | 62.9 | 28.3 |
| W460 | 0.10 | 11.3 | 63.6 | 32.7 |
| W470 | 0.01 | 6.8 | 57.8 | 20.2 |
| W480 | 0.07 | 10.9 | 58.8 | 36.1 |
| W490 | 0.05 | 7.5 | 55.0 | 34.5 |
| W500 | 0.01 | 6.4 | 62.0 | 9.7 |
| W510 | 0.04 | 7.0 | 56.7 | 25.1 |
| W520 | 0.06 | 12.6 | 63.3 | 23.7 |
| W530 | 0.23 | 10.6 | 61.1 | 47.8 |
| W540 | 0.00 | 11.3 | 77.2 | 3.5 |
| W550 | 0.01 | 11.7 | 64.3 | 13.5 |
| W560 | 0.01 | 11.1 | 60.0 | 14.5 |
| W570 | 0.01 | 12.0 | 69.1 | 11.1 |
| W580 | 0.02 | 12.2 | 68.5 | 12.7 |
| W590 | 0.13 | 6.9 | 56.4 | 62.8 |
| W600 | 0.03 | 9.8 | 72.4 | 15.1 |
| W610 | 0.17 | 12.1 | 64.1 | 38.1 |
| W620 | 0.00 | 3.4 | 77.4 | 3.4 |
| W630 | 0.05 | 7.1 | 65.3 | 34.0 |
| W640 | 0.01 | 6.4 | 77.0 | 11.7 |
| W650 | 0.06 | 9.3 | 62.3 | 31.4 |
| W660 | 0.28 | 10.9 | 61.3 | 48.8 |

## F. Modeling Scenarios

20. To obtain results that would enable conclusions for a variety of conditions, the following scenarios were modeled using HEC-HMS and the data described previously. The order of the scenarios increases in anticipated inundated area due to floodwater detention upstream of the Lane Road Culvert.

21. <u>Scenario 1 (“EcoStrategies” Model)</u>.[5]

    a. Beaver dams omitted from the model (reflecting their destruction/nonpresence);

    b. Initial water surface elevation at the Lane Road Culvert set to 1215.94 ft (inlet invert);

    c. Initial water surface elevation at the Sharp Road Culverts set to 1215.60 ft (same as the outlet invert of the Lane Road Culvert, representing a lowering of the Sharp Road culvert by 1.70 ft; in reality, this would require substantial downstream channel modification given existing topography); and,

    d. Average soil moisture conditions at the time of rainfall.

22. <u>Scenario 2</u>.

    a. Beaver dams omitted from the model (reflecting their destruction/nonpresence);

    b. Initial water surface elevations at the Lane Road and Sharp Road Culverts set to 1217.30 ft (representing conditions observed during the site visit of October 16-17, 2017); and,

    c. Average soil moisture conditions at the time of rainfall.

23. <u>Scenario 3 (“Current” Circumstances - conditions during October 16-17, 2017 site visit)</u>.

    a. Beaver dams are present in the model;

    b. Initial water surface elevations at the Lane Road and Sharp Road Culverts set to 1217.30 ft; and,

    c. Average soil moisture conditions at the time of rainfall.

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[5] Defendants Robert Brace and Robert Brace & Sons, Inc., provided the United States with a “Wetland Evaluation Report,” dated August 5, 2015, drafted by EcoStrategies Civil Engineering (“EcoStrategies’ Report”). *See* EPA0001238-1242. The EcoStrategies Report suggests that Defendants’ alleged hydrologic issues would be alleviated if beaver dams were removed and the Sharp Road Culvert lowered. *See* EPA0001239-1240.

24. Scenario 4.

    a. Beaver dams are present in the model;

    b. Initial water surface elevations at Lane Road and Sharp Road Culverts set to 1218.5 ft with a corresponding flow rate of 40 $ft^3/s$ to model Elk Creek at bankfull condition as determined from DEM; and,

    c. Average soil moisture conditions at the time of rainfall

25. Scenario 5.

    a. Beaver dams are present in the model;

    b. Initial water surface elevations at the Lane Road and Sharp Road Culverts set to 1217.30 ft (representing current conditions);

    c. Wetter-than-average soil moisture conditions at the time of rainfall (requiring adjustments to CN and lag values). Based on standard methods of classifying soil moisture condition using (a) the location of the AOI, (b) daily rainfall data for the Erie FAA weather station (KERI) for Jan 1, 1926 to December 21, 2016, (c) an assumed crop of corn, with (d) a growing season of May 1 to October 31, these conditions are estimated to exist approximately 12.9% of the time.

26. Scenario 6 (“Severe” Circumstances).

    a. Beaver dams are not present in the model;

    b. Initial water surface elevations at Lane Road and Sharp Road Culverts set to 1218.5 ft with a corresponding flow rate of 40 $ft^3/s$ to model Elk Creek at bankfull condition; and,

    c. Wetter-than-average soil moisture conditions at the time of rainfall (requiring adjustments to CN and lag values). Based on the location of the AOI and assuming a crop of corn, with a growing season of May 1 to October 31, these conditions are estimated to exist approximately 12.9% of the time.

Differences among the scenarios are represented in Table 8.

**Table 8. HEC-HMS modeling scenarios.**

| | **Scenario** | | | | | |
|---|---|---|---|---|---|---|
| **Variable** | **1 "Ecostrategies"** | **2** | **3 "Current"** | **4** | **5** | **6 "Severe"** |
| Beaver Dams | Absent | Absent | Present | Present | Present | Absent |
| Lane Road Downstream Channel Elevation | 1215.6 | 1217.3 | 1217.3 | 1217.3 | 1217.3 | 1217.3 |
| Lane Road Upstream Water Surface Elevation | 1215.94 | 1217.3 | 1217.3 | 1218.5 | 1217.3 | 1218.5 |
| Sharp Road Inlet Invert Elevation | 1215.6 | 1217.3 | 1217.3 | 1217.3 | 1217.3 | 1217.3 |
| Soil Moisture | Average | Average | Average | Average | Wetter than Average | Wetter than Average |

# VI. Modeling Results

## A. Scenario 1 - "EcoStrategies" Model

27. Results for Scenario 1 are given in Table 9. Based on WSE upstream of the Lane Road Culvert, floodwaters do not begin to exceed the boundaries of the CDA until return periods of 25 years or more. At greater return periods, only very small portions of plots 1, 6 and 7 experience any flooding.

28. Flooded surfaces are demonstrated in Figs. 15-17 for return periods of 10, 100 and 1000 years, respectively. As indicated in Table 10, however, flooded areas within the adjoining plots are very small (a maximum of only 0.03 ac at the 1000-year return period) with maximum depths of 1.41 ft. Table 10 also indicates flooded durations, or the time during which any portion of any of the adjoining plots experiences any flooding. Flooded durations range from zero to a maximum of 3.25 hours

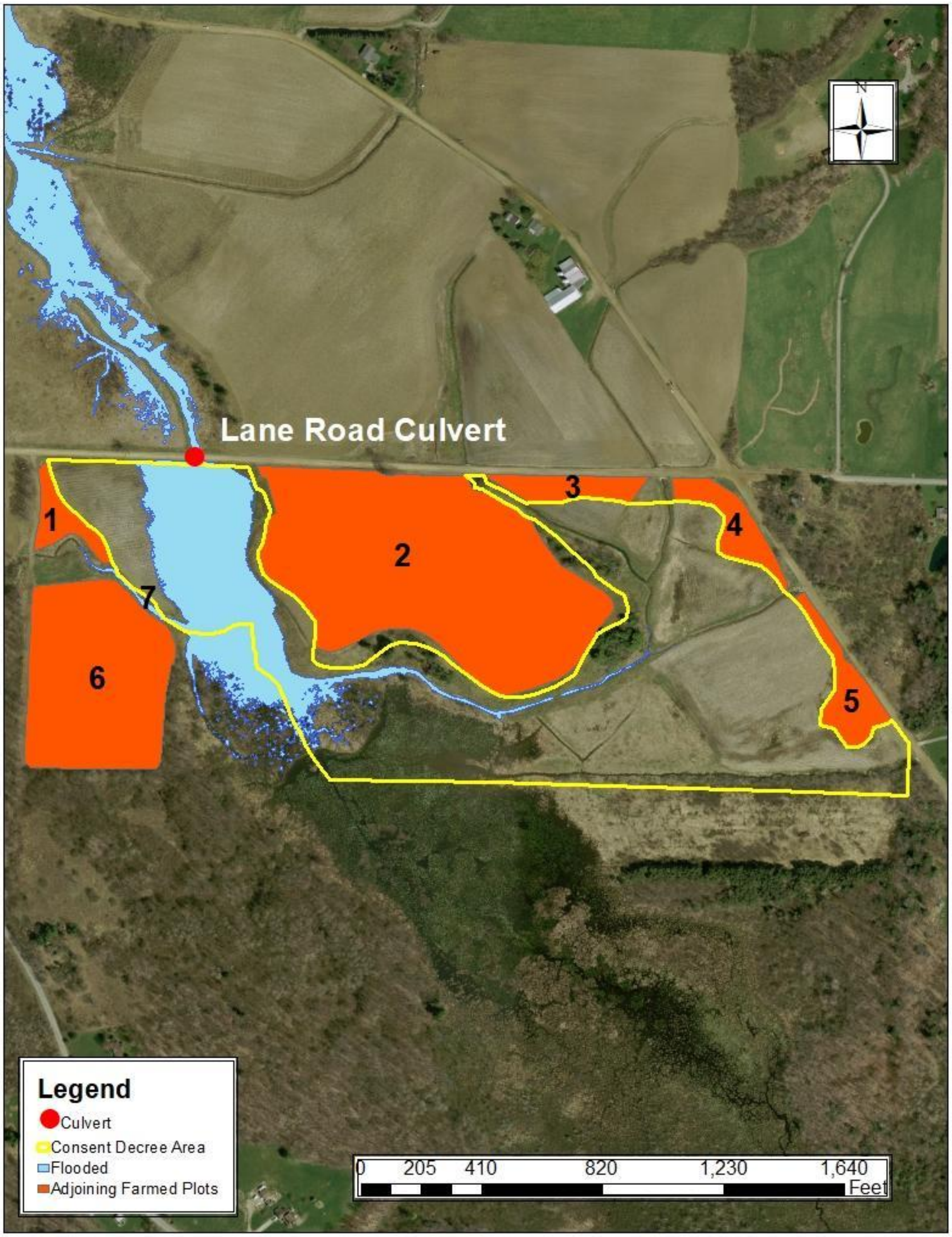
**Table 9. Simulation results for Scenario 1 (beaver dams absent, Sharp Road Culvert inlet invert lowered to 1215.90 ft). Data are peak culvert discharges and maximum upstream water surface elevation (WSE).**

| Return | Lane Road Culvert | | Sharp Road Culvert | |
|---|---|---|---|---|
| Period (years) | Peak Discharge (ft3/s) | WSE (ft) | Peak Discharge (ft3/s) | WSE (ft) |
| 2 | 39 | 1217.4 | 46 | 1217.1 |
| 5 | 125 | 1220.3 | 128 | 1219.2 |
| 10 | 201 | 1222.0 | 191 | 1220.1 |
| 25 | 373 | 1223.3 [1,2] | 257 | 1221.0 |
| 50 | 593 | 1223.7 [1,2] | 322 | 1221.9 |
| 100 | 835 | 1223.9 [1,2] | 462 | 1222.6 [2] |
| 500 | 1475 | 1224.3 [1,2] | 1323 | 1223.4 [2] |
| 1000 | 1814 | 1224.5 [1,2] | 1786 | 1223.6 [2] |

[1] Extends outside Consent Decree Area into at least one adjoining plot.

[2] Overtopping roadway

Fig. 15. Scenario 1- Flooded surface for 10-year return period.[6]



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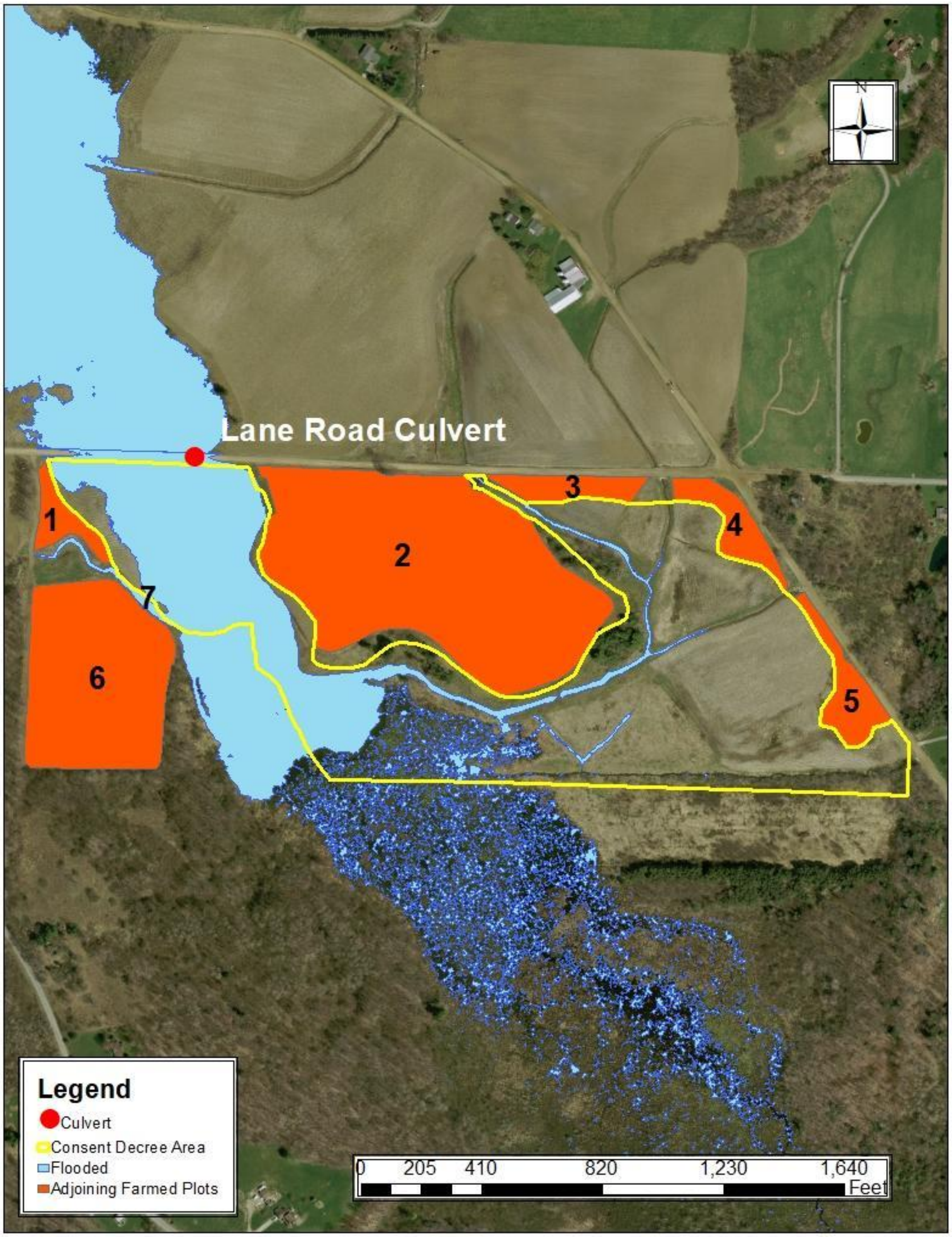
[6] There is no flooding of adjoining plots at this return period.

**Fig. 16. Scenario 1 - Flooded surface for 100-year return period.**[7]



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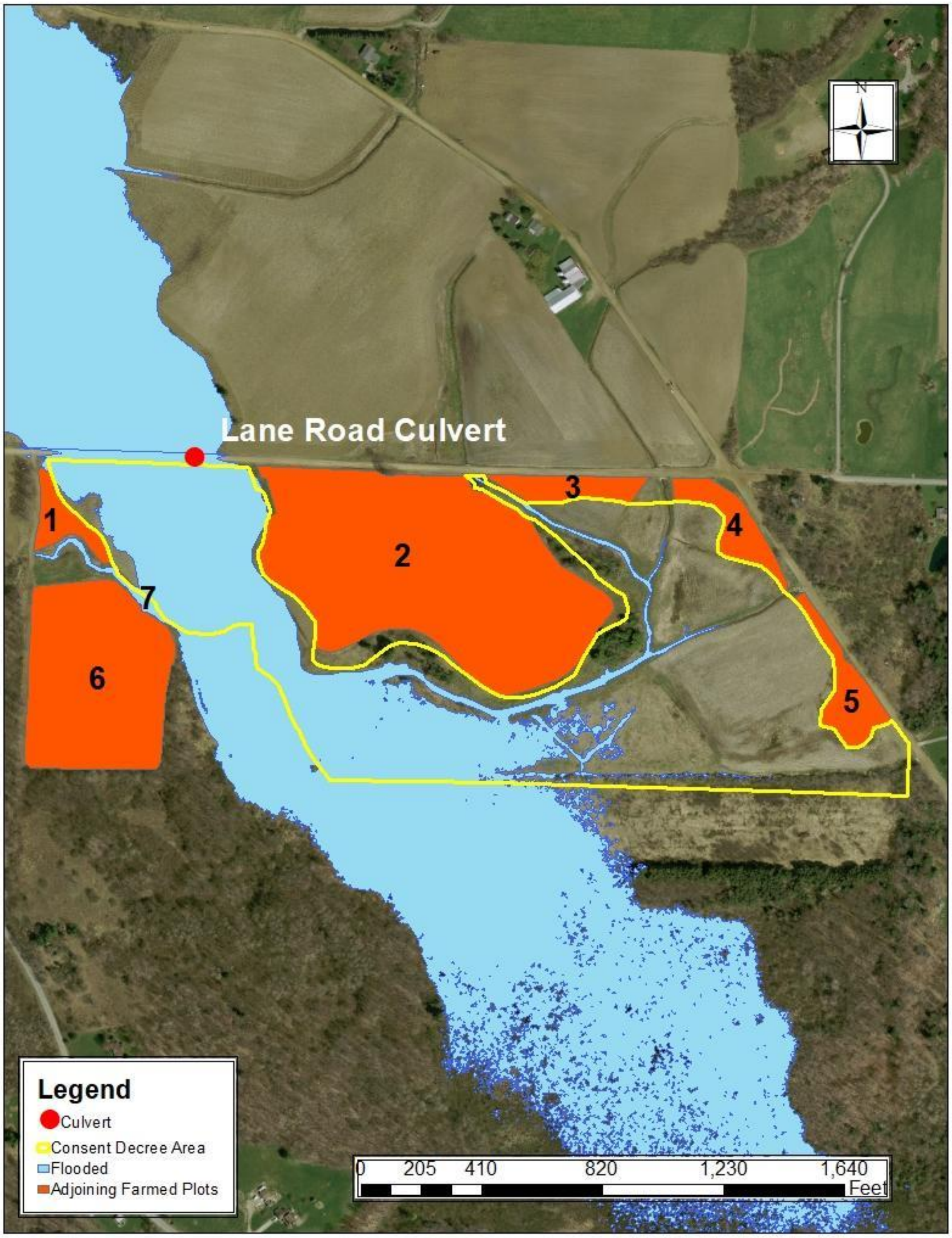
[7] Small portions of plots 1, 6, and 7, totaling 0.0148 ac (0.0615% of the total adjoining area), experience flooding at this return period.

Fig. 17. Scenario 1 - Flooded surface for 1,000-year return period.[8]



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[8] Small portions of plots 1, 6, and 7, totaling 0.0336 ac (0.1394% of the total adjoining area), experience flooding at this return period.

**Table 10. Adjoining plot flooding for Scenario 1.**

| Return Period (years) | Flooded Area (ac) | Fraction of Plot Area % | Average Depth (ft) | Maximum Depth (ft) | Maximum Duration (hours) |
|---|---|---|---|---|---|
| 10 | None | N/A | N/A | N/A | N/A |
| 25 | 0.0001 | 0.0006 | 0.08 | 0.16 | 0.75 |
| 50 | 0.0034 | 0.0141 | 0.50 | 0.61 | 1.42 |
| 100 | 0.0148 | 0.0615 | 0.66 | 0.89 | 1.92 |
| 500 | 0.0294 | 0.1220 | 0.82 | 1.21 | 2.75 |
| 1000 | 0.0336 | 0.1394 | 0.89 | 1.41 | 3.25 |

## B. Scenario 2

29. Results for Scenario 2 are given in Table 11. Identical to Scenario 1, floodwaters are not predicted to extend into the adjoining plots until return periods of 25 years or more (Plots 1, 6 and 7).

30. Flooding for this scenario is illustrated in Figs. 18-20. As indicated in Table 12, flooded areas and depths in the adjoining plots are again small and, for practical purposes, identical to results from Scenario 1. Comparison of results from Scenarios 1 and 2 suggests that lowering the Sharp Road Culvert (again, putting aside feasibility) would have no significant effect on flooding upstream of the Lane Road Culvert.

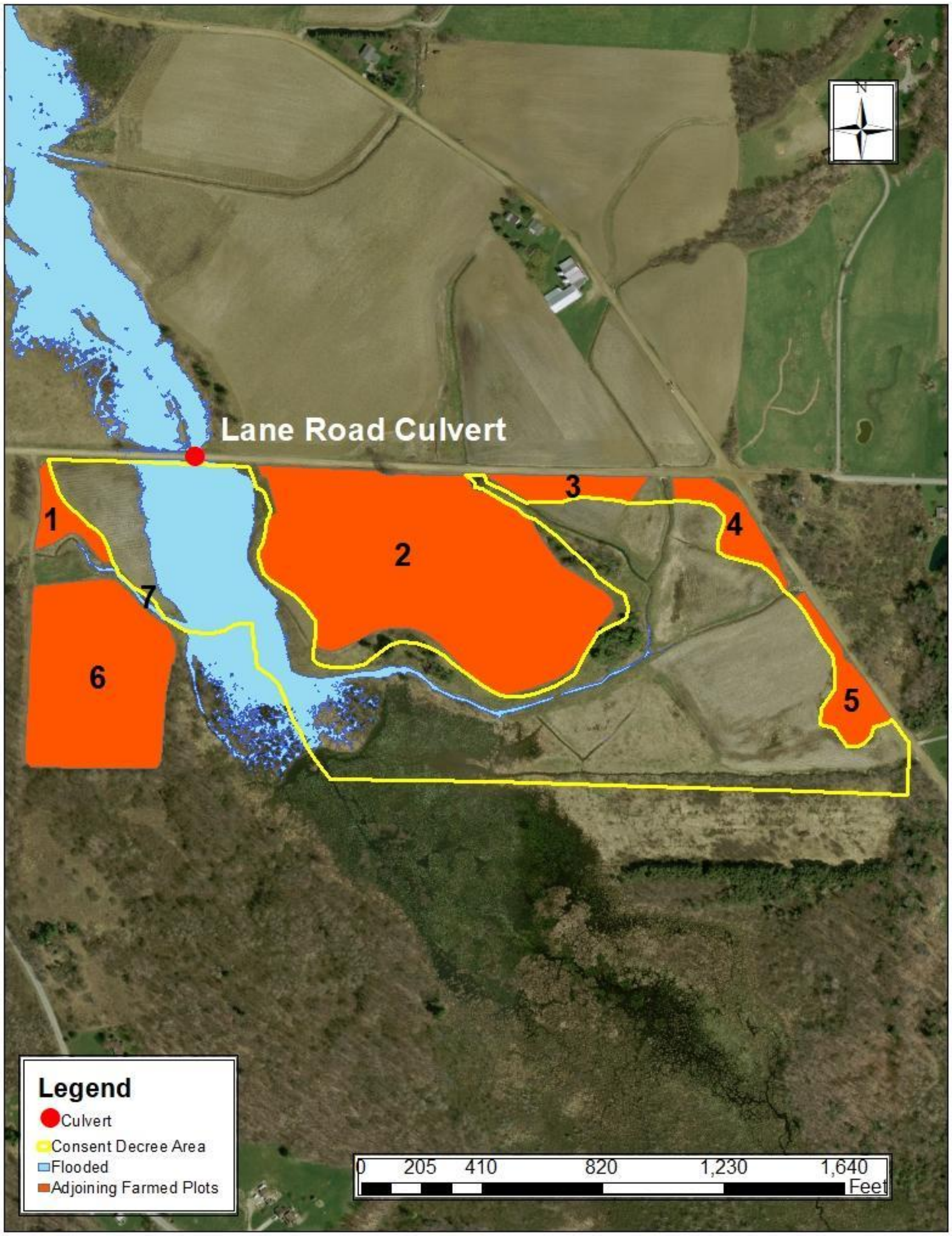
**Table 11. Simulation results for Scenario 2 (beaver dams absent, Sharp Road Culvert inlet invert as current). Data are peak culvert discharges and maximum upstream water surface elevation (WSE).**

| Return | Lane Road Culvert | | Sharp Road Culvert | |
|---|---|---|---|---|
| Period (years) | Peak Discharge ($ft^3/s$) | WSE (ft) | Peak Discharge ($ft^3/s$) | WSE (ft) |
| 2 | 38 | 1218.4 | 31 | 1218.2 |
| 5 | 122 | 1220.7 | 100 | 1220.4 |
| 10 | 195 | 1222.2 | 134 | 1220.9 |
| 25 | 381 | 1223.3 [1,2] | 197 | 1221.9 |
| 50 | 597 | 1223.7 [1,2] | 283 | 1222.5 [2] |
| 100 | 835 | 1223.9 [1,2] | 513 | 1222.9 [2] |
| 500 | 1475 | 1224.3 [1,2] | 1380 | 1223.5 [2] |
| 1000 | 1814 | 1224.5 [1,2] | 1839 | 1223.8 [2] |

[1] Flooding in at least one adjoining plot.

[2] Overtopping roadway

**Fig. 18. Scenario 2 - Flooded surface for 10-year return period.**[9]



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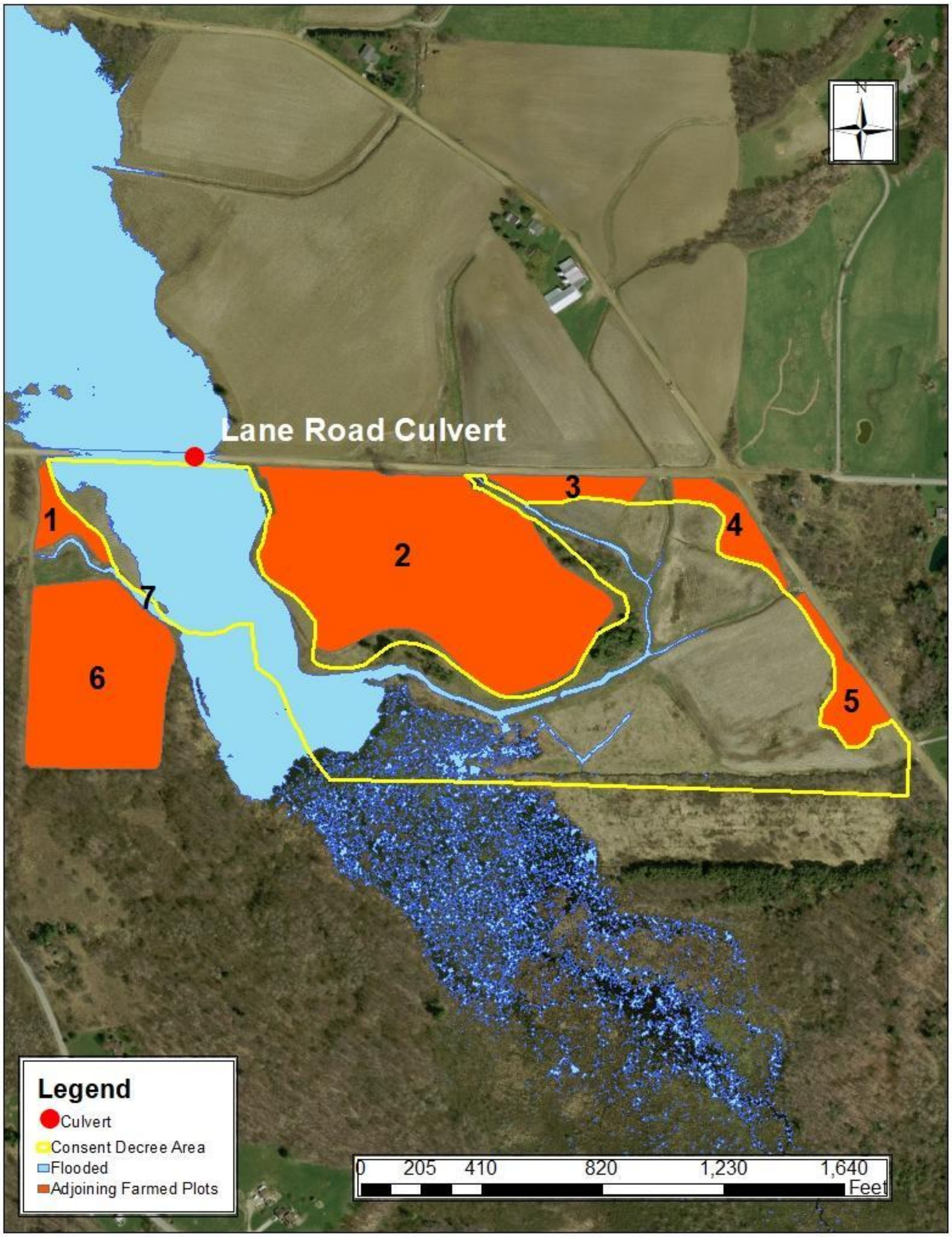
[9] There is no flooding of adjoining plots at this return period.

**Fig. 19. Scenario 2 - Flooded surface for 100-year return period.**[10]



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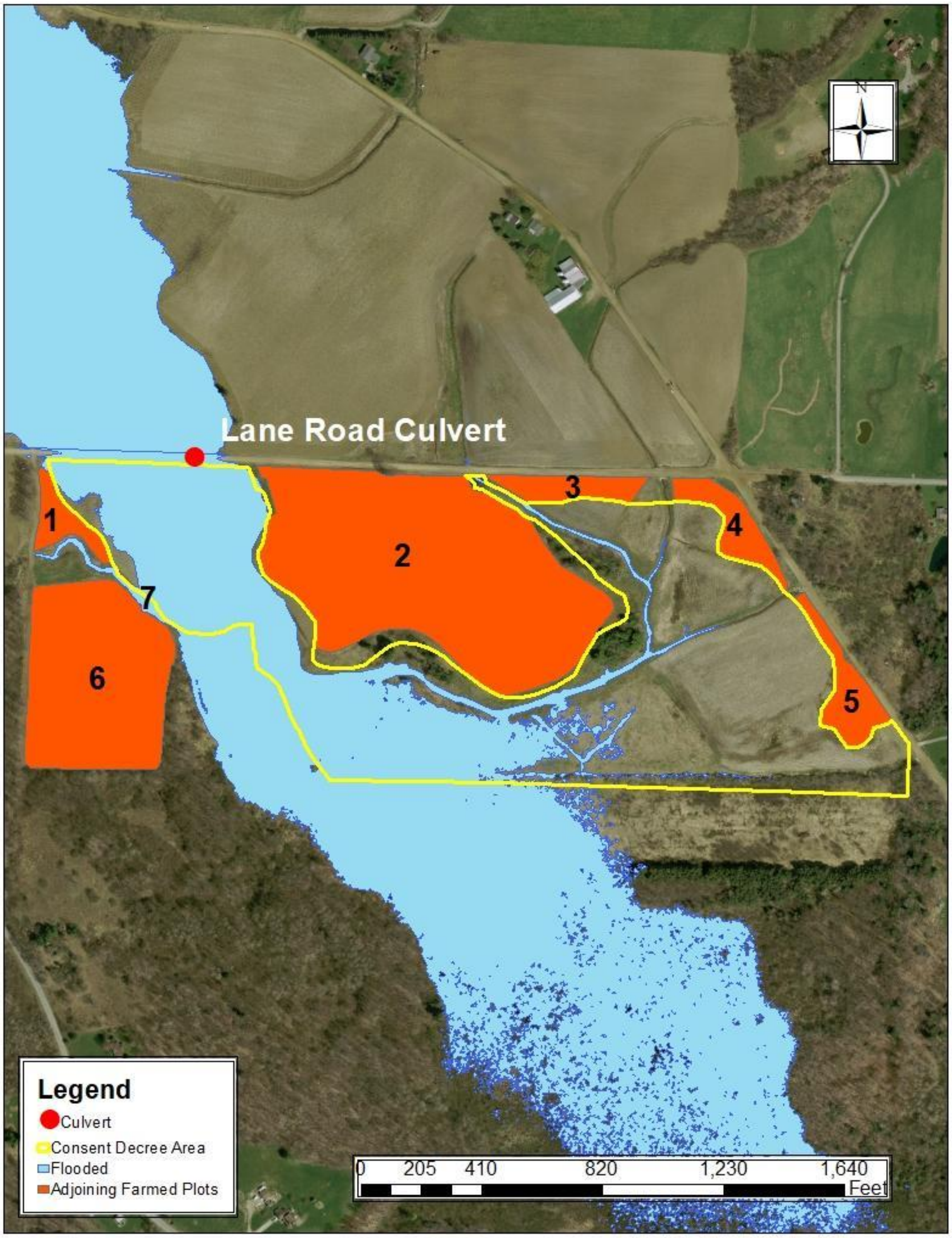
[10] Small portions of plots 1, 6, and 7, totaling 0.0148 ac (0.0615% of the total adjoining acreage), experience flooding at this return period.

Fig. 20. Scenario 2 - Flooded surface for 1,000-year return period.[11]



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[11] Small portions of plots 1, 6, and 7, totaling 0.0336 ac (0.1394% of the total adjoining acreage), experience flooding at this return period.

**Table 12. Adjoining plot flooding for Scenario 2.**

| Return Period (years) | Flooded Area (ac) | Fraction of Plot Area % | Average Depth (ft) | Maximum Depth (ft) | Maximum Duration (hours) |
|---|---|---|---|---|---|
| 10 | None | N/A | N/A | N/A | N/A |
| 25 | 0.0001 | 0.0006 | 0.08 | 0. 16 | 0.92 |
| 50 | 0.0034 | 0.0141 | 0.50 | 0.61 | 1.42 |
| 100 | 0.0148 | 0.0615 | 0.66 | 0.89 | 1.92 |
| 500 | 0.0294 | 0.1220 | 0.82 | 1.21 | 2.75 |
| 1000 | 0.0336 | 0.1394 | 0.89 | 1.41 | 3.25 |

## C. Scenario 3 - "Current" Circumstances

31. Results for Scenario 3, which represent the circumstances that existed during the site visit on October 16-17, 2017, are given in Table 13 with flooded surfaces shown in Figs. 21-23. Measures of flooding in adjoining plots are given in Table 14. This scenario differs from the preceding two in that generally less flooding occurs upstream of the Lane Road Culvert (as evidenced by lower peak discharges and WSE values). This finding is attributed to the presence of the upstream beaver dams, which function to store a portion of incoming flows and release the stored floodwaters more slowly. As with the previous scenarios, small portions of adjoining plots 1, 6 and 7 are predicted to be flooded (but only at return periods of 25 years – at which the flooded area amounts to approximately eight square inches - and more), and there are no large differences in this regard from previous scenarios. Maximum flooded duration is slightly longer (3.42 hours) than for the previous scenarios due to the beaver dam storages.

32. Neither lowering the Sharp Road Culvert nor removing the two major beaver dams reduces flooding upstream of the Lane Road Culvert; in fact, removing the beaver dams is predicted to increase the flooding, as can be seen by comparing flood depths in Table 14 to those in Tables 10 and 12.

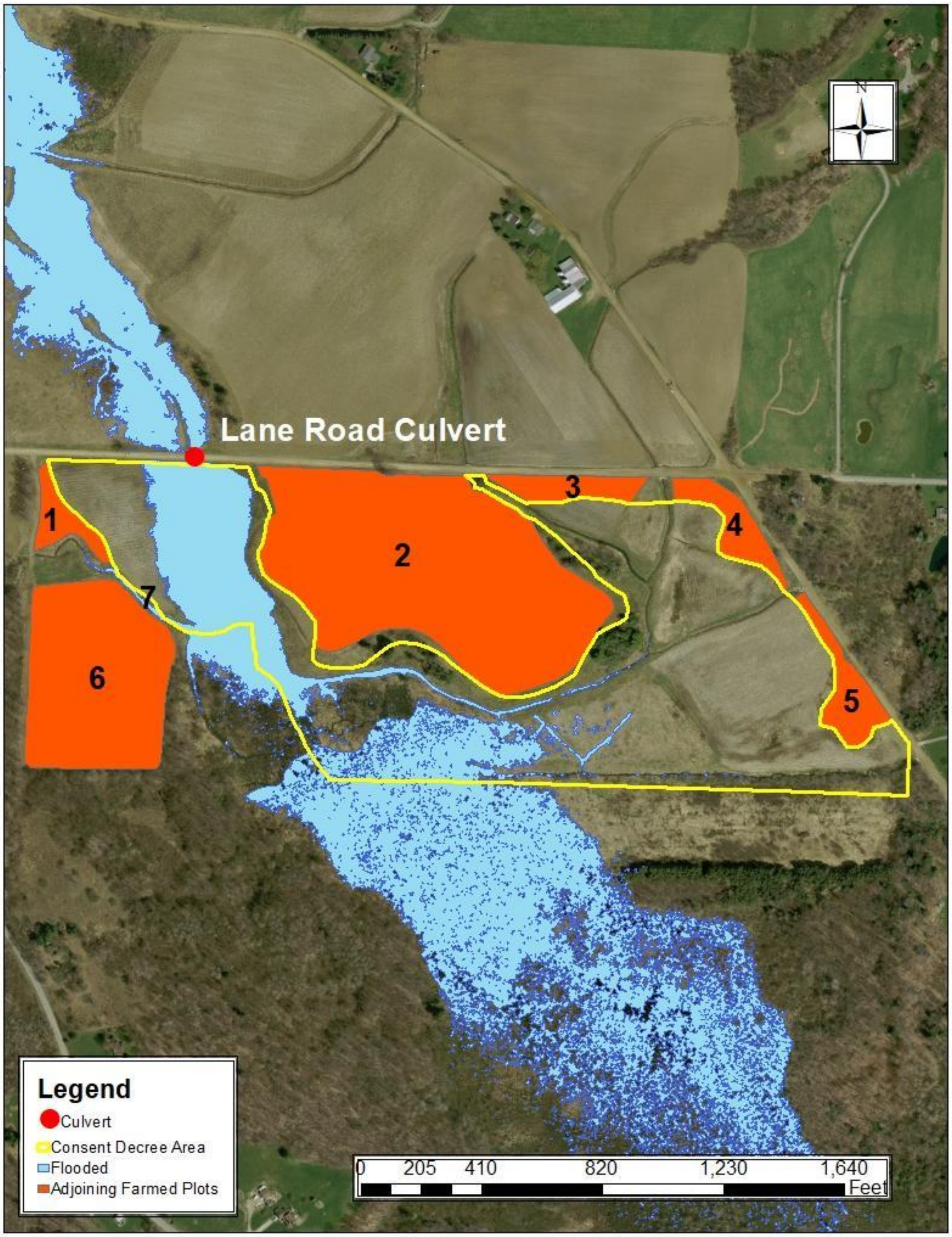
**Table 13. Simulation results for Scenario 3 (current conditions; beaver dams present, Sharp Road Culvert inlet invert as current). Data are peak culvert discharges and maximum upstream water surface elevation (WSE).**

| Return | Lane Road Culvert | | Sharp Road Culvert | |
|---|---|---|---|---|
| Period (years) | Peak Discharge ($ft^3/s$) | WSE (ft) | Peak Discharge ($ft^3/s$) | WSE (ft) |
| 2 | 35 | 1218.3 | 30 | 1218.2 |
| 5 | 113 | 1220.5 | 96 | 1220.2 |
| 10 | 179 | 1221.8 | 131 | 1220.8 |
| 25 | 326 | 1223.2 [1,2] | 192 | 1221.8 |
| 50 | 509 | 1223.6 [1,2] | 272 | 1222.4 [2] |
| 100 | 709 | 1223.8 [1,2] | 471 | 1222.8 [2] |
| 500 | 1265 | 1224.2 [1,2] | 1226 | 1223.4 [2] |
| 1000 | 1556 | 1224.3 [1,2] | 1624 | 1223.6 [2] |

[1] Flooding in at least one adjoining plot.

[2] Overtopping roadway

Fig. 21. Scenario 3 - Flooded surface for 10-year return period.[12]



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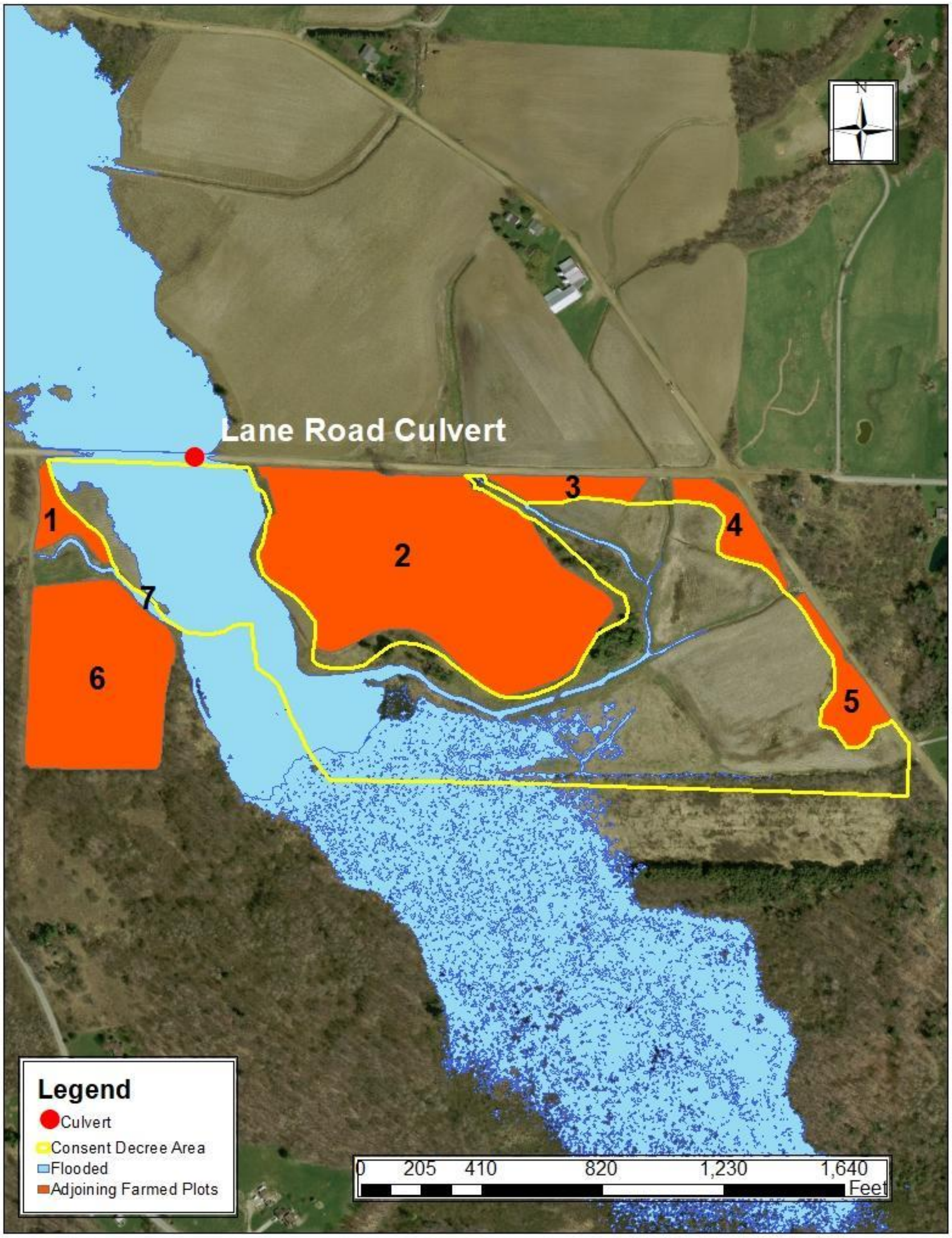
[12] There is no flooding of adjoining plots at this return period.

**Fig. 22. Scenario 3 - Flooded surface for 100-year return period.**[13]



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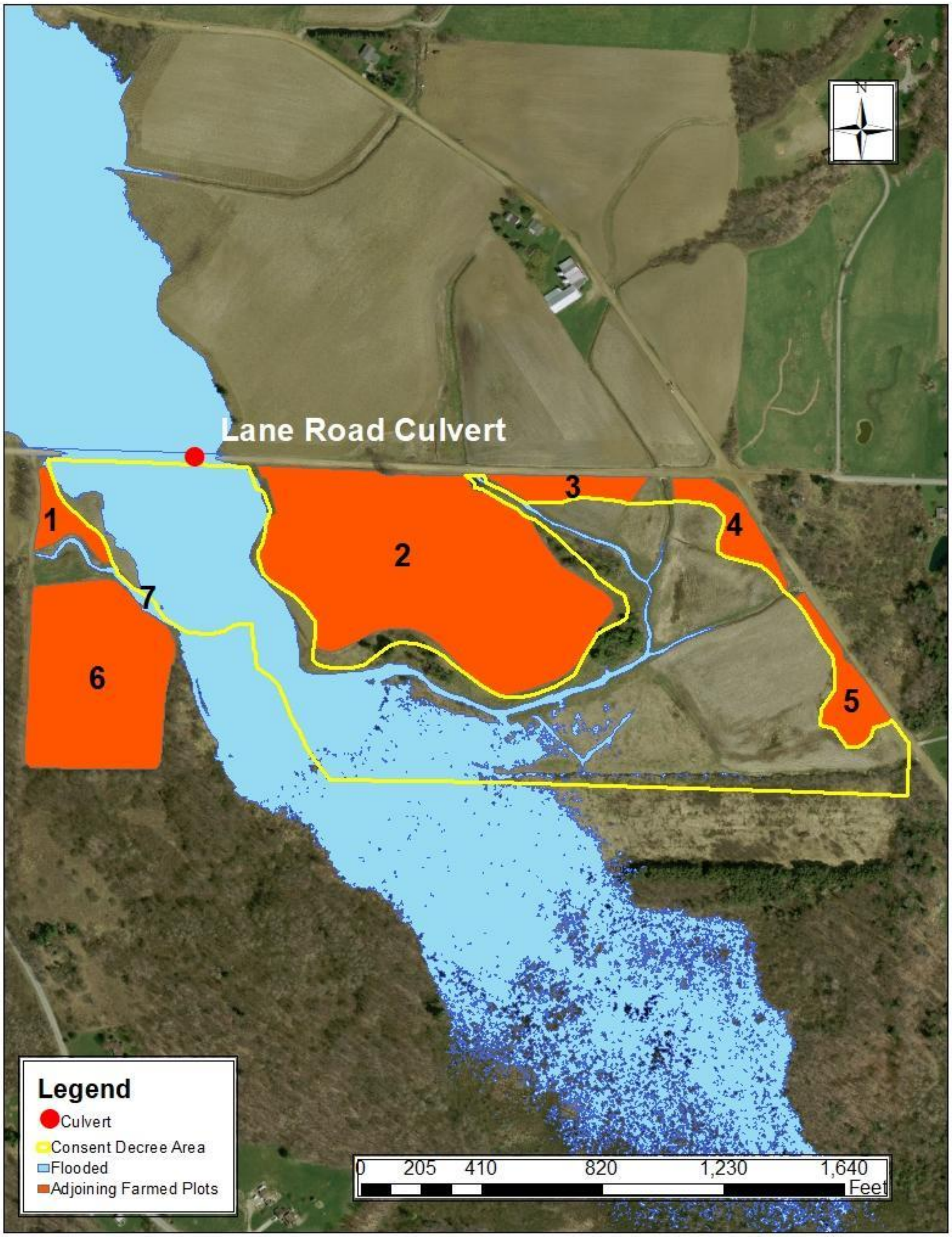
[13] Small portions of plots 1, 6, and 7, totaling 0.0094 ac (0.0392% of the total adjoining acreage), experience flooding at this return period.

**Fig. 23. Scenario 3 - Flooded surface for 1,000-year return period.**[14]



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[14] Small portions of plots 1, 6, and 7, totaling 0.0294 ac (0.122% of the total adjoining acreage), experience flooding at this return period.

**Table 14. Adjoining plot flooding for Scenario 3.**

| Return Period (years) | Flooded Area (ac) | Fraction of Plot Area % | Average Depth (ft) | Maximum Depth (ft) | Maximum Duration (hours) |
|---|---|---|---|---|---|
| 10 | None | N/A | N/A | N/A | N/A |
| 25 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.75 |
| 50 | 0.0010 | 0.0041 | 0.42 | 0.57 | 1.58 |
| 100 | 0.0094 | 0.0392 | 0.61 | 0.77 | 2.08 |
| 500 | 0.0256 | 0.1077 | 0.78 | 1.11 | 3.00 |
| 1000 | 0.0294 | 0.1220 | 0.82 | 1.21 | 3.42 |

## D. Scenario 4

33. Results for Scenario 4 are given in Table 15. Relative to Scenario 3, peak discharges upstream of Lane Road Culvert are increased as a result of Elk Creek being modeled as bankfull from the onset. However, these differences are of decreasing significance at the higher return periods. Flooded surfaces are given in Figs. 24-26. Flooding in adjoining plots is described in Table 16, which is highly consistent with the results for Scenario 3.

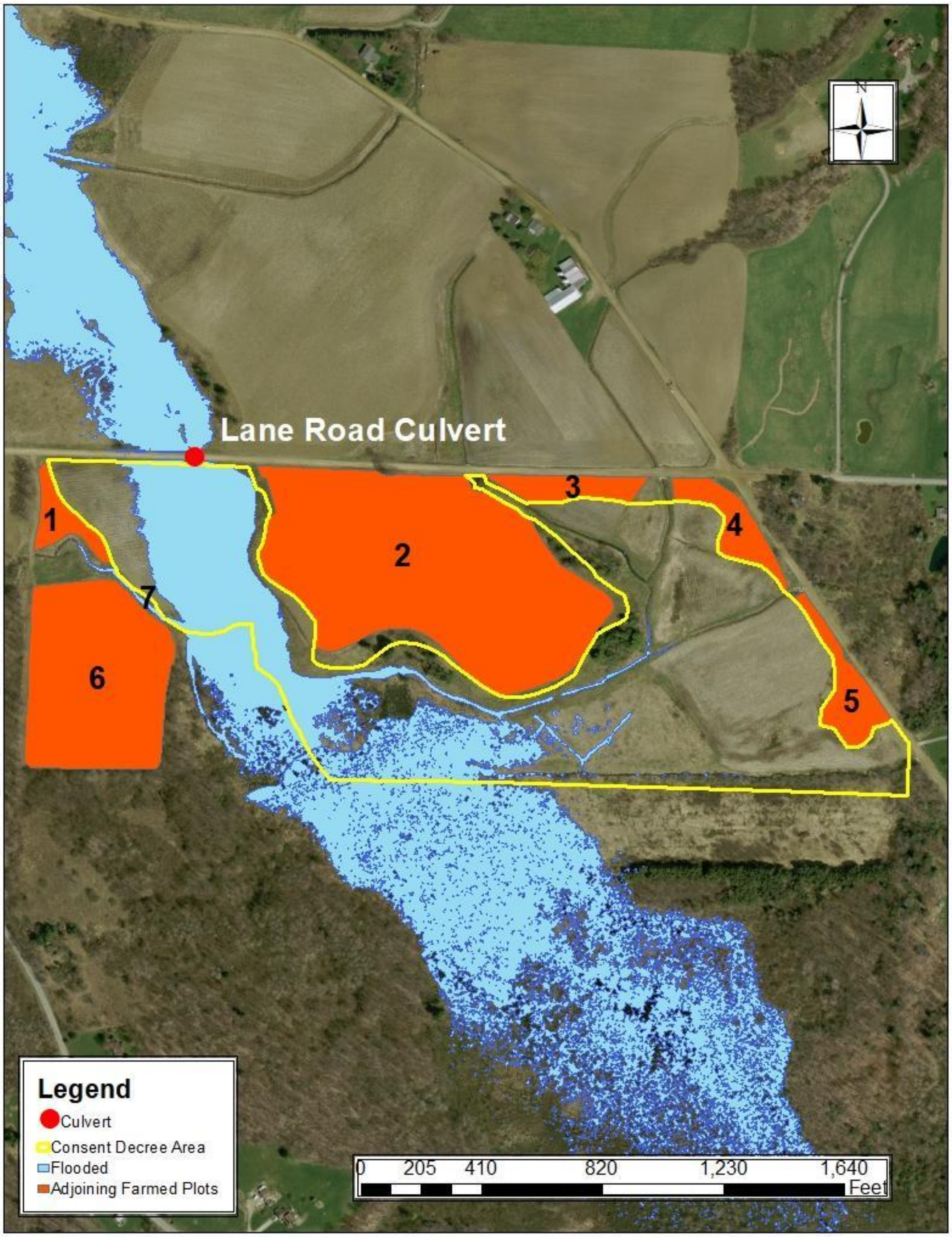
**Table 15. Simulation results for Scenario 4 (current conditions; except that Elk Creek is flowing under bankfull conditions). Data are peak culvert discharges and maximum upstream water surface elevation (WSE).**

| Return | Lane Road Culvert | | Sharp Road Culvert | |
|---|---|---|---|---|
| Period (years) | Peak Discharge ($ft^3/s$) | WSE (ft) | Peak Discharge ($ft^3/s$) | WSE (ft) |
| 2 | 75 | 1219.5 | 70 | 1219.4 |
| 5 | 144 | 1221.1 | 118 | 1220.6 |
| 10 | 212 | 1222.4 | 155 | 1221.2 |
| 25 | 381 | 1223.4 [1,2] | 218 | 1222.1 [2] |
| 50 | 557 | 1223.6 [1,2] | 326 | 1222.6 [2] |
| 100 | 750 | 1223.8 [1,2] | 554 | 1222.9 [2] |
| 500 | 1305 | 1224.2 [1,2] | 1300 | 1223.5 [2] |
| 1000 | 1596 | 1224.3 [1,2] | 1689 | 1223.7 [2] |

[1] Flooding in at least one adjoining plot.

[2] Overtopping roadway

**Fig. 24. Scenario 4 – Flooded surface for 10-year return period.**[15]



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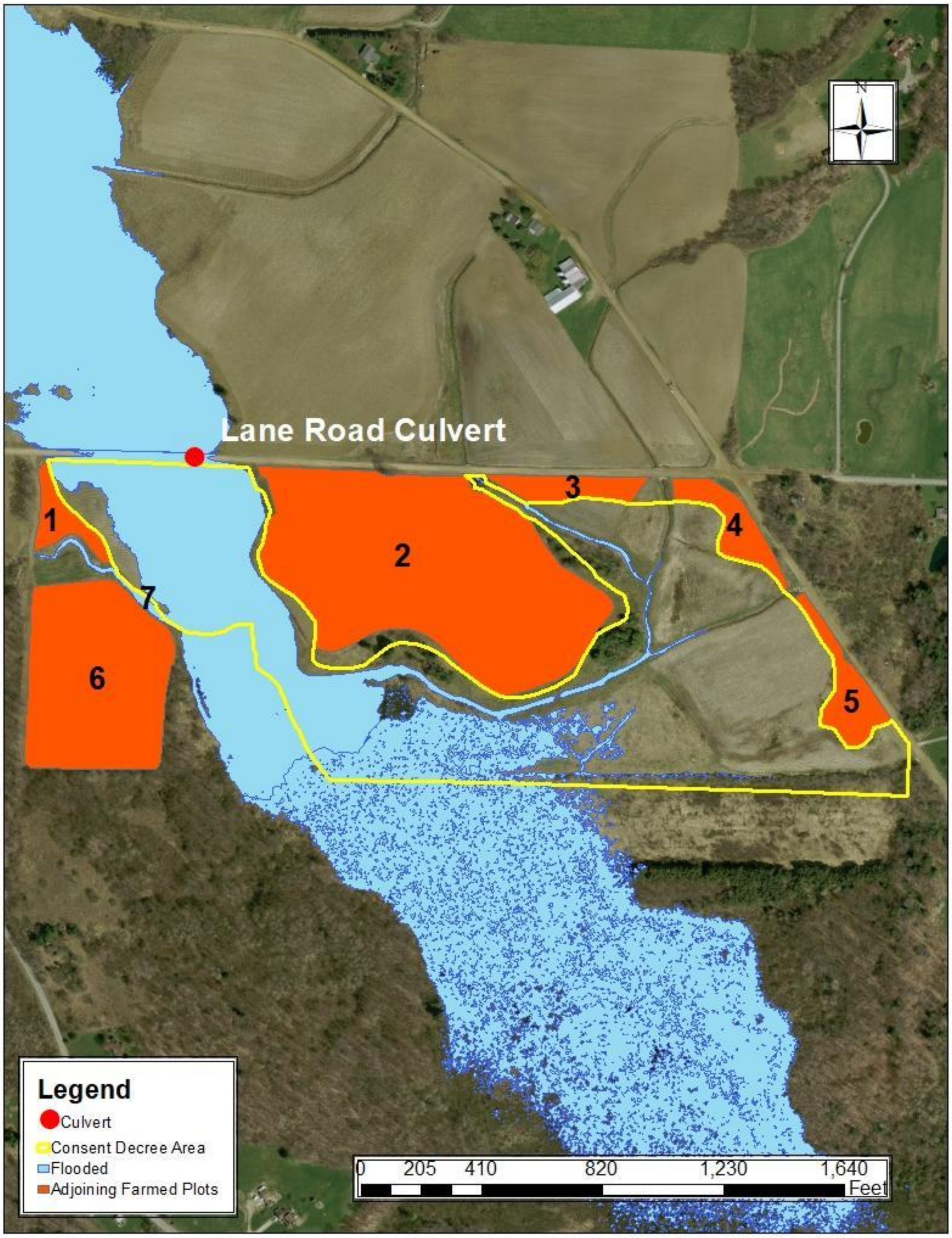
[15] There is no flooding of adjoining plots at this return period.

**Fig. 24. Scenario 4 – Flooded surface for 100-year return period.**[16]



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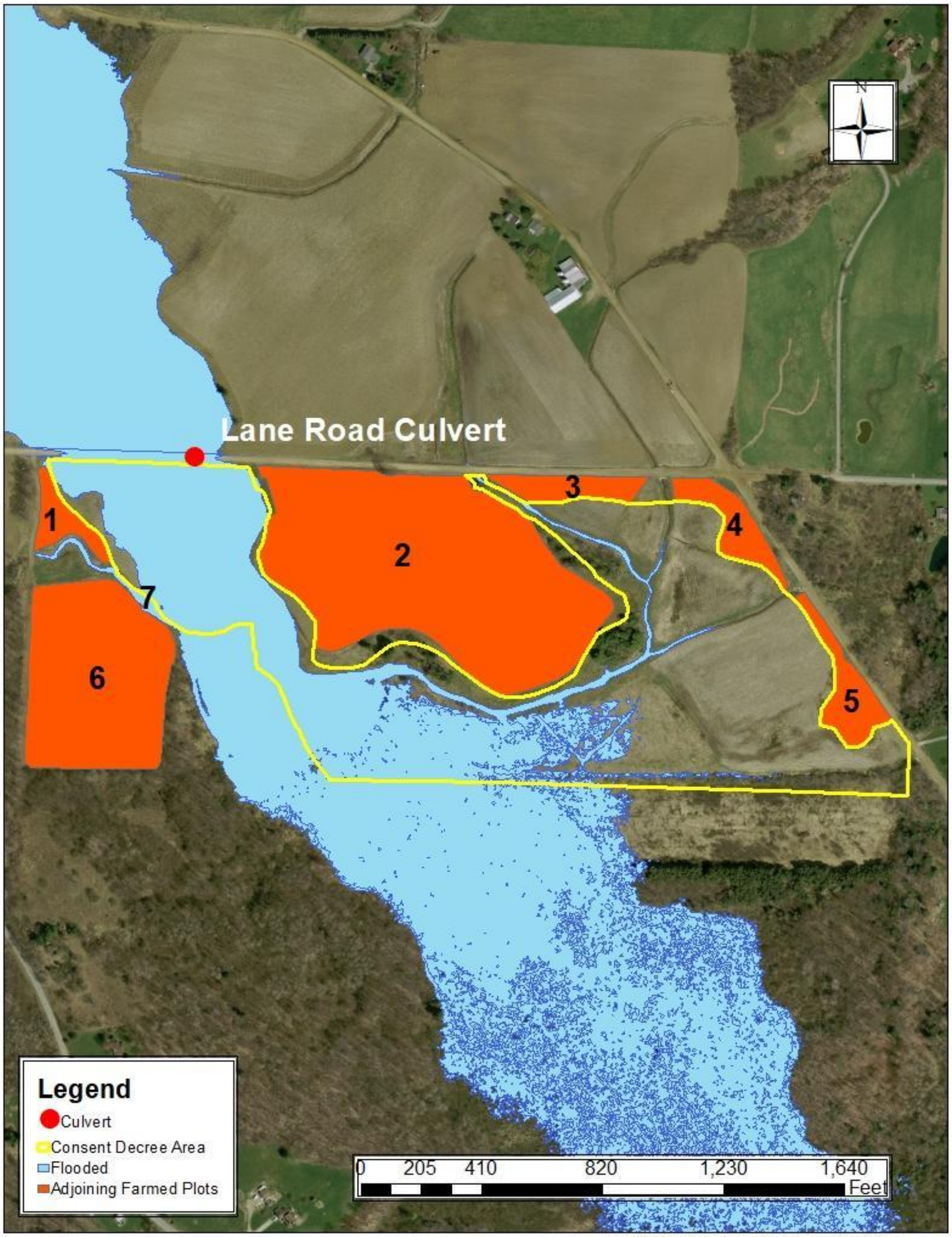
[16] Small portions of plots 1, 6, and 7, totaling 0.0094 ac (0.0392% of the total adjoining acreage), experience flooding at this return period.

**Fig. 26. Scenario 4 – Flooded surface for 1,000-year return period.**[17]



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[17] Small portions of plots 1, 6, and 7, totaling 0.0294 ac (0.122% of the total adjoining acreage), experience flooding at this return period.

**Table 16. Adjoining plot flooding for Scenario 4.**

| Return Period (years) | Flooded Area (ac) | Fraction of Plot Area % | Average Depth (ft) | Maximum Depth (ft) | Maximum Duration (hours) |
|---|---|---|---|---|---|
| 10 | None | N/A | N/A | N/A | N/A |
| 25 | 0.0001 | 0.0005 | 0.08 | 0.16 | 1.08 |
| 50 | 0.0010 | 0.0041 | 0.42 | 0.57 | 1.75 |
| 100 | 0.0094 | 0.0392 | 0.61 | 0.77 | 2.33 |
| 500 | 0.0256 | 0.1077 | 0.78 | 1.11 | 3.42 |
| 1000 | 0.0294 | 0.1220 | 0.82 | 1.21 | 3.92 |

## E. Scenario 5

34. Results for Scenario 5 are given in Table 17. As suggested by magnitudes of peak discharges relative to Scenarios 1-4, this scenario is quite severe in terms of flooding (peak discharges and WSE values) predictions. Lane Road is predicted to overtop at all return periods investigated, and Sharp Road for return periods > 2 years. The flooded surfaces are demonstrated in Figs. 27-29. As indicated in Table 18, flooding in the adjoining plots occurs at return periods of 5 years and greater and covers roughly double the area (including a portion of Plot 2 at return periods of 500 years and greater) as the preceding four scenarios. Even so, the flooded surfaces remain small (0.06 ac and less), and average depth of flooding is below 1.3 ft for the return periods investigated. Flooded duration is seen to increase slightly over previous scenarios (a maximum of 4.17 hours) due to higher flood magnitudes.

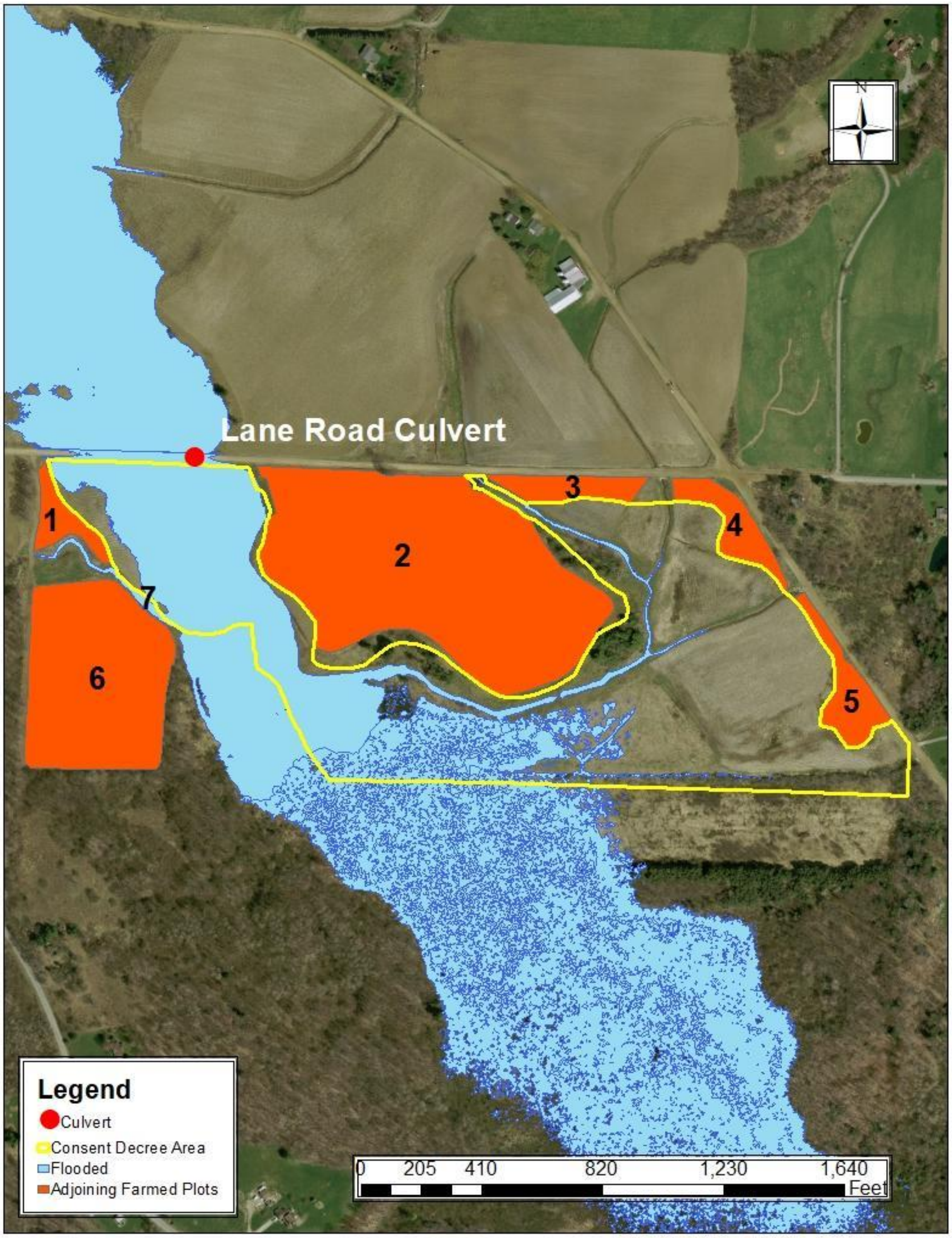
**Table 17. Simulation results for Scenario 5 (current conditions with higher-than-average soil moisture). Data are peak culvert discharges and maximum upstream water surface elevation (WSE).**

| Return | Lane Road Culvert | | Sharp Road Culvert | |
|---|---|---|---|---|
| Period (years) | Peak Discharge ($ft^3/s$) | WSE (ft) | Peak Discharge ($ft^3/s$) | WSE (ft) |
| 2 | 266 | 1222.9 [2] | 158 | 1221.3 |
| 5 | 613 | 1223.7 [1,2] | 272 | 1222.4 [2] |
| 10 | 873 | 1223.9 [1,2] | 499 | 1222.9 [2] |
| 25 | 1230 | 1224.1 [1,2] | 941 | 1223.3 [2] |
| 50 | 1522 | 1224.3 [1,2] | 1362 | 1223.5 [2] |
| 100 | 1845 | 1224.5 [1,2] | 1792 | 1223.7 [2] |
| 500 | 2725 | 1224.8 [1,2] | 2991 | 1224.2 [2] |
| 1000 | 3169 | 1225.0 [1,2] | 3553 | 1224.4 [2] |

[1] Flooding in at least one adjoining plot.

[2] Overtopping roadway

**Fig. 27. Scenario 5 - Flooded surface for 10-year return period.**[18]



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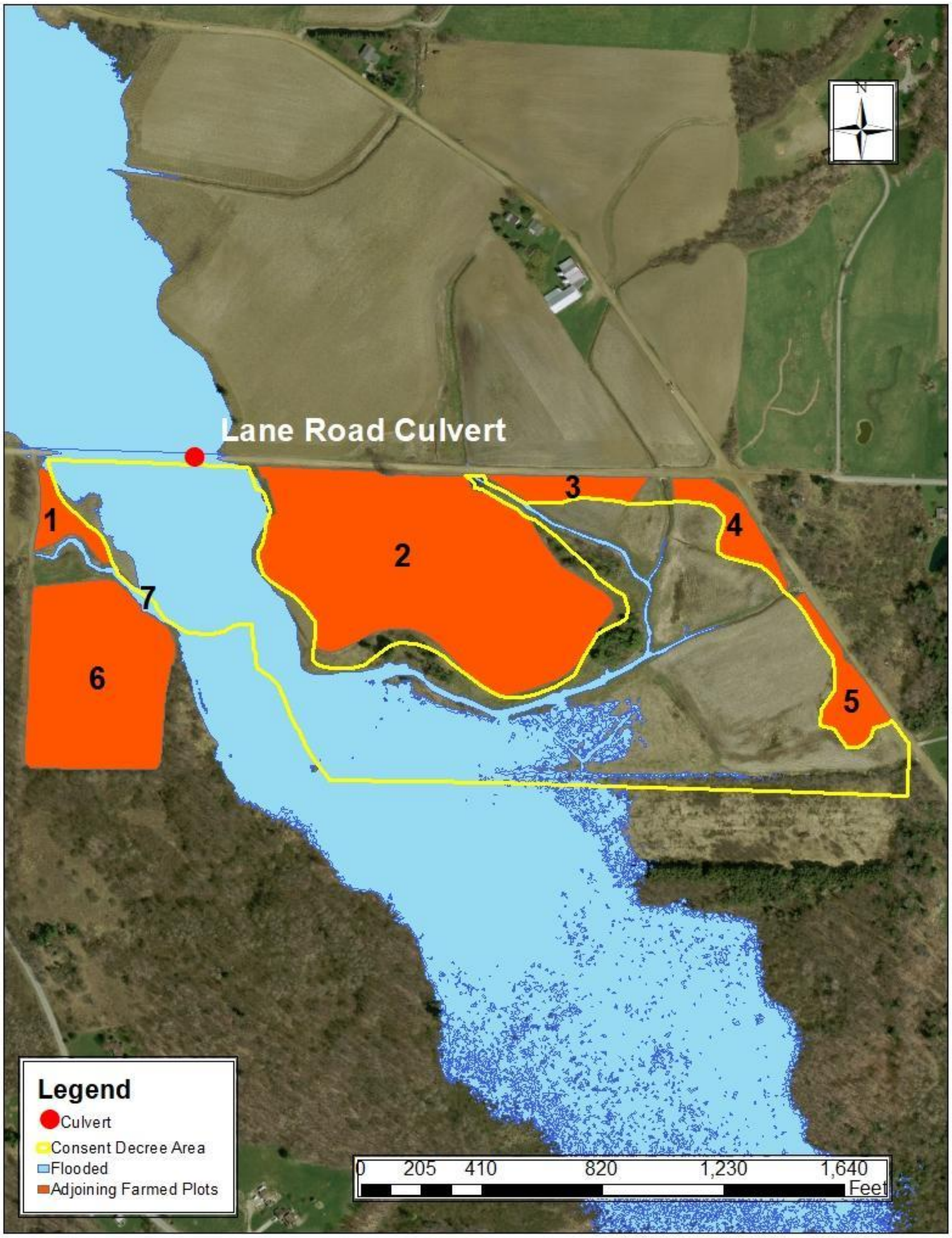
[18] Small portions of plots 1, 6, and 7, totaling 0.0148 ac (0.0615% of the total adjoining acreage), experience flooding at this return period.

**Fig. 28. Scenario 5 - Flooded surface for 100-year return period.**[19]



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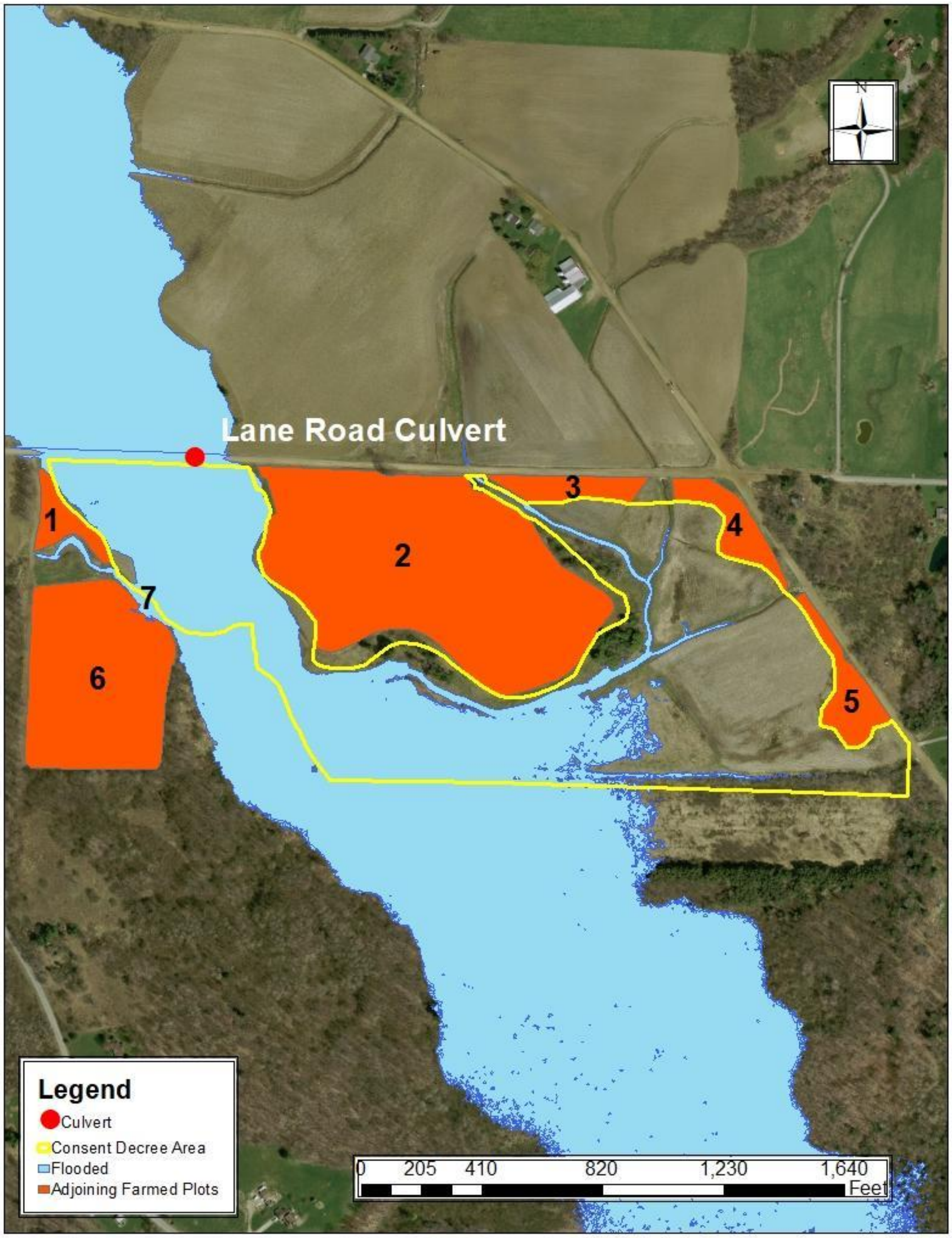
[19] Small portions of plots 1, 6, and 7, totaling 0.0336 ac (0.1394% of the total adjoining acreage), experience flooding at this return period.

**Fig. 29. Scenario 5 - Flooded surface for 1,000-year return period.**[20]



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[20] Small portions of plots 1, 2, 6, and 7, totaling 0.0636 ac (0.2641% of the total adjoining acreage), experience flooding at this return period.

**Table 18. Adjoining plot flooding for Scenario 5.**

| Return Period (years) | Flooded Area (ac) | Fraction of Plot Area % | Average Depth (ft) | Maximum Depth (ft) | Maximum Duration (hours) |
|---|---|---|---|---|---|
| 2 | None | N/A | N/A | N/A | N/A |
| 5 | 0.0034 | 0.0141 | 0.50 | 0.61 | 1.33 |
| 10 | 0.0148 | 0.0615 | 0.66 | 0.89 | 1.75 |
| 25 | 0.0229 | 0.0949 | 0.74 | 1.01 | 2.17 |
| 50 | 0.0294 | 0.1220 | 0.82 | 1.21 | 2.42 |
| 100 | 0.0336 | 0.1394 | 0.88 | 1.41 | 2.67 |
| 500 | 0.0464 | 0.1926 | 1.09 | 1.78 | 3.58 |
| 1000 | 0.0636 | 0.2641 | 1.28 | 1.97 | 4.17 |

## F. Scenario 6 - Severe Conditions

35. Results for the most severe scenario (Elk Creek flowing at bankfull conditions, no beaver dams, and wetter-than-average soil moisture) are given in Table 19 and depicted in Figs. 30-32. Despite the severity of this scenario, there are no major differences from Scenario 5 in terms of flooding in the adjoining plots (Table 20); flooded area remains small (0.0636 ac and less), average depth of flooding is 1.28 ft and less, and the same four plots (1, 2, 6 and 7) are predicted to be affected by flooding. Flooded duration is increased over the previous scenario (to a maximum of 4.92 hours) as a result of the simulated bankfull conditions at the onset of rainfall.

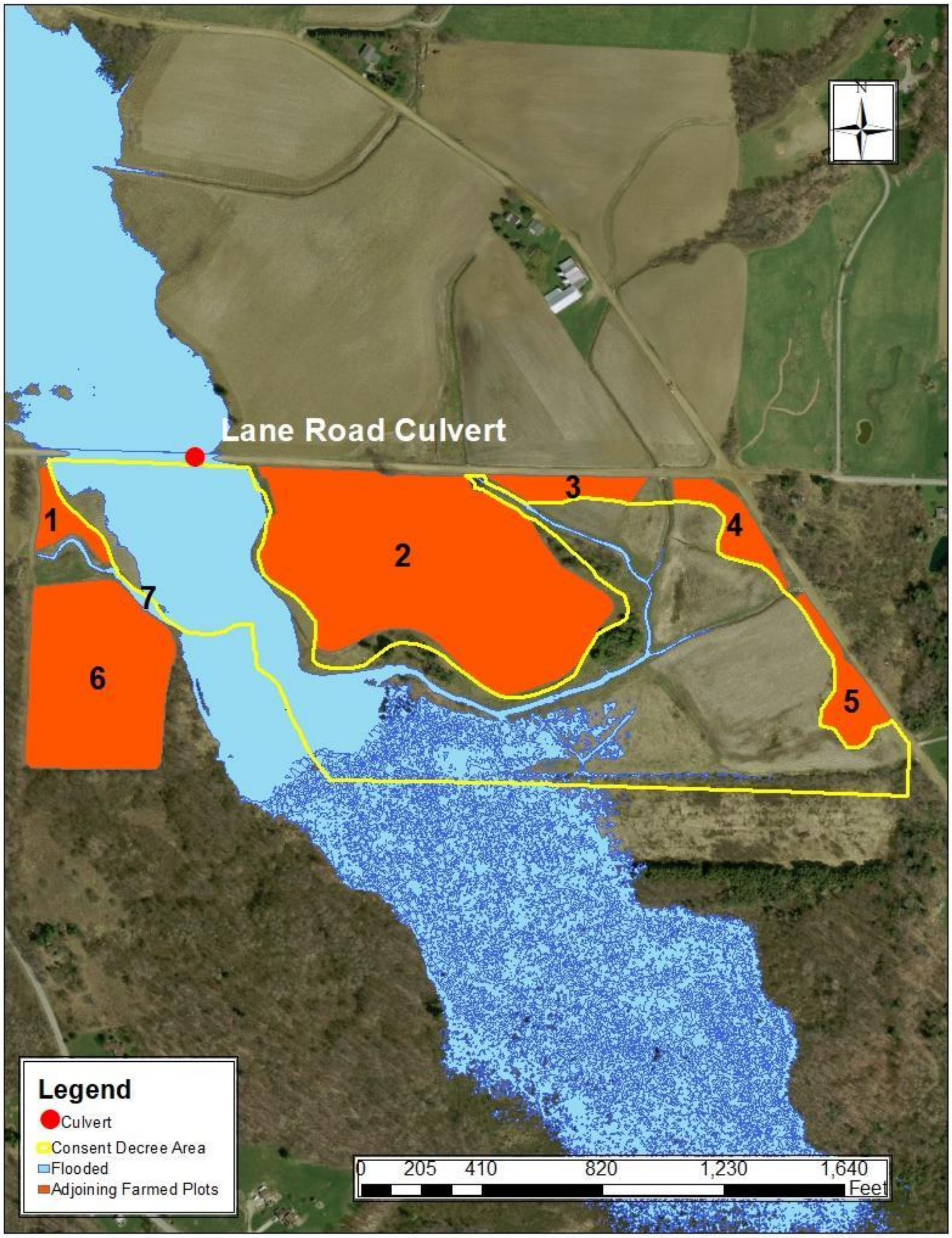
**Table 19. Simulation results for Scenario 6 (Elk Creek flowing at bankfull conditions, no beaver dams, higher-than-average soil moisture). Data are peak culvert discharges and maximum upstream water surface elevation (WSE).**

| Return | Lane Road Culvert | | Sharp Road Culvert | |
|---|---|---|---|---|
| Period (years) | Peak Discharge ($ft^3/s$) | WSE (ft) | Peak Discharge ($ft^3/s$) | WSE (ft) |
| 2 | 329 | 1223.2 [1,2] | 181 | 1221.6 |
| 5 | 677 | 1223.8 [1,2] | 319 | 1222.6 [2] |
| 10 | 921 | 1224.0 [1,2] | 599 | 1223.0 [2] |
| 25 | 1263 | 1224.2 [1,2] | 1075 | 1223.3 [2] |
| 50 | 1552 | 1224.3 [1,2] | 1493 | 1223.6 [2] |
| 100 | 1873 | 1224.5 [1,2] | 1925 | 1223.8 [2] |
| 500 | 2739 | 1224.8 [1,2] | 3118 | 1224.2 [2] |
| 1000 | 3171 | 1225.0 [1,2] | 3689 | 1224.4 [2] |

[1] Flooding in at least one adjoining plot.

[2] Overtopping roadway

**Fig. 30. Scenario 6 - Flooded surface for 10-year return period.**[21]



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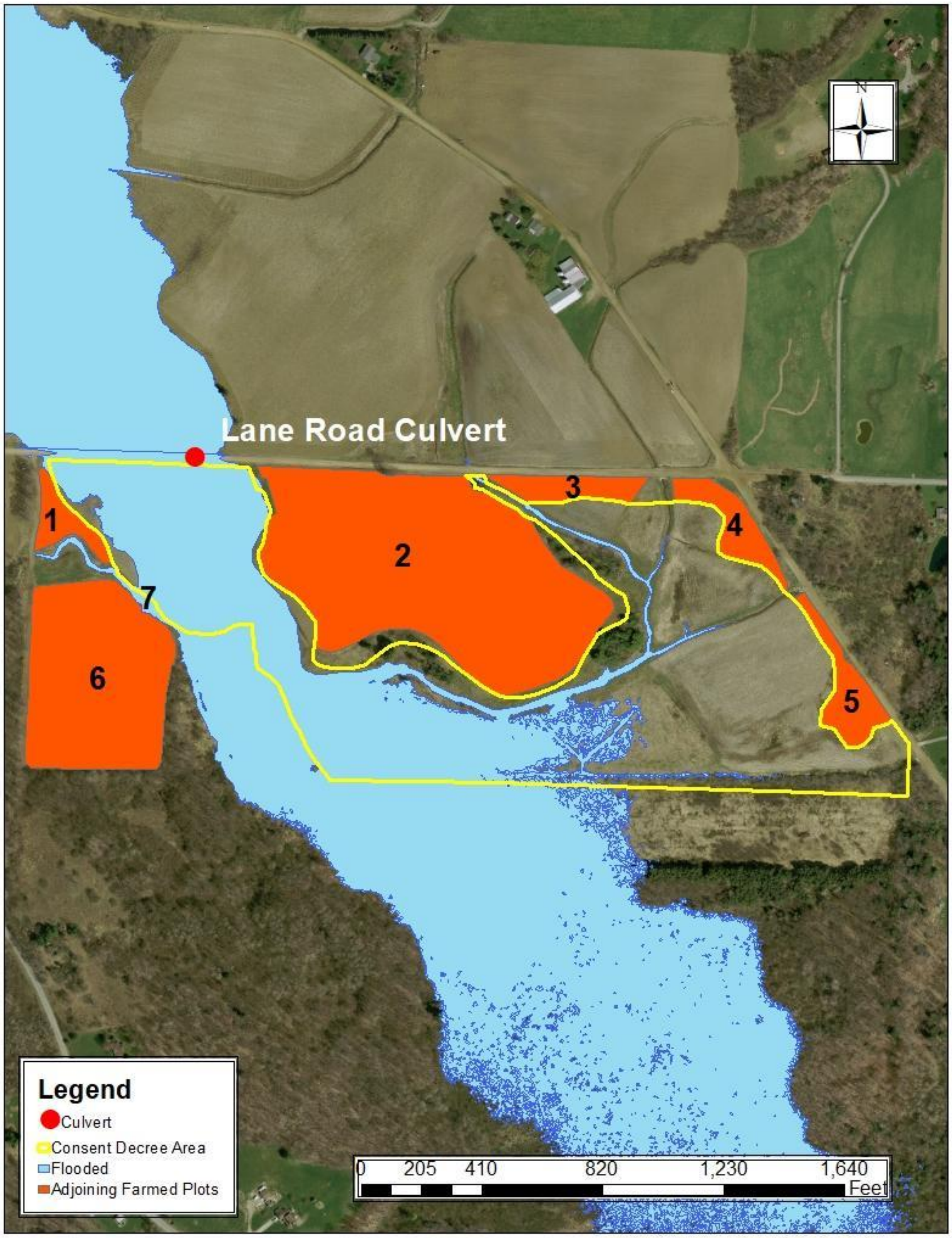
[21] Small portions of plots 1, 6, and 7, totaling 0.0188 ac (0.0782% of the total adjoining acreage), experience flooding at this return period.

**Fig. 31. Scenario 6 – Flooded surface for 100-year return period.**[22]



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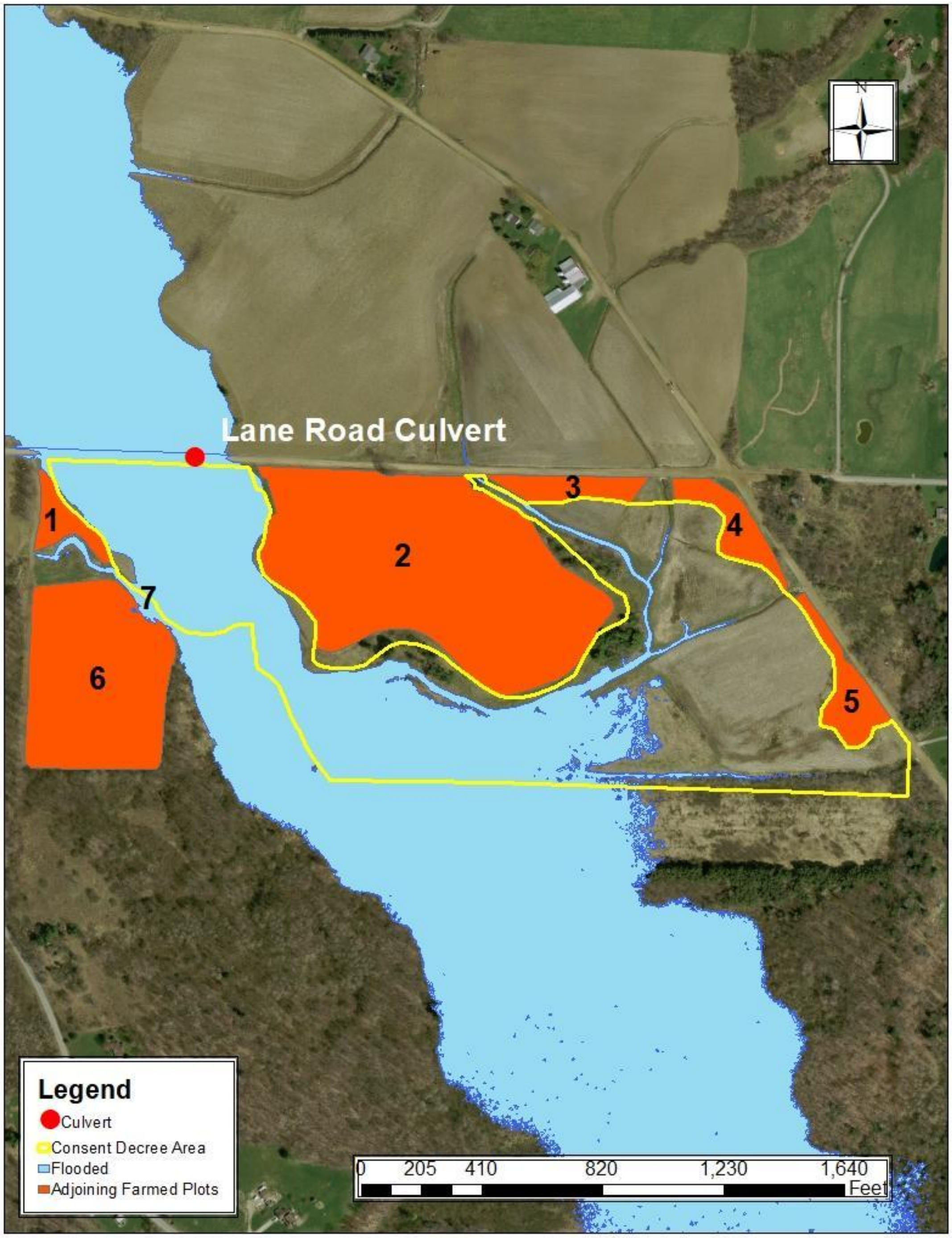
[22] Small portions of plots 1, 6, and 7, totaling 0.0336 ac (0.1394% of the total adjoining acreage), experience flooding at this return period.

**Fig. 32. Scenario 6 – Flooded surface for 1,000-year return period.**[23]



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[23] Small portions of plots 1, 2, 6, and 7, totaling 0.0636 ac (0.2641% of the total adjoining acreage), experience flooding at this return period.

**Table 20. Adjoining plot flooding for Scenario 6.**

| Return Period (years) | Flooded Area (ac) | Fraction of Plot Area % | Average Depth (ft) | Maximum Depth (ft) | Maximum Duration (hours) |
|---|---|---|---|---|---|
| 2 | 0.0000 | 0.0000 | 0.00 | 0.00 | 0.60 |
| 5 | 0.0094 | 0.0392 | 0.61 | 0.77 | 1.50 |
| 10 | 0.0188 | 0.0782 | 0.70 | 0.94 | 1.92 |
| 25 | 0.0256 | 0.1077 | 0.78 | 1.11 | 2.33 |
| 50 | 0.0294 | 0.1220 | 0.82 | 1.21 | 2.75 |
| 100 | 0.0336 | 0.1394 | 0.88 | 1.41 | 2.92 |
| 500 | 0.0464 | 0.1926 | 1.09 | 1.78 | 4.33 |
| 1000 | 0.0636 | 0.2641 | 1.28 | 1.97 | 4.92 |

## VII. Conclusions

36. I considered a multitude of scenarios in evaluating flooding upstream of the Lane Road Culvert, especially flooding of plots adjoining the CDA. The scenarios collectively describe a spectrum of conditions, ranging from hypothetical modifications of current conditions ("EcoStrategies" Model) to quite severe conditions.

37. My consistent finding has been that very little farmed land adjoining the CDA, if any, floods under any conditions. "Improvements" such as removing existing beaver dams or, if it were a practical option, lowering the Sharp Road Culvert, do nothing to reduce flooding and, in the case of beaver dam removal, exacerbates it.

38. Under Scenarios 1-4 (average soil moisture), no adjoining farmland is predicted to flood at return periods of less than 25 years. Even at return periods of 1,000 years, only a maximum of 0.0336 acres of the approximately 24.1 total adjoining plot acreage (less than one-quarter of one percent of the total upland acreage adjoining the CDA) is predicted to flood. Flooded depths under these conditions are predicted to average 0.89 ft and less, with maximum depths of 1.41 ft.

39. Under Scenarios 5-6 (above-average soil moisture), at least some adjoining farmland is predicted to flood at all return periods considered (except for Scenario 5, 2-year return period). However, even at a return periods of 1,000 years, only 0.0636 acres (equivalent to an area of roughly 50 ft by 50 ft), at most, of the approximately 24.1 total adjoining plot acreage (roughly one-quarter of one percent of the total upland acreage adjoining the CDA) is predicted to flood. This is equivalent to "buffer area" extending roughly 3.5 inches outside the entire perimeter (including the southern border) of the CDA. Flooded depths under Scenarios 5 and 6 are predicted to average 1.28 ft and less, with maximum depths of 1.97 ft.

40. In his answer to the United States' Second Set of Interrogatories Directed to Robert Brace, Defendant Robert Brace asserts that "periodic ongoing surface flooded occurred on or around the edge of the Consent Decree area, expanding out into the upland portion of the Murphy Farm and the adjacent Homestead Farm by approximately five to ten feet." Answer to Interrog. No. 2. This assertion is not supported by my modeling analysis. A buffer area of 5 ft. extending beyond the CDA, for example, would encompass 1.1 ac – this is more than 17 times the modeled findings for the most severe conditions at a 1,000 year return period. Additionally, a more significant buffer area of 10 ft, would encompass 2.2 ac – this is more than 30 times the modeled findings for the most severe conditions at a 1,000 year return period.

41. The flooded conditions identified as a result of HEC-HMS modeling are very transient. To use Scenario 6 (the most severe conditions) as an example, simulations indicate that

no adjoining upland acreage will experience flooding for more than 4.92 hours. Flooded durations were shorter for other scenarios.

42. Finally, for return periods greater than 10 years, the peak flow estimates produced in this study are likely to be higher – especially at the higher return periods – than would be actually observed. Moreover, "dryer-than-average" soil moisture conditions (as defined in the context of NRCS runoff estimation methods) are much more likely to exist (66% of the time) than "wetter-than-average" (13% of the time) or even "average" soil moisture conditions (21%). Rare flooding events are thus likely not to be as severe in reality as estimated in this study.

43. Summarizing these findings, flooding under severe conditions is judged to affect a relatively miniscule amount of adjoining farmland and to a very modest degree. In view of the substantial time (days) often required for soil trafficability to be restored following heavy rainfall, the flooding itself would likely have no significant impact on land use or any immediately-following, customary anthropogenic activities. The finding that severe conditions are assessed as having little impact on adjoining farmland flooding might seem contrary to intuition, but this is only a reflection of the physics of the situation. Water surface elevations upstream of Lane Road during flooding are largely dictated by the crest of the road itself, and flooding in adjoining plots is dictated by the superior elevations of the adjoining plots relative to Lane Road, the CDA, and Elk Creek. Nature finds it difficult to overcome these two important variables.

# Appendix A.

# Curriculum Vitae

**Dwayne R. Edwards, Ph.D., P.E.**
Biosystems and Agricultural Engineering Department
University of Kentucky

## SUMMARY

### Research

Publications

| | |
|---|---|
| Peer-Reviewed Articles: | 82 (80 in print/press, 2 in review) |
| Book Chapters: | 1 |
| Peer-Reviewed Proceedings: | 3 |
| Other Reviewed: | 9 |
| Conference Proceedings: | 26 |
| Professional Meeting Papers: | 35 |
| Major Completion Reports: | 17 |
| Other Publications: | 8 |
| Funded Proposals: | $2.06M ($1.42M external, $0.64M internal) |

### Service

Academic: 14 formal service memberships, including Director of Graduate Studies.
Professional: 17 formal service memberships, including journal editorship.
Community: 8 service activities, including non-profit Board of Directors.

### Teaching

Courses Taught

| | |
|---|---|
| BAE 343 (Fluid Mechanics): | 10 Semesters |
| BAE 437 (Land and Water Resources): | 8 semesters |
| BAE 536 (Fluvial Hydraulics): | 22 semesters |
| BAE 662 (Stochastic Hydrology): | 13 semesters |
| BAE 775 (Professional Practices): | 11 semesters |

Graduate Student Advising:

| | |
|---|---|
| Ph.D. | 4 (two expected in 2017) |
| M.S. | 10 |
| Committees: | 24 |

### Leadership

Service in U.S. Army Reserve, retired in 2014 at rank of Brigadier General
More than 30 years in command/principal staff assignments
Primary responsibility for organizations of up to 3,000 with budgets > $30M
Formal training and experience in strategic planning and executive leadership.

# Dwayne R. Edwards, Ph.D., P.E.

Biosystems and Agricultural Engineering Department
University of Kentucky

## EDUCATION

2005: M.S. Strategic Studies, U.S. Army War College
1988: Ph.D. Agricultural Engineering, Oklahoma State University
1986: M.S. Agricultural Engineering, University of Arkansas
1984: B.S. Agricultural Engineering, University of Arkansas

## PROFESSIONAL EXPERIENCE

2000 - Present: Professor, Biosystems and Agricultural Engineering Department, University of Kentucky, Lexington
1994 - 2000: Associate Professor, Biosystems and Agricultural Engineering Department, University of Kentucky, Lexington.
1993 - 1994: Associate Professor, Biological and Agricultural Engineering Department, University of Arkansas, Fayetteville.
1988 - 1993: Assistant Professor, Biological and Agricultural Engineering Department, University of Arkansas, Fayetteville.

## PROFESSIONAL SPECIALTY

Water resources and environmental research to identify sustainable solutions for agricultural producers. Published research topics include hydrologic and water quality assessments as related to confined animal production, forage and row crop production, climate variables, organic/inorganic amendments and others. Responsible for all program components, including identification of topics, resource procurement, dissemination of findings and professional training for undergraduate and graduate students. Further responsible for formal undergraduate and graduate instruction on bioenvironmental engineering and analysis of hydrologic data as well as standards of research and communication in the larger professional context.

## AWARDS

American Society of Agronomy Excellence in Extension Award, 2016
ASABE New Holland Young Researcher Award, 2000
Honorable Mention, ASABE Paper Competition, 1999
Environmental Excellence Award, U.S. Environmental Protection Agency, 1993,1995

Outstanding Researcher, Bio & Agri Engr Dept, University of Arkansas, 1991, 1992
Honorable Mention, ASABE Paper Competition, 1988

## RESEARCH ACTIVITIES

### PROGRAM OVERVIEW

My current major research efforts involve (a) evaluating the hydrologic impacts of climate change on major Kentucky water resources, (b) field assessments of surface water quality benefits of chemical treatments to organic soil amendments for high-productivity soils in Kentucky, (c) refinement of methods to estimate urban runoff and peak flow rates to ensure adequate flood mitigation and water quality protection and (d) improved mathematical descriptions of the physics of runoff and water quality processes. These lines of effort represent an evolution of previous research involving field- and watershed-scale investigations of best management practices for organic soil amendment application; reconnaissance studies involving nutrients, microorganisms, sediments, pesticides and endocrine disruptors; and use of field data to improve hydrologic/water quality simulation models.

### PEER-REVIEWED JOURNAL ARTICLES (last 10 years)

1. Edwards, D.R. and S. Chattopadhyay. 2017. Evaluation of global climate model suitability for hydrologic and water quality analysis. *Trans. ASABE* (in review).

2. Anderson, K., P. Moore, D. Miller, P. DaLaune, D. Edwards, P. Kleinman, and B. Cade-Menun. 2017. Phosphorus Leaching from Soil Cores from a Twenty Year Study Evaluating Alum-treatment of Poultry Litter. *Journal of Environmental Quality* (in review).

3. Chattopadhyay, S., D.R. Edwards, Y. Yu and A. Hamidisepehr. 2017. Assessment of climate change impacts on future water availability and droughts in the Kentucky River Basin. *Environmental Processes* 4:477-507.

4. Chattopadhyay, S., D.R. Edwards and Y. Yu. 2017. Spatiotemporal variability of extreme precipitation indices in the Kentucky River Basin: Historical and future perspectives. *Water* 9:109 -128

5. Edwards, D.R. 2016. Spatio-temporal variation of runoff curve number for grassed plots in central Kentucky. *Water Resources Management* 31(11):3491-3505.

6. Williams, R.E. and D.R. Edwards. 2016. Effects of biochar treatment of municipal biosolids and horse manure on quality of runoff from fescue plots. *Trans.of the ASABE* 60(2):409-417.

7. Lidong, H., P.A. Moore, Jr., P.J.A. Kleinman, K.R. Elkin, M.C. Savin, D.H. Pote and D.R. Edwards. 2016. Reducing phosphorus runoff and leaching from poultry litter with alum: twenty-year small plot and paired-watershed studies. *Journal of Environmental Quality* 45:1413-1420.

8. Bullock, E.L., D.R. Edwards, P.A. Moore, Jr. and R.S. Gates. 2016. Effects of chemical amendments to swine manure on runoff quality. *Trans. ASABE* 59(6):1651-1660. doi: 10.13031/trans.59.11636

9. Chattopadhyay, S. and D.R. Edwards. 2016. Long-Term Trend Analysis of Precipitation and Air Temperature for Kentucky, United States. *Climate* 4(1): 10-24.

10. Maupin, T.P., C.T. Agouridis, D.R. Edwards, C.D. Barton, R.C. Warner, and M.P. Sama. 2013. Specific Conductivity Sensor Performance: II. Field Evaluation. 2013. *International Journal of Mining, Reclamation & Environment*: 1-21. Published online March 22, 2013.

11. Barnett, J.R., R.C. Warner, C.T. Agouridis, and D.R. Edwards. 2010. Ability of a Weep Berm to Enhance Grass Filter Performance in a Simulated Grazed System: Preliminary Results. *Natural & Environ. Sci.* 1(1): 12-20.

12. Tyagi, P., D.R. Edwards and M.S. Coyne. 2009. Distinguishing between human and animal sources of fecal pollution in waters: A review. *International Journal of Water* 5(1):1-15.

13. Tyagi, P., M.S. Coyne and D.R. Edwards. 2009. Fecal sterol and bile acid biomarkers: Runoff concentrations in animal waste-amended pastures. *Water, Air and Soil Pollution* 198 (1-4): 45-54.

14. Tyagi, P., M.S. Coyne and D.R. Edwards. 2008. Use of sterol and bile acid biomarkers to identify domesticated animal sources of fecal pollution. *Water, Air & Soil Pollution* 187 (1-4): 263-274.

15. Tyagi, P., M.S. Coyne and D.R. Edwards. 2007. Use of selected chemical markers in combination with a multiple regression model to assess the contribution of domesticated animal sources of fecal pollution in the environment. *Chemosphere* 69(10): 1617-1624.

# SERVICE AND PROFESSIONAL ACTIVITIES

## DEPARTMENTAL SERVICE

### (University of Kentucky)

Director of Graduate Studies, 2003 – 2013
Graduate Research Committee, 2013 – present
Undergraduate Curriculum Committee, 2013 – present
Awards Committee, 1995, 1998, 2001-2004. Chair, 1995, 1998
Computers Committee, 1999. Chair, 1999

### (University of Arkansas)

Promotion and Tenure Committee, 1993-94
Chair, Faculty Search Committee, 1991-92
Undergraduate Recruiting Committee, 1989-91
Undergraduate Retention Committee, 1990-92
Retreat Organizing Committee, 1990-91

## COLLEGE OF AGRICULTURE SERVICE

### (University of Kentucky)

Information Technology Review Committee (Chair), 2002-2003
SB-271 Advisory Committee, 1995-2005. Chair, 1999-2005
Turner Leadership Academy, 2009

### (University of Arkansas)

Arkansas Farm Research Editorial Board, 1994-1995
Department Head Search Committee, 1992
Water Quality Strategic Planning Committee, 1990

## COLLEGE OF ENGINEERING SERVICE

### (University of Kentucky)

Engineering Faculty Advisory Committee, 2002-2004
Graduate Research Committee, 2003-2013

### (University of Arkansas)

Engineering Cooperatives Committee, 1988-92 (Chair, 1990)
Service Course Committee, 1989-92 (Chair, 1991)

## UNIVERSITY OF KENTUCKY SERVICE

Graduate Council Committee on Fellowships and Traineeships, 2016 –.
Kentucky Water Institute Oversight Committee, 1997-2002. Chair, 1999.
Kentucky Water Resources Institute Director Search Committee, 1998
Tracy Farmer Center for the Environment Research Committee, 2003 – 2006.

## PROFESSIONAL SERVICE

Editor, Soil and Water Division, *Transactions of the ASABE*, 1997-2000.
Associate Editor, Soil & Water Division, *Transactions of the ASABE*, 1993-7.
Publications Council, ASABE, 2002 – 2006. Chair, 2004 – 2006.
ASABE Young Researcher Award Committee, 2004 – 2006.
Refereed Publications Committee, ASABE, 1997-2006. Chair, 2004-2006.
Soil and Water Division Executive Committee (SW-01), 1998-2000.
Soil and Water Division Steering (SW-02), ASABE, 1997-2000.
Hydrology Group (SW-21), ASABE, 1993-2009.
Publications Review Committee (SW-05), ASABE, 1993-2000.
Precipitation/Runoff Committee, ASABE, 1989-1995. Vice Chair, 1994-1995.
Hydraulic Processes Committee, ASABE, 1989-1995. Vice Chair, 1994-1995.
Regional Research Project S-211, 1989-1991.
Regional Research Project S-249, 1992-1996. Vice Chair, 1992-1993. Chair, 1993-1994.
Regional Research Project S-273, 1997-2001.
Regional Research Project S-1004, 2002-2006.
Regional Research Project S-1042, 2007-2011
Regional Research Project S-1063, 2012 – present.
Reviewer of manuscripts for *Transactions of the ASABE, Journal of the American Water Resources Association, Climate, Water, Energy Sources, Journal of Water, Air, and Soil Pollution, Journal of Environmental Quality, Journal of Environmental Management* and others.

## PROFESSIONAL SOCIETIES

American Society of Agricultural and Biological Engineers
American Society of Engineering Education
American Water Resources Association
Arkansas Society of Professional Engineers
National Society of Professional Engineers

## HONORARY SOCIETIES

Alpha Epsilon (Honor society of Agricultural Engineering)
Gamma Sigma Delta (Honor society of College of Agriculture graduate students)
Phi Kappa Phi (Honor society for graduate students)

Tau Beta Pi (Honor society for Engineering)

## TEACHING AND STUDENT ACTIVITIES

### COURSES TAUGHT

**University of Kentucky**

BAE 343, Fluid Mechanics of Biosystems.  This was our “in-house” basic fluids course that covered fluid statics, fluid dynamics, fluid transport systems, pumps, and related topics, and I was fully responsible for its development. Following improvements to similar courses in other engineering departments, we discontinued the course in 2005.  Average teaching rating was 3.6±0.3

BAE 437, Land and Water Resources Engineering.  Our introductory course for the bioenvironmental specialty, covering precipitation, runoff, erosion, open channel analysis and design, flow control structures, and similar topics. I took over the course in 2010 following the departure of the instructor, after which it has been fully revised.  Average teaching rating is 3.4±0.5.

BAE 536, Fluvial Hydraulics.  Our advanced/practitioner course in the bioenvironmental area, covering frequency analysis, runoff hydrographs, steady and unsteady open channel flow analysis, erosion and sediment yield with significant exposure to practical software packages in “real world” situations.  I fully developed this course, and my average teaching rating is 3.6±0.3.

BAE 662, Stochastic Hydrology.  A graduate course drawing from Civil Engineering, Earth Sciences, and Crop and Soil Science departments.  The content includes probability theory, Monte Carlo simulation, time series analysis, correlation and regression analysis, Kalman filtering, multivariate analysis and geospatial analysis.  I developed the course, and my average teaching rating is 3.5±0.3.

BAE 775, Professional Practices Seminar.  This is a two-part course intended to provide our graduate students (all specialties) with the skills and perspectives required to succeed in both their program and their next job. The first (Fall) part is focused on conduct and evaluation of science, budgeting and project management, culminating in the research proposal. The second (Spring) part is highly focused on written and oral communication, emphasizing different media and audiences.  I developed both parts of this course, and my average rating is 3.2±0.2.

## GRADUATE STUDENT ADVISING

Cara Peterman, Ph.D., 2017 (expected; Co-Chair with Alan Fryar)
Somsubhra Chattopadhyay, Ph.D., 2017 (expected)
Rachel Williams, M.S., 2016.
Carmen Agouridis, Ph.D., 2004.
Sheila Youngblood, M.S., 2001.
Elizabeth Rockaway, M.S., 2000.
Elizabeth Busheé, M.S., 1999.
Mike Williams, Ph.D., 1998 (Co-Chair with Joe Taraba).
Christopher Moss, M.S., 1998.
Teng Lim, M.S., 1997.
Puneet Srivastava, M.S., 1995.
Yang Wang, Ph.D., 1995.
Indrajeet Chaubey, M.S., 1994.
Oswald Marbun, M.S., 1990.

## GRADUATE COMMITTEE MEMBERSHIPS

Zhang Xi, Ph.D., Plant and Soil Sciences, 2018 (expected).
Moran Gerlitz, M.S., Biosystems and Agricultural Engineering, 2018 (expected).
Bakkiyalakshmi Palanisamy, Ph.D., Biosystems and Agricultural Engineering, 2010.
Joe Luck, M.S., Biosystems and Agricultural Engineering, 2007.
Mohammad Tufail, Ph.D., Civil Engineering, 2006
Dhandayudhapani Ramalingam, Ph.D., Civil Engineering, 2006
Seth Bradley, M.S., Civil Engineering, 2006
Ken Casey, Ph.D., Biosystems and Agricultural Engineering, 2005.
Joe Pursewell, Ph.D., Biosystems and Agricultural Engineering, 2005.
Sebastian Torrealba, M.S., Biosystems and Agricultural Engineering, 2004.
John Barnett, M.S., Biosystems and Agricultural Engineering, 2004.
Virginia-Bibb Golden, Biosystems and Agricultural Engineering, 2004.
Eric Dawalt, M.S., Biosystems and Agricultural Engineering, 1999.
Jihad Hallany, M.S., Biosystems and Agricultural Engineering, 1999.
Guilleaume Cornilleau, M.S., Biosystems and Agricultural Engineering, 1999.
Brenda Miller, M.S., Biosystems and Agricultural Engineering, 1999.
Adam Reed, M.S., Agronomy, 1996.
David Marshal, M.S., Geology, 1996.
Dan Pote, Ph.D., Agronomy, 1996.
Dan Pote, M.S., Agronomy, 1993.
Patrick Adams, M.S., Agronomy, 1993.
Sharon Townsend, M.S., Home Economics, 1992.
Tyler Dutton, M.S., Civil Engineering, 1993.
Babiker Ibrahim, Ph.D., Agronomy, 1991.

# ADDENDUM OF MILITARY/LEADERSHIP EXPERIENCE

## RETIRED RANK

Brigadier General, United States Army Reserve, nominated by the President and confirmed by the US Senate in September 2009, retired in September 2014.

## SIGNIFICANT FORMAL TRAINING

Infantry Officer Basic Course (Ft Benning)
Infantry Officer Advanced Course (Ft Benning)
Combined Arms and Services Staff School (Ft Leavenworth)
United States Army Command and General Staff College (Ft Leavenworth)
United States Army War College (Carlisle Barracks)
Advanced National Security Studies (Syracuse University)
Senior Leader Development Program (Washington, DC)
Advanced/Executive Leader Development Program (Notre Dame University)

## DUTY ASSIGNMENTS

Support Command Deputy Commanding General, November 2012 – Retirement.
Division Commanding General, Rochester, NY, July 2010 – November 2012.
Deputy Commanding General, Charlotte, NC, May 2009 – July 2010.
Deputy Chief of Staff for Training Operations, Richmond, VA, May 2007 – May 2009.
Brigade Commander, Salem, VA, May 2005 – May 2007.
Battalion Commander, Fort Knox, KY, March 2003 – May 2005.
Brigade Operations Officer, Louisville, KY, February 2001 – March 2003.
Battalion Operations Officer, Nashville, TN, March 1996 – February 2001.
Assistant Brigade Operations Officer, Lexington, KY, March 1993 – November 1994.
Company Commander, Fayetteville, AR, March 1993 – November 1994.
Psychological Operations Officer, Fayetteville, AR, August 1988 – March 1993.
Company Commander, Stillwater, OK, October 1986 – August 1988.
Executive Officer, Stillwater, OK, January 1986 – October 1986.
Executive Officer, DeQueen, AR, October 1983 – January 1986.
Heavy Weapons Platoon Leader, Mena, AR, October 1982 – October 1983.
Infantry Platoon Leader, DeQueen, AR, March 1982 – October 1982.

## SIGNIFICANT AWARDS

Legion of Merit (two awards). Received for conceiving and implementing metrics-based organizational leadership and physical relocation of a large Army Reserve headquarters, to include relocation of full-time professional staff.

Meritorious Service Medal (six awards). Received for leadership and oversight of geographically-dispersed training centers, development of robust training management policies and processes, increased unit strength and readiness, and other accomplishments.

## KEY ASSIGNMENTS DESCRIPTION

The overviews of my last six assignments indicate that, not only was I an individual candidate for a combat zone deployment, I was also heavily engaged in training junior and mid-grade enlisted Soldiers as well as future junior officers for the Army. The assignments are progressive in terms of responsibility and authority, geographic footprint, and numbers of reporting units/personnel. The assignments also represent a continuum of leadership and administrative duties. At lower levels of command, I was commonly involved in direct leadership, planning and oversight. At the higher levels of command, I exercised more indirect leadership with increased focus on strategic vision, organizational direction, and logistical/facilities readiness. The higher-level leadership positions also required heavy emphasis on personnel management, including evaluations, promotions, duty assignment selections, and mentoring. Among those whose careers I helped to guide, 11 became battalion commanders, six became brigade commanders, and three became General Officers.

<u>Deputy Commanding General</u> (99th Regional Support Command, Fort Dix, NJ). The mission of this major Army Reserve Command was to provide facilities, maintenance and personnel support to Army Reserve units and their roughly 50,000 Soldiers in 13-states of the northeastern US. We were heavily involved in the process of constructing, maintaining, servicing and renovating over 300 Army Reserve centers as well as hundreds of auxiliary buildings. Our highly-dispersed maintenance activities provided all levels of service (and often concentrated storage) to all vehicles and major equipment in the supported units' respective inventories. My basic responsibilities were similar to those for my previous Deputy Commanding General assignment. During this assignment, however, I interfaced more with civic organizations, elected leaders, and key civilians, and I became much more highly involved in facilities management, maintenance operations, and the processes and organizational principles required for effectiveness.

<u>Commanding General</u> (98th Training Division, Rochester, NY). This unit was a subordinate to the 108th Training Command with the mission of providing Drill Sergeants to Forts Benning, Leonard Wood and Jackson. The unit

strength was approximately 3,000, with units located throughout the eastern US from Maine to Florida, with a unit also stationed in Puerto Rico. My responsibilities involved the usual command functions but with significantly enhanced authorities with respect to personnel selections, resources and allocation, disciplinary issues, personnel actions, and individual initiatives intended to enhance awareness and build support. Additionally, substantially more time was devoted to interfacing with external audiences such as elected civilian leaders, civic organizations, outside commands, and higher-level Army organizations. I was supported by a staff of approximately 75 officers, enlisted Soldiers and civilians, half of whom were full-time employees. My efforts led to the successful initial training of approximately **5000** new Soldiers as well as **2,500** Soldiers preparing for combat zone deployment.

Deputy Commanding General (108th Training Command, Charlotte, NC). Another major Army Reserve Command with units and responsibilities located throughout the Nation, the primary unit mission was to provide Drill Sergeants to the four Army Training Centers (Forts Benning, Jackson, Sill and Leonard Wood). My responsibility was to act as commander in absence of the Commanding General but also included direct leadership in areas such as major process initiatives, staff processes and products, disciplinary action, leader development, and others as required. My efforts directly facilitated the combat zone deployment training for **3,000** Soldiers and initial entry training for another **10,000** new Soldiers.

Deputy Chief of Staff (80th Training Command, Richmond, VA). The unit was a major Army Reserve Command with the nation-wide mission of conducting all Reserve Component reclassification training in the fields of combat support and combat service support. I was the principal staff officer responsible for all training operations associated with our annual training load of in excess of **30,000** students enrolled in roughly **250** courses across the continental US. More specifically, I was responsible for securing and aligning all required resources (instructors, billets, dining facilities, classrooms, training areas, computing equipment, training supplies, transportation requirements, etc.), staying in communication with supporting units within the Training Command, monitoring and allocating resources, maintaining awareness of issues and following up on corrective actions, site visits and consultation with customer units. My support staff consisted of approximately 30 officers and enlisted Soldiers, half being full-time employees.

Brigade Commander (80th Division, Salem, VA). The unit mission was to conduct advanced training to ROTC cadets (a training load of roughly **5000** cadets over a 12-week period), provide personnel support to reception operations at Army Training Centers (e.g., Ft Benning and Ft Jackson, with incoming loads of **10,000** new Soldiers), and to support other 80th Division training with logistic, maintenance and transportation assets. My responsibilities as commander of the 400 assigned Soldiers were similar to those stated before (mission accomplishment, strength, morale, welfare, personnel qualification, discipline and compliance), but with overall success increasingly dependent on selection of personnel for key command/staff positions and working with higher commanders and staffs to influence mission, resources and policy. My support staff consisted of approximately 30 officers and enlisted Soldiers with half being full-time employees.

Battalion Commander (100th Division, Fort Knox, KY). The unit mission was to train Army ROTC cadets in basic soldiering and leadership skills. Our training load was approximately **3,000** cadets over a 12-week summer period. As commander of the 150-Soldier unit, I was responsible for all aspects of mission accomplishment (resources forecasting and acquisition, staffing, training and qualification of unit personnel, scheduling, safety, and other others) as well as the unit strength, morale, welfare, discipline, and compliance with Army and higher headquarter policies and regulations. My support staff included roughly 12 officers and enlisted Soldiers, half of whom were full-time employee

# Appendix B.

# List of Materials Considered

1. Berry, J. 2017. Harvest calendar. Pennsylvania State University, State College. Available online at https://extension.psu.edu/harvest-calendar
2. Haan, C.T., B.J. Barfield and J.C. Hayes. Design hydrology and sedimentology for disturbed watersheds. 588 p. Academic Press. San Diego, California.
3. Historical imagery. Available online at http://maps.psiee.psu.edu/ImageryNavigator/
4. Historical imagery. Available from Google Earth Pro, v. 7.3.0.3832
5. Huffman, R.L., D.D. Fangmeier, W.J. Elliot and S.R. Workman. 2013. Soil and water conservation, 7th Edition. 523 p. ASABE, St. Joseph, MI.
6. Hydrologic Engineering Center. 2015. Hydrologic Modeling System HEC-HMS User's Manual. Version 4.1. US Army Corps of Engineers, Davis, CA. 584 p. Available online at http://www.hec.usace.army.mil/software/hec-hms/documentation.aspx
7. Larson, Z. 2017. Planting date, temperature, spacing, and emergence: What really matters? Pennsylvania State University, State College. Available online at https://extension.psu.edu/planting-date-temperature-spacing-and-emergence-what-really-matters
8. Lake Erie Watershed LiDAR 2015 – DEM. Available online at http://www.pasda.psu.edu/uci/DataSummary.aspx?dataset=3204.
9. Lake Erie Watershed 2015 Orthoimagery – CIR. Available online at http://www.pasda.psu.edu/uci/DataSummary.aspx?dataset=3201.
10. National Hydrography Dataset, NHDFlowline – Erie. 2004. US Geological Survey. Available online at http://www.pasda.psu.edu/uci/DataSummary.aspx?dataset=770.
11. National Land Cover Database. Available online at http://www.pasda.psu.edu/uci/DataSummary.aspx?dataset=3141.
12. National Wetlands Inventory for Pennsylvania. 2009. US Fish and Wildlife Service. Available online at http://www.pasda.psu.edu/uci/DataSummary.aspx?dataset=1457.
13. Natural Resources Conservation Service. 1986. Urban hydrology for small watersheds. Technical Release 55. U.S. Department of Agriculture, Washington, DC. 164 p. Available online at https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/stelprdb1044171.pdf
14. Roland, M.A. & Stuckey, M.H. 2008. Regression equations for estimating flood flows at selected recurrence intervals for ungaged streams in Pennsylvania. U.S. Geological Survey Scientific Investigations Report 2008-5102. 57 p. Reston, Virginia.

15. Soil Survey Geographic database. Available online at https://datagateway.nrcs.usda.gov/GDGOrder.aspx.
16. The Pennsylvania State Climatologist. 2017. Data archive – historical. Available online at http://climate.psu.edu/data/
17. United States of America, Plaintiff, v. Robert Brace and Robert Brace Farms, Inc., Defendants, No. 90-cv-229, Defendants' Objections and Answers to Plaintiff's Second Set of Interrogatories Directed to Robert Brace
18. Field notes from site visit on October 16-17, 2017 (attached as Appendix D).
19. Survey notes from site visit on October 16-17, 2017 (attached as Appendix E).
20. Photos of Beaver Dams taken during site visit on October 16-17, 2017 (attached as Appendix F).
21. Materials related to the Sharp Road Culvert provided by William C. Koller, P.E., Commonwealth of Pennsylvania, Department of Transportation (attached as Appendix G).
22. Spreadsheet drafted by Defendants identifying alleged flooded acreage (attached as Appendix H).
23. The following bates-stamped documents produced by the United States in this litigation:
    a. CD-FRC0000156-164
    b. EPA0000368-390
    c. EPA0001238-1266
    d. USACE0000359

# Appendix C.

## Prior Expert Testimony since December 2013

I have not been deposed or testified at trial as an expert in the past four years.

## Current Compensation

I was hired under contract with the United States Department of Justice to provide expert services. I am being compensated at the rate of $250 per hour for preparing my expert report and for deposition and trial testimony. None of my compensation is based on the outcome of my analysis or this case.

# Appendix D.

**Attorney Work Product – Privileged & Confidential**

## Dr. Dwayne Edwards Brace Site Visit Notes – Oct. 16-17, 2017

### Mon. Oct. 16 - Brace Farm - 9:30 A.M.

- Western Lane Rd. Culvert
  - 70 inch inside diameter
  - Steel Material
  - Photo #1 - Lane Rd. Culvert Outlet
  - Outlet invert appears clear
  - Photo #2 - Same as Photo #1; Lane Rd. Culvert Outlet
  - WSE - 2 feet relative to outlet invert
  - Photo #3 - Lane Rd. Culvert Inlet
  - Photo #4 - Lane Rd. Culvert Inlet
  - WSE - 28 inches relative to inlet invert
- Photo #5 - Flood Debris -16 inches relative to WSE
- Photo #6 - Flood Debris - 28 inches relative to WSE
- Photo #7 - Flood Debris - 36 inches relative to WSE
- Photo #8 - Beaver Dam #1
- Photo #9 - Confluence approx. 50 feet upstream from Beaver Dam #1
- Photo #10 - Corn located ENE of Beaver Dam #1
- Photo #11 - Beaver Dam #1 (Most Upstream)
- Photo #12 - Beaver Dam #2 (Middle)
- Photo #13 - Beaver Dam #2
- Photo #14 - Beaver Dam #3 (Most Downstream)
- Beaver Dam #2 - WSE difference approx. 37 inches
- Beaver Dam #3 - WSE difference approx. 12 inches
- Beaver Dam #1 - WSE difference approx. 12 inches
- Photo #15 - Misplaced wood debris
- Photo #16 - Bog - looking south from uplands near 1st tree (moving south & east)
- Photo #17 - Tree referenced in Photo #16 - looking south from uplands onto bog
- Eastern Lane Rd. Culvert
  - Outlet
    - 2 corrugated plastic pipe culverts outlet (flows south)
    - 24 inch diameter for #1
      - 8 inches of sediment at bottom
      - 8 inches WSE on top of sediment
    - 18 inch diameter for #2
      - outlet clear
      - WSE approx. 1 inch
      - may drain road - enters west
    - Photo #18 - Eastern Lane Rd. Culvert Outlet
    - Photo #19 - Corrugated plastic pipe entering from west
      - 12 inch diameter
      - 2 inches WSE relative to invert

  - Inlet
    - 1 corrugated plastic pipe culvert inlet
    - 5 inches of sediment on bottom
    - 3 inches WSE on top of sediment
    - Photo #20 - Eastern Lane Rd. Culvert Inlet
- Photo #21 - Lane Rd. Western Culvert Benchmark
- Sharp Rd. Culvert
  - CSP culvert
  - Inlet
    - 69 inches from invert to top
    - Max width - 115 inches
    - Water depth - 6 inches
    - WSE 6 inches relative to invert
    - Concrete apron extends approx. 16 feet upstream of inlet
  - Outlet
    - WSE 4 inches relative to invert
    - Concrete apron extends approx. 12 feet downstream of outlet
  - Both outlet & inlet appear clear
  - Photo #22 - Sharp Rd. Culvert Inlet
  - Photo #23 - Sharp. Rd. Culvert Inlet
  - Photo #24 - Sharp. Rd. Culvert Inlet
  - Photo #25 - Upstream view from Inlet - Sharp Road
  - Photo #26 - Sharp Rd. Culvert Outlet
  - Photo #27 - Sharp Rd. Culvert Outlet
  - Photo #28 - Sharp Rd. Culvert Outlet
  - Photo #29 - Downstream view from Sharp. Rd. Culvert Outlet

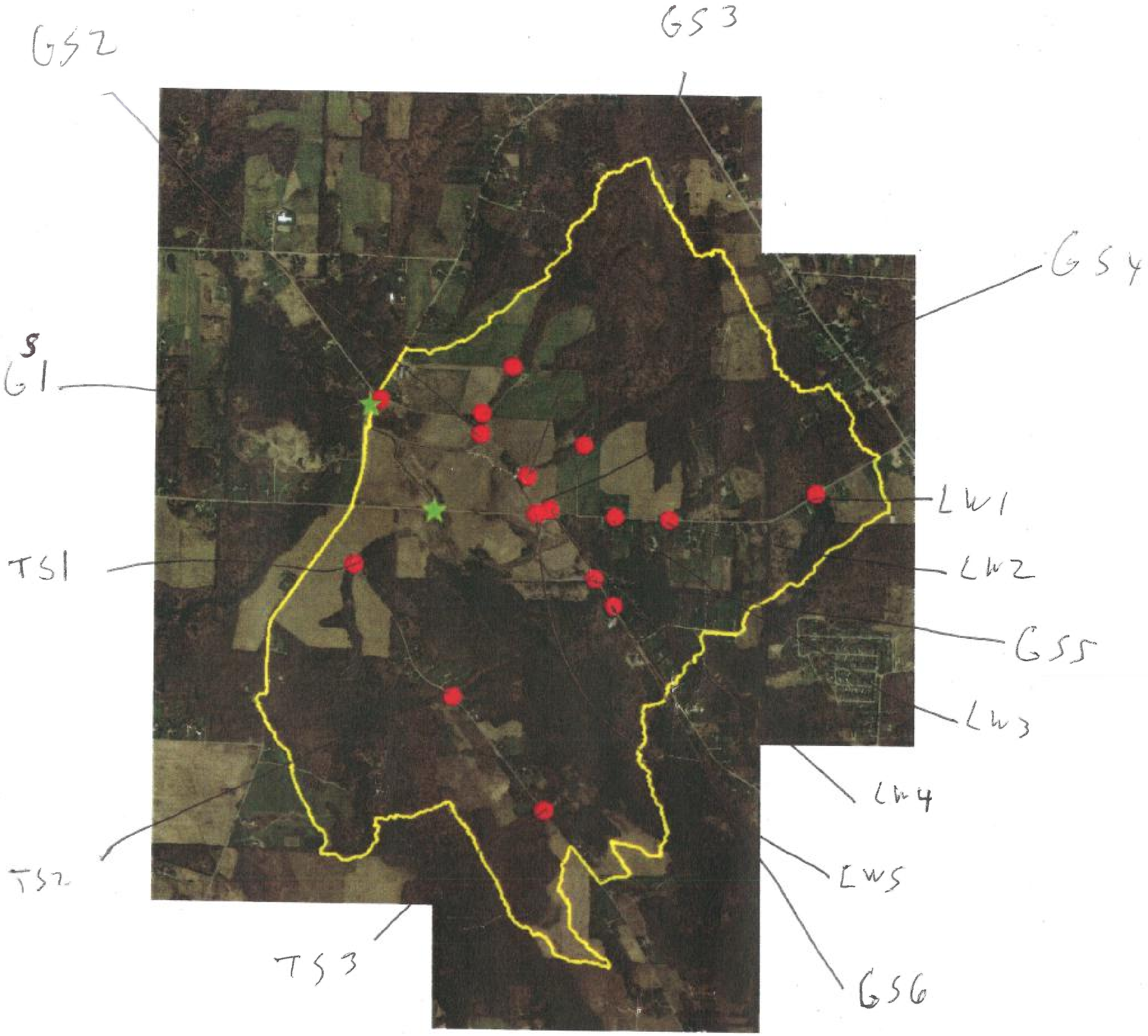
**Tues. Oct. 17 - Brace Farm - 9:30 A.M.**

- Photo #30 - Location GS1
  - Location as assumed
  - Concrete 18 inch ID
- Photo #31 - Location GS3
  - Location as assumed
  - 2 pipes
    - 24 inch ID
    - 42 inch ID
- Photo #32 - Location GS2
  - Location as assumed
  - 5 foot ID
- Photo #33 - Location LW1
  - Location as assumed
  - 3 foot ID

**Attorney Work Product – Privileged & Confidential**

**Dr. Dwayne Edwards Brace Site Visit Notes – Oct. 16-17, 2017**

- Photo #34 - Location LW2
    - Location as assumed
    - 3 foot ID
    - runs diagonally under Lane Road north to south
- Photo #35 - Location LW3
    - Location as assumed
    - 42 inch ID
- Photo #36 - Location LW4
    - Location as assumed
    - 18 inch ID
    - runs directly under Lane Road
- Photo #37 - Location GS4
    - just north of intersection of Lane Road & Greenlee Road
    - runs east to west
    - 18 inch ID
- Photo #38 - Location LW5
    - Location as assumed
    - 42 inch ID
    - runs north to south
- Photo #39 - Location GS5
    - Location as assumed
    - 30 inch ID
- Photo #40 - Location GS6
    - Location as assumed
    - 48 inch ID
- Photo #41 - Location TS1
    - Location as assumed
    - 18 inch ID
    - inlet is 50% obstructed with sediment
- Photo #42 - Location TS2
    - Location as assumed
    - 36 inch ID
- Photo #43 - Location TS3
    - Location as assumed
    - 30 inch ID
- Photo #44 - Hand (End of Notes)



Watershed relative to Sharp Road culvert (green star, northwest edge of boundary).

Red circles: visual verification of drainage network (i.e., where does the water flow).

Green stars: potentially key culverts; need culvert diameters, slopes, elevations, photos.

# Appendix E.

Survey Brace Property 16 Oct 2017
Began by surveying Lane Road Culvert.
Benchmark established as per photo -highest corner of western slab of headwall concrete.
Then surveyed Sharp Road Culvert with new instrument setup.
Established turning point midway along Sharp Road toward Lane Road, new setup at intersection of Sharp and Lane Roads.
Closed loop by surveying benchmark from Sharp/Lane intersection setup.

Lane Road Culvert
Aged/rusted steel. Circular, 6' diameter. Manning's n taken as 0.017.

BM ELEV 1000

| PtID | Northing | Easting | Elevation | Description | REL TO BM | ELEV | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 5000.00 | 5000.00 | 100.000 | BRACE | | | | | |
| 2 | | | | | | | | | |
| 3 | 5038.40 | 5024.87 | 98.715 | LANE CUL OUT INV | -7.026 | 992.974 | 1215.604 | | |
| 4 | 5038.67 | 5024.95 | 104.767 | LANE CUL OUT TOP | -0.974 | 999.026 | 1221.656 | INLET INVERT | 1215.94 |
| 5 | 5034.35 | 5017.79 | 101.028 | LANE CUL OUT WSE | -4.713 | 995.287 | 1217.917 | OUTLET INVERT | 1215.60 |
| 6 | 5072.45 | 5033.21 | 105.265 | LANE CUL IN TOP | -0.476 | 999.524 | 1222.154 | CULVERT LENGTH | 34.54 |
| 7 | 5072.94 | 5032.65 | 99.047 | LANE CUL IN INV | -6.694 | 993.306 | 1215.936 | CULVERT SLOPE | 0.009612 |
| 8 | 5075.25 | 5028.95 | 100.861 | LANE CUL IN WSE | -4.880 | 995.120 | 1217.750 | CULVERT HEIGHT | 6.14 |
| 9 | 5040.41 | 5022.53 | 105.741 | LANE CUL OUT BM | 0.000 | 1000.000 | 1222.630 | | |

Sharp Road Culvert
Corrugated steel, pipe arch, rough concrete bottom.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1 | 5000.00 | 5000.00 | 100.000 | BRACEA | | | | |
| 2 | 4959.56 | 5004.58 | 97.552 | SHP CUL IN INV | 994.653 | 1217.283 | CULVERT LENGTH | 32.18005 |
| 3 | 4958.03 | 4999.65 | 98.028 | SHP CUL IN WSE | 995.129 | 1217.759 | CULVERT SLOPE | -0.001678 |
| 4 | 4959.80 | 5005.23 | 103.319 | SHP CUL IN TOP | 1000.420 | 1223.050 | CULVERT HEIGHT | 5.6465 |
| 5 | 4991.27 | 5023.38 | 103.132 | SHP CUL OUT TOP | 1000.233 | 1222.863 | INLET FLOW DEPTH | 0.476 |
| 6 | 4991.74 | 5023.90 | 97.606 | SHP CUL OUT INV | 994.707 | 1217.337 | | |
| 7 | 4993.83 | 5028.82 | 98.034 | SHP CUL OUT WSE | 995.135 | 1217.765 | | |
| 8 | 5096.39 | 4519.15 | 103.944 | SHP RD 1 | | | | |
| 9 | 5071.68 | 4116.13 | 107.009 | SHP RD 2 | 1004.110 | 1226.74 | | |
| 10 | 5025.36 | 5725.22 | 94.072 | SHP RD 2 BS | 1004.110 | 1226.740 | | |
| 11 | 3772.07 | 5273.41 | 89.962 | LAN CUL BM | 1000.000 | 1222.630 | | |

# Appendix F.

# Appendix G.

County ERIE

L.R. 25032 (Pa 86)

Station 450+95

Date 4-26-78

Looking Ahead

Looking Back

Looking Upstream (Rt. Side)

Looking Downstream (Lt. Side)

LOOKING DN. STREAM INTO STRUCTURE, CMPPA

COUNTY ERIE S. R. 3025 SEG. 0220 OFF. 2157 DATE 3-1-94

3 18'96

LOOKING SEGMENTS AHEAD

3 18'96

LOOKING SEGMENTS BACK

3 18'96

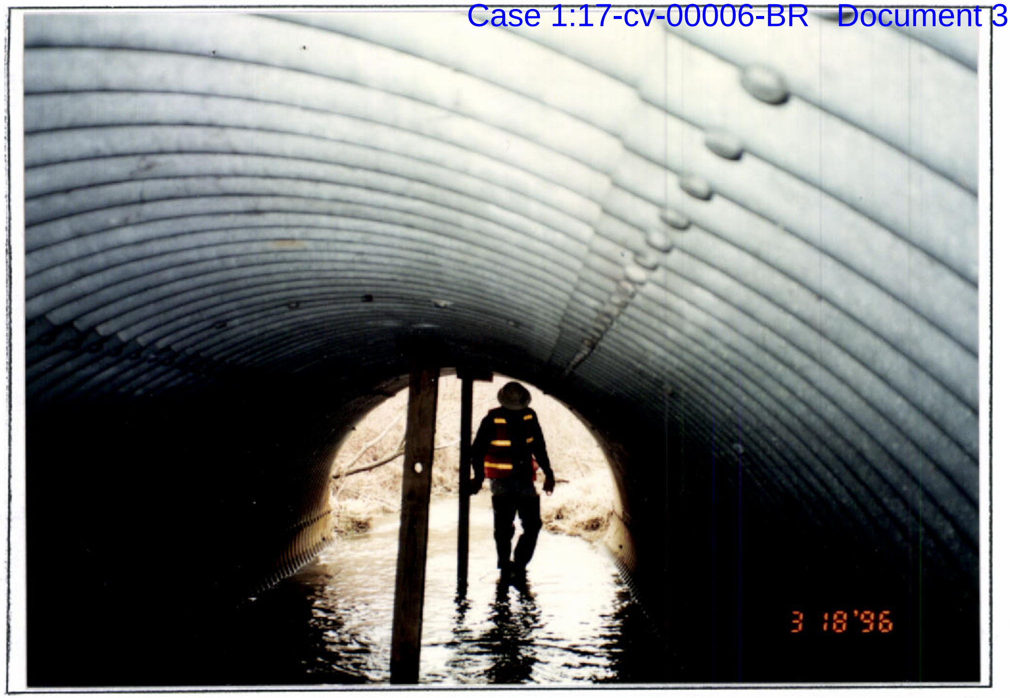
LOOKING @ LEFT SIDE OUTLET

3 18'96

LOOKING @ RIGHT SIDE INLET

COUNTY ERIE S. R. 3025 SEG. 0220 OFF. 2147 DATE 3/18/96

(L.R. , STA. )


3 18'96

UNDER LOOKING DOWNSTREAM AT SUPPORTS

COUNTY ERIE S. R. 3025 SEG. 0220 OFF. 2147 DATE 3/18/96
(L.R. , STA. )

BEAVER DAM BlockinG INLET

DERiS & DRiFT colecting on shoring

COUNTY Erie 25 S. R. 3025 SEG. 0220 OFF. 2147 DATE 02/23/00

(L.R. , STA. )

Looking Ahead

Looking Back

Left Side Outlet

Right Side Inlet

BMS NUMBER:**25-3025-0020-2147**

OVER:**Elk Creek**

DATE:**2/28/2002**


Inlet


Looking Under Toward Outlet


Looking Down Stream From Outlet


Through > u/s --- note: debris caught on shoring

BMS NUMBER: **25-3025-0020-2147**

OVER: **Elk Creek**

DATE: **2/28/2002**

2004.2.17Insp.xls

12/18/2017

**BMS NUMBER:** **25-3025-0220-2147**

**OVER:** **Elk Creek**

**DATE:** **2/17/2004**

# Appendix H.

# BRACE FARM MURPHY, HOMESTEAD AND MARSH TRACTS
# LOST CROP REVENUES FROM 1996 - 2016*
# ARISING FROM EPA'S NEGLIGENT AND WRONGFUL
# ENFORCEMENT OF THE 1996 DOJ CONSENT DECREE

ALL Data Upon Which This Spreadsheet is Based is USDA Economic Research Service Data
(*Published Internet-Accessible 2016 USDA Figures Not Available at this Time)

**Assumption #1**: Claimants Robert Brace, Inc. and Robert Brace and Sons, Inc., Would Have Chosen the Most Profitable of the Three More Profitable Crops to Farm on the Portions of Each of the Three Contiguous and Adjacent Tracts Set Forth Below and in the Accompanying Spreadsheets during the years in question.

**Assumption #2**: The Three More Profitable Crops Grown in Nutrient-Rich Soil of the Type on Brace Farms Include, in Order of Profitability, Onion, Cabbage and Potatoes. The Harvest Revenues for Each Such Crop is Set Forth Below and in the Accompanying Spreadsheets.
Such Data Were Derived From the United States Department of Agriculture's Economic Research Service as Indicated in the Accompanying Spreadsheets.
The Harvest Revenues That Could Have Been Earned, But Were Lost, For Each of Onions, Cabbage and Potatoes are Set Forth Below and in the Accompanying Spreadsheets:

| Tract | Acreage Flooded | Period | Crop | Cabbage | Onions | Potatoes |
|---|---|---|---|---|---|---|
| Homestead | 14 Acres | 1996-2016 | | $1,034,560.80 | $1,430,338.00 | $582,851.50 |
| Murphy | 32.5 Acres;<br>25.5 Acres for 7 Yrs | 1996-2016<br>2006-2012 | | $3,147,375.90 | $4,380,551.75 | $1,730,068.18 |
| Marsh | 20 Acres | 1996-2012 | | $1,477,944.00 | $2,043,340.00 | $832,645.00 |
| | | | | $5,659,880.70 | $7,854,229.75 | $3,145,564.68 |

**Finding #1**: Claimant Robert Brace Will Incur Additional Costs to Repair Each of the Three Flooded Properties to Return them to their Prior Maximum Use for Growing and Harvesting the Crops Identified Above.
The Repair Costs that Will be Incurred as the Result of EPA's Negligent and Wrongful Enforcment of the 1996 Consent Decree Consist of the Following:

| | |
|---|---|
| Repairing Real Property (Installation Drainage, Ditching) | $217,003.00 |
| Removal/Repair of Check Dam (by Fed'l Gov't) | $0.00 |
| Removal of Beaver Dams (by State Gov't) | $0.00 |
| Removal, Replacement, Cleaning of Culverts (by State Gov't) | $0.00 |
| | $217,003.00 |

**Finding #2**: The Total Amount of Claimant(s)' FTCA Claims for **Real Property Damage** Filed Against the EPA, Corps and FWS is: **$217,003.**

**Finding #3:** The Total Amount of Claimant(s)' FTCA Claims For **Personal Property Damage** Filed Against the EPA, Corps & FWS is **$7,854,229.75**.

**Finding #4:** The Total Amount of Claimaint(s)' FTCA Claims for **Real Property and Personal Property Damage** Filed Against the EPA, Corps & FWS is: **$8,071,232.75**.