# Deep River Tributary Drainage Analysis:

## Hydraulic Modeling

## Summary and Analysis

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## Contents

## Introduction

The following report summarizes the findings of the drainage assessment performed along UNT Deep River in the vicinity of US6 and County Line Road in Hobart, Indiana. The study was performed in response to concerns identified in the reach arising from existing drainage issues, or those that may be exacerbated by way of the County Line Road Project.

## Site Location and Existing Site Conditions

The study site is located east of Hobart along the reach of UNT Deep River from the downstream boundary of US 6 and extending a short distance upstream of County Line Road. Residents downstream of County Line Road have expressed concerns about existing drainage issues and the potential effects that the proposed County Line Road Improvements may have on those issues. See Figure 1 for an approximation of the study area. The UNT flows from the southeast to the northwest. Of chief concern are the effects of the two culverts conveying the flow of the UNT Deep River underneath County Line Road. The proposed road project includes replacement and upsizing of the existing culverts. Table 1 summarizes the existing and the analyzed County Line Road culvert configurations.

| UNT Deep River Culvert Analysis | | | |
|---|---|---|---|
| | | Proposed Dimensions | |
| Crossing | Existing Dimensions and Shape | A | B |
| South Branch Culvert | 5'x2.5' ellipse | 6'x5' box, 1' sump | 5'x4' box, 1' sump |
| North Branch Culvert | 6' round | 6'x5' box, 6"' sump | 5'x4' box, 1' sump |
| Oak Savannah Trail Culvert | 4.5'x6' box | 8'x6' box | 12'x6' box |

Table 1: Culvert Summary

Two different culvert sizes replacing the existing County Line Road culverts are analyzed in this report. In addition, a preliminary analysis on the Oak Savannah Trail culvert is included in this report. Standard premanufactured box culvert dimensions are input into the model to determine the potential effects that increasing the conveyance capacity of the culvert would have upstream. While not within the scope of the County Line Road project, improvements to the trail culvert are being considered. Final dimensions would be determined with a formal design.

Drainage area maps for the north and south County Line Road culverts are included in Appendix D. Additional drainage and accompanying storm flow is contributed to the stream upstream of the Oak Savannah Trail culvert from the storm drainage system servicing the Arbor Lane subdivision located to the south. Under the proposed road improvement conditions, additional surface runoff due to increased impervious pavement surfaces will be added to the drainage basin.

The upstream drainage areas of the river system to the east of County Line Road are a mix of residential, wooded, and agricultural use surfaces. Surface runoff is generally routed to the streams via surface routes. There are some closed conduit field tiles and storm drains as well. The north and south branches of the tributary convey additional surface runoff from residential properties to the west of County Line Road. Some sections of the south tributary flow line have been lined with concrete and are routed through small residentially installed culverts. In addition, there are several small pedestrian crossings traversing the streams in the area of the residences. These features were accounted for and included in the modeling efforts. Downstream of the confluence of the north and south branches and convergence into the main channel, the stream flows through a wooded area on its way to the US 6 bridge and eventual confluence with Deep River. Observation of the area and plant speciation upstream of the Oak Savannah Trail Culvert suggests that the area commonly features standing or slow moving water above normal pool depth. It is likely that this ponding can be attributed to the conveyance capacity of the trail culvert and has upstream impacts. Downstream of the trail culvert, the channel width of the stream widens and deepens, suggesting a more natural and meandering flow pattern where stream flow energy and momentum under high flow conditions is dissipated.


Figure 1: Existing Conditions Aerial with Culvert Locations

## Modeling

In order to determine the effects of the proposed County Line Road project and the improvements to the north and south culverts, a HEC-RAS hydraulic and hydrologic analysis was performed on the stream. This program will indicate what the expected water surface elevations (WSEL) and the corresponding water surface extents are under the conditions of the modeled storm event. The model requires stream geometry data and flow data for execution.

The Indiana Department of Natural Resources is the governing body in the state on construction projects occurring along mapped waterbodies and their published guidelines for modeling will be used as a governing basis for this effort. The IDNR model library was consulted to determine if there are any existing H&H models along the stream. An older Water-Surface PROfile (WSPRO) computations model was performed in coordination with a project replacing the US 6 bridge. The relevant data from the WSPRO model was incorporated into the HEC-RAS model. IDNR personnel were contacted and confirmed the methods of the analysis as consistent with the IDNR modeling standards and inclusive of the past project data. The US 6 bridge is currently the upstream limit of any modeling that is available in the State's database that is considered regulatory and required for inclusion in any future construction efforts and accompanying modeling. Similarly, there is no IDNR or FEMA mapped floodway for the tributary, though the drainage area at the OST culvert is such that any construction efforts or improvements at that location fall under IDNR permitting jurisdiction. The County Line Road culvert contributing drainage areas are below the minimum threshold for IDNR permitting and instead fall under local and INDOT requirements.

Model Geometry

The geometry data used to plot the stream cross sections and channel was compiled using elevation and station data from a field survey performed in August of 2020 and supplemented with county contour and State flown LiDAR data to plot the overbanks. Maps with the locations of the modeled cross sections are included in the Appendix. Cross sections are labeled in feet above the downstream-most limit of the study. Flow area surface characteristics of the streambed flowline and stream overbanks were estimated from aerial photography and site field investigation. The corresponding Manning's "n" roughness coefficients are within the expected range for small tributary streams in suburban and rural areas in the state.

Dimensions and elevations of the existing bridge and culverts were taken from recent survey data and compared to past permits and construction plans. The model uses the more conservative computation method of the energy, momentum, and pressure/weir flow analysis methods when simulating low flow and high flow conditions through the structures used to quantify the effects of the structure on water surface elevations and represent the worst case scenario.

The only variations in geometry between the existing and various proposed conditions scenario models are the culverts. The proposed models replace the existing culverts with those that are proposed as noted in Table 1.

Model Discharge

The stream discharge flow rates associated with the 100-year (1%) storm event are used in this analysis. This is the minimum design flow rate consistent with state agency regulatory standards. The IDNR Peak Discharge Determination Tool was used to determine the Q100 stream discharge values to use with the model. This method is approved and prioritized by IDNR, INDOT, and IDEM for use in culvert analysis for streams crossing under roads. The tool compiles flows from a variety of sources including those from similarly sized streams and drainage basins monitored by the IDNR that are within the same watershed as the stream being analyzed as well as IDNR coordinated discharges, USGS stream gauge data, and the regression equation data developed by Purdue University. The trendline created by the tool was used to estimate the flows relative to the delineated subbasin areas contributing to the culverts in question.

An AutoCAD Storm and Sanitary Analysis (SSA) model was generated to determine the peak runoff resulting from the Arbor Lane Subdivision. The storm collection system structure details were compiled using the county GIS data and subdivision plans for use in the model. Using the composite time of concentration for the studied stream system in its entirety, a peak flow rate for the system and corresponding time of occurrence within the design storm event was determined, the flows from the storm system at the peak time were extracted and used in the HEC-RAS model to create a composite discharge occurring at the appropriate locations and cross sections along the stream. Storm event duration and subsequent rainfall rates are based on the approximate time of concentration based on the longest flow path through surface and pipe flow determined for each subbasin drainage area within the subdivision.

For the proposed conditions model, additional runoff due to the road improvements was included. The peak rate of additional discharge is 15.8 cfs as determined in the road improvements report. This flow rate and drainage data was input into the unit hydrograph for the system produced in the SSA model to determine the flow rate contributed by the road improvements at the time of peak system discharge. Table 2 summarizes the discharge rates used in the model and the corresponding cross sections and location descriptions.

The subbasins served by the Arbor Lane subdivision collection system and road improvement runoff conveyance system have comparatively short times of concertation when observing the development time of the stream system in its entirety. Therefore, the peak storm runoff flow rates from the noted subbasins reach key points in the stream, like the OST culvert, prior to the peak flows from other subbasins. In this manner, the peak flow rates are attenuated by the time the larger upstream basins with higher flow rates reach the same corresponding key points along the stream.

| River Station | Existing Flows (cfs) | Proposed Flows (cfs) | Location |
|---|---|---|---|
| 5975-4410 | 130 | 130 | South Branch |
| 5900-4598 | 119 | 119 | North Branch |
| 4407-3650 | 249 | 249 | Confluence |
| 3502 | 255.3 | 259.9 | Arbor Lane Storm Outlet |
| 3043-1275 | 261.5 | 266.1 | At Oak Savannah Trail |
| 300-100 | 298.3 | 302.9 | At US 6 Bridge |

Table 2: Model Discharges

## Modeling Results

The inclusion of the proposed County Line Road culverts affects the water surface elevations in the residential areas downstream of the culverts. Appendix A has tables detailing the impacts of the culverts. Table 3 summarizes expected water surface elevations around the residential structures with some of the proposed structures that were modeled**. Improving the road and accompanying culverts results in an approximate surcharge in the range of 0.00'-0.12' around the residences.** For Construction in a Floodway Permitting as regulated by the IDNR, in accordance with FEMA guidelines, the allowable surcharge impacts in response to structure construction along regulated waterbodies is a maximum of 0.14' above the existing levels using acceptable modeling procedures. As detailed in this modeling effort, the expected surcharge in the residential area falls within the acceptable and permittable range.

When observing the impacts of just the CLR culverts, there is virtually no difference in the water surface elevation effects near the noted residences with the installation of 6'x5' box culverts compared to 5'x4' box culverts. However, east, and upstream of County Line Road, the smaller 5'x4' culverts have an adverse effect on the WSEL and increase the potential WSEL stage. Therefore, 6'x5' box culverts are recommended.

Installing a new OST culvert with increased flow conveyance capacity in conjunction with the proposed 6'x5' culverts under CLR has a markedly improved effect on the expected water surface elevations. The preliminary modeling appears to support the hypothesis that the impacts of the existing OST culvert has a more dynamic impact on the WSEL in the study area than the CLR culverts. The restrictive capacity of the OST culvert is contributing to backwater effects upstream.

| River Station, Near Residential Structure | Existing Q100 W.S. Elevation | Proposed 6'x5' CLR Culverts Q100 W.S. Elevation | Proposed 6'x5' CLR Culverts + 12'x6' OST Culvert Q100 W.S. Elevation | Nearest, Lowest Residential Finished Floor Elevation |
|---|---|---|---|---|
| | (ft) | (ft) | (ft) | (ft) |
| 5465 (South) | 624.01 | 622.39 | 622.39 | 630.13 |
| 5038 (South) | 620.34 | 620.34 | 620.35 | 622.10 |
| 4801 (South) | 619.50 | 619.50 | 619.47 | 620.16 |
| 4638 (South) | 617.61 | 617.61 | 617.70 | 619.94 |
| 4598 (South) | 616.44 | 616.45 | 616.29 | 619.94 |
| 5009 (North) | 617.25 | 617.37 | 617.19 | 628.22 |
| 4867 (North) | 617.25 | 617.37 | 617.18 | 620.26 |
| 4770 (North) | 616.32 | 616.38 | 615.92 | 620.26 |
| 4598 (North) | 616.27 | 616.33 | 615.83 | 619.94 |

Table 3: Water Surface Elevation Summary around Residences of Concern

An upsized OST culvert in conjunction with the proposed CLR culverts results in decreased expected water surface elevations at the majority of cross sections upstream of the trail along the studied reach. The tables in Appendix A and the maps in Appendix C detail the extents of the WSEL change and the corresponding adjustments to the expected water surface elevation extents.

## Summary

The hydraulic modeling efforts along UNT Deep River made in accordance with the proposed County Line Road Improvements Project indicate that the proposed project results in water surface elevation surcharges that are in compliance with the surcharge limits due to Construction in a Floodway as permitted and regulated by the Indiana Department of Natural Resources and the Federal Emergency Management Administration. The proposed project is not anticipated to have substantial negative effects on the existing conditions of the site. While there are some noted deficiencies in the existing site conditions, the proposed project is not anticipated to substantially exacerbate these issues. It is the assessment of the engineer that this project is in compliance with the Construction in a Floodway requirements of the Flood Control Act and should be permittable as designed and reported.

For any additional questions or comments, please contact the undersigned or Andrea Langille at ALangille@bfsengr.com, (317) 713-4615.

Sincerely,
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**Deep River Tributary Drainage Analysis**

**Existing County Line Road Culvert Conditions**
**vs**
**Proposed 6' x 5' County Line Road Culvert Conditions**

| Reach | River Station | | Existing Peak Section Analysis Q* | Proposed Peak Section Analysis Q* | Existing W.S. Elev | Proposed CLR Culverts W.S. Elev | Surcharge | Existing Flow Width | Proposed CLR Culverts Flow Width | Delta Flow Width |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | (cfs) | (cfs) | (ft) | (ft) | (ft) | (ft) | (ft) | (ft) |
| South Branch | 5975 | | 130 | 130 | 624.46 | 625.17 | 0.71 | 14.13 | 16.26 | 2.13 |
| South Branch | 5465 | | 130 | 130 | 624.01 | 622.39 | -1.62 | 101.66 | 13.99 | -87.67 |
| South Branch | 5148 | | 130 | 130 | 624.01 | 621.85 | -2.16 | 126.01 | 73.50 | -52.51 |
| South Branch | 5093 | 95+11 Culvert | | | | | | | | |
| South Branch | 5038 | | 130 | 130 | 620.34 | 620.34 | 0.00 | 62.17 | 62.17 | 0.00 |
| South Branch | 4801 | | 130 | 130 | 619.5 | 619.5 | 0.00 | 82.59 | 82.68 | 0.09 |
| South Branch | 4638 | | 130 | 130 | 617.61 | 617.61 | 0.00 | 44.08 | 43.77 | -0.31 |
| South Branch | 4598 | | 130 | 130 | 616.44 | 616.45 | 0.01 | 31.85 | 32.28 | 0.43 |
| South Branch | 4568 | | 130 | 130 | 616.51 | 616.52 | 0.01 | 102.34 | 102.38 | 0.04 |
| South Branch | 4410 | | 130 | 130 | 616.1 | 616.19 | 0.09 | 97.89 | 100.44 | 2.55 |
| North Branch | 5900 | | 119 | 119 | 617.82 | 617.86 | 0.04 | 114.64 | 120.48 | 5.84 |
| North Branch | 5650 | | 119 | 119 | 617.49 | 617.57 | 0.08 | 59.21 | 59.63 | 0.42 |
| North Branch | 5310 | | 119 | 119 | 617.28 | 617.4 | 0.12 | 83.4 | 85.3 | 1.90 |
| North Branch | 5009 | | 119 | 119 | 617.25 | 617.37 | 0.12 | 121.18 | 133.37 | 12.19 |
| North Branch | 4867 | | 119 | 119 | 617.25 | 617.37 | 0.12 | 153.24 | 153.86 | 0.62 |
| North Branch | 4813 | 100+48 Culvert | | | | | | | | |
| North Branch | 4770 | | 119 | 119 | 616.32 | 616.38 | 0.06 | 89.72 | 90.26 | 0.54 |
| North Branch | 4598 | | 119 | 119 | 616.27 | 616.33 | 0.06 | 73.95 | 75.28 | 1.33 |
| Main Channel | 4407 | | 249 | 249 | 616.16 | 616.23 | 0.07 | 163.82 | 168.42 | 4.60 |
| Main Channel | 4051 | | 249 | 249 | 615.86 | 615.95 | 0.09 | 58.53 | 60.33 | 1.80 |
| Main Channel | 3650 | | 249 | 249 | 615.86 | 615.96 | 0.10 | 184.32 | 185.72 | 1.40 |
| Main Channel | 3502 | | 255.3 | 259.9 | 615.85 | 615.95 | 0.10 | 184.2 | 185.6 | 1.40 |
| Main Channel | 3043 | | 261.5 | 266.1 | 615.84 | 615.93 | 0.09 | 157.42 | 158.23 | 0.81 |
| Main Channel | 2947 | Trail Culvert | | | | | | | | |
| Main Channel | 2850 | | 261.5 | 266.1 | 612.08 | 612.12 | 0.04 | 93.08 | 94.4 | 1.32 |
| Main Channel | 2150 | | 261.5 | 266.1 | 611.05 | 611.09 | 0.04 | 57.3 | 59.97 | 2.67 |
| Main Channel | 1275 | | 261.5 | 266.1 | 608.15 | 608.18 | 0.03 | 24.51 | 24.71 | 0.20 |
| Main Channel | 300 | | 298.3 | 302.9 | 607.46 | 607.5 | 0.04 | 143.43 | 143.71 | 0.28 |
| Main Channel | 180 | Bridge | | | | | | | | |
| Main Channel | 160 | | 298.3 | 302.9 | 606.47 | 606.48 | 0.01 | 137.51 | 137.53 | 0.02 |
| Main Channel | 100 | | 298.3 | 302.9 | 606.42 | 606.42 | 0.00 | 138.11 | 138.11 | 0.00 |

* Negative values represent a decrease in flow depth or floodway width

**Deep River Tributary Drainage Analysis**

**Existing County Line Road Culvert Conditions**
**vs**
**Proposed (5'x4') County Line Road Culvert Conditions**

| Reach | River Station | | Existing Peak Section Analysis Q* | Proposed Peak Section Analysis Q* | Existing W.S. Elev | Proposed CLR Culverts W.S. Elev | Surcharge | Existing Flow Width | Proposed CLR Culverts Flow Width | Delta Flow Width |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | (cfs) | (cfs) | (ft) | (ft) | (ft) | (ft) | (ft) | (ft) |
| South Branch | 5975 | | 130 | 130 | 624.46 | 624.76 | 0.30 | 14.13 | 15.03 | 0.90 |
| South Branch | 5465 | | 130 | 130 | 624.01 | 623.19 | -0.82 | 101.66 | 73.62 | -28.04 |
| South Branch | 5148 | | 130 | 130 | 624.01 | 623.27 | -0.74 | 126.01 | 112.74 | -13.27 |
| South Branch | 5093 | 95+11 Culvert | Culvert | Culvert | | | | | | |
| South Branch | 5038 | | 130 | 130 | 620.34 | 620.34 | 0.00 | 62.17 | 62.17 | 0.00 |
| South Branch | 4801 | | 130 | 130 | 619.5 | 619.5 | 0.00 | 82.59 | 82.68 | 0.09 |
| South Branch | 4638 | | 130 | 130 | 617.61 | 617.61 | 0.00 | 44.08 | 43.77 | -0.31 |
| South Branch | 4598 | | 130 | 130 | 616.44 | 616.45 | 0.01 | 31.85 | 32.28 | 0.43 |
| South Branch | 4568 | | 130 | 130 | 616.51 | 616.52 | 0.01 | 102.34 | 102.38 | 0.04 |
| South Branch | 4410 | | 130 | 130 | 616.1 | 616.19 | 0.09 | 97.89 | 100.44 | 2.55 |
| North Branch | 5900 | | 119 | 119 | 617.82 | 619.17 | 1.35 | 190.05 | 218.18 | 28.13 |
| North Branch | 5650 | | 119 | 119 | 617.49 | 619.14 | 1.65 | 59.21 | 67.67 | 8.46 |
| North Branch | 5310 | | 119 | 119 | 617.28 | 619.12 | 1.84 | 83.4 | 106.83 | 23.43 |
| North Branch | 5009 | | 119 | 119 | 617.25 | 619.12 | 1.87 | 169.48 | 267.4 | 97.92 |
| North Branch | 4867 | | 119 | 119 | 617.25 | 619.11 | 1.86 | 153.24 | 162.84 | 9.60 |
| North Branch | 4813 | 100+48 Culvert | Culvert | Culvert | | | | | | |
| North Branch | 4770 | | 119 | 119 | 616.32 | 616.38 | 0.06 | 89.72 | 90.26 | 0.54 |
| North Branch | 4598 | | 119 | 119 | 616.27 | 616.33 | 0.06 | 73.95 | 75.28 | 1.33 |
| Main Channel | 4407 | | 249 | 249 | 616.16 | 616.23 | 0.07 | 163.82 | 168.42 | 4.60 |
| Main Channel | 4051 | | 249 | 249 | 615.86 | 615.95 | 0.09 | 58.53 | 60.33 | 1.80 |
| Main Channel | 3650 | | 249 | 249 | 615.86 | 615.96 | 0.10 | 184.32 | 185.72 | 1.40 |
| Main Channel | 3502 | | 255.3 | 259.9 | 615.85 | 615.95 | 0.10 | 184.2 | 185.6 | 1.40 |
| Main Channel | 3043 | | 261.5 | 266.1 | 615.84 | 615.93 | 0.09 | 157.42 | 158.23 | 0.81 |
| Main Channel | 2947 | Trail Culvert | Culvert | Culvert | | | | | | |
| Main Channel | 2850 | | 261.5 | 266.1 | 612.08 | 612.12 | 0.04 | 93.08 | 94.4 | 1.32 |
| Main Channel | 2150 | | 261.5 | 266.1 | 611.05 | 611.09 | 0.04 | 57.3 | 59.97 | 2.67 |
| Main Channel | 1275 | | 261.5 | 266.1 | 608.15 | 608.18 | 0.03 | 24.51 | 24.71 | 0.20 |
| Main Channel | 300 | | 298.3 | 302.9 | 607.46 | 607.5 | 0.04 | 143.43 | 143.71 | 0.28 |
| Main Channel | 180 | Bridge | Bridge | Bridge | | | | | | |
| Main Channel | 160 | | 298.3 | 302.9 | 606.47 | 606.48 | 0.01 | 137.51 | 137.53 | 0.02 |
| Main Channel | 100 | | 298.3 | 302.9 | 606.42 | 606.42 | 0.00 | 138.11 | 138.11 | 0.00 |

* Negative values represent a decrease in flow depth or floodway width

**Deep River Tributary Drainage Analysis**

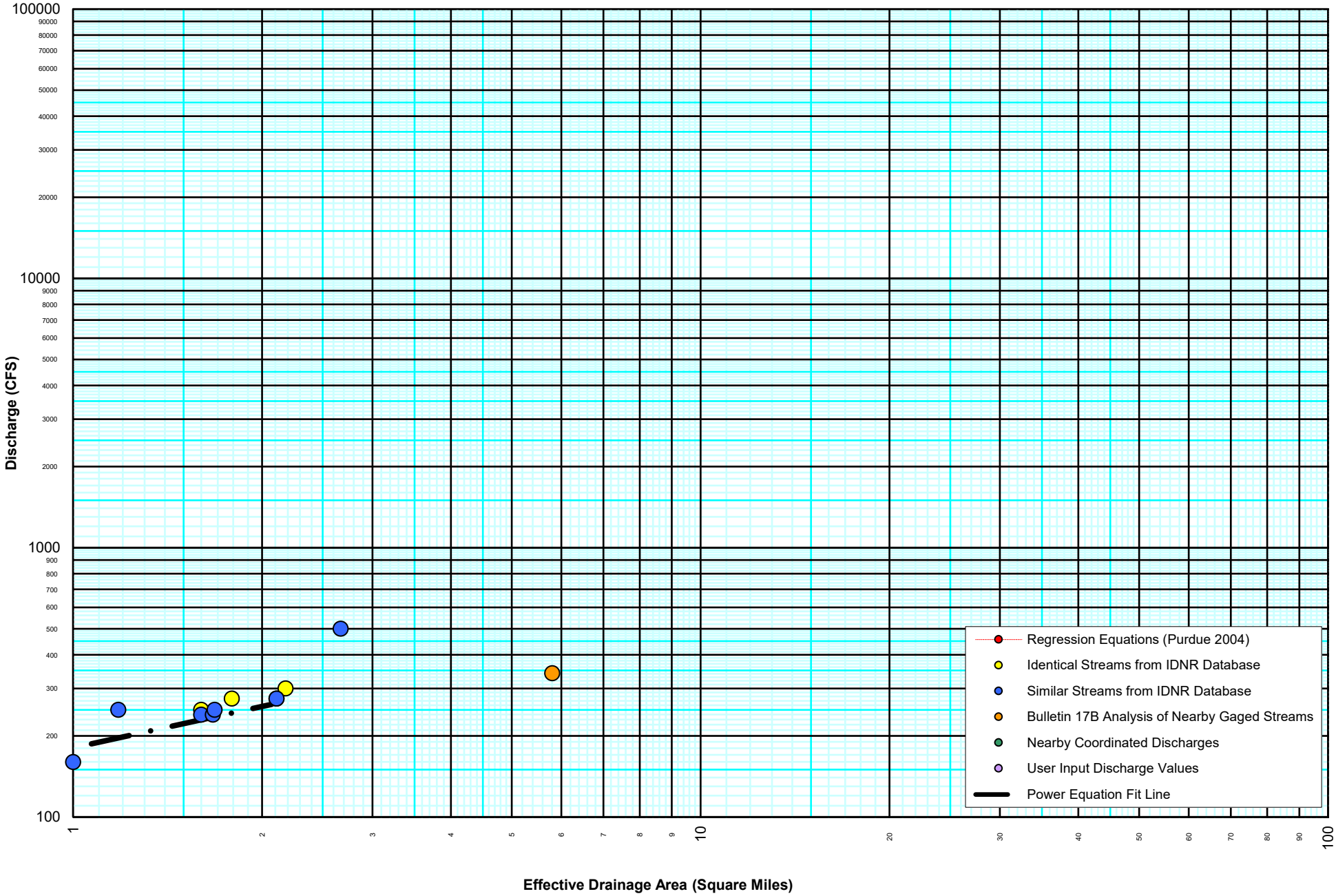
**Existing County Line Road Culvert Conditions**
**vs**
**Proposed 6' x 5' County Line Road Culvert Conditions**
**Oak Savannah Trail Culvert Replacement**

| | | | | | 1 | 2 | 3 | 4 | | | | 5 | 6 | 7 | 8 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Reach | River Station | | Existing Peak Section Analysis Q* | Proposed Peak Section Analysis Q* | Existing W.S. Elev | Proposed CLR Culverts W.S. Elev | Proposed CLR Culverts + 8'x6' OST Culvert W.S. Elev | Proposed CLR Culverts + 12'x6' OST Culvert W.S. Elev | Surcharge (ft) | | | Existing Flow Width | Proposed CLR Culverts Flow Width | Proposed CLR Culverts + 8'x6' OST Culvert Flow Width | Proposed CLR Culverts + 12'x6' OST Culvert Flow Width | Delta Flow Width (ft) | | |
| | | | (cfs) | (cfs) | (ft) | (ft) | (ft) | (ft) | (2-1) | (3-1) | (4-1) | (ft) | (ft) | (ft) | (ft) | (6-5) | (7-5) | (8-5) |
| South Branch | 5975 | | 130 | 130 | 624.46 | 625.17 | 625.17 | 625.17 | 0.71 | 0.71 | 0.71 | 14.13 | 16.26 | 16.26 | 16.26 | 2.13 | 2.13 | 2.13 |
| South Branch | 5465 | | 130 | 130 | 624.01 | 622.39 | 622.39 | 622.39 | -1.62 | -1.62 | -1.62 | 101.66 | 13.99 | 13.99 | 13.99 | -87.67 | -87.67 | -87.67 |
| South Branch | 5148 | | 130 | 130 | 624.01 | 621.85 | 621.85 | 621.85 | -2.16 | -2.16 | -2.16 | 126.01 | 73.50 | 73.50 | 73.50 | -52.51 | -52.51 | -52.51 |
| South Branch | 5093 | 95+11 Culvert | | | | | | | | | | | | | | | | |
| South Branch | 5038 | | 130 | 130 | 620.34 | 620.34 | 620.35 | 620.35 | 0.00 | 0.01 | 0.01 | 62.17 | 62.17 | 62.22 | 62.22 | 0.00 | 0.05 | 0.05 |
| South Branch | 4801 | | 130 | 130 | 619.50 | 619.50 | 619.47 | 619.47 | 0.00 | -0.03 | -0.03 | 82.59 | 82.68 | 81.53 | 81.50 | 0.09 | -1.06 | -1.09 |
| South Branch | 4638 | | 130 | 130 | 617.61 | 617.61 | 617.70 | 617.70 | 0.00 | 0.09 | 0.09 | 44.08 | 43.77 | 38.79 | 38.89 | -0.31 | -5.29 | -5.19 |
| South Branch | 4598 | | 130 | 130 | 616.44 | 616.45 | 616.29 | 616.29 | 0.01 | -0.15 | -0.15 | 31.85 | 32.28 | 23.90 | 23.73 | 0.43 | -7.95 | -8.12 |
| South Branch | 4568 | | 130 | 130 | 616.51 | 616.52 | 616.35 | 616.35 | 0.01 | -0.16 | -0.16 | 102.34 | 102.38 | 101.40 | 101.37 | 0.04 | -0.94 | -0.97 |
| South Branch | 4410 | | 130 | 130 | 616.10 | 616.19 | 615.42 | 615.46 | 0.09 | -0.68 | -0.64 | 97.89 | 100.44 | 36.84 | 37.48 | 2.55 | -61.05 | -60.41 |
| North Branch | 5900 | | 119 | 119 | 617.82 | 617.86 | 617.81 | 617.81 | 0.04 | -0.01 | -0.01 | 114.64 | 120.48 | 98.59 | 99.32 | 5.84 | -16.05 | -15.32 |
| North Branch | 5650 | | 119 | 119 | 617.49 | 617.57 | 617.44 | 617.45 | 0.08 | -0.05 | -0.04 | 59.21 | 59.63 | 58.99 | 59.00 | 0.42 | -0.22 | -0.21 |
| North Branch | 5310 | | 119 | 119 | 617.28 | 617.40 | 617.22 | 617.22 | 0.12 | -0.06 | -0.06 | 83.40 | 85.30 | 82.34 | 82.40 | 1.90 | -1.06 | -1.00 |
| North Branch | 5009 | | 119 | 119 | 617.25 | 617.37 | 617.19 | 617.19 | 0.12 | -0.06 | -0.06 | 121.18 | 133.37 | 107.16 | 108.34 | 12.19 | -14.02 | -12.84 |
| North Branch | 4867 | | 119 | 119 | 617.25 | 617.37 | 617.18 | 617.18 | 0.12 | -0.07 | -0.07 | 153.24 | 153.86 | 152.89 | 152.91 | 0.62 | -0.35 | -0.33 |
| North Branch | 4813 | 100+48 Culvert | | | | | | | | | | | | | | | | |
| North Branch | 4770 | | 119 | 119 | 616.32 | 616.38 | 615.90 | 615.92 | 0.06 | -0.42 | -0.40 | 89.72 | 90.26 | 66.67 | 68.01 | 0.54 | -23.05 | -21.71 |
| North Branch | 4598 | | 119 | 119 | 616.27 | 616.33 | 615.81 | 615.83 | 0.06 | -0.46 | -0.44 | 73.95 | 75.28 | 63.15 | 63.71 | 1.33 | -10.80 | -10.24 |
| Main Channel | 4407 | | 249 | 249 | 616.16 | 616.23 | 615.56 | 615.59 | 0.07 | -0.60 | -0.57 | 163.82 | 168.42 | 123.41 | 124.28 | 4.60 | -40.41 | -39.54 |
| Main Channel | 4051 | | 249 | 249 | 615.86 | 615.95 | 614.81 | 614.89 | 0.09 | -1.05 | -0.97 | 58.53 | 60.33 | 25.17 | 31.71 | 1.80 | -33.36 | -26.82 |
| Main Channel | 3650 | | 249 | 249 | 615.86 | 615.96 | 613.66 | 613.53 | 0.10 | -2.20 | -2.33 | 184.32 | 185.72 | 154.20 | 151.17 | 1.40 | -30.12 | -33.15 |
| Main Channel | 3502 | | 255.3 | 259.9 | 615.85 | 615.95 | 613.41 | 612.92 | 0.10 | -2.44 | -2.93 | 184.20 | 185.60 | 146.70 | 107.03 | 1.40 | -37.50 | -77.17 |
| Main Channel | 3043 | | 261.5 | 266.1 | 615.84 | 615.93 | 613.26 | 612.55 | 0.09 | -2.58 | -3.29 | 157.42 | 158.23 | 134.58 | 124.91 | 0.81 | -22.84 | -32.51 |
| Main Channel | 2947 | Trail Culvert | | | | | | | | | | | | | | | | |
| Main Channel | 2850 | | 261.5 | 266.1 | 612.08 | 612.12 | 612.12 | 612.12 | 0.04 | 0.04 | 0.04 | 93.08 | 94.40 | 94.40 | 94.40 | 1.32 | 1.32 | 1.32 |
| Main Channel | 2150 | | 261.5 | 266.1 | 611.05 | 611.09 | 611.09 | 611.09 | 0.04 | 0.04 | 0.04 | 57.30 | 59.97 | 59.97 | 59.97 | 2.67 | 2.67 | 2.67 |
| Main Channel | 1275 | | 261.5 | 266.1 | 608.15 | 608.18 | 608.18 | 608.18 | 0.03 | 0.03 | 0.03 | 24.51 | 24.71 | 24.71 | 24.71 | 0.20 | 0.20 | 0.20 |
| Main Channel | 300 | | 298.3 | 302.9 | 607.46 | 607.50 | 607.50 | 607.50 | 0.04 | 0.04 | 0.04 | 143.43 | 143.71 | 143.71 | 143.71 | 0.28 | 0.28 | 0.28 |
| Main Channel | 180 | Bridge | | | | | | | | | | | | | | | | |
| Main Channel | 160 | | 298.3 | 302.9 | 606.47 | 606.48 | 606.48 | 606.48 | 0.01 | 0.01 | 0.01 | 137.51 | 137.53 | 137.53 | 137.53 | 0.02 | 0.02 | 0.02 |
| Main Channel | 100 | | 298.3 | 302.9 | 606.42 | 606.42 | 606.42 | 606.42 | 0.00 | 0.00 | 0.00 | 138.11 | 138.11 | 138.11 | 138.11 | 0.00 | 0.00 | 0.00 |

* Negative values represent a decrease in flow depth or floodway width

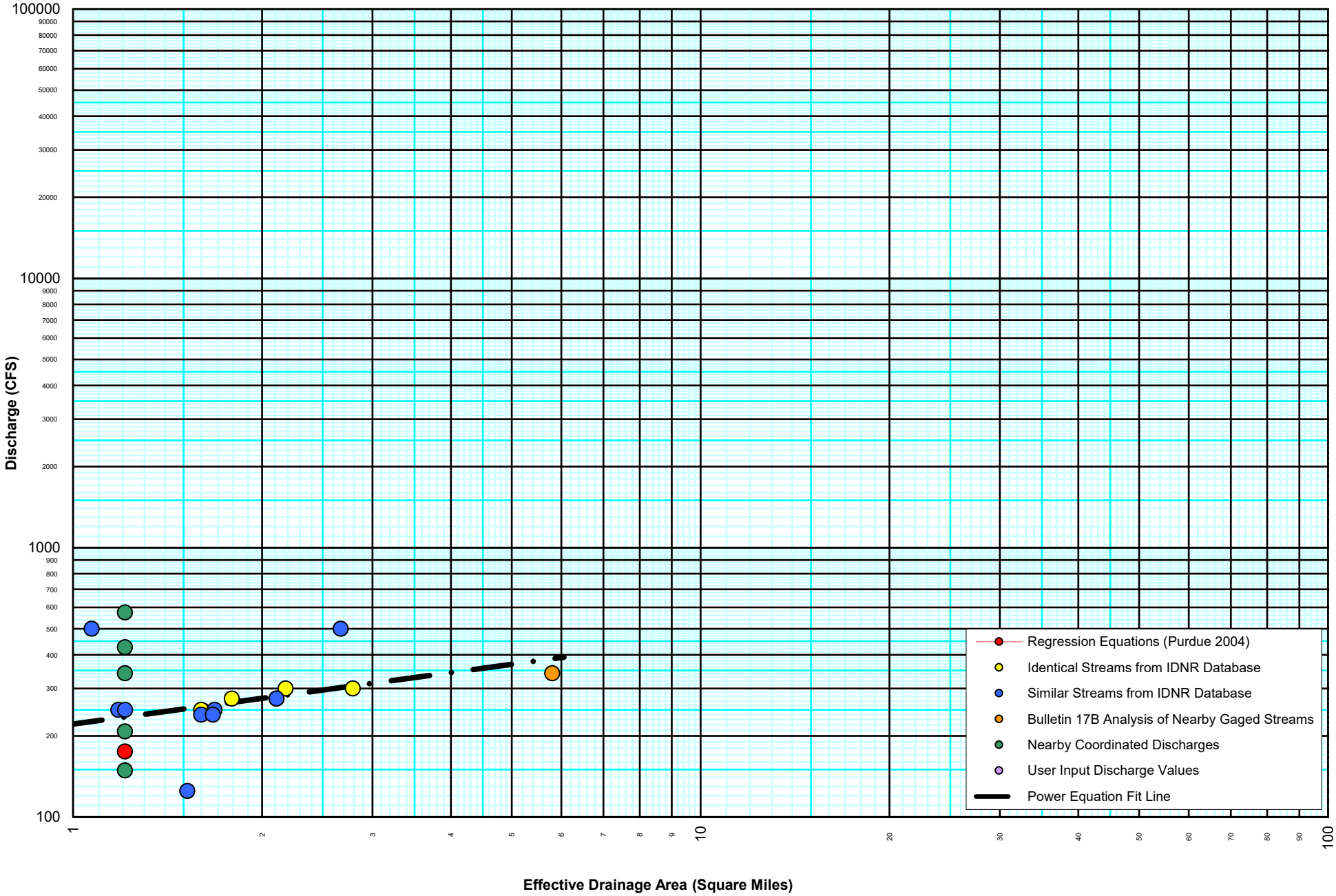
# Unnamed Tributary Deep River  Portage, Porter County

## North CLR Culvert (DA = 0.418 sq mi)



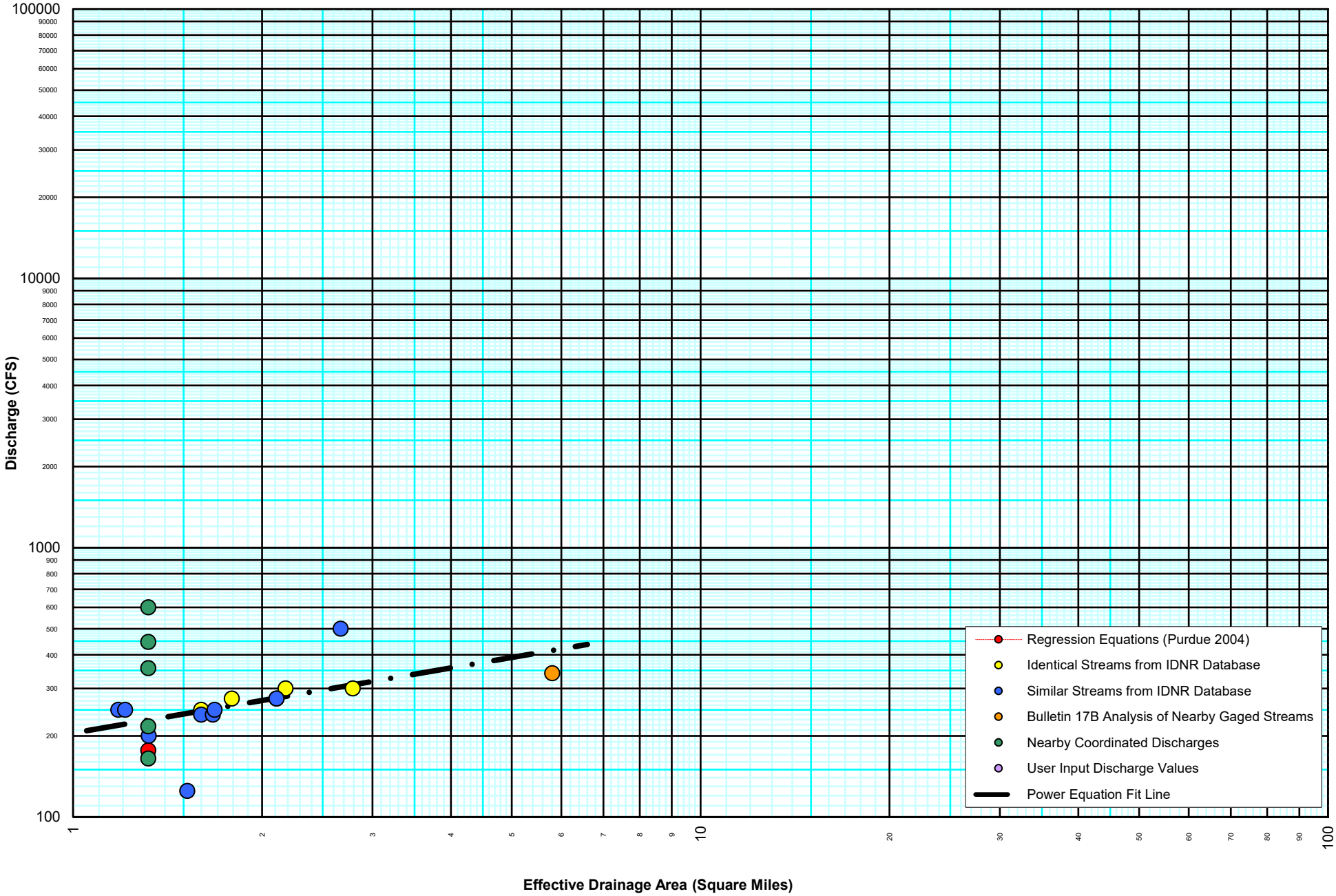
# Unnamed Tributary Deep River Hobart, Porter County

## County Line Road crossing (DA = 1.209 sq mi)



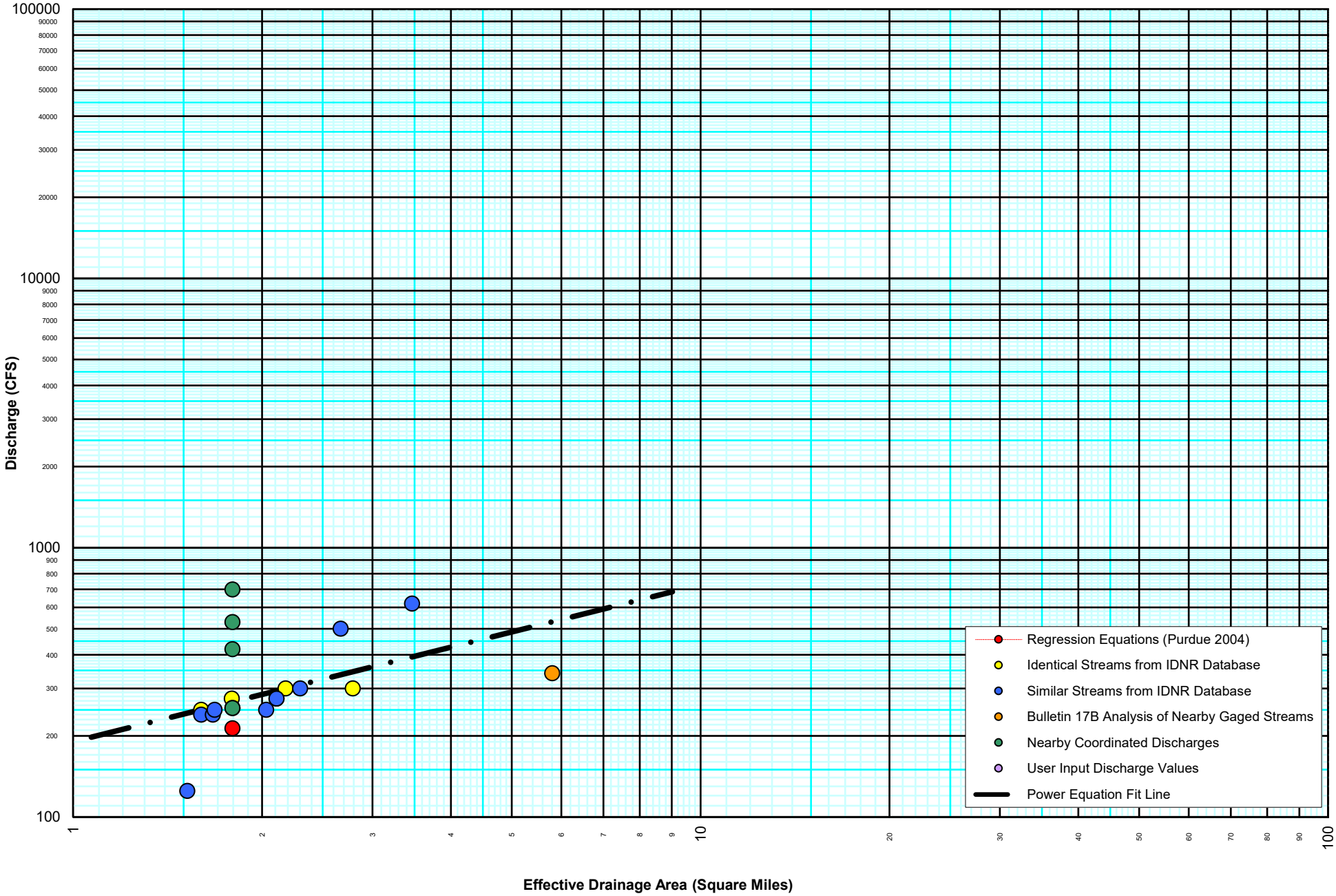
# Unnamed Tributary Deep River  Hobart, Lake County

## Oak Savannah Trail (DA = 1.317 sq mi)



# Unnamed Tributary Deep River  Hobart, Lake County

US 6 (DA = 1.794 sq mi)




River Stations

Finished Floor Elevation

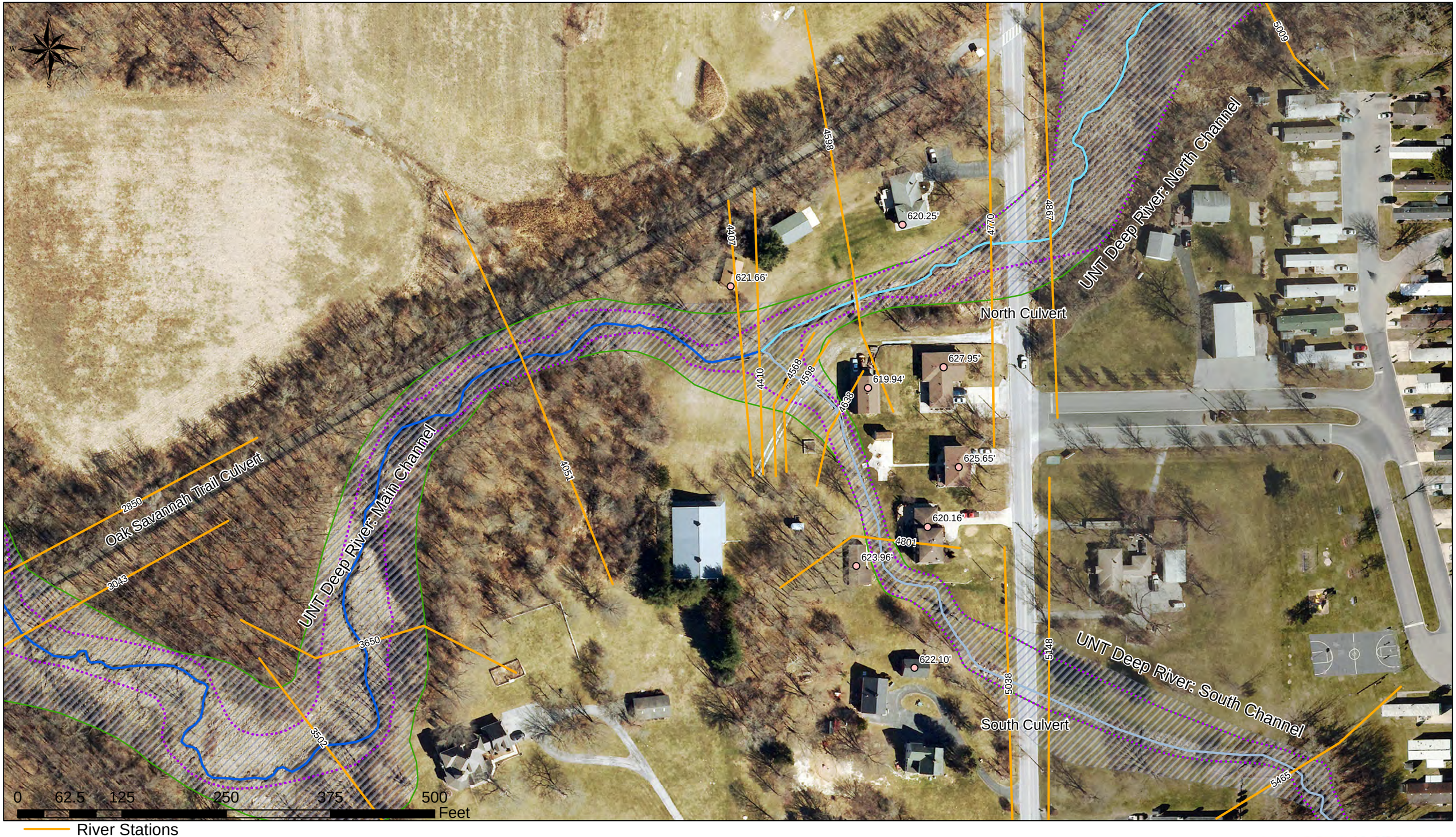
Approximate Existing Q100 WSEL Extents

Approximate Proposed Q100 WSEL Extents

Approximate Proposed With OST Redesign

# Deep River Tributary
# Drainage Analysis
## Exhibit 1: Analysis Study Area

BF&S
CIVIL ENGINEERS




River Stations

Finished Floor Elevation

Approximate Existing Q100 WSEL Extents

Approximate Proposed Q100 WSEL Extents

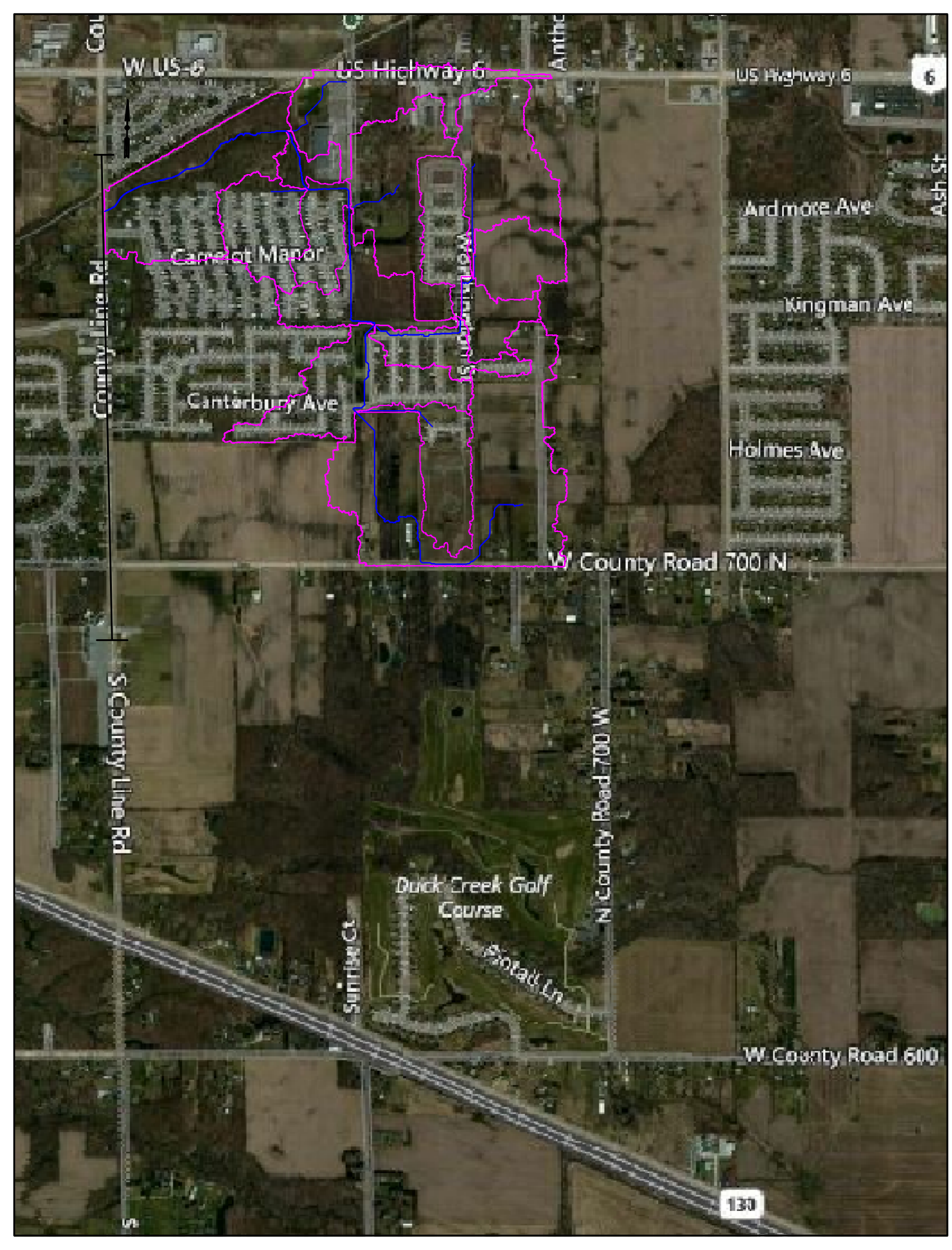
Approximate Proposed With OST Redesign

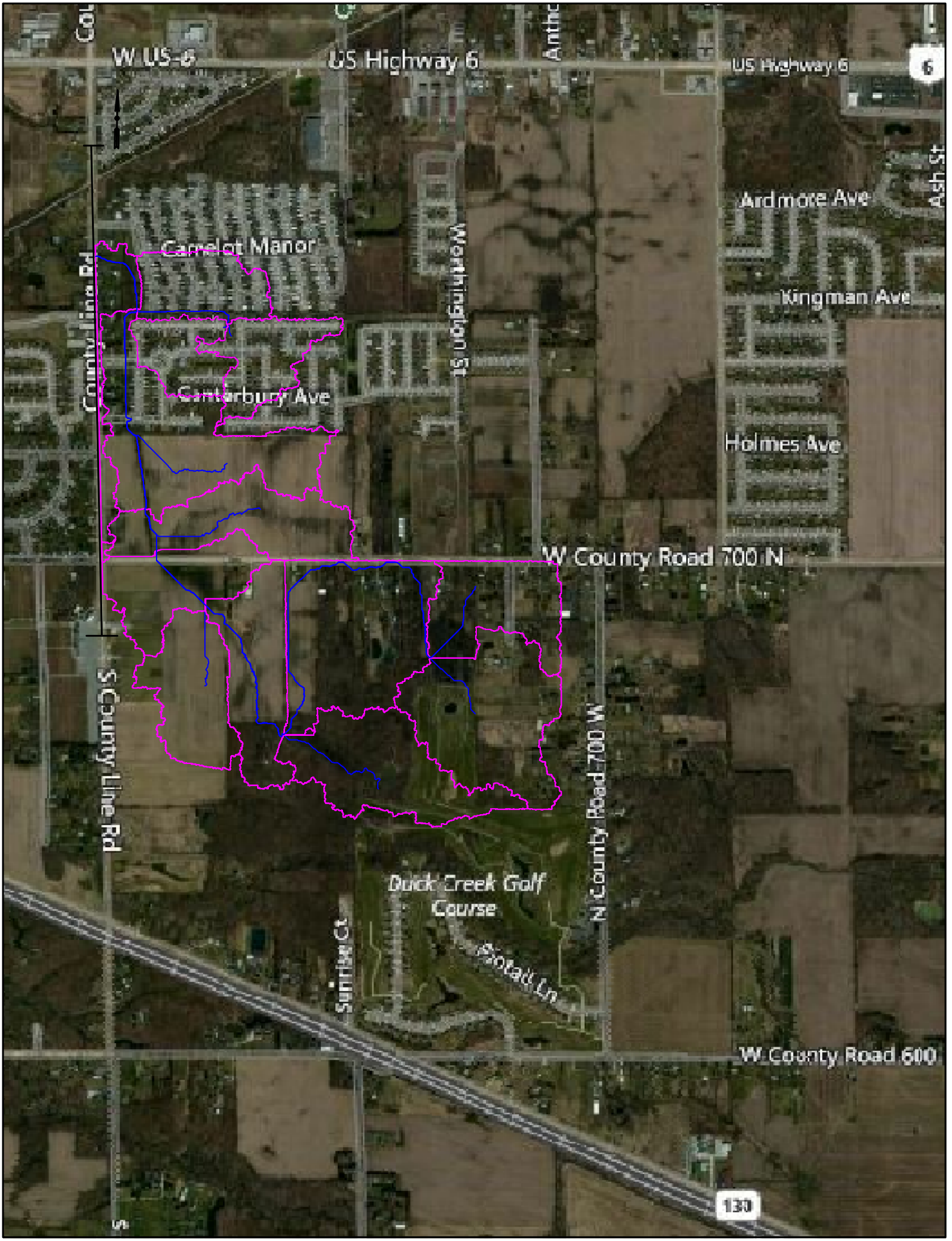
# Deep River Tributary Drainage Analysis

## Exhibit 2:

## County Line Road Impacted Areas

BF&S CIVIL ENGINEERS


W US-6
US Highway 6
US Highway 6
6
Ash St
Ardmore Ave
Kingman Ave
Holmes Ave
Camelot Manor
Canterbury Ave
County Line Rd
Worthington St
W County Road 700 N
S County Line Rd
N County Road 700 W
Duck Creek Golf Course
Sunrise Ct
Foxtail Ln
W County Road 600
130


W US-6
US Highway 6
US Highway 6
6
Ash St
Ardmore Ave
Carrelot Manor
Kingman Ave
Worthington St
Canterbury Ave
Holmes Ave
W County Road 700 N
S County Line Rd
N County Road 700 W
Duck Creek Golf Course
Sunrise Ct
Foxtail Ln
W County Road 600
130