CE 413 Term Project

Flood risk assessment for Highway 395 near Crane Creek Road in Oregon

Nathan Boechler

[OSU Student Website - Nathan Boechler - Crane Creek GIS Report]

Crane Creek Watershed

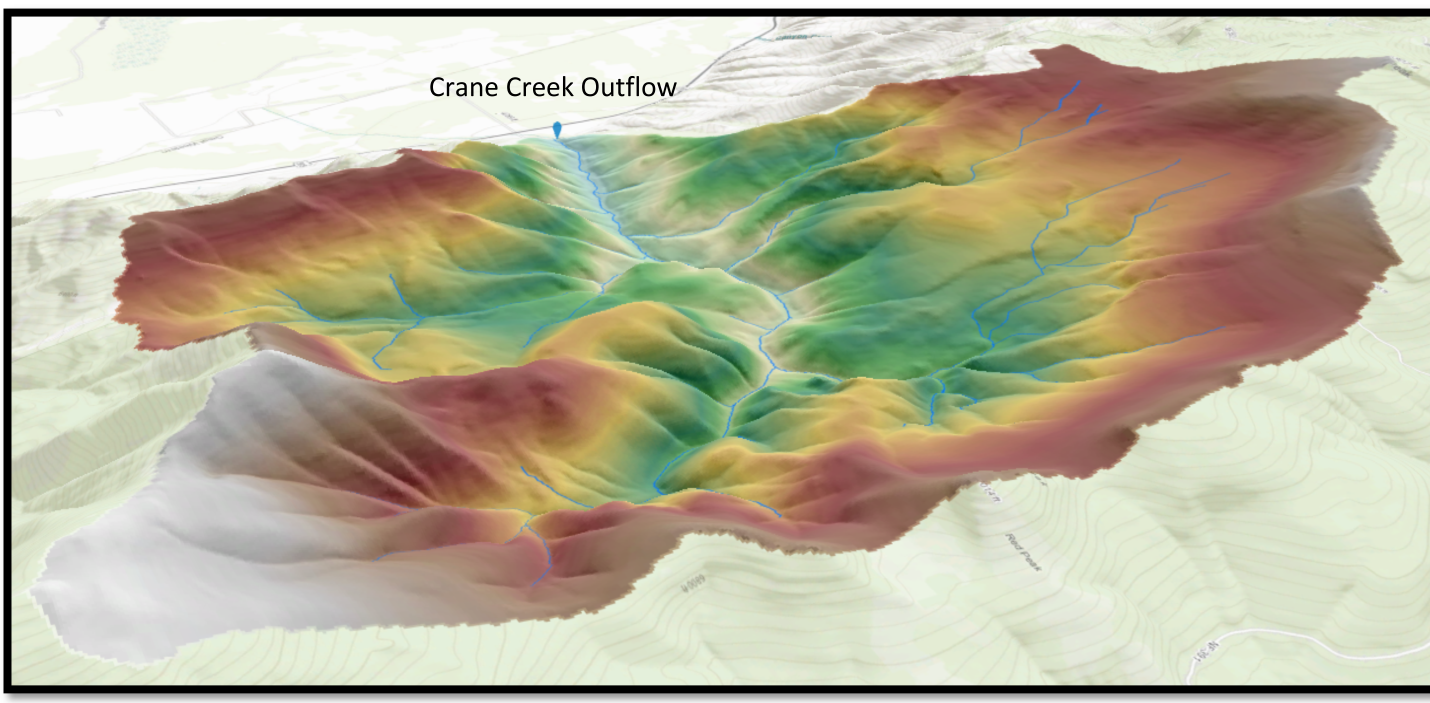


Table of Contents

Introduction:

For my term project I used GIS data to confirm a known flooding risk on sections of Crane Creek County Road and Highway 395 near Crane Creek in southern Oregon. I am currently redesigning a culvert, as part of a team capstone project for ODOT. They have had recent failures to control waterflow that has led to topping of the highway during high water events. This flooding has damaged sections of the highway and is a danger to roadway users during high water events. In order to ensure the safest possible roadway conditions ODOT has begun research into possible failure modes and corrective actions.

Objective:

Using the data from the Oregon Spatial Data Library, I collected and processed various data types, using ArcGIS, to show the same flood risk that is known to exist physically can be calculated and verified using GIS systems. Using known failure points and design data, I am showing how GIS data can be used to prevent future flooding risks by accurate assessments of peak flows in watersheds before the physical event occurs.

Site Description:

The site location is a zone around Crane Creek, approximately 5 miles south of the town of Lakeview Oregon. The culvert is beneath Highway 395 just south of the intersection of Highway 395 and Crane Creek Road. The layout below provides visual data of the site. The temperature in the area can fluctuate from mid 80s during the summers to lows near 20 degrees in the winters. The yearly rainfall is approximately 14 inches and the snow accumulations are approximately 45 inches per year. There is a variety of soil classes in the watershed and mixed vegetation including forest and plains sections.

Project site map location for Crane Creek Culvert

Figure 1: Site project map

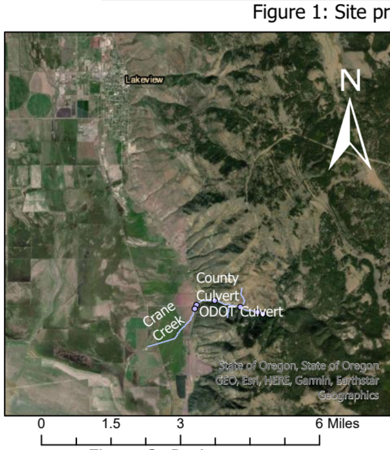


Figure 2: Project area

The ODOT culvert at Crane Creek is located approximately
5 miles south of Lakeview Oregon.

Figure 1 above shows the site location as well as the location of the culvert in reference to crane creek and U.S. 395.

Figure 2 to the left shows the project site in reference to the town of Lakeview.

Figure 1

The watershed area contributing to Crane Creek is much larger than the project zone. The area of the watershed is approximately 12.3 square miles and has an elevation change of 2100 feet. The watershed is completely east of the project area, so terrain analysis of both locations was completed as well as flow analysis of the watershed.

Data Description:

I am using geospatial data from the Oregon Spatial Data Library and NHDs data. All data sources have been projected on the NAD 1983 (2011) State Plane Oregon South FIPS 3602 (Intl Feet) to ensure consistency. Since the DEM layer is 10-meter resolution, some characteristics of the stream have been assumed based on contour mapping. All the data was sourced from the Oregon Spatial Data Library.

- The DEM is a 10-meter raster layer for the state of Oregon. It has a 10-meter resolution and has been reprojected to reflect distance in Intl Feet.
- The NHD flow data used is vector data of streams in the state of Oregon. The data has a 1/100,000 resolution.
- ODOT transportation data is vector data of roadways and culverts in the state of Oregon. This vector data was used primarily to mark roadway locations of interest.

Methodology:

The first analysis I did for the Crane Creek watershed was watershed delineation and flow line creation. I began by creating a point data file from GPS coordinates where Crane Creek split into north and south bound flows. I used the GIS watershed creation tool to find the outline and general shape of the watershed as shown in Figure 2 below.

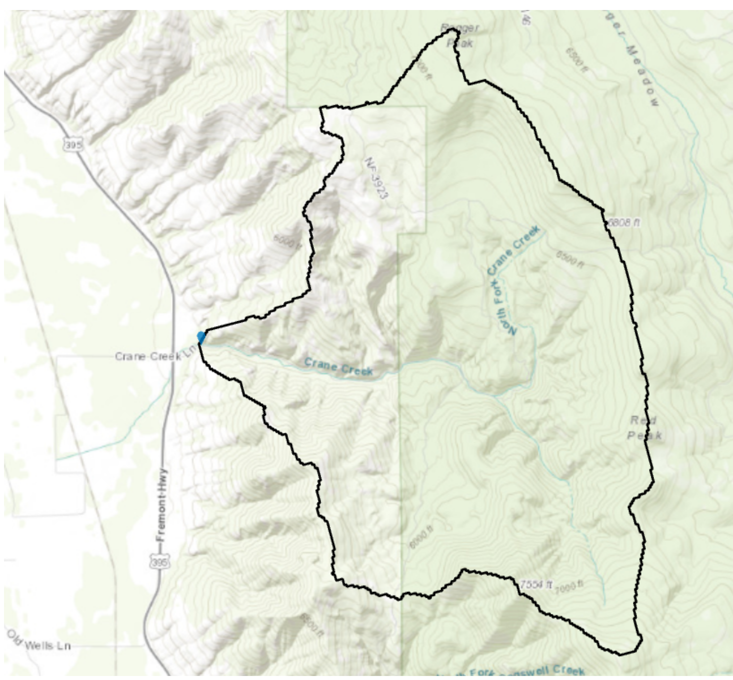


Figure 2

Once the watershed was located, I created a 100-foot buffer zone around the watershed and extracted the DEM file so that it covered the area of interest. Once the DEM, watershed, and point were established I projected my data set and reprojected the DEM into NAD 1983 (2011) State Plane Oregon South FIPS 3602 (Intl Feet). This allows me to have consistency across my measurements.

From this point I began analyzing the watershed using multiple GIS processes. The first process I completed was filling the DEM file to ensure there were no sections of the watershed that would not contribute to flow. Once the fill process was complete, I used the difference in DEM and fill raster values to find areas that had been filled and to check how large those areas are.

Figure 23 shows the areas that were filled in the DEM.

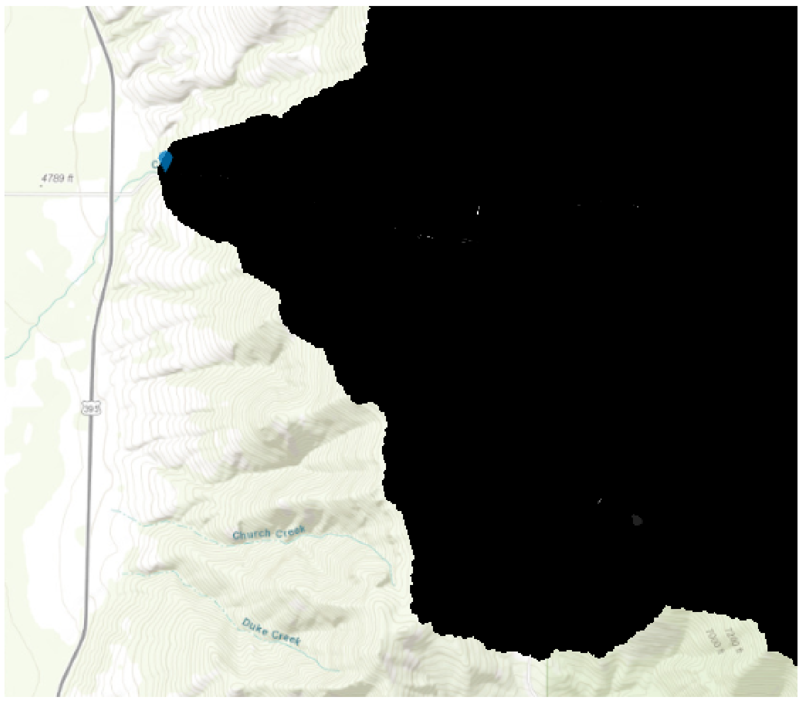


Figure 3

The areas and depths filled were not significant and can be ignored for the calculations I am researching. Once the fill was complete, I created 100ft contour mapping of the watershed which aligned with the DEM elevation model and shows the overall formation of the watershed in more detail. The contour mapping verified the high elevation edges of the watershed that flows into Crane Creek.

Contour mapping in Figure 4 shows the elevation contours at 100-foot increments.

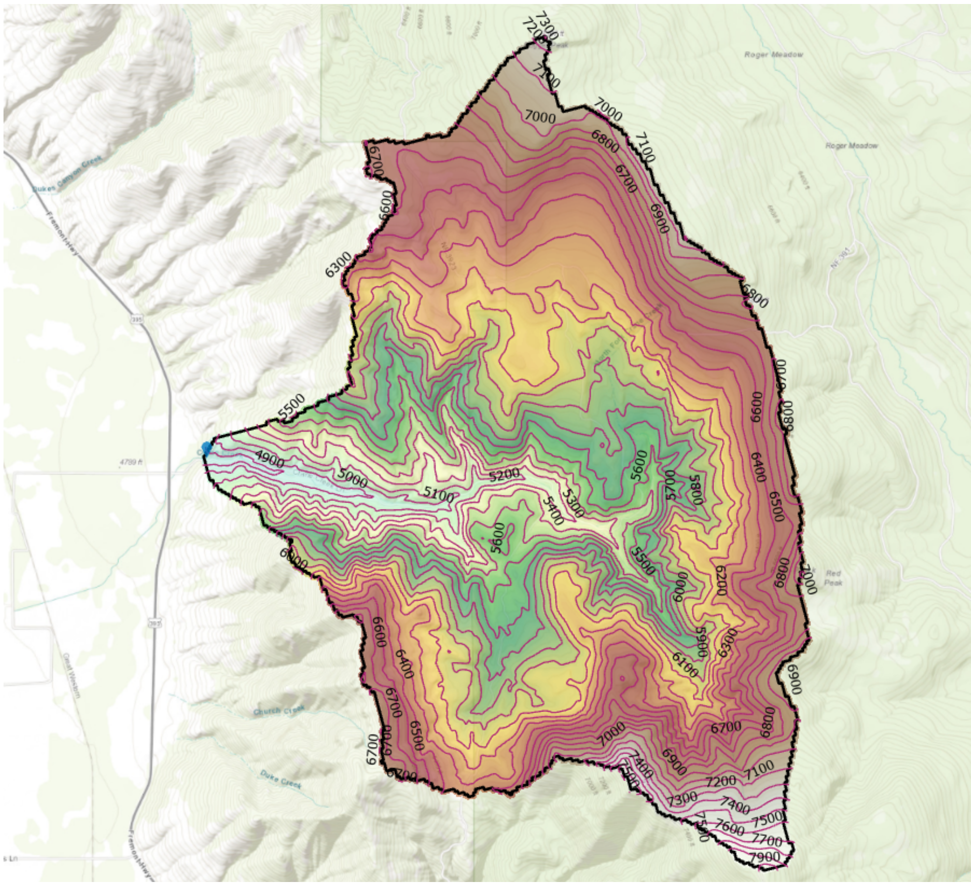


Figure 4

I then created a Hillshade layer of the watershed using the DEM layer. Combining the DEM, Contour, and Hillshade layers into one image the watershed shape becomes very clear and allows general analysis even without calculations by observations. This can be very helpful as more detailed information is collected as a check for reasonableness.

Figure 5 shows the final watershed terrain analysis.

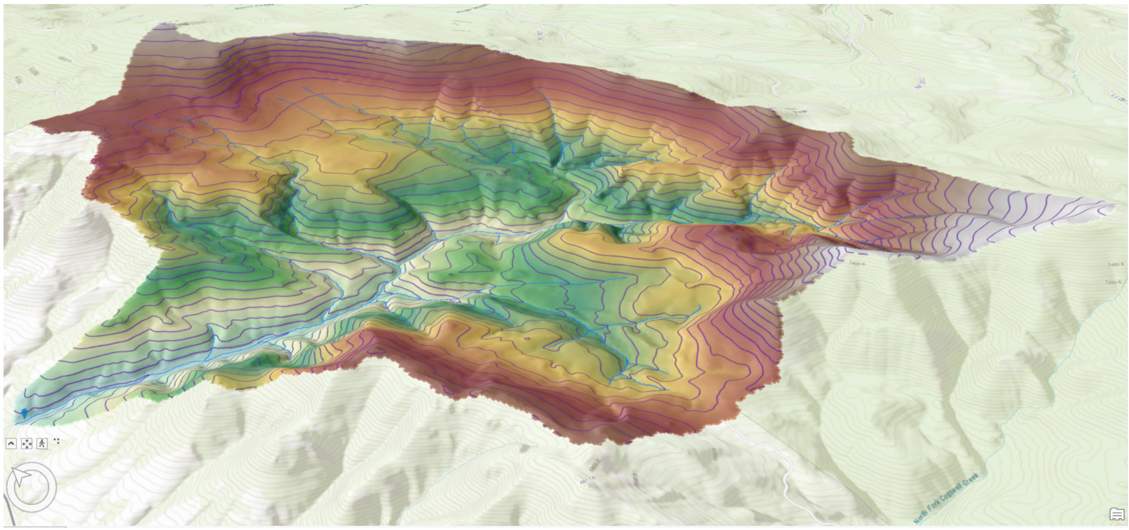


Figure 5

Once the terrain analysis was completed, I began flow analysis on the watershed. The first step of this process was identifying the flow directions within the watershed. I completed this using the GIS flow direction with D8 flow directions, that produced outputs of both a flow direction and drop raster. Then using the flow direction raster, I created a flow accumulation model and adjusted the symbology so that it was clear what amount of grid cells were flowing into the different sections.

Figure 6 shows the flow accumulation with adjusted symbology using cell counts.

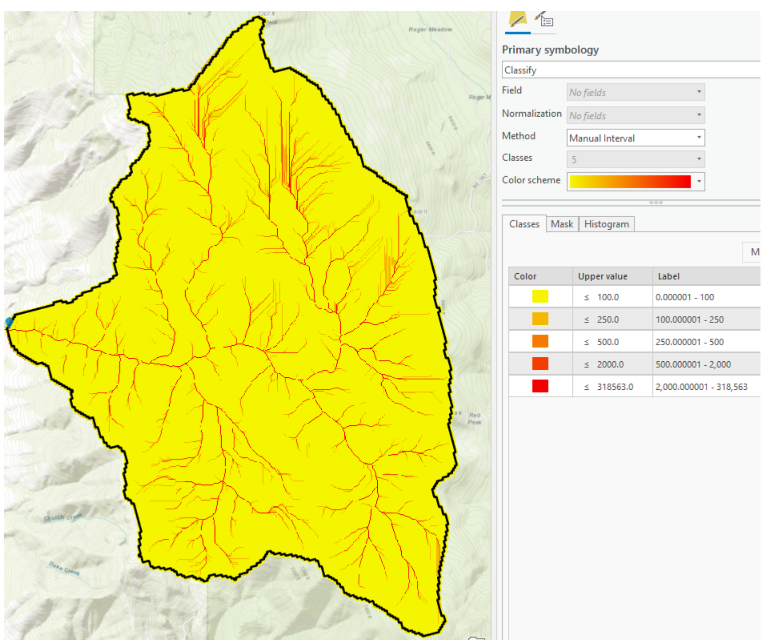


Figure 6

Once the flow accumulations were completed, I was able to calculate the area of the watershed that flows directly into Crane Creek. Based on the grid cell size of 32.8 by 32.8 feet and a total grid count of 318419 cells, I found the total drainage area to be 342643205.8 square feet or 12.3 square miles.

Figure 7 shows the cell count found at the outflow of the watershed into Crane Creek.

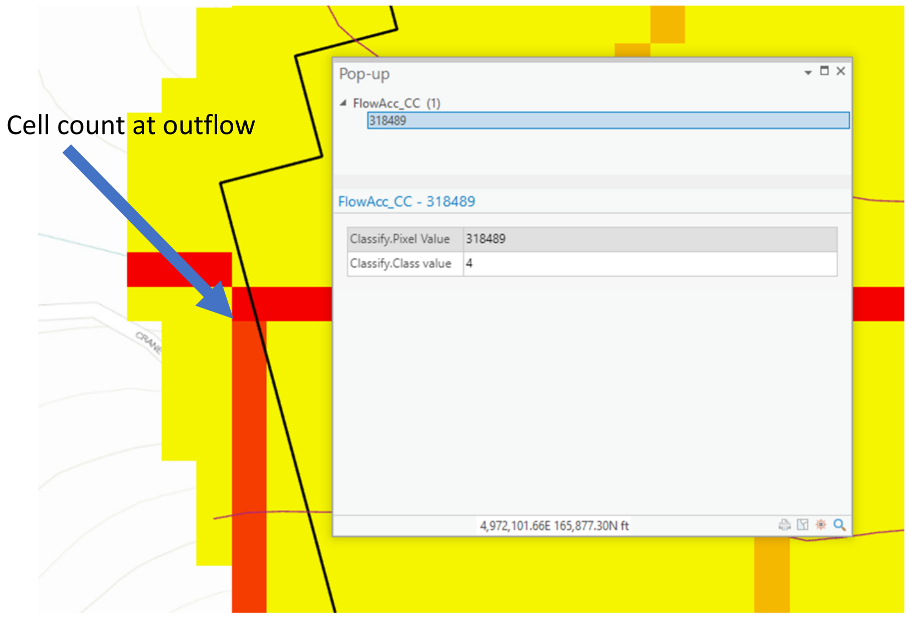


Figure 7

Once the flow accumulation was complete, I used that data to set a minimum threshold for stream definition. I used a value of 2500 cells as a minimum number of cells flowing into a section and was able to define a clear stream system within the watershed. I then compared my results with the NHD flowline data and found my streams to be very similar to NHD stream data. The smaller amount of stream lengths on my GIS data are based on my minimum threshold for cell count.

Figure 8 shows the comparison of stream definition using GIS flow accumulation (Blue) vs the NHD flowlines (Red).

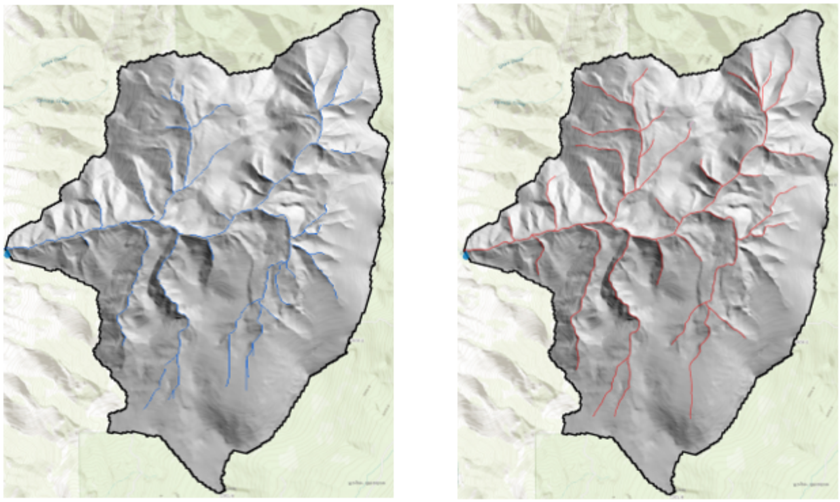


Figure 8

The next step was to create stream links between all the sections of defined streams using the GIS stream link function. This allows for each stream section to have a unique identifier and to create smaller catchments within the whole watershed. I then used the GIS watershed function with the flow direction and stream links to create a layer that shows all the individual catchments within the watershed. The total count according to the catchment function was 73 individual catchments.

Figure 10 shows the breakdown of catchments within the Crane Creek watershed.

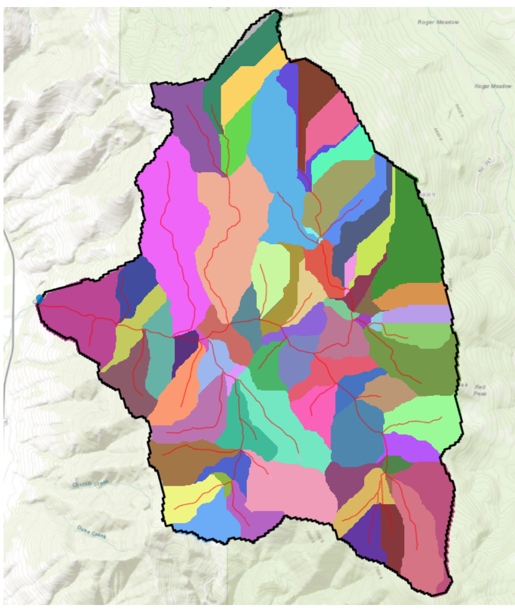


Figure 9

Once the flow analysis was complete, I then performed a TR-55 analysis using the GIS data. This was to find the peak flow value based on total watershed area, travel time of water through the watershed, soil class and vegetation, and precipitation based on 100-year interval storm values in the watershed area. The data collected from this analysis are shown in the results section of the report.

I collected a soil class sample from the USGS soil survey within the watershed, that was used to calculate a composite runoff curve number. This number is used to calculate the total runoff using the TR-55 method.

Figure 10 shows the breakdown of soil types in the watershed.

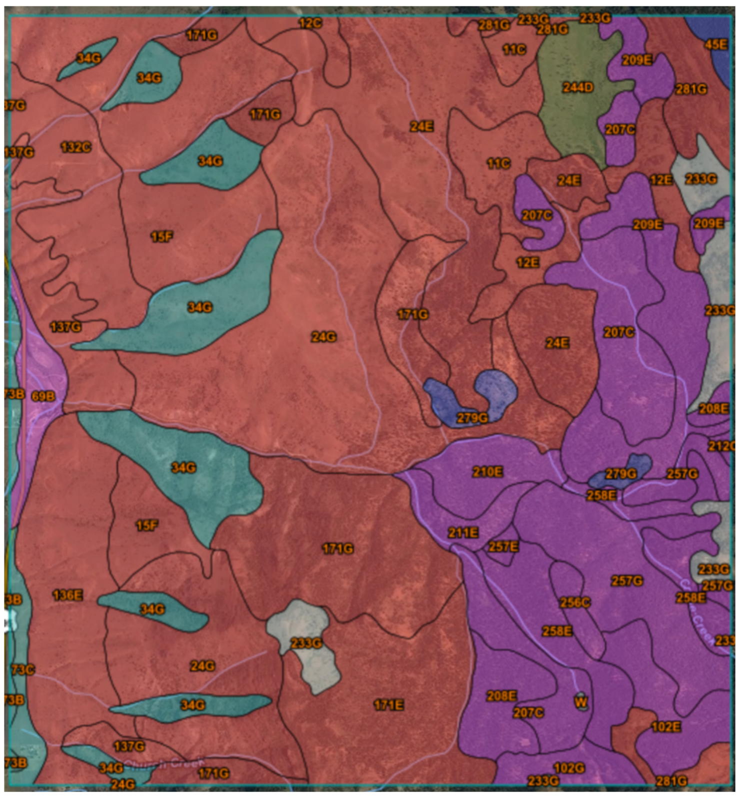


Figure 10

Based on the variation of the soil composition and vegetation, I estimated a curve number between 65 and 70 for the longest plow path. I then used the Atlas 2 Volume 10 for Oregon to estimate a rainfall of 2.80 inches for the Crane Creek watershed based on a 24-hour 100-year storm.

The next calculation I made was the travel time along the longest flow path. I used Manning's kinematic equation for overland sheet flow velocity, TR-55 Figure 3-1 for shallow concentrated flow, and Manning's equation for velocity in open channels, to solve for the travel time across the flow path. Based on the composite flows and stream lengths I found an average travel time for water to be 4 hours. I then completed the TR-55 hand calculations to estimate a peak flow value for Crane Creek.

The next section of my analysis was to create a topographic analysis of the project area and Crane Creek to calculate the potential risk of flooding. I used both 1 foot contour intervals and flow direction to estimate the stream location and Highway 395, then verified using NHD and ODOT transportation data.

Figure 11 shows the project location stream estimation with NHD known stream location (Blue), ODOT roadway location (Black), and ODOT Culvert (Red).

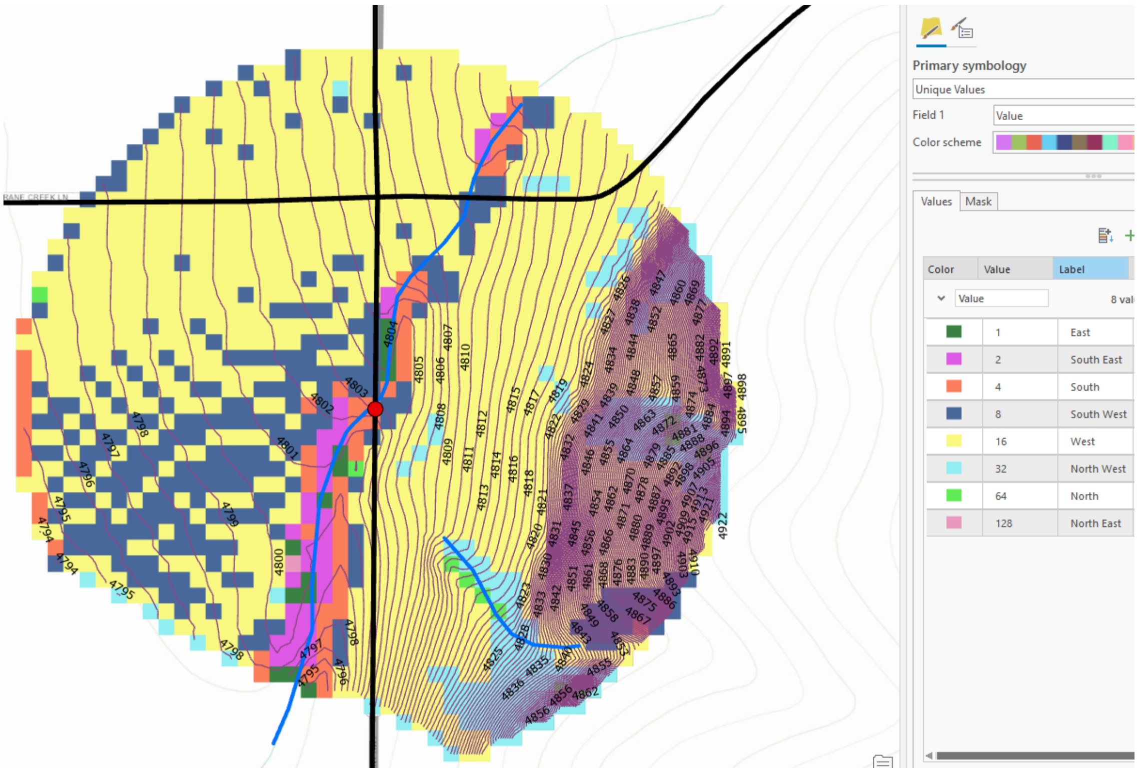


Figure 11

The location of the stream was found where flow directions face towards each other or in the same direction forming a "stream" where flows concentrate, and then verified using the stream flowlines from NHDS. Using the contour mapping elevations, flow directions from GIS and ODOT roadway data, I calculated the average height of the road surface north of Crane Creek Culvert. Based on visual analysis of this data I was able to assume potential flood risk locations based on surface heights and flow directions.

Figure 12 shows area north of ODOT culvert where both elevation and flow direction contribute to highway overtopping risk.

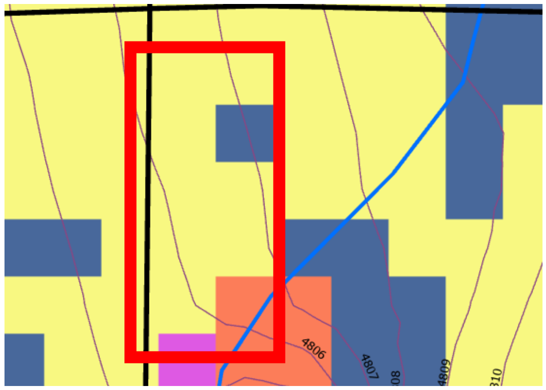


Figure 12

I used the peak flow and known culvert dimensions to calculate head height at peak flow, using the HY-8 program provided by the Federal Highway Administration. Figures 13 and 14 show the Hy-8 outputs.

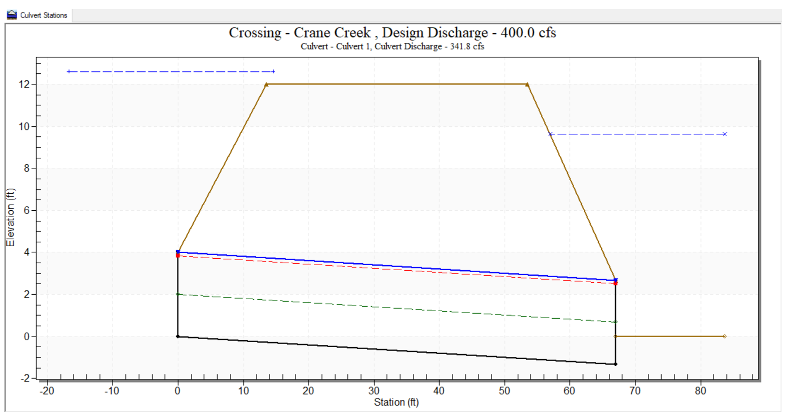
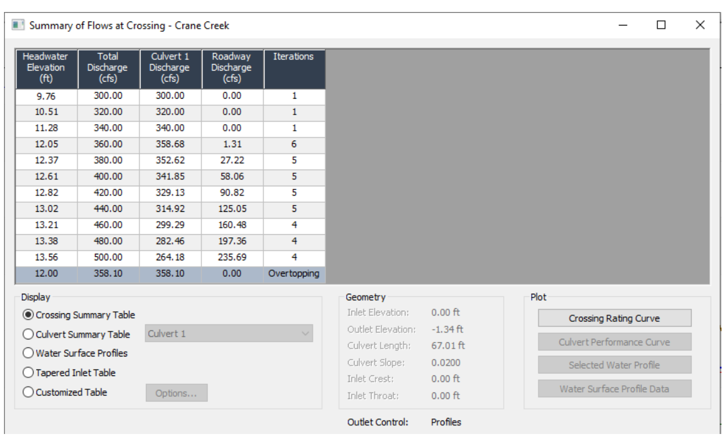


Figure 13


Summary of Flows at Crossing - Crane Creek

Headwater Elevation (ft)	Total Discharge (cfs)	Culvert 1 Discharge (cfs)	Roadway Discharge (cfs)	Iterations
9.76	300.00	300.00	0.00	1
10.51	320.00	320.00	0.00	1
11.28	340.00	340.00	0.00	1
12.05	360.00	358.68	1.31	6
12.37	380.00	352.62	27.22	5
12.61	400.00	341.85	58.06	5
12.82	420.00	329.13	90.82	5
13.02	440.00	314.92	125.05	5
13.21	460.00	299.29	160.48	4
13.38	480.00	282.46	197.36	4
13.56	500.00	264.18	235.69	4
12.00	358.10	358.10	0.00	Overtopping

Display
Crossing Summary Table
Culvert Summary Table Culvert 1
Water Surface Profiles
Tapered Inlet Table
Customized Table Options...

Geometry
Inlet Elevation: 0.00 ft
Outlet Elevation: -1.34 ft
Culvert Length: 67.01 ft
Culvert Slope: 0.0200
Inlet Crest: 0.00 ft
Inlet Throat: 0.00 ft

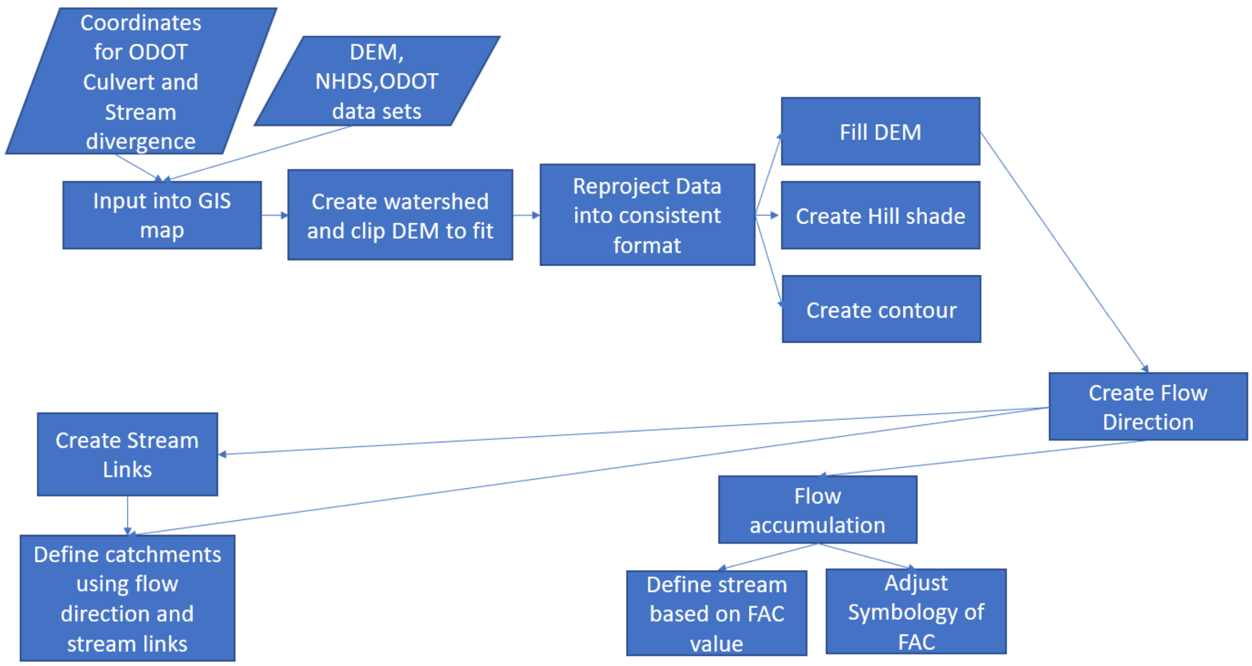
Plot
Crossing Rating Curve
Culvert Performance Curve
Selected Water Profile
Water Surface Profile Data

Outlet Control: Profiles

Figure 14

Process Flow

GIS analysis Process Flowchart



Results:

From the terrain and flow analysis of the project location and Crane Creek watershed I was able to calculate the following:

- Total watershed area of 12.3 square miles
- Within the watershed the longest flow path was approximately 6 miles.
- Travel time for water along the longest plow path is approximately 4 hours.
- The composite runoff curve number for TR-55 method was between 65-70
- Average height difference between stream bed and ODOT roadway surface is 4 to 6ft.
- Peak flow based on variation of CN and amount of flow split north and south was 300-500 CFS at the ODOT culvert.
- Hy-8 modeling showed that Culvert dimensions would need to be increased to accommodate flows above 350 CFS.
- Area of roadway found to be at risk was located at known highway flood area.

Discussion:

Based on the results of the GIS analysis, I was able to obtain enough information to verify the flood risk associated with the Highway 395 Crane Creek culvert. The area north of the culvert are both lower in elevation and have slopes that would move the water towards the highway surface once flows rose above stream height. With the average peak flows for a major storm event, there would be headwater heights well above the roadway surface near the culvert, if there was no outlet area for the water other than the culvert or stream channel.

Based on the flow directionality the water would move north to the lower elevation area, as it raised above the stream channel height and pool near the highway until the height of the water raised above the roadway surface. Although this data does not give an exact point of failure for the culvert, it could be refined further or used as a risk assessment tool for similar areas.

I attempted to use HAND methods to verify flood risk originally, but because the culvert sits in a relatively flat zone, away from the watershed it collects from, GIS would add false catchments. I believe this is due to the combination of having only a 10-meter resolution DEM for contours and flow directions, and the north and south split for Crane Creek. If higher resolution raster data were available, it would be possible to contour map the stream and calculate flow volume that would create flood stages as used in the HAND method. I could see that at the point of north/south split there would be flood risks, but this data was discarded as it would not be acceptable for the project.

The use of GIS to collect watershed data and apply it to a project area at a distance from the watershed does lead to some known discrepancies depending on that distance. There would be additional flows into the stream and other factors, such as man-made divergences in the stream or water pumps could affect the data. However, I feel that even with these potential errors the data can be very useful to gain insight into the hydraulic properties of a project area.

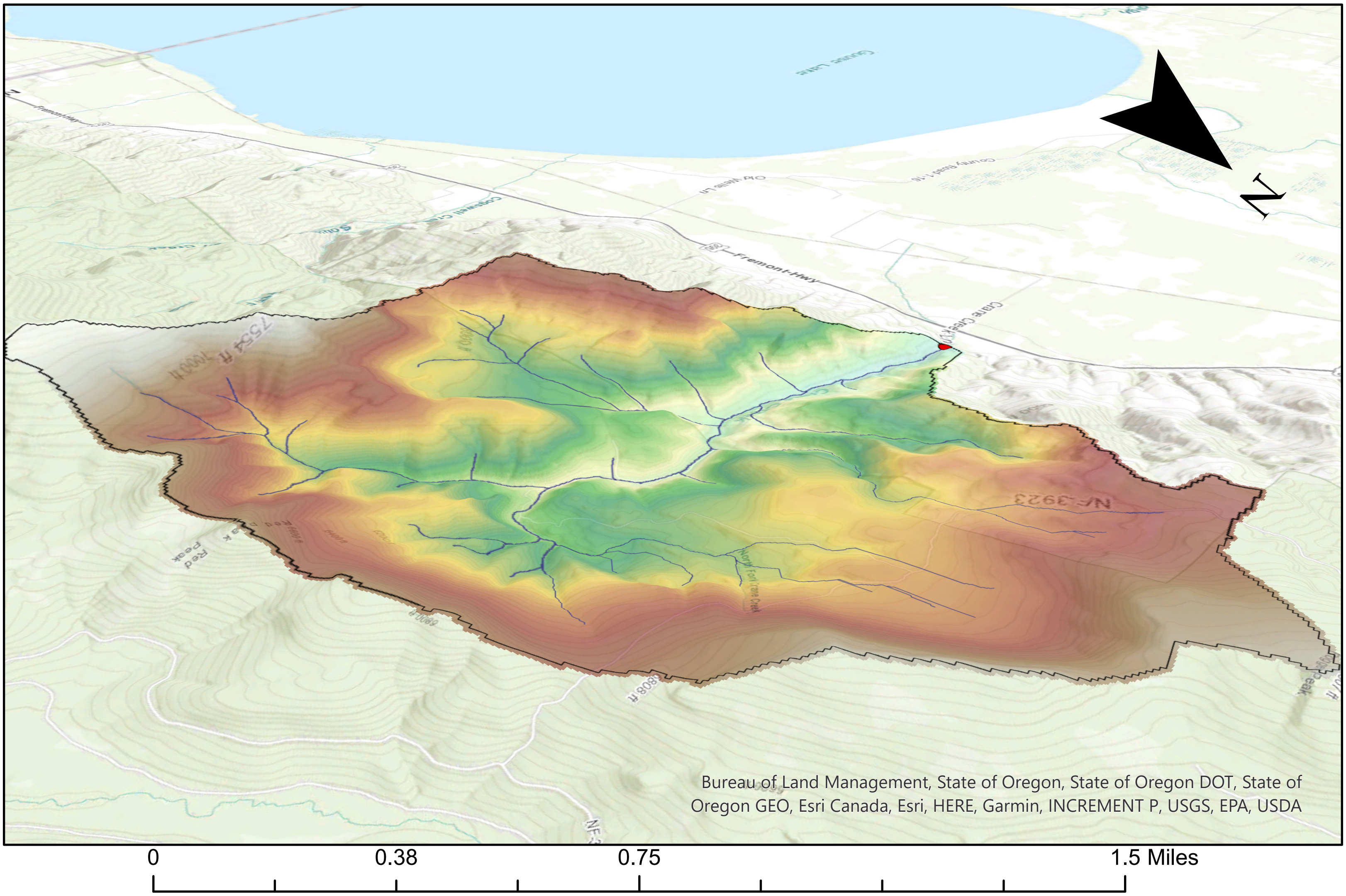
References:

"Highway Design Manual." *Oregon Department of Transportation : Highway Design Manual : Engineering : State of Oregon*, 2012, www.oregon.gov/ODOT/Engineering/Pages/Hwy-Design-Manual.aspx.

"Hydraulics Manual." *Oregon Department of Transportation : Hydraulics Manual : Geo-Environmental : State of Oregon*, 2014, www.oregon.gov/ODOT/GeoEnvironmental/Pages/Hydraulics-Manual.aspx.

Web Soil Survey (WSS), 4 Mar. 2016, www.usgs.gov/data-tools/web-soil-survey-wss.

Crane Creek Watershed and ODOT culvert project zone



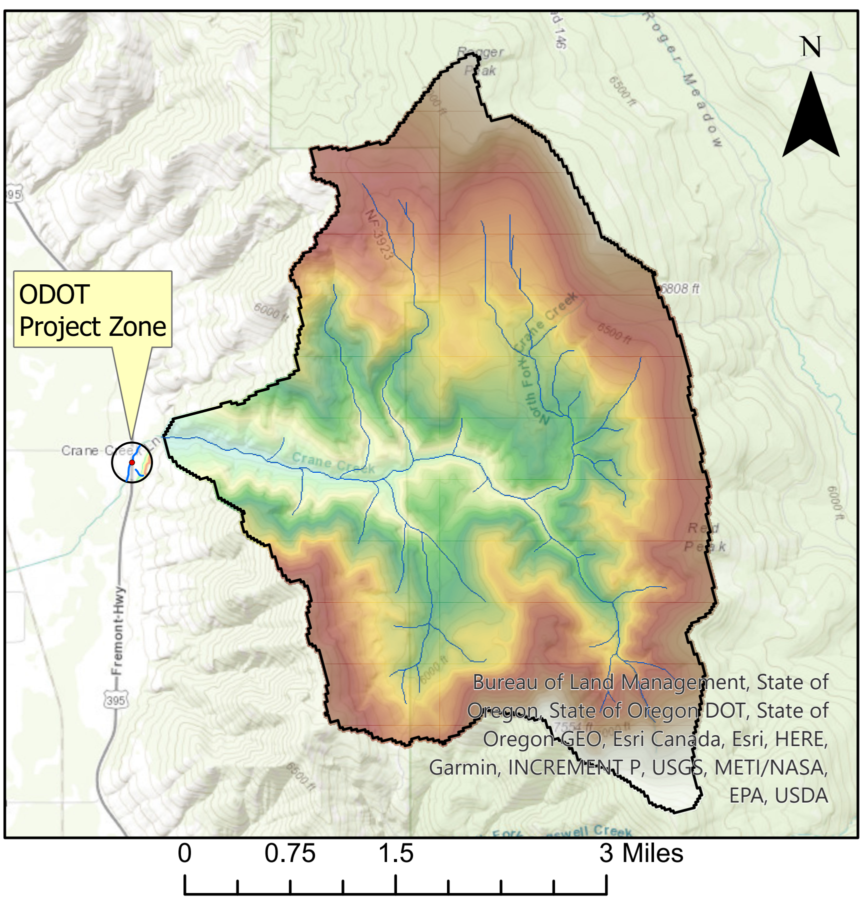
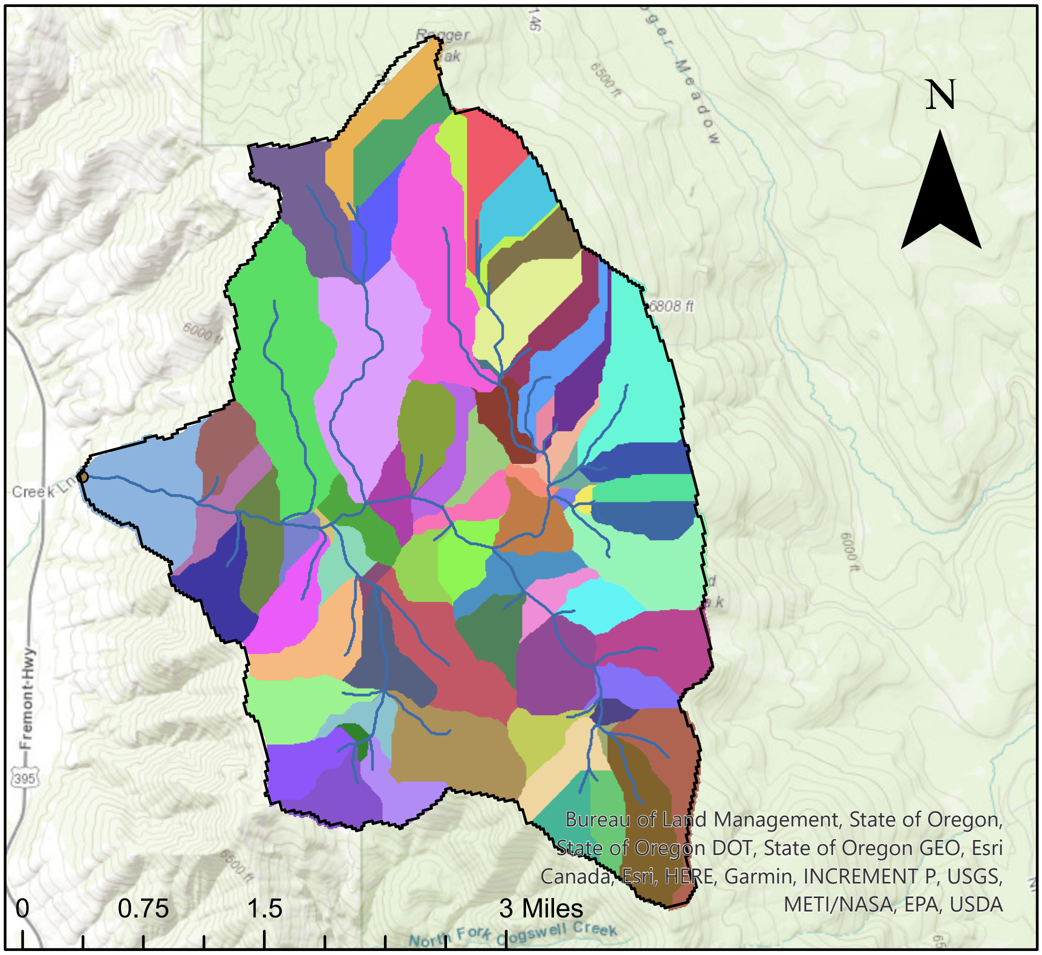


Figure 1 above shows the topographic layout for the Crane Creek watershed in Lake County Oregon. The watershed is located approximately 5 miles south of the town of Lakeview. The watershed flows into Crane Creek before the stream splits north and south.

Figure 2 left shows the ODOT culvert project zone near the Crane creek watershed. The culvert allows the flow of South Crane Creek below Highway 395. The ODOT project is concerning the possible reconstruction of the culvert based on the current design not meeting flow requirements at high flow conditions.



Crane Creek Watershed Catchments

Summary of Catchment Data

Area: 12.3 Square miles

Catchments: 73

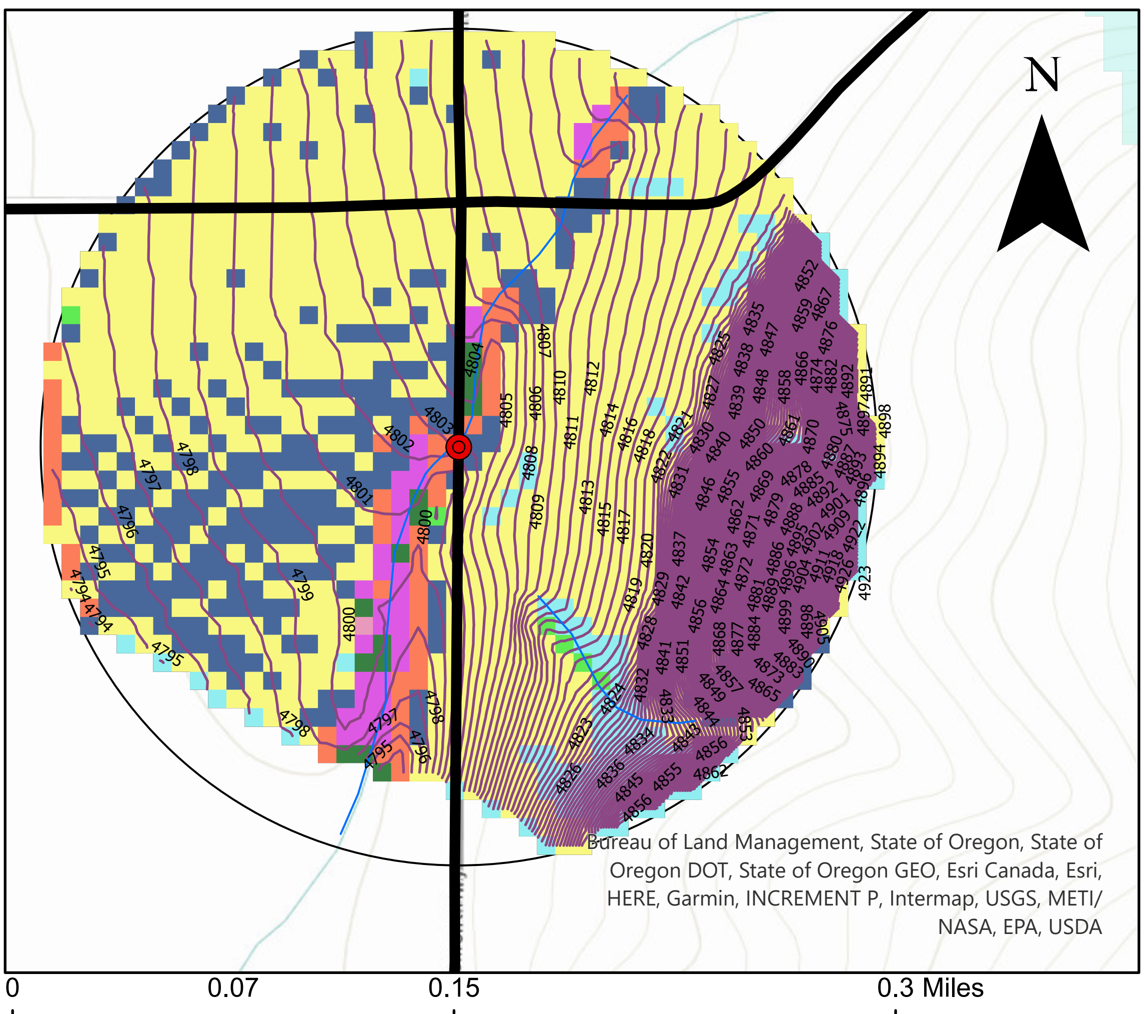
Average area of catchment: 4364 square feet

Total stream length: 24.25 miles

Longest flow path: 6 miles

Figure 1 (Left) shows the final data collected from the watershed delineation of the Crane Creek watershed.

ODOT Project Zone
750 foot buffer from Culvert



ODOTCulvert

ODOT roadways

Project Flow Direction

- East
- South East
- South
- South West
- West
- North West
- North
- North East

Figure 2 (left) shows the flow direction of the ODOT project area and contour mapping.

The known locations of Crane Creek. Highway 395, and Crane Creek road are displayed to show reasonableness of stream location using flow direction and contour mapping.