DEPARTMENT OF TRANSPORTATION

Extreme Flood Vulnerability Analysis

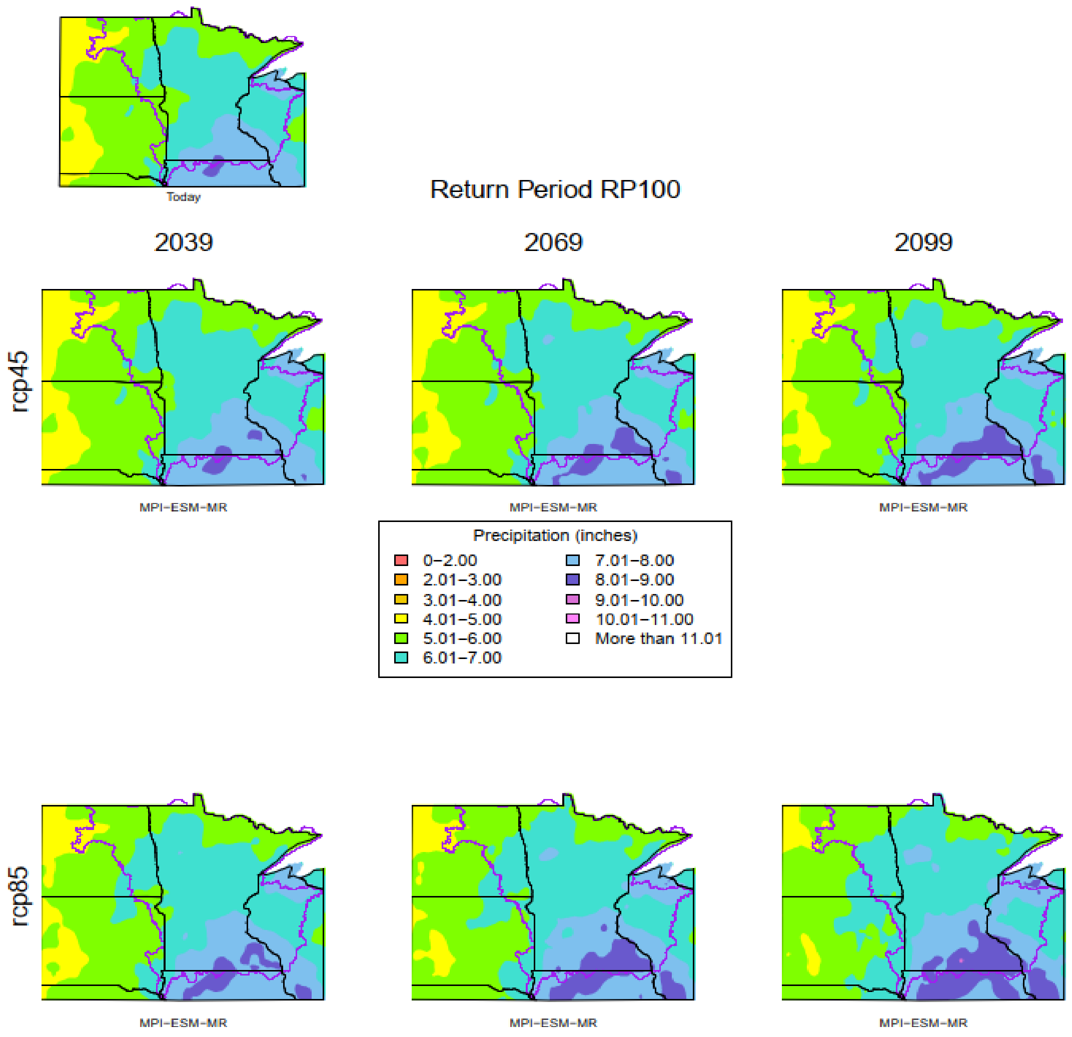
Chris Dorney (WSP) | PM
Josh Amos (WSP)
Gregg Cornetski (WSP)
Peter Enright (WSP)
Tim Grose (WSP)

Agenda

- Introduction to the project
- Methodology overview
  - Phase 1: Flood Exposure Analysis
  - Phase 2: Risk Analysis
- Next steps

Introduction to the Project

- Motivation: Extreme precipitation is increasing; develop a method to efficiently understand current and future (climate change-influenced) flood risk to MnDOT…
  - Bridges
  - Bridge-culverts
  - Pipes
- Assets to which the method is not applicable
  - Bridges on large rivers with drainage areas exceeding regression equation maximums
  - Small pipes with drainage areas smaller than regression equation minimums



Key Project Outputs

- Flood exposure data by asset

P_2261376		1xPipe Ellipse 69"x49" INV: 1149.192					
Road EL:	1155.77	Culvert Crown EL:	1153.22		Low Road EL:	1155.67	
Return Period	Current	RCP 4.5			RCP 8.5		
		2039	2069	2099	2039	2069	2099
2	1151.61	1151.81	1151.96	1152.13	1151.89	1152.15	1152.41
5	1153.09	1153.22	1153.34	1153.45	1153.29	1153.45	1153.63
10	1154.09	1154.20	1154.30	1154.40	1154.26	1154.40	1154.55
25	1155.40	1155.59	1155.78	1155.82	1155.69	1155.77	1155.83
50	1156.06	1156.08	1156.10	1156.13	1156.09	1156.11	1156.15
100	1156.28	1156.27	1156.32	1156.32	1156.31	1156.37	1156.36
500	1156.70	1156.76	1156.74	1156.72	1156.70	1156.72	1156.77

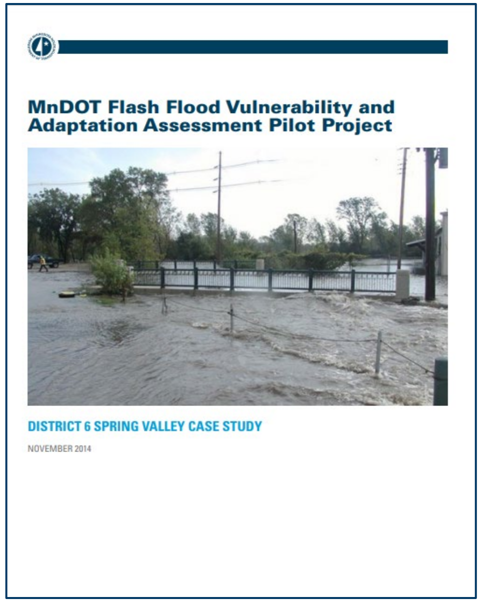
Water Above Minimum Bridge Deck Elevation or Road Elevation Above Culvert	->	
Water Above Bridge Low Chord Elevation or Top of Culvert Elevation	->	
Water Above Roadway Sump Elevation	->	###
Glass-Walling Occuring	->	###

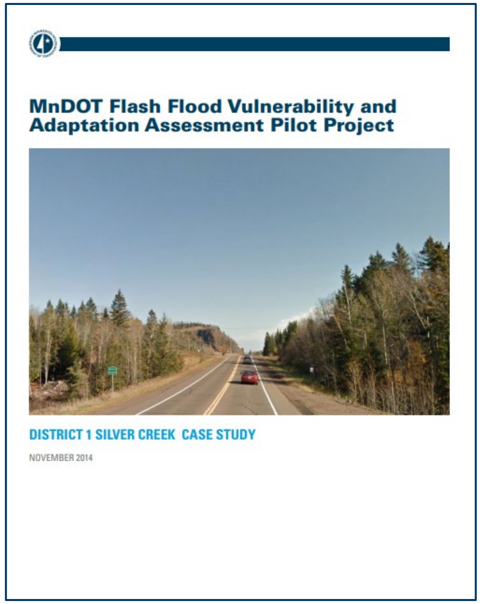
- Flood risk data by asset
  - "Do-nothing" lifecycle costs through the year 2100

Asset	Moderate Climate Scenario (RCP 4.5)					High Climate Scenario (RCP 8.5)				
	Total Costs (Median)	Total Costs (Lower Conf. Int.	Total Costs (Upper Conf. Int.)	Agency Costs	User Costs	Total Costs (Median)	Total Costs (Lower Conf. Int.	Total Costs (Upper Conf. Int.)	Agency Costs	User Costs
1	$	$	$	$	$	$	$	$	$	$
2	$	$	$	$	$	$	$	$	$	$
...	$	$	$	$	$	$	$	$	$	$
N	$	$	$	$	$	$	$	$	$	$

Potential Use Cases for the Outputs

- Prioritizing assets for facility-level adaptation assessments
- Development of the transportation asset management plan (TAMP)
- Informing emergency response planning
- Identifying potential enhancements to operations and maintenance activities





DEPARTMENT OF TRANSPORTATION

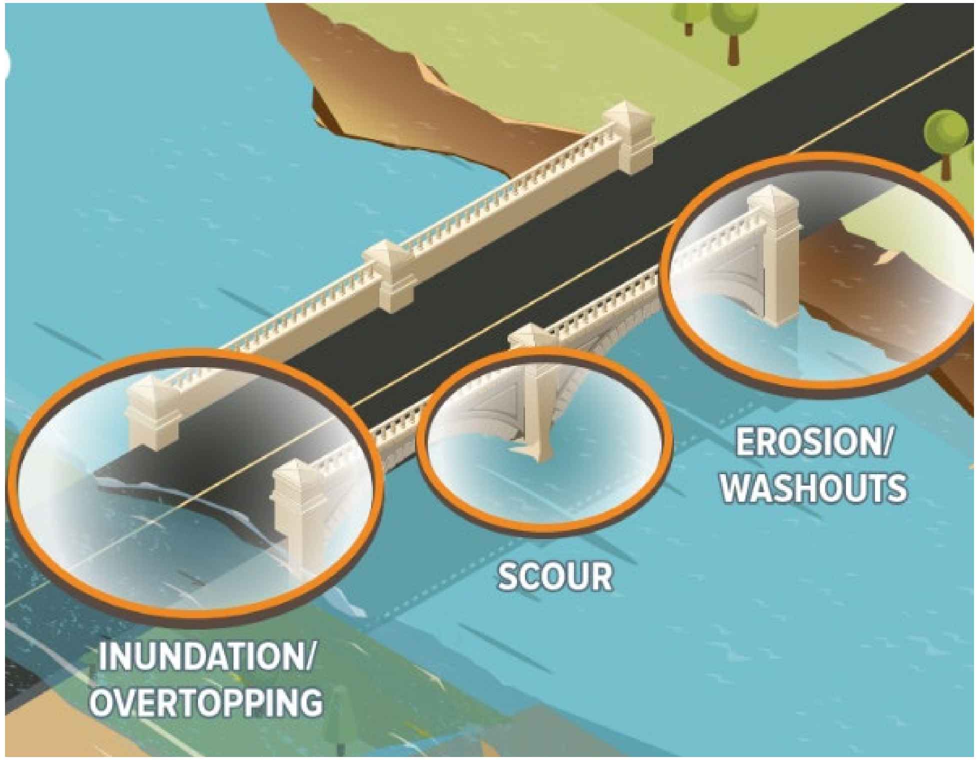
Methodology Overview

A Quantitative Risk Approach

- Calculate expected costs (risk) to assets from climate stressors if no adaptation actions are taken
- Costs estimates include
  - Damage and repair costs
  - Costs to system users

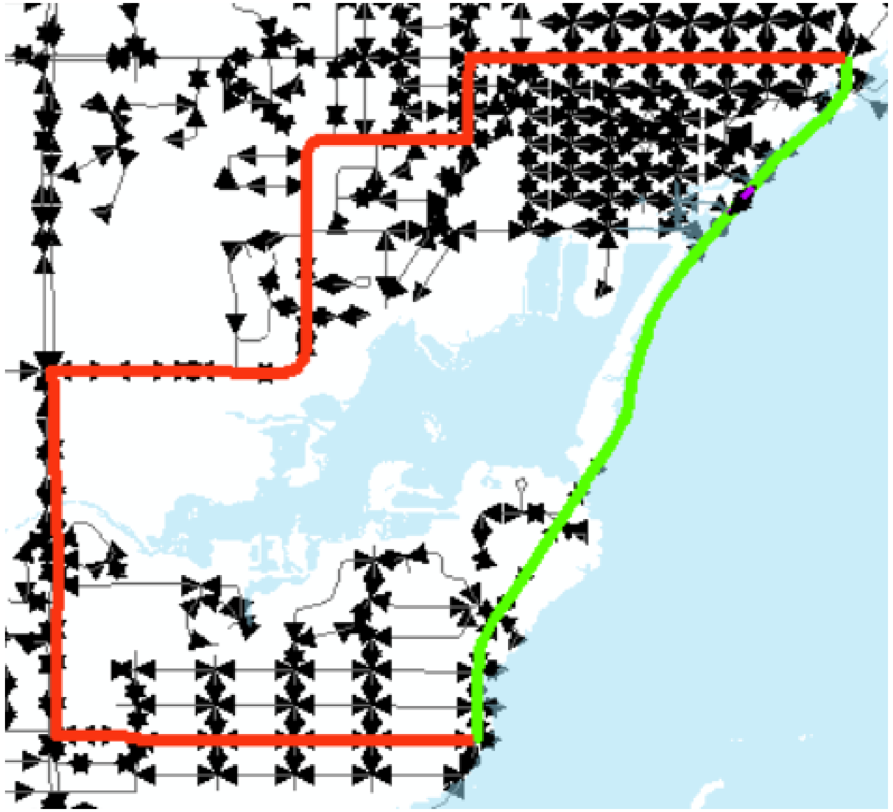
Physical Damage Assessment

- Estimate damage costs at each asset from projected flood events
- Roadway damage model (approaches)
  - Pavement delamination
  - Embankment erosion
- Culvert damage model
  - Loss via embankment erosion
  - Outfall erosion
- Bridge damage model
  - Pavement delamination
  - Deck damage/displacement
  - Pier, abutment, & contraction scour



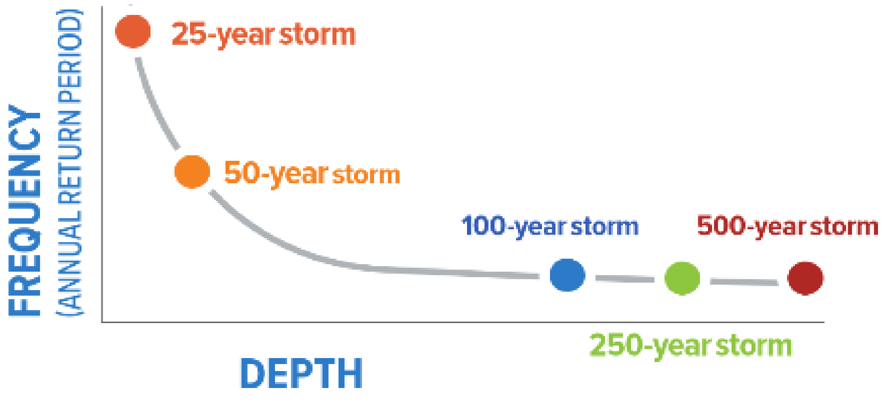
User Impacts Assessment

- Estimate costs to the traveling public for detouring around a flood-impacted asset considerate of…
  - Traffic volumes
  - Network redundancy
  - Estimated outage durations
  - Time, fuel, & operating costs
- To be implemented through a custom-designed detour routing algorithm run in GIS

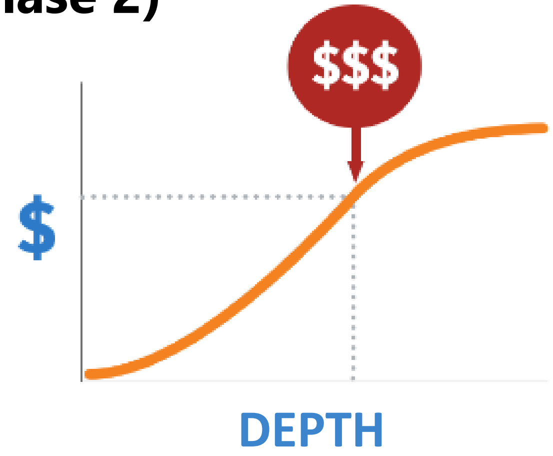


Quantifying Flood Risk

Exposure Likelihood (Phase 1)



Physical Damage & User Costs (Phase 2)



Total Expected Flooding Costs Through 2099 (Phase 2)

Key Steps in the Methodology

- Phase 1: Flood exposure analysis
  1. Preparation of hydraulic model inputs
  2. Running the hydraulic model
  3. Incorporating hydraulic model outputs in GIS
- Phase 2: Risk analysis
  1. Preparation of risk model asset data inputs
  2. Preparation of risk model user data inputs
  3. Running the risk models

DEPARTMENT OF TRANSPORTATION

Preparation of Hydraulic Model Inputs (Phase 1)

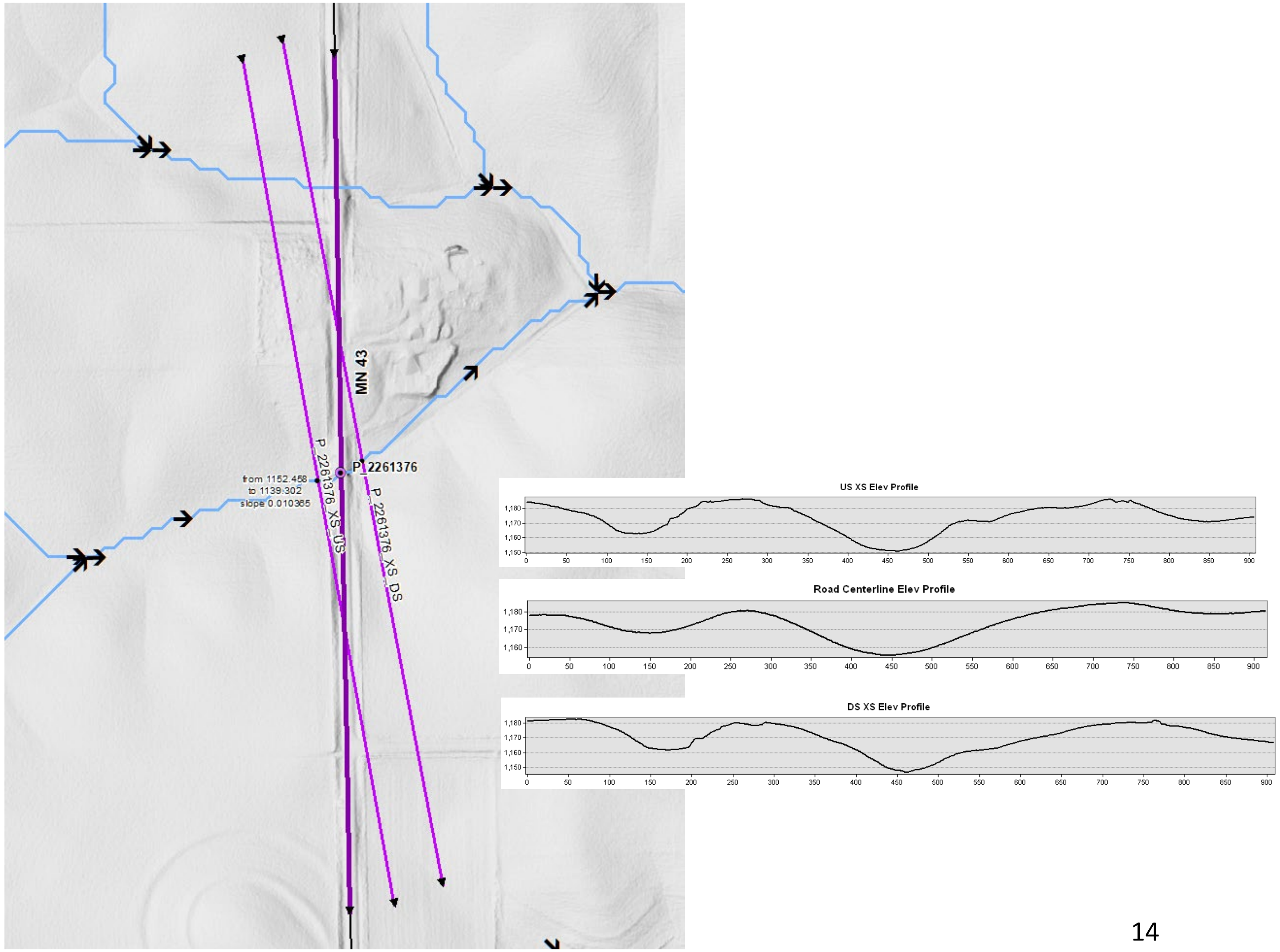
Gregg Cornetski

Required Data

- DEM
- MnDOT Stream Crossing Assets
  - Bridges, Bridge Culverts, Pipes
  - With MnDOT and NBI attributes, particularly the structure dimensions and other physical characteristics.
- Road Centerlines
- Stream Flow Lines
  - USGS StreamStats raster stream grid converted to stream flow lines
- Land Cover
- Current and Future Precipitation Depth Data
- Supplemental Reference Data
  - Aerial Imagery, Oblique Imagery, Google Earth, Google Maps, Google Streetview, NHD, MN DNR Hydrography

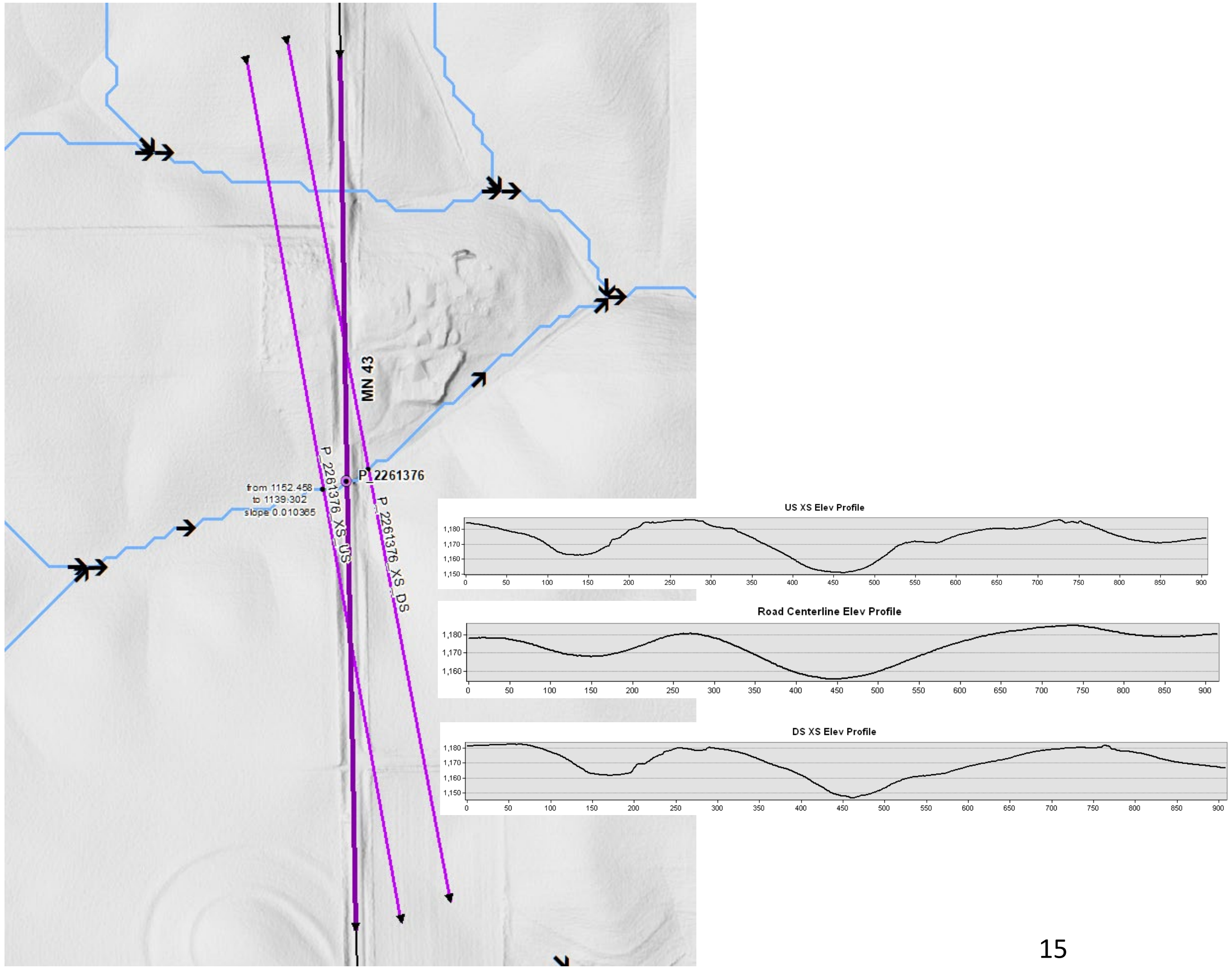
Prepare Inputs

- MnDOT stream crossing asset as point
  - Snap to intersection of the stream flow line it conveys and the road centerline it carries.
- Stream slope
- Stream cross section (XS) lines (1 upstream, 1 downstream)
- Stream XS elevation and land cover profile with Manning's Roughness Coefficient
- Road centerline with bridges delineated
- Road centerline elevation profile
- USGS StreamStats current peak flow statistics and drainage area
  - At stream crossing asset, US XS, and DS XS.
- Future peak flow statistics
- Watershed storage series



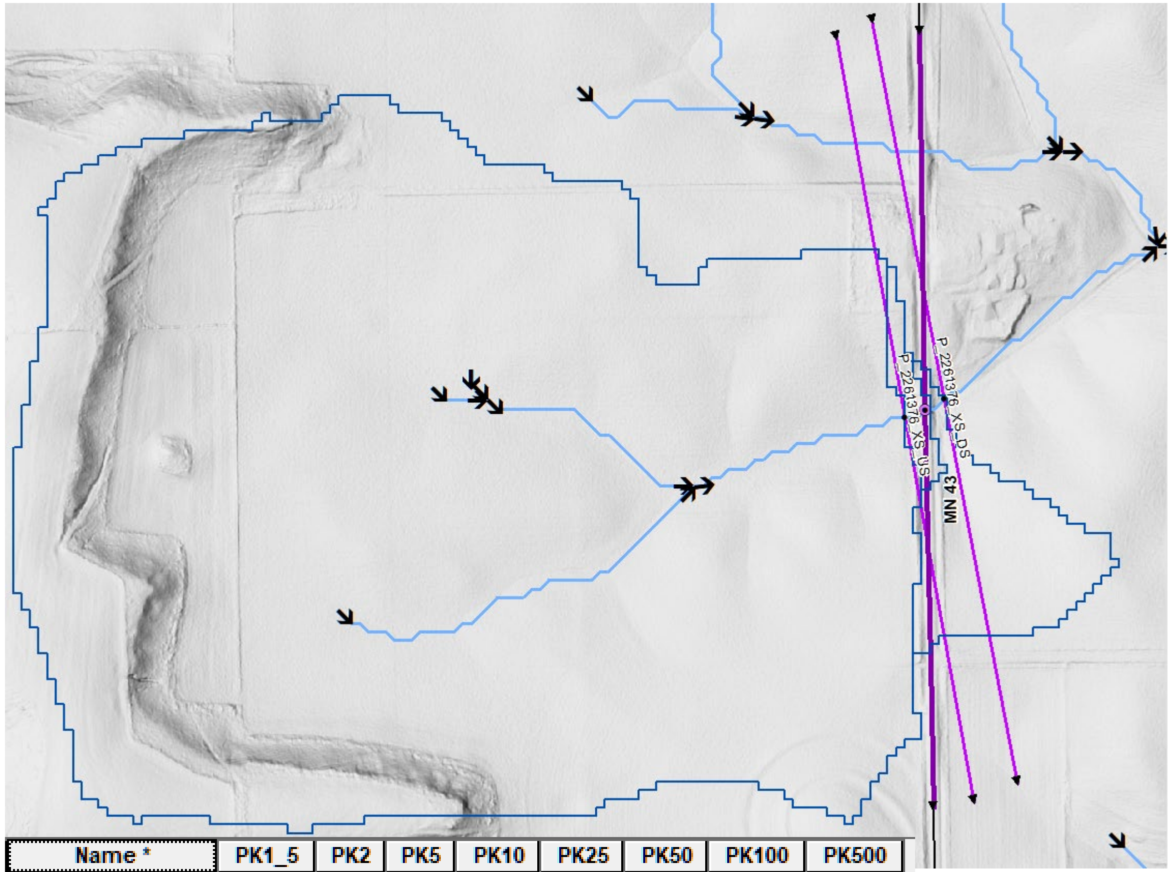
General Steps

1. Snap stream crossing asset point to the intersection of the stream it conveys and the road it carries
2. Determine slope of the stream conveyed by the asset
3. Create stream XS lines - 1 upstream, 1 downstream
4. Assign stream slope to stream XS lines
5. Create profile along stream XS line that depicts the elevation (from DEM), land cover (from land cover source), and Manning's Roughness Coefficient (function of land cover code) at each point along the XS line
6. Create profile along the road centerline carried by the stream crossing asset that depicts the elevation (from DEM) at each point along the road
7. Obtain current peak flow statistics and drainage area polygons from USGS StreamStats at stream crossing asset, US XS, and DS XS
8. Transform the current peak flow statistics to future peak flow statistics using current precipitation depth data and future precipitation depth data from climate models.
9. Calculate water storage capacity series in the stream crossing asset's watershed
10. Export stream crossing asset attribute table with current and future peak flows; road elevation profile table; stream XS lines attribute table with current and future peak flows; stream XS profile table; and watershed storage series
11. Determine flood water elevations and other metrics in the hydraulic model
12. Incorporate results from hydraulic model into GIS and assess the flood exposure (e.g. flood depths) at the asset and along its the road



Closer Look: USGS StreamStats and Current Peak Flows

- Query USGS StreamsStats application using its Batch Processing Tool
- Query the location on the stream where the asset is located and where its XSs are centered
- StreamStats returns peak flow statistics and drainage area polygons, among other information



Name *	PK1_5	PK2	PK5	PK10	PK25	PK50	PK100	PK500
P_2261376	33.7	53.9	128	199	316	428	558	946
P_2261376_XS_DS	34.6	54.9	129	199	315	425	552	930
P_2261376_XS_US	33.5	54	130	204	327	445	582	997

Closer Look: Future Peak Flows – The Flow Scaling Technique

1. Obtain current peak 2, 5, 10, 25, 50, 100, and 500-year stream flows from USGS StreamStats

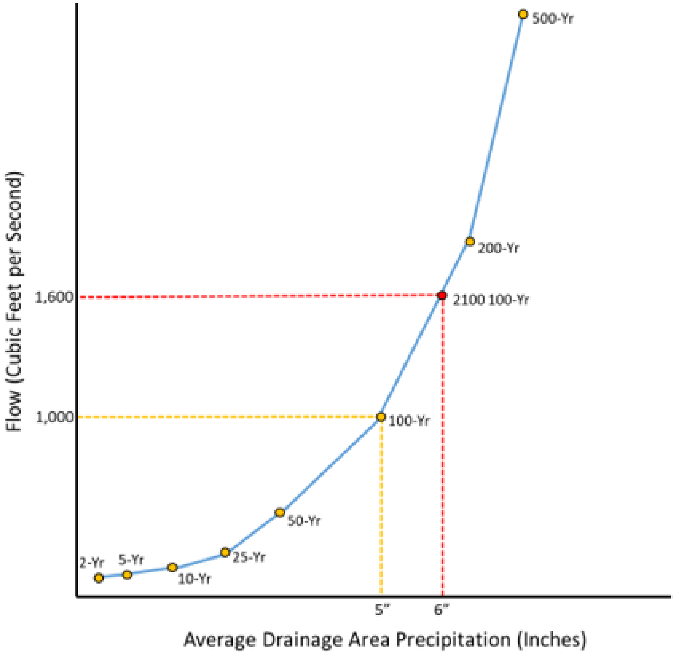
2. Obtain current 24-hour duration 2, 5, 10, 25, 50, 100, 200, and 500-year precipitation depths in the drainage area. AWM precip depths within each drainage area calculated using the drainage area polygon from StreamStats and the NOAA Atlas 14 gridded datasets of current precipitation depths.

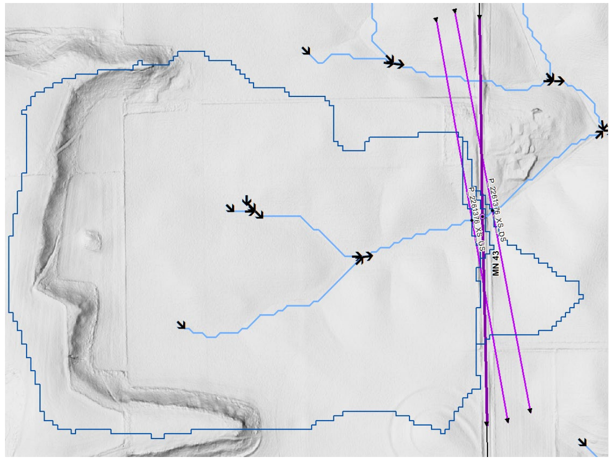
3. Associate the current peak stream flows with the current peak precipitation depths in the drainage area.

4. Create a relationship between the current peak stream flows and the current peak precipitation depths in the drainage area. See graph.

5. Obtain future 24-hour duration 2, 5, 10, 25, 50, 100, 200, and 500-year precipitation depths in the drainage area for each horizon year (early-, mid-, late-century) and each RCP (4.5, 8.5).

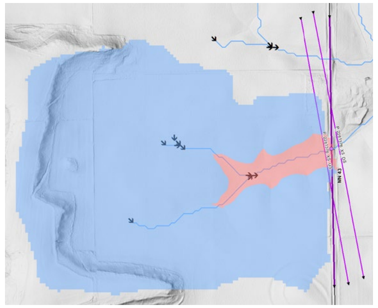
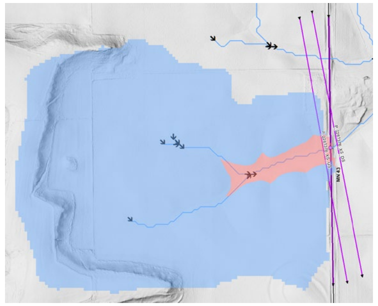
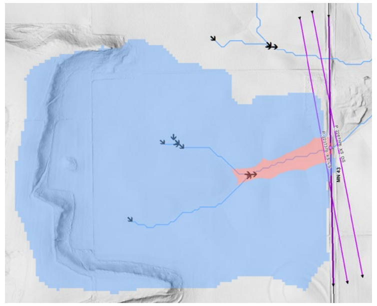
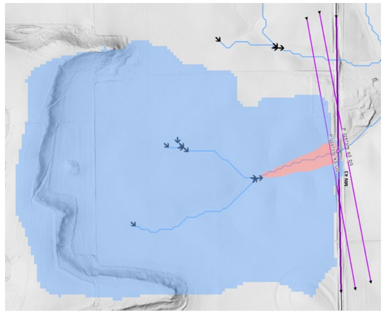
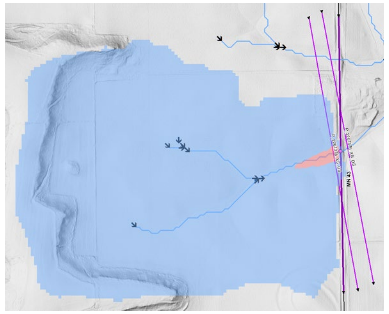
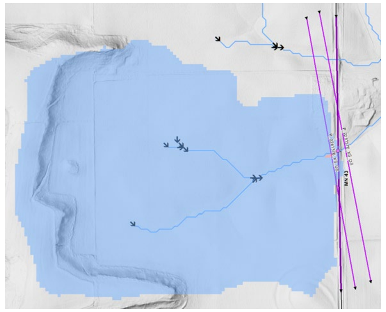
6. Estimate future 2, 5, 10, 25, 50, 100, 200, and 500-year peak stream flows for each horizon year (early-, mid-, late-century) and each RCP (4.5, 8.5). (Table shows only future 100-year peak flows for brevity).





Name *	PK1_5	PK2	PK5	PK10	PK25	PK50	PK100	PK500	Flw_100_Early_45	Flw_100_Mid_45	Flw_100_Late_45	Flw_100_Early_85	Flw_100_Mid_85	Flw_100_Late_85
P_2261376	33.7	53.9	128	199	316	428	558	946	571.35289	583.458726	595.595529	576.82155	594.017926	611.643823
P_2261376_XS_DS	34.6	54.9	129	199	315	425	552	930	565.0649	576.905091	588.770451	570.396807	587.196351	604.410018
P_2261376_XS_US	33.5	54	130	204	327	445	582	997	596.2023	609.084103	622.004372	602.024147	620.330787	639.105384

Closer Look: Watershed Storage Capacity Series

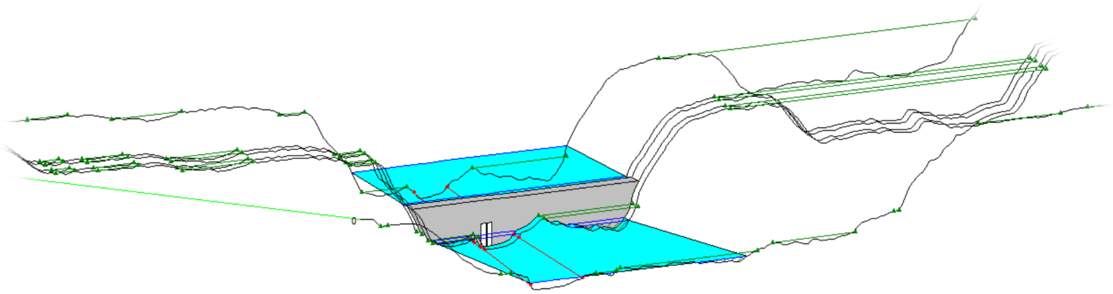
- Calculate the water storage capacity (i.e. volume) in the stream crossing asset’s watershed at an incremental series of water elevations above and below the elevation of the roadway embankment under which the bridge culvert or pipe is located
- Begins at 5 feet above the elevation of the roadway embankment and progresses downward in ½-foot increments to the elevation of the roadway embankment, and downward further until the elevation is reached at which there is no storage capacity.
- Enables the hydraulic tool to account for upstream storage and its attenuation of peak flows

Running the Hydraulic Model (Phase 1)

Peter Enright

Interfacing with HEC-RAS Hydraulic Models

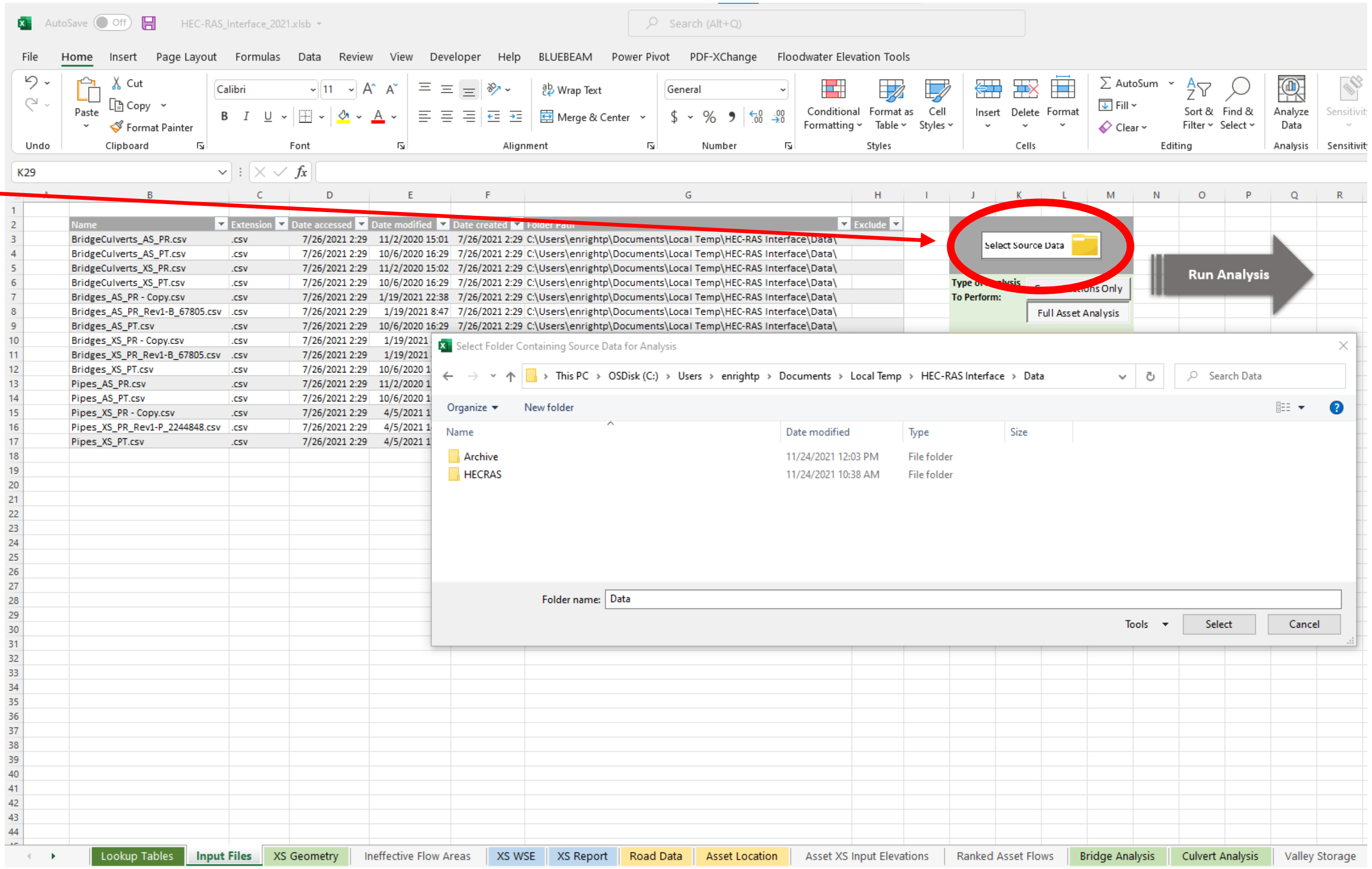
- Automated interface tools build and run HEC-RAS models to predict water surface elevations, velocities and other outputs for a range of scenarios
- Three distinct model types for:
    - Free flowing rivers
    - Bridge structures/obstructions
    - Culvert structures/obstructions



- Tools pre-process data and provide user opportunity to validate model inputs
- Model outputs can be reviewed by user before being exported

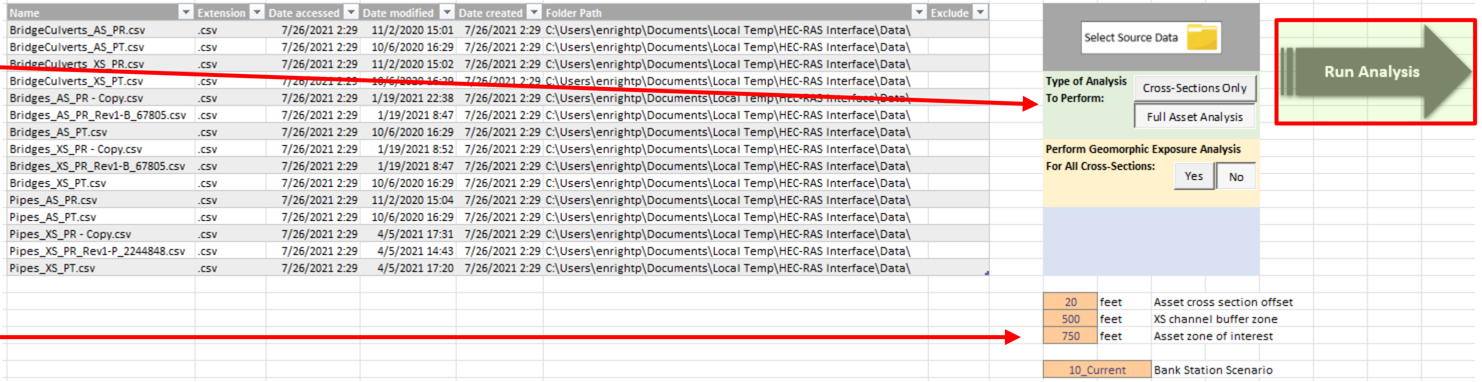
Importing Model Inputs and Pre-Processing

- Input Files sheet
  - ➢ Select Source Data button opens File Dialog
- User selects folder where all input files are stored
- Refresh input query tables
- Check input data tables
  - o Cross section geometry
  - o Asset location and properties
  - o Flow scenarios



Running Tools to Generate Model Results

- Two Modes:
  - Cross Sections Only
  - Full Asset Analysis
- Simulation Parameters



Name	Extension	Date accessed	Date modified	Date created	Folder Path	Exclude
BridgeCulverts_AS_PR.csv	.csv	7/26/2021 2:29	11/2/2020 15:01	7/26/2021 2:29	C:\Users\enrightp\Documents\Local Temp\HEC-RAS Interface\Data\	
BridgeCulverts_AS_PT.csv	.csv	7/26/2021 2:29	10/6/2020 16:29	7/26/2021 2:29	C:\Users\enrightp\Documents\Local Temp\HEC-RAS Interface\Data\	
BridgeCulverts_XS_PR.csv	.csv	7/26/2021 2:29	11/2/2020 15:02	7/26/2021 2:29	C:\Users\enrightp\Documents\Local Temp\HEC-RAS Interface\Data\	
BridgeCulverts_XS_PT.csv	.csv	7/26/2021 2:29	10/6/2020 16:29	7/26/2021 2:29	C:\Users\enrightp\Documents\Local Temp\HEC-RAS Interface\Data\	
Bridges_AS_PR - Copy.csv	.csv	7/26/2021 2:29	1/19/2021 22:38	7/26/2021 2:29	C:\Users\enrightp\Documents\Local Temp\HEC-RAS Interface\Data\	
Bridges_AS_PR_Rev1-B_67805.csv	.csv	7/26/2021 2:29	1/19/2021 8:47	7/26/2021 2:29	C:\Users\enrightp\Documents\Local Temp\HEC-RAS Interface\Data\	
Bridges_AS_PT.csv	.csv	7/26/2021 2:29	10/6/2020 16:29	7/26/2021 2:29	C:\Users\enrightp\Documents\Local Temp\HEC-RAS Interface\Data\	
Bridges_XS_PR - Copy.csv	.csv	7/26/2021 2:29	1/19/2021 8:52	7/26/2021 2:29	C:\Users\enrightp\Documents\Local Temp\HEC-RAS Interface\Data\	
Bridges_XS_PR_Rev1-B_67805.csv	.csv	7/26/2021 2:29	1/19/2021 8:47	7/26/2021 2:29	C:\Users\enrightp\Documents\Local Temp\HEC-RAS Interface\Data\	
Bridges_XS_PT.csv	.csv	7/26/2021 2:29	10/6/2020 16:29	7/26/2021 2:29	C:\Users\enrightp\Documents\Local Temp\HEC-RAS Interface\Data\	
Pipes_AS_PR.csv	.csv	7/26/2021 2:29	11/2/2020 15:04	7/26/2021 2:29	C:\Users\enrightp\Documents\Local Temp\HEC-RAS Interface\Data\	
Pipes_AS_PT.csv	.csv	7/26/2021 2:29	10/6/2020 16:29	7/26/2021 2:29	C:\Users\enrightp\Documents\Local Temp\HEC-RAS Interface\Data\	
Pipes_XS_PR - Copy.csv	.csv	7/26/2021 2:29	4/5/2021 17:31	7/26/2021 2:29	C:\Users\enrightp\Documents\Local Temp\HEC-RAS Interface\Data\	
Pipes_XS_PR_Rev1-P_2244848.csv	.csv	7/26/2021 2:29	4/5/2021 14:43	7/26/2021 2:29	C:\Users\enrightp\Documents\Local Temp\HEC-RAS Interface\Data\	
Pipes_XS_PT.csv	.csv	7/26/2021 2:29	4/5/2021 17:20	7/26/2021 2:29	C:\Users\enrightp\Documents\Local Temp\HEC-RAS Interface\Data\	

- User must specify which cross sections / assets to analyze

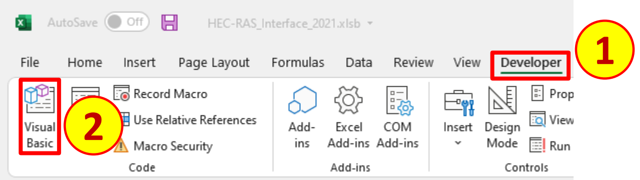
"XS WSE" sheet:

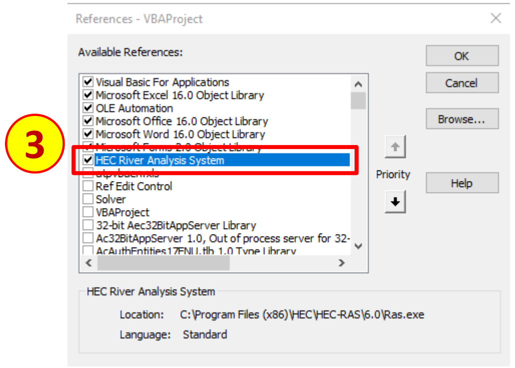
	A	B	C	D
1	XS Water Surface Elevation Output Table			
2	XSID	Analyze	LB_Sta	RB_Sta
3	B_19094_XS_DS	TRUE		
4	B_19094_XS_US	TRUE		
5	B_23005_XS_DS			
6	B_23005_XS_US			

"Output" sheet:

	A	B	C
1	Asset Output Table		
2	AssetID	Structure Category	Analyze
3	B_19094	Bridge	
4	B_23005	Bridge	TRUE
5	B_33004	Bridge	

- Visual Basic > Tools > References > HEC River Analysis System
  - HEC-RAS API must be referenced





Review of Model Results and Output

- Cross Section Output Table:
  - Left and Right Bank Stations

XS Water Surface Elevation Output Table			
XSID	Analyze	LB_Sta	RB_Sta
B_19094_XS_DS	TRUE		
B_19094_XS_US	TRUE		
B_23005_XS_DS			
B_23005_XS_US			

- Cross Section Report Table:
  1. Raw model-predicted WSE
  2. Overflow depths (left and right)
  3. Adopted WSE (deducts overflow depth)
  4. High-level geomorphic output (if run)
  5. Management of outliers

XS Simulation Report Table

XSID	Scenario	Flow (cfs)	WSE (ft)	Left Overflow (ft)	Right Overflow (ft)	Adopted WSE (ft)	Velocity (ft/s)	Shear (lb/sf) Ave.	Shear (lb/sf) LOB	Shear (lb/sf) Channel	Shear (lb/sf) ROB	Rank	RankIndex	Min	Max	Rolling	StdDev	Unexpected	Outlier	Interpolated WSE (ft)
B_19094_XS_DS	1.5_Current	354	890.3831177			890.3831177	1.512874484	0.04630594	3.4E+38	0.04630594	3.4E+38	56	56		890.72					890.3831177
B_19094_XS_DS	2_Current	509	890.7160645			890.7160645	1.405277729	0.053622641	3.4E+38	0.053622641	3.4E+38	55	55	890.38	890.81					890.7160645
B_19094_XS_DS	5_Current	1010	891.4004517			891.4004517	1.480014443	0.098738134	3.4E+38	0.098738134	3.4E+38	48	48	891.19	891.46	891.32	0.20			891.4004517
B_19094_XS_DS	10_Current	1440	891.8483276			891.8483276	1.60703671	0.126554847	0.001635383	0.128079638	0.003822589	41	41	891.71	891.90	891.80	0.14			891.8483276
B_19094_XS_DS	25_Current	2080	892.3990479			892.3990479	1.773444772	0.155643135	0.020266084	0.165764078	0.025404261	34	34	892.10	892.45	892.29	0.21			892.3990479
B_19094_XS_DS	50_Current	2630	892.8083496			892.8083496	1.897061229	0.179681972	0.034114756	0.193790957	0.044210173	27	27	892.64	892.86	892.75	0.15			892.8083496
B_19094_XS_DS	100_Current	3260	893.2282715			893.2282715	2.024459839	0.204956576	0.048382174	0.222814068	0.06408713	20	20	893.05	893.27	893.17	0.15			893.2282715
B_19094_XS_DS	500_Current	4910	894.182251			894.182251	2.28883791	0.249212623	0.074285664	0.288012981	0.082876876	7	7	893.87	894.23	894.07	0.22			894.182251

Review of Model Results and Output Cont.

- Asset Output Table:
  1. Error messages
  2. Abutment geometry
  3. Vertical geometry

Asset Output Table

AssetID	Structure Category	Analyze	Disqualification	Notes	LeftAbutSta	LeftAbutElev	RightAbutSta	RightAbutElev
B_19094	Bridge				1396.068589	896.9721416	1516.113715	896.3054749
B_23005	Bridge				1478.653756	878.4865767	1562.744197	877.6719441
B_33004	Bridge				1423.863439	949.432117	1570.38727	949.8163034
B_38009	Bridge				1449.92987	1059.342554	1645.840053	1060.176215
B_6502	Bridge				1400.472801	1134.025955	1520.22297	1132.243475
B_67805	Bridge				3869.495098	1438.340881	4072.405849	1438.140094

AssetID	BridgeMidSta	BridgeMidElev	SumpSta	SumpElev	Soffit/TOP	PXS_Reach_Length	Asset XS Adjust	HighChordMin	LowChordMin	RoadMin
B_19094	1456.091152	896.6388083	961.1049974	895.7142675	894.2258083	110.3	-11.355496	896.3054749	893.8924749	895.714268
B_23005	1520.698977	878.0792604	2311.555859	871.2280463	874.5792604	72	-12.9370765	877.6719441	874.1719441	871.228046
B_33004	1497.125355	949.6242102	1378.41829	949.2959621	946.9572102	78.1	31.0628485	949.432117	946.765117	949.295962
B_38009	1547.884962	1059.759385	1436.834635	1059.333367	1054.291385	82.1	41.915291	1059.342554	1053.874554	1059.33337
B_6502	1460.347886	1133.134715	2023.467599	1126.729039	1127.978515	72.2	-72.8071265	1132.243475	1127.087275	1126.72904
B_67805	3970.950474	1438.240488	4811.899204	1436.812994	1435.440488	81.1	-1.5E-06	1438.140094	1435.340094	1436.81299

- Asset Report Table:
  1. Base WSE (culverts only)
  2. Modified WSE (culverts only)
  3. Modified Flow (culverts only)
  4. Raw model-predicted WSE
  5. Overflow depths (left and right)
  6. Adopted WSE (deducts overflow depth)

Asset Simulation Report Table

AssetID	Scenario	Flow (cfs)	Base WSE (ft)	Mod WSE (ft)	Modified Flow (cfs)	WSE (ft)	Left Overflow (ft)	Right Overflow (ft)	Adopted WSE (ft)
B_19094	1.5_Current	355		0	0	890.4884033			890.4884033
B_19094	2_Current	510		0	0	890.8418579			890.8418579
B_19094	5_Current	1010		0	0	891.6272583			891.6272583
B_19094	10_Current	1440		0	0	892.157959			892.157959
B_19094	25_Current	2080		0	0	892.8291626			892.8291626
B_19094	50_Current	2630		0	0	893.3410034			893.3410034
B_19094	100_Current	3260		0	0	893.8786011			893.8786011
B_19094	500_Current	4920		0	0	895.2937012			895.2937012

Exporting Hydraulic Model Outputs

- Once user has reviewed model results, outputs can be exported to GIS
- Query combines all asset outputs into single table on "GIS" sheet

	A	B	C	D	E	F	G	H	I	J
1	AssetID	PXS_Reach_Length	LeftAbutSta	RightAbutSta	HighChordMin	LowChordMin	RoadMin	MaxGWD	DSPXS_WSE_100_Crnt	DSPXS_WSE_100_Early_45
2	B_19094	110.3	1396.068589	1516.113715	896.3054749	893.8924749	895.7142675	0	893.355835	893.4006958
3	B_23005	72	1478.653756	1562.744197	877.6719441	874.1719441	871.2280463	0	875.2835083	875.3776855
4	B_33004	78.1	1423.863439	1570.38727	949.432117	946.765117	949.2959621	0	945.7420654	945.7876587
5	B_38009	82.1	1449.92987	1645.840053	1059.342554	1053.874554	1059.333367	0	1051.284912	1051.40564
6	B_6502	72.2	1400.472801	1520.22297	1132.243475	1127.087275	1126.729039	0	1132.806152	1132.87915
7	B_67805	81.1	3869.495098	4072.405849	1438.140094	1435.340094	1436.812994	0	1430.547852	1430.56665

- Export steps:
  1. Refresh "Asset_Results_Export" query table
  2. Copy contents of query table to blank workbook
  3. Save As a .csv file type

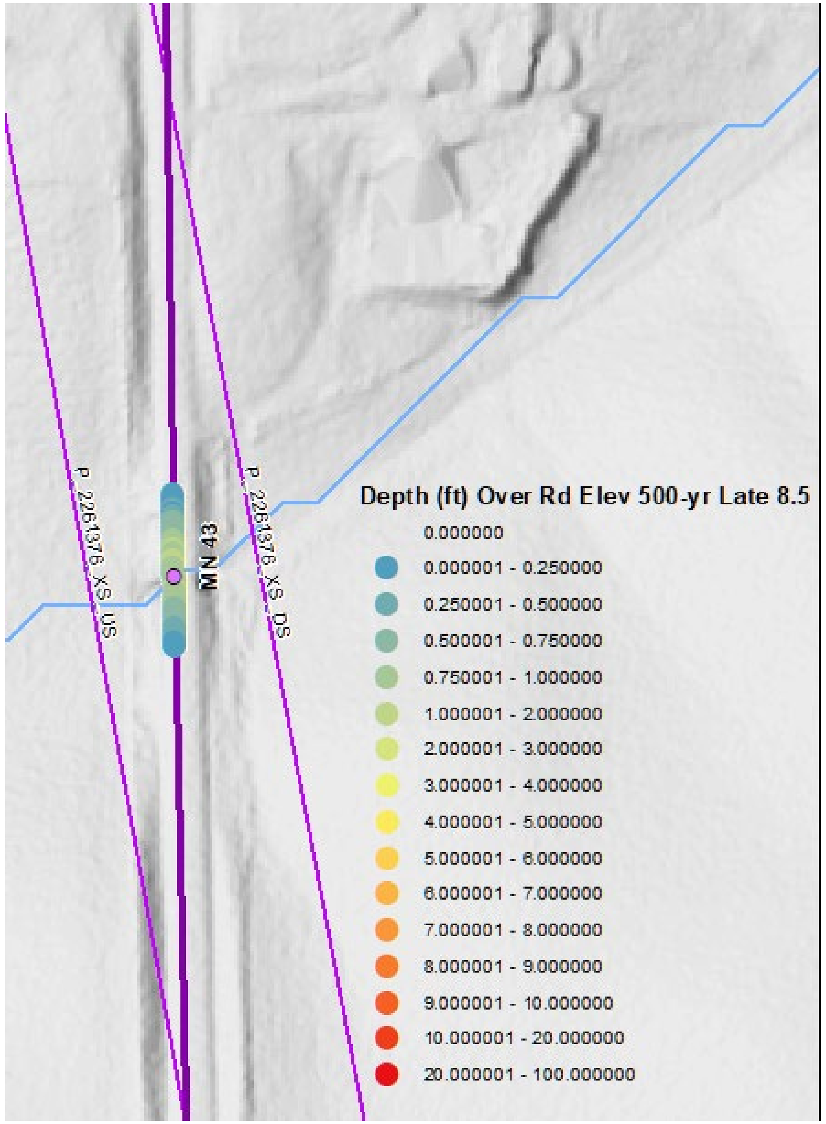
DEPARTMENT OF TRANSPORTATION

Incorporating Hydraulic Model Outputs in GIS (Phase 1)

Gregg Cornetski

Example of Exposure

- Join hydraulic model output metrics table to GIS data: to the stream crossing asset point and to its road profile.
- For example, determine the depth of flooding at each point along the roadway
  - Here the depth during 500-year return period flow event, late-century, RCP 8.5



Preparation of Risk Model Asset Data Inputs (Phase 2)

Josh Amos

Roadway Physical Characteristics for Costing

- Lane count and width
- Pavement material and condition (e.g., asphalt, concrete)
- Shoulder type and width (e.g., gravel, curbs, paved)
- Median type and width, (e.g., high-tension flexible cables)
- AADT, car and truck
- Embankment presence, volume and material
- Federal functional classification (assists with gap-filling missing data)
- Fixed costs (used for debris cleanup and mobilization)

*Primarily from HPMS

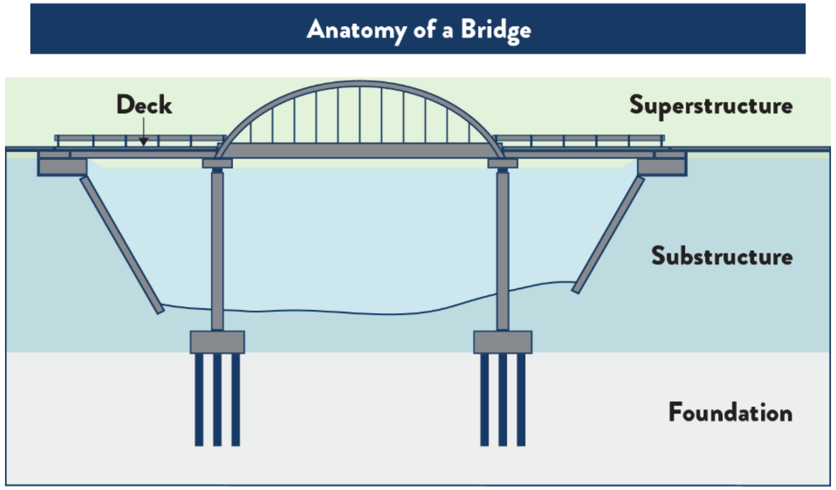
Geoprocessing routines to attribute roadway centerlines with HPMS attributes

Toolbox
- Model 0. Process AADT
- Model 0.1_Process_MnDOT_Supplied_Event_Tables
- Model 0.2_Take Most Recent Survey
- Model 1. Overlay Route Events
- Model 2. Separate D and I Routes
- Model 2.1 Manual Step to Remove Stacked Routes that Affect the AADT Transfer via Mixed Route
- Model 3. Planarize D Routes
- Model 4. Planarize I Routes
- Model 5. Trunk Routes Planarize & Create Intersection to Intersection ID
- Model 6. Bring together D and I Routes
- Model 7. Script to Find Nearest Corresponding D or I Route
- Model 8. Attribute aadt to Planarized Routes
- Model 9.2 Collect Values
- Model 9.3 Transfer AADT
- Model 9.4 Attribute aadt to remaining roads
- Model 9.5. Compute AADT
- Model 9.6. Update AADT Calculations

Culvert and Bridge Physical Characteristics for Costing

- Culverts:
  - Presence of riprap apron
  - Barrel count, shape (e.g., box, pipe arch), height, width
  - Material and condition
- Bridges:
  - Main span (e.g., beam span steel, deck girder concrete)
  - Structure type (e.g., timber footing pile, concrete footing pile)
  - Presence of piers
  - Pavement material and condition

*Primarily from MnDOT asset management databases & NBI



Relate Physical Asset Characteristics to Unit Costs

- Given asset's physical characteristics, estimate a repair and replacement cost
- Embankment fill example
  - Unit cost was estimated to be $13.19 per cubic yard.
  - Weighted average cost of item numbers 2106507/00130 (assumed to comprise 10% of the embankment volume) and 2106507/00080 (assumed to comprise 90% of the embankment volume)

Average Bid Prices for Awarded Contracts
State Aid Projects Not Included
1/1/2020 to 12/31/2020

Page 22

Item Group	Item Number	Item Description	Units	Quantity	Dollars (000S)	Average Price	Contract Occur.
2105	2105609/00125	HAUL AND DISPOSE OF LEAD CONTAMINATED SOIL	TON	320.00	$30.40	$95.00	1
2105	2105609/00126	HAUL AND DISPOSE OF MERCURY CONTAMINATED SOIL	TON	166.00	$125.33	$755.00	1
2105	2105609/00128	HAUL AND DISPOSE OF EXCAVATED MATERIAL	TON	43,200.00	$475.20	$11.00	1
2105	2105609/00130	EXCAVATION SPECIAL	TON	19,245.00	$167.43	$8.70	5
2105	2105619/00020	MINOR GRADING	RDST	554.00	$44.32	$80.00	1
					$0.00		

Item Group	Item Number	Item Description	Units	Quantity	Dollars (000S)	Average Price	Contract Occur.
2106	2106507/00010	EXCAVATION - COMMON	C Y	2,469,397.80	$19,532.94	$7.91	99
2106	2106507/00025	EXCAVATION - ROCK	C Y	80.00	$20.40	$255.00	1
2106	2106507/00030	EXCAVATION - MUCK	C Y	48,491.00	$470.85	$9.71	8
2106	2106507/00040	EXCAVATION - SUBGRADE	C Y	191,797.00	$1,764.53	$9.20	16
2106	2106507/00050	EXCAVATION - CHANNEL AND POND	C Y	91,604.00	$1,149.63	$12.55	6
2106	2106507/00070	GRANULAR EMBANKMENT (CV)	C Y	44,258.00	$729.81	$16.49	7
2106	2106507/00080	SELECT GRANULAR EMBANKMENT (CV)	C Y	841,392.00	$11,829.97	$14.06	47
2106	2106507/00090	SELECT GRANULAR EMBANKMENT MOD 5% (CV)	C Y	37,350.00	$616.28	$16.50	1
2106	2106507/00100	SELECT GRANULAR EMBANKMENT MOD 7% (CV)	C Y	185,660.00	$5,575.37	$30.03	8
2106	2106507/00110	SELECT GRANULAR EMBANKMENT MOD 10% (CV)	C Y	52,250.00	$1,149.50	$22.00	11
2106	2106507/00120	SELECT GRANULAR EMBANKMENT SUPER SAND (CV)	C Y	80,314.00	$1,905.85	$23.73	8
2106	2106507/00130	COMMON EMBANKMENT (CV)	C Y	1,656,397.00	$8,878.29	$5.36	96

* Primarily from MnDOT's Average Bid Prices for Awarded Contracts by Year (2020)

Approach Roadway Risk Model Costing Preparation

Modeled Asset	Road		Clean up Costs (fixed costs)		Driving Surface					Driving Surface – Pavement Layer 1					Driving Surface – Pavement Layer 2				
AssetID	Route Label	Functional Class	Debris Clean Up C	Mobilization Cost	Dual Carriage Way	Segment Length (l	Surface Area (sq f	Number of Lanes	Lane Width	Thickness (inches	Material	Pavement Layer 1	Units	Total Cost	Thickness (inches	Material	Pavement Layer 1	Units	Total Cost
B_19094	MN 3	Minor Arterial	$2,182	20%		960	23,042	1	12	7.5	Bituminous	$42	sq yards	$107,428	4	Bituminous	$36	Cubic Yards	$10,380
B_19094	MN 3	Minor Arterial	$1,023	20%		450	10,801	1	12	7.5	Bituminous	$42	sq yards	$50,357	4	Bituminous	$36	Cubic Yards	$4,866
B_19094	MN 3	Minor Arterial	$886	20%		390	9,361	1	12	7.5	Bituminous	$42	sq yards	$43,642	4	Bituminous	$36	Cubic Yards	$4,217
B_19094	MN 3	Minor Arterial	$1,568	20%		690	16,562	1	12	7.5	Bituminous	$42	sq yards	$77,214	4	Bituminous	$36	Cubic Yards	$7,461
B_19094	MN 3	Minor Arterial	$68	20%		30	720	1	12	7.5	Bituminous	$42	sq yards	$3,357	4	Bituminous	$36	Cubic Yards	$324
B_19094	MN 3	Minor Arterial	$68	20%		30	720	1	12	7.5	Bituminous	$42	sq yards	$3,357	4	Bituminous	$36	Cubic Yards	$324
B_19094	MN 3	Minor Arterial	$818	20%		360	8,641	1	12	7.5	Bituminous	$42	sq yards	$40,285	4	Bituminous	$36	Cubic Yards	$3,893
B_19094	MN 3	Minor Arterial	$205	20%		90	2,160	1	12	7.5	Bituminous	$42	sq yards	$10,071	4	Bituminous	$36	Cubic Yards	$973
B_23005	MN 43	Major Collector	$6,988	20%		3,075	73,796	1	12	8	Bituminous	$55	sq yards	$454,827	2	Bituminous	$36	Cubic Yards	$16,622
B_33004	MN 70	Major Collector	$6,818	20%		3,000	72,000	1	12	8	Bituminous	$55	sq yards	$443,762	5	Bituminous	$36	Cubic Yards	$40,545
B_38009	MN 1	Minor Arterial	$6,919	20%		3,044	73,062	1	12	1.5	Bituminous	$55	Assume 6" and 14	$145,641	18	Bituminous	$36	Cubic Yards	$148,112
B_6502	MN 32	Minor Arterial	$2,869	20%		1,262	30,293	1	12	1.5	Bituminous	$55	Assume 6" and 14	$60,386	8	Bituminous	$36	Cubic Yards	$27,294
B_6502	MN 32	Minor Arterial	$683	20%		301	7,213	1	12	1.5	Bituminous	$55	Assume 6" and 14	$14,378	8	Bituminous	$36	Cubic Yards	$6,498
B_6502	MN 32	Minor Arterial	$2,869	20%		1,262	30,293	1	12	1.5	Bituminous	$55	Assume 6" and 14	$60,386	8	Bituminous	$36	Cubic Yards	$27,294
B_6502	MN 32	Minor Arterial	$410	20%		180	8,655	1	24	1.5	Bituminous	$55	Assume 6" and 14	$17,253	8	Bituminous	$36	Cubic Yards	$7,798
B_67805	I 90	Principal Arterial -	$17,672	20%	Dual Carriageway	3,888	186,611	2	24	9	Bituminous	$81	sq yards	$1,678,464	5.25	Bituminous	$36	Cubic Yards	$110,338
B_67805	I 90	Principal Arterial -	$361	20%	Dual Carriageway	79	3,808	2	24	9	Bituminous	$81	sq yards	$34,254	5.25	Bituminous	$36	Cubic Yards	$2,252
B_67805	I 90	Principal Arterial -	$16,950	20%	Dual Carriageway	3,729	201,369	2	27	9	Concrete	$81	sq yards	$1,811,200	5.25	Concrete	$36	Cubic Yards	$119,064
B_67805	I 90	Principal Arter																	
B_67805	I 90	Principal Arter																	
C_4108	MN 18	Minor Arterial																	
C_4108	MN 18	Minor Arterial																	
C_424	MN 1	Minor Arterial																	
C_5648	MN 61	Principal Arter																	
C_5648	MN 61	Principal Arter																	
C_5648	MN 61	Principal Arter																	
C_5648	MN 61	Principal Arter																	
C_5648	MN 61	Principal Arter																	
C_5648	MN 61	Principal Arter																	
C_5722	US 63	Principal Arter																	
C_8566	MN 60	Minor Arterial																	
C_91285	MN 23	Principal Arter																	
P_2195327	MN 95	Minor Arterial																	
P_2195327	MN 95	Minor Arterial																	
P_2195327	MN 95	Minor Arterial																	
P_2195327	MN 95	Minor Arterial																	
P_2195327	MN 95	Minor Arterial																	
P_2195327	MN 95	Minor Arterial																	

Modeled Asset	Median				Curbs			Left Shoulder					Right Shoulder					Embankment Fill	
AssetID	Description	Width	Unit Cost ($/linear f	Total Cost	Description	Unit Cost ($/linear f	Total Cost	Description	Width (ft)	Surface Area (Sq	Unit Cost	Total Cost	Description	Width (ft)	Surface Area (Sq	Unit Cost	Total Cost	Volume (CY)	Fill Unit Cost (CY)
B_19094																		6,223	$13
B_19094																		2,917	$13
B_19094																		2,528	$13
B_19094																		4,473	$13
B_19094																		194	$13
B_19094																		194	$13
B_19094																		2,334	$13
B_19094																		583	$13
B_23005																		0	$13
B_33004																		8,994	$13
B_38009													bituminous concre	3	1,015	surface 3" depth $	$21,329	26,763	$13
B_6502													bituminous concre	2	280	surface 3" depth $	$5,896	0	$13
B_6502													bituminous concre	2	67	surface 3" depth $	$1,404	0	$13
B_6502													bituminous concre	2	280	surface 3" depth $	$5,896	0	$13
B_6502					Raised 6"	$29	$10,383				surface 3" depth $54.97; base 6" depth $40.00							0	$13
B_67805								bituminous concre	3	1,296	surface 3" depth $	$27,239	bituminous concre	10	4,320	surface 3" depth $	$90,797	9,057	$13
B_67805								bituminous concre	3	26	surface 3" depth $	$556	bituminous concre	10	88	surface 3" depth $	$1,853	185	$13
B_67805								bituminous concre	3	1,243	surface 3" depth $	$26,127	bituminous concre	8	3,315	surface 3" depth $	$69,672	8,687	$13
B_67805								bituminous concre	3	26	surface 3" depth $	$556	bituminous concre	8	71	surface 3" depth $	$1,482	185	$13
B_67805													bituminous concre	8	141	surface 3" depth $	$2,965	370	$13
C_4108													bituminous concre	7	1,727	surface 3" depth $	$36,293	0	$13
C_4108													bituminous concre	7	607	surface 3" depth $	$12,752	0	$13
C_424													bituminous concre	2	683	surface 3" depth $	$14,358	8,281	$13
C_5648													bituminous concre	4	393	surface 3" depth $	$8,264	0	$13
C_5648													bituminous concre	4	502	surface 3" depth $	$10,544	0	$13
C_5648													bituminous concre	9	610	surface 3" depth $	$12,824	0	$13
C_5648													bituminous concre	9	122	surface 3" depth $	$2,565	0	$13
C_5648													bituminous concre	9	31	surface 3" depth $	$641	0	$13
C_5648													bituminous concre	9	275	surface 3" depth $	$5,771	0	$13
C_5722					Raised 6"	$29	$141,320											0	$13
C_8566													bituminous concre	2	669	surface 3" depth $	$14,064	35,159	$13
C_91285													bituminous concre	10	3,334	surface 3" depth $	$70,068	34,934	$13
P_2195327													bituminous concre	6	183	surface 3" depth $	$3,843	1,057	$13
P_2195327													bituminous concre	6	81	surface 3" depth $	$1,708	470	$13
P_2195327													bituminous concre	6	20	surface 3" depth $	$418	115	$13
P_2195327													bituminous concre	6	122	surface 3" depth $	$2,562	705	$13
P_2195327													bituminous concre	5	356	surface 3" depth $	$7,473	2,466	$13
P_2195327													bituminous concre	5	85	surface 3" depth $	$1,779	587	$13
P_2195327													bituminous concre	5	406	surface 3" depth $	$8,540	2,818	$13
P_2195327													bituminous concre	6	20	surface 3" depth $	$427	117	$13
P_2195327													bituminous concre	6	325	surface 3" depth $	$6,832	1,879	$13
P_2195327													bituminous concre	6	265	surface 3" depth $	$5,560	1,529	$13

Total Replacement Costs: Approach Roadway Risk Model

Roadway Risk Model Total Replacement Cost

Asset ID	AAADT Car	AAADT Truck	Embankment Fill	Debris Clean up	Driving Surface Layer 1	Driving Surface Layer 2	Driving Surface Layer 3	Median	Left Shoulder	Right Shoulder	All Pavement Material
B_19094	12,200	439	$237,656	$3,674	$180,859	$17,476				$12,308	$210,643
B_23005	580	85	$155,617	$3,631	$236,319	$8,637				$3,041	$247,997
B_33004	950	80	$105,738	$3,766	$245,094	$22,393				$3,154	$270,641
B_38009	880	75	$328,879	$3,882	$81,713	$83,100				$16,844	$181,657
B_6502	2,066	324	$19,285	$3,692	$77,716	$35,127				$10,680	$123,523
B_67805	5,050	775	$175,064	$7,757	$1,566,095	$102,951			$11,956	$35,847	$1,716,850
C_4108	4,550	425	$210,950	$3,409	$71,763	$58,790				$24,523	$155,077
C_424	330	50	$99,329	$3,410	$221,934	$12,166				$7,008	$241,108
C_5648	6,513	329	$499,396	$3,399	$73,262	$47,600				$17,314	$138,176
C_5722	5,800	1,000		$3,407	$481,136	$26,340	$19,755			$0	$613,555
C_8566	5,500	475	$444,060	$3,410	$221,943	$31,431				$17,006	$270,380
C_91285	2,700	470	$424,151	$3,408	$71,749	$72,966				$35,025	$179,740
P_2195327	7,400	610	$138,156	$3,379	$87,659	$34,668				$19,769	$142,096
P_2206647	8,300	2,125	$411,164	$6,795	$1,452,250	$95,468		$70,116	$10,475	$27,932	$1,656,241
P_2244848	1,800	175	$7,384	$3,405	$77,640	$6,580				$4,278	$88,497
P_2251120	3,450	550	$198,806	$3,412	$71,817	$73,035				$35,059	$179,911
P_2261376	790	105	$40,776	$3,404	$221,560	$4,049				$2,851	$228,460
P_2286414	435	35	$96,810	$3,409	$59,808	$40,549				$10,511	$110,868
P_2295972	3,000	235	$63,374	$3,412	$71,819	$36,519				$10,518	$118,856
P_2298309	5,050	775	$235,513	$6,811	$1,293,784	$85,050			$13,997	$34,994	$1,427,825
P_2311335	650	185	$209,898	$3,405	$71,683	$42,524				$5,705	$119,912
P_2402064	1,450	85	$71,103	$3,399	$258,131	$42,452				$2,848	$303,430
Total	**79,444**	**9,407**	**$4,173,110**	**$87,676**	**$7,195,734**	**$979,871**	**$19,755**	**$70,116**	**$36,428**	**$337,215**	**$8,725,443**

Total Replacement Costs: Bridges, Bridge-Culverts, and Pipes

Bridges

AssetID	Structure Type	Bridge Unit Cost (sq ft)	Bridge Total Replacement Cost	Bridge Superstructure Replacement Cost	Bridge Substructure Replacement Cost	MAINSPANS	Foundation_Description	ABUT_FND	PIER_FND	HighChordMin	LowChordMin	STUCT_LEN	DECKWIDTH	Paved_Surface_Area_SqFt	Wear_Surf_Type
B_19094	Slab	$176	$1,555,778	$1,166,833	$388,944	3	CONC FTG PILE	CONC FTG PILE	CONC FTG PILE	896	894	126	70	8,453	LOW SLUMP CONC
B_23005	Tee-Beam	$176	$269,568	$202,176	$67,392	1	STEEL PILE BENT	STEEL PILE BENT	N/A	878	874	48	32	1,442	LOW SLUMP CONC
B_33004	Slab	$176	$927,424	$695,568	$231,856	3	CONC FTG PILE	CONC FTG PILE	CIP PILE BENT	949	947	139	38	4,822	LOW SLUMP CONC
B_38009	Tee-Beam	$176	$1,157,047	$867,785	$289,262	2	CONC SPRD ROCK	CONC SPRD ROCK	CONC SPRD ROCK	1,059	1,054	157	42	6,071	LOW SLUMP CONC
B_6502	Girder	$176	$805,282	$603,961	$201,320	3	TIMBER FTG PILE	TIMBER FTG PILE	CONC SPRD SOIL	1,132	1,127	143	32	4,133	LOW SLUMP CONC
B_67805	Slab	$176	$1,399,332	$1,049,499	$349,833	3	CONC FTG PILE	CONC FTG PILE	CONC FTG PILE	1,438	1,435	194	41	7,333	LOW SLUMP CONC

Bridge-culverts

AssetID	Culvert Barrel Unit Cost Item Number	Pipe Barrel Unit Cost (sq ft)	Culvert Barrel Cost	Culvert End Section Item Number	Culvert End Section Unit Cost	Culvert End Section Cost	Culvert Total Replacement Cost	RipRap_Apron_Flag	CulvertSha	BarrelsHei	BarrelsNum	BarrelsWid	MAIN_SPAN_	CULVRATING
C_4108	2412503/10040	$949.08	$67,384.68	2412502/10040	$10,560.00	$21,120.00	$88,504.68	0	Box	4	1	10	113 - Box Culvert Concrete	4
C_424	2501503/15017	$41.00	$3,034.00	N/A	$0.00	$0.00	$3,034.00	1	Pipe Arch	10	1	16	315 - Pipe Arch Steel	5
C_5648	2412503/10100	$807.86	$106,637.52	2412502/10100	$18,856.67	$37,713.34	$144,350.86	1	Box	10	2	10	113 - Box Culvert Concrete	5
C_5722	2412503/12060	$1,050.00	$70,350.00	2412502/16120	$30,000.00	$60,000.00	$130,350.00	1	Box	6	3	12	113 - Box Culvert Concrete	5
C_8566	2412503/10060	$943.51	$126,430.34	2412502/16100	$19,000.00	$38,000.00	$164,430.34	1	Box	6	1	10	113 - Box Culvert Concrete	6
C_91285	2501503/14017	$25.00	$2,950.00	N/A	$0.00	$0.00	$2,950.00	1	Pipe Arch	9	1	10	515 - Pipe Arch Prestress or Precast	6

Pipes

AssetID	Culvert Unit Cost Item Number	Pipe Barrel Unit Cost (sq ft)	Culvert Barrel Cost	Culvert End Section Item Number	Culvert End Section Unit Cost	Culvert End Section Cost	Culvert Total Replacement Cost	RipRap Apron Flag	CulvertSha	BarrelsHei	BarrelsNum	BarrelsWid	Pipe Shape	Material	Condition
P_2195327	2501503/12036	$90.22	$6,676.28	N/A		$0.00	$6,676.28	1	Pipe Round	3	1	3	Round	Liner HDPE	1 - Like New
P_2206647	2501503/19732	$311.11	$52,888.70	N/A		$0.00	$52,888.70	1	Pipe Arch	3	1	5	Arch	Concrete	2 - Fair
P_2244848	2501503/12024	$53.31	$2,132.40	N/A		$0.00	$2,132.40	0	Pipe Round	2	1	2	Round	Corg. Steel (CSP)	0 - Unable to Inspect
P_2251120	2501503/19732	$311.11	$22,399.92	N/A		$0.00	$22,399.92	0	Pipe Arch	6	1	4	CattlePass	Concrete	3 - Poor
P_2261376	2501503/12072	$159.00	$6,678.00	N/A		$0.00	$6,678.00	1	Pipe Ellipse	6	1	4	Elliptical	Corg. Steel (CSP)	4 - Severe
P_2286414	2501503/12015	$51.51	$2,575.50	N/A		$0.00	$2,575.50	0	Pipe Round	2	1	2	Round	Corg. Plastic (HDPE)	1 - Like New
P_2295972	2501503/19882	$655.00	$31,440.00	N/A		$0.00	$31,440.00	1	Pipe Arch	5	1	7	Arch	Concrete	2 - Fair
P_2298309	2501503/13602	$290.00	$49,590.00	N/A		$0.00	$49,590.00	1	Pipe Round	5	1	5	Round	Concrete	3 - Poor
P_2311335	2412503/06060	$950.00	$40,850.00	2412502/06060	$20,000.00	$40,000.00	$80,850.00	0	Box	6	1	6	Box	Concrete	2 - Fair
P_2402064	2501503/19882	$655.00	$39,300.00	N/A		$0.00	$39,300.00	1	Pipe Arch	5	1	7	Arch	Concrete	1 - Like New

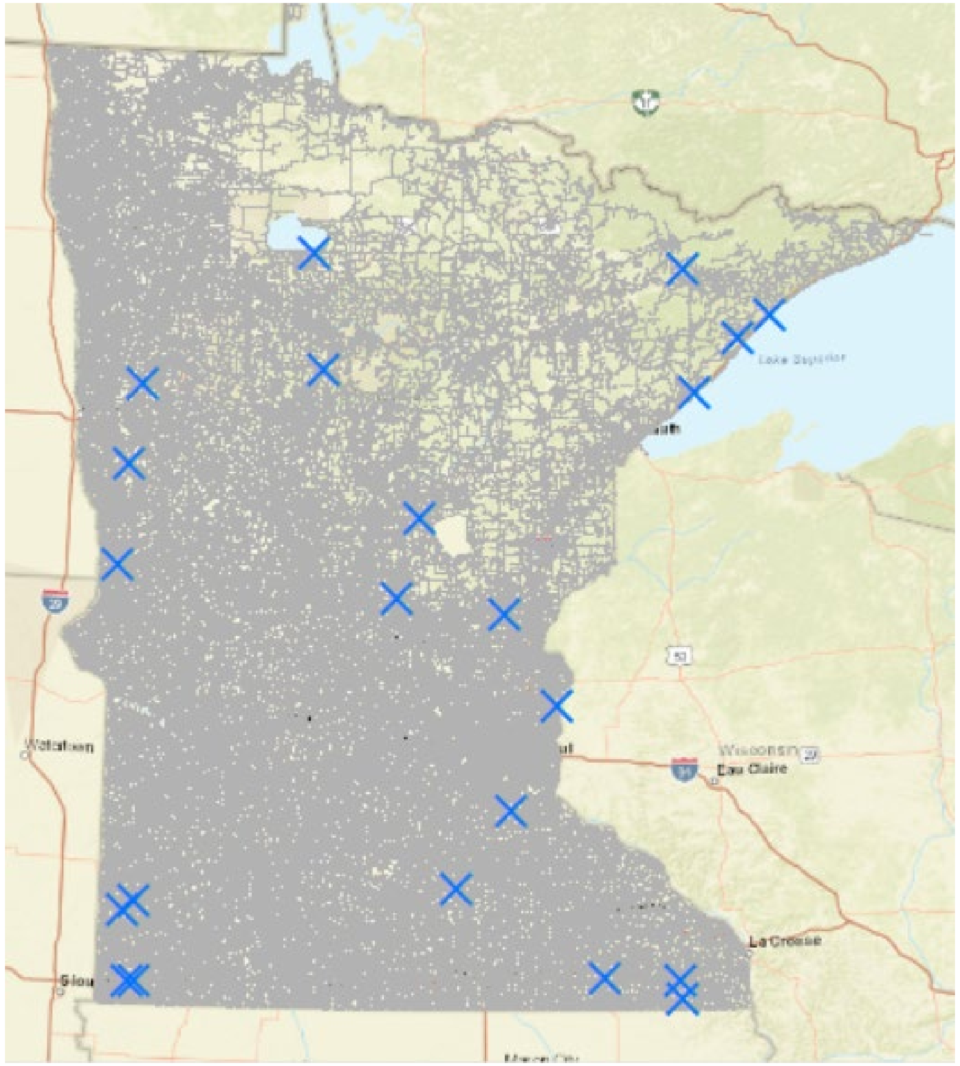
DEPARTMENT OF TRANSPORTATION

Preparation of Risk Model User Data Inputs (Phase 2)

Tim Grose

Background on Approach

- Development of user impact data relies on a GIS-based detour routing tool
- Detour tool is implemented with Python scripts
- Uses ArcPy package for ArcGIS functionality
- Requires ArcGIS for Desktop license and ArcGIS Network Analyst license
- Uses free version of ESRI Streets network dataset for routing
- To run the tool, MNDOT assets must be associated with segments on a modified version of this network dataset (see right).



Running the Detour Tool

- Run mndot_detour_controller_00.py script (need to adjust some variable assignments in the script, such as folder path)
- This produces detour and non-detour routes (green and red shown in example on right)
- Manually review
- Run mndot_detour_postprocess.py script (need to adjust some variable assignments in the script, such as folder path)
- Manual detours in Google Maps when needed
- Output of automated and manual detours is incremental detour length and time for each asset

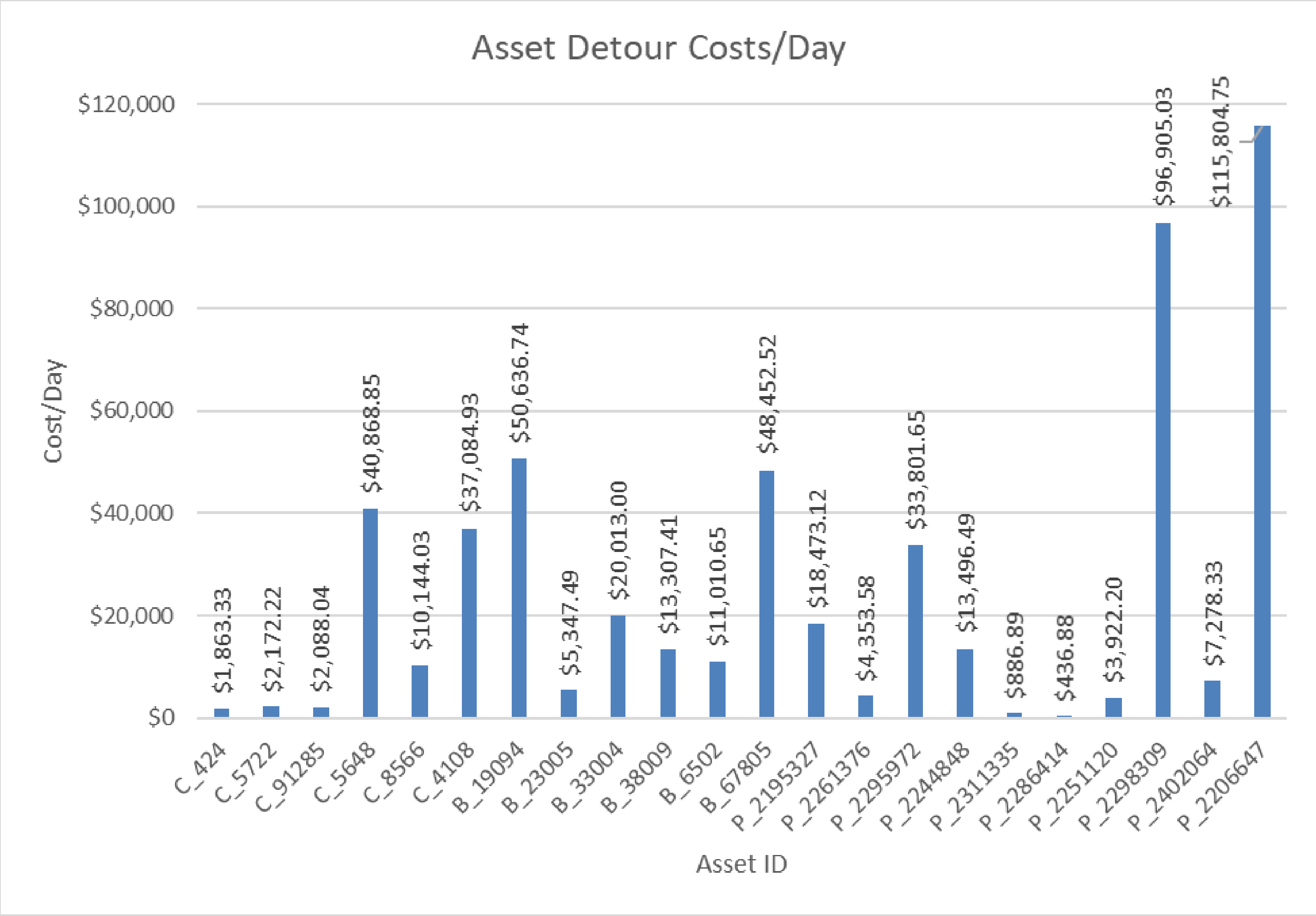
Calculation of User Costs

Inputs	Units	Value	Notes
Real Discount Rate	Percent	0.7%	https://www.dot.state.mn.us/planning/program/pdf/Table%20A.1%20SV%20L-ML-H%201-July-2021.pdf
Analysis Start	Date	1/1/2021	
Analysis End	Date	1/1/2100	
Auto Value of Time (VOT)	$/person hour	$ 22.50	https://www.dot.state.mn.us/planning/program/pdf/Table%20A.1%20SV%20L-ML-H%201-July-2021.pdf
Truck VOT	$/person hour	$ 33.60	https://www.dot.state.mn.us/planning/program/pdf/Table%20A.1%20SV%20L-ML-H%201-July-2021.pdf
Value of Time Year	Date	1/1/2021	See previous
Inflation Rate	Percent	1.9%	Only for adjusting Value of Time for analysis year. Not used in expected cost calculation. Calculated using average annual percent increase in US BLS CPI-U over past ten years. https://data.bls.gov/pdq/SurveyOutputServlet
Auto Operating and Emissions cost	$/mile	$ 0.34	https://www.dot.state.mn.us/planning/program/pdf/Table%20A.1%20SV%20L-ML-H%201-July-2021.pdf
Truck Operating and Emissions cost	$/mile	$ 0.95	https://www.dot.state.mn.us/planning/program/pdf/Table%20A.1%20SV%20L-ML-H%201-July-2021.pdf
Vehicle Operating Cost Year	Date	1/1/2021	See previous
Fatal Crash Cost	$/fatal crash	$ 13,300,000	https://www.dot.state.mn.us/planning/program/pdf/Table%20A.1%20SV%20L-ML-H%201-July-2021.pdf
Injury Crash Cost to Fatality Crash Cost Ratio	injury crash cost/fatality crash cost	0.02	For crosswalk between MNDOT crash costs which are on KABCO scale and NHTSA crash rate data which is are on a Fatality-Injury-PDO scale. To crosswalk between the two scales, we used the fatality cost from MNDOT and used the ratio of injury crash cost to fatality crash cost from US DOT. Then we multiply that ratio times the MNDOT fatality crash cost to get an injury crash cost that aligns with MNDOT data. https://www.transportation.gov/sites/dot.gov/files/2021-02/Benefit%20Cost%20Analysis%20Guidance%202021.pdf
Fatal Crash Vehicles Per Crash	vehicles/crash	1.09	https://www.transportation.gov/sites/dot.gov/files/2021-02/Benefit%20Cost%20Analysis%20Guidance%202021.pdf
Injury Crash Vehicles Per Crash	vehicles/crash	1.44	https://www.transportation.gov/sites/dot.gov/files/2021-02/Benefit%20Cost%20Analysis%20Guidance%202021.pdf
Crash Cost Year	Date	1/1/2021	https://www.dot.state.mn.us/planning/program/pdf/Table%20A.1%20SV%20L-ML-H%201-July-2021.pdf
Fatality Rate	fatalities/ 100 million vehicle miles	1.11	https://cdan.nhtsa.gov/tsftables/National%20Statistics.pdf
Injury Rate	injuries/ 100 million vehicle miles	84	https://cdan.nhtsa.gov/tsftables/National%20Statistics.pdf
Average Vehicle Occupancy	People/Vehicle	1.67	https://www.transportation.gov/sites/dot.gov/files/2021-02/Benefit%20Cost%20Analysis%20Guidance%202021.pdf

Calculated Parameters	Units	Value	Notes
Adjusted Per-Minute Auto Cost	*$/Minute*	*$ 0.63*	*Input to detour results: Multiply by incremental detour minutes and AADT to get $/day*
Ajusted Per-Minute Truck Cost	*$/Minute*	*$ 0.56*	*Input to detour results: Multiply by incremental detour minutes and AADT to get $/day*
Adjusted Per-Mile Auto Cost	*$/Mile*	*$ 0.66*	*Input to detour results: Multiply by incremental detour miles and AADT to get $/day*
Adjusted Per-Mile Truck Cost	*$/Mile*	*$ 1.27*	*Input to detour results: Multiply by incremental detour miles and AADT to get $/day*

Calculation of User Costs Cont.

- Use MNDOT_DetourCost_Inputs_20211220.xlsx spreadsheet to estimate $/minute and $/mile costs for auto and truck users (see screenshot on previous slide)
- Use mndot_detours_wformulas.xls spreadsheet to apply these to AADTs and incremental time and distance for each asset
- Final product is table of $/day user costs by asset (charted on right)



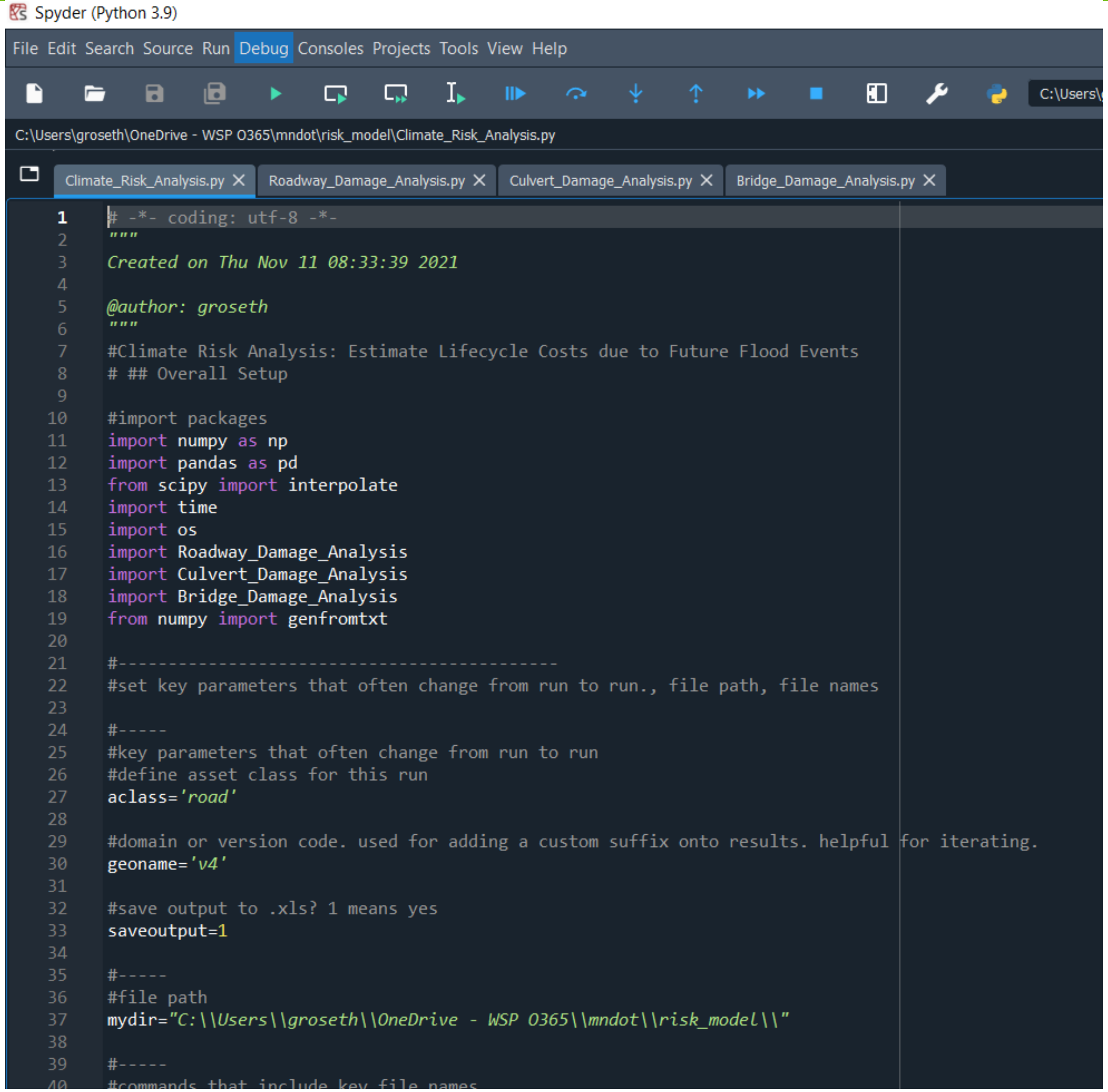
DEPARTMENT OF TRANSPORTATION

Running the Risk Models (Phase 2)

Tim Grose

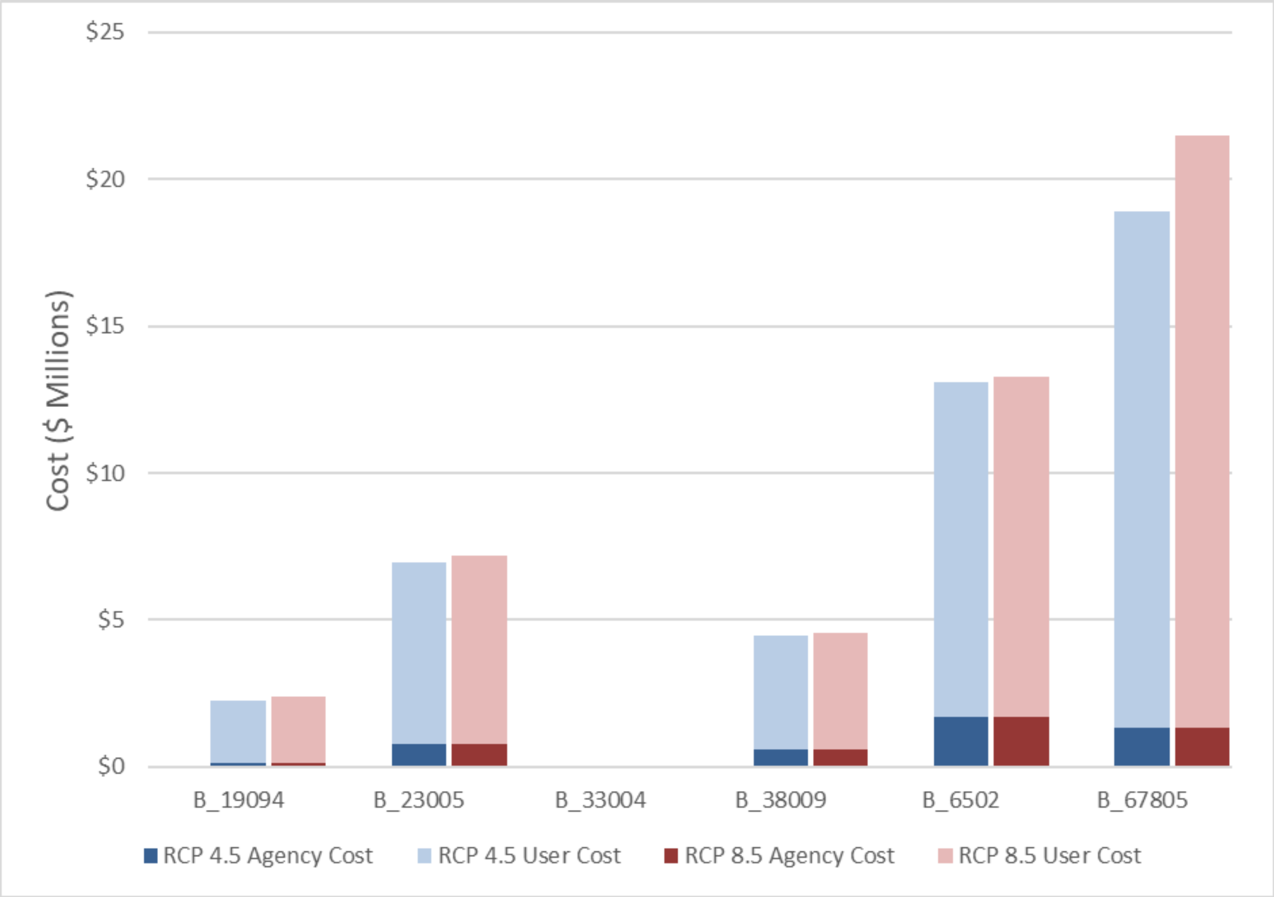
Running the Risk Models

- Risk model implemented with Python scripts (screenshot shown on right) that leverage free, open-source packages
- Inputs are a series of .csv tables read into the scripts (copies included in submittal). These include exposure, cost data, and several lookup tables
- To use the risk model for an asset class, run the Climate_Risk_Analysis.py script.
    - Make sure .csv input files are updated if running the model on new set of assets
    - Need to adjust some variable assignments in the script, such as asset class name and folder path



Running the Risk Models Cont.

- Road risk model needs to be run before bridges or culverts (outputs required for bridge or culvert risk)
- Despite MNDOT using two separate asset classes for culverts (pipe culverts and bridge-like culverts), the risk model itself does not distinguish between these two types of culverts. Thus, some manual renaming of input files is needed.
- Risk model tallies cost by damage mechanism by year and simulation for each climate scenario and asset. These are then discounted (0.07%) and summed across years
- Outputs of risk model saved to .csv showing expected cost (with confidence intervals), agency cost, user cost, etc. by climate scenario and asset. Join to GIS data.
- Script can also output this as formatted .xlsx (charted version of outputs shown on right)



DEPARTMENT OF TRANSPORTATION

Next Steps

Chris Dorney

Next Steps Cont.

- Phase 2 pilot (2022)
  - Goals
    - Pilot test the method to develop a per asset level of effort estimate
    - Make any necessary enhancement to improve the accuracy of the results
  - Focus on District 6
  - Proceed county-by-county
    1. Dodge
    2. Steele
    3. Houston
    4. Others?
- Statewide implementation (2023 and beyond)

DEPARTMENT OF TRANSPORTATION

Questions?