Texas A&M
Transportation
Institute

Using Surface Geometry to Identify Potential Hydroplaning Locations

Technical Report 0-7098-R1

Cooperative Research Program

TEXAS A&M TRANSPORTATION INSTITUTE
COLLEGE STATION, TEXAS

sponsored by the
Federal Highway Administration and the
Texas Department of Transportation
https://tti.tamu.edu/documents/0-7098-R1.pdf

Technical Report Documentation Page

1. Report No. FHWA/TX-23/0-7098-R1	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle USING SURFACE GEOMETRY TO IDENTIFY POTENTIAL HYDROPLANING LOCATIONS		5. Report Date Published: August 2023
		6. Performing Organization Code
7. Author(s) Charles Gurganus, Arvind Devadas, and Saber Messhenas		8. Performing Organization Report No. Report 0-7098-R1
9. Performing Organization Name and Address Texas A&M Transportation Institute The Texas A&M University System College Station, Texas 77843-3135		10. Work Unit No. (TRAIS)
		11. Contract or Grant No. Project 0-7098
12. Sponsoring Agency Name and Address Texas Department of Transportation Research and Technology Implementation Office 125 E. 11th Street Austin, Texas 78701-2483		13. Type of Report and Period Covered Technical Report: July 2020–August 2022
		14. Sponsoring Agency Code

15. Supplementary Notes

Project sponsored by the Texas Department of Transportation and the Federal Highway Administration.
Project Title: Determine Drainage Basin Mapping and Estimation of Hydroplaning Potential
URL: https://tti.tamu.edu/documents/0-7098-R1.pdf

16. Abstract

Hydroplaning occurs because of a series of unfortunate events that result from a combination of driver behavior, vehicle characteristics, and roadway features. Surface geometry and roadway texture are two variables within the control of the managing agency. This study identified hydroplaning vulnerable areas using mobile light detecting and ranging (LiDAR) measurements to measure the roadway surface and map roadway drainage basins. Identifying these areas allows managing agencies to develop a hydroplaning mitigation plan, addressing the geometric variables within the agency's control. This study first displayed the technological ability to collect, process, and analyze data necessary to identify vulnerable hydroplaning locations. Initially, this process used multiple software tools. The second part of this study streamlined the process to limit manual intervention and expedite analysis.

17. Key Words Hydroplaning, Mobile LiDAR, Pavement Geometry, Drainage Basins, Hydroplaning Speed	18. Distribution Statement No restrictions. This document is available to the public through NTIS: National Technical Information Service Alexandria, Virginia https://www.ntis.gov

19. Security Classif. (of this report) Unclassified	20. Security Classif. (of this page) Unclassified	21. No. of Pages 30	22. Price

Form DOT F 1700.7 (8-72) Reproduction of completed page authorized

USING SURFACE GEOMETRY TO IDENTIFY POTENTIAL HYDROPLANING LOCATIONS

by

Charles Gurganus, Ph.D., P.E.
Research Engineer
Texas A&M Transportation Institute

Arvind Devadas
Research Specialist
Texas A&M Transportation Institute

and

Saber Messhenas
Assistant Research Scientist
Formerly of Texas A&M Transportation Institute

Report 0-7098-R1
Project 0-7098
Project Title: Determine Drainage Basin Mapping and Estimation of Hydroplaning Potential

Sponsored by the
Texas Department of Transportation
and the
Federal Highway Administration

Published: August 2023

TEXAS A&M TRANSPORTATION INSTITUTE
College Station, Texas 77843-3135

DISCLAIMER

This research was sponsored by the Texas Department of Transportation (TxDOT) and the Federal Highway Administration (FHWA). The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of FHWA or TxDOT. This report does not constitute a standard, specification, or regulation.

This report is not intended for construction, bidding, or permit purposes. The engineer in charge of the project was Charles F. Gurganus, P.E. #101096.

ACKNOWLEDGMENTS

This project was sponsored by TxDOT and FHWA. The authors thank the project manager, Wade Odell, and the project monitor committee member, Lacy Peters of the TxDOT Atlanta District.

TABLE OF CONTENTS

Page

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

The top priority of all roadway agencies is to deliver a safe system to its users. This priority becomes complicated because while the managing agency controls the physical asset, it cannot control the users' actions. For example, hydroplaning occurs because of a series of unfortunate events that result from a combination of driver behavior, vehicle characteristics, and roadway features. Surface geometry and roadway texture are two variables within the control of the managing agency. These variables play a role in hydroplaning, even when users exercise caution and have vehicles in the appropriate operating conditions. This study identified hydroplaning vulnerable areas using mobile light detecting and ranging (LiDAR) measurements to measure the roadway surface and map roadway drainage basins. Identifying these areas allows managing agencies to develop a hydroplaning mitigation plan, addressing the geometric variables within the agency's control. While doing this will help deliver a safer system, managing agencies should remember that the purpose of this tool is to address only elements within the agency's control.

With proper knowledge of surface geometry and macrotexture, roadway managers can calculate water film thickness (WFT) during a given storm event. Figure 1 illustrates WFT and shows that hydroplaning occurs when the tire becomes separated from the roadway surface. This is different than slippage due to lack of texture. In addition to the intensity of a storm event, drainage basin area, water runoff length, and water runoff slope influence WFT. Use of a LiDAR unit mounted to a vehicle allows for the collection of geometric data at highway speeds. Processing and analyzing these data allow for the identification of roadway drainage basins and their corresponding elements such as length, average width, and slope.

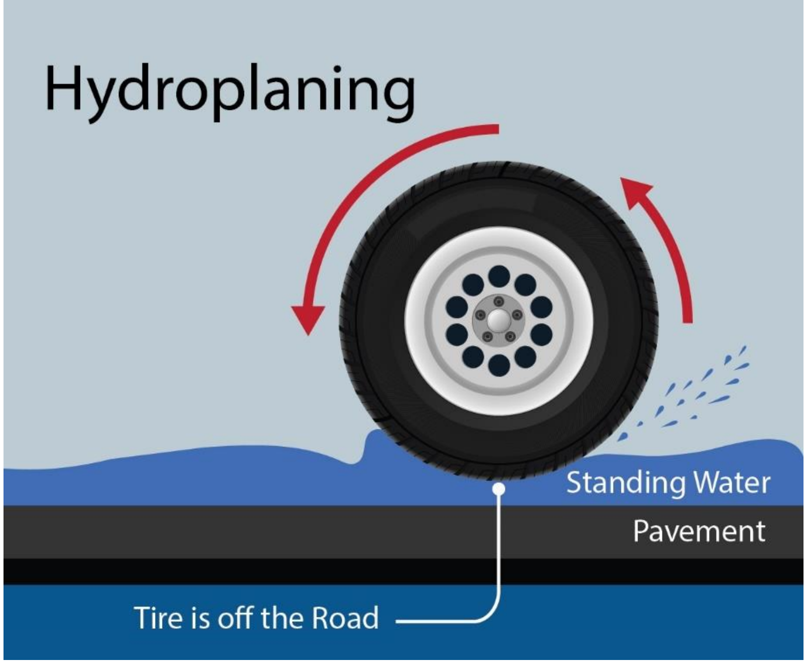


Figure 1. Representation of Water Film Thickness and Hydroplaning.

BACKGROUND

PREVIOUS WORK

The ability to use mobile LiDAR to map drainage basins on a roadway surface was identified in a previous Texas Department of Transportation (TxDOT) study entitled Developing a Surface Drainage Rating for Inclusion in TxDOT's Asset Management System. The goal of the previous study was to capture roadway and roadside geometric features and develop a surface drainage rating using those measurements. During this previous study, researchers were able to convert mobile LiDAR measurements into gridded elevation data of the paved surface. Using LiDAR data converted to gridded data allowed researchers to use existing algorithms (i.e., the D8 algorithm) to map drainage basins on the pavement surface.

Once basins were mapped, the size of each basin was easily converted to an area. A storm event with a given intensity was simulated on the drainage area, and the amount of runoff was calculated at the critical point (i.e., the point of highest accumulation). For hydroplaning vulnerability, high-intensity, short-duration storm events were used. Because drainage basins on a paved surface are relatively small compared to large land-use watersheds, the entire basin contributes water simultaneously to the critical point. Therefore, time of concentration and a lag in water accumulation do not apply to the WFT calculations on roadway surfaces.

Detailed information on overall surface drainage, hydroplaning, and mobile LiDAR measurements is available in the final report for the previous TxDOT project: https://tti.tamu.edu/documents/0-6896-R1.pdf.

CURRENT WORK

TxDOT has a Wet Weather Accident Reduction Program (see https://ftp.txdot.gov/pub/txdot-info/tta/ih635/FINAL%20REQUEST%20FOR%20PROPOSALS_9-18-07/6%20-%20REFERENCE%20INFORMATION%20DOCUMENTS/11%20-%20STUDIES%20AND%20REPORTS/Technical%20Resources/070530wwarp.pdf) that has three specific purposes:

- "identify locations with wet weather accidents, evaluate and determine the cause or causes of high accident incidents during wet weather; determine corrective measures and take appropriate actions in a timely and systematic manner,
- ensure that surfaces have adequate, durable friction properties; and
- ensure that available resources, including high quality aggregates and local materials, are properly used to enhance accident reduction in a cost-effective manner."

Furthermore, TxDOT's Wet Weather Accident Reduction Program guidelines require a field review of locations identified as having a high number of wet weather crashes. Within this field review, the reviewer is asked to identify potential areas that could contribute to wet weather crashes. These areas include:

- “rutting or wheel path channelization
- build up on shoulder edges that cause ponding on the road surface
- bleeding of pavements
- drainage issues that result in water on the pavement
- geometrics (grade & curvature).”

Mobile LiDAR accurately captures the geometry associated with all the bullet points above except bleeding pavements. Mobile LiDAR provides a geometric fingerprint that allows for the mapping of water flow along the paved surface. For example, rutting is easily measured by mobile LiDAR, and when a rain event is simulated over a drainage area with rutting, the simulated water channelizes into the ruts when applying the D8 algorithm to determine water flow and calculate water accumulation. The same is true for buildup on the shoulder. The LiDAR measurements capture an increased elevation near the edge of the pavement. When simulating water flow over a drainage basin with this condition, the algorithm moves the water to the edge but does not allow it to escape, and thus additional accumulation occurs on the roadway surface within that drainage basin. In summary, mobile LiDAR captures measurements that better inform the field study required in the Wet Weather Accident Reduction Program guidelines. Soon, deploying other technology at highway speeds to collect macrotexture and coupling it with mobile LiDAR should address other textural elements that were assumed as part of this study.

Within this study, researchers used mobile LiDAR measurements to identify potentially vulnerable sections of pavements, ignorant of whether these sections were areas with high wet weather accidents. This ignorance was built in to allow researchers to compare vulnerable locations with the locations of wet weather accidents only after performing the drainage basin mapping and hydroplaning speed calculation. If vulnerable locations also had a high number of wet weather accidents, the method could potentially be used as a proactive tool, identifying vulnerable locations and addressing them prior to experiencing a high number of wet weather accidents.

INITIAL FIELD APPLICATION

ATLANTA DISTRICT NEED

IH 20 through TxDOT's Atlanta District carries over 40,000 vehicles per day. From 2015 through 2019, IH 20 in Harrison County averaged over 92 wet surface crashes per year. The annual number of wet surface crashes exceeded the average number of days with more than 0.1 inch of rainfall, which averaged 78 days over the same time. When comparing wet surface crashes on IH 20 with wet surface crashes on other roadways in the Atlanta District, researchers found that IH 20 had the highest percent of wet surface crashes per annual average daily traffic. For these reasons, the TxDOT Atlanta District was interested in evaluating the surface geometry of IH 20 to determine if locations with poor roadway geometry existed and potentially impacted wet weather roadway performance.

IH 20—ATLANTA DISTRICT DATA COLLECTION

The initial data collection on IH 20 was constrained by the file size created by the mobile LiDAR video. Because of this, data collection was divided into lengths of approximately 5 mi, as shown in Table 1. This limitation was addressed through system improvement during this project, as discussed later in the report.

Table 1. IH 20 Atlanta District Data Collection Sections.

Section	Begin Reference Marker	End Reference Marker
Eastbound No. 1	County Line	602
Eastbound No. 2	602	607
Eastbound No. 3	607	612
Eastbound No. 4	612	616
Eastbound No. 5	616	620
Eastbound No. 6	620	625
Eastbound No. 7	625	630
Eastbound No. 8	630	State Line
Westbound No. 1	State Line	631
Westbound No. 2	631	626
Westbound No. 3	626	622
Westbound No. 4	622	618
Westbound No. 5	618	613
Westbound No. 6	613	608
Westbound No. 7	608	603
Westbound No. 8	603	County Line

IH 20 data were collected from the outside lane (i.e., slow travel lane) at approximately 60 mph. The mobile LiDAR device used in this study was capable of capturing strings of data on approximately 10-inch increments when the data collection vehicle traveled at 60 mph. The data on the paved surface were aggregated into 1-ft × 1-ft increments and used to calculate the cross slope of the passing lane (i.e., left lane) and the slow lane (i.e., right lane). Finally, researchers placed the mobile LiDAR data into 3-ft × 3-ft grids from edge of pavement (EOP) to EOP to map drainage basins and evaluate water accumulation to identify geometrically vulnerable locations.

IH 20—INITIAL DATA ANALYSIS AND VULNERABLE SECTION IDENTIFICATION

Any drainage basin measuring larger than 4,500 SF was identified as a potentially vulnerable location. This threshold was used because the potential existed for a vehicle to hydroplane when traveling below the posted speed limit if a drainage basin was this large. Ten geometrically vulnerable locations were identified using the mobile LiDAR data. These locations are listed in prioritized order below and summarized in Table 2. The analysis included a cross-slope analysis plotted on the horizontal alignment of IH 20. Figure 2 is an example of the horizontal and cross-slope output. The purple stars in Figure 2 represent high water accumulation locations that required additional analysis. Similarly, the profile grade along the center skip striping was plotted for each data collection section.

1. Westbound between Texas Reference Marker (TRM) 598.0 and TRM 597.4.
    a. Within this 0.6 mi, there are five high accumulation locations.
    b. Through a left curve, the water seems to flow down the profile grade in the left-lane inside wheel path rather than effectively shedding off the pavement.
2. Westbound between TRM 624.91 and TRM 624.56.
    a. Within this area, three locations of high accumulation occur.
    b. This area occurs in a left curve, but the superelevation remains flat and the profile grade controls the surface flow.
3. Eastbound between TRM 614.55 and TRM 614.75.
    a. Two high accumulation locations occur within this span.
    b. Near this location, the SH 43 entrance ramp ties in with IH 20 without an acceleration lane. Additionally, IH 20 is in a left horizontal curve and a downhill profile grade. The downhill grade exceeds the superelevation.
4. Westbound between TRM 611.0 and TRM 610.95.
    a. This location is a very short area where two high accumulation sites occur.
    b. IH 20 is in a left curve, but the transition back to the crown seems to cause drainage problems.
5. Eastbound between TRM 627.0 and TRM 627.35.
    a. This high accumulation location occurs as IH 20 rolls out of a left curve but must roll quickly back into a right curve. Additionally, the profile grade is steeper than the superelevation, which remains slightly too flat.
6. Westbound between TRM 612.85 and TRM 612.65.
    a. Three high accumulation locations occur within this 1,000 ft.

    b. IH 20 is in a left curve requiring a 2 percent superelevation, but that superelevation is never completely achieved. The flat superelevation combined with a 2.94 percent profile grade leads to the high accumulations.

7. Eastbound between TRM 602.9 and TRM 603.5.
    a. This location coincides with a left curve and uphill profile grade. It seems that the entrance of the curve occurs when the profile grade is approximately 2.90 percent and the roadway rolls to flat between the crown and the superelevation.
8. Eastbound between TRM 616.25 and TRM 616.70.
    a. This location occurs in the transition from a left curve to a right curve along a profile grade with a slope of approximately 2.42 percent. The highest accumulation occurs near the sag in a vertical curve.
9. Westbound between TRM 635.15 and TRM 634.8.
    a. IH 20 westbound at this location is rolling out of a gentle left curve requiring a 2 percent superelevation while also traveling along an uphill grade.
    b. The superelevation seems to be offset from the actual point of curvature and point of tangency for the curve.
10. Westbound between TRM 628.32 and TRM 628.37.
    a. This is a very isolated location of high accumulation near the US 80 entrance ramp.

Table 2. Prioritized Locations.

Priority	Direction of Travel	Begin Reference Marker	End Reference Marker
1	WB	598	597.4
2	WB	624.91	624.56
3	EB	614.55	614.75
4	WB	611	610.95
5	EB	627	627.35
6	WB	612.85	612.65
7	EB	602.9	603.5
8	EB	616.25	616.7
9	WB	635.15	634.8
10	WB	628.32	628.37

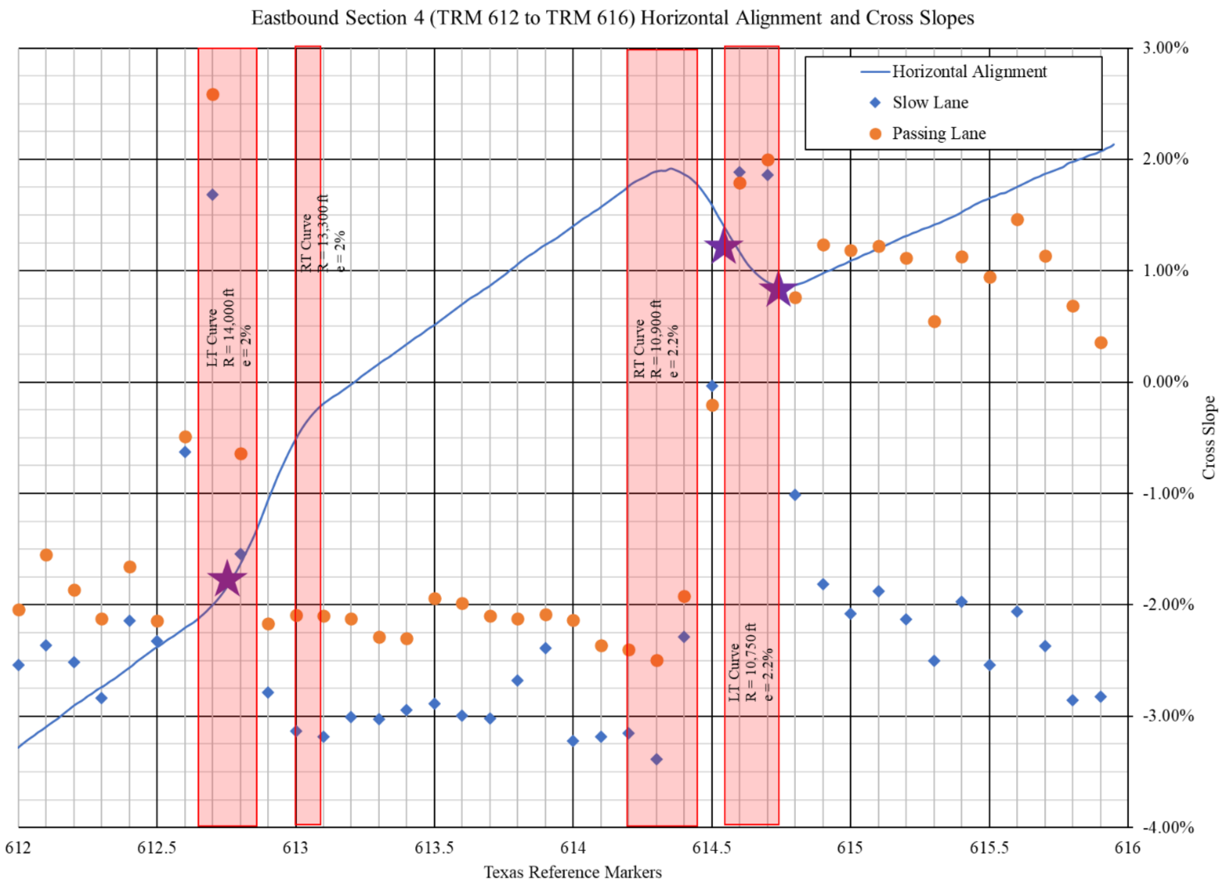


Figure 2. Example Chart for Horizontal Alignment and Cross Slopes.

The goal of this project was to take the analysis described above and develop a user-friendly reporting mechanism. To this end, researchers developed a mapping tool that utilizes a Google Earth .kmz file to present results to the end user.

IH 20—VULNERABLE SECTION VISUALIZATION

An additional analysis of mobile LiDAR data along IH 20 used the calculated difference between the posted speed limit and the predicted hydroplaning speed to identify vulnerable areas. A difference of 10 mph was used, and 8 vulnerable locations along the eastbound roadbed and 13 vulnerable locations along the westbound roadbed were identified. Details on these calculations are located in the final report for the previous TxDOT project, Developing a Surface Drainage Rating for Inclusion in TxDOT’s Asset Management System (https://tti.tamu.edu/documents/0-6896-R1.pdf).

Researchers developed .kmz files for visualization of vulnerable sections in Google Earth. These .kmz files include layers with additional information and navigational functions. When the .kmz file is clicked, Google Earth opens the file and zooms to the location (i.e., IH 20 within the Atlanta District). The master visualization in the .kmz file provides reference markers, an icon for crash locations, and icons on 0.1-mi increments in each lane for the average cross slope. Layers are then loaded on the side of the Google Earth window for each vulnerable area. Double-clicking on these layers zooms to the area of interest within Google Earth and pops-up a drainage basin information window. This pop-up window contains a digital rendering of the vulnerable area and provides drainage basin characteristics (i.e., basin size, average basin slope, water film thickness, and hydroplaning speed).

Figure 3 through Figure 7 show examples of the visualization within Google Earth. Figure 3 shows the Google Earth window created when opening the .kmz file. Figure 4 is created in Google Earth by double-clicking on one of the vulnerable areas on the right side of Figure 3. Figure 4 provides a better view of the data visualized within the .kmz file. All icons in Figure 4 have additional information attached. Additional information can be displayed for each of these icons by clicking them within Google Earth. Figure 5 shows the additional data for cross-slope information obtained by clicking on a triangle, while Figure 6 shows crash record information obtained by clicking on the triangled exclamation mark. Finally, Figure 7 shows the pop-up window created in Google Earth by double-clicking on a vulnerable area. The table within Figure 7 provides additional information on the drainage basin.

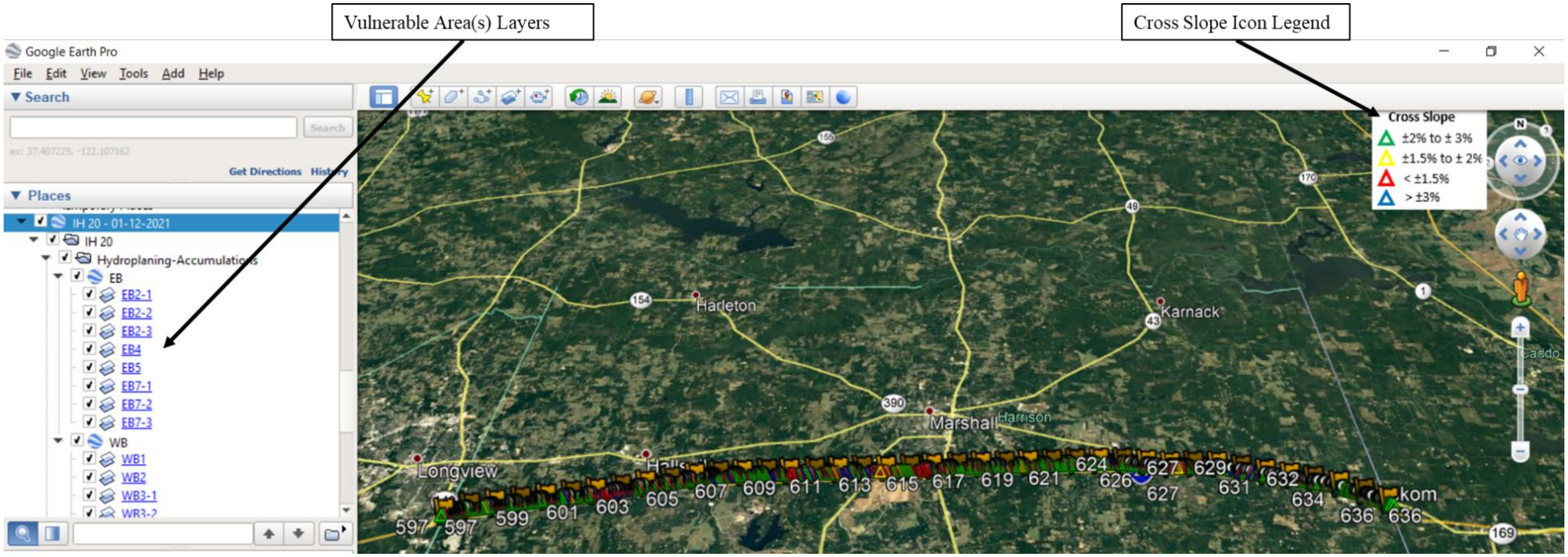


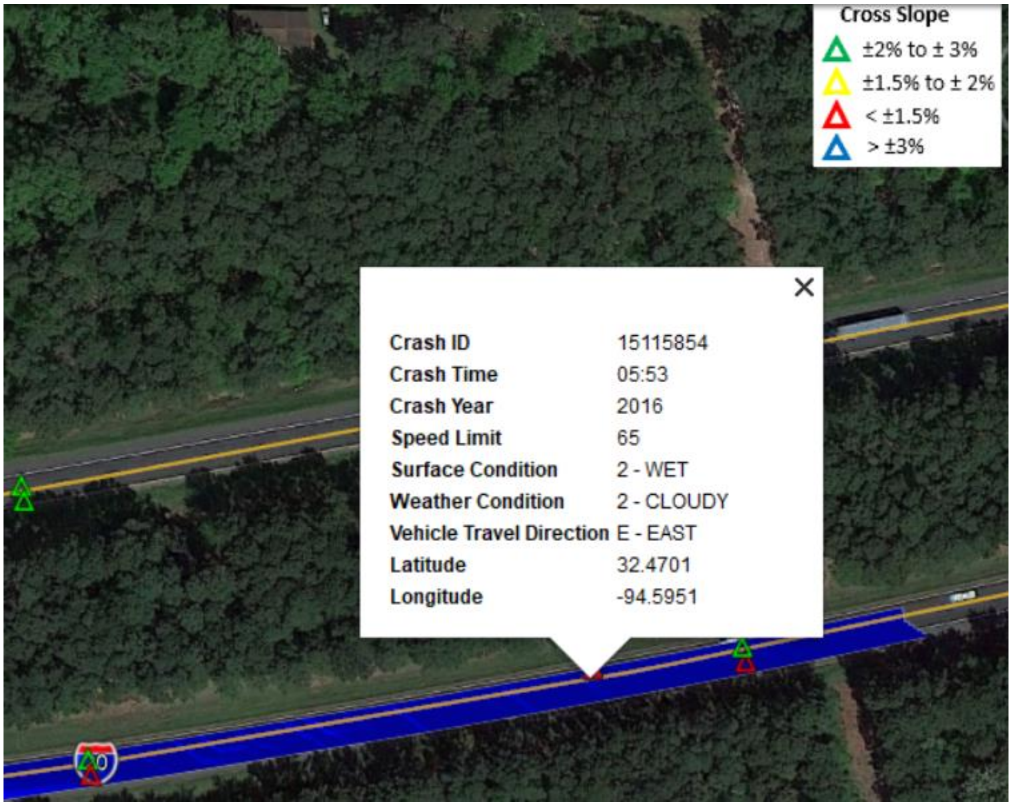
Figure 3. Visualization of .kmz File in Google Earth.

Figure 4. Zoomed Google Earth Location of Vulnerable Area.

Slow Lane - Cross Slope (%): 1.23

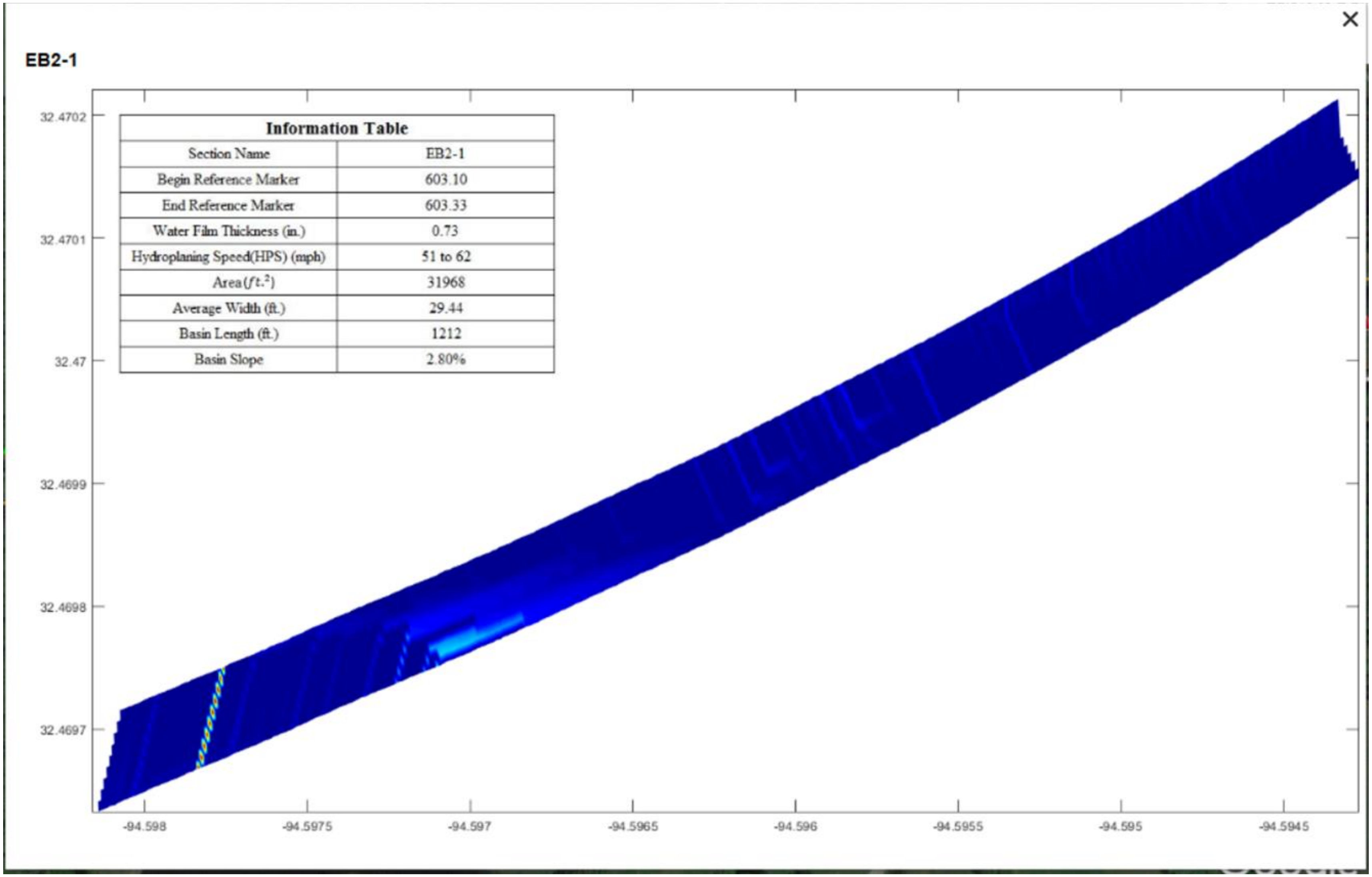
Directions: To here - From here

Figure 5. Visualization of Average Cross-Slope Data.



Crash ID	15115854
Crash Time	05:53
Crash Year	2016
Speed Limit	65
Surface Condition	2 - WET
Weather Condition	2 - CLOUDY
Vehicle Travel Direction	E - EAST
Latitude	32.4701
Longitude	-94.5951

Figure 6. Visualization of Crash Information.



Information Table

Section Name	EB2-1
Begin Reference Marker	603.10
End Reference Marker	603.33
Water Film Thickness (in.)	0.73
Hydroplaning Speed(HPS) (mph)	51 to 62
Area ($ft.^2$)	31968
Average Width (ft.)	29.44
Basin Length (ft.)	1212
Basin Slope	2.80%

Figure 7. Pop-Up Window in Google Earth with Vulnerable Basin Information.

IH 20—ATLANTA DISTRICT SUMMARY

During the analysis of the IH 20 data, researchers noticed that the original cross-slope construction of IH 20 extends the roadway crown to the middle of the divided median. While IH 20 consists of two roadbeds, the original construction treated the right-of-way as a single entity, thus creating eastbound and westbound roadbeds with single slopes across both travel lanes. Figure 8 was taken from a TxDOT plan set for a project on control-section-job (CSJ) 0495-08-136 and shows the cross-slope geometry of IH 20. Figure 8 shows that each roadbed has a typical cross slope of 2 percent. With this type of geometry, a raindrop that falls on the high side of the roadbed flows across both travel lanes to exit the roadway. This configuration contrasts with a typically crowned roadway with a high spot in the center that sheds water in both directions.

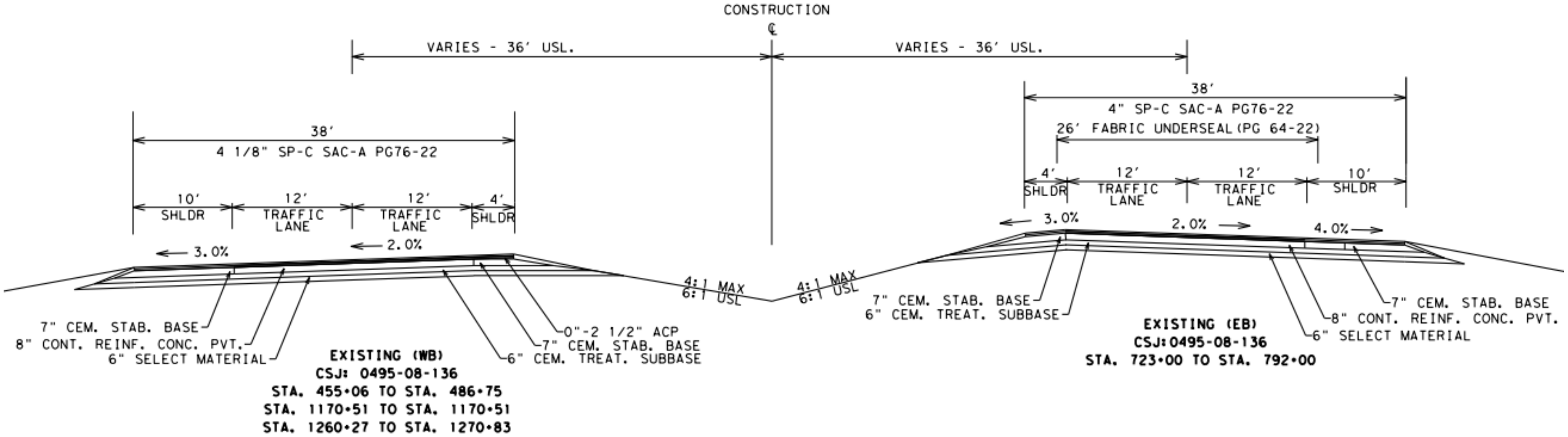


Figure 8. IH 20 Typical Section (taken from CSJ 0495-08-136).

Researchers discovered that the most vulnerable areas along IH 20 included a vertical and horizontal curve at the same location. The mobile LiDAR showed that as a horizontal curve rolls from the straight cross slope with a negative value to a superelevated section with a straight cross slope with a positive value, the water struggles to reverse direction and leave the pavement. Combining this roll in the geometry with a vertical grade, the water tries to reverse itself and gets pulled longitudinally down the roadway by the vertical grade. This creates a worst-case scenario for water film development.

Solving this complex geometric problem requires complete reconstruction of the roadbed; thus, other solutions are needed. The Atlanta District was able to use the information gained about the vulnerable areas to develop a spot location permeable friction course (PFC) project. Placing a PFC creates a surface that eliminates WFT by allowing the water to flow through the surface to the underlying layer. The advantages of the results of this project were the district's ability to determine a likely cause of the hydroplaning, recognize that geometrically little could change, and accurately identify locations to place the PFC. Using the results of this project allowed the district to feel comfortable about the locations to place PFC and confident that doing so would address the problem.

SYSTEM IMPROVEMENT

INITIAL CHALLENGES

While the project was successful in identifying the drainage basins for IH 20 in the Atlanta District, the process required streamlining. The initial process followed the steps below:

1. Collect data in segments no larger than 6 mi to maintain a small file size.
2. Process each segment of data and manually identify pavement striping and pavement edges in LiDAR post-processing software.
3. With knowledge of the edge conditions, extract gridded elevation data using the LiDAR post-processing software.
4. Move the LiDAR data into a text file and reorient it.
5. Process the text file through a MATLAB computer code to identify drainage basins and basin accumulation and output the data in a Microsoft (MS) Excel sheet.
6. Utilize MS Excel to manually identify drainage basin characteristics (i.e., length, average width, slope).
7. With the necessary drainage basin characteristics, perform WFT calculations and run the HPS Monte Carlo simulation in MATLAB.
8. Sort the Monte Carlo simulation output to identify the most critical basins.

TOOL DEVELOPMENT FOR IMPROVEMENT

As part of this research project, a new system was developed to address the cumbersome nature of dealing with multiple programs to produce the identification of critical drainage basins.

The first step in the improvement process was the creation of a data collection system that allows for collection over much longer runs. The existing requirement to collect data in segments lowers the efficiency of data collection and creates safety issues with stopping and starting collection along the roadway. The reason for segmentation was twofold: (1) memory footprint constraints, and (2) post-processing software instability. Video collection constrains the reduction of the memory footprint and remains relatively unchanged. However, the existing LiDAR software crashes when the number of data elements approaches 10,000,000. With strings of data created every 1 ft and approximately 100 measurements in each data string, the maximum length limitation of a data run is approximately 19 mi. However, because of the use of MS Excel to analyze much of the data, the file size was further reduced.

The research team created a program called LiPRO that facilitates unlimited data collection lengths and serves as the processing and analysis program. The list below details the process in LiPRO:

- Load reflectivity and elevation data from an untruncated LiDAR collection.
  - The elevation data are gridded into 3-ft × 3-ft grids (or whatever grid is preferred by the user).
  - Global positioning system and inertial measurement unit data are also loaded.
- Employ built-in tools to identify left and right EOP with reflectivity data.
- Extract reflectivity data and elevation data within each EOP to perform the hydroplaning analysis.
- Perform hydroplaning calculations using the traditional D8 algorithm and a newly developed D3 algorithm.
  - The D3 algorithm deals with edge conditions and ensures that artificial sinks that trap the water are not created.
  - Once the basins are developed using the D8 and D3 algorithms, basin calculations are performed automatically to determine the basin area, basin slope, basin length, basin width, and ultimately hydroplaning speed.
- With a hydroplaning speed attached to each basin, identify critical basins where the difference between the posted speed limit and the hydroplaning speed limit exceeds 20 mph.
- Prioritize critical basins located within the travel lanes based on speed limit difference and stored within LiPRO.
  - The stored drainage basins are converted to a Google Earth .kml file for visualization and provided to the end user.

While the output from this process is nearly identical to the output from the Atlanta District process, the steps have been united into a single program. Prior to the system advancement, raw LiDAR data were processed in a LiDAR software program before being extracted to an MS Excel sheet. Data from the Excel sheet were moved to a text file that could be read by MATLAB to perform the D8 algorithm. Because the MATLAB version of the D8 algorithm did not deal with boundary conditions, these data were dealt with in Excel. After addressing boundary conditions, accumulation values from MATLAB were placed in Excel to determine areas with the largest accumulation. After these areas were identified, basins were manually identified and basin features were manually calculated. Next, values were placed in a text file to be read by Monte Carlo simulation code processed in MATLAB. Ultimately, this led to a hydroplaning speed that could be used to understand the criticality of the basins. If a basin was identified as critical, the geospatial information was manually extracted to use in the mapping function.

The steps outlined above accomplish all of the same things but do so in a single program. The bulk of the manual intervention comes in identifying the EOP. This process has also been streamlined to allow the user to employ a drag-over box to approximately identify the edges and then allow the program to intelligently fill in gaps or adjustments. These improvements expedite the process and bring the tool to an implementation point.

The new process was successfully tested on IH 20 in the TxDOT Tyler District and US 59/US 259 in the TxDOT Lufkin District.

IMPLEMENTATION

With the advancement of the tool to facilitate faster processing and visualization, the products developed as part of this study are ready for implementation. The process has reached a level of maturity where researchers can work with TxDOT districts to scan multiple roadways and provide critical areas in a Google Earth format.

As part of the implementation process, researchers recommend utilizing network-level macrotexture measurements for WFT calculations. During the initial development of this tool, literature values were used for the texture input. However, over the past few years, technology has advanced to collect texture measurements on all roadways. Adding this measurement into the process requires no additional research; rather, it is just an input into the calculations. Texture data can be provided by the TxDOT Maintenance Division from its pavement management system with minimal effort. If necessary, researchers can collect these measurements on specific roadways of interest.