FINAL REPORT

# A STUDY TO IDENTIFY HYDROPLANING ACCIDENTS

TSD-330-77

TRAFFIC and
SAFETY
DIVISION

MICHIGAN DEPARTMENT OF STATE HIGHWAYS
AND TRANSPORTATION

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By

Nejad Enustun



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MICHIGAN DEPARTMENT OF STATE HIGHWAYS AND TRANSPORTATION

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# ACKNOWLEDGMENT

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SUMMARY

Studded tire wear on road pavements led to a study of the possible effects of such damage on the proliferation of hydroplaning accidents. The objectives of the study were to identify such accidents and their locations, to examine road, vehicle and weather conditions associated with hydroplaning, and to try to prevent recurrence of identified hydroplaning accidents.

The study had three phases: (1) library research, (2) review of existing accident reports, and (3) compilation of supplementary data through bi-level police reporting. Phases 1 and 2 led to the design of a supplementary accident report form which was filled out by all police agencies for wet-pavement accidents on the state trunkline system, and attached to the regular accident report.

Approximately 1,400 bi-level reports were obtained during a six-month period, which comprised only 13 percent of the known total of wet-pavement accidents. With the available knowledge, it was only possible to determine with certainty which accidents could not have been caused by hydroplaning. The rest indicated possibility of having involved hydroplaning. This latter group was less than five percent of the sample of wet-pavement accident reports received.

An analysis of the reported conditions resulted in a list of frequency of parameters associated with possible hydroplaning. Sixty-eight locations were selected for field investigations to determine if roadway improvements might be warranted.

It is concluded that, although impossible of absolute identification, true hydroplaning accidents on the highways are rare, and certainly below five percent of wet-pavement accidents. It is recommended that a greater effort be made to educate the public as to the degree of deterioration of tire capabilities on wet pavements under high speeds. Opportunities to apply the results of new research and development should also be explored, including acquisition and application of new and unconventional materials.

CONTENTS

# 1. INTRODUCTION

The phenomenon called hydroplaning, whereby automobile tires float on a layer of water at high speed and cause loss of driver control, started to attract public attention in Michigan in 1972. Technical and lay literature on the subject, and the appearance of localized wear along tire tracks on the highways, caused by studded winter tires which had become popular for the previous few years, made the public and highway administrators concerned about the possible frequency of hydroplaning incidents.

The Michigan Department of State Highways and Transportation (MDSHT) looked with disfavor upon studded tires. This was because of their possible contribution to accidents due to tire hydroplaning on water accumulating in ruts caused by studs, and because of the excessive and uneven pavement wear experienced since use of tire studs became popular. The present study was initiated to determine the extent of hydroplaning accidents by trying to identify such accidents; to examine road, vehicle, and weather conditions associated with hydroplaning; to improve highway segments which such accidents reveal; and to recommend future action by the Department to alleviate any serious problem if it exists, or to carry out further research toward that end. Any positive evidence that studded tires were causing hydroplaning would strengthen the Department's position in promoting legislation to prohibit their use. It was specified that the study would be confined to hydroplaning and not be involved in wet-skidding conditions.

An advisory committee was created during the early part of the study to reach a concensus on the methodology to be adopted. It was originally made up of Messrs. Robert Addy, Arthur Yang and Nejad Enustun of the Research Studies Unit, Mr. Stanley Lingemen of the Accident Analysis Unit, and Messrs. Allen Lampela and Wilhelm Leuchtenmueller of the Standards and Development Unit. Mr. Romeo Portigo replaced Mr. Leuchtenmueller when the latter was transferred to the Design Division. Mr. Peter DeCamp, Research and Development Engineer, also participated in several of the committee meetings.*

The study evolved into three principal phases. The first phase was literature review, which also extended well into the two remaining phases. The second phase was a search of the computerized accident files for clues to hydroplaning. The third phase was the design, distribution, compilation, and analysis of a special supplementary report attached to the official accident report by the investigating officer. The remaining sections of this report will reflect the activities which made up the various phases of the study and the results and conclusions obtained.

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*Unit names and titles are those of the Traffic and Safety Division organization in 1972, which has subsequently changed.

## 2. LITERATURE REVIEW

An extensive bibliography is included at the end of this report. Some of these references contain more information on the subject of skid resistance than on the specific subject of hydroplaning. This is inevitable since an understanding of the behavior of automobile tires on wet pavements is essential to examine the special condition of hydroplaning. This section of the report will attempt to bring out the salient points of the bibliography, with or without direct reference, which are relevant to the objectives of the present study.

The dangers of hydroplaning were first discovered on airport runways where aircraft landing speeds are high and drainage of surface water is difficult because pavement slopes have to be kept to a minimum. Subsequently, the geometric standards of new highways allowed very high automobile speeds, and the danger of hydroplaning started to appear on highways as well.

It is essential to have an understanding of the basic forces involved between the tire and the pavement. Figure 1 (1)* shows the forces acting on an automobile tire moving under engine power. The road is assumed to be horizontal. L is the longitudinal, driving force. T is the transverse force, at right angle to L, which may, in many instances, be caused by centrifugal force. The forces L and T have a resultant force R which is equal to fV where f is the coefficient of friction being utilized at that instant, and V is the wheel load. The coefficient of friction f may vary anywhere from a small value approaching

*The numbers in parentheses refer to publications listed in the Bibliography at the end of the report.

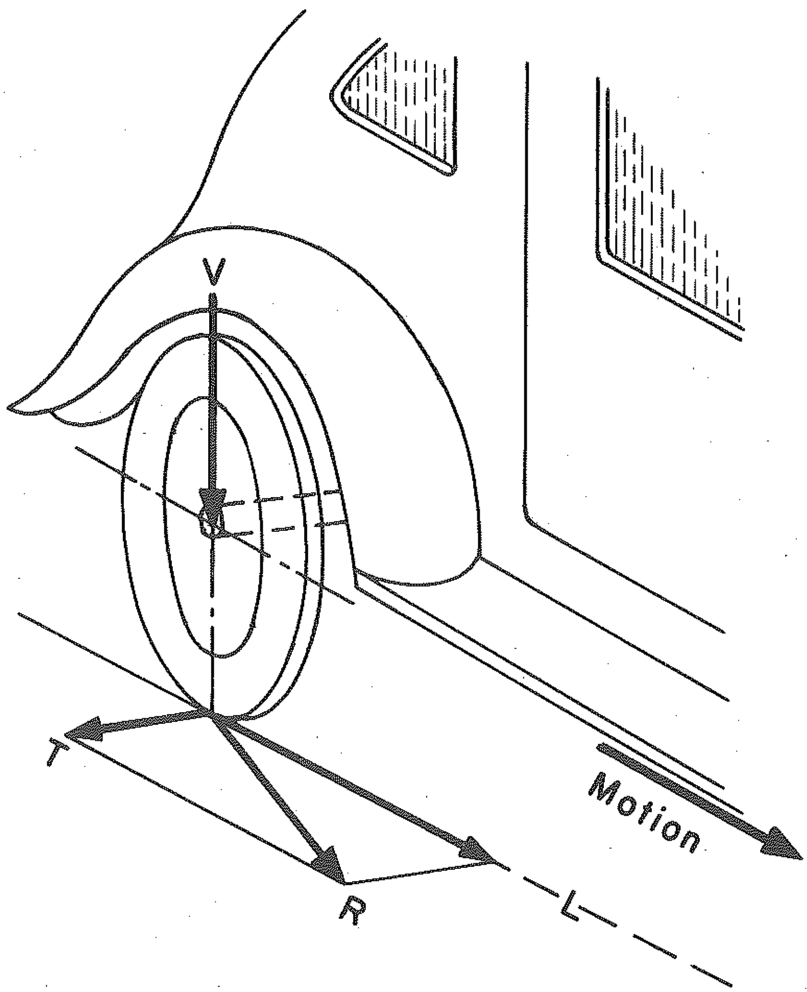


FIGURE 1: FORCES ACTING ON A TIRE.

zero to unity under exceptionally good road and tire conditions and high acceleration. The limiting value of f is $f_u$ which is the ultimate coefficient of friction possible with given road and tire conditions.

From Figure 1 we can write:

$$f_u V = R$$

And since

$$R = \sqrt{L^2 + T^2}$$

Then

$$f_u V = \sqrt{L^2 + T^2}$$

By transposing and squaring, we have

$$1 = \left(\frac{L}{f_u V}\right)^2 + \left(\frac{T}{f_u V}\right)^2$$

This equation, which represents the limiting conditions, is that of a circle with radius one, as shown in Figure 2. This shows that longitudinal and tranverse forces acting on a tire are directly related. For example, if we utilize the entire ultimate coefficient of friction $f_u$ for propelling the vehicle in the longitudinal direction, we have no reserve frictional force in the transverse direction to resist the slightest centrifugal force, lateral wind force, or gravitational force if the road has a lateral slope. In terms of Figure 1, this would mean that the resultant friction force R coincides with L, and therefore T = 0 and the vehicle is in an unstable condition.

Getting back to Figure 2, if we utilize 95 percent of the available force for propelling the vehicle, we only have 30 percent remaining for lateral stability. If we assume a possible coefficient of friction of

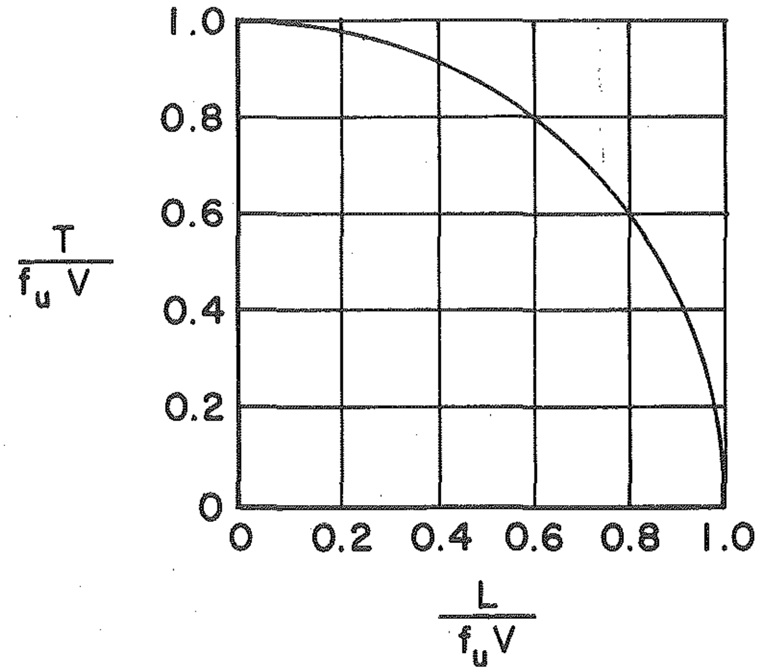


FIGURE 2: DIAGRAM OF RESULTANT OF ACTING FORCES.

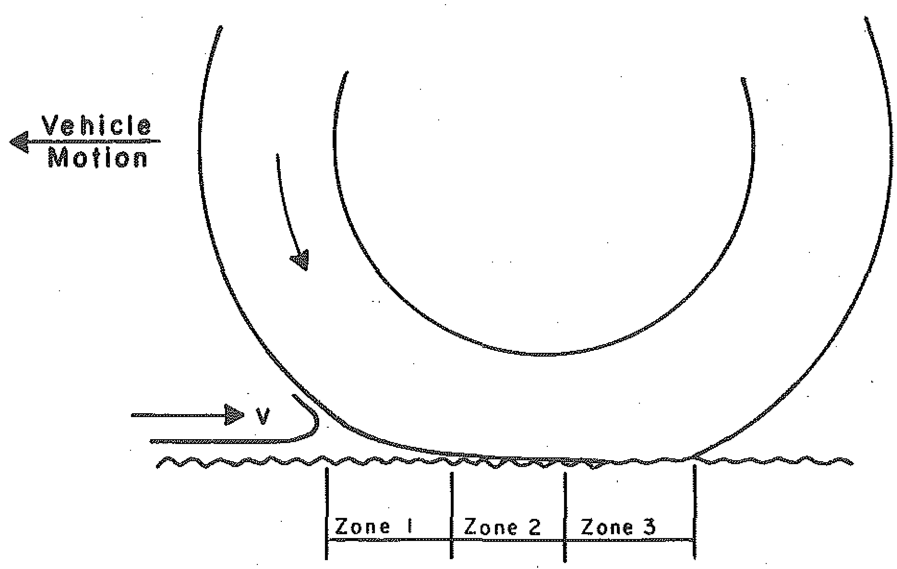


FIGURE 3: DISPLACEMENT OF WATER BY TIRE IN SUCCESSIVE ZONES.

0.60 and utilize 95 percent of it for traction, in the subject case, we would have 0.95 x 0.60 x 100 = 57% of the wheel load for traction, and 0.30 x 0.60 x 100 = 18 % for side loads. If the road were icy and the ultimate friction coefficient only 0.1, the lateral force available would decrease to 0.30 x 0.1 x 100 = 3% of the wheel load if 95 percent of the friction were used for traction.

In a situation where the vehicle is braking, rather than accelerating as in the foregoing examples, the direction of the force L would be reversed, but the same relations would hold true.

From the foregoing analyses, it becomes apparent why some skidding accidents look and feel like hydroplaning. In such cases, no braking may be involved, nor may the vehicle be rounding a curve, but directional control may be lost because the available frictional force is being used for acceleration in the longitudinal direction with no lateral component to provide stability. In fact, some researchers have concluded that full hydroplaning on highways is a rare occurrence (22, 28, 52).

The coefficient of sliding friction between the tire and the road surface is multiplied by one hundred and called the skid number (SN). The skid number varies according to the speed of the skid test trailer. The tests are normally run at a speed of 40 miles per hour. It would be possible to estimate with some accuracy the skid number for speeds higher than the test speed if precise knowledge were available on the character of the pavement surface, and if empirical information existed on the variation with speed of the skid number on typical pavement surfaces, which could then be matched with the specific pavement being tested. Unfortunately, such information is in a research and development stage (4, 5, 11, 14, 19, 50).

Pavements having a so-called harsh surface with small, but sharp texture provide a higher coefficient of friction under low speed, such as at an urban intersection. High-speed skid-resistance, on the other hand, requires large, open surface texture. Road surfaces can thus be designed to suit the requirements of traffic. Certain characteristics of aggregates play a big role in continued non-skid quality of pavements (33). Some of these characteristics also deter hydroplaning.

The decrease of the skid number with speed is closely related to the ability to expel water from the tire/pavement interface. This ability, in turn, depends on the existence of sufficient escape channels for the water on the pavement surface, as well as sufficient tread grooves and "sipes" (slits) in the tire. If the water in the tire/pavement contact area can be expelled readily by the interaction between a rough or macrotextured pavement surface and properly inflated tires with sufficient tread configuration, the reduction of the skid number with increasing vehicle speed is small. The converse situation of a smooth road surface combined with bald tires causes the skid number to decrease very rapidly with increased vehicle speeds.

Hydroplaning is a special condition of the wet pavement/tire skidding condition where the water cannot escape and hydro-dynamic pressure is built up which sustains the floating tire over it. Figure 3(11) represents a tire rolling on wet pavement. If the tire were stationary, all three zones shown would be fully in contact with the pavement. In motion, zone 1 of the tire print has lost contact with the pavement proper, and is riding on a wedge of water. In zone 2, the tire is just touching the high spots (asperities) of the solid pavement and partly bearing on a thin layer of water. Zone 3 has been wiped relatively dry by the tire earlier so that the tire is in full contact with the road surface. As the speed of the tire increases, zone 1 will extend into zone 2, and zone 3 will now be similar to zone 2. With further increase in speed, zone 1 will extend all the way into zone 3 so that now the tire will bear on the pressurized water layer which will have occupied the entire tire patch, and full hydroplaning will occur.

Although theoretical explanations of the conditions causing hydroplaning abound in technical literature, empirical information is too scarce to convert the theory into given, practical road and tire conditions. This makes it impossible, with today's state of the art, to predict precisely at what vehicle-speed full hydroplaning will occur under various road surface, water depth and tire conditions. An empirical formula, $S = k \quad P$, is sometimes used to predict the speed S at which hydroplaning will start, as a function of the tire pressure P. The coefficient k represents all of the other variables, and is given a value of about 9 or 10 to reflect the most adverse conditions when S is expressed in MPH and P in pounds per square inch.

It is not possible to determine for a fact, under field situations, whether a certain accident was the consequence of hydroplaning or simply wet skidding (26,45). Under laboratory conditions, some researchers suggest 10 percent spin-down* of the tire to be accepted as the start of hydroplaning (40,54).

Research is being done to standardize laboratory methods of testing the surface drainage capacity of pavement specimens so that these will make it possible to evaluate a given road surface and predict precisely the skid numbers at various speeds, and the critical speed and water depth values for impending hydroplaning (4, 21, 55). One method uses a special device to measure the time it takes for a certain amount of water to seep under the wall of a cylinder which bears on the pavement specimen. Other methods use fine sand, plastic putty, and photographs to measure the texture depth of the pavement surface. There are known methods of predicting the depth of water on a road surface due to rain (42). These would complement the information from the laboratory tests.

Tire construction, type of plies, rubber composition, and tread depth and configuration are important factors related to skidding and hydroplaning. A tire company representative contends that 50 percent improvement has been achieved in a decade in the stopping and cornering ability of tires (8). He states: "Under fully flooded conditions, on smooth surfaces, we can now achieve braking coefficients in excess of 0.50" although speed is not mentioned.

A recent report (51) on tire traction grading concludes that ". . . tire grading is possible on concrete. . . Classifications must take into account that the longitudinal performance of a tire correlates very

*Reduction in rotation speed of a freely rolling wheel.

poorly with the lateral performance. . . . In addition, this study shows that, on wet surfaces, the maximum lateral force capability of most tires exceeds the maximum braking force capability. Also, the 'skid number' is shown to classify the asphalt pavement as significantly 'slipperier' than the concrete surface, while lateral force measurements shows the asphalt to be equal or superior to the concrete on the basis of traction."

From tire tread depth measurements on accident-involved and other cars, an Ohio study derived the likelihood of accident involvement versus tread depth (27, 46). The economic study resulted in a recommendation to increase the legal minimum allowable tread depth from 2/32 inch to 4/32 inch.

Research on the effect of studded tires on pavements (20) indicates that skid tests within the worn wheel paths result in a reduction in the skid number of no more than 2 or 4 points compared to skid numbers outside the paths. The area affected in the wheel paths was found to be approximately 2 1/2 feet wide for each wheel path.

In Hearings Before the Subcommittee on Public Works, House of Representatives (28), testimony of a state of New York research engineer, on the question of tire studs polishing the pavement, included this statement: ". . . it would be our opinion that this would not increase the slipperiness of the pavement as a result of the polishing of the aggregates. This is more of a picking action as we see it in New York, where our bituminous or asphalt pavements are rough."

Tire pressures and wheel loads are two of the factors that affect the critical speeds for obtaining hydroplaning. Higher values of tire pressure result in higher critical speeds. The effect of wheel loads may be positive or negative depending on tire tread depth (43) and construction. The problem of inaccurate air pressure measurement is brought out in the above-mentioned House hearings by reference to a National Bureau of Standards study which found that the air towers (tire inflation pumps) at service stations were seldom calibrated.

Although vehicle speed is a very important consideration which, in most cases, makes the difference between an accident and safe operation in wet weather, one study (10) showed there was very little difference in speed between dry and wet weather traffic. Little likelihood of actual hydroplaning on highways is attributed to the fact that when rain is intense enough to fill the surface voids of a well-designed road mixture, visibility is reduced and majority of drivers slow down (16). Texas reports (40, 43, 48) recommend reduction of the speed limit to 50 MPH on any highway section where water can accumulate to a depth of 0.1 inch or more.

Highway curvature is sometimes considered to contribute to serious wet skidding and hydroplaning. An abstract of a Texas study on curve design (36) states: "Current design practice for horizontal curves assumes that vehicles follow the path of the highway curve with geometric exactness. The adequacy of this assumption was examined by conducting photographic field studies of vehicle maneuvers on highway curves. Results indicate that most vehicle paths, regardless of speed, exceed the degree of highway curve at some point on the curve. For example, on a 3-degree highway curve, 10 percent of the vehicles can be expected to exceed 4.3 degrees." A new design approach is recommended to compensate for the true vehicle trajectories. A Virginia highway engineer proved that curves on approaches from the left produced twice as many accidents as curves from the right (47).

A situation demanding maximum tire adhesion is the passing maneuver on two-lane, two-way roads in wet weather, since both longitudinal and lateral friction are being utilized to full capacity. The driver normally goes through four distinctly curved trajectories for pulling onto the left lane and back to the right lane at high speed.

Longitudinal pavement grooving is shown to have reduced wet weather accidents on some California highways in one year from 253 to 9(15). Another researcher states: "The grooving process is practical on roadway surfaces where the skid resistance is slightly below acceptable level; it is not generally satisfactory for very slippery pavements"(30).

In the House of Representatives hearings referred to earlier, among the testimony by a professor of the Ohio State University, the following opinion was noted: "I would dare to say that not one driver in a thousand has any comprehension at all of the massive reduction in traction capability that he has at his control which occurs when the rain starts to fall."

Replacements for conventional aggregates for highway use was the subject of an NCHRP report (44). Here are some quotations from that report:

"Ceramic coatings that wear unevenly, or alternate coatings with varying hardness, may be used to improve skid resistance in aggregates. . . . For some uses, aggregates may be upgraded to the necessary standards by blending in other aggregates or materials with specific characteristics. Silica sand and particles of cast iron are examples of materials that can be used to increase polishing resistance and improve skid-resistance characteristics of pavement surfaces".

## 3. STUDY PROCEDURES

In addition to the library research, the remaining activities on this project involved studies of the accident data contained in the Department's files, and the design, distribution, collection and analysis of a supplementary accident report form. Computerized accident files were used only to identify and select the various accidents, and the reports themselves were examined individually.

### 3.1 - FATAL ACCIDENTS IN RAIN

During 1971, there were 96,114 reported accidents on Michigan state trunkline highways excluding property-damage and injury accidents in the city of Detroit. Of this total, 9,179 or 9.5 percent, happened during rain. These rainy-weather accidents included 68 fatals. Accident reports for these fatal accidents were studied in detail. Hydroplaning possibility was ruled out in about 30 cases because of the particular circumstances. The data provided in the official accident reports for the remaining 38 cases did not rule out hydroplaning but were not sufficient to render further judgment.

### 3.2 - ACCIDENTS PER 0.2 MILE SEGMENTS

The next phase in the study of existing accident data was a review of the reports for rainy-weather accidents which showed concentrations on short road segments. One of the existing computer programs used for identifying critical segments of the highway system searched accidents within each 0.2 mile segment. This program was utilized to identify those road segments containing a selected minimum number of accidents of certain types. For the purpose of examining those accident reports which might contain clues for hydroplaning, accidents that happened during rain were specified. Right angle, backing, bicycle and pedestrian accident types were not considered. A computer search of accidents during 1971 revealed the following:

| Mininum Accidents per 0.2 Mile Segment | Number of Road Segments | Number of Accidents |
|---|---|---|
| 5 | 363 | 2,315 |
| 6 | 209 | 1,545 |
| 7 | 124 | 1,030 |
| 8 | 75 | 675 |
| 9 | 44 | 444 |
| 10 | 22 | 246 |

First, the 246 accident reports with a concentration of 10 per segment were studied. Roadway type and alignment, speed limit, reported speeds, and the main cause of the system failure resulting in the accident were determined for each case. Fifty-seven of the 246 reported accidents showed the possibility of hydroplaning.

Next, reducing the minimum concentration to 9 per segment, 198 additional accident reports were scrutinized in the same way. An additional 34 accidents indicated possibility of hydroplaning.

These efforts were effective in ruling out which of the examined accidents could not have been caused by hydroplaning. It was not, however, sufficient for determining with reliability which accidents might have involved hydroplaning. This was largely because official accident reports lacked the detailed information necessary to study the possibility of hydroplaning. Rain intensity, water depth, pavement condition, vehicle speed, tire condition, and other particulars regarding vehicle behavior and skidding were thought to be the minimum data necessary for a more reliable diagnosis. It was evident that a supplementary accident report was needed for this purpose.

## 3.3 - SUPPLEMENTARY ACCIDENT REPORTS

The design and use of any supplementary report to be attached by the investigating police officer to the official accident report form (UD-10) require approval by a standing committee named the Steering Committee for Bi-Level Reporting. This committee is chaired by the Commanding Officer, Safety and Traffic Division, Michigan Department of State Police (MDSP). MDSHT; Michigan Sheriffs' Association; Lansing Police Department; Detroit Police Department; and Highway Safety Research Institute, University of Michigan, are represented in the committee.

Several meetings of that committee were held at which the project and its data requirements were discussed. Any supplementary accident report requires extra time and attention by the police officer. The objectives of research and law enforcement always pose a dilemma in such a situation. Research requires special details, but enforcement duties do not allow spending a long time to obtain such details. Consequently, a compromise has to be reached.

Several items were discussed at the Steering Committee meetings that are worthy of note. The difficulty of labeling an accident as a hydroplaning accident was admitted from the start. To prevent any bias on the data, it was first suggested not to mention the word hydroplaning in the report form. However, this would not tell the investigating officer why he was filling out the form. It was therefore decided to indicate the subject and purpose of the study on the report form.

Another item of discussion was the establishment of limiting conditions for requiring the completion of a report in any accident. It would serve no purpose for this study to include low-speed accidents. Furthermore, the occurrence of hydroplaning was very unlikely unless it was raining during the accident. It was suggested that a supplementary report would be required only when it was raining during the accident and the minimum vehicle speed prior to the accident was 50 miles per hour. However, administrative and psychological considerations made it undesirable to set such limiting conditions. It was thought that specifying rain as a condition would possibly raise some questions, since most of the accident investigations are made at some time after the accident. Speed threshold was similarly considered improper because it is not normally reported in the official report, and might cause doubt or hesitation on the part of the investigating officer. Therefore, a supplementary report was required whenever the "wet" box was checked for road condition in the official report. This decision was taken in spite of the excessively large number of reports to be compiled.

### 3.3.1 - The Pilot Study

Every effort was made to keep the supplementary report as simple as possible so that it could be filled out in a short time at the site of the accident. To prove its practicality, the Steering Committee decided to try the form in a pilot study in the fall of 1973 on all categories of streets and highways in the State Police Fourth District, which contains Branch, Calhoun, Hillsdale, Jackson, and Lenawee Counties. Two thousand copies of the supplementary report form were printed in late October, 1973. Reporting of wet pavement accidents continued for about one month and ended in late November. Each supplementary report was stapled to a copy of the official accident report and transmitted to the MDSHT for review and evaluation.

Seventy-eight reports were received and reviewed in this pilot study. The committee had directed compiling 100 samples, but this figure did not materialize in the trial period. Sixty-four of the reports were completed by State Police officers and 14 by the Lenawee County Sheriff's deputies. There were no reports from the remaining four county sheriff departments nor from any city police departments.

Examination of these reports, together with the information in the official accident reports, indicated that there were very few, minor errors which could be detected. Few suggested improvements on the trial report form were offered by the investigating officers. The following are the only responses:

- All needed information is on report. Report is clear and simple to prepare.

- Fine report but does not apply to this accident (parking accident involving a low-speed second car).

- Fine. Need more studies like this one.

- Sufficient.

- Boxes 13 and 14 do not have enough choices for why and when brakes applied. (These two questions were expanded before the main study, to include more possible cases.)

- Good.

The pilot study proved the practicality of the supplementary report form, at least as far as the Department of State Police and Lenawee County Sheriff were concerned, and there appeared to be no cause for difficulty for other investigating officers. An interim report was prepared in January, 1974, and distributed to Steering Committee members. Some minor revisions in the form were made and instructions on the reverse side were revised, requesting the report for state trunkline system accidents only. A sample of the supplementary accident report form (after revision) is presented in the Appendix.

### 3.3.2 - MAIN STUDY WITH SUPPLEMENTARY REPORTS

The oil shortage experienced in the autumn of 1973 and subsequent reduction of the statewide speed limit to 55 MPH in March, 1974, suggested reconsidering continuation of the project since lowered speeds would greatly reduce hydroplaning incidents. Speed surveys in April, 1974, however, indicated a large percentage of vehicles exceeding the speed limit, although the 85th percentile speeds were considerably lower than the pre-crisis period. As long as there was a significant number of motorists exceeding the statutory speed limit it was decided to proceed with the field reporting.

The next decision to be made was the duration of the bi-level reporting period. Three to six months of reporting possibility was considered. The following tabulation of total and injury accidents, including fatals, on wet pavement and in rain on state trunklines in 1973 shows the number of accidents that would be involved, depending on the choice of possible study durations.

1973 State Trunkline Accidents

| | Total Wet | Injuries on Wet | Rain | Injuries in Rain |
|---|---|---|---|---|
| April through September = 6 months | 9952 | 1703 | 7457 | 1191 |
| June through November = 6 months | 10534 | 1744 | 7739 | 1289 |
| April through August = 5 months | 8314 | 1402 | 6131 | 957 |
| July through November = 5 months | 8800 | 1446 | 6446 | 1064 |
| April through July = 4 months | 7442 | 1226 | 5476 | 826 |
| August through November = 4 months | 7318 | 1212 | 5247 | 871 |
| April through June = 3 months | 5960 | 992 | 4277 | 633 |
| September through November = 3 months | 6446 | 1036 | 4592 | 740 |

At its meeting on February 14, 1975, the Committee reviewed the interim report and approved the main study. The foregoing table was reviewed, and it was decided to implement the reporting for the six-month period from June through November, 1975, which would provide the largest data base.

The logistics of supplying enough report forms to the individual police agencies was planned by the MDSP. Involved were 351 agencies, made up of 65 State Police posts, 83 county sheriffs, and 203 township and municipal police departments having jurisdiction on any portion of the state trunkline system. Twenty-five thousand forms were printed. The initial distribution packages varied from 10 to 60 forms depending on the expected number of reports. This used up about 9,000 forms. The remaining 16,000 were kept at the State Police headquarters in East Lansing for future distribution according to demand. Letters of transmittal to State Police commanders and other police agencies dated May 1, 1975, are reproduced in the Appendix.

Toward the end of July, 1975, after almost two months of the six-month reporting period had passed, it appeared that the rate of reporting was not as high as desirable, compared with the number of wet-pavement accidents reported for the corresponding months of past years. Furthermore, no accidents were being received from the city of Detroit. These observations were reported to the MDSP. Their Safety and Traffic Division solicited further cooperation from Detroit, but only eight reports were received from the city throughout the study period.

The MDSP sent a letter to all police agencies again on August 7, 1975, (see Appendix) reminding them that a number of wet-pavement accidents were being received without the supplement attached and requesting added effort and cooperation.

Each supplementary report received by the MDSHT, attached to the official accident report, was scrutinized by the project engineer. After carefully evaluating all available information in both reports, a judgment was made as to the possibility of hydroplaning in that particular accident. This was no more than an educated guess, as it was apparent from a review of past research that no known method existed to absolutely distinguish between wet-skidding and full hydroplaning accidents. However, the degree of detail available from the supplementary report made such judgment much more reliable than was possible with only the official accident report.

## 4. RESULTS

The total supplementary reports received were 1,393. Earlier concern about a low return ratio, unfortunately, materialized. The total number of wet-pavement accidents reported on state trunklines, not including Detroit, for the six-month period from June through November, 1975, was 10,464. Thus the ratio of reporting was 13 percent.

MDSP opinion is that State Police posts probably provided better response than the local police agencies. There might be several reasons why a bi-level report of this nature would produce low response: (1) insufficient instruction reaching down to every individual police officer, (2) inability to provide report form blanks at all times for all police vehicles, and (3) possibility that some officers may have ruled out the occurrence of hydroplaning in many accidents because of low speed or other conditions and therefore did not fill out a report. This last reason would not have materially affected the results of the study. It is not possible to determine how prevalent this reason was in comparison with the first two. It is reasonable to suppose that if the police officer suspected hydroplaning but did not have a blank form in his patrol car, as supposed in reason 2, he would make an effort to obtain and complete a form later.

Sixty-eight reports out of the total of 1,393, or 4.9 percent, were judged to have hydroplaning possibility. The locations of the accidents are described in a list in the Appendix. This list was transmitted to the Safety Programs Unit in March, 1976 for field investigations and possible programming for improvement. It should again be emphasized that these accidents show a strong likelihood of hydroplaning according to the reported data, but it is not possible to state with confidence that all of them were, in fact, hydroplaning accidents. Considering the fact that hydroplaning is the ultimate condition in the gradual decrease of the tire/pavement contact area, it is only of academic interest whether a particular accident was caused by hydroplaning or high-speed wet skidding. In either case, the remedy calls for improving surface drainage even if the skid coefficient is satisfactory at lower speed.

Eight of the 68 locations in the list (see Appendix, pages 44-48) are marked by asterisks. These asterisks for adjacent listings indicate locations in close proximity which may warrant particular attention. Four such road segments were discovered. The remainder of the listings are single-incident locations. The four repetitive segments were brought to the attention of the affected District Traffic and Safety Engineers (DTSE) in January, 1976. In the case of the District 4 location in Otsego County, the DTSE reported that the affected portion of I-75 was treated with a heater-planer to eliminate a slippery condition in late fall of 1975. Regarding the Metro District location on eastbound I-96, the DTSE recommended elimination of pavement depressions or provision of proper catch basins to prevent water accumulation. Field investigations were not concluded by District 7 on westbound I-94 in Berrien County or by District 8 on southbound I-75 in Monroe County at the writing of this report.

Thirteen parameters were studied by examining the frequency of their occurrence in the accidents involving likelihood of hydroplaning. The results are as follows:

FREQUENCY OF REPORTED CONDITIONS
IN ACCIDENTS HAVING LIKELIHOOD OF
HYDROPLANING

| | | Number | Percent* |
|---|---|---|---|
| 1. | Presence of Rain: | | |
| | Raining | 66 | 97 |
| | Not Raining | 2 | 3 |
| 2. | Rain Intensity: | | |
| | Light | 13 | 19 |
| | Medium | 27 | 40 |
| | Heavy | 26 | 38 |
| | Not Reported | 2 | 3 |
| 3. | Water Accumulation on Road: | | |
| | Accumulating | 55 | 81 |
| | Not Accumulating | 11 | 16 |
| | Not Reported | 2 | 3 |
| 4. | Depth of Water Accumulation: | | |
| | 1/16 Inch | 21 | 31 |
| | 1/8 Inch | 15 | 22 |
| | 1/4 Inch or More | 18 | 26 |
| | Not Reported | 14 | 21 |
| 5. | Pavement Ruts in Wheel Path | | |
| | Ruts Present | 17 | 25 |
| | No Ruts | 50 | 74 |
| | Not Reported | 1 | 1 |
| 6. | Road Alignment: | | |
| | Tangent | 49 | 72 |
| | Curving Left | 12 | 18 |
| | Curving Right | 6 | 9 |
| | Not Reported | 1 | 1 |
| 7. | Road Grade: | | |
| | Horizontal | 48 | 71 |
| | Uphill | 12 | 18 |
| | Downhill | 8 | 12 |
| 8. | Pavement Type: | | |
| | Portland Cement Concrete | 36 | 53 |
| | Bituminous | 32 | 47 |
| 9. | Vehicle Speed: | | |
| | Under 40 MPH | 1 | 1 |
| | 40 to 49 MPH | 9 | 13 |
| | 50 to 59 MPH | 45 | 66 |
| | 60 to 69 MPH | 12 | 18 |
| | 70 MPH or Above | 1 | 1 |

*Percentages do not always add to 100 because of rounding the last digit.

| | | Number | Percent | |
|---|---|---|---|---|
| 10. | Tire Condition | | | |
| | At Least One Bald Tire | 10 | 15) | |
| | At Least One Tire with Shallow Grooves but no Bald Tire | 12 | 18) | 33 |
| | At Least One Medium-Worn Tire but no Shallow-Grooved or Bald Tires | 36 | 53) | |
| | All Tires New | 7 | 10) | 63 |
| | Not Reported | 3 | 4 | |
| 11. | Highway Type | | | |
| | Freeway | 38 | 56 | |
| | 4-lane divided | 3 | 4 | |
| | 5-lane | 1 | 1 | |
| | 4-lane undivided | 3 | 4 | |
| | 2-lane | 23 | 34 | |
| 12. | Accident Type | | | |
| | Head-on | 4 | 6 | |
| | Sideswipe same direction | 10 | 15 | |
| | Sideswipe opposite direction | 1 | 1 | |
| | Rear-end | 2 | 3 | |
| | Ran-off-road | 51 | 75 | |
| 13. | Accident Severity | | | |
| | Fatal | 2 | 3 | |
| | Injury | 26 | 38 | |
| | Property damage | 40 | 59 | |

It will be observed from the foregoing analysis that 97 percent of the accidents suspected of hydroplaning occurred during actual rain, a great majority being under medium and heavy rain. Eighty-one percent of the time, water was accumulating on the road to some degree. Ruts in the wheel paths did not appear to have much bearing on hydroplaning since they were reported in only 25 percent of the cases.

Tangent road sections accounted for 72 percent of the 68 cases. Left-curving roadways made up 18 percent, and right-curving roads 9 percent, which appears to substantiate a Virginia report that left curvature produces twice as many accidents as right curvature (47). Horizontal grades had 71 percent of the accidents. Ascending grades accounted for

18 and descending grades for 12 percent. Pavement type (bituminous versus portland cement concrete) did not indicate significant difference.

Sixty-six percent of the incidents took place within a vehicle speed range of 50 to 59 MPH. Faster speeds were involved in only 19 percent. This information would tend to indicate danger of hydroplaning at speeds less than would normally be supposed; however, speed information from police reports is one of the least reliable, since accident victims usually report lower than actual speeds.

Review of tire tread depth revealed that 63 percent of the vehicles involved had medium-worn or better tires, and less than a third of the vehicles had any shallow-grooved or bald tires.

The majority of the incidents happened on freeways, and about a third on two-lane rural roads. Other road types did not contribute to any great extent.

Three-fourths of the accidents were of the ran-off-road type. Same-direction sideswipes ranked second with 15 percent. Other types made up only 10 percent.

Accidents resulting in only property damage accounted for 59 percent of the cases. Injury accidents resulted in 38 percent. There were two fatal accidents.

# 5. CONCLUSIONS

1. At the present state of the art, it is not possible to predict the critical automobile speed which will result in complete hydroplaning of a tire. Promising laboratory procedures that measure the rate of water-drainage capability of a pavement sample may make this possible in the future.

2. It is not possible to differentiate with absolute certainty between a high-speed, wet-pavement skidding accident and a true hydroplaning accident. For practical purposes, this may not be important for a highway department, since both situations require properly textured pavement with good drainage characteristics.

3. Supplementary reports have been very useful in locating accident sites where there was possibility of hydroplaning, but such reports have failed to indicate all such locations, due to a low ratio of reports returned. Bi-level or supplementary police reports cannot be relied upon for full coverage of any type of accident on a total road system.

4. There were much fewer accidents possibly related to hydroplaning on curves than tangent sections.

5. Hydroplaning on Michigan state trunklines is an infrequent phenomenon. The ratio of accidents caused by hydroplaning to all wet-pavement accidents is less than 5 percent.

## 6. RECOMMENDATIONS

1. Each location included in the appended list should be studied in the field by competent investigators. If any deficiencies are found in pavement slopes or other surface drainage conditions, they should be improved by grade correction, drainage inlets, or pavement grooving, if justified. Locations appearing to have low skid resistance should be skid-tested and skid-proofed if necessary.

2. More effort should be directed to educate the driving public concerning the dynamics of driving and the degree of reduction in traction, braking and lateral tire forces on wet pavements at high speeds.

3. Recent research and development on new types of pavements which would provide more durable skid resistance and prevent hydroplaning should be followed closely with a view to adopting those which are feasible. Some synthetic aggregates (39) and permeable bituminous wearing courses show possibilities.

4. Future research may be justified for looking into the possibilities of novel portland cement concrete mixes. Proportioning of concrete has traditionally been based on the requirement for optimum structural strength which requires a dense mix. This concept has also been carried over to road building. It is known that worn out concrete pavements are frequently poor in wet skid resistance partly because of this dense composition. Experiments with concretes of low density and higher voids may provide the remedy. Reduced structural strength can possibly be compensated for by heavier reinforcement or by

using two-course pavements, the bottom course providing structural strength and the top course good traction. Alternately, this concrete can be improved in strength by new methods such as vacuum impregnation (44), which is said to increase the strength of the concrete more than four times.

5. The idea of nonconventional paving materials can be extended to developing modular, prefabricated surfacing materials, like tiles, manufactured to desired micro- and macrotexture requirements and having prolonged skid resistance. Machinery can be developed to lay or dig up such surface modules at a fast pace. This would allow partial replacement of a road surface, such as parts rutted by tire wear. Depressed joints between the pavement modules would provide water escape channels to prevent partial or full hydroplaning.

6. Existing information on some 1,400 wet-pavement accidents, which represent a 13 percent sample, could be utilized in a study of other problems related to skidding which are outside the scope of the present project.

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# A P P E N D I X

TEMP. 81 (3/75)

# HYDROPLANING STUDY

## SUPPLEMENTARY ACCIDENT REPORT

Investigating Dept.

Complaint No.

*READ INSTRUCTIONS ON REVERSE SIDE BEFORE FILLING OUT THIS REPORT.*

**WEATHER & ROAD INFORMATION**

| | |
|---|---|
| 1. Was it raining at time of accident? (See instruction 6) | Col. 9 Yes ☐ No ☐ |
| 2. If answer to # 1 is Yes, what was the rain intensity? | Col. 10 Light ☐ Medium ☐ Heavy ☐ |
| 3. Was water accumulating or standing on road? | Col. 11 Yes ☐ No ☐ |
| 4. If answer to # 3 is Yes, what was the estimated water depth on road? | Col. 12 1/16" ☐ 1/8" ☐ 1/4" or more ☐ |
| 5. Are there ruts in the wheel path on the pavement? | Col. 13 Yes ☐ No ☐ |
| 6. Is the road on a curve? | Col. 14 Yes ☐ No ☐ |
| 7. If answer to # 6 is Yes, show the curve in the sketch on the Official Traffic Accident Report (Form UD-10). | |
| 8. Is the road on an incline? | Col. 15 Yes ☐ No ☐ |
| 9. If answer to #8 is Yes, fill in the applicable box to indicate the upward direction (See instruction 7) | Col. 16 North-bound ☐ South-bound ☐ East-bound ☐ West-bound ☐ |
| 10. Pavement type. | Col. 18 Cement concrete ☐ Asphalt ☐ |

**VEHICLE INFORMATION**

| | VEHICLE NUMBER 1 | VEHICLE NUMBER 2 |
|---|---|---|
| 11. Travel speed (See instruction 8) | Col. 19 ______ Miles per hour | Col. 29 ______ Miles per hour |
| 12. Were the brakes applied? | Col. 21 Yes ☐ No ☐ | Col. 31 Yes ☐ No ☐ |
| 13. If answer to # 12 is Yes, why were brakes applied? (Mark all applicable boxes) | Col. 22 To slow down for road curve. ☐<br>To slow down for traffic ahead ☐<br>To stop or slow down for traffic control device. ☐<br>To avoid running off roadway. ☐<br>To avoid hitting an object on/off roadway. ☐ | Col. 32 To slow down for road curve. ☐<br>To slow down for traffic ahead. ☐<br>To stop or slow down for traffic control device. ☐<br>To avoid running off roadway. ☐<br>To avoid hitting an object on/off roadway. ☐ |
| 14. If answer to #12 is Yes, when were brakes applied? (Mark all applicable boxes.) | Col. 23 Before vehicle went out of control. ☐<br>After vehicle went out of control ☐<br>Before vehicle ran off roadway. ☐<br>After vehicle ran off roadway. ☐<br>Before vehicle collided ☐ | Col. 33 Before vehicle went out of control. ☐<br>After vehicle went out of control ☐<br>Before vehicle ran off roadway. ☐<br>After vehicle ran off roadway. ☐<br>Before vehicle collided ☐ |
| 15. Did vehicle skid? | Col. 24 Yes ☐ No ☐ | Col. 34 Yes ☐ No ☐ |

| 16. Tire tread depth: (See instruction 9.) | Col. 25 Left Front | Col. 26 Right Front | Col. 27 Left Rear | Col. 28 Right Rear | Col. 35 Left Front | Col. 36 Right Front | Col. 37 Left Rear | Col. 38 Right Rear |
|---|---|---|---|---|---|---|---|---|
| Bald tire | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Shallow grooves | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| Medium worn | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| New tire | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

*17. Driver comments, if any, on loss of control of vehicle:*

*18. Driver comments, if any, on any unusual vehicle response:*

*19. Officer's comments, if any, on this accident:*

## PURPOSE OF THE STUDY

When there is a film of water on a smooth road surface, tire tread is worn, tire pressure is low, and vehicle speed is high, a vehicle may hydroplane. When total hydroplaning occurs, the tire is fully floated on the water film without touching the ground. The tire then loses traction, braking and steering ability, and the vehicle gets out of control. The purpose of this study is to discover any locations on roads and streets that may be prone to such hydroplaning accidents, and try to correct the situation.

Although hydroplaning normally can occur only when vehicle speed and water depth are relatively high, this auxiliary report form requires reporting of accidents at all ranges of pavement wetness and speed so that useful information will be obtained for skidding as well as hydroplaning accidents.

## INSTRUCTIONS

1. All departments will complete a copy of this supplement only for accidents on a STATE TRUNK LINE whenever the "WET" box for the ROAD SURFACE condition is marked on the official traffic accident report (Form UD-10) BECAUSE OF RAIN.
2. A State Trunk Line is a roadway having an M, US or I route designation.
3. If more than two vehicles are involved, use a second form.
4. Be sure to use the same vehicle number as designated on your official traffic accident report (Form UD-10).
5. Fill in each blank line and place an X in each appropriate box.
6. For Questions 1 through 4, if you were not in the vicinity of the accident at that time, obtain the information about rainfall and water depth from the drivers involved or from witnesses.
7. For Question 9, fill in the appropriate box to show the upward direction. If the road does not run exactly in any of the four cardinal directions, such as northeast-bound etc., then fill in two of the direction boxes to indicate the proper compass direction. For example "Northbound [X] . . . . Eastbound [X] " would mean Northeast-bound.
8. For Question 11, the required speed is the speed before any attempt by the driver to slow down to avoid the accident, and will be the officer's best judgment. This may not be the same speed at which the vehicle eventually collided.
9. For Question 16, use the following criteria to classify tread depth:

   Bald tire: No grooves, or some barely visible ones.
   Shallow grooves: Less than the legal 1/16 inch depth.
   An easy way to measure this is to insert a Lincoln penny into the groove. If the top of his hair is visible the groove is less than 1/16 inch.
   Medium worn: Grooves more than 1/16 inch.
   New tire: New tire grooves may be 3/8 inch or more.

   For trucks with more than four tires, omit tread depth information.
10. Attach this report to the completed copy of the official traffic accident report (Form UD-10) and forward to the Safety and Traffic Division of the Michigan State Police in East Lansing.

# MICHIGAN STATE POLICE

## Inter-Office Correspondence

**Date** : May 1, 1975

**Subject:** Hydroplaning Study

**To** : District Commanders, Post Commanders and Safety and Traffic Division Fieldmen

The Michigan Department of State Highways and Transportation is requesting a bi-level hydroplaning accident study on the state trunkline system for a period of six months, June 1975 through November 1975. The objective of the proposed study is to evaluate areas where implementation of a new grooving project is being initiated, and to indicate the high problem areas where hydroplaning is occurring.

I am requesting that all police agencies within Michigan take part in this study to insure adequate data to assess the validity of hydroplaning accident conditions.

The supplement, which is printed on yellow paper, shall be attached to the ORIGINAL copy of the Official Michigan Traffic Accident Report, UD-10, and forwarded to the Safety and Traffic Division at East Lansing Headquarters.

Refer any inquiries to the Safety and Traffic Division, East Lansing Headquarters.

Your added efforts and cooperation will be greatly appreciated.

DIRECTOR

GLH:st



UD-40A

STATE OF MICHIGAN

WILLIAM G. MILLIKEN, GOVERNOR

DEPARTMENT OF STATE POLICE

714 S. HARRISON RD., EAST LANSING, MICHIGAN 48823

COL. GEORGE L. HALVERSON, DIRECTOR

May 1, 1975

TO: All Police Agencies

SUBJECT: Hydroplaning Study

The Michigan Department of State Highways and Transportation is requesting a bi-level hydroplaning accident study on the state trunkline system for a period of six months, June 1975 through November 1975. The objective of the proposed study is to evaluate areas where implementation of a new grooving project is being initiated, and to indicate the high problem areas where hydroplaning is occurring.

I am requesting that all police agencies within Michigan take part in this study to insure adequate data to assess the validity of hydroplaning accident conditions.

The supplement, which is printed on yellow paper, shall be attached to the STATE copy of the Official Michigan Traffic Accident Report, UD-10, and forwarded to the Safety and Traffic Division of the Michigan Department of State Police.

Refer any inquiries to the Michigan Department of State Police, Safety and Traffic Division, 714 South Harrison Road, East Lansing, Michigan, 48823, telephone number 373-2823.

Your added efforts and cooperation will be greatly appreciated.

George L. Halverson

DIRECTOR

MICHIGAN THE GREAT LAKE STATE

STATE OF MICHIGAN

WILLIAM G. MILLIKEN, GOVERNOR

DEPARTMENT OF STATE POLICE

714 S. HARRISON RD., EAST LANSING, MICHIGAN 48823

COL. GEORGE L. HALVERSON, DIRECTOR

August 7, 1975

TO: All Police Agencies

SUBJECT: Hydroplaning Study

The Michigan Department of State Highways and Transportation requested a hydroplaning accident study on the state trunkline system for a period of six months, June 1975 through November 1975. The objective of the proposed study is to evaluate areas where implementation of a new grooving project is being initiated and to indicate the high problem areas where hydroplaning is occurring.

In May, the hydroplaning supplement, which is printed on yellow paper, was mailed to all departments, and a request was made for their cooperation in submitting this hydroplaning report in an effort to study the data.

A number of accident reports have been received without the supplement attached since the study began in June. This type of submission does not make for an accurate or worthwhile evaluation of the existing problem.

Again, I request your added efforts, and your cooperation will be greatly appreciated.

DIRECTOR

MICHIGAN THE GREAT LAKE STATE

LOCATIONS OF POSSIBLE HYDROPLANING ACCIDENTS

| COUNTY | ROUTE NO. | ROAD OR STREET | CITY, TWP., ETC. | DESCRIPTION | ACCIDENT DATE |
|---|---|---|---|---|---|
| **District 1** | | | | | |
| Baraga | US-41 | | Village of Baraga | 0.7 mile north of Superior Street | May 29, 1975 |
| Gogebic | US-2 | | Bessemer Township | 250 feet east of Ramsay Road | August 23, 1975 |
| Marquette | US-41 M-28BR | S. Front Street | City of Marquette | 70 feet south of Rock Street | June 13, 1975 |
| **District 2** | | | | | |
| Alger | M-28 | | Grand Island Township | 0.2 mile east of Old Golf Course Road | September 7, 1975 |
| School-craft | M-77 | | Germfask Township | 0.7 mile north of H-44 | June 15, 1975 |
| School-craft | US-2 | | Mueller Township | 2.2 miles west of C.R. 433 | June 15, 1975 |
| **District 3** | | | | | |
| Benzie | M-22 | Pilgrim Highway | Crystal Lake Township | 80 feet south of Mar-quette Court | August 17, 1975 |
| Kalkaska | M-72 | | Bear Lake Township | 0.5 mile east of Bear Lake Township | August 31, 1975 |
| Lake | M-37 | | Webber Town-ship (Section 27) | 1.0 mile north of US-10 | August 23, 1975 |
| Lake | M-37 | | Pleasant Plains Town-ship (Section 34) | 10 feet south of Oak Street | August 21, 1975 |
| Mason | M-116 | | Hamlin Township | 2.0 miles north of Piney Ridge Road | August 2, 1975 |
| **District 4** | | | | | |
| Ogemaw | Sbd. I-75 | | Ogemaw Township | 300 feet north of M-30 | June 11, 1975 |

| | | | | | |
|---|---|---|---|---|---|
| Otsego | Sbd. I-75 | | Corwith Township | 0.1 mile south of Alexander Road | August 28, 1975 |
| Otsego | Nbd. I-75 | | Otsego Lake Township | 0.3 mile south of Old State Road | September 1, 1975 |
| Otsego | Sbd. I-75 | | Corwith Township | 0.4 mile south of Otsego-Cheboygan County Line | September 21, 1975 |
| * Otsego | Sbd. I-75 | | Corwith Township | 0.2 mile south of Cheboygan County Line | September 12, 1975 |
| * Otsego | Sbd. I-75 | | Corwith Township | 0.8 mile south of Cheboygan County Line | September 12, 1975 |
| Presque Isle | US-23 | | Roger Township | 1.0 mile north of Petersville Road | September 5, 1975 |
| <u>District 5</u> | | | | | |
| Ionia | M-50 | | Campbell Township | 0.8 mile west of Nash Road | June 17, 1975 |
| Kent | Sbd. US-131 | | City of Grand Rapids | 200 feet north of Crosby Street, N.W. | June 15, 1975 |
| Kent | Nbd. US-131 | | City of Grand Rapids | 0.1 mile north of Downtown Exit Ramp | June 14, 1975 |
| Montcalm | M-45 | | Richland Township | 100 feet west of Crystal Road | June 3, 1975 |
| Muskegon | M-120 | Nbd. Causeway | City of Muskegon | At Muskegon River (middle channel) | June 11, 1975 |
| <u>District 6</u> | | | | | |
| Bay | Nbd US-23 | | Kawkawlin Township | 0.5 mile south of Beaver Road | August 29, 1975 |
| Bay | Wbd. US-10 | | Williams Township | 0.8 mile west of Garfield Road | August 30, 1975 |
| Genesee | Wbd. M-21 (I-69) | | City of Burton | 0.3 mile east of Belsay Road | August 3, 1975 |
| Genesee | Nbd. I-75 | | Grand Blanc Township | At southbound I-475 | August 21, 1975 |
| Genesee | Ebd. I-69 | | Flint Township | 0.25 mile east of I-75 | August 2, 1975 |

| | | | | | |
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| Huron | M-142 | | Sand Beach Township | 0.25 mile west of Klug Road | June 11, 1975 |
| Saginaw | Ebd. I-675 | | City of Saginaw | at Michigan | June 3, 1975 |
| Saginaw | Sbd. I-675 | | Carrolton Township | at Weiss Street | June 4, 1975 |
| Tuscola | M-24 | Mertz Road | Indian Fields Township | 0.10 mile north of Bliss Road | August 13, 1975 |

District 7

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|---|---|---|---|---|---|
| *Berrien | Wbd. I-94 | | Lincoln Township | 300 feet west of Puetz Road | June 11, 1975 |
| *Berrien | Wbd. I-94 | | Lincoln Township | at Puetz Road | June 11, 1975 |
| Berrien | Wbd. I-94 | | New Buffalo Township | 1.0 mile northeast of Laporte Road | June 15, 1975 |
| Calhoun | BL-94 | Dickman Road | City of Springfield | 0.2 mile east of Skyline Drive (BL-94) | June 24, 1975 |
| Kalamazoo | M-43 | West Main Street | Oshtemo (Section 13) | Over US-131 | August 29, 1975 |
| Kalamazoo | Wbd. I-94 | | City of Kalamazoo | 20 feet east of Kilgore (overpass) | December 6, 1975 |
| St. Joseph | M-86 | | Lockport Township | 0.25 mile west of Strobel Road | June 18, 1975 |
| St. Joseph | M-66 | | Sturgis Township | 300 feet north of Indiana State Line | July 18, 1975 |
| St. Joseph | M-66 | | Mendon Township | 300 feet north of Simpson Road | August 25, 1975 |
| Van Buren | M-43 | | Geneva Township | 0.30 mile northwest of 58th Street | June 25, 1975 |

District 8

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|---|---|---|---|---|---|
| Jackson | Nbd. US-127 | | Blackman Township | 0.1 mile north of Springport Road | June 20, 1975 |
| Lenawee | M-50 | | Franklin Township | 0.2 mile west of Carson Highway | August 5, 1975 |
| Living-ston | Wbd. I-96 | | Brighton Township | 0.4 mile west of Ken-sington Road | August 15, 1975 |

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|---|---|---|---|---|
| Living-ston | Nbd. US-23 | Hartland Township | 1.0 mile south of Clyde Road | September 5, 1975 |
| *Monroe | Sbd. I-75 | Berlin Township | 100 feet south of South Huron River Drive | June 24, 1975 |
| *Monroe | Sbd. I-75 | Berlin Township | at South Huron River Drive | July 12, 1975 |
| Monroe | US-223 | Whiteford Township | 0.2 mile northwest of Sterns Road | August 2, 1975 |
| Washtenaw | Ebd. I-94 | Scio Township | at M-14 Fork | June 17, 1975 |
| Washtenaw | US-12 | Bridgewater Township | 0.50 mile west of Neblo Road | June 24, 1975 |
| Washtenaw | Ebd. I-94 | Ypsilanti Township | 0.50 mile west of Huron Street Exit | June 24, 1975 |
| Washtenaw | Nbd. US-23 | Northfield Township | at Six Mile Road | August 31, 1975 |
| Washtenaw | Ebd. I-94 | City of Ypsilanti | 0.25 mile east of Huron Street | September 11, 1975 |

Metro District

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|---|---|---|---|---|
| Macomb | Wbd. I-94 | City of St. Clair Shores | at 9 Mile Road (over-pass) | June 11, 1975 |
| Oakland | Wbd. I-96 | Lyon Township | 0.5 mile west of South Hill Road | June 4, 1975 |
| Oakland | Wbd. I-96 | Lyon Township | 0.6 mile west of Kent Lake Road | July 8, 1975 |
| Oakland | Sbd. I-75 | City of Hazel Park | 0.25 mile north of East Meyers Street | July 10, 1975 |
| Oakland | Sbd. I-75 | Bloomfield Township | 300 feet north of Square Lake Road (BL-75) | July 12, 1975 |
| *Oakland | Ebd. I-96 | Lyon Township | at Kent Lake Road | August 24, 1975 |
| *Oakland | Ebd. I-96 | Lyon Township | 0.25 mile west of Kent Lake Road | August 30, 1975 |
| St. Clair | M-21 | Emmet Township | 0.1 mile west of Keegan Road | June 2, 1975 |
| St. Clair | M-25 | Burtonville Township | 50 feet south of Memoir Street | June 17, 1975 |

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|---|---|---|---|---|---|
| Wayne | Ebd. I-94 | | City of Romulus | 0.10 mile west of Ozga Road | June 7, 1975 |
| Wayne | Sbd. M-39 | South-field Freeway | City of Allen Park | at Oakwood (overpass) | June 11, 1975 |
| Wayne | Sbd. M-85 | Fort Street | Brownstown Township | at Allen Road | July 12, 1975 |
| Wayne | Ebd. I-94 | | City of Allen Park | 0.25 mile east of Oak-wood (overpass) | August 30, 1975 |

*Possible locations of repetitive hydroplaning type of accidents