# AN EVALUATION OF THE EFFECTS OF TREAD DEPTH, PAVEMENT TEXTURE, AND WATER FILM THICKNESS ON SKID NUMBER-SPEED GRADIENTS

by

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Virginia Highway & Transportation Research Council
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## ABSTRACT

Thirty-one sites representing the types of pavement surfaces on the highways of Virginia were tested by the Virginia Highway and Transportation Research Council skid trailer in an effort: (1) to determine the influence that tire tread depth, pavement texture, and water film thickness have on the deterioration of skid numbers with increased test speeds, and (2) to develop curves which will provide a means of predicting skid numbers for given combinations of these factors other than those employed during testing.

The tests which employed six tire conditions, four water conditions, and five test speeds for each site were conducted between September 21, 1972 and une 6, 1974.

Based on the data gathered in this study, the following conclusions regarding Virginia's pavement surfaces are warranted:

1. High skid number-speed gradients are common to pavements that do not contain a relatively high degree of macrotexture. This finding, of course, only substantiates the observations of many others. However, it should be pointed out that if the surface has a sharp microtexture, its skid resistance can be excellent at all legal speeds with legal tires. Bald tires on such surfaces can provide extremely low skid numbers.

2. The converse of number 1 is also true; i.e., the slope of the skid number-speed gradient curve decreases with increased macrotexture. However, the degree of this decrease is strongly influenced by the characteristics of the microtexture. Pavements such as grooved portland cement concrete that provide ample means of water escape might have quite steep skid number-speed gradients if the microtexture is not harsh. It follows that the same is true for open-graded bituminous mixes containing polish susceptible aggregates.

3. Pavements that have essentially the same skid number-speed gradients can have quite different relationships between treaded and bald tires. This difference is due to the difference in macrotexture; i.e., as the macrotexture increases, the divergence between the treaded and bald tire skid numbers decreases until the values

for the two tires are the same; in fact, in some cases the values for the bald tire become higher than those for the treaded tires.

4. The highest skid numbers recorded in the study were at low speeds in the steep speed gradient group, which means that a low macrotexture - high microtexture surface provides the best skid resistance at low speeds (40 mph (17.9 m/s) and below).

5. Grooving does not greatly influence the skid resistance or the skid number-speed gradient slope for treaded tires, but does manifestly increase the skid resistance for bald tires. The latter fact may account for some of the reduction in wet pavement accidents where concrete pavements have been grooved.

6. The skid number-speed gradient curves developed in this study can be used to predict skid numbers for speeds other than those at which tests are run on Virginia pavements.

7. The skid number decreases as the test tire tread decreases. This decrease averages about $1\frac{1}{4}$ SN per 2/32 in. (0.16 cm) increment in tread depth for a total loss of 5 SN from 11/32 in. (0.87 cm) to 3/32 in. (0.24 cm). A correction for this change in skid number can be made on a straight-line basis.

8. After a tire has worn beyond 3/32 in. (0.24 cm) tread depth, it has a high reaction to pavement macrotexture and should, therefore, not be used for routine testing.

9. Because of the small change in skid number with a change in water film, the normal fluctuation in water output by the test trailer should not be a matter of concern.

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Highway agencies the world over are concerned with problems associated with pavement skid resistance, and their success in finding solutions is highly dependent upon the availability of detailed knowledge of the factors that influence the friction at the tire-pavement interface. Part of the effort to gain this knowledge is the development of test methods to measure the parameters involved. In this country, the most notable test method developed to date is ASTM Designation E 274-70,[1] a brainchild of the society's Committee E-17. While this method is undoubtedly a very valuable tool, the committee itself feels that research is needed to further refine it and expand its usefulness.

It is very likely that the test conditions specified in E 274 do not simulate the more undesirable conditions under which some skidding accidents occur; that is, bald tires and thick films of water during heavy rainstorms. Thus, the skid number-speed gradient obtained by this test procedure might not be the critical one, and research is needed to determine the independent and collective effects of the tread depth, pavement texture, and water film thickness. Additionally, more knowledge of skid number-speed gradients is needed to permit predictions of skid numbers for conditions other than those under which tests are made.

Some years ago the National Aeronautics and Space Administration found that a combination of high speed, great water depth, bald tires, and smooth pavement produces hydroplaning, a phenomenon in which the tire loses contact with the pavement surface and rides on the water.[2] It has also been shown photographically that hydroplaning is a stage phenomenon; i.e., it is not an all or nothing state, but rather ranges from a small portion of the tire footprint being supported by water to the total print riding on water.[3,4]

In air travel, total hydroplaning is a serious danger in landings and takeoffs. However, in highway travel, partial hydroplaning is probably of much more importance. This is the state in which the portion of the tire footprint riding on the water is just sufficient to materially reduce traction and the braking capabilities of the vehicle.

The principle or theory used in this study was that the skid number-speed gradient curves are dependent upon pavement texture, tire tread depth, and water film thickness. It was believed that the degree of influence of these factors could be defined by performing a series of skid tests at various speeds with differing water film thickness and with tires worn to different tread depths on typical pavement surfaces found in Virginia.

While it was expected that this research would provide information helpful in the design of skid resistant pavements, it was not expected that any new knowledge would be gained regarding the hydroplaning phenomenon.

It should also be recognized that there were limitations in the measurements of water film thickness and pavement texture depth. Rather than the film thickness being measured, it is assumed to be at a particular value based on the calculated water outflow; and rather than the texture asperities being measured, the surface characteristics are indicated through verbal and pictorial depictions.

## OBJECTIVES OF THE STUDY

The specific objectives of this study were: (1) To determine the influence that tire tread depth, pavement texture, and water film thickness have on the deterioration of skid numbers with increased test speeds, and (2) to develop curves which will provide a means of predicting skid numbers for given combinations of these factors other than those employed during testing.

## TESTING

The 31 test sites included in the study were tested between September 21, 1972, and June 6, 1974. Descriptive information on the sites is shown in Table 1. For the most part, a test site was a lane mile (1.6 km). It was tested five times in the left wheel path at about 1/5 mile (0.32 km) intervals for each condition; a condition being a specified tread depth, speed, and water film. On the 31 test sites there were 2,668 test conditions under which a total of 13,365 individual tests were performed. The tests were performed according to ASTM E 274-70 and, as prescribed by this test method, a skid number which differed by more than five units from the mean was discarded and the mean was recalculated. Tables A1 through A31 of the Appendix give the mean skid numbers.

The test variables were tire tread depth, water condition, test speed, and test site. A general description of the variables follows.

### Tire Tread Depth

All test tires were ASTM E-249 varying in tread depth from new (11/32 in.) (0.87 cm) to bald (no tread). To obtain specified tread depths, the tires were buffed by a local recapping company. The tires were then subjected to ordinary wear on the right, or non-testing, wheel of the skid trailer until the rough surface created by the buffing was removed. At the beginning of the testing six tread depths were employed

Table 1. Site Information

| Site No. | Route | County | Mix Type | Year Placed | Lane | Acc. Traffic |
|---|---|---|---|---|---|---|
| 1 | I-64 | Fluvanna | Concrete | 1970 | EBTL | 4,028,870 |
| 2 | | Louisa | Concrete | 1970 | WBPL | 1,007,218 |
| 3 | | | S-5* | 1970 | EBTL | 4,028,870 |
| 4 | | | S-5 | 1970 | WBPL | 1,007,218 |
| 5 | 340 | Augusta | S-1 | 1968 | N&SBTL | 3,149,950 |
| 6 | I-95 | Greenville | Concrete | 1959 | SBTL | 17,212,962 |
| 7 | | | Concrete | 1959 | SBPL | 4,303,240 |
| 8 | | | Klarcrete | 1974 | SBTL | 0 |
| 9 | | | Klarcrete | 1974 | SBPL | 0 |
| 10 | I-264 | Chesapeake | S-5 | 1969 | EBTL | 4,411,755 |
| 11 | | | S-5 | 1969 | WBTL | 4,411,755 |
| 12 | | | S-5 | 1969 | EBPL | 1,102,939 |
| 13 | | | S-5 | 1969 | WBPL | 1,102,939 |
| 14 | I-381 | Bristol | Bit.-Urban Mix | 1971 | SBTL | 3,255,800 |
| 15 | | | Bit.-Urban Mix | 1971 | SBPL | 3,255,800 |
| 16 | I-81 | Augusta | Popcorn | 1973 | NBTL | 2,285,630 |
| 17 | | | Popcorn | 1973 | SBPL | 571,408 |
| 18 | | | S-5 | 1968 | NBTL | 9,187,050 |
| 19 | | | S-5 | 1968 | SBPL | 2,296,762 |
| 20 | I-64 | New Kent | Concrete | 1973 | EBTL | 2,106,780 |
| 21 | | | Concrete | 1973 | WBPL | 526,695 |
| 22 | I-64 | Henrico | Concrete | 1968 | EBTL | 13,430,175 |
| 23 | | | Concrete | 1968 | EBPL | 7,815,106 |
| 24 | | | Grooved | 1968 | EBTL | 13,430,175 |
| 25 | | | Grooved | 1968 | EBPL | 7,815,106 |
| 26 | Route 1 | Caroline | Surface Treatment | 1969 | NBPL | 534,542 |
| 27 | | | Surface Treatment | 1969 | SBTL | 2,138,170 |
| 28 | Route 1 | Hanover | Surface Treatment | 1970 | NBPL | 449,680 |
| 29 | | | Surface Treatment | 1970 | SBTL | 1,798,720 |
| 30 | 460 | Bedford | S-5 | 1965 | WBPL | 2,342,388 |
| 31 | | | S-5 | 1965 | EBTL | 9,369,550 |

* Specifications for Virginia's S-5 bituminous concrete, S-1 sand asphalt, and bituminous-urban mix are in the Appendix.

(bald, 3/32 in., 5/32 in., 7/32 in., 9/32 in., and new) (bald, 0.24 cm, 0.40 cm, 0.56 cm, 0.71 cm, and new). However, because of the great amount of time consumed and the fact that sites tested indicated that the slope or the change in skid numbers with reduced tread depth was constant as long as the tread depth was large, the number of tread depths was reduced to four (bald, 3/32 in., 5/32 in., and $\geq$7/32 in. (bald, 0.24 cm, 0.40 cm, and $\geq$ 0.56 cm) for the remaining sites.

## Water Conditions

Four water conditions were employed. In addition to the .020 in. (0.05 cm) depth prescribed by ASTM, depths of .015 in., .030 in., and .040 in. (0.04 cm, 0.08 cm, and 0.10 cm) were employed. The Council skid trailer has two water pumps, one for each test wheel and each normally geared to deliver a water film thickness of .020 in. (0.05 cm) to the pavement for test speeds varying from 10 mph (4.5 m/s) to 70 mph (31.3 m/s). For this study, by using an additional set of pulleys and belts and connecting the two water lines together, the system was made capable of delivering calculated thicknesses of .015 in., .020 in., .030 in., and .040 in. (0.04 cm, 0.05 cm, 0.08 cm, and 0.10 cm) for the test speeds employed. To ensure the proper water output, static water tests were made. Although the static tests indicated the output to be satisfactory, it is believed that at times the amount deviated from that planned.

## Test Speeds

Five test speeds were employed, 30, 40, 50, 60, and 70 mph (13.4, 17.9, 22.4, 26.8, and 31.3 m/s); and for each test speed, five repeat tests were performed. On some sites the test speeds had to be changed for safety reasons. The changes will be noted as the sites are discussed under Analysis.

## Test Sites

Of the 31 sites tested, 12 were concrete, 15 were bituminous plant mix, and the remaining 4 were surface treatments. The textures of concrete pavements ranged from old smooth surfaces to relatively new longitudinally tined surfaces and included both grooved and chipped surfaces. The textures on the bituminous concrete pavements ranged from a smooth sand mix finish to a very open-graded popcorn mix surface. Also included in the bituminous concrete group were dense graded mixes which have open surfaces as well as one dense graded mix which has become quite smooth.

# TEST DATA

The test sites were numbered 1 — 31 in the sequence they were tested. As previously stated, the testing period spanned a 21-month interval. During this time there were delays due to breakdowns, adverse weather, and other uncontrollable events. Thus at times for a given condition (test site, tread depth, and water film) data were obtained on several different days and some sites were tested over an extended period of time. Table 2 gives the testing days for each site. The equipment breakdowns, especially the one requiring major repair, and the extended data collection affected the consistency of the data. In addition, there was the normal testing error. In order to relate the data before and after the major repair, adjustments based on skid number-stopping distance number (SN-SDN) correlations were made, and in order to compensate for the testing error the data were massed.

## Correlation Adjustments

Sites 1 through 4 were tested simultaneously, beginning in September 1972; however, prior to completion of the tests, the pumps on the trailer started malfunctioning. After the pumps were repaired, the weather was not conducive to testing and testing was not resumed until April. By May 21, sites 1 through 4 were completed. Site 5 was tested between May 30 and June 7. Sites 6 through 9 were tested simultaneously between June 11 and July 9. Sites 10 through 13 were tested simultaneously beginning July 18, but were not completed prior to water pump trouble on August 14. The water system was repaired and the testing of sites 10 through 13 was completed on October 16 and 17. On these two days, the 9/32 in. and 11/32 in. (0.71 cm and 0.87 cm) tread depth tires were tested. These data were later rejected because they were considered manifestly faulty.*

After the completion of sites 10 through 13 but before testing sites 14 and 15, the trailer was involved in an accident and had to undergo extensive repari. Prior to this incident, the Virginia trailer had historically provided higher readings than other skid trailers, as well as higher readings than the Virginia stopping distance car. However, since its repair in November and December of 1973, its readings have been lower than before. In order to relate the data from the first 13 sites to those of the remaining 18 sites, the former were adjusted through the use of correlation data between the Virginia trailer and the Virginia stopping distance car. Fortunately, 40 mph (17.9 m/s) stopping distance tests were performed on the first 9 sites. With this information and a correlation curve developed by Stephen N. Runkle[5] (see Figure 1), the data were adjusted in the following manner. The $SDN_{40}$ from the test site was plugged into Runkle's curve to obtain a predicted skid number ($PSN_{40}$) at 40 mph (17.9 m/s).

Then: $$C = \frac{PSN_{40}}{SN_{40}}$$

Where: $C$ = correcting factor

$SN_{40}$ = $SN_{40}$ data from test site

*The raw data and resulting curves generated in this project are voluminous and are, therefore, not included in the text. However, they are included in a Supplement to the report which will be on file at the Virginia Highway and Transportation Research Council and the FHWA.



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Table 2. Order of Testing.

| Site Number | Test Condition | Date |
|---|---|---|
| 1 - 4 | 11/32 in. Tread Depth<br>.020 in. Water Film<br>.040 in. Water Film | 9/21/72 to 9/28/72 |
| | 9/32 in. & 7/32 Tread Depth<br>0.15 in. Water Film<br>0.30 in. Water Film | 9/21/72 to 9/28/72 |
| | Remaining | 4/5/73 to 5/21/73 |
| 5 | All | 5/30/73 to 5/7/73 |
| 6 - 9 | All | 6/11/73 to 7/9/73 |
| 10 - 13 | Bald, 3/32, 5/32 in. Tread Depth | 7/18/73 to 8/14/73 |
| Repairs to Water System | | 8/14/73 to 10/16/73 |
| 10 - 13 | 9/32, 11/32 in. Tread Depth | 10/16/73 to 10/17/73 |
| Repairs to Trailer | | End of Oct. & Dec. |
| 16 - 19 | All | 1/29/74 to 2/1/74 |
| 20 - 21 | All | 2/5/74 to 2/14/74 |
| 22 - 25 | All | End of Feb. to 1st of Apr. |
| 26 - 29 | 11/32 in. Tread Depth<br>.020 in. Water Film<br>.040 in. Water Film | 4/10/74 |
| Correlation Between Car & Trailer | | 4/10/74 to 5/20/74 |
| 21 - 29 | Remaining | 5/21/74 to 5/29/74 |
| 30 - 31 | All | 6/3/74 to 6/6/74 |

1 inch = 2.54 cm

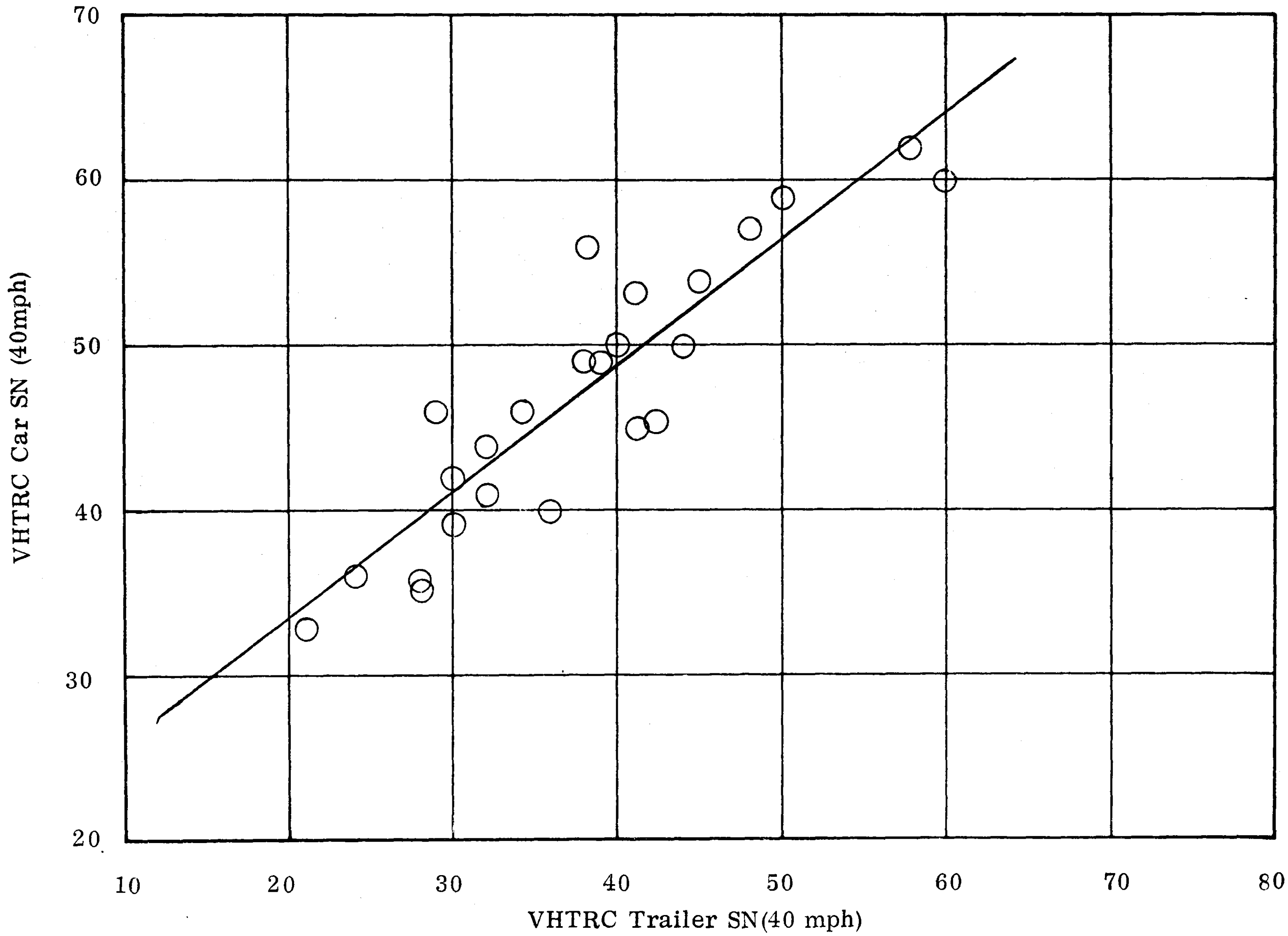


Figure 1. Virginia Highway and Transportation Research Council trailer and car correlation curve derived by Stephen N. Runkle.(5) (1 mph = .4470 m/s)

(See Table 3 for the correction factors.) Each data point was then multiplied by the correction factor as derived for that site. Since stopping distance tests were not performed on sites 10 through 13, the average correction factor for the first 9 sites was used to adjust these data.

## Massing Data

As does any large volume of data, the measurements obtained in this project contained data points removed from the expected trend lines. Some of these seemingly erroneous data points are valid and, upon additional research, will lead to the uncovering of new knowledge; others are the result of testing error. It is believed that in this project, the second case prevails. Several examples of the type of data points referred to are shown in Figure 2 and discussed below.

### Water Film

The first of the three examples depicts the skid numbers for the four water film conditions, for one tire condition and one speed on site 2, in which the .015 in. and .030 in. (0.04 cm and 0.08 cm) depths gave the same value, and the .020 in. and .040 in. (0.05 cm and 0.10 cm) depths gave the same value; whereas, the expected shape of the curve would be a rather constant negative slope to the right, or with the increase of water. The writer feels that in this case the second pump was probably malfunctioning. Although the example given is extreme, after careful study of the data it is felt that probably at no time did the water system operate perfectly. So, for the water film portion of the study, even after massing the data, little was learned. The water data were massed by combining the values for all tread depths for each speed and water level for each site. Bald tires were treated separately.

The writer feels that by this massing of data the testing error was reduced; but again, it is doubtful if the watering system functioned perfectly at any time. Therefore, the water film portion of the project contributed less to additional understanding than did the other variables studied.

### Tread Depth

The second curve in Figure 2 comes from site 1 and depicts the effect that tread depth has on skid resistance. As can be seen, the data for the 9/32 in. (0.71 cm) tread depth and the 5/32 in. (0.40 cm) depth do not fit the expected pattern. Massing was performed here as for the water film data; i.e., the data were massed for all speeds and water films, and finally for all sites with like texture. The writer feels that the results provide a good profile of the effect that tread depth has on skid numbers.

### Speed

The third curve in Figure 2 also comes from site 1 and indicates the effect of speed on skid resistance with a water film of .020 in. (0.05 cm) and a 9/32 in. (0.71 cm) tread depth. The writer feels that the steep drop in skid numbers between 30 and 40 mph (13.4 m/s and 17.9 m/s) and then the gradual increase to 60 mph (26.8 m/s) are solely

Table 3. Correction Factors Derived from Stopping Distance Tests and Runkle's Trailer-Car Correlation Curve. (5)

| Site Number | Location | Correction Factor |
| --- | --- | --- |
| 1 | I-64 Fluvanna | 0.920 |
| 2 | I-64 Fluvanna | 0.9531 |
| 3 | I-64 Fluvanna | 0.300 |
| 4 | I-64 Fluvanna | 0.8023 |
| 5 | Rt. 340 Augusta | 0.6875 |
| 6 | I-95 Greenville | 0.7050 |
| 7 | I-95 Greenville | 0.7520 |
| 8 | I-95 Greenville | 0.7290 |
| 9 | I-95 Greenville | 0.8304 |

Average — 0.7977

S. D. = 0.0920

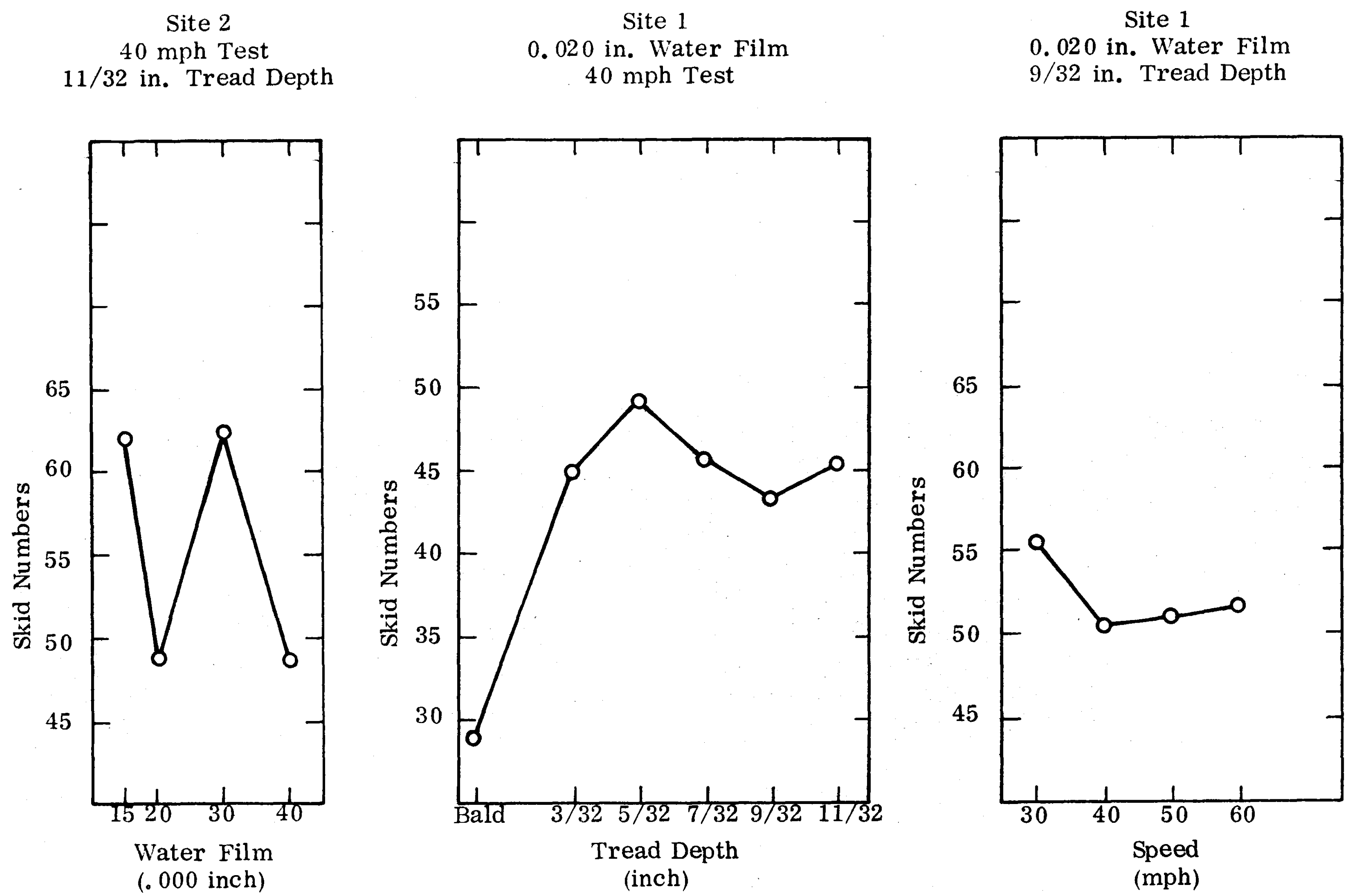


Figure 2. Examples of erroneous data points for individual test conditions.
(1 mph = .4470 m/s) (1 inch = 2.54 cm)

due to testing error. Again, to compensate for the testing error, the data were massed; i.e., the tread depth (bald tires treated separately) and water film data were combined for each speed for the site and then combined with the data for the other sites in the same texture group. It is felt that valid skid number-speed gradient curves resulted.

## METHODS OF ANALYSIS

As was mentioned earlier, the data from this project are voluminous and some have been bound under separate cover as a Supplement to this report. Although the basic data are not contained in the text, the writer felt it important to select an example for each test condition for detailed treatment so that the reader could become more familiar with the condensing procedures used in the analysis. Site 7 was selected for demonstration for several reasons, including the facts that it contained six tire conditions and the skid number-speed gradient curves for the treaded and bald tires were divergent enough to allow the plot of eight curves in one figure. Because it was one of the first 13 sites tested, the data were corrected by use of Runkle's correlation curve.

For site 7, data were taken for four water films, six tire conditions, and four speeds, for a total of 96 conditions. Five repeat skid tests were made for each conditions, which gave a total of 480 tests. The data were keypunched and then treated for outlying values as prescribed by E-274. Under this method the mean for the five repeat tests for a condition is calculated; then any skid number differing by more than five units is discarded and the mean recalculated. This procedure is repeated until no skid number within a condition differs by more than five units from the mean. The data were computer processed through a program which also provided plots of the averaged data.

This process yielded 24 skid number-speed gradient curves (Figure 3), 16 tread depth curves (Figure 4), and 24 water film curves (Figure 5), for a total of 64 curves. With this number of curves for just one of the 31 sites, the reader can easily understand that some combining had to be done. In combining or condensing these data, the most important consideration was to meet as fully as possible the objectives of the study. With this primary consideration, the slopes of the curves are extremely important and the relative magnitudes of the skid numbers are of little moment.

Because of the inconsistencies in the data within sites, data for groupings of sites with selected tread depth groupings (i.e., bald vs. treaded) were averaged in order to better indicate trends. The groupings chosen are discussed in some detail later in the report, but were essentially texture-dependent for speed gradient and tread depth and with a single group for water film thickness. A single group (for each site) was chosen for water film since the pump problem discussed previously seemed to exist at several sites and much water film data were meaningless. For this reason, in the author's opinion the portion of the study dealing with the effects of water film is less meaningful than those dealing with the effects of tread depth and speed. For these last two variables it is felt that the averaging of data indicated very meaningful trends.

### Skid Number-Speed Gradient

The skid number-speed gradient curves in Figure 3 were combined in the following manner. The data for all of the treaded tires for the .015 in. (0.04 cm) water film

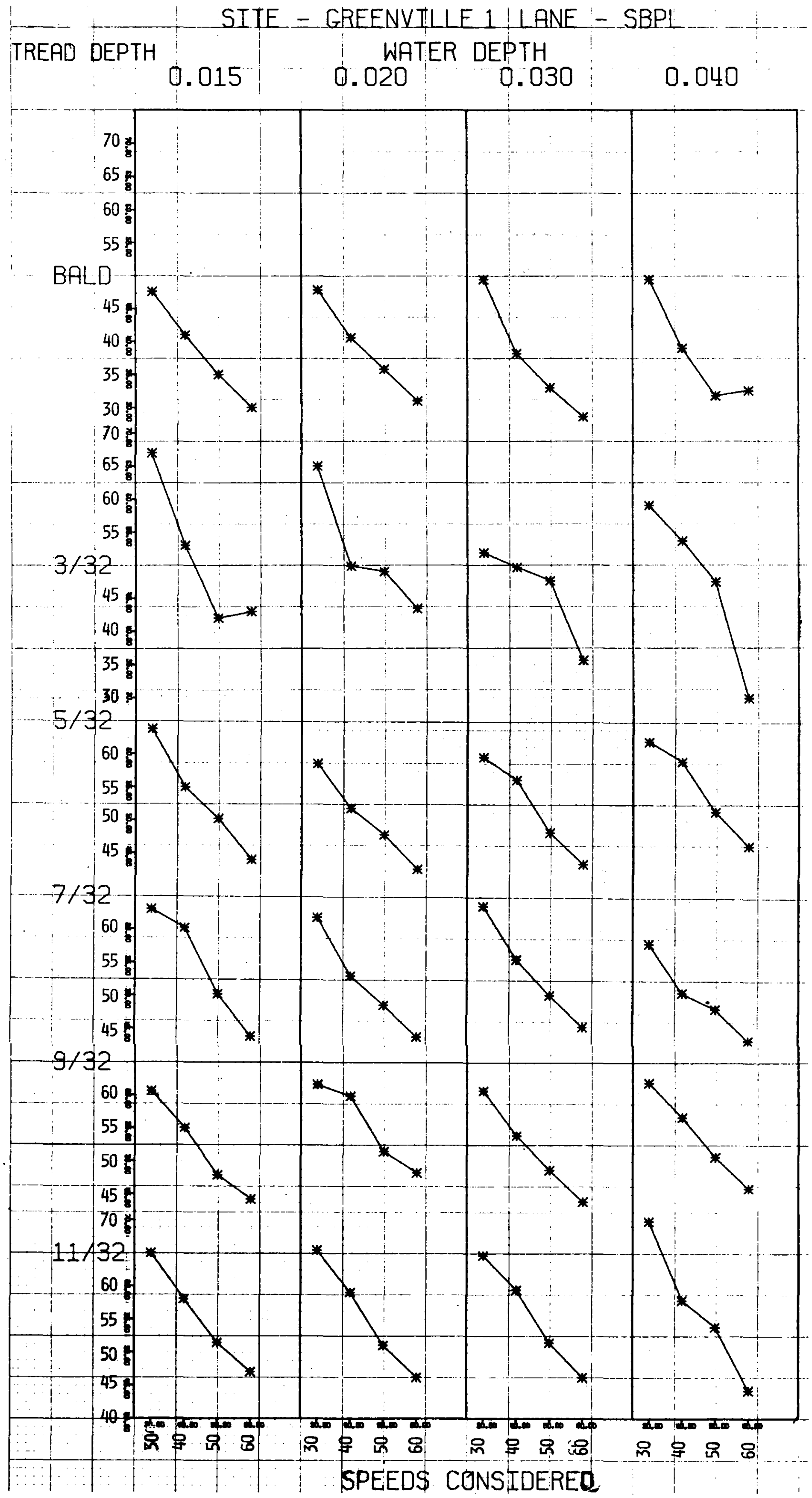


**Figure 3.** Skid number-speed gradient curves for all tire and water conditions on site 7. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

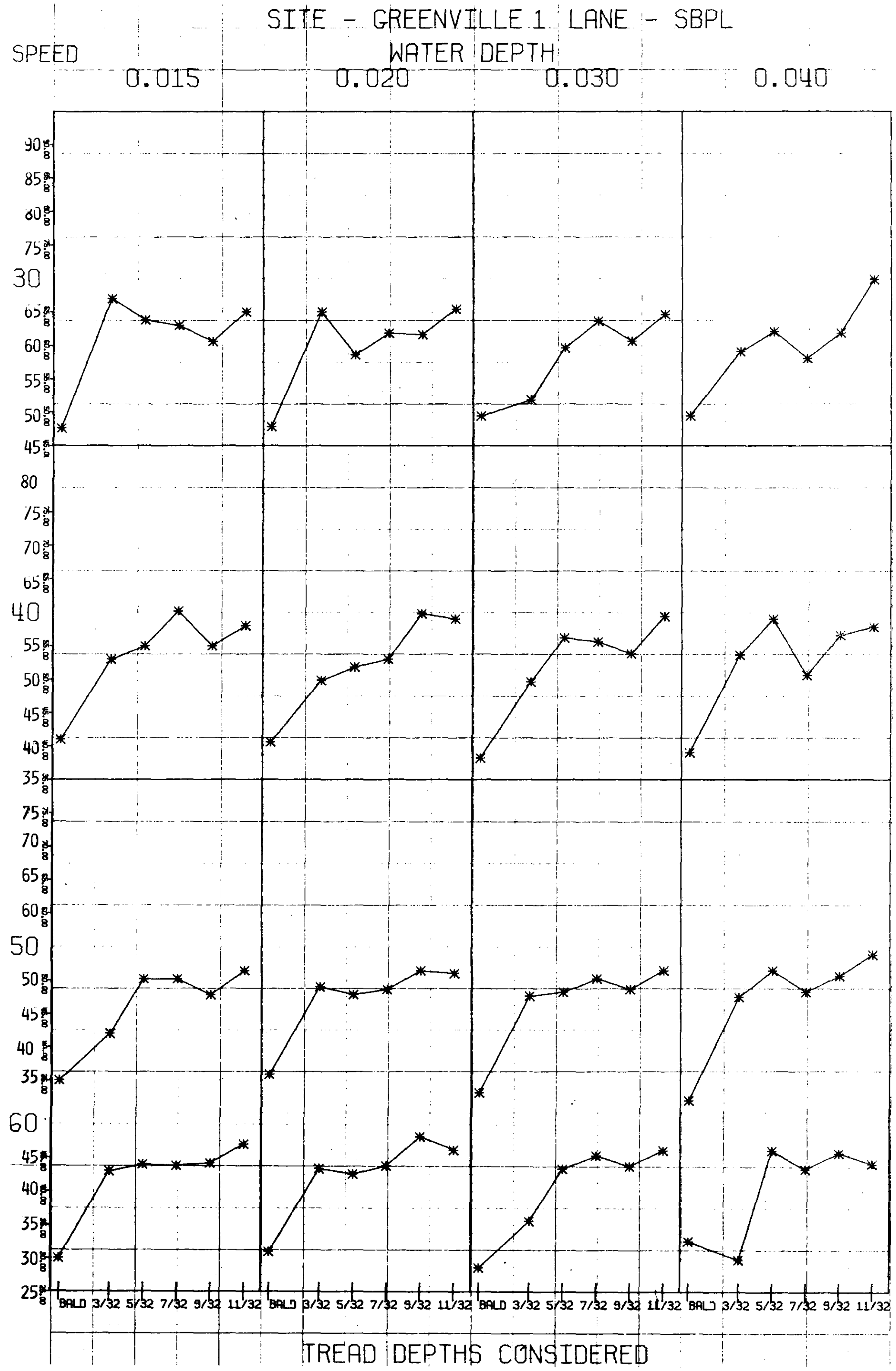


**Figure 4.** **Curves depicting the relationship between the skid number and the tread depth for each of the four water conditions and test speeds on site 7. (1 mph = .4470 m/s) (1 inch = 2.54 cm)**

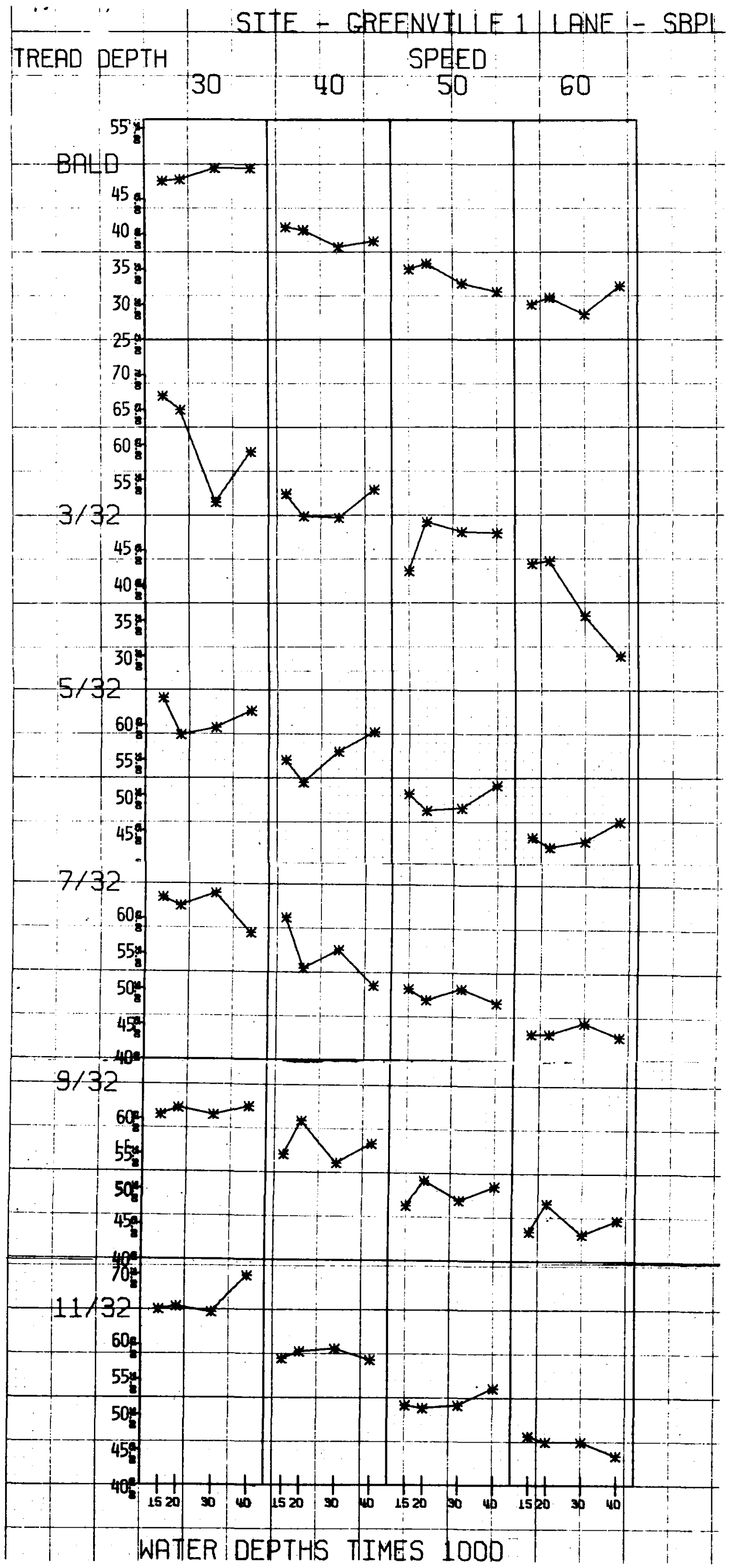


Figure 5. Curves showing the relationship between the skid number and the water film thickness for each tread depth and test speed on site 7. ( 1 mph = .4470 m/s) ( 1 inch = 2.54 cm)

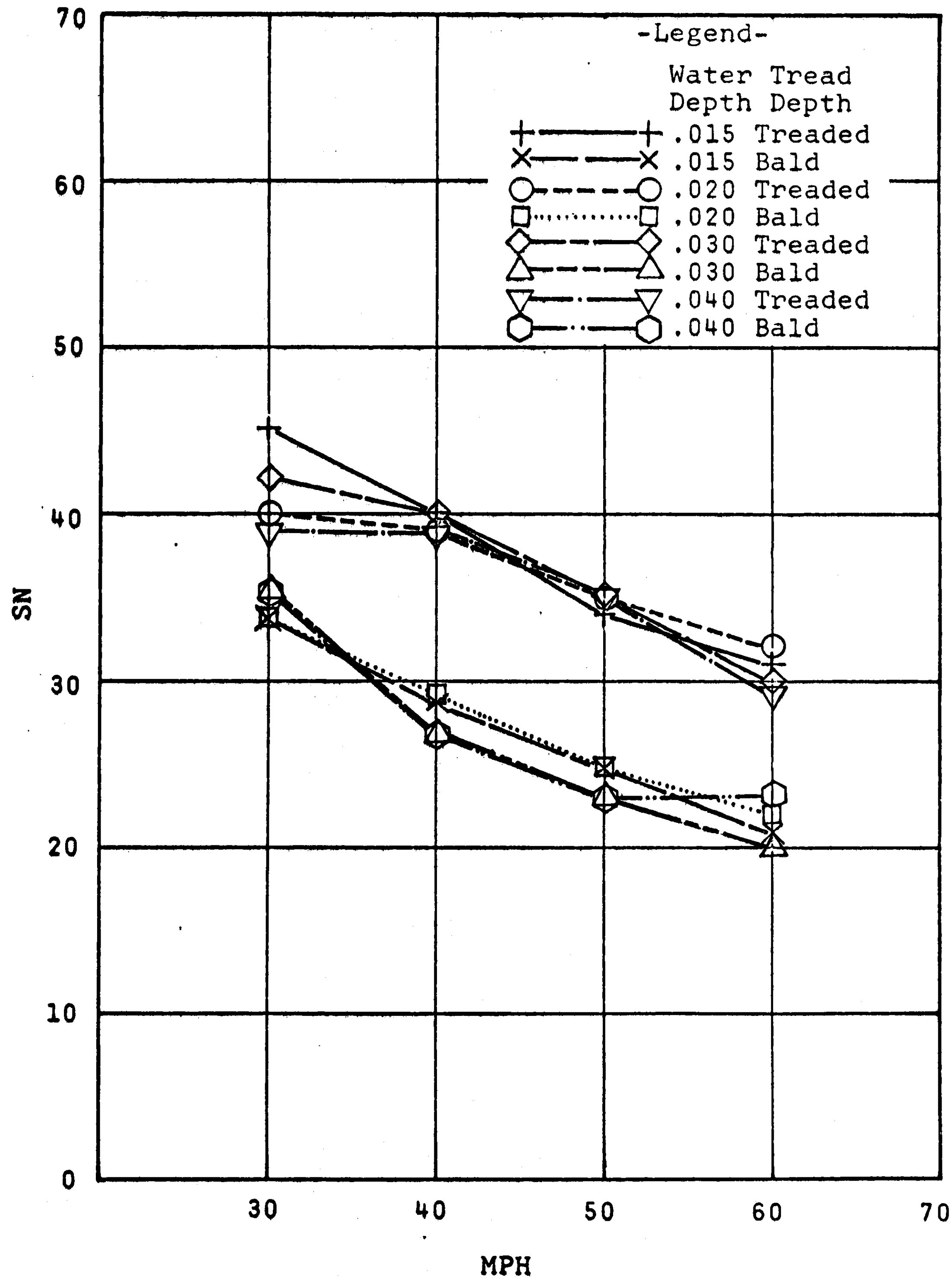


Figure 6. Average speed gradient curves for each of the water film thicknesses for treaded and bald tires on site 7. (1 mph = .4470 m/s) (1 inch = 2.54 cm)

were combined to form one curve; the bald tire data were treated separately and, therefore, constituted a second curve. This procedure followed for each water film and thus resulted in eight curves, four for treaded and four for bald tires. They were then corrected as described under the section on Correlation Adjustment and then plotted as shown in Figure 6. The data in this form for all sites are shown in the Appendix as Figures A1 through A31. However, since eight curves on the same graph are difficult to follow, all of the water depths were combined to produce a treaded tire curve and a bald tire curve which are plotted along with the .020 in. (0.05 cm) water film data for both the treaded and bald tire, as shown in Figure 7. This is the form in which the data will be presented in the text.

### Tread Depth

For the tread depth analysis, the data for the tire tread depth and water film thickness were combined for each speed. Again, for the first 13 sites, the data were corrected as described under the section on Correlation Adjustment. They were plotted as shown in Figure 8. These curves were used in the analysis but rather than being shown in the text, are included as Figures A32 through A60 in the Appendix.

### Water Film

For the water film evaluation, the various tread depths tested at 30 mph (13.4 m/s) were combined to form one curve. The data for the bald tire tests at 30 mph (13.4 m/s) constituted a second curve. This procedure was repeated for each test speed to form the eight curves shown in Figure 9. As is discussed in the water film portion of the analysis, the data for sites 1, 2, 3, 4, 20, 21, 22, 23, 24, 25, and 29 were so erratic that they are included in the Supplement. Sites 14 and 15 were not included in the water film portion of the study. The remaining sites are shown in the same form as that shown in Figure 9 in Figures A61 through A78 of the Appendix.

## ANALYSES

### Skid Number-Speed Gradient

It will be recalled that one of the objectives of the study was to determine the influence that pavement texture has on the deterioration of skid numbers with increased test speeds. It will also be recalled that surface texture was not measured, but is described verbally and pictorially. In the analysis, it was found that the skid number-speed gradients could be very nicely spearated into three groups: one with a rather steep slope, one with an intermediate slope, and one with a rather flat slope. Based on the data for all water film thicknesses and tread depths, except bald, the slope groups were as follows: steep slope — 0.4 SN/mph and greater, intermediate slope — 0.2 to 0.4 SN/mph, and flat slope — 0.2 SN/mph and less. The three groups are discussed below.

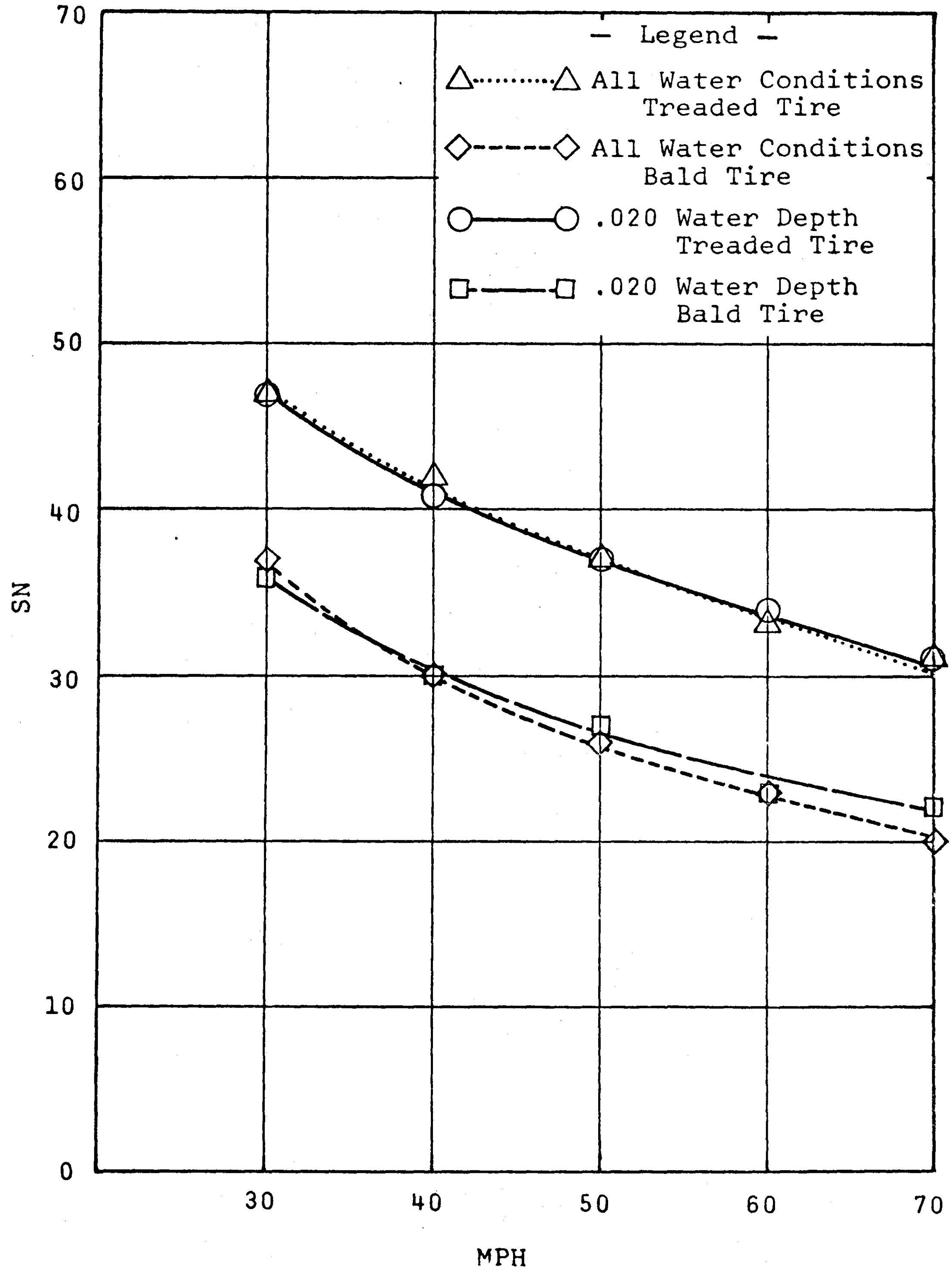


Figure 7. Average speed gradient curves with water films combined for bald and treaded tires in site 7. (1 mph = .4470 m/s; (1 inch = 2.54 cm)

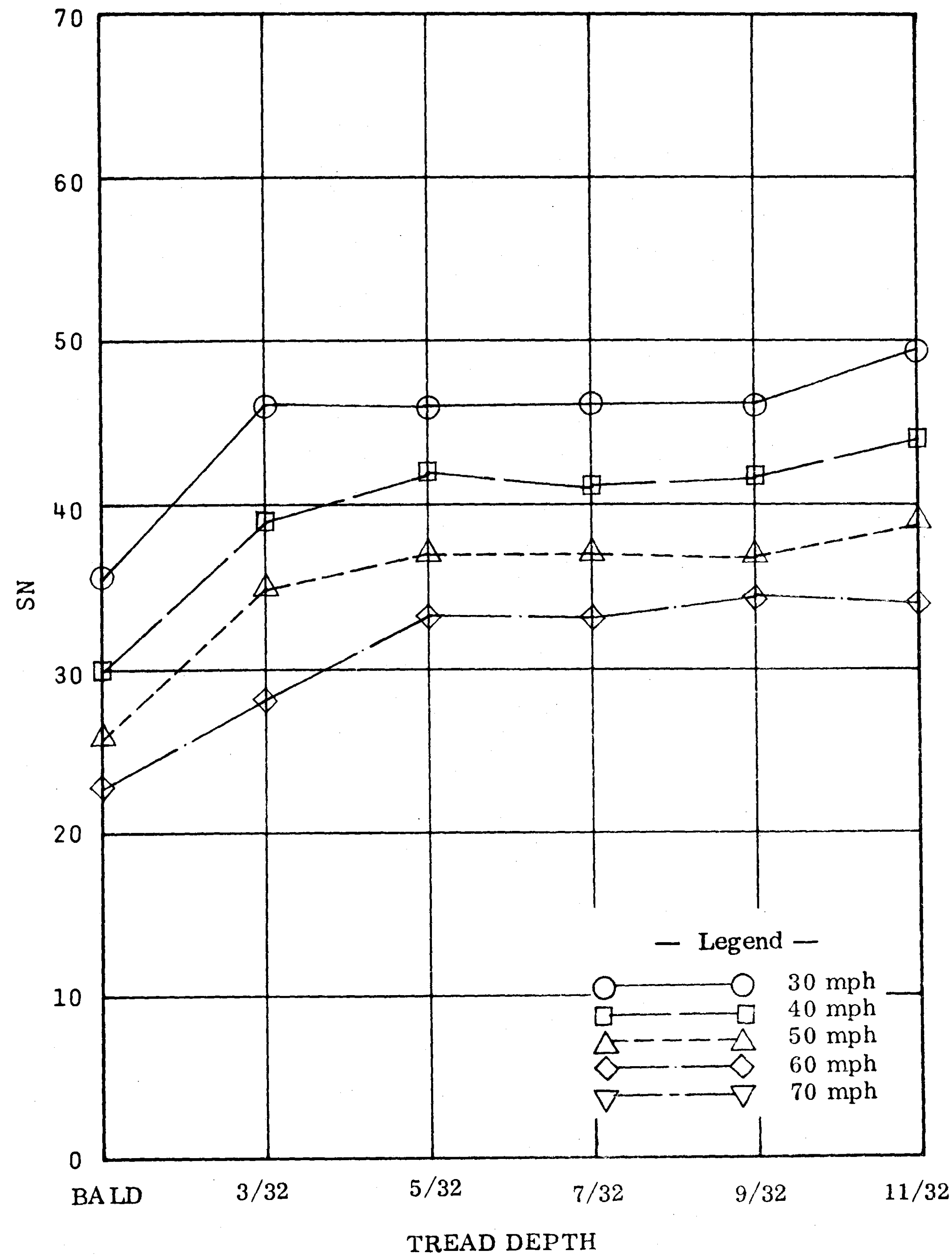


Figure 8. Skid numbers for different test speeds at different tread depths with water conditions combined in site 7. (1 inch = 2.54 cm; 1 mph = .4470 m/s)

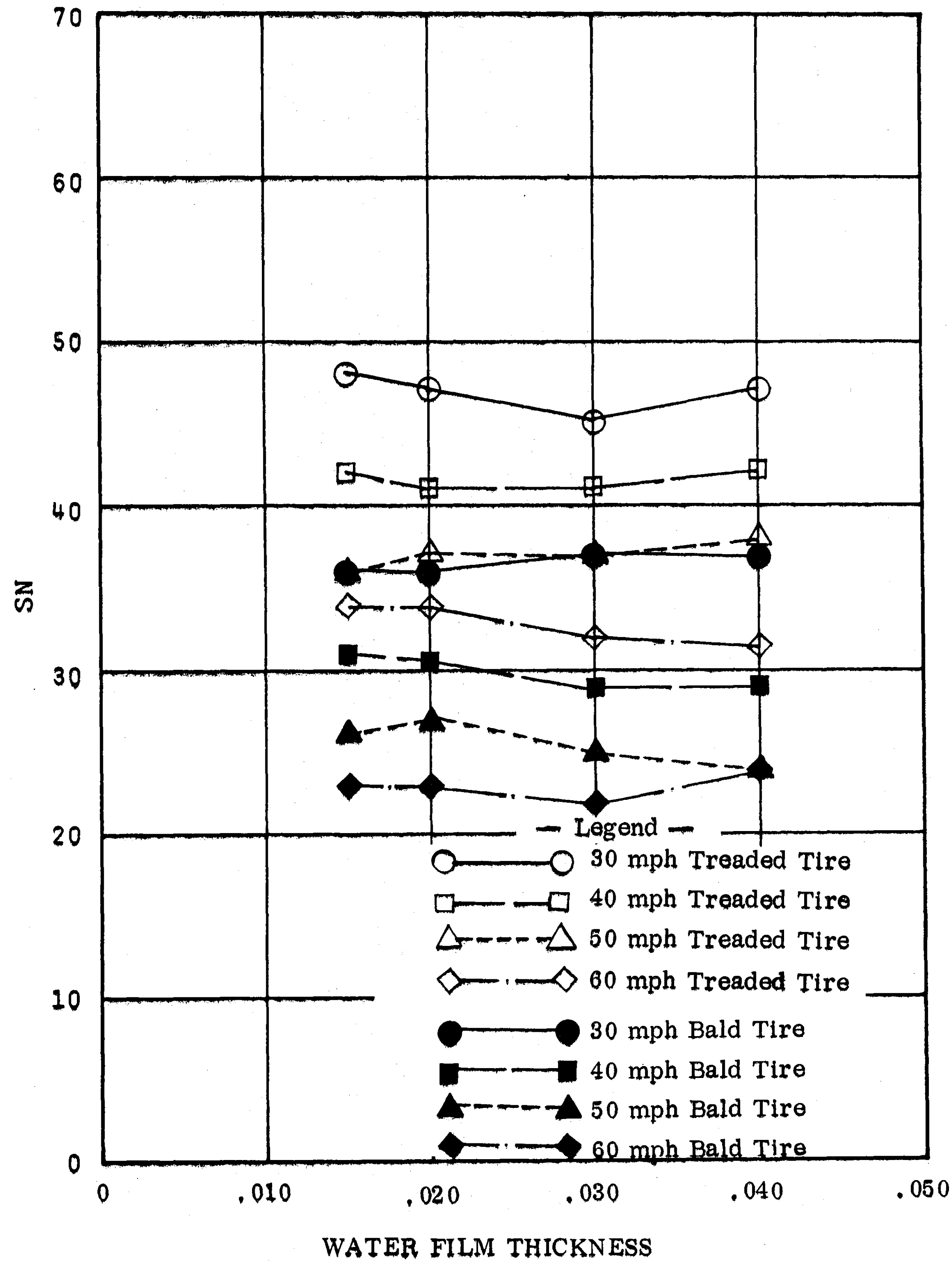


Figure 9. Skid numbers for the various water films for treaded and bald tires at the different test speeds in site 7. (1 inch = 2.54 cm; 1 mph = .4470 m/s)

Steep Slope Speed Gradient Group

Six of the 31 sites provided skid number-speed gradient changes of 0.4 SN/ mph or greater. They were sites 1 and 2, smooth concrete; site 5, a sand asphalt; site 23 a smooth concrete; site 25, a smooth concrete that had been grooved; and site 31, a well-worn S-5 bituminous concrete.

The skid number-speed gradient curves for sites 1 and 2, shown in Figures 10 and 11, are for the traffic and passing lanes, respectively, of a concrete section of Interstate 64 in Fluvanna County. Photographs of the two sites are shown in Figures 12 and 13. The pavement was built in 1970 and was finished with a multiple burlap drag. Prior to the construction of this pavement, Virginia had always employed a single burlap drag for finishing, but at that time was experimenting with means of imparting a harsh texture to concrete pavements. The state was not satisfied with the texture obtained with the multiple drag used on sites 1 and 2 and has since progressed to longitudinal striations imparted by metal tines, the type of finish on sites 20 and 21, which are discussed later. The traffic lane had experienced about four million vehicle passes at the time of testing, while the passing lane had been exposed to about one million. The speed gradient slopes for sites 1 and 2, based on all water and tread depths, were about 0.55 and 0.65 SN/mph, respectively. It can be noted here, as it can throughout the examination of the speed gradients, that the data for the .020 in. (0.05 cm) water film and those for the combined water films were very similar.

The data for the 70 mph (31.3 m/s) test speed are skimpy on these first two sites. Since all of the data points for this speed were not available, the computer program used in processing the data and drawing the curves discarded the data for 70 mph (31.3 m/s), and those shown here were processed by hand. Although some of the data are missing, the treaded tire values at 70 mph (31.3 m/s) coincided with the expected curve. However, the bald tire data for the 70 mph (31.3 m/s) tests were not sufficient to be included.

Site 5 is an S-1 sand mix (see Table A32 for Virginia bituminous mix specifications) on Route 340 in Augusta County and was placed in 1968. At the time of testing, the pavement had received a little over three million vehicle passes. A photograph of the surface is shown in Figure 14. The speed gradient of 0.7 SN, see Figure 15, was the highest of any site tested. However, it should be noted that even though the site had a steep speed gradient, its skid resistance was excellent.

Sites 23 and 25, the curves for which are shown in Figures 16 and 17, are in the passing lane of a single burlap dragged section of concrete pavement on I-64 in Henrico County. Photographs of the surfaces are shown in Figures 18 and 19. Site 25 is on a curve and because it had experienced a number of wet pavement accidents it was grooved in 1971. This grooving was the only difference in the two sites. At the time of testing they had experienced seven and three-quarter million vehicle passes. Their speed gradients were 0.55 SN/mph and 0.4 SN/mph, respectively. Several things regarding these sites are worthy of attention. First, although site 25 is grooved and thus obviously provides amply for the escape of water, its skid number-speed gradient slope was steep. This finding dispells the idea held by some people that an open, high void surface will always provide a flat slope skid number-speed gradient. Since the tire contact areas of this surface are smooth, there is an indication that, in addition to high voids or an open surface, a pronounced microtexture is a necessary ingredient for a flat speed gradient. The word "pronounced" is used since both surfaces had very good skid resistance, which indicated, as was true, that

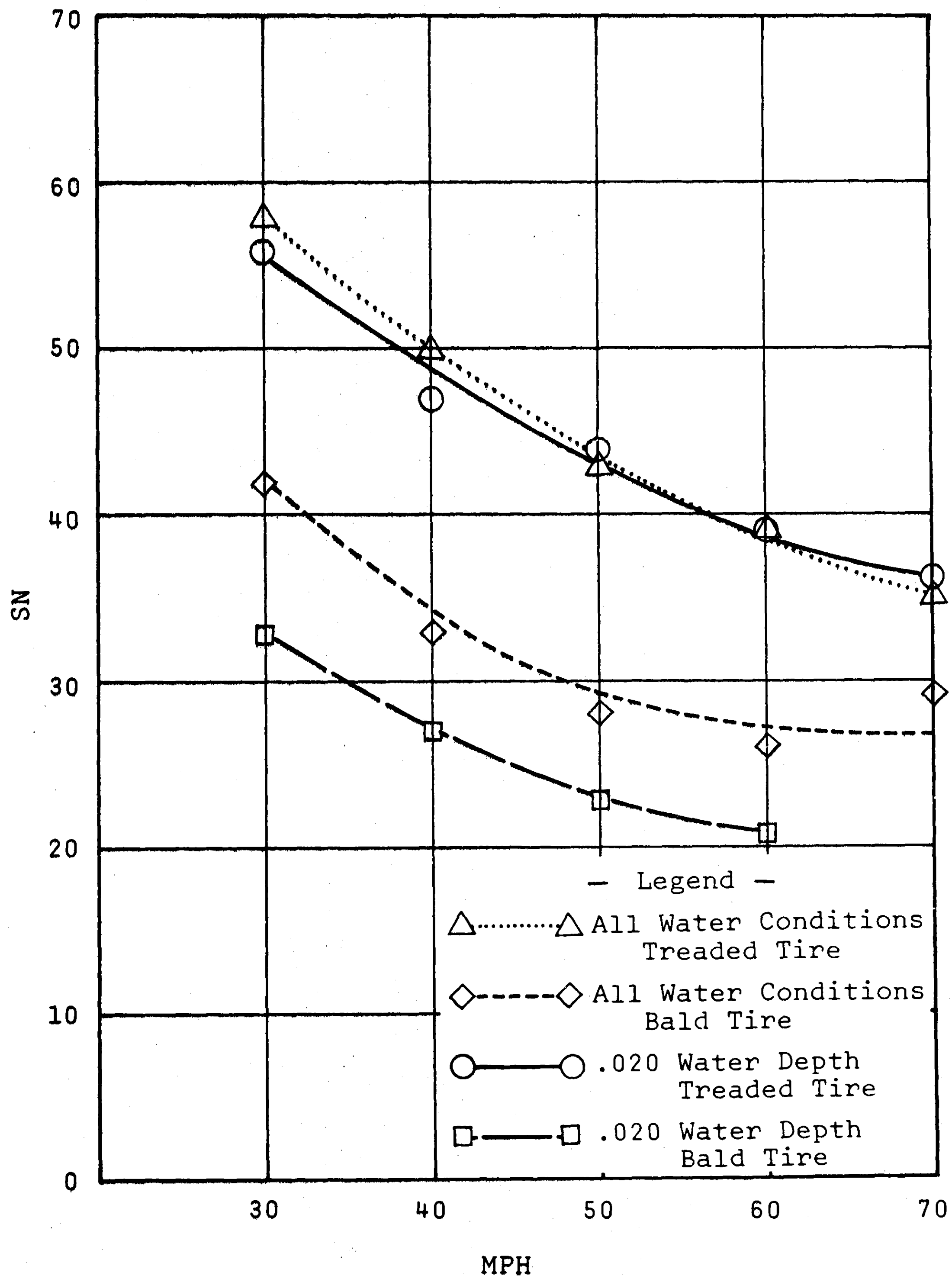


Figure 10. Average speed gradient curves for site 1, the traffic lane of a concrete surface placed in 1970 that had an accumulated traffic count of 4,028,870 vehicles. (1 inch = 2.54 cm; 1 mph = .4470 m/s)

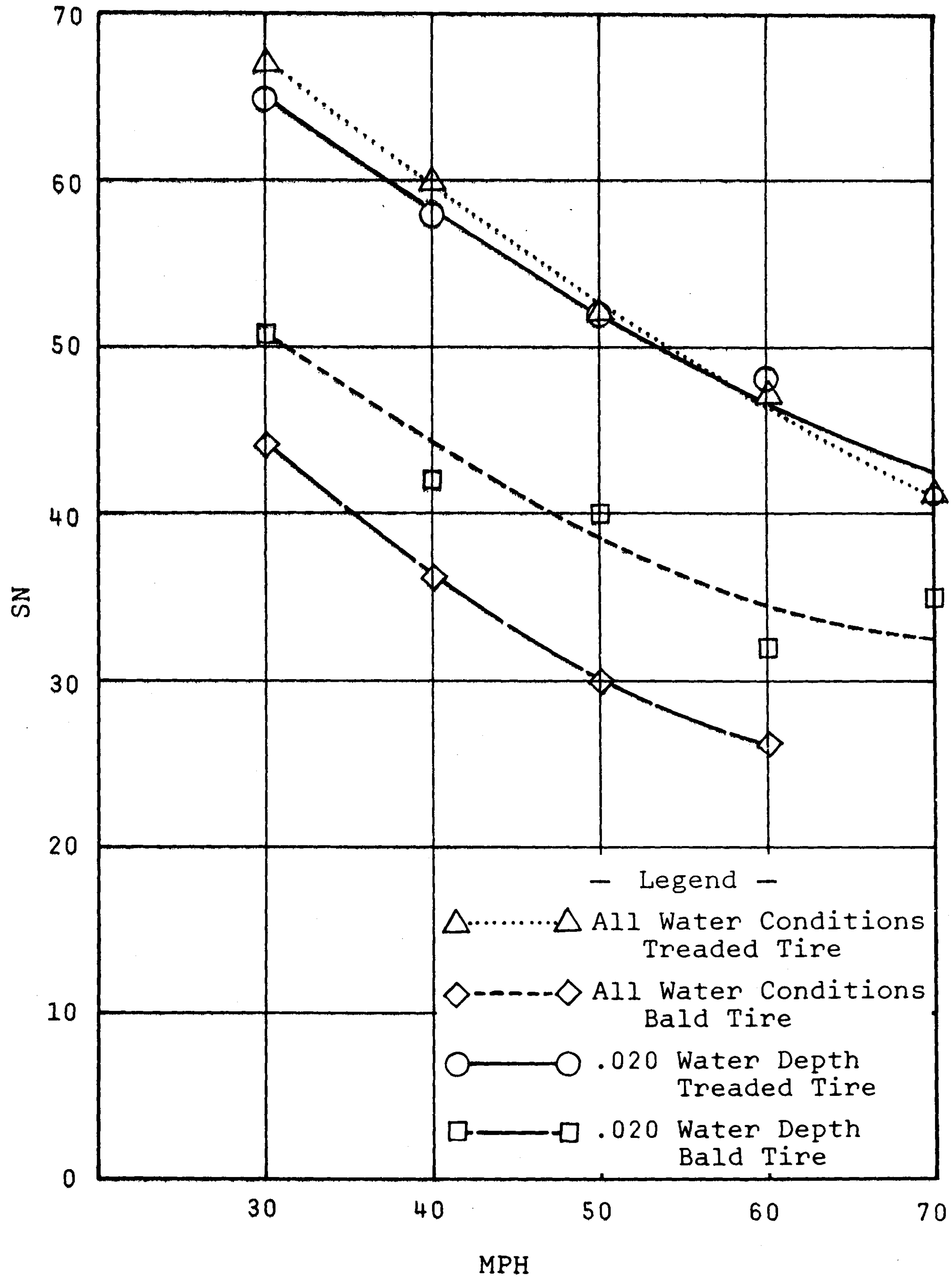


Figure 11. Average speed gradient curves for site 2, the passing lane of a concrete surface placed in 1970 that had an accumulated traffic count of 1,007,218 vehicles. (1inch = 2.54 cm; 1 mph = .4470 m/s)

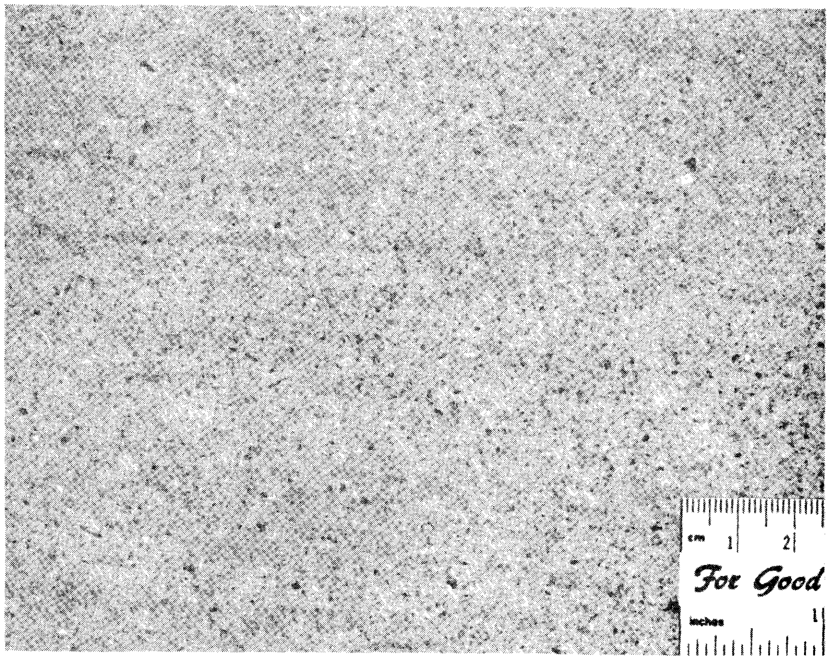


Figure 12. Surface texture of site 1.

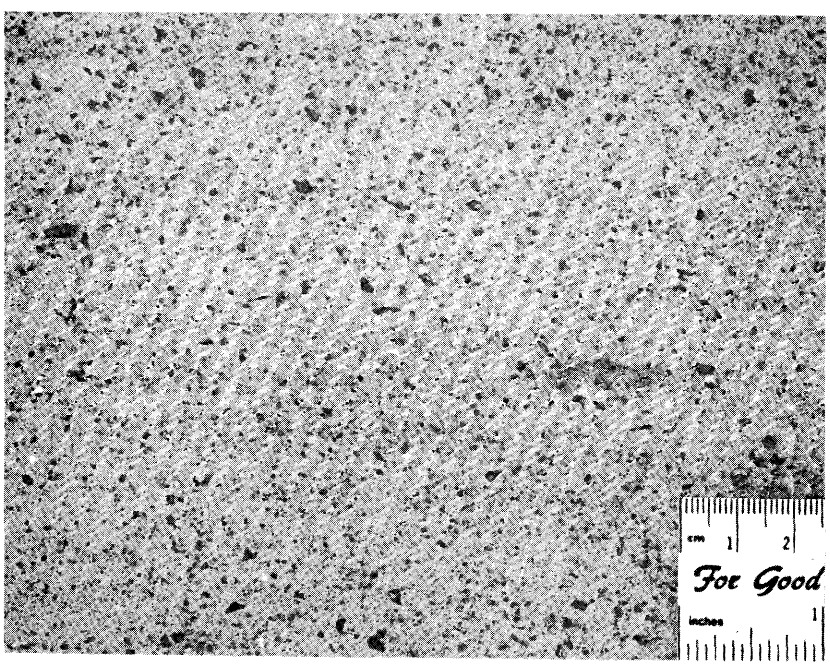


Figure 13. Surface texture of site 2.

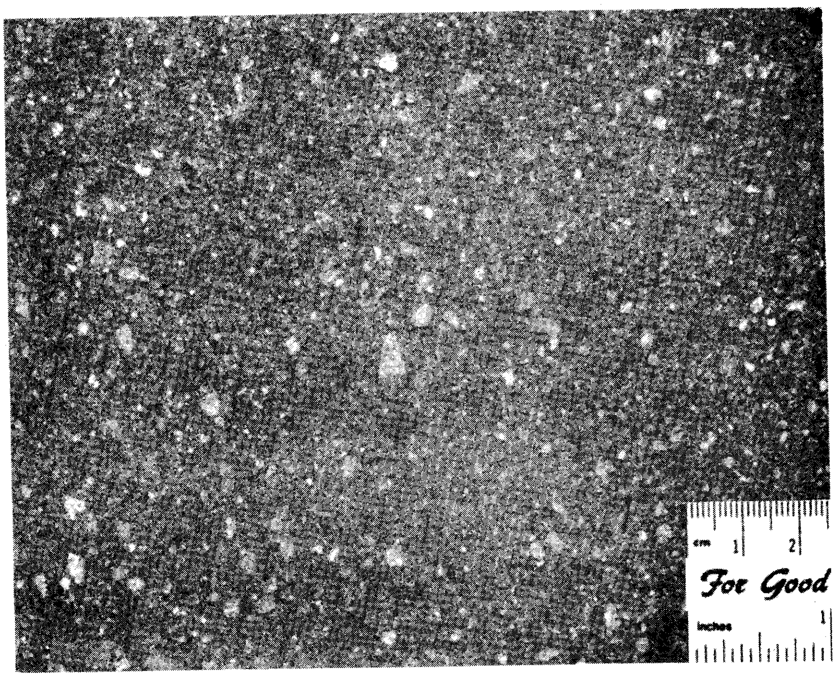


Figure 14. Surface texture for site 5.

they had a fine microtexture. This leads to the conclusion that in order to have good skid resistance and a flat speed gradient, an open surface, a find microtexture, and a harshness somewhere between the two are needed.

The second item of interest becomes obvious when viewing the curves. The bald tire provided higher skid resistance than the treaded tires on the surface that had been grooved. The writer attributes this phenomenon to two things: first, there was more than ample provision for water displacement due to the grooves, and the tread in the tire thus was not needed; and second, because the water was displaced the bald tire provided more contact area. Therefore, in essence, the skid resistance was higher for the bald tire for the same reason it is on a dry pavement; there is an abundance of contact between the tire and the pavement, in this case a silicious microtexture. It is an established fact that grooved pavements have reduced wet pavement accidents, although the $SN_{40}$ is not improved through grooving. Some of the accident reduction could be credited to the great increase in skid resistance for badly worn tires. This subject deserves further investigation.

Site 31 (see Figures 20 and 21) has a counterpart, site 30, in the intermediate group. While site 31 is in the traffic lane of arterial Route 460 in Bedford County, site 30, which is discussed later, is the passing lane. The surface was an S-5 bituminous concrete, was placed in 1965, and had experienced about nine million vehicle passes at the time of testing. The skid number-speed gradient slope was 0.55 SN/mph.

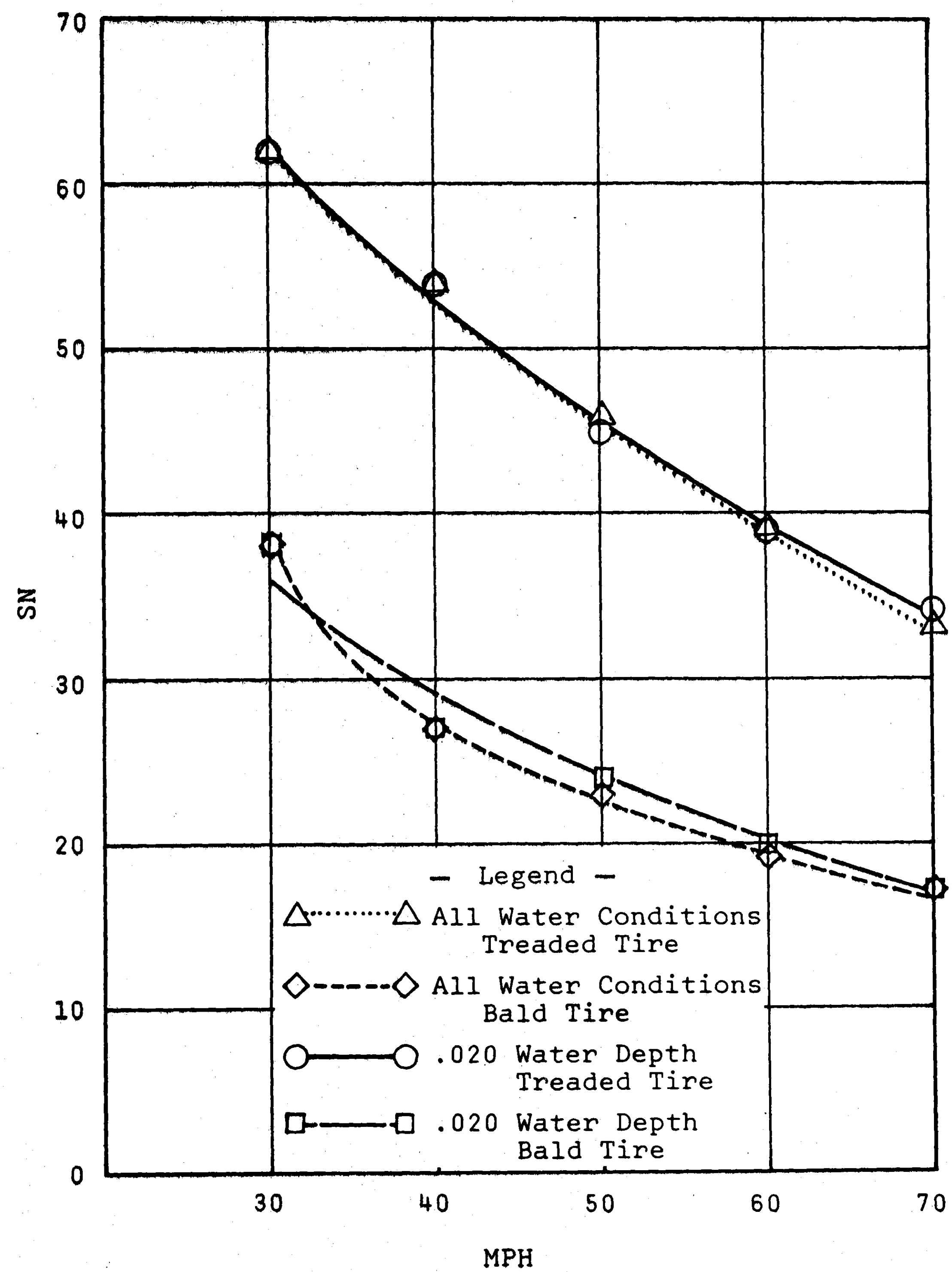


Figure 15. Average speed gradient curves for site 5, the traffic lanes of an S-1 sand asphalt surface placed in 1968 that had an accumulated traffic count of 3,149,950 vehicles. (1 inch = 2.54 cm/ 1 mph = .4470 m/s)

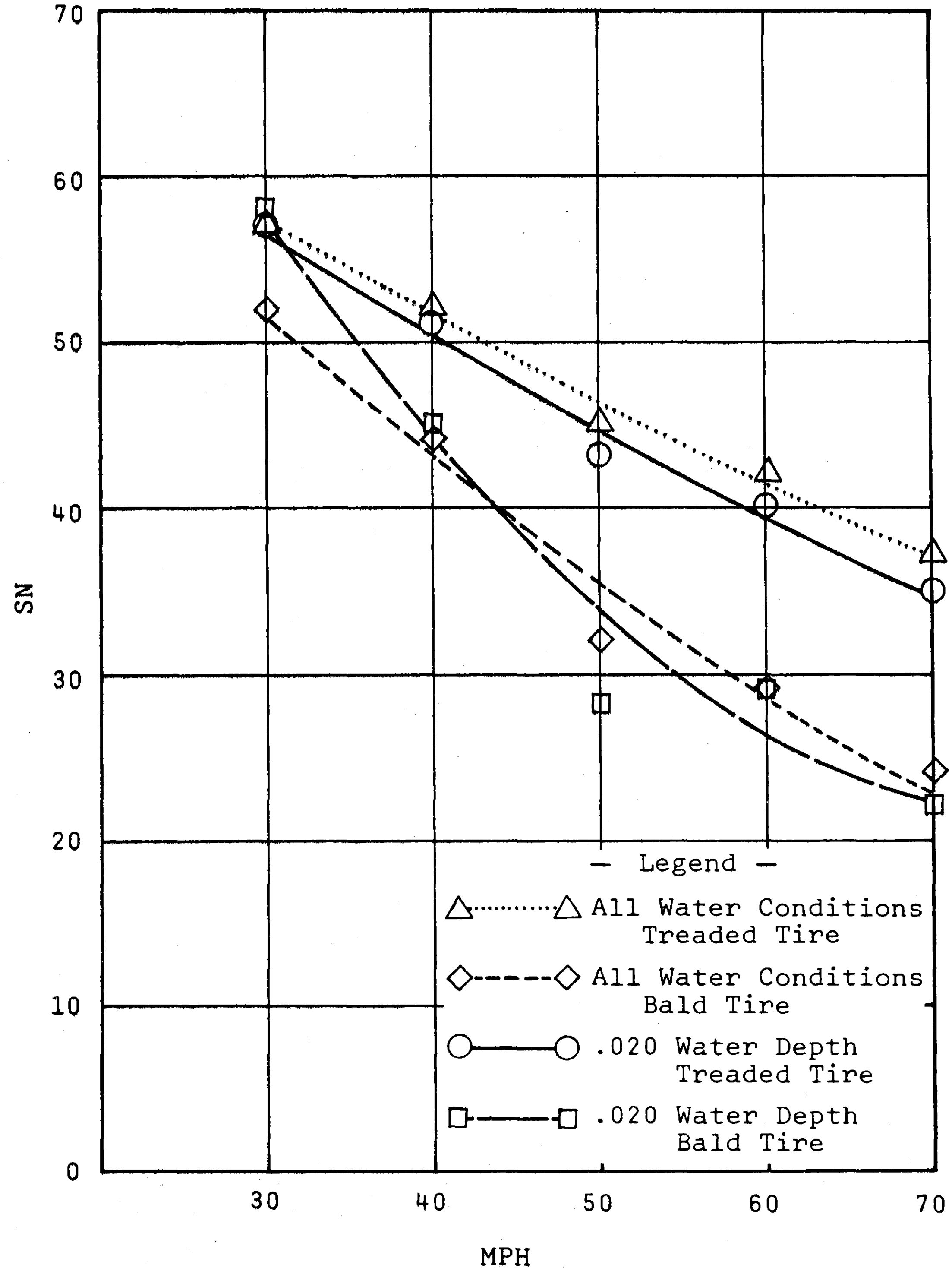


Figure 16. Average speed gradient curves for site 23, the passing lane of a concrete surface placed in 1968 that had an accumulated traffic count of 7,815,106 vehicles. (1 inch = 2.54 cm; 1 mph = .4470 m/s)

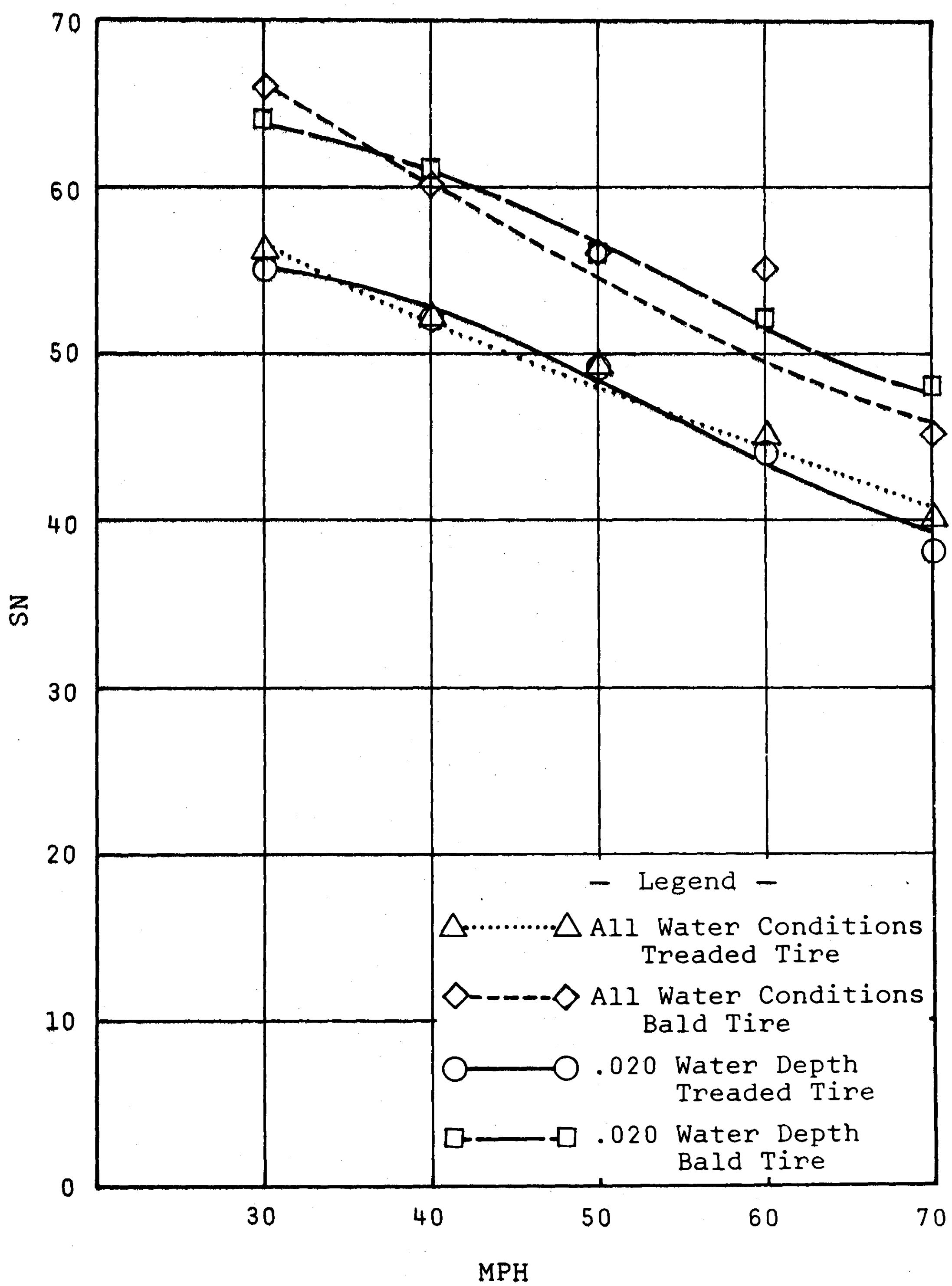


Figure 17. Average speed gradient curves for site 25, the passing lane of a grooved portland cement concrete surface placed in 1968 that had an accumulated traffic count of 7,815,106 vehicles. (1 inch = 2.54 cm; 1 mph = .4470 m/s)

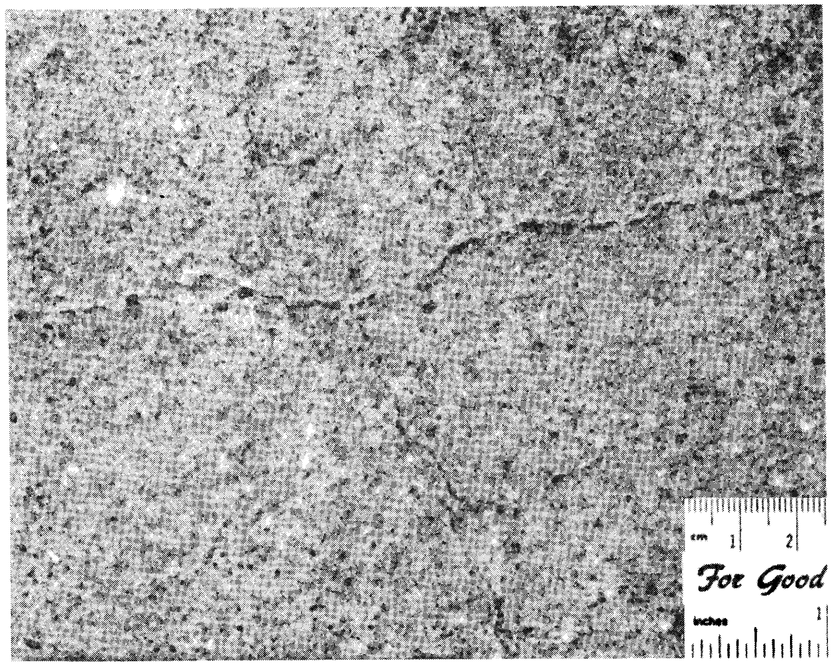


Figure 18. Surface texture of site 23.

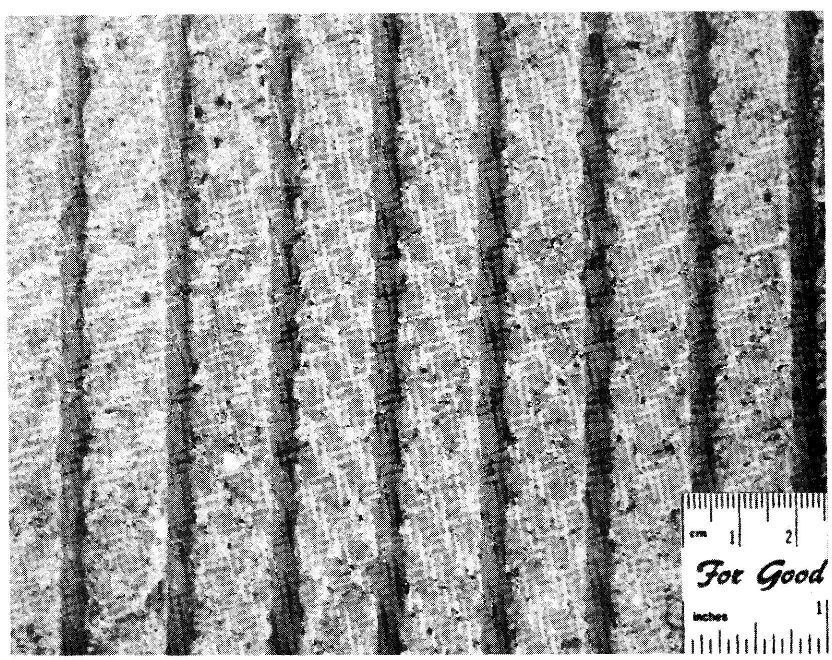


Figure 19. Surface texture of site 25.

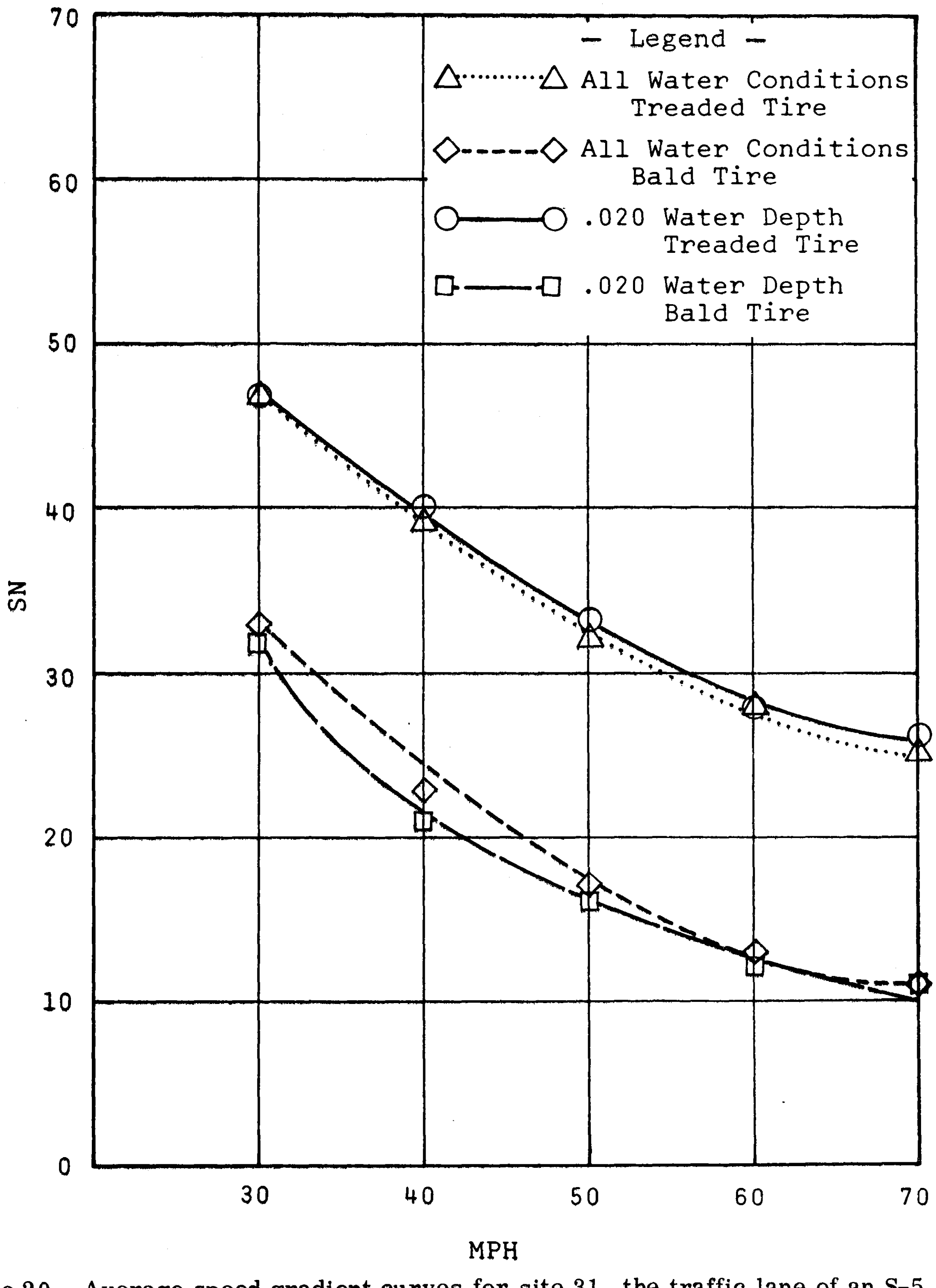


Figure 20. Average speed gradient curves for site 31, the traffic lane of an S-5 bituminous concrete surface placed in 1965 that had an accumulated traffic count of 9,369,550 vehicles. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

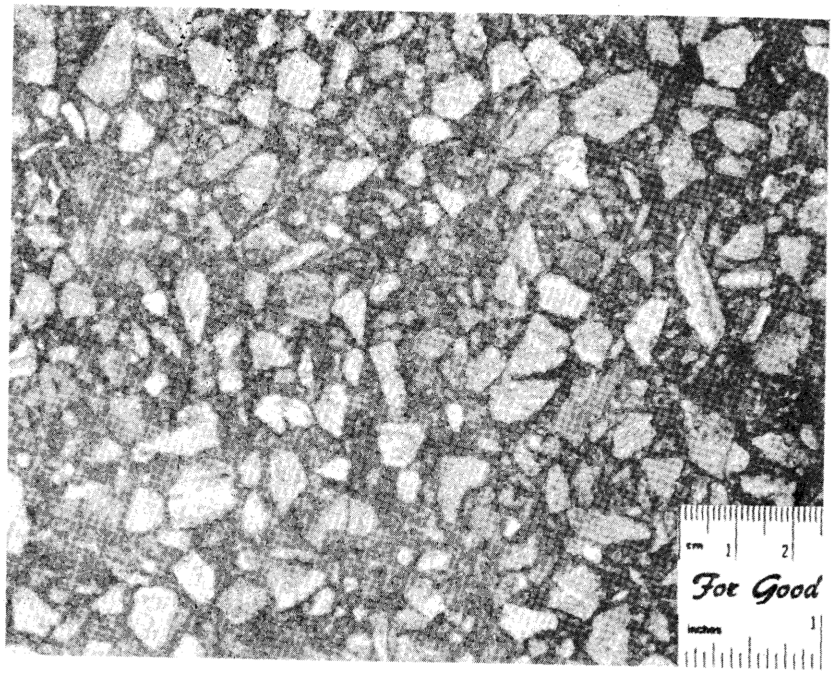


Figure 21. Surface texture for site 31.

When these data are viewed in combination with the data from site 30, which are presented in the intermediate slope group, two facts are apparent. First, the aggregate is prone to polishing. The $SN_{40}$ for this site, which had about nine million passes, was 48. The other fact is that the type of harshness that gives a low skid number-speed gradient had worn away. This is demonstrated by the fact that this, the traffic lane, had a slope of 0.55 SN/mph, while the passing lane (site 30) had a slope of 0.35 SN/mph.

In an overall evaluation of the steep speed gradient group, it should be noted that the bald tire provided a much lower skid resistance than the treaded tire for all except the grooved concrete, which, of course, is a special type of surface. More about the difference between bald and treaded tire skid resistance will be discussed in later sections.

## Intermediate Slope Speed Gradient Group

As should be expected, the majority, 19, of the 31 sites fit in the intermediate speed gradient group.

The first two are sites 3 and 4, for which the speed gradient curves are depicted in Figures 22 and 23. The sites are for the traffic and passing lanes, respectively, and the surface courses are the Virginia designation S-5 bituminous mix. Photographs of the surfaces are shown in Figures 24 and 25. The accumulated vehicle passes on these

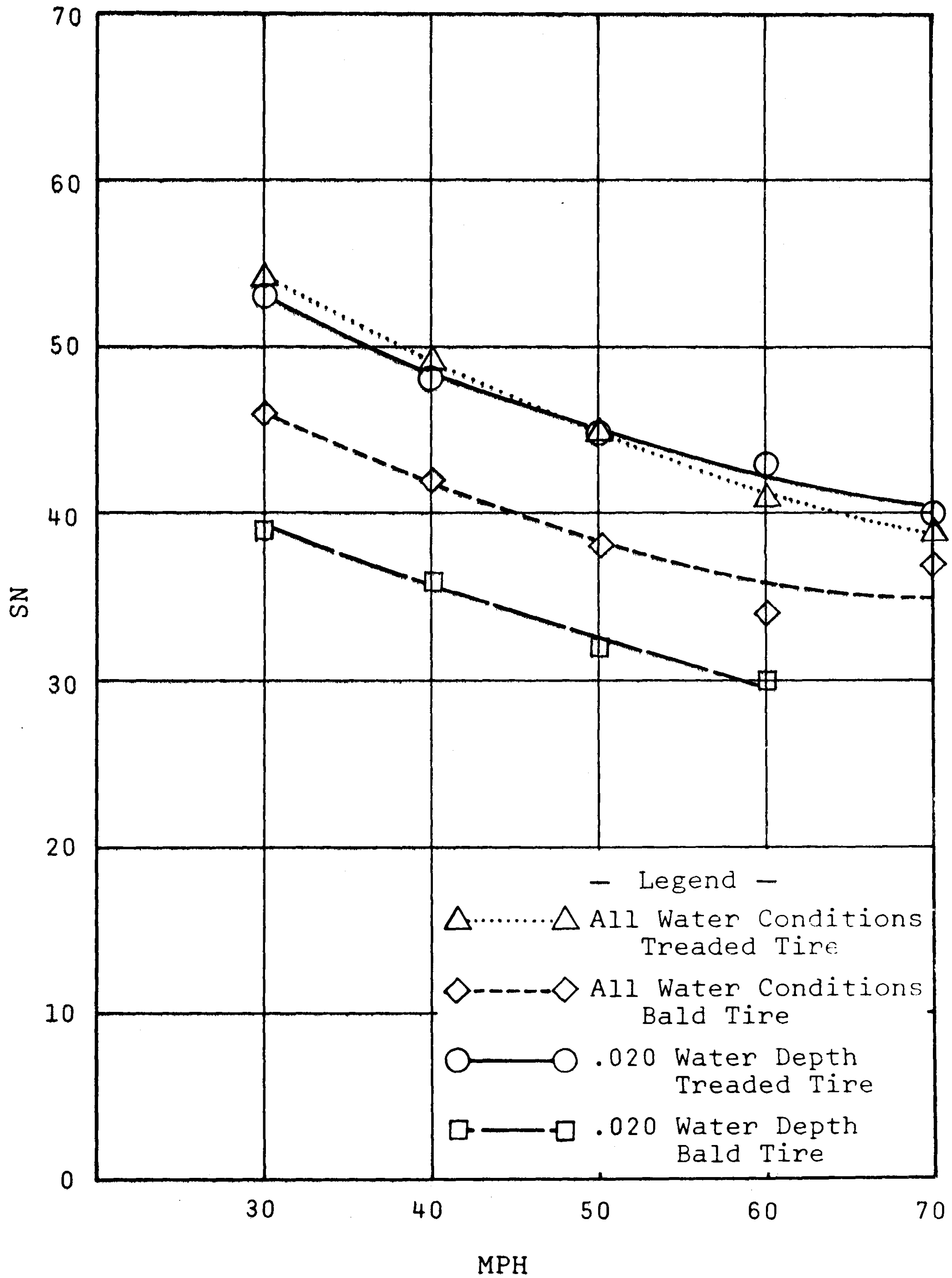


Figure 22. Average speed gradient curves for site 3, the traffic lane of an S-5 bituminous concrete surface placed in 1970 that had an accumulated traffic count of 4,028,870 vehicles. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

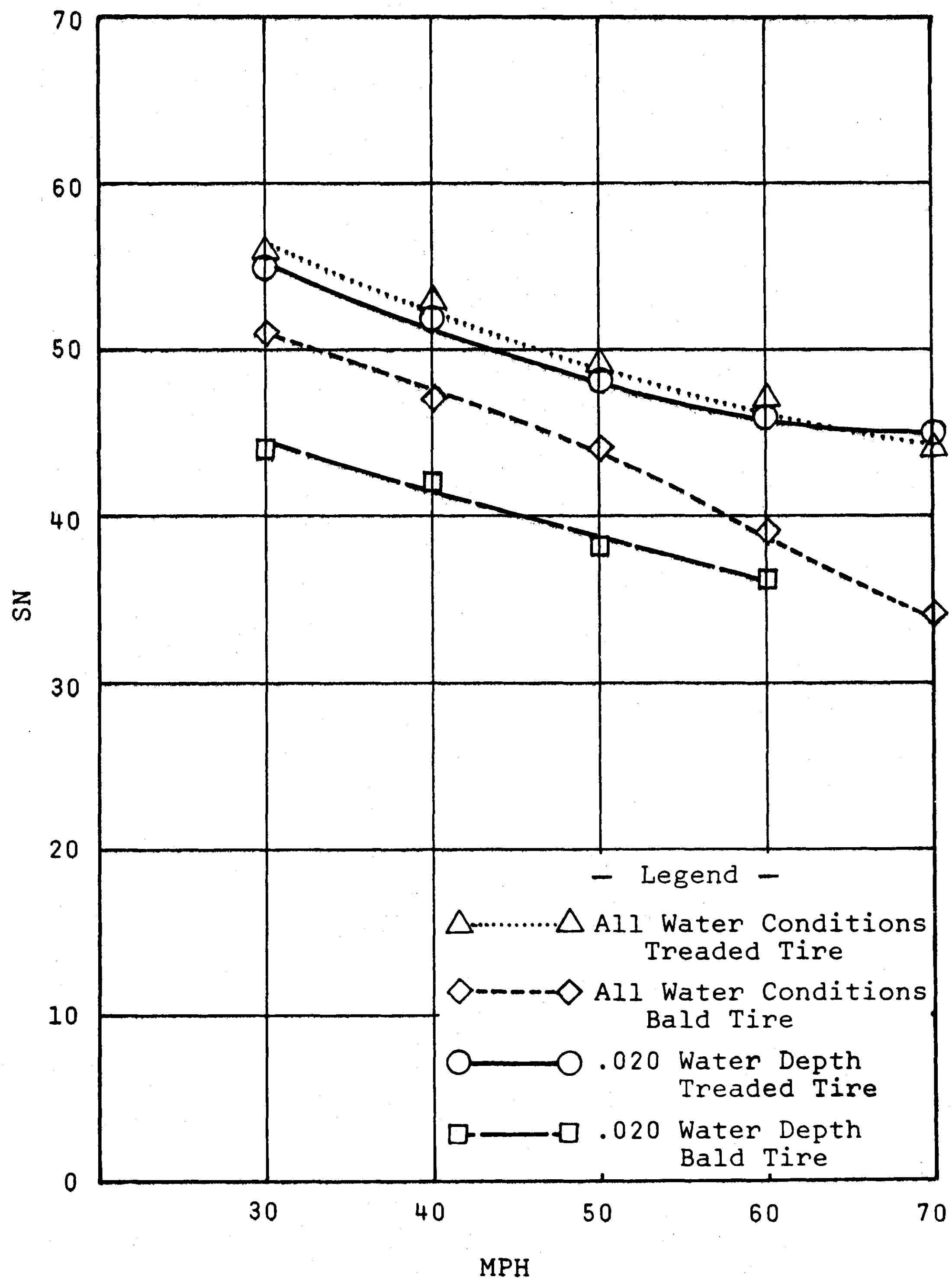


Figure 23. Average speed gradient curves for site 4, the passing lane of an S-5 bituminous concrete surface placed in 1970 that had an accumulated traffic count of 1,007,218 vehicles. ( 1 inch = 2.54 cm/ 1 mph = .4470 m/s)

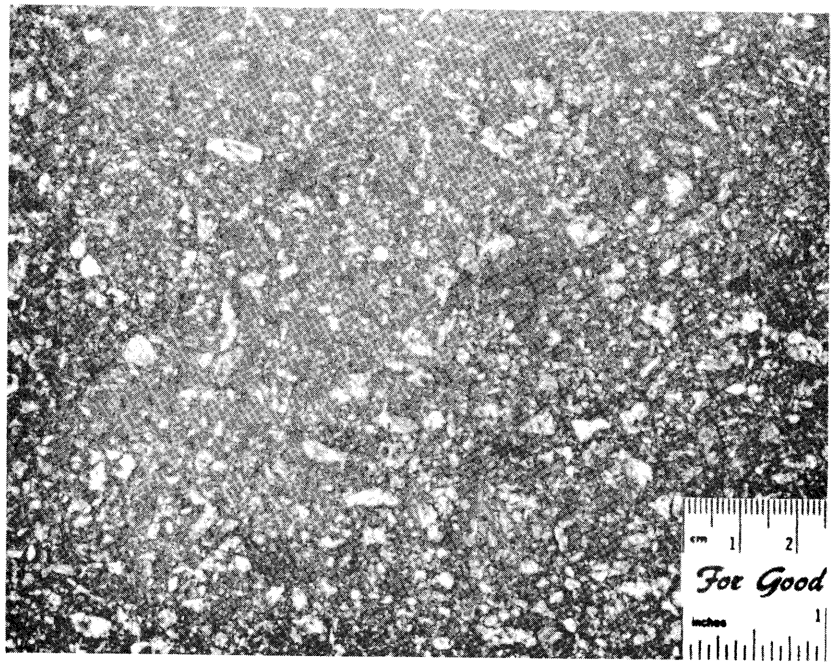


Figure 24. Surface texture of site 3.

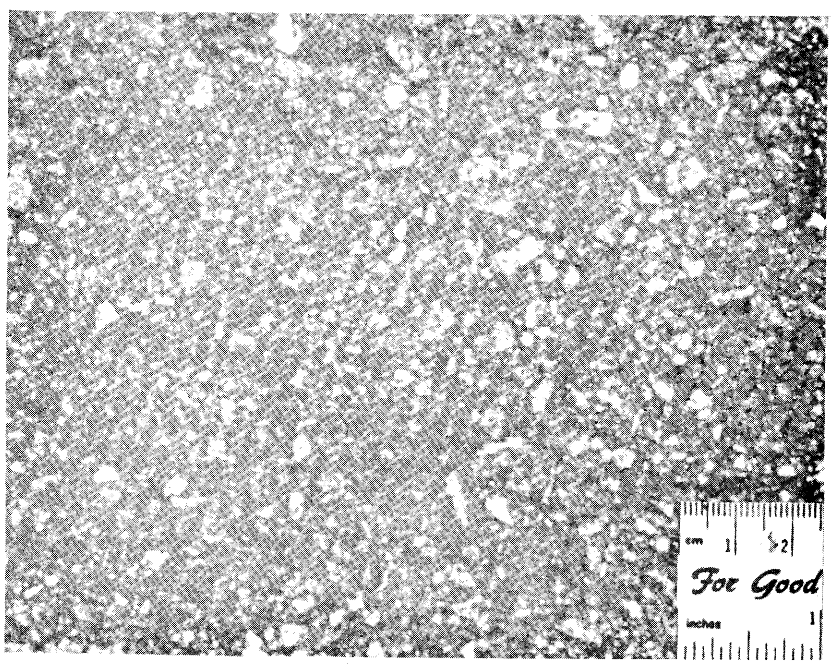


Figure 25. Surface texture of site 4.

two surfaces at the time of testing were four and one million, respectively, and the skid number-speed gradients were 0.37 SN/ mph and 0.3 SN/mph.

The data for the 70 mph (31.3 m/s) test speed on these two sites are skimpy. Since all of the data points for this speed were not available, the computer program used in processing the data and drawing the curves discarded the data for 70 mph (31.3 m/s), and those shown here were processed by hand. Although some of the data are missing, the treaded tire values at 70 mph (31.3 m/s) coincided with the expected curve. However, the bald tire data for the 70 mph (31.3 m/s) tests were not sufficient to be included.

It should be noted in Figures 22 and 23 that, as was the case for the rest of the intermediate slope data, the bald tire friction was much closer to that of the treaded tire than was the case for the steep slope group. It should also be noted, and expected, that the passing lane did provide a little higher skid resistance than did the traffic lane.

Sites 6 and 7, see skid number-speed gradient curves in Figures 26 and 27, are the traffic and passing lanes of a burlap drag finish concrete section of Interstate 95 in Greenville County that was built in 1959. At the time of testing they had experienced about seventeen and four million vehicles passes, respectively. Photographs of the surfaces are shown in Figures 28 and 29. While the skid numbers shown seem low, the relationships between the car and trailer should be remembered. These trailer numbers actually equate to relatively good stopping distance numbers. In fact, the $SDN_{40}$ values were 43 and 56 for the traffic and the passing lane, respectively. Again, as was the case with sites 3 and 4, the traffic lane had lower skid numbers than did the passing lane. The speed gradient slopes for these two sites were 0.35 SN/mph. and .40 SN/mph.

Sites 8 and 9 (Figures 30 through 33) have the same history as sites 6 and 7, except that in the summer of 1973 they were bushhammered as described by Creech[6] to provide a harsh texture. The speed gradient of site 8 was 0.3 SN/mph and the slope of site 9 was 0.35 SN/mph. Again, even though the surface had been roughened, the skid numbers in the traffic lane were lower than those in the passing lane. It also should be noted that although the roughening of the pavement caused a slight improvement of friction with respect to the treaded tires, the improvement with respect to the bald tires was pronounced. Also of interest is the fact that the bald tire data moved closer to the treaded tire data for the harsh pavements, as would be expected.

Sites 10 and 11, see Figures 34 and 35 for skid number-speed gradient curves, are the east- and westbound traffic lanes of an S-5 bituminous concrete surface on Interstate 264 in Chesapeake. Figures 36 and 37 are photographs of these surfaces. The accumulated traffic count for each was about four and one-third million vehicle passes and they were both built in 1969. They should have produced like data, and, in fact, did, with the exception of several points on the bald tire data curve. The skid number-speed gradient slopes for sites 10 and 11 were 0.3 SN/mph and 0.25 SN/mph. The passing lanes for these two sites will be discussed with the low slope group, at which time a comparison between the traffic and passing lanes will be made.

Sites 14 and 15, for which the skid number-speed gradients are shown in Figures 38 and 39, are a special urban bituminous mix [7] used in Virginia (mix design in Table A33)

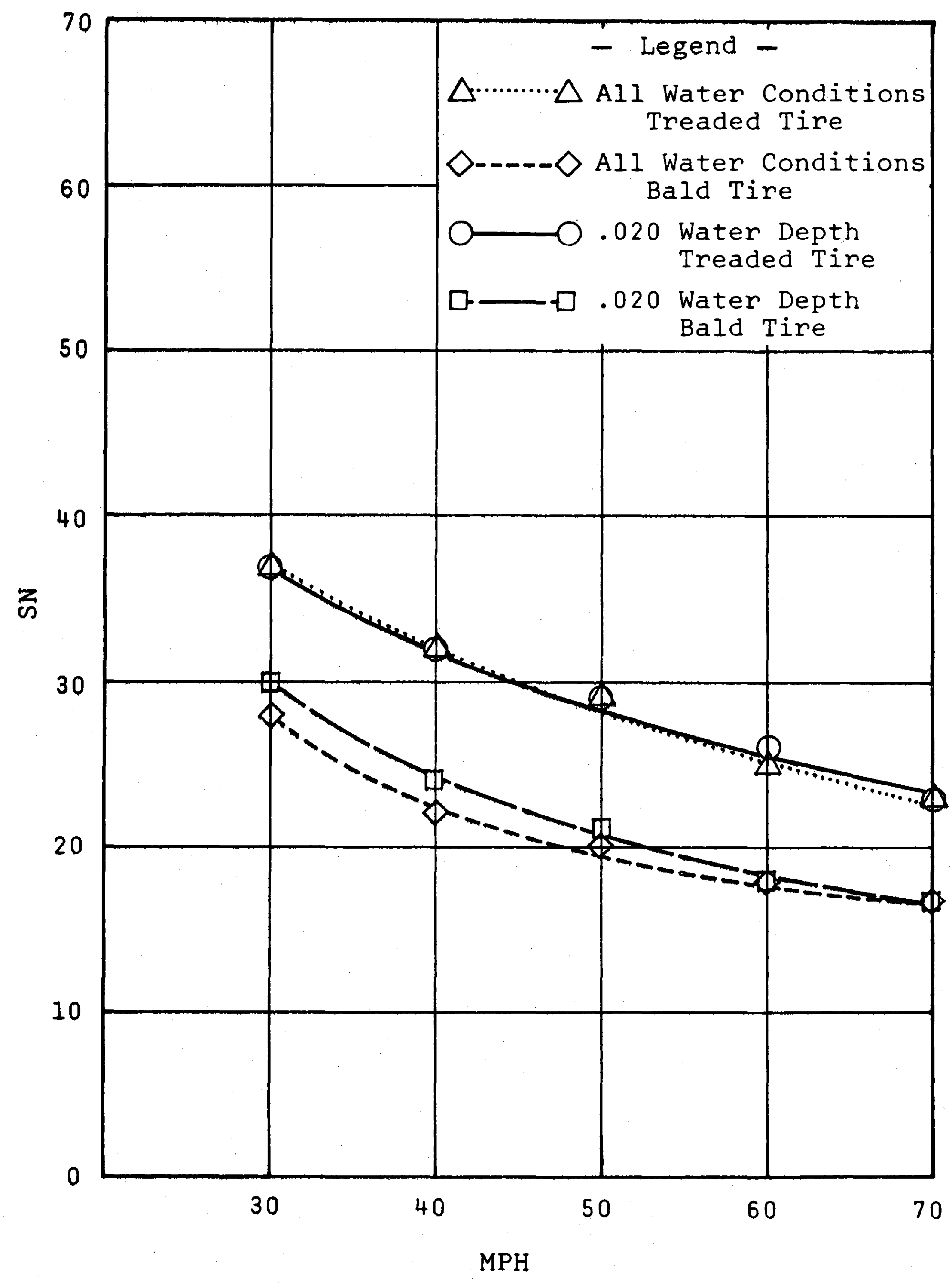


Figure 26. Average speed gradient curves for site 6, the traffic lane of a portland cement concrete surface placed in 1959 that had an accumulated traffic count of 17,212,962 vehicles. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

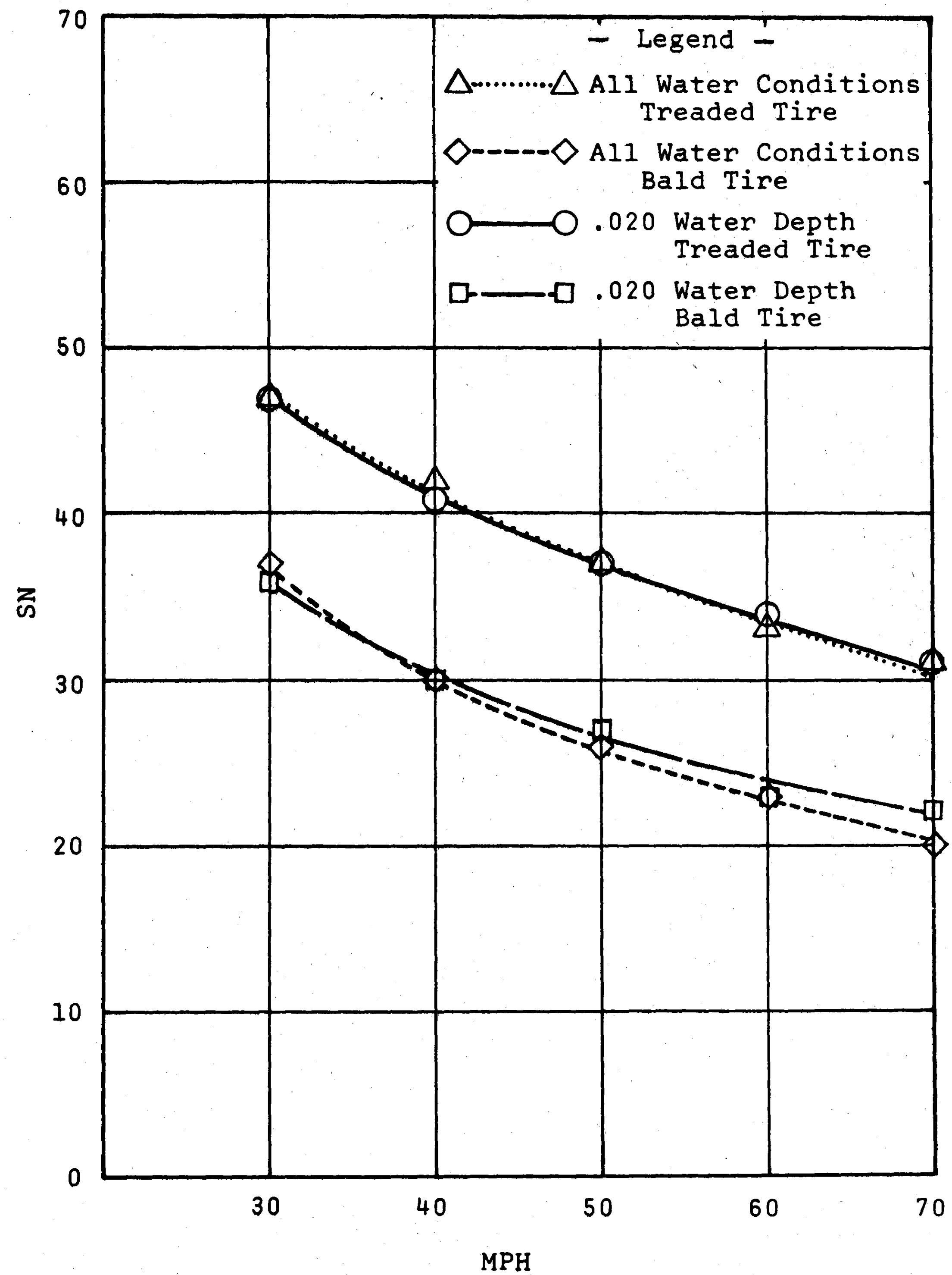


Figure 27. Average speed gradient curves for site 7, the passing lane of a portland cement concrete surface placed in 1959 that had an accumulated traffic count of 4,303,240 vehicles. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

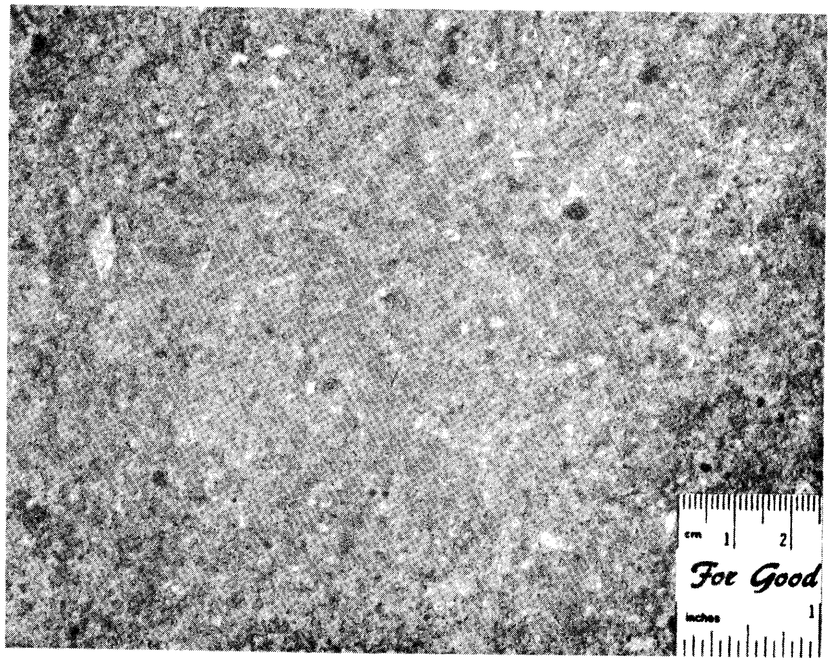


Figure 28. Surface texture of site 6.

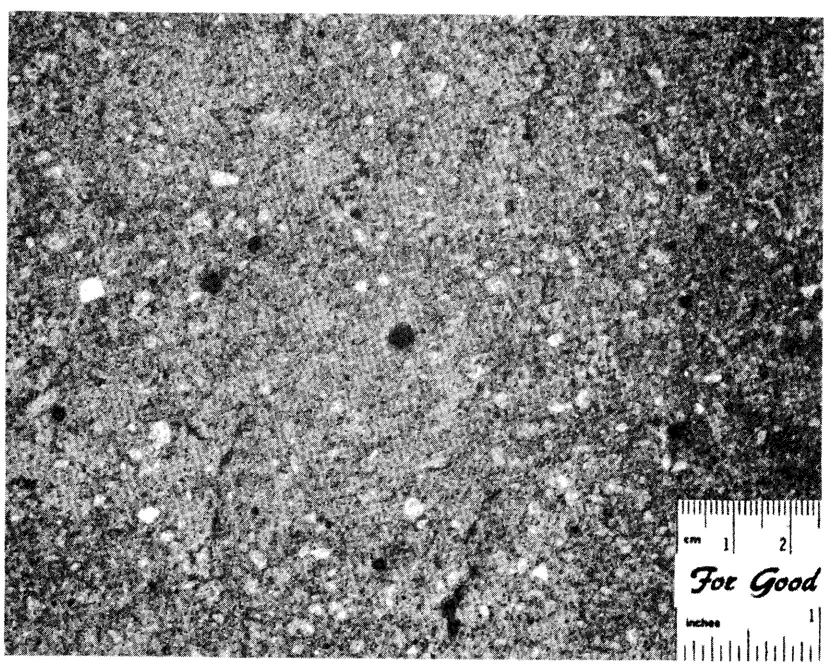


Figure 29. Surface texture of site 7.

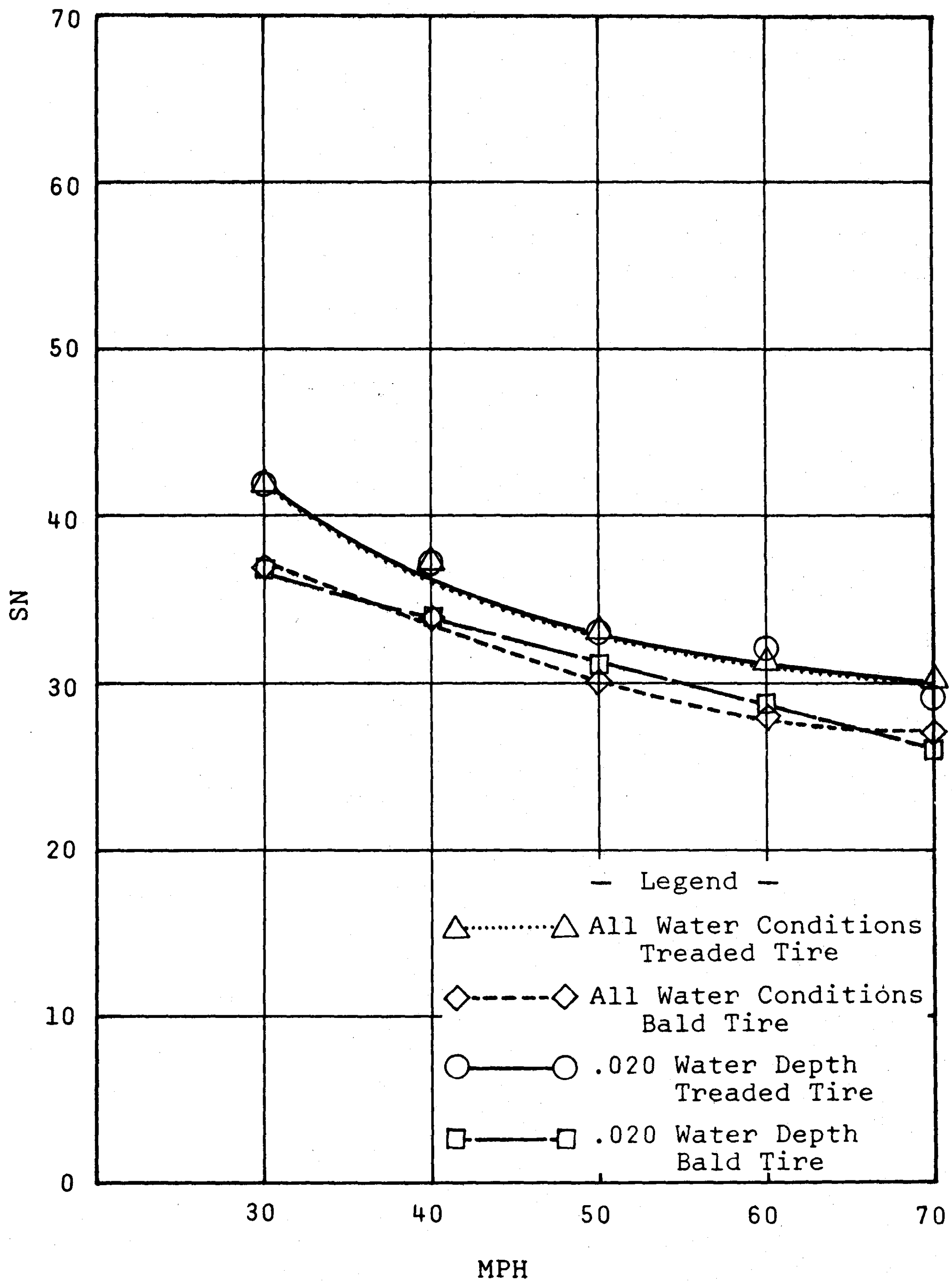


Figure 30. Average speed gradient curves for site 8, the traffic lane of mechanically chipped portland cement concrete surface placed in 1974 that had an accumulated traffic count of 0 vehicles. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

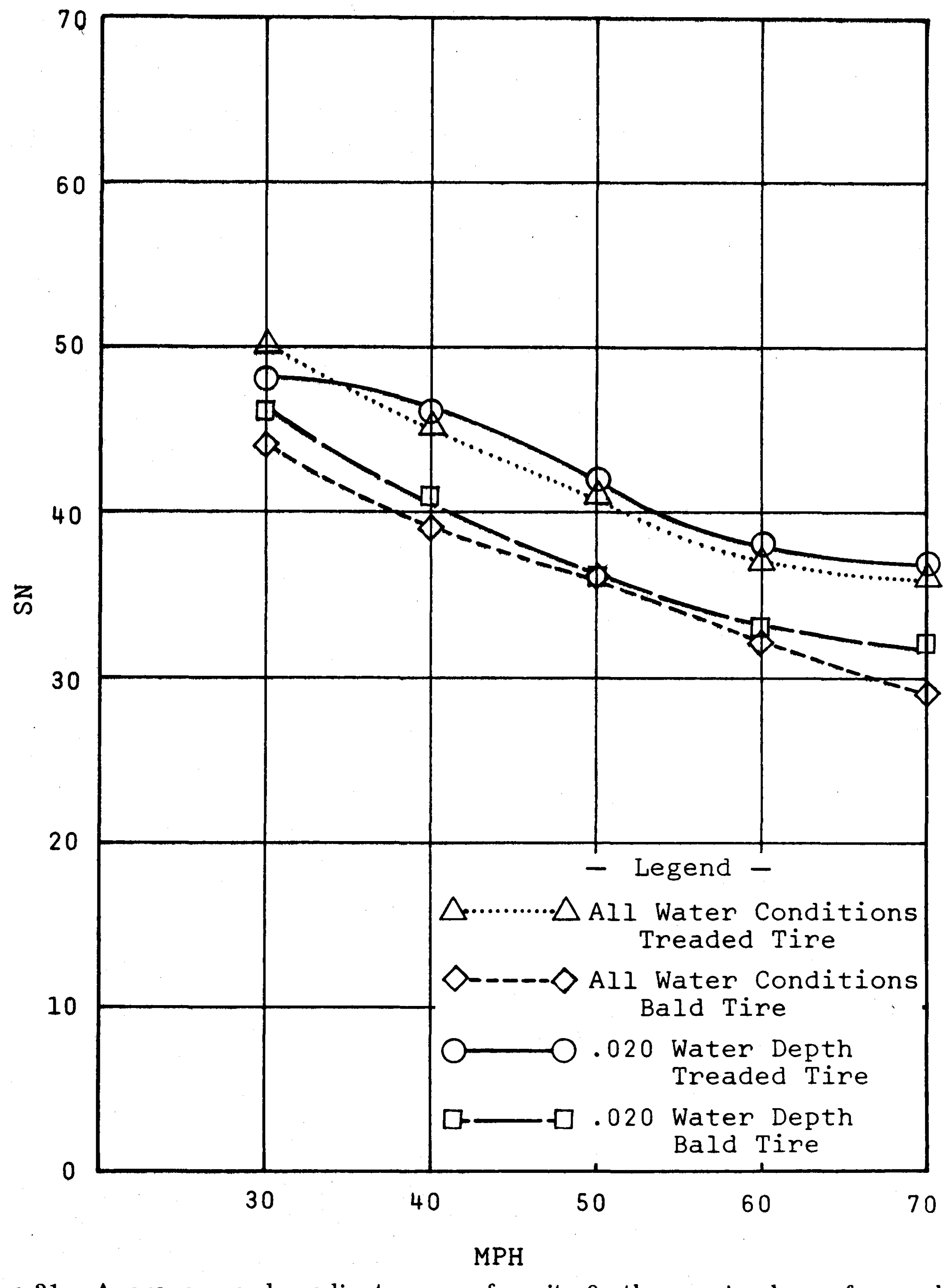


Figure 31. Average speed gradient curves for site 9, the passing lane of a mechanically chipped portland cement concrete surface placed in 1974 that had an accumulated traffic count of 0. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

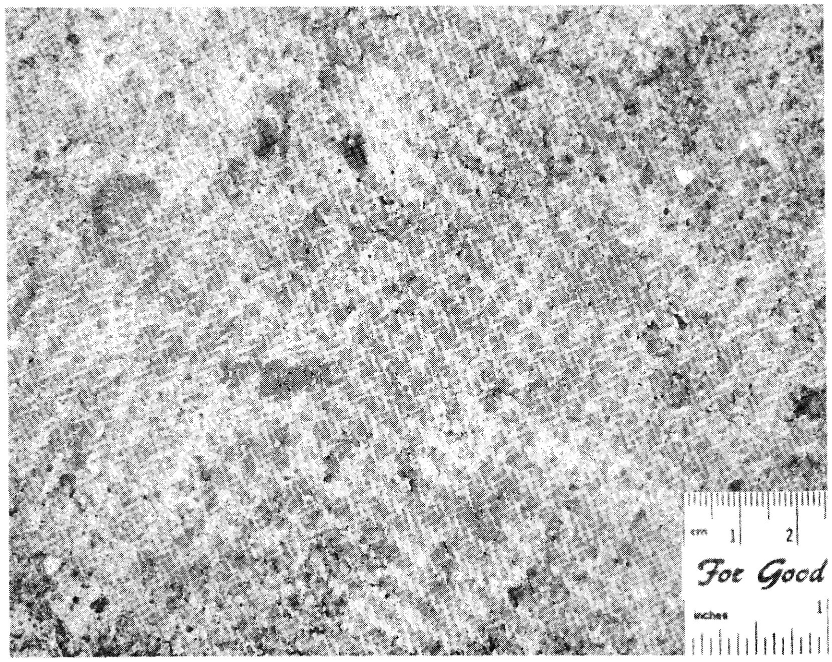


Figure 32. Surface texture of site 8.

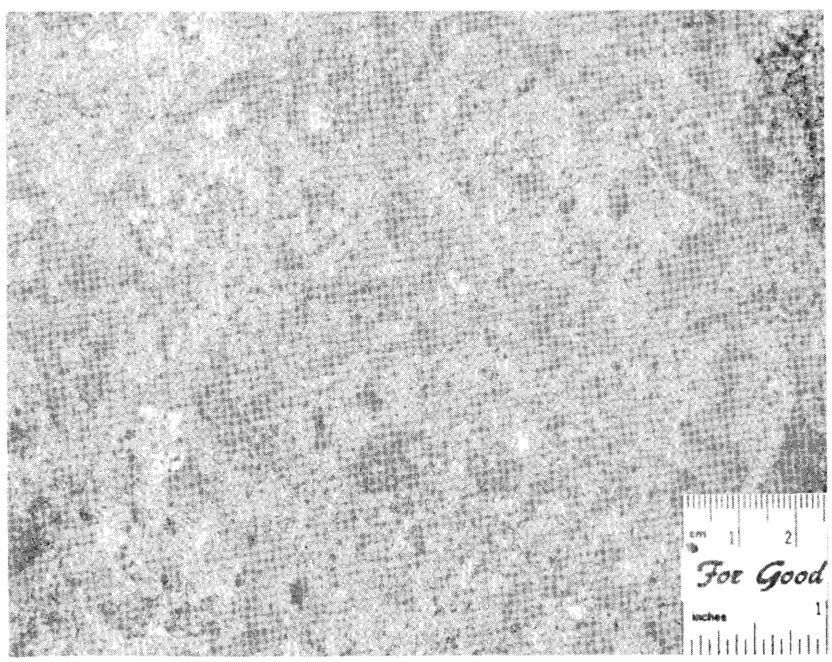


Figure 33. Surface texture of site 9.

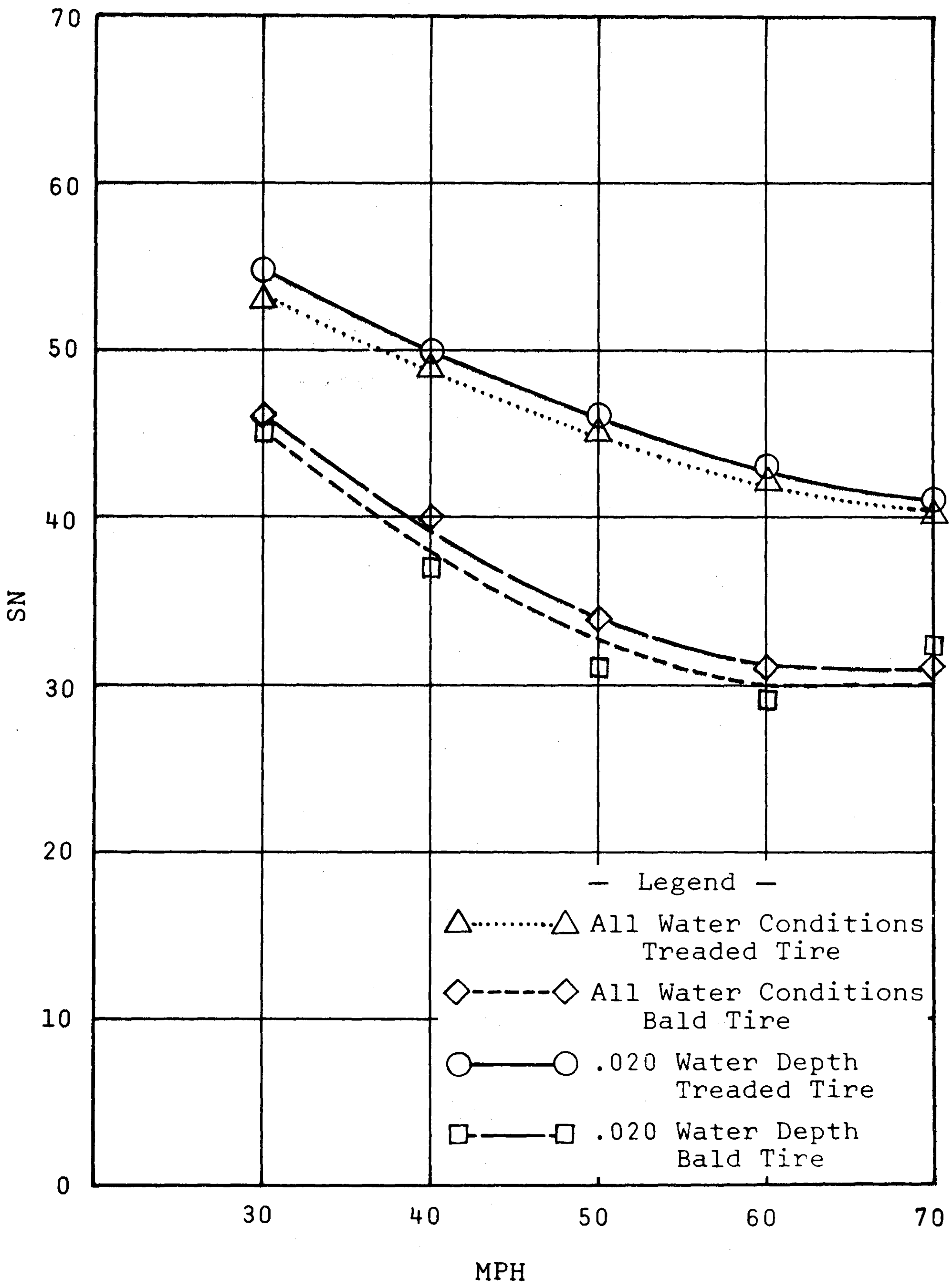


Figure 34. Average speed gradient curves for site 10, the traffic lane of an S-5 bituminous concrete surface placed in 1969 that had an accumulated traffic count of 4,411,755 vehicles. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

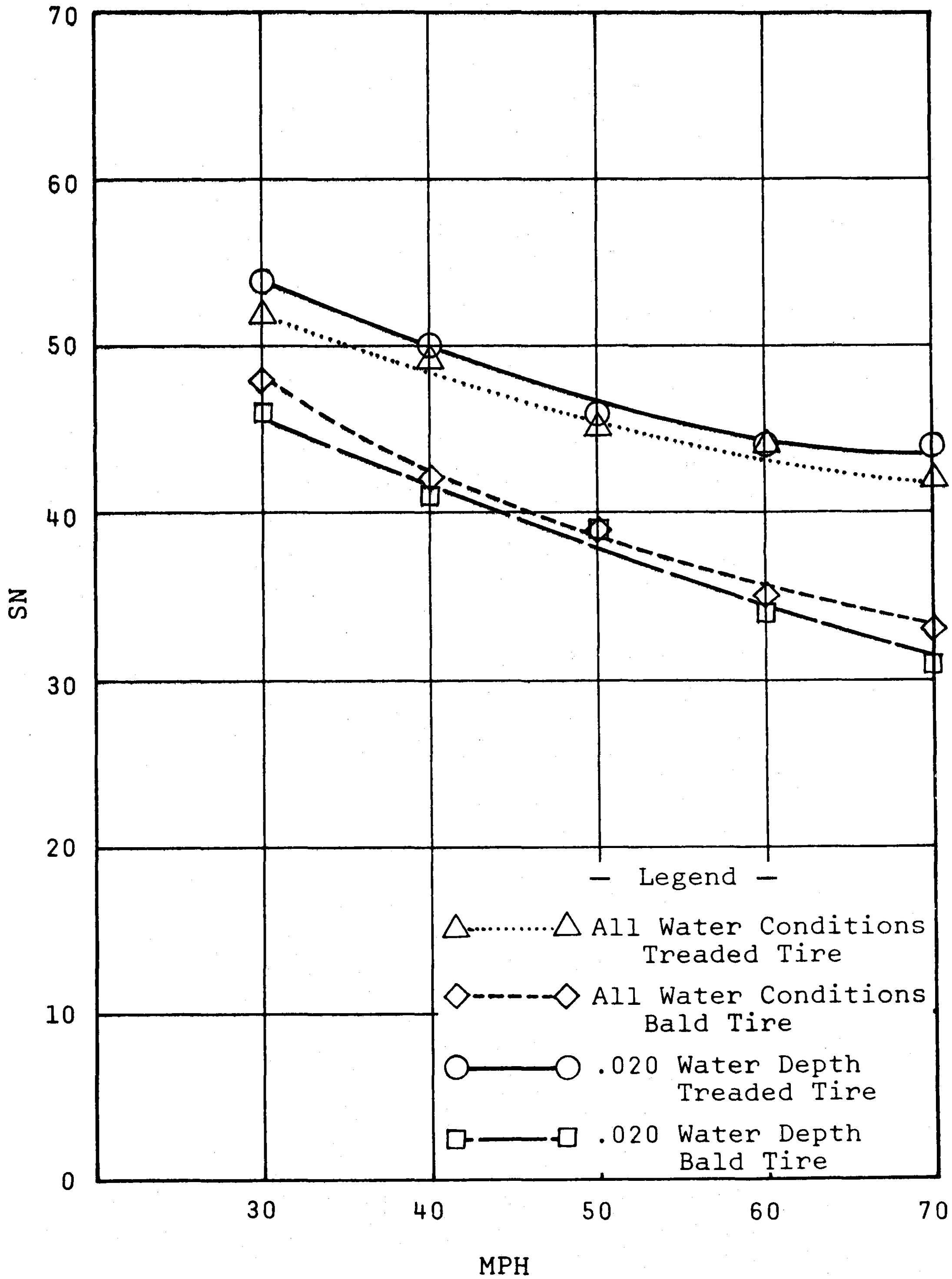


Figure 35. Average speed gradient curves for site 11, the traffic lane of an S-5 bituminous concrete surface placed in 1969 that had an accumulated traffic count of 4,411,755 vehicles. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

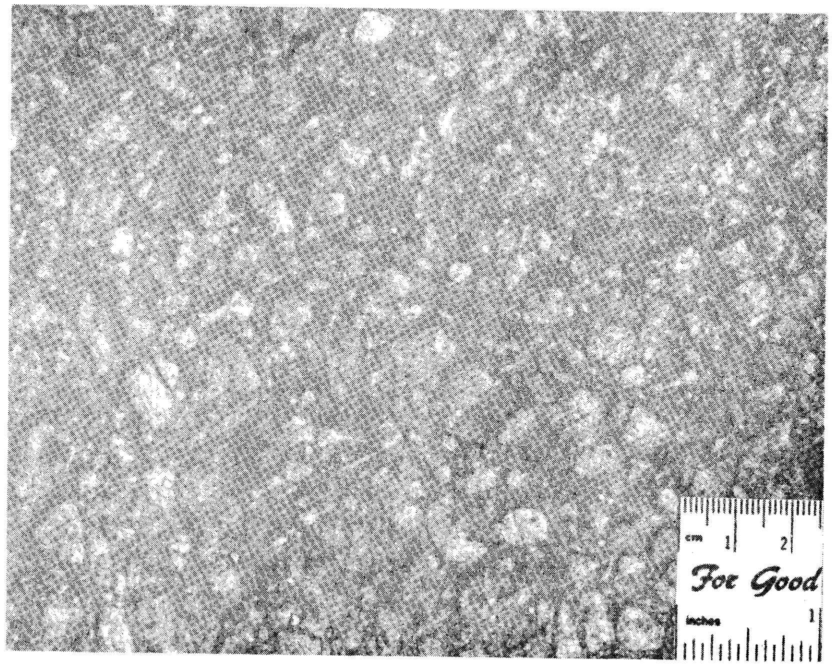


Figure 36. Surface texture of site 10.

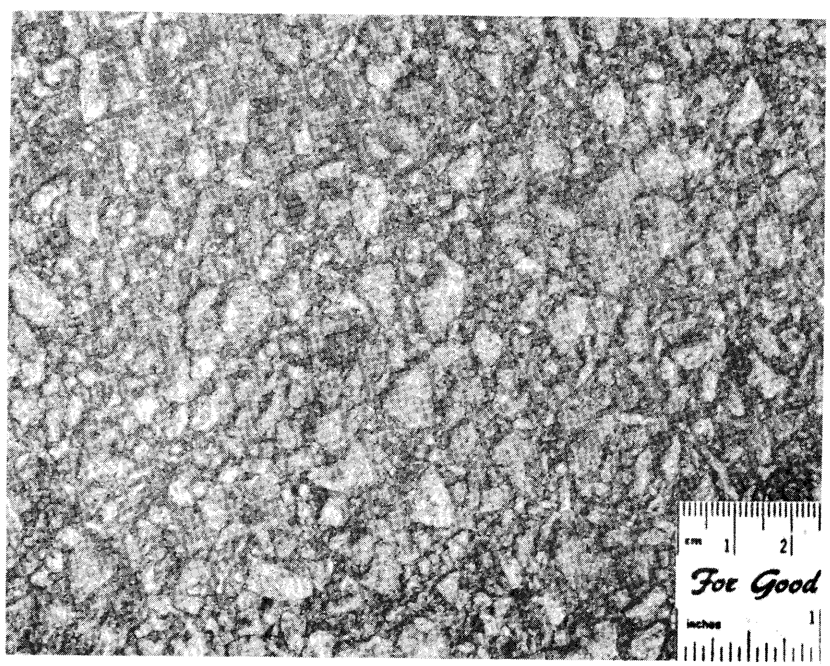


Figure 37. Surface texture of site 11.

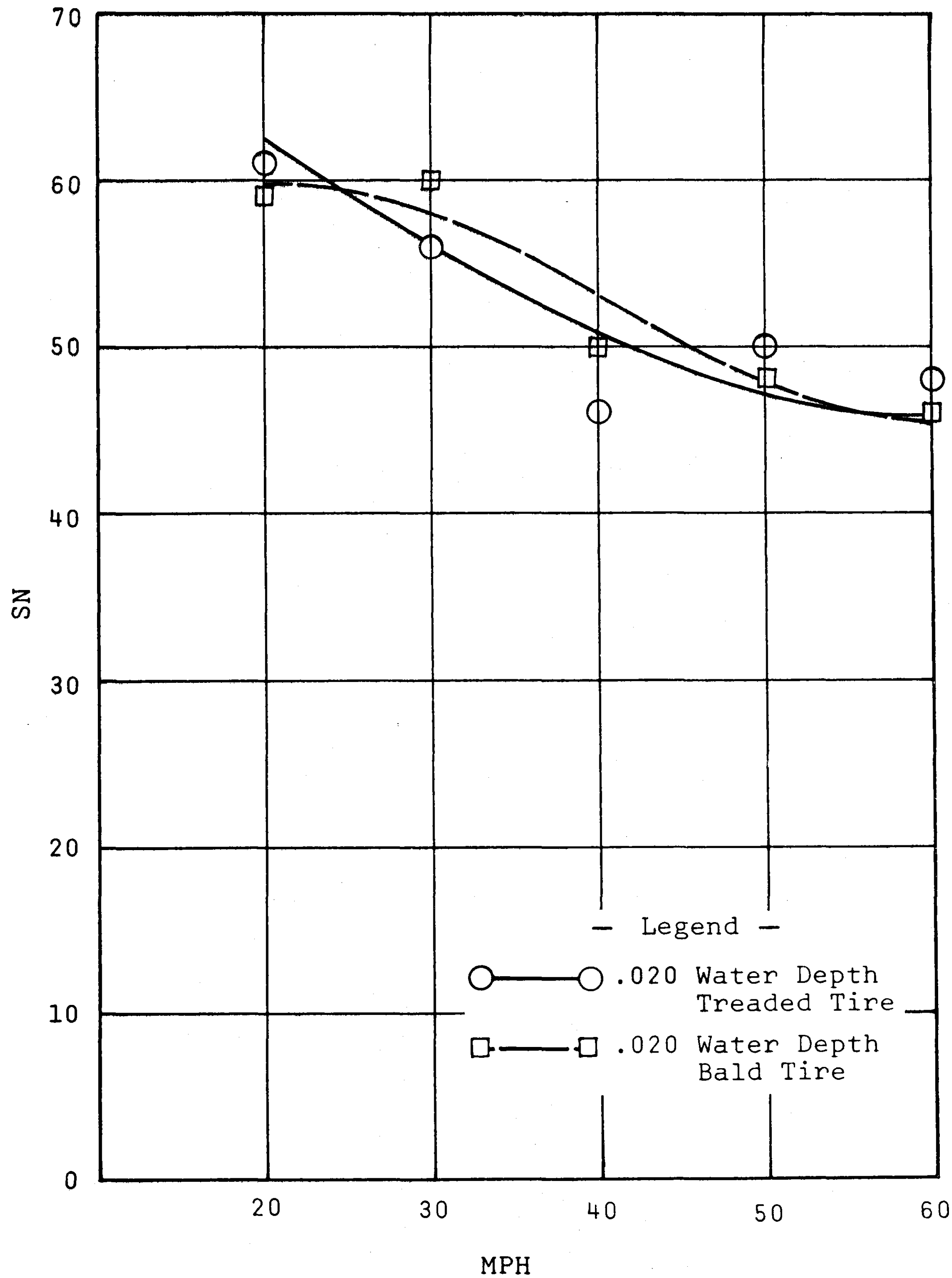


Figure 38. Average speed gradient curves for site 14, the traffic lane of a Bituminous-Urban Mix placed in 1971 that had an accumulated traffic count of 3,255,800 vehicles. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

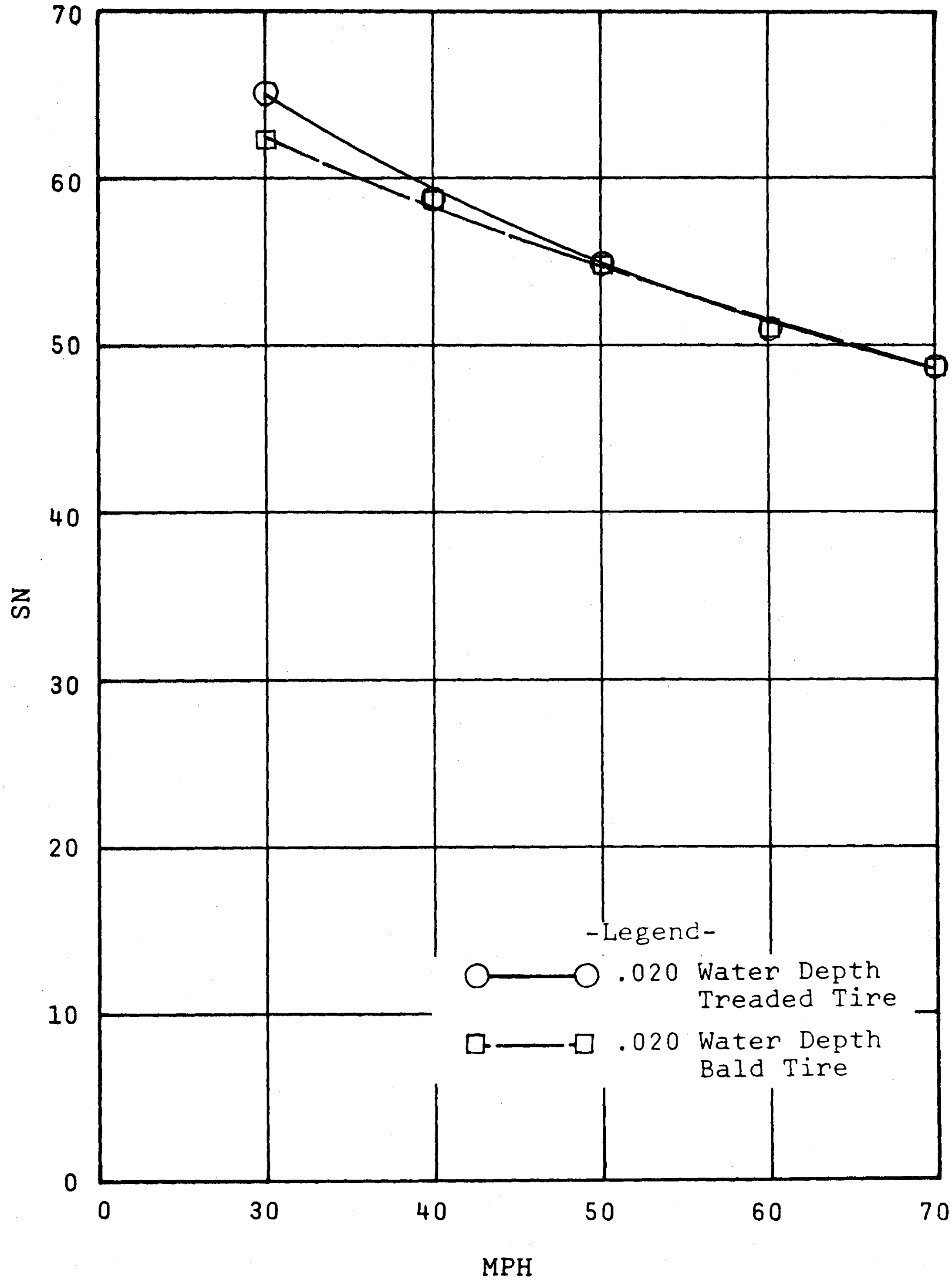


Figure 39. Average speed gradient curves for site 15, the passing lane of a Bituminous-Urban Mix placed in 1971 that had an accumulated traffic count of 3,255,800 vehicles. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

for the prevention of rutting, or washboarding, at stop and start locations. The sites are in the traffic and passing lanes of I-381 where it terminates at Route 11 in Bristol. The surfaces were placed in 1971 and had experienced three and one-quarter million vehicle passes each. Figures 40 and 41 are photographs of these surfaces. These sites are located at a very difficult place for skid testing and consequently were not tested anywhere near as extensively as the other sites in this study. In fact, the only tests performed were for the .020 in. (0.05 cm) water condition for a good treaded tire and a bald tire for speeds of 20, 30, 40, 50, and 60 mph (8.9, 13.4, 17.9, 22.4, and 26.8 m/s). The tests had to be conducted at night and the 70 mph (31.3 m/s) test could not be conducted for safety reasons.

The mix that constitutes these surfaces is quite dense, but has a harsh macrotexture that provides for the escape of water, which fact accounts for the close proximity of the skid numbers for the bald and treaded tires. The skid number-speed gradients for sites 14 and 15 were 0.3 SN and 0.4 SN, respectively. The curves suggest that since the skid numbers were about the same for the two sites at higher speeds but higher for the passing lane than the traffic lane at the lower speeds, it is the microtexture rather than the water escape channels of the passing lane that causes the higher slope.

Sites 18 and 19, see the skid number-speed gradient curves in Figures 42 and 43, are surfaced with an S-5 bituminous mix and are located in the traffic and passing lanes of Interstate 81 in Augusta County. Photographs of the two surfaces are shown in Figures 44 and 45. The skid number-speed gradient slopes were 0.35 SN/mph and 0.3 SN/mph and the curves for the treaded and bald tires were very close, except for the lowest speed in the traffic lane where the bald tire skid number was greater than the treaded tire values. The fact that the bald and treaded tires provided like data probably reflects the influence of good micro- and macrotextures.

Sites 20 and 21, the skid number-speed gradients are shown in Figures 46 and 47 and the surfaces in Figures 48 and 49, are longitudinally tined concrete surfaces placed in 1973 and had received two million and one-half million vehicle passes, respectively, at the time of testing. Site 20 is in the traffic lane and has striations at about $\frac{3}{4}$ inch (1.92 cm) intervals. While site 21 is in the passing lane and has striations at about $\frac{1}{4}$ inch (0.64 cm) intervals. The speed gradients were 0.3 SN/mph and 0.37 SN/mph. The bald tire data for both sites intermingles with those for the treaded tire and in some cases are higher.

Since the two sites had experienced relatively little traffic, the difference in skid numbers could not be attributed to traffic wear. The writer feels the reason for the higher skid numbers on site 21 is caused by the closer spaced striations in the surface finish.

Sites 22 and 24, (see Figures 50 through 53), are both in the traffic lane of Interstate 64 in Henrico County. This concrete pavement was constructed in 1968 and finished with a single burlap drag. It had received thirteen and one-third million accumulated vehicle passes. The only difference in the two sites was that site 24 had been grooved. The speed gradients were about 0.35 SN/mph and 0.25 SN/mph. As in the case of sites 23 and 25, which were discussed with the steep slope group, the grooving of the pavement did little to improve the skid resistance for the treaded tire but did a great deal for the bald tire. Also as with sites 23 and 25, several things are worthy of attention.

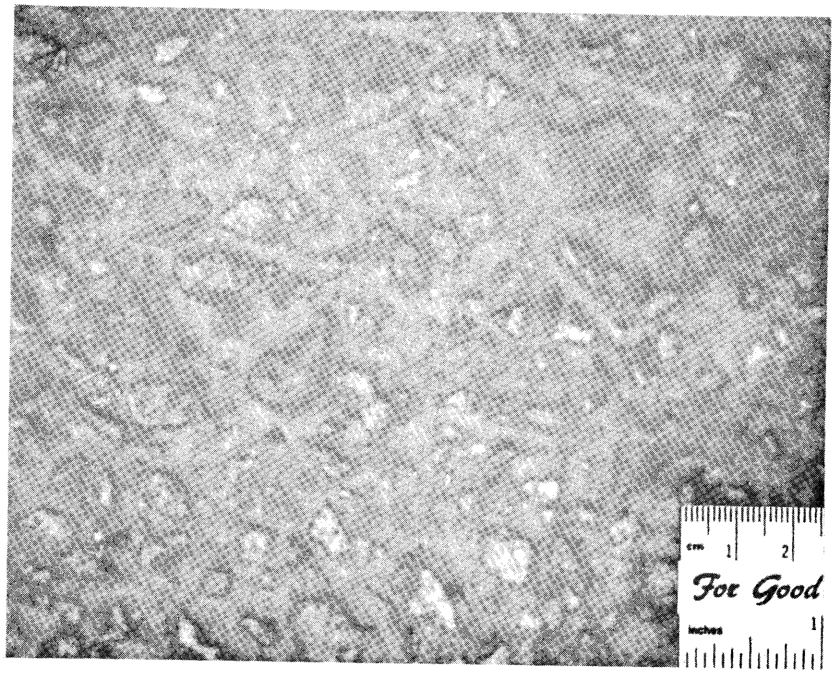


Figure 40. Surface texture of site 14.

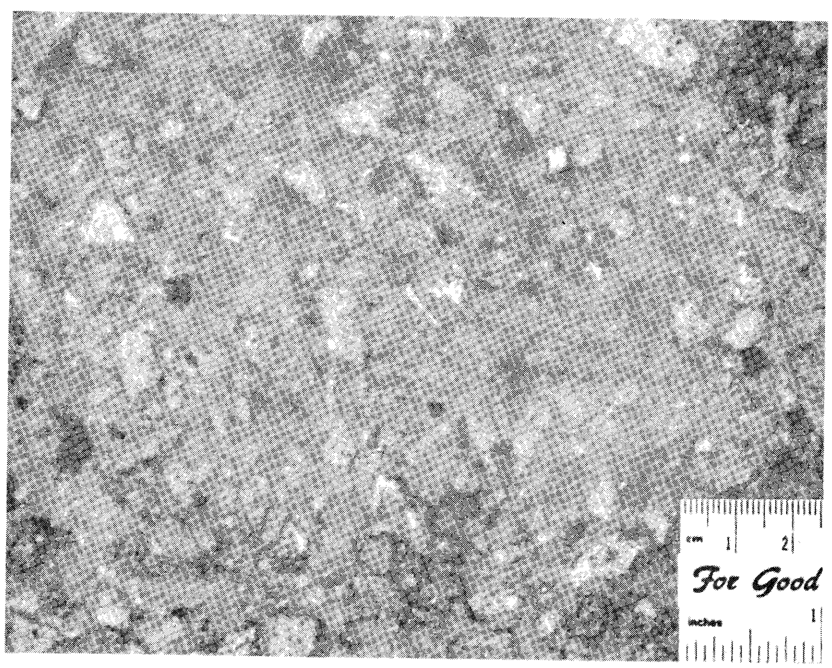


Figure 41. Surface texture of site 15.

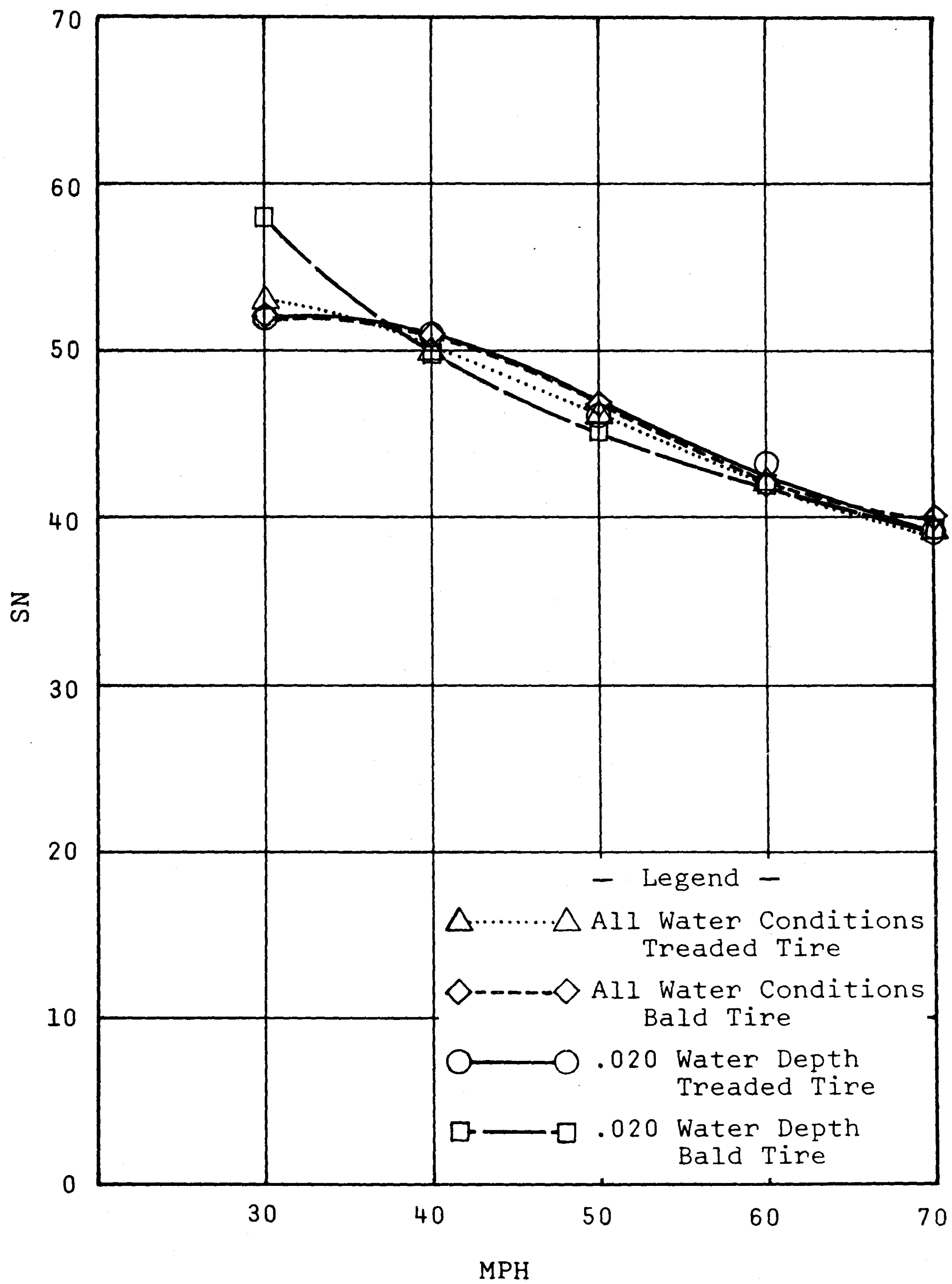


Figure 42. Average speed gradient curves for site 18, the traffic lane of an S-5 bituminous concrete surface placed in 1968 that had an accumulated traffic count of 9,187,050 vehicles. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

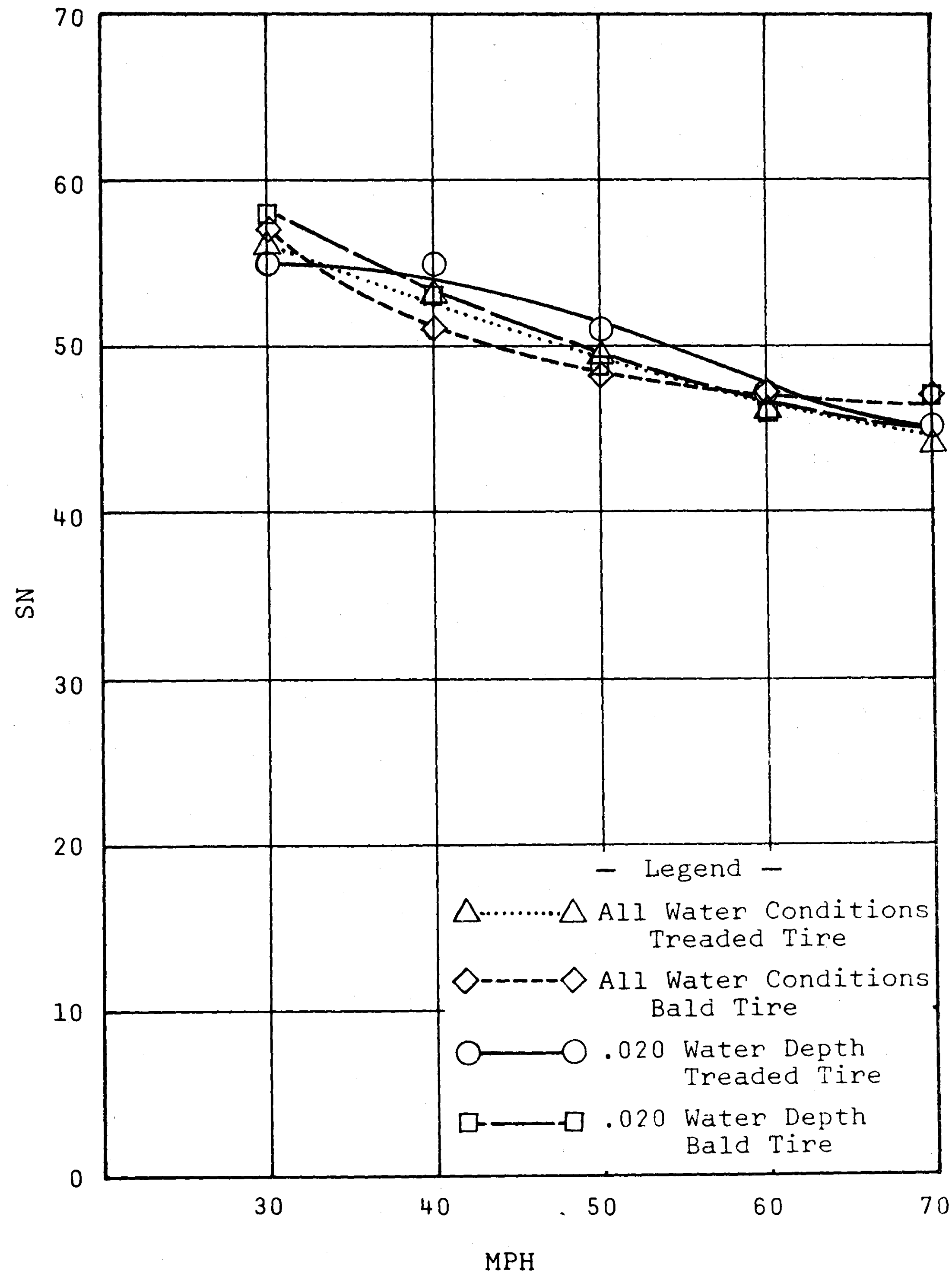


Figure 43. Average speed gradient curves for site 19, the passing lane of an S-5 bituminous concrete surface placed in 1968 that had an accumulated traffic count of 2,296,762 vehicles. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

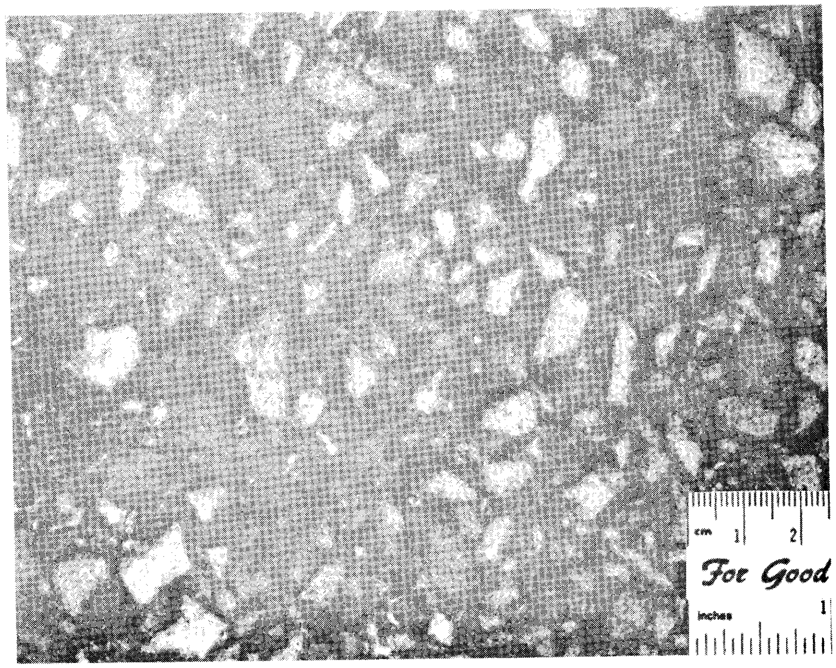


Figure 44. Surface texture of site 18.

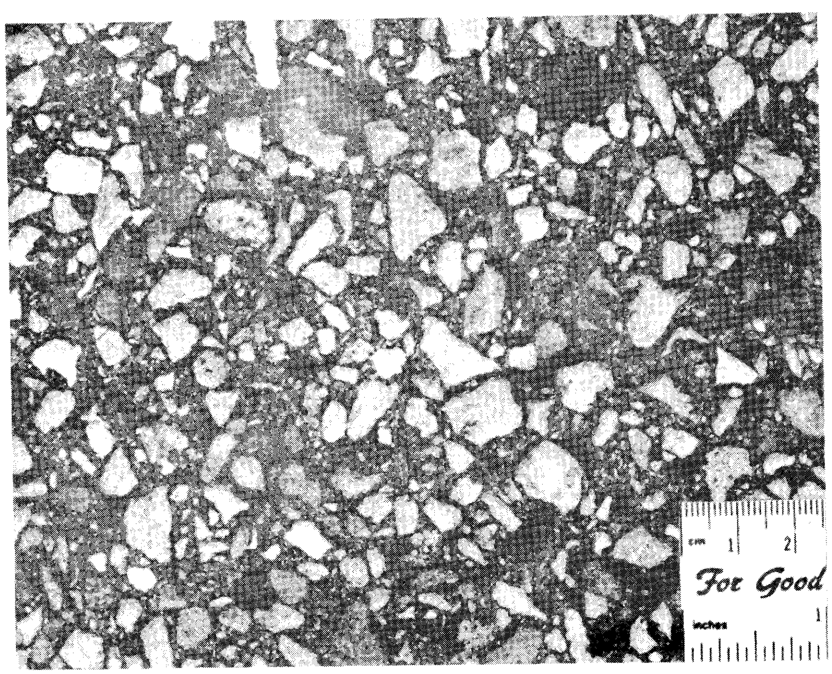


Figure 45. Surface texture of site 19.

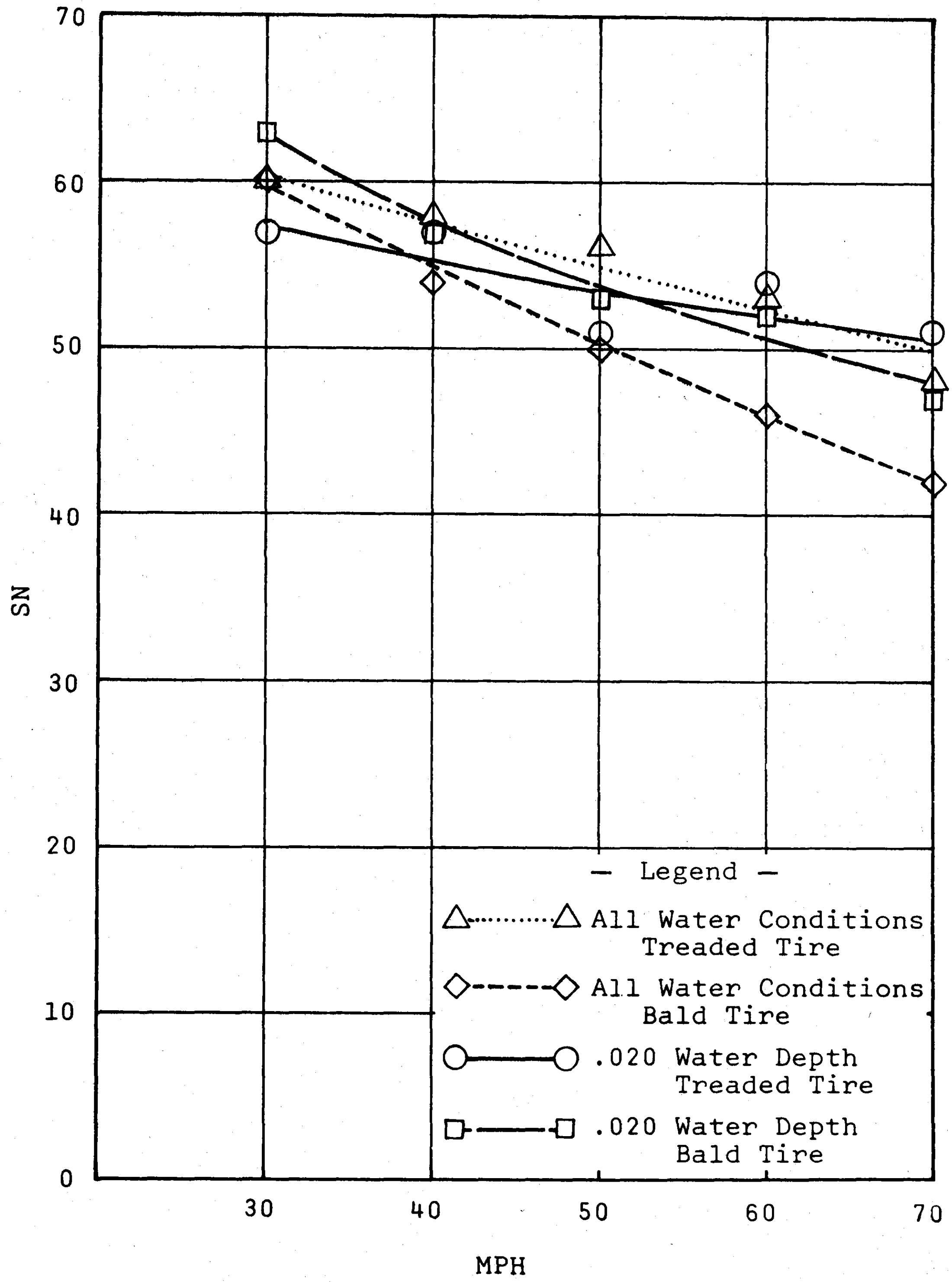


Figure 46. Average speed gradient curves for site 20, the traffic lane of a tined portland cement concrete surface placed in 1973 that had an accumulated traffic count of 2,106,780 vehicles. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

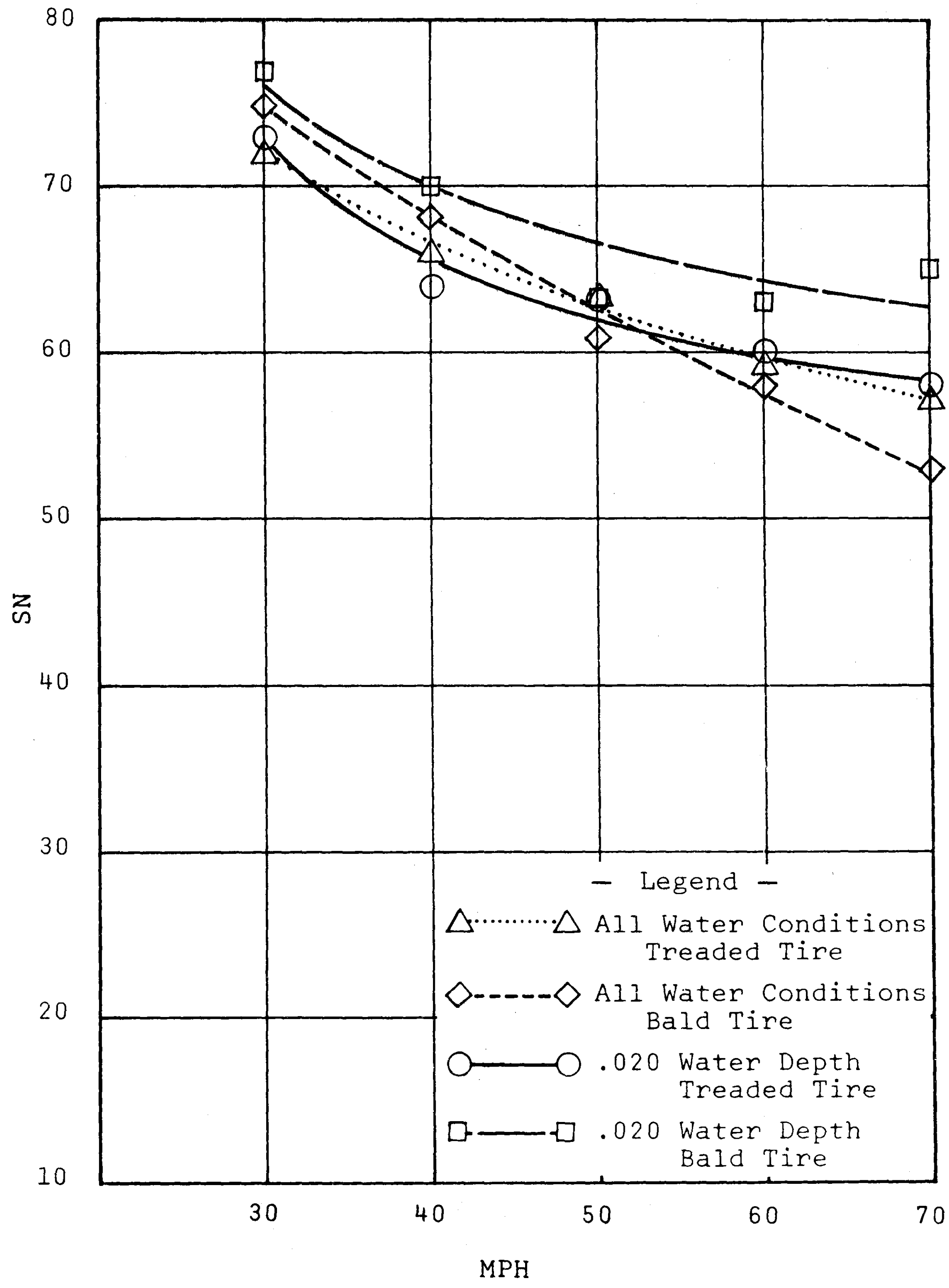


Figure 47. Average speed curves for site 21, the passing lane of a tined portland cement concrete surface placed in 1973 that had an accumulated traffic count of 526,695 vehicles. (1 inch = 2.54 cm; 1 mph = .4470 m/s)

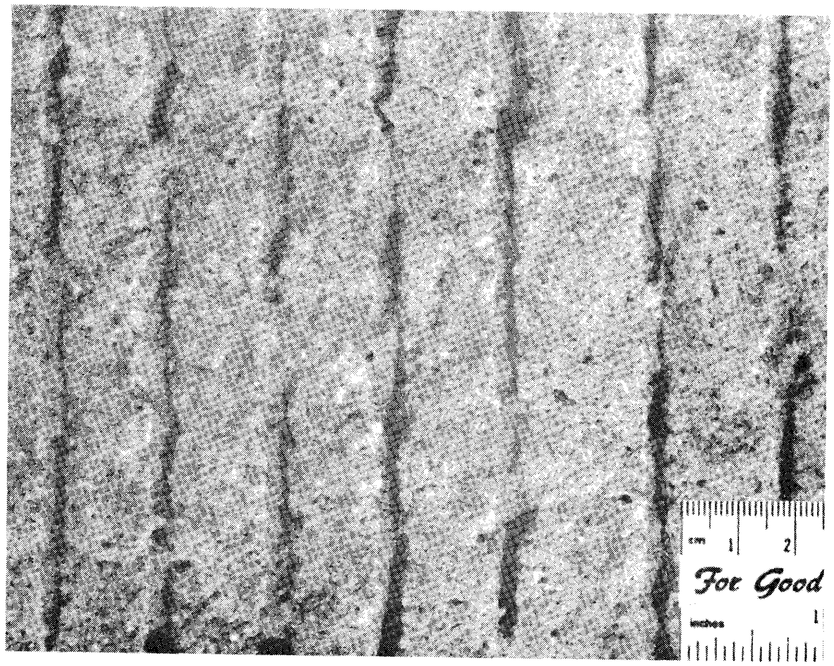


Figure 48. Surface texture of site 20.

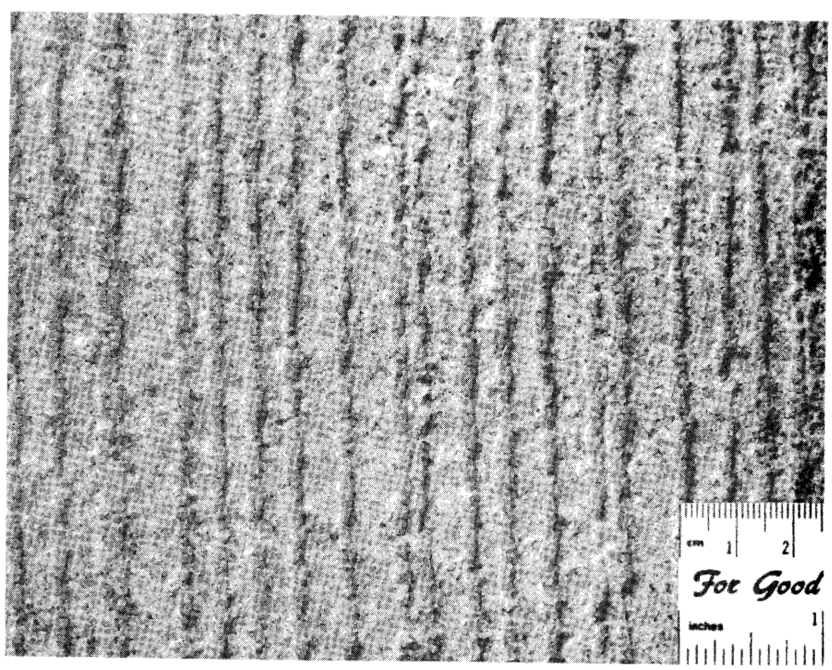


Figure 49. Surface texture of site 21.

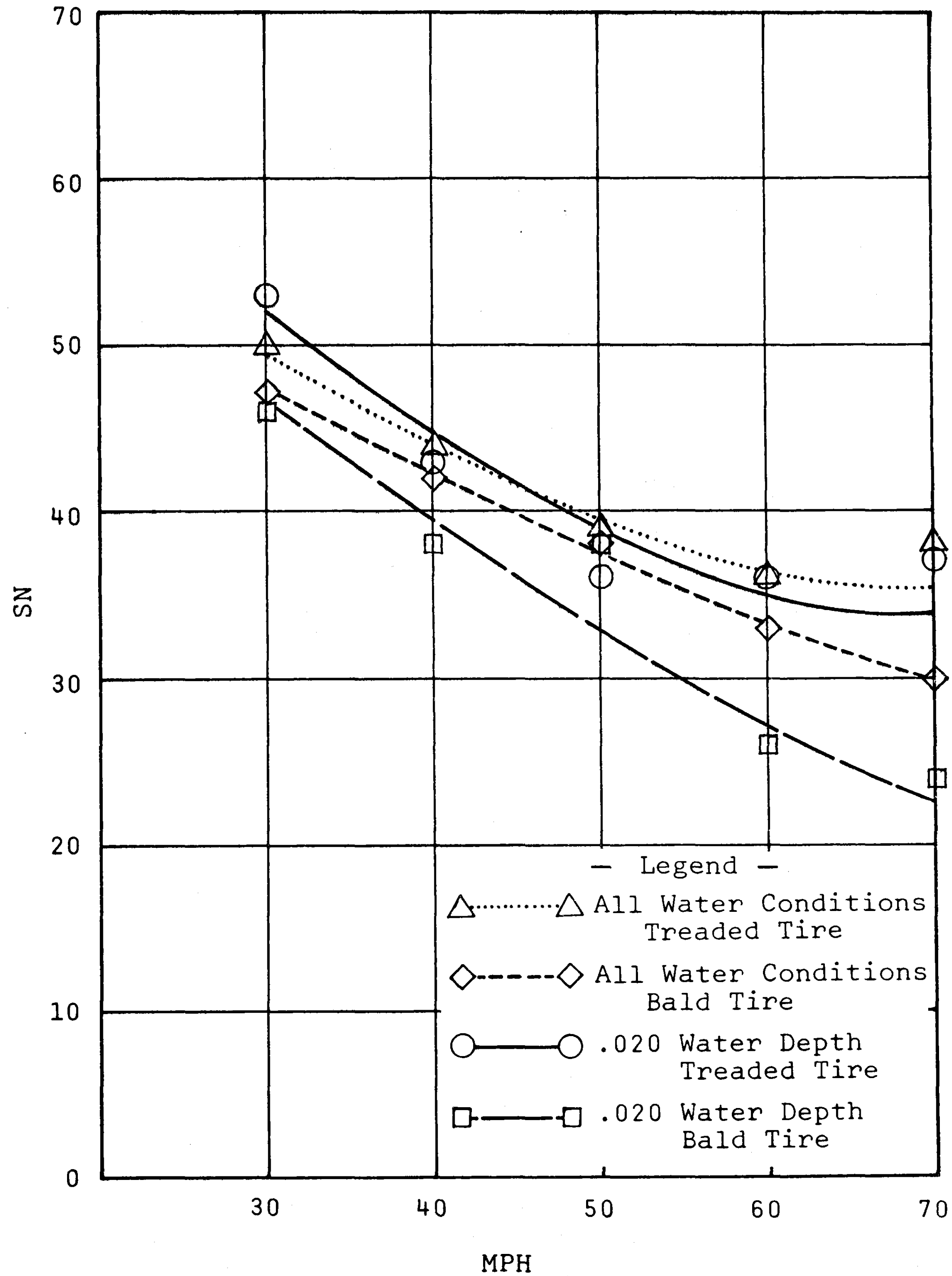


Figure 50. Average speed gradient curves for site 22, the traffic lane of a portland cement concrete surface placed in 1968 that had an accumulated traffic count of 13,430,175 vehicles. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

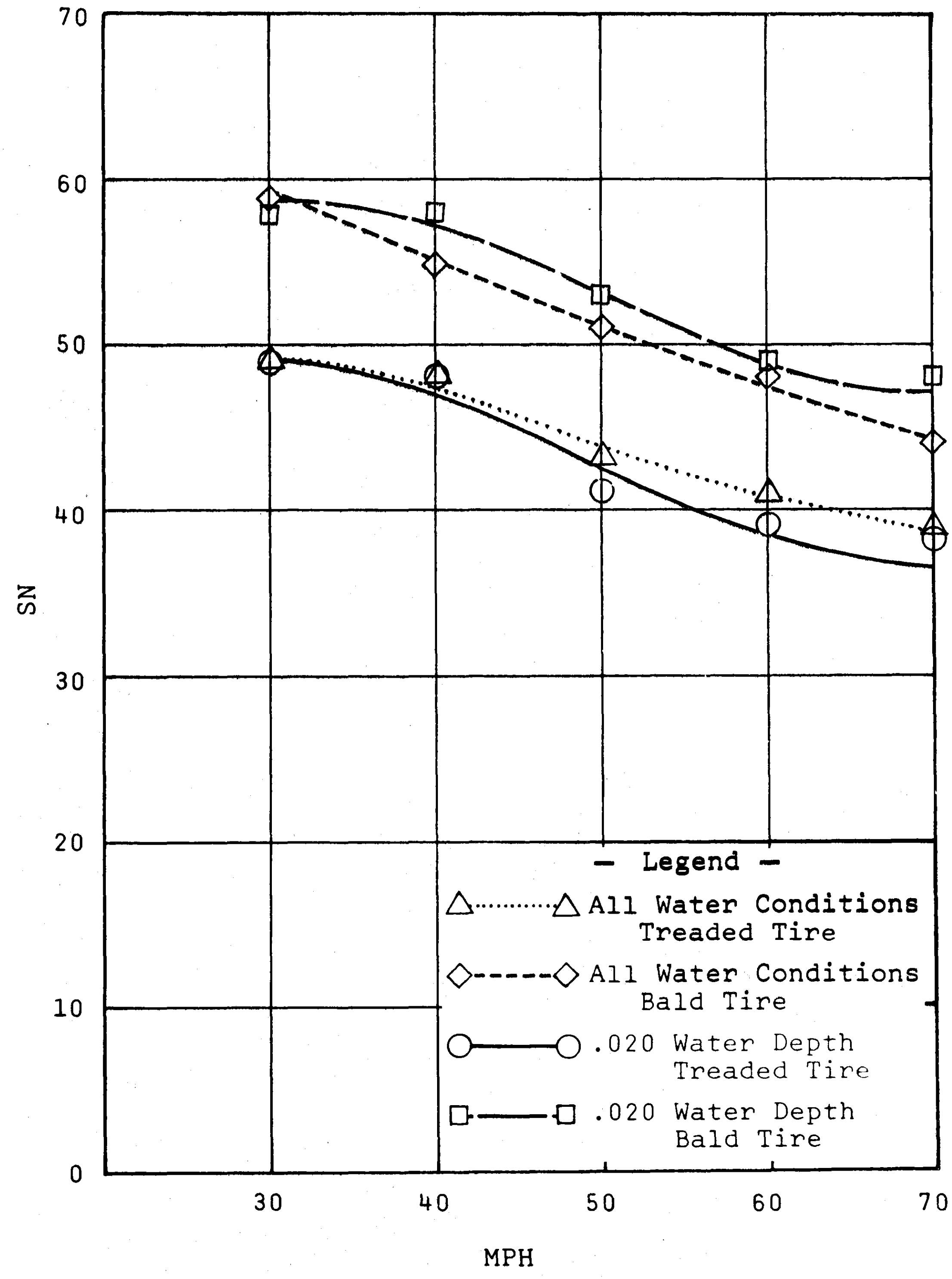


Figure 51. Average speed gradient curves for site 24, the traffic lane of a mechanically chipped portland cement concrete surface placed in 1968 that had an accumulated traffic count of 13,430,175 vehicles. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

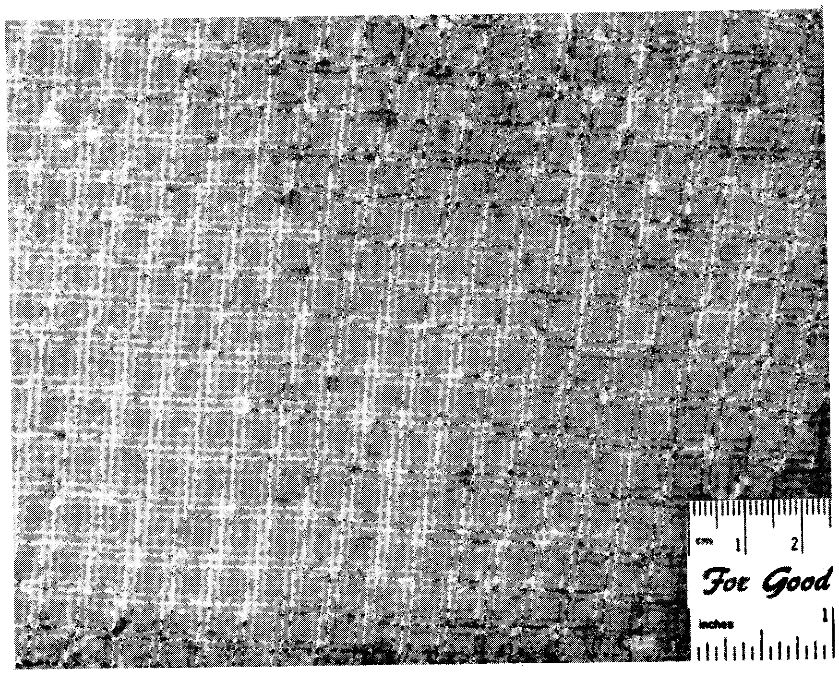


Figure 52. Surface texture of site 22.

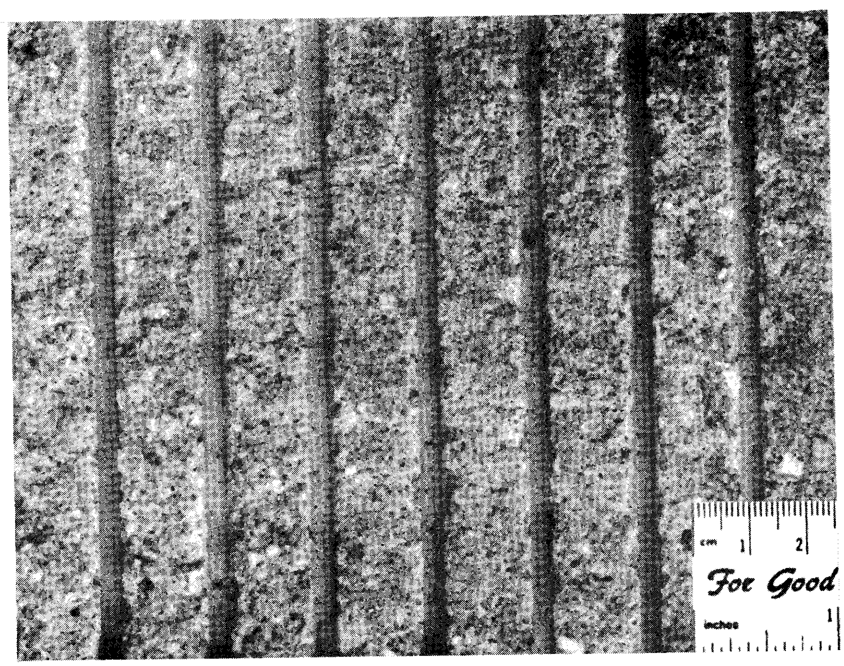


Figure 53. Surface texture of site 24.

First, although site 24 is grooved and thus obviously provides amply for the escape of water, its skid number-speed gradient slope was steep, which shows that an open, high voids surface will not always provide a flat slope skid number-speed gradient. The fact that the areas between the grooves are smooth indicates that, in addition to high voids or an open surface, a pronounced microtexture is a necessary ingredient for a flat speed gradient.

The second item of interest is that the bald tire provided higher skid numbers than did the treaded tires on the grooved surface, a phenomenon attributed to two things: first, there was more than ample provision for water displacement due to the grooves and the tread in the tire thus was not needed; and second because the water was displaced, the bald tire provided more contact area.

Sites 27 and 29, see skid number-speed gradient curves in Figures 54 and 55 and surfaces in Figures 56 and 57, are surface treated sections in the traffic lanes on Route 1 in Caroline and Hanover Counties, respectively. Site 27 was placed in 1969 and had received over two million vehicle passes at the time of testing; site 29 was placed in 1970 and had received about one and three-quarter million passes. The slopes of the curves were about 0.27 SN/mph. It should be noted that the bald tire data are not as divergent from the treaded tire data as for some of the other sites presented. This is because of the relatively pronounced macrotexture of the surfaces. Site 26 and 28, which are the passing lanes at the same locations, will be discussed with the low, or flat, slope group. A comparison will then be made with the two sites presented here.

Site 30, see Figure 58 and Figure 59 for skid number-speed gradient curve and surface texture, is an S-5 bituminous concrete in the passing lane of Route 460 in Bedford County. The surface had experienced about two and a third million vehicle passes at the time of testing and its slope was about 0.35 SN/mph. The reader should compare the skid numbers, surface texture, and slope shown here with the curves (Figure 20), texture (Figure 21), and slope (0.55 SN/mph) shown earlier for site 31. As was pointed out earlier, the aggregate in the traffic lane had polished a great deal, which lowered the skid resistance. In addition, the macrotexture had worn away in the traffic lane and thus increased the slope of the skid number-speed gradient curve.

## Low Slope Skid Number-Speed Gradient

Sites 12 and 13, for which skid number-speed gradient curves are shown in Figures 60 and 61, are S-5 bituminous concrete surfaces in the passing lanes of I-264 in Chesapeake. The data for the traffic lanes of these two locations were presented with the intermediate slope group. Photographs of the two surfaces are shown in Figures 62 and 63. Both sites were placed in 1969, had experienced a little over one million vehicle passes, and their slopes were about 0.2 SN/mph. The curves for these two sites are almost identical, as should be expected since the only difference between them is that site 12 is in the eastbound passing lane whereas site 13 is in the westbound passing lane.

When these two sites, which are the passing lanes, are compared to sites 10 and 11, which are the traffic lanes, two things should be noted. First, for the tread-

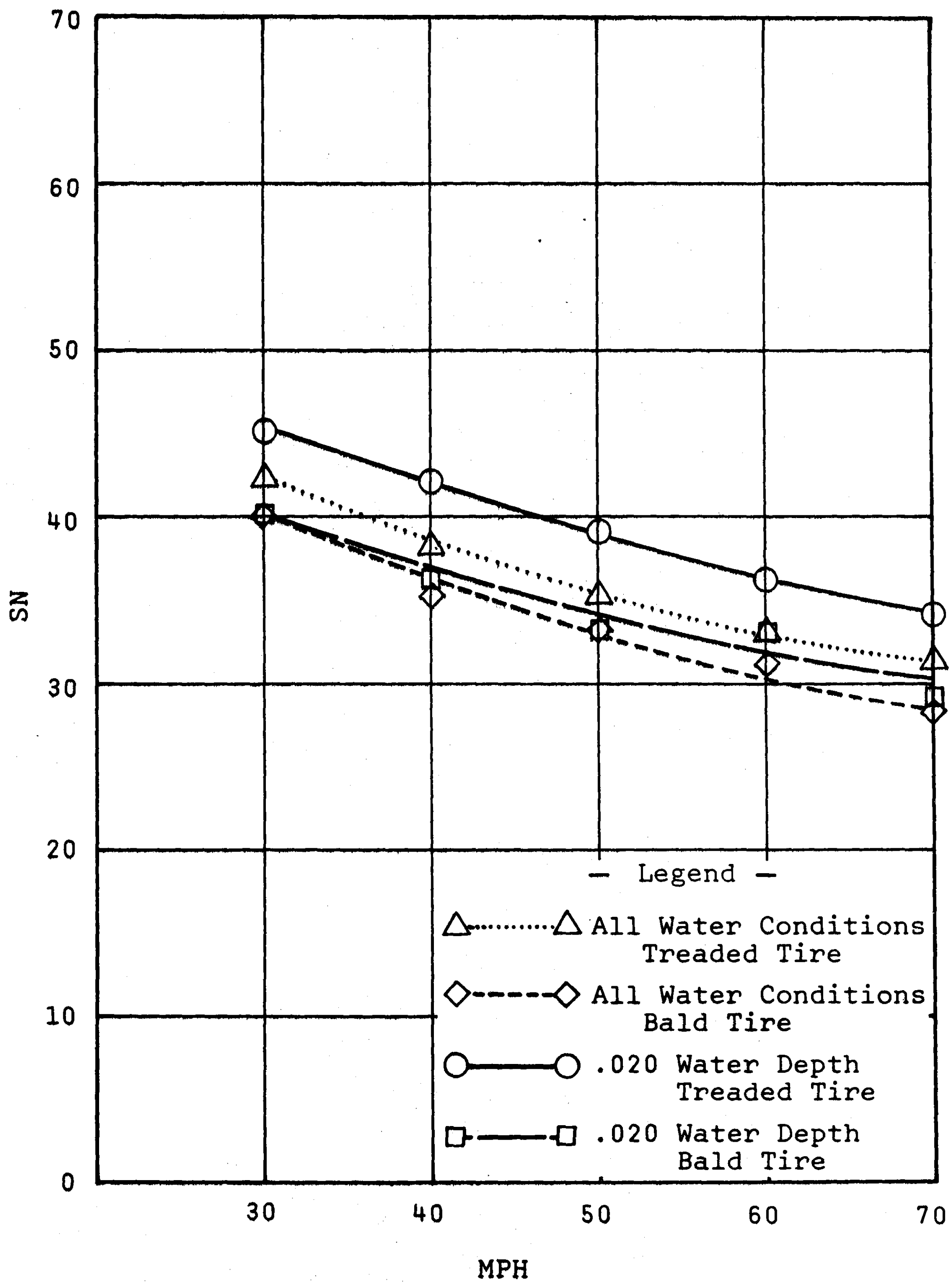


Figure 54. Average speed gradient curves for site 27, the traffic lane of a surface treatment placed in 1969 that had an accumulated traffic count of 2,138,170 vehicles. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

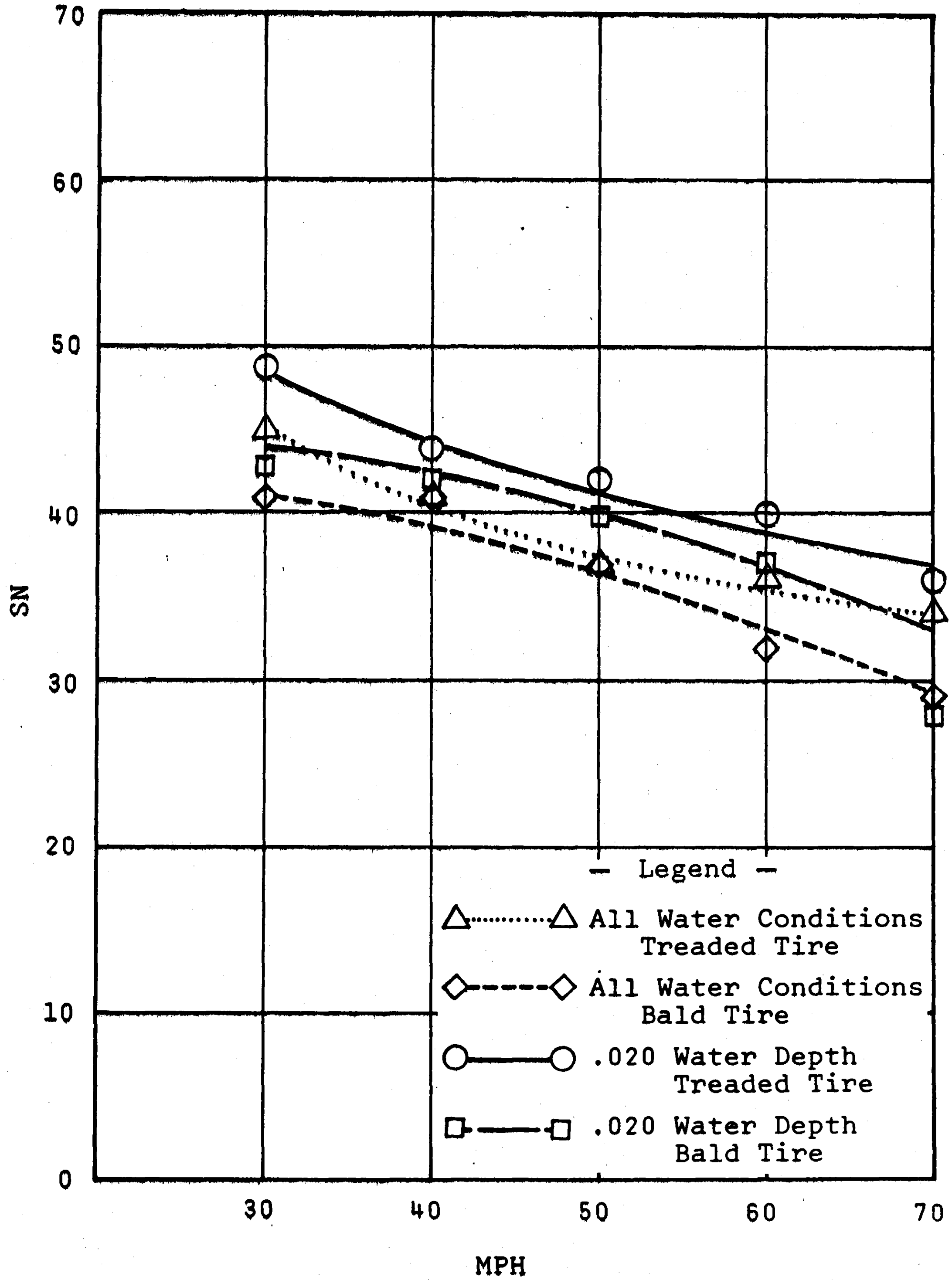


Figure 55. Average speed gradient curves for site 29, the traffic lane of a surface treatment placed in 1970 that had an accumulated traffic count of 1,798,720 vehicles. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

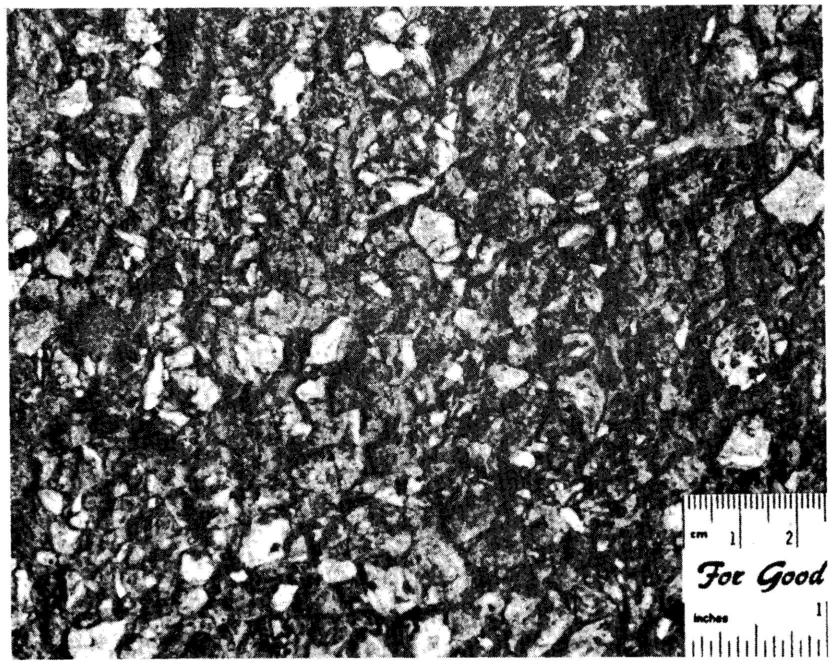


Figure 56. Surface texture of site 27.

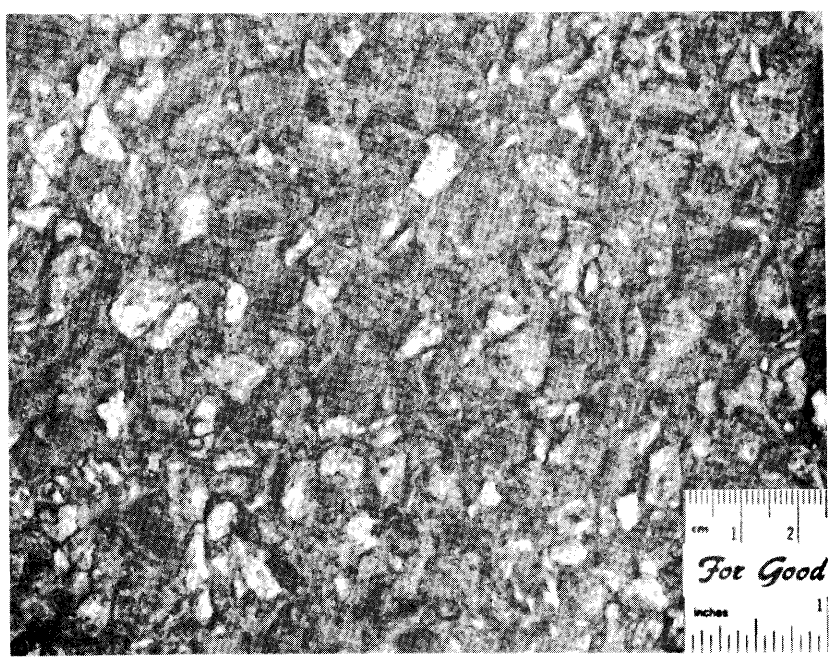


Figure 57. Surface texture of site 29.

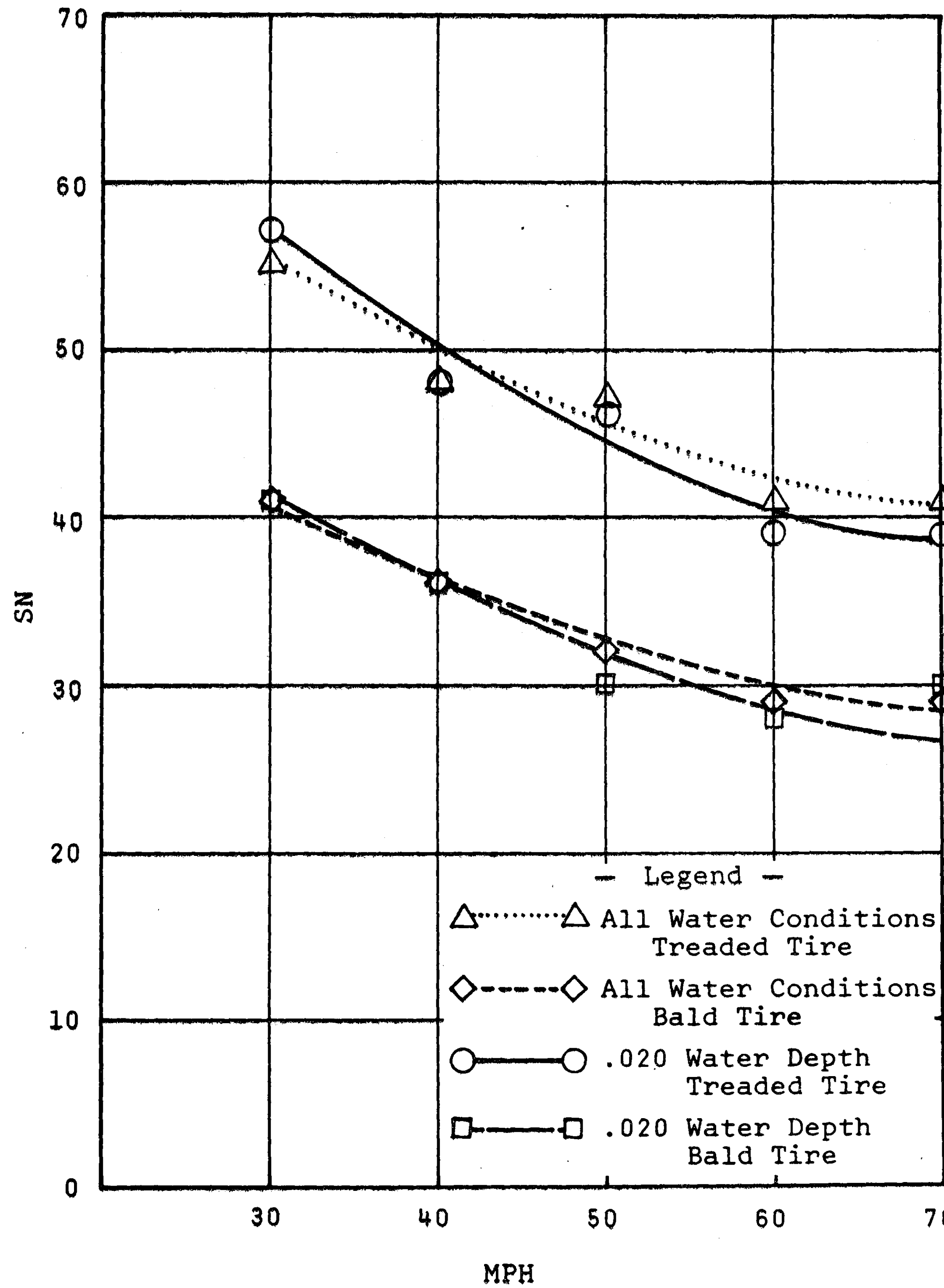


Figure 58. Average speed gradient curves for site 30, the passing lane of an S-5 bituminous concrete surface placed in 1965 that had an accumulated traffic count of 2,342,388 vehicles. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

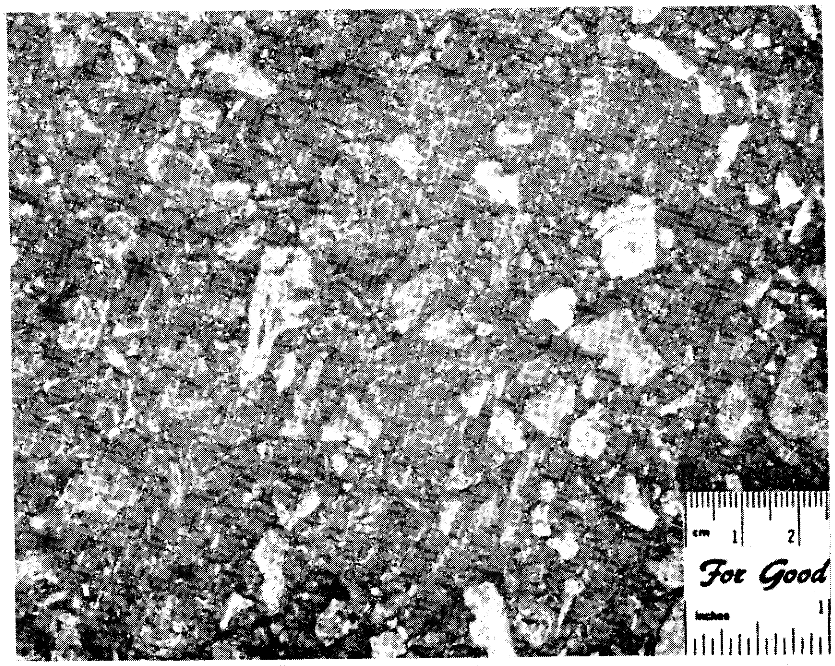


Figure 59. Surface texture for site 30.

ed tires the skid numbers are the same for the low speeds but are higher for the high speeds in the passing lanes than in the traffic lanes; and second, for the bald tires the skid resistance is higher at all speeds in the passing lanes as compared to the traffic lanes. The writer feels that these findings indicate that the micro-texture on the traffic lanes is as good as that on the passing lanes, but the macro-, or water draining, texture is better on the passing lanes than the traffic lanes. The phogotraphs in Figures 62 and 63 seem to support this hypothesis since it appears that the matrix of the mix had begun to fill the surface voids in the passing lanes.

Sites 16 and 17, see Figures 64 through 67, are the traffic and passing lanes of an open-graded (popcorn) bituminous surface on Interstate 81 in Augusta County. They were placed in 1973 and at the time of testing had received about two and a quarter million and one-half million vehicle passes, respectively. The slopes for these curves were about 0.1 SN/mph. It is interesting to note that the skid resistance values for the two sites were almost identical, which, in conjunction with the facts that the slopes were almost flat and the bald tire data and the treaded tire data were the same for the two sites, indicates that both the micro- and macrotextures were good, even in the traffic lane which had received about four times the traffic of the passing lane. However, the data for these two sites should be compared to those for site 19, an S-5 bituminous concrete previously discussed and which had as much or more traffic than either of these two. All three sites had about the same skid numbers at the high speeds but the surface of site 19, which is not as open as the popcorn mix of sites 16 and 17, had higher skid numbers at the lower speeds. Site 19 has a harsh surface but provides more tire-pavement contact surface than does the popcorn mix. The writer believes that this greater contact is an asset, that the

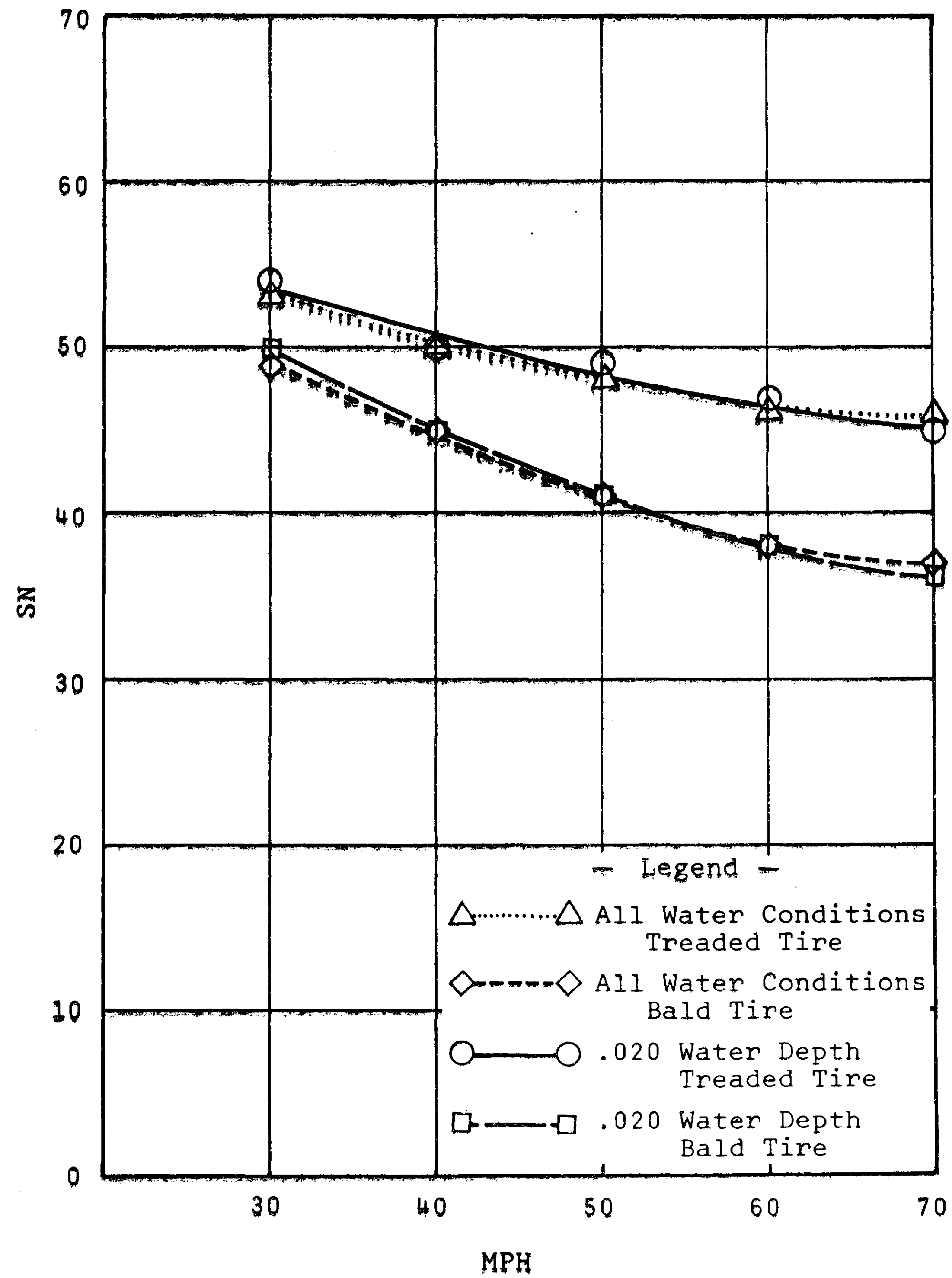


Figure 60. Average speed gradient curves for site 12, the passing lane of an S-5 bituminous concrete surface placed in 1969 that had an accumulated traffic count of 1,102,939 vehicles. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

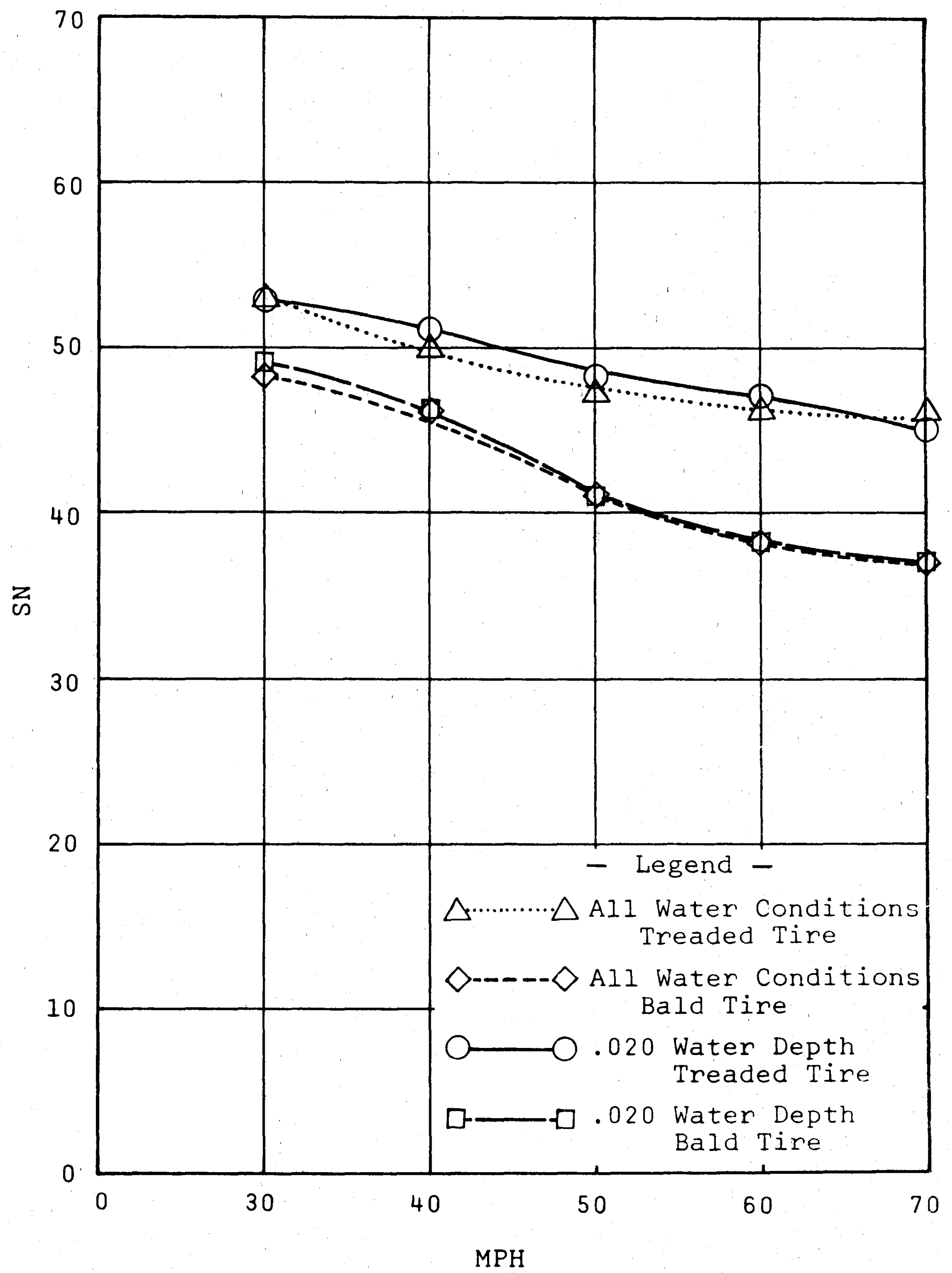


Figure 61. Average speed gradient curves for site 13, the passing lane of an S-5 bituminous concrete surface placed in 1969 that had an accumulated traffic count of 1,102,939 vehicles. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

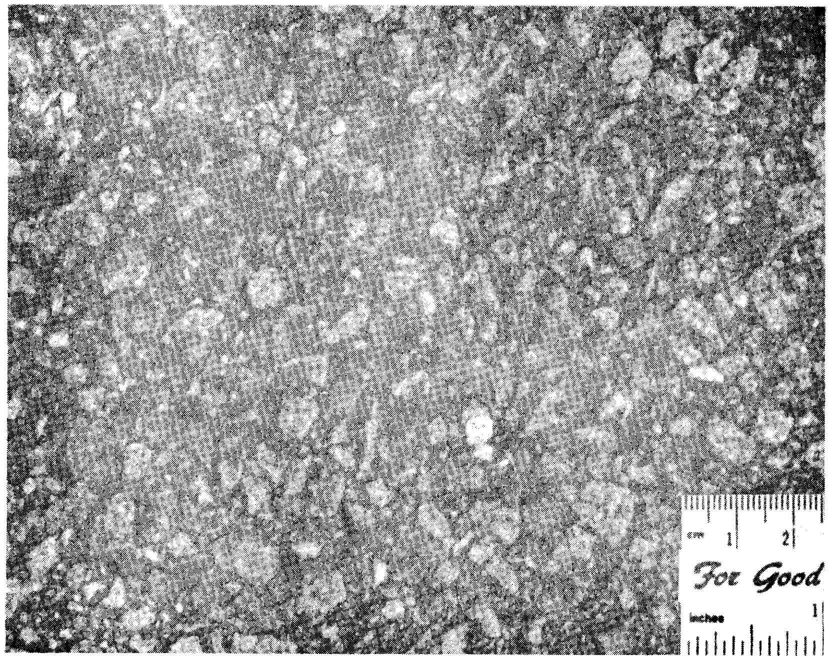


Figure 62. Surface texture of site 12.

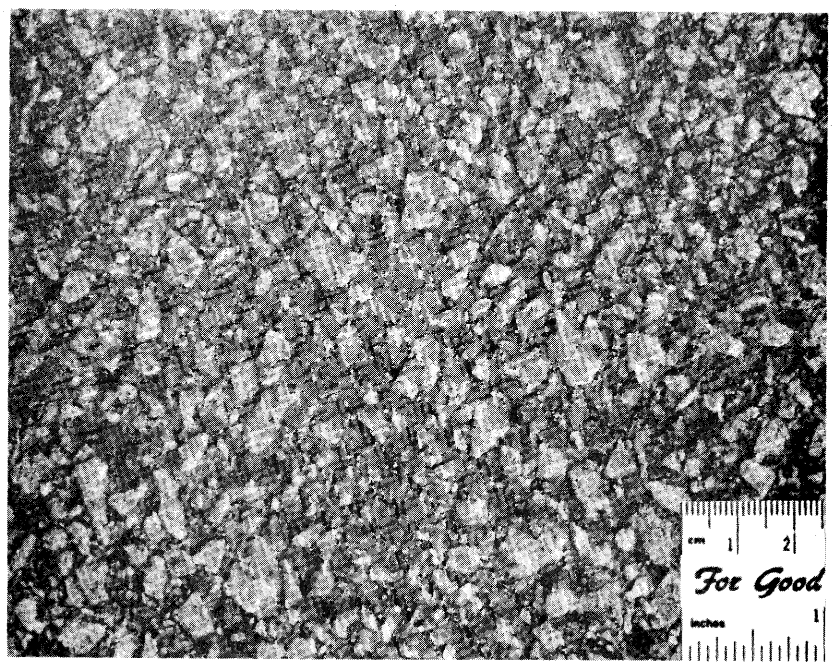


Figure 63. Surface texture of site 13.

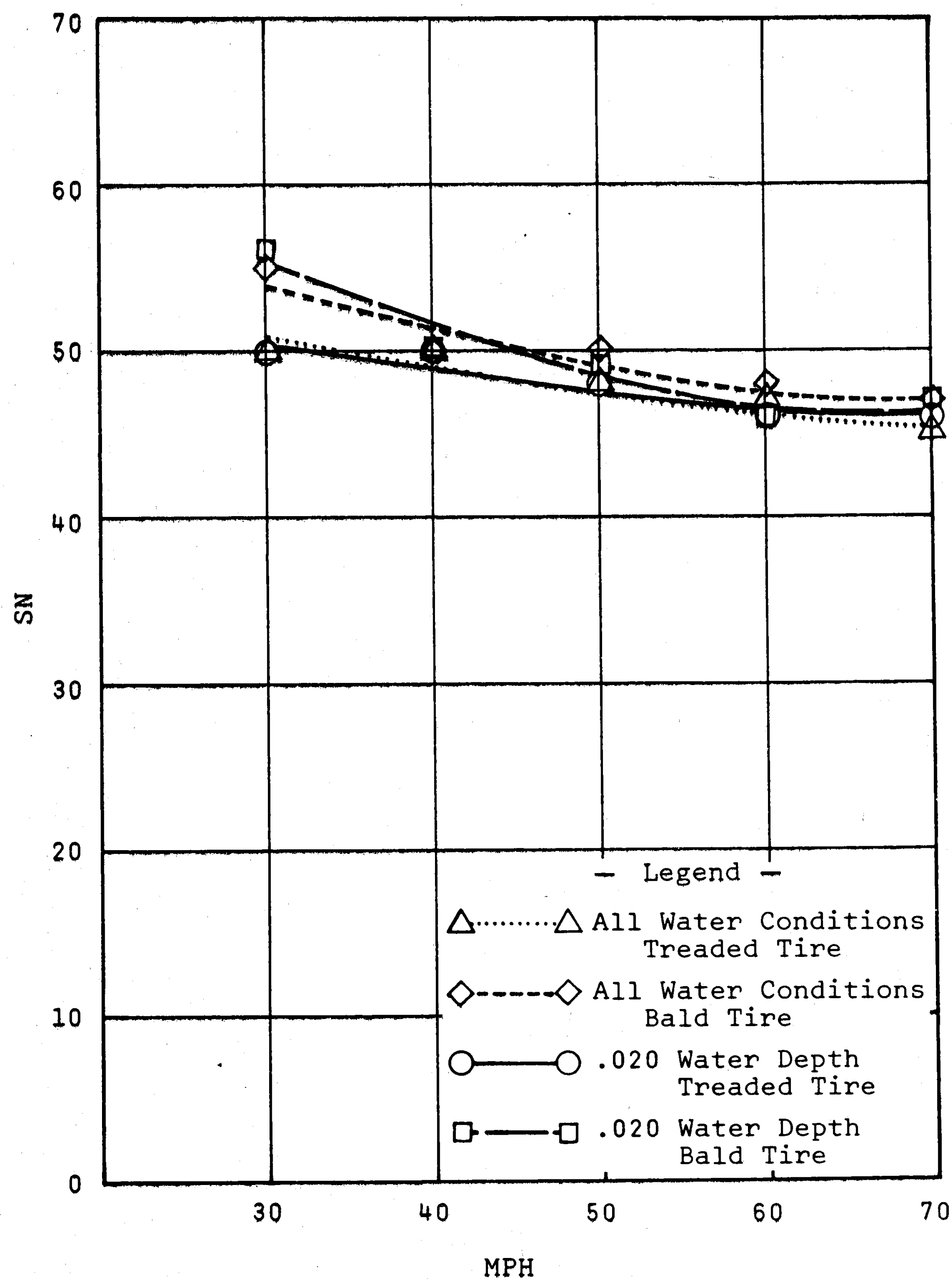


Figure 64. Average speed gradient curves for site 16, the traffic lane of an open-graded bituminous mix (popcorn) surface placed in 1973 that had an accumulated traffic count of 2,285,630 vehicles. ( 1 inch - 2.54; 1 mph = .4470 m/s)

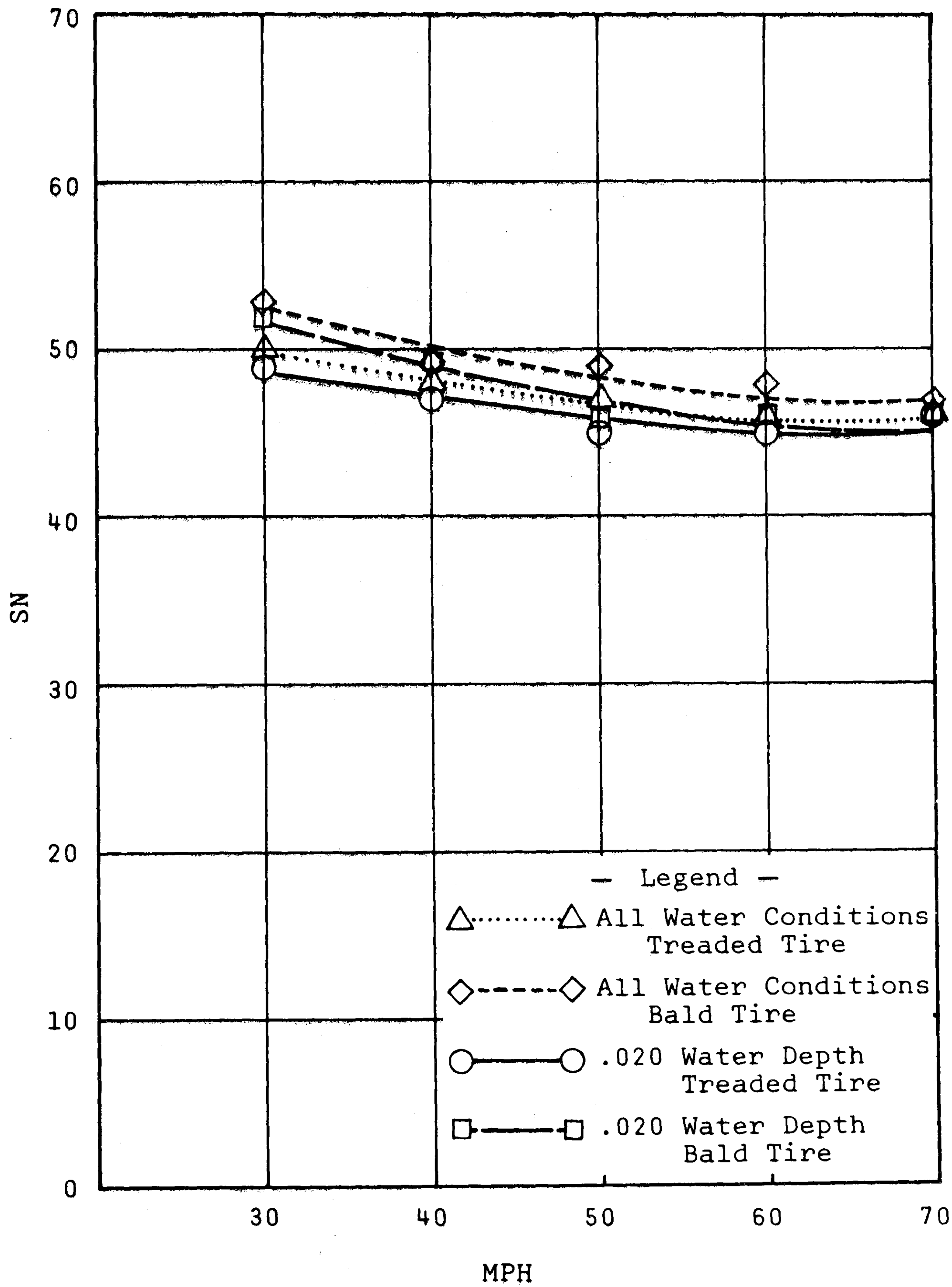


Figure 65. Average speed gradient curves for site 17, the passing lane of an open-graded bituminous mix (popcorn) surface placed in 1973 that had an accumulated traffic count of 571,408 vehicles. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

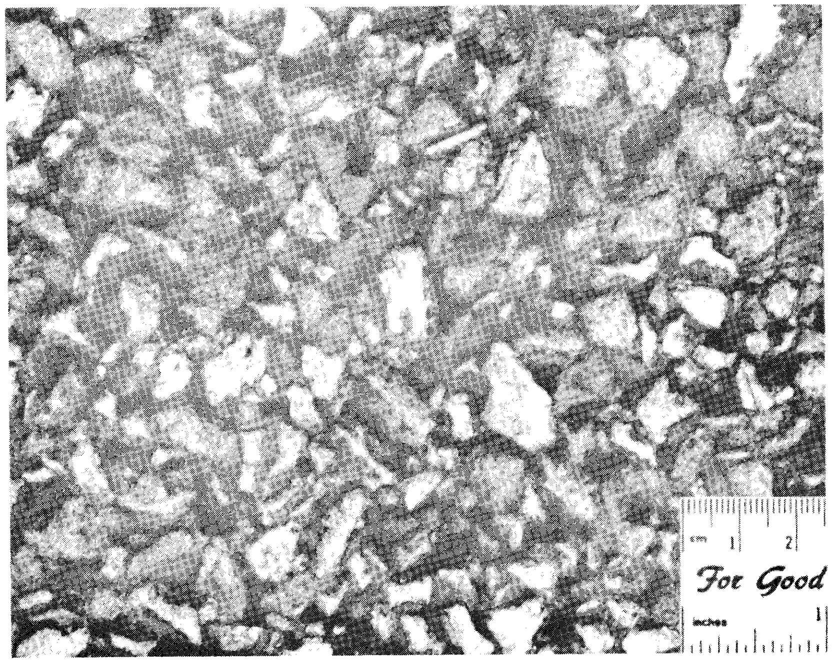


Figure 66. Surface texture of site 16.

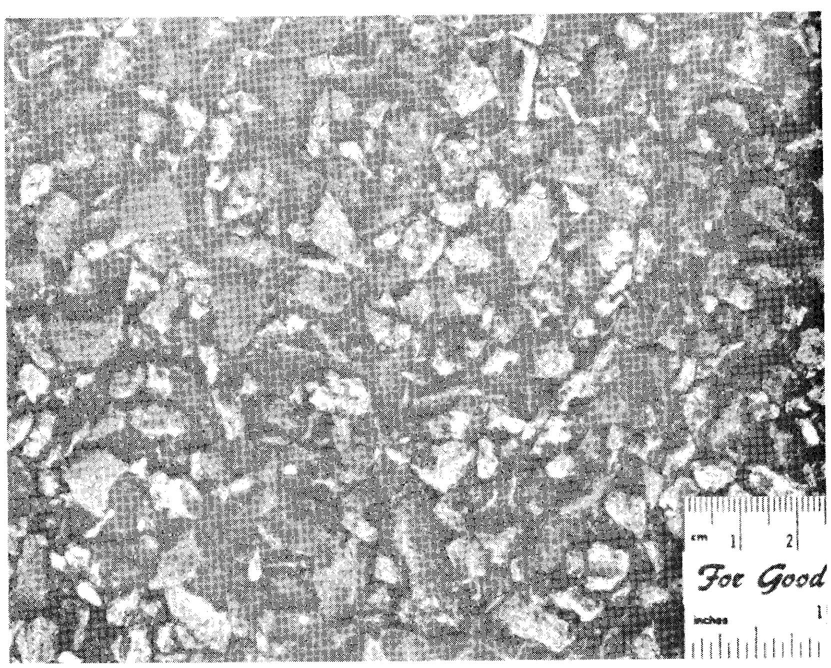


Figure 67. Surface texture of site 17.

popcorn mix might not have enough contact surface, and that the S-5 mix, since it provides the same skid numbers at the high speeds and higher skid numbers at lower speeds, provides the better surface. For pavements such as at site 19, the steep skid number-speed gradient slope is an advantage.

Sites 26 and 28, see Figures 68 through 71, are the passing lanes of surface treatments placed on Route 1 in 1969 and 1970 in Caroline and Hanover Counties, respectively. Their slopes were about 0.2 SN/mph and they carried about a half million vehicle passes. When the data from these two sites are compared to those for the traffic lanes at the same location, sites 27 and 29, it can be seen that the skid numbers for the latter were lower for all speeds, and this trend was more pronounced at the higher speeds than at the lower ones. These findings indicate that there was some loss of both micro- and macrotexture friction.

Before leaving the skid number-speed gradient portion of the report, two additional items will be discussed as they relate to each of the three groups. The first item is the overall relationship of treaded tires to bald tires, and the second is the average skid number-speed gradient curves for the groups.

Treaded to Bald Tire Relationships

To study the relationships of the treaded tires to the bald tire, the three speed gradient groups were divided into six subgroups. Within subgroups, the data were combined by separately averaging all of the treaded tire and all of the bald tire data for each test speed. The bases of the subgroups' division were the similarity of the speed gradients and of the treaded to bald tire relationships on the different sites. The subgroups are as follows:

(1) All of the sites from the steep speed gradient group (see Figure 72) except site 25.

(2) Sites 3, 4, 6, 7, 9, 10, 11, and 30 from the intermediate speed gradient group (Figure 73).

(3) Sites 8, 14, 15, 18, 19, 20, 21, 22, 27, and 29 from the intermediate speed gradient group (Figure 74).

(4) Sites 24 and 25, which are grooved concrete pavements and which had a profound difference in the treaded to bald tire relationship as compared to the other sites in the steep and intermediate speed gradient group from which they came (Figure 75).

(5) Sites 12, 26, 28, and 31 from the low speed gradient group (Figure 76).

(6) Sites 16 and 17 from the low speed gradient group (Figure 77).

In the first subgroup, Figure 72, the reader will note the symmetry of the two curves as well as the low skid values for the bald tire. It is felt that these data well demonstrate that pavement surfaces without macrotexture but with good microtexture can produce excellent skid resistance for cars equipped with good tires. On the other hand, for badly worn tires the skid resistance on these type surfaces is likely to be quite low and, in fact, in this study averaged about 15 SN lower than the treaded tire values. However, if these surfaces are economical to build, there is no reason to avoid their use on most highways, especially those for which the mean driving speed

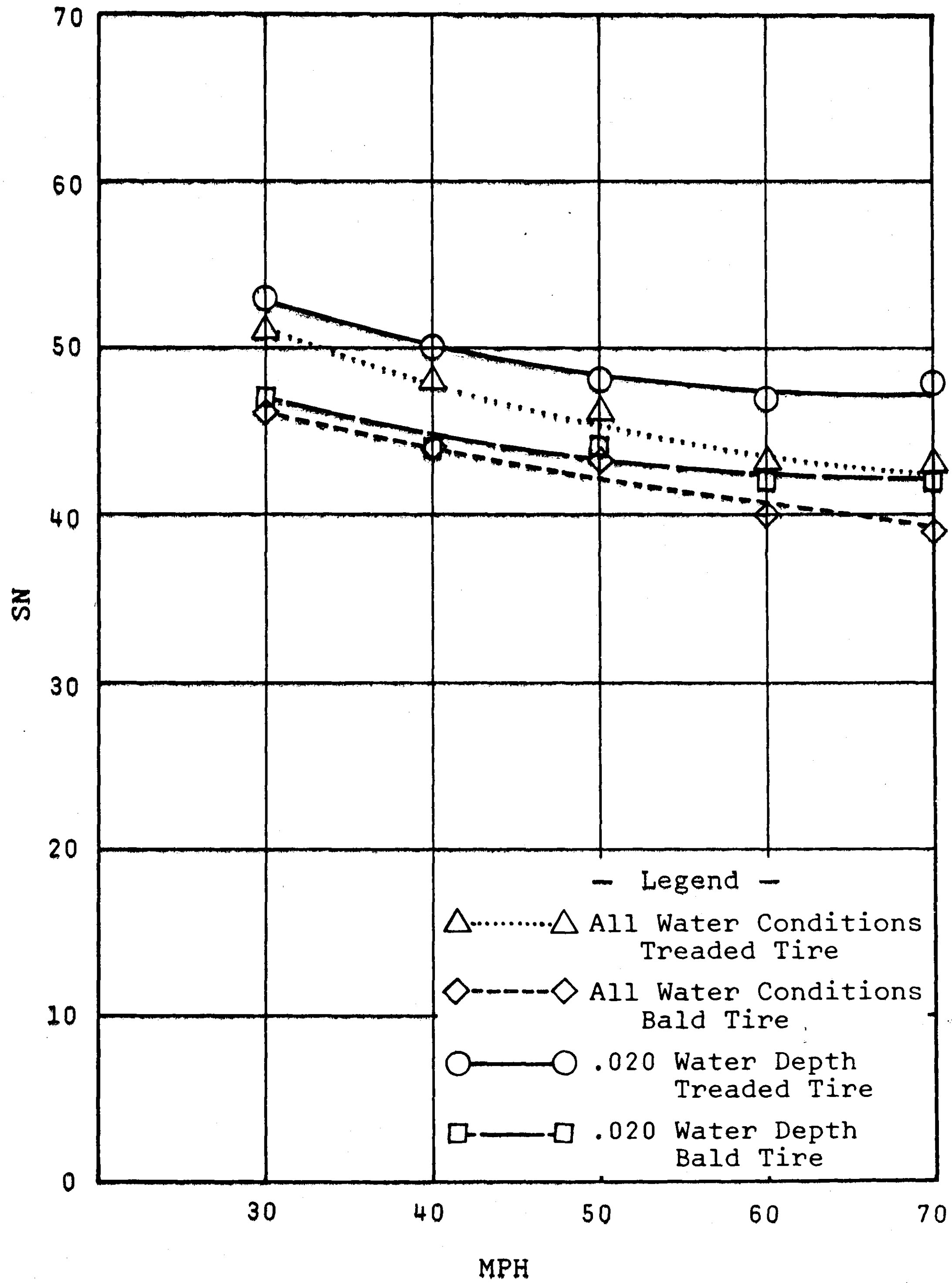


**Figure 68.** Average speed gradient curves for site 26, the passing lane of a surface treatment placed in 1969 that had an accumulated traffic count of 534,542 vehicles. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

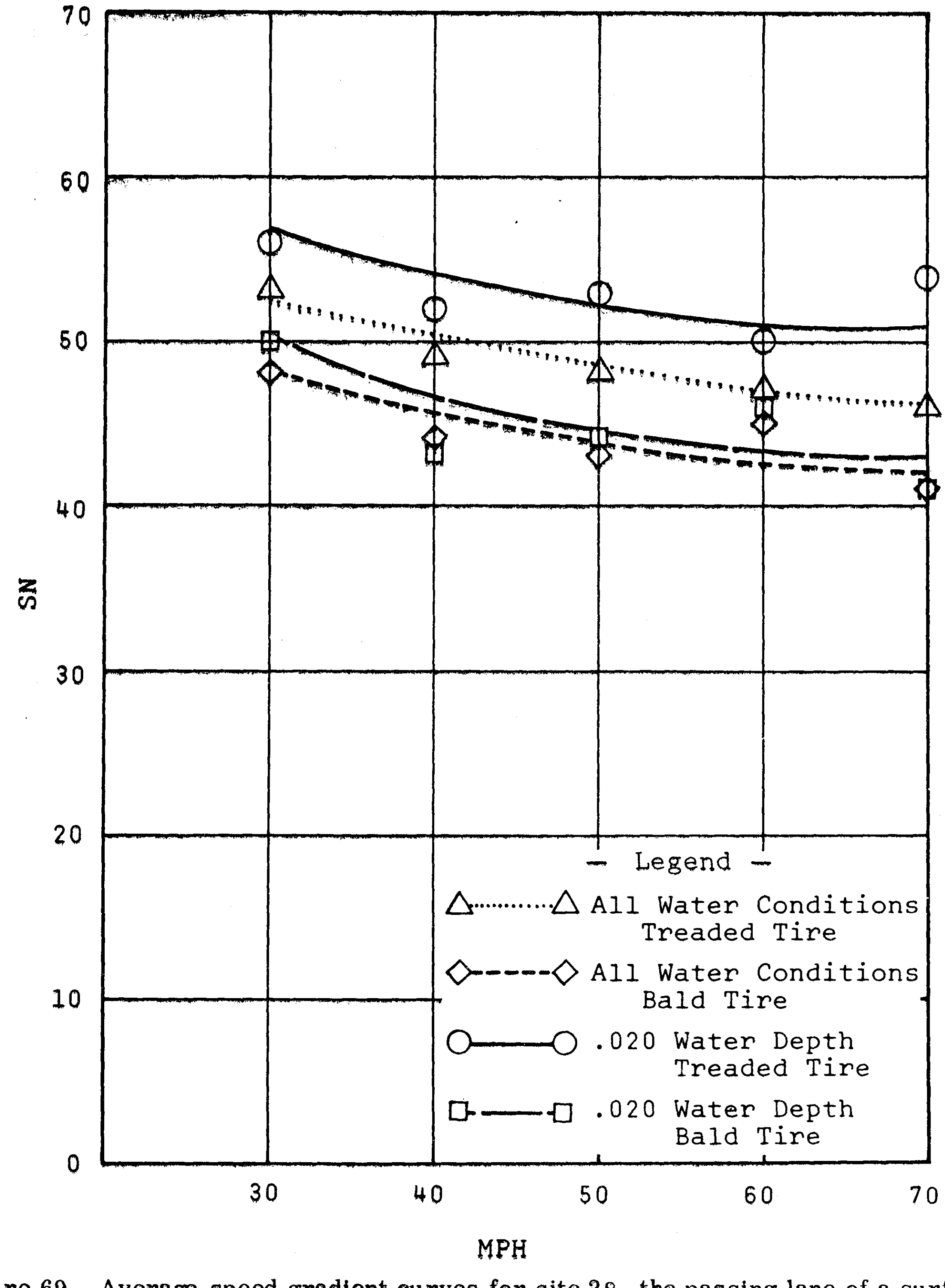


Figure 69. Average speed gradient curves for site 28, the passing lane of a surface treatment placed in 1970 that had an accumulated traffic count of 449,680 vehicles. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

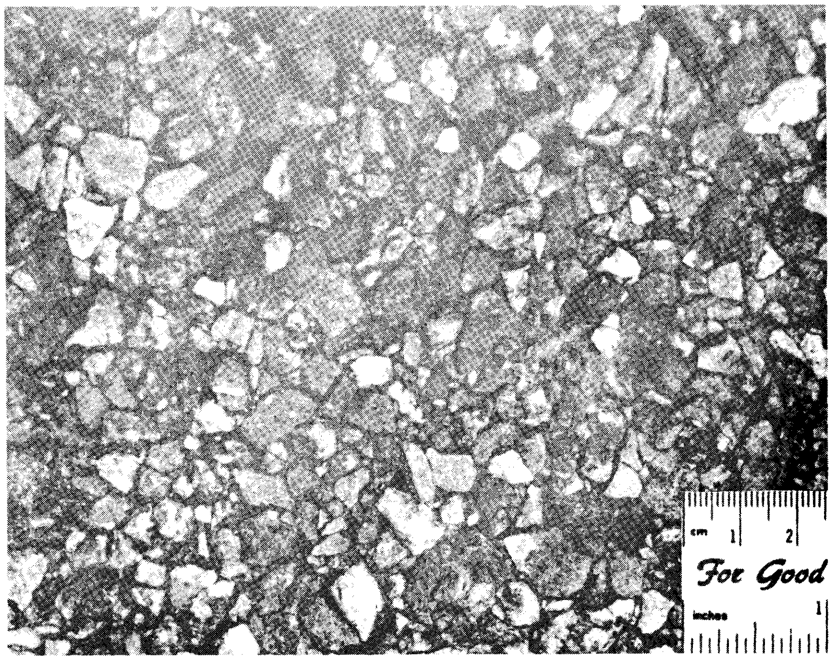


Figure 70. Surface texture of site 26.

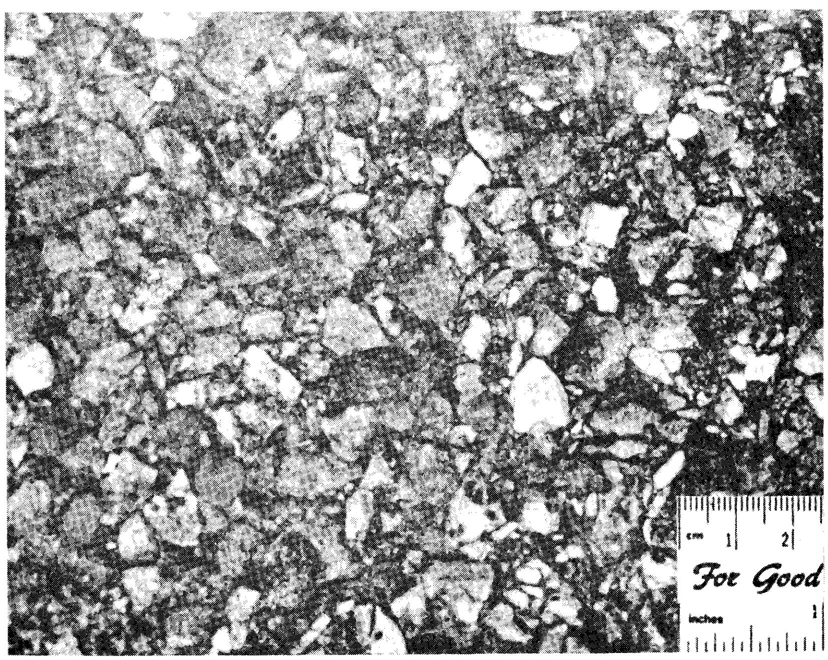


Figure 71. Surface texture of site 28.

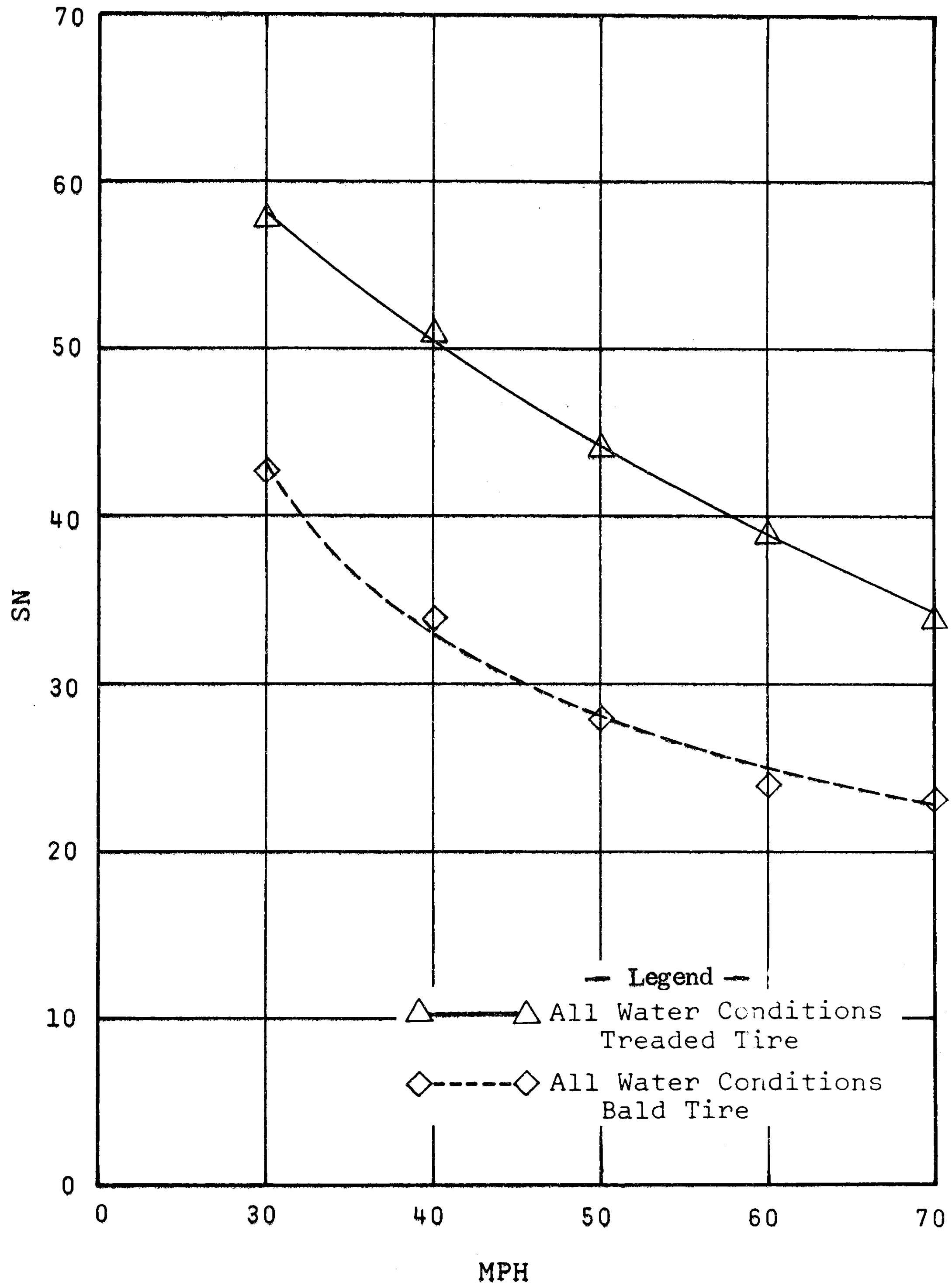


Figure 72. Average skid number-speed gradient for treaded and bald tires for sites 1, 2, 5, 23, and 31. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

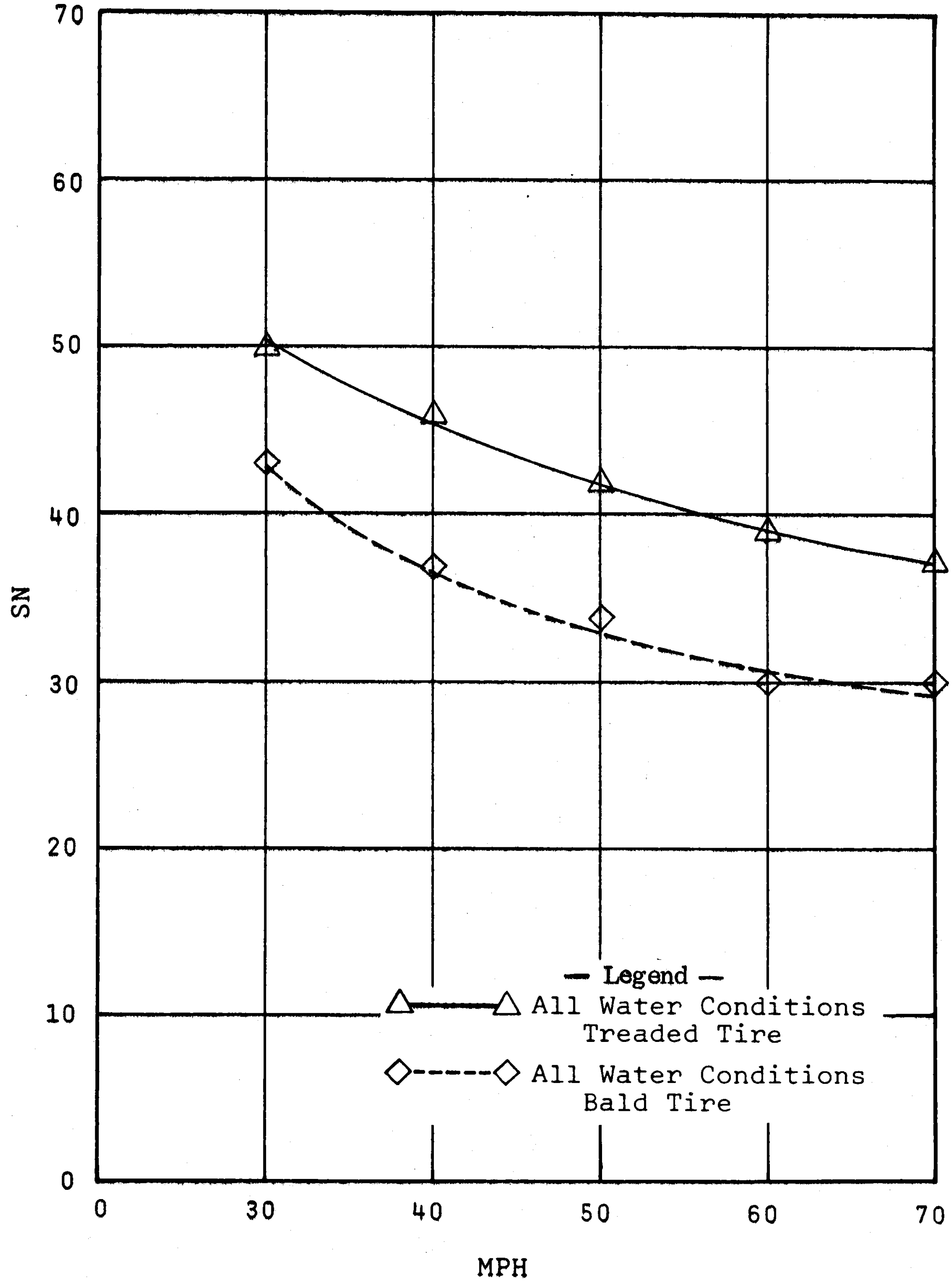


Figure 73. Average skid number-speed gradient for treaded and bald tires for sites 3, 4, 6, 7, 9, 10, 11, and 30. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

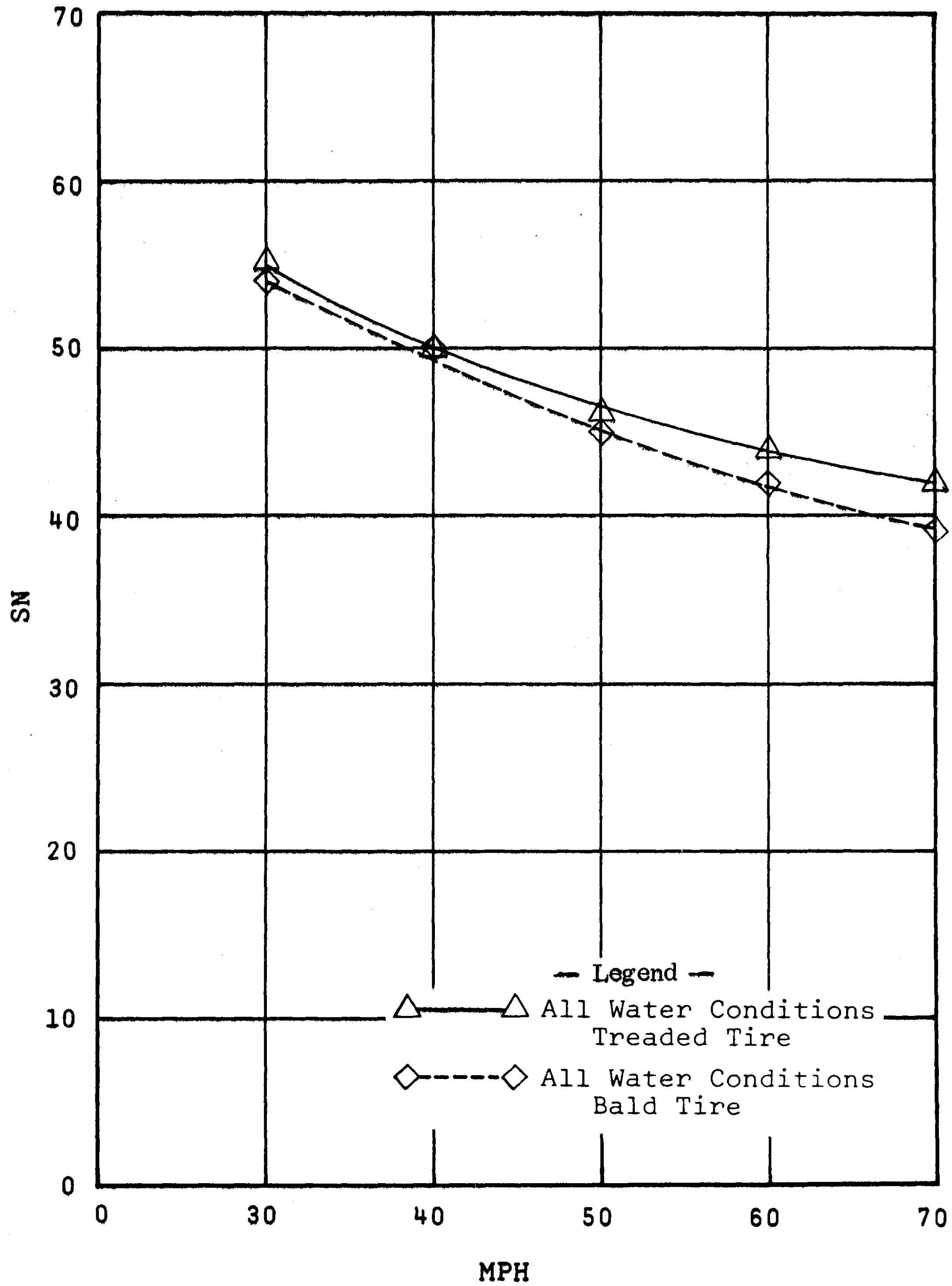


Figure 74. Average skid number-speed gradient for treaded and bald tires for sites 8, 14, 15, 18, 19, 20, 21, 22, 27, and 29. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

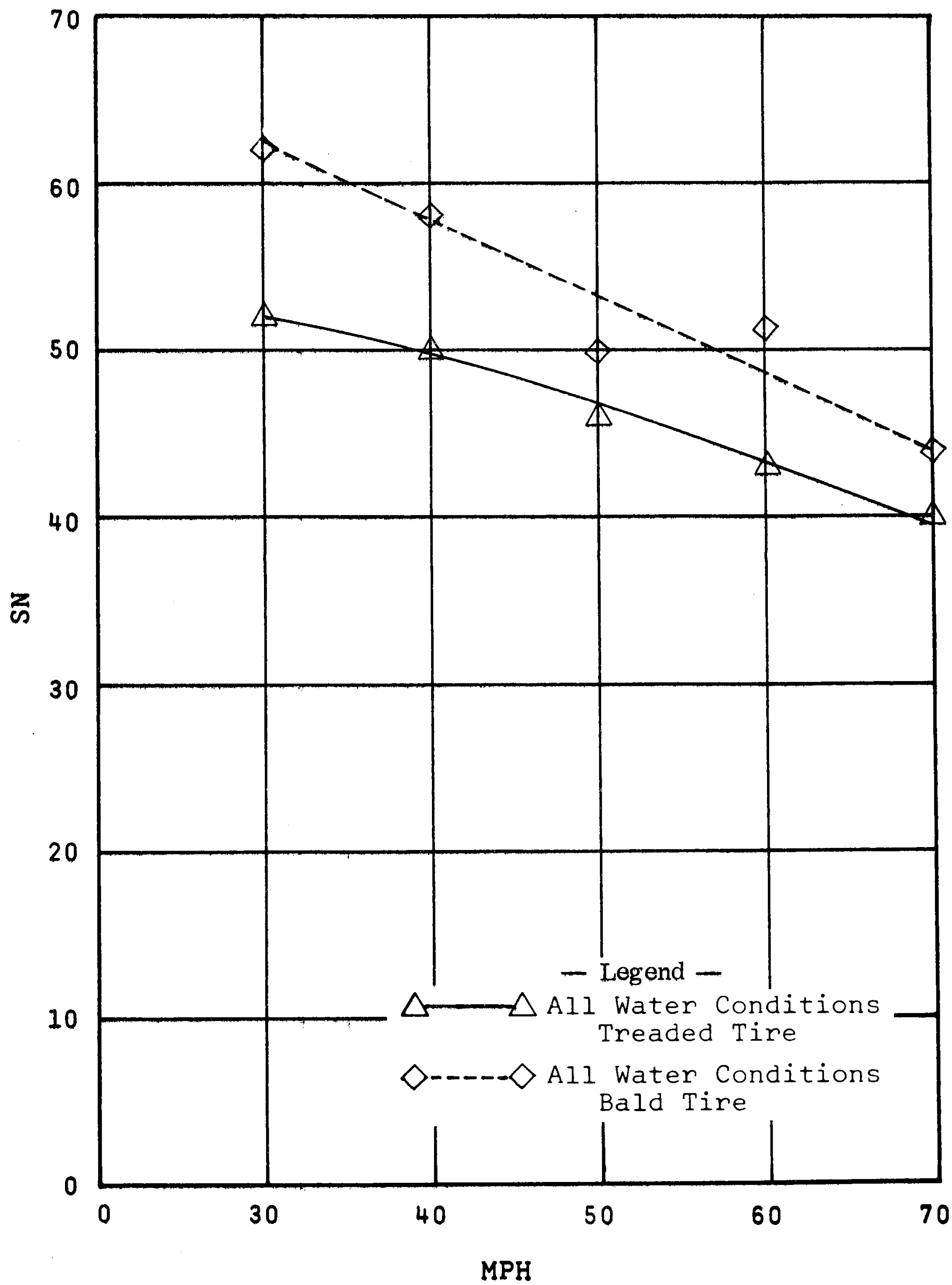


Figure 75. Average skid number-speed gradient for treaded and bald tires for sites 24 and 25 which were grooved concrete pavements. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

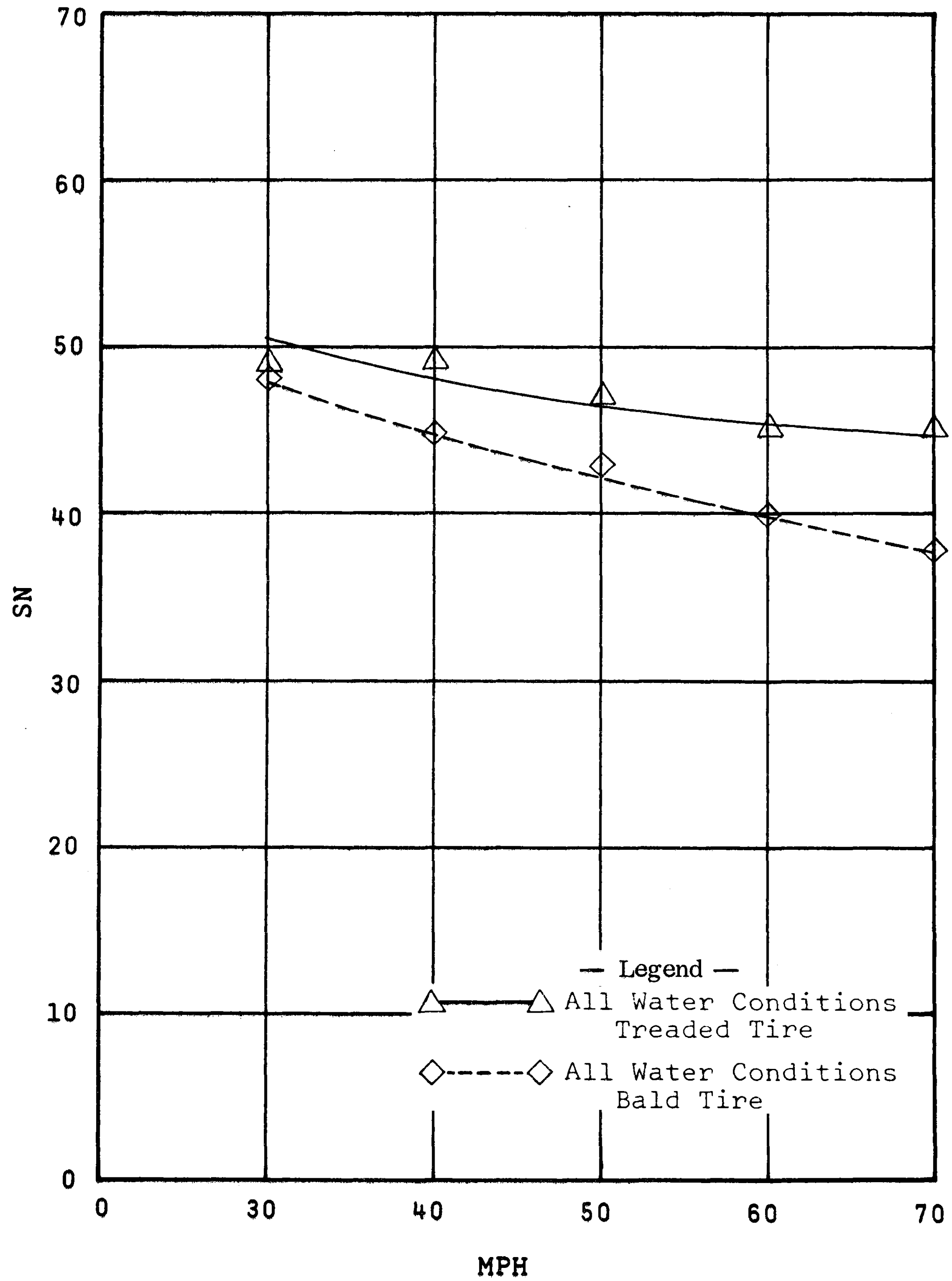


Figure 76. Average skid number-speed gradient for treaded and bald tires for sites 12, 26, 28, and 31. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

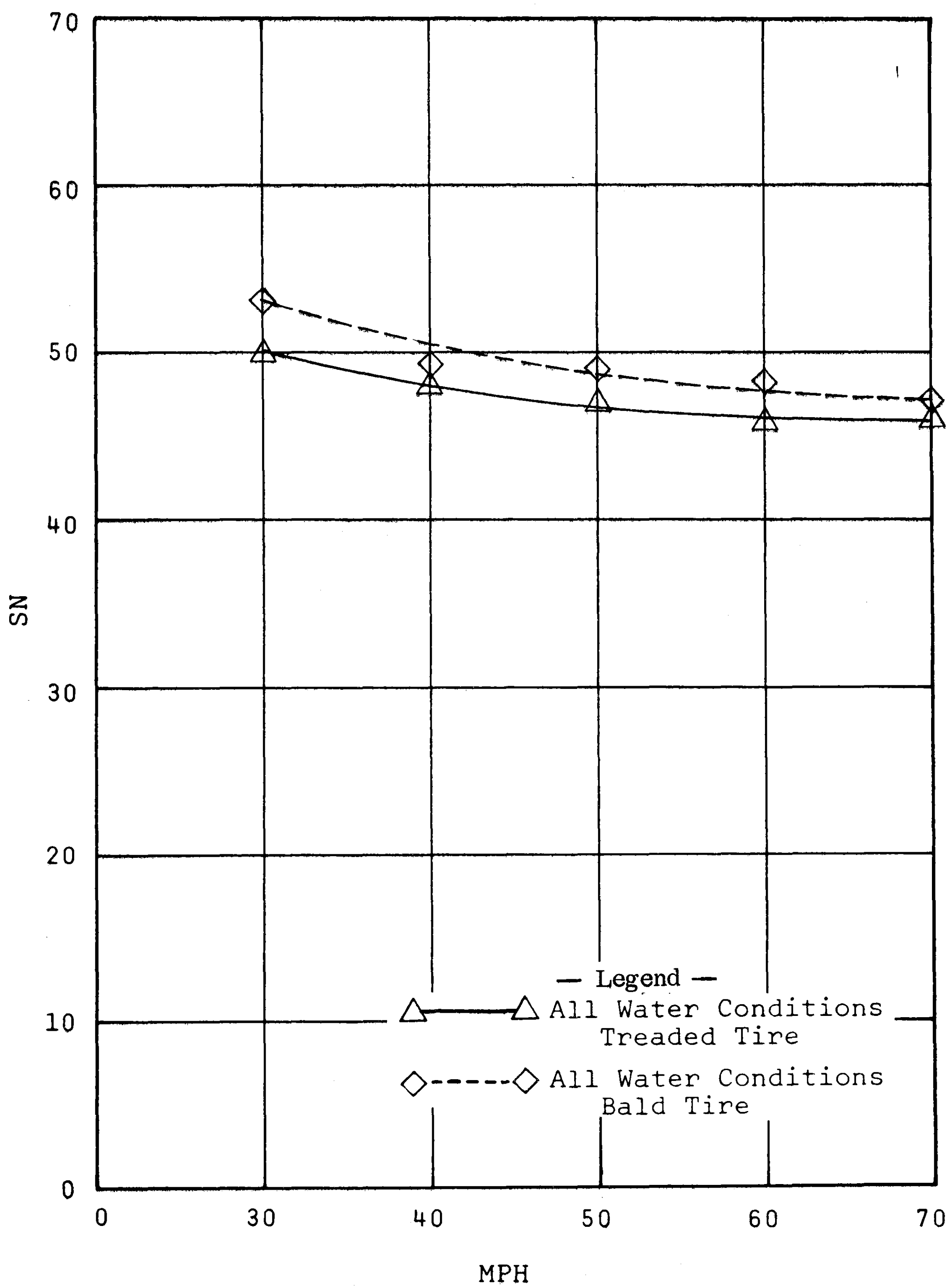


Figure 77. Average skid number-speed gradient for treaded and bald tires for sites 16 and 17 which is an open graded bituminous mix ( popcorn). ( 1 inch = 2.54 cm: 1 mph = .4470 m/s)

is 60 mph (26.8 m/s) or less. However, for those roads where the mean speed is expected to be 65 mph (29.0 m/s) or greater, a harsher macrotexture should be used.

The second subgroup, see the curves in Figure 73, contains eight sites and has an average difference of 7 SN or more between the treaded and bald tires.

The third subgroup (the curves are in Figure 74) contains ten sites and has a very small average difference in skid numbers between the treaded and bald tires. In fact, the difference of from 1 SN to 3 SN as shown by the curves is probably not significant when the confidence levels for the values produced by any skid trailer are considered.

The fourth subgroup consisted of sites 24 and 25. The average curves for these two sites are shown in Figure 75. These sites are the traffic and passing lanes of a smooth concrete surface that was grooved. As can be noted, the bald tires produced higher skid numbers than did the treaded tires. Again, this may be part of the reason for the wide scale reduction in wet pavement accidents after pavements are grooved although their skid resistance is not improved.

The fifth subgroup, for which the curves are shown in Figure 76, consisted of sites 12, 13, 26, and 28. The bald tires provided values from 1 SN to 3 SN lower than those for the treaded tires at the low test speeds, and about 6 SN or 7 SN lower at the higher test speeds.

The sixth subgroup for which the average curves for sites 16 and 17 can be seen in Figure 77, shows that the bald tires produced skid numbers several units higher than those for the treaded tires.

## Average Skid Number-Speed Gradients

Figures 78, 79, and 80 depict the average skid number-speed gradient curves for the steep, intermediate, and flat skid number-speed gradient groups. The average skid number includes all water depths and tire conditions except bald. The slopes are given in Table 4. It should be noted that the speed gradient generally decreased as the test speed increased, and that the gradient between 40 mph (17.9 m/s) and 60 mph (26.8 m/s) was quite similar to the gradient from 30 mph (13.4 m/s) to 70 mph (31.3 m/s). Also there is no question that the slopes of the curves decreased with increased macrotexture, provided there was also good and relatively large-scale microtexture as was the case for most of the surfaces included in the study. The grooved concrete pavements, on which the grooves or macrotexture provided ample water escape routes, had rather steep speed gradients. By the same token, if an open-graded bituminous mix is manufacured with highly polish susceptible aggregate, not only will it become slippery, it will probably also have a rather steep skid number-speed gradient.

Table 4. Skid Number-Speed Gradients
( 1 mph = .4470 m/s)

| Group | Speed | | | |
|---|---|---|---|---|
| | 30 - 50 mph | 40 - 60 mph | 50 - 70 mph | 30 - 70 mph |
| | | Slopes (SN/mph) | | |
| Steep | 0.65 | 0.55 | 0.50 | 0.58 |
| Intermediate | 0.45 | 0.30 | 0.20 | 0.32 |
| Flat | 0.25 | 0.15 | 0.05 | 0.15 |

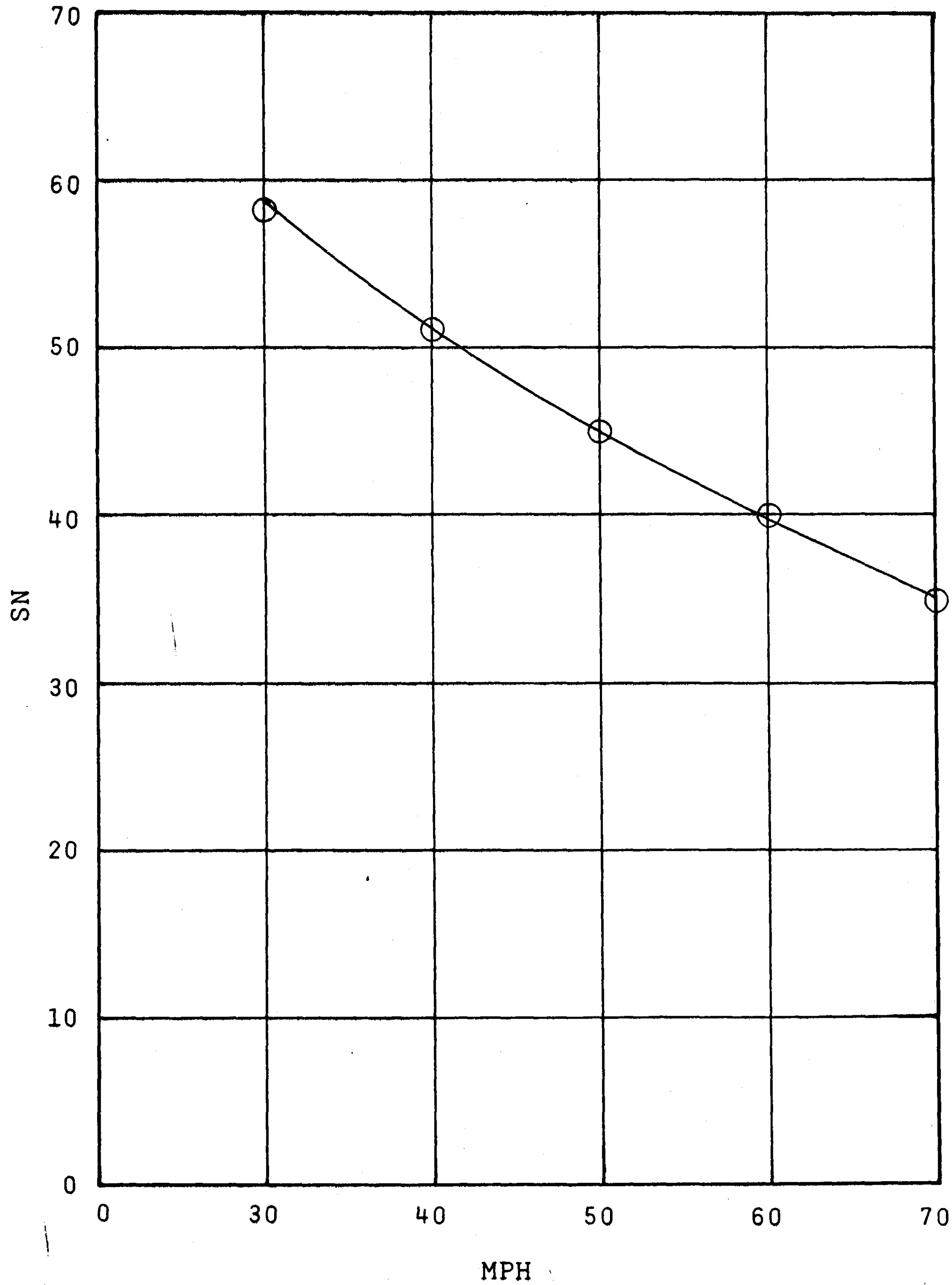


Figure 78. Skid number-speed gradient curve for the steep speed gradient group. The average slope is 0.58. (1 mph = .4470 m/s)

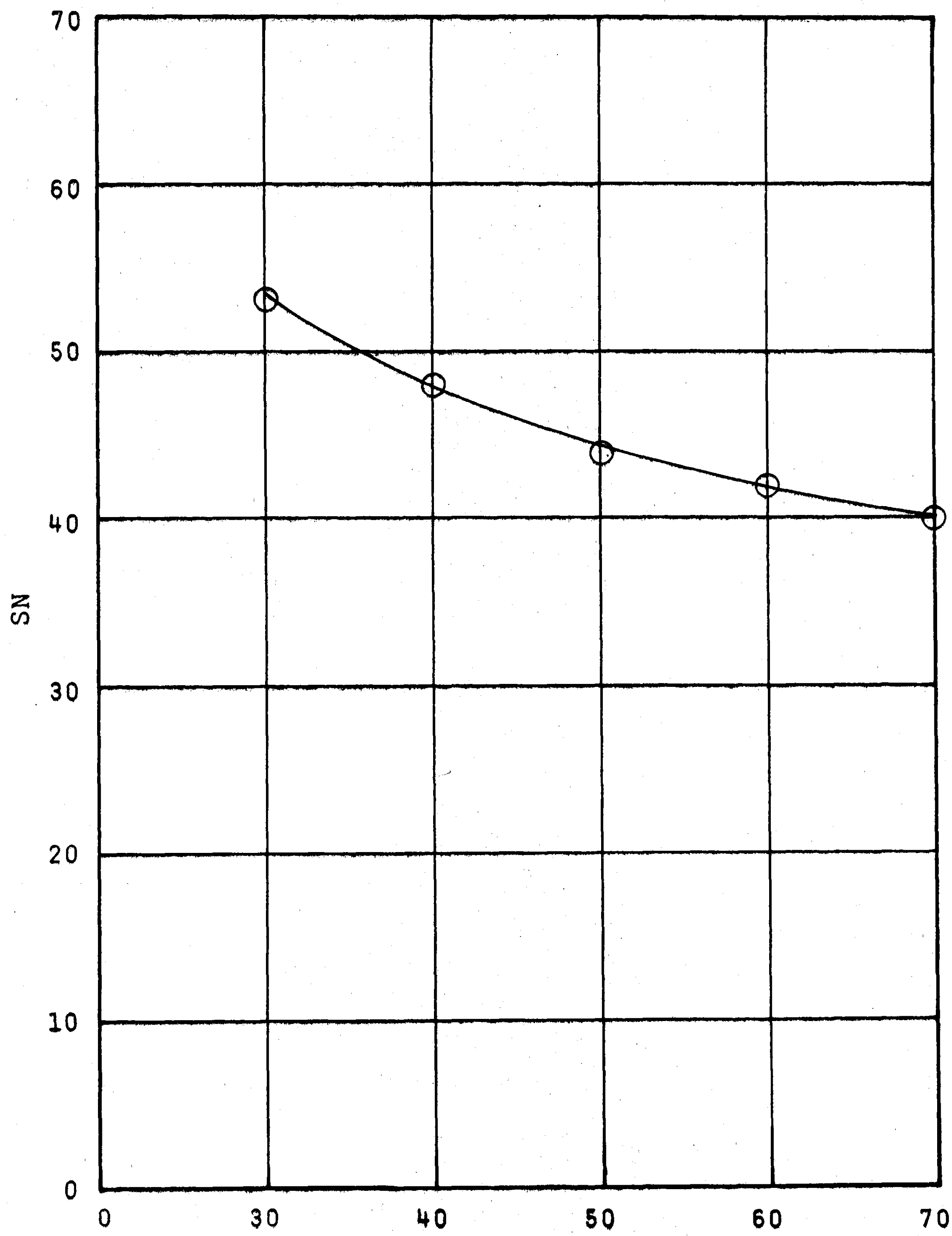


Figure 79. Skid number-speed gradient curve for the intermediate speed gradient group. The average slope is 0.32. (1 mph = .4470 m/s)

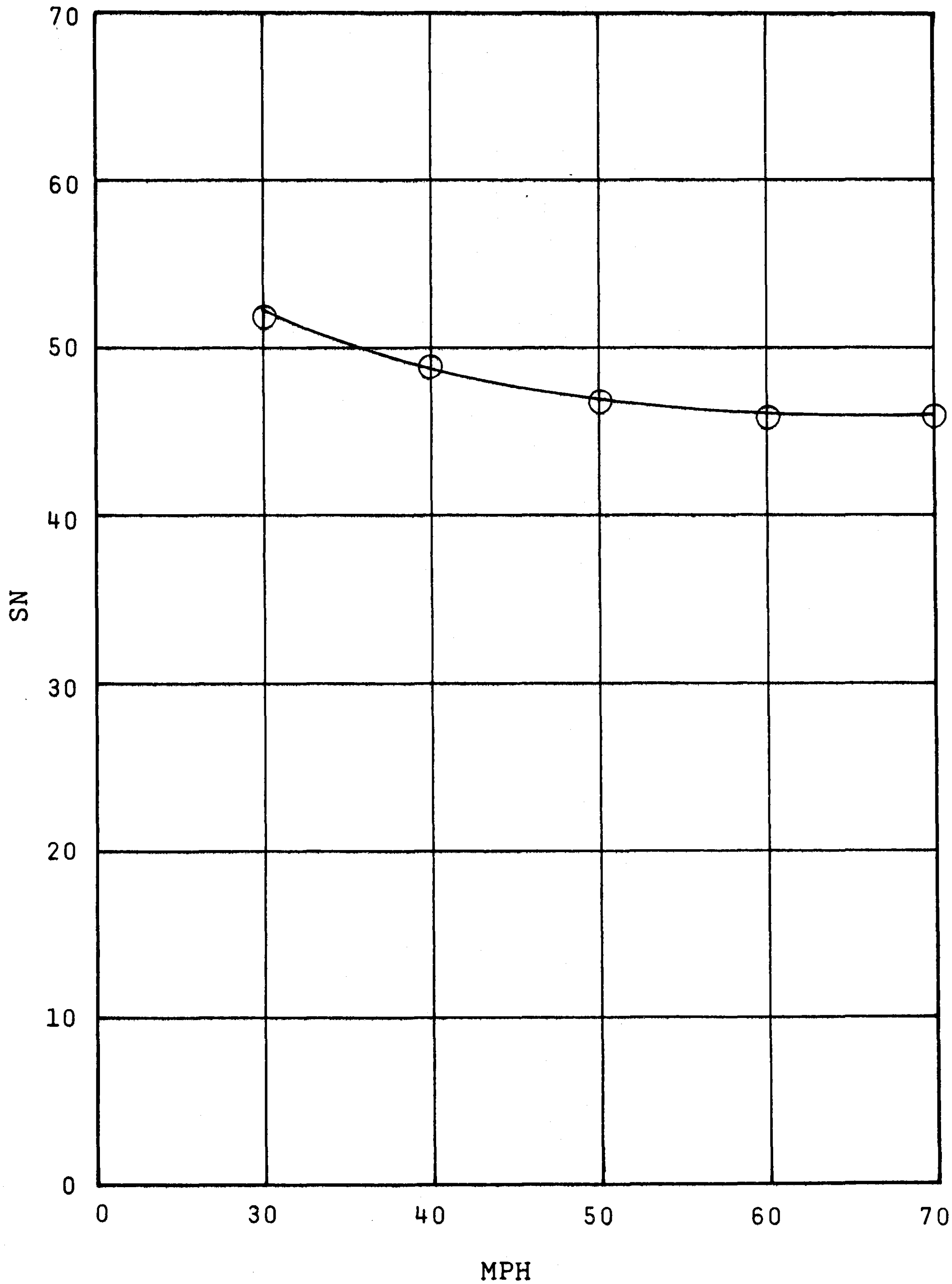


Figure 80. Skid number-speed gradient curve for the low speed gradient group. The average slope is 0.15. ( 1 mph = .4470 m/s)

The curves in Figures 78, 79, and 80 can be used in Virginia to predict skid numbers for speeds other than the test speeds by testing at two speeds to determine which skid number-speed gradient curve to use, or by a less desirable method that consists of testing at one speed and selecting the appropriate skid number-speed gradient curve on the basis of a rather thorough knowledge of the texture and materials of the surfaces in the study and throughout Virginia.

In summarizing the skid number-speed gradient aspect of the study, the following observations are made. High skid number-speed gradients are common to pavements that do not have a relatively high degree of macrotexture. This fact, of course, only substantiates the observations of many others. However, it should be pointed out that if the surface has a sharp microtexture, as is the case for all locations except site 31 in the steep slope group, its skid resistance can be excellent at all legal speeds with legal tires even though the speed gradient may be relatively steep. On such surfaces, the use of bald tires can lead to disastrous accidents and it is therefore hoped that police authorities will continue to strictly enforce the restriction against the use of tires with less than a 3/32 in. (0.24 cm) tread depth.

The intermediate skid number-speed gradient group demonstrates that pavements could have essentially the same skid number-speed gradients and yet respond quite differently to treaded as opposed to bald tires (see Figures 73 and 74). This phenomenon is also illustrated in Figures 75 and 77. This difference in response results from a difference in macrotexture; i.e., as the macrotexture increases, the skid number-speed gradient decreases and the relationship between the treaded and bald tire is greatly altered. On smooth macrotexture pavements the bald tire values are quite a bit lower than the treaded tire values, whereas on a harsh macrotexture the inverse sometimes occurs.

The highest skid numbers recorded in the study were at low speeds in the steep speed gradient group, which means that a low macrotexture - high microtexture provides the best skid resistant surface at low speed (40 mph (17.9 m/s) and below). Cities and counties should take this into account when they are paving low speed streets.

Grooving does not improve the skid resistance or the skid number-speed gradient for treaded tires, but does manifestly increase the skid resistance for bald tires. This fact may account for some of the reduction in wet pavement accidents where concrete pavements have been grooved.

Since grooving does not decrease the skid number-speed gradient slope, it is suggested that the mere provision for water escape does not indicate that the pavement surface will have a flat skid number-speed gradient.

Lastly, the skid number-speed gradient curves in Figures 78, 79, and 80 can be used to predict skid numbers for speeds other than those tested, as long as the surfaces fit into the same categories as those represented by these three curves.

## Tread Depth

As did the speed gradient curves, the tread depth curves fell into three distinct categories, which were pavement texture dependent. However, they did not always remain in the same grouping as did the speed gradients. In addition, the tread depth data for sites 10 through 13 were manifestly faulty, so were not included (for these curves see the Appendix Figures A41 through A44) and no tread depth data were obtained for sites 14 and 15 because only two tire conditions were tested. Also, it should be realized that one of the most important facets of tire effect, namely, the relationships between the bald and treaded tires, has already been considered to a large extent.

## Smooth Textured Surfaces

The smooth textured group consisted of sites 1, 2, 6, 7, 22, and 23, all of which were smooth portland cement concrete pavements; site 5, a smooth sand asphalt cement; and sites 30 and 31, highly worn S-5 bituminous concrete surfaces. None of these surfaces possesses macrotexture.

The dominant characteristic of the curves for this group is a slight deterioration of skid number with a decrease in tread depth down to 3/32 in. (0.24 cm), and then a sharp drop with the bald tire.

Figure 81 is a composite curve for all of the speeds and sites in this grouping. The curve is drawn as a straight line from the 11/32 in. (0.87 cm) to the 3/32 in. (0.24 cm) tread depth, although the data point at 5/32 in. (0.40 cm) does not fall right on the line. The curve then drops off rapidly, as has been discussed before when comparing bald to treaded tires on smooth pavements.

## Intermediate Textured Surfaces

The intermediate textured surface group is comprised of 8 sites; sites 3 and 4 S-5 bituminous concretes, sites 8 and 9 are bushhammered concretes, and 26, 27, 28, and 29 are surface treatments. This group has a fair or intermediate macrotexture. Figure 82 is a composite curve for all speeds and water depths. This curve is a straight line.

## Open Textured Surfaces

The open textured surface group consists of 8 surfaces with a pronounced macrotexture. Sites 16 and 17 are open-graded (popcorn) bituminous mixes, sites 18 and 19 are S-5 bituminous concretes, sites 20 and 21 are portland cement concrete with longitudinal striations imparted with a tine finish, and sites 24 and 25 are grooved portland cement concrete surfaces. Figure 83 is a composite curve for this group of surfaces. For this curve, there are no data points for the 7/32 in. (0.56 cm) and 9/32 in. (0.71 cm) tread depths.

The writer believes that the three curves in Figures 81-83 could be used to adjust data for tread depths. If the slopes are treated as straight lines from 11/32 in. (0.87 cm) to 3/32 in. (0.24 cm) tread depth, these slopes are: smooth texture, 1 SN, intermediate texture, 1.5 SN, and open texture, 1.25 SN, per 2/32 in. (0.16 cm) loss of tread depth. However, since only four increments of 2/32 in. (0.16 cm) are involved between 3/32 in. (0.24 cm) and 11/32 in. (0.87 cm), the writer suggests that a correction of $1\frac{1}{4}$ SN be made for each 2/32 in. (0.16 cm) increment. Adoption of this suggestion would mean that a skid test tire could be used from the time it is new until it reaches 3/32 in. (0.24 cm) tread depth if the adjustment for the 5 SN loss is made. However, once the tire wears below 3/32 in. (0.24 cm) tread depth, it probably should not be used for routine testing.

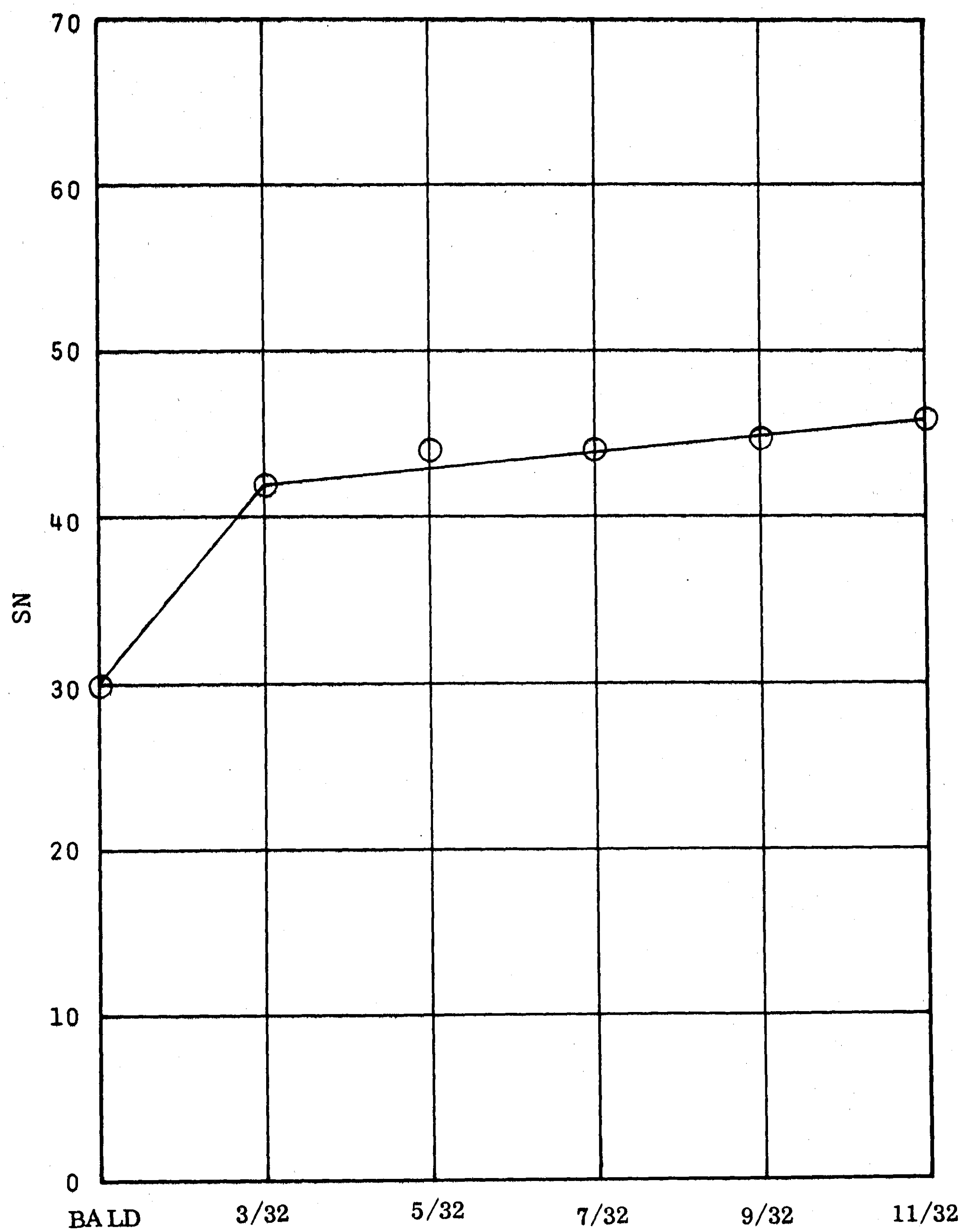


Figure 81. The average skid numbers for the different tread depths on smooth macrotexture surfaces for sites 1, 2, 5, 6, 7, 22, 23, 30, and 31 which were included in this group. ( 1 inch = 2.54 cm)

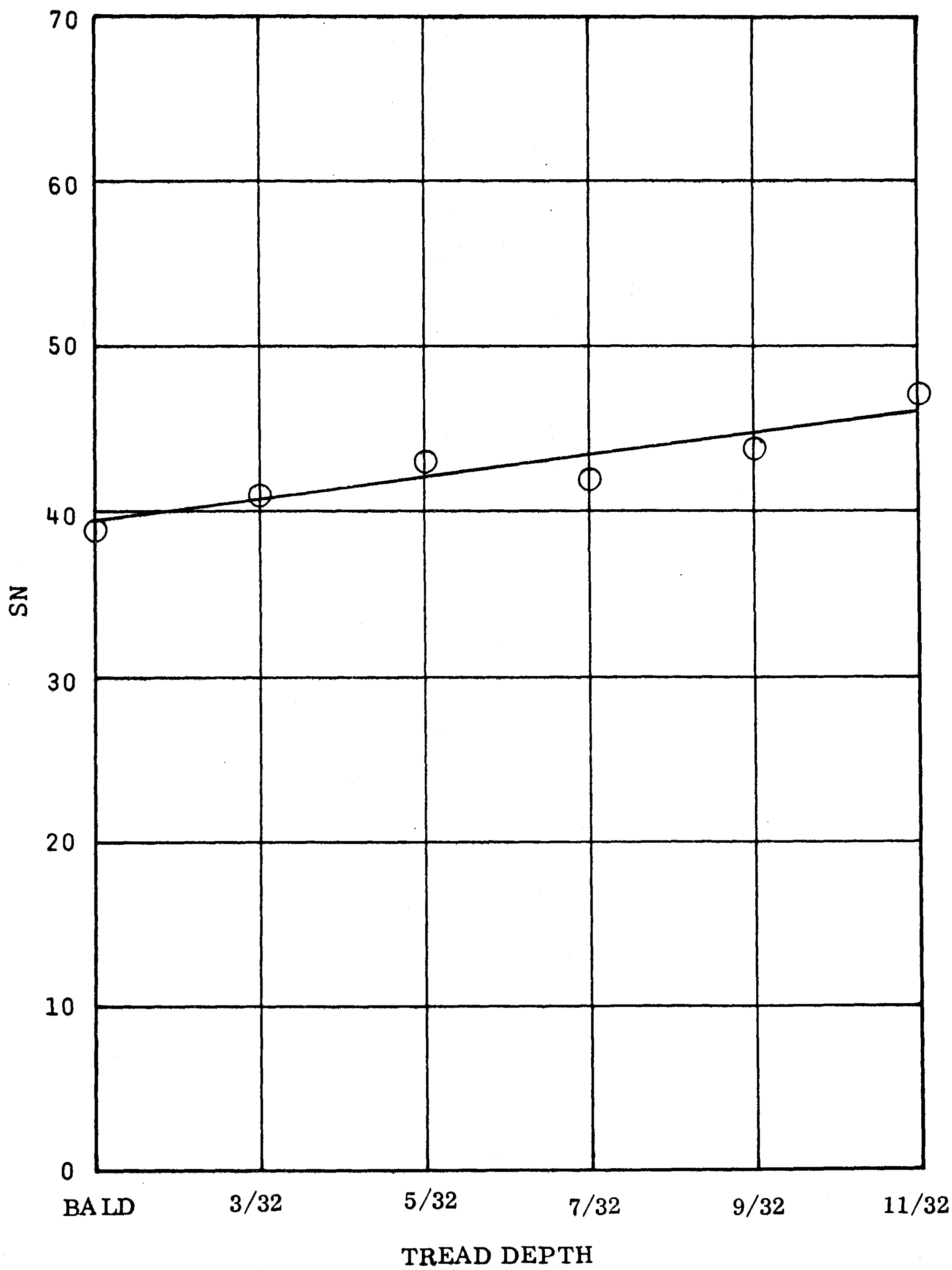


Figure 82. The average skid numbers for the different tread depths on the intermediate macrotexture surfaces on sites 3, 4, 8, 9, 26, 27, 28, and 29 which were included in this group. (1 inch = 2.54 cm)

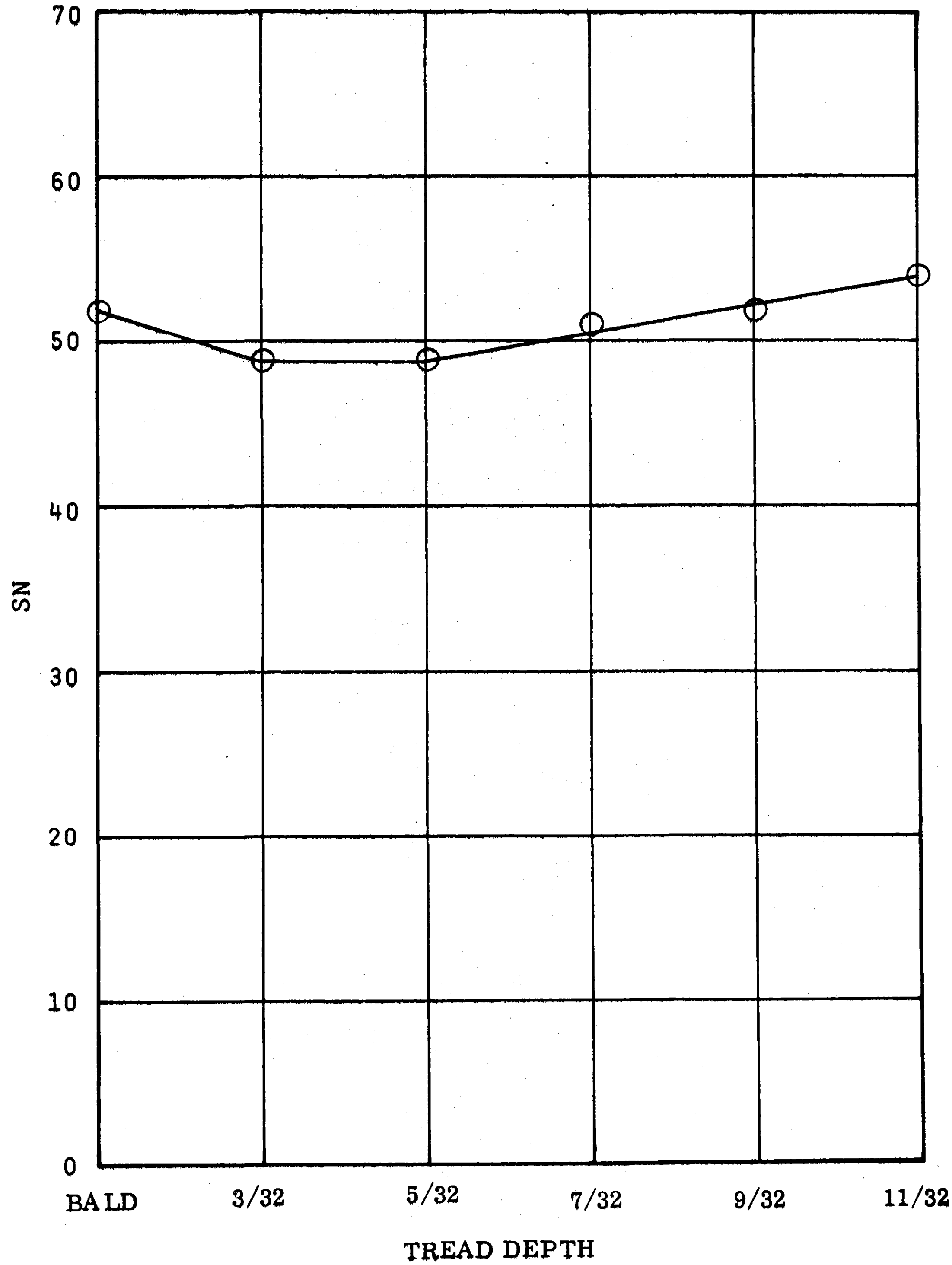


Figure 83. The average skid numbers for different tread depths on open textured surfaces on sites 16, 17, 18, 19, 20, 21, 24 and 25 which were included in this group. ( 1 inch = 2.54 cm)

## Water Film Thickness

As was mentioned earlier, the water film portion of the study was not as successful as the other portions. The data for many of the sites are so erratic that they are manifestly faulty. For this reason, in the consideration of water depths, sites 1, 2, 3, 4, 20, 21, 22, 23, 24, 25, and 29 have been relagated to the Supplement and are not discussed in the text; sites 14 and 15 were not included in the water film study. However, the data for the remainder of the sites were analyzed to determine their skid number-water gradients. Individual speed data for these sites, for both the bald and treaded tires, are given in graphic form in Figures A61 through A78 in the Appendix. In the text, only one graph is shown, Figure 84, which gives two composite curves, one for the treaded tires and one for the bald tires, for all speeds for the sites that were analyzed.

The two curves are about parallel, with the bald tire averaging six skid numbers less than the treaded tires. The gradient is a loss of about 1 SN per .010 in. (0.02 cm) of water increase. The writer does not place much reliance in the water depths being precise and is, therefore, reluctant to accept the fact that the average skid numbers changed by only three units when the depth of water increased from .015 in. (0.04 cm) to .040 in. (0.10 cm). However, the writer does feel that the water output did not remain constant and, in fact, did deviate from .020 in. (0.05 cm) by quite a bit during the study. Therefore, it is concluded that in the light of the small change in skid number with the change in water film in Figure 84, the normal fluctuation of water output by skid trailers in routine testing should not be a matter for concern.

# SUMMARY

Thirty-one sites representing the types of pavement surfaces on the highways of Virginia were skid tested between September 21, 1972, and June 6, 1974. The tests were performed with the Virginia Highway and Transportation Research Council skid trailer, which meets ASTM E 274-70 specifications. The variables tested were four water film thicknesses — .015 in. (0.04 cm), .020 in. (0.05 cm), .030 in. (0.08 cm), and .040 in. (0.10 cm); six tread depths — new, 9/32 in. (0.71 cm), 7/32 in. (0.56 cm), 5/32 in. (0.40 cm), 3/32 in. (0.24 cm), and bald; and five test speeds — 30, 40, 50, 60, and 70 mph (13.4, 17.9, 22.4, 26.8, 31.3 m/s). After tests of the first fifteen sites the 9/32 in. (0.71 cm) and 7/32 in. (0.56 cm) tread depth tests were abandoned and in a few cases a water film or a test speed was not included.

It is felt that the study of textures and tread depths as they interrelate and as they relate to test speed was quite successful. The water film portion of the study, due to the lack of control of the water output, was not as enlightening.

# CONCLUSIONS

Based on the data gathered in this study, the following conclusions regarding Virginia's pavement surfaces are warranted:

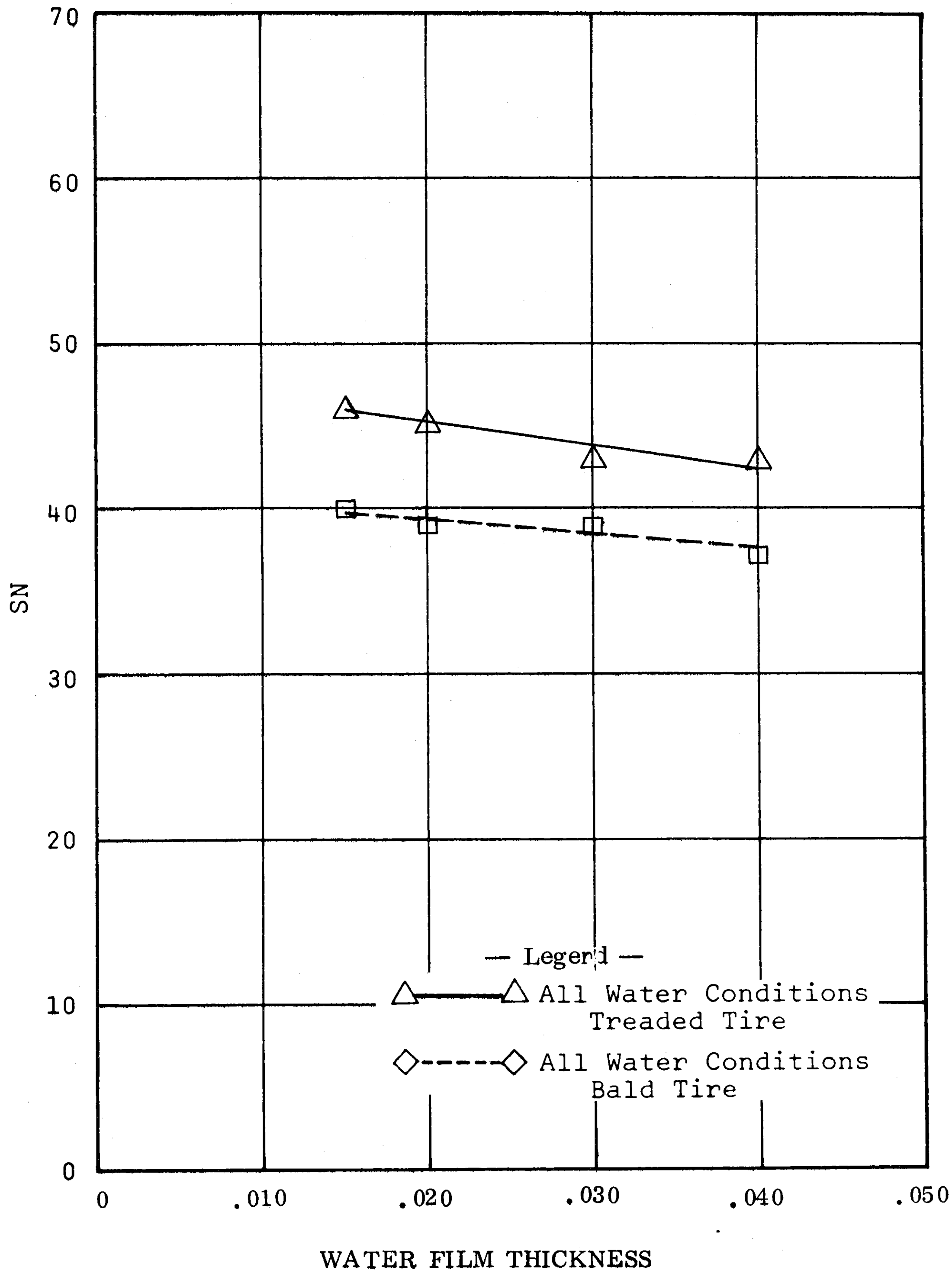


Figure 84. The average skid numbers for the different water film thickness for sites 5, 6, 7, 8, 9, 10, 11, 12, 13, 16, 17, 18, 19, 26, 27, 28, 30, and 31. ( 1 inch = 2.54 cm)

1. High skid number-speed gradients are common to pavements that do not contain a relatively high degree of macrotexture. This finding, of course, only substantiates the observations of many others. However, it should be pointed out that if the surface has a sharp microtexture, its skid resistance can be excellent at all legal speeds with legal tires. Bald tires on such surfaces can provide extremely low skid numbers.

2. The converse of number 1 is also true; i.e., the slope of the skid number-speed gradient curve decreases with increased macrotexture. However, the degree of this decrease is strongly influenced by the characteristics of the microtexture. Pavements such as grooved portland cement concrete that provide ample means of water escape might have quite steep skid number-speed gradients if the microtexture is not harsh. It follows that the same is true for open-graded bituminous mixes containing polish susceptible aggregates.

3. Pavements that have essentially the same skid number-speed gradients can have quite different relationships between treaded and bald tires. This difference is due to the difference in macrotexture; i.e., as the macrotexture increases, the divergence between the treaded and bald tire skid numbers decreases until the values for the two tires are the same; in fact, in some cases the values for the bald tire become higher than those for the treaded tires.

4. The highest skid numbers recorded in the study were at low speeds in the steep gradient group, which means that a low macrotexture - high microtexture surface provides the best skid resistance at low speeds (40 mph (17.9 m/s) and below).

5. Grooving does not greatly influence the skid resistance or the skid number-speed gradient slope for treaded tires, but does manifestly increase the skid resistance for bald tires. The latter fact may account for some of the reduction in wet pavement accidents where concrete pavements have been grooved.

6. The skid number-speed gradient curves developed in this study can be used to predict skid numbers for speeds other than those at which tests are run on Virginia pavements.

7. The skid number decreases as the test tire tread decreases. This decrease averages about $1\frac{1}{4}$ SN per 2/32 in. (0.16 cm) increment in tread depth for a total loss of 5 SN from 11/32 in. (0.87 cm) to 3/32 in. (0.24 cm). A correction for this change in skid number can be made on a straight-line basis.

8. After a tire has worn beyond 3/32 in. (0.24 cm) tread depth, it has a high reaction to pavement macrotexture and should, therefore, not be used for routine testing.

9. Because of the small change in skid number with a change in water film, the normal fluctuation in water output by the test trailer should not be a matter of concern.

## RECOMMENDATIONS

Based on the findings of this study, it is recommended that Virginia:

1. Use the skid number-speed gradient curves developed to predict skid numbers for speeds other than those tested.

2. Use the skid number-tread depth relationship found to adjust routine inventory skid data.

3. Not be concerned with normal fluctuations of water output by the skid test trailer.

4. Continue to be concerned primarily with using skid resistant aggregate in both concrete and bituminous surfaces.

5. Continue to use the type of bituminous mixes presently being used for most conditions.

6. In special situations, give consideration to placing open-graded mixes.

7. In low speed situations, give consideration to placing low macrotexture - high microtexture surfaces.

8. Continue to tine finish concrete pavement surfaces.

9. In addition to tine-finishing concrete pavement surfaces, draw up specifications for tine-finishing the surfaces of portland cement concrete bridge decks.

10. Continue to strictly enforce the law that makes the use of tires with less than a 3/32 in. (0.24 cm) tread depth illegal.

## ACKNOWLEDGEMENTS

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Special thanks go to Chuck Payne, David Hill, and Fred Huckstep for the responsibility they assumed in gathering and organizing the data. Greatest appreciation is expressed for the very unselfish manner in which Jamie Freeman organized her time to arrange and type the manuscript.

## REFERENCES


1. American Society for Testing and Materials, 1970 Annual Book of ASTM Standards, "E 274-65T, Method of Test for Skid Resistance of Paved Surfaces Using a Full-Scale Tire," April 1970.

2. Leland, Trafford J. W., and W. B. Horne, "Consideration on Tire Hydroplaning and Some Recent Experimental Results," presented at the Paper Session of Committee E-17, American Society for Testing Materials, Atlantic City, New Jersey, June 26, 1963, NASA Langley Research Center, Langley Station, Hampton, Virginia.

3. Horne, W. B., and R. C. Dreher, "Phenomena of Pneumatic Tire Hydroplaning," NASA TN D-2056, NASA Langley Research Center, Langley Station, Hampton, Virginia.

4. Horne, W. B., and Upshur T. Joyner, "Pneumatic Tire Hydroplaning and Some Effects on Vehicle Performance," Paper 970C, International Automotive Engineering Congress, Detroit, Michigan, January 1965, Society of Automotive Engineers, New York, New York.

5. Runkle, Stephen N., "Evaluation of the New Virginia Department of Highways & Transportation Skid Trailer," Virginia Highway & Tranasportation Research Council, February 1975.

6. Creech, M. F., "Mechanical Alteration of the Texture of Old Concrete Pavement with the Klarcrete Machine," Transportation Research Board Record 484, 1974, pp. 9-23.

7. Mahone, D. C., C. S. Hughes, and G. W. Maupin, "Skid Resistance of Dense-Graded Asphaltic Concrete Mixes," presented at the Annual Meeting of the Transportation Research Board, Washington, D. C., January 1974.

# APPENDIX

Table A1. Site 1 — Mean Skid Numbers for Treaded and Bald Tires for the Different Test Speeds and Water Film Thicknesses. A Portland Cement Concrete Surface in the EBTL of I-64 in Fluvanna County. (1 inch = 2.54 cm; 1 mph = .4470 m/s)

**Data Adjusted by use of Runkle's Correlation Curve**

**Correction Factor: .92**

| | | .015 | .020 | .030 | .040 | Average All Water Depth |
|---|---|---|---|---|---|---|
| **Treaded Tires:** | | | | | | |
| | **30** | 57 | 56 | 57 | 60 | 58 |
| | **40** | 50 | 47 | 50 | 54 | 50 |
| | **50** | 42 | 44 | 43 | 44 | 43 |
| | **60** | 40 | 39 | 38 | 38 | 39 |
| | **70** | 38 | 36 | 30 | 37 | 35 |
| **Bald Tires:** | | | | | | |
| | **30** | 48 | 33 | 52 | 35 | 42 |
| | **40** | 37 | 27 | 40 | 27 | 33 |
| | **50** | 33 | 23 | 32 | 22 | 28 |
| | **60** | 30 | 21 | 33 | 18 | 26 |
| | **70** | 30 | — | 27 | — | 29 |

**Data Before Adjustment**

| | | .015 | .020 | .030 | .040 | Average All Water Depth |
|---|---|---|---|---|---|---|
| **Treaded Tires:** | | | | | | |
| | **30** | 62 | 61 | 62 | 65 | 62 |
| | **40** | 55 | 51 | 55 | 59 | 55 |
| | **50** | 46 | 48 | 46 | 48 | 47 |
| | **60** | 44 | 42 | 41 | 41 | 42 |
| | **70** | 41 | 39 | 33 | 40 | 38 |
| **Bald Tires:** | | | | | | |
| | **30** | 52 | 36 | 57 | 38 | 46 |
| | **40** | 41 | 30 | 44 | 30 | 36 |
| | **50** | 36 | 25 | 35 | 24 | 39 |
| | **60** | 33 | 23 | 36 | 20 | 28 |
| | **70** | 33 | — | 29 | — | 31 |

Table A2. Site 2 — Mean Skid Numbers for Treaded and Bald Tires for the Different Test Speeds and Water Film Thicknesses. A Portland Cement Concrete Surface in the WBPL of I-64 in Louisa County. (1 inch = 2.54 cm; 1 mph = .4470 m/s)

**Data Adjusted by use of Runkle's Correlation Curve**

**Correction Factor: .95**

| | .015 | .020 | .030 | .040 | Average All Water Depth |
|---|---|---|---|---|---|
| **Treaded Tires:** | | | | | |
| 30 | 65 | 65 | 68 | 70 | 67 |
| 40 | 60 | 58 | 59 | 61 | 60 |
| 50 | 53 | 52 | 52 | 52 | 52 |
| 60 | 48 | 48 | 46 | 46 | 47 |
| 70 | 43 | 41 | 40 | 40 | 41 |
| **Bald Tires:** | | | | | |
| 30 | 56 | 44 | 60 | 44 | 51 |
| 40 | 46 | 36 | 52 | 34 | 42 |
| 50 | 51 | 30 | 48 | 31 | 40 |
| 60 | 41 | 26 | 38 | 24 | 32 |
| 70 | 38 | — | 32 | — | 35 |

**Data Before Adjustment**

| | .015 | .020 | .030 | .040 | Average All Water Depth |
|---|---|---|---|---|---|
| **Treaded Tires:** | | | | | |
| 30 | 68 | 68 | 71 | 74 | 70 |
| 40 | 62 | 61 | 62 | 64 | 62 |
| 50 | 56 | 54 | 54 | 55 | 55 |
| 60 | 51 | 50 | 48 | 49 | 50 |
| 70 | 46 | 43 | 42 | 42 | 43 |
| **Bald Tires:** | | | | | |
| 30 | 58 | 46 | 63 | 46 | 53 |
| 40 | 48 | 38 | 55 | 35 | 44 |
| 50 | 54 | 32 | 50 | 32 | 40 |
| 60 | 43 | 28 | 40 | 25 | 34 |
| 70 | 40 | — | 34 | — | 37 |

Table A3. Site 3 — Mean Skid Numbers for Treaded and Bald Tires for the Different Test Speeds and Water Film Thicknesses. An S-5 Bituminous Concrete Mix in the EBTL of I-64 in Louisa County. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

**Data Adjusted by use of Runkle's Correlation Curve**

**Correction Factor: .80**

| | .015 | .020 | .030 | .040 | Average All Water Depth |
|---|---|---|---|---|---|
| **Treaded Tires:** | | | | | |
| **30** | 53 | 53 | 53 | 57 | 54 |
| **40** | 49 | 48 | 48 | 51 | 49 |
| **50** | 45 | 45 | 44 | 46 | 45 |
| **60** | 42 | 43 | 40 | 39 | 41 |
| **70** | 41 | 40 | 36 | 40 | 39 |
| **Bald Tires:** | | | | | |
| **30** | 52 | 39 | 54 | 40 | 46 |
| **40** | 49 | 36 | 49 | 34 | 42 |
| **50** | 44 | 32 | 43 | 32 | 38 |
| **60** | 39 | 30 | 40 | 27 | 34 |
| **70** | 38 | — | 36 | — | 37 |

**Data Before Adjustment**

| | .015 | .020 | .030 | .040 | Average All Water Depth |
|---|---|---|---|---|---|
| **Treaded Tires:** | | | | | |
| **30** | 66 | 66 | 66 | 72 | 68 |
| **40** | 62 | 60 | 60 | 64 | 62 |
| **50** | 56 | 56 | 54 | 57 | 56 |
| **60** | 53 | 53 | 50 | 49 | 51 |
| **70** | 52 | 50 | 44 | 50 | 49 |
| **Bald Tires:** | | | | | |
| **30** | 65 | 49 | 67 | 51 | 58 |
| **40** | 61 | 45 | 62 | 42 | 52 |
| **50** | 55 | 41 | 54 | 40 | 48 |
| **60** | 49 | 37 | 50 | 34 | 42 |
| **70** | 47 | — | 45 | — | 46 |

Table A4. Site 4 — Mean Skid Numbers for Treaded and Bald Tires for the Different Test Speeds and Water Film Thicknesses. An S-5 Bituminous Concrete Mix in the WBPL of I-64 in Louisa County. (1 inch = 2.54 cm; 1 mph = .4470 m/s)

**Data Adjusted by use of Runkle's Correlation Curve**

**Correction Factor: .80**

| | | .015 | .020 | .030 | .040 | Average All Water Depth |
|---|---|---|---|---|---|---|
| **Treaded Tires:** | **30** | 55 | 55 | 56 | 59 | 56 |
| | **40** | 52 | 52 | 52 | 55 | 53 |
| | **50** | 49 | 48 | 48 | 50 | 49 |
| | **60** | 49 | 46 | 46 | 45 | 47 |
| | **70** | 47 | 45 | 42 | 41 | 44 |
| **Bald Tires:** | **30** | 57 | 44 | 59 | 44 | 51 |
| | **40** | 53 | 42 | 53 | 38 | 47 |
| | **50** | 53 | 38 | 51 | 34 | 44 |
| | **60** | 44 | 36 | 44 | 32 | 39 |
| | **70** | 45 | — | 42 | — | 44 |

**Data Before Adjustment**

| | | .015 | .020 | .030 | .040 | Average All Water Depth |
|---|---|---|---|---|---|---|
| **Treaded Tires:** | **30** | 69 | 69 | 70 | 74 | 70 |
| | **40** | 65 | 64 | 64 | 69 | 66 |
| | **50** | 62 | 60 | 60 | 62 | 61 |
| | **60** | 62 | 58 | 57 | 56 | 58 |
| | **70** | 58 | 57 | 53 | 51 | 55 |
| **Bald Tires:** | **30** | 71 | 54 | 74 | 55 | 64 |
| | **40** | 66 | 53 | 67 | 48 | 58 |
| | **50** | 66 | 47 | 64 | 43 | 55 |
| | **60** | 55 | 45 | 55 | 40 | 49 |
| | **70** | 56 | — | 52 | — | 54 |

Table A5. Site 5 — Mean Skid Numbers for Treaded and Bald Tires for the Different Test Speeds and Water Film Thicknesses. An S-1 Sand Asphalt Mix in the N&SBL's of Route 340 in Augusta County. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

**Data Adjusted by use of Runkie's Correlation Curve**

**Correction Factor: .69**

| | | .015 | .020 | .030 | .040 | Average All Water Depth |
|---|---|---|---|---|---|---|
| Treaded Tires: | 30 | 62 | 62 | 62 | 63 | 62 |
| | 40 | 54 | 54 | 54 | 54 | 54 |
| | 50 | 45 | 45 | 46 | 46 | 46 |
| | 60 | 40 | 38 | 38 | 38 | 39 |
| | 70 | 35 | 34 | 34 | 30 | 33 |
| Bald Tires: | 30 | 39 | 38 | 37 | 37 | 38 |
| | 40 | 29 | 27 | 28 | 26 | 27 |
| | 50 | 23 | 24 | 22 | 23 | 23 |
| | 60 | 21 | 20 | 17 | 18 | 19 |
| | 70 | 17 | 17 | 15 | 17 | 16 |

**Data Before Adjustment**

| | | .015 | .020 | .030 | .040 | Average All Water Depth |
|---|---|---|---|---|---|---|
| Treaded Tires: | 30 | 90 | 90 | 90 | 91 | 90 |
| | 40 | 78 | 78 | 78 | 78 | 78 |
| | 50 | 65 | 65 | 67 | 67 | 66 |
| | 60 | 58 | 55 | 55 | 55 | 56 |
| | 70 | 51 | 49 | 49 | 43 | 48 |
| Bald Tires: | 30 | 55 | 55 | 54 | 54 | 54 |
| | 40 | 42 | 38 | 40 | 38 | 40 |
| | 50 | 33 | 35 | 32 | 33 | 33 |
| | 60 | 30 | 29 | 25 | 26 | 28 |
| | 70 | 25 | 25 | 22 | 25 | 24 |

Table A6. Site 6 — Mean Skid Numbers for Treaded and Bald Tires for the Different Test Speeds and Water Film Thicknesses. A Portland Cement Concrete Surface in the SBTL of I-95 in Greenville County. (1 inch = 2.54 cm; 1 mph = .4470 m/s)

**Data Adjusted by use of Runkle's Correlation Curve**

**Correction Factor: .71**

| | .015 | .020 | .030 | .040 | Average All Water Depth |
|---|---|---|---|---|---|
| **Treaded Tires:** | | | | | |
| **30** | 38 | 37 | 37 | 36 | 37 |
| **40** | 33 | 32 | 32 | 32 | 32 |
| **50** | 30 | 29 | 28 | 28 | 29 |
| **60** | 25 | 26 | 26 | 24 | 25 |
| **70** | 23 | 23 | 23 | 23 | 23 |
| **Bald Tires:** | | | | | |
| **30** | 27 | 30 | 28 | 28 | 28 |
| **40** | 22 | 24 | 21 | 23 | 22 |
| **50** | 20 | 21 | 20 | 18 | 20 |
| **60** | 19 | 18 | 18 | 16 | 18 |
| **70** | 19 | 17 | 16 | 15 | 17 |

Data Before Adjustment

| | .015 | .020 | .030 | .040 | Average All Water Depth |
|---|---|---|---|---|---|
| **Treaded Tires:** | | | | | |
| **30** | 54 | 53 | 53 | 51 | 53 |
| **40** | 47 | 46 | 46 | 46 | 46 |
| **50** | 43 | 41 | 40 | 40 | 41 |
| **60** | 36 | 37 | 37 | 34 | 36 |
| **70** | 33 | 33 | 33 | 33 | 33 |
| **Bald Tires:** | | | | | |
| **30** | 38 | 43 | 40 | 40 | 40 |
| **40** | 31 | 34 | 30 | 33 | 32 |
| **50** | 28 | 30 | 28 | 26 | 28 |
| **60** | 27 | 26 | 26 | 23 | 26 |
| **70** | 27 | 24 | 23 | 21 | 24 |

*No data for 70 mph, 11/32 in., .020 in.

Table A7. Site 7 — Mean Skid Numbers for Treaded and Bald Tires for the Different Test Speeds and Water Film Thicknesses. A Portland Cement Concrete Surface in the SBPL of I-95 in Greenville County. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

**Data Adjusted by use of Runkle's Correlation Curve**

**Correction Factor: .75**

| | | .015 | .020 | .030 | .040 | Average All Water Depth |
|---|---|---|---|---|---|---|
| **Treaded Tires:** | **30** | 48 | 47 | 45 | 47 | 47 |
| | **40** | 42 | 41 | 41 | 42 | 42 |
| | **50** | 36 | 37 | 37 | 38 | 37 |
| | **60** | 33 | 34 | 32 | 32 | 33 |
| | **70** | 31 | 31 | 29 | 30 | 31 |
| **Bald Tires:** | **30** | 36 | 36 | 37 | 37 | 36 |
| | **40** | 31 | 30 | 29 | 29 | 30 |
| | **50** | 26 | 27 | 25 | 24 | 26 |
| | **60** | 23 | 23 | 22 | 24 | 23 |
| | **70** | 21 | 22 | 19 | 18 | 20 |

Data Before Adjustment

| | | .015 | .020 | .030 | .040 | Average All Water Depth |
|---|---|---|---|---|---|---|
| Treaded Tires: | **30** | 64 | 63 | 60 | 63 | 62 |
| | **40** | 56 | 55 | 55 | 56 | 56 |
| | **50** | 48 | 49 | 49 | 51 | 49 |
| | **60** | 44 | 45 | 43 | 43 | 44 |
| | **70** | 41 | 41 | 39 | 40 | 40 |
| Bald Tires: | **30** | 48 | 48 | 49 | 49 | 48 |
| | **40** | 41 | 40 | 39 | 39 | 40 |
| | **50** | 35 | 36 | 33 | 32 | 34 |
| | **60** | 31 | 31 | 29 | 32 | 30 |
| | **70** | 28 | 29 | 25 | 24 | 26 |

*No data for 70 mph, 9/32 in., .020 in.

Table A8. Site 8 — Mean Skid Numbers for Treaded and Bald Tires for the Different Test Speeds and Water Film Thicknesses. A Mechanically Chipped Surface in the SBTL of I-95 in Greenville County. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

**Data Adjusted by use of Runkle's Correlation Curve**

**Correction Factor: .73**

| | .015 | .020 | .030 | .040 | Average All Water Depth |
|---|---|---|---|---|---|
| **Treaded Tires:** | | | | | |
| **30** | 42 | 42 | 42 | 41 | 42 |
| **40** | 38 | 37 | 37 | 35 | 37 |
| **50** | 34 | 33 | 33 | 33 | 33 |
| **60** | 32 | 32 | 30 | 29 | 31 |
| **70** | 31 | 29 | 29 | 29 | 30 |
| **Bald Tires:** | | | | | |
| **30** | 40 | 37 | 37 | 35 | 37 |
| **40** | 35 | 34 | 33 | 32 | 34 |
| **50** | 32 | 31 | 29 | 28 | 30 |
| **60** | 29 | 28 | 28 | 26 | 28 |
| **70** | 30 | 26 | 27 | 24 | 27 |

**Data Before Adjustment**

| | .015 | .020 | .030 | .040 | Average All Water Depth |
|---|---|---|---|---|---|
| **Treaded Tires:** | | | | | |
| **30** | 58 | 58 | 58 | 56 | 58 |
| **40** | 52 | 51 | 51 | 48 | 50 |
| **50** | 46 | 45 | 45 | 45 | 45 |
| **60** | 44 | 44 | 41 | 40 | 42 |
| **70** | 42 | 40 | 40 | 40 | 40 |
| **Bald Tires:** | | | | | |
| **30** | 55 | 51 | 51 | 48 | 51 |
| **40** | 48 | 46 | 45 | 44 | 46 |
| **50** | 44 | 42 | 40 | 38 | 41 |
| **60** | 40 | 40 | 40 | 36 | 39 |
| **70** | 41 | 36 | 37 | 33 | 37 |

*No data for 70 mph, 11/32-in., .020 in.

Table A9. Site 9 — Mean Skid Numbers for Treaded and Bald Tires for the Different Test Speeds and Water Film Thicknesses. A Mechanically Chipped Surface in the SBPL of I-95 in Greenville County. (1 inch = 2.54 cm; 1 mph = .4470 m/s)

**Data Adjusted by use of Runkle's Correlation Curve**

**Correction Factor: .83**

| | | .015 | .020 | .030 | .040 | Average All Water Depth |
|---|---|---|---|---|---|---|
| Treaded Tires: | 30 | 51 | 48 | 51 | 51 | 50 |
| | 40 | 44 | 46 | 45 | 44 | 45 |
| | 50 | 41 | 42 | 40 | 41 | 41 |
| | 60 | 38 | 38 | 36 | 36 | 37 |
| | 70 | 38 | 37 | 35 | 34 | 36 |
| Bald Tires: | 30 | 46 | 46 | 43 | 43 | 44 |
| | 40 | 39 | 41 | 37 | 37 | 38 |
| | 50 | 36 | 36 | 35 | 35 | 36 |
| | 60 | 33 | 33 | 30 | 31 | 32 |
| | 70 | 30 | 32 | 27 | 27 | 29 |

Data Before Adjustment

| | | .015 | .020 | .030 | .040 | Average All Water Depth |
|---|---|---|---|---|---|---|
| Treaded Tires: | 30 | 61 | 58 | 61 | 61 | 60 |
| | 40 | 53 | 55 | 54 | 53 | 54 |
| | 50 | 49 | 51 | 48 | 49 | 49 |
| | 60 | 46 | 46 | 43 | 43 | 44 |
| | 70 | 46 | 44 | 42 | 41 | 43 |
| Bald Tires: | 30 | 55 | 55 | 52 | 52 | 54 |
| | 40 | 47 | 49 | 44 | 44 | 46 |
| | 50 | 43 | 43 | 42 | 42 | 42 |
| | 60 | 40 | 40 | 36 | 37 | 38 |
| | 70 | 36 | 38 | 32 | 32 | 34 |

Table A10. Site 10 — Mean Skid Numbers for Treaded and Bald Tires for the Different Test Speeds and Water Film Thicknesses. An S-5 Bituminous Concrete Mix in the EBTL of I-264 in Chesapeake. ( 1 inch = 2.54 cm; 1 mph= .4470 m/s)

**Data Adjusted by use of Runkle's Correlation Curve**

**Correction Factor: .80**

| | | .015 | .020 | .030 | .040 | Average All Water Depth |
|---|---|---|---|---|---|---|
| **Treaded Tires:** | 30 | 54 | 55 | 49 | 53 | 53 |
| | 40 | 49 | 50 | 48 | 49 | 49 |
| | 50 | 46 | 46 | 43 | 45 | 45 |
| | 60 | 44 | 43 | 41 | 42 | 42 |
| | 70 | 42 | 41 | 37 | 38 | 40 |
| **Bald Tires:** | 30 | 48 | 45 | 46 | 46 | 46 |
| | 40 | 38 | 37 | 50 | 37 | 40 |
| | 50 | 36 | 31 | 36 | 35 | 34 |
| | 60 | 31 | 29 | 34 | 30 | 31 |
| | 70 | 31 | 32 | 31 | 31 | 31 |

Data Before Adjustment

| | | .015 | .020 | .030 | .040 | Average All Water Depth |
|---|---|---|---|---|---|---|
| Treaded Tires: | 30 | 68 | 69 | 61 | 67 | 66 |
| | 40 | 62 | 63 | 60 | 61 | 62 |
| | 50 | 58 | 58 | 54 | 57 | 57 |
| | 60 | 55 | 54 | 52 | 53 | 54 |
| | 70 | 53 | 52 | 46 | 48 | 50 |
| Bald Tires: | 30 | 60 | 56 | 58 | 58 | 58 |
| | 40 | 48 | 46 | 63 | 46 | 51 |
| | 50 | 45 | 39 | 45 | 44 | 43 |
| | 60 | 39 | 36 | 42 | 37 | 38 |
| | 70 | 39 | 40 | 39 | 39 | 39 |

Table A11. Site 11 — Mean Skid Numbers for Treaded and Bald Tires for the Different Test Speeds and Water Film Thicknesses. An S-5 Bituminous Concrete Mix in the WBTL of I-264 in Chesapeake. (1 inch = 2.54 cm; 1 mph = .4470 m/s)

**Data Adjusted by use of Runkle's Correlation Curve**

**Correction Factor: .80**

| | | .015 | .020 | .030 | .040 | Average All Water Depth |
|---|---|---|---|---|---|---|
| **Treaded Tires:** | **30** | 53 | 54 | 47 | 53 | 52 |
| | **40** | 50 | 50 | 47 | 48 | 49 |
| | **50** | 45 | 46 | 44 | 45 | 45 |
| | **60** | 44 | 44 | 44 | 43 | 44 |
| | **70** | 43 | 41 | 41 | 41 | 42 |
| **Bald Tires:** | **30** | 49 | 46 | 48 | 46 | 48 |
| | **40** | 45 | 41 | 42 | 41 | 42 |
| | **50** | 40 | 39 | 39 | 37 | 39 |
| | **60** | 36 | 34 | 36 | 35 | 35 |
| | **70** | 33 | 31 | 34 | 34 | 33 |

**Data Before Adjustment**

| | | .015 | .020 | .030 | .040 | Average All Water Depth |
|---|---|---|---|---|---|---|
| **Treaded Tires:** | **30** | 66 | 68 | 59 | 66 | 65 |
| | **40** | 63 | 63 | 59 | 60 | 61 |
| | **50** | 57 | 58 | 55 | 57 | 57 |
| | **60** | 55 | 55 | 55 | 54 | 55 |
| | **70** | 54 | 52 | 51 | 51 | 52 |
| **Bald Tires:** | **30** | 62 | 58 | 60 | 58 | 60 |
| | **40** | 57 | 52 | 53 | 51 | 53 |
| | **50** | 50 | 47 | 49 | 46 | 48 |
| | **60** | 45 | 43 | 45 | 44 | 44 |
| | **70** | 41 | 39 | 42 | 43 | 41 |

Table A12. Site 12 — Mean Skid Numbers for Treaded and Bald Tires for the Different Test Speeds and Water Film Thicknesses. An S-5 Bituminous Concrete Mix in the EBPL of I-264 in Chesapeake. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

**Data Adjusted by use of Runkle's Correlation Curve**

**Correction Factor: .80**

| | .015 | .020 | .030 | .040 | Average All Water Depth |
|---|---|---|---|---|---|
| **Treaded Tires:** | | | | | |
| **30** | 53 | 54 | 53 | 52 | 53 |
| **40** | 50 | 50 | 49 | 50 | 50 |
| **50** | 48 | 49 | 47 | 47 | 48 |
| **60** | 48 | 47 | 45 | 45 | 46 |
| **70** | 48 | 45 | 44 | 45 | 46 |
| **Bald Tires:** | | | | | |
| **30** | 50 | 50 | 48 | 49 | 49 |
| **40** | 47 | 45 | 46 | 43 | 45 |
| **50** | 44 | 41 | 41 | 38 | 41 |
| **60** | 43 | 38 | 39 | 34 | 38 |
| **70** | 40 | 36 | 37 | 34 | 37 |

Data Before Adjustment

| | .015 | .020 | .030 | .040 | Average All Water Depth |
|---|---|---|---|---|---|
| **Treaded Tires:** | | | | | |
| **30** | 67 | 68 | 66 | 65 | 66 |
| **40** | 63 | 63 | 62 | 63 | 63 |
| **50** | 60 | 62 | 59 | 59 | 60 |
| **60** | 60 | 59 | 57 | 56 | 58 |
| **70** | 61 | 57 | 55 | 56 | 57 |
| **Bald Tires:** | | | | | |
| **30** | 63 | 63 | 60 | 62 | 62 |
| **40** | 59 | 56 | 58 | 54 | 57 |
| **50** | 55 | 51 | 52 | 48 | 52 |
| **60** | 54 | 48 | 49 | 43 | 48 |
| **70** | 50 | 45 | 47 | 43 | 46 |

Table A13. Site 13 — Mean Skid Numbers for Treaded and Bald Tires for the Different Test Speeds and Water Film Thicknesses. An S-5 Bituminous Concrete Mix in the WBPL of I-264 in Chesapeake. (1 inch = 2.54 cm; 1 mph = .4470 m/s)

**Data Adjusted by use of Runkle's Correlation Curve**

**Correction Factor: .80**

| | .015 | .020 | .030 | .040 | Average All Water Depth |
|---|---|---|---|---|---|
| **Treaded Tires:** | | | | | |
| **30** | 53 | 53 | 53 | 52 | 53 |
| **40** | 51 | 51 | 49 | 49 | 50 |
| **50** | 48 | 48 | 46 | 46 | 47 |
| **60** | 48 | 47 | 45 | 44 | 46 |
| **70** | 48 | 45 | 44 | 45 | 46 |
| **Bald Tires:** | | | | | |
| **30** | 49 | 49 | 49 | 47 | 48 |
| **40** | 47 | 46 | 45 | 47 | 46 |
| **50** | 43 | 41 | 42 | 38 | 41 |
| **60** | 41 | 38 | 38 | 37 | 38 |
| **70** | 41 | 37 | 37 | 34 | 37 |

Data Before Adjustment

| | .015 | .020 | .030 | .040 | Average All Water Depth |
|---|---|---|---|---|---|
| **Treaded Tires:** | | | | | |
| **30** | 67 | 67 | 66 | 65 | 66 |
| **40** | 64 | 64 | 62 | 61 | 63 |
| **50** | 60 | 60 | 58 | 58 | 59 |
| **60** | 60 | 59 | 56 | 55 | 58 |
| **70** | 61 | 57 | 55 | 57 | 58 |
| **Bald Tires:** | | | | | |
| **30** | 62 | 62 | 62 | 60 | 62 |
| **40** | 59 | 58 | 56 | 59 | 58 |
| **50** | 54 | 51 | 53 | 48 | 52 |
| **60** | 52 | 48 | 48 | 46 | 48 |
| **70** | 51 | 47 | 47 | 42 | 47 |

Table A14. Site 14 — Mean Skid Numbers for Treaded and Bald Tires for the Different Test Speeds and Water Film Thicknesses. A Bituminous-Urban Mix in the SBTL of I-381 in Bristol. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

| | .015 | .020 | .030 | .040 | Average All Water Depth |
|---|---|---|---|---|---|
| Treaded Tires: | | | | | |
| 20 | | 61 | | | |
| 30 | | 56 | | | |
| 40 | | 46 | | | |
| 50 | | 50 | | | |
| 60 | | 48 | | | |
| Bald Tires: | | | | | |
| 20 | | 59 | | | |
| 30 | | 60 | | | |
| 40 | | 50 | | | |
| 50 | | 48 | | | |
| 60 | | 46 | | | |

*New and bald run on for .020 water with speeds 20 - 60 mph.

Table A15. Site 15 — Mean Skid Numbers for Treaded and Bald Tires for the Different Test Speeds and Water Film Thicknesses. A Bituminous-Urban Mix in the SBPL of I-381 in Bristol. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

| | .015 | .020 | .030 | .040 | Average All Water Depth |
|---|---|---|---|---|---|
| Treaded Tires: | | | | | |
| 20 | | 65 | | | |
| 30 | | 59 | | | |
| 40 | | 55 | | | |
| 50 | | 51 | | | |
| 60 | | 49 | | | |
| Bald Tires: | | | | | |
| 20 | | 62 | | | |
| 30 | | 59 | | | |
| 40 | | 55 | | | |
| 50 | | 51 | | | |
| 60 | | 49 | | | |

Table A16. Site 16 — Mean Skid Numbers for Treaded and Bald Tires for the Different Test Speeds and Water Film Thicknesses. An Open-Graded Bituminous Mix (Popcorn) in the NBTL of I-81 in Augusta County. ( 1 inch = 2.54 cm: 1 mph = .4470 m/s)

| | .015 | .020 | .030 | .040 | Average All Water Depth |
|---|---|---|---|---|---|
| **Treaded Tires:** | | | | | |
| **30** | 50 | 50 | 52 | 49 | 50 |
| **40** | 49 | 50 | 50 | 50 | 50 |
| **50** | 48 | 48 | 48 | 48 | 48 |
| **60** | 48 | 46 | 48 | 46 | 47 |
| **70** | 47 | 46 | 44 | 44 | 45 |
| **Bald Tires:** | | | | | |
| **30** | 52 | 56 | 56 | 57 | 55 |
| **40** | 49 | 50 | 50 | 52 | 50 |
| **50** | 52 | 49 | 48 | 50 | 50 |
| **60** | 51 | 46 | 48 | 49 | 48 |
| **70** | 47 | 47 | 47 | 48 | 47 |

Table A17. Site 17 — Mean Skid Numbers for Treaded and Bald Tires for the Different Test Speeds and Water Film Thicknesses. An Open-Graded Bituminous Mix (Popcorn) in the SBPL of I-81 in Augusta County. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

| | .015 | .020 | .030 | .040 | Average All Water Depth |
|---|---|---|---|---|---|
| **Treaded Tires:** | | | | | |
| **30** | 50 | 49 | 51 | 50 | 50 |
| **40** | 48 | 47 | 48 | 47 | 47 |
| **50** | 48 | 45 | 47 | 47 | 46 |
| **60** | 48 | 45 | 45 | 44 | 46 |
| **70** | 50 | 46 | 44 | 45 | 46 |
| **Bald Tires:** | | | | | |
| **30** | 51 | 52 | 49 | 52 | 51 |
| **40** | 48 | 49 | 49 | 47 | 48 |
| **50** | 50 | 46 | 49 | 46 | 48 |
| **60** | 51 | 46 | 46 | 44 | 47 |
| **70** | 50 | 46 | 45 | 46 | 46 |

Table A18. Site 18 — Mean Skid Numbers for Treaded and Bald Tires for the Different Test Speeds and Water Film Thicknesses. An S-5 Bituminous Concrete Mix in the NBTL of I-81 in Augusta County. (1 inch = 2.54 cm; 1 mph = .4470 m/s)

| | | .015 | .020 | .030 | .040 | Average All Water Depth |
|---|---|---|---|---|---|---|
| Treaded Tires: | 30 | 55 | 52 | 53 | 52 | 53 |
| | 40 | 52 | 51 | 49 | 48 | 50 |
| | 50 | 49 | 46 | 44 | 43 | 46 |
| | 60 | 47 | 43 | 40 | 39 | 42 |
| | 70 | 47 | 39 | 35 | 35 | 39 |
| Bald Tires: | 30 | 54 | 58 | 58 | 62 | 58 |
| | 40 | 51 | 50 | 52 | 50 | 51 |
| | 50 | 50 | 45 | 47 | 45 | 47 |
| | 60 | 47 | 42 | 40 | 40 | 42 |
| | 70 | 41 | 39 | 39 | 40 | 40 |

Table A19. Site 19 — Mean Skid Numbers for Treaded and Bald Tires for the Different Test Speeds and Water Film Thicknesses. An S-5 Bituminous Concrete Mix in the SBPL of I-81 in Augusta County. (1 inch = 2.54 cm; 1 mph = .4470 m/s)

| | | .015 | .020 | .030 | .040 | Average All Water Depth |
|---|---|---|---|---|---|---|
| Treaded Tires: | 30 | 58 | 55 | 55 | 54 | 56 |
| | 40 | 54 | 55 | 51 | 51 | 53 |
| | 50 | 54 | 51 | 47 | 46 | 50 |
| | 60 | 52 | 47 | 43 | 42 | 46 |
| | 70 | 51 | 45 | 40 | 40 | 44 |
| Bald Tires: | 30 | 55 | 58 | 56 | 57 | 57 |
| | 40 | 50 | 53 | 53 | 50 | 51 |
| | 50 | 52 | 49 | 48 | 45 | 48 |
| | 60 | 53 | 46 | 46 | 42 | 47 |
| | 70 | 54 | 47 | 43 | 43 | 47 |

Table A20. Site 20 — Mean Skid Numbers for Treaded and Bald Tires for the Different Test Speeds and Water Film Thicknesses. A Portland Cement Concrete Surface in the EBTL of I-64 in New Kent County. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

| | .015 | .020 | .030 | .040* | Average All Water Depth |
|---|---|---|---|---|---|
| **Treaded Tires:** | | | | | |
| 30 | 64 | 57 | 55 | 63 | 60 |
| 40 | 59 | 57 | 54 | 64 | 58 |
| 50 | 60 | 51 | 54 | 58 | 56 |
| 60 | 55 | 54 | 49 | 54 | 53 |
| 70 | 51 | 51 | 46 | 46 | 48 |
| **Bald Tires:** | | | | | |
| 30 | 52 | 63 | 60 | 63 | 60 |
| 40 | 51 | 57 | 52 | 58 | 54 |
| 50 | 46 | 53 | 44 | 57 | 50 |
| 60 | 43 | 52 | 37 | 51 | 46 |
| 70 | 40 | 47 | 37 | 43 | 42 |

*No data for : .040 3/32 all speeds

Table A21. Site 21 — Mean Skid Numbers for Treaded and Bald Tires for the Different Test Speeds and Water Film Thicknesses. A Portland Cement Concrete Surface in the WBPL of I-64 in New Kent County. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

| | .015 | .020 | .030 | .040* | Average All Water Depth |
|---|---|---|---|---|---|
| **Treaded Tires:** | | | | | |
| 30 | 73 | 73 | 69 | 71 | 72 |
| 40 | 67 | 64 | 64 | 69 | 66 |
| 50 | 66 | 63 | 59 | 64 | 63 |
| 60 | 62 | 60 | 56 | 60 | 59 |
| 70 | 57 | 58 | 54 | 58 | 57 |
| **Bald Tires:** | | | | | |
| 30 | 72 | 77 | 77 | 75 | 75 |
| 40 | 67 | 70 | 62 | 72 | 68 |
| 50 | 59 | 63 | 57 | 65 | 61 |
| 60 | 57 | 63 | 50 | 63 | 58 |
| 70 | 47 | 65 | 49 | 53 | 53 |

*No data for .040 3/32 all speeds

Table A22. Site 22 — Mean Skid Numbers for Treaded and Bald Tires for the Different Test Speeds and Water Film Thicknesses. A Portland Cement Concrete Surface in the EBTL of I-64 in Henrico County. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

| | | .015 | .020 | .030 | .040* | Average All Water Depth |
|---|---|---|---|---|---|---|
| Treaded Tires: | 30 | 48 | 53 | 48 | 43 | 50 |
| | 40 | 46 | 43 | 44 | 38 | 44 |
| | 50 | 45 | 36 | 35 | 35 | 39 |
| | 60 | 38 | 36 | 34 | 22 | 36 |
| | 70 | 42 | 37 | 36 | 22 | 38 |
| Bald Tires: | 30 | 36 | 46 | 59 | 43 | 47 |
| | 40 | 33 | 38 | 55 | 33 | 42 |
| | 50 | 24 | 38 | 52 | 24 | 38 |
| | 60 | 24 | 26 | 48 | 25 | 33 |
| | 70 | 24 | 24 | 43 | 17 | 30 |

*.040 water depth used only a 3/32 tire, so average will not include .040 water depth

Table A23. Site 23 — Mean Skid Numbers for Treaded and Bald Tires for the Different Test Speeds and Water Film Thicknesses. A Portland Cement Concrete Surface in the EBPL of I-64 in Henrico County. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

| | | .015 | .020 | .030 | .040* | Average All Water Depth |
|---|---|---|---|---|---|---|
| Treaded Tires: | 30 | 56 | 57 | 57 | 53 | 57 |
| | 40 | 53 | 51 | 52 | 48 | 52 |
| | 50 | 49 | 43 | 43 | 36 | 45 |
| | 60 | 45 | 40 | 41 | 36 | 42 |
| | 70 | 41 | 35 | 34 | 28 | 37 |
| Bald Tires: | 30 | 52 | 58 | 47 | 49 | 52 |
| | 40 | 45 | 45 | 43 | 39 | 44 |
| | 50 | 37 | 28 | 32 | 31 | 32 |
| | 60 | 31 | 29 | 27 | 28 | 29 |
| | 70 | 28 | 22 | 23 | 28 | 24 |

* .040 water depth used only 3/32 tire, so average will not include .040 water depth

Table A24. Site 24 — Mean Skid Numbers for Treaded and Bald Tires for the Different Test Speeds and Water Film Thicknesses. A Grooved Portland Cement Concrete Surface in the EBTL of I-64 in Henrico County. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

| | | .015 | .020 | .030 | .040* | Average All Water Depth |
|---|---|---|---|---|---|---|
| Treaded Tires: | 30 | 48 | 49 | 50 | 50 | 49 |
| | 40 | 47 | 48 | 48 | 46 | 48 |
| | 50 | 44 | 41 | 44 | 43 | 43 |
| | 60 | 41 | 39 | 42 | 39 | 41 |
| | 70 | 40 | 38 | 39 | 36 | 39 |
| Bald Tires: | 30 | 60 | 58 | 59 | 58 | 59 |
| | 40 | 53 | 58 | 55 | 54 | 55 |
| | 50 | 48 | 53 | 52 | 50 | 51 |
| | 60 | 46 | 49 | 48 | 48 | 48 |
| | 70 | 40 | 48 | 43 | 40 | 44 |

*.040 water depth used only a 3/32 tire, so ayerage will not include .040 water depth

Table A25. Site 25 — Mean Skid Numbers for Treaded and Bald Tires for the Different Test Speeds and Water Film Thicknesses. A Grooved Portland Cement Concrete Surface in the EBPL of I-64 in Henrico County. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

| | | .015 | .020 | .030 | .040 * | Average All Water Depth |
|---|---|---|---|---|---|---|
| Treaded Tires: | 30 | 54 | 55 | 58 | 57 | 56 |
| | 40 | 52 | 52 | 53 | 54 | 52 |
| | 50 | 48 | 49 | 50 | 46 | 49 |
| | 60 | 47 | 44 | 45 | 43 | 45 |
| | 70 | 43 | 38 | 39 | 40 | 40 |
| Bald Tires: | 30 | 65 | 64 | 69 | 65 | 66 |
| | 40 | 59 | 61 | 60 | 59 | 60 |
| | 50 | 37 | 56 | 57 | 54 | 50 |
| | 60 | 57 | 52 | 56 | 43 | 55 |
| | 70 | 48 | 48 | 38 | 32 | 45 |

*.040 water depth used only a 3/32 tire, so average will not include .040 water depth

Table A26. Site 26 — Mean Skid Numbers for Treaded and Bald Tires for the Different Test Speeds and Water Film Thicknesses. A Surface Treatment in the NBPL of Route 1 in Caroline County. (1 inch = 2.54 cm; 1 mph = .4470 m/s)

| | .015 | .020 | .030 | .040 | Average All Water Depth |
|---|---|---|---|---|---|
| **Treaded Tires:** | | | | | |
| 30 | 53 | 53 | 48 | 51 | 51 |
| 40 | 50 | 50 | 44 | 47 | 48 |
| 50 | 49 | 48 | 42 | 44 | 46 |
| 60 | 37 | 47 | 41 | 42 | 42 |
| 70 | 48 | 48 | 40 | 39 | 43 |
| **Bald Tires:** | | | | | |
| 30 | 44 | 47 | 46 | 47 | 46 |
| 40 | 45 | 44 | 44 | 43 | 44 |
| 50 | 46 | 44 | 42 | 41 | 43 |
| 60 | 43 | 43 | 36 | 37 | 40 |
| 70 | 44 | 42 | 38 | 32 | 39 |

Table A27. Site 27 — Mean Skid Numbers for Treaded and Bald Tires for the Different Test Speeds and Water Film Thicknesses. A Surface Treatment in the SBTL of Route 1 in Caroline County. (1 inch = 2.54 cm; 1 mph = .4470 m/s)

| | .015 | .020 | .030 | .040 | Average All Water Depth |
|---|---|---|---|---|---|
| **Treaded Tires:** | | | | | |
| 30 | 43 | 45 | 37 | 42 | 42 |
| 40 | 38 | 42 | 33 | 37 | 38 |
| 50 | 36 | 39 | 32 | 34 | 35 |
| 60 | 35 | 36 | 30 | 30 | 33 |
| 70 | 33 | 34 | 28 | 27 | 31 |
| **Bald Tires:** | | | | | |
| 30 | 42 | 40 | 40 | 37 | 40 |
| 40 | 39 | 36 | 34 | 32 | 35 |
| 50 | 36 | 33 | 33 | 30 | 33 |
| 60 | 35 | 33 | 30 | 24 | 31 |
| 70 | 34 | 29 | 25 | 25 | 28 |

Table A28. Site 28 — Mean Skid Numbers for Treaded and Bald Tires for the Different Test Speeds and Water Film Thicknesses. A Surface Treatment in the NBPL of Route 1 in Hanover County. (1 inch = 2.54 cm; 1 mph = .4470 m/s)

| | .015 | .020 | .030 | .040 | Average All Water Depth |
|---|---|---|---|---|---|
| **Treaded Tires:** | | | | | |
| **30** | 54 | 56 | 50 | 54 | 53 |
| **40** | 50 | 52 | 46 | 47 | 49 |
| **50** | 51 | 53 | 44 | 45 | 48 |
| **60** | 51 | 50 | 44 | 43 | 47 |
| **70** | 51 | 54 | 39 | 40 | 46 |
| **Bald Tires:** | | | | | |
| **30** | 48 | 50 | 47 | 47 | 48 |
| **40** | 46 | 43 | 44 | 43 | 44 |
| **50** | 45 | 44 | 43 | 41 | 43 |
| **60** | 46 | 46 | 41 | 46 | 45 |
| **70** | 46 | 41 | 40 | 36 | 41 |

Table A29. Site 29 — Mean Skid Numbers for Treaded and Bald Tires for the Different Test Speeds and Water Film Thicknesses. A Surface Treatment in the SBTL of Route 1 in Hanover County. (1 inch = 2.54 cm; 1 mph = .4470 m/s)

| | .015 | .020 | .030 | .040 | Average All Water Depth |
|---|---|---|---|---|---|
| **Treaded Tires:** | | | | | |
| **30** | 44 | 49 | 41 | 45 | 45 |
| **40** | 42 | 44 | 36 | 40 | 41 |
| **50** | 38 | 42 | 32 | 38 | 37 |
| **60** | 37 | 40 | 31 | 35 | 36 |
| **70** | 36 | 36 | 31 | 30 | 34 |
| **Bald Tires:** | | | | | |
| **30** | 42 | 43 | 43 | 38 | 41 |
| **40** | 42 | 42 | 42 | 37 | 41 |
| **50** | 39 | 40 | 38 | 30 | 37 |
| **60** | 40 | 37 | 26 | 27 | 32 |
| **70** | 42 | 28 | 26 | 22 | 29 |

Table A30. Site 30 — Mean Skid Numbers for Treaded and Bald Tires for the Different Test Speeds and Water Film Thicknesses. An S-5 Bituminous Concrete Mix in the WBPL of Route 460 in Bedford County. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

| | | .015 | .020 | .030 | .040 | Average All Water Depth |
|---|---|---|---|---|---|---|
| **Treaded Tires:** | **30** | 57 | 57 | 52 | 54 | 55 |
| | **40** | 53 | 48 | 44 | 48 | 48 |
| | **50** | 51 | 46 | 48 | 44 | 47 |
| | **60** | 49 | 39 | 39 | 37 | 41 |
| | **70** | 47 | 39 | 40 | 38 | 41 |
| **Bald Tires:** | **30** | 43 | 41 | 39 | 40 | 41 |
| | **40** | 41 | 36 | 33 | 36 | 36 |
| | **50** | 42 | 30 | 29 | 26 | 32 |
| | **60** | 35 | 28 | 24 | 28 | 29 |
| | **70** | 39 | 30 | 26 | 21 | 29 |

Table A31. Site 31 — Mean Skid Numbers for Treaded and Bald Tires for the Different Test Speeds and Water Film Thicknesses. An S-5 Bituminous Concrete Mix in the EBTL of Route 460 in Bedford County. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s

| | | .015 | .020 | .030 | .040 | Average All Water Depth |
|---|---|---|---|---|---|---|
| **Treaded Tires:** | **30** | 48 | 47 | 46 | 48 | 47 |
| | **40** | 42 | 40 | 38 | 37 | 39 |
| | **50** | 35 | 33 | 28 | 31 | 32 |
| | **60** | 30 | 29 | 26 | 26 | 28 |
| | **70** | 27 | 26 | 24 | 23 | 25 |
| **Bald Tires:** | **30** | 34 | 32 | 32 | 32 | 33 |
| | **40** | 26 | 21 | 23 | 20 | 23 |
| | **50** | 21 | 16 | 15 | 16 | 17 |
| | **60** | 17 | 12 | 12 | 9 | 13 |
| | **70** | 16 | 11 | 10 | 7 | 11 |

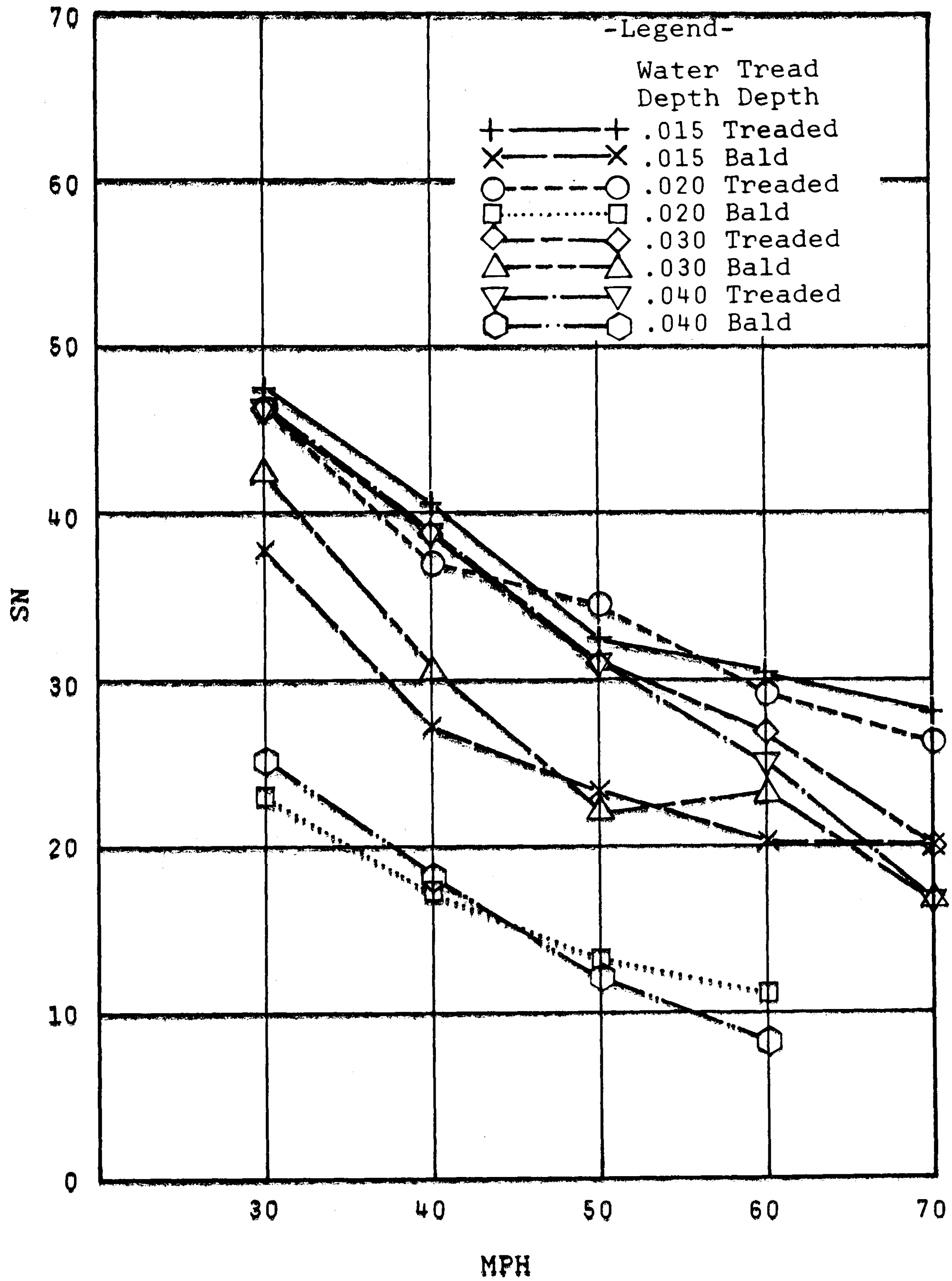


Figure A1. Site 1 — Speed gradient curves for treaded and bald tires for each water film. A portland cement concrete mix in the EBTL of I-64 in Fluvanna County. (1 inch = 2.54 cm; 1 mph = .4470 m/s)

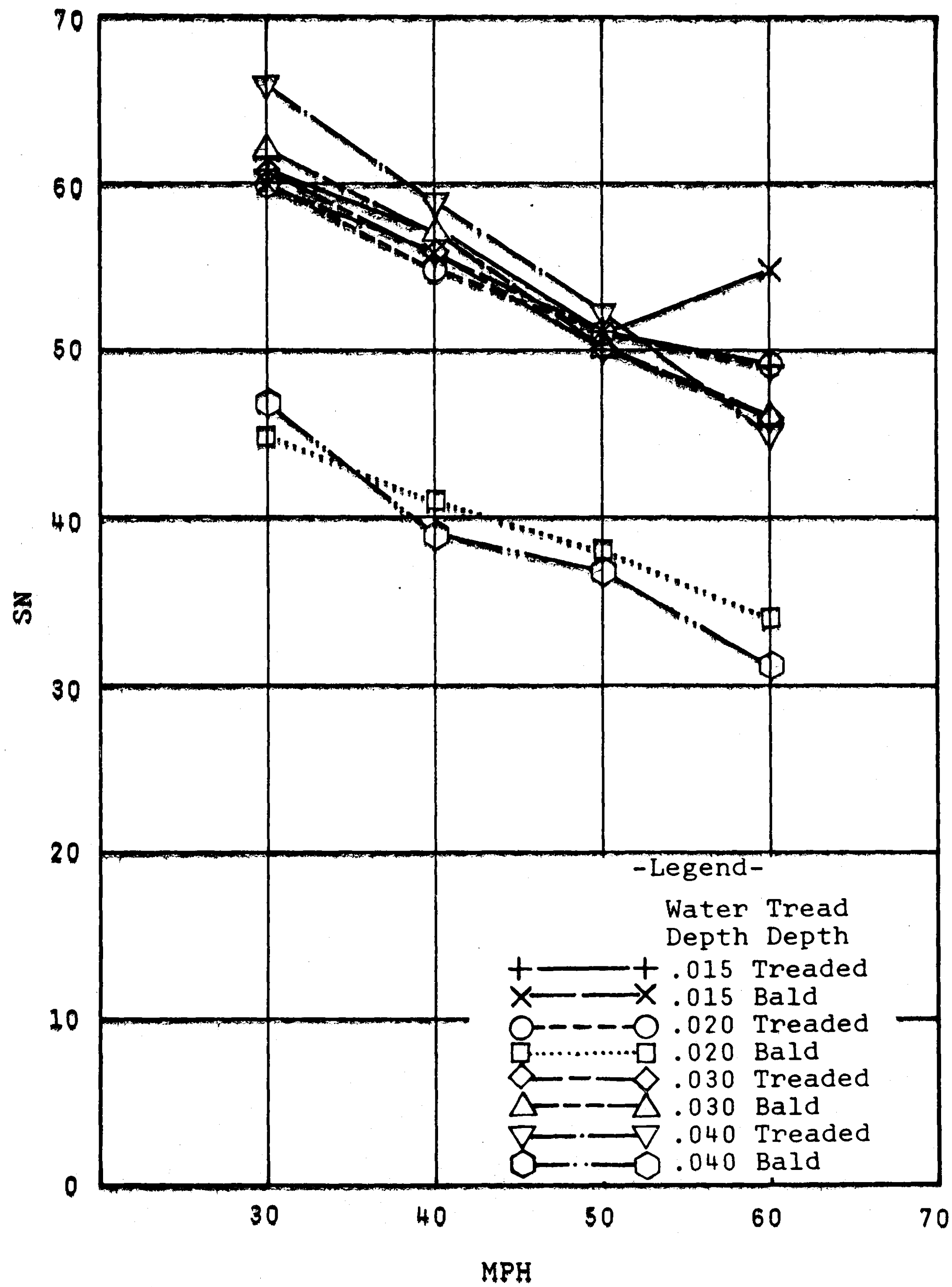


Figure A2. Site 2 — Speed gradient curves for treaded and bald tires for each water film. A portland cement concrete mix in the WBPL of I-64 in Louisa County. (1 inch = 2.54 cm; 1 mph = .4470 m/s)

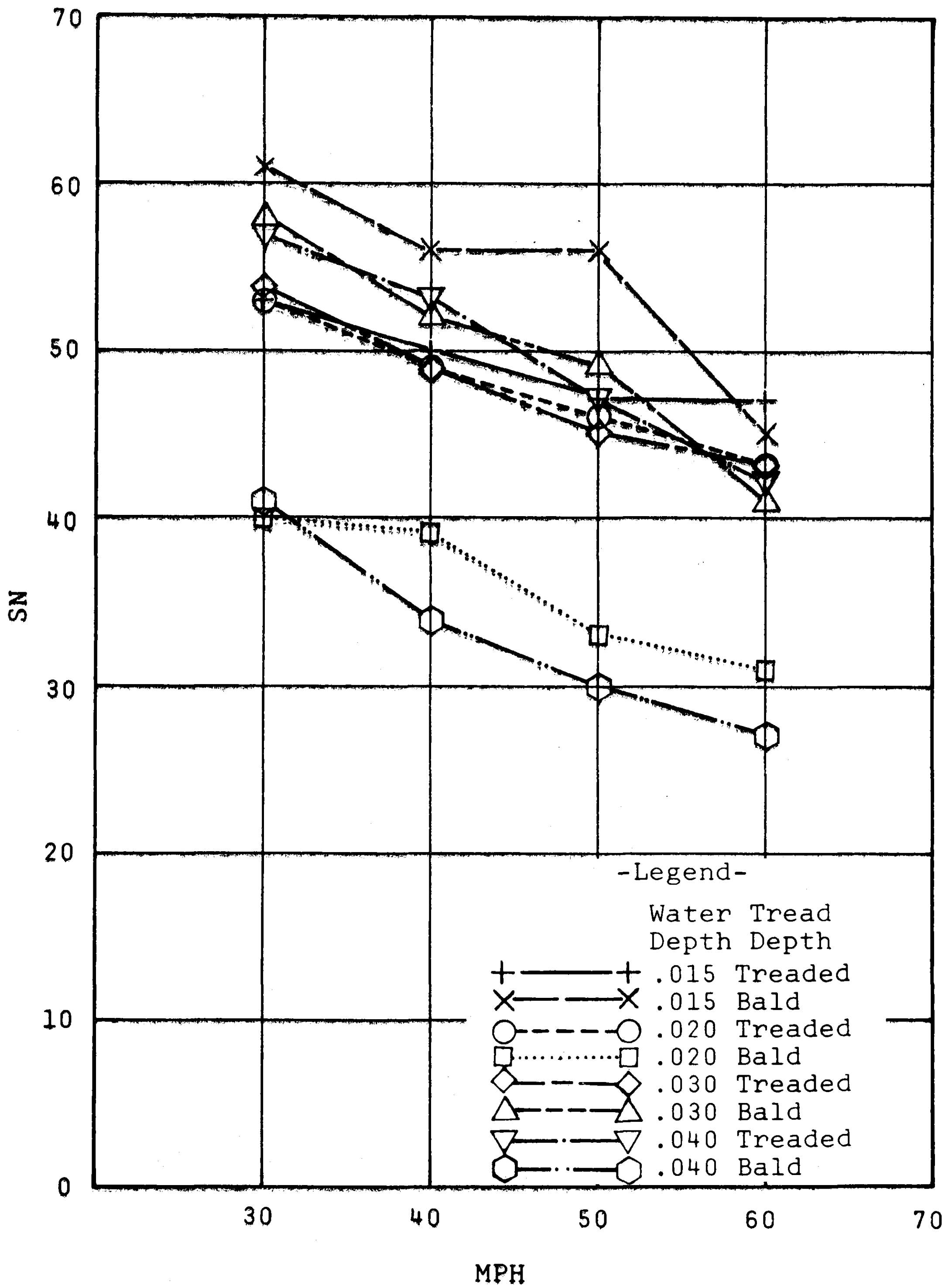


Figure A3. Site 3 — Speed gradient curves for treaded and bald tires for each water film. An S-5 bituminous mix in the EBTL of I-64 in Louisa County. (1 inch = 2.54 cm; 1 mph = .4470 m/s)

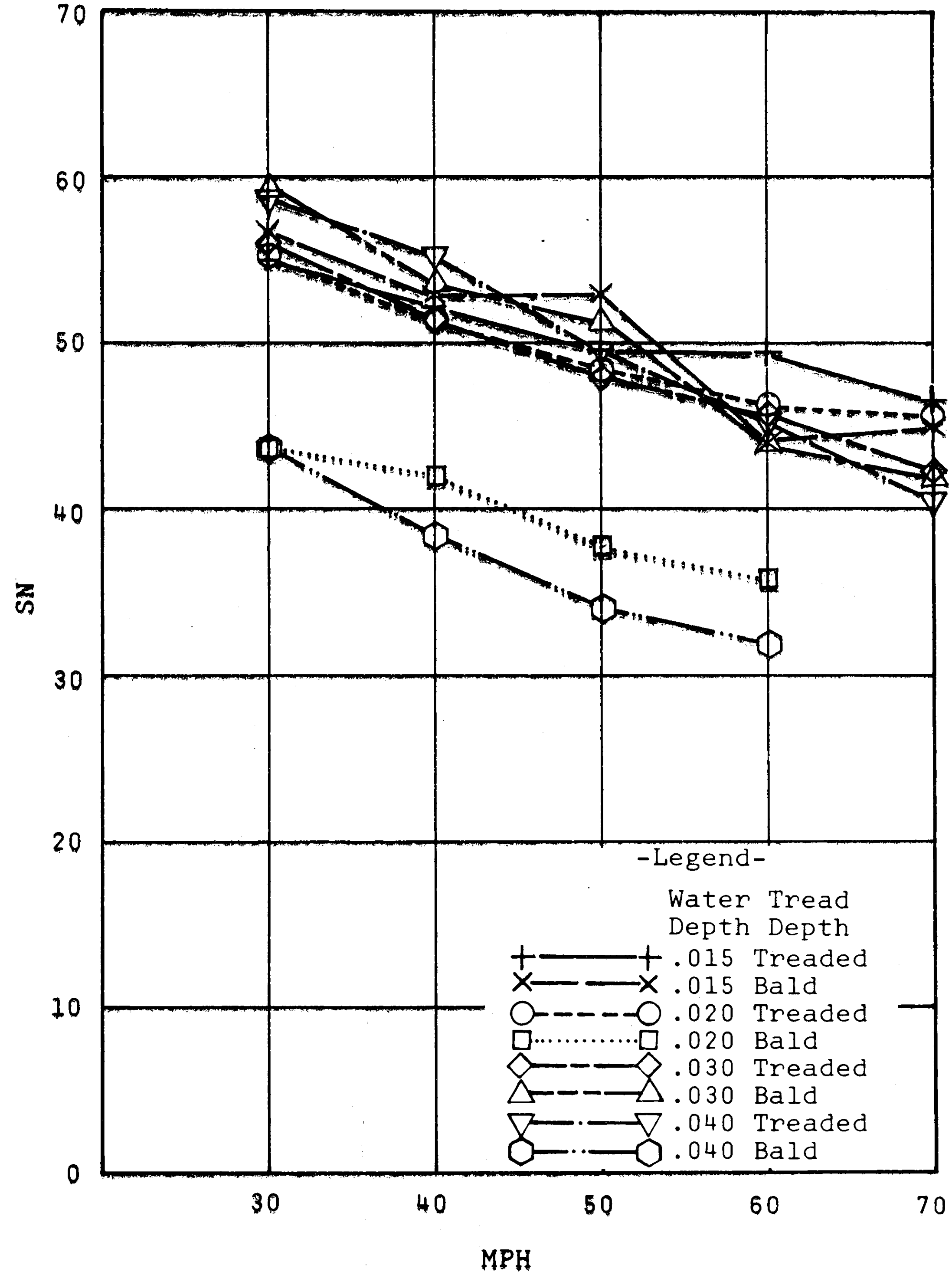


Figure A4. Site 4 — Speed gradient curves for treaded and bald tires for each water film. An S-5 bituminous concrete mix in the WBPL of I-64 in Louisa County. (1 inch = 2.54 cm; 1 mph = .4470 m/s)

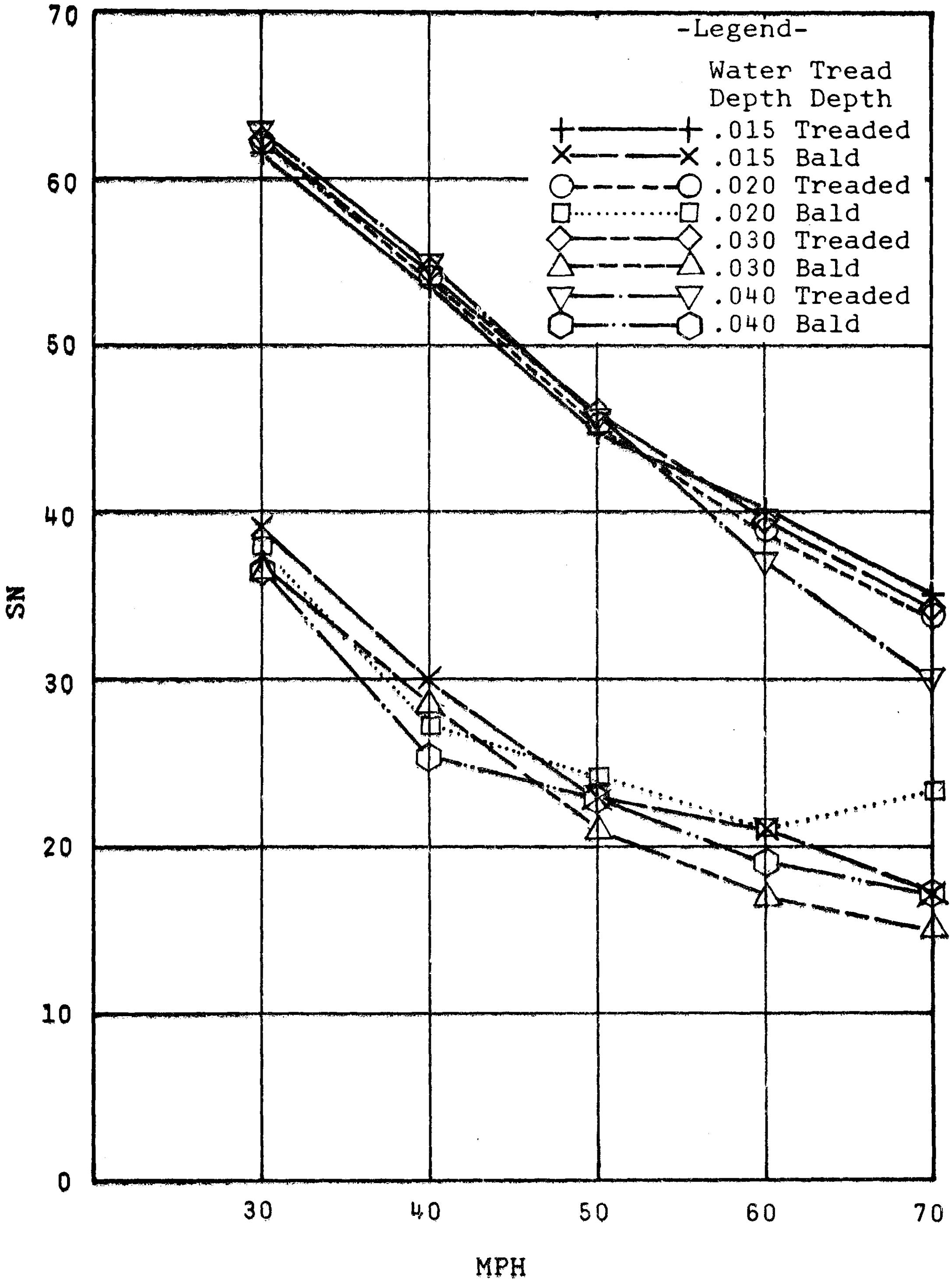


**Figure A5.** Site 5 — Speed gradient curves for treaded and bald tires for each water film. An S-1 sand asphalt mix in the N&SBTL's of Route 340 in Augusta County. (1 inch = 2.54 cm; 1 mph = .4470 m/s)

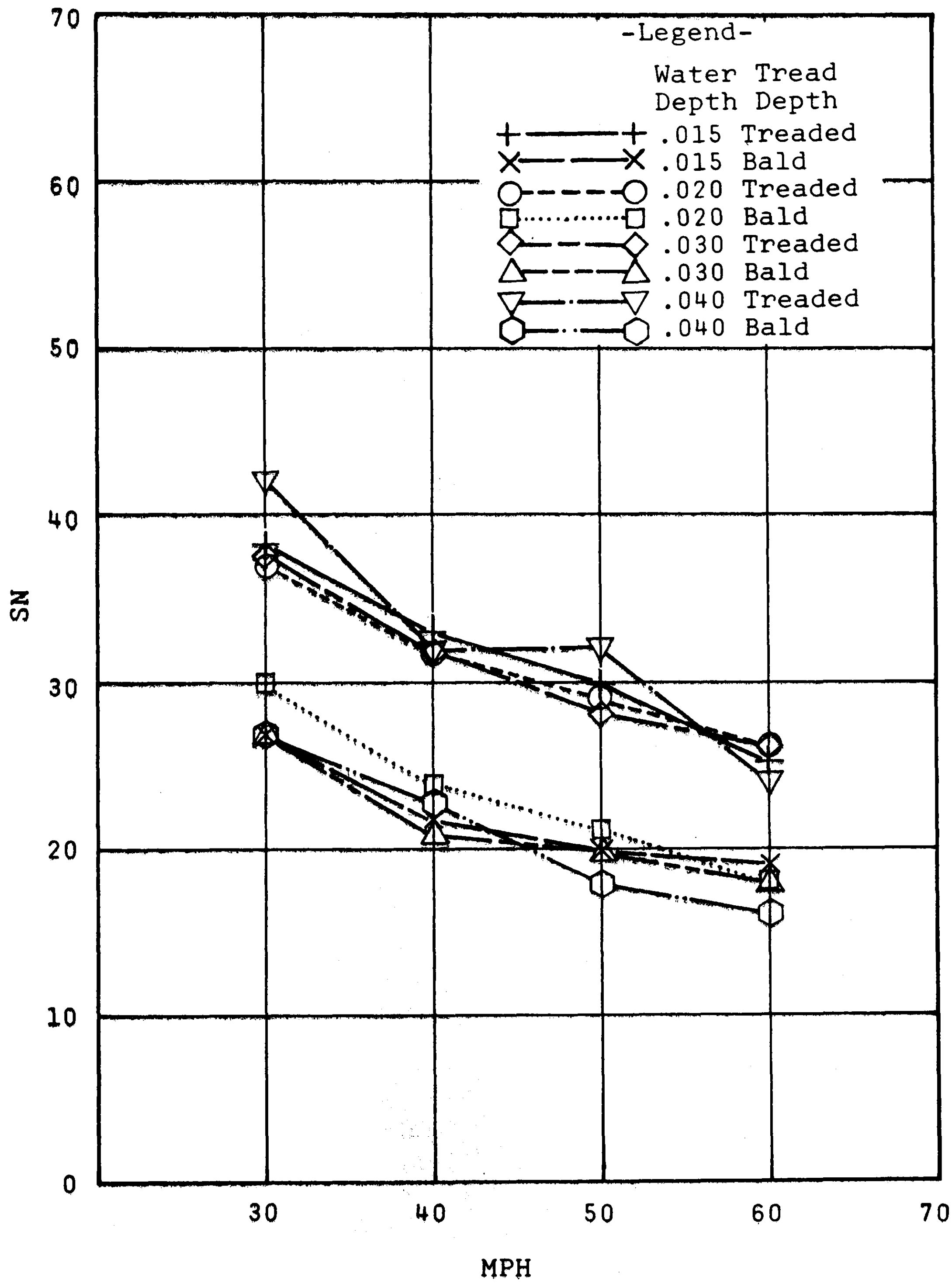


Figure A6. Site 6 — Speed gradient curves for treaded and bald tires for each water film. A portland cement concrete mix in the SBTL of I-95 in Greenville County. (1 inch = 2.54 cm; 1 mph = .4470 m/s)

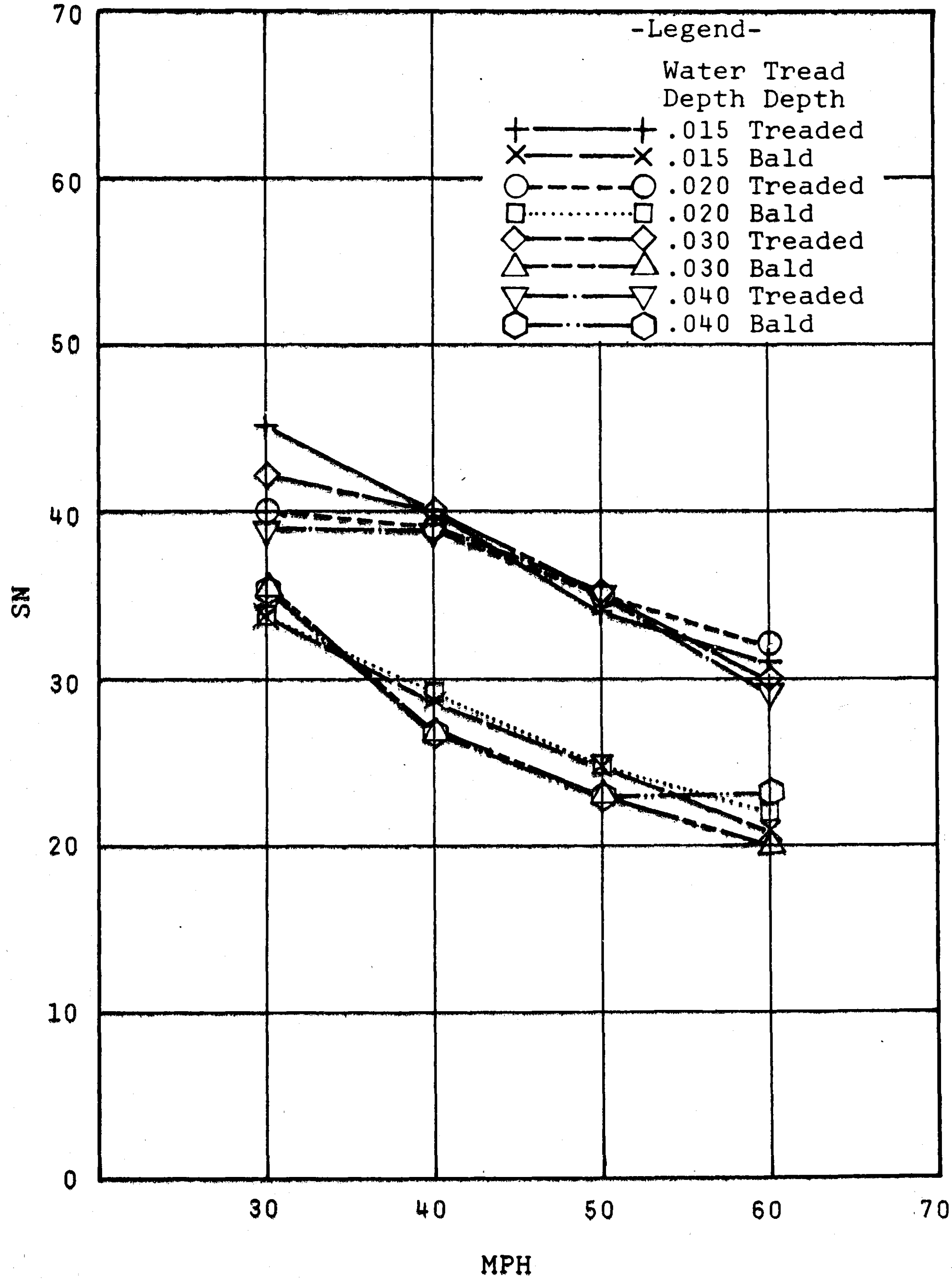


Figure A7. Site 7 — Speed gradient curves for treaded and bald tires for each water film. A portland cement concrete mix in the SBPL of I-95 in Greenville County. (1 inch = 2.54 cm; 1 mph = .4470 m/s)

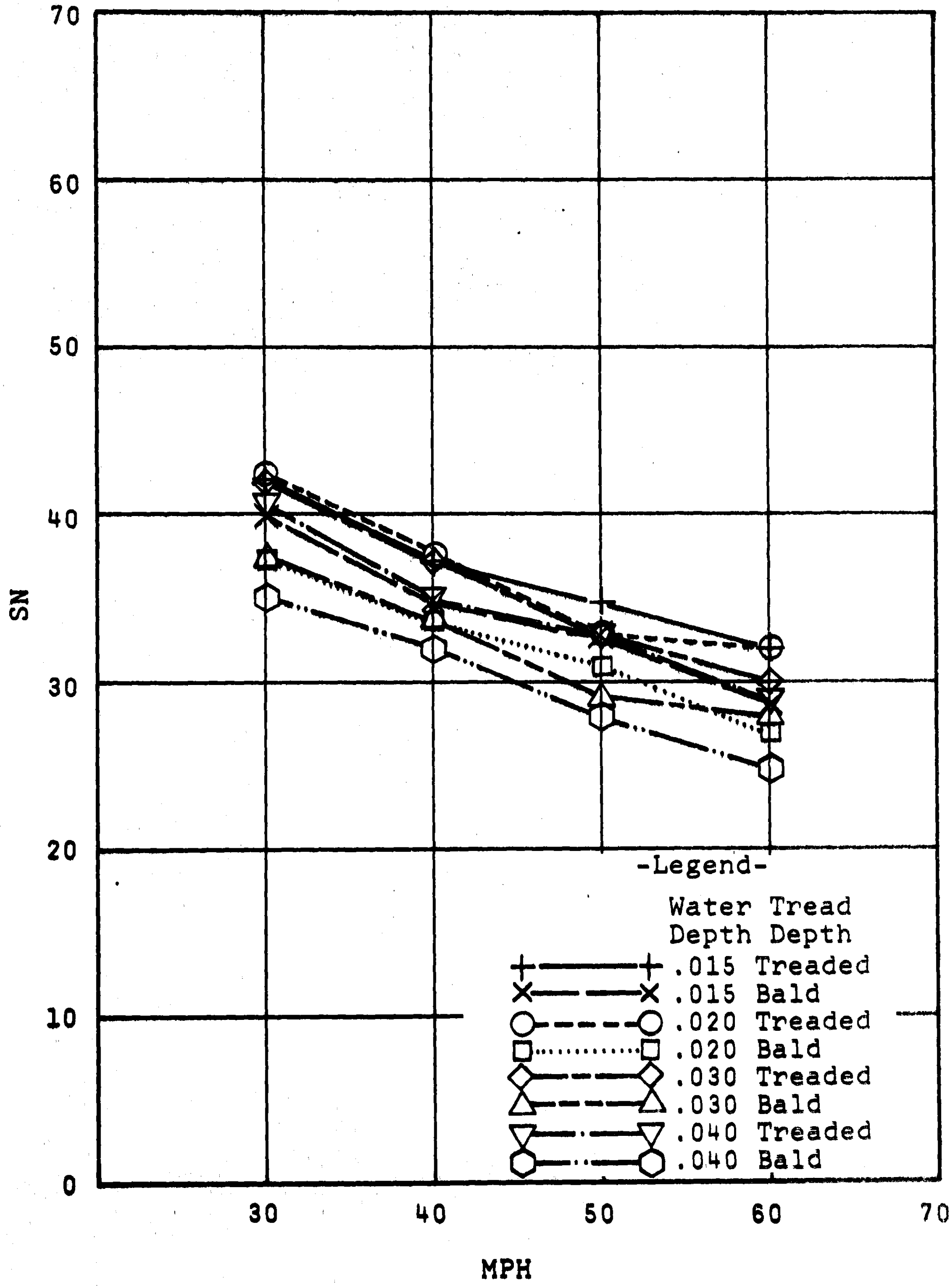


Figure A8. Site 8 — Speed gradient curves for treaded and bald tires for each water film. A mechanically chipped surface in the SBTL of I-95 in Greenville County. (1 inch = 2.54 cm; 1 mph = .4470 m/s)

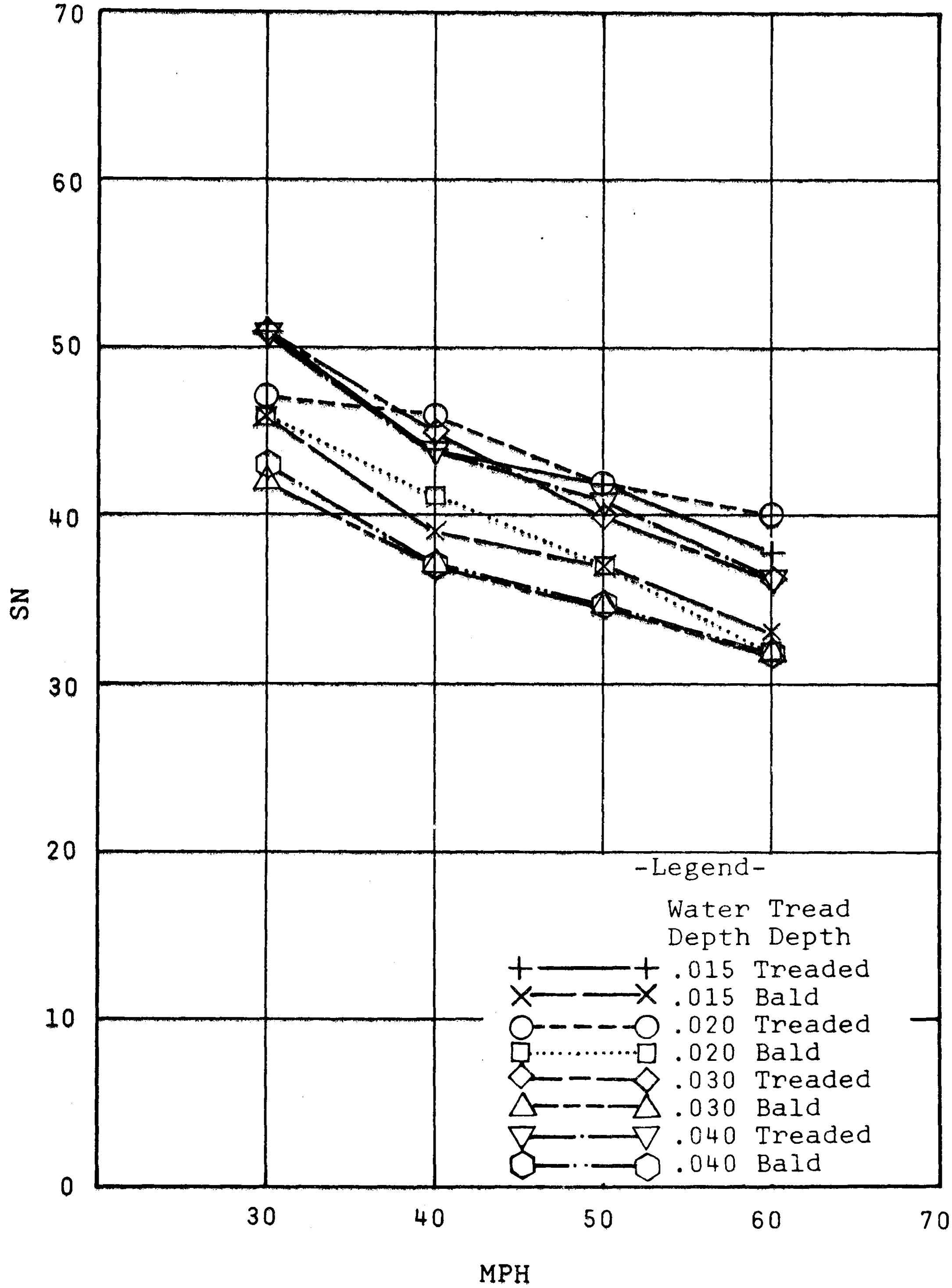


Figure A9. Site 9 — Speed gradient curves for treaded and bald tires for each water film. A mechanically chipped surface in the SBPL of I-95 in Greenville County. (1 inch = 2.54 cm; 1 mph = .4470 m/s)

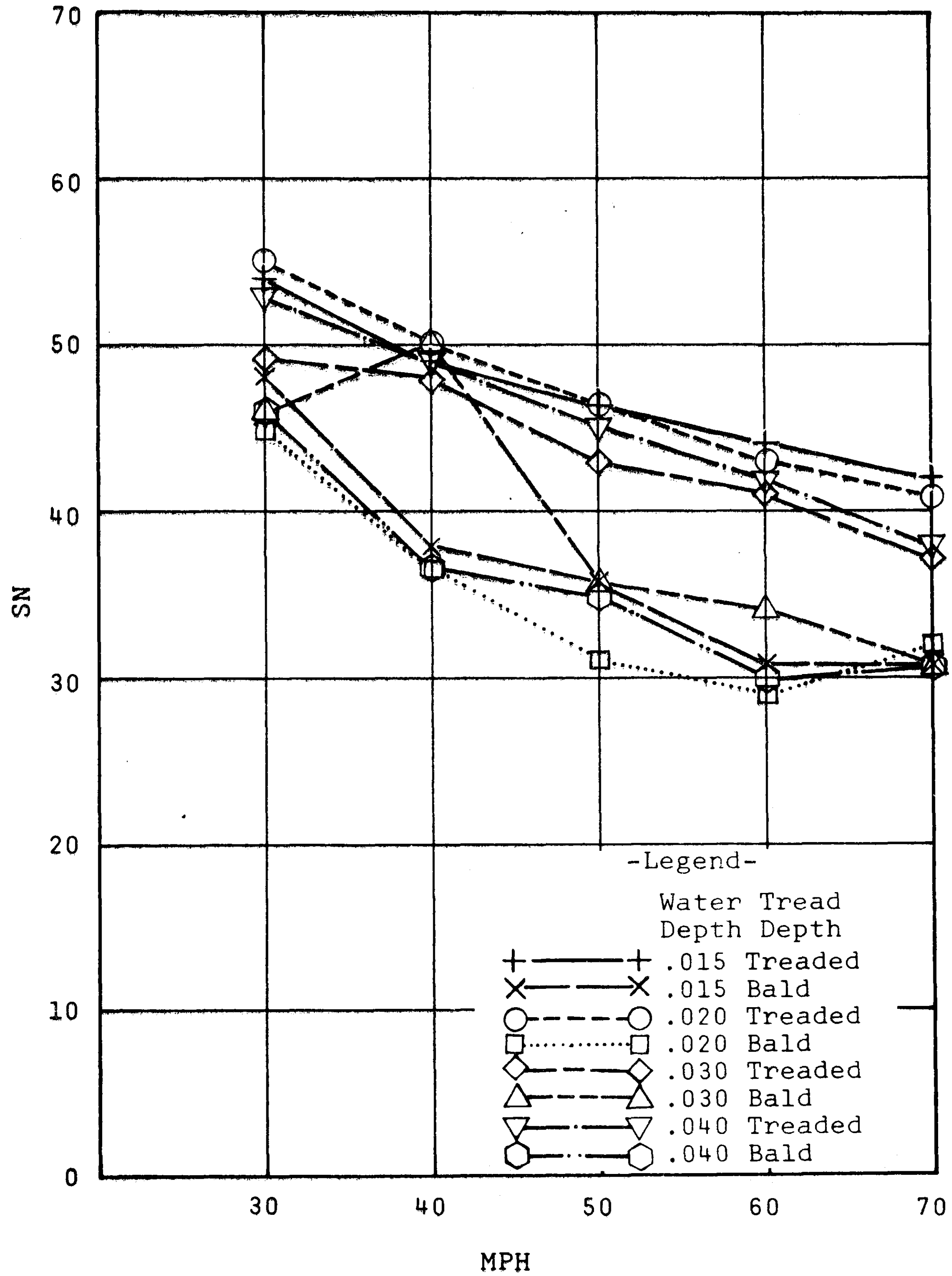


Figure A10. Site 10 — Speed gradient curves for treaded and bald tires for each water film. An S-5 bituminous concrete mix in the EBTL of I-264 in Chesapeake. (1 inch = 2.54 cm; 1 mph = .4470 m/s)

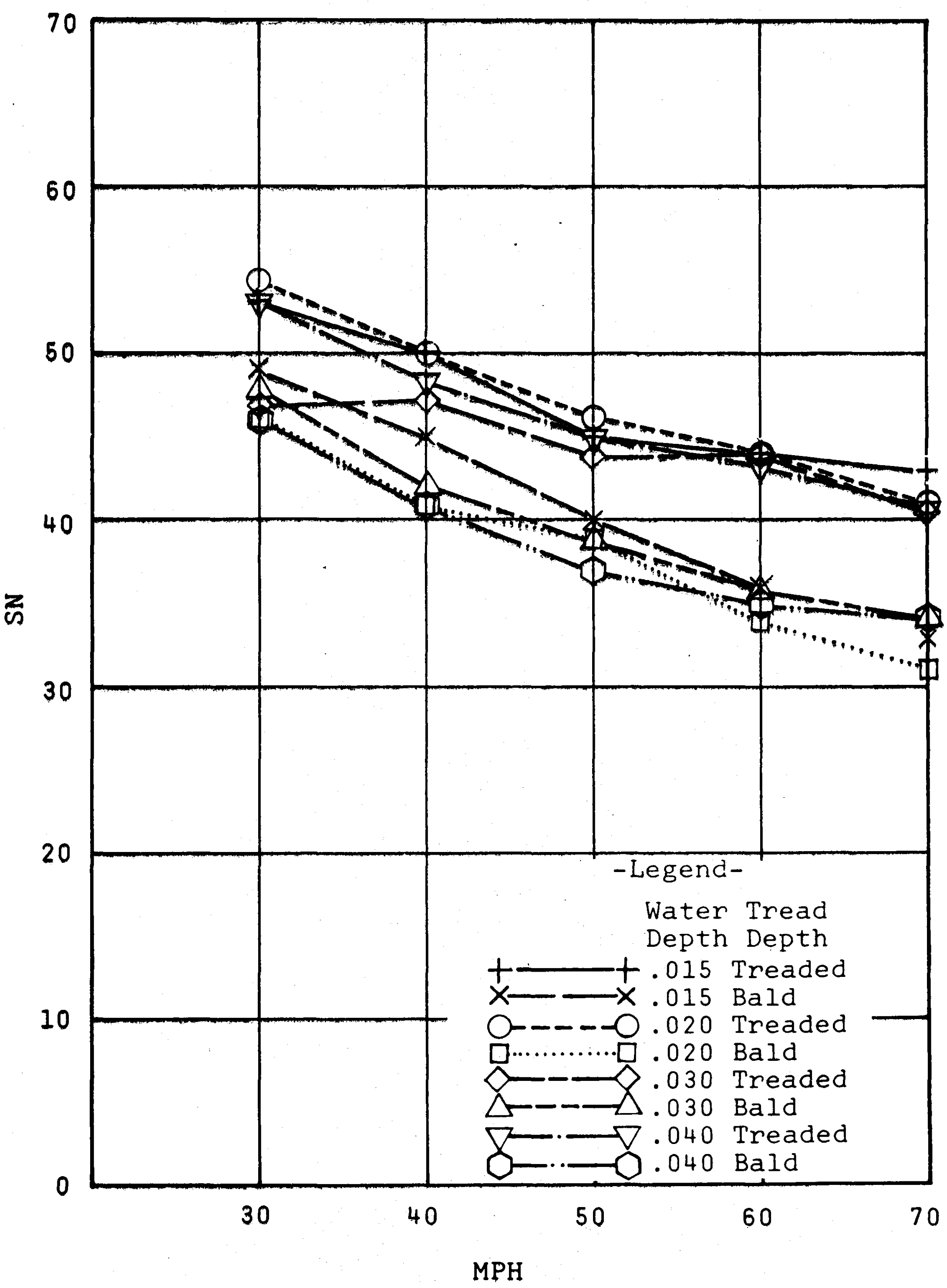


Figure A11. Site 11 — Speed gradient curves for treaded and bald tires for each water film. An S-5 bituminous concrete mix in the WBTL of I-264 in Chesapeake. (1 inch = 2.54 cm; 1 mph = .4470 m/s)

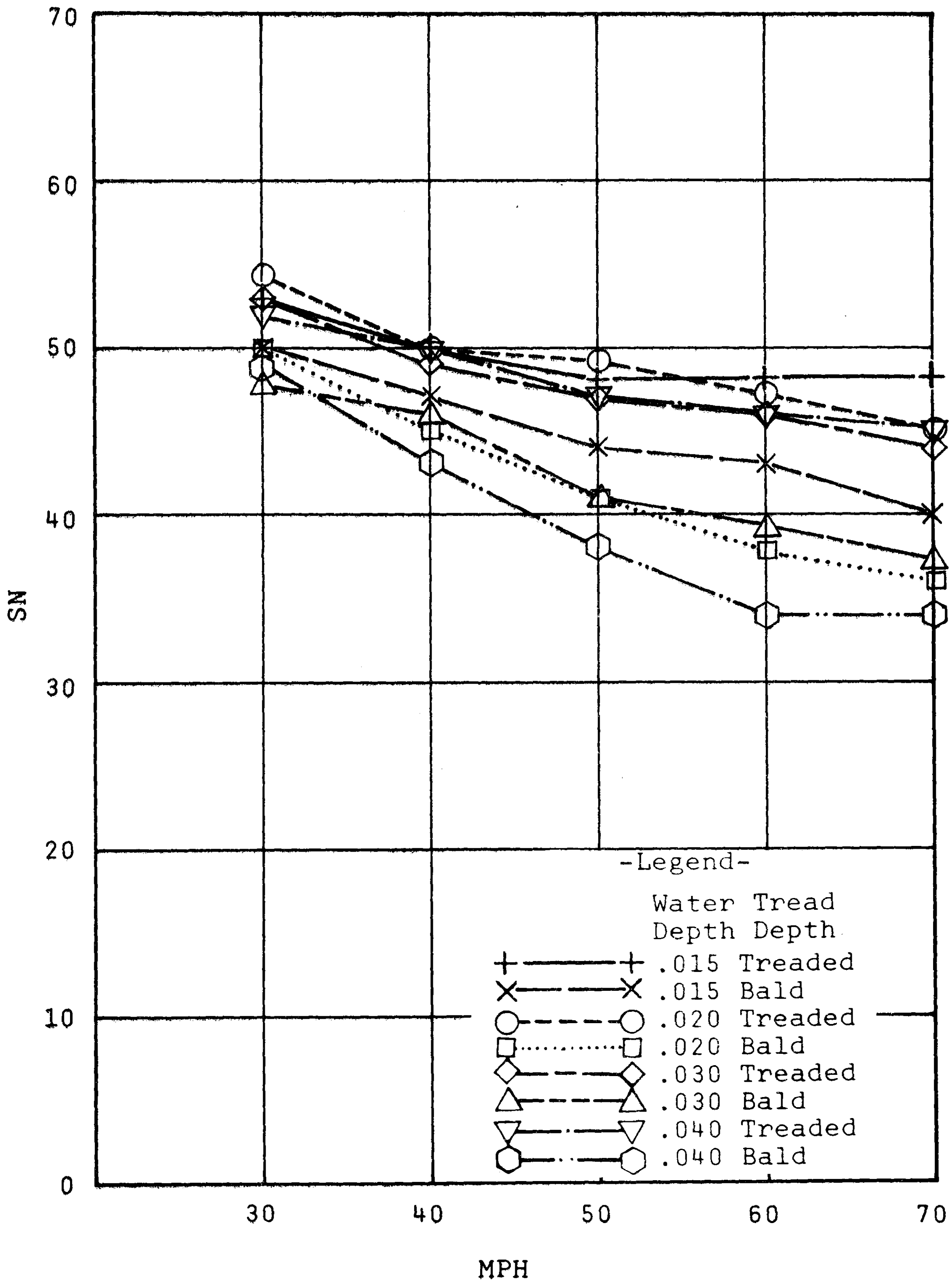


Figure A12. Site 12 — Speed gradient curves for treaded and bald tires for each water film. An S-5 bituminous concrete mix in the EBPL of I-264 in Chesapeake. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

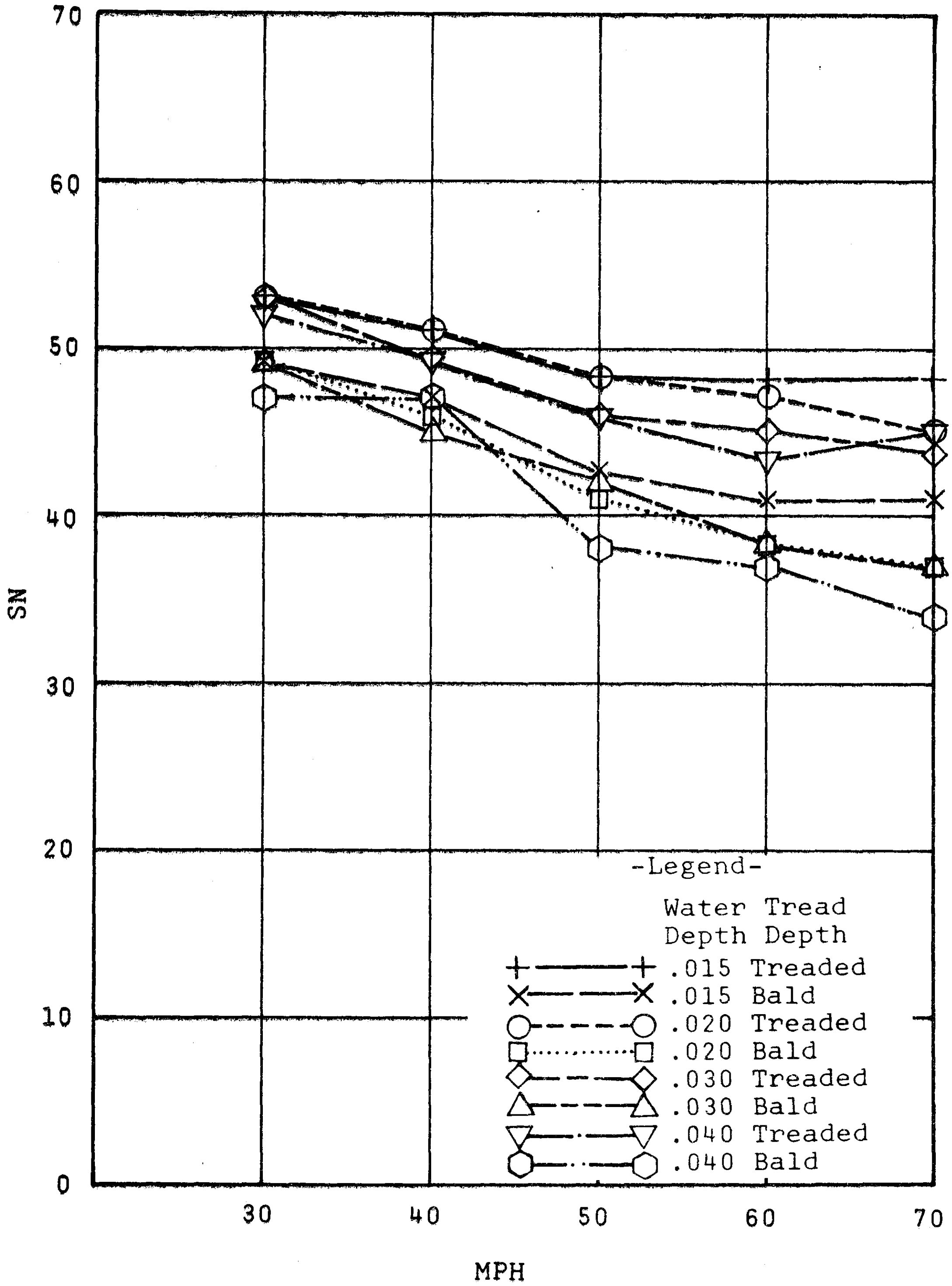


Figure A13. Site 13 — Speed gradient curves for treaded and bald tires for each water film. An S-5 bituminous concrete mix in the WBPL of I-264 in Chesapeake. (1 inch = 2.54 cm; 1 mph = .4470 m/s)

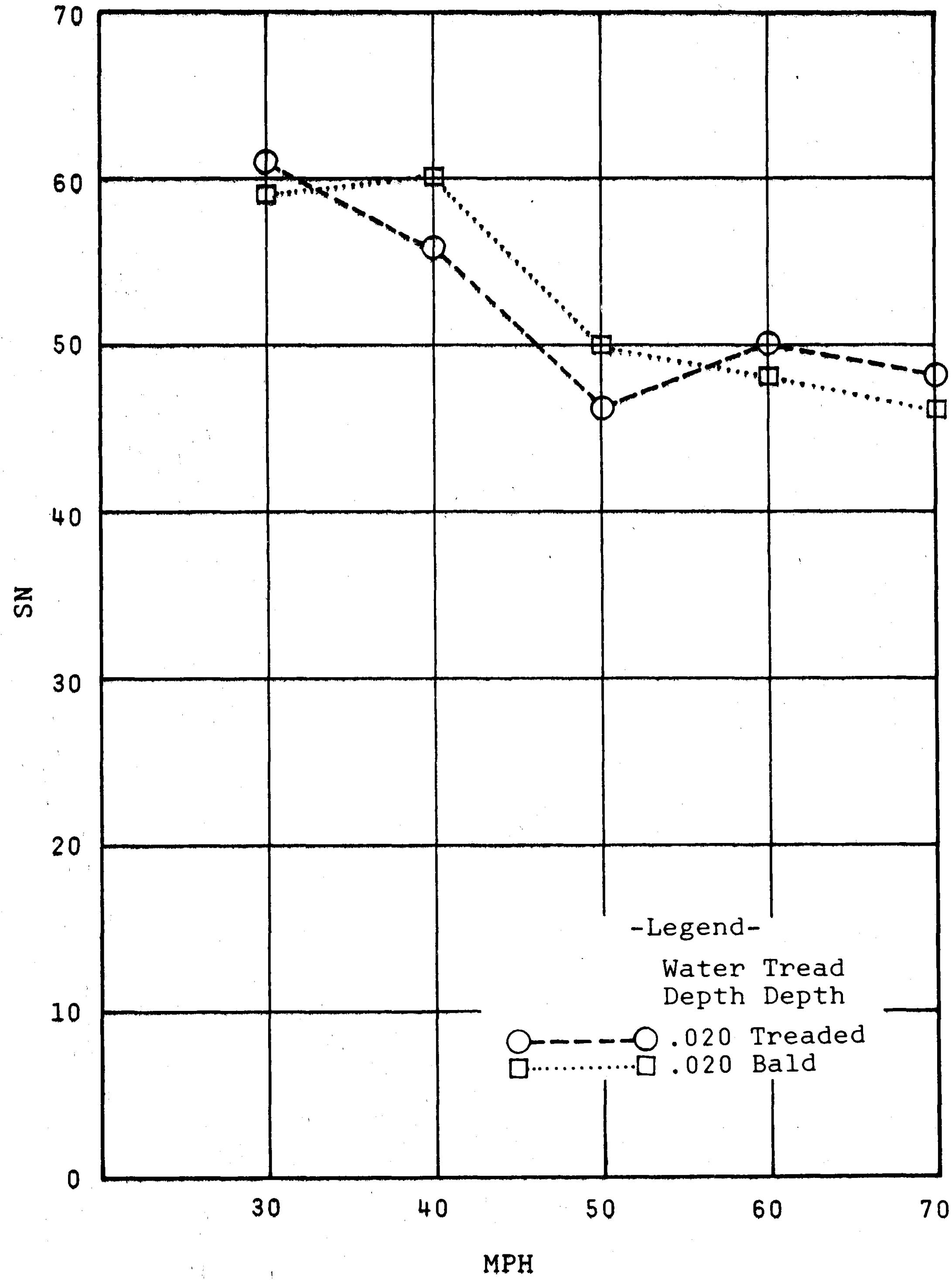


Figure A14. Site 14 — Speed gradient curves for treaded and bald tires for each water film. A bituminous-urban mix in the SBTL of I-381 in Bristol. (1 inch = 2.54 cm; 1 mph = .4470 m/s)

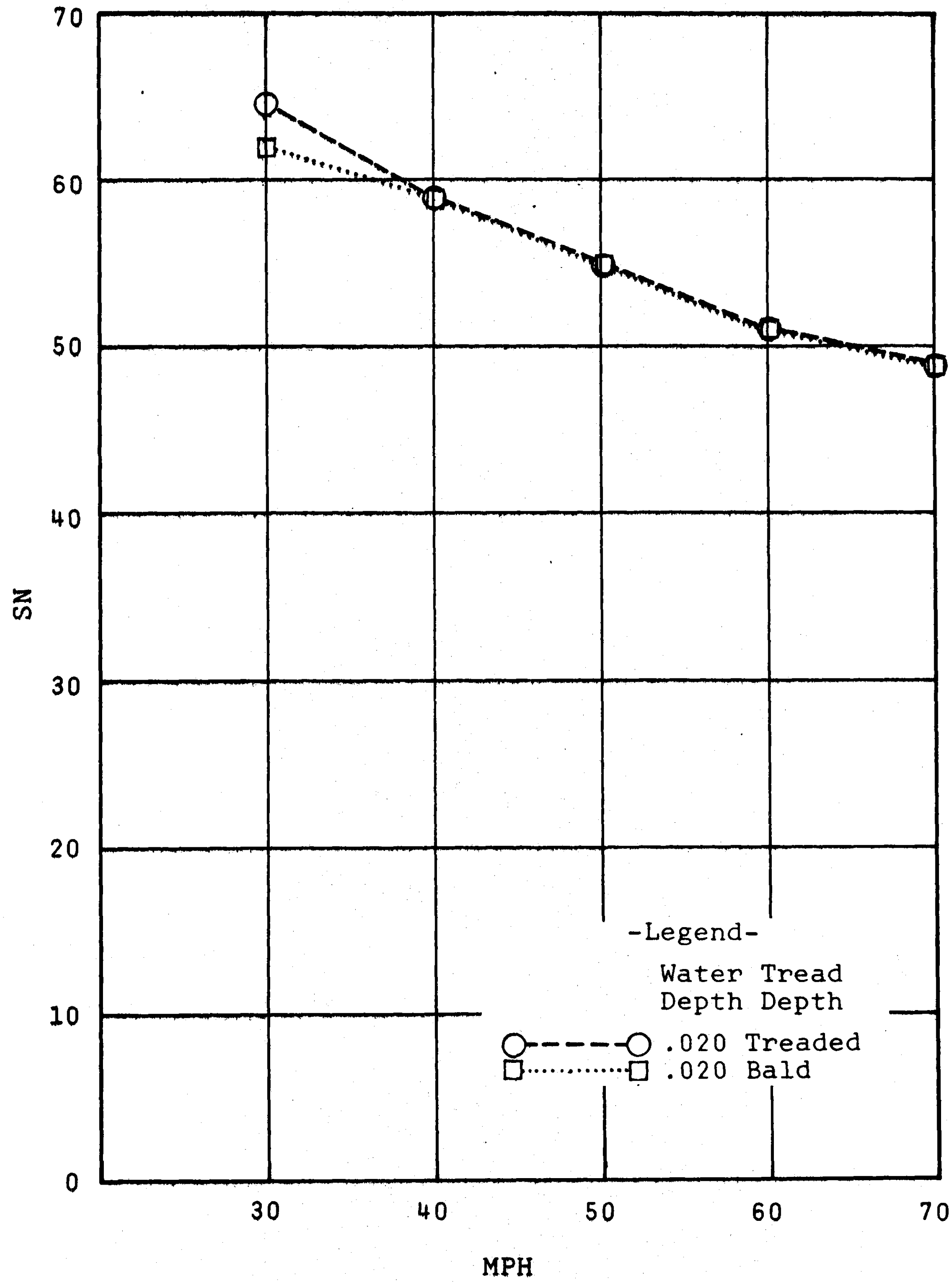


Figure A15. Site 15 — Speed gradient curves for treaded and bald tires for each water film. A bituminous-urban mix in the SBTL of I-381 in Bristol. (1 inch = 2.54 cm; 1 mph = .4470 m/s)

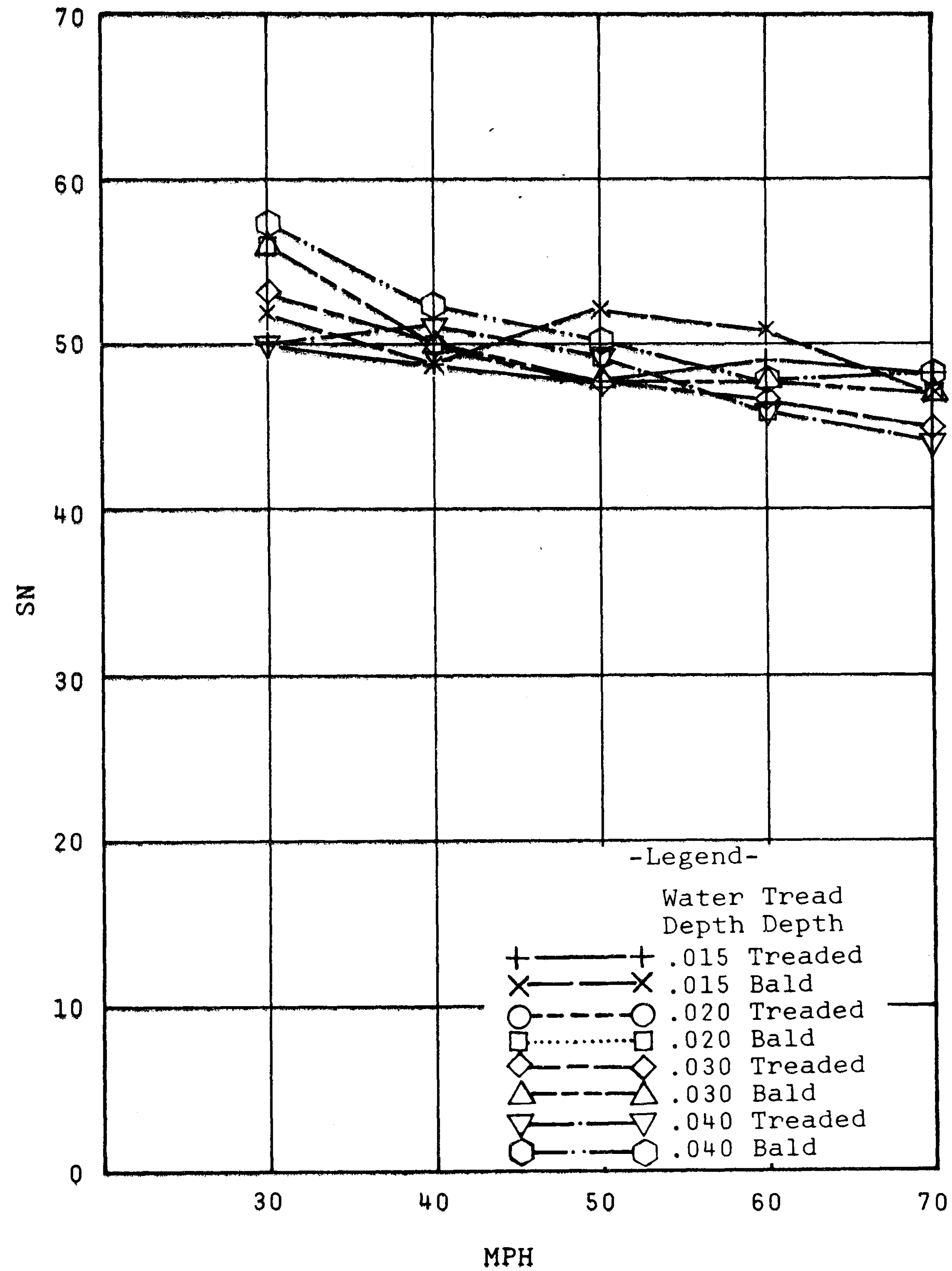


Figure A16. Site 16 — Speed gradient curves for treaded and bald tires for each water film. An open-graded bituminous mix (popcorn) in the NBTL of I-81 in Augusta County. (1 inch = 2.54 cm; 1 mph = .4470 m/s)

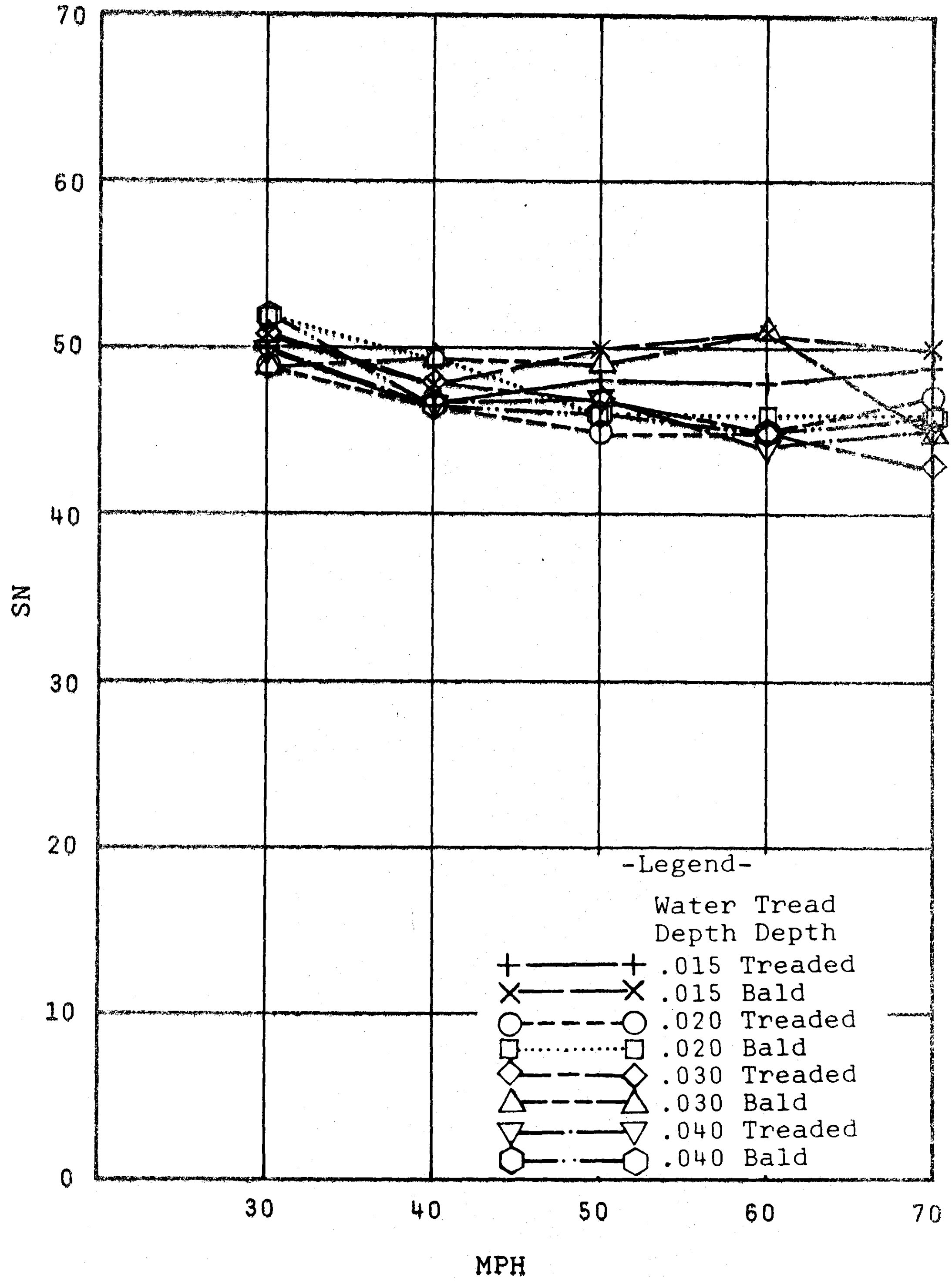


Figure A17. Site 17 — Speed gradient curves for treaded and bald tires for each water film. An open-graded bituminous mix (popcorn) in the SBPL of I-81 in Augusta County. (1 inch = 2.54 cm; 1 mph = .4470 m/s)

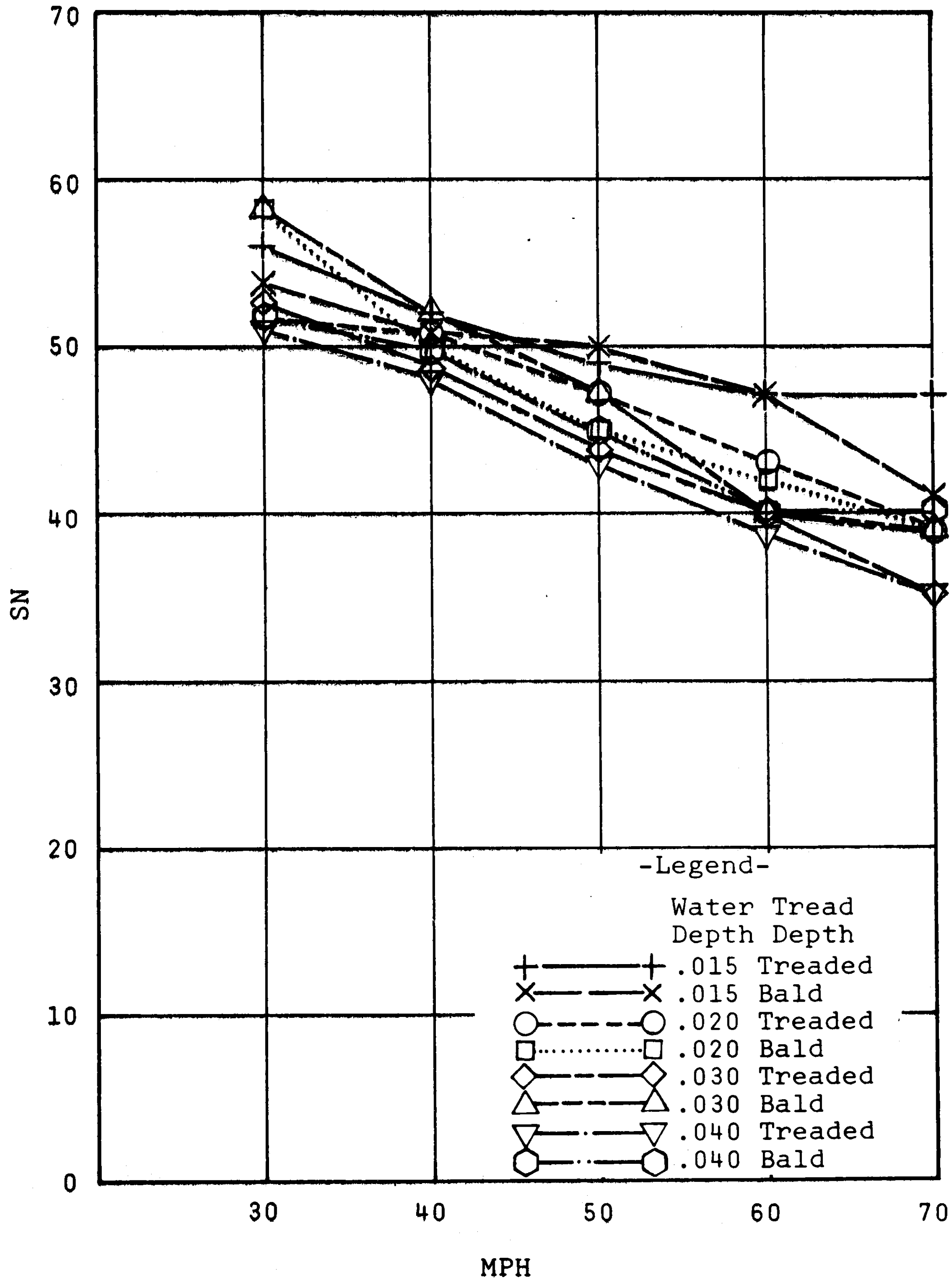


Figure A18. Site 18 — Speed gradient curves for treaded and bald tires for each water film. An S-5 bituminous concrete mix in the NBTL of I-81 in Augusta County. (1 inch = 2.54 cm; 1 mph = .4470 m/s)

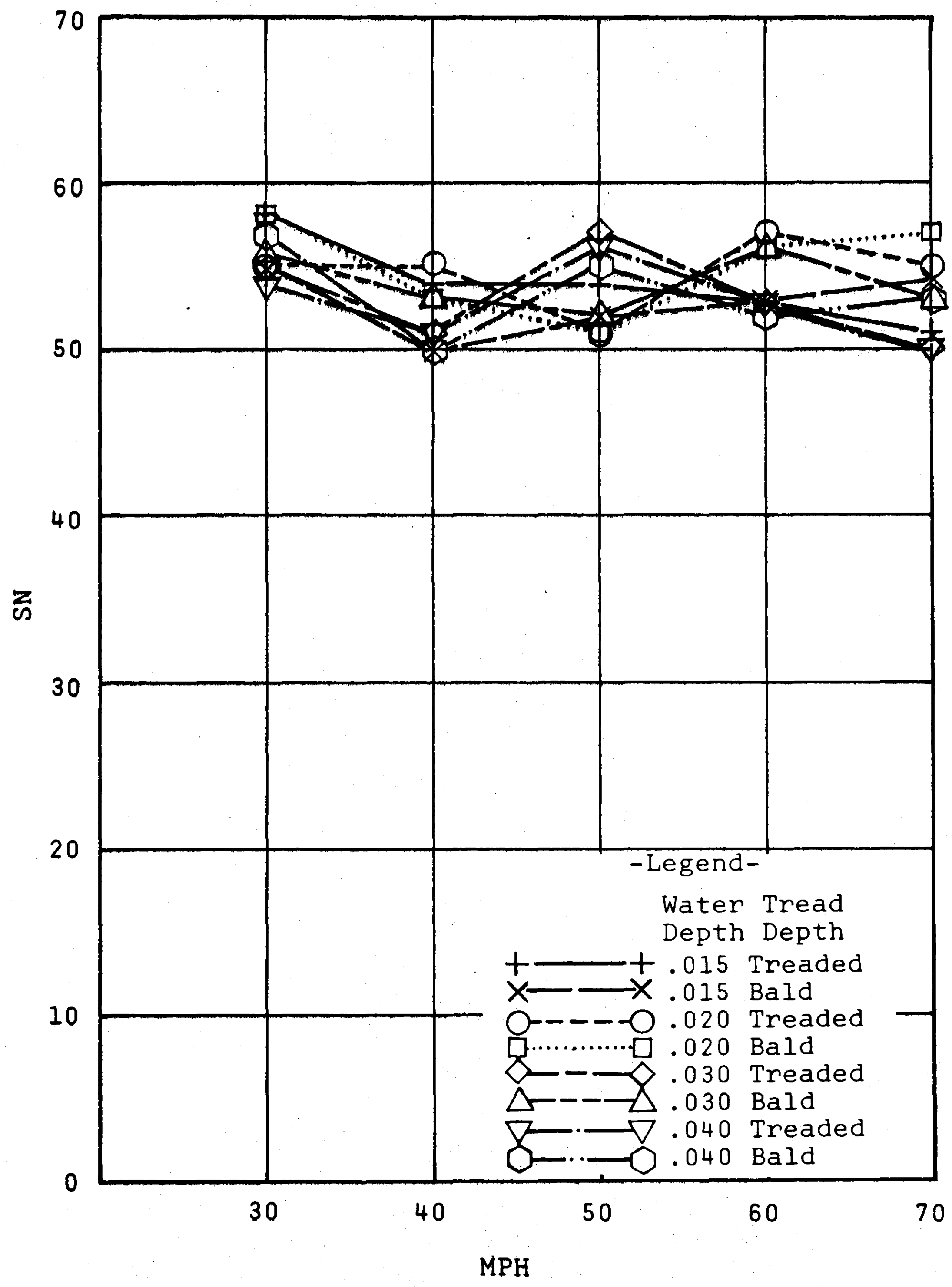


Figure A19. Site 19 — Speed gradient curves for treaded and bald tires for each water film. An S-5 bituminous concrete mix in the SBPL of I-81 in Augusta County. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

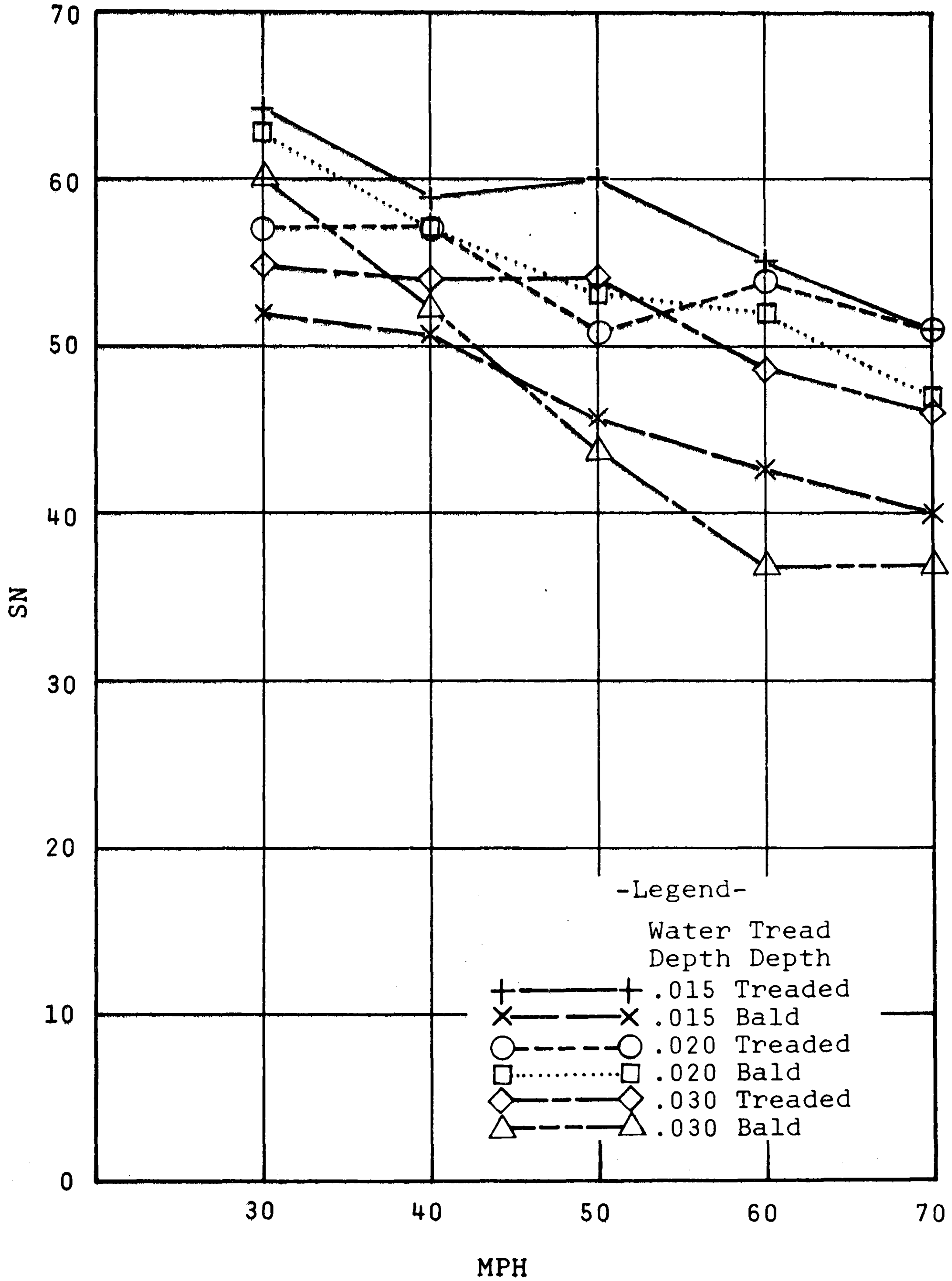


Figure A20. Site 20 — Speed gradient curves for treaded and bald tires for each water film. A portland cement concrete mix in the EBTL of I-64 in New Kent County. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

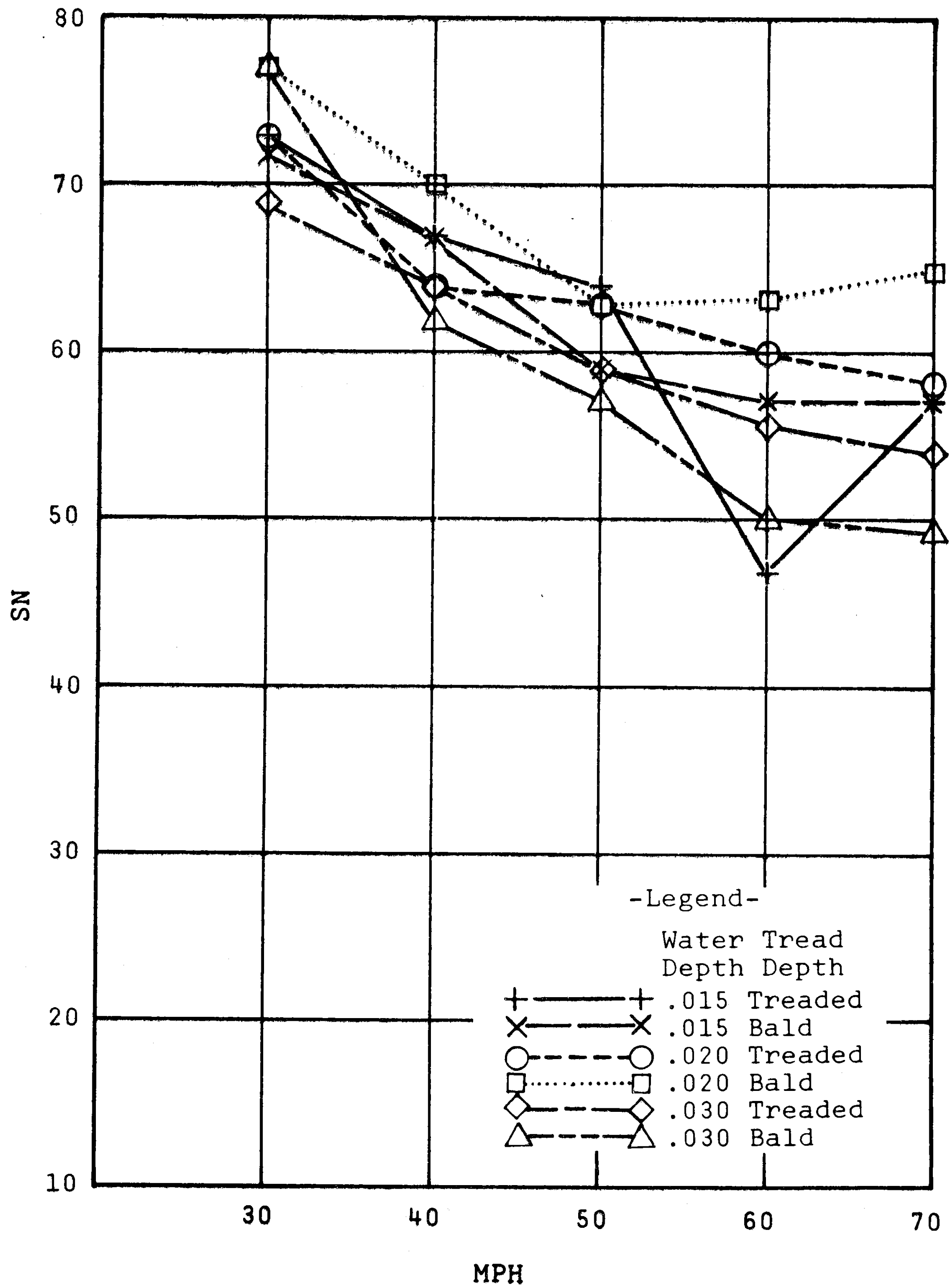


Figure A21. Site 21 — Speed gradient curves for treaded and bald tires for each water film. A portland cement concrete mix in the WBPL of I-64 in New Kent County. (1 inch = 2.54 cm; 1 mph = .4470 m/s)

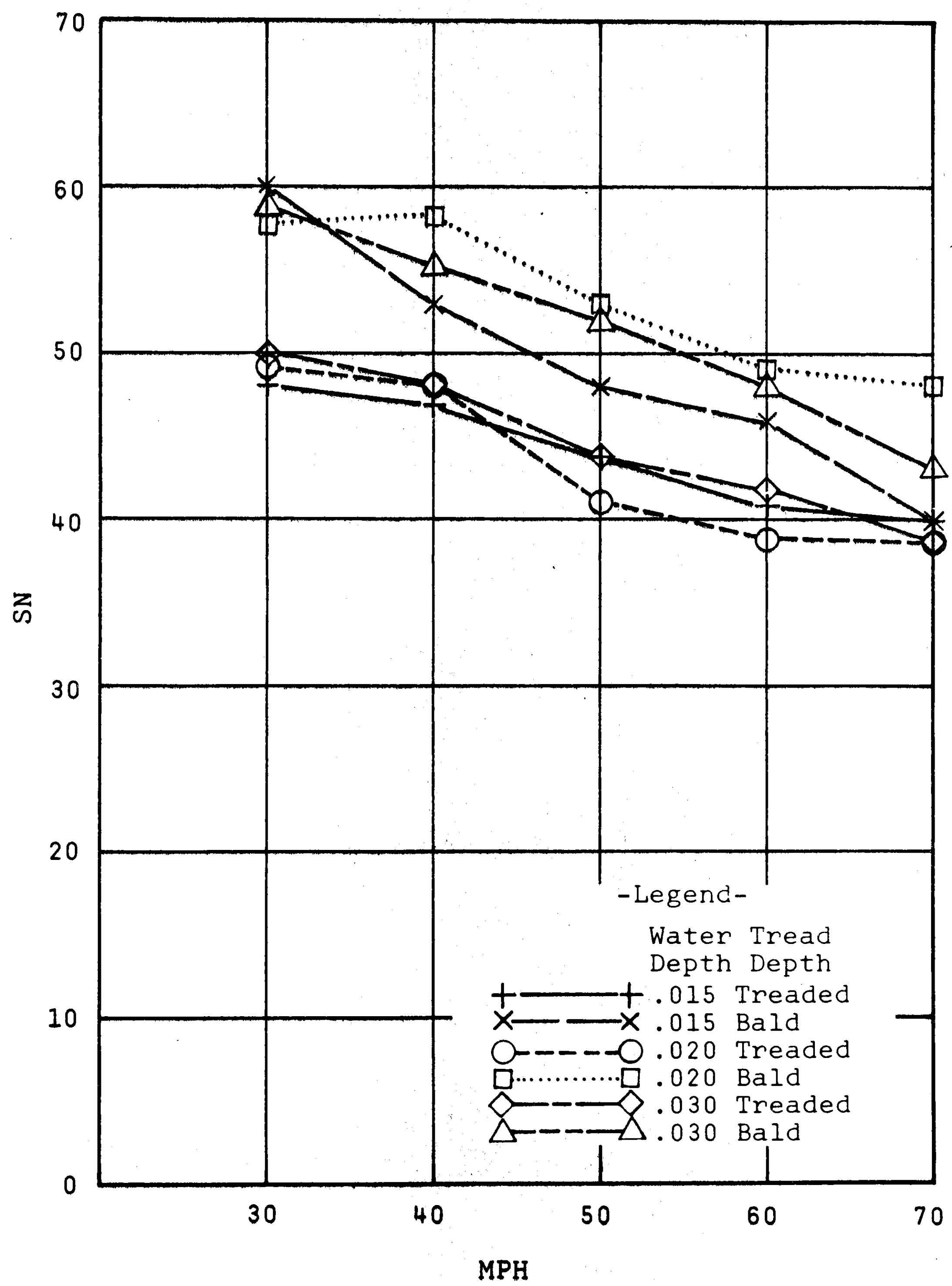


Figure A22. Site 22 — Speed gradient curves for treaded and bald tires for each water film. A portland cement concrete mix in the EBTL of I-64 in Henrico County. (1 inch = 2.54 cm; 1 mph = .4470 m/s)

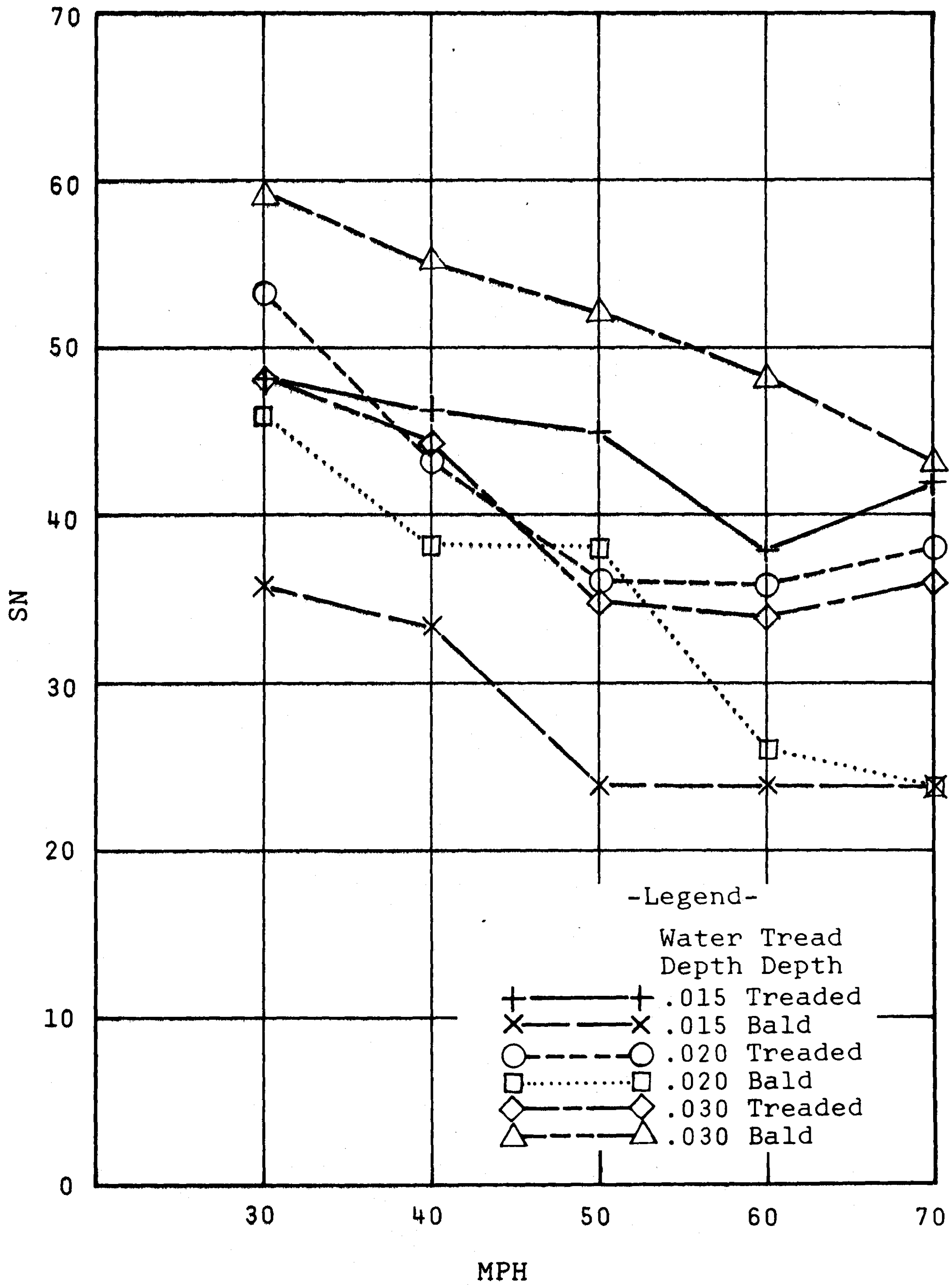


Figure A23. Site 23 — Speed gradient curves for treaded and bald tires for each water film. A portland cement concrete mix in the EBPL of I-64 in Henrico County. (1 inch = 2.54 cm; 1 mph = .4470 m/s)

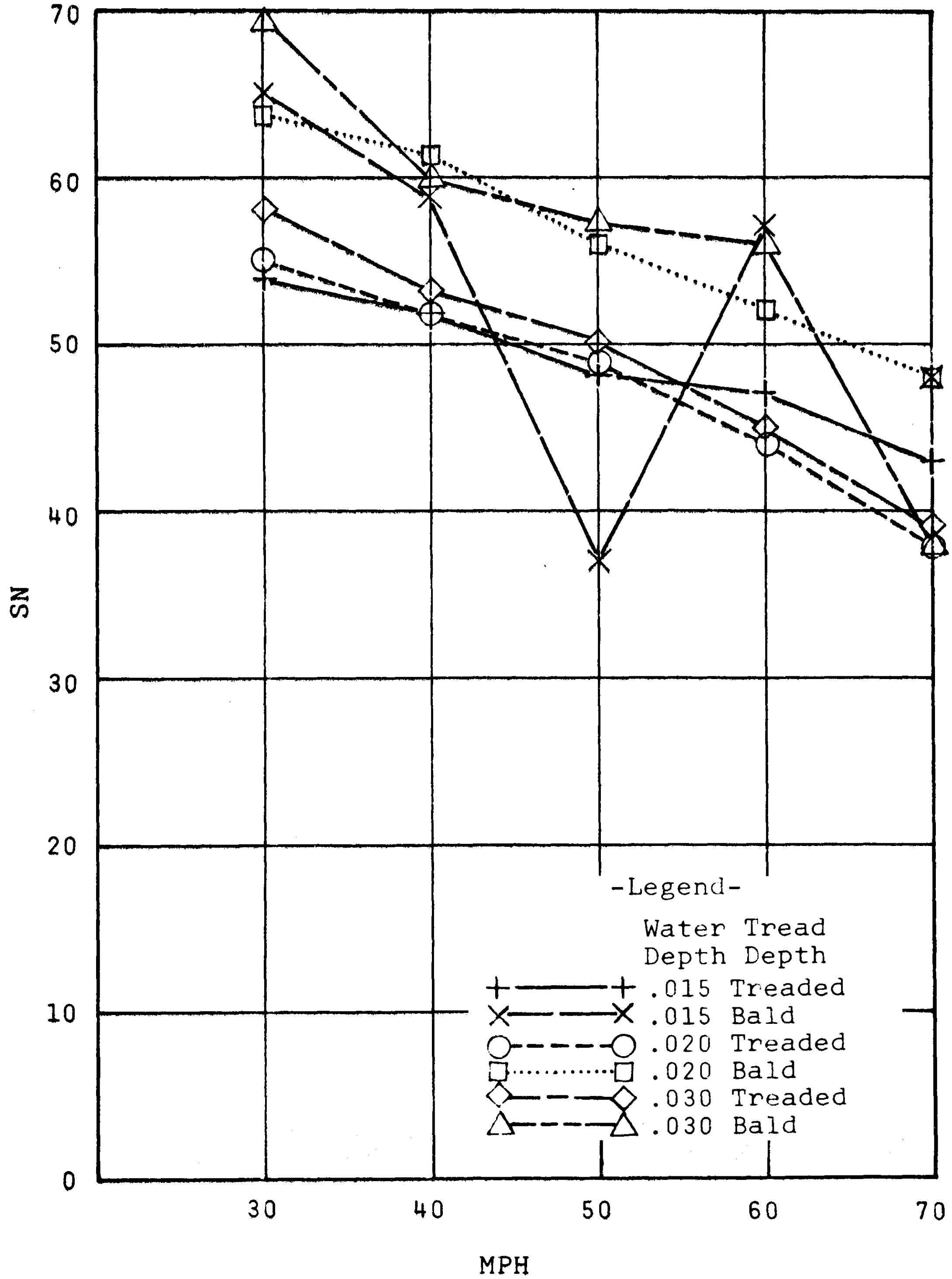


Figure A24. Site 24 — Speed gradient curves for treaded and bald tires for each water film. A grooved portland cement concrete mix in the EBTL of I-64 in Henrico County. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

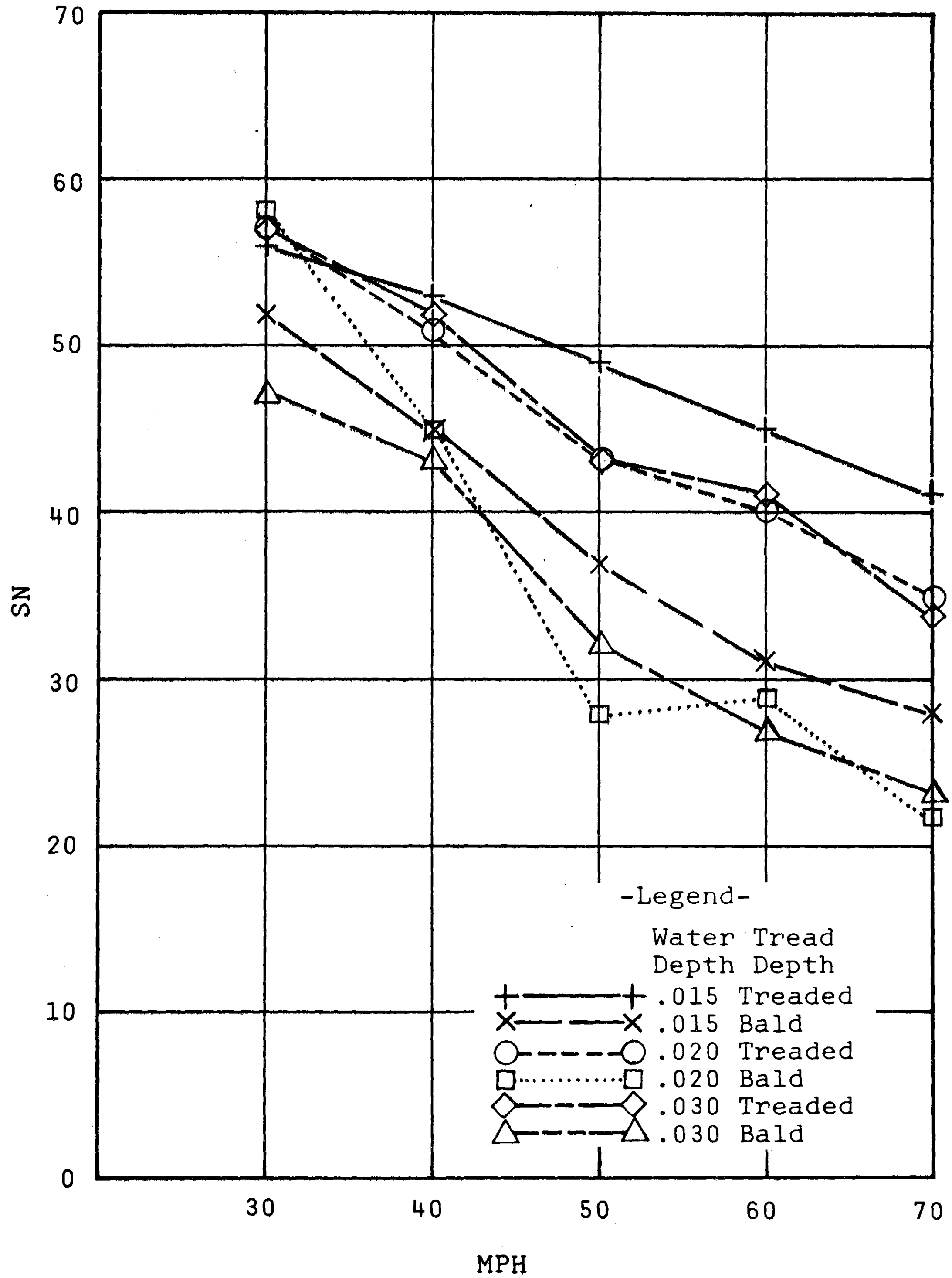


Figure A25. Site 25 — Speed gradient curves for treaded and bald tires for each water film. A grooved portland cement concrete mix in the EBPL of I-64 in Henrico County. ( 1 inch = 2.54 cm/ 1 mph = .4470 m/s)

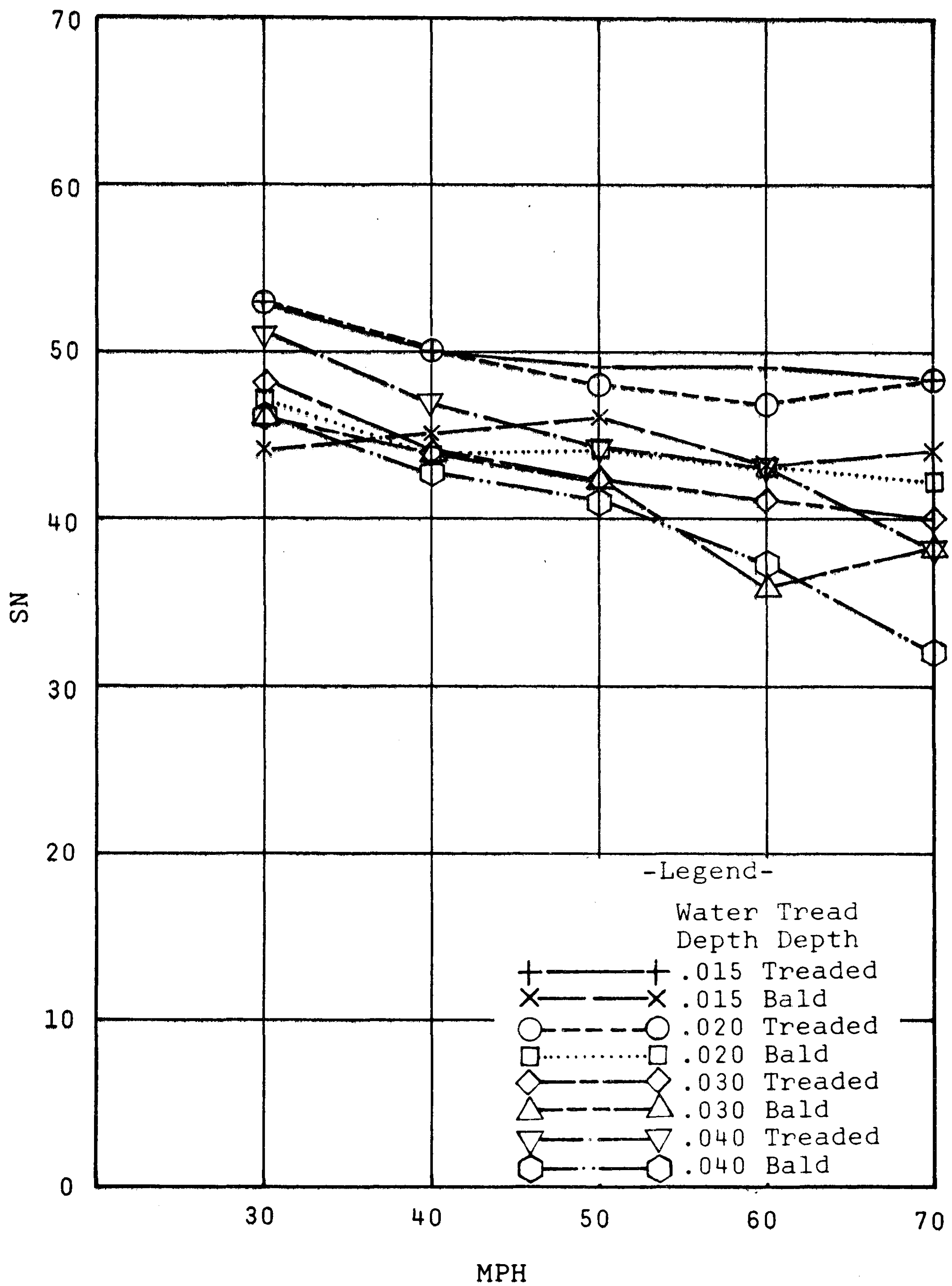


Figure A26. Site 26 — Speed gradient curves for treaded and bald tires for each water film. A surface treatment in the NBPL of Route 1 in Caroline County. (1 inch = 2.54 cm; 1 mph = .4470 m/s)

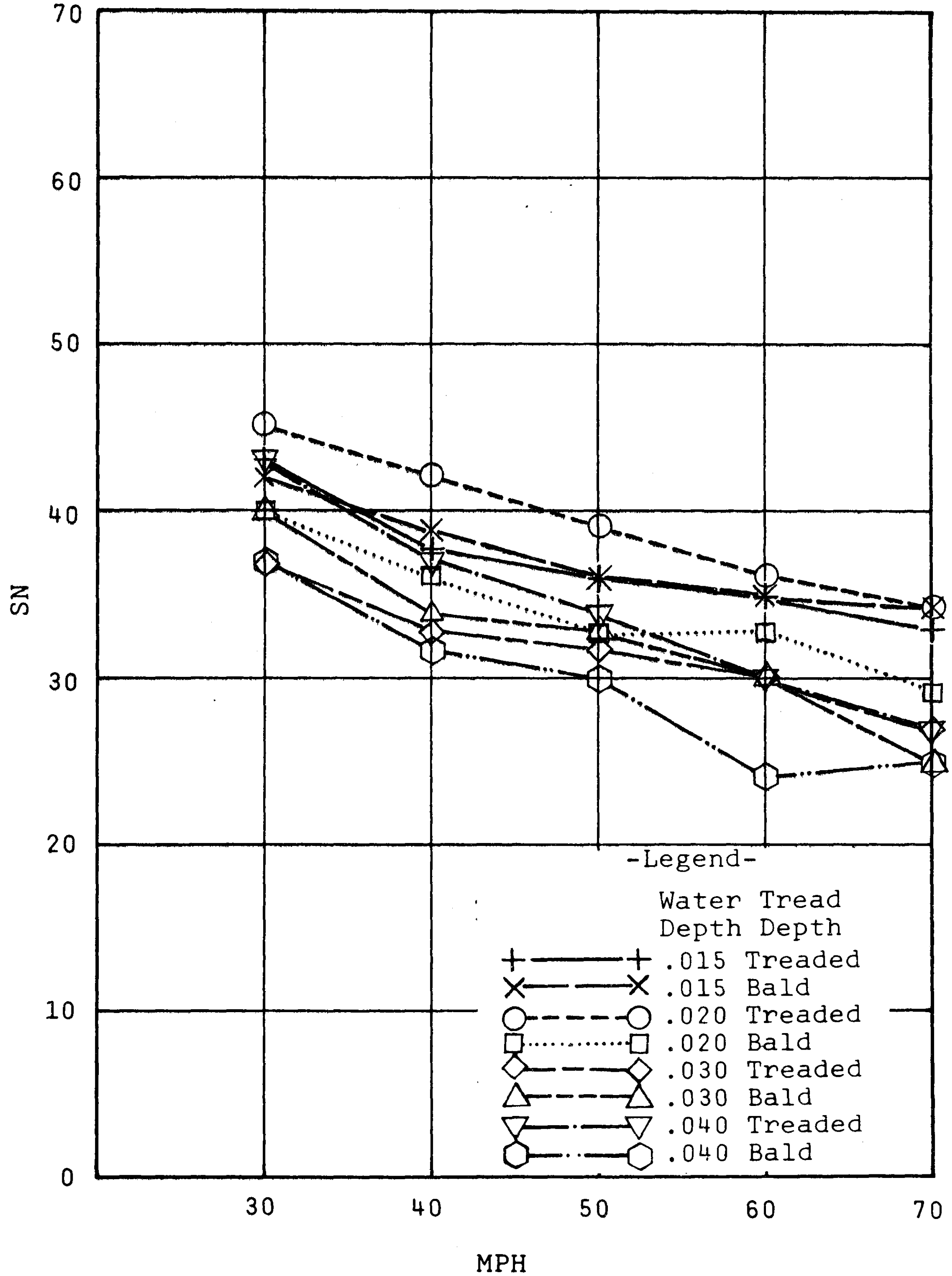


Figure A27. Site 27 — Speed gradient curves for treaded and bald tires for each water film. A surface treatment in the SBTL of Route 1 in Caroline County. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

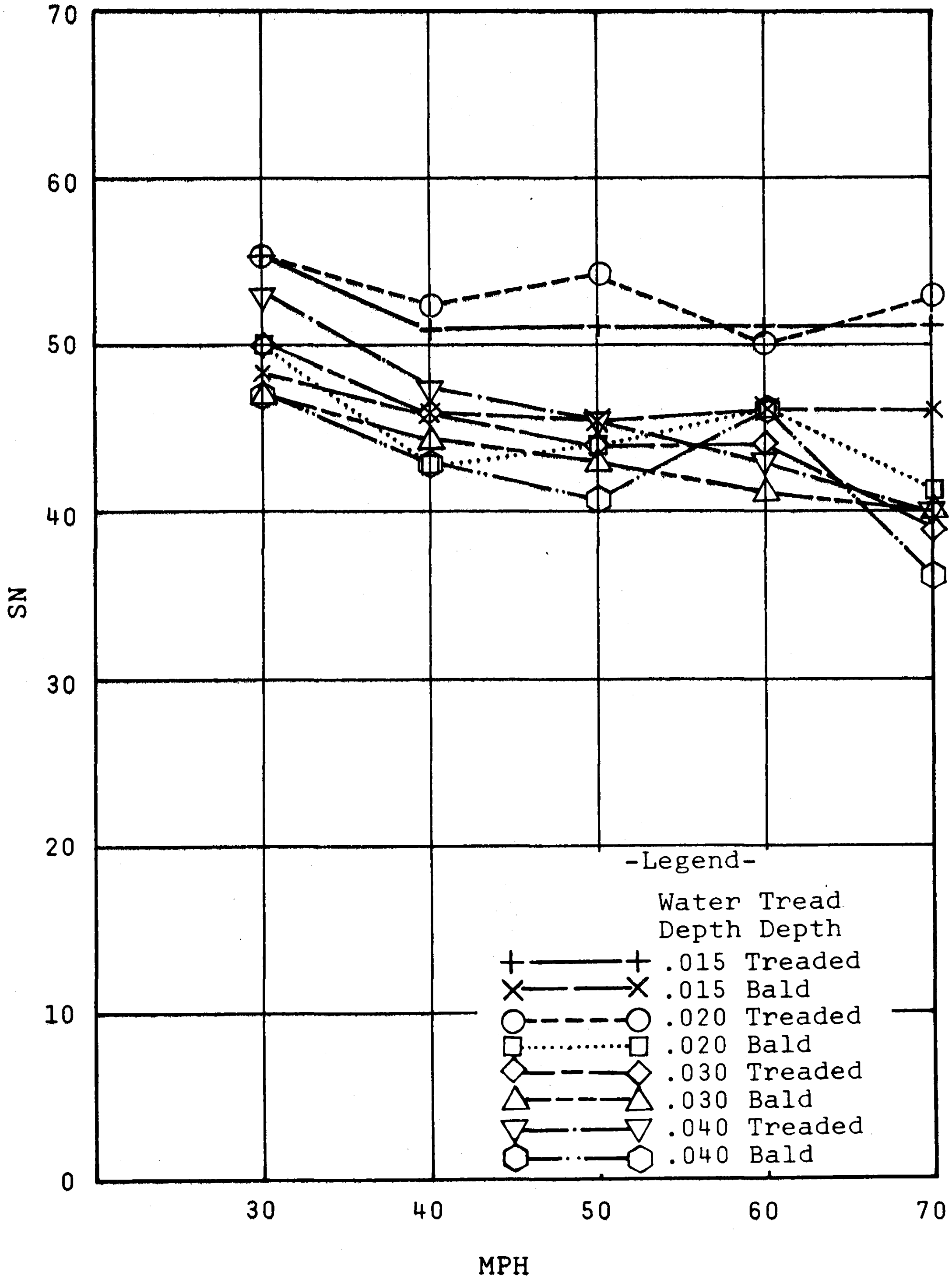


Figure A28. Site 28 — Speed gradient curves for treaded and bald tires for each water film. A surface treatment in the NBPL of Route 1 in Hanover County. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

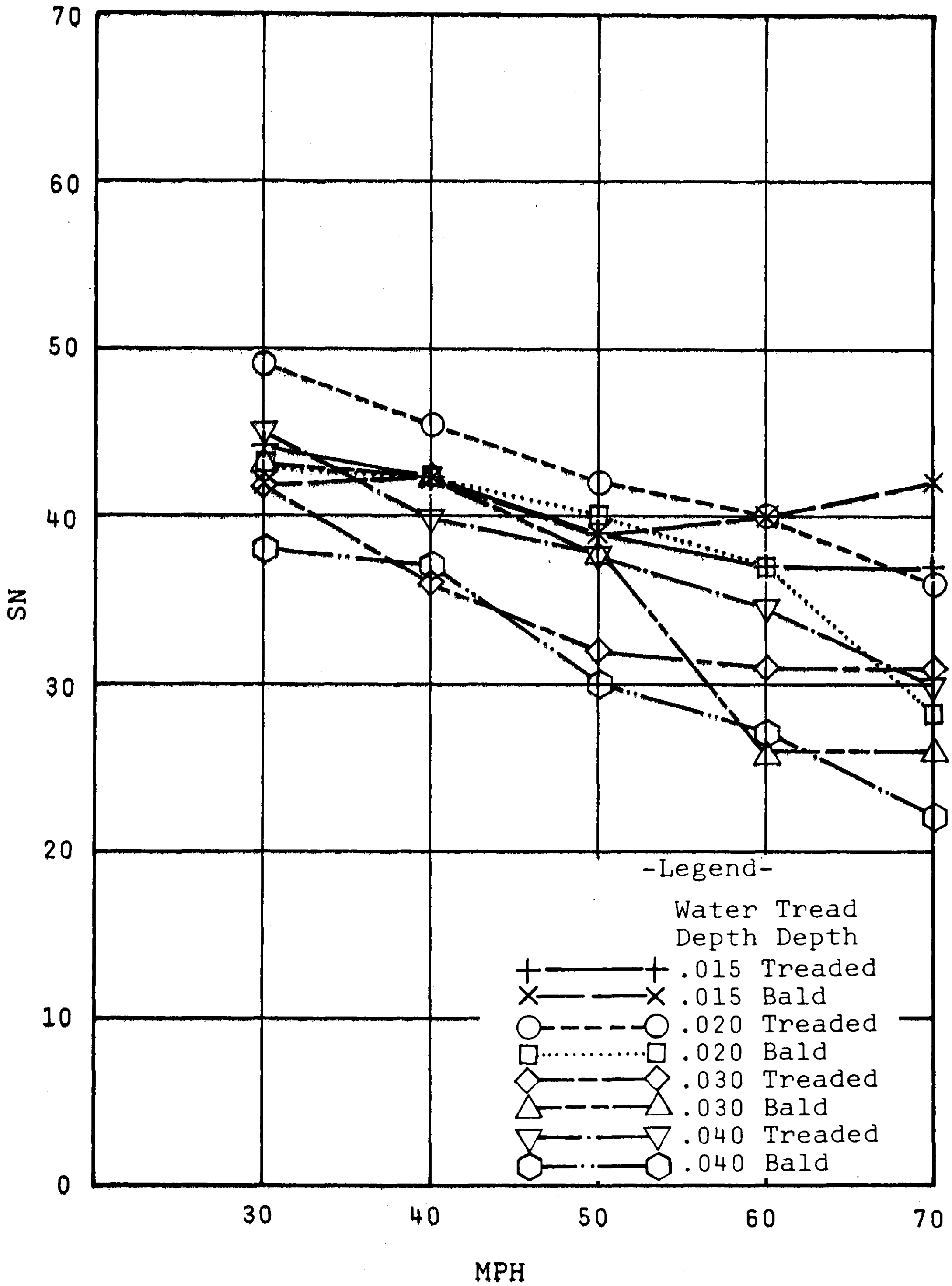


Figure A29. Site 29 — Speed gradient curves for treaded and bald tires for each water film. A surface treatment in the SBTL of Route 1 in Hanover County. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

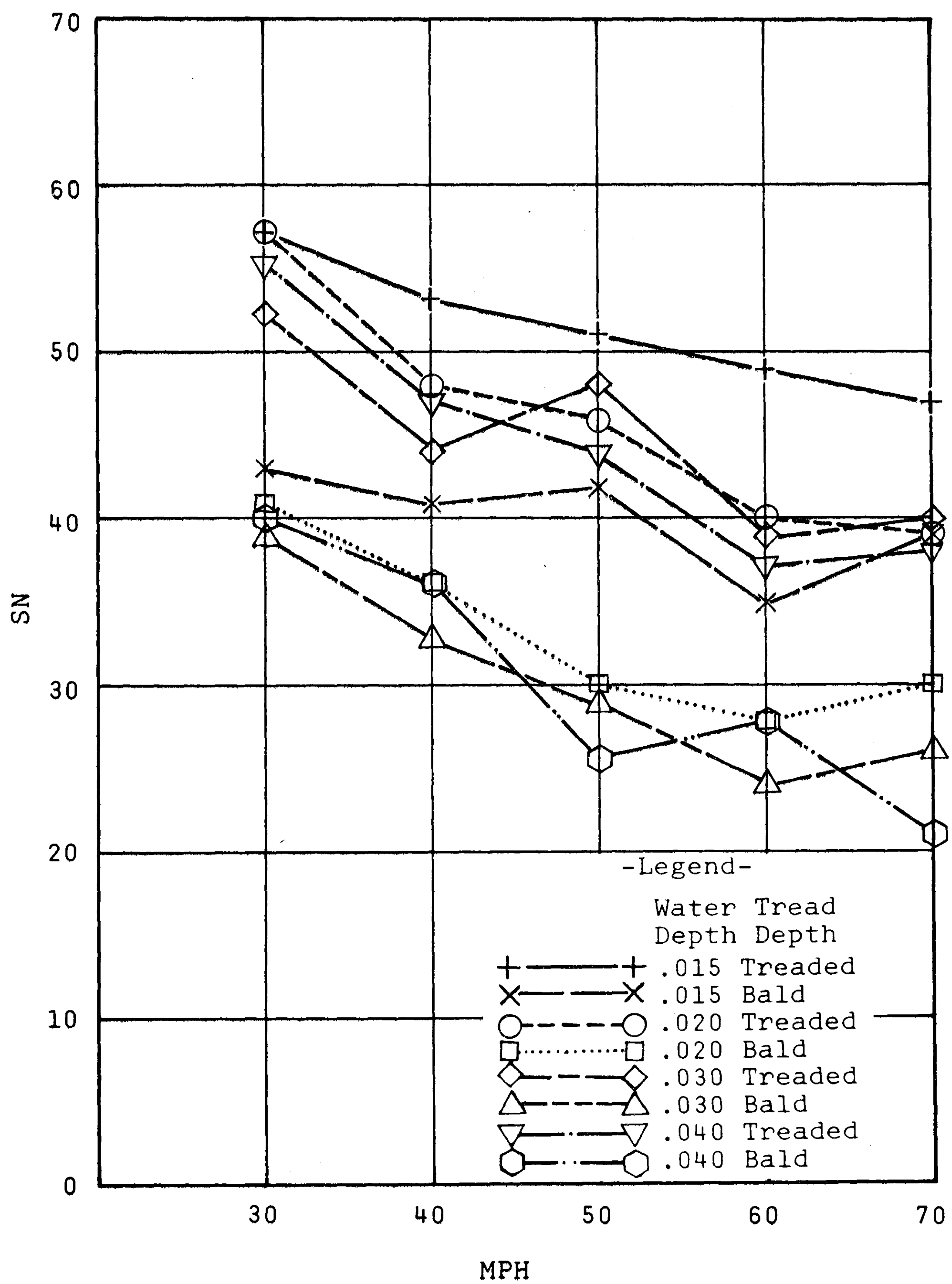


Figure A30. Site 30 — Speed gradient curves for treaded and bald tires for each water film. An S-5 bituminous concrete mix in the WBPL of Route 460 in Bedford County. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

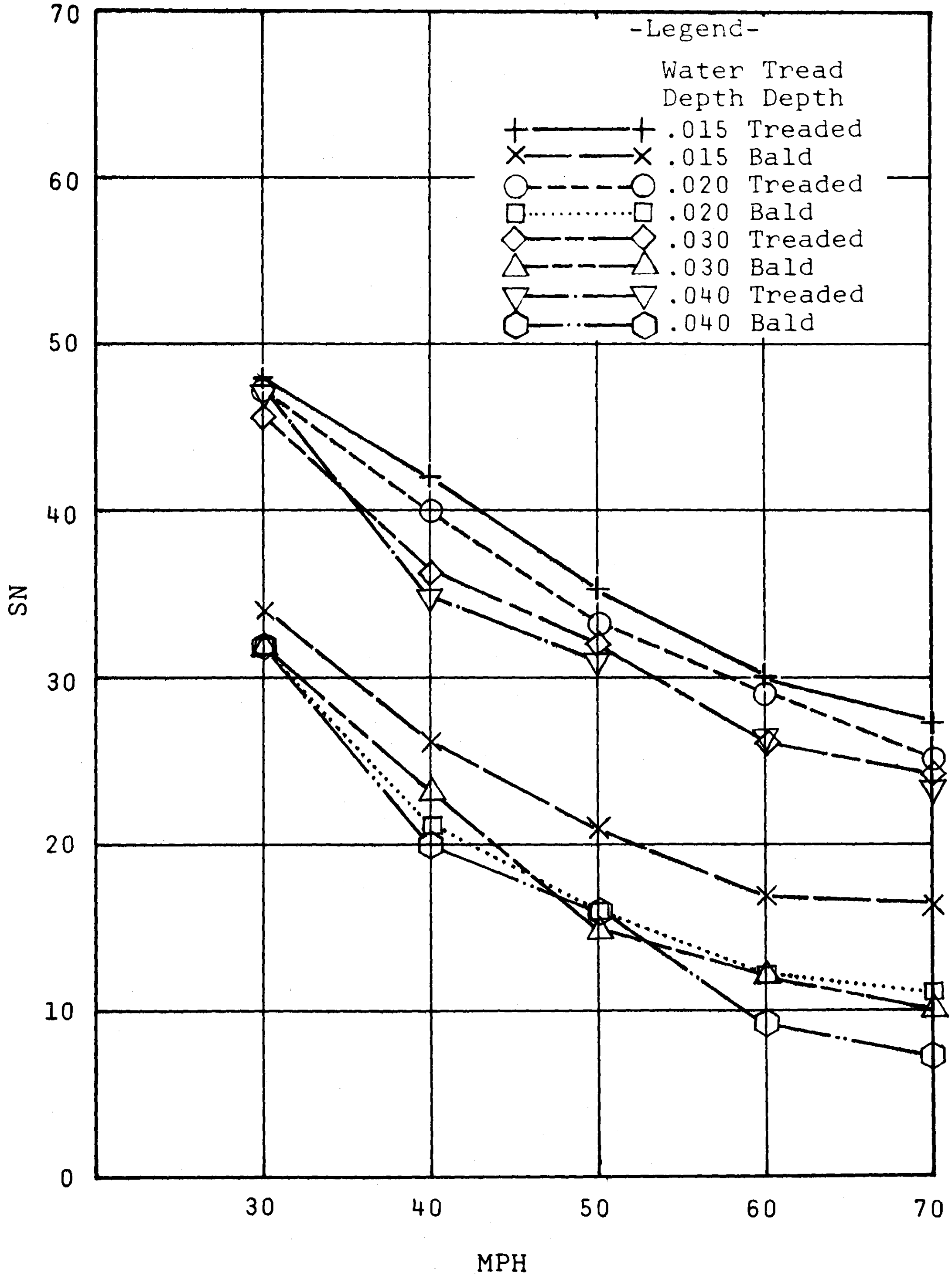


Figure A31. Site 31 — Speed gradient curves for treaded and bald tires for each water film. An S-5 bituminous concrete mix in the EBTL of Route 460 in Bedford County. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

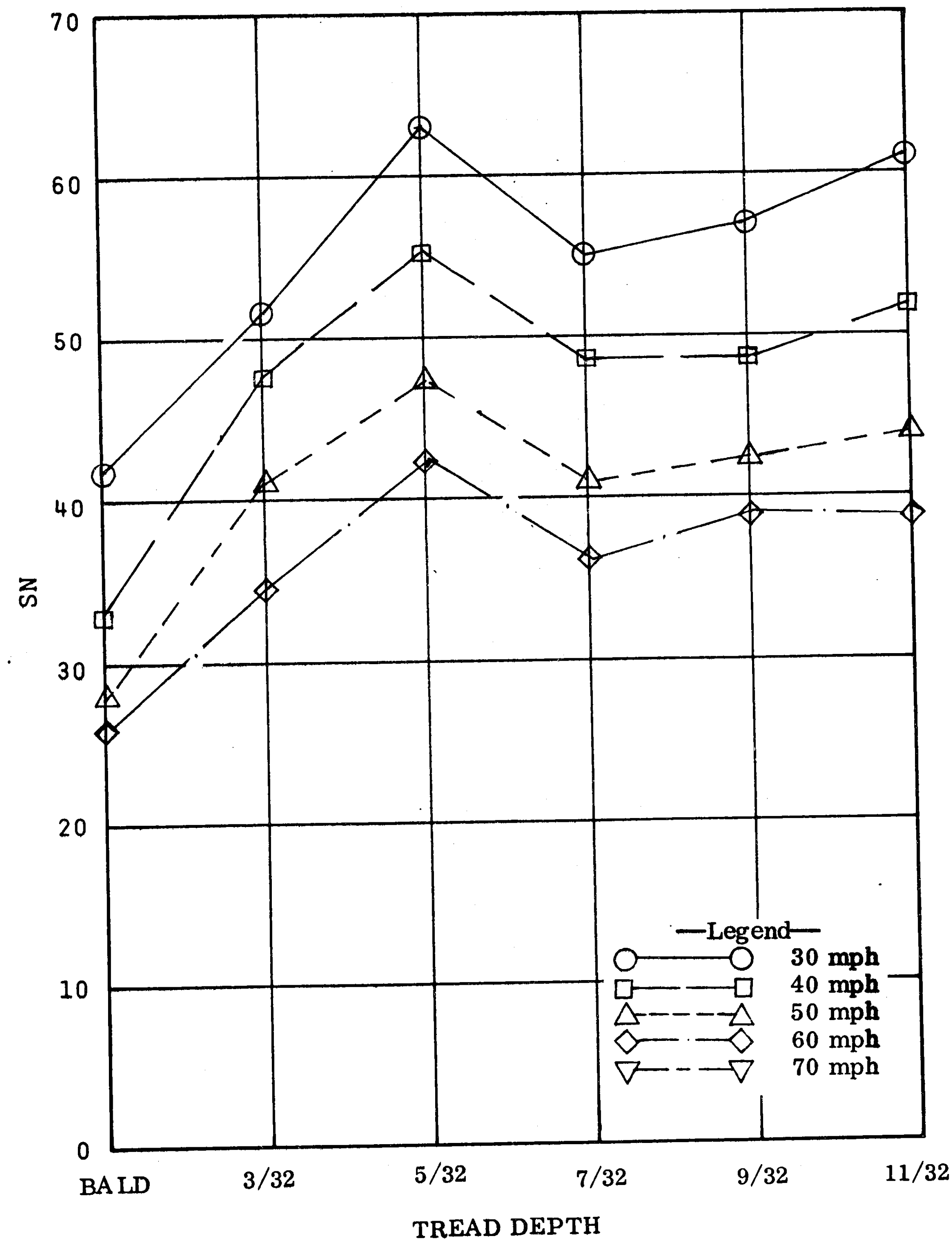


Figure A32. Skid number-tread depth curves for which the data for all water conditions were combined for the different test speeds on site 1. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

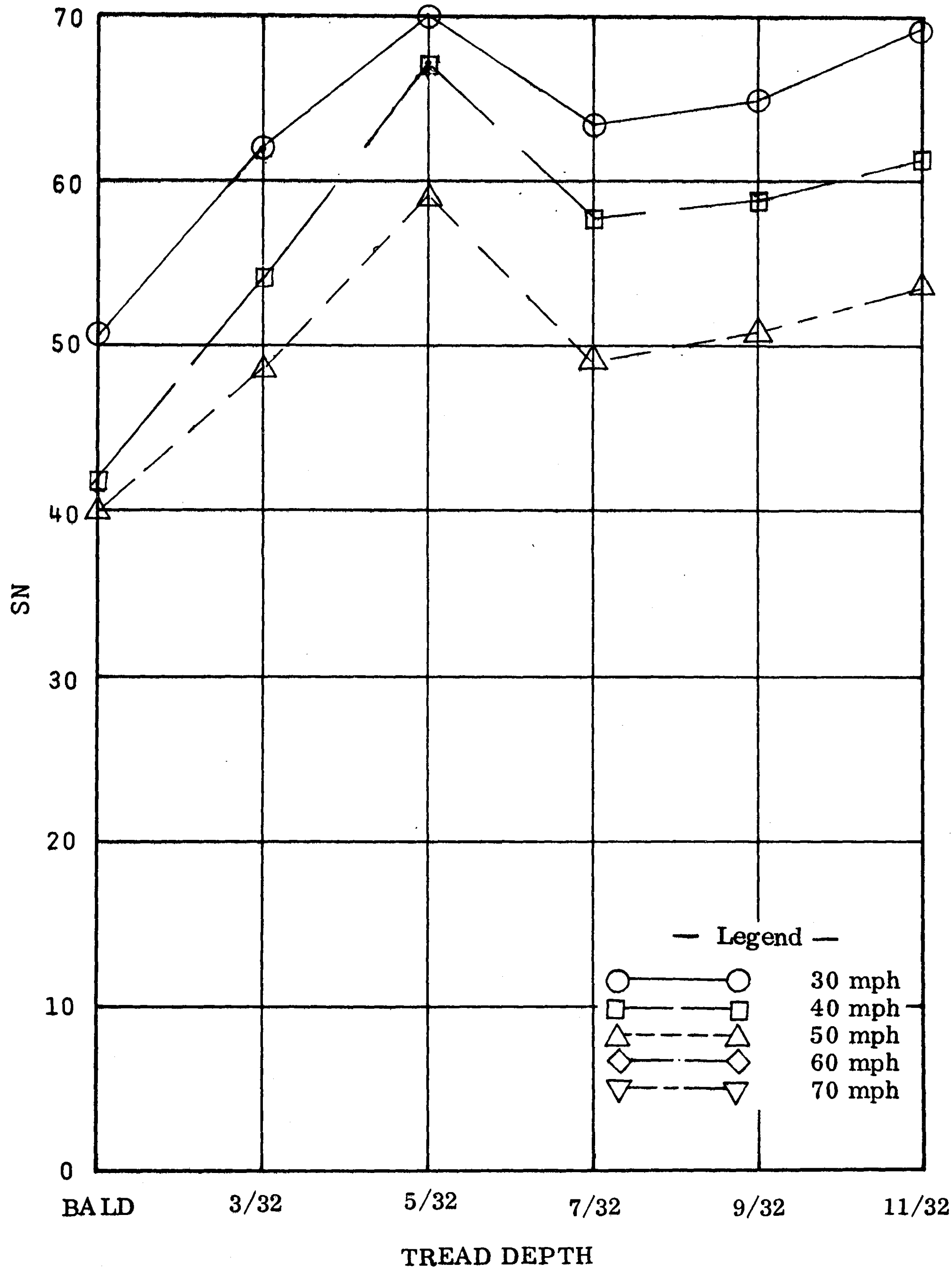


Figure A33. Skid number-tread depth curves for which the data for all water conditions were combined for the different test speeds on site 2. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

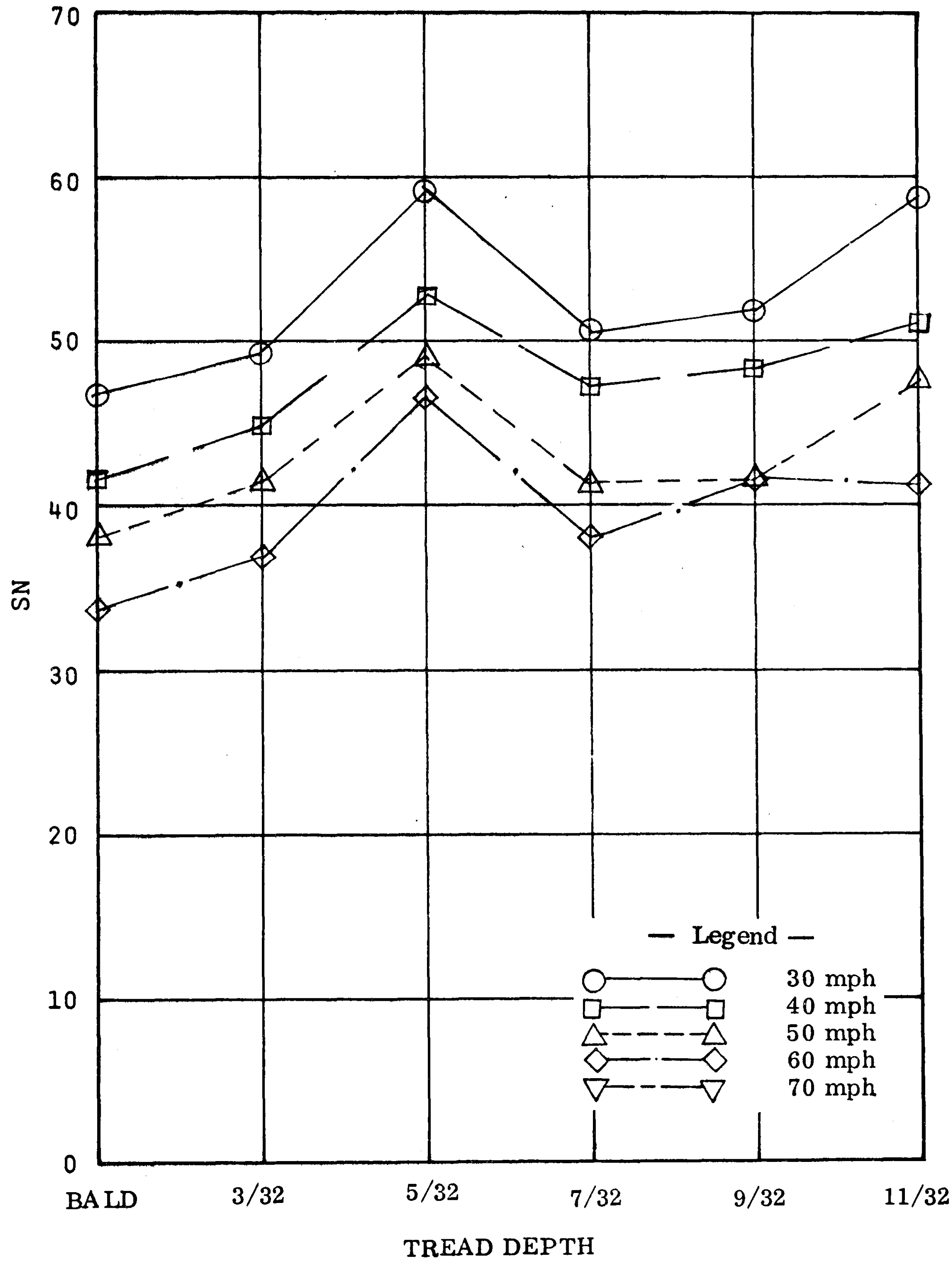


Figure A34. Skid number-tread depth curves for which the data for all water conditions were combined for the different test speeds on site 3. (1 inch = 2.54 cm; 1 mph = .4470 m/s)

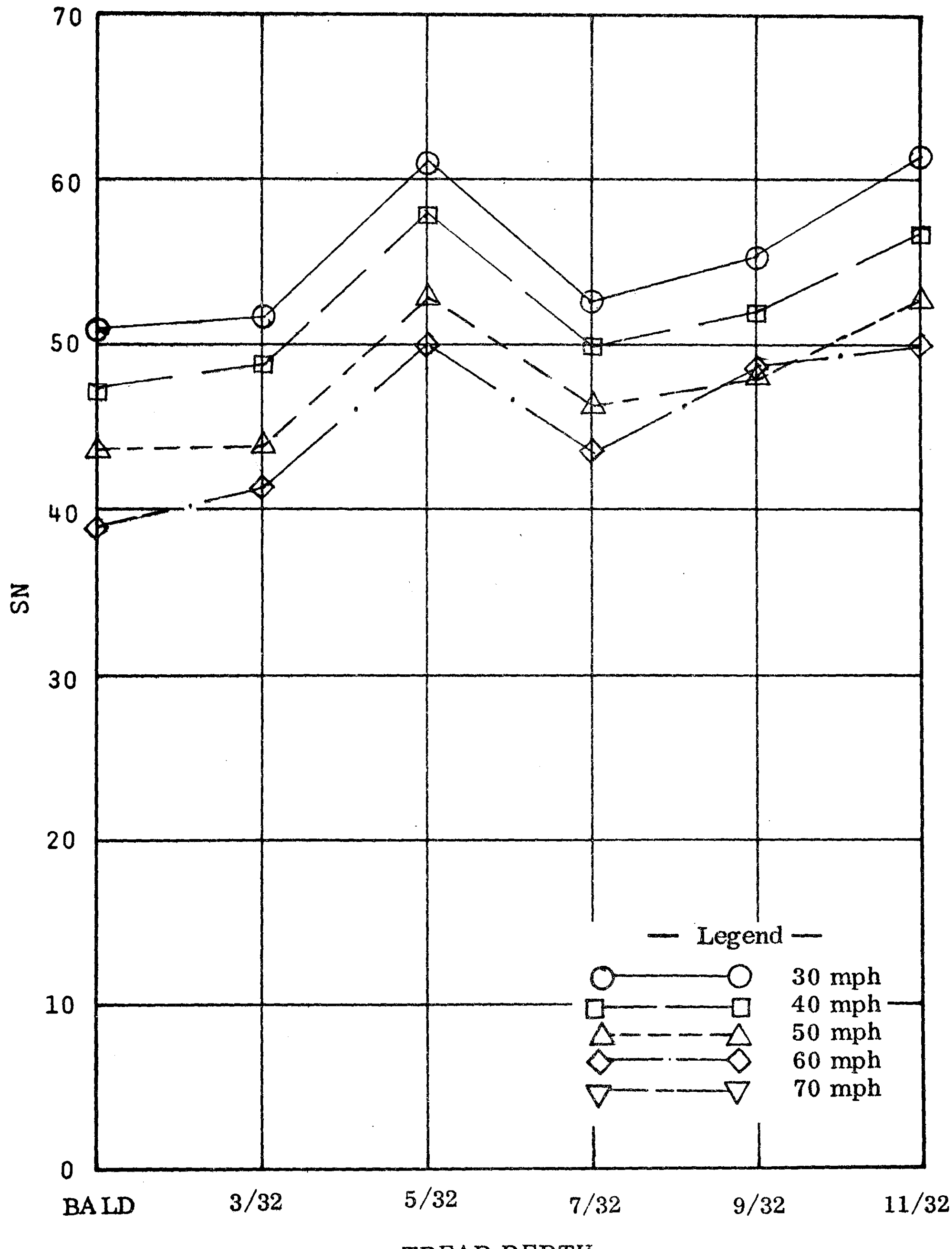


Figure A35. Skid number-tread depth curves for which the data for all water conditions were combined for the different test speeds on site 4. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

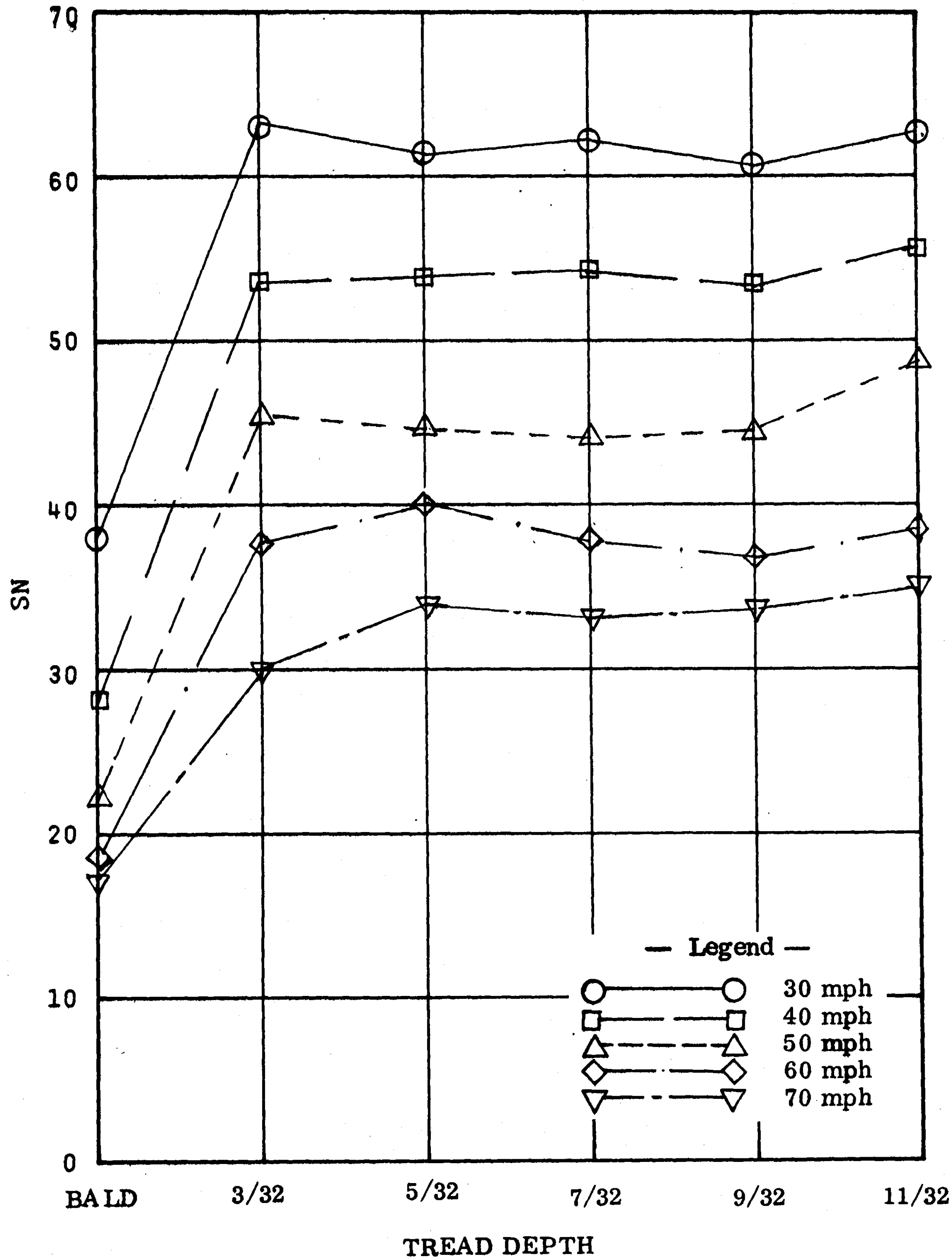


Figure A36. Skid number-tread depth curves for which the data for all water conditions were combined for the different test speeds on site 5. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

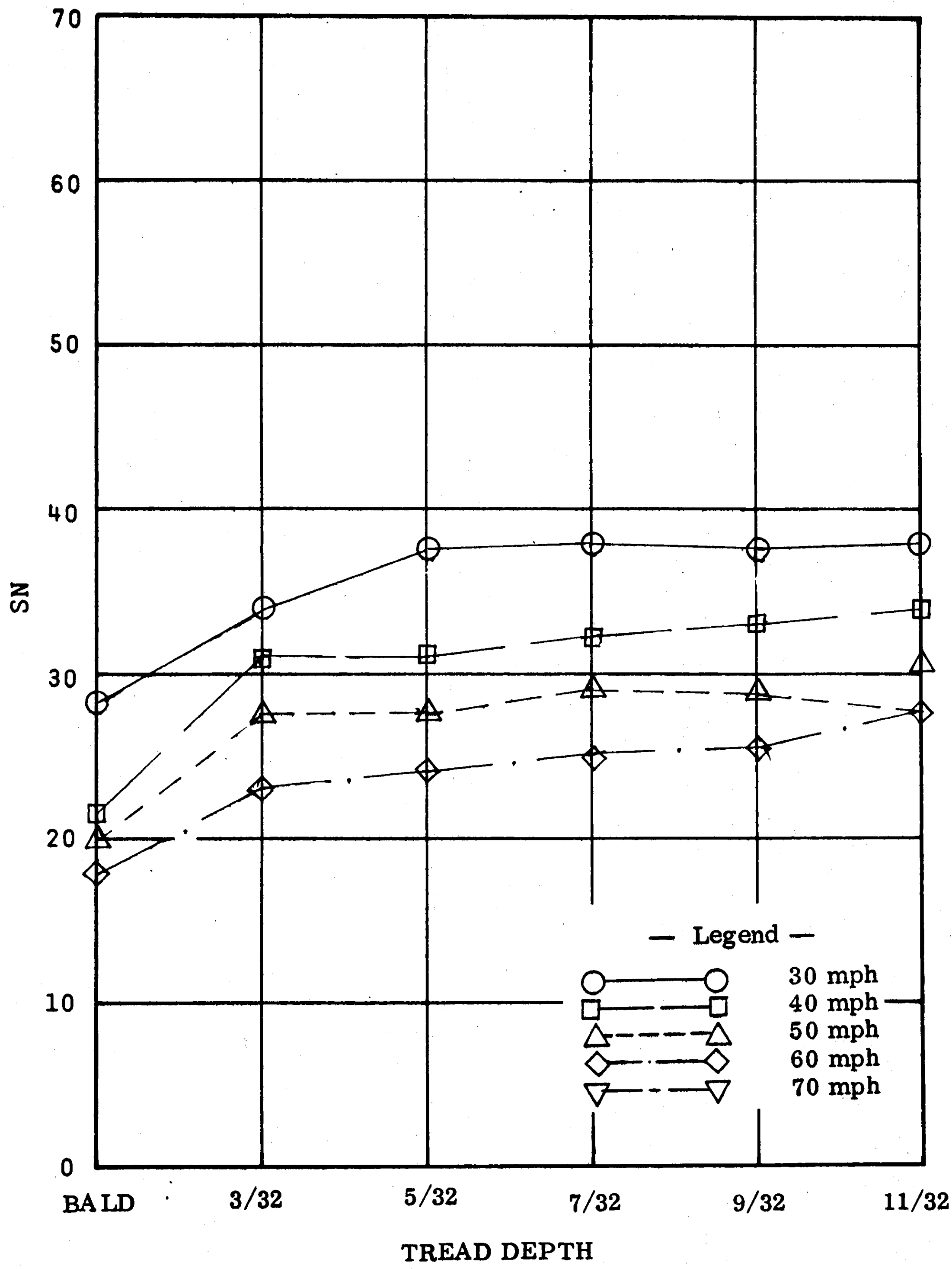


Figure A37. Skid number-tread depth curves for which the data for all water conditions were combined for the different test speeds on site 6. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

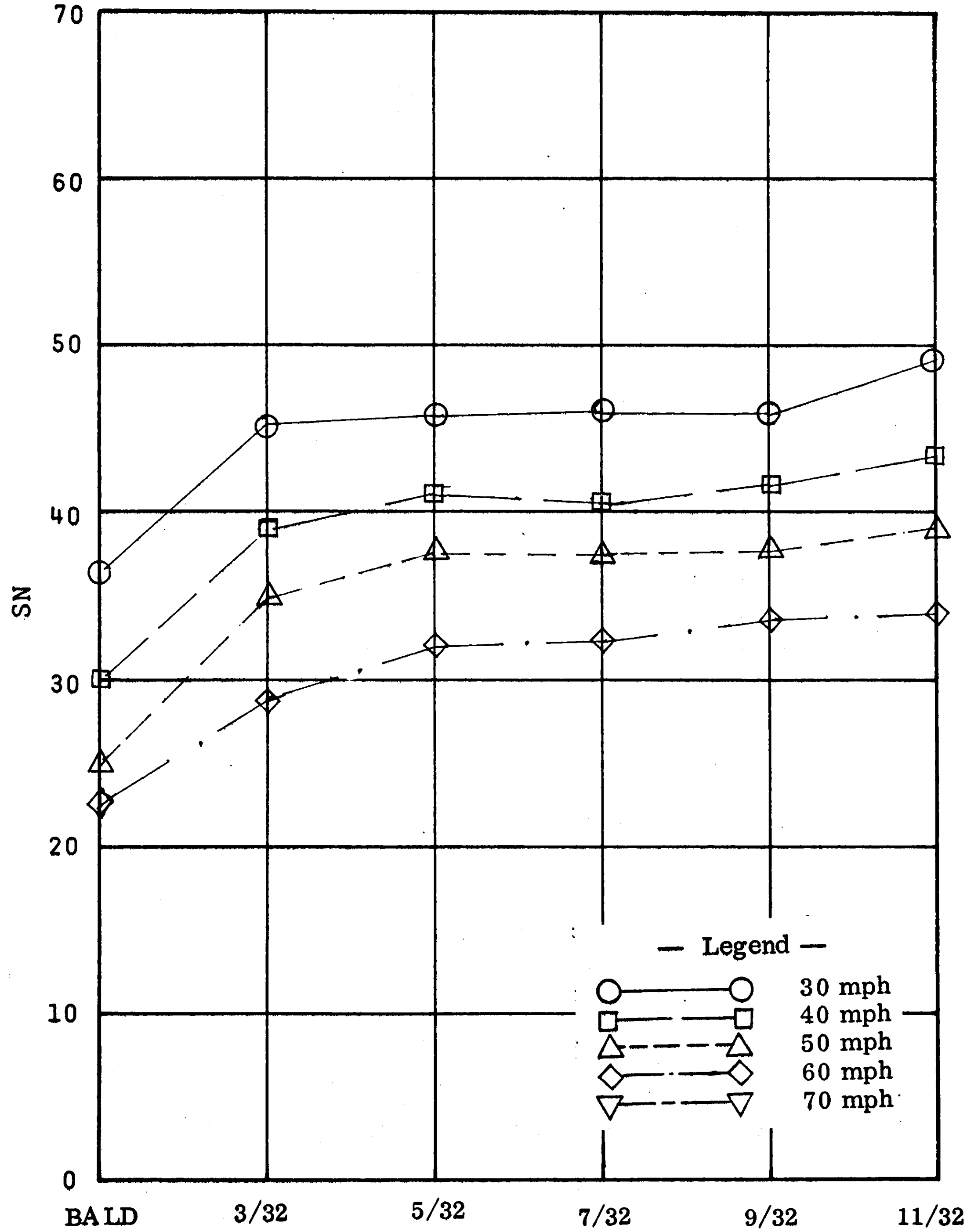


Figure A38. Skid number-tread depth curves for which the data for all water conditions were combined for the different test speeds on site 7. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

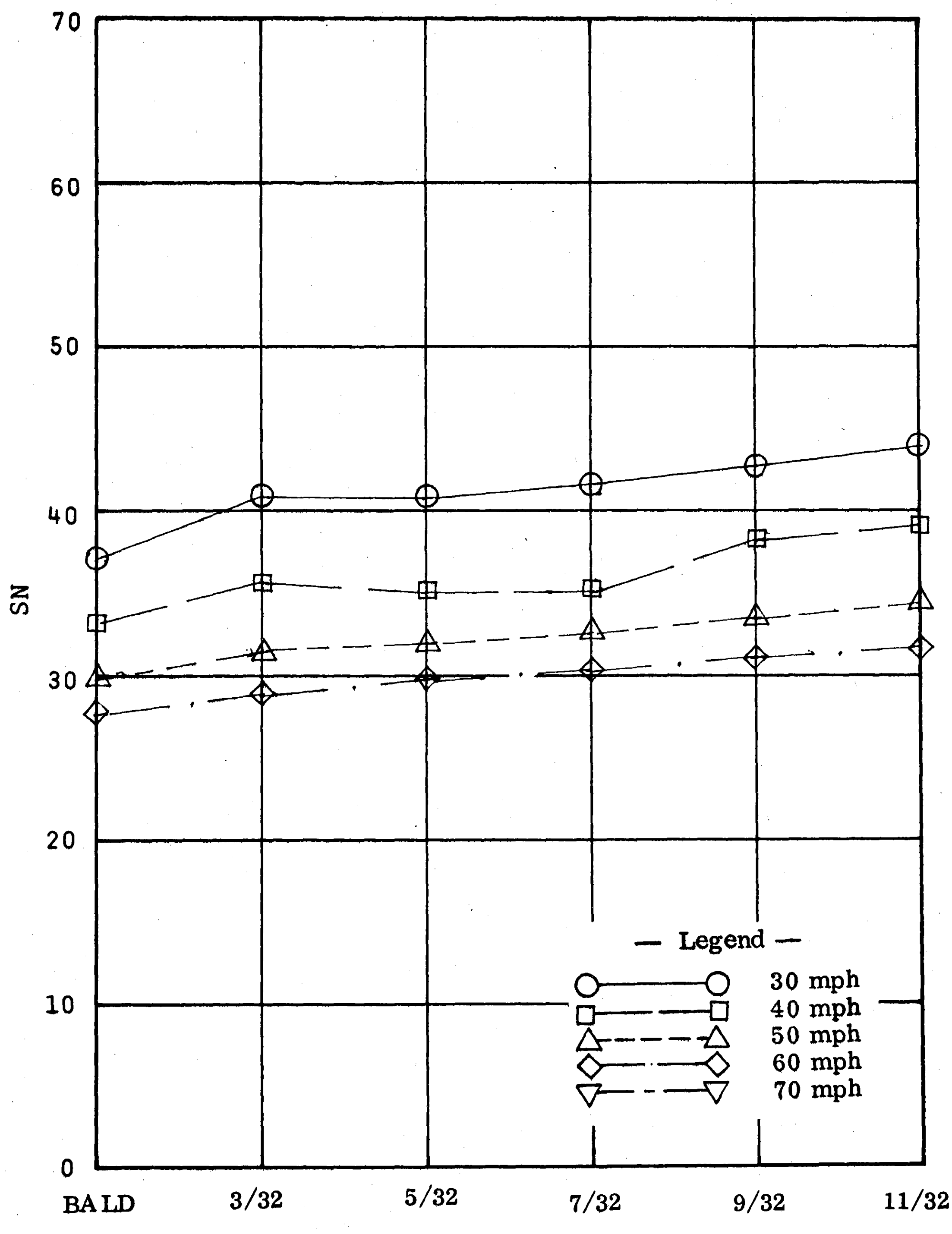


Figure A39. Skid number-tread depth curves for which the data for all water conditions were combined for the different test speeds on site 8. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

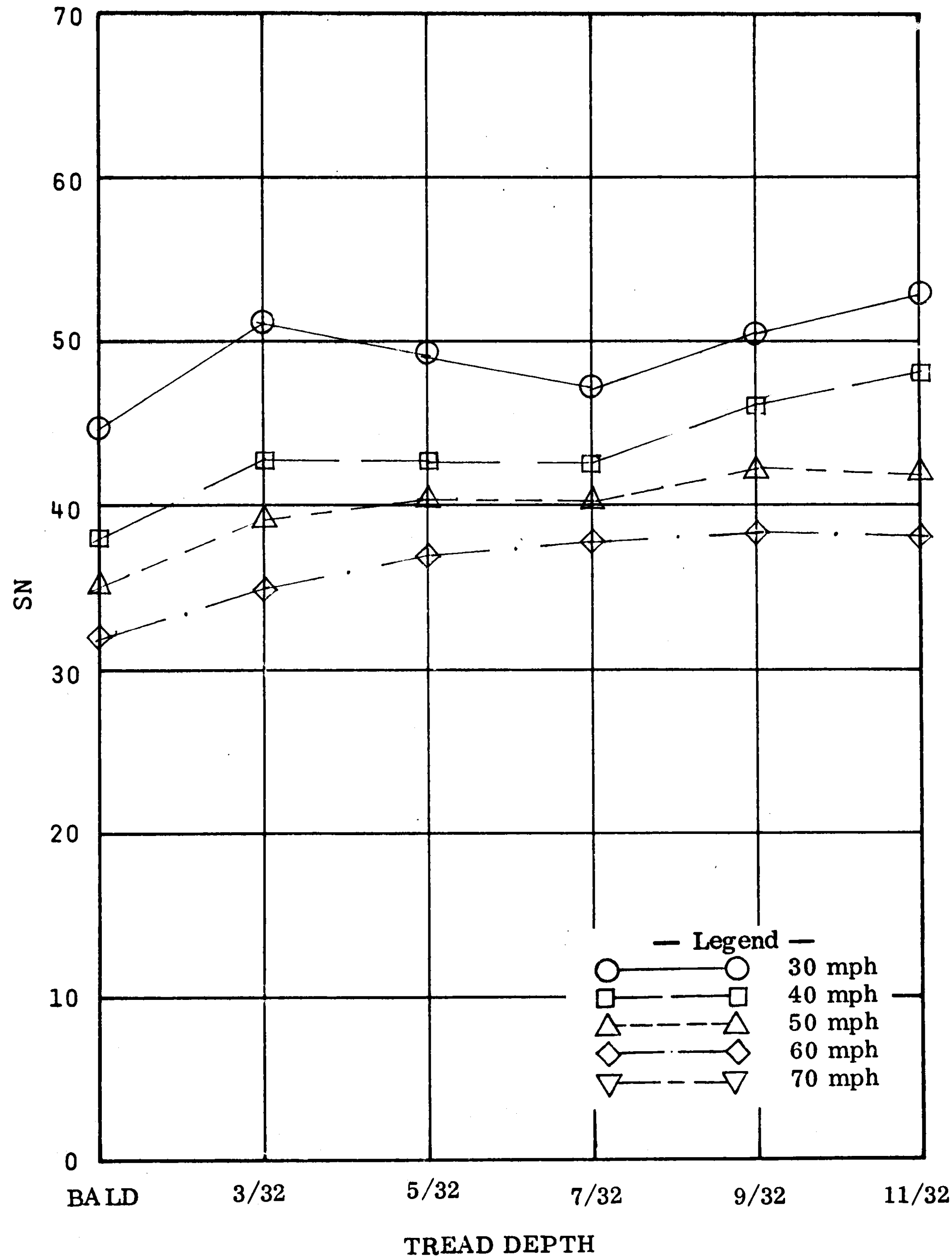


Figure A40. Skid number-tread depth curves for which the data for all water conditions were combined for the different test speeds on site 9. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

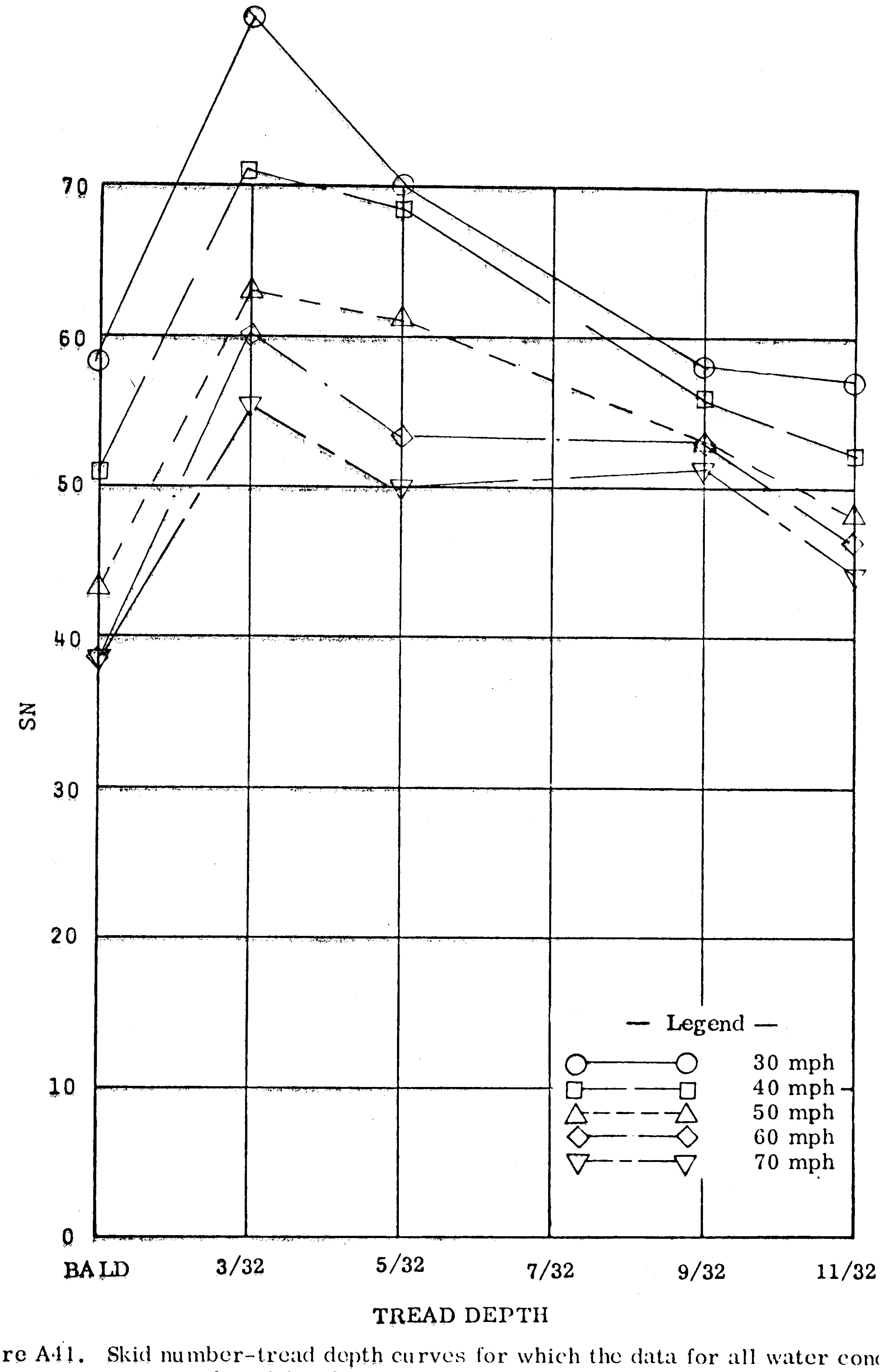


Figure A41. Skid number-tread depth curves for which the data for all water conditions were combined for the different test speeds on site 10. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

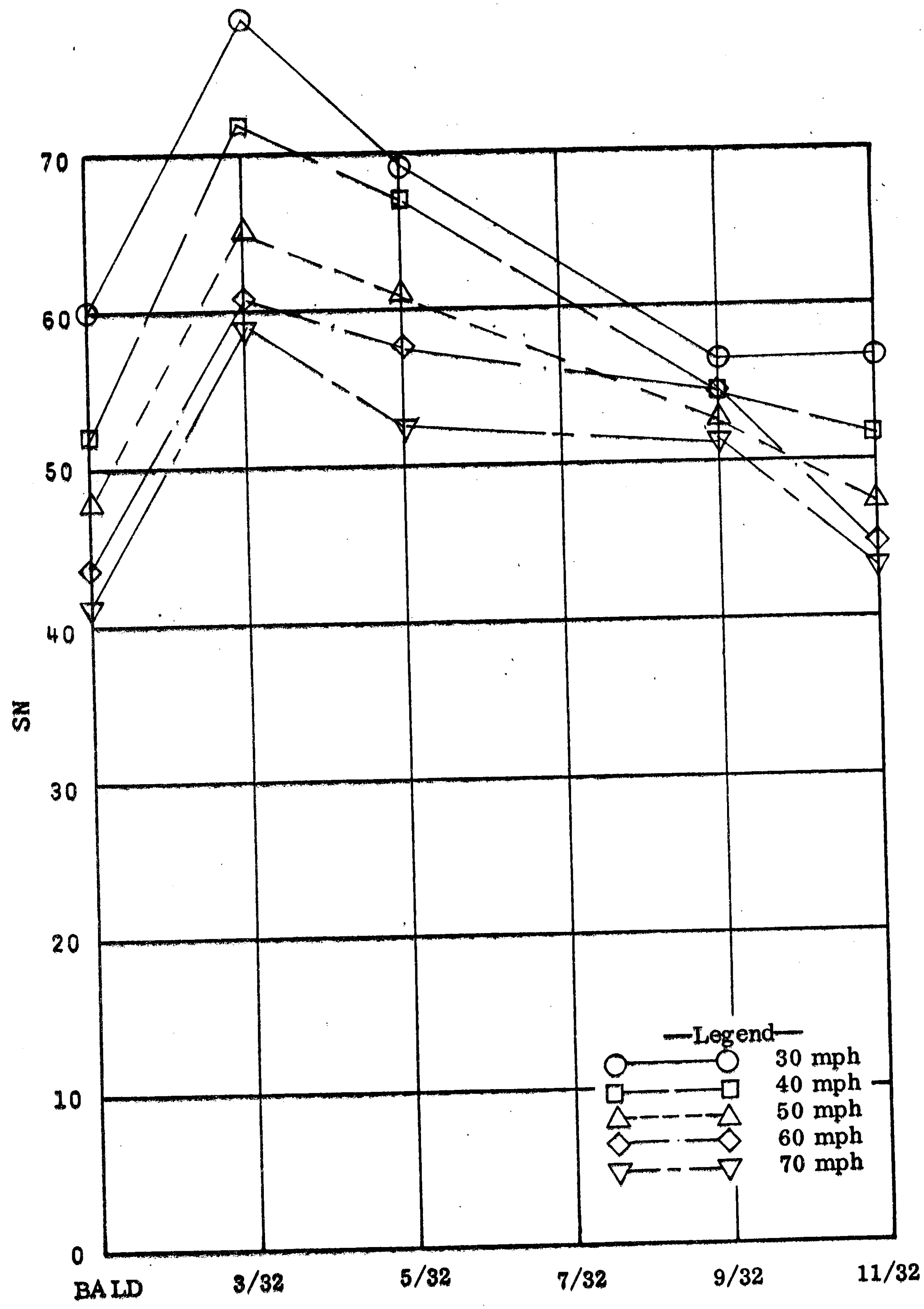


Figure A42. Skid number-tread depth curves for which the data for all water conditions were combined for the different test speeds on Site 11. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

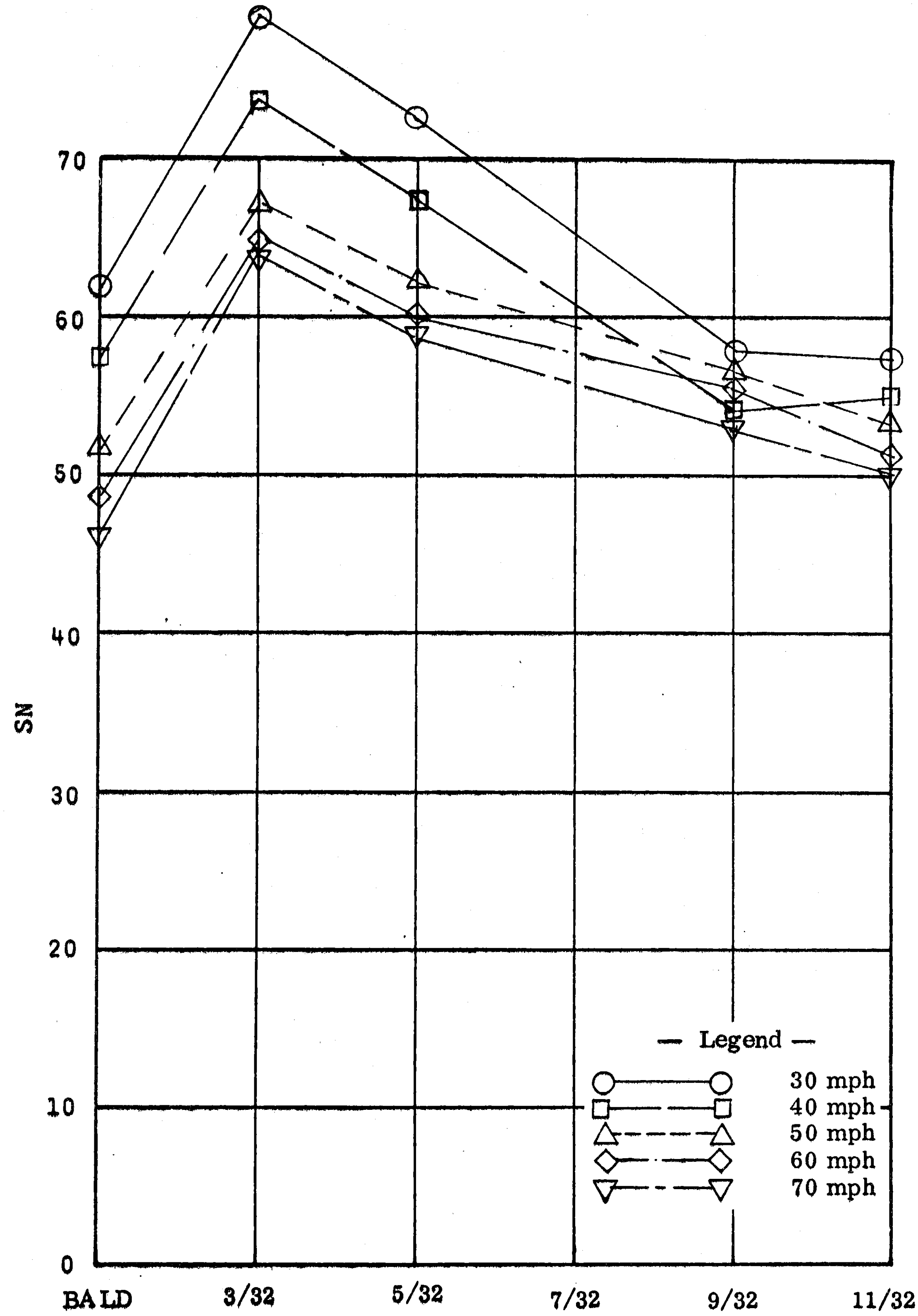


Figure A43. Skid number-tread depth curves for which the data for all water conditions were combined for the different test speeds on site 12. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

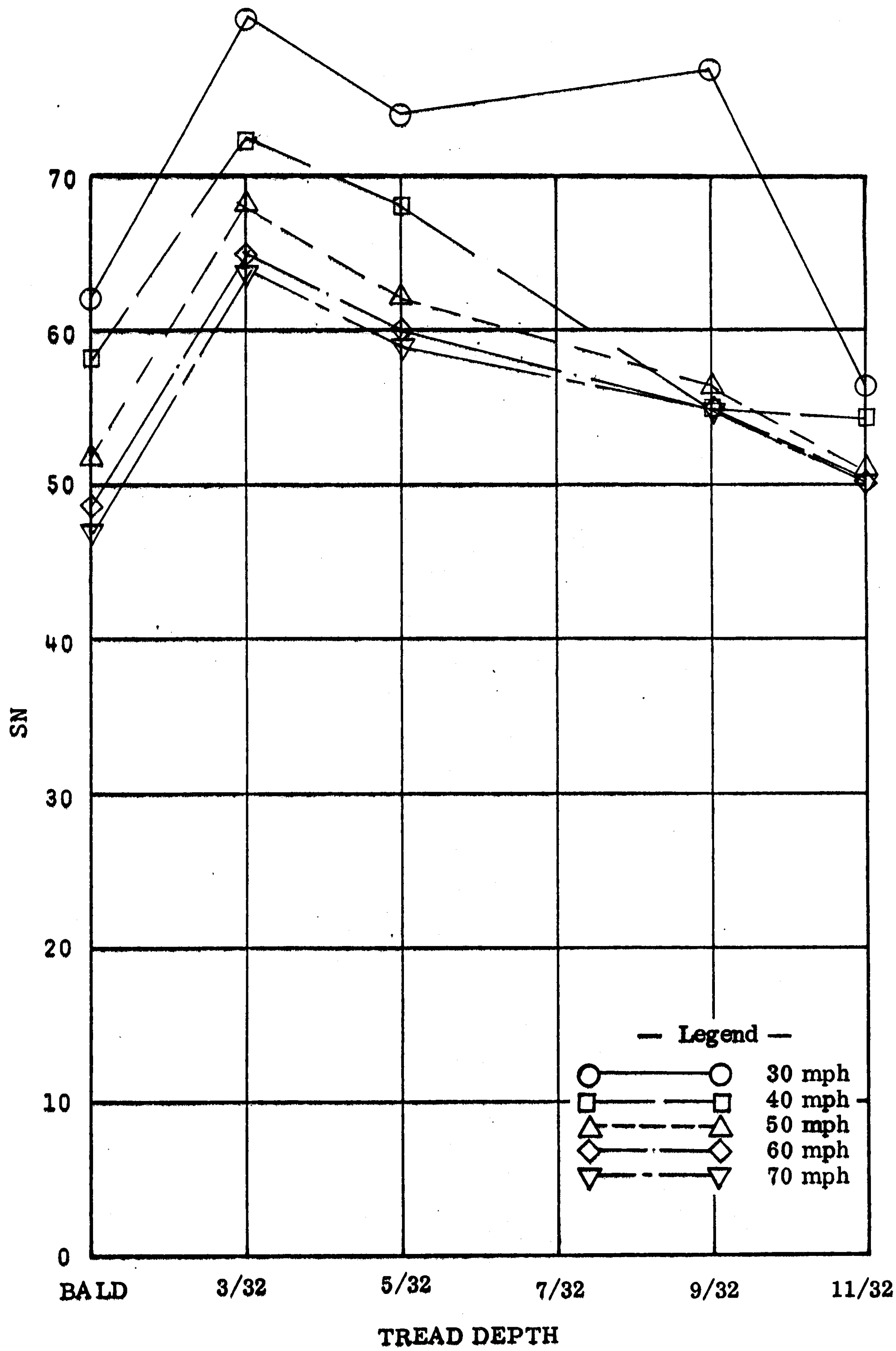


Figure A44. Skid number-tread depth curves for which the data for all water conditions were combined for the different test speeds on site 13. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

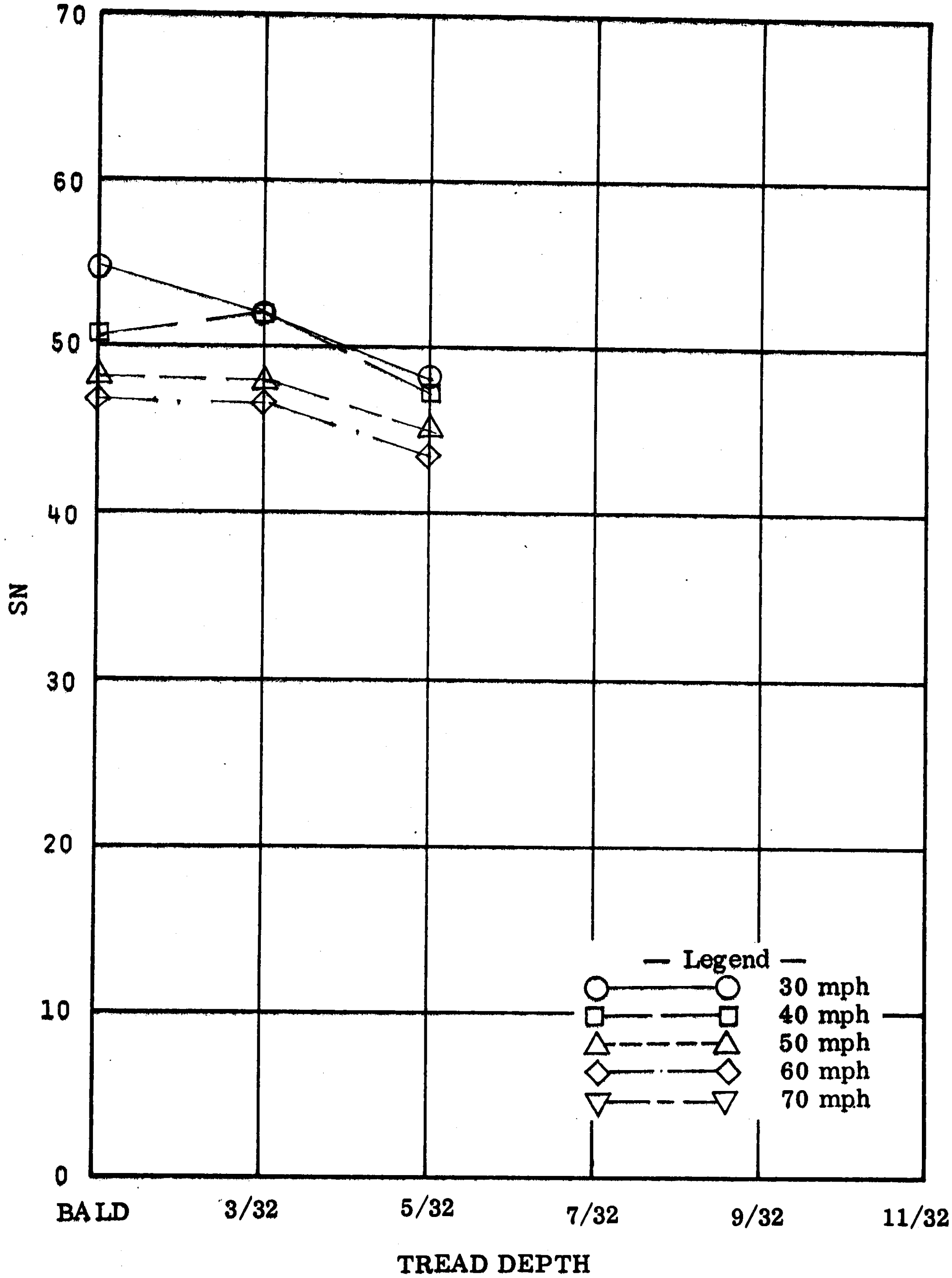


Figure A45. Skid number-tread depth curves for which the data for all water conditions were combined for the different test speeds on site 16. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

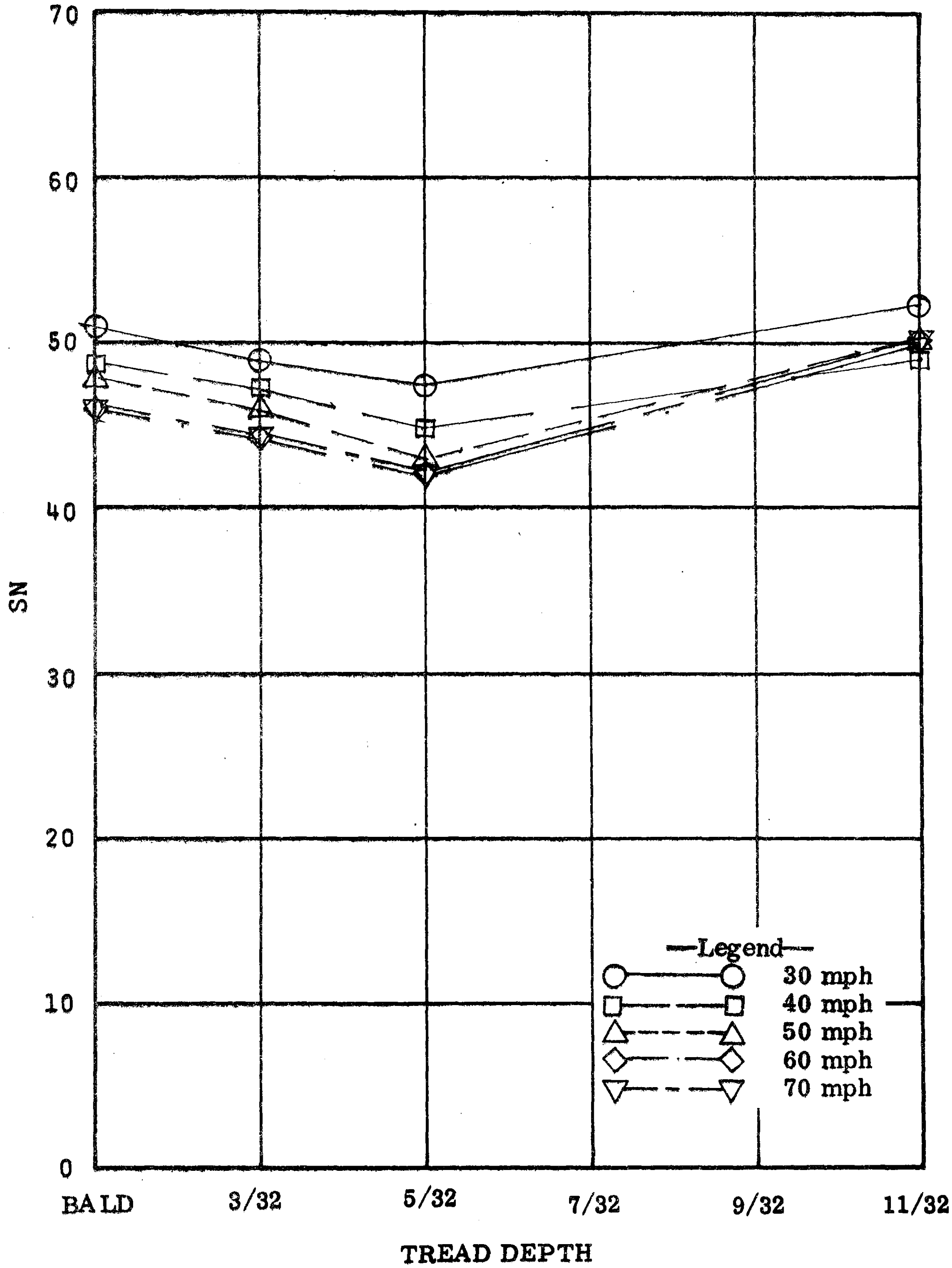


Figure A46. Skid number-tread depth curves for which the data for all water conditions were combined for the different test speeds on site 17. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

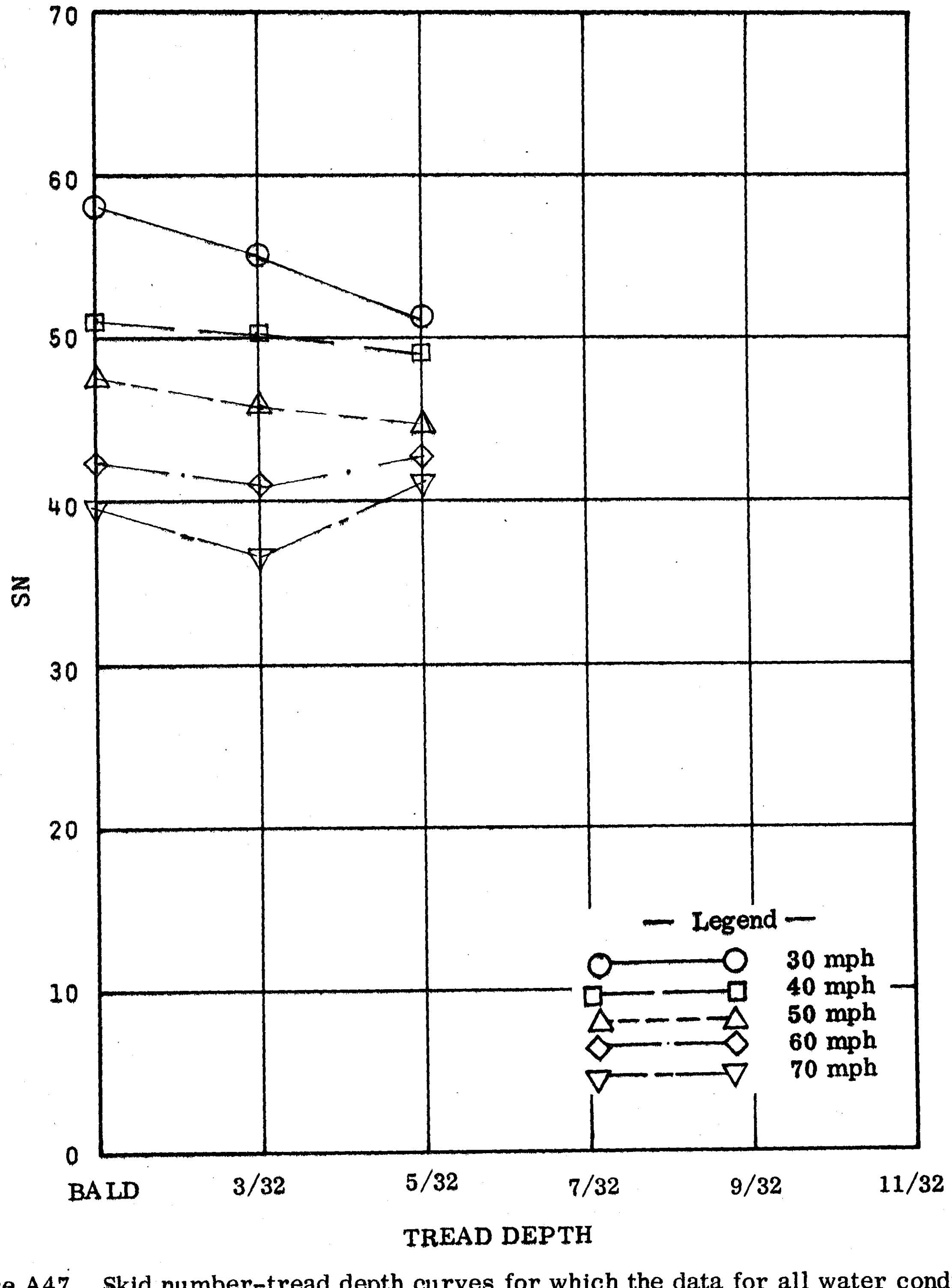


Figure A47. Skid number-tread depth curves for which the data for all water conditions were combined for the different test speeds on site 18. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

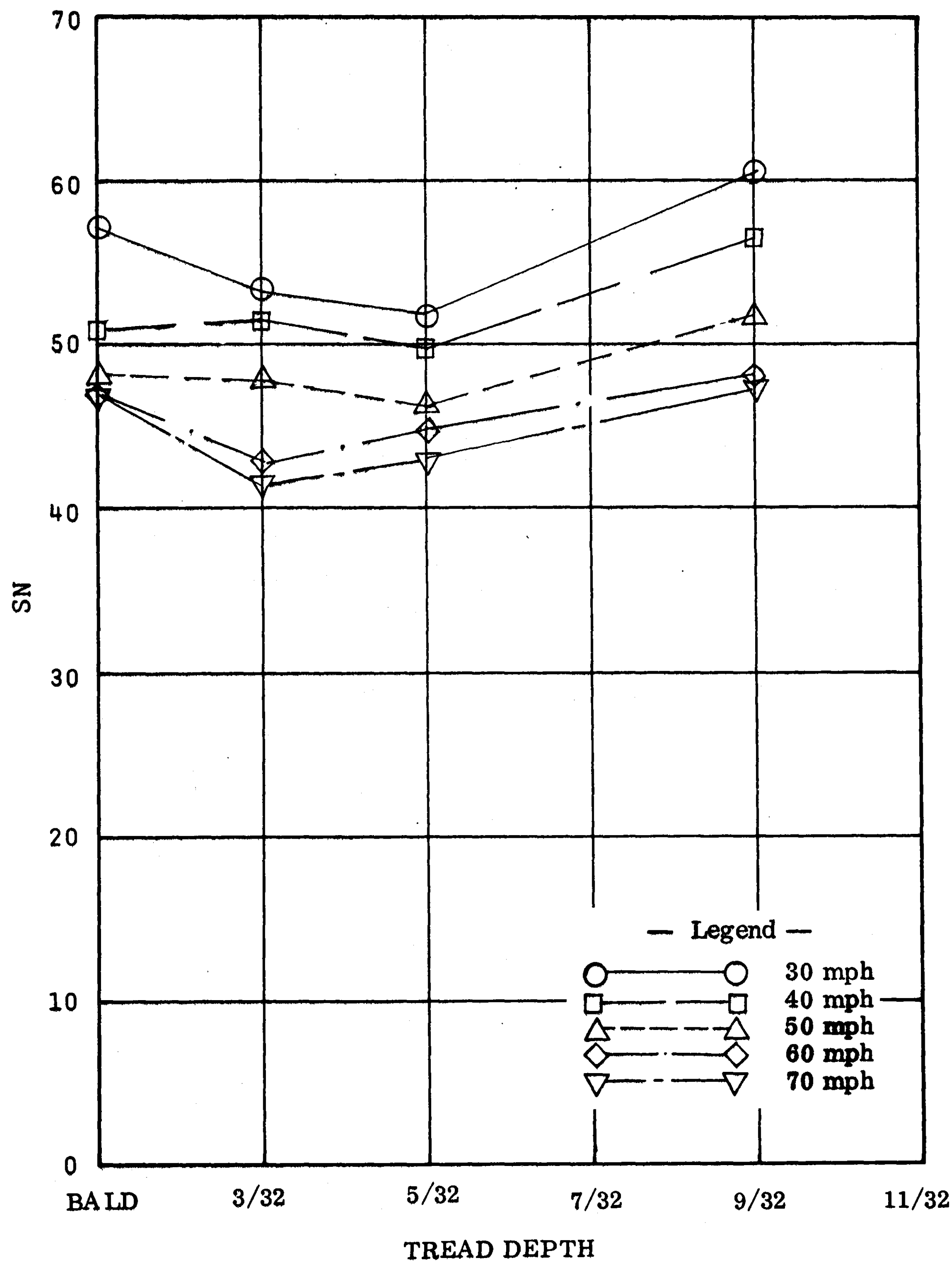


Figure A48. Skid number-tread depth curves for which the data for all water conditions were combined for the different test speeds on site 19. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

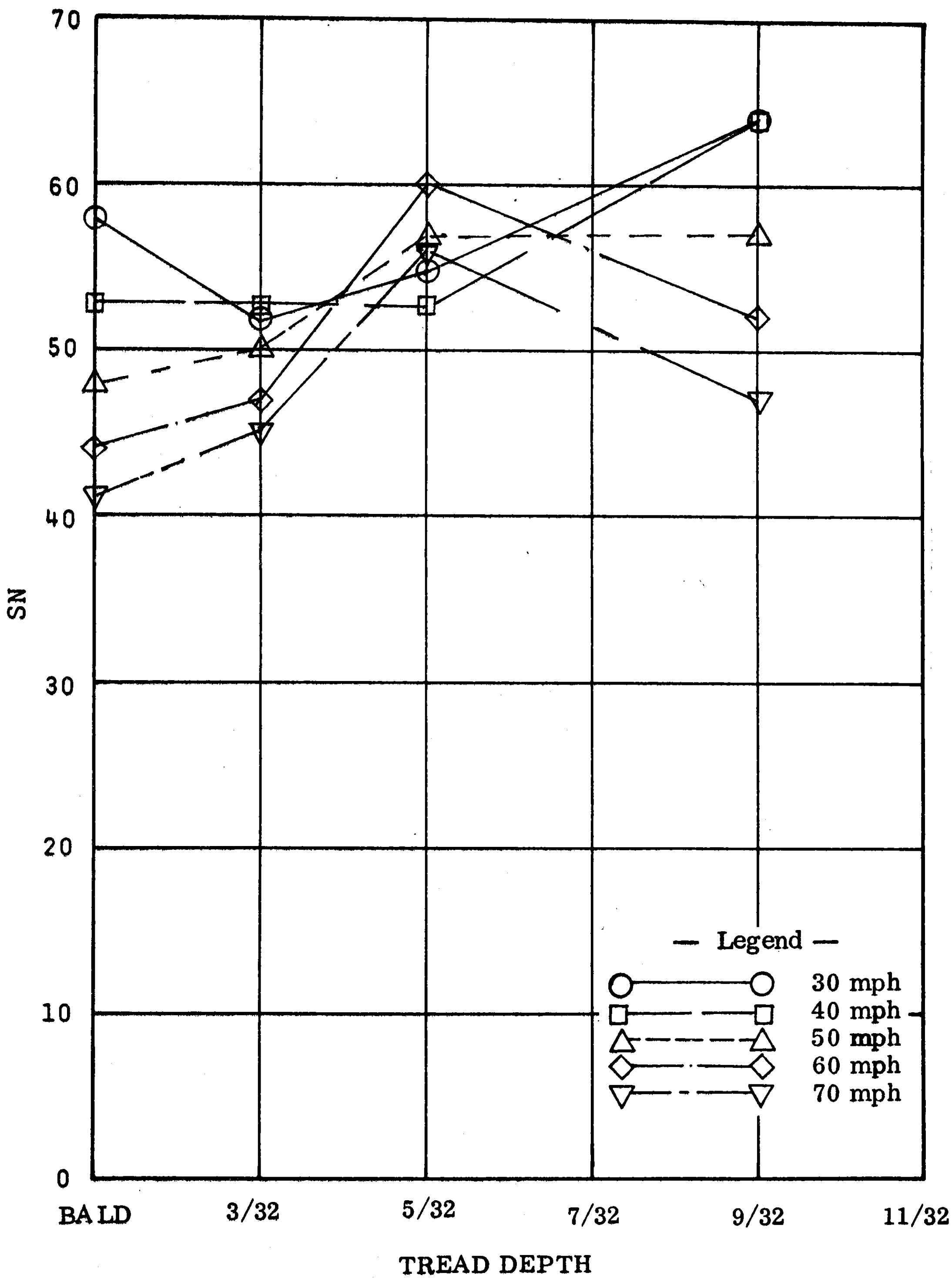


Figure A49. Skid number-tread depth curves for which the data for all water conditions were combined for the different test speeds on site 20. (1 inch = 2.54 cm; 1 mph = .4470 m/s)

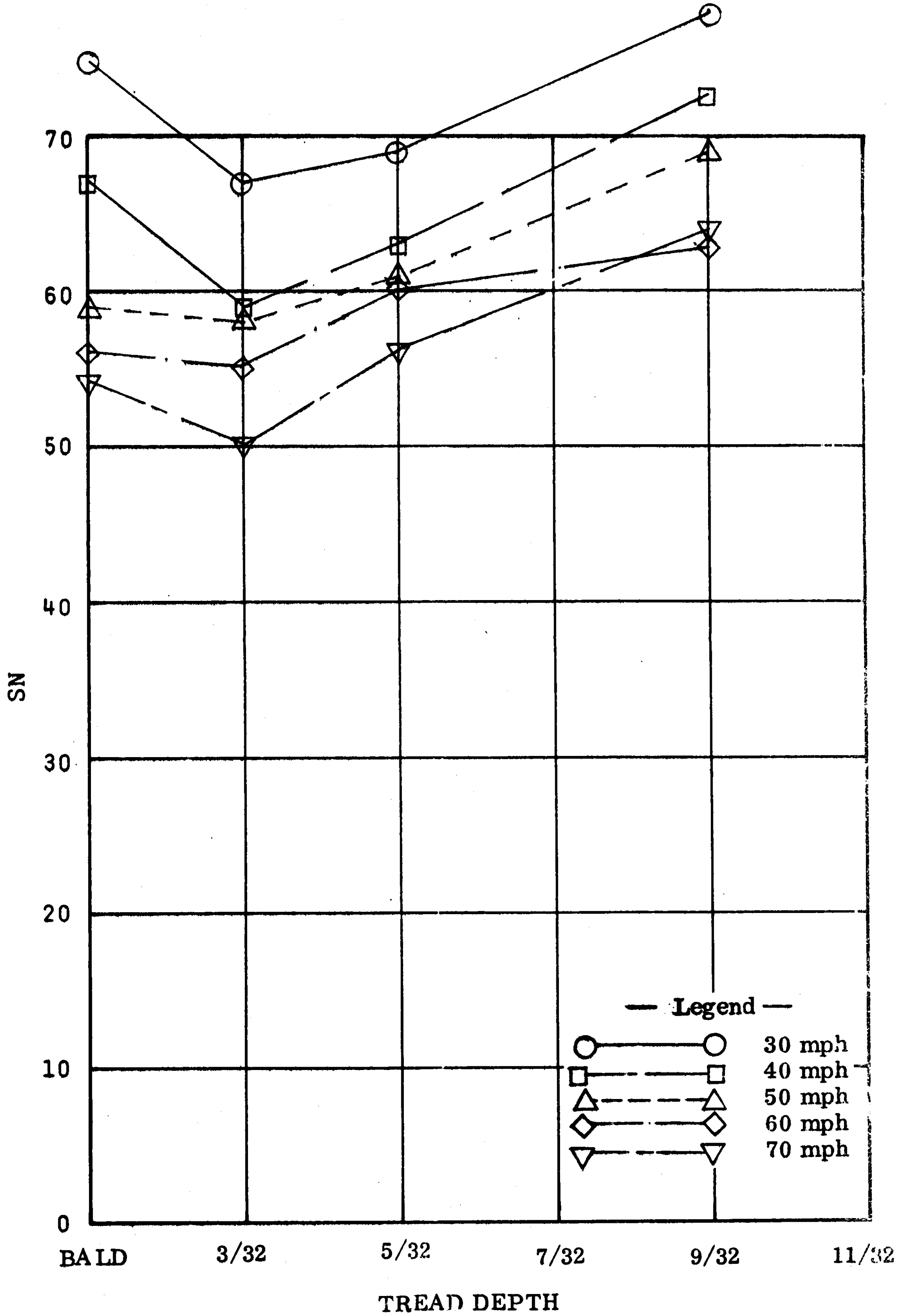


Figure A50. Skid number-tread depth curves for which the data for all water conditions were combined for the different test speeds on site 21. (1 inch = 2.54 cm; 1 mph = .4470 m/s)

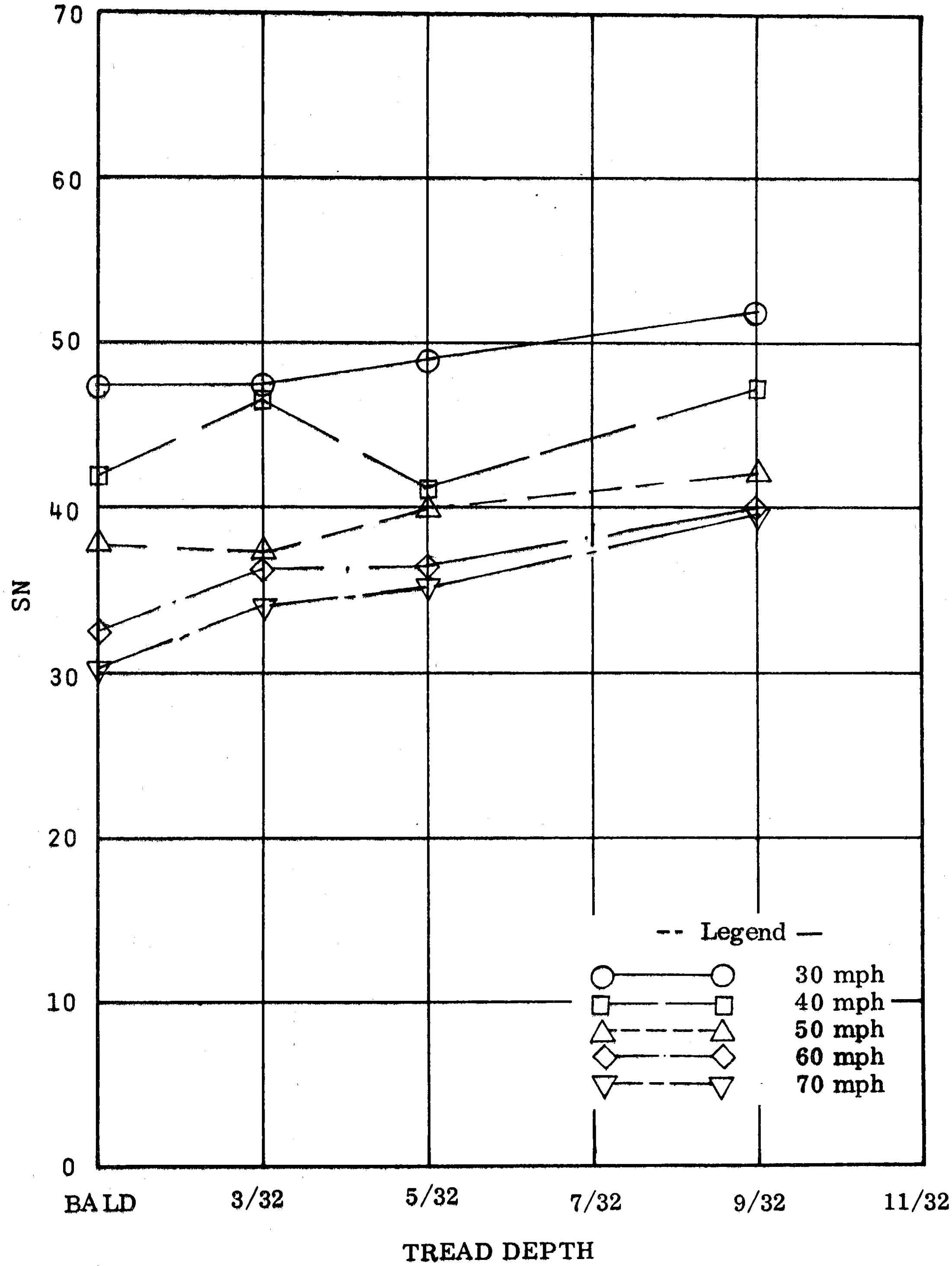


Figure A51. Skid number-tread depth curves for which the data for all water conditions were combined for the different test speeds on site 22. (1inch = 2.54 cm; 1 mph = .4470 m/s)

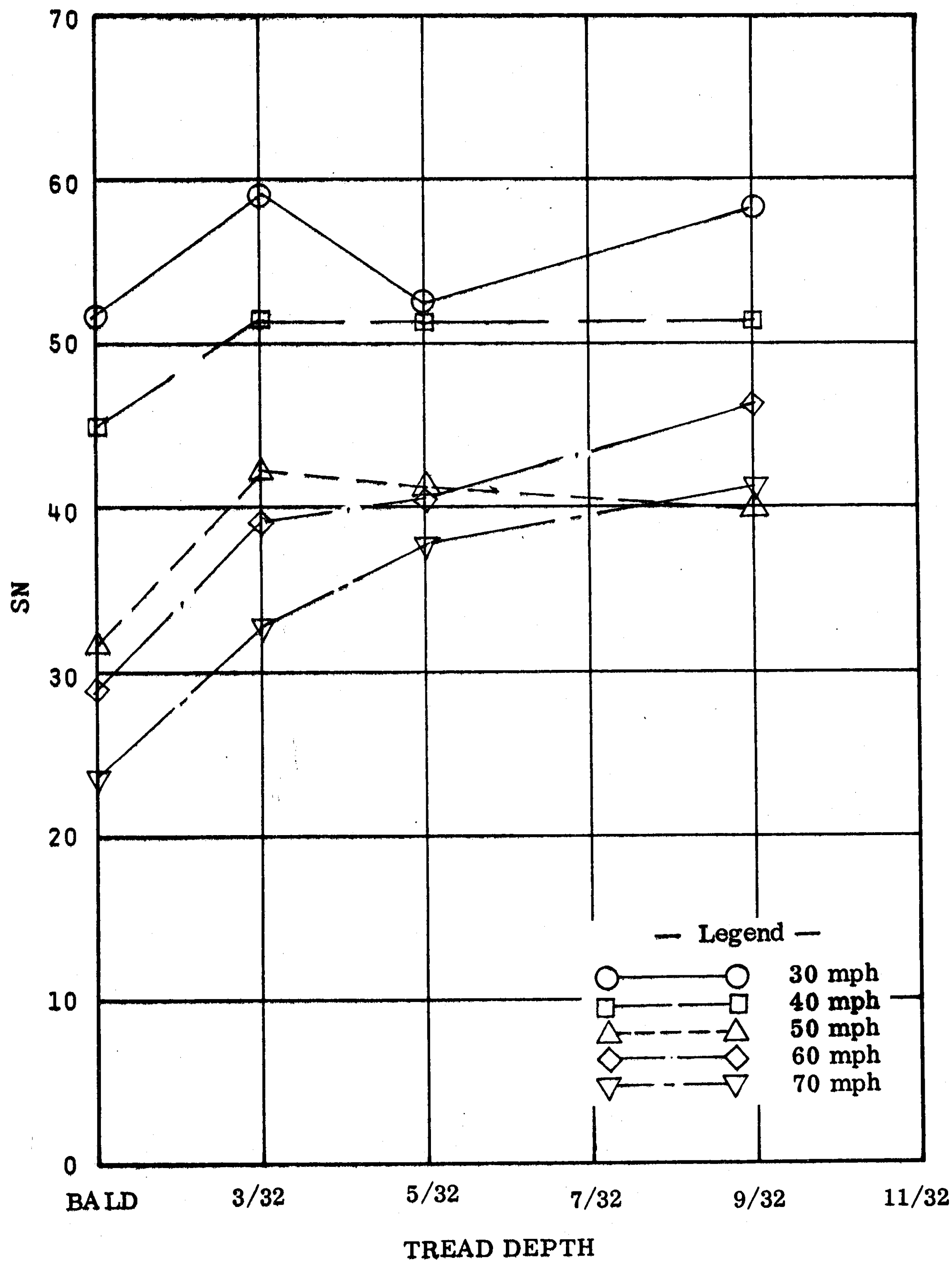


Figure A52. Skid number-tread depth curves for which the data for all water conditions were combined for the different test speeds on site 23. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

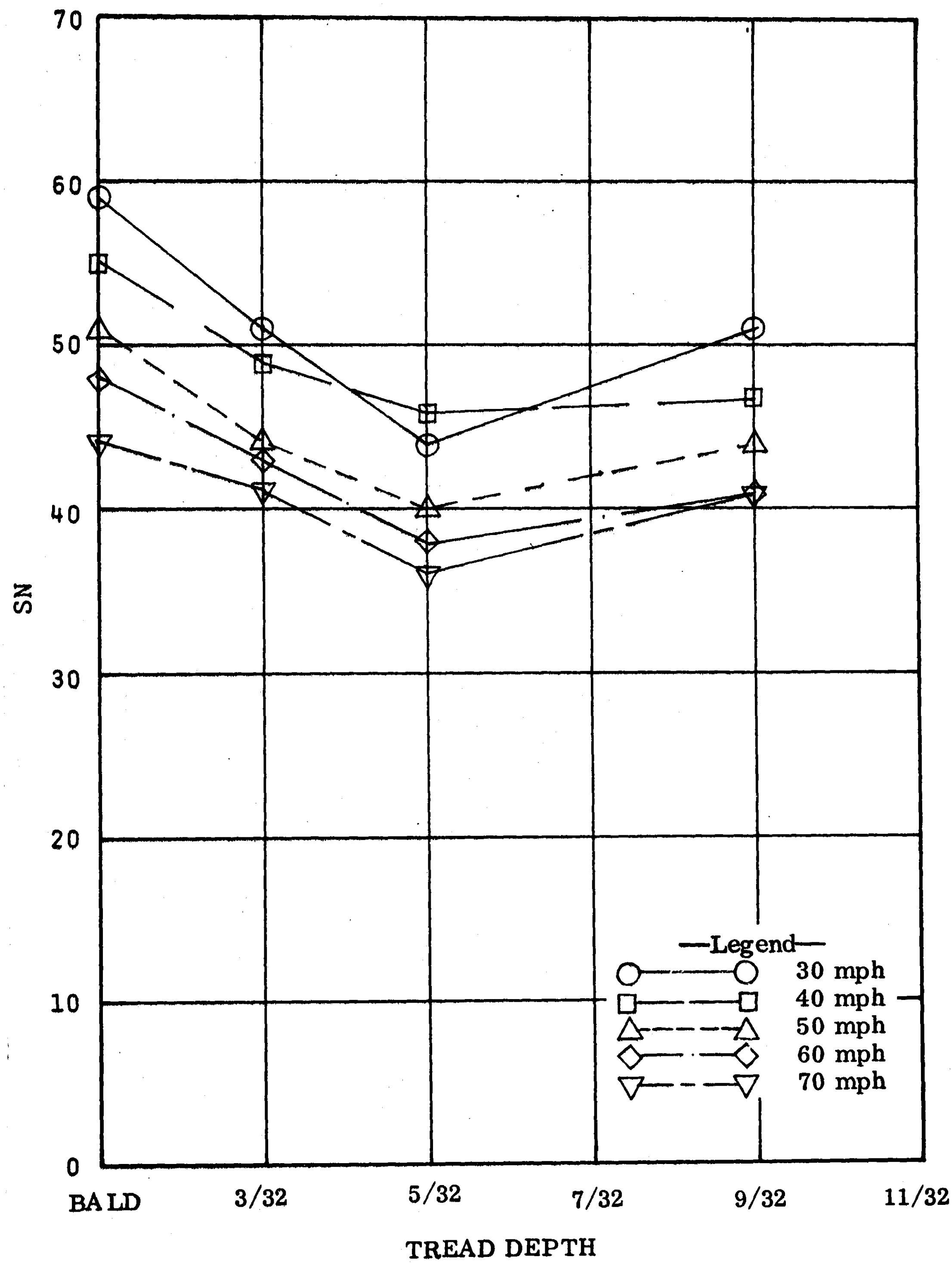


Figure A53. Skid number-tread depth curves for which the data for all water conditions were combined for the different test speeds on site 24. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

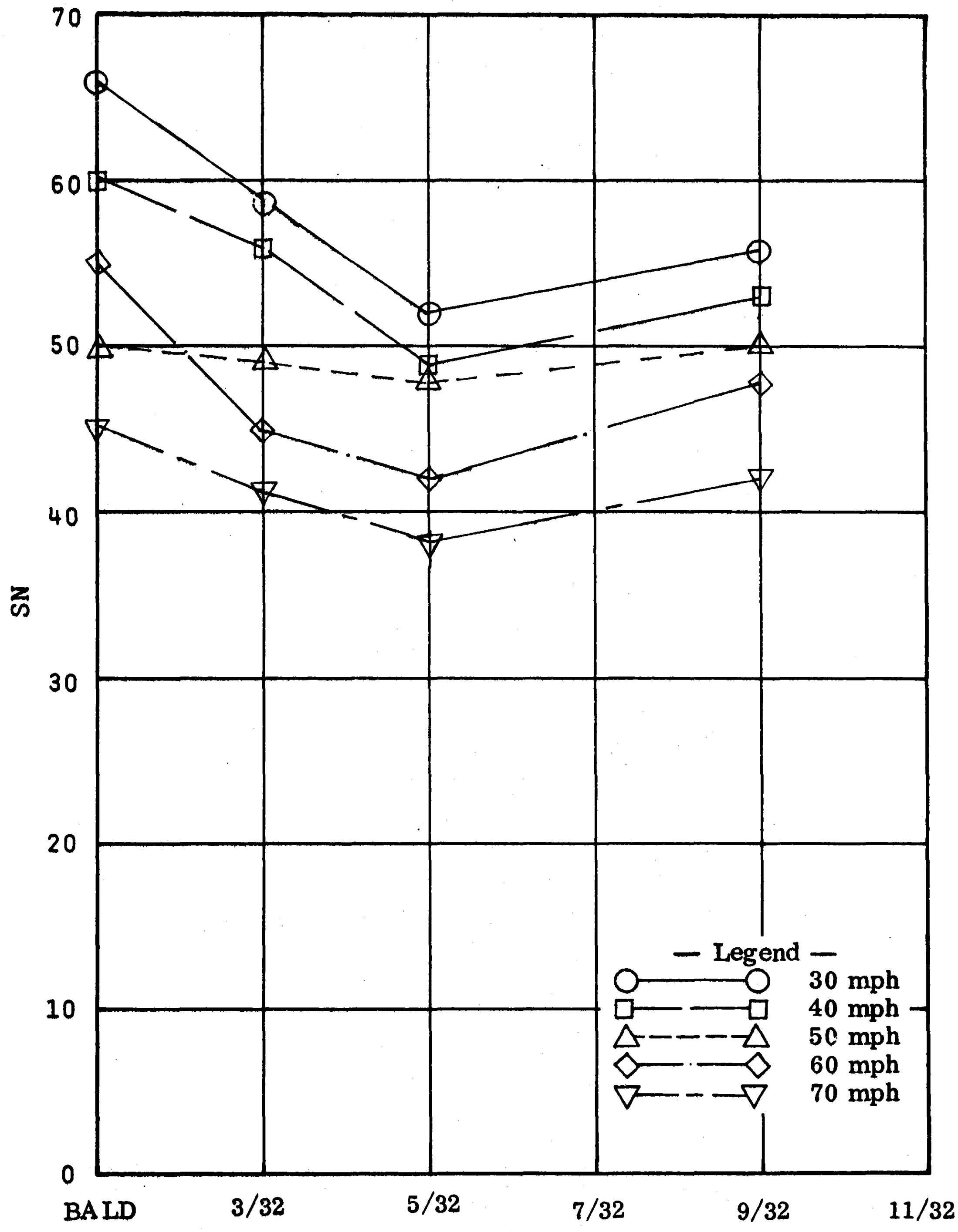


Figure A54. Skid number-tread depth curves for which the data for all water conditions were combined for the different test speeds on site 25. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

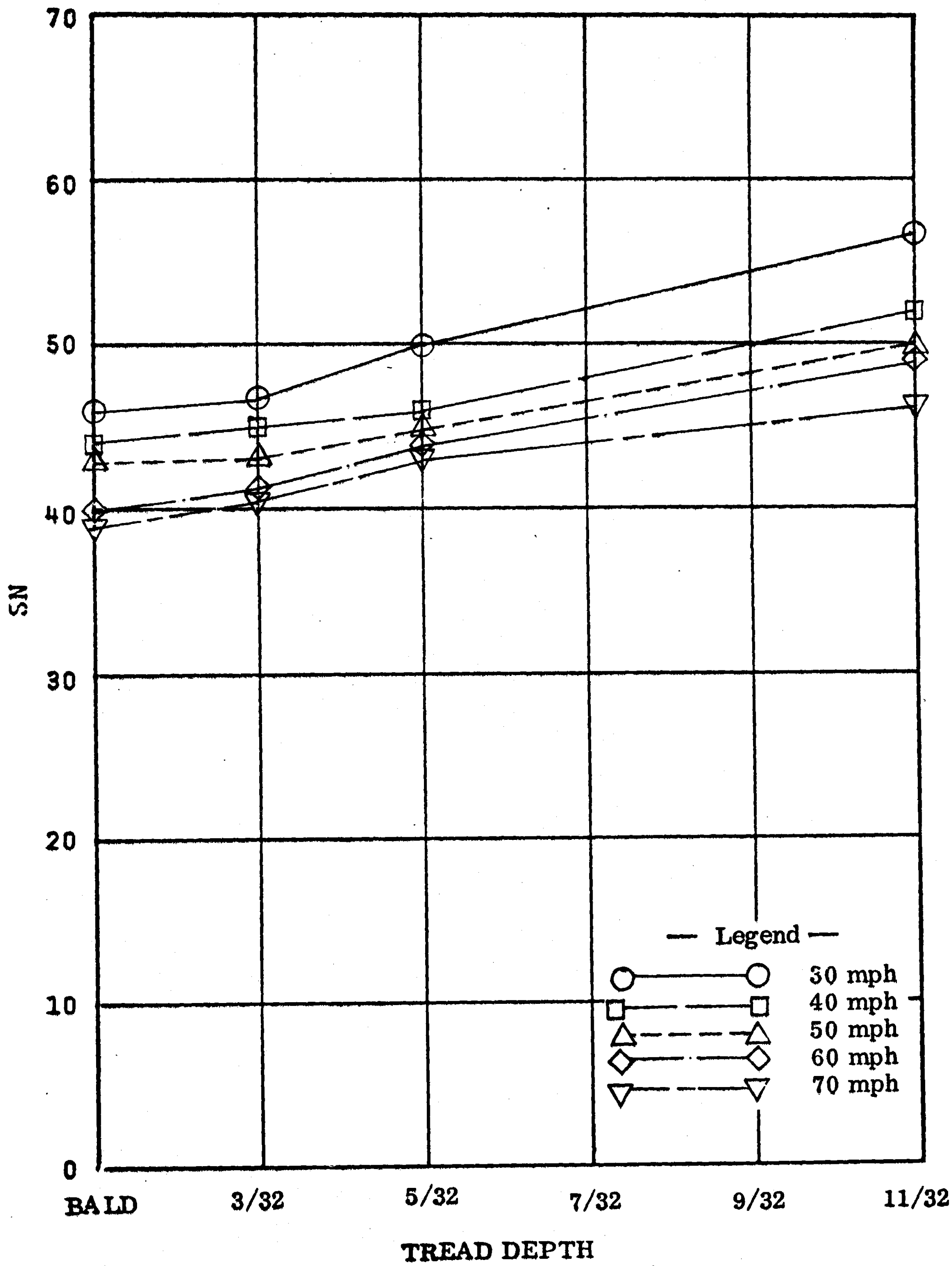


Figure A55. Skid number-tread depth curves for which the data for all water conditions were combined for the different test speeds on site 26. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

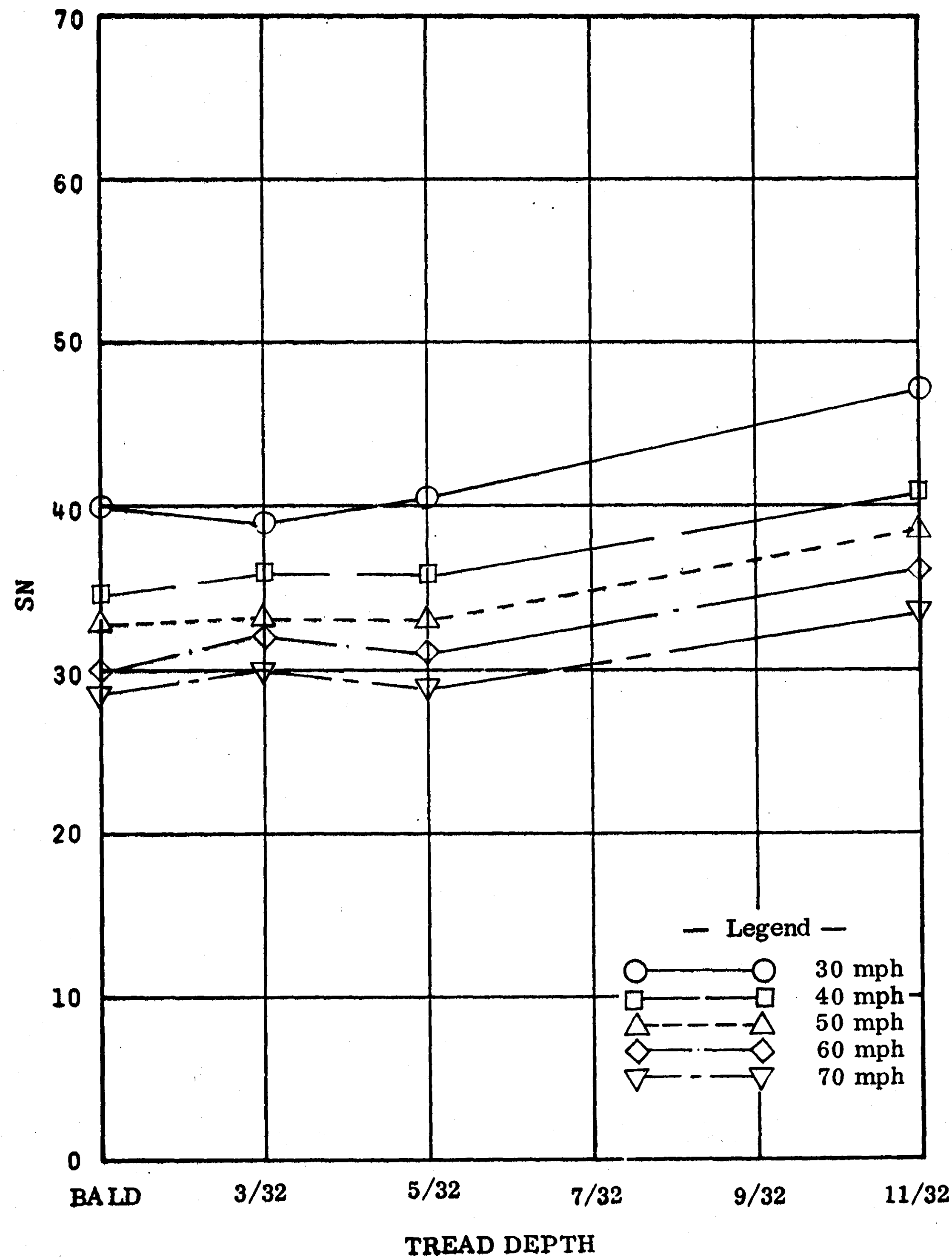


Figure A56. Skid number-tread depth curves for which the data for all water conditions were combined for the different test speeds on site 27. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

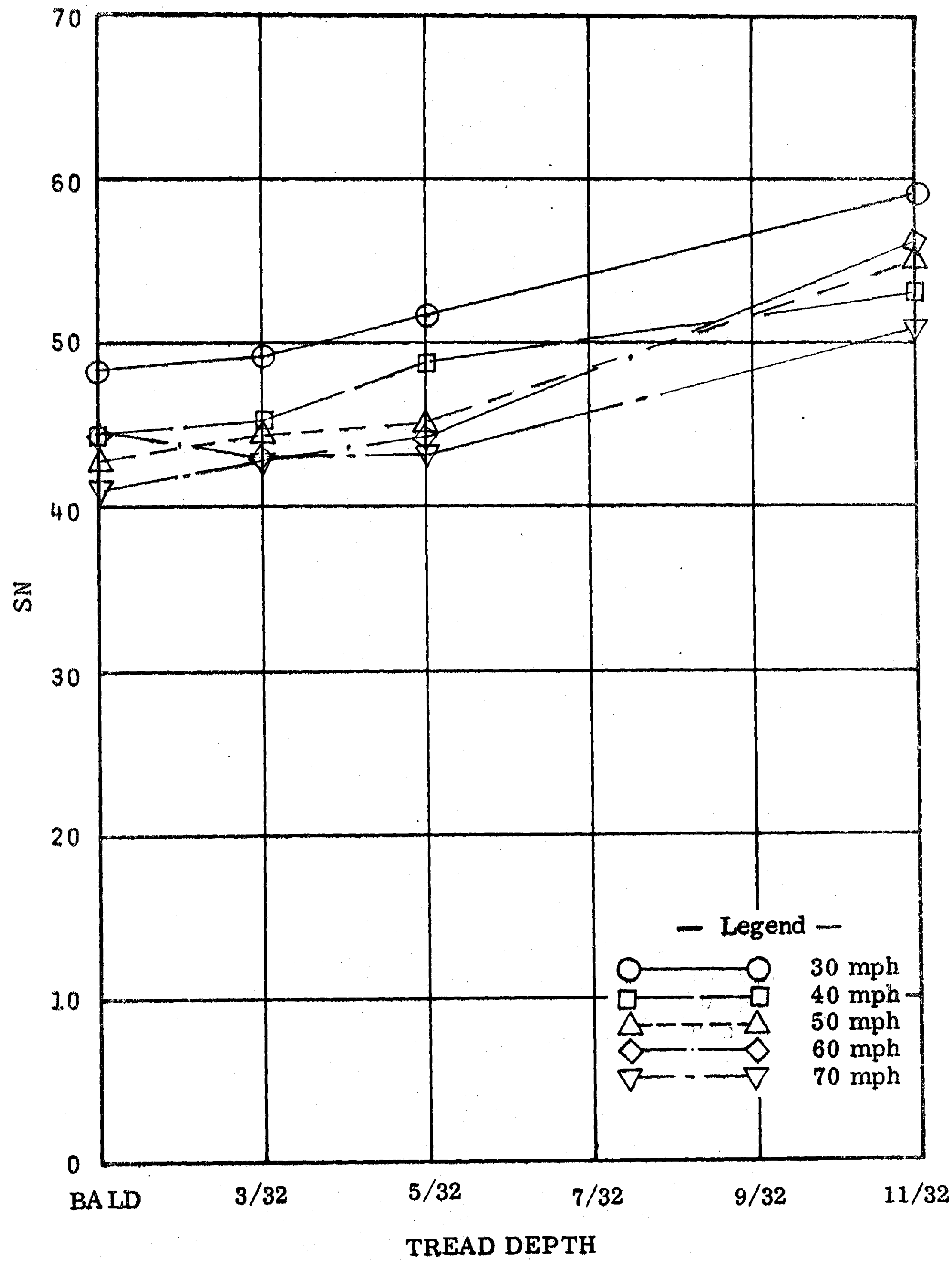


Figure A57. Skid number-tread depth curves for which the data for all water conditions were combined for the different test speeds on site 28. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

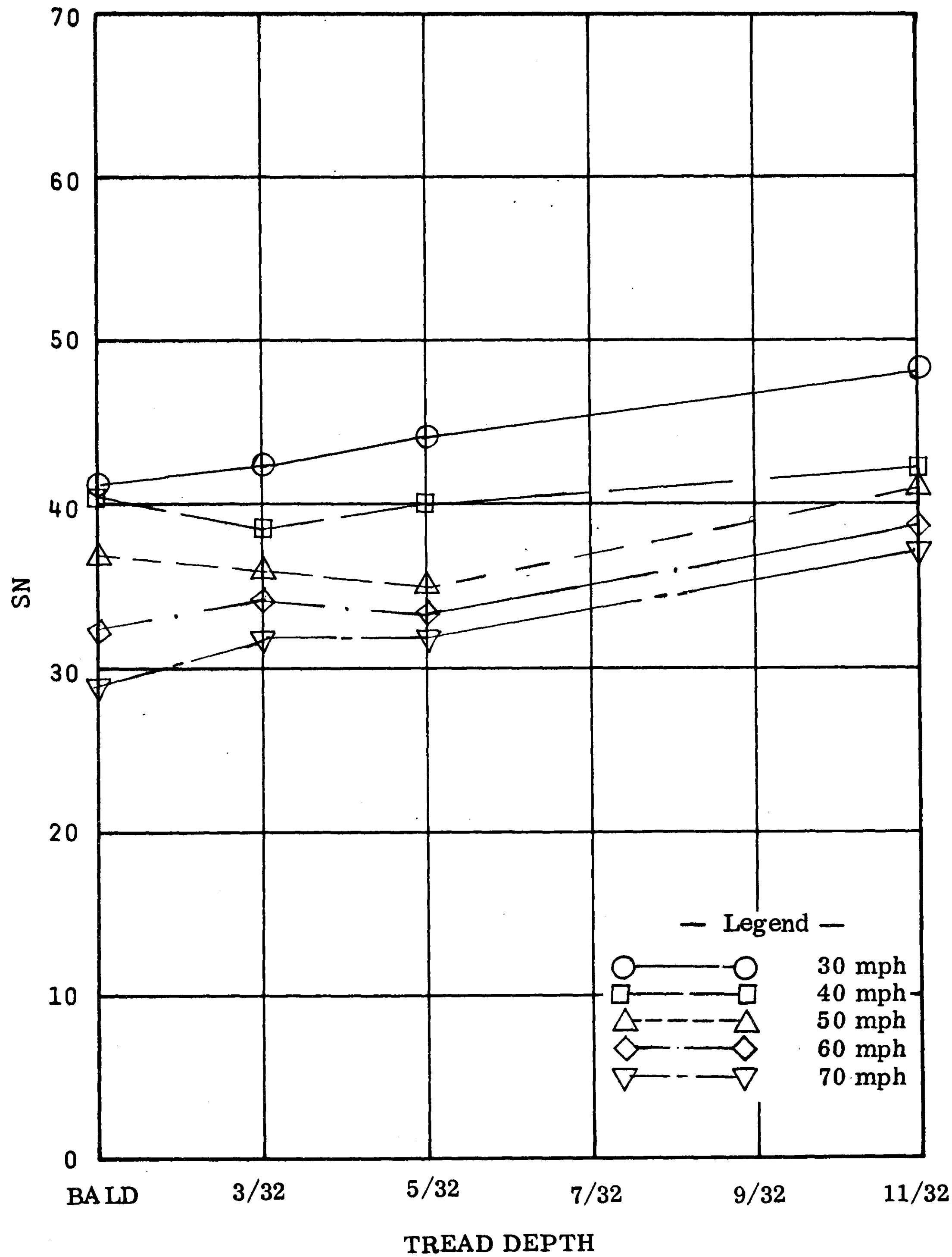


Figure A58. Skid number-tread depth curves for which the data for all water conditions were combined for the different test speeds on site 29. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

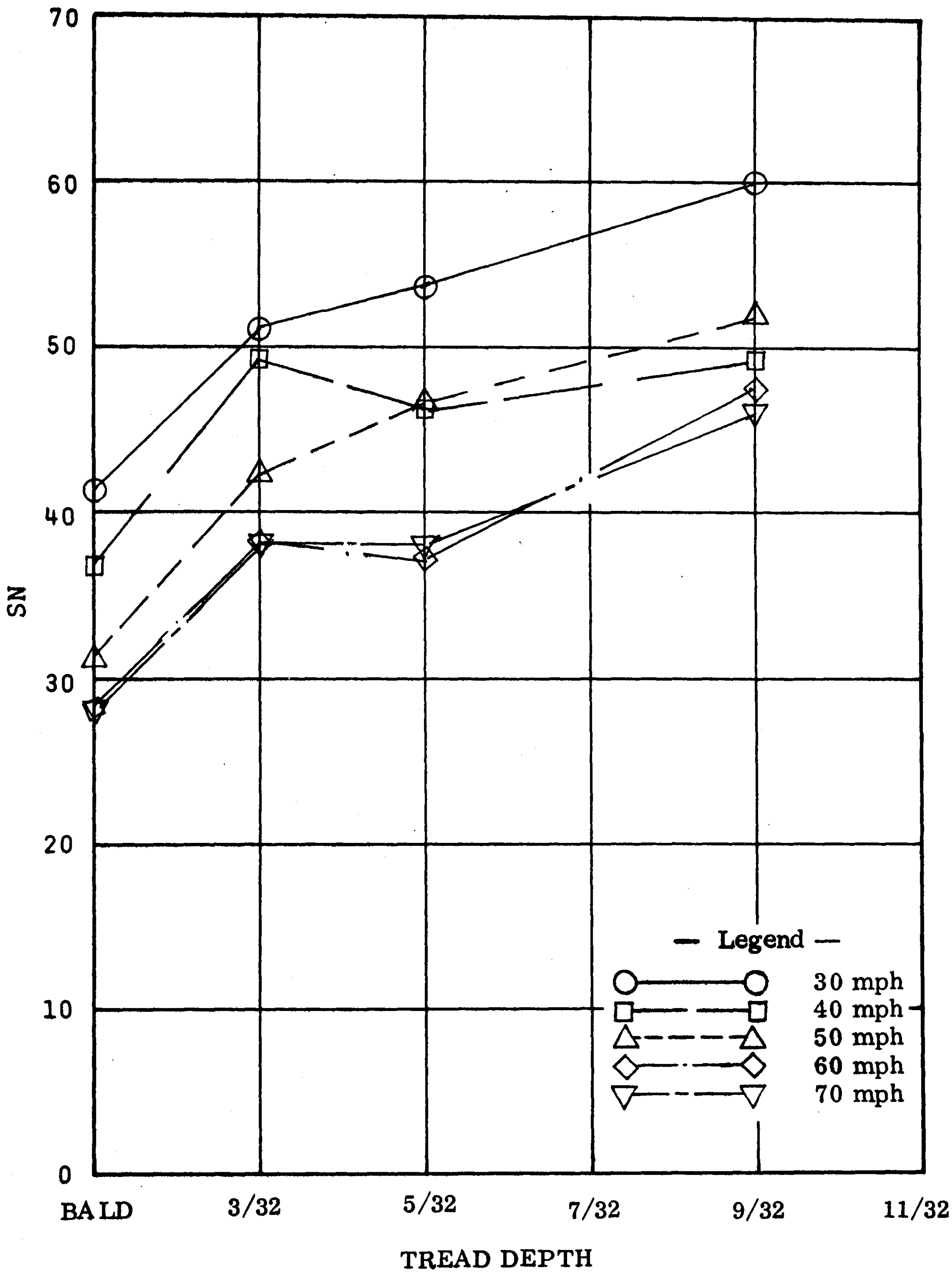


Figure A59. Skid number-tread depth curves for which the data for all water conditions were combined for the different test speeds on site 30. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

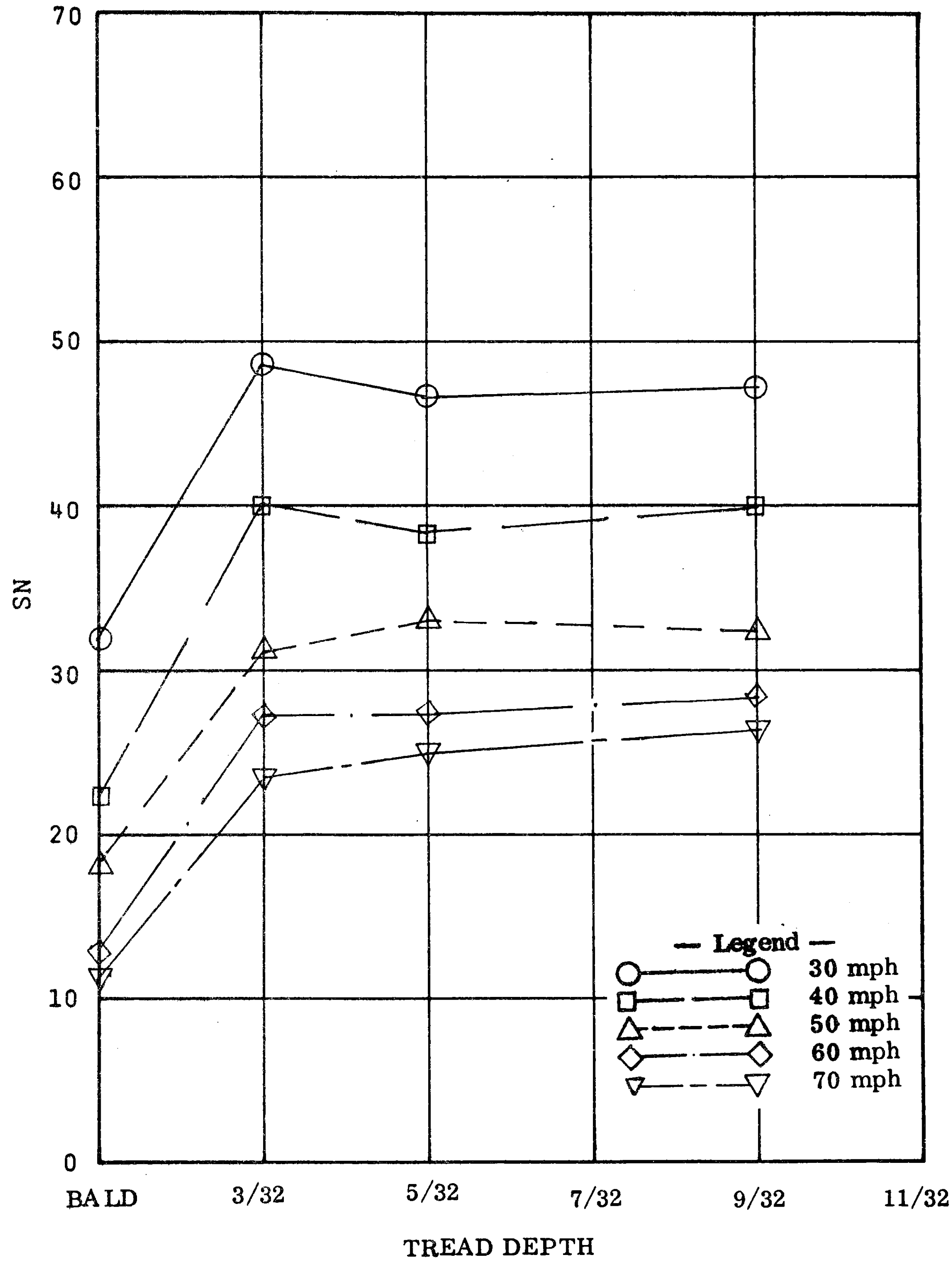


Figure A60. Skid number-tread depth curves for which the data for all water conditions were combined for the different test speeds on site 31. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

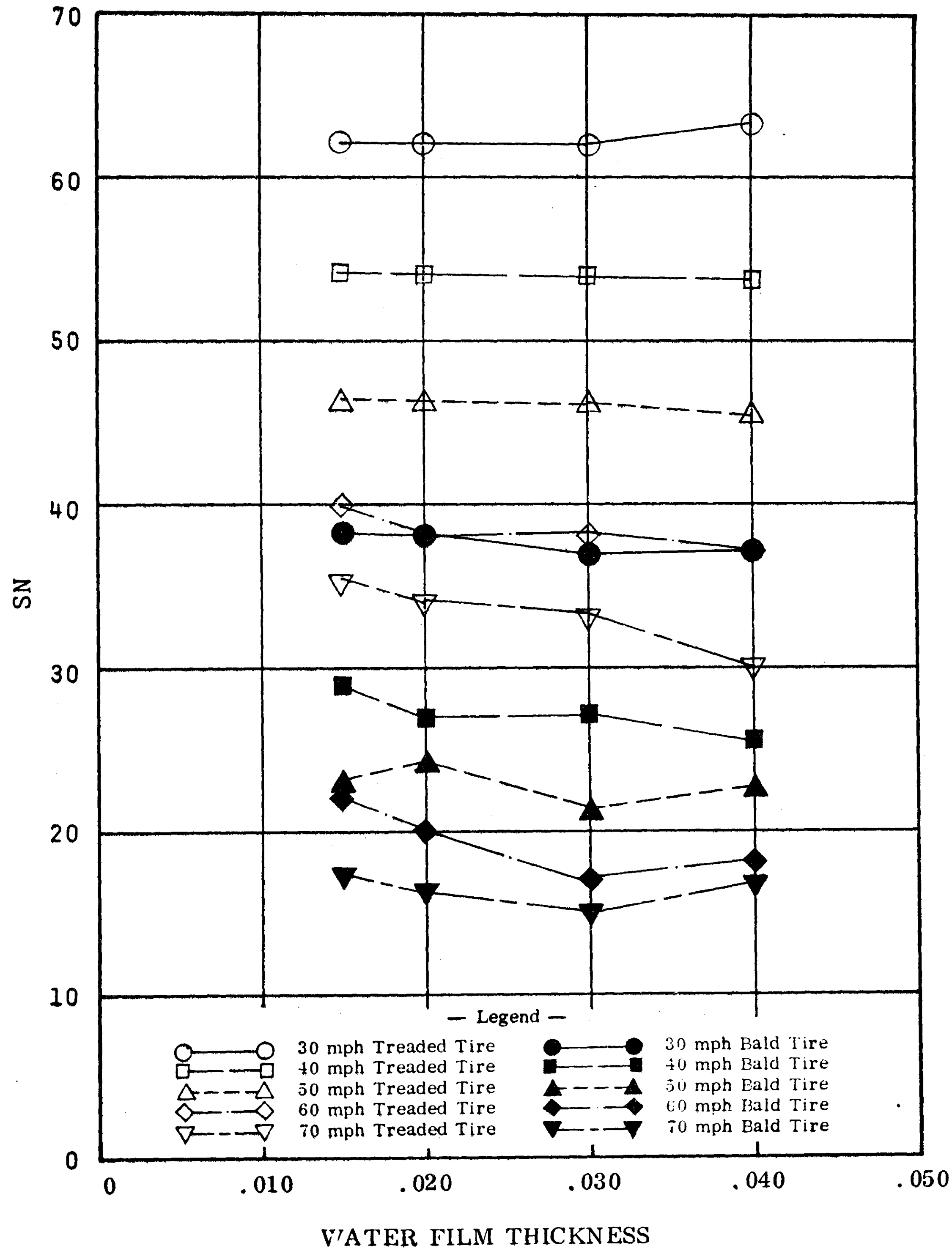


Figure A61. Skid number-water film thickness curves for the different test speeds on site 5. The data for the different tread depth tires were combined and provided the treaded tire data. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

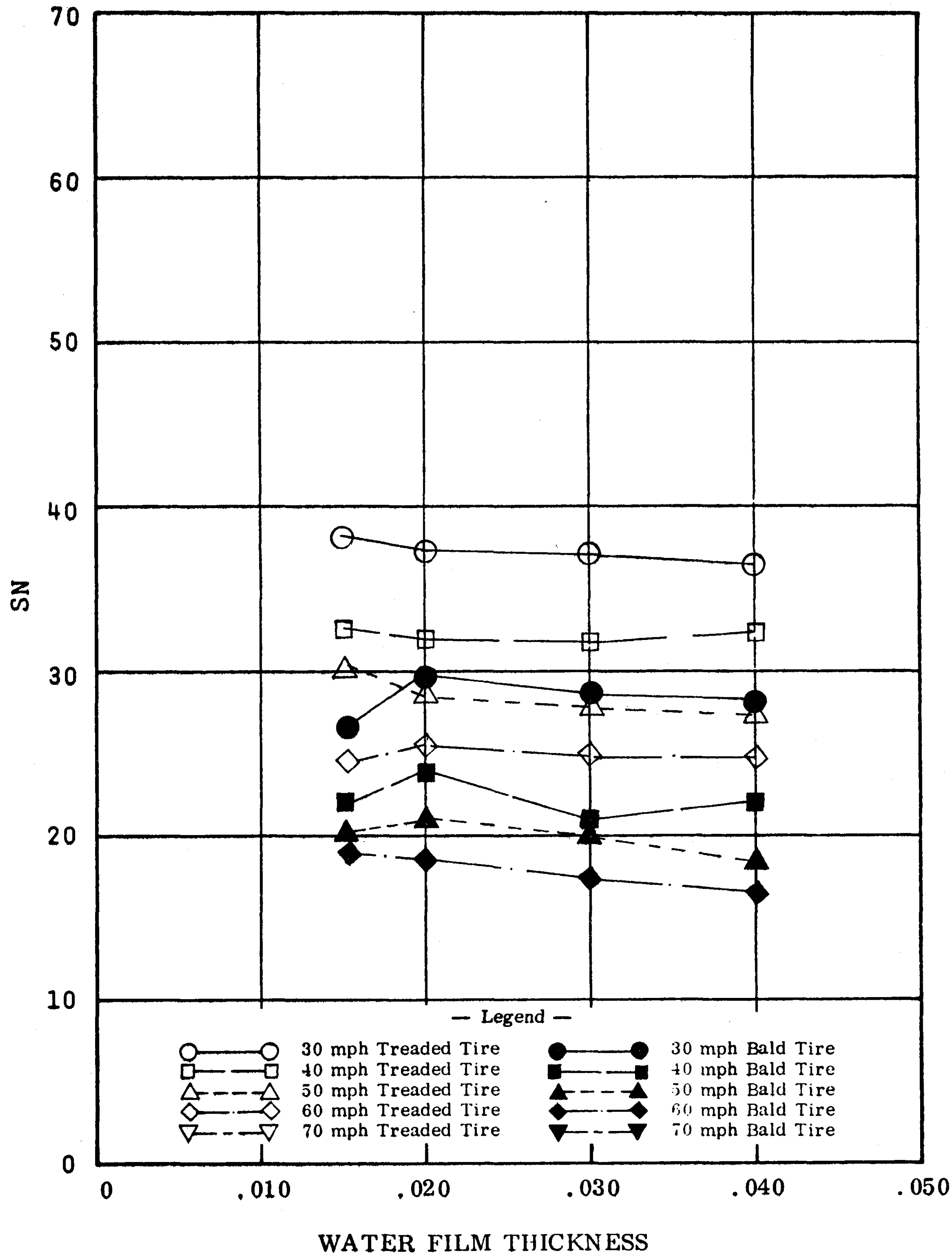


Figure A62. Skid number-water film thickness curves for the different test speeds on site 6. The data for the different tread depth tires were combined and provided the treaded tire data. ( 1 inch = 2.54 cm/ 1 mph = .4470 m/s)

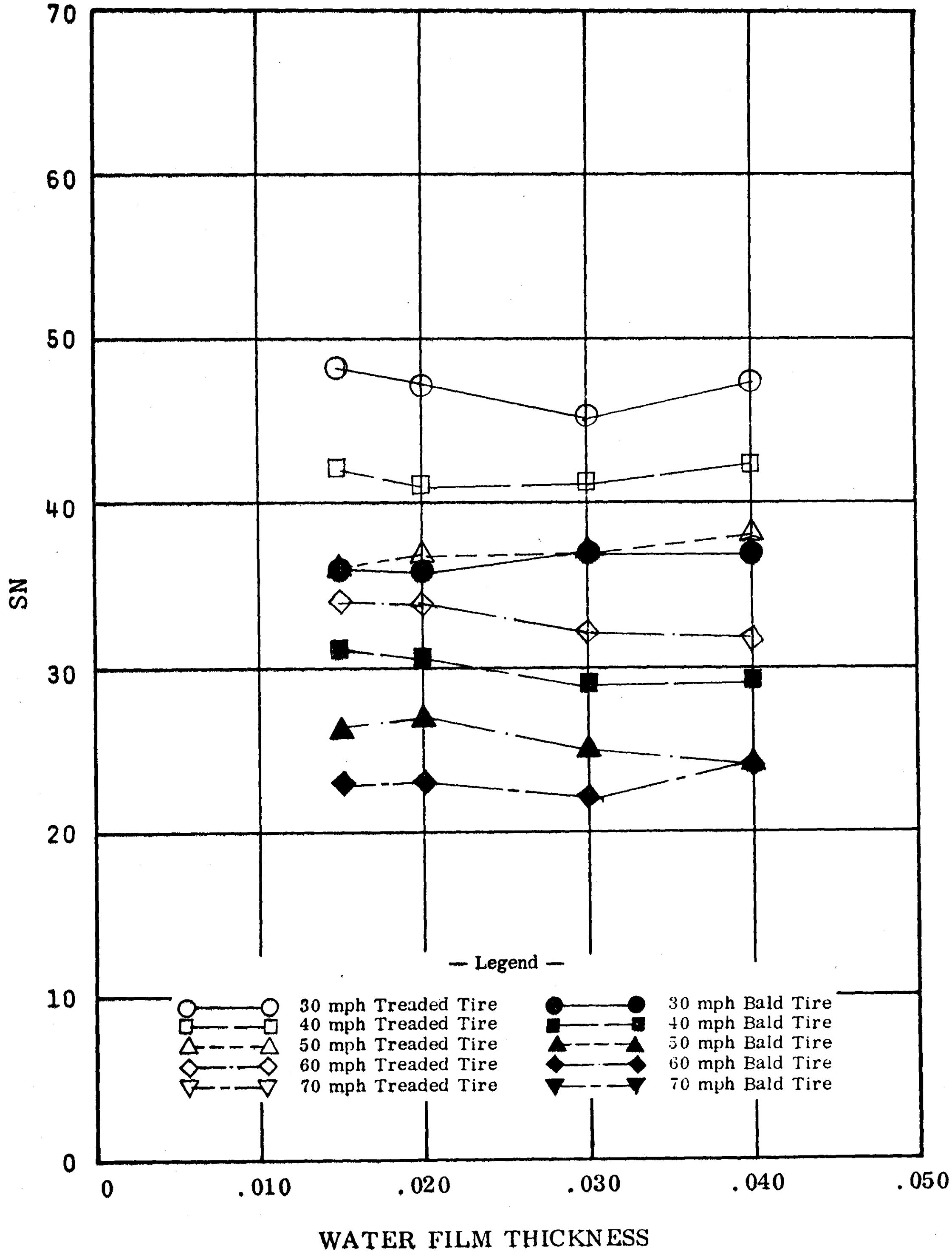


Figure A63. Skid number-water film thickness curves for the different test speeds on site 7. The data for the different tread depth tires were combined and provided the treaded tire data. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

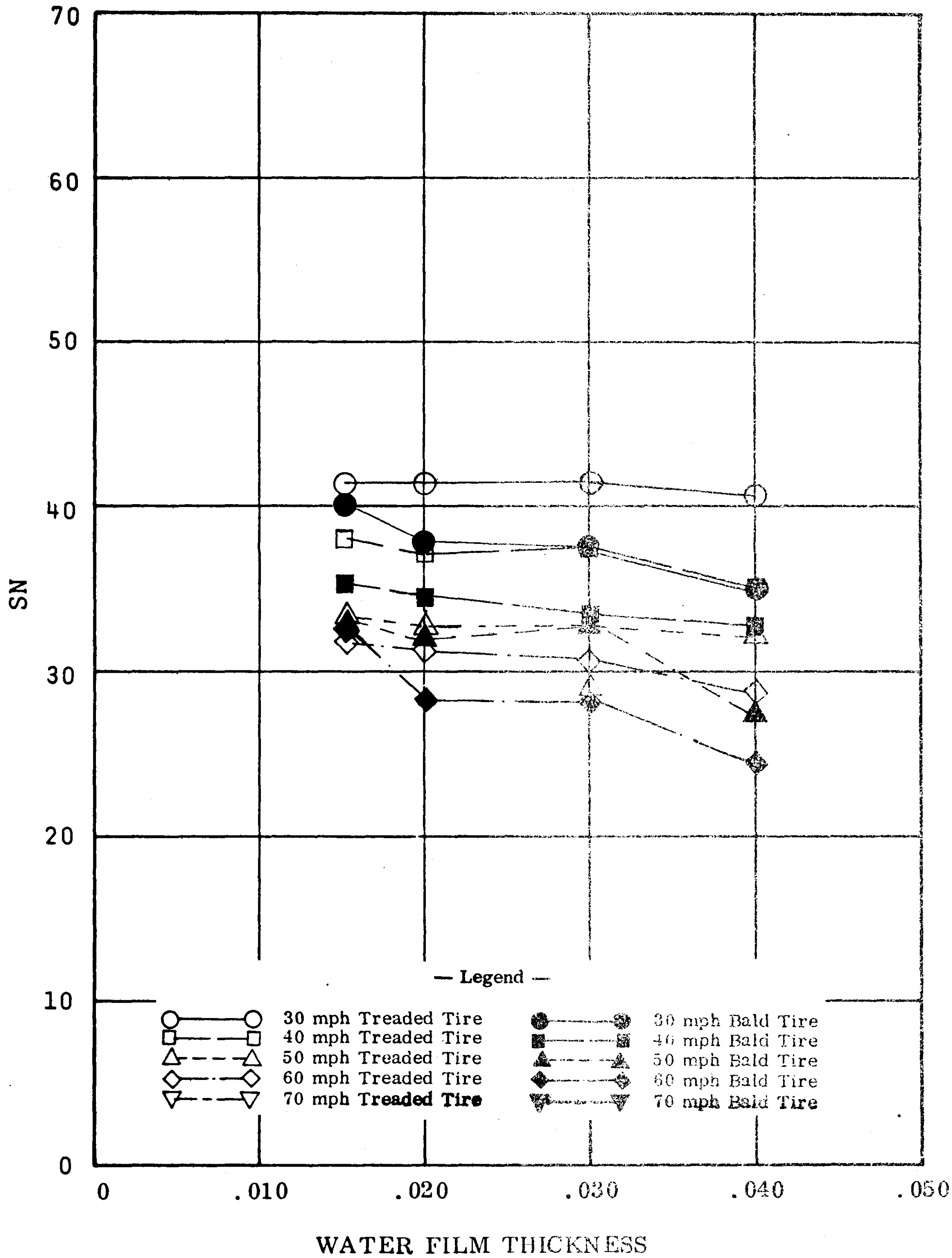


Figure A64. Skid number-water film thickness curves for the different test speeds on site 8. The data for the different tread depth tires were combined and provided the treaded tire data. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

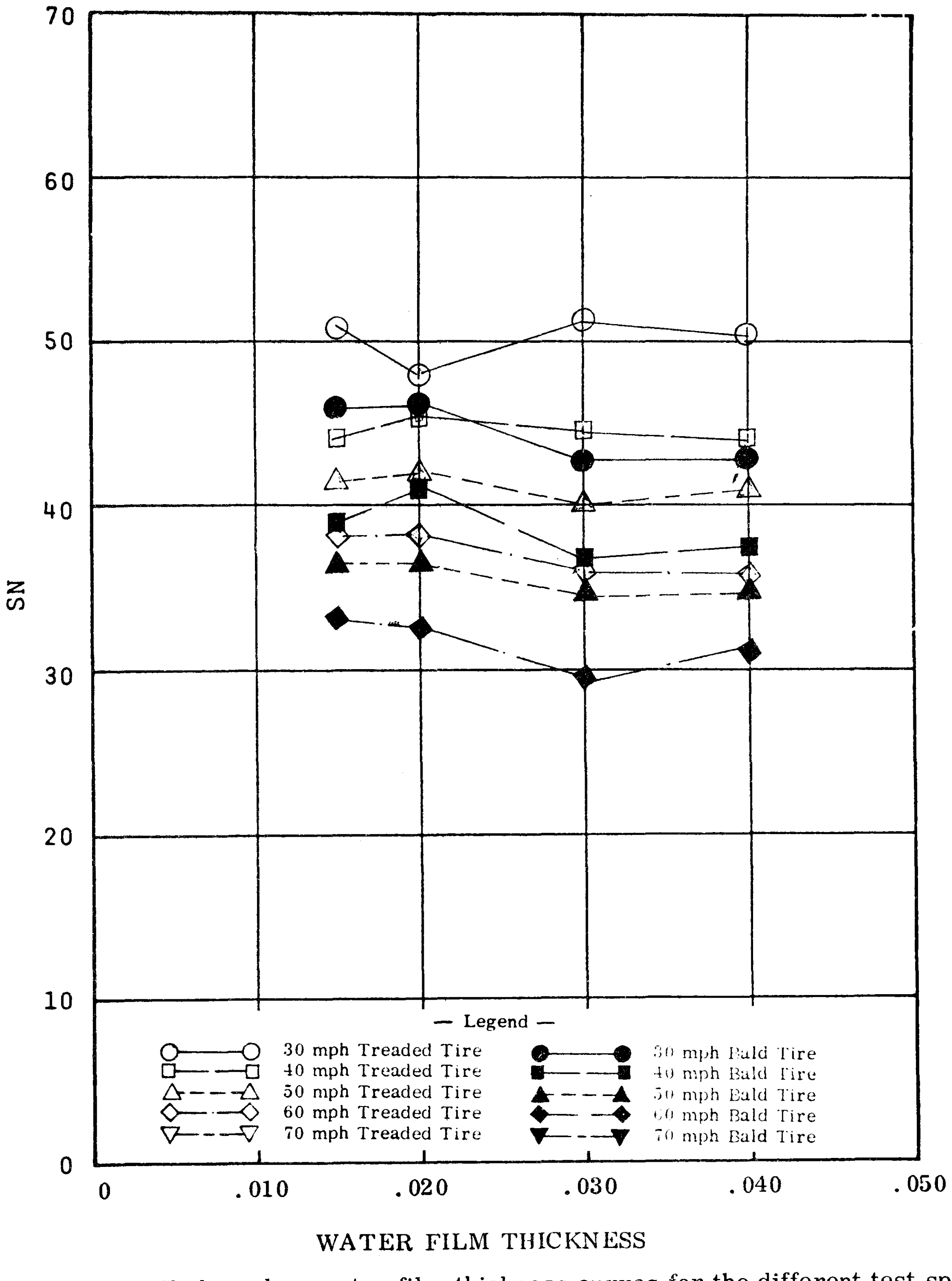


Figure A65. Skid number-water film thickness curves for the different test speeds on site 9. The data for the different tread depth tires were combined and provided the treaded tire data. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

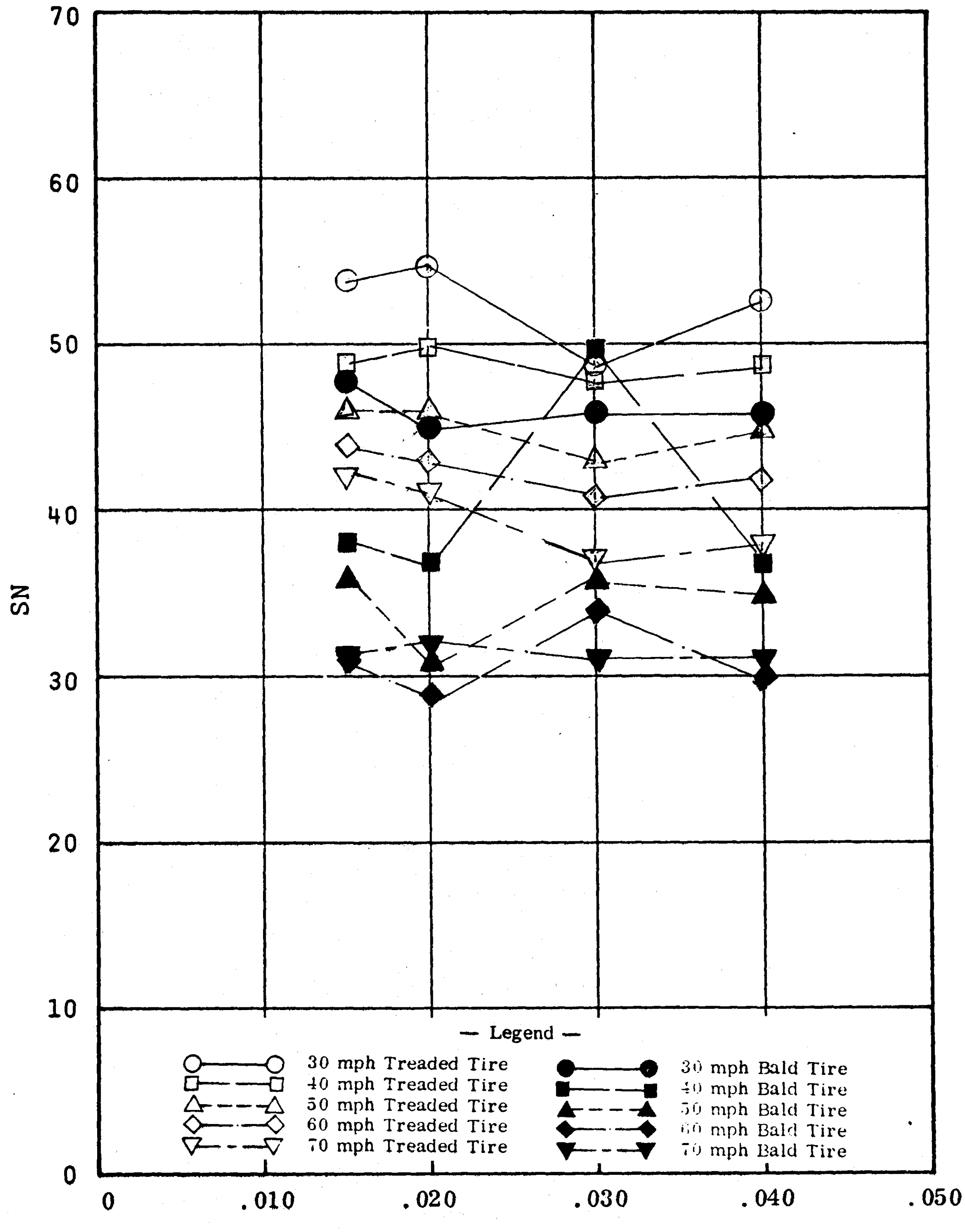


Figure A66. Skid number-water film thickness curves for the different test speeds on site 10. The data for the different tread depth tires were combined and provided the treaded tire data. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

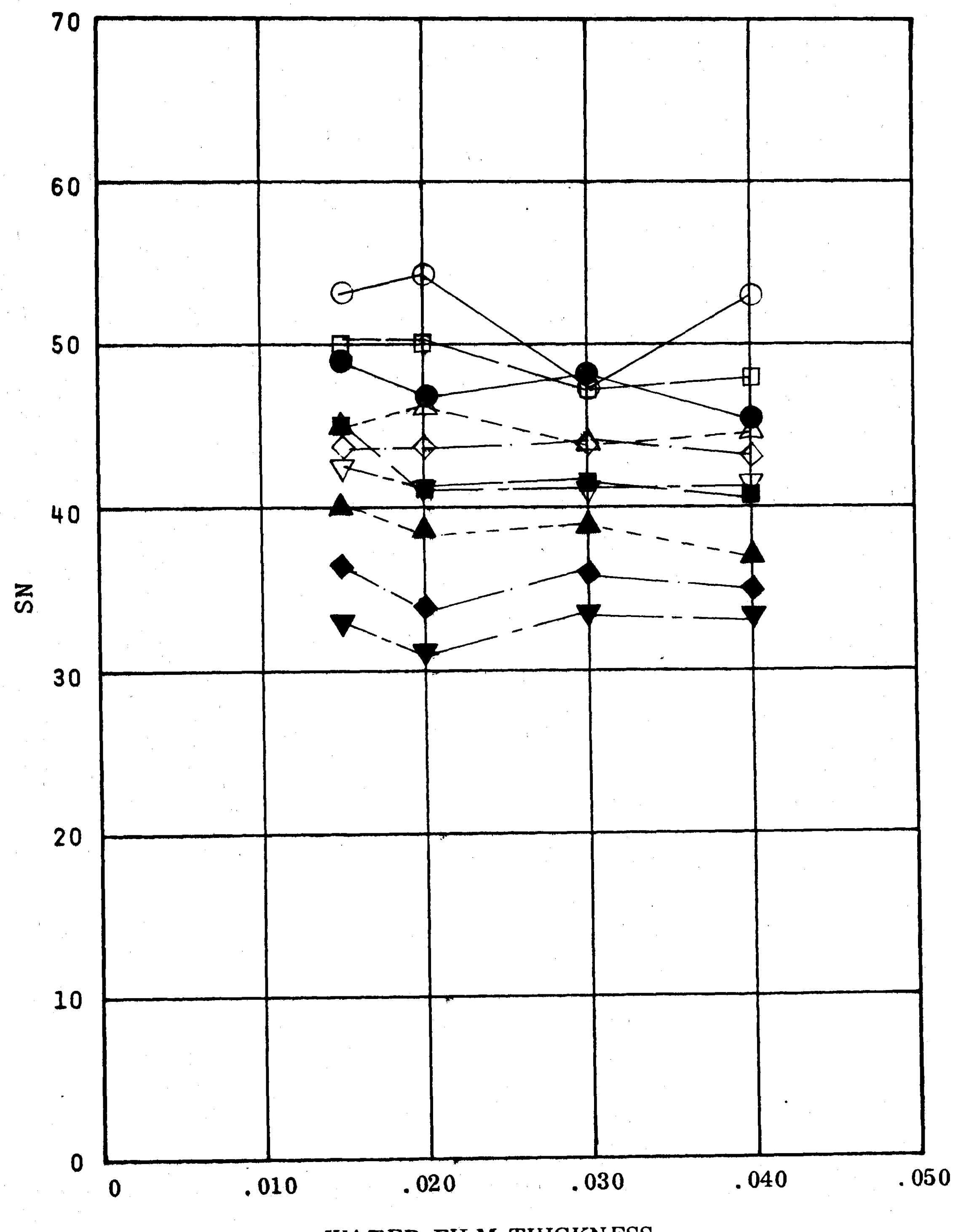


Figure A67. Skid number-water film thickness curves for the different test speeds on site 11. The data for the different tread depth tires were combined and provided the treaded tire data. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

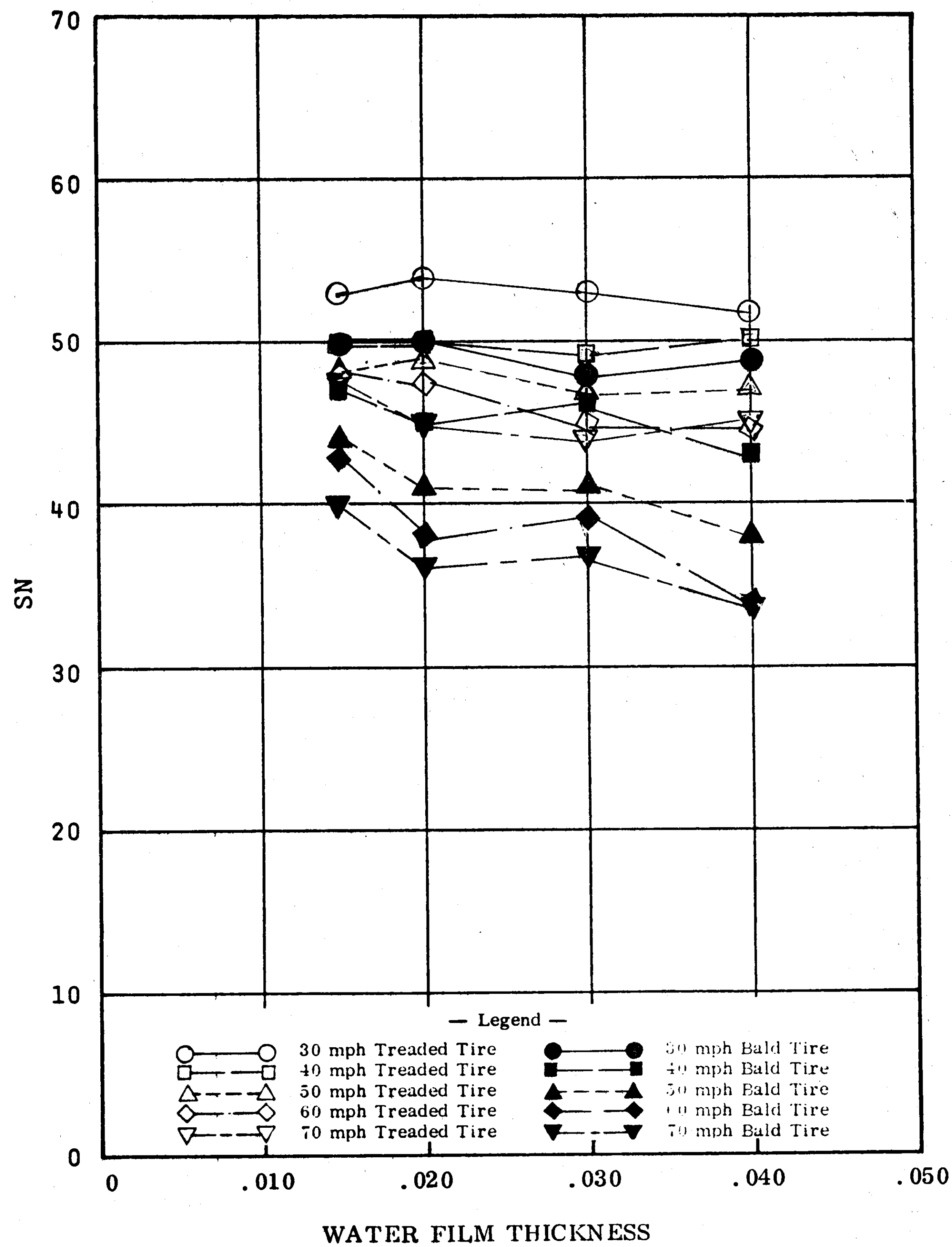


Figure A68. Skid number-water film thickness curves for the different test speeds on site 12. The data for the different tread depth tires were combined and provided the treaded tire data. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

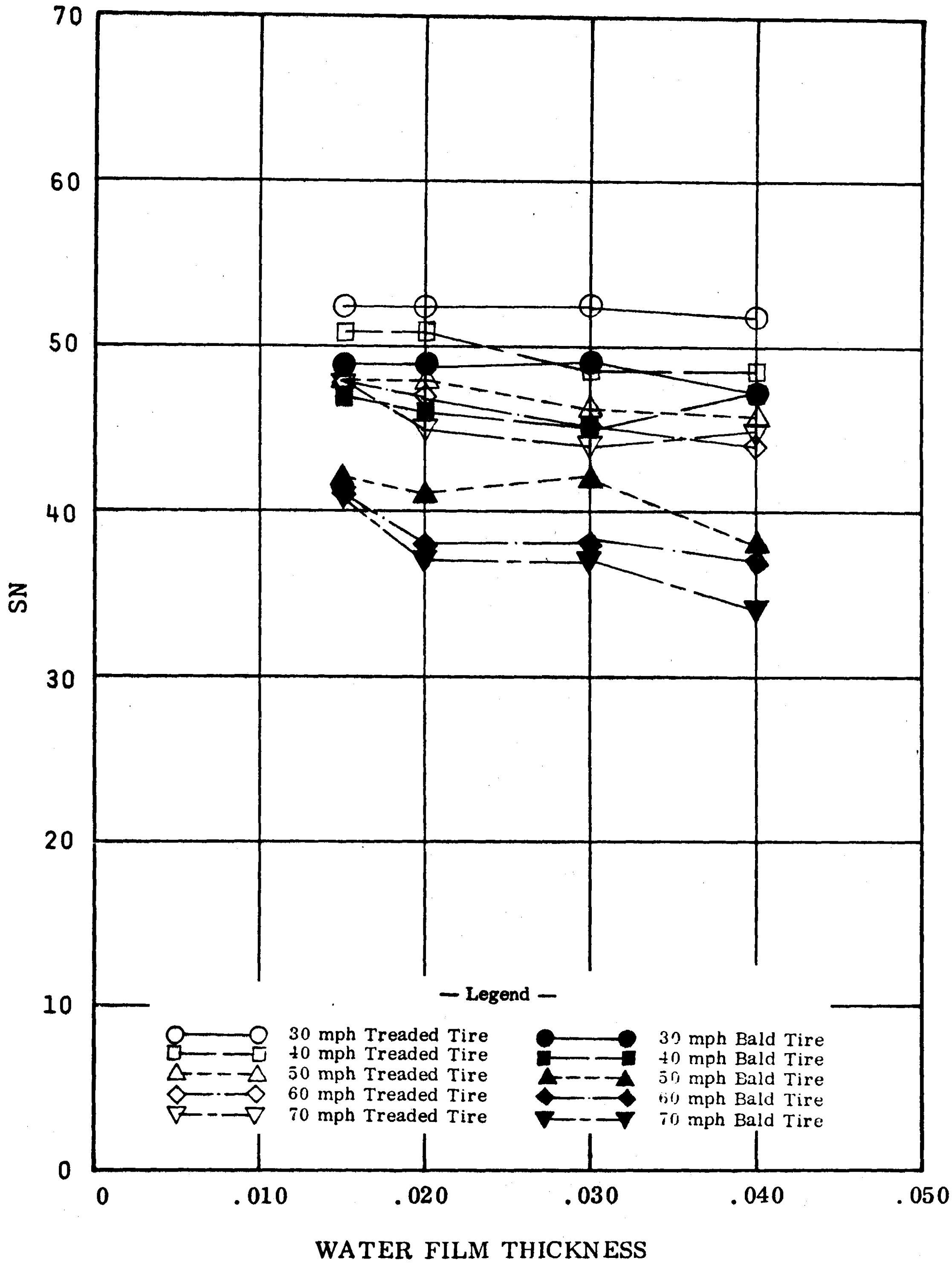


Figure A69. Skid number-water film thickness curves for the different test speeds on site 13. The data for the different tread depth tires were combined and provided the treaded tire data. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

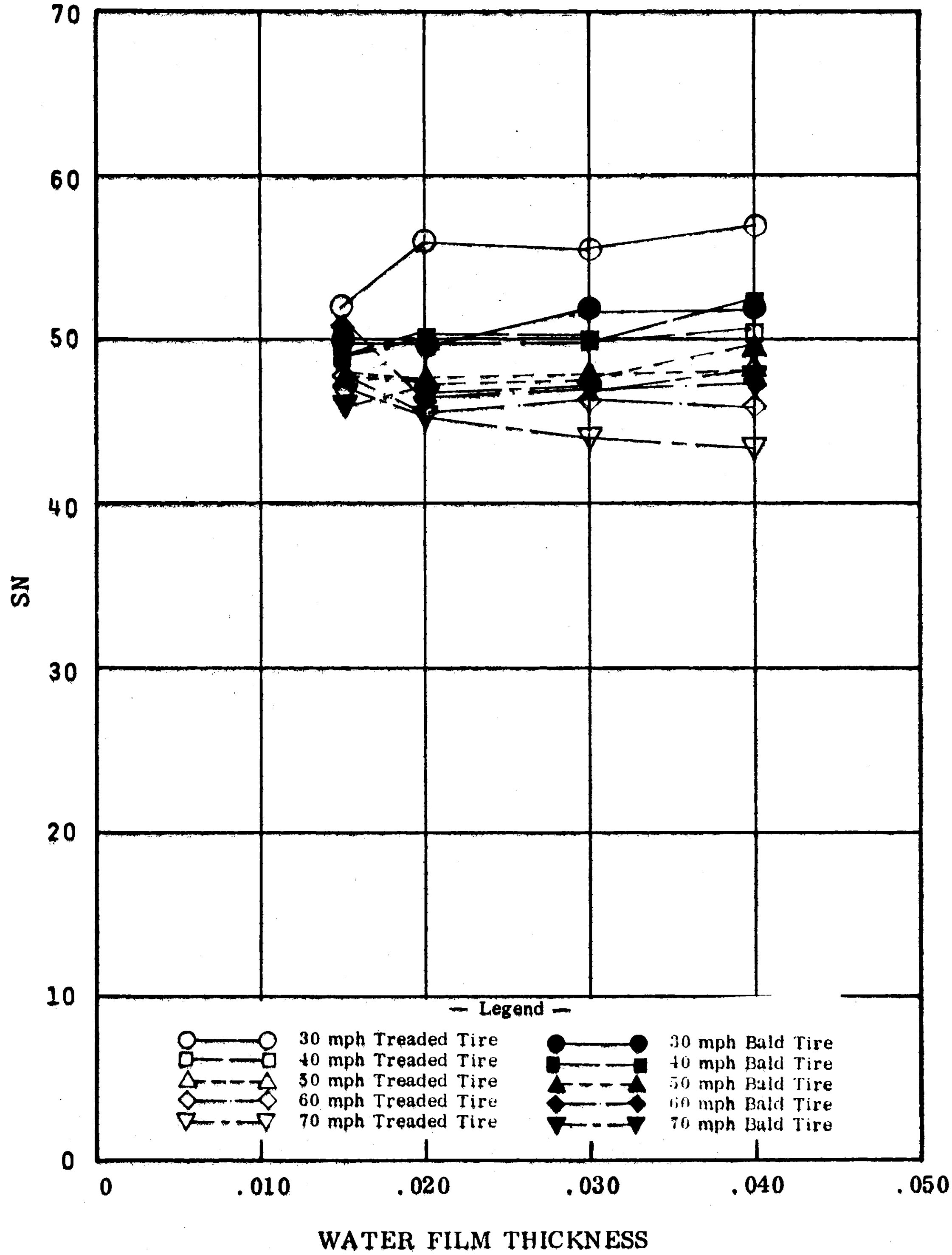


Figure A70. Skid number-water film thickness curves for the different test speeds on site 16. The data for the different tread depth tires were combined and provided the treaded tire data. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

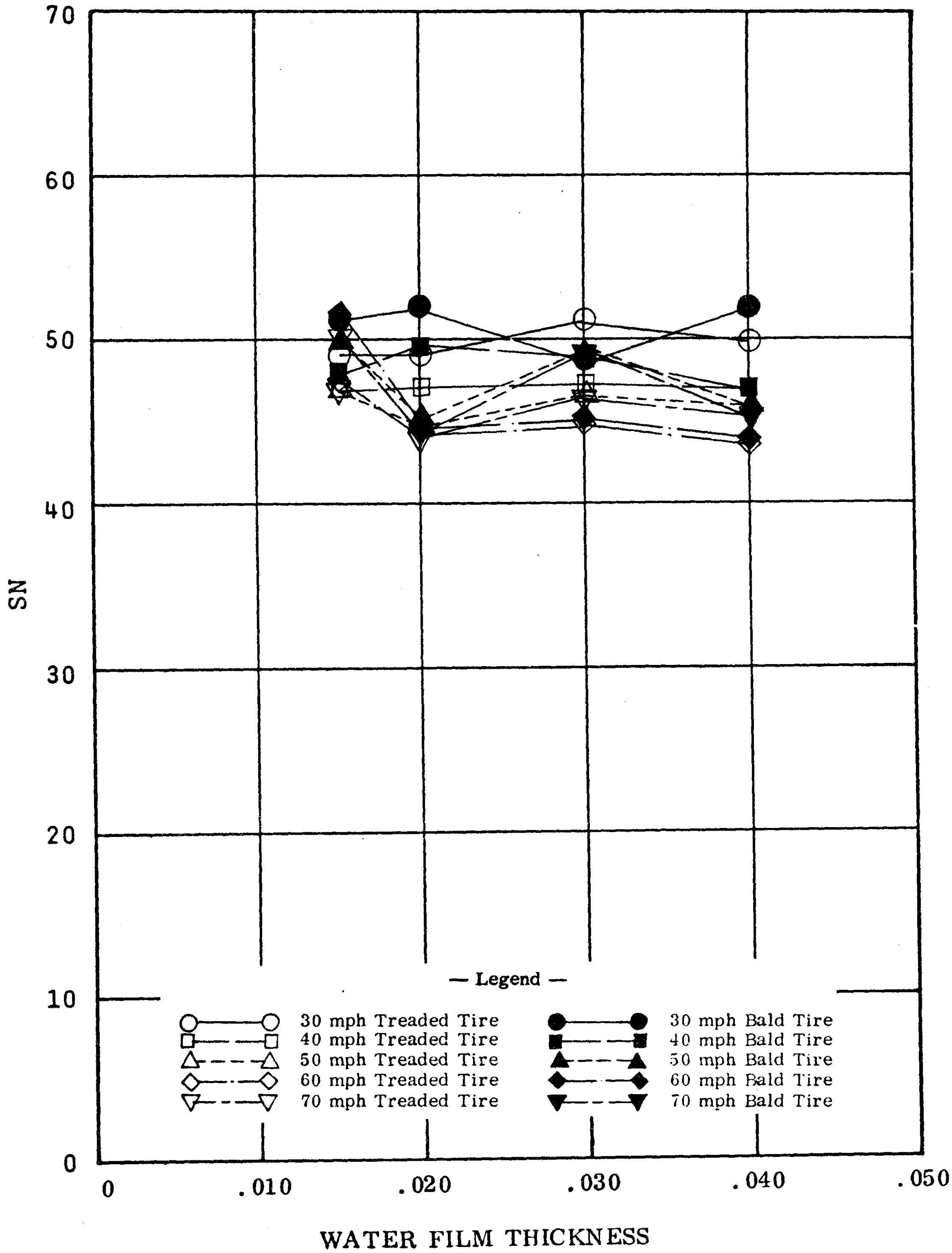


Figure A71. Skid number-water film thickness curves for the different test speeds on site 17. The data for the different tread depth tires were combined and provided the treaded tire data. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

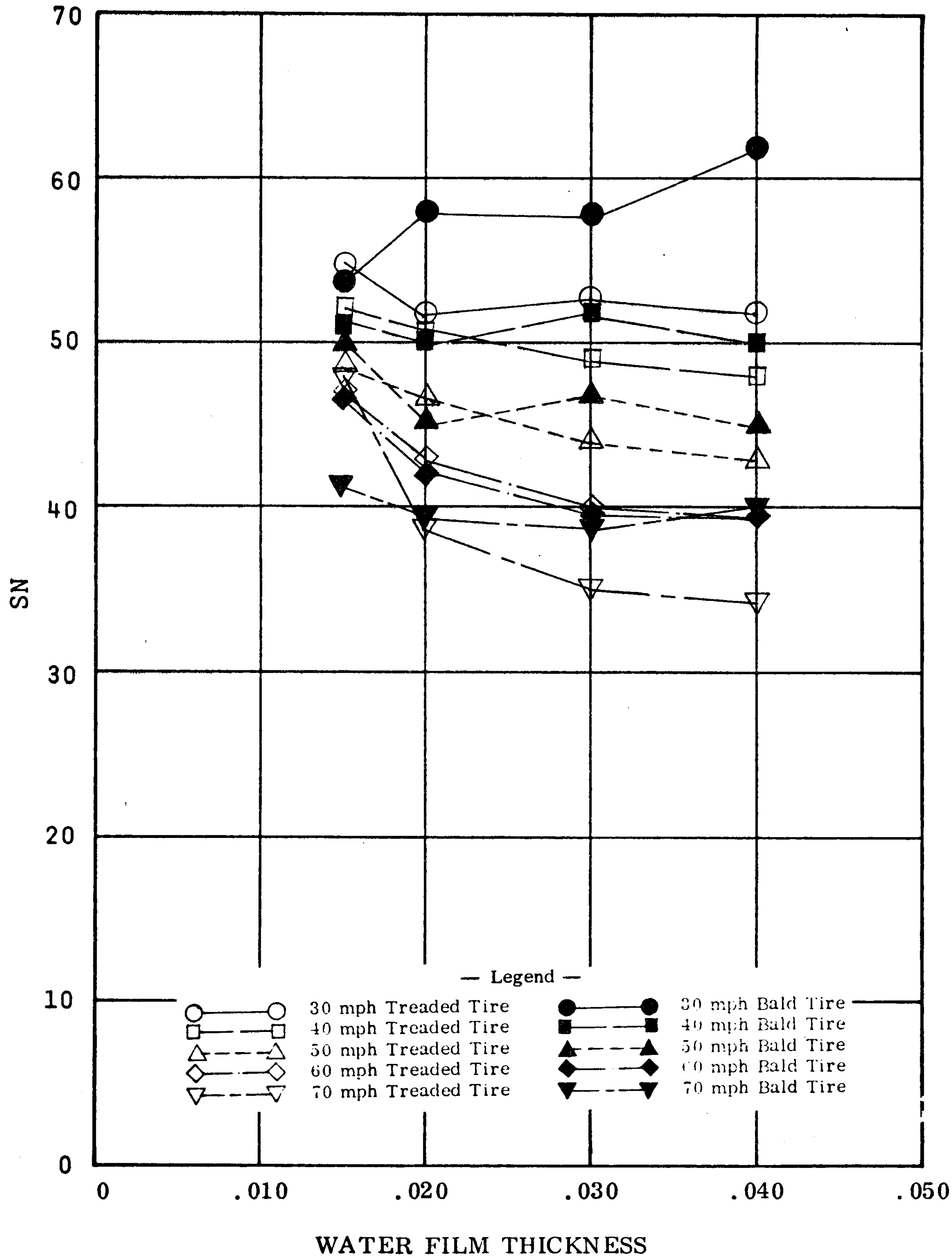


Figure A72. Skid number-water film thickness curves for the different test speeds on site 18. The data for the different tread depth tires were combined and provided the treaded tire data. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

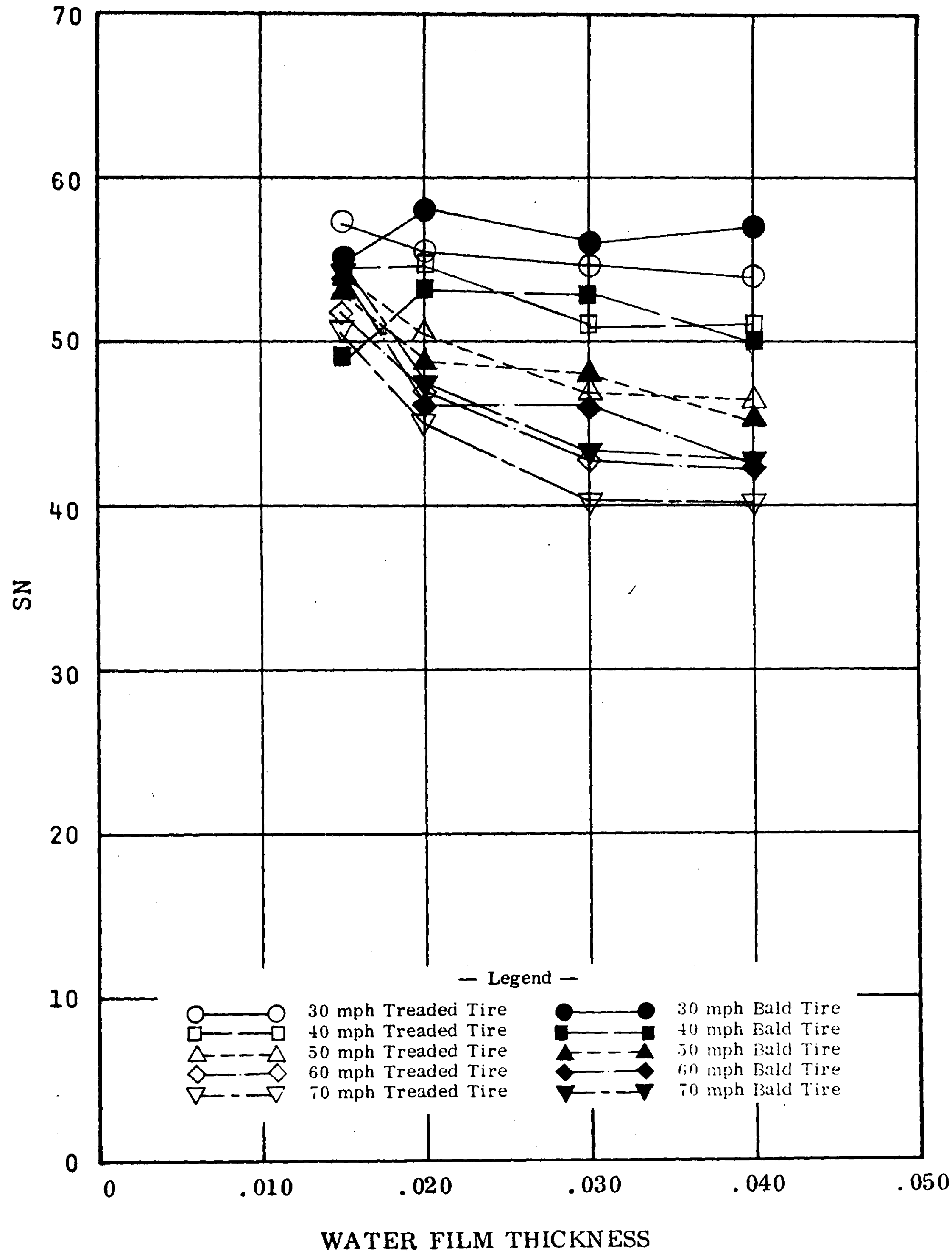


Figure A73. Skid number-water film thickness curves for the different test speeds on site 19. The data for the different tread depth tires were combined and provided the treaded tire data. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

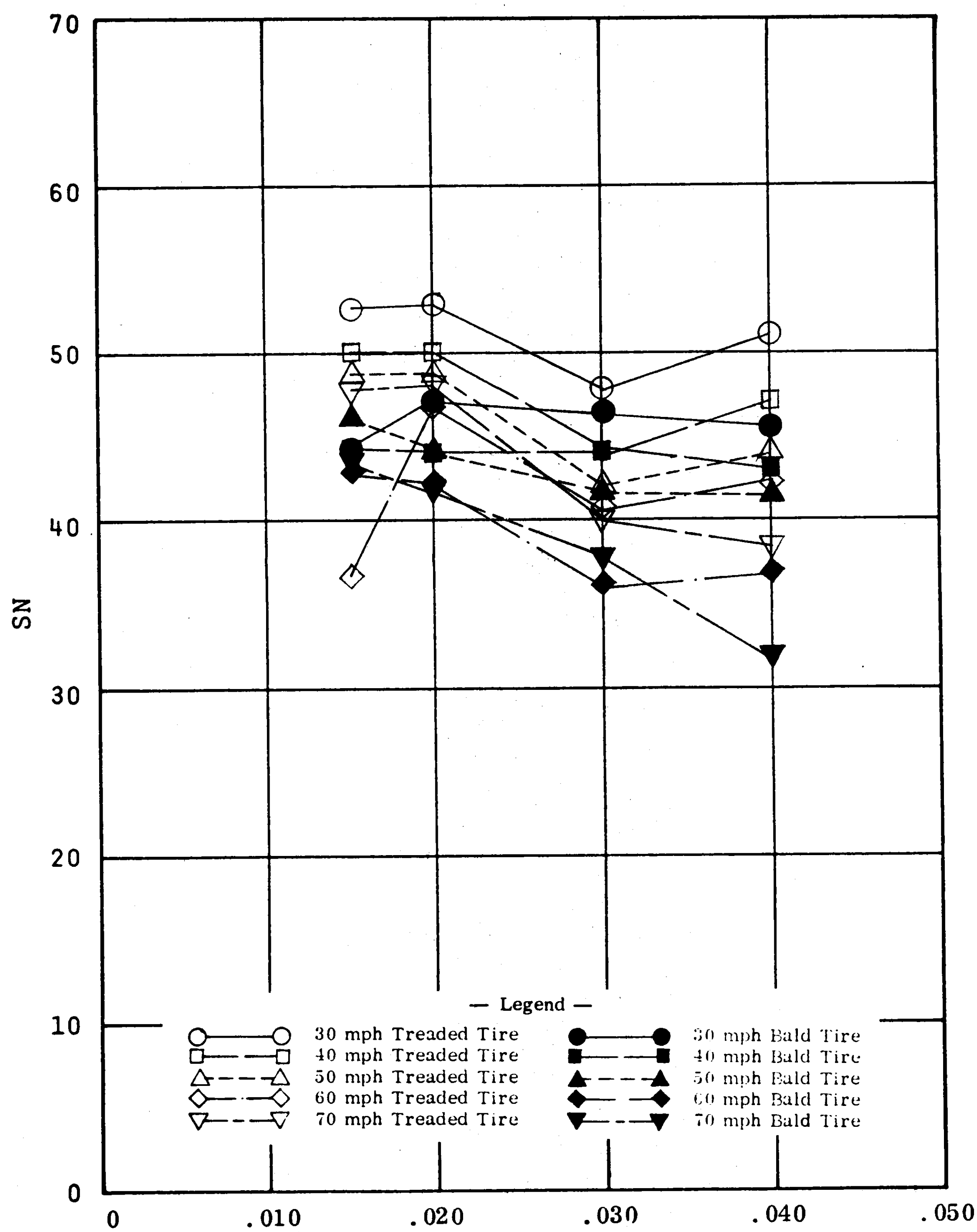


Figure A74. Skid number-water film thickness curves for the different test speeds on site 26. The data for the different tread depth tires were combined and provided the treaded tire data. ( 1 inch = 2.54 cm; 1mph = .4470 m/s)

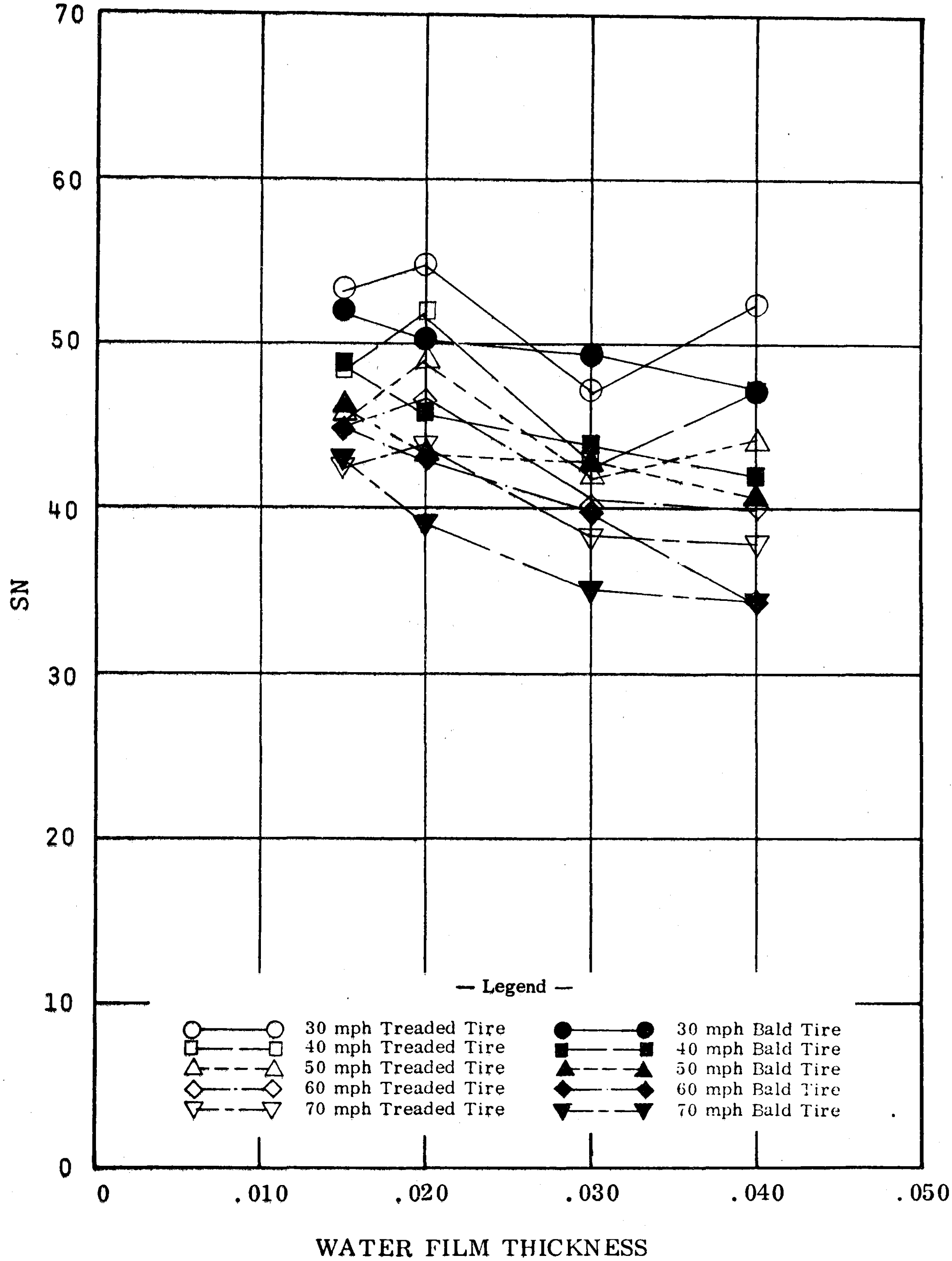


Figure A75. Skid number-water film thickness curves for the different test speeds on site 27. The data for the different tread depth tires were combined and provided the treaded tire data. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

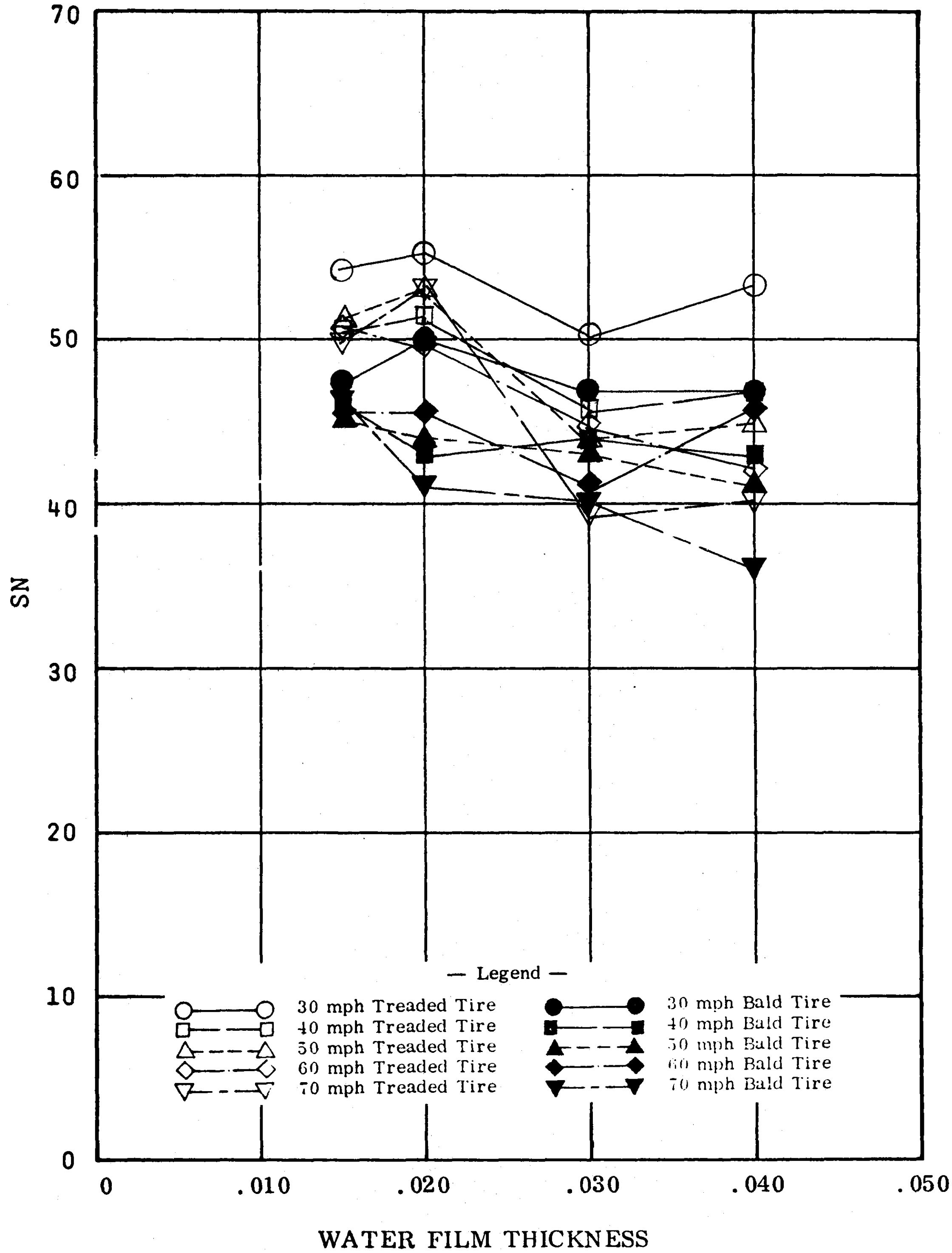


Figure A76. Skid number-water film thickness curves for the different test speeds on site 28. The data for the different tread depth tires were combined and provided the treaded tire data. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

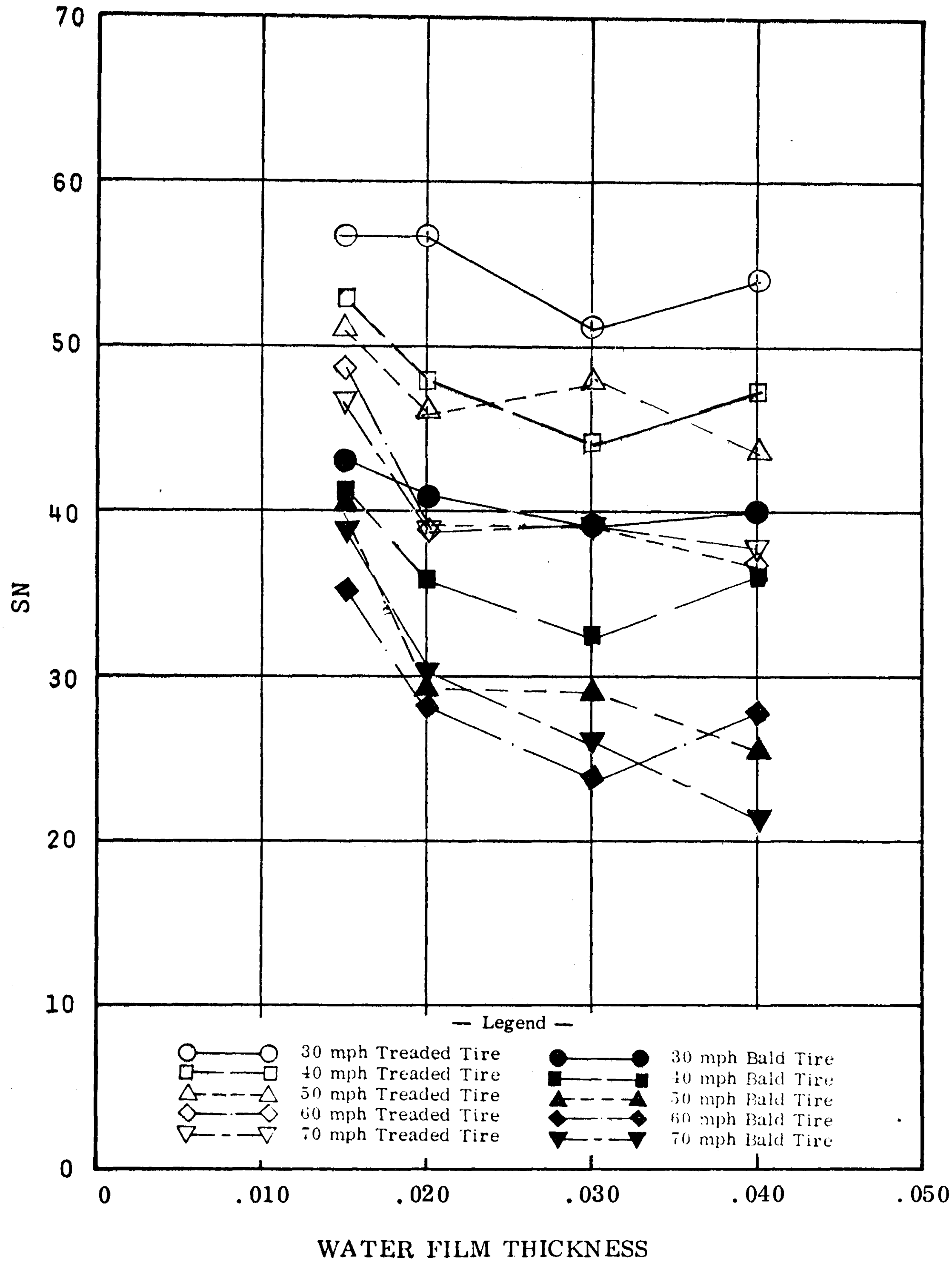


Figure A77. Skid number-water film thickness curves for the different test speeds on site 30. The data for the different tread depth tires were combined and provided the treaded tire data. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

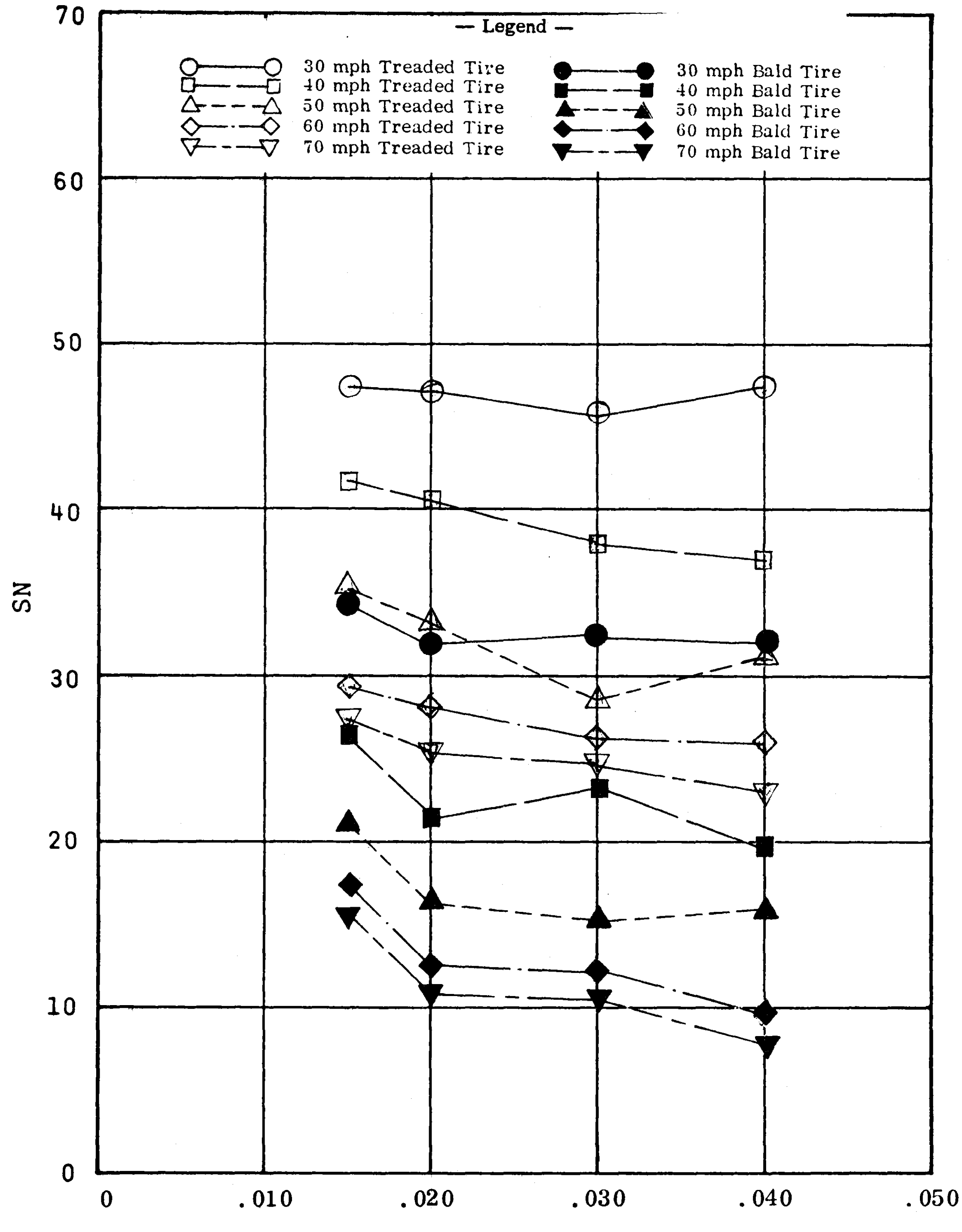


Figure A78. Skid number-water film thickness curves for the different test speeds on site 31. The data for the different tread depth tires were combined and provided the treaded tire data. ( 1 inch = 2.54 cm; 1 mph = .4470 m/s)

Table A32. Virginia Design Specifications for Bituminous Concrete Mixtures.

| Type | Percentage by Weight Passing Square Mesh Sieves* | | | | | | | | | | Percent Bituminous Materials | Mix Temperature (At Plant) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1½ | 1 | ¾ | ½ | ⅜ | No. 4 | No. 8 | No. 30 | No. 50 | No. 200 | | |
| S-1 | | | | | | 100 | 95-100 | 50-95 | 25-65 | 0-8 | 8.5-10.5 | 225-300°F |
| S-2 | | | | | 100 | 95-100 | 60-85 | 20-40 | 10-30 | 2-10 | 9.5-12.0 | 225-300°F |
| S-3 | | | | | 100 | 90-100 | 70-95 | 25-55 | 15-35 | 2-12 | 6.5-10.5 | 200-240°F |
| S-4 | | | | 100 | 90-100 | | 60-80 | 25-45 | 10-30 | 2-10 | 5.5- 9.5 | 225-300°F |
| S-5 | | | | 100 | 80-100 | | 35-55 | 15-30 | 7-22 | 2-10 | 5.0- 8.5 | 225-300°F |
| I-1 | | 100 | 90-100 | | 85-100 | 75-100 | 60-95 | 25-60 | 12-35 | 2-12 | 5.0- 7.5 | 225-300°F |
| I-2 | | 100 | 95-100 | | 60-80 | 40-60 | 25-45 | | 5-14 | 1-7 | 4.5- 8.0 | 225-300°F |
| B-1 | | 100 | 90-100 | | | 70-100 | 55-95 | 25-65 | 12-40 | 0-10 | 3.0- 6.5 | 225-300°F |
| B-2 | 100 | | 50-75 | | | 20-35 | 15-25 | | | 0-5 | 4.0- 6.0 | 200-240°F |
| B-3 | 100 | | 72-87 | | | 35-50 | 28-38 | | | 2-6 | 4.0- 7.0 | 225-300°F |
| C-1 | | | | 100 | 90-100 | 65-80 | 45-65 | 25-40 | 13-23 | 6-10 | 6.0- 9.0 | 305-345°F |
| S-6 | Gradation determined by Marshall design—See Section 212.25. | | | | | | | | | | 7.5-11.5 | 225-300°F |

*In inches except where otherwise indicated. Numbered Sieves are those of the U. S. Standard Sieve Series.

1 inch = 2.54 cm
$1^{o}$ F = $.55^{o}$C

Table A33. Gradation of Urban Mix

| Sieve Size | Percent Passing by Weight |
|---|---|
| 1" | 100 |
| 3/4" | 95-100 |
| 3/8" | 63-77 |
| #4 | 43-57 |
| #8 | 31-39 |
| #50 | 6-14 |
| #200 | 2-6 |

1 inch = 2.54 cm