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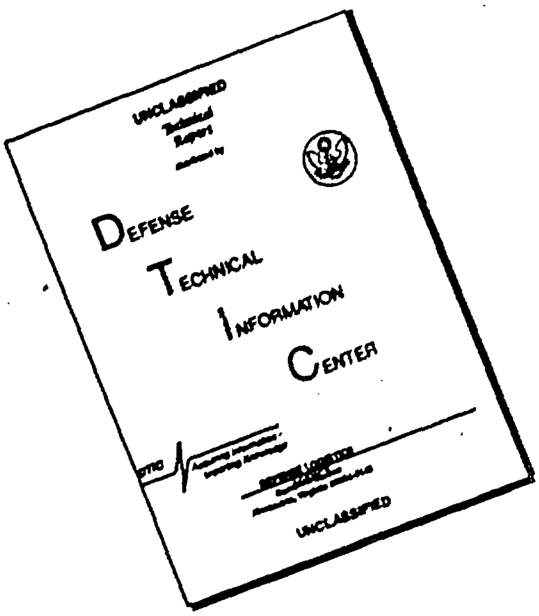

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TRAFFICABILITY OF SOILS

TESTS ON COARSE-GRAINED SOILS WITH SELF-PROPELLED AND TOWED VEHICLES, 1956 AND 1957

TECHNICAL MEMORANDUM NO. 3-240

FIFTEENTH SUPPLEMENT

June 1959

U. S. Army Engineer Waterways Experiment Station
CORPS OF ENGINEERS
Vicksburg, Mississippi

ARMY-MRC VICKSBURG MISS

PREFACE

The tests reported herein are part of the studies conducted by the U. S. Army Engineer Waterways Experiment Station under Corps of Engineers Subproject 8-70-05-400, "Trafficability of Soils as Related to the Mobility of Military Vehicles," and were also financed in part by the Bureau of Yards and Docks, Department of the Navy.

Acknowledgment is made to the consultants for trafficability studies and to the representatives of the Bureau of Yards and Docks, Department of Agriculture, Detroit Arsenal, and Office, Chief of Engineers, who participated in a conference at the Waterways Experiment Station on 12 May 1955 and offered suggestions for conducting the tests reported herein. Special acknowledgment is made to Dr. A. A. Warlam, consultant, for his participation in the Pacific islands test program.

These tests were performed by personnel of the Army Mobility Research Center, Soils Division, Waterways Experiment Station, under the supervision of Messrs. W. J. Turnbull, C. R. Foster, and S. J. Knight. Engineers actively engaged in the study were Messrs. A. A. Rula and E. S. Rush. This report was prepared by Mr. Rush.

Directors of the Waterways Experiment Station during the conduct of this study and preparation of this report were Col. A. P. Rollins, Jr., CE, and Col. Edmund H. Lang, CE. Mr. J. B. Tiffany was Technical Director.

CONTENTS

SUMMARY

Three types of vehicle tests (self-propelled, towing, and towed) were conducted with several military vehicles over a range of vehicle weights, tire pressures, and sand strengths and conditions for the following purposes:

- a. To determine whether the trafficability characteristics of coral and volcanic sands differ from those of quartz sands previously tested.
- b. To establish more definitive relations between sand condition and vehicle mobility by testing vehicles on softer sands than previously tested.
- c. To determine towing abilities of self-propelled vehicles over a range of sand conditions.
- d. To determine towing-force requirements of various vehicles over a range of sand conditions.

Single self-propelled wheeled vehicles were tested on undisturbed coral and volcanic sands on Pacific islands, and on quartz sand (desert and beach) in the United States. Towing tests with self-propelled vehicles were conducted on harrowed desert quartz sands near Yuma, Arizona. Towed wheeled trailers were tested on disturbed and undisturbed quartz sand at Camp Lejeune, North Carolina. Principal conclusions were that: (a) performance of single self-propelled wheeled vehicles can be expressed in cone index-slope climbing ability terms; (b) wet sands are more trafficable than dry-to-moist sands; (c) performance, as defined by the cone index-slope climbing curves, is the same regardless of sand source (quartz, volcanic, or coral) or location (beach or desert); (d) towing ability of self-propelled vehicles (wheeled and tracked) on harrowed sand slopes can be computed with reasonable accuracy from performance measurements obtained in tests of the respective vehicles on level harrowed sand; and (e) towing-force requirements of wheeled trailers can be correlated with cone index and tire pressure.

TRAFFICABILITY OF SOILS

TESTS ON COARSE-GRAINED SOILS WITH SELF-PROPELLED AND TOWED VEHICLES 1956 AND 1957

PART I: INTRODUCTION

Purpose and Scope of Test Program

1. The tests reported herein are part of a study to establish relations between coarse-grained soils and the ability of military vehicles to negotiate them. These tests had the following specific objectives:

   a. To determine whether the trafficability characteristics of coral and volcanic sands differ from those of quartz sands previously tested.

   b. To establish more definitive relations between sand condition and vehicle mobility by testing vehicles on softer sands than previously tested.

   c. To determine towing abilities of self-propelled vehicles over a range of sand conditions.

   d. To determine towing-force requirements of various vehicles over a range of sand conditions.

2. Objectives a and b were accomplished by tests on the beaches of certain islands in the Pacific Ocean. Objective c was partially accomplished by tests on desert sands near Yuma, Arizona, and objective d was partially accomplished by tests at Camp Lejeune, North Carolina. Testing of additional vehicles on a wider range of sand conditions will be necessary to complete these latter two objectives.

Previous Investigations

3. Since 1945 the Waterways Experiment Station has conducted a large number of traffic tests with military vehicles on a variety of soil conditions. Results of this work have been published in a series of reports with the general title "Trafficability of Soils," Technical Memorandum No. 3-240, which are listed on the inside of the front cover of this volume. Most of the tests were conducted on fine-grained soils, as these

were believed to cause the greatest trafficability problems. The development of instruments and techniques for measuring the trafficability of these soils is considered to be essentially completed. Work to develop methods of measuring trafficability of coarse-grained soils is continuing.

Pilot Study of Coarse-grained Soils

4. In October 1953, a joint Army-Navy ad hoc committee assigned the responsibility for studying means of determining the trafficability of beaches (particularly those with coarse-grained soils) to the Waterways Experiment Station. The first phase of this project was a pilot study to provide background information concerning mobility problems on coarse-grained soils, and to determine whether instruments and techniques that have been successful in defining trafficability of fine-grained soils would also be successful in coarse-grained soils. This study was accomplished in 1954 and is reported in Technical Memorandum 3-240, 13th Supplement. All the vehicle tests reported in the 13th Supplement were conducted on quartz-type sands found on inland areas and beaches of the United States. The important findings of this pilot study are summarized as follows:

a. Sand categories. Two distinct sand categories, each requiring a different technique for the determination of its trafficability, were recognized: (1) clean sands that reacted in a frictional manner to traffic, and (2) sand with fines, poorly drained, that reacted in a more plastic manner.

b. Instruments. The cone penetrometer was found to be as accurate an instrument for measuring sand trafficability as any tested, and was recommended for future use in sands, mainly on the basis of its ability to determine profile conditions but also because it had been previously accepted for use in fine-grained soils.

c. Remolding effects. No necessity was found for predicting strength changes under vehicle traffic for most sands (see subparagraph d). For sands with fines, poorly drained, strength changes had to be estimated and a technique for doing this was developed.

d. Repetition of traffic. In general, the first pass was found to be the most difficult for a wheeled vehicle in a sand area. Succeeding passes were made with increasingly less difficulty and smaller and smaller increases in rut depth. An exception to this occurred in some crusted sand. The surface crust supported the vehicle for one pass (or a few) but suddenly broke on a subsequent pass, causing the vehicle to become immobilized or making operation more difficult in the much softer sand and deeper ruts. Because only a few tests were conducted on crusted sands, no attempt was made to devise a means of predicting break-through.

e. Tire pressure. Among individual vehicle characteristics, tire pressure was the most influential single factor in the performance of wheeled vehicles in sand.

f. Critical layer. For all vehicles tested, the critical layer of the various sands appeared to be the top 6 in.

Definitions

5. Certain soil, beach, test-media, and vehicle terms used in this report are defined for the convenience of the reader.

Soil terms

Fine-grained soil (fines). A soil of which more than 50% of the grains, by weight, will pass a No. 200 U. S. standard sieve (smaller than 0.074 mm in diameter).

Coarse-grained soil. A soil of which more than 50% of the grains, by weight, will be retained on a No. 200 sieve (larger than 0.074 mm in diameter).

Sand. A coarse-grained soil with the greater percentage of the coarse fraction (larger than 0.074 mm) passing the No. 4 sieve (4.76 mm).

Sand with fines, poorly drained. A sand that contains some fine-grained soil and is slow-draining. When wet, such sands behave similarly to very wet fine-grained soils under vehicular traffic.

D_n. Particle diameter, in millimeters, that is larger than the grain diameter of n per cent by weight of the sample (e.g., $D_{60} = 0.30$ means that 60% of the sample, by weight, has a grain diameter less than 0.30 mm).

Effective size. The effective size of a soil is that particle diameter, in millimeters, that is larger than the grain diameter of 10% by weight of the sample (D_{10}).

Uniformity coefficient $(C_u) = \frac{D_{60}}{D_{10}}$. An index reflecting the shape of the grain-size curve. A material composed entirely of grains of the same diameter would have a uniformity coefficient of 1.0.

<u>Median diameter.</u> The median diameter is that particle diameter that is larger (or smaller) than the grain diameter of 50% by weight of the sample (D_{50}).

<u>Density.</u> The unit weight of the soil in pounds per cubic foot. Unless otherwise stated, the density is the dry unit weight.

<u>Moisture content or water content.</u> The ratio, expressed as a percentage, of the weight of water in the soil to the dry weight of the solid particles.

<u>Cone index.</u> An index of the shearing resistance of soil obtained with the cone penetrometer. The value is a dimensionless number representing the resistance of the soil to penetration of a 30-deg cone of 0.5-sq-in. base or projected area. The number, although considered dimensionless, actually denotes pounds of force on the handle divided by the area of the cone base in square inches.

<u>Trafficability.</u> The capacity of a soil to support the traffic of military vehicles.

<u>Bearing capacity.</u> The ability of a soil to support a vehicle without undue settlement.

<u>Traction capacity.</u> The ability of a soil to provide sufficient resistance to the push of the track or wheel of the vehicle to furnish the necessary thrust to move it.

<u>Critical layer.</u> The layer of soil regarded as being most pertinent to establishing the relation between soil strength and vehicle performance. (For coarse-grained soils, this appears to be the 0- to 6-in. layer.)

<u>Liquefaction.</u> The puddling and drastic reduction in strength of saturated (although initially firm) soil under the action of repetitive loading.

<u>Erosion.</u> The washing away of soil particles by water moving under and around that portion of a wheel or track in contact with the soil.

<u>Beach terms</u>

<u>Foreshore (FS).*</u> That part of the beach ordinarily traversed by the uprush and downrush of waves as the tide rises and falls.

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* The beach terms noted with an asterisk were extracted from Appendix A, Beach Erosion Board Bulletin, Special Issue No. 2, March 1953. Other terms pertain to specific areas in which vehicular tests were conducted but which are not defined in the above-mentioned reference.

Backshore (BS).* That part of the beach between the foreshore and the forward dune apron (if present) or the coast line.

Berm crest (BC) or beach berm.* The seaward limit of the backshore; usually a relatively flat area paralleling the foreshore and occasionally wetted by waves at high tide.

Berm backslope (BBS). A backshore area between the berm crest and the forward dune apron, usually sloping gently downward and landward.

Forward dune apron (FDA). The concave seaward slope of a line of dunes.

Dune area (DA), coastal. An area of wind-deposited sand between the forward dune apron and the coast line. Coastal dunes may be active or partially stabilized by vegetation.

Dune area, desert. An area of active sand dunes with little or no vegetation present. Desert dunes are much higher and much larger in area than coastal dunes.

Cusp.* One of a series of naturally formed low mounds of sand separated by crescent-shaped troughs spaced at more or less regular intervals along the foreshore.

Scarp, beach.* A line of steep slopes facing seaward, caused by wave erosion of the beach.

Test-media terms

Harrowed sand. Sand that has been harrowed to at least a 12-in. depth and the surface smoothed with a light drag.

Disturbed sand. Sand disturbed by traffic.

Undisturbed sand. A sand that apparently has not been recently disturbed.

Vehicle terms

Pass. One trip of the vehicle over the test course.

Immobilization. In this report, failure of a self-propelled vehicle to travel forward over sand, although it could possibly back up in its ruts. In this report, immobilizations of wheeled vehicles also were considered to have occurred whenever the drive wheels began to jerk violently and the vehicle began to make very labored, slow progress.

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* See footnote on preceding page.

Maximum drawbar pull. The maximum amount of sustained towing effort a self-propelled vehicle can produce at its drawbar under given test conditions.

Towing-force requirements. The amount of force required to tow a given vehicle under given test conditions.

Tractive coefficient. The ratio of the maximum drawbar pull to the gross weight of a vehicle.

Slip. The percentage of track or tire movement ineffective in thrusting the vehicle forward.

Ply rating (PR).* A term used to identify a given tire with its maximum recommended load when used in a specific type of service. It is an index of tire strength and does not necessarily represent the number of cord plies in the tire.

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* American Tire and Rim Association [illegible] rt [illegible], 195[illegible].

PART II: TEST PROGRAMS

6. As stated earlier, tests were conducted on a number of Pacific islands, at Yuma, Arizona, and at Camp Lejeune, North Carolina. The test program on the Pacific islands consisted in operating single self-propelled, rubber-tired vehicles across level and sloping sand beaches. At Yuma, both rubber-tired and tracked vehicles were tested as single self-propelled and towing vehicles on level and sloping natural sand and harrowed sand lanes. At Camp Lejeune, single self-propelled or towing, and trailer or towed-type wheeled vehicles were tested on disturbed and undisturbed sand, and asphalt. Measurements and/or observations of vehicle performance and pertinent sand data were made for each test. Details of the program are described in the following paragraphs. Locations of test sites on the various Pacific islands are shown in plates 1 and 2. Plate 3 shows the locations of the Yuma and Camp Lejeune sites used in tests reported herein, as well as the sites used in the pilot study reported in TM 3-240, 13th Supplement.

Pacific Island Test Areas

7. Brief descriptions of the islands visited and beaches tested are contained in the following paragraphs. All the beaches tested are of coral and shell origin except the following four: Kalapana Beach on Hawaii, Talofofo Beach on Guam, and the famed Red and Yellow Beaches on Iwo Jima, all of which are of volcanic origin. Representative grain-size curves for the sands at the various test sites are shown in plate 4; supplementary physical property data are presented in table 1. Average beach profiles and cone index isopleths are shown in the figures accompanying the text descriptions. Isopleths show the general strength profile of each beach to assist in a more complete beach description; however, they are not considered in the actual analysis.

Oahu, T. H.

8. Oahu, the third largest island in the Hawaiian Islands chain, is of volcanic origin, but there is no volcano activity there at the present time. The ocean beaches on Oahu are of three types: sand, rocky or

cliffed, and silty clay with vegetation growing down to the water's edge. Only the sand beaches were tested. They consist mainly of coral sands deposited by wind and wave action, but they also include seashell fragments and sand eroded from rock formations which can be seen just below the waterline at low tide on some of the beaches. Vehicle tests were run on five beaches, and cone index profiles and sand samples were obtained on four others. The locations of the beaches are shown in plate 1; they are described in the following paragraphs.

9. Mokuleia Beach. This beach, located on the northwestern shore of Oahu approximately one and one-half miles west of Mokuleia Station, is about 1000 ft long and 250 ft wide (fig. 1). A profile of the beach is shown in fig. 2. The foreshore averages 15 ft in width, has a 30% slope, and is entirely covered with water at high tide and partly covered at low tide.

Fig. 1. Oahu, T. H., Mokuleia Beach

Above the foreshore is a flat berm crest (which comprises all of the backshore) averaging 12 ft in width, frequently wetted by wave action. Beyond the berm crest is a

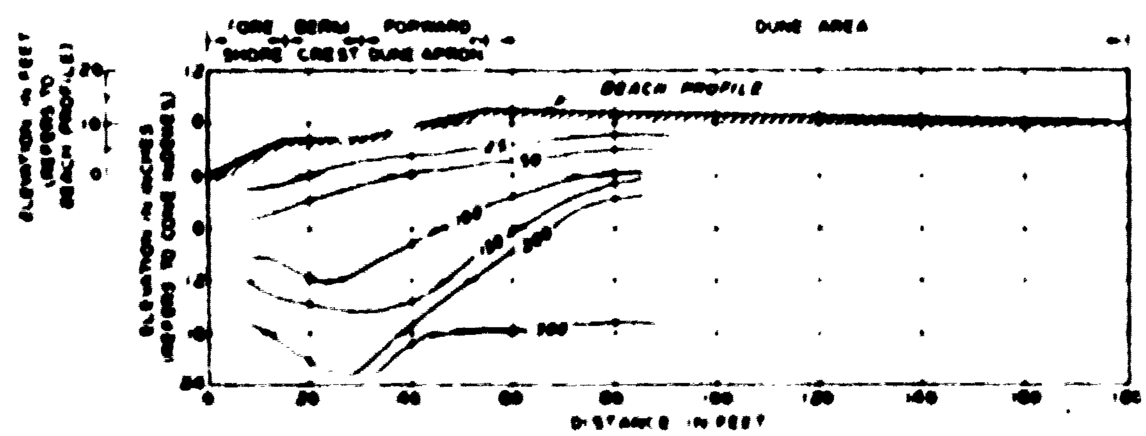


Fig. 2. Beach profile and cone index isopleths,* Mokuleia Beach

* This and all subsequent beach profiles include cone index isopleths, which are lines of equal cone index and denoted by —25—. Elevations are referred to mean low tide. Cone indexes were measured at the surface and at 3-in. vertical increments to a maximum depth of 24 in.

forward dune apron averaging 25 ft in width, with a 24% slope, on which 1-1/2 in. of dry, loose sand overlies deep, moist sand. The dune area, some 200 ft in width, is relatively flat with 4 in. of dry, loose sand overlying deep, moist sand. On the landward side of the dune area, where the beach sand has mixed with alluvium, there is some vegetation.

10. Vehicle tests were run on the berm-crest and dune-area portions of Mokuleia Beach. The foreshore was too short and the forward-dune-apron slopes too irregular to be suitable test areas. Vehicle tests were run parallel to the shore line on the berm crest, and both parallel and perpendicular to the shore line in the dune area. A representative sample revealed the soil to be a poorly graded (SP) medium sand (plate 4, fig. 1). The cone index for the 0- to 6-in. depth ranged from 14 to 51. Characteristics of the sand are listed in table 1.

11. Drone Beach. Drone Beach is on the same coast as Mokuleia Beach and approximately 3/4 mile farther west (plate 1). This beach is approximately 800 ft long and averages 200 ft in width. A profile of the beach is shown in fig. 3. The foreshore averages 20 ft in width, has a 30% slope, and is entirely covered with water at high tide and partly covered at low tide. Rock outcrops can be seen underneath the water at the foot of the foreshore. Above the foreshore is a berm crest (which comprises all of the backshore) approximately 15 ft wide and fairly flat, which is frequently wetted by waves at high tide. Beyond the berm crest is a forward dune apron that averages 50 ft in width, has a 15% slope, and is covered with loose, fairly dry sand. The dune area is relatively flat near the forward dune apron but slopes downward as it extends inland.

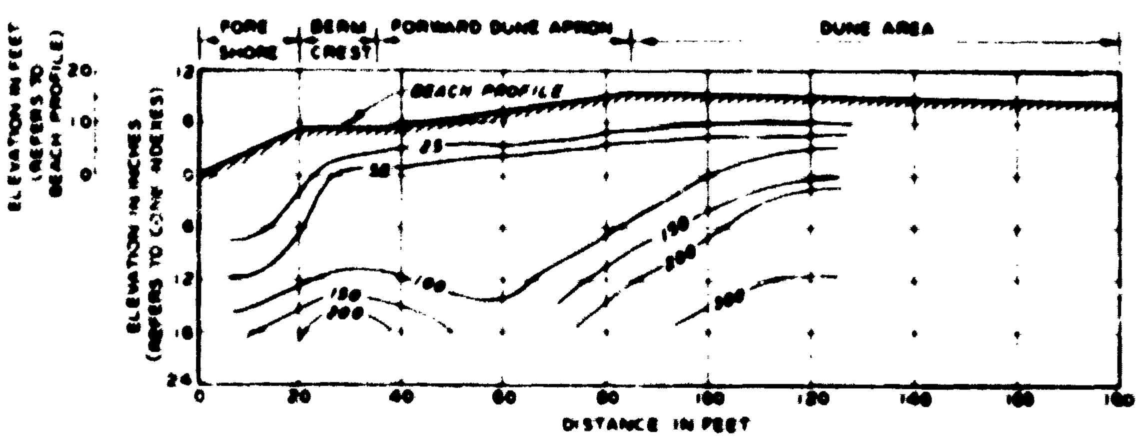


Fig. 3. Beach profile, Drone Beach

12. Vehicle tests were run parallel to the shore on the berm crest and perpendicular to the shore on the forward dune apron. No tests were run on the foreshore because of its narrow width, or in the dune area

because of vegetation and irregularity of the surface. The sand was uniform in gradation over the entire beach; a representative sample revealed poorly graded sand (SP), medium-textured (plate 4, fig. 1). The cone index for the 0- to 6-in. depth ranged from 21 to 48. Characteristics of the sand are listed in table 1.

13. Makua Beach. This beach is located on the western shore of Oahu, 3 miles south along the coast from Kaena Point (see plate 1), and is approximately 3/4 mile long and averages 200 ft in width (fig. 4). A profile of the beach is shown in fig. 5. The foreshore is approximately 30 ft wide and has an average slope of 25%. At high tide the foreshore is almost covered with water. Most of the foreshore is underlain by rock, which can be seen as outcrops some distance out from the water's edge. Occasionally, the shore line is broken by crescent-shaped troughs which extend to the forward dune apron. The berm crest averages 15 ft in width, is relatively flat, and is occasionally wetted by wave action. Landward of the berm crest is the berm backslope, which averages 50 ft in width; its slope averages 6% downward as it continues inland. The berm backslope is seldom wetted by surf except when the waves are unusually high. Beyond the berm slope is the forward dune apron, which averages

Fig. 4. Oahu, T. H., Makua Beach

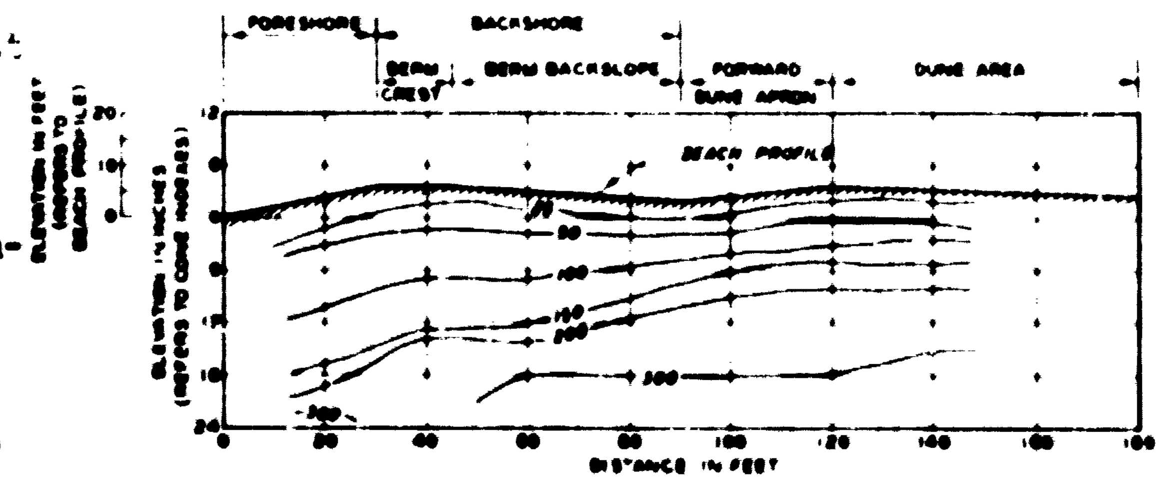


Fig. 5. Beach profile, Makua Beach

25 ft in width and has an uneven surface that is partly due to an old railroad bed over which beach sand has been deposited by wind. Some portions of the dune area were suitable for testing.

14. Vehicle tests were run on all areas of Makua Beach. The tests on the berm crest were run parallel to the shore line, and most of the tests on the forward dune apron were run perpendicular to the shore line. Only a small portion of the foreshore was suitable for vehicle tests. The sand was poorly graded (SP) and fine to medium in texture (plate 4, fig. 1, and table 1); in the dune area the sand was darker in appearance than that of the other areas and had little or no fines. The cone index for the 0- to 6-in. depth ranged from 22 to 136.

15. Crescent Beach. Crescent Beach (fig. 6), located approximately 1 mile southeast of Makua Beach, is not as uniform throughout its length as the beaches described previously and thus is represented by two different profiles, one through a crescent-shaped trough area between cusps, designated area one (fig. 7), and the other through an area with no cusps, designated area two (fig. 8).

Fig. 6. Oahu, T. H., Crescent Beach

16. An average profile through area one shows a foreshore that is long and relatively flat for foreshores in this area. It averages 50 ft in width, has a 6% slope, and is entirely covered by surf during periods of high tides and occasionally wetted during low tides. Rocks are exposed at the toe of the foreshore

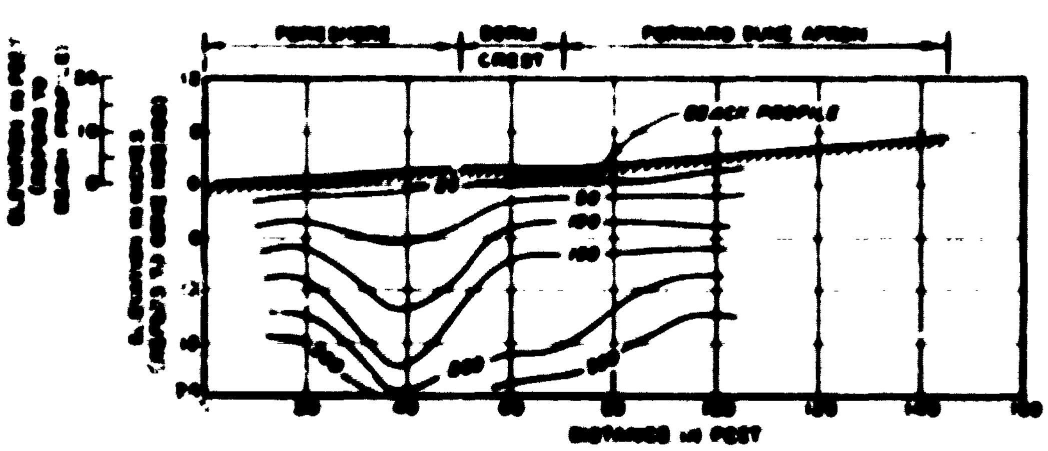


Fig. 7. Beach profile, Crescent Beach, area one

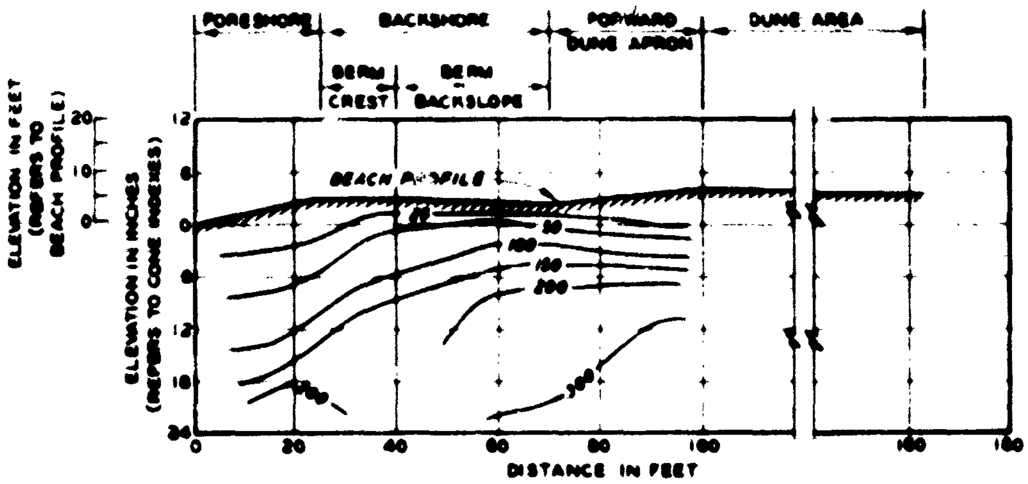


Fig. 8. Beach profile, Crescent Beach, area two

during low tide. Landward of the foreshore is the berm crest, which averages 20 ft in width. No berm backslope is evident, and the forward dune apron rises directly from the berm crest. It averages 75 ft in width and has an 8% slope. The dune area on this beach is a mixture of sand and silt and supports vegetation to such an extent that it was impractical to run vehicle tests on it.

17. An average profile of beach area two is similar to the profile of Makua Beach. The foreshore averages 25 ft in width, has a 25% slope, and leads up to a berm crest approximately 15 ft in width. Landward of the berm crest is the berm backslope, which averages 30 ft in width and slopes downward toward the forward dune apron on an average slope of 4%. The forward dune apron averages 30 ft in width, has a 10% slope, and leads up to a dune area on which are found vegetation such as trees and underbrush.

18. Vehicle tests were run on all portions of Crescent Beach except the dune area. Foreshore tests in the vicinity of the crescent-shaped troughs were run both parallel and perpendicular to the shore line. Tests on the berm crest were run parallel to the shore line, and tests on the berm backslope were run perpendicular to the shore line. A representative sample of sand from Crescent Beach shows a poorly graded (SP), fine-textured material (plate 4, fig. 1, and table 1). The cone index for the 0- to 6-in. depth ranged from 18 to 66.

19. <u>Bunker Beach.</u> This beach (fig. 9), adjacent to the southeast end of Crescent Beach, is approximately 2000 ft long and has two distinct profiles, one of which is similar to the profile of Makua Beach.

20. Area one profile (fig. 10) shows a foreshore averaging 30 ft in width, with an average slope of 25%. The berm crest is about 20 ft wide and is wetted occasionally by high waves. Beyond the berm crest is the berm backslope, averaging 50 ft in width; it has an average slope of 5%

downward as it extends inland. The forward dune apron is about 25 ft wide, and has a 15% slope leading up to a dune area on which some vegetation is growing.

21. Area two profile (fi 11) represents an area in which the berm backslope slopes downward, leaving a low area behind the beach in which water no doubt stands for some time after heavy rains. The foreshore of this profile resembles other beaches mentioned in that it averages 30 ft in width and has a 25% slope. The berm crest averages 20 ft in width and is relatively flat. Landward, the berm backslope averages 100 ft in width and slopes downward on an average slope of 6%.

Fig. 9. Oahu, T. H., Bunker Beach

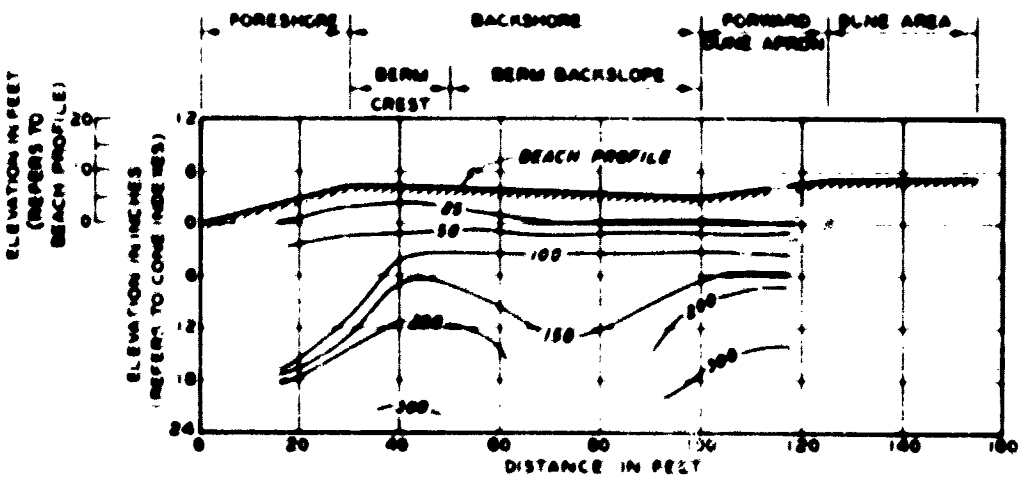


Fig. 10. Beach profile, Bunker Beach, area one

22. Vehicle tests were run on the berm crest (parallel to the shore line), the berm backslope (perpendicular to the shore line), and on the forward dune apron (perpendicular to the shore line). The foreshore slope was too steep for vehicle tests, and the dune area contained too much vegetation. The sand

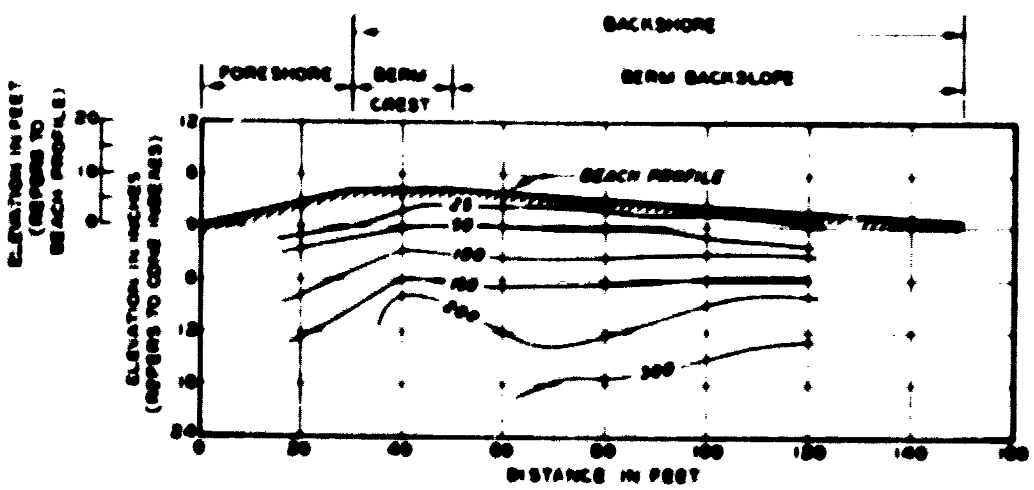
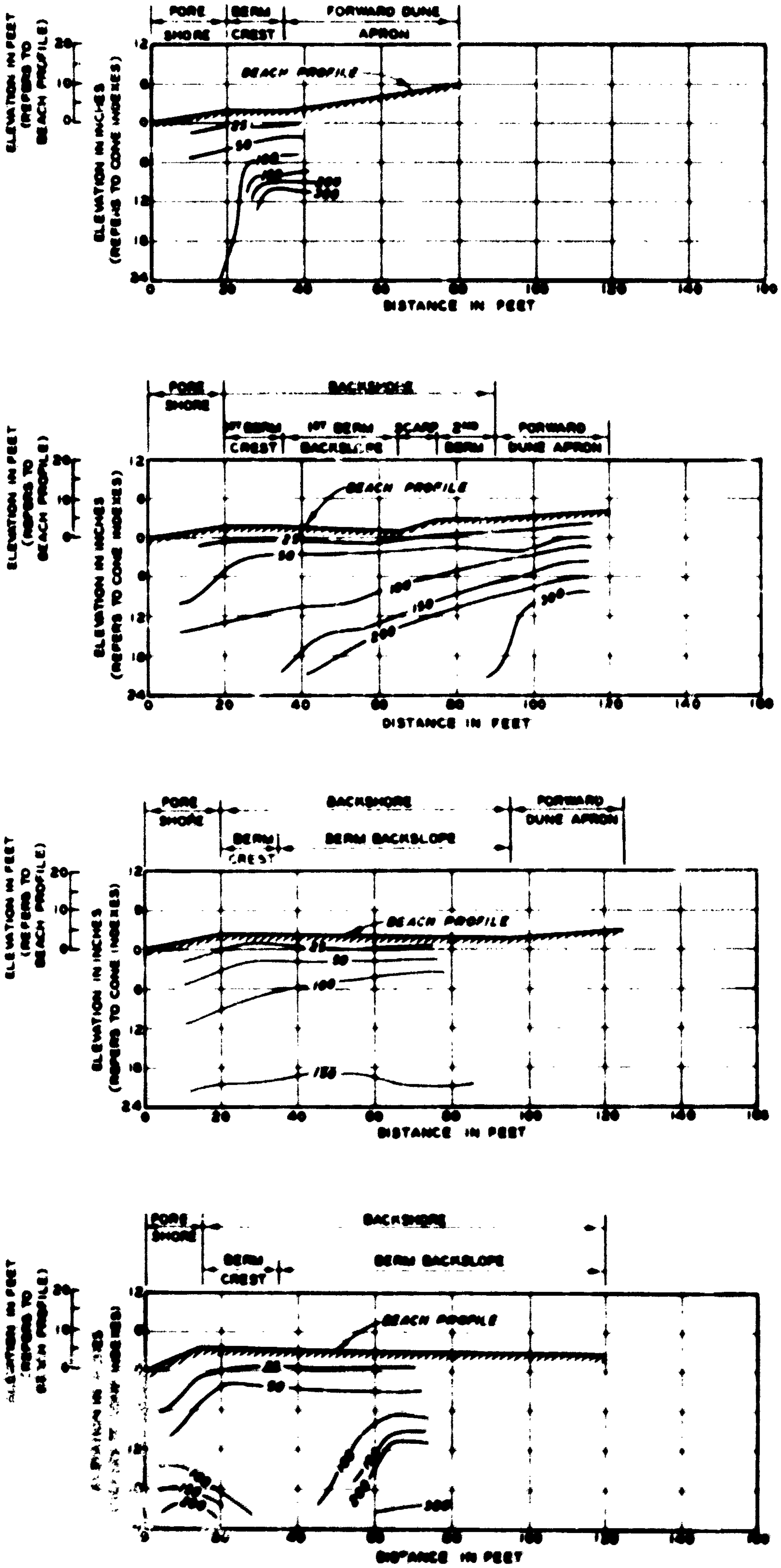


Fig. 11. Beach profile, Bunker Beach, area two



Pokai Bay 1

Pokai Bay 2

Naval Ammunition Depot (NAD)

Last Beach

Fig. 12. Beach profiles and cone index isopleths, Oahu

was poorly graded (SP), with almost equal amounts of medium and fine sizes (plate 4, fig. 2, and table 1). The cone index for the 0- to 6-in. depth ranged from 39 to 85.

23. Other beaches. Only cone index and sand data were obtained on the beaches at Pokai Bay 1, Pokai Bay 2, Naval Ammunition Depot (NAD), and Last Beaches. Profiles of these beaches are shown in fig. 12. The sands from these beaches were all poorly graded (SP) and ranged in texture from medium for Last and Pokai Bay 1 Beaches, to fine-to-medium for NAD and Pokai Bay 2 Beaches (see table 1). The cone index for the 0- to 6-in. depth ranged from 28 to 31 for Pokai Bay 1 Beach, 22 to 52 for Pokai Bay 2 Beach, 26 to 51 for NAD Beach, and 11 to 27 for Last Beach.

Hawaii, T. H.

24. Hawaii is the largest island of the Hawaiian Islands chain and, like Oahu, is of volcanic origin. It is the only island of this chain that has an active volcano at the present time. For the most part the shores of Hawaii are rocky and cliffed, but there are a few sand beaches.

Fig. 13. Hawaii, T. H., Kalapana Beach

25. The beach tested on Hawaii is covered with b[illegible] sand derived from lava rock (fig. 13). A beach profile is shown in fig. 14. Because the beach itself is almost inaccessible by vehicle, no trafficability tests were performed; however, cone index profiles and sand samples were obtained. Kalapana

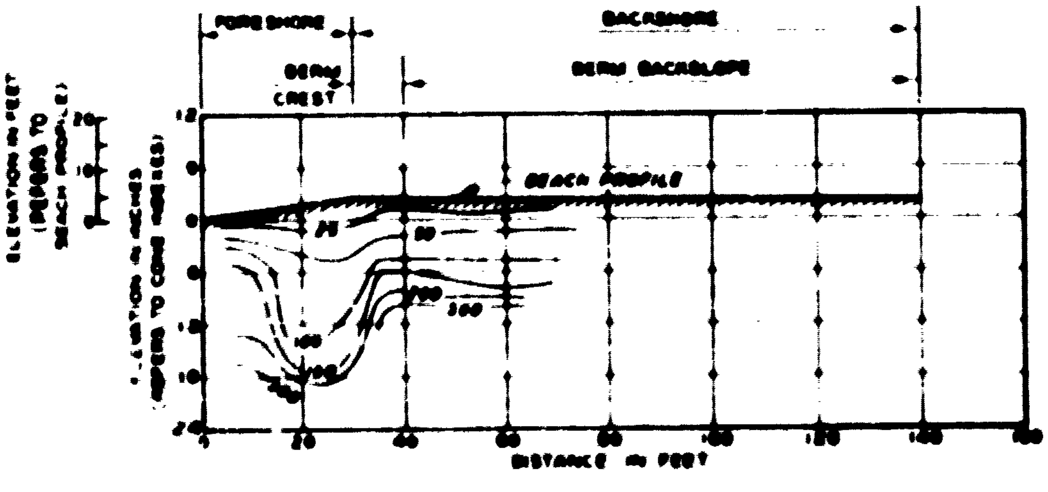


Fig. 14. Beach profile, Hawaii, Kalapana Beach

Beach is approximately 1/4 mile long and about 150 ft wide. The foreshore is approximately 30 ft wide and has a 12% slope. Bedrock can be seen at the toe of the slope and is partially exposed at low tide. The entire foreshore is wetted during high tide. A berm crest at the top of the foreshore averages 10 ft in width, and the backshore slopes gently downward as it continues inland, with palm trees growing near the berm crest. The sand was poorly graded (SP), fine- to medium-textured (plate 4, fig. 3, and table 1). The cone index for the 0- to 6-in. depth ranged from 25 to 68.

Kwajalein Atoll

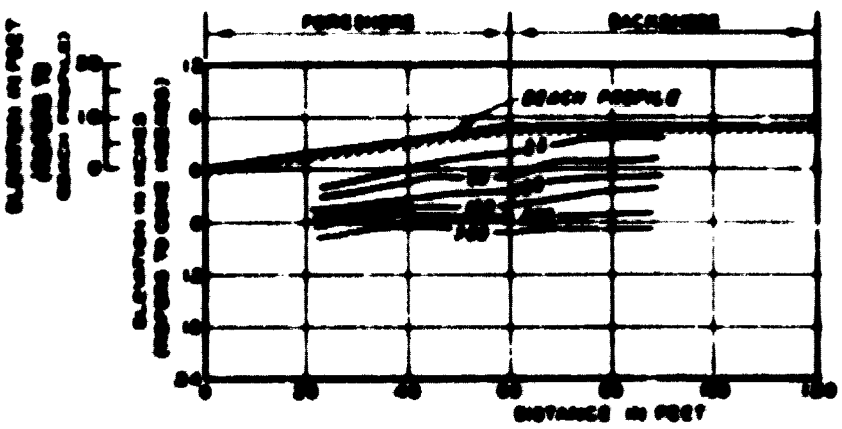
26. Kwajalein Atoll (plate 1), one of the largest atolls in existence, is approximately 75 miles long from the western to the southern tip. It consists of coral reefs and small sand bars surrounding a lagoon. Kwajalein, its largest island, is located on the southern tip of the atoll and is approximately 3 miles long and 1/2 mile wide; most of this area is used for an airfield. A profile across the island shows the beaches on the ocean side to be primarily gravel (fig. 15) and somewhat steeper than the coral sand beaches on the lagoon side (fig. 16). The sand on the ocean-side beaches is only a few inches deep and overlies bedrock.

Fig. 15. Kwajalein Atoll, ocean side

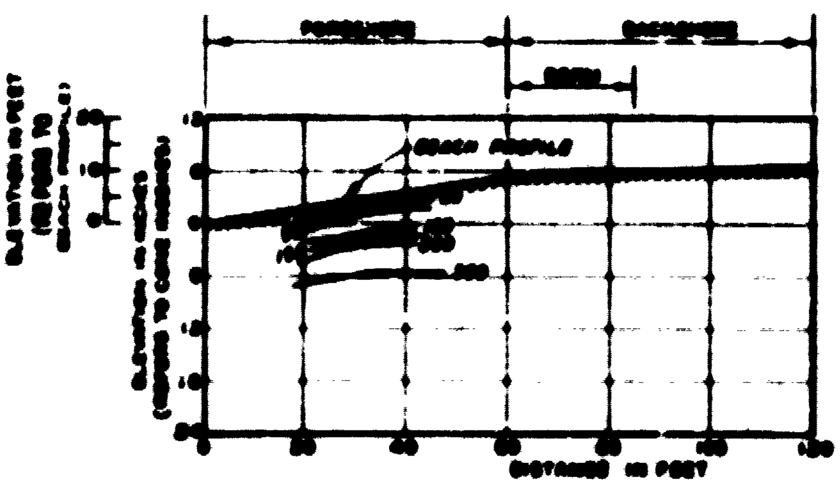
Fig. 16. Kwajalein Atoll, lagoon side

Also, it should be noted that the ending foreshore and beginning of backshore on the lagoon beaches of Kwajalein are not as well defined as on Oahu, where berm crests were present on nearly every beach. Nine vehicle tests were run on three beaches (designated numbers 5, 6, and 7) on the lagoon side of the island where American landings were made in 1944; in addition, cone index and sand data were obtained on another lagoon beach (designated number 1). These four beaches are described in the following paragraphs, and profiles of each are shown in fig. 17. Gradation and characteristics of the sand found on them are given in plate 4 (figs. 3 and 4) and table 1, respectively.

27. <u>Beach No. 1.</u> This beach is located approximately midway along the lagoon coast line of the island. As shown in fig. 17a, the foreshore is 60 ft wide and has a slope of 14%; it is underlain by coral rock at a depth of about 7 in. The backshore extends 60 ft inland and is fairly flat. The sand from this beach was poorly graded (SP) and fine-textured. Range of cone index for the 0- to 6-in. depth was 47-52.



a. Beach No. 1



b. Beach No. 5

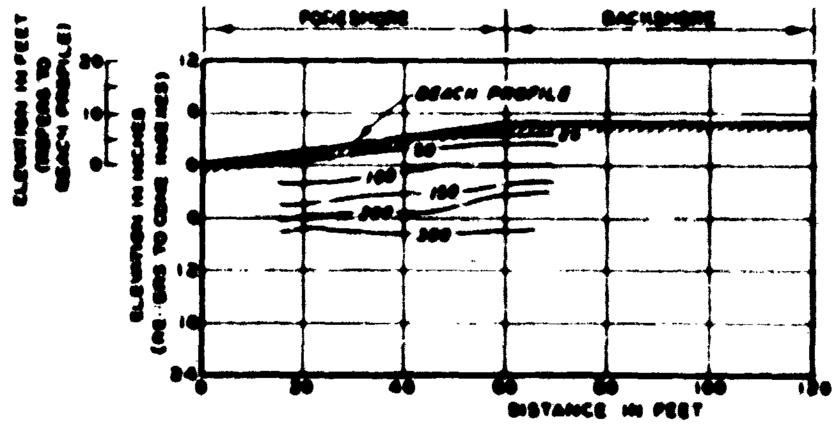
Fig. 17a and b. Beach profiles and cone index isopleths, Kwajalein

28. <u>Beach No. 5.</u> This beach is located about 1000 ft west of Beach No. 1. Its foreshore averages 60 ft in width and has a 13% slope (fig. 17b). The backshore extends 60 ft inland, rising slightly. The sand was poorly graded (SP), fine- to medium-textured. Cone index for the 0- to 6-in. depth ranged from 107 to 128.

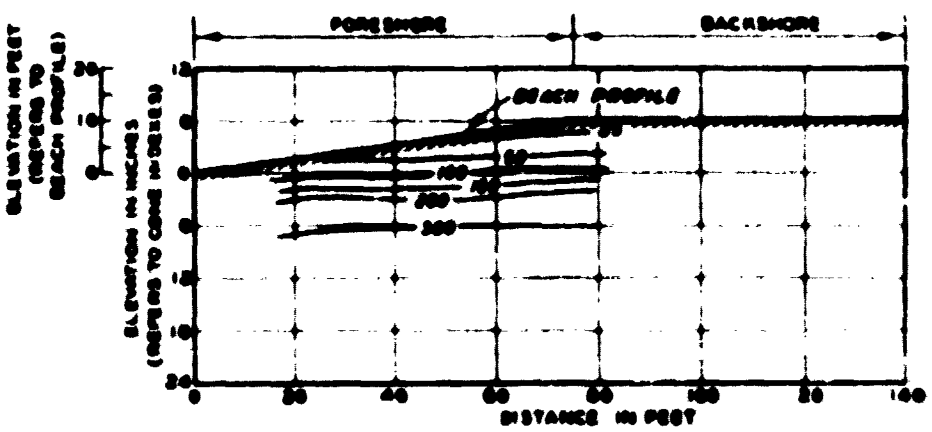
29. <u>Beach No. 6.</u> Located about 2000 ft west of the northernmost tip of the island, this beach has been modified by a hydraulic fill which was pumped in from the lagoon. As shown in fig. 17c, the

foreshore averages 60 ft in width and has a 13% slope. The backshore extends 60 ft inland and is fairly flat. A representative sample from this beach revealed the sand to be poorly graded (SP), medium- to fine-textured, with some silt. Cone index for the 0- to 6-in. depth ranged from 50 to 153.

30. Beach No. 7. Located on the northern tip of the island, this beach has a foreshore that averages 75 ft in width and has an average slope of 13% (fig. 17d). The backshore extends 65 ft inland and is fairly flat. The sand was poorly graded (SP), medium- to fine-textured. Cone index for the 0- to 6-in. depth ranged from 62 to 136.



c. Beach No. 6



d. Beach No. 7

Fig. 17c and d. Beach profiles and cone index isopleths, Kwajalein

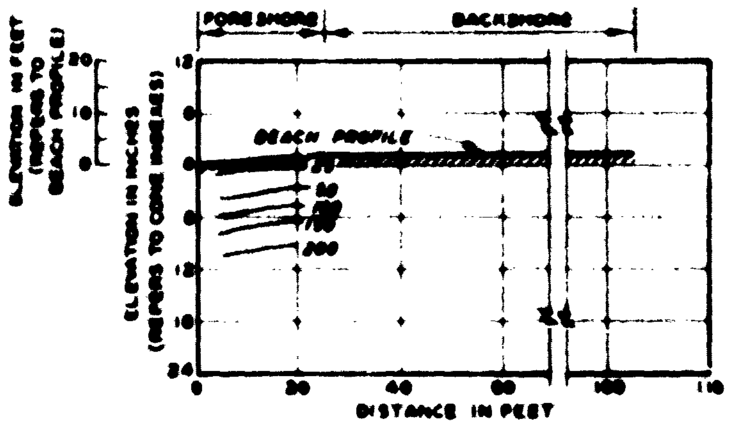
Guam

31. The island of Guam (plate 2) is approximately 30 miles long, 4 to 8 miles wide, and about 275 square miles in area. It consists essentially of volcanic rock and coral limestone, with a fringing reef of coral around most of the island. All beaches tested were coral except Talofofo, which was made up of volcanic materials. In the beach descriptions, the backshore areas are not separated into berm crest and berm backslope since these beach areas on Guam were not as pronounced as on Oahu. Seven vehicle tests were run on four beaches, and sand and cone index data were obtained on two additional beaches. The beaches are described in the following paragraphs, and gradation and characteristics of the beach materials are shown in plate 4 and table 1, respectively.

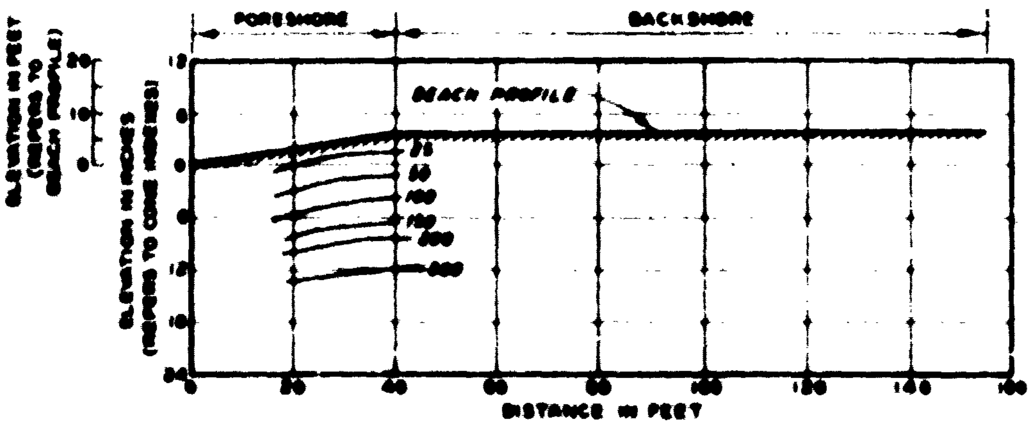
32. Nimitz Beach is located on the west coast of Guam approximately mile south of New Agat. A beach profile is shown in fig. 18. The foreshore in the vicinity of the test area slopes 8% and is approximately 25 ft

wide. The backshore is relatively flat and extends 80 ft inland (fig. 18a). The sand on this beach was poorly graded (SP) and fine-textured. The cone index for the 0- to 6-in. depth ranged from 52 to 68.

33. Jones Beach, located on the east coast of Guam approximately 1-1/2 miles north of Talofofo Bay, has a foreshore approximately 40 ft in width, with a 14% slope. As shown by the profile in fig. 18b, the backshore is 110 ft wide and fairly flat. Sparse vegetation grows on the backshore. The sand was poorly graded (SP) and medium-textured. The cone index for the 0- to 6-in. depth ranged from 31 to 52.



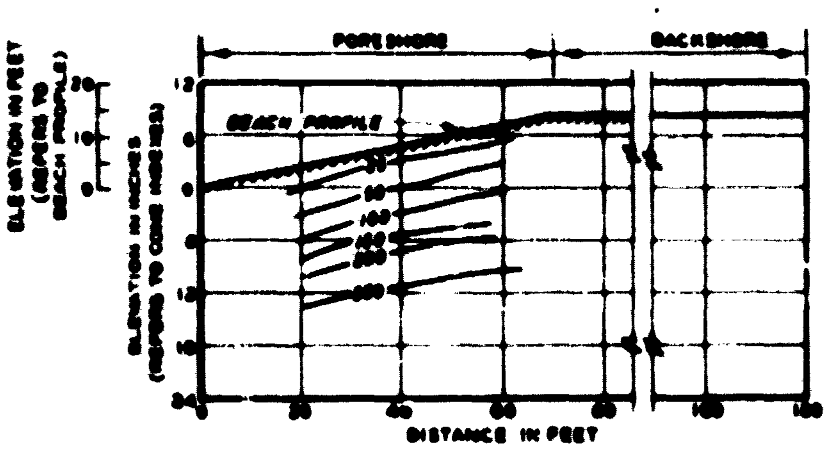
a. Nimitz Beach



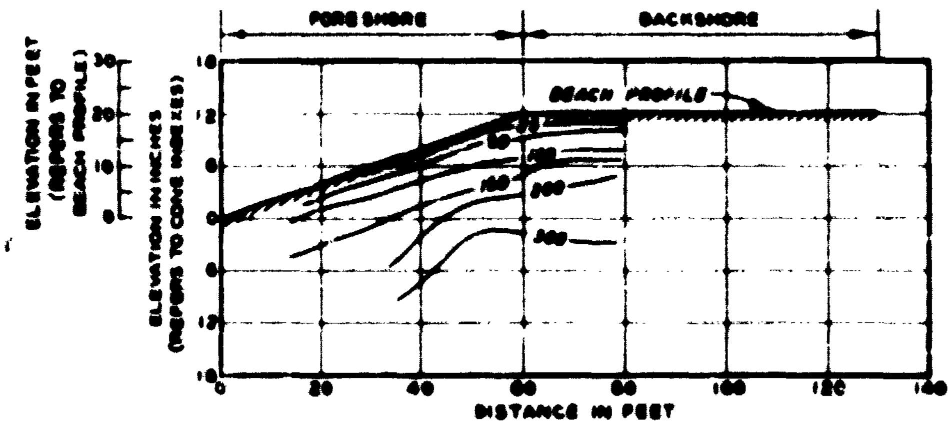
b. Jones Beach

Fig. 18a and b. Beach profiles and cone index isopleths, Guam

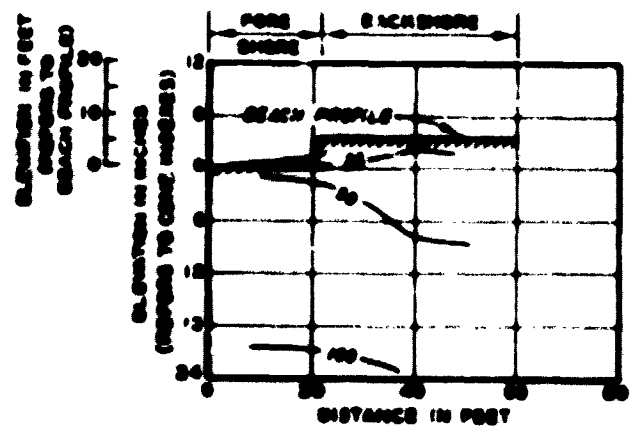
34. Tarague Beach, located on the northern coast, midway between Ritidian Point and Pati Point, is about 180 ft wide. The foreshore averages 70 ft in width and has a 20% slope; the backshore is flat (fig. 18c). The sand was poorly graded (SP), medium- to fine-textured. Cone index for the 0- to 6-in. depth was 40 to 41. Fig. 19 is a view of this beach.



c. Tarague Beach



d. NCS Beach



e. Talofofo Bay Beach

Fig. 18c, d, and e. Beach profiles and cone index isopleths, Guam

35. NCS Beach is located on the western shore about 1 mile south of Haputo Point. The foreshore is about 60 ft wide with a 20% slope. The backshore is flat and 70 ft in width (fig. 18d). The sand was poorly graded (SP), fine- to medium-textured. Cone index for the 0- to 6-in. depth ranged from 79 to 86.

Fig. 19. Guam, Tarague Beach

36. Talofofo Beach is located on the eastern shore near the neck of Talofofo Bay. The foreshore is about 20 ft wide with a 10% slope. Beyond it is a 4-ft-high scarp (fig. 18e), exposed to erosion by waves during high tide. Above the scarp is a fairly level backshore, 40 ft wide. This beach is inaccessible to wheeled vehicles. A representative sample of soil

showed it to be a poorly graded (SP), medium- to fine-textured sand containing some silt. Range of cone index for the 0- to 6-in. depth was 32-61.

37. Tumon Beach is located on the western shore of Guam, near the southern end of Tumon Bay. As shown in fig. 20, the foreshore averages 60 ft in width and has a 20% slope. The backshore also averages 60 ft in width and slopes downward from the foreshore. Some vegetation is growing on the backshore. The sand is poorly graded (SP), medium- to fine-textured. The cone index for the 0- to 6-in. depth ranged from 102 to 144.

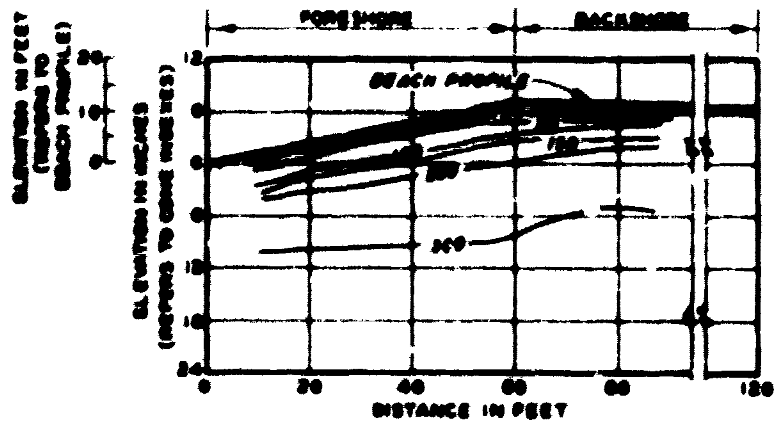


Fig. 20. Beach profile, Tumon Beach

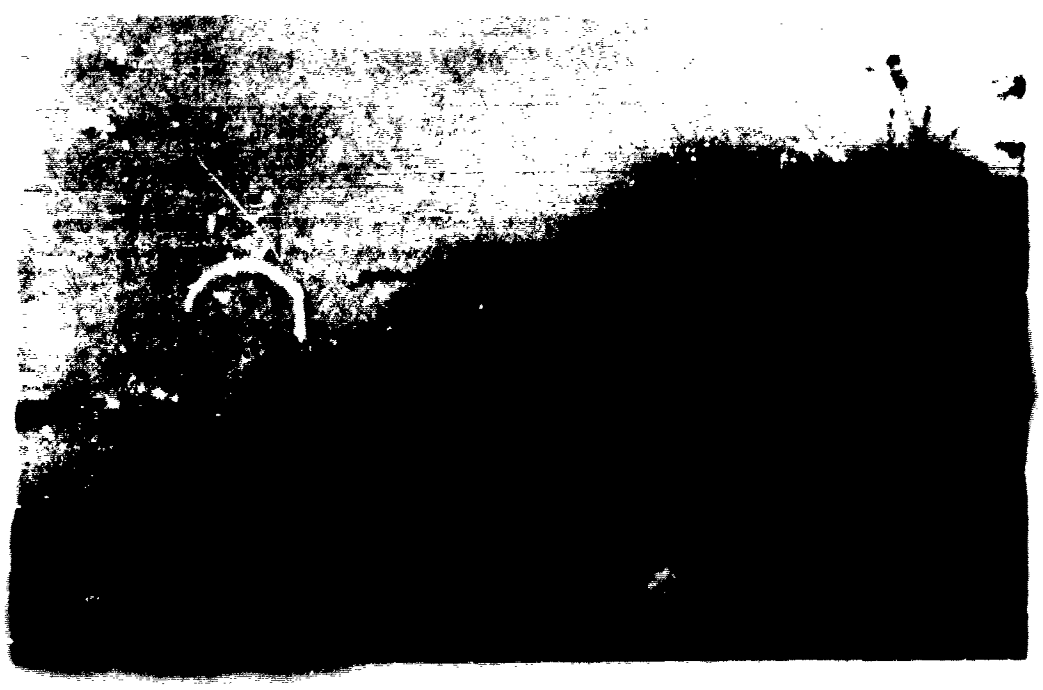


Fig. 21. Luzon, P. I., Lido Beach

Luzon, P. I.

38. Luzon, the largest island of the Philippine Islands group, measures some 40,420 square miles in area. Beaches are numerous but ecause of the great distance between most beaches and any military reservation, only one beach, Lido, was tested. Lido (fig. 21) is located approximately 20 miles south of Manila on Manila Bay. The foreshore area tested averages 60 ft in width and has a slope of 18%. The backshore extends 100 ft inland and slopes gently downward (see fig. 22). The Lido Beach grain-size curve showed a poorly graded (SP), fine to medium sand (plate 4, fig. 6, and table 1). Cone index for the 0- to 6-in. depth ranged from 97 to 131.

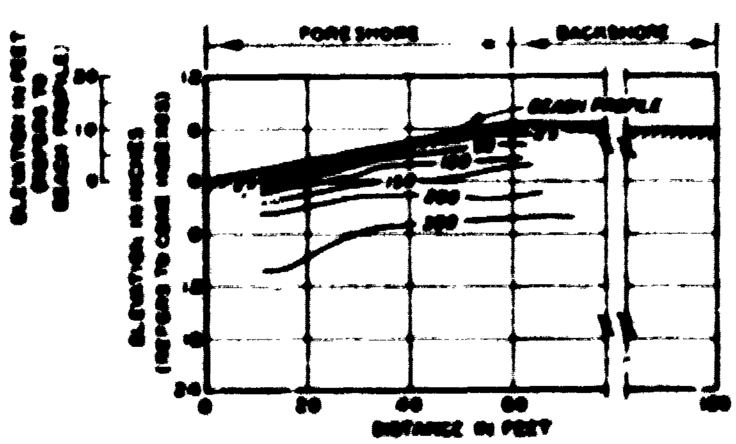


Fig. 22. Beach profile, Lido Beach

Midway Atoll

39. Midway Atoll is located 1300 miles west of Oahu, near the end of the Hawaiian chain. It is circular in shape, the diameter within the encircling reef being about 6 miles. The atoll includes two islands, Sand and Eastern, which have a combined area of approximately 2 square miles. Tests were performed only on Officers' Club Beach (fig. 23), which is located on the northern shore of the lagoon side of Sand Island.

Fig. 23. Midway Atoll, Officers' Club Beach

The foreshore averages 60 ft in width and has a slope of 12%. The backshore is fairly flat and is 75 ft wide (fig. 24). A representative sample showed a poorly graded (SP), fine- to medium-textured sand (plate 4, fig. 6, and table 1). The cone index for the 0- to 6-in. depth ranged from 34 to 72.

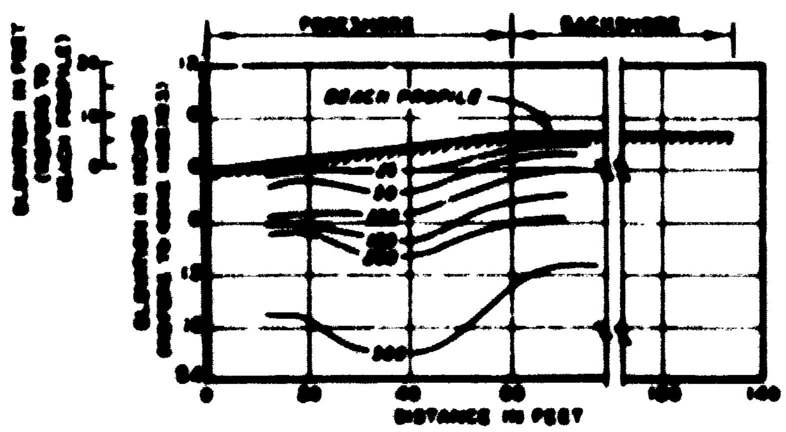


Fig. 24. Beach profile, Officers' Club Beach

Iwo Jima

40. Iwo Jima, the central one of three small islands that make up the Volcano Islands chain, is 5 miles long and 2-1/2 miles wide. The northern portion of the island is a ravine-cut dome, which descends southward through a rough plateau and is connected to Mount Suribachi by an isthmus. Vehicle tests were performed on the two beaches on Iwo Jima on which severe military losses were suffered in 1945, Red Beach and Yellow Beach. Both beaches consisted of weathered volcanic ash.

41. Red Beach. Red Beach (fig. 25) is located on the west shore of Iwo Jima, and extends approximately 2-1/2 miles northward from Mount

Fig. 25. Iwo Jima, Red Beach

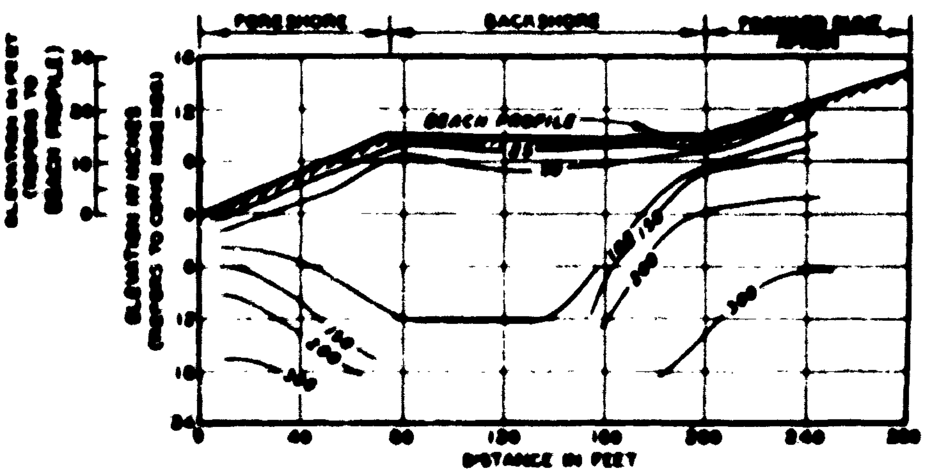


Fig. 26. Beach profile, Red Beach

Suribachi. The foreshore averages 75 ft in width and has a 20% slope. The backshore extends 125 ft inland and has two berms (see fig. 26). Beyond the backshore the forward dune apron extends 800 ft, and its slope averages 15%. The dune area is partially stabilized by vegetation. The Red Beach grain-size curve showed a poorly graded (SP), fine to medium sand (plate 4, fig. 6, and table 1). The cone index for the 0- to 6-in. depth ranged from 24 to 141.

42. Yellow Beach. This beach (fig. 27) is located on the east shore of Iwo Jima and

Fig. 27. Iwo Jima, Yellow Beach

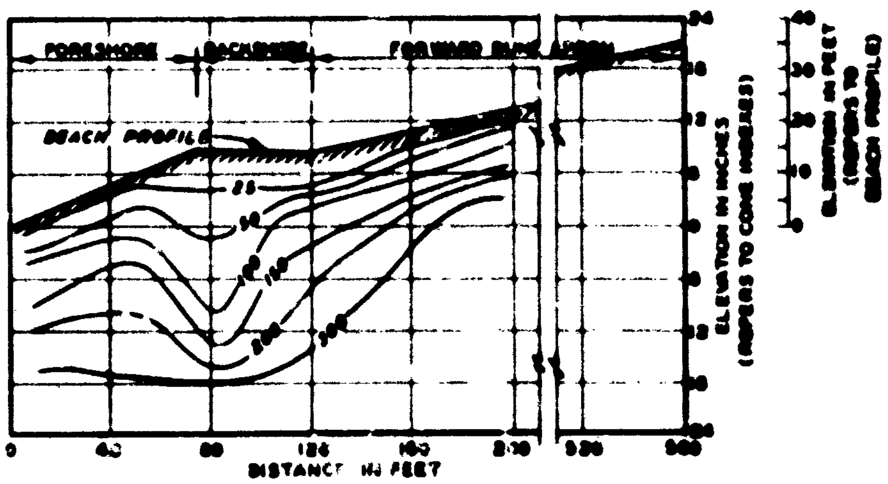


Fig. 28. Beach profile, Yellow Beach

extends approximately 1-1/2 miles northward from Mount Suribachi. The foreshore is 75 ft in width and has a 20% slope. Beyond the foreshore the backshore averages 45 ft in width and slopes slightly downward. The forward dune apron extends 450 ft inland, and its slope averages 12% (fig. 28). The sand was poorly graded (SP), and medium-textured (plate 4, fig. 6, and table 1). The cone index for the 0- to 6-in. depth ranged from 18 to 88.

Yuma, Arizona, Test Areas

Test Station area

43. Testing at the Yuma Test Station (plate 3), located approximately 25 miles north of Yuma, Arizona, on the east bank of the Colorado River, was confined to prepared test lanes. The test lanes are shown in fig. 29. Towing tests were performed on the prepared lanes, but no single self-propelled vehicle tests.

44. The test lanes, approximately 300 ft long and 40 ft wide, were prepared by harrowing to a depth of 20 in. and smoothing the surface with an aluminum I-beam attached behind the harrow. The test sites included one level area and three slopes with grades of approximately 10, 15, and 20%, respectively. Analyses of samples revealed the

Fig. 29. Yuma Test Station area

sand to be medium- to fine-textured, with a small percentage of fines (see table 1). A representative grain-size curve is shown in fig. 7 of plate 4.

Dune area

45. Tests were also conducted in a sand dune area referred to herein as the Yuma dune area, although it is actually located in California, approximately 20 miles west of Yuma, Arizona (see plate 3). Fig. 30 shows the general appearance of the test area, which consists of active sand dunes, some as high as 300 ft, although the majority are less than 100 ft high. Analyses of samples from the test area showed the sand to be medium- to fine-grained. A representative grain-size curve is shown in plate 4, and supplementary sand data are presented in table 1. Cone index for the 0- to 6-in. depth ranged from 21 to 141. The moisture content of the 0- to 6-in. depth during the test period was approximately 2.0% by weight, unusually high for this area. This was attributed to the fact that the first general rain in about two years occurred at the beginning of testing.

Fig. 30. Yuma dune area

Camp Lejeune, N. C., Test Area

46. Tests were conducted on Onslow Beach (fig. 31) which is located on the Atlantic Coast within the reservation boundaries of Camp Lejeune, N. C. (see plate 3 for location). It is approximately 5 miles long and consists of firm quartz sand. A beach profile is shown in fig. 32. The foreshore ranges in width from 15 to 20 ft at high tide to as much as 100 ft during low tide. The average foreshore slope is about 6%. Cone index for the 0- to 6-in. depth ranged from 50 to 167. Beyond the foreshore was a very short forward dune apron with dune area sand extending to the

Fig. 31. Onslow Beach, Camp Lejeune

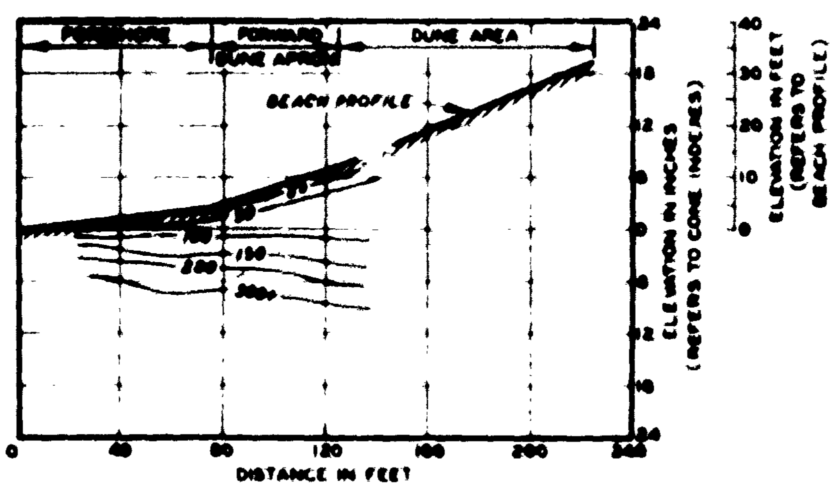


Fig. 32. Beach profile, Camp Lejeune

foreshore in some areas. Dune area slopes were short and steep, with only a few low passages through the dunes. Gradation curves for the 0- to 6-in. depth show a poorly graded (SP), fine-textured sand. A representative grain-size curve is shown in plate 4, and supplementary sand data are presented in table 1. All towed-vehicle tests were conducted on the foreshore, parallel to the water's edge. Tests of self-propelled vehicles were conducted on the forward dune apron and dune area.

Instruments Used to Obtain Test Data

47. The cone penetrometer for measuring strength and a hand level for measuring slope were used throughout the three test programs. Tire pressures were checked with laboratory-type test gages during all three test programs. Dynamometers were used only during the Yuma and Camp Lejeune tests; the slip meter was used only at Yuma. These various items of equipment are described in the following paragraphs.

Sand data

48. Cone penetrometer. The cone penetrometer is a field instrument consisting of a 30-deg cone with a 0.5-sq-in. base area mounted on one end of a shaft in such a way that it can be forced into the soil by hand. The penetrometer in use is illustrated in fig. 33. A proving ring and calibrated-dial assembly are mounted on the other end of the shaft and are used to measure the load applied. The penetration resistance (read from the dial) is termed cone index (see "Definitions"). This is the same instrument used to measure the trafficability of fine-grained soils.

Fig. 33. Cone penetrometer in use

49. Hand level. A hand level accurate to 0.5% was used for determining the slope prior to each vehicle test. Slope readings were made by placing the hand level in the center of a 6-ft plank adjacent to the vehicle and parallel to the vehicle path. Slope measurements recorded were the average of several measurements around the vehicle.

Vehicle data

50. Tire-pressure gage. The laboratory-type test gages used to regulate tire-inflation pressures during the tests were accurate to 0.25 psi throughout the range of tire pressures tested. Fig. 34 shows a tire-pressure check being made on one of the test vehicles.

51. Dynamometers. The dynamometers used were electrically recording load cells suitable for measuring forces in tension by translating changes in force into changes in electrical energy. These load cells are hermetically sealed and operate without mechanically moving parts. The sensing element is a high-strength load-carrying member to which are bonded special SR-4 strain gages that undergo resistance changes precisely proportional to applied strain. The dynamometers, used to measure drawbar pulls during the

Fig. 34. Tire-pressure check before testing

towing and towed tests, were connected between the test vehicle and the load vehicle, and measured the amount of pull exerted by the towing vehicle. Dynamometers ranged in capacity from 1000 to 50,000 lb, depending upon the amount of force to be measured.

52. Slip meter. The distance a point on the periphery of a wheel or track traveled during a given time and the distance the vehicle traveled during the same time were determined by a slip meter. The meter recorded the number of revolutions the vehicle wheel made while propelling the vehicle, and the number of revolutions made by a nonslipping bicycle wheel trailing the test vehicle and attached to it.

53. Recorder for dynamometer and slip measurements. During the drawbar-slip tests the force exerted on the dynamometer, and the events experienced by the slip meter were amplified and recorded simultaneously as traces on paper tape moving through a six-channel direct-inking recorder. Tests with the 2-1/2-ton M135 utilized all six channels, since electrical contacts were placed on four rear wheels and the bicycle wheel, and one channel was required for recording the dynamometer measurements. Towed-vehicle tests utilized a smaller recorder of the same type since only one channel for recording dynamometer measurements was needed.

54. The complex system of measuring drawbar slip required "instrumenting" an M29C weasel with a recorder, amplifiers, and power supply; this vehicle traveled alongside the test vehicle during testing as shown in

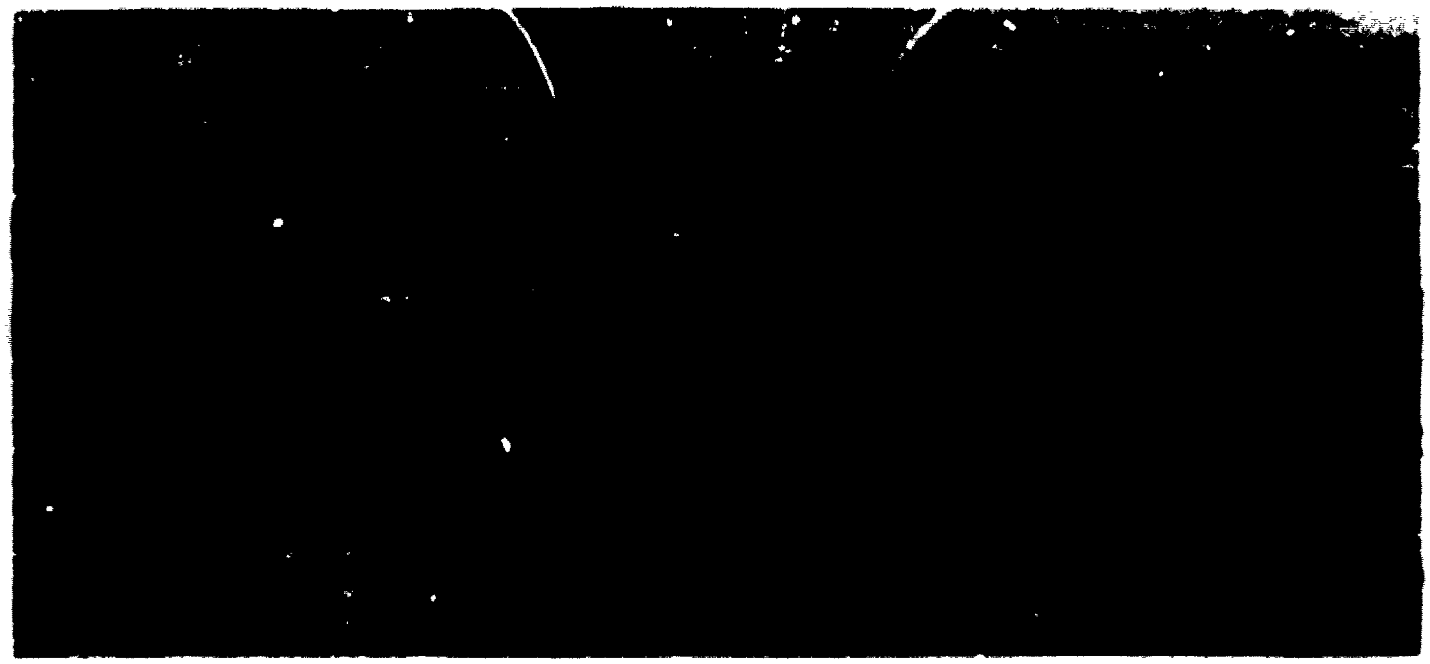


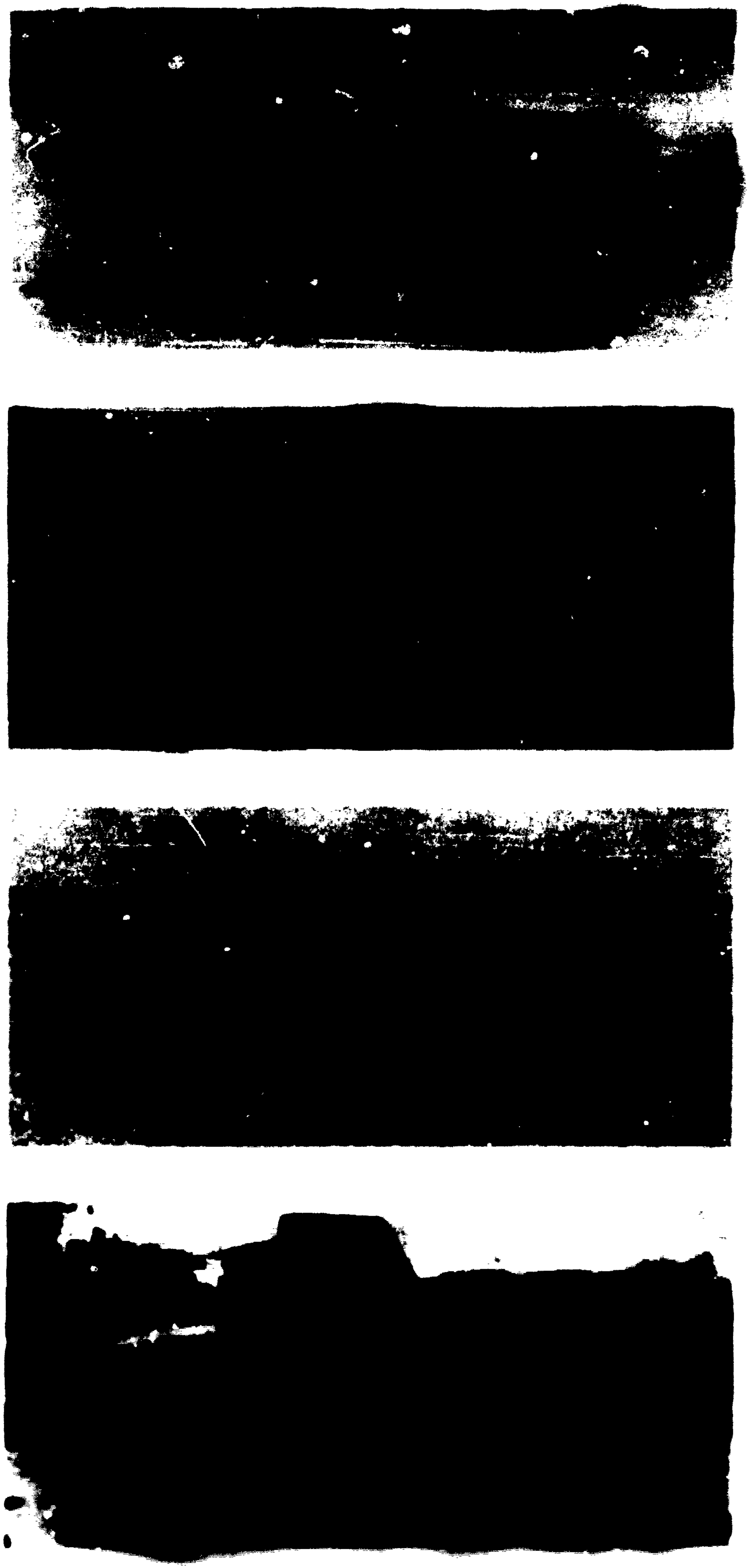
Fig. 35. Towing tests, drawbar pull

fig. 35. Electric cables, connecting the test vehicle and the instrumented vehicle, transmitted the measurements to the recorder. For the simple towed-vehicle tests, recorder, amplifier, and power supply were mounted in the towing vehicle.

Vehicles Tested

Pacific islands

55. The vehicles tested were furnished by military units on each island. They included the 1/4-ton M38A1 4x4 truck, the 3/4-ton M37 4x4 truck, the 2-1/2-ton M211 6x6 truck, the 2-1/2-ton M215 6x6 truck, and an unnumbered 2-1/2-ton 6x6 truck. These vehicles are shown in figs. 36 and 37. The test vehicles were equipped with standard equipment and tires, except that the 2-1/2-ton M215 was tested with six 11.00x20 12-ply tires, single tandem (this vehicle normally is equipped with ten 9.00x20 tires). All the vehicles were tested at their rated off-highway payload (nominal capacity) and, in addition, the M215 was tested at one-half the rated payload, and the M211 was tested empty. Vehicle weights, test loads, and tire descriptions are shown in the tabulation on page 32; additional vehicle data are given in table 2.



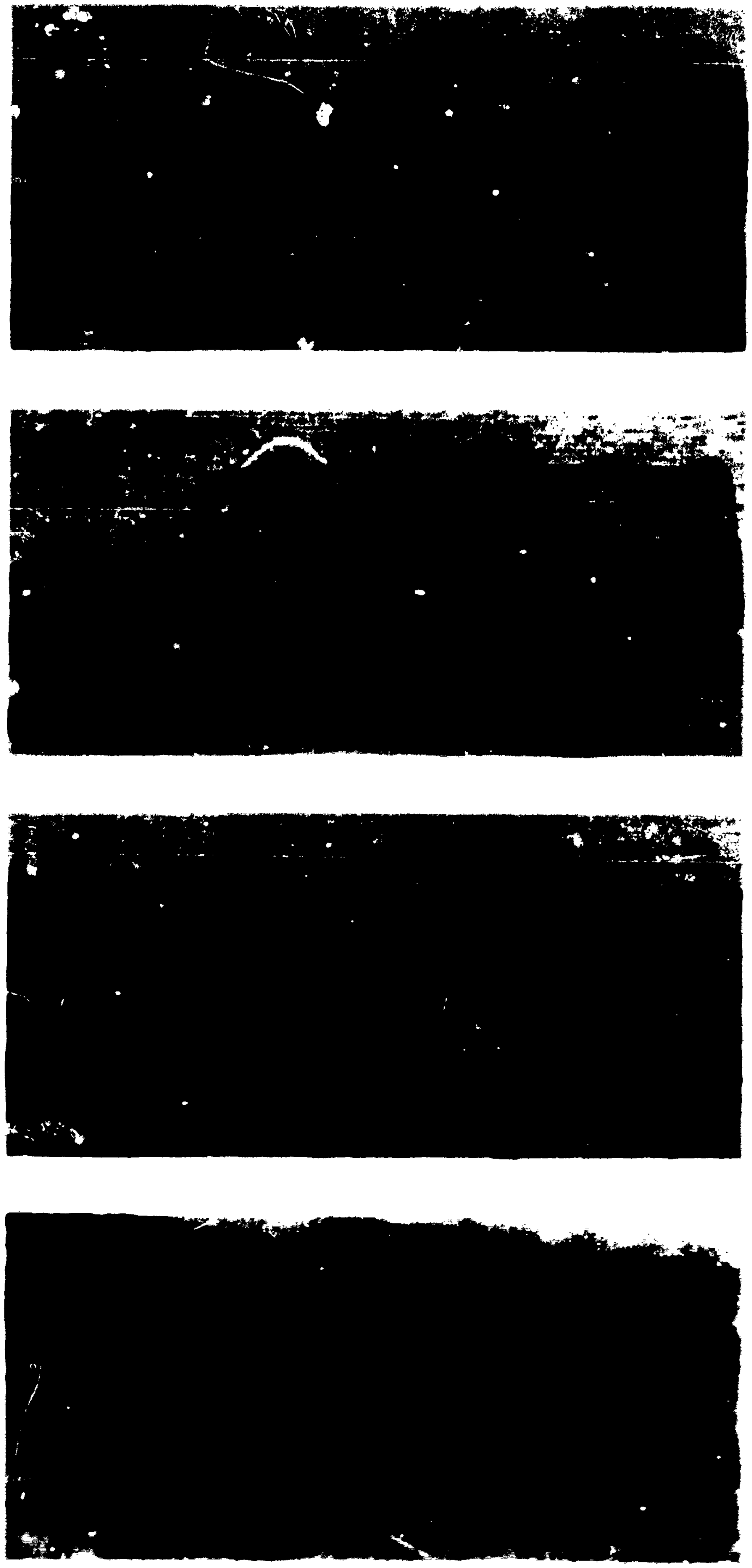
a. 1/4-ton M38A1 4x4 truck

b. 3/4-ton M37 4x4 truck

c. 2-1/2-ton M211 6x6 truck

d. 2-1/2-ton M215 6x6 truck

Fig. 36. Self-propelled wheeled vehicles used in tests



a. 2-1/2-ton 6x6 truck

b. 2-1/2-ton M135 6x6 truck

c. 5-ton M41 6x6 truck

d. 5-ton M54 6x6 truck

Fig. 37. Self-propelled wheeled vehicles used in tests

Vehicle	Vehicle Wt, lb Empty	Approx Load	Gross	Tire Data Size	Ply Rating	No.
1/4-ton M38A1 4x4 truck	2,625	500	3,125	7.00x16	6	4
3/4-ton M37 4x4 truck	5,917	1,500	7,417	9.00x16	8	4
2-1/2-ton M211 6x6 truck	13,120	0	13,120	9.00x20	8	10
	13,120	5,000	18,120	9.00x20	8	10
2-1/2-ton M215 6x6 truck	14,820	2,500	17,320	11.00x20	12	6
	14,820	5,000	19,820	11.00x20	12	6
2-1/2-ton 6x6 truck	11,000	4,800	15,800	8.25x20	--	6

56. The truck weights were taken from the identification-data plates inside the cab; however, the 2-1/2-ton 6x6 truck used on Kwajalein had no identification data and its weight was estimated. This truck was very old but still functioned well. Its tire size was 8.25x20, which apparently was not standard for the truck. The drive shaft of the 3/4-ton truck used on Guam broke during a difficult maneuver on the foreshore of NCS Beach. Otherwise, all vehicles tested appeared to be in very good mechanical condition, and were able to spin their wheels when immobilized. The tires on most of the vehicles tested were worn, but otherwise in good condition (no large cuts or bulges).

Yuma, Arizona

57. The vehicles tested were furnished by the Yuma Test Station and are shown in figs. 36, 37, and 38. All wheeled vehicles were equipped with standard military, nondirectional, cross-country tires. The following table lists the vehicles tested and pertinent vehicle data; additional vehicle data are given in table 2.

Wheeled Vehicles

Vehicle	Vehicle Wt, lb Empty	Approx Load	Gross	Tire Data Size	Ply Rating	No.
1/4-ton M38A1 4x4 truck	2,475	500	2,975	7.00x16	6	4
3/4-ton M37 4x4 truck	5,545	0	5,545	9.00x16	8	4
		750	6,275			
		1,500	7,085			
		2,300	7,805			
2-1/2-ton M135 6x6 truck	12,450	0	12,450	11.00x20	12	6
		2,500	15,000			
		5,000	17,330			
		7,500	20,500			
		10,000	22,705			

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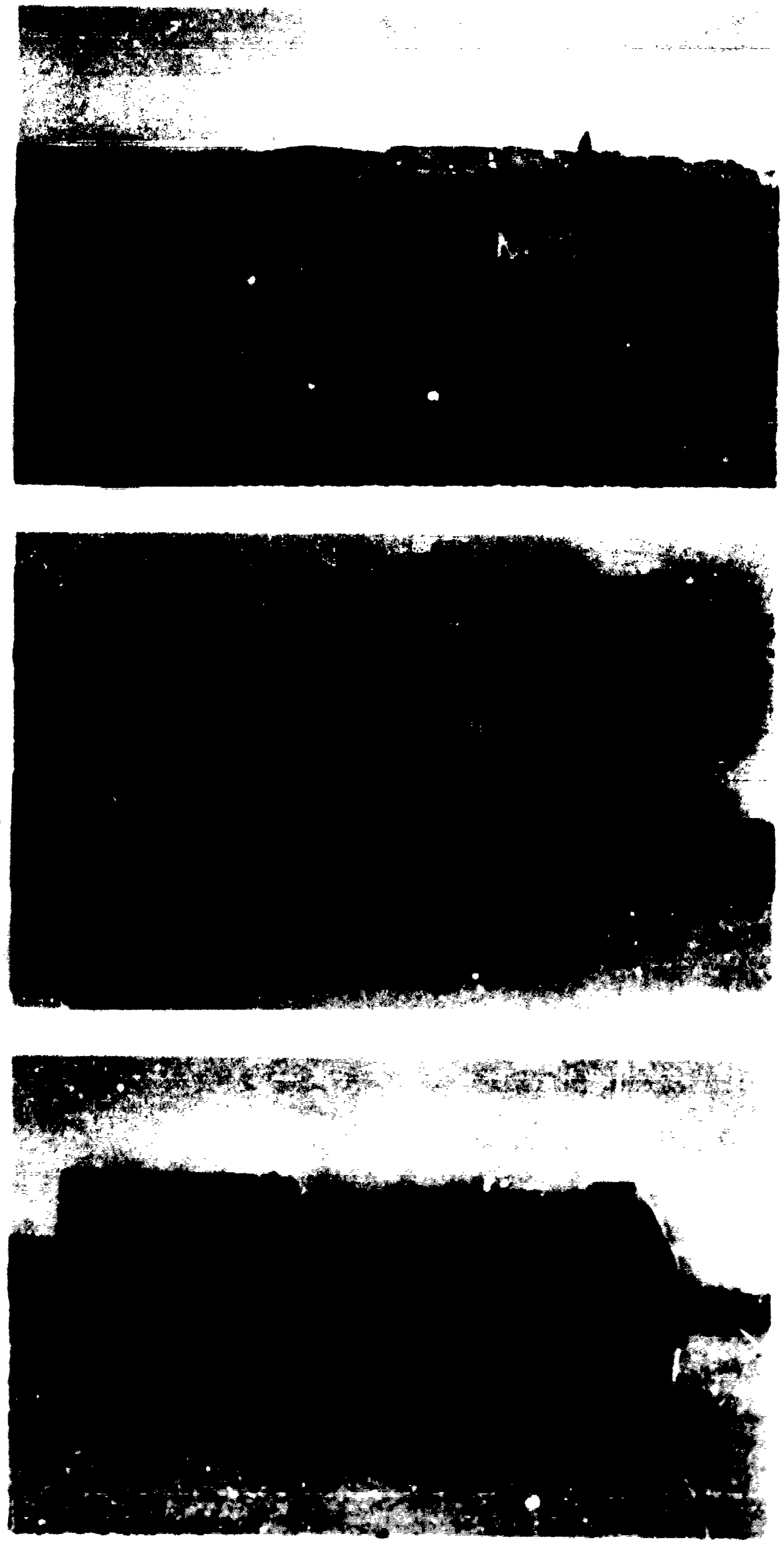


a. 1/4-ton M29C cargo carrier (weasel)

b. 18-ton M4A2 hi-speed tractor

c. 38-ton M6 hi-speed tractor

Fig. 38. Self-propelled tracked vehicles used in tests

Wheeled Vehicles (Cont'd)

Vehicle	Vehicle Wt, lb Empty	Approx Load	Gross	Tire Data Size	Ply Rating	No.
5-ton M41 6x6 truck	18,115	0	18,115	14.00x20	12	6
		5,000	24,275			
		10,000	28,175			
		15,000	32,380			
5-ton M54 6x6 truck	20,635	10,000	30,635	11.00x20	12	10

Tracked Vehicles

Vehicle	Vehicle Wt, lb Empty	Approx Load	Gross	Track Dim. Length in.	Width in.	Average Contact Pressure, psi
1/4-ton M29C weasel	5,970	0	5,970	78	20	1.9
		1,000	6,970			2.2
18-ton M4A2 hi-speed tractor	36,910	0	36,910	126	24	6.1
38-ton M6 hi-speed tractor	76,000	0	76,000	176	22	9.8

58. All vehicles appeared to be in good mechanical condition and, with the exception of the M135 when loaded with 10,000 lb, each vehicle was able to spin its wheels or tracks when immobilized while operating under full load. Testing with the M41 loaded with 15,000 lb was limited because severe side-wall buckling of the tires occurred when the truck was operated with tires inflated to 10-psi pressure.

Camp Lejeune, N. C.

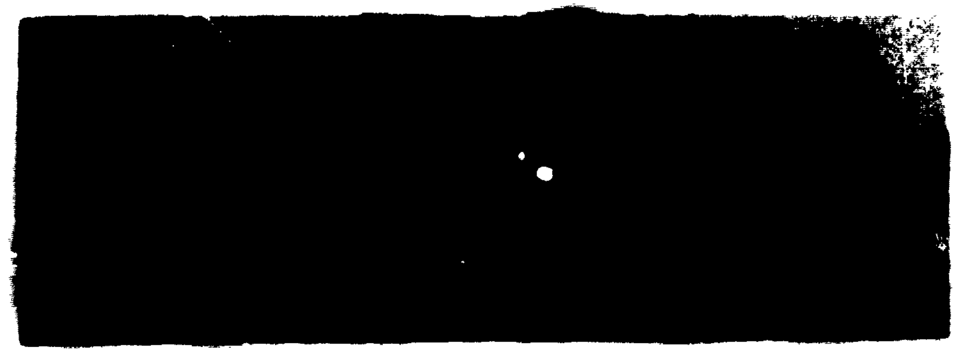
59. The wheeled trailers tested were furnished by the Motor Officer at Camp Lejeune and are shown in fig. 39. The self-propelled tests were conducted with vehicles of the types shown in figs. 36a and b, and fig. 37b. The following table lists the vehicles tested and pertinent vehicle data; additional vehicle data are given in table 2.

Vehicle	Vehicle Wt, lb Empty	Approx Load	Gross	Tire Data Size	Ply Rating	No.
		Self-propelled Vehicles				
1/4-ton M38A1 4x4 truck	2,775	200	2,975	7.00x16	6	4
3/4-ton M37 4x4 truck	6,067	0	6,067	9.00x16	8	4
2-1/2-ton M135 6x6 truck	12,450	5,000	17,450	11.00x20	12	6

(Continued)

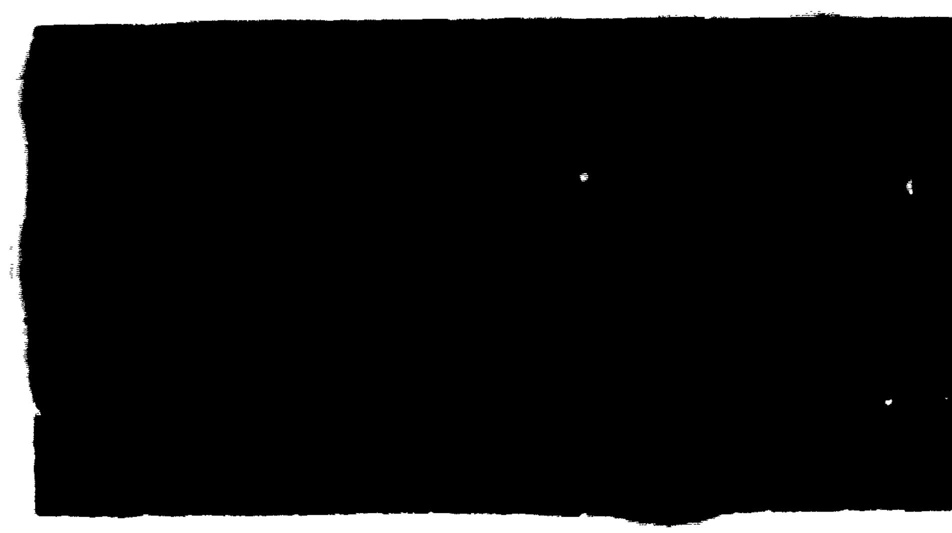
a. 1/4-ton M100 cargo trailer

b. 3/4-ton M101 cargo trailer



c. 1-1/2-ton XM105 cargo trailer

d. 37.5-kw generator trailer



e. 6-ton cargo trailer

Fig. 39. Wheeled trailers used in towed-vehicle tests at Camp Lejeune, N. C.

Vehicle	Vehicle Wt, lb Empty	Approx Load	Gross	Tire Data Size	Ply Rating	No.
Towed Wheeled Vehicles						
1/4-ton M100 cargo trailer	569	0	569	7.00x16	6	2
		250	782			
		500	1,127			
		750	1,211			
3/4-ton M101 cargo trailer	1,339	750	2,089	9.00x16	8	2
		1,500	2,960			
		2,250	3,679			
1-1/2-ton XM105 cargo trailer	2,450	1,500	4,110	9.00x20	8	2
		3,000	5,648			
		4,500	7,482			
37.5-kw generator trailer	7,153	0	7,153	7.00x20	8	4
6-ton cargo trailer	10,960	0	10,960	10.00x20 (front)	10	4
		6,000	17,160			
		12,000	25,520	11.00x20 (rear)	12	4

60. All vehicles tested were in good condition. The three two-wheeled trailers were equipped with standard military tires, and the two four-wheeled trailers were equipped with standard commercially available tires.

Tests Conducted

61. The tests were of three types: single self-propelled vehicle tests, towing tests, and towed-vehicle tests. A single self-propelled vehicle test indicated the ability of the vehicle to negotiate various sand conditions and slopes. Towing tests were made for two general purposes: to determine the maximum drawbar (towing) force the test vehicle could exert while moving slowly forward over a range of soil conditions and slopes, and to develop drawbar pull-slip relations. The towed-vehicle tests were made to measure the force required to tow a given vehicle. The following paragraphs enumerate the types of tests and number of each type

conducted with each vehicle for each of the three general test areas, Pacific islands, Yuma, and Camp Lejeune.

Pacific islands

62. In this test program, 24 beaches located on 7 islands were visited. Vehicle tests were not conducted on 10 of these beaches, but soil classification and cone index data were collected. The vehicle tests on the other 14 beaches were all of the single, self-propelled vehicle type.

63. Single self-propelled tests. The following table shows the number of tests conducted at each beach with each wheeled vehicle.

Island	Beach	Number of Vehicle Tests					
		Vehicle					
		M38A1	M37	M211	M215	2-1/2-TT	Total
Oahu	Mokuleia	7	6	--	1	-	17
	Drone	8	--	--	--	-	8
	Makua	12	57	41	43	-	153
	Crescent	--	40	14	7	-	61
	Bunker	14	--	20	3	-	37
Kwajalein	5	--	1	--	--	-	1
	6	--	4	--	--	3	7
	7	--	--	--	--	1	1
Guam	Nimitz	--	1	--	--	-	1
	Jones	--	2	--	--	-	2
	Tarague	--	3	--	--	-	3
Luzon	Lido	--	1	--	--	-	1
[illegible]	Red	34	20	34	--	-	88
	Yellow	--	15	2	--	-	17
Total		75	150	111	57	4	397

64. Other tests. The beaches on which cone index and soil data were obtained but no vehicle tests performed are as follows:

Island	Beach	Island	Beach
Oahu	Pokai Bay 1	Kwajalein	1
	Pokai Bay 2	Guam	Talofofo
	NAD		NCS
	Last		Tumon
Hawaii	Kalapana	Midway Atoll	Officers' Club

Yuma, Arizona

65. Single self-propelled tests. Four wheeled vehicles (M38A1, M37, M135, and M41) were tested at various tire pressures on slopes in the natural dune area. All the vehicles, with the exception of the M38A1, were also tested at various payloads. The following tabulation shows the number of tests conducted with each vehicle.

Number of tests With Each Vehicle				Total
M38A1	M37	M135	M41	Tests
14	102	122	167	405

66. Towing tests. Maximum-drawbar-pull tests (D) were conducted on natural and prepared level and sloping terrain with five wheeled vehicles (M38A1, M37, M135, M41, and M54) and three tracked vehicles (M29C, M4A2, and M6); drawbar pull-slip (S) characteristics were determined only for the M135 2-1/2-ton truck and the M29C weasel. The number of tests conducted with each vehicle on prepared lanes and in the sand dunes is listed below.

	Number of Vehicle Tests																			
	Wheeled Vehicles												Tracked Vehicles							
Test	M38A1		M37		M135		M41		M54		Total		M29C		M4A2		M6		Total	
Area	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S	D	S
Prepared lanes	6	0	5	0	31	50	15	0	7	0	64	50	13	32	4	0	3	0	20	32
Sand dunes	4	0	10	0	2	0	0	0	0	0	16	0	3	0	5	0	0	0	8	0
Total	10	0	15	0	33	50	15	0	7	0	80	50	16	32	9	0	3	0	28	32

Camp Lejeune, N. C.

67. At Camp Lejeune, single self-propelled tests were conducted on slopes with three vehicles. Towed-vehicle tests were conducted with five trailers, at various loads and tire pressures, on undisturbed sand (by towing the trailer with a long cable, see fig. 40, page 41), and disturbed sand (by towing a trailer coupled directly behind the towing vehicle, see fig. 39). No towing tests were conducted.

68. Single self-propelled tests. Three wheeled vehicles (M38A1, M37, and M135) loaded to nominal capacities were tested at various tire

pressures on dune slopes. The number of tests made with each vehicle is as follows:

Number of Tests With Each Vehicle			Total
M38A1	M37	M135	Tests
17	29	37	83

69. Towed-vehicle tests. Tests with wheeled trailers were conducted on undisturbed sand, disturbed sand, and asphalt pavement. The following tabulation shows the number of tests conducted with each vehicle.

	Number of Tests with Each Trailer					
Test Surface	1/4-ton M100	3/4-ton M101	1-1/2-ton XM105	37.5-kw Generator	6-ton	Total
Undisturbed sand	16	12	12	4	12	56
Disturbed sand	16	12	12	4	12	56
Asphalt pavement	16	12	12	4	12	56
Total	48	36	36	12	36	168

Vehicle-test Procedures and Data Obtained

Single self-propelled tests

70. All single self-propelled tests were performed in the same manner insofar as possible. Most of the tests on the Pacific islands were performed with vehicles loaded to their off-road payload capacities; the loads were secured to prevent shifting. The tests at Yuma were performed with vehicles empty and loaded to 1/2, 1, and 1-1/2 times their off-road payload capacities. Tire pressures were carefully regulated and checked before each test. The same driver was used with the same vehicle insofar as possible. Each test was made with the vehicle traveling in a straight-line path in low gear, low range, at slow, steady speed, and with all wheels driving. Since previous tests had indicated that the first pass was the most difficult one to make in sand, the tests reported herein were concerned only with one-pass traffic. Test areas were selected on the basis of accessibility, surface smoothness, and absence of vegetation or litter. The tests conducted on beaches were run both parallel and perpendicular to the water's edge. Soils data were obtained, vehicle performance was observed, and pertinent notes were recorded.

4

Towing tests

71. The vehicle-performance data obtained in these tests consisted of notes concerning immobilizations, general ease or difficulty with which the vehicle traversed the test area, spinning or jerking of wheels, and other pertinent observations. These data are included in tables 3-7.

72. Maximum drawbar pull. The maximum-drawbar-pull tests were performed on prepared lanes and dune slopes at Yuma with the test vehicle towing a second vehicle by means of a cable. As the train moved slowly forward, the load was gradually increased (by application of the brakes on the towed vehicle) until a load condition was established that was thought to be just short of that which would cause immobilization of the test vehicle. This maximum drawbar pull was verified if a slight increase in load caused a halt in the forward progress.

73. The data obtained consisted of continuous measurements of drawbar pull recorded on an oscillograph. The maximum drawbar pull for each test was noted and is given in table 8.

74. Drawbar slip. Drawbar-slip tests were conducted in the same way as the maximum-drawbar-pull tests, except that at several stages between no drawbar pull and maximum drawbar pull records were obtained of the forward speed of the vehicle and the absolute speed of the track or wheel as well as of drawbar pull. The first two measurements permitted the computation of slip. These data are also given in table 8.

Towed tests

75. In these tests, conducted on asphalt pavement and sand at Camp Lejeune, a dynamometer attached to a cable between the towing and towed, trailer-type vehicles was used to measure the towing force. Repetitive tests in the same path were not performed.

76. The vehicle data obtained consisted of towing force required to move the towed vehicle at a slow, steady speed; these data are given in table 9.

77. Long-coupled tests. Tests in which a long cable was used between the two vehicles permitted the offsetting of the towing vehicle slightly so that the towed vehicle straddled the ruts created by the towing vehicle and thus traveled on undisturbed sand. A specially built sled was used to support the tongue of a two-wheel trailer in these tests. This

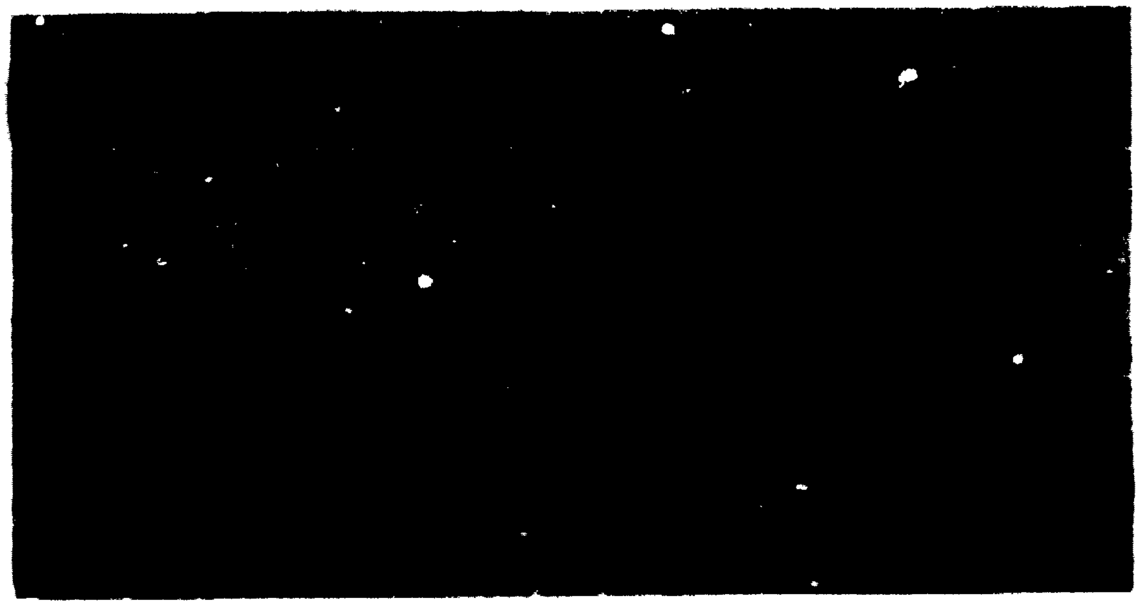


Fig. 40. Long-coupled hitch for towed tests, Camp Lejeune

sled also contained the dynamometer, which was positioned to the rear of the sled so that it measured only the force required to pull the trailer (see fig. 40).

78. Short-coupled tests. The force required to tow a trailer connected to the drawbar pintle of the towing vehicle in normal fashion also was measured by means of a dynamometer between the two vehicles. In these tests the towed vehicle usually operated in sand that had been disturbed by the towing vehicle.

Sand Data Obtained

Cone index

79. In the self-propelled tests, when a vehicle had successfully traversed a given area, it was halted, and a number of cone index measurements were made along its path. The measurements were made fairly close to the ruts but at a distance believed to be outside the zone of soil actually disturbed by the vehicle. When a vehicle was immobilized, the cone index readings were made in the undisturbed areas along both sides of the vehicle. These readings were made at the surface and at 3-in. vertical increments to a depth of at least 15 in. Ten sets of cone index readings usually were made for each test. Average cone indexes for each depth and

each test are shown in tables 3-8. The cone index averages for the 0- to 6-, 6- to 12-, and 0- to 12-in. depths are also shown.

80. For the towing tests, cone indexes representative of the area in which the maximum drawbar pull occurred are shown in table 8. In the tables of data obtained in the towing and towed-vehicle tests, tables 8 and 9, cone index is given only for the 0- to 6-in. depth.

81. In towed-vehicle tests cone indexes were determined before traffic and in the ruts after passage of the vehicle. This was not done in the single self-propelled tests since previous studies on coarse-grained soils have shown that trafficability of the soil usually improves with traffic even though the cone index does not necessarily increase. Average cone indexes for each test are shown in table 9.

Moisture content

82. Quantitative moisture-content determinations were not made for each individual test because the small variation in moisture content that might have occurred between tests on the same component of a beach did not justify the time required to make such measurements. However, a qualitative moisture content in one of the five categories defined below was selected for each test on the basis of appearance and feel of the sand and is shown in tables 3-8. Quantitative measurements of moisture content were made for each major test area, and are tabulated in paragraph 84.

83. The five categories of qualitative moisture contents are defined as follows:

a. Dry sand. Sand that was light-colored, loose, and free-flowing when poured from the hand was termed "dry." Dry sand usually occurred on the surface of all components of the beaches except the foreshore, but seldom extended deeper than 5 in. before becoming moist. Where test data are available for comparison, sand classed as dry on the basis of visual observation contained less than 1.5% moisture by weight.

b. Moist sand. "Moist" sand usually lay directly beneath the dry sand layer. It was usually darker in color, showed slight cohesion, and was cooler to the touch. In general, moist sand was found to contain about 1.5 to 5.0 per cent moisture by weight when actual moisture-content determinations were made.

c. Wet sand. Sand on the foreshore that was being wetted by waves but was not under a finite depth of water during the time of testing was termed "wet." Wet sand exhibited a considerable amount of cohesion, and free water could be squeezed out of it.

d. Inundated sand. Sand covered by water during the time of testing was termed "inundated." This term refers to that portion of the foreshore at the time actually covered by water from wave action. NOTE: A spot on the foreshore "inundated" at one moment during the uprush of a wave might become "wet" a few seconds later when the wave receded.

e. Quick-condition sand. Loose, yielding, wet, or more commonly, inundated sand that had water flowing through it vertically and became liquefied under the moving wheels of a vehicle (thereby causing immobilization of the vehicle) was termed "quick." (Erosion of the sand away from the wheels contributed to the immobilization.)

A discussion of the effect of sand in these five moisture categories on vehicle performance is presented in paragraphs 90 and 91.

84. Quantitative moisture contents for beaches on Oahu and the Yuma Test Station and dune areas are shown in the following table. Moisture contents for Camp Lejeune tests are shown in table 9 and are averages of several moisture-content values obtained in a series of tests on the same area of beach.

Moisture Content (Per Cent)

Location	Depth, in. 0-3	3-6	6-12	12-18	Remarks
Oahu					
Makua Beach					
Foreshore	5.9	7.2	8.4	6.8	
Berm crest	3.8	4.6	4.9	5.3	
Berm backslope	2.2	3.6	4.6	4.4	
Forward dune apron	2.2	3.2	4.4	4.6	
Dune area	1.2	3.4	4.1	7.2	12- to 18-in. depth contained some silt
Mokuleia Beach					
Foreshore	6.0	7.8	7.6	---	
Berm crest	5.7	6.0	6.7	---	
Forward dune apron	1.1	1.9	4.5	---	
Dune area	0.7	2.6	5.5	---	
Crescent Beach, Area 1					
Foreshore (near water)	25.1	24.1	26.0	---	Free water
Foreshore (inland)	7.1	13.9	23.6	---	3- to 12-in. depth contained free water

(Continued)

Moisture Content (Per Cent) (Cont'd)

Location	Depth, in. 0-3	3-6	6-12	12-18	Remarks
Oahu (Cont'd)					
Crescent Beach, Area 1 (Cont'd)					
Berm crest	5.7	7.3	8.3	10.1	
Forward dune apron	0.9	3.4	4.8	3.9	
Crescent Beach, Area 2					
Foreshore	10.5	13.6	20.5	24.4	6- to 18-in. depth contained free water
Berm crest	11.3	8.1	17.1	20.3	6- to 18-in. depth contained free water
Berm backslope	5.5	8.3	---	7.8	
Forward dune apron	1.8	2.8	4.4	3.8	
Bunker Beach, Area 1					
Foreshore	4.6	6.5	8.5	8.4	
Berm crest	4.1	4.3	5.2	6.7	
Berm backslope	1.1	1.9	3.6	4.2	
Forward dune apron	0.9	1.9	4.3	4.1	
Bunker Beach, Area 2					
Foreshore	5.2	7.9	10.4	7.3	
Berm crest	9.6	8.3	8.8	8.1	
Berm backslope	3.8	4.6	5.6	7.3	
Drone Beach					
Foreshore	4.2	5.9	8.4	---	
Berm crest	4.8	6.2	6.6	---	
Forward dune apron	0.5	1.0	5.1	---	
Dune area	0.5	2.7	4.5	---	

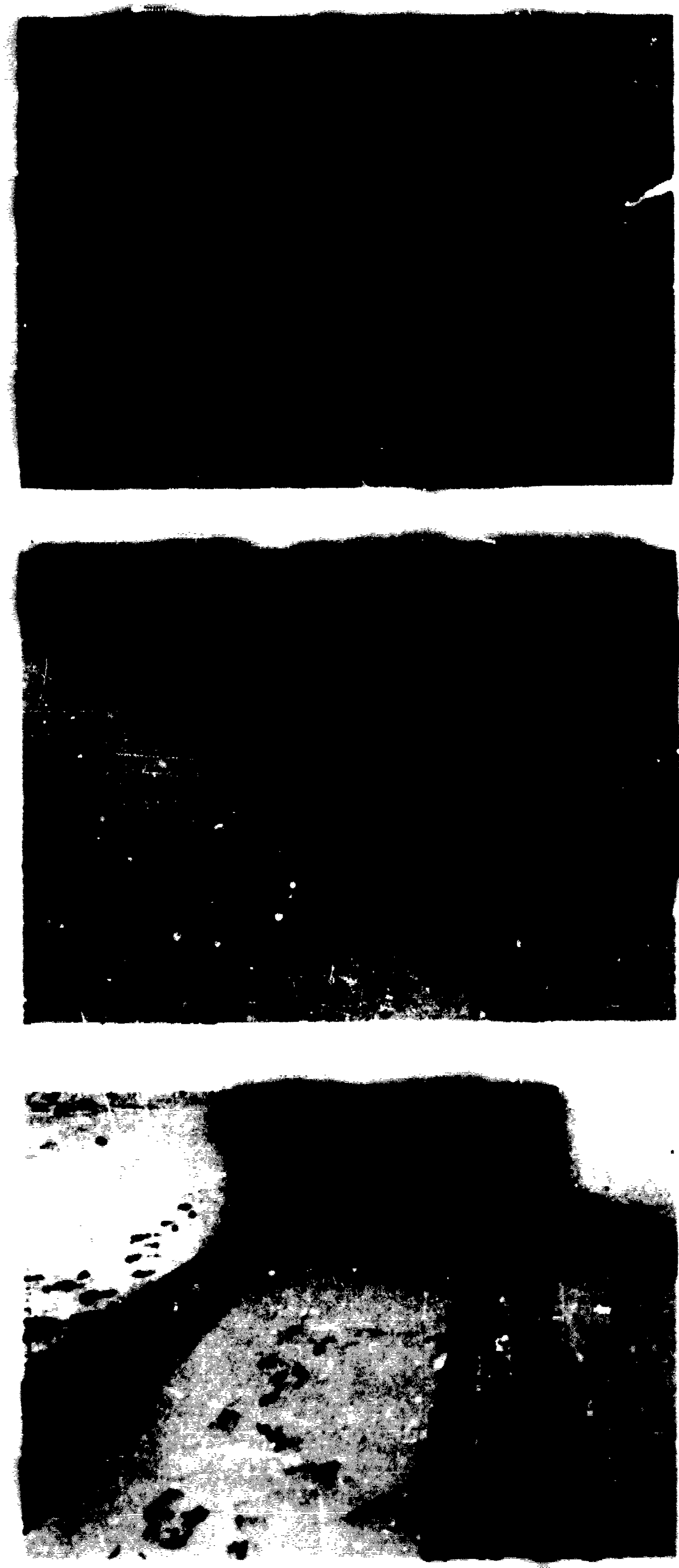
Location	0-6	6-12
Yuma, Arizona		
Test Station area	4.0	1.6
Dune area	1.9	1.1

Slopes

85. The slope for each test area was determined as described in paragraph 49. If a vehicle negotiated a slope, several slope readings were made in the area of maximum slope; however, if the vehicle was immobilized, slope readings were made along both sides of the vehicle at the site of the immobilization. Slope measurements for each test are shown in tables 3-8.

<u>Rut depth</u>

86. Rut-depth measurements were made for most tests; however, they are not reliable as a measure of vehicle performance in cases of immobilization or difficult travel because in some immobilizations the vehicle was allowed to spin its wheels longer than in others. In tests where the vehicle left a smooth rut, the rut depth was measured as the vertical distance from the original sand surface to the bottom of the rut. Where spinning occurred and the rut surface was not easily distinguishable, the rut depth was determined by measuring from the center of the wheel to the original sand surface and then subtracting that distance from the distance between the center of the wheel and the bottom of the tire, which was determined while the wheel was resting on a flat rigid surface. Rut-depth measurements for each test are shown in tables 3-9, and several rut configurations are shown in figs. 41 and 42.



a. Dry sand, Makua Beach, 3/4-ton M37 truck

b. 2-in. dry sand, moist below, Makua Beach, 3/4-ton M37 truck

c. Moist sand, Makua Beach, 2-1/2-ton M211 truck

Fig. 41. One-pass rut designs

a. Moist sand dune area, Yuma, Arizona, 2-1/2-ton M135 truck

b. Wet sand, Crescent Beach, 2-1/2-ton M215 truck

c. Wet sand, Crescent Beach, liquefaction in one rut, 2-1/2-ton M215 truck

Fig. 42. One-pass rut designs

PART III: ANALYSIS OF DATA

87. The data collected in this test program are analyzed under four headings: Single Self-propelled Tests, Towing Tests, Towed-vehicle Tests, and Notes and Observations. The conditions and assumptions upon which the analysis is based are described in the following section.

Basis of Analysis

Sand types

88. Three principal types of sand were tested in this program: coral, volcanic, and quartz. The coral and volcanic sands were tested in the Pacific islands, and the quartz sand was tested in the vicinities of Yuma and Camp Lejeune. Field observations and preliminary analysis of the data revealed no significant difference in the performance of the test vehicles as a result of sand type; therefore, all similar vehicle tests on sand are grouped together for analysis purposes.

Sand-trafficability categories

89. In the pilot study, TM 3-240, 13th Supplement, two broad categories of sands were recognized from a trafficability standpoint, clean sands, and sands with fines, poorly drained. Sand in the latter category, when nearly saturated, reacts to traffic in a manner similar to fine-grained soils. It generally contains more than 7% fines. From the sand data reported herein it is apparent that all soils tested were in the clean-sand category. The sand in the Yuma dune area contains about 7% fines and may possibly react as a sand with fines, poorly drained, but it is in a desert area where the moisture content of the soil does not attain a high enough level to permit a poorly drained condition to develop.

Moisture categories

90. These categories are defined in paragraph 83. It was expected that the moisture content of a sand would play an important part in its trafficability characteristics. Dry sands were expected to be loose and yielding at the surface under the horizontal shearing action of a wheel and thus have poor traction capacity. Moist sands were expected to have bearing capacities at least as high as that of dry sand and higher traction

capacities because of increased cohesion between grains due to capillary pressures. Some increase in trafficability was expected with further increase in moisture content for the same reason. However, at some stage of increasing moisture content (at or near saturation), it was expected that the intergranular pressure would be partially relieved by the development of pressure in the pore water and that the bearing and traction capacities would be reduced. This condition was anticipated in inundated or submerged sands because of buoyancy. In sands with a definite flow of water through them, and especially an upward flow or gradient, liquefaction of the sand and immobilization of the vehicle were expected. It was further anticipated that the various degrees of trafficability described above could be measured with the cone penetrometer.

91. As will be brought out subsequently, the general pattern of expected behavior described above did occur in these tests. However, the variation in trafficability with moisture content was such that the sands could be grouped into two categories according to their moisture content, with a third category representing high moisture and a pressure condition of the void pore water. The two categories according to moisture content are "dry-to-moist" and "wet-to-inundated." The third category is referred to as a "quick condition."

92. As will be discussed later, separate curves of cone index vs vehicle performance were drawn for the two categories, and results of the tests conducted on quick-condition sands were plotted with the results of tests of the wet-to-inundated category sands.

Immobilization

93. Dry-to-moist sands. During this test program no immobilizations in which a vehicle had to be towed away by another vehicle occurred on dry and moist sands. In cases in which a vehicle could no longer move forward, it was always able to back out in its own tracks. In some cases a wheeled vehicle was almost immobilized but was able to inch itself forward slowly with violent jerks and a great amount of wheel slip. However, for analysis purposes, these two conditions were considered to be immobilizations.

94. Wet-to-inundated sands. Several wheeled-vehicle immobilizations occurred because of the liquefaction of sand under the tires when the vehicle operated in the surf. (These sand conditions are referred to as

quick conditions in this report.) These vehicles were completely immobilized and had to be towed from the test area.

95. Yuma dune sand. Tests at the Yuma dune area presented a problem not previously encountered in that a vehicle occasionally could travel over an area for which the cone index-slope combination previously determined indicated that the vehicle should become immobilized. In such tests slight shear planes usually appeared in the ruts, indicating that immobilization was imminent. When this happened the tests were rerun as follows: the vehicle was allowed to come to a complete stop on the slope, and if it could not progress from this stopped position, the vehicle was considered to be immobilized. Cone index criteria for vehicle performance on sand dunes are, therefore, somewhat conservative. The fact that the vehicle could traverse an area the first time was probably due to the momentum it developed on the gradually increasing slopes typical of the sand dunes.

Critical soil layer

96. Previous tests on coarse-grained soils (TM 3-240, 13th Supplement) indicated that the best correlations of vehicle performance with cone index measurements were obtained for the 0- to 6-in. sand layer. Other layers were considered in this analysis but none showed better correlations; hence, the 0- to 6-in. layer is used as the critical layer in this analysis also.

Single Self-propelled Tests

Data used and method of analysis

97. The single self-propelled vehicle test program included a total of 885 tests. A summary of data and test results is presented in tables 3-7.

98. Where applicable, test data reported in TM 3-240, 13th Supplement, were also used in this analysis. The data used were results of tests on three trucks, a 3/4-ton with 9.00x16 tires, a 2-1/2-ton with 9.00x20 tires (dual), and a 2-1/2-ton with 11.00x20 tires (single), since these data were considered comparable to data collected during the current test program. Some of the 13th Supplement data on these vehicles were reevaluated on the basis of sand condition. Data were not used from tests

conducted on (1) prepared sand slopes, (2) sands with more than 7% fines, and (3) crusted desert sands where immobilizations were reported to have occurred after the first pass was completed. Crusted sands were not tested in the current test program. The curves of cone index vs slope reported herein differ only slightly from corresponding curves presented in the 13th Supplement.

99. The method of analysis and the factors considered in this analysis are the same as those described in TM 3-2[illegible], 13th Supplement. In brief, the factors considered were soil strength, slope, and vehicle characteristics. Soil strength is important in that it reflects the soil's bearing capacity as well as its capability to permit a vehicle to develop the necessary traction force to propel the vehicle forward. In this report soil strength is expressed in terms of cone index. Slope was considered as a factor because of the increased soil strength required for a given vehicle to negotiate a slope as compared to that required on level terrain. Furthermore, no level, dry or moist sand condition was found that would cause complete immobilization of the vehicles tested; therefore, slopes were used to obtain vehicle immobilizations. A change in tire pressure materially affects the performance of wheeled vehicles; therefore, this vehicle characteristic was also considered as a factor.

100. The method of analysis consisted in plotting the slope and cone index pertinent to all tests with the same vehicle at the same tire pressure, and indicating whether or not immobilization occurred. A line was then drawn that essentially separated the immobilizations and nonimmobilizations. This line thus represented the maximum slope that the vehicle at the given tire pressure could climb, over a range of cone index conditions. Clear-cut separation of immobilizations and nonimmobilizations was not always possible. Consequently, the line was drawn so that the majority of immobilizations would plot above and to the left of the line. In so doing, many nonimmobilizations also plot above and to the left of the separation line. The curve is therefore somewhat conservative. The final position of the line was also influenced by similar lines for the same vehicle at other tire pressures. Curves for the same vehicle at various loads and tire pressures were combined into a family of curves.

Cone index-slope-tire
pressure correlations

101. Cone index-slope-tire pressure relations were established for five trucks having tire sizes ranging from 7.00x16, 6-ply rating, to 14.00x20, 12-ply rating. The tire pressures used in the test program ranged from 10 to 45 psi. A maximum of 40-45 psi was used because little or no change in contact area occurred at tire pressures greater than 40 psi and hence little or no change in vehicle performance. Ten psi was used as a lower limit because at pressures less than this, the tire was subject to rim slippage or excessive tire buckling. The relations established for the various vehicles and tires tested are described in the following paragraphs.

102. 1/4-ton, 4x4, M38A1 with 7.00x16 6 PR tires. The following tabulation gives the number of tests of the M38A1 at the various tire pressures shown for which data were taken from table 3 and plotted in plate 5 or 6 according to sand moisture conditions.

Tire Pressure, psi	No. of Tests Plotted: Plate 5, Wet-to-inundated Sand	No. of Tests Plotted: Plate 6, Dry-to-moist Sand
30	11	10
20	3	19
15	0	25
10	13	19
Total	27	73

The results of the five tests at 25 psi and one test at 5 psi are not plotted because of the small number of tests performed at these tire pressures.

103. Twenty-seven tests were run on the wet-to-inundated sand, with a gross vehicle weight of 2975 lb and three tire pressures. An examination of the data plots in plate 5 shows that four tests in which immobilization occurred do not plot on the proper side of the curve. Plotted in fig. 1, test 3-49* (cone index of 39 and slope of 6%) was an immobilization that occurred while the vehicle was traveling at about a 45-deg angle to the slope face, causing a vehicle side tilt of 10%. Had the vehicle been

* First number refers to table number, and second number refers to item number in that table.

operated perpendicular to the slope, it probably would not have been immobilized, as indicated by the location of the plotted point in regard to the separation line. No explanation can be given for test 3-55 (cone index of 62 and slope of 18%) plotting incorrectly in fig. 2. In fig. 3, tests 3-71 (cone index of 62 and slope of 17%) and 3-40 (cone index of 22 and slope zero) plot incorrectly. These were tests in which the vehicle was operating on the foreshore and when the sand was inundated by surf, the vehicle began to sink although cone index measurements indicated that it should have traveled with ease. In test 3-71 the vehicle was operating perpendicular to the water's edge, and it is believed that excessive sinkage was probably due to a combination of liquefaction beneath the wheels and erosion of sand around the wheels by the surf. In the case of test 3-40, the vehicle was operating parallel to the water's edge, causing it to assume a side tilt of 13%.

104. The results of the 73 tests run on dry-to-moist sand with test vehicles operating at 2975 and 3125 lb, at four tire pressures, are shown in plate 6. Two immobilizations plot with the nonimmobilizations: in fig. 2, test 3-8 (cone index of 62 and slope of 6%), and in fig. 3, test 3-18 (cone index of 76 and slope of 10%), both of which were run on Bunker Beach, Oahu. No reason can be given for these tests plotting as outliers. Eleven other tests on Bunker Beach plot on the correct side of the curve.

105. A comparison of plates 5 and 6 indicates that the 1/4-ton M38A1 performs better on wet sands than on moist or dry sands. For example, at 20-psi tire pressure and on soil having a cone index of 40, it can climb a 16% slope on wet sands but only a 3% slope on dry sands.

106. On the basis of one test at 5-psi tire pressure (3-41, not plotted), the M38A1 performance was improved by lowering the tire pressure below 10 psi, but tire life would probably be greatly reduced because of side-wall buckling and rim slippage.

107. 3/4-ton, 4x4, M37 with 9.00x16 8 PR tires. The tabulation on the following page gives the number of tests of the M37 at the various tire pressures shown for which data were taken from table 4 and the 13th Supplement, and plotted in plates 7 and 8 according to sand moisture. Fourteen of the tests listed in table 4 are not plotted in plates 7 and 8. Four of these tests (two at 40-psi, one at 30-psi, and one at 15-psi tire pressure)

were run on negative slopes. Nine were run at miscellaneous tire pressures and do not justify extra plots. One test (4-108) on wet sand at 20 psi was not plotted because it is obviously in error.

Tire Pressure psi	No. of Tests From 13th Supplement Plotted		No. of Tests From Table 4 Plotted	
	Plate 7, Wet-to-inundated Sand	Plate 8, Dry-to-moist Sand	Plate 7, Wet-to-inundated Sand	Plate 8, Dry-to-moist Sand
45	0	0	0	15
40	0	7	0	16
30	0	0	0	49
20	2	3	7	50
15	0	5	6	56
10	0	4	17	51
Total	2	19	30	237

108. Thirty-six tests were run on wet-to-inundated sands at tire pressures of 40, 30, 20, 15, 10, and 8 psi. Data plots (plate 7) were made only for the 20-, 15-, and 10-psi tire pressures since only one test was run at each of the other tire pressures. Two hundred and forty-five tests were run on dry-to-moist sand (only 237 tests are plotted in plate 8), mainly at tire pressures of 45, 40, 30, 20, 15, and 10 psi. Curves separating the immobilizations from the nonimmobilizations for both wet-to-inundated sands and dry-to-moist sands are shown for each pressure for which enough data are available.

109. For the wet and inundated sands (plate 7), three tests resulted in immobilizations where the vehicle should have traveled. Test 4-75 (cone index of 23 and slope of zero), plotted in fig. 2 of plate 7, was an immobilization due to liquefaction, and cone indexes taken around the vehicle did not actually indicate the very soft conditions that probably existed when the vehicle became immobilized.

110. Fig. 3, plate 7, reveals three tests on wet-to-inundated sand that are not on the proper side of the curve. Test 4-94 (cone index of 23 and slope of 5%) was another immobilization due to liquefaction. No explanation can be given for the other two tests plotting incorrectly.

111. On dry and moist sands the M37 was tested at four gross weights, 5645, 6067-6275, 7085-7417, and 7805 lb (see plate 8). All tests are plotted together since a variation in weight apparently did not significantly affect vehicle performance. Seven tests, one each at tire pressures

of 40, 30, 20, and 10 psi and three tests at 15 psi, indicate immobilizations where they should not have occurred according to the separation curve. Four of these occurred at the Yuma dune area: tests 4-176 and 4-244 at 15 psi, test 4-234 at 30 psi, and test 4-239 at 20 psi. For test 4-148 (cone index of 62 and slope of 15%) on Iwo Jima at 10 psi, the truck was operated on a 5% tilt, which may have caused the immobilization.

112. The family of curves for the wet and inundated sands, fig. 4 of plate 7, indicates that there is little difference in vehicle performance at 10-, 15-, and 20-psi tire pressures below a cone index of 30. The family of curves for dry and moist sands, fig. 7 of plate 8, indicates a different pattern. The vehicle performance improves more between 10 and 15 psi than between 15 and 20 psi, but even at 10 psi the M37 cannot climb as steep a slope on any given strength of dry-to-moist sand as it can at 20 psi on wet sand.

113. 2-1/2-ton, 6x6, M211 with 9.00x20 8 PR tires. The following tabulation gives the number of tests of this vehicle for which data were taken from table 5 and the 13th Supplement and plotted in plate 9 according to tire pressure and sand moisture.

Tire Pressure, psi	No. of Tests From 13th Supplement Plotted Dry-to-moist Sand	No. of Tests From Table 5 Plotted Wet-to-inundated Sand	No. of Tests From Table 5 Plotted Dry-to-moist Sand
45	0	4	24
30	4	0	11
20	3	0	27
15	4	0	5
10	7	11	24
Total	18	15	91

Results of nine tests on dry-to-moist sand shown in table 5 were not plotted in plate 9. Four of these tests at 50-psi and two at 32-psi tire pressure were not plotted because of an insufficient number of tests at the respective tire pressures; three tests, two at 45 psi and one at 10 psi, were run on negative slopes and therefore were not plotted.

114. Fifteen tests were run on wet-to-inundated sands at two vehicle weights, 13,120 and 18,120 lb, and two tire pressures, 45 and 10 psi.

Eleven of the fifteen tests are at 10 psi, and an approximate separation curve between immobilizations and nonimmobilizations is shown for these points (fig. 5, plate 9). The curve shows the M211 to be capable of climbing two to three times steeper slopes at cone indexes of 20 to 60 in wet sand than on dry-to-moist sand. Data on wet-to-inundated sands are insufficient for establishing curves for other tire pressures.

115. One hundred and nine tests run with the M211 at vehicle weights of 13,120 and 18,120 lb on dry-to-moist sands are plotted in plate 9. All tests at the same tire pressure are plotted together since variation in weight apparently did not affect performance. Separation curves were developed. Of the six tests that indicate immobilizations where they should not have occurred, five were run in the Yuma dune area and were reported in the 13th Supplement. The other, test 5-53 (cone index of 38 and slope zero), shown in fig. 3 of plate 9, was an immobilization on the berm crest of Makua Beach, Oahu. In this test, the vehicle was operating on a 4% tilt, which no doubt hindered its forward progress.

116. 2-1/2-ton unnumbered truck with six 8.25x20 tires. Four tests were conducted with this vehicle on two Kwajalein beaches. These tests are listed in table 5, items 112 through 115, but as stated earlier no plots are shown because results from such a limited number of tests are inconclusive. A comparison of results of these tests with results of tests of the 2-1/2-ton M211 at 45 psi and the M135 at 40 psi shows that these test results are not out of place.

117. 2-1/2-ton truck with 11.00x20 12 PR tires. Various models of 2-1/2-ton trucks with 11.00x20 tires have been tested during the sand trafficability program. Supplement 13 reports tests on three models: M34, M47, and M135. The M135 was again tested during this test program (at Yuma). The M215 2-1/2-ton truck was tested on the Oahu Island beaches and, as mentioned in paragraph 55, although it is normally equipped with dual tandem 9.00x20 tires, for this test program it was equipped with 11.00x20 tires.

118. The tabulation on the following page lists the number of tests from table 6 and the 13th Supplement that are plotted in plate 10. Three tests, one at 50 psi and two at 18-1/2 psi, were not plotted. The three tests on wet-to-inundated sands (tests 6-17, -36, -55) were plotted, but no

separation curve could be constructed for them. Tests 6-17 and 6-36 at 20 psi were nonimmobilizations on Crescent foreshore; test 6-55 at 10 psi was an immobilization due to liquefaction of the sand when hit by surf.

Tire Pressure, psi	No. of Tests From 13th Supplement Plotted Dry-to-moist Sand	No. of Tests From Table 6 Plotted	
		Wet-to-inundated Sand	Dry-to-moist Sand
40	1		14
30	14		44
20	26	2	64
15	16		45
10	13	1	43
Total	70	3	210

119. A total of 213 tests were conducted in the current program on dry-to-moist sand at vehicle weights of 12,450, 14,950-15,000, 17,320-17,450, and 19,820-20,500 lb. All tests are plotted together, however, since a variation in weights apparently did not affect vehicle performance. The plots also include 70 tests from the 13th Supplement.

120. Twenty-nine of the total number of 280 tests on dry-to-moist sand do not plot properly. Eight of these tests are immobilizations where the vehicle should have traveled, and three of these eight tests are from the 13th Supplement. The five remaining immobilizations that do not plot properly occurred during the 1957 test program at Yuma; one test can be seen in fig. 2, plate 10; one in fig. 3; one in fig. 4; and two in fig. 5. The remaining twenty-one outliers are nonimmobilizations that plot above and to the left of the separation curve, thus indicating that the curves are somewhat conservative. Test records do not reveal any reasons for these tests being outliers.

121. <u>5-ton, 6x6, M41 with 14.00x20 12 PR tires.</u> Vehicle-performance plots for the 5-ton M41 are shown in plate 11. Figs. 1-4 show plots of cone index vs per cent slope at four tire pressures (30, 20, 15, and 10 psi), and the family of tire-pressure curves is shown in fig. 5. This vehicle was tested only at the Yuma dune area on dry-to-moist sand.

122. The tabulation on the following page lists the number of tests of the M41 at each tire pressure given in table 7 and plotted in plate 11.

Tire Pressure, psi	No. of Tests From Table 7 Plotted, Dry-to-moist Sand
30	44
20	49
15	46
10	28
Total	167

123. The tests were run at four vehicle weights, 18,115, 24,275, 28,175, and 32,380 lb, but all are plotted together as the variations in weight did not affect vehicle performance. Twelve tests do not plot on the proper side of the separation curve or near enough to it to be considered borderline tests, and two of these tests (in figs. 1 and 2, plate 11) are immobilizations where the vehicle should have traveled. Test records do not reveal any reasons for these tests being outliers.

124. Suitable test areas with low cone indexes and flatter slopes were not found in the sand dune area; therefore, the separation lines for the low slopes are merely estimated and shown as dashed lines in the various plots in plate 11.

Towing Tests

125. The towing tests with self-propelled vehicles (five wheeled and three tracked) were conducted principally on harrowed sand lanes in the Yuma Test Station area, with a few conducted on natural sand in the Yuma dune area. Summary data and test results for all towing tests are presented in table 8.

126. The tests were conducted to determine the relation between towing ability and varying weights and tire pressures of individual vehicles, and also to compare towing abilities of vehicles on harrowed sand and undisturbed sand. However, changes in the test program precluded conclusive testing on undisturbed sand; therefore, this analysis deals only with the harrowed-sand tests, although data from a few tests on undisturbed sand are included in table 8.

127. Analysis of towing-test data is presented by vehicle types: wheeled vehicles and tracked vehicles. Under each vehicle type the

analysis consists of (1) a comparison of maximum drawbar pull with vehicle characteristics, (2) drawbar pull vs slip, and (3) a comparison of computed maximum drawbar pulls vs actual drawbar pulls measured on the test slopes.

Wheeled vehicles

128. Maximum drawbar pull vs tire pressure and test weights. Twenty-eight maximum-drawbar-pull tests were run on level harrowed sand at the Yuma Test Station with five vehicles at four different tire pressures for each vehicle. The 2-1/2-ton M135 was tested with three loads; all others were tested with their respective recommended cross-country payloads. These tests and average maximum drawbar pull-tire pressure curves for each vehicle are shown in figs. 1-5, plate 12.

129. The maximum drawbar pull of a given vehicle increased with a reduction in tire pressure. The maximum drawbar pulls for all vehicles tested at 10-psi tire pressure ranged from 22.2% of test weight for the 5-ton M54 at 30,635 lb up to 36.0% for the 2-1/2-ton M135 at 12,450 lb. The 3/4-ton M37 test (8-14) was not considered since examination of fig. 2, plate 12, shows this test is probably in error. At 30-psi tire pressure the maximum drawbar pulls ranged from 9.4% for the 1/4-ton M38A1 at 2975 lb to 16.1% for the 2-1/2-ton M135 at 12,450 lb.

130. Fig. 3, plate 12, shows the effect of varying loads on the performance of the 2-1/2-ton M135 truck. As the load was increased in approximately 5000-lb increments, the maximum drawbar pull decreased about 2.5% at all tire pressures. The maximum percentage of pull developed was 36.0 at 10 psi and test weight of 12,450 lb (truck empty).

131. A comparison of the towing capabilities of vehicles of similar size but equipped with different tires can be made by examining the data for the two 5-ton trucks (both tested with a 10,000-lb payload) in figs. 4 and 5, plate 12. The 5-ton M41 with 14.00x20 tires (single) had about 5% more drawbar ability at all tire pressures than the 5-ton M54 with 11.00x20 tires (dual).

132. Drawbar pull vs wheel slip. These tests were run on the 2-1/2-ton M135 at three loads and four tire pressures to determine the effect of varying loads on its drawbar pull-slip characteristics. Results of tests with the M135 are shown in figs. 1-3, plate 13.

133. Maximum drawbar pull occurred at about 25% slip for all loads

tested at 10-psi tire pressure; as tire pressure was increased, maximum drawbar pull occurred at a lower percentage of wheel slip for all loads. The rate of decrease in maximum drawbar pull in regard to increased tire pressure was uniform, and at 30-psi tire pressure maximum drawbar pull occurred at about 15% wheel slip for all loads.

134. Comparison of computed maximum drawbar pull with actual drawbar pull measured in tests on harrowed sand slopes. Maximum-drawbar-pull data shown in table 8 for the five wheeled vehicles were used to determine the correlation between computed and actual maximum drawbar pulls on slopes of harrowed sand. The computed drawbar pulls on slopes were developed from measured drawbar pulls on level sand by the formula:

$$P' = P \cos \phi - W \sin \phi$$

where

P' = maximum drawbar pull on slope, computed

P = maximum drawbar pull on level, measured

W = gross weight of vehicle, lb

ϕ = angle of the slope, deg

135. Sixty determinations of maximum drawbar pull were made on harrowed sand, 28 on level sand, and 32 on slopes. The following table shows the measured and computed results and the difference between them. A comparison of computed and actual test results is shown graphically by the round symbols in plate 14.

Tire Pressure	Meas Max Drawbar Pull on Level Sand		Meas Max Drawbar Pull on Slopes			Computed Max Drawbar Pull on Slopes, lb	Difference	
psi	lb	Item No. Table 8	Slope %	lb	Item No. Table 8		lb	%*
			1/4-ton M38A1 Truck - 2,975 lb					
15	550	3	10	200	6	250	+50	25.0
			3/4-ton M37 Truck - 7,085 lb					
10	1400	14	10	1000	15	751	-316	24.9

(Continued)

* $\frac{\text{Computed} - \text{Measured}}{\text{Measured}} \times 100.$

Tire Pressure psi	Meas Max Drawbar Pull on Level Sand: lb	Meas Max Drawbar Pull on Level Sand: Item No. Table 8	Meas Max Drawbar Pull on Slopes: Slope %	Meas Max Drawbar Pull on Slopes: lb	Meas Max Drawbar Pull on Slopes: Item No. Table 8	Computed Max Drawbar Pull on Slopes, lb	Difference lb	Difference %
			2-1/2-ton M135 truck - 12,450 lb					
15	3400	11	10	2000	52	2144	+144	5.7
10	4500	47	10	3200	53	3240	+40	1.2
10	4500	47	12	2900	54	3040	+140	4.8
10	4500	47	15	2400	55	2600	-200	8.3
			2-1/2-ton M135 Truck - 17,330 lb					
20	3200	66	10	1300	73	1460	+160	12.3
15	4300	67	10	2000	74	2555	+550	27.7
15	4300	67	14	2000	75	1855	-145	7.2
10	5200	72	10	3800	76	3450	-350	9.2
10	5200	72	13	2800	77	2923	+123	4.4
			2-1/2-ton M135 Truck - 22,705 lb					
20	4200	87	10	2000	102	1940	-60	3.0
15	5000	90	10	3000	103	2730	-270	9.0
15	5000	90	12	2000	104	2260	+260	13.0
15	5000	90	15	1600	105	1580	-20	1.3
10	6000	100	12	3300	106	3260	-40	1.2
10	6000	100	15	2600	107	2570	-30	1.2
10	6000	100	10	3800	108	3720	-80	2.1
			5-ton M41 Truck - 28,175 lb					
30	3400	109	8	1200	113	1146	-54	4.5
30	3400	109	10	600	114	576	-24	4.0
20	5400	110	8	2700	115	3140	+440	15.6
20	5400	110	10	2500	116	2580	+80	3.2
15	6500	111	10	4000	117	4225	+225	5.6
15	6500	111	15	2000	118	2260	+260	13.0
15	6500	111	15	2200	119	2247	+47	2.1
10	9000	112	10	5000	120	6000	+1000	20.6
10	9000	112	13	4200	121	5300	+1100	26.2
10	9000	112	15	4000	122	4740	+740	18.5
10	9000	112	20	2800	123	3459	+659	23.5
			5-ton M54 Truck - 30,635 lb					
15	5600	126	10	2000	128	2310	+310	15.5
10	6800	127	8	3000	129	3097	+97	3.2
10	6800	127	12	3000	130	3143	+143	4.8
						Avg (regardless of sign)		10.0

136. From an examination of the preceding table it can be seen that the computed drawbar pulls are usually slightly higher than those actually obtained in the tests. This is probably explained by the fact that even though the sand was essentially in the same condition for both slopes and level lanes, the rear wheels sank deeper than the front ones on slopes, thus increasing the actual slope that the test vehicle was attempting to climb.

137. The average percentage of absolute deviation between computed and actual test results was 10.0. Considering sign, the computed pulls were an average of 5.7% higher than measured pulls. The large percentage deviations for the lightweight 1/4-ton and 3/4-ton trucks are probably attributable to the small magnitudes of the pulls and the relative inaccuracy of the dynamometer in the low range.

Tracked vehicles

138. Maximum drawbar pull vs vehicle test weight. Nine maximum-drawbar-pull tests were run on level harrowed sand with three vehicles: M29C weasel at 5970 lb and 6970 lb; 18-ton M4A2 hi-speed tractor at 36,910 lb; and 38-ton M6 hi-speed tractor at 76,000 lb. Data for these tests are presented in table 8, and average drawbar pull for each vehicle is shown graphically in plate 15.

139. In these tests the tracked vehicles had a maximum drawbar-pull ability ranging from 50 to 65% of their test weight. (The highest drawbar-pull ability of wheeled vehicles was around 35% when operating at 10-psi tire pressure.) The weasel, the lightest of the vehicles (5970 and 6970 lb) and the one with the lowest contact pressure (1.9 and 2.2 psi), developed the highest drawbar-pull ability (62-65%) of the three tracked vehicles tested. The M6, the heaviest vehicle and the one with the highest contact pressure (76,000 lb and 9.8 psi, respectively), developed the lowest drawbar-pull ability (50%). Tests are needed on a wider range of vehicles and sand conditions in order to clarify the relations between the maximum drawbar pull of tracked vehicles and the sand on which they operate.

140. Drawbar pull vs track slip. Tests were run on the M29C weasel to show the relations of drawbar pull, track slip, and vehicle weight. Table 8 lists tests on this vehicle for three sand conditions: before harrowing (tests 131-137), after one pass of the harrow (tests 138-148),

and after completion of harrowing (tests 149-155, and 161-176). One pass of the harrow did not leave the test lane uniform enough in strength for reliable testing. Data from items 149 through 155 and 168 through 176 are shown in fig. 4 of plate 13, in which drawbar pull is correlated with track slip and changes in vehicle weight. This plot indicates no change in track slip for the maximum drawbar pull when the vehicle weight is increased 1000 lb, i.e., the track slip at maximum drawbar pull for both weights is 37%. But for the same drawbar pulls below the maximum, track slip is greater for the lesser weight.

141. Comparison of computed and measured maximum drawbar pulls on harrowed sand slopes. Computed maximum drawbar pulls on slopes were developed from applicable measured maximum drawbar pulls on level sand by means of the formula given in paragraph 134. Nine measurements of maximum drawbar pull on slopes were made. A comparison of computed and actual test results is shown graphically by the square symbols in plate 14. The following table lists actual test results, computed maximum drawbar pulls, and the differences between the two.

Meas Max Drawbar Pull on Level Sand		Meas Max Drawbar Pull on Slope			Computed Max Drawbar Pull on Slopes, lb	Difference	
lb	Item No. Table 8	Slope %	lb	Item No. Table 8		lb	%*
1/4-ton M29C Weasel, 5,970 lb, Contact Pressure = 1.9 psi							
3,250	146	20	2,000	156	2,020	+20	1.0
3,250	146	15	2,300	157	2,325	+25	1.1
1/4-ton M29C Weasel, 6,970 lb, Contact Pressure = 2.2 psi							
4,400	165	15	2,600	177	3,320	+720	27.7
4,400	165	15	3,000	178	3,320	+320	4.6
18-ton M4A2 Hi-speed Tractor, 36,910 lb, Contact Pressure = 6.1 psi							
20,000	179	8	15,000	180	16,960	+1960	13.1
20,000	179	12.5	15,000	181	15,262	+262	1.7
20,000	179	15	12,000	182	14,300	+2300	19.2
38-ton M6 Hi-speed Tractor, 76,000 lb, Contact Pressure = 9.8 psi							
38,000	188	8	29,000	189	31,829	+2829	9.6
38,000	188	12.5	28,000	190	28,267	+287	1.0
					Avg (regardless of sign)		8.6

$*\ \dfrac{\text{Computed} - \text{Measured}}{\text{Computed}} \times 100.$

142. The average deviation (expressed as a percentage difference between computed and measured drawbar pull) is 8.8% for all vehicles tested, and for all tests the computed drawbar pulls are higher than those actually measured. In examining the summary of test data in table 8 it may be noted that cone index for tests of the two hi-speed tractors on level sand (items 179 and 188) was much higher than the cone indexes on slopes. Had the cone indexes on slopes been the same as on level ground the maximum drawbar pulls developed might have been closer to computed results.

Towed-vehicle Tests

143. The towed-vehicle test program included tests on two- and four-wheeled trailers. One hundred and sixty-eight tests were run with five trailers (three two-wheeled and two four-wheeled), at loads varying from empty to 1-1/2 times their payload capacities, and at four tire pressures. A summary of the test conditions and results is presented in table 9.

144. Tests were conducted on asphalt pavement, undisturbed sand, and disturbed sand. The analysis of data was made only for tests conducted on sand, since towing-force requirements of all vehicles on asphalt were in the range of only 1.0 to 2.0%. The towing force on asphalt is a measure of the internal mechanical friction of the vehicle wheels plus the external frictional rolling resistance of the wheels on a hard, essentially unyielding, surface. In this report the forces (which were small) required to overcome the internal resistance are included in the gross towing force required on sand.

145. The results of tests on undisturbed sand, made by towing the test vehicle with a long cable as described in paragraph 77, are shown in plate 16 as open symbols. Results of tests on disturbed sand, made with the test vehicle towed at close hitch behind the towing vehicle, are shown in plate 16 as closed symbols.

146. A good correlation exists between the towing force required, cone index before traffic, and tire pressures for all vehicles. Apparently, disturbance of the sand by the towing vehicles had little or no measurable effect on the towing force required for the trailers since, for the range of cone indexes tested, rut depths were shallow and little or no

change in strength occurred after passage of the test vehicle.

147. A family of tire-pressure curves for towing force required vs cone index (before traffic) is shown in fig. 8, plate 16. The curves (if extrapolated) tend to converge at cone indexes above 200 and towing forces below 2%, and "fan out" uniformly to a cone index of 75 (which is near the lowest cone indexes measured) where the towing force required ranges from 10% at 10-psi tire pressure to 23% at 60-psi pressure. The average deviation (in per cent towing force required) of individual tests from the average line for each tire pressure is approximately 1.0%.

148. In summary, it appears that towing force required (per cent of test weight) is a function of sand strength and tire pressure for the range of vehicle weights tested (empty to 1-1/2 times payload capacity). The effect of number of wheels (two or four), tire arrangement (single or dual), and number of axles (one or two) on towing force is small when considered independently of the effects of test weight, tire pressures, and sand strength. Tests are needed of additional vehicles on lower-strength sands and on sands different from those at Camp Lejeune in order to determine more fully the relations between vehicle characteristics and towing-force requirements over a wide range of sand conditions.

Notes and Observations

149. During the course of the approximately 900 single self-propelled vehicle tests on beach and desert areas, a few observations were made of several immeasurable factors that nevertheless influence vehicle mobility. These observations are discussed in the following paragraphs.

Liquefaction and erosion

150. Several wheeled-vehicle immobilizations occurred on inundated beach sands when slopes were about 14% and the beach face was inundated by wave action. It is believed that along with the slope factor, liquefaction and erosion of sand from around the wheels by the surf contributed to the immobilizations. On several occasions when immobilizations did not occur, it was observed that the top 2 to 4 in. of sand in the ruts was liquefied. Had the proper combination of loading and drainage occurred simultaneously, sand beneath the wheels might have liquefied to a depth that would have caused immobilization.

151. Observations of vehicles operating in the surf also revealed that if a vehicle was stalled or purposely stopped for a few minutes, erosion of sand from around the wheels by wave action usually resulted in an immobilization.

152. Immobilizations did not occur on inundated sands as long as the water was not moving over or through the sand, as in lagoon areas of clean sand protected from the open sea or areas where water was trapped during periods of low tides.

Borderline conditions

153. When a vehicle is immobilized in sand it is usually because of traction failure. Traction failure is the inability of the sand surface to resist the horizontal dynamic stresses applied to it by a powered wheel or track. Thus, the thrust necessary to propel the vehicle cannot be developed. Close observation revealed that a vehicle operating on a slope-strength combination borderline between immobilizations and nonimmobilizations will leave slight shear planes in its ruts. These conditions were retested by repeating the operation parallel to the old ruts, but on the rerun the vehicle was allowed to come to a complete stop in the area under question and start again. In nearly every case the vehicle could not complete passage through the area. This was done to check the assumption that the reason a vehicle usually negotiated a borderline condition was that the momentum it developed in making its approach to the test area carried it through. In tests in which the vehicle did not leave these slight shear planes, it had no trouble in moving from a stopped position. For tests run on sand where the slope-strength combinations were much below the borderline conditions, immobilizations occurred almost simultaneously with the beginning of traction failure.

Effects of vehicle characteristics

154. Tire pressure. Tire pressure is the single vehicle characteristic that has the most influence on the performance of a given vehicle in sand. Careful adjustment of tire pressures is essential in conducting accurate tests or obtaining the expected performance from a vehicle. It was found that in order to achieve the accuracy desired, low tire pressures had to be measured with a pressure gage more accurate than the usual "stick gages." Most stick gages register only as low as 10 psi and have been

found in some cases to be as much as 3 psi off at low pressures.

155. Careful and constant regulating of tire pressures during testing was essential because of the tire-pressure changes that resulted from changes in tire temperature. At least four conditions were encountered that caused tire temperatures and hence tire pressures to vary during testing: (1) changes in ambient air temperature during testing; (2) operation of the tires in wet and inundated sand after the tire pressure had been adjusted on warm dry sand; (3) starting tests on sand after the vehicle had been operating on a hard surface at high speeds; and (4) permitting wheels to slip for an extended period of time.

156. Tire pressure also apparently has an effect on the peculiar action of vehicle "jerking" when traction failure occurs. For the 2-1/2-ton and 5-ton trucks, the "jerking" action was violent at higher tire pressures and much more gentle at the lower tire pressures of 10 and 15 psi.

157. Tire condition. All military vehicles tested were equipped with the standard nondirectional cross-country tire; however, the physical condition of these tires varied considerably as some were new, some recapped, and some had little or no tread. Although it is generally thought that tire condition has some effect on vehicle performance, the observations made during this test program do not appear to bear this out. This is indicated by the fact that although the same tires or vehicles were not used for the complete test program, the performance of a given type of vehicle and size of tire was consistent.

158. The theory that tire conditions (within the range of tire conditions tested) have little effect on vehicle performance in coarse-grained soils is also supported by measurements of the contact area of the tires on the 3/4-ton M37 tested at Yuma. This vehicle was equipped on one side with two newly recapped tires and on the other side with two old, well-worn tires; however, the contact areas for these tires were practically the same at a given tire pressure, with neither set consistently greater or smaller than the other. Some difference in the shape of the tire print was apparent, however; worn tires generally produce a more rectangular pattern than new or newly recapped tires.

159. Rut configuration. Ruts made by the 2-1/2-ton and 5-ton trucks operating at low tire pressures (10 and 15 psi) on the soft harrowed sand

contained a slight bulge (convex upward) along the center of the rut surface. This bulge was approximately 1/4 to 1/2 in. in height with respect to the depth along the sides of the rut wall. Ruts made in tests in the undisturbed sand areas at low tire pressures showed an indication of this bulge but it was not nearly so pronounced as in the harrowed sand. The higher strength of the undisturbed sand yielded less to rutting and hence less bulging occurred in the center of the rut. This configuration, although slight, may be a clue to the confining effect of the side walls of the tire on the sand beneath the tire, and may be the cause of the improvement in vehicle performance in sand when tire pressures are reduced.

160. Transmission type. Vehicles with both automatic and manual transmissions were used throughout the test program. No conclusive observations were made as to the advantage of one over the other from the standpoint of vehicle performance. It is recognized, however, that the automatic transmission does eliminate the "driver effect" more than the mechanical transmission by partially assisting in a smooth movement from a stopped position on slopes. It may be possible that for a few tests near the borderline conditions of cone index-slope as described in paragraph 153, the positive connection of the mechanical transmission may have caused the tires to shear the sand surface initially and to start a process of shearing that eventually led to immobilizations, whereas an automatic-transmission type vehicle might not have become immobilized.

Sand strength

161. The use of the cone penetrometer and other instruments for measuring the existing strength of the 0- to 6-in. layer of soil was discussed in the 13th Supplement of the "Trafficability of Soils" series. The following paragraphs discuss the relations of sand strength (as measured by the cone penetrometer) and other sand characteristics.

162. Variations of strength with depth. The standard test procedure for all vehicle tests included the collection of cone index data to a depth of 15 in. or greater whenever possible. The best correlation between cone index and vehicle performance was obtained by considering average before-traffic cone index for the 0- to 6-in. depth; measurements taken at the surface, 3-in., and 6-in. depths are used in determining the average value. Except for a few cases, the strength of a sand consistently increased with

depth. It was found essential that the cone index be read at exactly the correct depth. The increase in strength with depth is usually of sufficient magnitude that, unless the cone index measurements are made with considerable care, the results can be very erroneous. The following table shows an example of what would happen if measurements were made 1 in. below the prescribed depths. For this example it was assumed that the data shown in table 6 for item 40 were correctly taken. Cone index was plotted against depth, and a curve was drawn. Readings were then taken at depths 1 in. lower than those prescribed, and the two were compared.

	Depth in.	Cone Index	Depth in.	Cone Index
	0	2	1	9
	3	38	4	62
	6	128	7	160
	9	240	10	284
Avg 0- to 6-in. layer		56		77

163. An examination of test 40 (cone index 56, slope 15%, fig. 4 of plate 10) reveals what would happen to this test were it plotted at a cone index of 77 rather than at 56. The test was an immobilization that would plot on the wrong side of the line of separation if plotted at a cone index of 77. The fact that large differences in average readings can be introduced by reading cone index values at improper depths may well explain why some of the tests plot near or on the wrong side of the line of separation.

164. Variations of strength with moisture. As shown by plots of vehicle slope-climbing ability vs cone index, a given vehicle at a given tire pressure can operate more easily on a wet sand than on a dry or moist sand of equal cone index. This precludes any correlation that might be attempted between strength (as measured by the cone penetrometer) and vehicle performance without considering moisture condition of the sand. However, use of the cone index as a measure of expected vehicle performance in actual operation would give the lower limit of performance expected and, as moisture content increases, the performance of the vehicle would increase accordingly until a near-saturated state is reached and then the vehicle performance is less predictable. Any refinement that includes moisture condition will improve the over-all accuracy of measuring sand trafficability.

PART IV: CONCLUSIONS AND RECOMMENDATIONS

Conclusions

165. The following conclusions are based on analysis of the data collected in the three test programs reported herein. The basic guide for these test programs was the findings reported in the 13th Supplement of the "Trafficability of Soils" series; therefore, these conclusions are also applicable for all coarse-grained soil tests conducted to date.

Single self-propelled wheeled vehicles

- a. Vehicle performance expressed in cone index-slope climbing ability terms is influenced by the moisture condition of the sand. Wet-to-inundated sands are more trafficable than dry-to-moist sands. Inundated sands, however, are apt to be in a quick condition if the water is in motion over and through the sand. Quick condition sands are not able to support traffic.
- b. The performance of self-propelled vehicles on dry-to-moist sands, as defined by the cone index-slope climbing curves, is the same regardless of sand source (quartz, volcanic, or coral) or location (beach or desert).
- c. Payload variations from empty to 1-1/2 times the rated load had no major effect on the slope-climbing ability of the self-propelled vehicles tested.

Towing tests with self-propelled vehicles

- a. The maximum drawbar pull for wheeled vehicles on level harrowed sand ranges between 20 and 40% of their gross weight; tracked vehicles are capable of maximum drawbar pulls of as much as 50 to 60% of their test weight.
- b. Load increase on the 2-1/2-ton M135 from empty to 10,000 lb decreased the maximum towing-force ability by 2.5% of the test weight at all tire pressures tested. For a given tracked vehicle (1/4-ton M29C), an increase in test weight of 1000 lb reduces the maximum towing-force ability by 3.5% of the test weight.
- c. The single-tandem 5-ton M41 has a 5% higher drawbar-pull ability than the dual-tandem 5-ton M54.
- d. For wheeled vehicles, maximum drawbar pull occurs at about 25% wheel slip for all loads at 10-psi tire pressure. At 30-psi tire pressure, maximum drawbar pull occurs at approximately 15% wheel slip. For tracked vehicles, track

slip is 37% at maximum drawbar pull for the 1/4-ton M29C at two test weights. At lower drawbar pulls, the percentage of track slip is less for the lighter load.

e. Towing-force ability on harrowed sand slopes can be computed from test results on level harrowed sand, with an average difference of about 10% between actual and computed results.

Towed-vehicle tests

a. Towing-force requirements for wheeled trailers can be correlated with cone index and tire pressure.

b. For the tire pressures tested, sand disturbance by the towing vehicle has little effect on towing-force requirements when the towed and towing vehicles are operated at the same tire pressures.

Recommendations

166. It is recommended that:

a. A rapid method be developed for confident recognition of the three moisture conditions of sand that are important from the trafficability standpoint--dry to moist, wet to inundated, and quick condition.

b. Additional single self-propelled vehicle tests be made, with emphasis on wheeled vehicles of more than 5-ton capacity.

c. Detailed studies of the effect of wheel load, tire pressure, and other vehicle characteristics on performance of vehicles in sand be continued.

d. Towing tests on undisturbed sand with a range of military vehicles be conducted.

e. Additional towed-vehicle tests, including tests with tractor-trailer combinations, be conducted.

f. Work be conducted on procedures to derive means of evaluating performance of vehicles not tested.

g. Vehicle tests on gravel beaches be conducted.

h. Work on estimating the trafficability of untested beaches be continued.

Table 1

Physical Properties of Sand from the 0- to 6-in. Depth at Test Sites

Location	Beach	Sand Origin	Mechanical Analysis, % Sand* Coarse	Mechanical Analysis, % Sand* Medium	Mechanical Analysis, % Sand* Fine	Fines**	Uniformity Coefficient**	Median Diameter** mm	Effective Diameter** mm	Specific Gravity	Unified Soil Classification Symbol	Unified Soil Classification Name
							Pacific Islands Test Sites					
Oahu, T. H.	Mokuleia	Coral	0	92	8	0	1.62	0.61	0.42	2.73	SP	Medium sand
	Drone	Coral	0	97	3	0	1.56	0.71	0.50	---	SP	Medium sand
	Makua	Coral	0	77	23	0	1.37	0.50	0.38	2.74	SP	Fine to medium sand
	Crescent	Coral	0	12	88	0	1.58	0.28	0.19	2.80	SP	Fine sand
	Bunker	Coral	0	49	51	0	1.58	0.41	0.26	2.83	SP	Medium to fine sand
	Pokai Bay 1	Coral	3	87	10	0	1.46	0.57	0.41	---	SP	Medium sand
	Pokai Bay 2	Coral	3	85	12	0	1.63	0.58	0.38	---	SP	Fine to medium sand
	NAD	Coral	0	73	27	0	1.41	0.50	0.37	---	SP	Fine to medium sand
	Last	Coral	0	98	2	0	1.40	0.66	0.50	---	SP	Medium sand
Hawaii, T. H.	Kalapana	Volcanic	0	76	24	0	1.84	0.56	0.32	---	SP	Fine to medium sand
Kwajalein	1	Coral	0	9	91	0	2.27	0.22	0.11	---	SP	Fine sand
	5	Coral	10	50	40	0	4.69	0.51	0.13	2.79	SP	Fine to medium sand
	6	Coral	0	28	69	3	3.26	0.26	0.10	---	SP	Medium to fine sand, some silt
	7	Coral	0	13	87	0	2.42	0.20	0.09	---	SP	Medium to fine sand
Guam	Nimitz	Coral	0	9	91	0	1.47	0.22	0.17	---	SP	Fine sand
	Jones	Coral	4	89	7	0	1.70	0.73	0.47	---	SP	Medium sand
	Tarague	Coral	1	23	76	0	1.64	0.32	0.22	---	SP	Medium to fine sand
	NCS	Coral	0	52	48	0	2.35	0.41	0.23	---	SP	Fine to medium sand
	Talofofo	Volcanic	0	19	79	2	1.75	0.25	0.16	---	SP	Medium to fine sand, some silt
	Tumon	Coral	0	20	80	0	2.45	0.22	0.11	---	SP	Medium to fine sand
Luzon, P. I.	Lido	Coral	3	55	42	0	2.57	0.47	0.21	---	SP	Fine to medium sand
Midway	Officers' Club	Coral	0	56	44	0	2.27	0.44	0.22	---	SP	Fine to medium sand
Iwo Jima	Red	Volcanic	0	64	36	0	1.92	0.48	0.26	2.71	SP	Fine to medium sand
	Yellow	Volcanic	5	88	7	0	2.40	0.91	0.49	2.72	SP	Medium sand
							Yuma Test Site					
Test station	---	Quartz	0	21	75	4	2.75	0.28	0.12	---	SP-SM	Medium to fine sand, some silt
Dune area	---	Quartz	0	19	74	7	3.50	0.23	0.08	---	SP-SM	Medium to fine sand, some silt
							Camp Lejeune Test Site					
	Onslow	Quartz	0	0	100	0	0.76	0.21	0.25	2.68	SP	Fine sand

* Coarse sand--per cent by weight of sample retained on No. 10 U. S. Standard sieve (2.00 mm) but passing No. 4 sieve (4.76 mm).
Medium sand--per cent by weight of sample retained on No. 40 U. S. Standard sieve (0.42 mm) but passing No. 10 sieve (2.00 mm).
Fine sand--per cent by weight of sample retained on No. 200 U. S. Standard sieve (0.074 mm) but passing No. 40 sieve (0.42 mm).
** See definitions, paragraph 5.

Table 2

Vehicle Data

Vehicle	Empty Weight lb	Approx Load lb	Test Weight lb	Tire Description: Width in.	Rim Diam in.	Ply Rating	No. of Tires	Tire Pressure psi	Total Contact Area sq in.*	Average Contact Pressure psi**	Average Tire Print, in.†: Length	Width
					Pacific Islands Test Program							
					Self-propelled Wheeled Vehicles††							
1/4-ton M38A1 4x4 truck	2,625	500	3,125	7.00	16	6	4	30	100.4	31.1	6.5	5.0
								20	133.8	23.4	7.4	5.3
								15	164.4	19.0	8.4	5.4
								10	188.6	16.6	8.6	5.6
3/4-ton M37 4x4 truck	5,917	1,500	7,417	9.00	16	8	4	30	224.4	33.0	8.7	7.4
								20	-----	----	---	---
								15	297.8	24.9	10.8	7.6
								10	341.7	21.7	11.9	7.6
2-1/2-ton M211 6x6 truck	13,120	5,000	18,120	9.00	20	8	10	30	401.3	45.2	8.4	9.6‡
								20	454.9	39.8	9.0	9.9‡
								15	508.7	35.6	9.7	10.0‡
								10	591.5	30.6	10.9	10.2‡
2-1/2-ton M225 6x6 truck	14,820	2,500	17,320	11.00	20	12	6	30	399.0	43.4	11.2	7.1
								20	449.6	38.5	11.9	7.3
								15	502.2	34.5	13.0	7.4
								10	569.6	30.4	14.4	7.5
		5,000	19,820	11.00	20	12	6	30	426.1	46.5	11.8	7.0
								20	492.2	40.3	13.0	7.4
								15	530.5	37.4	13.4	7.5
								10	607.6	32.6	14.5	7.6
2-1/2-ton unnumbered 6x6 truck	11,000 est	4,800	15,800	8.25	20	--	6	50	-----	----	----	----
					Yuma Test Program							
					Self-propelled Wheeled Vehicles‡‡							
1/4-ton M38A1 4x4 truck	2,475	500	2,975	7.00	16	6	4	30	98.6	30.2	6.7	4.4
								20	121.7	24.4	7.5	4.7
								15	141.3	21.1	8.2	4.8
								10	167.5	17.8	9.2	5.0
3/4-ton M37 4x4 truck	5,645	0	5,645	9.00	16	8	4	30	178.7	31.6	7.8	6.7
								20	217.4	26.0	8.6	7.2
								15	247.3	22.8	9.1	7.5
								10	290.9	19.4	10.2	7.6
		750	6,275	9.00	16	8	4	30	197.7	31.7	8.0	7.1
								20	236.2	26.6	8.8	7.3
								15	262.5	23.9	9.4	7.5
								10	306.0	20.5	10.7	7.6
		1,500	7,085	9.00	16	8	4	30	223.1	31.8	9.0	7.2
								20	265.7	26.7	9.9	7.5
								15	301.0	23.5	10.7	7.6
								10	338.8	20.9	11.6	7.6
		2,300	7,805	9.00	16	8	4	30	241.2	32.4	9.0	7.2
								20	281.1	27.8	10.2	7.6
								15	317.4	24.6	10.7	7.6
								10	363.6	21.5	12.2	7.7
2-1/2-ton M135 6x6 truck§	12,450	0	12,450	11.00	20	12	6	30	324.9	38.3	9.9	6.3
								20	372.8	33.4	10.7	6.6
								15	436.9	28.5	11.8	6.9
								10	499.8	24.9	12.9	7.1
		5,000	17,330	11.00	20	12	6	30	419.4	41.3	11.7	6.8
								20	494.0	35.1	12.8	7.2
								15	566.1	30.6	13.9	7.5
								10	637.7	27.2	15.1	7.8
		10,000	22,705	11.00	20	12	6	30	550.0	41.3	13.6	7.5
								20	638.3	35.6	14.9	7.7
								15	710.4	32.0	15.9	8.0
								10	823.8	27.6	17.4	8.4

(Continued)

* Determined from tire prints on a hard surface.
** Computed by dividing test weight by total contact area, except where noted.
† Average of greatest length and width of each tire.
†† Empty weights from data plate on each vehicle; tire prints made for one side of vehicle only.
‡ Dual tires are considered as one for determining width.
‡‡ Vehicles weighed on platform scales and tire prints made for all tires.
§ Total contact area, average contact pressure, and average tire print not determined for 15,000- and 20,500-lb test weights.

Table 2 (Continued)

Vehicle	Empty Weight lb	Approx Load lb	Test Weight lb	Tire Description: Width in.	Rim Diam in.	Ply Rating	No. of Tires	Tire Pressure psi	Total Contact Area sq in.	Average Contact Pressure psi	Average Tire Print, in. Length	Width
Yuma Test Program (Continued)												
Self-propelled Wheeled Vehicles (Continued)												
5-ton M41 6x6 truck	18,115	0	18,115	14.00	20	12	6	30	568.0	31.9	11.9	8.9
								20	684.6	26.5	13.3	9.4
								15	788.8	23.0	14.6	9.5
								10	915.9	19.8	16.3	9.9
		5,000	24,275	14.00	20	12	6	30	689.6	35.2	13.3	9.4
								20	852.5	28.5	15.6	9.9
								15	970.3	25.0	16.9	10.2
								10	1197.2	20.3	19.9	10.7
		10,000	26,175	14.00	20	12	6	30	795.7	35.4	14.8	10.0
								20	955.3	29.5	16.5	10.3
								15	1062.4	26.5	17.8	10.7
								10	1[illegible]9.2	21.8	20.5	11.1
		15,000	32,380	14.00	20	12	6	30	979.9	35.6	16.0	10.4
								20	1078.3	30.0	18.2	10.6
								15	1211.1	26.7	19.8	10.9
								10	1480.2	21.9	22.6	11.3
5-ton M54 6x6 truck	20,635	10,000	30,635	11.00	20	12	10	30	773.4	39.6	12.8	12.0*
								20	1004.6	30.5	15.1	12.9*
								15	1128.4	27.2	16.7	13.1*
								10	1307.6	23.4	18.2	13.7*

Self-propelled Tracked Vehicles**

Vehicle	Test Weight lb	One Track in. Length	Width	Both Tracks Total Contact Area sq in.	Average Contact Pressure psi
1/4-ton M29C weasel	5,970	78	20	3,120	1.9
	6,970	78	20	3,120	2.2
18-ton M4A2 hi-speed tractor	36,910	126	24	6,048	6.1
38-ton M6 hi-speed tractor	76,000	176	22	7,754	9.8

Vehicle	Empty Weight lb	Approx Load lb	Test Weight lb	Tire Description: Width in.	Rim Diam in.	Ply Rating	No. of Tires	Tire Pressure psi	Total Contact Area sq in.	Average Contact Pressure psi	Average Tire Print, in. Length	Width
Camp Lejeune Test Program												
Self-propelled Wheeled Vehicles§§												
1/4-ton M38A1 4x4 truck	2,775	200	2,975	7.00	16	6	4	30	98.6	30.2	6.7	4.4
								20	121.7	24.4	7.5	4.7
								15	141.3	21.1	8.2	4.8
								10	167.5	17.8	9.2	5.0
3/4-ton M37 4x4 truck	6,067	0	6,067	9.00	16	8	4	30	178.7	31.6	7.8	6.7
								20	217.4	26.0	8.6	7.2
								15	247.3	22.8	9.1	7.5
								10	290.9	19.4	10.2	7.6
2-1/2-ton M135 6x6 truck	12,450	5,000	17,450	11.00	20	12	6	30	419.4	41.3	11.7	6.8
								20	494.0	35.1	12.8	7.2
								15	566.1	30.6	13.9	7.5
								10	637.7	27.2	15.1	7.8

(Continued)

* Dual tires are considered as one for determining width.
** Vehicles weighed on platform scales.
§§ Total contact area, average contact pressure, and average tire print length and width are assumed to be same as Yuma, Ariz., data.

Table 2 (Continued)

Vehicle	Empty Weight lb	Approx Load lb	Test Weight lb	Tire Description: Width in.	Rim Diam in.	Ply Rating	No. of Tires	Tire Pressure psi	Total Contact Area sq in.	Average Contact Pressure psi	Average Tire Print, in.: Length	Width	Distribution of Weight, lb: Tongue	Wheels
Camp Lejeune Test Program (Continued)														
Towed Wheeled Vehicles**														
1/4-ton M100 cargo trailer	569	0	569	7.00	16	6	2	25	29.9	16.5¶	4.4	4.4	75	494
								20	31.4	15.7¶	4.7	4.6		
								15	37.7	13.1¶	5.0	4.7		
								10	41.2	12.0¶	5.2	4.7		
		250	782	7.00	16	6	2	25	31.0	22.8¶	4.8	4.2	75	707
								20	33.0	21.4¶	4.8	4.3		
								15	38.6	18.3¶	5.1	4.8		
								10	44.7	15.8¶	5.6	5.0		
		500	1,127	7.00	16	6	2	25	43.7	23.5¶	5.7	5.0	101	1,026
								20	47.1	21.8¶	5.9	5.0		
								15	54.5	18.8¶	6.0	5.2		
								10	61.5	16.7¶	7.0	5.2		
		750	1,211	7.00	16	6	2	25	47.0	23.8¶	6.0	5.2	94	1,117
								20	51.2	21.8¶	6.6	5.1		
								15	55.7	20.0¶	6.6	5.2		
								10	65.0	17.2¶	7.4	5.3		
3/4-ton M101 cargo trailer	1,339	750	2,089	9.00	16	8	2	45	58.3	33.4¶	6.5	5.8	140	1,949
								30	71.3	27.3¶	6.7	6.4		
								20	81.6	23.9¶	7.0	6.6		
								10	111.5	17.5¶	8.6	7.1		
		1,500	2,960	9.00	16	8	2	45	75.7	36.7¶	7.0	6.8	183	2,777
								30	96.3	28.8¶	8.0	7.2		
								20	113.9	24.4¶	8.8	7.5		
								10	155.7	17.8¶	10.9	7.6		
		2,250	3,679	9.00	16	8	2	45	90.5	38.4¶	7.6	7.2	207	3,472
								30	104.6	33.2¶	8.2	7.5		
								20	132.3	26.2¶	9.8	7.7		
								10	171.2	20.3¶	11.8	7.7		
1-1/2-ton M105 cargo trailer	2,450	1,500	4,110	9.00	20	8	2	45	100.5	37.4¶	9.0	7.0	352	3,758
								30	121.6	30.9¶	9.9	7.1		
								20	144.7	26.0¶	11.0	7.4		
								10	196.0	19.2¶	13.7	7.6		
		3,000	5,648	9.00	20	8	2	45	120.9	43.9¶	10.1	7.4	340	5,308
								30	140.5	37.8¶	10.6	7.5		
								20	188.6	28.1¶	13.4	7.7		
								10	269.7	19.7¶	17.0	8.0		
		4,500	7,482	9.00	20	8	2	45	145.4	49.4¶	11.0	7.5	201	7,179
								30	177.5	40.4¶	12.6	7.7		
								20	224.4	32.0¶	15.0	7.9		
								15	262.8	27.5¶	17.1	8.0		
6-ton cargo trailer	10,960	0	10,960	(10.00 / (11.00	20 / 20	10 / 12	4)¶¶ / 4)	60	258.5	42.4	7.1	5.5		
								45	307.5	35.6	7.6	6.1		
								30	358.3	30.6	8.2	6.6		
								15	461.9	23.7	9.3	7.2		
		6,000	17,150	(10.00 / (11.00	20 / 20	10 / 12	4)¶¶ / 4)	60	377.2	45.5	8.4	6.8		
								45	433.3	39.6	9.0	7.1		
								30	498.1	34.4	9.8	7.4		
								15	660.5	26.0	12.0	7.5		
		12,000	25,520	(10.00 / (11.00	20 / 20	10 / 12	4)¶¶ / 4)	60	490.4	52.0	9.8	7.3		
								45	533.8	47.8	10.6	7.5		
								30	638.0	40.0	11.6	7.5		
								15	799.6	31.9	13.7	7.4		
37.5-kW generator trailer	7,153	0	7,153	7.00	20	8	4	60	128.5	55.7	8.2	4.9		
								45	146.2	48.9	8.8	5.0		
								30	175.4	40.8	9.8	5.1		
								15	243.8	29.3	12.4	5.0		

** Vehicles weighed on platform scales and tire prints made for all tires.
¶ Computed from weight on wheels instead of total test weight.
¶¶ 10.00x20 tires on front wheels and 11.00x20 tires on rear wheels.

Table 3

Summary of Data and Test Results, Single Self-propelled Vehicle Tests

1/4-ton M38A1, 4x4 Truck (Four 7.00x16 Tires)

Item No.	Location	Beach	Beach Area*	Test No.	Slope %	Tire Pressure psi	Immobilized	Cone Index at Depth of 0 in.	3 in.	6 in.	9 in.	12 in.	15 in.	Cone Index Averages by Soil Layers 0- to 6-in.	6- to 12-in.	0- to 12-in.	Rut Depth in.	Remarks
Pacific Islands Test Program																		
Vehicle Test Weight 3,125 lb, Approximate Load 500 lb																		
1	Oahu	Makua	NBS	57	4	30	Yes	2	23	60	92	136	102	28	96	63	8	Sand dry to 2 in., moist below
2		Makua	NBS	56	0	30	No	2	30	56	75	114	146	29	82	55	8	Slight jerking motion
3		Mokuleia	DA	69	0	30	No	2	34	116	214	288	300+	51	206	131	6	Dry sand, easy travel
4		Mokuleia	DA	70	0	30	No	2	26	80	148	222	232	36	150	96	7	Dry sand, slight jerking motion
5		Mokuleia	NC	71	0	30	Yes	2	20	56	86	100	87	26	81	53	12	Moist sand
6		Makua	NBS	58	6	25	Yes	2	25	60	84	116	124	29	87	57	8	Sand dry to 2 in., moist below
7		Bunker	NBS	270	9	20	Yes	2	47	108	174	252	300+	52	178	117	6	Wheels spinning
8		Bunker	NBS	271	6	20	Yes	5	59	130	206	230	274	62	189	124	6	Sand dry to 1-1/2 in., moist below
9		Bunker	NBS	272	5	20	No	5	44	110	160	142	106	53	137	92	3	Sand dry to 1-1/2 in., moist below
10		Bunker	NBS	269	5	20	No	4	35	114	196	268	300+	51	193	124	4	Sand dry to 1 in., easy travel
11		Drone	FDA	76	5	20	Yes	2	20	61	105	146	143	28	104	67	8	Sand dry to 4 in., wheels spinning
12		Drone	FDA	77	4	20	No	2	38	92	142	162	194	44	132	87	7	Sand dry to 4 in., slight spinning
13		Makua	NBS	59	2	20	Yes	2	20	70	116	130	90	31	105	68	8	Wheels spinning
14		Makua	NBS	61	1	20	No	2	28	72	126	134	154	34	111	72	7	Sand dry to 3 in., slight spinning
15		Mokuleia	NC	72	0	20	Yes	2	20	56	86	100	86	26	81	53	12	Moist sand, wheels spinning
16		Makua	NBS	60	0	20	No	2	28	75	102	108	121	35	95	63	6	Sand dry to 4 in., no difficulty
17		Drone	FDA	78	10	15	Yes	2	18	50	88	105	103	23	81	53	9	Sand dry to 5 in., wheels spinning
18		Bunker	FDA	275	10	15	Yes	2	70	156	178	182	226	76	172	118	5	Sand dry to 2-1/2 in., wheels spinning
19		Drone	FDA	79	8	15	No	2	38	94	162	216	296	45	157	102	6	Easy travel
20		Bunker	FDA	276	8	15	No	2	54	120	174	22[illegible]	---	59	173	115	5	Easy travel
21		Bunker	NBS	274	8	15	Yes	2	40	90	166	250	---	44	171	111	8	Sand dry to 1-1/2 in.
22		Bunker	NBS	277	6	15	No	2	48	120	132	216	234	[illegible]	156	104	4	Sand dry to 4 in.
23		Bunker	FDA	278	6	15	No	2	52	104	152	192	---	53	149	100	4	Easy travel
24		Makua	NBS	63	5	15	Yes	2	26	56	74	82	90	28	71	48	7	Sand dry to 2 in., violent jerking motion
25		Makua	NBS	62	4	15	No	2	28	72	108	103	104	34	94	63	6	Sand dry to 2 in., some wheel spinning
26		Bunker	NBS	273	3	15	No	2	48	104	218	238	220	51	187	122	5	Easy travel
27		Drone	NC	80	0	15	No	2	24	56	78	85	93	27	73	49	8	Moist sand, considerable effort
28		Mokuleia	NC	73	0	15	Yes	2	24	43	69	77	91	23	63	43	12	Moist sand, jerking motion
29		Bunker	FDA	282	18	10	Yes	2	38	100	162	202	---	47	155	101	6	Sand dry to 2-1/2 in.
30		Bunker	FDA	280	16	10	No	2	72	136	208	300+	---	72	215+	145+	1.5	Easy travel
31		Bunker	FDA	279	14	10	No	2	84	168	192	196	220	85	185	128	5	Easy travel
32		Drone	FDA	81	13	10	Yes	2	15	45	67	71	75	21	61	40	10	Sand dry to 4 in., jerking motion
33		Drone	FDA	82	10	10	Yes	2	27	60	112	156	180	33	112	73	8	Sand dry to 4 in., jerking motion
34		Bunker	NBS	281	9	10	No	2	40	100	124	174	280	47	133	87	5	Easy travel
35		Makua	NBS	65	6	10	Yes	5	29	52	72	73	81	29	67	47	7	Moist sand, jerking motion
36		Makua	NBS	64	6	10	No		32	64	104	126	92	33	98	66	6	Moist sand, slight jerking motion
37		Drone	FDA	83	[illegible]	10	No	2	34	108	178	226	296	[illegible]	171	[illegible]	5	Easy travel
38		Mokuleia	NC	74	0	10	No	2	24	43	69	77	94	23	63	43	8	Moist sand, easy travel
39		Mokuleia	NC	75	0	10	No	2	25	45	72	96	100	24	71	48	9.5	Moist sand, difficult travel
40		Makua	FB	67	0	10	Yes	2	16	48	80	115	155	22	81	52	---	Inundated area, 1% tilt
41		Makua	FDA	66	13	5	No	2	28	78	138	208	260	36	141	91	1	Dry sand, easy travel
42	Iwo Jima	Red	FB	74	16	30	Yes	10	42	60	62	80	170**	60	70	52	6	Sand wet
43		Red	FB	73	15	30	No	5	90	145	110	300+	---	90	185+	130+	2	Sand wet
44		Red	FB	72	14	30	Yes	10	42	54	61	66	100**	35	67	50	6	Sand wet, wheels spinning

(Continued)

* See "Beach Terms" under "Definitions" in text.
** 18-in. depth.

Sheet 1 of 3 sheets

Item No.	Location	Beach	Beach Area*	Test No.	Slope %	Tire Pressure psi	Immo-bilized	Cone Index at Depth of 0 in.	3 in.	6 in.	9 in.	12 in.	15 in.	Cone Index Averages by Soil Layers 0- to 6-in.	6- to 12-in.	0- to 12-in.	Rut Depth in.	Remarks
								Pacific Islands Test Program (Continued)										
								Vehicle Test Weight 3,125 lb, Approximate Load 500 lb (Continued)										
45	Iwo Jima (Continued)	Red	FB	76	14	30	No	8	75	70	165	300+	---	51	178+	124+	3	Sand wet, easy travel
46		Red	FB	70	11	30	Yes	5	35	44	48	82	300+**	28	58	43	5	Sand wet, wheels spinning
47		Red	FB	72	10.5	30	Yes	5	35	45	50	100	90**	28	65	47	8	Sand wet
48		Red	FB	68	8	30	Yes	5	45	62	72	82	80**	37	72	53	6	Sand wet
49		Red	FB	67	6	30	Yes	10	48	58	78	78	82**	39	71	54	6	Sand wet, 10% tilt
50		Red	FB	69	9	30	No	5	38	72	88	100	142**	38	87	61	4	Sand wet
51		Red	FB	66	4	30	No	5	42	60	65	80	102**	36	68	50	5	Sand dry to 3 in., wet below, 8% tilt
52		Red	FB	71	3	30	No	5	36	45	50	52	120**	29	49	38	6	Sand wet, wheels spinning
53		Red	FB	81	19	20	Yes	5	72	102	152	175	190**	60	143	101	6	Sand moist, wheels spinning
54		Red	FB	78	18	20	Yes	5	35	52	62	68	85**	31	61	44	7	Sand moist
55		Red	FB	80	18	20	Yes	5	32	130	183	300+	---	62	204+	134+	3	Sand wet, some spinning
56		Red	FB	82	18	20	No	5	80	160	205	300+	---	[illegible]	222+	150+	5	Sand wet, easy travel
57		Red	FB	77	15	20	Yes	10	40	65	88	60	150**	38	71	53	5	Sand moist
58		Red	FB	79	10	20	No	10	35	48	55	85	120**	31	63	47	5	Sand wet, 10% tilt
59		Red	FB	103	27	10	Yes	5	38	40	68	100	300+**	28	69	50	8	Sand dry to 3 in., wet below
60		Red	FB	83	26	10	Yes	10	38	52	58	68	100**	33	59	45	4	Sand wet, wheels spinning
61		Red	FB	102	24	10	No	10	40	62	92	205	300+**	37	120	82	5	Sand wet
62		Red	FB	98	22.5	10	Yes	5	30	58	115	300+	---	31	158+	102+	8	Sand wet, wheels spinning
63		Red	FB	97	22	10	Yes	8	40	50	95	300+	---	33	148+	99+	4	Sand wet, wheels spinning
64		Red	FB	85	21.5	10	Yes	5	25	42	90	100	300+**	24	77	52	7	Sand moist
65		Red	FB	84	20	10	Yes	3	31	65	70	75	62**	33	70	49	4	Sand dry to 2 in., moist below
66		Red	FB	84A	20	10	Yes	3	32	62	78	72	55**	32	71	49	7	Sand dry to 3 in., moist below
67		Red	FB	86	20	10	Yes	5	25	42	90	100	300+**	24	77	52	5	Sand moist
68		Red	FB	81A	19	10	No	5	72	102	152	175	190**	60	143	101	-	Sand moist, easy travel
69		Red	FB	96	17.5	10	No	3	38	55	68	105	300+**	32	76	54	6	Sand wet
70		Red	FB	94	17	10	Yes	3	32	52	90	162	300+**	29	101	68	8	Sand wet, wheels spinning
71		Red	FB	101	17	10	Yes	15	62	110	190	300+	---	62	200+	135+	-	Inundated, quick condition
72		Red	FB	93	15	10	No	5	33	53	88	165	300+**	30	102	69	4	Sand wet, easy travel
73		Red	FB	99	12	10	No	9	30	55	110	300+	---	31	155+	101+	4	Sand wet, 12% tilt
74		Red	FB	100	12	10	Yes	5	25	42	60	90	117+**	24	64	44	8	Sand wet, 12% tilt
75		Red	FB	95	11	10	No	5	35	45	40	50	300+**	28	45	35	9	Sand wet
								Yuma Test Program										
								Vehicle Test Weight 2,975 lb, Approximate Load 500 lb										
76	Dune area			65	12	30	Yes	17	96	118	218	269	300+	77	202	143		Sand dry on surface, moist below
77				66	21	30	Yes	17	104	149	230	245	254	90	203	149		Sand dry on surface, moist below
78				67	11	30	No	17	113	145	172	204	226	92	174	130		Sand dry on surface, moist below
79				68	11	30	Yes	15	109	110	203	266	300+	78	193	141		Sand dry on surface, moist below
80				69	10	30	No	17	110	155	287	300+	---	97	247+	176+		Sand dry, easy travel
81				72	21.5	20	Yes	14	96	127	176	227	281	79	177	128		Sand dry on surface, moist below
82				73	20	20	No	14	117	102	185	276	282	74	188	137		Sand dry on surface, moist below
83				78	22	15	Yes	10	65	59	72	108	209	45	80	63		Sand dry on surface, moist below
84				79	21.5	15	No	15	106	108	190	300+	---	76	199+	144+		Sand dry on surface, moist below
85				80	22	15	No	10	97	118	218	265	300+	75	200	142		Sand dry on surface, moist below
86				81	24	15	No	10	106	126	191	260	269	81	192	139		Sand dry on surface, moist below
87				82	25	15	Yes	8	74	109	224	300+	---	64	211+	143+		Sand dry on surface, moist below

(Continued)

* See "Beach Terms" under "Definitions" in text.
** 18-in. depth.

Table 3 (Continued)

Item No.	Location	Beach	Beach Area*	Test No.	Slope %	Tire Pressure psi	Immobilized	Cone Index at Depth of 0 in.	3 in.	6 in.	9 in.	12 in.	15 in.	Cone Index Averages by Soil Layers 0- to 6-in.	6- to 12-in.	0- to 12-in.	Rut Depth in.	Remarks
								Yuma Test Program (Continued)										
								Vehicle Test Weight 2,975 lb, Approximate Load 500 lb (Continued)										
88	Dune area			86	30	10	Yes	6	45	74	100	134	171	42	105	73		Sand dry on surface, moist below
89	(Continued)			87	23	10	No	7	108	154	161	172	194	90	162	120		Sand dry on surface, moist below
								Camp Lejeune Test Program										
								Vehicle Test Weight 2,975 lb, Approximate Load 200 lb										
90	Onslow Beach		FDA	23	30	25	Yes	19	72	104	192	300+	---	65	199+	137+		Moist sand
91			FDA	25	24	25	Yes	16	132	246	300+	---	---	132	---	---		Moist sand
92			FDA	22	13	25	No	15	102	245	300+	---	---	121	---	---		Moist sand
93			FDA	24	12	25	No	17	92	253	300+	---	---	121	---	---		Moist sand
94			FDA	27	23	20	Yes	17	72	208	300+	---	---	99	---	---		Moist sand
95			FDA	29	20	20	Yes	17	62	143	257	300+	---	74	233+	156+		Moist sand
96			FDA	26	14	20	No	19	104	252	300+	---	---	125	---	---		Moist sand
97			FDA	28	12	20	No	16	82	242	300+	---	---	113	---	---		Moist sand
98			FDA	31	30	15	Yes	18	136	260	300+	---	---	138	---	---		Moist sand
99			FDA	34	21	15	Yes	17	58	75	127	280	300+	50	161	111		Moist sand
100			FDA	30	20	15	No	17	62	143	257	300+	---	74	233+	156+		Moist sand
101			FDA	35	19	15	No	13	55	82	162	300+	---	50	181+	122+		Moist sand
102			FDA	32	17	15	No	18	91	189	257	300+	---	99	249+	171+		Moist sand
103			FDA	33	17	15	No	18	128	233	300+	---	---	126	---	---		Moist sand
104			FDA	37	16	15	Yes	16	56	99	164	281	---	57	181	123		Moist sand
105			FDA	36	12	15	No	14	121	264	300	---	---	133	---	---		Moist sand
106			FDA	38	20	10	No	13	55	190	270+	300+	---	86	253+	166+		Moist sand

* See "Beach Terms" under "Definitions" in text.

Table 4

Summary of Data and Test Results, Single Self-propelled Vehicle Tests

3/4-ton M37, 4x4 Truck (Four 9.00x16 Tires)

Item No.	Location	Beach	Beach Area*	Test No.	Slope %	Tire Pressure psi	Immo-bilized	Cone Index at Depth of 0 in.	3 in.	6 in.	9 in.	12 in.	15 in.	Cone Index Averages by Soil Layers 0- to 6-in.	6- to 12-in.	0- to 12-in.	Rut Depth in.	Remarks
							Pacific Islands Test Program											
							Vehicle Test Weight 7,417 lb, Approximate Load 1,500 lb											
1	Oahu	Mokuleia	DA	1	0	45	No	2	29	96	185	274	---	42	185	117	10	Sand dry to 5 in., moist below, slight jerking motion
2		Makua	DA	199	4	40	Yes	5	46	88	196+	248+	300+	46	177+	117+	5	Sand dry to 2 in., moist below, wheels spinning
3		Makua	DA	198	3	40	Yes	5	48	82	108	144	254	45	111	77	6	Sand dry to 2 in., moist below, wheels spinning
4		Makua	DA	203	2	40	Yes	5	31	62	100	156	226	33	106	71	8	Sand dry to 2 in., moist below, wheels spinning
5		Makua	DA	205	2	40	No	5	57	128	192	284+	300+	63	201+	133+	6	Moist sand
6		Makua	DA	197	1.5	40	No	5	45	98	172	264	300	49	178	117	6	Moist sand, some spinning
7		Makua	DA	200	1	40	No	5	36	94	132	174	186	45	133	88	8	Sand dry to 2 in., moist below, some spinning
8		Makua	DA	202	0	40	Yes	2	31	70	114	156	282+	34	123	81	7	Sand dry to 2 in., moist below, wheels spinning
9		Makua	DA	204	0	40	Yes	5	40	102	170	260+	300+	49	177+	115+	8	Moist sand
10		Makua	DA	196	-1	40	No	4	66	142	230	300+	300+	71	224	148	4	Moist sand, easy travel
11		Makua	DA	201	-5	40	No	2	45	96	162	216	280+	48	158	104	6	Sand dry to 2 in., moist below, easy travel
12		Makua	DA	212	8	30	Yes	5	41	100	176	214	256+	49	153	101	8	Sand dry to 2 in., moist below, wheels spinning
13		Makua	DA	210	6	30	Yes	2	40	96	176	264+	300+	46	179+	116+	6	Sand dry to 2 in., moist below, wheels spinning
14		Makua	DA	211	5	30	No	5	136	288+	300+	300+	300+	136	296+	202+	2	Sand dry to 2 in., moist below, easy travel
15		Makua	DA	209	4	30	No	2	54	116	220	280+	300+	57	205+	134+	3	Sand dry to 2 in., moist below, easy travel
16		Makua	DA	208	3	30	No	10	102	240	300+	300+	300+	117	270+	190+	2	Sand moist, easy travel
17		Makua	DA	207	3	30	No	5	66	126	196	272+	300+	66	198+	133+	4	Sand moist, some spinning
18		Makua	DA	206	3	30	Yes	2	30	84	152	220	288+	39	152	98	8	Sand moist, wheels spinning
19		Makua	BBB	213	0	30	Yes	5	17	56	69	72	74	33	66	49	8	Sand dry to 2 in., wheels spinning
20		Mokuleia	DA	2	-	30	Yes	2	26	87	201	267	300+	38	185	117	10	Sand dry to 5 in., moist below, jerking motion
21		Makua	BBB	6	-2	30	Yes	2	26	58	94	124	300+	29	92	61	12	Sand moist, jerking motion
22		Crescent	BBB	108	4	22	Yes	5	42	87	123	143	170	45	118	80	7	Sand moist, jerking motion
23		Crescent	FB	118	14	20	Yes	2	19	44	77	124	171	22	82	53	14	Inundated, quick sand, sank quickly
24		Makua	FDA	231	14	20	Yes	5	52	106	118	148	200	54	124	86	6	Sand moist, wheels spinning
25		Crescent	FB	122	1	20	Yes	7	47	73	53	97	114	42	84	61	6	Sand moist, wheels spinning
26		Crescent	FDA	246	4	20	No	5	54	132	198	256	288+	64	195	129	5	Sand dry to 2 in., easy travel
27		Crescent	FB	243	7	20	Yes	5	46	130	160	244	300	50	168	111	8	Sand moist, wheels spinning
28		Crescent	FDA	123	7	20	Yes	2	33	64	91	118	171	33	91	62	8	Sand dry to 3 in., wheels spinning
29		Crescent	FB	121	7	20	No	2	17	50	113	184	125	23	116	73	3	Inundated area
30		Crescent	FB	120	5	20	No	3	22	44	73	119	96	23	79	52	4	Sand wet, easy travel
31		Crescent	FDA	245	5	20	No	5	54	96	130	184	292+	52	138	95	5	Sand dry to 1 in., moist below, easy travel
32		Makua	BC	215	5	20	Yes	5	37	92	130	122	128	41	105	71	8	Sand moist
33		Makua	FDA	230	4	20	Yes	5	38	76	134	178	300+	40	129	86	6	Sand moist, wheels spinning

(Continued)

* See "Beach Terms" under "Definitions" in text.

Sheet 1 of 7 sheets

Table 4 (Continued)

Item No.	Location	Beach	Beach Area	Test No.	Slope %	Tire Pressure psi	Immo-bilized	Cone Index at Depth of 0 in.	3 in.	6 in.	9 in.	12 in.	15 in.	Cone Index Averages by Soil Layers 0- to 6-in.	6- to 12-in.	0- to 12-in.	Rut Depth in.	Remarks
								Pacific Islands Test Program (Continued)										
								Vehicle Test Weight 7,417 lb, Approximate Load 1,500 lb (Continued)										
34	Oahu (Continued)	Makua	BBS	214	3	20	Yes	5	35	70	84	96	92	37	83	58	8	Sand dry to 2 in., moist below
35		Crescent	FB	242	3	20	No	5	58	114	204	250	284+	59	189	126	3	Sand moist, no trouble
36		Crescent	FB	244	3	20	No	5	45	126	148	210	268+	59	161	107	4	Sand moist, easy travel
37		Crescent	FDA	247	3	20	No	2	64	94	110	110	108	53	105	76	3	Sand dry to 3 in., moist below
38		Makua	BC	216	0	20	Yes	5	33	59	82	92	80	32	78	54	8	Sand moist
39		Crescent	FB	219	0	20	No	4	23	46	81	126	194	24	84	56	--	Sand wet, easy travel
40		Mokuleia	DA	68	0	20	No	2	25	108	200	260	194	45	189	119	5	Sand dry to 6 in.
41		Crescent	BC	109	0	20	No	10	58	124	120	135	132	64	127	90	4	Sand moist, easy travel
42		Crescent	FB	110	0	20	Yes	6	21	26	34	48	68	18	36	27	17	Inundated, quick condition, quickly sank
43		Crescent	FB	129	24	15	Yes	6	18	37	75	136	193	20	83	54	--	Inundated, quick cond, quickly stuck
44		Crescent	FB	131	18	15	Yes	6	28	43	[illegible]	112	198	26	81	56	--	Inundated, quick cond, quickly stuck
45		Crescent	FB	130	14	15	No	8	38	77	97	120	180	41	98	68	--	Sand wet, some slippage
46		Crescent	FB	126	14	15	Yes	4	24	46	[illegible]	124	88	23	81	54	6	Inundated area
47		Crescent	FB	116	14	15	No	4	17	36	60	106	172	19	67	44	4	Inundated area, easy travel
48		Crescent	FDA	117	14	15	Yes	2	28	[illegible]	90	162	260	30	104	68	6	Sand dry to 5 in., tilt 3%
49		Makua	FDA	233	14	15	Yes	5	52	106	118	148	200	54	124	86	6	Sand dry to 1 in., wheels spinning
50		Crescent	FDA	252	13	15	Yes	2	35	82	118	162	240	40	121	80	9	Sand dry to 3 in., wheels spinning
51		Crescent	FDA	253	10	15	Yes	2	36	103	164	254	284	47	174	112	8	Sand dry to 3 in., wheels spinning
52		Crescent	FDA	255	10	15	Yes	2	40	99	138	194	262	47	144	95	10	Sand dry to 3 in., wheels spinning
53		Crescent	FDA	127	10	15	Yes	2	36	81	120	166	216	40	122	81	9	Sand dry to 2 in., wheels spinning
54		Crescent	FDA	128	10	15	Yes	2	39	76	135	181	246	39	131	87	8	Sand dry to 2 in., wheels spinning
55		Crescent	FDA	125	9	15	Yes	2	32	68	104	143	169	34	105	70	-	Sand dry to 3 in., slight jerking motion
56		Crescent	FDA	248	8	15	No	2	42	124	172	170	200	56	155	102	4	Sand dry to 3 in., easy travel
57		Crescent	FB	251	7	15	Yes	5	31	57	80	104	188	31	80	55	8	Sand moist, wheels spinning
58		Crescent	FDA	124	7	15	No	2	33	64	91	118	171	33	91	62	--	Sand dry to 3 in., easy travel
59		Makua	BBS	220	7	15	Yes	5	31	100	124	104	104	45	109	73	7	Sand dry to 2 in., moist below
60		Crescent	FDA	240	6	15	No	3	62	133	111	158	230	66	134	93	4	Sand dry to 3 in., 5% tilt, easy travel
61		Crescent	FB	250	5	15	No	5	59	111	156	228	300+	58	165	112	4	Sand moist, easy travel
62		Crescent	FDA	254	4	15	No	2	53	118	158	216	272	58	164	109	4	Sand dry to 3 in., easy travel
63		Crescent	BBS	256	4	15	No	2	55	124	122	158	244	60	135	92	5	Sand moist, easy travel
64		Makua	FDA	232	4	15	No	5	38	76	134	178	300+	60	129	86	7	Sand dry to 1 in., moist below, some difficulty
65		Makua	BC	234	3	15	No	5	36	60	124	168	238	36	120	80	5	Sand moist
66		Makua	BC	235	3	15	No	5	48	96	134	174	238	48	133	91	6	Sand moist
67		Makua	BC	236	3	15	Yes	5	39	52	74	92	180	32	75	54	[illegible]	Sand moist, wheels spinning
68		Makua	BC	219	2	15	No	5	39	80	94	106	94	41	93	65	8	Sand moist, slight jerking but moving easy
69		Mokuleia	DA	3	1	15	No	2	30	103	188	202	300+	45	164	105	5	Sand dry to 5 in., easy travel
70		Mokuleia	BC	4	0	15	Yes	2	25	49	68	81	64	25	66	45	15	Sand moist, wheels spinning
71		Makua	BBS	8	0	15	No	5	32	100	126	145	300+	46	124	82	--	Sand moist, easy travel
72		Makua	BC	9	0	15	No	5	32	79	137	173	300+	39	130	85	10	Sand moist, easy travel
73		Makua	BC	10	0	15	Yes	2	27	58	60	70	300+	29	63	43	12	Sand moist, wheels spinning
74		Makua	BC	11	0	15	Yes	2	28	64	57	58	300+	31	60	42	--	Sand moist, wheels spinning
75		Makua	BC	12	0	15	Yes	5	23	42	55	50	46	23	49	35	--	Sand wet, sank quickly
76		Makua	BC	217	0	15	No	5	36	66	96	126	154	36	96	66	7	Sand moist, some slippage
77		Makua	BC	218	0	15	No	5	40	73	112	168	174	39	118	80	6	Sand moist, easy travel
78		Makua	BBS	7	-2	15	Yes	5	24	57	56	50	300+	29	54	38	12	Sand moist, jerking motion

(Continued)

Table 4 (Continued)

Item No.	Location	Beach	Beach Area	Test No.	Slope %	Tire Pressure psi	Immo-bilized	Cone Index at Depth of 0 in.	3 in.	6 in.	9 in.	12 in.	15 in.	Cone Index Averages by Soil Layers 0- to 6-in.	6- to 12-in.	0- to 12-in.	Rut Depth in.	Remarks
								Pacific Islands Test Program (Continued)										
								Vehicle Test Weight 7,417 lb, Approximate Load 1,530 lb (Continued)										
79	Oahu (Continued)	Crescent	FDA	132	15	10	Yes	4	30	64	143	161	206	33	113	74	--	Sand dry to 6 in., moist below, wheels spinning
80		Makua	FDA	229	13	10	No	5	51	114	130	132	156	57	125	86	1.5	Sand dry to 1/2 in., moist below, easy travel
81		Makua	BC	15	10	10	Yes	5	32	81	114	137	300+	39	110	73	--	Sand moist, wheels spinning
82		Crescent	FS	114	7	10	No	5	26	53	102	152	224	28	102	68	3	Sand wet to inundated, easy travel
83		Makua	BBS	226	7	10	Yes	5	24	36	54	86	120	22	59	41	9	Sand moist
84		Makua	BBS	239	7	10	Yes	5	30	61	81	79	88	32	74	51	9	Sand moist, wheels spinning
85		Makua	BBS	241	7	10	Yes	2	34	63	83	99	113	33	82	56	8	Sand moist
86		Makua	BBS	225	6	10	Yes	5	27	46	62	90	128	26	66	46	7	Sand dry to 1 in.
87		Crescent	FS	113	6	10	No	8	24	44	78	106	162	25	76	52	3.5	Sand wet, 1% tilt, easy travel
88		Makua	BBS	222	6	10	No	5	44	66	84	108	136	38	67	61	9	Sand moist, easy travel
89		Makua	BBS	224	5	10	No	5	29	55	79	106	124	30	80	55	6	Sand dry to 2 in., easy travel
90		Makua	BBS	221	5	10	No	5	30	71	112	86	100	35	90	61	5	Sand moist
91		Makua	BBS	227	5	10	No	5	36	62	70	86	86	34	73	52	6	Sand moist, easy travel
92		Makua	BBS	238	5	10	No	3	28	80	128	106	106	37	105	69	5	Sand dry to 3 in., moist below, easy travel
93		Makua	BBS	240	5	10	No	2	31	77	126	116	98	37	106	70	5	Easy travel
94		Makua	FS	17	5	10	Yes	5	28	37	53	64	61	23	51	37	--	Inundated, quick cond, quickly stuck
95		Makua	BC	228	3	10	No	5	30	50	66	72	76	28	63	45	6	Sand moist, easy travel
96		Makua	BC	14	2	10	No	5	32	60	90	115	300+	32	88	60	--	Sand moist, some difficulty
97		Makua	FS	16	[illegible]	10	No	5	27	50	81	96	300+	27	76	52	--	Sand wet, easy travel
98		Makua	BC	237	[illegible]	10	No	3	25	53	92	106	114	27	84	56	5	Sand moist, easy travel
99		Makua	FS	[illegible]	0	10	No	2	24	67	96	76	300+	31	80	53	12	Sand moist
100		Mokuleia	BC	5	0	10	No	3	25	57	78	81	67	28	72	49	6	Sand moist
101		Crescent	FS	111	0	10	No	10	50	76	112	118	112	45	102	73	5	Inundated, 2% tilt, easy travel
102		Crescent	FS	112	0	10	No	3	20	44	64	90	125	22	66	44	3.5	Inundated, 3% tilt, easy travel
103		Crescent	FS	115	0	10	No	4	19	33	56	90	126	19	60	40	7	Inundated, 9% tilt, easy travel
104	Kwajalein	6	FS	a	12.8	50	Yes	24	75	178	260+	---	---	92	---	---	1.5	Surface moist, wetter with depth
105		6	FS	b	16	40	Yes	14	45	95	158	---	---	51	---	---	1.5	Surface moist, wetter with depth
106		5	FS	5	13	32	No	18	85	250	300+	---	---	118	---	---	2.0	Surface moist, wetter with depth
107		6	FS	c	13	30	Yes	12	63	120	213	---	---	65	---	---	1.5	Surface moist, wetter with depth
108		6	FS	d	14.5	20	Yes	17	73	133	212	---	---	74	---	---	--	Surface moist, wetter with depth
109	Guam	Nimitz	FS	1	8.5	45	No	16	63	100	170	230	---	60	167	116	2.5	Tire pressure 32 psi front; 45 psi rear; easy travel
110		Jones	FS	2a	25	32	Yes	8	29	57	105	190	220	31	117	78	--	Sand moist
111		Tarague	FS	3	20	32	Yes	8	32	80	125	215	260+	40	140	92	--	Sand moist
112		Jones	FS	2	13.5	32	No	10	47	100	157	260+	---	52	172	115	2.5	Sand moist
113		Tarague	FS	3a	20	20	Yes	8	36	78	110	180+	---	41	123	82	--	Sand moist
114		Tarague	FS	3b	21.5	15	Yes	8	35	80	138	180+	---	41	133	88	--	Sand moist
115	Luzon	Lido	FS	1	18	40	Yes	15	86	130	300+	---	---	97	---	---	--	Sand moist, truck empty
116	Iwo Jima	Red	FS	2	6	45	Yes	9	39	62	79	92	93**	37	77	56	[illegible]	Sand moist, 6% tilt
117		Red	FS	1	4	45	Yes	5	34	61	54	51	75**	33	55	41	6	Sand moist, 6% tilt
118		Red	FS	3	4	45	Yes	11	52	75	73	72	75	46	73	57	10.5	Sand moist
119		Red	FS	5	2.5	45	Yes	8	52	85	98	92	55	48	92	67	8	Sand moist, 10% tilt
120		Red	FS	4	2	45	No	10	42	82	92	78	75	45	84	61	8	Sand moist, 7% tilt
121		Red	BC	6	1	45	Yes	8	41	65	76	77	85	38	73	53	5	Sand moist, 10% tilt
122		Yellow	BC	21	3	30	Yes	5	35	60	135	215	300+	33	137	90	6	Sand dry to 2 in., moist below 2% tilt

(Continued)

** 18-in. depth.

Table 4 (Continued)

Item No.	Location	Beach	Beach Area	Test No.	Slope %	Tire Pressure psi	Immobilized	Cone Index at Depth of 0 in.	3 in.	6 in.	9 in.	12 in.	15 in.	Cone Index Averages by Soil Layers 0- to 6-in.	6- to 12-in.	0- to 12-in.	Rut Depth in.	Remarks
Pacific Islands Test Program (Continued)																		
Vehicle Test Weight 7,417 lb, Approximate Load 1,500 lb (Continued)																		
123	Iwo Jima (Continued)	Yellow	BC	22	3	30	Yes	3	15	35	45	58	95	18	46	31	11	Sand moist
124		Yellow	FS	24	3	30	Yes	6	45	70	180	300+	300+	40	183+	120+	--	Sand moist, 8% tilt
125		Yellow	FS	26	1	30	Yes	8	44	65	112	165	188	39	114	79	10	Sand moist, 14% tilt
126		Yellow	FS	23	[illegible]	30	No	5	50	112	300+	---	---	56	---	---	5	Sand dry to 2 in., 8% tilt
127		Yellow	FS	25	0	30	No	5	49	65	168	190	170	40	141	95	8	Sand moist, 5% tilt
128		Red	FS	10	10	20	Yes	3	48	65	75	70	95	40	70	55	9	Sand moist, 5% tilt
129		Red	FS	13	8	20	Yes	5	36	52	58	65	101	31	58	45	10	Sand moist, 14% tilt
130		Red	FS	9	6	20	No	5	45	65	90	100	115	38	85	61	3.5	Sand wet
131		Red	FS	12	6	20	No	5	38	64	79	68	90	36	70	51	8	Sand wet, [illegible] tilt
132		Red	FS	7	5	20	Yes	9	44	71	75	78	80	41	75	55	9	Sand moist, 3% tilt, wheels spinning
133		Red	FS	8	5	20	No	10	48	64	80	75	95	41	73	55	4	Sand moist, 5% tilt, wheels spinning
134		Red	BC	11	2	20	No	[illegible]	42	81	95	122	218	42	99	69	6	Sand moist, 5% tilt
135		Yellow	FS	28	24	10	Yes	10	35	82	136	142	300+	42	121	81	7	Sand moist
136		Yellow	FS	35	24	10	Yes	10	45	78	130	172	212	44	127	87	11	Sand wet
137		Red	FS	15	22	10	Yes	8	45	78	68	70	75	44	72	54	9	Sand wet
138		Red	FS	18	22	10	Yes	8	45	42	50	60	113	32	51	41	5	Sand wet
139		Red	FS	16	21	10	No	5	32	58	61	150	275	32	90	61	4	Sand wet
140		Red	FS	17	21	10	Yes	8	48	64	66	70	65	40	67	51	9	Sand wet
141		Red	FS	14	20	10	No	5	35	92	112	178	208	44	111	74	2	Sand wet
142		Yellow	FS	29	20	10	Yes	6	45	92	135	162	200	48	130	88	10	Sand moist
143		Yellow	FS	30	20	10	Yes	10	45	100	168	188	300+	51	152	102	--	Sand wet
144		Red	FS	19	17	10	No	5	40	62	65	67	60	36	64	48	3	Sand wet
145		Yellow	FS	34	17	10	No	10	39	108	122	130	300+	52	140	94	3	Sand wet
146		Red	FS	20	17	10	Yes	8	30	55	110	275	---	31	147	96	12	Inundated
147		Yellow	BC	31	15	10	Yes	10	50	85	120	168	188	48	124	87	5	Sand moist
148		Yellow	BC	33	15	10	Yes	5	60	122	148	132	162	62	141	97	8	Sand moist, 5% tilt
149		Yellow	BC	32	10	10	No	5	60	112	150	180	---	62	147	103	6	Sand moist, 4% tilt
150		Yellow	FS	27	24	8	Yes	8	45	70	140	175	---	38	128	86	8	Inundated area - not plotted
Yuma Test Program																		
Vehicle Test Weight 5,645 lb, No Load																		
151	Dune area			113	17.5	30	Yes	5	108	194	300+	300+	300+	102	265	181	----	Sand dry on surface, moist below
152				118	16.5	30	Yes	10	84	110	220	300+	---	68	210	145	----	
153				114	15	30	No	12	113	148	239	296	300+	91	228	162	1.50	
154				116	11.5	30	Yes	5	50	82	101	135	222	46	106	75	----	
155				115	10.5	30	No	10	114	136	268	300+	---	87	235	166	1.50	
156				117	9.5	30	No	7	112	176	210	263	248	98	210	150	1.00	
157				120	9.5	30	Yes	5	58	91	136	174	224	51	134	93	----	
158				119	8.5	30	No	6	80	118	188	238	260	68	181	126	2.0	
159				121	6	30	No	6	96	158	222	244	284	86	208	145	1.25	
160				127	19.5	20	Yes	5	76	102	124	160	200	61	129	93	----	
161				130	17.5	[illegible]	Yes	5	111	149	238	296	300+	88	288	160	----	
162				131	16.5	20	Yes	5	98	145	275	286	292	83	235	162	----	
163				128	16	20	No	6	116	163	224	218	140	95	202	145	1.75	
164				129	14	20	No	5	107	168	248	300+	300+	93	239	166	1.50	
165				126	14	20	Yes	5	45	63	74	94	148	38	77	56	----	
166				125	13.5	20	No	5	73	135	214	274	296	71	208	140	1.50	
167				122	9.5	20	Yes	5	54	88	136	176	340	49	134	92	----	

(Continued)

Table 4 (Continued)

Item No.	Location	Beach	Beach Area	Test No.	Slope %	Tire Pressure psi	Immobilized	Cone Index at Depth of 0 in.	3 in.	6 in.	9 in.	12 in.	15 in.	Cone Index Averages by Soil Layers 0- to 6-in.	6- to 12-in.	0- to 12-in.	Rut Depth in.	Remarks
											Yuma Test Program (Continued)							
											Vehicle Test Weight 5,645 lb, No Load (Continued)							
168	Dune area (Continued)			123	9.5	20	Yes	5	58	91	136	174	224	51	134	93	----	Sand dry on surface, moist below
169				124	9.5	20	Yes	5	51	80	110	148	216	45	113	79	----	
170				141	21	15	Yes	5	88	117	222	260	288	70	200	138	----	
171				132	20	15	No	5	107	162	286	300+	300+	91	249	172	----	
172				136	17.5	15	Yes	5	66	146	274	300+	---	72	240	158	----	
173				133	15	15	Yes	3	23	38	66	82	66	21	62	42	----	
174				140	15	15	Yes	7	88	102	128	164	194	66	131	98	----	
175				137	14	15	No	5	98	216	288	300+	---	106	268	181	----	
176				138	14	15	Yes	5	88	127	160	162	172	73	150	108	----	
177				139	14	15	Yes	5	58	38	34	36	32	34	36	34	----	
178				134	13	15	No	5	108	166	[illegible]	260	284	93	210	149	----	
179				135	9.5	15	No	5	67	116	196	270	292	63	194	131	----	
180				142	21	10	No	5	38	117	222	260	288	70	200	138	1.50	
181				149	19.5	10	Yes	5	55	85	110	136	170	48	110	78	----	
182				150	19.5	10	No	5	97	182	300+	---	---	95	261	177	----	
183				151	17.5	10	Yes	5	58	100	128	156	158	54	128	89	----	
184				143	16	10	No	5	146	212	284	300+	---	121	265	189	1.0	
185				145	16	10	Yes	5	43	100	132	136	160	49	123	83	----	
186				146	16	10	No	5	82	164	230	254	300+	84	216	147	----	
187				148	14	10	Yes	5	34	41	38	40	39	27	40	32	----	
188				144	8.5	10	Yes	5	25	38	104	176	248	23	106	70	----	
189				147	8.5	10	No	5	98	130	216	280	219	78	209	146	----	
											Vehicle Test Weight 6,275 lb, Approximate Load 750 lb							
190	Dune area			159	12	30	Yes	5	89	139	218	300+	---	78	219	150	----	Sand dry on surface, moist below
191				156	11	30	Yes	5	89	128	194	246	300+	74	189	132	----	
192				158	10	30	Yes	10	59	76	165	142	184	48	108	79	----	
193				152	9.5	30	Yes	5	75	137	234	280	300+	72	217	146	----	
194				153	8.5	30	No	5	91	176	272	300+	---	91	249	169	----	
195				154	8.5	30	Yes	5	65	99	141	197	232	56	146	101	----	
196				157	8	30	No	5	112	188	260	288	292	102	245	171	----	
197				155	7	30	No	6	92	172	244	288	300+	90	235	160	----	
198				160	7	30	No	5	115	159	285	300+	---	93	248	173	----	
199				164	19.5	20	Yes	5	97	171	208	277	300+	91	219	152	----	
200				168	16	20	Yes	5	72	151	280	300+	---	76	244	162	----	
201				162	15	20	No	5	96	160	246	300+	300+	87	235	161	----	
202				161	14	20	No	5	87	163	260	300+	---	85	241	163	----	
203				163	14	20	No	5	108	166	188	160	198	93	171	125	----	
204				166	12	20	Yes	5	87	110	155	190	184	67	138	101	----	
205				167	9.5	20	No	5	86	165	229	300+	300+	85	231	197	----	
206				165	8.5	20	No	5	67	166	236	290	300+	79	231	153	----	
207				170	17.5	15	No	5	108	166	248	278	300+	93	231	161	----	
208				171	17.5	15	Yes	5	38	65	127	240	300+	36	144	95	----	
209				175	17.5	15	Yes	5	67	74	75	71	62	49	73	98	----	
210				174	16.5	15	No	5	114	178	240	280	300+	99	233	163	----	
211				169	16	15	No	5	73	120	180	278	300+	66	192	130	----	
212				173	11.5	15	No	5	103	137	232	300+	---	82	223	195	----	
213				172	10.5	15	No	5	78	109	167	180	[illegible]	64	165	104	----	
214				180	26.5	10	Yes	5	90	146	218	288	300+	80	217	149	----	

(Continued)

Table 4 (Continued)

Item No.	Location	Beach	Beach Area	Test No.	Slope %	Tire Pressure psi	Immobilized	Cone Index at Depth of 0 in.	3 in.	6 in.	9 in.	12 in.	15 in.	Cone Index Averages by Soil Layers 0- to 6-in.	6- to 12-in.	0- to 12-in.	Rut Depth in.	Remarks
								Yuma Test Program (Continued)										
								Vehicle Test Weight 6,275 lb, Approximate Load 750 lb (Continued)										
215	Dune area (Continued)			178	24	10	Yes	5	108	135	171	244	300+	83	183	133	----	Sand dry on surface, moist below
216				179	21	10	No	5	113	164	181	248	296	94	198	142	----	
217				182	17.5	10	No	5	136	208	288	300+	---	116	265	187	----	
218				177	17.5	10	Yes	5	48	61	55	56	64	38	57	45	----	
219				181	16.5	10	Yes	5	42	54	84	135	187	34	91	64	----	
220				176	16	10	No	5	102	140	167	186	224	82	164	120	----	
								Vehicle Test Weight 7,085 lb, Approximate Load 1,590 lb										
221	Dune area			64	13	30	Yes	16	106	161	277	300+	---	94	246	172	----	Sand dry on surface, moist below
222				70	11	30	Yes	12	80	119	172	218	280	70	170	120	----	
223				71	11	30	No	13	105	147	240	298	300	88	228	161	----	
224				74	17.5	20	Yes	14	103	143	203	209	254	87	185	134	----	
225				75	17	20	Yes	11	52	66	136	254	299	43	152	104	----	
226				76	16	20	No	14	90	119	187	227	242	74	178	127	----	
227				83	22	15	Yes	10	105	158	269	299	292	91	242	168	----	
228				77	18.5	15	Yes	10	83	154	258	300+	---	82	237	161	----	
229				84	30	10	Yes	10	55	68	112	142	220	44	107	77	----	
230				85	25.5	10	No	8	80	134	280	300	214	74	238	160	----	
								Vehicle Test Weight 7,805 lb, Approximate Load 2,300 lb										
231	Dune area			185	13	30	Yes	5	107	180	247	286	296	97	238	165	----	Sand dry on surface, moist below
232				186	8.5	30	No	5	113	154	226	251	223	91	210	149	1.5	
233				188	8.5	30	Yes	5	82	109	199	296	300+	65	201	138	2.75	
234				189	8	30	Yes	5	95	156	242	300+	---	85	233	160	----	
235				187	7	30	Yes	5	69	112	159	244	272	63	172	118	----	
236				190	7	30	No	5	117	173	242	282	288	97	232	163	1.75	
237				191	3.5	30	No	7	163	254	292	300+	---	141	262	203	1.0	
238				195	18.5	20	Yes	5	102	170	268	300+	---	92	246	169	1.0	
239				194	12	20	Yes	5	101	174	272	300+	300+	93	249	170	----	
240				193	8.5	20	No	5	98	127	195	244	288	77	189	134	----	
241				192	8	20	No	5	95	156	242	300+	---	85	233	160	1.0	
242				197	21	15	No	5	104	169	256	296	300+	93	244	168	----	
243				196	18.5	15	Yes	5	97	122	148	216	247	75	162	118	----	
244				179	16	15	Yes	5	75	175	179	288	268	85	214	144	----	
245				198	15	15	Yes	5	59	59	72	70	43	41	67	53	----	
246				168	14	15	Yes	5	34	37	41	54	64	85	44	34	----	
247				369	10.5	15	No	5	106	149	209	276	300+	87	211	149	----	
248				200	8.5	15	No	5	116	180	228	276	300+	100	289	161	----	
249				370	18.5	10	Yes	5	83	77	91	112	89	55	93	74	----	
250				371	17.5	10	No	5	115	166	258	300+	---	95	241	169	1.0	
251				372	16	10	No	5	79	118	177	259	300+	67	185	188	1.5	
252				373	16	10	Yes	5	43	81	76	112	184	43	96	67	----	

(Continued)

Table 4 (Continued)

Item No.	Location	Beach	Beach Area	Test No.	Slope %	Tire Pressure psi	Immo-bilized	Cone Index at Depth of 0 in.	3 in.	6 in.	9 in.	12 in.	15 in.	Cone Index Averages by Soil Layers 0- to 6-in.	6- to 12-in.	0- to 12-in.	Rut Depth in.	Remarks
								Camp Lejeune Test Program										
								Vehicle Test Weight [illegible] lb, No Load										
253	Onslow Beach		FDA	72	12	45	Yes	18	81	183	274	300+	---	94	252+	171+	----	Moist sand
254			FDA	68	9	45	Yes	17	85	173	300+	---	---	92	---	---	1.5	
255			FDA	71	8	45	No	[illegible]	94	217	300+	---	---	109	---	---	----	
256			FDA	67	8	45	No	17	117	242	300+	---	---	125	---	---	----	
257			FDA	70	8	45	Yes	14	80	175	300+	---	---	90	---	---	----	
258			FDA	73	8	45	No	17	94	180	300+	---	---	97	---	---	----	
259			FDA	69	6	45	No	15	128	264	300+	---	---	142	---	---	----	
260			FDA	78	[illegible]	40	Yes	17	60	111	227	300+	---	61	213+	143+	----	
261			FDA	80	12	40	Yes	15	71	155	267	300+	---	81	240+	161+	----	
262			FDA	74	10	40	No	[illegible]	95	236	300+	---	---	116	---	---	----	
263			FDA	76	9	40	No	18	102	207	297	300+	---	109	268+	185+	1.0	
264			FDA	79	9	40	No	16	64	184	300+	---	---	86	---	---	----	
265			FDA	75	8	40	No	15	88	238	300+	---	---	114	---	---	----	
266			FDA	77	8	40	No	15	69	120	233	300+	---	68	218+	147+	2.0	
267			FDA	84	21	30	Yes	20	65	82	77	180	300+	56	113	85	----	
268			FDA	82	21	30	Yes	18	109	212	253	300+	---	113	238+	178+	----	
269			FDA	86	16	30	Yes	18	77	186	300+	---	---	94	---	---	----	
270			FDA	83	12	30	No	17	128	170	244	300+	---	105	238+	172+	----	
271			FDA	85	11	30	No	17	91	231	300+	---	---	113	---	---	----	
272			FDA	81	9	30	No	16	122	179	272	300+	---	106	250	175+	----	
273			FDA	90	21	20	Yes	19	113	229	300+	---	---	120	---	---	----	
274			FDA	88	17	20	Yes	18	89	174	247	300+	---	90	237+	164+	----	
275			FDA	87	1	20	No	15	83	177	263	300+	---	92	247+	168+	----	
276			FDA	89	[illegible]	20	No	15	87	205	275	300+	---	102	290+	176+	----	
277			FDA	129	12	10	Ye	20	173	253	300+	---	---	149+	---	---	----	
278			FDA	131	24	10	No	15	144	290+	300+	---	---	149+	---	---	----	
279			FDA	127	22	10	No	15	98	171	242	238+	300+	95	217+	153+	----	
280			FDA	130	[illegible]	10	No	15	152	265	300+	---	---	[illegible]	---	---	----	
281			FDA	128	16	10	No	15	143	287	300+	---	---	148+	---	---	----	

Table 5

Summary of Data and Test Results, Single Self-propelled Vehicle Tests

2-1/2-ton M211, 6x6 Truck (Ten 9.00x20 Tires)

2-1/2-ton Unnumbered 6x6 Truck (Six 8.25x20 Tires)

Item No.	Location	Beach	Beach Area*	Test No.	Slope %	Tire Pressure psi	Immo-bilized	Cone Index at Depth of 0 in.	3 in.	6 in.	9 in.	12 in.	15 in.	Cone Index Averages by Soil Layers 0- to 6-in.	6- to 12-in.	0- to 12-in.	Rut Depth in.	Remarks
								Pacific Islands Test Program, M211 Truck										
								Vehicle Test Weight 13,120 lb, No Load										
1	Iwo Jima	Yellow	MS	37	14	45	Yes	10	72	130	300+	---	---	71	---	---	5	Sand moist
2		Yellow	MS	36	9	45	No	5	90	170	240	300+	---	88	237+	161+	2	Sand dry to 2 in., wet below
3		Red	FS	87	28	10	Yes	4	32	52	85	125	---	29	87	60	9	Sand wet
4		Red	FS	88	22	10	Yes	4	22	52	118	300+	---	26	157+	99+	9	Sand wet
5		Red	FS	89	18	10	No	5	35	50	55	140	300+	30	82	57	4	Sand wet, some difficulty
6		Red	FS	92	18	10	Yes	3	35	48	70	58	72**	29	59	43	12	Sand moist
7		Red	FS	90	17	10	Yes	5	30	48	60	80	108**	28	63	45	8	Sand moist
8		Red	FS	91	14	10	No	5	58	75	105	185	---	44	122	84	--	Sand wet
								Vehicle Test Weight 18,120 lb, Approximate Load 5,000 lb										
9	Oahu	Bunker	FDA	137	7	45	Yes	5	34	78	180	160	236	39	119	79	10	Sand moist, severe jerking motion
10		Bunker	MBS	136	6	45	Yes	7	45	116	156	197	238	56	156	104	5	Sand moist, slight jerking motion
11		Makua	MBS	167	6	45	Yes	5	34	77	110	131	174	39	106	71	11	Sand moist, severe jerking motion
12		Bunker	MBS	138	5	45	Yes	5	49	103	142	179	220	52	141	96	6	Sand moist, severe jerking motion
13		Makua	MBS	173	4	45	Yes	5	30	72	106	142	194	36	107	71	18	Sand moist, 7% tilt, wheels spinning
14		Makua	MBS	171	3	45	Yes	5	28	67	113	161	232	33	114	75	11	Sand moist, wheels spinning
15		Makua	MBS	166	2	45	Yes	5	34	76	110	140	166	38	109	73	5	Sand moist, slight jerking motion
16		Makua	MBS	170	1.5	45	Yes	5	28	67	113	161	232	33	114	75	9	Sand moist
17		Makua	MBS	172	1	45	Yes	5	28	60	100	128	193	31	96	64	18	Sand moist, wheels spinning
18		Bunker	BC	133	1	45	No	8	56	114	157	130	132	59	134	93	7	Sand moist, slight turn
19		Bunker	BC	134	0	45	No	7	54	108	137	205	237	56	150	102	6	Sand moist, easy travel
20		Bunker	BC	135	0	45	No	5	38	100	127	167	222	48	131	87	5	Sand moist, easy travel
21		Makua	BC	160	0	45	Yes	5	30	49	67	93	126	28	70	49	9	Sand moist, 4% tilt, some spinning
22		Makua	MBS	168	0	45	No	5	36	75	113	140	182	39	109	74	6	Sand moist, easy travel
23		Makua	MBS	169	0	45	No	5	35	75	113	140	182	39	109	74	7	Sand moist, some spinning
24		Makua	[illegible]	159	-1	45	No	5	30	49	67	93	126	29	70	49	8	Sand moist, 4% tilt, some spinning
25		Makua	DA	179	3	32	Yes	5	35	80	138	204	300	40	141	92	14	Sand dry to 2-1/2 in., moist below, jerking motion
26		Makua	DA	178	0	32	No	6	43	82	128	192	318	43	134	90	5	Sand dry to 2-1/2 in., easy travel
27		Bunker	MBF	259	7	30	Yes	5	42	112	176	258	306	53	182	119	8	Sand moist
28		Bunker	FDA	139	[illegible]	30	Yes	3	37	86	140	204	274	42	143	94	11	Sand moist, wheels spinning
29		Bunker	MBS	260	5	30	Yes	5	42	108	186	268	300	52	187	122	7	Sand dry to 2 in., moist below
30		Bunker	MBS	262	5	30	Yes	5	42	100	150	202	278	49	151	100	7	Sand dry to 2 in., moist below
31		Bunker	FDA	140	3	30	Yes	3	36	94	142	196	258	43	143	94	5	Sand moist, severe jerking motion
32		Makua	DA	181	2	30	Yes	5	26	67	63	76	96	26	62	43	8	Sand moist
33		Bunker	MBS	258	2	30	No	5	60	84	170	232	292	63	175	118	7	Sand moist
34		Bunker	MBS	261	2	30	No	5	60	110	182	254	304	52	182	118	6	Sand dry to 2 in.
35		Makua	BC	161	0	30	Yes	5	37	67	105	189	158	36	100	69	8	Sand moist, gentle jerking motion
36		Makua	MBS	180	0	30	No	8	49	94	178	204	274	50	159	107	5	Sand moist, easy travel
37		Bunker	BC	257	0	30	No	7	56	130	180	234	290	63	181	120	7	Sand dry to 2 in., slight slippage
38		Crescent	FDA	146	9	20	Yes	3	34	87	137	193	318	61	179	[illegible]	9	Sand dry to 4 in.
39		Crescent	FDA	142	5	20	Yes*	3	36	92	140	198	272	44	143	94	10	Sand moist, jerking motion
40		Bunker	MBS	263	8	20	Yes	5	52	128	190	254	294	62	191	126	8	Sand moist

(Continued)

* See "Beach Terms" under "Definitions" in text.
** 14-in. depth.

Table 5 (Continued)

No.	Location	Beach	Beach Area	Test No.	Slope %	Tire Pressure psi	Immo-bilized	Cone Index at Depth of 0 in.	3 in.	6 in.	9 in.	12 in.	15 in.	Cone Index Averages by Soil Layers 0- to 6-in.	6- to 12-in.	0- to 12-in.	Rut Depth in.	Remarks
								Pacific Islands Test Program, M211 Truck (Continued)										
								Vehicle Test Weight 18,120 lb, Approximate Load 5,000 lb (Continued)										
41	Oahu (Continued)	Bunker	[illegible]	265	6	20	Yes	5	52	118	132	204	272	58	151	102	8	Sand moist, 7% tilt
42		Bunker	[illegible]	266	6	20	Yes	5	46	90	132	172	264	47	131	89	6	Sand moist
43		Bunker	[illegible]	268	6	20	Yes	5	52	106	146	140	150	54	131	90	6	Sand dry to 1-1/2 in., moist below
44		Crescent	FDA	145	5	20	Yes	5	36	88	143	193	271	43	141	93	8	Sand moist, jerking motion
45		Crescent	FDA	144	4	20	No	3	37	99	161	210	252	46	157	102	6	Sand moist
46		Crescent	FDA	141	3	20	No	5	37	91	149	204	230	44	148		9	Sand moist, slight jerking motion
47		Makua	[illegible]	184	2.5	20	Yes	5	32	52	80	106	108	30	79	55	6.5	Sand moist
48		Bunker	[illegible]	264	2.5	20	No	5	34	106	202	290	308	48	199	127	6	Sand moist, 7% tilt
49		Bunker	[illegible]	267	2	20	No	5	39	128	268	300	300	57	232	148	5	Sand dry to 1-1/2 in., easy travel
50		Makua	[illegible]	185	1.5	20	Yes	5	35	58	84	112	160	33	85	59	9.5	Sand moist
51		Crescent	[illegible]	143	1	20	No	4	49	96	131	154	208	50	127	87	4	Sand moist, easy travel
52		Makua	[illegible]	186	1	20	Yes	5	32	56	71	86	114	31	71	50	10	Sand moist, wheels spinning
53		Makua	BC	162	0	20	Yes	5	37	72	114	141	165	38	109	74	9	Sand dry to 2 in., 4% tilt
54		Makua	DA	182	0	20	Yes	5	25	44	72	86	104	25	67	46	9	Sand moist, wheels spinning
55		Makua	[illegible]	183	0	20	No	5	48	86	124	164	246	46	125	85	--	Sand moist, easy travel
56		Crescent	FDA	148	[illegible]	15	Yes	5	34	90	141	214	286	43	148	97	8	Sand moist, jerking motion
57		Crescent	FDA	149	6	15	Yes	2	33	82	135	180	248	39	132	86	8	Sand dry to 2 in., jerking motion
58		Crescent	FDA	147	4	15	No	5	34	90	141	214	286	43	148	97	8	Sand moist
59		Makua	[illegible]	188	2.5	15	Yes	5	33	64	90	108	144	34	87	60	12	Sand moist, wheels spinning
60		Makua	[illegible]	187	1	15	No	5	31	61	89	136	178	32	95	64	6	Sand moist, slight spinning
61		Crescent	FDA	152	11	10	Yes	2	32	66	119	186	248	[illegible]	124	81	8	Sand moist, wheels spinning
62		Makua	FDA	176	11	10	Yes	5	37	87	154	219	275	43	153	100	8	Sand moist, wheels spinning
63		Crescent	FDA	151	10	10	Yes	3	36	92	126	181	242	44	133	88	8	Sand moist, wheels spinning
64		Crescent	FDA	154	8	10	Yes	2	32	85	129	167	* 213	40	127	83	8	Sand moist, wheels spinning
65		Makua	[illegible]	195	8	10	Yes	5	31	49	66	88	108	28	68	48	9	Sand moist, jerking motion
66		Makua	DA	165	7	10	Yes	2	35	77	112	160	253	38	116	77	9	Sand dry to 6 in., severe jerking motion
67		Makua	FDA	177	7	10	No	5	44	90	168	261	300+	46	177	114	2	Sand moist, easy travel
68		Crescent	FDA	150	6	10	No	2	33	82	135	180	248	39	132	86	2	Sand moist, some spinning
69		Makua	[illegible]	194	6	10	No	5	33	64	86	120	132	34	90	62	5	Sand moist
70		Makua	[illegible]	190	5.5	10	Yes	5	32	57	67	74	86	31	66	47	12	Sand moist
71		Crescent	FDA	153	5	10	No	2	34	95	127	169	271	40	127	83	3	Sand moist
72		Makua	[illegible]	156	5	10	Yes	2	30	[illegible]	110	178	205	33	118	77	8	Sand dry to 3 in., moist below, wheels spinning
73		Makua	[illegible]	191	5	10	No	5	31	59	84	102	108	32	82	56	7	Sand moist, no trouble
74		Makua	[illegible]	193	5	10	No	5	35	62	100	116	170	34	93	64	4	Sand moist
75		Makua	BC	157	4	10	Yes	4	35	63	104	150	238	34	105	71	6	Sand moist, wheels spinning, slight turn
76		Makua	[illegible]	174	4	10	No	5	32	64	101	140	175	34	102	68	8	Sand moist
77		Makua	FDA	175	4	10	No	5	38	75	113	172	230	39	120	81	6	Sand moist, easy travel
78		Makua	[illegible]	189	4	10	No	5	31	62	90	114	126	33	[illegible]	60	5.5	Sand moist, easy travel
79		Makua	[illegible]	192	4	10	No	5	39	73	108	148	[illegible]	39	110	75	4	Sand moist, easy travel
80		Makua	[illegible]	155	2	10	No	2	28	65	134	[illegible]	270	32	130	84	5	Sand dry to 3 in., moist below
81		Makua	BC	158	0	10	No	5	37	73	106	135	165	38	105	71	4.5	Sand moist, easy travel
82		Makua	BC	163	0	10	No	5	36	65	93	117	146	35	[illegible]	63	4	Sand moist, easy travel
83		Makua	DA	164	4	10	No	3	23	[illegible]	120	180	273	32	123	79	4	Sand dry to 6 in.
84	Iwo Jima	Red	BC	42	12	45	Yes	5	48	86	91	95	97*	46	91	65	9	Sand moist
85		Red	FB	43	11	45	Yes	4	40	98	130	155	190*	47	128	85	--	Sand inundated, quick sand, quickly sank
86		Red	[illegible]	58	11	45	Yes	25	115	168	220	300+	---	103	[illegible]	166+	7	Sand dry to 2-1/4 in., moist below

(Continued)

* 18-in. depth.

Table 5 (Continued)

Item No.	Location	Beach	Beach Area	Test No.	Slope %	Tire Pressure psi	Immo-bilized	Cone Index at Depth of 0 in.	3 in.	6 in.	9 in.	12 in.	15 in.	Cone Index Averages by Soil Layers 0- to 6-in.	6- to 12-in.	0- to 12-in.	Rut Depth in.	Remarks
								Pacific Islands Test Program, M211 Truck (Continued)										
								Vehicle Test Weight 18,120 lb, Approximate Load 5,000 lb (Continued)										
87	Iwo Jima (Continued)	Red	FS	40	10	45	Yes	10	105	115	208	300+	---	77	208+	145+	6	Sand moist
88		Red	FS	39	9	45	No	6	114	300+	---	---	---	140+	---	---	2	Sand wet
89		Red	BS	57	8	45	No	30	65	140	300+	---	---	78	---	---	3	Sand dry to 3 in., hard crust
90		Red	FS	38	7	45	Yes	16	160	247	300+	---	---	141	---	---	5	Sand wet, quick condition, quickly sank
91		Red	BS	55	7	45	Yes	22	75	136	178	182	188**	78	166	119	4	Sand moist
92		Red	BS	56	7	45	Yes	12	55	98	118	118	125**	55	111	80	9	Sand dry to 3 in., moist below
93		Red	BS	53	6	45	No	29	88	170	205	212	170**	96	196	141	6	Crusted sand to 1 in.
94		Red	BS	54	4	45	No	30	75	110	105	130	140**	72	115	90	3	Crusted sand to 1 in.
95		Red	BC	41	-1.5	45	No	5	58	49	58	62	278**	37	56	46	5	Sand moist
96		Red	FS	44	11	20	Yes	5	45	61	75	88	152**	37	75	55	9	Sand moist
97		Red	BS	46	11	20	Yes	5	66	155	190	220	300+**	75	188	125	4	Sand dry to 3 in.
98		Red	BS	48	10	20	No	14	90	170	193	300+	---	91	221+	153+	1.5	Sand dry to 3 in.
99		Red	BS	51	10	20	Yes	5	40	58	60	62	90**	34	60	45	9	Sand moist
100		Red	BS	52	8	20	No	5	38	62	70	85	102**	35	72	52	5	Sand dry to 3 in.
101		Red	BS	47	7	20	No	5	94	170	242	210	125**	90	207	144	2	Sand moist
102		Red	BS	49	5	20	Yes	10	65	90	200	230	300+**	55	173	119	5	Sand dry to 3 in.
103		Red	BS	50	4	20	No	5	62	102	158	215	300+**	56	158	108	3	Sand dry to 3 in.
104		Red	BC	45	3	20	No	5	55	94	86	90	90**	51	90	66	8	Sand moist
105		Red	FS	65	38	10	Yes	5	48	70	100	105	117**	41	92	66	8	Sand wet
106		Red	FS	64	37	10	Yes	5	25	45	70	70	85**	25	62	43	5	Sand wet
107		Red	FS	63	24	10	No	20	55	82	180	300+	---	52	187+	127+	2	Sand wet
108		Red	FS	62	21	10	No	5	42	55	60	70	168**	34	62	46	3	Sand wet
109		Red	FS	60	19	10	No	5	40	55	60	65	95**	33	60	45	3	Sand wet
110		Red	FS	61	14	10	No	5	28	52	62	145	75**	28	86	58	4	Crusted sand 1/2 in., wet below
111		Red	FS	59	13	10	No	10	42	72	85	95	300+**	41	84	61	3	Sand wet
								Pacific Islands Test Program, 2-1/2-ton Unnumbered Truck										
								Vehicle Test Weight 15,800 lb, Approximate Load 4,800 lb										
112	Kwajalein	6	FS	[illegible]	14	50	No	60	98	300	---	---	---	153	---	---	2	
113		6	FS	[illegible]	14	50	No	31	77	133	260	300	---	80	231	160	2	
114		7	FS	[illegible]	13	50	Yes	33	77	190	248+	---	---	100	---	---	--	
115		6	FS	[illegible]	0	50	No	20	55	128	300	---	---	68	---	---	5	

** 18-in. depth.

Table 6

Summary of Data and Test Results, Single Self-propelled Vehicle Tests

2-1/2-ton M215 and M135, 6x6 Trucks (Six 11.00x20 Tires)

Item No.	Location	Beach	Beach Area*	Test No.	Slope %	Tire Pressure psi	Immobilized	Cone Index at Depth of 0 in.	3 in.	6 in.	9 in.	12 in.	15 in.	Cone Index Averages by Soil Layers 0- to 6-in.	6- to 12-in.	0- to 12-in.	Rut Size, in. Width	Depth	Remarks
								Pacific Islands Test Program - M215 Truck											
								Vehicle Test Weight 17,320 lb, Approximate Load 2,500 lb											
1	Oahu	Bunker	BC	55	1	40	No	2	62	136	178	224	218	7	179	120		6	Sand moist, easy travel
2		Makua	DA	41	5	40	Yes	2	25	95	140	140	230	41	125	80		13	Sand dry, some difficulty
3		Bunker	BC	54	0	40	No	2	62	136	178	224	218	67	179	120		6	Sand moist, easy travel
4		Makua	DA	42	2	30	Yes	2	34	85	116	148	228	41	116	77		14	Sand dry, slow creep forward
5		Makua	BC	46	2	30	Yes	2	45	90	110	118	137	46	106	73		16	Sand moist
6		Bunker	BC	53	2	30	No	2	60	148	192	148	124	70	163	110		11	Sand moist
7		Makua	BBB	47	7	20	Yes	2	39	70	87	92	93	44	90	62		16	Sand dry on surface, moist below
8		Makua	BC	45	2	20	No	2	45	90	110	118	137	46	106	73		10	Sand moist, easy travel
9		Makua	BBB	43	1	20	No	2	34	80	118	130	168	39	109	73		11	Sand dry on surface, moist below
10		Makua	BBB	44	1	20	No	2	42	107	124	152	180	50	127	85		--	Sand dry on surface, moist below
								Vehicle Test Weight 19,820 lb, Approximate Load 5,000 lb											
11	Oahu	Makua	BBB	18	6	50	Yes	3	30	78	142	195	234	37	138	90		17	Sand dry to 3 in., moist below
12		Makua	BBB	19	6	40	Yes	3	30	78	142	195	234	37	138	90		17	Sand dry to 3 in., moist below, wheels spinning
13		Mokuleia	DA	25	0.5	40	Yes	1	28	95	190	248	284	41	178	112		11	Sand dry to 5 in., moist below, wheels spinning
14		Makua	BBB	20	6	30	Yes	2	26	60	114	149	215	29	108	70		18	Sand dry to 3 in., moist below, wheels spinning
15		Crescent	FDA	104	14.5	20	Yes	2	40	86	128	191	280	43	136	90		12	Sand dry to 6 in., moist below
16		Crescent	FDA	105	10	20	Yes	2	40	63	124	184	260	42	130	87		12	Sand moist, slight jerking motion
17		Crescent	FB	103	7	20	No	10	42	76	88	104	112	43	89	64		9	Sand wet, easy travel
18		Crescent	FDA	107	7	20	No	2	46	104	148	222	246	51	158	104		6	Sand dry to 3 in., moist below
19		Makua	BBB	21	6	20	Yes	2	26	60	114	149	215	29	108	70		18	Sand dry to 3 in., moist below
20		Makua	BC	30	5	20	Yes	3	34	51	72	88	87	29	70	50		16	Sand moist, wheels jerking
21		Makua	BC	31	5	20	Yes	2	28	83	103	112	190	38	99	66		16	Sand moist, wheels jerking
22		Makua	BC	35	5	20	Yes	2	31	76	79	56	54	36	70	49		8	Sand moist
23		Makua	FDA	84	5	20	No	2	58	158	262	300+	300+	73	240	156		1	Sand moist, easy travel
24		Makua	BBB	90	5	20	Yes	2	36	70	129	184	202	46	128	84		11	Sand moist, wheels spinning
25		Crescent	FDA	106	5	20	No	2	44	90	154	256	294	45	167	109		8	Sand dry to 6 in., moist below, easy travel
26		Makua	FDA	86	4	20	No	2	39	84	162	252	300+	42	166	108		7	Sand moist, easy travel
27		Makua	BC	34	3	20	Yes	2	35	66	120	138	122	34	108	72		18	Sand moist, wheels spinning
28		Makua	BBC	91	3	20	No	2	30	84	140	158	174	39	127	83		13	Sand moist, some wheel spinning
29		Makua	FDA	85	2	20	No	2	33	82	138	194	274	39	138	90		5	Sand moist, easy travel
30		Makua	BBB	89	2	20	No	2	40	98	172	200	206	47	157	102		10	Sand moist
31		Makua	BC	38	1	20	Yes	2	31	63	112	152	88	32	109	72		16	Sand moist
32		Mokuleia	DA	26	0	20	No	1	28	95	190	248	284	41	178	112		5	Sand dry to 5 in., moist below, easy travel
33		Mokuleia	BC	27	0	20	Yes	1	14	26	37	56	90	14	40	27		17	Sand moist, 9% tilt, wheels spinning
34		Makua	BC	33	0	20	No	2	32	78	126	140	190	37	115	76		8	Sand moist, easy travel
35		Crescent	BC	101	0	20	No	4	24	38	40	42	55	22	40	30		10	Sand moist, easy travel
36		Crescent	FG	102	0	20	No	5	30	63	101	154	224	33	104	71		3	Sand wet, easy travel
37		Makua	BBB	87	5	18.5	No	2	34	74	128	144	126	37	115	76		10	Sand dry to 3 in., moist below
38		Makua	BBB	88	5	18.5	Yes	2	33	60	123	175	148	34	122	80		14	Sand dry to 3 in., moist below, wheels spinning
39		Makua	FDA	95	16	15	Yes	2	60	100	174	268	300	54	181	121		15	Sand dry to 4 in., moist below
40		Makua	FDA	100	15	15	Yes	2	36	178	240	270+	300+	56	213+	136+		10	Sand dry to 6 in., moist below, wheels spinning
41		Makua	FDA	98	15	15	Yes	2	48	90	124	170	230	43	125	85		12	Sand dry to 6 in., moist below
42		Makua	FDA	97	14	15	No	2	68	116	176	300+	300+	62	197	132		1.5	Sand dry to 4 in., moist below
43		Makua	FDA	96	11	15	No	5	66	136	252	300+	300+	69	229	152		1.5	Sand dry to 4 in., moist below
44		Makua	FDA	99	11	15	No	2	55	123	176	250	252+	60	183	121		2	Sand moist, easy travel
45		Makua	BBB	22	6	15	No	5	32	77	127	128	108	36	106	71		5	Sand moist
46		Makua	BC	32	5	15	No	2	28	83	103	112	190	38	99	66		7	Sand moist, easy travel
47		Makua	BBB	92	5	15	Yes	2	27	60	89	104	104	30	84	56		9.5	Sand moist, wheels spinning

(Continued)

* See "Beach Terms" under "Definitions" in text.

Table 5 (Continued)

Item No.	Location	Beach	Beach Area	Test No.	Slope %	Tire Pressure psi	Immobilized	Cone Index at Depth of 0 in.	3 in.	6 in.	9 in.	12 in.	15 in.	Cone Index Averages by Soil Layers 0- to 6-in.	3- to 12-in.	0- to 12-in.	Rut Size, in. Width	Depth	Remarks
Pacific Islands Test Program - M215 Truck (Continued)																			
Vehicle Test Weight 19,820 lb, Approximate Load 5,000 lb (Continued)																			
48	Oahu (Cont'd)	Mahana	BBS	93	3	15	No	2	30	84	148	180	224	39	137	89		7	Sand moist, easy travel
49		Mahana	BBS	94	3	15	No	2	35	64	74	74	70	34	71	50		9	Sand moist, easy travel
50		Makua	BC	36	2	15	No	2	31	76	79	56	54	36	70	49		8	Sand moist
51		Makua	BC	37	2	15	No	2	33	68	83	103	108	34	85	58		8	Sand moist, easy travel
52		Makua	FDA	39	18	10	Yes	2	46	106	192	276	300	51	191	124		7	Sand dry to 6 in., moist below, wheels spinning
53		Makua	FDA	40	14	10	No	2	40	97	197	255	300	46	183	118		6	Sand dry to 6 in., moist below, easy travel
54		Makua	BBS	23	6	10	No	5	32	70	127	122	108	36	106	71		4	Sand moist, easy travel
55		Makua	FB	24	0	10	Yes	2	34	60	80	95	86	32	78	54		18	Sand inundated frequently by surf, quick cond
56		Mokuleia	BC	28	0	10	No	1	14	28	37	56	90	14	40	27		6	Sand moist, easy travel
57		Makua	FB	29	0	10	No	2	32	90	120	143	184	41	118	77		4	Sand moist, easy travel
Yuma Test Program - M135 Truck																			
Vehicle Test Weight, 12,450 lb, No Load																			
58	Dune area			B-75	10.5	30	No	5	87	148	252	296	---	80	232	158	13.5	3.5	Sand dry on surface, moist below
59				B-73	10.5	30	Yes	5	87	148	252	296	300+	80	232	158	13.5	3.5	
60				B-71	9	30	Yes	5	100	208	292	300+	---	104	267	181	----	---	
61				B-72	8	30	No	5	116	204	280	300+	---	108	261	181	12.0	2.5	
62				B-76	8	30	Yes	5	76	120	194	230	---	67	181	125	15.0	3.0	
63				B-77	7	30	No	5	98	140	176	144	142	80	153	113	14.0	4.5	
64				B-73	7	30	Yes	5	73	126	186	228	180	68	180	124	----	---	
65				B-74	6	30	No	5	71	150	252	292	---	75	231	154	14.0	3.5	
66				B-85	15	20	Yes	5	67	112	160	216	242	61	163	112	----	---	
67				B-83	14	20	Yes	10	72	133	193	188	215	72	171	119	----	---	
68				B-80	13	20	Yes	10	68	140	288	300+	---	73	243	161	14.0	2.5	
69				B-81	12	20	Yes	5	94	168	248	280	292	89	232	159	----	---	
70				B-86	11	20	No	5	106	164	300+	---	---	92	---	---	11.0	2.5	
71				B-84	10	20	No	10	101	172	225	190	229	94	196	140	12.5	2.0	
72				B-82	10	20	No	5	98	170	288	240	252	91	213	148	10.5	1.25	
73				B-79	9	20	No	5	90	154	244	252	236	83	217	149	15	3.0	
74				B-93	20	15	Yes	5	67	80	108	126	154	64	105	73	----	---	
75				B-87	19	15	Yes	10	89	117	120	96	50	72	111	96	----	---	
76				B-94	18	15	No	10	120	203	296	300+	---	111	266	186	13.0	2.00	
77				B-92	17.5	15	No	10	91	183	270	300+	---	95	251	171	14.0	1.50	
78				B-88	17	15	No	10	108	158	208	222	272	92	196	141	12.0	1.50	
79				B-89	15	15	No	10	114	166	208	252	254	90	202	146	13.0	2.0	
80				B-95	15	15	Yes	5	40	62	68	92	104	29	67	49	----	---	
81				B-90	12	15	Yes	10	60	93	103	132	172	54	111	81	----	---	
82				B-91	9	15	No	10	70	126	206	280	300+	69	204	136	12.0	2.0	
83				B-96	24	10	No	5	98	184	276	300+	---	96	253	173	----	---	
84				B-98	22	10	Yes	5	39	72	96	110	126	39	96	66	19.0	4.5	
85				B-99	22	10	Yes	5	40	37	35	15	35	27	36	30	----	---	
86				B-100	21.5	10	Yes	5	42	58	41	55	36	33	43	35	----	---	
87				B-102	20	10	Yes	5	83	77	91	112	69	55	93	74	----	---	
88				B-101	14	10	No	5	113	156	250	300+	---	91	236	165	16.0	1.5	
89				B-97	14.5	10	No	5	67	80	104	126	154	64	103	72	----	---	
Vehicle Test Weight 15,000 lb, Approximate Load 2,500 lb																			
90	Pass area			B-117	17	20	Yes	5	108	170	296	288	300+	94	288	159	----	---	Sand dry on surface, moist below
91				B-119	16	20	No	5	94	156	228	276	300+	85	220	152	----	---	
92				B-120	12	20	Yes	5	72	94	115	173	300+	57	171	92	----	---	
93				B-118	11	20	No	5	124	174	244	288	300+	109	236	167	----	---	

(Continued)

Table 6 (Continued)

Item No.	Location	Beach	Beach Area	Test No.	Slope %	Tire Pressure psi	Immobilized	Cone Index at Depth of 0 in.	3 in.	6 in.	9 in.	12 in.	15 in.	Cone Index Averages by Soil Layers 0- to 6-in.	6- to 12-in.	0- to 12-in.	Rut Size, in. Width	Depth	Remarks
								Yuma Test Program - M135 Truck (Continued)											
								Vehicle Test Weight 15,000 lb, Approximate Load 2,500 lb (Continued)											
94	Dune area (Cont'd)			B-116	36	15	Yes	5	90	114	166	235	284	70	172	122	----	---	Sand dry on surface, moist below
95				B-115	24	15	No	5	94	138	186	266	296	79	197	136	13.5	2.0	
96				B-114	24	15	Yes	5	84	107	118	127	142	67	117	88	----	---	
97				B-111	23	15	No	5	129	195	252	300+	---	103	249	176	----	---	
98				B-110	20	15	No	5	132	172	256	300+	---	96	243	169	12.0	1.25	
99				B-113	20	15	No	5	96	152	204	276	300+	84	211	147	12.0	1.50	
100				B-112	14	15	Yes	5	61	91	117	163	197	52	124	87	----	---	
101				B-106	30	10	Yes	5	70	136	244	296	300+	70	225	150	----	---	
102				B-108	27	10	Yes	5	64	126	264	300+	---	65	230	152	----	---	
103				B-107	25	10	No	5	78	170	268	300+	---	84	246	164	----	---	
104				B-103	25	10	No	10	91	162	231	288	---	82	227	156	----	---	
105				B-105	24	10	Yes	10	84	107	118	129	142	67	118	90	----	---	
106				B-104	22.5	10	No	10	102	144	232	280	292	85	219	154	----	---	
107				B-109	22	10	No	5	62	96	136	142	220	56	125	89	18.5	4.5	
								Vehicle Test Weight 17,330 lb, Approximate Load 5,000 lb											
108	Dune area			B-39	13	30	No	5	72	142	256	300+	---	73	233	155	----	---	Sand dry on surface, moist below
109				B-38	11	30	Yes	5	71	140	296	296	300+	72	231	154	----	---	
110				B-36	11	30	Yes	5	53	80	105	193	210	46	126	87	----	---	
111				B-34	11	30	Yes	5	73	145	194	232	264	76	190	131	----	---	
112				B-31	10	30	No	5	100	166	272	292	300+	90	243	167	----	---	
113				B-30	10	30	Yes	5	76	125	234	276	288	69	212	143	----	---	
114				B-29	10	30	No	8	85	166	236	284	300+	86	229	156	----	---	
115				B-28	10	30	Yes	8	93	146	194	220	241	82	187	132	----	---	
116				B-37	9.5	30	No	5	83	156	238	292	300+	81	229	155	----	---	
117				B-32	8.5	30	Yes	5	65	99	141	197	232	56	146	101	----	---	
118				B-33	7	30	No	6	92	172	244	288	300+	90	235	160	----	---	
119				B-35	6	30	No	5	79	129	127	158	216	70	138	100	----	---	
120				B-44	18	20	No	7	108	152	212	236	240	89	200	143	----	---	
121				B-40	16	20	Yes	8	86	128	184	208	180	74	173	123	----	---	
122				B-42	14	20	Yes	10	96	134	252	284	290	80	223	155	----	---	
123				B-47	13	20	Yes	5	48	78	76	59	73	44	71	53	----	---	
124				B-46	12	20	Yes	7	54	73	88	120	172	45	94	65	----	---	
125				B-45	12	20	No	5	104	174	298	300+	---	94	257	176	----	---	
126				B-48	11.5	20	No	10	110	149	184	300+	---	87	211	151	----	---	
127				B-43	10	20	No	5	84	114	192	242	296	68	183	127	----	---	
128				B-41	8	20	No	5	70	94	174	267	286	56	178	122	----	---	
129				B-53	20	15	No	10	100	160	264	300+	---	90	241	167	----	---	
130				B-52	19	15	No	10	96	154	252	300+	---	87	235	162	----	---	
131				B-51	18.5	15	Yes	5	84	132	286	284	300	74	214	146	----	---	
132				B-56	18	15	No	5	113	156	260	288	300+	91	235	164	----	---	
133				B-54	16	15	Yes	5	54	56	66	68	76	38	63	50	----	---	
134				B-58	15	15	No	10	82	100	178	254	292	64	177	125	----	---	
135				B-49	13	15	Yes	5	48	78	76	59	73	44	71	53	----	---	
136				B-50	11.5	15	No	10	110	149	184	300+	---	89	211	151	----	---	
137				B-57	11	15	Yes	5	87	156	240	300+	---	83	239	162	----	---	
138				B-55	10.5	15	No	5	134	172	252	190	186	94	205	145	----	---	
139				B-67	30	10	Yes	10	50	64	96	128	164	41	96	70	----	---	
140				B-68	28	10	Yes	5	65	113	107	112	196	68	111	84	----	---	
141				B-69	24.5	10	Yes	5	80	144	210	272	300+	75	209	142	----	---	
142				[illegible]	24	10	Yes	5	167	130	161	200	294	94	164	129	----	---	
143				B-66	23.5	10	No	10	79	137	186	177	172	75	167	118	----	---	
144				B-70	22.5	10	Yes	5	100	84	77	100	132	63	87	73	----	---	

(Continued)

Table 6 (Continued)

Item No.	Location	Beach	Beach Area	Test No.	Slope %	Tire Pressure psi	Immobilized	Cone Index at Depth of 0 in.	1 in.	6 in.	9 in.	12 in.	15 in.	Cone Index Averages by Soil Layers 0- to 6-in.	6- to 12-in.	0- to 12-in.	Rut Size, in. Width	Depth	Remarks
								Yuma Test Program - M135 Truck (Continued)											
								Vehicle Test Weight 17,330 lb, Approximate Load 5,000 lb (Continued)											
145	Dune area (Cont'd)			B-64	21.5	10	Yes	10	116	225	224	235	249	117	229	163	----	---	Sand dry on surface, moist below
146				B-62	20	10	No	5	82	148	200	264	288	78	204	140	----	---	
147				B-65	19	10	No	10	88	110	143	183	253	69	145	107	----	---	
148				B-60	17	10	No	9	110	98	152	236	292	72	162	121	----	---	
149				B-59	16	10	No	5	57	76	90	95	178	46	87	65	----	---	
150				B-61	15	10	No	5	112	176	244	300+	---	98	240	167	----	---	
								Vehicle Test Weight 20,500 lb, Approximate Load 7,500 lb											
151	Dune area			B-9	19	30	Yes	10	121	193	289	300+	---	108	261	183	----	---	Sand dry on surface, moist below
152				B-8	18	30	Yes	10	125	193	283	300+	---	109	259	182	----	---	
153				B-12	16	30	Yes	10	91	137	175	194	181	79	168	121	----	---	
154				B-7	15	30	Yes	10	129	202	284	300+	---	114	262	185	----	---	
155				B-6	13	30	No	10	113	208	280	300+	---	115	263	182	----	---	
156				B-5	13	30	Yes	10	103	183	231	285	300+	99	233	162	----	---	
157				B-4	12	30	No	10	113	190	260	300+	---	104	250	175	----	---	
158				B-1	12	30	No	10	97	148	220	297	300+	85	222	154	----	---	
159				B-11	11	30	Yes	10	121	132	182	194	227	88	169	128	----	-	
160				B-10	10	30	No	10	154	193	244	299	296	119	245	180	----	---	
161				B-2	10	30	Yes	10	70	100	148	175	183	60	141	101	----	---	
162				B-3	9	30	No	10	105	162	255	300+	300+	92	239	166	----	---	
163				B-19	22	20	Yes	10	135	178	235	288	300+	108	234	169	----	---	
164				B-18	22	20	No	10	126	167	236	280	300+	101	228	164	----	---	
165				B-16	20	20	No	10	120	196	282	292	300+	109	257	180	----	---	
166				B-15b	19	20	Yes	10	123	165	264	296	200+	99	242	172	----	---	
167				B-13a	16	20	Yes	10	107	167	206	198	177	95	190	138	----	---	
168				B-17	15	20	No	10	140	212	300+	300+	---	121	271	192	----	---	
169				B-14	14	20	No	10	123	138	134	252	296	90	195	143	----	---	
170				B-15a	13	20	No	10	123	165	264	296	300+	99	242	172	----	---	
171				B-13b	12	20	No	10	107	167	206	198	199	95	190	138	----	---	
172				B-20	22	15	Yes	5	59	126	217	264	280	63	202	134	----	---	
173				B-22	16	15	No	3	42	64	100	132	144	36	99	68	----	---	
174				B-23	16	15	No	5	61	117	196	272	300+	61	195	130	----	---	
175				B-21	15.5	15	No	5	60	110	170	220	184	58	167	113	----	---	
176				B-27	22.5	10	No	10	86	144	244	268	288	80	219	150	----	---	
177				B-26	22	10	Yes	5	59	126	217	264	280	63	202	134	----	---	
178				B-24	14.5	10	No	5	61	117	196	272	300+	61	195	130	----	---	
179				B-25	12	10	No	3	42	64	100	132	144	36	99	68	----	---	
								Camp Lejeune Test Program - M135 Truck											
								Vehicle Test Weight 17,450 lb, Approximate Load 5,000 lb											
180	Onslow Beach		FMA	226	15	40	Yes	13	90	206	300+	---	---	103	---	---			Moist sand
181			FMA	229	15	40	Yes	17	113	212	300+	---	---	115	---	---			
182			FMA	227	14	40	Yes	16	100	201	300+	---	---	106	---	---			
183			FMA	223	12	40	Yes	15	91	207	300+	---	---	104	---	---			
184			FMA	222	11.5	40	Yes	15	75	174	300+	---	---	88	---	---			
185			FMA	224	8	40	No	20	145	223	300+	---	---	129	---	---			
186			FMA	230	8	40	No	27	137	221	300+	---	---	128	---	---			
187			FMA	225	6	40	No	30	174	300+	---	---	---	167+	---	---			
188			FMA	228	5	40	No	19	153	300+	---	---	---	157+	---	---			
189			FMA	231	20	30	Yes	29	117	217	300+	---	---	119	---	---			

(Continued)

Table 6 (Continued)

Item No.	Location	Beach	Beach Area	Test No.	Slope %	Tire Pressure psi	Immobilized	Cone Index at Depth of 0 in.	3 in.	6 in.	9 in.	12 in.	15 in.	Cone Index Averages by Soil Layers 0- to 6-in.	6- to 12-in.	0- to 12-in.	Rut Size, in. Width	Depth	Remarks
								Camp Lejeune Test Program - M135 Truck (Continued)											
								Vehicle Test Weight 17,450 lb, Approximate Load 5,000 lb (Continued)											
190	Onslow		FDA	231	14	30	Yes	16	86	172	300+	---	---	91	---	---			Moist sand
191	Beach		FDA	235	13	40	Yes	29	75	100	119	128	280+	65	116	88			
192	(Cont'd)		FDA	234	12	30	No	20	91	166	300+	---	---	92	---	---			
193			FDA	236	12	40	Yes	19	85	188	300+	---	---	96	---	---			
194			FDA	238	12	30	No	21	[illegible]	[illegible]	220	---	---	97	228	162			
195			FDA	232	11	30	No	[illegible]	85	170	300+	---	---	89	---	---			
196			FDA	237	11	40	No	[illegible]	99	203	300+	---	---	108	---	---			
197			FDA	241	28	20	Yes	20	91	198	300+	---	---	103	---	---			
198			FDA	239	26	20	Yes	21	118	225	300+	---	---	121	---	---			
199			FDA	247	25	20	Yes	32	142	198	300+	---	---	124	---	---			
200			FDA	248	25	20	Yes	36	106	158	220	300+	---	98	226	162+			
201			FDA	243	24	20	Yes	21	119	184	300+	---	---	108	---	---			
202			FDA	244	22	20	Yes	29	149	245	300+	---	---	141	---	---			
203			FDA	242	19	20	No	28	131	201	300+	---	---	120	---	---			
204			FDA	245	19	20	No	22	132	235	300+	---	---	130	---	---			
205			FDA	246	18	20	No	30	129	214	300+	---	---	124	---	---			
206			FDA	240	15	20	No	23	126	220	300+	---	---	123	---	---			
207			FDA	220	20	15	No	31	149	239	300+	---	---	140	---	---			
208			FDA	221	20	15	No	30	179	260	300+	---	---	159	---	---			
209			FDA	250	35	10	Yes	32	137	236	300+	---	---	135	---	---			
210			FDA	253	35	10	Yes	24	114	160	240	300+	---	99	237+	170+			
211			FDA	251	33	10	No	33	143	238	300+	---	---	138	---	---			
212			FDA	255	30	10	No	24	129	242	300+	---	---	132	---	---			
213			FDA	249	27	10	No	20	116	184	268	300+	---	107	251+	178+			
214			FDA	254	26	10	No	25	82	182	272	300+	---	96	251+	172+			
215			FDA	252	25	10	No	31	137	238	300+	---	---	135	---	---			
216			FDA	256	22	10	No	25	128	224	300+	---	---	126	---	---			

Table 7

Summary of Data and Test Results, Single Self-propelled Vehicle Tests

5-ton M41, 6x6 Truck (Six 14.00x20 Tires)

Yuma Test Program -- Dune Area

Item No.	Test No.	Slope %	Tire Pressure psi	Immobilized	Cone Index at Depth of 0 In.	3 In.	6 In.	9 In.	12 In.	15 In.	Cone Index Averages by Soil Layers 0- to 6-in.	6- to 12-in.	0- to 12-in.	Rut Size, in. Width	Depth	Remarks
								Vehicle Test Weight 18,115 lb, No Load								
1	357	13	30	Yes	5	54	108	138	180	219	59	143	99	------	-----	Sand dry on
2	360	12.5	30	Yes	5	77	151	228	292	294	78	124	151	------	-----	surface,
3	361	11.5	30	Yes	5	50	84	116	176	219	46	125	86	------	-----	moist below
4	356	11	30	Yes	5	70	91	107	142	185	55	113	83	------	-----	
5	363	10	30	Yes	5	59	110	163	272	300	58	182	122	------	-----	
6	365	9.5	30	Yes	5	55	91	120	153	208	54	121	86	------	-----	
7	367	9	30	No	5	104	150	168	162	156	86	160	118	16-1/2	3-1/2	
8	366	7	30	No	5	100	170	240	292	300+	92	234	161	14	1-1/2	
9	364	7	30	No	5	99	173	232	290	300+	98	232	160	15	3	
10	358	7	30	Yes	5	60	134	141	180	230	58	142	99	------	-----	
11	362	6.5	30	No	5	63	148	232	300+	---	69	223	148	------	-----	
12	359	5	30	No	5	82	129	180	243	300+	72	184	128	14	4	
13	348	23	20	Yes	5	74	110	191	266	292	63	189	129	------	-----	
14	341	18	20	No	5	77	162	220	226	224	81	203	138	14	2-1/2	
15	344	18	20	Yes	5	60	90	100	120	132	56	105	78	------	-----	
16	346	16	20	Yes	5	36	44	56	62	56	28	54	41	------	-----	
17	343	15	20	No	5	80	116	206	262	300+	68	195	134	15	2-1/2	
18	351	14	20	Yes	5	71	92	133	192	244	55	139	99	------	-----	
19	347	14	20	Yes	5	24	37	35	34	40	22	35	27	------	-----	
20	342	13	20	No	5	75	116	177	212	85	65	168	117	------	-----	
21	345	13	20	No	10	102	174	254	296	300+	95	242	167	14-1/2	2-1/2	
22	350	12.5	20	No	10	84	130	188	232	280	75	183	129	14-3/4	2-1/4	
23	353	12	20	No	5	84	123	176	208	296	71	160	114	14	1	
24	352	11	20	No	5	82	126	176	222	260	71	175	122	17-1/2	3-1/2	
25	354	11	20	No	5	78	109	155	169	196	64	144	10	19	4	
26	355	11	20	No	5	67	92	114	153	192	55	120	86	------	-----	
27	349	6.5	20	No	5	72	105	156	176	200	61	146	103	------	-----	
28	332	28	15	Yes	5	44	104	188	288	300+	51	193	122	------	-----	Sand wet to
29	337	25.5	15	Yes	5	46	64	88	156	190	39	103	72	------	-----	1 in.,
30	334	24.5	15	No	5	74	162	228	300+	---	86	230	154	15-1/2	1-1/2	moist below
31	332	24	15	Yes	5	70	86	84	134	138	54	105	78	------	-----	
32	333	22.5	15	Yes	5	42	68	79	104	106	38	84	60	------	-----	
33	330	21.5	15	Yes	5	46	81	12	132	235	44	128	87	------	-----	
34	331	20.5	15	No	5	62	138	222	300+	---	58	220	145	15	1-1/4	
35	328	20	15	Yes	5	40	70	91	114	154	48	92	64	------	-----	
36	340	18	15	No	5	56	132	236	300+	---	64	223	146	15	1	
37	339	18	15	No	5	54	120	136	160	244	59	149	101	17	4	
38	329	17.5	15	No	5	46	80	102	140	156	44	103	72	16	2-1/2	
39	338	16.5	15	Yes	5	54	74	79	101	127	44	95	62	------	-----	
40	337	15	15	No		48	106	180	262	300+	53	183	120	16		
41	319	48	10	Yes		51	60	52	48	48	39	53	43	------	-----	
42	324	31	10	Yes	5	68	73	91	188	270	46	117	85	------	-----	
43	325	28	10	No	5	52	101	176	250	300+	54	177	118	15-1/2	1	
44	322	28	10	Yes	5	40	76	92	138	216	40	102	70	------	-----	
45	321	27	10	Yes	5	30	44	44	68	74	26	52	38	------	-----	
46	323	26.5	10	No	5	56	140	216	300+	---	68	219	143	19	2-1/2	
47	326	24.5	10	No	5	48	74	96	155	200	42	108	76	15-1/2	2	
48	327	23.5	10	No	5	48	66	60	58	80	39	61	47	------	-----	
49	318	20	10	No	5	32	74	90	148	146	37	104	70	17	1	
50	320	19	10	No	5	28	66	108	168	212	33	114	75	16-1/2	1-1/2	
								Vehicle Test Weight 24,275 lb, Approximate Load 5,000 lb								
51	292	15	30	Yes	5	54	136	214	300+	---	62	213	140	------	-----	Sand dry on
52	285	11	30	Yes	5	51	101	141	210	300+	52	151	106	------	-----	surface,
53	287	11	30	Yes	5	56	134	200	266	300+	65	200	132	------	-----	moist below
54	286	9.5	30	No	5	64	144	172	192	260	71	169	115	18	3-1/4	
55	289	7	30	Yes	5	55	86	110	168	216	49	121	85	------	-----	
56	290	9	30	No	5	66	130	184	288	300+	67	201	135	15	2	
57	288	8	30	No	5	94	112	188	292	300+	70	197	138	18	3	
58	293	7	30	No	5	78	178	254	300+	---	87	244	163	15	2	
59	291	6	30	Yes	5	44	104	156	166	198	51	140	94	------	-----	
60	294	5	30	No	5	78	156	224	170	118	79	184	127	------	-----	
61	299	24	20	Yes	5	86	132	130	124	170	74	129	95	------	-----	
62	302	23.5	20	No	5	72	126	172	284	300+	68	194	132	16-1/2	2	
63	303	22	20	Yes	5	84	136	180	252	292	75	189	131	------	-----	
64	301	21.5	20	No	5	86	162	222	272	264	84	219	149	15	1-1/2	
65	298	21	20	No	5	80	158	232	296	300+	81	229	154	16	1-1/2	
66	304	20	20	Yes	5	44	90	142	258	300+	46	163	108	------	-----	
67	297	17	20	Yes	5	43	86	134	140	170	46	110	77	------	-----	
68	305	16	20	No	5	61	120	152	206	241	63	159	109	15	2	
69	300	15	20	Yes	5	98	98	91	104	140	94	98	71	------	-----	
70	296	13.5	20	No	5	73	154	204	300+	---	77	226	151	15-1/2	1-1/2	
71	295	10	20	No	5	48	84	106	180	120	46	103	73	16-1/2	3	
72	311	29	15	Yes	5	48	116	176	296	300+	56	203	138	------	-----	Sand wet to
73	313	26.5	15	Yes	5	80	140	171	156	154	75	156	110	------	-----	1 in.,
74	312	26	15	No	5	62	126	216	300+	---	64	214	142	17	1-1/2	moist below
75	309	25	15	Yes	5	58	96	140	[illegible]	276	57	153	103	------	-----	
76	314	24	15	No	5	80	148	236	300+	---	[illegible]	243	156	16-1/2	1-1/2	
77	308	[illegible]	15	No	5	60	94	[illegible]	[illegible]	300+	53	[illegible]	125	17-1/2	2-1/2	
78	307	[illegible]	15	No	5	[illegible]	146	196	[illegible]	300+	[illegible]	197	132	16-1/2	3	
79	306	[illegible]	15	Yes	5	[illegible]	[illegible]	168	177	[illegible]	51	[illegible]	87	------	-----	
80	310	18.5	15	No	5	[illegible]	[illegible]	300+	---	---	105	---	---	15-1/2	1	
81	[illegible]	[illegible]	10	Yes	5	[illegible]	[illegible]	[illegible]	150	[illegible]	[illegible]	[illegible]	[illegible]	------	-----	
82	[illegible]	[illegible]	10	No	5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	79	175	117	------	-----	
83	[illegible]	[illegible]	10	No	5	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	111	77	------	-----	
84	[illegible]	[illegible]	10	No	5	[illegible]	[illegible]	[illegible]	[illegible]	300+	[illegible]	[illegible]	[illegible]	[illegible]	1-1/4	

(Continued)

Sheet 1 of 2 sheets

Table 7 (Continued)

Item No.	Test No.	Slope %	Tire Pressure psi	Immobilized	Cone Index at Depth of 0 in.	3 in.	6 in.	9 in.	12 in.	15 in.	Cone Index Averages by Soil Layers 0- to 6-in.	6- to 12-in.	0- to 12-in.	Rut Size, in. Width	Depth	Remarks
							Vehicle Test Weight 28,175 lb, Approximate Load 10,000 lb									
85	278	24	10	No	5	51	76	85	105	158	54	89	70	24	5	
86	281	23.5	10	No	5	72	110	130	148	168	62	129	93	------	-----	
87	282	23	10	Yes	5	53	63	70	83	116	40	75	56	------	-----	
88	284	23	10	No	10	128	176	232	288	---	105	232	167	18	1-1/2	
89	283	22.5	10	No	10	54	85	122	150	210	49	119	84	23	4-1/4	
90	279	20	10	No	10	106	152	140	168	188	89	156	117	------	-----	
91	243	16	30	Yes	5	107	160	212	264	292	91	212	150	------	-----	Sand wet to 1 in., moist below
92	240	16	30	Yes	5	61	72	68	79	74	46	70	55	------	-----	
93	236	12.5	30	Yes	5	64	112	138	236	264	60	179	121	19-1/2	3-1/2	
94	237	10.5	30	No	5	64	145	218	268	300+	71	210	140	------	-----	
95	244	10.5	30	No	10	100	143	198	258	288	84	200	142	------	-----	
96	242	10	30	Yes	5	86	160	208	256	292	84	208	143	------	-----	
97	241	10	30	No	5	85	138	198	236	264	76	189	131	20-1/2	4-3/4	
98	239	9	30	Yes	5	53	79	113	154	206	45	[illegible]	81	------	-----	
99	238	7	30	No	5	71	96	160	246	296	57	167	116	20-1/2	5	
100	249	22	20*	Yes	5	62	121	178	228	268	63	176	119	------	-----	
101	248	21	20	No	5	86	120	162	208	260	70	163	116	18-1/2	2	
102	251	20.5	20	Yes	5	75	82	71	61	58	54	71	59	------	-----	
103	253	20	20	Yes	5	85	122	169	178	192	71	156	112	------	-----	
104	252	19	20	No	10	133	182	254	288	---	108	241	173	16	1-1/4	
105	247	19	20	Yes	5	38	30	32	37	39	24	32	28	------	-----	
106	246	18	20	Yes	5	30	35	41	47	44	23	41	32	------	-----	
107	255	15.5	20	Yes	5	67	90	133	166	176	54	130	92	------	-----	
108	250	15	20	No	10	97	122	184	234	276	73	180	127	18-1/2	2-1/2	
109	245	14	20	No	10	119	176	248	296	300+	102	240	170	16-1/2	1-1/2	
110	256	13	20	Yes	5	50	83	106	137	178	46	129	76	------	-----	
111	254	11.5	20	No	5	93	134	171	212	248	77	172	123	22-1/2	5-1/4	
112	262	27	15	Yes	5	61	57	59	57	63	41	58	48	------	-----	
113	258	25	15	Yes	10	77	120	180	216	228	69	172	121	------	-----	
114	261	25	15	No	10	120	[illegible]	284	300+	---	177	259	181	18-1/2	[illegible]	
115	263	23.5	15	No	10	116	172	220	252	292	99	215	154	18	1-1/2	
116	260	23	15	No	10	82	130	164	212	252	74	169	120	19	2-1/2	
117	257	21.5	15	No	10	122	174	220	260	286	102	218	157	18	2	
118	264	20.5	15	Yes	10	50	68	88	158	188	43	105	75	------	-----	
119	269	20	15	Yes	10	90	86	82	136	158	62	101	81	------	-----	
120	259	19	15	No	10	95	140	188	252	292	82	193	137	19	2-1/2	
121	265	19	15	No	10	84	56	58	66	81	50	60	55	19	2-1/2	
122	266	19	15	Yes	10	72	95	125	168	204	59	129	94	------	-----	
123	267	18	15	Yes	10	64	80	94	122	146	51	99	74	------	-----	
124	268	18	15	No	10	120	164	236	277	288	98	226	161	24	4	
125	271	29	10	No	5	58	100	152	256	300+	54	169	114	21	2-1/2	
126	274	27	10	No	5	61	57	59	57	63	41	58	48	------	-----	
127	272	25	10	Yes	5	39	65	100	134	152	36	100	79	------	-----	
128	273	22	10	No	5	40	62	96	112	130	36	90	63	25	4-1/2	
129	275	22	10	No	10	46	106	156	208	268	54	157	105	26	5	
130	276	22	10	Yes	10	46	56	82	126	146	37	89	64	------	-----	
131	277	22	10	No	5	73	112	156	228	268	63	165	115	25	4-1/2	
132	270	20	10	No	10	90	86	82	136	158	62	101	81	------	-----	
							Vehicle Test Weight 32,380 lb, Approximate Load 15,000 lb									
133	207	14	30	Yes	5	45	101	186	244	276	50	177	116	------	-----	Sand wet to 1 in., moist below
134	203	11	30	Yes	5	64	126	157	203	283	63	160	110	------	-----	
135	206	10.5	30	Yes	5	49	92	146	204	264	49	147	89	------	-----	
136	204	10	30	No	5	75	158	272	300+	---	79	241	162	------	-----	
137	202	[illegible]	30	No	5	59	120	204	209	264	61	178	119	------	-----	
138	212	10	30	No	5	82	146	200	247	280	78	198	136	------	-----	
139	211	9	30	Yes	5	80	109	132	288	240	65	176	123	------	-----	
140	210	9	30	No	5	101	176	264	300+	---	94	247	169	------	-----	
141	213	8	30	No	5	73	137	186	284	300+	72	202	[illegible]	------	-----	
142	211	8	30	No	5	101	164	224	284	300+	92	221	156	------	-----	
143	21[illegible]	7	30	No	5	78	152	267	297	300+	78	239	160	------	-----	
144	208	6.5	30	No	5	92	128	206	248	264	75	193	135	------	-----	
145	209	6	30	Yes	5	31	72	104	140	174	36	105	75	------	-----	
146	221	20	20	No	8	133	172	229	300+	---	104	235	169	------	-----	
147	224	19	20	No	5	106	163	216	288	300+	91	222	157	------	-----	
148	214	18	20	Yes	5	74	108	124	172	274	62	135	97	------	-----	
149	223	17	20	No	5	108	152	212	272	300+	88	212	150	------	-----	
150	218	16	20	Yes	5	48	136	216	220	244	54	181	119	------	-----	
151	215	15	20	No	5	104	140	200	276	300+	83	205	145	------	-----	
152	220	15	20	Yes	5	98	145	192	268	288	83	204	142	------	-----	
153	222	14	20	Yes	5	85	97	96	69	92	62	77	64	------	-----	
154	219	14	20	No	5	88	136	158	192	272	73	159	114	------	-----	
155	216	12	20	Yes	5	36	68	94	126	156	36	96	66	------	-----	
156	217	10	20	No	5	60	118	212	292+	---	61	207	133	------	-----	
157	234	26.5	15	Yes	5	84	112	107	86	44	67	102	79	------	-----	
158	230	24	15	Yes	5	36	48	51	54	56	29	51	37	------	-----	
159	235	21	15	No	10	136	187	240	288	225	110	218	160	20	2-1/2	
160	231	21	15	Yes	5	40	46	52	51	57	30	50	37	------	-----	
161	227	20.5	15	No	5	71	108	67	70	90	61	82	64	------	-----	
162	232	18.5	15	Yes	5	56	70	100	86	99	43	85	63	------	-----	
163	229	18	15	No	5	51	92	105	132	146	49	110	77	------	-----	
164	228	16	15	No	7	80	74	95	156	224	54	108	82	------	-----	
165	226	16	15	No	5	65	97	117	114	179	56	109	80	------	-----	
166	233	15.5	15	No	5	82	140	224	300+	---	75	181	150	19-1/2	2	
167	225	15	15	No	5	76	136	117	85	70	72	112	83	------	-----	

Table 8

Summary of Data and Test Results, Towing Tests

Yuma Test Program

Item No.	Test Area	Test No.	Slope %	Tire Pressure psi	Drawbar Pull lb	Wheel Slip %	Drawbar Pull % of Test Weight	Cone Index 0- to 6-in. Depth before Traffic	Remarks
	Wheeled Vehicles								
	1/4-ton M38A1, 4x4 Truck, Test Weight 2,975 lb								
1	Yuma Test Station	47	0	30	280*	----	9.4	14	Moist sand
2		48	0	20	450*	----	15.2	14	
3		49	0	15	550*	----	18.5	14	
4		50	0	10	790*	----	26.6	14	
5		52A	10	15	0	----	----	24	Moist sand, could not pull enough to register
6		52B	10	15	200*	----	6.7	24	
7	Dune area	94A	1	10	800*	----	26.9	89	Dry sand on surface, moist below
8		94B	1.5	10	800*	----	26.9	102	
9		94C	2	10	700*	----	23.5	132	
10		94D	2	10	700*	----	23.5	1[illegible]	
	3/4-ton M37, 4x4 Truck, Test Weight 7,085 lb								
11	Yuma Test Station	54	0	30	800*	----	11.3	19	Moist sand
12		55	0	20	1,300*	----	18.4	19	
13		56	0	15	1,600*	----	22.6	19	
14		57	0	10	1,400*	----	19.7	19	
15		53	10	15	1,000*	----	14.1	27	
16	Dune area	91B	1	15	1,900*	----	26.8	120	Dry sand on surface, moist below
17		91A	4	15	1,400*	----	19.8	92	
18		88	6.5	15	1,200*	----	16.9	108	
19		90A	6.5	15	1,200*	----	16.9	11[illegible]	
20		89	10	15	1,000*	----	14.1	112	
21		90B	10	15	1,100*	----	15.5	122	
22		92B	0	10	1,900*	----	26.8	112	
23		92A	2	10	1,800*	----	25.4	108	
24		92C	2.5	10	1,500*	----	21.2	96	
25		93	5	10	1,000*	----	14.1	78	
	2-1/2-ton M135, 6x6 Truck, Test Weight 12,450 lb								
26	Yuma Test Station	42A	0	30	2,000*	14.5	16.1	29	Moist sand
27		42B	0	30	1,800	17.5	14.5	29	
28		42C	0	30	1,800	8.5	14.5	29	
29		42D	0	30	1,200	3.0	9.6	29	
30		42E	0	30	800	1.0	6.4	29	
31		43A	0	20	1,600	4.0	12.9	44	
32		43B	0	20	2,700*	16.5	21.7	44	
33		43C	0	20	2,500	11.5	20.1	44	
34		43D	0	20	2,000	8.5	16.1	44	
35		43E	0	20	2,500	28.5	20.1	44	
36		43F	0	20	2,400	28.0	19.3	44	
37		44A	0	15	1,200	1.5	9.6	19	
38		44B	0	15	2,100	5.0	16.9	19	
39		44C	0	15	2,400	7.0	19.3	19	
40		44D	0	15	2,700	13.5	2[illegible]	19	
41		44E	0	15	3,400*	19.5	27.3	19	
42		44F	0	15	2,800	11.0	22.5	19	
43		45A	0	10	2,300	5.5	18.5	26	
44		45B	0	10	1,000	0	8.0	26	
45		45C	0	10	3,700	12.0	29.7	26	
46		45D	0	10	4,100	16.0	32.9	26	
47		45E	0	10	4,500*	23.0	36.0	26	
48		45F	0	10	4,100	40.0	32.9	26	
49		37	12	30	0	----	----	31	
50		38A	10	30	0	----	----	25	
51		38B	10	20	0	----	----	25	
52		39	10	15	2,000*	----	16.0	25	
53		40	10	10	3,200*	----	25.7	25	
54		41A	12	10	2,900*	----	23.3	31	
55		41B	15	10	2,400*	----	19.2	31	
	2-1/2-ton M135, 6x6 Truck, Test Weight 17,330 lb								
56	Yuma Test Station	23A	0	30	2,200*	15.0	12.7	29	Moist sand
57		23B	0	30	1,600	41.5	9.2	29	
58		23C	0	30	1,500	23.0	8.7	29	
59		23D	0	30	2,000	11.5	11.5	29	
60		24A	0	20	1,000	3.0	5.8	24	
61		24B	0	20	2,500	10.5	14.4	24	
62		24C	0	20	2,300	45.0	13.3	24	
63		24D	0	20	2,200	59.0	12.7	24	
64		24E	0	20	3,000	12.0	17.3	24	
65		24F	0	20	2,600	9.0	15.0	24	
66		24G	0	20	3,200*	18.5	18.5	24	
67		25A	0	15	4,300*	21.0	24.8	19	
68		25B	0	15	3,700	47.5	21.4	19	
69		25C	0	15	3,300	8.0	19.0	19	
70		26A	0	10	3,800	53.5	21.9	19	
71		26B	0	10	3,500	76.0	20.2	19	
72		26C	0	10	5,200*	26.0	30.0	19	
73		18	10	20	1,300*	----	7.5	13	

(Continued)

* Maximum drawbar pull.

Table 8

Summary of Data and Test Results, Towing Tests

Yuma Test Program

Item No.	Test Area	Test No.	Slope %	Tire Pressure psi	Drawbar Pull lb	Wheel Slip %	Drawbar Pull % of Test Weight	Cone Index 0- to 6-in. Depth before Traffic	Remarks
				Wheeled Vehicles					
				1/4-ton M38A1, 4x4 Truck, Test Weight 2,975 lb					
1	Yuma Test Station	47	0	30	280*	----	9.4	14	Moist sand
2		48	0	20	450*	----	15.2	14	
3		49	0	15	550*	----	18.5	14	
4		50	0	10	790*	----	26.6	14	
5		52A	10	15	0	----	----	24	Moist sand, could not pull enough to register
6		52B	10	15	200*	----	6.7	24	
7	Dune area	94A	1	10	800*	----	26.9	89	Dry sand on surface, moist below
8		94B	1.5	10	800*	----	26.9	102	
9		94C	2	10	700*	----	23.5	132	
10		94D	2	10	700*	----	23.5	118	
				3/4-ton M37, 4x4 Truck, Test Weight 7,085 lb					
11	Yuma Test Station	54	0	30	800*	----	11.3	19	Moist sand
12		55	0	20	1,300*	----	18.4	19	
13		56	0	15	1,600*	----	22.6	19	
14		57	0	10	1,400*	----	19.7	19	
15		53	10	10	1,000*	----	14.1	27	
16	Dune area	91B	1	15	1,900*	----	26.8	120	Dry sand on surface, moist below
17		91A	4	15	1,400*	----	19.8	92	
18		88	6.5	15	1,200*	----	16.9	108	
19		90A	6.5	15	1,200*	----	16.9	113	
20		89	10	15	1,000*	----	14.1	112	
21		90B	10	15	1,100*	----	15.5	122	
22		92B	0	10	1,900*	----	26.8	112	
23		92A	2	15	1,800*	----	25.4	108	
24		92C	2.5	10	1,500*	----	21.2	96	
25		93	5	10	1,000*	----	14.1	78	
				2-1/2-ton M135, 6x6 Truck, Test Weight 12,450 lb					
26	Yuma Test Station	42A	0	30	2,000*	14.5	16.1	29	Moist sand
27		42B	0	30	1,800	17.5	14.5	29	
28		42C	0	30	1,800	8.5	14.5	29	
29		42D	0	30	1,200	3.0	9.6	29	
30		42E	0	30	800	1.0	6.4	29	
31		43A	0	20	1,600	4.0	12.9	44	
32		43B	0	20	2,700*	16.5	21.7	44	
33		43C	0	20	2,500	11.5	20.1	44	
34		43D	0	20	2,000	8.5	16.1	44	
35		43E	0	20	2,500	28.5	20.1	44	
36		43F	0	20	2,400	28.0	19.3	44	
37		44A	0	15	1,200	1.5	9.6	19	
38		44B	0	15	2,100	5.0	6.9	19	
39		44C	0	15	2,400	7.0	19.3	19	
40		44D	0	15	2,700	13.5	21.3	19	
41		44E	0	15	3,400*	19.5	27.3	19	
42		44F	0	15	2,800	[illegible]	22.5	19	
43		45A	0	10	2,300	5.5	18.5	26	
44		45B	0	10	1,000	0	8.0	26	
45		45C	0	10	3,700	12.0	29.7	26	
46		45D	0	10	4,100	16.0	32.9	26	
47		45E	0	10	4,500*	23.0	36.0	26	
48		45F	0	10	4,100	40.0	32.9	26	
49		37	12	40	0	----	----	31	
50		38A	10	30	0	----	----	25	
51		38B	10	20	0	----	----	25	
52		39	10	15	2,000*	----	16.0	25	
53		40	10	10	3,200*	----	25.7	25	
54		41A	12	10	2,900*	----	23.3	31	
55		41B	15	10	2,400*	----	19.2	31	
				2-1/2-ton M135, 6x6 Truck, Test Weight 17,130 lb					
56	Yuma Test Station	23A	0	30	2,200*	15.0	12.7	29	Moist sand
57		23B	0	30	1,600	41.5	9.2	29	
58		23C	0	30	1,500	23.0	8.7	29	
59		23D	0	30	2,000	11.5	11.5	29	
60		24A	0	20	1,000	3.0	5.8	24	
61		24B	0	20	2,500	10.5	14.6	24	
62		24C	0	20	2,300	45.0	13.3	24	
63		24D	0	20	2,200	59.0	12.7	24	
64		24E	0	20	3,000	12.0	17.3	24	
65		24F	0	20	2,600	9.0	15.0	24	
66		24G	0	20	3,200*	18.5	18.5	24	
67		25A	0	15	4,300*	21.0	[illegible]	19	
68		25B	0	15	3,700	47.5	[illegible]	19	
69		25C	0	15	3,300	8.0	19.0	19	
70		26A	0	10	3,800	53.5	21.9	19	
71		26B	0	10	3,500	76.0	20.2	19	
72		26C	0	10	5,200*	86.0	30.0	19	
73		18	10	20	1,300*	----	7.5	13	

(Continued)

* Maximum drawbar pull.

Table 8 (Continued)

Item No.	Test Area	Test No.	Slope %	Tire Pressure psi	Drawbar Pull lb	Wheel Slip %	Drawbar Pull % of Test Weight	Cone Index 0- to 6-in. Depth before Traffic	Remarks
				Wheeled Vehicles (Continued)					
				2-1/2-ton M135, 6x6 Truck, Test Weight 17,[illegible]0 lb (Continued)					
74	Yuma Test Station (Continued)	19	10	15	2,000*	----	11.5	13	Moist sand
75		21	14	15	2,000*	----	11.5	14	
76		20	10	10	3,800*	----	21.9	13	
77		22	13	10	2,800*	----	16.2	14	
78	Dune area	183	9	15	2,000*	----	11.5	103	Dry sand on surface, moist below
79		184	9	10	2,400*	----	13.8	97	
				2-1/2-ton M135, 6x6 Truck, Test Weight 22,705 lb					
80	Yuma Test Station	27A	0	30	2,000	10.5	8.8	20	Moist sand
81		27B	0	30	2,300	12.5	10.1	20	
82		27C	0	30	2,500*	17.5	11.0	20	
83		27D	0	30	2,200	36.0	9.7	20	
84		27E	0	30	2,000	46.0	8.8	20	
85		28A	0	20	[illegible]	5.0	13.2	34	
86		28B	0	20	4,100	15.0	18.1	34	
87		28C	0	20	4,200*	20.5	18.5	34	
88		28D	0	20	2,000	6.5	8.8	34	
89		28E	0	20	2,300	62.0	10.1	34	
90		29A	0	15	5,000*	25.0	22.0	30	
91		29B	0	15	4,000	54.0	17.6	30	
92		29C	0	15	4,500	40.0	19.8	30	
93		29D	0	15	2,300	5.0	10.1	30	
94		29E	0	15	3,700	8.0	16.3	30	
95		29F	0	15	4,600	14.5	20.3	30	
96		29G	0	15	4,800	17.5	21.1	30	
97		30A	0	10	3,000	5.0	13.2	31	
98		30B	0	10	3,800	[illegible]	16.7	31	
99		30C	0	10	4,700	9.0	20.7	31	
100		30D	0	10	6,000*	25.5	26.4	31	
101		30E	0	10	5,000	69.0	22.0	31	
102		32	10	20	2,000*	----	8.8	25	
103		33	10	15	4,000*	----	17.2	25	
104		34A	12	15	2,000*	----	8.8	31	
105		34B	15	15	1,600*	----	7.0	31	
106		35A	12	10	3,300*	----	14.5	31	
107		35B	15	10	2,600*	----	11.5	31	
108		36	10	10	3,800*	----	16.7	25	
				5-ton M41, 6x6 Truck, Test Weight 28,175 lb					
109	Yuma Test Station	59	0	30	3,400*	----	12.1	14	Moist sand
110		60	0	20	5,400*	----	19.2	14	
111		61	0	15	6,500*	----	23.1	14	
112		62	0	10	9,000*	----	32.0	14	
113		95A	8	30	1,200*	----	4.3	29	
114		95B	10	30	600*	----	2.1	29	
115		96A	8	20	2,700*	----	9.6	29	
116		96B	10	20	2,500*	----	8.9	29	
117		99	10	15	4,000*	----	14.2	22	
118		97	15	15	2,000*	----	7.1	27	
119		98	15	15	2,200*	----	7.8	27	
120		100	10	10	5,000*	----	17.8	22	
121		101A	13	10	4,200*	----	14.9	20	
122		101B	15	10	4,000*	----	14.2	20	
123		102	20	10	2,800*	----	9.9	42	
				5-ton M54, 6x6 Truck, Test Weight 30,635 lb					
124	Yuma Test Station	105	0	30	3,000*	----	9.8	[illegible]	Moist sand
125		106	0	20	3,900*	----	12.7	[illegible]	
126		107	0	15	5,400*	----	18.[illegible]	[illegible]	
127		108	0	10	6,800*	----	22.2	[illegible]	
128		112	10	15	2,000*	----	[illegible]	--	
129		111	8	10	[illegible]	----	[illegible]	--	
130		110	12	10	[illegible]	----	[illegible]	22	
				Tracked Vehicles					
				1/4-ton M29C Weasel, Test Weight [illegible] lb					
131**	Yuma Test Station	2A	0	--	2,200	13.0	[illegible]	157*	Moist sand
132**		2B	0	--	2,[illegible]00	11.[illegible]	[illegible]	15[illegible]*	
133**		2C	0	--	2,800	11.5	46.9	157*	
134**		2D	0	--	2,[illegible]	12.5	[illegible]	157*	
135**		2E	0	--	[illegible],200*	44.0	58.[illegible]	157*	
136**		2F	0	--	2,500	17.0	46.[illegible]	157*	
137**		2G	0	--	3,400	[illegible]	57.0	157*	
138†		5A	0	--	2,200	10.0	[illegible]	[illegible]	
139†		5B	0	--	3,200	25.[illegible]	[illegible]	[illegible]	
140†		5C	0	--	2,200	[illegible]	[illegible]	14	
141†		5D	0	--	2,800	[illegible]	[illegible]	14	
142†		5E	0	--	3,[illegible]	15.[illegible]	59.[illegible]	14	
143†		5F	0	--	3,[illegible]	26.5	5[illegible].6	14	
144†		5G	0	--	[illegible],400*	41.5	57.[illegible]	14	

(Continued)

* Maximum drawbar pull.
** Tests 131-137 conducted on test lane before harrowing.
† Tests 138-144 conducted on test lane after one pass of the harrow.

Table 8 (Continued)

Item No.	Test Area	Test No.	Slope %	Tire Pressure psi	Drawbar Pull lb	Wheel Slip %	Drawbar Pull % of Test Weight	Cone Index 0- to 6-in. Depth before Traffic	Remarks
				Tracked Vehicles (Continued)					
				1/4-ton M29C Weasel, Test Weight 5,970 lb (Continued)					
145†	Yuma Test Station	5H	0	--	3,000	25.0	50.3	14	Moist sand
146†	(Continued)	5I	0	--	3,250*	55.0	54.4	14	
147†		5J	0	--	3,250*	62.0	54.4	14	
148†		5K	0	--	3,250*	79.0	54.4	14	
149		6A	0	--	3,600	40.0	60.3	5	
150		6B	0	--	3,600	50.0	60.3	5	
151		6C	0	--	1,300	5.0	21.8	5	
152		6D	0	--	3,400	24.0	57.0	5	
153		6E	0	--	700	2.0	11.7	5	
154		6F	0	--	3,500	26.0	58.6	5	
155		6G	0	--	3,700*	37.0	62.0	5	
156		3	20	--	2,000*	----	33.5	44	
157		4	15	--	2,300*	----	38.5	40	
158	Dune area	387	8	--	2,800*	----	46.9	64	Dry sand on surface, moist below
159		389	10	--	2,300*	----	38.5	56	
160		388	14	--	2,600*	----	43.6	90	
				1/4-ton M29C Weasel, Test Weight 6,970 lb					
161	Yuma Test Station	7A	0	--	1,600	7.5	23.0	9	Moist sand
162		7B	0	--	1,500	5.0	21.5	9	
163		7C	0	--	2,400	10.0	34.4	9	
164		7D	0	--	3,800	47.0	54.5	9	
165		7E	0	--	4,400*	40.0	63.1	9	
166		7F	0	--	4,400*	38.0	63.1	9	
167		7G	0	--	2,600	10.0	37.3	9	
168		8A	0	--	1,600	[illegible]	23.0	10	
169		8B	0	--	3,600	12.0	51.6	10	
170		8C	0	--	1,500	[illegible]	21.5	10	
171		8D	0	--	3,000	9.0	43.0	10	
172		8E	0	--	3,400	10.0	48.8	10	
173		8F	0	--	4,200	27.0	60.3	10	
174		8G	0	--	4,200	25.0	60.3	10	
175		8H	0	--	4,500*	[illegible]	64.5	10	
176		8I	0	--	3,600	13.0	51.6	10	
177		10	15	--	2,600*	----	37.3	29	
178		11	15	--	[illegible],000*	----	[illegible]	31	
				18-ton M4A2, Hi-speed Tractor, Test Weight [illegible] lb					
179	Yuma Test Station	374	0	--	20,000*	----	54.2	41	Dry sand to 6 in., moist below
180		376A	8	--	15,000*	----	40.[illegible]	16	
181		376B	12.5	--	15,000*	----	40.6	12	
182		376C	15	--	12,000*	----	32.5	12	
183	Dune area	384	9	--	11,000*	----	23.8	71	Dry sand on surface, moist below
184		386	11	--	10,000*	----	27.1	27	
185		382	15	--	8,000*	----	21.7	[illegible]	
186		385	15	--	9,500*	----	25.7	[illegible]	
187		383	16	--	7,500*	----	20.[illegible]	51	
				38-ton M6, Hi-speed Tractor, Test Weight 76,000 lb					
188	Yuma Test Station	378	0	--	38,000*	----	50.0	41	Dry sand to 6 in., moist below
189		377A	8	--	29,000*	----	38.1	[illegible]	
190		377B	12.5	--	28,000*	----	36.8	12	

* Maximum drawbar pull.
† Tests 14[illegible]-148 conducted on test lane after one pass of the Weasel.

Table 9

Summary of Data and Test Results, Towed-vehicle Tests; Onslow Beach, Camp Lejeune

Item No.	Type of Test Surface*	Test No.	Tire Pressure psi	Towing Force Required lb	Towing Force as % of Test Weight	Cone Index 0- to 6-in. Depth Before Traffic	Cone Index 0- to 6-in. Depth After One Pass	Rut Depth One Pass in.	Average Moisture Content 0- to 6-in. Depth	Sand Condition
	1/4-ton M100 Trailer, Test Weight 569 lb									
1	Asphalt pavement	9	25	12	2.1	---	---	------		
2	Asphalt pavement	10	20	12	2.1	---	---	------		
3	Asphalt pavement	11	15	15	2.6	---	---	------		
4	Asphalt pavement	12	10	18	3.2	---	---	------		
5	Disturbed sand	5	25	30	5.3	156	155	1/2		Wet
6	Disturbed sand	6	20	30	5.3	155	153	0		Wet
7	Disturbed sand	7	15	30	5.3	154	153	0		Wet
8	Disturbed sand	8	10	30	5.3	153	153	0		Wet
9	Undisturbed sand	1	25	22	3.9	176	174	0		Wet
10	Undisturbed sand	2	20	22	3.9	173	174	0		Wet
11	Undisturbed sand	3	15	20	3.5	174	174	0		Wet
12	Undisturbed sand	4	10	18	3.2	174	175	0		Wet
	1/4-ton M100 Trailer, Test Weight 782 lb									
13	Asphalt pavement	63	25	21	2.7	---	---	------		
14	Asphalt pavement	64	20	17	2.2	---	---	------		
15	Asphalt pavement	65	15	17	2.2	---	---	------		
16	Asphalt pavement	66	10	17	2.2	---	---	------		
17	Disturbed sand	18	25	51	6.5	152	152	1/16	4.0	Wet
18	Disturbed sand	19	20	38	4.9	156	156	1/16	4.0	Wet
19	Disturbed sand	20	15	38	4.9	155	155	1/16	4.0	Wet
20	Disturbed sand	21	10	46	5.9	126	125	1/16	4.0	Wet
21	Undisturbed sand	13	25	53	6.8	151	151	1/8	4.0	Wet
22	Undisturbed sand	14	20	60	7.6	147	147	1/8	4.0	Wet
23	Undisturbed sand	16	15	47	6.0	148	148	1/8	4.0	Wet
24	Undisturbed sand	17	10	50	6.4	123	124	1/8	4.0	Wet
	1/4-ton M100 Trailer, Test Weight 1,127 lb									
25	Asphalt pavement	59	25	22	2.0	---	---	------		
26	Asphalt pavement	60	20	22	2.0	---	---	------		
27	Asphalt pavement	61	15	22	2.0	---	---	------		
28	Asphalt pavement	62	10	25	2.2	---	---	------		
29	Disturbed sand	43	25	65	5.8	149	152	1	11.1	Wet
30	Disturbed sand	44	20	56	5.0	110	114	1	11.1	Wet
31	Disturbed sand	45	15	56	5.0	151	152	5/8	11.1	Wet
32	Disturbed sand	46	10	40	3.6	152	153	1/2	11.1	Wet
33	Undisturbed sand	39	25	75	6.7	151	156	1/4	11.1	Wet
34	Undisturbed sand	40	20	87	7.7	151	152	1/4	11.1	Wet
35	Undisturbed sand	41	15	82	7.3	149	151	1/4	11.1	Wet
36	Undisturbed sand	42	10	60	5.3	150	151	1/4	11.1	Wet
	1/4-ton M100 Trailer, Test Weight 1,211 lb									
37	Asphalt pavement	55	25	23	1.9	---	---	------		
38	Asphalt pavement	56	20	23	1.9	---	---	------		
39	Asphalt pavement	57	15	32	2.6	---	---	------		
40	Asphalt pavement	58	10	43	3.6	---	---	------		
41	Disturbed sand	47	25	72	5.9	153	152	3/4	6.2	Wet
42	Disturbed sand	48	20	72	5.9	146	148	1	6.2	Wet
43	Disturbed sand	49	15	60	5.0	150	150	3/4	6.2	Wet
44	Disturbed sand	50	10	54	4.5	150	151	5/8	6.2	Wet
45	Undisturbed sand	51	25	118	9.7	145	147	3/4	6.2	Wet
46	Undisturbed sand	52	20	92	7.6	146	148	1/2	6.2	Wet
47	Undisturbed sand	53	15	75	6.2	151	154	1/4	6.2	Wet
48	Undisturbed sand	54	10	63	5.2	156	157	1/4	6.2	Wet
	3/4-ton M101 Trailer, Test Weight 2,089 lb									
49	Asphalt pavement	132	45	27	1.3	---	---	------		
50	Asphalt pavement	133	30	29	1.4	---	---	------		
51	Asphalt pavement	134	20	32	1.5	---	---	------		
52	Asphalt pavement	135	10	35	1.7	---	---	------		
53	Disturbed sand	91	45	196	9.4	153	154	1-1/2	6.1	Wet
54	Disturbed sand	92	30	149	7.1	153	154	1-1/2	6.1	Wet
55	Disturbed sand	93	20	112	5.4	153	155	1-1/4	6.1	Wet
56	Disturbed sand	94	10	90	4.3	157	157	1	6.1	Wet
57	Undisturbed sand	95	45	150	7.2	167	168	1/8	13.3	Wet
58	Undisturbed sand	96	30	121	5.8	166	167	1/8	13.3	Wet
59	Undisturbed sand	97	20	110	5.3	169	170	1/4	13.3	Wet
60	Undisturbed sand	98	10	100	4.8	172	173	1/16	13.3	Wet

(Continued)

* See "Test Media" terms under "Definitions" in text.

Table 9 (Continued)

Item No.	Type of Test Surface	Test No.	Tire Pressure psi	Towing Force Required lb	Towing Force, as % of Test Weight	Cone Index 0- to 6-in. Depth: Before Traffic	Cone Index 0- to 6-in. Depth: After One Pass	Rut Depth One Pass in.	Average Moisture Content 0- to 6-in. Depth	Sand Condition
				3/4-ton M101 Trailer, Test Weight 2,960 lb						
61	Asphalt pavement	123	45	29	1.0	---	---	------		
62	Asphalt pavement	124	30	32	1.1	---	---	------		
63	Asphalt pavement	125	20	40	1.4	---	---	------		
64	Asphalt pavement	126	10	50	1.7	---	---	------		
65	Disturbed sand	103	45	350	11.8	145	149	1-3/4	4.2	Wet
66	Disturbed sand	104	30	278	9.4	146	147	1-3/8	4.2	Wet
67	Disturbed sand	105	20	220	7.4	145	147	1-1/4	4.2	Wet
68	Disturbed sand	106	10	185	6.2	145	147	3/4	4.2	Wet
69	Undisturbed sand	99	45	210	7.1	160	161	0	19.3	Wet
70	Undisturbed sand	100	30	170	5.7	161	161	1/8	19.3	Wet
71	Undisturbed sand	101	20	195	6.6	152	153	1/4	19.3	Wet
72	Undisturbed sand	102	10	170	5.7	150	151	1/4	19.3	Wet
				3/4-ton M101 Trailer, Test Weight 3,679 lb						
73	Asphalt pavement	119	45	30	0.8	---	---	------		
74	Asphalt pavement	120	30	36	1.0	---	---	------		
75	Asphalt pavement	121	20	42	1.1	---	---	------		
76	Asphalt pavement	122	10	56	1.5	---	---	------		
77	Disturbed sand	107	45	404	11.0	142	144	2	11.0	Wet
78	Disturbed sand	108	30	355	9.6	126	115	1-1/2	11.0	Wet
79	Disturbed sand	109	20	304	8.[illegible]	117	[illegible]	1	11.0	Wet
80	Disturbed sand	110	10	219	6.0	121	124	1/2	11.0	Wet
81	Undisturbed sand	115	45	312	8.5	151	152	1/4	17.1	Wet
82	Undisturbed sand	116	30	230	6.3	160	161	1/4	17.1	Wet
83	Undisturbed sand	117	20	177	4.8	166	167	1/16	17.1	Wet
84	Undisturbed sand	118	10	150	4.1	171	172	1/32	17.1	Wet
				1-1/2-ton M10[illegible] Trailer, Test Weight 4,110 lb						
85	Asphalt pavement	144	45	62	1.5	---	---	------		
86	Asphalt pavement	145	30	62	1.5	---	---	------		
87	Asphalt pavement	146	20	62	1.5	---	---	------		
88	Asphalt pavement	147	10	62	1.5	---	---	------		
89	Disturbed sand	140	45	488	11.9	129	138	1-1/2	9.0	Wet
90	Disturbed sand	141	30	412	10.0	118	105	1-1/4	9.0	Wet
91	Disturbed sand	142	20	550	13.4	95	91	2	9.0	Wet
92	Disturbed sand	143	10	390	9.5	[illegible]	70	1-1/4	9.0	Wet
93	Undisturbed sand	136	45	510	12.4	1[illegible]	100	1	18.6	Wet
94	Undisturbed sand	137	30	420	10.2	[illegible]	106	1	18.6	Wet
95	Undisturbed sand	138	20	350	8.5	[illegible]	112	5/8	18.6	Wet
96	Undisturbed sand	139	10	280	6.8	121	112	1/4	18.6	Wet
				1-1/2-ton M105 Trailer, Test Weight 5,648 lb						
97	Asphalt pavement	148	45	65	1.2	---	---	------		
98	Asphalt pavement	149	30	76	1.3	---	---	------		
99	Asphalt pavement	150	20	76	1.3	---	---	------		
100	Asphalt pavement	151	10	92	1.6	---	---	------		
101	Disturbed sand	152	45	1,017	18.[illegible]	95	[illegible]	2	2.6	Moist
102	Disturbed sand	153	30	815	14.4	[illegible]	59	2	2.6	Moist
103	Disturbed sand	154	20	548	9.7	87	85	1-1/4	2.6	Moist
104	Disturbed sand	155	10	508	9.0	[illegible]	[illegible]	1-1/4	2.6	Moist
105	Undisturbed sand	156	45	925	16.4	92	90	2	3.4	Moist
106	Undisturbed sand	157	30	750	13.3	8[illegible]	88	1-1/4	3.4	Moist
107	Undisturbed sand	158	20	650	11.5	[illegible]	[illegible]	1	3.4	Moist
108	Undisturbed sand	159	10	600	10.6	[illegible]	[illegible]	1/4	3.4	Moist
				1-1/2-ton M105 Trailer, Test Weight 7,482 lb						
109	Asphalt pavement	168	45	62	0.8	---	---	------		
110	Asphalt pavement	169	30	88	1.2	---	---	------		
111	Asphalt pavement	170	20	88	1.2	---	---	------		
112	Asphalt pavement	171	15	88	1.2	---	---	------		
113	Disturbed sand	160	45	1,270	17.0	96	93	2-1/4	2.6	Moist
114	Disturbed sand	161	30	1,060	14.2	87	94	2-1/2	2.6	Moist
115	Disturbed sand	162	20	890	11.9	86	[illegible]	1-3/4	2.6	Moist
116	Disturbed sand	163	15	780	10.4	89	88	1-1/4	2.6	Moist
117	Undisturbed sand	164	45	1,125	15.0	98	92	1-1/2	2.9	Moist
118	Undisturbed sand	165	30	925	12.4	97	[illegible]	1-1/4	2.9	Moist
119	Undisturbed sand	166	20	750	10.0	109	108	3/4	2.9	Moist
120	Undisturbed sand	167	15	675	9.0	125	125	1/2	2.9	Moist

(Continued)

Table 9 (Concluded)

Item No.	Type of Test Surface	Test No.	Tire Pressure psi	Towing Force Required lb	Towing Force as % of Test Weight	Cone Index 0- to 6-in. Depth Before Traffic	Cone Index 0- to 6-in. Depth After One Pass	Rut Depth One Pass in.	Average Moisture Content 0- to 6-in. Depth	Sand Condition
				37.5-KW Generator Trailer, Test Weight 7,153 lb						
121	Asphalt pavement	216	60	97	1.4	---	---	------		
122	Asphalt pavement	217	45	116	1.6	---	---	------		
123	Asphalt pavement	218	30	126	1.8	---	---	------		
124	Asphalt pavement	219	15	203	2.8	---	---	------		
125	Disturbed sand	208	60	1,310	18.3	116	131	------	9.6	Wet
126	Disturbed sand	209	45	1,212	15.9	114	119	------	9.6	Wet
127	Disturbed sand	210	30	1,019	14.2	98	103	------	9.6	Wet
128	Disturbed sand	211	15	700	9.8	95	94	------	9.6	Wet
129	Undisturbed sand	212	60	480	6.7	172	171	------	21.7	Wet
130	Undisturbed sand	213	45	380	5.3	174	174	------	21.7	Wet
131	Undisturbed sand	214	30	280	3.9	194	197	------	21.7	Wet
132	Undisturbed sand	215	15	240	3.4	198	200	------	21.7	Wet
				6-ton Trailer, Test Weight 10,960 lb						
133	Asphalt pavement	196	60	100	0.9	---	---	------		
134	Asphalt pavement	197	45	100	0.9	---	---	------		
135	Asphalt pavement	198	30	130	1.2	---	---	------		
136	Asphalt pavement	199	15	200	1.8	---	---	------		
137	Disturbed sand	204	60	1,090	9.9	162	162	1	14.5	Wet
138	Disturbed sand	205	45	690	6.3	176	173	1/2	14.5	Wet
139	Disturbed sand	206	30	450	4.1	174	[illegible]	3/8	14.5	Wet
140	Disturbed sand	207	15	320	2.9	184	[illegible]	------	14.5	Wet
141	Undisturbed sand	200	60	1,920	17.5	112	114	1-1/4	1.0	Moist
142	Undisturbed sand	201	45	[illegible]	14.6	104	112	1-1/8	1.0	Moist
143	Undisturbed sand	202	30	1,040	9.5	129	127	1/2	1.0	Moist
144	Undisturbed sand	203	15	720	6.6	136	138	1/4	1.0	Moist
				6-ton Trailer, Test Weight 17,160 lb						
145	Asphalt pavement	192	60	220	1.3	---	---	------		
146	Asphalt pavement	193	45	220	1.3	---	---	------		
147	Asphalt pavement	194	30	230	1.3	---	---	------		
148	Asphalt pavement	195	15	340	2.0	---	---	------		
149	Disturbed sand	184	60	1,600	9.3	169	159	1-3/8	5.5	Wet
150	Disturbed sand	185	45	2,800	16.3	115	113	2	5.5	Wet
151	Disturbed sand	186	30	2,200	12.8	102	94	2-1/4	5.5	Wet
152	Disturbed sand	187	15	1,900	11.1	87	85	1-1/2	5.5	Wet
153	Undisturbed sand	188	60	2,500	14.6	128	118	1-1/8	6.7	Wet
154	Undisturbed sand	189	45	2,000	11.7	121	112	1-1/2	6.7	Wet
155	Undisturbed sand	190	30	1,600	9.3	127	120	1-1/4	6.7	Wet
156	Undisturbed sand	191	15	900	5.2	159	161	1-1/4	6.7	Wet
				6-ton Trailer, Test Weight 25,520 lb						
157	Asphalt pavement	180	60	440	1.7	---	---	------		
158	Asphalt pavement	181	45	450	1.8	---	---	------		
159	Asphalt pavement	182	30	500	2.0	---	---	------		
160	Asphalt pavement	183	15	700	2.7	---	---	------		
161	Disturbed sand	172	60	4,200+	16.5+	94	---	1-3/8	4.7	Moist
162	Disturbed sand	173	45	4,600	18.0	87	89	2-3/4	4.7	Moist
163	Disturbed sand	174	30	3,600	14.1	97	97	2-1/8	4.7	Moist
164	Disturbed sand	175	15	2,100	8.2	110	97	1	4.7	Moist
165	Undisturbed sand	176	60	5,900	23.1	72	81	5	6.8	Wet
166	Undisturbed sand	177	45	4,910	19.2	82	---	------	6.8	Wet
167	Undisturbed sand	178	30	4,400	17.2	78	75	2	6.8	Wet
168	Undisturbed sand	179	15	4,800	15.8	78	84	------	6.8	Wet

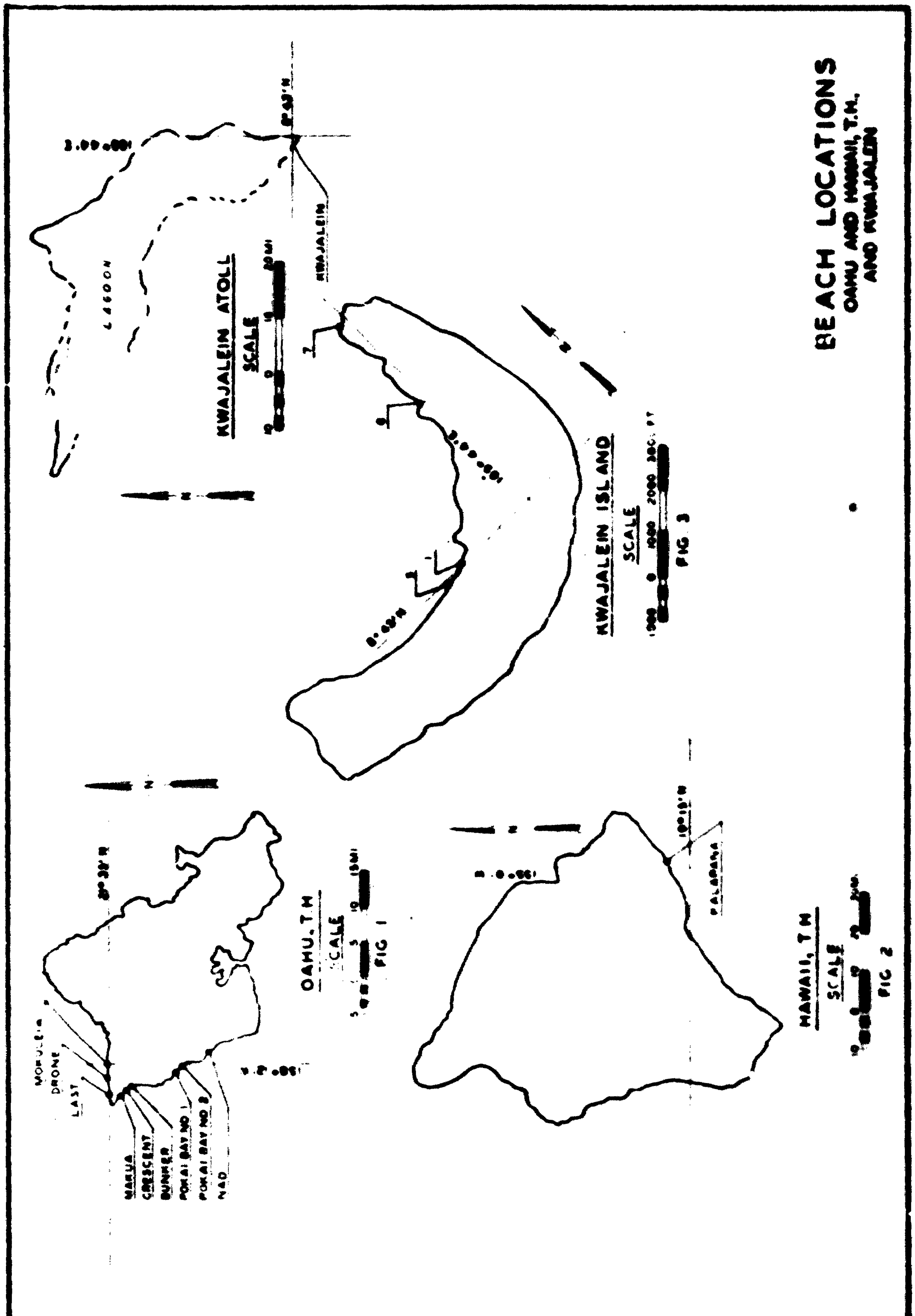
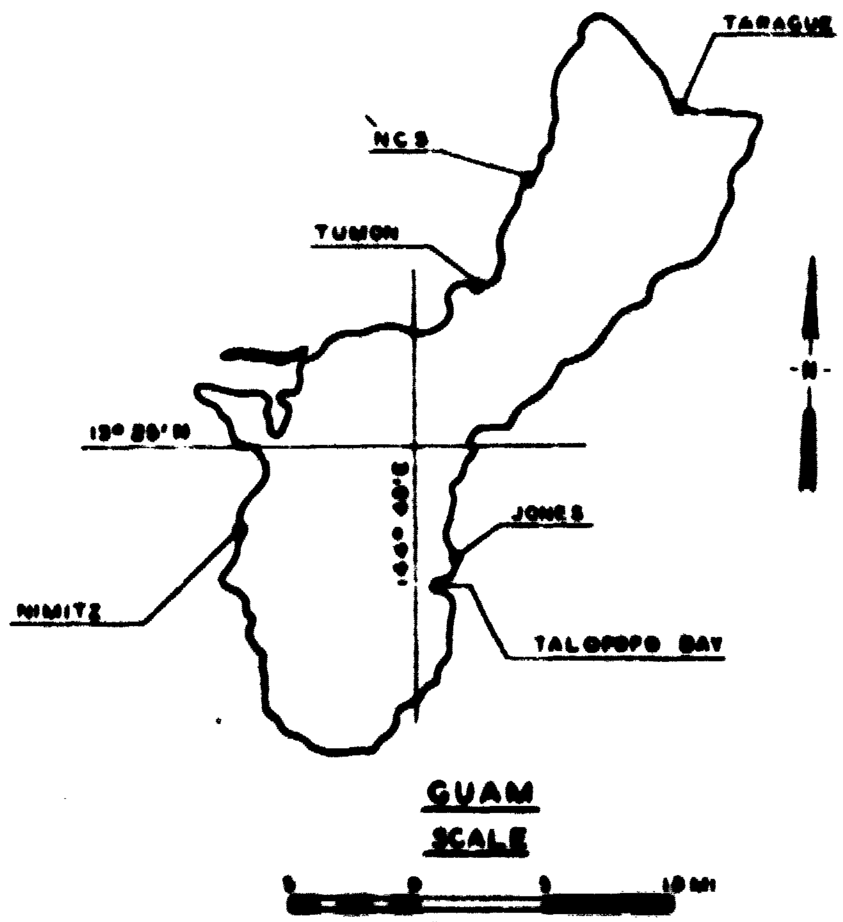
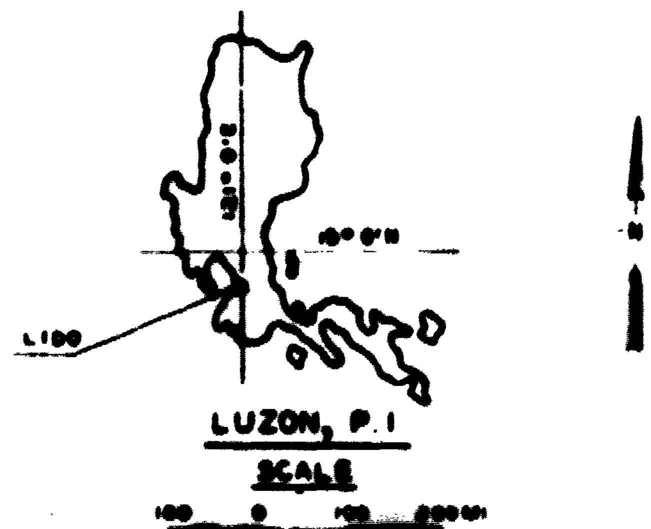

BEACH LOCATIONS
OAHU AND HAWAII, T.H.
AND KWAJALEIN
KWAJALEIN ATOLL
SCALE
LAGOON
KWAJALEIN
KWAJALEIN ISLAND
SCALE
FIG 3
OAHU, T.H
SCALE
FIG 1
MOKULEIA
DRONE
LAST
MAKUA
CRESCENT
BUNKER
POKAI BAY NO 1
POKAI BAY NO 2
NAD
HAWAII, T.H
SCALE
FIG 2

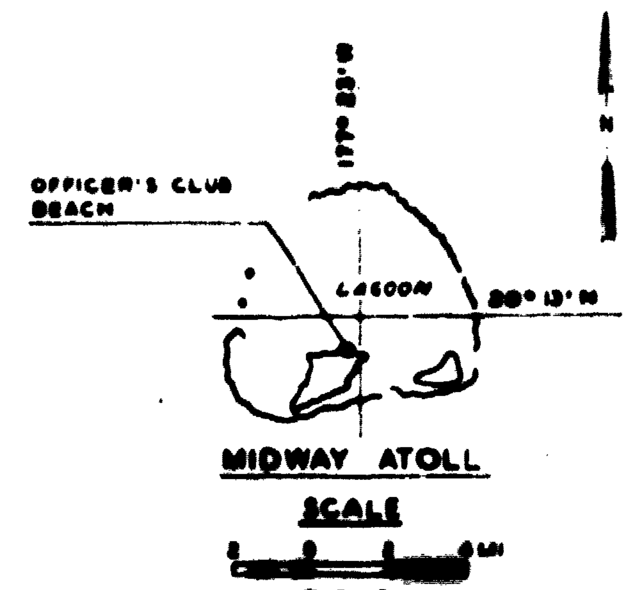
PLATE I



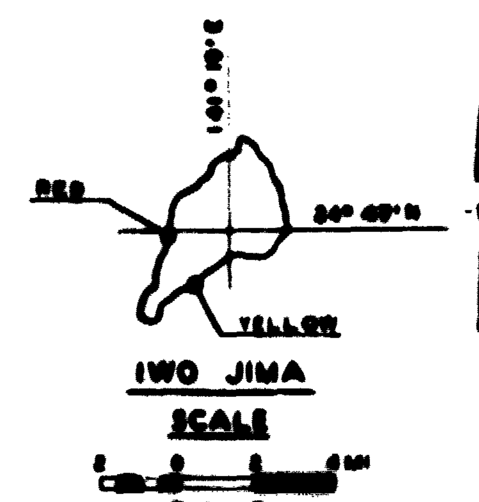
GUAM
SCALE
FIG. 4



LUZON, P. I
SCALE
FIG. 5



MIDWAY ATOLL
SCALE
FIG. 6



IWO JIMA
SCALE
FIG. 7

BEACH LOCATIONS
GUAM, LUZON, P.I., MIDWAY,
AND IWO JIMA

PLATE 2

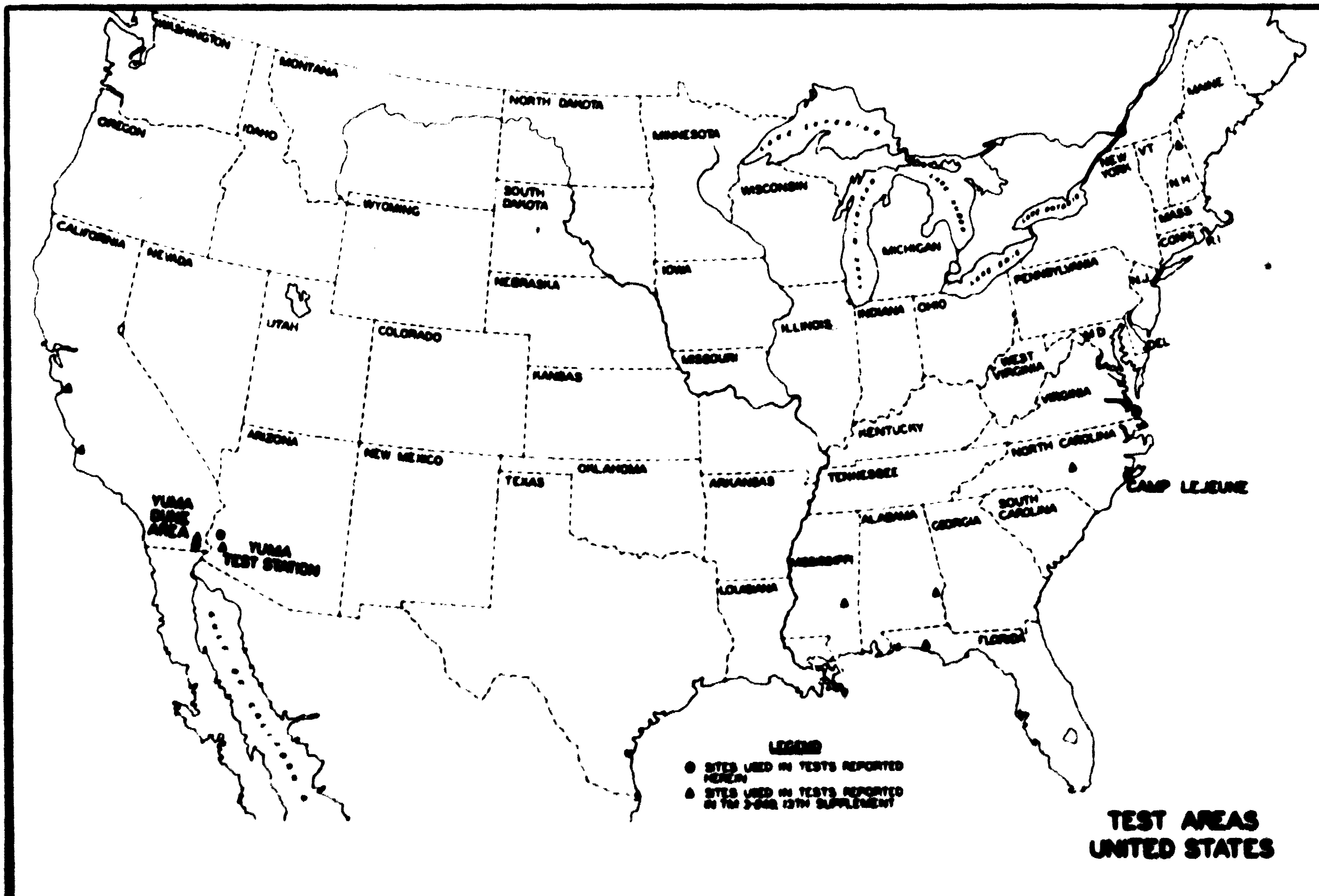

WASHINGTON
MONTANA
OREGON
IDAHO
NORTH DAKOTA
MINNESOTA
WISCONSIN
MICHIGAN
NEW YORK
VT
N H
MAINE
MASS
CONN
R I
SOUTH DAKOTA
WYOMING
CALIFORNIA
NEVADA
NEBRASKA
IOWA
ILLINOIS
INDIANA
OHIO
PENNSYLVANIA
N J
UTAH
COLORADO
KANSAS
MISSOURI
WEST VIRGINIA
MD
DEL
VIRGINIA
KENTUCKY
ARIZONA
NEW MEXICO
OKLAHOMA
NORTH CAROLINA
TEXAS
ARKANSAS
TENNESSEE
CAMP LEJEUNE
YUMA DUNE AREA
YUMA TEST STATION
ALABAMA
GEORGIA
SOUTH CAROLINA
MISSISSIPPI
LOUISIANA
FLORIDA
LEGEND
SITES USED IN TESTS REPORTED HEREIN
SITES USED IN TESTS REPORTED
TEST AREAS
UNITED STATES

PLATE 3

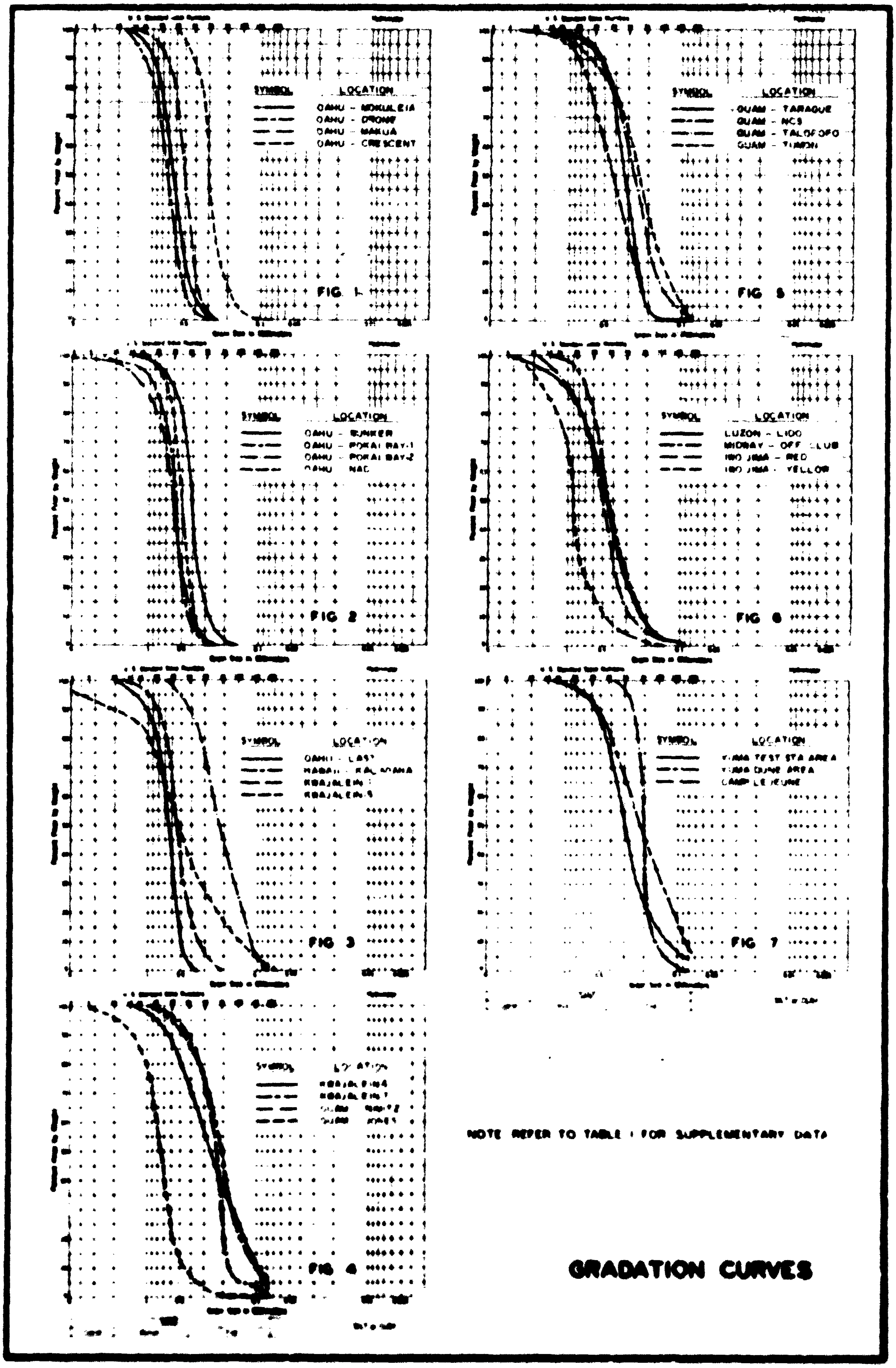

SYMBOL LOCATION
OAHU - MOKULEIA
OAHU - MAKUA
OAHU - CRESCENT
FIG. 1
SYMBOL LOCATION
OAHU - BUNKER
OAHU - POKAI BAY-1
OAHU - POKAI BAY-2
FIG. 2
SYMBOL LOCATION
KWAJALEIN-1
KWAJALEIN-5
FIG. 3
SYMBOL LOCATION
KWAJALEIN-4
KWAJALEIN-7
GUAM - JONES
FIG. 4
SYMBOL LOCATION
GUAM - TARAGUE
GUAM - NCS
GUAM - TALOFOFO
GUAM - TUMON
FIG. 5
SYMBOL LOCATION
LUZON - LIDO
MIDWAY - OFF. CLUB
IWO JIMA - RED
IWO JIMA - YELLOW
FIG. 6
SYMBOL LOCATION
YUMA TEST STA. AREA
YUMA DUNE AREA
CAMP LEJEUNE
FIG. 7
NOTE: REFER TO TABLE 1 FOR SUPPLEMENTARY DATA
GRADATION CURVES

PLATE 4

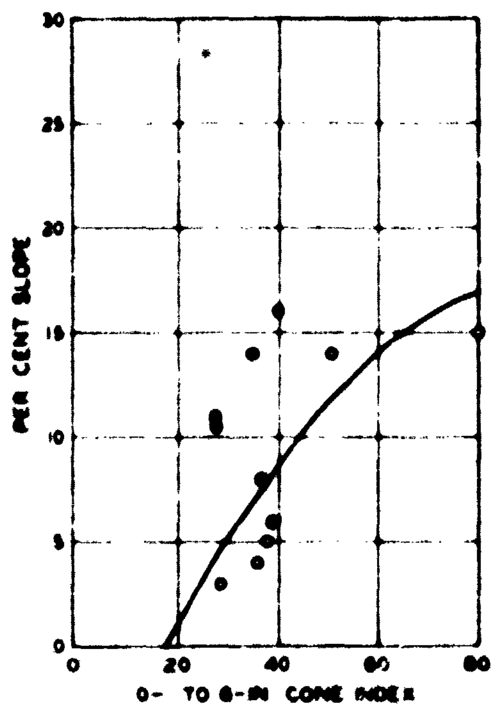


FIG. 1. 30-PSI TIRE PRESSURE

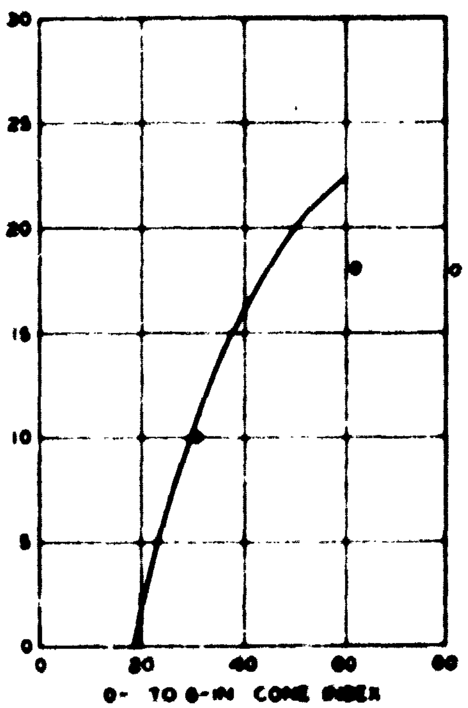


FIG. 2. 20-PSI TIRE PRESSURE

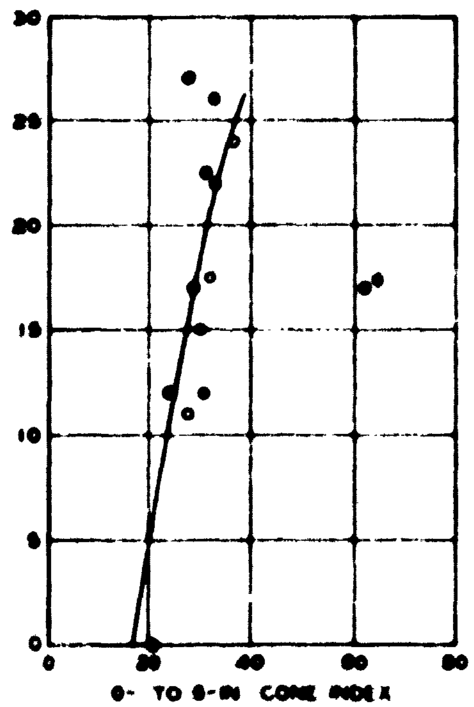


FIG. 3. 10-PSI TIRE PRESSURE

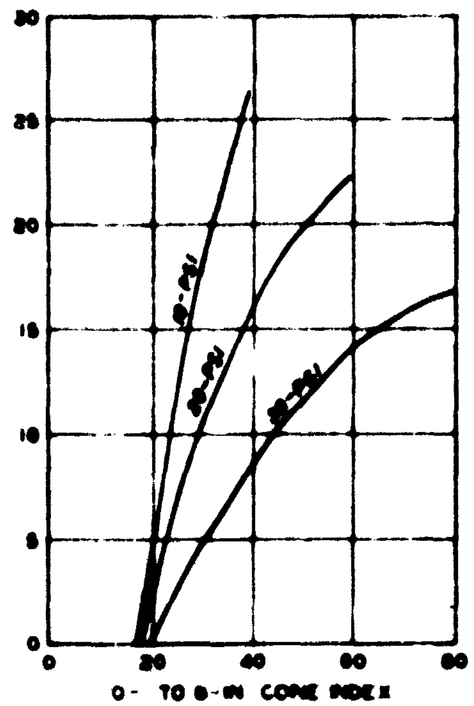


FIG. 4. FAMILY OF TIRE PRESSURE CURVES

NOTE PLOTTED POINTS ARE FROM TABLE 3
OPEN SYMBOLS ARE NONIMMOBILIZATIONS
CLOSED SYMBOLS ARE IMMOBILIZATIONS
* BY SYMBOL INDICATES TEST ON
A QUICK CONDITION

VEHICLE PERFORMANCE
SINGLE SELF-PROPELLED VEHICLE TESTS
WET TO INUNDATED SAND
PER CENT SLOPE VS CONE INDEX
$\frac{1}{4}$-TON M38A1 4X4 TRUCK, 7.00X16 6PR TIRES
GROSS WT 2975-3125 LB

PLATE 5

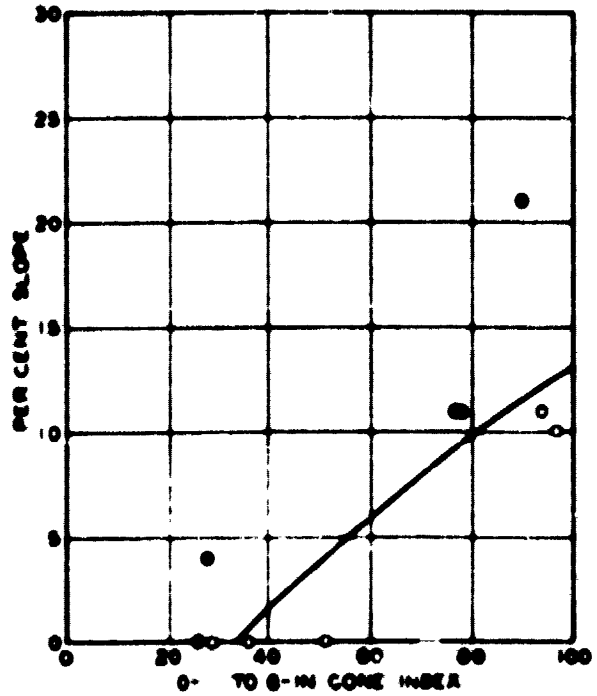


FIG. 1 30-PSI TIRE PRESSURE

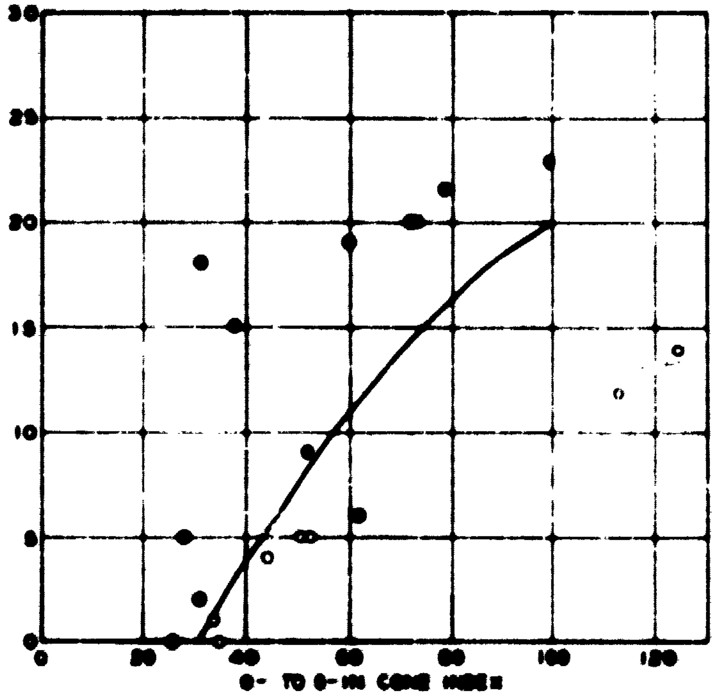


FIG. 2 20-PSI TIRE PRESSURE

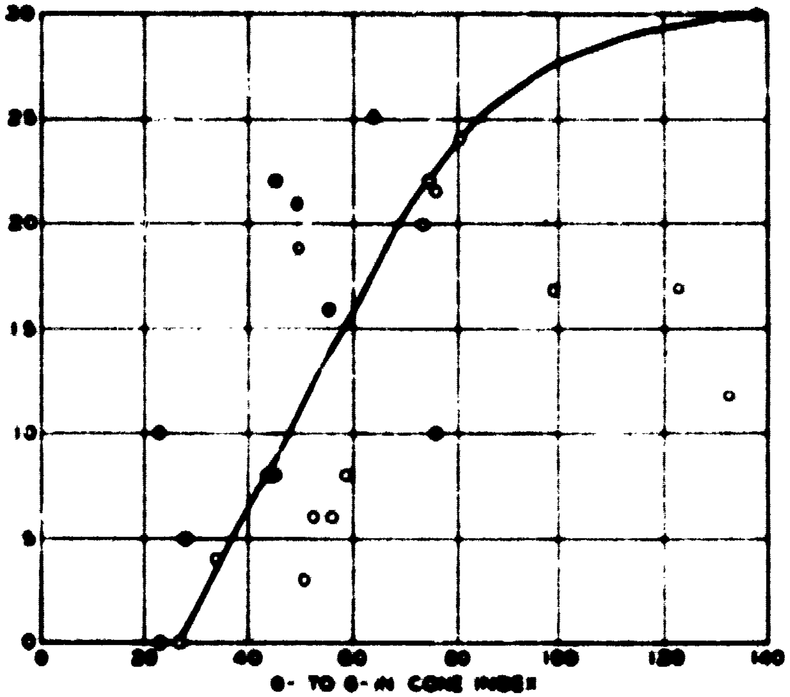


FIG 3 15-PSI TIRE PRESSURE

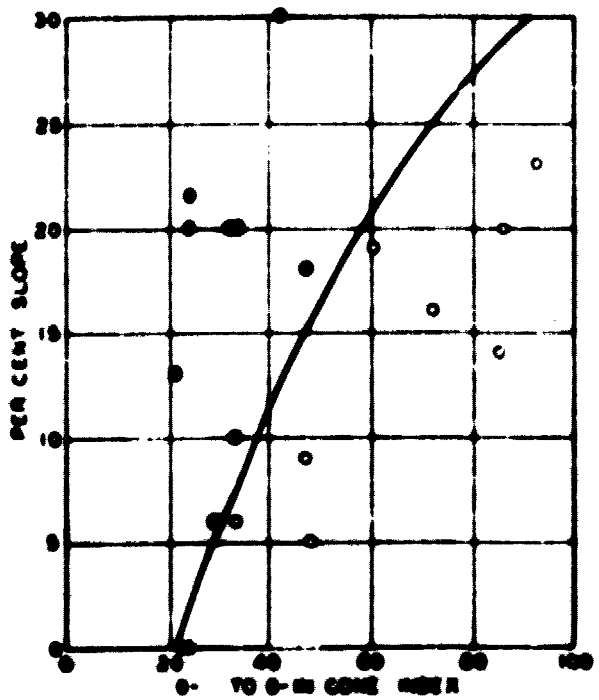


FIG 4 10-PSI TIRE PRESSURE

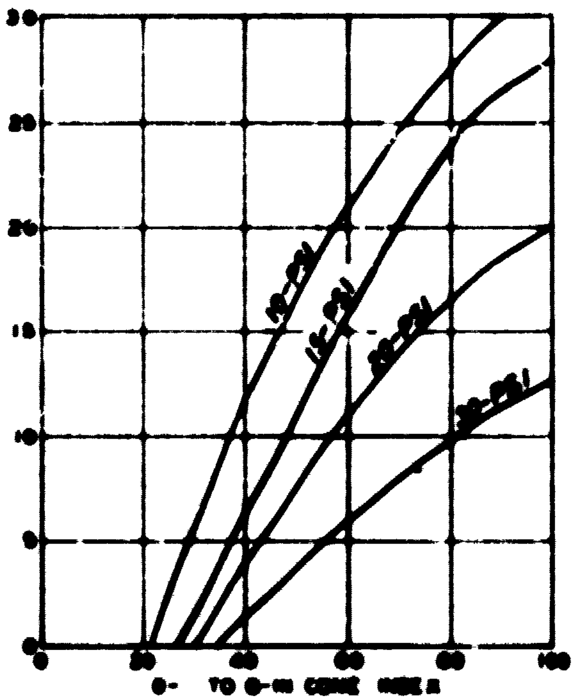


FIG 5 FAMILY OF TIRE PRESSURE CURVES

NOTE PLOTTED POINTS ARE FROM TABLE 3
OPEN SYMBOLS ARE NONIMMOBILIZATIONS
CLOSED SYMBOLS ARE IMMOBILIZATIONS

VEHICLE PERFORMANCE
SINGLE SELF-PROPELLED VEHICLE TESTS

DRY TO MOIST SAND
PER CENT SLOPE VS CONE INDEX
1/4-TON M38A1 4X4 TRUCK,
7.00X16 6PR TIRES
GROSS WT 2075-3125 LB

PLATE 6

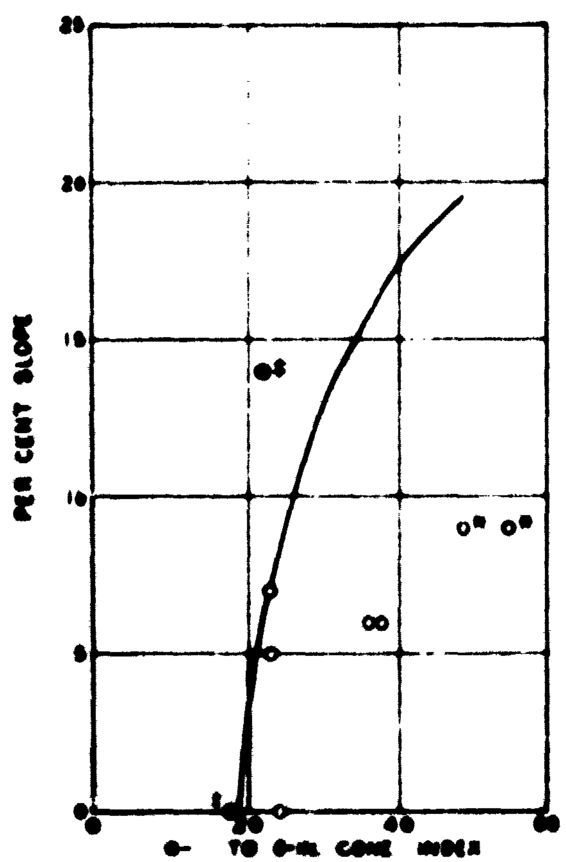


FIG. 1. 20-PSI TIRE PRESSURE

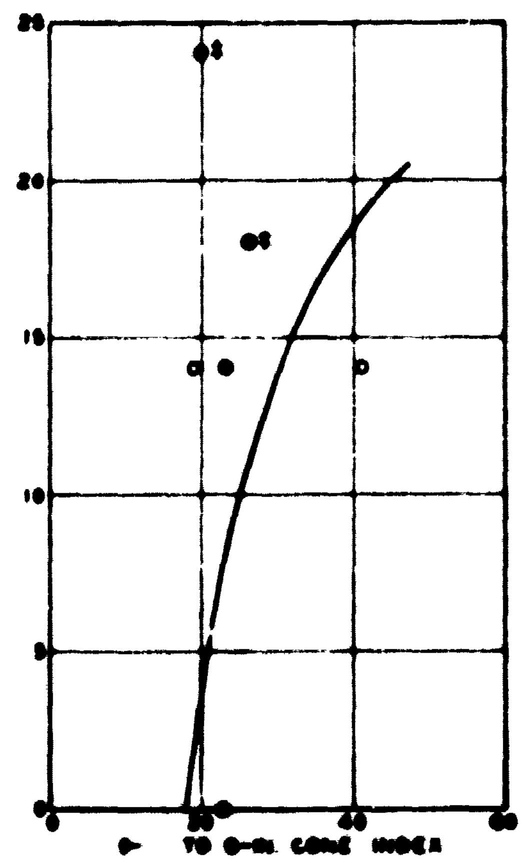


FIG. 2. 15-PSI TIRE PRESSURE

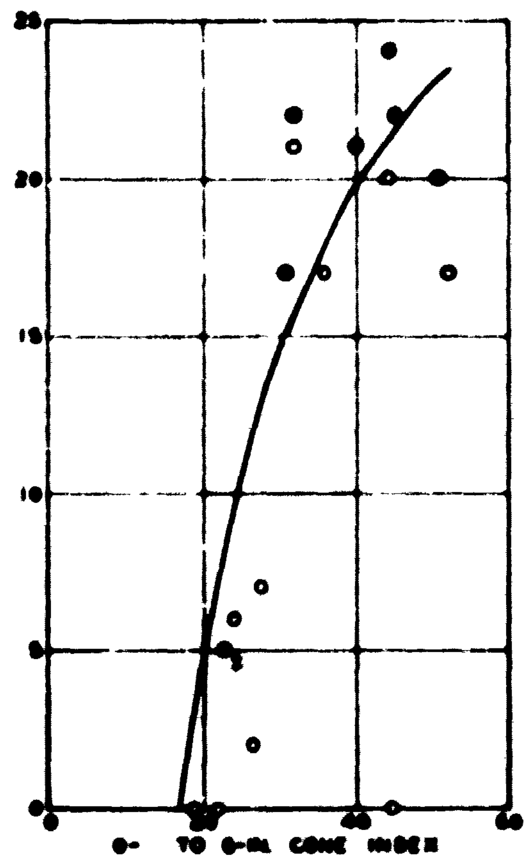


FIG. 3. 10-PSI TIRE PRESSURE

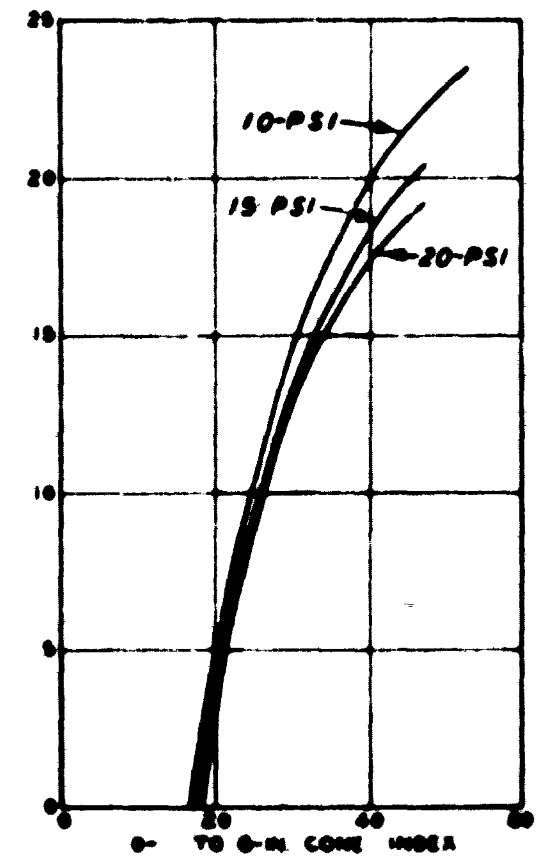


FIG. 4. FAMILY OF TIRE PRESSURE CURVES

NOTE R BY SYMBOL INDICATES 13TH SUPPLEMENT DATA
Q BY SYMBOL INDICATES TEST ON A QUICK CONDITION
OTHER SYMBOLS ARE ITEMS FROM TABLE 4
OPEN SYMBOLS ARE NONIMMOBILIZATIONS
CLOSED SYMBOLS ARE IMMOBILIZATIONS

VEHICLE PERFORMANCE
SINGLE SELF-PROPELLED VEHICLE TESTS

WET TO INUNDATED SAND
PER CENT SLOPE VS CONE INDEX
$\frac{3}{4}$-TON M37 4X4 TRUCK, 9.00X16 8PR TIRES
GROSS WT 7417 LB

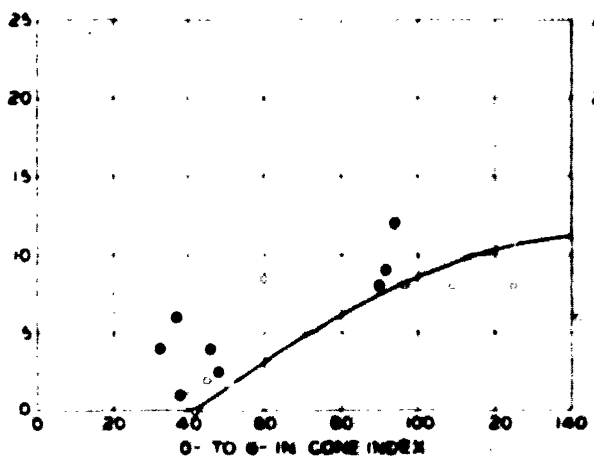


FIG. 1. 45-PSI TIRE PRESSURE

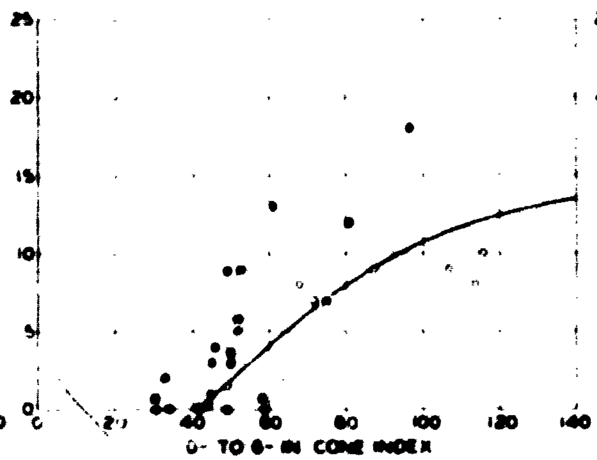


FIG. 2. 40-PSI TIRE PRESSURE

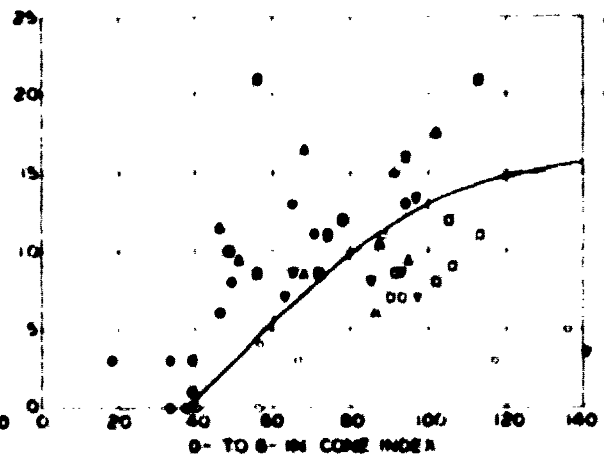


FIG. 3. 30-PSI TIRE PRESSURE

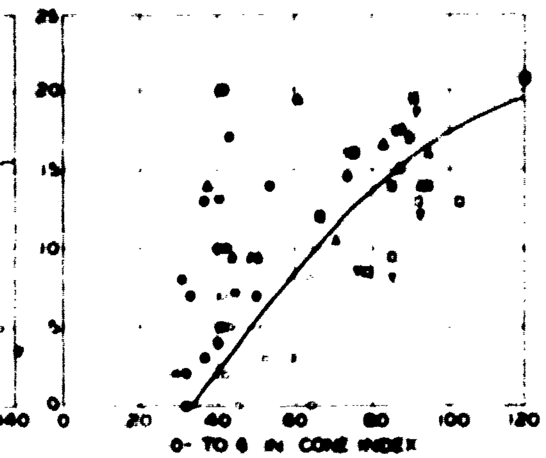


FIG. 4. 20-PSI TIRE PRESSURE

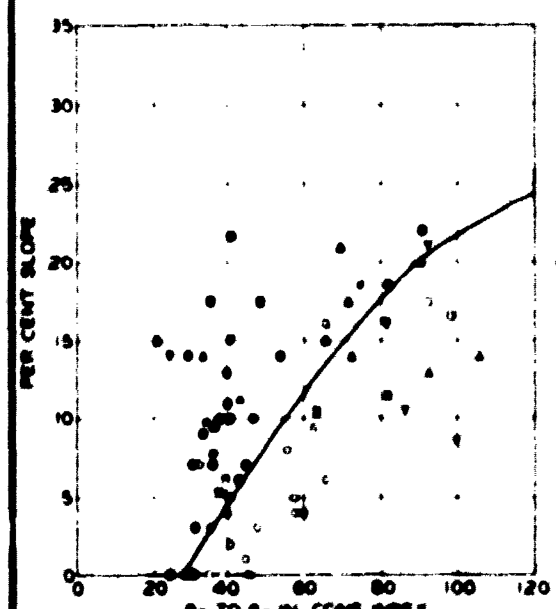


FIG. 5. 15-PSI TIRE PRESSURE

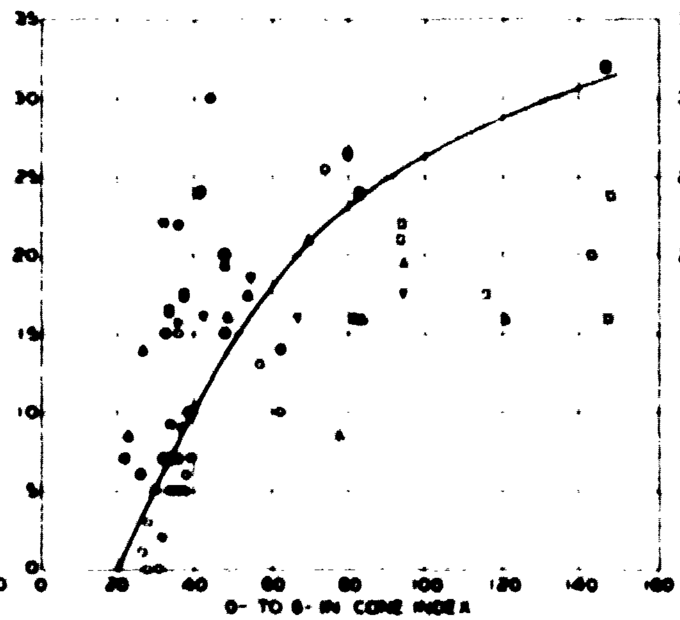


FIG. 6. 10-PSI TIRE PRESSURE

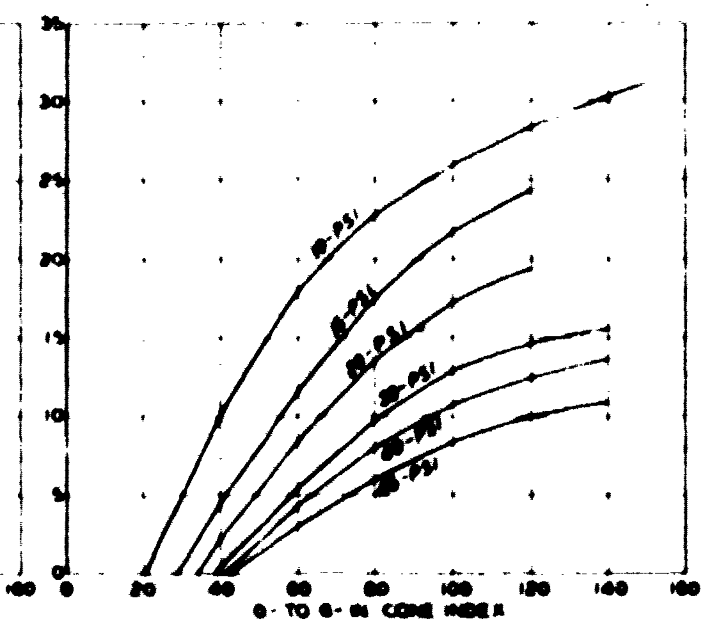


FIG. 7. FAMILY OF TIRE PRESSURE CURVES

LEGEND

GROSS WT-LB	IMMOBILIZATION	NONIMMOBILIZATION
5645	▲	△
6067 - 6275	■	□
7085 - 7417	●	○
7805	▼	▽

• BY SYMBOLS INDICATES 13TH SUPPLEMENT DATA
OTHER PLOTTED POINTS ARE FROM TABLE 4

VEHICLE PERFORMANCE
SINGLE SELF-PROPELLED VEHICLE TESTS
DRY TO MOIST SAND
PER CENT SLOPE VS CONE INDEX
$\frac{3}{4}$ - TON M37 4 X 4 TRUCK
900 X 16 8PR TIRES

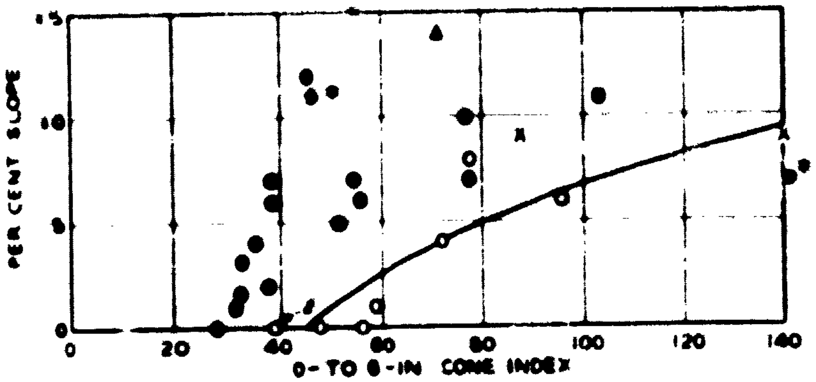


FIG. 1 45-PSI TIRE PRESSURE

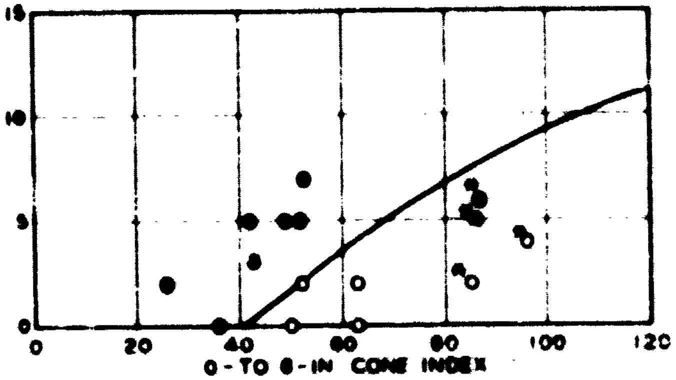


FIG. 2. 30-PSI TIRE PRESSURE

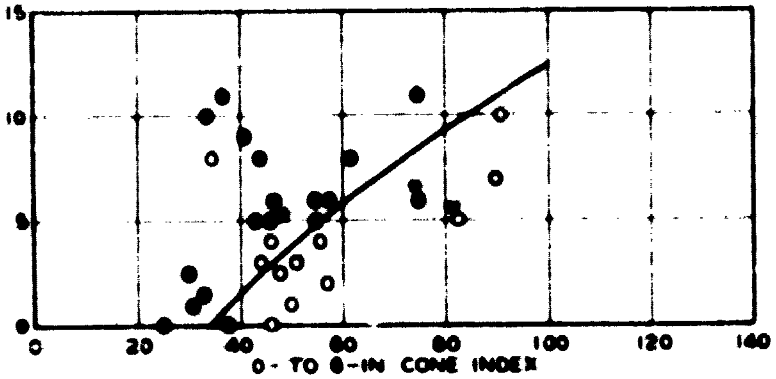


FIG. 3 20-PSI TIRE PRESSURE

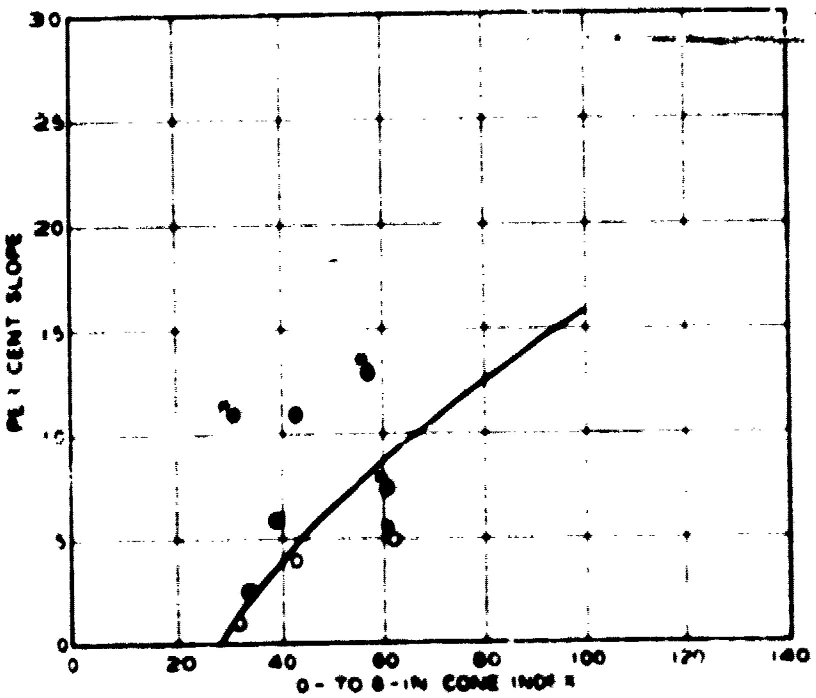


FIG. 4 15-PSI TIRE PRESSURE

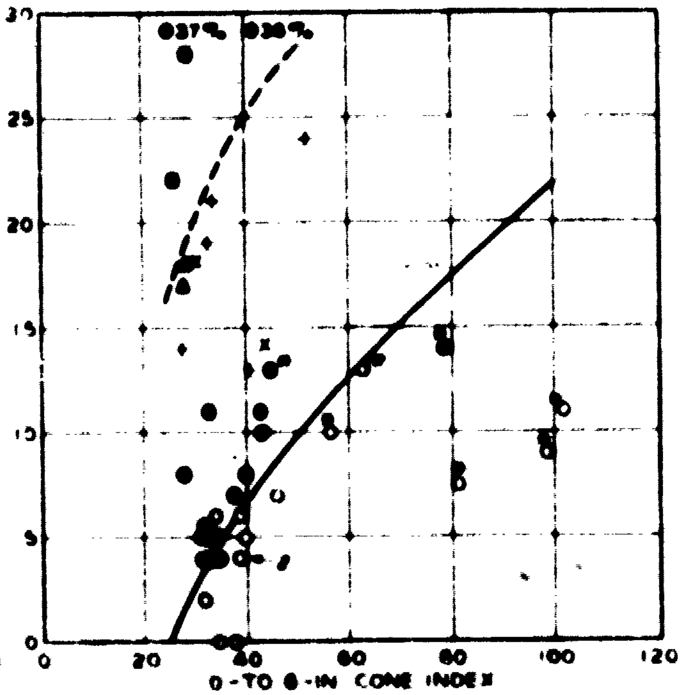


FIG. 5 10-PSI TIRE PRESSURE

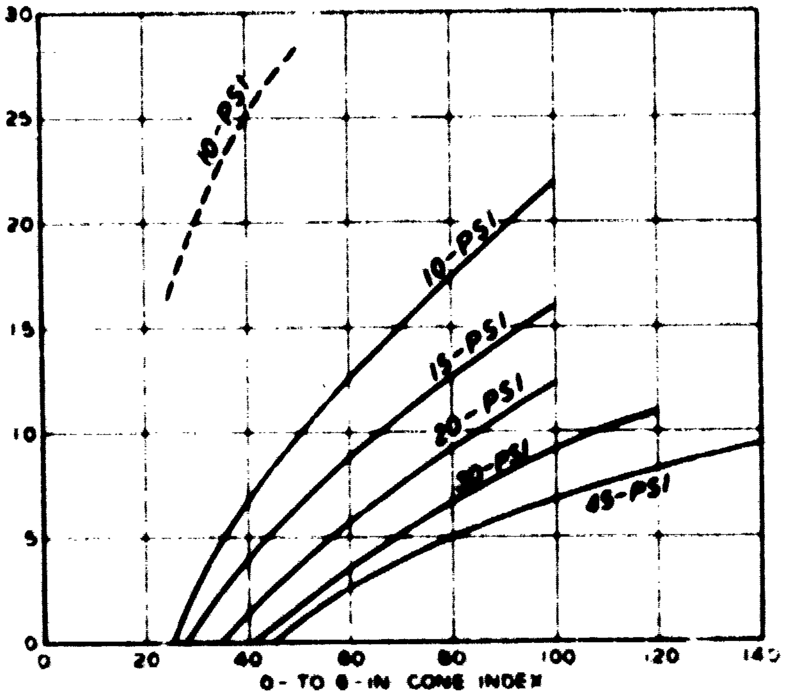


FIG. 6 FAMILY OF TIRE PRESSURE CURVES

LEGEND

SAND CLASS	GROSS WT-LB	SYMBOLS: IMMOBILIZATION	SYMBOLS: NON-IMMOBILIZATION	SEPARATION CURVE
WET TO INUNDATED	13,180	●	■	- - - - -
WET TO INUNDATED	10,180	●	+	
DRY TO MOIST	13,180	▲	△	———
DRY TO MOIST	16,400	●	○	

X BY SYMBOLS INDICATES 13TH SUPPLEMENT DATA OTHER PLOTTED POINTS ARE FROM TABLE 5

• BY SYMBOLS INDICATES TEST ON A QUICK CONDITION

VEHICLE PERFORMANCE
SINGLE SELF-PROPELLED VEHICLE TESTS

PER CENT SLOPE VS CONE INDEX
$2\frac{1}{2}$-TON M 211 6 X 6 TRUCK,
9.00 X 20 8 PR TIRES (DUAL)

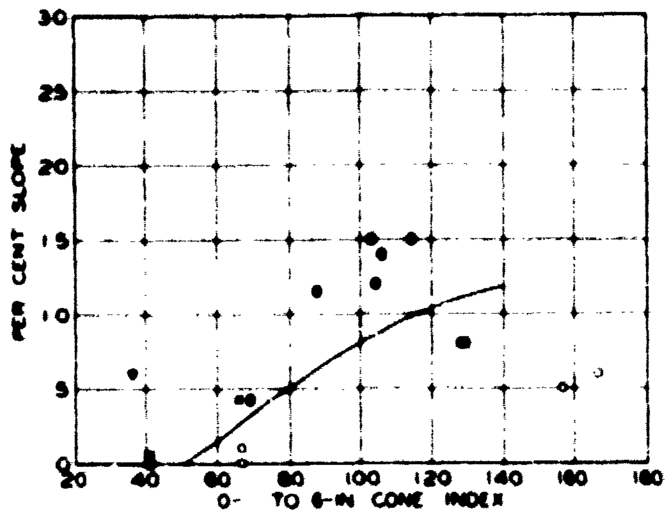


FIG 1 40-PSI TIRE PRESSURE

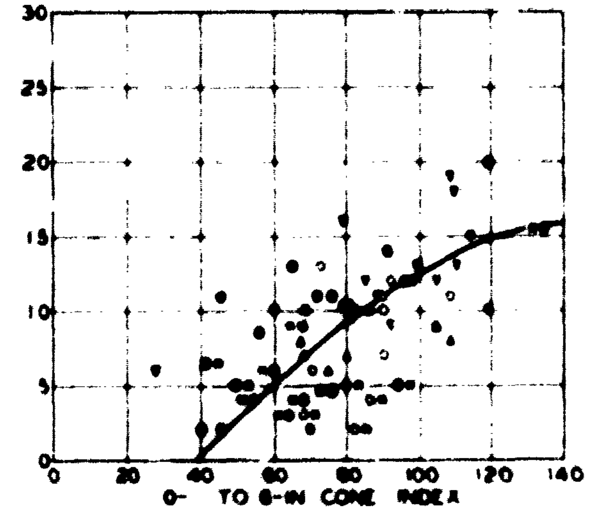


FIG 2 30-PSI TIRE PRESSURE

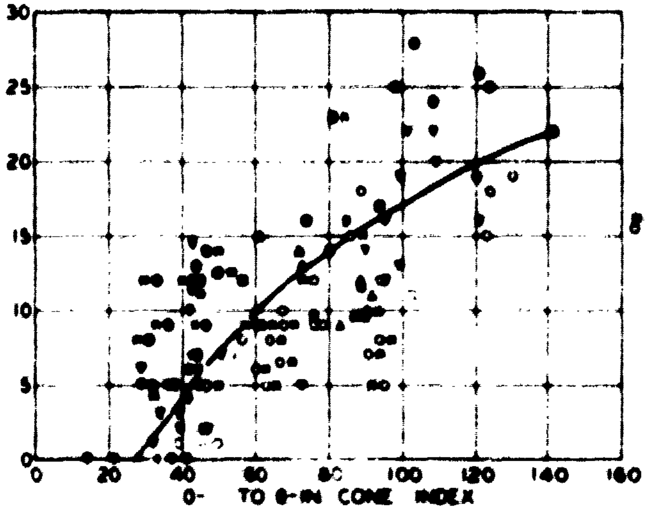


FIG 3 20-PSI TIRE PRESSURE

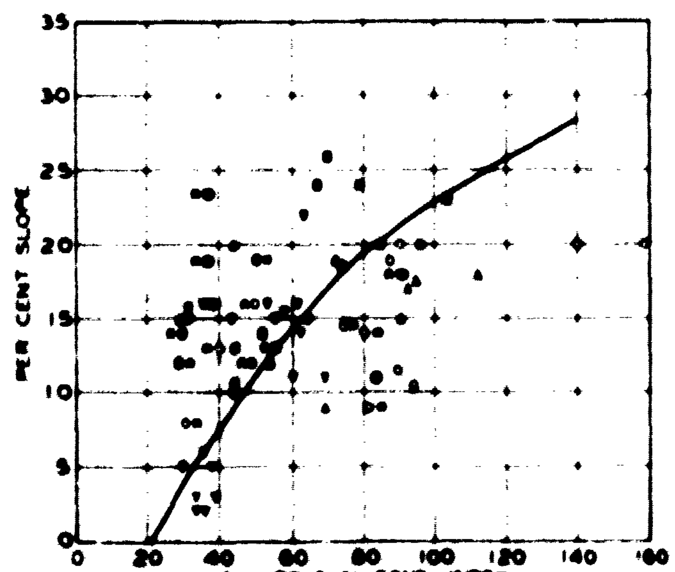


FIG 4 15-PSI TIRE PRESSURE

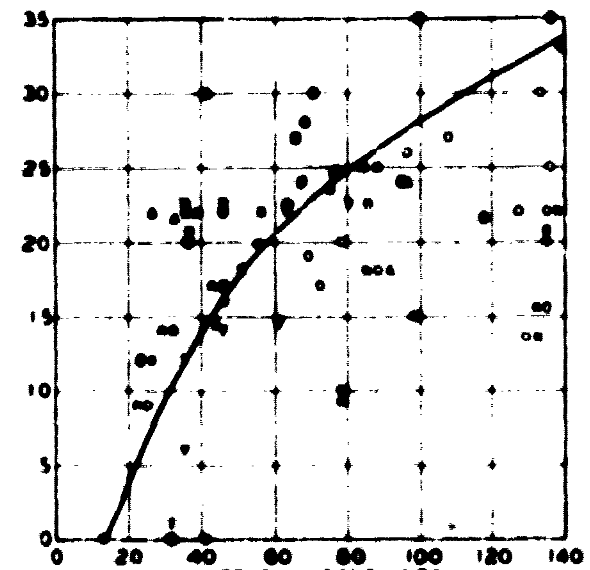


FIG 5 10-PSI TIRE PRESSURE

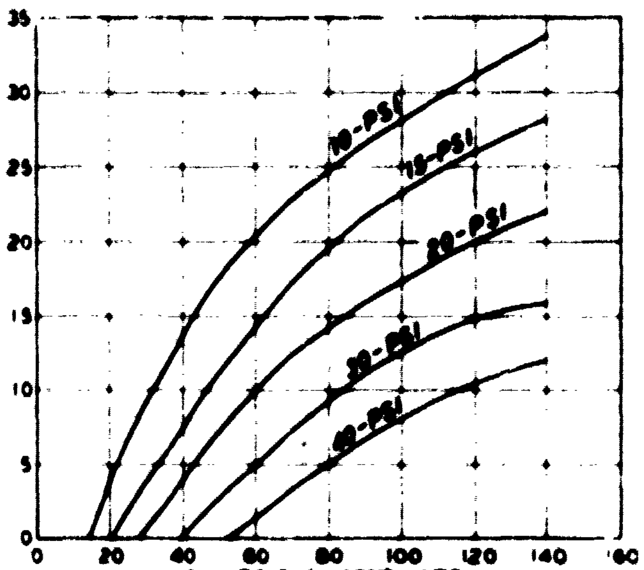


FIG 6 FAMILY OF TIRE PRESSURE CURVES

LEGEND

SAND CLASS	GROSS WT-LB	IMMOBILIZATION	NONIMMOBILIZATION
WET TO INUNDATED	10,820	●	↓
DRY TO MOIST	12,450	▲	△
DRY TO MOIST	14,950 - 15,000	■	□
DRY TO MOIST	17,320 - 17,450	●	○
DRY TO MOIST	19,820 - 20,300	▼	▽

a BY SYMBOLS INDICATES 13TH SUPPLEMENT DATA
OTHER PLOTTED POINTS ARE FROM TABLE 6
q BY SYMBOL INDICATES TEST ON A QUICK CONDITION

VEHICLE PERFORMANCE SINGLE SELF-PROPELLED VEHICLE TESTS

PER CENT SLOPE VS CONE INDEX
2½-TON 6X6 TRUCKS.
11.00X20 12PR TIRES (SINGLE)

PLATE 10

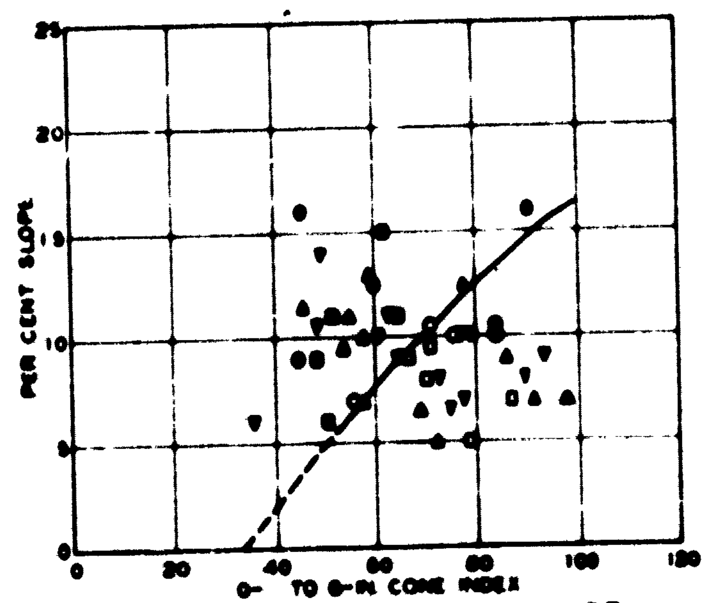


FIG 1 30-PSI TIRE PRESSURE

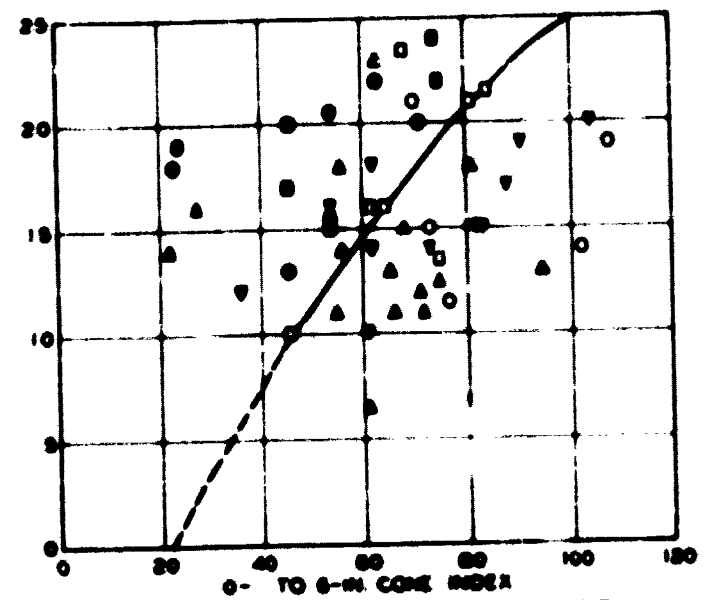


FIG. 2 20-PSI TIRE PRESSURE

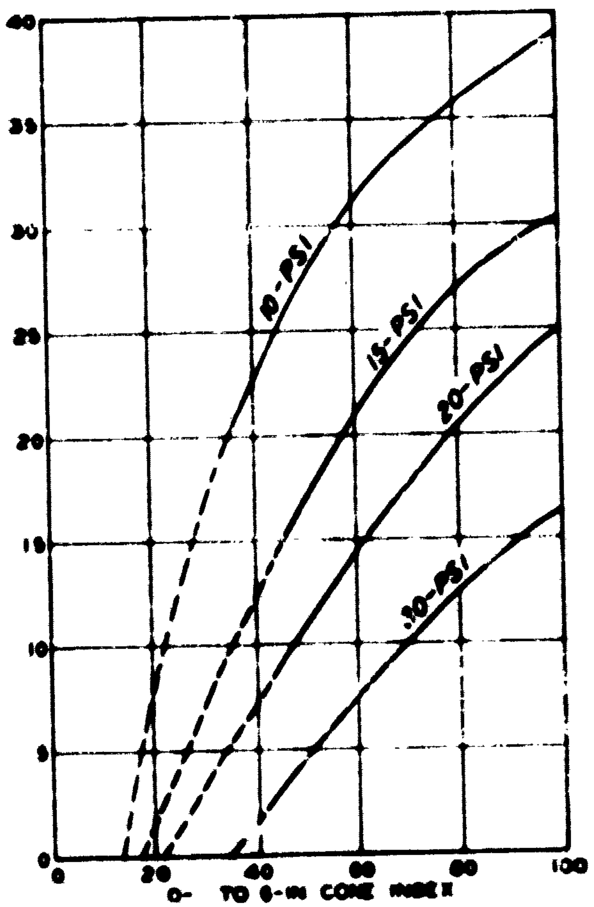


FIG 5 FAMILY OF TIRE PRESSURE CURVES

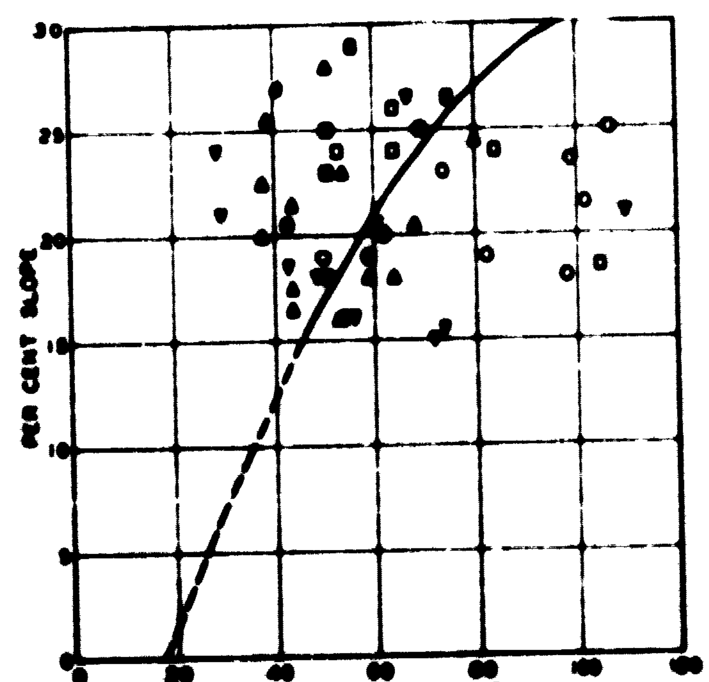


FIG. 3 15-PSI TIRE PRESSURE

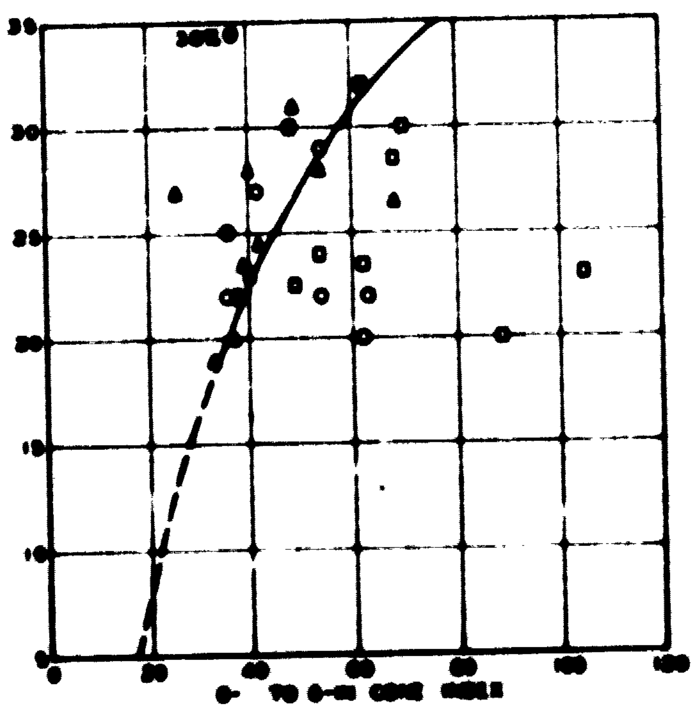


FIG 4 10-PSI TIRE PRESSURE

LEGEND

GROSS WT-LB	MOBILIZATION	NONMOBILIZATION
16,115	▲	△
24,275	■	□
30,175	●	○
32,300	▼	▽

PLOTTED POINTS ARE FROM TABLE 7

VEHICLE PERFORMANCE
SINGLE SELF-PROPELLED VEHICLE TESTS

DRY TO MOIST SAND
PER CENT SLOPE VS CONE INDEX
5-TON M41 6X6 TRUCK,
14.00X20 12PR TIRES (SINGLE)

PLATE II

PLATE 12

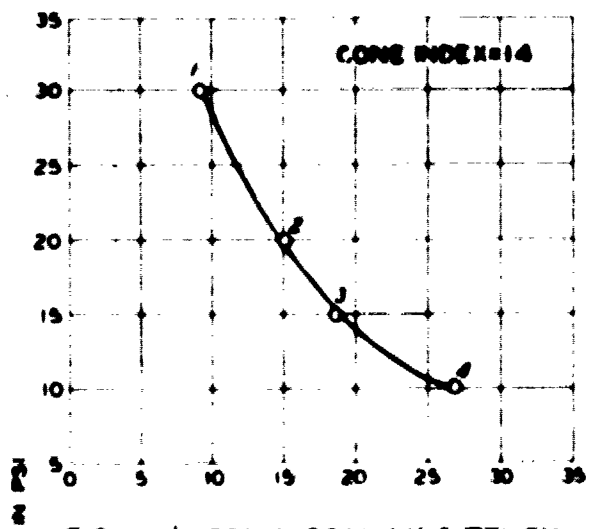


FIG 1 $\frac{1}{4}$-TON M38A1 4 X 4 TRUCK
TEST WEIGHT 2975 LB

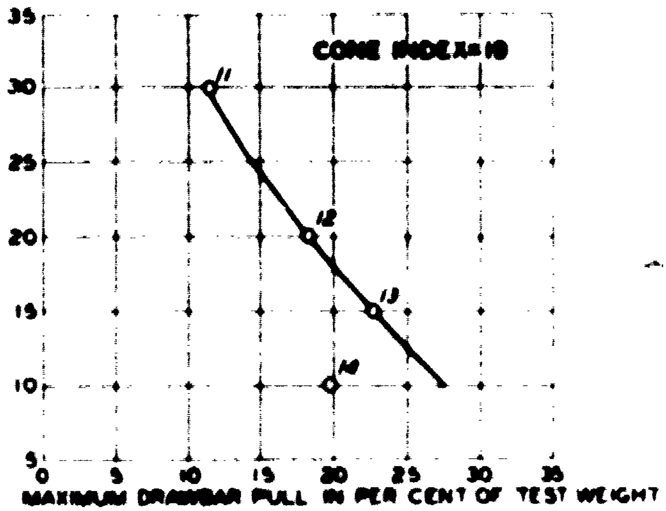


FIG 2 $\frac{3}{4}$-TON M37 4 X 4 TRUCK
TEST WEIGHT 7085 LB

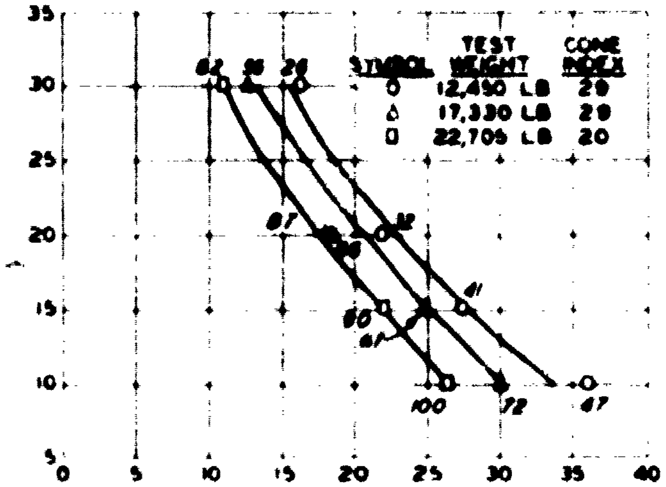


FIG 3 $2\frac{1}{2}$-TON M135 6 X 6 TRUCK

NOTE NUMBERS NEAR PLOTTED POINTS REFER TO ITEMS IN TABLE 8

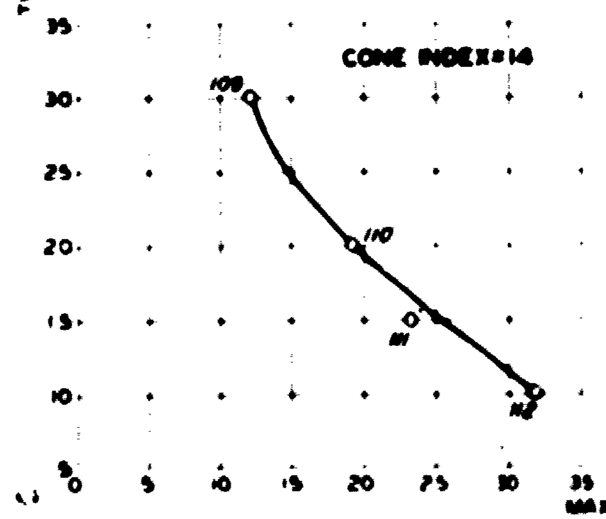


FIG 4 5-TON M41 6X6 TRUCK
TEST WEIGHT 28,175 LB

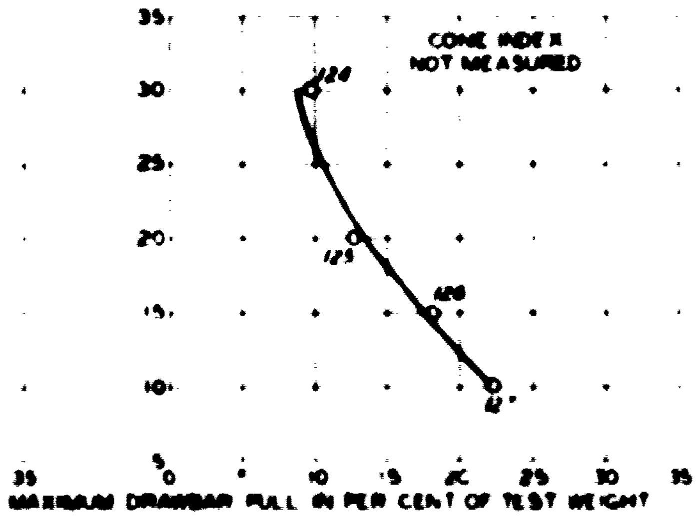


FIG 5 5-TON M54 6X6 TRUCK
TEST WEIGHT 30,835 LB

VEHICLE PERFORMANCE
TOWING TESTS WITH
SELF-PROPELLED WHEELED VEHICLES
HARROWED SAND
MAXIMUM DRAWBAR PULL
VS TIRE PRESSURE

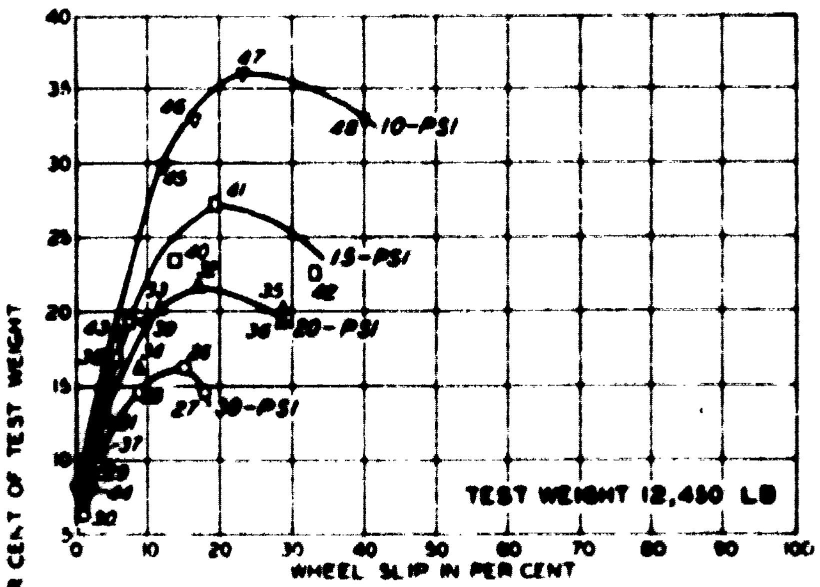


FIG. 1. 2½-TON M135 6X6 TRUCK

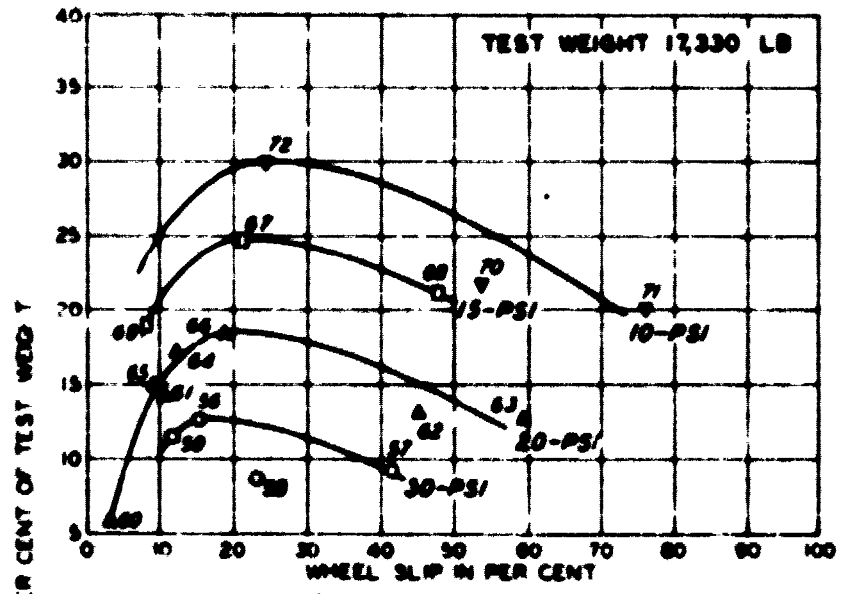


FIG. 2. 2½-TON M135 6X6 TRUCK

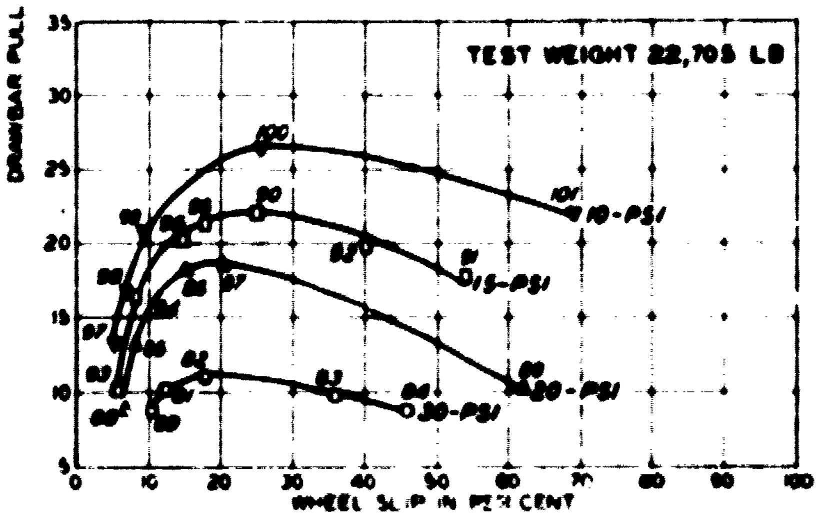


FIG. 3. 2½-TON M135 6X6 TRUCK

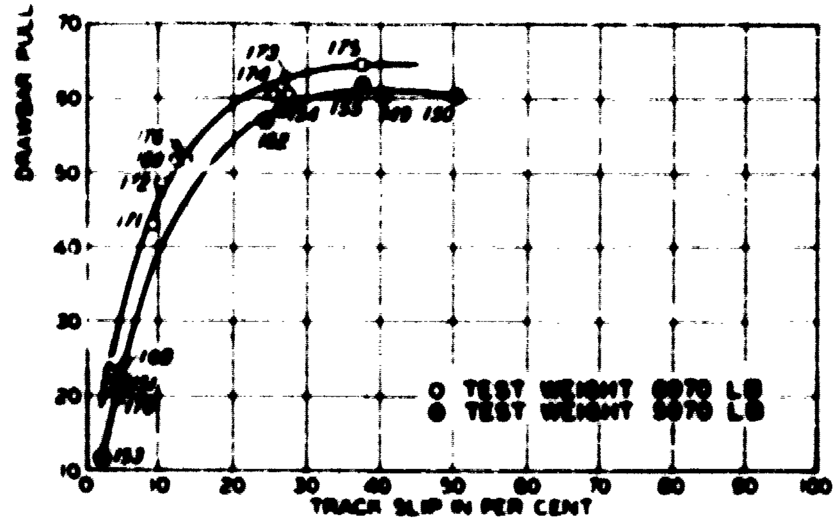


FIG. 4. ½-TON M29C WEASEL

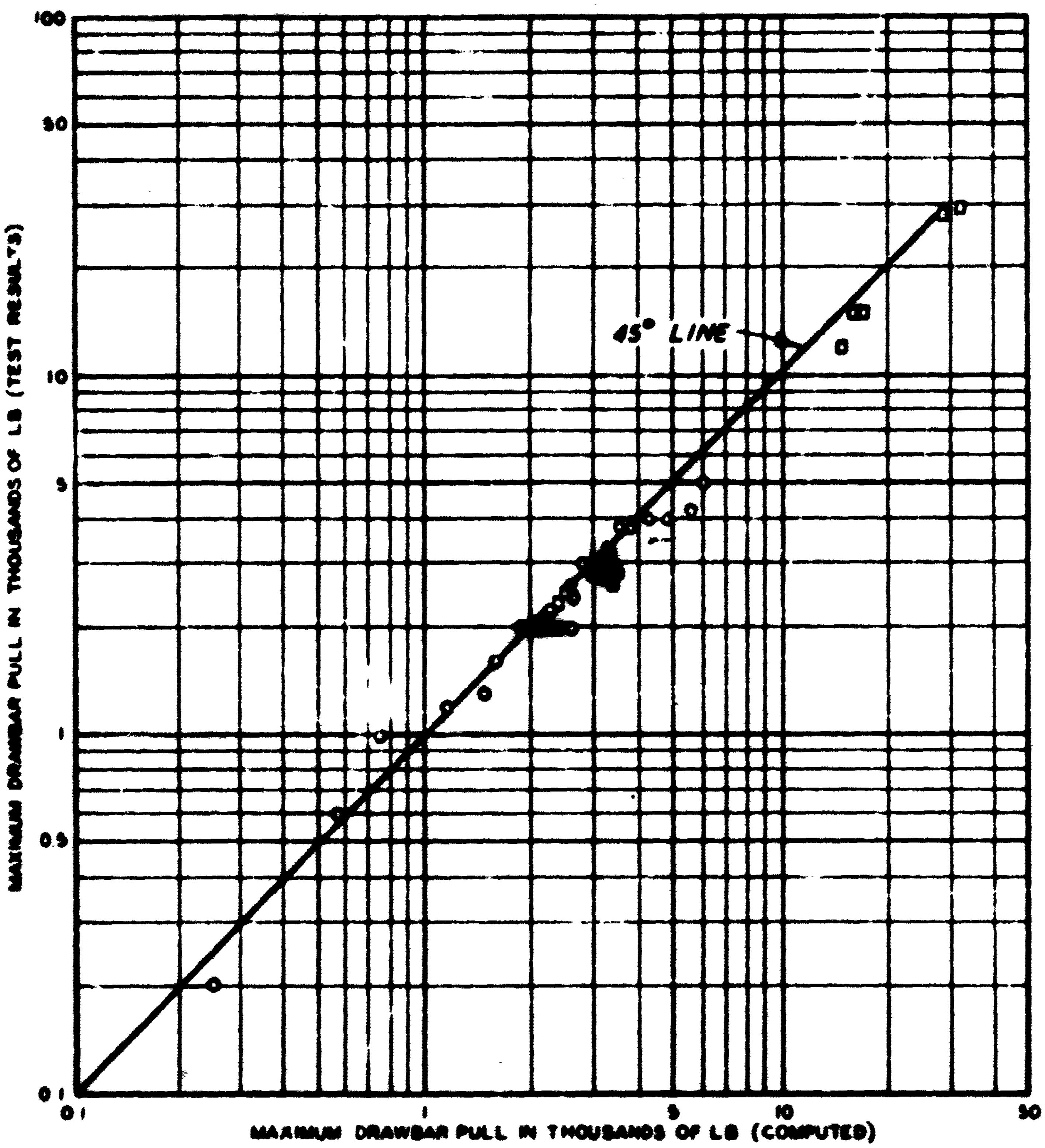
LEGEND

SYMBOL	TIRE PRESSURE
▽	10 PSI
□	15 PSI
△	20 PSI
○	30 PSI

NOTE REFER TO TABLE 8 FOR SUPPLEMENTARY DATA
NUMBERS NEAR PLOTTED POINTS REFER TO ITEM NUMBERS

VEHICLE PERFORMANCE

TOWING TESTS WITH SELF-PROPELLED VEHICLES
HARROWED SAND
DRAWBAR PULL VS SLIP



LEGEND

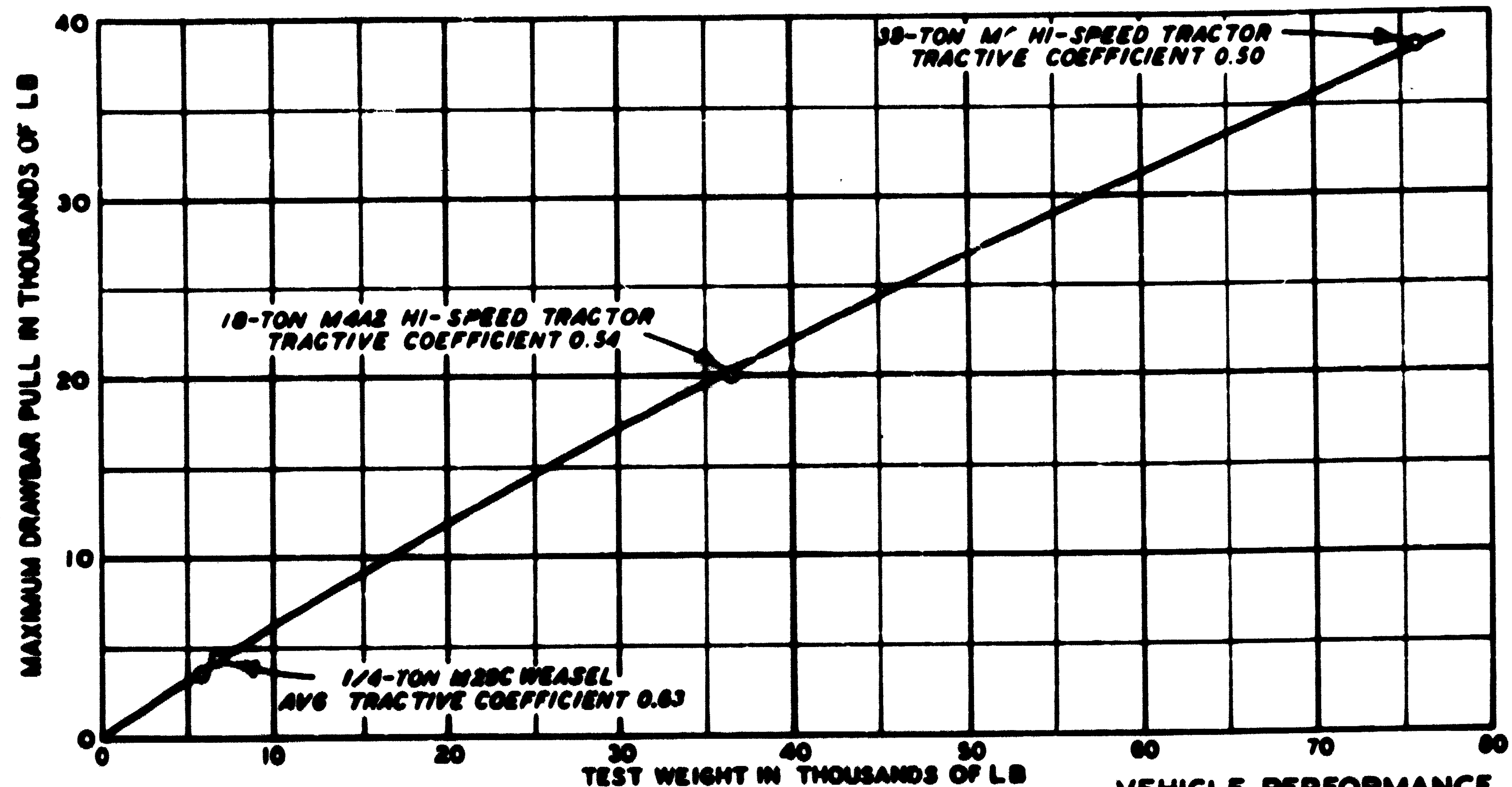
- O WHEELED VEHICLES
- ◻ TRACKED VEHICLES

NOTE: REFER TO TABLE 8 AND TOWING TEST SECTION IN TEXT FOR SUPPLEMENTARY DATA.

TEST RESULTS VS COMPUTED MAXIMUM DRAWBAR PULLS

WHEELED AND TRACKED VEHICLES

HARROWED SAND



NOTE: REFER TO TABLE 8 FOR SUPPLEMENTARY DATA.

VEHICLE PERFORMANCE
TOWING TESTS
WITH SELF-PROPELLED
TRACKED VEHICLES

HARROWED SAND
MAXIMUM DRAWBAR PULL
VS TEST WEIGHT

TOWING FORCE REQUIREMENTS IN PER CENT OF TEST WEIGHT

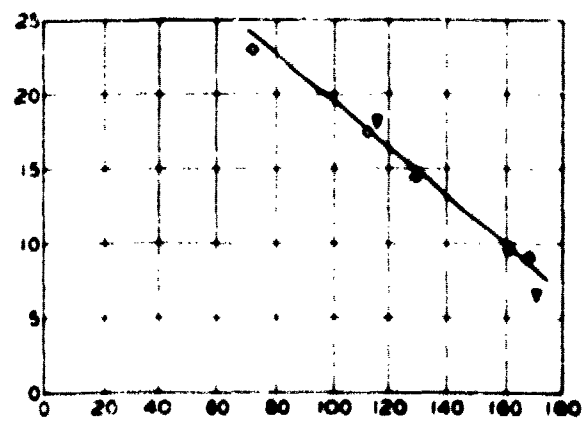


FIG. 1 60-PSI TIRE PRESSURE

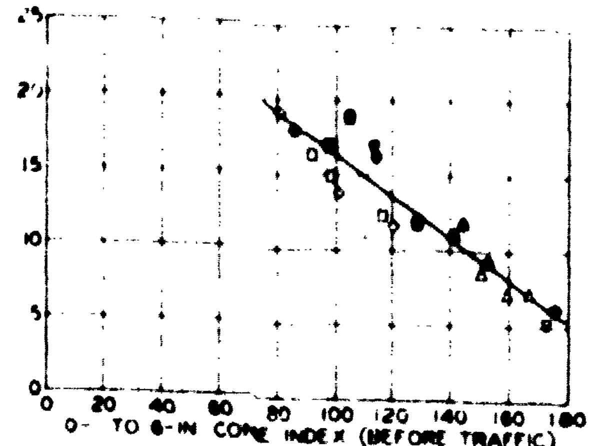


FIG. 2 45-PSI TIRE PRESSURE

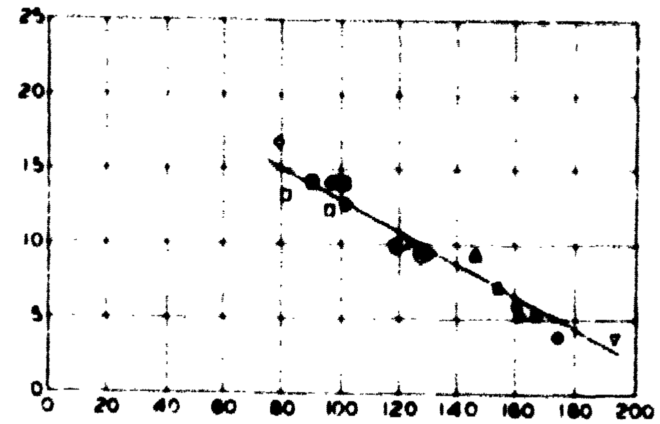


FIG. 3 30-PSI TIRE PRESSURE

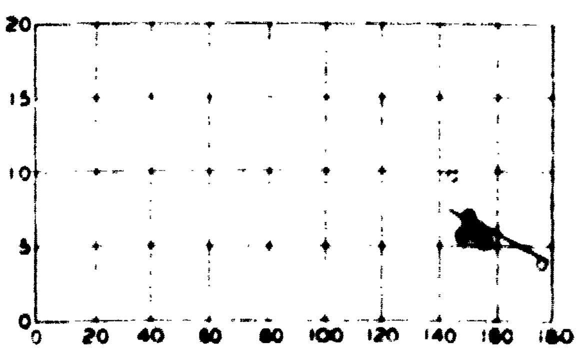


FIG. 4 25-PSI TIRE PRESSURE

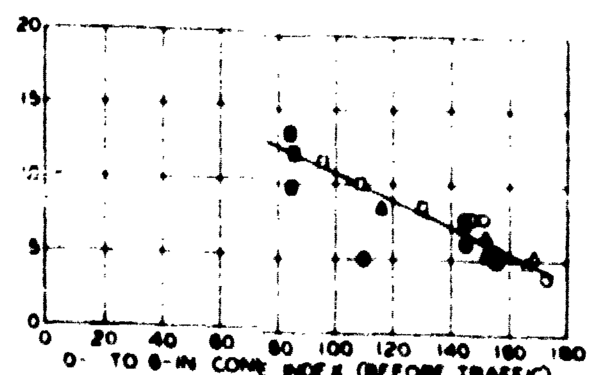


FIG. 5 20-PSI TIRE PRESSURE

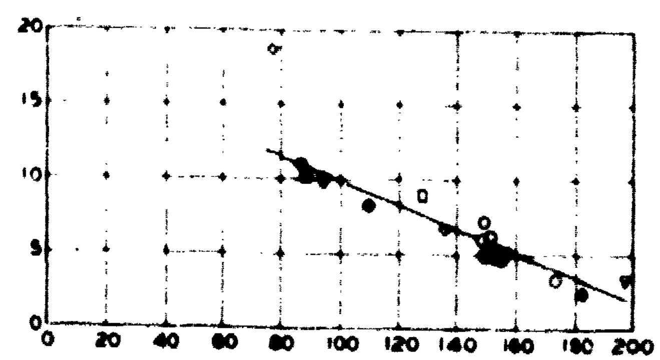


FIG. 6 15-PSI TIRE PRESSURE

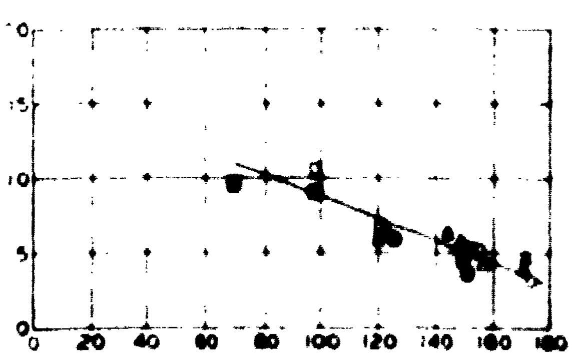


FIG. 7 10-PSI TIRE PRESSURE

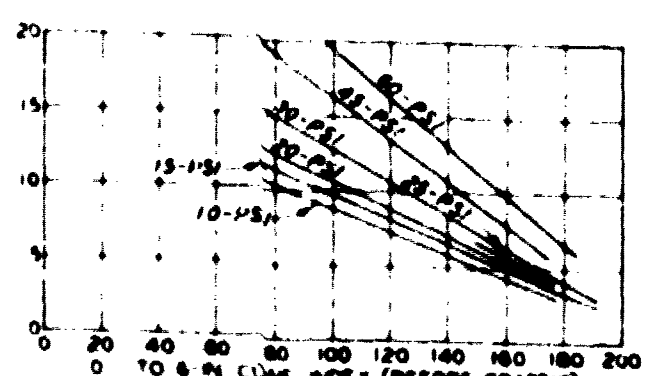


FIG. 8 FAMILY OF TIRE PRESSURE CURVES

LEGEND

SYMBOL		VEHICLE	SYMBOL		VEHICLE
○	●	$\frac{1}{4}$-TON M100 TRAILER	▽	▼	37.5 KW GEN TRAILER
△	▲	$\frac{3}{4}$-TON M101 TRAILER	◇	◆	6-TON TRAILER
□	■	$1\frac{1}{2}$-TON XM105 TRAILER			

NOTE: OPEN SYMBOLS DENOTE UNDISTURBED SAND TESTS
CLOSED SYMBOLS DENOTE DISTURBED SAND TESTS
FOR SUPPLEMENTARY DATA REFER TO TABLE 9

VEHICLE PERFORMANCE

TOWED WHEELED VEHICLE TESTS
TOWING FORCE REQUIREMENTS
VS
CONE INDEX