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USATECOM PROJECT NO. 7-5-0524-01-9

FINAL REPORT OF
MILITARY POTENTIAL TEST OF
MARSH SCREW AMPHIBIAN
(PLAN A - M113)

DECEMBER 1964

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U S ARMY
GENERAL EQUIPMENT TEST ACTIVITY
FORT LEE, VIRGINIA

HEADQUARTERS
U.S. ARMY GENERAL EQUIPMENT TEST ACTIVITY
FORT LEE, VIRGINIA

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FINAL REPORT OF MILITARY POTENTIAL TEST OF MARSH SCREW AMPHIBIAN (PLAN A - M113)

USATECOM PROJECT NO. 7-5-0524-01-9

Sponsored by Advanced Research Projects Agency
of the Office of the Secretary of Defense
ARPA Order No. 400 Amendment 6

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HEADQUARTERS

U S ARMY TEST AND EVALUATION COMMAND

Aberdeen Proving Ground, Maryland 21005

AMSTE-GE

SUBJECT: Final Report, USATECOM Project No. 7-5-0524-01, Military Potential Test of Marsh Screw Amphibian

TO: Commanding General
U. S. Army Materiel Command
ATTN: AMCRD-DM-E
Washington, D. C. 20315

1. Forwarded, inclosure 1, is a copy of subject report.

2. The military potential test of the Marsh Screw Amphibian was conducted in five locations, representing fresh and brackish water, mud flats and mud banks, marsh and swamp terrain, dense multiple-vegetated waters, and turf and heavy brush areas. Three of the test site locations were in Virginia and two in Louisiana. The results of the test indicate:

a. The Marsh Screw Amphibian's performance is most efficient and attains its greatest loaded speed (12.5 mph) when operated in extremely soft, liquefied mud. In heavily vegetated water which acts as a cushion, the efficiency and speed are only slightly reduced as compared with operation in liquefied mud. When operated in open water, speed was reduced to 7.7 mph with payload. (The speed of the M113 with combat load was 3.9 mph.) For operation in these areas, the Marsh Screw Amphibian is considered to have a military potential.

b. The Marsh Screw Amphibian is inefficient and steering control is erratic when operated over firm moist soil with high bearing strength and when operated over uneven terrain. It would have no military potential in these areas.

c. Six combat equipped personnel or 1,000 pounds of loose cargo can be transported by the Marsh Screw Amphibian over those terrains where the vehicle can operate.

d. Maintenance time per hours of operation on the Marsh Screw Amphibian was excessive.

AMSTE-GE
SUBJECT: Final Report, USATECOM Project No. 7-5-0524-01, Military Potential Test of Marsh Screw Amphibian

e. The Marsh Screw Amphibian must be transported between areas where it can operate by a special trailer and must be lifted off with a crane if a suitable launching area at a river or lake is not available.

f. The Marsh Screw Amphibian with payload can be carried as an external load by the CH-34 helicopter.

3. It is recommended that:

a. The Marsh Screw Amphibian tested be considered as having military potential only for use in open and heavily vegetated water, and in extremely soft mud.

b. The appropriate agency determine if a military requirement exists for a vehicle capable of operating in the limited marginal terrain described above.

c. If it is found a requirement does exist and appropriate QMR or SDR is prepared, the Marsh Screw Amphibian's deficiencies be corrected and engineering/service tests be conducted to determine if the modified vehicle meets the requirement.

FOR THE COMMANDER:

1 Incl
as

OLIVER H. ASPINWALL, JR.
Capt, ACC
Asst Adjutant Officer

Copy furnished: w/o incl
CO, USAGETA

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HEADQUARTERS
U. S. ARMY GENERAL EQUIPMENT TEST ACTIVITY
FORT LEE, VIRGINIA

USATECOM 7-5-0524-01-9

Final Report of
Military Potential Test of
Marsh Screw Amphibian
(Plan A - M113)

Conducted in the Appomattox and Chickahominy Rivers, Virginia; the Messick area in the tidewater section of Virginia; Bonnet Carre Spillway, Norco, Louisiana; and Bayou Du Large area, Houma, Louisiana.

December 1964

Abstract

A military potential test of the Marsh Screw Amphibian was conducted by the General Equipment Test Activity during the period 26 August through 20 October 1964 to determine the military potential of the vehicle and its suitability for operation in difficult off-road terrain similar to that found in Southeast Asia. Tested concurrently with the Marsh Screw Amphibian was the Swamp Spryte, a tracked amphibian cargo carrier designed for cargo up to 1,000 pounds. All tests were performed with both loaded and unloaded vehicles and consisted of land mobility and maneuverability tests; river and bayou swimming; helicopter lifts; land and water speed tests; land and water fuel consumption tests; and vehicle freeboard determinations.

It is concluded that the Marsh Screw Amphibian attains its greatest efficiency, and greatest loaded speed (12.5 mph) when operated in extremely soft liquefied mud and is considered to have military potential. The MSA is inefficient when operated over uneven terrain and is not considered to have military potential in this area. Test results show that six combat equipped personnel or 1,000 pounds of loose cargo can be transported over terrains where the vehicle can operate; maintenance time was excessive; the MSA must be transported between operable areas by a special trailer; and it can be carried as an external load by the CH-34 helicopter.

It is recommended that consideration be given to determine if a military requirement exists for a vehicle capable of operating in open and heavily vegetated water, and extremely soft mud. If such a requirement does exist then a QMR or SDR should be prepared outlining specific requirements. If a QMR or SDR for a vehicle to operate in the environment cited is approved, the deficiencies of the MSA should be corrected and engineering/service tests be conducted to determine if the modified vehicle meets the requirement.

SECTION 1 - GENERAL

1.1 REFERENCES

1.1.1. Chrysler Corporation Test Report Marsh Screw Amphibian, 5 July 1963.

1.1.2. U.S. Army Engineer Waterways Experiment Station Technical Report No. 3-641, January 1964, subject: "Trafficability Tests with the Marsh Screw Amphibian on Coarse-Grained and Fine-Grained Soils."

1.1.3. Letter, CRD/D 416, 20 April 1964, subject: "Marsh Screw Vehicles."

1.1.4. Memorandum, CRD/X, 12 June 1964, subject: "Marsh Screw Amphibian (MSA)."

1.1.5. Memorandum, III - 152/64, 15 July 1964, subject: "Marsh Screw Amphibian (MSA)."

1.1.6. Letter, CRD/S, 27 July 1964, subject: "Marsh Screw Amphibian (MSA)."

1.1.7. Letter, SWG-MR, 30 July 1964 and 1st indorsement thereto AMCRD-DM-E (30 Jul 64) 3 Aug 1964, subject: "Military Potential Test of the Marsh Screw and the Swamp Spryte Vehicles."

1.1.8. Message AMCRD-DM-E 7-2249, 3 August 1964.

1.1.9. Plan of Test For Military Potential Test of Marsh Screw Amphibian, Project No. 7-5-0524-01-9.

1.1.10. Military Standard, Slinging Eyes and Attachments for Lifting and Tying Down Heavy Military Equipment (MIL-STD-209), 6 January 1955.

1.2 AUTHORITY

1.2.1. Letter, AMSTE-GE, Headquarters, U.S. Army Test and Evaluation Command, 14 August 1964, subject: "Test Directive, USATECOM Project No. 7-5-0524-01/02, Military Potential Test of Marsh Screw Amphibian (MSA) and Swamp Spryte (ARPA and USACDC)."

1.3 OBJECTIVE

To determine the military potential of the Marsh Screw Amphibian and its suitability for operation in difficult off-road terrain similar to that found in Southeast Asia.

1.4 RESPONSIBILITIES

The U.S. Army General Equipment Test Activity was responsible for test plan preparation, test execution and test reporting.

1.5 DESCRIPTION OF MATERIEL

1.5.1 MARSH SCREW AMPHIBIAN

The Marsh Screw Amphibian is a new vehicle designed for operation and use in adverse terrain. Based on the principle of the Archimedean screw, two rotating pontoons with spiral blades propel the vehicle. Rotation of the two pontoons in opposite direction causes the vehicle to move forward or in the reverse direction depending upon direction of rotation of the pontoons. On hard surfaces the vehicle can be made to travel sideways by disengaging one pontoon and spinning the other. Design speed is 20 mph in snow and 8 mph in water.

1.5.1.1 Technical Data

Empty weight, lb. (as tested) (includes driver and fuel)	2860 (actual weight)
Loaded weight, lb. (includes driver, fuel, and a 1000-lb. payload)	3860
Ground pressure (at 3-in. penetration) loaded, psi	0.52
Ground pressure (at 3-in. penetration) loaded, psi	0.72
Computed VCI (2860 lb.)	8

Computed VCI (3860 lb.)	10.7
Length, overall, ft.	13.66
Width, overall, ft.	8.16
Height, overall, ft.	4.75
Rotor spacing (center to center), in.	66
Rotor diameter (drum only), in.	26
Rotor diameter (over helix), in.	31
Rotor length (overall), in.	152
Rotor length (in contact with ground, no rut), in.	129.5
Ground clearance, in.	20
Engine	Spark ignition, slant 6-cylinder, water cooled, OHV, 225 cu. in., 116 hp @ 3600 rpm.
Power Train Transmission	3-speed transmission with electric clutch/brake controlled by a steering wheel through a chain-driven, double-reduction final drive, ratio 6.55:1

Electrical system	12-volt/w alternator
Body and rotors	6061 T6 aluminum
Engine block	Aluminum
Transmission housing	Aluminum
Final drive housing	Aluminum

1.5.2 CONTROL VEHICLE

The M113 is a carrier, personnel, full tracked, armored, weighing approximately 23,900 pounds combat loaded. It has a ground pressure of 7.3 psi.

1.5.3 CONCURRENT TEST VEHICLE

The Swamp Spryte was tested concurrently in the same environment as the Marsh Screw Amphibian and results are contained in the Annex. The Swamp Spryte is a tracked amphibian cargo carrier designed for cargo up to 1,000 pounds. It has an aluminum body with removable aluminum cab. Length is 157 inches; width, 77 1/2 inches; overall height with and without cab is 79 inches and 63 inches respectively. The Swamp Spryte is designed for a top speed of 35 mph on land and 4.2 mph in water at normal engine cruising speed.

1.6 BACKGROUND

An automotive firm was awarded a contract in 1962 to develop for the U.S. Navy an amphibian capable of transporting six combat-equipped men plus a driver through fresh and salt water, over beach sand, rice paddies, swamps, mud banks, earth banks, bogs, and to occasionally

cross hard-surface roads. Requirements for the vehicle and funds for its development originated at the Advanced Research Projects Agency (ARPA).

The prototype MSA was completed in January 1963. Tests to date which have been reported include a 100-hour operational test conducted by the firm and trafficability tests conducted by U.S. Army Engineer Waterways Experiment Station (Ref. 1. 1(2)). The U.S. Marine Corps conducted a three-week test on the MSA in April and May 1964.

As a result of the reported performance of the vehicle, ARPA offered the U.S. Army an opportunity to evaluate the MSA to determine its military potential. Accordingly, Office, Chief of Research and Development, directed USAMC and USACDC to prepare a coordinated test program on the MSA which would provide information as to the potential applications of the vehicle, desirable configurations, and whether further development was warranted (Ref. 1. 1(3)).

A test program was prepared by the U.S. Army Test and Evaluation Command in accordance with instructions from USAMC and OCRD. The program offered two plans, A and B, as outlined in OCRD memorandum to ARPA (Ref. 1. 1(4)). Plan A recommended to ARPA called for testing two MSA's against the M113 only as control. Plan B, suggested by USACDC, called for testing two MSA's and two Swamp Sprytes (Thiokol) against the M113 and M116 vehicles as control. ARPA, in reply dated 15 July 1964 (Ref. 1. 1(5)) indicated preference for and would agree to funding only Plan A.

OCRD directed USAMC and USACDC to implement conduct of the Plan A test on an expedited basis over a period of 30 days and indicated that any expansion of the test to include other vehicles would have to be funded by USACDC (Ref. 1. 1(6)). USACDC indicated a desire to include the Swamp Spryte in the test and was prepared to fund this phase. USAMC requested USATECOM expedite the Plan A test modified by inclusion of the Swamp Spryte vehicles desired by USACDC (Ref. 1. 1(7)).

On 28 August 1964 a directive from USATECOM to USAGETA extended the test period to 12 October 1964 and included testing in Louisiana swamps. This report of test covers the operation of the MSA and the M113 control vehicle.

1.7 FINDINGS

a. Approximately 16 hours of operational time on the vehicle was required by the operators to become proficient in operation over most terrains encountered.

b. Although all repairs of the vehicle were performed by the manufacturer's mechanic with assistance from military maintenance personnel, it was felt that a concentrated two-week training program for military personnel with an automotive mechanic MOS would enable them to maintain the vehicle.

c. The Marsh Screw Amphibian was able to easily negotiate the following types of terrain:

(1) Tidal mud flats in the Appomattox River area with cone penetrometer readings of 0 to 18.

(2) Vegetation entangled waterways of the Chickahominy River and Bonnet Carre Spillway test areas.

(3) Floating grass mats found in the swamps of the Bayou Du Large area of Louisiana.

(4) Soft soils with vegetation cover or any surface where the MSA is in float condition or with water furnishing sufficient lubrication to overcome friction forces which otherwise inhibited or restrained the rotors.

d. The Marsh Screw Amphibian could not negotiate marsh terrains with no surface covering of water in the Messick area where cone penetrometer readings exceeded 60.

e. Steering of the Marsh Screw Amphibian could not be controlled when the vehicle was operated over uneven terrain or areas where the soil consistency was different under each rotor.

f. Firm moist soils, devoid of vegetation, did not provide lubrication for the vehicle's rotors and prevented movement in the forward direction. These areas could be crossed by operating the vehicle laterally but with poor or no directional control.

g. Heavy vegetational growth in areas with firm moist soils provided sufficient lubrication for the rotors to permit them to rotate freely and propel the vehicle forward.

h. The Marsh Screw Amphibian was able to negotiate vertical vegetated soft soil river banks up to six inches when exiting from the water.

i. Water speed of the Marsh Screw Amphibian was 8.1 mph empty and 7.7 mph when carrying its rated payload. See Appendix I, Table II.

j. The speed of the Marsh Screw Amphibian, when operated over mud flats having a cone penetrometer reading of 0 to 18, was 14.4 mph empty and 12.5 mph when carrying its rated payload, but decreased rapidly as moisture content decreased and the soil became firmer. See Appendix I, Table I.

k. The M113 control vehicle combat loaded, which weighed six times as much as the loaded Marsh Screw Amphibian, was unable to negotiate the mud flats, floating grass mats, vegetation entangled waterways and those waters with a depth less than 66 inches and a soft bottom. It could negotiate all other terrains encountered during the tests.

l. The Marsh Screw Amphibian with payload was capable of being lifted from firm soil, water, and mud and being transported as an external sling load by the CH-34 helicopter, but could not be lifted by the CH-21.

m. The Marsh Screw Amphibian was capable of carrying six combat equipped men plus the driver along and across inland waterways and soft soil terrain adjacent thereto.

n. Personnel riding in the cargo area adjacent to the engine and the exposed exhaust system were subjected to considerable discomfort due to the extreme heat generated by those components. In warm or hot climates, this would reduce the number of personnel carried to four.

o. The cargo bed of the Marsh Screw Amphibian as tested was not suitable for transporting palletized or drummed cargo, but could be easily loaded with boxed cargo by hand or crane. No cargo tiedown facilities were provided.

p. Ride characteristics including shock and vibration were acceptable over soft soil and water; but, when the vehicle was operated over firm ground and banks, the erratic movement of the vehicle and the lack of any suspension system subjected personnel to extremely uncomfortable tossing about and vertical shock.

q. Down time for repairs on the Marsh Screw Amphibian was excessive. Pilot Number 1 was deadlined for repairs 58 hours including 34.5 hours awaiting parts for 64.5 hours of operation. Pilot Number 2 was deadlined for repairs 62 hours including 45.5 hours awaiting parts for 74.5 hours of operation.

r. The Marsh Screw Amphibian must be transported between operational areas by a special trailer. If a suitable river bank with sufficient water depth is available, it may be launched from the trailer like a boat, but otherwise must be lifted off by a crane.

s. Special permits are required when the Marsh Screw Amphibian is transported on its trailer over highways as it is two inches over the allowable width of 96 inches for unrestricted movement over highways.

t. Lifting eyes and tie downs did not comply with MIL-STD-209 (Ref. 1.1(10)).

1.8 CONCLUSIONS

a. The Marsh Screw Amphibian's performance is most efficient and attains its greatest loaded speed (12.5 mph) when operated in extremely soft, liquefied mud. In heavily vegetated water which acts as a cushion, the efficiency and speed are only slightly reduced as compared with operation in liquefied mud. When operated in open water, speed was reduced to 7.7 mph with payload. (The speed of the M113 with combat load was 3.9 mph.) For operation in these areas, the Marsh Screw Amphibian is considered to have a military potential.

b. The Marsh Screw Amphibian is inefficient and steering control is erratic when operated over firm moist soil with high bearing strength and when operated over uneven terrain. It would have no military potential in these areas.

c. Six combat equipped personnel or 1,000 pounds of loose cargo can be transported by the Marsh Screw Amphibian over those terrains where the vehicle can operate.

d. Maintenance time per hours of operation on the Marsh Screw Amphibian was excessive.

e. The Marsh Screw Amphibian must be transported between areas where it can operate by a special trailer and must be lifted off with a crane if a suitable launching area at a river or lake is not available.

f. The Marsh Screw Amphibian with payload can be carried as an external load by the CH-34 helicopter.

1.9 RECOMMENDATIONS It is recommended that:

a. Consideration be given to determining if a military requirement exists for a vehicle capable of operating only in open and heavily vegetated water, and extremely soft mud. If such a requirement does exist then a QMR or SDR should be prepared outlining the specific requirements.

b. If a QMR or SDR for a vehicle to operate in the environment cited is approved, the Marsh Screw Amphibian's deficiencies be corrected and engineering/service tests be conducted to determine if the modified vehicle meets the requirement.

SECTION 2 - DETAILS AND RESULTS OF SUB-TESTS

2.0 INTRODUCTION

a. The military potential test of the Marsh Screw Amphibian (MSA) was performed in accordance with the Plan of Test (Ref. 1.1 (9)). An amphibious, armored, personnel carrier (M113) was utilized as the control vehicle. The Swamp Spryte was operated at the same time and in the same environment (see Annex).

b. All tests were performed with both loaded and unloaded vehicles during the period 26 August to 20 October 1964. Tests consisted generally of the following types:

(1) Land mobility and maneuverability tests through heavy brush, swamps, ditches, marshes, stump infested areas, and seemingly bottomless pot holes.

(2) River and bayou swimming through dense surface and subsurface vegetation, and operation over the mud banks adjacent to the waterways.

(3) Helicopter lifts from firm ground, deep mud, and from a river surface.

(4) Land and water speed tests.

(5) Land and water fuel consumption tests.

(6) Vehicle freeboard determinations.

c. Five test site locations were utilized, representing fresh and brackish water, mud flats and mud banks, and marsh/swamp terrain. Dense multiple-vegetated waters, turf and heavy brush land areas were also present. Test site locations, general physical properties, and periods of test were:

(1) Appomattox River area, Chesterfield and Prince George Counties (vicinity: Ft. Lee, Virginia): This is a tidal river area having exposed mud flats and mud beaches during periods of low tide. A four-mile portion of this river and Cobbs Island were included in the

test area. Period of test: 26 August 1964 to 4 September 1964.

(2) Messick area (vicinity: Langley Field, Virginia): This peat marsh area included a 15-foot wide water filled drainage ditch. Period of test: 8 September 1964.

(3) Chickahominy River area, New Kent County (vicinity: Providence Forge, Virginia): This swamp site provided a dammed river area abounding with surface and sub-surface vegetation (see para. 2.3.3.4). Period of test: 9-17 September 1964.

(4) Bonnet Carre Spillway, Norco, Louisiana (vicinity: 18 miles north of New Orleans off U.S. Highway 61): A government leased 3,790-acre grass matted and stump filled marsh area located between and adjacent to Lake Pontchartrain and the Mississippi River. Period of test: 24 August to 6 October 1964.

(5) Bayou De Large area, Terrebonne Parish (vicinity: 20 miles southwest of Houma, Louisiana): This 4,000-acre swamp area was typical bayou, low-lying marshland. The only access to the test area was by crossing Bayou Du Large and a four to seven-foot spoil-bank on the far shore. This was an extremely treacherous area for vehicles. Period of test: 7-12 October 1964.

d. Soils characteristic data were collected at each of the five test sites within the specific operating areas. This work included the obtaining of Cone Index Values, moisture content determinations, Remold Index determinations and grain size analysis.

e. Both test items were left exposed to the weather throughout the test period. Exposure included the effects of Hurricane Hilda as it swept through Louisiana, 3-4 October 1964.

f. The requirements listed in the Plan of Test were not considered restrictive. All pertinent information which was considered of value in determining suitability of the item was observed and is commented on in this report.

2.1 FAMILIARIZATION AND TRAINING

2.1.1 OBJECTIVE

To determine the degree of operating and mechanical skill required to operate and maintain the equipment, and the time required to train personnel to adequately perform these tasks.

2.1.2 METHOD

Personnel were selected and given necessary instruction in the operation, maintenance and safety of the test item using available manufacturer's publications and the manufacturer's technical representatives.

2.1.3 RESULTS

a. The two individuals selected to operate the Marsh Screw Amphibians were both specialists, fifth class. One had an assigned MOS of 642.10 (Heavy Vehicle Operator) and the other a 622.20 (Heavy Engineer Equipment Repairman). Neither had previous experience with a vehicle similar to the Marsh Screw, nor with tracked or amphibious tactical vehicles.

b. Basically, initial operation of the Marsh Screw Amphibian by an untrained person is relatively simple. Any individual familiar with the operation of an automobile can, with five to ten minutes instruction, move the vehicle across soft mud or a water surface and perform simple turning and backing maneuvers. However, to realize the designed mobility potential of the vehicle over varied terrain, both in conventional directions and laterally, a minimum of 12 to 16 hours of operational experience was required. This is not considered to be excessive. Increased operator proficiency, however, was gained subsequent to this training period.

c. The test item consisted of many standard automotive components and was not unduly complex or difficult to maintain in spite of its unconventional design. Repairs were frequent but were accomplished with relative ease by a highly trained manufacturer's mechanic assisted by military mechanics. It is believed that a concentrated two-week training program for military personnel with an automotive mechanic MOS

would qualify them to perform all organizational level maintenance.

2.1.4 ANALYSIS

a. The most difficult operational phase for the operator to master was movement across irregular surfaces with little or no free standing water. Each drive rotor on the MSA was capable of being separately rotated clockwise, counterclockwise, idled (free wheeled) or locked in position. Maximum vehicle operational efficiency was dependent upon the operator properly selecting and intermixing each rotor's movements through two panel switches, an electric clutch brake steering wheel and a push button transmission control which provided reverse, neutral, and two drive ranges. Operator proiiciency was attained only through continued operation of the vehicle over various surfaces, both in a loaded and an unloaded condition.

b. The statement regarding ability of military trained automotive mechanics to maintain the vehicle is based on observations of the Project Director and is supported by military mechanics assigned to the project.

2.2 PRE-OPERATIONAL INSPECTION

2.2.1 OBJECTIVE

To insure that the test items were in proper condition for test operation.

2.2.2 METHOD

a. Available technical data concerning the item were reviewed to determine extent of preparation required prior to test operation.

b. Preparation requirements including inspection, adjustments, lubrication, cleaning and required repairs were performed.

2.2.3 RESULTS

a. Pilot Number 2, MSA arrived at Fort Lee, Virginia, on 30 July 1964. Inspection of the vehicle disclosed no mechanical deficiencies. After servicing, which included draining and refilling of the final drive, the vehicle was considered ready for test.

b. Pilot Number 1, MSA arrived 10 August 1964. Pre-operational inspection of this vehicle revealed a leaking final drive seal and a dead battery. Replacement of the seal required removal of one rotor (pontoon). The vehicle was considered ready for test after servicing and installation of a new battery, new oil seal, a lock pin for the final drive chain (lost during reassembly), and replacement of three stripped bolts on the final drive housing (vehicle operator error while assisting mechanic).

2.2.4 ANALYSIS

Not applicable.

2.3 MOBILITY TEST

2.3.1 OBJECTIVE

a. To determine the overall surface mobility characteristics of the Marsh Screw Amphibian during actual operations in areas which are considered analogous to those found in Southeast Asia.

b. To compare performance of the test vehicle with the M113 during these operations.

2.3.2 METHOD

a. Vehicles tested were operated by trained military operators under the same conditions and environment to the maximum extent practicable to reduce possibility of biased results.

b. The vehicles were operated simultaneously with full rated loads (cargo and personnel) and also unloaded, in random patterns over the following terrain conditions:

(1) In open water of varying depths.

(2) In water with vegetation growths such as lily pads, sub-surface and surface matted grass, high grass and weeds.

(3) In mud of various consistencies including highly liquefied and plasticized or viscous found in marsh areas and tidal mud flats.

(4) Over marshlands, spongy dirt or grass covered terrain (indicating existence of sub-surface water).

(5) Through dense brush and vegetation in and out of water.

(6) Over banks or slopes adjacent to streams and/or water crossings.

(7) Across ditches.

(8) From soft mud terrain to hard surfaces.

c. The Rating Cone Index, moisture content and Grain Size Analysis of the soft soils on which the vehicles were operated was obtained.

d. Vehicles were maintained in readiness condition and operated to the maximum extent possible during the entire test period.

2.3.3 RESULTS

2.3.3.1 General

Surface mobility tests were conducted in each of the five test sites. Vehicles were run through each course and in random patterns first without load and then in a loaded condition. Detailed test site description, activities and test results were as follows:

2.3.3.2 Appomattox River Test Area (Virginia)

The Appomattox is a tidal river. Two hours prior to and subsequent to mean low tide, mud flats and mud beaches become exposed. These mud areas are devoid of vegetation and are of a gradual gradient from the water's edge inland. The soils on these flats were identified as inorganic clays of high plasticity, and inorganic silts, all with high moisture content. Cone Index readings varied between 0 and 18 with the majority of the readings falling in the 0 area indicating that no support for vehicles could be expected. Soil moisture content ranged between 24 percent and 215 percent with a majority of the values falling between 90 percent and 175 percent. See Section 3, Appendix I, for detailed soils data.

a. Marsh Screw Amphibian:

The Marsh Screw Amphibian easily exited the river and negotiated the beaches and mud flats in both a loaded and unloaded condition. Top speeds, reduced speeds and angle approaches failed to immobilize the test item. As the leading end of the rotor helix came in contact with the mud, a decided and sustained increase in speed was experienced until the vehicle again became water borne where a noticeable decrease in speed occurred. This increase in speed when operating on the mud flats is attributed to the reduced drag on the vehicle as sinkage in mud is less than in water and the mud acted as a lubricant for the rotors.

b. M113 Armored Personnel Carrier:

Eight unsuccessful attempts were made with the empty M113 within a three-mile section of the river to exit from the water and move onto the tidal mud flats and mud beaches. Each time, the M113 became immobilized. The more its tracks were rotated, the deeper it became mired and the more difficult it was to retrieve. Only twice was it able to extricate itself and move back into the river. This was accomplished only after 1 to 10 minutes of churning the mud from under its tracks in order to regain a full float condition. Forceful beach approaches, slow approaches and angle approaches to the land mass failed to overcome this mobility problem. The M113 was only able to enter and exit the river at the concrete boat launching ramp.

c. Speed tests, fuel consumption and freeboard determinations:

(1) Mud speed tests: Maximum throttle speed tests over a measured 528-foot straight line course were conducted on a tidal mud flat which is exposed during low tide periods. Soils on the course were identified as inorganic clays or high plasticity and inorganic silts. Cone penetrometer values of 0 to 18 were recorded; wind velocity was .05 to 1 mph. Three passes each were made over the course by the MSA in an unloaded and loaded condition. The M113 could not negotiate the low soil strength mud flats; therefore, it was not able to participate in the speed test. See Table I, Appendix I, for detailed results.

(2) Water speed tests: Maximum throttle tests over a 528-foot straight line measured water course were conducted in the Appomattox River. The MSA and the M113 each made two timed passes upstream and two downstream to negate the effects of the river current and a 1.5 mph breeze. See Table II, Appendix I, for detailed results.

(3) Fuel consumption tests: The two vehicles were filled to maximum with fuel while in a level position and then operated at normal cruising speed on land for a specified time period. At the completion of the run, the vehicles were again repositioned as before and again filled to maximum with fuel. Measurement of fuel was by metered flow. The same procedure was followed to obtain fuel consumption in water. See Table III and IV, Appendix I, for detailed results.

(4) Freeboard determinations were conducted on each vehicle by measuring the distance from the four lowest points of the sides of the vehicle down to the water line. Determinations were made with a light vehicle and with its rated payload. The empty MSA had an average freeboard of 34-1/2 inches at the bow and 27-3/4 inches at the stern with no list. The loaded MSA had an average freeboard of 34-3/4 inches at the bow and 23 inches at the stern with no list. The empty M113 had an average freeboard at the bow of 13.5 inches and 13 inches at the stern with no list. The loaded M113 had an average freeboard at the bow of 12-3/4 inches and 10 inches at the stern with the left front corner of the vehicle being 1/2 inch lower in the water than the right front corner.

2.3.3.3 Messick Test Area (Virginia)

This site consists of a level peat marshland bounded by the Chesapeake Bay and Back River. It lies two miles northeast of Langley Air Force Base. Sparse brush, a spongy grass mat and other low marsh grasses comprise the vegetation. Moisture content increases considerably towards the east and south in the direction of the bay and soil strengths grow progressively lower.

Mobility and maneuverability tests of the MSA were conducted in this area. The M113 did not participate at this site since tests of previous years with the M113 at Messick indicated that this vehicle was capable of negotiating all areas within this site. Access to the test area is from an asphalt roadway which runs parallel to a 15-foot wide water filled mosquito control ditch. A mobile crane was required to remove the MSA from its special trailer and to place the test item into the ditch. The MSA was operated in the ditch parallel to the roadway for approximately 100 feet and then turned out of the ditch and driven over the three-foot dry, firm spoil bank.

The ditch, constructed subsequent to the previously mentioned vehicle tests, had effectively drained off most of the moisture from the immediate adjacent marshland. This created a firm soil with only sparse vegetation which provided no rotor lubrication for the MSA's rotors. After 75 feet of labored, slow and erratic operation, it became immobilized and was unable to negotiate the terrain in the forward or reverse direction. Surface cone readings of 60 to 300 and Moisture Content Values of 15 percent to 18 percent were recorded in this specific area of difficulty. Attempts to turn and move at right angles to and away from the ditch in order to find greater surface moisture were unsuccessful. Numerous attempts were made to move the vehicle in a lateral direction but due to irregularities in ground surface and brush growth only 10 to 15 feet could be traversed and it was not possible to drive the vehicle to more favorable terrain. Attempts to reposition the vehicle by forward and reverse movements of the rotors were unsuccessful due to insufficient torque at the rotors even at full throttle to rotate them. Many times the engine would "load up" and stall. While endeavoring to return to the ditch because of overheating in the final drive area, the vehicle's drive clutches became inoperative.

Tests in this area were terminated and the vehicle returned to the organizational maintenance shop at Fort Lee, Virginia. Disassembly of the unit revealed that one rotor drive clutch was completely burned out and that the other was damaged but repairable.

2.3.3.4 Chickahominy River Test Area (Virginia)

This test site was within the dammed portion of the Chickahominy River and consisted of the vegetated waters thereof and two leased swamp and marsh areas approximately two miles distant from one another. Area vegetation consisted of pickerelweed, water primrose, duckweed, cattails, waterweeds, and lily pads.

a. Pilot Number 1, MSA, was able to move with ease through each of the various test areas that the M113 had negotiated or had attempted to negotiate. The MSA's shallow draft (eight to ten inches) kept it from contacting the river bottom most of the time. However, in the upper reaches of the river and its tributaries and when approaching the beaches, contact with the soft mud bottom resulted in a very noticeable gain in speed as its helixes obtained added purchase from that medium. The entangled, rooted, floating mass of grass also was no barrier. The moment the leading portion of the rotor helixes touched the growth, the vehicle's speed increased perceptibly as it climbed up onto the mass and continued on across it.

b. Excessive steering correction was required to keep the MSA on the proper course during water travel if cargo or passengers caused the vehicle to list to one side or the other. It was found that a careful balancing of cargo and/or passengers would correct the list and reduce this problem.

c. There was no wind up of vegetation on the rotors or in the rotor support areas during these tests. At no time during the Chickahominy River tests did the MSA become immobilized.

d. The M113 armored personnel carrier was subjected to swimming tests through the surface and sub-surface growths as listed above. In a full float condition, the vehicle was able to slowly pass through those areas where the vegetative growth was not heavily concentrated. In a half float condition, the vehicle would proceed with great difficulty even in water without vegetation. Under this condition,

where the vehicle's tracks were in slight contact with the river bottom, even small amounts of water vegetation were sufficient to halt all forward movement. The operator, however, was able to reverse direction and free the vehicle; and, in some cases, the operator was able to find a route which circumvented the vegetated areas. Frequently the vehicle was immobilized and became completely mired. Very seldom was the M113 able to extricate itself. The M113 could not be relied upon to negotiate any portion of the river unless it was able to maintain a full float condition; this required a minimum of 66 inches of water. Where water depth was less than 66 inches, the vehicle would sink into the river bottom mud until it became mired. Retrieving was difficult and time consuming, requiring the use of the M116 unarmored personnel carrier (gross weight, 10,600 pounds). The M116 had to be positioned on firm ground or lashed to a tree before its winch could be utilized to extricate the 23,900 pound M113. In one particular area, heavy-rooted growth floated on the surface of the water for acres in large concentrated masses. Water depths varied from 3 1/2 to 6 feet deep under the masses. The M113 whether in a swimming condition or with its tracks in contact with the soft bottom could only negotiate this growth three to four feet before losing all forward motion.

2.3.3.5 Bonnet Carre Test Area (Louisiana)

This test site comprised approximately 4,000 acres containing many submerged or grass-hidden tree stumps and areas having denser vegetation which concealed three to four-foot gullies and soft mud holes. Free standing water on a grass mat partially covered the northern portion of the land mass adjacent to Lake Pontchartrain.

a. Two to five-foot deep borrow ditches (drainage canals) matted with alligator weed and having exposed sloping mud sides 4 to 18 inches high ran parallel to a dirt roadway for two miles. Land vegetation consisted of entangled briars, cypress weeds, Roseau Cane, cocklebur weeds, sunflower weeds, willow bushes and small buttonwood, ash and tupelo trees. Swamp areas contained pickerelweed and other typical wet land waterweeds.

b. Only MSA Pilot No. 1 and the control vehicle were available for tests at this site due to the second MSA having been withdrawn for a Navy demonstration. Test activities in this area included attempted negotiation of all terrain features and waterways within the

site. Additionally, a one-half mile cross country speed course was staked out which had a progressive decrease in moisture content from a wet surface start to a fairly dry finish line. The course included submerged and otherwise hidden stumps, two raised dirt roadways which crossed the route at right angles and a cross section of the varied vegetation found within the spillway area. Prior to negotiating this course, the operators were instructed to exercise due caution but to operate at the maximum speed commensurate with safety. The MSA completed the course in 13.64 minutes for an average speed of 2.2 mph. The M113 covered the route in 10.20 minutes for an average speed of 2.9 mph.

c. On the second day of operation in this area, the MSA was deadlined for repairs to one of its rotor helixes. The rotor had forcefully struck a number of stumps during its tests which caused a helix to be torn loose for 18 inches along the helix-rotor weld point. A tear was also present where two sections of the T-6 aluminum helix had been welded together to extend the thread for the required rotor length. Total down time for repairs was seven hours.

d. Swimming tests in the borrow ditch resulted in the M113 being unable to proceed for more than 50 to 60 feet at a stretch before becoming immobilized due to the mud bottom, a log, or concentrations of alligator weed. The denser growths of this weed would stop the M113 within ten feet. In the non-vegetated portions of the ditch, where the M113 was able to operate, very little control could be exercised over direction of travel as the vehicle would continually wear sharply from one side of the ditch to the other when its tracks came in contact with the sloping banks. Constant backing off the banks, churning of tracks and excessive manipulation of the steering-brake controls were required to correct this condition and control the desired direction. The control vehicle could not climb out of the deeper portions of the drainage ditch unassisted.

e. The MSA easily negotiated the densely vegetated portions of the waterway, traveling the entire two-mile length. It easily exited and re-entered the canal at various points and could cross the 20-foot roadway from the canal side to the marsh on the opposite side. This was accomplished in a forward direction where a grass mat existed or laterally where no vegetation was present or the surface was fairly dry.

f. Cross country, random pattern travel throughout the test site, excluding water movements, resulted in both vehicles successfully moving through dense brush, marsh, swamp, gullies and fairly firm ground having no free water but with a Burmuda grass cover. Maintaining directional control of the MSA during cross country travel constituted the greatest operator problem due to varying surfaces, moisture conditions and uneven terrain. The test item tended to veer and suddenly move laterally where the terrain under the rotors was of different characteristics (soft soil on one rotor and a firm surface on the other).

g. While the MSA was not designed to travel over firm dirt roads in a forward direction, this means of travel was achieved during a heavy rainstorm. Forty-five minutes of rainfall had lubricated the dirt road to the extent that the MSA was able to travel three-quarters of a mile at approximately two to three mph. Full throttle was utilized and there was no overheating of the drive clutches, final drive or engine.

h. At the completion of testing in this area and after eight hours of operation subsequent to the initial rotor repairs, it was evident that the rotors were in extremely poor condition. Both had suffered multiple helix tears, helix-rotor weld breaks, extended breaks along radial welds on the rotor skin at compartment locations, and at the welds at the circular plates or plugs used to close the rotor compartments after filling the rotors with styrofoam. All welds beads on the rotorskin had been worn down by surface friction and all had failed simultaneously. A total of 64.5 hours had been accumulated on the rotors on Pilot Number 1 during this period. Previous operational hours are unknown but were said to be extensive by the manufacturer. Rotors were considered to be uneconomically repairable by the technical representative and the vehicle was deadlined.

2.3.3.6 Bayou Du Large Test Area (Louisiana)

This site was an Army leased area located west of and adjacent to Bayou Du Large. Pilot No. 2 with steering system parts from Pilot No. 1 was used in this area. Soils were composed of a sand-silt mixture with low plasticity. The test vehicle was required to cross the 120-foot bayou and negotiate a four to seven-foot spoil bank in order to gain access to the test area. Many small tributary bayous and ponds

existed within the marshy site as did floating grass mats and mucky pot holes. Moisture content increased noticeably in the area towards the Gulf of Mexico. The M113 was not transported to this site due to the presence of extremely soft soils and the difficulties anticipated in retrieving a heavy vehicle (23, 900 lbs) immobilized in this remote area. The range of cone indexes in the Bayou Du Large test site was very low with a typical value of 25 at the 6" level.

a. Operation of the MSA in this area consisted of random patterns for maneuverability and mobility determinations. Included was negotiation of the firm dry spoil areas adjacent to the bayou and entering and exiting the bayou and its tribitaries. As a result of Hurricane Hilda and its six to seven-foot tides, considerable debris littered the entire area. The rotors traveled over large timbers with protruding nails, barbed wire, and other typical severe storm rubble without difficulty or damage.

b. The sheer, firm bank of the bayou could not be negotiated by the MSA where the wall height from the water line was greater than six inches. Under this condition the center of the rotor's nose cone butted firmly against the bank's perpendicular wall. Soft mud banks of this height or greater could be progressively flattened to an acceptable angle of approach by repeatedly driving the vehicle against them. Repositioning cargo and/or passengers to the extreme rear permitted the vehicle to clear an additional one to two inches of wall height. However, this created a dangerous tipping angle and also the danger of swamping by the stern as the excessive angle of climb forced the rear of the vehicle down deep into the water.

c. After exiting from the bayou, extremely erratic steering was experienced as the vehicle attempted to negotiate the firm, irregular surfacr of the spoil bank. Careful manipulation of the various controls was required in this area to prevent the vehicle from suddenly moving in a dangerous, powered, lateral manner down the slope. This condition also existed if an angle approach to a slope or bank was made creating a shift of weight to the downhill rotor giving that drive member more tractive effort.

d. The only soft-soil immobility of the MSA during the entire test program occurred in this test area. The loaded vehicle was driven into a three-foot deep, ten-foot wide ravine and the front end of the vehicle's rotors came to rest on the forward wall while the vehicle was supported on the opposite slope. Lateral movement was possible but would have resulted in the vehicle dropping down further into larger holes on either side. There was insufficient torque to turn the rotors in either a reverse or forward direction. After initial attempts were made to extricate the MSA under its own power this method was abandoned as it was felt that it might become mired deeper. Base of operations for the test site was over a half-mile distant, through snake infested marsh, much of which would not support a man on foot. It was decided to transfer the payload to the accompanying vehicle to afford that vehicle better traction and to lighten the weight of the immobilized MSA. A line was affixed between the vehicles and, with power to the rotors of the MSA operating in reverse travel, the recovery vehicle was able to retrieve the MSA with little trouble.

e. A major part of this test site was covered with a floating grass mat of heavier and more buoyant consistency than that in the Chickahominy River area. Its entangled, submerged root mass ranged between 6 and 12 inches in depth, while the exposed grass portion stood between two and three feet tall. Local inhabitants of this area referred to this growth as FLO/TON or FLO/TANT. They claimed that trappers or other people familiar with the area and conditions could travel over this growth. However, an attempt by project personnel to stand on this mat while maintaining a firm hold of the MSA was not successful. As the vehicles traveled over this mat, a large undulating bow wave would be generated ahead of and to the sides of the vehicle. This floating mass was interspersed with large and small openings in the mat (locally referred to as pot holes) which were barren of most vegetation and contained a very soft, silt-like muck which registered "0" readings on the cone penetrometer. The MSA has no difficulty in negotiating these pot holes. In a few instances, these holes contained a heavy, sandy, damp mud, and tall clumps or portions of the floating mat. These areas made controlled movement of the MSA extremely difficult. In trying to traverse these areas, the torque, in some short instances, was insufficient at the rotors to rotate them effectively. Based on operations in other areas it is believed the M113 could not have remained mobile in this soft soil area.

2.3.4 ANALYSIS

While the Marsh Screw Amphibian is considered to be a test bed vehicle built for the purpose of checking out the feasibility of the propulsion system, the rotor deficiencies which developed in the Bonnet Carre test site should be considered and corrected if possible in the event of further development.

Mobility performance data obtained on the two vehicles during the eight-week test period are considered to be reliable and valid since the results were consistent under the myriad conditions encountered by five separate and distinct test areas.

The operation of a vehicle over difficult terrain in remote areas causes extreme fatigue to the operator. Irregular, fairly firm surface, which gave the MSA operator difficulty and caused fatigue, could be traversed with ease by a conventional tracked vehicle. On the other hand, the MSA was less fatiguing than the tracked vehicle when operating on soft soils and heavily vegetated waterways. The suspension design of the MSA did not generate excessive shock or produce unsatisfactory riding characteristics for its operator or passengers except when cresting a bank or similar terrain feature. It is believed that shock absorbing seat mountings could improve this condition and provide a more satisfactory ride. The present operator's seat was uncomfortable, tiring and inadequate.

Accessibility of vehicle controls could be improved by moving the floor mounted accelerator to a more natural position. Present position is too far to the right. The clutch control toggle switches located on the dashboard should be positioned to the left in a position within normal reach of the operator. A position just under the temperature gauge would improve this condition.

2.4 HELICOPTER LIFT TEST

2.4.1 OBJECTIVE

To determine whether the Marsh Screw Amphibian can be transported over impassable terrain by utilizing H-21 and H-34 helicopters.

2.4.2 METHOD

a. The test item was studied to determine whether the size, weight, sling attachments, and sling clearances imposed any limitations on external transport by Army helicopters.

b. The test item was rigged using the Army standard helicopter sling. Time required to rig and unrig, and method utilized, was recorded. Lift operations were attempted from hard surfaces, mud, and water, in both loaded and unloaded conditions.

c. Transporting tests over impassable terrain consisted of the MSA being air lifted from a river, after having crossed it under its own power, and then air transported to a marsh area approximately ten minutes distant. Maximum and ideal air speeds were determined and recorded.

d. The MSA was operated through the marsh area over a course consisting of terrain which was negotiable by the MSA. Lifts were made of the test item to move it from one operational area to another within the general test area including lifts from water, soft mud, and firm ground.

e. Weather, temperature, altitude, and humidity levels and type of surface from which exits were made were recorded for all lifts conducted.

2.4.3 RESULTS

2.4.3.1 General

Study of the test item as concerns external transport by Army helicopter indicated that the vehicle's size, weight and sling locations

were within the external lift capability of the aircraft selected. Sling eye dimensions did not comply with MIL-STD-209 (Reference 1.1 (10)) in that minimum size requirements were not met. The manufacturer, however, stated that the reinforced aluminum lifting eyes as furnished with the vehicle had been designed as lift points and would support a gross vehicle weight lift. The average time required for two men to affix the slings to the four lift points with shackles was 47 seconds. Unrigging required only 25 seconds.

2.4.3.2 CH-34 (Choctaw)

Six lifts of the MSA were made by a CH-34 helicopter. The item was picked up in both an empty and loaded condition from firm ground, very soft mud and from the Appomattox River. The initial lift was made using an Army standard helicopter 12-foot external sling. Discussion with the pilot immediately after the lift indicated that a shorter length sling would probably provide him with a better air cushion ground effect for lift purposes. He considered this to be especially needed for lifts from water surfaces and for all maximum weight vehicle lifts. A nine-foot sling was secured and utilized for the remainder of the tests and found to be satisfactory.

The empty MSA assumed a fairly level attitude and traveled without oscillation. It stabilized in a sideways to line-of-flight position. When loaded, the MSA rode with its stern low, but at an acceptable angle, and stabilized with the stern in the direction of air travel with no swinging motion. Maximum air speed was determined to be 60 knots but resulted in oscillation subsequent to turning maneuvers. Ideal air speed was established at 45 knots where there was no load oscillation.

During one lift of the loaded MSA, the windshield of the vehicle was blown off by the down wash of the helicopter rotors. Later, a sling leg bent the upright muffler exhaust pipe unit as the sling slack was being taken up by the lift. In another instance, as the MSA was being lowered to the ground, the pilot released the load prematurely causing the vehicle to drop approximately two to three feet to the ground. A subsequent inspection of the vehicle revealed a broken motor mount and hull rivet damage which was attributable to this drop.

While positioning the loaded MSA for a lift from a sticky clay surface, the rotor helixes accumulated an appreciable amount of the mud. It was considered advisable under the circumstances to remove the mud before take off to prevent an increase of weight since the pilot indicated he had been very close to his maximum engine manifold pressure when lifting the empty MSA.

As the slings were being prepared for one of the lifts, it was discovered that one leg of the sling had fallen between the MSA engine and the hot exhaust pipe, causing the nylon to burn through half of its width. Replacement of that leg was necessary prior to further lifts.

For lifts from soft mud surfaces (incapable of supporting a man), it was necessary to position a second MSA adjacent to the one being lifted to enable to hookup and to afford the personnel a means of safe travel away from the helicopter prior to the lift. No difficulties were experienced by use of this method.

The CH-34 was able to lift the MSA both in a loaded and unloaded condition. See Appendix I, Table XLIV, for detailed lift data.

2.4.3.3 CH-21 (Shawnee)

Four separate attempts were made with the CH-21 to lift and transport the empty MSA. All were unsuccessful. Each attempt was made from a hard level surface under ideal weather and altitude conditions. See Appendix I, Table XLIV, for detailed data on these attempts.

2.4.4 ANALYSIS

a. Although both aircraft have the same horsepower engine and the same 3,200-pound lift capacity, the CH-21 could not pick up the 2,660-pound empty MSA. The CH-34 had no difficulty with the MSA lift and was designed for external sling loads. It should be noted that the CH-21 was carrying 330 pounds more fuel than the CH-34 during a similar lift.

b. The canted attitude of a loaded MSA being transported by helicopter can be corrected by repositioning cargo forward to the operator-passenger compartment.

2.5 MILITARY POTENTIAL

2.5.1 OBJECTIVE

a. To determine the capability of the MSA to transport six combat-equipped men plus a driver through fresh and salt water; terrain similar to rice paddies, swamps, mud banks, marsh, and to occasionally cross hard surface roads.

b. To determine the capability of the MSA to transport logistical supplies required by counterinsurgency forces under conditions as stated in the previous paragraph.

2.5.2 METHOD

a. Six combat-equipped men plus a driver boarded the MSA and were transported along and across an inland waterway; over soft soil, vegetated water and grass, underbrush, and tree-covered swamps; over mud banks; entered and exited from water over earth banks and occasionally attempted to cross dirt surface roads. At various times and under various conditions where footing could be supported, the combat-equipped personnel disembarked from the MSA, dispersed and again boarded the vehicle.

b. In addition to loading the vehicle with cargo during mobility tests a study was made to determine types of logistical cargo which the vehicle could carry.

2.5.3 RESULTS

2.5.3.1 The Marsh Screw Amphibian as a Troop Carrier

Six combat-equipped personnel experienced no difficulty in boarding or exiting the MSA. Noise levels were acceptable. Brush was easily and effectively deflected by the bow-type front of the vehicle. Personnel found no protruding sharp projections, but were concerned over the considerable amount of mud which was thrown on them as the vehicle's rotors were turning inboard (reverse). Passengers in the two outside forward seats became quite wet from water thrown up by the rotors during water travel. Strengthening of the engine compartment

hatch would provide an additional walk-on surface which could be utilized in movement of personnel between the forward and rear areas of the vehicle. The greatest complaint, was the extreme heat experienced by the four men riding in the cargo/personnel area. The uninsulated, unducted engine compartment and the open exhaust pipe and muffler made it extremely uncomfortable for personnel to remain within three feet of these heat generating units if the vehicle had been operating more than 15 to 20 minutes. This limited the rear compartment to two men and their gear for extended travel rather than the designed capacity of four. While an open mesh guard surrounds the pipe and muffler assembly, superficial burns were sustained by personnel who touched the guard when attempting to use the stack as a hand hold. The troops found the MSA's straight ahead riding characteristics quite acceptable; however, uneven, fairly firm surface travel with its sudden lateral moves and rapid deceleration gave them considerable discomfort as they were jolted and thrown against one another and against the sides of the vehicle. It was found that sitting on the gunwales of the vehicle in order to escape the engine heat was extremely dangerous because of the item's ride characteristics.

2.5.3.2 The Marsh Screw Amphibian as a Logistical Carrier

Although no specific tests were conducted, a study of the MSA revealed the following:

The test bed configuration could not accommodate palletized cargo; however, folding or removable-type troop seats would permit one standard warehouse-type pallet (40" x 48") to be transported. Any palletized load, however, must be restricted to the cargo capacity (1,000 pounds total weight including passengers). Loose boxed general cargo can be loaded and unloaded from the vehicle by hand; overhead loading and unloading is also possible. No cargo tie-down devices were provided, but large or bulky items can be secured by blocking and chocking methods. The continuous grab rail running from the front of the vehicle along the outside to the back can be utilized for a tie-down if not overstressed or if designed for this purpose.

Drummed cargo such as 55-gallon Class III items can be transported if folding or removable troop seats are provided. Two such drums would constitute a full load with a driver and assistant driver.

2.5.4 ANALYSIS

The MSA cargo compartment will require redesign before the vehicle can be efficiently utilized as a personnel and cargo carrier.

2.6 SAFETY

2.6.1 OBJECTIVE

a. To determine any adverse safety condition which may exist during operation or maintenance.

b. To determine the adequacy of engineered safety features.

2.6.2 METHOD

Maximum safety precautions were exercised during all phases of operations. All pertinent safety regulations were observed. Operators and mechanics and other project personnel observed and prepared reports of any adverse safety conditions encountered during the test.

2.6.3 RESULTS

a. Certain safety observations have been commented on throughout this report as they occurred in relationship to the operation or test phase being discussed. These include extreme heat in the passenger compartment, hot exhaust stack, and ride qualities. Most safety hazards were a result of the unconventional configuration and operational characteristics of the MSA. Personnel learned early not to stand or walk alongside the MSA when it was operational since it could suddenly move laterally through inadvertent actions of the operator or as a result of the vehicle's movement over uneven or dissimilar ground surfaces under the rotors. An additional safety hazard which was of concern to passengers and unsecured cargo was sudden stops caused by the operator releasing the accelerator too quickly when moving over fairly firm ground. Results were quite similar to a conventional vehicle's panic stop while moving at a similar speed.

b. The absence of a windshield wiper, horn and rear view mirror all constituted safety hazards, but no adverse results occurred during the test program.

2.6.4 ANALYSIS

The nature of the vehicle and its ride characteristics present a continuous safety hazard to personnel being transported unless the driver and passengers are continuously alert to changing terrain conditions and take proper precautionary actions.

2.7 SUPPLEMENTARY DATA

2.7.1 OBJECTIVE

a. To determine the adequacy of maintenance instructions and the ease of maintenance of the item.

b. To determine the transportability characteristics of the item.

2.7.2 METHOD

a. Available technical instructions and other material concerning the item were reviewed to determine preventive and repair maintenance procedures.

b. Data on all repairs effected were observed and recorded.

c. The item's dimensional characteristics were reviewed in conjunction with AR 705-8 (DOD Engineering for Transportability Program) and MIL-STD-209 (Reference 1.1 (10)). All movements by various modes of transportation were observed and recorded.

2.7.3 RESULTS

2.7.3.1 Maintenance

No maintenance doctrine accompanied the vehicle. The manufacturer's technical representatives had limited published instructions and adequate knowledge, drawings and schematics to accomplish required maintenance.

The MSA's electric steering brake and drive clutches required frequent maintenance in order to keep them operable. Smoke

rising from Pilot Number 1 final drive assembly during the operator's water training phase was the initial indication of trouble in this area. Tear down of the unit revealed that the left steering brake had suffered extreme heat damage. The mechanic attributed this failure to maladjustment of the brakes. A new unit was obtained and installed. Within ten minutes, the new assembly began to overheat. Adjustment was again made and the vehicle returned to service but again overheating occurred. Thorough inspection of the entire assembly and housing disclosed what appeared to be a misalignment of the output shaft with the center line of the brake anchor plate. Correction of this presumed misalignment required a replacement of the final drive housing, but none was available. The technical representative decided to remove the left steering brake and allow the vehicle to proceed with the tests. The lack of this brake resulted only in an increased steering radius for left turns. The drive clutches on MSA Number 1 failed during tests in the Messick area. See para. 2.3.3.3. Disassembly revealed destroyed insulation on the coil windings of one clutch solenoid which required replacement. The other clutch was cleaned, adjusted and returned to service. The manufacturer's technical representative was of the opinion that the failure was caused by improper adjustment. Drive clutches were closely watched and clearances adjusted throughout the remainder of the tests. Each adjustment required on an average of one hour if the vehicle was on land, and 45 minutes if the vehicle was in water, so that the rotors could be more precisely turned to align adjusting components within the clutch assembly housing.

MSA Pilot Number 1 arrived at Fort Lee with a final drive oil seal leak. See para. 2.2.3.b. Total replacement time was 15 hours, including 6 1/2 hours awaiting parts.

MSA Pilot Number 2 suffered a fractured motor mount during helicopter lifts. See para. 2.4.3.2.

The main body wiring harness on MSA Pilot Number 2 shorted out against a bulkhead of the hull during operation in the Bayou Du Large test area. Inspection disclosed shafing of the alternator-ammeter battery line.

The rotor helixes were vulnerable to tearing during operations in tree stump areas. These were rewelded initially; however, as the test progressed, wearing of the weld points, such as the radial welds of the pontoons and the styrofoam fill points, became evident. Cause was attributed to friction between the rotor and surfaces traversed. Breaks occurred all along these welds during tests in Louisiana. The surrounding metal (T6 aluminum) was worn so thin that repairs were not practical and the vehicle was deadlined.

MSA down time was excessive in that the down time for MSA Pilot Number 1 was 34.5 hours awaiting parts and 23.5 hours for repair time, or 58.0 hours total for 64.5 hours of operation. Down time for MSA Pilot Number 2 was 45.5 hours awaiting parts and 16.5 hours repair time, or a total down time of 62 hours for 74.5 operational hours.

Down time for the M113 was 2 hours for 58.5 hours of operation. See Appendix II and III (Figures 24 and 25) for additional maintenance data and down time information.

2.7.3.2 Transportability

a. The MSA's configuration required it to be transported between soft soil or water operational areas. A modified boat trailer was utilized to deliver the item to Fort Lee, Virginia, from the manufacturer's plant in Michigan. Towing was done by a standard civilian station wagon. This trailer remained with the test item throughout the program and proved to be a valuable asset. Off loading and loading of the MSA was accomplished by moving the trailer into the water and either floating the vehicle on or off, the same as a boat would be launched or picked up. If no water was available, a crane was required to lower or replace the item on the trailer. The second MSA was transported on a flat bed vehicle by a special cradle which prevented contact of the rotors with the truck bed. The MSA rested on the cradle at the center underportion of its hull. A crane was required to load and unload this vehicle.

b. The overall width of the MSA (98 inches) required special road clearance permits when being transported over public roadways (AR 705-8). Maximum allowable width for unrestricted travel over highways is 96 inches.

c. The MSA was not moved by rail. The return of the two items by rail movement to the manufacturer's plant at the termination of the tests in Louisiana was considered but discarded since no humping tests had been conducted and possible damage could not be forecast.

d. Proper location, size and number of lifting points have been discussed in paragraph 2.4, Helicopter Lift Test.

2.7.4 ANALYSIS

a. Since the MSA was developed to test a radical propulsion concept, there is no criteria to evaluate whether the mechanical shortcomings and deficiencies cited in the preceding paragraphs are excessive or normal for this type propulsion system.

b. The MSA in its current configuration requires either a boat-type trailer or a conventional truck and cradle to transport it between operational areas. For transport by truck, a crane is required to load and unload. Both of these conditions are considered to create a logistical problem.

SECTION 3 - APPENDICES

Appendix I - Test Data

Appendix II - Deficiencies and Shortcomings

Appendix III - Photographs

Annex

Distribution

APPENDIX I

TEST DATA

TABLE I

PERFORMANCE OF TEST VEHICLES IN MUD SPEED TESTS

Cone Index: 0-18

Course: 528-foot straight line course (1/10 mile)

Maximum Throttle

Crew: One

Soils: Inorganic clays of high plasticity and inorganic silts

a. Marsh Screw Amphibian

		Empty		Loaded (1000 Lbs. Plus Operator)	
Pass	Drive Range	Time (minutes)	mph	Time (minutes)	mph
1	2	.420	14.3	.470	12.8
2	2	.430	14.0	.485	12.4
3	2	.400	15.0	.490	12.2
Average			14.4		12.5
			14.4		12.5

b. Armored Personnel Carrier, M113: Became immobilized prior to reaching course due to its high ground pressure.

APPENDIX I

TABLE II

PERFORMANCE OF TEST VEHICLES IN WATER SPEED TESTS

Course: 528-foot straight line course (1/10 mile)

Maximum Throttle

Crew: One

Vehicle	Direction	Empty		With Payload	
		Time (minutes)	mph	Time (minutes)	mph
MSA (2nd Gear Range)	Downstream	.750	8.0	.760	7.9
	Upstream	.740	8.1	.795	7.5
	Downstream	.735	8.2	.770	7.8
	Upstream	.740	8.1	.780	7.7
M113 (1-4 Gear Range)	Downstream	.144	4.2	.144	4.2
	Upstream	.176	3.4	.161	3.7
	Downstream	.138	4.3	.142	4.2
	Upstream	.174	3.4	.165	3.6
Average mph:	MSA		8.1		7.7
	M113		3.8		3.9

APPENDIX I

TABLE III

FUEL CONSUMPTION OF TEST VEHICLES ON WATER COURSE

Water Course

Crew: One

Fuel: Gasoline, 94 Octane

	Empty				With Payload			
Vehicle	Duration of Operation (minutes)	rpm	Number of Gallons Consumed	Gallons Per Hour	Duration of Operation (minutes)	rpm	Number of Gallons Consumed	Gallons Per Hour
MSA (2nd Gear Range)	80	2600 3000	8.3	6.2	90	2600 3000	12.8	8.5
M113 (3-4 Gear Range)	60	3200 3400	7.0	7.0	120	3200 3400	14.5	7.2

APPENDIX I

TABLE IV

FUEL CONSUMPTION OF TEST VEHICLES ON FIRM GROUND

Firm Ground

Crew: One

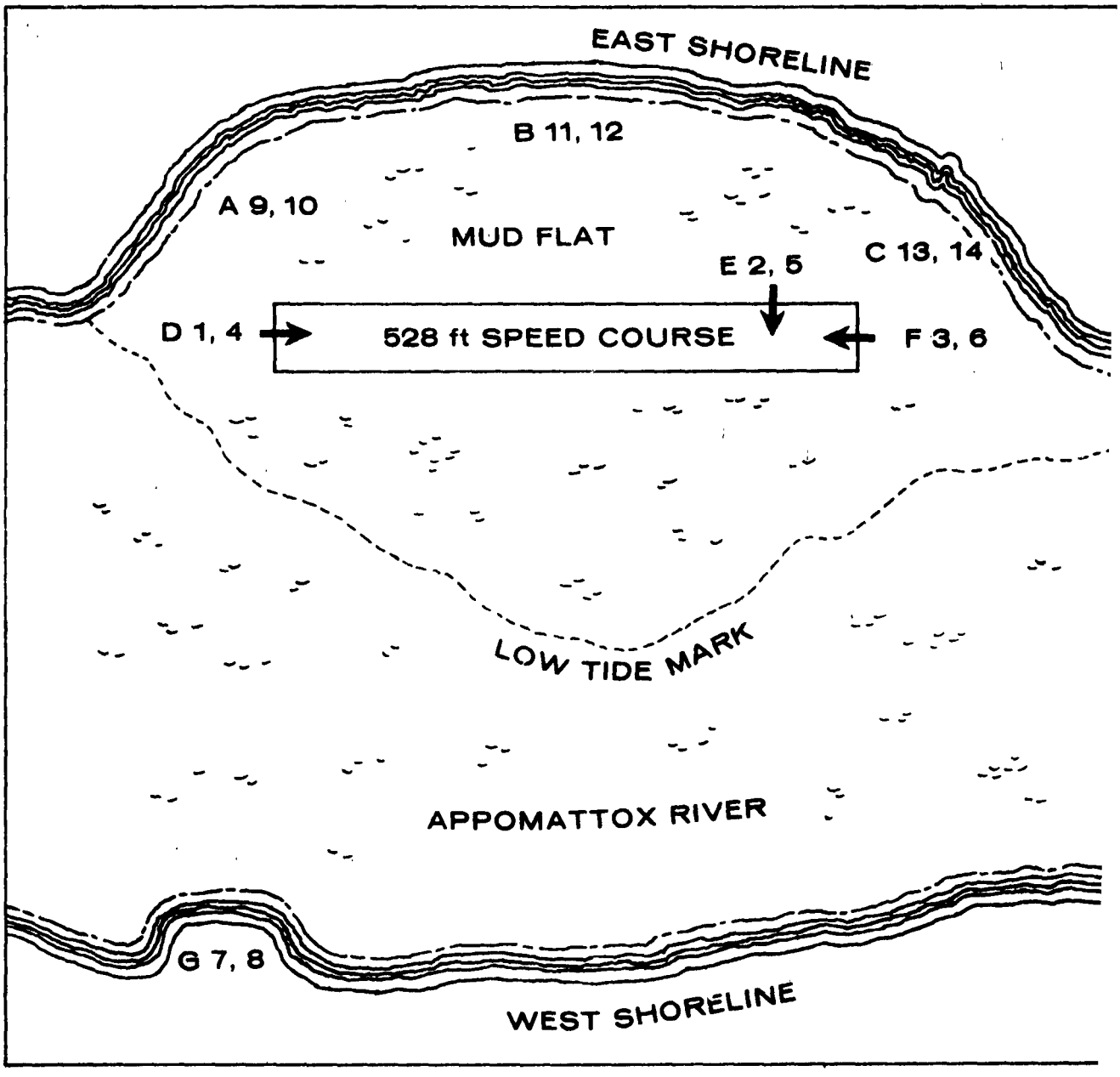
Fuel: Gasoline, 94 Octane

Vehicle	Duration of Operation	Gear Range	Number of Gallons Consumed	Gallons Per Hour
M113 (With Payload)	60	3-4	6.9	6.9
MSA	No Go	--	--	--

Appendix I

AREA MAP I

APPOMATTOX RIVER TEST SITE FORT LEE, VIRGINIA



NOTE:

Letter = site for soil sample

Number = soil sample extracted

APPENDIX I

TABLE V

CONE PENETROMETER DATA
AT APPOMATTOX TEST SITE

Location (Area Map I)	Cone Index Values				Remold 2 to 8 Inches	Rating Cone Index
	Surface	6 Inches	12 Inches	18 Inches		
A	0	0	0	0	None	None
B	0	10	0	0	66.00	660
C	0	18	0	0	1.00	18
D	0	0	0	0	None	None
E	0	0	0	0	None	None
F	0	0	0	0	None	None
G	0	0	0	0	None	None

Soils are classified CH and MH by the Unified Soil Classification System. They are described as inorganic clays of high plasticity and inorganic silts.

APPENDIX I

TABLE VI

MOISTURE CONTENT OF SOIL AT APPOMATTOX TEST SITE

Sample Number	Location (Area Map I)	Depth (inches)	Prior to MSA Traversing Course (%)	After MSA Traversed Course (%)
1	D	6	123.08	156.67
2	E	6	114.29	170.34
3	F	6	115.81	114.91
4	D	12	116.11	215.14
5	E	12	93.90	131.83
6	F	12	24.09	93.36
7	G	6	145.93	NA
8	G	12	74.68	NA
9	A	1	215.20	NA
10	A	6	122.40	NA
11	B	6	34.00	NA
12	B	18	104.90	NA
13	C	1	174.50	NA
14	C	6	48.00	NA

APPENDIX I

TABLE VII

SOIL GRAIN SIZE AT TEST SITE

LOCATION: Appomattox - See D, Area Map I
DATE: 27 August 1964
SAMPLE NO: 1 (Taken at 6" depth before traffic)
WEIGHT ORIGINAL SAMPLE (gms): 32.4262

Sieve No. a	Weight Retained on Sieve (gms) b	Passing Sieve	
		Weight (gms) c	Percent d
8	0	32.3403	100.0%
16	0	32.3403	
30	4.4891	27.8512	86.1%
50	9.4094	18.4418	57.0%
100	6.7790	11.6628	36.1%
Pan	11.6628	-	-

32.3403 gms. Total Weight of Fractions (total of all entries in column b)

0.0859 gms. Error (orig. weight - total weight of fractions)

0.26 % Percent error $\left(\frac{\text{Error (gms)} \times 100}{\text{Original wt (gms)}} \right)$

APPENDIX I

TABLE VIII

SOIL GRAIN SIZE AT TEST SITE

LOCATION: Appomattox - See D, Area Map I
DATE: 27 August 1964
SAMPLE NO: 1 (Taken at 6" depth after traffic)
WEIGHT ORIGINAL SAMPLE (gms): 45.1145

Sieve No. a	Weight Retained on Sieve (gms) b	Passing Sieve	
		Weight (gms) c	Percent d
8	0	45.1145	100.0%
16	1.8316	43.2829	95.9%
30	8.2125	35.0704	77.7%
50	11.9036	23.1668	51.4%
100	8.3808	14.7860	32.8%
Pan	14.7860	-	-

45.1145 gms. Total Weight of Fractions (total of all column b entries)

0.00 gms. Error (orig. weight - total weight of fractions)

0.00 % Percent Error $\left(\frac{\text{Error (gms)} \times 100}{\text{Original wt (gms)}} \right)$

APPENDIX I

TABLE IX

SOIL GRAIN SIZE AT TEST SITE

LOCATION: Appomattox - See D, Area Map I
DATE: 27 August 1964
SAMPLE NO: 4 (Taken at 12" depth before traffic)
WEIGHT ORIGINAL SAMPLE (gms): 32.3708

Sieve No. a	Weight Retained on Sieves (gms) b	Passing Sieve	
		Weight (gms) c	Percent d
8	0	31.7959	100.0%
16	0.9806	30.8153	96.9%
30	7.4584	23.3569	73.5%
50	5.9821	17.3748	54.6%
100	5.2693	12.1055	38.1%
Pan	12.1055	-	-

31.7959 gms. Total Weight of Fractions (total of all column b entries)

0.5749 gms. Error (orig. weight - total weight of fractions)

1.78 % Percent Error $\left(\frac{\text{Error (gms)} \times 100}{\text{Original wt (gms)}} \right)$

APPENDIX I

TABLE X

SOIL GRAIN SIZE AT TEST SITE

LOCATION: Appomattox - See D, Area Map I
DATE: 27 August 1964
SAMPLE NO: 4 (Taken at 12" depth after traffic)
WEIGHT ORIGINAL SAMPLE (gms): 21.7005

Sieve No. a	Weight Retained on Sieve (gms) b	Passing Sieve	
		Weight (gms) c	Percent d
8	0	21.2791	100.0%
16	0	21.2791	100.0%
30	1.3388	19.9403	93.7%
50	5.1895	14.7508	69.3%
100	9.0260	5.7348	27.0%
Pan	5.7248	-	-

21.2791 gms. Total Weight of Fractions (total of all column b entries)

0.4214 gms. Error (orig. weight - total weight of fractions)

1.94 % Percent Error $\left(\frac{\text{Error (gms)} \times 100}{\text{Original wt (gms)}} \right)$

APPENDIX I

TABLE XI

SOIL GRAIN SIZE AT TEST SITE

LOCATION: Appomattox - See E, Area Map I
DATE: 27 August 1964
SAMPLE NO: 2 (Taken at 6" depth before traffic)
WEIGHT ORIGINAL SAMPLE (gms): 35.0703

Sieve No. a	Weight Retained on Sieve (gms) b	Passing Sieve	
		Weight (gms) c	Percent d
8	0	34.2575	100.0%
16	3.8671	30.3904	88.7%
30	7.9393	22.4511	65.5%
50	4.5838	17.8673	52.2%
100	9.9117	7.9556	23.2%
Pan	7.9556	-	-

34.2575 gms. Total Weight of Fractions (total of all column b entries)

0.8128 gms. Error (orig. weight - total weight of fractions)

2.32 % Percent Error $\left(\frac{\text{Error (gms)} \times 100}{\text{Original wt (gms)}} \right)$

APPENDIX I

TABLE XII

SOIL GRAIN SIZE AT TEST SITE

LOCATION: Appomattox - See E, Area Map I
DATE: 27 August 1964
SAMPLE NO: 2 (Taken at 6" depth after traffic)
WEIGHT ORIGINAL SAMPLE (gms): 53.4800

Sieve No. a	Weight Retained on Sieve (gms) b	Passing Sieve	
		Weight (gms) c	Percent d
8	0	53.4642	100.0%
16	0.1468	53.3174	99.7%
30	0.2277	53.0897	99.3%
50	8.2395	44.8502	83.9%
100	15.3355	29.5147	55.2%
Pan	29.5147	-	-

53.4642 gms. Total Weight of Fractions (total of all column b entries)

0.0158 gms. Error (Orig. weight - total weight of fractions)

0.03 % Percent Error $\left(\frac{\text{Error (gms)} \times 100}{\text{Original wt. (gms)}} \right)$

APPENDIX I

TABLE XIII

SOIL GRAIN SIZE AT TEST SITE

LOCATION: Appomattox - See F, Area Map I
DATE: 27 August 1964
SAMPLE NO: 5 (Taken at 12" depth before traffic)
WEIGHT ORIGINAL SAMPLE (gms): 26.6457

Sieve No. a	Weight Retained on Sieve (gms) b	Passing Sieve	
		Weight (gms) c	Percent d
8	0	26.3711	100.0%
16	0	26.3711	100.0%
30	0.4293	25.9418	98.4%
50	7.4090	18.5328	70.3%
100	5.9491	12.5837	47.7%
Pan	12.5837		-

26.3711 gms. Total Weight of Fractions (total of all column b entries)

0.2746 gms. Error (orig. weight - total weight of fractions)

1.03 % Percent Error $\left(\frac{\text{Error (gms)} \times 100}{\text{Original wt (gms)}} \right)$

APPENDIX I

TABLE XIV

SOIL GRAIN SIZE AT TEST SITE

LOCATION: Appomattox - See E, Area Map I
DATE: 27 August 1964
SAMPLE NOS (Taken at 12" depth after traffic)
WEIGHT ORIGINAL SAMPLE (gms) :46.4382

Sieve No. a	Weight Retained on Sieve (gms) b	Passing Sieve	
		Weight (gms) c	Percent d
8	0	46.4382	100.0%
16	0	46.4382	100.0%
30	2.3460	44.0922	94.9%
50	7.2347	36.8575	79.4%
100	7.8296	29.0279	62.5%
Pan	29.0279	-	-

46.4382 gms. Total Weight of Fractions (total of all column b entries)

0 gms. Error (orig. weight - total weight of fractions)

0 % Percent Error $\left(\frac{\text{Error (gms)} \times 100}{\text{Original wt (gms)}} \right)$

APPENDIX I

TABLE XV

SOIL GRAIN SIZE AT TEST SITE

LOCATION: Appomattox - See F, Area Map I
DATE: 27 August 1964
SAMPLE NO: 3 (Taken at 6" depth before traffic)
WEIGHT ORIGINAL SAMPLE (gms): 42.6502

Sieve No. a	Weight Retained on Sieve (gms) b	Passing Sieve	
		Weight (gms) c	Percent d
8	0	42.4025	100.0%
16	0.5120	41.8905	98.8%
30	1.4123	40.4782	95.5%
50	6.3388	34.1394	80.5%
100	8.6658	25.4736	60.1%
Pan	25.4736	-	-

42.4025 gms. Total Weight of Fractions (total of all column b entries)

0.2477 gms. Error (orig. weight - total weight of fractions)

0.58 % Percent Error $\frac{\text{(Error (gms) x 100)}}{\text{(Original wt (gms))}}$

APPENDIX I

TABLE XVI

SOIL GRAIN SIZE AT TEST SITE

LOCATION: Appomattox - See F, Area Map I
DATE: 27 August 1964
SAMPLE NO: 3 (Taken at 6" after traffic)
WEIGHT ORIGINAL SAMPLE (gms): 145.4817

Sieve No. a	Weight Retained on Sieve (gms) b	Passing Sieve	
		Weight (gms) c	Percent d
-	-	*143.2354	100.0%
8	1.0195	142.2159	99.3%
16	4.7410	137.4749	94.5%
30	21.7917	115.6832	80.8%
50	31.4005	84.2827	58.8%
100	43.3031	40.9796	28.6%
Pan	40.9796	-	-

143.2354 gms. Total weight of Fractions (total of all column b entries)

2.2463 gms. Error (orig. weight - total weight of fractions)

1.54 % Percent Error $\frac{\text{(Error (gms) x 100)}}{\text{(Original wt. (gms))}}$

*Original weight less error

APPENDIX I

TABLE XVII

SOIL GRAIN SIZE AT TEST SITE

LOCATION: Appomattox - See F, Area Map I
DATE: 27 August 1964
SAMPLE NO: 6 (Taken at 12" depth before traffic)
WEIGHT ORIGINAL SAMPLE (gms): 40.2029

Sieve No. a	Weight Retained on Sieve (gms) b	Passing Sieve	
		Weight (gms) c	Percent d
8	0	39.7794	100.0%
16	0	39.7794	100.0%
30	0.1827	39.5967	99.5%
50	8.9302	30.6665	77.1%
100	6.8886	23.7779	59.8%
Pan	23.7779	-	-

39.7794 gms. Total Weight of Fractions (total of all column b entries)

0.4235 gms. Error (orig. weight - total weight of fractions)

1.05 % Percent Error $\frac{\text{(Error (gms) x 100)}}{\text{(Original wt. (gms))}}$

APPENDIX I

TABLE XVIII

SOIL GRAIN SIZE AT TEST SITE

LOCATION: Appomattox - See F, Area Map I
DATE: 27 August 1964
SAMPLE NO: 6 (Taken at 12" depth after traffic)
WEIGHT ORIGINAL SAMPLE (gms): 53.5615

Sieve No. a	Weight Retained on Sieve (gms) b	Passing Sieve	
		Weight (gms) c	Percent d
-	-	*51.6828	100.0%
8	0.1348	51.5480	99.7%
16	2.3904	49.1576	95.1%
30	1.8366	47.3210	91.6%
50	6.1756	41.1454	79.6%
100	23.4324	17.7130	34.3%
Pan	17.7130	-	-

51.6828 gms. Total Weight of Fractions (total of all column b entries)

1.8787 gms. Error (orig. weight - total weight of fractions)

3.51 % Percent Error $\frac{\text{(Error (gms) x 100)}}{\text{(Original wt. (gms))}}$

*Original weight less error

APPENDIX I

TABLE XIX

SOIL GRAIN SIZE AT TEST SITE

LOCATION: Appomattox - See G, Area Map I
DATE: 27 August 1964
SAMPLE NO: 7 (Taken at 6" depth before traffic)
WEIGHT ORIGINAL SAMPLE (gms): 51.2547

Sieve No. a	Weight Retained on Sieve (gms) b	Passing Sieve	
		Weight (gms) c	Percent d
-	-	*50.8407	100.0%
8	0.2367	50.6040	99.5%
16	2.2439	48.3601	95.1%
30	7.8493	40.5108	79.7%
50	8.8883	31.6225	62.2%
100	9.5897	22.0328	43.3%
Pan	22.0328	-	-

50.8407 gms. Total Weight of Fractions (total of all column b entries)

0.4140 gms. Error (orig. weight - total weight of fractions)

0.81 % Percent Error $\frac{(\text{Error (gms)} \times 100)}{(\text{Original wt. (gms)})} = 0.81\%$

*Original weight less error

APPENDIX I

TABLE XX

SOIL GRAIN SIZE AT TEST SITE

LOCATION: Appomattox - See G, Area Map I
DATE: 27 August 1964
SAMPLE NO: 8 (Taken at 12" depth before traffic)
WEIGHT ORIGINAL SAMPLE (gms): 59.6300

Sieve No. a	Weight Retained on Sieve (gms) b	Passing Sieve	
		Weight (gms) c	Percent d
-	-	*59.1192	100.0%
8	0.1601	58.9591	99.7%
16	0.4549	58.5042	99.0%
30	1.0000	57.5042	97.3%
50	5.5850	51.9192	87.8%
100	22.0907	29.8285	50.5%
Pan	29.8285	-	-

59.1192 gms. Total Weight of Fractions (total of all column b entries)

0.5108 gms. Error (orig. weight - total weight of fractions)

0.86 % Percent Error $\frac{\text{(Error (gms) x 100)}}{\text{(Original wt. (gms))}}$

*Original weight less error

APPENDIX I

TABLE XXI

SOIL GRAIN SIZE AT TEST SITE

LOCATION: Appomattox - See A, Area Map I
DATE: 19 August 1964
SAMPLE NO: 9 (Taken at 1" depth before traffic)
WEIGHT ORIGINAL SAMPLE (gms): 121.6645

Sieve No. a	Weight Retained on Sieve (gms) b	Passing Sieve	
		Weight (gms) c	Percent d
-	-	*121.6044	100.0%
8	2.7466	118.8578	97.7%
16	9.7009	109.1569	89.8%
30	14.3865	94.7704	77.9%
50	15.4636	79.3068	65.2%
100	33.5015	45.8053	37.7%
Pan	45.8053	-	-

121.6044 gms. Total Weight of Fractions (total of all column b entries)

0.0601 gms. Error (orig. weight - total weight of fractions)

0.05 % Percent Error $\frac{\text{(Error (gms) x 100)}}{\text{(Original wt. (gms))}}$

*Original weight less error

APPENDIX I

TABLE XXII

SOIL GRAIN SIZE AT TEST SITE

LOCATION: Appomattox - See A, Area Map I
DATE: 19 August 1964
SAMPLE NO: 10 (Taken at 6" depth before traffic)
WEIGHT ORIGINAL SAMPLE (gms): 87.2920

Sieve No. a	Weight Retained on Sieve (gms) b	Passing Sieve	
		Weight (gms) c	Percent d
-	-	*87.2282	100.0%
8	0.5723	86.6559	99.3%
16	1.7100	84.9459	97.3%
30	1.9801	82.9658	95.1%
50	3.2813	79.6845	91.4%
100	16.7552	62.9293	72.1%
Pan	62.9293	-	-

87.2282 gms. Total Weight of Fractions (total of all column b entries)

0.0638 gms. Error (orig. weight - total weight of fractions)

0.07 % Percent Error $\frac{\text{(Error (gms) x 100)}}{\text{(Original wt. (gms))}}$

*Original weight less error

APPENDIX I

TABLE XXIII

SOIL GRAIN SIZE AT TEST SITE

LOCATION: Appomattox - See B, Area Map I
DATE: 19 August 1964
SAMPLE NO. 11 (Taken at 6" depth before traffic)
WEIGHT ORIGINAL SAMPLE (gms): 52.0635

Sieve No. a	Weight Retained on Sieve (gms) b	Passing Sieve	
		Weight (gms) c	Percent d
-	-	*51.4309	100.0%
8	0.6066	50.8243	98.8%
16	6.0360	44.7883	87.1%
30	10.8341	33.9542	66.0%
50	7.6461	26.3081	51.2%
100	6.6355	19.6726	38.3%
Pan	19.6726	-	-

51.4309 gms. Total Weight of Fractions (total of all column b entries)

0.6326 gms. Error (orig. weight - total weight of fractions)

1.22 % Percent Error $\frac{\text{(Error (gms) x 100)}}{\text{(Original wt. (gms))}}$

*Original weight less error

APPENDIX I

TABLE XXIV

SOIL GRAIN SIZE AT TEST SITE

LOCATION: Appomattox - Sec B, Area Map I
DATE: 19 August 1964
SAMPLE NO: 12 (Taken at 18" depth before traffic)
WEIGHT ORIGINAL SAMPLE (gms): 31.1090

Sieve No. a	Weight Retained on Sieve (gms) b	Passing Sieve	
		Weight (gms) c	Percent d
8	0	31.0087	100.0%
16	0	31.0087	100.0%
30	2.2015	28.8072	92.8%
50	7.1896	21.6176	69.8%
100	6.7167	14.9009	48.5%
Pan	14.9009	-	-

31.0087 gms. Total Weight of Fractions (total of all column b entries)

0.1003 gms. Error (orig. weight - total weight of fractions)

0.32 % Percent Error $\frac{\text{(Error (gms) x 100)}}{\text{(Original wt. (gms))}}$

APPENDIX I

TABLE XXV

SOIL GRAIN SIZE AT TEST SITE

LOCATION: Appomattox - See C, Area Map I
DATE: 19 August 1964
SAMPLE NO: 13 (Taken at 1" depth before traffic)
WEIGHT ORIGINAL SAMPLE (gms): 46.5625

Sieve No. a	Weight Retained on Sieve (gms) b	Passing Sieve	
		Weight (gms) c	Percent d
8	0	46.1300	100.0%
16	0	46.1300	100.0%
30	0	46.1300	100.0%
50	0	46.1300	100.0%
100	8.3615	37.7685	81.9%
Pan	37.7685	-	-

46.1300 gms. Total Weight of Fractions (total of all column b entries)

0.4325 gms. Error (orig. weight - total weight of fractions)

0.93 % Percent Error $\frac{\text{(Error (gms) x 100)}}{\text{(Original wt. (gms))}}$

APPENDIX I

TABLE XXVI

SOIL GRAIN SIZE AT TEST SITE

LOCATION: Appomattox - See C, Area Map I
DATE: 19 August 1964
SAMPLE NO: 14 (Taken at 6" depth before traffic)
WEIGHT ORIGINAL SAMPLE (gms): 28.3200

Sieve No. a	Weight Retained on Sieve (gms) b	Passing Sieve	
		Weight (gms) c	Percent d
8	0	27.8253	100.0%
16	0	27.8253	100.0%
30	0	27.8253	100.0%
50	0	27.8253	100.0%
100	11.7976	16.0277	57.6%
Pan	16.0277	-	-

27.8253 gms. Total Weight of Fractions (total of all column b entries)

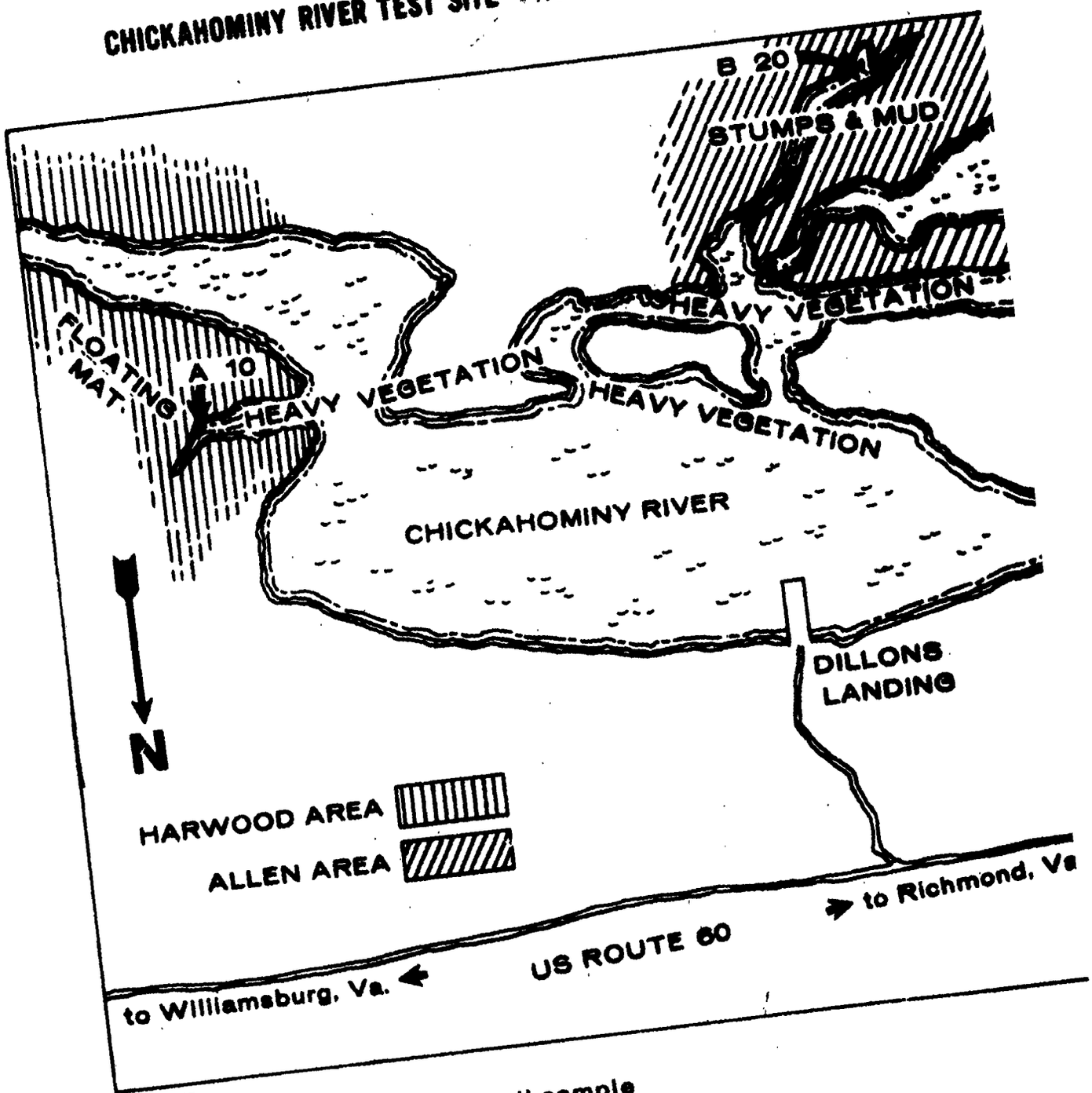
0.4947 gms. Error (orig. weight - total weight of fractions)

1.75 % Percent Error $\frac{\text{(Error (gms) x 100)}}{\text{(Original wt. (gms))}}$

Appendix I

AREA MAP II

CHICKAHOMINY RIVER TEST SITE PROVIDENCE FORGE, VIRGINIA



NOTE:

Letter = site for soil sample

Number = soil sample extracted

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APPENDIX I

SOILS DATA

CHICKAHOMINY RIVER AREA (VIRGINIA)

The Chickahominy River area soils are classified Pt by t
Soil Classification System. They are described as soils com
peat and high organic materials. No cone penetrometer read
shown as all tests were either in vegetated water areas or on
where no soil values were obtainable.

APPENDIX I

TABLE XXVII

SOIL GRAIN SIZE AT TEST SITE

LOCATION: Chickahominy River - See A, Area Map II
DATE: 14 September 1964
SAMPLE NO: 19 (Harwood Area) (Taken off clump of floating vegetation)
ORIGINAL WEIGHT (gms): 18.1936
MOISTURE CONTENT: 16.1%

Sieve No. a	Weight Retained on Sieve b	Passing Sieve	
		Weight (gms) c	Percent d
-	-	*17.2636	100.0%
8	0.0	17.2636	100.0
16	0.4178	16.8458	97.6
30	2.0253	14.8205	85.8
50	3.6173	11.2032	64.9
100	2.2000	9.0032	52.2
Pan	9.0032	-	-

17.2636 gms. Total Weight of Fractions (total of all column b entries)

0.9300 gms. Error (original weight - total weight of fractions)

0.51 % Percent error $\frac{\text{(error (gms) X 100)}}{\text{(original wt. (gms))}}$

* Original weight less error

APPENDIX I

TABLE XXVIII

SOIL GRAIN SIZE AT TEST SITE

LOCATION: Chickahominy River - See B, Area Map II
DATE: 14 September 1964
SAMPLE NO: 20 (Allen Area)(Taken off a clump of vegetation that was submerged three inches)
ORIGINAL WEIGHT (gms): 13.2603
MOISTURE CONTENT: 22.9%

Sieve No. a	Weight Retained on Sieve b	Passing Sieve	
		Weight (gms) c	Percent d
-	-	*13.1707	100.0%
8	0.0113	13.1594	99.9
16	0.5430	12.6164	95.8
30	2.4111	10.2053	77.5
50	2.0103	8.1950	62.2
100	2.1345	6.0605	46.0
Pan	6.0605	-	-

13.1707 gms. Total Weight of Fractions (total of column b)

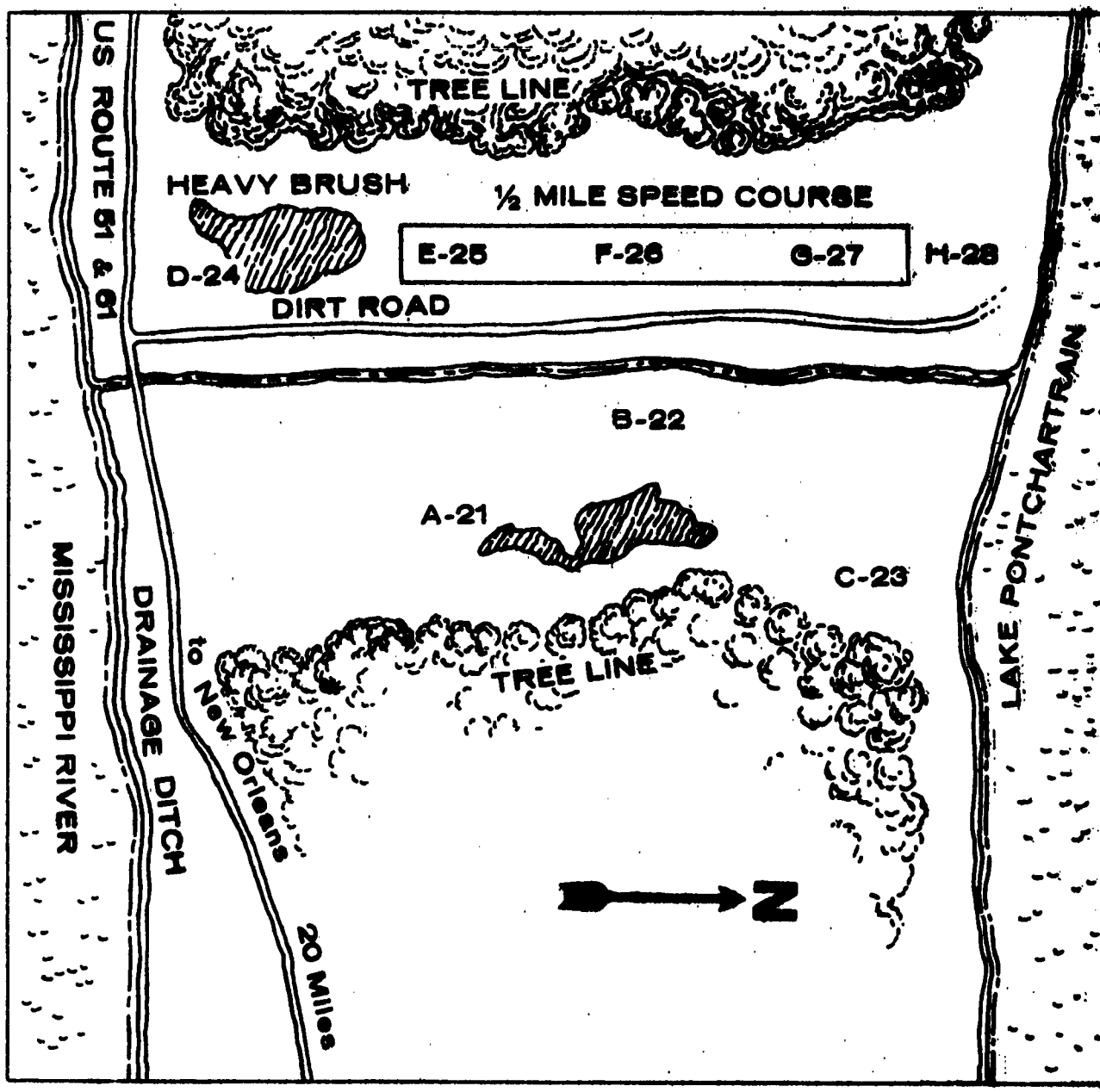
0.0896 gms. Error (original weight - total weight of fractions)

0.07 % Percent error $\frac{\text{(error (gms) X 100)}}{\text{(original wt. (gms))}}$

* Original weight less error

Appendix I
AREA MAP III

BONNET CARRE TEST SITE LOUISIANA



APPENDIX I

TABLE XXIX

CONE PENETROMETER DATA AND MOISTURE CONTENT OF SOILS AT BONNET CARRE TEST AREA

Location	Moisture Content (3" Level)%	Cone Index Values			
		Surface	6"	12"	18"
A	37.5	11	170	155	0
B	33.2	8	50	40	80
C	28.6	0	120	135	100
D	26.9	10	90	60	45
E	37.4	35	160	0	0
F	31.9	40	125	200	NA
G	33.8	45	155	130	200
H	29.2	60	120	90	100

Remolding Index

Location	Surface	1"	2"	3"	4"
A	20	20	80	125	10
B	0	0	20	75	20
C	15	140	220	NA	NA
D	10	20	200	NA	NA
E	10	40	55	90	135
F	30	95	160	220	NA
G	15	25	35	55	110
H	10	30	35	45	60

Soils are classified SM by the Unified Soil Classification System. They are described as silty sands or sand and silt mixtures, well impacted with an appreciable amount of fines.

APPENDIX I

TABLE XXX

SOIL GRAIN SIZE AT TEST SITE

LOCATION: Louisiana - See A, Area Map III
DATE: 19 October 1964
SAMPLE NO: 21
WEIGHT, ORIGINAL SAMPLE: 64.6435

Sieve No. a	Weight Retained on Sieve b	Passing Sieve	
		Weight (gms) c	Percent d
-	-	*63.9818	100.0%
8	0.6097	63.3721	99.0
16	0.9630	62.4091	97.5
30	6.7557	55.6514	87.0
50	6.8401	48.8113	76.3
100	5.1069	43.7064	68.3
Pan	43.7064	-	-

63.9818 gms. Total Weight of Fractions (total of column b)

0.6617 gms. Error (original weight - total weight of fractions)

1.02 % Percent error $\frac{\text{(error (gms) X 100)}}{\text{(original wt. (gms))}}$

* Original weight less error

APPENDIX I

TABLE XXXI

SOIL GRAIN SIZE AT TEST SITE

LOCATION: Louisiana - See B, Area Map III
DATE: 19 October 1964
SAMPLE NO: 22
WEIGHT, ORIGINAL SAMPLE: 78.7009

Sieve No. a	Weight Retained on Sieve b	Passing Sieve	
		Weight (gms) c	Percent d
-	-	*77.9371	100.0%
8	0.0	77.9371	100.0
16	0.4335	77.5036	99.4
30	5.5659	71.9377	92.3
50	7.3515	64.5862	82.9
100	6.4327	58.1535	74.6
Pan	58.1535	-	-

77.9371 gms. Total Weight of Fractions (total of all column b entries)

0.7638 gms. Error (original weight - total weight of fractions)

0.97 % Percent error $\frac{\text{(error (gms) X 100)}}{\text{(original wt. (gms))}}$

* Original weight less error

APPENDIX I

TABLE XXXII

SOIL GRAIN SIZE AT TEST SITE

LOCATION: Louisiana - See C, Area Map III
DATE: 19 October 1964
SAMPLE NO: 23
WEIGHT, ORIGINAL SAMPLE: 71.2463

Sieve No. a	Weight Retained on Sieve b	Passing Sieve	
		Weight (gms) c	Percent d
-	-	*70.3578	100.0%
8	0.0	70.3578	100.0
16	2.9372	67.4206	95.8
30	8.4096	59.0110	83.9
50	8.2508	50.7602	72.1
100	6.2237	44.5365	63.3
Pan	44.5365	-	-

70.3578 gms. Total Weight of Fractions (total of all column b entries)

0.8885 gms. Error (original weight - total weight of fractions)

1.25 % Percent error $\frac{\text{(error (gms) X 100)}}{\text{(original wt. (gms))}}$

* Original weight less error

APPENDIX I

TABLE XXXIII

SOIL GRAIN SIZE AT TEST SITE

LOCATION: Louisiana - See D, Area Map III
DATE: 19 October 1964
SAMPLE NO: 24
WEIGHT, ORIGINAL SAMPLE: 78.6578

Sieve No. a	Weight Retained on Sieve b	Passing Sieve	
		Weight (gms) c	Percent d
-	-	*78.3770	100.0%
8	0.0	78.3770	100.0
16	1.0024	77.3747	98.7
30	4.7875	72.5872	92.6
50	5.6404	66.9468	85.4
100	7.1457	59.8010	76.3
Pan	59.8010	-	-

78.3770 gms. Total Weight of Fractions (total of all column b entries)

0.2808 gms. Error (original weight - total weight of fractions)

0.36 % Percent error $\frac{\text{(error (gms) X 100)}}{\text{(original wt. (gms))}}$

* Original weight less error

APPENDIX I

TABLE XXXIV

SOIL GRAIN SIZE AT TEST SITE

LOCATION: Louisiana - See E, Area Map III
DATE: 19 October 1964
SAMPLE NO: 25
WEIGHT, ORIGINAL SAMPLE: 78.7568

Sieve No. a	Weight Retained on Sieve b	Passing Sieve	
		Weight (gms) c	Percent d
-	-	*78.6175	100.0%
8	0.0	78.6175	100.0
16	0.1761	78.4414	99.8
30	2.0307	76.4107	97.2
50	6.3604	70.0503	89.1
100	6.1970	63.8533	81.2
Pan	63.8533	-	-

78.6175 gms. Total Weight of Fractions (total of all column b entries)

0.1393 gms. Error (original weight - total weight of fractions)

0.18 % Percent error $\frac{\text{(error (gms) X 100)}}{\text{(original wt. (gms))}}$

* Original weight less error

APPENDIX I

TABLE XXXV

SOIL GRAIN SIZE AT TEST SITE

LOCATION: Louisiana - See F, Area Map III
DATE: 19 October 1964
SAMPLE NO: 26
WEIGHT, ORIGINAL SAMPLE: 98.8084

Sieve No. a	Weight Retained on Sieve b	Passing Sieve	
		Weight (gms) c	Percent d
-	-	*97.9272	100.0%
8	0.0286	97.8986	99.9
16	0.1433	97.7553	99.8
30	1.5386	96.2167	98.3
50	2.7112	93.5055	95.5
100	3.5031	90.0024	91.9
Pan	90.0024	-	-

97.9272 gms. Total Weight of Fractions (total of all column b entries)

0.8812 gms. Error (original weight - total weight of fractions)

0.89 % Percent error $\frac{\text{(error (gms) X 100)}}{\text{(original wt. (gms))}}$

* Original weight less error

APPENDIX I

TABLE XXXVI

SOIL GRAIN SIZE AT TEST SITE

LOCATION: Louisiana - See G, Area Map III
DATE: 19 October 1964
SAMPLE NO: 27
WEIGHT, ORIGINAL SAMPLE: 94.2672

Sieve No. a	Weight Retained on Sieve b	Passing Sieve	
		Weight (gms) c	Percent d
-	-	*94.2631	100.0%
8	0.0118	94.2513	99.9
16	0.2831	93.9682	99.7
30	2.5585	91.4097	97.0
50	5.8473	85.5624	90.8
100	5.4011	80.1613	85.0
Pan	80.1613	-	-

94.2631 gms. Total Weight of Fractions (total of all column b entries)

0.0041 gms. Error (original weight - total weight of fractions)

0.004 % Percent error $\frac{\text{(error (gms) X 100)}}{\text{(original wt. (gms))}}$

* Original weight less error

APPENDIX I

TABLE XXXVII

SOIL GRAIN SIZE AT TEST SITE

LOCATION: Louisiana - See H, Area Map III
DATE: 19 October 1964
SAMPLE NO: 28
WEIGHT, ORIGINAL SAMPLE: 85.7859

Sieve No. a	Weight Retained on Sieve b	Passing Sieve	
		Weight (gms) c	Percent d
-	-	*84.8639	100.0%
8	0.0	84.8639	100.0
16	0.4408	84.4231	99.5
30	4.4177	80.0054	94.3
50	7.1171	72.8883	85.9
100	6.6595	66.2288	78.0
Pan	66.2288	-	-

84.8639 gms. Total Weight of Fractions (total of all column b entries)

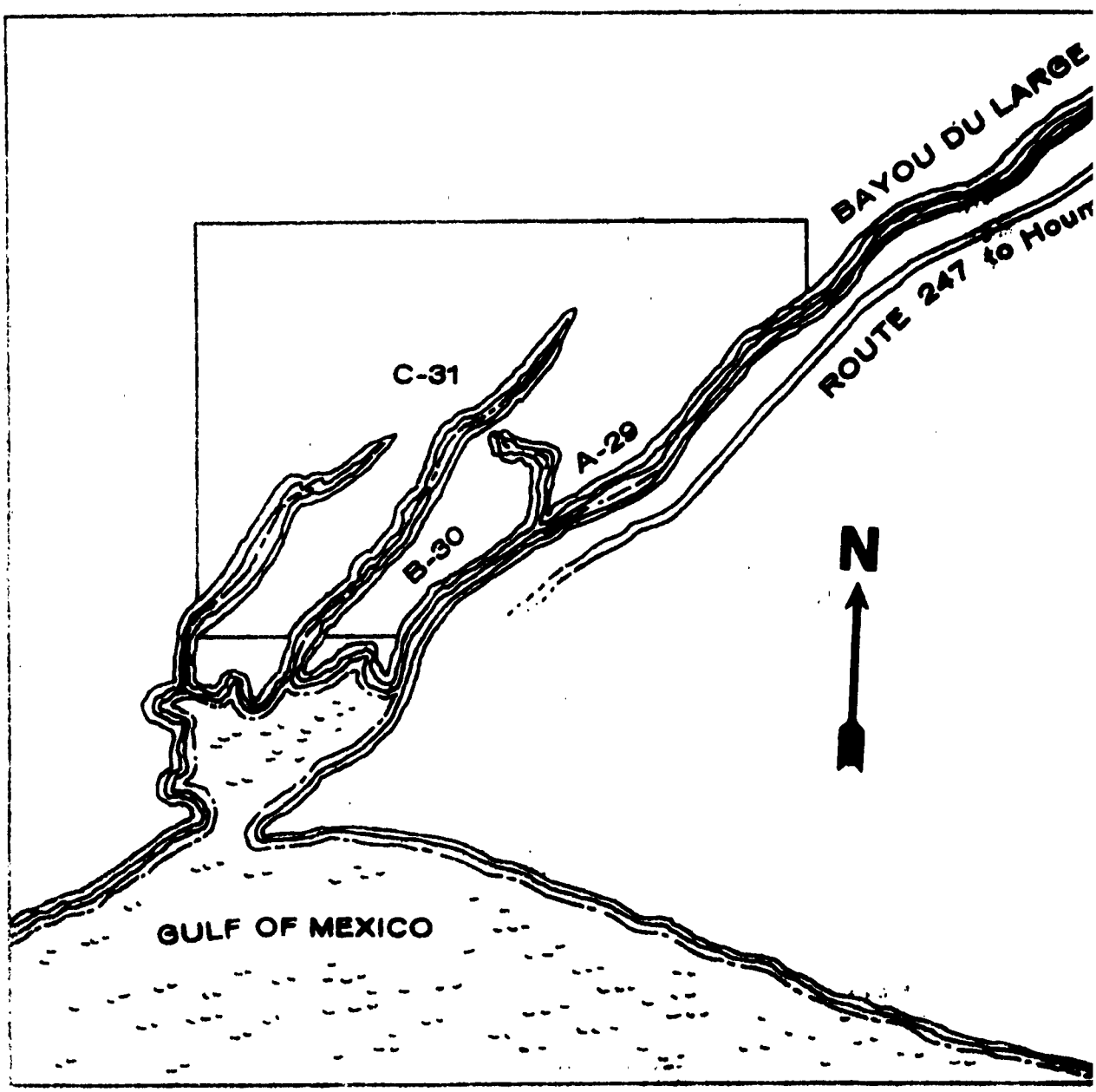
0.9220 gms. Error (original weight - total weight of fractions)

1.07 % Percent error $\frac{\text{(error (gms) X 100)}}{\text{(original wt. (gms)}}$

* Original weight less error

Appendix I
AREA MAP IV

BAYOU DU LARGE TEST SITE HOUMA, LOUISIANA



APPENDIX I

TABLE XXXVIII

CONE PENETROMETER DATA AND MOISTURE CONTENT AT BAYOU DU LARGE TEST AREA

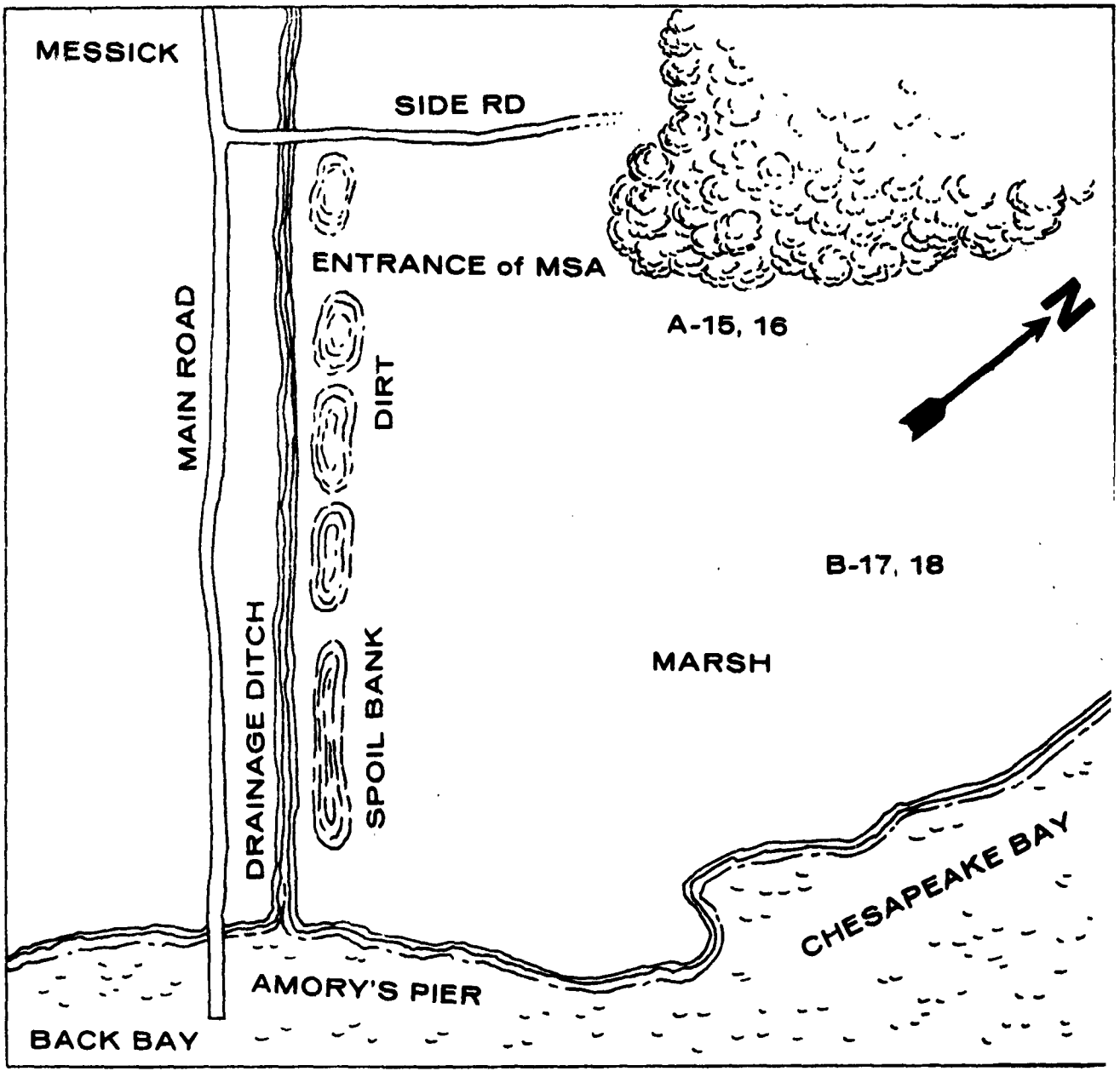
Location and Sample No.	Moisture Content (%)	Cone Index				Remold Index (1-3" Level)
		Surface	6"	12"	18"	
A - 29	24.0*	0	70	87	115	48
B - 30	407.5	0	0	3	18	0
C - 31	294.0	5	25	35	43	0

No Grain Size Analysis conducted due to questionable toxicity of samples, a result of flooding of this area during Hurricane Hilda. Soils are classified Pt by the Unified Soil Classification System. They are described as peat and high organic soils.

*Sample received at laboratory in broken glass jar. Reading not reliable.

Appendix I
AREA MAP V

MESSICK TEST SITE LANGLEY FIELD, VIRGINIA



APPENDIX I

TABLE XXXIX

CONE PENETROMETER DATA AND MOISTURE CONTENT OF SOILS AT MESSICK TEST SITE AREA

Location	Sample No.	Moisture Content (%)		Cone Index Values				Remold Index	
		3"	9"	Surface	6"	12"	18"	0"-6"	6"-12"
A	15	15.8	-	60	110	160	300	0.83	
A	16	-	18.4	60	110	160	300		0.76
B	17	50.6	-	10	45	50	160	0.97	
B	18	-	54.2	10	45	50	160		0.85

Soils are classified Pt by the Unified Soils Classification System. They are described as soils composed of peat and high organic material.

APPENDIX I

TABLE XL

SOIL GRAIN SIZE AT TEST SITE

LOCATION: Messick, Virginia - See A, Area Map V
DATE: 8 September 1964
SAMPLE NO: 15 (Taken at 3" depth before traffic)
WEIGHT, ORIGINAL SAMPLE (gms): 116.5256

Sieve No. a	Weight Retained on Sieve b	Passing Sieve	
		Weight (gms) c	Percent d
-	-	*116.1798	100.0%
8	0.6028	115.5770	99.5
16	2.3204	113.2566	97.5
30	5.4554	107.8012	92.8
50	10.5412	97.2600	83.7
100	19.3015	77.9585	67.1
Pan	77.9585	-	-

116.1798 gms. Total Weight of Fractions (total of all column b entries)

0.3458 gms. Error (original weight - total weight of fractions)

0.30 % Percent error $\frac{\text{(error (gms) X 100)}}{\text{(original wt. (gms))}}$

* Original Weight Less Error

APPENDIX I

TABLE XLI

SOIL GRAIN SIZE AT TEST SITE

LOCATION: Messick, Virginia - See A, Area Map II
DATE: 8 September 1964
SAMPLE NO: 16 (Taken at 9" depth before traffic)
WEIGHT, ORIGINAL SAMPLE (gms): 65.3430

Sieve No. a	Weight Retained on Sieve b	Passing Sieve	
		Weight (gms) c	Percent d
-	-	*65.2121	100.0%
8	.00	65.2121	100.0
16	.8324	64.3797	98.7
30	2.6751	61.7046	94.6
50	6.0897	55.6149	85.3
100	14.4306	41.1843	63.2
Pan	41.1843	-	-

65.2121 gms. Total Weight of Fractions (total of all column b entries)

.1309 gms. Error (original weight - total weight of fractions)

0.20 % Percent error $\frac{\text{(error (gms) X 100)}}{\text{(original wt. (gms))}}$

* Original Weight Less Error

APPENDIX I

TABLE XLII

SOIL GRAIN SIZE AT TEST SITE

LOCATION: Messick, Virginia - See B, Area Map V
DATE: 8 September 1964
SAMPLE NO: 17 (Taken at 3" depth before traffic)
WEIGHT, ORIGINAL SAMPLE (gms): 64.7064

Sieve No. a	Weight Retained on Sieve b	Passing Sieve	
		Weight (gms) c	Percent d
-	-	*64.6202	100.0%
8	0.0778	64.5424	99.9
16	1.3480	63.1944	97.8
30	3.2601	59.9343	92.7
50	4.4301	55.5042	85.9
100	9.3623	46.1419	71.4
Pan	46.1419	-	-

64.6202 gms. Total Weight of Fractions(total of all column b entries)

0.0862 gms. Error (original weight - total weight of fractions)

0.13 % Percent error $\frac{\text{(error (gms) X 100)}}{\text{(original wt. (gms))}}$

* Original Weight Less Error

APPENDIX I

TABLE XLIII

SOIL GRAIN SIZE AT TEST SITE

LOCATION: Messick, Virginia - See B, Area Map V
DATE: 8 September 1964
SAMPLE NO: 18 (Taken at 9" depth before traffic)
WEIGHT, ORIGINAL SAMPLE (gms): 76.4878

Sieve No. a	Weight Retained on Sieve b	Passing Sieve	
		Weight (gms) c	Percent d
-	-	*76.4705	100.0%
8	0.0857	76.3848	99.9
16	2.6576	73.7272	96.4
30	3.9450	69.7822	91.3
50	5.0769	64.7053	84.6
100	10.6180	54.0873	70.7
Pan	54.0873	-	-

76.4705 gms. Total Weight of Fractions (total of all column b entries)

0.0173 gms. Error (original weight - total weight of fractions)

0.02 % Percent error $\frac{\text{(error (gms) X 100)}}{\text{(original wt. (gms))}}$

* Original Weight Less Error

APPENDIX I

TABLE XLIV

ENVIRONMENTAL AND TECHNICAL DATA FOR HELICOPTER LIFTS

	CH-21*	CH-34					
	Firm Ground	Firm Ground Lift		Water Lift		Soft Mud Lift	
	Empty	Empty	Loaded	Empty	Loaded	Empty	Loaded
Weather	Clear	Clear	Clear	Clear	Clear	Clear	Clear
Air Temp	82.5	69	69.5	80.0	81.5	69.0	69.3
Wind Velocity (mph)	4.2	8.0	8.0	5.0	5.0	5.2	5.2
Humidity (%)	40.0	66.6	66.6	58.5	58.5	90.0	90.0
Altitude (ft)	100	100	100	0	0	2	2
Vehicle Weight (lbs)	2660	2660	3960	2660	3960	2260	3960
Helicopter Fuel (lbs)	900	570	550	445	420	410	400
Hookup Time (seconds)	85	40	35	24	NA	25	25
Manifold Pressure (in)	51.5	53.0	53.5	53.5	54.0	54.5	55.0
Rpm at Pick Up	2780	2800	2800	2800	2800	2800	2800
Air Flight Time (min)	0	5	13	20	16	8	12

* Data refers to unsuccessful attempts to lift by CH-21.

APPENDIX II

DEFICIENCIES AND SHORTCOMINGS

1. DEFICIENCIES

DEFICIENCY	SUGGESTED CORRECTIVE ACTION	REMARKS
a. Left electric steering brake overheated during water tests. This assembly was a replacement component and had only 15 minutes of operation prior to this incident. (MSA Pilot No. 1)	Recommend a stiffening of final drive housing to prevent what appeared to be distortion of that unit.	Distortion of final drive housing was from an unknown cause and resulted in a misalignment of the output shaft and center line of brake anchor plate.
b. Both rotor/helix assemblies completely failed structurally during mobility tests. (MSA Pilot No. 1)	Strengthen the pontoons and the helixes to withstand the shock of moving over tree stumps and other typical hard objects found in swamps and marshes.	Fractures were visible throughout various weld points on the helixes, rotor compartments and rotor styrofoam fill points. Rotors were considered beyond repair and the vehicle was returned to the manufacturer in this condition.
c. Loss of steering was experienced when the rheostat sweep arm broke off. Failure occurred during mobility tests. (MSA Pilot No. 2)	Provide more rigid steering stops to prevent greater than 170-degree rotation either side of center.	Sweep arm of steering clutch rheostat broke off causing loss of steering.

APPENDIX II

DEFICIENCIES AND SHORTCOMINGS

2. SHORTCOMINGS

SHORTCOMING	SUGGESTED CORRECTIVE ACTION	REMARKS
Fuel tank developed a leak around top edge of tank after approximately ten hours of operation. (MSA Pilot No. 2)	Provide a better closure method for top edge of fuel tank.	Discovered during refueling operations. Cause is attributed to vibration continually loosening screws along tank top cover panel.

3. CORRECTED DEFICIENCIES/SHORTCOMINGS

DEFICIENCY/SHORTCOMING	CORRECTIVE ACTION	REMARKS
a. Failure of final drive oil seal. Vehicle was delivered to test activity with this deficiency. (MSA Pilot No. 1)	Installed replacement oil seal.	Leaking oil seal was discovered during the test item's pre-operational inspection. Cause unknown, thought to be a defective seal.
b. Left electric steering brake burned out during water operations. (MSA Pilot No. 1)	Installed replacement brake unit.	Smoke was seen rising from final drive assembly after 45 minutes of water operation. It is not known whether cause was from brake maladjustment or from a presumed misaligned output shaft and brake anchor plate, a result of a distorted final drive housing. In the event of the latter, recommend engineering analysis and appropriate stiffening of final drive housing.

APPENDIX II

DEFICIENCIES AND SHORTCOMINGS

DEFICIENCY/SHORTCOMING	CORRECTIVE ACTION	REMARKS
c. Both electric drive clutches became inoperative during mobility tests. (MSA Pilot No. 1)	Heat destroyed the insulation on the coil windings of one clutch solenoid, requiring replacement of this unit. Other clutch was readjusted and returned to service.	Vehicle became immobile due to failure of the drive clutches. It is believed that both clutches had been improperly adjusted which permitted the armatures to bottom out at end of their travel without permitting sufficient axial force to be applied to the clutch disc. This permitted slippage and heat build-up under the severe operating conditions at Messick, Virginia.
d. Left rotor helix sustained weld fractures during water travel when it struck a submerged tree stump. (MSA Pilot No. 1)	Rewelded helix to rotor and rewelded helixes where torn.	After twenty hours of operation in a tree-stump area, inspection of the vehicle revealed these deficiencies.
e. Engine mount broke when vehicle was inadvertently dropped during helicopter lifts. (MSA Pilot No. 2)	Replaced engine mount and repaired damaged area where mounting was riveted to hull.	Deficiency was noted when fan/radiator interference developed. Engine mounting was not able to withstand the shock of a two to three-foot drop, a not too uncommon occurrence during helicopter lifts.

APPENDIX II

DEFICIENCIES AND SHORTCOMINGS

DEFICIENCY/SHORTCOMING	CORRECTIVE ACTION	REMARKS
f. Main body wiring harness shorted out (alternator-ammeter battery line). Occurred during mobility tests.	Replaced damaged wires.	Smoke was seen rising from electrical wiring harness next to an amidship bulkhead. Cause was from chafing.

Figure 1. Marsh Screw Amphibian (MSA)

Figure 2. Carrier, Personnel, Full Tracked, Armored, M113 (Control Vehicle)

Figure 3. Marsh Screw Amphibian during water speed test.

Figure 4. Marsh Screw Amphibian easily negotiating the tidal mud flats of the Appomattox River.

Figure 5. Soils samples being collected in mud flat area of the Appomattox River.

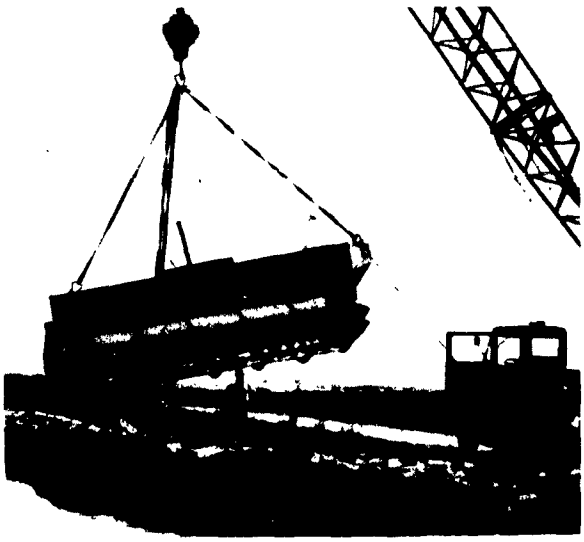


Figure 6. Marsh Screw Amphibian being unloaded and placed in drainage ditch at Messick test site.

Figure 7. Marsh Screw Amphibian negotiating ditch bank at Messick test site.

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TEST TECOM 7-5-0524-01-9

NEGATIVE 15, 34G, 58G

APPENDIX III-2

Figure 8. Type of swamp terrain at Messick test site. The Marsh Screw was unable to negotiate this area in forward direction.

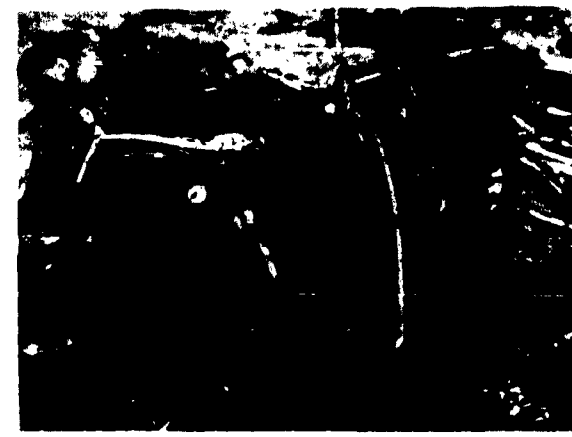

Figure 9. Typical heavily vegetated water area at the Chickahominy test site. The roots and vegetation have been lifted from the water to show density.

Figure 10. Marsh Screw Amphibian negotiating heavily vegetated water area at Chickahominy test site.

Figure 11. The M113 immobilized in heavily vegetated water area at the Chickahominy test site. Recovery vehicle is the M116 personnel carrier.

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NEGATIVE 59G, 30G, 32G, 9G

APPENDIX III-3

Figure 12. Typical light subsurface vegetation in water at Chickahominy test site. M113 could negotiate this light vegetation.

Figure 13. Typical vegetation in the Bonnet Carre test site. Notice surface water covering.

Figure 14. M113 immobilized in canal at the Bonnet Carre test site.

Figure 15. The Marsh Screw Amphibian negotiating the bank of a canal in the Bonnet Carre test site area. MSA proceeded across the roadway and into the marshes beyond.

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42G, 14FF, 7FF
NEGATIVE 10FF

APPENDIX III-4

Figure 16. Typical cross section of floating grass mat found in the Bayou Du Large test site. Root mass depth ranged between 8 and 12 inches.

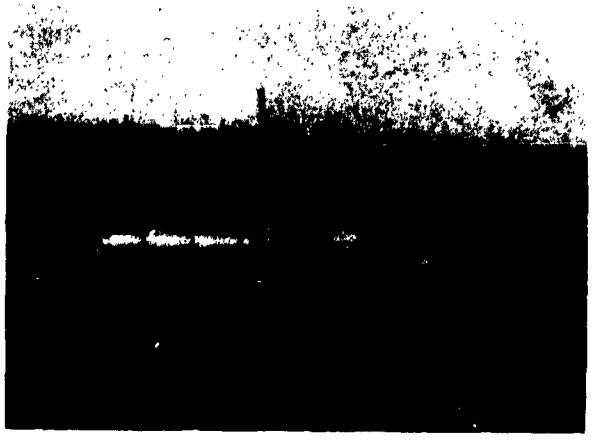

Figure 17. Marsh Screw Amphibian negotiating floating marsh area at Bayou Du Large test site.

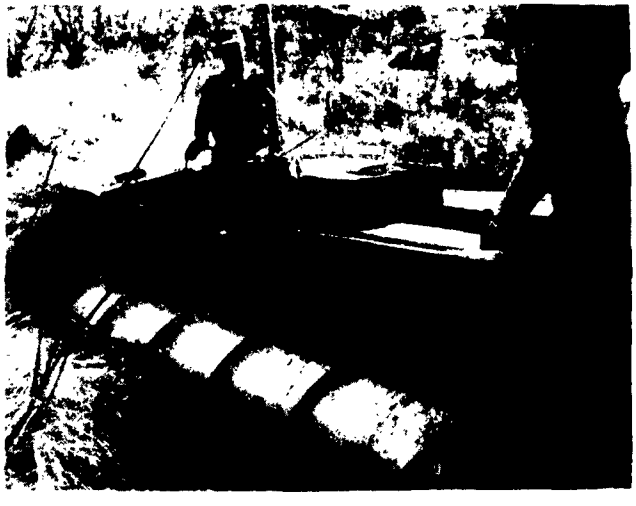

Figure 18. Marsh Screw Amphibian immobilized in depression at Bayou Du Large test site. Front of vehicle is against forward bank while rear of vehicle is on near bank.

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GETA
FORT LEE, VA.

TEST TECOM 7-5-0524-01-9
12FF, 4FF, 31FF

NEGATIVE _____

APPENDIX III-5

Figure 19. CH-34 transporting the Marsh Screw Amphibian.

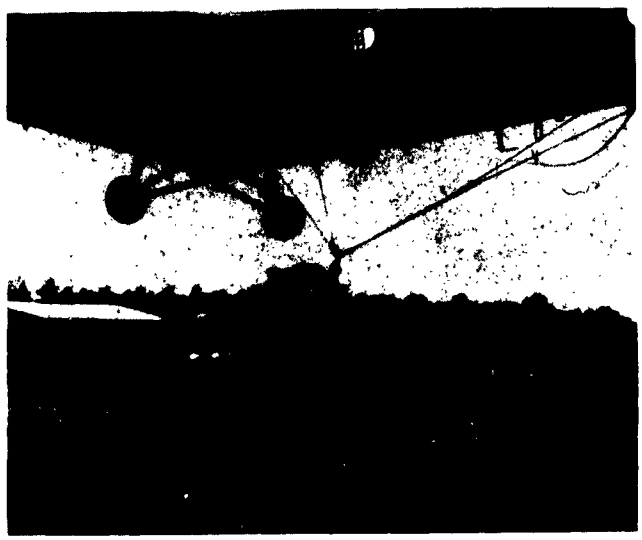

Figure 20. CH-21 unsuccessfully attempting to lift the Marsh Screw Amphibian.

Figure 21. Marsh Screw Amphibian transporting personnel through a vegetated swamp in the Appomattox River area.

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TEST TECOM 7-5-0524-01-9

NEGATIVE 33,136,127

APPENDIX III-6

Figure 22. Personnel disembarking at the water's edge. The Marsh Screw Amphibian could not traverse the sand beach.

Figure 23. Special trailer needed to transport the Marsh Screw Amphibian between operational areas.

Figure 24. Distorted engine mounts caused by a two to three-foot drop when the helicopter pilot prematurely released the Marsh Screw Amphibian.

Figure 25. (1) Torn rotor helix thread; (2) fractured weld bead at base of thread; (3) failure of styrofoam fill point welds; and (4) the compartment radial weld crack.

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TEST TECOM 7-5-0524-01-9

NEGATIVE 117, 2, 82, 17FF

APPENDIX III-7

ANNEX

SWAMP SPRYTE PERFORMANCE DATA

During Period 19 August 1964 - 12 October 1964

Concurrently with the testing of the Marsh Screw Amphibian, two Swamp Spryte vehicles were tested under USATECOM Project No. 7-5-0524-02-9. The findings of these tests are as follows:

a. Approximately ten hours of operational time on the vehicle were required for the operator to obtain a satisfactory degree of proficiency.

b. A qualified tracked vehicle mechanic should be capable of performing all maintenance with the aid of published technical data without additional training.

c. The Swamp Spryte mobility and maneuverability performance in each of the test areas was as follows:

(1) Appomattox River: The Swamp Spryte was not able to negotiate the gradual slope from the water onto the exposed tidal mud flats. After a number of attempts, the vehicle was assisted onto the mud flat and an attempt was made to negotiate the course. As the vehicle proceeded, it gradually sank into the mud until, after approximately 50 feet of travel, it became completely immobilized when it bellied out. Water speed of the vehicle over a measured straight line course with payload was 4.1 mph and the maneuverability of the vehicle in deep water was better than the M113 but not as good as the M116. Fuel consumption of the vehicle during swimming tests with payload was 2.5 gallons per hour. During operation on firm soil and over secondary roads, the vehicle was able to operate at speeds up to 35 mph dependant on the terrain conditions. Maneuverability over this type of terrain was excellent. Fuel consumption of the vehicle was 1.3 gallons per hour when operating cross country.

(2) Chickahominy River: The Swamp Spryte in a full-float condition was able to negotiate water with surface and subsurface vegetation, except where the vegetation was dense or it became compacted in front of the vehicle. The large areas of floating vegetational mats at this site could not be negotiated by the vehicle. The Swamp Spryte's mobility in the swamp and marsh terrain areas where the vehicle was not in a swimming condition was acceptable. The exposed four axles under the hull were the cause of immobilization and partial immobility as they became hung on stumps, heavy clumps of water vegetation, deep soft mud, and other debris. Installation of a skid plate to cover the axles would greatly improve the vehicle's performance in this area.

(3) Bonnet Carre Area: The Swamp Spryte traversed all ground surfaces in this area including three-foot gullies and areas with dense brush and saplings. The Spryte could not negotiate the narrow shallow waterways (2 1/2 to 3 1/2 feet deep) due to the inability of the operator to control the direction of the vehicle. As one track or the other came in contact with the bottom, the vehicle would swing toward the shore and become immobilized in the soft bottom. The vehicle was able to extricate itself each time, but attempts to negotiate the two shallow waterways in this area were abandoned due to this lack of control. The vehicle was able to easily negotiate a long slope of 63%. The surface of this slope was firm soil with a grass cover that had been rain soaked.

(4) Bayou Du Large Area: The Swamp Spryte could not negotiate the large soft pot holes in the floating grass mat found in this area. These critical areas were avoided after two immobilizations. The Spryte was able to travel over the denser floating grass mat providing access was from fairly firm ground and not from the water or soft mud side. The Swamp Spryte was able to negotiate the bayou and exit from the bayou over the vertical eight to ten-inch exposed bank. The six to seven-foot high spoil bank of the bayou was easily negotiated by the vehicle.

d. The Swamp Spryte was capable of carrying six combat equipped men plus the driver along and across inland waterways and across the terrain previously listed. In warm weather climates, one less passenger can be accommodated due to the location of the two engine/transmission heat duct outlets. Relocation of these ducts outside the cargo/personnel compartment would eliminate this problem. Personnel can easily embark and debark from the vehicle and the ride characteristics of the vehicle are good.

e. Cargo utility characteristics were acceptable. Cargo loading and unloading can be accomplished by hand or by crane. No cargo tie-down devices were present in the test vehicles. The cargo compartment will accommodate one 40"x48" warehouse type pallet or three 55-gallon drums which constitute a full payload for this vehicle.

f. Driver fatigue, noise level versus driver tolerance, and accessibility of controls were acceptable.

g. No safety hazards were observed; however, no horn or rear view mirror was furnished for the vehicle.

h. Down time for repairs on the two Sprytes was acceptable. For 110 hours of operation, the vehicle was deadlined for 37.7 hours of which 20.5 hours was awaiting parts.

i. Vulnerable vehicle components were:

(1) Fractures occurred at the center section of three track grousers. Subsequent operation of the vehicle results in ruptured tires.

(2) The reverse idler gear bronze bearing failed prematurely. They are not able to withstand operation in reverse for periods of time over one minute.

(3) The starting motor would bind when trying to restart the engine after operation. The operator had to wait 15 to 20 minutes to allow the unit to cool off in order to permit free turning of the starter.

j. The Swamp Spryte was easily transportable over highway and by rail and did not exceed limitations as indicated in AR 705-8.

k. The lifting eyes did not comply with MIL-STD-209.

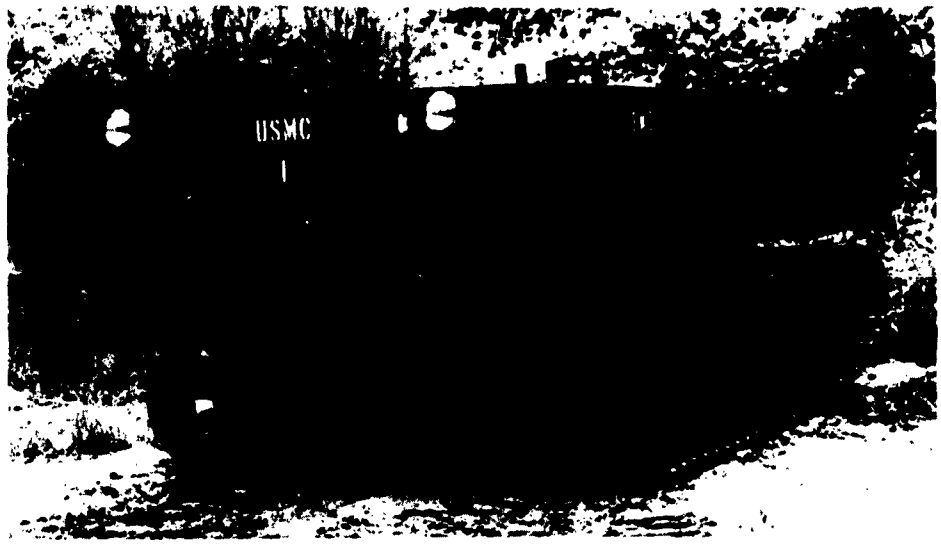

Figure 1. Swamp Spryte Amphibian.

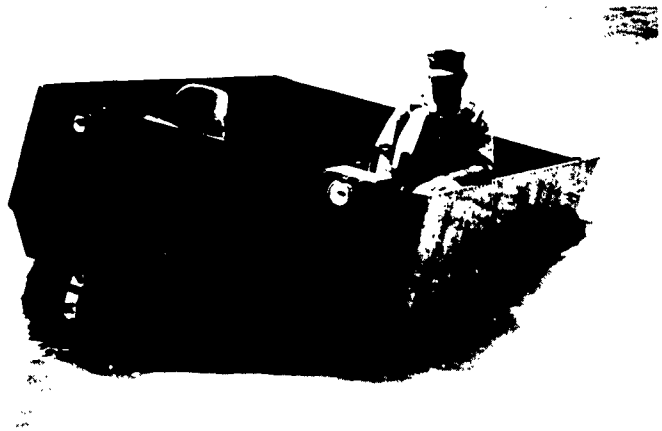

Figure 2. The Swamp Spryte immobilized due to the soft mud bottom of the Appomattox River.

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ANNEX

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(TECOM Project No. 7-5-0526-01-9) Unclassified Report

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2. Marsh Screw Amphibian
3. Swamp Spryte
4. Mobility
5. Maneuverability
6. Transportability
7. Terrain
8. Cargo Vehicles
10. Tracked Vehicles
11. Air Transportation
12. Helicopter, CH-21 (Shawnee)
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It is concluded that the Marsh Screw Amphibian attains its greatest efficiency, and greatest loaded speed (12.4 mph) when operated in extremely soft liquefied mud and is considered to have military potential. The MSA is inefficient when operated over uneven terrain and is not considered to have military potential in this area. Test results show that six combat equipped personnel or 1,000 pounds of loose cargo can be transported over terrains where the vehicle can operate. maintenance time was excessive; the MSA must be transported between operable areas by a special trailer; and it can be carried as an external load by the CH-34 helicopter.

It is recommended that consideration be given to determine if a military requirement exists for a vehicle capable of operating in open and heavily vegetated water, and extremely soft mud. If such a requirement does exist then a QMR or SDR should be prepared outlining specific requirements. If a QMR or SDR for a vehicle to operate in the environment cited is approved, the deficiencies of the MSA should be corrected and engineering/service tests be conducted to determine if the modified vehicle meets the requirement.

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