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14. ABSTRACT
This TOP describes procedures for evaluating the fording ability of military wheeled and tracked vehicles and the effectiveness of fording kits. The types of fording (shallow water, deep water, and underwater) are considered with respect to safety hazards; performance, including water ingress and egress capability; effects on vehicle operation on land; and endurance. Fording kits are evaluated for time required for installation, ease of application, proper fit, reliability, functional suitability, and safety. When applicable, comparisons are made between the vehicle/kit under test and comparable standard equipment.

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Deep Water Fording
Under Water Fording
Technical Manuals
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Maximum Allowable Water Line

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US ARMY DEVELOPMENTAL TEST COMMAND
TEST OPERATIONS PROCEDURE

*Test Operations Procedure 2-2-612 21 November 2007
DTIC AD No.: ADA481302

FORDING

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1. SCOPE. This TOP describes procedures for evaluating the fording ability of military wheeled and tracked vehicles and the effectiveness of fording kits. The types of fording (shallow water, deep water, and underwater) are considered with respect to safety hazards; performance, including water ingress and egress capability; effects on vehicle operation on land; and endurance. Fording kits are evaluated for time required for installation, ease of application, proper fit, reliability, functional suitability, and safety. When applicable, comparisons are made between the vehicle/kit under test and comparable standard equipment.

Amphibious vehicles, which are tested according to TOP 2-2-501[1**], are not included in this document.

2. FACILITIES AND INSTRUMENTATION.

2.1 Facilities.

Item	Requirement
Fording basin	See Appendix B, Figure B-1
Underwater fording facility	See Appendix B, Figure B-2
Offshore fording area	See Apendix B, Figure B-3
Safety equipment	Life jackets, life rings, emergency signaling equipment, rescue craft, rescue equipment, and scuba diving equipment

Note: These facilities are currently available at Aberdeen Test Center (ATC) and Yuma Test Center (YTC).

2.2 Instrumentation.

Item	Maximum Error of Measurement
Depth markings on side of vehicle (outside)	±2.5 cm (±1 in.)
Depth markings on side of vehicle (inside)	±2.5 cm (±1 in.)
Sonar depth measuring equipment	±0.3 meters (±1 ft)
Sounding rod	±2.5 cm (±1 in.)
Slope gage	±1 degree
Engine tachometer	±0.5 percent full scale
Toxic gas measuring equipment	See TOP 2-2-614[4]

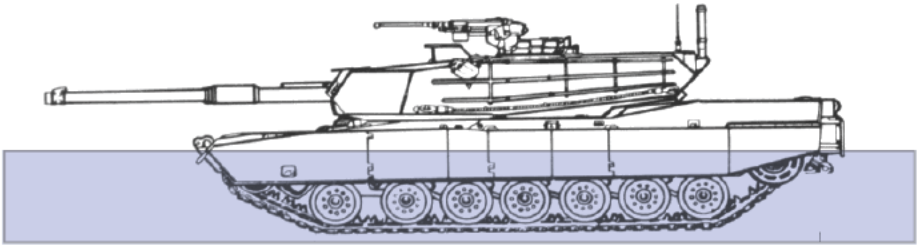
** Superscript numbers correspond to those in Appendix C, References.

3. REQUIRED TEST CONDITIONS.

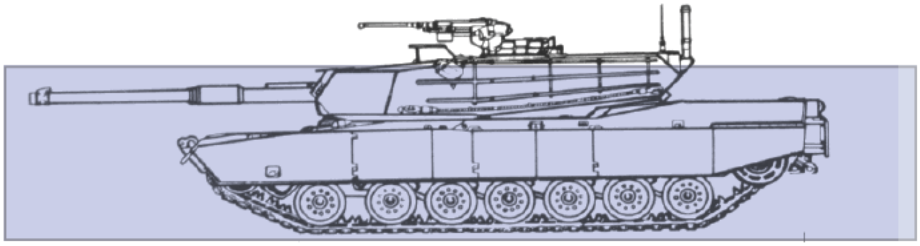
3.1 Selection of Test. Select the type of fording test(s) based upon requirements. There are three modes of fording: shallow water, deep water, and underwater. All modes involve contact of the wheels or tracks with the ground (Figure 1). Distinguishing features of these modes are as follows:

a. Shallow Water Fording. The vehicle engine air intake, driver, and cargo are not underwater and no special kit application is required.

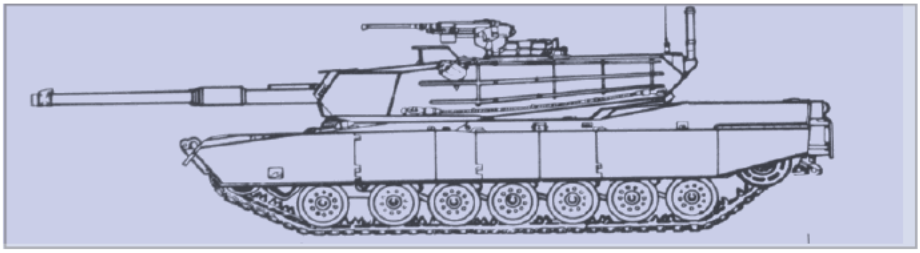
b. Deep Water Fording. This condition may require the application of a kit containing seals and snorkels. One or more hatches are always above water for use as an escape route and visual observation. The depth of deep water fording for each type of vehicle will vary depending upon the extent of protection provided. This test is conducted in a basin, but may also be conducted in a natural environment if a suitable body of water at the right depth exists.



Shallow Fording



Deep Water Fording



Underwater Fording

Figure 1 Water Fording Phases

c. Underwater Fording. The vehicle is operated under the surface of the water and requires snorkels for engine and/or crew compartments. Extensive sealing is required for this mode of operation. The fordable water depth for this mode is governed by the height of the snorkel, at least 0.6 meters (2 feet) of which should be above the water surface.

3.2 Preliminary Activities.

Method

a. Use the procedures described by the following publications prior to conducting the required test phases:

Title	Publication No.
Vehicle Characteristics	TOP 2-2-500[2]
Preliminary Operation	TOP 2-2-505[3]

Particular attention should be given to the ignition system, intake and exhaust systems, generator and electrical system, turret seal, door and hatch seals, and all openings or holes in hull or bulkheads. Inspect all visible wiring for insulation damage; fording should not continue until wiring is repaired.

b. During the preparation of vehicles that will operate with a flooded engine compartment, close the engine intake and exhaust manifold ducting and the snorkels, and pressurize the engine to approximately 34.5 kilo Pascals (kPa) (5 pounds per square inch (psi)) and check for leaks. Soapy water applied with a brush to joints, seams, and welds will reveal air leaks. A ducted generator or other susceptible system should be checked in the same manner.

c. The vehicle shall be marked on the exterior and interior with water level lines to indicate water depth during testing.

d. The test officer shall mark the maximum allowable water line (MAWL) on the interior of the test vehicle. If the water rises above the MAWL, the test vehicle must be immediately removed from the water and the test is aborted.

e. Mount video recorders inside of vehicle, angled toward water level lines and any other areas deemed critical to the test.

f. Flood the vehicle floor to a limited depth, excluding water sensitive components, to provide an indication of leakage points; e.g., at bottom plates. When this is being accomplished, the bilge pump intake should be under water and should be checked for proper functioning and capacity. Provisions for preventing debris from entering the pump intake are also checked; more important, the full floor is inspected to assure that debris which would clog the pump are not present.

g. Test vehicles and direct test support vehicles shall be suitably equipped with fully charged fire extinguishers capable of extinguishing electrical, fuel, or oil fires. Test vehicle operators shall inspect the fire extinguishers daily during test operations to make sure seals have not been broken and the extinguishers remain fully charged.

h. The test officer will monitor wind direction and abort testing if exhaust is blown into the test vehicle or into personnel occupied areas.

i. A recovery vehicle, such as an M88 with tow cables attached, shall be in place and ready for an emergency extraction of the test vehicle in the event the test vehicle becomes immobile in the water.

j. Take oil, fuel and lubricant samples from all sources exposed to water for pretest petroleum analysis.

4. TEST PROCEDURES.

Follow Operational Checklist in Appendix C.

a. Establish emergency exit procedures (see Appendix A) and provide adequate exit instructions in this regard to the test personnel.

b. If it appears that the installation of the fording kit may alter the engine exhaust flow in a way to cause safety problems for crew, carbon monoxide is measured in accordance with TOP 2-2-614[4].

4.1 Shallow Water Fording.

4.1.1 Method. Conduct testing as follows in a controllable-depth, fresh water fording basin (Appendix B, Figure B-1), starting with the water level at the maximum required depth per vehicle specification:

a. Drive the vehicle into the water slowly, stopping frequently to check for water leakage. After maximum fording depth is reached, stop and start the engine three times, or more if starting is erratic.

b. Remain in the water for a period of 15 minutes, if no major water leakage is noted. Back the vehicle out of the basin at least once during this period to assure that sealing is adequate under this condition. Note: The 15 minutes do not include when the vehicle is being backed out of the basin. Check continuously for water leakage.

c. Operate the vehicle for 8 kilometers (5 miles) on a hard level surface to ensure operational temperatures of vehicle subsystems have been reached.

CAUTION: Steer control and braking should be functionally checked before operating at speeds in excess of 16 km/hr (10 mph). If braking is inadequate, the brake linings should be dried by repeatedly braking until normal braking is restored.

d. With the water level at the maximum depth, attempt vehicle operation in the basin at increased speeds, to the maximum obtainable safe speed.

CAUTION: Care should be taken not to reach speeds that could force water into the vehicle air-intake system.

e. After item 4.1.1.d. is completed, inspect the vehicle systems (engine, transmission, transfer case, etc.) for the presence of water. Oil will turn grayish-white when contaminated by water.

f. Operate the vehicle at varying speeds to maximum, on a hard level surface, for 16 kilometers (10 miles) to dry out the vehicle systems and determine proper operation.

4.2 Deep Water Fording - In Fording Basin

4.2.1 Method

4.2.1.1 Fording Kit. Install the fording kit in accordance with applicable technical manuals (TM's) for the system that is being tested.

4.2.1.2 Preparation of Vehicle. Check the following features, as applicable, prior to entering the water:

a. Radio and intercom, including any exposed cabling.

b. Oil and lubricant levels. Check and record oil levels on dipsticks on engine, transmission, etc. For other gearboxes, adjust lubricant levels to "full" condition as specified in the vehicle's TM.

c. Exhaust system. While using extreme caution, and using the appropriate personal protection equipment (PPE), tighten all clamps while hot from operation.

d. Drain valves. Verify the drain valves are in the closed position. Drain plugs shall also be installed.

e. Fuel caps (should be tight) and ensure fuel system cap vents are operating properly where applicable.

f. Ensure a fording sealer application on hatches or doors below the anticipated water level, periscopes, and fire extinguisher external remote controls, if applicable.

g. Bilge pumps. Check to ensure that they are operational, intake screens are clear of obstructions, and outlet valve is in place. Measure the bilge pump output and present the data in units gallons/minute. Compare the output to bilge pump specifications.

h. Gun muzzle plug(s) is installed and gun covers are in place if applicable.

i. Engine. Start and check for full performance by conducting an engine high stall test. Refer to the applicable TM to conduct this check properly.

j. Record the test vehicle odometer reading prior to any fording operation.

k. Air pressurization systems (on vehicles so equipped). Check for leaks, valve functioning, etc. When engine shutdown is prescribed, the air pressurization system should maintain the required pressure during the shutdown period.

4.2.1.3 Tow Cables. Attach two tow cables to the test vehicle, one secured to a tow eye on each end (front and back) of the vehicle. The free end of each cable should be tied down on top of the vehicle for ready access for emergency recovery operations. A flotation buoy should be connected near the free end of the tow cables.

4.2.1.4 Exit Route. Assure an unobstructed exit route from the vehicle crew station for each crew member, with particular emphasis on the driver's station (see Appendix A).

4.2.1.5 Emergency Breathing Apparatus. Check that an emergency breathing apparatus is available for each crew member. This apparatus should include an air bottle with regulator valve and breathing tube, and a mask for each individual. Each crew member should be instructed and certified in the use of this equipment.

4.2.1.6 Test Site and Personnel.

a. Ensure that test control, recovery personnel and equipment are at the fording site prior to test operations.

b. Ensure a portable liquid containment tarp and liquid absorbing material are available in the event of a significant POL spill.

c. Conduct a pretest safety meeting and instruct test personnel on fording operations and actions to take in case of emergency.

d. The number of persons permitted in test vehicles will be limited to the absolute minimum necessary to accomplish the test objectives and provide for safe operations.

4.2.1.7 Test Runs. Prior to the actual fording test, subject the test vehicle to deep water fording in the fording basins (Appendix B). After the initial fording basin run has proven satisfactory, operate the test vehicle for 8-km (5-miles) on a hard level surface in order to achieve operating temperatures of the applicable vehicle subsystems.

4.2.1.8 Follow-Up Land Operations. Following the fording test and the test vehicle has exited the fording basin, remove the specific fording items in accordance with the applicable TM’s. Operate the test vehicle on a hard level surface at various speeds for 8 km (5-miles) to ensure the vehicles subsystems are dry.

CAUTION: Steer control and braking should be functionally checked before operating at speeds in excess of 16 km/hr (10 mph).

a. At the conclusion of each day's testing, the vehicle’s engine shall be continuously operated for a total of 1 hour to dry out moisture accumulations.

b. At the completion of deep water fording operations, the vehicle shall be operated for 16 kilometers (10 miles) on a hard level surface for to determine proper vehicle operation.

c. At the completion of the test, the remaining fording kit parts are removed and the vehicle examined for leakage.

d. Sample and chemically analyze all fuel, oil, and lubricants for water contamination. Samples should be taken from the lowest point in the system's sumps or reservoirs.

4.3 Deep Water Fording - In Natural Environment This subtest is not essential for every vehicle system, but may be conducted at the discretion of the evaluator, and when a suitable body of water exists with a flat bottom and proper depth.

4.3.1 Method

4.3.1.1 Pretest. Conduct the "Deep Water Fording - In Fording Basin" operations first. Before actual deep fording in the natural environment, carefully reconnoiter or sound the course area to ensure that it does not exceed the prescribed maximum depth and that there are no holes, quicksand, or obstacles that could create too great a depth that could put the vehicle or personnel at risk. For offshore or lake operation, mark the area with a minimum of three buoys to define the permissible operating area; for a stream or river, mark the route with a minimum of four buoys. Appropriate rigging should be added with buoys attached so that if the vehicle sinks or becomes stranded, its underwater location is marked for recovery. Care must be taken in attaching rigging so as to not interfere with normal vehicle operations or egress from the vehicle in event of an emergency. Note the characteristics of the test site.

4.3.1.2 Test Runs

a. The initial entry into a natural body of water would be made carefully to assure the adequacy of the vehicle for fording and the compatibility of the environment selected. A figure eight course shall be used when fording operations are conducted from a beach (Appendix B, Figure B-3).

b. Attach a tow cable, at the front of the test vehicle, to a suitable wrecker or recovery vehicle and back the test vehicle into the water to the desired depth. When the desired depth has been obtained, select the applicable transmission forward gear in accordance with the TM to allow easy egress in an emergency. Vehicles equipped with manual clutch can remain in neutral gear if the TM allows during static operation, as engine loading can be controlled by slowly disengaging the clutch during vehicle exit.

c. After the test vehicle has fully entered the water, vehicle stationary, engine running, and at the prescribed maximum fording depth, observe the vehicle for 15-minutes giving special attention to submerged seals and operating bilge pumps.

d. After the vehicle exits the basin, disconnect the recovery vehicle cable and, with the fording kit installed, operate the test vehicle for a minimum distance of 8 kilometers (5 miles) before reentering the water. Record detrimental effects of the fording kit on test item performance.

e. Deep fording shall be conducted with the transmission in the various gear positions, beginning with the lowest gear to the highest applicable gear. This operation will determine the optimum gear range for fording operations.

f. Exercise caution when attempting to reduce vehicle speed while underwater. Operate the brakes to slow the vehicle rather than lowering the engine rpm due to the possibility of stalling the engine and ingesting water through the engine exhaust system. If the engine should stall, attempt to restart immediately. If the fording kit does not allow for underwater starting, initiate the emergency recovery procedures immediately.

g. If the fording kit allows for an underwater engine start, stop and start the engine in two minute intervals three times, or more if starting is erratic.

h. When the driver is submerged, he must be kept on course by instructions through the vehicle intercom system or other suitable communication systems.

4.3.1.3 Follow-Up Land Operations (same as Paragraph 4.2.1.8.)

4.4 Underwater Fording.

4.4.1 Method

a. Follow all of the procedures and perform all of the checks used for shallow and deep water fording.

b. Insert plugs where required.

c. Inspect underwater fording components to ensure proper fit and function.

d. Inspect and perform functional checks on the air supply system for the crew as well as the engine prior to entering the water.

e. Secure life jackets for quick release.

f. Inspect and verify all emergency breathing apparatuses are operational and stowed near a manned crew station.

g. Attach a slender vertical indicator near the vehicle front to aid the director in maintaining directional orientation. This will be particularly useful in moving water.

NOTE: As the fording depth increases, stronger currents are encountered which makes reconnoitering of the bottom more difficult and more critical. Because the driver is operating "blind" in some deep water fording and always in underwater fording, guidance of the vehicle is more difficult. Also, because of the difficulty in handling and connecting heavy cables in underwater fording, recovery of the vehicle is more difficult.

h. Follow the same follow-up land operations as in Paragraph 4.2.1.8.

5. DATA REQUIRED.

5.1 Preliminary Activities.

a. Vehicle identification and description, including traction devices, types of tires or track, etc.

b. Test facility and course descriptions. Identify by name and location (ref to Appendix B); include water depths, length and percent of grades, and course lengths. Identify paved or gravel courses used for the 8-kilometer (5-mile) warming runs and 16-kilometer (10-mile) final runs.

c. Indications of leaks and actions taken to reduce them.

d. Fording equipment data.

e. Level of carbon monoxide in vehicle if it has been taken without kit and with kit (see Paragraph 4).

f. Video footage of wireless digital camcorder on water depth markings, to include time stamp, indicating rise time of water entry.

5.2 Shallow Water Fording.

a. Depth(s) of fording.

b. Actions taken, if any, to reduce possibilities of leakage.

c. Observations of leakage.

d. Time spent in water.

e. Maximum safe allowable speed achieved during fording operations.

f. Observations of starting problems.

g. Evidence of water in oil first visually and then through a detailed petroleum analysis.

5.3 Deep Water Fording - In Fording Basin.

a. Fording Kit Installation:

(1) Time, man-hours, and number of personnel required for installation.

(2) Special tools required, if any.

(3) Difficulties encountered, if any.

(4) Adequacy of installation instructions.

(5) Adequacy of on-board stowage for crew-installed fording kit components.

b. Test Runs:

(1) Duration of fording operation.

(2) Tendency of the vehicle to float (measurable free board around the vehicle).

(3) Vehicle speeds attained.

(4) Vehicle and kit failures.

(5) Effects of water on the operational performance of the test item.

(6) Location and amount of leakage observed in each area, if any.

(7) Fuel consumption.

(8) Adequacy of bilge pumps.

(9) Conditions prejudicial to crew and passenger safety in the event that the test item must be abandoned in the water.

(10) Water velocity and direction verses vehicle direction.

(11) Wave height.

(12) Water depth.

(13) Engine rpm and gear position.

(14) Human factors observations - adequacy of vehicle operation relative to steering, engine operation, speed, safety, starting, vehicle control, and psychological responses of personnel, and space requirements for emergency and escape routes.

c. Follow-Up Land Operations:

(1) Adequacy of means provided to remove components of the kit, if applicable.

(2) Reusable components which have been removed. Any adverse effects on vehicle performance from kit components not removed.

(3) Any adverse effects on steer control or brake performance after fording.

(4) Results of oil and fuel contamination tests.

(5) Motion pictures of special operations.

(6) Time and man-hours required to remove all fording kit parts.

(7) Adequacy of instructions for removal of the fording kit.

(8) Difficulties in returning the vehicle to normal operating conditions.

(9) Evidence of leakage that is visible after removal of inspection plates, doors, and storage covers.

5.3 Deep Water Fording - In Natural Environment.

a. With regard to entry and exit from the water, record the range of entrance and exit slopes negotiated, the amount of water that has entered, and problems encountered.

b. Record other pertinent data shown in Paragraph 5.2.

c. Record the following, with regard to the body of water:

(1) Type of water obstacle (stream, river, etc.).

(2) Salt or fresh water.

(3) Maximum depth of water.

(4) Water or current velocity and direction of the flow relative to the vehicle heading.

(5) Type of bottom (clay, gravel, sand, etc.).

d. For salt water operations, record the effects of corrosion on the test vehicle, its subsystems, and fording kit components.

5.4 Underwater Fording. Obtain the same data as in Paragraph 5.2, as applicable.

6. PRESENTATION OF DATA.

Tabulate and chart all performance data and test conditions and present in the final report.

APPENDIX A. EMERGENCY EXIT PROCEDURES.

Emergency Exit Practices. The following items are important emergency procedures and should be covered by the SOP covering the fording operation undertaken:

a. Emergency escape routes should be clearly established with procedures for use.

b. Personnel should be briefed on emergency escape procedures just prior to entering the water during fording operations.

c. Most important, personnel should be instructed that if the vehicle sinks when hatches are closed, the vehicle must be nearly filled with water or the pressure equalized on both sides of the hatches before the hatches can be opened.

d. Obstructions to escape routes should be eliminated where possible or adequately acknowledged by operating personnel.

e. Escape routes should be checked to ensure adequacy.

f. Emergency breathing equipment shall be provided each crew member for all fording tests except shallow water fording. The equipment shall be readily accessible and portable.

g. An escort craft shall accompany the test vehicle during all deep water and underwater fording operations at natural sites. The escort craft shall contain a person qualified in first aid (including artificial respiration), a scuba diver, and life rings on ropes. All test vehicles will have a minimum crew to conduct safe operations. In deep water fording, the upper most hatch (or cover for trucks) shall remain open; in underwater fording, hatches will be closed. If necessary, escape hatches shall be so modified so that they can be opened by lever or wrench from the outside.

h. Proposed water access routes and test water courses will be sounded, prior to use, for depth and navigability. Fording will be prohibited if swift currents, obstacles, or flotation characteristics may cause the vehicle to capsize or otherwise endanger escape or rescue operations.

i. DC portable light(s) should be temporarily mounted high in the vehicle interior, above the crew compartment, to light up aisle ways.

APPENDIX B. EXAMPLES OF FORDING FACILITIES.

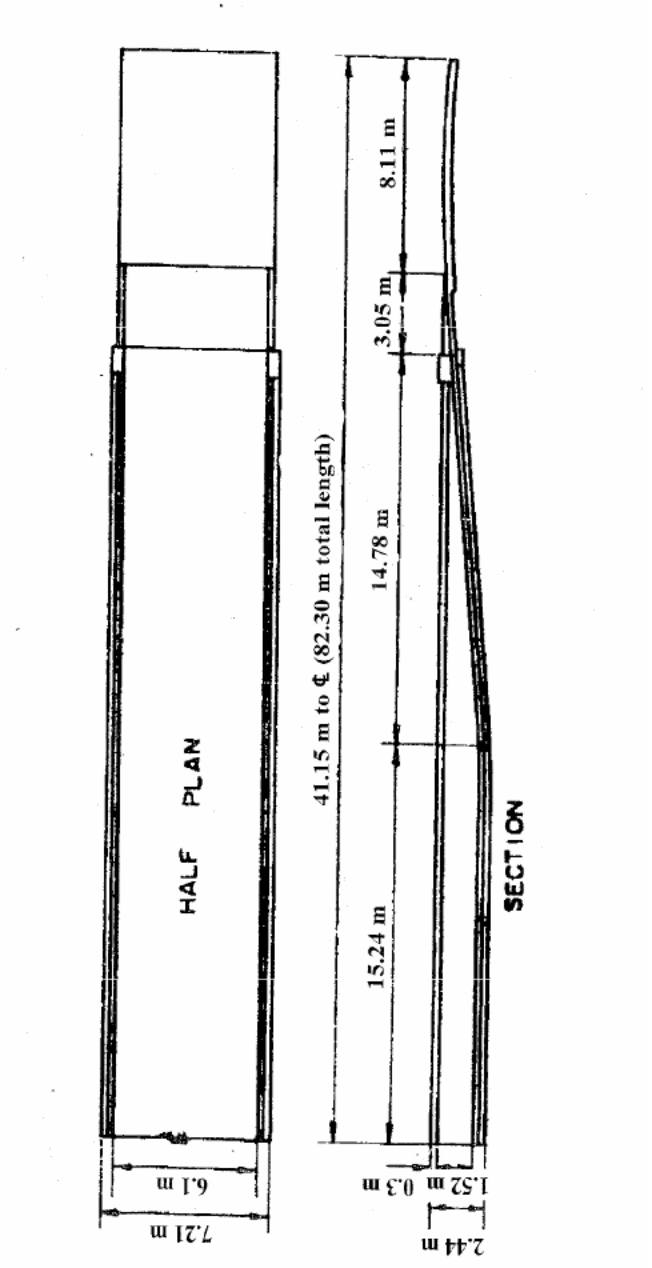


FIGURE B-1. Half plan and section of fording basin

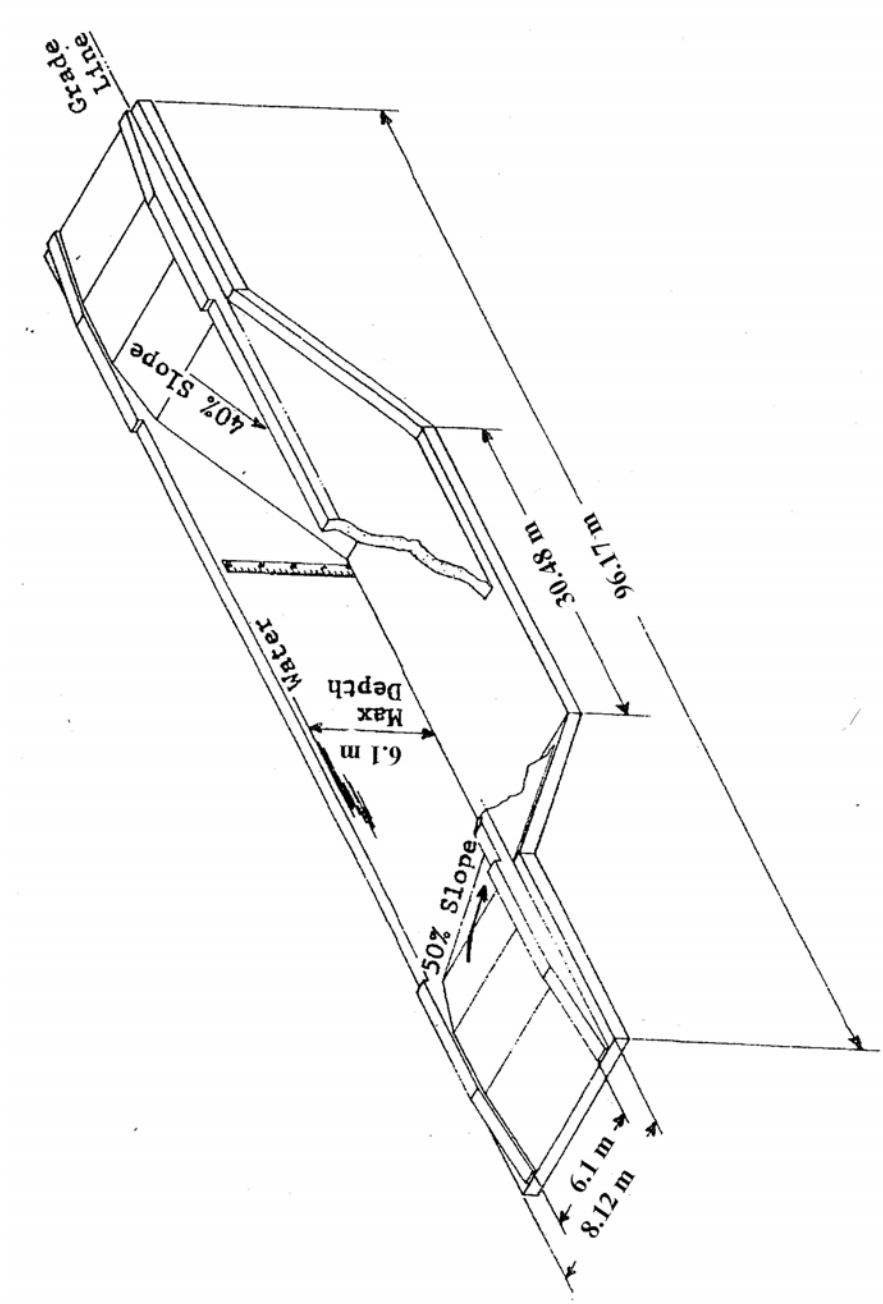


FIGURE B-2. Underwater fording facility

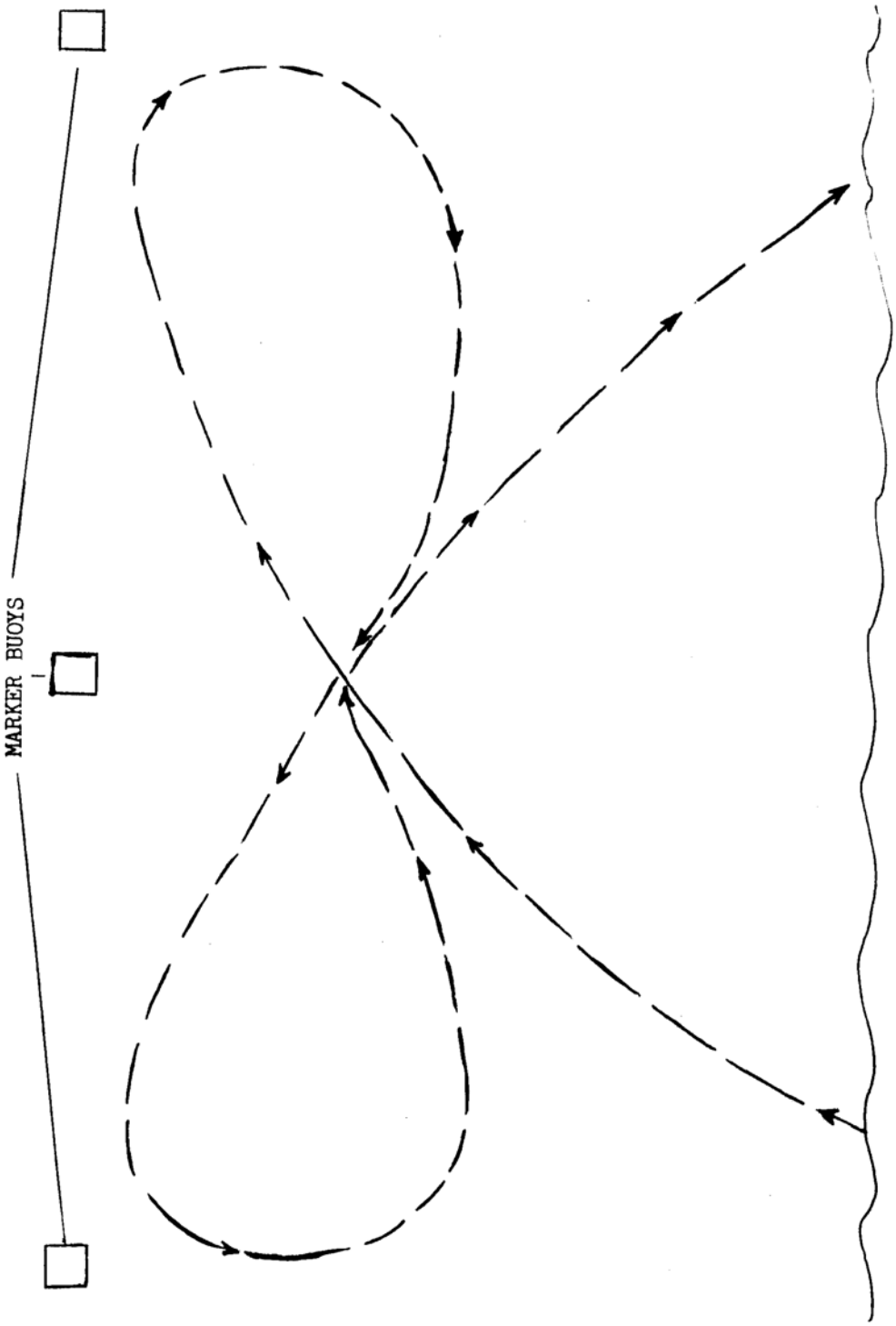


FIGURE B-3. Course layout of Figure 8 off-shore fording

APPENDIX C. OPERATIONAL CHECKLIST

Item No.	Item	Comment
1	Selection of Test-Shallow, deep or underwater. Prior to deep or under water fording, shallow water fording must be conducted.	
2	Mark externally and internally the water level line.	
3	Take oil, fuel and lubricant samples.	
4	Ensure the onboard fire extinguisher system is active.	
5	Ensure recovery cables are attached to the test vehicle front and rear.	
6	Have a recovery vehicle and crew available on stand-by or on site.	
7	Check vehicle floor for obvious water leakage areas and instruct the driver to monitor as required.	
8	Ensure air inlet and exhaust extensions are installed if required.	
9	Follow appropriate installation SOP and use the SOP's safety checklist. If a checklist is not available prepare a safety checklist.	
10	Establish emergency exit procedures IAW Appendix A	
11	Ensure all personnel are equipped with appropriate PPE.	
12	Ensure correct water depth.	
13	Conduct a pre-test safety briefing.	
14	Enter water, stop and start engine, record the actual time in the water, check for leakage.	
15	Exit water and operate vehicle.	
16	Enter water and determine maximum fording speed.	
17	Exit water and operate vehicle.	
18	Inspect the vehicle and take oil, fuel and lubricant samples.	
19	Record data IAW Section 5.	

APPENDIX D. REFERENCES

1. TOP 2-2-501, Swimming Tests of Wheeled and Tracked Vehicles, 18 November 1980.

2. TOP 2-2-500, Vehicle Characteristics, 3 December 1981.

3. TOP 2-2-505, Inspection and Preliminary Operation of Vehicles, 4 February 1987.

4. TOP 2-2-614, Toxic Hazards Test for Vehicles and Other Equipment, 28 February 1995.

Forward comments, recommended changes, or any pertinent data which may be of use in improving this publication to the following address: Test Business Management Division (TEDT-TMB), U.S. Army Developmental Test Command, 314 Longs Corner Road, Aberdeen Proving Ground, MD 21005-5055. Technical information may be obtained from the preparing activity: Combat and Automotive Systems Division (TEDT-YP-YT), U.S. Army Yuma Proving Ground, 301 C. Street, Yuma, AZ 85365-9498. Additional copies are available from the Defense Technical Information Center, 8725 John J. Kingman Rd., Suite 0944, Fort Belvoir, VA 22060-6218. This document is identified by the accession number (AD No.) printed on the first page.