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FIELD MANUAL FOR PLUNGING WATER JET USE IN OIL SPILL CLEANUP

by

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FORWARD

The U.S. Environmental Protection Agency was created because of increasing public and government concern about the dangers of pollution to the health and welfare of the American people. Noxious air, foul water, and spoiled land are tragic testamonies to the deterioration of our natural environment. The complexity of that environment and the interplay of its components requires a concentrated and integrated attack on the problem.

Research and development is that necessary first step in problem solution; it involves defining the problem, measuring its impact, and searching for solutions. The Municipal Environmental Research Laboratory develops new and improved technology and systems to prevent, treat, and manage wastewater and solid and hazardous waste pollutant discharges from municipal and community sources, to preserve and treat public drinking water supplies, and to minimize the adverse economic, social, health, and aesthetic effects of pollution. This publication is one of the products of that research and provides a most vital communications link between the researcher and the user community.

This report is a field manual intended for use by On-Scene Coordinators (OSC's) and personnel responding to spills of oil and other floating pollutants in currents too swift for conventional cleanup equipment. This manual shows in detail how plunging water jets may be used to move the floating pollutant laterally across the current into one of the naturally occurring, low velocity areas (such as the inside of stream bends) where conventional equipment can function effectively. Principles of operation and instructions for rapid fabrication from locally available materials are provided.

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Municipal Environmental Research
Laboratory

ABSTRACT

The use of plunging water jets can often make possible the control (and, as a consequence, the cleanup) of spilled oil and other floating pollutants in currents too swift for conventional equipment. This short, illustrated manual provides practical information for field and planning personnel on the principles of plunging water jet operation, rapid fabrication of the equipment (from readily available materials), and use in the field.

The plunging water jet system is based on a concept first envisaged by Mason and Hanger-Silas Mason Co., Inc.'s Michael Johnson (patent pending) and developed under EPA sponsorship at the OHMSETT research facility. Water jets aimed vertically downwards from above the water surface carry entrained air into the water column. The expansion of this air returning to the surface generates a horizontal surface current which carries the floating pollutant laterally relative to the direction of stream flow. This lateral motion can be used in a diversionary manner to carry the floating pollutant into naturally occurring regions of the low flow, where conventional equipment works efficiently. This system is relatively unaffected by waves and works well in currents up to at least 6 knots.

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FIGURES

FIGURES (continued)

INTRODUCTION

This manual is intended for the use of both managers and field personnel concerned with the cleanup of spilled pollutants floating on fast moving streams and estuaries. It will provide them with the detailed, practical knowledge they need to use plunging water jets so that floating pollutants can be moved from faster currents into slower areas in which conventional spill cleanup equipment works effectively.

The concept on which this manual is based was first envisaged by Michael G. Johnson in 1978 ("Plunging Water Jets for Oil Spill Containment and Recovery", patent pending) and developed primarily with EPA sponsorship in contracts with Mason and Hanger-Silas Mason Co., Inc., the OHMSETT research facility operating contractor.

THE PLUNGING WATER JET

A plunging water jet is a stream of water (and entrained air) from a simple, straight, 18-mm-diameter (3/4 in.) nozzle aimed vertically downwards near the edge of a floating pollutant from a height of about 3/4 of a meter (30 in.) (see Figures 1a & 1b).

The purpose of a plunging water jet is to generate a horizontal, surface water current that will carry floating pollutants (such as oil) laterally across fast-moving or still water to locations more desirable for cleanup activities (Figure 2).

The entrained air in the plunging water jet's relatively small vertical flow of water acts as a fluid amplifier, causing a large horizontal flow of water across the polluted surface.

The relatively narrow, coherent, vertical flow of water propelled downward through the nozzle under pressure strikes the natural water surface and sets up a rimmed crater with a bow-wave effect (Figure 1). This bow wave helps keep any natural current from carrying floating pollutant into the jet impact area and, thus, reduces entrainment by the jet.

The water stream from the jet directed downward at the surface of the polluted water body carries air with it down below the surface. After the downward motion slows and stops, these air bubbles float back up in a "cylinder" centered on the downward-flowing jet, expand, and induce an upward flow of water 10 to 20 times greater than the downward flow through the jet nozzle (Figures 3a & 3b). This upward, induced water flow appears at the surface first as a "boil" and then as an outward-flowing (from the boil) horizontal surface current. The smaller air bubbles, rising more slowly than the larger ones, continue coming up over the next 15 or so seconds and maintain the outward horizontal surface flow.

THE CLEARED AREA

Where there is no natural surface current, the surface horizontal currents resulting from the plunging water jet radiate out from it equally in every direction. If the water surface is initially covered with a floating pollutant, starting up the jet clears a circular area centered at the point where the jet strikes the water surface (Figure 4). The diameter of the cleared area depends on the amount of air entrained by the water jet; the bigger the nozzle diameter and the greater the water pressure in the nozzle, the stronger the induced horizontal surface currents and the larger the cleared area.

Where there is a natural surface current initially carrying a floating pollutant downstream, a plunging water jet clears a surface area shaped like a parabola (Figure 5). The boil is near the head (focal point) at the upstream end of the parabola, and the major axis extends downstream parallel to the direction of the current.

Water jets can serve as diversionary booms; tests have shown them to be effective in nonbreaking waves and in streams flowing at speeds up to 6 knots. Moderate amounts of floating oil can be moved almost any useful distance by a succession of offset water jet "parabolas" arranged en echelon (Figure 6).

Water jets can be particularly useful in current conditions too fast for conventional equipment. For example, floating pollutants in a fast stream can be guided into naturally occurring portions of the stream (such as the inside of bends) where the current is slow eonough for conventional cleanup equipment to be used successfully (Figures 2 & 7). Another example would be the use of water jets to divert a floating pollutant past threatened water intakes or to keep it from drifting under docks.

Water jets can also be used in low current conditions to maintain a clear area through which divers or equipment can enter and leave polluted waters.

For both cases, vessel traffic and large debris can pass through the area easily.

FABRICATION

a) One straight 0.2-m (7-in.) length of 36-mm (1.5 in) inside diameter threaded pipe; a threaded, right angle elbow (same diameter); a threaded reducer to go from 36 mm to 18 mm (3/4 in.) inside diameter; and a straight 0.4-m (15 in.) length of 18-mm inside diameter pipe, threaded on one end (Figure 8). Provision may be made on the 36-mm pipe section for a pressure gage, if desired.

b) A (centrifugal) pump capable of at least 18.1 m^3/h (80 gallons per minute) at 138 kPa (20 lb/sq. in.) and a suitable power source. Fire pumps are particularly useful when a single pump is required to supply more than one nozzle.

c) The necessary hose and connectors to carry water from the source (through a suitable strainer) to the pump, and from the pump to the nozzle. The latter hose system should be at least 36 mm (1.5 in.) in diameter.

d) A water supply for the pump (usually the same body of water the pollutant is floating on).

e) A suitable support for each system, e.g., a boat or float of some sort supporting the entire system (Figure 9); or the pump on a river bank with the jet nozzle suspended on lines above the stream (Figure 10), or supported by a boat or float in the stream, or fastened to a tripod (Figure 11) or a piling on or in the stream bottom.

PLACEMENT

Water jets are primarily useful in moving a floating pollutant at right angles to (across) existing stream currents (and NOT in opposing them directly). Tests have shown that the average speed of the water leaving the boil during its first second of escape is 0.75 m/s (150 ft/min). This momentum is very short lived. Three to four seconds from the boil, the average speed is down to 0.06 m/s (12 ft/min), and by 10 seconds, the speed is practically zero. Therefore, even moderate stream currents will overwhelm the effect of a water jet trying to oppose them directly. Water jets are excellent for diverting and herding, but they should not be used to contain a floating pollutant in the presence of a current.

The radius of influence R is the maximum distance, in meters, a water jet can push a floating pollutant laterally. Its magnitude can be predicted from the knowledge of four quantities, i.e., relative stream speed (U) and the nozzle pressure (P), diameter (d), and height (h) of the nozzle from the surface (Figure 12). Tests at EPA's OHMSETT research facility suggest that a practical value for nozzle height h (above the still water surface) is about 0.75 m (30 in.) and, for the inside nozzle diameter d, about 18 mm (3/4 in.). The two remaining variables have been graphed in Figures 13 and 14 to summarize their effect on the radius of influence R. These two variables are the nozzle pressure P and the horizontal speed U of the jet's nozzle (boil) relative to the water body.

Where the horizontal distance the pollutant must be moved is so great that more than one jet will be required, the following procedure may be used to estimate the number needed.

1. Determine the total horizontal distance the pollutant is to be moved by the jets, D.

2. Measure the average stream velocity U (e.g., by timing a floating stick over a distance measured off on the stream bank).

3. From Figure 14, find the radius of influence R for the appropriate stream velocity U and the available nozzle pressure P.

4. Divide the distance the pollutant must be moved horizontally D by the effective radius of influence in this situation R to obtain the number of jets needed N (round up to the nearest whole number).

$$\frac{D}{R} = \text{(number of water jets required)}$$

5. To obtain the recommended spacing of the jets (Figure 15) in the downstream direction, multiply U in meters (feet) per second by 12 seconds to get the separation in meters (feet).

$$U \times 12 = \text{separation}$$

For clarity in presenting the concept, the stream flow is shown as being straight in Figure 15. For a curved inland stream, however, the distance separating successive jets must be measured along a curved path (Figure 2). Note that the horizontal (bank to bank) variation in current speed and the stream curvature also affect the radius of influence R.

The foam line at the edge of the parabola of jet influence must be carefully observed, when actually installing water jets in the field. By studying the foam line, placement of the next jet will be obvious (see Figure 7, 15 and, especially, 2). In the fastest current, jets will be spaced farther apart in the downstream direction (but the lateral offset will be less). As slower regions are entered, however, the jets will be closer together in the downstream direction (but the lateral offset will be greater).

The field situation can be used to advantage. For example, a fallen tree may deflect the flow from the bank toward the middle; the tree acts as a water jet impacting the stream near the bank (Figure 7). Using the tree-deflected water flow may make possible the use of one less water jet.

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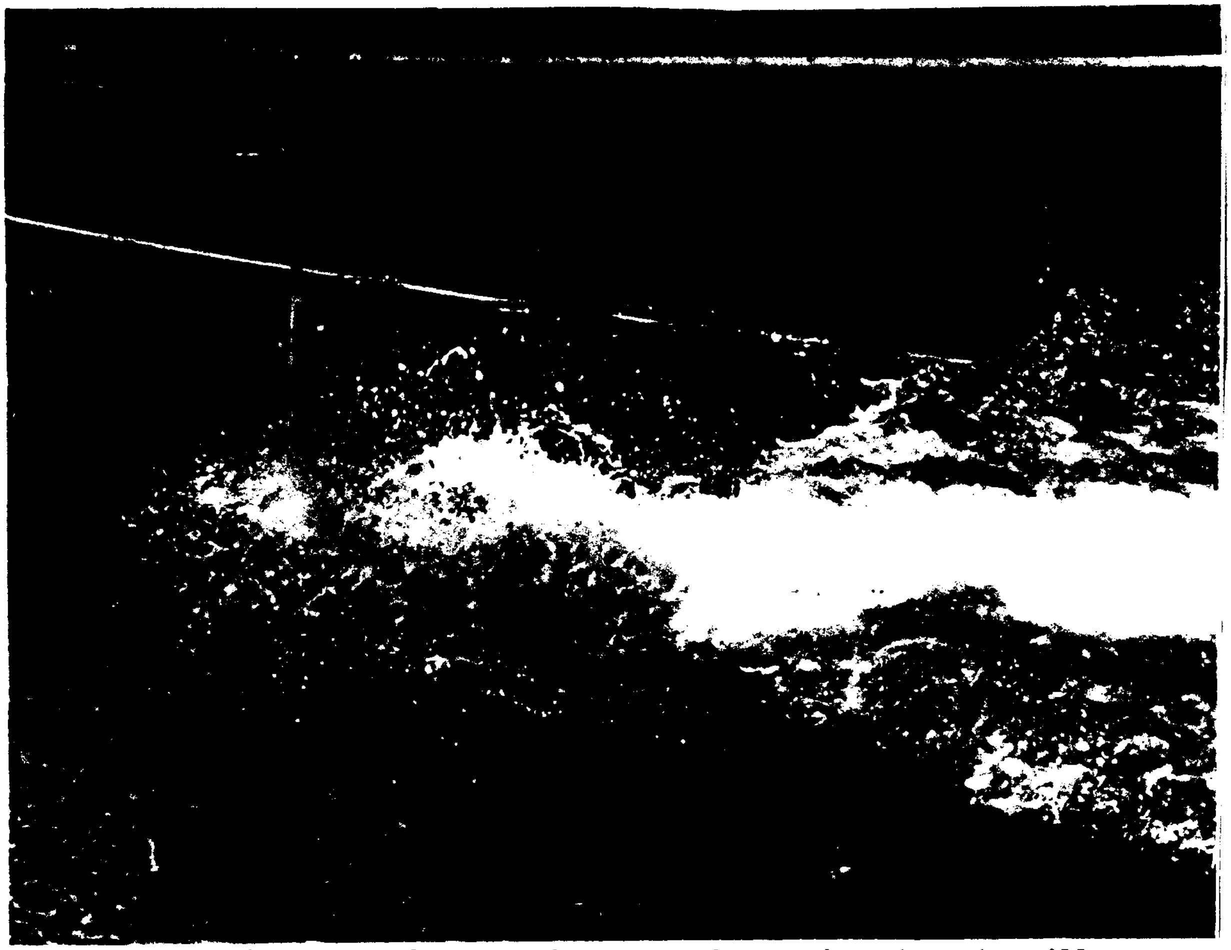


Figure 1a. 3/4 view of a plunging water jet moving through still water.

Figure 1b. Top view of plunging water jet moving through still water showing both the crater area (center) and the "boil" (right).

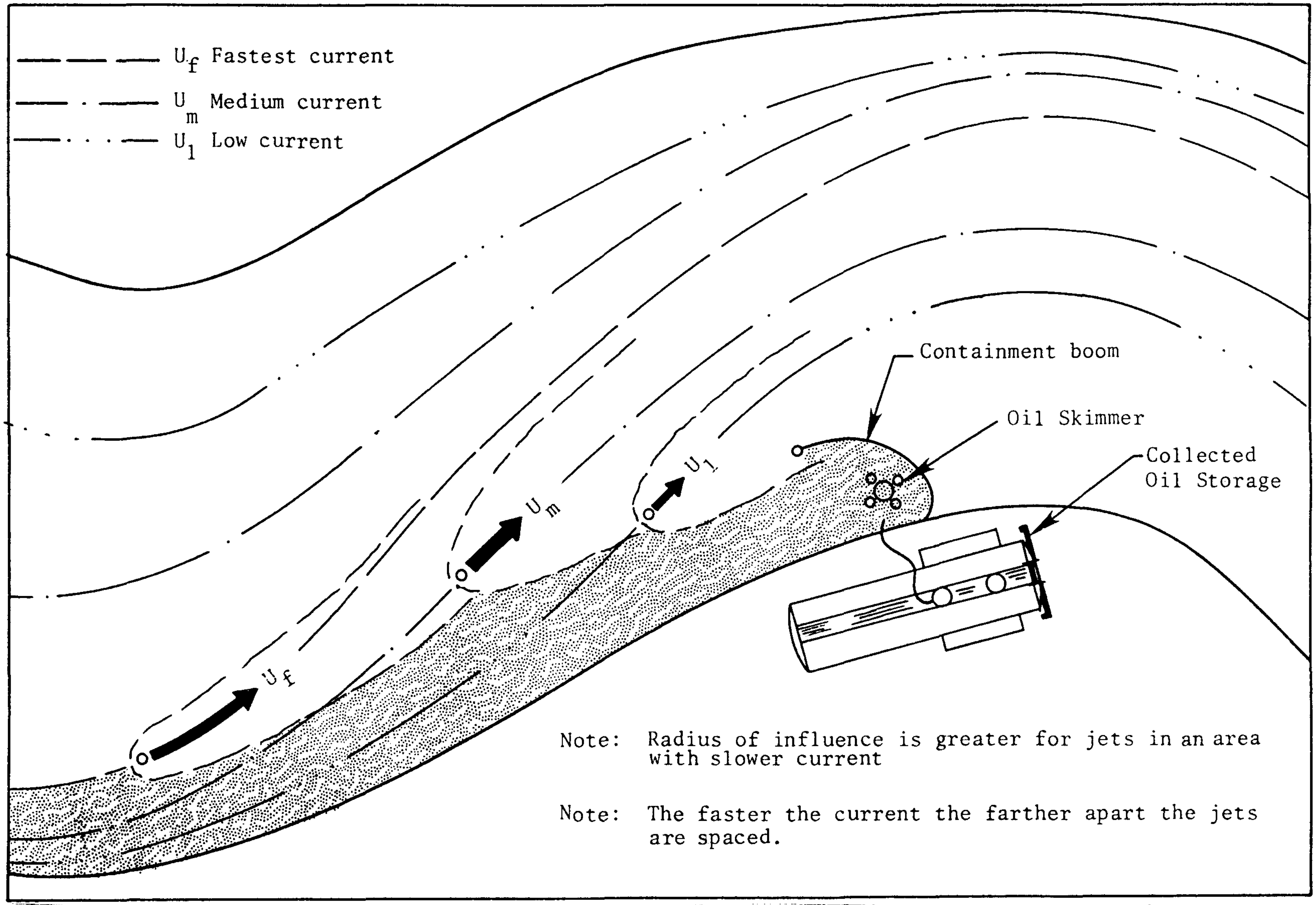


Figure 2. Effective use of a plunging water jet in a curved stream depends on observing the location of the fastest current region.

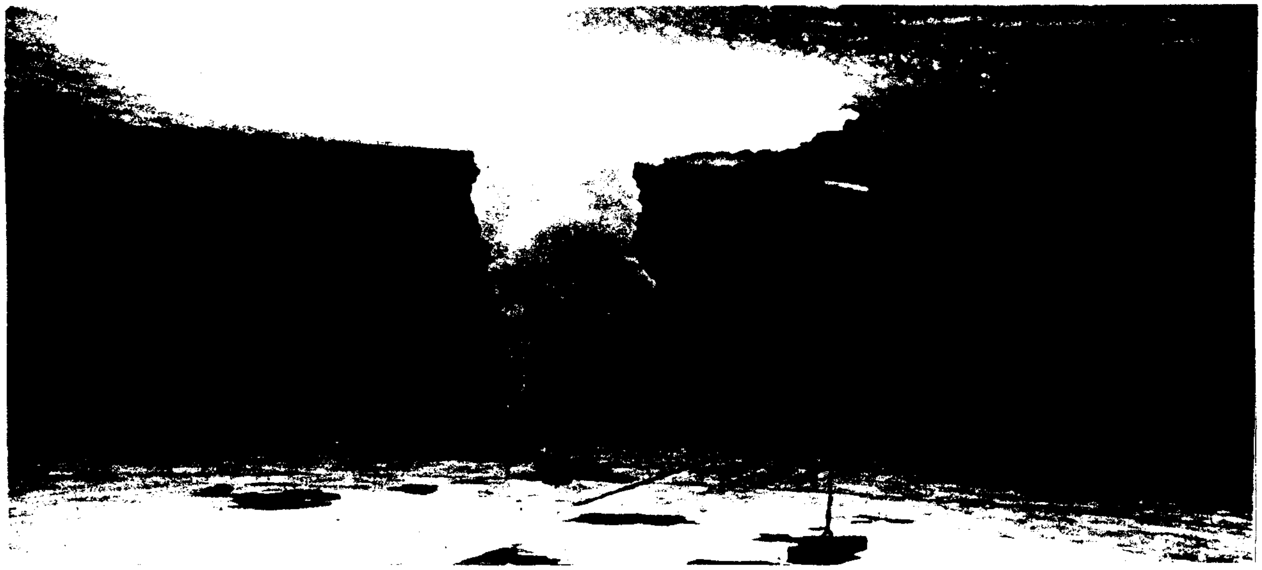


Figure 3a. Horizontal underwater view showing a stationary plunging water jet just after it has been turned on.

Figure 3b. Horizontal underwater view showing the same stationary plunging water jet several seconds later, when the surface current is better developed.

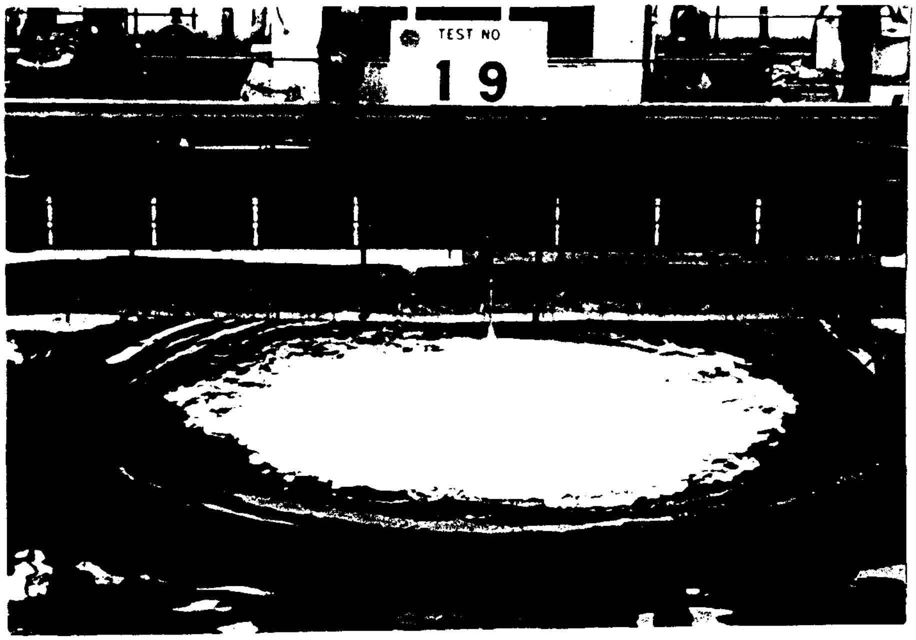


Figure 4. The horizontal surface current generated by a stationary plunging water jet will clear a circular area of floating oil.

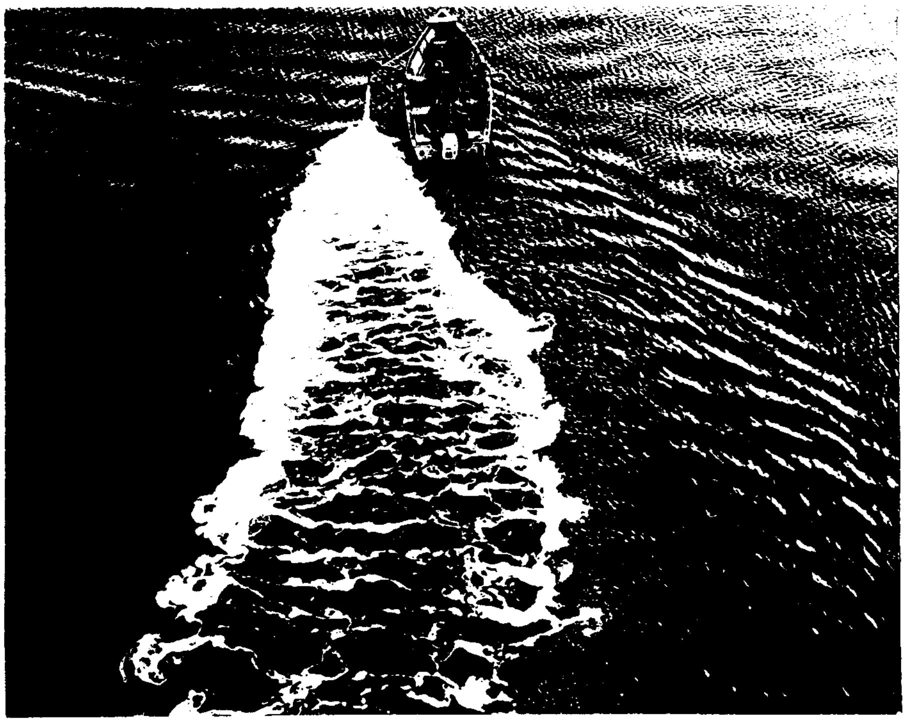


Figure 5. The horizontal surface current generated by an advancing plunging water jet will clear a parabolic area of floating pollutant, as illustrated here by the air bubbles.

Figure 6. Multiple, advancing plunging water jets can move moderate amounts of floating oil horizontally almost any useful distance.

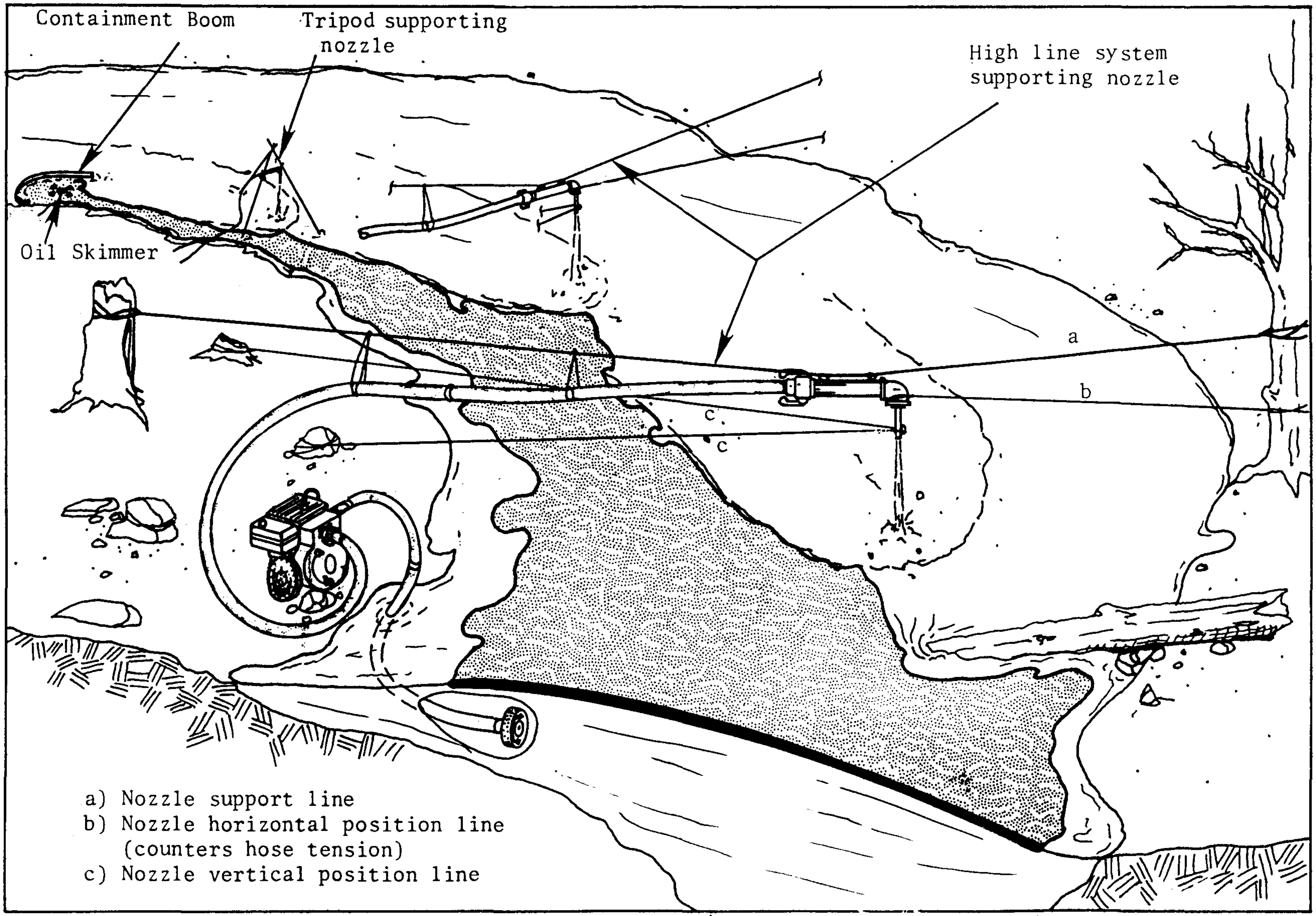
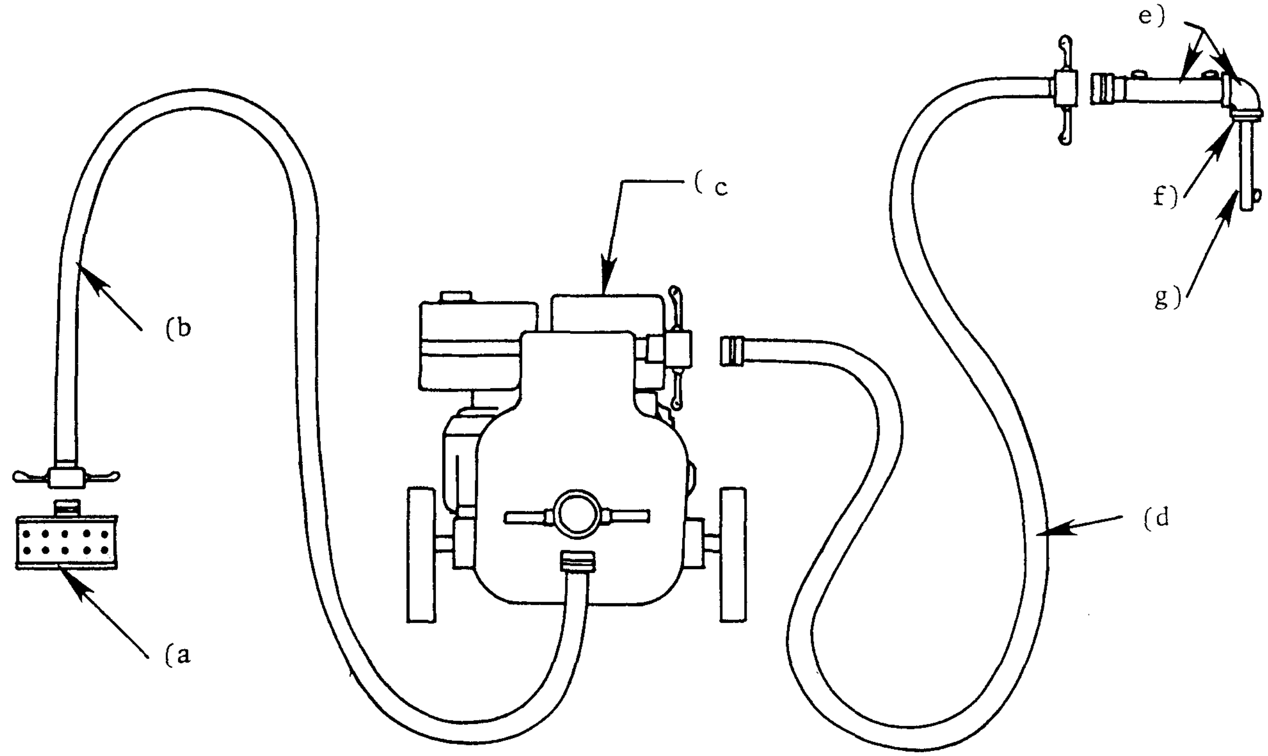


Figure 7. Plunging water jets can be used to divert floating oil to a low-current area on the inside of a stream bend.



a) Intake screen
b) Suction hose
c) Centrifugal pump (80 gal/min @ 20 lbs/sq. inch) and suitable power unit
d) 1.5 inch I.D. hose to nozzle
e) 1.5 inch I.D. pipe (7 inches long) and 90° elbow
f) 1.5 inch to .75 inch I.D. reducer
g) .75 inch I.D. by 15 inches long pipe (nozzle)

Figure 8. The components of a plunging water jet are readily obtainable.

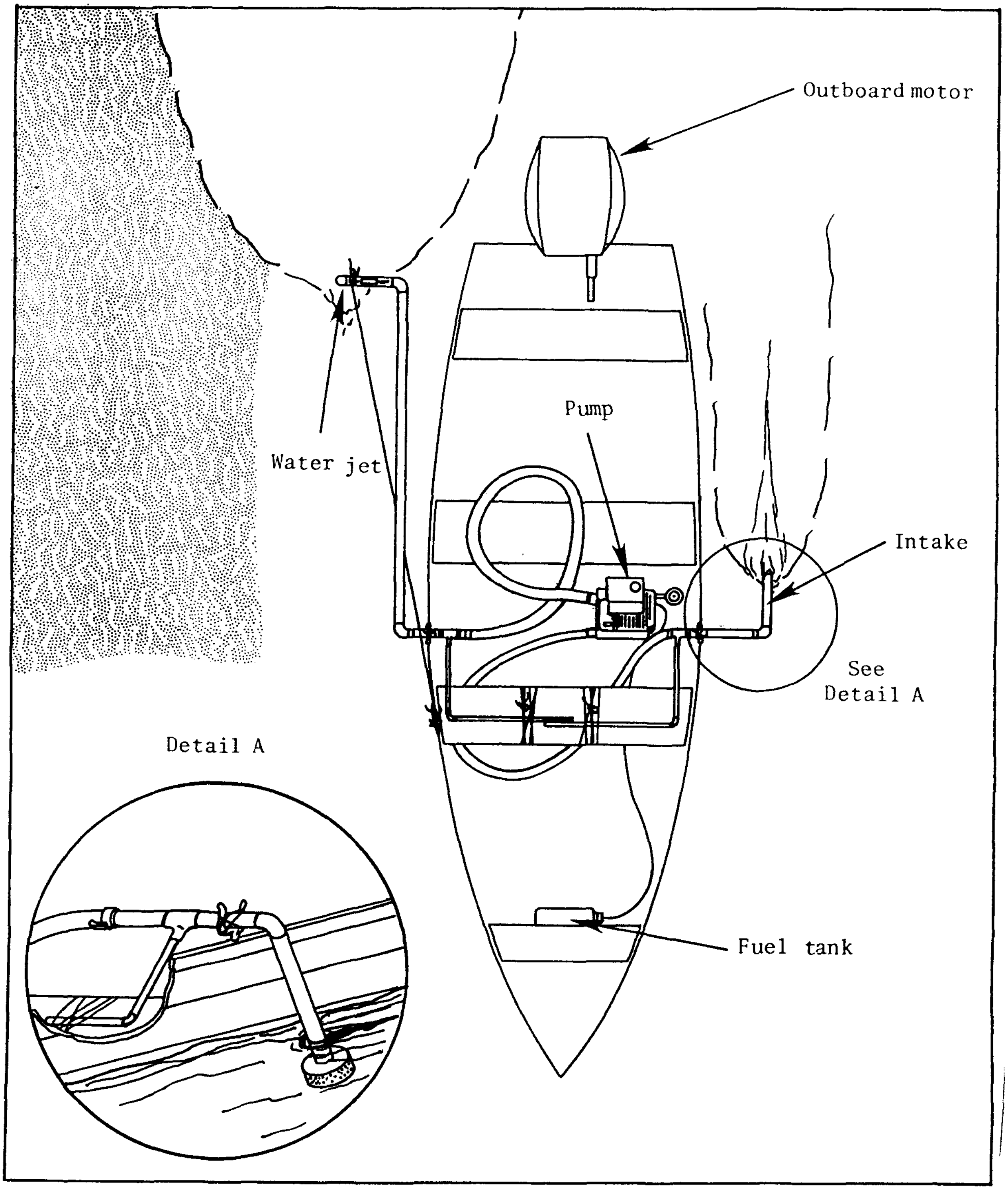


Figure 9. An outboard vessel 4 m long can be used as a mobile support for a plunging water jet system.

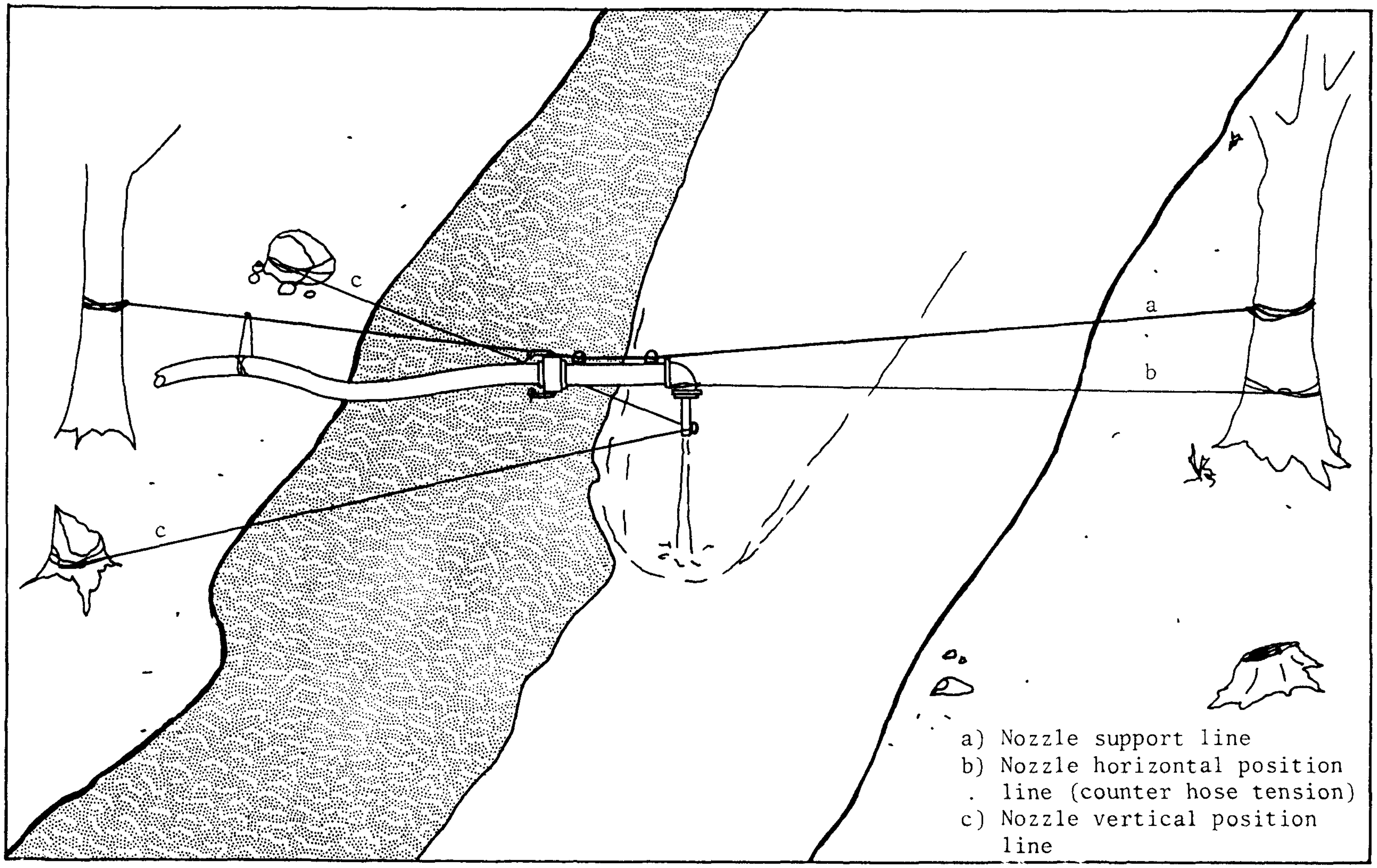


Figure 10. A high line suspension system can support a plunging water jet.

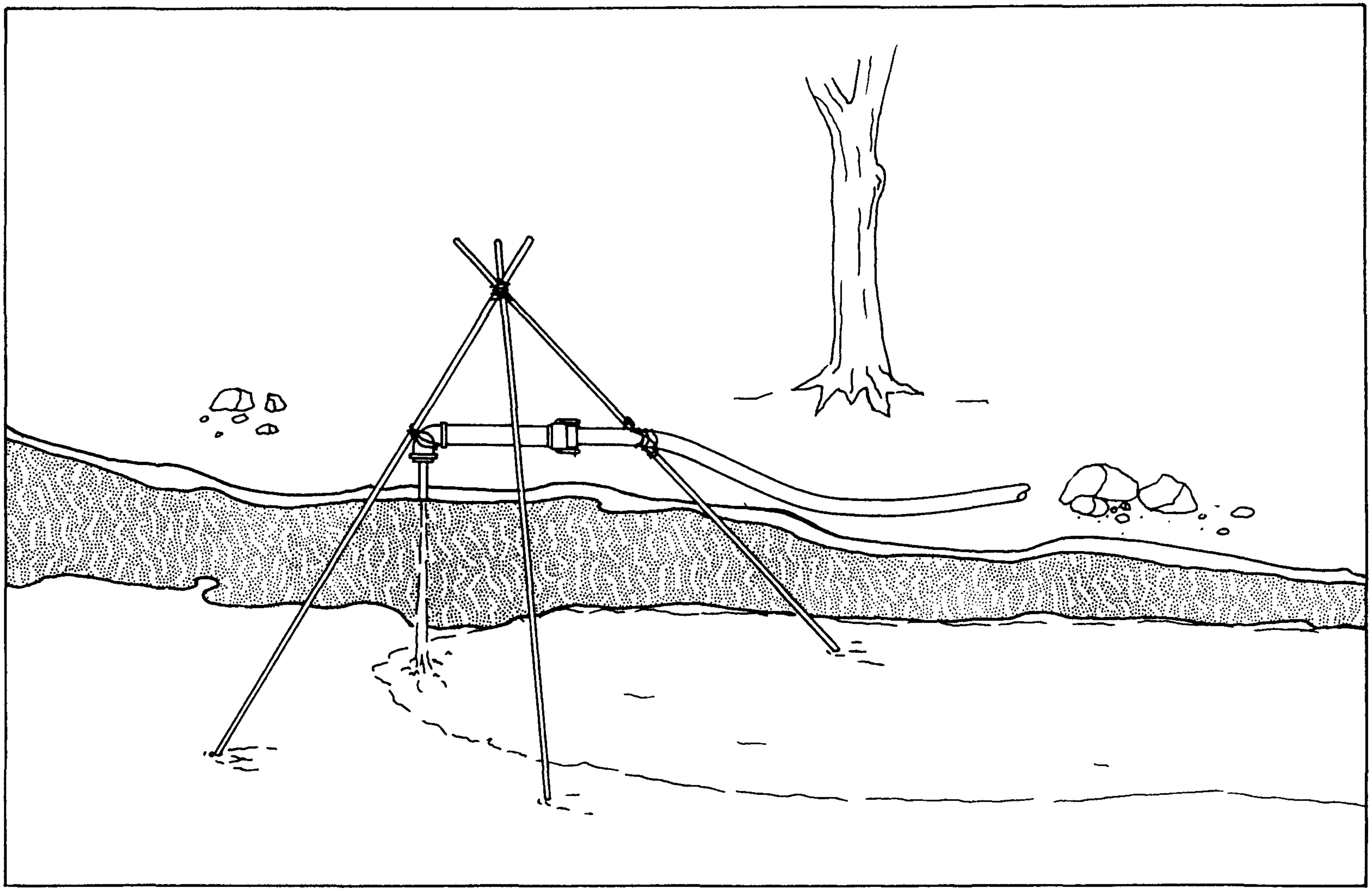


Figure 11. A tripod on the stream bottom can support a plunging water jet.

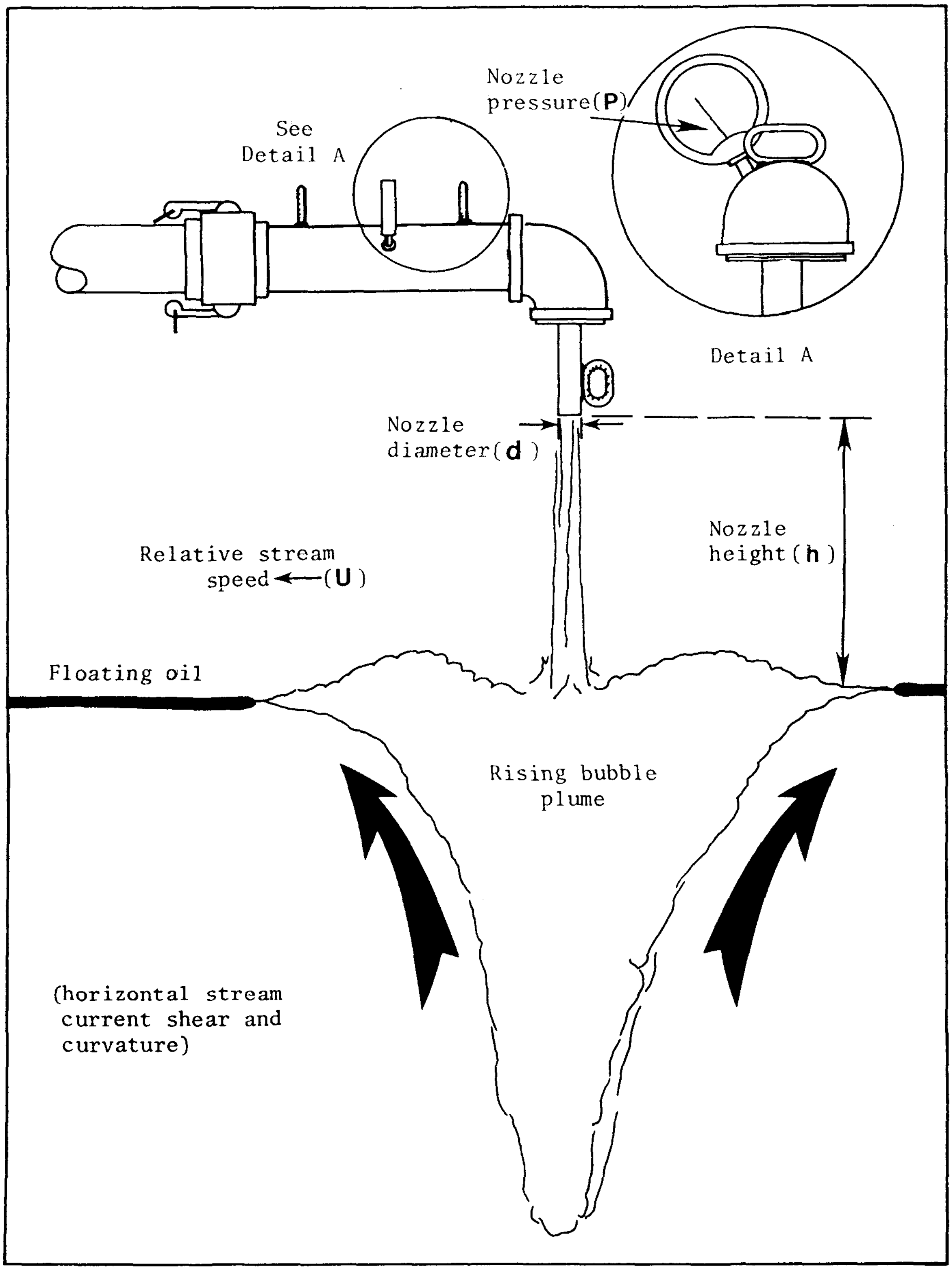


Figure 12. This vertical cross section of a plunging water jet shows the factors affecting the radius of influence.

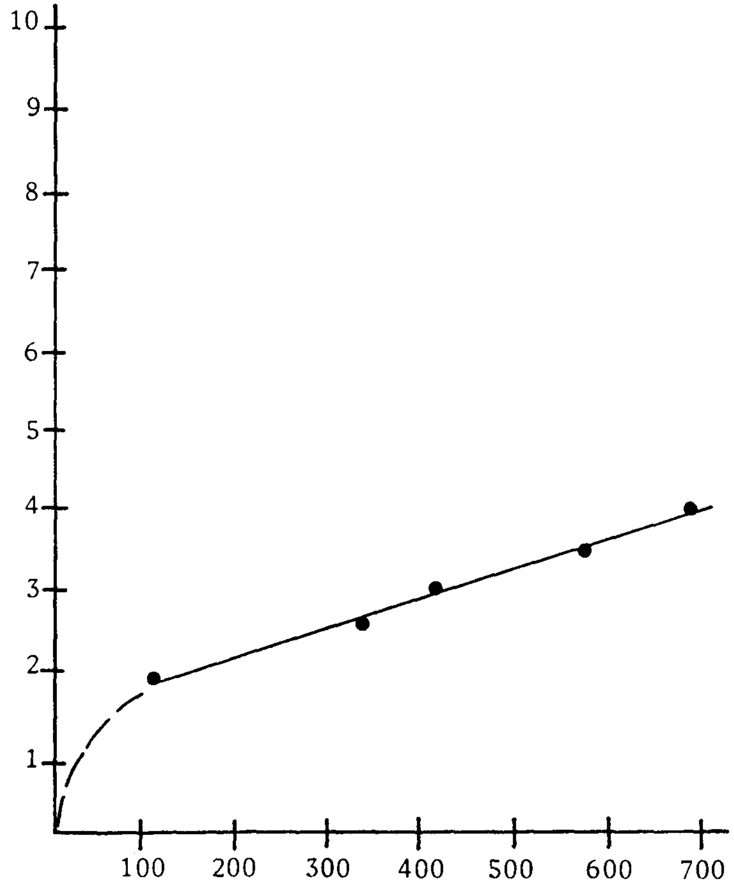


Figure 13. Radius of influence versus nozzle pressure.

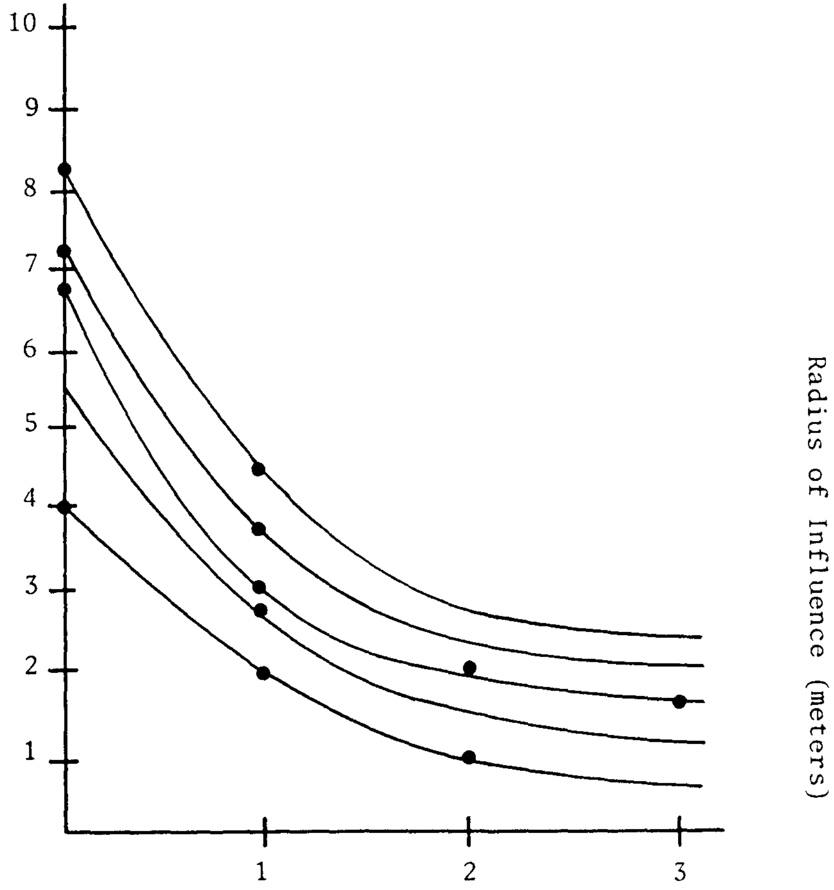


Figure 14. Radius of influence versus stream speed, for increasing nozzle pressures.

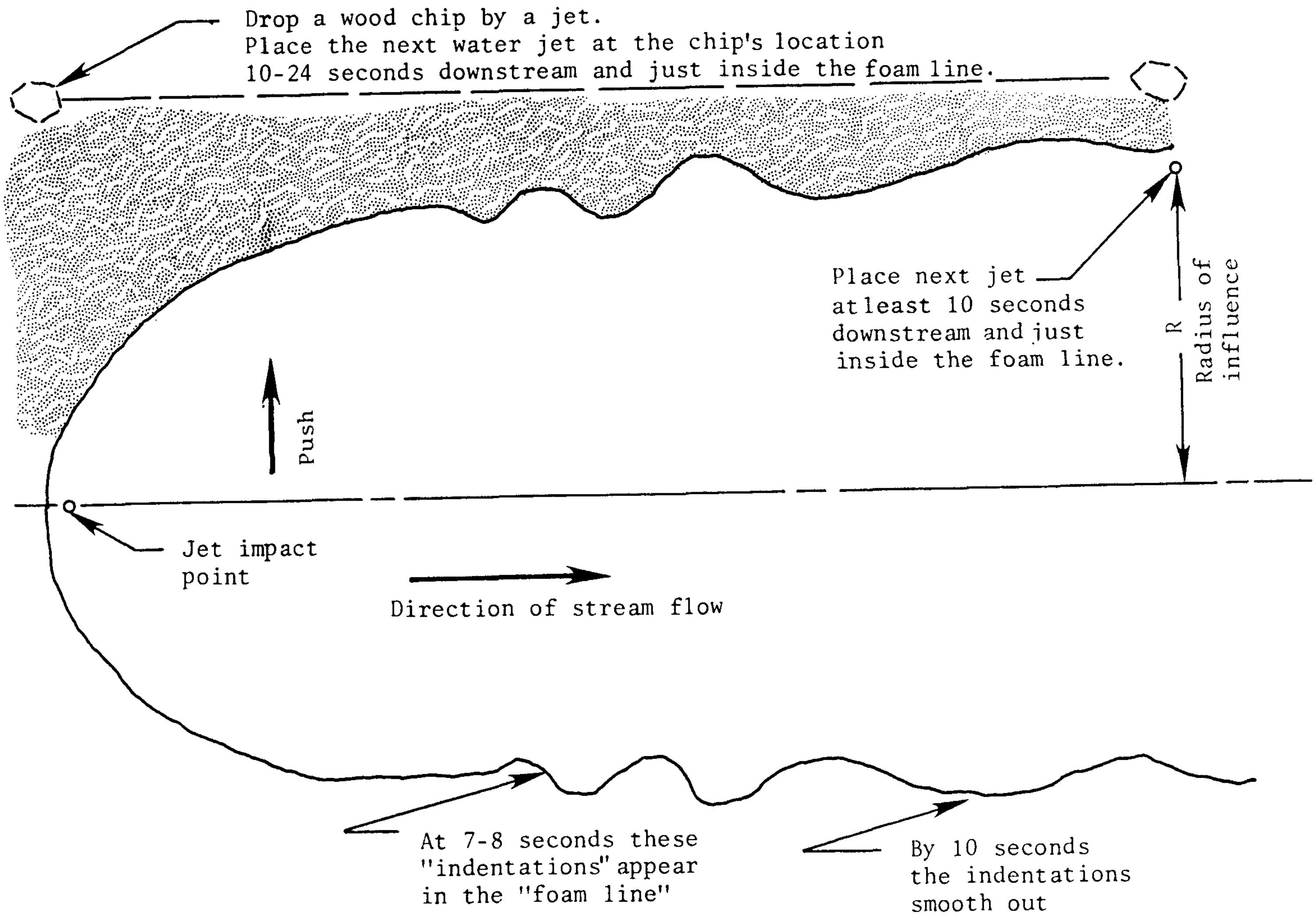


Figure 15. An effective field method for locating the next plunging water jet downstream and some important general features in the jet's region of influence.

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16. ABSTRACT
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