


Hydraulics Section I: Basics

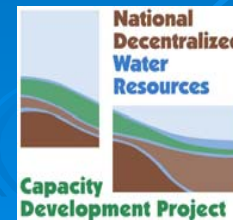
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University Curriculum Development
for Decentralized Wastewater
Management



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Section Objectives:

- Use and convert typical hydraulic measurements of interest in the on-site arena.
 - Make simple computations related to water; Flow rate, velocity and volume.
 - Compute the loss of head as water is pumped to other elevations and along pipes and fittings.
 - Compute the total head required to pump water from a tank to a disposal field for a given flow rate.
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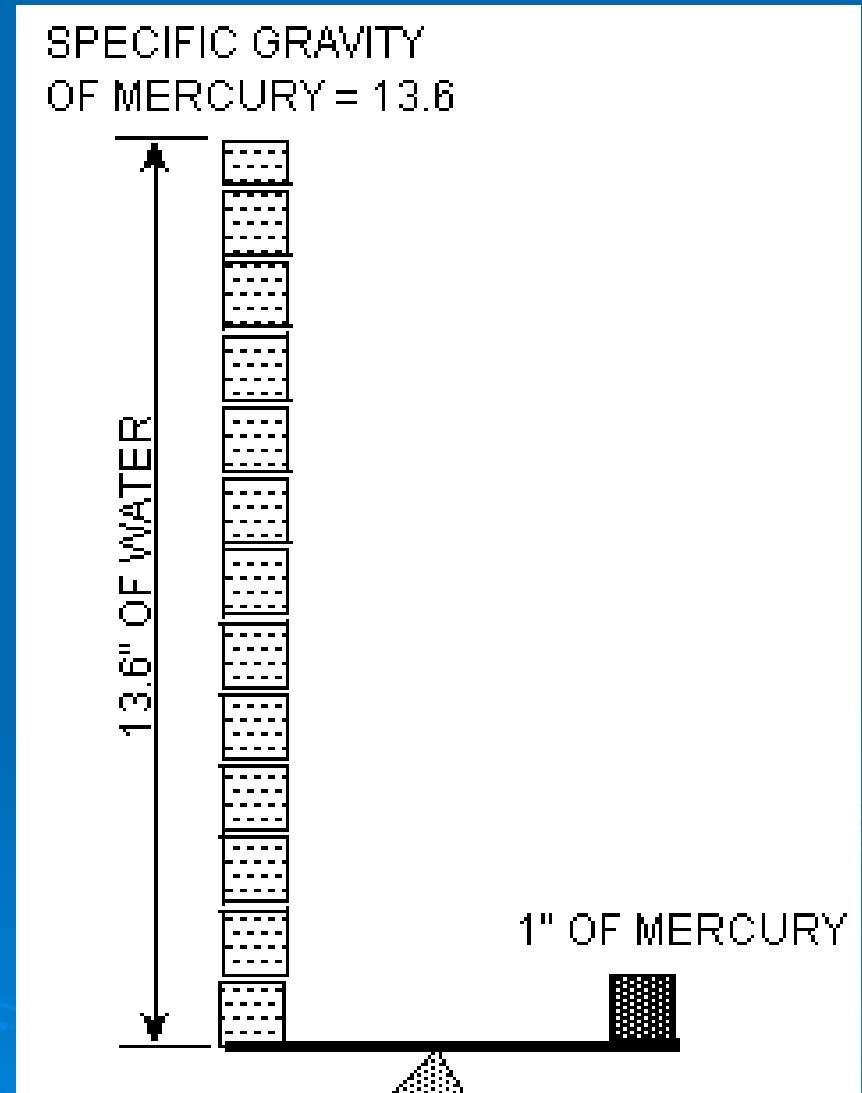
Fundamental Properties of Water

➤ Density:

The ratio of the mass of a given amount of a substance to the volume occupied.

➤ Relative Density (Specific Gravity)

This is the ratio of the density of a substance to that of water.

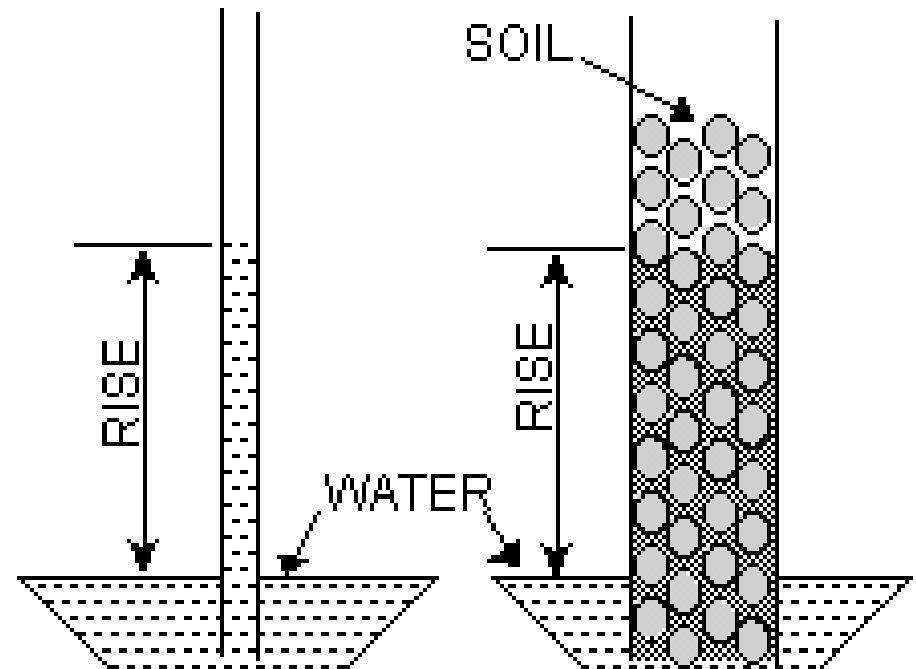


Fundamental Properties of Water

- **Viscosity**
- **Surface Tension**
- **Compressibility**
- **Vapor Pressure**

CAPILLARY RISE
IN A THIN TUBE
PLACED IN WATER

CAPILLARY RISE
IN A SOIL CYLINDER
PLACED IN SOIL



Fluid Statics:

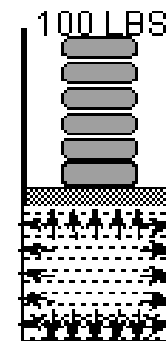
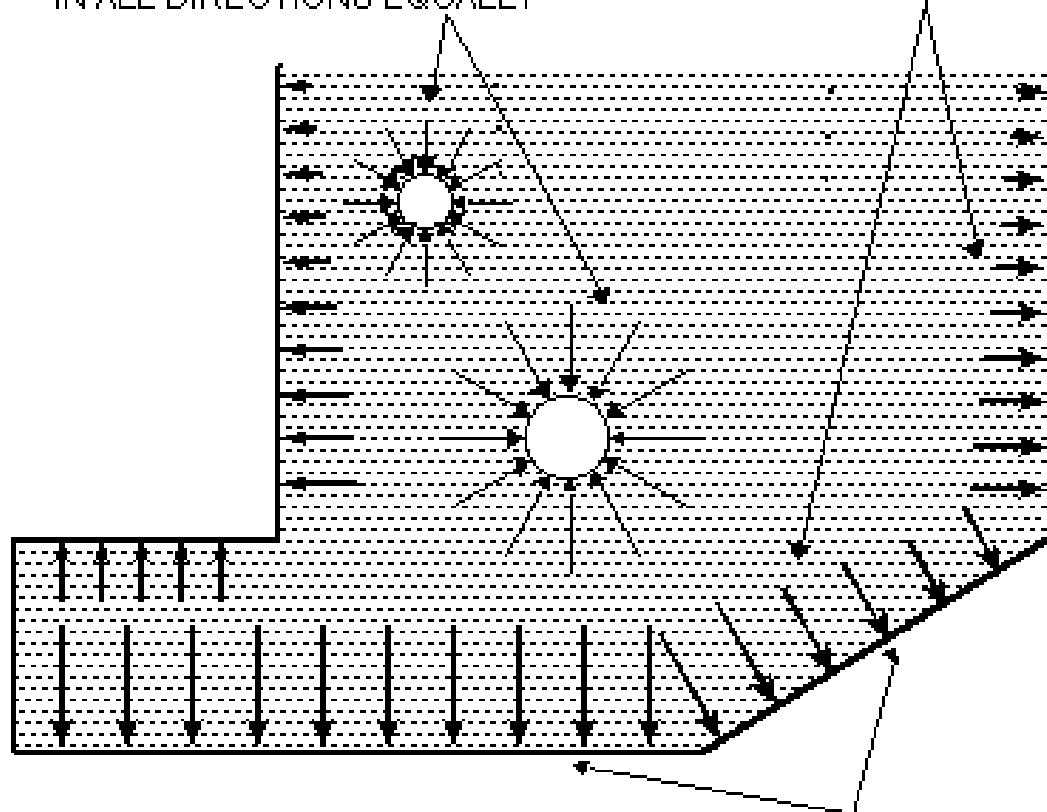
Pressure and its Measurement

PRESSURE CONCEPTS:

PRESSURE ACTS ON A POINT
IN ALL DIRECTIONS EQUALLY

PRESSURE INCREASES
WITH DEPTH

PRESSURE CAUSED
BY EXTERNAL FORCE



PRESSURE ACTS PERPENDICULAR
TO THE SURFACE

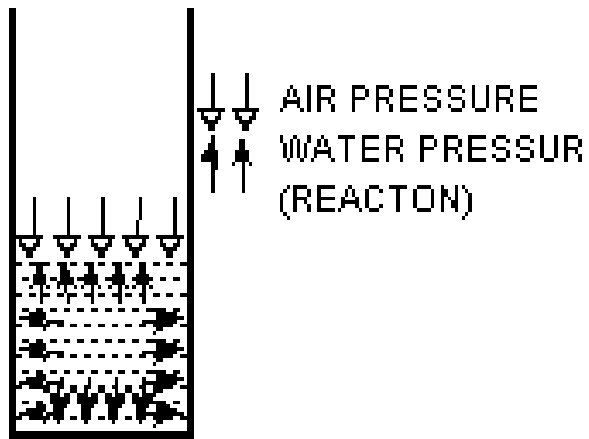
Pressure Definition :

IN A STATIC FLUID PRESSURE IS THE SAME
AT ALL LOCATIONS WITH THE SAME DEPTH

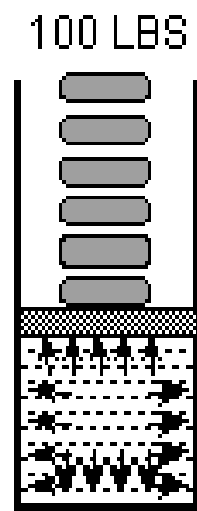
Pressure = force per unit area

Air Pressure and Pressure from External Forces

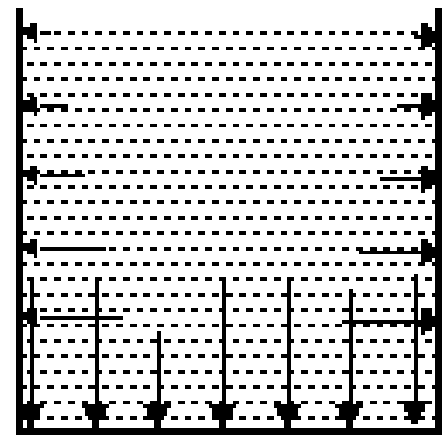
AIR PRESSURE PRESSURIZES THE ENTIRE VOLUME OF WATER WITH THE SAME FORCE IN ALL DIRECTIONS



PRESSURE CAUSED BY EXTERNAL FORCE



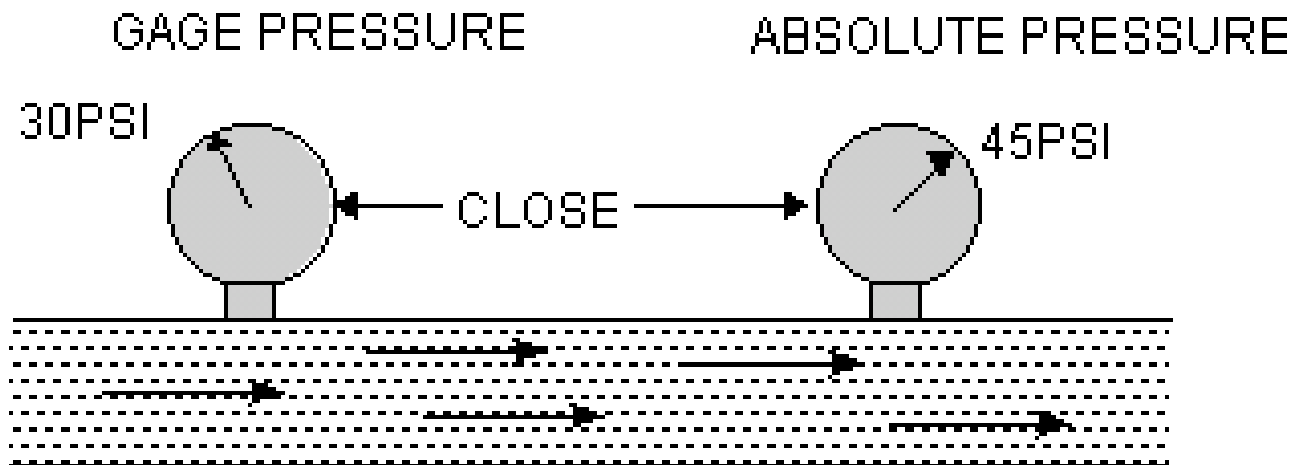
PRESSURE CAUSED BY INTERNAL FORCE OF WATER ITSELF
0 AT TOP
INCREASES WITH DEPTH
CONSTANT AT SPECIFIC DEPTH



Gage Versus Absolute

- **Absolute Pressure:** Total force per unit area.
- **Gauge Pressure:** Difference in pressure from the atmospheric pressure

RELATIONSHIP BETWEEN GAGE PRESSURE AND ABSOLUTE PRESSURE
(EXAMPLE)

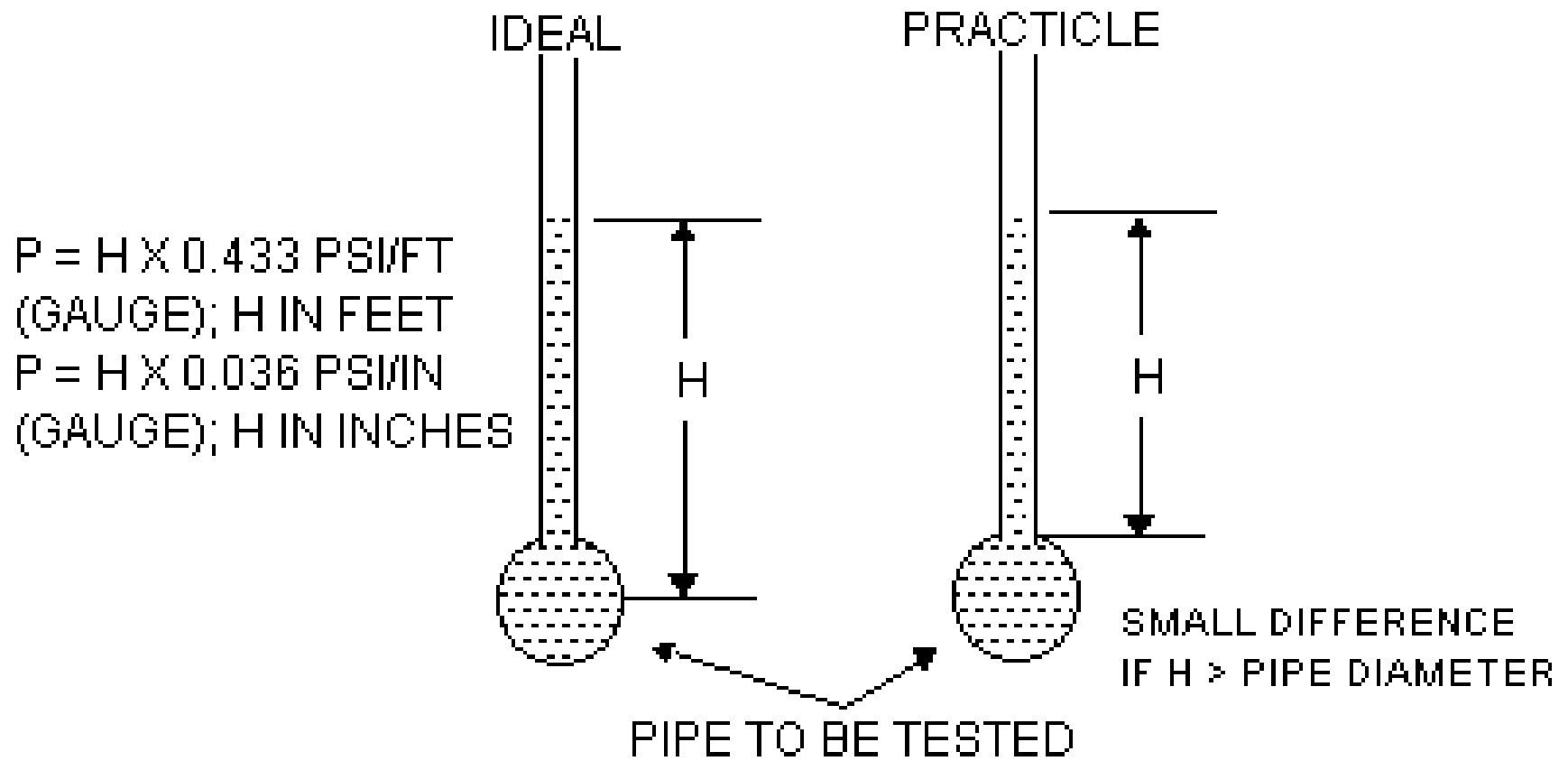


ABSOLUTE PRESSURE INCLUDES AIR PRESSURE (APPROX 15 PSI)
WHICH ACTS MOST EVERYWHERE AND TENDS TO CANCEL OUT

The Manometer

The manometer is a useful device for measuring gauge pressure in the field because all it takes is a clear tube and a measurement

A SIMPLE MANOMETER FOR FIELD MEASUREMENT OF PRESSURE

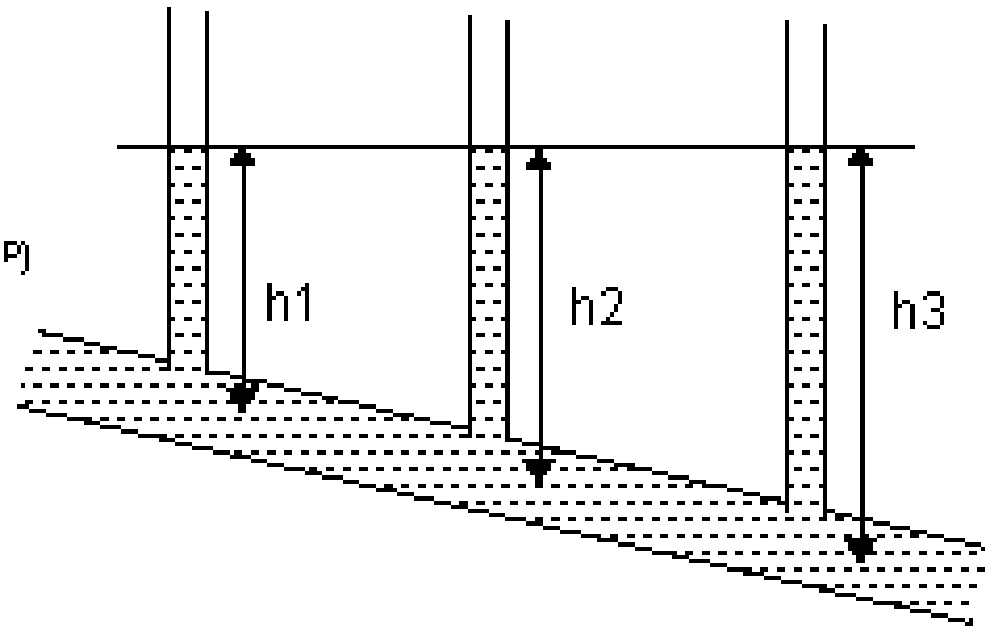


Pressure & Depth

The height of water recorded in the manometer tubes (measured from the pipe) increases with the pipe's pressure although the absolute height that the water raises (measured from a horizontal datum) is the same.

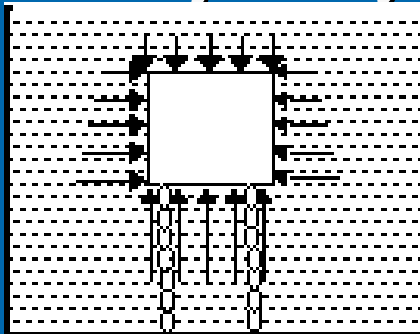
PRESSURE INCREASES WITH DEPTH

$$P = 0.433 \times h$$



Buoyancy

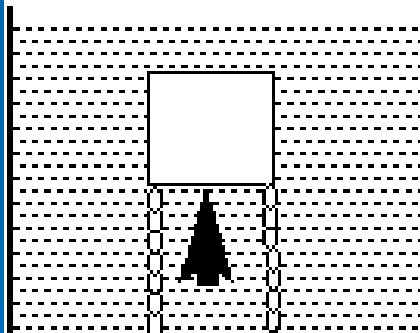
Buoyancy = The net upward force exerted on an object by the surrounding body of water.



PRESSURE ON LEFT = PRESSURE ON RIGHT
ACT IN OPPOSITE DIRECTIONS AND CANCEL

PRESSURE ON BOTTOM > PRESSURE ON TOP
BY EXACTLY THE DEPTH OF WATER WHICH IS NOT THERE

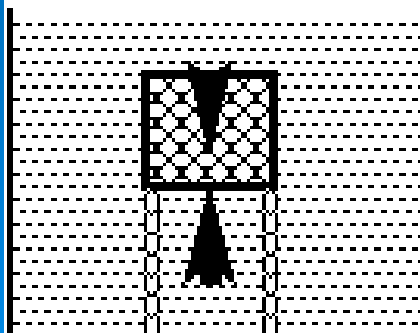
THE DIFFERENCE IN PRESSURE FROM TOP TO BOTTOM
IS EQUAL TO THE WEIGHT OF WATER WHICH IS "DISPLACED"



THE NET UPWARD FORCE ON THE BOX IS EXACTLY
EQUIVALENT TO THE WEIGHT OF THE WATER
WHICH HAS BEEN DISPLACED



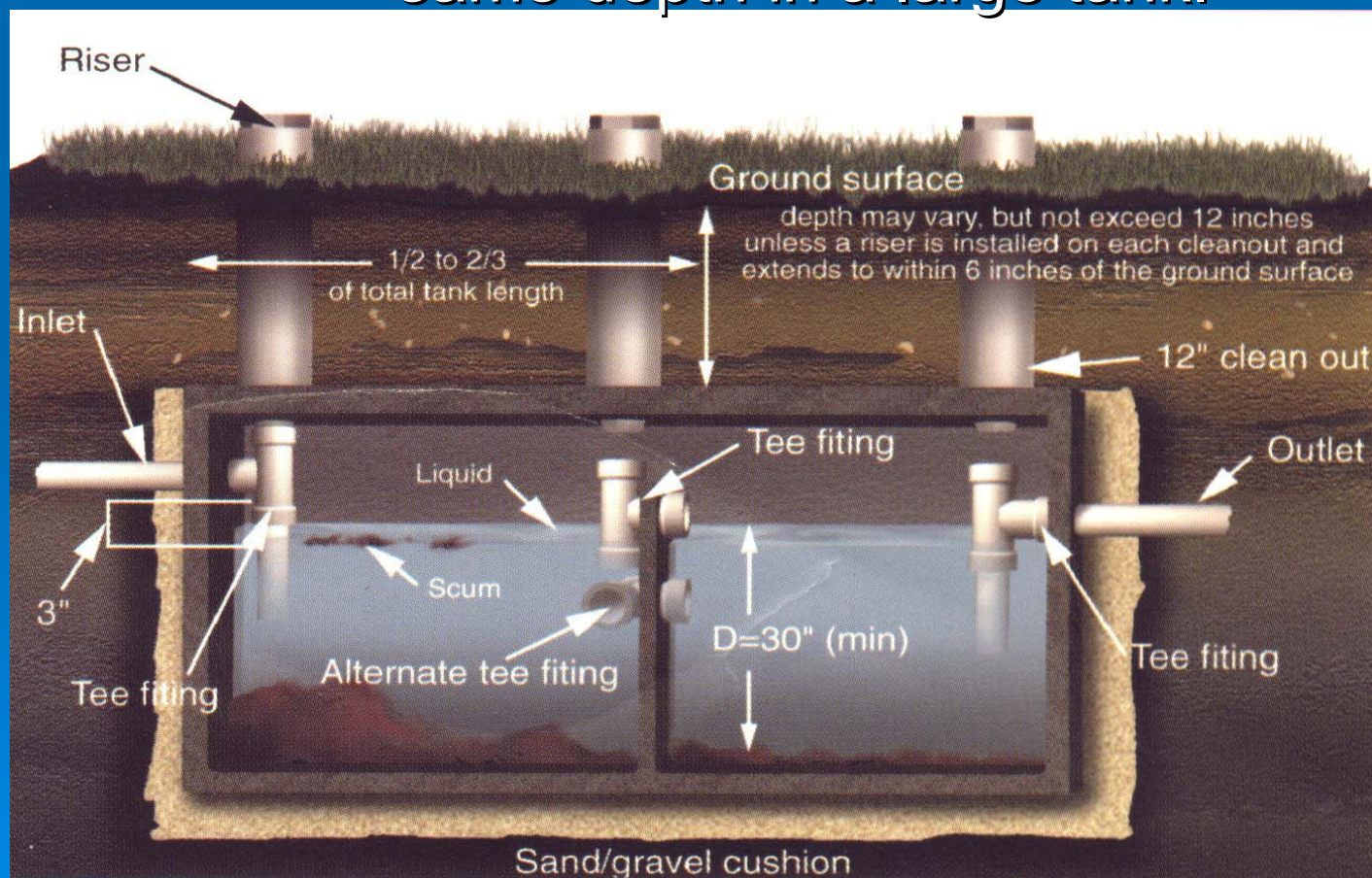
CHAIN TO BOTTOM



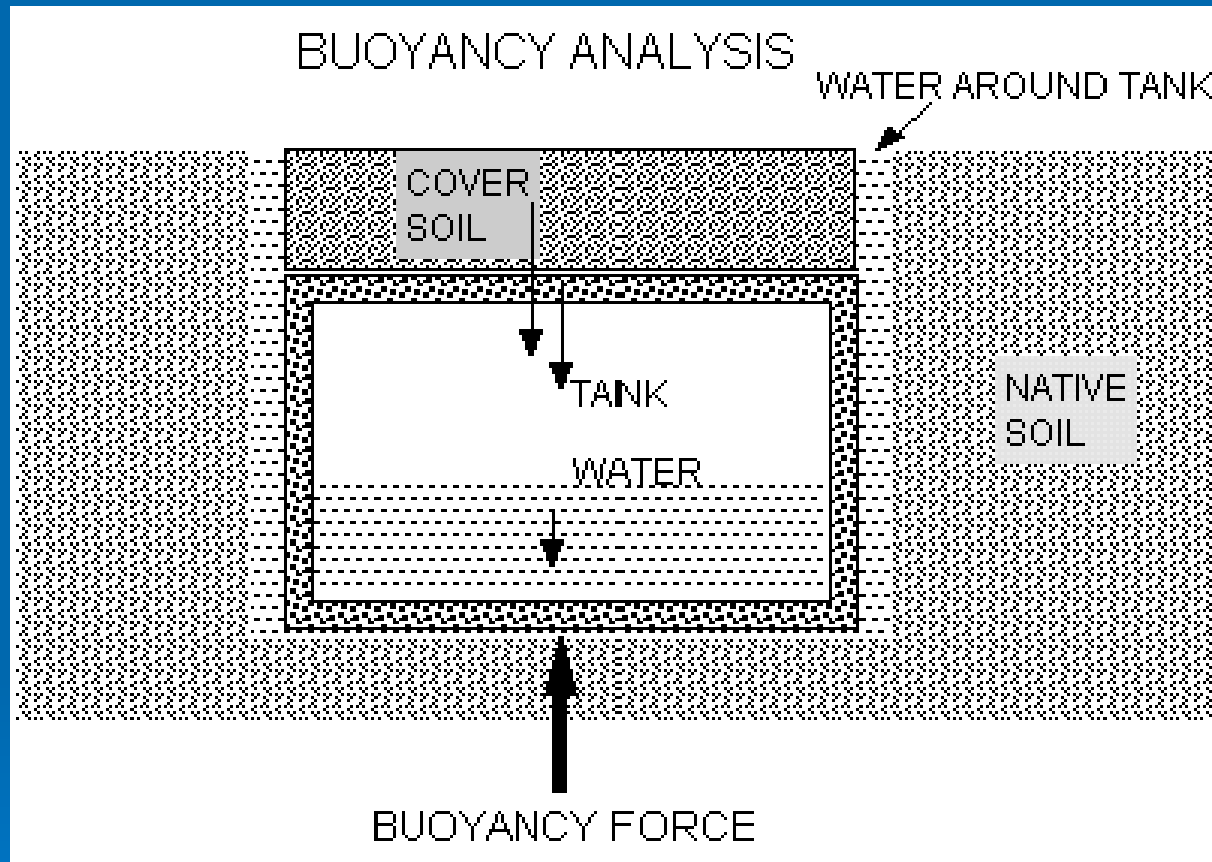
IF THE BOX AND ITS CONTENTS HAVE WEIGHT
THE UPWARD FORCE ON THE BOX IS EXACTLY
THE SAME BUT THE NET UPWARD FORCE IS
EQUIVALENT TO THE WEIGHT OF THE WATER
WHICH HAS BEEN DISPLACED - MINUS THE WEIGHT
OF THE BOX AND ITS CONTENTS.
THIS IS WHAT WE CALL THE BOUYANT FORCE

Consider a septic tank set in an area, which is subject to seasonal high ground water

The water surrounds the tank and even though the tank is not in a large body of water the surrounding water exerts the same pressure it would if the tank were submerged to the same depth in a large tank.



Simplified View



$W_t + W_w + W_s > B$ the tank will not float

$W_t + W_w + W_s < B$ the tank will float.

Continuity

In Checkbook:

$$\text{Deposits} - \text{Withdrawals} = \text{Change in Balance}$$

In hydraulics:

$$\text{Total Inflow} - \text{Total Outflow} = \text{Change In Volume}$$

Or,

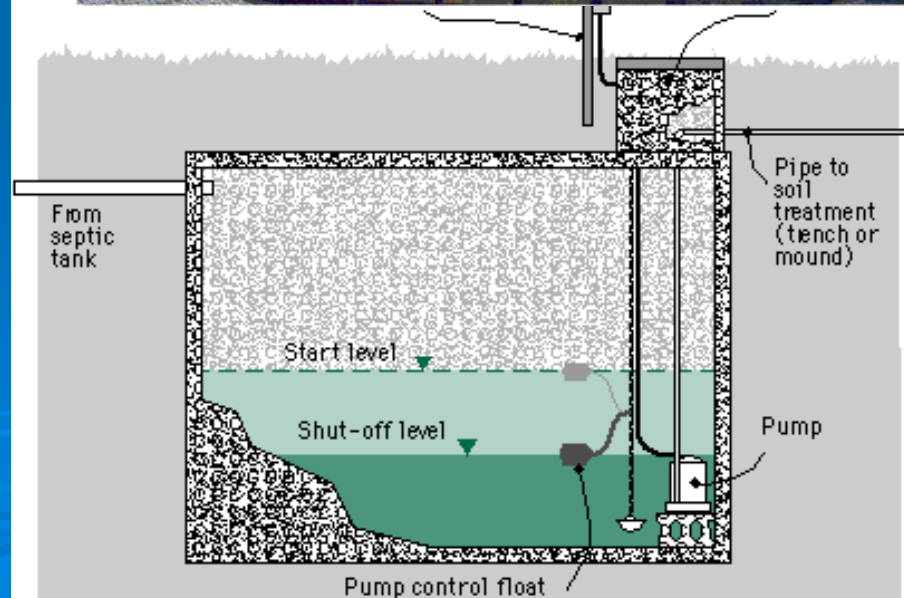
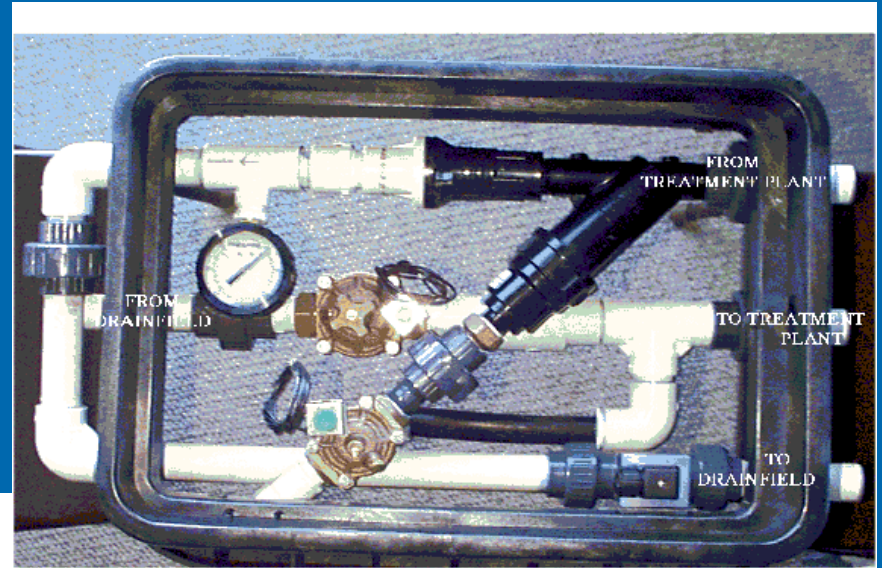
$$\text{Final Volume} = \text{Initial Volume} + \text{Total Inflow} - \text{Total Outflow}$$

Continuity

Closed Systems

And

Open Systems

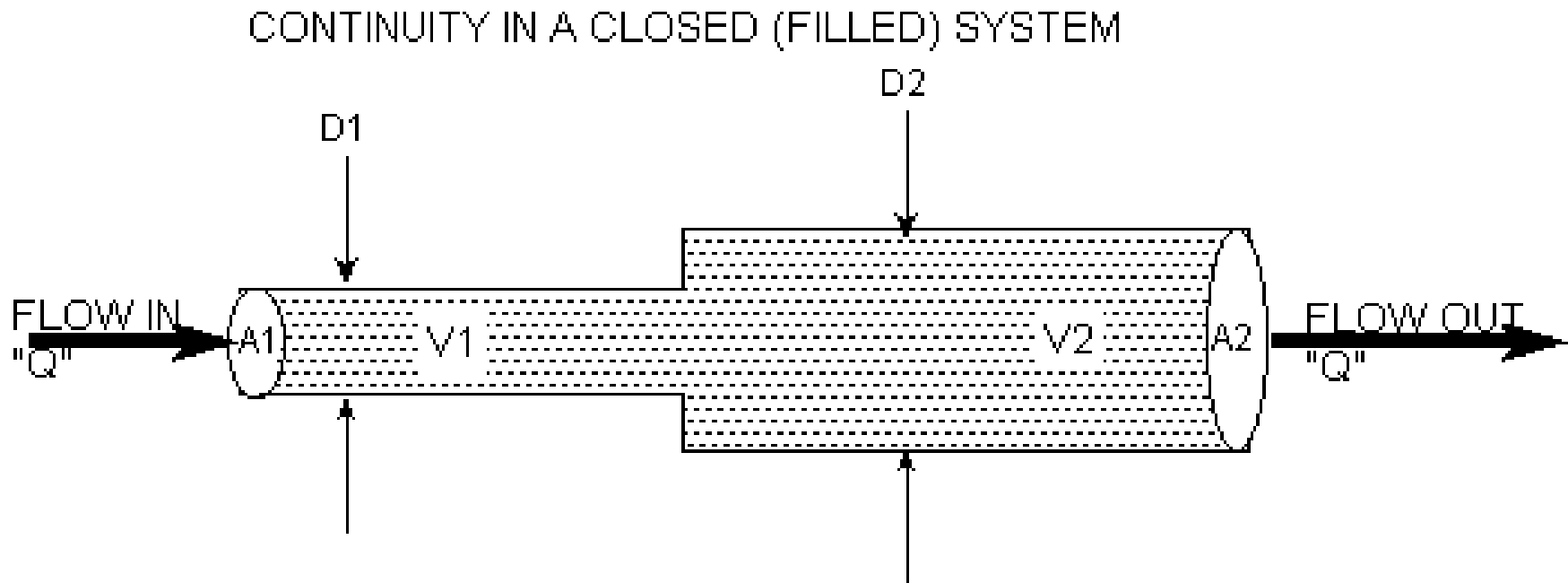


Continuity In Closed Systems

In a closed and filled system where there is no place for either additional storage or release of water continuity simplifies to:

Deposits – Withdrawals = 0 Or,

Deposits = Withdrawals



Continuity In Open Systems

Example #1:

A 200 gallon tank initially holds 100 gallons. 50 gallons are added and 25 gallons are removed.

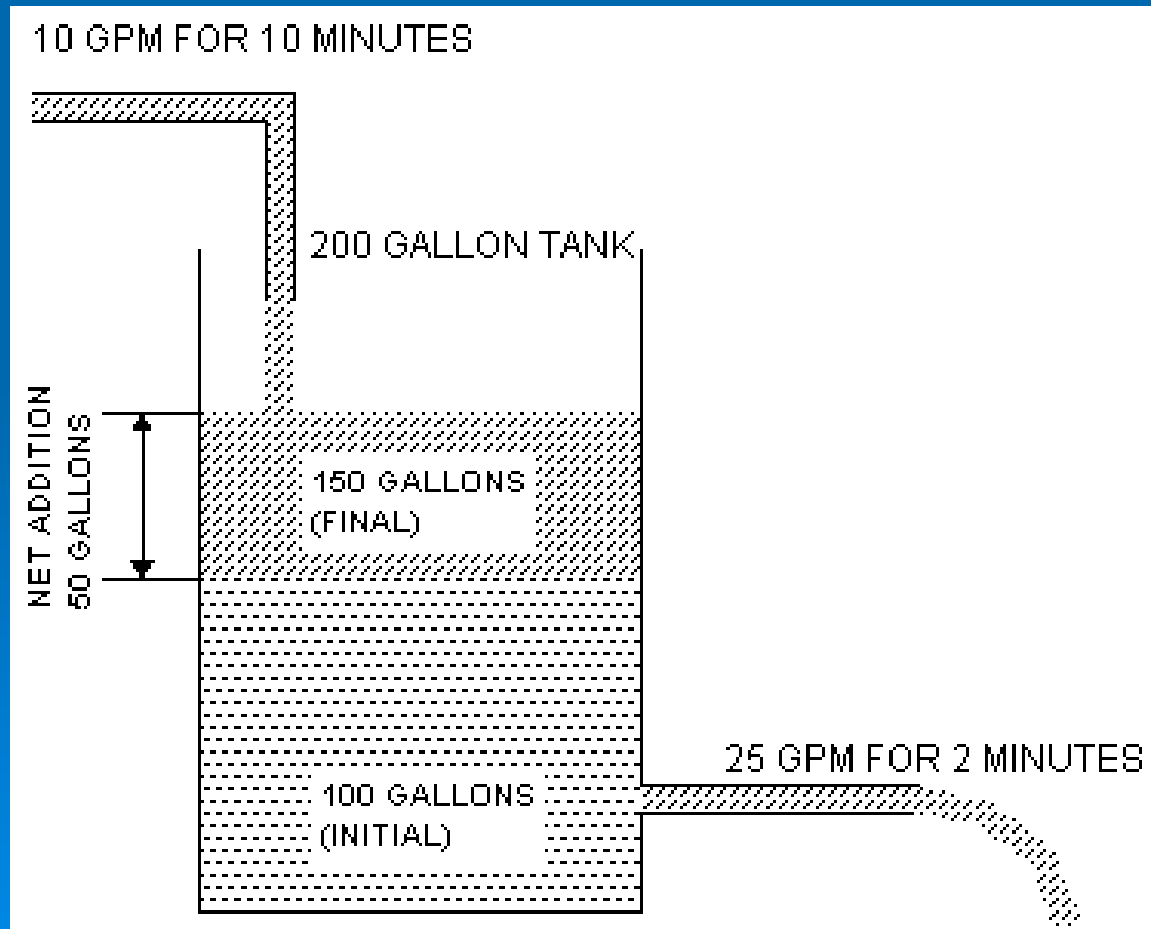
At the end of the process 125 gallons remain in the tank

Using flow rates make things a bit more complicated but not much.

Inflow (rate) x Inflow time - Outflow (rate) x Outflow time = Change in Volume

Example #2

A 200gallon tank initially holds 100 gallons. 10 gallons/minute are added for 10 minutes and 25 gallons/minute are removed for 2 minutes. At the end of the process 150 gallons remain in the tank

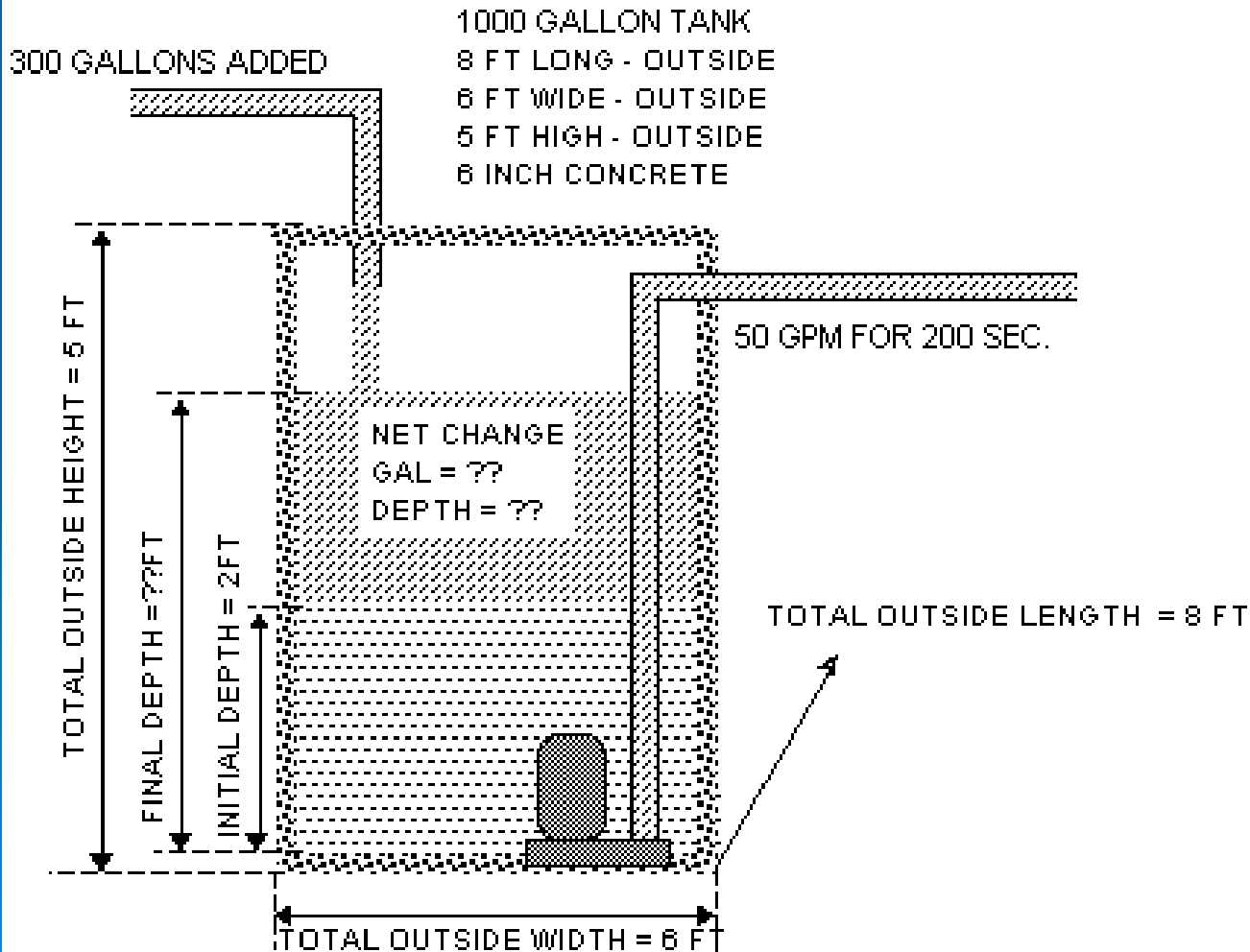
$$\text{Final Volume} = 100 \text{ gallons} + 10 \text{ g/minute} \times 10 \text{ m} - 25 \text{ g/minute} \times 2 \text{ m} = 150 \text{ gallons}$$


Example #3

A 1000 gallon pump tank has outside dimensions of 8 feet long x 6 feet wide x 5 feet deep. The concrete used is 0.5 feet thick (all around).

Initially there is 2 feet of water in the tank. 300 gallons are added from household use and the pump goes on for 200 seconds, pumping 50 gallons per minute. What is the final water surface elevation in the tank?

CHANGE OF TANK LEVEL WITH INFLOW AND OUTFLOW



Answer:

First compute the outflow in gallons:

$$50 \text{ gpm} \times 200 \text{ seconds} / 60 \text{ seconds/min} = 166.6 \text{ gal}$$

Next compute the total change in volume:

$$300 \text{ gal}(\text{inflow}) - 166.6 \text{ gal}(\text{outflow}) = 133.4 \text{ gal} (\text{change})$$

Next convert gallons to cubic feet.

$$133.4 \text{ gal} / 7.48 \text{ gal/ ft}^3 = 17.83 \text{ ft}^3$$

The inside dimensions of the tank are obtained by subtracting the wall thickness (twice – once for each side)

$$8 \text{ ft} - 0.5 \text{ ft} - 0.5 \text{ ft} = 7 \text{ ft} \quad \text{and}$$

$$6 \text{ ft} - 0.5 \text{ ft} - 0.5 \text{ ft} = 5 \text{ ft}$$

Now divide the change in volume by the inside area.

$$17.83 \text{ ft}^3 / (7 \text{ ft} \times 5 \text{ ft}) = 0.51 \text{ ft}$$

Finally, convert the change in elevation to inches.

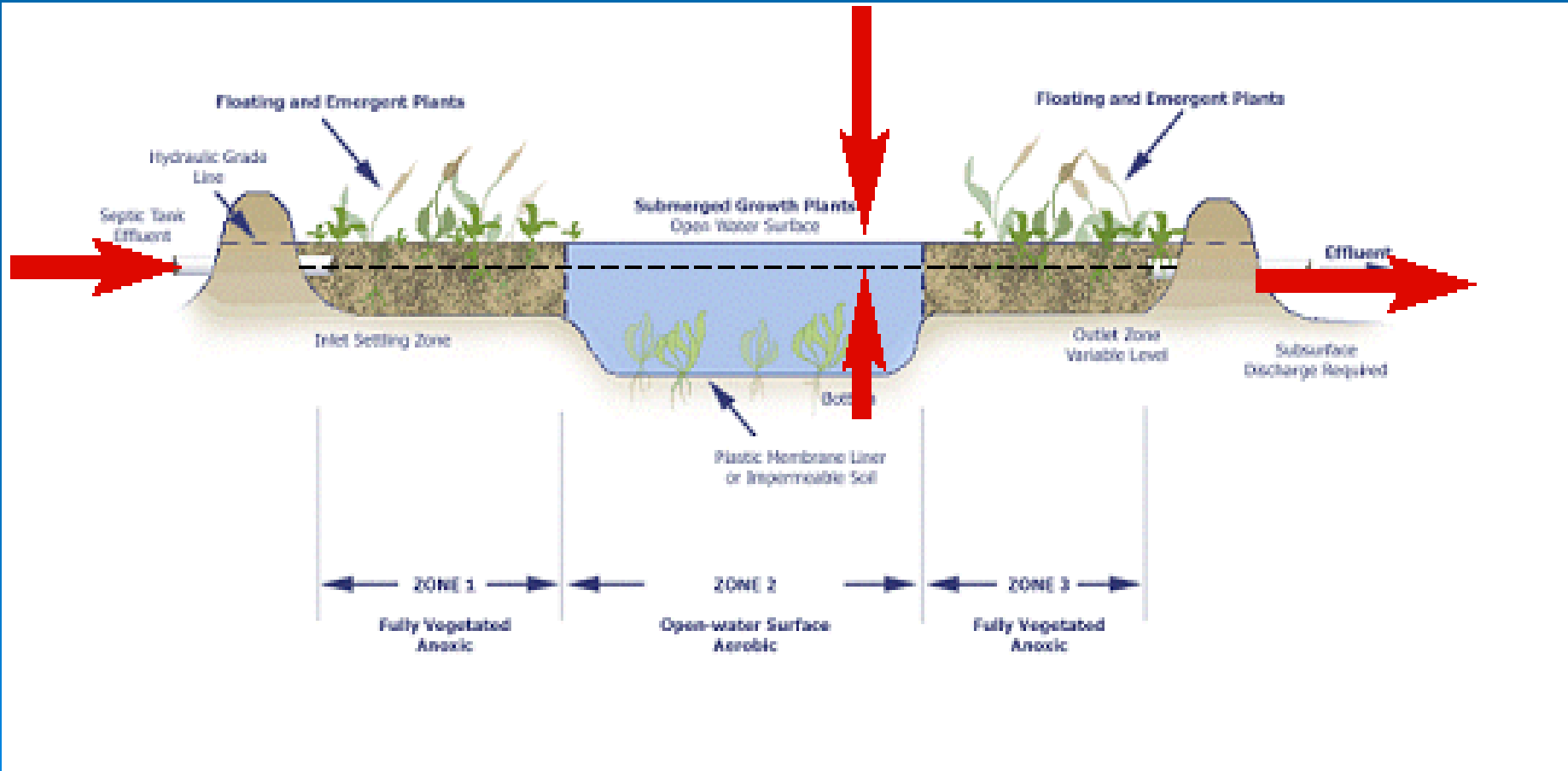
$$0.51 \text{ ft} \times 12 \text{ in/ft} = 6.11 \text{ in} \text{ (which is the change in tank depth)}$$

Since more came in than went out the final tank elevation

$$2.51 \text{ ft} \text{ or } 2 \text{ ft} + 6.11 \text{ inches (or } 30.11\text{'')} \text{ (which is the final tank depth—The answer !)}$$

Continuity in a Constructed Wetland

INFLOW – OUTFLOW = CHANGE IN INTERNAL VOLUME STORED IN A CONSTRUCTED WETLAND (SEABLOOM)

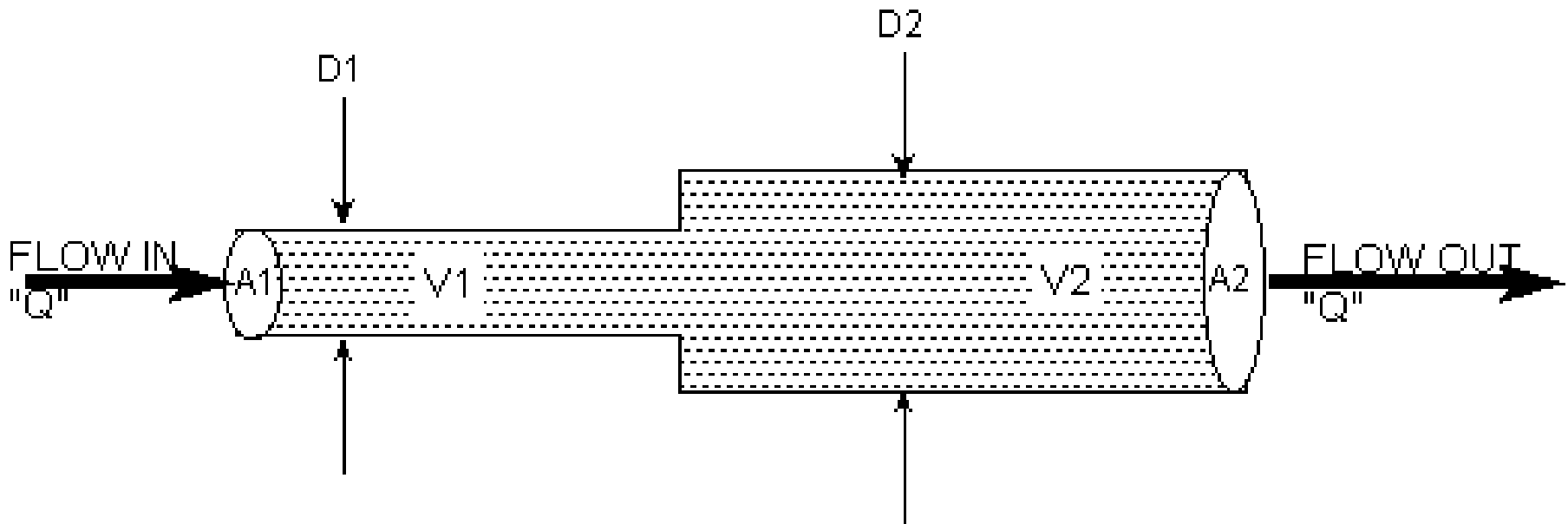


Continuity for Water in Motion

$$V_1 \times A_1 = V_2 \times A_2 = Q$$

$$V_1/V_2 = A_2/A_1 = (R_2/R_1)^2 = (D_2/D_1)^2$$

CONTINUITY IN A CLOSED (FILLED) SYSTEM



Example:

$D_1 = 1$ inches

$D_2 = 2$ inches

and $Q = 500$ gpm

Example #4

Consider again the flow division system shown previously. Pipe Systems with both Diameter Changes and Flow Division Changes shows this same system with pipe diameters labeled.

A flow of 30 gpm enters the system through the 2-inch supply line. What is the velocity of flow in each of the laterals?

