CHAPTER 1 - INTRODUCTION

IRRIGATION **is the artificial application of water to soil for the purpose of supplying the moisture essential for plant growth.**

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7. To reduce the hazard of frost.
8. To reduce the hazard of soil piping.

IRRIGATION DEVELOPMENT IN THE PHILIPPINES

Potential Service Area = 3.16 M hectares

Year	Irrigated Area (has.)	Percentage
1922-1930	80,130	
1946	201,481	6.44
1950-1953	266,000	
1957	400,000	12.80
1964	541,000	
1972		23.75
1985	1.437 M	45.96
1986	1.458 M	46.06
1987	1.487 M	47.07
1988	1.515 M	48.00
1989	1,538 M	49.00
2000	2.300 M	

THE PANTABANGAN DAM

Cost: P242 M

Inauguration Date: September 7, 1974

Height:	**107 m**
Length:	**1,615 m**
Base Width at Max. Section:	**480 m**
Crest Width:	**12 m**
Storage Capacity:	**3 billion cu. m.**
Type:	**Zoned-earthfill**
Irrigable Area:	**83,700 has. (wet season)**
	78,700 has. (dry season)

THE MAGAT DAM

Inauguration Date: October 27, 1982

Storage Capacity:	1.25 billion cu. m.
Length:	4,160 m
Height:	114 m
Base:	102 m
Crest:	12 m
Irrigable Area:	102,000 has.
Type:	Earth-rockfill
Cost:	P3.3 billion

SOURCES OF WATER FOR PLANTS' USE

1. Precipitation (rainfall, snow, hail, sleet)

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3. Groundwater
4. Irrigation water

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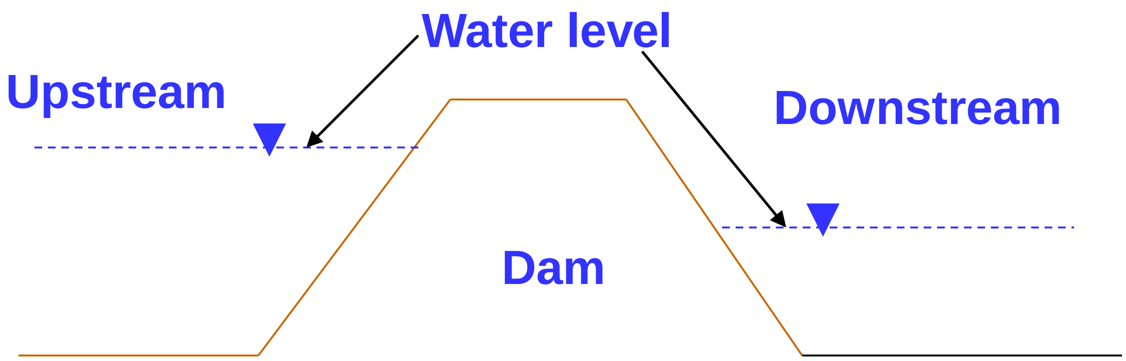
1. Precipitation (rainfall, snow, hail, sleet)
2. Surface waters (rivers, lakes, ponds, reservoirs, low lying areas)
3. Groundwater
4. Irrigation water
5. Atmospheric water other than precipitation

DAM TYPES ACCORDING TO FUNCTION

1. Diversion Dam – also called run-of-the-river type of dam
2. Reservoir Dam – also called storage type of dam

A diversion dam is used to control the flow of water from its source, like rivers or any stream channels, by raising the head of water up to a certain height and then diverting it to a diversion or main canal that is constructed immediately at the upstream portion of the dam. It is effective during the periods of high stream flows which normally occurs during the rainy or wet season. Thus, water flow from the diversion dam is almost continuous, especially during the rainy season. It could not store the excess amount of water flow for future use.



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A reservoir type of dam stores water during the rainy periods so that it can be used during the dry periods of the year.

Two rice cropping seasons may be done in a year if there is a reservoir dam, like the Pantabangan and the Magat dams.

It is most likely not possible to have 2 rice cropping seasons if there is only a diversion dam due to lack of water during the dry months of the year.

COMPONENTS OF AN IRRIGATION SYSTEM

1. Water source (river, lakes, ponds, reservoir, groundwater)

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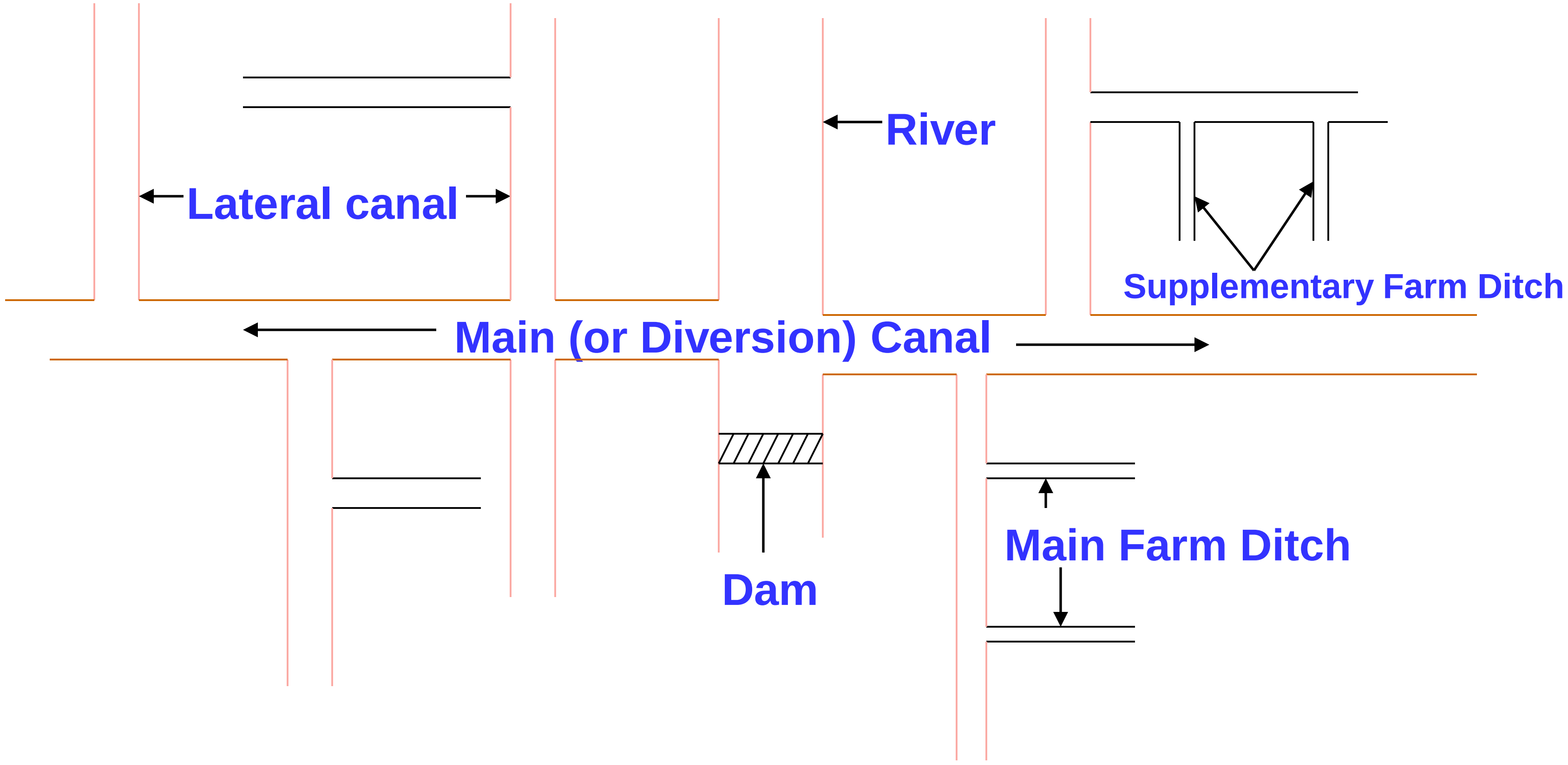
Diversion or main canal is the biggest sized canal. It is connected to the upstream portion of a diversion dam, or to the main outlet of a reservoir dam. It supplies water to the lateral canals.



TYPICAL COMPONENTS OF AN IRRIGATION SYSTEM

COMPONENTS OF AN IRRIGATION SYSTEM

Diversion or main canal is the biggest sized canal. It is connected to the upstream portion of a diversion dam, or to the main outlet of a reservoir dam. It supplies water to the lateral canals.

Lateral canals are connected to the diversion or main canal and supplies water to the main farm ditches.

Main farm ditches are connected to the lateral canals and supplies water to the supplementary farm ditches.

Supplementary farm ditches are the smallest sized canals found inside a farmer’s field. They are normally temporary in nature and are constructed every now and then by the farmers themselves.

QUESTIONS

1. Define irrigation.
2. List six purposes for applying irrigation water to the soil.
3. What are the four major sources of irrigation water?
4. Is all of the precipitation that falls on cropland available to the crops? Explain.
5. Does groundwater contribute directly to the water needs of plants? When? When is it harmful?
6. How does the need for irrigation in humid areas differ from that in arid regions?
7. What are the advantages of small ponds and reservoirs for irrigation?

QUIZ

A. Define:

1. Irrigation **2. Bulk Density**

3. Soil Texture **4. Apparent Specific Gravity**

5. Soil Structure

B. List five (5) sources of water for plant's use

C. Give five (5) purposes of irrigation

D. What are the two (2) types of dam?

E. Give two (2) components of an irrigation system.

F. What is the most important part of an irrigation system?

CHAPTER 2

BASIC SOIL-PLANT-WATER RELATIONS

SOIL PHYSICAL PROPERTIES AFFECTING STORAGE & MOVEMENT OF WATER IN THE SOIL

1. Soil Texture – refers to the size of the soil particles

3 Major Soil Textural Classification

Coarse - - - Sand

Medium - - - Silt

Fine - - - - Clay

Soil Texture	Storage	Water Movement
Coarse	Lowest	Fastest
Medium	Moderate	Moderate
Fine	Highest	Slowest

SOIL PHYSICAL PROPERTIES AFFECTING STORAGE & MOVEMENT OF WATER IN THE SOIL

1. Soil Texture – refers to the size of the soil particles

The ISSS Soil Textural Classification

Soil Texture	Diameter range (mm)
Clay	<0.002
Silt	0.02 – 0.002
Fine Sand	0.20 – 0.02
Coarse Sand	2.00 – 0.20

SOIL PHYSICAL PROPERTIES AFFECTING STORAGE & MOVEMENT OF WATER IN THE SOIL

2. Soil Structure – refers to the shape and arrangement of the soil particles and voids

Soil Texture	Shape	Arrangement
Coarse	Granular/Spherical	Rhombic/Cube
Medium	Blocklike	Columnar
Fine	Platelike	Like sheets of paper placed on top of each other

3. Soil Bulk Density – ratio of oven-dry mass of soil to its bulk volume

$\rho_b = (OD)/(V_b)$

ρ_b = soil bulk density (g/cm^3, kg/m^3, lbs/ft^3)

OD = soil oven dry mass (g, kg, lbs)

V_b = soil bulk volume (cm^{3,} m^3, ft^3)

$V_b = V_s + V_a + V_w$

V_s = volume of soil particles (cm^3 , m^3 , ft^3)

V_a = volume of air in the soil (same units as above)

V_w = volume of water in the soil (same units as above)

The more compact the soil, the higher the bulk density.

The finer the soil texture, the higher the bulk density.

Bulk density is lowest at the top and highest at the bottom of a soil column.

Soil Texture	Bulk Density
Coarse	Lowest
Medium	Moderate
Fine	Highest

SOIL PHYSICAL PROPERTIES AFFECTING STORAGE & MOVEMENT OF WATER IN THE SOIL

4. Soil Apparent Specific Gravity – ratio of soil bulk density to the density of water

$A_s = (\rho_b/\rho_w)$

A_s = soil apparent specific gravity (unitless)

ρ_b = soil bulk density (g/cm^3, kg/m^3, lbs/ft^3)

ρ_w = water density (g/cm^{3,} kg/m^3, lbs/ft^3)

The more compact the soil, the higher the A_s.

The finer the soil texture, the higher the A_s.

A_s is lowest at the top and highest at the bottom of a soil column.

Soil Texture	A_s
Coarse	Lowest
Medium	Moderate
Fine	Highest

SOIL PHYSICAL PROPERTIES AFFECTING STORAGE & MOVEMENT OF WATER IN THE SOIL

5. **Soil Particle Density – ratio of oven-dry mass of a single soil particle to the volume of that single soil particle**

ρ_p = (oven-dry mass of a single soil particle)/(volume of that single soil particle)

ρ_p = soil particle density (g/cm^3, kg/m^3, lbs/ft^3)

The more compact the soil, the higher the particle density.

The finer the soil texture, the lower the particle density.

Particle density is lowest at the top and highest at the bottom of a soil column.

Soil Texture	Particle Density
Coarse	Highest
Medium	Moderate
Fine	lowest

SOIL PHYSICAL PROPERTIES AFFECTING STORAGE & MOVEMENT OF WATER IN THE SOIL

6. Real Specific Gravity – ratio of soil particle density to the density of water

$R_s = (\rho_p/\rho_w)$

R_s = real specific gravity of the soil (unitless)

ρ_p = soil particle density (g/cm^3, kg/m^3, lbs/ft^3)

ρ_w = water density (g/cm^{3,} kg/m^3, lbs/ft^3)

SOIL PHYSICAL PROPERTIES AFFECTING STORAGE & MOVEMENT OF WATER IN THE SOIL

7. **Soil Depth – the soil column where water is applied and where plant roots grow.**

Soil Texture	Soil Depth
Coarse	Deepest
Medium	Moderate
Fine	Shallowest

MOVEMENT OF WATER IN THE SOIL

8. Soil Porosity – the space between soil particles that are occupied by air and water.

Kinds of Pore Spaces

Micropores – dominant in fine-textured soils

Macropores – dominant in coarse-textured soils

Soil Texture	No. of Micropores	No. of Macropores
Coarse	Lowest	Highest
Medium	Moderate	Moderate
Fine	Highest	Lowest

SOIL PHYSICAL PROPERTIES AFFECTING STORAGE & MOVEMENT OF WATER IN THE SOIL

8. Soil Infiltration – the downward movement of water from the soil surface into the soil

9. Infiltration Rate – the time rate at which water will percolate from a level soil surface into the soil.

10. Intake Rate – the rate of infiltration from a furrow into the soil.

Soil Texture	Infiltration Depth/ Intake Depth	Infiltration Rate/ Intake Rate
Coarse	Lowest	Highest
Medium	Moderate	Moderate
Fine	Highest	Lowest

SOIL MOISTURE CONSTANTS

1. **Wilting Point** – moisture content that is left in the soil when the all plant organs are wilted or virtually dead.

2. **Field Capacity** – moisture content that is left in the soil when all gravitational or excess water has been drained.

   - moisture content that is left in the soil 2 to 3 days after a heavy rain or application of water.

3. **Saturation Point** – moisture content that is present in the soil when almost all, if not all, the soil pore spaces are filled with water.

4. **Available Water** – the difference between field capacity and wilting point of the soil

   - moisture content that is present in the soil and is available for plant's use.

   - also called available moisture

SOIL MOISTURE CONSTANTS

4. Available Moisture – the difference between field capacity and wilting point of the soil

   - moisture content that is present in the soil and is available for plant's use.

   - also called available water

   A. M. = F.C. – W.P.

   A.M. = available moisture or water (%, depth, volume)

   F.C. = soil field capacity (%, depth, volume)

   W.P. = soil wilting point (%, depth, volume)

5. Readily Available Moisture – 75% of available moisture

   R.A.M. = 0.75(A.M.)

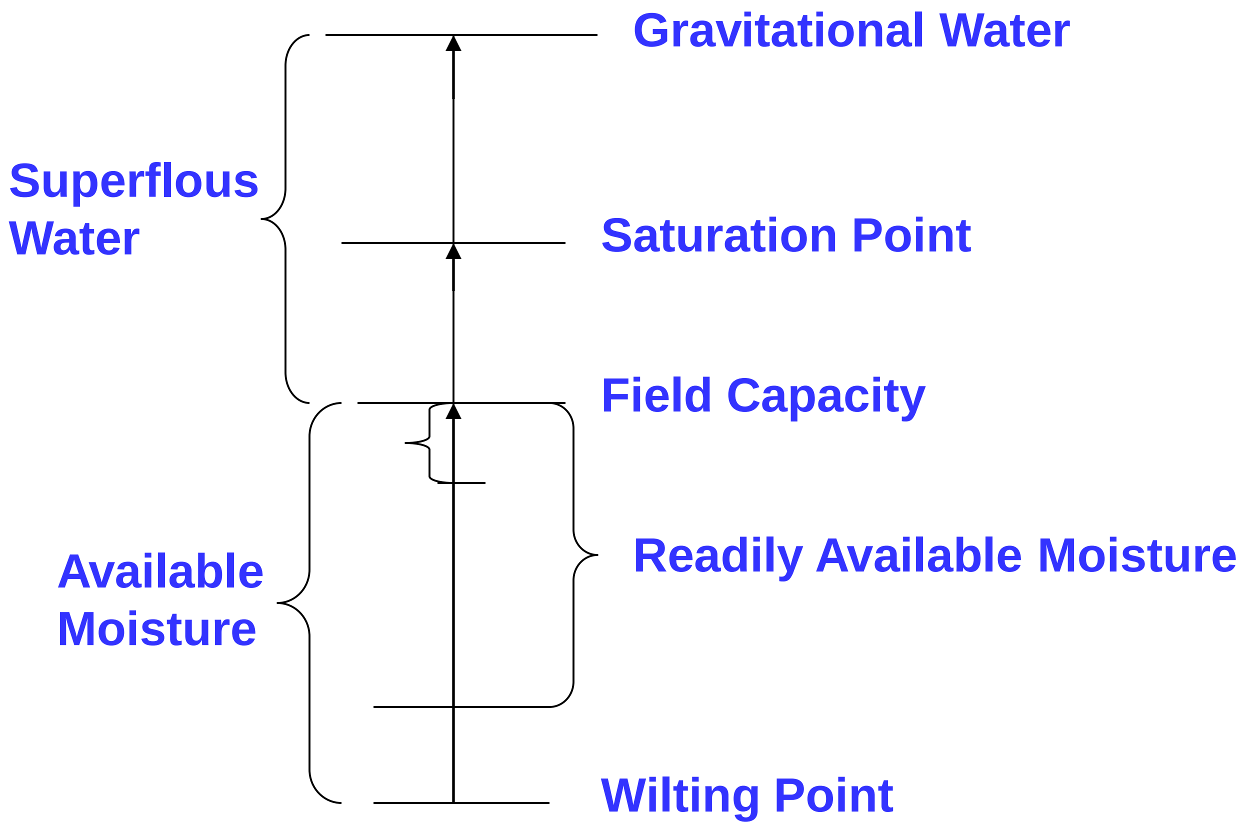
   = 0.75(F.C. – W.P.)

6. Hygroscopic Water – moisture content at wilting point and is unavailable for plant's use

SOIL MOISTURE CONSTANTS

7. Gravitational Water – water in excess of, or above, field capacity

- also called superflous water, excess water, gravitational or drainage water



SOIL MOISTURE TENSIONS

At Field Capacity = -1/10 to -1/3 atmosphere

At Wilting Point = - 40 to -15 atmosphere

SOIL MOISTURE EXPRESSIONS

1. Percent Moisture Content by Weight, P_w

$$P_w = \frac{(F.W. - O.D.)}{O.D.} \times 100 \text{ (unit in \%)}$$

F.W. = fresh weight of soil sample, g

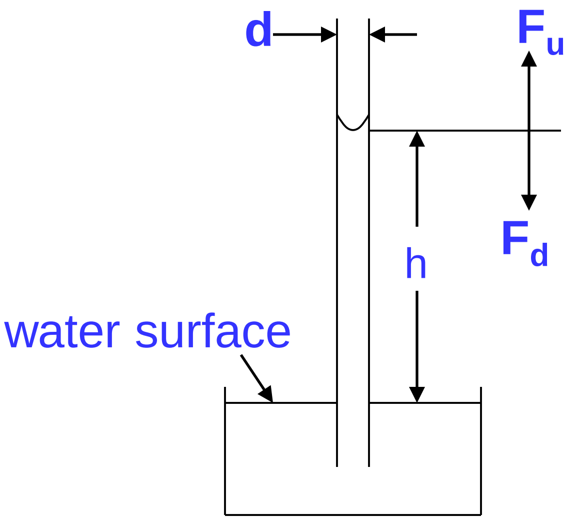
O.D. = oven dry weight of soil sample, g

2. Moisture Content by Volume, P_v

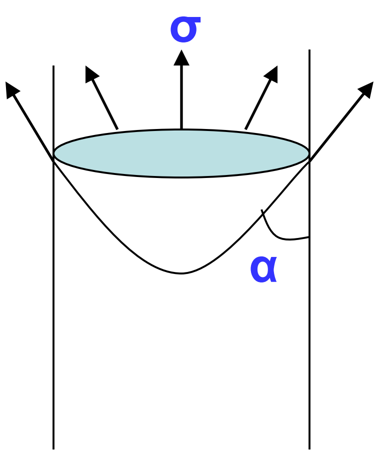
$$P_v = (P_w/100) \bullet A_s$$

A_s = apparent specific gravity of the soil

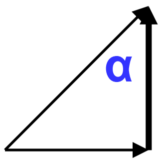
SOIL MOISTURE TENSION



σ= surface tension



α = contact angle



h = height of rise of water in the capillary tube at equilibrium

Fu = 2πrσcosα

σ = 75.6 dynes/cm and its specific weight is 980 dynes/cm^3

Fd = ρg(πr^2h)

At equilibrium, Fu = Fd

2πrσcosα = ρg(πr^2h)

h = 2σcosα/ρgr

r = 2σcosα/ρgh

d = 2r

d = diameter of capillary tube

r = radius of capillary tube

SOIL MOISTURE EXPRESSIONS

3. Depth of Water, d

   $d = (P_w/100) \bullet A_s \bullet D = (P_v)D$

   D = soil depth that is used to store soil moisture

4. Volume of Water, V

   $V = A \bullet d$

   A = irrigated area

5. Discharge of Water, q

   $q = (A \bullet d)/t$

   t = irrigation water application time

6. $qt = Ad$

QUESTIONS

1. Distinguish between the *real* and the *apparent* specific gravity of a soil.
2. What substances occupy the pore spaces of a soil? Is the percentage pore space of a soil influenced by its water content?
3. Why is the rate of water-flow into soils of importance in irrigation practice?
4. For a soil of given texture and structure, will a 1.4 meter depth of well-drained root zone soil hold twice as much irrigation water as one of 0.7 meter depth? Assume that the water table is 10 meters or more below the land surface.
5. What properties of the soil determine the percentages of these three classes of moisture in the soil: hygroscopic, capillary and gravitational?

QUESTIONS

6. Are irrigated soils that are naturally well-drained ever completely saturated? Explain.

7. How can the concept of field capacity be determined and used even though there is no point on the moisture drainage curve that uniquely defines field capacity?

8. A sharp-edged cylinder 150 mm in diameter is carefully driven into the soil so that negligible compaction occurs. A 200-millimeter column of soil is secured. The wet weight is 5525 grams and the dry weight is 4950 grams. a) What is the percent moisture on a dry weight basis? b) What is the apparent specific gravity of the soil?

QUESTIONS

9. A cylinder was carefully pushed into the soil without compressing or disturbing the soil. The cross-sectional area of the cylinder was 0.025 m^2. The length of the column within the cylinder was 0.30 m. The weight of the soil within the cylinder was 9.5 kg when it was dried. The weight of the soil before drying was 11.4 kg. Determine P_w, A, P_v.

10. A stream of 115 lps is used to apply 130 hectare-mm of water per hectare to a 3.5-hectare field. How long will it take to irrigate the field?

11. An irrigator uses a stream of 100 lps for two days (48 hours) to irrigate 12 hectares of sugar beets. What is the average depth of water applied?

QUIZ 070507

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QUESTIONS

12. A farmer desires to irrigate a border which is 12 meters wide and 150 meters long. He wants to apply an average of 75-mm depth of water to the area with a stream of 60 lps. How long will it take him to irrigate this border?

13. The soil moisture at field capacity is 27.2% and the moisture content at the time of irrigating is 19.0%. The apparent specific gravity is 1.3 and the depth of soil to be wetted is 1 meter. a) How many hectare-mm/hectare of water must be applied? b) How long will it take to irrigate the 5 hectares with a 115 lps stream?

QUESTIONS

14. Soil samples indicate an average moisture and apparent specific gravity in the soil as follows:

Depth	P(dry wt)	A
0-300 mm	14.7	1.34
300-600 mm	15.3	1.36
600-900 mm	17.6	1.32
900-1200 mm	18.2	1.30

Compute the depth of water held in the first 1.2 meters.

CHAPTER 3. MEASUREMENT OF SOIL MOISTURE

Methods of Measuring Soil Moisture:

1. Feel and Appearance Method

    Wet soils – dark in appearance

    Dry soils – light in appearance

    Clay soils – sticky when wet, forms clods together with other soil particles when moist, serves as a binder to other soil particles making up the soil

    Medium-textured soils – powdery when dry, crumbles when dry

    Coarse-textured soils – granular, particles do not cling to each other even when wet, crumbles when dry

    Feel and Appearance method could not quantify the amount of soil moisture. It can only say if the soil is wet, moist or dry.

CHAPTER 3. MEASUREMENT OF SOIL MOISTURE

Methods of Measuring Soil Moisture:

2. Resistance of Soil to Penetration

Hard objects like steel rod, shovel, hoe, soil auger, etc. can be used to test the resistance of soil to penetration.

Dry soils are relatively difficult to penetrate than wet soils.

Like the Feel and Appearance Method, the Resistance of Soil to Penetration could not quantify the amount of moisture that is present in the soil. It can only tell if the soil is wet, moist or dry.

3. Oven-drying or Gravimetric Method

Soil sample of at least 200 grams should be collected from the field.

The fresh weight of the soil sample is determined before it is oven-dried for 12 to 24 hours at a temperature of about 105^{o}C, after which the soil oven-dry weight is determined. Moisture content is then computed by

$$P_w = \frac{(F.W. - O.D.)}{O.D.} \times 100$$

CHAPTER 3. MEASUREMENT OF SOIL MOISTURE

Methods of Measuring Soil Moisture:

4. Soil Tensiometer Method

Soil tensiometer measures soil moisture tension.

The higher the soil moisture tension, the lower the soil moisture and vice versa

It makes use of a capillary tube (transparent plastic pipe) of about one inch in diameter and varies in length. The lower end of the tube is plugged with a porous cup while its upper end is used to fill the tube with water. A vacuum gage pressure is attached to the upper end of the tube. The gage is calibrated from zero to 100. Gage readings towards the zero mark corresponds to high soil moisture. The porous cup serves as passageway for water into or out of the tube.

When the soil is dry, water from the tensiometer will be emitted by passing through the porous cup and then absorbed by the soil. The gage of the tensiometer registers the corresponding soil moisture tension.

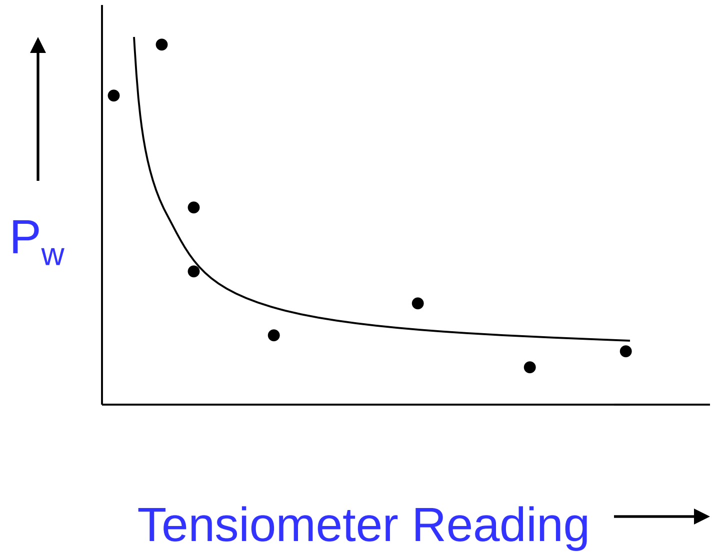
When the soil is wet, water from the soil enters the tensiometer through the porous cup. The gage registers the corresponding soil moisture tension.

CHAPTER 3. MEASUREMENT OF SOIL MOISTURE

Methods of Measuring Soil Moisture:

4. Soil Tensiometer Method

Soil tensiometer is calibrated against the oven-drying method before it could be used.



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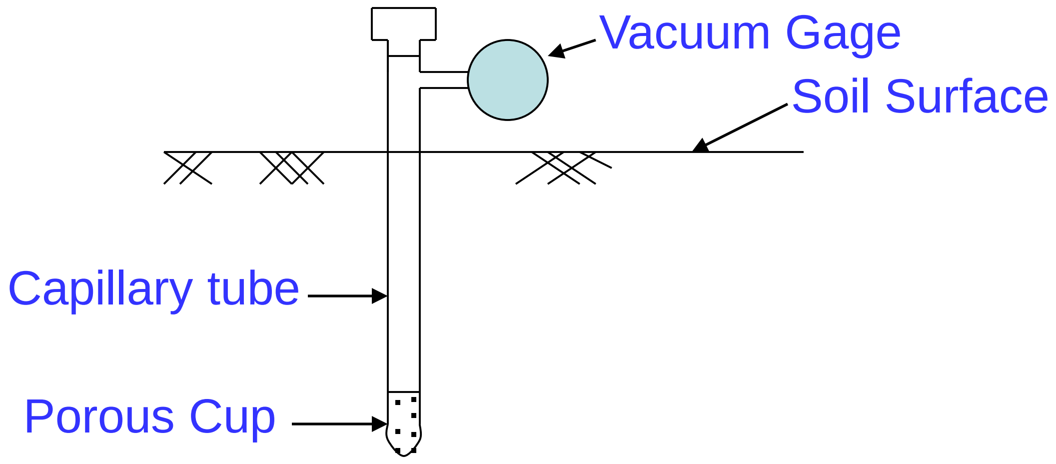

Typical Installation of Tensiometer in the Field

CHAPTER 3. MEASUREMENT OF SOIL MOISTURE

Methods of Measuring Soil Moisture:

4. Soil Tensiometer Method

It is relatively easy and simple to use.

Cheap.

Needs calibration.

5. Electrical Resistance Method

An electrical resistance meter, sometimes called Bouyoucous meter, measures the amount of electrical resistance present in the soil.

One end of two lead wires are imbedded and molded in a porous block, made of gypsum of plaster of Paris. The porous block is installed at the required soil depth. It serves as a passageway for moisture that is present in the soil. The other end of the two lead wires are connected to an electrical resistance meter.

The higher the soil moisture, the lower is the corresponding electrical resistance.

CHAPTER 3. MEASUREMENT OF SOIL MOISTURE

Methods of Measuring Soil Moisture:

5. Electrical Resistance Method

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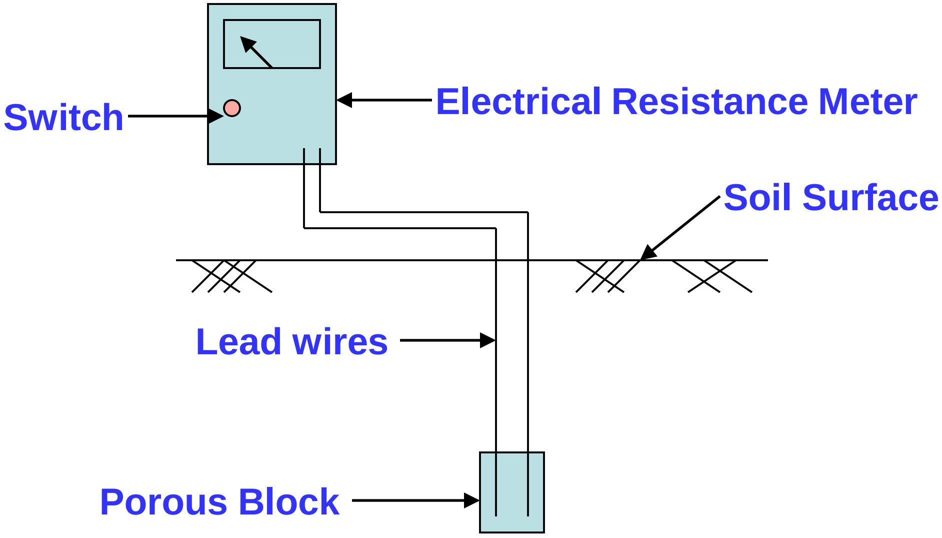

Typical installation of an electrical resistance meter and porous block in the field.

CHAPTER 3. MEASUREMENT OF SOIL MOISTURE

Methods of Measuring Soil Moisture:

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Electrical Resistance Method
It is relatively easy and simple to use.
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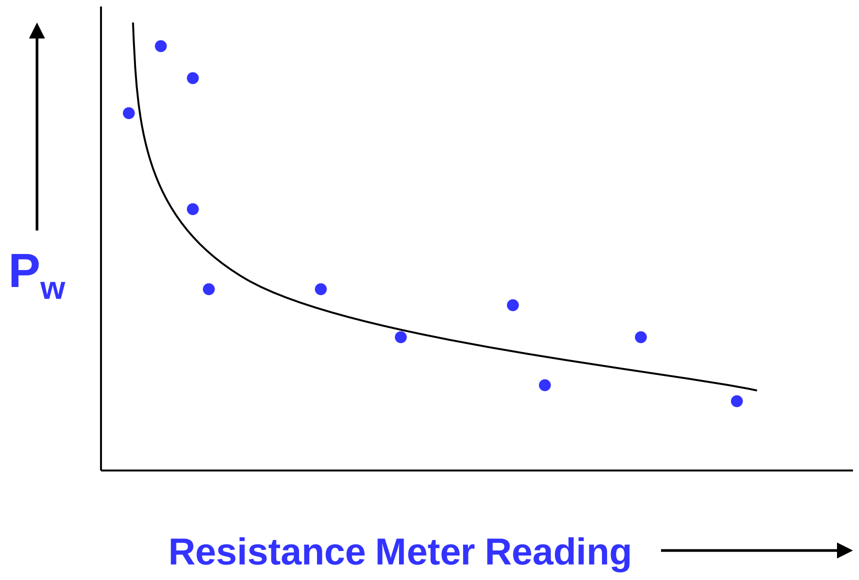


Sample electrical resistance calibration curve.

CHAPTER 3. MEASUREMENT OF SOIL MOISTURE

Methods of Measuring Soil Moisture:

6. Neutron Scattering Method

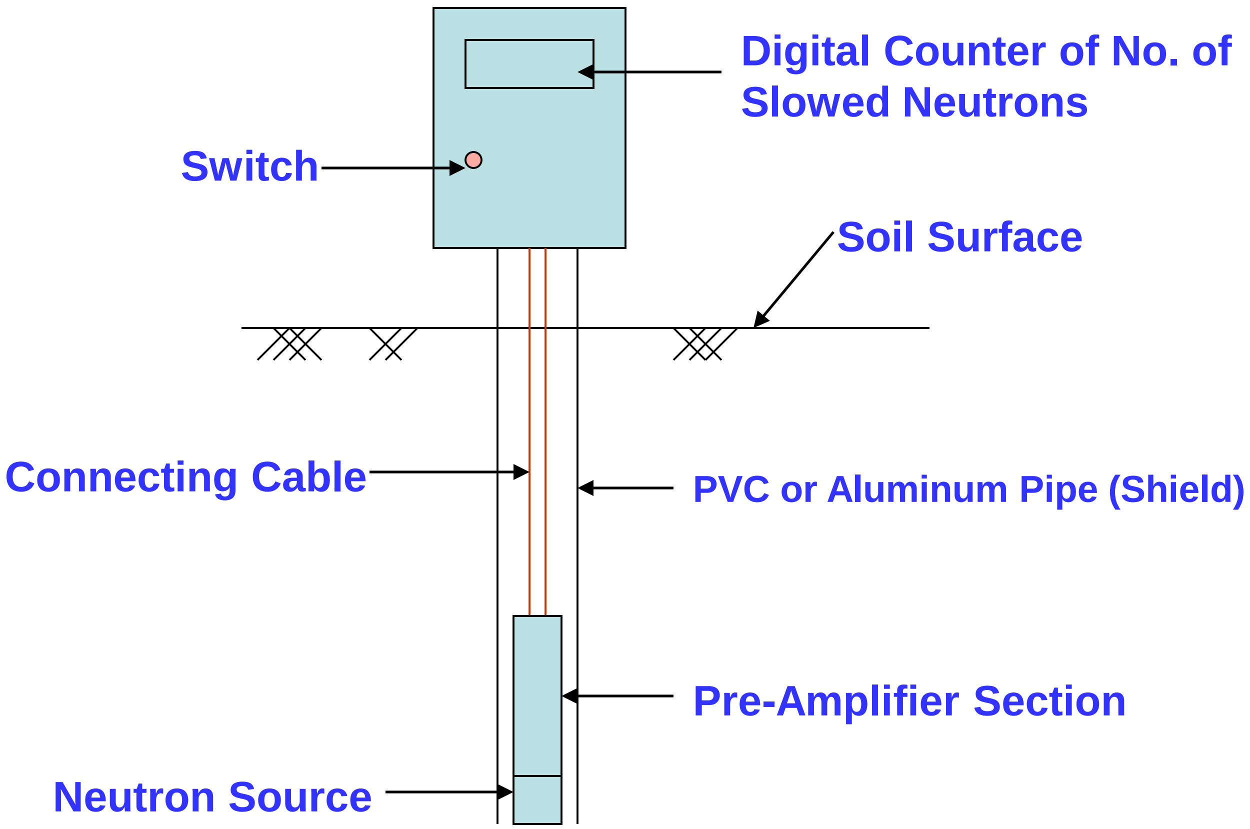
A neutron source (e.g. Am/Be) is used to measure the amount of moisture present in the soil. The neutron source is imbedded in the soil at the required soil depth where moisture is to be measured. The neutron source emits fast neutrons. Some fast neutrons will then collide with the hydrogen molecules that are present in the soil which will then be slowed down. Hydrogen molecules will be present in the soil if there is water or moisture in it.

The number of slowed neutrons will be counted by the neutron scattering device. The higher the moisture content present in the soil, the higher will be the number of hydrogen molecules present in the soil and the higher will be the number of slowed down neutrons.

CHAPTER 3. MEASUREMENT OF SOIL MOISTURE

Methods of Measuring Soil Moisture:

6. Neutron Scattering Method



Typical installation of a Hydroprobe, a neutron scattering device for soil moisture measurement.

CHAPTER 3. MEASUREMENT OF SOIL MOISTURE

Methods of Measuring Soil Moisture:

6. Neutron Scattering Method

It is the most accurate method of soil moisture measurement.

It is the most expensive method of soil moisture measurement.

It needs calibration.

CHAPTER 3. MEASUREMENT OF SOIL MOISTURE

Methods of Measuring Soil Moisture:

7. **Use of Thermal Properties (Thermocouple)**

   Thermocouple is used to measure temperature.

   Soil temperature changes according to the change in soil moisture content. The wetter the soil, the lower is its temperature and vice versa.

   However, soil temperature also varies with depth. The deeper the soil, the lower is the temperature. Change in depth affects soil moisture measurement.

CHAPTER 4. FLOW OF WATER INTO AND THROUGH SOILS

Water has energy.

Energy of Flowing Water.

1. Potential Energy, P. E. = $(P/\gamma) + y$

(P/γ) = pressure head

γ = specific weight of water

y = elevation head

CHAPTER 4. FLOW OF WATER INTO AND THROUGH SOILS

Energy of Flowing Water.

2. Kinetic Energy, K. E. = $(v^2/2g)$

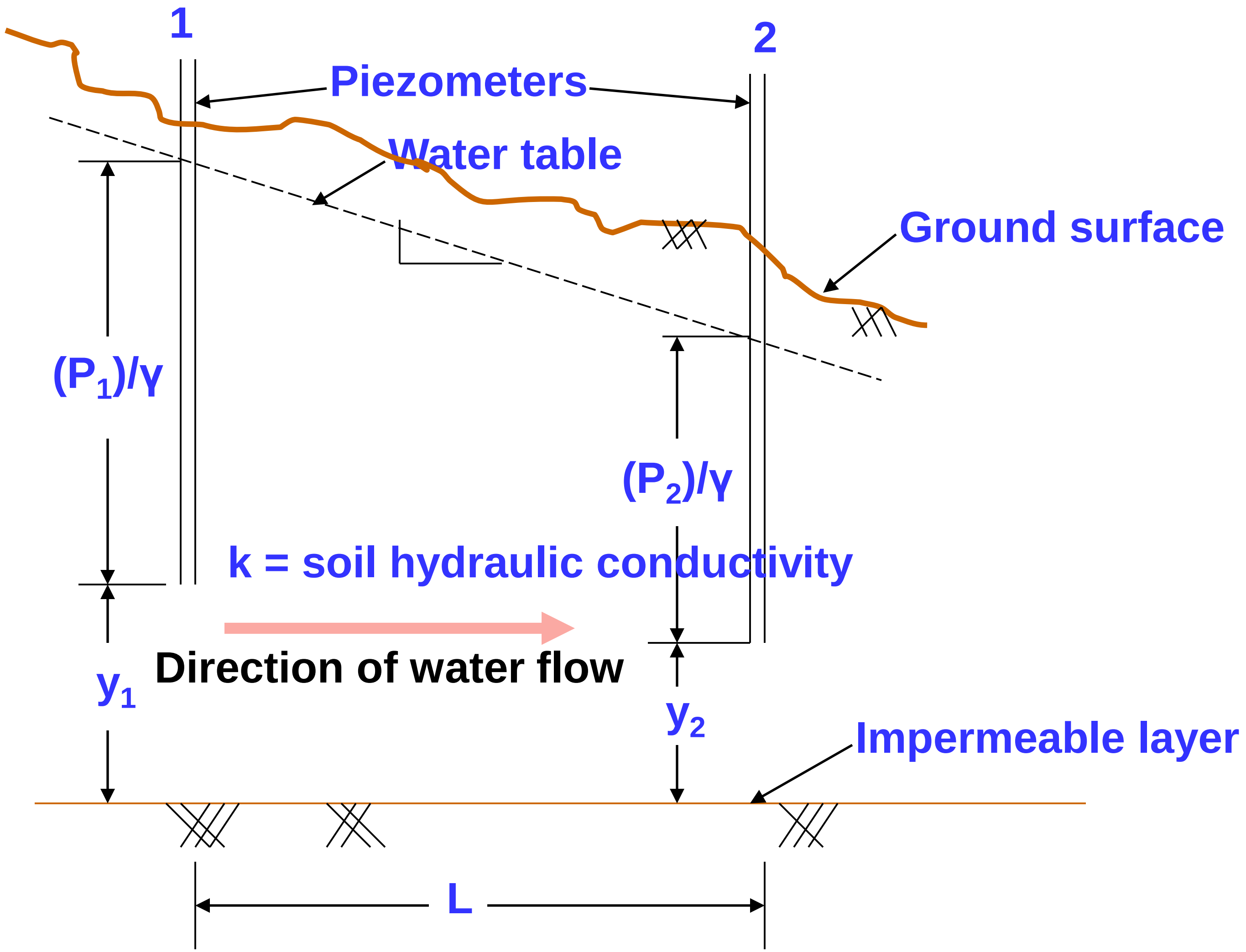
$$v^2/2g = \text{velocity head}$$

Combined Energy H = P.E. + K.E.

$$\text{or } H = (P/\gamma) + y + v^2/2g$$

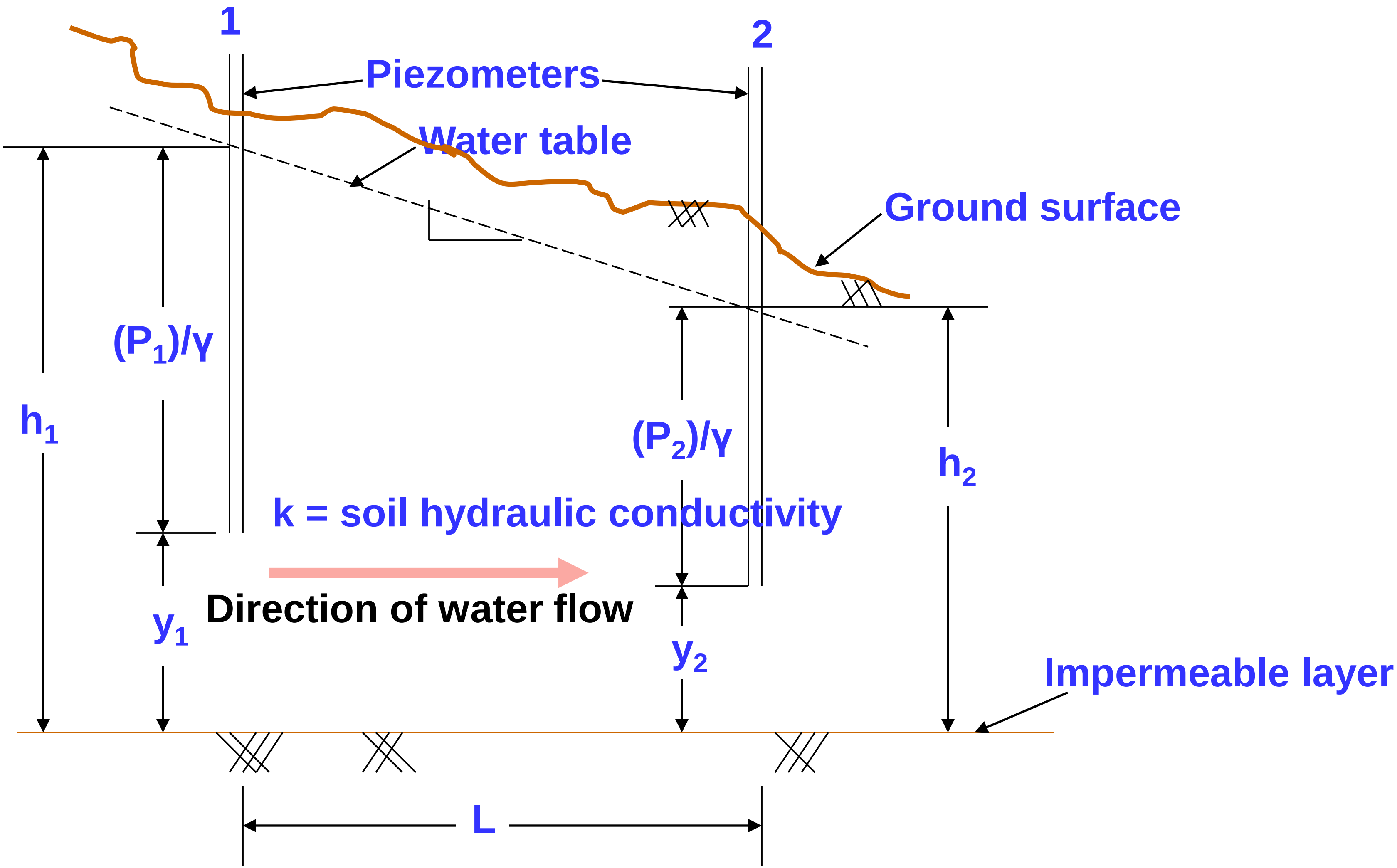
This is also known as Bernoulli's equation.

Hydraulic head, $h = (P/\gamma) + y$



$h_1 = p_1/\gamma + y_1$ Hydraulic gradient, $i_1 = h_1/L$, $i_2 = h_2/L$ $i = \Delta h/L$

$h_2 = p_2/\gamma + y_2$ Hydraulic head loss, $h_l = h_1 - h_2 = \Delta h$



$h_1 = p_1/\gamma + y_1$ Hydraulic gradient, $i_1 = h_1/L$, $i_2 = h_2/L$ $i = \Delta h/L$

$h_2 = p_2/\gamma + y_2$ Hydraulic head loss, $h_l = h_1 - h_2 = \Delta h$

Example:

At Piezometers 1 and 2:

$h_1 = (p_1/\gamma) + y_1 = 50$ m

$h_2 = (p_2/\gamma) + y_2 = 40$ m

Flow distance, L = 100 m

$i = (\Delta h/L) = (h_1 - h_2)/L = (50 - 40)/100 = 10/100$

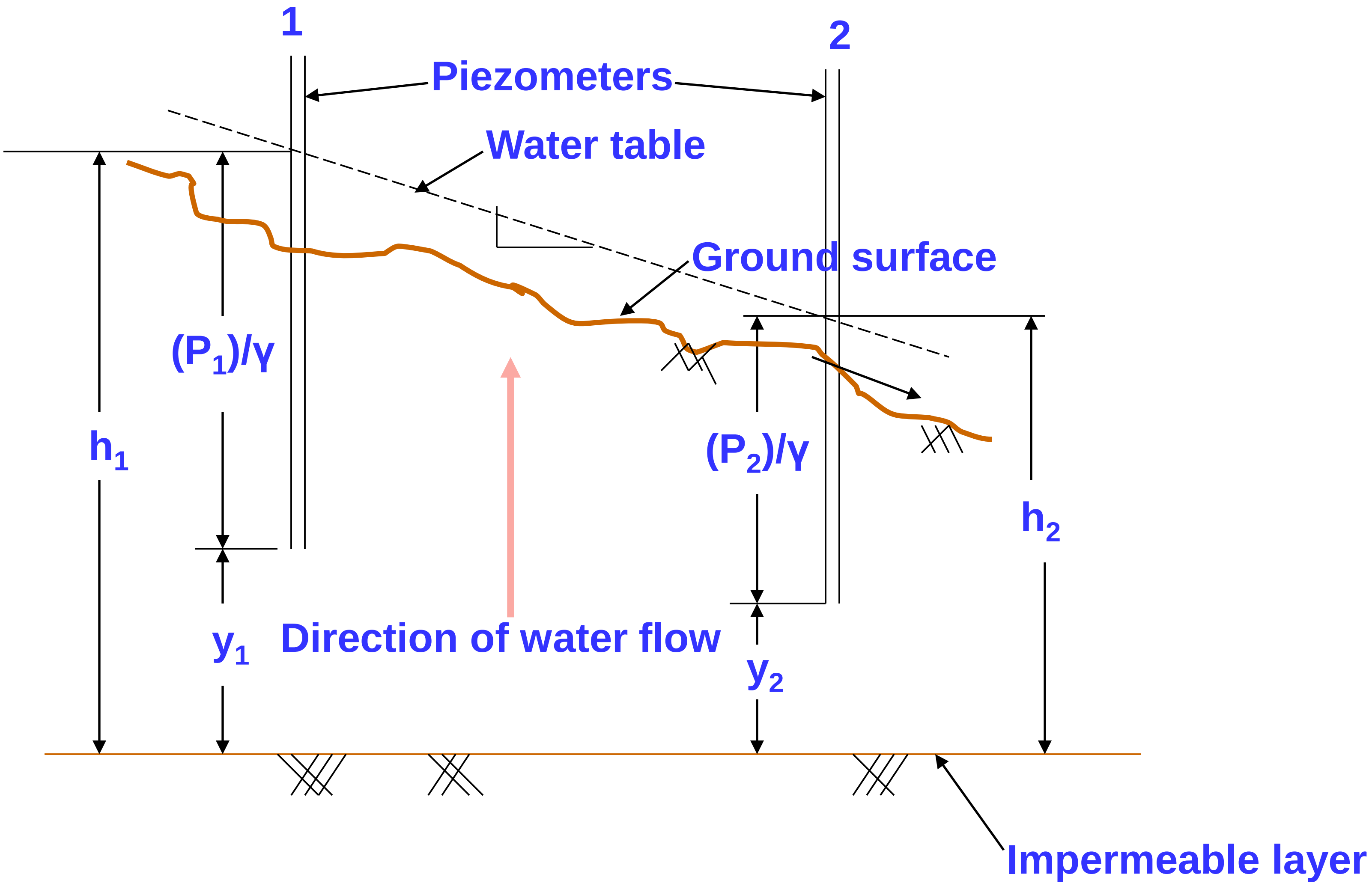
i = slope or hydraulic gradient

k = 350 m/year

A = 1000 m wide, 20 m deep

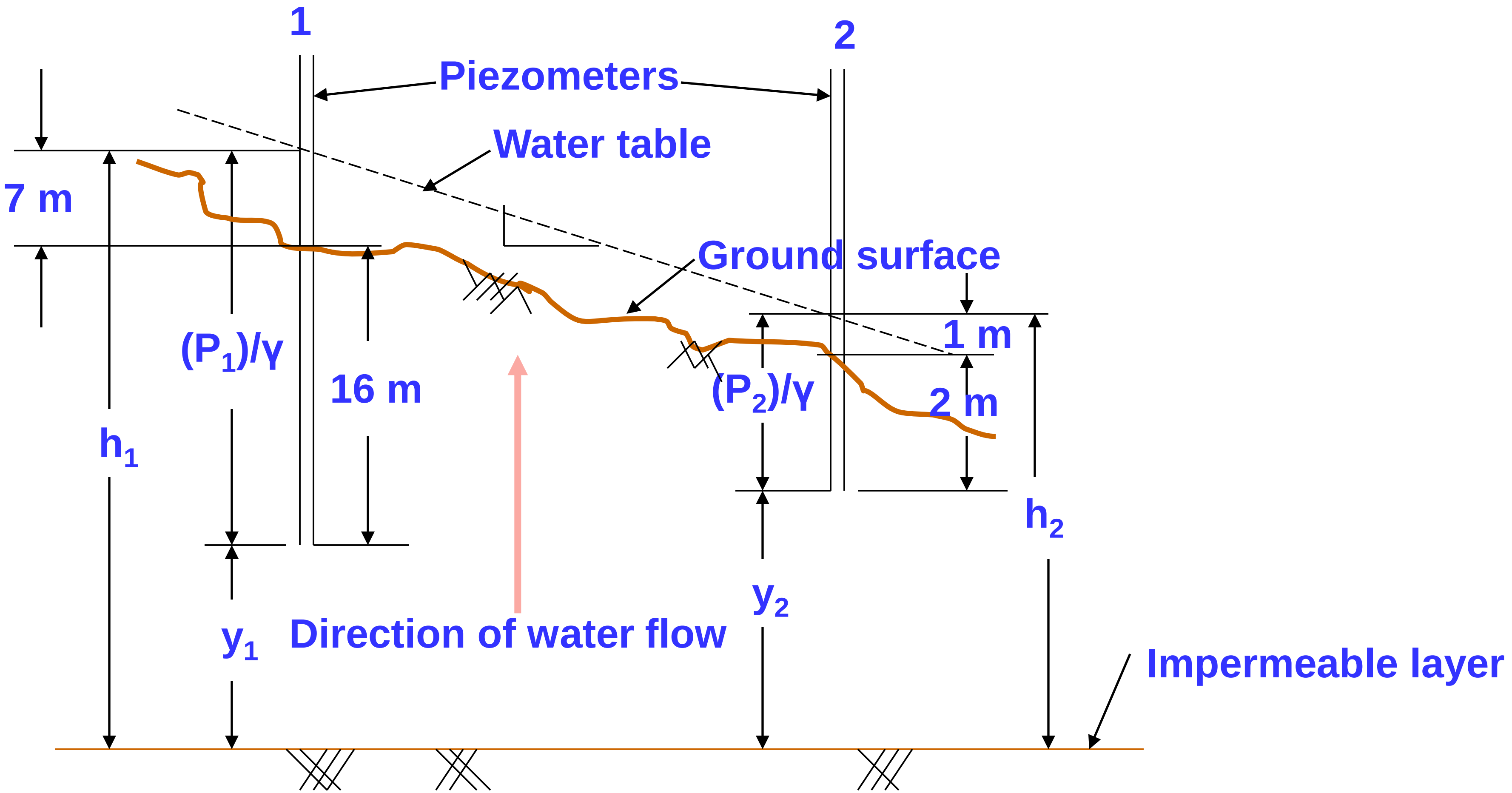
$Q = Aki = (1000 \times 20)(350)(10/100) = 700{,}000\ m^3/yr$

Q = flow through the section 1000 m wide, 20 m deep



$h_1 = p_1/\gamma + y_1$ **Hydraulic gradient,** $i_1 = h_1/L$, $i_2 = h_2/L$ $i = \Delta h/L$

$h_2 = p_2/\gamma + y_2$ **Hydraulic head loss,** $h_l = h_1 - h_2 = \Delta h$



$h_1 = p_1/\gamma + y_1 = 23 + y_1$

$h_2 = p_2/\gamma + y_2 = 3 + y_2$

$y_2 = y_1 + 14$

$h_2 = 3 + y_1 + 14 = 17 + y_1$

$h_L = h_1 - h_2 = (23 + y_1) - (17 + y_1) = 6$

$h_L/L = 6/(16\text{-}2) = 0.43$

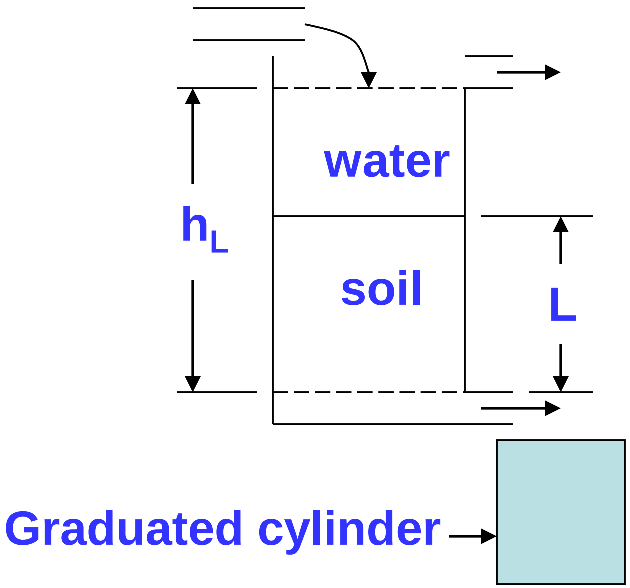
If k = 2 m/yr & A = 1 ha, then

$v = kh_L/L = 2(0.43) = 0.86$ m/yr

$Q = Av = 1\text{ha} \times 0.86$ m/yr

$= 0.86$ ha-m/yr

CONSTANT HEAD PERMEAMETER



$v = ki = kh_L/L$

$A = \pi d^2/4$

d = diameter of permeameter

$Q = Av = Akh_L/L$

$k = QL/(Ah_L)$

Example: