**Al- karkh University**

**Collage of Energy and Environment science**

**Environment science Department**

# Water Resources Lab

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# Lab. 1 Climate Elements

Climate is defined as the weather changes in a large area and for a period of time long enough to identify all its statistical features. Climatological change represents the differences in the data of the average climatic readings or among sequential climatological times.

Climate elements are including rainfall, relative humidity, temperature, evaporation, sun shine, wind speed and evapotranspiration.

## Water availability of climate elements

Water availability elements including rainfall and relative humidity, where are important elements in the climate and water surplus occurred.

1- **Rainfall (mm)** :To calculate the monthly averages of rainfall for a specified period (number of years) by dividing the total monthly values by the number of years.

2- **Relative humidity (RH%)** : is defined the ratio between the pressures of water vapor real to pressure saturated water vapor in the air at the same temperature.

## Water losses climate elements

The basic elements of water losses are temperature, evaporation, sun shine, wind speed and evapotranspiration.

1- **Temperature** (C°): Temperature represents an important factor in the evaporation and Evapotranspiration, which results in worming air. Temperature is one of the climate elements that have great role in the hydrological cycle .

2- **Sunshine** (hour/day): is a solar number of hours in one day and hour brightness functions as solar influence on the temperature and relative humidity and also effects on the real evapotranspiration.

3- **Wind Speed** (m/sec): is a great role in the amount of evaporation as the rate of evaporation increases with the excess of the wind speed.

4- **Evaporation From Class (A) Pan** (mm): is an important element in water balance and hydrological cycle and it is one of the water loss parameters connected with other factors temperature, relative humidity, wind speed, sun shine, and area of evaporation surfaces.

For example:

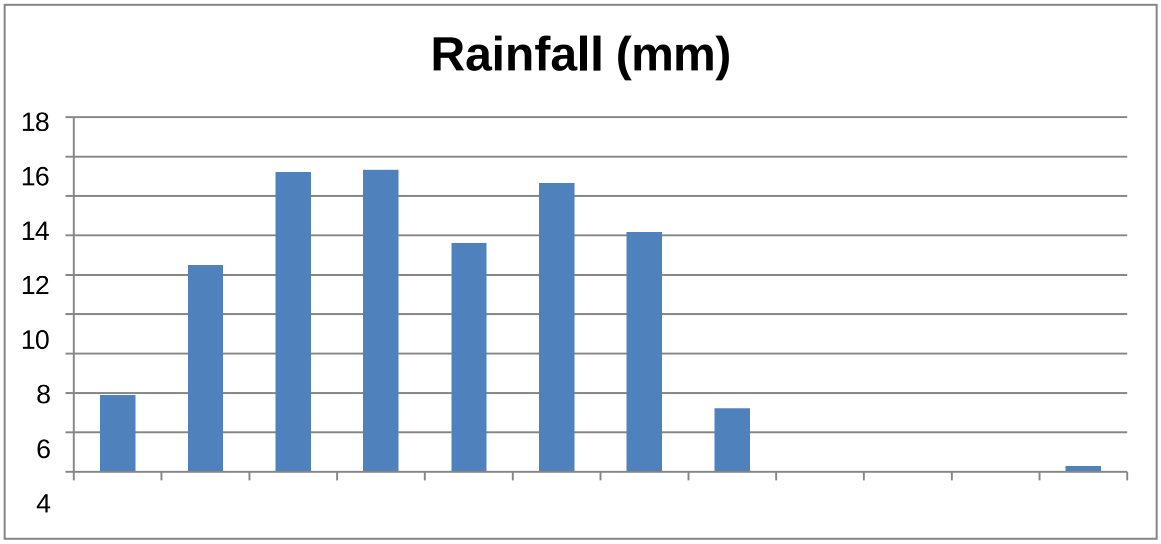
To calculate the monthly averages of rainfall for a specified period (number of years) by dividing the total monthly values by the number of years.

Example 1/ calculated the monthly averages of rainfall for the period (2002-2012) and draw the chart of monthly averages values.

| year | JAN. | FEB. |
|---|---|---|
| 2002 | 24.1 | 2.4 |
| 2003 | M | 1 |
| 2004 | 16.2 | 1.8 |
| 2005 | 20.7 | 11.7 |
| 2006 | 13.3 | 28.9 |
| 2007 | 21.1 | 8.8 |
| 2008 | 20.4 | 9.9 |
| 2009 | 2.2 | 1.5 |
| 2010 | 1.6 | 26.1 |
| 2011 | 31.3 | 27.5 |
| 2012 | 2.4 | 8.4 |
| total | 153.304 | 128 |
| average | 15.33 | 11.63 |

Example 2/

| Month | Rainfall (mm) |
|---|---|
| **Oct.** | **3.9** |
| **Nov.** | **10.5** |
| **Dec.** | **15.2** |
| **Jan.** | **15.33** |
| **Feb.** | **11.63** |
| **Mar.** | **14.64** |
| **Apr.** | **12.14** |
| **May** | **3.22** |
| **Jun.** | **0.01** |
| **July.** | **0** |
| **Aug.** | **0** |
| **Sep.** | **0.29** |




The annual rainfall is equal to the sum of the monthly average values for a year or a specified period (number of years).

**Problem 1:** calculated the monthly averages of the following climate elements for the period (2007-2016) .

## Rainfall (mm)

| YEAR | JAN. | FEB. | MAR. | APR. | MAY. | JUN. | JUL. | AUG. | SEP. | OCT. | NOV. | DEC. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2007 | 12.4 | 2.4 | 0.001 | 8.3 | 0.001 | 0.0 | 0.0 | 0.0 | 0.0 | 0.001 | 0.001 | 12.8 |
| 2008 | 19.6 | 1.0 | 0.5 | 0.2 | 2.0 | 0.0 | 0.0 | 0.001 | 0.0 | 28.8 | 0.5 | 19.8 |
| 2009 | 0.001 | 5.8 | 19.5 | 16.8 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 7.4 | 5.1 | 9.5 |
| 2010 | 2.7 | 14.8 | 5.9 | 13.4 | 8.6 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 4.9 |
| 2011 | 21.8 | 19.8 | 4.8 | 21.9 | 1.6 | 0.001 | 0.0 | 0.0 | 0.0 | 0.3 | 0.001 | 1.1 |
| 2012 | 0.2 | 3.9 | 2.8 | 0.2 | 1.7 | 0.0 | 0.0 | 0.0 | 0.0 | 2.4 | 15.7 | 21.9 |
| 2013 | 27.6 | 3.2 | 0.001 | 0.001 | 20.0 | 0.0 | 0.0 | 0.0 | 0.0 | 1.9 | 103.3 | 0.1 |
| 2014 | 37.7 | 2.6 | 26.3 | 12.6 | 0.001 | 0.001 | 0.0 | 0.0 | 0.0 | 2.9 | 16.0 | 1.8 |
| 2015 | 4.8 | 5.5 | 3.4 | 1.6 | 6.7 | 0.0 | 0.0 | 0.0 | 0.001 | 38.4 | 46.6 | 32.7 |
| 2016 | 5.7 | 29.1 | 23.8 | 7.0 | 0.001 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.001 | 28.6 |

## Relative humidity

| Year | Jan. | Feb. | Mar. | Apr. | May. | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2007 | 69 | 63 | 50 | 48 | 33 | 27 | 23 | 28 | 31 | 39 | 50 | 60 |
| 2008 | 63 | 55 | 41 | 36 | 33 | 26 | 24 | 27 | 37 | 52 | 64 | 61 |
| 2009 | 61 | 58 | 50 | 48 | 39 | 30 | 27 | 28 | 35 | 43 | 58 | 65 |
| 2010 | 57 | 53 | 44 | 43 | 31 | 27 | 22 | 21 | 27 | 36 | 41 | 55 |
| 2011 | 70 | 61 | 42 | 39 | 30 | 30 | 22 | 21 | 31 | 40 | 51 | 55 |
| 2012 | 62 | 52 | 39 | 31 | 26 | 21 | 22 | 25 | 27 | 41 | 65 | 60 |
| 2013 | 65 | 60 | 40 | 33 | 44 | 24 | 23 | 24 | 30 | 36 | 76 | 65 |
| 2014 | 79 | 56 | 51 | 40 | 28 | 24 | 23 | 24 | 31 | 44 | 57 | 69 |
| 2015 | 62 | 53 | 44 | 35 | 26 | 26 | 27 | 26 | 26 | 46 | 69 | 70 |
| 2016 | 63 | 58 | 47 | 35 | 26 | 22 | 19 | 22 | 28 | 37 | 42 | 64 |

## MAX. Temperature (C°)

| Year | Jan. | Feb. | Mar. | Apr. | May. | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2007 | 15.6 | 20.9 | 25.5 | 30.1 | 42.3 | 44.4 | 46.1 | 46.1 | 43.2 | 36.7 | 27.3 | 19.4 |
| 2008 | 13.5 | 20.0 | 30.9 | 34.6 | 38.7 | 43.4 | 46.1 | 46.1 | 42.3 | 33.6 | 26.4 | 19.6 |
| 2009 | 17.9 | 22.8 | 25.9 | 30.8 | 38.6 | 44.3 | 44.5 | 45.5 | 40.2 | 35.4 | 24.7 | 21.5 |
| 2010 | 21.8 | 23.2 | 28.8 | 32.0 | 39.3 | 44.9 | 46.8 | 46.3 | 42.6 | 36.4 | 28.3 | 21.6 |
| 2011 | 16.4 | 19.3 | 25.2 | 31.3 | 37.6 | 42.9 | 45.4 | 45.1 | 41.0 | 32.3 | 21.7 | 18.2 |
| 2012 | 17.4 | 18.7 | 23.6 | 33.3 | 39.0 | 44.0 | 46.6 | 45.1 | 41.7 | *35.2* | 25.8 | 19.5 |
| 2013 | 18.0 | 22.2 | 27.3 | 32.4 | 35.8 | 42.4 | 44.9 | 44.8 | 40.7 | *32.5* | 23.8 | 17.2 |
| 2014 | 16.6 | 20.5 | 26.5 | 33.0 | 39.2 | 42.8 | 45.1 | 46.2 | 41.2 | 33.4 | 23.9 | 21.0 |
| 2015 | 18.3 | 21.4 | 26.3 | 32.0 | 39.9 | 43.3 | 47.1 | 46.5 | 43.8 | 35.9 | 23.6 | 17.3 |
| 2016 | 17.3 | 22.2 | 26.6 | 33.6 | 38.9 | 44.1 | 46.7 | 47.5 | 41.1 | 45.6 | 25.5 | 17.1 |

## MIN. Temperature (C°)

| Year | Jan. | Feb. | Mar. | Apr. | May. | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2007 | 4.1 | 9.2 | 12.0 | 17.1 | 25.3 | 27.9 | 29.6 | 29.3 | 26.0 | 21.0 | 12.6 | 6.4 |
| 2008 | 3.4 | 7.2 | 15.2 | 19.8 | 23.2 | 28.2 | 27.4 | 27.4 | 27.1 | 20.5 | 12.1 | 6.0 |
| 2009 | 3.8 | 10.5 | 12.6 | 17.7 | 24.6 | 28.4 | 28.4 | 28.9 | 25.0 | 20.7 | 12.1 | 9.2 |
| 2010 | 7.9 | 10.3 | 14.6 | 18.9 | 24.5 | 28.6 | 30.7 | 31.7 | 27.6 | 22.1 | 12.9 | 8.1 |
| 2011 | 6.2 | 8.3 | 12.0 | 18.3 | 23.7 | 23.7 | 30.7 | 29`7 | 26.1 | 18.7 | 9.2 | 8.1 |
| 2012 | 5.9 | 7.2 | 10.6 | 19.7 | 25.0 | 28.2 | 30.7 | 29.4 | 25.7 | 21.7 | 14.9 | 9.2 |
| 2013 | 7.8 | 10.0 | 14.0 | 18.2 | 23.1 | 28.0 | 29.6 | 30.5 | 25.4 | 17.3 | 14.6 | 8.8 |
| 2014 | 7.5 | 8.2 | 14.8 | 19.7 | 25.0 | 28.1 | 30.3 | 31.0 | 27.1 | 20.9 | 12.0 | 9.6 |
| 2015 | 6.9 | 9.5 | 12.7 | 17.1 | 25.1 | 28.0 | 31.4 | 30.4 | 29 | 23.6 | 13.1 | 7.1 |
| 2016 | 6.9 | 10.0 | 14.3 | 19.8 | 24.6 | 29.2 | 31.1 | 32.1 | 26.5 | 20.7 | 11.5 | 6.4 |

Problem 2: calculated and draw the annual averages of rain fall and evaporation for the last 6 years

## Wind Speed (m/sec)

| Year | Jan. | Feb. | Mar. | Apr. | May. | Jun. | Jul. | Aug. | Sep. | Oct. | Nov. | Dec. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2007 | 1.0 | 1.8 | 1.9 | 2.6 | 2.0 | 2.7 | 2.3 | 2.1 | 2.4 | 1.2 | 0.9 | 0.9 |
| 2008 | 1.1 | 2.1 | 1.7 | 2.2 | 2.0 | 3.6 | 2.3 | 1.6 | 1.5 | 1.6 | 0.9 | 1.7 |
| 2009 | 1.4 | 1.7 | 2.3 | 1.8 | 1.7 | 2.0 | 2.5 | 1.5 | 1.8 | 1.4 | 1.0 | 0.9 |
| 2010 | 1.6 | 1.8 | 2.0 | 1.6 | 1.8 | 2.3 | 2.6 | 1.6 | 1.5 | 1.5 | 0.6 | 1.2 |
| 2011 | 1.1 | 1.7 | 2.3 | 2.2 | 1.9 | 3.1 | 2.2 | 2.1 | 1.2 | 1.6 | 1.3 | 1.4 |
| 2012 | 1.4 | 2.3 | 2.1 | 2.0 | 1.9 | 2.3 | 2.0 | 1.8 | 1.5 | 1.2 | 1.1 | 1.6 |
| 2013 | 2.0 | 1.9 | 2.3 | 2.1 | 2.3 | 3.1 | 3.0 | 2.1 | 1.7 | 1.9 | 1.6 | 1.9 |
| 2014 | 1.9 | 2.0 | 2.0 | 2.1 | 2.4 | 2.4 | 2.5 | 2.3 | 1.7 | 1.7 | 1.5 | 1.3 |
| 2015 | 1.7 | 1.7 | 1.6 | 1.9 | 2.1 | 1.9 | 2.1 | 1.5 | 1.1 | 0.7 | 1.2 | 1.2 |
| 2016 | 1.1 | 1.4 | 2.2 | 1.4 | 2.0 | 1.9 | 2.3 | 1.3 | 1.9 | 1.1 | 1.8 | 0.9 |

## Sunshine (hour/day)

| Year | JAN | FEB | MAR | APR | MAY | JUN | JULY | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2007 | 5.9 | 7.1 | 8.0 | 6.7 | 9.2 | 11.7 | 11.9 | 11.2 | 10.5 | 8.5 | 8.0 | 6.8 |
| 2008 | 4.8 | 6.5 | 7.8 | 7.4 | 8.8 | 9.4 | 10.9 | 10.5 | 8.4 | 7.6 | 7.9 | 6.5 |
| 2009 | 6.9 | 6.0 | 7.1 | 7.7 | 8.2 | 9.1 | 10.2 | 10.2 | 9.8 | 7.3 | 5.5 | 5.1 |
| 2010 | 6.5 | 6.0 | 6.5 | 7.0 | 7.5 | 9.7 | 10.3 | 10.4 | 8.8 | 7.8 | 7.9 | 5.9 |
| 2011 | 5.2 | 6.0 | 8.0 | 6.7 | 8.3 | 9.7 | 10.3 | 10.5 | 9.7 | 8.3 | 7.1 | 6.8 |
| 2012 | 6.4 | 6.6 | 7.9 | 7.9 | 6.2 | 10.4 | 10.6 | 10.5 | 10.1 | 5.8 | 5.5 | 6.1 |
| 2013 | 5.8 | 7.5 | 7.3 | 8.8 | 7.5 | 10.4 | 10.9 | 10.7 | 9.8 | 8.5 | 5.0 | 6.0 |
| 2014 | 8.3 | 9.4 | 7.9 | 8.4 | 9.2 | 9.7 | 10.6 | 10.6 | 10.3 | 7.6 | 6.5 | 6.4 |
| 2015 | 6.0 | 6.8 | 8.4 | 8.9 | M | 9.5 | 9.8 | 9.6 | 7.2 | 8.3 | 6.5 | 6.0 |
| 2016 | 5.8 | 6.4 | 8.4 | 8.4 | 9.7 | 11.9 | 11.3 | 10.3 | 10.6 | 9.2 | 8.0 | 5.9 |

## Evaporation (mm)

| YEAR | JAN. | FEB. | MAR. | APR. | MAY. | JUN. | JUL. | AUG. | SEP. | OCT. | NOV. | DEC. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2007 | 66.3 | 110.1 | 219.6 | 271.6 | 407.0 | 546.4 | M | M | 415.1 | 277.9 | 148.8 | 103.1 |
| 2008 | 69.1 | 129.9 | 257.4 | 310.6 | 408.1 | 525.3 | 551.4 | 494.3 | 357.1 | 237.0 | 111.0 | 94.2 |
| 2009 | 82.4 | 132.0 | 190.4 | 219.5 | 295.6 | 369.0 | 425.1 | 453.3 | 340.8 | 239.1 | 137.2 | 58.5 |
| 2010 | 92.5 | 109.7 | 217.3 | 340.7 | 411.5 | 510.3 | 579.0 | 480.7 | 387.1 | 277.4 | 144.5 | 117.1 |
| 2011 | 74.5 | 91.2 | 180.7 | 204.8 | 280.0 | 403.0 | 429.6 | 409.7 | 296.9 | 192.5 | 94.6 | 66.8 |
| 2012 | 70.1 | 106.4 | 154.9 | 239.0 | 332.3 | 390.7 | 385.2 | 402.1 | 294.7 | 176.1 | 81.6 | 52.7 |
| 2013 | 55.6 | 88.8 | 181.9 | 216.8 | 246.5 | 391.3 | 435.9 | 375.7 | 276.9 | 190.5 | 67.3 | 48.0 |
| 2014 | 38.2 | 83.1 | 123.7 | 198.8 | 286.7 | 346.4 | 422.0 | 384.2 | 296.9 | 157.8 | 77.9 | 48.5 |
| 2015 | 62.3 | 82.1 | 124.0 | 197.9 | 305.6 | 376.7 | 455.5 | 377.3 | 293.4 | 181.2 | 95.5 | 47.2 |
| 2016 | 61.7 | 84.7 | 126.3 | 210.1 | 324.2 | 362.1 | 400.6 | 408.6 | 286.3 | 175.9 | 101.1 | 53.7 |

# Lab. 2 Classification of the climate

There are several classification for climate to find and determine the type of the climate. The wet period in Iraq was determined according to rainfall, it's confined for months from October to May (Kettaneh and Gangopadhyaya, 1974), (Ali *et al*, 2000), three of these classifications will be used to find the type of climate in area as follows:

## A- Mather (1974) classification:

Climate had been classified in to three classes according to climate index of Mather (1974), based on the relationship between rainfall and evapotranspiration . The climate Index is given as:

Im = ] (P / PE) -1[ * 100...........................................(1)

Where:

Im = Climate index

P = Rainfall

PE = Potential evapotranspiration.

When (Im) negative value they represent dry climate, and when (Im) positive value represents a humid climate.

**Table 1: Classification of the climate according to (Mather, 1974)**

| Claimant Type | Range of Im |
|---|---|
| Dry-sub humid | 0.0 to -33.3 |
| Semi-Arid | -33.3 to -66.7 |
| Arid | -66.7 to -100 |

For example:

- What is the type of climate of the following data: P= 89.85 mm, PE = 1077.18 mm.
- Solution :

Im = ] (P / PE) -1[ * 100

Im = - 91.7   the climate type is arid in the area.

**B- Brown and Cocheme (1973) classification:**

According to ( Brown and Cocheme, 1973) classification the humidity index (H.I) depended on the ratio between rainfall and potential evapotranspiration comparable to the following equation

H.I = P/ PEc -------------------------------------------(2)

H.I: Humidity index.

P: Annual rainfall (mm).

PE: Potential evapotranspiration (mm).

**Table 2:Classification of the climate according to (Brown and Cocheme, 1973).**

| Climate type | | Range HI |
|---|---|---|
| Humid | | HI > 1 |
| Most | Not humid | HI< 1< 2HI |
| Moist to Dry | | 2HI< 1< 4HI |
| Dry | | 4HI< 1< 10HI |
| V. Dry | | 10HI < 1 |

For example:

- What is the type of climate of the following data: P= 17.5 mm, PEc = 5.06 mm in Jan. month.
- Solution :

H.I = P/ PEc

H.I = 3.46 the climate type is humid in the Jan.

**C- Al-Kubaisi (2004) Classification:**

The classification suggested by Al-Kubaisi (2004) to find the climate type by using the annual dryness treatment (AI) depending on mean annual rainfall and temperature according to the following equation:

AI.1 = 1.0 × P / (11.525 × t) -------------------------(3)

AI.2 = $2\sqrt{p}$ /t --------------------------------------(4)

Where:

AI: Annual dryness index.

P: Mean annual rainfall (mm).

t: Mean annual temperature (C°).

The value of the (AI.1) represents the classification of the dominated climate, while the value (AI.2) represents a modification of the latter classification and as it is shown in Table 3.

**Table 3: Classification of climate according to (Al-Kubaisi, 2004)**

| Type 1 | Evaluation | Type 2 | Evaluation |
|---|---|---|---|
| AI.1 > 1.0 | Humid to Moist | AI.2 ≥ 4 | Humid |
| | | 2.5 ≤ AI.2 < 4 | Humid to Moist |
| | | 1.85 ≤ AI.2 < 2.5 | Moist |
| | | 1.5 ≤ AI.2 < 1.85 | Moist to sub arid |
| AI. 1 < 1.0 | Sub arid to Arid | 1.0 ≤ AI.2 < 1.5 | Sub arid |
| | | AI.2 < 1.0 | Arid |

For example:

- AI.1 = 0.32 it means that the dominated climate in the area is sub arid to arid.
- AI- 2 = 0.79 it means that the climate in the area is arid.

**Homework 1:** what is the classification of climate using the following data?

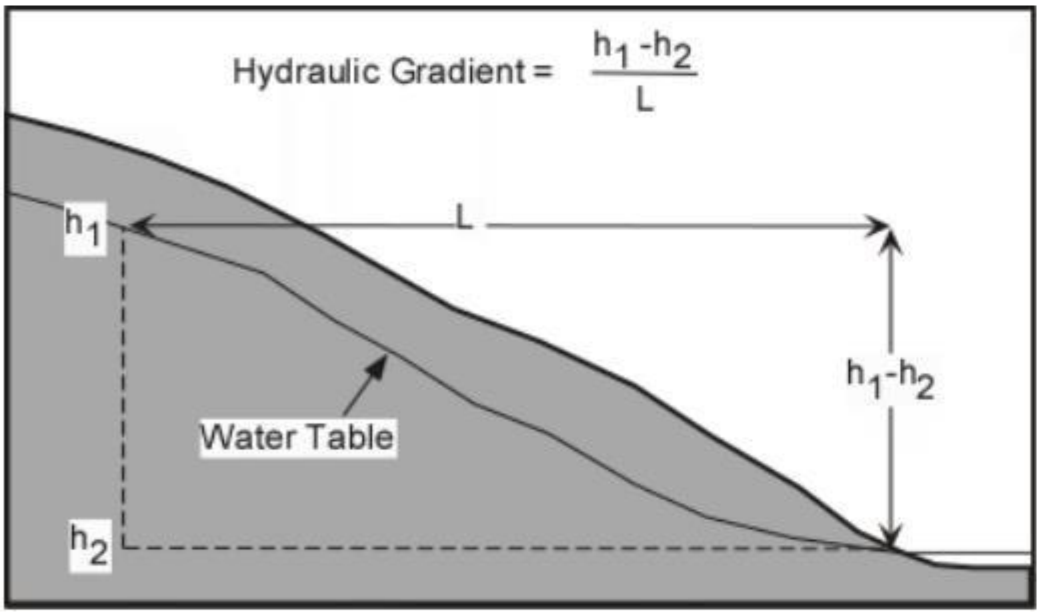
| Months | P (mm) | PEc (mm) | Temp. (C°) |
|---|---|---|---|
| Oct. | 3.9 | 67.67 | 26.5 |
| Nov. | 10.5 | 17.56 | 17.05 |
| Dec. | 15.2 | 6.61 | 12.4 |
| Jan. | 16.34 | 4.02 | 10.3 |
| Feb. | 13.51 | 6.75 | 12.33 |
| Mar. | 14.64 | 21.34 | 17.5 |
| Apr. | 12.11 | 50.18 | 23.7 |
| May | 3.22 | 109.92 | 30.1 |
| Jun. | 0.01 | 176.87 | 34.3 |
| Jul. | 0 | 293.58 | 36.2 |
| Aug. | 0 | 196.58 | 35.4 |
| Sep. | 0.29 | 126.10 | 31.4 |
| Total | | | |

## Ground Water Flow Nets

Groundwater flow occurs on a variety of scales. Local – Shallow flow occurs over short times and distances, whereas, deep long distance flow occurs over time scales of centuries.

The rate at which groundwater moves through the saturated zone depends on the permeability of the rock and the hydraulic head. The hydraulic head is defined as the difference in elevation between two points on the water table.

The hydraulic gradient is the hydraulic head divided by the distance between two points on the water table.




The velocity, V, is of groundwater flow is given by:

V = K (h2- h1) / L .................................... (1)

where K is the hydraulic conductivity, which is a measure of the permeability of the material through which the water is following.

If we multiply this expression by the area, A, through which the water is moving, then we get the discharge ( Q) which is Darcy's Law.

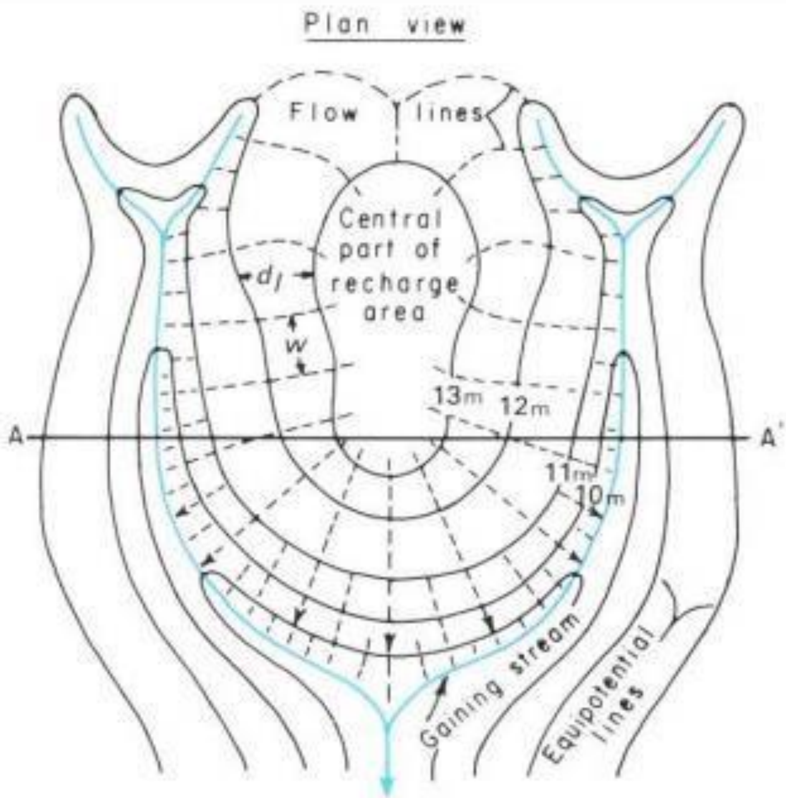
Q = A K (h2 - h1) / L..........................(2)

It simply states that discharge is proportional to the hydraulic gradient times the permeability.

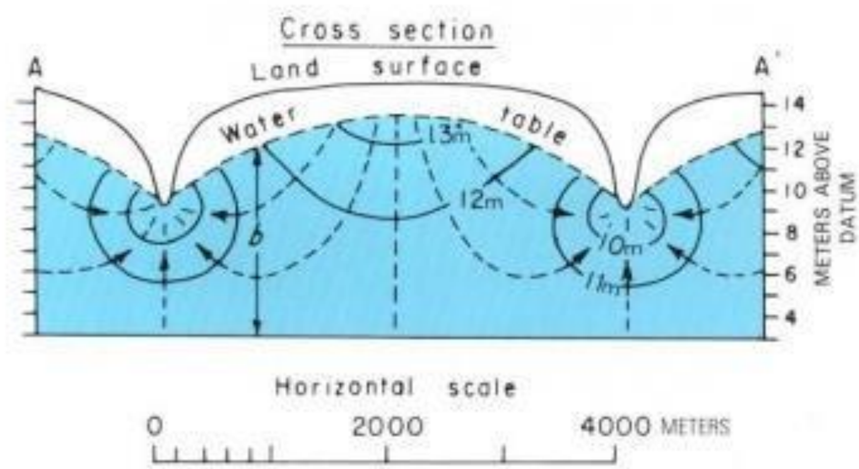
Discharge is higher if the hydraulic gradient is high and/or of the permeability is high.

Note that like stream discharge, Q has units of volume per time

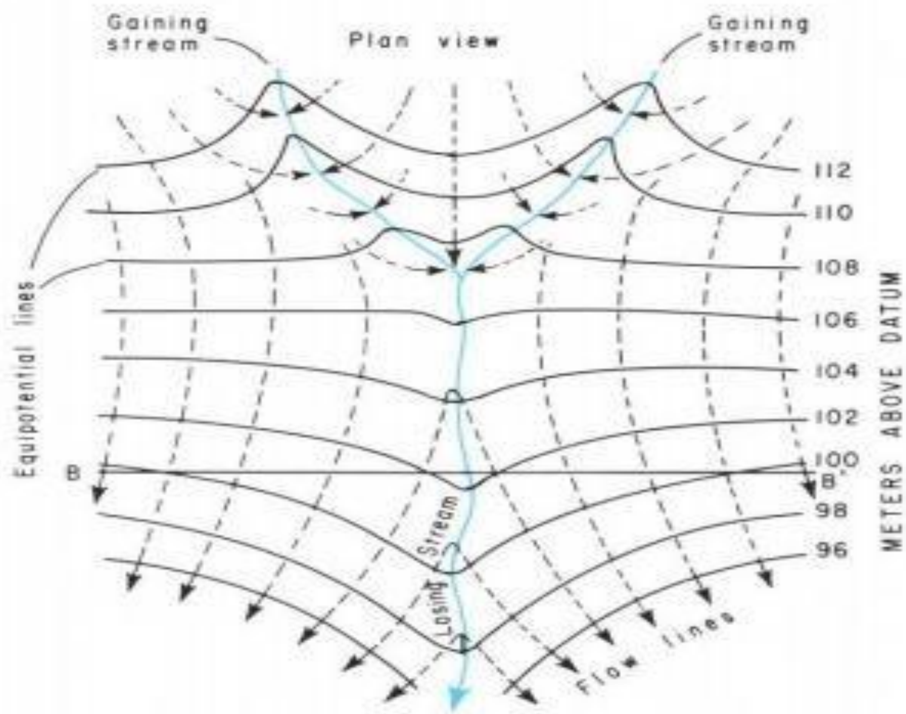
(i.e. cubic meters per second).


Plan view
Flow lines
Central part of recharge area
$d_l$
w
13m
12m
11m
10m
A
A'
Gaining stream
Equipotential lines

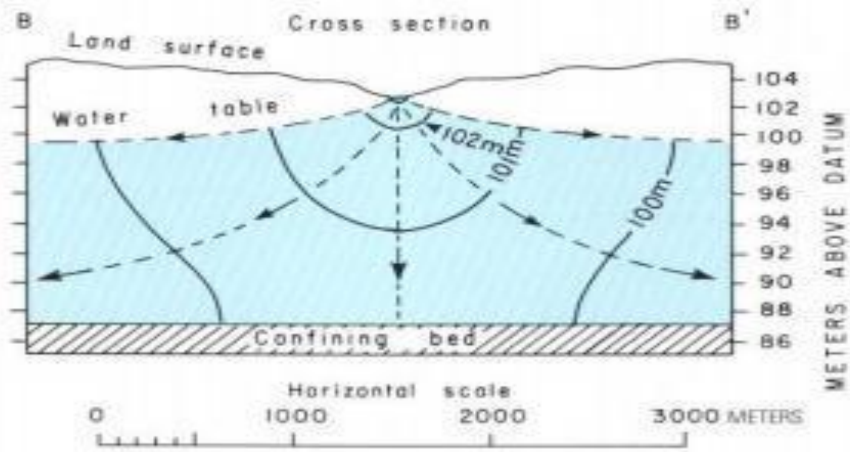
(1)


Cross section
A
A'
Land surface
Water table
13m
12m
10m
11m
b
14
12
10
8
6
4
METERS ABOVE DATUM
Horizontal scale
0
2000
4000 METERS

(2)


Gaining stream
Plan view
Gaining stream
Equipotential lines
112
110
108
106
104
102
100
B
B'
98
96
METERS ABOVE DATUM
Losing Stream
Flow lines

(3)


B
Cross section
B'
Land surface
Water table
102m
101m
100m
104
102
100
98
96
94
92
90
88
86
METERS ABOVE DATUM
Confining bed
Horizontal scale
0
1000
2000
3000 METERS

(4)

Homework 1: **Draw flow net map of the following wells, defining the flow directions.**

| Well No. | Elevation (m) (1) | Depth to groundwater (m) (Water Table) ( 2) | Water head on s.l. (m) (3) | Well No. | Elevation (m) (1) | Depth to groundwater (m) ( 2) | Water head on s.l. (m) (3) |
|---|---|---|---|---|---|---|---|
| W1 | 190 | 17 | 183 | W15 | 179 | 9 | |
| W2 | 191 | 3 | | W16 | 181 | 16 | |
| W3 | 156 | 18 | | W17 | 162 | 4 | |
| W4 | 156 | 11 | | W18 | 220 | 13 | |
| W5 | 174 | 16 | | W19 | 205 | 8 | |
| W6 | 178 | 1 | | W20 | 132 | 6 | |
| W7 | 188 | 7 | | W21 | 135 | 8 | |
| W8 | 144 | 9 | | W22 | 149 | 5 | |
| W9 | 158 | 5 | | W23 | 171 | 6 | |
| W10 | 149 | 10 | | W24 | 184 | 9 | |
| W11 | 131 | 9 | | W25 | 190 | 9 | |
| W12 | 141 | 9 | | W26 | 210 | 15 | |
| W13 | 163 | 13 | | W27 | 216 | 13 | |
| W14 | 171 | 12 | | W28 | 177 | 17 | |

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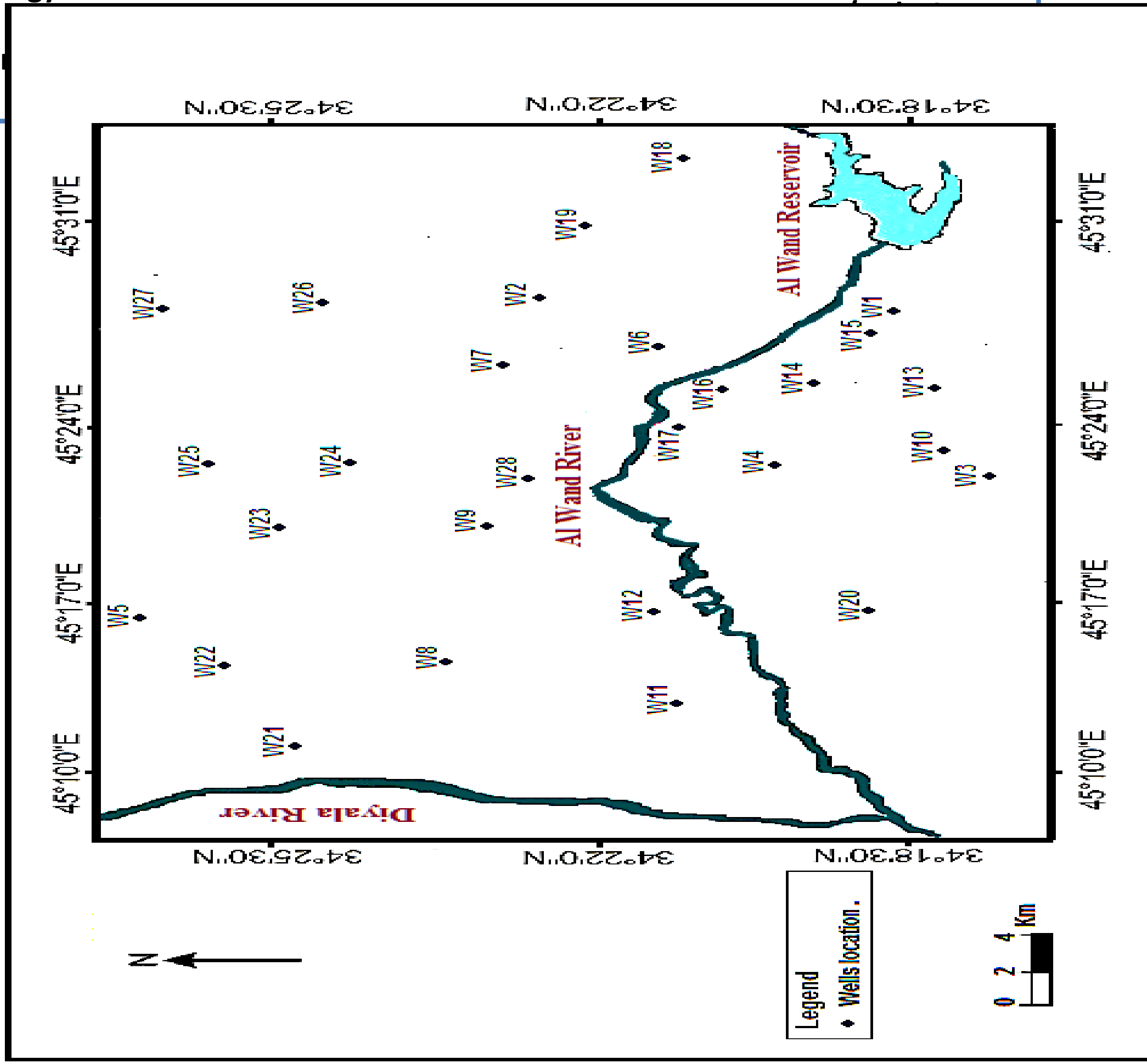

# Lab. 4 Quality of Water

The quality of water is a consequence of the natural physical and chemical properties of the water. The main physical properties include electrical conductivity (EC), total dissolved solids (TDS), hydrogen ion concentration (pH), Total hardness (TH), temperature, color and odor while the main chemical properties include the major ions Na, Mg, Ca and K as cations and Cl, $SO_4$ , $HCO_3$ , $NO_3$  as anions.

# Q/ how to classify the water according to TDS?

The total dissolved solids (TDS) is the term applied to material residue left in a vessel after evaporation of a water sample and subsequent drying of the residue. The concentration of the dissolved ions within natural water depends on the type of soil and rocks that are in contact with it and the period of tangency process and climate. The TDS represents a total summation of ionic concentrations of cations and anions. It is measured by the (ppm) or (mg/L) units. There are three classifications of water (Altoviski, 1962; Drever, 1997 and Todd, 2007).

| Water Class | Altoviski, 1962 | Drever(1997) | Todd(2007) |
|---|---|---|---|
| **Fresh Water** | **0 - 1000** | **< 1000** | **10 - 1000** |
| **Slightly-brackish Water** | **1000 – 3000** | **1000 - 2000** | **-----** |
| **Brackish Water** | **3000 - 10000** | **2000- 20000** | **1000 – 10000** |
| **Salty (Saline) Water** | **10000 - 50000** | **35000** | **10000 - 100000** |
| **Brine Water** | **> 50000** | **> 35000** | **> 100000** |

**For example:**

Q/ The TDS values of water samples is given in Table1, wright the average of TDS and what is the classifications of water according the (Drever, 1997 ) classification?

| Water samples | W1 | W2 | W3 | average |
|---|---|---|---|---|
| TDS (ppm) | 2350 | 1514 | 2204 | 2022.7 |

**Solution:**

$$\text{average} = \frac{\sum TDS\ values}{number\ of\ samples} = \frac{w1+w2+w3}{3} = \frac{2350+1514+2204}{3}$$

= **2022.7** ppm

**The water is classified as brackish water in w1, w3 and as Slightly-brackish Water in w2**

# classifications of water according to EC

Electrical Conductivity (EC) is the ability of water to conduct an electric current or its ability to contact ($1cm^3$) of water to electrical current at ($25C^\circ$). It is measured in the unit of (μS/cm) and also named micro Siemens per cm.

The EC depends on water temperature, where an increase in water temperature of one degree ($C^o$) causes an increase in electrical conductivity by (2%). Also the EC increases with the increase of the total dissolved salts (TDS).

The water type can be determent by the relationship between EC and mineralization degree of water according to (Detay, 1997) classification.

| EC μS/cm | Mineralization |
|---|---|
| <100 | Very Weakly Mineralized water |
| 100-200 | Weakly Mineralized water |
| 200-400 | Slightly Mineralized water |
| 400-600 | Moderately Mineralized water |
| 600-1000 | Highly Mineralized water |

| | |
|---|---|
| >1000 | Excessively Mineralized water |

**For example:**

Q/ The EC values of water samples is given in Table1, what is the classifications of water according the (Detay, 1997 ) classification?

| Water samples | S1 | S2 | S3 |
|---|---|---|---|
| EC (µS/cm) | 350 | 614 | 1600 |

**Solution:**

**The water type is classified as Slightly Mineralized water in S1 and as Highly Mineralized water in S2 and as Excessively Mineralized water in S3.**

# classifications of water according to TH

**Total hardness (TH) mainly reflects water contents of calcium and magnesium ions and it is expressed by its equivalent from calcium carbonate according to the following equation:**

$$TH = 2.497\ Ca + 4.115\ Mg \text{ ----------- } (1)$$

**Where TH, Ca, Mg are all measured in ppm.**
**Hardness is an important criterion for determining the usability of water for domestic, drinking and many industrial uses**

**The classification of water hardness according to (Boyd,2000 and Todd, 2007) classification.**

| Type of water | Total Hardness (ppm) | |
|---|---|---|
| | Boyd (2000) | Todd (200 |
| Soft | 0 - 50 | 0 – 60 |
| Moderate Hard | 50 - 150 | 60 - 120 |
| Hard | 150 - 300 | 120 – 180 |
| Very hard | > 300 | > 180 |

**For example:**

Q/ what is the classifications of water hardness if you know The TH value of water sample = 200 ppm?

**Solution:**

The water type according to Boyd is classified as hard water and according to Todd is classified as very hard water.

## Lab. 5 Types of water

The types of water are connected with the chemical and physical properties which change relatively with respect time and place. These changes are slow in groundwater comparing with surface water.

The chemical properties include the major ions Na, Mg, Ca and K as cations and Cl, SO4 , HCO3 , NO3 as anions.

There are many methods to classification of water from the hydrochemical aspect such as (Piper, 1944; Sulin, 1946; Kurolov, 1968; Schoeller, 1972; Collins,1975; Schoeller and Sulin, 1981; and Chadha, 1999). All these classifications depend on the main cations and anions concentrations by unit equivalent weight of ion (epm).

**epm = ion concentration in ppm x charg / m.w.**

| Cations | Charg | M.W. |
|---|---|---|
| Ca | +2 | 40 |
| Mg | +2 | 24 |
| Na | +1 | 23 |
| K | +1 | 39 |
| **Anions** | | |
| Cl | -1 | 35.5 |
| SO4 | -2 | 96 |
| HCO3 | -1 | 63 |

**Example 1/ calculated the epm and epm% for the sample?**

| Sample | Ca ppm | Mg ppm | Na ppm | K ppm | Cl ppm | $SO_4$ ppm | $HCO_3$ ppm |
|---|---|---|---|---|---|---|---|
| S1 | 125 | 82 | 470 | 14 | 641 | 512 | 264 |

| **Solution /** | **epm** | **epm %** |
|---|---|---|
| Ca = 125*2 /40 | 6.25 | 6.25/33.86 *100= 18.45 |
| Mg = 82*2 /24 | 6.83 | 20.17 |
| Na = 470*1 /23 | 20.43 | 60.33 |
| K = 14*1 /39 | <u>0.35</u> | 1.03 |
| | ∑ = 33.86 | |

| | | |
|---|---|---|
| Cl = 641*1/ 35.5 | 18.05 | 54.86 |
| $SO_4$ = 512*2 / 96 | 10.66 | 32.40 |
| $HCO_3$ = 264*1 / 63 | <u>4.19</u> | 12.7 |
| | ∑ = 32.9 | |

1- **Hydrochemical Formula** (**Kurolov formula**)

This formula depends on the ratio of the main ions, (cations and anions) expressed by (epm %) that are arranged in descending order which have more than (15%) ratio of availability as the following formula :

$$\text{TDS (mg /l)} \quad \frac{\text{(Anions epm\% in decreasing order)}}{\text{(Cations epm\% in decreasing order)}} \quad \text{pH} \qquad \ldots\ldots.1$$

**Example 2/ what is the Hydrochemical formula and water type of the following sample ?**

| Sample | Ca ppm | Mg ppm | Na ppm | K ppm | Cl ppm | $SO_4$ ppm | $HCO_3$ ppm | TDS (mg /l) | PH |
|---|---|---|---|---|---|---|---|---|---|
| S1 | 125 | 82 | 470 | 14 | 641 | 512 | 264 | 2137 | 7.31 |

## Solution /

| Hydrochemical formula | water type |
|---|---|
| $2137 \quad \frac{\text{Cl (54.86)SO4(32.40)}}{\text{Na(60.33) Mg(20.17)Ca(18.45)}} \quad 7.31$ | NaCl |

Homework 1: **What is the Hydrochemical formula and water type of the following samples ?**

| well No. | PH | TDS ppm | $Ca^{+2}$ ppm | $Mg^{+2}$ ppm | $Na^{+}$ ppm | $K^{+}$ ppm | $Cl^{-}$ ppm | $SO_4$ ppm | $HCO_3$ ppm |
|---|---|---|---|---|---|---|---|---|---|
| **W2** | **7.21** | **1514** | **60** | **31** | **280** | **13** | **205** | **525** | **72** |
| **W3** | **7.11** | **2204** | **71** | **35** | **347** | **12** | **280** | **500** | **210** |
| **W6** | **7.22** | **2226** | **126** | **83** | **135** | **12** | **242** | **546** | **66** |
| **W14** | **7.21** | **2100** | **125** | **91** | **385** | **14** | **530** | **569** | **265** |

# Lab. 6 Classification of water

**1- Hydrochemical formula**

**2- Piper Diagram**

Piper (1944) proposed adiagram that permits the classification of water. The Piper diagram is consists of two trilinear plots and a diamond plot. These diagrams depend on dissolved contents in natural water which represent cations and anions by unit (epm%) .

Piper diagram is divided in to seven types as shown in Figure 1 as follows: 

Normal earth Alkaline water:

**a-** with prevailing bicarbonate

**b-** with prevailing bicarbonate and sulfate or chloride

**c-** with prevailing sulfate or chloride

 Earth Alkaline water with increase portion of alkalis:

**d-** with prevailing bicarbonate

**e-** with prevailing sulfate and chloride

 Alkaline water:

**f-** with prevailing bicarbonate

**g-** with prevailing sulfate and chloride

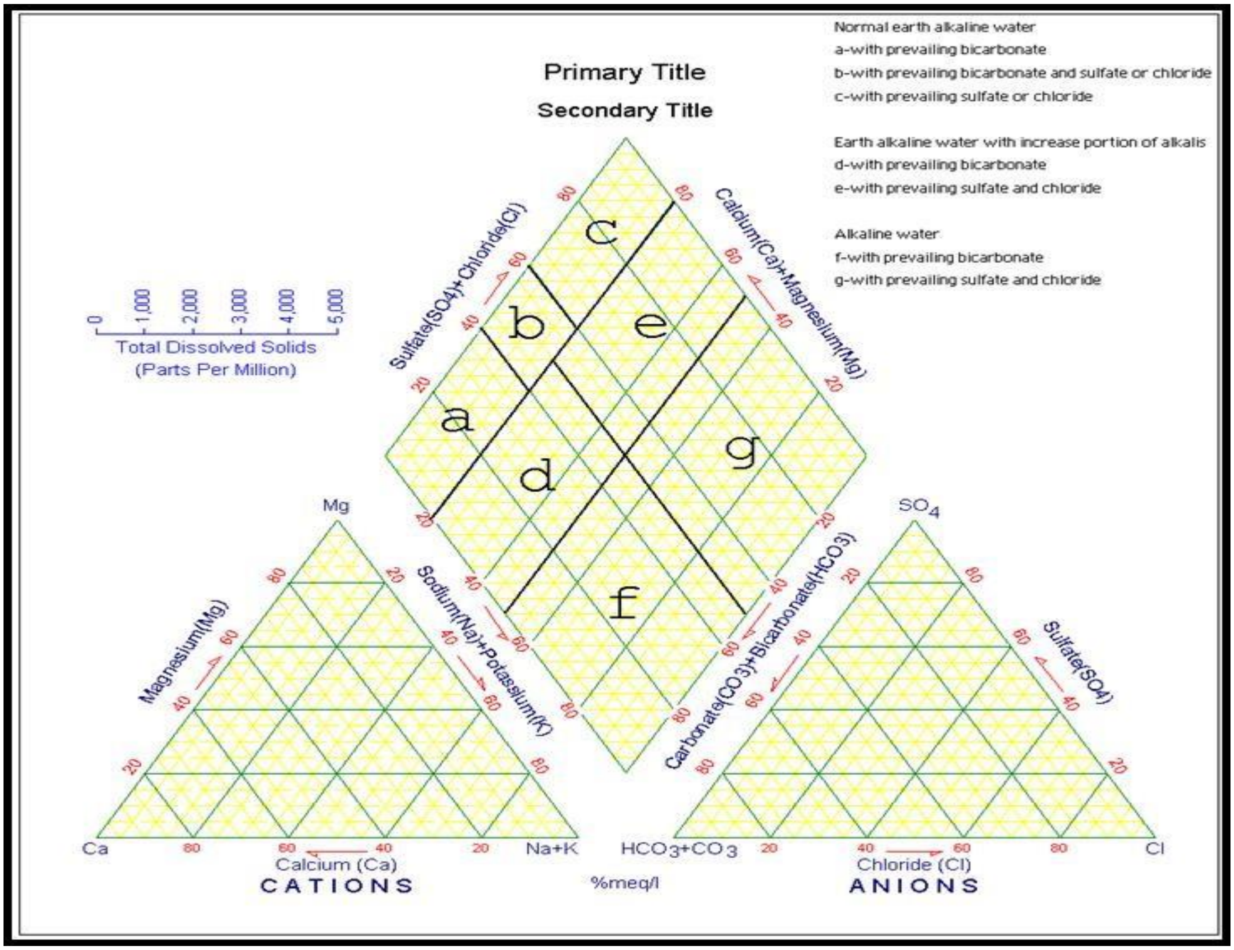


Figure 1: Piper diagram

**Example 1/** what is the classification of water depend on Piper diagram of the following sample ?

| Sample | Ca ppm | Mg ppm | Na ppm | K ppm | Cl ppm | $SO_4$ ppm | $HCO_3$ ppm |
|---|---|---|---|---|---|---|---|
| S1 | 18.45 | 19.96 | 60.52 | 1.05 | 54.67 | 32.24 | 13.08 |

## Solution /

The sample is located in (g) type. This means the type of water is Alkaline water with prevailing sulfate and chloride" respectively.

### 3- Schoeller Classification

This classification uses semi logarithmic graph to plot the concentrations of the anions and cations. The concentrations are plotted in epm % units.

| Sample | Type | | Family | Group |
|---|---|---|---|---|
| | Anion | Cation | | |
| W1 | $rCl>SO_4>HCO_3$ | rNa>Mg>Ca>K | Na -Cl | Cl |

## <u>Water suitability for different purposes</u>

### 1- Water suitability for human drinking purposes

Water suitability depends on several parameters (major and minor elements , inorganic , organic chemicals and biological constituents). For the purpose of evaluating the suitability of water for human drinking, Iraqi standard (IQS, 2009) and World Health Organization Standard (WHO, 2007) were used to determine its suitability as drinking water.

| Parameter | IQS (2009) | WHO (2007) |
|---|---|---|
| EC(µs/cm) | 1500 | 1530 |
| TDS(ppm) | 1000 | 1000 |
| pH (ppm) | 6.5-8.5 | 6.5-8.5 |
| T.H(mg/l) | 500 | _ |
| Ca(ppm) | 150 | 75 |
| Mg(ppm) | 100 | 125 |
| Na (ppm) | 200 | 200 |
| K (ppm) | _ | 12 |
| Cl (ppm) | 350 | 250 |
| $SO_4$(ppm) | 400 | 250 |
| $NO_3$(ppm) | 50 | 50 |
| Zn (ppm) | 3 | 3 |
| Mn (ppm) | 0.1 | 0.1 |
| Pb (ppm) | 0.01 | 0.01 |
| Ni (ppm) | 0.02 | 0.02 |
| Cd (ppm) | 0.003 | 0.003 |
| Cu (ppm) | 1 | 1 |
| Co (ppm) | _ | 0.5 |
| Fe (ppm) | 0.3 | 0.3 |

## 2- Water suitability for livestock purposes

Water specifications for livestock consumption according to Altoviski (1962).

| Elements& Parameters (ppm) | Very good Water | Good Water | Acceptable Water for use | Can be used | High limits |
|---|---|---|---|---|---|
| $Na^{+}$ | 800 | 1500 | 2000 | 2500 | 4000 |
| $Ca^{+2}$ | 350 | 700 | 800 | 900 | 1000 |
| $Mg^{+2}$ | 150 | 350 | 500 | 600 | 700 |
| $CL^{-}$ | 900 | 2000 | 3000 | 4000 | 6000 |
| $SO_4^{-2}$ | 1000 | 2500 | 3000 | 4000 | 6000 |
| T.D.S | 3000 | 5000 | 7000 | 10000 | 15000 |
| T.H | 1500 | 3200 | 4000 | 4700 | 54000 |

### 3- Water suitability for industrial purposes

Water quality standard for industrial uses according to Hem (1985).

| Parameters | Textiles | Chemical pulp and paper | | Wood chemicals | Synthetic rubber | Petroleum products | Canned, dried, frozen fruits and vegetables | Soft-drinks bottling | leather tanning | Hydraulic cement manufacture |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Unbleached | Bleached | | | | | | | |
| $Ca^{2}$ | -- | 20 | 20 | 100 | 80 | 75 | -- | 100 | -- | -- |
| $Mg^{+2}$ | -- | 12 | 12 | 50 | 36 | 30 | -- | -- | -- | -- |
| $CL^{-}$ | -- | 200 | 200 | 500 | -- | 300 | 250 | 500 | 250 | 250 |
| $SO_4^{2-}$ | 0 | -- | -- | 100 | -- | -- | 250 | 500 | 250 | 250 |
| $HCO_3^{-}$ | 0 | -- | -- | 250 | -- | -- | -- | -- | -- | -- |
| $NO_3^{-}$ | 0 | -- | -- | 5 | -- | -- | 10 | -- | -- | -- |
| Cu | 0.01 | -- | -- | -- | -- | -- | -- | 500 | -- | -- |
| Zn | -- | -- | -- | -- | -- | -- | -- | -- | -- | -- |
| pH | 2.5 – 10.5 | 6 - 10 | 6 - 10 | 6.5-8.0 | 6.5 – 8.3 | 6 - 9 | 6.5 – 8.5 | -- | 6 - 8 | 6.5 - 8.5 |
| TDS | 100 | -- | -- | 1000 | -- | 1000 | 500 | -- | -- | 600 |
| TH | 25 | 100 | 100 | 900 | 350 | 350 | 250 | -- | Soft | -- |

### 4- Water suitability for building purposes

Water quality standard for building purposes according to Altoviski (1962).

| Ions | Permissible Limit | Average concentrations |
|---|---|---|
| $Na^{+}$ | 1160 | |
| $Ca^{2+}$ | 437 | |
| $Mg^{2+}$ | 271 | |
| $Cl^{-}$ | 2187 | |
| $SO_4^{=}$ | 1460 | |
| $HCO_3^{-}$ | 350 | |

### 5- Water suitability for agriculture and irrigation purposes.

Todd classification (2007) for the tolerance of crops by relative salt concentrations for agriculture.

| Crop Division | Low Salt Tolerance crops EC (µS /cm) | Medium Salt Tolerance crops Ec (µS /cm) | High Salt Tolerance crops Ec (µS /cm) |
|---|---|---|---|
| Fruit Crops | (0 – 3000) Limon, Peach, Pear Apricot, Orange, Apple. | (3000 – 4000) Cantaloupe, Olive, Figs, Pomegranate. | (4000 – 10000) Date palm |
| Vegetable Crops | (3000 – 4000) Green beans, Celery, Radish. | (4000 – 10000) Cucumber, Peas, Onion, Carrot,Potatoes, Lettuce, Cauliflower, Tomato. | (10000 – 120000) Spinach, beets |
| Field Crops | (4000 – 6000) Field beans | (6000 – 10000) Sunflower, Corn, Rice, Flax, Sorghum | (10000 – 16000) Cotton, Sugar beet, Barley (grains) |

**Homework 1:** What is the Hydrochemical classification and water type of the following samples ?

| well No. | $Ca^{+2}$ ppm | $Mg^{+2}$ ppm | $Na^{+}$ ppm | $K^{+}$ ppm | $Cl^{-}$ ppm | $SO_4$ ppm | $HCO_3$ ppm |
|---|---|---|---|---|---|---|---|
| **W2** | **60** | **31** | **280** | **13** | **205** | **525** | **72** |
| **W3** | **71** | **35** | **347** | **12** | **280** | **500** | **210** |
| **W6** | **126** | **83** | **135** | **12** | **242** | **546** | **66** |
| **W14** | **125** | **91** | **385** | **14** | **530** | **569** | **265** |

**Homework 2:** What is the water suitability for different purposes of the following samples above?