Definition:The Hydrology

- It isthe science that deal with water in the global ,its appearance ,circulation & distribution, its chemical & physical characteristics and its relation with the environment & living being ,and it's a branch of geology science so it deals with streams rivers…….,and it related with other sciences like chemistry physical and fluid.

Some branches of hydrology

1-Limnology(the science that studies the lakes)

2-Cryology(the science that studies the snow and ice)

3-Geohydrology (the science that deal with ground water)

4-Potamology (the science that studies the over ground or the rivers that running on the ground, or the surface water)

5-Hydrometeorology (the science that deal with hydrology &climate to gather)

6-Chemical hydrology is the study of the chemical characteristics of water

Some purposes for studying the hydrology

1-Design the water resources plants such as irrigation, water supply, water´s energy ,waste water plants, bridges.

2-Estimating the capacity of water reservoir and dams.

3-Quantity and capacity of floods to control them.

4-Minimum and maximum flow from resource.

5-Determination of probable maximum precipitation for channel and spillways, and also to design water and rain water pipes. Analyzing the impacts of antecedent moisture on sanitary sewer systems.

6-Determining the water balance of a region.

Units you need

1 Doname	2500 m^2
1 Hectare(ha.)	10^4 m^2
1 Acre	0.4047 ha.
1 Acre	4047 ~4000 m^2
1 Acre	43560 ft^2
Acre-ft	43560 ft^3
1ft	0.3048 m
1 ft	12 inches
1 m	3.28 ft
1 ft^3	$23*10^{-6}$ acre-ft
1 acre-ft	3048 m^3

Note Units of runoff(R) may be by :m or m^3 or m^3/s or acre-ftThe area from which the calculations be on it namedWater shed , catchment area,basin area.

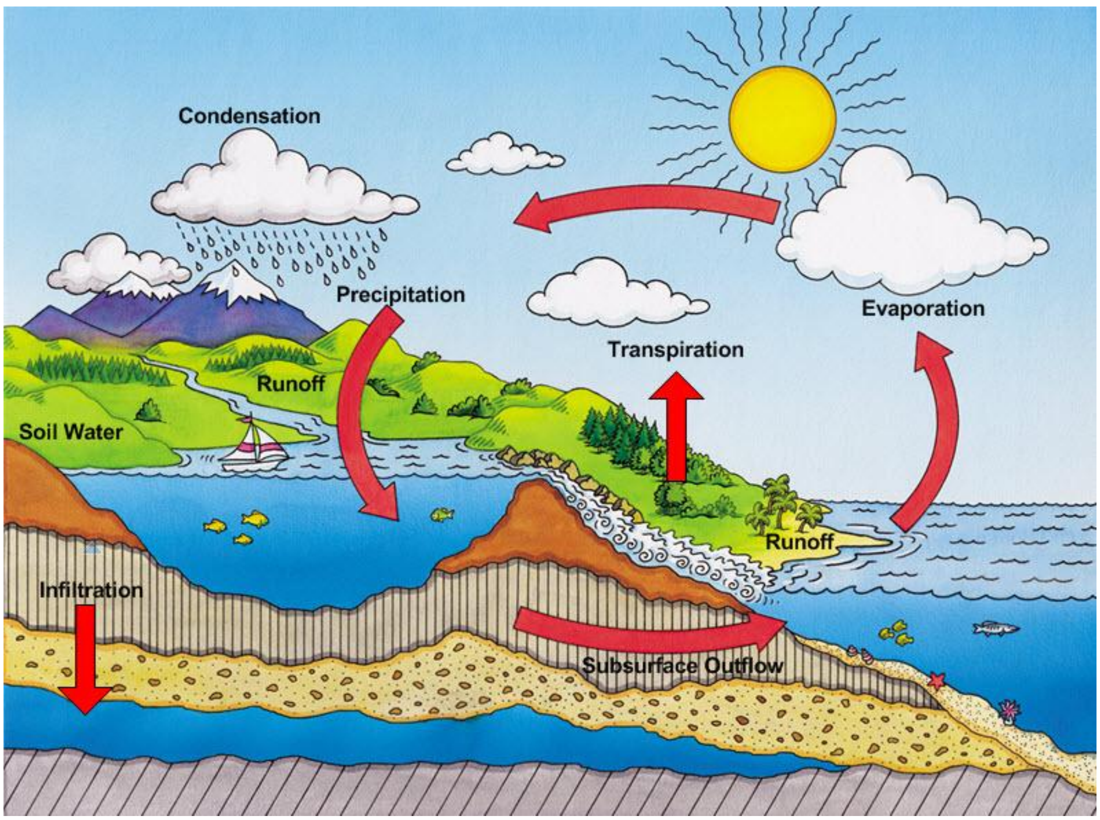
Water budget (balance equation)

In fact the water recirculation in the nature yields to the water budget equation andtakes this formula:

$$I - O = \Delta S$$

Where:

I : inflow , O:out flow ,ΔS:change in storage



Each income to the watershed take the plus sign and each outcome take the minus sign

P :precipitation or rainfall(+)

R:directrunoff (+)

I:infiltration (-)

E:evaporation (-)

Qin (+)

Qout(-) and so on

So the equation my take another shapes

$P+R+Qin-E-I-Qout=\Delta s$

When there is no change in storage then $\Delta s=0$

Definitions

Over flow :the flow of water over surface

Interflow :the lateral flow of water in the surface of soil.

Direct flow: the summation of over land flow and inter flow.

Runoff :water leaving land surface to the stream.

Base flow :inter flow +ground flow.

Total flow :direct runoff+base flow.

Examples:

Ex.1-estimate the amount of depression storage in a 2.5 hectar parking for the following data ,rainfall=0.88 in ,runoff= 5 cfs for 1 hour ?by meters.

P=(0.88/12) * 0.3048=0.022 m

R=5 *$(0.3048)^3$*1 *3600=509.7 m^3

R=509.7/2.5*10^4 =0.02 m

Δs=p+r

=0.022+0.02

=0.042 m

Ex.2-For a lake surface area=3000 acre and annual evaporation =50 inches ,what is the daily evaporation ?(m^3/day)

(50 ″/yr*365) = 0.137 ″/d

(0.137/12)*0.3048*3000*4000=4175 m^3/d

Ex.3-What is the infiltration rate from 1000 ha. Lake area if the annual infiltration=40

Inches?(acre-ft)

40″/12=3.34′

1000 ha./0.4047=2470.9acre

3.34*2470.9=8253.02 acre-ft

E4-Twelve cubic feet of water per second added to a vertical –walled reservoir

With surface area =600 acres,how many hours will it take to raise the water lavel up

To oneft?

$600*43560*1=26.13*10^6$ ft^3 (to convert area in acre to vol. in ft^3)

$12*3600 = 43200$ ft^3/hr.

$(26.13*10^6)/43200=605$ hrs.

((because Q=vol./t))

Precipitation

Precipitation is the general terms for all forms of moisture emanating from the

Clouds and falling to the ground,from the time of its formation in the atmosphere until it

Reaches to the ground.

Forms of precipitations:

1-Rain: drops usually greater than 0.5 mm in dia. it may reach to 6 mm.

2-Snow:is a precipitation in the form of ice crystals resulting from sublimation(water vapor directly to ice) and its density =0.1 gm/cm³.

3-Drizzle: water drop s under 0.5 mm dia.

4-Glaze:ice coating formed when drizzle or rain freezes as it comes in contact with cold object at the ground.

5-Sleet:frozen rain drops cooled to the ice stage while falling through air at freesing temperature.

6-Hail:precipitation in the form of balls of ice over 8 mm.

7-Storm: heavy rains

Measurement of precipitation

A variety of instruments and techniques have been developed for gathering information s on various phases of P .

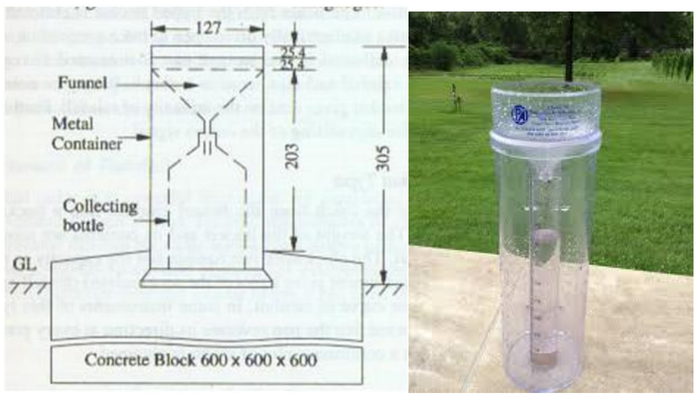
*Disdrometer - precipitation characteristics

- Radar - cloud properties, rain rate estimation, hail and snow detection

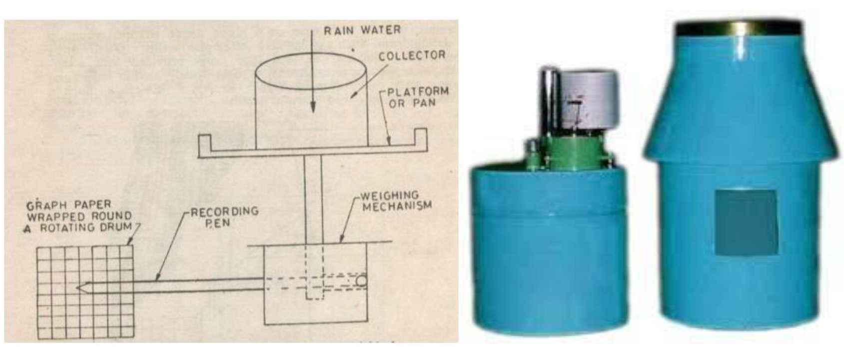
- Rain gauge - rain and snowfall
- Satellite - rainy area identification, rain rate estimation, land-cover/land-use, soil moisture
- Sling psychrometer– humidity

All form of P are measured on the base of the vertical depth of water that would accumulate on a level of surface if the P remained where it fell.

Types of rain gauges



Non recording rain gage



Recording gage

1-Non recording gauge

Any open receptacle with vertical sides it is a pan and a collector inside the pan with 12 cm dia. And 30 cm depth andthera is a scale to read the water high ,when there is a snow the collector is removed from the pan.

2-The recording gauge

-Tipping bucket gauge

-Weighing bucket gauge

The distribution of rain gauges depends on meteorological and topographical factors

Estimating of missing data

Many rain gage stationshave a short breaks in their recorded because of absences of the observer because of instrumental failures .here it is necessary to estimate the missing record .

If the normal annual P at each of index station is within 10% of that with the station with the missing record ,a simple arithmetic average of the P at the index station provides the estimated amount .

If the average annual P at any of the index station differs from that at station in question by more than 10% the normal ratio method is used.

Nx: the average annual P @ missing sta.

Ni: the average annual P @ others sta.

Px:the missing data sta.

Pi:data for other stas.

For checking

(Ni-Nx)/Nx<=10%

$Px=\frac{1}{n}(p1+p2+p3+\ldots\ldots\ldots)$

(Ni-Nx)/Nx>10%

$Px= \frac{Nx}{n}(\frac{P1}{N1}+\frac{P2}{N2}+\cdots$

examples

Ex.1-the normal annual P of five stations (A,B,C,D &E)are respectively (125,102,76,118,137)cm during a storm the P recorded for stations (A,B,C,&D) are (13.2,9.2,6.8, &10.2)cm ,estimate the missing data @ sta. E?

Check

$\frac{125-137}{137}=0.08<0.1$

$\frac{102-137}{137}=0.255>0.1$

Use normal ratio equ.

$Px=\frac{Nx}{n}(\frac{p1}{N1}+\frac{p2}{N2}+\ldots..)$

$Px=\frac{137}{4}(\frac{13.2}{125})+(\frac{9.2}{102})+(\frac{6.8}{76})+\frac{(10.2}{113})=12.86$ cm

Average precipitation over an area:

1-\Simple arithmetic mean

This method is used for a flat ,wide and little number of gages

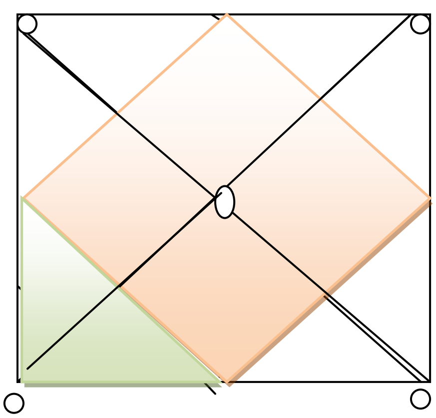
Pav.=(p1+p2+p3+……+pn)/n

2-Thiessen method

This method is used at a flat(or nearly),uniform distribution and the area takes a geometrical shape

Pav.=$\frac{P1A1}{At}$+$\frac{P2A2}{At}$+….$\frac{PnAn}{At}$

Pav. $= \sum_{i=1}^{n}(\text{Pi} * \text{Ai})/\text{At}11\ \ 2$



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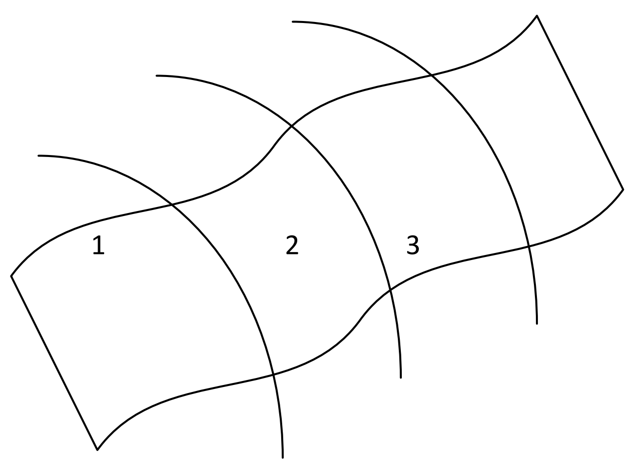
3-Isohyetal method

When the arrangementof stations are non uniform and the area is not flat (like mountain)with a lot of gages this method is used

Pav.=$\frac{(p1+p2)}{2}$*($\frac{A1}{At}$)+$\frac{(P2+P3)}{2}$*($\frac{A2}{At}$)+…+

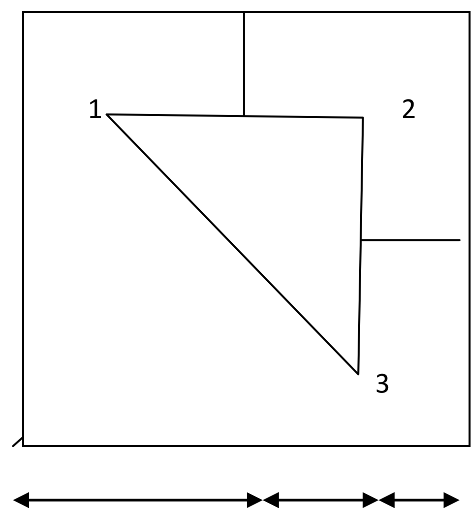


$$Pav. = \sum_{i=1}^{n} \left(\frac{Pi + Pi + 1}{2} \right) * \left(\frac{Ai}{At} \right)$$

Examples

Ex.1-Asquare area of 100 km² is gauged by three rainfall gauges @ 2.5 km from sides (fig.) estimate the average precipitation?

Sta.	1	2	3
P(mm)	106	152	127



5 km 2@ 2.5 km

A1=square +triangular

=5*5+0.5*5*5

=37.5 km²=A3

A2=5*5

=25 km²

At=10 *10

100 km²

Pav.=p1($\frac{A1}{At}$)+P2($\frac{A2}{At}$))+P3($\frac{A3}{At}$)

=(106*37.5+25*152+127*37.5)/100

=125.4 mm

Ex.2 Isohyets drawn for a storm gave the following data

pcm	15-12	12-9	9-6	6-3	3-1
areakm²	92	128	120	175	85

Estimate the average precipitation over the catchment?

Pav.=(($\frac{5+12}{2}$)*92+ ($\frac{12+9}{2}$) *128+($\frac{9+6}{2}$)*120+($\frac{6+3}{2}$)*175+($\frac{3+1}{2}$)/2 *85)/At

= cm

Ex3-Acircle shaped area of 50 km radius gauges fixed @ the points 1,2,3,4 &5 with data below ,compute the value of average P by thiessen´s method ?

Sta.	1	2	3	4	5
Pcm	3.2	4.8	5.4	6	4.5

Total area = $50^2 * Л$

= $7580\ km^2$

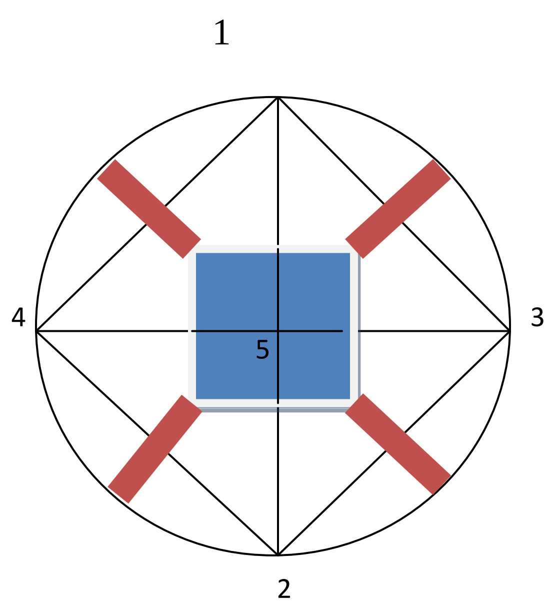
$A5 = 50 * 50 = 2500\ km^2$

$A1 = A2 = A3 = A4 = (7850 - 2500)/4 = 1337.5\ km^2$

Pav.=$(A1P1+A2P2+A3P3+A4P4+A5P5)/AT$

$= 2500*4.5 + (1337.5(3.2+4.8+5.4+6))/7850$

$= 3.4$ cm



Rainfall information

Some definitions related to the rainfall information:

Intensity(i):

It is a measuring of the quantity of rainfall during a given time

$$i=\frac{dept\ h}{time}=\frac{p}{t}(\text{mm/hr.})$$

Duration (t):

It is a period of time during which rain falls. (Hr, second…)

Frequency(N):

This refers to the expectation that a given depth of rainfall will fall in a given time such an amount may be equal or exceeded in a given number of days or years.

i.e. how many times during 10 years the rain fall more than the normal.

Return period(T):

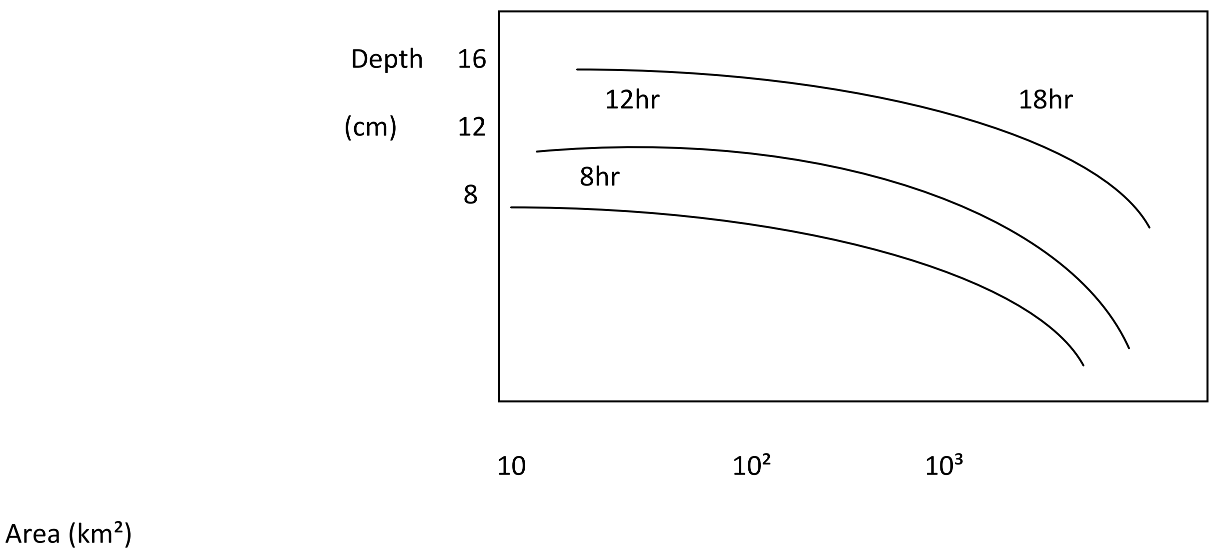
The average period within which rain of a given depth will equaled or exceeded once.

this mean during a long period (40 yrs.)Howmany timesthe up normal amount of rainfall doesfrequent?

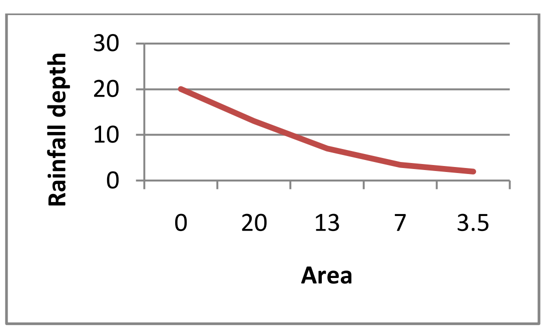
Relations between rainfall information

Depth –Area –Duration (D-A-D)

The relation between the depth of rainfall and the area of catchment is diversely by the time (this mean within the time the depth increase but when the area increase the depth decrease)



The depth of rainfall in the center of the catchment h maximum and it decrease with the area increasing (at area =0, P =maximum)



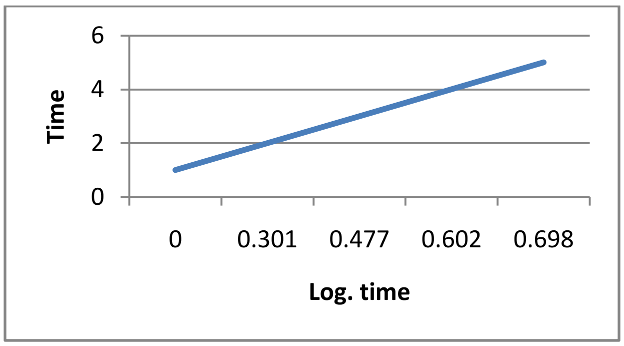
The previous curve is drawn by depending on the following formula:

$$\frac{P'}{P} = 1 - \frac{0.3 - \sqrt{A}}{t*}$$

Where :P average depth

P point depth at the center (mm)

t* invers gamma function



Example:

What is the average rainfall intensity over an area =5 km², during one hour storm, if t*=5.6 & i=23 mm/hr.?

$$\frac{P'}{P} = 1 - \frac{0.3 - \sqrt{A}}{t*}$$

P=i * t

=23*1=23 mm

$$\frac{P'}{23} = 1 - \frac{0.3 - \sqrt{5}}{5.6}$$

p´=20 mm , i=20 /1 =20 mm/hr.

Intensity -duration relation

The relationbetween the intensity & the duration take the formula

$I=\frac{a}{t+b}$ when $t\leq 2$ hr.

$I=\frac{c}{t^{n}}$ when $t>$ 2 hr.

Where amebicand n are constants

When two variables situations be x & y values are measured and a relation between these two is determined. The relation can be linear .Assume a linear or nonlinear does exist and given by

$y'=a+bx+\varepsilon$

y', x variables

a, b constants and ε error

Constants may be obtained from many methods like least square method and matrix

Using the least square method to find amebic&, n

1-Write the equation by the formula of straight line eq.

$Y=Ax+B$

2- $\sum y=A\sum x+NB$

$\sum X=A\sum X^{2}+B\sum x$

3After solving the last two equations simultaneously

A=$\frac{\sum xy - N y' x'}{\sum x^2 - N x'^2}$

B=y´-Ax´

x´=∑x/N

y´= ∑y/N

Example

Given the relation between the intensity and the duration i=$\frac{a}{t+b}$ calculate the variables a& b depending on the following data

i(mm/hr.) 30 20 15

t(min) 20 40 60

y=Ax+B

$$\frac{1}{i} = \frac{1}{a}t + \frac{b}{a}$$

∴y=$\frac{1}{i}$ x= t A=$\frac{1}{a}$ B=$\frac{b}{a}$

t=x	y=1/i	my	x^2
20 40 60	0.033 0.05 0.67	0.667 2 4	400 1600 3600
∑120	∑0.15	∑6.67	∑5600

x´=∑x/N=40

y´=∑y/N=0.05

A=$\frac{6.67-3*40*0.05}{5600-3*40^2}$=0.00083

B=0.05-0.00083*40=0.0167

a=1/A=1200 b=a*B=20

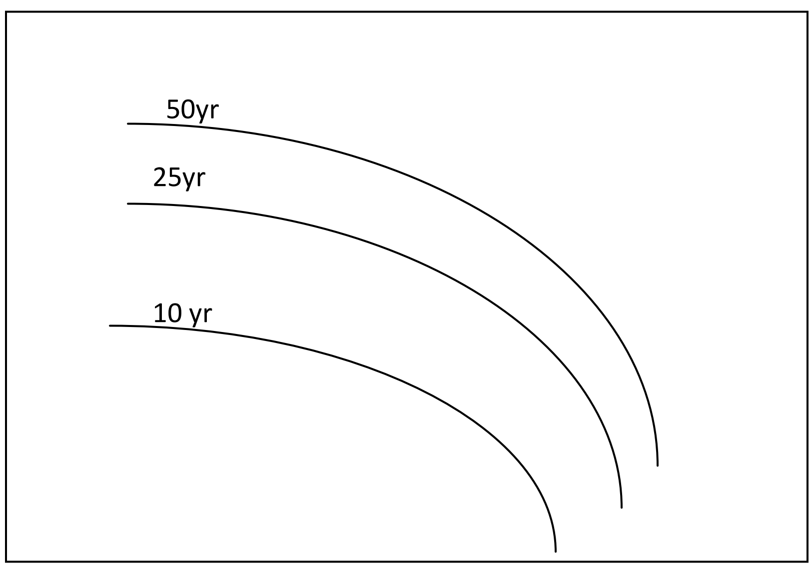
$\therefore i = \frac{1200}{t+20}$

Intensity- duration –frequency(IDF)

Structures designed to control stormwater volumes and flows need quantitative criteria to determine their size. Two important stormwater parameters ,intensity and duration ,can be statistically related to a frequency of occurrence .the graphical representation of this relationship is the intensity-duration-frequency (IDF).The (IDF)curve is a plot of average rainfall intensity versus rainfall duration for various frequency of occurrence is shown in fig. below

Rainfall intensity

(mm/hr.)



Within the time the intensity become decrease for any frequency ,this curve can be expressed as the following formula: $I=\frac{aT^m}{(b+t)^n}$Where:

I :intensity(mm/hr.)

T: frequency(yr.)

T:duration(hrs.)

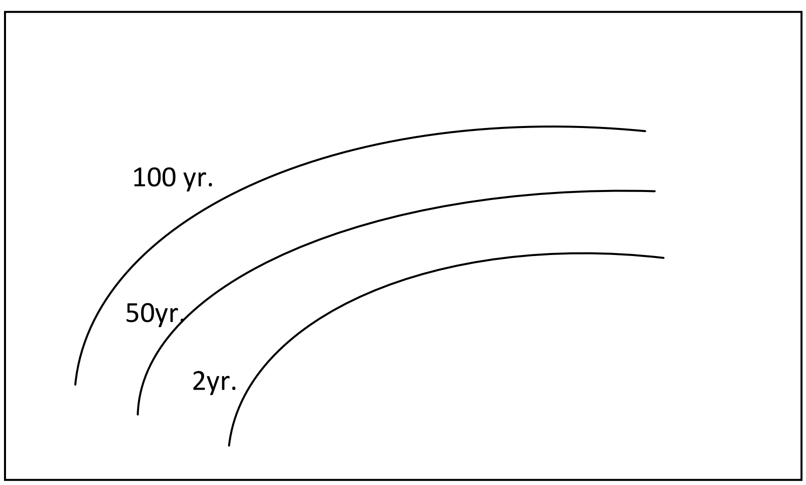
A ,b, m,   & n   coefficient varying from one region to another

The common form of the last equation used for hydrologic analysis is one that fixes the frequency of occurrence ,thus we eliminate t and m from the equation and assume the exponent n to equal unity resulting in :

$$I=\frac{a}{b+t}$$

Also within the time the depth increaseas it shown in fig.:

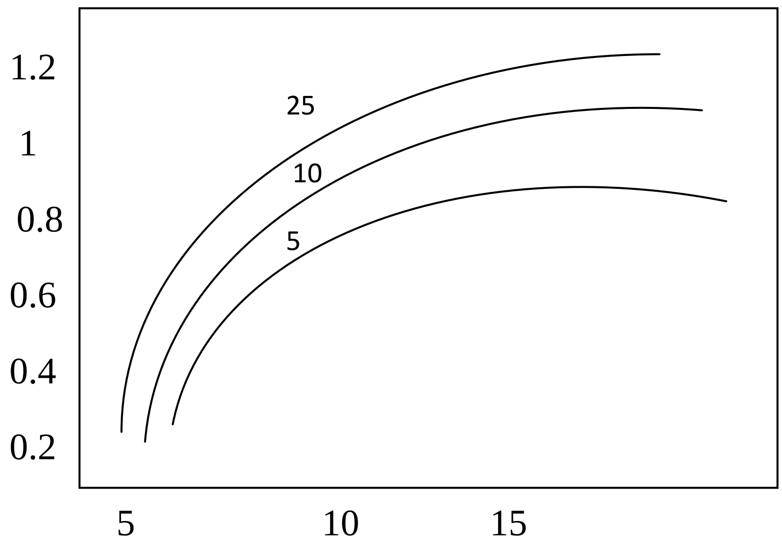
Depth(mm)



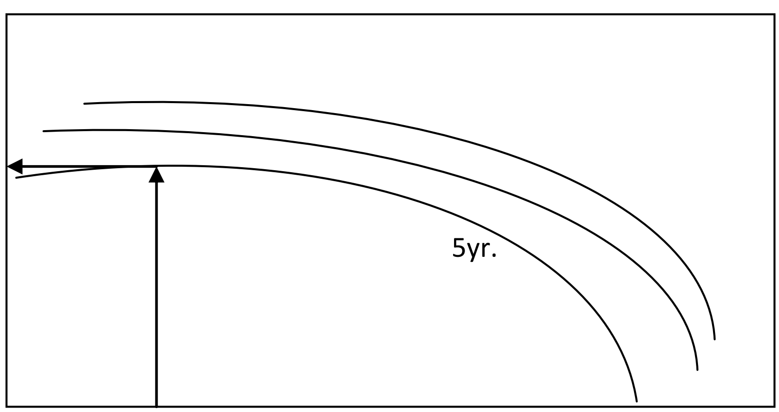
Time(hr.)

Example: Drive the IDF curve from data below and find intensity for duration 6 sec. and frequency 5 yrs.?

T(yr.) t(sec)	5	10	15
5	0.4	0.82	1.03
10	0.56	0.9	1.21
25	0.67	0.98	1.35



T(yr.)/ t(sec)	5	10	15
5	o.o8	0.082	0.068
10	0.11	0.09	0.08
25	0.13	0.098	0.09



There are another formulas that connect the depth, duration,frequency & return period one of them is Bilham formula as follows

$N=\frac{10}{T}=1.214*10^5\, t\, (p+2.54)^{-3.55}$

N:no. of occurrence in 10 yrs.

T:returne period

P:depth

t:dutation

Example:

Determine the rainfall intensity (cm/hr.) for 40 yrs. return period storm occurred during 30 min. on 10 hectare watershed ,what is the volume of water applied on this area?

$\frac{10}{T}=1.214*10^5\, t\, (p+2.54)^{-3.55}$

$P=(\frac{1.214*10^5}{10})^{1/3.55}\ -2.54$

$=(\frac{1.214*10^5}{10}*40*\frac{30}{60})^{1/3.55}\ -2.54$

=30.3 mm

I=p/t

$=\frac{30.3}{30/60}=60.6$ mm/hr.

Vol.=$30.3*10^{-3}*10*10^4=3034.3$ m³

Abstractions from precipitation

*Evaporation

Evaporation is understood to be a cooling process because heat is removed from the surface where evaporation has taken place. Energy must be available for the evaporation process and are chiefly solarvapor pressure and advective(wind).

There are three general methods commonly in use for measuring evaporation which mainly indirect methods

1-Measrerment from evaporation pan.

2-Water budget.

3-Correlation with climatic data.

Evaporation pans: the class A pan is the most widely used(fig.)it is a cylinder made of galvanized iron with 122 cm dia. &2 cm depth,the pan restson a leveled wooden.

It is usually filled to a depth of 20 cm and re filled when the depth has fallen to ≤18cm.the water surface is measured daily with a hook gage.

Also there are another types of pans like Indians standard pan(the same as class A) and Colorado sunken pan (is square ,1 m on a side and 0.5 m deep it buried in the ground to within 5 cm so it look like a lake or water surfaces.

Pan evaporation.is used to calculate lake evaporation.(El) by

Using a pan coef.(Pc)

El=PcEp

2-Water budget:

Another estimate depends on an accurate water budget in which evaporation is the only unknown variable=P+R-O+∆S………………..1

3-Correlation to climatic data

Empirical formulas has been developed to rate either pan or actual evaporation to atmospheric measures. The form of the equation are similar and in general are related to vapor pressure and wind speed.

$E=f(\Delta e,U)$ (mass transfer eq.)…………….2

where

Δe=change in vapor pressure from the water to the air.

U=wind speed.

Atypical equation developed in connection with 1&2(Hefner)

$Et=0.0024(e_o-e_a)U8$……………………3

E=evaporation(in/d)

e_o=saturation vapor(in)

e_a=vapor pressure(inches of Ag)

U8=wind speed (miles/d)

Also the correlation was further as follow(by Kohler et al.)

$Ep=(e_o-e_a)^n(m+Bu)$ ……………..4 where

Ep=daily evaporation(in/d)

e_o=saturation vapor(in of Hg)

e_a=atm. Vapor pressure(in of Hg)

U=wind movement(mpd)-6in.above pan rim.

n,m&b constants.

Other important climate variable are mean daily air and watervtemperature,windmovement,and solar radiation, not all the advective energy is used for evaporation .

To estimate lake evaporation a general formula can be used with different in temperature ,mean daily air speed and elevation above sea level

Transpiration from vegetation can be estimated

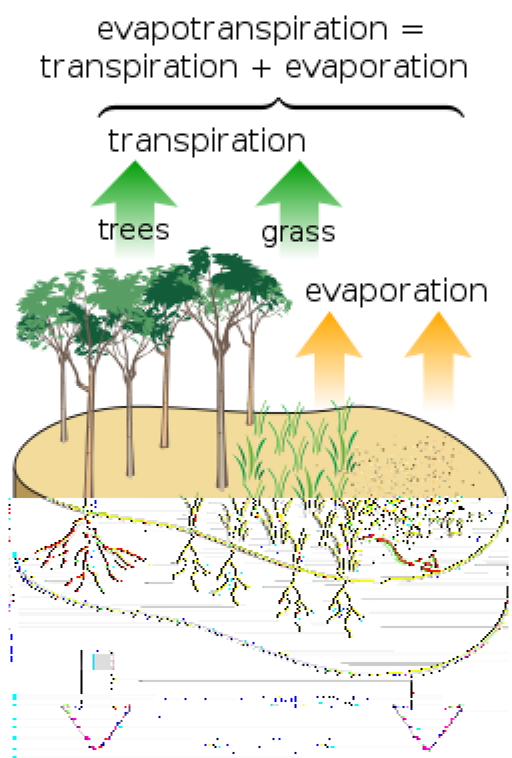
By the formula:

T=ET-E

T=transpiration rate(mm/time)

ET=evapotranspiration(mm/time)

E=evapo.(mm/time)



Infiltration (f)

It is a passage of water through the soil surface in to the soil under gravity and capillary force

Infiltration capacity I.C.

It is the maximum rateat which water can enter the soil at a particular points at any time (cm/hr)

Soil and fluid characteristics effect on the I.C.

The rate and quantity of water which infiltrate is a function of soil type ,soil moisture ,soil permeability ,ground cover ,drainage conditions ,depth of water table and intensity and volume of precipitation

Infiltration measurement:

It measures by infiltrometeris a device used to measure the rate of water infiltration into soil or other porous media. Commonly used infiltrometers are single ring or double ring infiltrometer,

Single ring infiltrometer

The single ring involves driving a ring into the soil and supplying water in the ring either at constant head or falling head condition. Constant head refers to condition where the amount of water in the ring is always held constant. Because infiltration capacity is the maximum infiltration rate, and if infiltration rate exceeds the infiltration capacity, runoff will be the consequence, therefore maintaining constant head means the rate of water supplied corresponds to the infiltration capacity. The supplying of water is done with a Mariotte's bottle Falling head refers to condition where water is supplied in the ring, and the water is allowed to drop with time. The operator records how much water goes into the soil for a given time period. The rate of which water goes into the soil is related to the soil's hydraulic conductivity

Infiltration calculations:

1-Green –Ampt method

Is based on darcy's law

$Kt=F(t)-\eta\Psi \ln \left(\frac{\eta\Psi+F(t)}{\eta\Psi}\right)$

K=hydraulic conductivity of the soil (L/T)

Ψ=capillary suction of the soil at the wetting front(L)

Ŋ=effective soil porosity

T=time

F(t)=cumulative infiltration volume at time t(L)

2-Horton equations

Infiltration can be written by Horton's equation ,this method gives an expression for varying infiltration :

$F(t)=fc + (f_o-fc)\, e^{-kt}$

Wheref(t)=infiltration rate as a function of time cm/hr.

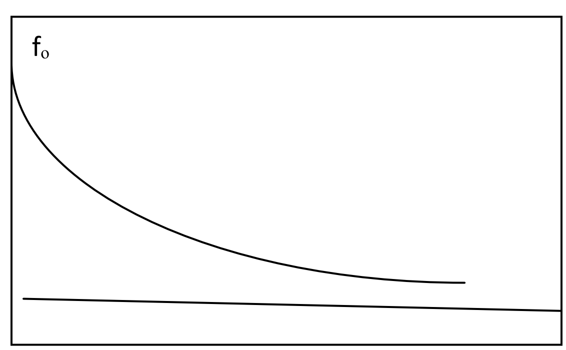
Fc=final or ultimate infiltrationrate

f_o=initial infiltration rate.F(t)

K=constant(hr^{-1})

T=time.

fc



3-*Water budget*

If infiltration is the only unknown in the water budget (and the other variables can be measured then the water budget would produce accurate results.

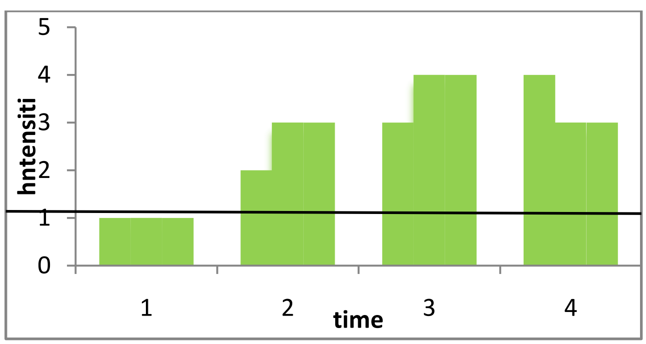
3-*Infiltration indices*

-Ø index.

-w index.

Ø index:It is the average rainfall above which the volume of rainfall equal the volume of runoff

It depends on the soil ,vegetationcover,moistur,duration,intensity,



Φ

p=the whole area

I=lower part

R=upper part

w-index:it is the average infiltration index w=$\frac{P-R}{t}$

examples:

ex1:for total rainfall of 75mm and runoff 33 mm, find Ø index for the data below

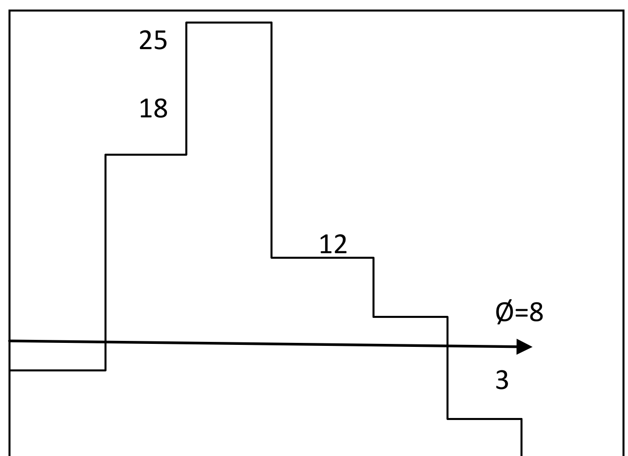
I(mm/hr.)	7	18	25	12	10	3
T(hr.)	1	2	3	4	5	6

7(1)+6(2)+2(3)+x(4)=33

X=2

Ø=10-2=8mm/hr.

W=P-R/T=75-33/6=7mm/hr.



Ex2:the table below shows the data of a number of stormsare observed on a river ,compute the w-index for all storms and its average?

No.	1	2	3	4	5	6	7
Av.P	2.82	2.98	4.55	14.2	2.87	3.91	8.1
Av.R	1.32	1.02	2.46	7.42	0.43	0.48	1.93
T	12	48	24	72	18	24	36
P-R/t	0.125	0.041	0.087	0.094	0.136	0.143	0.172

$\frac{P-R}{t}=w$ $\Sigma w=0.798$ w av.=0.798/7=0.114 cm/hr.

Ex 3:

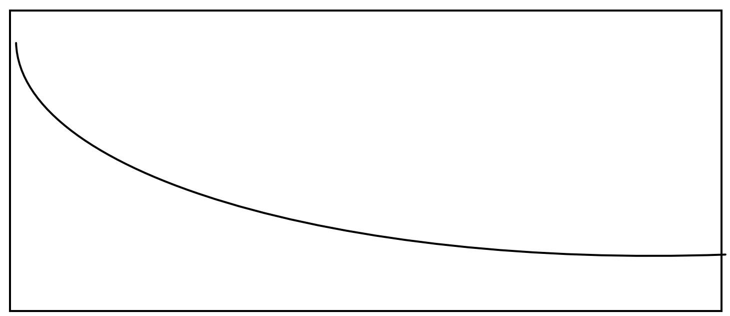
If you have the following data fc=0.53 in/hr., f_o=3 in/hr., k=4.18 hr^{-1}, find the infiltration rate (f) after 0 , 0.5 , 1.0 , 1.5 and 2 hr.with curve?

$F=fc+(f_o-fc)\ e^{-kt}$

$F=0.53+(3-0.53)\ e^{-4.18\,t}$

t	0	0.5	1	1.5	2
f	3	0.83	0.567	0.534	0.5305

F(in/hr.)



T(hr.)

Stream flow

Measurement of stream flow(discharge)

Direct meas.(non uni.)	Indirect meas.(uni.)
1-Area velocity 2-Dillution technique 3-Electromagnetic 4-Ultra sonic	1-Structures -weir -flum -gates 2-formulas

Water stage :is the elevation of the water surface at a specified station above some arbitrary zero datum sometime taken as mean sea level .

The simplest way to measure river stage is by means of **staff gage** .a scale set so that a portion of it is immersed in the water at all time.the gage may attached to a bridge pier or other structure.

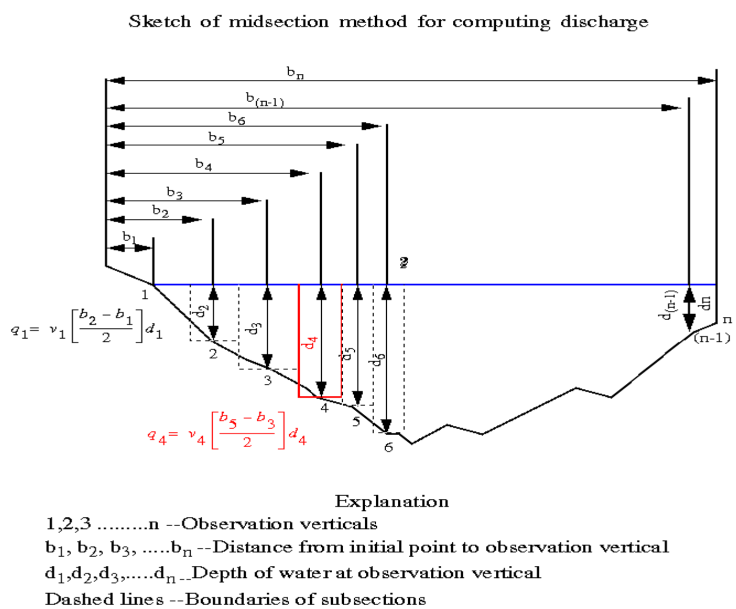
Another type of manual gage is the **suspended-weight gage**in which is lowered from a bridge or other overhead structure until it reaches the water surface.by subtracting the length of line paid out from the elevation of a fixed reference point on the bridge,the water elev. Can be determined.

Also there are another types of gages like recording gage ,crest gage,floot gage and bubble gage.

1-Area velocity method:

a-Mean section

$$Q=\sum \frac{Vi+Vi+1*}{2}\frac{di+di+1*}{2}(bi+1 \ -bi)$$

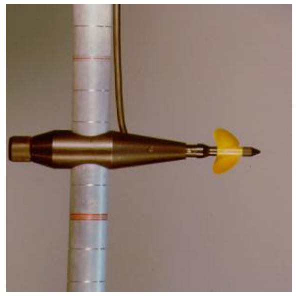


b-Mid section:

$$Q=\sum vi\ di*(\frac{bi+1\ - bi-1)}{2}$$

Vi:is a velocity @ each section in the river measured @ one point @ each distance of (0.6 D)from the surface of water or two points @(0.2 & 0.8 D)from the surface .

V av.=$\frac{V0.2+V0.8}{2}$



2-Dilution technique

By spray a tracer powder(no dissolved) with stream flow till it dilute then the discharge calculate.

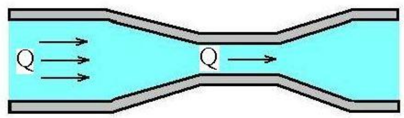
3-Electromagneti

4-Ultrasonic method

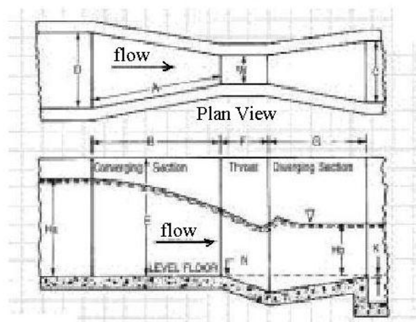
By using the ultrasonic to calculate the velocityand then thedischarge.

1-Structurs

Flume: by venture flume



Flow Through a Venturi Flume



Top & Side View of a Parshall Flume

A1=b1*y1

A2=b2*y2

A1 V1=A2 V2

V1=$\frac{A2*V1}{A1}$ ……………………1

$\frac{p1}{ϒ}$+$\frac{v1}{2g}$+z1=$\frac{p2}{ϒ}$+$\frac{v2}{2g}$+z2………..2Bernoulli

Qth=$\frac{A1A2}{\sqrt{A1-A2}}\sqrt{2g(y2-y1}$

Qact=cd*Qth.

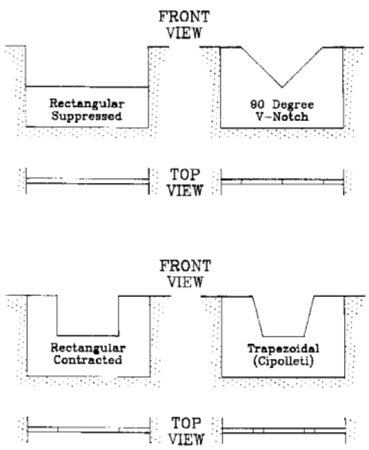
Cd=0.95-0.99

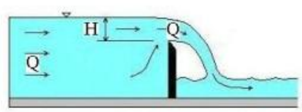
-weirs

It is a notch in a wall built across a stream ,it may be rectangular ,trapezoidal or triangular.

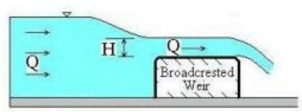
It may be a board crestbuilt parallel to the stream flow @ the floor of channel

Or may be a sharp crested weir





Flow Over a Sharp Crested Weir



Flow Over a Broad Crested Weir

2-Formulas

Manning's	Chezy's
$Q=\frac{1}{n}R^{2/3}\ S^{1/2}\ A$ Hydraulic radius=A/P P wetted parameter S slope of bed channel N manning coef. A=B*Y P=B+Z*Y(rectangular)	$Q=C\ A\sqrt{RS}$ C Chezy'scoef. $A=B*Y+Z*Y^2$ $P=B+2*Y\sqrt{1+Z^2}$ (trapezoidal)

Examples:

Ex1:

Compute the stream flow discharge for the measurements data below

Distance(m)	0	10	20	40	60	76	86
Depth(m)	0	2	3	5	4	2	0
Velocity(m/s)	0	0.5	0.8	1	0.9	0.6	0

By mean section

Q=$\sum \frac{vi + vi+1}{2} \frac{di + di+1}{2}$* (bi+1 - bi)

$= \frac{0+0.5}{2} * \frac{0+2}{2}$ *(10-0) $+ \frac{0.5+0.8}{2} * \frac{2+3}{2}$ *(20-10) + $\frac{0.8+1}{2} * \frac{3+5}{2}$ *(40-20) $+ \frac{1+0.9}{2} * \frac{5+4}{2}$ *(60-40)+

$\frac{0.9+0.6}{2} * \frac{4+2}{2}$ *(76-60)$+ \frac{0.6+0}{2} * \frac{2+0}{2}$ *(86-76)= 215.25 m^3/s

By mid-section

Q=$\sum vi * di * \frac{b\ i+1-bi}{2}$

Q=0.5 *2 *$\frac{20-0}{2}$+ 0.8* 3*$\frac{40-10}{2}$ +1* 5*$\frac{60-20}{2}$ + 0.9* 4* $\frac{76-40}{2}$ +0.6* 2* $\frac{86-60}{2}$=223.5 m^3/s

---

Ex2

A trapizoidalchannel lined with concrete ,c=130,B=10 m,side slope=1:1,depth=5m,channel slope =0.0004,find discharge?

Q=C B $\sqrt{RS}$

A=B Y+Z Y^2,R=A/P, P=B+2Y$\sqrt{1+Z^{2}}$=24.1 m ⟹R=75/24.1=3.11m

Q=130*75*$\sqrt{3.11 * 0.0004}$ = 343 m^3/s

Runoff

It is the flow ordischarge of precipitation on the catchment or through a surface channel during a time till it reach to the surface water .the flow over land occurs when soil is infiltrated to full capacity and excess water from rain.

During a precipitation a mass of total volume of rainfall onto and flow on soil .initial abstraction is water intercepted by vegetation IA, also there are evaporation TranspirationT,inflitration F and initial abstraction ,trhen the storage change is written as

R(rainfall excess)=P-E-T-F-Ia

Over land flow :flow of water over the surface of land.

Inter flow: lateral flow of water in the surface of soil.

Flow open channel:flow of water in the through many channels to the stream.

Direct runoff: the sum. Of over land flow and inter flow.

Base flow: inter flow and ground water .

Volume of runoff

More complex methods for the determination of runoff are available .they require a more detailed mathematical description of the watershed characteristics.The volume of runoff may estimate as an annual or monthly or daily or even for hours.

1-relation between P &R

2-Emprircal equations

3-catchment area

4-inflitration indices

5-rational equation

6-hydrograph

1& 2 through many relations between R&P like:

R=CPorR=aP+b or R=0.85P-30.5

3-it is the budget eq. O-I=ΔS

4-is was explained before
5-Q=C*I*A
6- (next section)

Rational equation(CIA)

The rational methods are one of the oldest and were originally used to estimate the peak discharge. the simplest model of watershed runoff the rational equation (Q=CIA). Q:peakdischarge,C:runoffcoef. ,I:rainfall intensity ,A:watershed area.in this equation the watershed is modeled with two watershed characteristics, the rational coefficient(c) and the watershed area the infiltration and depression storage are incorporated into the value of (c).so the volume of runoff will depend on the watershed area ,it is :the total surface area of the drainage basin. This area can subdivide in to two areas: pervious area and the impervious area. The pervious area allows for soil infiltration where the impervious does not. If the area were 100%impervoius then the infiltration term of the mass balance would be zero.

Time of concentration:

The time of concentration is the longest travel time it takes a particle of water to reach a discharge point in a watershed.

1-**Izzard´s formula**

Tc=$\frac{41KL}{i}$

Tc:time (min) , L:over flow distances(ft.) , i:rainfall intensity(in/hr.)

K=$\frac{0.0007\ i+cr}{s}$

S:slope, ce:retardnacecoef.(kind of surface)

2-**Kerby´s equation**

Tc=c(Lns$^{-0.5}$)

Tc:time ,L:lengh of flow(ft) , s: slope , c:0.83(when using ft)1.44(when using m)

N:retardness roughness coef.

3-Kirpich´s equation

tc=o.oo78(L$^{0.77}$ /S$^{0.385}$)

tc;time(min)

L:lengh of travel(ft,m)

S:slopn(m/m)

Examples

Ex1

Design a pipe of storm sewer system that receive a drainage water from area 10000m^2.the length =189m.slope channel=0.004m/rainfall depth=28.7mm,runoffcoef.=0.6,relevant slope=0.005m/m,?

$Tc=0.02*(189)^{0.77}(0.004)^{-0.365}$

$=9.487$ min

$I=p/t=\frac{28.7}{9.487/60}=181.5$ mm/hr

Q=cia

$=0.6*\frac{181.5}{1000}*\frac{1}{3600}*10000=0.302\ m^3/s$

$Q=\frac{1}{n}R^{2/3}\ S^{1/2}\ A$

$=\frac{1}{N}(A/P)^{2/3}\ S^{1/2}\ A$

R=A/P=D/4

$Q=\frac{1}{N}*(\frac{D}{4})^{2/3}\ S^{1/2}\frac{D^2*\pi}{4}$

D=0.52 m

Ex2

Compute the diameter of the outfall sewer required to drain storm water from the watershed (fig.)which given the length of lines ,area & times .c=0.3,5 year, velocity=0.75m/s?

A1=0.016km^2	T=5min.
A2=0.023km^2	T=5min.
A3=0.024 km^2	T=8 min.

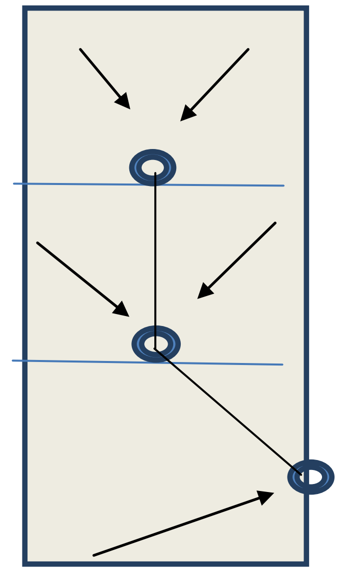
1 to 2

T=l/v=$\frac{120}{0.75*60}$=2.7 min

2 to 3

t=$\frac{180}{0.75*60}$=4min

for A1 t=5+2.7+4=11.7 min



for A2 t=5+4=9 min

for A3 t=8min

from fig. ,for 11.8min & 5 yr

i=115 mm/hr.

Q=cia

=0.27*0.3*115(0.016+0.032+0.024)=0.67 m^3/s

From monograph Q=670l/s, v=0.75m/s ,D~1050mm ,slope=0.00055m/m

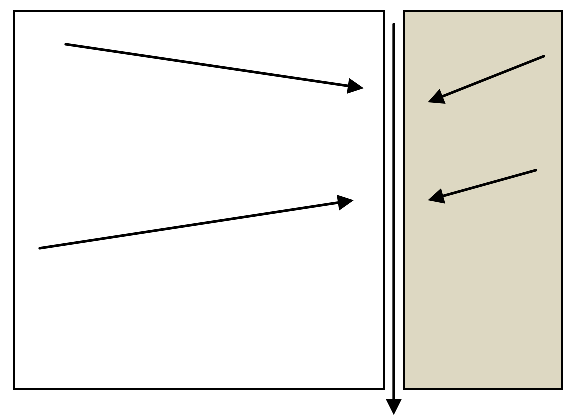
<u>Ex3</u>

For 10 year storm on a given area the data as follow

T(min)	5	10	20	30	60
P(mm)	8	12	18	23	26

Find 10-yr design flow at the outlet from this composite area parking ($60*300\ m^2$), (c=0.9)&playground($240*30\ m^2$),(c=0.3)the lateral flow time =5min(parking) & 40 min (playground),channel flow velocity=0.9m/s?

Channel flow time=$\frac{300}{0.9*60}$=5.56min



tc1=5.56+5=10.56 min

tc2=5.56+40=45.54 min

Q=cia

$I=\frac{p}{t} \Rightarrow \frac{26-p}{60-45.56}=\frac{p-23}{45.56-30}$ $\quad$ $p \Rightarrow 24.5$mm

imax.=$\frac{24.56*10}{45.56}$ =$0.537*10^{-3}$ m/min

Q=cia1+cia2

=$0.9*0.537*10^{-3}(60*300)+0.3*0.537*10^{-3}*240*300$

=$0.34 m^3/s$

The Hydrograph

1) The hydrograph is a graph of flow rate versus time .It is also reference as a listing of flow rate data versus time .It is one of the more useful concepts of hydrology is used frequently in stormwater management.

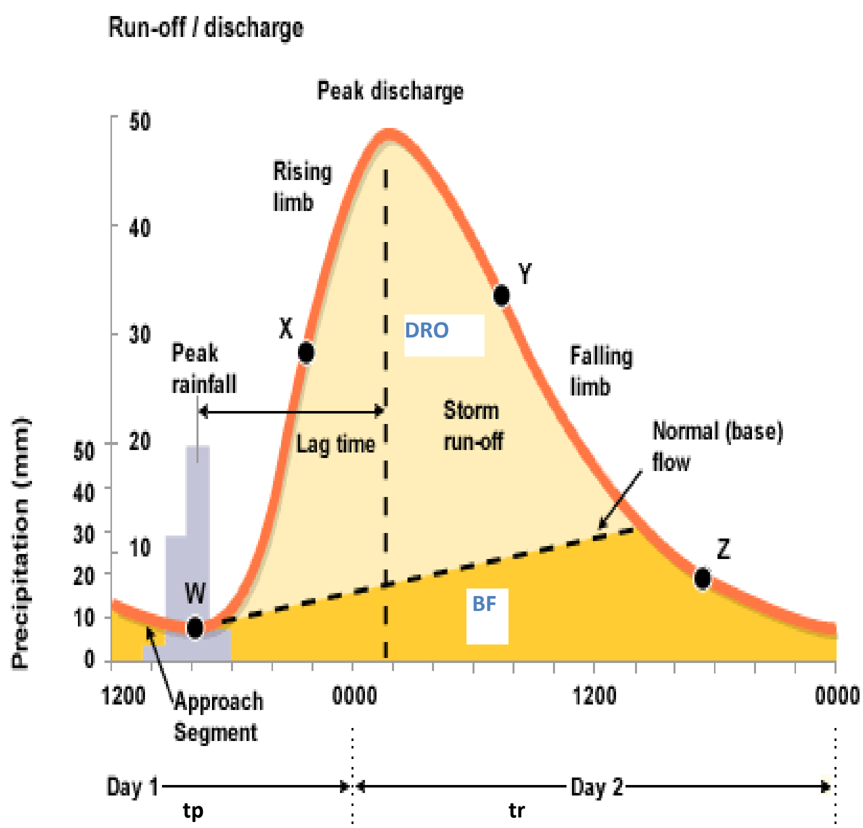
Atypical surface runoff is shown in figure, the hydrograph consist of three general parts ,(1)rising limp,(2)crest segment,(3)falling limp, the runoff hydrograph will have the following properties:

1-Time of peak(t_p).

2-Recession time(t_r).

3-Time of base(t_b).

The shape of the hydrograph depend on many factors,watershed shape ,area,slope,depth,the earth impervious,the land use,the rainfall intensity,evaporation …etc.



DRO : direct runoff

B.F: base flow

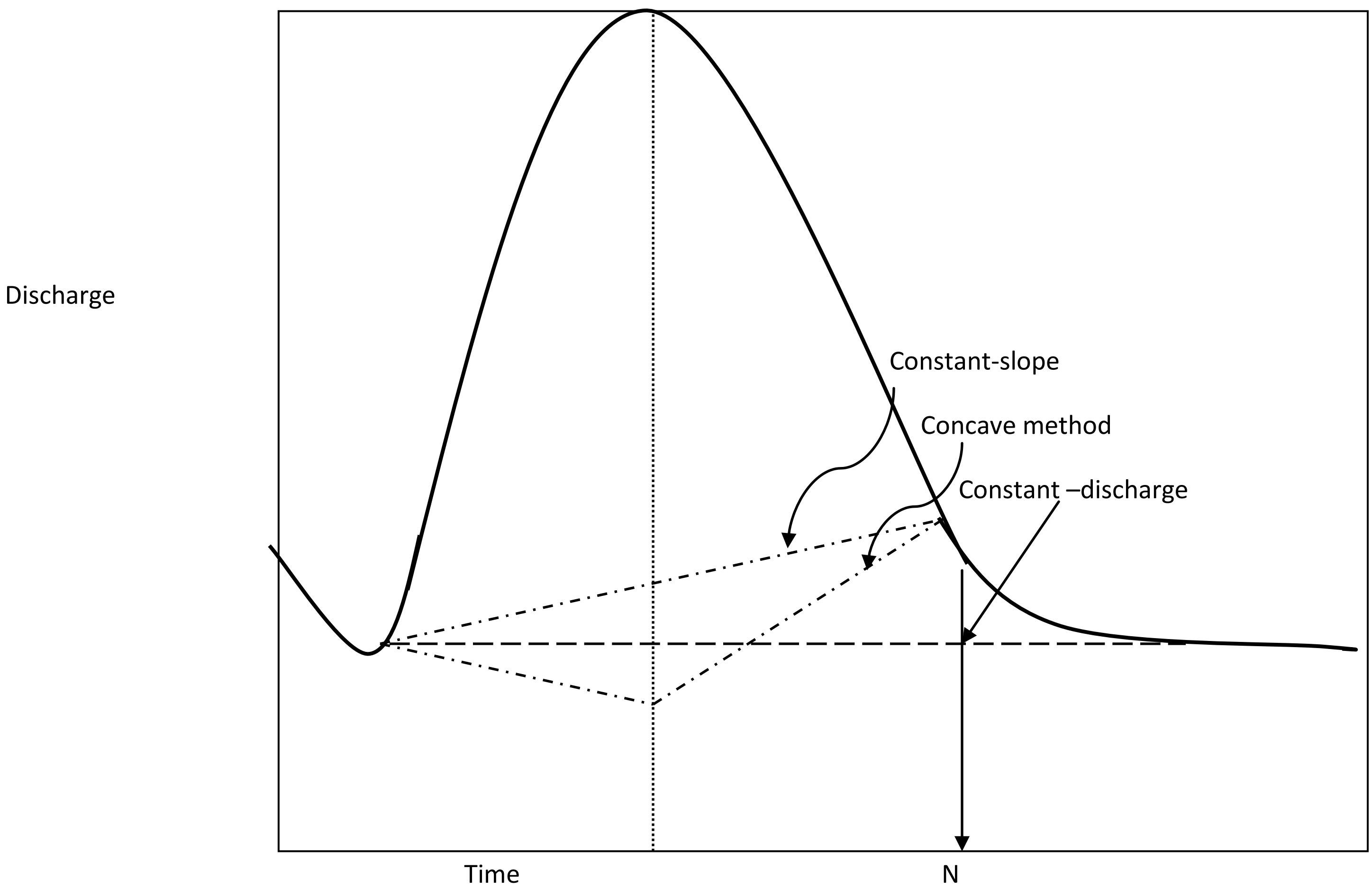
Hydrograph separation:

Several techniques exist to separate DRO from B.F based on the analysis of ground water recession curves or type and amount of measured data available . The direct runoff hydrograph is the difference between the total runoff and the base flow function.

1-Straight line (constant slope)method.$N=0.83\ A^{0.2}$(N days and A area km^2)

2-Fixed based (concave baseflow) method.

3-Variable slope (constant discharge) method.



Unit Hydrograph

U.H defined as ;basin outflow resulting from onecentimeter or one inch of direct runoff generated uniformly over the drainage area at a uniform rainfall rate during a specified period.

For a specific watershed,the U.H .for a given quantity of rainfall excess can be used to geΔnerate another hy. If the storm duration is the same.

The following general rules should be observed in developing U.H:

1-Storms should be selected with a simple structure with relatively uniform spatial and temporal distribution.

2-Watershed size should generally fall 1000 ac. -1000 mi^2.

3-Direct runoff should range from 0.5-2 inch .

4-Duration of rainfall excess should be 25-30% of t_p.

5-Anumber of sterms of similer duration should be analyzed to obtain an average unit hydrograph for that duration.

The following are essential steps for developing a U.H from a single storm hydrograph.

1-Analyze the hydrograph and separate the base flow.

2-Measure the total volume of direct runoff (DRO) under the hydrograph and convert this to in ,cm ,over the watershed.

3-Convert the total rainfall to rainfall excess and evaluate duration for the DRO and U.H.

4-Divide the ordinate of the DRO hy. By the volume and plot these results as the U.H for the basin. The time is assumed constant for storms of egual duration and thus it will not change.

.$t_1 = t_2$

.$i_1 \neq i_2$

$Q_1/Q_2 = d_1/d_2 \longrightarrow d = \frac{\sum DRO * \Delta t}{A}$

Examples

Ex1:given the ordinate of a flood hy. For 1700 km^2 during 12 hrs.drive 12 hrs.U.H?

$\frac{d1}{d2} = \frac{Q1}{Q2}$so Q$_1$=Q$_2\frac{d1}{d2}$

T(hr)	Q1(YH.)	Q2(U.H.)
0	0	0
12	30	3
24	100	10
36	365	36.5
48	645	64.5
60	700	70
72	585	58.5
84	475	47.5
96	360	36
108	275	27.5
120	180	18
132	125	12.5
144	85	8.55
156	50	5
168	25	2.5
180	0	0

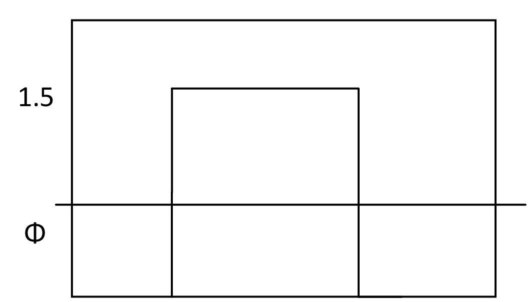
d=$\frac{\sum DRO*\Delta t}{A}$ =$\frac{4000*12*3600}{1700*10^{\wedge}6}$ =0.1 m

Q1=Q2 *$\frac{0.01}{0.1}$ =0.1 * Q2

Ex2:

Convert the DRO hy.Into a 2 hrs. U.H. .The rainfall hyetograph is given in fig.and the Φ index for the storm was 0.5 in/hr.The base flow in the channel was 100 cfs.what are the $t_p$and t_b ?

1.5 in/hr* 2 hr -0.5 in /hr *2= 2 in



T=2hrs.

T_p =4 hrs.

T_b=10 hrs.

T(HR.)	Q(CFS)	DRO	2hr.U.H
0	0	0	0
1	100	0	0
2	300	200	100
3	700	600	300
4	1000	900	450
5	800	700	350
6	600	500	250
7	400	300	150
8	300	200	100
9	200	100	50
10	100	0	0
11	100	0	0

How to Convert the duration of unit hydrograph

The linear property of U.H. can be used to generate U.H. of a larger or smaller duration .There are two methods to convert U.H. duration"

1-Superposition method:

It is applied to convert duration from shot to long time, and t_2/t_1=integer number.

To generate the U.H. of t_2 ,the U.H. of t_1 is legged till it reach to t_2, then by taking the summation of the lagged unit hydrographs.

Example 1:

Given the ordinate of 2 hr. U.H..Drive the ordinate of 6 –hr U.H,?

-Lagging 2-hr.

-Lagging 2-hr.

-Sum.of three storms.

-Multiply by 2/6.

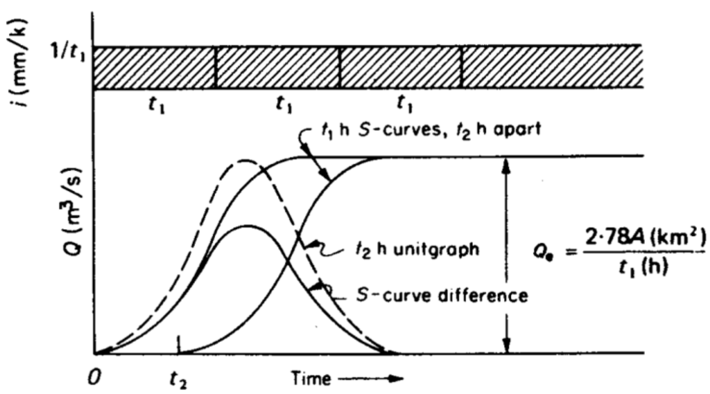
T(hr.)	2-hr.U.H	LAG.2-HR	LAG.2HR.	SUM	6HR.U.H.
0	0	-	-	0	0
2	300	0	-	300	100
4	720	300	0	1020	340
6	800	720	300	1820	606.6
8	540	800	720	2060	686.6
10	300	540	800	1640	546.6
12	170	300	540	1010	336.6
14	100	170	300	570	190
16	50	100	170	320	106.6
18	10	50	100	160	53.3
20	0	10	50	60	20

2-S-curve method:

Allows construction of a U.H.of any duration .Assume that a U.H. of duration t is known and that we wish to generate a U.H. of t' ,the first step by adding a series of unit hydrographs of duration t ,each lagged by t ,then by shifting the S-curve by t' ,then subtract the acummilated U.H. finally ,we must multiply all hydrograph by t/t' .

-Shift by t_1 with accumulation.

-Add the last two columns.



-Shift by t_2 without accumulation.

-subtract last two columns.

-Multiply by t_1/t_2.

Example:

Convert the following tabulated 2-hr. U.H. To 3-hr U.H. using the S-curve method?

T	2-hr U.H	Lag.2hr.	Sum.	Lag 3hr	Sub.	*2/3
0	0	-	0	-	0	0
1	75	-	75	-	75	50
2	250	0	250	-	250	166.6
3	300	75	375	0	375	250
4	275	250	525	75	450	300
5	200	375	575	250	325	216.6
6	100	525	625	375	250	166.6
7	75	575	650	525	125	83.3
8	50	625	675	575	100	66.6
9	25	650	675	625	50	33.3
10	0	675	675	650	25	16.6
11		675		675	0	0

culvert

Culverts are common hydraulic structure .As such highway design manuals are devoted to the wide range of possible culverts. A culvert is a pipe or box that is located under a roadway ,embankment ,or service area to allow the passage of storm runoff .while culverts are often circular pipes made of either concrete or corrugated metal, other shapes including elliptical and arch pipes and rectangular box culvert are widely used. A culvert consist of an inlet structure ,the pipe or box ,and the outlet structure. In addition to the sheep, culverts are also classified according to the flow condition in the inlet and outlet:

1-Un-submerged inlet & outlet.

2-Submerged inlet ,um-submerged outlet .

3-Submerged inlet &outlet.

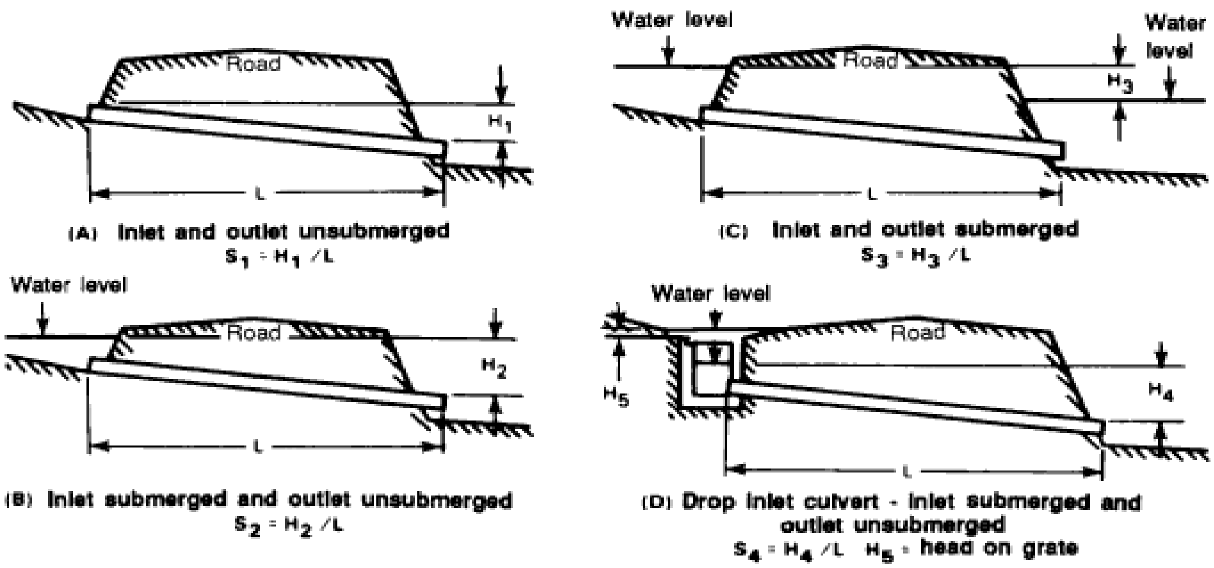


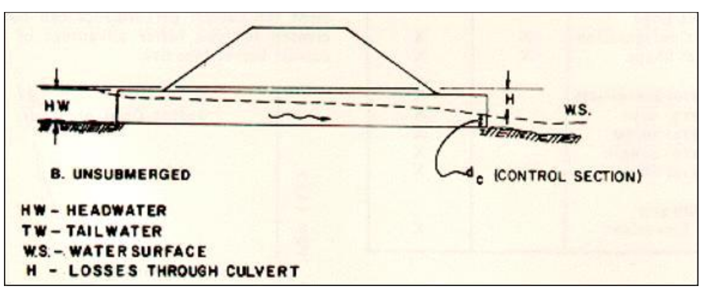
Figure 6-49. Hydraulic gradient, S, and heads, H, for culverts

Culverts are designed for the peak flow rate of the design storm .The peak flow is obtained from a U.H.at the culvert site.

Other factors affect the culvert design:

1-Head water depth: it is the invert water depth at the culvert inlet.

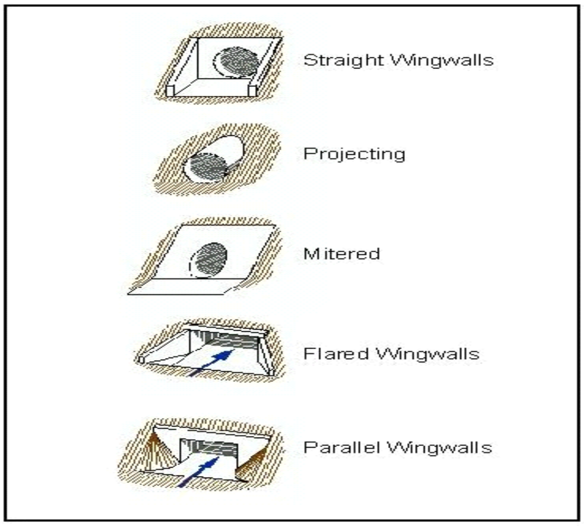
2-Tail water :it is the depth of water above the culvert outlet invert as the water flow out of the culvert.



<u>*Culvert hydraulic design:*</u>

1-Inlet control:

There are many factors that affect the performance of a culvert under inlet control:



-Inlet shape.

-Inlet configuration.

-Inlet area.

-Headwater depth.

The relation between H.W. and flow is:

-For un-submerged condition:

=+k - 0.5*S

=k

-For submerged condition:

=c()^2 + Y- 0.5*S

HWi:headwater depth.

D:height of culvert.

Hc: specific head @ critical depth($dc+vc^2/2g$)

Dc: critical depth.

Q:discharge.

A:barrel cross sec. area.

S:culvert slope.

K, M, C, Y constants depend on shape, material ,cross sec.)

V:velocity.

Vc:critical velocity.

<u>Computing invert inlet:</u>

<u>Example:</u>

Determine the required inlet invert for 5*5 ft^2 box culvert under inlet control if the peak discharge 250 ft^3/s, design HW ale. ELh=230.00 ft,stream bed ele. Inlet ELs=224.00 ft?

.from fig. 3 select points A& B

A:high of box and B= = = 50 $ft^3/s/ft$.

. For points A&B draw a straight line, then extend it find HW/D

HW/D=1.14

.the required headwater =1.41 *5 =7.1 ft

When velocity is not neglected HWi= HW $-V^2/2g$

When it is neglected vHWi= 7.1 ft.

.the required depression HWd = ELh -ELs

230 -224 =6.5 ft

HWi- HWd =7.1-6.5 =0.6 ft.(+,0,_)when (0 or _ use 0)

Invert ele.=224 – 0.6 =223.4 ft.

2-Outlet control:

When the barrel is capable of transporting as much flow as the inlet opening, then the design will be under outlet control.

The factors affect the outlet control will be:

-Inlet shape.

-Inlet configuration.

-Inlet area.

-Headwater Depth.   In addition:

-Tailwater depth.

Culvert characteristics (roughness, slope & length)

For the outlet there is a hydraulic analysis of flow based on the energy balance

H_L + He + H_f+H_E+H_b+H_j+H_g

L: total loss.

E:energy loss at entrance.

F:friction loss.

E:energy loss at exit.

B:bend loss.

J:loss at junction.

G:loss at grates.

I we neglect some losses

$H_L = (1+K_e +)\ v^2/ 2g$

Ke factor based on various configurations(from table).

R:hydraulic radius.

L:length.

V:velocity.

Example for outlet control:

Determine the HW ele. For a last example, if the culvert is full under outlet control, the tail water depth above the invert = 6.5 ft,the length of the culvert =200 ft and the natural stream slope @ 2%, ?

From chart 5 find the critical depth

Q/B dc = 4.3 ft or

Dc= 0.315

H_{TW} is the depth from the outlet to the hydraulic grade line =

Or tail water depth TW whichever is greater.

TW =6.5 ft.

H_{TW}= 4.7 ft

Locate the size ,length & k_e of the culvert at A and B ,then draw a straight line from A to B and locate the intersection C .

Locate D on the discharge scale and draw a straight line C to D, extend this line to head loss scale at E .

The required outlet head water ELh is

ELh = EL in+ H +H_{TW}

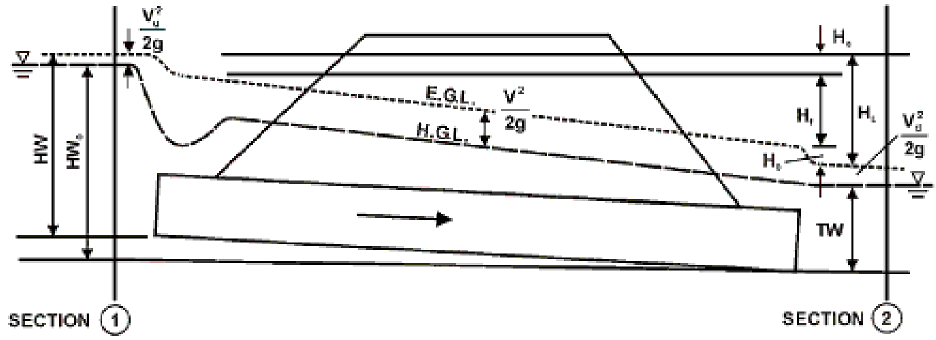
EL inv.: invert ele. At outlet.

ELhnv. =223.4 – 0.02 * 200 =219.4 ft.

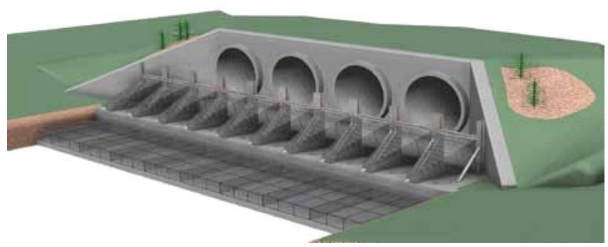
EL h =219.4 + 3.3 +6.5 +229.2 ft .

229.4 < 230

∴ Outlet HW < design HW ele.



<u>Circular Culvert Design:</u>



1-For un- submerged inlet and outlet:

Manning's equation is used to estimate the diameter of the circular pipe culvert.

$Q= A\ R^{2/3} / S^{1/2}$

$D= 1.33(Qn)^{3/8} / S^{3/16}$

Example:

The discharge between inlet and outlet is 5.7 cfs. Assume the pipe have roughness coef.. 0.014 ,slope 0.36% and the flow is full, calculate the diameter?

D= ()$^{0.375}$ =($^{0.375}$

=1.48 ft.

V =Q/A = =3.2 ft/s.

2-Submerged inlet ,un-submerged outlet:

In this case the system can be treated as an orifice.

Q = Cd A ……………….1

H+   = H ……………………..2

Substituting 2 in   1 yields

Q = Cd

(……h……)

Solving for D

$D^5 - 2\ hi\ D^4 +\ = 0$

3-Submerged inlet and outlet:

This case is treated as a special case where the depth of flow at the outlet equals the pipe diameter ,thus the energy equation between points on the head water and tail water surface is

+ +z1 -hL = + + z2

For large area v1 &v2 are neglected

Hi = pi/

Zi = S L

.h1+0 + SL – hL = h2 + 0 + 0

.hL = h1 – h2 + SL

After using Manning's equation and continuity equation the equation become:

.h1 - h2 + SL=(Kin + Kex) ( ) +

Kin=0.5   ,   Kex=1

Example

A new culvert is being discharged ,ponding cannot exceed 8 ft above the pipe invert inlet ,at the outlet ,the maximum pond of 5 ft is permitted.   Mannings n = 0.013, length = 110 ft ,S =0.02 ft/ft,Q= 82 cfs,calculate the diameter?

8 - 5 + 0.02 (110) = (0.5 + 1) (+   , D=

Flood forecasting

Flood forecasting :Is the use of real-time precipitation and streamflow data in rainfall-runoff and streamflow routing models to forecast flow rates and water levels for periods ranging from a few hours to days ahead, depending on the size of the watershed or river basin. Flood forecasting can also make use of forecasts of precipitation in an attempt to extend the lead-time available

Annual flood: maximum discharge of a river in one year

Flood estimating

1-Flood formula.

2-Frequency analysis.

Flood formula:

$Q=C\ A^n$

From which

Q=flood (m^3/s)

A=catchment area (km^2,$mile^2$)

N=index.(0.5 – 1.25)

C=locality coefficient.

But each formula indicate an area for example in India Deckne's formula can applied

$Q(ft^3/s)=825\ A^{0.75}(sq.mile)$

In Scotland Wales other formula applied

$Q(ft^3/s) = 3000A^{0.5}$(sq.mile)

Frequency analysis:

If the probability that flood will equal or larger than X for any year =P

Then T is the return period.

$P= \frac{1}{T}$ (probability to happening)

$.q = (1- p) = (1 - \frac{1}{T})$ (not happening)

$0 \leq p (xi) \leq 1$

$$\sum_{i=1}^{n} p(xi) = 1$$

$P_{r,n} = \frac{n!}{(n-r)!r\,!} p^{\,r}\; q^{\,n-r}$

N no. of years , r no. of happening

$P_{0\,n} = q^{\,n} = (1- p)^n$ احتمالية الحدوث صفر

$P_{1,n} = 1- q^{\,n} = 1 - (1- p)^n$

احتمالية الحدوث مرة واحدة على الاقل

When $p \leq x_o = (1- \frac{1}{T})^n$

$p \geq x_o = 1 - (1- \frac{1}{T})^n$

Example:

Analysis of data on maximum one-day rainfall depth indicated that a depth of 280 mm had a return period of 50 yr. Determine the probability of a one –day rainfall depth equal to or grater than 280 mm ,(1) once in 20 successive years (2) two times in 15 successive years (3) at least once in 20 yrs.?

$P=\frac{1}{50} = 0.02$

(1) N=20 yrs. r = 1 so $p_{\,1,20}=\frac{20!}{19!1!} * 0.02 * (0.98)^{\,19} = 0.272$

(2) N=15 r=2 so $p_{2,15}=\frac{15!}{13!2!}*0.02^{2}*(0.98)^{13}=0.323$

(3) $P=1-(1-0.02)^{20}=0.332$

determination of N year flood :

1-Graphical methods.

2-Mathematical methods.

Graphical methods:

a-compute T for all observed floods from

$T=\frac{n+1}{m}$ (Weibull formula)

From which:

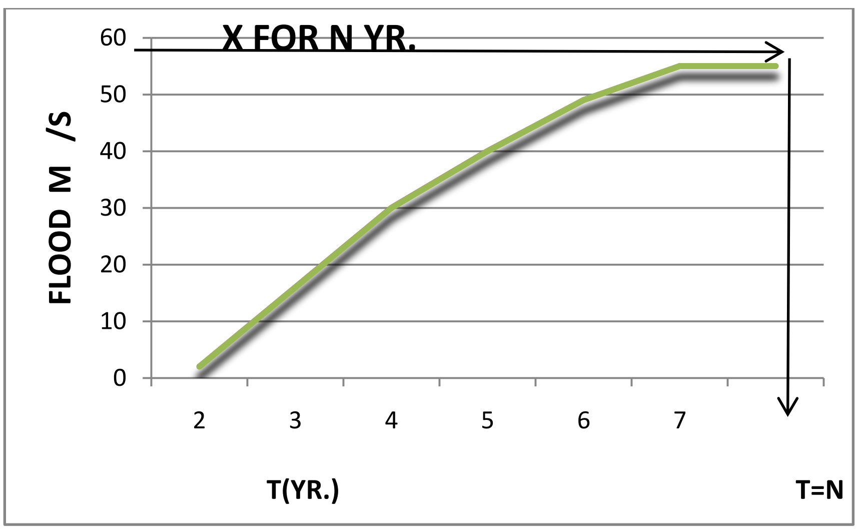
N:numberq of observed flood.

M:rank of flood with data arranged in descending order and m=1 for the largest flood.

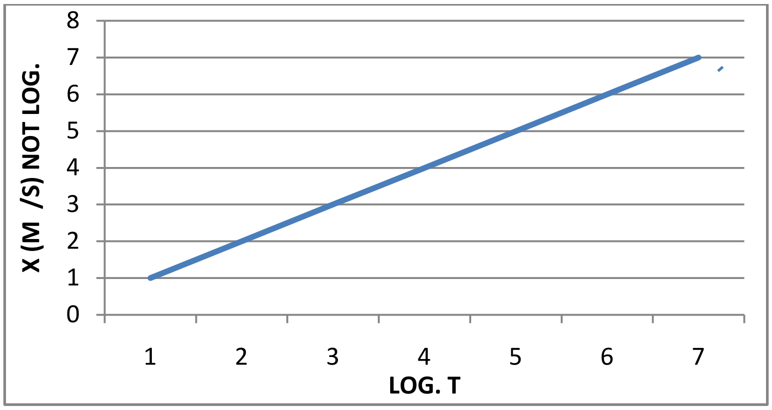
Or $T=\frac{n}{m}$ (California formula)

Then plot

1-Observed flood (X)against T



2-X against T on a semi-log paper



3-y=ln X against $P(X \geq x) = 1/T$ on a normal probability paper

Example

Determine 100-year flood from flood observation show

yr	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968
Flood	3120	2780	1710	2960	7500	4540	3450	6790	5040	5240
Rank	7	9	10	8	1	5	6	2	4	3
T=n+1/m	1.57	1.22	1.1	1.37	11	2.2	1.83	5.5	2.75	3.6
Log T	0.195	0.086	0.041	0.136	1.04	0.34	0.26	0.74	0.44	0.56

After plot at log (100) then $X=12100 m^3/s$.

Mathematical method:

a-fitting log-normal distribution.

1-compute y=ln x.

2-compute y=∑y/n (mean).

3-compute $y=\sqrt{\frac{\sum(yi-y)}{n-1}}$ (standard deviation of y)

4-compute $f(y_\circ)=P(y\leq y_\circ)=1-1/T$

5-let $f(y_\circ)=f(z_\circ)$.

6-$f(y_\circ)=\int_{-\infty}^{y_\circ} \frac{1}{2\pi \quad y} e^{-(y_\circ-y)/2 \quad y2} dy$

7-from statistical table find $z_\circ$

8-$z_\circ=y_\circ-y/ \quad y$ then $y_\circ=\ln \ X_\circ$ $X_\circ=e^{y_\circ}$

Example

Find 100-yrs. Flood by fitting log distribution

Yr.	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968
flood	3120	2780	1710	2960	7500	4540	3450	6790	5040	5240
Y=lnx	8.05	7.93	7.44	7.99	8.92	8.42	8.15	8.82	8.53	8.5

$Y'=\sum y/n = \frac{82.18}{10} = 8.281$

$Y=\sqrt{\sum(yi-y)}$ /n-1 =0.453

$F(y_\circ)=1-\frac{1}{T}=1-\frac{1}{100}=0.99$

$F(z_\circ)=0.99-0.5=0.49$

From table $z_\circ=2.325$

$z_{\circ}$=$y_{\circ}$-y' / y

$2.325=\frac{y_{\circ}-8.281}{0.453}$

$z_{\circ}$=9.33

$2.325 =\frac{Y_{\circ}-8.281}{0.453}$

$Y_{\circ}$=9.33

$X_{\circ}=e^{y_{\circ}}$ =11318.85 m^3/s.

B-Fitting the Gumble distribution

1-P(X≥$X_{\circ}$)=$\frac{1}{T}$ =1-e^{-e}

Or b=ln (1/ln($\frac{1}{1-\frac{1}{T}}$)

2-b=$\frac{1}{0.78}$ ($x_{\circ}$-x'+0.45)

3-find x'=$\frac{\sum x}{n}$

4-find $=\sqrt{\frac{\sum(xi-x')^2}{n-1}}$

Example

The same previous example:

x'=$\frac{\sum x}{n}$=4313

=1852 ,1/100=0.01

B=ln($\frac{1}{\ln(\frac{1}{1-0.01})}$=4.6

4.6=$\frac{1}{0.78*1852}$($x_{\circ}$-4313+0.45*1852)

$x_{\circ}$=10124 m^3/s

Flood routing

The flood hydrograph is in fact a wave .the stage and discharge hydrographs represent the passage of waves of stream depth and discharge respectively .As this wave moves down ,the shape of the waves gets modified due to channel storage ,resistance,lateral addition or withdrawal of flows . Flood routing is the technique to determining the flood hydrograph at a section of a river by utilizing the data of flood flow at one or more upstream section .Flood routing is used in(1)flood forecasting(2)flood protection (3)reservoir design ,and(4)design of spillway and outlet structures

Flood routing types :

1-reservoir routing   2-channel routing

A variety of routing methods are available and can grouped into

a-hydrologic   b-hydraulic

hydrologic methods employ essentially the continuity equation ,and hydraulic method use continuity equation along with the equation of motion of unsteady flow .

Basic equation for hydrologic routing:

The passage of a flood hydrograph through a reservoir or a channel is gradually varied unsteady flow .If we consider some hydrologic system with input I(t),output O(t),and storage S(t),then the equation of continuity in hydrologic routing method is the following :

$I\text{-}O=\frac{dS}{dt}$

I Δt- OΔt=Δ

$\frac{I1+I}{2}\Delta t-\frac{O1+O2}{2}\Delta t=S2-S1$

$\frac{I1+I2}{2}\Delta t+S1-\frac{O1\Delta t}{2}=S2+\frac{O2\Delta t}{2}$

$(I_{1}+I_{2})+(\frac{2S1}{\Delta t}-O_{2})=(\frac{2S2}{\Delta t}+O2)$

<u>Steps for routing</u>

1-drive the relation between O $\&\frac{2S1-O1}{\Delta t}\&\frac{2S2+O2}{\Delta t}$

2-select O1on the curve 1,then find a value

The calculate $I_1+I_2+(\frac{2S1}{\Delta t}-O1)=\frac{2S2}{\Delta t}+O2$

(1) (2)

3-the value(2) we obtained from step 2 we select it on the curve to obtain O

4-the value of O select it to find(1) and calculate $I_1+I_2+(1)=(2)$

5-the value of (2)select it on the curve to obtain O and so on .

Example

Find the outflow hydrograph for a given 3 hours inflow hydrograph at a reservoir of initial outflow =1 m^3/s.?

t	I(m^3/s)	2S/Δt-O	2S/Δt+O	O	O(m^3/s)	S(m^3*10^6)
0	2	49	207	1	0.3	1.21
3	156 158	199	610	7.5	0.62	3.42
6	255	516	983	29	0.96	6.27
9	212	884	1280	49	1.35	9.66
12	184	1146	1488	67	1.71	13.5
15	158	1328	1622	80	2.1	17.75
18	136	1445	1692	88	2.57	22.36
21	116	1511	1726	93	3	27.32
24	99	1537	1721	95	3.25	32.6
27	85	1532	1691	94	4.5	44.1
					5.68 6.2	56.6 63.2

<u>2-Channel routing</u>

In a very long channels the entire flood wave also travels a considerable distance resulting in a time redistribution and time of translation as well. Thus ,in a river ,the redistribution due to storage effects modifies the shape .while the translation changes its position in time .In the reservoir the storage was unique function of the outflow discharge S=f(O),however in channel the storage is a function of both outflow and inflow discharge .The water surface in a channel reach is not only parallel to the channel bottom but also varies with time .The total volume in storage considered as a prism +wedge. The prism storage is constant while the wedge storage is changes from a positive at an advancing flood to a negative during a receding flood .assuming the volume of prism is KO ,where K is a proportionality coefficient (the time of travel of flood through the channel)and the volume of wedge is KX(I-O),X is $0<X<0.5$ the total storage is the sum of:

$S=K(XI+(1-X)O)$ (Muskingum)

Then the value of storage at time j and j+1 is:

$S_J=K(XI_j+(1-X)O_j)$ and

$S_{j+1}=K(XI_{j+1}+(1-X)O_{j+1})$

The change in storage over time Δt is:

$S_{j+1}-S_j=K(X(I_{j+1}-I_j)+(1-X)(O_{j+1}-O_j))$

From continuity eq.:

$$\left(\frac{Ij+Ij+1}{2}\right)\Delta t-\left(\frac{Oj+Oj+1}{2}\right)\Delta t=S_{j+1}-S_j$$

Equating two eq.

$$\left(\frac{Ij+Ij+1}{2}\right)\Delta t-\left(\frac{Oj+Oj+1}{2}\right)\Delta t=K(X(I_{j+1}-I_j)+(1-X)(O_{j+1}-O_j))$$

The after simplifying

$O_{j+1}=C_1\ I_{J+1}+C_2\ I_J+C_3O_j$

$(O_2=C_{\circ}I_2+C_1I_1+C_2O_1)$

From which:

$$C_{\circ}=\frac{0.5\ \Delta t-KX}{K(1-X)+0.5\Delta t}$$

$$C_1=\frac{0.5\ \Delta t+KX}{K(1-X)+0.5\ \Delta t}$$

$C_2 = \frac{K(1-X)-0.5\ \Delta t}{K(1-X)+0.5\ \Delta t}$

$C_\circ + C1 + C2 = 1$

EXAMPLE

Rout the flood for a river when K=12 hr. X=0.2 ,for initial outflow=10m^3/s

T(hr)	0	6	12	18	24	30	36	42	48	54
Qin(m^3/s	10	20	50	60	55	45	35	27	20	15

$c_\circ = \frac{-12*0.2+0.5*6}{12-12*0.2+0.5*6} = 0.048$

$c_1 = \frac{-12*0.2+0.5*6}{12.6} = 0.429$

$c_2 = \frac{12-12*0.2+0.5*6}{12.6} = 0.523$

$I_1=10$ $C_1I_1=4.29$

$I_2=20$ $C_\circ I_2=0.96$

O1=10 $C_2O_1=5.23$

O=10.48 M^3/S

($O_2=C_\circ I_2+C_1I_1+C_2O_1$)

T(HR)	I	$C_\circ I_2+$	C_1I_1	C_2O_1	O
0	10				10
6	20	0.96	4.29	5.23	10.48
12	50	2.4	8.58	5.48	16.46
18	60	2.88	21.45	8.61	32.49
24	55	2.64	25.74	17.23	45.61
30	45	2.16	23.6	23.85	46.93
36	35	1.68	19.3	25.95	40.87
42	27	1.3	15.02	24.55	33.92
48	20	0.96	11.58	21.38	27.04
54	15	0.72	8.58	17.74	