National University of Laos
Faculty of Engineering
In cooperation with DAAD, University of Siegen

Estimation of Rainfall- Runoff and Ground Water Recharge in the Xebanghieng River Basin By Using SCS and Base Flow Separation Methods

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Introduction (1)

- In Lao PDR, the most common natural disasters are floods and droughts.

- On September 19, 2009, Typhoon Ketsana hit the five southernmost provinces of Lao PDR: Savannakhet, Salavan, Attapeu, Sekong, and Champassak. Ketsana brought severe flooding that affected over 180,000 people (23% of the population in these provinces) and resulted in 28 storm related deaths (GOL 2009)

Source: Minister of Planning and Investment, Aug 2011

Impact of floods and drought in Lao PDR from 1966 to 1995

Year	Details of Floods and Droughts	Cost of Impacts (US$)
1966	Large floods (Vientiane, central and southern)	Inaccurate data
1967	Drought (Central and southern)	5,200,000
1968	Flood (Southern)	2,830,000
1969	Flood (Central)	1,020,000
1970	Flood (Central)	30,000
1971	Large flood	3,573,000
1972	Flood and drought	40,000
1973	Flood (Central)	3,700.000
1974	Flood (Southern)	80,000
1975	Drought	Data not available
1976	Flash flood	9,000,000
1977	Severe drought	15,000,000
1978	Large flood (Central and Southern)	5,700,000
1979	Flood and drought	3,600,000
1980	Flood	3,000,000
1981	Flood	682,000
1983	Drought	<50% of total production
1987	Drought	5,000,000
1988	Drought and crop pest pandemic	4,000,000
1989	Drought	20,000,000
1991	Flood and drought	70.000 ha
1994	Flood	36.382 ha
1995	Flood	63,820 ha

Source: DoP, Ministry of Agriculture and Forestry/ National Disaster Management Office, 1996.

National Water Resource Strategy from Now Until 2020 and Water Resources Action Plan for 2011-2015

Program 1 Improvement of implementation coordination

Program 2 Legislation, plan, and implementation

Program 3 River basin and sub-basin water resource management planning

Program 4 Groundwater management

Program 5 Collection, analysis and management of water resource data and information

Program 6 Water allocation

Program 7 Protection of water quality for surface water, groundwater and aquatic ecosystem

Program 8 Wetland management

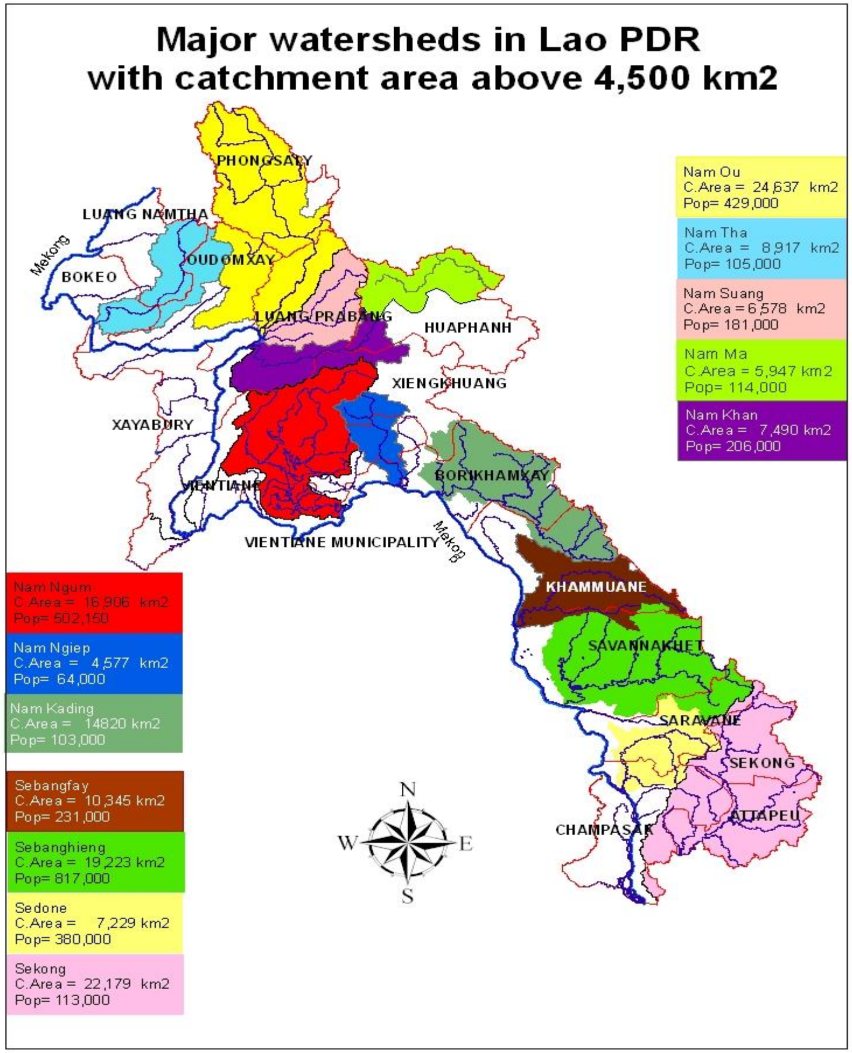
Program 9 Flood and drought management

Program 10 Manage water resources for impact mitigation and adaptation to climate change

Program 11 Financial aspects of water resource management and climate change adaptation in water sector

Source: MoNRE, DWR, 2014

Introduction (2)



Source: WREA, 2008

10 River Basin Priorities

1. Nam Ngum
2. Nam Theun-Cading
3. XeBangFai
4. XeBangHieng
5. XeDone
6. Nam Ou
7. XeKong
8. Nam Tha
9. Nam Seung
10. Nam Khan

Introduction (3)

<u>Location</u>:

- River Basin Area: **19,195** km2
  (Source data: wgs84, MRC)
- Mean annual rainfall: **1,600 mm**
- Mean annual discharge: **560 m3/s**
- Q max: **7,274 m3/s**
- Q min : **18.5 m3/s**
  At Kengdon Station
  (Sources data: Water Balance , 2007)

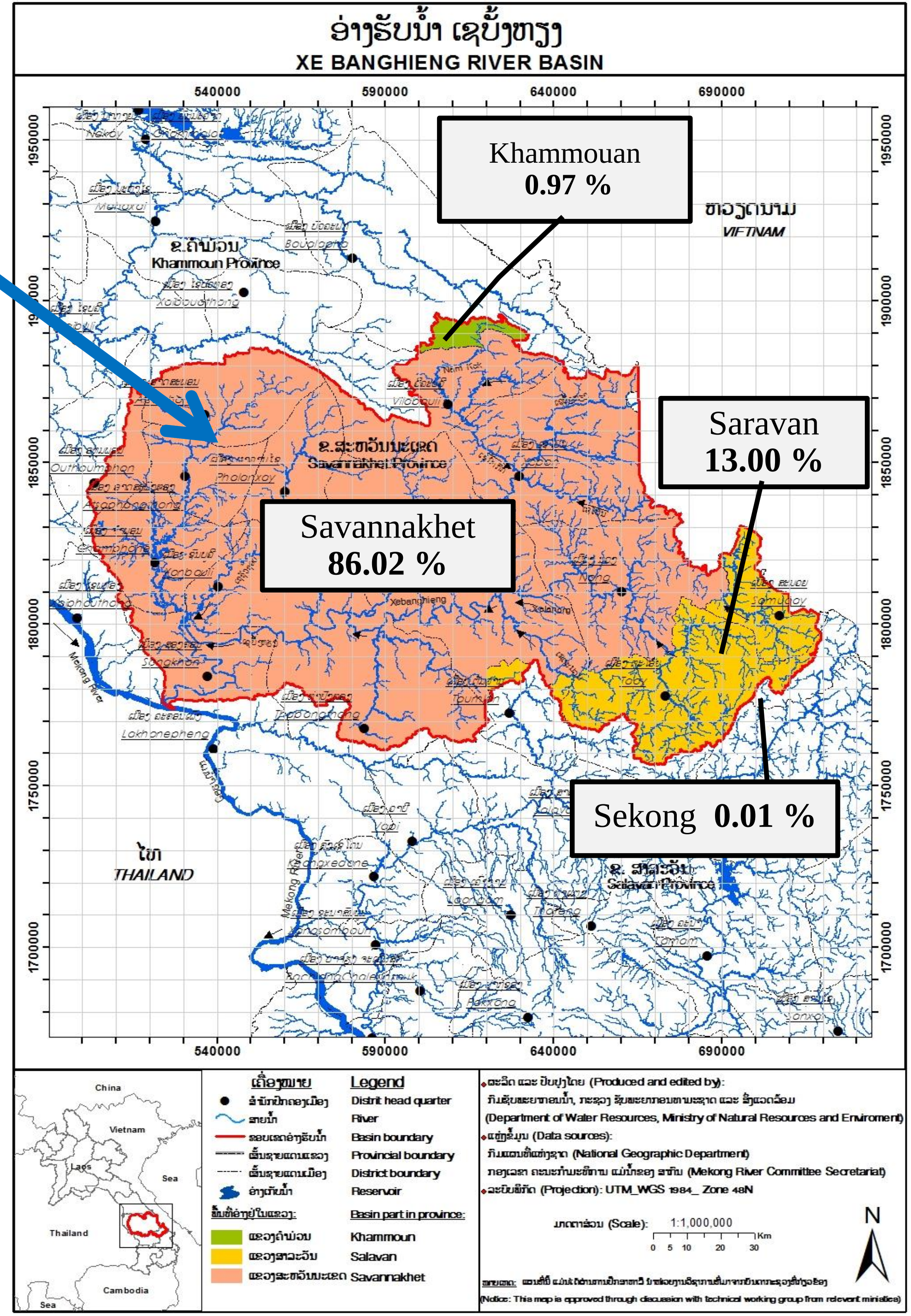
<u>Irrigation water demand</u>

- Wet season : **0.17 m3/s**
- Dry season : **0.32 m3/s**

(Sources data: Dept of Irrigation , 1998)

<u>Water Supply for Domestic use</u> (Khanthaboury, Outhomphone and Songkhon Districts).

- Population in service area: **107,628 people**
- Population served water supply: **1,460 people**
- Service coverage **1%**
  (Sources data: WASA,2004)



Introduction (4)

<u>Challenge</u>

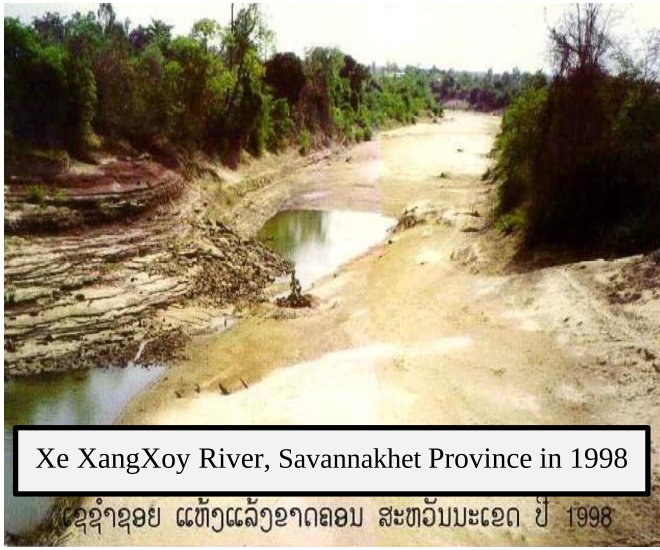
Flood and drought in every years

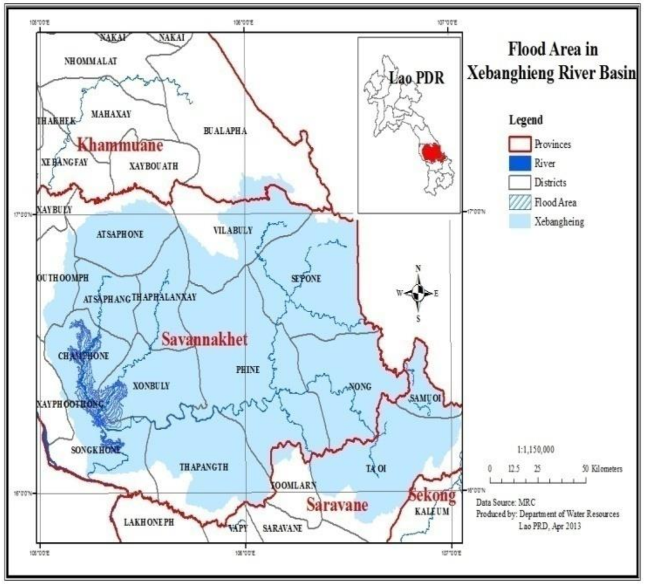
- 1996 has rice field affected by **flood 21,038 ha** province. Dry season of 1996 has rice field affected by **droughts : 14, 468 ha**

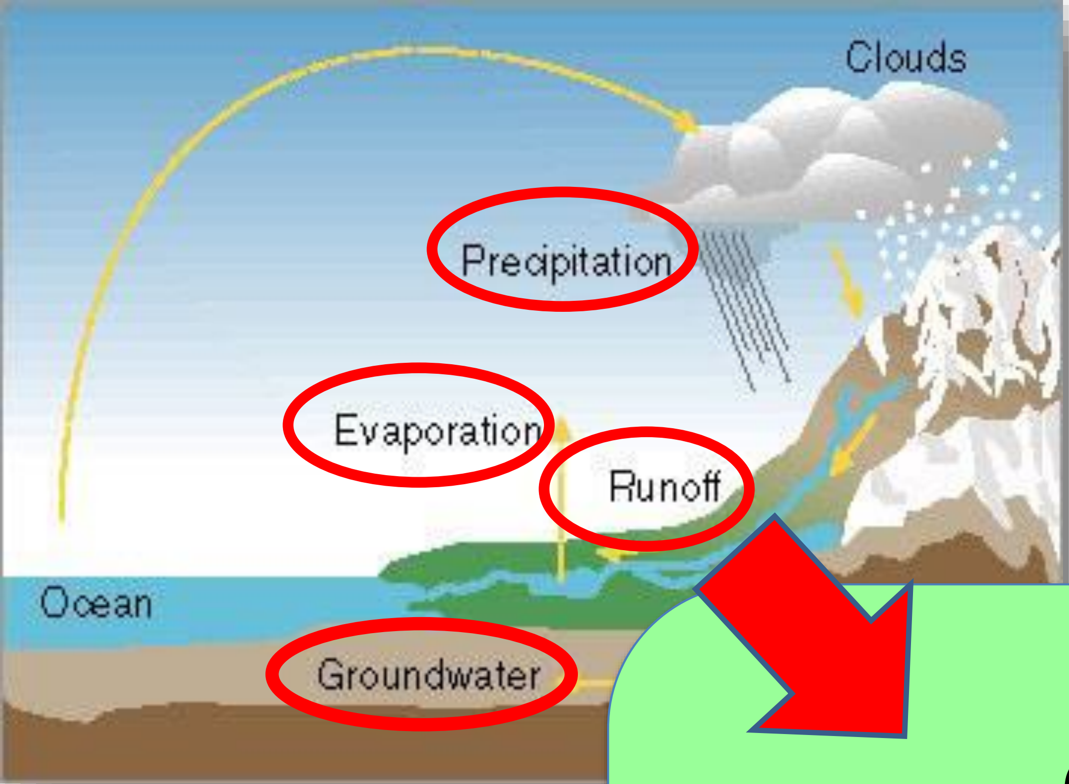
  (Sources data: Climate Change 2009)

<u>Issue</u>

- The Lao PDR had water balance study in 2005 and 2007 which the both versions **are unclear methods on hydrological analysis.**
- The XBH river basin has **very limited dry season flows**.
- **Limited information on water availability** to water resources management, planning and monitoring in river basin.


Xe XangXoy River, Savannakhet Province in 1998





Question

"How much rainfall- runoff and groundwater recharge in XBH River Basin?"

Why using Soil Conservation Service (SCS) and Base Flow Separation Methods?

The Mekong River Commission (MRC) applied the **SWAT** model to analysis water resources in Lower Mekong River countries. The SWAT model uses SCS method to analysis runoff and this method is **basic method and a good analysis runoff** for the small scale river basin and land use change.

Base flow separation is a basic method for estimation groundwater recharge by use discharge data.

, **SCS and base flow separation are the basic methods** for estimating rainfall-runoff and groundwater recharge.

Objectives

- To estimate **rainfall-runoff** at gauging stations in the XBH river basin.
- To analyse statistics of flow data for determining **flood-low flow** with difference return period in the XBH river basin.
- To estimate **ground water**.

Contents

Literature Review (1)

Water Budget Equation

$$P = E + R + G + \Delta S$$

P = precipitation (mm)
E = evapotranspiration (mm)
R = run off (mm)
G = subsurface outflow (mm)
ΔS = change in storage (mm)

Note:
Not Consider evapotranspiration

Rainfall

- Double-Mass Curve

Rainfall-Runoff

- Runoff Coefficient
- Soil Conservation Service (SCS)
- Log –Pearson Type III

Groundwater Recharge

- Base Flow Separation by use method of Nathan and McMahon (1990)

Literature Review (2)

Water Balance Study 2005 and 2007 of DMH

Objectives:

1. To estimate the monthly runoff in un-gauged basins
2. To analyze the monthly runoff
3. To complete the frequency analysis of both events in hydrological cycle.

Rainfall and Runoff	Water Balance Study of DMH 2005	Water Balance Study of DMH 2007
Average Rainfall (mm)	1,500	1,600
Average Runoff (mm)		875
Average Annual Discharge (m3/s)	497	
Maximum Discharge (m3/s)	4,689	7,274
Minimum Discharge (m3/s)	17	27

- "Estimation of Runoff for Agricultural Watershed Using SCS Curve Number and GIS" written *by Samanh AL-Jabari; Majed Abu Sharkh*

There are not runoff observation data available

- "Regional Estimation of Base Flow Recharge to Groundwater Using Water Balance and a Base-Flow Index" *by Jozef Szilagyi, F. Ediwin*

It does not require complex hydrogeologic modeliling nor detailed knowledge of soil characteristrics, vegetation cover, or land use practices

Contents

Methodology

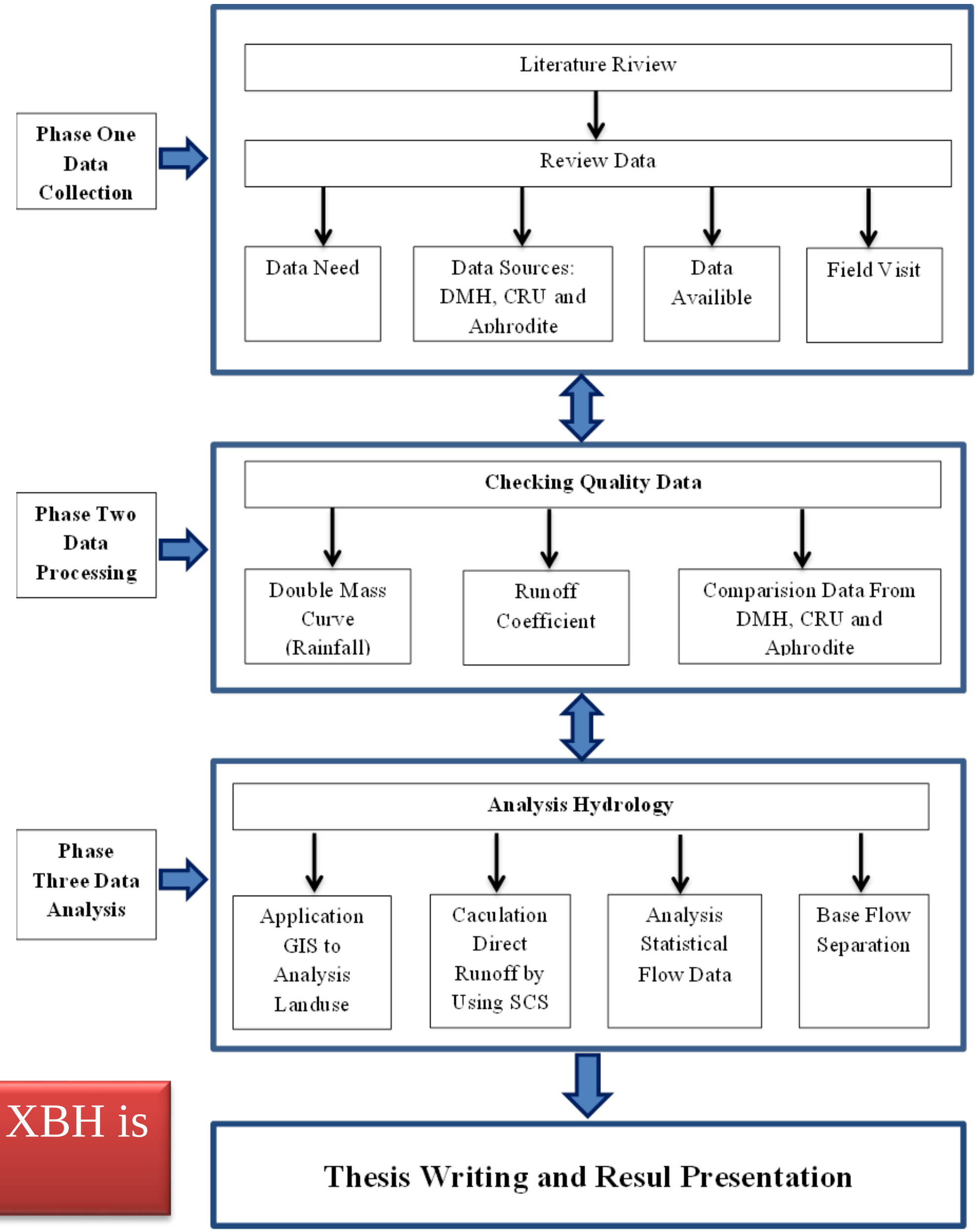
Step 1: **Data Collection** is a literature review, review data, identified data need, collected data from DMH, CRU and Aphrodite, checking data available and field

Step 2: **Data Processing** is used double mass curve to check the consistency, use runoff coefficient to analysis of rainfall-runoff and compare results from rainfall data of DMH, CRU and Aphrodite and;

Step 3: **Data Analysis** is applied GIS to analysis land use and soil type, calculate **rainfall direct runoff by using the SCS** method, analysis **flood-low flow use flow data and use Log-Pearson Type III** or Extreme Volume method and; apply **base flow separation to estimate groundwater recharge**

Rainfall, Runoff and Groundwater Recharge at XBH is **quantitative research**

Post-field work



Data for Analysis and Estimation of Rainfall-Runoff

Rainfall-Runoff

- Rainfall data use during 1985 to 2004 of DMH, CRU and Aphrodite (*For comparing result water balance study 2005 and 20017 of DMH*) and **checking quality** data.
- Discharge data use during 1960 to 2004 of the DMH

Flood-Low flow

- Monthly discharge data use during 1960 to 2004 of the DMH

Groundwater Recharge

- Daily discharge data of the DMH
- To selected only one year from the runoff coefficient and has a value more than 0.8 in each station

Contents

RESULT AND DISCUSSION

- To estimate **rainfall-runoff** at gauging stations in the XBH river basin.

- To analyse statistics of flow data for determining **flood-low flow** with difference return period in the XBH river basin.

- To estimate **ground water**.

Rainfall and Runoff

Data → Checking quality data → Rainfall-Runoff → Flood & Low Flow → Ground Water Recharge

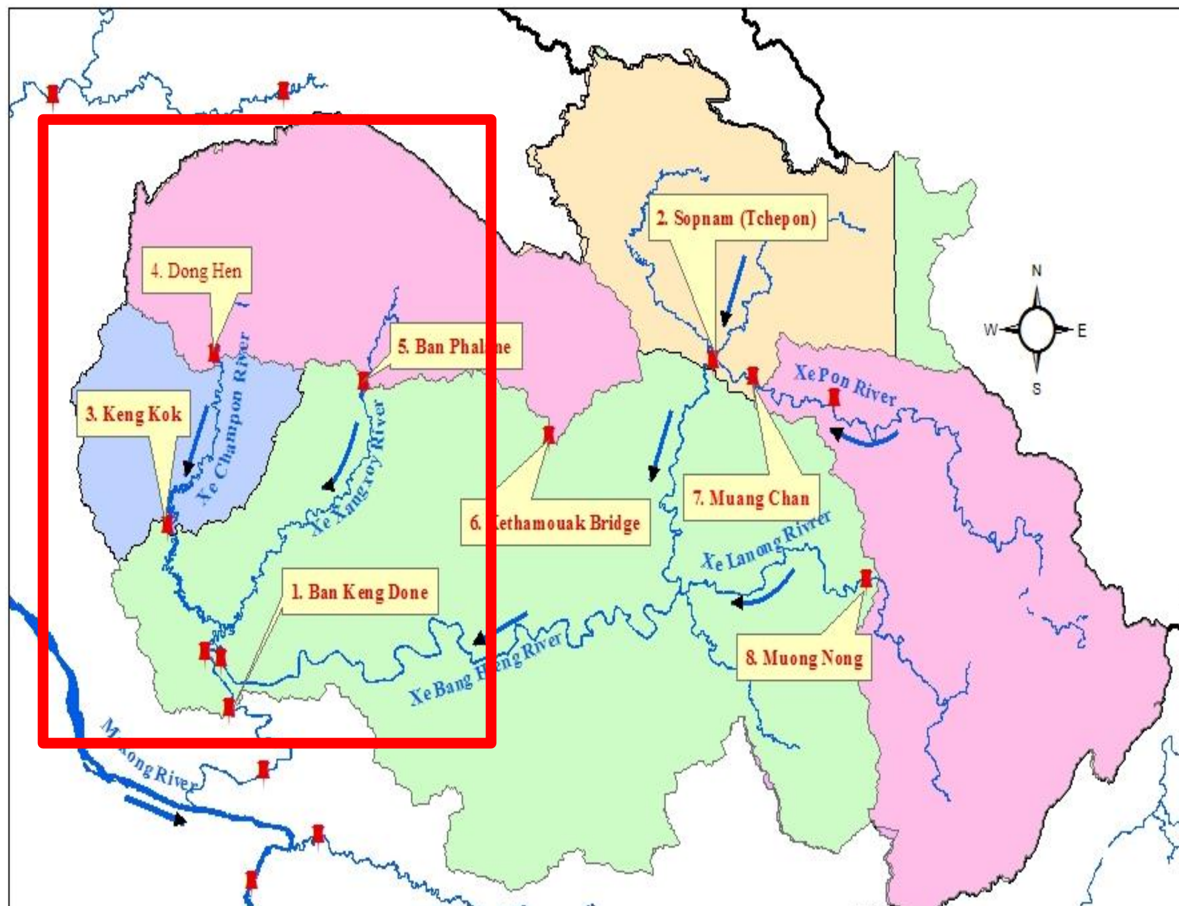
Data Available

Selection data at Phalan, Donghen, Kengkok and Kengdon because there is data more 15 years

1. Department of Meteorology and Hydrology **(DMH) 1985-2004**

2. Climatic Research Unit (**CRU) 1957-2007**

3. Asian Precipitation-Highly Resolved Observation Data Integration Towards Evaluation (**Aphrodite**) **1957-2006**



Rainfall and Runoff

No	Name of Station	Source Data	Data available	Missing Data	Note
1	Ban KengDone	DMH	1/1/1992-31/12/2006	1/1/1993-31/12/1993	
				1/1/1990-31/12/1996	
				1/1/1998-31/12/1999	
				1/1//2005-31/12/2005	
2	Kengkong	DMH	1/1/1961-31/12/2008	No Missing Data	Not Missing Data
3	Dong Hen	DMH	1/1/1965-31/12/2008	1/5/1965-30/6/1965	
				1/8/1967-10/9/1967	
				1/8/1968-30/8/1968	
				1/7/1969-30/9/1969	
				1/1/1971-31/12/1977	
				1/1/1980-31/12/1984	
4	Ban Phalan	DMH	1/1/1980-31/12/2002	No Missing Data	Not Missing Data

No	Name Station	Source Data	Data Available
1	Ban Keng Done	Aphodite	1951-2006
2	Tchepon	Aphodite	1951-2006
3	Keng Kok	Aphodite	1951-2006
4	Dong Hen	Aphodite	1951-2006
5	Ban Phalane	Aphodite	1951-2006
6	Highway bridge	Aphodite	1951-2006
7	Ban Muong Chan	Aphodite	1951-2006
8	Muong Nong	Aphodite	1951-2006

No	Name Station	Source Data	Data Available
1	Ban Keng Done	CRU	1951-2007
2	Tchepon	CRU	1951-2007
3	Keng Kok	CRU	1951-2007
4	Dong Hen	CRU	1951-2007
5	Ban Phalane	CRU	1951-2007
6	Highway bridge	CRU	1951-2007
7	Ban Muong Chan	CRU	1951-2007
8	Muong Nong	CRU	1951-2007

Rainfall and Runoff

Data → Checking quality data → Rainfall-Runoff → Flood & Low Flow → Ground Water Recharge

Situation

- Technical staff reads the value of water level from 08:30 to 09:30 and from 15:00 to 16:00 and reading is a guess value
- Cross section change because the sediment is increase every year
- This station, rainfall and water level measurement tool is broken and too old

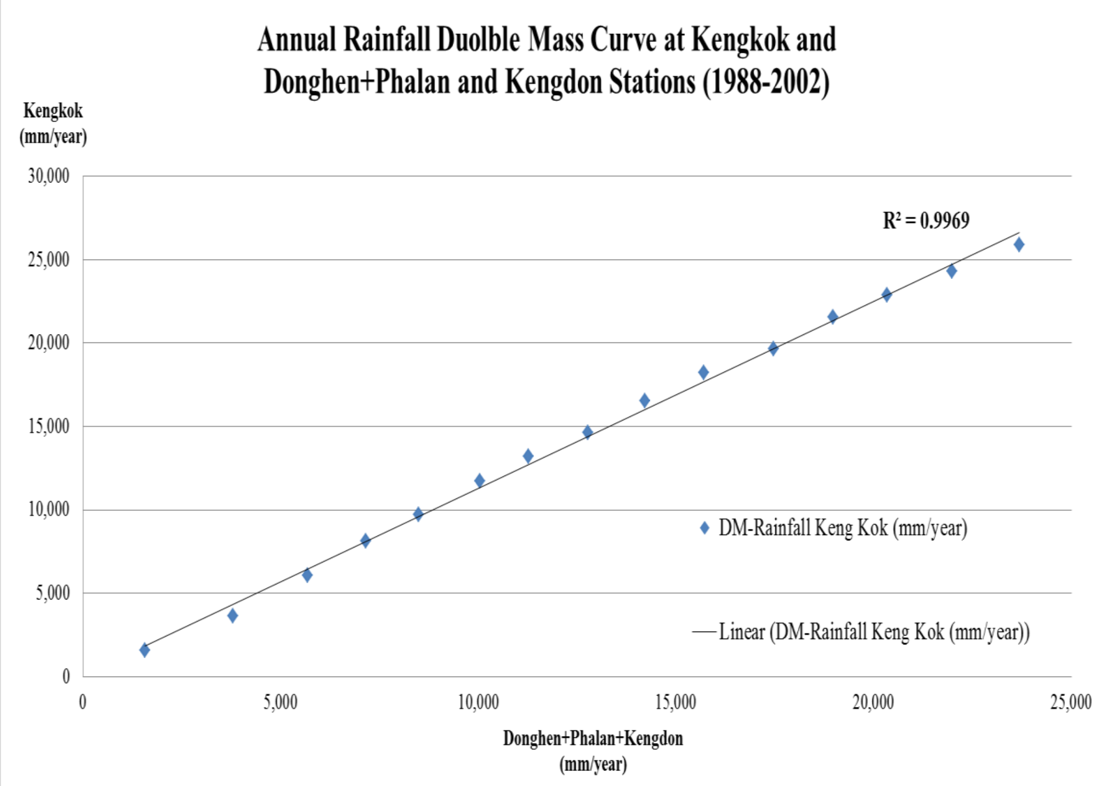

Rain Gauge
3 Meters
5 Meters
Donghen Station
Hole in rain gauge
Kengkok Station
Kengdon Station
24/12/2016
4. Dong Hen
3. Keng Kok
5. Ban
(Tchepon)
6. Xethamouak Bridge
7. Muang Chan
1. Ban Keng Done
8. Muong Nong
Xe Pon River
Xe Lanong River
Xe Bang Hieng River
N
S
W
E

Rainfall

Data | **Checking quality data** | Rainfall-Runoff | Flood & Low Flow | Ground Water Recharge

Double Mass Curve

Checking rainfall data is apply "Double –Mass Curve method" are used as a **check on the consistency of precipitation records**. A substantial change in the relative catch of precipitation may result from change in observer, location, observation procedure and exposure such as caused by tree growth or construction.



R-squared is a statistical measure of how close the data are to the fitted regression line. It is also known as the coefficient of determination, or the coefficient of multiple determination for multiple regression.

Runoff Coefficient

Data → **Checking quality data** → Rainfall-Runoff → Flood & Low Flow → Ground Water Recharge

$$K = \frac{\text{Runoff [mm]}}{\text{Rainfall [mm]}}$$

The **runoff coefficient** from an individual rainstorm is defined as runoff divided by the corresponding rainfall both expressed as a depth over the catchment area

No	Name of Station	Runoff Coefficient		
		DMH	CRU	Aphrodite
1	Phalan (1990-2004)	0.60	0.43	0.63
2	Donghen (1990-2004)	0.46	0.51	0.71
3	Kengkok (1990-2004)	0.43	0.58	0.50
4	Kengdon (1993-2001)	0.85	0.98	1.31
	Average:	**0.58**	**0.69**	**0.84**

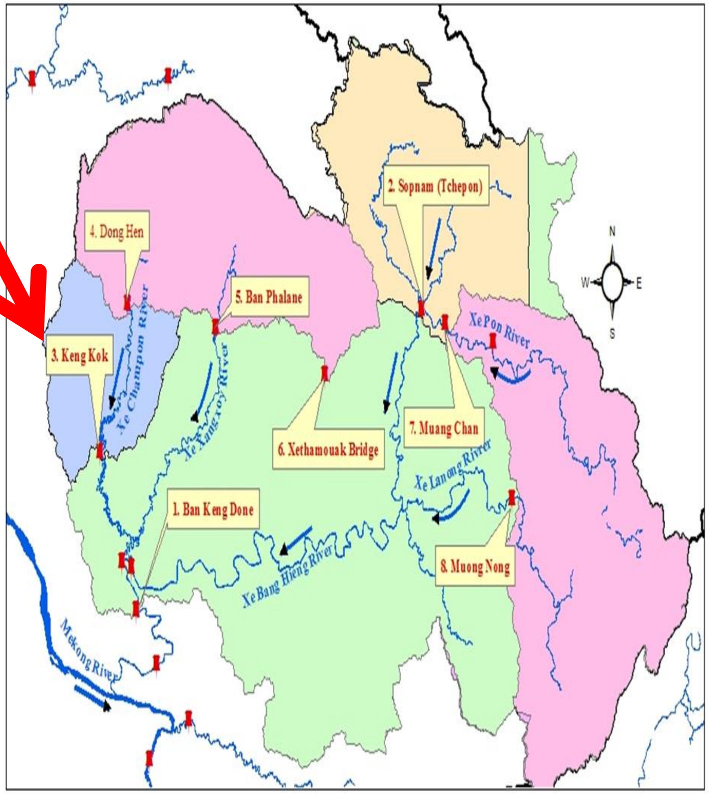
Good Data

Not Good Data

R	0.75	0.80	0.85	0.90	0.95
R^2	0.6	0.7	0.8	0.9	
Daily Flows	Poor	Fair	Good	Very Good	
Monthly Flows	Poor	Fair	Good	Very Good	

Issue

- Technical staff reads the value of water level from **08:30 to 09:30 and from 15:00 to 16:00** and reading is a guess value
- Cross section change because the **sediment is increased** every year



Estimation Rainfall-Runoff

by using Soil Conservation Service (SCS)

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S}$$

where:

- Q = accumulated direct runoff (in)
- P = accumulated rainfall or potential maximum runoff (in)
- I_a = initial abstraction including surface storage, interception, evaporation, and infiltration prior to runoff (in)
- S = potential maximum soil retention (in) = 1000/CN-10

SCS approach is more sophisticated in that it also considers the time distribution of the rainfall, the initial rainfall losses due to interception and depression storage, and an infiltration rate that decreases during the course of a storm

Note:

- The higher the CN, the higher the runoff potential
- Soil properties influence the relationship between runoff and rainfall since soils have differing rates of infiltration.
- **Group A:** Soils having a low runoff potential due to high infiltration rates.
- **Group B:** Soils having a moderately low runoff potential due to moderate infiltration rates.
- **Group C:** Soils having a moderately high runoff potential due to slow infiltration rates.
- **Group D:** Soils having a high runoff potential due to very slow infiltration rates.

Source: Soil Conservation Service, 1986

Soil Conservation Service at Phalan	Landuse 1997	Landuse 2003	Difference Landuse 1997-2003
Total area	83,332	83,332	
Landuse			
Paved; curbs and storm drains (excluding ringht-of-way)	47,948	1,167	46,781
Wood or ferestland: good cover	25,776	73,724	(47,948)
Culltivated land: with consevation treatment	3,642	3,642	-
Wood or forestland: thin stand, poor cover	4,771	4,771	-
Paved parking lots, roofs, driveways, etc. (excluding right-of-way)	1,167		1,167
Good condition (grass cover > 75%)	28	28	-
Soil groups			
Soil group A (%)	0.33	1.17	(0.84)
Soil group B (%)	99.67	98.83	0.84
Curve Numbers (CN)	60	57	2.95
Potential maximum soil retention (S) at Phalan	173	195	(22.26)
Rainfall observe of DMH (mm)	1,365	1,365	
Accumulated rainfall (P scs) at Phalan (mm)	1,178	1,157	
Accumulated direct runoff (Q scs) at Phalan (Mm3/year)	982	964	
Discharge (Q obs) of DMH at Phalan (Mm3/year)	680	680	

Soil Conservation Service at Donghen	Landuse 1997	Landuse 2003	Difference
	Area (ha)	Area (ha)	
Total Area(ha)	152,122	152,122	
Landuse			
Paved; curbs and storm drains (excluding ringht-of-way)		10,540	(10,540)
Wood or ferestland: good cover	93,774	111,859	(18,084)
Good condition (grass cover > 75%)		4,295	(4,295)
Culltivated land: with consevation treatment	25,601	20,451	5,150
Wood or ferestland: thin stand, poor cover	32,747	4,977	27,770
Soil groups			
Soil group A (%)	15.89	15.89	0
Soil group B (%)	74.29	69.92	4
Soil group C (%)	9.82	14.19	(4)
Curve Numbers (CN)	57.42	58.56	(1)
Potential maximum soil retention (S) at Donghen	188	180	9
Rainfall observe of DMH (mm)	2,211	2,204	
Accumulated rainfall (P scs) at Donghen (mm)	2,002	2,004	
Accumulated direct runoff (Q scs) at Donghen (Mm3/year)	3,045	3,048	
Discharge (Q obs) of DMH at Donghen (Mm3/year)	1,457	1,457	

Soil Conservation Service at Kengkok	Landuse 1997	Landuse 2003	Difference
	Area (ha)	Area (ha)	
Total Area (ha)	113,078	113,078	
Landuse			
Paved; curbs and storm drains (excluding ringht-of-way)	9,073	40,547	(31,474)
Wood or ferestland: good cover	33,215	19,278	13,937
Good condition (grass cover > 75%)	2,354	3,972	(1,618)
Culltivated land: with consevation treatment	61,835	49,137	12,698
Wood or ferestland: thin stand, poor cover	6,400	22	6,378
Urban districts: industrial	201	122	79
Soil groups			
Soil group A (%)	16	16	0
Soil group B (%)	74	70	4
Soil group C (%)	10	14	(4)
Curve Numbers (CN)	62	62	-
Potential maximum soil retention (S) at Kengkok &Donghen	158	158	-
Rainfall observe of DMH at Kengkok &Donghen (mm)	1,792	1,792	
Accumulated rainfall (P scs) at Kengkok &Donghen (m3)	1,616	1,616	
Accumulated direct runoff (Q scs) at Kengkok &Donghen (Mm3/year)	1,872	1,872	
Discharge (Q obs) of DMH at Kengkok &Donghen (Mm3/year)	2,055	2,055	

Soil Conservation Service at at Kengdon	Landuse 1997	Landuse 2003	Difference
	Area (ha)	Area (ha)	
Total Area (ha)	871,320	871,320	
Landuse			
Wood or forestland: thin stand, poor cover	20,929	32,669	(11,740)
Paved; curbs and storm drains (excluding right-of-way)	133,741	518,956	(385,215)
Wood or ferestland: good cover	484,058	228,152	255,906
Cultivated land: with conservation treatment	231,157	88,956	142,201
Good condition (grass cover > 75%)	1,318	1,836	(518)
Urban districts: industrial	117	751	(634)
Soil groups			
Soil group A (%)	3.43	3.42	0.01
Soil group B (%)	92.81	92.81	0
Soil group C (%)	2.39	2.39	0
Soil group D (%)	1.36	1.36	0
Curve Numbers (CN)	66	83	-17
Potential maximum soil retention (S) at Kengdon	131	54	77
Rainfall observe of DMH at Kengdon (mm)	2,022	2,022	
Accumulated rainfall (P scs) at Kengdon (mm)	1,873	1,959	
Accumulated direct runoff (Q scs) at Kengdon (Mm3/year)	16,324	17,070	
Discharge (Q obs) of DMH at Kengdon(Mm3/year)	15,158	15,158	

$$Q = \frac{(P - I_a)^2}{(P - I_a) + S}$$

- **Runoff** is defined as *precipitation excess* p (inches), from rainfall **(P)** (inches).
- **Surface Runoff** = *f (curve number* (CN))
- **S** is Potential Maximum Soil Retention

Data Sources:

- **Rainfall:** DMH
- **Flow:** DMH
- **Land use 1997 and 2003 :** MRC and NDG
- **Soil type** : MRC

Cover Description	Cover Type and Hydrologic Condition	Average Percent Impervious Area[2]	Curve numbers for Hydrologic Soil Groups A	B	C	D
Cultivated land:	without conservation treatment		72	81	88	91
	with conservation treatment		62	71	78	81
Pasture or range land:	poor condition		68	79	86	89
	good condition		39	61	74	80
Meadow	Generally mowed for hay		30	58	71	78
Wood or forest land:	thin stand, poor cover		45	66	77	83
	good cover		25	55	70	77
Open space (lawns, parks, golf course, cemeteries, etc.)[3]	poor condition (grass cover <50%)		68	79	86	89
	fair condition (grass cover 50% to 75%)		49	69	79	84
	good condition (grass cover > 75%)		39	61	74	80
Impervious areas:	paved parking lots, roofs, driveways, etc. (excluding right-of-way)		98	98	98	98
Streets and roads:	paved; curbs and storm drains (excluding right-of-way)		98	98	98	98
	paved; open ditches (including right-of-way)		83	89	92	93
	gravel (including right-of-way)		76	85	89	91
	dirt (including right-of-way)		72	82	87	89
Urban districts:	commercial and business	85%	89	92	94	95
	industrial	72%	81	88	91	93
Residential districts:	1/8 acre or less (town houses)	65%	77	85	90	92
	1/4 acre	38%	61	75	83	87
	1/3 acre	30%	57	72	81	86
	1/2 acre	25%	54	70	80	85
	1 acre	20%	51	68	79	84
	2 acres	12%	46	65	77	82
Developing urban areas and newly graded areas (pervious areas only, no vegetation)			77	86	91	94

Estimation Rainfall-Runoff

by using Soil Conservation Service (SCS)

Curve Numbers (CN) and Potential Maximum Soil Retention (S) of Land use 1997 and 2003

Name of Stations	Total Area	Land Use 1997				Land Use 2003			
	ha	Curve Numbers (CN)	Potential maximum soil retention (S)	Accumulated direct runoff (Mm3/year)	Accumulated direct runoff (mm/year)	Curve Numbers (CN)	Potential maximum soil retention (S)	Accumulated direct runoff (Mm3/year)	Accumulated direct runoff (mm/year)
Phalan (1990-2004)	83,332	60	173	562	1,178	57	195	524	1,157
Donghen (1990-2004)	152,122	57	188	1,891	1,995	59	180	1,930	2,004
Kengkok (1990-2004)	113,078	62	158	1,827	1,616	62	158	1,827	1,616
Kengdon (1993-2001)	871,320	66	131	16,324	1,873	83	54	17,070	1,959

Accumulation Direction Runoff (from SCS)

Name of Stations	Total Area	Rainfall observe of DMH	Accumulated direct runoff of Landuse 1997	Accumulated direct runoff of Landuse 2003	Average Accumulated direct runoff
	ha	mm	Mm3/year	Mm3/year	Mm3/year
Phalan	83,332	2,344	982	964	973
Donghen	152,122	2,296	3,045	3,048	3,046
Kengkok	113,078	1,799	1,827	1,827	1,827
Kengdon	871,320	1,523	16,324	17,070	16,697
Average		**1,990**	**5,544**	**5,727**	**5,636**

Estimation Rainfall-Runoff

by using Soil Conservation Service (SCS)

Distribution Accumulation Direction Runoff (from SCS)

Name of Stations	Total Area	Average Direction Runoff			Rainy Season			Dry Season		
	ha	Mm^3/year	m3/s	mm/year	Mm^3/year	m3/s	mm/year	Mm^3/year	m3/s	mm/year
Phalan (1990-2004)	83,332	562	49	674	555	48	1,331	14	1	17
Donghen (1990-2004)	152,122	1,674	145	1,995	1,660	143	1,091	14	1	9
Kengkok (1990-2004)	113,078	1,258	109	1,643	1,027	89	1,836	32	3	28
Kengdon (1993-2001)	871,320	12,286	734	975	11,916	1,030	1,540	369	32	42
	Average	**3,945**	**259**	**1,322**	**3,790**	**327**	**1,450**	**107**	**9**	**24**

Distribution Discharge (Data Observe)

Name of Stations	Total Area	Average Disharge			Rainy Season			Dry Season		
	ha	Mm^3/year	m3/s	mm/year	Mm^3/year	m3/s	mm/year	Mm^3/year	m3/s	mm/year
Phalan (1990-2004)	83,332	640	55	768	612	53	734	28	2	33
Donghen (1990-2004)	152,122	1,457	126	129	1,441	125	948	16	1	10
Kengkok (1990-2004)	113,078	2,258	195	1,997	2,189	189	1,936	68	6	61
Kengdon (1993-2001)	871,320	15,158	1,310	1,740	13,415	1,159	1,540	1,742	151	200
	Average	**4,878**	**421**	**1,158**	**4,414**	**381**	**1,289**	**464**	**40**	**76**

RESULT AND DISCUSSION

- To estimate **rainfall-runoff** at gauging stations in the XBH river basin.

- To analyse statistics of flow data for determining **flood-low flow** with difference return period in the XBH river basin.

- To estimate **ground water**.

Analyse on Flood and Low Flow

*by using Log-Pearson Type III or Extreme Volume method***.**

Data | Checking quality data | Rainfall-Runoff | **Flood & Low Flow** | Ground Water Recharge

Flood & Low Flow

Analyses statistical flow data to determine **flood and low flow** with different return period by using ***Log-Pearson Type III or Extreme Volume method.***

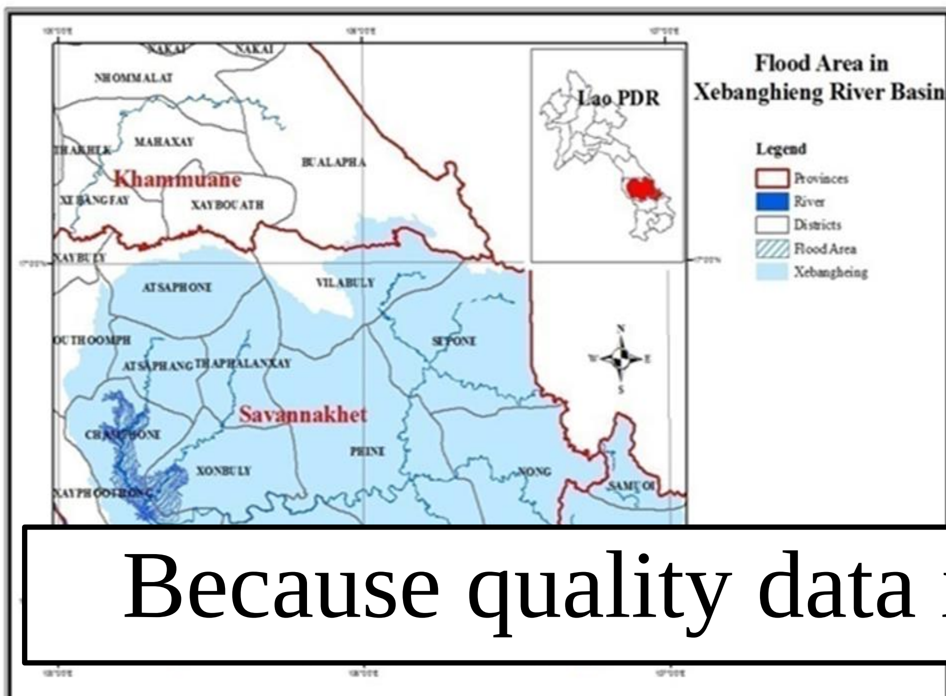
$$f(x) = \frac{\lambda^{\beta}(y-\varepsilon)^{\beta-1}e^{-\lambda(y-\varepsilon)}}{\Gamma(\beta)} \qquad y = log\ x \geq \varepsilon$$

Extreme Values – maximum or minimum values of sets of data

- Annual maximum discharge, annual minimum discharge
- When the number of selected extreme values is large, the distribution converges to one of the three forms of EV distributions called Type I, II and III

Flood

River	Area (ha)	Return Period Tr years					
		2	5	10	25	50	100
Phalan	83,332	442	799	1,118	1,632	2,107	2,673
Donghen	152,122	699	979	1,110	1,229	1,292	1,340
Kengkok	113,078	391	537	640	779	888	1,002
Kengdon	871,320	4,489	6,613	7,954	9,563	10,695	11,770



Flood history of Xebangheng River Basin Form 1960-2004 based on a statistical analysis of the annual volume of flow

No	Year	Kengdon	Kengkok	Donhen	Phalan
1	1960	3,940			
2	1961	6,360			
3	1962	4,950			
4	1963	5,440			
5	1964	7,070			
6	1965	2,250			
7	1966	3,970			
8	1967	4,100			
9	1968	7,540			
10	1969	4,930			
11	1970	4,220			
12	1971	5,760			
13	1972	5,046			
14	1973	2,790			
15	1974	8,450			
16	1975	4,710			
17	1976	4,020			
18	1977	3,150			
19	1978	8,678	508		
20	1979	5,920	285		
21	1980	4,282	296		
22	1981	2,865	278		
23	1982	3,450	230		
24	1983	2,910	204		
25	1984	2,820	389		
26	1985	2,699	293		
27	1986	5,445	293		
28	1987	8,354	325		
29	1988	2,860	392		
30	1989	1,720	318		
31	1990	5,360	635	706	764
32	1991	5,340	429	728	1,100
33	1992	6,800	337	204	1,340
34	1993	1,700	274	366	349
35	1994	3,513	417	538	345
36	1995	3,707	442	728	507
37	1996	6,371	857	897	1,352
38	1997	4,502	526	814	502
[illegible]	[illegible]	[illegible]	338	521	432
[illegible]	[illegible]	[illegible]	458	929	438
[illegible]	[illegible]	[illegible]	603	905	327
[illegible]	[illegible]	[illegible]	777	1,013	361
[illegible]	[illegible]	[illegible]	633	713	270
[illegible]	[illegible]	[illegible]	430	346	193
45	2004	5,508	502	854	171

15 Years

Because quality data is not good

Low Flow

River	Area (ha)	Return Period Tr years					
		2	5	10	25	50	100
Phalan	83,332	1.36	2.24	3.04	4.37	5.61	7.14
Kengkok	113,078	1.15	1.42	1.86	2.69	3.58	4.78
Kengdon	871,320	20.22	27.96	40.34	63.30	87.61	120.10

Minimum monthly discharge at Donghen = 1 m3/s (Not consider low flow)

Low flow history of Xebangheng River Basin Form 1960-2004 based on a statistical analysis of the annual volume of flow

No	Year	Kengdon	Kengkok	Phalan
1	1960	12.00		
2	1961	15.00		
3	1962	29.00		
4	1963	21.00		
5	1964	23.00		
6	1965	30.00		
7	1966	24.00		
8	1967	22.00		
9	1968	22.00		
10	1969	19.00		
11	1970	18.00		
12	1971	25.00		
13	1972	**3.00**		
14	1973	16.00		
15	1974	29.00		
16	1975	27.00		
17	1976	10.00		
18	1977	7.00		
19	1978	4.00	1.00	
20	1979	8.00	1.00	
21	1980	31.00	1.00	
22	1981	25.00	1.00	
23	1982	26.00	1.00	
24	1983	22.00	1.00	
25	1984	9.00	1.00	
26	1985	21.00	1.00	
27	1986	28.00	1.00	
28	1987	21.00	1.00	
29	1988	9.00	1.00	
30	1989	13.00	1.00	
31	1990	26.00	2.00	1.00
32	1991	16.00	1.00	1.00
33	1992	7.00	1.00	1.00
34	1993	71.00	1.00	1.00
35	1994	14.00	1.00	1.00
36	1995	18.00	1.00	2.00
37	1996	30.00	1.00	4.00
[illegible]	[illegible]	[illegible]	1.00	1.00
[illegible]	[illegible]	[illegible]	1.00	1.00
[illegible]	[illegible]	[illegible]	1.00	1.00
[illegible]	[illegible]	[illegible]	3.00	1.00
[illegible]	[illegible]	[illegible]	3.00	2.00
[illegible]	[illegible]	[illegible]	3.00	3.00
44	2003	27.00	1.00	2.00
45	2004	26.00	1.00	3.00

27 years

Because quality data is not good

RESULT AND DISCUSSION

- To estimate **rainfall-runoff** at gauging stations in the XBH river basin.

- To analyse statistics of flow data for determining **flood-low flow** with difference return period in the XBH river basin.

- To estimate **ground water**.

Groundwater Recharge

Hydrological | Checking Quality Data | Checking Quality Data | Rainfall-Runoff | Flood & Low Flow | **Ground Water Recharge**

Base Flow

Base flow can be separated from measured discharge value for a give stream by applying a digital filter to the time-series data, as discussed by **Nathan and McMahon (1990)**. Chapman (1991) presented the filter relationship of Nathan and McMahon (1990) in terms of base flow, Qb (L3 T-1), and total stream discharge:

$$Q_b(i) = kQ_b(i-1) + \frac{1-k}{2}[Q(i) + Q(i-1)]$$

Where **k** is the filter parameter (dimensionless) and Q (L^3T^{-1}) is the measured mean daily stream discharge at day **i**. The resulting base-flow values are constrained by the concurrent observed stream discharges.

The filter parameter K starting from a minimum trial value of 0.01 and increasing it by **0.01 until k<1**, resulting in an optimum of **k=0.93over** the gauging station

Selection data for Base Flow

(Reference on Rainfall and Runoff)

Data → **Checking quality data** → Rainfall-Runoff → Flood & Low Flow → Ground Water Recharge

$$K = \frac{Runoff\,[mm]}{Rainfall\,[mm]}$$

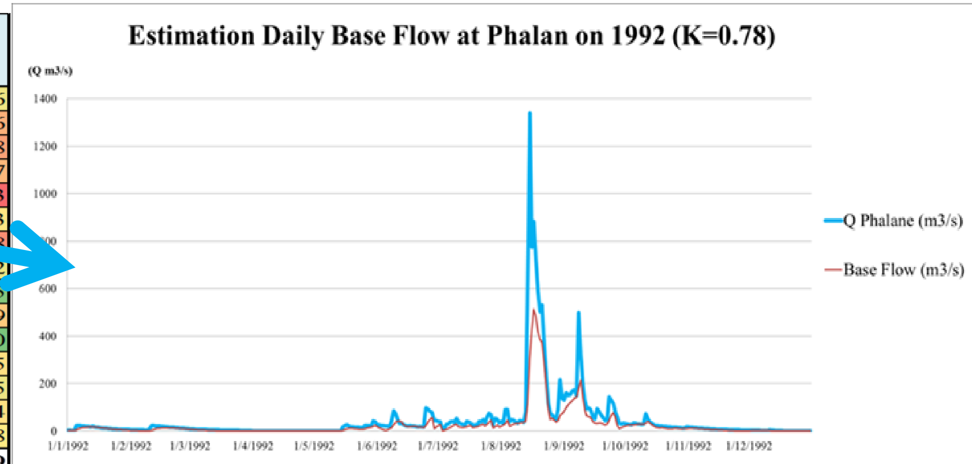
The **runoff coefficient** from an individual rainstorm is defined as runoff divided by the corresponding rainfall both expressed as a depth over the catchment area

No	Name of Station	Runoff Coefficient		
		DMH	CRU	Aphrodite
1	Phalan (1990-2004)	0.60	0.43	0.63
2	Donghen (1990-2004)	0.46	0.51	0.71
3	Kengkok (1990-2004)	0.43	0.58	0.50
4	Kengdon (1993-2001)	0.85	0.98	1.31
	Average:	**0.58**	**0.69**	**0.84**

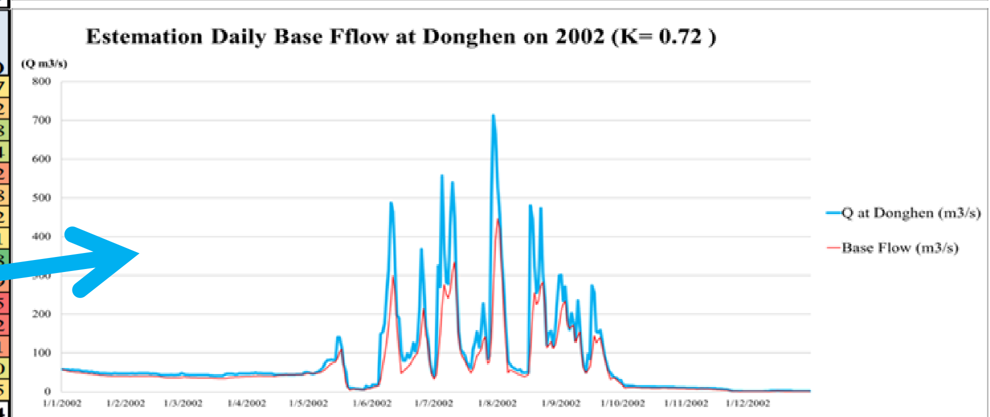
Good Data

Not Good Data

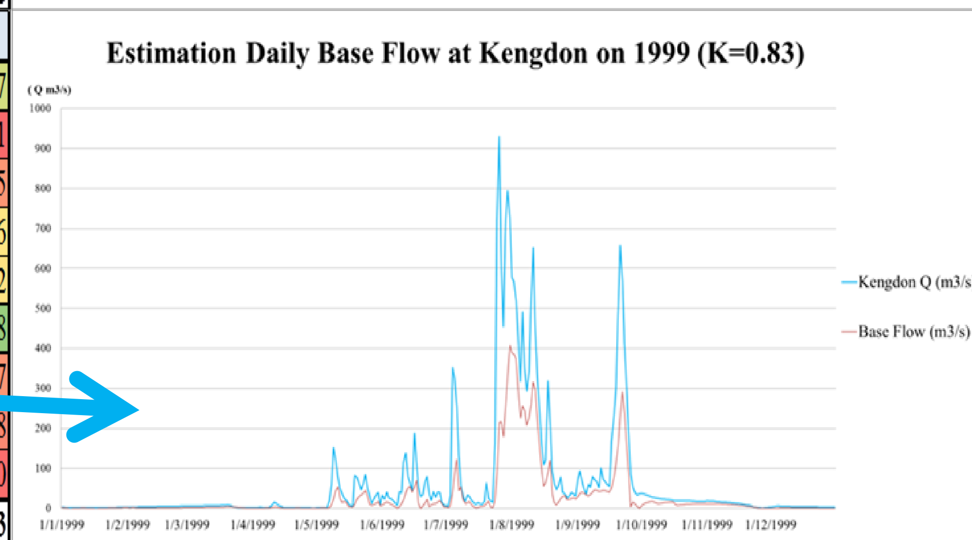
Year	Rainfall of DMH at Phalan Station (mm/year)	Rainfall of CRU at Phalan Station (mm/year)	Rainfall of Aphrodite at Phalan Station (mm/year)
1990	0.6252	0.3438	0.4976
1991	0.6746	0.7485	0.8086
1992	0.8782	0.3198	0.8808
1993	0.4707	0.5134	0.7727
1994	0.8599	[illegible]	1.1393
1995	0.3478	0.3938	0.5553
1996	0.8537	0.7003	[illegible]
1997	0.6338	0.3943	0.4942
1998	0.2402	0.1713	0.2415
1999	0.5043	0.5149	0.6819
2000	0.2232	0.1558	0.2150
2001	0.6700	0.2885	0.5835
2002	0.6958	0.3399	0.4945
2003	0.6958	0.3844	0.5834
2004	0.6718	0.4739	0.5308
Avearege	0.6030	0.4345	0.6299



Year	Rainfall of DMH at Donghen (mm/year)	Rainfall of CRU at Donghen (mm/year)	Rainfall of Aphrodite at Donghen (mm/year)
1990	0.3407	0.3883	0.5517
1991	0.5206	0.6164	0.6932
1992	0.1894	0.2080	0.3418
1993	0.2150	0.2728	0.3874
1994	0.6199	0.6996	0.9852
1995	0.5006	0.4851	0.7028
1996	0.3991	0.4532	0.6052
1997	0.3165	0.4211	0.5441
1998	0.0991	0.0782	0.1158
1999	0.5184	0.7246	[illegible]
2000	0.8051	0.9061	1.2465
2001	0.6054	[illegible]	1.1772
2002	0.8304	0.7167	0.9861
2003	0.4206	0.3671	0.4540
2004	0.4942	0.4771	0.5725
Average:	0.4585	0.5105	0.7144



Year	DMH_Average Kengdon_Rainfall	CRU_Kengdon_Rainfall	Aph_Kengdon_Rainfall
1993	0.5060	0.6372	0.8467
1994	0.8770	1.3259	1.7841
1995	0.8247	1.1298	1.5255
1996	1.0957	0.8521	1.0616
1997	0.8515	0.9177	1.0812
1998	0.4133	0.3487	0.5878
1999	0.9568	1.2435	1.5257
2000	1.0289	1.3189	1.6058
2001	1.0569	1.0142	1.7650
Average	0.8456	0.9764	1.3093

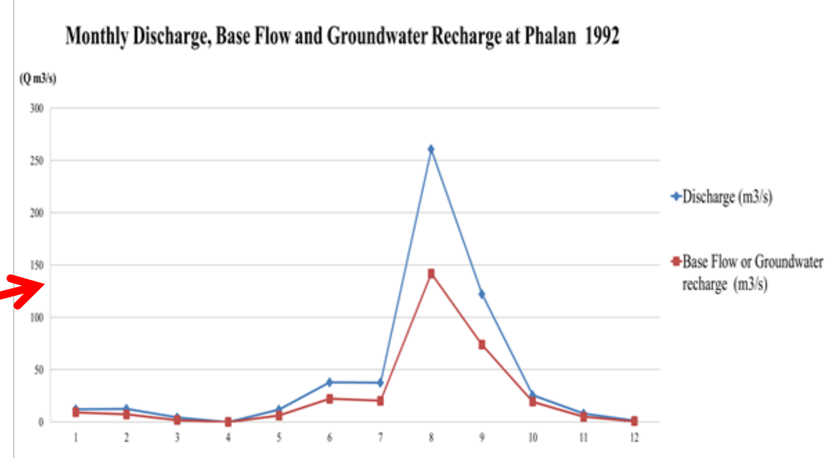


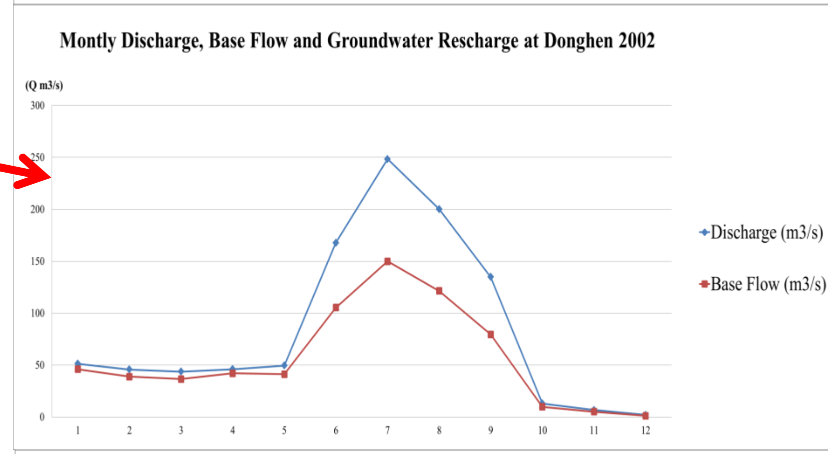
Monthly Discharge, Base Flow, Base Flow Index and Groundwater Recharge

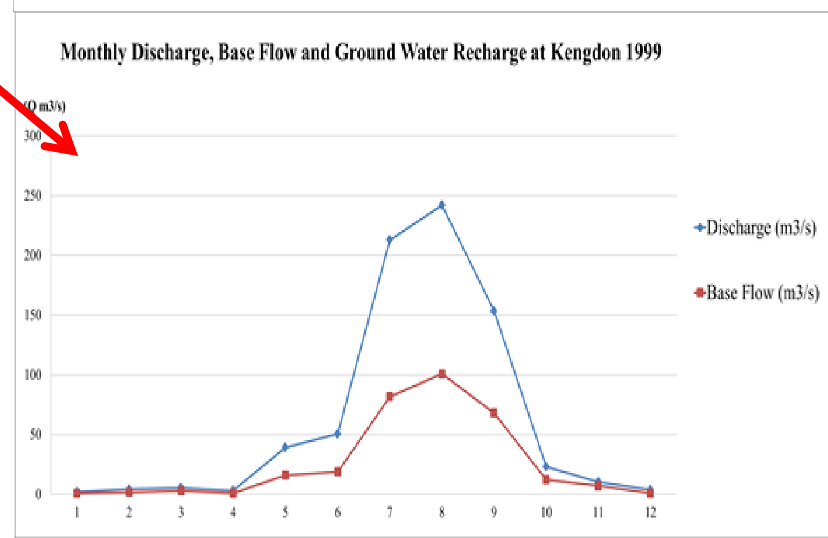
Phalan	1	2	3	4	5	6	7	8	9	10	11	12	Average
Discharge (m3/s)	12	12	4	0	12	38	38	260	122	26	8	1	44
Base Flow or Groundwater recharge (m3/s)	9	7	2	0	6	22	20	142	74	20	5	1	26
Base Flow Index (m3/s)	0.76	0.58	0.44	0.00	0.52	0.59	0.54	0.55	0.60	0.76	0.65	0.63	0.58

Donghen	1	2	3	4	5	6	7	8	9	10	11	12	Average
Discharge (m3/s)	51	46	44	46	50	168	249	200	135	13	7	2	84
Base Flow or Groundwater recharge (m3/s)	46	39	37	42	41	105	150	121	80	10	5	1	56
Base Flow Index (m3/s)	0.90	0.85	0.83	0.91	0.83	0.63	0.60	0.61	0.59	0.76	0.77	0.60	0.67

Kengdon	1	2	3	4	5	6	7	8	9	10	11	12	Average
Discharge (m3/s)	2	4	6	3	39	51	213	242	154	23	11	4	63
Base Flow or Groundwater recharge (m3/s)	1	2	3	1	16	19	82	101	68	12	7	1	26
Base Flow Index (m3/s)	0.49	0.40	0.54	0.32	0.41	0.37	0.38	0.42	0.44	0.54	0.68	0.26	0.42







Groundwater Recharge

Name Stations	Phalan	Donghen	Kengdon	Average
Discharge (m3/s)	44	85	63	64
Base Flow (m3/s)	26	62	26	38
Base Flow Index (m3/s)	0.58	0.73	0.42	0.57
Groundwater Recharge (m3/s)	19	23	37	26

Contents

Conclusion

Objectives

- To estimate **rainfall-runoff** at gauging stations in the XBH river basin.
- To analyse statistics of flow data to determine **flood and low flow** with different return periods in the XBH river basin.
- To estimate **ground water recharge** by using.

Conclusion

Checking Data Quality

- Field Visit ; Double Mass Curve

Rainfall and Runoff

- Coefficient Runoff and SCS

Groundwater

- Nathan and McMahon (1990)

Conclusion

Water Balance Study 2007

- ***Annual flow***

Ea = QaTy/s / (1000 S)

- ***Flood Peak***

PQ= 12 Q / S 0.75

- ***Minimum monthly***

Emin = QMminTy/s / (1000 S)

Rainfall, Runoff and Groundwater Recharge

- ***Rainfall –Runoff***

SCS

- ***Flood and Low flow***

Log-Pearson Type III or Extreme Volume method

Conclusion

Rainfall and Runoff	Water Balance Study of DMH 2005	Water Balance Study of DMH 2007	Estimation on Rainfall, Runoff and Groundwater recharge
Average Rainfall (mm)	1,500	1,600	1,523
Average Runoff (mm)		875	1,740
Average Annual Discharge (m3/s)	497		1,310
Maximum Discharge (m3/s)	4,689	7,274	4,111
Minimum Discharge (m3/s)	17	27	3

Question

"How much rainfall, runoff and ground water recharge in XBH River Basin?"

Rainfall - Runoff (Data Observe)

Name of Station	Area (ha)	Name of River	Oulet	Average Rainfall	Average Run off	Average Annual Discharge		Average Annual Maximum Dichare		Average Annual Minimum Discharge	
				(mm)	(mm)	(m3/s)	(mm)	(m3/s)	(mm)	(m3/s)	(mm)
Phalan (1990-2004)	83,332	Xexangxoy	Xebangheing	2,344	768	55	2,094	1,352	51,235	7	265
Donghen (1990-2004)	152,122	Xechamphon	Xebangheing	2,296	129	126	2,614	684	14,199	9	187
Kengkok (1990-2004)	113,078	Xechamphon	Xebangheing	1,799	1,997	195	5,448	857	23,933	1	28
Kengdon (1993-2001)	871,320	Xebanghieng	Mekong	1,523	1,740	1,310	4,746	4,111	14,899	3	11
			Avergae	**1,523**	**1,740**	**1,310**	**4,746**	**4,111**	**14,899**	**3**	**11**

Groundwater Recharge

Name Stations	Phalan	Donghen	Kengdon	Average
Discharge (m3/s)	44	85	63	64
Base Flow or Groundwater recharge (m3/s)	26	62	26	38
Base Flow Index (m3/s)	0.58	0.73	0.42	0.57

Output

- Support Information **to Water and Water Resources Law**
- **National Water Resource Strategy from now until 2020 and Water Resource Action Plan for 2011-2015**

Program 2	Legislation, plan, and implementation
Program 3	River basin and sub-basin water resource management planning
Program 4	Groundwater management
Program 5	Collection, analysis and management of water resource data and information
Program 6	Water allocation
Program 9	Flood and drought management

- **Sharing Information to Procedures for Maintenance of Flow on the Mainstream (PMFP, MRC)**

Recommendation

Meteorology and Hydrology Data

- Improving on collection data and equipment
- Data management

Rainfall-Runoff

- Application to other sub-river basins in XBH river basin
- Update land use data

Flood and Low Flow

- Log-Pearson Type III or Extreme Volume method good for flood
- Testing FDC or ARI of Low Flow
- Study on water use

Ground water

- Calculating on groundwater recharge is needed application modelling to estimation and compression result with this study.

References

- **(Aphrodite)** Asian Precipitation-Highly Resolved Observation Data Integration Towards Evaluation of the Water Resources., http://www.chikyu.ac.jp/precip/
- **(MRC, 2013)** BDP., MRC., Procedures for Maintenance of Flow on the Mainstream, Third draft, October 2013.
- **(Data Aphrodite)**: https://climatedataguide.ucar.edu/climate-data/aphrodite-asian-precipitation-highly-resolved-observational-data-integration-towards
- **(DMH. 2005 and 2007)** Water Balance Study of DMH
- **(DONALD M.GRAY, 1970)** Hand book on the Principles of Hydrology, Water Information Center, INC. Copyright @ 1970 by the National Research Council of Canada.
- **(Flood Studies Update Programme, 2009)** Work Package 5.2: Base Flow Index derived from soils, Draft Final Report, August 2009.
- **(Walter J. Hickel, Secretary & William T. Pecora; 1849)** Director. Flow-Duration Curve, Manual of Hydrology, Part 2. Low-Flow Technical., Geological survey water-supply paper1542, U.S. Department of the Interior, March 3, 1849,. United States Department of the Interior., Geological. http://streamflow.engr.oregonstate.edu/analysis/flow
- **(JozsefSzilagy, F. EdwimHarvery, and Jerry F. Ayers; 2002):** Groundwater, Regional Estimation of Base Recharge to Ground Water Using Water Balance and a Base-Flow Index by JozsefSzilagy, F. EdwimHarvery, and Jerry F. Ayers; Vol.41, No.4-GROUND WATER-July-August 2002.
- **Valéria, R. (2007):** Assessment of The Base Floe in The Upper part of Torysa River Catchment, Department of Land and Water Resources Management, Faculty of Civil Engineering, Slovak University Technology, Slovakia. 12 December 2007, page 9.
- **J.G.Arnold, P.M.Allen, R.Muttiah, and G. Bernhardt. (1995):** Automated Base Flow Separation and Recession Analysis Techniques, Vol. 33, No.6-GROUND WATER, Noverber – December 1995, Page; 1011 and 1013.
- **Adane, A and Gerd, F. (2006):** Catchment Characteristics as Predictors of Base Flow Index (BIF) In Wabi Sheblel River Basin, East Africa. Research Institute for Water Environment, Civil Engineering Department, University of Siegen, Germany. Page 1 and 3.
- **NJSBMP Manual. (2004):** New Jersey Stormwater Best Management Practices Manual. Chapter 6 Groundwater Recharge, April 2004. Page 6-3.
- **Samah A; Majed; and Ziad A (2009)**: Estimation of Runoff for Agricultural Watershed Using SCS Curve Number and GIS. College of Engineering and Technology, Palestine Polytechnic University; Institute of Environment and Water Studies, Birzeil University. 2009. Page 1214-1216.

Thank you