Flood forecasting system and flood management in Lao PDR

Abstract

Even though, the Lao People's Democratic Republic is a landlocked country, it is also a land linked with the other countries of the Southeast Asia effecting by the Tropical disturbances: Monsoons and Typhoons. Lao PDR has been incessantly damaged by natural disasters that floods and droughts are the Two mains hazards, but flood occurred more frequently not only since 1966 large flood, but also in the historic floods occurring in 1924, 1939 and so one….

This study has for objectives to overview to the existing system for flood forecasting, flood prevention: Structural and nonstructural measures. Methods used for short range forecast and long term forecast. Flood mitigation and flood management in some target areas are also given for cases of study.

I. <u>Introduction</u>

The Lao People's Democratic Republic, in abbreviation Lao PDR is an elongated country in the Northwest-Southeast direction has a total area of 236.800 km2. Geographically, the Lao PDR is dominated by two features: The mountains of the North and East and the Mekong river and its eastern bank tributaries with torrential flow regime. The climate is tropical monsoon with alternating wet and dry seasons. Both have six mouths duration. Wet season from May-October and dry season from November-April. Since 1966, the country has experienced 25 floods of different magnitudes, and duration. Although, floods and droughts are the mains hazards, floods of high magnitude have occurred more frequently e g ,.. In 1995 flood with 87.300 ha inundated, the recent flood in 2005 has also 87.725 ha inundated according to the latest report.

Drought has also occurred in 2005 with damaged areas 1.125 ha. Since the largest portion of the Lao population lives in rural areas and depends largely on subsistence agriculture, they are most vulnerable to periodic flooding. This paper reviews the actual flood forecasting and flood warning system currently used that include structural and non-structural measurers.

II. <u>Back ground</u>

Flood forecasting started during the 1970 Mekong flood season, on a trial basis, to demonstrate the feasibility of a centralized forecasting system using advanced computer techniques and the application of mathematical models called "SSARR model". Since then the operation has been carried out annually says seasonally during the flood season from July to October. The large flood in 1978 and the severe flood in 1981 in the Vientiane plain called for the expansion of the forecasting programmed to cover flood forecasting for major tributaries and inflow forecasting for existing reservoirs in the basin, especially for Nam Ngum reservoir. Prior to 1984 the flood forecasting and warning system in Lao PDR are largely based on the Lower Mekong river basin wide flood forecasting operation.

It is recalled that a series of recommendation for Lao PDR were made by the missions to the Typhoon Committee area on flood loss prevention and management in

East Asia from November-December 1987-March 1988. Detail of recommendation for promoting flood loss prevention activities are:

1. Implementation of flood loss prevention projects in Lao PDR, such as the flood control project in the Vientiane plain making use of external assistances.
2. Since restriction of land use based on flood risk an analysis is effective to prevent and mitigated flood damage.
3. It is recommended to review the existing flood forecasting and warning systems and flood mitigation schemes to ensure comprehensive flood loss prevention and management with a view to maximize on feasible projects in the whole country.
4. In reviewing the existing flood forecasting and warning systems,
    - Floods from the Mekong river
    - Flood from its tributaries, and
    - Flooding due to local rainfall

    Forecasting system should be improved using new techniques such as remote sensing to predict high water levels of the Mekong river; rainfall data gathering network needs to be strengthened in order to provide advances warning for possible flooding from the tributaries usually in flashy conditions.
5. In order to improve the flood forecasting systems in Lao PDR, it is essential to establish additional rain gauge and water gauge station and rehabilitate existing ones, particularly in the Nam Ngum and Nam Lick river basins. Introduction of radar systems for meteorological purposes and establishment of telecommunication systems would be of great significance in flood forecasting.
6. In formulating flood mitigation schemes, it would be important to preserve retention function of existing swamps and if possible to include retarding ponds in the system taking future land use plan into account.
7. In addition to the projects in the Vientiane plain, consideration should be given to promotion of flood loss prevention project in the Sebang hieng and Sedone basins, as they are some of the most important areas for agricultural production in the country.
8. As the first step of the project promotion in the Sebang hieng and Sedone basins, establishment of flood forecasting and warning systems in the basins should be given serious consideration. Subsequently, formulation of a master plan on flood loss prevention in the Sebang hieng and Sedone basins is recommended.
9. Training of adequate number of personnel to operate the present and projected equipment requirement for successful operation of the flood forecasting and warning systems, therefore assistance from international agencies and donor countries would be required to augment the government ‘s efforts.

Based on the observations and recommendations cited above, flood Forecasting and warning systems in Lao PDR is going to be improved such as: Improvement of weather and flood forecasting capacity in the near future from: Installation of C band Doppler Radar and MTSAT-IR satellite receiving will operate in Mach 2006 under Japan’s Crant Aids project, Improvement of Meteorological and Hydrological Services for Lao PDR an ongoing project of technical cooperation assistance from Jica; project on Meteorological and Hydrological network and facilities for weather forecasting in 2005 and for the future plan 2006-2010 (assistance from Vietnam government).

III. Flood forecast methods

In Lao PDR there are six important flood pone areas. Five along the Mekong river plain and one in the Sekong basin. From (figure 1) the area 1 in the Vientiane plain, 2 in the Borikhamxay province, 3 in the Sebang fay plain, 4 in the large plain of the Sebang hieng basin, 5 Sedone in Champasak province and 6 in the middle reach of Sekong in Attapeu province. Flood propagation time along the Mekong river is approximately as below (Table 1):

HoueiSai (Bokeo) - Luangprabang	302 km	33.55 h	1.4 day
Luangprabang - Vientiane	426 km	49.306 h	02 days
Vientiane - Pakngum	100 km	12.62 h	0.5 day
Pakngum - Pakcading	125 km	15.783 h	0.66 day
Pakcading - Thakhek	133 km	18.472 h	0.71 day
Thakhek - Savannakhet	90 km	13.899 h	0.58 day
Savannakhet - Sebang hieng	100 km	16.340 h	0.68 day
Sebang hieng - Pakse	157 km	26.43 h	1.10 day

For a total distance of 1.433 km, flood propagation time is about 8 days of duration. The routing procedure is followed the model of flood forecasting for the basin wide.

- For Statistical methods.

The statistical methods selected for adoption in the development of the flood forecasting procedure for the Mekong River was the correlation method. Correlation methods are widely used by flood forecasting agencies in Australia and a simplified version of this method is what is currently used by the Department of Meteorology and Hydrology.

In this correlation method the correlation between upstream and downstream river levels is sued to forecast the flood levels at the downstream site. The downstream river levels are plotted against the upstream river with the upstream river levels being the dependent variable and the downstream river levels the independent variable. A regression line is drawn through the points using the method of least square. Typically the type of regression line which is fitted to the data points is a polynomial curve of the first, second, or third order.

Correlation relationships were derived for the sets of data shown in (Table2)

A range of correlation relationships were tried to determine the optimal fit for each set of data. These included using a split regression, where different relationships were derived for different height ranges and using different orders of polynomial equations. In general, the complete set of data from each station was used to determine the regression relationship.

Table 2: Station used for derivation of correlation relationships

Upstream station name	Upstream station number	Downstream station name	Downstream station number
Luangprabang	011201	Vientiane	011901
Vientiane	011901	Paksan	012703
Paksane	012703	Thakhek	013102
Thakhek	013102	Savannakhet	013401
Savannakhet	013401	Pakse	013901

However, for station for which long periods of record existed shorter periods of more recent data were also tried in order to identify possible change in the relationships over the period of record. In addition, both the whole year data set and the data set pertaining to the wet season months of June to October were tried.

The "goodness" of the fit of the regression relationship war assessed by the value of the coefficient of determination, r^2, and by the degree to which the resultant polynomial curve(s) described the complete set of data. Although the objective war to achieve the optimal fit possible over the whole range of data, where it was necessary to compromise this objective, priority was given to reproducing the high flows. The rationale behind this decision was that in a flood forecasting procedure it is accurate reproduction of high flows which is the main criterion rather than reproduction of low flows.

Details of the regression relationships adopted for the pairs of stations listed in Table 2, the period of record used, and the coefficient of determination are shown in Thable 3.

Thable 3: correlation relationships

Station	Period of record	Months of record	Lag	Range of relationship	Regression Relationship	Coefficient of determination
Luangprabang - Vientiane	1960-1992	June-October	2 days	0-14 meters 14-18meters > 18 meters	Y=0.08453x-2.0794 Y=0.6757x-0.2089 Y=0.1309x+9.7821	0.9829 0.9409 0.9374
Vientiane – Paksane	1976-1992	June-October	1 day	Complete range	$Y=-0.0018x^3 + 0.0247x^2 + 0.9348x + 1.7297$	0.9188
Paksane – Thakhek	1976-1992	June-October	1 day	Complete range	$Y=-0.0002x^3 = 0.0062x^2 + 0.904.x + 0.8187$	0.9399
Thakhek – Savannakhet	1972-1992	June-October	1 day	Complete range	$Y=-0.0022x^3 + 0.0401x^2 + 1.1823 – 0.9904$	0.9904
Savannakhet - Pakse	1972-1992	June-October	1 day	Complete range	$Y=-0.0001x^3 + 0.0032x^2 + 1.0668x = 0.9312$	0.9312

$™_t$ = the error at time, t

As can be seen from Table 3, good results were obtained using the correlation method. The lowest coefficient of determination value was 0.9188 and the highest 0.9904. This compares very favorably with the coefficient of determination of the method currently used by Department of Meteorology and Hydrology which has a value of 0.699.

On the basis of these results it was thought that the regression relationships could confidently be adopted in a flood forecasting procedure for the Mekong River.

IV. Flood forecasting system in the Vientine plain

4.1: Structural measures for flood control

Structural measures exist in the Vientiane plain only. For Vientiane Capital the first dyke protection against floods was built after two large floods occurred in 1940. In 1960 under an urbanization plan for Vientiane City all dykes were demolished. The disastrous flood in August-September 1966 gave a good lesson and people realized that floods can cause considerable property damage and loss of life. At present all dyker are rehabilited and there are about 62 flood gate along the protection dykes e g.., Kaolieo, Hatxayphong districts.

4.2: Non-Structural measures

Flood forecasting and flood warning systems are the main non-structural measures currently used.

For the Vientiane plain there are two important problems to be considered, flood from the Mekong river and floods from the Nanngum, NamLik and from local rainfall in downstream of the Namngum Dam.(See location map of the vientine plain in fugure 2 and the Namngum basin in duding Namlik in fugure 3). Details of the method used are given in the following section 4.3:

4.3: case study of flood forecasting in Vientiane plain

4.3.1: General

The large plain of Vientiane is complied by Vientiane province in the Northern part and Vientiane Capital in Southeastern comprising 9 administrative districts. The total areas of Vientiane city or Vientiane prefecture is 3.267 square kilometers with a population of about 580.000 persons in 2005, or 12.6 % of the national population. The topography is generally flat with evaluation varies from EL 169 m to EL 175 m. Elevated area or terraces witch are free from flooding have been developed and public facilities such as factories, government agencies, universities… are situated along.

The trunk roads running in this elevated areas. However due to rapid urbanization, growth of population residential areas are forced to disperse into the low elevations, vulnerable to fragment flooding. In this populated area there are some structural measures to protect against flood. It is evident that optimum benefit can only be obtained approach is referred to as comprehensive flood loss prevention and management: Flood forecasting and warning; flood plain management, evacuation and relief. That is a long term program adopted as its 11th session in 1978 of the Typhoon committee where un the hydrological component, Lao PDR has selected the Namngum basin as priority.

The following sections will provide some information about several methods used for an operational flood forecasting system in the Vientiane plain especially since a network improvement in 1996.

4.3.2: Statistical methods

In addition to the SSARR forecast the statistical method selected for adoption in the development of the flood forecasting procedure for the Mekong river was the correlation method for the flood prone – area 1 of the Vientiane plain (figure 2), location of 6 major flood prone area in Lao PDR and the whole plain location in (figure 3) Namngum and Mekong river. In this method, the correlation between upstream, Luangprabang and downstream, Vientiane river levels is used to forecast the flood levels at downstream site, where the upstream rivers being the dependent variable. A regression line is drowning though the points using the method of least squares. Typically the type of regression line which is fitted to the data points is a polynomial curve of the first, second or third order. This war used from the period record of data 1960 – 1992 by the regression equation of

$Y = 0.845\, x – 2.0794..$ (1)

With high correlation coefficient $r = 0.9829$
And with a lag time 2 days (48 hours)

See figure 3. The sub – basin of the Mekong between Luangprabang and Vientiane with a length of 426 km. Equation…(1) above is applicable when the water level at Luangprabang is below 14 meters, between 14 – 18 meters equation is used:

$Y = 0.675\, x – 0.2089$ (2)

With correlation $r = 0.9374$
To extent the forecast period up to 3 days (72 hours) water levels at Pakbeng (Mekong river) and Nam Ou at MuangNgoy are sued.

4.4: Empirical methods

4.4.1: Short range forecast

This method was established in 1982 and express by the equation of:

$Hv = [(H1 + 267.195) + ..Hr) – 158.04$ (4)

Where

Hr = 48 hours of water level forecasting at Vientiane
Hi = daily read of water level at Luangprabang at 7 am
ΔHr = forecast of the difference elevation of the zero gauge height.
Luangprabang 267.195 msl and Vientiane 158.04 msl respectively.

An other method for the stage forecast, mathematically it can be described by the following equation:

H vt = K x dH lb(24) + H vt for 24 hours.
H vt = K x dH lb(48) + H vt for 48 hours.

Where

H vt(24) and H vt(48) are the forecast stage 24.48 hours for Vievtiane.
K = An empirically determined coefficient when the stage at Vientiane still below 9 m.

K = 0.30 ~ 0.35 When the stage at Vientiane is between 9 ~ 11.5 m.
K = 0.40 ~ 0.45 and K = 0.15, K = 0.10 When the water levels at Vientiane between 11.50 m – 12.00 m and 12.00 m – 12.50 m respectively.

4.4.2: Medium-long range forecast (up to 1 month)

The method use more effective; it consists to estimate the water balance from Luangprabang, Sayabuary and Vientiane for the month of July S of each year and then correlate with the gauge height difference of the first August and the critical height 11.50 m (D = H 1/8 – 11.50). Plot S and D in a scatter diagram that divided into 2 zones (area) for zone (1) the maximum peak flood will reach or exceed the critical height 11.50 m; for zone (2) the maximum height will not reach and exceed 11.50 m, see table (1) for 1995, 1996, 1998 tests by taking S mm in ordinate and D abscissa (figure 4).

The method is based on the 17 years 1959 – 1980 (correlation between water surplus S in July and the **Maxi G.H in Vientiane** . The correlation was 0.77; because for some wet year e.g. 1960, 1965, 1966,1979 the maximum gauge heights occurred in September. This method for one month forecast is very useful for flood control and management in the urban area of the Vientiane plain. It should be investigated and improved continuously.

Table1: Computation the water surplus from rainfall (P)

Year 1995	June	July	August	September	H = 7.98 m (1 / 8 / 1995)
Luangprabang	P=469.7 mm	792.4 mm	479.3 mm	134.4 mm	D =11.50 – 7.98 = 3.52 m
Sayabuary	258.8	660.9	488.0	164.7	Zone (1)
Vientiane	258.8	660.9	488.0	164.7	H max = 11.95 m
Total	1290.2	2478.0	1625.4	474.8	(23 / 8 / 1995)
Average	430	859.3	541.8	158.3	
Soil accounting	100	100	100	100	
Surplus	330	759	442	58	
Year 1996					
Luangprabang	P=219.9 mm	291.8 mm	302.4 mm	176.6 mm	H = 10.27 m (1 /8 /1996)
Sayabury	208.4	211.6	255.6	252.0	D=11.50 – 10.27= 1.23 m
Vientiane	357.3	222.8	196.6	369.2	Zone (2)
Total	785.6	726.2	754.6	797.2	H max = 11.48 m
Average	261.9	242.0	251.5	265.7	(25 / 8 / 1996)
Soil accounting	100	100	100	100	
Surplus	162	142	152	166	
Year 1998					
Luangprabang	P=116.7 mm	161.0 mm	261.6 mm		H =10.27 m (1 / 8 / 1998)
Sayabury	129.3	197.2	162.0		D=11.50 – 7.75 = 3.75 m
Vientiane	276.4	312.3	395.4		Zone (2)
Total	522.4	670.5	819.0		Hmax = 8.77m (25/8/98)
Average	174.1	223.5	273.0		For H=8.28m (1/9/98)
Soil accounting	100	100	100		D=11.50 – 8.25=3.22 m
Surplus	74.1	123.5	173.0		Zone (2)
					H max= 10.38 m (9/9/98)

V. National Disaster Management in Lao PDR

5.1. General:

In an effort to reduce the impact of natural disasters in the future, the Lao government is focusing on natural disaster management issues, Prioritizing the need for early warning systems and natural disaster preparedness for communities.

Since 1966 the Lao PDR has been incessantly damaged by natural calamities, mainly flood and drought for a large scale and occasionally by severe local thunderstorm in Mach / April of each year. It was hardest hit between 1994 – 1996 during a long episode of heavy rainfall and continuous flooding. Damages amounted officially to 91.222.400 US$.

Additionally, destructive incidents involved rat invasions in 1993 – 1994 and further flooding in 1996 – 1997. The latest ELNINO in 1998 characterized the severe drought and low flow in the region. Flooding conditions were observed again from1999 – 20001. However, a National Disaster Management Office, supported by the UNDP, was organized to help for reducing the devastating impact of these disasters.

The Lao Government, in its efforts to minimize these effects has assigned duties to Ministries and provinces concerned to assume responsibilities for natural disaster prevention, in order to protect the properties of the individual and state from natural disaster to relieve the Victims and to restore devastated plantations. During the harvest-time flood of 1996 – 1997 (cited as example) the government established an emergency-working group that consisted of representatives of Ministries and other organizations to manage and solve the problems encountered.

To solve and reduce the impacts of these natural disasters (natural hazards), each year the Lao government has allocated funds toward this activity. Meanwhile the victims have received sympathy, assistance and cooperation to help alleviate their suffering, such as the provision of rice, medicine, fertilizer, clothes and other equipment through assistance granted by the UNDP, the World Flood Program (WFP) and the Food and Agriculture Organizations (FAO). Together with these organizations, assistance was also granted from China, Vietnam, Australia, India, the United States of America, Canada and Thailand totaling 19 million US$ (only for 1996/1997). Percentage of worldwide National hazards continuously occur and shape the environment on which our societies depend, but there is a lot that scientific knowledge and appropriate public policies can do to prevent human disaster resulting from them disasters resulting from natural hazards are on the in crease around the world their number was three times higher the past ten year which caused economic boss to be eight times, exceeding more than 60 billion US$ a year (based on the world statistics). For the three years from 1993 – 1995 the USA sub-committee on disaster reduction estimated that the annual loss from natural disasters in the world averaged one billion dollars per week. The planning committee of China estimates that the current national loss from disasters in China ranges between 4-8 percent of the Gross Domestic Product (GDP) severely affecting the annual rate of National Economic Growth (NEG).

5.2. Hazards

The main hazards in Lao PDR are flood and droughts both are dependent on the amount of rainfall. If there is less than 2.000 mm rainfall in the year, drought sensitive areas will be effected. More than 200 mm in 2 days certainly leads to floods along the Mekong plain. Cyclones are therefore not direct hazard, since their force in normally diminished once they have reached Lao from the South China Sea, but they can produce flood as a consequence of heavy rainfall. Up to three cyclones hit the country annually, while flood, droughts and land-slight occur irregularly.

Another virulent hazard is deforestation. It is direct hazard to the effects of " Normal " hydro-meteo phenomena, causing an increase of the surface runoff in quantity and velocity (natural flood mitigation is lost).

In recent years natural disasters resulting from climate abnormalities have occurred more frequently especially drought and flood. The natural disaster are recorded droughts and floods from 1966-2005, at below:

<u>Table 2</u> : Damage caused by Natural Disaster in Lao PDR from 1966-2005

No	Year	Types of Damage	Damage Cost (US$)	Place of Damage
1	1966	***Large flood***	13.800.00	Central
2	1967	Drought	5.120.000	Central and Southern
3	1968	Flood	2.830.000	Southern
4	1969	Flood	1.020.000	Central
5	1970	Flood	30.000	Central
6	1971	***Large flood***	3.573.000	Central
7	1972	Flood and Drought	40.000	Central
8	1973	Flood	3.700.000	Central
9	1974	Flood	180.000	
10	1975	Drought	Not available	Central
11	1976	Flash flood	9.000.000	Central
12	1977	Severe Drought	15.000.000	Northern
13	1978	***Large flood***	5.700.000	Central and Southern
14	1979	Flood and Drought	3.600.000	North(D),Southern(F)
15	1980	Flood	3.000.000	Central
16	1981	Flood	682.000	Central
	1982	Drought	Not available	
17	1983	Drought	50% damaged	
18	1984	Flood	3.430.000	Central and Southern
19	1985	***Large flood***	1.000.000	Northern
20	1986	Flood and Drought	2.000.000	Central and Southern
21	1987	Drought	5.000.000	Central and Southern
22	1988	Drought	40.000.000	Southern
23	1989	Drought	20.000.000	Southern
24	1990	Flood	100.000	Central
25	1991	Flood and Drought	3.650.000	Central
26	1992	Flood, Drought and Forest fires	302.151.200	Central (F), and Northern (D)
27	1993	Flood and Drought	21.827.927	Central and Southern
28	1994	Flood	21.150.000	Central and Southern
29	1995	Flood	15.300.000	Central
30	1996	***Large flood and Drought***	10.500.000	Central
31	1997	Flood and Drought	1.860.300	Southern
32	1998	Drought	5.762.715	Northern and Southern

33	1999	Flood	7.450.000	Central
34	2000	Flood	12.500.000	Central and Southern
35	2001	***Flash flood***	8.000.000	Central and Southern
36	2002	***Large flood ,Flash flood and land- slight***	24.454.546	Northern, Central and Southern
37	2003	Drought	16.500.000	Northern and Central
38	2004	Flood	20.750.000	Southern
39	2005	***Flash flood and land- slight***	218.304	Central and Southern

5.3: Dissemination the weather and flood forecast.

- To media radio
- To news paper
- To Television
- To Ministry concerned
- To Disaster Management Organization
- To Meteorological stations in provincial

5.4: Early warning system for weather and flood forecast.

A part from drought, tropical cyclones with associated flood resulted in more lost of agriculture production, properties and more times loose of lives.

The existing system is based on daily synoptic observation network and satellite information is not so good for analysis and forecasting. The Meteorological and Hydrological information were disseminated to the general public though the media radio telecommunication system is urgently needed to be improved.

Flood are still major problems, torrential rain associated with Typhoons and Monsoons caused flash floods in the mountainous region of Lao PDR therefore, an accurate forecast and an appropriate warning are required to extend delay to have enough time fore preparing the counter-measures, In the Central provinces, the antecedent condition of moisture e.g. in year 2005 heavy rainfall from high water level in late August. Damage in estimated.

VI. Conclusion

To develop the flood forecasting system in the Vientane plain it was through that the regression relationship and the stage correlation method could confidently be adopted in a routine flood forecasting procedure under normal condition that means, when there is no significant weather phenomenon producing heavy rainfall between Sayabuary and Vientiane. More sophisticated programs and packages should be considered as for research purposes because it was considered that their increased complexity did not result in a concomitant increase in accuracy but rather only served to make their application more difficult. However the correlation method applied for Numngum between Thalat – Thangone did not give high accuracy due to the complexity of the river: mild shop, very wear hydraulic gradient back water effect from the Mekong river.

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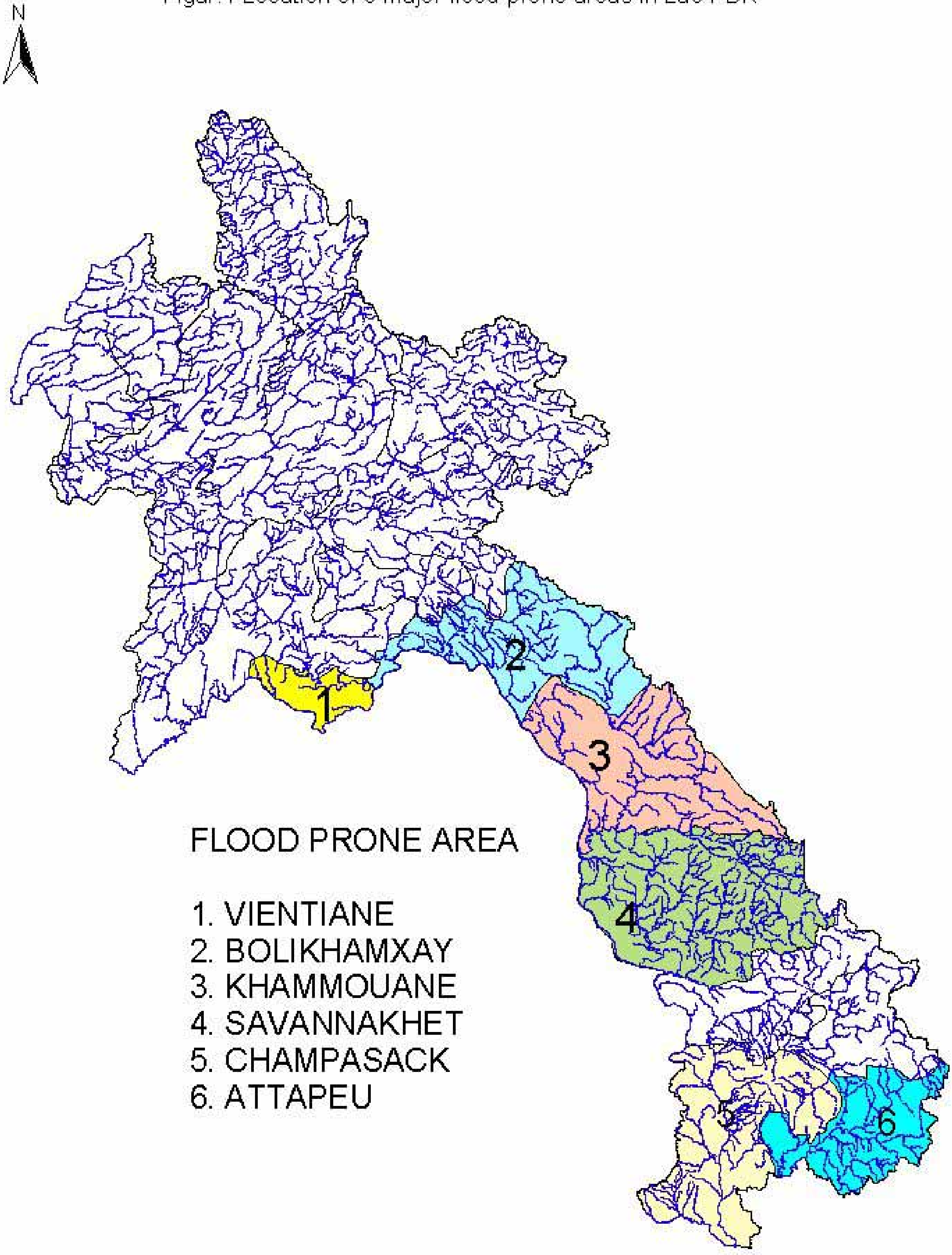
Figur.1 Location of 6 major flood-prone areas in Lao PDR



Scale 1 : 4.500.000