



EUROPEAN COMMISSION  
JOINT RESEARCH CENTRE

25 July 2018 15:00 UTC

## Lao People's Democratic Republic Flash Flood due to Dam Collapsing

23 July - ongoing

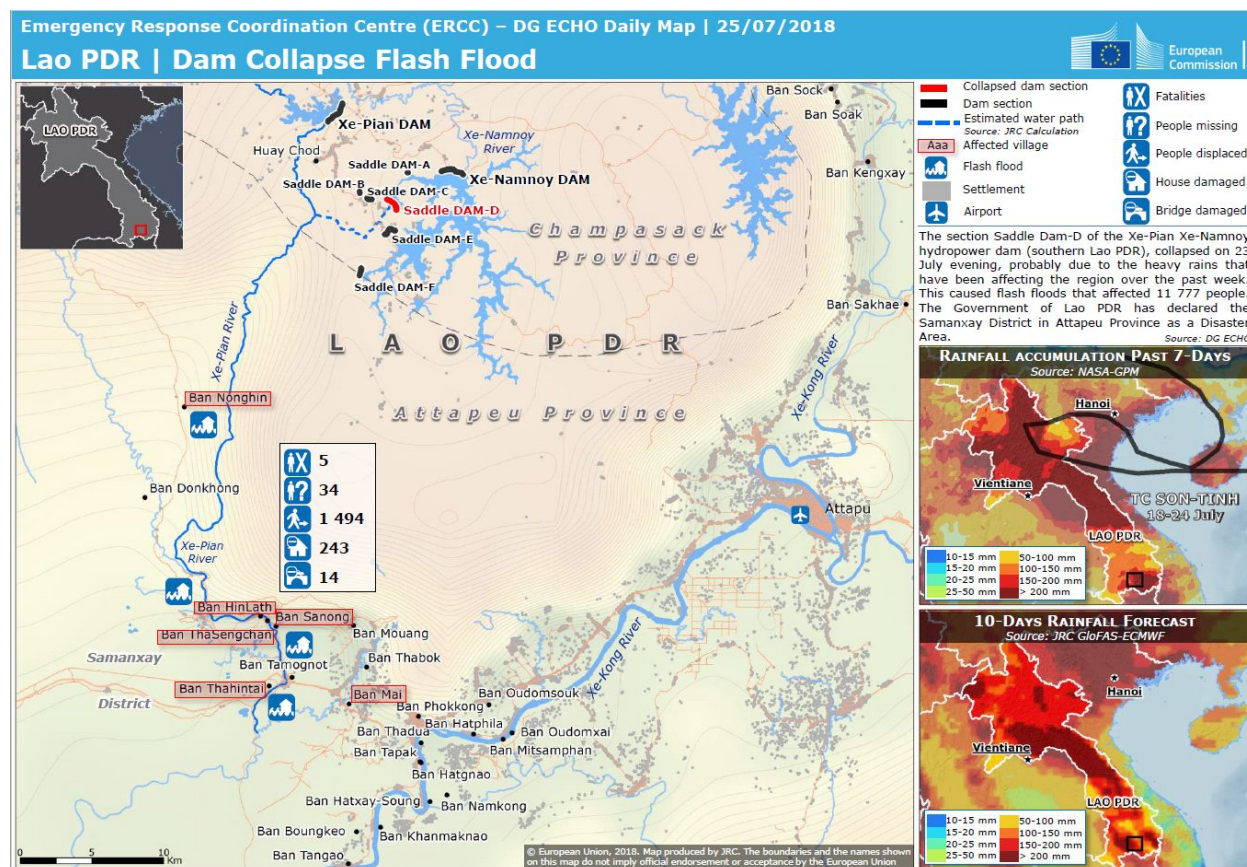


Fig 1 - Situation overview of the affected area

## 1. Executive Summary

- Extensive flood occurred on **23 July**, downstream one of the dams of the **Xe-Pian Xe-Namnoy Power Project**, under-construction in southern Lao People's Democratic Republic (Lao PDR); the flood was due to the partial failure of the dam as a result of the recent heavy rains that affected the area over the last week.

- The event caused flash flooding in many villages of **Sanamxay district (Attapeu Province)**, casualties and damage: **Mai, HinLath, ThaSengchan, Thahintai, Sanong, Thae, Phonsa-ath and Nongkhae**; Hinlath and Mai were the most affected ones.
- The number of fatalities is still under verification: OCHA reported on 24/7 **5 people dead** while media report today up to **19**; over **30 people** are missing and **12,000 affected**. Search and rescue operations are still ongoing.
- LAO's Government has declared the affected areas as National Disaster Area.
- More rain is forecast to affect the area, which could further worsen the situation.
- UN OCHA established an emergency section in VOSOCC, to collect information and offers for helps.

## **2. Current Situation**

### **2.1. Dam situation**

- A partial failure of one of the dams of the **Xe-Pian Xe-Namnoy Power Project**, under-construction in southern Lao PDR, occurred on **23 July** evening, causing the release of about 5 billion cubic meters of water and causing flash flooding in many villages of **Sanamxay district (Attapeu Province)**, casualties and damage (see Section 2.2).
- The event was probably due to the recent heavy rains caused by the monsoon season and the passage of Tropical Storm **Son-Tinh** (see Section 2.3) that affected several areas of Lao PDR, causing floods and damage. **GDACS** issued the first **Orange Alert** on 15 July for the possible impact TC Son-Tinh in the Philippines, China, Viet Nam and **Lao PDR**.
- The villages mostly affected by the floods are: **Mai, HinLath, ThaSengchan, Thahintai, Sanong, Thae, Phonsa-ath and Nongkhae**.
- An urgent evacuation notice (see Figure 3) was published on 23 July indicating that *the **Saddle Dam D** was unsafe due to heavy rainfall, with very dangerous conditions (water overflowing the dam crest), if the **Saddle Dam D** fail, over five billion tons of water would flow downstream of Xe-Pain River*, and informing the people living in the villages near downstream Xe-Pian River to evacuate to high level locations.
- Over the next few days more heavy rain is forecast to affect the area, which could further worsen the situation.
- The dam is under-construction (90% complete, according to media) and had been set to start operating commercially in 2019. According to media reports, fractures were first discovered on the dam on 22 July, before it collapsed (see Event Timeline Appendix A.2.).

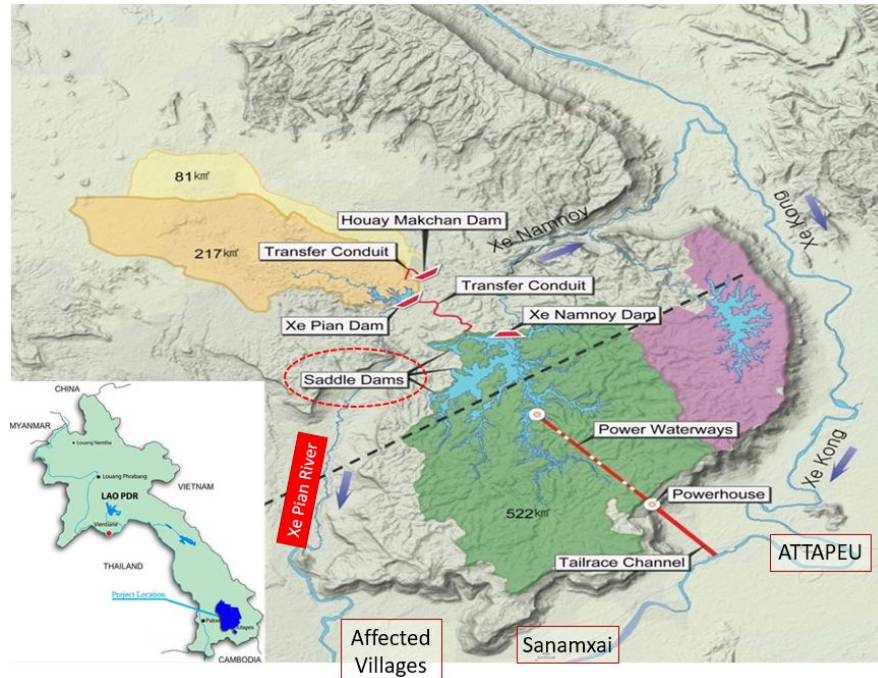


Fig 2 - Saddle Dam location

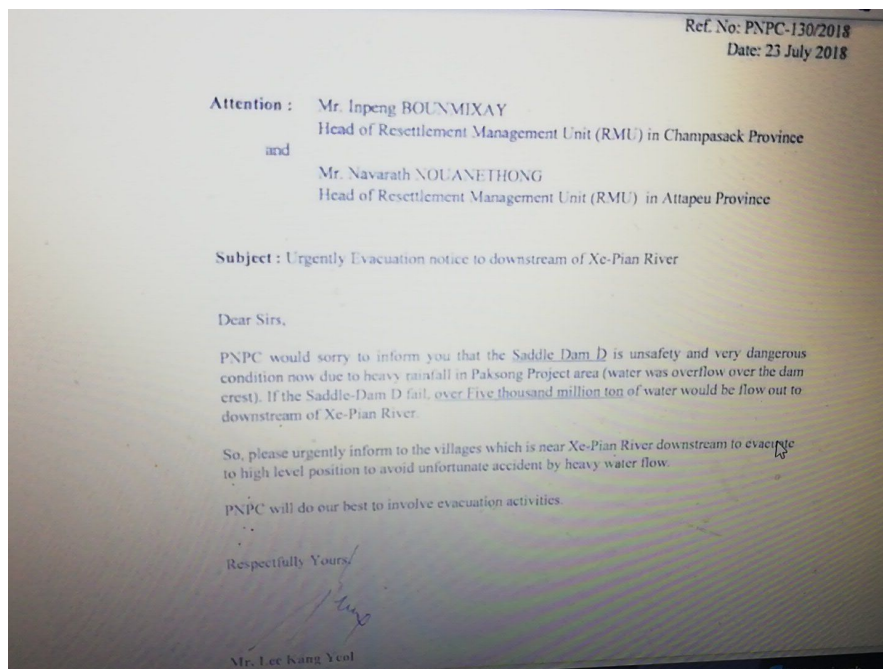


Fig 3 - Evacuation notice (source: <https://twitter.com/laosnews2011>)





Fig 4 - A computer-generated image of a dam being built in Laos by Xe-Pian Xe-Namnoy Power Company (source: <http://www.pnpclaos.com/index.php/en/project>)



Fig 5 - Water overflowing the dam

[https://twitter.com/search?q=laos+dam+collapse&ref\\_src=twsrc%5Egoogle%7Ctwcamp%5Eserp%7Ctwg%5Esearch](https://twitter.com/search?q=laos+dam+collapse&ref_src=twsrc%5Egoogle%7Ctwcamp%5Eserp%7Ctwg%5Esearch)



Fig. 6 - <https://twitter.com/Zeno7Inc/status/1021680781498888192> video showing the section of the dam that was broken, with the water flowing below.

The timeline of the levels of the river in the surrounding can be obtained from the Near Real Time Hydrometeorological Monitoring in the area, <http://monitoring.mrcmekong.org/> which shows one river sensor located not exactly along the flooded river, but can provide information on the raining timeline in the area. The Mekong River's water levels have increased rapidly during the period of July 15 – 24, with a rise of over four meters in some stations along the mainstream (see: <http://www.mrcmekong.org/news-and-events/news/rapid-increase-in-water-levels-caused-by-extremely-high-rainfall-from-tropical-storm-son-tinh/> )

The image shows a large increase of the river level in correspondence with the passage of Tropical Storm SON-TINTH on 20th - 21st July and peaking the maximum level on 24th July.

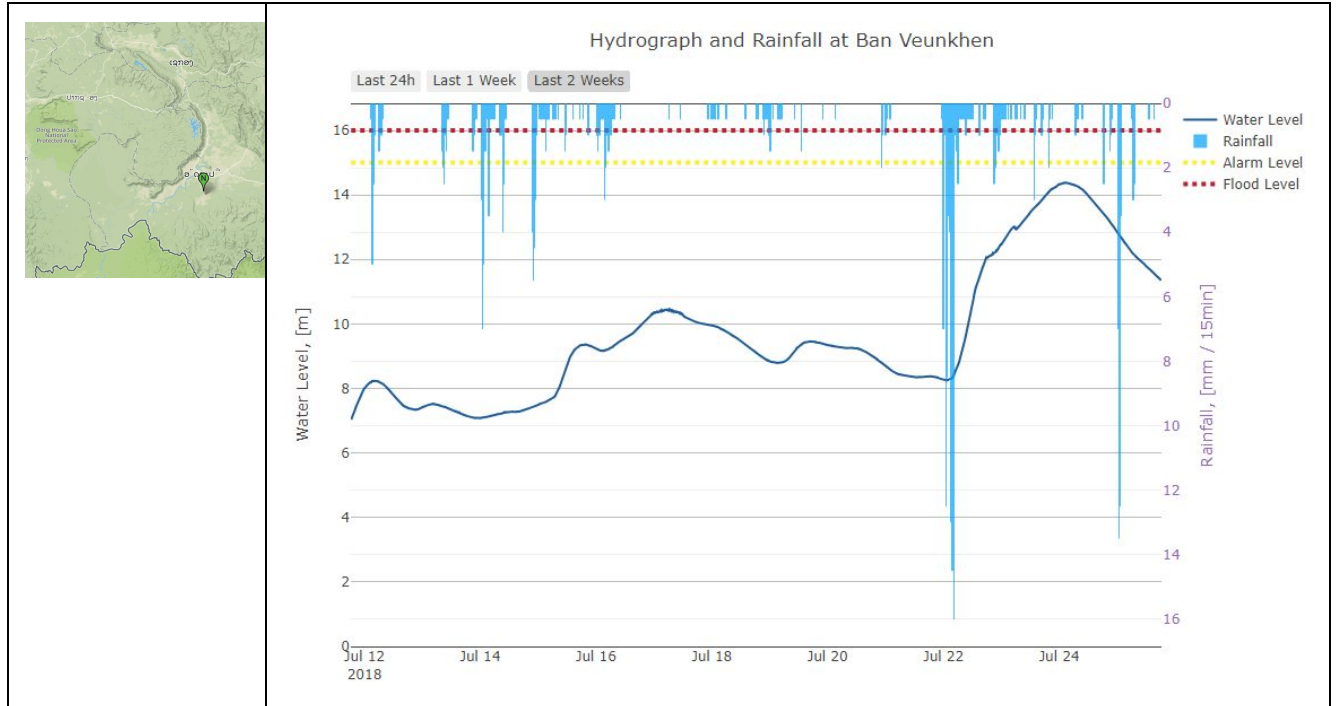


Fig. 7 - Hydrograph and Rainfall at Ban Veunkhen (source: <http://monitoring.mrcmekong.org/>)

## 2.2. Humanitarian situation

The current situation is shown in the table below. Search and rescue operations are still ongoing, therefore these figures could still change. Moreover,

- On 24 July, the Government has declared the affected areas in Sanamxay District (Attapeu province) as **National Disaster Area**.
- The needed items include clothing, food items, drinking water, medicines, cash and other relief items.
- UN OCHA has established an emergency section in VOSOCC, to collect information and offers for helps.
- The IFRC Country Cluster Support Team (CCST) in Bangkok will deploy one member of its team to Laos tomorrow to provide in-country coordination and is preparing to dispatch 1,400 food relief kits in coordination with the Thai Red Cross Society (TRCS).
- The Thai Prime Minister has instructed officials to provide assistance to Lao PDR
- Over the next few days, more heavy rain is forecast to affect the area over the next few days, which could further worsening the situation

Lao PDR - Situation (as of 25 July)	
Dead / Missing	Source OCHA 5 dead (media report up to 19 dead) >30 missing → numbers not yet confirmed, still under verification
Affected	12,000 people affected
Evacuated	1,500 people evacuated
Rescued	2,800 people reported rescued (media) → more would require rescue from trees and the roofs of houses
Damaged houses, infrastructures	> 200 damaged houses 14 bridges damaged several roads damaged
Areas mostly Affected	Province: Attapeu District: Sanamxay Villages: Mai, HinLath, ThaSengchan, Thahintai, Sanong, Thae, Phonsa-ath, Nongkhae

Table 1 - Situation in Lao PDR (as of 25 July, media, UN OCHA).



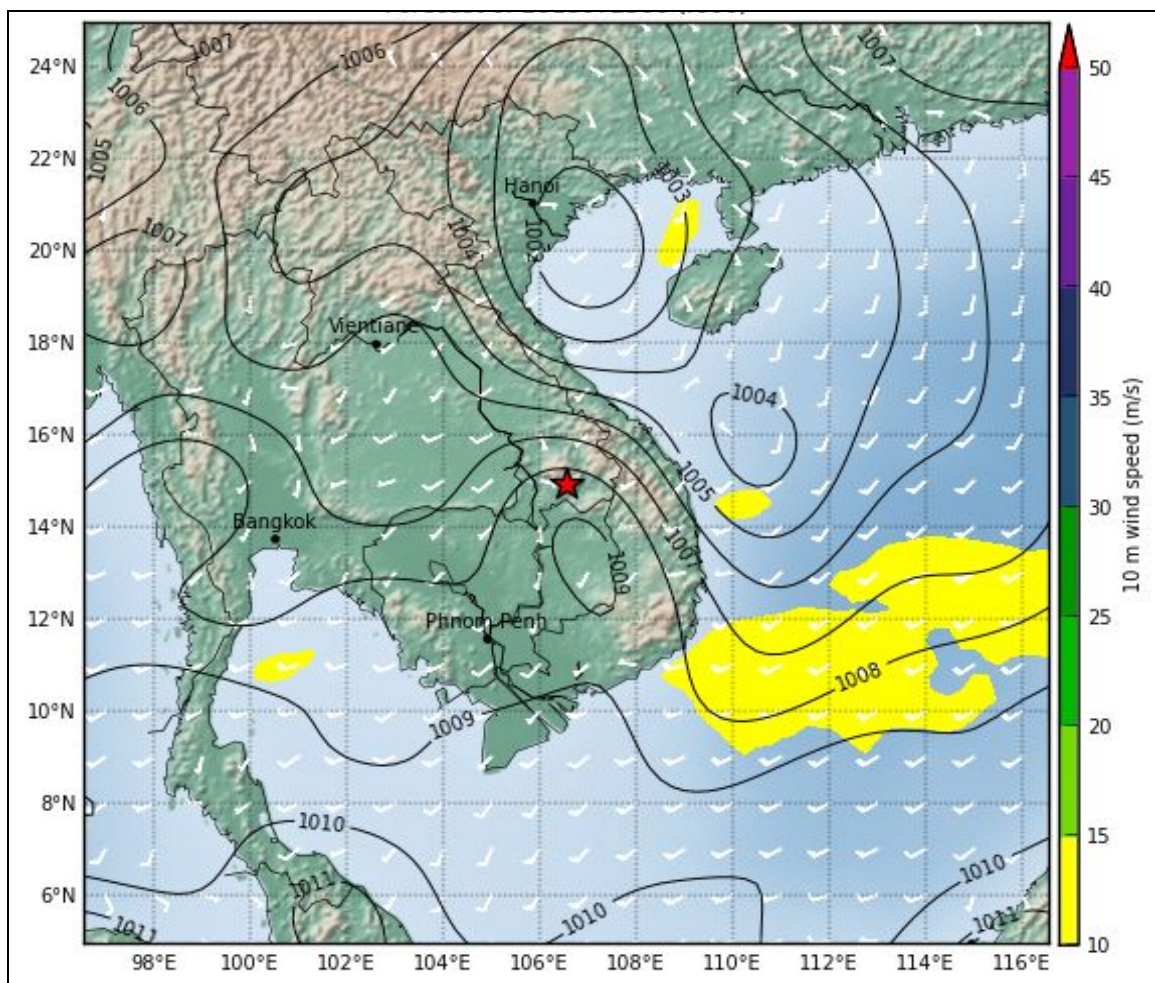


Fig 7- Floods due to the dam break (Source: <http://kpl.gov.la/en/detail.aspx?id=36398> )



## 2.3. Meteorological situation

Recent heavy rainfall may have influenced the dam failure as the region has endured frequent downpours in recent weeks. The wet (East Asian Monsoon) season in southern Laos runs from June into early October when roughly 1,650 mm (mean climatological value) are recorded of the annual total amount of ~2,000 mm based on WMO climatological assessment with reference point the weather station of Pakse at about 55 km to the west of Xepian-Xe area (see Appendix B3 for details). The current surface weather map, including the low pressure area (1002 hPa) over Vietnam coasts that is affecting most areas of Laos, is shown in Fig. 8.



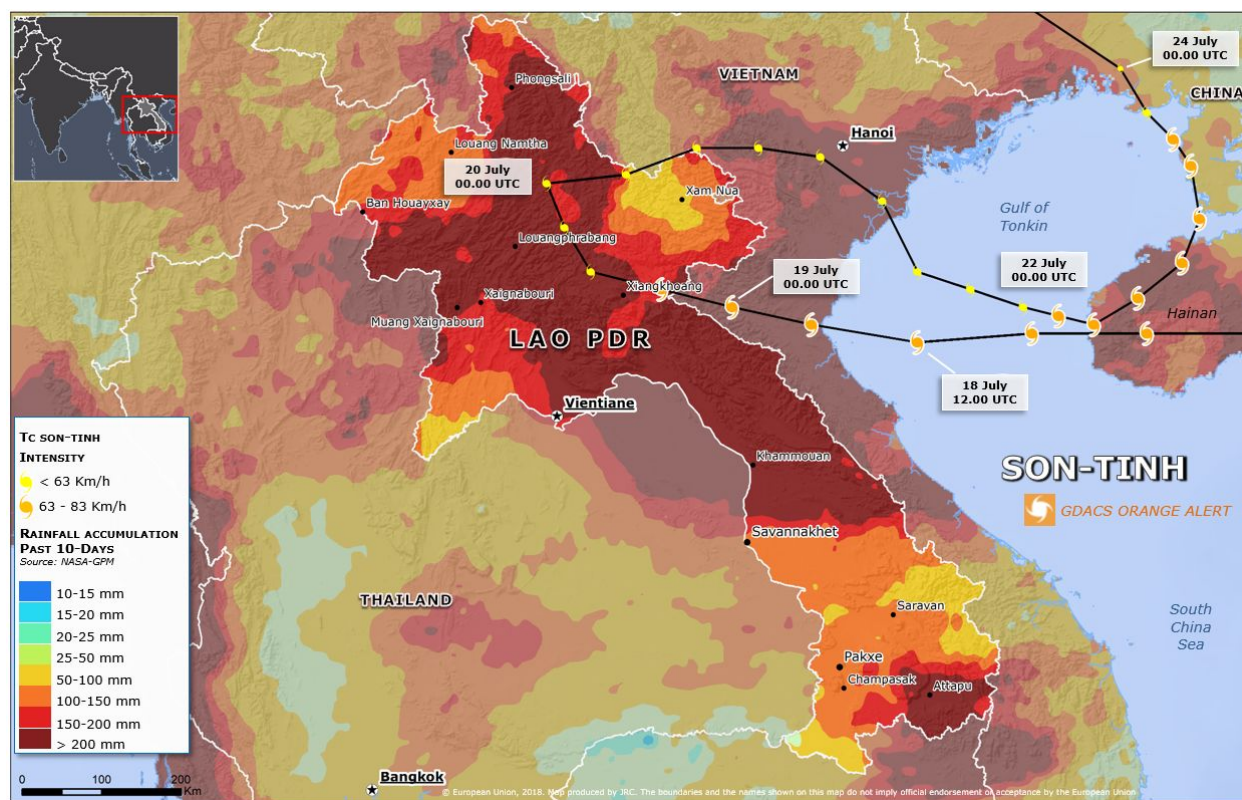
**Figure 8** - Surface map (analysis) valid for 25 July 2018 00 UTC. 10-meter winds and isotach lines of equal speed are also plotted defining various color shaded areas - data source NOAA-GFS.

The recent heavy rains are linked to the **prevailing monsoon conditions** and the passage of the **Tropical Storm SON-TINH** over northern Lao PDR (see TC SON-TINH track and last 10 days rainfall accumulation in Fig. 9).

**TC SON-TINH:** SON-THIN formed over the Philippine Sea on 15 July and started moving west, strengthening. It moved through the Babuyan group of islands (Philippines) on 16 July, over Hainan island (China) on 18 July and reached northern Vietnam on 18 July, as a Tropical Storm. After the landfall, it moved over northern Vietnam and northern Lao PDR weakening into a low pressure area and making a clockwise loop, moving again towards the Gulf of Tonkin. Once the remnants of SON-THIN reached the water, it regenerated into a Tropical Depression on 21 July and strengthened into a Tropical Storm on 22 July. It crossed again Hainan on 22 July, then moved over Guangdong and Guangxi provinces (China) weakening and dissipating on 24 July. During its passage SON-TINH caused heavy rain, floods and damage in several areas of China, Vietnam and Lao PDR. In particular in Lao PDR, combined with the monsoon conditions, it caused floods across the country in **349 villages** of 41 districts of the following provinces: Attapeu, Savannakhet, Khammouan, Xayabuly, Bolikhamxay, Luang Prabang, Bokeo, Sekong, Xiengkhouang and Oudomxay.

**GDACS** issued the first **Orange Alert** on 15 July for the possible impact **TC Son-Tinh** in the Philippines, China, Viet Nam and **Lao PDR**.

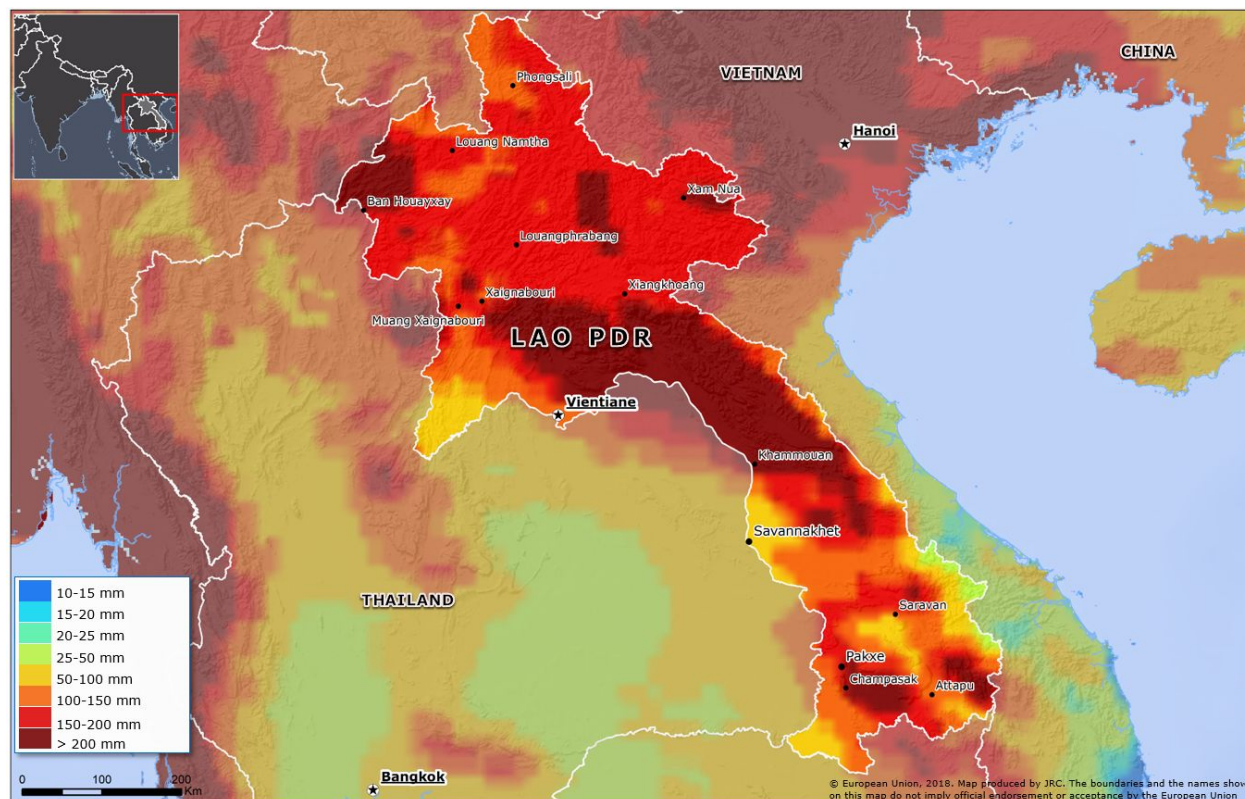
Significant amounts (locally higher than 200 mm) of rainfall have been recorded during the past 10 days (from 15 to 24 July 2018) over the greater area of interest mainly due the passage of Tropical Storm Son-Tinh (besides contribution of the East Asian Monsoon) as shown in Fig.9.



**Figure 9** - Past 10-Day accumulated rainfall (NASA-GPM) and the track of TC SON-TINH (black line).



Significant amounts also (locally higher than 200 mm) of rainfall are anticipated for the coming 10 days (from 25 July to 3 August 2018) over the greater area of interest based on the high-resolution forecast of the ECMWF as shown in Fig.10.



**Figure 10 - 10-Day accumulated rainfall based on the high-resolution forecast of ECMWF.**

Additional meteorological / weather analysis details and forecasts can be found in:

- Appendix B1: On going events - alerts - warnings (Lao PDR Weather Service)
- Appendix B2: Short-range rainfall forecast based on WRF (Lao PDR Weather Service)
- Appendix B3: Climatological assessment based on WMO
- Appendix B4: 10-Day (max horizon of high-resolution) based on HIRES (ECMWF)
- Appendix B5: 2-Week (max horizon of ensembles) based on EPS (ECMWF)
- Appendix B6: Monthly forecast based on MFS of ECMWF
- Appendix B7: Seasonal forecast based on SEAS5 of ECMWF

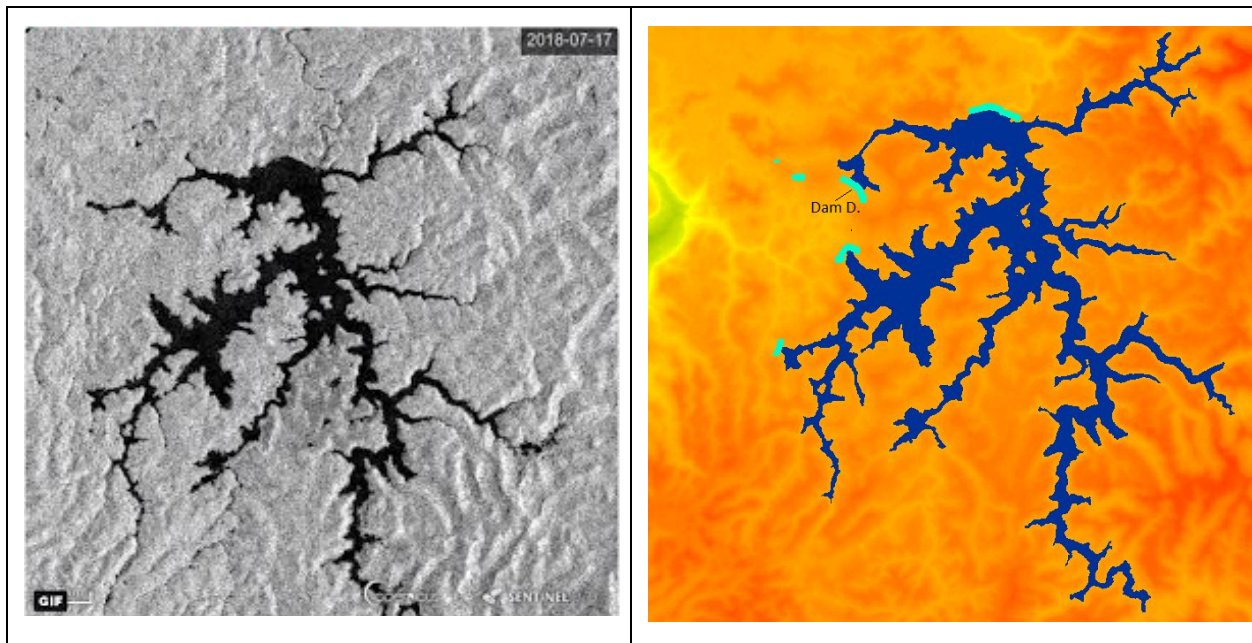
### 3. Preparatory activities for the Dam Break Analysis

This chapter is dedicated to the Dam break analysis of this event. Before starting the discussion it is necessary to point out the Limitations and Uncertainties. We do not have a detailed topography of the area but are deducing it from available global datasets. Also we don't know specific details about the dams in the area although from the topography we are able to identify where the dams should be located.

An analysis is being performed with the following objectives: to identify the possible extent of the flooding, the time of arrival of the wave and the expected dynamic behaviour following the break of the dam. In order to do that a numerical model is being built based on STRM-30 digital elevation model. In this model we have identified that the level of the water is in the order of 780-790 m above sea level with an available jump of about 700 m. Therefore the water ejected from the dam will have a large acceleration when it will reach the downstream areas.

The analysis will be performed by creating artificial dams where they are needed to keep the water level at 780 m and leaving completely open the dam named as Saddle Dam D, that is the one that collapsed.

EU Copernicus Sentinel image below has been obtained 17 July and it shows quite clearly the form of the lake before the dam break.

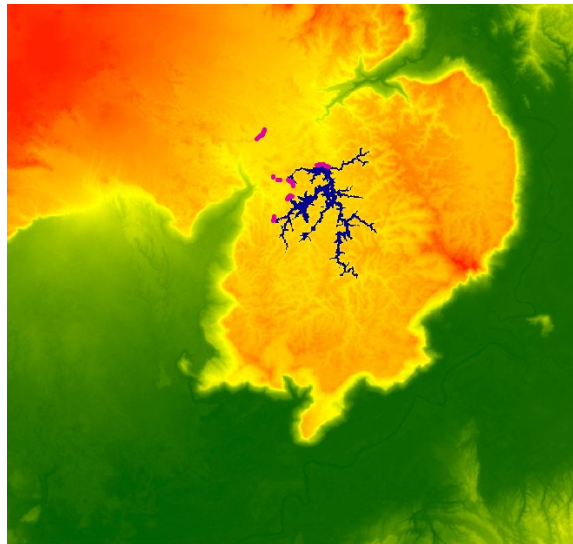


*EU Copernicus Sentinel radar image of the lake upstream the dam (left); the digital elevation model with the indication of the Dams. The Dam that was broken is identified with the Dam D. label*



This image can be compared with the numerical model of the lake as obtained from the SRTM-30 dataset. This is the calculation extent with in blue identified the form of the lake, considered at elevation 790 m. The form is very close to the one present in the Sentinel image above.

The calculation will be performed with the bounding box shown below and a cell size of 10 m. The results will be ready in the next days.



## **4. Other information**

### **4.1. JRC involvement**

#### **4.1.1. JRC Support to ERCC**

In the period after the end of ARISTOTLE services and the beginning of the new 24h service that is being prepared, JRC supplies ERCC with a similar service during working hours. In this case a request for an emergency report was made on 25 July. The objective was to provide more information and perform dam break calculations of the event.

JRC sent an e-mail to the ERCC on 24 July morning, providing a short description of the event and included more information in the JRC Draft ECHO Flash of 25 July.

A daily map will produced and updated in the ERCC portal on 25 July afternoon. The same map on the event will be uploaded in the Virtual OSOCC web site (Appendix C).

#### 4.1.2. Copernicus EMS activation

Copernicus Emergency Mapping service not yet activated.

#### **4.2. ERCC activation of UCPM**

Not yet.

#### **4.3. Virtual OSOCC Activation**

An emergency has been activated in Virtual OSOCC on 24 July afternoon. Several reports from regional organizations (i.e. AHA) and International Federation of Red Cross have been uploaded in the site.

#### **4.4. International Charter activation**

Activated on 24 July afternoon. At the time of writing no map has been produced so far.

### **5. Expected Updates**

JRC is following the situation and will produce an updated report if more information are available.

## **6. References and contact points within JRC**

Contact points within JRC: Disaster Risk Management Unit

Technical Responsible:

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## 8. Relevant Links

- GDACS:
  - Floods: <http://www.gdacs.org/report.aspx?eventid=1000210&episodeid=1&eventtype=FL>
  - TC SON-TINH: <http://www.gdacs.org/report.aspx?eventid=1000469&episodeid=26&eventtype=TC>
- ERCC portal: <http://erccportal.jrc.ec.europa.eu/>
- Copernicus EMS: <http://emergency.copernicus.eu/mapping>
- Disaster Charter Activation: <https://disasterscharter.org/web/guest/activations/-/article/flood-in-lao-people-s-democratic-republic-activation-578-ic-republic-activation-578->
- Reliefweb: Lao PDR Floods: <https://reliefweb.int/disaster/ff-2018-000118-lao>

### Dam information:

- Xe-Pian Xe-Namnoy Hydroelectric Power Project: <http://www.pnpclaos.com/index.php/en/project/project-in-brief>
- <https://www.power-technology.com/projects/xe-pian-xe-namnoy-hydroelectric-power-project/>
- <https://www.hydroworld.com/articles/2015/11/us-1-02-billion-410-mw-xe-pian-xe-namnoy-hydroelectric-project-includes-3-dams.html>

### Government websites:

- Lao PDR gov: <http://www.laogov.gov.la>
- Champasak Province: <http://www.champasack.gov.la/>
- Attapeu Province: <http://attapeu.gov.la/>  
→ ATTAPEU Province Map: [http://attapeu.gov.la/images/map/administrative\\_map.jpg](http://attapeu.gov.la/images/map/administrative_map.jpg)

### Lao News Agency: <http://kpl.gov.la/En/Default.aspx>

- <http://kpl.gov.la/En/Detail.aspx?id=36354>
- <http://kpl.gov.la/En/Detail.aspx?id=36356>
- <http://kpl.gov.la/en/detail.aspx?id=36398>
- [http://www.vientianetimes.org.la/FreeContent/FreeContent\\_Dam.php](http://www.vientianetimes.org.la/FreeContent/FreeContent_Dam.php)

### Rivers monitoring:

- <http://monitoring.mrcmekong.org/>
- [http://portal.mrcmekong.org/station\\_hydro](http://portal.mrcmekong.org/station_hydro)

UN OCHA:

- Situation report 1 (24 July):  
<https://reliefweb.int/report/lao-peoples-democratic-republic/lao-pdr-flooding-office-un-resident-coordinator-situation>

AHA Centre reports:

- Situation report 1 (24 July):  
<https://reliefweb.int/report/lao-peoples-democratic-republic/aha-centre-flash-update-no-6-effect-tropical-storm-11-son>
- Situation report 1 (25 July):  
[https://reliefweb.int/sites/reliefweb.int/files/resources/AHA-Situation\\_Update\\_no\\_2\\_Effect-of-TS-11-Son-Tinh-to-Lao-PDR\\_rev.pdf](https://reliefweb.int/sites/reliefweb.int/files/resources/AHA-Situation_Update_no_2_Effect-of-TS-11-Son-Tinh-to-Lao-PDR_rev.pdf)

Twitter:

- [https://twitter.com/search?q=laos+dam+collapse&ref\\_src=twsrc%5Egoogle%7Ctwcamp%5Eserp%7Ctwgr%5Esearch](https://twitter.com/search?q=laos+dam+collapse&ref_src=twsrc%5Egoogle%7Ctwcamp%5Eserp%7Ctwgr%5Esearch)
- <https://twitter.com/laosnews2011>

Media:

- <https://www.bbc.com/news/world-asia-44935495>
- <https://www.bbc.com/news/world-asia-44935495>
- <https://apnews.com/d2a2cf719ff1432d9f035b1ab222e477/Flooding-from-Laos-hydroelectric-dam-leaves-hundreds-missing>
- <https://news.sky.com/story/dam-collapse-in-laos-leaves-hundreds-missing-and-unknown-number-feared-dead-11446938?dcmp=snt-sf-twitter>
- <https://www.reuters.com/article/us-laos-accident-dam/at-least-100-missing-after-laos-dam-collapse-media-idUSKBN1KE0WC>
- <http://www.abc.net.au/news/2018-07-24/laos-dam-collapse-leaves-several-dead-hundreds-missing/10031084>
- <https://www.news.com.au/world/asia/laos-several-dead-hundreds-missing-after-dam-collapse/news-story/b8bef627c5247a3535b36f10174d9b5a>
- <https://www.aseanbreakingnews.com/2018/07/hundreds-of-downstream-houses-flood-as-laos-subdam-breached/>



## Appendix A - Xe-Pian Xe-Namnoy Hydroelectric Power Project

### A.1. Background information

As reported in the Xe-Pian Xe-Namnoy Power Co., Ltd. website:

*“The 410 MW capacity **Xe-Pian Xe-Namnoy Hydroelectric Power Project** foresees the construction of a series of dams, reservoirs and water transfer conduits to contain and divert the waters of the **Houay Makchanh**, the **Xe-Namnoy** and **Xe-Pian** rivers on the **Bolaven Plateau** in **Champasack Province** and thence to a hydropower generating plant at the base of the Plateau along the Province of **Attapeu**, all in Southern Laos.*

*The dams, reservoirs, upper water channels and surge shaft are located in the eastern corridor of the Plateau in **Champasack Province**, while the lower water channels, vertical pressure shaft, high pressure tunnel, penstock, powerhouse, switchyard and tail race water channel are positioned about 5 km to the northwest of the base of the Plateau in the **Province of Attapeu**.*

*The hydraulic potential of a system of river flows on the Bolaven Plateau will be exploited rationally. Water from the Houay Makchanh will be impounded and diverted to the Xe-Pian catchment along the Xe-Pian River whose waters will likewise be impounded. The water from the Xe-Pian catchment will then be channeled to the Xe-Namnoy Reservoir which is also fed by the Xe-Namnoy River. The Xe-Namnoy Reservoir will in turn convey water through an underground water transfer conduit, vertical pressure shaft, high pressure tunnel and penstock to drive the turbines of a Pelton and three Francis generators at the powerhouse to produce electricity. Meanwhile, a tailrace water channel will discharge water from the Powerhouse to the Xe Kong River before it reaches the Mekong River. To ensure that the environmental and ecological integrity of the river below the Xe-Pian Dam is maintained, the Xe-Namnoy Reservoir will provide a constant and environmental release flow.*

*Upon completion, the Project is expected to generate 1,879 Gwh per year. The Project will export 90% of the electric power it generates to Thailand under a Power Purchase Agreement between the Electricity Generating Authority of Thailand and the PNPC, while the remaining 10% will be sold to the local grid under a Power Purchase Agreement between the PNPC and the Electricite du Laos.*

*The PNPC will operate and manage the Project during the 27-years Concession Period after the 5-years Construction Period and commencement of **commercial operations by 2019**. After the expiry of the Concession Period, the PNPC will transfer the Operations and Management of the Project to the Government of Laos.”*

Source: <http://www.pnpclaos.com/index.php/en/project/project-in-brief>



*Fig - A computer-generated image of a dam being built in Laos by Xe-Pian Xe-Namnoy Power Company (source: <http://www.pnpclaos.com/index.php/en/project>)*

## Technical Information:

As reported in the Xe-Pian Xe-Namnoy Power Co., Ltd. website:

*"The principal components of the Project consists of a main large reservoir impounded by a dam on the Xe-Namnoy River, a long underground waterway to develop a high head of some 650m, an open air switchyard and a powerhouse at the base of the Bolaven Plateau and a straight tailrace channel that connects the powerhouse to the Xe Kong River.*

*Supplementing the volume of water in the Xe-Namnoy Reservoir for power generation purposes is achieved by diverting the run-off from two neighboring sources, the Houay Makchanh and the Xe-Pian. The diversion is made in cascades which starts from the Houay Makchanh to the Xe-Pian catchment which likewise stores water from the Houay Namliang and then to the Xe-Namnoy Reservoir. The structures foreseen for this diversion system are a bottom intake on the Houay Makchanh and a dam and intake in the Xe-Pian River. Two underground water conduits, one working under free flow from the Houay Makchanh to the Xe-Pian Reservoir, and the second one under both pressurized and free flow conditions from the Xe-Pian Reservoir to the Xe-Namnoy Reservoir, will ensure the transfer of water to the Xe-Namnoy Reservoir.*

*From the Xe-Namnoy Reservoir, water is conveyed to the powerhouse units by means of a power intake, a 13.7 km. of low pressure headrace of concrete lined tunnel, 550m concrete lined vertical shaft, 1,300m of steel lined high pressure headrace tunnel, 750m penstock and steel water flow distribution manifolds. At the powerhouse, a Pelton unit and three Francis units are in charge of power generation. Plant output at rated net head is 410MW. After power generation, water is released into the tailrace channel which conveys the flow some 6 km. downstream to be discharged to the Xe Kong River. Ninety percent of the power generated is exported to Thailand by a 500kV and 230kV transmission line and the rest to the local grid by a 115kV transmission line, respectively."*

Source: <http://www.pnpclaos.com/index.php/en/project/technical-information>

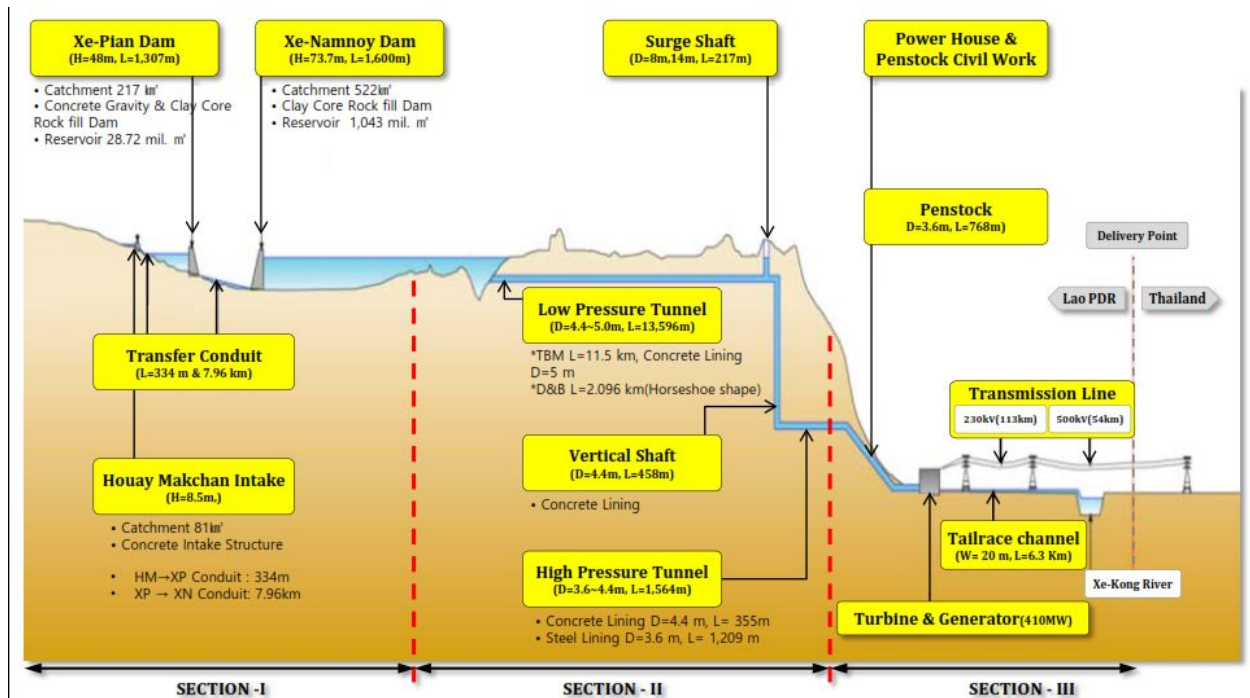




Fig - Cross-Section Xe-Pian Xe-Namnoy Hydroelectric Power Project

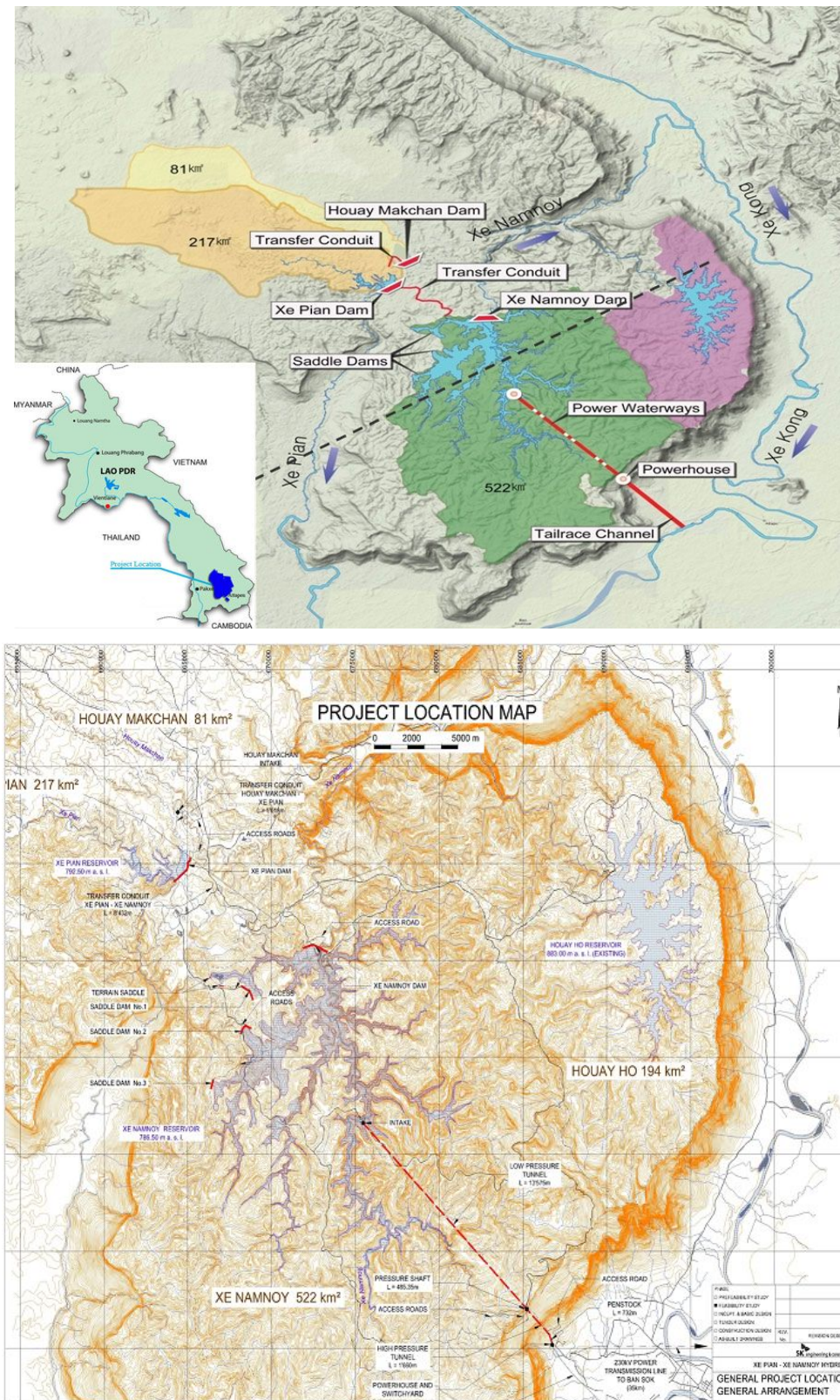
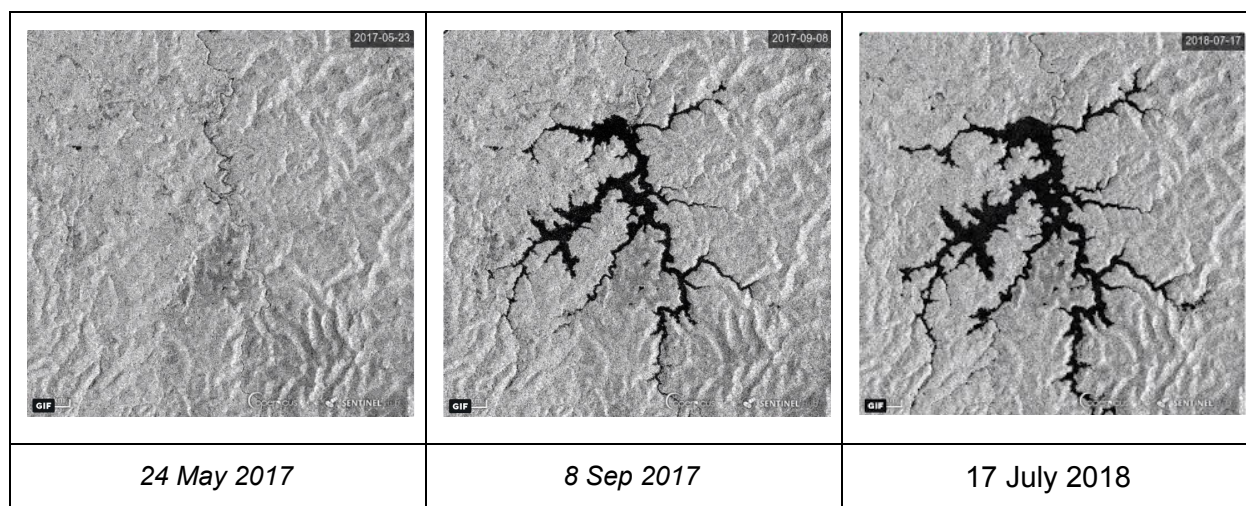


Fig - Xe-Pian Xe-Namnoy Hydroelectric Power Project





## A.2. Project History and Event Timeline

### 2018 - Dam break (Source: BBC <https://www.bbc.com/news/world-asia-44947185> )

- 22 July 21:00 local time (14:00 GMT) - The dam is found to be partially damaged. The authorities are alerted and villagers near the dam start to be evacuated. A team is sent to repair the dam - but is hampered by heavy rain, which has also damaged many roads.
- 23 July 03:00 - Water is discharged from one of the main dams (Xe-Namnoy dam) to try to lower water levels in the subsidiary dam.
- 23 July 12:00 - The state government orders villagers downstream to evacuate after learning that there could be further damage to the dam.
- 23 July 18:00 - More damage is confirmed at the dam.
- By 24 July 01:30, a village near the subsidiary dam is flooded, and by 09:30 seven villages are flooded.

### 2015 - 2017 (Source: <http://www.pnpclaos.com/index.php/en/project> )

- April 9, 2015 The Xe-Namnoy River is diverted.
- February 16, 2015 The Xe-Pian River is diverted.

### 2012 - 2014 (Source: <http://www.pnpclaos.com/index.php/en/project> )

- February 6, 2014 Financial Close with Lenders and Initial Drawdown.
- November 28, 2013 Project Financing Documents are signed.
- November 28, 2013 Construction Supervision Contract between PNPC and RATCH is signed.
- November 15, 2013 Engineering, Purchase and Construction Agreement between PNPC and SE&C is signed.
- November 14, 2013 Operations and Maintenance Agreement between PNPC and KOWEPO
- August 22, 2013 Certificates of Fire Prevention and Protection Plan is issued.
- May 10, 2013 The PNPC-EDL Power Purchase Agreement is signed.

- April 18, 2013 Annex G of the Concession Agreement is signed by the Ministry of Natural Resources and Environment.
- March 26, 2013 Certificates for the EIA, EMMP and RMP Report are issued.
- March 23, 2013 Concession Registration Certificate is issued.
- February 6, 2013 PNPC-EGAT Power Purchase Agreement is signed.
- February 1, 2013 Land Lease Agreement is signed between PNPC and the GOL.
- December 6, 2012 Tariff MOU with Electricite du Laos between PNPC and EDL is signed.
- October 22, 2012 Certificates for the Xe-Pian Dam, Xe-Namnoy Dam, Houay Makchanh Weir, Saddle Dams, Powerhouse and Operator's Village are signed.
- October 19, 2012 Concession Agreement between PNPC and the GOL is signed.
- May 2, 2012 Electricity Business Operations License is issued.
- April 18, 2012 Official Seal approved.
- March 23, 2012 The PNPC is founded by the four major Shareholders.
- March 12, 2012 Certificate of Taxpayer Identification is issued.

**2009 - 2011** (Source: <http://www.pnpclaos.com/index.php/en/project> )

- June 15, 2011 Shareholders' Agreement is signed by all major Shareholders.
- September 29, 2011 Enterprise Name Approval Certificate is issued.
- August 16, 2010 Tariff MOU with the Electricity Generating Authority of Thailand is signed.

**2006 - 2008** (Source: <http://www.pnpclaos.com/index.php/en/project> )

- November 14, 2008 Project Development Agreement between the GOL, SKE&C, RATCH and KOWEPO is signed.
- August 6, 2007 Joint Development Agreement between RATCH and SKE&C is signed.
- August 3, 2006 Project Development MOU between the GOL and initial consortium is signed.

**2006 - 2008** (Source: <http://www.pnpclaos.com/index.php/en/project> )

- October 23, 2003 MOU between the Korea & Laos Power Development Company and The Government of Laos (GOL) is signed.
- July 19, 2005 Project Development MOU between SKE&C and the KOWEPO is signed.

## Appendix B - Meteorological Situation: *Assessment of Precipitation*

### B.1 - On going events and alerts

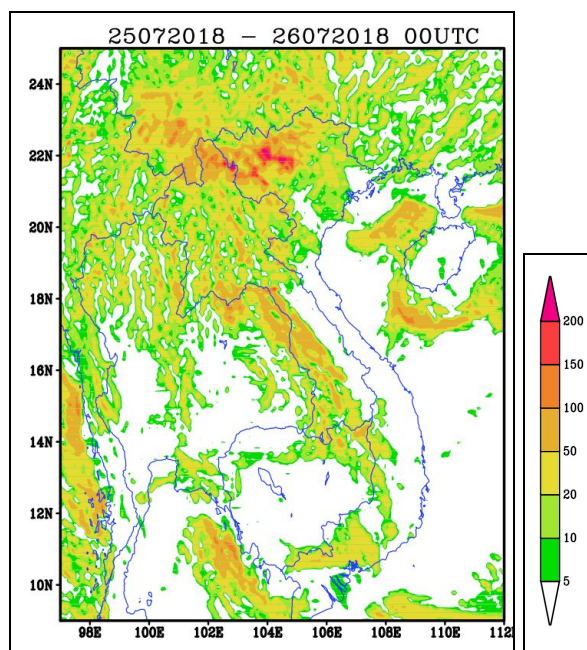
Recent heavy rainfall may have influenced the dam failure as the region has endured frequent downpours in recent weeks. The country has been under the influence of East Asian Monsoon (EASM) that is responsible for significant precipitation amounts over the country. The (EASM) wet season in southern Laos runs from June into early October. No red alerts for extreme weather phenomena have issued although it should be kept in mind that we are in the middle of East Asian Monsoon period and precipitation phenomena may locally be very intense as shown in Fig. B1.1 (red precipitating clouds) referring to the last 24-hour recorded rain measurements.

Station	Trend	Flag	Rain	Date	Water Level (m)	Level variation in cm/h (last 6 hours)	Rain mm (last 24h)
PhaVieng				7/25/18 17:00	13.91	2.4	64.4
Sebangfai B.				7/25/18 17:00	-1.69	0.0	16.8
Saang				7/17/18 11:00	0.35	-12.2	84.7
Ban Dong				6/21/18 22:00	1.02	0.1	1.1
Selanong				7/25/18 16:00	4.60	3.4	18.6
Kengdone				7/24/18 13:00	11.82	3.5	0.5
Sobnam				7/25/18 17:00	8.53	-0.3	47.6
Sethamouak				7/25/18 17:00	4.35	-2.2	23.8
Xieng Hom				7/25/18 17:00	7.56	2.5	28.9
Mahaxai				7/25/18 17:00	14.82	1.4	67.7
Ban Tonhen				7/25/18 17:00	13.64	1.3	11.5
Boung Bao				7/6/18 7:00	0.04	-0.0	10.6
Tad Hai				6/20/18 2:00	2.21	-1.5	9.4
Sokbo				6/6/18 8:00	5.39	0.5	3.7

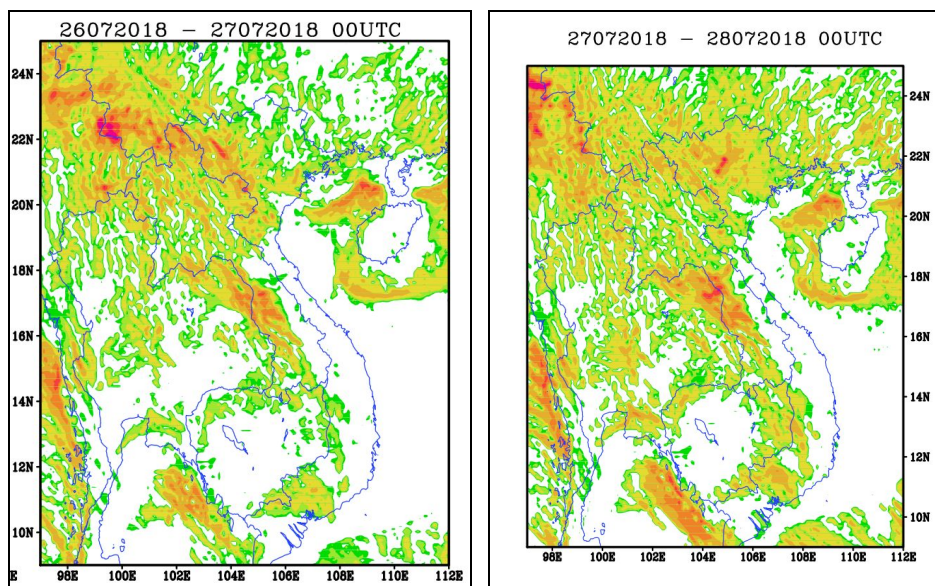
**Figure B1.1** - Last 24-hour recorded accumulated rainfall as recorded in 14 Hydrologic Stations (Sebangfai and Sebanghiang) - details at <http://www.newcdmh.com/newc/index.php>

## B.2 - Short-range forecast

Based on the mesoscale WRF (Weather Research and Forecasting) model significant amounts of rain are anticipate during the next 3 days over the area of interest as shown in Fig. B2.1 (day 1), Fig. B2.2 (day 2 and day 3). The model (WRF) is run on tactical (daily) basis by the National Weather Service of Lao PDR.



**Figure B2.1** - 24-hour accumulated rainfall during 25 July 2018 - data source:Lao PDR

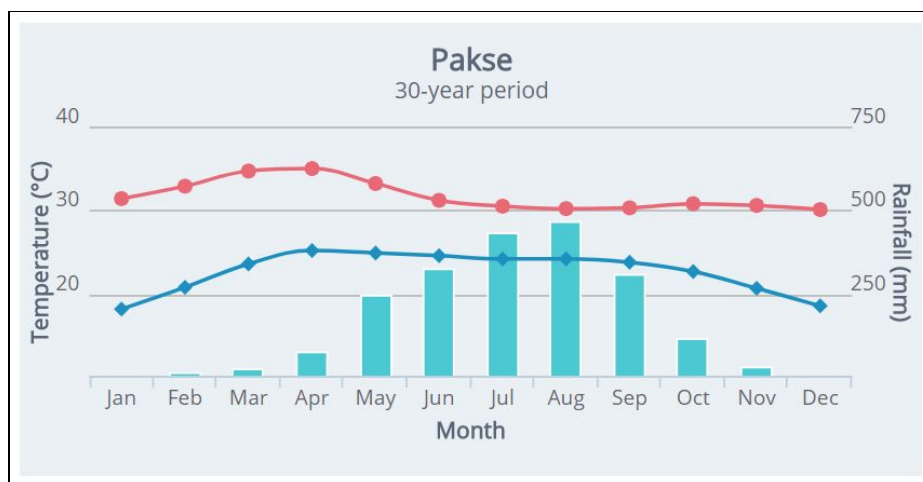


**Figure B2.2** - 24-hour accumulated rainfall during 26 July 2018 (left panel) and during 27 July 2018 (right panel) - data source:Lao PDR Weather Service (<http://www.newcdmh.com/newc/index.php>)



### B.3 - Climate information for the greater area of interest

Climatological assessment for the greater area of interest is referring to the weather station of Pakse that is suited ~ 55 km to the west of Xepian-Xe area.



**Figure B3.1** - Mean (climatological) monthly values for Pakse weather station.

Details can be found at WMO's (World Meteorological Organization) dedicated site for both precipitation and temperature parameters <http://worldweather.wmo.int/en/city.html?cityId=646>

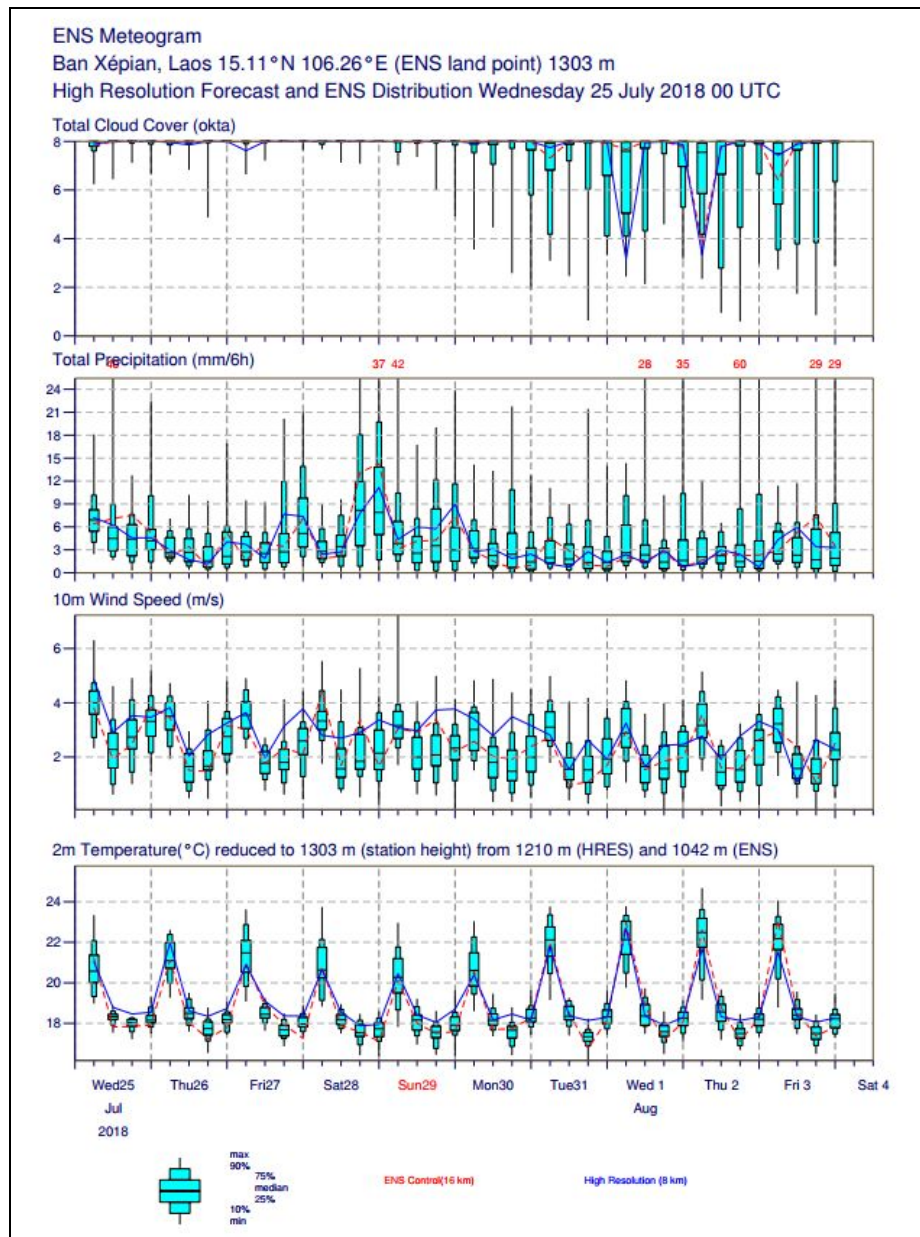
**Table B3.1** - Monthly mean temperature and accumulated values of precipitation for Pakse

Month	Mean Daily Minimum Temperature (°C)	Mean Daily Maximum Temperature (°C)	Mean Total Rainfall (mm)	Mean Number of Rain Days
Jan	18.2	31.4	1.8	0.0
Feb	20.8	32.9	16.3	1.0
Mar	23.6	34.7	25.0	4.0
Apr	25.2	35.0	75.2	9.0
May	24.9	33.2	245.0	18.0
Jun	24.6	31.2	323.6	22.0
Jul	24.2	30.5	433.6	24.0
Aug	24.2	30.2	467.5	25.0
Sep	23.8	30.3	308.7	20.0
Oct	22.7	30.8	115.9	14.0
Nov	20.7	30.6	29.8	5.0
Dec	18.6	30.1	2.0	1.0

The footprint of East Asian Monsoon is clearly seen in Fig. B3.1 initiating from months of May-June spanning through September-October. During June to September all monthly accumulated rainfall values are well above 250 mm. Details for both temperature and precipitation are contained in Table B3.1. Mean number of monthly rainy days are also included.

#### B.4 - 10-Day Meteogram for Xepian-Xe area (max horizon of HIREs)

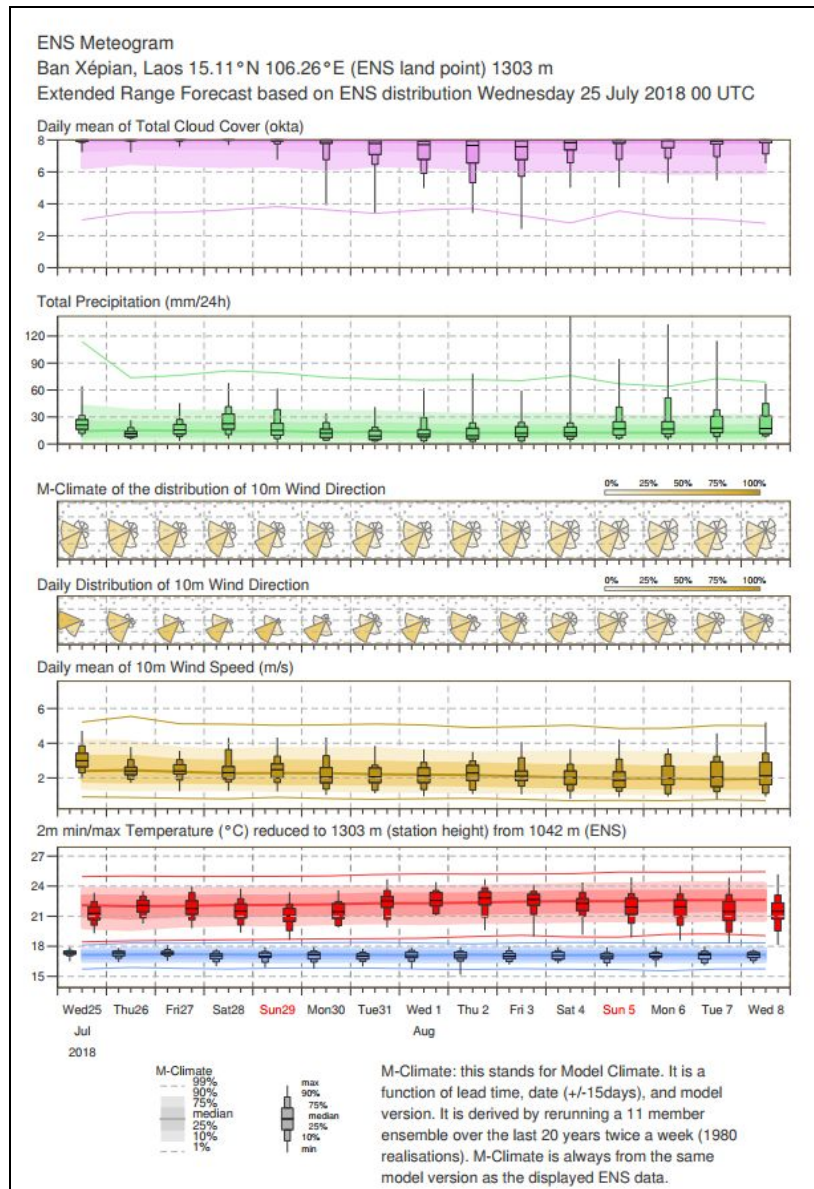
A pinpoint Meteogram over the next 10 days for the reference closest grid point (3 km to the south-west) to Xepian-Xe based on both the high-resolution (HIREs) operational forecast and the Ensemble Prediction System (EPS) of ECMWF has been compiled comprising main weather elements as cloudiness (in okta), precipitation (in mm/6h), wind (m/s) and temperature (deg Celsius). Based on the Meteogram of Figure B4.1, almost overcast conditions are forecast for Xepian-Xe area with local heavy rains and thunder showers during the whole 10-day period.



**Figure B4.1** - 10-Day Meteogram for Xepian-Xe area based on 25 May 00 UTC high-resolution operational forecast and ensembles of ECMWF EPS.

## B.5 - 2-Week (15-Day) Meteogram for Xe-Pian area (max horizon of EPS)

A pinpoint Meteogram over the next 15 days for the reference closest grid point (3 km to the south-west) to Xepian-Xe based on the Ensemble Prediction System (EPS) of ECMWF has been compiled comprising main weather elements. M-Climate (model climate) values are also included for reference. Based on the Meteogram of Figure B5.1, almost overcast conditions are forecast for Xepian-Xe with local intense rains and thunder showers during the 15-day period.



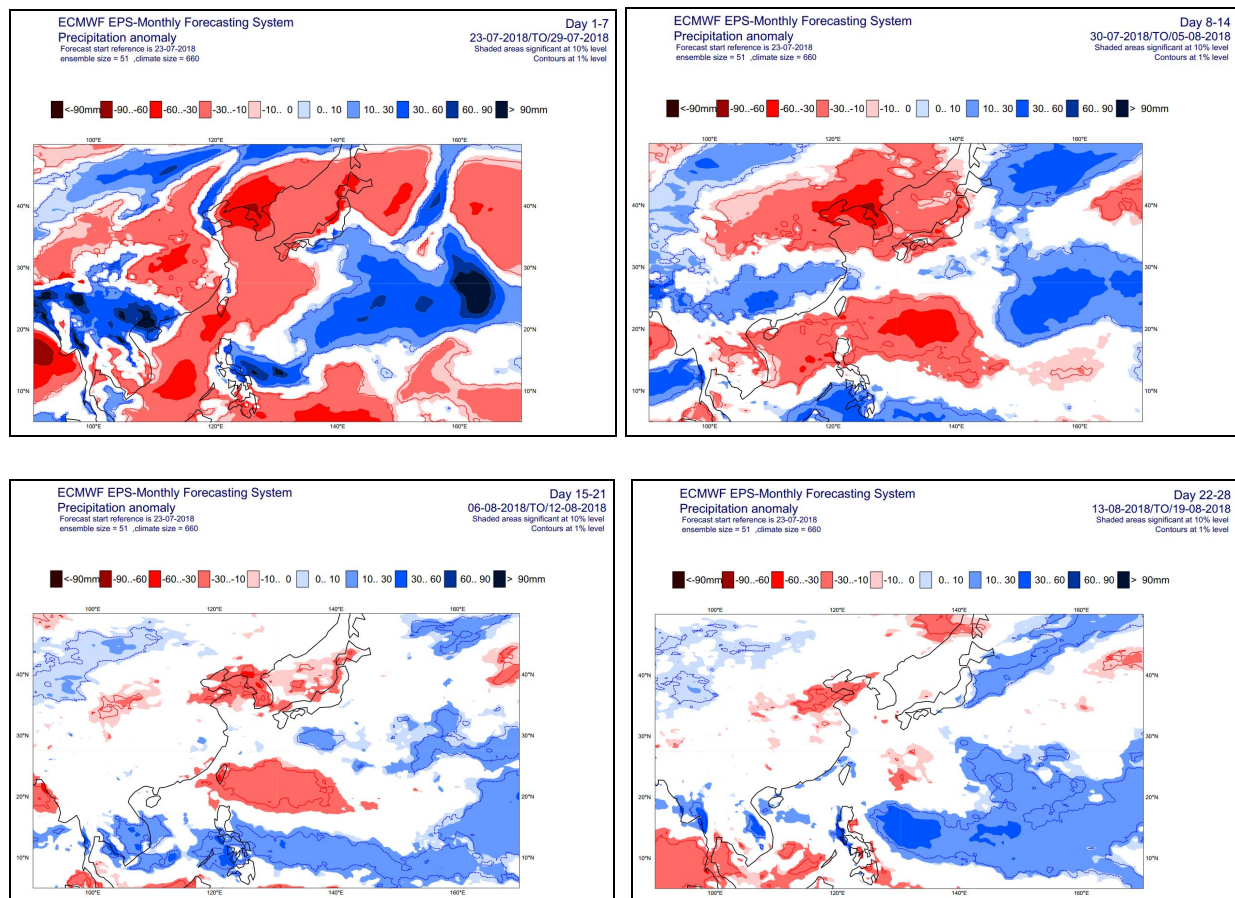
**Figure B5.1** - 2-Week (15-Day) Meteogram for Xepian-Xe area based on 25 May 00 UTC EPS (Ensemble Prediction System) of ECMWF.



## B.6 - Weekly anomalies based on MFS of ECMWF

Utilising the monthly forecast platform of ECMWF named MFS (Monthly Forecast System) 7-day (weekly) anomalies of precipitation have been retrieved referring to the coming period of the next 4 weeks (Week 1: 23 to 29 July 2018 - Week 2: 30 July to 5 August 2018 - Week 3: 6 to 12 August 2018 - Week 4: 13 to 19 August 2018).

Results are focusing on the ensemble mean and anomalies are defined from the model climate (M-climate) that that resembles as close as possible the real atmosphere. Details are shown in Fig. B6.1.



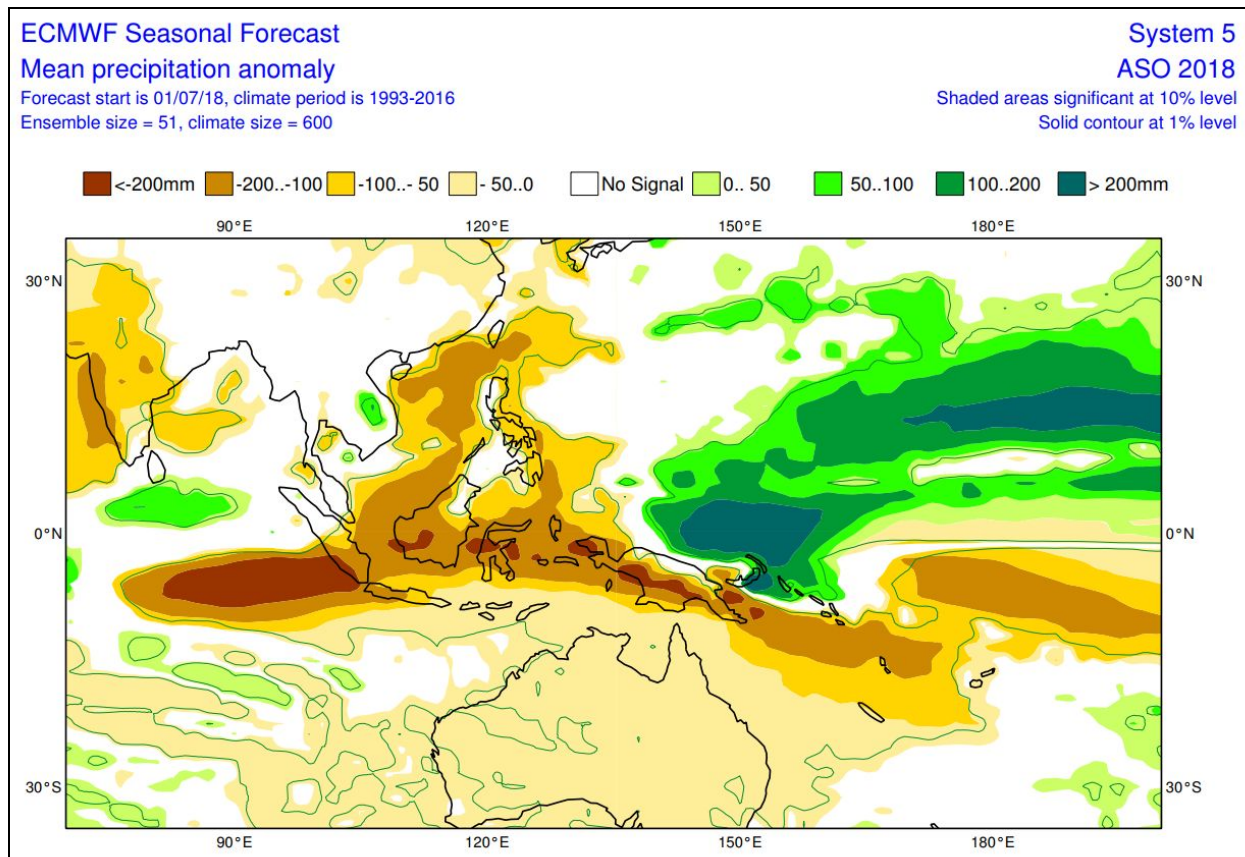
**Figure B6.1** - Weekly anomalies of precipitation based on MFS of ECMWF for week 1 (upper left panel), week 2 (upper right panel), week 3 (lower left panel) and week 4 (lower right panel).

Based on Fig. B6.1 it becomes clear that excluding week 2, wetter (in the range of 30 to 60 mm) than normal conditions are forecast over the greater area of interest.

That means that besides the mean climatological reference precipitation weekly value (about 115 mm) additional 30 to 60 mm are to be anticipated (forecast) during each of the week 1, week 3 and week 4 over the greater area of interest.

## B.7 - 3-Monthly anomalies based on SEAS5 of ECMWF

Utilising the seasonal forecast platform of ECMWF named SEAS5 (Seasonal System 5) 3-monthly anomalies of precipitation have been retrieved referring to the coming period of August-September-October that represents the end time interval of the East Asian Monsoon period. Results are focusing on the ensemble mean and anomalies are defined from the model climate (M-climate) that resembles as close as possible the real atmosphere. Details are shown in Fig. B7.1.



**Figure B7.1** - 3-Monthly anomalies based on the SEAS5 of ECMWF for ASO (August-September-October) 2018

Based on Fig. B7.1 it becomes clear that wetter (in the range of 50 to 100 mm) than normal conditions are forecast over the greater area of interest.

That means that besides the mean climatological reference precipitation value (close to 900 mm) additional 50 to 100 mm are to be anticipated (forecast) during the remaining Monsoon period of ASO (August-September-October) 2018.



# Appendix C - Daily Map for ERCC

