



2025

LuangPrabang

Optioneering Report for drought risk reduction

Aluvium and Hydrotech
Consulting

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Abbreviations

DAFO	District Agriculture and Forestry Office
DICT	Department of Information, Culture and Tourism
DLSW	Department of Labour and Social Welfare
DONRE	Department of Natural Resources and Environment
DPI	Department of Planning & Investment
DPH	Department of Public Health
DPWT	Department of Public Works and Transport
DWR	Department of Water Resources
EbA	Ecosystem-based Adaptation
GEDSI	Gender equality, disability, and social inclusion
GPT	Gross pollutant trap
GRET	Group for Research and Technology Exchanges
ICFMS	Integrated Climate-Resilient Flood Management Strategy
LPC	Luang Prabang City
LPSIUS	LPC Smart and Integrated Urban Strategy
LSWO	Labour and Social Welfare Office of Luangprabang District
LWU	Lao Women's Union
MPWT	Ministry of Public Works and Transport
O&M	Operation and maintenance
PAFO	Provincial Agriculture and Forestry Office
PONRE	Provincial Office of Natural Resources and Environment
PWTO	Public Works and Transport Office
RUCAS	Resilient Urban Centres and Surrounds
UN	United Nations
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization
USO	Urban Services Office
WHMD	World Heritage Management Division
WSCA	Water Sensitive Cities Australia

Definitions:

Fluvial Flooding: Fluvial flooding, also known as river flooding, happens when a river, stream, or other watercourse overflows its banks due to excessive rain or snowmelt upstream. This leads to the inundation of surrounding land. Fluvial floods are often more extensive and can affect both rural and urban areas, depending on the scale of the river system involved.

Gross pollutant trap: A gross pollutant trap is a type of stormwater treatment system designed to capture large debris, litter, and coarse sediments from urban runoff before it enters waterways.

Pluvial Flooding: Pluvial flooding occurs when heavy rainfall overwhelms drainage systems or accumulates on the ground due to poor absorption, leading to localised flooding. This type of flooding can happen even if a body of water (such as a river or lake) is not nearby. It is commonly associated with urban areas where stormwater drainage systems are insufficient to handle intense rainfall.

Sluice gate: A sluice gate is a movable barrier that controls the flow of water in channels, rivers, or dams. It can be raised or lowered to regulate water levels, control flow rates, or manage water releases.

Notes:

(i) All photos by Alluvium, unless stated otherwise.

(ii) Cover image of UNESCO World Heritage pond in LPC managed on private land as part of a hotel and restaurant complex (February 2024).

1 Introduction

This Optioneering Report is prepared for the United Nations Development Program (UNDP) and Department of Water Resources (DWR) as part of the *Technical support for enhancing climate resilience through Integrated Catchment Management and Ecosystem Based Adaptation (RFP-005-2023)* project.

This project falls within Component 1 of the UNDP-GEF LDCF “Integrated Water Resource Management and Ecosystem-based Adaptation in the Xe Bang Hieng River Basin and Luang Prabang City” project. The UNDP-GEF LDCF project includes three complementary components, namely:

- Component 1: Developing national and provincial capacities for Integrated Catchment Management (ICM) and integrated urban Ecosystem-based Adaptation (EbA) for climate risk reduction.
- Component 2: Ecosystem-based Adaptation (EbA) interventions, with supporting protective infrastructure, and livelihood enhancement.
- Component 3: Knowledge management and Monitoring and Evaluation (M&E).

Technical support for Component 1 is being provided by the Alluvium Group (Alluvium) and Hydrotech Consulting (HTC) as a Joint Venture. For simplicity, all references to Alluvium should be read to refer to the Alluvium and HTC team (unless stated otherwise).

The Optioneering Report presents a range of protective infrastructure and Ecosystem-based Adaptation (EbA) options designed to address flooding issues identified by government stakeholders in Luang Prabang City (LPC). The report consists of:

- A summary of existing strategies and actions related to optioneering in LPC.
- A description of flood hotspots and related sites in LPC visited by the project team in February 2024, this includes an overview of options for flood mitigation at each of the flood hotspots.
- Optioneering of flood mitigation options for flood hotspots, including a description of challenges and recommendations.

The outputs of the Optioneering Report are designed to support the following related, and separately documented, project outputs:

- (a) Economics Report exploring the valuation of ecosystem services provided by urban riparian areas, wetlands and streams in LPC
- (b) Integrated Climate-Resilient Flood Management Strategy (ICFMS) for LPC.

2 Existing strategies and actions

Luang Prabang Smart and Integrated Urban Strategy

The Luang Prabang Smart and Integrated Urban Strategy (2023) outlines a smart city strategic infrastructure plan to achieve Luang Prabang's ambition to become a more liveable heritage city for all. This ambition is supported by three strategic pillars:

1. Integrated Tourism and Heritage Destination
2. Clean and Safe Environment
3. Sustainable Villages and a 15-Minute City

The strategy will be implemented under the supervision of a steering committee chaired by the provincial governor and supported by multisector working groups. Each working group will oversee one of the three strategic pillars, and smart city projects required to realize Luang Prabang's liveable heritage city ambition.

The strategy and supporting Urban Assessment Report highlights that:

- Severe rainfall and floods are the most pressing climate change risk.
- Floods have a disproportional impact on women, older persons, people with disabilities, and other marginalized and vulnerable groups.
- Litter and the lack of solid waste management exacerbates local flooding, and water and land pollution issues.
- Heritage asset protection from flood and other disasters is important. Specific smart technologies to detect, report, and trigger rapid responses to floods (or fires) is proposed.
- Gross pollutant traps will be piloted in roadside drains to improve current solid waste collection systems by managing accumulated drain litter which have been found to obstruct water flow in drains and impact effluent quality. The installation of gross pollutant traps can contribute to:
 - Improved drain conditions with reduced occurrences of clogged drains and localized flooding.
 - Improved water quality in surface water systems.
- There is a loss of flood detention capacity due to ponds being backfilled for development. To prevent further loss in flood detention capacity, existing ponds should be preserved, retrofitted with suitable flood resilient designs, and rehabilitated to provide added recreational value for the city.
- There is an opportunity to integrate "blue-green" infrastructure which uses nature based solutions with flood risk reduction measures.
- One of the factors that contributes to flooding is the proximity of communities to the Mekong River and its tributaries, such as the Nam Khan. High water levels result in fluvial flooding of urban areas.
- A poorly maintained drainage system, suffering from blockages due to improper solid waste management, contributes to localized flooding in the city, reducing conveyance capacity of drains.
- Other factors, such as insufficient flood risk reduction measures and infrastructure, urbanization, and poor urban planning may also contribute to flooding risks.
- During localized flooding, wastewater in the existing decentralized sanitation infrastructure in the city (pit latrines and septic tanks) contaminates stormwater, leading to elevated public health risks.

Several relevant interventions are proposed under *Strategic Objective 2.2: Disaster Management System is Improved*, including hazard risks assessment, flood risk zoning, flood defence mechanisms, smart early flood response and a social inclusion study, with GEDSI mainstreaming considerations. A detailed list of relevant projects identified in the LPC Smart and Integrated Urban Strategy are provided in Figure 1 (p5).

The Urban Assessment Report notes that flood maps were generated in the World Bank Disaster Risk Management Project. The project team has not yet been able to access the underlying data for these flood maps, however, copies of the flood maps provided are provided in the Urban Assessment Report (see Figure 2, p6). These maps appear to show fluvial flooding for both sides of the Nam Khan River and certain tributaries along the Mekong River for six different rainfall return periods (2-, 5-, 10-, 20-, 50-, and 100-year). They indicate that the low-lying areas along the major tributaries are prone to inundation, especially within the Nam Dong and Houay Hop catchments.

Figure 1. Relevant projects identified in the LPC Smart and Integrated Urban Strategy

Pillar	Project	Name	Relevance	Urgency	Responsibility	Page #	Related work
1	4	Heritage Disaster Risk Management (DRM) Policy and Plans	<ul style="list-style-type: none"> Implement measures and smart technologies to detect, report and trigger rapid responses to threats or actual immediate risks such as fires or floods 	Medium	Department of Information, Culture and Tourism (DICT)	79-80	Hydrology and Meteorology section of PONRE is developing a standardised alarm system is being developed, supported by a modern command centre, to handle alerts for various emergencies, including fires and floods.
2	9	Gross Pollutant Traps (GPTs)	<ul style="list-style-type: none"> Pilot project to support the waste management process and reduce flooding. 	High	Public Works and Transport Office (PWTO), Urban Services Office (USO)	99-100	The Department of Natural Resources and Environment (DONRE) is proposing to implement an awareness raising campaign to encourage better waste management for target villages: Nasangwei, Nasamphan, Nalouang, Phouxangkham, That Louang.
2	12	Hazard and Risk Assessment	<ul style="list-style-type: none"> Identify high risk areas, e.g., flood inundation areas by developing and calibrating relevant models. Produce hazard maps, e.g., flood maps, to serve as foundation for resilience strategies development. 	High	Department of Public Works and Transport (DPWT)	101-2	DONRE previously conducted a survey to map the flood zones from the Nam Khan River to Xiengngeun District, as part of the integrated water management project. They are now drafting a proposal to install water level warning signs along the Mekong River tributaries.
2	13	Flood Risk Zoning	<ul style="list-style-type: none"> Produce flood-proof spatial plans and design, e.g., avoid locating critical infrastructure in in flood-prone areas. Develop land use processes to guide new developments and upgrading of existing developments in flood-prone areas. Prepare clear building regulations, considering high water levels to eliminate downstream flooding impact. Prepare clear action plans to relocate existing critical infrastructure and developments in flood-prone areas. 	High	DPWT	103-4	DONRE is working on plans for flood protection, including changing the land title conditions and land zoning to prevent construction in flood-prone areas.
2	14	Flood Defense Mechanisms	<ul style="list-style-type: none"> Flood defense through risk mitigation and adaptation focuses on measures that prevent stormwater from inundating urbanized areas, through implementation of infrastructure such as dikes or nature-based solutions. Detention volume can also be added through implementation of detention ponds or widening of drains or rivers. For example, the installation of GPTs can offer surface runoff pre-treatment and filter out the debris to prevent the drainage system from blocking, hence, runoff could enter the drainage and flow out of the site without obstruction. 	High	DPWT	103-4	DWR has issued legislation regulating the opening and closing of water channels during the dry and rainy seasons, based on water level fluctuations. DWR is also working to modify the drainage channel in areas like Ban Kok Nguyue and Nasamphan to reduce the risk of sudden flooding.
2	15	Social Inclusion Study, with GEDSI Mainstreaming Considerations	<ul style="list-style-type: none"> Conduct a social inclusion study as part of the program to ensure that flood resilience measures are adapted to support vulnerable groups. 	High	Department of Labour and Social Welfare (DLSW)	105-6	Stakeholders suggest that regular evacuation drills are needed to prepare for disasters, along with the creation of effective response mechanisms. Additionally, a rain warning system is proposed to notify communities when heavy rainfall occurs over extended periods.
2	16	Smart Early Flood Response System	<ul style="list-style-type: none"> Smart early warning systems with real-time data capture can be developed based on the results of the existing flood maps to ensure that communities are equipped to respond to flood events in a timely manner. 	High	DLSW	105-6	Stakeholders suggest flow and rainfall modelling tools should be used for real-time monitoring and to support timely response planning for potential flood events.
General comment		A project proposal is being prepared by PONRE for the 2025 fiscal year, focusing on water resource management and ecosystem adaptation in the Xe Bang Hiang water basin and Luang Prabang town, covering five target villages. Ban Kok Nguyue village is also being considered for inclusion in the study plan. Key activities for the 2025 plan have been identified, but challenges remain in securing sufficient budget, vehicles, and equipment for implementation.					

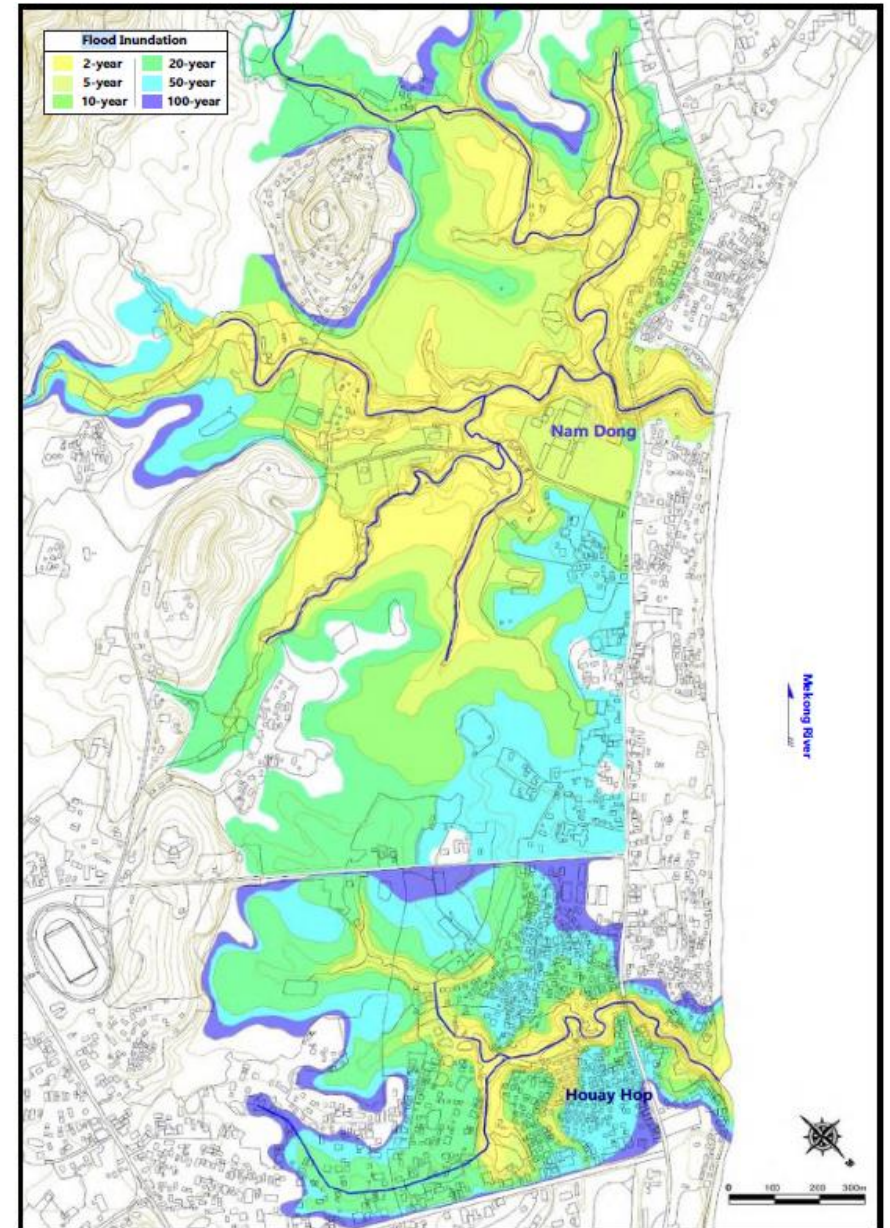
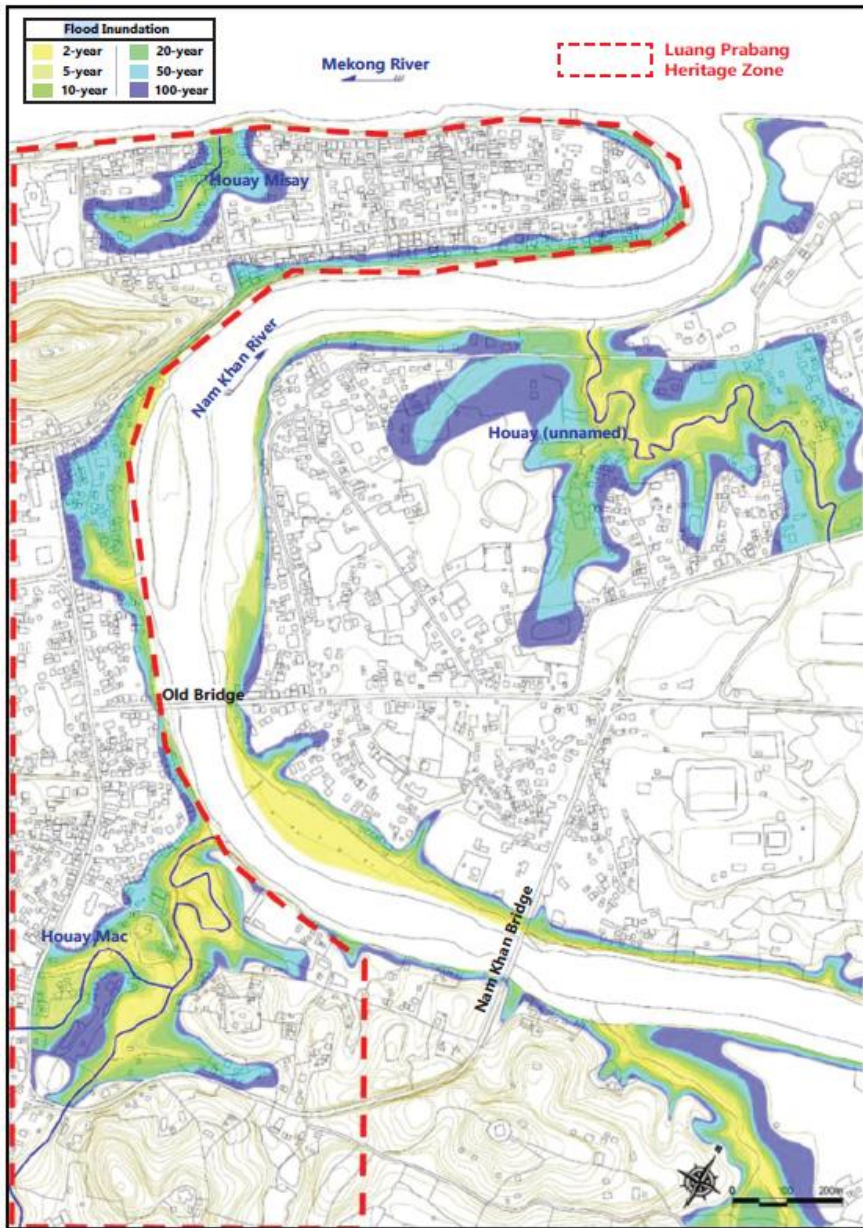


Figure 2. Flood Map for Nam Khan River and its Tributaries (left) and Nam Dong and Houay Hop Catchments (right) (extracted from the Urban Assessment Report)

Drainage and Sewerage System Master Plan

The Luang Prabang Drainage and Sewerage System Master Plan (2013) splits the municipality (72 villages) into three different Zones (Figure 3, p7), namely:

- Zone I is the World Heritage Protection Area and divided into two major areas:
 - Zone I-A: the old Centre without natural wetlands
 - Zone I-B: the Area with Natural Wetlands.
- Zone II is a high population density zone.
- Zone III is a low population density zone, mainly the Rural Areas of the municipality.

The Master Plan states that a drainage system was constructed in 2003 in Zone I. However, in Zone II and III, most of the streets have no formally constructed drainage channels for stormwater collection. Drainage problems are mainly caused by blockages which affect the operation of natural and constructed drainage.

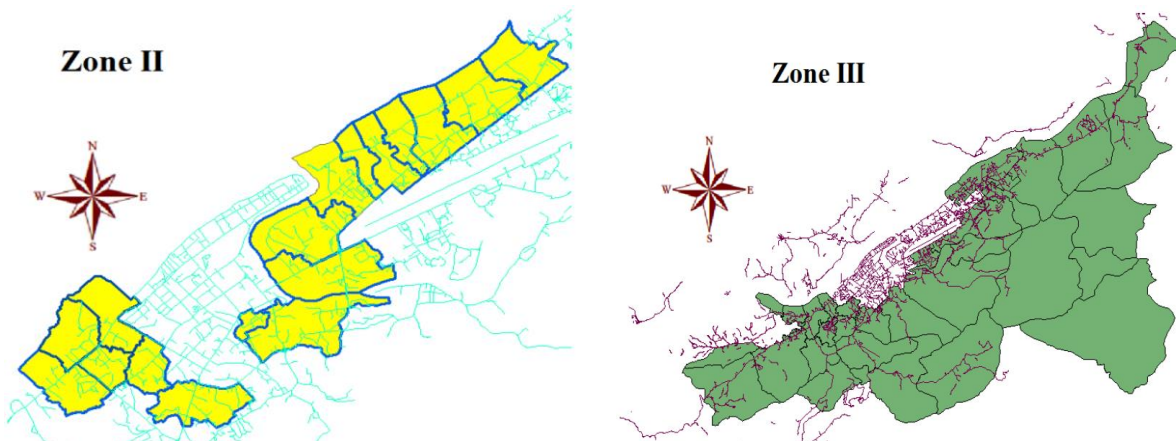
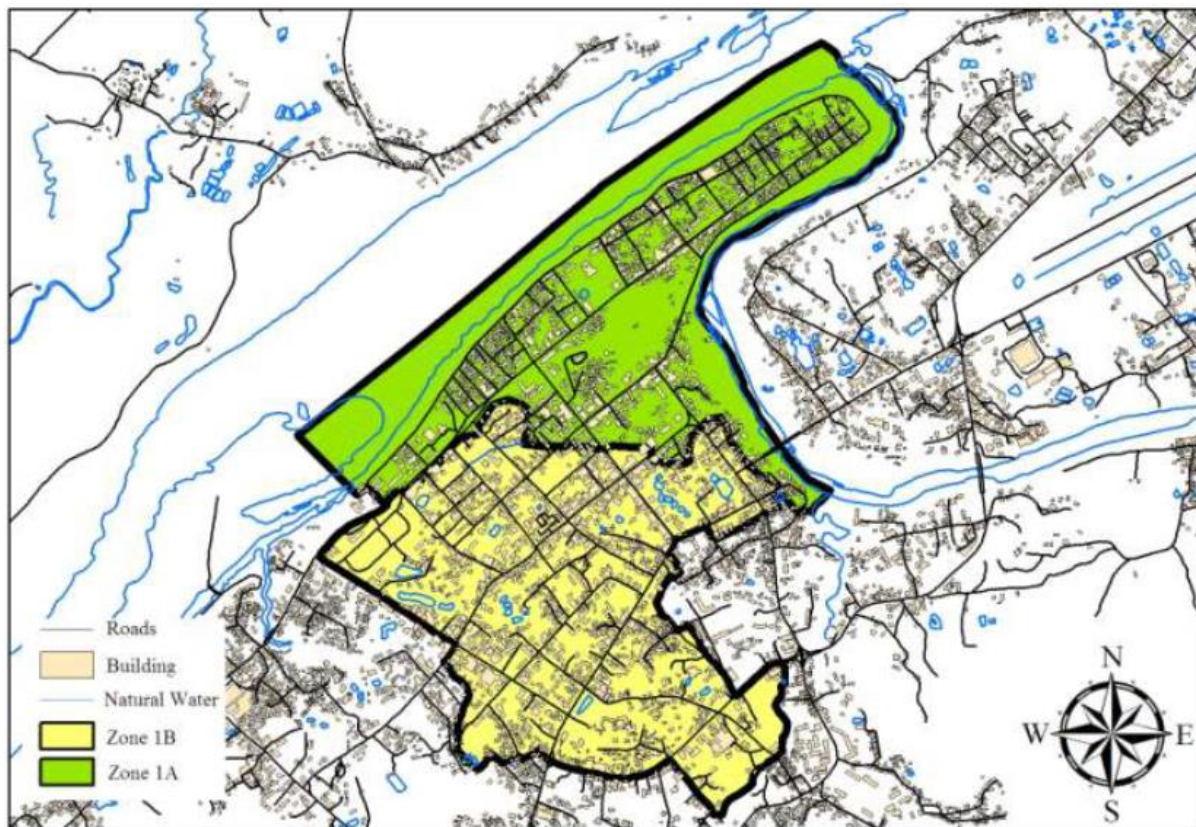


Figure 3. Luang Prabang City drainage zones.

The masterplan notes that:

- Urban development has one of the highest impacts on infrastructures in Luang Prabang municipality.
- Maintenance is not efficiently executed on a regular basis for all investments.
- Due to rapid urban growth, there is a big lag of drainage and sewerage systems.
- Each year a maintenance plan should be provided including all the assets of the municipality, enough financial budget and workforce should be made available to execute these tasks.
- It is highly recommended that repairs of the drainage network are given high priority to keep infrastructure in good condition.
- it is very important to keep the river banks and the creek banks free from obstacles, like buildings or other structures. The Luang Prabang Urban Development Plan has made strict Regulations about the distance for building along the river banks - firm control and enforcement is required.
- It is recommended to improve or restore the ecological and hydrological functions of all the wetlands.

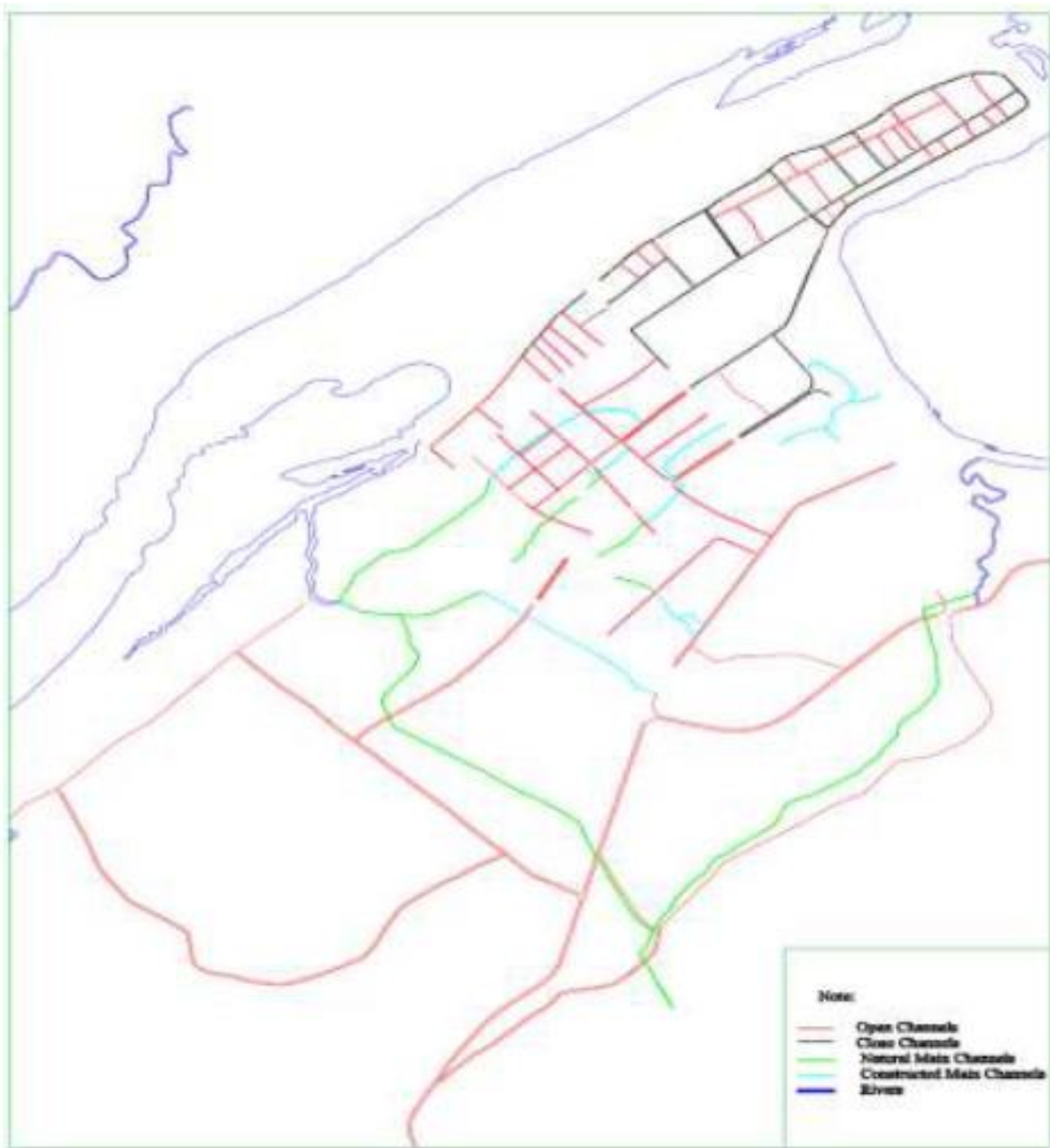


Figure 4. Existing drainage system in Zone I and part of Zone II in 2012 (sourced from the Luang Prabang Drainage and Sewerage System Master Plan, 2023)



Figure 5. Left: Cleaning activities of Drainage channel by UDAA, Right: Picture of Drainage repair works by UDAA (sourced from the Luang Prabang Drainage and Sewerage System Master Plan, 2023)

Key masterplan actions relevant to this optioneering report include:

- Zone I & 2
 - To prepare Urban Development Plan in order to produce appropriate guidelines for future urban extension and give direction to a 25 year master plan for drainage and sewerage system of Luang Prabang Municipality.
 - To operate, maintain, and improve the existing drainage and sewerage system continuously at highest level.
 - To maintain and recover the wetlands within Luang Prabang Municipality in order to protect the natural ecological waste water treatment systems, buffers against flooding, and protection of the natural ecosystem.
 - To provide as a minimum standard, small scale preliminary waste water treatment units for all municipality waste water which must be treated before draining into natural rivers.
 - To launch Public Awareness to local community pertaining the Policy and Management of drainage and sewerage systems.
 - To preserve rain infiltration areas by controlling and protecting the pervious areas from urban development.
 - To manage and control the quality of waste water from industrial sectors regarding to environmental standards before discharging into natural rivers.
 - To protect and preserve natural drainage networks like rivers, creeks, streams, brooks, to ensure the physical surface water draining in the future.
- Zone I
 - To control and manage the discharge of waste water from local consumption to public drainages to protect the environment and capacity of drainage system.
- Zone II
 - To provide new construction of drainage and sewerage systems based on the needs of specific area and future urban development plan of Luang Prabang municipality.
 - To improve municipal waste collection system in Luang Prabang Municipality to minimize the waste exposure, pollution to drainage system, and urban environment.

The masterplan also includes the following general recommendations for institutional improvements:

- Set up a dedicated Department for Drainage and Sewerage Operation & Maintenance;
- Roles and responsibilities for the system must be clearly specified for the responsible organization;
- Close cooperation should be established with the Land Office;
- Strengthen the Urban Development Planning Department;
- Town Development Planning activities should be integrated and consensus attained from all concerned;
- Regulations on Urban Development should be strongly enforced by the Municipality.

3 Field Mission

Meetings and site visits were conducted in LPC from 28th -29th February 2024. The meetings and site visits sought to investigate key flooding hotspots, explore the network of interconnected urban ponds that are listed as a UNESCO World Heritage site and understand the broader city and catchment insofar as it related to flooding. Stakeholders consulted are summarised in Table 1, this chapter also includes:

- Key findings from the LPC stakeholder meeting (Figure 6).
- An overview of the sites visited (Figure 7, p11) and supporting maps (Figure 8 to Figure 11, p12-15).
- Detailed site descriptions and observations for each site (p 16 onwards).

Table 1. Stakeholders consulted

DAFO – District Agriculture and Forestry Office	DWR - Department of Water Resources
DICT – Department of Information and Communications Technology	LWU - Lao Women's Union
DONRE – District Office of Natural Resources and Environment	PAFO – Provincial Agriculture and Forestry Office
DPWT - Department of Public Works and Transport	PONRE – Provincial Office of Natural Resources and Environment
DLSW - Department of Labour and Social Welfare	UNDP – United Nations Development Programme
DPH – Department of Public Health	WHMD – World Heritage Management Division

Stakeholder meeting

Notes from the LPC stakeholder meeting held in the PONRE office in LPC on the 28th of February 2024 are provided in Figure 6. In general, the stakeholders consulted in LPC were more concerned with stormwater (or pluvial) flooding than riverine (or fluvial) flooding from the Mekong River or Nam Khan River. However, there is an interaction between these two types of flood events. Furthermore, the construction of hydropower dams on the Mekong River and Nam Khan River also influence flooding in LPC.

Figure 6. Notes from the LPC stakeholder meeting

Organisation	Notes
PONRE	<ul style="list-style-type: none"> • Extreme events are more regular and significant than in the past. It is now more than a local issue; it is a regional and global issue. Examples include: <ul style="list-style-type: none"> ○ In 2016 there was very heavy flooding in LPC, especially in August. In a period of one month there were three heavy floods. ○ In 2023 there were also flood impacts and landslides in Luang Prabang District. ○ In 2019 and 2023 high temperatures were experienced from Feb-May (50 degrees+). ○ Luang Prabang is also impacted by forest fires, with burning in the area leading to air quality of PM2.5 and last year many flights were cancelled due to smoke. • These issues create a broad range of impacts spanning socio-economic development, especially within the agriculture, transport and tourist sectors. • Flooding is particularly bad in LPC, with impacts on a yearly basis due to the compact and crowded nature of the city with insufficient drainage and modification to wetlands by local people. These challenges are a result of development but also individual action (e.g. pollution). • PONRE are seeking solutions to reduce flooding, improve garbage/solid waste management and increase water storage for the dry season. • PONRE offered to construct a reservoir at Houay Mao creek for flood and drought risk mitigation and a sluice gate with pump station on the Nam Khan river; as well as raise awareness concerning garbage management to communities in LPC.
DWR	<ul style="list-style-type: none"> • Development is changing the natural hydrology of the waterways.

	<ul style="list-style-type: none"> • It is important to meet with villagers to understand the issues. • Data collection is needed to inform future planning and development.
UNDP	<ul style="list-style-type: none"> • Provided an overview of the Integrated Water Resource Management and Ecosystem-based Adaptation in the Xe Bang Hieng River Basin and Luang Prabang city project
DONRE	<ul style="list-style-type: none"> • LPC is generally flat area, especially Nalouang and Nasamphan villages. As a result, when there is heavy rain it regularly floods for one to two hours. • Flooding impacts public property, it can also result in loss of life (as experienced in Nasangwei village). • Community action can exacerbate flooding challenges, for example: <ul style="list-style-type: none"> ○ Plastic waste is blocking the drainage system. ○ Land use change and loss of buffer zones is contributing to flooding.
DPWT	<ul style="list-style-type: none"> • DPWT need to upgrade road drainage and construct a sluice gate at the Nam Khan river but lack budget for these activities. • Dam construction upstream of Luang Prabang has led to a rise in the water level of the Mekong and Nam Khan rivers.
DLSW	<ul style="list-style-type: none"> • A fund is needed to train communities in at risk areas in disaster risk management.
WHMD	<ul style="list-style-type: none"> • The Night Market Road is impacted by flooding. • Open channels have been piped (or covered) and are now at capacity due to build up of pollution.
PAFO	<ul style="list-style-type: none"> • The urban drainage system should be extended • The Early Warning System committee prepare for evacuation – they have to prioritise vulnerable communities (e.g. the elderly, children etc)
LWU	<ul style="list-style-type: none"> • Rubbish is a challenge that impacts flooding. • Flood warnings/announcement are needed to make people aware and give them time to prepare for flooding. • After past floods women have asked for funds to be donated to provide food and money for response and recovery.

Site visit overview

The sites visited in LPC are summarised in Figure 7, with maps provided in Figure 8 to Figure 11 (p12-15).

Figure 7. Overview sites visited in LPC, including known flood hotspots

Site	Name	Reason for site visit	Catchment	Village
1.	Huai Mao bridge	Flood hotspot	#1	Nasangwei
1.a	Upstream road culvert	Catchment context	#1	Nasangwei
1.b	Upstream catchment (separate subcatchment)	Catchment context	#1	Nasangwei
1.c	Downstream bridge on Road 13	Catchment context	#1	Nasangwei
1.d	Downstream Nam Khan sluice gate	Catchment context	#1	Viengmai
2.	Road 13 Corner Junction	Flood hotspot	#2	Nasamphan
2.a	Upstream road drainage	Catchment context	#2	Nasamphan
2.b	Upstream channel (separate subcatchment)	Catchment context	#2	Nasamphan
2.c	Upstream headwater catchment	Catchment context	#2	Nalouang
2.d	Downstream outlet to Mekong (Houay Hope River bridge)	Catchment context	#2	Saylom(Left) & Phabat(Right)
3.	Bridge at Phouangkham village	Flood hotspot	#3	Phouangkham
3.a	Upstream village drainage	Catchment context	#3	Phouangkham
4.	Pond development	World Heritage Pond	#1	That Louang

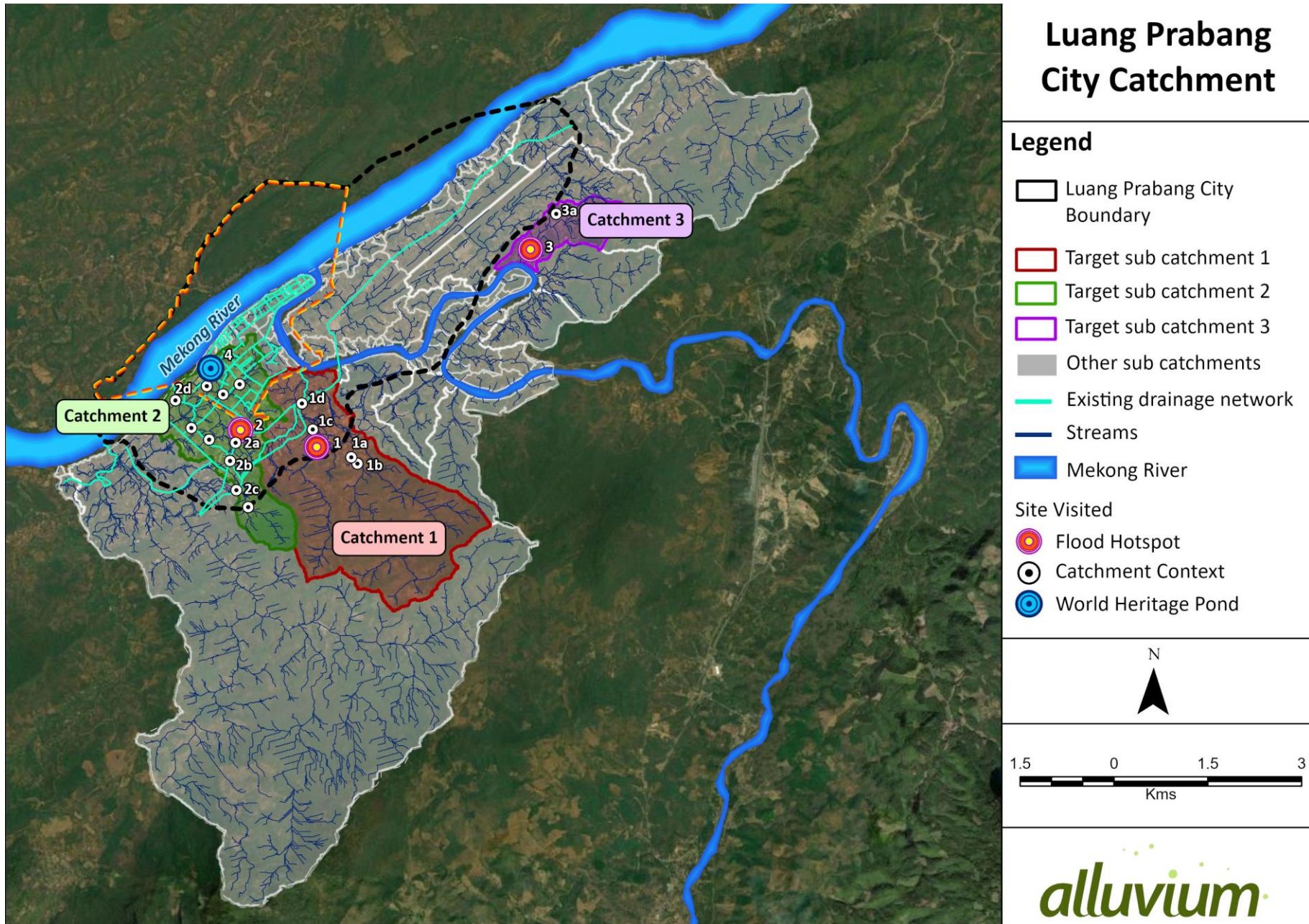


Figure 8. Map of flood hotspots and related sites in LPC
 Luang Prabang City (LPC) – Optioneering Report

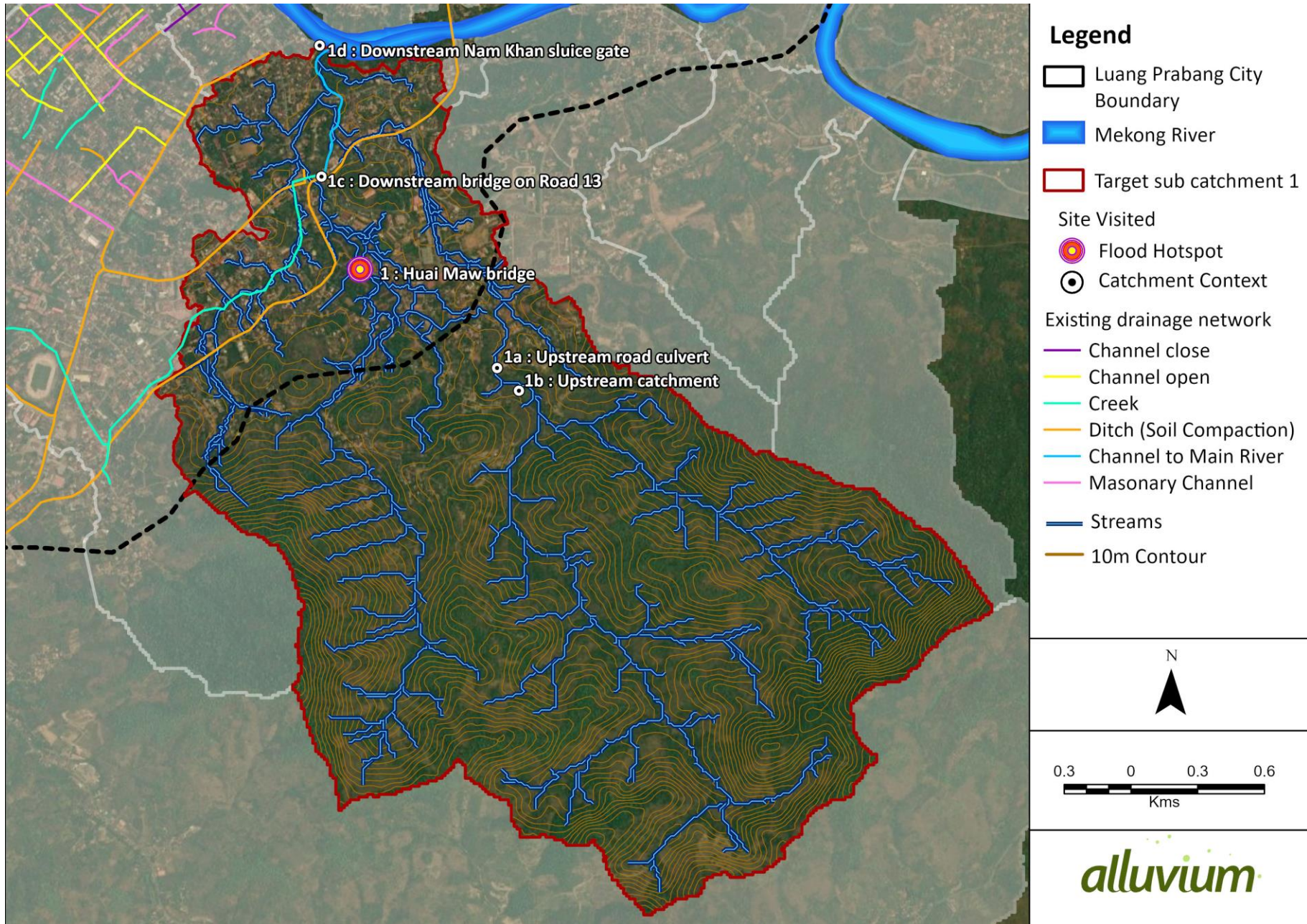


Figure 9. Catchment 1

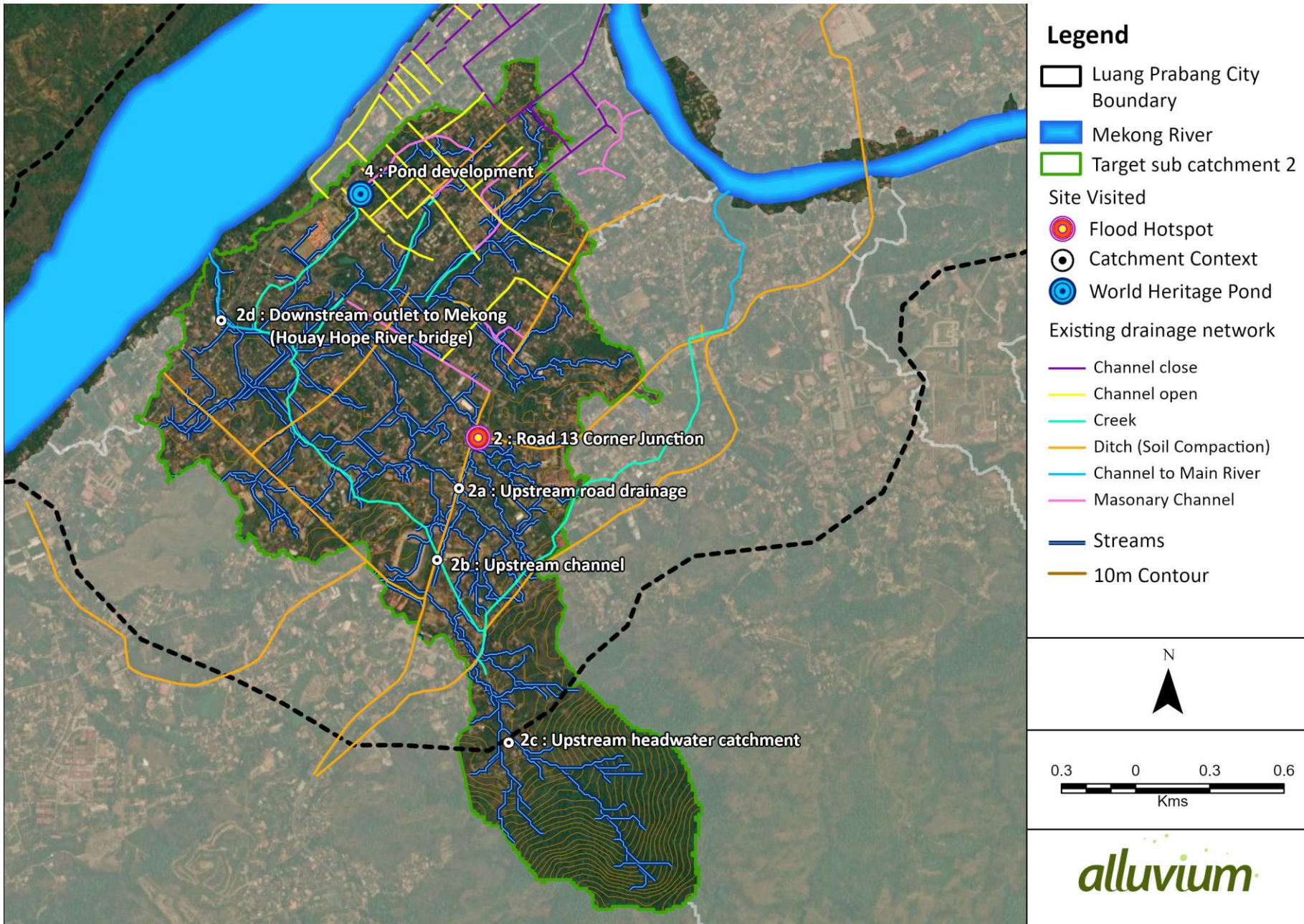


Figure 10. Catchment 2

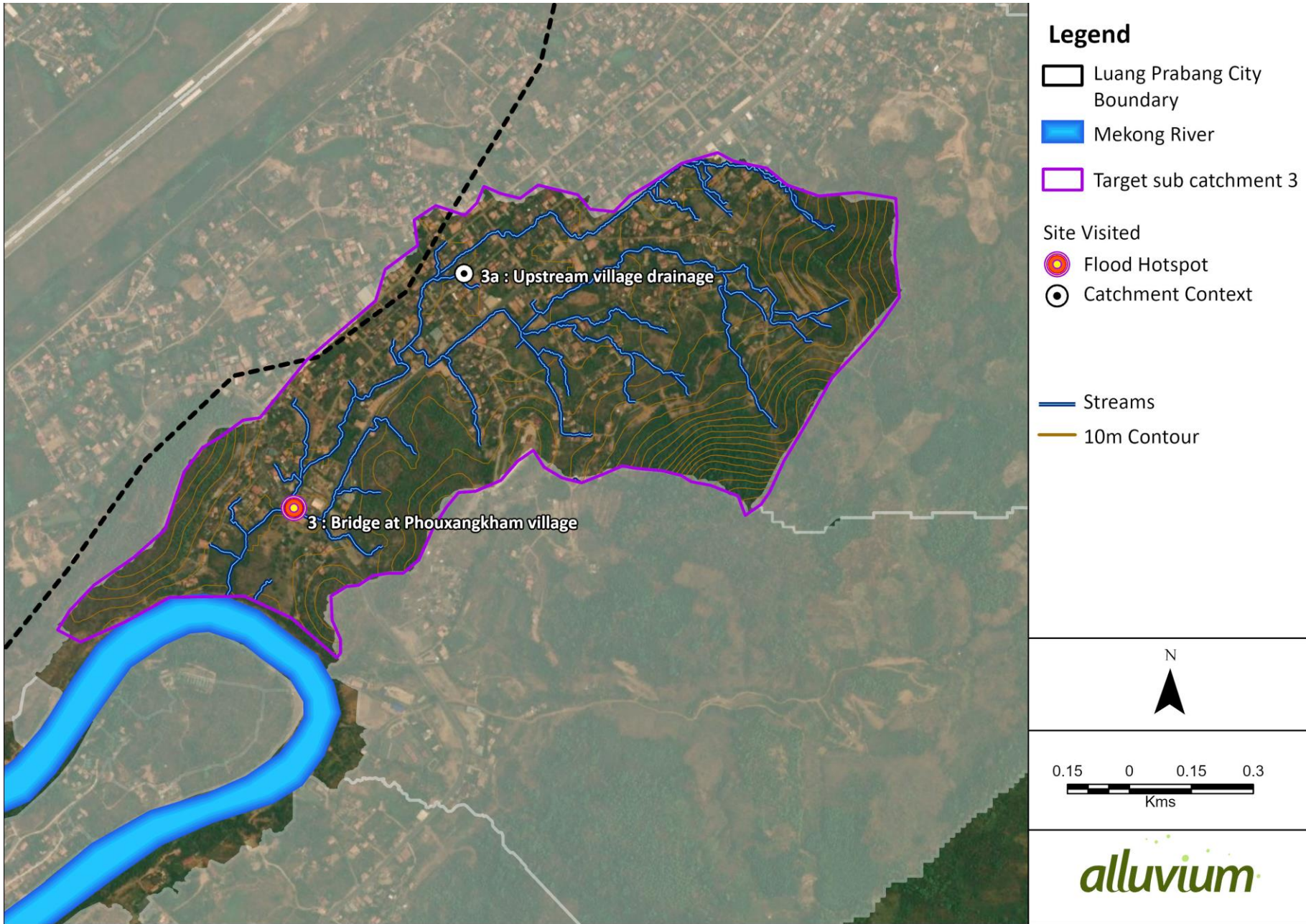


Figure 11. Catchment 3

Site 1. – Huai Mao bridge

The current Huai Mao Bridge (Figure 12) was built in 2010 to replace an old bridge at the site that sat at a lower height relative to the creek bed. Stakeholders reported that:

- The old bridge was prone to flash flooding, with stakeholders reporting inundation of up to ~1m during the wet season.
- The bridge and surrounds were impacted in 2018 by backwater flooding resulting from heavy rainfall that resulted in increased water levels in the Mekong River and release of water from the Nam Khan hydropower dam.
- The new bridge was constructed to fix the flash flooding at the site. However, as recently as June 2023 stakeholders reported the area as impacted by flash flooding, resulting in loss of life.¹

Inspection of the site identified:

- Constriction of the creek channel due to placement of bridge abutment.
- Litter in the creek, including suspected dumping at the site.
- Accumulation of debris (litter, vegetation etc.) at the central footing of the bridge.
- Encroachment of buildings within the waterway corridor (likely reducing flow capacity) and evidence of exposed footings (safety risk of building owners).
- Stakeholders commented during the visit that adjacent buildings are still impacted by flooding (no detail on the type or specific location of impacts were described). Inspection indicated that:
 - If the bridge is overtopped during larger flood events, the flood water is expected to have a substantial impact on buildings (inundating entire levels) and transport.
 - Stains on walls on a building downstream of the bridge may indicate past flooding. As the stains are well below the top of the creek bank, this may be indicative of more regular and localised flooding due to inadequate minor drainage, as opposed to overtopping of the creek.
 - Footings of buildings upstream of the bridge are exposed and likely impacted by floodwater.



Figure 12. Huai Mao Bridge, Nasangvuey village (facing downstream)

¹ Refer to UNDP Mission Report Summary (04 July 2023).



Figure 13. Huai Mao Bridge, Nasangvuey village (facing upstream)

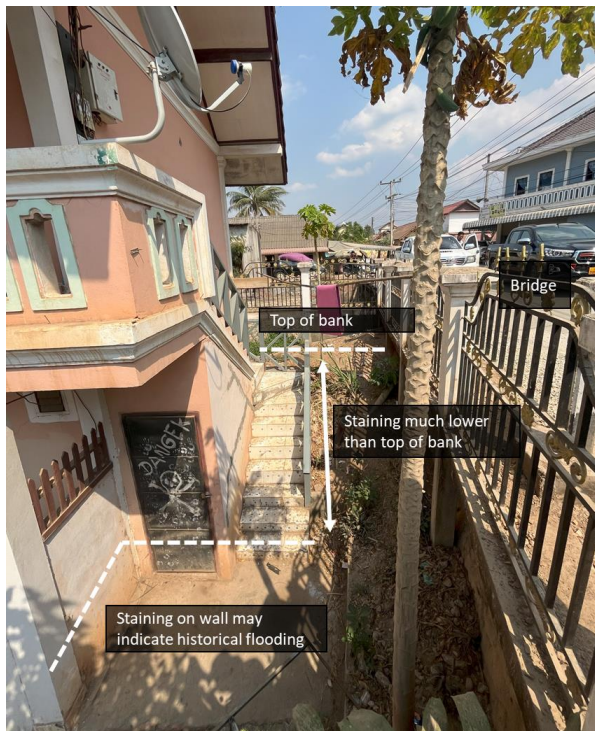


Figure 14. Private building adjacent to Huai Mao Bridge (northern edge of bridge)

Options to address flooding at this site include:

- Redesign bridge, removal of buildings and reprofiling of the creek channel to increase the conveyance capacity of the creek.
- Upstream flood storage to slow and detain flood flows. It is noted that PONRE have previously proposed upstream interventions, such as storage, to mitigate flooding at the site.²
- Catchment management strategies, including maintaining perviousness in upper catchment and carefully managing development to ensure adequate flood storage and drainage, limit channel modification and encroachment.
- Solid waste management (city scale) to help reduce litter accumulation in the creek and improve conveyance of flood water.

² Refer to UNDP Mission Report Summary (04 July 2023).

Site 1.a – Upstream road culvert

A road culvert and drainage channel upstream of Huai Mao Bridge (Site 1) was visited to provide catchment context. This site had not previously been identified by stakeholders as a priority flooding hotspot, however, it was anecdotally reported by stakeholders during the visit that the road is overtopped during heavy rainfall events (depth and frequency unknown). The site visit indicated:

- Litter, debris and vegetation within the channel bed.
- A highly constrained channel upstream of the existing culvert, bounded by vertical channel and building walls on both sides.
- Multiple drainage and/or greywater/wastewater connections from adjacent buildings (presumably informal).
- Potential to increase the capacity of the culvert below the road.

It is noted that drainage capacity at the site could be increased by increasing the size of the existing culvert. Without further investigation it is unclear if the impacts at this site warrant this investment.



Figure 15. Road culvert (facing downstream)

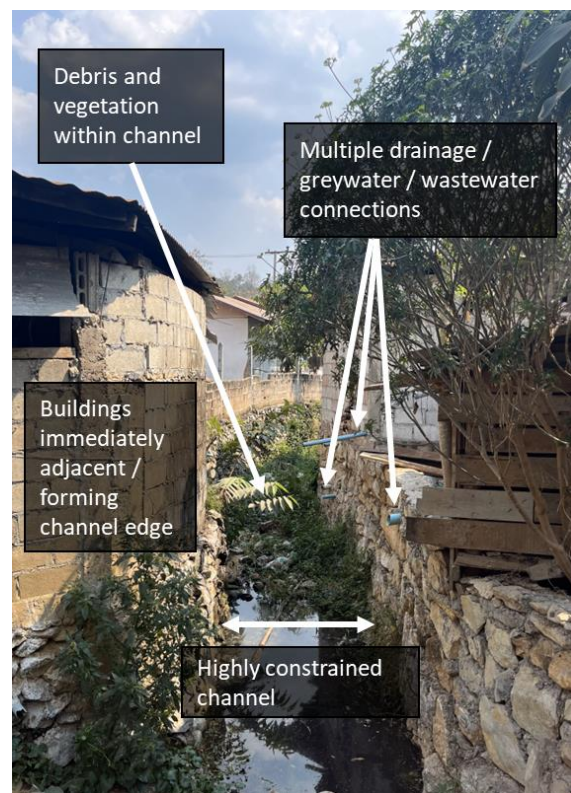


Figure 16. Road culvert (facing upstream)

Site 1.b – Upstream catchment (separate subcatchment)

A catchment further upstream was also visited. This upstream catchment area is a separate sub-catchment of the major catchment that contains the Huai Mao Bridge (Site 1). It was observed that:

- The upstream catchment has lower density development than the Huai Mao Bridge area. However, there are signs of ongoing construction and anecdotally it appears that the upper catchment area may be subject to increasing development pressure.
- There is evidence of encroachment into the waterway channel, this includes formalized concrete and stone retaining walls, as well as permeable (or semi-permeable) fencing and agriculture.
- The upper catchment is hilly, however, there are some flatter areas that provide opportunities for a wider channel form and could be modified to provide additional flood storage.
- Further upstream agricultural and forest land use dominates the catchment. It is understood that PAFO are considering a check-dam in the lower reaches of the forested area in the upper catchment.

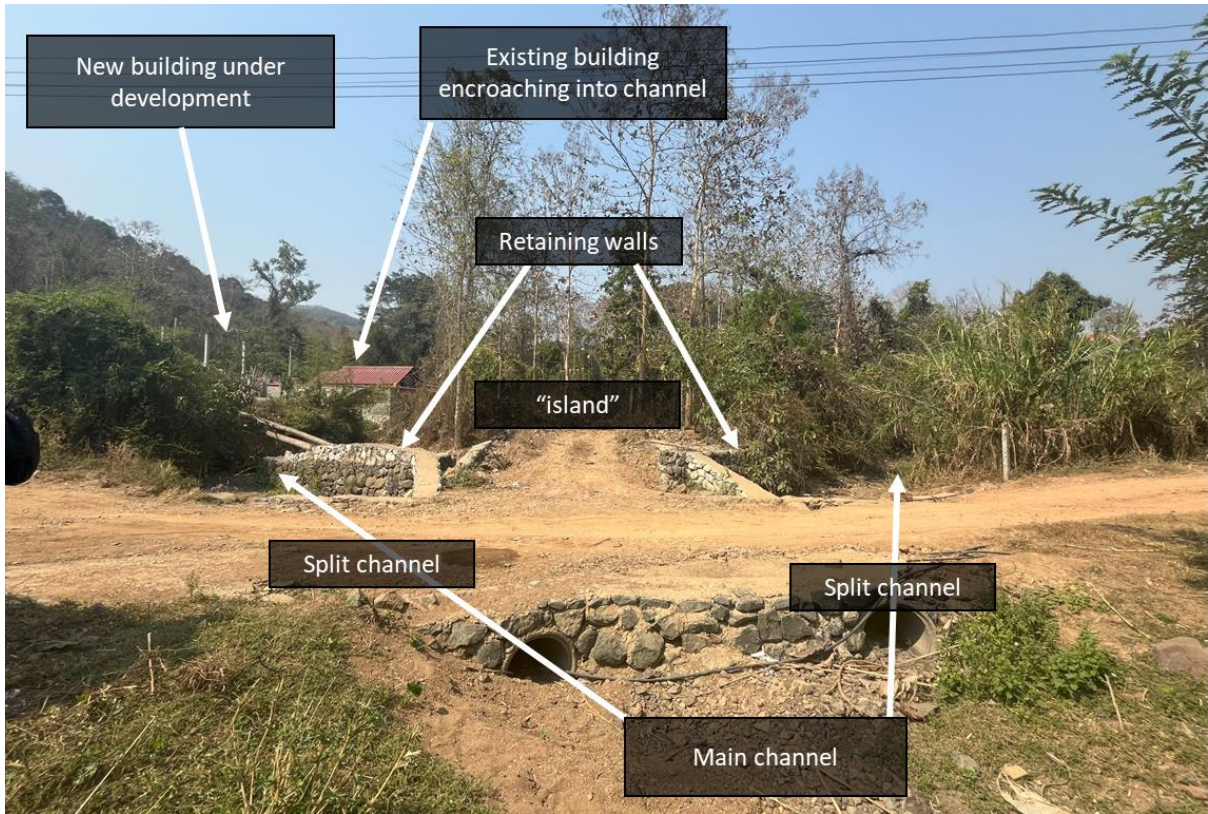


Figure 17. Channel split at road crossing (facing downstream)



Figure 18. Channel rejoined (downstream of "island")



Figure 19. Single channel (upstream of road crossing)

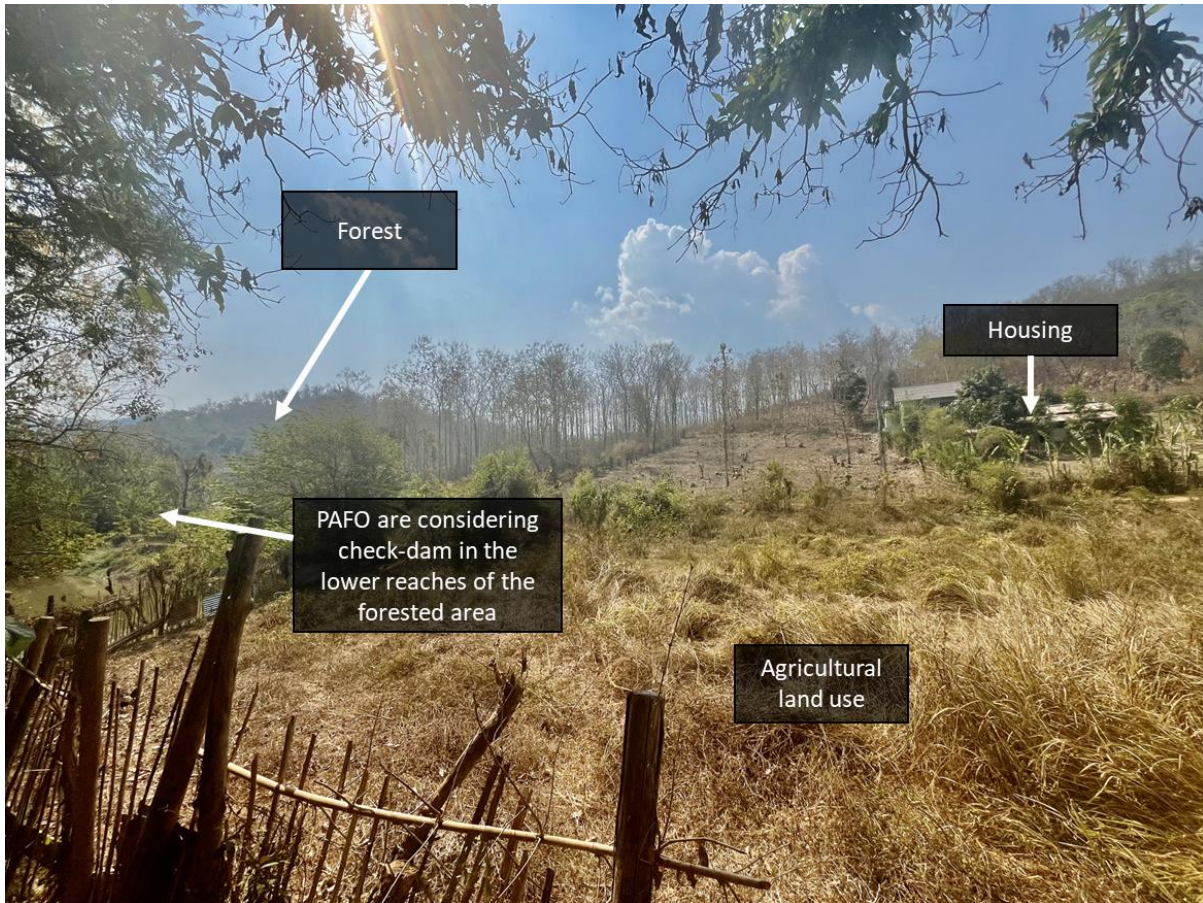


Figure 20. Largely pervious catchment with low density housing and mix of forest and agricultural land use.

Site 1.c – Downstream bridge on Road 13

A bridge along Road 13, downstream of the Huai Mao Bridge (Site 1), was visited to provide catchment context. This site had not previously been identified by stakeholders as a priority flooding hotspot, however, it was anecdotally reported by stakeholders during the visit that:

- The site is/was impacted by backwater of the Nam Khan (presumably during the 2018 flood).
- No works are proposed at the site (other than downstream sluice gate proposed at the outlet of the creek on the Nam Khan)

The site visit indicated:

- A wider and deeper channel form than the Huai Mao Bridge site.
 - Facing upstream, the channel is constrained on both sides by development.
 - Facing downstream, the channel is constrained by development on the northern bank. The southern bank has stretches of limited to no development and is generally wider and deeper than upstream.
- Litter, debris and vegetation within the channel bed.

It is noted that development controls should be considered to preserve channel depth and width in areas not yet constrained by development (e.g. downstream southern bank).



Figure 21. Road 12 Bridge (facing upstream)

Site 1.d – Downstream outlet to Nam Khan (proposed sluice gate)

The outlet of the Houay Mao River as it enters the Nham Khan River was visited. The lower reaches of the Houay Mao River are characterized by steep embankments with exposed bedrock in some locations. There is also evidence of farming and cultivation along the base and on the embankments of the river. A sluice gate and pump house are proposed at this site to prevent backwatering of floodwaters from the Nham Khan River. It is understood that the sluice gate is proposed, in part, due to the impacts of the 2018 flood event in the Nham Khan River which also led to widespread flooding in the Houay Mao River.

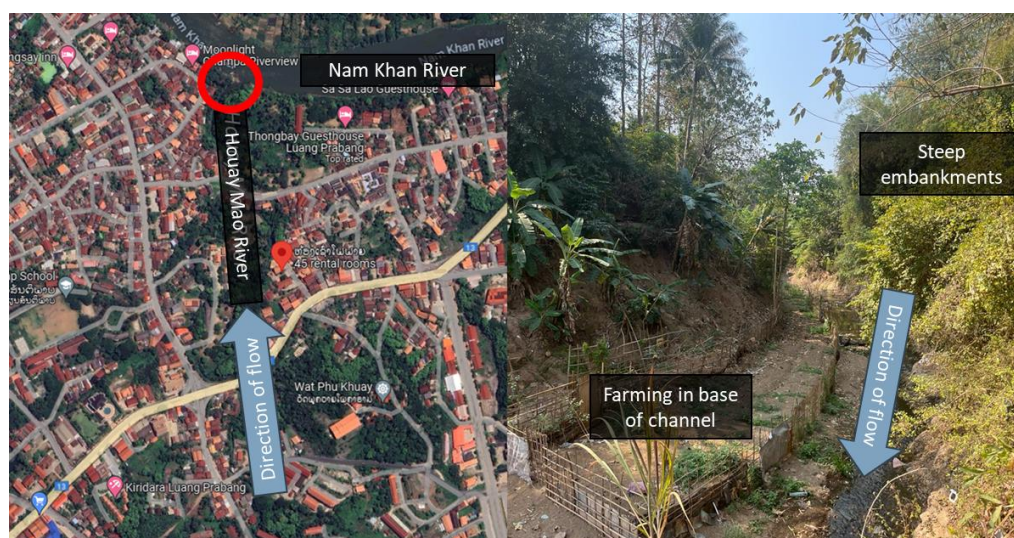


Figure 22. Left: Location of proposed sluice-gate (red circle) on the Houay Mao River as it enters the Nham Khan River in LPC (modified from Google Maps), Right: Houay Mao River as it enters the Nham Khan River.

Site 2. – Road 13 corner junction

The second flood hotspot visited is located on a curved junction of Road 13. Stakeholders indicated that this site is subject to flash flooding 2-3 times per year, with the depth of flooding relatively shallow (approximately below knee deep). It is understood that there may be plans to upgrade the road, it is unclear if this includes upgrades to the drainage or just the road surface.

The team were unable to inspect the drainage immediately downstream of the road junction as it could not be located. It is unclear if flooding at the junction is due to a lack of drainage capacity immediately downstream causing backwatering or insufficient capacity at the inlet that conveys water below the road. Standing water was observed during the site visit, as well as a buildup of litter, suggesting some constriction or blockage in the drainage network.

Options to address flooding at this site include:

- Upgraded drainage capacity. It is not clear which location(s) in the network are constrained and therefore if upgrades would be required directly below, downstream or upstream of the junction (or a combination of these locations).
- Solid waste management, this could be a combination of:
 - Site scale installation of a gross-pollutant trap (noting these are being promoted as part of the LPC Smart and Integrated urban Strategy)
 - City scale program(s) to help reduce litter accumulation in the drainage network and improve conveyance of flood water.
- Upstream flood storage to slow and detain flood flows. Noting that there is limited space available at the road junction. Flood storage options include storage ponds or belowground tanks to capture runoff, or aboveground tanks to collect roof runoff.



Figure 23. Left: Road 13 corner junction (facing downstream). Right: Road 13 corner junction (facing upstream)

Site 2.a – Upstream road drainage

The drainage network further upstream of the junction was inspected, it is understood from consultation during the site visit that:

- The roadside drainage network used to be an open channel but has since been largely covered.

- Several of the junctions in the drainage network observed met at ~90 degrees. This can be problematic as 90-degree junctions can slow down the flow of water, increase turbulence, and create areas where sediment and debris can accumulate, leading to blockages over time. Junctions with gentler angles (say 30 to 45 degrees) are typically recommended to avoid these issues.
- DPWT could improve the road drainage by adding parallel culverts or changing to box culverts.
- A new drain was installed to reduce flooding impacts at the junction.
- Every year there is flash flooding at Sokphankham junction and at the crossroads near Daonuea restaurant. In periods of heavy rain (e.g. August) the drainage channel becomes blocked and water overflows road at a depth of ~40-50cm, preventing motorbikes from passing.
- There is no scheduled cleaning of the drains (or budget for this), all maintenance is reactionary.



Figure 24. Examples of covered channels with perpendicular junctions

Site 2.b – Upstream channel (separate subcatchment)

An additional site, further up into the catchment and along the road, was also visited. At this site a separate channelized creek heading north-west was identified. From visual inspection, the capacity of the open channel appears to be larger than that of the road drainage network. It is unclear which part of the upstream catchment is intended to drain down the road (in a north-east direction) towards the Road 13 corner junction, and which portion is intended to drain via the open channel/creek.

The interaction between the upstream catchment and the two drainage networks is unclear. It may be that changes to the upstream catchment have led to some of the runoff intended for the open channel being redirected to the road drainage. Regardless, there may be an opportunity to redirect some of the catchment that drains to the road into the open channel (however, the capacity of the open channel would need to be verified before this option is pursued). The section of open channel inspected showed problematic construction of a building or shed over the channel, constricting the open channel both vertically and horizontally. It is unclear if the building was a legal development. It is recommended that the planning conditions of the site are reviewed and if the building is illegally developed action be taken to return the channel to its original design capacity.



Figure 25. Plan view of assumed flow paths

Site 2.c – Upstream headwater catchment

The upper catchment that ultimately drains to the Road 13 Corner Junction was visited. Key observations include:

- The area consists of two narrow and steep gullies and is less developed than the lower catchment. However, new buildings were under construction at the time of the visit, suggesting the area may be under development pressure.
- The headwater creek in the northern gully:
 - Shows signs of being constrained by embankments, likely the result of efforts to regrade the surrounding landscape.
 - Was not flowing at the time of the site visit.
 - Contained pipework, water collection bottles and an empty wet well, this suggests that runoff is used as a water source,
 - Appears to be founded on bedrock, with the presence of boulders and cobbles in the creek bed. This indicates that the creek may be characterized by rapid, intense flows during rain events, with limited water retention and storage capacity, leading to a dynamic, high energy and potentially erosive environment.
- The same headwater creek, slightly further downstream, contained dark, stagnant water with a strong odour, indicative of contamination with blackwater or greywater. This is considered quite likely given (a) the presence of several pipe connections extruding from buildings into the creek and (b) the fact that a short distance upstream no runoff was observed in the creek.



Figure 26. Example of existing and new developments in the upper catchment

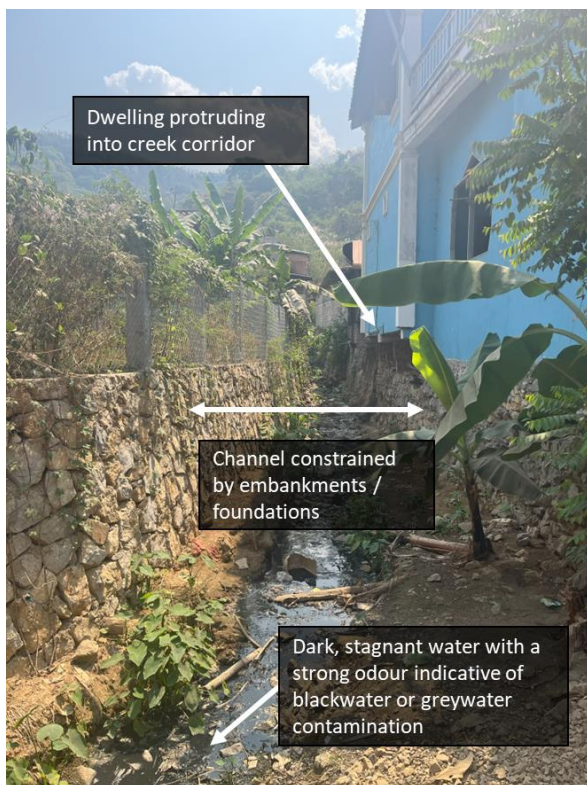


Figure 27. Creek located in lower density village



Figure 28. Creek upstream of village

Site 2.d – Downstream outlet to Mekong (Houay Hope River bridge)

The drainage from Road 13 corner junction (Site 2) ultimately joins the Houay Hope River which discharges into the Mekong River a few hundred metres downstream of the Houay Hope River bridge. At Houay Hope River bridge, the channel was deep and wide, with steep embankments on either side. There was evidence of new development within the channel, with retaining walls constructed to modify the natural channel form. This encroachment creates a safety risk, as the foundations and columns supporting the new development are at risk of damage during flood events. At the bridge/road level, the minor drainage network along the road was visible, with suspected greywater or wastewater discharge entering the waterway via these drains.



Figure 29. View toward of the Houay Hope River from the Houay Hope River bridge with an example of the minor drainage system at bridge/road level shown inset.

Site 3. – Bridge at Phouxangkham village

Phouxangkham village is ~11 years old and located south of the Luang Prabang International Airport. Development of the village has reduced the floodplain available to the Nam Khan and the tributary of the Nam Khan that flows through the village. The bridge visited was reportedly flooded to a depth of 1-1.2m above the bridge surface level in 2018 due to backwater flooding from the Nam Khan/Mekong River. Anecdotally the primary issue at this site is backwater flooding from the Nam Khan, if this is the case a sluice gate with pumps is proposed to address flooding at this site include. The effectiveness of detention basins within the catchment should also be considered. Rainwater tanks and riparian buffer zones may also alleviate flooding, however, it's unlikely these interventions would address the scale or type of flooding reported during the site visit.



Figure 30. Left: Bridge at Phouxangkham village, Right: Tributary of the Nam Khan facing north east from bridge

Site 3.a – Upstream village drainage

The team travelled further upstream to examine drainage in Phouxangkham village. In this area, constrained waterways were observed, with suspected illegal development encroaching into the waterway corridor. Stakeholders noted the:

- Lack of easily obtainable information regarding the legal offsets from waterways/drains.
- The challenge of enforcing against development into waterway channels (in terms of both funding for enforcement, and the culture of enforcement).
- Barriers to returning waterway corridors once development has occurred.



Figure 31. Examples of waterways impacted by encroachment and channelisation from adjacent buildings

Site 4. – Pond development

This site demonstrates the challenges of managing the network of World Heritage listed ponds located in LPC. This site is under private ownership and was in the process of being converted from a vegetated pond to a new commercial development (understood to be a restaurant and accommodation). This site was significantly modified at the time of the site visit, including evidence of: (a) Construction of a road (understood to be temporary for construction works), (b) Pumped dewatering of the pond (understood to be temporary for construction works), (c) Removal of vegetation.

Stakeholders present during the site visit reported that:

- The development was (or had been) referred to the Heritage Office for approval.
- There is poor coordination across referral authorities who have different roles and responsibilities in the review and approval process. This includes the World Heritage Management Division, Urban Development Authority, Public Works and Drainage and DONRE.
- Construction was approved in part because it will be founded on wooden stilts, allowing the pond to remain below, noting that final structure will cover the majority of the ponds surface area.

It is also noted that during past consultation PONRE also expressed a desire to clean the pond and improve its water treatment capacity.³ Given this site is already under development the options to change the modifications and function of the pond are likely limited. For other ponds in Luang Prabang, a mixture of structural (e.g. wetland creation or restoration, and the preservation of riparian buffer zones) and non-structural (e.g. land use planning, flood zoning, public education) interventions are recommended.

³ Refer to UNDP Mission Report Summary (04 July 2023).

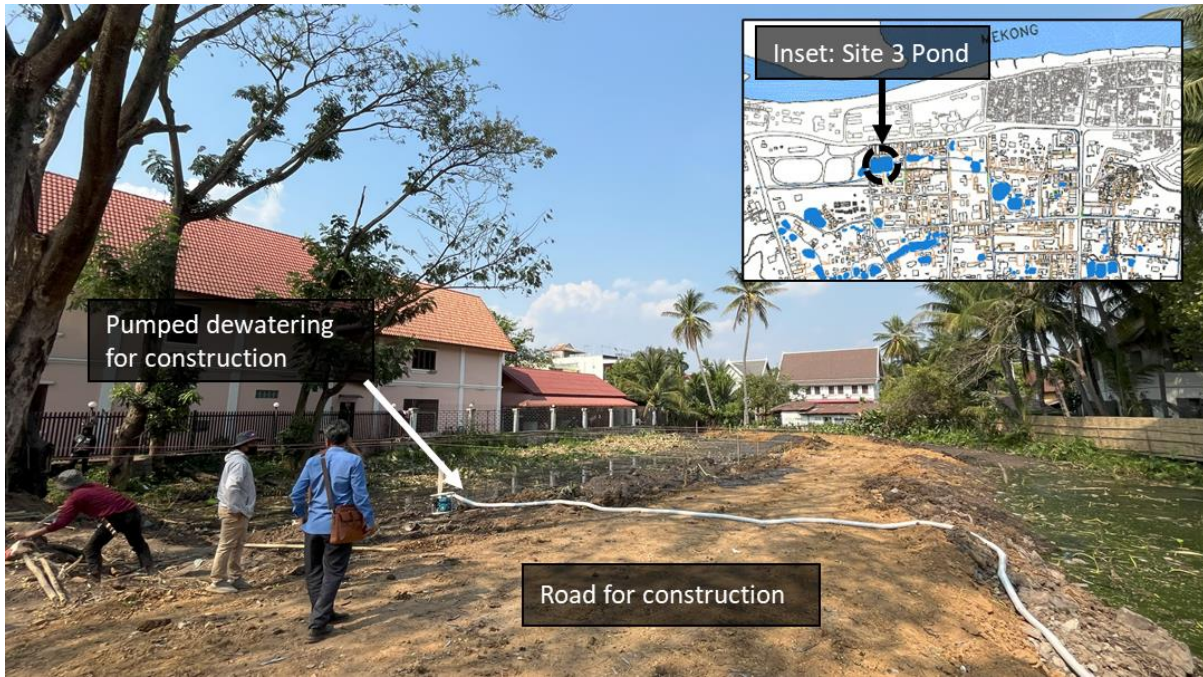


Figure 32. World Heritage Pond Redevelopment (photo Alluvium February 2024, inset map from GRET 2024)⁴



Figure 33. Google Streetview image of the same pond from January 2016 (Google 2024)⁵

The Group for Research and Technology Exchanges (GRET) is leading an existing project (WISE) exploring community-based management for protecting and rehabilitating urban ponds in Luang Prabang. GRET provided a tour of the WISE project area to help the project team understand some of the pressures and opportunities for other ponds in Luang Prabang (Figure 34).

⁴ Refer <https://gret.org/en/projet/sanitation-and-integrated-management-of-urban-hydrosystems-in-luang-prabang/>, accessed 20/08/2024.

⁵ Refer <https://www.google.com.au/maps>, accessed 20/08/2024



Figure 34. Example of chain of UNESCO Heritage pond / wetland systems located in area where GRET is supporting community led governance approaches, including support for greywater treatment via sub-surface flow wetlands (bottom left) and pond de-sludging and vegetation removal (bottom right).

4 Optioneering

Flood management options have been described and assessed for each for the four flood hotspots in Table 2 and Table 3 (p32 and 34). This includes options for:

- Site 1. – Huai Mao Bridge
- Site 2. – Road 13 corner junction
- Site 3. – Bridge at Phouxangkham village
- Site 4. – Pond development. *Note that this site is unique as it is in private ownership and has already undergone planning approval and is being developed. As such, many of the options explored are not relevant to flooding at the site. Rather, they relate to options that should be considered as part of the LPC ICFMS to support greater protection and enhancement of other ponds in the city.*

The options are categorised according to:

- Type:
 - Structural, including protective engineering or ecosystem-based adaptation
 - Non-structural
- Scale (Local, Catchment or City)
- Cost
- Complexity

These categories are described below.

Type

Both structural and non-structural approaches are essential for comprehensive flood management, often working best in combination to reduce flood risks effectively.

Structural options

Structural solutions involve physical infrastructure designed to control or redirect water flow. Examples include retention basins, dams, channel modifications and levees. The benefits and risks of structural measures are typically easier to quantify, however, they often require significant investment and time to implement. Structural options for each flood hotspot are presented in Table 2 (p32).

For the purposes of this optioneering assessment, structural options can be divided into protective engineering or ecosystem-based adaptation. Both approaches play a key role in flood management, with protective engineering offering immediate, strong protection and ecosystem-based adaptation providing long-term, sustainable resilience.

- Protective engineering (or "grey infrastructure") refers to traditional, human-made structures designed to control or mitigate flood risks. These options are often highly technical, involving significant construction and design efforts, and aim to provide immediate, reliable protection from flooding.
- Ecosystem-based adaptation (EbA) focuses on using and enhancing natural systems to mitigate the impacts of floods. These solutions harness the natural ability of ecosystems to absorb, store, and slow down floodwaters while providing additional ecological and social benefits.

Non-structural options

Non-structural solutions focus on policies, planning, and community engagement rather than physical structures. Examples include land use planning, early warning systems and insurance. Non-structural measures can be adapted more easily to changing circumstances and often place a greater emphasis on community engagement and education. Non-structural options are presented in Table 3 (p34). As these options are not site specific, they aren't considered in detail for each flood hotspot. Rather, they are presented to support a holistic consideration of options to support the development of the Integrated Climate-Resilient Flood Management Strategy (ICFMS) for LPC.

Scale

Options have been considered at several scales, namely:

- Local scale, here the focus is often on structural solutions at the site which may be limited by existing conditions.
- Catchment scale, here the focus is on looking in the catchment for opportunities to reduce flood impacts at the site.
- City scale, these solutions (or programs) apply across the entire city, however, they should still provide some benefit for the specific catchment and site being impacted.

Capital cost

The relative cost of different options have been compared at a high level using qualitative descriptions with indicative cost ranges. This approach provides a generic and simplified means to compare options. The actual costs of implementing options will vary considerably based on site conditions, design solutions and the scale of the intervention.

- Very Low: Involves minimal financial outlay (e.g. <\$10,000 USD).
- Low: Requires modest funding (e.g. \$10,000 - \$100,000USD).
- Medium: Demands a moderate budget (e.g. \$100,000 - \$1 million USD).
- High: Requires considerable investment (e.g. \$1 million - \$10 million USD).
- Very High: Represents a major financial commitment (e.g. >\$10 million USD).

Complexity

The relative complexity of implementing different options has been compared qualitatively. This approach provides a generic and simplified means to compare options. The actual complexity of delivering site-specific options will vary based on many factors.

- Very Low: Simple, can be implemented with little specialised knowledge.
- Low: Basic complexity, requires some expertise but can be widely applied.
- Medium: Moderately complex, involving multiple steps and technical knowledge.
- High: Complex, requiring advanced technical expertise, collaboration, or coordination.
- Very High: Extremely complex, involving cutting-edge technology, large-scale coordination, and high expertise.

Table 2. Structural flood hotspot options

Name	Type	Scale	Description	Key Site Factors for Success ⁶	Implementation Challenges ⁷			Site 1. – Huai Mao Bridge	Site 2. – Road 13 corner junction	Site 3. – Bridge at Phouangkham village	Site 4. – Pond development
					Capital cost	Complexity	Key risks				
Levees & Dikes	Structural – Protective	Local	Earthen or concrete barriers to control water flow and prevent flooding in designated areas.	<ul style="list-style-type: none"> Flat or gently sloping land Adequate space for construction Compacted, non-erodible soils preferred 	Very High	Medium	<ul style="list-style-type: none"> Potential failure in extreme events 	Unlikely to be feasible (lack of space)	Not applicable	May be feasible but not recommended due to cost and complexity of bridge/levee interface.	Not applicable
Floodwalls	Structural – Protective	Local	Vertical barriers built along rivers or coasts to hold back floodwaters.	<ul style="list-style-type: none"> Stable soil to support the wall Adequate space for construction 	Very High	High	<ul style="list-style-type: none"> Potential failure in extreme events 	May be feasible but not recommended due to cost and complexity of bridge/flood wall interface	Not applicable	May be feasible but not recommended due to cost and complexity of bridge/flood wall interface	Not applicable
Stormwater Drainage Network	Structural – Protective	Local or catchment	Creation or upgrade of networks of drains, culverts, and channels designed to collect and divert excess water during storms.	<ul style="list-style-type: none"> Mild slopes preferred, steep or flat areas are more challenging Flexibility in placement / space available to achieve desirable layout Low water table Low risk of erosion 	Medium to High	Medium to High	<ul style="list-style-type: none"> Limited capacity during intense rainfall Risk of blockage 	Not applicable	Recommended for consideration – site investigations and hydraulic modelling required to verify which part(s) of the existing network requires upgrade	Not applicable	Not applicable
Detention Basins	Structural – Protective	Local or catchment	Reservoirs to temporarily hold floodwaters and release them slowly to prevent flooding downstream.	<ul style="list-style-type: none"> Low-lying areas Adequate space for construction at the right strategic location in the catchment Preferrable to be in an area with underlying clay with clay or other impermeable soils 	High	Medium	<ul style="list-style-type: none"> Environmental impact of land use change Potential failure in extreme events (more relevant where basin walls are higher than surrounding areas) 	Recommended for consideration ⁸ - catchment analysis required to identify potential sites, followed by hydraulic modelling and site investigations.	Recommended for consideration – catchment analysis required to identify potential sites, followed by hydraulic modelling and site investigations.	Recommended for consideration – catchment analysis required to identify potential sites, followed by hydraulic modelling and site investigations.	Not applicable
Sluice Gates (incl pump)	Structural – Protective	Local or catchment	Movable gates to control water flow, particularly in flood-prone urban or coastal areas.	<ul style="list-style-type: none"> Stable foundation for gate installation Access to power/control systems 	Very High	Very High	<ul style="list-style-type: none"> Highly technical solution requiring specialised knowledge Potential failure or malfunction in extreme events 	Recommended for consideration - a sluice gate is already proposed downstream where the creek enters the Nam Khan. ⁹	Not applicable	Recommended for consideration - a sluice gate could be considered downstream where the creek enters the Nam Khan.	Not applicable
Rainwater tanks	Structural – Protective/EbA	Local or catchment	Captures and stores excess rainwater, reducing the volume of runoff. Can also provide a water supply	<ul style="list-style-type: none"> Roof catchment with downpipes Soil conditions suitable for tank foundation 	Low	Low to Medium	<ul style="list-style-type: none"> Water quality risks if stored rainwater also used for water supply 	Recommended for consideration in LPC ICFMS, unlikely to address all flood issues at specific hotspots, but if systematically implemented can contribute to flood risk reduction and provide other services and value for the city (e.g. water supply).			Not applicable
Wetland Creation or Restoration	Structural - EbA	Local or catchment	Creating or rehabilitating degraded wetlands to act as natural buffers,	<ul style="list-style-type: none"> Low-lying, flat areas Poorly drained or waterlogged soils 	Medium	Medium	<ul style="list-style-type: none"> Risk of choking or blockage 	Unlikely to be feasible (no existing or historic wetland sites identified upstream of each site).			Recommended for consideration in the LPC ICFMS to address risks to similar

⁶ Other factors that are common to most solutions are not listed and include proper design and maintenance, accurate hydrological modelling, funding and political support, collaboration with communities.

⁷ Note that long-term maintenance burden is a common factor to all structural and non-structural options. However, the scale and complexity of this burden does vary.

⁸ PONRE have previously proposed upstream interventions, such as storage, to mitigate flooding at the site, refer to UNDP Mission Report Summary (04 July 2023).

⁹ Refer above to comments from PONRE and DPWT during the stakeholder meeting. .

Name	Type	Scale	Description	Key Site Factors for Success ⁶	Implementation Challenges ⁷			Site 1. – Huai Mao Bridge	Site 2. – Road 13 corner junction	Site 3. – Bridge at Phouangkham village	Site 4. – Pond development
					Capital cost	Complexity	Key risks				
			absorbing floodwaters and reducing downstream flow.	<ul style="list-style-type: none"> Proximity to water bodies Adequate water availability 							ponds. ¹⁰ It is also recommended that the value of preserving and enhancing similar ponds be explored in the LPC Economics Report.
Floodplain Restoration	Structural - EbA	Local or catchment	Allowing rivers to access their floodplains, reducing pressure on embankments and enhancing natural flood control.	<ul style="list-style-type: none"> Flat or gently sloping land adjacent to the river Land in public ownership, or a willingness to be transferred to public ownership 	High	Medium	<ul style="list-style-type: none"> Resistance from existing landholders or users of the land 	Recommended for consideration in the upper catchment. ¹¹	Unlikely to be feasible at the site as areas adjacent to the river have fragmented ownership and are already developed.		Not applicable
Green roofs	Structural - EbA	Local or catchment	Vegetated rooftops absorb rainwater and reduce surface runoff.	<ul style="list-style-type: none"> Suitable roof structures, preferably large with mild slopes, good waterproofing and adequate structural support 	Medium	Medium	<ul style="list-style-type: none"> Maintenance requirements / risk of roof leakage / plant loss during extended dry periods 	Unlikely to be feasible as expensive to retrofit on existing roofs and expected to be costly relative to the volume of water attenuated. Recommended for consideration for new large public buildings on a case-by-case basis.			Not applicable
Riparian Buffer Zones	Structural - EbA	Local or catchment	Vegetative buffers along riverbanks to stabilise banks and absorb floodwaters.	<ul style="list-style-type: none"> Land availability adjacent to water bodies Erosion-resistant soils 	Low	Low	<ul style="list-style-type: none"> Enforcement / encroachment by development Maintenance of vegetation 	Recommended for consideration in LPC ICFMS, unlikely to address all flood issues at specific hotspots, but if systematically implemented can contribute to flood risk reduction and provide other ecosystem services and value for the city. It is also recommended that the value of preserving and enhancing riparian buffers be explored in the LPC Economics Report.			Recommended for consideration in the LPC ICFMS to address risks to similar ponds. ¹²
Reforestation	Structural - EbA	Local or catchment	Planting trees in upstream areas to enhance soil absorption and reduce surface runoff that leads to flooding.	<ul style="list-style-type: none"> Moderately fertile soils Sufficient space for large-scale planting 	Medium	Low	<ul style="list-style-type: none"> Land-use competition 	Unlikely to be feasible at a large scale given current extent of development and forecast growth of LPC. It is recommended that a greater focus be placed on land use planning to preserve existing forested and areas in upper catchments, as opposed to reforestation of existing agricultural or urban areas.			Not applicable

¹⁰ Unlikely to be feasible at this specific site as it is already under development.

¹¹ Unlikely to be feasible at the site as areas adjacent to the river have fragmented ownership and are already developed.

¹² Unlikely to be feasible at this specific site as it is already under development.

Table 3. Non-structural options

Name	Type	Scale	Description	Key Factors for Success	Implementation Challenges ¹³			Comment
					Capital cost	Complexity	Key risks	
Flood Forecasting & Monitoring	Non-structural	Catchment or city	Systems for tracking river and rainfall data to predict potential flood events and inform response plans. Flood forecasting and monitoring provides the technical data for predicting floods, while early warning systems (discussed below) integrates this data with communication tools to trigger timely responses.	<ul style="list-style-type: none"> • Access to monitoring stations • Skilled personnel for analysis • Reliable data collection and expertise for quality assurance, quality control and analysis 	Medium	High	<ul style="list-style-type: none"> • Maintenance of equipment • Difficulty predicting extreme events 	Extent of existing flood forecasting and monitoring systems in LPC, and potential improvements, to be considered in developing the LPC ICFMS.
Early Warning Systems	Non-structural	Catchment or city	Technology-based systems that forecast flood risks and notify communities to evacuate or take action.	<ul style="list-style-type: none"> • Access to telecommunications infrastructure • Timely availability of information 	Medium	Medium	<ul style="list-style-type: none"> • Dependence on accurate forecasting and timely communication • Failure of communication networks during flood events 	Extent of existing early warning systems in LPC, and potential improvements, to be considered in developing the LPC ICFMS.
Land Use Planning	Non-structural	City	A broad, strategic process that involves managing how land is used and developed to reduce flood risks. It includes strategic planning of land use to prevent development in flood-prone areas or integrate flood-resilient designs (e.g. through building codes, and environmental management practices).	<ul style="list-style-type: none"> • Accurate flood mapping and risk assessment tools • Clear property ownership • Government land-use regulation frameworks • Collaboration with urban planners • Enforcement of regulations 	Low	Medium	<ul style="list-style-type: none"> • Lack of political support • Conflict with development goals and resistance from developers • Enforcement challenges 	The availability of accurate floodplain mapping is a major limitation in LPC, especially for pluvial flooding. Land ownership and lack of enforcement are also critical challenges. It is recommended that the value of preserving forest and agricultural land use in the upper catchments be explored in the LPC Economics Report.
Flood Zoning	Non-structural	Catchment or city	A more specific regulatory tool within land use planning that involves designating areas based on their flood risk levels. High-risk areas are typically identified for limited development or specific flood-resistant activities.	<ul style="list-style-type: none"> • Accurate flood mapping • Clear property ownership • Government land-use regulation frameworks • Enforcement of regulations 	Low	Medium	<ul style="list-style-type: none"> • Lack of political support • Resistance from landowners • Conflict with development goals and resistance from developers • Enforcement challenges • Maintaining up-to-date zoning maps 	The availability of accurate floodplain mapping is a major limitation in LPC, especially for pluvial flooding. Land ownership and lack of enforcement are also critical challenges.
Public Education	Non-structural	Catchment or city	Programs to educate communities about flood risks, preparation, and response strategies.	<ul style="list-style-type: none"> • Consistent and effective messaging tailored to the target audience • Coordination with media outlets or community centres or programs 	Very Low	Very Low	<ul style="list-style-type: none"> • Reaching the right groups • Ensuring long-term engagement • Difficult to assess the impact of the program 	-
Insurance & Risk Transfer	Non-structural	City	Offering insurance solutions that transfer flood risk to insurance companies, reducing individual financial risk.	<ul style="list-style-type: none"> • Accurate flood mapping and risk assessment tools • Clear property ownership • Affordable premiums • Awareness and uptake 	Medium	Medium	<ul style="list-style-type: none"> • Limited access for low-income communities • Complex claims process • Reluctance to invest in coverage 	Unlikely to be feasible for majority of households impacted by flooding and does not address flood impacts to transport networks

¹³ Note that long-term maintenance burden is a common factor to all structural and non-structural options. However, the scale and complexity of this burden does vary.
LPC – Optioneering Report

5 Conclusion

The consultation and site visits indicate that nuisance stormwater flooding occurs on a regular basis (e.g. every year) at several sites in LPC, with low flood depths (<1 m) and short durations (a few hours). The impacts of stormwater flooding are typically damage to property and transport impacts. However, in larger rainfall events when the water level in the Nam Khan (or Mekong River) is high, flood hotspots can be impacted by backwatering from fluvial flooding. This poses significant safety risks and has led to loss of life from flooding.

Pluvial stormwater flooding in LPC is impacted by urbanisation and lack of enforcement of planning laws and regulations¹⁴ that lead to:

- Increased runoff due to an increase in catchment imperviousness due to urbanisation of agricultural and forested land use¹⁵.
- Reduced drainage capacity due to loss of ponds, or reduced storage capacity of ponds.
- Reduced drainage capacity due encroachment of development into waterways corridors.

The capacity of the existing drainage network to safely convey floodwater from the city is also impacted by:

- Lack of maintenance budget and action leading to build up of litter and debris that reduces capacity.
- Lack of a coherent drainage master planning that considers (a) increasing development and (b) increased frequency and intensity of rainfall due to climate change.
- Poor asset design or construction.
- Lack of participation of local communities in drainage design (as reported by a head of Nasamphan village during the site visits).

In addition to considering short-term drainage issues (e.g. interventions at the flood hotspots visited), a longer-term view is required to avoid exacerbating and perpetuating current drainage challenges (e.g. it is apparent that better integration of drainage planning and land use planning is needed). Protective and ecosystem-based adaption solutions recommended for each of the flood hotspots visited are summarised below in Table 4. It is also recommended that the potential for these interventions be supported by a range of non-structural options be examined in the LPC ICFMS. Finally, the three options recommended for further analysis of their ecosystems values in the LPC Economics report are preservation and enhancement of (a) forest and agricultural land use in upper catchments, (b) riparian buffers / waterway corridors and (c) ponds.

Table 4. Summary of recommended structural flood hotspot options for Site 1. – Huai Mao Bridge, Site 2. – Road 13 corner junction, Site 3. – Bridge at Phouxangkham village and Site 4. – Pond development

Name	Description	Site			
		1	2	3	4
Stormwater Drainage Network	Creation or upgrade of networks of drains, culverts, and channels designed to collect and divert excess water during storms.		✓		
Detention Basins	Reservoirs to temporarily hold floodwaters and release them slowly to prevent flooding downstream.	✓	✓	✓	
Sluice Gates	Movable gates to control water flow, particularly in flood-prone urban or coastal areas.	✓		✓	
Rainwater tanks	Captures and stores excess rainwater, reducing the volume of runoff. Can also provide a water supply	✓	✓	✓	
Wetland Creation or Restoration	Creating or rehabilitating degraded wetlands to act as natural buffers, absorbing floodwaters and reducing downstream flow.				✓
Riparian Buffer Zones	Vegetative buffers along riverbanks to stabilise banks and absorb floodwaters.	✓	✓	✓	✓

¹⁴ E.g. clause 29 of water and water resource law(revised 2017) which identified waterway buffer zones.)

¹⁵ In addition to urbanisation, agricultural activity on private land is also a cause of deforestation.



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