

## **DESIGN OF STORM WATER DETENTION POND**

### **A. Background**

1. Chuxiong Yi Autonomous Prefecture (Chuxiong prefecture) is located at about 160 kilometer (km) west of Kunming, the provincial capital of Yunnan province. The climate condition in Chuxiong prefecture is categorized as subtropical climate with short winter and summer, and long spring and autumns. Due to rapid and unbalanced urbanization, key cities and towns in Chuxiong prefecture (including the three project cities in Chuxiong Municipality, Lufeng County, and Wuding County) face serious urban development challenges including lack of infrastructure, poor road networks, and poor sanitary facilities.

2. Four rivers run through the urban areas of the three project cities and all have a flood history, with property damages and loss of lives.<sup>1</sup> Existing early flood warning systems are inadequate to reduce the flood damages in the events of severe storms. The annual average precipitation in Chuxiong prefecture is over 900 millimeter, and rainfall is concentrated from July to September. Severe storms and heavy rainfall are common during this period and flooding in the urban areas occurs from time to time. Flooding is aggravated as a result of urban development with increased impermeable areas and inadequate storm water drainage system and river embankments. The water quality of the project rivers is currently Class IV or worse. This situation will continue to block new initiatives to promote sustainable urban development unless pollution prevention and abatement measures are implemented.

3. The Yunnan Chuxiong Urban Environment Improvement Project aims to promote balanced and environmentally sustainable urbanization and socioeconomic development in the three project cities. The project will support sustainable urban transportation, urban sanitation service facilities, and integrated urban flood control and river enhancement works including an advanced storm water management.

### **B. Principle of flood and storm water management practice**

#### **1. Flood management principles**

4. Generally, flood management is an approach to achieve a compromise—a trade-off between the costs of social, economic, and environmental benefits of occupation and usage of flood prone areas against the risk, hazard, and consequences to these activities that cause flooding. Several common principles are applied to ensure safe and sustainable use of flood prone land under the project:

- (i) a proactive response to flood management in lieu of a reactive approach,
- (ii) management of risk and the flexibility to adapt to future uncertainties,
- (iii) an integrated mix of structural and non-structural measures,
- (iv) appropriate land use based on the level of hazard to minimize risk,
- (v) meeting community expectations with regard to adopted levels of protection and communication of risk to raise awareness, and
- (vi) enforced new or ongoing monitoring and evaluation systems.

5. **Integrated risk management.** Flood risk management measures are typically described as structural or non-structural measures:

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<sup>1</sup> Longchuan River in Chuxiong Municipality, East River and West River in Lufeng County, and Wulong River in Wuding County.

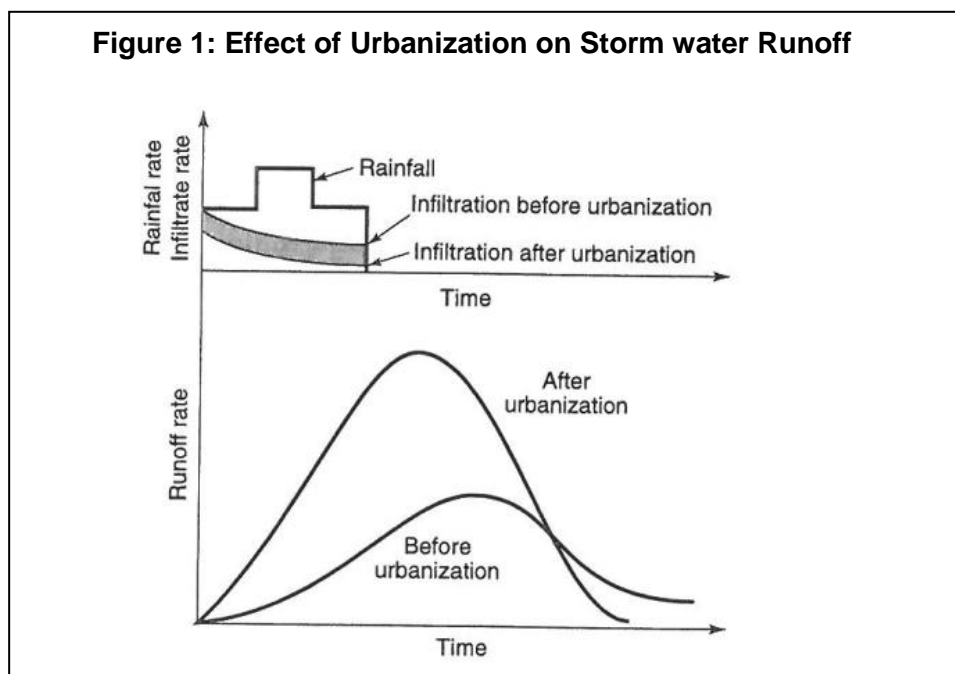
- (i) Structural measures aim to reduce flood hazard by modifying the behavior of the flood, e.g., reducing flood levels or velocities, or by preventing floodwaters from entering areas under threat. These are also often referred to as flood control measures.
- (ii) Non-structural measures aim to modify exposure to flood hazard or reduce vulnerability. This is done by either modifying the response of the population at threat, or by better planning and management of urban development in flood prone areas.

6. Structural and non-structural measures are complementary and one should not be considered to preclude the other. The rapid rate of urbanization and threat of climate change may prompt a move away from an overreliance on hard-engineered defences towards more adaptable and incremental non-structural solutions. For the project, an integrated flood management strategy was adopted by combining both, with a strategy linked to urban planning and management policy and practices. Consideration was given to the level and characteristics of existing risk and likely future changes in risk in order to achieve an effective investment in storm water management.

## 2. Storm water management principles

7. Traditionally, urban storm water management has focused on rapidly collecting and conveying storm water runoff to disposal in receiving waters. Based on this approach, urban development has changed watershed hydrology by increasing the amount of impervious surfaces, reducing vegetation, and introducing land uses that generate pollutants. Increased impermeable area reduces natural infiltration and interception of rainfall resulting in increased runoff volumes and peak flow rates. This in turn leads to increased erosion and sedimentation, pollutant mobilisation and transport, and degraded aquatic ecosystems.

8. The effects of urbanization on storm water runoff include increased total volumes of runoff and peak flow rates (Figure 1). In general, major changes in flow rates in urban catchment are the result of: (i) an increase in the volume of water available for runoff because of the increased impermeable cover provided by roads, streets, buildings, parking lots, and roofs, which reduce the amount of infiltration; and (ii) changes in hydraulic efficiency associated with artificial channels, curbing, gutters, and storm drainage collection systems, which increase the velocity of flow and the magnitude of flood peaks.



9. In addition to the adverse impact on runoff quantity, storm water runoff in urban areas is one of the primary sources of pollutants in urban streams and waterways. Contaminated storm water washed off from roads, highways, parking lots, and lawns (often containing fertilizers and pesticides) is often classified as a type of nonpoint source pollution. Unlike other types of point sources, such as industrial discharge, wastewater plants and other operations, pollution in urban runoff is not attributed to one activity or even group of activities. Since it is not caused by an easily identified and regulated activity, urban runoff pollution sources are often treated as true nonpoint sources and require special storm water management approach to rectify the problem.

10. Urban storm water management in several developed countries has undergone transformation in recent years, from storm water being considered a nuisance requiring rapid disposal to a more integrated urban water cycle management approach to achieve ecologically sustainable development. This requires a holistic approach to the management of storm water runoff to integrate land use planning, urban landscape architecture, water resources management, and urban drainage infrastructure to address the multiple objectives of urban storm water management. This approach therefore aims to protect urban waterway health and also to consider storm water as a fit-for purpose water supply source.

11. Urban storm water management systems typically include detention or retention ponds to mitigate the negative impacts of urbanization on storm water drainage. Detention ponds empty after a storm, whereas retention ponds retain water much longer above a permanent pool of water. Retention ponds are beneficial for providing storm water abatement and the removal of pollutants from storm water.<sup>2</sup> The major functions and benefits of a retention pond include the following.

- (i) **To retain urban runoff before releasing it into streams or other bodies of water.** The urban runoff is released at flow rates and frequencies similar to those that existed under natural conditions (prior to land clearing and development). The flood volume held in a retention pond reduces the impact on downstream storm water systems.
- (ii) **To provide pollutant removal through settling and biological uptake (via aquatic vegetation).** A typical retention pond can remove 30%–80% of certain pollutants from water before it enters other bodies of water or watersheds. Common pollutants reduced are sediments, bacteria, greases, oils, metals, total suspended solids, phosphorous, nitrogen and trash. The retention pond is one of the most effective tool to provide channel protection and pollutant removal in urban streams.

12. Essentially, retention ponds provide both water quality and quantity control. Retention ponds are ideal partners for residential areas within proximity to any river, stream or watershed since retention ponds can enhance the environment and provide an aesthetically pleasing place for the residents.

### **C. Storm water and flood management features in the project**

13. Many cities in the People's Republic of China (PRC) lack an integrated, sustainable urban development concept. In the process of urban planning and development, while

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<sup>2</sup> In the US, many states such as California, Nevada, Idaho, North Carolina, and Florida realize the potential benefits of retention ponds. For example, in the 1980s the state of Florida began to reduce pollution associated with storm water runoff by requiring storm water treatment in any new developments. As a result, many storm water retention/detention ponds have been designed and built.

drainage is included, it is grossly overlooked and does not support development. Drainage provisions included in urban master plans do not include an overall consideration of drainage systems with a flood risk management concept. There is also no provision in case drainage facilities fail to perform. In order to overcome the shortfalls of the conventional urban planning and drainage design, the project adopted a risk-based approach.

## 1. Detention ponds

14. As a part of urban road construction component, a detention pond was proposed for Lufeng and Wuding subprojects as an effective way to control the runoff discharge rate. Both subprojects have road construction and development of new urban area will cover the earth with impermeable materials such as concrete and asphalt, which will cause surface runoff with the pollutants from streets to flows into the river in the downstream at faster speed and bigger volume in comparison to the undeveloped condition where the runoff will take much longer time to flow through the grass or earth surface and infiltration. Moreover, the detention pond provides flood storage, and offset the increase in runoff due to urbanization. The detention ponds provide both water quality and quantity control. They also enhance the environment and provide an aesthetically pleasing place for the residents with landscaping. The detention pond will collect and store the runoff and discharge it at a controlled low rate that is equivalent to the pre-development condition.

15. **Technical design.** The storm water drainage network is designed for a one in two-year return period in compliance with the design guidelines and practices in the PRC. Accordingly, the detention pond is sized for similar protection. The detention pond consists of three small ponds with different functions that will retain urban storm water runoff, intercepting pollutants of the first flush. These systems will serve an area of 1.6 square kilometer in the city of Lufeng County and 0.5 square kilometer in the city of Wuding County. In order to compensate the insufficient historical rainfall and runoff data in the cities of Lufeng County and Wuding County, the equation in the “Storm water Engineering Guidelines for Construction and Small Area Development” (GB50400-2006) was adopted to calculate the size of detention ponds.

$$V = \max \left[ \frac{600}{1000} (Q - Q') t_m \right]$$

in which,  $V$  = volume of detention pond ( $m^3$ ) ;

$t_m$  = retention time (min) (< 120 min) ;

$Q = \psi_m q F$  , where  $Q$  is the inflow (L/s) ,  $\psi_m$  is runoff coefficient ,  $q$  is the rainfall intensity [ $L/(s^2ha)$ ] ,  $F$  is the catchment area(ha);

$Q' = 1000W/t'$  , where  $Q'$  is the outflow(L/s) ,  $W = 10\psi_c h_y F$  ,  $W$  is the total runoff( $m^3$ ) ,  $\psi_c$  is runoff coefficient ,  $h_y$  is rainfall depth(mm) ;  
 $t'$  is the time for discharge(s) , normally 6–12 hours.

According to the equation, the results of the calculation are as follows:

Item	$\psi_m$	$q$	$F$	$Q$	$\psi_c$	$h_y$	$t'$	$t_m$	$Q'$	$V$
Lufeng	0.6	/	162	12,011	0.6	75	12	110	1,688	68,135
Wuding	0.6	/	52	4,210	0.6	75	6	90	1,083	16,884

Notes:

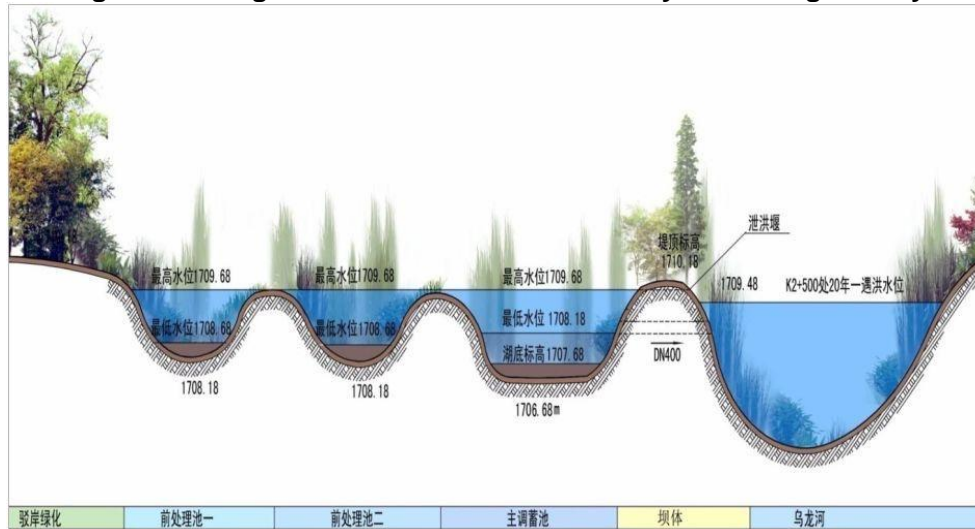
1.  $q$  is obtained from the Kunming rainfall intensity design.

2.  $Q$  is determined from the underground pipe network design.

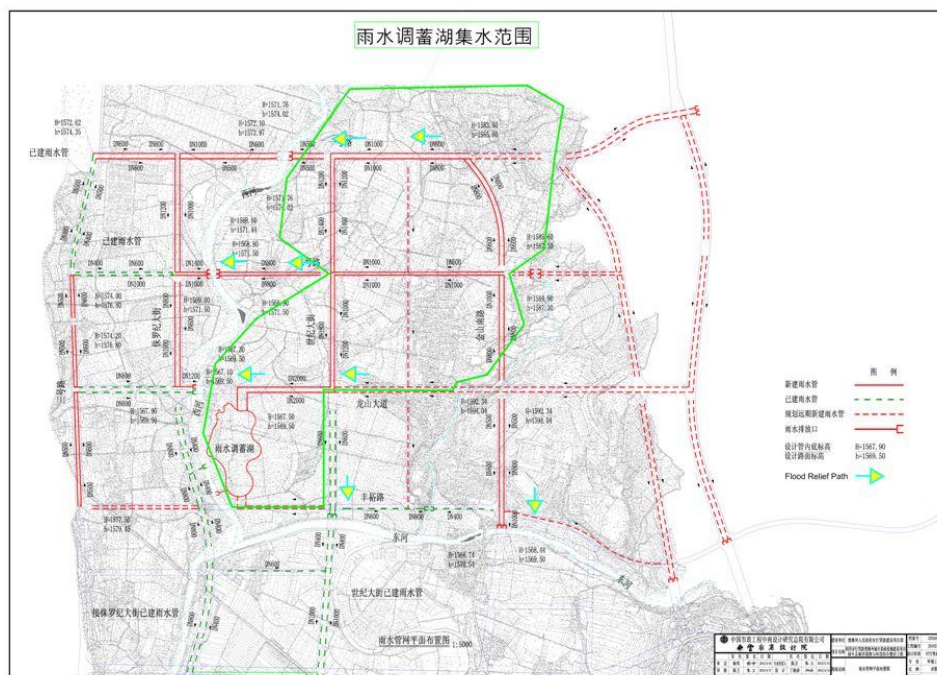
3.  $h_y$  is based on Yunnan's average 24-hour point rainfall depth.

16. The design of detention ponds was verified by the approach of American Association of State Highway Transportation Officials. The detention pond is capable of retaining excessive storm water for a two-year return period and is divided into three compartments. The first two are forebays with aquatic plants for initial urban runoff pollutant removal. The last (main) retention pond is designed to retain a great depth of water of two meters high. Figure 2 shows the general design of detention ponds in city of Wuding County. These flood relief paths indicate the possible routes that the storm water will run on the surface of the roads when the underground drainage system cannot cope with a severe rainstorm exceeding its capacity.

**Figure 2: Design of Detention Pond in the City of Wuding County**

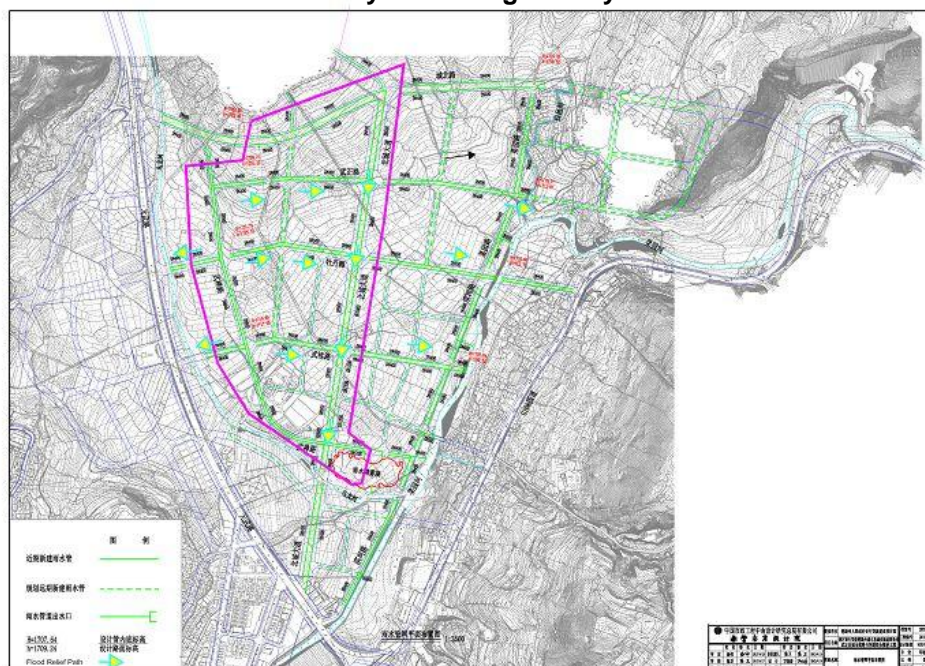


**Figure 3: Urban Drainage Network (red lines) Design and Flood Relief Paths (yellow arrows) in the City of Lufeng County**





**Figure 4: Urban Drainage Network (red lines) Design and Flood Relief Paths (yellow arrows) in City of Wuding County**



17. As an integrated urban water management approach, the project also finances a special design storm water collection and storage system installed along selected project roads. The system consists of granular infiltration strips, underground storage and piping to the urban storm water network. The system will reduce the direct discharge of runoff to the river system and the flood risk in the downstream, and will allow localized reuse of storm water for landscaping irrigation.

## 2. Operation and maintenance of detention ponds

18. The city management bureau of Lufeng county and Wuding county governments are responsible for the maintenance and landscaping of the detention ponds. An international and a national storm water management expert under the project management consulting service should assist the bureaus to prepare an appropriate operation and maintenance (O&M) plan, taking into account their respective resources, available equipment, and the conditions of the retention ponds. Some common practices in the O&M plan include:

- (i) Once constructed, the ponds should be inspected after several storm events to confirm drainage system functions, bank stability, and vegetation growth. The outlet structure should be inspected for evidence of clogging or outflow release velocities that are greater than design flow.
- (ii) At least twice during the rainy season, accumulated trash and debris should be removed from the side slopes, embankment, and spillway. All pond outlet devices should be protected from clogging. Sediment should be removed from the main ponds as necessary and at least once every two years (usually sooner rather than later).
- (iii) As the detention ponds are located close to residential areas, it would pose an added threat to the main ponds on algae bloom by such common activities as fertilizing and watering lawns, washing cars and painting houses. The simple act of water runoff from fertilization will increase the build up of nutrients in the main ponds. The ponds with shallow water under the warm weather can create an algae bloom that will cause the main ponds to attain a

green scum or large clumps of algae floating on the surface. This bloom can remove the oxygen from the water and kill off any fish or other aquatic inhabitants that are present, creating an unsightly and smelly mess. The main ponds must therefore be regularly inspected and cleaned up to avoid the problem.

- (iv) During the rainy season, the main ponds will retain about one meter depth of water. Warning signs and safety barriers must be provided to prevent any children from playing close to the ponds. More frequent inspections must be carried out to avoid any accidents. Alternatively, CCTV monitoring should be provided.

19. **Capacity building and training.** To ensure operational sustainability of detention ponds, the relevant management personnel and operators need to be trained. The project implementation consulting service should include a combination of international and national storm water management experts with 3 person-months each. Their scope of services should include (i) confirming the detailed design of storm water detention ponds to fully reflect the concept of innovative storm water retention ponds, (ii) drafting a detailed O&M manual for Lufeng and Wuding county governments, and (iii) conducting capacity building trainings for the operation department staffs in Lufeng and Wuding county governments.