A Study on Establishment of the Flood Protection Standard - A Case Study of Dali River Basin in Taiwan

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Abstract: Due to global climate change and rapid urbanization, the increasing impervious areas has resulted seriously human lives and property loss during flood disaster. The design standard of structural engineering measures could not stand with the extremely intensified flood disasters. In addition, such structural engineering measures might mislead the public that such areas are safe. In fact, urban stormwater integration planning and management has been implemented in the worldwide. After setting the flood protection "protection standards" for the region, the plan is adopted according to the standard. As a whole, it is the key to setting a reasonable, objective and scientific regional "protection standard" for the city. Therefore, the study will then clarify the theoretical connotation of “protection standards” and collect domestic and foreign past protection standards. Afterwards, the study will then develop a framework for “protection standards” suitable for operation in Dali River Basin in Taiwan. The cost-benefit analysis will then be applied to do the calculation.

Keywords: Global Climate Change; Protection Standard; Cost-Benefit Analysis; Floods

Introduction

Global climate change is very likely to increase the uncertainty of future water resources, and in particular there will be more extreme patterns in rainfall (Gelt et al., 1999; Serrat-Capdevila et al., 2007; Gallo et al., 2013). The report released by the United Nations and World Bank indicating that more people in urban area will suffer in the next 20 years for the influence of climate change, the extreme heavy rainfall caused by urban floods is more likely to expand its economic losses risk of today's 50 times. United Nations Office for Disaster Risk Reduction (UNISDR) stated in the Global Assessment Report on Disaster Risk Reduction 2015 that global economic losses might increase up to $300 billion every year. Due to global climate change and impermeable surface in urban settlement, the torrential rain and surface runoff put cities in increasing risks and threats than ever before.

Flooding is a challenging issue in the worldwide (Line and White, 2007). Traditional flood management relies on structural engineering measures largely including reservoirs, levees and flood walls, improvements to channels and the floodways (Thampapillai, 1985). However, multiple weaknesses have been identified. The risk of building damage and the loss of life are possible wherever development is allowed in hazardous areas. Taiwan is an island country, and may be the place on Earth most vulnerable to natural hazards, with 73 percent of its land and population exposed to three or more hazards (World Bank, 2005). With the global climate change, there is an increasing rainfall in warmer world and will likely intensify typhoons in south-western Pacific where

Taiwan located. In order to cope with serious flood issues, we have relied on hydraulic engineering heavily. According to Special Act for Flood Management in Taiwan, project of flood-prone areas has been budgeted 3.8 billion US dollar for eight years since 2006. Nevertheless, urban development changes land-use coverage directly which affects overall performance of hydraulic engineering and eventually leads to flood disaster (Beighley et al.,2003; Haase et al.,2009).

In the past, the government has been planning flood management via setting appropriate design standard for waterways. The design standard for flood management has been adopted to ensure the flooding capacity of the waterway under certain return period. However, the existing flood management and drainage facilities have been largely completed, and there is financial limitation to the increase in the amount of engineering facilities in response to runoff (Ministry of Water Resources and Water Resources Planning Laboratory, 2014). From the past flooding events - Netherlands, although the design standards have been continuously improved, it is impossible to avoid flooding. The design criteria for setting the 10,000-year return period in the coastal areas in the Netherlands have failed, and it occurred in the 1993 flood event.

As a whole, in order to cope with the above-mentioned engineering disaster reduction measures with their limits, and in response to climate change impacts on urban areas, Taiwan's water management measures have gradually changed into integrated flood management in recent years. Currently, the government is advocating the establishment of "Regional Flood Protection Standards" and the degree of protection specified by the protection standards, through engineering and non-engineering means to share floods to achieve a certain degree of protection in the region. International countries, especially the Netherlands, Japan, and the United States, have incorporated the concept of protection standards into flood management and developed protection standards. If the protection criteria are clearly defined, the governments can allocate a limited budget and resources for engineering and non-engineering measures in advance to maximize the efficiency of flood management. By promoting the concept of protection standards to the public, people's awareness of disasters is raised. Through the information disclosure of such flooding disasters, people can fully prepared in advanced with complete information. Therefore, this study attempts to review the practices of countries around the world in the protection standards, and attempts to develop a framework for possible operations in Taiwan.

Protection Standard

The term protection standard is derived from the risk evaluation criteria for technological hazards and is often used in hazardous installations such as nuclear industry, chemical industry, aviation transport, and rail transport etc. (European Maritime Safety Agency, 2015). In these categories of industries, it is basically inevitable that risk accidents will occur, even if such accidents are unlikely to occur, but if they occur, they may cause harm and loss to humans, the surrounding environment and economic aspects. Therefore, in order to ensure its safety, a "safety benchmark" is often established, and further safety measures are taken to reduce the risk level to protect human life and protect public safety. Nowadays, this concept is gradually applied to the field of flood management in natural disasters (Vrijling, 2001).

As far as the domestic situation is concerned, the concept of "protection standards" is often confused with the meaning of "design criteria" for water conservancy facilities for two main reasons. First, since the past flood management was limited by manpower, budget and technology, it was only managed in a "point" or "line" mode. Therefore, the so-called "protection standard" refers to flood management and drainage works. In fact, the implication is that in the past, the "design criteria" of the region were regarded as "protection standard." Secondly, in response to the impact of climate change, according to the comprehensive water management strategy to improve flooded areas, the protection standard has been revised to "regional flooding safety benchmark for flood disasters."

Netherlands is located in the western coastal areas of Europe. As the same time, due to the low terrain and two-thirds of the country's land below sea level, it is vulnerable to floods and tides. In 1953, Netherlands experienced the worst flooding in the country's history, invading the coastal areas of Netherlands, killing about 2,000 people and inundating more than 200,000 ha. Of land (Klijn and Deltares, 2013). Therefore, the Delta Committee was established the following year and is responsible for the improvement of the national flood management plan. When the Delta Plan was released in 1958, scholar Dantzig (1958) proposed a method for exploring design criteria using cost benefit analysis. Through this analysis, Netherlands has set design criteria for 14 coastal dike areas and decided to protect this extremely important and extremely vulnerable area for 10,000 years (Kind, 2014).

In 1993, the province of Limburg in the southeastern part of Netherlands was still suffering from flood, with more than 180 square kilometers of land accumulating 1.5 meters of flood; this time, water experts recommended dredging riverbeds, setting up flood detention areas and capping dikes. In 1995, just two years later, the scale of floods in the same location was once again surpassing the past. Although there were no major disasters at this time, the two flood threats forced policymakers to reflect on the traditional way of "fight against the water" and "living with water." The Netherlands launched the 21st Flood Protection Project and began to develop new protection standards and conduct necessary research. Because the country has experienced major flood losses and caused tens of thousands of deaths, it has placed great emphasis on the protection of "life" in flood prevention and mitigation strategies. Therefore, the concept is the threshold value that individuals can bear to ensure that everyone achieves the lowest level of safety.

Figure 1 Protection Standard in the Netherlands

In the past, due to over-exploitation of the land, Japan's impervious surface continued to expand, so that the rainwater could not be infiltrated smoothly, the collection time was shortened, and the natural water circulation rules were disrupted. As a result, when the urban area encounters heavy rain, it is prone to flooding. In order to solve the flooding disaster, the Japanese government began to implement the "Integrated Water Management" in 1977. The purpose is to meet the impact of rapid increase in surface runoff due to insufficient water retention and flood detention skills after rapid urbanization. Japan’s flood management mainly targets the basin, and breaks the boundaries of the territories according to the different characteristics of each river basin.

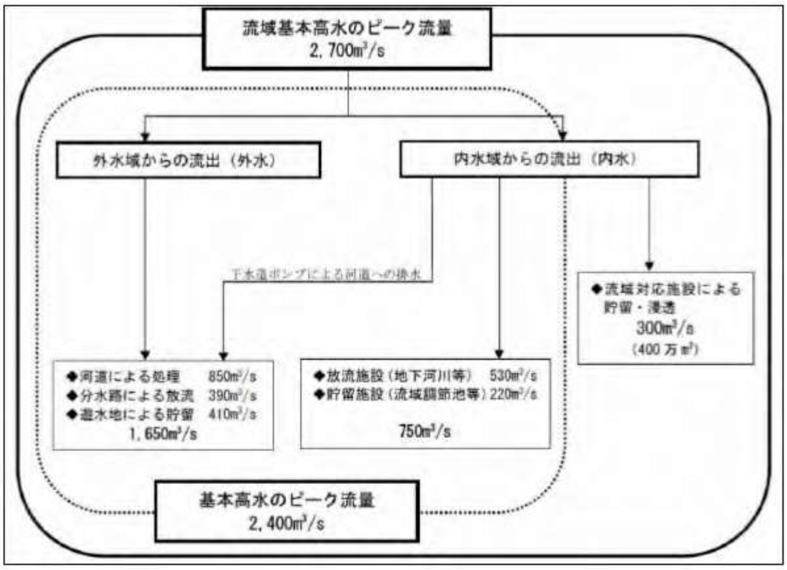


Figure 2 Flood management in Japan

New Orleans area is located on the delta plain of the Mississippi River in the United States, and the unique natural environment surrounding it makes the area vulnerable to flooding. Except for most of the area surrounded by water, it is estimated that more than half are below sea level, and some areas are below average sea level of 9.4 feet. Floods caused by storm surges have affected New Orleans, such as Hurricane Betsy in 1965, which flooded 164,000 houses and caused huge losses. Later, New Orleans began to work on the flood protection works, but it failed to withstand the unprecedented disaster caused by Hurricane Katrina. Therefore, the New Orleans began to review and discuss he protection standards in the local areas. The US protection standards are fairly similar to those in the Netherlands, and mainly use the concept of personal risk criteria as described above to ensure that everyone achieves a minimum level of safety.

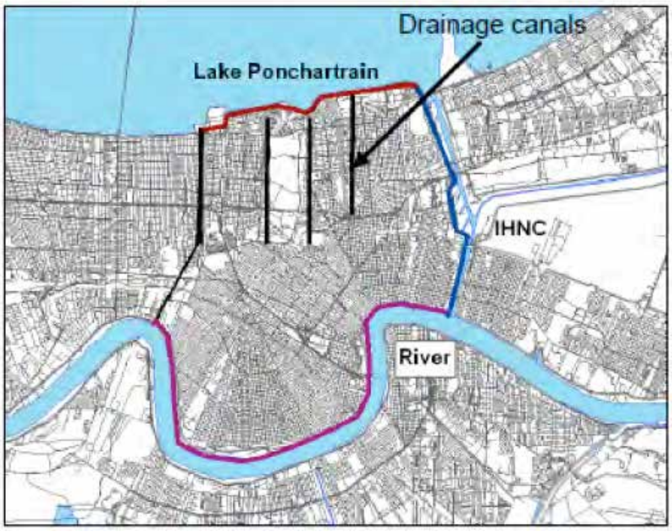


Figure 3 New Orleans

Research design

The study selected the Dali River Basin as the verification area. Dali River is located in the middle reaches of Wuxi River Basin. Dali River is an important tributary of the middle reaches if Wuxi. It originates form the hilly area in the east and flows into the Taichung Basin to the west. Because of the loss of the binding of the upstream valley in the downstream area, the actual flooding in the past floods are concentrated in the intersection of the lower reaches of Dali River and the other tributaries. Dali River flows through the highly developed area of Taichung City, Taiwan. The river basin contains and spans a total 12 urban planning areas. The threat of flooding to the industrial economy and the safety of life and property cannot be ignored. Therefore, it is necessary for the Dali River Basin to be planned for flood prevention.

The Dali catchment area belongs to the secondary catchment area of the Wuxi River Basin. There are 10 sub-catchments with a total area of 400.72 square kilometers, of which 35% are urban planning areas and 52% are non-urban land. Among them are 12 urban planning areas, mainly distributed in the western half, with the largest number of residential areas (32%), followed by scenic areas (19%). Non-urban land use zones are dominated by hillside conservation areas (65%), followed by specific agricultural areas 20%). According to the present land use, the Dali River basin is dominated by agricultural land (26%) and forest land (33%), and is distributed in the eastern and southern parts of the catchment. The land used for conservation (18%) is concentrated in the west and is consistent with the distribution of urban planning areas. As a whole, urbanized areas are concentrated in the western portion.

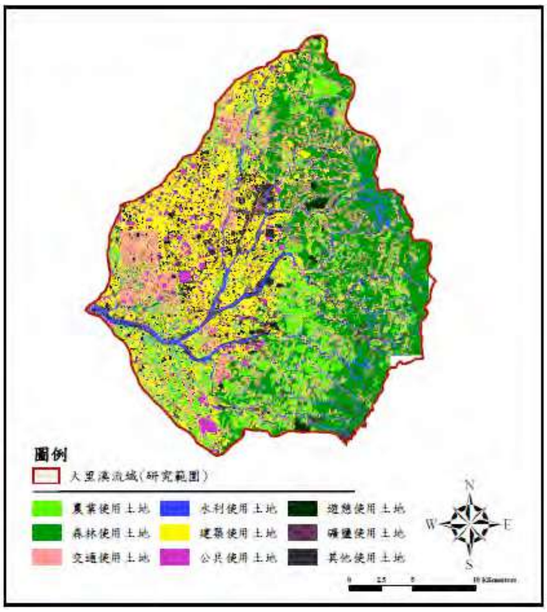
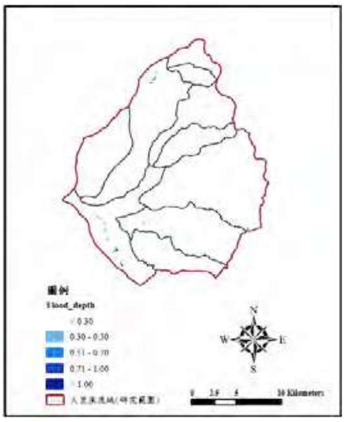
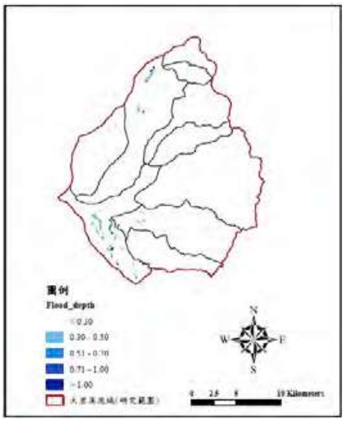


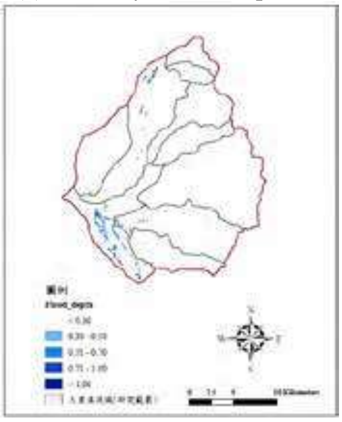
Figure 4 Study area

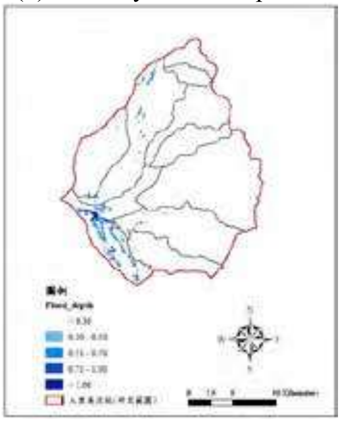
This study used the third-generation flooding prone map produced by the Water Resources Planning and Research Institute of the Ministry of Economic Affairs in 2014. The simulation considers the river, hydraulic structures (pumping stations, seawalls, etc), rainwater and underground waterway systems (rainwater manholes, rainwater pipelines etc), and has integrated the results of the flood management plan. Therefore, if the water cannot be withstanding by the engineering facilities might be regarded as flood disaster.



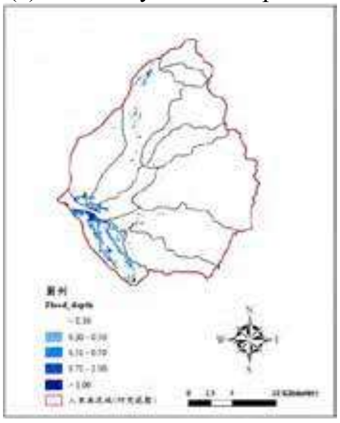


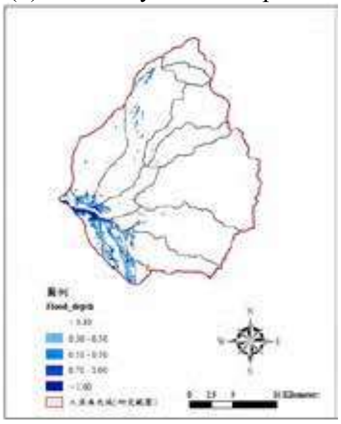
(a) 2-year return period (b) 5-year return period



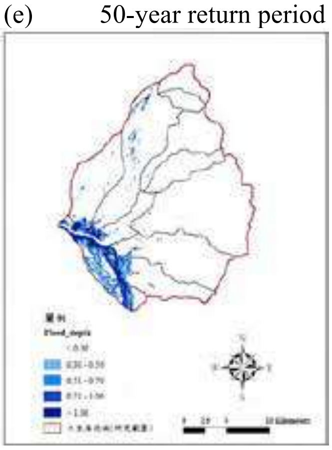


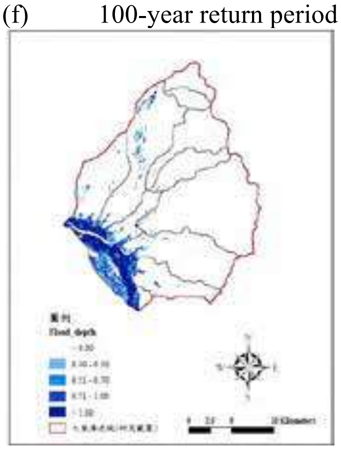
(c) 10-year return period (d) 25-year return period





(e) 50-year return period (f) 100-year return period





(g) 200-year return period (h) 500-year return period

Figure 5 The various return periods

Cost-benefit analysis is often used in decision-making by evaluating the cost and benefit of a comparison program to achieve the most cost-effective option (Kuiyu, 2001). In the field of disaster prevention, the cost is regarded as the amount of cost of disaster reduction engineering costs; “effectiveness” refers to disaster losses that can be avoided or reduced by disaster reduction projects (Kron, 2005; Penning-Rowsell, 2013). In the cost-benefit analysis, it can be further divided into “financial benefit analysis” and “economic benefit “analysis.” The financial benefit analysis is usually based on the view of operating revenue and expenditure. The analysis of the project from the perspective of “financial aspects” measures financial profitability; and the economic benefit analysis is based on the perspective of social benefits and social costs, form the “financial side.” The “economic aspect” and “environmental aspect” are three kinds of aspects to analyze the plan and measure its economic rationality.

According to the research topic, the setting of protection standards is quite high by the society and the public. As the same time, referring to foreign experience, such as Netherlands, it is seen in the cost-benefit analysis of the protection standard. The study not only considers the financial and economic aspects but also considers the elements of the “environmental surface” of the flood, such as nature, landscape, and cultural heritage (Kind, 2014). Based on the above, the study applies “economic benefit analysis” as a research tool to explore regional flood protection standards, and then explores its elated costs and benefits.

Results

The meaning of the “cost-benefit analysis” in this study is the benefit value that can be obtained for every cost of 100 million NT dollars. Therefore, if the result is less than 1 indicating that the structural engineering measures are inefficiency based upon the economic perspective. However, if the result is relative high indicating that such structural engineering measures are cost effective. In the 200 and 500 years of the recurrence period in the table, the profit ratio is less than 1, which means that if the protection standard in the Dali River Basin is increased to 200 and 500 years, the cost-effectiveness may not meet the economic benefits of flood control and disaster reduction. Although the protection ratios of the protection standards 2, 5, 10, 25, 50 and 100 are both greater than 1, they are still different in economic sense. At the same cost, the five-year economic benefit of the protection standard will be the most significant, which means that the basin can cost the same cost in the situation, but can achieve relatively high disaster reduction benefits. The protection standard for 10 years is second to none, and the second is the standard of protection.

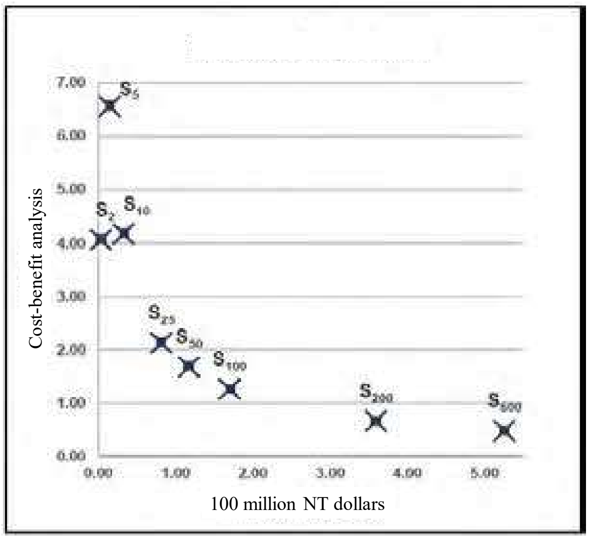


Figure 6 Study area

Conclusions

In the face of uncertain global climate change in the future, “no flooding” is an unrealistic goal and a misinformation that might leads people to confront relative high risk. In order to let the public know the threats and challenges, we should clarify the concept of “protection standards.” Therefore, this study proposes a framework for the protection that Taiwan can operate, and discusses the protection standards that Taiwan can operate. The basin was used as the main spatial unit while there are 10 sub-catchments in the basin and the socio-economic environment is quite different from the sub-catchments. Therefore, it is more appropriate to explore the regional protection standards form a relative smaller scale to improve such accuracy.

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