The dilemma and situation of detention pond in terms of extreme climate - a case study of Baoyeli detention pond

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Abstract. Constructing detention ponds to prevent flood has become a trend in recent years, but the utility of detention pond is yet to be confirmed. Therefore, in this study, we investigate detention pond’s function in terms of flood solving by analyzing the rainfall data, and comprehending the dilemma of detention pond in technology, also, we interview the user of detention pond to know the ordeal of detention pond in politic. We discover that detention pond is very effective in making up for the weaknesses in the drainage system, however, detention pond isn’t very effective in improving the overall flood control capacity of the drainage system. Furthermore, government needs to outreach policies to solve misunderstanding of public on infrastructures.

1. Introduction

In the heavy rain of August 28, 2018, the flood control system of Kaohsiung City faced a strong challenge. The extreme climate is normal nowadays. If the coping ability to flood control of the city cannot be improved, it will easily lead to the loss of people's lives and property. The government must adjust the policy according to the current development situation, to prevent the disasters. Therefore, this paper takes Baoyeli detention pond as the object, which was built in 2010. And the research region is Baoye Village, Sanmin District, Kaohsiung City, which Baoyeli detention pond located in, and Wenshan area, which is the watershed of the detention pond. Wenshan area includes Wende Village, Wenheng Village and Wenshan Village, Fengshan District, Kaohsiung City. In this study, we use hydrological data to analyze whether urban multi-purpose detention pond reduces flood occurrence under extreme rainfall conditions, and the function of detention pond in drainage system. Also, we investigate the opinion of the detention pond’s users, to understand the ordeal of detention pond in terms of extreme climate.

2. What is Baoyeli detention pond

2.1. Definition and function of detention pond

Everettwa City Government [1] indicates that detention pond treats rain to protect our creeks and streams, and during severe storms, helping prevent flooding. We define a facility that uses an artificial structure to store floods and discharge stored floods according to management needs.

With the progress of hydraulic engineering, the detention pond has gradually increased its functions. Not only can detention pond absorb the carbon dioxide by its vegetation, forming the cold island effect...
in the city, but also can it provide habitat for the wild animals.[2][3] In general, the multi-purpose detention pool has gradually replaced the traditional detention ponds.

2.2. Background information of Baoyeli detention pond

The northern part of Fengshan District where is nearby Niaosong District had been being still in the waters before 1898. Due to the urbanization, the surface of the land is gradually covered by concrete. The rainwater accumulated in the area slops westward along the terrain, emitting into Yihua road sewer. Kaohsiung City Government [4] pointed out the sewer can’t release the run-off caused by heavy rain, causing the flood in Chenqing-Yihua intersection. To solve the flood, Kaohsiung County Government was suggested to construct Chishan detention pond, but they canceled the plan because of the protest of residents. Kaohsiung City Government considered when the heavy rain happened the run-off would flow into Takao River, causing overflow, so Kaohsiung City Government still decided to build Baoyeli detention pond instead of NSTM detention pond. [5] The detention pond completed in 2012.

2.3. Design of Baoyeli detention pond

Baoyeli detention pond locates in Kaohsiung City 41 Urban Land Readjustment Implementation by the Private Sector. The detention pond should at least tolerate of 72mm/hr, 5-year return period, for an hour. [4] Kaohsiung City Government Water Resources Bureau [6] assessed that the detention pond could exceed a 50-years return period rainfall, 87.5mm/hr, for 2 hours. According to the paper [6], the area of the detention pond is 4.46 ha, the detention pond comprise north pond and south pond. It can contain $10^5$ t ton of water. The detention pond launches when the flows speed of Yihua road sewer come over 12cms. The entrance of detention pond connects to Chishan A main, and the exit connects to Yihua road sewer. The watershed is 100 ha.

3. Flood control capacity analyzing of Baoyeli detention pond

3.1. Selection of rainfall data

3.1.1. Analysis of rainfall frequency. According to the data [7], the rainfall frequency in Fengshan and Chenqing Lake is analyzed by generalized extreme value distribution as shown in Figure 1.

![Figure 1. IDF polyline of Fengshan and Chenqing Lake](image)

3.1.2. Selection of rainfall station and rainy event.

Selecting rainfall data of Fengshan Rainfall Station (No. 4, Yuanyi Lane, Wenshan Road, Fengshan District, Kaohsiung City), which is located in the watershed of the Baoyeli detention pond, and under jurisdiction of TCWB.

Collecting Taiwanese news and government reports, analyze the flooding of Chenqing road and the watershed of the Baoyeli detention pond, and selected the 2 hours and 24 hours during rainy event whose rainfall are largest. The data are shown in Table 1 and Table 2.
3.2. Before and after comparison of the construction of the detention pond

Table 1. Rainy event of 2 hours rainfall duration

| Rainy event  | Started time | Ended time |
|--------------|--------------|------------|
| Haitang 05   | 2005/7/19 6:00 | 2005/7/19 8:00 |
| Kong-rey     | 2013/8/29 8:00 | 2013/8/29 10:00 |
| Haitang 17   | 2017/7/30 23:00 | 2017/7/31 1:00 |
| 828 flood    | 2018/8/28 5:00 | 2018/8/28 7:00 |

Table 2. Rainy event of 24 hours rainfall duration

| Rainy event  | Started time | Ended time |
|--------------|--------------|------------|
| Haitang 05   | 2005/7/18 9:00 | 2005/7/19 9:00 |
| Kong-rey     | 2013/8/28 13:00 | 2013/8/29 13:00 |
| Haitang 17   | 2017/7/30 17:00 | 2017/7/31 17:00 |
| 828 flood    | 2018/8/27 20:00 | 2018/8/28 20:00 |

The rainfall data of 2 hours rainfall duration are shown in Table 3. And the data of 24 hours rainfall duration are shown in Table 4 and Figure 2. The larger average value of rainfall per hour showed the larger total rainfall. If the event has higher standard deviation and maximum of rainfall, it will have more concentrated rainfall time. Then we can know the rainfall type by analyzing these data.

In terms of short-rainfall-duration rainfall, according to Haitang 05, Kong-rey and Haitang 17, we can knew that facing of a rainfall which is not only short-term but also high-intensity, detention pond can effectively reduce the incidence of flooding. However, in terms of long-rainfall-duration rainfall, it can be found in the 828 flood, detention pond isn’t able to solve the long-term and high-intensity rainfall.

According to the design of the detention pond, the detention pond should at least tolerate of 72mm/hr, 5-year return period, for an hour. The rainfall of the 828 flood did exceed the capacity and caused flooding. However, Kaohsiung City Government [6] originally assessed that the detention pond could exceed a 50-years return period rainfall, 87.5mm/hr, for 2 hours. Because the happened of 828 flood, we can know the assessing is wrong.

It is also worth noting that the rainfall in Fengshan is different from that in Kaohsiung. In terms of rainfall in Fengshan, although the rainfall of 5-year return period is higher than that in Kaohsiung, Fengshan’s rainfall will be higher in 50-year return period. It is still unclear whether Kaohsiung City Government use of the rainfall in Kaohsiung as the standard for the design of the detention pond is right. In summary, the detention pond still has indeed improved the flood control capacity in research region.

Figure 2. Analysis of 24 hours rainfall duration

Table 3. Analysis of 2 hours rainfall duration

|               | Haitang 05 (Before) | Kong-rey (After) | Haitang 17 (After) | 828 flood (After) |
|---------------|---------------------|------------------|--------------------|-------------------|
| 1st hour      | 25.5 mm             | 28.5 mm          | 55.5 mm            | 44 mm             |
| 2nd hour      | 21 mm               | 42 mm            | 33 mm              | 77.5 mm           |
3.3. Analysis of 828 flood

When the watershed is smaller than 10 km$^2$, because rainfall duration will be longer than catchment basin, we can use rational formula:

$$Q = \frac{CIA}{360}$$

(1)

Q: Acre-inches/hour ($m^3/s$), C: Runoff coefficient (no unit), I: Rainfall Intensity (mm/hr), A: Area of watershed (ha)

Because research region are almost cover by concrete, and return period of 24 hours rainfall duration in 828 flood is over 10 years, according to the advice $[9]$, we chose 0.83 for runoff coefficient. The rainfall and hydrograph $[Q(t)]$ calculated by modified rational formula are shown in Figure 3. The catchment which is $V(t) = \int [Q(t)]dt$ is shown in Figure 4. The effect of detention pond on research region analyzed from runoff and catchment is shown in Table 5.

Table 4. Analysis of 24 hours rainfall duration

| Rainy event            | Haitang 05 (Before) | Kong-rey (After) | Haitang 17 (After) | 828 flood (After) |
|------------------------|---------------------|------------------|--------------------|-------------------|
| Average value          | 13.4 mm             | 9.3 mm           | 9.8 mm             | 16.8 mm           |
| Standard Deviation     | 7.6 mm              | 12.5 mm          | 14.1 mm            | 19.0 mm           |
| Maximum                | 30 mm               | 42 mm            | 55.5 mm            | 77.5 mm           |
| Rainfall Type          | Large, Dispersion   | Medium, Concentrative | Medium, Concentrative | Very Large, Concentrative |
| Flooding               | yes                 | no               | no                 | yes               |

Figure 3. The rainfall and hydrograph of 828 flood

Figure 4. The catchment of 828 flood

Table 5. The effect of detention pond under the ideal condition on flood in research region

| Flooding | Existence | Drain outlet                      |
|----------|-----------|----------------------------------|
| Detention| Existence | 1. No Flooding                   |
| pond     | Not Existence | 2. No Flooding                   |
|          |           | 3. 2018/8/28 02:00               |
|          |           | 4. 2018/8/27 20:00               |

3.3.1. The effect of detention pond in research region.

Table 5 show that, (1) If both Drain outlet and detention pond exist, since the runoff doesn’t exceed the allowable flow of the drain outlet, it will not cause flooding, and the detention pond will be activated at 2018/8/28 06:00 to control the flow of Yihua road sewer, letting the flow of the sewer be less than two-thirds of the allowable flow. (2) If only drain outlet existed, although it wouldn’t flood as stated in above, it will cause the flow of Yihua road sewer become 13.4 $m^3/s$ at 2018/8/28 06:00,
higher than two-thirds of the allowable flow. (3) If only detention pond existed, detention pond would be full at 2018/8/28 02:00, the 9th hours after the rain started, causing Flood. (4) If both Drain outlet and detention pond didn’t exist, it would be flood when the rain started. The above is in the condition of ideal. Actually, it flooded in Chenqing road at 2018/8/28 06:20 [8], He, Quan-feng indicated the flood swamped at 2018/8/28 09:00 [8]. It is different to the result we analyzed above, so it shows the hypothesis of the ideal condition may be wrong. The ideal condition above was the condition which is that Yihua road sewer was empty, but rainfall is continuous in everywhere, it not only rained in research region, but also rained in the watershed of Yihua road sewer, causing the run-off. So we conjecture that when the torrential rain first happened, namely, 2018/8/27 24:00, it was almost full at Yihua road sewer. Making the flow of Chishan A main line can’t release, launching the detention pond early. When the heaviest rain happened at 2018/8/28 06:00, detention pond was totally full, the run-off can’t release by Yihua road sewer and became overland flow. Because the evaluation [8] also supposed that Yihua road sewer were empty, it will overestimate the flood control capacity of detention pond. In conclusion, although it flooded at 2018/8/28 06:20, according the analysis above, if detention pond hadn’t been exist, it would have flooded at 2018/8/27 24:00. It showed that detention pond shortened the time that flooding affected users, and reduced the damage in research region. And the return period of 24 hours rainfall duration in this rainy event is 15 years, it has exceed the design guidelines that is 5-years return period.

4. The opinion of the detention pond’s users and the ordeal of detention pond

This chapter is divided into five main sections, each of which presents the results relating to flooding or detention pond. To understand the cognition of the detention pond’s users on flood controlling, we interviewed the Chief of Baoye Village, Mr. Lin Huan-ran, in 2018/12/7. To obtain the reliability, we wrote interview transcript before analyzing, and confirming with the interviewee whether the analysis of the results is different from what he want expressed.

4.1. The experience of flooding

According to what interviewee said, the relief of Baoye Village, where detention pond located in, is higher than others. “The flooding came from Benyang Village, then Yihua road and, Juemin road and Chenqing road” he said. Different from the neighbourhood, it won’t flood in village when the rain isn’t heavy. He also said that some stores in village have floodgates because of the flooding in their basement. In the case of 828 flood, there is no residents apply the subsidy for flood, it didn’t cause the catastrophe, only caused 10cm depth puddle on road. However, interviewee also said, “Benyang Village and Wende Village flooded”, the detention pond was originally designed to solve the flooding problem of Chenqing-Yihua intersection, and Chenqing-Yihua intersection is located in Benyang Village.

4.2. The cognition of flooding

When we talked about the definition of flooding, interviewee told author, “Flooding is that water comes up to sidewalk, and comes into houses, if it doesn’t come into houses, I call it puddle”. He considers that whether flood or not shouldn’t be decided by flooding depth, it should be decided by the risk to people's life and property. He also pointed out, it’s important to dredge the ditch usually to prevent flooding, and he thought the possibility of a flood like 828 flood happen in future is very high.

4.3. The cognition of detention pond

When the detention pond was planned to be built, interviewee campaigned for the Chief of Baoye Village. Interviewee said, “I agreed to the construction of detention pond at that time, but the ex-chief disagreed to this.” He also said, “The ex-chief thought that flooding is more severe in the nearby
village, but it didn’t cause large damage in our village. If the detention pond is built in our village, it will make our village flood.”

As explained earlier, same as the people who don’t know the operation of detention pond, the ex-chief thought detention pond is a facility which helps others at ours own expense, and then protest the building. For this, interviewee also said that Kaohsiung City Government has hosted a seminar, and invited residents for joining the seminar. From the previous discussion, it can be seen that Kaohsiung City Government has received the objection of residents, and propagandized the functions and concept of detention pond to residents.

During the interview, interviewee emphasized constantly that the construction of detention pond will not make the flooding severe, also, it is impossible that water overflow from detention pond. He said, “All of residents in our village know that detention pond won’t make flooding severe, unlike those media.” He also knew detention pond’s function is adjusting or detaining the flood, Detention pond can’t completely put an end to flooding, but reduce the probability of flooding. As explained in this section, it is clear that the advocacy to residents which has done by Kaohsiung City Government is effective.

4.4. The expectation of detention pond

Interviewee said, “The residents in village hope detention pond is also a park in ordinary.” Due to this, the detention pond was designed to construct some versatile facilities additionally, for example, open-air wooden stands and cement trails. The open-air wooden stands were used for holding open-air concerts originally, but interviewee thought the relief around the open-air wooden stands is uneven, so it is unsuitable for holding open-air concerts. He also told the author with a little worry, building cement trails is a good intention originally, however, because the underground water level in the detention pond is a little high, it possibly appears moss due to humidity, it is a potential danger to walker when the moss doesn’t be removed immediately. Furthermore, since the water in the detention pond is the sewage on the road, if we let residents immediately enter detention pond when clearing up, it may cause health concerns. Returning briefly to the subject of constructing versatile facilities, although interviewee thought these facilities caused some problems on management or using, he still agreed to take detention pond as park in ordinary.

During the interview, interviewee showed the confidence in flood control of detention pond repeatedly. He said, “Everyone said detention pond is good, because they (the residents) has compared, it didn’t flooded during the heavy rain after detention pond has been constructed.” He also said, “Actually, in the villages where flooded, the chiefs are stressful. So they also want the second detention pond can be constructed.” Interviewee thought the budget which Kaohsiung City Government has spent on detention pond is still not enough.

4.5. The dilemma of detention pond

This section discusses the findings which emerged from the analysis presented in the previous sections and previous chapter. After detention pond has been built, the residents in watershed think flooding is decrease. Most of residents have correct concepts of detention pond. In addition, despite detention pond can help the drainage system become more efficient, detention pond still has a fatal flaw, it will flood when the detention pond has been filled with water.

Hence, we consider detention pond is an expedient measure base on the considering funds and the effectiveness, it can be revealed by a comparison of budget spent on detention pond and other flood controlling facilities. Taipei area flood control plan which started from 1960 has spent over sixteen hundred billion New Taiwan Dollars, although it has spent such much money, its return period still less than 200 years [10], it even still flooded in Taipei after the plan has been executed completely. And Kaohsiung City even larger than Taipei City, to achieve the flood control effectiveness now, Kaohsiung City Government only spent sixty point eight billion New Taiwan Dollars. Under the condition of considering inflation, budget spent by Taipeiese is more than thirty times as many as
budget spending on detention pond in Kaohsiung. Thus, we consider constructing detention pond is very economical.

5. Conclusions

5.1. It’s important to consider the continuity of rainfall on space when we are doing hydrologic analysis.
When we are doing hydrologic analysis, not only the rainfalls inside watershed but also the rainfalls outside watershed cause runoff, and this runoff makes the allowable flow decreased. Therefore, if the continuity of rainfall on space is neglected, the capacity of flood discharge and detention will be overestimated.

5.2. Detention pond is efficient to make up for the weaknesses in the drainage system.
Detention pond can solve the flood in small region effectively, and helps the drainage system become more efficient. Also, because of its low cost, it is suitable for constructing in areas which don’t have so many budgets. However, detention pond can’t work well without other facility, like drain outlet. It still will flood when detention pond has been filled with water, thus, detention pond’s improvement of the whole flood control capacity of the drainage system is limited. The case study in Kaohsiung City reveals that drain outlet is more important than detention pond, and the function of detention pond is affected easily by underground water level and relief. Hence, under the situation of unlimited budget, if we want to do long-term planning, drainage system should be upgraded comprehensively to keep sewer expedite. Only in the case which allowable flow of sewers are not allow to be improved due to budget or other factor, detention ponds are used for flood controlling.

5.3. Government needs to outreach policies to solve misunderstanding of public on infrastructures.
People may resist new infrastructures or systems, this phenomenon should be improved through the publicity of government. However, government shouldn’t outreach policies unilaterally to public, but commutating with people to understand the reasons why they opposite, and trying solving the reasons. Also, if the infrastructures or systems have significant positive results after implementation, people will eager to accept these infrastructures and systems, even support it to keep implementing.

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