Influence of Seawall Line Choice on Tide Lock Drainage in Tidal Flat Inning

—— Cangdongpian Inning Area on the west part of Tiaozini Sand as a case study

LI Jialin [1], WANG Yanhong [2], ZHANG Renshun [3]

1. *Institute of Human Inhabiting Environment, Ningbo University, Ningbo* 315211*, Zhejiang, China*

2. *River and Harbor Department, Nanjing Hydraulic Research Institute, Nanjing* 210024*, Jiangsu, China*

3. *Institute of Ocean and Coastal Wetland, Nanjing Normal University, Nanjing* 210097*, Jiangsu, China*

Abstract: Most of the flood from the wide inner lowland plain discharges through tide locks on coast, and the influence of tidal flat inning projects on the tide lock drainage must be solved by seawall line choice. Taking the Cangdongpian inning area on the west side of Tiaozini Sand as a case study, the paper analyzed the compages and validity of ebb tide water to maintain the flood discharge creek below the tide lock for different projects of seawall line. Result indicates that a rational seawall line program has little influence on the flood discharge of lock during the mean tide or general spring tides, but has certain influences during a storm surge or an extreme spring tide in autumn. However it could be resolved by several times of artificial scour on the creek.

Keywords: tidal flat; inning; tide lock; discharge; influence

Introduction

The Jiangsu coast with a total length of 954km is located on the middle west of Huanghai Sea (Yellow sea) between the Shandong Peninsula and Changjiang River (Yangtze River) mouth. Its tidal flat is very wide and most of that is gradually growing. Reclamation of tidal flat has a buffer function on the cultivated land decrease, and it is very important to the balance of total amount of cultivated land. Flood discharge from the wide lowland plain behind the mud coast mostly depend on tide locks on seacoast, and the influence of tidal flat inning project on tide lock drainage should be solved through seawall line choice. Unsuitable seawall projects could enhance sedimentation in creeks below the tide lock, weaken the flood drain function of tide lock and accelerate abandon of tidal lock. Take Cangdongpian inning area on the west part of Tiaozini Sand as a case study, the paper analyzed the influence of seawall line choice of inning project on compages and validity of ebb tide water to maintain the flood discharge creek below the tide lock for different projects of seawall line.

1 Regional background and choice of seawall line for different designed inning projects

After the northward shift of Yellow River in 1855, Jiangsu coast no longer had abundant sediment

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supply and the erosion-deposition condition of the Radiate Sand Ridges changed rapidly. Tiaozini Sand is just located in the inner part of the well-known offshore Radiate Sand Ridge area. Due to the special dynamic sedimentary condition, the East China Sea advancing tidal waves from south to north converge with the South Yellow Sea rotary tidal waves from north to south (Fig.1), and the development of tidal creek systems and tidal basins is very sensitive to the hydrodynamic changes [1].

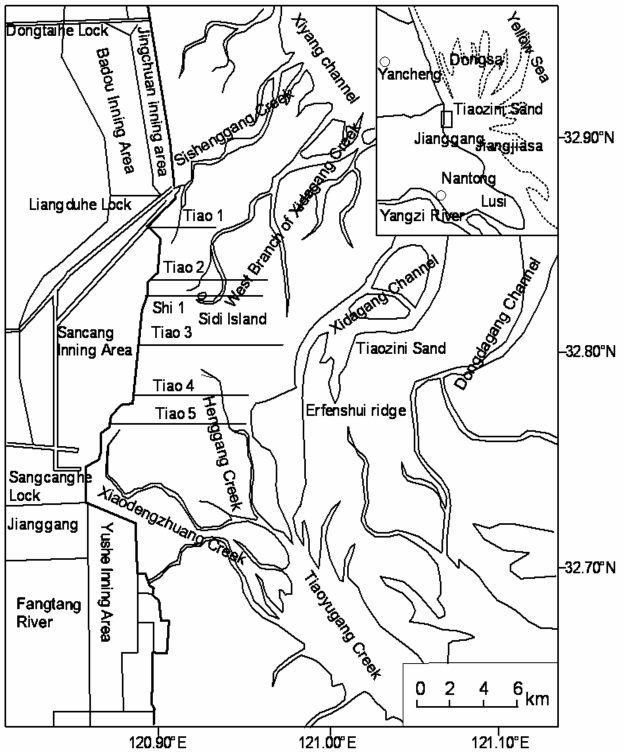

Fig. 1 The location of study area (According to Jan.2003 TM image)

The study area, western part of Tiaozini Sand, is connected with the Sancang inning area reclaimed in 1997 (Fig.1). Tidal current is complicated and strong in the area, and the tidal range increases gradually from north to south. And tidal basin systems are well developed on the tidal flat. The Liangduhe tide lock, built in the 1970s, is one of the most important locks in Dongtai County. It protrudes from the old embankment that was built in 1958. Flood from the lock could reach the outside tidal channel by a short creek of Sishenggang, added up with the frequent artificial scouring to the downstream creek, the lock ran favorably in the past decades. Besides, there developed a tidal creek named Erfenshui between the nearshore flat and the Tiaozini Sand before the 1980s. The creek ran approximately parallel to the coastline before the 1980s. The creek was connected southwardly with the Xiaodengzhuanggang creek outside of Jianggang and northwardly with the Sishenggang creek. Width depth of the cross section of waterway of the creek could reach more than 2.5 km and 0.9 m during spring tide at that time, however 2.0 km and 0.7 m during normal tides, respectively. During a spring rise and ebb circle, 0.1012×10^8 m^3

water volume flowed over the ridge of Erfenshui from south to north, and 0.030 2×10^8 m^3 during a neap tide[2,3]. The water entered the Sishenggang creek and played important roles in maintaining the flood discharge capacity of the Liangduohe tide lock.

From 1999 to 2003, elevation and topography of 5 sections in the study area were investigated, 15 times altogether. Based on the analysis of the investigated data and 11 remote sensing images (MSS, TM and ETM) since 1980, developing tendency of mean high water line on the tidal flat, formation process of the sand island (Sidi island) and development of tidal creeks near Tiaozini Sand are discussed. Meanwhile, relationship between flat elevation of seawall line and water level of tidal characteristic numbers, west-moving boundary of Xidagang and Henggang creeks, ecological influence of inning on the original salt marsh, integrated benefits of inning project and so on are studied as well. Based on these studies, three candidate inning projects of seawall line were designed, for analyzing the influence of tidal flat inning on the drainage of Sishenggang creek below tide lock (Fig.2).

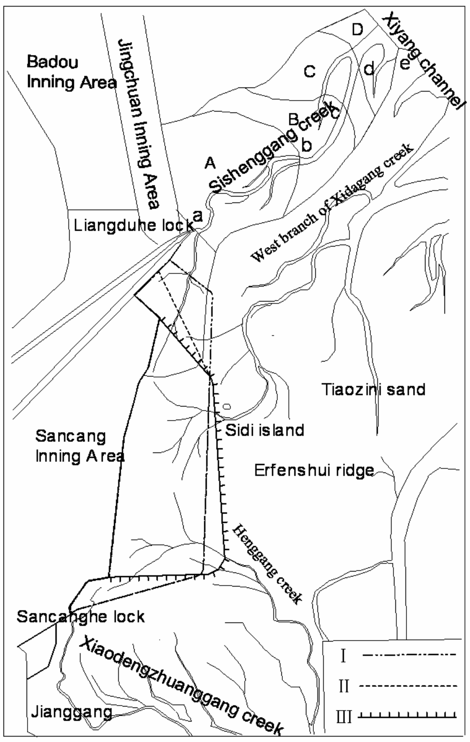

Fig. 2 The sea wall line of inning programs

2 Tidal creek system on the study area and subsection of the creek below Liangduhe tide lock

Cangdongpian inning area is between Liangduohe tide lock and Sancanghe tide lock. Creek systems on the tidal flat are mostly branches or tips of the tidal creek systems that belong to the tidal basins of Sishenggang, west branch of Xidagang, west branch of Henggang and Xiaodengzhuanggang.

Sishenggang tidal basin, located in the north part of the flat, discharge flood from Liangduhe River and a thin layer of tide water on tidal flat into offshore channel on the north Cangdongpian flat during the later ebb phase. West branch of Xidagang creek extends westward into the planned inning area from the south of Sidi Island and forms a tidal basin. It discharges tide water in the middle part of the planned inning flat to the Xiyang channel. The west branch of Henggang creek and Xiaodengzhuang creek extend into the planned inning flat from south-east and south, respectively. Tide water in the east and south parts of the flat flows by into the Tiaoyugang creek in this tidal basin.

Expect some tidal creeks and their vicinities, the surface elevation of the planned Cangdongpian inning area flat is mostly higher than the mean high water level. The planned seawall line will cut the branch creeks of Sishenggang, Xidagang, West Henggang and Xiaodengzhuanggang main creek. Consequently, the ebb tide water volume of these creeks will decrease.

Original tidal creek systems are usually selected as waterways for flood discharge from the plains behind tide locks. The creek could be divided into three stretches from tide lock to tidal channel or open sea. [4] Usually, the upper stretch means the artificial creek section or the section located on the supra-tidal flat. This stretch is similar to a river. Because the boundaries are restricted by artificial banks or high supra-tidal flats, the waterway is generally stable and straight. The lower stretch has developed on the lower inter-tidal flat, and has no stable banks. Because of the complexity of tidal current and wave on lower flats, the creek is generally wide and shallow. It can move widely on the flat. The middle stretch, on high inter-tidal flat, generally has an obvious trough. Because of the binary structure of sediment layers on the tidal flat, the creek is usually bended there. The flood discharging rivers in Jiangsu province, such as Xingyanggang River, Doulonggang River and Dongtai River usually develop more than one bend below tide locks, the waterway could even choose a short cut when the creek is deeply bended. The creek below tide lock is obviously affected by bidirectional hydrodynamics, landward and seaward. The upper stretch is mainly controlled by the runoff from the tide lock while the lower stretch by tidal current and wave dynamics. The middle stretch is a transitional part that is affected by land-ocean interaction greatly.

Based on results of flat elevation survey and interpretation of remote sensing images, subsection of the creek below the Liangduohe tide lock was divided as in Fig. 2. The upper stretch, from north and south tide locks of Liangduhe to the juncture (point a) of artificial waterways, has concreted banks, with lengths of 0.65 and 0.68 km, respectively. From the point a to the point b is the middle stretch, located on the middle part of the upper inter-tidal flat with a length of 5.1 km. From the point b to the point e is the lower stretch, on the lower part of inter-tidal flat with a length of 5.3 km.

3 Influence of various seawall line programs on the water mass supplied to the creek below the Liangduhe tide lock

As tidal waves spread from the lower section to the upper one along the gutter, stationary waves will come into being. Furthermore, the sedimentation process of silt carried by tidal waves has an obvious sediment delay effect on the tidal flat. Sediment will enrich near the tide lock gate and only the ebb tide current can transport it to sea. Otherwise, the drain flow below tide lock will not smooth. Water mass supplied to the creek below the Liangduhe tide lock is composed of the tidal current from the South Tiaozini ridge which traverses over the ridge of Erfenshui and flows into the Sishenggang creek, the river discharge from north and south tide locks of Liangduhe river, the intertidal storage volume of anthropical river below tidal lock, the thin layer of tide water on the tidal flat in the later ebb phase and storage volume in the creek system of Sishenggang tidal basin, et al. Tidal flat reclamation will change the volume of ebb water to the creek.

3.1 Composition and change of water volume to the creek below the Liangduohe tide lock

3.1.1 Tide water flow over the ridge of Erfenshui from south to north

As mentioned above, tide water traversing over the ridge of Erfenshu from the south has played an important role in maintaining the flood drain capability of the creek below the Liangduohe lock. Recently, due to large-scale deposition and accretion of the tidal flat, the Erfenshui creek was filled gradually. In the early 1980s, the frequency of traverse of tide water over the ridge of Erfenshui from south to north is about 20 days per month. However, in the early 1990s, it was only about 6 to 7 days per month, and the water valume decreased little by little with silting of the creek. In October 1999, the width of Erfenshui creek was only about 350 meters. And the elevation of Erfenshui creek bottom was 3.45 meters, higher than the mean spring high water level. This indicated that there was almost no tide water to the Sishenggang creek from south of Erfenshui Ridge, even during the spring tide. The flat 4 000 meters outside the seawall is lower than the mean spring water level. But the tidal water that traversed over the ridge flows into the Xidagang main channel directly or by west branches of Xidagang creek, rather than by the Sishenggang creek. Consequently, it made no contribution to the capability of flood drain of Sishenggang creek. Profile survey of Tiao4 in the past years showed that the Erfenshui creek was shrinking slowly. In Jan., 1999, the Erfenshui creek was about 1 500 meters wide on the profile, and seemed wider in the summer of 1999. But it was connected with the Xiyang channel directly, rather than by the Sishenggang creek. The elevation of the creek bottom was mostly higher than the mean spring water level and there was no tidal current at average tides in 2001. It means there was almost no tidal water traversing over the ridge of Erfenshui to the Sishenggang creek after 2001. So the seawall line choice project does not need to consider the influence of tidal water which traversed over the ridge of Erfenshui to the Sishenggang creek.

3.1.2 River discharge

The north and south tide locks of Liangduhe River were built in 1972 and 1983, respectively. Based on the statistics of hydrologic data in the past years, the yearly average water discharge of the two locks, the water discharge in the flood and dry seasons, the each tidal circle water discharge on the average during flood and dry seasons were calculated respectively (Tab. 1).

3.1.3 Tide water storage volume of the creek below the Liangduhe River tidal lock

Based on the analysis of tide data below the Liangduhe river tide locks, levels of mean high tide, mean high spring tide, autumnal extra high spring tide and high water of storm surge are 2.62 m, 3.00 m, 3.50 m and 4.00 m, respectively. Tide water storage volume of the creek downstream of south and north Liangduhe tidal locks can be calculated as follows:

$$V = (A_1 + A_2) \cdot L \cdot h / 2 \quad (1)$$

Where V is the volume of tide water storage in the tidal creek; A_1 and A_2 are the breadths of the creek at mean low water and high water respectively; L is the length of the creek; and h is the corresponding tide range.

Tab. 1 Water discharge of Liangduohe River

Items	Yearly water discharge on the average / 10^8 m^3	Water discharge in flood seasons on the average / 10^8 m^3	Water discharge in dry seasons on the average / 10^8 m^3	Water discharge per tide circle / 10^5 m^3	Water discharge in flood seasons per tide circle / 10^5 m^3)	Water discharge in dry seasons per tide circle / 10^5m^3
North lock	1.95	1.38	0.57	2.79	5.98	1.21
South lock	1.59	1.12	0.46	2.26	4.85	0.98
Total	3.53	2.5	1.03	5.05	10.83	2.19

Then the volume of tide water storage in the tidal creek below Liangduhe River tide locks at different water levels could be calculated. The results are shown in Tab. 2.

Tab. 2 Storage volume of anthropical river below Liangduhe River tide locks at different tidal water levels / 10^5 m^3

Tide level	Mean high water	Mean high water line of general spring tide	Mean high water line of spring tide in autumn	High water line of storm surge
Storage volume of tide water	1.14	1.42	1.68	1.97

3.1.4 Water mass supplied to the creek at middle and nether parts of creek below Liangduhe river tide locks

Water mass supplied to the creek at middle and nether parts of creek comes from the water mass on the tidal flat between the Chuanlonggang creek system and the south branch of Xidagang creek system. According to the analysis of TM image (January 2003) and survey on the topography of tidal flat, the tidal flat of the nether part of Sishenggang creek system is disported into 4 sections. There are parts A, B, C and, the part D where water mass flows into the inlet of Xiyang Channel (Fig.2). The area of tidal flats and water volume per tide were calculated as in Tab. 3.

Tab. 3 Flats area and water volume per tide at middle and nether parts of Sishenggang creek

section	A	B	C	D
area / km^2	10.56	3.10	12.82	3.48
water volume / 10^5 m^3	10.56	3.10	12.82	3.48

* Depth of water mass supplied creek is regarded as 10 centimeters because the tidal flat is almost all bare.

3.1.5 Loss of tide water storage volume caused by reclamation

The tail of Sishengang creek to the south of Liangduohe tide lock has shrunk gradually in recent decades. About 2.0 km^2 of high flat on both sides of the creek is out of the reach normal tide water inundation, and the *Imperata cylindrical var.major* community has become the main vegetation. The other 5.5 km^2 high flat has been densely covered by *Spartina alterniflora* and *Suaeda salsa*. Tide water from the flat could only supply the Sishengang creek during spring tide.

The project of reclamation will cut the upper and middle reaches of the Sishenggang creek. It may cause decrease of water storage volume of it. 2.05 km, 1.15 km and 0.55 km of the Sishengang creek with average widths of 30 m, 20 m and 15 m will be cut in the programs Ⅰ, Ⅱ and Ⅲ, respectively. Therefore, loss of water volume of Sishenggang creek caused by reclamation could be calculated. The results are shown in Tab. 4.

Tab. 4 Loss of water volume of Sishenggang creek caused by inning

Program	Ⅰ	Ⅱ	Ⅲ
High water level of storm surge	1.15×10^5 m^3	0.36×10^5 m^3	0.17×10^5 m^3
Mean high water line of autumnal spring tide	0.84×10^5 m^3	0.25×10^5 m^3	0.11×10^5 m^3
Mean high water line of general spring tide	0.54×10^5 m^3	0.13×10^5 m^3	0.06×10^5 m^3
Mean high water line	0.30×10^5 m^3	0.05×10^5 m^3	0.01×10^5 m^3

Because the elevation of most of the tidal flat in the planed reclamation is higher than the mean high water of spring tide, the water volume loss could only occur during spring tides, autumnal spring tides and storm surges. The inundated area by storm surge is regarded as the whole reclaimed area, that by the autumnal spring tide as the area of the dense *Suaeda salsa* community distributed, and that by normal spring tide as area of the sparse *Suaeda salsa* community. There is no water mass supplied to the creek at the mean high water line in all the three programs. Tide water loss caused by different programs is shown in Tab. 5.

Tab.5 Tide water loss caused by the reclamation for different programs

Program	Ⅰ	Ⅱ	Ⅲ
Storm surge	2.32×10^5 m^3	1.92×10^5 m^3	1.01×10^5 m^3
Autumnal spring tide	1.67×10^5 m^3	1.43×10^5 m^3	0.75×10^5 m^3
Spring tide	0.30×10^5 m^3	0.13×10^5 m^3	0.06×10^5 m^3
Mean high water line	0	0	0

* Depth of water mass supplied to the creek of *Spartina alterniflora* and dense *Suaeda salsa* flats is regarded as 15 cm, depth of water mass supplied to the creek of sparse *Suaeda salsa* and bare flats is regarded as 10 cm.

3.1.6 Newly added rainfall supplied to the Sishenggang creek

Currently (before reclamation), the tidal flat of the planed reclaimation area belongs to tidal basins of Sishenggang, west branch of Xidagang, Henggang and Xiaodengzhuanggang. Precipitation on the tidal flat is shared by all the tidal basins. After reclamation, all precipitation in the area will be supplied to the Sishenggang creek through an artificial water lock. About 70 % of annual precipitation in Dongtai County occurs during rainstorms that could form water flow on tidal flat. The runoff rate of rainstorm on the supra tidal flat is regarded as 0.7. Other rains hardly have runoff yield due to quick infiltration. So the newly added rainfall supplied to the Sishenggang creek could be calculated as in the equation (2).

$$Q = (M_1 - M_2) \cdot U \cdot 0.7 \cdot b \qquad (2)$$

Where Q is the added rainfall water mass supplied to the Sishenggang creek. M_1 is the reclamation area. M_2 is the area of Sishenggang basin that will be enclosed. U is the annual precipitation of the study area. b is the runoff rate of rainstorm on supra tidal flats (the value is 0.70).

Based on the equation (2), the newly added rainfall for the programs Ⅰ, Ⅱ and Ⅲ could be calculated. It is 0.28×10^5, 0.275×10^5 and 0.27×10^5 m^3, respectively.

3.2 Validity of water mass supplied to the creek to maintain the drain capability of creek below tide locks

Because of the difference of position, time, water volume and sediment concentration, various water masses supplied to the creek play different roles in maintaining the drain capability of creek below the tide lock. Generally, nearer to the tide lock, stronger the water scouring capability is. So the rain discharge from tide locks and the water storage volume in the artificial river are the most valid water masses to maintain the drain capability of creek. Water mass supplied to the creek in the outlet of the creek is of no avail for maintaining the drain capability of the creek. Because many variables are involved, it's hard to quantitatively estimate the validity currently. In this study, only the position and validity of water mass supplied to the creek are considered, and the linear equations of (3), (4) and (5) are employed.

$$\alpha_i = L_i / L \qquad (3)$$

Where α_i is the coefficient of validity to maintain the drain capability of the creek water depth. L_i is the length of creek from the entrance to the outlet of the creek. L is the length of Sishenggang creek.

$$B_i = \alpha_i \cdot V_i \qquad (4)$$

Where B_i is the validity of water mass supplied to the creek. V_i is the amount of water mass. And i is the number of water mass supplied to the creek.

$$P_i = B_i / \sum_{i=1}^{n} B_i \qquad (5)$$

Where P_i is the contribution rate of water mass supplied to the creek.

Based on the equations (3), (4) and (5), we can calculate the contribution rate of water mass supplied to the creek to maintain drain capability of Liangduhe creek. The results are shown in Tab. 6.

Tab. 6 Water volume and contribution rate to maintain the drain capability

Item	Rainfall discharge	Storage volume of artificial river	Storage volume of Sishenggang creek and tidal flats	Newly added rainfall	A	B	C	D
α_i	1	1	1	1	0.608	0.526	0.12	0
V_i Program Ⅰ	5.05	1.97	3.47(storm surge)	0.28	10.56	3.10	12.82	3.48
		1.68	2.51(autumnal spring tide)					
		1.42	0.84(spring tide)					
		1.14	0.30(mean high water)					
V_i Program Ⅱ	5.05	1.97	2.28(storm surge)	0.275	10.56	3.10	12.82	3.48
		1.68	1.68(autumnal spring tide)					
		1.42	0.26(spring tide)					
		1.14	0.05(mean high water)					
V_i Program Ⅲ	5.05	1.97	1.18(storm surge)	0.27	10.56	3.10	12.82	3.48
		1.68	0.86(autumnal spring tide)					
		1.42	0.12(spring tide)					
		1.14	0.01(mean high water)					
P_i Program Ⅰ	24.80	9.70	17.00(storm surge)	1.40	31.50	8.00	7.60	0
	26.40	8.80	13.10(autumnal spring tide)	1.50	33.60	8.50	8.10	0
	29.40	8.30	4.90(spring tide)	1.60	37.30	9.50	9.00	0
	30.90	7.00	1.80(mean high water)	1.70	39.20	10.00	9.40	0
P_i Program Ⅱ	26.40	10.30	11.90(storm surge)	1.40	33.50	8.50	8.00	0
	27.60	9.20	9.20(autumnal spring tide)	1.50	35.10	8.90	8.50	0
	30.40	8.60	1.60(spring tide)	1.70	38.70	9.80	9.20	0
	31.40	7.10	0.30(mean high water)	1.70	39.90	10.10	9.50	0
P_i Program Ⅲ	28.00	10.90	6.50(storm surge)	1.50	35.60	9.00	8.50	0
	28.50	11.10	4.80(autumnal spring tide)	1.50	36.20	9.20	8.70	0
	29.70	11.60	0.70(spring tide)	1.60	37.80	9.60	9.00	0
	29.90	11.70	0.06(mean high water)	1.60	38.00	9.70	9.04	0

* A, B, C and D are four sub-basins which supplied middle and lower reaches of Sishenggang creek.

Analysis of Table 6 shows, the amount of water mass that is supplied to the creek is the largest part of all water items. Its contribution rate to maintain the drain capability of Sishenggang creek is more than 45%, though its validity is lower. The contribution rate of rain discharge and storage volume of anthropical river is more than 30% too. The contribution rate of water volume of storage volume of Sishenggang creek and water mass of tidal flats is ranging from in 0.06 % - 17.00 % at different programs. The contribution rate of newly added rainfall will change in 1.40 % - 1.70 %.

Different programs could only cause the change of water volume of storage water mass of Sishenggang creek, the tide water on tidal flat in the later ebb phase and the newly added rainfall. Other items will not change. So the influence of different inning projects on the drain capability of Sishenggang creek can be regarded as the difference between water volume of storage volume of Sishenggang creek, water mass of tidal flats and newly added rainfall. The results are showed in Tab. 7.

Tab. 7 Influence on the drainage of Liangduo tide lock caused by reclamation

Tide level	Storm surge	Autumnal spring tide	Spring tide	Mean high water
Program Ⅰ	15.6%	11.6%	3.3%	0.1%
Program Ⅱ	10.5%	7.7%	-0.1%	-1.4%
Program Ⅲ	5.0%	3.3%	-0.8%	-1.54%

Because the elevation of tidal flats in the inning area is higher than the high water line of spring tide, the seawall line choice of project Ⅰ almost has no influence on the drain capability of Sishenggang creek. The influence is only 0.1 % and 3.3 % at the mean high water line and high water line of spring tide. In the programs Ⅱ and Ⅲ, seawall line choice is beneficial to maintaining the drain capability of Sishenggang creek because loss of water volume of upper and middle parts in the Sishenggang basin will be very little and the rainfall in middle and south parts of inning area will flow into the Sishenggang creek.
During storm surge and autumnal spring tide, the influence of inning project on the drain capability of Sishenggang creek is notable. The decreases are 15.6 % and 11.6 % in Program Ⅰ, 10.5 % and 7.7 % in Program Ⅱ, and 5.0 % and 3.3 % in Program Ⅲ respectively. The frequency of the water level higher than 3.0 m is 7 % (47 times one year), higher than 3.5 m in the autumnal spring tide is 1 % (6 or 7 times one year). And 4.0 meters in the storm surge is 0.1 % - 0.3 % (1 or 2 times one year). Therefore, the influence on the drain capability by the inning project could be resolved by some times of artificial scour.

3 Conclusion and discussion

Based on the analysis of the influence of different inning programs on the drain capability of Sishenggang creek, it is concluded that inning of supra tidal flats will only cut part of storage volume of the upside Sishenggang creek at the mean high water line. The decrease of water volume is quite notable during spring tide, autumnal spring tide and storm surge. It may cause silting at the Sishenggang creek below Liangduhe tide locks. Because the possibility of very high water is low, the settled sludge can be scoured artificially. Therefore, the program Ⅲ is considered to be the most reasonable one. That is to say that reasonable seawall line choice may decrease the influence and maintain the drain capability of creek below the tide lock with current technology.

Due to the difference in the position and time of water mass flow to the creek, and water volume and sediment concentration of different water masses, various water masses supplied to the creek play different roles in maintaining the drain capability of creek below tide locks. In this study, we only consider the position and validity of water mass supplied to the creek and uses the linear equation to calculate it. In addition, inning of supra tidal flats would not cause adjustment of the equilibrium state in tidal flats, but the twig of tidal creek may be cut off and the area of tidal basin will decrease. It may change the hydrodynamics and sediment condition of tidal flats and cause shift of creek below the tide lock. These studies should be strengthened in the future.

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滩涂匡围海堤选线对邻近涵闸排水的影响分析

——以条子泥西侧岸滩仓东片匡围为例

李加林[1]，王艳红[2]，张忍顺[3]

(1. 宁波大学人民环境研究所，浙江 宁波 315211；2. 南京水利科学研究院河流海岸研究所，江苏 南京 210024；

3. 南京师范大学海洋与滩涂研究所 江苏 南京 210097)

摘　要：淤泥质海岸后方大面积的低地平原主要通过海岸上建设的涵闸排水，潮滩匡围对沿海涵闸排水的影响是围垦工程必须解决的问题。文章以条子泥西侧岸滩仓东片匡围为例，探讨了不同堤线方案下邻近闸下流槽各种落潮水量组成及其维护闸下排水能力的有效性。结果表明，合理的滩涂匡围堤线方案，在平均潮汛及一般大潮汛时对邻近闸下排水能力影响较小，而在风暴潮或秋季大潮汛时有一定影响，但可以通过若干次冲淤保港来解决。

关键词：滩涂;匡围;涵闸;排水;影响