

CHAPTER 67

SHORE PROTECTION ON THE COAST OF "YAIZU"

Goichi Seo and Tatsuma Fukuchi
Director of Fishing Port Division, Fisheries Agency, Tokyo,
Japan and Deputy Chief of Fishing Port Planning Section, Ditto

ABSTRACT

This report describes the history of beach erosion and the countermeasures against it extending over the last few centuries on the coast of "YAIZU" Fishing Port. It also includes a study on the causes of erosion by analysing geographical, topographical and oceanographical conditions of the coastal area.

INTRODUCTION

"YAIZU" is one of the greatest fishing ports in Japan. It has been developed by fishing from the ancient days and today it has grown into an important base of pelagic fishing in our country. The area stretching out long and narrow along the coast line is concentrated by many residences, fish-processing plants, shipyards and other essential facilities. The dyke, length of 1,600 m running along the coast line, protects these facilities from natural sea disasters. This dyke, however, since the beginning of its construction, was subjected to damages many times, through severe waves and beach erosion, and human lives, assets and properties were often be endangered. The residents have paid great attention and made large efforts to maintain the dyke. Before 1939 when "YAIZU" Fishing Port was provided with the existing dock for large-size vessels, there was a wide beach in front of the dyke and the daily catch was sold on this shore. But today we can see only tidal water washing directly on to the foot of the dyke. (See Fig-1)

GEOGRAPHICAL AND TOPOGRAPHICAL CONDITION

GENERAL

"YAIZU" is on the west coast of "SURUGA" bay which is located in central Japan on the Pacific Ocean coast. The bay (as shown in Fig-2), outlining a V-shape coast line, is about 70 km long from the mouth to the base, being about 50 km wide at the mouth and about 20 km at the base. The water depth in the bay is very deep and the contour-line of 1,500 m deep goes to a distance of only 15 km from the coast near the foot of the bay. The four big rivers, "KANO", "FUJI", "ABE" and "OI" pour into the "SURUGA" bay and form alluvial plains respectively at their estuaries. Among them, the River "OI" spreads her low, flat and fertile plain out of her down-stream zone called "SHIDA" plain. The residential district of "YAIZU" locates near the northern part of this plain. At about 2.5 km south from "YAIZU", another fishing Port named "KOKAWA" is now being constructed. (See Fig-2)

CREATION OF THE "SHIDA" PLAIN

The northern part of "SHIDA" plain is a hill, mainly consisting of hard mudstone layers which are thought to be Tertiary deposit. The heights located on the west side of the plain are composed of alternate substratum of sandstone and clay rock. These layers, as they are newer than the former, are surmised to be Tertiary deposits of Cenozoic incipient. In the south west section, there is a plateau called "MAKINOHARA". It is covered by thick gravel and this fact shows that it was once a shallow sea which resulted from subsidence of Tertiary deposits, running-down from the River "OI", and finally resulted in its upheaval. It is, therefore, deduced that the extension bed of those Tertiary deposits lie under the plain. According to some boring data obtained from the plain, the depth of the bed stratum is shallow on the west part but goes more than 100 m deep on the shore side. It is, therefore, surmised that long ago (probably in the first alluvial age) the plain used to be an embayment of the sea and deposits from the River "OI" made the alluvial fan.

When rivers, flowing down from the mountains, meet an gradual gradient on the plain, they generally begin to deposit material they have conveyed and that results in silting of the river bed. Thus, the annual flooding easily changes the courses of the rivers, forming a net-work of streams and repeated floods which run over the delta make the conical flat fan. The River "OI" fan seems to have been generated in the same way. It draws about a 25 km circular arc between "YAIZU" and "YOSHIDA" on the coast line with its starting point near "SHIMADA". Ground level is 50-60 m high above sea level near "SHIMADA", 15 m high at the west end of "YAIZU", and about 3.5 m high at the residential area near the coast. The stratum composes alternate layers of cobble stone, gravel, sand and clay. It comprises of more gravel as it gets closer to the apex of the fan and the proportion of clay increases near the coast.

River "OI" has an 849 sq. km basin and a 900 m wide mouth. Its average slope is 1:280 and flood discharge is about 6,000 cu. m per sec. Its rapid flow was well known in Japan during the days when the flood control work was still poor. But today it flows safely owing to the solid protection of the levees which fix the stream solely on the southern part of the plain, keeping its mouth at 10 km south of "YAIZU". Before 1660, the levees on both sides had not yet been constructed. The stream has, therefore, changed its course in various places over the plain as the river overflowed. We can notice projecting land at "WADA" which is situated in the central part of the "SHIDA" plain. This shows that "WADA" used to be at the mouth of the River "OI" for a comparatively long period. According to the record written in 1560, there was a border dividing two fiefs of feudal age, which was fixed along the River "OI". This fact well confirms the abovementioned conjecture.

PROPERTIES OF THE COAST

Judging from the above-mentioned conclusions, it may be evident that the substratum of the coast originated from the running-down of the River "OI". The 1:280 slope of the river bottom generates such a swift stream that it discharges large particles of bed load into the sea. Its median grain size ranges from 16 mm to 20 mm near the river mouth,

10 mm at "KOKAWA" and about 5 mm at "YALZU" beach. The coast, south of the south breakwater of "KOKAWA" Fishing Port indicates that its beach line has been moving forward according to the extension of the breakwater, but its movement is rather stagnant now. On the contrary, the coast, north of the breakwater presents an exact reversed condition.

Sand-groins are arranged along the whole coast of "YALZU" and protect the dyke from scouring. At the south end of the dyke, groins do not carry out their sand depositing function. Thus, there is no beach in front of the dyke. On the northern part of the dyke, some sand and gravel deposits can be seen. They are the southern side of each groin but little on the opposite side.

It is observed, on the other hand, that the sand depositing function of the groins makes a beach of 10-20 m wide and 300 m long on the coast, adjacent to the southern part of the south breakwater at "YALZU" Fishing Port. The average sea-bottom gradient up to the -5 m depth point is, 1:10 at the south end, 1:15 at the central part of "YALZU" coast and about 1:30 at the south of the southern breakwater. While the -10 m depth contour projects seaward in front of the entrance of "YALZU" Fishing Port, though it runs parallel with the shore alongside the dyke. The -100 m contour lies 3 km off-shore of "YALZU" and that characterizes its marked entry near the coast in comparison with other sections. No shoal or bar is found along this coast. (See Fig.-4)

SEA CONDITIONS

"SURUGA" BAY CONDITIONS

It is known that the Pacific Coast of our country is frequently influenced by typhoons from the southern Pacific Ocean and low atmospheric pressures from the western Sea of Japan. When these conditions occur in the central coastal area of Japan, the "SURUGA" bay, because of its topographical characteristics, allows the swells and high wind-waves to make their way directly into the bay from the open sea without any loss of intensity.

Waves from typhoons - 233 typhoons during the past 72 years have been recorded giving an annual average of 3.3. They have come to within 400 km south of "OMAEZAKI", located at the most southern point of "SURUGA" bay. The waves from these typhoons are mainly transformed into swells and make a path into the bottom of the bay from a southern direction maintaining their strength all the way. Usually, the wave period averages 12-14 sec. and their height is 1-2 m, but sometimes 3-4 m. 237 typhoons, average 3.3 a year, have also been recorded, which have passed from SW to NE within a radius of 200 km from "OMAEZAKI", including those which have run through over the land behind it. In this cases, the intense southern winds sweep directly on to the bay with a mean velocity of more than 15-20 m/sec. and cause high wave in every part of the bay. Citing an instance from the record observed in 1958 at TAGONOURA", located at the bottom of the bay, indicates that in the largest train, the H 1/3 is 8 m and the period is 18 sec. as shown in Fig.-5.

Waves from low atmospheric pressure - The courses of low atmospheric pressure around the Japanese Island may be broadly divided into three types as follows,

- 1) Course which will go up north along the coast of the Pacific Ocean,
- 2) Course which will cross over Hokkaido through the Sea of Japan, and
- 3) Course which two low atmospheric pressure will pass through parallel with the coast of the Pacific Ocean and the Sea of Japan

Among these three mentioned above, course-1 occurs most frequently and has great effects on "SURUGA" bay. Course-2 usually does not seriously influence the bay, but when a front of low atmospheric pressure spread over the coast of the Pacific Ocean, high waves appear there.

Course-3, though frequently appearing, is not accompanied by high winds or waves under the similar influences of two low atmospheric pressures. Wave recordings for the years from June, 1964 to June, 1966 show that waves of more than 3 m high appeared 22 times due to low atmospheric pressure around the mouth of the "SURUGA" bay, of which, 50 % were according to course-1, 18 % course-2 and 32 % course-3.

Waves appearing in the bay owing to low atmospheric pressure, are commonly of the degree of 3.0-3.5 m in height.

Seasonable waves - During Dec., Jan. and Feb., west winds prevail and cause higher waves than those entering at the mouth of the bay. But there is no considerable influence of the seasonable waves on the west coast.

"YAIZU" COAST CONDITION

Waves - As the coast of "YAIZU" is located on the side away from the direction of waves entering the mouth of the bay, its waves are less than those at the bottom of the bay owing to refraction. According to the refraction diagrams, the refraction coefficient at "TAGONOURA" (vs. the mouth of the bay) is 1, while it is 0.5 at "YAIZU". From Sept. 1960 to Nov. 1962, "wave recording" by an automatic wave meter was carried out at a place (-9 m deep), 420 m off-shore at "YAIZU". Frequency of appearing waves is as per Fig.-6 and their probability of surpassing 1 m in height is 15 %. As for the direction of the waves, they are mainly between S-SE. The largest train during this period was observed as H max. 6.9 and H 1/3 was 4.5 m, period was 8.4 sec. The sea bottom gradient of the "YAIZU" coast is so steep that wave-breaking point is limited to within 60 m from the beach line. The waves, even after breaking, dash against the dyke sending up sprays of about 20 m which fall behind it. (See Fig.-6)

Tide and current - The characteristics of tides surveyed near "YAIZU" Fishing Port are as follows: Mean sea level is 0.963 m high above the harbour datum, Mean high water spring 1.663 m, Mean low water spring 0.053 m and Highest water level 2.115 m. Extraordinary high storm tides are seldom caused because of the depth of the water. The northward flowing current in the Pacific Ocean flows counterwise in "SURUGA" bay and separate currents flow along the coastline north of "YAIZU". The velocity of the current changes according to conditions in the main stream and the direction of the tide. At its maximum of 1 knot,

it has insufficient power to cause soil erosion. The extent of erosion is considered to depend on the waves and currents produced after they have broken.

TRANSITION OF THE BEACHLINE

The chronological records on the former states of the shore of "YAIZU" are found in several sheets of old drawings. One of them is shown in Fig.-7. According to them, there had already been a kind of shore protection structure even before 1772. They were built at advanced positions far from the existing ones and a small river flowed parallel at the back of them. At that time, there was an extensive beach which was covered with many flourishing pine trees.

It was recorded that in 1772, 1784 and 1797, severe storms attacked the protective structure which was broken and therefore the coast-line greatly receded, thus the old revetment and river disappeared in an 1803 drawing. Beach erosion was proceeding continuously and it was reported that the coastline receded approximately 100 meters until up to 1870. It was in 1899 that the revetments were built on the existing location. The working drawings of the revetment shows that there was still a beach 60-70 meters wide in front of the wall. Judging from the comparison of the present state with the drawing of the cross sections planned for the improvement work of "YAIZU" Fishing Port in 1935, the coastline seems to have receded a maximum of 30 meters and an average of 10 meters within these 30 years. The coastline has been surveyed four times every year since 1961. In this short period, this survey has not yet found any age-line of erosion.

CAUSES OF BEACH EROSION

Major conditions associated with beach erosion can be summarized as follows: the source of sand supply around the coast of the said alluvial plain, including "YAIZU", is thought to be the River "OI", and the direction of sand drift seems mainly from south to north. The main direction of waves on the coast is south, and they cause strong wave-currents to north. The grain size of beach sand becomes smaller going north of the "OI" river estuary. On the southern side, coastal structures such as, breakwaters, groins, jetties, etc. may be accumulated, but on the north side they would be destroyed.

In the case of erosion on the sea-side of "YAIZU", firstly it may be connected with the process of the changing of the River "OI". As stated previously, it is deducible that more than 300 years ago the stream of the river was constantly on the move, and it would frequently inundate over the alluvial plain. The estuary often located near "YAIZU" supplied a lot of sand to the coast. In 1604, river improvement was planned and some length of levee was constructed in 1633. Since then, the levee gradually extended down-stream and that restrained the river from moving freely. Towards 1660 the river was almost fixed at the present position. The estuary moved far away from "YAIZU" and consequently the supply of sand from the river to the coast decreased.

Secondly, beach erosion of the coast of "YAIZU" has been accelerating from the year 1900. This may be correlated with the dams constructed on the "up-stream" of the River "OI". 11 dams have been built since 1924 for flood control and their development as a source of electric power. Decrease in sand quantity discharged from River "OI" into the sea, though it has not yet been observed exactly, is estimated to be approximately ten million tons a year. Thirdly, erosion is connected with wave action. The sea bottom gradient of "YAIZU" is so steep that the wave-breaking point is near the beach line. The sand in front of beach line, therefore, is disturbed violently and is moved into deep water by strong wave back wash. In addition, a breakwater was constructed from 1932 to 1934 (It was extended later) on the adjacent coast to "YAIZU", extending from the land to the sea at right angles with the coast line. It cuts off sand coming from the up-stream coastal sand drift. It will be evident that the balance of shore process was broken by the above-mentioned factors and that caused this serious beach erosion.

HISTORY OF SHORE PROTECTION WORKS

As described in previous chapters, there has been a repeated history of construction and destruction of shore protection structures several times since the end of the 18th century. According to the old writings, severe disasters happened in 1772, 1784, 1797 and the existing structures were completely destroyed and disappeared at last in 1803. It can also be seen in the drawings that 1818 to 1843 many structures tried to challenge the waves, but never succeeded in standing many years.

Every time, the position of the sea wall to be reconstructed, was obliged to retreat gradually owing to erosion of the shore line. The details of these structures are unknown, but the vicissitudes of the coast can briefly be conjectured from the above-mentioned records. As the documents for the end of the 19th century exist, we can trace the story of construction, destruction and reconstruction. The oldest documents are of a sea wall that was constructed around 1890. It was executed by the structures shown in Fig.-9, extending over 1,090 meters out and was destroyed and washed away by a disaster in 1898. The next year, a substitute sea wall was constructed on trial under the specifications of stone masonry (as shown in Fig.-10) on a site 9 meters behind the former wall.

As this structure was certified to be durable against fairly high waves, a following extension of 1,050 meters was executed from 1900 to 1907, protecting an urgent and dangerous part of the hinterland. This is the origin of the existing dyke. The sea wall, over 6 meters high, was uncomparable in Japan at that time. But during its construction, it was found that the dyke could not prevent backyard flooding because of the lack of crown height. So it was made higher, from 6.20 m to 8.50 meter, by construction of an annex wall with stone masonry at the front and back edges of the crown (as shown in Fig.-11). The open central part of the crown was intended to be a splash basin for draining, but this function was not fulfilled effectively because the interim drainage was filled in with

gravel, and later the annex wall collapsed under the impact of the high waves. The interim vacancy was filled with concrete and then this structure was finally completed in 1910.

In 1911, immediately after completion, it was broken at several places by unexpectedly severe waves which flooded many houses nearby. On its restoration, subsidiary walls were built at the weaker points (as shown in Fig.-12) in addition to the reconstruction of the main dyke. At the same time, the length of the the dyke was increased to 1,320 meters, and boulders (approximately 100 kg a unit) were placed in front of the dyke to spend the wave dash and to protect the toe of the dyke. Also, an apron was constructed behind the existing sea wall, where a large quantity of tidal water splashed over.

As time passed, the more the materials at the foot of the dyke that were washed away, the stronger the waves become. Placed rubbles were thrown away quicker than they could be supplied with new material and the dyke body was often damaged during this time. These circumstances worried the persons concerned with restoration, and the "YAIZU" Sea Wall Protection Committee" was organized by the townfolk. From about 1925, concrete cube shaped blocks each weighting 10 tons were placed for foot protection in stead of stones, and a considerable quantity of concrete blocks were supplied for its annual maintenance.

During World War II, the maintenance of the dyke could not be done satisfactorily. In addition to these circumstances, gigantic typhoon passed every year from 1947 to 1949 and greatly damaged the dyke. Many cracks and hollows were generated and most of the foot protection blocks were washed away. Among them, during the calamity of 1948, about 20 meters length of the dyke was completely broken and fierce waves destroyed more than a hundred residential houses, and also caused the damage to a wide area by tidal deluge in the surrounding district. Thus, more than 2,500 of the residential houses and a total of several billion yen of industrial facilities stood in a serious situation. In 1954 and 1959 serious calamities reoccured.

The process of these disasters is as follows: Firstly, sand in front of dyke is washed away, secondly, the toe of the dyke is secured by stronger waves, thirdly, scouring causes the leaking out of the filling and the wall becomes weak by losing its filling, and stone masonry then loosens due to the shock of waves and finally the dyke is destroyed. To prevent this, the groins, 25 meters long and 4 meters wide, were constructed every 75 meter. The construction work was executed between 1949-1953. Considerable amount of sand was deposited immediately after the completion of the groins and the coastline was advanced. A few years later, however, the coastline commenced again to recede and at present, it seems that the groins do not entirely fulfil their purpose.

Recently, improvement work on the whole dyke and sand groins was planned in order to make sure of the coastal protection. The following items were taken into consideration in this plan and its standard cross section is shown in Fig.-15.

- 1) 8 ton armour blocks were placed at the foot of the dyke to decrease the scouring and wave power against the body,
- 2) Double steel sheet piles were driven -3.5 meters deep into the toe of the dyke to prevent the leaking out of the filling,
- 3) Concrete was cast inside the body,
- 4) The front face of the masonry wall was covered with concrete reinforcement.

This improvement scheme of the dyke was started in 1959 and is still progressing now. The armour blocks have been remarkably effective in the prevention of erosion. There has been no damage to the dyke, though, it has been attacked several times in the past by severe waves. At the same time, it has had a good effect on maintaining the beach sand, but the study of this takes much more time. The entire operation mentioned above will be completed by the spring in 1967.

CONCLUSION

Since "YAIZU" is carrying on a very important role of lively economical activity in our country, the protection of various facilities, properties and many human lives on the coast from the attack of sea water is paramountly important. Beach erosion on this coast will become more serious hereafter. Accordingly, the existing shore protection structures will be weakened and further reinforcement of them will be required again before long. We shall, therefore, have to continue the struggle against the gigantic natural force as ever. For the right of erosion, it may not be expected at this moment that any reasonable method to clear away the cause of erosion on the coast, i.e. to cease the attack of waves or to keep and supply a sufficient amount of sand effectively at cheap cost, will be found.

It may be one of the most suitable ways for the time being to replenish the armour blocks in front of the dyke accordingly as the beach is eroded. Study to find the effective countermeasure against the beach erosion is still going on through the periodical survey of the change of the shore line.



Fig. 1. Aerial view of the coast.

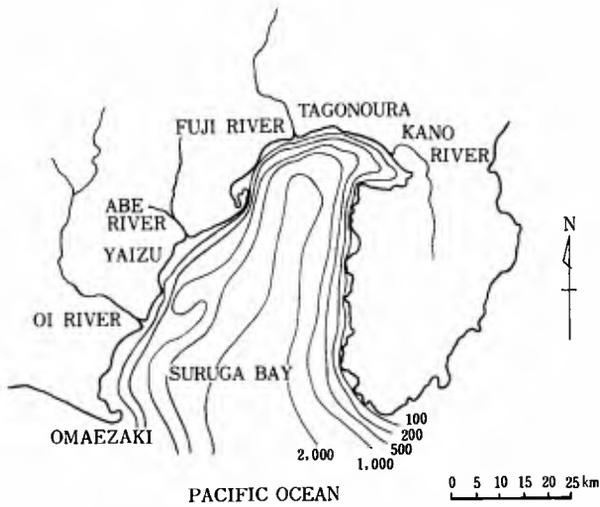


Fig. 2. "SURUGA" Bay.

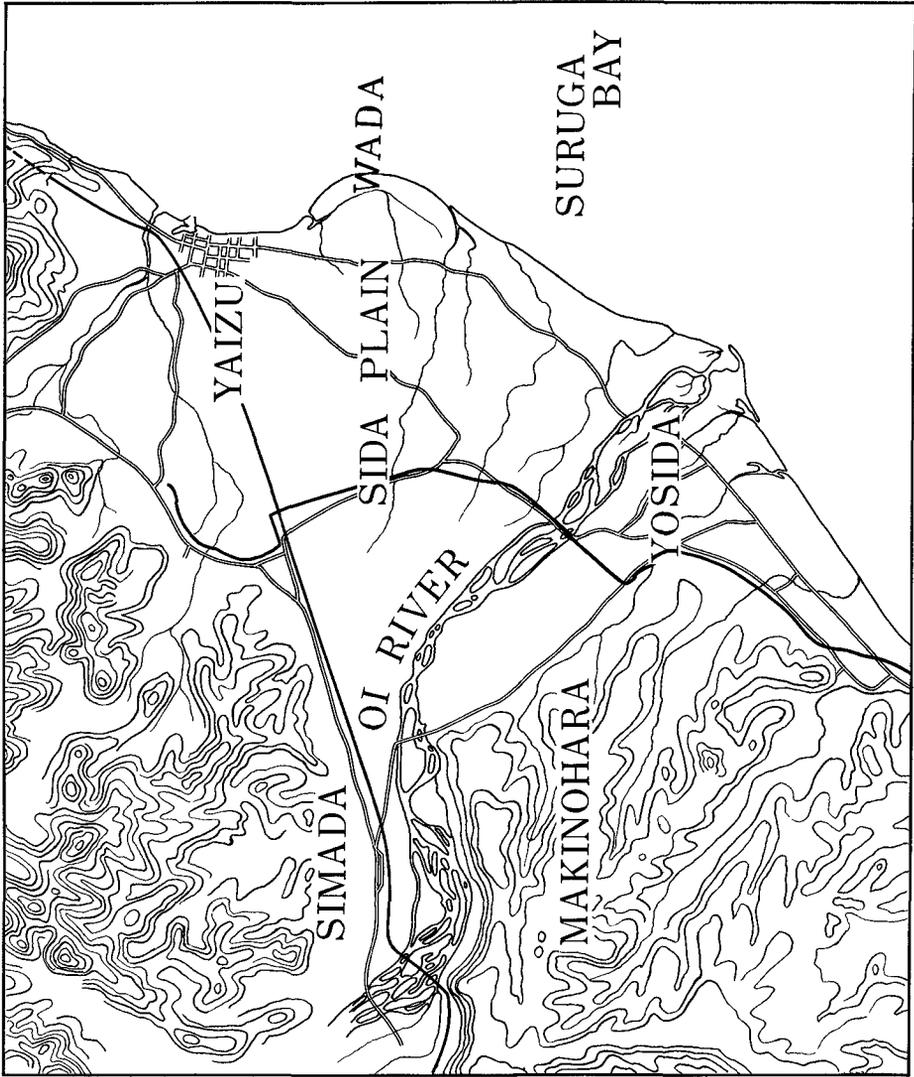


Fig. 3. Alluvial fan.



Fig. 4. General view of the coast.

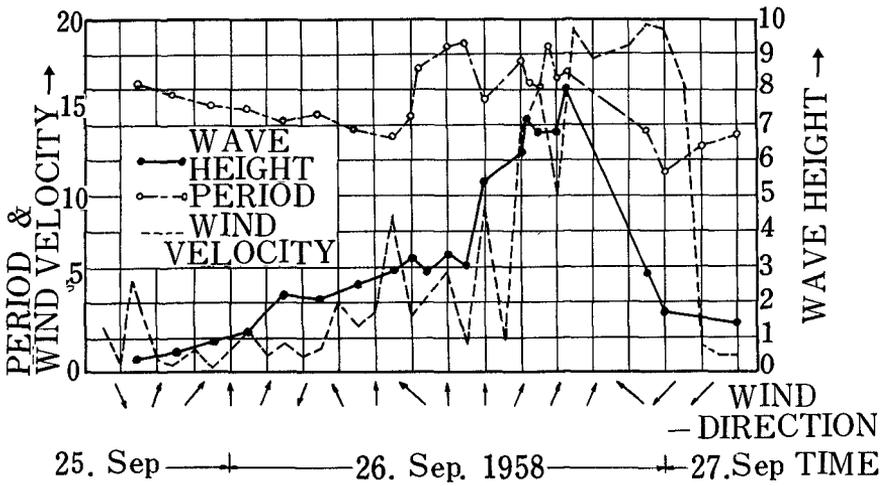


Fig. 5. Record of waves.

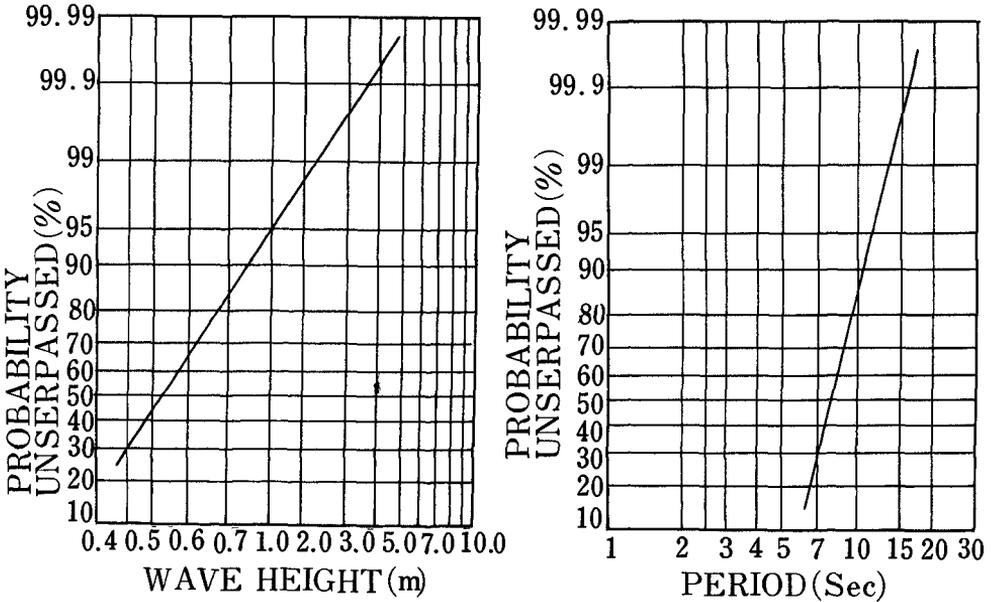


Fig. 6. Result of wave recording.

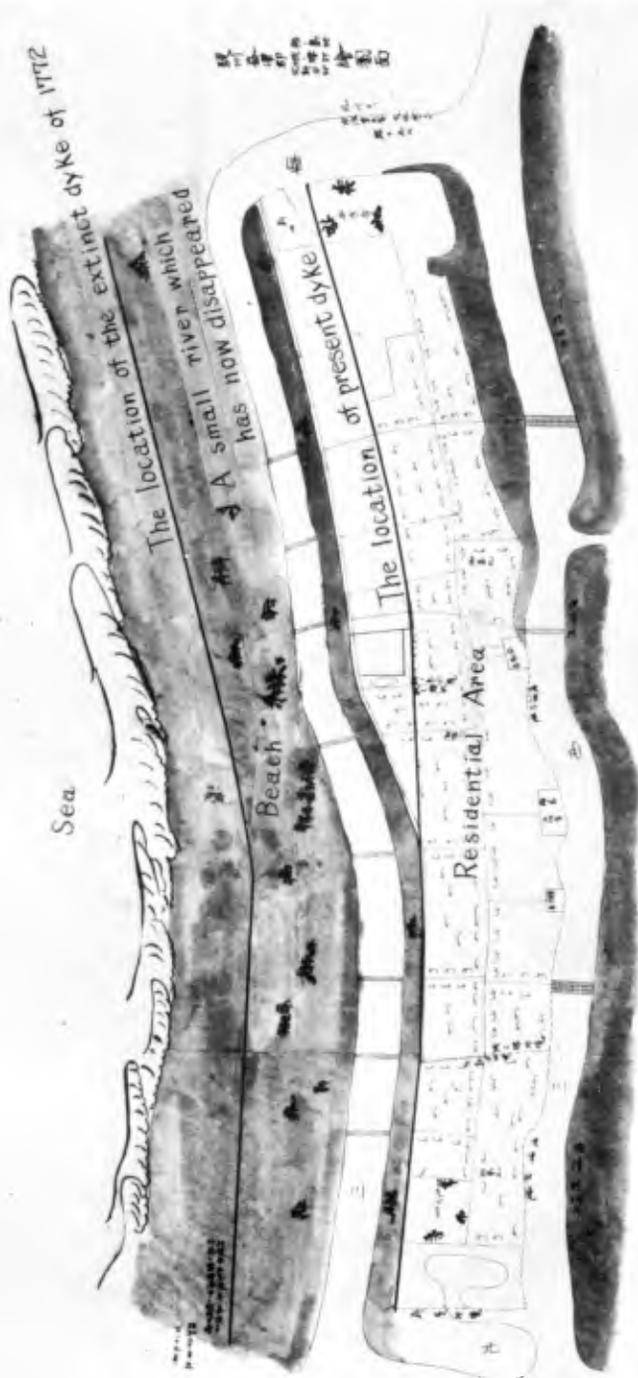


Fig. 7. One of the old drawings.

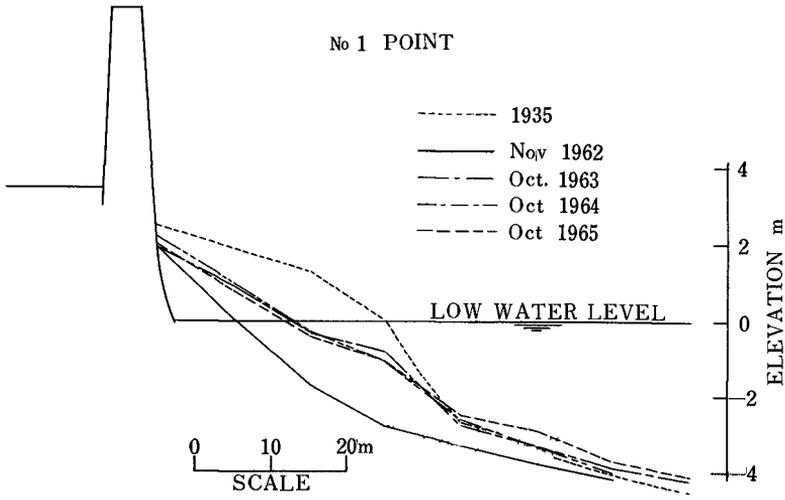


Fig. 8(a)

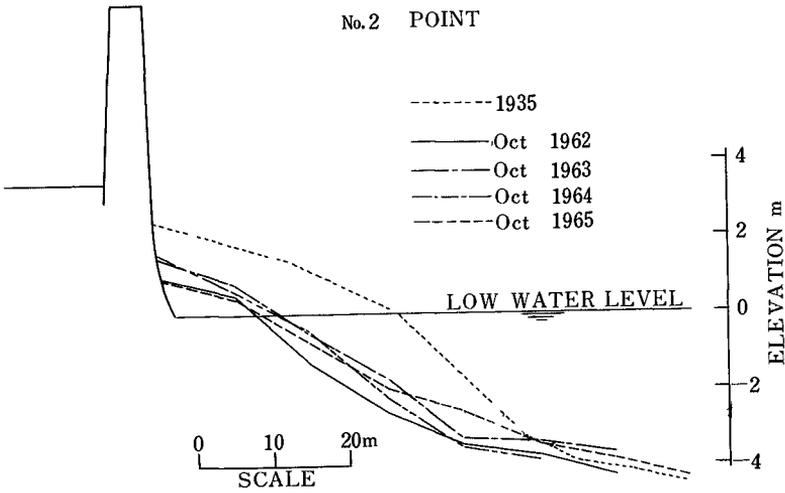


Fig. 8(b)

Fig. 8. Cross section of the shore.

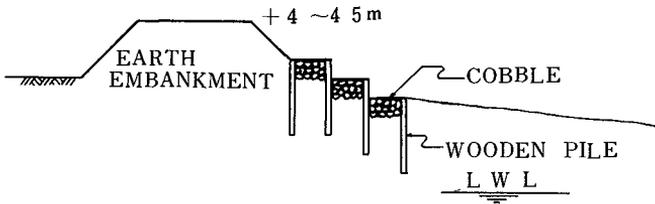


Fig. 9. Cross section of the dyke constructed in 1890.

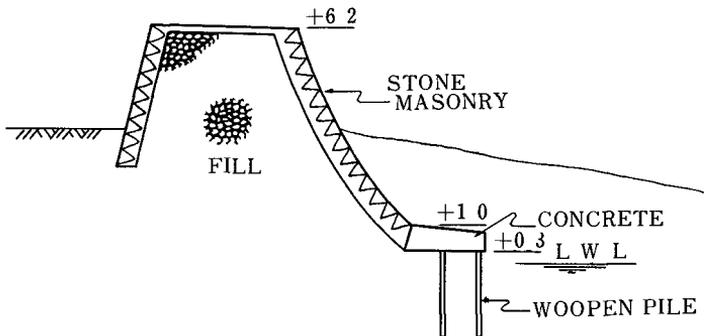


Fig. 10. Original section of the present dyke.

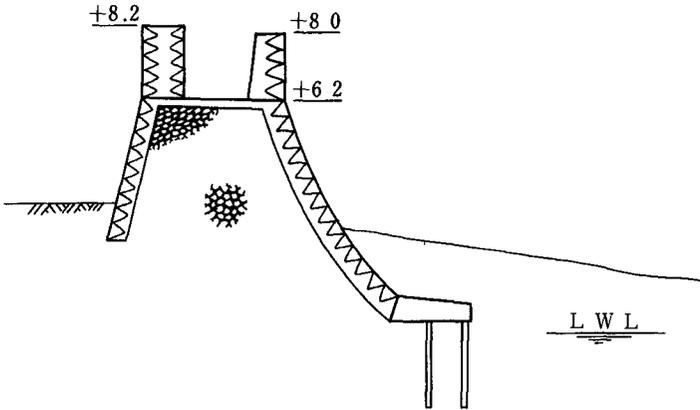


Fig. 11. Raising-up of wall.

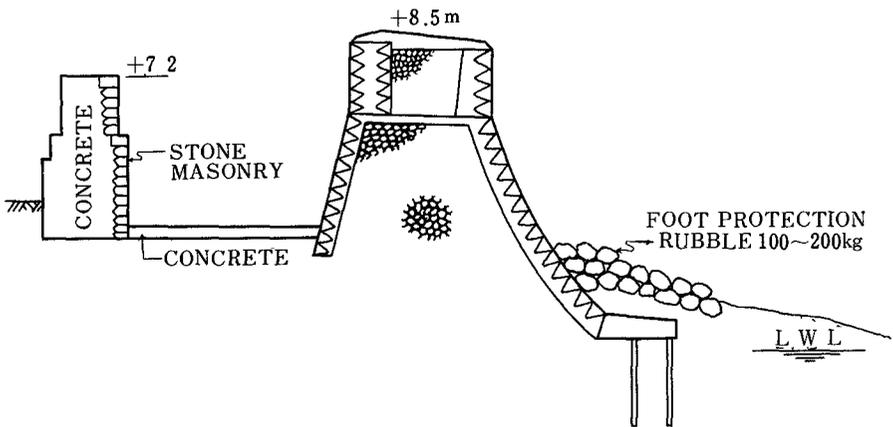


Fig. 12. Subsidiary wall.

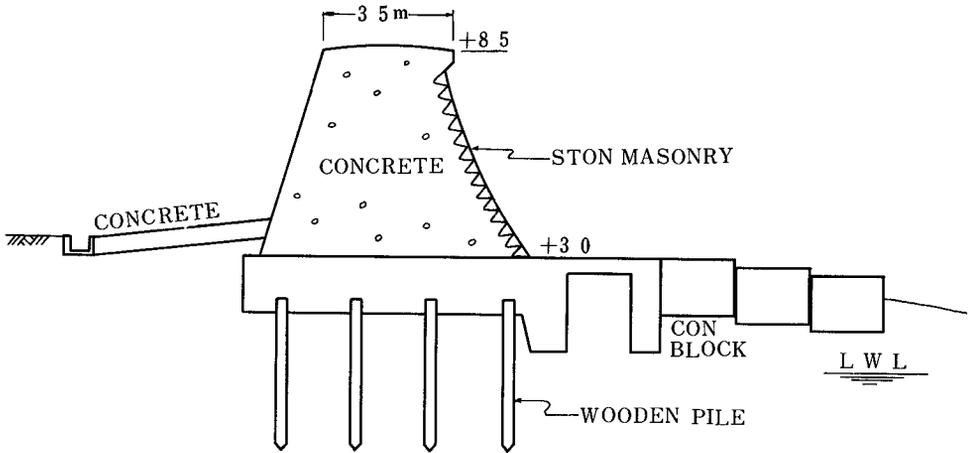


Fig. 13. Cross section of extension.



Fig. 14. Damaged state.

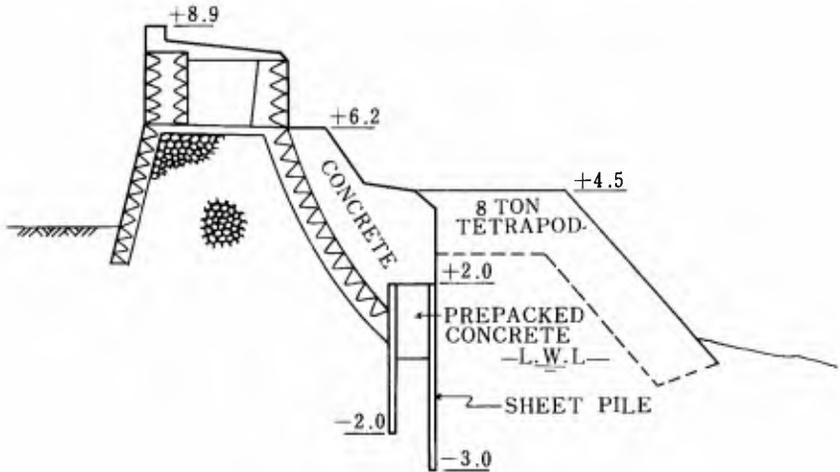


Fig. 15. Cross section of improvement work.