Chapter 4. Port Planning

4-1 The Development Policy

4-1-1 The Development Policy for Toamasina Port

Toamasina Port will be developed according to the following strategy.

(1) Harbor facilities will be constructed to promote growth of the national economy
(2) The potential of Toamasina Bay will be fully utilized.
(3) Enhancement of productivity will be attained.
(4) Safe navigation shall be attained
(5) Financial soundness of SPAT shall be maintained
(6) Technology transfer and promotion of employment opportunities will be implemented.
(7) Environmental safeguards will be secured in the construction stage.
(8) The road congestion and the air pollution will be alleviated at the outskirts of the harbor
(9) Harmony between the environment and development will be attained

4-1-2 The Targets and Scenarios

(1) Harbor facilities

Sufficient capacity and timely implementation is required to ensure the sound economic development of Madagascar.

①The GDP growth is estimated at 5~7 % annually until 2020.
②The increase of the containerized cargo corresponding to it is 10-13%. Assuming an increase rate of the containerized cargo of 10%, the handling demand for containerized cargo is 426,000TEU in 2020.
③Bulk / General cargo is projected as 983,000 tons (except Ambatovy Goods) in 2020.

To curtail investment risks, the minimum facilities will be constructed by 2017. However, if the cargo growth is faster than that forecast, the construction of additional facilities will become necessary. To be ready for both cases, the Plan for 2020 which includes additional port facilities should be formulated.

(2) Maximum utilization of the Potential of the Bay

Toamasina bay is sheltered by the grand reef and the Hastie reef. The shape of the water basin is oval with the major axis 2km, the minor axis 1.5km. The depth of the center of the water basin is 20m. The west shore is covered with the sand, and the coral is exposed at the eastern side of the bay. The gradient of the sea bottom is steep at the eastern side. The sub base of the bay area has enough strength to support the quay structure.

According to the topography, the bathymetry, and the present utilization, the bay area can be divided into 6 areas:

Area(C) is the area at the end of C3 quay.

Area (D) is the area of the grand reef.

Area (E) is the beach area at the end of the bay.

Area (F) is the area of the adjacent to the independent street.

Area (G) is the water area in front of the Tanio Point.

Of these, the Area (F) at the end of the independent street will be reserved for the citizen's open space to enjoy the scenery and walk.

The remaining areas (C), (D), (E), (G) have the development potential for the quays. (See Figure 4-1-1)

Presently, the waves intrude from the 500m open mouth between the grand reef and the top of the breakwater.

That is why (C) must be developed at first. With the breakwater construction, if the development of Area (C) is realized, (E) can be developed because the water basin of Area (E) will become calm. Area (D) is also possible to develop because the distance of separation between the grand reef and the breakwater will be shortened. Construction of the additional breakwater and the bridge to connect the road to Area(D) will not be difficult. If a breakwater is constructed by the development of Area (D), Area (G) could be developed because it would be calm.

Based on the above reasons, the sequence of the development shall be (C)-> (E) -> (D) -> (G).

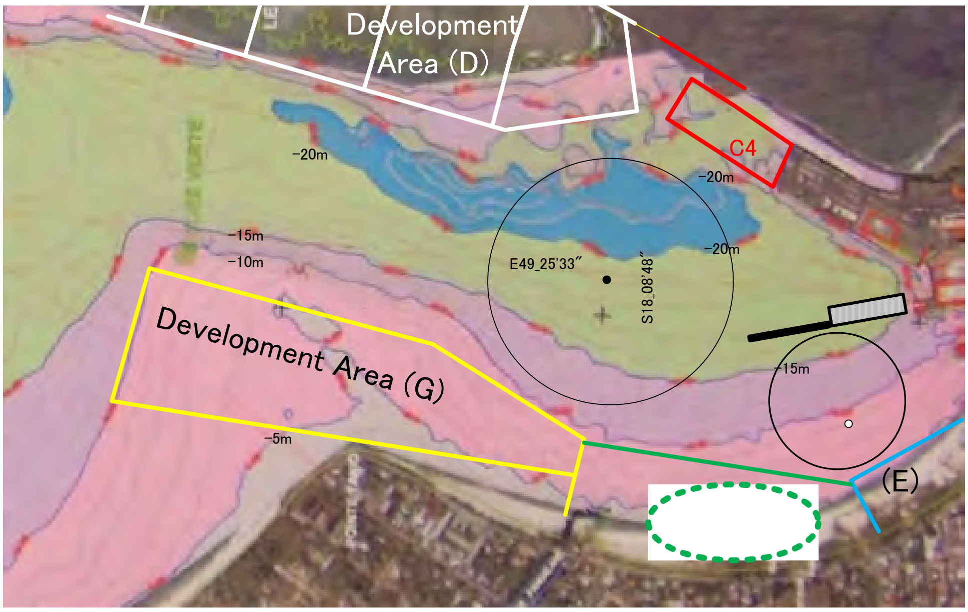


Figure 4-1-1 Potential Areas for Development in Toamasina Bay

The characteristics and the costs of development for each area are as follows.

Area(C) :

Originally, the depth of the area is sufficient to build a deep water quay, but the landfill for the quay needs a lot of materials. The construction cost for the breakwater is expensive because of the high waves of the open sea. The space demand for the container yard will be fulfilled at the Hastie reef, because it is too expensive to create a container handling yard at the rear of the quay.

Table 4-1-1 Cost for the Development of Area(C)

Facility	Scale	Cost (EURO million)
Breakwater	about 350m	38
Quay	-14x320m, space 5ha	61
CY (Hastie Reef)	10 ha	50
Total		149

Area (E):

A turning basin to turn a ship is necessary in this area. It will be created in front of the quay and will be dredged up to -14m.

Since the space behind the quay is limited, a back up area will be located at the Hastie reef. Presently, some part of the area is used as a tennis court and a football ground. These activities must be shifted to Area (F).

Table 4-1-2 Cost for the developing of Area (E)

Facility	Scale	Cost (EURO million)
Quay -14m, -9m, -7.5m	Quay500m, Shore Protection200m	41
Turning Basin	Dredging/Fill= 1million m3	11
Pavement	4ha	5
Open Stock Yard (Hastie)	10ha	50
Total		107

Area (D):

A breakwater from a grand reef and connection bridge to Area (C) will be constructed. The deep water quays will be constructed at the west side of the grand reef. The reef flat will be reclaimed and utilized for the container yards. Huge container terminals can be located in Area (D). This project may be implemented through BOT. However, the initiative of SPAT is necessary. The breakwater, the pass, and the first stage of the development should be conducted by SPAT.

Table 4-1-3 Cost for the development of Area (D)

Facility	Scale	Cost EURO million
Breakwater & Bridge	Length150ｍ, Bridge15m	22
Quay -16mx700m	-16mx350m,-16mx350m	88
CY (Reclamation, Paving)	40ha	120
Access	200m	3
Total		231

Area (G)：

After Area (D) is developed, this area will be calm and usable for the quays.

This area will be developed together with the dredging of the channels.

Erosion and sedimentation occur in this area because it is adjacent to the sand beach of the north coast.

The cost for the development of area (G) is shown in the Table 4-1-4.

Table 4-1-4 The development cost for Area (G)

Facility	Scale	Cost EURO million
Quay -14mx2	-14x700m	50
Shore Protection	500m	10
Reclamation/ Fill	Dredging 3.5 million m3	34
Pavement	21 ha	24
Total		118

(3) Enhanced productivity

(a) To enhance productivity of the port, SPAT should encourage the private sector to introduce modern machines such as gantry cranes, transfer cranes, dump trucks, belt conveyors, and forklifts.

① Faster chromite handling should be realized by upgrading the cargo-handling machine.

②Wooden chips should be transferred by belt conveyor from the open air storage ground to the quay and should be loaded by the loader.

(b) The walls and the buildings which hinder traffic in the port will be removed and the flow line of the trucks will be secured.

(c) Roads and the railroad should not intersect to the extent possible.

(d) An overpass will be constructed at the railroad crossing of NO.1 gate.

(4) Safe navigation

Enough space for the turning basin and the separation of navigation lanes should be reserved. Dangerous navigation as well as waiting time should be avoided. Dredging work should be carried out and navigation aids installed.

The concept of the water facilities are proposed below:

The fairway of the entrance channel should be two lanes. One lane is for out-going and the other is for in-coming.

The model ship is a container vessel of 59,000 DWT, which has a length over all of 288m, and a full draft of 13.3m. Based on the examination, the following recommendations are made:

- The total width of the two lanes should be 600m, with a wind speed of 10m/sec (direction 45 degrees), and a water current of 1.0 knots.
- The necessary radius for the bend of channel is 2,000m at the radar angle 15 degrees, and 1,000m at 35 degrees. Since it is difficult to maneuver ships under the influence of the winds and currents, 2,500m radius is proposed for the curve of the lanes.
- The depth of the channel should be -17m with a wave height of 3m, and wave period of 14sec. There are shallow sections in the course of the navigation. The shallow areas should be excavated and deepened up to -17m where ocean waves come directly. Areas which are not exposed to ocean waves, such as behind the grand reef, should be excavated up to -15m.
- The beacon is recommended as a navigation aid since it is reliable. Beacon A should be located at the beginning of the curve, where the depth of the water is -10m. Beacon B is also recommended for recognizing the center of separation between the two lanes. It is important that the place is accurately indicated, especially when the sea is rough and visibility is poor. Although the buoys are relatively cheap, they can easily be lost in stormy weather.

The cost for the two lane project is estimated as EURO 29 million. The cost breakdown is shown in Table. 4-1-5.

Table 4-1-5 Cost Breakdown of the Two-Lane Project

Work	Unit	Qty	Unit Price	COST(EURO)	Remarks
Dredging	M3	1,000,000	22.590	22,590,361	
Beacon	Set	2	3,012,048	6,024,096	
Leading Light	Set	2	150,602	301,205	Renewal
Communication and Monitoring Facilities	Sum	1	37,651	37,651	
Total				28,953,313	

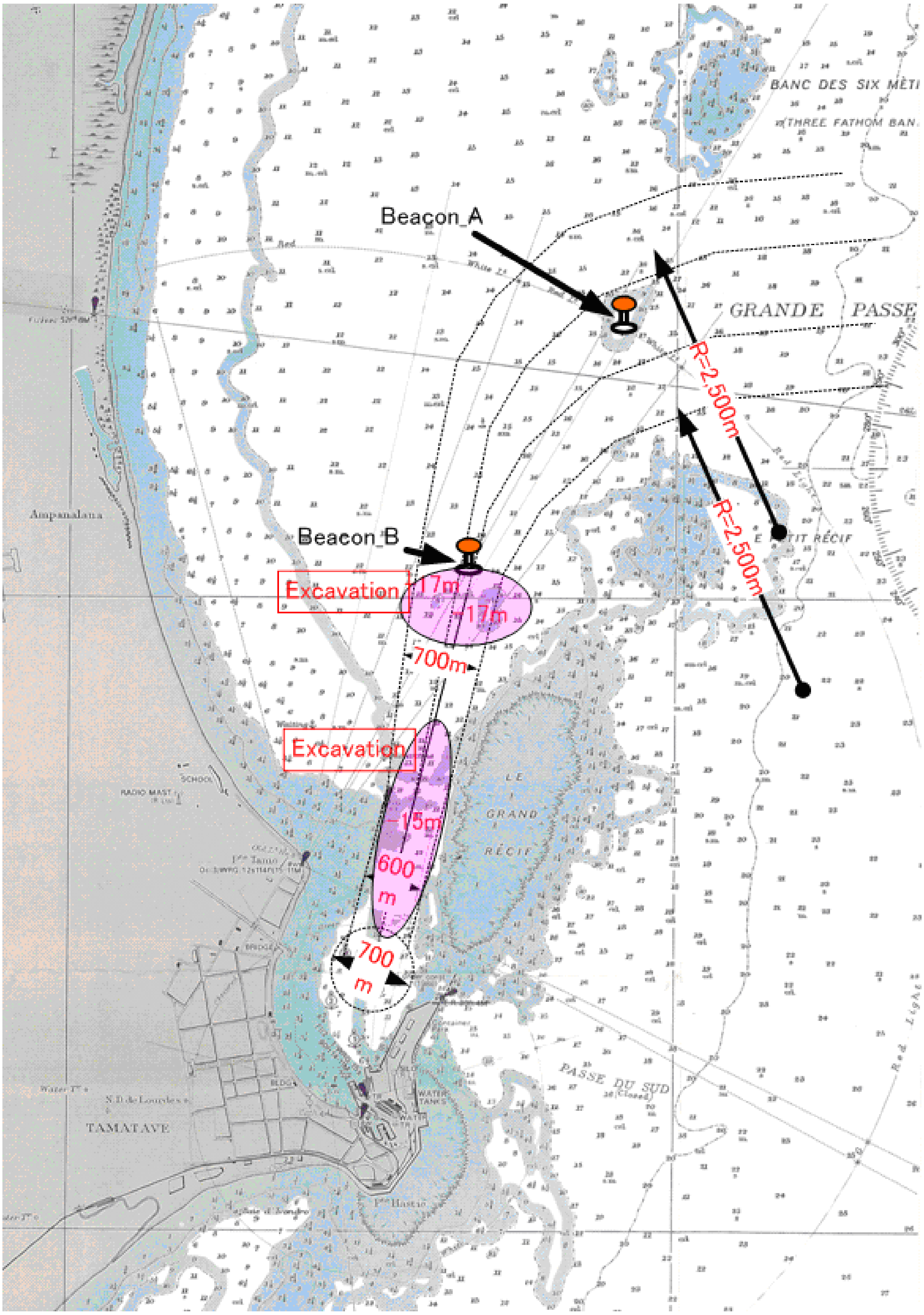


Figure 4-1-2 Fairway Channel

(5) Financial soundness

(a) Urgent Development Plan should be established to attain the biggest return by the smallest investment.
(b) In cooperation with the private sector, timely investment and the sharing of risk in investment can be achieved.

①MICTSL will be in charge of procuring the gantry cranes and paving the container terminal.
② Concerning the wood chips, SPAT provides stock space in the port, and the Oji will provide superstructure such as belt conveyors and ship loaders.

(c) In order to promote private participation, information on the port should be available on an internet site that can be easily accessed by private companies.

(6) Technology transfer and increased employment opportunities

If the project can promote technical transfer and increase the chance of employment, it is much more desirable than just the expansion project. The following ideas could decrease the project cost and bring more benefit than mere tendering.

- Saving the cost for mobilization/demobilization
  ① If there is no need to bring back the construction machines and materials, the constructor can save the demobilization fee. The bid specification should state that a constructor should bring new machines, such as dump trucks, pay loaders, etc. into Madagascar, and turn over them to SPAT after the construction is completed.
  ② Small work vessels or floating machine that are not expensive (such as less than EURO one million) should be handed over to SPAT instead of bringing them back.
  ③ The molds of the blocks can be used again and again. If they can be left after the project, the contractor can save the demobilization fee. Madagascan sides do not need to spend mobilization fee for the next phase of the project. Therefore, the specification should state that the bidders should offer the bid assuming that the molds are turned over to SPAT after the construction is completed.

- Option of the gravity type quay
  ① Caisson type structure
  Because the caisson-type quay is the prevailing technology in Japan, Japan can easily transfer this technology. In addition, the employment of local people will increase. Cost of the caisson type is slightly higher than a steel pile type platform, however, there is a great possibility that a caisson-type wharf is less expensive than the other types. Therefore, the SPAT should allow alternative bids.
    1. At the time of the bid, a caisson-type quay should be allowed as an alternative
    2. The SPAT side should provide the mooring place of the floating dock in the port area.
    3. It should be stated in the tender documents that SPAT is willing to accept the floating dock if the bidder is willing to turn it over at no cost.

  ② Block type quay
  Block Type structure is applicable to the C4 quay, since the site is deep and has a solid sub-base. In addition, Madagascar is not prone to large earthquakes.
  It would be wise for SPAT to call for the bid for the block type structure as well because there would be no extreme price hike in the case of concrete that is often seen in the case of steel, and the stall of the tender can be avoided. And more local manpower is used in this case. There are various types of the blocks applicable to the quay structure. The simplest type and stable structure for the quay is presented in Figure. 4-1-3.

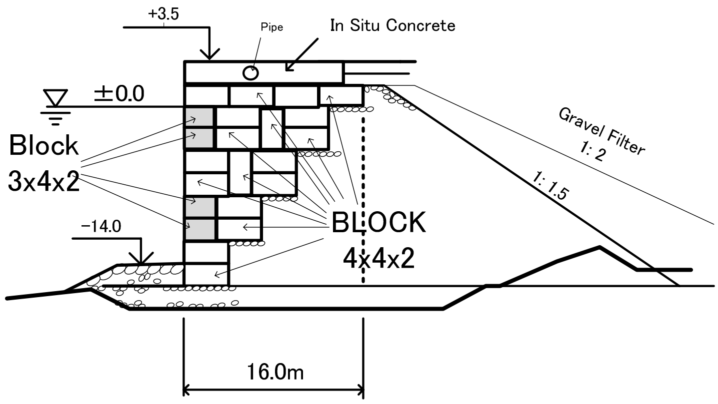


Figure 4-1-3 An example of the Block Type Quay Wall

The characteristics of this structure are:

(1) The blocks are piled up on the stepped slope (1:0.75).
(2) Only two kinds of blocks (4x4x2, 3x2x2) are used.
(3) The heaviest block is 80 tons.
(4) The stability can be examined by circular failure.
(5) If it is necessary to examine stability by normal retain wall check, the dashed line can be regarded as a vertical wall. In this case, the width of the retain wall body is 16m.

Because the heaviest block is 80 tons, the crawler crane of 160 tons will be used to pile up the blocks. The machine has the same capability as the crane for the breakwater construction. To level the mound of the stone for piling up blocks, any size of stone that is easy to handle can be used.

For the work yard, enough space with a quay is necessary. The necessary area of the yard will be 160mx80m. Area (E) in the Figure 4-1-1 (see page 4-2) will meet the demand for both space and the temporary quay. The temporary quay will be created by the contractor utilizing blocks that will be used for the C4 quay.

(7) Environmental safeguard in the construction stage

(a) Water quality will be monitored while dredging work is carried out, and necessary measures will be taken to prevent contamination at the coral slope.

(b) If dredging soil is contaminated with a toxic substance, the soil will be scooped with a sealed glove and will be carried by a watertight dump truck. The contaminated soil will be confined in the space surrounded by a water tight wall. When water includes a toxic substance that exceeds the permissible level, it will be purified by filters and exhaled when there is less toxic material than the standard. When the confining place reaches full capacity, the area will be capped with asphalt, so that rainwater may not seep.

(c) During the pile driving work, noise will be monitored and works will be controlled so that the noise does not exceed the permissible level in the city area.

(d) The route of trucks and the times which they are allowed to travel will be controlled in order not to exceed the allowable level of noise, vibration, and the air pollution.

(e) Toilets for the construction workers will be installed in the work area to prevent disease and maintain sanitary conditions in the construction site.

(8) Prevention of road congestion

Parking lots with an information system will be set up along the access road. The road congestion caused by the on-the-street parking should disappear. The useless idling of engines should be eliminated and exhaust gas will be reduced.

Bypass road (toll road) should be constructed in the future. It shall be constructed along the southern coastline for use by container trucks. The heavy vehicles should not be allowed to pass the city area during peak traffic hours. The road congestion in the city area and loss of lives by accidents need to be prevented.

1) Construction of by-pass road.

A by-pass road will prevent road congestion in the city area. The emission of CO_2 gas will also be reduced.

Since a new road shown in Figure.4-1-4 has already been constructed, the beach road (yellow line, about 10km) should be constructed.

2) To furnish Car Parks and Information Stations

A truck driver has to wait until his turn, so basically the car park is necessary even before entering into the port. Parking on city roads causes road congestion. To reduce unnecessary road congestion, some parking places which provide information about the sequence of the waiting queue are necessary.

If the entrance time is apparent for standing-by-trucks, there will be no need for cars to park on the road near the gate.

Once receiving the information, the trucks should wait at the parking place. However, while waiting, the drivers may use their air conditioners. This is a cause of air pollution and the emission of CO_2. To avoid unnecessary idling, tree shades and roof sheds should be provided. The roof sheds should be quipped with air conditioner and toilets to prevent diseases.

3) To locate an inland container depot

If the cars from outside of the city do not have to come to the port, the queue in the port and outside port will decrease. Traveling through the city will be avoided. The traffic volume and number of parked cars will be reduced. In this regard, the inland container depot is proposed. The size of the inland container depot will be 20ha.

Figure 4-1-4 shows the location of the car parks and the inland depot.

As shown in the Figureure, a car park has already been constructed. The size of the car park is 13ha and it can accommodate 550 cars. This must be fully utilized. The Plan indicates an additional car park at the beach outside of the gate. The size of the car park will be 2ha (150 cars). The inland container depot is also proposed to compensate the shortage of the custom facilities inside the port. The area will be 20ha.

The cost of the by-pass road, the car park and the inland depot are roughly presented in Table 4-1-6

Table 4-1-6 Cost for By-pass Road, Car Park, and Inland Depot

Name of Facility	Scale/Dimension	Rough Cost (EURO million)
By-pass Road	B=25m, L=10km	47
Calvert Section	30 places	5
Beach and a car park	B=500, L=200, Paving 2ha	10
Inland Depot	Paving 20ha	27
Total		89

The road will be run by a toll system. The majority of the users will be container trucks and dump trucks. If the coast area belongs to SPAT, there will be no need to spend time and money to obtain the land. That is why the beach road is preferred to the widening of the existing road. Although the road would be constructed promptly, the road will be damaged frequently by cyclones. So it would need frequent repair.

The width of the road should not be narrower than 25m. The reasons for this size are;

1) Small section can be easily washed away by high waves.
2) Port Road must have one lane for parking.
3) Some heavy duty cars run very slow.
4) Heavy & long trucks sometimes have to turn.

In addition to the space for the 25m road, an additional space, such as 25m for each side should be reserved for the repair of the road. The road should not interfere with the passing of people, cars, and animals. The Calvert tunnel should be located at 30 places.

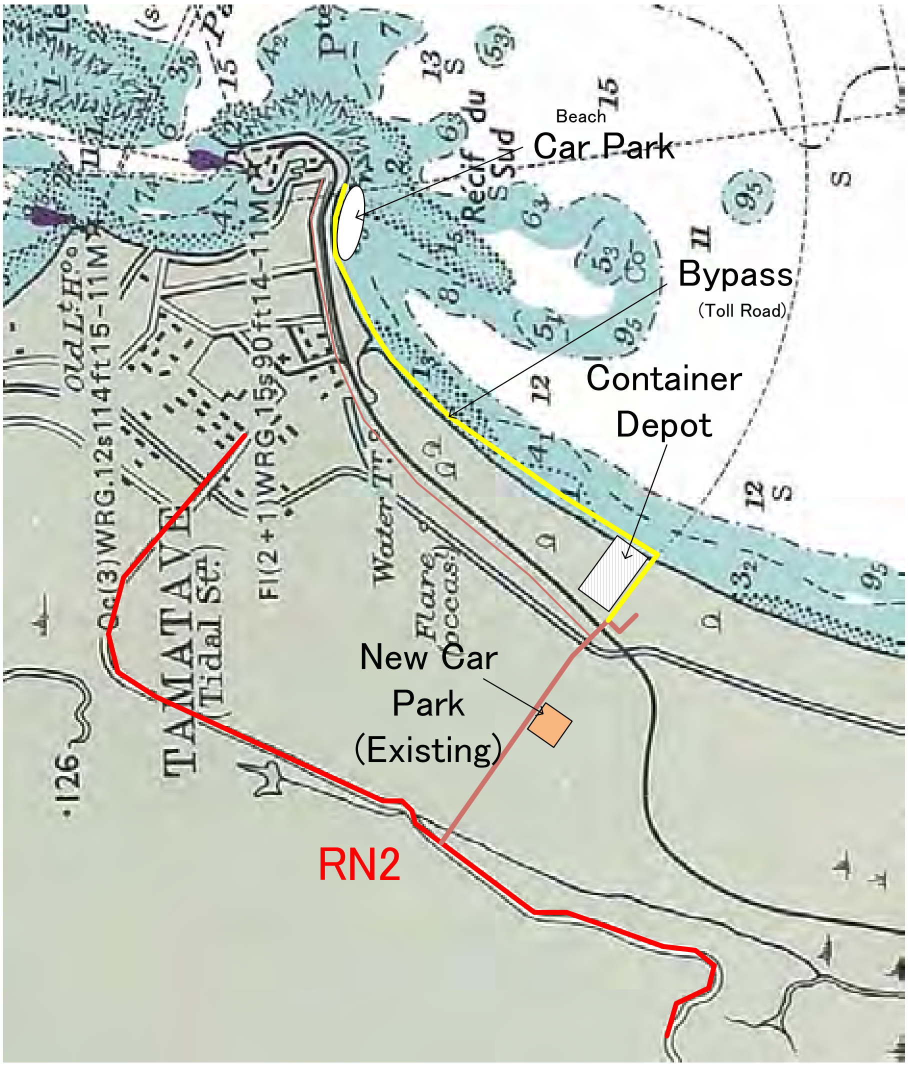


Figure 4-1-4 Proposed By-pass Road, Car Park, and Inland Depot

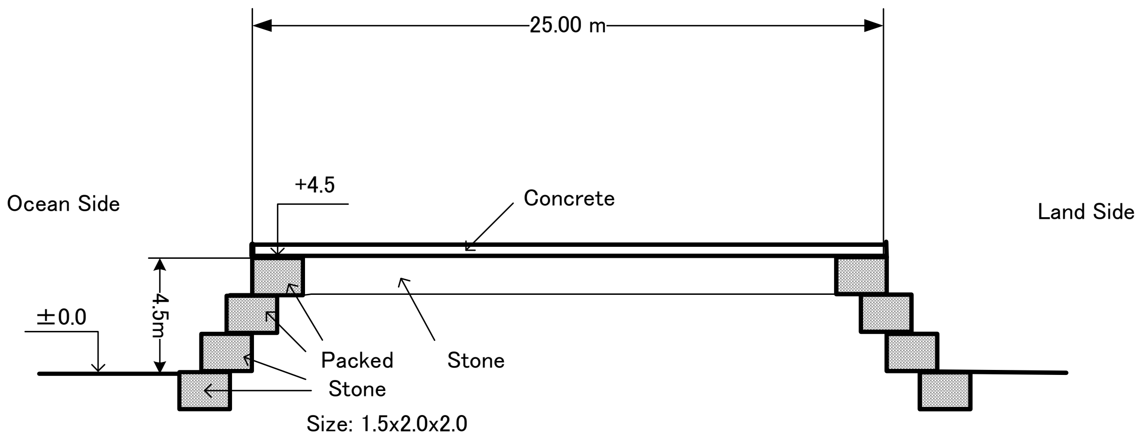


Figure 4-1-5 Proposed Section of the Beach Road

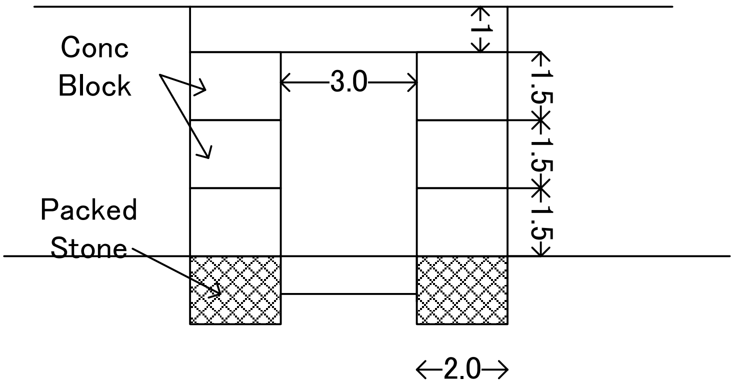


Figure 4-1-6 Proposed Section of the Calvert

(9) Harmony between the environment and development

1) Symbiosis with the corals

The 300km Coral barrier, the longest class in the world, exists in the southern part of Madagascar from Andavadoaka to Itanpolo.

The shoreline stretches southward 1000 km to Toamasina in a straight line. There are five coral reefs in the neighborhood of Toamasina. Two of them play a role in sheltering the port. The big reef is called the grand reef, and the small one is called the Hastie reef.

Figure 4-1-7 Coral reefs in the sea of Toamasina

Originally the two reefs were 1,000m away, but because of the construction of the breakwater and C3 quay in 1974, the distance was reduced to 500m.

There are 5 areas that have potential for development in the bay, namely (C), (D), (E), (F), and (G), as seen in the Figure 4-1-8. On the other hand, (F) will be preserved as an open space for citizens.

Areas (E), (G) are not usable unless the breakwater at (C) is constructed. Area (D) needs a bridge and it must wait for the breakwater of (C).

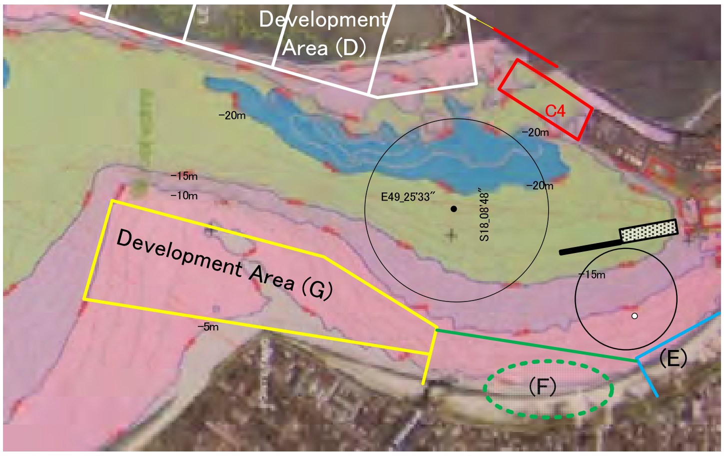


Figure 4-1-8 The Development Potential in Toamashina Port

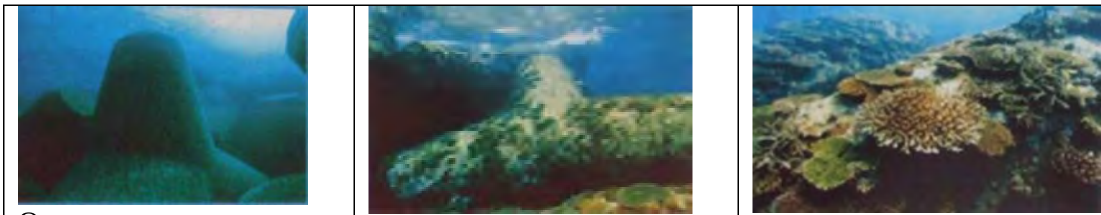
Accordingly, (C) must be developed initially. In developing the (C) and (D) area, the coral will inevitably be damaged.

The balance of harbor development and the protection of the coral must be kept in such a condition as the above.

By understanding the nature of the coral, a way to co-exist with the coral can be Planned:

(1) The coral perishes when water is muddy. That is why it is necessary to prevent muddy water from reaching the coral. For example, muddy water should not be allowed to spread during the construction. River should be trained so that the contaminated water may not reach the coral reef.

(2) It is known that even if the coral is crushed under the breakwater, coral will grow again on the slope of it and mature.



One year | 4year | 11 year

Figure 4-1-9 Coral on the Wave Dissipating Blocks in Okinawa (1)

(30 years after breakwater construction)

Figure 4-1-10 Coral on the Wave Dissipating Blocks in Okinawa

Figure 4-1-9~Figure 4-1-10 are the states of coral which are growing on the wave dissipating block. Coral also grows on the top of the C3 quay which was built in 1974. Figure 4-1-11 shows the coral on the rock foundation of the C3 quay.

That is why the construction of the breakwater or the quay at the slopes of the reef should be permitted.

Figure 4-1-11 Coral on the Rock foundation of C3 Quay (Toamasina Port)

(3) Coral perish when the temperature of the water of the reef flat becomes high. Perished coral is broken by the high waves at the time of the storm. Pieces of coral accumulate in central part of the reef flat where the sea is calm. Thus the land is formed gradually on the reef flat. This phenomenon can be observed in the photograph. In the Figure 4-1-7, the reef flat seen at the left side has already been covered by Plants. The reef flats in the neighborhood of Toamasina will eventually become land in the long run.
That is why the filling up of the reef flat of Toamasina for the port construction should be permitted.

(4) The port should try to keep the water clean so that the coral on the slope that faces the open sea may survive.
If the coral must inevitably be buried under the breakwater or the quay, the valuable stocks should be moved to the place where the coral can survive, such as the slope of a new breakwater. It is also recommendable to use wave dissipating blocks which have slakes to help epiphytes of the coral.

- In summary, symbiosis with the corals should be attained in the following manner.
  The filling up of the reef flat of Toamasina for the port construction should be granted. However, the unnecessary damage to the coral should be avoided.
  (a) To mitigate the loss of coral by the breakwater, wave dissipating blocks on which epiphytes of the coral easily form should be used.
  (b) To avoid extinction of the coral that exists on the slope inside the port, the code to restrict waste water should be established. The drain water should be monitored. The drainage that flows into the port area should be allowed only when the water quality is acceptable.
    ①Permission of SPAT should be required before a factory can dump waste water into the harbor and a penalty should be imposed when waste water regulations are not followed.
    ②The rainwater should be drained after the oil and the sediments are extracted.
    ③Toilets with a purifier of filthy water should be furnished in the port.

(c) To protect corals at the ocean side, suspended materials such as clay should be removed from the drainage that flows into a Hastie reef. Severe waste water control rules and management should be applied.

(d) To avoid eutrophication in the port basin, a canal should be excavated in future along the shore. It will collect the drainage water from the land area. The collected water will be led to the mouth of the bay (Tanio Point), and a fish pond will be located at the outlet of the canal. The fish pond has the function to consolidate nutrition as a form of algae or seaweed will be eaten by the fish. The management of the fish pond should be consigned to the local fishermen's association. Since the fish will be eaten by citizens at the final stage, the quality of the water in the pond should be controlled.

4-2 Middle Term Development Plan

4-2-1 Middle Term Development Plan

Following facilities are Planned to cope with the increase of the container cargo and dry cargo in 2020.

(1) Port Facilities

- Breakwater will be extended to 345m.
- C4, and C4-annex berth will be constructed at the end of the C3 berth. C4 berth has a length of 320m, and C4-annex has a length of 150m. The draft of the new berths will be -14m. New berths will be the container berth
- Hastie Reef will be reclaimed and utilized for the container yard and open storage yard. The reclaimed area will be 26.2 ha.
- Existing Container berth, which is the C3 berth, will be deepened up to -14m.
- Existing C1,C2 berths, which is utilized for Bulk/General Cargo will be deepened up to -13m, and will accommodate panamax vessels.
- An overpass will be constructed at the railroad crossing of NO.1 gate.

The end of the C4 quay will be extended (-14x150m). By furnishing the additional length of berth, additional container marshalling yard, and machine, the cargo will be handled quickly.

The aim of the additional Plan is to alleviate the waiting time of the vessels after 2020. However, the port will promptly have to proceed to the next step of the development, possibly the development of Area (D).

Table 4-2-1 indicates the facility, cost, and the expected source of funds for the year 2020 Plan. The layout is determined through the alternative examination of the several alternatives.

The most profitable Plan is selected for the Middle Term Development Plan, and it is presented in Figure 4-2-1.

Table 4-2-1 Cost for the Middle Term Development Plan and Responsible Organization

Facility	Cost: EURO(million)	Responsible Organization
(Urgent Phase)		
Breakwater (345m)	42.7	SPAT
C4 Quay(−14x320m)	55.4	SPAT
Reclamation 10ha	25.6	SPAT
Relocation & Paving	15.3	SPAT
Dredging (143,000m3)	3.8	SPAT
Deepening (C1,C2,C3)	9.8	SPAT
Over Pass (at No1 gate)	10.5	SPAT
Environment Protection	4.2	SPAT
Engineering Cost(Civil)	11.7	SPAT
Hargo Handling Machine	41.1	MICTSL
Total (1)	220.1	
Additional Port Facility (after 2017)		
C4−annex (+150m)	26.0	SPAT
Reclamation (+)16ha	41.0	SPAT
Engineering (Civil)	4.7	SPAT
Cargo Handling Machine	23.2	MICTSL
Total (2)	94.9	
(1)+(2)	315.0	

(Note : escalation is not included)

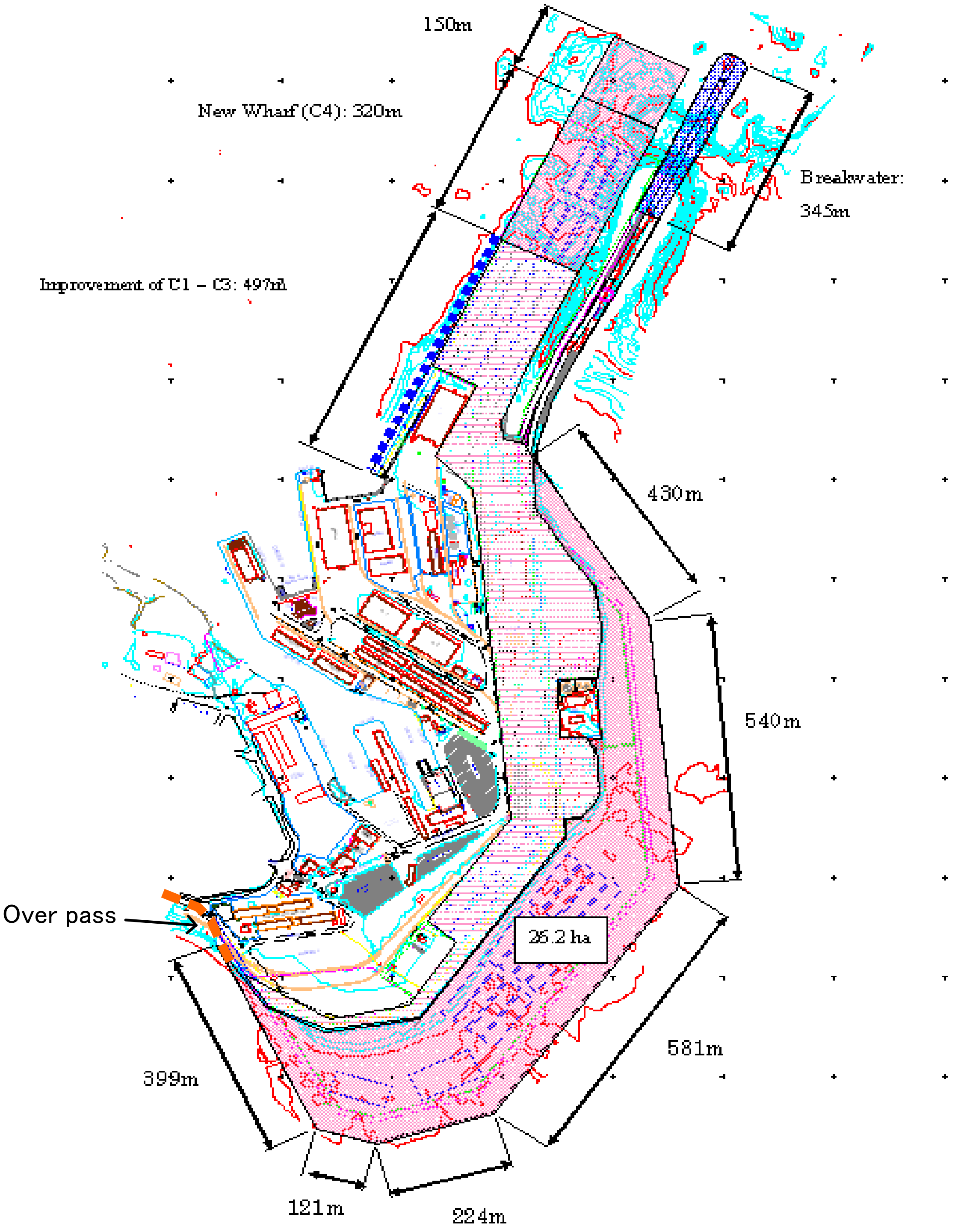


Figure 4-2-1 The Middle Term Development Plan

(2) The related facilities

In addition to the port facilities, the following measures are proposed to avoid aggravation of the environment. The necessity and the feasibility should be examined again after the Urgent Development Plan is completed.

- The new toll road (10km)
  It will be constructed along the coastline of the southern beach for the purpose of preventing air pollution and traffic accidents. A Car Park will be constructed adjacent to the Port in addition to the present car park which is located adjacent to the Anvatoby Factory.
- A Canal (B=15m, Length=2km)
  It will be created along the port beach (2km). The land side beach will be utilized for the citizen's free access. The canal will collect the sewage and utilized for the prevention of the contamination of the harbor basin.
- Groins (500m)
  The erosion and accretion will be controlled by groins and jetties.

The cost for the related project is indicated in Table 4-2-2.

The locations of facilities and sections are indicated in Figure 4-2-2~Figure 4-2-5

Table 4-2-2 The Cost for the Related Project

Facility	Cost: EURO (million)
By-pass road (B=25mx10km)	51.8
Car Park and Beach	9.8
Canal (B=15mx2km)	5.8
Groin for erosion protection	1.8
Engineering	4.8
Total	74.0

(Note: Escalation is not included)

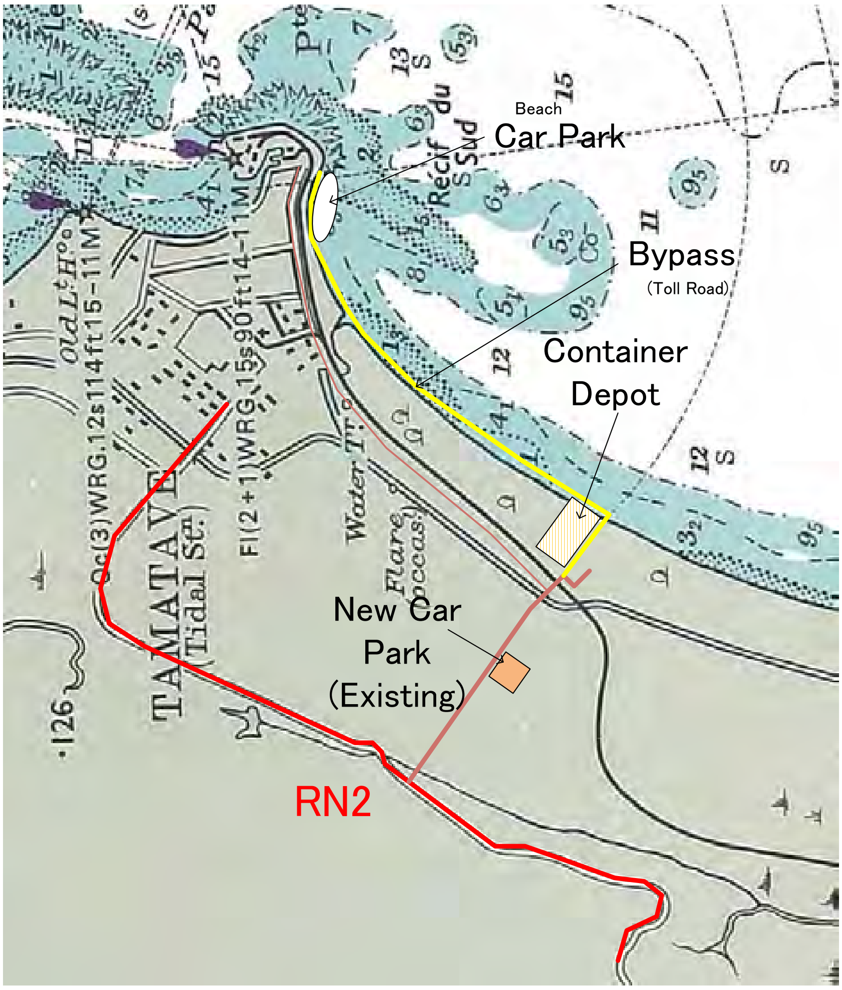


Figure 4-2-2 The Route Plan of the By-pass Road

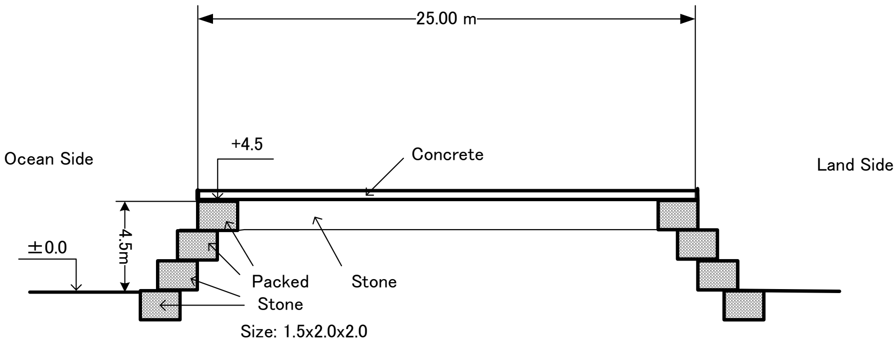


Figure 4-2-3 Standard Section of the By-pass Road (Toll Road)

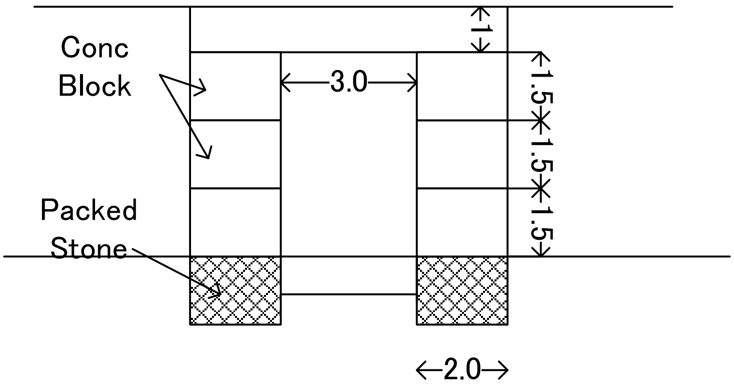


Figure 4-2-4 Standard Section of the Calvert

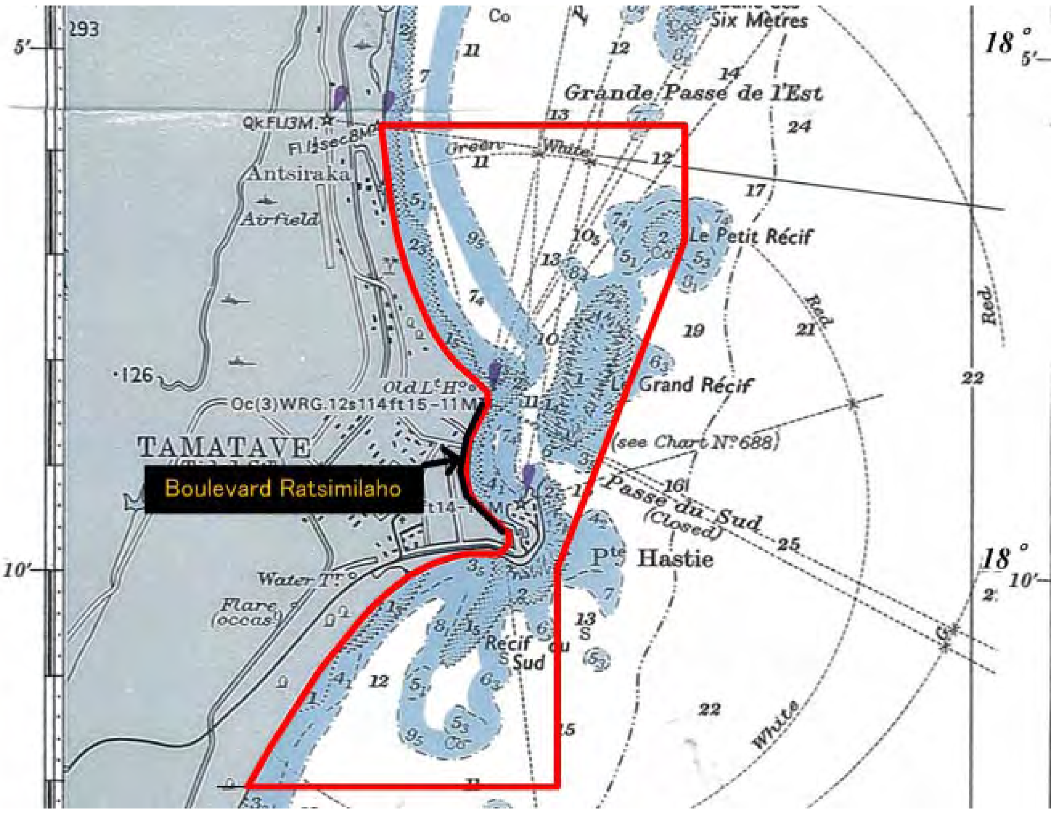


Figure 4-2-5 Beach Area of the Toamasina Bay

Ways to protect the port basin from the problem of eutrophication are as follows.

1) A new canal to collect the sewage along the beach road should be excavated. Total length of the canal will be 2,100 m.
2) In order to keep the water clean, the current running in the north direction should be created by pouring fresh water at the starting point of the canal.
3) The power source of the pump will be the natural energy. Since cyclones attack Toamasina, wind fan would collapse easily. Solar cells are recommended.
4) Outlet of the canal will be located at Tanio Point.
5) A sewage treatment will also be located to remove fiver material and harmful materials from the water.
6) A pond of about 2ha will be excavated and used to breed Plankton, algae, and fish.

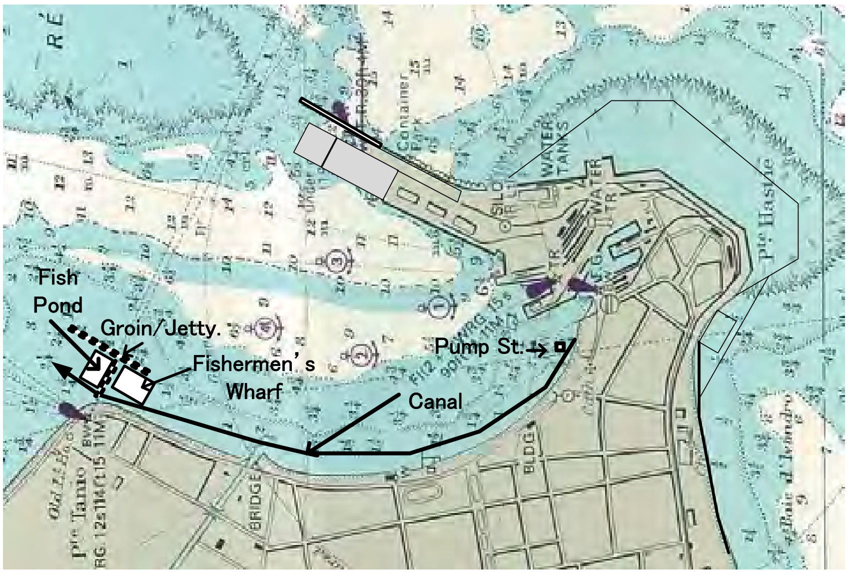


Figure 4-2-6 The Route of the Canal and Location of Groins

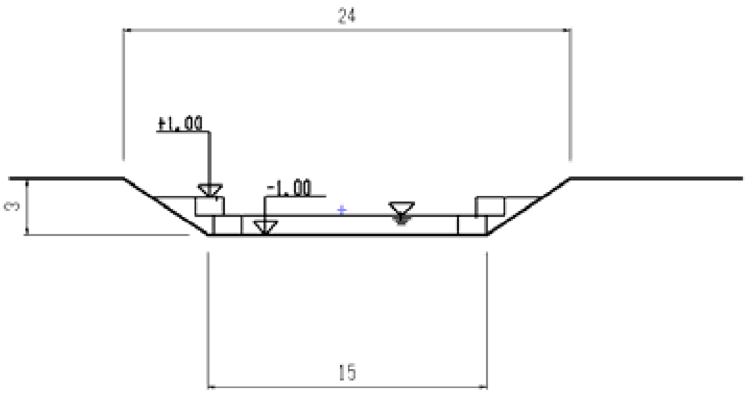


Figure 4-2-7 Section of the Canal

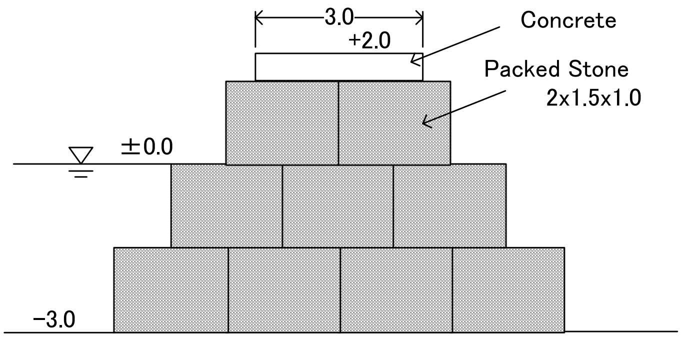


Figure 4-2-8 Section of the Groin

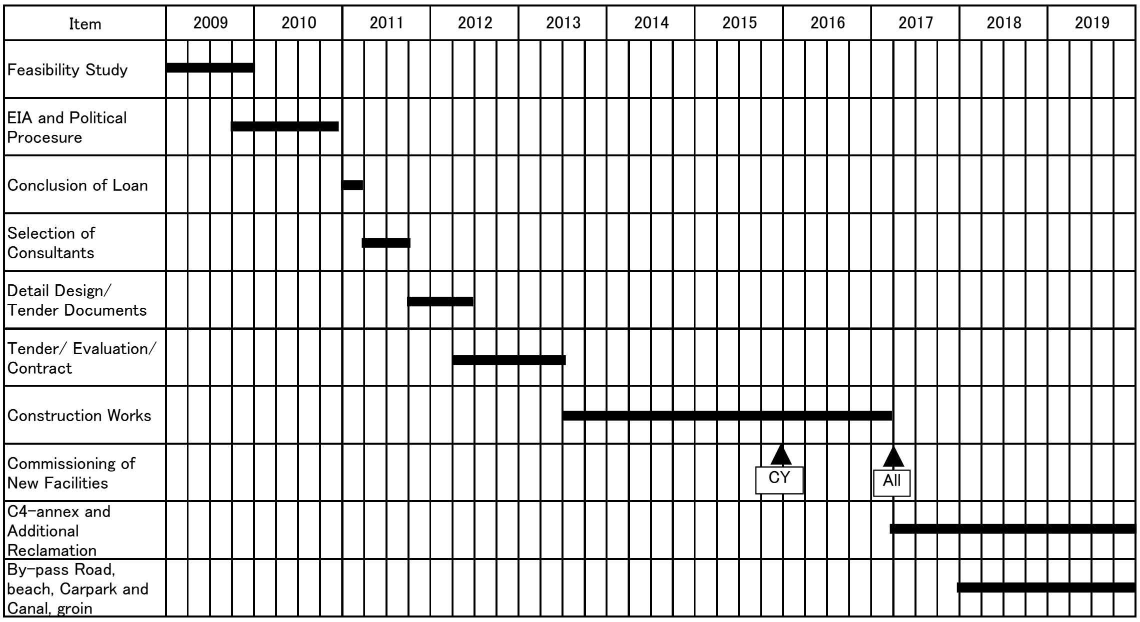


Figure 4-2-9 Implementation Schedule of the Year 2020 Plan

4-3 Urgent Development Plan

Targeting the year 2017, the Urgent Development Plan is comprised of the following.

- Breakwater will be extended by 345m.
- The C4 berth will be constructed at the end of the C3 berth.
- The container yard (10ha) will be constructed, by reclaiming the Hastie Reef.
- Existing container berth C3 berth will be deepened up to -14m
- C1,C2 berths will be deepened up to -13m.
- Open storage space of 4ha will be reserved for wood chips, and the wood chips will be handled at C1,C2 berths. Belt conveyers will transport chips from the open storage to the quay.
- An overpass will be constructed at the railroad crossing of NO.1 gate.

Although the open mouth (about 150m) between the grand reef and the break water remains, the length of the breakwater is sufficient to maintain calmness around C4 berth. Workable days are 95% in the year.

C4 berth has -14m draft and 320m length. It can accommodate a 3,200TEU container ship. Existing C3 berth will also be deepened up to -14m. C2,C3 berth will be deepened up to -14 ~-13m.

Since the space behind the quay C4 is not sufficient to handle containers, the container Yard (10ha) is Planned at Hastie reef.

An overpass is Planned because the wagons for the Anvatovy Factory stop the traffic of container trucks almost all the time.

The countermeasure for erosion and accretion are not included in the Urgent Phase, since it is advantageous to implement it after the port basin becomes calm. It should be implemented in the year 2020 Plan.

As eutrophication is not an urgent problem at this time, the countermeasure is not included in the Urgent Phase. It should be dealt with in the year 2020 Plan.

The countermeasure for the congestion of roads that is the By-pass road along the coastline should be implemented in the year 2020 Plan.

The layout for the Urgent Development Plan is presented in Figure 4-3-1.

The cost for the Urgent Development Plan is indicated in Table 4-3-1.

The Implementation Schedule is shown in Figure 4-3-2.

Table 4-3-1 Cost for the Urgent Development Plan

Facility	Cost: EURO(million)	Responsible Organization
(Urgent Development Plan)		
Breakwater (345m)	42.7	SPAT
C4 Quay(−14x320m)	55.4	SPAT
Reclamation 10ha	25.6	SPAT
Relocation & Paving	15.3	SPAT
Dredging (143,000m3)	3.8	SPAT
Deepening (C1,C2,C3)	9.8	SPAT
Over Pass (at No1 gate)	10.5	SPAT
Environment Protection	4.2	SPAT
Engineering Cost(Civil)	11.7	SPAT
Hargo Handling Machine	41.1	MICTSL
Total (Urgent Development Plan)	220.1	

(Escalation is not included)

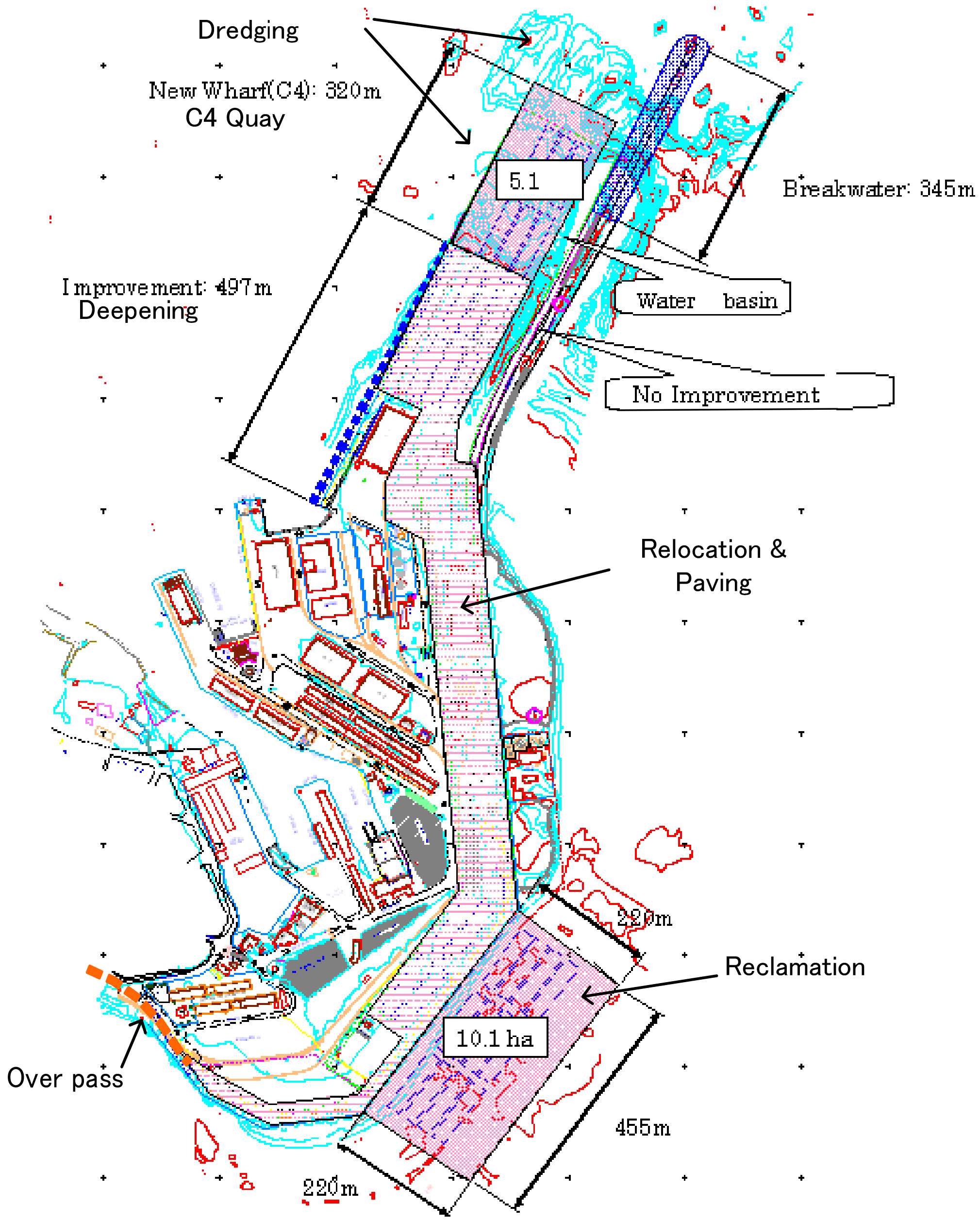


Figure 4-3-1 Urgent Development Plan

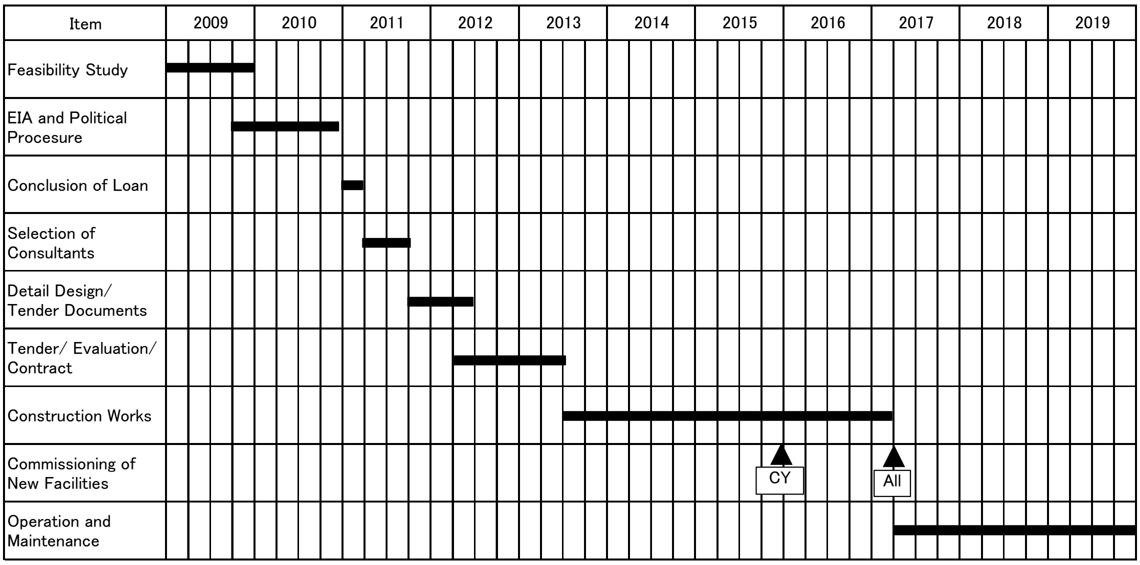


Figure 4-3-2 Implementation Schedule (Urgent Development Plan)

Taking into account the procedures for each organization, the start of the construction work will be in 2013 and the commissioning of the quay C4 will be in 2017.

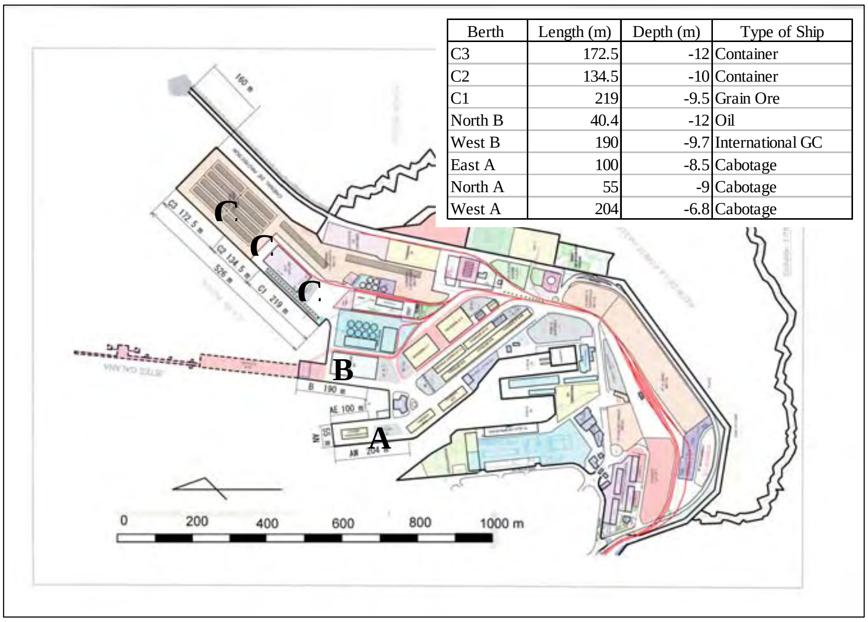
4-4 Problems to be Overcome by the Project

4-4-1 Problems to be Overcome by the Project

(1) Existing Situation of Toamasina Port

1) Facility layout and berth allocation

The existing wharves and their names are shown in Figure 4-4-1 as well as the dimensions of respective berths and the berth allocation.

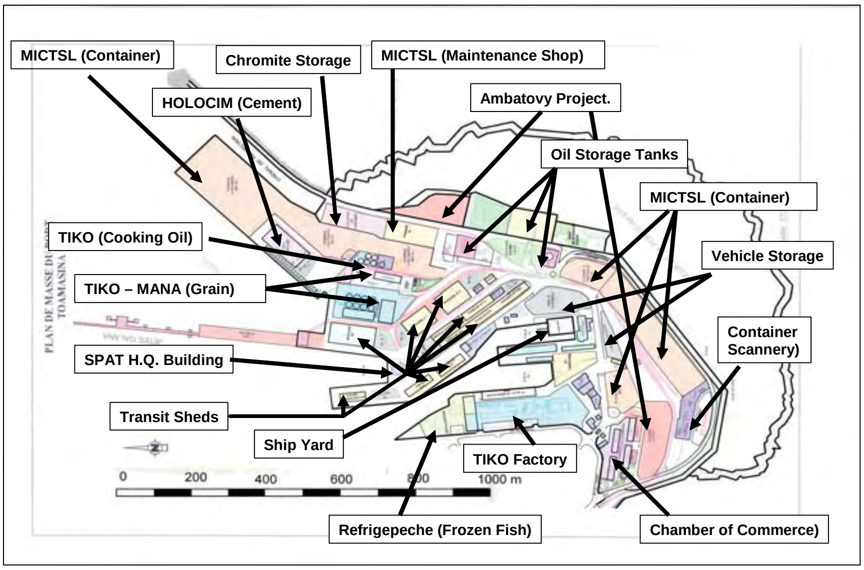


Berth	Length (m)	Depth (m)	Type of Ship
C3	172.5	-12	Container
C2	134.5	-10	Container
C1	219	-9.5	Grain Ore
North B	40.4	-12	Oil
West B	190	-9.7	International GC
East A	100	-8.5	Cabotage
North A	55	-9	Cabotage
West A	204	-6.8	Cabotage

Source: SPAT

Figure 4-4-1 Layout of the Existing Facilities of Toamasina Port

The current land use in the port area is shown in Figure 4-4-2. As seen in the Figure, besides those facilities directly related to port operation, many pieces of land areas are leased to various companies for the exclusive use for their businesses. Some of those are factories that are not necessarily located within the port area.

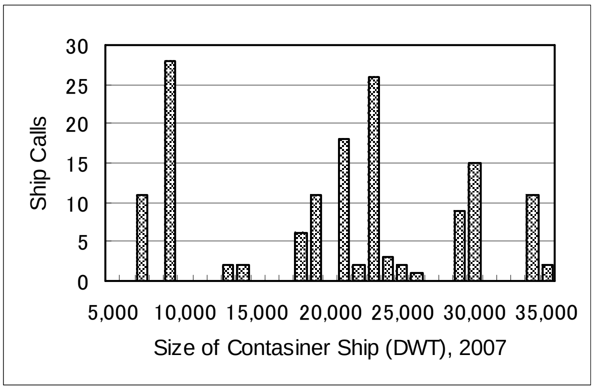


Source: SPAT, Edited by Study Team

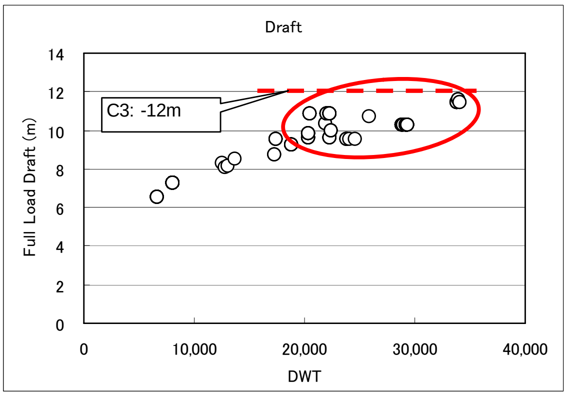
Figure 4-4-2 The Existing Land Use in Toamasina Port

2) Calling Ships

In 2007, the size of container ship varies from 7,000 DWT to 36,000 DWT. The histogram of ship calls by size is exhibited in Figure 4-4-3. It is observed in the Figure that the sizes of container ships fall on three groups: 10,000 DWT, 20,000 – 25,000 DWT and 30,000 – 36,000 DWT. The ship calls of container ships having DWT's over 30,000 DWT account for 20 %, Those container ships having DWT of 30,000 or larger cannot dock at the container berths with full load.(see Figure. 4-4-4) due to the draft restriction at C2 (water depth: -10 m) and C3 (water depth: -12 m) berths. Bulk and general cargo ships calling on the port tends to become larger sizes. They are also encountering difficulties to dock at the Port due to the draft restriction.



Source: SPAT edited by Study Team
Figure 4-4-3 Histogram of Ship Calls by Size



Source: SPAT edited by Study Team
Figure 4-4-4 Draft vs DWT

3) berth Occupancy rate

The berth occupancy rare at the berths are summarized in Table 4-4-1 The berth occupancy at Berth C2 and Oil Berth were low- Oil berth is specialized berth only for petroleum tankers- The low occupancy results from the short length of C2 and C3 and large ships that occupied both C2 and C3 berths were recoded to have docked at C3- Thus, in practice, C2 and C3 were often operated as just one berth to accommodate large ships-

Table 4-4-1 Ship-in-Port Time by Berth (2008)

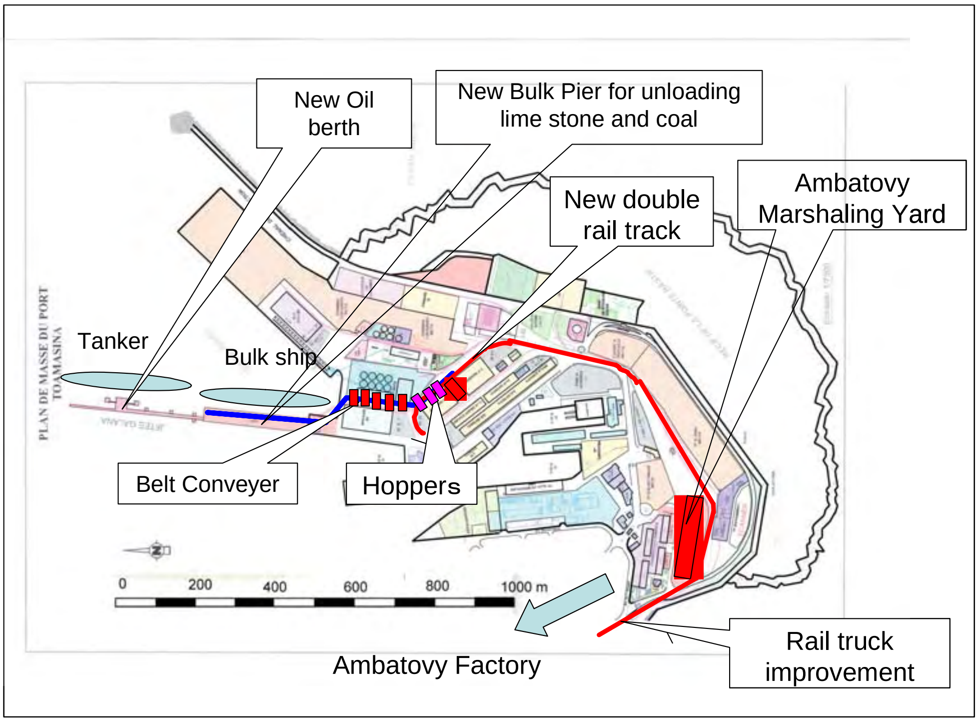
Berth	Total Berth-Hour	Ave. Hour/ship	Total Calls	Berth Occupancy Rate
AE	4,740	97	49	60%
AWN	4,106	242	17	52%
B	3,647	51	71	46%
C1	5,170	110	47	65%
C2	2,094	46	46	26%
C3*	5,652	17	330	65%
PB (Oil)	2,490	52	48	31%

* Figures for C3 were calculated by MICTSL for those ships carrying containers only
Source: SPAT and MICTSL, edited by Study Team

4) New users of the port

a) New Bulk pier of Ambatovy (nickel mining)

Ambatovy project is a large scale integrated project that ranges from developing a mine to constructing a processing - refinery plant- For the unloading of coal and limestone, a new bulk pier (Length of the extension is 280 m, which water depth of the pier is -13 m) is under construction at the location of the existing oil terminal at Mole B- A new oil berth is also being constructed at the end of the new pier- Figure 4-4-5 shows the new facilities that Ambatovy project plans to construct- In addition to the new pier and the oil berth, a belt conveyer and rail track will be constructed to transport the bulk cargoes from the pier to the factory of Ambatovy.



Source: SPAT, Edited by Study Team

Figure 4-4-5 New facilities planned in Toamasina Port for the Project of Ambatovy

As seen in Figure- 4-4-5, a new rail track will be constructed along the north side of the warehouses on Mole B and it is interconnected to the existing railway marshaling yard of Madarail- - The facilities that load bulk cargoes on the rail wagons is planned to be installed at the small open space between the warehouses- A 160-long train enters at the end of the new track- At this stage, the first wagon is located at the loading equipment, while the last portion of train is remain on Mole B- The 14 wagos will be filled with the bulk cargo, either coal or limestone one by one while the train is moving out slowly- It is estimated that the turn-around time of loading of a train is about 15 minutes-

b) Expansion of the capacity of Grain factory

Mana Madagascar, a flour company, is situated at a lot next to C1 berth- It has a processing capacity of 400 tons of grains per day- Now the company is installing an additional processing line that has a capacity of 600 tons per day, which will produce flour for export- The current storage capacity of grain silo is 32,000 tons, while the additional silos will provide 28,000 tons- The company wants to employ 32,000 DWT bulk carrier if a deep water berth is available-

Incidentally, the pneumatic unloader and belt conveyor system that leads to the silos have been completed- Because of the new unloading system, no heavy cargo handling equipment can enter C1 wharf- Therefore, C1 shall be mainly used by cement and wheat unloading- When the wharf is used for other cargoes, ship gears are the only possible way of handling cargoes-

c) Wood chip export by Oji-Paper Company, Japan

The Oji Paper, a Japanese paper producing company, is planning to export wood chip from Toamasina Port- The Oji Paper has started planting trees and is planning to employ a 55,000 DWT wood chip carrier for export to Japan- The full operation will start in 2016 and a deep draft berth and the stock yard having an area of at least 2-0 ha are required by that time-

(2) Identification of the problems to be settled in urgent development plan

Summing up the above discussion on the existing situation the problems to be settled or improved are summarized as follows

1) Existing Problems

a) Conflicts of traffic flows in the port area

Due to the lack of clear separation among the cargos, the cargo traffic flows are very complicated- Some of the serious states are several railway crossings- Just inside the port main gate, all the cargo trucks cross railway and then cross again in the middle of the port-

b) Access road to C1 berth

Berths C1, which is one of the key facilities for accommodating international general cargo and bulk ships, is enclosed by container terminal and grain and cement factories- The berth is used for unloading and loading various cargoes, i-e-, chrome ore/concentrate, vehicles and other general cargoes as well as wheat and cement in bulk- All the cargo trucks and imported vehicles used to pass through the narrow road between warehouse on Mole B and the fence of Mana grain factory, which is closed for the construction of the belt conveyer and the railway for the bulk cargoes of Ambatovy- Thus, the wharf B is the only the passage to access to C1- The apron of Wharf B is very messy because of the passage of many vehicles to and from C1 berth while Berth B is in service for a ship docking at the berth-

c) Lack of policy and guides line for the utilization port land area

While some buildings including warehouses in the port area are not used or under used, containers and other imported heavy vehicles are occupying all the available land spaces in the port due to the short of open storage yards- For the maximum use of limited resources, renovation of the port area under a proper policy and guidelines of scrap and build-

d) Short of water depth of the wharves

The sizes of ships called on Toamasina Port tend to increase- In fact, 20 % of the calling vessels in 2007 were inconvenienced by the restriction of the depth or the length of berth- Those vessels having DWT's over 30,000 had to adjust their draft by reducing the loads before calling on the port- This implies that the ships were not fully utilized, and this could have resulted in higher transport cost-

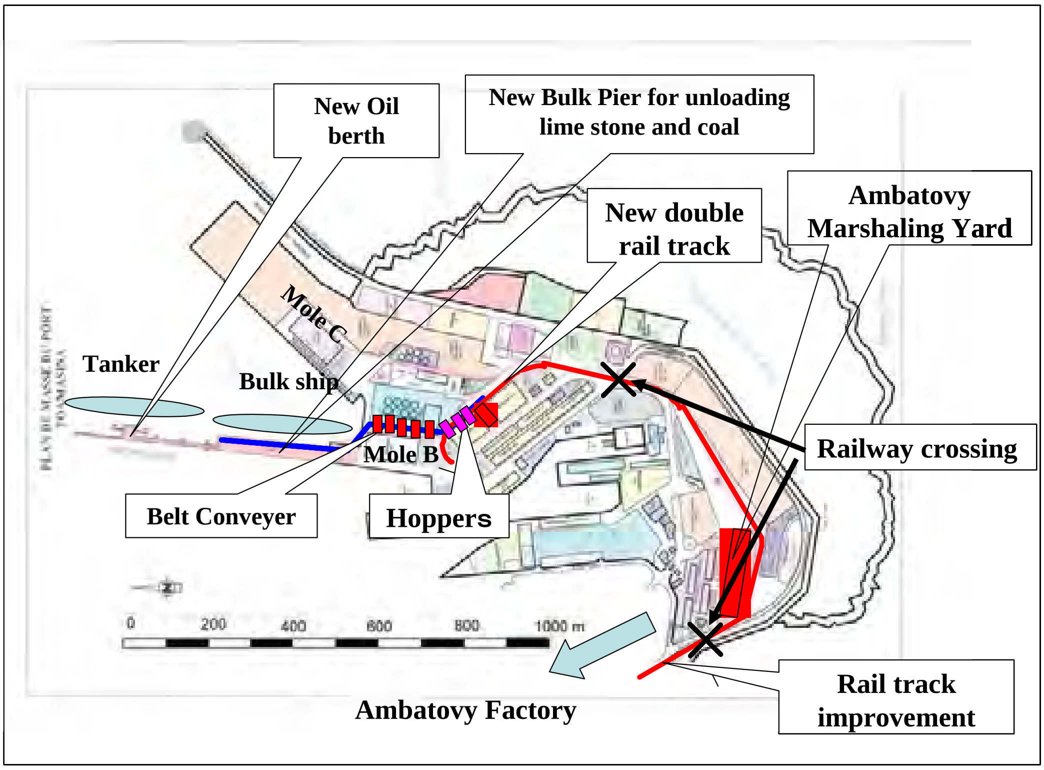
2) Problems anticipated

a) Cargo traffic demand in the coming years

The container handling capacity of the existing container terminal, which includes C2 and C3 berths, the container marshaling yard on Mole C and the empty container stock yards near the gate, is estimated to be 170,000 TEU per year- The container traffic volume is estimated to grow 426,000 TEU in 2020- Taking into considerations of the fact that the container traffic in 2008 exceeded 140,000 TEU's, It is very likely that the container cargo volume will to over flow the existing container terminal soon-

b) Start of the full operation of Ambatovy project

When Ambatovy starts full operation, the freight train operation on Mole B will completely block the existing access roads to Mole C including the container terminal and cement and grain factories- The frequency of train operation to and from the port will increase from few times a day to several times an hour- Thus, the railway crossing in the port will lead to serious restriction of the cargo traffic flow in the port area (see Figure- 4-4-6)- Thus, the port land area will be split in two parts: seaside and landside, and the movement across the railway will be difficult and not safe- - Therefore, the port needs to designate respective zones so that no traffic crossing railway is necessary-



Source: Study Team

Figure 4-4-6 Railway Operation for the Transportation of Bulk Cargoes of Ambatovy Project

3) Summary of the problems to be settled in the urgent development plan

Summing up above discussion the problems to be settled in the Urgent Development Plan have been identified as follows-

a) Zoning

The port lacks policy guideline for the development of the port- This results in piecewise land use of port area, which turned out to be complicated cargo flow system- As Ambatovy Project starts, the port land area is split into two parts, a proper zoning is indispensable to avoid conflict of cargo flows within the port- The road system needs to be re-arranged so that each zone will be productively utilized for designated functions-

b) Short of yard spaces

The cargo forecast indicates the container cargo volume will be tripled in a coming decade- There are several new port users who have requested SPAT for the use of wharf and yards for import and export businesses- Some of those are Oji Paper Company of Japan and another cement company- To cope with this, the port requires additional land area to make the cargo handling operation effective- Though there is a possibility to redevelop the existing port area by scrap and build, the additional land area that is used as the back up zone of Mole C should be provided sea side of the railway-

c) Short of draft of wharves

About 20 % of the ships calling on the port exceed the dimensions that the capacity of the existing wharves, i-e-, both water depth and length of the berths- Taking into considerations of such trends that shipping lines tend to deploy larger size ships for scale merit, the port need to have deep draft berth for both container and bulk cargo ships-

4-4-2 Urgent Requirement for physical port infrastructure

(1) Facility requirements

On the basis of the discussion of the urgent development plan should be drawn with the aim at to settle the identified problems-

The port facilities that should be included in the urgent development plan are as follows:

For International shipping

- Container yard
- Bulk cargoes (wood chip and chrome ore/concentrate)
- General cargoes(warehouses for grain, cement and open storage for imported vehicles)

Domestic trade

- cargo handling area for transshipment of (bagged cargoes such as salt, rice and cement, general cargoes such as sisal, construction material, cartons of consumables)

Summary of facility requirement for the urgent development

Wharves

International berth:

Design ship: Container and bulk ships having DWT of 55,000 tons

Wharf:: Container one 320 m long berth with gantry cranes, water depth -14m-

Bulk berth having a total length of 500 m, water depth -14m

Cement & wheat (deepening of C1 berth to -14 m)

Domestic: Existing facilities at: Mole A and Mole B

Additional berth at the west side berth of the new pier B

Yard space:

Container: 10 ha (minimum):

Bulk 3 ha (Wood chip 2 ha, Chrome ore 1 ha, minimum)

Port road

Separate access roads for Container, Bulk and general cargoes without crossing rail tracks-

(2) Premises for the preparation of the urgent development plan of Toamasina Port

The urgent development plan of Toamasina Port has been elaborated on the basis of the following premises:

a- Toamasina Port will remain as the principal gateway port of Madagascar- Even taking it into account that The Master Plan Study funded by the World Bank, has recommended the development of another deep sea port in the vicinity of Nosy Be, which is located on northwest coast of Madagascar, Toamasina has advantage of the proximity to Antananarivo, the capital, and the existing transport infrastructures and established transport services-

b- The current study focuses on clearing the existing and the anticipated problems of the port and on maximizing the use of the existing resources of Toamasina Port by the renovation and the redevelopment and then by investing on some new facilities to expand the capacity of the existing infrastructures- The urgent development plan should have flexibility as much as possible for the long-term development of the port-

c- It is assumed in the urgent development plan that the most of the existing structures, such as tanks, transit sheds, silos, fixed cranes and belt conveyers and office buildings, will remain as they are-

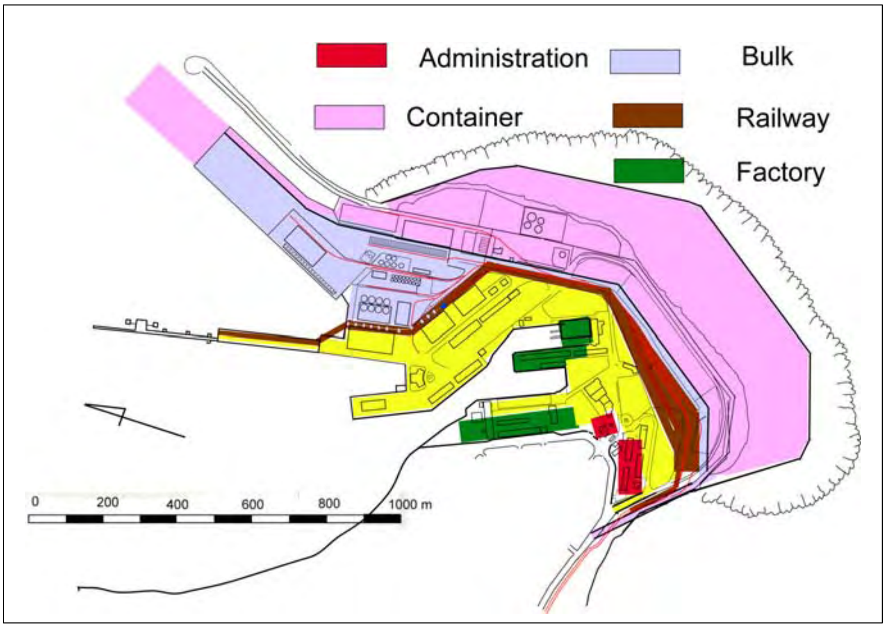
However, the effort to secure the smooth traffic is needed- The roads, railways and port gates shall be relocated or newly constructed when necessary-

d- Complete separation of cargo traffic flow in the port area is the key factor in the facility layout plan- Therefore, container zone, bulk zone, railway zone, oil zone, general cargo zone for International and domestic cargoes are delineated- Railway and oil zones have been already designated and the development of necessary infrastructure development is underway- It is also assumed that all the import bulk cargoes related to Ambatovy Project will be handled at the east side berth of the new B pier and all the petroleum is handled at the new oil berth, which start operation in September 2009-

(3) Zoning of the port area

Prior to the facility layout plan, zonig plan should be prepared for the smooth cargo flows of various types of cargoes to avoid conflict- The key element to be considered is to separate bulk, container and railway zones from each other- The conceptual zoning plan is shown in Figure- 4-4-7. The plan was drawn as the most realistic one that does not require large scale relocation of the existing structures for the urgent development-

Provided that new access road to bulk and general cargo zones are constructed, bulk, container, railway and general cargo zones are completely separated and each cargo has respective access road from the main gate of the port- The only conflict between rail and trucks remain at the railway crossing just inside the main gate- This conflict can be cleared by constructing rail overpass-



Source: Study Team

Figure 4-4-7 Zoning Plan of the Port

4-4-3 Layout plan of the urgent development

(1) Components of Urgent Development Plan

The following elements need to be developed urgently to cope with the container and bulk cargo traffic demands up to 2020:

a Reclamation of Point Hastie Reef (10 ha)
- construction of revetment
- reclamation landfill
  - Pavement of container terminal including new reclamation
- construction of container yard and ancillary facilities

b Extension of breakwater (354 m)

c Construction of a new wharf 320 m x 150 m
- Berth construction
  - -14 m container berth
  - -14 m bulk berth
- Reclamation of wharf
- Foundation of container quay cranes
- Pavement of the reclamation
- Construction of an access road to the new wharf
- Dredging of berth and basin

d Construction of a new access road from the main gate to wharf C- 1 wharf (for bulk cargoes)

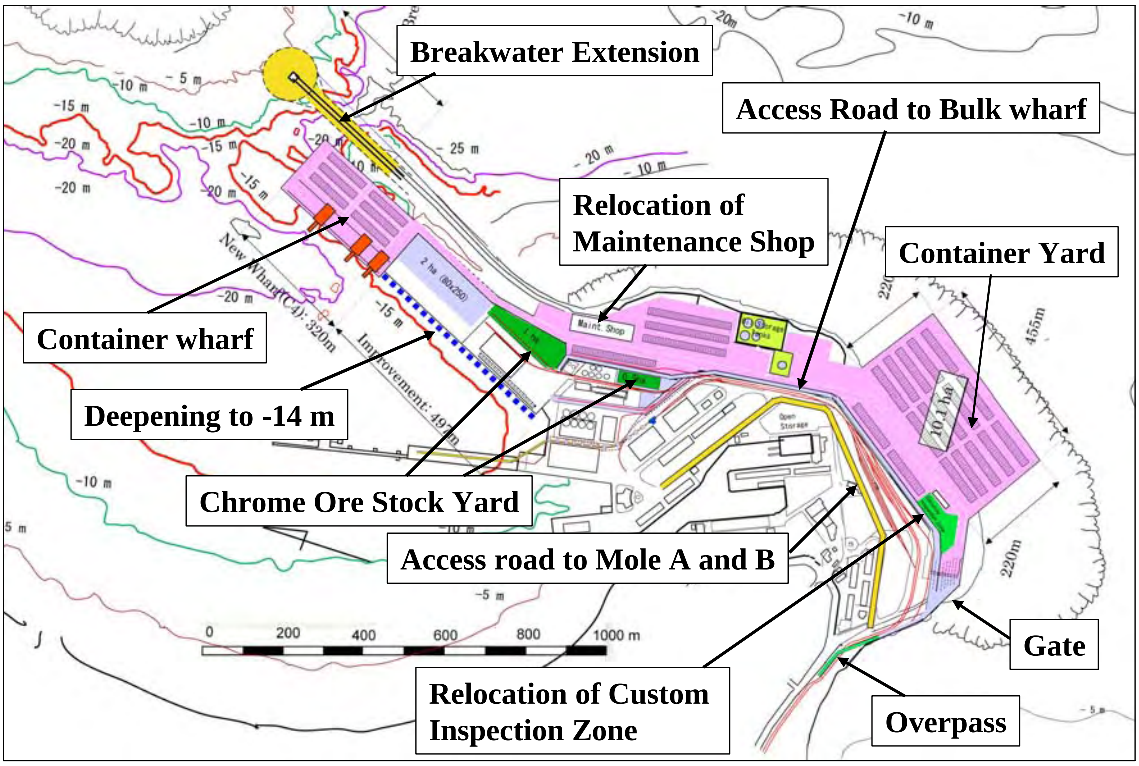
e Deepening of Berth C3, C2 and C1

f Construction of a flyover roadway at the main gate

g Installation of three units of container quay cranes and necessary number of RTG at the Yard

(2) Facility layout plan

The facility layout plan of the urgent development is shown in Figure 4-4-8. In the Figure, the locations of those elements to be developed in the plan are indicated-



Source: Study Team

Figure 4-4-8 Facility Layout of the Urgent Development Plan

Chapter 5. Cargo Handling Operation and Management

5-1 Container Operation

Container cargo handling capacity of Toamasina port by the existing facilities is around 175,000 TEU per annum according to MICTSL, the excusive container handling operator of the port. The container cargo volume reaches the capacity by 2011 based on the forecast of this study with the hypothesis that container cargo volume keeps increase at annual rate of 10% from 2005 to 2020. Thus, SPAT has to develop new container handling facilities by the time being: berth as well as container yard (CY).

Table 5-1-1 Container Volume Forecast of Toamasina Port

Unit: '000 TEU

Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Actual	141.9	123.0											
Estimated	135.8	149.3	164.3	180.7	198.8	218.6	240.5	264.6	291.0	320.1	352.1	387.3	426.1
Variance:	**4.5%**	**-17.6%**											

Source: MICTSL and Study Team

The urgent development plan proposed in the previous chapter is to develop a new container berth by extending Mole-C berth by 320 meters with a depth of 14 meters. The new container berth is good enough for handling container vessels having a load capacity of 4,000~5,000TEU. The plan also proposed to develop an additional container storage yard (CY) on Hastie Reef.

With three (3) units of Quay Gantry Cranes (QGC) on the new 320 meter long berth, capacity of the new container berth becomes 448,000 TEU per annum under the condition that the net productivity of these GCs is 30.0 lifts per hour per unit, and net utilization ratio of them is 45.0%. The capacity of the berth is just enough to cope with the increasing container cargoes up to the year of 2020 based on our forecast.

On the other hand, the container yard (CY) capacity on the C-4 wharf is not large enough for marshalling of 448,000 TEU of containers per annum because the width of the wharf is limited to only 150 meters by the existence of the breakwater. The CY on C-4 wharf has only 700 ground TEU slots at the maximum with RTG operational system, equivalent to the annual operational capacity of 230,000 TEU for storing export laden and empty containers with assumption that the average dwell-days is three days.

Therefore, SPAT needs to find an additional CY space capable to handle 220,000 TEU or more of containers per annum at the location desirably close to C-4 Berth, which is equivalent to 10.0 hectares for storing import containers by RTG system. The location has been chosen on Hastie Reef because the reef provides a space large enough for the purpose.

Once SPAT develops 10.0 hectares of CY (455 x 220 meters as proposed in the plan) there, another 2,088 of ground TEU slots becomes available, which is just enough for storing 220,000 TEU of import laden containers per annum assuming their dwell-days is 7 days on the average.

Summing up the capacity of both CYs, the annual handling capacity of the port becomes around 450,000 TEU, excluding empty container van-pool capacity; which is just the same volume as the annual container handling capacity at the berth. Thus, terminal capacity of the new container facilities in Toamasina port can be said to be 450,000 TEU per annum, which is large enough to handle the containers up to the year of 2020.

Since the new container facilities of the port is expected to be completed in 2016 (Off-dock CY) and 2017 (berth and On-dock CY) as the earliest; thus, SPAT or MICTSL have to develop an additional CY that is capable to handle 120,000 TEU of containers per annum desirably near C-3 terminal to cope with the increase of container cargoes until by the time when new facilities are operational.

[291,000 (volume estimated in 2016) -175,000 (max capacity of existing facilities) = 116,000]

In addition to gaining necessary CY capacity, MICTSL has to make effort to increase the productivity of their three (3) units of mobile cranes from current 14.0 lifts per hour per crane on the average to 16.0 or more for the purpose of increasing its berth capacity, and to develop the additional CY for balancing to the above mentioned new CY capacity (295,000 TEU). When MICTSL raises the productivity up to 16.0 lifts and 17.0 lifts per hour per crane on average, berth capacity of C-3 reaches to 280,000 TEU and 297,000 TEU per annum, respectively.

Furthermore, SPAT has to make another container terminal operational by the end of 2020 since C-4 berth/CY and its off-dock CY built on Hastie Reef will be overflowed by the year or so.

Grand Reef is the only frontier to develop a number of full-scaled modern container terminals (recommendable size of the terminal is 320-350 meter long berth with 500-600 meter wide CY each) and multi-purpose terminals for the port, the major gateway of Republic of Madagascar. These terminals should surely support the growth of economy of Madagascar for many decades to come; handling a lot of transshipment containers as well, competing with Port Louis in Mauritius.

5-2 General, Bulk and Other Cargo Operation

Toamasina port presently has 2.5 berths for handling international GC, bulk and other cargoes as B, C-1 and C-2 berths, as counting C-2 berth as 1/2 berth due to its short length of 134.5 meters only. These berths handled 793,818 tons of such cargoes in 2008, and the total berth-day was 437.4 days or 2.62 days per ship on the average as shown in a Table below.

Table 5-2-1 Berth Utilization in 2008, Except Mole A & Point B Berths

Berth	Berth Particular (L & D)	5 Vessel No. handled	Berth-days Total	Berth-days Average	Prod'ty (Lift/B-hour)	Berth Utili. Rate (%)	Type of Vessels handled
B	190m, -9.7	71	157.13	2.21		**43.0%**	Bulk, GC, Used-cars etc
*B		21	11.17	0.53	**0.78**	3.1%	Container: Handled by MICTSL
C1	219m, -9.5	46	195.38	4.25		**53.5%**	Bulk, Container, Used-cars etc
C2	134.5m, -10.0	46	84.01	1.83		**23.0%**	Bulk, Cars, Petroleum etc
*C2		16	12.14	0.76	**7.03**	3.3%	Container: Handled by MICTSL
C3	172.5m, -12.0	293	213.02	0.73	**20.54**	**58.4%**	Container, GC but handled Cont.
		4	0.85	0.21		**0.2%**	RoRo
S.Total		**460**	**650.38**	**1.41**		**178.2%**	
Except cont ship at C3:		167	437.4	2.62		**119.8%**	

This indicates that the average berth utilization ratio of these 2.5 berths was 47.9% in 2008, which was a little bit higher than desirable level for vessels called the port, because they have to be insisted to wait the berths for a while at off harbor sometimes.

Though the berths utilization is assessed to be a little high in 2008, Toamasina Port will start operation of another best-qualified berth for large conventional vessels in Pier-B extension area by the end of 2010. (The east-side berth of the new pier should be exclusively used for the cargoes of Ambatovy.)

Furthermore, once C-4 berth is completed in 2017 as the earliest, the whole container vessels' operation can be done at C-4 berth alone. Therefore, C-3 berth, which is currently used for container vessels, can be used for loading and discharging other type of cargoes, including wood chip bulk cargo of Oji Paper which is scheduled to start in 2016.

While the trend of total volume of GC, bulk and other cargoes handled at the port showed to keep increasing at annual rate of 3%, the total volume excluding bulk cement and wheat tends to decrease since 2005 as shown in Table 5-2-2. Thus, it can be said that the increase of these cargoes handled at the port is highly contributed by the increase of bulk cement and wheat.

Table 5-2-2 GC/Bulk Cargo Handling Volume Excluding Bulk Cement and Wheat

	2005	2006	2007	2008	2009
Excluding bulk Cement/Wheat + Domestic	522,066	372,064	419,128	446,203	327,607
Hike% against year-2005's volume	Base	-28.7%	-19.7%	-14.5%	-37.2%

Source: SPAT and SMMC

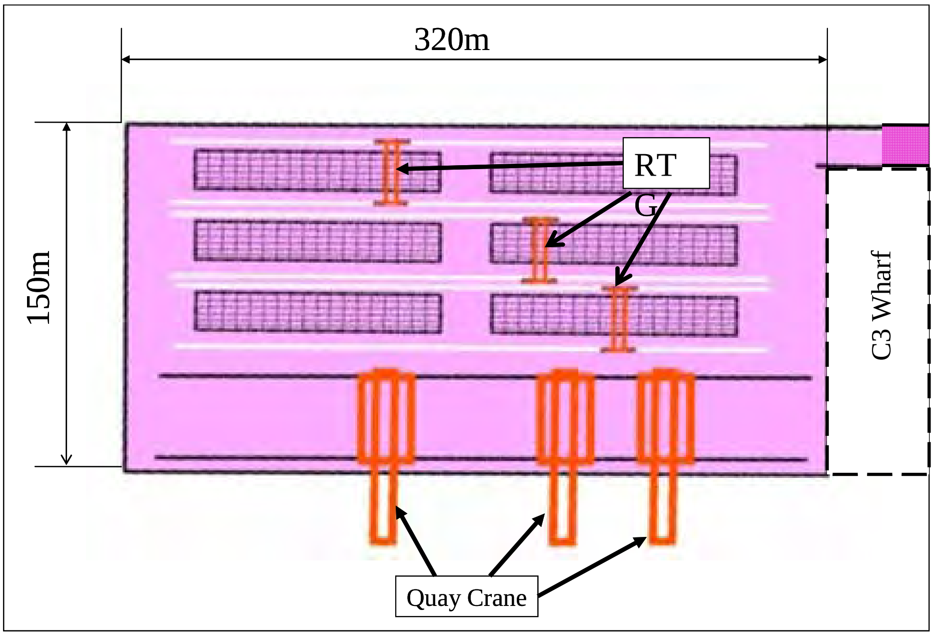


Figure 5-2-1 Container yard layout at the Wharf C4

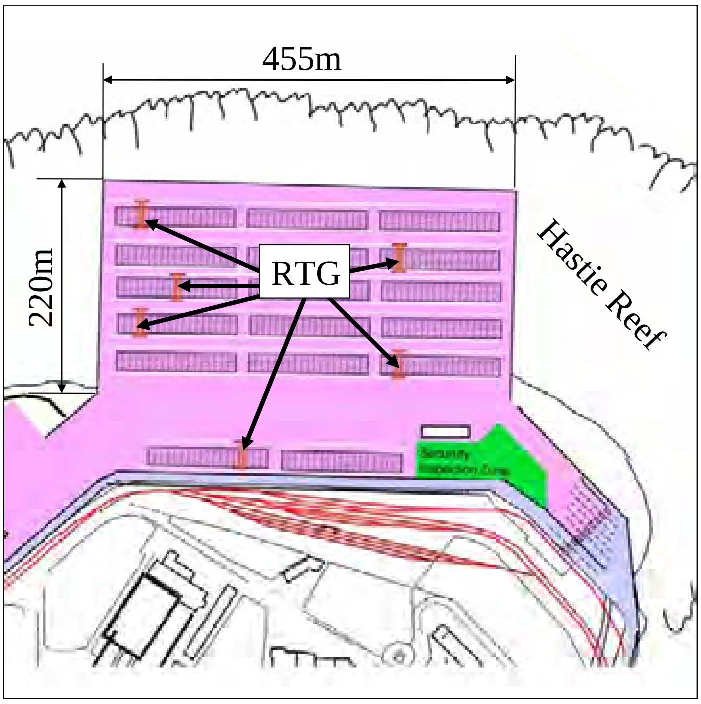


Figure 5-2-2 Container yard layout at the Hastie Reef Reclamation

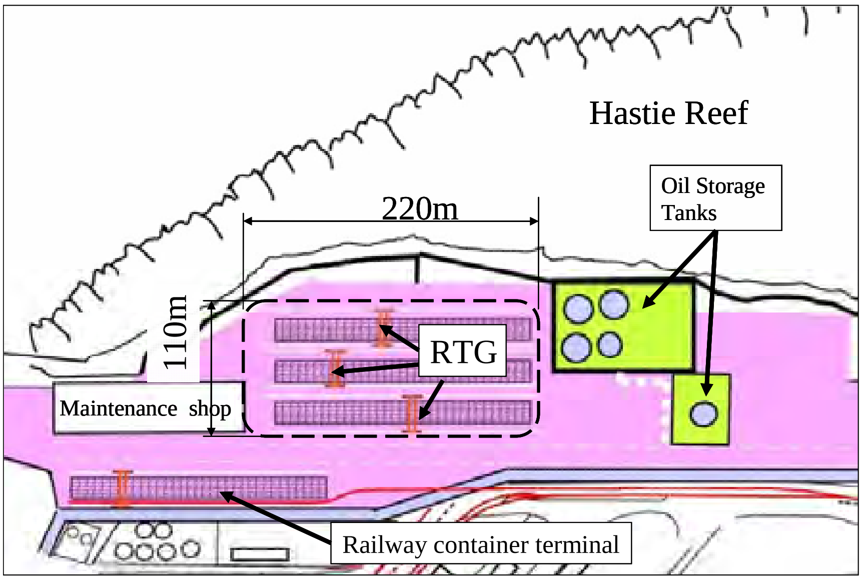


Figure 5-2-3 Container yard layout at the Existing Reclamation

The weighted average berth utilization ratio of the port has been forecasted as shown in Table 5-2-3 on the basis of the actual handling volume and the berth-days observed in 2008, and the cargo handling volumes up to 2020 forecasted with the constant annual growth rate of 3%.

Table 5-2-3 GC/Bulk Berths' Utilization Ratio Forecast

Year	*Official Forecast*	Actual/2nd Forecast	Assumption	Total Berth days	Available Berth No.	Mean Berth Utili Rate	Remarks
2005	*613,000*	633,018	Actual				
2006	*631,390*	532,569	Actual				
2007	*650,332*	713,517	Actual				
2008	*669,842*	**793,818**	**Actual**	**437.4**	**2.5**	**47.9%**	**Base**
2009	*689,937*	817,633	3% hike	450.5	2.5	**49.4%**	
2010	*710,635*	842,162	3% hike	464.0	2.5	**50.9%**	
2011	*731,954*	867,426	3% hike	478.0	**3.5**	37.4%	Able to use Pier-B-West
2012	*753,913*	893,449	3% hike	492.3	3.5	38.5%	
2013	*776,530*	920,253	3% hike	507.1	3.5	39.7%	
2014	*799,826*	947,860	3% hike	522.3	3.5	40.9%	
2015	*823,821*	976,296	3% hike	537.9	3.5	42.1%	
2016	*848,535*	1,005,585	3% hike	557.1	3.5	**45.6%**	Commence Oji Chip biz
2017	*873,991*	1,035,752	3% hike	573.8	3.5	**46.9%**	*Impact is 2.0% as average
2018	*900,211*	1,066,825	3% hike	591.0	**4.5**	37.5%	Able to use C-3
2019	*927,218*	1,098,830	3% hike	608.7	4.5	38.6%	
2020	*955,034*	1,131,795	3% hike	627.0	4.5	39.7%	

Source: Study Team

***Other Topics:**

1) <u>Wood Chip Exportation of Oji Paper</u> is scheduled to start with 25,200 tons in 2016 and 50,400 in 2017, 100,800 in 2018, 151,200 in 2019 and 201,600 in 2020 and after. Their productivity of the cargo handling operation is designed at around 9,000 tons per day. Thus the berth-days required for the loading of these volumes should be three (3) days in 2016, six (6) days in 2017, 12 days in 2018, 18 days in 2019 and 24 days in 2020 and after.

* Most probably, Oji Paper has to postpone the commencement of wood chip loading operation until C-3 terminal becomes available, because the Port has no other available berth wide enough for locating several units of movable wood-chip loaders (required 40-50 meter-wide areas at least).

2) <u>Ambatovy Project:</u>

The project is planned to start its partial operation in the end of 2010, and commence its full operation by around the end of 2012. Major commodities they handle are as follows;

a) Importation:

Commodity	Volume: Tons/Year	Vessel size (DWT)	Vessel calling No. per year	Total berth-days	Berth Util. Rates
Limestone	1,700,000	50,000	56	113	31%
Sulphur	700,000	50,000	23	58	16%
Coal	400,000	50,000	13	48	13%
Ammonia	60,000	Unknown	Unknown	Unknown	Unknown
Total	2,860,000		92 +	219 +	60%+

b) Exportation:

All the products of the project are planned to export by 20 feet containers as,

Nickel: 3,000 units of 20' container per year after full operation
Cobalt: 280 units of 20' container per year after full operation
Fertilizer: 10,500 units of 20' container per year after full operation
----
Total 13,780 units of 20' container per year after full operation

*** Problems foreseen:** Access to Mole C berths

Five (5) units of 150 meter-long trains will be employed for the transportation of their material cargoes from the port (East side of the new Berth-B) to Ambatovy's factory nearby. The hopper that loads import materials on the wagons of the train is installed on the existing B-wharf and the space between the warehouses and the wheat silos. Thus, the access road of Mole C including existing container terminal at C-3 will be blocked by the frequent train operation. Once the full operation starts, the access road is blocked for more than 200 days per year.

Therefore, SPAT has to build another access road to from C-3 terminal without crossing the rail trucks used by Ambatovy's operation. The width of the alternative access road should be 25 meters or more, because RTGs of MICTSL should move along the road once off-dock CY on Hastie Reef is developed.

These RTGs will not move between on-dock and off-dock CYs very often; but they have to pass through the road for the installation at the off-dock CY on Hastie Reef when imported from abroad after discharged from barge at C-3 or C-4 berth.

In addition to the 25m wide access road to C-3 container terminal, SPAT has to build another access road to C-1 and C-2 berths from the port gate. This road should be separated from an access road to C-3 terminal and it should not cross the rail trucks for Ambatovy operation. Two separate access roads to Mole C are very necessary because Berth C-3 and its backup area is proposed to be converted to a multi purpose terminal for handling Oji-Paper wood chips and others after C-4 terminal is completed.

Chapter 6. Engineering Aspects

6-1 Preliminary Design

6-1-1 Breakwater

(1) Layout and Necessary Extension of Breakwater

1) Layout of Breakwater

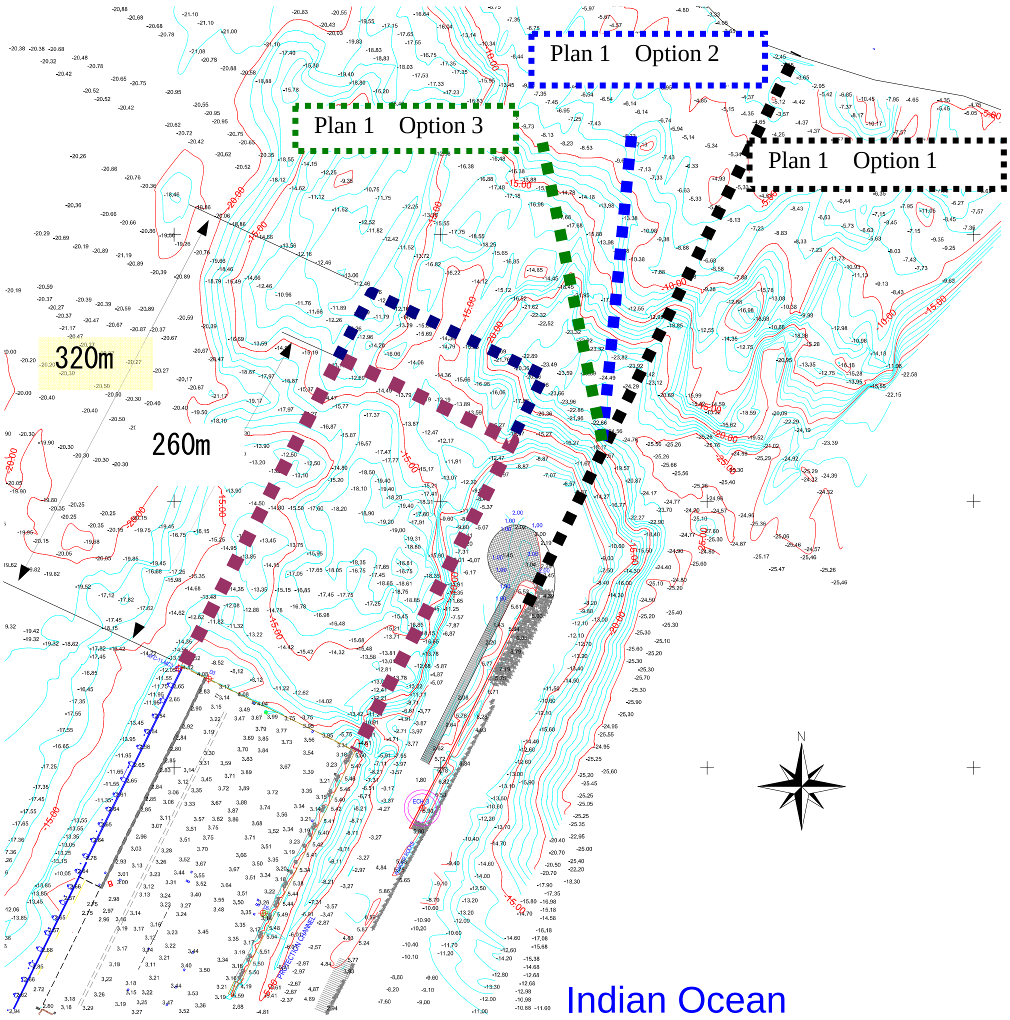


Figure 6-1-1 LayouH Options of Breakwater

The straight extension of the existing breakwater illustrated as Option 1 as above is determined with consideration of seabed topography and alignment of the extended container yard.

2) Necessary Extension of Breakwater

The necessary extension of the breakwater is determined as 345m with calculation of berth efficiency ration based on the combined distribution of wave heights and periods, referring to the existing criterion of the wave height for cargo handling at the berth, which is 0.6m against the wave height of a year return period.

Table 6-1-1 Berth Efficiency Ratio

Length of Breakwater & Wharf Length	Wharf	Berth Efficiency	
		Efficiency ratio(%)	Annual Operation Days
Breakwater: 345m Wharf: 320m	C4: 320m	94.5	345

(2) Structure of Breakwater

1) Design Criteria

i) Tide

	Wharvs	Breakwater, Seawalls
Normal	+1.0m	+1.5m
Enormously Rough	+1.5m	+2.0m
	+0.27m	+0.77m

ii) Waves

Period	15seconds		
Wave Height at Each Depth	Depth	−25m	-10m
	Wave Height	11.0m	8.5m

2) Typical Cross Sections of Breakwater

Typical cross sections of the extended breakwater at different depth are illustrated in Figures 6-1-2, 6-1-3 and 6-1-4.

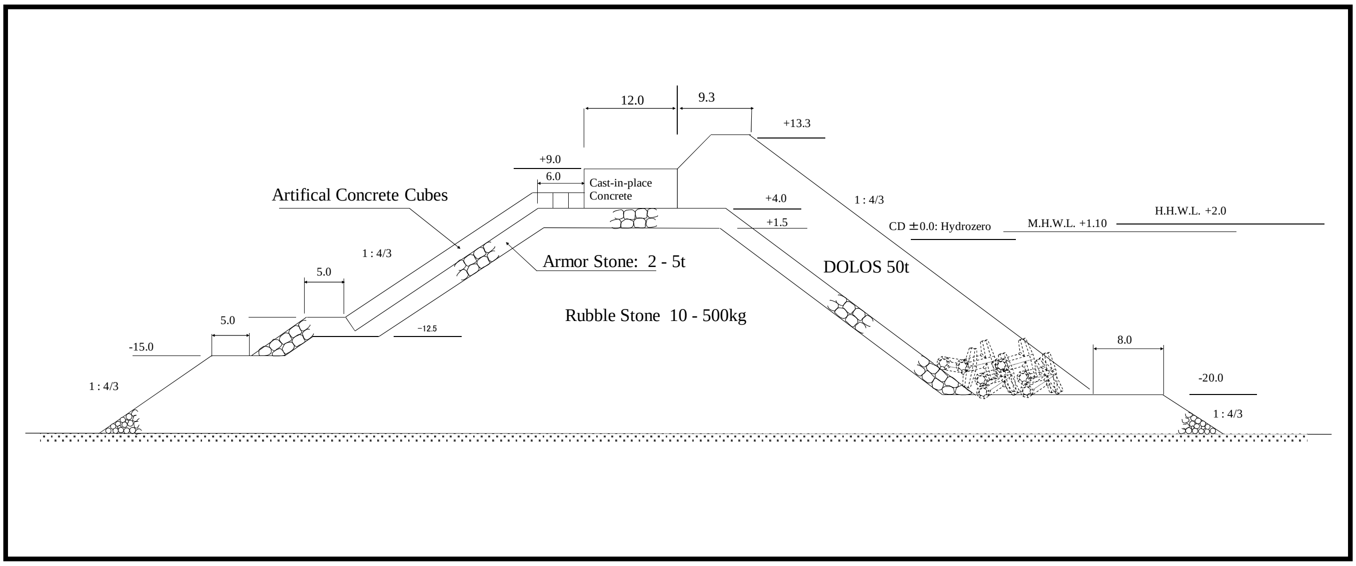


Figure 6-1-2 Typical Cross Section of Breakwater at -25m Depth

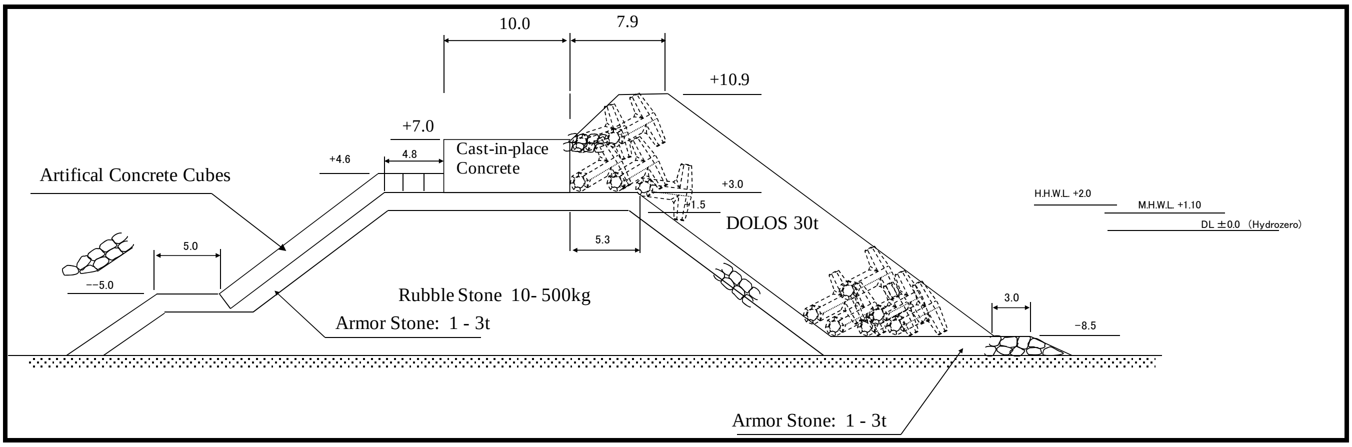


Figure 6-1-3 Typical Cross Section of Breakwater at -10m Depth

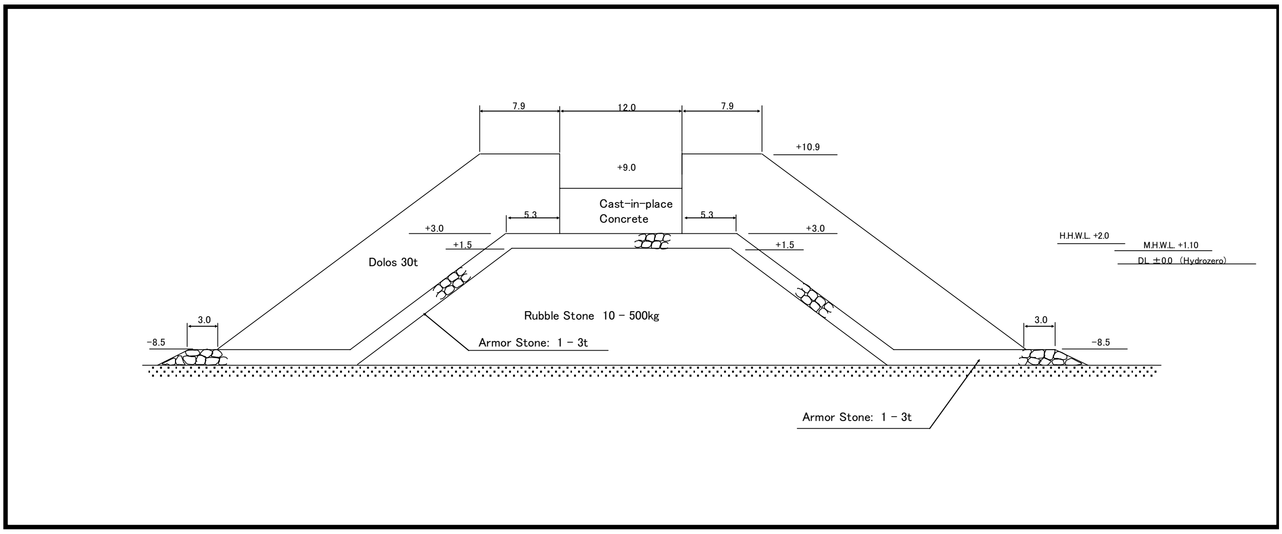


Figure 6-1-4 Typical Cross Section of Breakwater Head

6-1-2 Preliminary Design of New Terminal (C4)

(1) Design Criteria

Summary of design criteria is shown in the following table.

Table 6-1-2 Summary of Design Criteria (C4 Berth)

Particulars	C4 Berth	
I. Operational Conditions		
1. Object Vessel and Water Depth		
1.1 Object Vessels		
(1) Type	Container Vessel	Bulk Carrier
(2) Tonnage (ton)	50,000 DWT	55,000 DWT
1.2 Berth Length (m)	330	280
1.3 Berth Draft (m)	14.0	14.0
1.4 Mooring	100 tf/post	100 tf/post

1.5 Berthing	0.10m/s	0.10m/s
2. Surcharge and Live Load at Apron		
2.1 Surcharge (kN/m2)		
(1) Normal	30	30
(2) Seismic	15	15
2.2 Live Load		
(1) Quayside Crane (Self weight)	1,000 tf	Option
(2) Mobile Equipment	40 ft Container Truck	T-load, L-load
II. Natural Conditions		
1. Meteorology		
1.1 Temperature	Monthly average: 22.0~25.0℃	
1.2 Rainfall	Annual average: more than 4,000mm	
1.3 Wind	About 89 m/s for 100-year return period	
2. Oceanography & Hydrograph		
2.1 Tide	CDL: 0.00, LWL: 0.27, MSL: 0.67, HWL: 1.10, HHWL: 2.0m	
2.2 Current	0.1~0.3 m/s	
2.3 Wave	Negligible	
3. Geotechnical Conditions	See Figure 6-1-5	
4. Seismic Condition	Design seismic coefficient: 0.1	
III. Structural Conditions		
1. Materials		
1.1 Concrete		
(1) Grade and Strength (N/mm^2)	24.0 for marine reinforced concrete, 18.0 for plain concrete and 10.0 for lean concrete	
(2) Re-Bars (Grade, Allowable Stress N/mm^2)	SR295: fa=157 (Round Bar), SD345: fa=196 (Deformed Bar)	
1.2 Structural Steel (Grade, Yield & Allowable Stress N/mm^2)	SS400, SM400: fy=235, fa=140, SM490: fy=315, fa=185	
1.3 Steel Pipe Pile (Grade, Yield & Allowable Stress N/mm^2)	SKK400, SHK400, SKY400: fy=235, fa=140, SKK490, SHK490, SKY490: fy=315, fa=185	
1.4 Steel Sheet Pile (Grade, Yield & Allowable Stress N/mm^2)	SY295: fy=295, fa=180, SY390: fy=390, fa=235	
1.5 Corrosion Rate of Steel (mm/yr.)	Sea Side: above HWL: 0.3, HWL~LWL-1.0m: 0.2, LWL-1.0m ~seabed: 0.15 below seabed: 0.03 Land Side: above GL: 0.1, GL~GWL: 0.03, below GWL: 0.02	
1.6 Unit Weight (kN/m^3)	PC, RC: 24.0, Asphalt: 22.6, Stone: 26.0, Sand: 18.0, Steel: 77.0	
1.7 Fill Material	Sand, Unit weight 18 kN/m^3, Internal Friction Angle 30 deg.	
2. Other Consideration		
2.1 Increase in Allowable Stress	Seismic condition: 50%, Temporary loading condition: 33%	
2.2 Safety Factor (Factors in bracket: Seismic condition)		
(1) Slope	1.3 (1.0)	
(2) Gravity Type Structures	Sliding: 1.2 (1.0), Over Turning: 1.2 (1.1), Bearing Capacity: 1.2 (1.0)	
(3) Sheet Pile Wall	Stability of Moment Balance: 1.5 (1.2), Anchor Block Stability: 2.5 (2.0)	
(4) Shallow Foundation	Bearing Capacity: 2.5 (1.5)	
(5) Pile Foundation	Bearing Capacity: 2.5 (1.5), Pull out: 3.0 (2.5)	
2.3 Service Period	50 years	

+3.0m — Existing Ground Surface

Filling Sand for Reclamation

γ = 18 kN/m^3 γ'= 10 kN/m^3 ϕ = 30°

-12.0m

Sand & Coral

γ = 18 kN/m^3 γ'= 10 kN/m^3 ϕ = 35°

N average = 25

-19.0m

Sand & Coral

γ = 18 kN/m^3 γ'= 10 kN/m^3 ϕ = 35°

N average = 30

-29.0m

Figure 6-1-5 Subsoil Conditions

(2) Preliminary Design of New Wharf

A coupled piled open Deck type wharf shown in Figure 6-1-6 is recommended as the structure of Wharf C4 and a steel sheet pipe pile wall type wharf with a loading berm is considered as an alternative structure for reduction of construction cost.

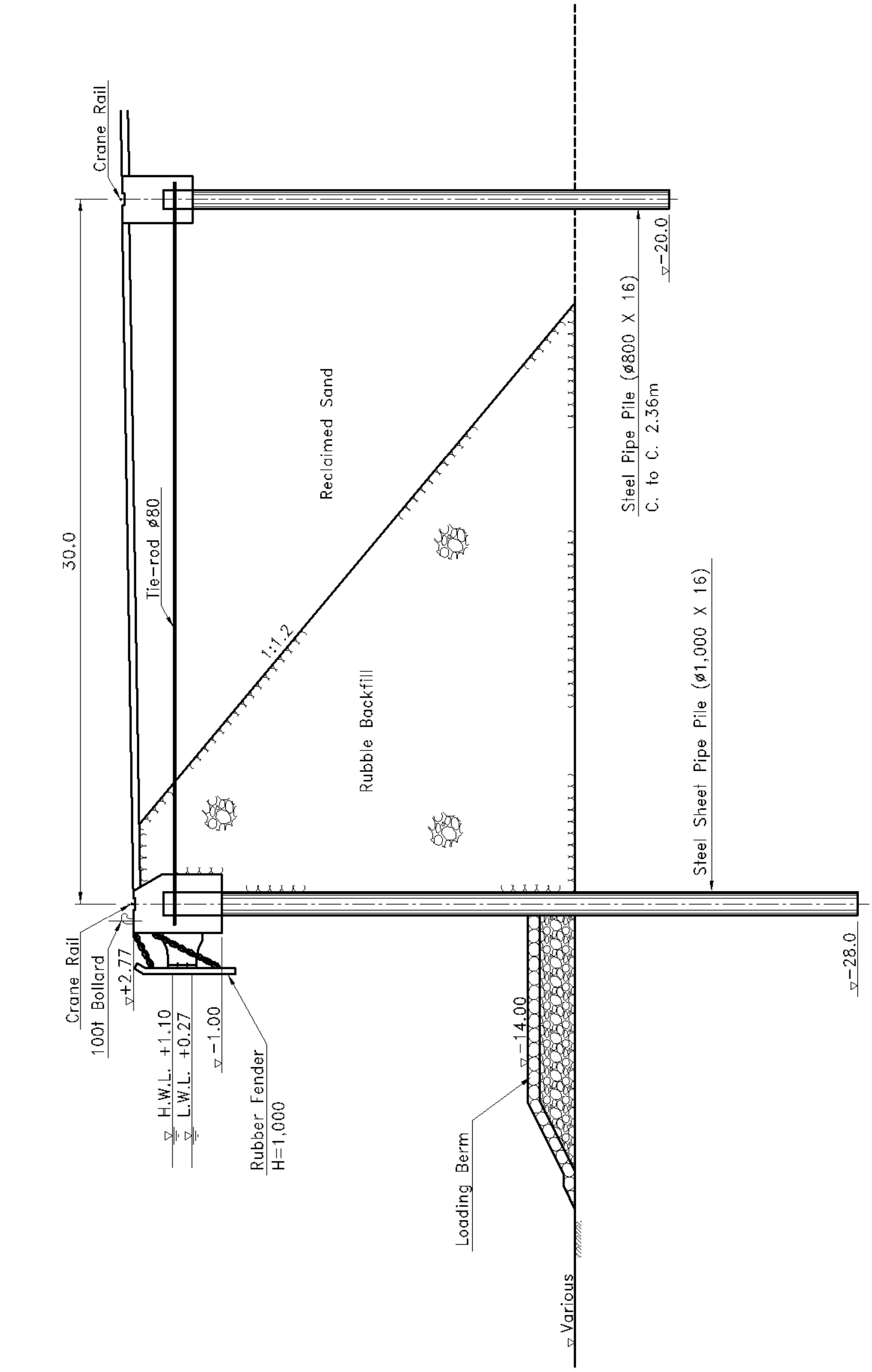


Figure 6-1-6 Steel Sheet Pipe Pile Wall Type Wharf with Loading Berm

(3) Improving the Existing Wharves (C1, C2 and C3)

1) Design criteria

Summary of the design criteria is shown in Table 6-1-3.

Table 6-1-3 Summary of Design Criteria (C1-C4 Berth)

Particulars	C2~C3 Berth	C1 Berth
I. Operational Conditions		
1. Object Vessel and Water Depth		
1.1 Object Vessels		
(1) Type	Container Vessel	Bulk Carrier
(2) Tonnage (ton)	50,000 DWT	55,000 DWT
1.2 Berth Length (m)	330	280
1.3 Berth Draft (m)	14.0	14.0
1.4 Mooring	100 tf/post	100 tf/post
1.5 Berthing	0.10m/s	0.10m/s
2. Surcharge and Live Load at Apron		
2.1 Surcharge (kN/m2)		
(1) Normal	30	20
(2) Seismic	15	10
2.2 Live Load		
(1) Quayside Crane (Self weight)	N. A.	N. A.
(2) Mobile Equipment	40 ft Container Truck	T-load, L-load
II. Natural Conditions		
1. Meteorology		
1.1 Temperature	Monthly average: 22.0~25.0℃	
1.2 Rainfall	Annual average: more than 4,000mm	
1.3 Wind	About 89 m/s for 100-year return period	
2. Oceanography & Hydrograph		
2.1 Tide	CDL: 0.00, LWL: 0.27, MSL: 0.67, HWL: 1.10, HHWL: 2.0m	
2.2 Current	0.1~0.3 m/s	
2.3 Wave	Negligible	
3. Geotechnical Conditions	See Fig. 6-1-7	
4. Seismic Condition	Design seismic coefficient: 0.1	
III. Structural Conditions		
1. Materials		
1.1 Concrete		
(1) Grade and Strength (N/mm^2)	24.0 for marine reinforced concrete, 18.0 for plain concrete and 10.0 for lean concrete	
(2) Re-Bars (Grade, Allowable Stress N/mm^2)	SR295: fa=157 (Round Bar), SD345: fa=196 (Deformed Bar)	
1.2 Structural Steel (Grade, Yield & Allowable Stress N/mm^2)	SS400, SM400: fy=235, fa=140, SM490: fy=315, fa=185	

1.3 Steel Pipe Pile (Grade, Yield & Allowable Stress N/mm^2)	SKK400, SHK400, SKY400: fy=235, fa=140, SKK490, SHK490, SKY490: fy=315, fa=185
1.4 Steel Sheet Pile (Grade, Yield & Allowable Stress N/mm^2)	SY295: fy=295, fa=180, SY390: fy=390, fa=235
1.5 Corrosion Rate of Steel (mm/yr.)	Sea Side: above HWL: 0.3, HWL~LWL-1.0m: 0.2, LWL-1.0m ~seabed: 0.15 below seabed: 0.03 Land Side: above GL: 0.1, GL~GWL: 0.03, below GWL: 0.02
1.6 Unit Weight (kN/m^3)	PC, RC: 24.0, Asphalt: 22.6, Stone: 26.0, Sand: 18.0, Steel: 77.0
1.7 Fill Material	Sand, Unit weight 18 kN/m^3, Internal Friction Angle 30 deg.
2. Other Consideration	
2.1 Increase in Allowable Stress	Seismic condition: 50%, Temporary loading condition: 33%
2.2 Safety Factor (Factors in bracket: Seismic condition)	
(1) Slope	1.3 (1.0)
(2) Gravity Type Structures	Sliding: 1.2 (1.0), Over Turning: 1.2 (1.1), Bearing Capacity: 1.2 (1.0)
(3) Sheet Pile Wall	Stability of Moment Balance: 1.5 (1.2), Anchor Block Stability: 2.5 (2.0)
(4) Shallow Foundation	Bearing Capacity: 2.5 (1.5)
(5) Pile Foundation	Bearing Capacity: 2.5 (1.5), Pull out: 3.0 (2.5)
2.3 Service Period	50 years

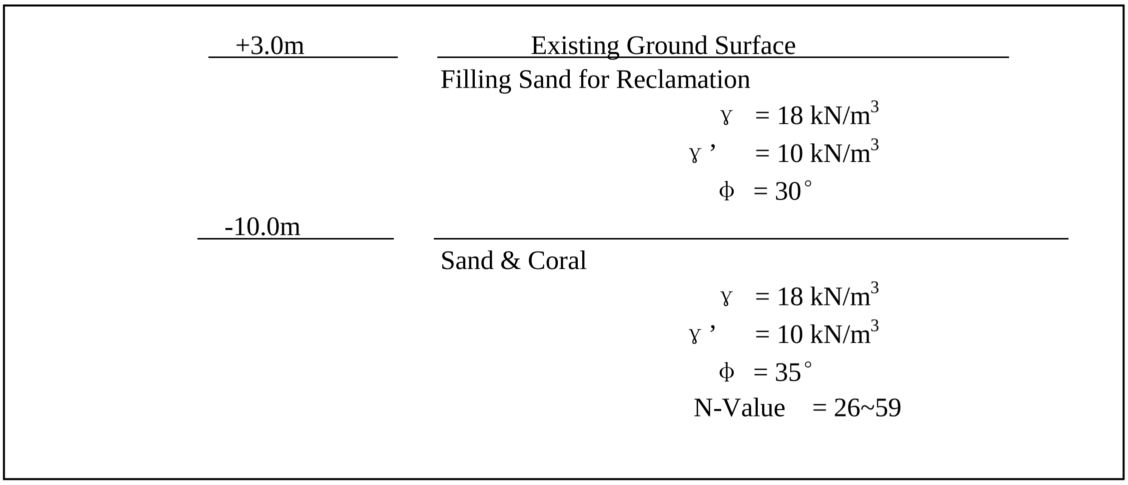


Figure 6-1-7 Subsoil Conditions

2) Preliminary Design for Improvement of the Existing Wharf

Figures 6-1-8 and 6-1-9 are proposed for the structure design of the existing wharves.

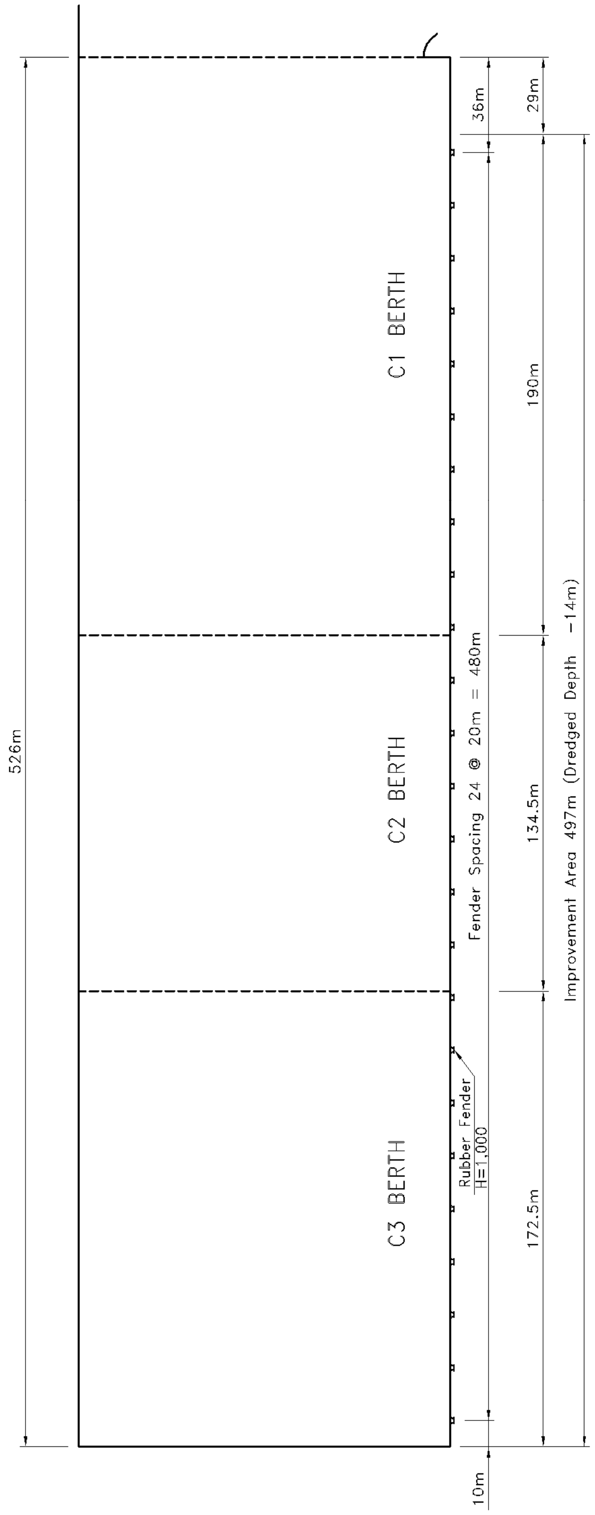


Figure 6-1-8 Layout Plan of Improvement Works

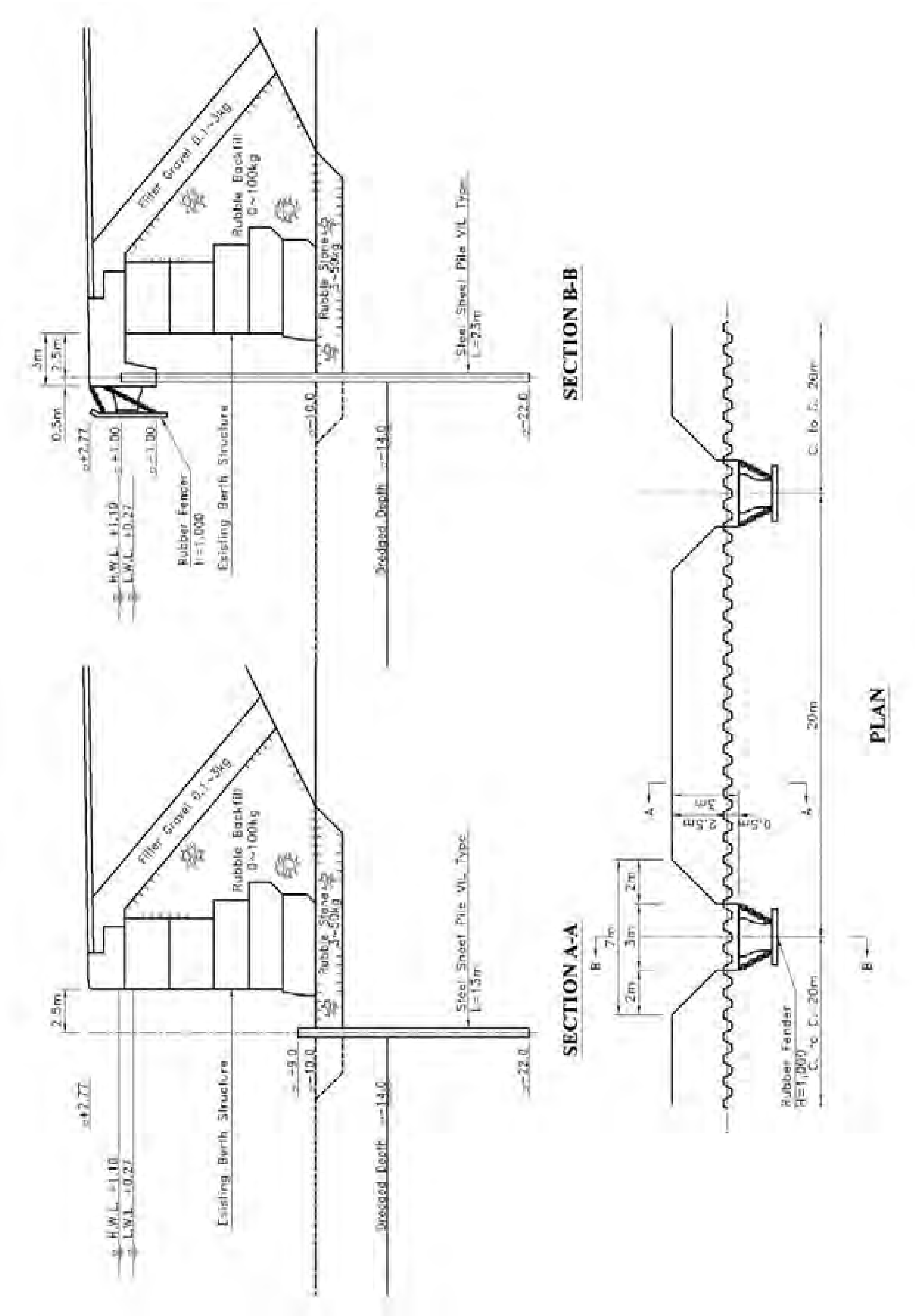


Figure 6-1-9 Plan and Sections for Improved Structures

6-1-3 Preliminary Design of Reclamation Seawall

The seawall structure is designed on the basis of the following criteria and a typical cross section is shown in Figure 6-1-10.

Distance from reef edge (m)	Rise of Sea Level ?$_{x=20}$(m)	Significant Wave Height $H_{1/3}$(m)	Design Wave Height $H_{1/3}$(m)
20	2.3	2.32	2.4

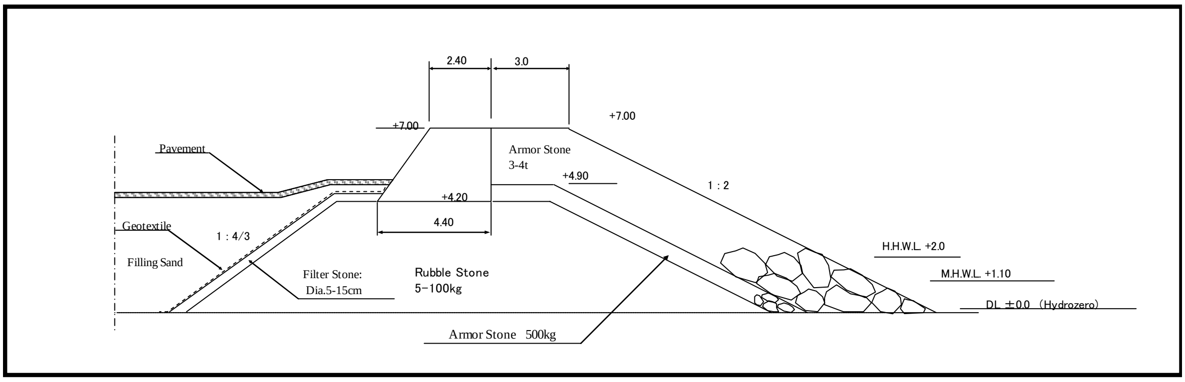


Figure 6-1-10 Typical Cross Section of Sewall on Reef

6-1-4 Preliminary Design of Road and Overpass

The summary of geometric standard is shown in Table 6-1-4.

Table 6-1-4 Summary of Geometric Standards

	Japanese Standard	**Applied Standard**	Note
Design Speed	40 km/h	**40 km/h**	
Number of Lane	2 lanes	**2 lanes**	
Cross Section	7.0 m	**8.0 m**	
Carriageway	3.0 m	**3.5 m**	In case the traffic volume of heavy vehicle is large, 3.5 m of carriageway is applied.
Shoulder	0.5 m	**0.5 m**	
Crossfall	2.0 %	**2.0 %**	
Min. Horizontal Radius	60 m	**60 m**	
Min. Horizontal Radius without Transition Curve	500 m	**500 m**	
Min. Curve Length	70 m	**70 m**	
Max. Superelevation	6.0 %	**6.0 %**	
Max. Grade	7.0 %	**4.0 %**	In order to secure the smooth traffic flow of heavy vehicles, 4.0 % of grade is applied.
Min. Vertical Curve			
Crest	450 m	**450 m**	
Sag	450 m	**450**	

The overpass is planned at the intersection between road and railway in order to secure the smooth traffic flow in the port. The summary of railway overpass is shown in Table 6-1-5.

Table 6-1-5 Summary of the Railway Flyover

Item	Description
Total Length	290 m
Bridge	10 m
Approach Road	140 m + 140 m
Type of Bridge	Pretention PC Slab Bridge
Girder Height	0.6 m
Cross Section	8.0 m
Carriageway	3.5 m x 2
Shoulder	0.5 m x 2
Grade	4.0 %
Type of Foundation	Concrete Pile Foundation

A general profile of railway overpass and general views of the overpass are shown in Figures 6-1-11 and 6-1-12 respectively.

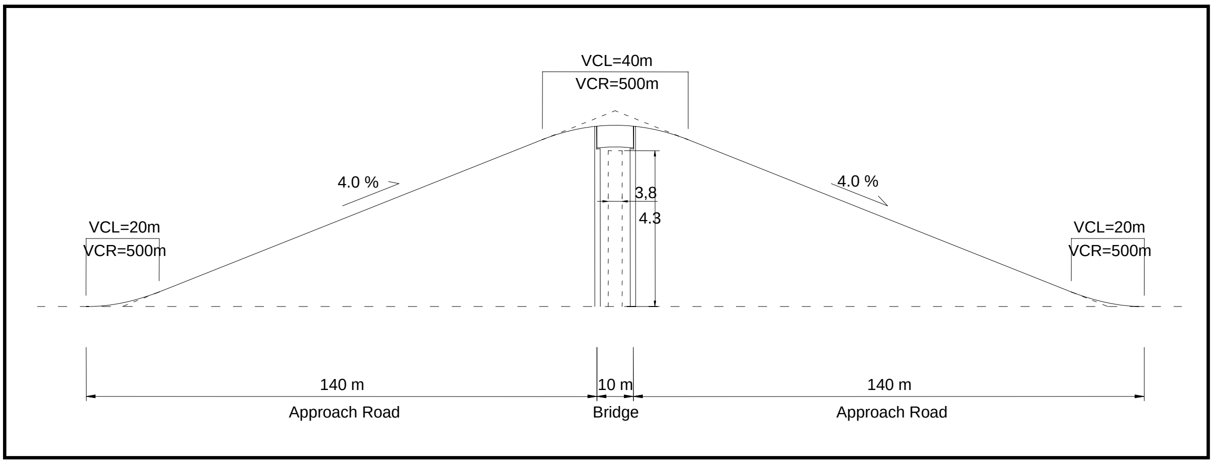


Figure 6-1-11 General Profile of Railway Overpass

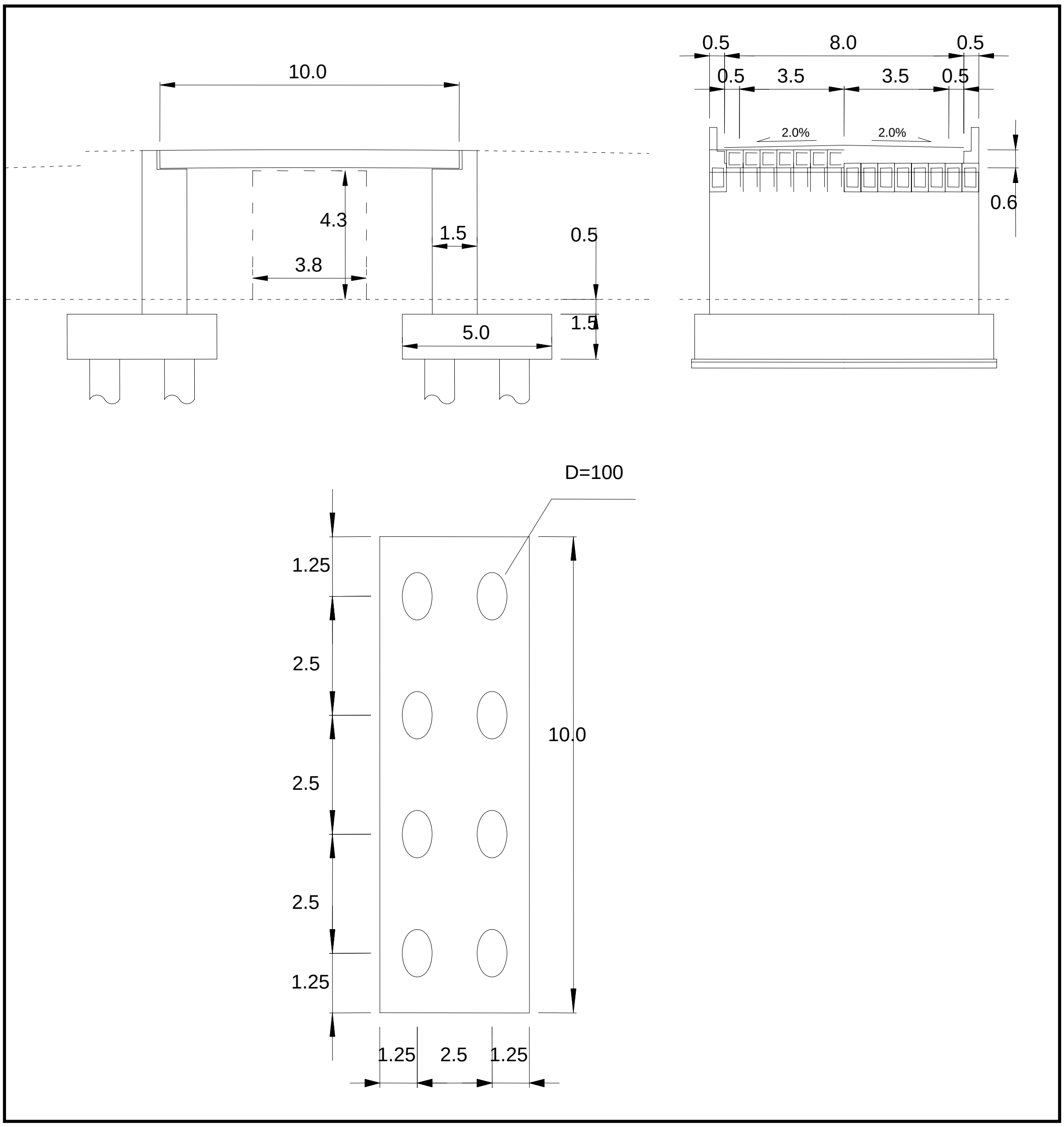


Figure 6-1-12 Preliminary Design of Overpass

6-2 Construction Planning and Cost estimate for Urgent Development Plan

6-2-1 Premises for Construction Planning and Cost Estimate

Construction planning and cost estimate are made, based on the premises that are prepared by the situations of construction business in Madagascar, especially in Toamasina.

- Construction materials will be imported except aggregate and stone materials.
- Construction equipment with low emission and plants for manufacturing concrete will be procured overseas.
- Skilled workers and special engineers from the third countries will be needed and local unskilled workers will be employed for this project.

6-2-2 Implementation Schedule

Total construction period including the preparation is expected to be about 4 years. Workable days were calculated 223 days in consideration of rainy days, public holidays and other days off.

Implementation schedule is shown in Figure 6-2-1.

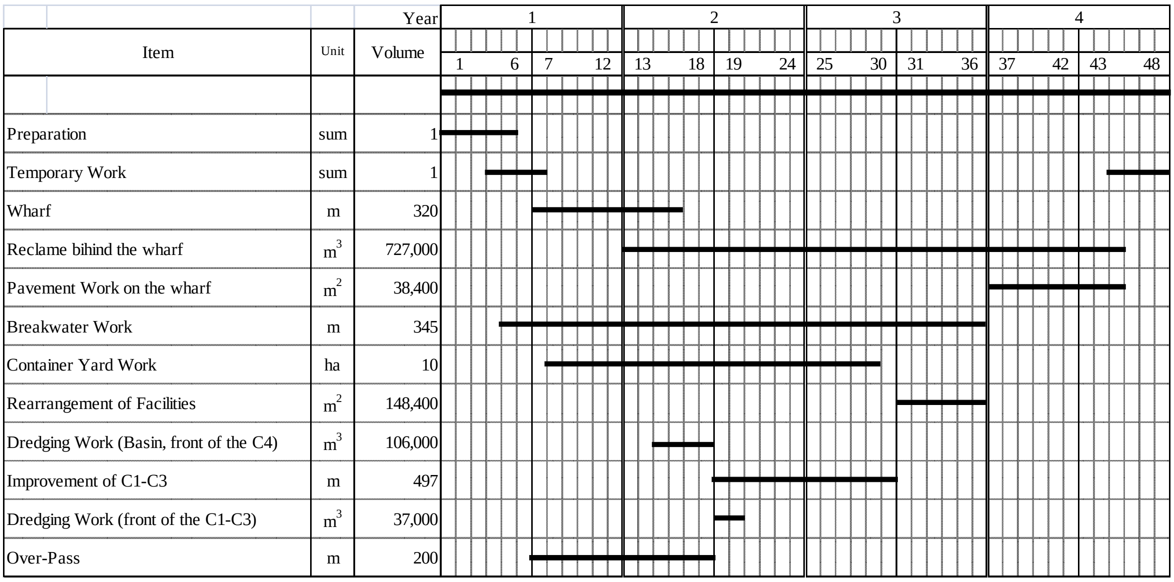


Figure 6-2-1 Implementation Schedule

6-2-3 Estimate of Project Cost

Project cost is estimated approximately 227,011,000 EUR. This cost estimation is provisional and would be further examined by the Government of Japan for the approval of the loan assistance.

(1) Cost Estimate

Table 6-2-1 Cost Estimation

Items		Cost Estimation (EUR)
Facilities		
	Breakwater Work	42,666,000
	C4 Berth Work	55,380,000
	Hasti Reef Container Yard Work	25,601000
	Rearrangement of Facilities	15,368,000
	Dredging Work	3,845,000
	C1, C2 and C3 Improvement Work	9,809,000
	Overpass Work	10,528,000
	Environment Consideration Work	4,188,000
	Total Construction Cost Estimation	**167,385,000**
Cargo Handling Equipment for MICTSL		
	3 Ganry Container Cranes	19,148,000(6,383,000)
	13 Rubber Tyre Mounted Gantry Cranes	13,829,000(1,064,000)
	28 Tractor Heads	2,931,000 (105,000)
	30 Chassis	1,740,000 (58,000)
	2 Reach Stackers	1,205,000 (603,000)
	6 Side Lifters	2,259,000 (377,000)
	Total Equipment Cost Estimation	**41,112,000**
Construction + Equipment Cost Estimation		**208,497,000**
Engineering Fee		10,145,000
Physical Contingency		8,369,000
Total Cost Estimation		**227,011,000**
Administration Fee Concerning SPAT Project		140,000

(2) Conditions of Cost Estimate

1) Cost Estimation Base: as of September 7, 2009
2) Exchange Rate: 1 EUR=132.79 Yen, 1MGA(Ariary)=0.049 Yen
3) Construction Period: as per Implementation Schedule
4) Physical Contingency: 5% of construction cost is calculated as contingency since the average inflation of Madagascar and Euro area is 4.5%.
5) Engineering Fee: Detail Design and Construction period included
6) Escalation: excluded
7) Procurement from third countries (Steel material, Reinforcement-bar, Fenders, Construction equipment and Construction barges & ships, etc.) excludes the import duty and VAT.
8) Local procurement (Fuel and Cement, etc.) includes the import duty but excludes VAT.

(3) Inflation

According to the IMF data, the inflation ratio of Madagascar in 2006 and 2007 was slightly more than 10% and it became about 9% in 2008. And, IMF predicts slightly more than 9% in 2009 and 2010 and it will be 5% in 2012 which is the last year of Madagascar Action Plan. In this project, the inflation ratio is set as 6% referring to the rates of 2011 and 2012. While, the average inflation ratio of Euro area from 2002 through 2008 were slightly less than 3% and the inflation ratio of Euro area is set as 3% in this project.

6-3 Analysis on Beach Process

The shore topography of Tamatave City is characterized in a shape of a salient and a tombolo which are formed behind the Grand reef and the Hasti reef, respectively (see Figure 6-3-1). The Toamasina Port is constructed behind the Hasti leaf. A breakwater has been constructed toward the Grand reef from the Hasti reef, as seen in Figure 6-3-1. Due to the construction of breakwater, the beach erosion occurred in the north beach and at the Tanio Point, the sand accumulated in the beach between the Tanio Point and the port, and the shoaling of mooring area at the mole A is continuing.

The extension of breakwater, which is planned at present, will accelerate these topographical changes. Then, an impact of breakwater extension on the beach has been predicted quantitatively and the countermeasures for reducing the shoreline changes have been examined by a numerical simulation, that is One-line simulation model.

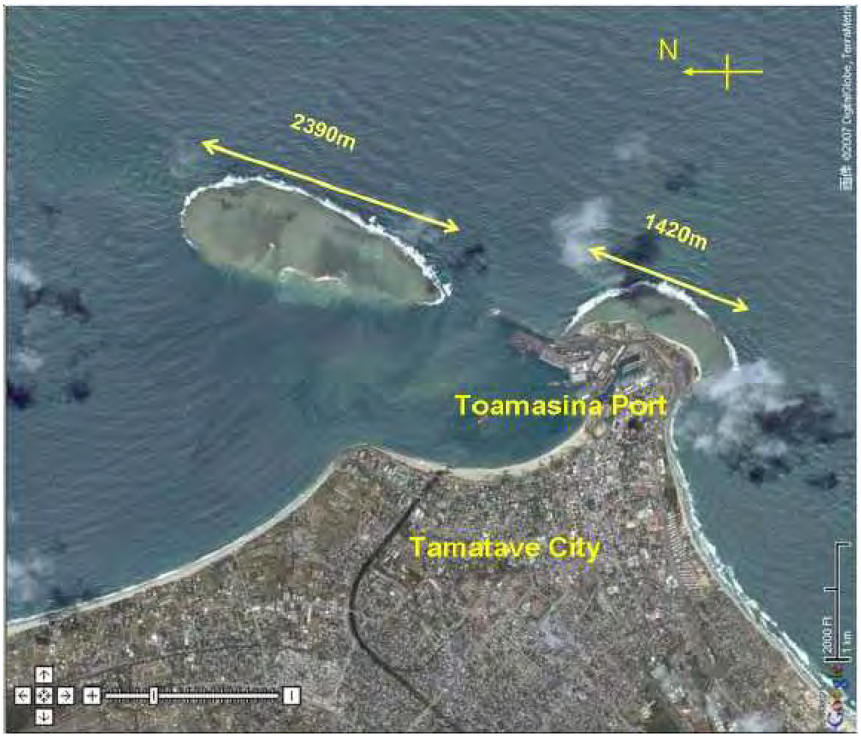


Figure 6-3-1 Toamasina Port

6-3-1 Characteristics of topography around the Toamasina Port and beach process

(1) Macroscopic understanding of topography around the Toamasina Port

There is a long straight sandy coast of about 800km long on the east coast of Madagascar, as shown by a red line in Figure 6-3-2. Figure 6-3-3 shows the characteristics of wave at the water depth of 40 meters, offshore the Toamasina Port. By arranging Figure 6-3-2 and Figure 6-3-3 side by side, it is easily understand that the mean direction of wave incidences is almost normal to the coastline colored in red. Therefore, it is inferred that there is no net longshore sand transport on this beach.

Figure 6-3-2 Straight coast on the east coast

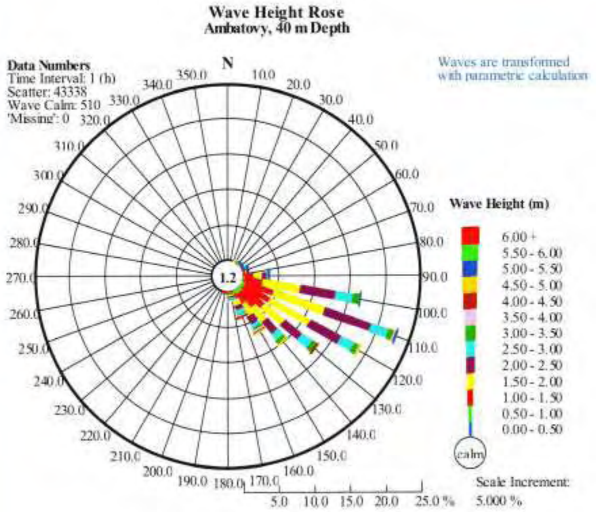


Figure 6-3-3 Wave rose (hindcasted, 2006)

Two convex topographies are developed on the sandy beach behind two reefs at the Toamasina Port, as seen in Figure 6-3-1. The breakwater has been constructed toward the Grand reef from the Hasti reef. After construction of the breakwater, the shoreline has changed into the new equilibrium configuration in the beach between the Tamasina Port and the Tanio Point. This beach is referred as the Port Beach hereinafter.

(2) History of breakwater construction

Figure 6-3-4 shows a history of breakwater construction. The first breakwater was constructed on the Hasti reef during a period from 1927 to 1930. The breakwater was prolonged 500 meters toward the Grand reef during 1930 to 1937. The water depth at the tip of breakwater was about 20 meters, and the width of reef-pass was reduced to be 600 meters.

After the disaster due to the cyclone in 1943, the destroyed sections of breakwater were repaired, or newly reconstructed. However, as the end part of breakwater, 80 meters long, was not restored. The breakwater has been extended 225 meters more during the years from 1972 to 1974, which reduced the width of reef-pass to 455 meters.

As the breakwater construction in 1972 to 74 was done in the deep water area and the reef-pass becomes narrower, the wave energy passing through the reef-pass into the bay decreased, which should has induced a large impact on the beach.

Then, the beach topographies before and after the construction of breakwater in 1972 to74, which is referred as “breakwater 72/74” hereinafter, were compared each other in order to understand the effect of breakwater construction.

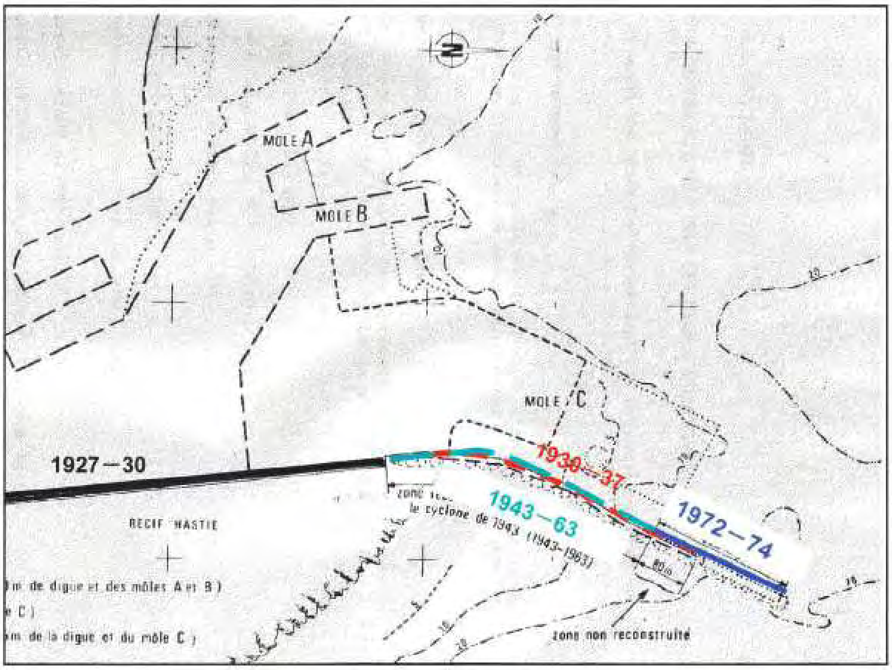


Figure 6-3-4 History of breakwater construction at Tamasina Port

(3) Beach process due to the extension of breakwater 72/74

Figure 6-3-5 shows the superimposing of shoreline in 1961 on the present aerial photograph. The beach around the Tanio Point, the salient tip, is eroded, and sand accumulation occurs on the Port Beach, especially in the vicinity of the port. This evolution of beach can be considered to be due to the construction of the breakwater 72/74.

Figure 6-3-6 shows the volume of sand accumulated in the Port Beach, which are estimated from the aerial photographs (and a topographical map in 1975) by multiplying the increased area of beach relative to the beach in 1961 and the assumed closure depth. A rate of sand accumulation increased after the construction of breakwater 72/74.

Figure 6-3-5 Superposition of the shoreline in 1961 on the recent aerial photograph

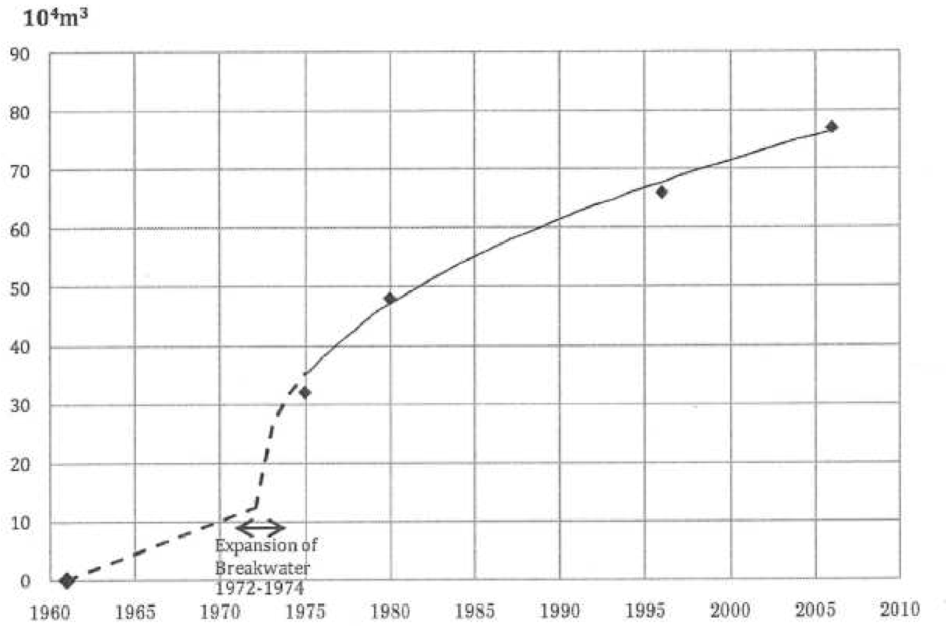


Figure 6-3-6 Sand Volume accumulated in the Port Beach, estimated by utilizing by aerial photographs and topographical map

(4) Route of sand transportation to the Port Beach

By comparing the areas of both erosion and accumulation in Figure 6-3-5, it is obvious that the area of accumulation is wider than that of erosion. The volume of sand accumulation in the Port Beach increased with years as explained in Figure 6-3-6. Figure 6-3-7 shows the beach erosion on the north beach and the sand accumulation on the Port Beach during about 7 years from 1972 and 1975 to 1981.

This evidence, a simultaneous occurrence of erosion and accumulation during the same term, suggests that the sand was transported from the north beach to the Port Beach around the tip of Tanio Point.

Figure 6-3-7 Topographical changes in the north beach and the Port Beach

6-3-2 Mechanism of sand transportation to the Port Beach through the Tanio Point

By referring Figure 6-3-8, it can be explained how the sand is transported from the north beach to the Port Beach around the tip of Tanio Point. The solid line and the broken-line are the shorelines before and after the breakwater construction, respectively. The solid line is in the equilibrium position without the breakwater.

At first,

(A) the breakwater is constructed.
(B) The sand movement occurs to the breakwater.
(C) As a result, the sand accumulation occurs on the beach near the port.
(D) At the same time, the erosion occurs in the vicinity of the salient tip, which extends to the left side beach by crossing through a centerline of the great reef.
(E) On the left beach the shoreline deviates from the equilibrium due to the erosion, which induces the sand movement to the tip of salient as shown by an arrow in Figure 6-3-8.
(F) As a result of sand transportation to the salient tip, the shoreline recovers to the original position.

From here on, the process goes back to the (B) and the endless loop will be established.

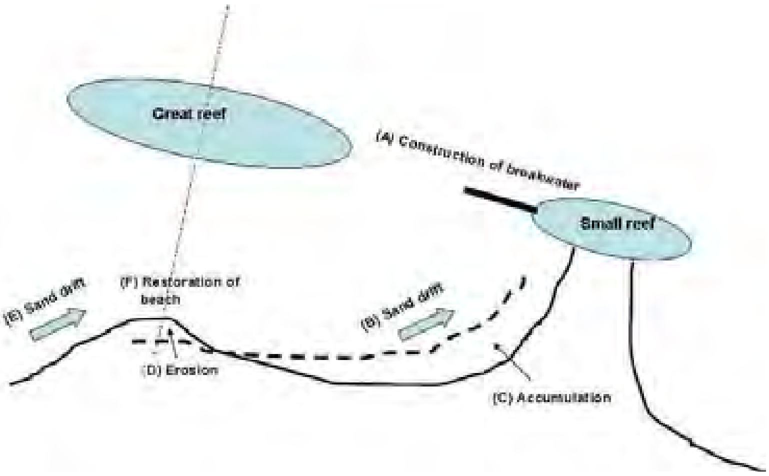


Figure 6-3-8 Conceptual illustration on the mechanism of sand transportation aroundthe salient tip to the Port Beach

6-3-3 Prediction of shoreline changes by One-line simulation

(1) Conditions of numerical simulation

【Area of calculation】: Figure 6-3-9 shows the aria of calculation. The wide area of 19.5km x 10.8km is for wave calculation, and the small area of 10.6km x 4.7km surrounded by a rectangular is for calculation of shoreline change by one-line simulation. The calculation of waves is based on the energy balance equation.

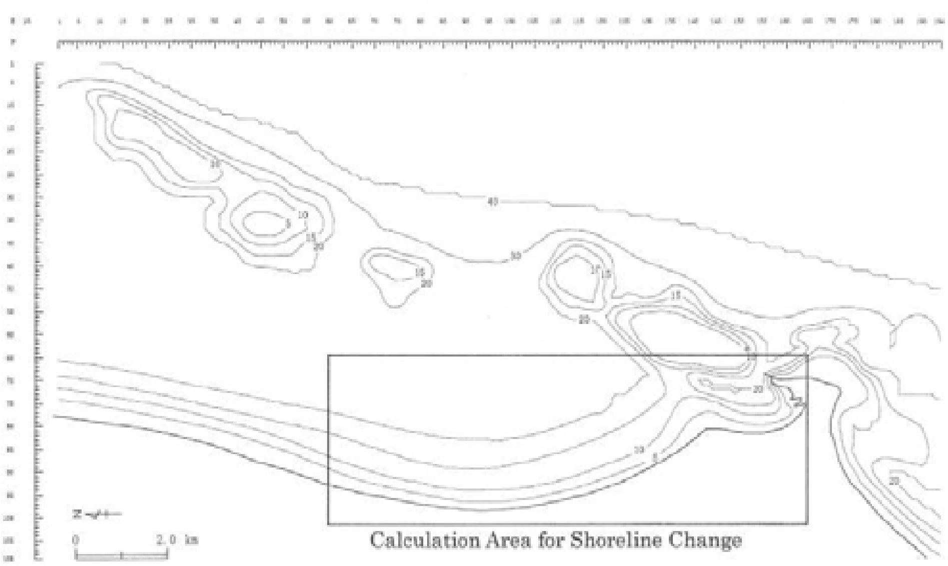


Figure 6-3-9 Area of calculation

【Wave conditions】: Based on this information of wave characteristics shown in Figure 6-3-3, eight representative waves are determined for every direction of ten degrees, see Table 6-3-1.

Table 6-3-1 Representative waves for simulation

No.	Direction	Height(m)	Period(s)	Occurrence frequency(%)
1	N90° E	1.74	9.8	5.0
2	N100° E	2.13	9.9	16.8
3	N110° E	2.09	9.9	23-1
4	N120° E	2.02	9.9	19.1
5	N130° E	2.04	9.9	13-9
6	N140° E	2.06	10.0	22.0
7	N150° E	2.13	10.0	6.9
8	N160° E	2.09	10.0	5.2

【Tide】: The tide level is fixed to be the mean water level, that is +0.67 meter above the datum line.

【Formula of longshore sand transport】: In the simulation of shoreline changes, the following formula is utilized for estimating sand transport rate on the beach sheltered by structures such as breakwater,

$$Q_y = \frac{(ECn)_b}{(1-\varepsilon)(\rho_s-\rho)g}\left(K_1 \cos\alpha_b \sin\alpha_b - \frac{K_2}{\tan\beta}\cos\alpha_b \frac{\partial H_b}{\partial y}\right),$$

where K_1(=0.028) and K_2 (=0.022) are the coefficients, EC_n: wave energy flux、ε: void content of sand、ρ_s: density of sand、ρ: density of sea water、α: angle of wave incidence、$\tan\beta$: beach slope、H: wave height. Suffix "*b*" means the value at wave breaking point.

(2) Prediction of shoreline changes under the present state, without port expansion

First of all, the prediction of shoreline changes has been done for the present state, without port expansion. Figure 6-3-10 shows the result of prediction, in which it is seen that the shoreline will advance with an almost constant speed in the Port Beach. On the other hand, the shoreline will recede slightly in the north beach.

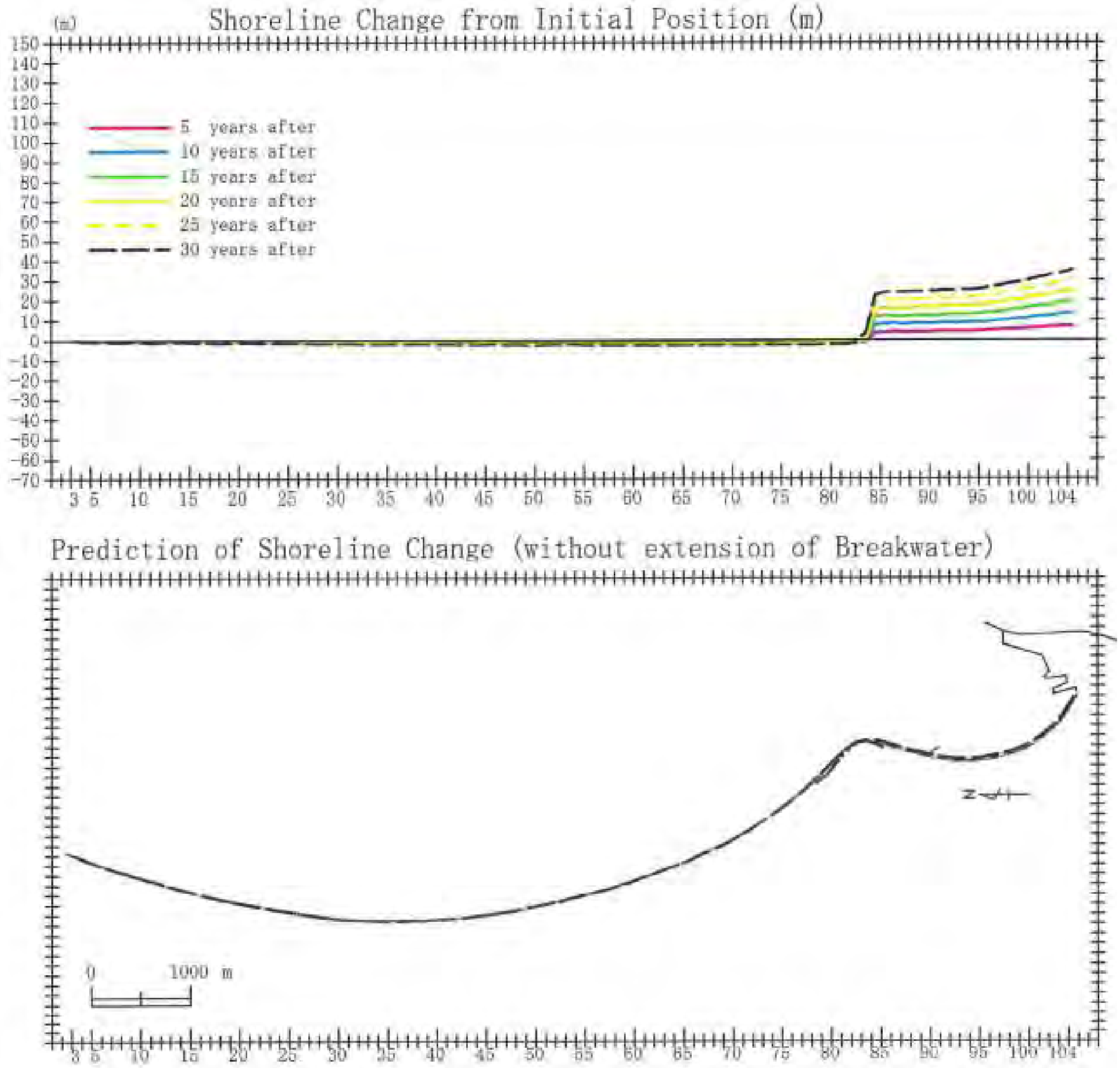


Figure 6-3-10 Predicted shoreline changes without port expansion (under the present state)

(3) Predicted shoreline changes for Alternative Plan 3

(The detail and an arrangement of facilities in Alternative Plan 3 are found in Chapter 4 and in Appendix.)

In the case of Alternative Plan 3, a berth is newly constructed at the land-side of grand reef, which is connected to the present port by a pier. As the waves pass through the pier without a loss of energy, the Alternative Plan 3 does not introduce the shoreline changes in the Port Beach, that is the shoreline changes are the same as those in Figure 6-3-10.

(4) Predicted shoreline changes for Alternative Plan 1

(The detail and an arrangement of facilities in Alternative Plan 1 are found in Chapter 4 and in Appendix.)

Figure 6-3-11 is the predicted shoreline changes for Alternative Plan 1, in which the breakwater is extended 480 meters and the reef-pass between the port and the grand reef is closed.

The beach erosion advances further on the north beach, the sand is transported to the Port Beach around the Tanio Point. The sand transported to the Port Beach is expected to deposit at the area around X93, where the shoreline advances about 50 meters during the first 5 years. As there is a mouth of canal at the location X91, this shoreline advance may induce the canal mouth closing. The shoreline close to the port, X104, advances gradually at first, and its speed has tendency to increase with time. Although the beach is eroded and shoreline goes back about 40 meters during the early years at the location of X85, it restores gradually due to the sand supply from the north beach.

The shoreline does not recess at the Tanio Point, X83, because the beach is protected by the sea wall.

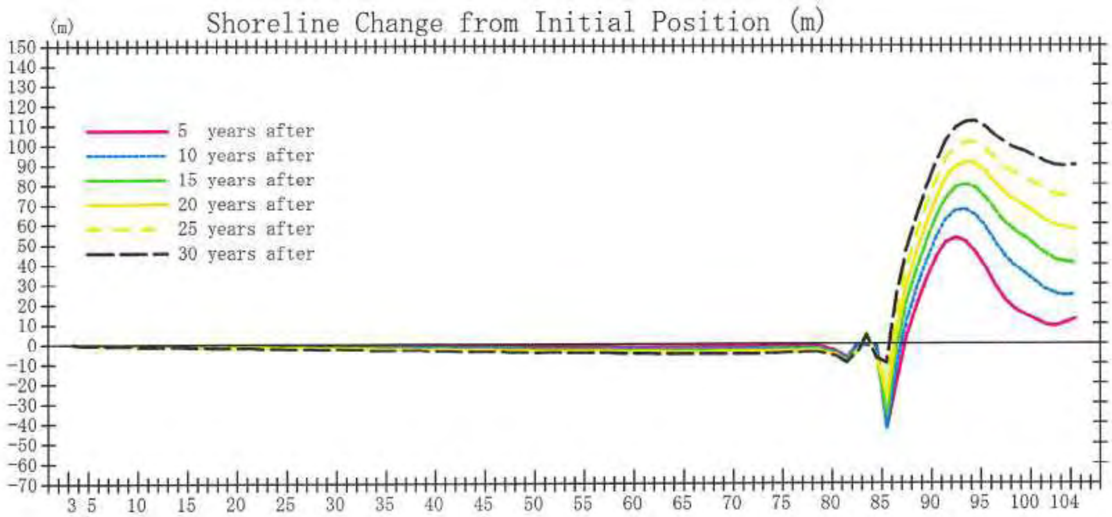


Figure 6-3-11 Predicted shoreline changes for Alternative Plan 1

(5) Predicted shoreline changes for Alternative Plan 2

(The detail and an arrangement of facilities in Alternative Plan 2 are found in Chapter 4 and in Appendix.)

Figure 6-3-12 shows the predicted shoreline changes for Alternative Plan 2, in which the extension length of breakwater is 345 meters which is 135 meters shorter than that of Plan 1. There is a small size opening of reef-pass between the port and the grand reef.

Even if Figure 6-3-12 and Figure 6-3-11 are compared, there is no difference between them on these figures, which means that almost same shoreline changes occur for Alternative Plan 1 and 2. It is considered that as the water depth of reef-pass opening in Plan 2 is very shallow and almost all energy of waves dissipated when they pass through the opening. Then the shoreline changes are same each other.

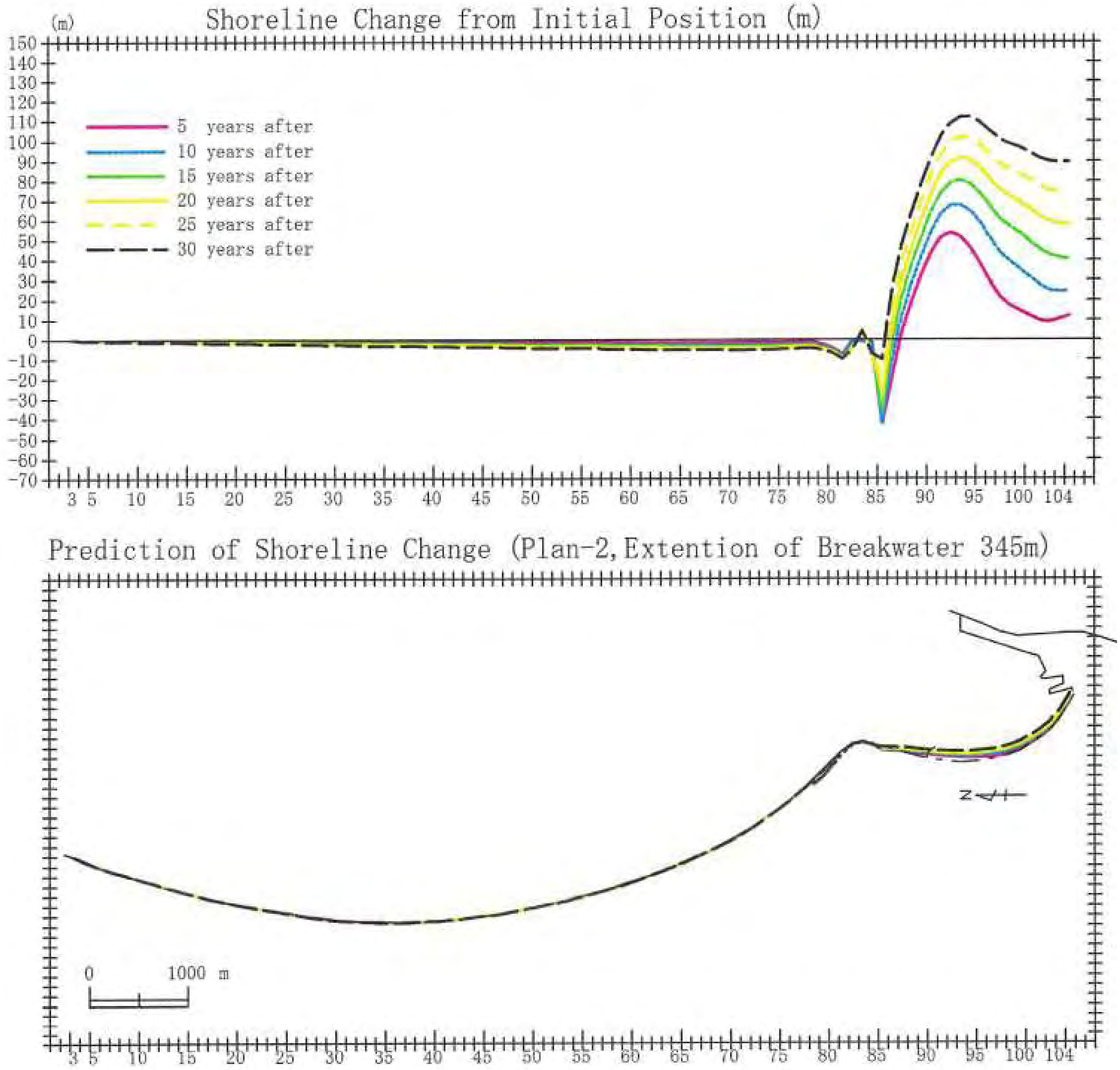


Figure 6-3-12 Predicted shoreline changes for Alternative Plan 2

6-3-4 Countermeasures against the shoreline changes for Alternative Plan 2

(The detail and an arrangement of facilities in Alternative Plan 2 are found in Chapter 4 and in Appendix.)

The results of shoreline predictions for three Alternative Plans are summarized as follows;

1) Alternative Plan 3 : There is no influence on the Port Beach.

2) Alternative Plan 1 and 2 : Both two plans have almost the same effect on the Port Beach, that is the shoreline advance in the Port Beach and the shoreline retreat in the north beach.

Then for the Alternative Plan 2, the countermeasures to reduce the change of shoreline are examined by the one-line simulation.

Countermeasure 1 : Jetty at the Tanio Point

Because the sand transported around the Tanio Point to the south is obstructed by the jetty, the shoreline advances at the north side of jetty and the beach erosion does not occur on the northbeach. The sand is not transported into the Port Beach. Therefore, the shoreline changes only with the budget of sand in the Port Beach. The volume of sand accumulation in the Port Beach is small, and the shoreline advance in the area around the canal mouth is also small. However, at the lee side of jetty, the beach erosion will occur.

Countermeasure 2 : L-type jetty at the Tanio Point

By changing the shape of jetty to the L-type, the rate of shoreline advance in the vicinity of the port could be decreased. However, the shoreline recession still occurs at the lee side of the L-type jetty. As the calculation of wave propagation is based on the energy balanced equation, the effect of wave diffraction is not fully estimated and the precision of shoreline prediction may not be good. Then, the erosion in the sheltered area behind the L-type jetty is expected to be decreased.

Countermeasure 3 : L-type jetty at the Tanio Point and two jetties in the Bort Beach

Figure 6-3-13 shows the predicted shoreline changes for the countermeasure 3, in which the L-type jetty is constructed at the Tanio Point and two jetties in the Port Beach tentatively. Although the shoreline configuration is discontinuous at the points where the jetties are constructed, not only at the port side of the L-type jetty, X85, but also in the area closed to the port, from X100 to X104, rates of shoreline changes decrease. Furthermore, the shoreline changes will reach to the final equilibrium configuration in 5 to 10 years.

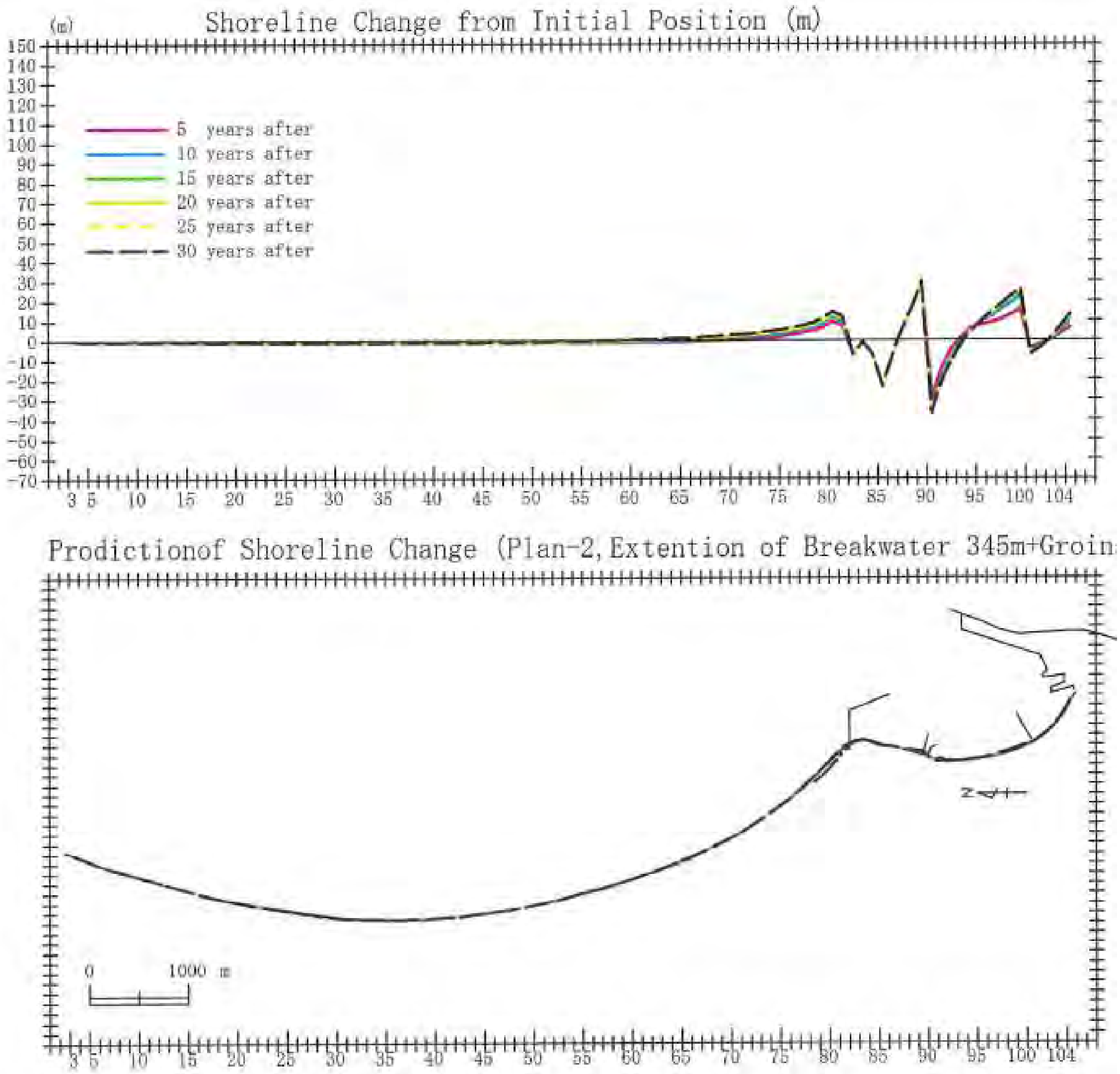


Figure 6-3-13 Countermeasure 3 (L-type jetty and two jetties)

6-4 Analysis of Ship Waiting Time

6-4-1 Purpose of Analysis

At present, Toamasina port is operated with one lane approach channel, where there is little ship waiting time. However ship waiting might occur in future if number of ship calls will be increased. The analysis of ship waiting time is conducted in order to forecast the waiting times in 2020 for various vessel types and to estimate the effect of the Urgent Development Plan.

6-4-2 Method of Analysis

(1) Software

The following software was used for the analysis

Name：WITNESS (Lanner Group Ltd.)
Version：2001

Specification: The program is multipurpose computerized program applicable to simulate manufacturing, logistics and transportation processes etc. In the program, various processes can be modeled and calculation can be monitored with visual animation on computer screen. Calculated result is used to comprehend and evaluate the effect of the processes.

(2) Cases of Analysis

The following four cases were selected for the analysis.

1) Reproduction of actual ship arrivals in 2007

Using ship calls data of 2007, model calibration was carried out by analyzing waiting time and berth occupancy rat.

2) Forecast for “Without Project Case”

The cargo demand forecast shows throughputs of container, bulk/general cargo and liquid cargo will increase with the growth rate of 10%, 3% and 2%, respectively. In the analysis, ship call of each category was increased in accordance with the growth rates, and the waiting times of 2020 were calculated.

Because the handling capacity of present terminal is estimated at 200,000 TEU, surplus containers beyond the capacity is assumed to be carried by small container vessels sized with approximately 500 TEU. These small vessels are able to load/unload containers at Mole A, B and C though usual large container vessel can berth at only C2 and C3. Cargoes for small vessel were assumed to be transshipped at Port Louis in Mauritius.

Regarding liquid cargo, ship sizes will be larger when new berth under preparation is commissioned. Number of ship calls is assumed to be decreased because the ship size will be larger.

3) Forecast for "With Project Case" – 1 Lane Approach Cannel

When the Urgent Development Project will be completed, new container berth C4 with -14m depth will be installed. As the result, sizes of container vessels will be larger, which is estimated at 3,000 TEU in average. The ship call of these large container vessels is assumed at 300 times in 2020.

4) Forecast for "With Project Case" – 2 Lane Approach Cannel

In case the ship calls will be increased, congestion might be induced by the limit of channel lane. Therefore 2 lane channel model was also analyzed with the same ship call data of 3) "With Project Case".

(3) Input Data

The input data of each case are shown in Table 6-4-1.

Table 6-4-1 Input Data

	Shiptype	Bulk/ General (1)	Bulk/ General (2)	Bulk/ General (3)	Container	Container Small Vessels	Pass./ Ferry	Car Carrier	Tanker	Bulk Ambatovy	Bulk Oji Paper	Others	Total
Ship Types & Sizes	LOA(m)	60	130	150	160	100	110	200	130	210	210	45	-
	B(m)	12	19	23	25	18	18	33	23	30	30	8	-
	Draft(m)	3.5	8	10	10	6	6.2	10	9	12	12	2.5	-
	DWT	1,300	10,000	20,000	20,000	5,000	3,500	20,000	20,000	48,000	50,000	-	-
	Average Berthing Hrs	290.0	160.0	80.0	20.0	60.0	18.0	10.0	40.0	71.0	120.0	24.0	-
Shipcall	2007 Shipcall	89	35	38	227	-	24	22	54	-	-	832	1321
	Without Project Case	131	48	48	400	450	24	22	50	71	5	832	2081
	With Project Case (1Lane)	131	48	48	300	-	24	22	50	71	5	832	1531
	With Project Case (2Lane)	131	48	48	300	-	24	22	50	71	5	832	1531

6-4-3 Result of Analysis

The result of analysis for average ship waiting time is shown in Table 6-4-2. The result for Berth occupancy ratio is shown in Table 6-4-3.

Table 6-4-2 Result of Analysis – Ship Waiting Time

	Average Ship Waiting Time (days)			
	2007	Without Project 2020	With Project 2020 (1 Lane)	With Project 2020 (2 Lane)
Bulk/General (1)	0.15	2.09	0.49	0.51
Bulk/General (2)	0.00	3.65	0.55	0.55
Bulk/General (3)	0.00	0.82	0.36	0.33
Container	0.01	3.38	0.01	0.01
Container Small Vessel	--	1.28	--	--
Pass./Ferry	0.04	2.41	0.21	0.19
Car Carrier	0.02	2.63	0.43	0.40
Tanker	0.22	0.01	0.01	0.00
Bulk Ambatovy	--	0.00	0.00	0.00
Bulk Oji Paper	--	1.18	0.46	0.44
Others	0.32	0.02	0.01	0.01

Table 6-4-3 Result of Analysis – Berth Occupancy Ratio

	Berth Occupancy Rate (%)			
	2007	Without Project 2020	With Project 2020 (1 Lane)	With Project 2020 (2 Lane)
MOLE A WEST(AW)	45.7	67.3	39.6	39.6
MOLE A EAST(AE)	37.4	66.6	39.6	39.6
MOLE B WEST(BW)	24.4	82.1	62.8	62.9
MOLE B WEST(New Berth)	28.0	80.6	37.2	34.6
MOLE B EAST (Ambatovy)	--	64.8	58.4	58.4
MOLE B New Oil Jetty	--	25.5	23.2	23.1
MOLE C1(C1)	39.3	66.3	21.6	21.7
MOLE C2 (C2)	33.5	89.6	18.5	18.5
MOLE C3 (C3)	33.7	89.7	38.5	38.5
MOLE C4 (C4)	--	--	34.6	34.6

Figure 6-4-1 shows the histogram showing the above calculation results. In the Figure, the calculated values of bulk/general and container which has 2 or 3 size categories are represented by average values. The ship waiting time of "Without Project Case" is estimated 2 ~ 3 days in average. If the Urgent Development Plan will be executed, waiting of container vessels will be nearly none, while other vessels waiting time can be lowered to about half day.

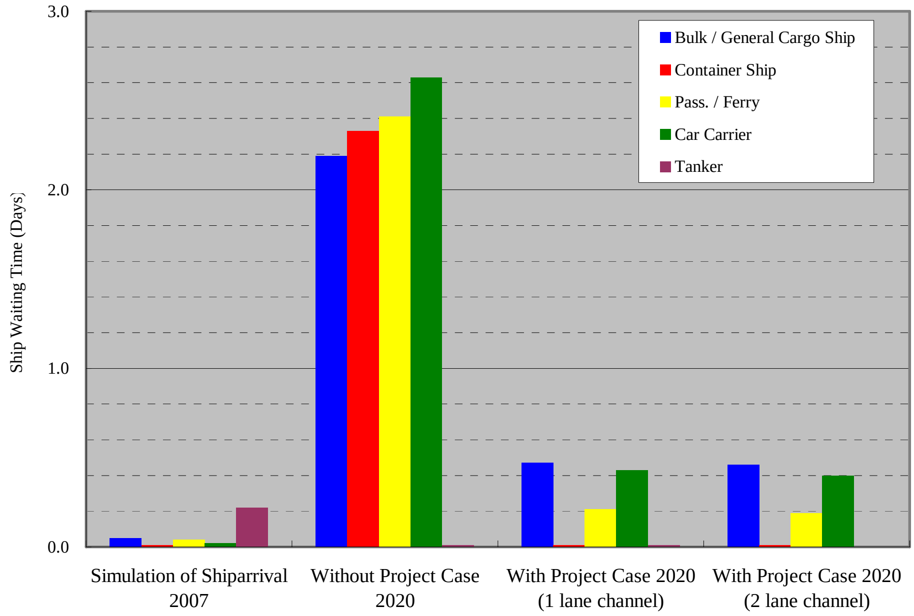


Figure 6-4-1 Summary of Analysis of Ship Waiting Time

Reffered Documents of Chapter 6-4
1) http://www.port-toamasina.com/ *(for Statistics of Ship Arrival & Departure)*
2) Lloyd's Resister Database *(for Ship Names & Dimensions)*