ORGANISATION POUR LA MISE

EN VALEUR DU FLEUVE SENEGAL

HYDRAULIC MODEL STUDIES

PORT OF SAINT LOUIS

MEMORANDUM ON BREAKWATER

LAYOUT AND CHANNEL ARRANGEMENT

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1. SUMMARY AND RECOMMENDATION

The Mobile Bed Model Study of various breakwater layouts and arrangements of the access channel to the port of Saint-Louis has now been completed. A series of 3-dimensional model tests of the recommended breakwater layout is scheduled to follow immediately after the termination of the Mobile Bed Study.

The present memo contains a brief presentation of the main findings in the Mobile Bed Model, and the results of an engineering and economic evaluation of the various schemes leading to a recommendation of the final layout to be tested in the 3-dimensional breakwater model.

Breakwater Layout and Sand Bypassing

Based on the model study it is concluded that a littoral barrier north of the channel is required in order to minimise sedimentation in the channel. Furthermore, it is concluded that artificial sand bypassing and beach nourishment south of the channel will be required in order to prevent wave induced erosion from cutting a new entrance to the estuary south of the channel.

The following three types of littoral barriers and sand bypassing schemes were studied:

Scheme A

A relatively long breakwater blocking the littoral drift incorporating sand bypassing by a cutter suction dredge working from shore on the north side of the breakwater, see Planche 10.3A and 10.3D.

Scheme B

A dredged reservoir protected by a detached breakwater incorporating sand bypassing by a cutter suction dredge working in the lee of a detached breakwater, see Planche 10.3B.

Scheme C

A dredged reservoir partly protected by a breakwater structure. incorporating sand bypassing by a trailing hopper suction dredge, see Planche 10.3C.

The model tests showed that both scheme A and B are viable solutions, whereas, scheme C proved to be less attractive. From a navigational point of view, scheme A with breakwater layout II-11, as shown in Planche 10.3D, is the preferred because of the better wave protection of the inner part of the channel.

A present worth analysis based on an interest rate of 8% and a project life of 50 years resulted in the following values for the construction and maintenance of the littoral barriers and sand bypassing schemes.

	Present Worth in Million U.S. $
Layout II-10	95.9
Layout II-31	99.6
Layout II-41	100.7
Layout II-11	95.9

Based on the above considerations and cost estimates, breakwater layout II-11, as shown in Planche 10.3D combined with sand bypassing by a cutter suction dredge working from shore on the north side of the breakwater is recommended.

Channel Arrangement

The following channel alignments have been studied in the Mobile Bed Model:

Alignment A: Channel alignment of 260 degrees from the turning basin in the port to deep water, see Planche 10.3A.

Alignment B: Channel alignment of 245 degrees from the turning basin in the port to a bend in the channel at a water depth of about 10 m. From the bend in deep water, the channel alignment is 260 degrees, see Planche 10.3D.

The model tests showed improved hydraulic and sedimentation conditions for the southerly channel alignment represented by Alignment B relative to Alignment A. An additional rotation of the channel to the south would likely improve current conditions further, however, such southerly channel directions are not attractive from a navigational point of view, and Alignment B is recommended.

2. LITTORAL DRIFT

The net southgoing littoral drift offshore at Saint Louis is in the range of 1 million m3 per year. This estimate is based on surveys of the accretion of sand at the southern tip of the Langue de Barbarie and on computations of the littoral drift from wave and current measurements.

Northgoing littoral drift generated by waves from south-westerly directions is estimated to be small and should have an very little effect on the proposed port access. South-westerly wave directions were recorded during the summer of 1983, however these wave conditions were rare, and no major storm waves were recorded from this direction.

When the proposed new access channel to the Port of Saint Louis has been dredged through the Langue de Barbarie it would act as a large sediment trap if the littoral drift is allowed to freely move southward along the coast. Almost all of the 1 million m3 per year of sediment would be deposited in the channel. This channel sedimentation would have a severe impact on the maintenance of a deep water access to the future port as maintenance dredging in the channel would be required on a continuous basis, and the dredging equipment would have to have a sufficiently high capacity to cope with the high sedimentation rate during storms. If the dredging equipment were ever to break down for a significant period of time the access channel would quickly fill in and close the port. Furthermore, the sedimentation area of the channel, if the channel is unprotected, would be fully exposed to wave action, making dredging operations very difficult and in some situations impossible. Therefore some means of eliminating or reducing the southgoing littoral drift is required north of the channel.

This reduction in littoral drift can be accomplished by creating a littoral barrier flanking the channel to the north. The littoral barrier will cause accretion of material to the north of the channel, and net erosion in the channel area and south of the channel. The sediment reservoir created by such a littoral barrier will gradually be filled and, when finally full, the littoral drift will bypass the barrier. At this point in time, the reservoir will either have to be increased in size, or the accumulated amount of sand in the reservoir reduced by dredging or excavation.

If a channel maintenance scheme consisting of expansion of the littoral reservoir is adopted, a total amount of approximately 1 million m3 of sand will be accumulated north of the channel every year. Because the amount of littoral drift reflects a delicate balance between supply of material and the transport capacity of waves and currents, an equal amount of about 1 million m3 per year will be eroded south of the channel. This erosion will lead to severe beach recession and eventually to a complete change of the configuration of the Langue de Barbarie. The Mobile Bed model tests with a littoral barrier, showed very concentrated and fast recession of the beach south of the channel. After 5 months a part of the Langue de Barbarie was eroded to a point where waves were washing over the top of the spit into the river. From a coastal engineering point of view, erosion and overtopping of the Langue de Barbarie is not considered to be of major importance. However, the erosion seen in the Mobile Bed Model developed to such a degree that the scour cut through the Langue de Barbarie and a new opening to the estuary formed south of the access channel. Such a new opening would affect the currents in the channel, and could lead to increased sedimentation in the channel.

If a channel maintenance scheme consisting of dredging of the sand accumulated in the littoral reservoir is adopted, the dredged material could be used to nourish the eroding beach south of the channel. The amount of sand that is artificially bypassed must on the average equal the littoral drift i.e. approximately 1 million m3 per year. Although the rate of littoral transport can be relatively high during storms, the littoral reservoir would provide a buffer, and the capacity of the dredging and pumping equipment would not need to be designed for the extreme sand transport rates generated by strong storms.

Based on the above and the results of the Mobile Bed Model tests, a littoral barrier to the north of the channel combined with sediment bypassing is required.

A littoral barrier north of the channel can either be created by dredging a reservoir in the littoral drift zone, by a breakwater structure blocking the sediment transport (which mainly takes place from the shore line to a water depth of 3 to 4 m), or by a combination of the two.

The following three types of littoral barriers and sand bypassing schemes were selected for detailed study in the Mobile Bed Model.

- A relatively long breakwater blocking the littoral drift incorporating sand bypassing by a cutter suction dredge working from shore on the north side of the breakwater, see Planche 10.3A and 10.3D.

- A dredged reservoir protected by a detached breakwater incorporating sand bypassing by a cutter suction dredge working in the lee of a detached breakwater, see Planche 10.3B.

- A dredged reservoir partly protected by a breakwater structure. incorporating sand bypassing by a trailing hopper suction dredge, see Planche 10.3C.

3. CHANNEL ALIGNMENT

The following two channel alignments have been studied in the Mobile Bed Model:

Alignment A: Channel alignment of 260 degrees from the turning basin in the port to deep water, see Planche 10.3A.

Alignment B: Channel alignment of 245 degrees from the turning basin in the port to a bend in the channel at a water depth of about 10 m. From the bend in deep water, the channel alignment is 260 degrees, see Planche 10.3D.

The Mobile Bed Model tests with Channel Alignment A, showed that the main direction of the strong ebb current was about 245 degrees i.e. approximately 15 degrees to the south relative to the channel direction. These cross channel currents will result in scouring of the channel side slope and will reduce the flushing effect of the ebb current resulting in increased channel sedimentation.

A slight southerly cross channel current was also observed for Channel Alignment B. However, in general the ebb current was more parallel to the channel and the hydraulic and sedimentation conditions are considered to be better than for Alignment A.

A channel alignment with a more southerly direction is likely to further improve the ebb current flow in the channel relative to alignment B. However, these more southerly channel directions are not attractive from a navigational and construction point of view and have been disregarded.

4. **LAYOUT II-10 and II-11**

These two layouts comprise the following littoral barrier and sand bypassing scheme:

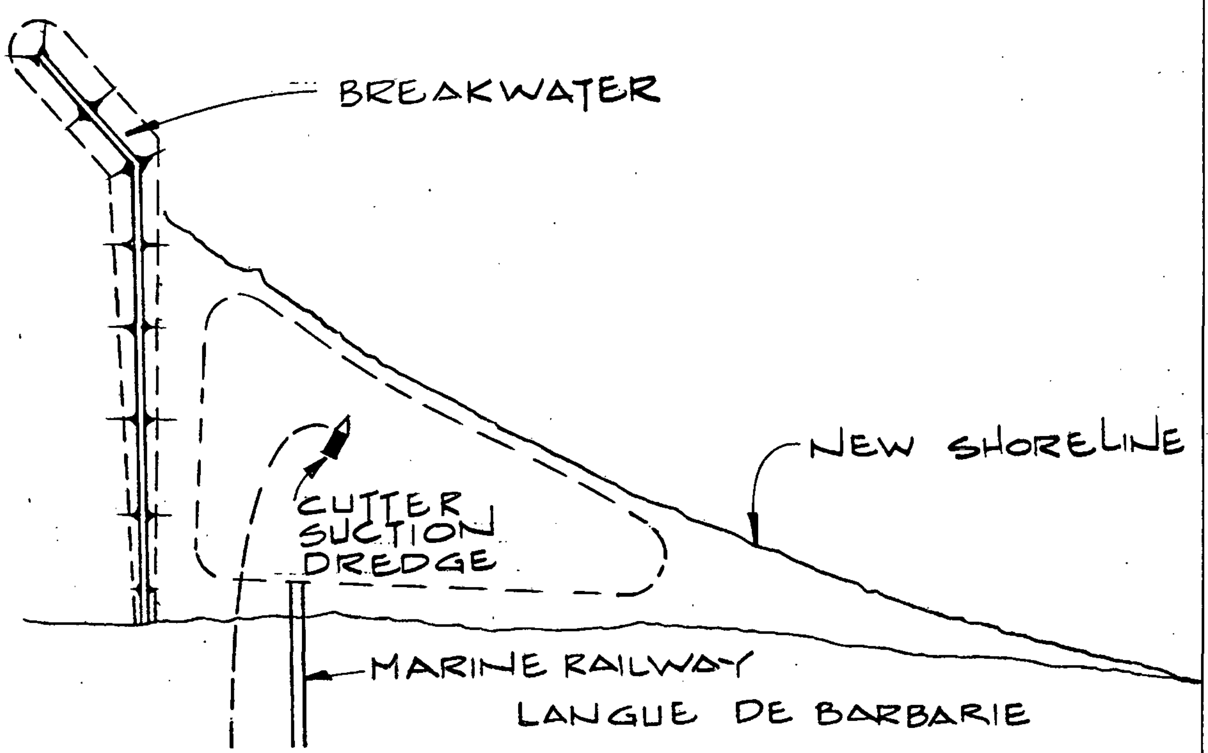
- A littoral barrier created by an 800 m long breakwater (hockey stick form) flanking the north side of the channel, see Planche 10.3A and 10.3D.

- Sand bypassing by a cutter suction dredge working in the littoral reservoir north of the breakwater and discharging material at the beach south of the channel.

- Shore protection south of the channel provided by a 250 m long corner groin and by beach nourishment.

Layout II-10 and II-11 have a relatively large sediment reservoir. The breakwater will initially act as a complete littoral barrier with sediment accretion on the north side. The new shoreline formed by the accumulated sand will be directly exposed to the waves from northwest with no breakwater protection. Because of this and because of the almost constant heavy wave activity along the coast, it will not be possible to dredge the accumulated material from the seaside.

It is envisaged that a cutter suction dredge will dredge the reservoir material from the shore. A marine railway across the Langue de Barbarie will transport the dredge from the estuary to the littoral reservoir. The suction dredge will be working in a relatively well protected pocket behind the new shoreline, as shown in the sketch below. The dredged material will be pumped to a booster station onshore which in turn will pump the sand across the entrance channel through a submerged pipeline to be spread on the eroding beach south of the channel.



The dredged pocket will be naturally filled by waves washing over the shore and pushing the newly formed beach backward. This infilling mechanism was studied in the Mobile Bed Model. The model test indicated that the natural infilling rate may not be high enough to completely stop the littoral drift. Dredging and sand bypassing must therefore be initiated before the reservoir is full, in this way, the reservoir has a buffer capacity, and, on calm days the dredge can excavate material from the area of the new shoreline.

The Mobile Bed Model tests of Layout II-10 showed that the breakwater will virtually stop all the littoral drift as long as the littoral reservoir is not full. Once the reservoir is full, the sediment transport will bypass the tip of the breakwater and move towards the shore along the south side of the breakwater, where accretion will take place. Such sediment movement and accretion could result in a high infilling rate in the channel, and should be avoided. The littoral reservoir should therefore be large enough to completely stop the littoral drift, and to provide enough room for the bypassing dredge to work. The proposed 800 m long breakwater is adequate for this purpose.

Model test results with a full upstream reservoir for breakwater layout II-11 showed significant deposition of sand in the area immediately south of the outer part of the breakwater. This sedimentation pattern is expected to result in less sedimentation in the access channel relative to layout II-10.

Maintenance dredging in the port basin, estimated at about 0.5 million m3 per year, will be performed by the cutter suction dredge used for the sand bypassing. A marine railway across the Langue de Barbarie will allow the dredge to move from one area to another as required.

In the outer channel, offshore of the breakwater wave conditions will be too rough for the cutter suction dredge to operate. The sedimentation in this part of the channel will be relatively small, with an estimated amount of 0.1 million m3 per year, so that regular maintenance will not be required. It is envisaged that this part of the channel will be dredged by a trailing hopper suction dredge.

COST ESTIMATE

In keeping with the recommendations of the Port Administration Report (No. 19) the maintenance dredging will be performed by contractors as follows:

- A portable 455 mm cutter suction dredge will be permanently stationed and continuously operating at the port.
- A trailing hopper suction dredge will be mobilized from the world market on a required basis.

Capital Costs, Fixed Structures	Million U.S. $
Breakwater Structures, 800 m long	45.0
Groin, 250 m long	5.0
Marine Railway	0.5
Total, fixed structures, Million U.S. $	50.5

Capital Costs, Dredging Equipment	Million U.S. $
Cutter Suction Dredge, 450 mm discharge pipe	5.3
Booster Station	1.9
500 m submerged pipe line	0.3
1300 m floating pipe line	1.3
1500 m shore pipe line	0.4
Total, dredging equipment, Million U.S. $	9.2

Maintenance Costs Per Year	Million U.S. $
Bypassing 1 million m3	1.2
Dredging .5 million m3 in port basin	0.6
Dredging .1 million m3 in outer channel	0.6
Maintenance of dredging equipment	0.3
Total, maintenance, Million U.S. $	2.7

PRESENT WORTH

The following present worth for scheme II-10 and II-11 has been calculated based on an interest rate of 8% and a project life of 50 years. The dredging equipment is assumed replaced twice during the life of the project.

	Present Worth Million U.S. $
Fixed structures, capital	50.5
Dredging equipment incl. replacement after 17 years and 34 years	12.4
Maintenance costs over 50 years	33.0
Total, Million U.S. $	95.9

5. LAYOUT II-31

This layout consists of the following littoral barrier and sand bypassing scheme:

- A littoral barrier created by a dredged basin protected towards the sea by a 450 m long detached breakwater. The longshore littoral drift is guided towards the dredged basin by a 200 m long groin as shown in Planche 10.3.B.

- Sand bypassing by a cutter suction dredge working in the reservoir basin in lee of the detached breakwater. The dredged sand will be discharged onto the beach south of the channel.

- Shore protection south of the channel provided by a 250 m long corner groin and by beach nourishment.

Layout II-31 has a relatively small dredged sediment reservoir. The total volume of the sediment basin taken between the bottom of the basin to the existing seabed is approximately 1.9 million m3. However, a complete filling of the reservoir will result in significant infilling in the access channel. It is envisaged that dredging in the reservoir and sand bypassing will commence immediately after the construction of the reservoir, and will be carried out on a regular basis to keep the amount of accumulated sand in the reservoir at a minimum.

The north groin will initially stop a major part of the littoral drift. After the reservoir north of the groin is filled, the groin will guide the coast parallel sediment transport through the gap between the tip of the groin and the breakwater and into the relatively well protected sedimentation basin. A cutter suction dredge will be working in the basin, and the dredged material will be pumped via a booster and a submerged pipeline under the channel to the beach south of the channel.

The Mobile Bed Model tests showed a quasi stable seabed with a water depth of about 3 to 4 m in the gap between the tip of the north groin and the breakwater. The littoral drift through the gap was in the model deposited on the south side of the groin and in the northeastern part of the reservoir basin. Wave heights in the breakwater protected reservoir basin were about 20 to 30 percent of the incoming wave heights. Wave diffraction is in the distorted model slightly exaggerated, and wave conditions in the reservoir basin will be calmer in the prototype than seen in the model.

Assuming a maximum wave height of 0.3 m for dredging, and a wave agitation of 20 percent in the reservoir, bypassing is expected to take place for incoming significant wave heights of up to Hs = 1.5 m. Such conditions will on the average occur for 90 percent of time i.e. for about 47 weeks during a year.

Maintenance dredging in the port basin and in the outer channel is envisaged similar to layout II-10, i.e. using the cutter suction dredge in the port and a trailing hopper suction dredge in the outer channel.

COST ESTIMATE

The cost estimate assumes the same configuration of dredges as is used for layout II-10.

Capital Costs, Fixed Structures	Million U.S. $
Breakwater Structure, 450 m long	37.0
North Groin, 200 m long	4.0
South Groin, 250 m long	5.0
Incremental cost of deepening the Access Channel	0.6
Dredging the Reservoir Basin	7.6
Total, fixed structures, Million U.S. $	54.2

Capital Costs, Dredging Equipment	Million U.S. $
Cutter Suction Dredge, 450 mm discharge pipe	5.3
Booster Station	1.9
500 m submerged pipe line	0.3
1300 m floating pipe line	1.3
1500 m shore pipe line	0.4
Total, dredging equipment, Million U.S. $	9.2

Maintenance Costs Per Year	Million U.S. $
Bypassing 1 million m3	1.2
Dredging .5 million m3 in port basin	0.6
Dredging .1 million m3 in outer channel	0.6
Maintenance of dredging equipment	0.3
Total, maintenance, Million U.S. $	2.7

PRESENT WORTH

The following present worth for scheme II-31 has been calculated based on an interest rate of 8% and a project life of 50 years. The dredging equipment is assumed replaced twice during the life of the project.

	Present Worth Million U.S. $
Fixed structures, capital	54.2
Dredging equipment incl. replacement after 17 years and 34 years	12.4
Maintenance costs over 50 years	33.0
Total, Million U.S. $	99.6

6.0 LAYOUT II-41

This layout consists of the following littoral barrier and sand bypassing scheme:

- A littoral barrier created by the combination of a 500 m long breakwater and a dredged littoral reservoir as shown in Planche 10.3C.

- Sand bypassing by a trailing hopper suction dredger working in the littoral reservoir created between the breakwater and the channel.

- Shore protection south of the channel provided by a 250 m long corner groin and by beach nourishment.

The 500 m long breakwater will create an upstream (north) reservoir with an estimated volume of about 3 million m3. The dredged reservoir south of the breakwater has a total dredged volume of approximately 1.7 million m3.

The breakwater will initially stop the southgoing littoral drift almost completely. Sand will accumulate north of the breakwater and form a new beach. Once the upstream reservoir is filled, the total littoral drift of about 1 million m3 per year will bypass the tip of the breakwater, and move into the dredged reservoir. The velocity of the longshore current will reduce in the relatively deep reservoir causing the sand to settle. It is envisaged that a trailing hopper suction dredge will dredge the accumulated sand on a regular basis. The dredged sand will be used for the beach nourishment south of the channel. A berthing dolphin structure with a light pipe trestle to the Langue de Barbarie will be constructed in the estuary south of the channel. This structure will serve as discharge facility for the hopper.

A hopper dredge requires a minimum water depth of about 6 m. The maintenance dredging in the reservoir basin must therefore commence at an early stage before the basin becomes too shallow by sedimentation i.e. shortly after the littoral drift starts to bypass the breakwater. It is expected that this will occur 1 to 2 years after the construction of the breakwater.

The Mobile Bed Model tests showed that, once the upstream reservoir is filled, sand will move around the tip of the breakwater and along the south side of the breakwater towards shore. The main sedimentation area was found to be along the north side of the channel where the channel cuts through the Langue de Barbarie. The concentrated sedimentation seen in the model is exaggerated because of inherent scale effects in the model. However, the results clearly indicate that significant sedimentation will occur in the channel, and the dredged reservoir will only catch a part of the sediment transport.

The layout of the breakwater provides only little wave protection in the reservoir basin and in the access channel. The side slopes of the channel were severely eroded in the model and significant erosion occurred along the beach between the channel and the groin south of the channel. These areas will require scour protection in order to secure the entrance through the Langue de Barbarie.

It is envisaged that a trailing hopper suction dredge will be used for maintenance dredging in the port basin, in the outer channel, as well as for the sand bypassing.

COST ESTIMATE

The cost estimated for maintenance dredging is based on the assumption that the trailing hopper suction dredge will be operated by a contractor on a continuous basis.

Capital Costs, Fixed Structures	Million U.S. $
Breakwater Structure, 500 m long	25.5
Groin, 250 m long	5.0
Shore facility for hopper discharge	0.2
Incremental cost of deepening the Access Channel	1.2
Dredging Reservoir Basin	11.9
Total, fixed structures Million U.S. $	43.8

Capital Costs, Dredging Equipment	Million U.S. $
Trailing Hopper Suction Dredger	12.0
1000 m shore pipe line	0.3
Total, dredging equipment Million U.S. $	12.3

Maintenance Costs Per Year	Million U.S. $
Bypassing 1 million m3	1.8
Dredging .5 million m3 in port basin	0.9
Dredging .1 million m3 in outer channel	0.2
Maintenance of dredging equipment	0.4
Total, maintenance, Million U.S. $	3.3

PRESENT WORTH

The following present worth for scheme II-41 has been calculated based on an interest rate of 8% and a project life of 50 years. The dredging equipment is assumed replaced twice during the life of the project.

	Present Worth Million U.S. $
Fixed structures, capital	43.8
Dredging equipment incl. replacement after 17 years and 34 years	16.5
Maintenance costs over 50 years	40.4
Total, Million U.S. $	100.7