3. PORT OF SAINT-LOUIS

3.1 Wave Measurements

Wave measurements were executed by the Contractor, using a Datawell wave recorder, from early July 1971 up to mid March 1972, with the exception of a brief period from September 24, 1971 to November 15, 1971, due to the parting of a buoy mooring line.

Since the period of the measurements comprises the major part of the two important seasons - the summer and the winter - it is now possible to evaluate the average wave conditions over a whole year.

Plan No. 15 shows the results of the wave measurements. The lowest curve represents the summer measurements included in Report No. 1; the uppermost curve represents the measurements carried out during the winter season subsequent to issuing Report No. 1.

The evaluation of average conditions over a whole year is based on the assumption that the measurements from 8th July to the 31st December represent the conditions for nine months of the year and the measurements from 1st January to 16th March represent the conditions for the other three months of the year. In this way, the curve entitled "Estimated Annual Distribution" was determined.

From this curve, the annual average of the square of the significant wave heights can be determined. The calculations of sand transport along the coast are based on this figure.

The significant wave height corresponding to this quantity is calculated to be 0.96 m. In the preliminary calculations, a value of 1.0 m was used. The difference between the two values is without practical importance and does not necessitate a revision of the estimate of annual litoral drift of 900,000 m^3.

During the first measuring period, the average period of the waves was found to be about 8.0 seconds and during the second period, about 10.0 seconds. These findings are compatible with normal expectations.

will be considerably less than those of a system based on transshipment between ocean and river vessels in a protected port at Saint-Louis. The transport system recommended for implementation in the initial stage of facility development is described in Section 2.1 of this report.

In both alternatives the wharves are designed as concrete platforms founded on piles and constructed above a protected slope. The large variations in water levels dictate the use of mobile cranes for cargo handling. In any case, this method of cargo handling is considered to be the most economic and the most efficient for this port.

At the inception of Phase III of these studies, the Contractor was informed by the U.N. that Kayes had been chosen as the site of the future Mali port for river traffic.

In accordance with the request of the U.N., an alternative harbour layout K3 was prepared during Phase III studies, incorporating a separate liquid fuel storage area. This modified harbour layout, as shown on Plans Nos. 22, 23 and 24, combines the advantages of both the K1 & K2 layouts, in that it provides short internal transport distances and it is close to existing facilities without encroaching upon presently occupied land.

Furthermore, a layout for a vessel repair and construction facility at Kayes was prepared during Phase III. This layout is shown on Plans Nos. 20 and 21. The slipway, which is of the side-slipping type, is located on the right river bank in order to utilize the more favourable water depths at this shore.

The construction cost of the recommended harbour facilities is estimated to be \$5.4 million U.S., excluding the vessel repair facility which is estimated to cost an additional \$1.4 million U.S. The layouts must be considered to be tentative and the cost estimates approximate due to the lack of sufficient information on site conditions.

2.8 Staged Development

The possibility of a staged development of the various port facilities has been kept in mind continually during the preparation of the harbour layouts. Thus, in the case of the Kayes terminal, the proposed layout is well suited for a staged development for which the cost of the individual stages will be approximately proportional to their respective capacities.

The transshipment harbour at Saint-Louis, however, does not lend itself to a staged development since, in this case, the cost of providing deep water access to the port constitutes a very important part of the total construction cost of the port, and this cost cannot be reduced in any way in any initial phase. Therefore, it appears that a staged development of river transport on the Senegal River will have to be implemented by the introduction of an initial transport system, for which the initial investments

In particular, this solution offers better possibilities for future expansion of the harbour facilities. Consequently, the general location and layout, T2/F2, were recommended by the Contractor in the Phase I report.

In Phase III the port layout T2/F2 has been modified to include provision of a fuel storage facility. This revision leads to the reduction of the number of berths required for ocean vessels from 7 to 6. The Mauritanian wharf is proposed to be used for ocean tankers. The modified alternative T2/F2 is shown on Plans 17, 18 and 19. The layout of the ship repair facility has also been modified into a side-slipping slipway with a capacity of 15 vessels. The construction cost of this alternative is estimated to be about $21.2 million U.S., including the provision of the new entrance channel. In addition, the construction costs of the fishing port and the barge repair facility not included in this figure are estimated to be $3.4 million U.S. and $1.8 million U.S., respectively.

While hydraulic model tests for the estuary entrance are not required for the preparation of approximate estimates of construction and maintenance costs, they are considered to be prerequisite to the preparation of the final design and layout.

At the request of the United Nations, during Phase III the Contractor studied the aspect of the intrusion of salt water into the river during the dry season, as well as the question of the exchange of water in the southernmost part of the estuary after the construction of the new entrance channel.

The conclusions of these studies are that a considerable increase in the maximum distance of salt water intrusion into the river must be expected to result from the increase of tidal effects in the estuary caused by the smaller hydraulic resistance of the new entrance. On the other hand, the calculations indicate that this reduction in hydraulic resistance will lead to an increased exchange of water in the lagoon formed by the southern part of the estuary when the new entrance has been provided and the old entrance has been closed. The exchange of water under these conditions appears to be sufficient to ensure satisfactory conditions in this region.

2.5 Fishing Port at Saint-Louis

Three different layouts for the fishing port at Saint-Louis were studied during Phase I. The first is located on the east coast of the Langue de Barbarie, while the other two are located on the east coast of the estuary and combined with the two variants proposed for the transshipment port. Moreover, a fishing port solution related to the planning of a coastal transshipment port has been outlined.

the construction of a paved highway to connect the town and the port to the infrastructural network of Senegal. The additional costs of these facilities have been estimated to be in the order of $7 million U.S.

The only advantage of this site is that the passage of river vessels through the Faidherbe Bridge is avoided. However, as mentioned above, the inconveniences caused by ship passages through the bridge may be reduced to such a point that it would no longer constitute any problem and this improvement may be realized at a very small cost.

On the basis of these considerations, no site investigations have been made at the site of Tialakt. Consequently, any detailed estimates of construction costs of port facilities at this site prepared at this time might be misleading.

The possibility of improving the existing river mouth has also been considered. However, this solution was rejected due to the unfavourable location of the river mouth. Furthermore, the solution would not offer any economic advantage.

During Phase 1 of the study, three alternatives were prepared for the transshipment port facilities at Saint-Louis. Two of these alternatives are located within the estuary and the third on the ocean coast of the Langue de Barbarie.

The two alternatives located within the estuary are situated on the east bank of the river within the region reserved for harbour and industrial development in the town planning for Saint-Louis. These port facilities are combined with the construction of a new deep water entrance to the estuary, protected by breakwaters and located about 3.5 km south of the Muslim Cemetery on the Langue de Barbarie. The location recommended for the transshipment port alternative on the ocean coast is located a little further south on the Langue de Barbarie. Each of these alternatives contains 7 berths for ocean vessels, 5 to 6 berths for river barges, wharves for service vessels and the storage facilities required for the specified cargo volumes.

The cost estimates show that the construction cost of the coastal port, including barge facilities on the estuary coast of the Langue de Barbarie, will be about $19 million U.S. A deep water port in the estuary, including the new entrance channel, may be constructed for about $20 million U.S. Even if the cost of the latter solution appears higher, the cost difference is more than compensated for by the additional costs of bridge improvements which would be required if the port is located on the Langue de Barbarie. Furthermore, the aspects of town planning, port planning and of the development of the entire Senegal River valley will be better served by the realization of the port in the estuary.

For these reasons a special study of the Faidherbe Bridge has been carried out within the present contract. This study has confirmed that the superstructure of the bridge is corroded to such an extent that remedial measures should be undertaken.

In its present condition, the opening of the swing span of the bridge takes from 20 to 30 minutes. The inconvenience arising from this may be avoided by the installation of an efficient electrical mechanism by which the opening and closing time may be reduced to one or two minutes. The cost of such an improvement would be less than $200,000 U.S., including replacement of the water pipeline on the bridge by a submerged pipeline. It is obvious that this cost, which has no connection with the advanced state of corrosion of the superstructure is minimal in comparison with the costs that might be incurred through the coastal erosion problems which would result from the construction of a port north of Saint-Louis.

The necessity of renovating or replacing the Faidherbe Bridge was studied in Phase I, ref. Section 10 of Report No. 1. The cost of the works required varies from $1.3 to $7.0 million U.S., according to the design criteria to be established.

2.4 Transshipment Port at Saint-Louis

It is concluded from the studies executed that it is technically feasible to provide deep water protected port facilities at Saint-Louis for transshipment of cargo between ocean vessels and river barges. This may be realized by:

- Construction of a protected deep water port on the ocean coast of the Langue de Barbarie, or

- Excavation of a new entrance channel from the sea to the estuary protected from sedimentation by breakwaters, and constructing a transshipment port within the estuary.

In both cases the port structures on the ocean coast should definitely be located south of Saint-Louis because of the serious coastal erosion problems which would arise at the town if these installations were located at a relatively short distance north of Saint-Louis.

The only site north of Saint-Louis which is sufficiently far away from the town to be considered as a possible harbour site is the coast off the old Tialakt River arm, located in Mauritania, about 18 km north of Saint-Louis. In this case, the Tialakt channel would be used to connect the port to the Senegal River. However, this site is located so far from Saint-Louis, and in a different country, that the location of a port at this site would require the development of a new town close to the port as well as

Since the littoral transport occurs almost exclusively within the breaker region, that is, in water depths less than 4 m, it is obvious that the construction of a protected port on the coast will block off this transport completely. This will result in an accumulation of sand north of the port and a corresponding erosion of the coast south of the port. This coastal erosion will occur over a distance of more than 10 km south of the port and may reach a maximum rate of as much as 30 m per year. Such phenomena will appear regardless of the nature of the structures constructed on the coast, except in the case of structures which provide no obstruction whatsoever to the waves, such as an open wharf.

The maintenance of sufficient water depths in the access leading to the port facilities, whether by dredging or by repeated extension of breakwaters, will result in a complete disruption of the normal southward sediment transport at the port site. If such maintenance were not carried out, nature would tend to reestablish the normal sediment transport pattern by eventually creating a continuous breaker zone extending from one side of the port to the other. This would require that a bar with water depths less than 4 m be formed around the harbour whereby the entrance channel would be obstructed.

The sedimentation problems in the estuary are of minor importance. In the dry season, which lasts for the major part of the year, the supply of sediments is almost nil. During the greater part of the rainy season, the sediment in suspension would be transported into the sea, even after the construction of a new deep water entrance channel to the estuary.

2.3 Faidherbe Bridge

In its present state, the Faidherbe Bridge constitutes a major obstacle to navigation in the estuary. Because of the long time required for opening the bridge, this operation can only be carried out two or three times a day at the maximum. Because of this condition, the idea of placing the transshipment port north of the town of Saint-Louis has been favoured in past considerations of the port development. Furthermore, the advanced state of corrosion of the bridge gives reason to serious doubts with regard to its safety.

On the other hand, it was evident from the start of the present study that there were very important reasons to prefer port locations south of the town, especially because of the fact that coastal erosion would present serious problems for the town of Saint-Louis if the port were constructed north of the town.

In view of this situation, detailed field studies were carried out in order to establish sufficient knowledge of the field conditions for the preparation of rational and economic solutions relative to the planning of deep water port facilities in this region. The field studies included surveys relative to topography, soil mechanics and depth conditions, studies of the hydraulic conditions in the sea and in the estuary and studies of civil engineering aspects.

The studies were carried out during an intensive phase from June to August 1971, followed by a phase concerned mainly with wave measurements up to March 1972. The information gathered showed that the water depths on the ocean coast of the Langue de Barbarie are favourable. The 10-m depth contour is found at only about 600 m from the coast. The depth conditions in the estuary are also relatively favourable. The water depth in the northern part of the estuary, including the area about 5 km to the south of the Faidherbe Bridge, is almost sufficient for ocean vessels. On the other hand, the depth conditions at the river mouth are very unfavourable. The water depths on the bar across the entrance are very unstable and often smaller than 3 m, even at high water.

The subsoil on the Langue de Barbarie consists mainly of sand. In contrast to this, the east coast of the estuary is dominated by deep layers of soft silt covering firmer soils located at about 8 m in depth.

The very considerable littoral transport encountered on the ocean coast of the Langue de Barbarie presents serious problems to the development of a deep water port in this region. This sand transport, which is caused exclusively by wave action, occurs mainly within the breaker region where the turbulence created by the breaking of the waves puts the sand into suspension, and the strong littoral current generated by the waves transports the sand along the coast. The direction of the littoral current and thus of the sand transport is determined by the direction of the propagation of the waves relative to the coast. The velocity of the littoral current is determined by the wave energy in combination with the direction of propagation of the waves. The quantity of sand put into suspension depends on the wave energy and the granulometry of the sand.

On the ocean coast of the Langue de Barbarie, waves normally arrive from within the sector north of the perpendicular to the coast. Thus, the littoral transport is towards the south. On the basis of the field investigations, the rate of littoral transport is estimated to be about 900,000 m^3 per year.

The tankage requirements have been determined on the assumption that the storage capacity should correspond to approximately 50% of the annual volume of fuel handled in the ports concerned and that the tank farm at Saint-Louis should be divided into three sections - one for each of the three countries concerned.

Report No. 1 contains specifications concerning the types and amount of cargo handling equipment required and an evaluation of the labour requirements in the various ports.

With respect to the fishing port at Saint-Louis, the requirements in terms of wharf lengths at different water depths corresponding to conditions forecast for 1980 were formulated in 1971 by the Fisheries Director of the Senegal Government and appear in terms of reference for a study of the fishing port at Saint-Louis. These terms of reference also specify the capacity of cold storage required.

Recommendations concerning the dimensions of a building for sale of fish by auction were established in Report No. 1. These recommendations were based on the conclusions of an investigation concerning the probable quantities of fish supplied to the new fishing port, taking seasonal variations into consideration.

2.2 Site Conditions at Saint-Louis

The town of Saint-Louis is located in the delta of the Senegal River at the northern end of the Langue de Barbarie, a narrow sandy formation which separates the river from the Atlantic Ocean over a length of about 30 km.

In 1971 the mouth of the river was located about 24 km south of Saint-Louis. The location of the mouth is subject to continual change in the form of a cyclic movement; the mouth is gradually moving towards the south until a situation is reached whereby the sea breaks through the Langue de Barbarie to form a new mouth 10 or 15 km further to the north, after which the former mouth is closed and the pattern of movement repeats itself.

These conditions are a clear indication of a very dynamic coastal situation which will create serious problems for any deep water port installations whether they are situated on the ocean coast or in the estuary because, in the latter case, deep water access through the Langue de Barbarie is required.

The results of the comparative cost analysis clearly indicate that for the first stage of development, System 1 is the more economical of the two initial systems studied in that only a small initial investment is required for the construction of such port facilities.

The analysis also indicates that the transport costs of System 2 are higher than those of System 1 because of the surcharge which, according to usual practice, will probably be applied to the freight tariffs due to the inevitable delays caused by cargo handling in the open sea.

The port capacity calculations indicate that for Transport System 1, one large berth at Kayes/Ambidedi can serve a cargo volume of about 47,000 tons per year. This corresponds to a total annual transport on the river of about 70,000 tons for the three countries combined. In this system no transshipment takes place at Saint-Louis and, therefore, there is no question as to the adequacy of the present harbour installations at Saint-Louis.

For Transport System 3, which is based on transshipment between ocean carriers and river barges in a protected port at Saint-Louis, the total annual cargo volume to be transshipped at Saint-Louis, according to the previous studies, is about 290,000 tons, of which 195,000 tons is cargo going to or coming from Mali. The handling of these volumes at Saint-Louis requires seven berths for ocean carriers if, as assumed, the port has to be divided into separate sections for each of the three countries involved. Six berths are required for river barges at Saint-Louis and four at Kayes/Ambidedi.

The storage area required at Saint-Louis is estimated to be 25,500 m^2 for open storage and 25,500 m^2 for closed storage and at Kayes/Ambidedi, 12,000 m^2 and 15,000 m^2, respectively.

These figures, representing the port facility requirements, are based on the assumption that liquid fuel is transported in barrels. If liquid fuel is handled in bulk and stored in tanks, the number of berths required for ocean vessels at Saint-Louis is reduced to six and the open storage area required is reduced to 19,000 m^2. If the liquid fuel is transported to Kayes as liquid bulk in special barge tankers and a tank farm is provided at Kayes, the open storage requirement at Kayes is similarly reduced to 9,000 m^2. The closed storage area requirements are not influenced by this change.

2. SUMMARY OF PHASES I AND III STUDIES

2.1 Traffic Forecasts and Port Capacity

Forecasts of the traffic on the Senegal River resulting from the development of port facilities at Saint-Louis and at the ports of call along the river were established in 1969 and 1970 by a team of United Nations experts. These forecasts form the basis for the determination of capacity requirements for port installations at Saint-Louis, Kayes and Ambidedi, the planning of which constitutes the principal object of the present study.

The determination of the port capacity requirements has required that the annual cargo volumes presented in the reports on the previous studies be transformed into maximum weekly cargo volumes. These calculations are based on an analysis of the seasonal distribution, taking into account the limited duration of the navigation season to Mali.

In order to determine the most economic way in which a phased development of the river transport may be realized, a comparative cost analysis of three transport systems has been carried out. The three transport systems are:

System 1: The transport on the river is carried out by special river/ocean-going ships, which can negotiate the river as well as navigate in the sea. They have a draught which permits them to cross the bar at the river mouth and to navigate up the river to Kayes. Thus they can transport cargo directly between ocean ports such as Dakar and river ports up to Kayes.

System 2: The ocean carriers are unloaded while anchored in the sea off the river mouth. The cargo is loaded into lighters for transportation to the transit port facility located in the estuary, from which the cargo is later loaded into river barges for transport to the river ports.

System 3: Transshipment between ocean carriers and river barges takes place in protected port installations at Saint-Louis. This system forms the basis of the present report.

It has been concluded that, because of the very considerable investment required for the construction of the protected transshipment port at Saint-Louis, i.e., System 3, the gradual development of the river traffic can only be realized economically by the initial implementation of a transport system which requires much smaller initial investments, i.e., System 1 or System 2.

Phase III of the studies was devoted mainly to making modifications to the scheme of development as recommended in Phase I. These modifications stemmed from suggestions made by the United Nations as a result of their Phase II studies. Phase III activities also included the preparation of a summary of the studies carried out under Phases I and III studies.

1. INTRODUCTION

This is the final report on the studies executed under Contract CON 51/71 - "Senegal River Ports and Navigability Studies, Harbour Studies at Saint-Louis, Kayes and Ambidedi", between the United Nations and Surveyer, Nenniger & Chênevert Inc., Consultants, Montreal, Canada.

The studies were carried out in three phases in collaboration with Chr. Ostenfeld & W. Jonson, Consulting Engineers, Copenhagen, Denmark, and with the assistance of the Danish Institute of Applied Hydraulics, and Knud E. Hansen, Consulting Engineers, also of Copenhagen, Denmark.

Phase 1 report, entitled "Report No. 1 - Preliminary Studies", consists of two volumes, Volume 1 - Main Report, and Volume 2 - Appendices. Volume 1 - Main Report, deals with the aspects of traffic forecasts and port capacity, site conditions and harbour planning and contains the presentation of the various harbour alternatives prepared for Saint-Louis, Kayes and Ambidedi. Volume 2 - Appendices, contains the results of the field investigations concerning topography, soil mechanics, hydraulics, civil engineering, traffic, water-borne transport and cargo handling. The English version of the report on the studies under Phase 1 of this Contract was submitted to the United Nations in February 1972 and the French version in April 1972.

Phase II of the studies was devoted to the study by the United Nations and the recipient governments of the results and conclusions of the Phase I report. During this phase, the United Nations prepared specifications relative to the studies to be executed by the Contractor during Phase III of the Contract. These specifications were transmitted to the Contractor in United Nations' letter dated September 6, 1972. A copy of these specifications is included in Appendix A to the present report. The Contractor expressed his agreement in his letter to the United Nations dated September 29, 1972, to execute the studies required by the United Nations and submitted comments relative to two points of the specifications. These points were discussed at a meeting in New York, October 6, 1972 between the United Nations and representatives of the Contractor. The decisions taken at this meeting were summarized in a letter from the United Nations to the Contractor dated October 13, 1972, a copy of which is included in Appendix C to the present report. This letter contains a request by the United Nations for the Contractor to submit an Inception Report and also a special excerpt from Report No. 1 relative to Faidherbe Bridge. The inception report was transmitted to the United Nations on November 10, 1972, and the excerpt concerning the Faidherbe Bridge was submitted on October 11, 1972.

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April 6, 1973

Ref: 3136-01-2450-113

United Nations
New York, N.Y. 10017

Attention: Mr. H.K. Ward-Smith
Chief, Purchase and Transportation Service

Dear Sirs:

Report No. 2 - Final Report
Your Ref: UN Contract CON 51/71

In accordance with our agreement, CON 51/71, dated May 15, 1971, as modified by Amendment No. 4 dated October 16, 1972, we are pleased to present "Report No. 2 - Final Report" covering Phase III of the "Senegal River Ports and Navigability Study".

The contents of this report are in accordance with the requirements as outlined in UN letters and attachments to SNC dated September 6, 1972 and March 2, 1973, and the discussions held with you in New York on October 6, 1972.

The report is presented in one volume and includes chapters describing the Port of Saint-Louis, the Entrance Channel, the Port of Kayes, and Appendices. A summary of studies carried out in both Phase I and Phase III is also given.

Yours very truly,

SURVEYER, NENNIGER & CHENEVERT INC.

R.J. Griesbach

R.J. Griesbach, Eng.
Project Manager

RJG/cr
Enc.

3.2 Port North of Saint-Louis

The concept of locating a transshipment port north of Saint-Louis, was discussed in Volume 1 of Report No. 1. These considerations have been summarized in Section 2 of the present report. According to these considerations, the only site that might be used for this concept is the coast adjacent to the Tialakt channel located approximately 18 km of north of Saint-Louis as shown on plan No. 16. However, for the reasons summarized in Section 2, no field investigations were carried out at this site. Consequently, the field data required for the preparation of harbour layouts and cost estimates are not available.

Since, in a general way, the field conditions appear to be uniform along this coast, the construction costs of the harbour facilities proper may be expected not to differ appreciably from those of the facilities located on the Langue de Barbarie south of Saint-Louis. These costs were estimated in Report No. 1 to be $19 million U.S.

The main deterrent for a port located in the region of Tialakt is that such a location would involve the development of a new townsite near the port as well as the construction of a paved highway to Senegal. The additional costs of such developments are evidently very important and could render this alternative economically unfeasible.

To illustrate this point, a very approximate evaluation of these costs has been made. This evaluation is based on the assumption that the operation of the port would require a labor force of about 1200 persons including the personnel required for auxiliary services. The additional costs of the urban and infrastructure development are estimated as follows:

1200 housing units @ $4,000	$4.8 million
Roads, sewage, water and electricity supply	$1.2 million
Road to Senegal, 15 km at $60,000/km	$0.9 million
Total	$6.9 million

The cost estimate for the housing and additional facilities is intended to cover only the additional cost of providing these accommodations at Tialakt instead of at Saint-Louis where labor is, to a large extent, readily available.

In addition to these costs, this solution would probably also require dredging of the Tialakt channel, the cost of which could easily exceed $0.2 million U.S.

It is concluded from these evaluations that the additional cost of the Tialakt alternative would be of the order of magnitude of $7 million U.S. It would appear extremely difficult to justify such additional costs - certainly not by the elimination of the passage of river traffic through the Faidherbe Bridge. This passage may be effectively improved by modifying the opening mechanism of the swing span, the cost of which is estimated to be only about $200,000. Since the bridge is required in any case, considerations of remedial measures to be taken on account of the advanced state of corrosion do not have a bearing on the reasoning.

3.3 Liquid Fuel Storage

The liquid fuel storage depot for Saint-Louis will be located at the north end of the facilities immediately adjacent to the eastern extremity of the Senegal section. This minimizes the interference of oil transfer operations with the general cargo activities. The unloading of petroleum products may impose restrictions, for safety reasons, on the activities at neighbouring berths relative to deep sea arrivals of general cargo vessels. However, arrivals of tankers will be extremely infrequent and such restrictions are not considered important. The river barges will be loaded at a separate wharf as shown on the plans. This operation is not expected to impose any restrictions on the general cargo movements.

The overall volumes of liquid fuel products to be handled at each location are as given in the United Nations report, "Rapport Technico-Economique sur le Développement des Transports sur le Fleuve Sénégal", Oct. 1969. The forecasted requirements for the 1975 calendar year are as follows:

Quantities in metric tons

	Senegal	Mauritania	Mali	Total
Saint-Louis	6,000	12,000	29,000	47,000
Kayes	-	-	29,000	29,000

Data is not available relative to forecasted 1975 volumes of specific fuels. However, in order to approximate these requirements, reference has been made by the C Contractor to data as contained in the referenced report to 1967 conditions and to the "Annuaire Statistique du Mali" of 1969. While the available data in these reports is sparse, the outcome of the study is believed to be sufficiently realistic to permit representative layouts to be made relative to approximate tank farm requirements and corresponding cost estimates. The resulting general arrangements shown on the plans attached to this Phase III report make provision for the following petroleum products which are required to be transported annually on the river:

Annual quantity in metric tons required for

Product	Senegal	Mauritania	Mali	Total
Gasoline	4,700	6,600	11,600	22,900
Gas oil	480	2,000	6,600	9,080
Petroleum	235	975	3,200	4,410
Carburéacteur	195	810	2,610	3,615
Diesel	170	700	2,320	3,190
Miscellaneous	-	-	2,610	2,610
Totals	5,780	11,085	28,940	45,805

In selecting the sizes and number of tanks, several assumptions were made, the most important of which are the following:

1. Components will be segregated by country of destination.

2. Components will not be segregated by particular oil companies.

3. There will be no transshipment facilities between storage on the wharf and railroad at Saint-Louis.

4. Components for which the demand is relatively small will be shipped in drums.

5. None of the stored products require heating.

Tankage facilities at Saint-Louis have been proportioned to store 50% of the annual tonnage to be transported on the river plus 10%. Tank storage has been provided for all products for each country with the exception of petroleum, carburéacteur and diesel products for Senegal where drum storage is considered to be more compatible with the small quantities required. Selected tank diameters at Saint-Louis are as follows:

For Senegal	For Mauritania	For Mali
1 - 18 m	1 - 21 m	2 - 21 m
1 - 9 m	1 - 15 m	1 - 18 m
1 - 6 m	1 - 11 m	2 - 15 m
	2 - 9 m	

Tank heights vary, but none would be higher than 15 m. The tanks will be laid out in rectangular plots, each plot being surrounded by a 3 m high dike. Piping from the dock face will be provided as shown on drawing number 18. It is assumed that the seagoing ships will have pumps capable of off-loading their product. It is intended that filling of the barges will be done by gravity flow, although a pump will be provided to handle the loading when tank levels are low, and to circulate, transfer or flush lines.

It is not considered necessary with the traffic volume envisaged to provide automatic read-out instrumentation nor remote operation of valves. All operations in the tankage area will be carried out manually. No metering facilities are provided, inventory control being by tank levels.

It is foreseen that water for fire fighting will be available from the river and that fire fighting vehicles will be able to take suction from the water source. Accordingly, no fire fighting system is included.

Rain water from the tank areas will be drained off to the river on a controlled basis and water contaminated with oil will be passed through an API separator to reduce oil content to 15 ppm in the return to the river. The oil skimmed off can be removed to a suitable disposal area either manually or by vacuum.

3.4 Revised Layout of Port Facilities

The Saint-Louis port facilities as recommended in Report No. 1 have been revised during Phase III studies to incorporate facilities to handle liquid petroleum products for transshipment to Kayes. Provision of a separate storage facility for liquid fuel, together with the assumption that such fluids will be transported as bulk cargo, gives rise to several modifications of the layout of the estuary port facilities. The elimination of these products from the general cargo section of the port produces changes relative to the number of berths and to the area requirements for open storage.

It would obviously be preferable to locate the liquid fuel storage at a site which is completely isolated from the other port facilities at a certain distance from the town. However, such a site with deep water close to the coast and favourable soil conditions only appears to exist on the estuary coast of the Langue de Barbarie.

Since the Langue de Barbarie north of the new entry to the estuary is intended to be used for tourist development, it does not appear appropriate to locate the liquid fuel storage in this region.

The east coast of the estuary has soil conditions and water depths which are much less favourable than on the western coast. Consequently, it is not economically feasible to develop independent facilities for petroleum product storage completely separated from the other port facilities in this general location on the eastern shore of the estuary. On the other hand, provision of a separate berth for ocean tankers may be avoided by locating the storage in the immediate vicinity of the general cargo port facilities, since the ocean berth of the Mauritanian port sector may be used as for this purpose. The occupancy rate of this berth is very low, about 15%, so this berth may be used by ocean tankers without causing any inconvenience to the general cargo traffic for Mauritania.

The utilization of the Mauritanian port sector for unloading ocean tankers leads to the concept of locating the storage facility at the northern end of the port. The most economical and most advantageous solution would then be to place the tank farm at the northeastern section of the area reclaimed for the port as shown on Plan No. 17. In this case, a berth for fuel barges may be provided on the north side of the tank farm area.

This solution does not compromise the expansion possibilities of the estuary port facilities, neither towards the north nor towards the south. The layout also provides sufficient distances from the fuel storage facilities to the other port facilities, to avoid any significant interference with normal port operations.

Provision of liquid fuel storage combined with handling of liquid fuel as bulk cargo permit a reduction in the number of berths and of open storage area while the closed storage area required remains unchanged. Thus, the number of berths required for the Mali sector of the port may be reduced from 5 to 4 without any appreciable increase in the berth utilization rate. Similarly, the open storage area required is reduced by about 25%.

On the basis of these considerations, a revised version of the estuary port alternative T2/F2 has been prepared. This revised layout has been shown on plan No. 17 to a scale of 1 to 10,000 and on plan No. 18 to a scale of 1 to 2,000. The latter plan also shows a barge repair facility modified according to the principles used for the corresponding facility at Kayes. The repair facility at Saint-Louis has been designed for a total of 15 barges which should be sufficient if a corresponding facility is provided at Kayes.

3.5 Cost Estimates

The modifications to the Estuary Harbour Alternative T2/F2 as carried out during Phase III studies have resulted in corresponding changes in the construction cost estimates. Revisions to Report No. 1 estimates for Saint-Louis Harbour pertain to:

1. Deletion of one deep draft berth.

2. Reduction of open storage requirements.

3. Addition of fuel berth.

4. Addition of tank farm.

5. Increase in quantity of dredging and corresponding fill quantities. This results from the addition of a fuel loading berth and corrections made to previous calculations.

As with Report No. 1, the estimated unit prices shown are intended to cover construction costs only and do not make any allowance for additional costs of contingencies, engineering and supervision of construction. Provision for these additional costs has been made by adding 20% to the sum total of the construction costs. Financing costs have not been included in these estimates. Costs are estimated at 1971 level.

Cost estimates for the entrance channel and associated protective works remain unchanged from the amounts as presented in Report No. 1 - Preliminary Projects.

Detailed cost estimates are given at the end of this Section 3. A summary of the estimates is as follows:

Estuary Harbour T2/F2	Cost in millions of U.S. dollars
New River Entrance:	7.20
Transshipment Harbour T2:	14.00
Fishing Harbour F2:	3.40
Barge Repair Facility B2:	1.80
Total estimated cost	26.40
Possible rail connection	0.30

SAINT-LOUIS

NEW RIVER ENTRANCE

CONSTRUCTION COST ESTIMATE

Item	Subject	Unit	Quantity	Price/ Unit $	Costs $ Millions Sub-total	Total
1.	Entrance channel					
1.1	Dredging. Outer part of channel, Langue de Barbarie, and a portion in the estuary	m^3	1,950,000	0.60	1.17	
1.2	Dredging in the estuary south of grid line 68,000	m^3	250,000	1.00	0.25	
1.3	Slope protection. Filter layer	m^3	17,000	12.00	0.20	
1.4	Slope protection. Armour layer	m^3	50,000	17.00	0.85	
					2.47	2.47
2.	North breakwater					
2.1	Timber bridge with rails and equipment	m	800	670.00	0.54	
2.2	Chalk for bottom protection and core	m^3	96,000	12.00	1.15	
2.3	Basalt for armour layer and core	m^3	60,000	17.00	1.02	
					2.71	2.71

Item	Subject	Unit	Quantity	Price/ Unit $	Costs $ Millions Sub-Total	Total
3.	Southern breakwater					
3.1	Timber bridge with rails and equipment				0.18	
3.2	Chalk for bottom protection	m^3	7,500	12.00	0.09	
3.3	Basalt for armour layer and core	m^3	21,500	17.00	0.38	
					0.65	0.65
4.	Road connection	m	2,500	60.00	0.15	0.15
	Total construction costs:					5.98
	Plus approximately 20% for administration and unforeseen costs					1.22
	New river entrance, total					7.20

SAINT-LOUIS

TRANSSHIPMENT HARBOUR T2

CONSTRUCTION COST ESTIMATE

Item	Subject	Unit	Quantity	Price/ Unit $	Costs $ Millions Sub total	Total
1.	Dredging and reclamation					
1.1	Dredging of harbour basin	m^3	1,060,000	1.00	1.06	
1.2	Dredging of soft soil in harbour area	m^3	910,000	1.00	0.91	
1.3	Sand fill in harbour area	m^3	1,492,000	0.60	0.90	
					2.87	2.87
2.	Wharf structures					
2.1	Wharf at depth 9.0 m	m	975	2,600	2.54	
2.2	Wharf at depth 2.0 m	m	810	700.00	0.57	
2.3	Slope protection	m^2	27,000	3.00	0.08	
					3.19	3.19
3.	Pavement, including drainage and lighting					
3.1	Roads, parking, etc.	m^2	82,400	10.00	0.82	
3.2	Access road	m	1,600	150.00	0.24	
					1.06	1.06

Item	Subject	Unit	Quantity	Price Unit $	Costs $ Millions Sub-total	Total
4.	Storage facilities					
4.1	Storage buildings	m^2	26,900	80.00	2.15	
4.2	Open storage	m^2	22,460	10.00	0.23	
					2.38	2.38
5.	Buildings					
	Administration, police, customs, workshops and labour welfare building	m^2	4,000	180.00	0.72	0.72
6.	Water and electricity supply	m	2,000	50.00	0.10	0.10
7.	Tank farm					1.40
	Total construction costs T2					11.72
	Plus approximately 20% for administration and unforeseen costs					2.28
	Transshipment Harbour T2, total					14.00

SAINT-LOUIS

FISHING HARBOUR F2

CONSTRUCTION COST ESTIMATE

Item	Subject	Unit	Quantity	Price/ Unit $	Costs $ Millions Sub-total	Total
1.	Wharves	m	330	1,965.	.649	
2.	Excavation of soft soil	m^3	71,000	1.00	0.071	
3.	Reclamation	m^3	203,000	0.60	0.122	
4.	Pavement on traffic areas	m^2	17,400	10.00	0.174	
					1.016	1.016
5.	Auction building	m^2	1,000	100.00	0.100	
6.	Cold store and freezing plant				1.500	
					1.600	1.600
7.	Water and electric supply				0.200	0.200
	Total construction costs F2:					2.816
	Plus approximately 20% for administration and unforeseen costs					.584
	Fishing harbour F2, total					3.400

SAINT-LOUIS

BARGE REPAIR FACILITY

CONSTRUCTION COST ESTIMATE

Item	Subject	Unit	Quantity	Price/ Unit $	Costs $ Millions Sub-total	Total
1.	Earthwork					
1.1	Dredging soft material	m^3	184,000	1.00	.184	
1.2	Sand fill	m^3	251,000	0.60	.150	
1.3	Cofferdam				.030	
1.4	Slope protection	m^2	8,100	3.00	.024	
					.388	.388
2.	Paving, drainage, lighting					
2.1	Paved surfaces	m^2	27,800	10.00	.280	
2.2	Fence	m	500	15.00	.075	
2.3	Lighting				.047	
					.402	.402
3.	Concrete work	m^3	1,825	170.00	.310	.310
4.	Structural steel					
4.1	Rails	tons	86	400.00	.035	
4.2	Carriages	tons	145	1000.00	.145	

Item	Subject	Unit	Quantity	Price Unit $	Costs $ Millions Sub-Total	Total
4.3	Machinery				.116	
4.4	Cranes	Each	2	20,000.	.040	
					.336	.336
5.	Workshops	Each	2	43,000.	.086	.086
	Total construction costs					1.522
	Plus approximately 20% for administration and unforeseen costs					.278
	Barge repair facility, total					1.800

4. SAINT-LOUIS ENTRANCE CHANNEL

4.1 Salinity Intrusion into the River

The investigations concerning salinity intrusion into the Senegal River executed within the present study are described in Appendix 2 - Volume 2 of Report No. 1.

During the greater part of the rainy season, it has been found that the front of salt water is located well downstream of Saint-Louis. When the river discharge exceeds 500 m^3 per second, the salt water appears to be almost completely swept out of the estuary.

The calculations made to evaluate the conditions obtaining after the construction of a new entrance channel to the estuary indicate that similar conditions would be obtained during the major part of the rainy season, and that the salt water intrusion in this season will take place in the form of a salt water wedge entering the river along the bottom covered by the fresh water of the river discharge.

During the dry season, the salinity intrusion conditions are completely different. According to investigations made prior to the present study, salt water may, under present conditions, penetrate as far as the region of Dagana, located about 200 km from the river mouth. In this case, there is hardly any difference between the salinity at the bottom and at the surface of the river while the salinity decreases gradually from about 33 parts per thousand at the river mouth to zero at the upper end of the intrusion.

During the dry season, the mechanism of intrusion of salt water into the river is obviously not that of a salt water wedge penetrating below the fresh water. In this season, the salt water is transported upstream through a mechanism of longitudinal diffusion generated by the tidal currents and the small river discharge.

Under such conditions, increased tidal action in the river, caused by a reduction of the hydraulic resistance at the river mouth, will result in an increase in the distance of intrusion of the salt water, because an increase in the tidal effects will give rise to stronger currents, and therefore to higher diffusion coefficients.

Under idealized conditions, viz, a constant river discharge, a constant area of the cross section of the river, a horizontal bed and a constant tidal range, it is possible to make an approximate calculation of the intrusion distance L_i of salt water.

One finds: $$L_i = B \times \left(\frac{Do}{\sqrt{B \times U_f}} - 1\right)$$

In this expression, B represents a characteristic distance of the tidal current near the river mouth. This distance is related to the tidal excursion length. D_o is the longitudinal dispersion coefficient at the river mouth, and U_f is the current velocity corresponding to the river discharge in the absence of any tidal effects. Although this expression is derived for ideal conditions, it may provide an evaluation of the relative importance of the different parameters that determine the salinity intrusion. It may be deducted from this expression that the intrusion length is proportional to $P_t^{1.5}$ in which P_t is the tidal prism at the river entrance. If, for instance, the tidal prism is increased by 30%, it follows that the total intrusion length is increased by about 50%.

It is quite possible that the construction of a new entrance to the estuary will result in an increase of 30% of the tidal prism. Thus, we conclude that the salinity intrusion length may be considerably increased as a result of the construction of the new entrance. In principle it is possible to perform an accurate calculation of the intrusion of salt water into the river. Such a calculation must, however, allow for the transitory or non-stationary character of this phenomenon caused by the seasonal variation of the river discharge.

Further, such a calculation requires the knowledge of the hydrography of the entire reach of salinity intrusion as well as continuous measurements of salinity and river discharge during a period of several months. The calculations require utilization of a digital computer. It has not been possible within the present study to carry out such a calculation due to the lack of necessary data and it is also felt that such a calculation would be beyond the scope of the present contract. Therefore, an accurate evaluation of the effects of the new entrance on the salinity intrusion into the river during the dry season has not been made.

The conclusions of these considerations may be summarized as follows:

During the rainy season, the effects of the new entrance upon the salinity intrusion will be small and unimportant. During the dry season, however, the maximum intrusion length may be increased from the 200 km obtaining under present conditions up to about 300 km. It should be kept in mind, however, that on the upper reach of this length, the salinities encountered are small and occur only during short periods of time. The increase in the intrusion of salt water may only be prevented by the construction of a barrier across the river located in the lower reach of the river.

4.2 Water Exchange in the Estuary

After the construction of a new entrance from the ocean to the estuary, the old river mouth will be closed. This will lead to a situation in which the southern part of the estuary will be transformed into a tidal lagoon connected to the ocean only by the new entrance channel. The length of this lagoon will be about 20 km and its width about 1 km. The mean water depth in the lagoon will be about 5 m.

In principle, such conditions are quite normal for this region. When the river mouth, in its periodic movements, has reached its southernmost possible location, a new mouth is formed somewhere on the Langue de Barbarie off the Village of Gandiole. After the formation of the new river mouth, the old mouth is closed and the southern part of the estuary is transformed into a lagoon. We have no knowledge of previous investigations concerning possible adverse effects resulting from an insufficient exchange of water in such lagoons. At any rate, the reports and previous studies to which we have had access have made no mention of such effects.

Approximate calculations on the residence time of the water in the lagoon may be carried out by considering the lagoon as a mono-dimensional basin with a constant water depth and assuming that the water is exchanged exclusively by tidal effects.

On the basis of these assumptions, the following expression for the residence time T expressed as a number of tidal periods is found:

$$T = \left(\frac{1}{\alpha 2} - \frac{1}{2\alpha}\right) \log_e \frac{L}{x}$$

In this expression α represents the ratio between the tidal amplitude and the average water depth. L represents the length of the lagoon and x the distance from the upper end of the lagoon to the point considered.

Application of this expression to the future conditions in the estuary yields a residence time of the water in the lagoon of about 50 days. Furthermore, the expression shows that if the value of α remains unchanged, the mean residence time, that is, the residence time at the half way point of the lagoon, remains the same. Thus it is probable that the mean residence time of the water in the lagoon will be shorter after the construction of the new entrance channel, because the tidal amplitude in the lagoon will be higher under these conditions than it is with a natural river mouth.

Normally a residence time of about 50 days would be considered rather long if there were any important sources of pollution within the lagoon. However, in the present case, important sources of pollution only exist north of the new entrance channel. These sources are therefore not expected to influence the conditions south of the new entrance channel to any significant extent.

It should also be kept in mind that the expression quoted above is based on the assumption that exchange of water is caused only by tidal effects. In reality, other factors will contribute significantly to the rate of exchange of water in the lagoon. In particular, the salinity variations in the estuary will give rise to an important additional water exchange, especially during the transitory periods between the seasons.

It may be concluded from these considerations that it is highly unlikely that the water exchange in the future lagoon will be insufficient and that adverse conditions resulting from pollution will occur. At any rate, the conditions after the construction of the new entrance channel will be more favourable than the conditions in the lagoon formed at the southern part of the estuary after the formation of a new natural river mouth, an occurrence which appears to be imminent in the present situation.

4.3 Hydraulic Model Tests

As mentioned in Report No. 1, hydraulic model tests will be required to study the details of the layout of the new entrance channel to the estuary. These tests must be made with a mobile bed so that sand accumulation and erosion effects in the entrance region will be reproduced in the model. Such a model requires scale distortion, that is, that the vertical scale be made greater than the horizontal scale.

This model will essentially be a model of the coast and of the entrance channel through the Langue de Barbarie. It will reproduce hydraulic and sedimentation phenomena on the coast and in the entrance channel, such as waves, littoral and tidal currents, sand movement, etc. The model will serve for the study of the effects of different layouts of the breakwaters protecting the entrance channel against sedimentation, local erosion effects at the ends of the jetties and in the entrance channel, and the extent of protective measures required against such erosion effects.

The detailed design of the breakwaters also requires the execution of another type of model tests, namely, model tests on a greater scale, to examine the stability of the breakwaters. Such model tests must be made in a model without distortion. The stability of the ends of the breakwaters presents a difficult problem due to the fact that costly measures to provide the required stability cannot be considered because of the necessity of extending the breakwater at short time intervals as discussed in Report No. 1.

These models will not be capable of providing answers to the questions of salinity intrusion into the river and of water exchange in the lagoon formed by the southern part of the estuary. If these questions should have to be studied in hydraulic models, they would require models of different types and different scales. However, these problems may be studied more efficiently and at lesser costs by means of hydraulic calculations based on supplementary field investigations.

5. PORT OF KAYES

5.1 Barge Repair and Construction Facility

The United Nations requested the Contractor to study in Phase III the possibilities of providing facilities for barge repair and construction as well as for liquid fuel storage at Kayes.

The provision of the barge repair facility at Kayes was already considered during Phase I of the study. However, the idea was abandoned at that stage because of the difficulties presented by the considerable variations of water level in the river during the year, which will render traditional solutions impracticable or very costly. Accordingly, a barge repair facility capable of serving the entire fleet of barges was included in the harbour plans at Saint-Louis, where the hydrographic conditions are favourable for the construction of such a facility.

Traditionally, a slipway consists of a gently sloping surface which permits the haulage of vessels out of the water by a relatively small force. One feasible solution would consist of a side-slipping slipway. Such an installation may be constructed with such a steep slope that the slipway may be constructed virtually on the natural slope of the river bank. In this case, the barges placed on the slipway would be aligned parallel to the river current, which would facilitate the manoeuvres at the slipway. This arrangement would provide reliable service and would lend itself to indigenously available maintenance facilities.

Another feasible solution would be that of a 'Synchrolift', which consists of a submersible platform suspended from cables. The platform carrying the vessel is hoisted by means of synchronized electrical winches mounted on fixed platforms. In the present case, the barges would have to be placed on a cradle on wheels placed on the synchrolift platform. The transfer of the vessels from the synchrolift to the repair area of the facility would require provision of a structure connecting the synchrolift to land. The structure would have to be designed as a completely open structure to avoid generation of current effects that would make the manoeuvre of the vessels to the synchrolift impossible or difficult. While it is a feasible solution it is a rather complicated installation which might present difficulties of maintenance when it is placed far from the site of manufacture which is located in the United States.

Either of the two alternatives could fulfill the site requirements. However, we have chosen the side-slipping slipway as being an appropriate solution for the purposes of this study and have indicated such a scheme on the drawings.

The selection of a suitable site for the construction of the slipway is determined, in the first place, by the fact that, at Kayes, the course of the river during the dry season runs close to the right bank of the river, that is, the bank opposite the town. By constructing the slipway on the right bank, it may be utilized even at very low water levels of the river, without involving more than a minimum amount of dredging. This point is very important, since it is highly likely that any artificial depression in the sandy bed of the river would be completely eliminated by sedimentation during the rainy season, so that frequent maintenance dredging operations would be required.

Unfortunately, no topographic or soils investigations have been executed on the right bank of the river. Therefore, the data required for site selection and preparation of layout and cost estimates are not available. Nevertheless, a tentative layout of the proposed ultimate facility has been prepared and is shown on Plans Nos. 20 and 21, so as to provide an idea of the proposed installation and order of magnitude of the construction costs. The plans mentioned show an overall view as well as typical sections.

The proposed installation consists of an inclined part constructed on the sloping river bank and of a horizontal part on the terrain bordering the river. It is provided with five rails. A carriage with a horizontal platform is mounted on the sloping part of the rails. The horizontal platform of the carriage is also provided with five rails, which are flush with the five rails on the horizontal part of the slipway when the carriage is in the uppermost position.

When mounted on the carriage, the barge rests on five transfer beams, each of which is provided with three short transversal hardwood beams upon which the hull of the barge rests directly. The transfer beams are provided with wheels rolling on the rails of the slipway.

Haulage of the carriage on the sloping rails is effected by means of two electric winches of a capacity of 20 tons each. The transfer to the horizontal part of the slipway is carried out by means of two other electric winches also having a capacity of 20 tons each.

The slipway may be utilized equally well for repairing and for construction of vessels. For repairs of a short duration, the barges may remain on the carriage which may be locked in its uppermost position.

The proposed slipway for ultimate development as shown on the plans has the capacity to serve twelve barges at the same time, which corresponds to half of the fleet required for the stage of transport System No. 3, which forms the basis of the present study.

Since the facility lends itself to a phased development, it may prove to be expedient to initially construct the facilities to accommodate a smaller number of barges. Consequently, an estimate has also been prepared for a facility to accommodate only three barges.

5.2 Liquid Fuel Storage

Tankage facilities at Kayes have been proportioned to store 50% of the annual tonnage to be transported on the river. Reference may be made to Section 3.3 of this report for estimated quantities of fuel requirements. Tank storage has been provided for all products except the miscellaneous products which are assumed to be handled in drums.

A logistics study to determine the optimal proportion of storage relative to the volumes to be transported by rail and by barge is beyond the scope of Phase III studies. However the 50% storage capacity is considered to be a reasonable assumption at this stage upon the broad assumption that the amounts of fuel products to be transported by rail would be somewhat reduced during the river transport period and that this would result in a faster rate of usage from the tanks. When all the fuel becomes depleted some time after the end of the navigation season, all fuel requirements for the remainder of the year would be brought in by rail. Thus the tankage is not proportioned to retain sufficient fuels upon completion of the navigation season to allow a uniform rate of depletion for the remainder of the year.

Tankage to be provide at Kayes consists of three 21 m diameter tanks, two 15 m diameter and another 15 m diameter. These have been laid out to follow the same design criteria that are described for Saint-Louis in Section 3.3, with the exception that at Kayes, facilities for loading railroad and road tankers are provided. The barges would be provided with suitable pumps for unloading their own cargo.

It has been assumed that gasoline in small quantities can be mixed with the other products during flushing operations without contamination. However, at the rail and truck loading racks, separate pumping and loading facilities are provided in order to preclude the possibility of having an objectionable degree of contamination at these loading points.

It is intended that measurement will be by meters to both the rail and road tankers rather than by weigh scale.

5.3 Modified Harbour Layout

The provision of a separate fuel storage facility gives rise to various modifications to the harbour plan for the port of Kayes presented in Report No. 1. Thus, the number of berths required for general cargo may be reduced from four to three. This reduction involves a small increase in the berth utilization rate, but the utilization rate remains lower than the assumed critical value of 80%. Also, the open storage area may be reduced by about 25%.

In report No. 1, it was concluded that the most advantageous layout for the port of Kayes was the harbour alternative K1, Plan No. 12, but located in the region west of the town as indicated on Plan No. 10 for alternative K2.

In alternative K1 the harbour facility was provided in the form of a relatively long and narrow harbour zone, provided with four berths grouped in two separate groups. The closed storage was provided in the form of two closed storage sheds, one at each of the two groups of berths, with the open storage placed between the two storage sheds and at the two ends of the harbour area.

The reduction of the number of berths from four to three gives rise to a slight change in the layout of the general cargo section of the port facility. In this case, it seems more appropriate to arrange the three berths individually and to combine each of them with its own storage shed with an area corresponding to one-third of the total storage area required for this port, and with the open storage located between the storage sheds.
Such a solution would also ensure short transport distances between the storage facilities and the wharves.

With regard to the barge tanker berth and the liquid fuel storage facility, it is preferable to locate these facilities at a certain distance from the other port facilities. This would not only satisfy considerations of security but would also provide good possibilities for future extensions of the various installations.

A solution according to these principles designated as harbour alternative K3 is shown on Plans Nos. 22, scale 1:10,000, and 23, scale 1:2,000. Plan No. 22 is essentially a general location plan which includes possible solutions for the road and rail access to the port, while Plan No. 23 indicates the detailed layout of the proposed port facilities. However, it must be kept in mind that field data relative to topography, hydrography and soil conditions of the site considered, are not available at this moment. Consequently, the layout and the cost estimate prepared for this port should be considered only as an indication of layout principles and order of magnitude of costs.

In comparison with the alternative K2, the separation of the various port facilities has required a relocation of the rail access, by which the access is provided to the west end of the general cargo port section instead of at the east end of the port.

Apart from this, the K3 layout proposed agrees with the principles of harbour alternative K1 modified as described above.

5.4 Cost Estimates

The modifications to the harbour at Kayes as carried out during Phase III studies have resulted in corresponding changes in the construction cost estimates. Revisions to Report No. 1 estimates for Kayes harbour pertain to:

1. Addition of Fuel Loading Berth.

2. Reduction of Open Storage Area.

3. Addition of Tank Farm.

4. Addition of Barge Repair Facility.

Reference is made to Section 3.5 of this report with respect to unit price validity.

The total estimated construction costs of the proposed facilities at Kayes are as follows:

	Cost in millions of U.S. dollars
Kayes Harbour, Alternative K3	5.40
Barge Repair Facility for 12 barges	1.40
Total Estimated Cost	6.80

Detailed cost estimates are given on the following pages.

Note: For an initial barge repair facility for three barges, the estimated cost is $0.7 million U.S. and the total estimated cost of the Kayes Harbour Alternative K3, combined with the barge repair facility for three barges would be $6.1 million U.S.

KAYES

HARBOUR K3

CONSTRUCTION COST ESTIMATE

Item	Subject	Unit	Quantity	Price/ Unit $	Costs $ Millions Sub-total	Total
1.	Dredging and reclamation					
1.1	Dredging	m^3	80,000	2.50	0.20	
1.2	Sand fill	m^3	8,000	3.50	0.03	
					0.23	0.23
2.	Wharf structure					
2.1	Concrete piles	m^3	400	300.00	0.12	
2.2	Beams and slabs, reinforced concrete	m^3	1,600	180.00	0.29	
2.3	Pavement	m^2	7,200	6.00	0.04	
2.4	Fenders, etc.	m	240	300.00	0.07	
					0.52	0.52
3.	Pavement, including drainage and lighting					
3.1	Roads, parking, etc.	m^2	30,000	10.00	0.30	0.30
4.	Storage facilities					
4.1	Warehouses	m^2	15,000	80.00	1.20	
4.2	Open storage	m^2	9,000	10.00	0.09	
					1.29	1.29

Item	Subject	Unit	Quantity	Price/ Unit $	Costs $ Millions Sub-total	Total
5.	Buildings					
5.1	Administration, welfare, garages, etc.	m^2	1,000	180.00	0.18	0.18
6.	Railway					
6.1	Marshalling yard	m	5,000	60.00	0.30	
6.2	Railway tracks in harbour area	m	3,400	85.00	0.29	
					0.59	0.59
7.	Miscellaneous					3.11
7.1	Slope protection	m^2	20,000	3.00	0.06	
7.2	Fence	m	1,500	15.00	0.02	
					0.08	0.08
8.	Fuel loading dock					0.57
9.	Tank farm including piping and machinery					0.70
	Total construction costs:					4.46
	Plus approximately 20% for administration and unforeseen costs					0.94
	Harbour K3, total					5.40

KAYES

BARGE REPAIR FACILITY

CONSTRUCTION COST ESTIMATE

Item	Subject	Unit	Quantity	Price/ Unit $	Costs $ Millions Sub-total	Total
1.	Earthwork					
1.1	Excavation and fill	m^3	26,000	1.60	.042	
1.2	Cofferdam				.020	
1.3	Slope protection	m^2	6,000	4.00	.024	
					.086	.086
2.	Paving, drainage, lighting, etc.					
2.1	Paved surfaces	m^2	23,500	7.00	.165	
2.2	Fence	m	650	20.00	.013	
2.3	Lighting	m^2	23,500	2.00	.047	
					.225	.225
3.	Concrete	m^3	1,825	170.00	.310	.310
4.	Structural steel					
4.1	Rails	tons	86	400.00	.035	
4.2	Carriages				.161	
4.3	Machines				.116	
					.312	.312
5.	Mobile cranes	each	2	20,000.00	.040	.040

Item	Subject	Unit	Quantity	Price/ Unit $	Costs $ Millions Sub-total	Total
6.	Workshops	m^2	600	143.00	.086	.086
7.	Water, electricity, etc.				.075	.075
	Total construction costs					1.134
	Plus approximately 20% for administration and unforeseen costs					.266
	Barge repair facility for 12 barges, total					1.400

Note: For an initial barge repair facility to accommodate three barges, the estimated construction cost is $0.7 million U.S.

APPENDIX A

UNITED NATIONS NATIONS UNIES

POSTAL ADDRESS ·ADRESSE POSTALE UNITED NATIONS, N.Y. 10017
CABLE ADDRESS—ADRESSE TELEGRAPHIQUE UNATIONS NEWYORK

REFERENCE CON 51/71

6 September 1972

Gentlemen,

Subject: Contract CON 51/71
Navigability of Port Studies

Please find attached hereto the following document which is self-explanatory:

Memorandum from Sheila Albuquerque to Mr. H. K. Ward-Smith dated 31 August 1972 with one (1) copy of all attachments.

Please proceed with Phase III of the project and forward your comments at your earliest convenience.

Sincerely yours,

H. K. Ward-Smith
Acting Chief, Contracts Section
Purchase & Transportation Service

cc. Ostenfeld & Jonson

Surveyer, Nenniger & Chenevert Inc.
1550 de Maisonneuve Blvd. West
Montreal 107, Quebec, Canada

A N N E X E

Etude de la Navigabilité et des Ports du fleuve Sénégal

Référence : P and T - CON No 51/71
OTC - REG 86

PHASE III

Etudes demandées au contractant Surveyer, Nenniger & Chênevert Inc.

Port de Saint-Louis

a) Possibilités de construction d'un port au Nord du Pont Faidherbe.

b) Comparaison des coûts totaux de construction des trois alternatives de port proposées pour le Sud du Pont Faidherbe, avec le coût de construction de la nouvelle proposition de port situé au Nord du Pont Faidherbe.

Avantages et inconvénients de chacune des 4 solutions.

c) Quelles que soient les alternatives de ports proposées au Nord et au Sud, il est demandé que la question stockage des hydrocarbures soit étudiée davantage. Il est rappelé que l'ordre de grandeur des prévisions de trafic annuel sur le fleuve est de 47.000 tonnes.

Chenal d'accès au port de Saint-Louis

a) Conséquences de la construction d'un chenal d'accès sur la remontée de l'eau salée dans le fleuve à l'étiage. Importance de cette remontée et remèdes.

b) Dangers de créer un bassin stagnant et malsain entre l'embouchure actuelle du fleuve qui tendra à se fermer et le chenal d'accès nouvellement créé. Recommandations au Gouvernement du Sénégal en ce qui concerne ce bassin.

La construction en laboratoire d'hydraulique d'un modèle réduit du chenal d'accès et du bassin à l'étude est-elle indispensable et quels renseignements complémentaires pourrait-elle apporter?

Port de Kayes

Le port de Kayes ayant été, au cours d'une réunion tenue à Bamako en janvier 1971, officiellement désigné comme port terminus de la navigation fluviale, il est demandé qu'au cours de la phase III le contractant étudie les possibilités d'ajouter au projet K1 proposé dans son rapport No 1 un chantier de réparations et construction de bateaux ainsi qu'une zone d'hydrocarbures (capacité 30.000 tonnes).

Une évaluation du coût de ces additions est à donner.

Pour permettre au Gouvernement du Mali d'éviter certains des problèmes créés par le projet K1 tel qu'il est donné au rapport No 1, il est demandé au contractant de proposer une variante K2, différente de K1.

Résumé des rapports No 1 et final

Il est demandé au contractant de résumer en 10 pages au maximum les points essentiels des études détaillées et des recommandations contenues dans les rapports No 1 et final.

Bien que ce résumé puisse pour des raisons d'économies être inclus dans le rapport final comme prémices à ses conclusions, il serait préférable qu'il fasse l'objet d'une brochure à part, à laquelle une diffusion différente de celle des rapports eux-mêmes pourrait être donnée.

Il est suggéré que le résumé soit présenté en français et en anglais et que son nombre d'exemplaires soit comme pour le rapport final de 30 pour chaque langue.

UNITED NATIONS NATIONS UNIES APPENDIX C

POSTAL ADDRESS—ADRESSE POSTALE UNITED NATIONS, N.Y. 10017
CABLE ADDRESS—ADRESSE TELEGRAPHIQUE UNATIONS NEWYORK

13 October 1972

REFERENCE

Gentlemen,

Subject: Senegal River Navigability and Port Studies
CON 51/71 - Phase III

Pursuant to the meeting held at the New York headquarters at which the following persons were present:

- Mr. Robert Griesbach (Surveyer, Nenniger & Chenevert Inc. Montreal)
- Mr. H. Talbot (Cowiconsult, Denmark)
- Mr. T. Sornsen (Danish Institute of Applied Hydraulics)
- Mr. X. Le Bourgeois (Resources and Transport Division)
- Mr. J. Paradis (Purchase and Transportation Service)
- Miss S. Albuquerque } Office of Technical Cooperation
- Mr. P. Astolfi } Office of Technical Cooperation

This is to confirm that the following points were agreed upon:

1. Phase III of the subject contract is to commence immediately. S.N.C. shall submit an inception report in the French language, in fifteen copies not later than 13 November 1972.

The inception report shall contain the following:

1.1 A summary of report No.1 including a review of the present situation.

1.2 A statement indicating clearly the reasons why the alternative offering the construction of harbour facilities on the shore North of St. Louis, has to be located 18 km North of St. Louis including an approximate cost comparison.

2. S.N.C. shall prepare an extract of chapter 10 "Bridge Considerations" in the French language as a special report (in 25 copies) which should be entitled "PONT FAIDHERBE" with a covering letter summarizing the findings and your conclusions. It was agreed

/ . . .

Surveyer, Nenniger & Chenevert Inc.
1550 De Maisonneuve W.
Montreal 107,
Canada

Att: Mr. R. J. Griesbach

RECEIVED
OCT 16 1972
SURVEYER, NENNIGER & CHENEVERT INC.

UNITED NATIONS NATIONS UNIES

that this "special report" on Pont Faidherbe shall be sent to the United Nations not later than the end of October.

3. A contract amendment will be prepared to show the latest programme of work.

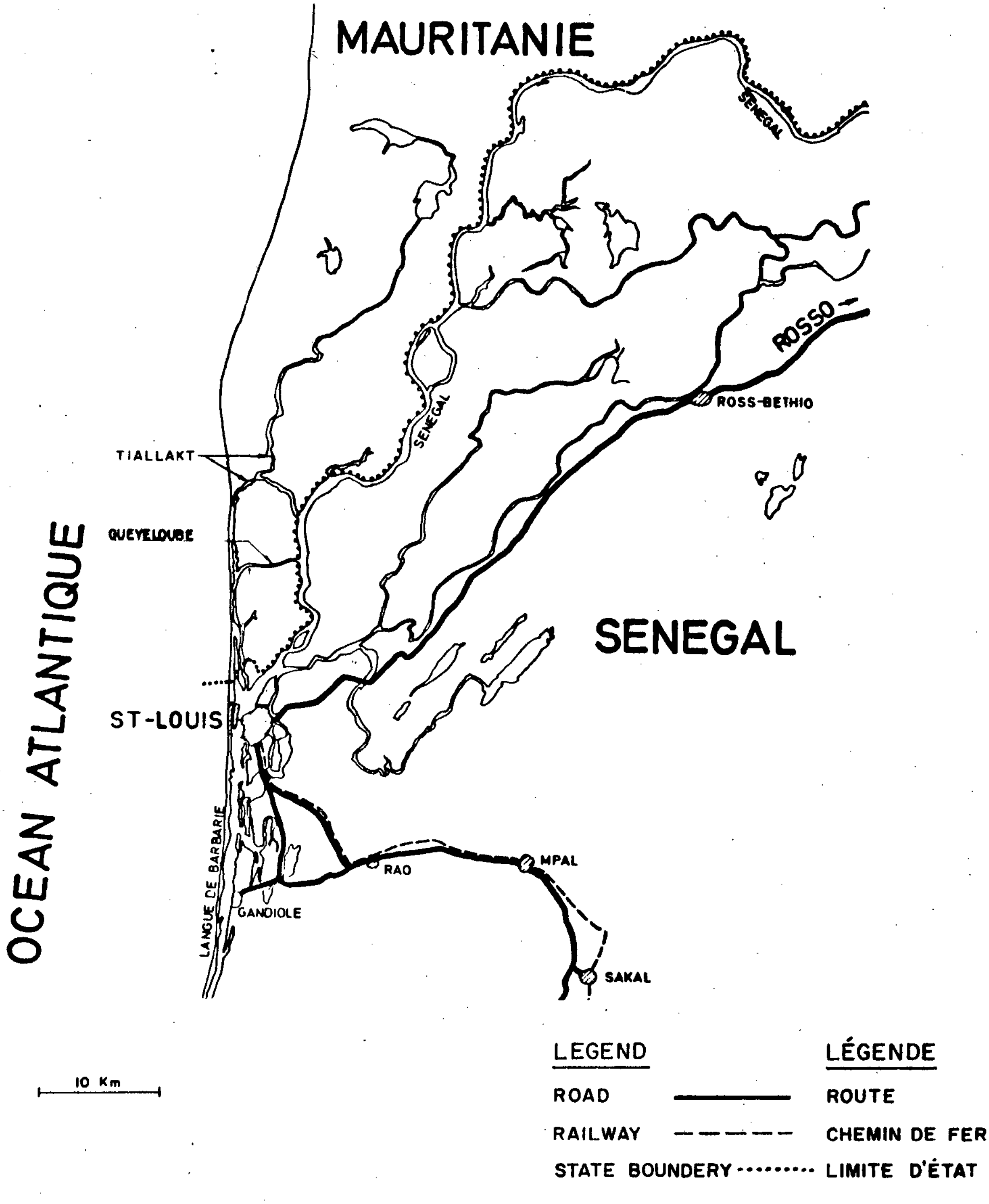
Very truly yours,

H. K. Ward-Smith
Acting Chief, Contracts Section
Purchase & Transportation Service

cc: Cowiconsult
8 Skjoldspade
Copenhagen, Denmark

DRAWING LIST

No.	TITLE
15	Cumulative Distribution of Significant Wave Heights
16	Map of Saint-Louis Area
17	Saint-Louis Estuary Harbour General Plan T2/F2
18	Saint-Louis Estuary Harbour Harbour Layout T2/F2
19	Saint-Louis Estuary Harbour Typical Cross-sections
20	Port of Kayes Barge Repair Facility - Plan
21	Port of Kayes Barge Repair Facility - Section
22	Port of Kayes General Location Plan K3
23	Port of Kayes Harbour Layout K3
24	Port of Kayes Typical Cross-section



UNITED NATIONS ORGANIZATION	ORGANISATION DES NATIONS UNIES
SENEGAL RIVER PORTS AND NAVIGABILITY STUDY PROJECT CON 51/71	ETUDE DE LA NAVIGABILITE ET DES PORTS DU FLEUVE SENEGAL - PROJET CON 51/71
MAP OF ST. LOUIS AREA	CARTE DE LA REGION DE ST-LOUIS

SURVEYER, NENNIGER & CHENEVERT INC. CONSULTANTS - MONTREAL, CANADA
IN ASSOCIATION WITH / EN ASSOCIATION AVEC
CHR. OSTENFELD & W. JØNSON CONSULTING ENGINEERS - COPENHAGEN, DENMARK
DANISH INSTITUTE OF APPLIED HYDRAULICS COPENHAGEN, DENMARK
KNUD E. HANSEN NAVAL ARCHITECTS - COPENHAGEN, DENMARK

DESIGNED BY / ETUDIE PAR
DRAWN BY / DESSINE PAR A.S.
APPROVED BY / APPROUVE PAR
DATE 15.DEC.72
DWG. NO / PLAN NO. 16