PROJECT TECHNICAL REPORT #56

LINING OF EGYPTIAN CANALS
TECHNIQUES AND ECONOMIC ANALYSIS

By:

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April - 1984

Prepared For

The Egypt Water Use and Management Project

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EWUP PROJECT TECHNICAL REPORT NO. 56

Prepared under support of

WATER DISTRIBUTION RESEARCH INSTITUTE, WATER RESEARCH CENTER

MINISTRY OF IRRIGATION, GOVERNMENT OF EGYPT

Contracting agencies

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All reported opinions, conclusions or recommendations are those of the writers and not those of the supporting or contracting agencies.

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ABSTRACT

This report initially reviews the advantages and disadvantages of canal linings, lining materials pertinent to Egyptian conditions, factors affecting lining selection and a description of field trials conducted in Egypt. To estimate lining costs and delineate construction techniques for the various lining materials, three canal sizes were selected for study, with design discharges of 0.035 and 0.700 and 7.000 m^3/sec respectively. A total of 7 lining materials have been considered, with a total of 15 variations of construction techniques. Design and construction costs have been estimated for the three canal sizes and for various lengths of canals until the marginal construction cost approaches its lowest level. Annual maintenance costs have also been estimated for these canal lengths. Potential benefits have also been estimated, though specific benefits require precise evaluation on a site-specific basis.

For the smallest canal size considered, concrete lined bricks, cast-in-place concrete and asphaltic concrete appear to be the three most economically viable methods of lining. For canals carrying approximately 0.700 m^3/sec, cast-in-place concrete, 10 ml buried poly-vinyl chloride and soil-cement are the most advantageous economically. While for the largest canal size considered, soil-cement, 10 or 20 ml poly-vinyl chloride and cast-in-place concrete are the most viable lining methods. It is recommended that if a nation-wide lining program is to be implemented, then cast-in-place concrete linings, using slipform construction techniques be adopted due to their anticipated life span, ease of maintenance and comparative cost advantage.

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مستخلص

يتضمن هذا التقرير مراجعة مبدئية تشتمل على المزايا والعيوب الخاصة بتبطين الترع وعلى المواد المستعملة للتبطين والتي تتلائم مع الظروف البيئية في مصر، وكذلك على العوامل المؤثرة على إختيار طرق التبطين ، كما يحتوى على وصف للتجارب العملية التي تمت في حقل من الحقول المصرية . هذا ولتقدير التكاليف الخاصة بالتبطين وشرح الطرق الفنية للإنشاء والخاصة بمواد التبطين المختلفة ، فقد تم إختيار ثلاثة أحجام مختلفة للترع للدراسة عليها يمر خلالها التصرفات الآتية : ٠٫٢٥ ، ٠٫٧٠٠ ، ٧ م^3 / ثانية على التوالى . هذا وقد تم أخذ ٧ مواد مختلفة للتبطين في الإعتبار مع ممارسة طرق فنية مختلفة للإنشاء عددها ١٥ طريقة . هذا وقد تم حساب وعمل التقديرات اللازمة لتكاليف التصميم والإنشاء للترع الثلاثة المختلفة في الحجم وفي الطول حتى وصلت التكاليف الحدية للإنشاء لأقل ما يمكن . كما تم تقدير تكاليف الصيانة السنوية لهذه الأطوال من الترع . وكذلك تم تقدير العائد المتوقع ، أما بالنسبة لتحديد العائد فهذا يتطلب الحساب الدقيق بالموقع .

وبالنسبة للترع ذات الحجم الصغير ، فقد إتضح أن أحسن الطرق التطبيقية للتبطين والملائمة إقتصاديا هي التبطين بالطوب الخرساني ، والخرسانة المشكلة بالموقع ، والخرسانة الأسفلتية . أما بالنسبة للترع التي يمر بها تقريبا تصرف قيمته ٠٫٧٠٠ م^3 / ثانية فإن الطرق المثلى اقتصاديا هي الخرسانة المشكلة بالموقع والـ ١٠ مللي ليتر كلوريد بولى فينيل المدفون ، والتبطين بالتربة الأسمنتية . أما بالنسبة للترع ذات الحجم الكبير فإن التبطين بالتربة الأسمنتية والـ ١٠ أو الـ ٢٠ مللي ليتر كلوريد بولى فينيل والخرسانة المجهزة بالموقع تعتبر من أفضل الطرق الملائمة للتبطين . ومن ضمن التوصيات في حالة التقدم ببرنامج لتعميم إستعمال مواد التبطين على مستوى الدولة هي طريقة التبطين بالخرسانة المجهزة بالموقع مع استعمال قوالب الإنشاء الفنية الخاصة بها حيث تعتبر من أحسن الطرق من حيث سهولة الصيانة والتحمل وطول العمر والانخفاض النسبي في التكاليف وذلك بالمقارنة للطرق الأخرى .

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ACKNOWLEDGEMENTS

According to the request of the Ministerial Commission For Production (August 4, 1980), a special committee was formed to study the feasibility and viability of canal lining and manufacture of the necessary material required for this purpose.

The committee consisted of H. E. Minister of State for Agriculture, H. E. Minister of State for Food Security, H. E. Minister of Irrigation and of State for Sudan Affiars and H. E. Minister of Industry and Mineral Wealth.

A Branch Committee was also composed consisting of representatives of the above-mentioned ministeries and was chaired by Dr. Hassan Wahby, Director of the Water Distribution and Irrigation Systems Institute.

The members of the Committee were:

Dr. Elhamy Riad	Technical Director of the Chemical Industries Sector, Ministry of Industry
Dr. Eng. Hakim Wanis Tawdros	Director of the Water Duty Department, Soil Research Institute
Dr. Osman Abu Zeid	Center for Development of Plastic Industries
Dr. Eng. Abdel Hamid M. Youssef	SIGWART Company
Eng. Nasrat Gayed Ghobrial	Medicinal Packing Company
Eng. Mohamed Abdel Rehim Abu Harga	General Industrialization Authority
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Of great assistance and contribution to the work of the Committee were Eng. Abdel Hamid Fahim, at that time Sub-Director of the Water Distribution and Irrigation Systems Institute and Mr. Gamal Ayad, Senior Economist.

The authors also wish to express their sincere thanks and appreciation for the contributions made to this paper by the staff of the Egypt Water Use and Management Project. Mr. David Martella was especially helpful in directing the course of the study and assiting in the economic evaluation as was Mr. Farouk Abdel Al who contributed significantly to the review of the report. For their assistance and direction in the field, special thanks are offered to the field teams at Mansuriya, Kafr el-Sheikh and El Minya.

LINING OF EGYPTIAN CANALS
TECHNIQUES AND ECONOMIC ANALYSIS

1.00 Introduction

Canal lining is, in general, a relatively high cost channel improvement technique and justification for a particular lining installation is a complicated procedure when considering the upgrading of an existing system. In many instances, the required information and data on which to base a decision may be insufficient or incomplete and potential benefits are difficult to predict quantitatively in many instances. Estimated design, construction and maintenance costs on the other hand may be predicted with a far higher degree of accuracy and confidence.

The objectives and advantages of irrigation canal lining may be numerous, and a summary of potential benefits follows:

1. Water Conservation

   Minimization of seepage losses.

   Minimization of evaporation losses through a reduction of canal top width.

   An increase in the distribution velocities allowing shorter application times and an overall increase in the systems efficiency.

2. Land Conservation

   A saving in land area due to the reduction of the canal cross sectional area.

   Reduction of adjacent land damage caused by canal seepage.

3. Reduction of operation and maintenance costs.
4. General stabilization of the canal side slopes (internal and external) and an increase in the overall structural safety of the system.
5. A reduction in weed growth within the canals.
6. Assist in the control of water quality.
7. A reduction in associated health problems
8. A reduction in construction costs within new projects.

Egypt has developed one of the most complex irrigation systems on earth, with approximately 30,000 km of government controlled canals. Situated on the alluvial Delta of the Nile River and the overbank flood plain areas upstream of the Delta, the soils are predominantly fine silts and in many instances, contain a high percentage of fine clays. Seepage losses ranging from 5 to 13% for the main canals and up to 20% for the distributary canals have been reported in alluvial soils. (Reference 1).

Many previous studies have been conducted on the Nile River irrigation system and a great deal of background material from previous EWUP studies has been used in compiling this report. Field research programs have been established to evaluate the performance of various canal lining materials on marwas and small distribution canals. With the primary objectives of water conservation and full implemenation of the available supply, canal lining field research has been conducted by the Water Distribution and Irrigation Systems Institute with the collaboration of the Egypt Water Use and Management Project in the El Mansuriya area.

The advantages and disadvantages of canal linings, a review of pertinent lining types, factors affecting lining selection and a description of field trials conducted in Egypt are reveiwed following. Research work is currently continuing on irrigation canal linings in conjunction with elevated channels and buried pipelines as means of controlling seepage within the Egyptian irrigation system. Field evaluation will continue for some of the different types of lining to assess the effectiveness and construction and economic viability of locally manufactured lining materials.

The following report considers the estimated costs and potential benefits of various types of irrigation canal lining materials for three representative canal sizes applicable to existing Egyptian field conditions. Design, construction and maintenance costs have been estimated from data supplied from both the public and private sectors. For each canal size, various construction lengths have been considered to determine the length at which the marginal construction cost per unit area approaches zero. These costs have then been used to determine the annual maintenance cost for the respective canal lengths and the total annual costs per unit area. Potential benefits are discussed in Section 7, though economic quantification of these is far more difficult than cost estimation and is far more site specific than construction cost determination.

Within the report, the following basic assumptions have been adopted.

1) Analysis has been conducted for an existing distribution system currently under consideration for future rehabilitation.

2) The design of the upgraded system is conducted by the Government. This will include complete system redesign if necessary, hydraulic design of the new canal, selection of the lining materials, preparation of the plans and specifications and in-field construction supervision.
3) Pre-construction, construction and maintenance are carried out by private contractors, with the contractor supplying all required labor, material and equipment.
4) Equipment costs are based on the initial purchase price of the machine being depreciated over its anticipated life, assuming normal service and maintenance as specified by the manufacturer.
5) Material and equipment are available to the contractor as needed, and within the scope of the specifications.

2.00 Applicable Canal Lining Materials

Following evaluation of all available lining types the following materials were considered the most viable for Egyptian field conditions and the most readily available within the Delta Region.

Concrete:	Cast-in-place:	(reinforced or unreinforced, dependant upon canal size)
	Pre-cast-sections:	(reinforced or unreinforced, dependant upon canal size)
Brickwork:	Cement-mortar lined.	
Stonework:	(Pitching)	
Fiberglass:	Reinforced Plastic:	(sheet or pre-cast sections.)
Membranes:	Exposed:	20 ml Poly-Vinyl Chloride (P.V.C.)*
		36 ml Reinforced P.V.C. (Hypalon®)
		35 ml Butyl Rubber
	Buried:	10 ml P.V.C.
		20 ml P.V.C.
		36 ml Reinforced P.V.C. (Hypalon®)
		35 ml Butyl Rubber

Asphaltic Concrete

Soil Cement (plastic)

* 1 ml = 0.025 mm

A brief description of these materials and their properties follows.

1. Unreinforced Concrete

The compostion of the concrete should be such so to provide a minimum 28 day compressive strength of 220 kg/cm^2. Concrete may be either mixed manually or mechanically on-site or may be in the form of pre-cast sections, the dimensions of which will be dictated by the proposed canal. General specifications for concrete mixes may be found in A.S.A.E. standard A.S.A.E. 5289, and referenced A.S.T.M. standards.

The thickness of unreinforced concrete is normally 5 cm to 8 cm for small cross-sections, and 8 cm to 10 cm for medium to large cross-sections. However, the wall thickness may reach 15 cm in the case of relatively large cross-sections.

This type of lining is designed through the use of the Manning formual for open channels; adopting a roughness coefficient range of from 0.011 to 0.017.

2. Reinforced Concrete

This is generally not used for small to medium sized canals due to the comparatively high initial construction cost.

The quantity of reinforcing normally ranges from 0.1% to 0.4% of the canal longitudinal concrete section, and from 0.1% to 0.2% of the canal concrete cross-section.

For all concrete linings, provision must be made for expansion joints. The span between joints depends on the lining concrete thickness, and general guidelines are as follows:

Thickness in centimeters: from 5 to 6.5; and from 7.5 to 10.
The span in meters: 3, and from 3.5 to 4.5.

In general, the expansion joint spacing is fifty times the concrete thickness, though the span between joints should not exceed 6 meters in order to avoid cracking.

3. Brickwork and Stonework (Pitching)

Kiln fired bricks have been used on small canals in isolated areas throughout the irrigation system. The invert and walls of the canals are normally lined with cement mortar for a thickness of from 1 to 2.5 cm to reduce seepage, and act as a protective layer for the bricks. Stonework has been used extensively in all canal sizes and consists of hand placing of individual stones with cement motar. Both of these lining types are highly labor intensive during construction.

4. Fiberglass Reinforced Plastic

Fiberglass reinforced plastics provide an extremely strong and impermeable lining material and various types of plastics are available that are suitable for reinforcing. The normal fiberglass content is from 5 to 80 %, with specific weights ranging from 1.2 to 2.2, and are capable of withstanding temperatures of from 150 to 400 degrees fahrenheit. Various types of fiberglass reinforced plastics are currently in production in Egypt under joint-venture arrangements with foreign companies and the Sigwart Company.

5. Membrane Lining Materials

a) Polyethylene

Low density polethylene sheets are currently produced in Egypt with a maximum width of 8 meters, a thickness of 250 microns and a density of 0.92 milligrams/cm^3. This material has a tensile strength of approximately 126 kg/cm^2 and a elongation rate of approximately 500%. Joining of sheets is readily accomplished through the use of heat, adhesive cements or splicing tape. The minimum recommended thickness of this material is 0.02 mm and is the least expensive of all plastic lining materials. However, this material decays rapidly when exposed to the elements and is highly sensitive to ultra-violet radiation. In general, it is not recommended for lining installation under Egyptian conditions.

b) Poly-vinyl Cholride

This material has been used extensively throughout the world for both exposed and buried applications. Poly-vinyl chloride membranes have an approximate density of 1.25 ml gms/cm^3 and a tensile strength of approximately 140 kg/cm^2. The elongation rate is approximately 300% and roll widths up to 19 meters have been produced. The recommended minimum thickness for exposed application is 0.2mm, though exposed application is not normally recommended due to deterioration caused by ultra-violet radiation. Sheets may be joined with heat, contact cement or poly-vinyl dissolvent. Significant increases in strength may be obtained through the use of fiberglass reinforcing, and although the most expensive of the synthetic membranes, this material has an extended life span compared to the plain fabrics. One of the most widely applied materials in this group is the DuPont manufactured "Hypalon" which is normally supplied for irrigation application in 35 ml thickness.

c) Un-reinforced Butyl Rubber

This material has an approximate density of 1.25 ml gms /m ^{3} and approximate tensile strength of 84 kg cm ^{2} , and elongation rate of approximately 300%. Sheet widths up to 14 meters have been used with contact rubber cement used for joining seams. The minimum recommended application thickness is 0.75 mm (0.30 mils). Though far more resistant to ultra-violet radiation than the previous membrane types, butyl rubber is the most expensive of these lining types.

6. <u>Asphaltic Concrete</u>

Asphaltic concrete is a mixtue of fine gravel and sands with asphalt added as a binding agent. Most asphaltic concrete is hot mixed and contains from 6.5 to 9.5 % asphalt. Lining thicknesses range from 5 to 15 cm dependant upon the size of the canal and have a useful working life of from 10 to 20 years, dependent upon location, sub-grade conditions and canal operation. Maximum recommended water velocity is 1.5 m/sec for this lining type.

Pre-cast asphaltic concrete slabs have also been used in some locations, but have not proven as successful as the cast-in-place hot-mix applications.

7. <u>Soil Cement</u>

Soil cement linings consisting of mixing the native material with cement to form, in most cases, a low strength concrete. The cement content is highly dependant upon native soil conditions and ususally requires from 5 to 12 % , with lining thicknesses ranging from 5 to 15 cm. Dependant upon the soil conditions, and the percentages of cement added, the useful life of the lining ranges from 5 to 15 years. As for concrete, expansion joints are required to prevent cracking, and the materials may either be mixed on or off site.

Bentonite may also be used as a lining material using similar mixing techniques as for soil-cement mixtures, with a minimum 20% bentonite used in the mixture. Due to its very short life span (usually one irrigation season), bentonite is not recommended for Egyptian conditions.

A summary of all potential lining types, as prepared by the F.A.O. in 1977 is given following. Various lining types may be applicable to any one situation, and the final lining type selection should be based on all of the following considerations.

1. The main objective of lining.
2. Native soil conditions.
3. Size of the water channel.
4. Groundwater table location and its water quality.
5. Future value of water and land in the area; or the extent of irrigation water scarcity and the value of land.
6. Local availability of construction materials.
7. Availability and conditions of labor, manual or mechanical construction equipment.
8. Availability of means of transport and the state of roads and canal banks.
9. The amount of tangible and non-tangible benefits from lining.

Following sections in this report consider potential annual costs and benefits for the various lining types. In some cases, the initial field evaluation may also dictate that closed conduits also be evaluated prior to the development of a construction decision.

THE FAO REVIEW OF IRRIGATION CANAL LININGS AND THEIR MAIN FEATURES

Type of Lining And Thickness	Durability (service life)	Water Losses ($m^3/m^2/24$ h)	Other Important Features
A. Hard-Surface Linings			
Portland Cement Concrete Reinforced, 5 cm As Above, but 7.6 cm As Above, but 10 cm and Reinforced	Commonly estimated to last 50 years	Below 0.03 if well constructed and maintained, but values up to 0.15 have been measured	Suitable for all sizes of canals, all topographical, climatical and operational condition; firm sub-soil required; susceptible to swelling clays; availability of aggregates near the job is essential; construction either by hand methods or slipform.
Pneumatically applied mortar Unreinforced, 5 cm	In mild climate and stable subgrade same as concrete (30 years have been reported)	0.03-0.06	As above, but no need for coarse aggregates; special equipment is necessary; generally not economical for large jobs; suitable on sub-grades of weathered rock.
Precast Concrete Blocks, 7 cm	About the same as above if properly maintained	If joints are well sealed, about 0.03 can be achieved	Advantageous where concrete lining is suitable, but remote pre-casting is more economical (lack of aggregates at site, transport facilities for precast material avaialble).

THE FAO REVIEW OF IRRIGATION CANAL LININGS AND THEIR MAIN FEATURES (Continued)

Type of Lining And Thickness	Durability (service life)	Water Losses ($m^3/m^2/24$ h)	Other Important Features
Soil-cement (dry mix), 13 cm Soil-cement (plastic), 7.6cm	Largely dependent on cement content; 23 years have been recorded	0.03-0.06	Although less durable than portland cement concrete, low initial costs make this an economic lining where suitable sandy soils are available from canal excavation or nearby.
Asphaltic Concrete, in place 5 cm Asphaltic concrete, prefabricated slabs, 3.8 cm	Seldom more than 15 to 20 years	About 0.03, but will increase considerably if weed infested	For the in-place type, availability of aggregates at site is essential because of shorter service life, asphaltic concrete does not offer any advantage over cement subgrades (swelling clays); offers better resistance against certain chemical deterioration; susceptible to weed penetration.
Brick and Stone	May be as high as cement concrete if properly constructed and maintained.	Brick with cement plaster; around 0.03. Stone; relatively permeable unless carefully mortared	Labor-intensive methods; availability of construction material at or near the site is essential.

THE FAO REVIEW OF IRRIGATION CANAL LININGS AND THEIR MAIN FEATURES (Continued)

Type of Lining And Thickness	Durability (service life)	Water Losses ($m^3/m^2/24$ h)	Other Important Features
B. Exposed Membranes Asphaltic Materials Polyvinyl (0.19mm; 8mil) Resins	Only a few irrigation seasons	Vary widely depending on weed penetration and other mechanical damage as well as weathering	Suitable only as temporary lining for seepage control.
Synthetic Rubber (1.44 mm; 60 mil)	Not yet known, but not less than 10 years.	Negligible if properly jointed and maintained	Offers permanent seepage control if protected from physical damage but is high in cost.

THE FAO REVIEW OF IRRIGATION CANAL LININGS AND THEIR MAIN FEATURES (Continued)

Type of Lining And Thickness	Durability (service life)	Water Losses ($m^3/m^2/24$ h)	Other Important Features
C. Buried Membranes			Suitability of excavated soil as cover material is important for economic reasons.
Sprayed-in-place asphalt	Depends largely on erosion resistance of cover material, maintenance (weed hazard, beaching, burrowing animals), and operation draw-down); records show a serviceable life of at least 15 years, but rubber membrane is likely to last much longer.	Below 0.06	Heater and spray equipment must move along canal; skilled per-sonnel are required.
Prefabricated asphaltic Membrane		Below 0.08	Easily transported and placed materials, but slippage of cover material casued particularly by drawdowns has sometimes been a problem.
Polyethylene (0.24 mm; 10 mil)		Below 0.06	
Polyvinyl (02.4 mm; 10 mil)		As above	
Synthetic Rubber (0.77 mm; 32 mil)		Below 0.03	
Bentonite Layer (4-5 cm)	Not reported	----------	--
Bentonite Layer (1-3 cm)	Less than 7 years	----------	After 7 years, water losses equal to unlined conditions.

THE FAO REVIEW OF IRRIGATION CANAL LININGS AND THEIR MAIN FEATURES (Continued)

Type of Lining And Thickness	Durability (service life)	Water Losses ($m^3/m^2/24$ h)	Other Important Features
E. Soil Sealants			
Waterbone Bentonite Sodium Carbonate Resinous Polymers, Petroleum, Asphalt Emulsions and other Chemicals sprayed on the sub-grade.	One or Two Irrigation Seasons	May average around 0.30 after treatment but varies widely	Means of temporarily controlling seepage in unlined canals. Sealing effect is high just after treatment but may be reduced to less than half after only one or two irrigation seasons. Because of low cost, repreated treatment may be an economical alternative to more durable types of lining.
F. Flumes and Pipes			
Concrete Flumes	Approx. 50 years	Negligible if joints are well sealed	Realtively independent of soil and topographic conditions; ratio of cost to carrying capacity is high; economical only when value of water is high.
Concrete Pipes (precast, cast in place)	More than 50 years	Negligible if joints are properly sealed	Particularly suitable for areas with irregular or rolling topography and intensive cultivation.
Lay-Flat Tubing	Not yet known	Practically nil	As above.

THE FAO REVIEW OF IRRIGATION CANAL LININGS AND THEIR MAIN FEATURES (Continued)

Type of Lining And Thickness	Durability (service life)	Water Losses ($m^3/m^2/24$ h)	Other Important Features
Sublining of Plastic Sheeting or Sprayed-In-Place Asphalt under Precast Concrete	Determined by service life of concrete lining	Practically water-tight if properly constructed	Very effective in preventing seepage concrete joints and cracks need not be sealed but evenutally filled with some material to protect the underlying membrane.
D. Earth Linings			
Thick compacted (approx. 90 cm thick)	For economy evaluations 20 years have been assumed	Below 0.08 (0.02 has been measured)	Suitable soil from canal excavation or nearby borrow pit area is essential for economy. Freezing-thawing and alternate wetting-drying are hazards to all compacted-earth linings because they loosen the compaction and increase the permeability.
Loosley Placed Earth (loam, clay)	------------	------------	Low initial cost, but with little effectiveness as to seepage control; little advantage against unlined canals; low durability.

Except for the P.V.C. and Reinforced P.V.C. membranes, all of the above materials are readily available in Cairo and prices have been determined locally for the lining materials from the private sector. Costs for membrane materials have been determined from United States suppliers with shipping and customs costs added in.

Estimates of the anticipated structural life of the lining types under Egyptian soil and climatic conditions have been made under the assumption that all annual maintenance requirements are carried out to ensure optimal delivery conditions in the canals. These estimates are given in Tables 12, 13 and 14, for the total annual canal lining and maintenance costs and have been based on the current life expectancies (both observed and estimated) of canals under similar climatic and soil conditions in Egypt, the U.S. and Australia.

Although fiberglass reinforced plastic has not been used extensively for canal linings, with appropriate ultra-violet stabilizers included within the bonding epoxy, a 15 year structural life should be achieved with the recommended preventative maintenance.

2.10 Review of Canal Lining Research in Egypt

The following in-field applications utilized material supplied by the Medicinal Packing Company of Egypt.

1. Farm Trial of the Nubaria West Company for seed production.

   A 240 meter length of canal was lined with 100 micron transparent polyethylene film during 1977. The canal width was 60 cms, with a depth of 50 cms. Prior to installation the sandy based canal had a loss rate of approximately 30 m^3 per hour, which was effectively reduced to zero following lining installation. The lining started to deteriorate due to ultra-violet radiation after about 6 months following installation. However, the lining was completely exposed during this period, and no water was conveyed at all during the peak summer period.

2. Watercourse Lining Trial conducted by the Hydraulic Research Institute, Delta Barrage.

During 1977, a polyethylene membrane, 150 microns thick, 6 meters wide and 20 meters in lenght was placed in a 1 meter deep canal with a bed width of 50 cms. Seepage losses were reduced to zero following installation, but no long term results of the trail are available.

3. Reservoir Lining in the New Valley: El Kharga Experimental Area.

The above surface water reservoir was lined with transparent polyethylene membrane in October 1977. The reservoir is 20 meters long, 15 meters wide, 1 meter in depth and has a capacity of approximately 300 m^3. Using 150 micron thick membrane, with a total weight of approximately 100 kilograms, the installation has proven reasonably successful, though following weed growth at the edges of the reservoir, the use of black membrane was recommended for future use.

4. Watercourse Lining conducted by the Agricultural Development Company.

Approximately 1000 meters of black polyethylene membrane, with a width of 1.5 meters were used for the lining of sandy-soil watercourses. Unfortunately, no data are available regarding performance of the lining.

5. Watercourse Lining in the El Khattara Area, Sharkia Governorate.

A 40 meter length watercourse was lined with black polyethylene membrane. The film was 150 microns thick and 1.6 meters wide. No data are currently available regrading the performance of this lining.

6. Canal Lining in the El Nubaria West Area.

Installed by the General Company for Land Reclamation during February, 1979, this low density black polyethylene membrane had a width of 3.5 meters, a length of 200 meters and a thickness of 150 microns. To stabilize the film against ultra-violet radiation, 2% tinovene was added to the film, and during an inspection in September, 1979, the lining appeared to be operating satisfactorily except for some tears on the bank lining due to insufficient cover.

In general the following results have been achieved from material supplied by the Medicinal Packing Company of Egypt.

1. Polyethylene membrane provides an efficient water saving material when material thicknesses of 200 microns or greater are used.

2. Extensive decay due to ultra-violet radiation has been observed on the field installations where the stabilizer "tinovene" has not been added to the material. However, even with this chemical additive, the estimated life span of polyethylene membrane under Egyptian field conditions is estimated to be comparatively short.

3. The mechanical qualities of the material indicate a high resistance to puncture caused by animals and general field conditions.

4. The material has exhibited acceptable resistance to weed growth when carbon black is added to the transparent film.

During this time period also, the Ministry of Irrigation lined the El Nasr Canal from Kilometer 31.0 to 55.4 using unreinforced, cast-in-place concrete in 1977. Due to the quality of the concrete, the lining of this large canal suffered numerous bank failures, and following this installation, standard concrete specifications were prepared for future linings.

The following field applications have been conducted by the Water Distribution and Irrigation System Institute (W.D.I.S.I.) of the Ministry of Irrigation and the Egypt Water Use and Management Project (E.W.U.P.).

These field trials were carried out on disbributary irrigation canals and small watercourses and no main canal lining has been conducted as yet.

1. Beni Magdul Canal Lining

In 1977, the Water Distribution and Irrigation System Research Institute implemented the lining of Beni Magdul Canal in order to minimize water losses, upgrade irrigation efficiency, lower the groundwater table, reduce the cross-sectional area and evaluate lining economics. The canal was lined with unreinforced cast-in-place plain concrete, with a wall and bed thickness of 8 cms. Expansion joints were placed every 20 meters, while lining joints are at 4.0 meter spans, and backfilled with bentomine.

This lining has been working efficiently since its construction, though the lining requires extensive maintenance due to the concrete quality and ensuring environmental conditions. The following table shows the different features of Beni Magdul Canal Lining.

	Before Lining	After Lining
Canal cross-sections	6.20 m^2	2.75 m^2
Bed Width:		
From km 0.00 to 0.85	3.0 m	1.25
From km 0.85 to 1.90	3.0 m	1.00
From km 1.90 to 2.94	2.0 m	0.75
Side Slope	3:2	1:1
Number of Outlets	24 legal + 37 illegal	25

Total cost of canal lining and change of outlets was L.E. 41,000, for a total length of 3.0 km, and a typical cross-section of the finished lining is shown in Figure 1. The completed lining is shown in photos 1 through 4.

During 1978, some of the mesqas leading from the Beni Magdul Canal were also lined with various materials. These mesqas ranged in length from 200 m to 1.0 km.

1. One mesqa was lined with L shaped pre-cast concrete sections, with a thickness of 8 cm. The total associated lining cost ranged from L.E. 4.00 to L.E. 5.00 per running meter. An adjacent mesqa was also lined with bentonite, but due to environmental and climatic conditions, this lining was unsuccessful. The material costs were approximately L.E. 1.00 per meter, and pre-construction and installation costs were approximately L.E. 3.00 per meter in 1978.

2. Butyl Rubber Lining. The Taurus Rubber Works of Budapest, Hungary, provided gratutiously approximately 200 meters of butyl rubber for evaluation under Egyptian field conditions. This lining was installed in 1981 on Mesqa #4, right hand side, and the pre-construction and installation costs were approximately L.E. 385.00. During an inspection in June 1983, the lining appeared to be in excellent

BENI MAGDUL CANAL CROSS-SECTION AFTER LINING

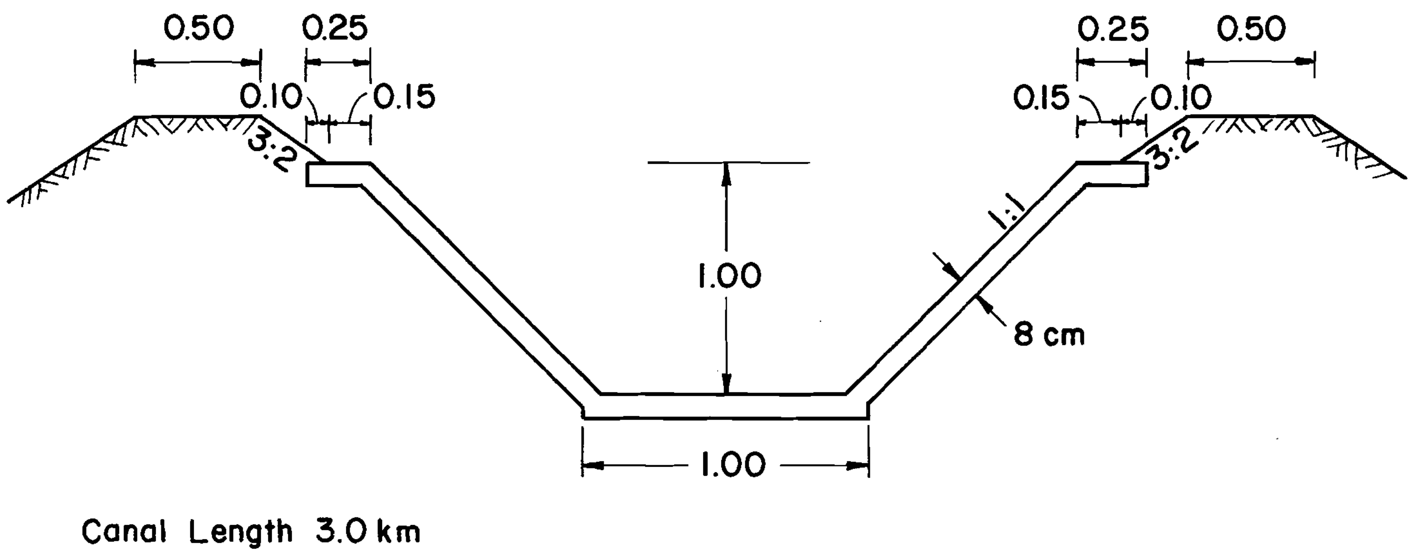


FIGURE 1. Beni Magdul Canal: Typical Finished Cross-Section.

PHOTO 1. BENI MAGDUL CANAL LINING

PHOTO 2 - BENI MAGDUL CANAL LINING

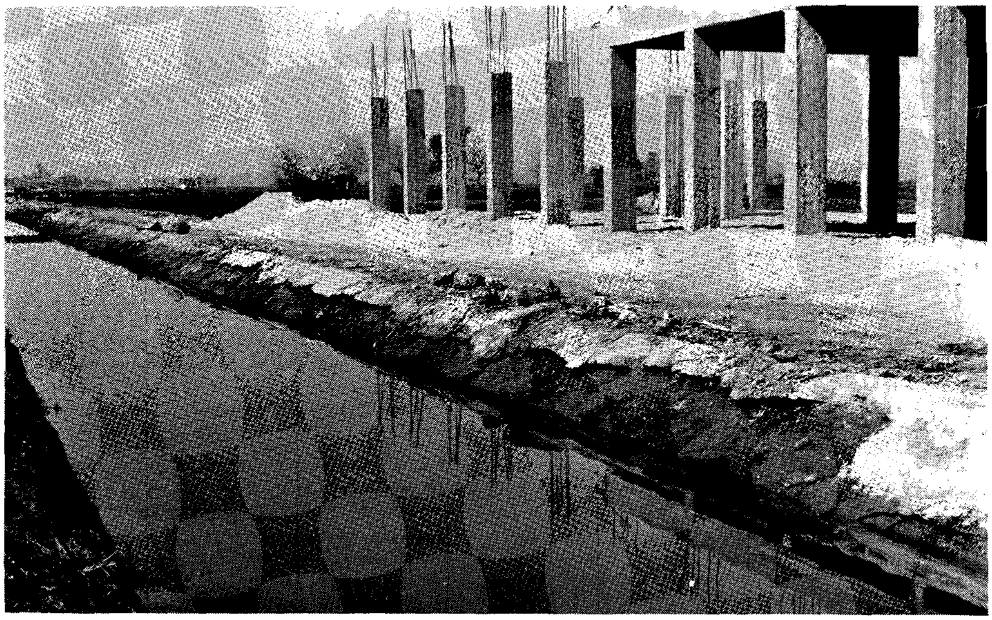


PHOTO 3 - BENI MAGDUL CANAL SHOWING BANK LINING FAILURE CAUSED BY EXTERNAL BANK LOADING.

PHOTO 4 - BENI MAGDUL CANAL LINING

condition, though some weed growth was observed in the bed of the canal. A typical cross-section of this lining installation is given in Figure 2, and a general view given in Photo 5.

3. Membrane and membrane/concrete linings. The Medicinal Packing Company of Egypt provided gratuitously approximately 210 meters of 250 micron polyetheylene film with a width of 2.40 meters. This material contained the tinovene stabilizer and cost approximately L.E. $0.25/m^2$.

Watercourse No. 6 R.H.S. Beni Magdul Canal with a length of 210 m was chosen for testing this plastic membrane. The first 70 m was lined with the polyethylene film without any cover. The second 70 m was lined with the polyethylene film and covered with concrete tiles. The third reach was lined with the film and covered with concrete tiles plus cement morter. Concrete titles were provided by the Sigwart Company and the general tile dimensions are given in Figure 3. The approximate total lining costs for these alternatives were L.E. $1.77/m^2$, L.E. $8.17/m^2$ and L.E. $8.87/m^2$ respectively. During a June 1983 inspection, the exposed polyethylene film had deteriorated extensively and its application was marginally effective. However, the other two lining alternatives appeared to be operating satisfactorily with no major deterioration present. A typical cross-section of these mesqas is given in Figure 4, and applicaton of the concrete tiles over the membrane shown in photos 6 and 7.

Following is a summary of the observations and results of the field trials conducted on the Beni Magdul Canal and associated mesqas.

1. Initial water losses of from 9 to 13% were reduced to 1 to 3 % following lining.
2. On the Beni Magdul Canal, $4500m^2$ of land were reclaimed during reconstruction and converted to cultivation.
3. The groundwater table has been lowered 35 cm during the last 3 years.
4. Land savings have also facilitated the construction of access roads to the farming community.
5. Overall maintenance costs have been reduced compared to pre-lining requirements.

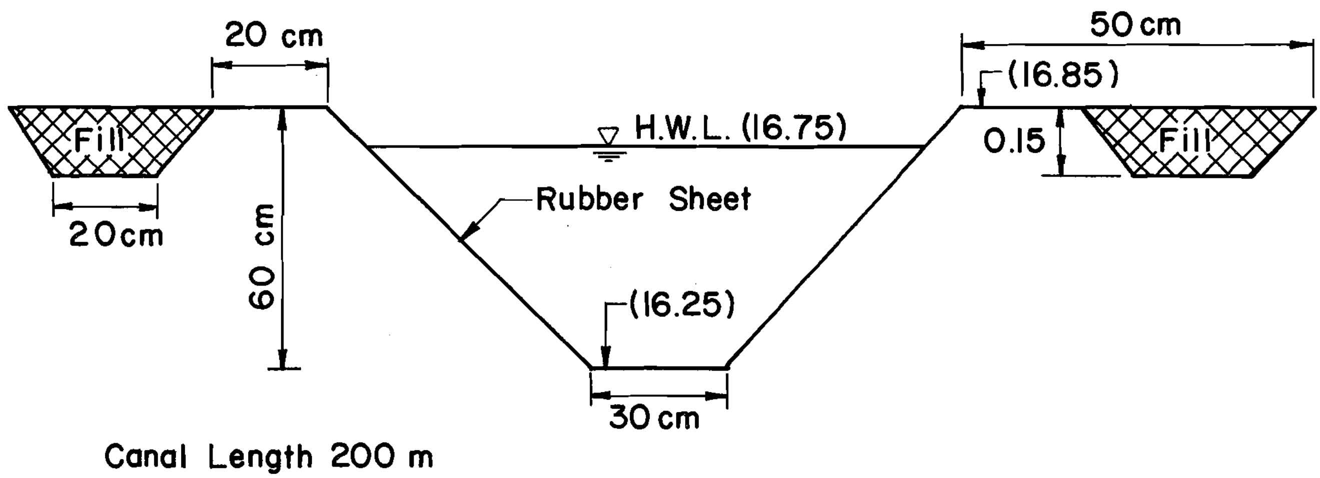


FIGURE 2. Lining Cross-Section With Butyl Rubber Sheets Produced by The Taurus Company, Budapest, Hungary

PHOTO 5- LINING WITH RUBBER SHEETS PRODUCED BY TAURUS RUBBER WORKS COMPANY

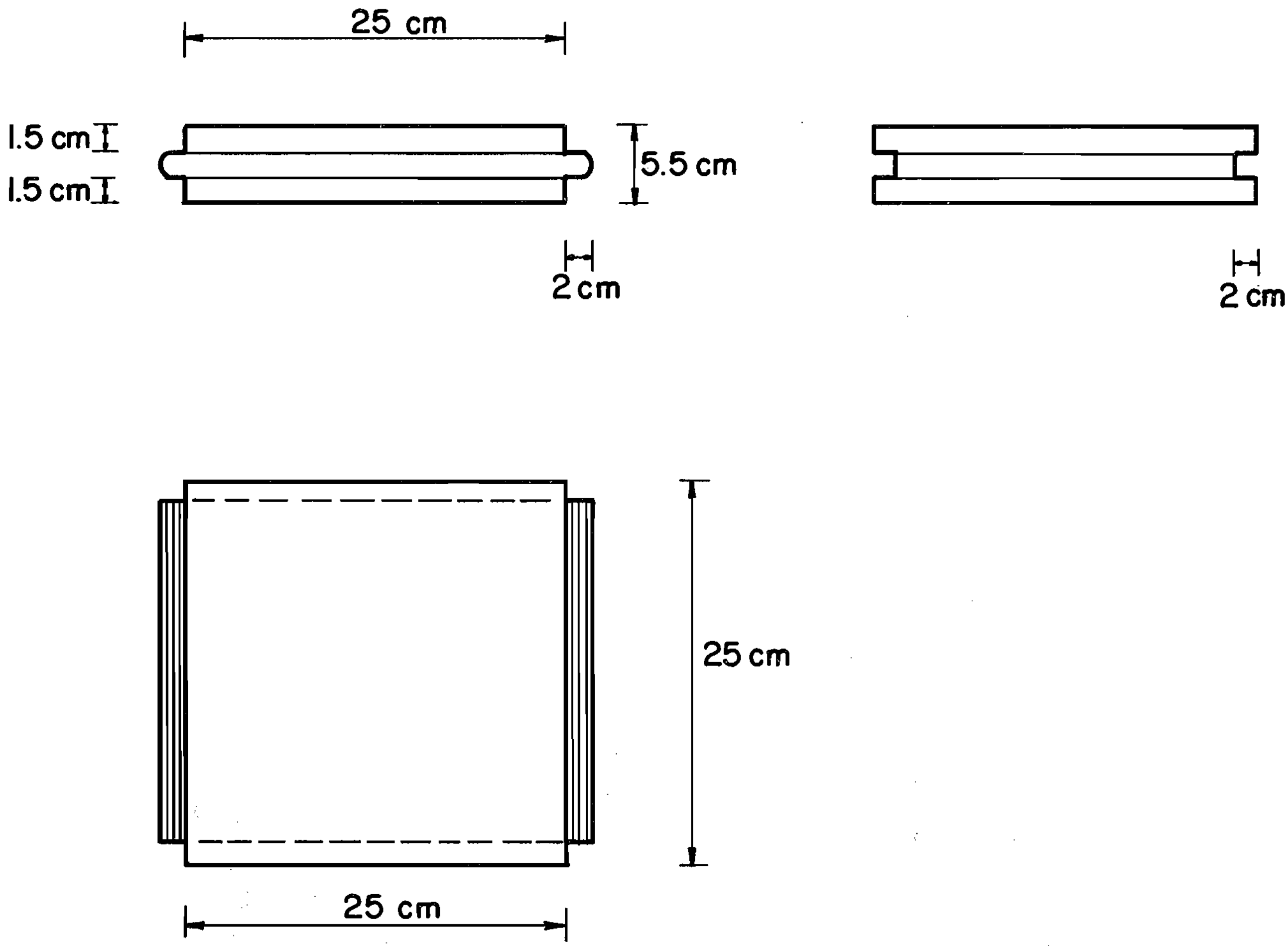


FIGURE 3. SIGWART COMPANY Pre-Cast Concrete Tiles

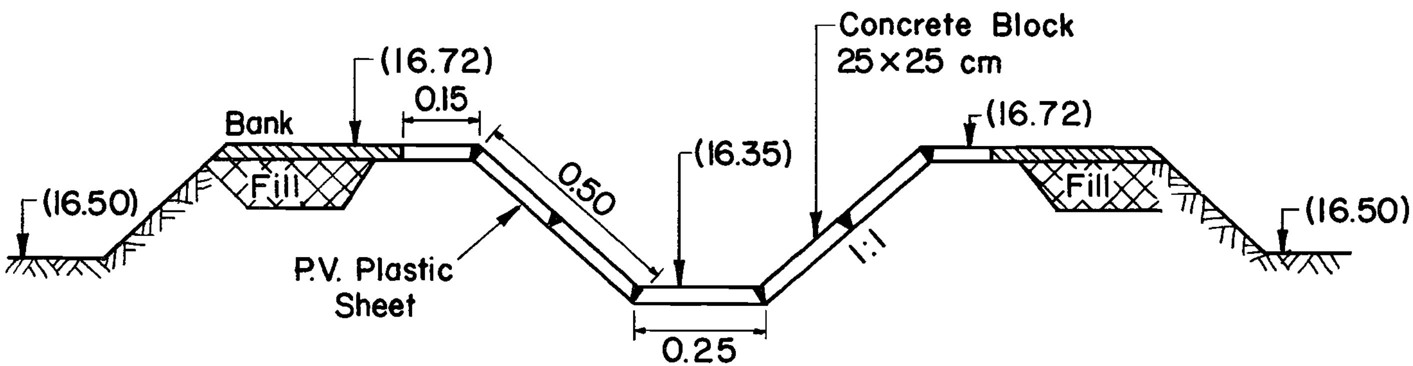
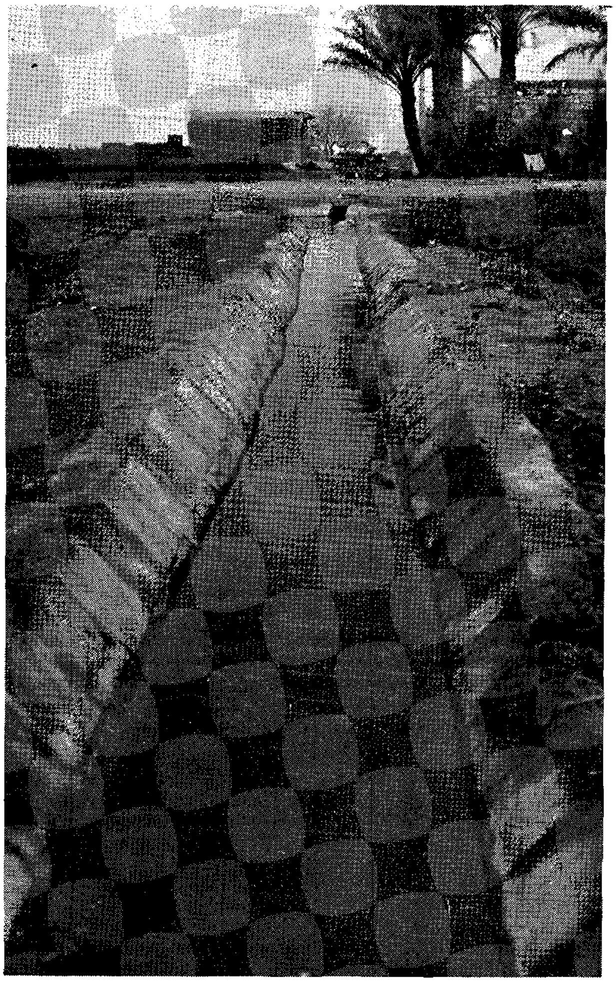


FIGURE 4. Lining With Polyehylene Sheets Covered With Concrete Tiles



PHOTOS 6 & 7 - LINING WITH PLASTIC MEMBRANE (POLYETHYLENE)

AND CONCRETE TILES

6. Other than the quality of the concrete, the canal is structurally sound, though the anticipated life of the concrete is less than 10 years.
7. A significant reduction in weed growth has been observed, allowing faster distribution and application times. Existing weed growth will require minimal maintenance to return the canal to its initial post-construction condition.

2.20 Representative Canal Sizes.

For construction purposes three size ranges have been adopted that are typical of the structural size and discharge carrying requirements of a majority of the canals found in Egypt. The adopted canal sizes are as follows:

Size 1: Structural top width - 0.30 to 1.00 m
Size 2: Structural top width - 1.00 to 3.00 m
Size 3: Structural top width - 3.00 to 10.00 m

Cost analysis for the various lining types is more dependant upon the structural shape and size of the required canal and the consequential construction equipment requirements than the discharge and the associated friction factor values. However, discharge and energy slope values have been determined from field conditions for the three canal sizes and a description of the applicability of the sizes follows.

2.21 Size 1

This size encompasses both typical marwas and small mesqas, with marwas typically running from 20 m to 200 m in length and mesqa lengths varying from 200 m to 3,000 m. While marwas may serve areas ranging from 0.25 to 5.0 feddans, mesqas may serve up to 1,000 feddans. Due to these differences in distribution requirements, a typical marwa design with a discharge capability of 0.035 m^3/sec and a bed slope of 0.0003 m/m has been adopted for cost versus length comparative purposes. An average marwa length of 60 m is typical for the Nile River region and this has been considered as the minimum construction length. Cost analysis was also conducted for 500 m, 1,000 m, 2500 m and 5,000 m construction contract lengths. (Bed slopes have been used in all of the following computations in lieu of energy slopes).

2.22 Size 2

Encompassing medium to large capacity mesqas and small distribution canals, canals of this size are typical in length from approximately 200 to 2,000 m. For cost comparison purposes, a minimum length of construction of 400 m has been adopted, with additional construction contract lengths of 2,000, 5,000, 10,000 and 20,000 m considered. A design discharge of 0.70 m^3/sec and a design bed slope of 0.0003 m/m have been used for all lining types.

2.23 Size 3

This size range encompasses large mesqas to medium sized distribution canals. Typical lengths of individual canals will run from approximately 1,000 to 4,000 m dependant upon the canal type and the area being served. A minimum construction length of 1,000 m has been adopted with incremental lengths of 2,500, 5,000, 10,000 and 20,000 m considered in the cost estimating. A design discharge of 7.0m^3/sec, with a bed slope of 0.0001 m/m have been used for all lining types. Table 1 following summarizes the initial design parameters for the three adopted canal sizes.

TABLE 1 - SUMMARY OF CANAL SIZES

Size	Structural Top Width (m)	Minimum Construction Length (m)	Design Discharge (m^3/sec)	Bed Slope (m/m)
1	0.30 to 1.00	60	0.035	0.0003
2	1.00 to 3.00	400	0.700	0.0003
3	3.00 to 10.00	1000	7.000	0.0001

2.30 Adopted Canal Sections and Hydraulic Design

A hydraulically optimal trapezoidal canal shape has been adopted for all lining types except for concrete lined brickwork for sizes 1 and 2 where a rectangular channel has been adopted. Using Manning's equation, the hydraulically optimal bed width/water depth ratio ($\frac{B}{D}$) was computed for each canal lining type and size given the following input parameters; side slope (Z); bed slope (S); discharge (Q); Manning's friction factor (n) and for buried linings the required cover depth (c) and the anchor trench lining depth and width (t). Using an HP-34C calculator, a program was developed to solve the following two basic equations.

$$K = \frac{Qn}{S^{1/2}} = \frac{[BD + ZD^2]^{5/3}}{[B + 2D(1 + Z^2)^{1/2}]^{2/3}} \qquad (1)$$

$$B = 2D\,[1 + Z^2]^{1/2} - 2ZD \qquad (2)$$

These two equations give the solutions for B and D and the following equations used to solve for wetted cross-sectional area (A), wetted perimeter (P), average velocity (V), wetted top width (W) and buried membrane lining width (P').

$$A = BD + ZD^2 \qquad (3)$$

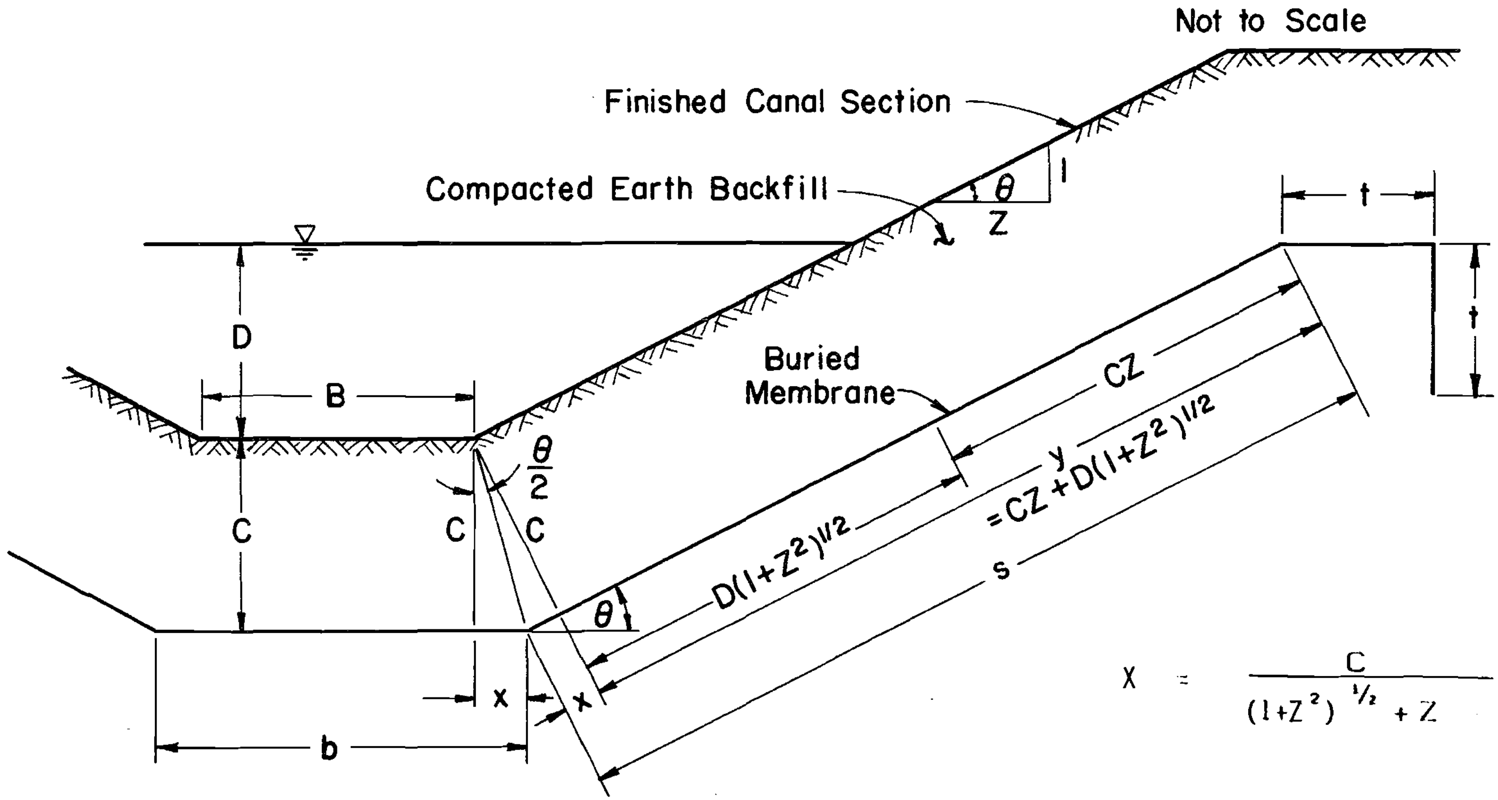
$$P = B + ZD(1 + Z^2)^{1/2} \qquad (4)$$

$$V = \frac{Q}{A} \qquad (5)$$

$$W = B + 2ZD \qquad (6)$$

$$P' = 2\,[cZ + D(1 + Z^2)^{1/2}] + 4\,[c(1 + Z^2)^{1/2} + z)^{-1} + t] + B \qquad (7)$$

Figure 5 gives the definition sketch of equation 7 for buried membrane linings. Table 2 following gives the maximum recommended Z values for the predominantly heavy soil conditions throughout the Nile Basin in conjunction with the adopted general side slope values.



$$X = \frac{C}{(1+Z^2)^{1/2} + Z} \qquad (8)$$

where:

P'	=	Lining width (m)
C	=	Cover depth (m)
Z	=	Horizontal to vertical side slope ratio
D	=	Water Depth (m)
B	=	Canal bed width (m)
b	=	Plastic bed width (m)
t	=	Trench depth and width (m)

FIGURE 5. Lining Width For Buried Lining

TABLE 2

MAXIMUM AND ADOPTED CANAL SIDE SLOPES

Lining Type		Maximum Side Slopes	Adopted Side Slopes
Concrete:	Cast in place	Vertical	1:1
	Pre-cast sections	Vertical	1:1
	Pre-cast slabs	1:1	1:1
Bricks:	Concrete Lined	Vertical	Vertical*
Stonework:		1:1	1.5:1
Fiberglass Reinforced Plastic		Vertical	1:1
Membranes:	Exposed	1:1	1.5:1
	Buried	1:1	2:1
Asphaltic Concrete:		1:1	1.5:1
Soil Cement:		1:1	2:1

*For size 3 canals, a 1:1 side slope was adopted.

For the respective design discharges and slopes, Tables 3 through 5 tabulate the input and output design parameters for the three canal sizes. Of these parameters, the wetted perimeter (P) and the buried lining width (P') are the two most significant for construction cost estimating as they determine the quantities of materials required and type of equipment necessary for construction.

3.00 Canal Design and Construction Methodology

In estimating the time and material necessary to reconstruct and operate the canals, the overall reconstruction activity has been broken into the following segments:

TABLE 3
SIZE I
HYDRAULIC AND PHYSICAL PROPERTIES

$Q = 0.035 m^3/sec$

$S = 0.0003 m/m$

Lining Type	Input Parameters				Output Parameters						
	z	n	c	t	D	B	A	V	P	W	P'
Concrete: Cast in Place	1	0.015	---	---	0.26	0.22	0.12	0.29	0.94	0.72	---
Pre Cast Sect.	1	0.018	---	---	0.28	0.23	0.14	0.26	1.00	0.78	---
Pre Cast Slabs	1	0.018	---	---	0.28	0.23	0.14	0.26	1.00	0.78	---
Bricks: Concrete Lined	0	0.015	---	---	0.25	0.50	0.12	0.29	1.00	0.50	---
Stonework (Pitching)	1.5	0.025	---	---	0.30	0.18	0.18	0.19	1.24	1.06	---
Fiberglass Reinforced Plastic:	1	0.011	---	---	0.23	0.19	0.10	0.37	0.84	0.65	---
Membranes: Exposed	1.5	0.015	0	0.15	0.25	0.15	0.13	0.28	1.02	0.87	1.62
Buried	2	0.022	0.15	0.15	0.27	0.13	0.17	0.20	1.30	1.18	2.65
Asphaltic Concrete:	1.5	0.016	---	---	0.25	0.15	0.13	0.27	1.05	0.90	---
Soil Cement:	2	0.020	---	---	0.26	0.12	0.16	0.22	1.26	1.14	---

where
Q = maximum design discharge (m^3/sec)
S = bed slope (m/m)
z = horizontal component of side slope
n = Manning's friction factor
c = burial cover depth (m)
t = anchor trench depth and berm width (m)
D = canal depth (m)
B = canal bottom width (m)
A = hydraulic cross sectional area (m^2)
V = average velocity (m/sec)
P = wetted perimeter (m)
W = hydraulic top width (m)
P' = buried lining width (m)

TABLE 4
SIZE 2
HYDRAULIC AND PHYSICAL PROPERTIES

$Q = 0.70 m^3/sec$

$S = 0.0003 m/m$

Lining Type	Input Parameters				Output Parameters						
	z	n	c	t	D	B	A	V	P	W	P'
Concrete: Cast in Place	1	0.015	—	—	0.79	0.65	1.13	0.62	2.88	2.22	—
Pre Cast Sect.	1	0.018	—	—	0.84	0.70	1.30	0.54	3.08	2.38	—
Pre Cast Slabs	1	0.018	—	—	0.84	0.70	1.30	0.54	3.08	2.38	—
Bricks: Concrete Lined	0	0.015	—	—	0.76	1.52	1.16	0.61	3.04	1.52	—
Stonework (Pitching)	1.5	0.025	—	—	0.90	0.55	1.72	0.41	3.80	3.26	—
Fiberglass Reinforced Plastic:	1	0.011	—	—	0.70	0.58	0.90	0.78	2.56	1.98	—
Membranes: Exposed	1.5	0.015	0	0.25	0.75	0.45	1.17	0.60	3.14	2.70	4.14
Buried	2	0.022	0.20	0.30	0.81	0.38	1.62	0.43	4.01	3.63	6.20
Asphaltic Concrete:	1.5	0.016	—	—	0.77	0.46	1.23	0.57	3.22	2.76	—
Soil Cement:	2	0.020	—	—	0.78	0.37	1.51	0.46	3.87	3.50	—

where
Q = maximum design discharge (m^3/sec)
S = bed slope (m/m)
z = horizontal component of side slope
n = Manning's friction factor
c = burial cover depth (m)
t = anchor trench depth and berm width (m)
D = canal depth (m)
B = canal bottom width (m)
A = hydraulic cross sectional area (m^2)
V = average velocity (m/sec)
P = wetted perimeter (m)
W = hydraulic top width (m)
P' = buried lining width (m)

TABLE 5
SIZE 3
HYDRAULIC AND PHYSICAL PROPERTIES

$Q = 7.0 m^3/sec$

$S = 0.0001 m/m$

Lining Type	Input Parameters				Output Parameters						
	z	n	c	t	D	B	A	V	P	W	P'
Concrete: Cast in Place	1	0.015	---	---	2.29	1.90	9.59	0.73	8.38	6.48	---
Pre Cast Sect.	1	0.018	---	---	2.45	2.03	11.00	0.64	8.97	6.94	---
Pre Cast Slabs	1	0.018	---	---	2.45	2.03	11.00	0.64	8.97	6.94	---
Bricks: Concrete Lined	1	0.015	---	---	2.29	1.90	9.59	0.73	8.38	6.48	---
Stonework (Pitching)	1.5	0.025	---	---	2.63	1.59	14.58	0.48	11.08	9.49	---
Fiberglass Reinforced Plastic:	1	0.011	---	---	2.04	1.69	7.60	0.92	7.46	5.77	---
Membranes: Exposed	1.5	0.015	0	0.60	2.17	1.32	9.94	0.70	9.15	7.83	11.55
Buried	2	0.022	0.20	0.60	2.36	1.12	13.79	0.51	11.68	10.56	15.07
Asphaltic Concrete:	1.5	0.016	---	---	2.23	1.35	10.43	0.67	9.37	8.03	---
Soil Cement:	2	0.020	---	---	2.28	1.08	12.84	0.55	11.27	10.19	---

where
- Q = maximum design discharge (m^3/sec)
- S = bed slope (m/m)
- z = horizontal component of side slope
- n = Manning's friction factor
- c = burial cover depth (m)
- t = anchor trench depth and berm width (m)
- D = canal depth (m)
- B = canal bottom width (m)
- A = hydraulic cross sectional area (m^2)
- V = average velocity (m/sec)
- P = wetted perimeter (m)
- W = hydraulic top width (m)
- P' = buried lining width (m)

i) Design
ii) Preconstruction
iii) Canal Construction
iv) Intake Headbox reconstruction

and these individual requirements are discussed in the following sub-sections.

3.10 Design Requirements

Reconstruction of any canal will require an initial survey of the existing canal and possible re-alignment, office design of the new canal given the input parameters, preparation of specifications, distribution of specifications to qualified construction companies, and evaluation of bids. The initial survey requirements will be the same for all lining types, with additional soil analysis and soil-cement ratio testing for soil-cement type linings. Office design requires computation of the canal shape given the discharge and bed slope parameters, and selection of the lining type for the given location and soil conditions. Following selection of the lining type, specifications for material, construction requirements and timing of construction will be prepared by the design engineers. These engineers should also be responsible for evaluation of the completed bids with respect to anticipated finished quality and overall cost.

3.20 Preconstruction Requirements

Preconstruction requires the recutting of the existing canal, dewatering of the canal foundation if necessary, compaction of the canal foundation, replacing and compacting fill and cutting and reshaping of the new canal.

Recutting of the canal requires the excavation of the bed and banks of the existing or re-aligned canal, stockpiling the material on one side and dewatering of the excavation so that optimum soil density can be obtained during re-compaction. The native material in the bed of the canal should be compacted to optimum density prior to the replacement of the excavated material in 10 to 15 cm layers. Upon completion of backfiling, the new canal section is cut in the compacted fill, prefereably using a mechanical canal shaper. As the incremental cuts are made, the new bank material should be compacted using mechanical hand operated tampers for the smaller canals, and sheeps-foot rollers where space permits on the larger canals

Preconstruction also includes removal of the existing headgate and the associated construction of a temporary dam on the upstream distributing canal. Foundations for the new headgate require the same soil preparation as listed above, especially for the larger canals. Following subgrade preparation on the canal, outlet locations should be cut and recompacted.

3.30 Canal Construction

Construction includes the supply and delivery of the selected lining material, installation of the material, construction and filling of expansion joints, joining of the material dependent upon the various section lengths, and construction of the required outlets. Specific material and labor requirements are dependant upon the individual lining types and canal sizes and the respective canal shapes and physical properties are given following for the various lining materials and sizes. Minimum freeboard allowances have been made for each cross-section in determining the structural sizes.

3.31 Concrete: Cast in Place

Size 1: Unreinforced, slip form placed.
Wall thickness: 5 cm,
Joint spacing: 2 m
Cross sectional properties as per Table 3

Size 2: Unreinforced, slip form placed
Wall thickness: 8 cm
Joint spacing: 5 m
Cross sectional properties as per Table 4

Size 3: Reinforced, slip form placed
Wall thickness: 10 cm
Joint spacing: 10 m
Reinforcing: 10 cm x 10 cm x 0.5 cm welded wire fabric; single layer.
Cross sectional properties as per Table 5

3.32 Concrete: Pre-cast Sections

Size 1: Unreinforced, pre-cast in full sections 25 cm in length.
Wall thickness 8 cm
Joint spacing 0.25 m
Cross sectional properties as per Table 3

Size 2: Reinforced, pre-cast in half sections, 25 cm in length
Wall thickness: 6 cm
Joint spacing: 0.25 m
Reinforcing: 5 cm x 5 cm x 0.25 cm welded wire fabric or equivalent; single layer
Cross sectional properties as per Table 4

Size 3: Reinforced, pre-cast in 6 sections, 1 m in length
Wall thickness: 15 cm
Joint spacing: 1 m
Reinforcing: 10 cm x 10 cm x 0.5 cm welded wire fabric or equivalent: single layer.
Cross sectional properties as per Table 5

3.33 Concrete: Pre-cast Slabs

Sizes 1 & 2: Unreinforced, 25 cm x 25 cm x 5.5 cm interlocking slabs.
Cross sectional properties as per Table 3 and 4 respectively.

Size 3: Unreinforced, 25 cm x 25 cm x 10 cm interlocking slabs.
Cross sectional properties as per Table 5.

3.34 Bricks: Concrete Lined

Size 1: Brick size: 25 cm x 12.5 cm x 6 cm
Canal bed: 5 bricks placed on their flat side
Canal walls: bricks placed on edge
Sand-cement lining thickness: 1 cm
Cross sectional properties as per Table 3

Size 2: Brick size: 25 cm x 12.5 cm x 6 cm
Canal bed: 12 bricks placed on their flat
Canal Walls: 3 walls of bricks placed on edge; 6 bricks in the first wall, 5 in the second and 4 in the third.
Sand-cement lining thickness: 1 cm
Cross sectional properties as per Table 4

Size 3: Brick size: 25 cm x 25 cm x 6 cm
Canal bed: 14 bricks placed on their flat
Canal walls: single brick layer placed on their flat. (trapezoidal canal shape)
Cross sectional properties as per Table 5.

3.35 Stonework

Sizes 1, 2 and 3: Rock size: approximately 10 cm x 10 cm x 25 cm
Material: preferably hard sedimentary or igneous type rock. Soft limestones would be unacceptable due to their short life span and high maintenance requirements.
Cross sectional properties as per Tables 3, 4, and 5 respectively.

3.36 Fiberglass Reinforced Plastic

Size 1: F.R.P. size: 5 m x 1 m x 2 mm flat sheets formed with bending grooves for trapezoidal section.
Joint Spacing: 5 m
Overlapping joints bonded with resin.
Cross sectional properties as per Table 4.

Size 2: Pre-molded canal sections
F.R.P. Thickness: 8 mm
Section Lengths: 5 m
Overlapping joints bonded with resin.
Cross sectional properties as per Table 5.

3.37 Membranes: Exposed

Sizes 1, 2 and 3: All material delivered in a 3 m wide roll, with an approximate roll weight of 500 kg.
All lining types anchored in berm trenches.
Overlapping joints bonded with the appropriate cement.
Cross sectional properties as per Tables 3, 4 and 5.

3.38 Membranes: Buried

As for 3.37, with burial depths also given in the appropriate tables

3.39 Asphaltic Concrete

Size 1: Hot mixed off-site, slipform placed.
Wall Thickness: 5 cm
Cross sectional properties as per Table 3

Size 2: Hot mixed off-site; slipform placed.
Wall Thickness: 8 cm
Cross sectional properties as per Table 4.

Size 3: Hot mixed off-site; slipform placed
Wall Thickness: 12 cm
Cross sectional properties as per Table 5

3.39.1 Soil Cement Lining

Size 1: Soil-Cement ratio: 6 bags per m^3
Mixed in-situ, and slipformed to shape.
Wall Thickness: 6 cm
Joint Spacing: 5m
Cross sectional properties as per Table 3.

Size 2: Soil-Cement ratio: 6 bags per m^3
Mixed in-situ, and slipformed to shape.
Wall Thickness: 8 cm
Joint Spacing: 5 m
Cross sectional properties as per Table 4.

Size 3: Soil-Cement ratio: 6 bags per m^3
Mixed in-situ and slipformed to shape
Wall Thickness: 12 cm
Joint Spacing: 10 m
Cross sectional properties as per Table 5.

3.40 Intake Headbox Reconstruction.

For all canal sizes, reconstruction will require the removal of the existing intake structure and reconstruction to accomodate the new canal shape. Following construction of a temporary diversion dam and removal of the old structure the foundations will require dewatering and recompacting. Extensive research has been conducted in Egypt pertaining to the most viable outlet structures and the results of this research has been documented in previous E.W.U.P. reports. For the size 1 canals, it is recommended that intake headboxes be constructed from bricks with cement mortar covering and manually operated sluice gates, or an outlet of the type given in previous E.W.U.P. reports. For the size 2 and 3 canals, the intake headboxes should be constructed of reinforced concrete with mechanically operated sluice gates.

3.50 Example Time and Material Estimation

An example of the estimation techniques adopted for the design and construction methodology is given following for a concrete, cast-in-place size 2 canal. It has been assumed that the construction site is approximately 1 hour travel time from Cairo, and that the smallest reconstruction length is 400 m. Manpower, material and equipment time estimates are given for the construction of 400 and 2000 meters of canal in the example, with the same methods used for the other canal lengths considered. The post scripts (G) and (P) refer to Government and Private personnel respectively with all material and equipment provided by the private sector.

A. Design Time and Equipment Estimates

	400 m	2000m
a. Initial survey and re-alignment		
Engineer (G)	18 hrs.	54 hrs.
Surveyors (G)	18 hrs.	54 hrs.
Technicians (G)	18 hrs.	54 hrs.
Driver (G)	18 hrs.	54 hrs.
Auto	300 km	500 km
b. Office design		
Engineer (G)	12 hrs.	24 hrs.
Technician (G)	12 hrs.	24 hrs.
c. Specification Preparation and Bid Evaluation		
Engineer (G)	36 hrs.	36 hrs.
Technician (G)	18 hrs.	18 hrs.

TOTAL DESIGN ESTIMATES

Engineer (G)	66 hrs.	114 hrs.
Surveyor (G)	18 hrs.	54 hrs.
Technician (G)	48 hrs.	96 hrs.
Accountant (G)	36 hrs.	36 hrs.
Driver (G)	18 hrs.	54 hrs.
Auto	300 km	500 km

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B. Pre-Construction Time and Equipment Estimates.

For 400 meters of canal, the total estimated time for pre-construction is 5 days, with canal recutting requiring 2 days, re-compacting requiring 2 days and 1 day for shaping the new canal. For 2000 meters the total re-construction time will be approximately 20 days.

		400 m	2000m
a. Personnel			
	Engineer (G)	40 hrs.	160 hrs.
	Engineer (P)	40 hrs.	160 hrs.
	Surveyor (P)	40 hrs.	160 hrs.
	Laborers (4) (P)	160 hrs.	160 hrs.
	Drivers (G)	40 hrs.	640 hrs.
b. Equipment			
i.	Small track-type bulldozer with blade and ripper (Cat D6 or equivalent)		
	For recutting canal	16 hrs.	64 hrs.
	For towing roller	16 hrs.	64 hrs.
	For towing shaper	8 hrs.	32 hrs.
ii.	Sheeps-foot roller	16 hrs.	64 hrs,
iii.	Canal Shaper	8 hrs.	32 hrs.
iv.	Dewatering pumps	64 hrs.	256 hrs.
v.	Low-boy for equipment delivery	6 hrs.	6 hrs.
vi.	Auto	200 km	800 km

c. Construction Time, Material and Equipment Estimates.

The wall thickness of the canal is designed as 8 cm and the computed perimeter is 2.88 m. Adopting a finished concrete perimeter of 3.00 m, approximately 100 m^3 of concrete is required for 400 m of canal and 500 m^3 for 2000 m. For 100 m^3, it is recommended that concrete be delivered to the site using self powered concrete mixing trucks, and for 500 m^3 a small batch plant be installed on the site. Aproximately five days will be necessary for pouring and slipforming 400 m of canal, and approximately 20 days for 2000 m.

1. Lining Installation

		400 m	2000 m
a. Personnel			
	Engineer (G)	40 hrs.	160 hrs.
	Engineer (P)	40 hrs.	160 hrs.
	Surveyor (P)	40 hrs.	160 hrs.
	Driver (G)	40 hrs.	160 hrs.
	Laborers (4) (P)	160 hrs.	640 hrs.

b. Material and Equipment

i.	Concrete	100 m^3	500 m^3
ii.	Slipform	40 hrs.	160 hrs.
iii.	Truck-type tractor for towing slipform	40 hrs.	160 hrs.
iv.	8 ton truck: equipment delivery	4 hrs.	4 hrs.
v.	Auto	300 km	500 km

2. Expansion Joints

a. Personnel		
Laborers (P)	8 hrs	32 hrs.
b. Material		
Bitumen	0.20 m^3	1.0m^3

3. Canal Outlets

The canal discharge of 0.70 m^3/sec will serve appproximately 20 marwas each carrying 0.035 m^3/sec simultaneously. Assuming that each outlet serves 2 marwas, then 10 outlet structures will be required per 400 m of canal.

a. Personnel		
Laborers (P)	40 hrs.	160 hrs.
b. Material		
i. Outlet gates	10	50
ii. Concrete included in canal lining installation		

TOTAL PERSONNEL TIME ESTIMATES FOR CONSTRUCTION

Engineer (G)	40 hrs.	160 hrs.
Engineer (P)	40 hrs.	160 hrs.
Surveyor (P)	40 hrs.	160 hrs.
Laborers (P)	208 hrs.	832 hrs.
Driver (G)	40 hrs.	160 hrs.

D. Intake Headbox

The reconstructed intake headbox will require a manually operated screw-type gate, approimately 0.70 m wide and 1 m high. It has been assumed that the maximum length of a canal of this size will be approximately 2,500 m.

a.	Personnel			
		Laborers (P)	64 hrs.	64 hrs.
b.	Material			
	i.	Concrete	$0.6m^3$	$0.6m^3$
	ii.	Gate	1	1

Tabluation of the above estimates are given in Appendix 2, pages A 2-1 and A 2-2, and similar time, material and equipment estimates have been prepared for all canal sizes for all of the various lining types and are tablulated in Appendices 1 through 3.

4.00 Personnel, Equipment and Material Cost Estimation

Cost information has been derived from both the public and private sectors for personnel, and from the private sector for equipment and material. All costs are based on June 1983 prices for the Cairo area.

4.10 Personnel Costs

Public sector personnel costs have been adopted from the September 1980 report entitled, "Technology for Construction and Maintenance of Irrigation and Drainage Works in Egypt: A Preliminary Assessment," by M. H. Amer, Director, Drainage Research Institute, Water Research Center, Ministry of Irrigation, Cairo. The 1979 rates quoted in this report have been inflated at an average annual rate of 10 percent to determine 1983 values, though the figures quoted in the report do not appear to include general and administration overhead rates. As no specific G & A overhead rates were available during compilation of this report, an arbitary overhead rate of 60 percent has been adopted, though this figure in reality, may be far too low. Private sector costs have been determined from personal communication with numerous private contractors in the Cairo area, and hourly rates used include all overheads and profit.

Various classes, and associated salary scales, exist within each professional personnel classification for both the private and public sectors and the following average figures are based on personnel with approximately 5 to 8 years of experience, following completion of tertiary education.

Table 6 following lists the adopted hourly personnel costs for the public and private sectors, with all costs given in Egyptian pounds.

TABLE 6
Average Personnel Costs per Hour
(June 1983 Values)

Classification	Public Sector (L.E./hr)	Private Sector (L.E./hr)
Engineers	1.70	4.00
Surveyors	1.00	2.60
Accountants	1.00	2.60
Laborers	0.70	2.40
Drivers	1.50	1.75
Technicians	1.00	2.60

4.20 Equipment Costs

All equipment cost estimates have been derived from personal communication with private sector construction companies and represent bid price costs including fuel costs, maintenance, depreciation and repair. For equipment requiring operators, the cost of the operator is included in the hourly rental costs of the machine. Table 7 following lists the equipment necessary for the canal siszes considered and their respective hourly rental rates. Cost estimates for canal slipforms and canal shapers have been determined by estimating the design and fabrication costs in Cairo, and distributing these costs over the anticipated equipment life span. However, it is believed that this equipment is currently available in Alexandria.

TABLE 7
Average Equipment Costs Per Hour
(June 1983 Values)

Equipment Type	Cost Per Hour (L.E.)
Track mounted tractors	
Cat D6 or equivalent	60.00
Cat D3 or equivalent	35.00
Lowboy and Prime Mover	10.00

TABLE 7 (continued)
Average Equipment Costs Per Hour
(June 1983 Values)

Equipment Type	Cost Per Hour (L.E.)
Trucks	
4 ton	7.00
8 ton	10.00
Sheeps-foot Roller	
small	4.00
large	8.00
Canal Shaper	
Canal Size 1:	4.00
Canal Size 2:	8.00
Canal Size 3:	16.00
Canal Slipforms:	
Canal Size 1:	4.00
Canal Size 2:	8.00
Canal Size 3 (self-propelled):	60.00
Soil Mixer (discing equip. or equivalent)	5.00
Dewatering Pumps	6.00
Vibrating Compactors (hand-held)	3.00
Mechanical Conveyors	
small	6.00
medium	8.00
Concrete Mixers:	
Stationary 1m^3 capacity	5.00
Self Powered Cranes	
1/2 Ton	10.00
1 Ton	15.00
Front End Loader: 1 m^3 capacity	8.00

4.30 Material Costs

Material costs have been derived from both private contractors and suppliers within Cairo. Figures given reflect ex-Cairo prices, excluding delivery, unless otherwise noted. Membrane costs have been determined from the current United States prices with shipping, import duty and delivery costs added to the F.O.B. price from the U.S. East coast. A summary of these costs are given in Table 8 following.

4.40 Total Construction Cost Estimation

The respective personnel, equipment and material unit costs for the required quantities and for each canal size and lining type were combined with the time and material quantities estimation to compute the total design and construction costs for the various canal lengths. The total estimated costs are given in Appendices 1, 2, and 3 for the three canal sizes. From the total cost computations the costs per running meter and costs per square meter of lining have been computed. Tables 9, 10 and 11 summarize the intital construction costs per square meter for the three canal sizes, and Figures 6 through 11 give the plots of these costs for the various canal lengths considered. Note should be made that the equipment costs are based on prices quoted from private sector contractors under the assumption of normal average annual utilization.

For the smallest canals considered, the incremental cost per unit area for membrane linings reaches its lowest level when canal lengths greater than 500 meters are constructed, while for soil cement and asphaltic concrete this occurs at approximately 1,000 meters. For all concrete canal types and stonework, the marginal cost approaches its lowest level for lengths greater than 2, 500 meters. This length has been used in computing the comparative annualized costs for each lining type.

For the size 2 canals, the lowest marginal construction cost is attained at approximately 5,000 meteres for flexible linings and at approximately 10,000 meters for the rigid boundary linings. Annualized costing for this size has thus been computed for 10,000 meters for all canal lining types. The lowest marginal construction cost for all size 3 canal lining types is attained at approximately 5,000 meters of construction and this length has been used for the following computations.

TABLE 8

UNIT MATERIAL COSTS
June 1983 Values

MATERIAL	UNIT	COST PER UNIT (L.E.)
Concrete		
0 to 5m^3	m^3	50.00
6 to 300m^3	m^3	45.00
301 to 2000m^3	m^3	35.00
>2000m^3	m^3	32.50
Pre-Cast Concrete Sections		
i) Size 1 <240 units	each	3.40
240 to 2,000	"	2.20
2,000 to 4,000	"	2.10
>4,000	"	1.80
ii) Size 2 <4,000 units	each	2.55
4,000 to 10,000	"	2.25
>10,000	"	2.10
Pre-cast Concrete Slabs		
i) Sizes 1 & 2 10,000 units	each	0.45
10,000 to 20,000	"	0.40
20,000	"	0.35
ii) Size 3	each	0.62
Bitumen	m^3	55.00
Bricks <10,000 units	each	0.45
10,000 to 50,000	"	0.40
>50,000	"	0.35
Stonework <50m^3	m^3	12.00
50 to 200	m^3	11.00
>200	m^3	9.00
Fiberglass Reinforced Plastic		
i) Flat sheet <500 m^2	m^2	15.00
500 to 2,000	m^2	9.00
2,000 to 10,000	m^2	6.00
>10,000	m^2	5.00
ii) Molded Sections		
a. 4 mm thick < 500 m^2	m^2	19.25
500 to 2,000	m^2	11.50
2,000 to 10,000	m^2	8.75
> 10,000	m^2	8.25

TABLE 8 (Continued)
UNIT MATERIAL COSTS
June 1983 Values

MATERIAL	UNIT	COST PER UNIT (L.E.)
b. 8 mm thick < 5,000 m^2	m^2	16.00
Fiberglass Cloth or Matt	m^2	1.40
Fiberglass Resin	kg	1.10
Membrane Material (Includes joining solvent)		
10 ml P.V.C	m^2	2.00
20 ml. P.V.C	m^2	3.10
36 ml Reinforced P.V.C	m^2	8.35
35 ml Butyl Rubber	m^2	12.20
Asphaltic Concrete		
< 5 m^3	m^3	25.00
5 to 300	m^3	21.00
300 to 2,000	m^3	18.00
> 2,000	m^3	16.00
Cement		
< 100 kg (bags)	kg	0.08
1,000 to 10,000 (bags)	kg	0.07
> 10,000 (bulk)	kg	0.055
Intake Headbox Gates		
i) Size 1	each	20.00
ii) Size 2	each	100.00
iii) Size 3	each	200.00
Outlet Gates		
i) Size 1	each	20.00
ii) Size 2	each	20.00
iii) Size 3	each	100.00
Steel: Welded Wire Fabric	Tons	420.00

TABLE 9
SIZE I
SUMMARY OF CONSTRUCTION COSTS
(June 1983 Prices in L.E.)
COSTS PER SQUARE METER OF CANAL

Lining Type		Canal Lengths				
		60m	500m	1000m	2500m	5000m
Concrete:	Cast in Place	21.27	10.88	10.04	9.31	9.26
	Pre Cast Sections	23.64	13.10	12.52	10.99	10.94
	Pre Cast Slabs	17.31	11.52	11.33	10.22	10.18
Bricks:	Concrete Lined	14.38	8.40	7.95	7.38	7.32
Stonework:	(Pitching)	14.35	8.39	7.65	7.36	7.31
Fiberglass Reinforced Plastic:		24.52	18.01	11.67	8.20	8.14
Membranes:						
Exposed:	20 ml P.V.C	14.25	8.22	8.00	7.51	7.48
	36 ml Hypalon	23.26	17.23	17.01	16.52	16.49
	35 ml Butyl	29.87	23.82	23.61	23.14	23.10
Buried:	10 ml P.V.C	13.57	7.26	6.98	6.44	6.38
	20 ml P.V.C	15.88	9.53	9.25	8.70	8.65
	36 ml Hypalon	26.90	20.34	20.07	19.50	19.47
	35 ml Butyl	34.98	28.28	28.01	27.44	27.40
Asphaltic Concrete:		17.14	8.00	7.26	6.60	6.55
Soil Cement:		15.82	7.33	6.68	6.12	6.08

TABLE 10
SIZE 2
SUMMARY OF CONSTRUCTION COSTS
(June 1983 Prices in L.E.)
COSTS PER SQUARE METER OF CANAL

Lining Type		Canal Lengths				
		400m	2,000m	5,000m	10,000m	20,000m
Concrete:	Cast in Place	10.66	8.11	7.61	7.16	6.97
	Pre Cast Sections	13.23	10.83	10.58	10.44	10.34
	Pre Cast Slabs	13.60	12.22	11.94	11.81	11.71
Bricks:	Concrete Lined	11.85	10.32	9.54	9.29	9.19
Stonework:	(Pitching)	9.12	8.04	7.62	7.49	7.41
Fiberglass Reinforced Plastic:		16.26	12.23	11.43	11.28	11.17
Membranes:						
Exposed:	20 ml P.V.C	8.25	7.14	6.86	6.73	6.63
	36 ml Hypalon	15.31	14.18	13.89	13.75	13.66
	35 ml Butyl	20.48	19.34	19.04	18.90	18.81
Buried:	10 ml P.V.C	6.89	5.95	5.75	5.64	5.56
	20 ml P.V.C	8.66	7.71	7.51	7.40	7.32
	36 ml Hypalon	17.07	16.12	15.91	15.80	15.71
	35 ml Butyl	23.24	22.27	22.06	21.95	21.86
Asphaltic Concrete:		9.08	7.30	6.84	6.47	6.32
Soil Cement:		7.23	6.01	5.64	5.44	5.36

TABLE 11
SIZE 3
SUMMARY OF CONSTRUCTION COSTS
(June 1983 Prices in L.E.)
COSTS PER SQUARE METER OF CANAL

Lining Type		Canal Lengths (m)				
		400m	2,000m	5,000m	10,000m	20,000m
Concrete:	Cast in Place	11.59	10.52	10.09	9.98	9.97
	Pre Cast Sections	19.83	18.09	18.77	18.72	18.70
	Pre Cast Slabs	19.19	18.44	18.12	18.12	18.12
Bricks:	Concrete Lined	9.58	8.54	8.17	8.10	8.10
Stonework:	(Pitching)	9.43	8.49	8.07	8.01	7.98
Fiberglass Reinforced Plastic:		21.22	20.40	20.03	20.03	20.03
Membranes:						
Exposed:	20 ml P.V.C	7.97	7.28	6.97	6.96	6.96
	36 ml Hypalon	14.55	13.86	13.55	13.54	13.54
	35 ml Butyl	19.37	18.68	18.37	18.36	18.36
Buried:	10 ml P.V.C	6.27	5.68	5.41	5.40	5.40
	20 ml P.V.C	7.69	7.09	6.83	6.82	6.82
	36 ml Hypalon	14.46	13.87	13.60	13.59	13.59
	35 ml Butyl	19.42	18.83	18.57	18.56	18.56
Asphaltic Concrete:		8.77	7.73	7.40	7.39	7.39
Soil Cement:		8.77	7.73	7.40	7.39	7.39

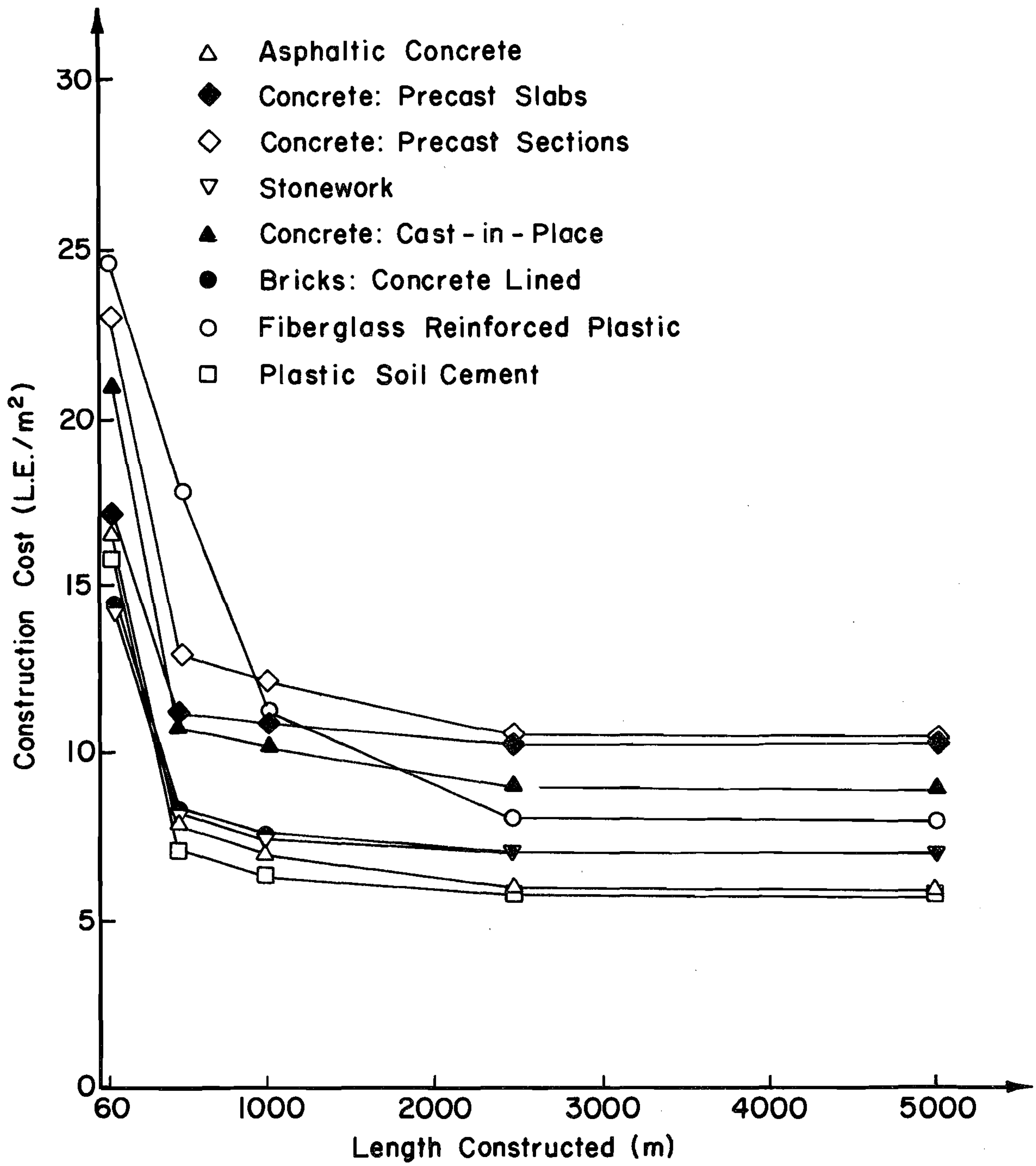

FIGURE 6. Size 1 Canal Construction Costs

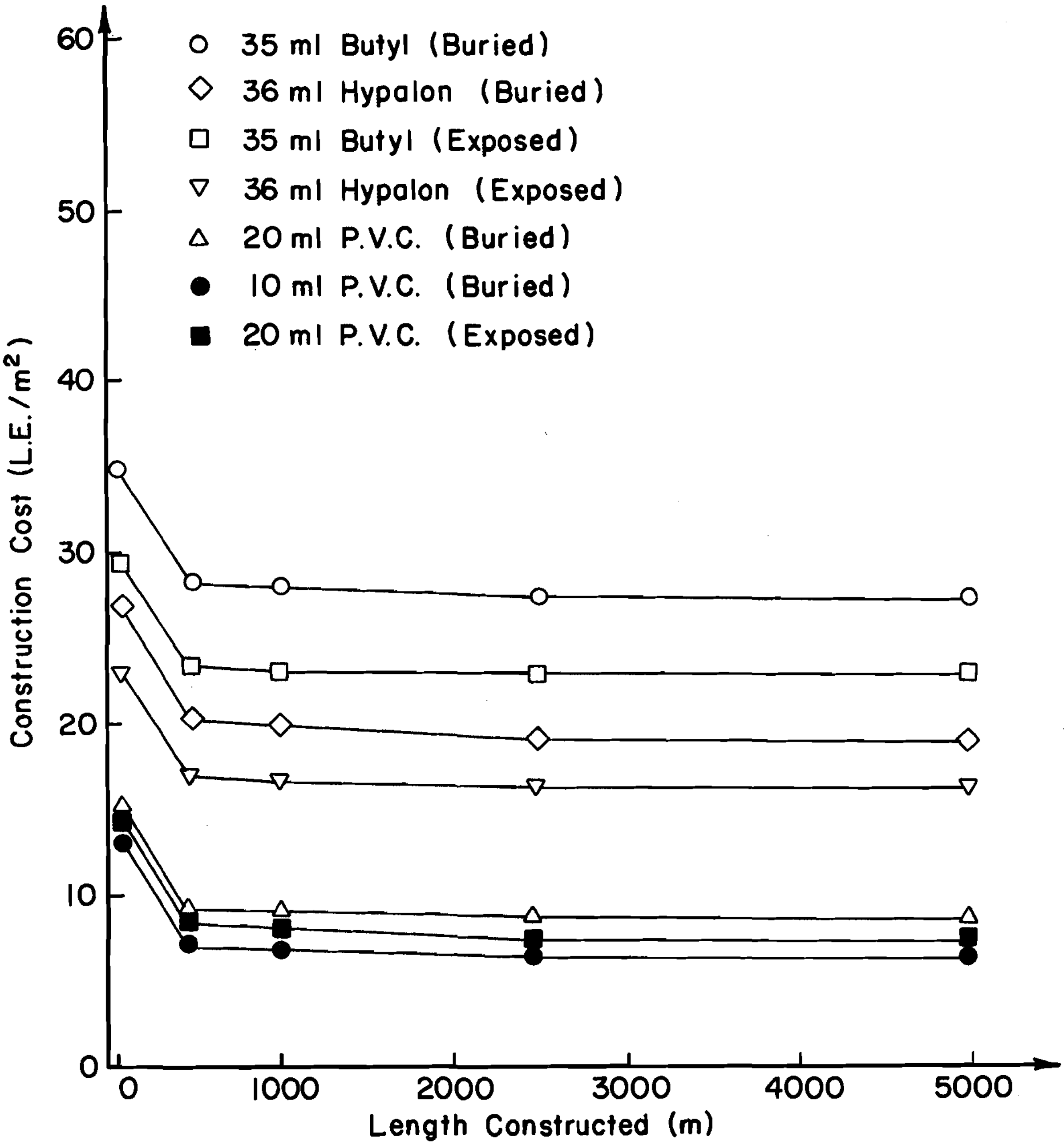

FIGURE 7. Size I: Canal Construction Costs

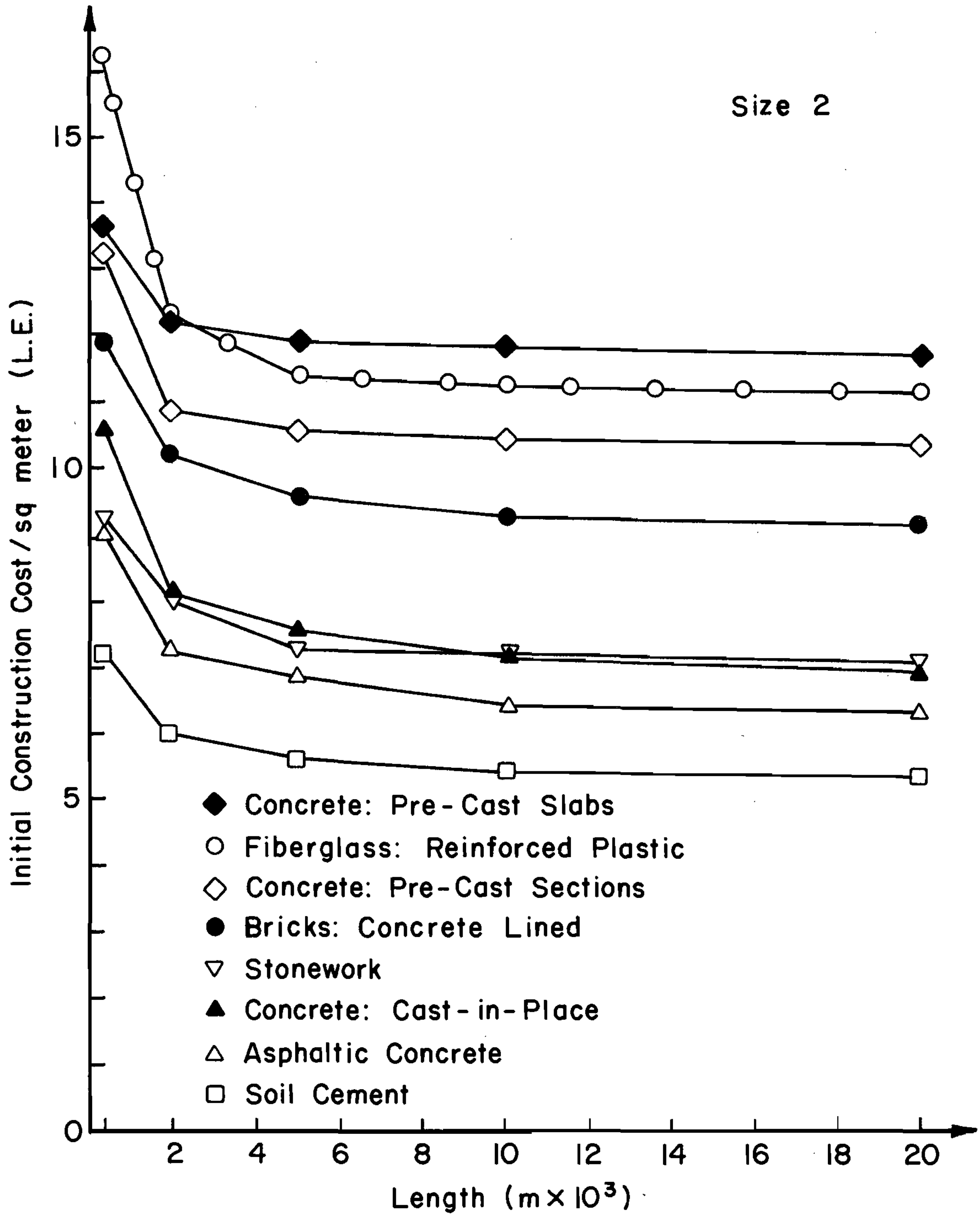

FIGURE 8.

Size 2: Canal Construction Costs

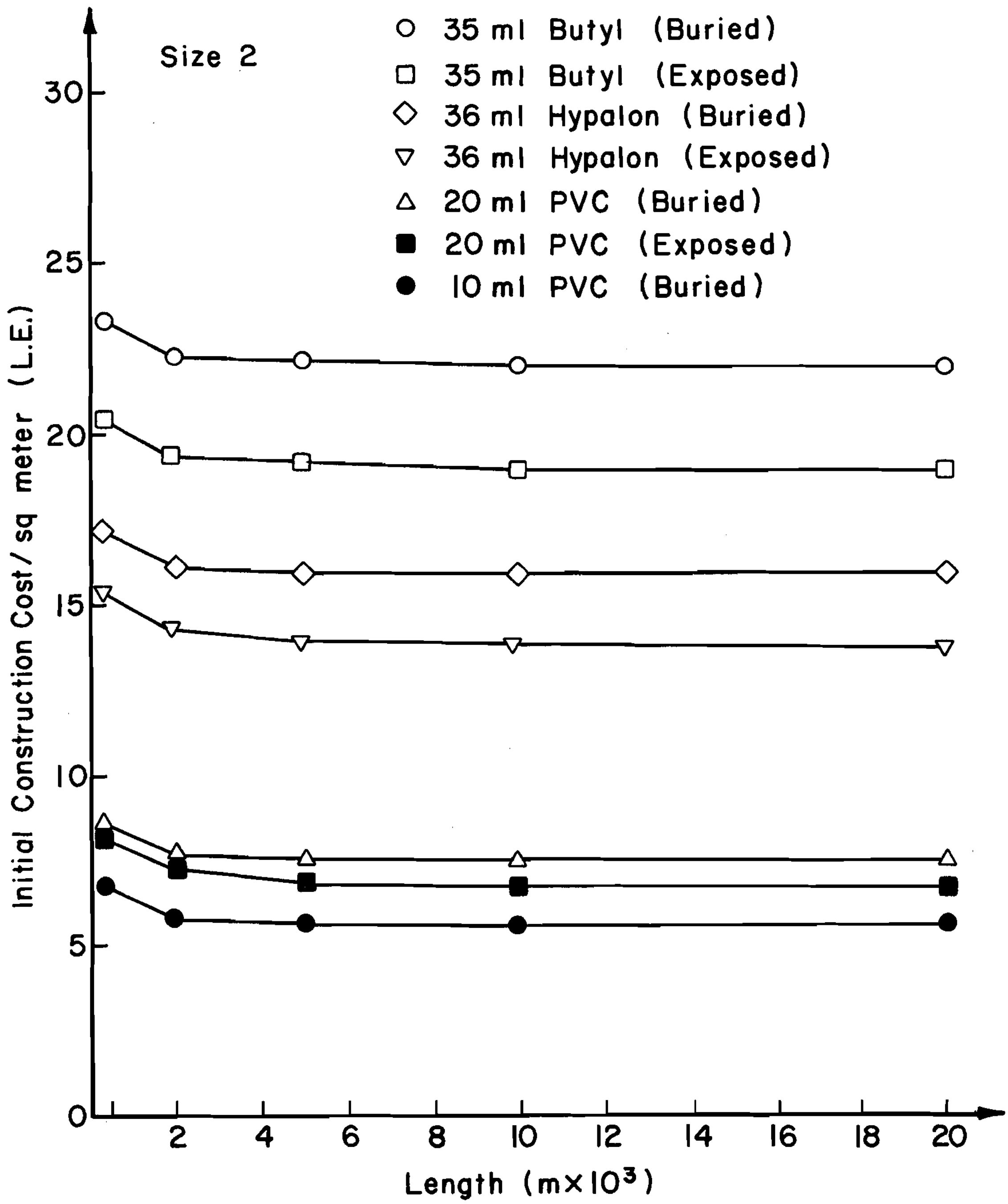

FIGURE 9.

Size 2: Canal Construction Costs

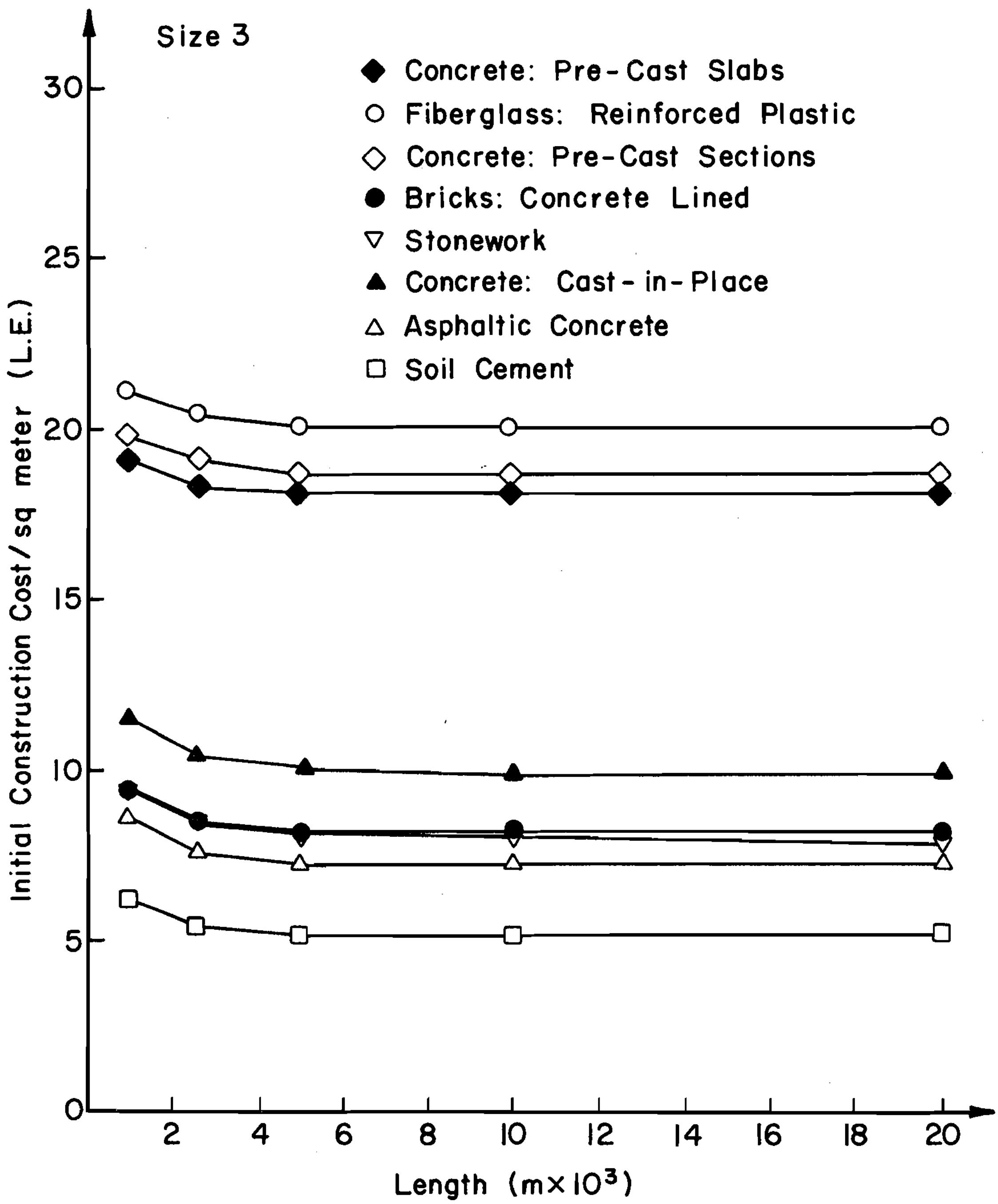

FIGURE 10.
Size 3. Canal Construction Costs

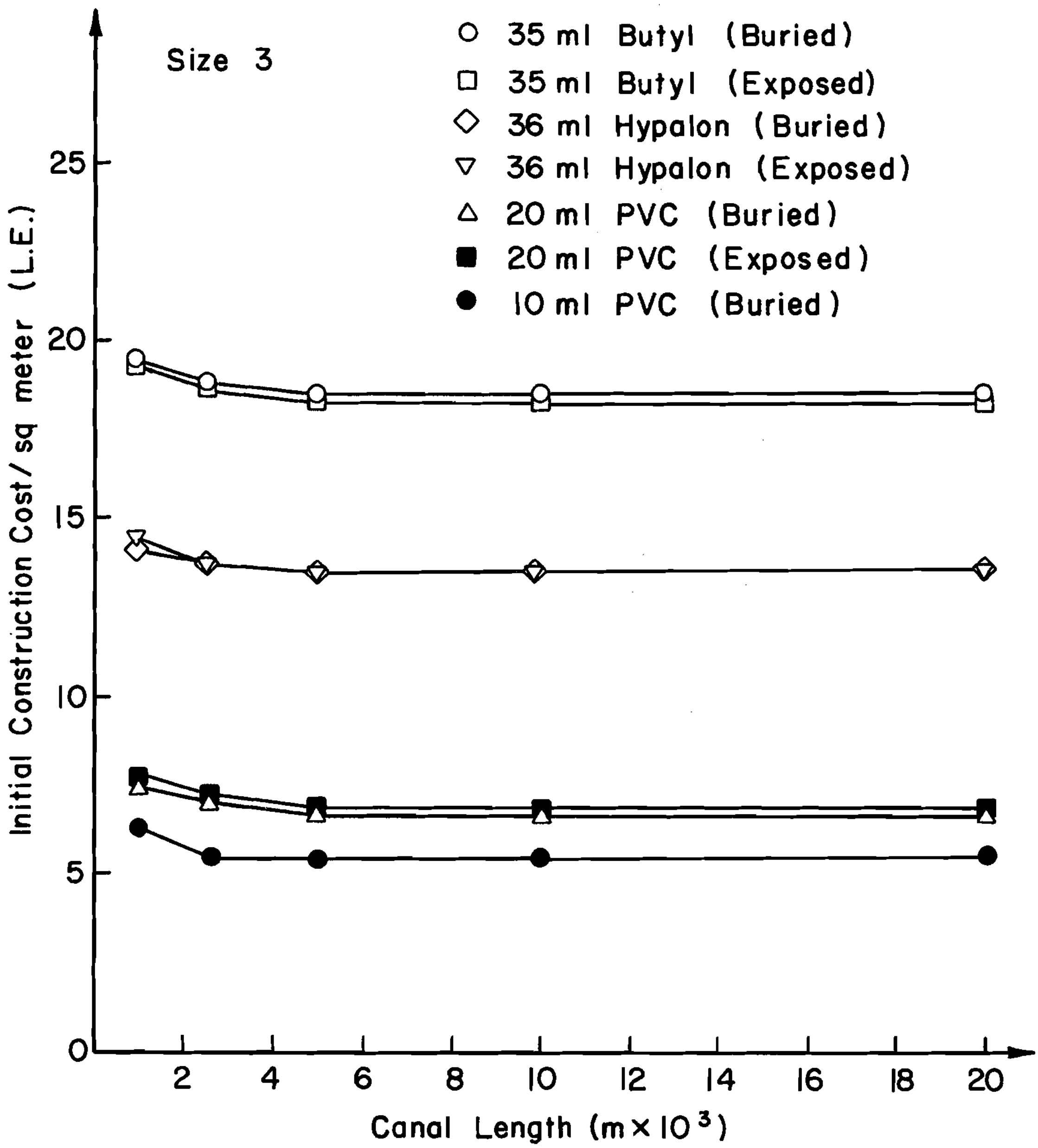

FIGURE 11.

Size 3: Canal Construction Costs

5.00 Annual Maintenance Requirements and Cost Estimation

The annual maintenance costs have been computed for the marginal construction cost lengths computed in the previous section. Adopted maintenance requirements for the individual lining types are given following.

5.10 Maintenance Requirements

In general, the required annual maintenance will involve sediment and weed removal approximately twice per year, the replacement or repair of cracked or broken sections, and the resealing of joints for rigid boundary canals and exposed flexible linings. For size 1 & 2 canals, it has been assumed that sediment and weed removal is conducted manually, and for size 3 canals, mechanically using a self-powered mechanical slipform and conveyor/excavator. The replacement of cracked or broken sections, and the resealing of joints will be conducted manually for all canal sizes. Specific maintenance requirements for the individual lining types are given following.

5.11	Concrete: Cast-In-Place	Sediment and weed removal: twice per year Replacement/repair of cracked or broken sections: 1 meter per 100 meters requires complete replacement each year. Resealing joints: 5 joints per 100 meters per year.
5.12	Concrete: Pre-Cast Sections	As for 5.11
5.13	Concrete: Concrete Lined	Sediment and weed removal: once per year. Replacement/repair of cracked or broken sections: 1 meter per 100 meters requires complete replacement each year. Lining repair: 5 meters per 100 meters per year.
5.14	Stonework:	Sediment and weed removal: twice per year. Replacement/repair of cracked or broken sections: 1 meter per 100 meters requires complete replacement each year. Reasealing joints: 3 meters per 100 meters per year.

5.15	Fiberglass Reinforced Plastic	Sediment and weed removal: once per year. Replacement or cracked or broken sections: 1 meter per 100 meters per year. Crack repair: 5 meters per 100 meters per year requires overlaying with new fiberglass matt and resin.
5.16	Membranes: Exposed	Sediment and weed removal: twice per year. Replacement, repair and resealing joints: 2 meters per 100 meters per year.
5.17	Membranes: Buried	Sediment and weed removal: twice per year. Replacement and recompaction of backfill: 5 meters per 100 meters per year.
5.18	Asphaltic Concrete:	Sediment and weed removal: twice per year. Replacement and repair of sections: 1 meter per 100 meters per year.
5.19	Soil Cement:	Sediment and weed removal: twice per year. Replacement and repair of sections: 1 meter per 100 meters per year.

5.20 <u>Example Annual Maintenance Cost Estimation</u>

Following is an example of the methods used in determining the annual maintenance costs using the size 2 cast-in-place concrete canal for 10,000 m of canal. It has been assumed that all maintenance is conducted by private contractors supplying all necessary labor, material and equipment.

i) Sediment and weed removal.

This will be conducted manually, twice per year, with the canal dry.

Assuming that one laborer can clear 15 running meters per hour, then for 10,000 m,

$$\text{Labor time} = \frac{10000}{15} \simeq 670 \text{ hrs/ cleaning}$$

$\therefore$ 1340 hrs/annum @ L.E. 2.40/hr = 3,216.00

ii) Replacement and repair of sections.

Assuming that 1 m per 100 m per year requires reconstruction, and reconstruction is carried out manually, thus, the total reconstruction length is 100 meters.

Concrete required = 0.25 m^3/meter
= 25 m^3 for 100 meters

Concrete Cost = 25m^3 @ L.E. 45.00/m^3 = 1,125.00
Labor 240 hrs @ 2.40/hr. = 576.00

iii) Resealing Joints

Assuming 5 joints per 100 meters require partial or full repair, then the total number of joints per year = 500

Bitument 0.50m^3 @ L.E. 55.00/m^3 = 27.50
Labor 16 hrs @ L.E. 2.40/hr = 38.40

TOTAL COST L. E. $4,982.90

ADOPT L.E. 5,000.00

The above method was employed for all canal sizes and lining types, and these estimated costs are given in Table 12, 13, and 14 in the following section

6.00 Total Annual Canal Costs

The annual canal costs following include the average annual recovery cost of construction together with the estimated annual maintenance costs, but exclude annual operational costs.

For the anticipated structural life of each of the lining types, the annual capital recovery cost has been computed from the formulae

$$P_A = C \frac{i(1+i)^n}{(1+i)^n - 1} \quad (9)$$

Where P_A = amount of each payment at the end of each year
n = anticipated useful structural life
i = annual interest rate (10% adopted)
C = total construction cost.

Table 12, 13 and 14 following tabulate the computed average annual capital recovery costs and the resulting total annual lining costs per unit area, including annual maintenance costs, for the three canal sizes respectively.

7.00 Estimation of Potential Benefits

The estimation of benefits derived from the construction of canal linings is a far more difficult task under Egyptian conditions than estimating canal lining costs. Many potential benefits are intangible and difficult, if not impossible, to express in economic terms. The benefits derived from an increase in application efficiency are not static, and water will decrease in value as the demand decreases due to increased operational efficiency with a constant supply. However, this decrease in demand may allow the development of new areas and a significant increase in overall benefits realized by the country.

The following section outlines the basic tangible benefits to be realized through canal lining, and where basic data are available, estimates these benefits in economic terms.

7.10 Water Savings

Probably the most beneficial use of canal linings is the saving of water through prevention of seepage losses. However, this benefit is extremely site specific and is solely dependant upon the geology of the area. A large percentage of the "old land" irrigation area within the Nile Valley consists of soils with high clay contents, and actual seepage losses to the groundwater table are negligible as reported within previous EWUP reports. As such, a lowering in the groundwater table and resulting potential production increases may be better achieved through changes in on-farm irrigation practices than canal lining in high clay content soils. An additional water saving may be achieved with canal linings through a reduction in travel time to the farm, though this may be partially achieved through a viable and on-going maintenance and upgrading program of the existing canals. Again, it is stressed, that quantitative water savings are site-specific and each proposed lining program must be considered as an entity.

Within the existing "old land" system, no direct charges are currently levied for water, and consequently there is no incentive by the water user to conserve or to upgrade privately owned on-farm distribution systems. As such the tangible

TABLE 12
SIZE I
TOTAL ANNUAL CANAL LINING
AND MAINTENANCE COSTS
FOR 2500 METERS OF CANAL
(June 1983 Prices in L.E.)

Lining Type		Total Construction Costs	Anticipated Structural Life (Years)	Average Annual Capital Recovery Costs	Annual Maintenance Costs	Lining Area ($m^2 x 10^3$)	Total Annual Cost L.E./m^2
Concrete:	Cast in Place	21,900	30	2,323	375	2.35	1.15
	Pre-Cast Sections	27,500	20	3,230	500	3.13	1.19
	Pre-Cast Slabs	32,000	20	3,758	500	3.13	1.36
Bricks:	Concrete Lined	18,500	15	2,432	200	2.50	1.05
Stonework:		22,800	12	3,346	450	3.10	1.22
Fiberglass Reinforced Plastic:		17,200	15	2,261	330	2.10	1.23
Membranes:							
Exposed:	20 ml P.V.C.	19,200	6	4,408	760	2.55	2.03
	36 ml Hypalon	42,100	10	6,851	1,330	2.55	3.21
	35 ml Butyl	59,000	10	9,602	1,720	2.55	4.44
Buried:	10 ml P.V.C	21,100	12	3,097	800	3.28	1.19
	20 ml P.V.C.	28,500	15	3,747	800	3.28	1.39
	36 ml Hypalon	63,900	20	7,506	800	3.28	2.53
	35 ml Butyl	89,900	30	9,536	800	3.28	3.15
Asphaltic Concrete:		17,300	12	2,539	550	2.63	1.17
Soil Cement:		19,900	10	3,239	625	3.25	1.19

TABLE 13
SIZE 2
TOTAL ANNUAL CANAL LINING
AND MAINTENANCE COSTS
FOR 10,000 METERS OF CANAL
(June 1983 Prices in L.E.)

Lining Type		Total Construction Costs	Anticipated Structural Life (Years)	Average Annual Capital Recovery Costs	Annual Maintenance Costs	Lining Area ($m^2 x 10^3$)	Total Annual Cost L.E./m^2
Concrete:	Cast in Place	214,700	30	22,775	5,000	30.0	0.93
	Pre-Cast Sections	323,800	20	38,033	6,500	31.0	1.44
	Pre-Cast Slabs	366,000	20	42,990	7,000	31.0	1.61
Bricks:	Concrete Lined	289,798	15	38,100	6,100	31.2	1.42
Stonework:		299,600	12	43,970	5,200	40.0	1.23
Fiberglass Reinforced Plastic:		315,800	15	41,519	5,900	28.0	1.69
Membranes:							
Exposed:	20 ml P.V.C.	215,300	6	49,434	6,800	32.0	1.76
	36 ml Hypalon	440,100	10	71,624	11,300	32.0	2.59
	35 ml Butyl	605,000	10	98,460	14,600	32.0	3.53
Buried:	10 ml P.V.C	226,200	12	33,198	10,100	40.0	1.08
	20 ml P.V.C.	236,800	15	39,021	10,100	40.0	1.23
	36 ml Hypalon	633,500	20	74,410	10,100	40.0	2.11
	35 ml Butyl	880,200	30	93,371	10,100	40.0	2.59
Asphaltic Concrete:		237,900	12	34,915	5,400	34.0	1.19
Soil Cement:		217,700	10	35,430	8,100	40.0	1.09

TABLE 14
SIZE 3
TOTAL ANNUAL CANAL LINING
AND MAINTENANCE COSTS
FOR 5000 METERS OF CANAL
(June 1983 Prices in L.E.)

Lining Type		Total Construction Costs	Anticipated Structural Life (Years)	Average Annual Capital Recovery Costs	Annual Maintenance Costs	Lining Area ($m^2 x 10^3$)	Total Annual Cost L.E./m^2
Concrete:	Cast in Place	438,900	30	46,400	6,800	43.5	1.22
	Pre-Cast Sections	872,900	20	102,530	9,600	46.5	2.41
	Pre-Cast Slabs	842,800	20	99,000	9,900	46.5	2.34
Bricks:	Concrete Lined	355,600	15	46,750	9,750	43.5	1.30
Stonework:		457,800	12	67,200	7,150	56.75	1.31
Fiberglass Reinforced Plastic:		781,300	15	102,720	7,630	39.0	2.83
Membranes:							
Exposed:	20 ml P.V.C.	329,300	6	75,600	9,420	47.25	1.80
	36 ml Hypalon	640,100	10	104,180	15,490	47.25	2.53
	35 ml Butyl	868,100	10	141,280	19,930	47.25	3.41
Buried:	10 ml P.V.C	324,700	12	47,650	15,120	60.0	1.05
	20 ml P.V.C.	409,800	15	53,880	15,120	60.0	1.15
	36 ml Hypalon	816,100	20	95,860	15,120	60.0	1.85
	35 ml Butyl	1,114,100	30	118,180	15,120	60.0	2.22
Asphaltic Concrete:		358,700	12	52,640	7,200	48.5	1.23
Soil Cement:		299,200	10	48,690	10,284	58.0	1.02

benefit to the farmers for the water saved is zero from upgrading the system. However, in considering the entire Nile River irrigation system direct benefits may be significant if the additional water saved is diverted to new lands.

A reduction in seepage losses will also reduce the required carrying capacities, maintenance and operation of the drainage system, though again the quantity of canal seepage in heavy clay soils returning to the drainage system may be insignificant compared to runoff resulting from inefficient on-farm irrigation practices.

7.20 Maintenance Cost Reduction

Lined canals offer signifcant savings in maintenance costs compared to uncompacted natural soil canals. Under the existing canal conditions, maintenance costs have been computed for the three canal size ranges under the assumption that maintenance is conducted to deliver maximum conveyance efficiency, as has been assumed for the lined canal cases. To achieve this efficiency, it has been assumed that canals require complete sediment and weed removal six times per year, with any required reconstruction being conducted during these cleanings. The estimated structural life of the various lining types may be extended with additional maintenance, and consequental additional annual cost. For the three canal sizes, the individual maintenance costs will thus be approximately equivalent to the sediment and weed removal costs associated with buried membrane linings. The following costs are based on maintenance being conducted by private sector contractors.

7.21 Size 1 Canals

For 2,500 meters of canal and assuming that the canals are cleaned manually and that the canal cross sectional shape is similiar in area to buried membrane canal, one laborer will clean approximately 20 m^2/hr.

Total canal area = 3.28×10^3 m^2

Total labor hours/cleaning = 164

Total cleaning cost/annum = 6 x 164 x L. E. 2.40 = L.E. 2,361.60

Adopt: L. E. 2,400.00

This total cost is equivalent to an annual maintenance cost of L. E. 0.72/m^2. For buried membrane canals, the total annual maintenance cost is L. E. 800.00 or L. E. 024/m^2. The saving in maintenance costs for these canals (or in effect the benefit attributable to canal lining) is L. E. (0.72 - 0.24)/m^2 = L. E. 0.48/m^2/annum. The potential benefits derived through the reduction in maintenance costs are given in Table 15 following for all canal lining types.

7.22 Size 2 Canals

The same assumptions apply to these canals as for the size 1 canals. For 10,000 meters of buried membrane canal the total canal area = 40,000 m^2.

Total labor hours per cleaning = 2,000

Total cleaning cost per annum = 6 x 2,000 x L. E. 2.40 = L. E. 28,800.

Annual maintenance cost per unit area = L. E. 0.72

Benefits derived from the savings in maintenance costs are given in Table 15 for the respective lining types.

7.23 Size 3 Canals

Annual maintenance costs per unit area are the same as for the previous canal sizes, and the associated potential benefits are given in Table 15.

7.30 Land Area Savings

Dependant upon the comparative lining type, significant benefits may be obtained through the introduction of additional crops on land reclaimed following canal lining. The benefit derived will be directly dependant upon the additional land area available, the type of crop grown, anticipated crop yields per unit area, and the farmers return on the crop.

Under the previous assumption that existing canals have similar cross sectional properties as buried membrane linings, the land saved will be a direct proportion of the respective top widths of the canals. For the size 1 canals and using the previous design criteria that 60 m of marwa serves 1 feddan, then the additional land available from the reconstruction of the canal is given by (1.20 - w) 60 m^2 where 1.20 = assumed top width of existing canal (m), and w = top width of the reconstructed canal (m). Thus, for 2,500 meters of canal, which

TABLE 15
BENEFITS DERIVED FROM A REDUCTION IN
MAINTENANCE COSTS
(June 1983 Prices)

Lining Type	Maintenance Cost Saving (L.E./m^2)		
	Size 1	Size 2	Size 3
Concrete:			
Cast-in-place	0.56	0.55	0.56
Pre-Cast Sections	0.56	0.51	0.51
Pre-Cast Slabs	0.56	0.49	0.51
Bricks:			
Concrete Lined	0.64	0.52	0.50
Stonework:	0.57	0.59	0.59
Fiberglass Reinforced Plastic:	0.56	0.51	0.52
Membranes:			
Exposed: 20 ml P.V.C.	0.42	0.51	0.52
36 ml Hypalon	0.20	0.37	0.39
35 ml Butyl	0.05	0.26	0.30
Buried: 10 ml P.V.C.	0.48	0.47	0.47
20 ml P.V.C.	0.48	0.47	0.47
36 ml Hypalon	0.48	0.47	0.47
35 ml Butyl	0.48	0.47	0.47
Asphaltic Concrete:	0.51	0.56	0.57
Soil Cement:	0.53	0.52	0.54

would serve approximately 42 feddans, the total land saving is given by 2500 (1.20 - w) m^2. As an example of potential benefits from land savings, reference 2 for the Abu Raya Site within the Kafr El Sheikh Governorate, provides the following data (Table IV-10, p. 58).

Average farm area: 6.21 Feddans.
Average annual net farm income = L. E. 2,492.90
Average net income per feddan = L. E. 401.43.

For cast-in-place concrete lining, with a top width of 0.72 m, the additional land area available following reconstruction is 2500 (1.20 - 0.71) m^2 = 0.29 feddans, and the average annual net income from the area is L. E. 116.41. The total lining area for this lining type, and 2,500 meters is 2,350 m^2 and the resulting net benefit is thus 116.41/2,350 = L. E. 0.05/m^2.

Similar computations may be cnducted for all of the lining types and for the various canal sizes. However, the average net farm incomes per feddan reflect large variations between the study areas, and no attempt to generalize these estimates has been made due to their site-specific nature.

7.40 Operational and Management Cost Reduction

With the reconstruction and lining of any size canal, the annual maintenance and operational costs will be reduced significantly for hard surface linings and to a lesser extent for buried membrane linings. The reconstruction of intake and outlet gates will allow more precise metering of turnouts, and allow a reduction in time of operation and head gate position shifts. These benefits will be reflected in both the field and office management time requirements. The magnitude of these benefits will again be dependent upon the size of the system reconstructed and the canal sizes and should be determined on a site-specific basis.

By Government decree various lifting devices are currently installed in many of the distribution canals and mesqas in an attempt to restrain water use by the farmers. In some instances within the "old land" system, lifting may not appear to be hydraulically necessary, and the redesign and reconstruction of canals and outlet works may allow an overall increase in the efficiency of the distribution system, and a significant reduction in the energy requirements. In systems where lifting devices are employed, their removal and the consequental savings in energy should be included as benefits within the economic analysis.

7.50 On-Farm Distribution Benefits

Well maintained lined canal systems allow higher conveyance velocities and consequential lower on-farm irrigation times. Evaporation losses will thus be reduced in the distribution system together with water losses resulting from ponding in both the old canals and the drainage system. Faster on-farm application of water may also provide increased corp production through a more even water distribution pattern, and a reduction in losses to groundwater. These benefits are primarily dependent upon the crop and soil types, and will require site specific data from research areas prior to their quantification.

8.00 Results and Conclusions

Table 16 following summarizes the basic design parameters for the three canal sizes considered, the minimum recommended construction lengths, and the estimated total annual costs per unit area for the various lining types. Although the recommended minimum construction length for the size 2 canals is 10,000 meters, very little difference will occur in the annual costs per sqaure meter between the 10,000 and 5,000 meters construction lengths, especially for the flexible linings.

For the size 1 canals, very little difference exists in the total annual unit costs except for the exposed membrane linings and the two heaviest material buried membranes. The most economically viable canal linings are concrete lined bricks, which also has one of the lowest initial construction costs. Cast-in-place concrete, pre-cast concrete sections or asphaltic concrete would also be economically viable canal linings materials for marwas.

Cast-in-place concrete appears as the cheapest lining method for size 2 canals, followed by 10 ml buried P.V.C and soil-cement linings. However, due to the uncertainty of the stability of soil-cement (potential weed penetration, etc.) and the comparatively short life span of the buried 10 ml P.V.C., cast-in-place concrete using towed slipform construction techniques, is recommended for this canal size.

Although the buried 10 ml P.V.C and the soil cement linings are the two cheapest linings for the size 3 canals, either asphaltic concrete or cast-in-place concrete are recommended for the reasons given previously. Of these two linings, cast-in-place concrete is preferred due to the comparatively short anticipated structural life of asphaltic concrete. If the Egyptian Government is to establish a design team for the design and construction supervision of major canal rehabilitation schemes, then from economic considerations, concentration on cast-in-place concrete is suggested for all potential canal sizes. However, as previously stressed, the foregoing analysis should be conducted for selected lining types, for each individual area under consideration, as rigid boundary canal linings may not be physically or economically viable under some soil conditions (e.g. highly expansive, bentonite type, clays).

The costs of lining existing canals may probably be justified by the increase in agricultural benefits. However, additional studies are required regarding the actural price of water per unit volume delivered to the farm; the net incomes per unit land areas for additional specific areas within the "old-land" system of the Nile Basin and current management and operational costs of the system.

TABLE 16
SUMMARY OF CANAL DESIGN PARAMETERS AND LINING COSTS

Parameters	Size 1		Size 2		Size 3	
Design discharge (m^3/sec)	0.035		0.70		7.00	
Bed slope (m/m)	0.0003		0.0003		0.0001	
Structural top width range (m)	0.30-1.00		1.00-3.00		3.00-10.00	
Recommended minimum construction length (m)	2,500		10,000		5,000	
Total Annual Canal Lining and Maintenance Costs						
	LE/m^2	LE/m	LE/m^2	LE/m	LE/m^2	LE/m
Concrete:						
Cast-in-place	1.15	1.08	0.93	2.79	1.22	10.61
Pre-Cast Sections	1.19	1.49	1.44	4.46	2.41	22.41
Pre-Cast Slabs	1.36	1.70	1.61	4.99	2.34	21.76
Bricks:						
Concrete Lined	1.05	1.05	1.42	4.43	1.30	11.31
Stonework:	1.22	1.51	1.23	4.92	1.31	14.87
Fiberglass Reinforced Plastic:	1.23	1.03	1.69	4.73	2.83	22.07
Membranes:						
Exposed: 20 ml P.V.C.	2.03	2.07	1.76	5.63	1.80	17.01
36 ml Hypalon	3.21	3.16	2.59	8.29	2.53	23.91
35 ml Butyl	4.44	4.53	3.53	11.30	3.41	32.22
Buried: 10 ml P.V.C.	1.19	1.56	1.08	4.32	1.05	12.60
20 ml P.V.C.	1.39	1.82	1.23	4.92	1.15	13.80
36 ml Hypalon	2.53	3.32	2.11	8.44	1.85	22.20
35 ml Butyl	3.15	4.13	2.59	10.36	2.22	26.64
Asphaltic Concrete:	1.17	1.23	1.19	4.05	1.23	11.93
Soil Cement:	1.19	1.55	1.09	4.36	1.02	11.83

9.00 References

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2. "Farm Record Summary and Analyses for Study Cases at Abyuha, Mansuriya and Abu Raya Sites. 1981-1982," EWUP Economics Team, March, 1983.

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AMERICAN EQUIVALENTS OF EGYPTIAN ARABIC TERMS AND MEASURES COMMONLY USED IN IRRIGATION WORK

LAND AREA	IN SQ METERS	IN ACRES	IN FEDDANS	IN HECTARES
1 acre	4,046.856	1.000	0.963	0.405
1 feddan	4,200.833	1.038	1.000	0.420
1 hectare (ha)	10,000.000	2.471	2.380	1.000
1 sq. kilometer	100×10^4	247.105	238.048	100.000
1 sq. mile	259×10^6	640.000	616.400	259.000

WATER MEASUREMENTS	FEDDAN-CM	ACRE-FEET	ACRE-INCHES
1 billion m^3	23,809,000.000	810,710.000	
1,000 m^3	23.809	0.811	9.728
1,000 m^3/Feddan (= 238 mm rainfall)	23.809	0.781	9.372
420 m^3/Feddan (= 100 mm rainfall)	10.00	0.328	3.936

OTHER CONVERSION		METRIC	U.S.
1 ardab	=	198 liters	5.62 bushels
1 ardab/feddan	=		5.41 bushels/acre
1 kg/feddan	=		2.12 lb/acre
1 donkey load	=	100 kg	
1 camel load	=	250 kg	
1 donkey load of manure	=	0.1 m^3	
1 camel load of manure	=	0.25 m^3	

EGYPTIAN UNITS OF FIELD CROPS

CROP	EG. UNIT	IN KG	IN LBS	IN BUSHELS
Lentils	ardeb	160.0	352.42	5.87
Clover	ardeb	157.0	345.81	5.76
Broadbeans	ardeb	155.0	341.41	6.10
Wheat	ardeb	150.0	330.40	5.51
Maize, Sorghum	ardeb	140.0	308.37	5.51
Barley	ardeb	120.0	264.32	5.51
Cottonseed	ardeb	120.0	264.32	8.26
Sesame	ardeb	120.0	264.32	
Groundnut	ardeb	75.0	165.20	7.51
Rice	dariba	945.0	2081.50	46.26
Chick-peas	ardeb	150.0	330.40	
Lupine	ardeb	150.0	330.40	
Linseed	ardeb	122.0	268.72	
Fenugreek	ardeb	155.0	341.41	
Cotton (unginned)	metric qintar	157.5	346.92	
Cotton (lint or ginned)	metric qintar	50.0	110.13	

EGYPTIAN FARMING AND IRRIGATION TERMS

fara = branch
marwa = small distributer, irrigation ditch
masraf = field drain
mesqa = small canal feeding from 10 to 40 farms
qirat = cf. English "karat", A land measure of 1/24 feddan, 175.03 m^2
qaria = village
sahm = 1/24th of a qirat, 7.29 m^2
saqia = animal powered water wheel
sarf = drain (vb.), or drainage. See also masraf, (n.)

EGYPT WATER USE AND MANAGEMENT PROJECT

PROJECT TECHNICAL REPORTS

NO.	TITLE	AUTHOR
PTR#1	Problem Identification Report for Mansuriya Study Area, 10/77 to 10/78.	By: Egyptian and American Field Teams.
PTR#2	Preliminary Soil Survey Report for the Beni Magdul and El-Hammami Areas.	By: A. D. Dotzenko, M. Zanati, A. A. Abdel Wahed, & A. M. Keleg.
PTR#3	Preliminary Evaluation of Mansuriya Canal System, Giza Governorate, Egypt.	By: American and Egyptian Field Teams.
PTR#5	Economic Costs of Water Shortage Along Branch Canals.	By: A. El Shinnawi M. Skold & M. Nasr
PTR#6	Problem Identification Report For Kafr El-Sheikh Study Area.	Egyptian and American Field Teams.
PTR#7	A Procedure for Evaluating the Cost of Lifting Water for Irrigation in Egypt.	By: H. Wahby, M. Quenemoen, and M. Helal.
PTR#9	Irrigation & Production of Rice in Abu Raya, Kafr El-Sheikh Governorate.	Compiled By: R. Tinsley.
PTR#10	Soil Fertility Survey in Kafr El-Sheikh, El Mansuriya and El-Minya Pilot Projects.	By: Zanati, Soltanpour, Mostafa, & Keleg.
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PTR#12	Use of Feasibility Studies in the Selection and Evaluation of Pilot Studies for Alternative Methods of Water Distribution in Egypt.	By: R. McConnen, F. Abdel Al, M. Skold, and G. Ayad.
PTR#13	The Role of Rural Sociologists in an Interdisciplinary, Action-Oriented Project: An Egyptian Case Study.	By: J. Layton and M. Sallam.

AUTHOR	NO.	TITLE
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PTR#18	Population Growth and Development in Egypt: Farmers' and Rural Development Officials' Perspectives.	By: M. Sallam, E.C. Knop and S.A. Knop.
PTR#19	Effective Extension for Egyptian Rural Development: Farmers' and Officials' Views on Alternative Strategies.	By: E.C. Knop, M. Sallam, and S.A. Knop.
PTR#20	The Rotation Water Distribtuion System vs. The Continual Flow Water Distribution System.	By: M. El-Kady, J. Wolfe and H. Wahby.
PTR#21	El-Hammami Pipeline Design.	By: Fort Collins Staff Team.
PTR#22	The Hydraulic Design of Mesqa 10, An Egyptian Irrigation Canal.	By: W.O. Ree, M. El-Kady, J. Wolfe, and W. Fahim.
PTR#23	Farm Record Summary and Analysis for Study Cases at Abyuha, Mansuriya and Abu Raya Sites, 79/80.	By: F. Abdel Al, and M. Skold.
PTR#24	Agricultural Pests and Their Control.	By: E. Attalla.
PTR#26	Social Dimensions of Egyptian Irrigation Patterns.	By: E.C. Knop, M. Sallam, S.A. Knop and M. El-Kady.
PTR#28	Economic Evaluation of Wheat Trials at Abyuha, El-Minya Governorate. Winter 79/80-80/81 in Awad.	By: N. Farrag and E. Sorial.
PTR#29	Irrigation Practices Reported by EWUP Farm Record Keepers.	By: F. Abdel Al, M. Skold and D. Martella.
PTR#30	The Role of Farm Records in the EWUP Project.	By: F. Abdel Al and D. Martella.

NO.	TITLE	AUTHOR
PTR#35	Farm Irrigation System Design.	By: T.W. Ley.
PTR#36	Discharge and Mechanical Efficiency of Egyptian Water-Lifting Wheels.	By: R. Slack, H. Wahby and W. Clyma.
PTR#37	Allocative Efficiency and Equity of Alternative Methods of Charging for Irrigation Water: A Case Study in Egypt.	By: R. Bowen and R. Young.
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MANUALS

NO.	TITLE	AUTHOR
MAN.#1	Trapezoidal Flumes for the Egypt Water Use Project.	By: A. R. Robinson.
MAN.#2	Programs for the HP Computer Model 9825 for EWUP Operations.	By: M. Helal, D. Sunada, J. Loftis, M. Quenemoen, W. Ree, R. McConnen, R. King, A. Nazr and R. Stalford.

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APPENDIX I

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Size I

CONCRETE: PRE-CAST SECTIONS

Constr. Phase	Pers'l	Equip.	Mat'l	Units	L.E. per Unit	60 m #Units	60 m Total L.E.	500 m #Units	500 m Total L.E.	1000 m #Units	1000 m Total L.E.	2500 m #Units	2500 m Total L.E.	5000m #Units	5000m Total L.E.
A.)Design Costs i)Site Survey	Eng'r(G)			hrs	1.70	6	10.20	12	20.40	20	34.00	40	68.00	70	119.00
	Surv's(G)			hrs	1.00	6	6.00	12	12.00	20	20.00	40	40.00	70	70.00
	Tech's(G)			hrs	1.00	6	6.00	12	12.00	20	20.00	40	40.00	70	70.00
	Driv.(G)			hrs	1.50	6	9.00	12	18.00	20	30.00	40	60.00	70	105.00
		Auto		km	0.20	100	20.00	300	60.00	600	120.00	1500	300.00	3000	600.00
ii)Off. Design Spec's Bidding	Eng'r(G)			hrs	1.70	20	34.00	40	68.00	60	102.00	100	170.00	180	306.00
	Tech's(G)			hrs	1.00	10	10.00	20	20.00	40	40.00	80	80.00	160	160.00
	Acc't(G)			hrs	1.00	20	20.00	40	40.00	60	60.00	100	100.00	180	180.00
B.)Pre-Constr. Costs	Eng'r(G)			hrs	1.70	6	10.20	12	20.40	20	34.00	40	68.00	80	136.00
	Eng'r(P)			hrs	4.00	6	24.00	12	48.00	20	80.00	40	160.00	80	320.00
	Sur'v(G)			hrs	1.00	6	6.00	12	12.00	20	20.00	40	40.00	80	80.00
	Driv.(G)			hrs	1.50	6	9.00	12	18.00	20	30.00	40	60.00	80	120.00
		Cat		hrs	35.00	3	105.00	10	350.00	20	700.00	40	1,400.00	80	2,800.00
		Roller		hrs.	4.00	3	12.00	12	48.00	20	80.00	40	160.00	80	320.00
		LowBoy		hrs	10.00	3	30.00	3	30.00	6	60.00	6	60.00	6	60.00
		Shaper		hrs	4.00	3	12.00	8	32.00	16	64.00	40	160.00	80	320.00
		Auto		km	0.20	100	20.00	300	60.00	600	120.00	1500	300.00	3000	600.00
C.Const. Costs			Conc. Sec.	/unit	▲	240	816.00	2000	4,400.00	4000	8,400.00	10,000	18,000.00	20,000	36,000.00
i)Del.		8T.Tr.		hrs	10.00	10	100.00	60	600.00	120	1,200.00	300	3,000.00	600	6,000.00

CONCRETE: PRE-CAST SECTIONS (Continued)

Constr. Phase	Pers'l	Equip.	Mat'l	Units	L.E. per Unit	60 m		500 m		1000 m		2500 m		5000m	
						#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.
ii) Instal.	Eng'r(G)			hrs	1.70	6	10.20	12	20.40	20	34.00	40	68.00	70	119.00
	Eng'r(P)			hrs	4.00	6	24.00	12	48.00	20	80.00	40	160.00	70	280.00
	Lab's(P)			hrs	2.40	12	28.80	90	216.00	180	432.00	450	1,080.00	900	2,160.00
	Driv.(G)			hrs	1.50	6	9.00	12	18.00	20	30.00	40	60.00	80	120.00
		Auto		km	0.20	100	20.00	300	60.00	600	120.00	1000	200.00	2000	400.00
iii) Seal.	Lab's(P)			hrs	2.40	12	28.80	90	216.00	180	432.00	450	1,080.00	900	2,160.00
iv) Outlet Const.	Lab's(P)			hrs	2.40	4	9.60	30	72.00	60	144.00	150	360.00	300	720.00
v) Seal. Concrete			Conc.	m^3	*	0.25		2.0		4		10		20	
D. Intake Headbox			Bricks	/Unit	0.45	30	13.50	30	13.50	60	27.00	150	67.50	300	135.00
			Conc.	m^3	*	0.2	10.00	0.2	10.00	0.4	20.00	2.0	100.00	4.0	200.00
	Lab's(P)			hrs	2.40	2	4.80	2	4.80	4	9.60	10	24.00	20	48.00
			TOTAL COST				1,418.00		6,547.50		12,542.60		27,465.50		54,708.00
	(P = 1.00 m)		COST PER SQUARE METER				23.64		13.10		12.52		10.99		10.94

▲ Cost for 240 Units: L.E. 3.40/Unit
Cost for 2,000 Units: L.E. 2.20/Unit
Cost for 4,000 Units: L.E. 2.10/Unit
Cost for 10,000 Units: L.E. 1.80/Unit
Cost for 20,000 Units: L.E. 1.80/Unit

* - Concrete Costs:			
	0 to $5m^3$:	L.E. $50.00/m^3$	Mixed at Site: Manually or Portable Mixer
	6 to $300m^3$:	L.E. $45.00/m^3$	Portable, Self-Powered Concrete Truck
	301 to $2000m^3$	L.E. $35.00/m^3$	Small Batch Plant on Site
	$> 2000m^3$	L.E. $32.50/m^3$	Permanent Batch Plant

Size I

CONCRETE: PRE-CAST SLABS

Constr. Phase	Pers'l	Equip.	Mat'l	Units	L.E. per Unit	60 m		500 m		1000 m		2500 m		5000m	
						#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.
A.)Design Costs (as for conc. pre-cast sections)							115.20		250.40		426.00		858.00		1,610.00
B.)Pre-Const. Costs (as for conc. pre-cast sec.)							228.20		618.40		1,188.00		2,408.00		4,756.00
C.)Constr. Costs i)Conc.Slab			Conc. Slab	/Unit	▲	1200	540.00	10,000	4,000.00	20,000	8,000.00	50,000	17,500.00	100,000	35,000.00
ii)Del.		8T.Tr.		hrs	10.00	10	100.00	60	600.00	120	1,200.00	300	3,000.00	600	6,000.00
iii)Instal.	Eng'r(G)			hrs	1.70	8	13.60	24	40.80	32	54.40	70	119.00	120	204.00
	Eng'r(P)			hrs	4.00	8	32.00	24	96.00	32	128.00	70	280.00	120	480.00
	Lab's(P)			hrs	2.40	60	144.00	420	1,008.00	840	2,016.00	2100	5,040.00	4,200	10,080.00
	Driv.(G)			hrs	1.50	8	12.00	24	36.00	32	48.00	70	105.00	120	180.00
		Auto		km	0.20	100	20.00	300	60.00	600	120.00	1000	200.00	2000	400.00
iv)Seal. Concrete	Lab's(P)			hrs	2.40	18	43.20	120	288.00	240	576.00	600	1,440.00	1,200	2,880.00
			Conc.	m^3	*	0.25	12.50	2	100.00	4	200.00	10	450.00	20	900.00
v)Outlet Const.	Lab's(P)			hrs	2.40	4	9.60	30	72.00	60	144.00	150	360.00	300	720.00

Size 1

CONCRETE: PRE-CAST SLABS (Continued)

Constr. Phase	Pers'l	Equip.	Mat'l	Units	L.E. per Unit	60 m		500 m		1000 m		2500 m		5000m	
						#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.
D.) Intake Headbox (as for conc.: pre-cast sec.)							28.30		28.30		56.06		191.50		383.00
			TOTAL COST				1,298.60		7,197.90		14,157.00		31,951.50		63,593.00
		(P=1.25 m)	COST PER SQUARE METER				17.31		11.52		11.33		10.22		10.18

▲ Cost for 1200 Units: L.E. 0.45/Unit
Cost for 10,000 to 20,000: L.E. 0.40/Unit
Cost for > 20,000: L.E. 0.35/Unit

(Costs are for 25x25x6 cm interlocking slabs)

Size I

CONCRETE LINED BRICKS

Constr. Phase	Pers'l	Equip.	Mat'l	Units	L.E. per Unit	60 m		500 m		1000 m		2500 m		5000m	
						#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.
A.)Design Costs (as for conc. pre-cast sec.)							115.20		250.40		426.00		858.00		1,610.00
B.)Pre-Const.Costs (as for conc. pre-cast sec. delet.shaper)							216.20		586.40		1,124.00		2,248.00		4,436.00
C.)Const. Costs															
i)Bricks			Bricks	/Unit	▼	2160	97.20	18,000	720.00	36,000	1,440.00	90,000	3,150.00	180,000	6,300.00
ii)Conc. for lay.			Conc.	m^3	*	0.8	40.00	6.5	292.50	13.0	585.00	32.5	1,462.50	65	2,925.00
iii)Del.		8T.Tr.		hrs.	10.00	10	100.00	60	600.00	120	1,200.00	300	3,000.00	600	6,000.00
iv)Instal.	Eng'r(G)			hrs	1.70	8	13.60	24	40.80	32	54.40	70	119.00	120	204.00
	Eng'r(P)			hrs	4.00	8	32.00	24	96.00	32	128.00	70	280.00	120	480.00
	Lab's(P)			hrs	2.40	36	86.40	300	720.00	600	1,446.00	1500	3,600.00	3000	7,200.00
	Driv.(G)			hrs	1.50	8	12.00	24	36.00	32	48.00	70	105.00	120	180.00
		Auto		km	0.20	100	20.00	300	60.00	600	120.00	1000	200.00	2000	400.00
v)Conc. Lining	Lab's(P)			hrs	2.40	24	57.60	180	432.00	300	720.00	720	1,728.00	1,440	3,456.00
			Conc.	m^3	*	0.6	30.00	5	250.00	10	450.00	25	1,125.00	50	2,250.00
vi)Outlet Const.	Lab's(P)			hrs	2.40	6	14.40	36	86.40	64	153.60	160	384.00	320	768.00

Size I

CONCRETE LINED BRICKS (Continued)

Constr. Phase	Pers'l	Equip.	Mat'l	Units	L.E. per Unit	60 m		500 m		1000 m		2500 m		5000m	
						#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.
D.) Intake Headbox (as for conc. pre-cast sec.)							28.30		28.30		56.60		191.50		383.00
TOTAL COST							862.90		4,198.80		7,945.60		18,451.00		36,592.00
(P=1.00m) COST PER SQUARE METER							14.38		8.40		7.95		7.38		7.32

▼ Brick Costs:

0 to 10,000	L.E. 0.045 Each
10,000 to 50,000	L.E. 0.040 Each
> 50,000	L.E. 0.035 Each

STONEWORK (PITCHING)

Constr. Phase	Pers'l	Equip.	Mat'l	Units	L.E. per Unit	60 m		500 m		1000 m		2500 m		5000m	
						#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.
A.)Design Costs (as for conc. pre-cast sec.)							115.20		250.40		426.00		858.00		1,610.00
B.)Pre-Const.Costs (as for conc. pre-cast sec.)							228.20		618.40		1,188.00		2,408.00		4,756.00
C.)Const. Costs															
i)Stonework			Stone	m^3	■	16.5	198.00	135	1,485.00	270	2,430.00	675	6,075.00	1,350	12,150.00
ii)Del.		8T.Tr.		hrs	10.00	12	120.00	80	800.00	160	1,600.00	400	4,000.00	800	8,000.00
iii)Instal.	Eng'r(G)			hrs	1.70	8	13.60	24	40.80	32	54.40	70	119.00	120	204.00
	Eng'r(P)			hrs	4.00	8	32.00	24	96.00	32	128.00	70	280.00	120	480.00
	Lab's(P)			hrs	2.40	48	115.20	300	720.00	500	1,392.00	1,450	3,480.00	2,900	6,960.00
	Driv.(G)			hrs	1.50	8	12.00	24	36.00	32	48.00	70	105.00	120	180.00
		Auto		km	0.20	100	20.00	300	60.00	600	200.00	1000	200.00	2,000	400.00
iv)Stone Work Seal.	Lab's(P)			hrs	2.40	40	96.00	240	576.00	450	1,080.00	1,125	2,700.00	2,250	5,400.00
			Conc.	m^3	*	1.5	75.00	9	405.00	18	810.00	45	2,025.00	90	4,050.00
v)Outlet Const.	Lab's(P)			hrs	2.40	6	14.40	36	86.40	64	153.60	160	384.00	320	768.00

Size I

STONEWORK (PITCHING)(Continued)

Constr. Phase	Pers'l	Equip.	Mat'l	Units	L.E. per Unit	60 m		500 m		1000 m		2500 m		5000m	
						#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.
D.) Intake Headbox (as for conc. pre-cast sec.)							28.30		28.30		56.60		191.50		383.00
TOTAL COST							1,067.90		5,202.30		9,486.60		22,825.50		45,341.00
(P=1.24m) COST PER SQUARE METER							14.35		8.39		7.65		7.36		7.31

■ Stonework Costs:

0 to 50 m^3	L.E. 12.00/m^3
50 to 200 m^3	L.E. 11.00/m^3
> 200 m^3	L.E. 9.00/m^3

Size I

FIBERGLASS REINFORCED PLASTIC

Constr. Phase	Pers'l	Equip.	Mat'l	Units	L.E. per Unit	60 m		500 m		1000 m		2500 m		5000m	
						#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.
A.)Design Costs (as for conc. pre-cast sections							115.20		250.40		426.00		858.00		1,610.00
B.)Pre-Const. Cost (as for conc. pre-cast sec.)							216.20		586.40		1,124.00		2,248.00		4,436.00
C.)Const. Costs															
i)Material			G.R.P	m^2	△	52	780.00	430	6,450.00	860	7,740.00	2150	12,900.00	4300	25,800.00
ii)Del.		4T.Tr.		hrs	7.00	3	21.00	3	21.00	3	21.00	6	42.00	6	42.00
iii)Instal.	Eng'r(G)			hrs	1.70	4	6.80	8	13.60	8	23.80	14	57.80	68	115.60
	Eng'r(P)			hrs	4.00	4	16.00	8	32.00	14	56.00	34	136.00	68	272.00
	Lab's(P)			hrs	2.40	4	9.60	8	19.20	14	33.60	34	81.60	698	163.20
	Driv.(G)			hrs	1.50	4	6.00	8	12.00	14	21.00	34	51.00	68	102.00
		Auto		km	0.20	100	20.00	300	60.00	600	120.00	1000	200.00	2000	400.00
iv)Joining	Lab's(P)			hrs	2.40	2	4.80	6	14.40	12	28.80	30	72.00	60	144.00
			Resin	kg	1.10	2	2.20	16	17.60	32	35.20	80	88.00	160	176.00
v)Outlet Const.	Lab's(P)			hrs	2.40	4	9.60	24	57.60	48	115.20	120	288.00	240	576.00

FIBERGLASS REINFORCED PLASTIC (Continued)

Constr. Phase	Pers'l	Equip.	Mat'l	Units	L.E. per Unit	60 m		500 m		1000 m		2500 m		5000m	
						#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.
D.) Intake Headbox (as for conc. pre-cast sec.)							28.30		28.30		56.60		191.50		383.00
TOTAL COST							1,235.70		7,562.50		9,801.20		17,213.90		34,219.80
(P=0.84 m) COST PER SQUARE METER							24.52		18.01		11.67		8.20		8.14

△ G.R.P. Costs:

0 to 500 m^2	L.E. 15.00/m^2
500 to 2000m^2	L.E. 9.00/m^2
2000 to 10,000m^2	L.E. 6.00/m^2
> 10,000m^2	L.E. 5.00/m^2

MEMBRANES: EXPOSED

Constr. Phase	Pers'l	Equip.	Mat'l	Units	L.E. per Unit	60 m		500 m		1000 m		2500 m		5000m	
						#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.
A.)Design Costs (as for conc. pre-cast sec.)							115.20		250.40		426.00		858.00		1,610.00
B.)Pre-Const. Costs (as for conc. pre-cast sec.)							228.20		618.40		1,188.00		2,408.00		4,756.00
C.)Const. Costs															
i)Membrane															
a)20ml PVC			Mem	m^2	3.10	105	325.50	875	2,712.50	1750	5,425.00	4,375	13,562.50	8,750	27,125.00
b)36ml hypalon			Mem	m^2	8.35	105	876.75	875	7,306.25	1750	14,612.50	4,375	36,531.25	8,750	73,062.50
c)35ml Butyl			Mem	m^2	12.20	105	1,281.00	875	10,675.00	1750	21,350.00	4,375	53,375.00	8,750	106,750.00
ii)Del.															
a)		4T.Tr.		hrs	7.00	3	21.00	3	21.00	3	21.00	3	21.00	3	21.00
b)		4T.Tr.		hrs	7.00	3	21.00	3	21.00	3	21.00	3	21.00	6	42.00
c)		4T.Tr.		hrs	7.00	3	21.00	3	21.00	3	21.00	6	42.00	6	42.00
iii)Instal.	Eng'r(G)			hrs	1.70	8	13.60	16	27.20	24	40.80	40	68.00	80	136.00
	Eng'r(P)			hrs	4.00	8	32.00	16	64.00	24	96.00	40	160.00	80	320.00
	Lab's(P)			hrs	2.40	24	57.60	120	288.00	240	576.00	500	1,200.00	1000	2,400.00
	Driv.(G)			hrs	1.50	8	12.00	16	24.00	24	36.00	40	60.00	80	120.00
		Auto		km	0.20	100	20.00	300	60.00	600	120.00	1000	200.00	2000	400.00
iv)Joining	Lab's(P)			hrs	2.40	4	9.60	20	48.00	36	86.40	80	216.00	180	432.00
v)Outlet Constr.	Lab's(P)			hrs	2.40	4	9.60	20	48.00	36	86.40	90	216.00	180	432.00

MEMBRANES: EXPOSED (Continued)

Constr. Phase	Pers'l	Equip.	Mat'l	Units	L.E. per Unit	60 m		500 m		1000 m		2500 m		5000m	
						#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.
D.) Intake Headbox (as for conc. pre-cast sec.)							28.30		28.30		56.60		191.50		383.00

		60 m	500 m	1000 m	2500 m	5000m
a) 20ml P.V.C.	TOTAL COST	872.60	4,189.80	8,158.20	19,161.00	38,135.00
P=1.02 m	COST PER SQUARE METER	14.25	8.22	8.00	7.51	7.48
b) 36ml Hypalon	TOTAL COST	1,423.85	8,783.55	17,345.70	42,129.75	84,093.50
	COST PER SQUARE METER	23.26	17.23	17.01	16.52	16.49
c) 35ml Butyl	TOTAL COST	1,828.10	12,152.30	24,083.20	58,994.50	117,781.00
	COST PER SQUARE METER	29.27	23.82	23.61	23.14	23.10

Size I

MEMBRANES: BURIED

Constr. Phase	Pers'l	Equip.	Mat'l	Units	L.E. per Unit	60 m		500 m		1000 m		2500 m		5000m	
						#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.
A.)Design Costs (as for conc. pre-cast sec.)							115.20		250.40		426.00		858.00		1,610.00
B.)Pre Const. Costs (as for conc. pre-cast sec.)							228.20		618.40		1,188.00		2,408.00		4,756.00
C.)Const. Costs															
i)Membrane															
a)10 ml PVC			Mem	m^2	2.00	165	330.00	1,350	2,700.00	2700	5,400.00	6,750	13,500.00	13,500	27,000.00
b)20 ml PVC			Mem	m^2	3.10	165	511.50	1,350	4,185.00	2700	8,370.00	6,750	20,925.00	13,500	41,850.00
c)36 ml Hypalon			Mem	m^2	8.35	165	1,377.75	1350	11,272.50	2700	22,545.00	6750	56,362.50	13,500	112,725.00
d)35 ml Butyl			Mem	m^2	12.20	165	2,013.00	1350	16,470.00	2700	32,940.00	6750	82,350.00	13,500	164,700.00
ii)Del.															
a)		4T.Tr.		hrs	7.00	3	21.00	3	21.00	3	21.00	3	21.00	6	42.00
b)		4T.Tr.		hrs	7.00	3	21.00	3	21.00	3	21.00	3	21.00	6	42.00
c)		4T.Tr.		hrs	7.00	3	21.00	3	21.00	3	21.00	6	42.00	6	42.00
d)		4T.Tr.		hrs	7.00	3	21.00	3	21.00	3	21.00	6	42.00	6	42.00
iii)Instal.	Eng'r(G)			hrs	1.70	16	27.20	32	54.40	48	81.60	80	136.00	160	272.00
	Eng'r(P)			hrs	4.00	16	64.00	32	128.00	48	192.00	80	320.00	160	640.00
	Lab's(P)			hrs	2.40	24	57.60	120	288.00	240	576.00	500	1,200.00	1000	2,400.00
	Driv.(G)			hrs	1.50	16	24.00	32	48.00	48	72.00	80	120.00	160	240.00
		Auto		km	0.20	200	40.00	600	120.00	1200	240.00	1000	200.00	2000	400.00

MEMBRANES: BURIED (Continued)

Constr. Phase	Pers'l	Equip.	Mat'l	Units	L.E. per Unit	60 m		500 m		1000 m		2500 m		5000m	
						#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.
iv)Joining	Lab's(P)			hrs	2.40	4	9.60	20	48.00	36	86.40	90	216.00	180	432.00
v)Backfill & Compact	Lab's(P)			hrs	2.40	20	48.00	100	240.00	180	432.00	400	960.00	800	1920.00
		Scoop Load.		hrs	8.00	8	64.00	20	160.00	36	288.00	80	640.00	160	1280.00
vi)Outlet Const.	Lab's(P)			hrs	2.40	4	9.60	20	48.00	36	86.40	90	216.00	180	432.00
D.)Intake Headbox (as for conc. pre-cast sec.							28.30		28.30		56.60		191.50		383.00

		60 m	500 m	1000 m	2500 m	5000m
10ml P.V.C (P=1.31m)	TOTAL COST	1,066.70	4,752.50	9,146.00	21,086.50	41,807.00
	COST PER SQUARE METER	13.57	7.26	6.98	6.44	6.38
20ml P.V.C.	TOTAL COST	1,248.20	6,237.50	12,116.00	28,511.50	56,657.00
	COST PER SQUARE METER	15.88	9.53	9.25	8.70	8.65
36ml Hypalon	TOTAL COST	2,114.45	13,325.00	26,291.00	63,870.00	127,532.00
	COST PER SQUARE METER	26.90	20.34	20.07	19.50	19.47
35ml Butyl	TOTAL COST	2,749.70	18,522.50	36,686.00	89,857.50	179,507.00
	COST PER SQUARE METER	34.98	28.28	28.01	27.44	27.40

Size I

ASPHALTIC CONCRETE

Constr. Phase	Pers'l	Equip.	Mat'l	Units	L.E. per Unit	60 m		500 m		1000 m		2500 m		5000m	
						#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.
A.)Design Costs (as per conc. pre-cast sec.)							115.20		250.40		426.00		858.00		1,610.00
B.)Pre-Const. Costs (as for conc. pre-cast sec.)							216.20		586.40		1,124.00		2,248.00		4,436.00
C.)Const. Costs															
i)Material			Asphalt	m^3	⊕	3.5	87.50	28	588.00	56	1,176.00	140	2,940.00	280	5,880.00
ii)Instal.	Eng'r(G)			hrs	1.70	8	13.60	40	68.00	70	119.00	160	272.00	320	544.00
	Eng'r(P)			hrs	4.00	8	32.00	40	160.00	70	280.00	160	640.00	320	1,280.00
	Lab's(P)			hrs	2.40	32	76.80	240	576.00	450	1,080.00	1120	2,688.00	2240	5,376.00
	Surv'(P)			hrs	2.60	8	20.80	40	104.00	70	182.00	160	416.00	320	832.00
	Driv.(G)			hrs	1.50	8	12.00	40	60.00	70	105.00	160	240.00	320	480.00
		Cat		hrs	35.00	8	280.00	40	1,400.00	70	2,450.00	160	5,600.00	320	11,200.00
		Slip form		hrs	4.00	8	32.00	40	160.00	70	280.00	160	640.00	320	1,280.00
		LowBoy		hrs	10.00	8	80.00	6	60.00	6	60.00	6	60.00	6	60.00
		4T.Tr.		hrs	7.00	8	56.00	6	42.00	6	42.00	6	42.00	6	42.00
		Auto		hrs	0.20	100	20.00	300	60.00	600	120.00	1000	200.00	2000	400.00
iii)Outlet Const.	Lab's(P)			hrs	2.40	4	9.60	24	57.60	48	115.20	120	288.00	240	576.00

ASPHALTIC CONCRETE (Continued)

Constr. Phase	Pers'l	Equip.	Mat'l	Units	L.E. per Unit	60 m		500 m		1000 m		2500 m		5000m	
						#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.
D.) Intake Const. (as for conc. pre-cast sec.)							28.30		28.30		56.60		191.50		383.00
TOTAL COST							1,080.00		4,200.70		7,615.80		17,323.50		34,379.00
(P=1.05 m) COST PER SQUARE METER							17.14		8.00		7.26		6.60		6.55

⊕ Asphaltic Concrete Costs

0 to 5 m^3	L.E. 25.00/m^3
6 to 300 m^3	L.E. 21.00/m^3
301 to 2000 m^3	L.E. 18.00/m^3
$>$ 2000 m^3	L.E. 16.00/m^3

Size I

PLASTIC SOIL CEMENT

Constr. Phase	Pers'l	Equip.	Mat'l	Units	L.E. per Unit	60 m		500 m		1000 m		2500 m		5000m	
						#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.
A.)Design Costs (as for conc.pre-cast sec. plus soil analysis)							115.20		250.40		426.00		858.00		1,610.00
ii)Soil Analysis	Eng'r(G)			hrs	1.70	30	51.00	30	51.00	60	102.00	120	204.00	240	408.00
	Tech's(G)			hrs	1.00	20	20.00	20	20.00	40	40.00	80	80.00	160	160.00
B.)Pre-Const. Costs (as for conc. pre-cast sec.)							228.20		618.40		1,188.00		2,408.00		4,756.00
i)Material			Cement	kg	●	1500	105.00	12,500	687.50	25,000	1,375.00	62,500	3,437.50	125,000	6,875.00
ii)Instal.	Eng'r(G)			hrs	1.70	8	13.60	40	68.00	70	119.00	160	272.00	320	544.00
	Eng'r(P)			hrs	4.00	8	32.00	40	160.00	70	280.00	160	640.00	320	1,280.00
	Lab's(P)			hrs	2.40	40	56.00	300	720.00	560	1,344.00	1400	3,360.00	2800	6,720.00
	Driv.(G)			hrs	1.50	8	12.00	40	60.00	70	105.00	160	240.00	320	480.00
		Cat		hrs	35.00	8	280.00	40	1,400.00	70	2,450.00	160	5,600.00	320	11,200.00
		Slip form		hrs	4.00	8	32.00	40	160.00	70	280.00	160	640.00	320	1,280.00
		LowBoy		hrs	10.00	8	80.00	6	60.00	6	60.00	6	60.00	6	60.00
		4T.Tr.		hrs	7.00	8	56.00	6	42.00	6	42.00	6	42.00	6	42.00
		Auto		km	0.20	100	20.00	300	60.00	600	120.00	1000	200.00	2000	400.00
		Soil Mixer		hrs	5.00	8	40.00	40	200.00	70	350.00	160	800.00	320	1,600.00

PLASTIC SOIL CEMENT (Continued)

Constr. Phase	Pers'l	Equip.	Mat'l	Units	L.E. per Unit	60 m		500 m		1000 m		2500 m		5000m	
						#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.
iii)Expan. Joints	Lab's(P)			hrs	2.40	4	9.60	24	57.60	48	115.20	120	288.00	240	576.00
			Bitumen	m^3	55.00	0.1	5.50	0.9	49.50	1.7	93.50	4.2	231.00	8.4	462.00
iv)Outlet Const.	Lab's(P)			hrs	2.40	4	9.60	30	72.00	60	144.00	150	360.00	300	720.00
D.)Intake Headbox (as for conc. pre-cast sec.)							28.30		28.30		56.60		191.50		383.00
				TOTAL COST			1,234.00		4,764.70		8,690.30		19,912.00		39,556.00
			(P=1.30 m)	COST PER SQUARE METER			15.82		7.33		6.68		6.12		6.08

● Cement Costs
0 to 100 — L.E. 0.08/kg (bags) delivered
1000 to 10,000 — L.E. 0.07/kg (bags) delivered
> 10,000 — L.E. 0.055/kg (bulk) delivered

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APPENDIX 2

Size 2

CONCRETE: CAST IN PLACE

Constr. Phase	Pers'l	Equip.	Mat'l	Units	L.E. per Unit	400 m		2,000 m		5,000 m		10,000 m		20,000 m	
						#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.
A.)Design Costs Site Survey Office Des. Spec's. Bidding	Eng'r(G)			hrs	1.70	66	112	114	194	190	323	360	612	700	1,190
	Surv'(G)			hrs	1.00	18	18	54	54	100	100	180	180	340	340
	Tech.(G)			hrs	1.00	48	48	96	96	170	170	320	320	620	620
	Acc't(G)			hrs	1.00	36	36	36	36	60	60	100	100	160	160
	Driv.(G)			hrs	1.50	18	27	54	81	100	150	180	270	360	540
		Auto		km	0.20	300	60	500	100	800	160	1,500	300	2,500	500
B.)Pre-Const. Costs	Eng'r(G)			hrs	1.70	40	68	160	272	360	612	680	1,156	1,300	2,210
	Eng'r(P)			hrs	4.00	40	160	160	640	360	1,440	680	2,720	1,300	5,200
	Surv'(P)			hrs	2.60	40	104	160	104	360	936	680	1,768	1,300	3,380
	Lab's(P)			hrs	2.40	160	384	640	1,536	1,440	3,456	2,740	6,576	5,300	12,720
	Driv.(G)			hrs	1.50	40	60	160	240	360	540	680	1,020	1,300	1,950
		Auto		km	0.20	200	40	800	160	1,400	280	2,500	500	3,500	700
		Cat		hrs	60.00	40	2,400	160	9,600	360	21,600	680	40,800	1,300	78,000
		Roller		hrs	4.00	16	64	64	256	144	576	270	1,080	520	2,080
		Shaper		hrs	8.00	8	64	32	256	72	576	136	1,088	260	2,080
		LowBoy		hrs	10.00	6	60	6	60	6	60	6	60	6	60
		Pumps		hrs	6.00	64	384	256	1,536	576	3,456	1,100	6,600	2,140	12,840
C.)Const. Costs			Conc.	m^3	*	100	4,500	500	17,500	1,250	43,750	2,500	81,250	5,000	162,500
		Slip form		hrs	8.00	40	320	160	1,280	360	2,880	680	5,440	1,300	10,400
		Cat		hrs	60.00	40	2,400	160	9,600	360	21,600	680	40,800	1,300	78,000
		8T.Tr.		hrs	10.00	4	40	4	40	4	40	4	40	4	40

CONCRETE: CAST IN PLACE (Continued)

Constr. Phase	Pers'l	Equip.	Mat'l	Units	L.E. per Unit	400 m		2,000 m		5,000 m		10,000 m		20,000 m	
						#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.
	Eng'r(G)			hrs	1.70	40	68	160	272	360	612	680	1,156	1,300	2,210
	Eng'r(P)			hrs	4.00	40	160	160	640	360	1,440	680	2,720	1,300	5,200
	Surv'(P)			hrs	2.60	40	104	160	416	360	936	680	1,768	1,300	3,380
	Lab's(P)			hrs	2.40	208	500	832	1,997	1,872	4,492	3,600	8,640	7,020	16,848
	Driv.(G)			hrs	1.50	40	60	160	240	360	540	680	1,020	1,300	1,950
		Auto		km	0.20	300	60	500	100	800	160	1,500	300	2,500	500
			Gates	ea.	20.00	10	200	50	1,000	125	2,500	250	5,000	500	10,000
			Bitumen	m^3	55.00	0.2	11	1	55	2.5	138	5	275	10	550
D.) Intake Headbox			Gates	ea.	100.00	1	100	1	100	2	200	4	400	8	800
			Conc.	m^3	*	0.6	27	0.6	27	1.2	54	2.4	108	4.8	216
	Lab's(P)			hrs	2.40	64	154	64	154	128	308	256	616	512	1,232
			TOTAL COST				12,793		48,642		114,145		214,683		418,396
			COST PER METER				31.98		24.32		22.83		21.47		20.92
	(PO= 3.00 m)		COST PER SQUARE METER				10.66		8.11		7.61		7.16		6.97

* Concrete Costs: See Size 1. Pre-Cast Sections.

Size 2

CONCRETE: PRE-CAST SECTIONS

Constr. Phase	Pers'l	Equip.	Mat'l	Units	L.E. per Unit	400 m		2,000 m		5,000 m		10,000 m		20,000 m	
						#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.
A.)Design Costs (as for conc. cast in place)							301		561		963		1,782		3,350
B.)Pre-Const. (as for conc.cast in place)							3,788		14,660		33,532		63,368		121,220
C.)Const. Costs															
			Conc. Sec.	ea.	▲	3,200	8,160	16,000	33,600	40,000	84,000	80,000	168,000	160,000	336,000
i)Del.		8T.Tr.		hrs	10.00	200	2,000	1,000	10,000	2,500	25,000	5,000	50,000	10,000	100,000
ii)Seal. Material			Seal. Conc.	m^3	*	6	270	28	1,260	72	3,240	144	6,480	288	12,960
iii)Instal.	Eng'r(G)			hrs	1.70	40	68	160	272	360	612	680	1,156	1,320	2,244
	Eng'r(P)			hrs	4.00	40	160	160	640	360	1,440	680	2,720	1,320	5,280
	Lab's(P)			hrs	2.40	200	480	860	2,064	2,150	5,160	4,300	10,320	8,600	10,640
	Driv.(G)			hrs	1.50	40	60	160	240	360	540	680	1,020	1,320	1,980
		Auto		km	0.20	300	60	500	100	800	160	1,500	300	2,500	500
iv)Seal. Lab'	Lab's(P)			hrs	2.40	200	480	860	2,064	2,150	5,160	4,300	10,320	8,600	20,640
v)Outlet Const.			Gates	ea.	20.00	10	200	50	1000	125	2,500	250	5,000	500	10,000
	Lab's(P)			hrs	2.40	40	96	180	432	450	1,080	900	2,160	1800	4,320

CONCRETE: PRE-CAST SECTIONS (Continued)

Constr. Phase	Pers'l	Equip.	Mat'l	Units	L.E. per Unit	400 m		2,000 m		5,000 m		10,000 m		20,000 m	
						#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.
D.) Intake Headbox (as for conc. cast in place)							281		281		562		1,124		2,248
TOTAL COST							16,404		67,174		163,949		323,750		641,382
COST PER METER							41.01		33.59		32.79		32.38		32.07
(P=3.10 m) COST PER SQUARE METER							13.23		10.83		10.58		10.44		10.34

▲ Concrete Section Costs:

< 4000	L.E. 2.55/Unit
4,000 to 10,000	L.E. 2.25/Unit
> 10,000	L.E. 2.10/Unit

CONCRETE: PRE-CAST SLABS

Constr. Phase	Pers'l	Equip.	Mat'l	Units	L.E. per Unit	400 m		2,000 m		5,000 m		10,000 m		20,000 m	
						#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.
A.)Design Costs (as for conc. cast in place)							301		561		963		1,782		3,350
B.)Pre-Const. Costs (as for conc. cast in place)							3,788		14,660		33,532		63,368		121,220
C.)Const. Costs															
i)Material			Slabs	Unit	●	20,800	7,696	104,000	38,480	260,000	96,000	520,000	192,400	1,040,000	384,800
			Seal. Conc.	m³	*	4.2	210	21	945	52	2,340	105	4,725	210	9,450
ii)Del.		8T.Tr.		hrs	10.00	176	1,760	880	8,800	2,200	22,000	4,400	44,000	8,800	88,000
iii)Instal.	Eng'r(G)			hrs	1.70	40	68	160	272	360	612	680	1,156	1,320	2,244
	Eng'r(P)			hrs	4.00	40	160	160	640	360	1,440	680	2,720	1,320	5,280
	Lab's(P)			hrs	2.40	600	1,440	2,580	6,192	6,400	15,360	12,800	30,720	25,600	61,440
	Driv.(G)			hrs	1.50	40	60	160	240	360	540	680	1,020	1,320	1,980
		Auto		km	0.20	300	60	500	100	800	160	1,500	300	2,500	500
iv)Seal.	Lab's(P)			hrs	2.40	300	720	1,260	3,024	3,120	7,488	6,240	14,976	12,480	29,952
v)Outlet Const.			Conc.	m³	*	0.5	25	2.5	125	6.3	284	13	585	25	1,125
			Gates	Unit	20.00	10	200	50	1,000	125	2,500	250	5,000	500	10,000
	Lab's(P)			hrs	2.40	40	96	180	432	450	1,080	900	2,160	1,800	4,320

CONCRETE: PRE-CAST SLABS (Continued)

Constr. Phase	Pers'l	Equip.	Mat'l	Units	L.E. per Unit	400 m		2,000 m		5,000 m		10,000 m		20,000 m	
						#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.
D.) Intake Headbox (as for conc. cast in place)							281		281		562		1,124		2,248
TOTAL COST							16,865		75,752		185,061		366,036		725,909
COST PER METER							42.16		37.88		37.01		36.60		36.30
(P = 3.10 m) COST PER SQUARE METER								13.60		12.22		11.94		11.81	
11.71															

Slab Costs: 10,000 L.E. 0.45/Unit
10,000 to 20,000 L.E. 0.40/Unit
20,000 L.E. 0.35/Unit

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Size 2

STONEWORK

Constr. Phase	Pers'l	Equip.	Mat'l	Units	L.E. per Unit	400 m		2,000 m		5,000 m		10,000 m		20,000 m	
						#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.
A.)Design Costs (as for conc. cast in place)							301		562		963		1,783		3,350
B.)Pre-Const. Costs (as for conc. cast in place)							3,788		14,660		33,532		63,368		121,220
C.)Const. Costs															
i)Material			Rock	m^3	9.00	345	3,105	1,725	15,525	4,313	38,871	8,625	77,625	17,250	155,250
			Conc.	m^3	*	32	1,440	160	7,200	400	14,000	800	28,000	1,600	56,000
ii)Del.		8T.Tr.		hrs	10.00	276	2,760	1,300	13,000	3,100	31,000	6,100	61,000	12,200	122,000
iii)Instal.	Eng'r(G)			hrs	1.70	40	68	160	272	360	612	680	1,156	1,320	2,244
	Eng'r(P)			hrs	4.00	40	160	160	640	360	1,440	680	2,720	1,320	5,280
	Lab's(P)			hrs	2.40	960	2,304	4,600	11,040	11,500	27,600	23,000	55,200	46,000	110,400
	Driv.(G)			hrs	1.50	40	60	160	240	360	540	680	1,020	1,320	1,980
		Auto		km	0.20	300	60	500	100	800	160	1,500	300	2,500	500
iv)Outlet Const.			Gates	Unit	20.00	10	200	50	500	125	2,500	250	5,000	500	10,000
	Lab's(P)			hrs	2.40	30	72	120	288	280	672	540	1,236	1,080	2,592

Toc

STONEWORK (Continued)

Constr. Phase	Pers'l	Equip.	Mat'l	Units	L.E. per Unit	400 m		2,000 m		5,000 m		10,000 m		20,000 m	
						#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.
D.) Intake Headbox (as for conc. cast in place)							281		281		562		1,124		2,248
TOTAL COST							14,599		64,308		152,398		299,591		593,064
COST PER METER							36.50		32.15		30.48		29.96		29.65
(P=4.0m) COST PER SQUARE METER							9.12		8.04		7.62		7.49		7.41

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Size 2

FIBERGLASS REINFORCED PLASTIC

Constr. Phase	Pers'l	Equip.	Mat'l	Units	L.E. per Unit	400 m		2,000 m		5,000 m		10,000 m		20,000 m	
						#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.
A.)Design Costs (as for conc. cast in place)							301		561		963		1,782		3,350
B.)Pre-Const. Costs (as for conc. cast in place)							3,788		14,660		35,532		63,368		121,220
C.)Const. Costs i)Material			Mol'd. Sec't.	m^2	Δ	1,150	13,225	5,750	50,313	14,375	118,594	28,750	237,188	57,500	474,375
			Resin	kg	1.10	40	44	200	220	500	550	1,000	1,100	2,000	2,200
ii)Del		8T.Tr.		hrs	10.00	5	50	15	150	35	350	70	700	140	1,400
iii)Instal.	Eng'r(G)			hrs	1.70	16	27	64	108	144	245	270	459	520	884
	Eng'r(P)			hrs	4.00	16	64	64	256	144	576	270	1,080	520	2,080
	Lab's(P)			hrs	2.40	24	58	110	264	264	634	488	1,171	960	2,304
	Driv.(G)			hrs	1.50	16	24	64	96	144	216	270	405	520	780
		Auto		km	0.20	200	40	400	80	700	140	1,200	240	2,000	400
iv)Outlet Const.			Gates	Unit	20.00	10	200	50	1,000	125	2,500	250	5,000	500	10,000
			Fiber-Glass	m^2	1.40	2	3	10	14	25	35	50	70	100	140
			Resin	kg	1.10	10	11	50	55	125	138	250	275	500	550
	Lab's(P)			hrs	2.40	40	96	180	432	430	1,032	780	1,872	1,520	3,648

FIBERGLASS REINFORCED PLASTIC (Continued)

Constr. Phase	Pers'l	Equip.	Mat'l	Units	L.E. per Unit	400 m		2,000 m		5,000 m		10,000 m		20,000 m	
						#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.
D.) Intake Headbox (as for conc. cast in place)							281		281		562		1.124		2,248
TOTAL COST							18,212		68,490		160,067		315,834		625,579
COST PER METER							45.53		34.25		32.01		31.58		31.28
(P=2.8m) COST PER SQUARE METER							16.26		12.23		11.43		11.28		11.17

Molded G.R.P. Section Costs:
(4mm thick)

0 to 500 m^2	L.E. 19.25/m^2
500 to 2000 m^2	L.E. 11.50/m^2
2000 to 10,000 m^2	L.E. 8.75/m^2
> 10,000m^2	L.E. 8.25/m^2

Size 2

MEMBRANES: EXPOSED

Constr. Phase	Pers'l	Equip.	Mat'l	Units	L.E. per Unit	400 m		2,000 m		5,000 m		10,000 m		20,000 m	
						#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.
A.)Design Costs (as for conc. cast in place)							301		561		963		1,782		3,350
B.)Pre-Const. Costs (as for conc. cast in place)							3,788		14,660		33,532		63,368		121,220
C.)Const. Costs															
i)Membrance															
a.20ml PVC			Mem	m^2	3.10	1,720	5,332	8,580	26,598	21,400	66,340	42,800	132,680	85,600	265,360
b.36ml Hypalon			Mem	m^2	8.35	1,720	14,362	8,580	71,643	21,400	178,690	42,800	357,380	85,600	714,760
c.35ml Butyl			Mem	m^2	12.20	1,720	20,984	8,580	104,676	21,400	261,400	42,800	522,160	85,600	1,044,320
ii)Del.															
a.		8T.Tr.		hrs	10.00	3	30	3	30	6	60	9	90	21	210
b.		8T.Tr.		hrs	10.00	3	30	6	60	12	120	24	240	45	450
c.		8T.Tr.		hrs	10.00	3	30	6	60	12	120	24	240	45	450
iii)Instal.	Eng'r(G)			hrs	1.70	40	68	160	272	360	612	680	1,156	1,320	2,244
	Eng'r(P)			hrs	4.00	40	160	160	640	360	1,440	680	2,720	1,320	5,280
	Lab's(P)			hrs	2.40	70	168	320	768	780	1,872	1,560	3,744	3,120	7,488
	Driv.(G)			hrs	1.50	40	60	160	240	360	540	680	1,020	1,320	1,980
		Auto		km	0.20	300	60	500	100	800	160	1,500	300	2,500	500

MEMBRANES: EXPOSED (Continued)

Constr. Phase	Pers'l	Equip.	Mat'l	Units	L.E. per Unit	400 m		2,000 m		5,000 m		10,000 m		20,000 m	
						#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.
iv)Outlet Const. a.Material			Gates	Unit	20.00	10	200	50	1,000	125	2,500	250	5,000	500	10,000
			Bricks	Unit	▼	1000	45	5000	225	12,500	500	25,000	1,000	50,000	2,000
			Conc.	M^3	*	0.45	23	2.25	113	5.5	248	11	495	22	990
	Lab's(P)			hrs	2.40	20	48	80	192	180	432	340	816	680	1,632
D.) Intake Headbox as for conc. cast in place)							281		281		562		1,124		2,248

			400 m	2,000 m	5,000 m	10,000 m	20,000 m
a)	20 ml P.V.C	TOTAL COST	10,564	45,680	109,761	215,295	424,502
	(P=3.20m)	COST PER SQUARE METER	8.25	7.14	6.86	6.73	6.63
b)	36 ml Hypalon	TOTAL COST	19,594	90,755	222,171	440,145	874,142
	(P=3.20m)	COST PER SQUARE METER	15.31	14.18	13.89	13.75	13.66
c)	35 ml Butyl	TOTAL COST	26,216	123,788	304,561	604,925	1,203,702
	(P=3.20m)	COST PER SQUARE METER	20.48	19.34	19.04	18.90	18.81

▼ Brick Costs

▼ Brick Costs	0 to 10,000	L.E. 0.045 each
	10,000 to 50,000	L.E. 0.040 each
	> 50,000	L.E. 0.035 each

MEMBRANES: BURIED

Constr. Phase	Pers'l	Equip.	Mat'l	Units	L.E. per Unit	400 m		2,000 m		5,000 m		10,000 m		20,000 m	
						#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.
A.)Design Costs (as for conc. cast in place)							301		561		963		1,782		3,350
B.)Pre-Const. Costs (as for conc. cast in place)							3,788		14,660		33,532		63,368		121,220
C.)Const. Costs															
i)Membrane															
a) 10ml PVC			Mem	m^2	2.00	2,570	5,140	12,830	25,660	32,060	64,120	64,100	128,200	128,100	256,200
b) 20ml PVC			Mem	m^2	3.10	2,570	7,967	12,830	39,773	32,060	89,386	64,100	198,710	128,100	397,110
c) 36 ml Hypalon			Mem	m^2	8.35	2,570	21,459	12,830	107,130	32,060	267,701	64,100	535,235	128,100	1,069,635
d) 35 ml Butyl			Mem	m^2	12.20	2,570	31,354	12,830	156,526	32,060	391,132	64,100	782,020	128,100	1,562,820
ii)Del															
a)		8T.Tr.		hrs	10.00	3	30	3	30	6	60	9	90	15	150
b)		8T.Tr.		hrs	10.00	3	30	30	30	9	90	15	150	27	270
c)		8T.Tr.		hrs	10.00	3	30	9	90	18	180	36	360	69	690
d)		8T.Tr.		hrs	10.00	3	30	6	60	15	150	30	300	57	570
iii)Instal.	Eng'r(G)			hrs	1.70	40	68	160	272	360	612	680	1,156	1,320	2,244
	Eng'r(P)			hrs	4.00	40	160	160	640	360	1,440	680	2,720	1,320	5,280
	Lab's(P)			hrs	2.40	70	168	320	768	780	1,872	1,560	3,744	3,120	7,488
	Driv.(G)			hrs	1.50	40	60	160	240	360	540	680	1,020	1,320	1,980
		Auto		km	0.20	300	60	500	100	800	160	1,500	300	2,500	500

MEMBRANES: BURIED (Continued)

Constr. Phase	Pers'l	Equip.	Mat'l	Units	L.E. per Unit	400 m		2,000 m		5,000 m		10,000 m		20,000 m	
						#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.
iv)Backfill & Compact.	Lab's(P)			hrs	2.40	60	144	280	672	700	1,680	1,400	3,360	2,800	6,720
		Loader		hrs	8.00	40	320	180	1,440	480	3,840	960	7,680	1,920	15,360
		Lowboy		hrs	10.00	4	40	4	40	8	80	16	160	32	320
		Vibrat. Comp's		hrs	3.00	60	180	280	840	700	2,100	1,400	4,200	2,800	8,400
v)Outlet Const. (as for membranes exposed)							316		1,530		3,680		7,311		14,622
D.)Intake Headbox (as for conc. cast in place)							281		281		562		1,124		2,248

			400 m	2,000 m	5,000 m	10,000 m	20,000 m
a)	10 ml P.V.C	TOTAL COST	11,056	47,734	115,241	226,215	446,082
	(P=4.01 m)	COST PER SQUARE METER	6.89	5.95	5.75	5.64	5.56
b)	20 ml P.V.C	TOTAL	13,883	61,847	150,537	296,785	587,112
	(P=4.01 m)	COST PER SQUARE METER	8.66	7.71	7.51	7.40	7.32
c)	36 ml Hypalon	TOTAL COST	27,375	129,264	318,942	633,520	1,260,057
	(P=4.01 m)	COST PER SQUARE METER	17.07	16.12	15.91	15.80	15.71
d)	35 ml Butyl	TOTAL COST	37,270	178,630	442,343	880,245	1,753,122
	(P-4.01 m)	COST PER SQUARE METER	23.24	22.27	22.06	21,95	21,86

Size 2

ASPHALTIC CONCRETE

Constr. Phase	Pers'l	Equip.	Mat'l	Units	L.E. per Unit	400 m		2,000 m		5,000 m		10,000 m		20,000 m	
						#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.
A.)Design Costs (as for conc. cast in place)							301		561		963		1,782		3,350
B.)Pre-Const. Costs (as for conc. cast in place)							3,788		14,660		33,532		63,368		121,220
C.)Const. Costs															
i)Material			Asphalt	M^3	⊕	110	2,310	550	9,900	1,360	24,480	2,720	43,520	5,440	87,040
ii)Del.		8T.Tr.		hrs	10.00	186	1,860	900	9,000	2,200	22,000	4,400	44,000	8,800	88,000
iii)Instal.		Slip form		hrs	8.00	40	320	180	1,440	450	3,600	900	7,200	1,800	14,400
		Cat		hrs	60.00	40	2,400	180	10,800	450	27,000	900	54,000	1,800	108,000
		8T.Tr.		hrs	10.00	4	40	4	40	8	80	16	160	32	320
	Eng'r(G)			hrs	1.70	40	68	180	306	450	765	900	1,530	1,800	3,060
	Eng'r(P)			hrs	4.00	40	160	180	720	450	1,800	900	3,600	1,800	7,200
	Lab's(P)			hrs	2.40	160	384	720	4,128	1,800	4,320	3,600	8,640	7,200	17,280
	Driv.(G)			hrs	1.50	40	60	180	270	450	675	900	1,350	1,800	2,700
		Auto		km	0.20	300	60	500	100	800	160	1,500	300	2,500	500
iv)Outlet Const. (as for membranes exposed)							316		1,530		3,680		7,311		14,622

ASPHALTIC CONCRETE (Continued)

Constr. Phase	Pers'l	Equip.	Mat'l	Units	L.E. per Unit	400 m		2,000 m		5,000 m		10,000 m		20,000 m	
						#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.
D.) Intake Headbox (as for conc. cast in place)							281		281		562		1,124		2,248
TOTAL COST							12,348		53,736		123,617		237,885		469,940
(P=3.4m) COST PER SQUARE METER							9.08		7.90		7.27		7.00		6.31

Size 2

SOIL CEMENT

Constr. Phase	Pers'l	Equip.	Mat'l	Units	L.E. per Unit	400 m		2,000 m		5,000 m		10,000 m		20,000 m	
						#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.
A.)Design Costs (as for conc. cast in place)							301		561		963		1,782		3,350
Add. Soil Analysis	Eng'r(G)			hrs	1.70	40	68	180	306	420	714	800	1,360	1,600	2,720
	Tech.(G)			hrs	1.00	40	40	180	180	420	420	800	800	1,600	1,600
B.)Pre-Const. Cost (as for conc. cast in place)							3,788		14,660		33,532		63,368		121,220
C.)Const. Costs															
i)Material			Cement	kg	●	400.00	2,200	19.2500	10,580	48.1250	26,470	96.2500	52,940	192.5000	105,875
ii)Del.		8T.Tr.		hrs	10.00	40	400	192	1,920	481	4,810	962	9,620	1,925	19,250
iii)Instal.															
a. Mixing		1m³ Mixer		hrs	5.00	40	200	180	900	420	2,100	800	4,000	1,600	8,000
		Excav. Conv'.		hrs	6.00	40	240	180	1,080	420	2,520	800	4,800	1,600	9,600
b. Place-ment		Slip form		hrs	8.00	40	320	180	1,440	420	3,360	800	6,400	1,600	12,800
		Cat		hrs	60.00	40	2,400	180	10,800	420	25,200	800	48,000	1,600	96,000
		8T.Tr.		hrs	10.00	4	40	4	40	8	80	16	160	32	320

Size 2

SOIL CEMENT (Continued)

Constr. Phase	Pers'l	Equip.	Mat'l	Units	L.E. per Unit	400 m		2,000 m		5,000 m		10,000 m		20,000 m	
						#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.
	Eng'r(G)			hrs	1.70	40	68	160	272	360	612	680	1,156	1,300	2,210
	Eng'r(P)			hrs	4.00	40	160	160	640	360	1,440	680	2,720	1,300	5,200
	Lab's(P)			hrs	2.40	240	576	1,000	2,400	2,200	5,280	4,200	10,080	8,400	20,160
	Driv.(G)			hrs	1.50	40	60	160	240	360	540	680	1,020	1,300	1,950
		Auto		hrs	0.20	300	60	500	100	800	160	1,500	300	2,500	500
	Sur'y(P)			hrs	1.00	40	40	160	160	360	360	680	680	1,300	1,300
c. Expan. Joints	Lab's(P)			hrs	2.40	8	19	34	82	80	192	250	360	300	720
			Bitomen	m^3	55.00	0.25	14	1.25	69	3.1	170	6.3	347	12.5	688
iv)Outlet Const.			Gates	Unit	20.00	10	200	50	1,000	125	2,500	250	5,000	500	10,000
	Lab's(P)			hrs	2.40	40	96	160	384	360	864	680	1,632	1,300	3,120
D. Intake Headbox (as for conc. cast in place)							281		281		562		1,124		2,248
			TOTAL COST				11,571		48,095		112,849		217,649		428,831
		(P=4.00m)COST PER SQUARE METER					7.23		6.01		5.64		5.44		5.36

- Cement Costs:

Cement Costs:	0 to 1000 kg	L.E. 0.08/kg
	1000 to 10,000kg	L.E. 0.07/kg
	> 10,000 kg	L.E. 0.055/kg

APPENDIX 3

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Size 3

CONCRETE: CAST IN PLACE (Reinforced)

Constr. Phase	Pers'l	Equip.	Mat'l	Units	L.E. per Unit	1000 m (1 canal)		2,500 m (1 canal)		5,000 m (2 canals)		10,000 m (4-5 canals)		20,000 m	
						#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.
A.)Design Costs Site Survey Off. Design Spec.'s															
Bidding	Eng'r(G)			hrs	1.70	126	214	196	333	328	558	640	1,088		
	Sur'y(G)			hrs	1.00	54	54	100	100	180	180	360	360		
	Tech.(G)			hrs	1.00	102	102	196	196	278	278	540	540		
	Acc't(G)			hrs	1.00	48	48	60	60	100	100	200	200		
	Driv.(G)			hrs	1.50	54	81	100	150	180	270	360	540		
		Auto		km	0.20	500	100	1,000	200	1,750	350	2,500	500		
B.)Pre-Const.															
Cost	Eng'r(G)			hrs	1.70	240	408	400	680	720	1,224	1,440	2,448		
	Eng'r(P)			hrs	4.00	240	960	400	1,600	720	2,880	1,440	5,760		
	Sur'y(P)			hrs	2.60	240	624	400	1,040	720	1,872	1,440	3,744		
	Lab's(P)			hrs	2.40	1,440	5,760	2,400	9,600	4,320	17,280	8,640	34,560		
	Driv.(G)			hrs	1.50	240	360	400	600	720	1,080	1,440	2,160		
		Auto		km	0.20	1,200	240	2,000	400	3,600	720	7,200	1,440		
		Cat		hrs	60.00	240	14,400	640	38,400	1,152	69,120	2,304	138,240		
		Roller		hrs	8.00	96	768	160	1,280	288	2,304	576	4,608		
		Shaper		hrs	16.00	48	768	80	1,280	144	2,304	288	4,608		
		LowBoy		hrs	10.00	12	120	12	120	24	240	48	480		
		Pumps		hrs	6.00	1,200	7,200	2,000	12,000	3,600	21,600	7,200	43,200		
C.)Const.															
Costs	Eng'r(G)			hrs	1.70	100	170	220	374	400	680	800	1,360		
	Eng'r(P)			hrs	2.40	100	240	220	528	400	960	800	1,920		
	Sur'y(P)			hrs	2.60	100	260	220	572	400	1,040	800	2,080		

CONCRETE: CAST IN PLACE (Reinforced)(Continued)

Constr. Phase	Pers'l	Equip.	Mat'l	Units	L.E. per Unit	1,000 m		2,500 m		5,000 m		10,000 m		20,000 m	
						#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.
	Driv.(P)			hrs	1.50	100	150	220	330	400	600	800	1,200		
	Lab's(P)			hrs	2.40	1,656	3,974	3,940	9,456	7,880	18,912	15,760	37,824		
		Auto		km	0.20	600	120	1,000	200	2,000	400	4,000	800		
			Conc.	m^3	*	876	30,660	2,190	71,175	4,380	142,350	8,760	284,700		
			Gates	Unit	100.00	10	1,000	25	2,500	50	5,000	100	10,000		
			Bitumen	m^3	55.00	0.90	50	2.3	127	4.6	253	9.2	506		
			Reinf.	Tons	420.00	44	18,480	109	45,780	218	91,560	435	182,700		
		Slip form		hrs	60.00	90	5,400	220	13,200	400	24,000	800	48,000		
		Cat		hrs	60.00	90	5,400	220	13,200	400	24,000	800	48,000		
		8T.Tr.		hrs	10.00	56	560	128	1,280	256	2,560	496	4,960		
D.) Intake Headbox	Lab's(P)			hrs	2.40	160	384	160	384	320	768	640	1,536		
			Gates	Unit	200.00	4	800	4	800	8	1,600	16	3,200		
			Conc.	m^3	*	15	525	15	525	30	1,050	60	2,100		
			Reinf.	Tons	420.00	1	420	1	420	2	840	4	1,680		
		TOTAL COST					100,800		228,890		438,933		868,526	≈	1,734,000
(P=8.7m)COST PER SQUARE METER							11.59		10.52		10.09		9.98		≈ 9.97

* Concrete:

0 to 5 m^3	L.E. 50.00/m^3
6 to 300m^3	L.E. 45.00/m^3
300 to 2000m^3	L.E. 35.00/m^3
> 2000m^3	L.E. 32.50/m^3

CONCRETE: PRE-CAST SECTIONS

Constr. Phase	Pers'l	Equip.	Mat'l	Units	L.E. per Unit	1,000 m		2,500 m		5,000 m		10,000 m		20,000 m	
						#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.
A.)Design Costs (as for conc. cast in place)							600		1,040		1,740		3,230		
B.)Pre-Const. Cost (as for conc. cast in place)							31,610		67,000		120,620		241,250		
C.)Const. Costs															
i)Conc. Sections			Sect.	Unit	17.50	6000	105,000	15,000	262,500	30,000	525,000	60,000	1,050,000		
ii)Seal. Concrete			Conc.	m^3	*	45	2,025	112	5,040	225	10,125	450	15,750		
iii)Del.		8T.Tr.		hrs	10.00	1,720	17,200	4,300	43,000	8,600	86,000	17,200	172,000		
Del. & Instal.		1T.Cr.		hrs	15.00	1,030	15,450	2,575	38,625	5,150	77,250	10,300	154,500		
iv)Instal.	Eng'r(G)			hrs	1.70	150	255	330	561	600	1,020	1,200	2,040		
	Eng'r(P)			hrs	4.00	150	600	330	1,320	600	2,400	1,200	4,800		
	Lab's(P)			hrs	2.40	2,400	5,760	5,800	13,920	11,600	27,840	23,200	55,680		
	Driv.(G)			hrs	1.50	150	225	330	495	600	900	1,200	1,800		
		Auto		km	0.20	1,500	300	2,500	500	4,500	900	9,000	1,800		

CONCRETE: PRE-CAST SECTIONS (Continued)

Constr. Phase	Pers'l	Equip.	Mat'l	Units	L.E. per Unit	1,000 m		2,500 m		5,000 m		10,000 m		20,000 m	
						#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.
v)Seal. Labor	Lab's(P)			hrs	2.40	200	480	380	912	740	1,776	1,480	3,552		
vi)Outlet Const. (as for cast in place)			Gates	Unit	100.00	10	1,000	25	2,500	50	5,000	100	10,000		
			Conc.	m^3	*	5.5	248	14	630	28	1,260	55	1,925		
	Lab's(P)			hrs	2.40	640	1,536	1,500	3,600	2,850	6,840	5,700	13,680		
D.) Intake Headbox (as for conc. cast in place)							2,130		2,130		4,260		8,520		
TOTAL COST							184,418		443,773		872,931		1,740,527		≃ 3,478,000
(P=9.3m) COST PER SQUARE METER							19.83		19.09		18.77		18.72		≃ 18.70

CONCRETE: PRE-CAST SLABS

Constr. Phase	Pers'l	Equip.	Mat'l	Units	L.E. per Unit	1,000 m #Units	1,000 m Total L.E.	2,500 m #Units	2,500 m Total L.E.	5,000 m #Units	5,000 m Total L.E.	10,000 m #Units	10,000 m Total L.E.	20,000 m #Units	20,000 m Total L.E.
A.)Design Cost (as for conc. cast in place)							600		1,040		1,740		3,230		
B. Pre-Const. Costs (as for conc. cast in place)							31,610		67,000		120,620		241,250		
C.)Const. Costs															
i)Material			Slabs	Unit	0.62	152,000	94,240	380,000	235,600	760,000	471,200	1,520,000	942,400		
			Seal. Conc.	m^3	*	47	2,115	114	5,130	228	10,260	456	20,520		
ii)Del.		8T.Tr.		hrs	10.00	2,096	20,960	5,240	52,400	10,480	104,800	20,960	209,600		
iii)Instal.	Eng'r(G)			hrs	1.70	150	255	330	561	600	1,020	1,200	2,040		
	Eng'r(P)			hrs	4.00	150	600	330	1,320	600	2,400	1,200	4,800		
	Lab's(P)			hrs	2.40	8,450	20,280	21,000	50,400	42,000	100,800	84,000	201,600		
	Driv.(G)			hrs	1.50	150	225	330	495	600	900	1,200	1,800		
		Auto		km	0.20	1,500	300	2,500	500	4,500	900	9,000	1,800		
iv)Sealing	Lab's(P)			hrs	2.40	1,000	2,400	2,300	5,520	4,500	10,800	9,000	21,600		
v)Outlet Const. (as for conc. cast in place)							2,784		6,730		13,100		25,605		

CONCRETE: PRE-CAST SLABS (Continued)

Constr. Phase	Pers'l	Equip.	Mat'l	Units	L.E. per Unit	1,000 m		2,500 m		5,000 m		10,000 m		20,000 m	
						#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.
D.) Intake Headbox (as for conc. cast in place)							2,130		2,130		4,260		8,520		
TOTAL COST							178,499		428,826		842,800		1,684,765		
(P=9.3m) COST PER SQUARE METER							19.19		18.44		18.12		18.12	≃	18.12

Size 3

CONCRETE LINED BRICKS

Constr. Phase	Pers'l	Equip.	Mat'l	Units	L.E. per Unit	1,000 m		2,500 m		5,000 m		10,000 m		20,000 m	
						#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.
A.)Design Costs (as for conc. cast in place)							600		1,040		1,740		3,230		
B.)Pre-Const. Costs (as for conc. cast in place)							31,610		67,000		120,620		241,250		
C.)Const. Costs i)Material			Bricks	Unit	0.035	280,000	9,800	700,000	24,500	1,400,000	49,000	2,800,000	98,000		
			Sand												
			Cement	m^3	*	213	9,585	530	18,550	1,060	37,100	2,120	68,900		
ii)Del.		8T.Tr.		hrs	10.00	560	5,600	1,400	14,000	2,800	28,000	5,600	56,000		
iii)Instal.	Eng'r(G)			hrs	1.70	200	340	460	782	900	1,530	1,800	3,060		
	Eng'r(P)			hrs	4.00	200	800	460	1,840	900	3,600	1,800	7,200		
	Lab's(P)			hrs	2.40	4,670	11,208	11,500	27,600	22,600	54,240	45,200	108,480		
	Driv.(G)			hrs	1.50	200	300	460	690	900	1,350	1,800	2,700		
		Auto		km	0.20	1,000	200	2,000	400	3,600	720	7,200	1,440		
iv)Lining	Lab's(P)			hrs	2.40	3,480	8,352	8,500	20,400	16,800	40,320	33,600	80,640		
v)Outlet Const. (as for conc. cast in place)							2,784		6,730		13,100		25,605		

CONCRETE LINED BRICKS (Continued)

Constr. Phase	Pers'l	Equip.	Mat'l	Units	L.E. per Unit	1,000 m		2,500 m		5,000 m		10,000 m		20,000 m	
						#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.
D.) Intake Headbox							2,130		2,130		4,260		8,520		
			TOTAL COST				83,309		185,662		355,580		705,025	≃	1,410,000
			(P=8.7m) COST PER SQUARE METER				9.58		8.54		8.17		8.10	≃	8.10

Size 3

STONEWORK

Constr. Phase	Pers'l	Equip.	Mat'l	Units	L.E. per Unit	1,000 m		2,500 m		5,000 m		10,000 m		20,000 m	
						#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.
A.)Design Costs (as for conc. cast in place)							600		1,040		1,740		3,280		
B.)Pre-Const. Costs (as for conc. cast in place)							31,610		67,000		120,620		241,250		
C.)Const. Costs															
i)Material			Rock	m^3	9.00	2,430	21,870	6,075	54,675	12,150	109,350	24,300	218,700		
			Sand												
			Cement	m^3	*	227	10,215	560	19,600	1,120	39,200	2,240	72,800		
ii)Del.		8T.Tr.		hrs	10.00	1,952	19,520	4,800	48,000	9,400	94,000	18,800	188,000		
iii)Instal.	Eng'r(G)			hrs	1.70	240	408	400	680	720	1,224	1,440	2,448		
	Eng'r(P)			hrs	4.00	240	960	400	1,600	720	2,880	1,440	5,760		
	Lab's(P)			hrs	2.40	6,800	16,320	16,000	38,400	29,000	69,600	58,000	139,200		
	Driv.(G)			hrs	1.50	240	360	400	600	720	1,080	1,440	2,160		
		Auto		km	0.20	1,200	240	2,200	440	3,600	720	7,200	1,440		
iv)Outlet Const (as for conc. cast in place)							2,784		6,730		13,100		25,605		

STONEWORK (Continued)

Constr. Phase	Pers'l	Equip.	Mat'l	Units	L.E. per Unit	1,000 m		2,500 m		5,000 m		10,000 m		20,000 m	
						#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.
D) Intake Headbox (as for conc. cast in place)							2,130		2,130		4,260		8,520		
			TOTAL COST				107,017		240,895		457,774		909,113		≃ 1,812,000
		(P=11.35m)	COST PER SQUARE METER				9.43		8.49		8.07		8.01		≃ 7.98

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FIBERGLASS REINFORCED PLASTIC

Constr. Phase	Pers'l	Equip.	Mat'l	Units	L.E. per Unit	1,000 m		2,500 m		5,000 m		10,000 m		20,000 m	
						#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.
A.)Design Costs (as for conc. cast in place)							600		1,040		1,740		3,230		
B.)Pre-Const. Costs (as for conc. cast in place)							31,610		67,000		120,620		241,250		
C.)Const. Costs															
i)Material			G.R.P.	m^2	16.00	7,9720	127,520	19,925	318,800	39,850	637,600	79,700	1,275,200		
			Resin	kg	1.10	300	330	750	825	1,500	1,650	3000	3,300		
ii)Del.		8T.Tr.		hrs	10.00	40	400	100	1,000	200	2,000	400	4,000		
		Crane		hrs	10.00	16	160	40	400	80	800	160	1,600		
iii)Instal.	Eng'r(G)			hrs	1.70	40	68	90	153	160	272	320	544		
	Eng'r(P)			hrs	4.00	40	160	90	360	160	640	320	1,280		
	Lab's(P)			hrs	2.40	160	384	380	912	720	1,728	1,440	3,456		
	Driv.(G)			hrs	1.50	40	60	90	135	160	240	320	480		
		Auto		km	0.20	1,000	200	2,200	440	3,600	720	7,200	1,440		
		Crane		hrs	10.00	40	400	90	900	160	1,600	320	3,200		
iv)Outlet Const.			Gates	Unit	100.00	10	1,000	25	2,500	50	5,000	100	10,000		
			Fiber-Glass	m^2	1.40	70	98	175	245	350	490	700	980		
			Resin	kg	1.10	40	44	100	110	200	220	400	440		
	Lab's(P)			hrs	2.40	160	384	380	912	720	1,728	1,440	3,456		

Size 3

FIBERGLASS REINFORCED PLASTIC (Continued)

Constr. Phase	Pers'l	Equip.	Mat'l	Units	L.E. per Unit	1,000 m		2,500 m		5,000 m		10,000 m		20,000 m	
						#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.
D.) Intake Headbox (as for conc. cast in place)							2,130		2,130		4,260		8,520		
TOTAL COST							165,548		397,862		781,308		1,562,376		
(P=7.8m) COST PER SQUARE METER							21.22		20.40		20.03		20.03		≃ 20.03

MEMBRANES EXPOSED

Constr. Phase	Pers'l	Equip.	Mat'l	Units	L.E. per Unit	1,000 m		2,500 m		5,000 m		10,000 m		20,000 m	
						#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.
A.) Design Costs (as for conc. cast in place)							600		1,040		1,740		3,230		
B.) Pre-Const. Costs (as for conc. cast in place)							31,610		67,000		120,620		241,250		
C.) Const. Costs															
i) Membrane															
a) 20 ml PVC			Mem	m^2	3.10	11,840	36,704	29,600	91,760	59,200	183,520	118,400	367,040		
b) 36 ml Hypalon			Mem	m^2	8.35	11,840	98,864	29,600	247,160	59,200	494,320	118,400	988,640		
c) 35 ml Butyl			Mem	m^2	12.20	11,840	144,448	29,600	361,120	59,200	722,240	118,400	1,444,480		
ii) Del.															
a)		8T.Tr.		hrs	10.00	3	30	9	90	18	180	36	360		
b)		8T.Tr.		hrs	10.00	9	90	27	270	54	540	108	1,080		
c)		8T.Tr.		hrs	10.00	6	60	18	180	36	360	72	720		
iii) Instal.	Eng'r(G)			hrs	1.70	80	136	180	306	320	544	640	1,088		
	Eng'r(P)			hrs	4.00	80	320	180	720	320	1,280	640	2,560		
	Lab's(P)			hrs	2.40	180	432	420	1,008	800	1,920	1,600	3,840		
	Driv.(G)			hrs	1.50	80	120	180	270	320	480	640	960		
		Auto		km	0.20	1,500	300	2,500	500	4,000	800	7,200	1,440		

Size 3

MEMBRANES EXPOSED (Continued)

Constr. Phase	Pers'l	Equip.	Mat'l	Units	L.E. per Unit	1,000 m		2,500 m		5,000 m		10,000 m		20,000 m	
						#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.
iv)Outlet Const. (as for conc. cast in place)							2,784		6,730		13,100		25,605		
D.)Intake Headbox (as for conc. cast in place)							2,130		2,130		4,260		8,520		

			1,000 m	2,500 m	5,000 m	10,000 m	20,000 m
(P=9.45m^2)	a.) 20 ml P.V.C:	TOTAL COST	75,316	172,004	329,344	651,693	
		COST PER SQUARE METER	7.97	7.28	6.97	6.96	≃ 6.96
	b.) 36 ml Hypalon:	TOTAL COST	137,476	327,404	640,144	1,279,293	
		COST PER SQUARE METER	14.55	13.86	13.55	13.54	≃ 13.54
	c.) 35 ml Butyl:	TOTAL COST	183,060	441,364	868,064	1,735,133	
		COST PER SQUARE METER	19.37	18.68	18.37	18.36	≃ 18.36

MEMBRANES BURIED

Constr. Phase	Pers'l	Equip.	Mat'l	Units	L.E. per Unit	1,000 m		2,500 m		5,000 m		10,000 m		20,000 m	
						#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.
A.)Design Costs (as for conc. cast in place)							600		1,040		1,740		3,230		
B.)Pre-Const. Costs (as for conc. cast in place)							31,610		67,000		120,620		241,250		
C.)Const. Costs															
i)Membrane															
a)10 ml PVC			Mem	m^2	2.00	15,480	30,960	38,700	77,400	77,400	154,800	154,800	309,600		
b)20 ml PVC			Mem	m^2	3.10	15,480	47,988	38,700	119,970	77,400	239,940	154,800	479,880		
c)36 ml Hypalon			Mem	m^2	8.35	15,480	129,258	38,700	323,145	77,400	646,290	154,800	1,292,580		
d)35 ml Butyl			Mem	m^2	12.20	15,480	188,856	38,700	472,140	77,400	944,280	154,800	1,888,560		
ii)Del.															
a)		8T.Tr.		hrs	10.00	3	30	6	60	12	120	24	240		
b)		8T.Tr.		hrs	10.00	6	60	12	120	24	240	48	480		
c)		8T.Tr.		hrs	10.00	9	90	18	180	36	360	72	720		
d)		8T.Tr.		hrs	10.00	9	90	18	180	36	360	72	720		
iii)Instal.	Eng'r(G)			hrs	1.70	120	204	260	442	480	816	960	1,632		
	Eng'r(P)			hrs	4.00	120	480	260	1,040	480	1,920	960	3,840		
	Lab's(P)			hrs	2.40	225	540	550	1,320	1,000	2,400	2,000	4,800		
	Driv.)G)			hrs	1.50	120	180	260	390	480	720	960	1,440		
		Auto		km	0.20	1,500	300	2,500	500	4,000	800	7,200	1,400		

MEMBRANES BURIED (Continued)

Constr. Phase	Pers'l	Equip.	Mat'l	Units	L.E. per Unit	1,000 m		2,500 m		5,000 m		10,000 m		20,000 m	
						#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.
iv)Backfill & Compact.	Lab's(P)			hrs	2.40	500	1,200	1,100	2,640	2,000	4,800	4,000	9,600		
		Load.		hrs	8.00	300	2,400	720	5,760	1,440	11,520	2,880	23,040		
		LowBoy		hrs	10.00	4	40	4	40	8	80	16	160		
		Vibr. Comp's		hrs	3.00	500	1,500	1,100	3,300	2,000	6,000	4,000	12,000		
v)Outlet Const. (as for conc. cast in place)							2,784		6,730		13,100		25,605		
D.)Intake Headbox (as for conc. cast in place)							2,130		21,30		4,260		8,520		
(P=12.0m)	a) 10 ml P.V.C.	TOTAL COST					75,198		170,272		324,656		648,317		
		COST PER SQUARE METER					6.27		5.68		5.41		5.40		≃ 5.40
	b) 20 ml P.V.C.	TOTAL COST					92,226		212,842		409,796		818,587		
		COST PER SQUARE METER					7.69		7.09		6.83		6.82		≃ 6.82
	c) 36 ml Hypalon	TOTAL COST					173,496		416,017		816,146		1,631,297		
		COST PER SQUARE METER					14.46		13.87		13.60		13.59		≃ 13.59
	d) 35 ml Butyl	TOTAL COST					233,094		565,012		1,114,136		2,227,277		
		COST PER SQUARE METER					19.42		18.83		18.57		18.56		≃ 18.56

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Size 3

ASPHALTIC CONCRETE

Constr. Phase	Pers'l	Equip.	Mat'l	Units	L.E. per Unit	1,000 m		2,500 m		5,000 m		10,000 m		20,000 m	
						#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.
A.)Design Costs (as for conc. cast in place)							600		1,040		1,740		3,230		
B.)Pre-Const. Costs (as for conc. cast in place)							31,610		67,000		120,620		241,250		
C.)Const. Costs															
i)Material			Asphalt	m^3	⊕	1,164	20,952	2,910	46,560	5,800	92,800	11,600	185,600		
ii)Del.		8T.Tr.		hrs	10.00	1,920	19,200	4,600	46,000	9,200	92,000	18,400	184,000		
iii)Instal.		8T.Tr.		hrs	10.00	8	80	8	80	16	160	32	320		
		Slip form		hrs	60.00	90	5,400	210	12,600	400	24,000	800	48,000		
	Eng'r(G)			hrs	1.70	100	170	220	374	420	714	840	1,428		
	Eng'r(P)			hrs	4.00	100	400	220	880	420	1,680	840	3,360		
	Lab's(P)			hrs	2.40	600	1,440	1,350	3,240	2,600	6,240	5,200	12,480		
	Driv.(G)			hrs	1.50	100	150	220	330	420	630	840	1,260		
		Auto		km	0.20	1,000	200	2,200	440	3,600	720	7,200	1,440		
iv)Outlet Const. (as for conc. cast in place)							2,784		6,730		13,100		25,605		

ASPHALTIC CONCRETE (Continued)

Constr. Phase	Pers'l	Equip.	Mat'l	Units	L.E. per Unit	1,000 m		2,500 m		5,000 m		10,000 m		20,000 m	
						#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.
D.) Intake Headbox (as for conc. cast in place)							2,130		2,130		4,260		8,520		
TOTAL COST							85,116		187,404		358,664		716,493		
(P=9.7m) COST PER SQUARE METER							8.77		7.73		7.40		7.39		≃ 7.39

Size 3

SOIL CEMENT LININGS

Constr. Phase	Pers'l	Equip.	Mat'l	Units	L.E. per Unit	1,000 m		2,500 m		5,000 m		10,000 m		20,000 m	
						#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.
A.)Design Costs (as for conc. cast in place and soil analysis)							600		1,040		1,740		3,230		
	Eng'r(G)			hrs	1.70	80	136	120	204	160	272	320	544		
	Tech.(G)			hrs	1.00	80	80	120	120	160	160	320	320		
B.)Pre-Const. Costs (as for conc. cast in place)							31,610		67,000		120,620		241,250		
C.)Const. Costs															
i)Material			Cement	kg	0.055	418,000	22,990	1,045,000	57,475	2,090,000	114,950	4,180,000	229,900		
ii)Del.		8T.Tr.		hrs	10.00	425	4,250	1,048	10,480	2,096	20,960	4,192	41,920		
iii)Instal.															
a.Mixing		Slip form		hrs	60.00	100	6,000	220	13,200	420	25,200	840	50,400		
		8T.Tr.		hrs	10.00	8	80	8	80	16	160	32	320		
b.Placement	Eng'r(G)			hrs	1.70	100	170	220	374	420	714	840	1,428		
	Eng'r(P)			hrs	4.00	100	400	220	880	420	1,680	840	3,360		
	Sur'y(P)			hrs	1.00	100	100	220	220	420	420	840	840		
	Driv.(G)			hrs	1.50	100	150	220	330	420	630	840	1,260		
	Lab's(P)			hrs	2.40	600	1,440	1,350	3,240	2,600	6,240	5,200	12,480		
		Auto		km	0.20	1,000	200	2,200	440	3,600	720	7,200	1,440		

SOIL CEMENT LININGS (Continued)

Constr. Phase	Pers'l	Equip.	Mat'l	Units	L.E. per Unit	1,000 m		2,500 m		5,000 m		10,000 m		20,000 m	
						#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.	#Units	Total L.E.
iv)Expan. Joints	Lab's(P)			hrs	2.40	16	38	40	96	80	192	160	384		
			Bitumen	m^3	55.00	1.0	55	2.5	138	5	275	10	550		
v)Outlet Const. (as for conc. cast in place)															
D.)Intake Headbox (as for conc. cast in place)							2,130		2,130		4,260		8,520		
TOTAL COST							70,429		157,447		299,193		598,146		
(P=11.6 m) COST PER SQUARE METER							6.07		5.43		5.16		5.16		≈ 5.16

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