ANNEX-H

IRRIGATION AND DRAINAGE

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IRRIGATION AND DRAINAGE

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ANNEX - H IRRIGATION AND DRAINAGE

1. INTRODUCTION

This Annex details the irrigation and drainage plans and also the rehabilitation plan of related facilities for the selected five projects, that is, Ashaiman, Aveyime, Kpando-Torkor, Mankessim and Okyereko projects which were selected as the priority projects through a master plan level study given in Annex-A.

Chapter 2 shows the present project conditions of dams, pumps, canals, pipes, sprinklers, drains, roads, related structures and buildings, which were examined project by project in detail by means of inventory survey. The problems envisaged with the existing irrigation, drainage and road network systems are also clarified and mentioned in this chapter.

Chapter 3 presents the calculation results and procedure of irrigation water requirement based on the proposed attractive cropping patterns for the respective projects, and the optimum rehabilitation area through a water balance study for alternative plans, and the suitable irrigation methods well fitted to the each project condition which are worked out based on the lessons learnt from the problems mentioned above.

Chapter 4 relates the study results of drainage improvement based on the drainage water requirements estimated separately for paddy field and upland crops field. In Kpando-Torkor and Mankessim projects, careful attention in establishment of drainage improvement plan, is paid upon the control measures against soil erosion because of the undulated and/or sloped topography.

Chapter 5 mentions the proposed road and building improvement plan. In road improvement plan, need and type of pavement are discussed, and also road network is studied considering the existing one. In building improvement plan, the required building will be determined considering the smooth execution of agricultural activities as well as operation and maintenance of project facilities.

Chapter 6 gives the rehabilitation plan for the existing project facility relating to irrigation, drainage, road and building, which is elaborated based on the said irrigation plan, drainage plan and road plan. In study on rehabilitation plan, consideration is given to the capability of farmer's association because of operation and maintenance of them shall be executed by farmers themselves after rehabilitation.

Chapter 7 presents the work quantities necessary for rehabilitation and/or new construction of the facility. The required work quantities are made based on the topographic survey results and feasibility study level design.

Chapter 8 mentions the proposed water management and O & M of project facility which is prepared taking it into due consideration that all these activities will be executed by the farmers' organization.

2. PRESENT CONDITIONS

2.1 General

The selected five projects are presently operated and managed by GIDA. These projects, however envisage low level performance due to a combination of various constraints. The present conditions of the projects have been therefore examined in detail and clarified through an inventory survey for the existing project facilities, site inspection, interview with the farmers concerned as well as project staff in charge, and review of relevant projects in order to clarify these constraints and to make reference with them as lessons learnt from the existing projects when the rehabilitation plan for respective projects is elaborated. The present conditions of the projects are summarized in Table H-1.

2.2 Project Area

The potential area and developed area so far of respective projects are as follows:

Potential and Developed Areas

Project	Potential Area (ha)	Developed Area (ha)
Ashaiman	148	130
Aveyime	150	63
Kpando-Torkor	356	40
Mankessim	256	17
Okyereko	111	40
Total	1,021	290

Source : Head quarter and site offices of GIDA.

As can be seen in the above table, the actually developed area against potential one in four projects except Ashaiman project, is at low level. Such less developed area is mainly due to financial constraint.

2.3 Irrigation System

2.3.1 Irrigation Method

(1) Irrigation Type

The present water sources, intake method and irrigation type for the selected five projects are as follows:

Present Irrigation System

Project	Water Source	Facility	Irrigation Type
Ashaiman	Ashaiman reservoir	Dam/Intake valve	Gravity
Aveyime	Volta river	Pump	Gravity
Kpando-Torkor	Volta lake	Pump	Sprinkler
Mankessim	Apropong reservoir	Dam/Pump	Sprinkler
Okyereko	Okyereko reservoir	Dam/Intake gate	Gravity

(2) Irrigation Requirements

Ashaiman project has data on irrigation requirements for paddy which has been measured by the Irrigation Development Center (IDC), but other projects have no data. The measured results in Ashaiman project are given below:

(a) Major season from July to September

- Evaporation	:	1.9 mm/day
- Transpiration	:	4.2 mm/day
Total		6.1 mm/day
- Percolation	:	1.3 mm/day

(b) Minor season from October to November

- Evaporation	:	2.5 mm/day
- Transpiration	:	2.9 mm/day
Total		5.4 mm/day
- Percolation	:	1.3 mm/day

From these results and effective rainfall, and assuming 20% of loss, irrigation water requirements for both major and minor seasons have been estimated at 8,400 m3/ha and 7,400 m3/ha, respectively. These requirements which would be equivalent to 1.1 lit./s/ha and 1.4 lit./s/ha, respectively, are judged to be within a reasonable range.

(3) Irrigation Schedule

Only Ashaiman project has an irrigation schedule which has been prepared by IDC. While, other four projects have no definite irrigation schedule, and thus irrigation is made only based on the past experience and visual judgment to soil condition, in reply to the farmers' request. Since the farmers' idea to water supply is generally conservative, it is likely that water supply more than the required one may be made unnecessarily.

2.3.2 Intake Facility and Capacity

As mentioned above, Aveyime and Kpando-Torkor projects are provided with pumps to tap irrigation water from the Volta river and Volta lake, respectively, but these are severely deteriorated and will be totally replaced with new ones. On the other hand, Ashaiman, Mankessim and Okyereko projects are equipped with either intake valve or gate for supplying the required discharge to subsequent canals and finally each field. The existing intake gate and valve are still in good working condition so that any rehabilitation will not be required. The capacity of them is as follows:

Existing Intake Capacity

Project	Intake Capacity (m3/s)	Potential Area (ha)	Unit Discharge (lit/s/ha)*
Ashaiman	0.560	148	3.78
Mankessim	0.364	256	1.42
Okyereko	0.546	111	4.92

** : Calculated by dividing intake capacity by potential area at this time.*

The above table indicates that all the existing intake gate and valve have enough capacity to feed irrigation water even for whole potential area.

2.3.3 Water Delivery System

Water distribution method for the Project is divided into two methods: continuous and rotational methods. The former is applied for Ashaiman project only, and the latter for the remaining four projects. As tabulated below, irrigation interval and daily irrigation time in rotational method ranges from 2 to 10 days and 6 to 12 hours, respectively.

Water Distribution Method

Project	Irrigation Method	Irrigated Crops	Water Distribution Method
Ashaiman	Gravity	Paddy, Okra, Tomato	Daily irrigation time: 10.5 hours Continuous water supply
Aveyime	Gravity	Paddy	Daily irrigation time: 8 hours for 8 acres Irrigation interval : 10 days
Kpando-Torkor	Sprinkler	Okra	Daily irrigation time: 6 hours Irrigation interval : 2 to 3 days
Mankessim	Sprinkler	Okra, Gardenegg	Daily irrigation time: 6 hours Irrigation interval : 5 days
Okyereko	Gravity	Paddy	Daily irrigation time: 12 hours Irrigation interval : 10 days

2.3.4 Structures

An inventory survey was carried out for the existing structures, to grasp the present conditions of them. On the whole, most of them are severely deteriorated as shown in Table H-2, and require new construction or replacement accordingly. Besides, these structures are insufficient in number for proper operation of canal system. A measuring device which is an important facility for accurate water distribution, is not provided at all for four projects except Ashaiman project. It is found in all projects that crossing structures such as bridge and culvert are also inadequate in number to execute suitable agriculture activities.

2.3.5 Problems in Irrigation System

(1) Available Water Source

Of the selected five priority projects, Ashiaman, Mankessim and Okyereko projects have limited water source. These projects are provided with a reservoir, but an in-flow to the reservoir is absolutely insufficient for year-round irrigation with 80 % dependability according to the master plan level study as explained in Annex-A.

In particular, a high water shortage is foreseen in Ashaiman project. The main reason for such a high water shortage is due to (a) small catchment area against the present developed area and (b) low runoff coefficient which is observed by IDC. Even if the storage capacity of the reservoir is increased by heightening the crest elevation of spillway or dam, the increased amount of water would be consumed mostly by evaporation due to increase in water surface area in the reservoir. There could not find any other supplemental water source near the project.

Okyereko project also envisages water shortage. In order to cope with water shortage, GIDA has a plan to exploit a supplemental water source by installing pumps on the Ayensu river flowing near the project area. Then, the study is made considering this exploitation of supplemental water source.

The preliminary water balance study is also executed for Mankessim project. The study result shows that Mankessim project would be possible to be provided with an year-round irrigation with 80 % dependability if all areas are cultivated with upland crops.

Further water balance study will be made for these three projects based on the proposed cropping patterns and additionally collected hydrological data. The results are mentioned in Sub-section 3.3.2.

(2) Deterioration of Project Facility

As shown in Table H-2, most of existing facility are severely deteriorated, which finally result in low productivity of crops. In particular, the projects being served by pumps such as Aveyime, Kpando-Torkor and Mankessim projects, are suffered from insufficient water supply due to their serious deterioration. Pipes and sprinklers are also in poor condition. These pumps, pipes and sprinklers are required to be urgently replaced in order to recover their performance and thereby productivity.

In case of Ashaiman, Aveyime and Okyereko projects, irrigation canals and related structures have some problems mainly due to much water leakage from them caused by poor construction and long time use. But, dam and reservoir for Ashaiman and Aveyime projects are in good condition although regular minor maintenance work is required. Anyhow, it is judged that these canals and structures shall be newly constructed.

(3) Lack of Basic Technical Information of Irrigation Practice

There exist technical problems in irrigation practice. The major problems are the lack of basic technical information of irrigation practice. The four projects except Ashaiman project have no technical data and information to estimate irrigation requirements, and to prepare irrigation schedule including water management at farm level. In addition, no records on how much irrigation water is actually supplied to the field, which is indispensable for efficient use of available water are not available in the projects. It is therefore essential to assign an officer in-charge and also to strengthen the monitoring section of GIDA, aiming to settle such technical problems in irrigation practice.

2.4 Drainage System

2.4.1 Drainage Method

The excess water in the project area is eliminated by gravity through the said drainage system, and any mechanical drainage method is not employed.

2.4.2 Design Discharge

There does not find any definite design discharge for drainage system. In Ashaiman and Okyereko projects, the existing main drain is connected with the spillway of dam, but does not follow the design capacity of spillway.

2.4.3 Drainage Canal System

Drainage system is provided for Ashaiman, Aveyime and Okyereko projects, and the remaining two projects have no drainage system due to sloped topography. The existing drainage system generally consists of lateral and main drain for which unlined type is applied.

2.4.4 Structures

A few cross drains only are provided for Aveyime and Okyereko projects.

2.4.5 Problems in Drainage System

(1) Lack of Proper O & M Activities

The existing drainage canals are in poor condition due to lack of proper maintenance so that water logging and light salinity problem occur in Ashaiman, Aveyime and Okyereko projects. It is thus necessary to execute the maintenance activities such as desilting and grass cutting on time, aiming to settle such water logging and salinity problem.

(2) Soil Degradation

There is a negative possibility of future land degradation in Kpando-Torkor and Mankessim projects because of undulating topography and the existence of accumulated layer of iron concretions or gravel within the shallow soil layer. In order to mitigate or avoid soil erosion in advance, certain land conservation practice shall be applied for the sustainable agricultural development.

2.5 Road Network

The present conditions of the existing farm road network in the projects including short access to the main road are generally poor. The present poor road network in most of the projects will require cleaning by grass cutting and improvement of surface such as compacted gravel pavement, and in some projects additional construction of new farm roads would be required in connection with the expansion of irrigated land as well as the rehabilitation.

2.6 Project Buildings

Ashaiman project only has a good project office and quarter for O & M staff. The remaining projects are provided with office only, but is in very poor condition now. Such office will be replaced with new one, and in addition additional buildings such as office for farmer's organization, store house, garage, sorter house will also be required in connection with the project rehabilitation. Training facilities such as dormitory and lecture hall are considered for Ashaiman and Okyereko projects.

2.7 Review of Relevant Projects

The Dawhenya Irrigation Project (DIP) was reviewed as the most similar and recent case for the rehabilitation of the projects, since it was completed in 1993 and has launched into operation and maintenance stage.

DIP is located in the Greater Accra Region. The implementation of DIP was started from the construction of earth dam and spillway, both of which were completed in 1962. A small pump was installed on the dam crest and provided water eventually to an area of 60 ha. Water supply and land forming works proceeded and the diesel pump station was commissioned in 1974, and thus the command area were expanded up to about 200 ha by 1982. However, pump failures and consequent water shortage brought about a virtual shutdown of DIP by 1982/83. Thereafter, the pump station was recommissioned with electric pumps, and also improvement was made for the selected canals, roads, buildings and utilities. However, DIP still envisaged the severe water shortage due to deficiency in water management and the physical condition of the water supply network. Besides, inadequacies in the institutional arrangements for project operation and management, and support services to farmers prevented the full exploitation of the project potential. As for irrigation and drainage aspects, the major problems at that time were specified as follows :

(a) Lack of water control and measuring structures;
(b) Seepage and overtopping of canals;
(c) Poor in-field water management;
(d) Mixed stages of crop development within lateral units;
(e) Lack of training of water control staff;
(f) Absence of water control management system;
(g) Absence of suitable collector drains outlets through the reservoir flood protection dike; and
(h) Poor maintenance of drain leading to flooding and damage to the canal inspection roads.

In order to cope with these problems, further rehabilitation works and technical services were provided for DIP under the financial assistance of the European Economic Community (EEC). The further rehabilitation works included reconstruction of the main canalisation system, lateral and header ditches, remedial land leveling and the drainage and flood protection works.

Site inspection was made for the completed rehabilitation works in order to grasp the present condition of DIP after completion of rehabilitation works and technical services. Generally, most of facilities such as pump station, night storage reservoir, main canal, inspection roads and related structures are well maintained and are in satisfactory condition. However, further effort would be required for proper water management, because a definite irrigation calendar is not available in spite of the exist of O & M Manual. In addition, it is still observed that much weeds are growing in drains which would prevent the smooth elimination of excess water from cultivation land. From these findings, it is essential to strengthen water management and O & M activities urgently, and also to execute monitoring activities for collecting and analysing actual data which will be used for effective project management.

3. IRRIGATION PLAN

3.1 Basic Concept for Establishment of Irrigation Plan

At present, irrigation water supply is executed only by the past experience and visual judgment to soil moisture condition. In order to use water effectively, irrigation system should be developed in accordance with the definite irrigation plan prepared using the actual data and/or in a logical manner. In preparation of the irrigation plan, the following basic concept is to be considered:

(1) Crop water requirement and irrigation requirement should be estimated using the actually measured data and/or in a logical method.

(2) Proper irrigation method should be selected based on soil condition, available water source and crops to be cultivated.

(3) Irrigation time, irrigation interval, and irrigation intensity should be determined based on the actually measured data and/or in a logical manner, to heighten irrigation efficiency.

(4) Canal network should be prepared considering the easy operation and maintenance, to ensure stable water supply.

(5) Canal related structures should be rehabilitated from the viewpoints of easy water management as well as economic aspect.

3.2 Irrigation Plan and Water Requirements

(1) Proposed Irrigation Method

Of the five (5) projects, Kpando-Torkor and Mankessim projects, where upland crops are cultivated, are presently irrigated using the sprinkler system. The remaining three (3) projects where the main crop is paddy are of gravity type. In the former projects, a study is made on possibility for application of furrow irrigation. An application of drip irrigation is not included in this comparison study because it is not used in the country at all and such water supply facility after rehabilitation will have to be operated and maintained by farmers organization. Application conditions of sprinkler and furrow irrigation are tabulated below :

	Description	Furrow Irrigation	Sprinkler Irrigation
1	Influence of topography	Large	No
2	Land reclamation	Needed	No
3	Soil condition (basic intake rate)	Less than 50 mm/hr.	No limitation
4	Application loss	Large	Less
5	Water management in field	Difficult	Easy
6	Influence of wind	No	Less than 5m/s
7	Soil erosion	High possibility	Less possibility
8	Need of labour for water supply	Large	Less

According to the results of cylinder intake rate test, Mankessim project has a high basic intake rate, more than 50 mm/hr, and therefore application of furrow irrigation could not be recommended. Also in Kpando-Torkor project, it is difficult to apply furrow irrigation because of high possibility of soil erosion by steep land slope ranging from 1/30 to 1/50, when the present irrigated agriculture is intensified in the future. From these findings and study results, sprinkler system is recommended to be applied for these two (2) projects as they are. But in Aveyime and Okyereko projects where paddy is mainly cultivated, furrow irrigation will be applied for small upland crop area due to present irrigation method, soil condition and low construction cost.

(2) Irrigation Water Requirements

1) Proposed cropping patterns

The proposed cropping patterns under the "with-project" condition for respective projects which are discussed in Annex-E are presented in Figures H-1 to H-5.

2) Estimation of reference evapo-transpiration (ETo)

There are many methods to estimate crop evapotranspiration. Among them, the modified Penman method is proposed for this study, since it is likely to provide the most satisfactory results and is adopted for many projects in estimating the reference crop evapotranspiration. The modified Penman equation is as follows :

$$ETo = C \times \{W \times Rn + (1-W) \times F(u) \times (ea - ed)\}$$

where,

ETo	:	Reference crop evapotranspiration in mm/day
W	:	Temperature-related weightage factor
Rn	:	Net radiation in equivalent evaporation in mm/day
F(u)	:	Wind-related factor
(ea-ed)	:	Difference between the saturation vapor pressure at mean air temperature and the mean actual vapor pressure of the air, both in m bar, and
C	:	Adjustment factor to compensate for the effect of day and night weather conditions

Details are described in FAO Irrigation and Drainage Paper No.24. Table H-3 shows the potential evapotranspiration (ETo) calculated using the above equation and the meteorological data at respective sites discussed in Annex-B. In addition, ETo estimated by the Blaney-Criddle is also given in the same table for reference. ETo estimated by the modified Penman method is slightly higher than that by the Blaney-Criddle. The daily ETo for respective projects is summarised below :

Daily Evapo-Transpiration

(Unit:mm)

Project	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1 Ashaiman	5.0	5.4	5.7	5.6	5.2	4.1	3.8	4.0	4.5	5.3	5.3	4.8
2 Aveyime	4.8	5.6	5.7	5.4	4.9	4.0	3.9	3.3	4.3	4.7	4.8	4.4
3 Kpando-Torkor	5.0	5.4	5.5	5.4	5.0	4.1	3.7	3.7	4.1	4.8	5.1	4.7
4 Mankessim	4.5	5.1	5.3	5.2	4.8	3.8	3.6	3.6	4.0	4.8	4.9	4.4
5 Okyreko	4.5	5.1	5.3	5.2	4.8	3.8	3.6	3.6	4.0	4.8	4.9	4.4

On the other hand, field water requirement for the wet season paddy has been measured at Aveyime and Okyereko projects for cross-check purpose. The results are 4.4 mm to 6.7 mm for July to September at Aveyime project and 3.4 mm to 6.9 mm for August to October at Okyereko project. Details of measured values are given in Table H-4 for Aveyime project and Table H-5 for Okyereko project. Although the estimated values show lower tendency than the measured ones, these are considered to be still in allowable range.

3) Consumptive use by crop

The consumptive use of water by crops is estimated as a product of the reference crop evapotranspiration (ETo) and crop coefficient (Kc) at a given growing stage. The crop coefficients of respective crops are determined with reference to the FAO Irrigation and Drainage Paper No.24 as shown in Table H-6.

4) Deep percolation loss and intake rate

In this study, the following deep percolation loss in paddy field is determined by making reference with the actual measurement at field:

		Wet Season Paddy	Dry Season Paddy
- Ashaiman	:	0.8 mm/day	1.0 mm/day
- Aveyime	:	1.5 mm/day	2.4 mm/day
- Okyereko	:	1.4 mm/day	1.6 mm/day

The intake rate measurements were also executed at Kpando-Torkor and Mankessim projects for determination of irrigation intensity by sprinkler. The average basic intake rates are given below :

- Kpando-Torkor : 19.3 mm/hr.
- Mankessim : 58.4 mm/hr.

5) Puddling water and pre-irrigation requirements

Puddling water requirement depends on soil type, moisture content, ground water table, etc., and varies from season to season, and place to place. To grasp the water demand for puddling activity is indispensable for plan of paddy irrigation project, especially for rehabilitation plan of facilities, since the peak water demand in the paddy cultivation would generally occur at the puddling time. However, no data are available for puddling water requirement for the selected five projects. The measurement of puddling water requirement has therefore been executed for the three projects of Ashaiman, Aveyime and Okyereko where paddy is cultivated.

There are two methods in measurement on puddling water requirement of paddy. One is an actual measurement of water amount used for puddling activity by installing a measuring device at inlet and outlet points in one field plot, respectively. The other is an estimate from the cultivation depth and the porosity of soil to be cultivated which is known by soil tests, because it is generally understood that about 95 % of soil porosity would be filled with water through puddling activity. In this case, the latter method has been employed because of limited time and deterioration of irrigation facilities.

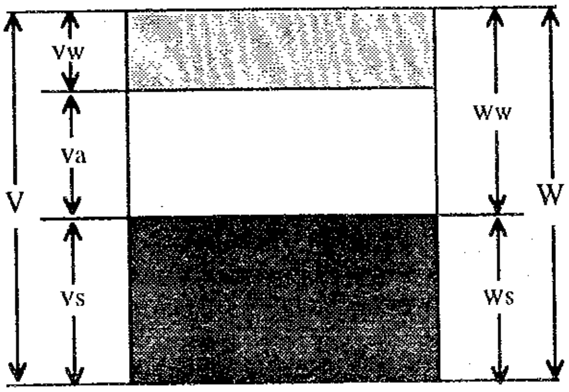
(a) Cultivation depth

The test pits executed in the last dry season shows that the cultivation depths for three projects ranges 8 to 38 cm. From this result, the average cultivation depth is assumed to 20 cm in this preliminary analysis.

(b) Porosity of soil

The porosity of soil is estimated using the following equations:

Soil Structure



Note

V : Volume of soil
vs : Volume of soil particle
va : Volume of air
vw : Volume of water
W : Weight of soil
ws : Weight of soil particle
ww : Volume of water
γw : Specific gravity of water

(i) Moisture content (w) = Ww/Ws x 100
(ii) Wetted density (g) = W/V
(iii) Dry density (gd) = Ws/V = g/(1+ w/100)
(iv) Specific gravity of soil (Gs) = Ws/(gw x Vs)
(v) Void of soil (e) = Vv/Vs = gw x Gs/gd - 1
(vi) Porosity of soil (n) = Vv/V x 100 = e/(1+e) x 100

The test results and subsequent calculation results are given in Table H-7.

(c) Puddling water requirement for wet and dry season paddy

From the above, a puddling water requirement for the wet and dry season paddy in case that puddling is commenced in July, would be estimated as follows:

Puddling Water Requirement for Wet Season Paddy

	Description	Unit	Ashaiman	Aveyime	Okyereko
(1)	Soil depth	mm	200	200	200
(2)	Porosity	%	52	40	37
(3)	Soil vapor phase	%	5	5	5
(4)	Soil moisture before water supply	%	32	25	19
(5)	Water to be supplied				
	- Saturation of soil profile	mm	30	20	26
	- Evaporation	mm	60	61	53
	- Percolation	mm	8	15	14
	- Standing water	mm	50	50	50
	Total	mm	148	146	143
			Say, 150	Say, 150	Say, 140

Puddling Water Requirement for Dry Season Paddy

	Description	Unit	Ashaiman	Aveyime	Okyereko
(1)	Soil depth	mm	200	200	200
(2)	Porosity	%	52	40	37
(3)	Soil vapor phase	%	5	5	5
(4)	Soil moisture before water supply	%	9	15	15
(5)	Water to be supplied				
	- Saturation of soil profile	mm	76	40	34
	- Evaporation	mm	56	63	56
	- Percolation	mm	10	24	16
	- Standing water	mm	50	50	50
	Total	mm	192	177	156
			Say, 190	Say, 180	Say, 160

On the other hand, pre-irrigation requirement for upland crops is to be 60 mm.

6) Effective rainfall

Effective rainfall varies with rainfall intensity and distribution, permeability and water holding capacity of soils, amount of irrigation water supply, irrigation management practices, type of field plot and topography of land, etc. In this study, the effective rainfall in paddy field and upland is separately calculated as explained in the following paragraph :

(a) Paddy field

The effective rainfall in paddy field is separately calculated on the basis of the daily water balance using daily rainfall data determined in Annex-B. A daily balance study is made on the following assumption :

- Ineffective rainfall : less than 5 mm/day
- Maximum depth of tank : 150 mm
- Minimum depth of tank : 50 mm

Based on the results of the daily water balance, correlation between the 10-day rainfall and effective rainfall is estimated for the purpose of calculating the long term assessment as shown in Figure H-6. The relation can be expressed as follows :

Effective Rainfall

Project	T1(mm)	T2(mm)	R10<T1	T1<R10<T2	R10>150
Ashaiman	15	155	ER10=0	ER10=0.9R10	ER10=140
Aveyime	15	158	ER10=0	ER10=0.9R10	ER10=142
Okyereko	18	118	ER10=0	ER10=0.9R10	ER10=106

Note: ER10 = 10-day effective rainfall in mm, R10= 10-day rainfall in mm.

(b) Upland

The U.S.Department of Agriculture Soil Conservation Service has developed a procedure for estimating effective rainfall by processing long term climatic and soil moisture data from 50 years of rainfall records at 22 experimental stations. A daily balance in the soil profile is carried out, and the following relationship is derived from monthly rainfall and crop consumptive use.

$$ER = 0.2 \times R^{0.95} \times Cu^{0.31}$$

Where,
- ER : Effective rainfall in mm
- R : Rainfall in mm
- Cu : Crop water requirement in mm

The effective rainfall should not exceed consumptive use by crop. Therefore, the lower value should be either the calculated ER or Cu.

7) Irrigation efficiency

Overall irrigation efficiency is made up of farm application, conveyance and operation losses and varies depending on soil conditions, type of canal regulating structures, water management practices, etc. Generally, the irrigation efficiency in the wet season seems to be lower than that in the dry season, because it is difficult to operate the regulating facilities quickly to respond to unfavorable rainfall events. However, due to the difficulties to evaluate difference in the dry and wet seasons, irrigation efficiency is uniformly applied throughout the year in this study.

As mentioned in Attachment, canal seepage rate measurements were carried out in Ashaiman and Okyereko for which gravity irrigation is applied. Canal seepage rate for lined canals show 2.11 lit/s/1000 m^2, and then canal conveyance loss is roughly calculated to be about 2 % of design discharge. Taking into consideration these results, size of canal and certain allowance, conveyance efficiency for main canal and lateral is assumed to be 10 %, respectively. In addition, conveyance loss of pipeline and field application loss for paddy field and upland crop field are assumed as follows, considering soil condition and water distribution method :

Irrigation Efficiency	Paddy	Upland Crops	
		Furrow/basin	Sprinkler
Delivery efficiency	81 %	81 %	90 %
Main canal	(90 %)	(90 %)	(95 %)*
Lateral/sub-lateral	(90 %)	(90 %)	(95 %)*
Application efficiency	75 %	60 %	80 %
Overall efficiency	61 %	49 %	72 %
Proposed efficiency	60 %	50 %	70 %

* : Pipeline

8) Irrigation water requirement

The irrigation water requirements for respective projects are calculated for 10-day period using the rainfall data as discussed in Annex-B. Table H-8 shows 80 % probable water requirements on 10-day basis for respective projects.

3.3 Determination of Optimum Rehabilitation Area

3.3.1 Alternative Plans

In the master plan level study, preliminary water balance study is made for each of Ashaiman, Okyereko and Mankessim where available water sources are limited to serve the whole potential irrigable area. On the basis of the water balance study, the first probability analysis is made to delineate the possible irrigable area with 80 % irrigation dependability, as shown below.

Possible Irrigable Area at Master Plan Level Study

Project	Potential Area (ha)	Developed Area (ha)	Possible Irrigable Area (ha)
Ashaiman	148	130	44
Aveyime	150	63	150
Kpando-Torkor	356	40	356
Mankessim	256	17	176
Okyereko	111	40	111 *
Total	1,021	290	837

* : *As the existing water resource is so small, supplimental one will be developed by installing and other necessary facilities on Ayensu river.*

Since the topographic maps on a scale of 1 to 5,000 covering each of the five priority projects are available for further study on the project area, field investigation is made at each project site, using these maps. In parallel with such a field investigation, public meetings were held, and the project boundary was confirmed together with farmers concerned at each project site. As a result, alternative plans of the project study area are taken up in order to prepare the most optimum rehabilitation plan for each project from both technical and economic points of view, as explained below:

(1) Aveyime Project (Figure H-7)

At Aveyime project, there are three (3) small blocks of land being cultivated by farmers, and they are located adjacent to the existing paddy field on the northern side (Extension Area -1), southern side (Extension Area-2) and the western side (Extension Area-3), respectively. Topographical, Extension Areas -1 and-3 could be irrigated by extending the existing irrigation network. In case of Extension Area-2, a small scale pump will be required to boost up the water again to irrigate higher land by gravity. Extension Area -1 is owned by one large farm family at present, and the family head is already a member of the Aveyime farmers society. At the public meeting, discussions with the family head and member farmers on whether this land can be included in the project were made, and finally the family head agrees to allocate his family land to other farmers after project rehabilitation. Extension Areas-2 and-3 are already owned by the project. Then, comparative study will be made on the following three (3) alternatives:

(a) Alternative 1 : Rehabilitation of existing paddy field only, covering 63 ha of land
(b) Alternative 2 : Rehabilitation of existing paddy field + Extension Areas -1 and- 3 covering 80 ha of land
(c) Alternative 3 : Rehabilitation of existing paddy field + Extension Areas-1,-2 and-3 covering 95 ha of land

(2) Kpando-Torkor Project (Figure H-8)

Potential irrigable area in this project which is divided into four (4) irrigation blocks, A, B, C and D, was preliminay measured at 356 ha, but re-measured at 415 ha using topographic maps of 1/5000 scale. Actual irrigated area at present is however 13 ha only (in Block-A) because of high deterioration of pumps and sprinkler equipment. The additional site inspection made in the wet season this year shows that farming activities in Block-A are more active as compared with those in the remaining three (3) blocks. Each block will be served by one complete set of pump, pipeline and sprinkler system independently, instead of commanding the whole project area by one large-scale pump set, in order to avoid the risks in case of out-of-order of the facility.

On the other hand, soil survey and study show that about 70 % of the total project area is classified into the restricted suitable (Class S4), due to undulating topography and the existence of accumulated layer of iron concretions or gravel within a shallow depth. Once the accumulated layer of iron concretions is exposed to repeated wetting and drying by erosion of surface soil, soils change irreversibly to iron hardpan. In fact, the accumulated layer of iron concretions is seen in part of Block-A due to active farming.

Block A is located near Dzigbe village which closely concerns the project rehabilitation, because all the lands in the project area belong to this village, and other blocks B, C and D are located in sequence from downstream to upstream. This means that Block-D would require rather long approach from the village for farming and electricity supply to the pump house as well.

The present land holding per family at this project is 0.28 acre. At the public meetings, discussions were made with the member farmers on optimum land holding size per family.

Most of them are requesting one acre of land holding at least in order to grow cash crops with irrigation during the dry season. In addition, they need more land to grow their main food crops such as maize and cassava mainly under rainfed condition in the wet season, in order to secure their food security. This suggests that sufficient area of land should be left as it is around the project area to meet this purpose.

On the other hand, potential irrigable land in each block can be divided into two parts, lower part and upper part, from topographic point of view. The lands in upper part generally have more steep land slope than those in lower part. This means that the lands in upper part will require higher density per acre or hectare of providing green belts and intercepting drains for soil erosion control than those in lower part. When sprinkler irrigation is introduced into these lands, two (2) separate pipeline systems, one for lower land and the other for higher land, will be required, because higher lands need more high water pressure than lower lands. If both lands are served by one pipeline system, operations of such a pipeline will become very complicated and difficult. The construction costs per acre or hectare of pipeline system for higher land will also be higher than those for lower lands. Preliminary design of the pipeline system shows that the lands in lower part will be those with an elevation of lower than 96 m above sea level, and the higher lands with an elevation between 96 m and 106 m, from technical point of view.

Then, comparative study will be made on combination of lower and higher lands and on development of lower land only for respective blocks.

(3) Mankessim Project (Figure H-9)

According to the original plan, Mankessim project is planned to be developed for both paddy and upland crops cultivation. Total potential area covering 256 ha of land is classified into 80 ha for paddy and 176 ha for upland crops, respectively. In the original plan, paddy field is located at lowland area along the Ochi river. Presently, this lowland area is severely inundated about one (1) meter high every year by flood from the Ochi river. According to the interview with inhabitants living nearby and leveling survey on flood marks, water level of flood in about 10 years probability is about El 14.5 m. Judging from the survey result, this flood would bring more than two (2) meters of inundation in the lowland area. In order to protect the area from the flood, a flood protection dike is considered as one of the countermeasures. It would need about US$ 340,000 of investment, equivalent to US$ 1,330/ha. When paddy is cultivated in this area, in addition, total irrigable area of the project would be restricted to 115 ha instead of 256 ha of potential land, according to water balance study. From such study results, it is proposed that this lowland area be excluded from the project area and that the project rehabilitation should be made, aiming at cultivation of upland crops which would be more profitable than rice.

Then, upland irrigation by sprinkler system is considered in the existing upland located in the downstream of the dam and undulating upland on the right bank of the dam. However, additional site inspection made in the wet season this year shows that the Ghana Export Promotion Company has a right to use 167 acres (about 67 ha) of land located in the existing upland on the right bank. This private company's land will have to be excluded from the alternative study of rehabilitation plan.

The present irrigated land by existing pump and sprinkler set is limited to 17 ha of upland located on the left bank of the dam, because the pump and sprinkler set are highly deteriorated. The present irrigated land could be expanded to 29 ha in total within the same area, when new pump and sprinkler sets are provided in connection with the project rehabilitation. In addition, there exist 80 ha of upland being cultivated by farmers on the right bank of the dam for which sprinkler irrigation could be applied, using water from the Mankessim reservoir. However, the right bank area includes upland with a steep land slope of more than 10 %, and soil erosion due to intensified irrigation farming will be foreseen in this case. Because such a steep slope land is generally located on higher portion of the hills, in addition, pumps with high lifting head and high water pressure pipeline will be required to supply water to sprinkler system. The area of steep slope land is estimated at 23 ha.

Then, the following two (2) alternative plans are considered for comparative study to determine the most optimum rehabilitation plan:

Alternative 1 : Existing Area and Extension Area - 1 (net irrigated land : 29 ha in total)

Alternative 2 : Alternative 1 + Extension Area - 2 excluding elevated land with steep land slope of more than 10 % (net irrigated land : 86 ha in total)

(4) Okyereko Project (Figure H-10)

Although potential irrigable area is estimated at 111 ha, developed area is 40 ha. Since its water source is Okyereko reservoir fed by rainfall only, the irrigated area is restricted at present. In fact, the irrigated area in the past five years from 1991 to 1995 ranges from 7.3 ha to 30.9 ha and averages 21.6 ha. As already reported, preliminary water balance study shows that irrigable area with 80 % irrigation dependability would only be 11 ha. Therefore, GIDA has a plan to provide supplemental water source by installing pumps on the Ayensu river which is located near the project. This plan is prerequisite for comparative study of all the alternatives. According to the topographic maps and site inspection, there are two blocks which could be irrigated by extending the existing irrigation network. These blocks are located in the downstream of the existing paddy field and on the left bank. Then, comparative study will be made on the following three (3) alternatives:

(a) Alternative 1 : Rehabilitation of existing area + construction of new pump station as a supplemental water source

(b) Alternative 2 : Alternative 1+ development of downstream block (Extension Area - 1)

(c) Alternative 3 : Alternative 2 + development of left bank block (Extension Area - 2)

Total irrigation area in case of Alternatives 1, 2 and 3 would be 39 ha, 63 ha and 81 ha, respectively.

3.3.2 Water Balance Study

(1) Condition of Water Balance Study

A water balance study is executed for each of Ashaiman, Mankessim, and Okyereko where available water sources are limited to serve potential irrigable area, to clarify the followings:

(a) Ashaiman and Mankessim projects: Irrigable area to be served in around 80 % irrigation dependability.

(b) Okyereko project : Pump capacity to realize respective alternative plans in 80 % irrigation dependability.

Then, water balance study is carried out under the following condition :

- A water balance calculation is executed on 10-day basis.
- Study period are 10 years from 1986 to 1995.
- A water level in the reservoir is full water level when calculation is commenced.
- Equation of water balance study is expressed as follows :

$$Q_s = Q_{s1} + Q_{in} - Q_{out} - Q_{ep} - Q_s - Q_l$$

where,

- Q_s : Storage volume (m^3)
- Q_{s1} : Storage volume in previous 10 days (m^3)
- Q_{in} : Inflow to reservoir (m^3)
- Q_{out} : Water release for irrigation (m^3)
- Q_{ep} : Evaporation (m^3)
- Q_s : Spilled discharge (m^3)
- Q_l : Other losses (m^3)

(2) Ashaiman Project

A water balance study is executed for the runoff estimated by the Tank Model method and the water demand to the proposed cropping pattern. The estimated possible irrigable area to the respective probability is as follows:

Irrigation Dependability (%)	Possible Irrigable Area (ha)
100	29
90	39
80	53
70	56

On the other hand, the existing irrigation system on the left bank area covers 56 ha in net. If the 80 % irrigation dependability is kept, the balance of 3 ha will be obliged to be curtailed from the project area to be rehabilitated and will come to the rainfed area. Taking it into consideration that the balance is too small and is presently irrigated under one irrigation unit, it is proposed that the rehabilitation shall be carried out for all the existing irrigation system covering 56 ha although the irrigation dependability become 70 %. The results of water balance study are given in Table H-9.

(2) Mankessim Project

In the same manner, a water balance study is executed for Mankessim project from 1986 to 1995. The estimated possible irrigable area to the respective probability is as follows:

Irrigation Dependability (%)	Possible Irrigable Area (ha)
100	114
90	139
80	142
70	158

As discussed above, the available area for Mankessim project is narrowed down to 86 ha including the extension area considering the flood and topographic conditions, which is about 60 % of the possible irrigable area with 80 % irrigation dependability. The results of water balance study for 142 ha are given in Table H-10.

(3) Okyereko Project

In case of Okyereko project, three alternative plans are worked out as mentioned above. A water balance study is therefore carried out for respective alternative plans to determine the pump capacity under the following conditions:

(a) Pump capacity shall serve the irrigable area for each alternative plan in 80 % irrigation dependability.

(b) Water tapping from Ayensu river by pumps shall be from June to November considering the availability of river discharge.

The pump capacity determined through a water balance study is as follows:

	Irrigable Area (ha)	Pump Capacity (m^3/min)
Alternative-1	39	4
Alternative-2	63	5
Alternative-3	81	6

The results of water balance study for three alternative plans are given in Tables H-11 to H-13. The pump capacity determined is used for further comparative study on alternative plans, to select the optimum plan.

3.3.3 Determination of Optimum Rehabilitation Area

(1) Ashaiman Project

As mentioned above, the left bank area of 56 ha where the existing facilities are provided will be determined as optimum rehabilitation area for Ashaiman project.

(2) Aveyime Project

Three alternative plans are elaborated for rehabilitation of Aveyime project. These are:

(a) Alternative-1 : Rehabilitation of existing paddy field only, covering 63 ha of land,
(b) Alternative-2 : Rehabilitation of existing paddy field + Extension Areas -1 and- 3 covering 80 ha of land, and
(c) Alternative-3 : Rehabilitation of existing paddy field + Extension Areas-1,-2 and-3 covering 95 ha of land.

The project facility to be required for respective alternative plans are also designed for cost comparative purpose. The estimated costs for them are as follows, of which details are given in Table H-14.

(a) Alternative-1 : 1,232 million Cedi, equivalent to US$ 11,506 /ha.
(b) Alternative-2 : 1,523 million Cedi, equivalent to US$ 11,203 /ha.
(c) Alternative-3 : 1,852 million Cedi, equivalent to US$ 11,467 /ha.

Of three alternatives, Alternative-2 is the lowest, although the difference with the second lowest, Alternative-3 is small.

Meanwhile, Alternative-3 presents the highest incremental benefit per ha as shown in the same table, and also the largest ratio of incremental benefit and cost per ha. From these study results, Alternative-3 is recommendable as optimum rehabilitation area for Aveyime project.

(3) Kpando-Torkor Project

Possible irrigable area for Kpando-Torkor project which was preliminarily estimated at 356 ha in net, is re-estimated at 415 ha in net using the new topographic maps with 1 to 5000 scale. The project area is divided into the following 4 Blocks which are further divided into lower and higher areas, except Block-D:

Net Irrigable Area for Respective Blocks

(Unit : ha)

Block	Lower Area	Higher Area	Lower+higher Areas
A	70	50	120
B	31	33	64
C	85	65	150
D	81	-	81

In order to determine the scale of development area, comparative study is carried out for them from the following various viewpoints.

(a) Priority of development

The basic concept of the project rehabilitation is to rehabilitate the existing facility. Therefore, the area where the existing irrigation system covers at present, will be given to top priority for development if its cost is within reasonable range as compared with others.

(b) Topography and present land use

There are no definite different topographic condition in four blocks. Project area is inclined toward the Volta Lake with slope ranging from 1/50 to 1/60, and block boundaries are formed by small streams flowing into the Lake. Lower and higher areas in one block also extend at the similar topographic condition although there could find partially steep places in higher area.

As mentioned in Annex-E, lower area of Block-A area out of four blocks is only irrigated although irrigation area is 40 ha and so small, and the remaining area is cultivated with maize and casaba under rainfed condition. Both Block-B and -C areas are moderately utilized for crop cultivation under rainfed condition, where cultivated crops are maize, sugarcane and tomato. Block-D area which is located at northern part of the project area, is very less cultivated due to its isolated location.

(c) Soil condition

The soil survey results show that soil conditions in Blocks-C and-D are more suitable for crop cultivation than those in Blocks-A and -B.

(d) Ensuring of cultivation area for staple foods (maize, yam and casaba)

As discussed in Annex-D, it is necessary to ensure additionally cultivation area of staple foods such as maize, yam and casaba, for the relevant farmers around the project area to be developed. The required cultivation area for this purpose is 0.3 ha per farmer. Accordingly, when scale of the project area to be developed is determined, such additional cultivation area shall be left in the surrounding area. Since the net arable area is estimated at 770 ha, the available development area is less than 190 ha.

(e) Intake method

The Akosonbo dam is presently operated within water level fluctuation of 9.14 m from El.75.59 m to El.84.73 m. On the other hand, land surface of the project area is sloped toward the Volta Lake with 1/50 to 1/60 gradient. Taking into consideration such dam operation rule and topographic condition, irrigation water is required to be pumped up from the Lake to the project area. In order to select the optimum pump intake method, the following 3 alternative plans are studied from technical and economical viewpoints:

- Floating pump plan
- Slantingly movable pump plan
- Fixed pump plan

These plans are illustrated in Figure H-11. Though a submergible pump plan is also considered, it is omitted from the study plan due to so difficulty in its maintenance work, especially for mechanical seal portion. The structure, construction, installation, operation, maintenance and cost on these plans are discussed in Table H-15.

As can be seen in Table H-15, the fixed pump plan indicates more difficulty on installation and maintenance works than the others although operation is easier. The movable pump plan on inclined strip, presents easier construction, installation and maintenance, but slight difficulty on operation due to change of position of delivery pipe and electricity distribution panel to the seasonal fluctuation of water level of Volta Lake. The floating pump plan is the slightly difficult and complicated position as a whole but does not show any decisive ones. It can be said that the floating and movable pump plans are technically at the similar level but the fixed one is at more difficult level. The lowest construction cost per ha is given to the floating pump plan, and the movable pump plan follows. Judging from such study results, it is proposed to select the floating pump plan. Subsequent cost comparison for determination of project area to be developed is therefore made by applying this floating pump plan for respective blocks.

(f) Cost comparison

The construction cost for respective blocks is estimated for cost comparison purpose, as shown in Table H-16. The estimated cost is summarized as follows:

- Block-A		
Lower (70 ha)	:	29,171,000 Cedi/ha (US$ 17,160/ha)
Lower + Higher (120 ha)	:	28,167,000 Cedi/ha (US$ 16,569/ha)
- Block-B		
Lower (31 ha)	:	48,839,000 Cedi/ha (US$ 28,729/ha)
Lower + Higher (64 ha)	:	34,063,000 Cedi/ha (US$ 20,037/ha)
- Block-C		
Lower (85 ha)	:	29,082,000 Cedi/ha (US$ 17,107/ha)
Lower + Higher (150 ha)	:	26,987,000 Cedi/ha (US$ 15,875/ha)
- Block-D		
Lower (81 ha)	:	29,444,000 Cedi/ha (US$ 17,320/ha)

As can be seen in the above table, the lowest construction cost per ha is seen for development of both lower and higher areas of Block-C, and the second lowest one for those of Block-A, although the difference among any case in three blocks except Block-B, is within about 8 % of the lowest cost.

(g) Determination of development area

The study on construction cost per ha shows that development of lower and higher areas of Blocks -A and -C is more attractive due to lower cost as mentioned above. In case of development of both blocks, total development area will become 270 ha. As previously discussed on ensuring of cultivation area for staple foods, about 812 ha will be additionally required at full development of both blocks under crop area rotation once four years, so that total required arable land will come to

1,082 ha which is larger than the net arable land of 770 ha. From this viewpoint, development of both blocks could not be proposed.

In four blocks, irrigation is being executed only for lower area of Block-A. Since the development cost for lower area of Block-A is not high and also considering the basic concept of project rehabilitation mentioned above, it is proposed to give a top priority in development upon it, which coincides with farmers' request at the public meeting, too. Thus, the remaining selection is narrowed down to either higher area (50 ha) of Block-A or lower area (85 ha) of Block-C because Block-B and -D present higher development cost. Finally, it is proposed to develop lower area of Block-C, together with lower area of Block-A, for the following reasons although construction cost becomes slightly high:

- Development is proposed from lower area to mitigate possibility of soil degradation since there find partially steep slope places in higher area.
- Soil condition of Block-C is more suitable for crop cultivation.
- In case of development of lower and higher areas of Block-A, four pumps will be installed at one barge of pump station, and operation will become complicated due to larger command area and increase of since connection activity of pumps with deliver pipes which shall be made at every 2 m interval according to water level fluctuation.
- Balance of development within Kpando-Torkor area shall be taken into consideration.

(4) Mankessim Project

Mankessim project has two alternative plans: Alternative-1 is to rehabilitate the irrigation facility for the existing area and also to provide new irrigation facility for the Extension Area-1 (net irrigated land : 29 ha in total), and Alternative-2 is to provide new irrigation facility for the Extension Area-2 in addition to Alternative-1 (net irrigated land : 86 ha in total). The construction cost for Alternative-1 and Alternative-2 are as follows, of which details are shown in Table H-17:

(a) Alternative-1 : 802 million Cedi, equivalent to US$ 16,275 /ha.
(b) Alternative-2 : 2,350 million Cedi, equivalent to US$ 16,075 /ha.

On the other hand, incremental benefit per ha for both alternatives will be the same since the same cropping pattern is applied. From these study results and the viewpoints of the maximum use of available water and land sources, and also considering the farmers' request at the public meeting, it is recommended to apply the Alternative-2 to rehabilitation of Mankessim project.

(5) Okyereko Project

In order to determine the optimum rehabilitation area for Okyereko project, three alternatives are worked out. The pump capacity is estimated through water balance study as mentioned above. The required construction costs for respective alternatives are calculated as follows :

(a) Alternative-1 : 1,322 million Cedi, equivalent to US$ 19,936 /ha.
(b) Alternative-2 : 1,506 million Cedi, equivalent to US$ 14,058 /ha.
(c) Alternative-3 : 1,761 million Cedi, equivalent to US$ 12,789 /ha.

Breakdown of construction costs is given in Table H-18. On the other hand, it is sure that incremental benefits per ha for Alternative-3 becomes higher than the others because the upland crops are cultivated more as discussed in Annex-E and Annex-J. Thus, it is concluded that Alternative-3 is the most attractive case for rehabilitation of Okyereko project.

3.4 Irrigation Method

(1) Paddy

1) Water supply method

Of five (5) projects, three (3) projects of Ashaiman, Aveyime, and Okyereko are mainly cultivated with paddy. Irrigation water is supplied to each field by gravity system after intake. At present, it is reported that continuous supply of irrigation water is practiced in Ashaiman project and that irrigation water supply in the remaining four projects is made intermittently. However, water demand is not calculated logically as mentioned previously, and also water supply is not made based on reasonable irrigation calendar.

Except Aveyime, other projects have rather limited water resources. Although Aveyime project has rich water source, irrigation water is tapped using pumps. This means that water supply should be made carefully to minimize water loss for efficient pump operations. In case of limited water source, rotational irrigation is sometimes employed, but it requires some conditions such as definite irrigation calendar and active water users association, especially for open canal network. If conditions are not matured, it would bring about more water loss and thus water conflicts among farmers, too.

Water supply system should be simple. Taking into account the present situations surrounding the projects, it is proposed to apply the continuous water supply method, but the rotational water supply is executed at puddling time.

2) Irrigation system

The irrigation system for three (4) projects for gravity irrigation, consists of intake facilities, main canal and lateral canal. One lateral canal covers about 5 ha of land. In Aveyime project, however, a distribution box will be provided after pump facilities, to divert irrigation water to each canal easily. The existing irrigation canal system is in principle used although all facilities and canals are rehabilitated due to their severe deterioration.

(2) Upland Crops

1) Water supply method

Kpando-Torkor and Mankessim projects are presently irrigated by sprinkler system. Rehabilitation will be made for the same sprinkler system

2) Water supply amount at one time

Water supply amount at one time is calculated on the following assumptions in this study:

- Effective root depth : 30 cm
- Soil moisture extraction pattern : Standard type (4 layers of 75 mm each)
- Available moisture : 20 %

From these assumptions, Total Readily Available Moisture (TRAM) is calculated to be 28 mm which correspond to water amount at one time.

2) Irrigation interval

Daily consumptive use is computed to be 4 mm/day for Kpando-Torkor project and 5 mm/day for Mankessim project, respectively. With this daily consumption and TRAM mentioned above, irrigation interval is calculated at 7 days for Kpando-Torkor project and 6 days for Mankessim project. From these results, irrigation interval for both projects is determined at 6 days. Extension Area-3 (15ha) of Aveyime project will be also irrigated in the same manner with Kpando-Torkor project and Mankessim project.

3) Sprinkler system

In this study, the following sprinkler system is proposed, taking into consideration the existing system, easy operation, topographic condition, soil condition, etc.:

- Semi-permanent system
- Arborescent pipeline system (galvanized steel pipe)
- Intermediate sprinkler
- Extent of sprinkling (15 m x 12 m)

Typical sprinkler system is given in Figure H-19. One sprinkler unit consisting of 8 sprinkler heads, 8 riser pipes, 93 m movable lateral (70 mm dia.), will cover 2.4 ha in 6 days rotation.

4) Furrow system

According to the soil survey, Extension Area -1 and Extension Area -2 of Aveyime project are covered with loamy sand and sandy clay loam, respectively. Extension Area -1 and Extension Area - 2 of Okyereko project are occupied by clay loam and clay/sandy loam, respectively. From these soil conditions, these areas are irrigated by furrow system. The proposed furrow length is as follows:

- Aveyime project
  - Extension Area - 1 : 100 m
  - Extension Area - 2 : 50 m

- Okyereko project
  - Extension Area - 1 : 100 m
  - Extension Area - 2 : 100 m

5) Proposed irrigation plan

The irrigation plans for respective projects are prepared based on the preliminary study results as shown in Table H-19. The design discharge diagrams for respective projects are given in Figures H-13 to H-17.

4. DRAINAGE PLAN

4.1 Basic Concept for Establishment of Drainage Plan

A drainage plan should be established in line with the following basic concept :

(1) Drainage water requirement shall be estimated considering the cultivated crops. For example, paddy would allow certain water stagnant, which would closely concern its growing stage, but upland crops do not allow any more.

(2) Drainage system shall be rehabilitated taking into account the condition of river to be drained or the effect by lagoon if any.

(3) Drainage system shall be so rehabilitated as to consider not only the elimination of excess water but also the soil erosion in case steep topography is prevailing over the project area.

4.2 Proposed Drainage System

The drainage facilities exist in three (3) projects of Ashaiman, Aveyime and Okyereko. These facilities do not function properly due to much sedimentation and grasses. It is therefore essential to remove them and to keep steady maintenance work. The proposed rehabilitation works of the drains will be to remove sedimentation and to finish the canal section as designed. In these projects, a main drain runs across the original project area so that a causeway will be provided for easy access to respective fields and transportation of agricultural products.

In upland irrigation projects such as Kpando-Torkor and Mankessim, intercepting drains and collector drains are proposed in connection with soil erosion control measures, as reported in the Interim Report. The intercepting drains will generally be provided along contour line, and be connected to collector drain. As a collector drain will run crossing the contour line, it will be lined with wet stone pitching to avoid erosion at inside surface of drain and to minimise canal flow section.

In addition, green belts will be provided along contour line at intervals of about 200 m in order to control soil erosion in Kpando-Torkor and along foot of higher land with slope more than 10 % in Mankessim areas.

4.3 Rainfall Analysis

In order to estimate the drainage requirements for respective projects, daily rainfall data to be used are determined through probability analysis as shown below:

Rainfall Analysis

(Unit: mm)

Project	Observation Site	Data Period	Daily Rainfall			3-days Consecutive Rainfall		
			2-years	5-years	10-years	2-years	5-years	10-years
Ashaiman	Tema	1976 to 95	72	94	109	88	112	128
Aveyime	Akuse	1980 to 95	70	93	110	92	127	156
Kpando-Torkor	Ho	1976 to 95	77	117	153	106	152	188
Mankessim	Saltpond	1976 to 95	94	121	135	121	152	171
Okyreko	Saltpond	1976 to 95	94	121	135	121	152	171

4.4 Estimate of Drainage Requirements

(1) General

The drainage system is designed based on need to remove excess irrigation and rainfall water from the fields. Drainage requirements are estimated for the following cases:

- Internal drains for paddy field
- Internal drain for upland crop field

(2) Paddy Field

The drainage requirements for internal drain are calculated through a simple water balance calculation under the following conditions:

- Initial depth of water on fields: 50 mm
- Design rainfall : 3-days consecutive rainfall with 1 in 10 year probability
- Allowable submergence depth : 150 mm

The water balance calculation is made using the following equation:

$$Hu = 50 + (Rd \times t)/3.0 - Qd \times t \times 8.64 \quad \text{for } t \leq 3 \text{ days}$$
$$Hd = 50 + Rd - Qd \times t \times 8.64 \quad \text{for } t > 3 \text{ days}$$

Where,

Hu : Submergence depth of water for 3 days (mm)
Hd : Submergence depth of water from 4th day (mm)
Rd : Design rainfall (mm)
Qd : Drainage requirement (lit/s/ha)
t : Period (day)

The calculation procedure and results are given in Figures H-18 to H-20. Drainage requirements for the corresponding projects are tabulated below:

- Ashaiman project : 1.0 lit/s/ha
- Aveyime project : 2.0 lit/s/ha
- Okyereko project : 3.0 lit/s/ha

(3) Upland Crops Field and Natural Stream with Small Catchment Area

In this study, drainage water requirements are estimated using the 10-year probable daily rainfall and the MacMath equation which is similar to the rational equation. In the use of this equation, rate of hourly rainfall is derived from the said daily rainfall data using the "Maximum Rainfall Intensity-Duration Frequencies in Ghana", Ghana Meteorological Services Department, Departmental Note No.23. Runoff coefficients for respective projects are determined from vegetation, soils and topography. Study results are given in Table H-20 and are summarised below:

- Ashaiman : $Qd = 0.070\ A^{4/5}$
- Kpando-Torkor : $Qd = 0.181\ A^{4/5}$
- Mankessim : $Qd = 0.138\ A^{4/5}$

Where,

Qd : Drainage discharge (m^3/s)
A : Drainage area (ha)

(4) Natural Streams with Middle and Large Catchment Area

Drainage requirements for natural streams related to the projects are as follows, for details are discussed in Annex-B.

Flood Discharge of Natural Rivers

Return Period	Ochi-Amisa River	Ayensu River	G. Akonu River
2-year	130 m3/s	145 m3/s	14 m3/s
5-year	200 m3/s	220 m3/s	18 m3/s
10-year	230 m3/s	255 m3/s	21 m3/s
25-year	330 m3/s	370 m3/s	-
50-year	360 m3/s	400 m3/s	-

(5) Proposed Drainage Diagram

The drainage diagrams for respective projects are shown in Figure H-21 to H-25.

4.5 Control Measures against Soil Erosion

Annex-F relates that Kpando-Torkor and Mankessim projects will have a possibility on soil erosion due to sloped topography, if proper countermeasures are not applied. Although there are some countermeasures against soil erosion, it is proposed in this case to use a green belt together with drainage system, which is simple and easily constructed. A green belt with intercepting drain will be provided along contour at about 200 m interval, and the excess water caught by intercepting drain will enter into collector drain. Flow velocity in collector drain will become higher, it will be lined with concrete. In addition to such a green belt, one irrigation service unit (one acre) will be surrounded by foot path covered with grass of which width is about one meter, although it shall be made by farmers' organization. This foot path is also expected to mitigate soil erosion.

5. FARM ROAD AND BUILDING PLAN

5.1 Basic Concept for Establishment of Farm Road Plan

A road plan shall be established in line with the following basic concept :

(1) Existing roads shall be incorporated into the new farm road network as much as possible.

(2) Lateral farm road shall be provided so as to connect directly with irrigation service unit (one acre) considering transportation of agricultural inputs and farm products.

(3) Main farm road shall be so provided as to inspect major canals and to link project office and pump station with public road, at least.

5.2 Proposed Farm Road Plan

All farm roads are generally poor and will require improvement for proper operation and maintenance of the project facilities as well as for conveyance of agricultural inputs and farm products. Taking into consideration such present condition and also the available local materials for pavement, it is proposed to apply the following farm road development plan:

(1) Main Farm Road

There are two types of development plan of main farm road. One is to improve the existing road, and the other is to construct the new one. The main road is of 5m wide including 3 m gravel pavement. For the existing road, its surface will be scarified, regraded and compacted prior to resurfacing. The gravel pavement will be provided for 10 cm thick. As for new construction, stripping, excavation, embankment and gravel pavement will be executed for the same dimension with rehabilitation of the existing one. The total thickness of road will be 30 cm consisting of 20 cm for embankment and 10 cm for gravel pavement.

(2) Lateral Farm Road

Lateral farm road is also divided into two types of improvement of the existing road and new construction. The lateral farm road is of 3 m wide and 25 cm laterite pavement. The construction method for lateral farm road will be the same with the main farm road.

(3) Access Road

In order to approach the project area smoothly, it is essential to improve the public road as an access road. These roads exist in Kpando-Torkor and Mankessim projects. The required works are scarifying, compaction and replacement of damaged cross drains with new ones. Any pavement will not be made by following the original condition.

5.3 Basic Concept for Establishment of Building Plan

A building plan shall be established in accord with the following basic concept:

(1) Buildings to be rehabilitated or newly constructed shall be minimized in number and size.

(2) Rehabilitation or construction of buildings shall be made taking into due consideration local style and manner.

(3) Needs of buildings shall be studied considering the effective execution of the agricultural activities as well as operation and maintenance of project facilitiy.

5.4 Proposed Building Plan

The required buildings are largely divided into three categories: O & M office, post-harvesting facility and training facility. Development plan for these buildings is as follows:

(1) O & M Office

The project offices, except for those in Ashaiman, are generally poor. These offices are therefore proposed to be replaced by new ones. A new O&M office shall be designed, taking into account the farmers' participation in the project operations.

(2) Post-harvesting Facility

Post-harvesting facility such as store house, sorter house, dry yard and garage are not sufficient at present in most of the projects, and will be newly constructed. The required number of these facility will be determined from the proposed cropping patterns.

(3) Training Facility

Training of the farmers is one of the important programs for improvement and strengthening of the farmers societies. Since the Irrigation Development Centre exists at Ashaiman project, it is proposed that most of the training activities be carried out at this centre. For this purpose, a lecture hall, a dormitory, guest house for visiting lectures will be provided at Ashaiman. In addition, a lecture hall will be constructed also at Okyereko.

6. REHABILITATION PLAN FOR PROJECT FACILITY

6.1 Basic Concept for Establishment of Rehabilitation Plan

The basic concept for rehabilitation plan for the existing irrigation and drainage facilities, is as follows :

(1) Dam

All dams for Ashaiman, Mankessim and Okyereko projects are in good condition, so that no major rehabilitation works will be required.

(2) Weir

There is no weir in five projects, but a weir will be newly constructed in Okyereko project as supplemental water source.

(3) Pump Facility

As all pumps are in unsatisfactory conditions due to deterioration, difficulty in procurement of spare parts and lowering of efficiency, these will be replaced by new ones. The existing pump houses for Aveyime and Mankessim projects are in poor condition, so that new ones will be required. For Kpando-Torkor project, a new pump house will also be required.

(4) Irrigation System

(a) Canal: the unlined main canal and lateral will be replaced into concrete flume type for less conveyance loss and easy maintenance. In case there find severe leakage in the presently lined canal, it will be replaced into concrete flume after dismantling the existing one.
(b) Pipeline: as most of pipe lines are leaked from joint and small holes due to deterioration, these will be replaced by new ones.
(c) Sprinkler set: as all sprinkler sets are in unsatisfactory conditions due to deterioration and lowering of efficiency, these will be replaced by new ones.

(5) Drainage System

All drains are severely covered with sediments and weeds, so that reconstruction will be required.

(6) Related Structures

(a) In case the structure does not function properly at all, it will be replaced by new one.
(b) In case the structure functions properly, but minor damages are observed, it will be repaired.
(c) In case the structure functions properly, and any damage is not observed, it will remain as it is.

(7) Farm Roads

Three types of road which are main farm road, lateral farm road and access road, will be considered for smooth execution of operation and maintenance of project facilities and also transportation of agricultural inputs and farm products. The main road will serve to connect the project office and pump station with the public road. The lateral road will function to link the main road or public road with the irrigation service unit. Access road is the existing unpaved public road to connect the project area with the public road, and will be rehabilitated for smooth transportation. In this connection, the related structures will also be rehabilitated.

(8) Building

Except Ashaiman, other projects have so poor project office. It will therefore be totally replaced by new one. In addition, as store house, sorter house, dry yard and garage are lacked in most of projects, these will be newly provided based on the required agricultural activities. Training to farmers is essential for successful project operation so that training facility shall be provided at the selected projects.

Based on the basic concept mentioned above, a rehabilitation plan for project facility for respective projects is prepared as mentioned below, and summarized in Table H-21.

6.2 Irrigation and Drainage Layout

(1) Ashaiman Project

The project area to be rehabilitated in Ashaiman, is presently covered with the existing irrigation and drainage system. Since these are totally deteriorated, the new system will be constructed. A layout of new system will follow the existing one because there does not find any technical problem. The new layout of irrigation and drainage system is shown in Figure H-26.

(2) Aveyime Project

Project area of Aveyime is divided into four areas: the existing area, Extension Area-1, Extension Area-2, and Extension Area-3. In the existing area, a new irrigation and drainage system will be constructed since the existing one is severely deteriorated, but its layout is the same with the existing one. In three Extension Areas, there are no irrigation and drainage system. Thus, these areas are provided with a new irrigation and drainage system which is designed considering the upland crops cultivation. Figure H-27 presents the new irrigation and drainage system layout.

(3) Kpando-Torkor Project

As mentioned above, the lower areas of Blocks -A and -C are selected as the project area to be developed. The pipeline layout is designed on the 1/5000 topo-maps considering the topographic condition and the irrigation service unit of one acre in net (0.4 ha). The drainage system consisting of intercepting drain and collector drain is also laid out on the same maps in connection with the green belt to avoid soil erosion. The designed layout is given in Figure H-28.

(4) Mankessim Project

Mankessim project consists of the existing area, Extension Area-1 and Extension Area-2. Since these areas are cultivated with upland crops, pipeline for sprinkler system is laid out on the 1/5000 topo-maps considering location of pump station and the irrigation service unit of one acre in net (0.4 ha). In Extension Area-1, pipeline layout is made centering the existing pump station although it is replaced by new one. In Extension Area-2, pipeline layout is executed putting care upon the soil erosion due to undulated topography. In order to prevent soil erosion, green belt, intercepting drain and collector drain are also laid out on the same maps . The designed layout is given in Figure H-29.

(5) Okyereko Project

Okyereko project is composed of the existing area, Extension Area-1 and Extension Area-2. The existing area is presently cultivated with paddy under the existing irrigation and drainage system. This existing irrigation and drainage system will be totally replaced by new one due to serious deterioration. In Extension Areas-1 and -2 where upland crops are cultivated, the same system will be provided because of similar topographic and soil conditions. Figure H-30 indicates the proposed irrigation and drainage canal layout.

6.3 Design Water Duties

The design water duties for respective projects which are estimated based on the irrigation water requirements and irrigation time, are calculated for design of pump, canals and related structures. The design water diagrams for respective projects are shown in Figures H-13 to H-17.

6.4 Dam and Reservoir

Out of five projects, Ashaiman, Mankessim and Okyereko projects are provided with earthfill dam. As these dam and reservoir are in good condition, any major rehabilitation work is not required. Only re-surfacing work will be carried out for top of dam in Mankessim project. For Okyereko project, it will be recommended that reforestation/green belt is provided around the reservoir by beneficiaries, in order to protect it from further siltation.

6.5 Intake Facility

6.5.1 Weir

No existing weir is in the selected five projects. In Okyereko project, however, it is necessary to construct an intake weir on the Ayensu river, in order to supply supplemental water to the reservoir. The proposed intake weir will be provided about 350 m downstream from the crossing point with the Accra - Sekondi national road as shown in Figure H-31. The intake weir is of concrete type with one scouring sluice gate of 1.0 m wide x 1.1 m high. The weir has a dimension of 13 m in length and 1.0 m in height. One intake gate of 0.7 m x 0.7 m will be installed as intake facility. Intake discharge is designed at 0.1 m^3/s.

As mentioned above, the proposed weir will be positioned about 350 m downstream from the crossing point with the national road. The sandwiched area between the national road and the proposed weir site is presently inundated during the wet season due to insufficient flow capacity of the river. This area where no cultivation is carried out during the wet season, serves as retarding area to flood. Inundation condition after construction of weir is therefore studied through non-uniform calculation based on the topo-survey result As a result, a difference between with and without weir is about 20 cm in water level to 10-years flood and water level with weir will become El.8.72 m at the crossing point, which is still lower than top of the national road (El.9.86 m). It is considered that such small difference between with and without weir may be mainly due to such large retarding area. In non-uniform calculation, the existing spillway (El.8.19m) just upstream of the proposed weir site , is not taken into account so that the said water level of El 8.72 m would actually be down.

Judging from these study results, it is recognized that construction of intake weir will not bring about severe backwater influence to the national road.

6.5.2 Pump Station

(1) Aveyime Project

In Aveyime project, two pump stations will be constructed: One is to supply irrigation water for total irrigation area of 95 ha, and the other is to further boost up water to irrigate the Extension Area-3 of 15 ha. The major features of pump and pump station are given in Table H-22.

(2) Kpando-Torkor Project

The lower areas of Blocks-A and -C will be irrigated with water tapped by pumps from the Volta Lake. The proposed pump intake method is designed putting care upon the seasonal fluctuation of water level of the Volta Lake. The major features of pump station are shown in Table H-22.

(3) Mankessim Project

The project area to be developed in Mankessim is divided into the existing area, Extension Area-1 and Extension Area-2. The existing area will be developed together with the Extension Area-1. These areas will be irrigated using the electrically driven pumps. Table H-22 presents the major features of pump station :

(4) Okyereko Project

Okyereko project will require the supplemental water source due to insufficient inflow into reservoir. The necessary additional water will be supplied into the reservoir by pumps from the Ayensu river. The major features of pump and pump station are presented in Table H-22.

(5) Bearing Capacity at Proposed Pump Station Sites

The bearing capacity at the proposed pump station sites is measured by cone penetrometer. The results are given in Table H-23. As can be seen in this table, respective pump station sites have enough bearing capacity to construct the pump station.

6.6 Distribution System

6.6.1 Gravity System

(1) Ashaiman Project

The project area of Ashaiman will be irrigated by gravity. Irrigation water will be taken by intake valve, and will be supplied to each field plot through main canal and lateral. The main and lateral canals are of concrete flume type, in order to minimize canal seepage loss and to ensure the structural stability because these canals are constructed on the backfilled foundation. The canal section is determined considering the flow velocity so as to divert canal flow easily, say less than 0.6 m/sec. Lateral is designed to be the same section from the beginning to end points due to small discharge. Irrigation water will be delivered to fields continuously. The designed canal dimensions are given in Table H-24.

(2) Aveyime Project

The distribution system for Aveyime project is also designed in the same concept with the Ashaiman project although a headrace is provided to connect the outlet of delivery pipe with the distribution box. The proposed distribution system is shown in Table H-24.

(3) Okyereko Project

Okyereko project will be provided with the new distribution system consisting of main canal, secondary canal and lateral for which layout is almost the same with the existing one. The existing lined canals will be totally replaced by concrete flume considering its stability and small discharge. The distribution system for Okyereko project is designed as shown in Table H-24.

6.6.2 Sprinkler System

(1) Aveyime Project

The Extension Area-3 of Aveyime project where upland crops will be cultivated, is irrigated by sprinkler system due to sandy soil. Layout of delivery pipes is designed based on irrigation service unit of one acre (0.4 ha). Irrigation water is taken from the main canal and boosted up by pump for sprinkler irrigation for upland crops. The delivery pipe which is made of steel, will require 1.3 km in length and the sprinkler system covering 2.4 ha for 6 days irrigation interval, will need 7 sets. Irrigation time at one time will be 10.5 hours at peak.

(2) Kpando-Torkor Project

The lower areas of Blocks-A and -C will be irrigated by sprinkler system. The respective irrigable area is divided into 175 irrigation service units for Block-A and 213 irrigation service units foe Block-C. The delivery pipes of which required length is estimated at 6.8 km for Block-A and 9.4 km for Block-C. Diameter of these pipes are determined based on the maximum allowable flow velocity of 1.6 m/sec for more than 200 mm dia. and 1.0 m/sec for less than 200 mm dia.

(3) Mankessim Project

Delivery pipes and sprinkler system will be installed for the existing area, Extension Area-1 and Extension Area-2. The designed irrigation service unit is 73 for the existing area and Extension Area-1 and 215 for the Extension Area-2. The length of delivery pipes which are designed in the same criteria mentioned above, is 3.3 km for the existing area and Extension Area-1 and 14.0 km for the Extension Area-2. In the Extension Area-2, air valve will be also equipped with pipeline.

6.7 Drainage System

Drainage system is of gravity type and any mechanical one is not employed. The proposed drainage system is classified into two systems: One is for paddy cultivated projects such as Ashaiman, Aveyime and Okyereko, and the other is for upland crops cultivated projects such as Kpando-Torkor and Mankessim. Rehabilitation plan of them is explained below:

(1) Paddy Cultivated Projects

(a) Ashaiman project

There is the existing drainage system consisting of main and lateral drains. The proposed drainage system will just follow the existing system. The existing main drain is connected with spillway of the reservoir of which design capacity is 85 m3/sec. According to the water balance study, no spillout is observed for ten years from 1986 to 1995 if 56 ha is cultivated as proposed. From this study result and taking it into account surrounding area along the main drain is agricultural land, rehabilitation of the existing drainage system is made based on the drainage requirement mentioned in Section 4.4 without applying this spillway capacity. The designed drainage system is given in Table H-25.

(b) Aveyime project

The drainage system of Aveyime project is also designed for rehabilitation of the existing one in the same manner with Ashaiman project. The design results are shown in Table H-25.

(c) Okyereko project

Okyereko project has also the existing drainage system although these do not function well due to much sediments place to place and highly grown weeds. The existing main drain is linked with the spillway of reservoir of which design capacity is 25 m3/sec. Water balance study shows that there is no spillout discharge if water is released for 81 ha crop area. On the other hand, topographic survey results on the main drain indicate the enough flow capacity to eliminate the excess water from the corresponding catchment area. Therefore the existing main drain will be so rehabilitated as to create the smooth flow condition by removing the said sediments and weeds only, and also by making minor excavation. As for secondary drain connecting with the spillway of the flood dike against the Ayensu river, it will be rehabilitated using the design discharge of 5 m3/sec which is estimated from the non-uniform calculation as mentioned in Sub-section 6.5.1 (overflow depth = El.8.72m - El.8.19m = 0.53m to 1/10 probability flood). The lateral drain will be designed in the same manner with Ashaiman project. Table H-25 gives the designed features of drainage system to be rehabilitated.

(2) Upland Crops Cultivated Projects

(a) Kpando-Torkor project

Drainage system is indispensable for Kpando-Torkor project in order to avoid soil erosion due to sloped topography. Drainage system is composed of intercepting drain and collector drain. Intercepting drain will be constructed together with a green belt which will be provided along contour at about 200 m interval. The intercepting drain will connect with collector drain. The collector drain which will run about perpendicularly to contour, will be lined with concrete because of high flow velocity. The designed drainage system for Kpando-Torkor project is given in Table H-26.

(b) Mankessim project

Since Mankessim project is also covered with sloped topography, the drainage system will be designed to protect the soil erosion. The designed drainage system is shown in Table H-26.

6.8 Farm Road

A required length of each road to be improved or constructed newly which is designed based on the farm road plan mentioned previously, is as follows:

Estimated Road Length

(Unit : m)

Project	Main Farm road		Lateral Farm Road		Access Road
	Rehabilitated	Newly Constructed	Rehabilitated	Newly Constructed	Rehabilitated
Ashaiman	1,580	0	3,670	310	0
Aveyime	1,950	980	3,650	2,390	0
Kpando-Torkor	750	2,540	2,240	7,840	4,300
Mankessim	620	400	0	11,860	0
Okyereko	2,190	0	3,730	3,870	0

6.9 Related Structures

6.9.1 Irrigation Structures

In order to execute proper water management, lots of related structures will be needed for irrigation canal network. Most of them are made of reinforced concrete. Location and function of them are briefly explained below:

(1) Outlet

Outlet will be provided at end of delivery pipe of pump, to transfer water to open canal smoothly. Outlet will be constructed in Aveyime project.

(2) Distribution Structure

Distribution structure will be provided at end of delivery pipe of pump, to transfer water to open canal smoothly. Distribution structure will be constructed where two or more laterals are branched off. Aveyime project will be provided with one distribution structure on main canal.

(3) Turnout and Check

Turnout will be constructed in Ashaiman, Aveyime and Okyereko projects. Turnout will be provided at the following diversion points on parent canal:

- Main canal to secondary canal
- Main canal to lateral
- Secondary canal to lateral

Turnout will be in principle combined with check for easy and accurate water division because canal discharge for these projects are so small even at peak time. Turnout and check will be equipped with small slide gate for regulation of intake discharge.

(4) Siphon

Siphon will be provided where irrigation canal passes under road or natural stream. Pipe siphon will be employed for easy construction and small canal discharge. Of five projects, Okyereko project only will be provided with this pipe siphon.

(5) Drop and Energy Dissipater

Drop will be provided to adjust canal gradient aiming to ensure proper flow velocity. The proposed drop is of vertical type because of small design discharge and drop height less than one meter. Ashaiman and Okyereko projects only will need drop due to comparatively steep slope topography.

Energy dissipater will be provided at downstream portion of main canal in Ashaiman project. This portion indicates steep slope topography so that excess energy will have to be dissipated by this structure. Energy dissipater is a simple reinforced concrete box in which partition wall with holes will be installed.

(6) Culvert

Culvert will be constructed on irrigation canal where canal will cross with road. Pipe type culvert will be used since size of irrigation canal is small for any project.

(7) Field Outlet

Field outlet will be provided at branching point of lateral to irrigation service unit. As field outlet commanding about 0.4 ha, is simple structure consisting of concrete box, pipe, and small slide gate.

(8) Measuring Device

Measuring device is essential for realizing proper water distribution. The proposed measuring device is a broad crested weir for easy construction and observation. The measuring device will be provided immediately downstream of turnout.

6.9.2 Drainage Structures

The required drainage structures are causeway and cross drain. These structures are made of reinforced concrete and pipes. The proposed number of them for respective projects is given below:

Drainage Related Structures

(Unit:no(s))

Structure	Ashaiman	Aveyime	K.-Torkor	Mankessim	Okyereko
Causeway	11	0	0	0	2
Cross Drain	1	14	20	24	5
Total	12	14	20	24	7

6.9.3 Road Structures

The related structures to farm roads are causeway and cross drain which will be constructed where natural streams cross. These structures will be composed of reinforced concrete-made wing walls and pipes. Causeway will be provided for comparatively large scale stream, and cross drain for small one. The required number of them is given below:

Road Related Structures

(Unit:no(s).)

	Main Farm Road		Lateral Farm Road		Access Road	
	Causeway	Cross Drain	Causeway	Cross Drain	Causeway	Cross Drain
Ashaiman	0	0	0	0	0	0
Aveyime	0	0	0	1	0	0
Kpando-Torkor	0	0	1	0	4	0
Mankessim	0	0	0	-	0	0
Okyereko	0	0	0	1	0	0
Total	0	0	1	2	4	0

6.10 Buildings and Related Facility

The buildings and related facility required for respective projects will be as follows:

(1) O&M Office

A O & M office will be provided for four projects except Ashaiman project. The proposed office consists of five rooms including one meeting room. Out of them, one room will be used for farmers' organization. The required office space will be 175 m2.

(2) Post-harvesting Facility

The required number of these facilities, which are estimated from the proposed crops and crop production, will be as follows:

Proposed Post-harvesting Facility

Project	Store House		Sorter House		Dry Yard		Garage	
Ashaiman	Not needed		1 no.	(300m2)	Not needed		Not needed	
Aveyime	1 no.	(200m2)	1 no.	(300m2)	1 no.	(300m2)	1 no.	(300m2)
Kpando-Torkor	2 nos.	(400m2)	2 nos.	(600m2)	2 nos.	(600m2)	2 nos.	(600m2)
Mankessim	1 no.	(200m2)	1 no.	(300m2)	1 no.	(300m2)	1 no.	(300m2)
Okyereko	1 no.	(200m2)	1 no.	(300m2)	1 no.	(300m2)	1 no.	(300m2)

(3) Training Facility

At Ashaiman project, the following training facility will be provided since IDC executes the farmers' training such as water management, strengthening of farmers' society and operation and maintenance activities, using the rehabilitated facilities:

- One lecture hall (32 m2 in floor)
- Two dormitories for officer (40 m2 each in floor)
- One dormitory (263 m2 in floor for about 20 trainees in one group)
- One dining with kitchen (40m2 in floor)

At Okyereko project, one lecture hall only will be provided to make light farmers' training mainly for farmers cultivating at Mankessim and Okyereko projects located western side. These training facility are made of concrete block and asbestos roof.

7. QUANTITIES ESTIMATE

7.1 General

Quantities for major works for all five projects are summarized below:

- Pump (Centrifugal type)	:	18 nos
- Stripping (t=0.15m)	:	226,450 m2
- Excavation	:	58,600 m3
- Backfill	:	27,100 m3
- Embankment	:	25,700 m3
- Reinforced concrete	:	8,470 m3
- Plain concrete	:	530 m3
- Reinforcement bar	:	411,140 kg
- Form	:	92,170 m2
- Dismantling work	:	2,800 m3
- Gravel pavement	:	5,100 m3
- Laterite pavement	:	23,400 m3
- Gabion mattress 50cm thick	:	1,200 m2
- Gabion mattress 30cm thick	:	350 m2
- Slide gate (400 x 350)	:	36 nos
- Slide gate (400 x 450)	:	40 nos
- Slide gate (500 x 450)	:	36 nos
- Slide gate (700 x 700)	:	1 no
- Slide gate (700 x 750)	:	2 nos
- Slide gate (1100 x 1100)	:	1 no
- Steel pipe D=350	:	640 m
- Steel pipe D=300	:	2,660 m
- Steel pipe D=250	:	740 m
- Steel pipe D=200	:	1,280 m
- Steel pipe D=150	:	6,130 m
- Steel pipe D=100	:	16,210 m
- Sprinkler system	:	109 sets

Quantities required for each project are mentioned below:

7.2 Ashaiman Project

Quantities for major civil works are calculated based on the survey results and preliminary design drawings. The results of quantity estimate are given below.

(1) Irrigation System

The main and lateral canals to be rehabilitated are 1.8 km and 4.6 km in length, respectively. The required quantities for major work items are as follows:

- Stripping (t=0.15m)	:	21,000 m2
- Excavation	:	700 m3
- Backfill	:	5,000 m3
- Embankment	:	2,300 m3
- Reinforced concrete	:	900 m3
- Reinforcement bar	:	34,100 kg
- Form	:	13,800 m2
- Dismantling work	:	300 m3

(2) Drainage System

The main and lateral drains to be rehabilitated are 3.5 km and 7.2 km in length, respectively. The required quantities for major work items are as follows:

- Clearing	:	24,100 m2
- Excavation	:	3,800 m3

(3) Farm Road System

The main and lateral roads to be rehabilitated and/or newly constructed are 1.6 km and 4.0 km in length, respectively. The required quantities for major work items are as follows:

- Stripping (t=0.15m)	:	21,000 m2
- Embankment	:	700 m3
- Laterite pavement	:	5,000 m3
- Gravel pavement	:	2,300 m3
- Grading and compaction	:	900 m3

(4) Related Structures

In order to operate and maintain the irrigation system properly, 330 structures will be required. The required quantities for major work items are as follows:

- Stripping (t=0.15m)	:	1,600 m2
- Excavation	:	1,400 m3
- Backfill	:	900 m3
- Reinforced concrete	:	140 m3
- Reinforcement bar	:	4,100 kg
- Form	:	1,730 m2
- Slide gate (400 x 450)	:	24 nos.

7.3 Aveyime Project

Quantities for major civil works are calculated based on the survey results and preliminary design drawings. The results of quantity estimate are given below.

(1) Pump Station

The centrifugal pumps of 5 nos. are required for tapping water from the Volta river. The required work quantities for pump stations are as follows:

- Stripping (t=0.15m)	:	600 m2
- Excavation	:	1,700 m3
- Backfill	:	800 m3
- Reinforced concrete	:	60 m3
- Plain concrete	:	30 m3
- Reinforcement bar	:	4,580 kg
- Form	:	410 m2

(2) Irrigation System

The head race, main, secondary and lateral canals to be rehabilitated are 0.4 km, 3.4 km, 0.3 km and 7.8 km in length, respectively. The required quantities for major work items in canal construction are as follows:

- Stripping (t=0.15m)	:	37,700 m2
- Excavation	:	1,900 m3
- Backfill	:	7,000 m3
- Embankment	:	7,800 m3
- Reinforced concrete	:	1,500 m3
- Reinforcement bar	:	66,000 kg
- Form	:	25,900 m2
- Dismantling work	:	800 m3

In addition to the canal system, pipeline of 1.3 km is also required for the Extension Area-3. The required length of steel pipe and sprinkler sets are as follows:

- Steel pipe, D=150	:	540 m
- Steel pipe, D=100	:	670 m
- Sprinkler system	:	7 sets

(3) Drainage System

The main, secondary and lateral drains to be rehabilitated are 1.3 km, 1.8 km and 12.3 km in length, respectively. The required quantities for major work items are as follows:

- Clearing	:	9,000 m2
- Excavation	:	3,800 m3

(4) Farm Road System

The main and lateral roads to be rehabilitated and/or newly constructed are 2.9 km and 6.0 km in length, respectively. The required quantities for major work items are as follows:

- Stripping (t=0.15m)	:	12,100 m2
- Embankment	:	1,300 m3
- Laterite pavement	:	1,900 m3
- Gravel pavement	:	900 m3
- Grading and compaction	:	20,800 m3

(5) Related Structures

In order to operate and maintain the irrigation system properly, 373 structures will be required. The required quantities for major work items are as follows:

- Stripping (t=0.15m)	:	1,500 m2
- Excavation	:	900 m3
- Backfill	:	700 m3
- Reinforced concrete	:	120 m3
- Plain concrete	:	30 m3
- Reinforcement bar	:	5,420 kg
- Form	:	1,840 m2
- Slide gate (400 x 350)	:	36 nos.
- Slide gate (400 x 450)	:	2 nos.
- Slide gate (500 x 450)	:	36 nos.
- Slide gate (700 x 750)	:	2 nos.

7.4 Kpando-Torkor Project

Quantities for major civil works are calculated based on the survey results and preliminary design drawings. The results of quantity estimate are given below.

(1) Pump Station

The centrifugal pumps of 6 nos. are required for tapping water from the Volta lake. The required work quantities for pump stations are as follows:

- Stripping (t=0.15m)	:	6,000 m2
- Excavation	:	21,700 m3
- Backfill	:	4,100 m3
- Embankment	:	3,400 m3
- Reinforced concrete	:	1,710 m3
- Plain concrete	:	110 m3
- Reinforcement bar	:	131,100 kg
- Form	:	3,960 m2

(2) Irrigation System

Pipeline of 16.2 km consisting of 2.9 km main pipe, 2.5 km secondary pipe and 10.8 km lateral pipe, is required for irrigation of lower areas of Block-A and Block-C. The required length of steel pipe and sprinkler sets are as follows:

- Steel pipe, D=350	:	640 m
- Steel pipe, D=300	:	730 m
- Steel pipe, D=250	:	380 m
- Steel pipe, D=200	:	1,180 m
- Steel pipe, D=150	:	3,250 m
- Steel pipe, D=100	:	10,020 m
- Sprinkler system	:	66 sets

(3) Drainage System

Collector drains to be newly constructed are 4.7 km in length. Green belts of 9.6 km are also constructed to mitigate soil erosion. The required quantities for major work items are as follows:

- Stripping (t=0.15m)	:	7,000 m2
- Excavation	:	6,700 m3
- Reinforced concrete	:	910 m3
- Reinforcement bar	:	37,360 kg
- Form	:	8,800 m2
- Sod facing	:	24,000 m2
- Dry stone pitching	:	6,700 m2

(4) Farm Road System

The main and lateral roads to be rehabilitated and/or newly constructed are 3.3 km and 10.1 km in length, respectively. In addition, access road will also be rehabilitated for smooth approach to the site from national road. The required quantities for major work items are as follows:

- Stripping (t=0.15m)	:	36,400 m2
- Embankment	:	3,300 m3
- Laterite pavement	:	6,300 m3
- Gravel pavement	:	1,000 m3
- Grading and compaction	:	32,000 m3

(5) Related Structures

In order to protect the project facility from heavy rain, 25 structures will be required. The required quantities for major work items are as follows:

- Stripping (t=0.15m)	:	550 m2
- Excavation	:	900 m3
- Backfill	:	600 m3
- Reinforced concrete	:	120 m3
- Plain concrete	:	140 m3
- Reinforcement bar	:	1,220 kg
- Form	:	1,000 m2
- Reinforced con. pipe(800)	:	80 m
- Reinforced con. pipe(1000)	:	60 m

7.5 Mankessim Project

Quantities for major civil works are calculated based on the survey results and preliminary design drawings. The results of quantity estimate are given below.

(1) Pump Station

The centrifugal pumps of 5 nos. are required for tapping water from the Mankessim reservoir. The required work quantities for pump stations are as follows:

- Stripping (t=0.15m)	:	700 m2
- Excavation	:	900 m3
- Backfield	:	200 m3
- Reinforced concrete	:	130 m3
- Plain concrete	:	80 m3
- Reinforcement bar	:	9,500 kg
- Form	:	750 m2

(2) Irrigation System

Pipeline of 9.5 km consisting of 1.7 km main pipe, 1.5 km secondary pipe and 6.3 km lateral pipe, is required for irrigation of all the project area. The required length of steel pipe and sprinkler sets are as follows:

- Steel pipe, D=300	:	1,130 m
- Steel pipe, D=250	:	360 m
- Steel pipe, D=200	:	100 m
- Steel pipe, D=150	:	2,340 m
- Steel pipe, D=100	:	5,520 m
- Sprinkler system	:	36 sets

(3) Drainage System

Collector drains to be newly constructed are 5.2 km in length. Green belts of 2.5 km are also constructed to mitigate soil erosion. The required quantities for major work items are as follows:

- Stripping (t=0.15m)	:	10,200 m2
- Excavation	:	4,900 m3
- Reinforced concrete	:	1,350 m3
- Reinforcement bar	:	52,020 kg
- Form	:	10,860 m2

- Sod facing	:	6,300 m2
- Dry stone pitching	:	1,750 m2

(4) Farm Road System

The main and lateral roads to be rehabilitated and/or newly constructed are 0.9 km and 8.9 km in length, respectively. The required quantities for major work items are as follows:

- Stripping (t=0.15m)	:	28,700 m2
- Embankment	:	500 m3
- Laterite pavement	:	7,100 m3
- Gravel pavement	:	200 m3
- Grading and compaction	:	2,400 m3

(5) Related Structures

In order to protect the project facility from heavy rain, 28 cross drains will be required. The required quantities for major work items are as follows:

- Stripping (t=0.15m)	:	300 m2
- Excavation	:	600 m3
- Backfill	:	500 m3
- Reinforced concrete	:	30 m3
- Plain concrete	:	40 m3
- Reinforcement bar	:	1,540 kg
- Form	:	500 m2
- Reinforced con. pipe(800)	:	110 m

7.6 Okyereko Project

Quantities for major civil works are calculated based on the survey results and preliminary design drawings. The results of quantity estimate are given below.

(1) Pump Station

The centrifugal pumps of 2 nos. are required for tapping water from the Ayensu river. The required work quantities for pump station are as follows:

- Stripping (t=0.15m)	:	400 m2
- Excavation	:	300 m3
- Backfill	:	100 m3
- Reinforced concrete	:	30 m3
- Plain concrete	:	20 m3
- Reinforcement bar	:	2,000 kg
- Form	:	210 m2

(2) Irrigation System

The main, secondary and lateral canals to be rehabilitated are 2.5 km, 0.3 km, and 6.7 km in length, respectively. The required quantities for major work items in canal construction are as follows:

- Stripping (t=0.15m)	:	25,800 m2
- Excavation	:	1,700 m3
- Backfill	:	5,700 m3
- Embankment	:	6,100 m3
- Reinforced concrete	:	1,200 m3

- Reinforcement bar	:	50,200 kg
- Form	:	20,300 m2
- Dismantling work	:	1,700 m3

(3) Drainage System

The main, secondary and lateral drains to be rehabilitated are 1.8 km, 1.7 km and 7.6 km in length, respectively. The required quantities for major work items are as follows:

- Clearing	:	18,800 m2
- Excavation	:	4,800 m3

(4) Farm Road System

The main and lateral roads to be rehabilitated and/or newly constructed are 2.2 km and 7.6 km in length, respectively. The required quantities for major work items are as follows:

- Stripping (t=0.15m)	:	11,600 m2
- Laterite pavement	:	3,100 m3
- Gravel pavement	:	700 m3
- Grading and compaction	:	22,200 m3

(5) Related Structures

In order to operate and maintain the irrigation system properly, 347 structures will be required. The required quantities for major work items are as follows:

- Stripping (t=0.15m)	:	2,500 m2
- Excavation	:	1,000 m3
- Backfill	:	700 m3
- Reinforced concrete	:	100 m3
- Plain concrete	:	20 m3
- Reinforcement bar	:	3,970 kg
- Form	:	1,430 m2
- Slide gate (400 x 450)	:	38 nos.
- Gabion mattress 50cm thick	:	1,200 m2

(6) Supplemental Water Supply Facility

Supplemental water supply facility is required for the project. These are pump station, weir, intake, head race, delivery pipe, outlet, and chute. Quantity for pump station is already mentioned in item (1). The remaining required quantity is given below:

- Stripping (t=0.15m)	:	800 m2
- Excavation	:	900 m3
- Backfill	:	800 m3
- Embankment	:	300 m3
- Reinforced concrete	:	170 m3
- Plain concrete	:	60 m3
- Reinforcement bar	:	8,030 kg
- Form	:	680 m2
- Slide gate (1100 x 1100)	:	1 no.
- Slide gate (700 x 700)	:	1 no.
- Gabion mattress 30cm thick	:	350 m2
- Steel pipe D=300	:	800 m

8. WATER MANAGEMENT AND O & M OF PROJECT FACILITY

8.1 General

At present, water management activities for all the projects do not reach the satisfactory level. The constraints to the proper water management activities which have been found through field investigation, are (i) unclear responsibility between GIDA and farmers' organisation, (ii) lack of experience of the staff, (iii) lack of basic data, (iv) no proper measuring devices, (v) poor conditions of the project facility, and (vi) insufficient activities of water users association. It is essential to eliminate these constraints for successful operation and management of the projects after rehabilitation of the project facilities. Since basic institutional development plan for proper water management and O & M works including staffing required is discussed in Annex-G, the discussion on this matter in this Section is made from technical point of view, as mentioned below :

8.2 Water Management

Water management activities are largely divided into two portions; one is to prepare and determine a proper water delivery and application program, and the other is to execute the water supply in line with this program. In this Section, the former issue, which is regarded as "software" in water management action, is discussed and the latter issue in the next Sub-section.

In general, a water delivery and application program is prepared based on the various data and information, because it should be well-fitted to the local and current conditions. As mentioned in Sub-section 2.3.1, however, no basic data and information are available for preparation of water delivery and application program in the projects, except Ashaiman project. Even in Ashaiman project, these are still limited. Thus, water supply to each farm plot is presently made on the farmers' demand basis only, and any logical water supply is not made. In order to improve this situation and to realize effective water use, such data and information as listed below should at first be prepared and/or collected.

- Detailed topographic maps (1/1000 or 1/2000) showing pipeline network, canal routes, field ridges, road, etc.
- Detailed soil maps (1/1000 or 1/2000)
- Cropping patterns and cropped areas
- Available water sources
- Physical conditions of soils such as water holding capacity, basic intake rate, etc.
- Meteorological data such as rainfall, temperature, related humidity, sunshine, wind speed and evaporation.
- Canal conveyance loss
- H-Q curve for each measuring device

In order to collect data and information, it is proposed that IDC should provide technical assistance for all the projects.

Irrigation requirements for respective projects which are very important factor for preparation of water delivery and application program are estimated using the same procedure as mentioned in Section 3.2.

In water management, another important issue is to monitor, analyse and evaluate the actual activities, and to reflect the results on the water delivery and application program in the next year. Hence, staffing and organisation should be ensured for effective execution of a monitoring activity. Details of monitoring work are described in Annex-G.

8.3 O & M of Project Facility

(1) Operation of Project Facility

Operation of the project facility in irrigation project means the execution of water management program mentioned above. It includes activation of pumps and gates so that the desired discharge can be supplied at the appropriate time, which is considered as the "hardware " of the water management action.

In this study, a continuous water supply method is proposed for paddy except puddling time, and a rotational one for upland crops, though further study should be made on the selected priority projects at the next stage. At puddling time for paddy field, a rotational water supply method will be applied for mitigating peak demand and farm labour force. In water supply for upland crops, water supply amount of 28 mm and irrigation interval of 6 days are employed for design of sprinkler irrigation system, as discussed in Section 3.2.

In the continuous water supply method, supply amount will be regulated by opening and closing the gates in the light of water delivery and application program. To simplify the gate operations, a measuring device is indispensable, and it should be provided for respective projects, if not available at present.

Water supply for upland crops will be conducted using pipes and sprinkler system. The water supply amount will be controlled by time. Therefore, moving and setting of lateral pipes and sprinklers should smoothly be executed in line with water delivery and application program. In this study, irrigation time at one time is calculated to be three (3) hours based on one time water supply amount and basic intake rate measured at field.

(2) Maintenance of Project Facility

In parallel with proper operation, suitable and continuous maintenance of the project facility is indispensable to secure proper and stable function of the facility as well as to ensure the realization of economic life of the facility. The maintenance work broadly consists of :

- regular maintenance work which is carried out regularly to maintain and improve the project facility,
- periodic maintenance work including repair of minor damages,
- emergency repair work which is conducted to repair the occasional damages of the project facility caused by flood, heavy rainfall or other causes, and
- annual maintenance which involves a large work quantity or requires special skill.

The maintenance work at the project level is briefly explained as follows :

1) Regular maintenance

Regular maintenance refers to the day-to-day maintenance of the project facility. It includes routing repair of pumps, pipes, embankment, measuring device, weeding , filling of holes on the inspection roads with earth and gravel, oiling of gates, etc. Satisfactory implementation requires an intensive daily inspection of the project facility.

2) Periodic maintenance

Periodic maintenance is defined as repair of minor damages which do not cause immediate danger or malfunction to the water supply system. However, the periodic maintenance work should be carried out by skilled workers and mechanics in order to protect the system from further damages. Minor improvements of the water supply system are also included in this periodic maintenance.

3) Emergency repair

Damages to the project facility will hamper the normal practices of irrigation. Therefore, repair of damaged facility should quickly and effectively be carried out under the category of the emergency repair. Since the damage is not predictable either with respect to the time of occurrence or to scale of damage, the agency concerned should always be ready to confront the occurrence of damage. The damages to the project facility may be resulted from (a) flood, (b) heavy rainfall, (c) careless operations of the facility, (d) violation acts, and (e) destruction by animals and vehicles.

4) Annual maintenance

Maintenance work which involves a large work quantities or requires special skill should be carried out under the category of annual maintenance. This maintenance work may be executed by the contractor(s) to be selected through open tendering.

8.4 O & M Equipment

In order to operate and maintain the project facility satisfactorily, certain O & M equipment is necessary. The following O & M equipment is proposed taking into consideration present constraints on O & M works for the projects, such as lack of vehicle for inspection and communication system, and need of regular removal of weed and sediments from drain to avoid salinity problem, shifting of sprinkler unit and carrying of embankment materials for minor repairs for canals and roads.

Proposed O & M Equipment

Project	Pick-up (4 x 4)	Backhoe (0.3 m3)	Tractor (60hp)	Grass Cutter	Radio Communication	Bus
1. Ashaiman	1 no.	1 no.	1 no.	3 nos.	1 no.	1 no.
2. Aveyime	1 no.	-	1 no.	3 nos.	1 no.	-
3. Kpando-Torkor	1 no.	-	2 nos.	4 nos.	1 no.	-
4. Mankessim	1 no.	-	1 no.	3 nos.	1 no.	-
5. Okyereko	1 no.	-	1 no.	3 nos.	1 no.	-

The equipment necessary for extension services is mentioned in Annex-G.

TABLES

Table H-1 Present Conditions of the Projects (1/2)

Description	Ashaiman	Aveyime	Kpando-Torkor
1 Administration			
(1) Region	Greater Accra	Volta	Volta
(2) District	Tema	Tongu	Kpando
2 Planned command area*	148 ha	150 ha	356 ha
3 Actually developped area*	130 ha	63 ha	40 ha
4 Area to be expanded	18 ha	87 ha	316 ha
5 Construction activities			
(1) Commencement	1966	1962	Not available
(2) Completion	1968	1975	1976
6 Water source	Ashaiman reservoir	Volta river	Volta lake
7 Intake method	Butterfly valve	Pumps	Pumps
8 Irrigation and drainage facilities (Details are given in Table H.3.1)	Dam (5.8 million m3) Main canal (unlined, L=4.8 km) Laterals (unlined, L=11.0 km) Main drain (unlined, L=3.0 km) Lateral drains (unlined, L=6.0 km) Structures (577 nos.)	Main canal (concrete, L=0.4 km) Lateral canals (concrete, L=3.0 km) Main drain (unlined, L= 1.0 km) Lateral drains (unlined, L= 3.0 km) Structures (43 nos.)	2 movable centrifugal pumps Main pipeline (L=0.6 km) Lateral pipeline (L= 0.2 km) 60 sprinkler system 30 rain guns
9 Project organization	Site officer (1 no.) Extension officer (1 no.) Gate operator (1 no.) Watchman (1 no.)	Project manager (1 no.) Agri. extension worker (1 no.) Agronomist (1 no.) Mechanics (1 no.) Watchman (2 nos.) Cleaner (1 no.)	Project manager (1 no.) Pump attendant (1 no.) Watchman (1no.)
10 Irrigation period	April to December	April to July	November to January
11 Water distribution method	10.5 hrs. per day and Continuouse supply	8 hrs from 7:00 to 15:00 per day and 10 days interval	6 hrs. per day and 2 to 3 days rotation
12 Irrigated crops	Paddy, Okra, Tomato	Paddy	Okra
13 Major problems on irrigation drainage	(a) Deterioration of canals and structures. (b) Water shortage. (c) Much sediment and grasses in drains. (d) Concentration of salinity in parts of the project area. (e) Lack of rice mill, dry yard and storage facilities. (f) Insufficient space of of O & M office. (g) No vehicle for O & M.	(a) Deterioration of pumps (b) Leakage of canals (c) No measuring device (d) Much grasses and sediments in drains. (e) No water supply record.	(a) Deterioration of pumps and sprinkler system. (b) No water management manual. (c) No O & M manual. (d) No definite irrigation schedule based on cropping pattern and water requirement. (e) No water supply record. (f) Insufficient number of O & M staff. (g) Poor O & M office. (h) No vehicle/motor cycle for O & M. (i) Deteriortion of tractor for carring movable pumps.

Table H-1 Present Conditions of the Projects (2/2)

Description	Mankessim	Okyereko
1 Administration		
(1) Region	Central	Central
(2) District	Mfantsiman	Gomoa
2 Planned command area*	256 ha	111 ha
3 Actually developped area*	17 ha	40 ha
4 Area to be expanded	239 ha	71 ha
5 Construction activities		
(1) Commencement	1974	1976
(2) Completion	1981	1988
6 Water source	Apropong reservoir	Okyereko reservoir
7 Intake method	Intake valve and pumps	Intake valve
8 Irrigation and drainage facilities (Details are given in Table H.3.1)	Dam (5.7 million m3) Intake gate/valve 2 pumps Main pipeline (L = 0.9 km) Lareral pipeline (L = 0.4 km) 45 sprinkler system	Dam (2.71 million m3) Main canal (lined,L=1.3 km) Laterals and sub-laterals (L=2.8 km) Main drain (unlined, L=2.0 km) Lateral drain (unlined, L=2.0 km) Structures (74 nos.)
9 Project organization	Project manager (1 no.) Topo-surveyor (1 no) Driver/Mechanic (1 no) Pump Attendant (1 no) Watchman (1 no)	Project manager (1 no.) Gate operator (1no.)
10 Irrigation period	December to April	September to January
11 Water distribution method	6 hrs. per day for 3.4 ha and 5 days rotation	12 hrs. for 2 laterals 10 days rotation
12 Irrigated crops	Okra, watermelon, garden egg	Paddy
13 Major problems on irrigation drainage	(a) Deterioration of pumps and sprinkler system. (b) Severe innundation by flood every year. (c) No water management manual. (d) No O & M manual. (e) No definite irrigation schedule based on cropping pattern and water requirement. (f) No water supply record. (g) Deterioration of O & M office. (h) Damage of bridge for spillway. (i) Much grasses in spillway drain.	(a) Deterioration of canals and structures. (b) Water shortage. (c) Much sediment and grasses in drains. (d) Concentration of salinity in parts of the project area. (e) No water management manual. (f) No O & M manual. (g) No definite irrigation schedule based on cropping pattern and water requirement. (h) Insufficient number of O & M staff. (i) Deterioration of O & M office. (j) No vehicle for O & M.

Table H-2 Inventory Survey Results of Project Facility (1/5)

Project name : 1.Ashaiman
Constructed year : 1968
Developed area 130 ha
Irrigated area : 59 ha
Irrigation type : Gravity

Facilities	Number or Quantity		Existng Condition	Description	Judgment
1 Dam					
(1) Embankment			Good		
- Total capacity	5.8	MCM			
- Effective capacity	5.2	MCM			
- Crest length	700	m			
- Crest height	11.9	m			
(2) Spillway	1	nos	Good		
- Design discharge	84.95	m3/s			
2 Weir	-	nos		Not applied	
3 Intake					
(1) Gate	-	nos			
(2) Valve	2	nos	Moderate	Right bank canal,Left bank canal	Rehabilitation
- Design discharge	0.28	m3/s		Same capacity for both canal.	
(3) Pump	-	nos		Not applied	
- Set up year	-				
- Out put	-	m3/hr			
- Total head	-	m			
- Type	-				
4 Irrigation system					
(1) Canal					
(a) Main	4.8	km	Poor	R.canal =3.4km,L.canal =1.4km	Rehabilitation
(b) Lateral	11	km	Poor		Rehabilitation
(2) Pipeline system				Not applied	
(a) Main	-	km			
(b) Lateral	-	km			
(c) Sprinkler	-	nos			
5 Drainage system					
(1) Drainage canal					
(a) Main	3	km	Poor	Weeds	Rehabilitation
(b) Lateral	6	km	Poor	Weeds	Rehabilitation
(c) Intercept	-	km		Not applied	
(d) Spillway canal	-	km		Not applied	
6 Related structure					
(1) Farm pond	-	nos		Not applied	
(2) Turnout					
(a) Main	26	nos	Poor		Rehabilitation
(b) Lateral	260	nos	Poor		Rehabilitation
(3) Check					
(a) Main	26	nos	Poor		Rehabilitation
(b) Lateral	-	nos		Not applied	
(4) Syphon					
(a) Main	1	no			
(b) Lateral	-	nos		Not applied	
(5) Aqueduct	-	nos		Not applied	
(6) Drop					
(a) Main	-	nos		Not applied	
(b) Lateral	260	nos	Poor		Rehabilitation
(7) Spillway	-	nos		Not applied	
(8) Wasteway	-	nos		Not applied	
(9) Impact box	-	nos		Not applied	
(10) Measuring device	-	nos		Not applied	
(11) Bridge	-	nos		Not applied	
(12) Irrigation crossing	4	nos	Poor		Rehabilitation
(13) Drainage culvert	-	nos		Not applied	
(14) Drainage gate	-	nos		Not applied	
7 Farm road	16	km	Poor		Rehabilitation
8 Project building					
(1) Pump house	-	nos		Not applied	
(2) Office	6	nos	Good		
(3) Store	1	no	Good		
(4) Garage	1	no	Good		
(5) Dry yard	1	no	Good		
(6) Souter house	-	nos		Not applied	
9 Others					
Drainage culvert under High way out of project area	4	nos	Good	Drain from Asaiman town shall be improved.	

Table H-2 Inventory Survey Results of Project Facility (2/5)

Project name : 2.Aveyime
Constructed year : 1975

Developed area 63 ha
Irrigated area : -
Irrigation type : Pump + Gravity

Facilities	Number or Quantity		Existng Condition	Description	Judgment
1 Dam				Not applied	
(1) Embankment					
- Total capacity	-	MCM			
- Effective capacity	-	MCM			
- Crest length	-	m			
- Crest height	-	m			
(2) Spillway	-	nos			
- Design discharge	-	m3/s			
2 Weir	-	nos		Not applied	
3 Intake					
(1) Gate	-	nos			
(2) Valve	-	nos			
(3) Pump	1	no	Poor		Renew
- Set up year	198				
- Out put	2040	m3/hr			
- Total head	10	m			
- Type	Centrifugal				
4 Irrigation system					
(1) Canal					
(a) Main	0.4	km	Poor		Rehabilitation
(b) Lateral	3	km	Poor		Rehabilitation
(2) Pipeline system					
(a) Main	0.128	km	Good		
(b) Lateral	-	km		Not applied	
(c) Sprinkler	-	nos		Not applied	
5 Drainage system					
(1) Drainage canal					
(a) Main	1	km	Poor		Rehabilitation
(b) Lateral	3	km	Poor		Rehabilitation
(c) Intercept	-	km		Not applied	
(d) Spillway canal	-	km		Not applied	
6 Related structure					
(1) Farm pond	-	nos		Not applied	
(2) Turnout					
(a) Main	1	no	Poor		New consruction
(b) Lateral	27	nos	Poor		New consruction
(3) Check				Not applied	
(a) Main	-	nos			
(b) Lateral	-	nos			
(4) Syphon					
(a) Main	-	nos		Not applied	
(b) Lateral	13	nos	Poor		Rehabilitation
(5) Aqueduct	-	nos		Not applied	
(6) Drop				Not applied	
(a) Main	-	nos			
(b) Lateral	-	nos			
(7) Spillway	-	nos		Not applied	
(8) Wasteway	-	nos		Not applied	
(9) Impact box	-	nos		Not applied	
(10) Measuring device	-	nos		Not applied	
(11) Bridge	-	nos		Not applied	
(12) Irrigation crossing	-	nos		Not applied	
(13) Drainage culvert	2	nos	Moderate		
(14) Drainage gate	-	nos			
7 Farm road	5	km	poor		Rehabilitation
8 Project building					
(1) Pump house	1	no	poor		Rehabilitation
(2) Office	2	nos	poor		Rehabilitation
(3) Store	1	no	poor		Rehabilitation
(4) Garage	1	no	poor		Rehabilitation
(5) Dry yard	-	nos		Not applied	
(6) Souter house	-	nos		Not applied	
9 Others					

Table H-2 Inventory Survey Results of Project facility (3/5)

Project name : 3.Kpando-Torkor
Constructed year : 1981

Developed area 40 ha
Irrigated area : 13 ha
Irrigation type : Pump + Sprinkler

Facilities	Number or Quantity		Existing Condition	Description	Judgment
1 Dam				Not applied	
(1) Embankment					
- Total capacity	-	MCM			
- Effective capacity	-	MCM			
- Crest length	-	m			
- Crest height	-	m			
(2) Spillway	-	nos			
- Design discharge	-	m3/s			
2 Weir	-	nos		Not applied	
3 Intake					
(1) Gate	-	nos		Not applied	
(2) Valve	-	nos		Not applied	
(3) Pump	2	nos	Poor		Renew
- Set up year	1981				
- Out put	120	m3/hr			
- Total head	64	m			
- Type	Centrifugal				
4 Irrigation system					
(1) Canal				Not applied	
(a) Main	-	km			
(b) Lateral	-	km			
(2) Pipeline system					
(a) Main	0.6	km	Poor		Renew
(b) Lateral	0.2	km	Poor		Renew
(c) Sprinkler	60	nos	Poor		Renew
5 Drainage system					
(1) Drainage canal				Not applied	
(a) Main	-	km			
(b) Lateral	-	km			
(c) Intercept	-	km			
(d) Spillway canal	-	km			
6 Related structure					
(1) Farm pond	-	nos		Not applied	
(2) Turnout				Not applied	
(a) Main	-	nos			
(b) Lateral	-	nos			
(3) Check				Not applied	
(a) Main	-	nos			
(b) Lateral	-	nos			
(4) Syphon				Not applied	
(a) Main	-	nos			
(b) Lateral	-	nos			
(5) Aqueduct	-	nos		Not applied	
(6) Drop				Not applied	
(a) Main	-	nos			
(b) Lateral	-	nos			
(7) Spillway	-	nos		Not applied	
(8) Wasteway	-	nos		Not applied	
(9) Impact box	-	nos		Not applied	
(10) Measuring device	-	nos		Not applied	
(11) Bridge	-	nos		Not applied	
(12) Irrigation crossing	-	nos		Not applied	
(13) Drainage culvert	-	nos		Not applied	
(14) Drainage gate	-	nos		Not applied	
7 Farm road	2	km	Poor		Rehabilitation
8 Project building					
(1) Pump house	-	nos		Not applied	
(2) Office	1	no	Poor		Rehabilitation
(3) Store	-	nos		Not applied	
(4) Garage	-	nos		Not applied	
(5) Dry yard	-	nos		Not applied	
(6) Souter house	-	nos		Not applied	
9 Others					

Table H-2 Inventory Survey Results of Project Facility (4/5)

Project name : 4.Mankessim
Constructed year : 1978

Developed area 17 ha
Irrigated area : 26 ha
Irrigation type : Pump + Sprinkler

Facilities	Number or Quantity		Existng Condition	Description	Judgment
1 Dam					
(1) Embankment			Good		
- Total capacity	5.67	MCM			
- Effective capacity	4.81	MCM			
- Crest length	1.95	m			
- Crest height	10.4	m			
(2) Spillway	1	nos	Moderate		Partial repair
- Design discharge	97	m3/s			
2 Weir	-	nos		Not applied	
3 Intake					
(1) Gate	1	no	Moderate		Partial repair
- Design discharge	0.84	m3/s			
(2) Valve	1	no	Moderate		
- Design discharge	0.364	m3/s			
(3) Pump	2	nos	Poor		Renew
- Set up year	1983				
- Out put	135	m3/hr			
- Total head	90	m			
- Type	Centrifugal				
4 Irrigation system					
(1) Canal					
(a) Main	0.01	km	Poor		Rehabilitation
(b) Lateral	-	km		Not applied	
(2) Pipeline system					
(a) Main	0.9	km	Poor		Rehabilitation
(b) Lateral	0.35	km	Poor		Rehabilitation
(c) Sprinkler	45	nos	Poor		Rehabilitation
5 Drainage system					
(1) Drainage canal				Not applied	
(a) Main	-	km			
(b) Lateral	-	km			
(c) Intercept	-	km			
(d) Spillway canal	0.5	km	Poor		Rehabilitation
6 Related structure					
(1) Farm pond	-	nos		Not applied	
(2) Turnout				Not applied	
(a) Main	-	nos			
(b) Lateral	-	nos			
(3) Check				Not applied	
(a) Main	-	nos			
(b) Lateral	-	nos			
(4) Syphon				Not applied	
(a) Main	-	nos			
(b) Lateral	-	nos			
(5) Aqueduct		nos		Not applied	
(6) Drop				Not applied	
(a) Main	-	nos			
(b) Lateral	-	nos			
(7) Spillway	-	nos		Not applied	
(8) Wasteway	-	nos		Not applied	
(9) Impact box	-	nos		Not applied	
(10) Measuring device	-	nos		Not applied	
(11) Bridge	-	nos		Not applied	
(12) Irrigation crossing	-	nos		Not applied	
(13) Drainage culvert	1	no	Moderate	Capacity is too small to flow design flood discharge.	Rehabilitation
(14) Drainage gate	-	nos		Not applied	
7 Farm road	3	km	Moderate		Rehabilitation
8 Project building					
(1) Pump house	1	no	Poor		Rehabilitation
(2) Office	1	no	Poor		Rehabilitation
(3) Store	-	nos		Not applied	
(4) Garage	-	nos		Not applied	
(5) Dry yard	-	nos		Not applied	
(6) Souter house	-	nos		Not applied	
9 Others					

Table H-2 Inventory Survey Results of Project Faclity (5/5)

Project name : 5.Okyereko
Constructed year : 1988

Developed area 40 ha
Irrigated area : 40 ha in 1994
Irrigation type : Gravity

Facilities	Number or Quantity		Existng Condition	Description	Judgment
1 Dam					
(1) Embankment			Good		
- Total capacity	2.96	MCM			
- Effective capacity	2.71	MCM			
- Crest length	6.24	m			
- Crest height	11.4	m			
(2) Spillway	1	no	Good		
- Design discharge	25	m3/s			
2 Weir	-	nos		Not applied	
3 Intake					
(1) Gate	-	nos		Not applied	
(2) Valve	2	nos	Good		
- Design discharge		m3/s		Right=0.958m3/s, Left=0.479m3/s	
(3) Pump	-	nos		Not applied	
- Set up year	-				
- Out put	-	m3/hr			
- Total head	-	m			
- Type	-				
4 Irrigation system					
(1) Canal					
(a) Main	1.3	km	Poor		Improvement
(b) Lateral	2.8	km	Poor		Improvement
(2) Pipeline system				Not applied	
(a) Main	-	km			
(b) Lateral	-	km			
(c) Sprinkler	-	nos			
5 Drainage system					
(1) Drainage canal					
(a) Main	2	km	Poor		Rehabilitation
(b) Lateral	2	km	Poor		Rehabilitation
(c) Intercept	-	km		Not applied	
(d) Spillway canal	-	km		Not applied	
6 Related structure					
(1) Farm pond	-	nos		Not applied	
(2) Turnout					
(a) Main	6	nos	Poor		Rehabilitation
(b) Lateral	30	nos	Poor		Rehabilitation
(3) Check					
(a) Main	1	no	Moderate		Rehabilitation
(b) Lateral	-	nos			
(4) Syphon					
(a) Main	-	nos			
(b) Lateral	-	nos			
(5) Aqueduct	-	nos			
(6) Drop					
(a) Main	2	nos	Poor		Rehabilitation
(b) Lateral	30	nos	Poor		Rehabilitation
(7) Spillway	-	nos			
(8) Wasteway	-	nos			
(9) Impact box	-	nos			
(10) Measuring device	1	no	Moderate		Rehabilitation
(11) Bridge	-	nos			
(12) Irrigation crossing	1	no	Poor		Rehabilitation
(13) Drainage culvert	3	nos	Good		
(14) Drainage gate	-	nos			
7 Farm road	7	km	Poor		Rehabilitation
8 Project building					
(1) Pump house	-	nos			
(2) Office	1	no	Poor		Rehabilitation
(3) Store	1	no	Poor		Rehabilitation
(4) Garage	1	no	Poor		Rehabilitation
(5) Dry yard	-	nos			
(6) Souter house	-	nos			
9 Others					
Spillway of Ayensu river	1	no	Moderate		
Ayensu river drain	1	km	Poor		Rehabilitation

Table H-3 Potential Evapotranspiration (ETp)

Description	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct	Nov.	Dec.
1 Ashaiman												
(a) Modified Penman (mm/day)	5.0	5.4	5.7	5.6	5.2	4.1	3.8	4.0	4.5	5.3	5.3	4.8
(b) Blaney-Criddle (mm/day)	4.8	4.9	4.9	5.1	5.0	4.5	4.3	4.3	4.3	4.6	4.8	4.8
2 Aveyime												
(a) Modified Penman (mm/day)	4.8	5.6	5.7	5.4	4.9	4.0	3.9	3.3	4.3	4.7	4.8	4.4
(b) Blaney-Criddle (mm/day)	4.9	5.1	5.2	5.3	5.2	4.6	4.5	4.6	4.5	4.7	4.9	4.8
3 Kpando-Torkor												
(a) Modified Penman (mm/day)	5.0	5.4	5.5	5.4	5.0	4.1	3.7	3.7	4.1	4.8	5.1	4.7
(b) Blaney-Criddle (mm/day)	4.9	5.1	5.0	5.2	5.1	4.5	4.4	4.5	4.4	4.5	4.9	4.9
4 Mankessim												
(a) Modified Penman (mm/day)	4.5	5.1	5.3	5.2	4.8	3.8	3.6	3.6	4.0	4.8	4.9	4.4
(b) Blaney-Criddle (mm/day)	4.7	4.9	4.9	5.1	5.0	4.4	4.3	4.4	4.3	4.4	4.8	4.7
5 Okyereko												
(a) Modified Penman (mm/day)	4.5	5.1	5.3	5.2	4.8	3.8	3.6	3.6	4.0	4.8	4.9	4.4
(b) Blaney-Criddle (mm/day)	4.7	4.9	4.9	5.1	5.0	4.4	4.3	4.4	4.3	4.4	4.8	4.7

Table H-4 Field Water Requirement for Wet Season Paddy at Aveyime in 1996

(Unit: mm)

JULY

Date	Rainfall	ET + P	E + P	E	P	ET	Rejection
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
Sub-total							
Average							
11		3.0	4.0	0.0	4.0	-1.0	x
12		-	-	-	-	-	x
13	21.1	-	-	-	-	-	x
14		8.0	5.0	3.0	2.0	6.0	
15		2.0	2.0	5.0	-	-	x
16		4.0	4.0	1.0	-	-	x
17		0.0	0.0	1.0	-	-	x
18		4.3	3.0	2.0	-	-	x
19	3.3	5.0	6.3	-	-	-	x
20		5.0	5.0	5.0	0.0	5.0	
Sub-total	**24.4**	**31.3**	**29.3**	**17.0**	**6.0**	**11.0**	
Average		**3.3**	**3.4**	**2.4**	**2.0**	**5.5**	
21		8.0	6.0	3.0	3.0	5.0	
22		8.0	4.0	4.0	0.0	8.0	
23		7.0	5.0	5.0	0.0	7.0	
24		4.0	5.0	4.0	1.0	3.0	
25		3.0	5.0	4.0	1.0	2.0	
26		8.0	9.0	6.0	3.0	5.0	
27		6.0	6.0	4.0	2.0	4.0	
28		6.0	7.0	3.0	4.0	2.0	
29		5.0	5.0	4.0	1.0	4.0	
30		4.0	4.0	6.0	-	-	x
31		4.0	4.0	2.0	2.0	2.0	
Sub-total		**55.0**	**54.0**	**42.0**	**14.0**	**37.0**	
Average		**5.9**	**5.6**	**4.5**	**1.4**	**4.1**	
Total	**24.4**	**86.3**	**83.3**	**59.0**	**20.0**	**48.0**	
Average		**4.8**	**4.6**	**3.6**	**1.7**	**4.4**	

AUGUST

Date	Rainfall	ET + P	E + P	E	P	ET	Rejection
1		3.0	3.0	3.0	0.0	3.0	
2		2.0	2.0	3.0	-	-	x
3		2.0	5.0	2.0	3.0	-	x
4		2.0	2.0	0.0	2.0	-	x
5		2.0	4.0	2.0	2.0	-	x
6		3.0	-	5.0	-	-	x
7		7.0	-	4.0	-	-	x
8		8.0	-	-	-	-	x
9		5.0	-	3.0	-	-	x
10		6.0	-	6.0	-	-	x
Sub-total	**0.0**	**40.0**	**16.0**	**28.0**	**7.0**	**3.0**	
Average		**4.0**	**3.2**	**3.1**	**1.8**	**3.0**	
11		4.0	-	5.0	-	-	x
12		7.0	-	2.0	-	-	x
13		6.0	-	3.0	-	-	x
14		4.0	-	4.0	-	-	x
15		7.0	-	-	-	-	x
16		8.0	-	5.0	-	-	x
17	1.0	-	2.0	4.0	-	-	x
18		7.0	5.0	3.0	-	-	x
19		6.0	3.0	3.0	-	-	x
20		7.0	4.0	0.0	4.0	3.0	
Sub-total	**1.0**	**56.0**	**14.0**	**29.0**	**4.0**	**3.0**	
Average		**6.2**	**3.5**	**3.2**	**4.0**	**3.0**	
21		3.0	6.0	5.0	1.0	2.0	
22		-	6.0	2.0	4.0	-	x
23		7.0	3.0	3.0	0.0	7.0	
24		-	2.0	-	-	-	x
25	12.4	-	-	-	-	-	x
26		10.0	4.0	2.0	2.0	8.0	
27		4.0	0.0	1.0	-	-	x
28		1.0	0.0	2.0	-	-	x
29		8.0	0.0	3.0	-	-	x
30		9.0	5.0	4.0	1.0	8.0	
31		10.0	2.0	3.0	-	-	x
Sub-total	**12.4**	**49.0**	**22.0**	**20.0**	**7.0**	**23.0**	
Average		**7.0**	**2.4**	**2.5**	**1.4**	**5.8**	
Total	**24.4**	**145.0**	**52.0**	**77.0**	**18.0**	**29.0**	
Average		**5.4**	**2.7**	**2.9**	**1.8**	**4.8**	

SEPTEMBER

Date	Rainfall	ET + P	E + P	E	P	ET	Rejection
1		8.0	4.0	2.0	2.0	6.0	
2		8.0	3.0	2.0	-	-	x
3		10.0	5.0	3.0	2.0	-	x
4		10.0	-	2.0	-	-	x
5		8.0	-	5.0	-	-	x
6		13.0	-	4.0	-	-	x
7		12.0	-	2.0	-	-	x
8		6.0	-	7.0	-	-	x
9		-	-	5.0	-	-	x
10		-	-	4.0	-	-	x
Sub-total	**0.0**	**75.0**	**12.0**	**36.0**	**4.0**	**6.0**	
Average		**9.4**	**4.0**	**3.6**	**2.0**	**6.0**	
11		-	-	-	-	-	x
12	6.3	-	-	1.0	-	-	x
13		-	-	2.0	-	-	x
14		-	-	5.0	-	-	x
15		-	-	4.0	-	-	x
16		-	-	3.0	-	-	x
17		-	-	1.0	-	-	x
18		-	-	4.0	-	-	x
19		8.0	9.0	2.0	-	-	x
20		-	4.0	1.0	3.0	-	x
Sub-total	**6.3**	**8.0**	**13.0**	**23.0**	**3.0**	**-**	
Average		**8.0**	**6.5**	**2.6**	**3.0**	**-**	
21		12.0	2.0	3.0	-	-	x
22		6.0	4.0	3.0	1.0	-	x
23		5.0	3.0	2.0	1.0	4.0	
24		-	4.0	-	-	-	x
25		-	3.0	3.0	-	-	x
26		12.0	4.0	2.0	2.0	10.0	
27		7.0	7.0	3.0	-	-	x
28		-	-	1.0	-	-	x
29		-	-	3.0	-	-	x
30		-	8.0	2.0	6.0	-	x
31							
Sub-total	**0.0**	**30.0**	**33.0**	**19.0**	**10.0**	**14.0**	
Average		**6.0**	**4.1**	**2.1**	**1.4**	**7.0**	
Total	**6.3**	**113.0**	**58.0**	**78.0**	**17.0**	**20.0**	
Average		**8.1**	**4.5**	**2.8**	**2.4**	**6.7**	

Table H-5 Field Water Requirement for Wet Season Paddy at Okyereko in 1996

(Unit: mm)

Date	AUGUST Rainfall	ET + P	E + P	E	P	ET	Rejection
1	3.5	2.3	0.0	0.5	-	-	x
2		3.0	0.2	0.3	-	-	x
3		6.0	2.8	2.7	0.1	5.9	
4	4.0	5.0	7.0	5.0	2.0	3	
5	5.0	2.0	-	0.0	-	-	x
6		3.7	3.5	3.7	-	-	x
7	3.5	6.1	5.3	5.1	0.2	5.9	
8	5.3	1.0	0.0	0.0	0.0	1	
9		3.0	1.0	0.2	0.8	2.2	
10		0.7	0.2	0.4	-	-	x
Sub-total	21.3	32.8	20.0	17.9	3.1	18.0	
Average		3.3	2.2	1.8	0.6	3.6	
11		1.8	0.2	0.4	-	-	x
12		1.5	0.1	0.5	-	-	x
13		7.0	5.5	5.6	-	-	x
14	6.0	1.5	0.5	0.5	0.0	1.5	
15		0.2	0.2	0.5	-	-	x
16		3.3	0.3	0.3	0.0	3.3	
17		2.0	1.1	1.3	-	-	x
18	1.1	2.0	0.0	0.1	-	-	x
19		1.0	0.5	0.1	0.4	0.6	
20		2.2	0.0	0.3	-	-	x
Sub-total	**7.1**	**22.5**	**8.4**	**9.6**	**0.4**	**5.4**	
Average		**2.3**	**0.8**	**1.0**	**0.1**	**1.8**	
21		2.0	0.2	0.3	-	-	x
22		8.5	6.8	6.7	0.1	8.4	
23	6.5	2.0	0.0	0.2	-	-	x
24		2.0	0.2	0.1	0.1	1.9	
25		9.0	9.6	9.8	-	-	x
26	10.0	2.2	0.0	0.3	-	-	x
27		1.0	0.2	4.0	-	-	x
28		4.9	2.0	2.0	0.0	4.9	
29		3.0	1.0	0.0	1.0	2.0	
30		1.5	0.2	0.0	0.2	1.3	
31		6.4	0.3	0.2	0.1	6.3	
Sub-total	**16.5**	**40.5**	**20.3**	**23.3**	**1.5**	**24.8**	
Average		**4.1**	**2.0**	**2.3**	**0.3**	**4.1**	
Total	**44.9**	**95.8**	**48.7**	**50.8**	**5.0**	**48.2**	
Average		**3.1**	**1.6**	**1.6**	**0.4**	**3.4**	

Date	SEPTEMBER Rainfall	ET + P	E + P	E	P	ET	Rejection
1		6.5	1.5	0.6	0.9	5.6	
2		4.0	3.0	1.9	1.1	2.9	
3		3.5	0.2	0.2	0.0	3.5	
4		3.7	0.7	0.1	0.6	3.1	
5		7.0	1.1	1.3	-	-	x
6		1.4	1.0	0.4	0.6	0.8	
7		5.7	0.8	0.2	0.6	5.1	
8		2.8	1.2	0.1	1.1	1.7	
9		7.0	0.5	1.0	-	-	
10		9.5	1.0	0.1	0.9	8.6	x
Sub-total	**0.0**	**51.1**	**11.0**	**5.9**	**5.8**	**31.3**	
Average		**5.1**	**1.1**	**0.6**	**0.7**	**3.9**	
11		4.7	0.1	0.0	0.1	4.6	
12	6.3	2.8	0.0	0.1	-	-	x
13		5.7	0.4	0.2	0.2	5.5	
14		8.0	0.5	0.2	0.3	7.7	
15		9.5	0.3	0.2	0.1	9.4	
16		9.0	0.2	0.2	0.0	9	
17		10.0	0.5	0.2	0.3	9.7	
18		8.5	0.5	0.3	0.2	8.3	
19		11.0	1.2	0.0	1.2	9.8	
20		10.0	1.3	0.3	1.0	9.0	
Sub-total	**6.3**	**79.2**	**5.0**	**1.7**	**3.4**	**73.0**	
Average		**7.9**	**0.5**	**0.2**	**0.4**	**8.1**	
21		9.5	0.5	0.0	0.5	9.0	
22		8.0	0.3	0.0	0.3	7.7	
23		11.0	1.7	0.5	1.2	9.8	
24		8.0	0.5	0.5	0.0	8.0	
25		10.0	0.1	0.0	0.1	9.9	
26		10.0	0.9	0.0	0.9	9.1	
27		10.0	1.5	0.0	1.5	8.5	
28		10.5	0.5	0.5	0.0	10.5	
29		10.0	0.5	0.4	0.1	9.9	
30		11.0	2.0	0.0	2.0	9.0	
31							
Sub-total	**0.0**	**88.5**	**8.0**	**1.9**	**6.1**	**82.4**	
Average		**8.9**	**0.8**	**0.2**	**0.6**	**8.2**	
Total	**6.3**	**218.8**	**24.0**	**9.5**	**15.3**	**186.7**	
Average		**7.3**	**0.8**	**1.0**	**0.6**	**6.9**	

Date	OCTOBER Rainfall	ET + P	E + P	E	P	ET	Rejection
1		10.5	1.3	1.0	0.3	10.2	
2		9.8	0.7	0.2	0.5	9.3	
3		10.0	1.5	0.3	1.2	8.8	
4		10.0	2.0	0.2	1.8	8.2	
5		10.0	2.2	0.1	2.1	7.9	
6		7.5	1.5	0.0	1.5	6.0	
7		9.2	1.8	0.2	1.6	7.6	
8		10.0	3.0	0.0	3.0	7.0	
9		9.0	1.0	0.0	1.0	8.0	
10		9.8	2.9	0.5	2.4	7.4	
Sub-total	**0.0**	**95.8**	**17.9**	**2.5**	**15.4**	**80.4**	
Average		**9.6**	**1.8**	**0.3**	**1.5**	**8.0**	
11		9.1	0.7	0.1	0.6	8.5	
12		4.5	0.1	0.2	-	-	x
13		4.1	0.5	0.0	0.5	3.6	
14		5.5	0.1	0.2	-	-	x
15		1.8	-	0.8	-	-	x
16		9.5	1.1	0.0	1.1	8.4	
17		5.0	0.6	-	-	-	x
18	26.0	6.0	1.3	1.2	0.1	5.9	
19		7.5	1.2	1.3	-	-	x
20		7.6	0.2	0.3	-	-	x
Sub-total	**26.0**	**60.6**	**5.8**	**4.1**	**2.3**	**26.4**	
Average		**6.1**	**0.6**	**0.5**	**0.6**	**6.6**	
21		0.2	0.3	0.1	0.2	0.0	
22		2.5	0.6	0.0	0.6	1.9	
23		7.5	0.0	0.1	-	-	x
24		8.0	1.8	0.0	1.8	6.2	
25		5.9	2.0	0.2	1.8	4.1	
26		2.1	2.7	0.0	2.7	-	x
27		8.8	2.0	0.1	1.9	6.9	
28		10.8	1.5	0.1	1.4	9.4	
29		5.5	2.1	0.3	1.8	3.7	
30		2.1	3.6	0.0	3.6	-	x
31		0.4	0.5	0.0	0.5	-	x
Sub-total	**0.0**	**53.6**	**16.8**	**0.8**	**16.1**	**32.2**	
Average		**4.9**	**1.5**	**0.1**	**1.6**	**4.6**	
Total	**26.0**	**210.0**	**40.5**	**7.4**	**33.8**	**139.0**	
Average		**6.8**	**1.3**	**0.2**	**1.4**	**6.6**	

Table H-6 Crop Coefficients (Kc)

No. Crop	Crop Coefficient by Growing Stage (10 days basis)														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
(1) Paddy (120 days)	1.10	1.10	1.10	1.15	1.18	1.22	1.25	1.25	1.25	1.23	1.18	1.08			
(2) Maize	0.45	0.50	0.60	0.80	0.95	1.05	1.05	1.05	1.05	0.80					
(3) Tomato	0.48	0.52	0.65	0.90	1.02	1.05	1.02	0.95	0.75						
(4) Onion	0.48	0.62	0.85	0.92	0.95	0.95	0.87	0.77	0.62						
(5) Okra/egggplant	0.48	0.52	0.60	0.70	0.85	0.95	0.95	0.90	0.65						
(6) Groundnuts	0.50	0.53	0.60	0.72	0.88	0.92	0.95	0.88	0.70						
(7) Cowpeas	0.50	0.58	0.75	0.92	1.05	1.05	0.05	1.00	0.95						
(8) Watermelon	0.50	0.52	0.60	0.70	0.85	0.90	0.90	0.90	0.80						
(9) Pepper	0.50	0.50	0.60	0.78	0.90	0.95	0.95	0.88	0.60						
(10) Sweetpotato	0.50	0.65	0.65	0.82	1.00	1.05	1.05	0.95	0.80						

Table H-7 Soil Test Results and Calculation of Soil Porasity

Description	Sample-1	Sample-2	Sample-3	Sample-4	Sample-5	Sample-6
1. Ashaiman project						
(a) Weight of wetted soil including can (g)	259.07	244.67	250.48	238.57	249.74	239.02
(b) Weight of dry soil including can (g)	223.49	210.59	212.01	198.72	214.17	199.37
(c) Weight of can (g)	93.28	93.26	93.52	93.45	93.22	93.26
(d) Bulk of soil (cm3)	100.00	100.00	100.00	100.00	100.00	100.00
(e) Moisture content (%)	27.33	29.05	32.47	37.86	29.41	37.37
(f) Wetted density (g/cm3)	1.66	1.51	1.57	1.45	1.57	1.46
(g) Dry density (g/cm3)	1.30	1.17	1.18	1.05	1.21	1.06
(h) Specific gravity of soil	2.42	2.42	2.42	2.42	2.42	2.42
(i) Void ratio of soil	0.86	1.06	1.04	1.30	1.00	1.28
(j) Porasity of soil (%)	46	52	51	57	50	56
(k) Average porosity of soil (%)						52
(l) Average moisture content (%)						32
2. Aveyime project						
(a) Weight of wetted soil including can (g)	260.60	273.64	265.48	291.53	276.29	291.62
(b) Weight of dry soil including can (g)	226.20	235.90	231.28	253.78	236.09	253.78
(c) Weight of can (g)	93.34	93.42	93.38	93.42	93.33	93.38
(d) Bulk of soil (cm3)	100.00	100.00	100.00	100.00	100.00	100.00
(e) Moisture content (%)	25.89	26.49	24.80	23.54	28.16	23.59
(f) Wetted density (g/cm3)	1.67	1.80	1.72	1.98	1.83	1.98
(g) Dry density (g/cm3)	1.33	1.42	1.38	1.60	1.43	1.60
(h) Specific gravity of soil	2.42	2.42	2.42	2.42	2.42	2.42
(i) Void ratio of soil	0.82	0.70	0.75	0.51	0.70	0.51
(j) Porasity of soil (%)	45	41	43	34	41	34
(k) Average porosity of soil (%)						40
(l) Average moisture content (%)						25
3. Okyereko project						
(a) Weight of wetted soil including can (g)	274.23	282.86	269.22	273.82	262.16	278.26
(b) Weight of dry soil including can (g)	245.02	254.57	236.93	245.51	236.70	247.19
(c) Weight of can (g)	93.44	93.39	93.39	93.59	93.49	93.54
(d) Bulk of soil (cm3)	100.00	100.00	100.00	100.00	100.00	100.00
(e) Moisture content (%)	19.27	17.55	22.50	18.63	17.78	20.22
(f) Wetted density (g/cm3)	1.81	1.89	1.76	1.80	1.69	1.85
(g) Dry density (g/cm3)	1.52	1.61	1.44	1.52	1.43	1.54
(h) Specific gravity of soil	2.47	2.47	2.47	2.32	2.32	2.32
(i) Void ratio of soil	0.63	0.53	0.72	0.53	0.62	0.51
(j) Porasity of soil (%)	39	35	42	35	38	34
(k) Average porosity of soil (%)						37
(l) Average moisture content (%)						19

Note: Soil tests were executed at IDC.

Table H-8 10-Day 80% Probable Water Requirements for the Projects

(Unit: lit/s/ha)

Project	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
1 Ashaiman												
1 -10	0.76	0.14	0.33	0.67	0.69	0.73	0.71	0.00	0.00	0.38	0.65	1.00
11 -20	0.45	0.06	0.50	0.84	1.11	0.83	0.42	0.00	0.00	0.53	0.81	1.14
21 - end	0.19	0.16	0.56	0.86	0.87	0.97	0.10	0.00	0.15	0.64	1.04	1.06
2 Aveyime												
1 -10	1.18	1.34	0.83	0.07	0.80	0.81	0.91	0.90	0.63	0.04	1.01	1.16
11 -20	1.14	1.25	0.44	0.11	1.26	1.01	1.00	0.88	0.31	0.05	1.47	1.22
21 - end	1.14	1.25	0.06	0.41	1.18	1.01	0.98	0.86	0.05	0.42	1.45	1.07
3 Kpando-Torkor												
1 -10	0.59	0.36	0.13	0.03	0.38	0.38	0.46	0.14	0.00	0.03	0.43	0.49
11 -20	0.49	0.28	0.05	0.09	0.44	0.36	0.25	0.06	0.00	0.08	0.51	0.54
21 - end	0.39	0.21	0.00	0.25	0.53	0.44	0.25	0.00	0.00	0.22	0.58	0.58
4 Mankessim												
1 -10	0.42	0.66	0.71	0.21	0.00	0.01	0.37	0.47	0.67	0.31	0.00	0.20
11 -20	0.56	0.75	0.52	0.08	0.00	0.03	0.51	0.54	0.62	0.14	0.00	0.26
21 - end	0.57	0.75	0.35	0.00	0.00	0.18	0.51	0.60	0.51	0.00	0.08	0.31
5 Okyreko												
1 -10	1.11	0.70	0.00	0.70	0.79	0.55	0.94	0.42	0.00	0.65	1.01	1.18
11 -20	1.09	0.36	0.00	1.04	0.98	0.86	0.86	0.23	0.00	0.94	1.19	1.19
21 - end	0.94	0.03	0.24	0.96	0.77	0.99	0.69	0.03	0.26	0.99	1.20	1.12

Table H-9 Summary of Water Balance Study for Ashaiman Project

Irrigation Area 56 ha

Year	Initial (MCM) (1)	Runoff (MCM) (2)	Evaporation (MCM) (3)	Loss (MCM) (4)	Irrigation Use (MCM) (5)	Balance (MCM) (6)	Minimum Capacity (MCM)	Comment
1986	5.656	0.775	2.728	0.708	0.802	2.193	2.193	O.K.
1987	2.193	2.430	1.920	0.310	0.818	1.576	1.119	O.K.
1988	1.576	2.290	1.841	0.288	0.676	1.061	1.009	O.K.
1989	1.061	2.000	1.553	0.185	0.693	0.630	0.612	O.K.
1990	0.630	1.668	1.143	0.078	0.705	0.372	0.006	O.K.
1991	0.372	2.805	1.525	0.174	0.681	0.797	0.049	O.K.
1992	0.797	1.757	1.431	0.153	0.734	0.236	0.236	O.K.
1993	0.236	1.522	1.013	0.050	0.663	0.032	0.000	No
1994	0.032	1.445	0.953	0.050	0.474	0.000	0.000	No
1995	0.000	5.332	1.921	0.350	0.513	2.547	0.000	No

Note : Effective Dam Capacity 5.656 MCM

(6) = (1) + (2) - (3) - (4) - (5)

"O.K." means that irrigation is possible for 56 ha.

"No" means that irrigation is not possible for 56 ha because minimum capacity becomes less than effective capacity.

Table H-10 Summary of Water Balance Study for Mankessim Project

Irrigarion Area 142 ha

Year	Initial (MCM) (1)	Runoff (MCM) (2)	Evaporation (MCM) (3)	Loss (MCM) (4)	Spilling (MCM) (5)	Irrigation Use (MCM) (6)	Balance (MCM) (7)	Minimum Capacity	Comment
1986	5.637	3.252	2.035	0.245	0.739	1.304	4.565	4.343	O.K.
1987	4.565	3.479	1.831	0.200	0.000	0.942	5.071	3.125	O.K.
1988	5.071	2.924	1.885	0.227	0.000	1.142	4.741	3.880	O.K.
1989	4.741	2.382	1.863	0.220	0.000	1.214	3.825	3.825	O.K.
1990	3.825	1.009	1.647	0.124	0.000	1.264	1.799	1.712	O.K.
1991	1.799	6.416	1.765	0.182	0.610	1.180	4.479	0.829	O.K.
1992	4.479	1.771	1.794	0.187	0.000	1.298	2.971	2.971	O.K.
1993	2.971	0.919	1.554	0.094	0.000	1.231	1.011	1.011	O.K.
1994	1.011	2.780	1.126	0.073	0.000	0.918	1.674	0.658	No
1995	1.674	3.328	1.506	0.104	0.000	1.260	2.132	0.802	No

Note : Effective Dam Capacity 4.187 (5.637-0.820) MCM

(7) = (1) + (2) - (3) - (4) - (5) - (6)

"O.K." means that irrigation is possible for 142 ha.

"No" means that irrigation is not possible for 142 ha because minimum capacity becomes less than effective capacity.

Table H-11 Summary of Water Balance Study for Okyereko Project, Alternative-1

Irrigation Area 39 ha
Pump Capacity 5,150 m3/day

Year	Initial (MCM) (1)	Runoff (MCM) (2)	Pump Water (MCM) (3)	Evaporation (MCM) (4)	Loss (MCM) (5)	Irrigation Use (MCM) (6)	Balance (MCM) (7)	Minimum Capacity	Comment
1986	2.860	0.447	0.942	1.293	0.108	1.017	1.831	1.803	O.K.
1987	1.831	0.833	0.942	0.962	0.068	1.067	1.508	0.976	O.K.
1988	1.508	0.515	0.942	0.836	0.056	1.038	1.035	0.800	O.K.
1989	1.035	0.514	0.942	0.673	0.043	0.997	0.779	0.513	O.K.
1990	0.779	0.502	0.942	0.489	0.027	0.968	0.739	0.224	No
1991	0.739	1.659	0.942	0.805	0.062	0.939	1.535	0.289	O.K.
1992	1.535	0.367	0.942	0.824	0.055	1.105	0.861	0.861	O.K.
1993	0.861	0.343	0.942	0.517	0.029	1.080	0.520	0.254	O.K.
1994	0.520	0.496	0.942	0.444	0.025	0.871	0.618	0.188	No
1995	0.618	0.800	0.942	0.554	0.035	0.982	0.790	0.270	O.K.

Note : Effective Dam Capacity 2.610 (2.860-0.250) MCM

(7) = (1) + (2) + (3) - (4) - (5) - (6)

"O.K." means that irrigation is possible for 39 ha.

"No" means that irrigation is not possible for 39 ha because minimum capacity becomes less than effective capacity.

Table H-12 Summary of Water Balance Study for Okyereko Project, Alternative-2

Irrigation Area 63 ha

Pump Capacity 6,760 m3/day

Year	Initial (MCM) (1)	Runoff (MCM) (2)	Pump Water (MCM) (3)	Evaporation (MCM) (4)	Loss (MCM) (5)	Irrigation Use (MCM) (6)	Balance (MCM) (7)	Minimum Capacity	Comment
1986	2.860	0.447	1.237	1.292	0.108	1.252	1.892	1.707	O.K.
1987	1.892	0.833	1.237	0.973	0.070	1.341	1.578	0.932	O.K.
1988	1.578	0.515	1.237	0.863	0.059	1.276	1.132	0.761	O.K.
1989	1.132	0.514	1.237	0.716	0.047	1.228	0.892	0.518	O.K.
1990	0.892	0.502	1.237	0.539	0.031	1.183	0.878	0.211	No
1991	0.878	1.659	1.237	0.863	0.068	1.156	1.687	0.331	O.K.
1992	1.687	0.367	1.237	0.879	0.060	1.363	0.989	0.886	O.K.
1993	0.989	0.343	1.237	0.583	0.034	1.275	0.675	0.249	O.K.
1994	0.675	0.496	1.237	0.492	0.028	1.184	0.704	0.154	No
1995	0.704	0.800	1.237	0.592	0.038	1.213	0.898	0.288	O.K.

Note : Effective Dam Capacity 2.610 (2.860-0.250) MCM

(7) = (1) + (2) + (3) - (4) - (5) - (6)

"O.K." means that irrigation is possible for 63 ha.

"No" means that irrigation is not possible for 63 ha because minimum capacity becomes less than effective capacity.

Table H-13 Summar of Water Balance Study for Okyereko Project, Alternative-3

Irrigation Area 81 ha
Pump Capacity 7,960 m3/day

Year	Initial (MCM) (1)	Runoff (MCM) (2)	Pump Water (MCM) (3)	Evaporation (MCM) (4)	Loss (MCM) (5)	Irrigation Use (MCM) (6)	Balance (MCM) (7)	Minimum Capacity	Comment
1986	2.860	0.447	1.457	1.290	0.108	1.426	1.940	1.636	O.K.
1987	1.940	0.833	1.457	0.982	0.071	1.544	1.632	0.895	O.K.
1988	1.632	0.515	1.457	0.883	0.061	1.452	1.208	0.733	O.K.
1989	1.208	0.514	1.457	0.749	0.050	1.398	0.981	0.526	O.K.
1990	0.981	0.502	1.457	0.578	0.034	1.341	0.987	0.207	No
1991	0.987	1.659	1.457	0.906	0.073	1.317	1.807	0.367	O.K.
1992	1.807	0.367	1.457	0.923	0.065	1.554	1.090	0.911	O.K.
1993	1.090	0.343	1.457	0.612	0.036	1.520	0.720	0.250	O.K.
1994	0.720	0.496	1.457	0.516	0.030	1.347	0.780	0.141	No
1995	0.780	0.800	1.457	0.626	0.041	1.383	0.986	0.292	O.K.

Note : Effective Dam Capacity 2.610 (2.860-0.250) MCM

(7) = (1) + (2) + (3) - (4) - (5) - (6)

"O.K."means that irrigation is possible for 81 ha.

"No" means that irrigation is not possible for 81 ha because minimum capacity becomes less than effective capacity.

Table H-14 Comparison on Alternative Plans for Aveyime Project

(Unit : 10^3 Cedi)

Work Item	Alternative-1	Alternative-2	Alternative-3
1 Cost			
(1) Irrigable area	63 ha	80 ha	95 ha
(2) Pump station	339,677	360,230	558,177
(3) Irrigation system	526,377	728,842	834,306
(4) Drainage system	21,641	25,041	28,441
(5) Farm road	57,638	92,753	97,011
(6) Related structures	58,047	86,698	94,612
(7) Buildings and electric line	228,877	230,067	239,333
Total	1,232,257	1,523,631	1,851,880
Cost per ha	19,560	19,045	19,493
(Cost per ha in US$)	11,506	11,203	11,467
2 Incremental benefit			
(1) Average incremental benefit per ha*	3,796	4,126	4,319
3 Incremental Benefit/Cost	0.194	0.217	0.222

* : Average incremental benefit per ha is estimated as follows.

(1) Alternative-1: (3,310 x 48 + 5,350 x 15)/53 = 3,796

(2) Alternative-2: (3,310 x 48 + 5,350 x 32)/80 = 4,126

(3) Alternative-3: (3,310 x 48 + 5,350 x 47)/95 = 4,319

Incremental Benefits at Aveyime

Crops	Without Project			Without Project			Incremental Benefit
	Area (ha)	Net Return per Hectare (Cedis 10^3)	Total Value (Cedis 10^3)	Area (ha)	Net Return per Hectare (Cedis 10^3)	Total Value (Cedis 10^3)	(Cedis 10^3)
Paddy Field	48.0			48.0			
Wet Paddy	-	-	-	48.0	1,740	83,500	83,500
Dry Paddy	-	-	-	48.0	1,740	83,500	83,500
Maize	18.5	50	900	-	-	-	-900
Cassava	16.0	450	7,200	-	-	-	-7,200
Total	34.5	-	8,100	96.0	-	167,000	158,900
Average per Ha (Cedis 1,000/ha)							3,310
Upland Field	47.0			47.0			
Okra	-	-	-	11.7	1,650	19,300	19,300
Tomato	-	-	-	11.8	6,130	72,300	72,300
Onion	-	-	-	23.5	6,230	146,400	146,400
Maize	18.1	50	900	23.5	540	12,700	11,800
Cowpea/Groundnut		-	-		370	8,700	8,700
Cassava	15.6	450	7,000	-	-	-	-7,000
Total	33.7	-	7,900	94.0	-	259,400	251,500
Average per Ha (Cedis 1,000/ha)							5,350

Table H-15 Comparion on Respective Alternative Pump Plans

Item	Floating Pump Plan	Slantingly Movable Pump	Fixed Pump
1 Structure	(1) Centrifugal pump is used. (2) Pump station is fixed. (3) Pump will be vertically moved using barge in well, to fluctuation of water level of Volta Lake.	(1) Centrifugal pump is used. (2) No pump station is required. (3) Pump on trailer will be moved by tractor on the inclined concrete slab with side ditches on both sides to fluctuation of water level of Volta Lake.	(1) Mixed flow pump (vertical shaft) is used. (2) Pump station is fixed.
2 Construction	(1) Construction of pump station is not difficult since construction can be made under dry condition, but experienced contractor is required because of its shape.	(1) Construction of concrete slab with side ditches is not difficult due to simple structure.	(1) Construction of pump station is not difficult since construction can be made under dry condition.
3 Installation of pump and accessories	(1) Easy	(1) Easy.	(1) Difficult due to high accuracy is required.
4 Operation	(1) Slightly complicated due to change of delivery hose.	(1) Slightly complicated due to change of position of delivery pipe and electricity distribution panael to fluctuation of water level of Volta Lake.	(1) Easy.
5 Maintenance	(1) Easy	(1) Easy.	(1) Large working space is required. (2) Pulling up work of pump is not easy due to its size.
6 Safety	(1) Moderate.	(1) Slightly low due to the exposed electricity distribution panel.	(1) High.
7 Construction cost per ha*			
Pump & accessories	618 million Cedi (US$ 363,500)	927 million Cedi (US$ 545,300)	1,005 million Cedi (US$ 591,200)
Civil work	355 million Cedi (US$ 208,800)	267 million Cedi (US$ 157,100)	391 million Cedi (US$ 230,000)
Total	973 million Cedi (US$ 572,300)	1,194 million Cedi (US$ 702,400)	1,396 million Cedi (US$ 821,200)
8 Overall judgement	Recommendable		

* : Construction cost per ha is estimated using Lower area of Block-A for comparison purpose.

Table H-16 Cost Comparison on Respective Block Areas

(Unit:10^6 Cedi)

Cost Items	Block-A		Block-B		Block-C		Block-D
	Lower	Lower+Higher	Lower	Lower+Higher	Lower	Lower+Higher	Lower
1 Irrigable area	70 ha	120 ha	31 ha	64 ha	85 ha	150 ha	81 ha
2 Pump station	973	1,563	805	1,095	980	1,594	1,006
3 Pipeline	292	596	125	303	470	910	362
4 Sprinkler system	272	453	118	245	326	572	308
5 Collector drain	127	250	40	86	158	304	186
6 Related structurres	16	22	52	51	51	54	42
7 Farm road	54	95	69	87	124	159	98
8 Buildings	167	222	167	167	167	222	167
9 Electric system	90	95	114	115	129	131	176
10 Greenbelt	51	84	24	31	67	102	40
Total	2,042	3,380	1,514	2,180	2,472	4,048	2,385
11 Construction cost per ha*	29,171	28,167	48,839	34,063	29,082	26,987	29,444
12 Construction cost per ha in US$	17,160	16,569	28,729	20,037	17,107	15,875	17,320

Table H-17 Cost comparison on Alternative Plans for Mankessim Project

(Unit: 10^3 Cedi)

Work Item	Alternative-1	Alternative-2
1 Irrigable area	29 ha	86 ha
2 Pump station	279,415	746,763
3 Pipeline and sprinkler	226,254	786,969
4 Drainage system	14,954	393,935
5 Farm road	25,679	91,622
6 Related structure	4,924	30,758
7 Buildings	167,337	167,337
8 Electric line	79,390	97,410
9 Green belt	0	30,919
10 Minor repair of dam crest	4,420	4,420
Total	802,373	2,350,133
Cost per ha	27,668	27,327
Cost per ha in US$	16,275	16,075

Table H-18 Cost comparison on Alternative Plans for Okyereko Project

(Unit: 10^3 Cedi)

Work Item	Alternative-1	Alternative-2	Alternative-3
1 Irrigable area	39 ha	63 ha	81 ha
2 Pump station	243,892	251,928	271,866
3 Irrigation system	269,690	404,180	595,618
4 Drainage system	25,111	36,033	38,073
5 Farm road	45,815	61,676	86,904
6 Related structure	123,172	137,738	154,526
7 Building	188,009	188,009	188,009
8 Electric line	206,890	206,890	206,890
9 Supplemental water supply	219,197	219,197	219,197
Total	1,321,776	1,505,651	1,761,083
Cost per ha	33,892	23,899	21,742
Cost per ha in US$	19,936	14,058	12,789

Table H-19 Proposed Irrigation Plan

Description	Project				
	1.Ashaiman	2. Aveyime	3. Kpando-Torkor	4.Mankessim	5. Okyereko
Water source	Ashaiman reservoir	Volta river	Volta lake	Apropong reservoir	Okeyreko reservoir
Irrigable area (ha)	56	95	155	86	81
Prevailing soils (surface soil)	Clay loam	Clay loam	Clay loam	Sandy loam	Clay loam
Intake method	Intake valve	Pumps	Pumps	Intake valve	Pumps
Distribution method	Open canal system	Open canal system	Pipelines and sprinklers	Pipelines and sprinklers	Open canal system
Major crops	Paddy	Paddy	Maize, tomato, okra	Watermelon, eggplant	Paddy
Net irrigation requirement (lit/s/ha)	0.7	0.9	0.6	0.8	0.7
Irrigation efficiency (%)	60	60	70	70	60
Irrigation requirement (lit/s/ha)	1.2	1.5	0.9	1.1	1.2
Average basic intake rate (mm/hr)	14.3	N.A	19.3	58.4	N.A
Water supply method	Continuous	Continuous	Rotation	Rotation	Continuous
Irrigation time at one time	24 hours	24 hours	3.5 hours	3.5 hours	24 hours
Sprinkling intensity (mm/hr)	-	-	10	11	-
Space of sprinkler and sub-lateral	-	-	15m x 12 m	15m x 12 m	-
Supply amount (mm/day)	-	-	35	40	-
Irrigation interval (days)	-	-	6	6	-

Table H-20 Estimate on Internal Drainage Requirement for Upland Crop Field

(1) Qd = 0.0029 x C x i x S^1/5 x A^4/5

where,

Qd : Inner drainage module (m3/s)

C : Runoff coefficientdepending on vegetation, soils and topography

i : Rate of rainfall (mm/hr)

S : Fall of topography in m per 328m

A : Draiange area (ha)

(2) Rate of hourly rainfall (mm/hr.) is estimated using the follwinf equation:

Rt = (R24)/24 x (24/t)^ n

where,

Rt : (t) hours average rainfall intensity (mm/hrs.)

R24 : One day maximum rainfall (mm/day)

n : Coefficient estimated from "Maximum Rainfall Intensity-Duration Frequencies in Ghana", Ghana Meteorological Services Department, Departmental No.23

Ashaiman : 0.852

K-Torkor : 0.870

Mankessir : 0.899

Okyereko : 0.899

(3) Calculation

	C	R24	i	S	S^1/5	Equation	
Ashaiman	0.34	109	68	1.2	1.04	Qd =	0.070 A^4/5
Kpando-Torkor	0.43	153	101	6.1	1.44	Qd =	0.181 A^4/5
Mankessim	0.39	135	98	3.0	1.25	Qd =	0.138 A^4/5

Table H-21 Rehabilitation Plan for Respective Projects

Facilities	Ashaiman	Aveyime	K.-Torkor	Mankessim	Okyereko
1 Pump station					
(1) Pump	- no(s)	5 no(s)	6 no(s)	5 no(s)	2 no(s)
(2) House	- no(s)	2 no(s)	2 no(s)	2 no(s)	1 no(s)
2 Irrigation system					
(1) Canal					
(a) Head race	- km	0.4 km	- km	km	- km
(b) Main	1.8 km	3.4 km	- km	- km	2.5 km
(c) Secondary	- km	0.3 km	- km	- km	0.3 km
(d) Lateral	4.6 km	7.8 km	- km	- km	6.7 km
(2) Pipeline system					
(a) Main	- km	1.3 km	2.9 km	1.7 km	- km
(b) Secondary	- km	- km	2.5 km	1.5 km	- km
(c) Lateral	- km	- km	10.8 km	6.3 km	- km
(e) Sprinkler	- sets	7 sets	66 sets	36 sets	- sets
3 Drainage system					
(1) Main	3.5 km	1.3 km	- km	- km	1.8 km
(2) Secondary	- km	1.8 km	- km	- km	1.7 km
(3) Lateral	7.2 km	12.3 km	- km	- km	7.6 km
(4) Collector	- km	- km	4.7 km	4.9 km	- km
4 Related structure					
(1) Outlet	- no(s)	1 no(s)	no(s)	no(s)	- no(s)
(2) Distribution box	- no(s)	1 no(s)	- no(s)	- no(s)	- no(s)
(3) Inlet	- no(s)	1 no(s)	- no(s)	- no(s)	- no(s)
(4) Division structure	1 no(s)	1 no(s)	- no(s)	- no(s)	- no(s)
(5) Turnout	11 no(s)	36 no(s)	- no(s)	- no(s)	19 no(s)
(6) Check	11 no(s)	25 no(s)	- no(s)	- no(s)	19 no(s)
(7) Measuring device	13 no(s)	38 no(s)	- no(s)	- no(s)	19 no(s)
(8) Syphon	- no(s)	- no(s)	- no(s)	- no(s)	1 no(s)
(9) Drop	130 no(s)	3.0 no(s)	- no(s)	- no(s)	73 no(s)
(10) Energy dissipator	1 no(s)	- no(s)	- no(s)	- no(s)	- no(s)
(11) Culvert	8 no(s)	15 no(s)	- no(s)	- no(s)	6 no(s)
(12) Field outlet	140 no(s)	238 no(s)	- no(s)	- no(s)	203 no(s)
(13) Cross drain	11 no(s)	14 no(s)	20 no(s)	28 no(s)	6 no(s)
(14) Causeway	2 no(s)	- no(s)	5 no(s)	- no(s)	2 no(s)
(15) Drop for drain	1 no(s)	- no(s)	- no(s)	- no(s)	- no(s)
(16) Protection for spillway	700 m2	- m	- m2	- m2	1,200 m2
5 Farm road					
(1) Main	1.6 km	2.9 km	3.3 km	0.9 km	2.2 km
(2) Lateral	4.0 km	6.0 km	10.1 km	8.9 km	7.6 km
(3) Access road	- km	- km	4.3 km	- km	- km
6 Project building					
(1) Office	- no(s)	1 no(s)	1 no(s)	1 no(s)	1 no(s)
(2) Store	- no(s)	1 no(s)	2 no(s)	1 no(s)	1 no(s)
(3) Garage	- no(s)	1 no(s)	2 no(s)	1 no(s)	1 no(s)
(4) Dry yard	- no(s)	1 no(s)	2 no(s)	1 no(s)	1 no(s)
(5) Sorter house	1 no(s)	1 no(s)	2 no(s)	1 no(s)	1 no(s)
(6) Dormitory for officer	2 no(s)	- no(s)	- no(s)	no(s)	- no(s)
(7) Lecture hall	- no(s)	- no(s)	- no(s)	- no(s)	1 no(s)
(8) Dormitory for farmers	1 no(s)	- no(s)	- no(s)	- no(s)	- no(s)
(9) Fence for office	500 m	- no(s)	- no(s)	- m	- m
7 Electric line	- km	2.6 km	8.0 km	3.5 km	8.0 km
8 Green belt	- km	- km	9.6 km	2.5 km	- km
9 Supplymentary water supply facilities					
(1) Weir	- no(s)	- no(s)	- no(s)	- no(s)	1 no(s)
(2) Head race	- km	- km	- km	- km	0.2 km
(3) Pipe line	- km	- km	- km	- km	0.8 km
(4) Outlet	- no(s)	- no(s)	- no(s)	- no(s)	1 no(s)
(5) Chute	- km	- km	- km	- km	0.3 km

Table H-22 Major Features of Pump Station for Each Project

Item	Aveyime Project	Kpando-Torkor Project		Mankessim Project		Okyereko Project
		Lower Area of Block-A	Lower Area of Block-C	Existing Area+ Exten. Area-1	Extension Area-2	
1 Irrigable Area	95 ha	70 ha	85 ha	29 ha	57 ha	81 ha
2 Primary Pump and Pump House						
(1) Pump						
(a) Motive power	Electricity	Electricity	Electricity	Electricity	Electricity	Electricity
(b) Number incl. one spare	3 nos.	3 nos.	3 nos.	2 nos.	3 nos.	2 nos.
(c) Type	Horizontal centrifugal pump of double suction type	Horizontal centrifugal pump of single suction type	Horizontal centrifugal pump of single suction type	Horizontal centrifugal pump of single suction type	Horizontal centrifugal pump of single suction type	Horizontal centrifugal pump of single suction type
(d) Total required head	13 m	73 m	74 m	47 m	74 m	23 m
(e) Pump discharge	3.5 m3/min.per one pump	3.5 m3/min.per one pump	4.0 m3/min.per one pump	3.5 m3/min.per one pump	3.5 m3/min.per one pump	6.0 m3/min.per one pump
(2) Pump house						
(a) Pump house	Reinforced concrete made one floor type	Reinforced concrete made one floor type	Reinforced concrete made one floor type	Reinforced concrete made one floor type	Reinforced concrete made one floor type	Reinforced concrete made one floor type
(b) Floor area	77 m2	171 m2	171 m2	52 m2	77 m2	52 m2
3 Primary Pump and Pump House						
(1) Pump						
(a) Motive power	Electricity	-	-	-	-	-
(b) Number incl. one spare	2 nos.	-	-	-	-	-
(c) Type	Horizontal centrifugal pump of single suction type	-	-	-	-	-
(d) Total required head	48 m	-	-	-	-	-
(e) Pump discharge	2.0 m3/min.per one pump	-	-	-	-	-
(2) Pump house						
(a) Pump house	Reinforced concrete made one floor type	-	-	-	-	-
(b) Floor area	22 m2	-	-	-	-	-

Table H-23 Cone Bearing Capacity for Proposed Intake and Pumping Station Sites

(1) Spring constant : 15.3 N/cm

(2) Cone area : 0.5 cm2

(3) Constant factor : 30.6 N/cm3

(4) Test results

Project	Impression Indicated	Cone Resistance	Cone Bearing Capacity	qu*
(a) Kpand-Torkor				
Block A	8.0 cm	8.0 x 30.6 = 244.8 N/cm2 = 24.5 kg/cm2		
	7.5 cm	7.5 x 30.6 = 229.5 N/cm2 = 23.0 kg/cm2	**23.0 kg/cm2**	**4.6 kg/cm2**
Block B	6.7 cm	6.7 x 30.6 = 205.0 N/cm2 = 20.1 kg/cm2		
	7.2 cm	7.2 x 30.6 = 220.3 N/cm2 = 22.0 kg/cm2	**20.1 kg/cm2**	**4.0 kg/cm2**
Block C	8.5 cm	8.5 x 30.6 = 260.1 N/cm2 = 26.0 kg/cm2		
	3.9 cm	3.9 x 30.6 = 119.3 N/cm2 = 11.9 kg/cm2		
	6.2 cm	6.2 x 30.6 = 189.7 N/cm2 = 19.0 kg/cm2		
	5.0 cm	5.0 x 30.6 = 153.0 N/cm2 = 15.3 kg/cm2	**11.9 kg/cm2**	**2.4 kg/cm2**
(b) Mankessim				
Pump station	7.2 cm	7.2 x 30.6 = 220.3 N/cm2 = 22.0 kg/cm2		
(right side)	4.5 cm	4.5 x 30.6 = 137.7 N/cm2 = 13.8 kg/cm2		
	3.4 cm	3.4 x 30.6 = 104.0 N/cm2 = 10.4 kg/cm2		
	3.5 cm	3.5 x 30.6 = 107.1 N/cm2 = 10.7 kg/cm2		
	3.3 cm	3.3 x 30.6 = 101.0 N/cm2 = 10.1 kg/cm2	**10.1 kg/cm2**	**2.0 kg/cm2**
(c) Okyereko				
Pump station	8.7 cm	8.7 x 30.6 = 266.2 N/cm2 = 26.6 kg/cm2		
	>10.0 cm	10.0 x 30.6 = 306 N/cm2 = 30.6 kg/cm2		
	>10.0 cm	10.0 x 30.6 = 306 N/cm2 = 30.6 kg/cm2		
	8.5 cm	8.5 x 30.6 = 260.1 N/cm2 = 26.0 kg/cm2		
	>10.0 cm	10.0 x 30.6 = 306 N/cm2 = 30.6 kg/cm2	**26.0 kg/cm2**	**5.2 kg/cm2**
Intake site	8.2 cm	8.2 x 30.6 = 250.9 N/cm2 = 25.1 kg/cm2		
	>10.0 cm	10.0 x 30.6 = 306 N/cm2 = 30.6 kg/cm2	**25.1 kg/cm2**	**5.0 kg/cm2**

*: Unconfined Compressive Strength (= Cone Bearing Capacity/5)

Table H-24 Designed Canals in Gravity System

Item	Ashaiman Project	Aveyime Project	Okyereko Project
1 Main canal			
(a) Type	Concrete Flume		
(b) Design discharge	0.017 - 0.129 m3/sec	0.006 - 0.183 m3/sec	0.014 - 0.102 m3/sec
(c) Length	1,750 m	3,350 m	2,500 m
(d) Height	0.05 - 0.47 m	0.07 - 0.45 m	0.13 - 0.44 m
(e) Width	0.6 - 0.3 m	0.3 - 0.6 m	0.3 - 0.6 m
(f) Slope	1/2,000	1/1,000	1/1,000
(g) Flow velocity	0.48 - 1.49 m/sec	0.28 - 0.67 m/sec	0.36 - 0.54 m/sec
2 Secondary canal			
(a) Type	Concrete Flume		
(b) Design discharge	- m3/sec	0.004 - 0.008 m3/sec	0.009 m3/sec
(c) Total length	- m	290 m	250 m
(d) Height	- m	0.05 - 0.09 m	0.10 m
(e) Width	- m	1/1,000 m	0.3 m
(f) Slope	-	1/1,000	1/1,000
(g) Flow velocity	- m/sec	0.25 - 0.31 m/sec	0.32 m/sec
3 Lateral			
(a) Type	Concrete Flume		
(b) Design discharge	0.002 m3/sec	0.001 - 0.002 m3/sec	0.002 m3/sec
(c) Total length	4,580 m	7,800 m	6,700 m
(d) Height	0.2 m	0.03 - 0.10 m	0.03 - 0.15 m
(e) Width	0.3 m	0.3 m	0.3 m
(f) Slope	1/1,000	1/1,000	1/1,000
(g) Flow velocity	0.2 m/sec	0.16 - 0.33 m/sec	0.16 - 0.37 m/sec

Table H.25 Designed Drainage Canals for Paddy Cultivated Projects

Item	Ashaiman Project	Aveyime Project	Okyereko Project
1 Main drain			
(a) Type	Unlined		
(b) Design discharge	1.70 - 22.70 m3/sec	0.03 - 0.09 m3/sec	0.01 - 0.17 m3/sec
(c) Length	3,440 m	1,280 m	1,830 m
(d) Height	0.25 - 2.20 m	0.05 - 0.20 m	0.05 - 0.30 m
(e) Width	3.0 - 12.0 m	4.0 m	3.0 m
(f) Slope	1/25 - 1/1,500	1/400	1/300 - 1/2,000
(g) Flow velocity	0.53 - 1.70 m/sec	0.17 - 0.27 m/sec	0.13 - 0.23 m/sec
2 Secondary drain			
(a) Type	Unlined		
(b) Design discharge	- m3/sec	0.02 m3/sec	0.02 m3/sec
(c) Total length	- m	1,800 m	1,700 m
(d) Height	- m	0.4 m	0.4 m
(e) Width	- m	0.3 m	0.3 m
(f) Slope	-	1/300 - 1/500	1/300 - 1/500
(g) Flow velocity	- m/sec	0.20 m/sec	0.20 m/sec
3 Lateral			
(a) Type	Unlined		
(b) Design discharge	0.001 - 0.006 m3/sec	0.003 - 0.009 m3/sec	0.001 - 0.072 m3/sec
(c) Total length	7,240 m	12,340 m	7,590 m
(d) Height	0.3 m	0.3 m	0.3 m
(e) Width	0.3 m	0.3 m	0.3 m
(f) Slope	1/100 - 1/200	1/300 - 1/500	1/100 - 1/200
(g) Flow velocity	0.15 - 0.35 m/sec	0.18 - 0.26 m/sec	0.15 - 0.55 m/sec

Table H.26 Designed Drainage Canals for Upland Crops Cultivated Projects

Item	Kpando-Torkor Project	Mankessim Project
1 Collector drain		
(a) Type	Concrete lined	Concrete lined
(b) Design discharge	0.5 - 2.0 m3/sec	0.5 - 4.0 m3/sec
(c) Total length	4,670 m	5,170 m
(d) Height	0.6 m	0.6 m
(e) Width	0.3 - 0.5 m	0.5 - 1.0 m
(f) Slope	1/50	1/50 - 1/200
(g) Flow velocity	2.0 - 4.0 m/sec	2.0 - 4.0 m/sec
2 Intercepting drain		
(a) Type	Unlined	Unlined
(b) Design discharge	0.08 - 0.36 m3/sec	0.08 - 0.36 m3/sec
(c) Total length	9,580 m	2,500 m
(d) Height	0.3 - 0.6 m	0.3 - 0.6 m
(e) Width	0.3 - 0.5 m	0.3 - 0.5 m
(f) Slope	1/300 - 1/1,000	1/300 - 1/1,000
(g) Flow velocity	0.4 - 0.6 m/sec	0.4 - 0.6 m/sec