ARAB REPUBLIC OF EGYPT MINISTRY OF WATER RESOURCES AND IRRIGATION RESERVOIR AND GRAND BARRAGES SECTOR

THE ARAB REPUBLIC OF EGYPT THE PROJECT FOR CONSTRUCTION OF THE NEW DIROUT GROUP OF REGULATORS

DETAILED DESIGN STUDY

FINAL REPORT

May, 2017

JAPAN INTERNATIONAL COOPERATION AGENCY

SANYU CONSULTANTS INC.



Preface

The Detailed Design Study on the Project for Construction of the New Dirout Group of Regulators has started on 1st July 2015. The study was executed in two (2) phases, consists of natural condition survey and basic design study as the first half, and the detailed design study as the last half. The Study was executed in the total study periods of one (1) year and 11 months, until the 7th of July 2017 when the contract period for this study terminates.

In the course of execution of the studies, the Basic Design Report was submitted at the end of July 2016, the Interim Report was submitted at the end of November 2017 as the intermediate phase of the detailed design study. The Final Report consists of the issues consistently on design, drawings, bill of quantities (BQ), construction plan, project cost estimation and draft bidding documents.

For the preparation of the Final Report, we made due consideration on the convenience and acceleration of understanding on the contents of this report by the users who will be engaged for the first time in each expected stage of the Construction Project of the New Dirout Group of Regulators, for their confirmation and understanding of the design concept on this report.

It is our great honor to be engaged in the Japanese Yen Loan Project with condition of the STEP (Special Terms for Economic Partnership) which is the first case to be applied in the irrigation sector in Japan's Official Development Assistance. We sincerely desire that this Final Report will contribute to the high quality of works on the Construction of the New Dirout Group of Regulators, of which the implementation is expected to start in the near future.

Last of all, JICA Study Team wishes to express the sincerest appreciation to the officials concerned of the Japan International Cooperation Agency and Ministry of the Water Resources and Irrigation, the Arab Republic of Egypt who gave precious comments and guidance to the team.

May, 2017

EXECUTIVE SUMMARY

1. Outline of Design

The Dirout Group of Regulators (hereinafter referred to as "DGRs"), which is the subject of this study, is the core irrigation infrastructure to supply irrigation water to all the beneficiary area located in the middle Nile basin region. The DGRs delivers 9.6 BCM/year of irrigation water or 17% of the gross water resource of the Nile of 55.5 BCM/year taken from the Assiut Barrage into the beneficiary area of 0.6 million ha through the Ibrahimia main canal. The DGRs branches the Ibrahimia main canal into seven (7) main canals, and irrigation water is provided to the beneficiary area through these canals.

The Bahr Yusef canal is the largest canal in capacity among the seven (7) canals. Its length extends as long as 312 km and there are four (4) regulators, namely the Lahoun Regulator, the Mazoura Regulator, the Sakoula Regulator and the Dahab Regulator, all of which were rehabilitated by Japan's Grand Aid from 1995 to 2010.

The DGRs, which was constructed in 1872, is the oldest active regulator in the country, and the weirs cannot function well due to their age. The rehabilitation of the DGRs should, therefore, be urgently implemented. It is expected that the impacts of the rehabilitation of the DGRs should be significant considering the vast beneficiary area and very long canal networks by synergy with the rehabilitation of four (4) regulators in the Bahr Yusef canal.

In view of such a situation, Japan International Cooperation Agency (hereinafter referred to as "JICA") conducted the feasibility study, namely "The Preparatory Survey for the Rehabilitation and Improvement of the Dirout Group of Regulators in the Arab Republic of Egypt" (hereinafter referred to as "F/S"), in 2010 in order to formulate the rehabilitation plan of the DGRs and integrated water management plan for the operational management of the DGRs and other regulators along the Bahr Yusef canal.

The Egyptian Government requested of the Japanese Government the Official Development Assistance (hereinafter referred to as "ODA") loan, which applied Special Terms for Economic Partnership (hereinafter referred to as "STEP"), in March 2013. On March, 2015, JICA signed an ODA loan agreement for the Project for Construction of the New Dirout Group of Regulators (hereinafter referred to as "the Project") with the Egyptian Government after a series of discussions. This study will be conducted for twenty-two (22) months from July 2015 in compliance with the Record of Discussion (hereinafter referred to as "R/D") signed by JICA and the Ministry of Water Resources and Irrigation (hereinafter referred to as "MWRI") on March, 2015, in order to prepare the detailed designs and bidding of documents.

2. Design of the Regulators

2-1 Design conditions

Adherence to the Egyptian code is given first priority in the design criteria applied at the basic

design and the detailed design stages for NDGRs construction project, which is supplemented by " Part No.2 Design of Hydraulic Structure, Spillways, Regulators and Barrage" used as the design criteria for the hydraulic facility in Egypt. In the absence of a policy in the Egyptian code regarding an issue, Japanese design criteria in the field of the regulators and *Design Criteria for Irrigation and Drainage, Headworks* will be referred to.

Figure 2-1 and Table 2-1 show the outline of the NDGRs



Figure 2-1 General layout of NDGRs

Table 2-1 Outline of NDGRs

Name of Reg	ulator	_		Badr	aman	Abo	Gabal		
Name of Cana	al	- Bahr Yuset	Ibrahimia	Badraman	Diroutiah	AboGabal	Irad Delgaw	Sahelyia	Remarks
Design maxim	num discharge	227 m ³ /s	186 m ³ /s	9 m ³ /s	12 m ³ /s	7 m ³ /s	9 m ³ /s	5 m ³ /s	Total 455m ³ /s
Design minim	ium discharge	33.1 m ³ /s	23.6 m ³ /s	1.2 m ³ /s	1.7 m ³ /s	0.9 m ³ /s	1.3 m ³ /s	0.6 m ³ /s	Total 62.4m ³ /s
Design U/S h	igh water level	EL46.30m	EL46.30m	EL46.30m	EL46.30m	EL46.30m	EL46.30m	EL46.30m	
Design U/S lo	w water level	EL45.90m	EL45.90m	EL45.90m	EL45.90m	EL45.90m	EL45.90m	EL45.90m	
Design D/S hi	igh water level	EL45.82m	EL45.13m	EL45.90m	EL45.90m	EL45.90m	EL45.90m	EL45.90m	
Width of vent		6.00m	6.00m	2.00m	2.00m	2.0	0m	2.00m	
Number of ve	nt	4	4	2	3		4	2	
Gate sill eleva	ation	EL40.00m	EL40.00m	EL43.90m	EL44.20m	EL43	.60m	EL43.00m	
Gate crest ele	evation	EL46.55m	EL46.55m	EL46.55m	EL46.55m	EL46	i.55m	EL46.55m	
Total gate hei	ight	6.55m	6.55m	2.65m	2.35m	2.9	5m	3.55m	
	Main body	Cast-in-place RC pile	Cast-in-place RC pile	Raft foundation	Raft foundation	Raft fou	Indation	Raft foundation	
Foundation	Apron	Raft foundation	Raft foundation	Raft foundation	Raft foundation	Raft fou	Indation	Raft foundation	1
	L-shape wall	Cast-in-place RC pile	Cast-in-place RC pile	-	-		-	-	1
Downstream	Туре	L-type retaining wall	L-type retaining wall	RC flume	RC flume	RC f	lume	RC flume	
apron	Length	44.25m	44.25m	23.35m	22.77m	23.	87m	16.42m	Note(1)
Seepage cont	trol works	Steel sheet pile	Steel sheet pile	Steel sheet pile	Steel sheet pile	Steel sl	neet pile	Steel sheet pile	
		Riprap	Riprap	Riprap	Riprap				
Bed protection	n works	L=30.0m	L=30.0m	L=15.0m	L=15.0m		-	-	t : Thickness
	1	(D ₅₀ =0.40m,W ₅₀ =60kg,t=1.00m)	(D ₅₀ =0.40m,W ₅₀ =60kg,t=1.00m)	(D ₅₀ =0.20m,W ₅	₀ =10kg,t=0.50m)				including gravel (0.10m)
	D/S	Cantilevered type/Brace type steel sheet pile wall	Cantilevered type/Brace type steel sheet pile wall	Cantilevered sheet pile	Cantilevered sheet pile		-	_	
Bank		Gabion wall	Gabion wall	wall	wali				
works	U/S	Brace type steel sheet pile wall	Cantilevered type/Brace type steel sheet pile	Cantilevered sheet pile	Cantilevered sheet pile	Brace type stee	el sheet pile wall	Brace type steel sheet	
		Wet stone pitching	Wet stone pitching	wali	waii			pile wall	
Bridge		RC, Total width=12.5m	RC, Total width=12.5m	RC,Total width=12.5m	RC,Total width=12.5m	RC,Total v	vidth=6.0m	RC,Total width=6.0m	
	Туре	Double leaf	Double leaf	Single leaf	Single leaf	Singl	e leaf	Single leaf	
	Hoist	Hydraulic cylinder	Hydraulic cylinder	Electric motor	Electric motor	Electri	c motor	Electric motor	-
Coto focility	Operation speed	0.3 m/min	0.3 m/min	0.3 m/min	0.3 m/min	0.3 n	n/min	0.3 m/min	
Gale facility	Material		Rolled stee	el & Stainless steel(Guid	de frame, bolt & nut, wh	eels)			-
	_	1 set	1 set			2 sets			Note(2)
	Stoplogs	Height of one pie	ce=1.35m&1.20m		Height of one	e piece=0.95m&	0.85m		
		Remote control building: RC str	ucture, 2 floors (Stoplogs storage	je house is established to	ogether)	•			Location and the area is
Management	facility	Local control room: RC structure	e, 2 rooms (Bahr Yusef & Ibrahir	nia Regulator)	<u> </u>				under study
		2 sets	2 sets	2 sets	2 sets	3 s	ets	2 sets	t
Water level ga	auge	(U/S:1,D/S:1)	(U/S:1,D/S:1)	(U/S:1,D/S:1)	(U/S:1,D/S:1)	(U/S:1	,D/S:2)	(U/S:1,D/S:1)	Pressure type
L				,	,				

(1) Length of downstream apron for small regulators shows the distance from a gate sill to the existing structure. Note:

(2) One set means a pair of stoplogs for upstream and downstream. U/S:Upstream, D/S:Downstream

2-2 Operation and Maintenance of regulators

The outline of the operation and maintenance of the NDGRs are shown on the Table 2-2.

	duine of operation and maintenance of NDGNS
List of operation and	Outline of operation and maintenance
maintenance	
Management and control of	Management and control of the water distribution which is necessary to
water distribution	make the yearly plan should be cooperated with the other operators at
	U.S. and D.S. of NDGRs. The gate operators should control the water
	discharge from the gates depending on the water level at U.S and D.S.
Maintenance of structures and buildings in NDGRs	In order to secure the structure and function for the longtime, the status check and the rehabilitation are important to conduct properly.
Maintenance of equipment	The equipment, i.g, observation, machine and electric facility, needs proper maintenance. The method of maintenance on the gate facilities are shown as followings; Inspection \rightarrow Maintenance \rightarrow Operation. Those works flow should be repeated as the cycle works. The necessary rehabilitation and overhaul to the equipment and the facility should be done if the deteriorations are discovered.
Record of inspection and check	The as build drawings and the design document should be kept in the custody so as to use as the necessity. The records of the inspection and check should be organized into the database and kept for a long term.
Management of target canal bed	The sedimentation at the downstream of the gates could be made
elevation	adverse effect to the gate operation such as closing completely. The
	canal bed level at the vicinity of the regulators should be less than the
	sill level of the gates.

Table 2-2 Outline of operation and maintenance of NDGRs

2-3 Proposal for preservation works of the existing DGRs

(1) Prerequisites for examination of preservation measures

As the prerequisites for the proposal on the necessary and reasonable works of the preservation of the existing DGRs, the following purposes and the deterioration curve shown on Figure 2-2 should be utilized for the examination.

- ① To preserve the existing DGRs as a historical monument.
- ② To the practical functions of regulators by the removal of the gate or keeping the gates open completely.
- ③ To remain the bridge function with some traffic restrictions for large and heavy vehicles.

(2) Proposal for necessary survey and feasible measures based on present data

In order to explore the appropriate preservation measures, the visual inspection, the boring survey, the laboratory test and structural analysis should be done in addition to the past study and survey. The feasible measures based on the present available data are shown as followings;

- ✓ In order to reduce the burden load on the existing DGRs except for Abo Gabal and Sahelyia regulators, the passable traffic shall be restricted.
- ✓ All the gates shall be opened completely to alleviate the up-lift pressure to the basement of the regulators.

(The necessary dredging works should be done before the gates opens.)

✓ The significant damage found in the past (2010) survey such as eroded and fallen out bricks inside of the vents and the apron erosion at Bahr Yusef and Ibrahimia regulators should be rehabilitated.



Figure 2-2. Flow of examination of appropriate measure works

2-4 Groundwater simulation analysis

(1) Purpose of analysis

The construction of NDGRs will result in a rise in canal water level, which induces rise in the groundwater level around the DGRs such as mosques, station, highways, buildings in the markets

and resident area. There may be a serious concern of the damage of their structures, aggravating sanitary environment, the floating of buildings, and the deterioration of structure foundations, etc.

In this context, the aim of a groundwater simulation analysis is to predict and infer groundwater behavior after NDGRs construction, and to evaluate its environmental impact, and to provide data that is useful in deciding on the necessity and scale of mitigation measures.

(2) Result of the analysis

The case 12 which takes sheet pile works, bank protection works and embankment works (proposed in the D/D study) restricts the risk of groundwater rise to surrounded foundation and underground structures with at most 0.3m rise in water level even beside the canals. As shown in Table 2-3, it was found that complete offset work is difficult even in the case with further seepage control works (case 13). Therefore, continuous monitoring work of groundwater and its analysis are recommended in addition to the improvement work of public sewage system to mitigate the groundwater rise caused by civilization.

			Condition				Result	
Case	Canal Water Ievel	Sheet Pile	Embank ment	Seepage Control Work	Grouting	GW Rise	Inference Area	Increase in Seepage Amount
Case 12 (D/D design)	Plan	0	0	×	×	0.09m	300m (RB) 270m (LB)	39 m³/day
Case13 (Additional seepage control works)	ditto	0	0	0	0	0.06m	300m (RB) 290m (LB)	33 m³/day
		a 12		c	troi works	÷		
Sheet pile Note: Peemeability Sheetpile: I Embankme Scepage Co Grounting:	e :Em is given as $x-1.15x10^{-7}$ cm mt/Regulator b ontrol works: k : $k=1.15x10^{-5}$	bankment //sec x 1.25m ody: k=1.15x =1.15x10 ⁻⁵ c: cm/sec x 2.5	Reg thickness of thickness of thickness of	gulator body f wall(1 grid) x beds' thicknes i' thickness und wall(1 grid)	ss underlain lerlain the str	epage cont the stricter/e icter/embanl	rol work ///	Grouting work:

Table 2-3 Simulation conditions and their results

3. Formulation of Integrated Water Management System

3-1 Target facilities to be covered with integrated water management system

In order to distribute irrigation water fairly and appropriately to the Project area, integrated water management system will be formulated for realizing wide area monitoring of irrigation water and water allocation plan. Each facility in the irrigation system consists of water diversion facilities, regulators, main canals, intakes for branch canals, branch canals, farm land and drainage canals.

In order to efficiently distribute water to 600,000 ha-irrigation area in accordance with irrigation system requirements, each facility must fulfill its function satisfactorily. The scope of integrated water management system shall be included the irrigation facilities on the main canals under the supervision of the GDWD in Assist of MWRI and that of GDIs.

The target facility in water management covers the beginning facility of the main canal such as head regulator, the important facility for management along the main canal, and the branch canal intake with the large amount of water distribution from the main canal to the branch canal.

Ir	rigation facili	ties	Name of the Ta	arget facilities	Number.
	Bahr Yusef c	anal	Dahab Regulator	Lahoun Regulator	
or			Sakoula Regulator	Abo El Shekok Regulator	6
ulato			Mazoura Regulator	Regulator km39	
Reg	Ibrahimia ca	ınal	New Hafze Regulator Matay Regulator Maghagha Regulator	Sharahna Regulator El Gandy Regulator Ashmont Regulator	6
	Bahr Yusef	Intake	Manshat EL Dahab	Quftan	
	canal		El Hareka	Wesh El-Bab	6
			El Sabaa	EL-Giza	
		Weir	Hassan Wasef Weir		1
nch canal		Pump	New Kamdeer P.S. New Terfa P.S. Old Terfa P.S.	Old Sakoula P.S. Mazoura P.S.(2)	5
Bra	Ibrahimia canal	Intake	Irad El Maharak El Kosia East Hafze West Hafze Adkak	Gendia Abo Shosha EL Soultany Tansa El Mansour	10
		Weir	Serry Weir	Maghagha Weir	2
Ibrahimi	a main canal		Ibrahimia Head Regulator		1
Lake			Quarun Lake		1
		Total			38

Table 3-1 Facilities targeted for monitoring (1/2)

Table 3-2 Facilities	targeted	for monitorin	g	(2/2))
				· · · · ·	

Irrigation facilities	Name of th	e Target facilities	Number
Dirout Group of Regulators	Bahr Yusef Regulator Ibrahimia Regulator Irad Delgaw Regulator Abo Gabal Regulator	Badraman Regulator Dairotiah Regulator Sahelyia Regulator	7
Tota	al		7

3-2 Centralized management system

Remote monitoring of water level developed by the telemetry engineers and promoted by the CDT is expected to be utilized in the future following its wide dissemination because of its high

expansibility and technical simplicity. Therefore, the CDT-based monitoring system shall be used continuously for the remote monitoring of the water levels at the regulators in the main canals, at the intakes of the branch canals, and for data processing that converts water levels into flow rate. The existing water management system is using the GPRS communication network system. The access point (APN), that is, the facility for implementing TCP/IP data transmission by GPRS communication, is managed by MWRI. The integrated water management system uses the same communication method and data transmission method in order to integrate with the current telemetry system, and uses the same facility of APN.



Figure 3-1 Integrated water management system composition of GPRS communication

3-3 Design of gauging station and master station

In the water level gauging station installed in the regulators or branch canal intakes, the water levels upstream and downstream of the gate are measured. The monitored water level is used for grasping the status of water distribution and future's proper gate operation.

The central monitoring station (master station) will be installed in the same building of the control house for NDGRs. The central monitoring office has a function to be collected, recorded and evaluated water level data at each gauging stations.

		<u>g otation</u>
GPRS modem	Water level sensor	Protection pipe
RTU with Data logger	Enclosure	Frame of solar panel
Charge controller	Pole	Frame of enclosure
Battery	Foundation	Wiring cable
Solar panel	Junction box	

Table 3-3 Equipment of the gauging station

GPRS modem	Web & E-mail server	19 inch Rack
Router	KVM Switch	Monitoring terminal
L2-SW	KVM Monitor	Laser printer
Data acquisition server	Keyboard & Mouse	LCD Monitor
Water management server	UPS	

Table 3-4 Equipment of the central monitoring station (master station)

4. Construction Planning

4-1. Temporary Works

(1) Outline of the project

The construction site is located in an urban area, and the national railway and the national road run on the east and west sides, respectively, of the construction site. Both the temporary work plan and the construction plan were formulated using the field survey, the existing condition survey, and the construction equipment and materials survey, and take the actual conditions around the site into consideration.

The project consists of the following two components.

- (a) Construction of the NDGRs 140 m downstream from the existing DGRs.
- (b) Improvement of the communications facilities pertaining to the construction of the water distribution system.

Item	Structures
1) New Dirout Group of Regulators	
(a) Construction of new regulators	Construction work on six regulators
(b) Installation of gates	
Bahr Yusef	W 6.0 m × H 6.55 m, total 4 vents
Ibrahimia	W 6.0 m × H 6.55 m, total 4 vents
Abo Gabal	W 2.0 m × H 2.95 m, total 4 vents
Badraman	W 2.0 m × H 2.65 m, total 2 vents
Diroutiah	W 2.0 m × H 2.35 m, total 3 vents
Sahelyia	W 2.0 m × H 3.55 m, total 2 vents
(a) Improvement of peripheral facilities	Construction of parallel bridge
(c) improvement of periprieral facilities	Improvement of retaining walls
(d) Cofferdam works	Single and double cofferdams of steel sheet pile
2) Integrated Water Management	
(a) Main canal gates management system	Monitoring system installation work
(b) Branch canal intake management system	Monitoring system installation work
(c) Establishment of integrated water management centre	Construction of centre building

Table 4-1. Outline of the project

Figure 4-1 shows the layout plan of temporary works.



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4-2. Construction of the NDGRs and Water Management Facilities

In the construction of the NDGRs, the construction of Bahr Yusef regulator on the downstream side will begin first, and secondly the construction of Ibrahimia regulator will start. The construction of the other regulators, Badraman and Diroutiah, and on the upstream side, Abo Gabal and Sahelyia, will be performed in parallel with the construction of Bahr Yusef and Ibrahimia.



Figure 4-2. Regulator construction flow

The construction will start after the relocation of the mosque is completed by the Egypt side. Preparation work \rightarrow Temporary bridge \rightarrow Double sheet coffer dam \rightarrow Removal of existing facilities, Excavation inside site \rightarrow Foundation piles and waterstop sheet piles \rightarrow Construction of regulator structure \rightarrow Installation of gates and trial operation \rightarrow Removal of double sheet piles and switching diversion \rightarrow Revetment work and appurtenant work (road works and electrical work) \rightarrow Integrated trial operation/Operation training \rightarrow Finishing/Clearing

The manufacture and transport of the gates, machinery and electrical equipment, the building work and the revetment work proceed in parallel with the construction of the structures and the installation and trial operation of the gate.

4-3. Work procedure



Figure 4-3. Work procedure

Table 4-2. Construction schedule (large regulators)

																																_		
				Firs	tyear						Sec	ond ye	ear					Tł	hird yea	ar					Fou	irth yea	ar			Fifth	i year		Note	
reparatory and Procurement work	1	2 3	3 4	56	78	9	10 11	12	13 14	15 1	6 17	18 19	20 2	1 22 2	3 24	25 2	26 27 2	28 29	30 31	32 33	3 34 3	5 36	37 38	39 4	0 41 4	2 43	44 45	46 47	48 49	9 50	51 5	52		
01 Preparatory works		1 i	-																							Ш			Щ			1		
04 Procurement and Installation of the Concrete Plant	-																																	
Procurement of Steel materials for Temporary and Permanent	ļ																											444	Щ					
06 Procurement of the gate facility																	444		44	ЦЦ				_				╇	+++	44				
ritical Path of the Regulator Construction							11												11									\square	444					
Bahr-Yusef	-																	Ħ	44	ЦĻ			11			Ш			444					
Ibrahimia																												##	==					
Integration trial operation/Operation Training	+				+++												\square		++					+			+++	╇	+++	II F				
Finishing/Clearance/Handover																			+++									╇╋	┿┿┽					
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) Preparatory works	-																											+++						
Izeoging for Diversion Canal-Stone Kiprap for Kiverbed (t=0.5m)	+	HA	-						+++	H			\mathbb{H}	+++		++			+++-	┝┼┠┝	+++			++	+++	HH	++	╇	+++		\square			
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D4 remporary Double Sheet Pile Cotter Dam WC	+	HH		\square	┼┼┞		11		Ш	\square		++	HH	+++	++	+		+++	+++	┝┼┠┞	+ + +	+	+++	╫	+++	HH	+	₩₩	+++		H			
b Embankment for Temporary road - Hardening for Soft Soll		\mathbf{H}		\square	+++			↓↓		\square			HH	++						\mathbf{H}		+			+++	ΗЦ		₩₩	┿┿	44				
16 Earth work for Inside dam		H		\square	+++		+		┼┼ ┡	ЦН			HH	+++	++	+			++	H	+++	+	+++	╇	+++	HH	+	╫┼	+++		\square			
/ Cut-oli sneetpile		HH		HH	HH	+++		+++	₩.			++	HH	+++	++		<u> </u>	<u> </u>	<u> </u>	╎┤╿┤	+++	+	+++		+++	ΗН		╫┼	+++	#	H	<u> </u>		
8 Foundation Pile work-Removal for Temporary embankment	+	\parallel		\square	+++	+++													++	HH		+			+++	ΗЦ		+++	┿┿	Щ-	\square			
9 Structure Concrete Work																												+++	+++					
) Installation work of the gate and noist facility							1																											
Removal work or Temporary Bridge and Coner Dam																												╇	╇╋			<u> </u>		
2 Embankment-Gabion-Bank protection-Road Work							11		44										74				444					++++	444	44		1		
Ibrahimia																																		
1 Platform for Sheet pile inside Coffer Dam Dredging, Stone Riprap for Riverbed (t=0.5m)																+												444	44	Ш				
2 Temporary Double Sheet Pile Coffer Dam work																			11															
3 Embankment for Temporary road Hardening for Soft soil																																		
4 Earth work for inside dam																																		
5 Cut-off sheet pile																												┶	444					
6 Foundation Pile work-Removal for Temporary embankment																																		
7 Structure Concrete work																											Ħ							
Installation work of the gate and hoist facility																												# 11						
9 Removal work of Sheet pile for Coffer Dam																																		
0 Embankment-Gabion																														ĦL				
1 Bank protection																																		
2 Road Work		\square																Π							\square	ШТ				LE				
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5 Finishing/Clearance/Handover																															Ħ			
ch ReguLator Construction Schedule																																		
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2 Ibrahimia																+											-							
Badraman/Dairoutiah						H												ШП								ПТ	Π			Ш				
4 Abo Gabal/Sahelyia		Ш					T		ΠŤ																			Ш						
5 Finishing/Clearance/Handover																	HF	HT		HT		HT					11					1		
ildina Work		ĦĦ		++						HH			H													HH		ĦĦ	+++	HF	Ħ			
1 Control house/Monitoring hoise	+	HH	++										HH															╧╋┼┼┼	+++					
2 Stop log house	+		++										HH							╞┼╂┼			11	11		HT			╧╧╧╧					
3 Local control House for Babr-Yusef	+	╘┼┼┤		H		┿╋		++	++	H	+++	\square	\vdash	┝╋┼╋┥			+++	╘┼┼┤						╡┟╡		HH		HT I	ĦĦ	┓┼	\square	+		
4 Local control House for Ibrahimia	+			++																				ΗĒ	┓╫╢	HH		+++	++++					
ater Mnagement System																										HH		+++	+++					
Mater Meanward Crater	-	111		Hł	++++	1	* + +	+++	+++	++		11						111	44		+++	18	44	414			11	+*+*		11	11	1		

Table 4-3 Construction schedule (small regulators)

				First	/ear						Sec	cond y	year						Thi	d year						Fc	ourth y	ear				Fift	n year	r	Note	
Detail of Critical path for Small Regulator	1	2 3	4	5 6	7 8	9 1	10 11	12	13 14	15 16	6 17 1	18 19	20	21 22	23 2	24 25	26 2	27 28	29 3	0 31 3	2 33	34 3	5 36	37 38	39 40) 41	42 4	3 44	45 4	6 47	48 4	49 50	51	52		
Badraman					11	П				1 1		11		Π			~															11				-
-01 Preparatory w orks . Temporary Embankment for Coffer Dam. Steel Sheet Pile	\square				▦	Ш	11		Ш									Πſ	Ш							П										
-02 Hardning for Soft Soil.Earth Work.Cut-off Steel Sheet Pile				\square					ÌΠ									Пſ									11					11				
-03 Structure Concrete work															НП			ΠŤ																1		
-04 Installation work of the gate and hoist facility						ĦŦ												ΠŤ																		
-05 Bank Protection Stone Riprap Removal for Embankment for Coffer Dam & Sheet pile			TT			ĦT	11																									tt				
-06 Road Work Trial Operation					Ħ	ĦŦ		Ħ		╈					НП			ΠŤ																1		
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-01 Preparatory works - Temporary Embankment for Coffer Dam- Steel Sheet Pile						Ħ									ПП																					
-02 Hardning for Soft Soil Earth Work Cut-off Steel Sheet Pile						ĦŦ	11							ΠŤ	H			ΠŤ														11				
-03 Structure Concrete work						ĦŦ	11											ΠŤ																		
-04 Installation work of the gate and hoist facility						Ħ												ΠŤ	Ш													11				
-05 Bank Protection Stone Riprap Removal for Embankment for Coffer Dam & Sheet pile			TT			\square	ПÌ	Ш							ΠП			ΠŤ								Π						ttt				
-06 Road Work • Trial Operation						Ħ	11							ΠŤ	Ш			ΠŤ	Ш		T					\square						11				
Abo Gabal		11	111			Π		\square										ПÍ								П						111		1		
-01 Preparatory works . Embankment for Access Road . Sheet pile for Coffer Dam & Temporary Canal						\square	11			111																						ĦŤ				
-02 Hardning for Soft Soil.Earth Work.Cut-off Steel Sheet Pile						Ш	11		ΠT	111				ΠŤ	П																	111				
-03 Structure Concrete work						Ħ												ΠŤ														Πſ				
-04 Installation work of the gate and hoist facility						\square	11		ΠT	111								ΠŤ									111					ĦŤ				
-05 Bank Protection Stone Riprap Removal for Embankment for Coffer Dam & Sheet pile						Ħ	11											ΠŤ	Ш																	
-06 Trial Operation						ĦŦ	11							ΠŤ	H			ΠŤ														11				
Sahelyia						Ħ			ΠΠ					\square	ПП			ΠÌ		Ш	T															
-01 Preparatory works Embankment for Access Road Sheet pile for Coffer Dam & Temporary Canal						Ш												ΠŤ	Ш													Πſ				-
-02 Hardning for Soft Soil Earth Work Cut-off Steel Sheet Pile						Ш				11				ΠT	ПП																					
-03 Structure Concrete work						Ш	11		ΠT						Ш			ΠŤ	Ш		T					÷						Πſ				-
-04 Installation work of the gate and hoist facility						Ш																													-	
-05 Bank Protection Stone Riprap Removal for Embankment for Coffer Dam & Sheet pile						Ш																														
-06 Trial Operation																	www													L	- 10					
						Ш																													-	
Water Management System																																				
Civil works																																				
-01 Assiut (4 sites)																																				
-02 West Minia (6 sites)																																				
-03 East Minia (8 sites)						Ш																													-	
-04 Beni suef and Fayoum (8 sites)																																				
Electrical works																																				
-01 Master station (Dirout)																																				
-02 Monitoring station (Minia)					\square					\square								IT										Ħ				III				
-03 Assiut (4 sites)					\square					Π								IT										-								
-04 West Minia (6 sites)																																				
-05 East Minia (8 sites)					\square					\square								IT						$ \top $												
-06 Beni suef and Fayoum (8 sites)					\square					Π								IT																		
-07 Software development in cairo																																				
-08 Commissioning test	TT	ITT			ITT		IT			ITT		ITT	\square					ITT									Π					IT				

5. Project Cost Estimation

5-1. Criteria and manual of project cost estimation

- (1) Time of cost estimation January 2017
- (2) Expected commencement date February 2018
- (3) Exchange rate the average rate for the three months from February to April 2017

1USD = ¥113.34, 1EUR = ¥121.26, 1LE = ¥6.49

(4) Indirect cost

- Indirect cost for Civil and Temporary Works : 35% of each direct cost
- Indirect cost for Gate Manufacture : 3% of the direct cost
- (5) Unit price of manpower, materials, and rental fee of heavy equipment etc.
 - Procured from Japan: 90% of the average price between two books for monthly unit price published in Japan. When there was any item not described on the two books, competitive estimations from three companies were applied.
 - Procured in Egypt: 100% of the average price of the competitive estimations from three companies
- (6) Price escalation
 - Price escalation rate for LC :
 - total ratio is 18.9% (17.2% of recent price escalation + 1.0% per year during construction)
 - Price escalation rate for FC : total ratio is 4.2% (1.6% per year during construction)
- (7) Depreciation ratio for temporary steel material 50%

5-2. Estimation of the project cost

Item		Quantity		Total		
		Quantity	US\$	LE	YEN	(Exchange to "YEN")
I Construction Cost	L.S	1	6,138,654	377,480,579	2,219,659,487	5,365,263,000
(breakdown)						
A. Civil Works	L.S	1	1,422,252	213,048,447	1,870,904,765	3,414,787,000
B. Temporary works	L.S	1	4,309,402	117,144,168	348,754,722	1,597,447,000
C. Building works	L.S	1		4,589,565		29,786,000
D. Integrated Water Management System	L.S	1		42,698,399		277,112,000
E. Dispute Board	L.S	1	407,000			46,129,000
II Consultant Service	L.S	1		17,131,288	277,426,230	388,607,000

Table 5-1. Construction and project cost estimation (1/2)

Thomas	TTuit	Omentitur		Amount		Total	
Item	Umt	Quantity	US\$	LE	YEN	(Exchange to "YEN")	
III Contingency for Construction	L.S	1	577,647	93,785,050	208,869,958	883,006,000	
(breakdown)							
 Price Contingency 	L.S	1	257,823	71,343,829	93,225,698	585,469,000	
Phy sical Contingency	L.S	1	319,824	22,441,220	115,644,259	297,537,000	
* IV Contingency for Consultant Service	L.S	1		4,256,269	26,105,808	53,729,000	
(break down)							
Price Contingency	L.S	1		3,237,813	11,651,902	32,665,000	
Phy sical Contingency	L.S	1		1,018,455	14,453,907	21,064,000	
Ą							
V. Interest During Construction	L.S	1			20,100,000	20,100,000	
Project Cost (I~V)	-		6,716,301	492,653,185	2,752,161,483	6,710,705,000	
VI Other Cost Estimation	L.S	1		94,821,619		615,391,000	
(breakdown)							
 Administration Cost 	L.S	1		25,850,173		167,767,000	
VAT	L.S	1		68,971,446		447,624,000	
+ Front-end Fee	L.S	1					
<i>e</i>							
Total Project Cost (I~VI)	[6,716,301	587,474,805	2,752,161,483	7,326,096,000	

Detailed Design Study on the Project for Construction of the New Dirout Group of Regulators

Table 5-2. Construction and project cost estimation (2/2)

Table 5-3 the Ratio for STEP Loan

Item	Grade	Detail	Unit	Quantity	Amount
A-11. Gate manufactures and works					
1. Gate manufacture	gate leaf	6.0×6.55	L.S	2.0	324,769,300
	gate guide		L.S	2.0	272,305,220
	hoisting device	hydraulic	L.S	2.0	846,320,100
	remote operation system		L.S	2.0	228,439,580
1. Installation for manufactures	Japanese mechanical engineer		day	1,050.0	31,403,295
	Japanese electrical engineer for		day	1,050.0	35,009,415
	sub-total				1,738,246,910
A-12. Expense of the machine and facil	ities				
1. Rent fee for heavy equipment	2). Vibration hunmer (1)	Hydraulic, 232KW	day	1,507.0	42,926,895
	sub-total				42,926,895
B-1. Temporary Coffer Dam					
1. Double sheet pile	14). Japanese sheet pile opera		day	2,190.0	79,914,195
	sub-total				79,914,195
B-8. Transportation / Shipment		-			
	B-8-13. packing	951.0 F/T	L.S	1.0	12,754,883
	B-8-14. loading		L.S	1.0	7,095,825
	B-8-15. ocean transpotation		F/T	951.0	26,190,947
	sub-total				46,041,655
	Total				1,907,129,655

Ratio of the goods and services to be procured from Japan

1) Construction Cost

5,365,263 10³ YEN 1,907,130 10³ YEN 35.5% > 30%

2) Cost of the goods and services to be procured from Japan (2)/(1) =

6. Draft Bidding Documents

6-1. Contents of Works for the Preparation of Bidding Documents

6-1-1. Regulation and framework of procurement of public works in the Egyptian government

In Egypt, procurement of public works is made based on the Law No.89 of 1998 and its implementation regulations (Ministerial Decree No. 1367 of 1998), commonly referred to as "Tenders Law". Based on this law, executing agencies of public works prepare bidding documents, and execute pre-qualification, tendering and evaluation, and contract negotiations and signing.

According to the assessment of the procurement process of public works in Egypt, in the "Public Procurement Sector Assessment -Review of Laws and Practice in the SEMED Region," which was published by EBRD in 2013, there is no independent authority to handle claims related to public works, and there is also no single entity to formulate policies and execute government procurement process/procedures, even though transparency and efficiency are somewhat secure.

6-1-2. Differences between the regulations of the Egyptian government and JICA's guidelines for procurement under Japanese ODA Loans

At the early stage of works and discussions for the preparation of draft Bidding Documents for NDGRs project, the differences between laws and regulations related to procurement in Egypt and JICA's Procurement Guideline (*Handbook: Guideline for Procurement under Japanese ODA Loans* April 2012) were discussed (Refer to Table 1-2.1 of main report of "Vol. IV DRAFT BIDDING DOCUMENTS".)

In Article 4.7 of the Minutes of Discussions dated 21 May 2014 on the Loan Agreement for NDGRs, it was agreed that JICA Guidelines shall be applied for the procurements in this project. While JICA Guideline shall prevail, requests from RGBS to follow the Egyptian laws were also reflected in the documents as much as possible.

6-2. Preparation of Draft Bidding Documents

6-2-1. Contents of draft bidding documents

At the early stage of the preparation works on the draft Bidding Documents, RGBS made request to JICA to change the procurement process so as to combine the pre-qualification and bidding process to be made simultaneously, and bidding documents shall be made as "PQ-embedded bidding documents". This request was based on their intention to shorten the procurement process on the civil works contract. The team considered this issue as appropriate request, however the final decision shall be made by the direct discussion between RGBS and JICA. Under such circumstance, two patterns of draft Bidding Documents (PQ-embedded Documents, and separated PQ/Bidding Documents) were prepared, however discussions thereafter were made basically on PQ-embedded Documents.

For this issue, RGBS requested the study team to maintain both patterns for the decision in future. Therefore, PQ embedded Documents are adopted as the final product as part of the Final Report, and separated PQ/Bidding Documents are also submitted but only in electric file. 6-2-2. Contents of discussions and understanding with Egyptian side on draft Bidding Documents (except technical specifications)

The contents of discussions during '8th Assignment' and '9th Assignment' on the draft Bidding Documents, including initial presentation from the team, comments from RGBS, information from JICA Egypt Office, conclusion as of 24 February, comments from JICA thereafter, and conclusion as of 24 April, were summarized in Table 2-2.1 of the main report "Vol. IV DRAFT BIDDING DOCUMENTS".

After the completion of '9th Assignment', final comments were provided by RGBS on 10 May 2017 and by JICA on 19 May 2017. By reflecting these comments, the draft Bidding Documents were finalized as part of the Final Report of the Study. The summary of said comments and reflection on the final draft Bidding Documents are summarized in Table 2-2.2 of the main report "Vol. IV DRAFT BIDDING DOCUMENTS".

6-2-3. Draft bidding documents (technical specifications)

As for the technical specifications, an integral part of draft Bidding Documents, discussions with RGBS were started on '8th Assignment' in February 2017. After the confirmation of structure and contents, actual works on the preparation of technical specifications were started.

The contents of technical specifications are as follows:

1) General Provisions

- 2) General Technical Specifications
 - Civil Works
 - Mechanical and Electrical Works
- 3) Particular Technical Specifications
 - Civil Works
 - Mechanical and Electrical Works

For the preparation of technical specifications, attentions were paid on the consideration of fair risk allocation among contract parties, and also consistency with contents of general conditions of contract.

7. Environmental and Social Consideration

During the F/S of the Project in 2010, the EIA Report was prepared and it was approved by EEAA in the same year. The Report mentions the environmental monitoring in pre-construction stage, however, the monitoring implementation organization is not specified. Therefore, this matter was discussed at the 25th TAC Meeting, and it was concluded that the S/V consultant will be in charge of monitoring in the stage, which means that it is necessary to add the monitoring activities to the current TOR of the S/V consultant. On the other hand, environmental monitoring in construction stage and operation stage are to be done by the contractor and MWRI, respectively.

As a result of review of the EIA Report, some of the monitoring items are to be clarified or modified. According to EEAA, it is not needed to get re-approval of the EIA Report, as far as the project components, scale of the structures, location and so on are not changed, and the EIA Report

of the Project is still effective. In addition, if necessary, it is possible to modify the proposed environmental monitoring items and methods, under the condition that the reason for the modification is described. Still, it is noted that monitoring groundwater level and groundwater quality shall be implemented since the approval letter of the EIA report mentions the necessity of the monitoring of those items.

The Environment WG reviewed and examined the EIA report, focusing on the Environmental Evaluation, Environmental Management Plan and Monitoring Plan. According to realistic probability and necessity, some monitoring items are cancelled or added with those reasons. Moreover, frequency, sampling points, methodologies of monitoring and implementation organization are clarified through the discussion among the WG members.

As a point of concern in terms of environmental and social consideration, mosque transfer is planned for the Project implementation. There are three affected mosques that are requested to be resettled. New locations of the two mosques out of them, which are under control of the Ministry of Awqaf, have been fixed, and they will be relocated prior to the construction works. On the other hand, the last mosque, under the management of MWRI, is planned to be shifted within the area owned by MWRI in the construction stage. It is needed to monitor whether the transfer of those mosques is implemented as planned.

The groundwater monitoring results indicates that groundwater levels are significantly influenced by change of the water levels of Bahr Yusef canal and Ibrahimia canal. It is, therefore, necessary to monitor change of the groundwater level continuously, especially, those of BH-N10, BH-N11, BH-N12 and BH-N13, which correspond to the change of water level of the canals. Furthermore, the total (fecal) coliform was detected in the groundwater, and the cause is probably seepage from the sewage. Therefore, it is needed to improve current sewage treatment system.

Through of the Project implementation, it is proposed to establish the Security Management Committee, which coordinates, assesses various issues to maintain security of the project. It is proposed that the committee consists of RGBS staff of Dirout and Cairo, S/V consultant and the Contractor. Proposed major tasks of the committee are; 1) supervision of monitoring and examination of monitoring result, 2) taking measures if some problems are identified, 3) handling of complaints from the people, 4) Identification and counting of those who catch fish around the Dirout Regulators and their legalities, and taking measures, and 5) reporting, recording and information sharing, especially, any issues identified and measured taken.

8. Mathematical Model Analysis

8-1. Water Surface Profile Analysis

(1) Objectives of Analysis

The objective is to calculate the water surface profile impacted by the construction of NDGRs in order to check the discharge ability of the Ibrahimia canal. The analysis is conducted by

one-dimensional unsteady flow analysis using the Ibrahimia canal cross-section given in measurement results.

(2) Result of Analysis

Given by 0.20m increase of water level at the existing DGRs due to the new operation water level of the NDGRs, the water surface profile is impacted to the D.S. of Ibrahimia intake from the existing DGRs. The difference between water levels, however, is only 0.05 m at the upstream. Therefore, it was found that there is no large impact to the operation of the Ibrahimia intake besides the discharge capacity of the Ibrahimia canal is enough in the new conditions (new water level and new discharge volume) to the NDGRs.

8-2. Mathematical Model Analysis

(1) Objectives of Analysis

Since the NDGRs is required to divert accurately and stably the water to the seven main canals through the five regulators, those regulators should be secured for the necessary hydraulic function and capability. In order to clarify those capabilities, the mathematical model is applied. The sediment and the scouring phenomena around the NDGRs, furthermore, should be analyzed based on the result of the flow conditions analysis taken into consideration the gate operation by overflow and underflow.

In this report, the former analysis is regarded as the "Flow Analysis" and another is regarded as the "Riverbed Variation Analysis". As for the riverbed analysis, the present available data is utilized for the analysis. The followings show the result of analysis.

- (2) Result of Analysis
- Flow Analysis

It was found that the five regulators of the NDGRs have enough capability to divert to the seven canals properly. Under the conditions of existing canal sections, the maximum velocity on the bottom layer around the D.S. of the NDGRs is 0.8~1.0 m/s in the Bahr Yusef canal and 0.8 m/s in the Ibrahimia canal. As for the analysis to the planned canal sections, some uneven tendencies are observed among each vent in the distribution velocity of the new Ibrahimia regulator, but all of those are less than the allowable velocity (Va=2.00 m/sec). Accordingly, there is no hydraulically serious problem to the NDGRs.

Riverbed Variation Analysis

There is the tendency of sedimentation between the existing DGRs and the NGDRs due to the low water velocity. As for new Abo Gabal and Sahelyia regulators which are located on the U.S of existing regulators, the sedimentation around the new intake tend to decrease after NDGRs construction, but still remains the same tendency. Accordingly, the removal works to the sedimentation should be maintained periodically as maintenance works after the construction of NDGRs.

8-3. Integrated Evaluation of Hydraulic Model Test

(1) Objectives of Integrated Evaluation

As for the physical hydraulic model test conducted by HRI according to the contract with MWRI, the test condition should have the consistency with the mathematical analysis conducted by the D/D consultants in the test conditions. In this context, the objective is to organize and adjust the conditions between the physical hydraulic model test and mathematical model analysis by providing the information and advice on the hydraulic model experiments.

The target of the evaluation in this report is the 3D physical hydraulic model test for the flow condition in the vicinity of the NDGRs and the 2D physical hydraulic model test for the river bed protection of NDGRs. The evaluations are targeted for the two tests above.

(2) Result of Integrated Evaluation

As a result of consideration based on the recommendation of the physical hydraulic model test, the following recommendations are applied to the design of the NDGRs.

3D physical hydraulic model test

As a result of the 3D physical hydraulic model test, the embankment bank protection should be done at the D.S. of the left bank of the new Bahr Yusef regulator and the D.S. of the right bank of the new Ibrahimia regulator in order to alleviate the stagnant area (with slow vortex current)

2D physical hydraulic model test

As a result of the 2D physical hydraulic model test, the following design specification are identified and applied to the design of the NDGRs.

- 1) Length of bed protection
 - ✓ Large regulators (Bahr Yusef and Ibrahimia) : 30m
 - ✓ Small regulators (Badraman): 15m
 - ✓ Small regulators (Abo Gabal and Sahelyia) : no need
- 2) Type of bed protection
 - ✓ Ripraps

Table of Contents

Preface Executive Summary Table of Contents Abbreviations Location Map Panoramic Landscape of Dirout Group of Regulators Project Photo

- Volume I Design of Regulators
- Volume I Water Management System
- Volume Construction Planning and Cost Estimation
- VolumeIV Draft Bidding Document
- Volume V Environmental and Social Consideration
- VolumeVI Mathematical Model Analysis
- Volume M Recommendations

Appendix (1/3)

- A. Design of Regulators
- B. Water Management System
- **C.** Quantity Calculation Sheets
- **D.** Construction Planning

Appendix (2/3)

- E. Cost Estimation
- F. Environmental and Social Consideration
- G. Mathematical Model Analysis
- H. Minutes of Discussions

Appendix (3/3)

I. Drawings

Abbreviations

ADCP	: Acoustic Doppler Current Profiler
APN	: Access Point Name
ASTM	: American Society for Testing and Materials
BC	: Boundary Condition
BH	: Borehole
B/D	: Basic Design
CDSSD	: Central Directorate of Studies, Specifications and Designs
CDT	: Central Directorate for Telemetry
CDWD	: Central Directorate of Water Distribution
CRI	: Construction Research Institute
D/D	: Detailed Design
DGRs	: Dirout Group of Regulators
DO	: Dissolved Oxygen
DS	: Downstream
EBRD	: European Bank for Reconstruction and Development
EC	: Electrical Conductivity
ECRI	: Environment and Climate changes Research Institute
EEAA	: Egyptian Environmental Affairs Agency
EGSA	: Egyptian General Survey Authority
EIA	: Environmental Impact Assessment
EL	: Elevation
EMP	: Environmental Management Plan
EMoP	: Environmental Monitoring Plan
ENR	: Egyptian National Railways
FC	: Foreign Currency
FDM	: Finite Difference Method
FHT	: Falling Head Test
F/S	: Feasibility Study
GDIs	: General Directorates of Irrigations
GDWD	: General Directorate for Water Distribution
GPRS	: General Packet Radio Service
GPS	: Global Positioning System
GW	: Groundwater
HAD	: High Aswan Dam
HCWW	: Holding Company for Water & Wastewater
HD	: High Definition
HPPEA	: Hydro Power Plants Executive Authority
H-Q	: Height-Quantity
HRI	: Hydraulic Research Institute
ID	: Irrigation Department
IIS	: Irrigation Improvement Sector
IMF	: International Monetary Fund
IP	: Internet Protocol
KfW	: Kreditanstalt für Wiederaufbau (German government-owned development bank)
KVM	: Keyboard, Video, Mouse
JICA	: Japan International Cooperation Agency

JIS	: Japanese Industrial Standards
L2SW	: Layer 2 Switch
LC	: Local Currency
LCD	: Liquid Crystal Display
LE	: Livre Égyptienne (Egyptian Pound)
LLT	: Lateral Load Test
MCCB	: Molded Case Circuit Breaker
MD	: Minutes of Discussion
MED	: Mechanical and Engineering Department
MEE	: Ministry of Electricity and Energy
MERE	: Ministry of Electricity & Renewable Energy
MMA	: Mathematical Model Analysis
MOT	: Ministry of Transport
MWRI	: Ministry of Water Resources and Irrigation
Ν	: Number of Blows (value for SPT)
NDGRs	: New Dirout Group of Regulators
NTP	: Network Time Protocol
NWRC	: National Water Research Center
ODA	: Official Development Assistance
O&M or O/M	: Operation and Maintenance
PDCA	: Plan-Do-Check-Act cycle
pН	: Potential Hydrogen
PHMT	: Physical Hydraulic Model Test
PIU	: Project Implementation Unit
PQ	: Prequalification
Q3D	: Quasi-3 Dimensional
RC	: Reinforced Concrete
RD	: Record of Discussion
RGBS	: Reservoirs and Grand Barrages Sector
RTA	: River Transport Authority
RTU	: Remote Terminal Unit
SCADA	: Supervisory Control and Data Acquisition
SEMED	: Southern and Eastern Mediterranean
SMC	: Security Management Committee
SPT	: Standard Penetration Test
STEP	: Special Terms for Economic Partnership
TAC	: Technical Advisory Committee
TBM	: Temporary Benchmark
TCP	: Transmission Control Protocol
TDS	: Total Dissolved Solids
TSS	: Total Soluble Salts
UNESCO	: United Nations Educational, Scientific and Cultural Organization
US	: Upstream
VAT	: Value Added TAX
VGA	: Video Graphics Array
WG	: Working Group
WL	: Water Level

<u>Unit</u>

BCM	: billion cubic meter	l	: liter
cm	: centimeter	lb	: pound
fed	: feddan (1fed \doteq 0.42ha)	MPa	: mega pascal
ft	: feet	m	: meter
g	: gram	MCM	: million cubic meter
ha	: hectare	min	: minute
hr	: hour	mm	: millimeter
kg	: kilogram	Ν	: newton
km	: kilometer	%	: percentile
kN	: kilo newton	S	: second
kV	: kilo volt	t	: ton
kVA	: kilo volt ampere		

Currency

Exchange Rate (average from Feb. 2017 to Apr. 2017)

Egyptian Pound	(EGP or LE)	: 6.49 JPY/LE
Japanese Yen	(JPY)	
US Dollar	(USD)	: 113.34 JPY/USD
Euro	(EUR)	: 121.26 JPY/EUR

- PROJECT LOCATION MAP - PROJECT FOR CONSTRUCTION OF DIROUT GROUP OF REGULATORS -









Project Photo





Volume I DESIGN OF REGULATORS

		Page
1.Outli	ne of Design	I - 1
1-1	Design conditions	I - 1
1-2	Reference code	I - 4
1-3	Outline of facilities	I - 6
2.Topo	graphic and Geological Outline	I - 8
2-1	Topographic feature	I - 8
2-2	Geological feature	I - 9
2-3	Borehole logs	I - 9
3.Hydr	aulic Dimensions and Calculation	I -29
3-1	Purpose	I -29
3-2	Hydraulic calculation (Non-uniform flow analysis)	I -29
4. Dete	rmining the Regulator Axis	I -31
4-1	Background related to determining the regulator axis	I -31
4-2	Location of regulators axis	I -33
5. Weir	Туре	I -37
5-1	Determining weir type	I -37
5-2	Study of gate and hoist type	I -37
6.Widtl	h and Number of Vents	I -44
6-1	Two large scale regulators	I -44
6-2	Three small scale regulators	I -48
7.Eleva	ations of Main Structures	I -54
7-1	Sill elevation of apron	I -54
7-2	Gate top elevation and height	I -55
7-3	Bottom elevation of gate when fully opened	I -56
7-4	Elevation of downstream at the end of apron	I -56
8.Desig	gn of Weir Body·····	I -57
8-1	Design of weir body	I -57
8-2	Design of downstream apron	I -63
9.Desig	gn of Canal Bed Protection	I -67
9-1	Basic design concept	I -67
9-2	Length of canal bed protection	I -67
9-3	Stone size for the canal bed protection	I -70
10.Des	ign of Pier	I -75
10-1	Height and thickness of pier	I -75
10-2	Design of superstructure of pier	I -77
11.Stab	vility and Structural Calculation	I -78
11-1	Examination of stability for the large scale regulators	I -78
11-2	Examination of stability for the small scale regulators	I -88
11-3	Examination of regulators' structure	I -93
12.Fou	ndation Works for Regulator	I -129
12-1	Determining the foundation type	I -129
12-2	Specifications of piles	I -151
12-3	Results of pile foundation design	I -154

13.Desig	gn of Bank Protection Works	I -159
13-1	Selection of construction method	I -159
13-2	Design of steel sheet pile work	I -159
13-3	Design of bank slope protection work	I -168
14.Desig	gn of Ancillary Road and Bridge	I -172
14-1	Design conditions	I -172
14-2	Structural design for the ancillary bridge	I -174
15.Desig	gn of Gate Facilities	I -176
15-1	Design of gate leaf	I -176
15-2	Design of hoisting equipment	I -181
15-3	Design of control equipment	I -184
15-4	Design of electric facilities	I -190
15-5	Design of stoplogs	I -201
16.Arch	itectural Design	I -206
16-1	Design of control house	I -206
16-2	Design of local control house	I -211
16-3	Design of stoplogs storage house	I -213
17. Desi	gn of Auxiliary Facilities	I -216
17-1	Instrumentation equipment	I -216
17-2	Road crossings	I -217
18.Oper	ation and Maintenance of Regulators	I -220
18-1	Water utilization management	I -220
18-2	Design of local control house	I -221
18-3	Maintenance of equipment	I -221
18-4	Record of maintenance	I -223
18-5	Management of target canal bed elevation	I -224
19.Exan	nination of the Preservation Measures for Existing DGRs	I -226
19-1	Prerequisites for examination of preservation measures	I -226
19-2	Survey results	I -226
19-3	Recommendations for preservation measures	I -233
20.Grou	ndwater Simulation Analysis	I -238
20-1	Purpose of analysis and modeling approach	I -238
20-2	Preparation of regional model	I -240
20-3	Preparation of detail model	I -242
20-4	Simulation study (Case 11, 12 and 13)	I -254
20-5	Evaluation of seepage control works	I -259

List of Figures

Figure 1-3.1	General layout of NDGRs ······ I - 6
Figure 2-1.1	Satellite picture (Dirout to Malawi) ······ I - 8
Figure 2-1.2	Antique map (1826, Dirout to Malawi) ······ I - 8
Figure 2-2.1	Geological profile of the Nile (Aswan ~ Mediterranean sea) $\cdots I$ - 9
Figure 2-3.1	Location map of boreholes on NDGRs I -10
Figure 2-3.2	Geological cross sectional map (New Bahr Yusef regulator) ······ I -11
Figure 2-3.3	Geological cross sectional map (New Badraman to Diroutiah regulators) ······ I -12
Figure 2-3.4	Geological cross sectional map (New Ibrahimia regulator) I -13
Figure 2-3.5	Borehole log (BH-N1)····· I -14
Figure 2-3.6	Borehole log (BH-N2)····· I -15
Figure 2-3.7	Borehole log (BH-N2')····· I -16
Figure 2-3.8	Borehole log (BH-N2A) ····· I -17
Figure 2-3.9	Borehole log (BH-N2B)······ I -18
Figure 2-3.10	Borehole log (BH-N2C) ······ I -19
Figure 2-3.11	Borehole log (BH-N2D) ······ I -20
Figure 2-3.12	Borehole log (BH-N3) ····· I -21
Figure 2-3.13	Borehole log (BH-N3') ······ I -22
Figure 2-3.14	Borehole log (BH-N4) ····· I -23
Figure 2-3.15	Borehole log (BH-N4*)····· I -24
Figure 2-3.16	Borehole log (BH-N5) I -25
Figure 2-3.17	Borehole log (BH-N6) ······ I -26
Figure 2-3.18	Borehole log (BH-A1A) ······ I -27
Figure 2-3.19	Borehole log (BH-A1B) ······ I -28
Figure 3-2.1	Explanatory drawing for non-uniform flow calculation I -29
Figure 4-1.1	Preliminary layout of NDGRs' axis I -31
Figure 4-1.2	Layout of NDGRs' axis in the detailed examination stage I -31
Figure 4-2.1	Schematic sketch for calculation I -33
Figure 5-2.1	Example of gate facilities in Egypt I -38
Figure 7-1.1	Schematic drawing for the elevation of apron around gate sill I -54
Figure 7-2.1	Schematic drawing for top elevation of the gate and its height $\cdots $ I -55
Figure 8-1.1	Result of the hydraulic design for the length of apron and the thickness of the regulator body (Bahr Yusef regulator) I -59
Figure 8-1.2	Result of the hydraulic design for the length of apron and the thickness of the regulator body (Ibrahimia regulator) I -60
Figure 8-1.3	Result of the hydraulic design for the length of apron and the thickness of the regulator body (Diroutiah regulator) I -61
Figure 8-1.4	Result of the hydraulic design for the length of apron and the thickness of the regulator body (Badraman regulator) I -62
Figure 9-2.1	Relation between gate opening and discharge I -67
Figure 9-2.2	Type of hydraulic jump I -68
Figure 9-2.3	Relation between sequent depth (v2) and tailwater depth (v2')
0	at each discharge ······ I -68
Figure 9-2.4	Design concept of bed protection in Japan I -69
Figure 9-3.1	Typical section of bed protection I -72
Figure 9-3.2	Standard gravel size distribution of riprap stone I -73

Figure 10-1.1	Schematic drawing of the elevation of the bottom of the fully opened gate (EL 4) and pier top (EL 5)
Figure 10-1 2	Schematic drawing for pier width I -76
Figure 10-2 1	Schematic drawing of the top of pier (operation space)
Figure 11-1 1	Load condition for regulator (case 1 2)
Figure 11-1 2	Load condition for regulator (case 3, 4) I -82
Figure 11-1 3	Load condition for regulator (case 5, 6) I -83
Figure 11-1 4	Load condition for regulator (case 7, 8) I -84
Figure 11-1 5	Load condition for regulator (case 9, 10)
Figure 11-1 6	Load condition for regulator (case 11 12)
Figure 11-1.7	Load condition for regulator (case 13) I -87
Figure 11-3.1	Load condition for Bahr Yusef and Ibrahimia regulators
118010 11 5.1	(case 1, 2) I -95
Figure 11-3.2	Load condition for Bahr Yusef and Ibrahimia regulators
F ' 11.2.2	$(case 3, 4) \cdots 1 - 96$
Figure 11-3.3	Load condition for Bahr Yusef and Ibrahimia regulators
Figure $11-34$	Load condition for Bahr Yusef and Ibrahimia regulators
1 iguie 11-5.4	(case 7, 8)······ I -98
Figure 11-3.5	Load condition for Bahr Yusef and Ibrahimia regulators
C	(case 9, 10) ····· I -99
Figure 11-3.6	Load condition for Bahr Yusef and Ibrahimia regulators
Eigung 11 2 7	(case 11, 12)
Figure 11-5.7	(case 13) I -101
Figure 11-38	Load condition for Badraman regulator (case 1 2) I -102
Figure 11-3.9	Load condition for Badraman regulator (case 3, 4) I -103
Figure 11-3.10	Load condition for Badraman regulator (case 5, 6) I -104
Figure 11-3.11	Load condition for Badraman regulator (case 7, 8) I -105
Figure 11-3.12	Load condition for Badraman regulator (case 9, 10) I -106
Figure 11-3.13	Load condition for Badraman regulator (case 11, 12) I -107
Figure 11-3.14	Load condition for Badraman regulator (case 13) I -108
Figure 11-3.15	Load condition for Abo Gabal regulator (case 1, 2) I -109
Figure 11-3.16	Load condition for Abo Gabal regulator (case 3, 4) I -110
Figure 11-3.17	Load condition for Abo Gabal regulator (case 5, 6) I -111
Figure 11-3.18	Load condition for Abo Gabal regulator (case 7, 8) I -112
Figure 11-3.19	Load condition for Abo Gabal regulator (case 9, 10) I -113
Figure 11-3.20	Load condition for Abo Gabal regulator (case 11, 12) I -114
Figure 11-3.21	Load condition for Abo Gabal regulator (case 13) I -115
Figure 11-3.22	Load condition for Sahelyia regulator (case 1, 2) I -116
Figure 11-3.23	Load condition for Sahelyia regulator (case 3, 4) I -117
Figure 11-3.24	Load condition for Sahelyia regulator (case 5, 6) I -118
Figure 11-3.25	Load condition for Sahelyia regulator (case 7, 8) I -119
Figure 11-3.26	Load condition for Sahelyia regulator (case 9, 10)····· I -120
Figure 11-3.27	Load condition for Sahelyia regulator (case 11, 12) I -121
Figure 11-3.28	Load condition for Sahelyia regulator (case 13) I -122
Figure 11-3.29	Structural model of regulators I -123

Figure 12-1.1	Classification of foundation works	I -129
Figure 12-1.2	Flowchart of foundation works	I -129
Figure 12-1.3	Location of borehole for design	I -130
Figure 12-1.4	Concept of settlement by Egyptian code (1/2)	I -132
Figure 12-1.5	Concept of settlement by Egyptian code (2/2) ······	I -133
Figure 12-1.6	Relation between double sheet pile and structure	I -134
Figure 12-1.7	Br No. BH-2D Bahr Yusef regulator	I -137
Figure 12-1.8	Br No. BH-N2C Bahr Yusef regulator (L type wall)	I -138
Figure 12-1.9	Br No. BH-N3' Ibrahimia regulator	I -139
Figure 12-1.10	Br No. BH-N3 Ibrahimia regulator (L type wall)	I -140
Figure 12-1.11	Br No. BH-A1B Badraman regulator (Badraman canal)	I -141
Figure 12-1.12	Br No. BH-A1A Badraman regulator (Diroutiah canal)	I -142
Figure 12-1.13	Br No. BH-N5 Abo Gabal regulator	I -143
Figure 12-1.14	Br No. BH-N6 Sahelyia regulator	I -144
Figure 12-1.15	Structural concept of deep mixing treatment method	I -147
Figure 12-2.1	Model of displacement method	I -153
Figure 12-3.1	Pile layout and design of Bahr Yusef regulator and L-type wall	I -157
Figure 12-3.2	Pile layout and design of Ibrahimia regulator and L-type wall	I -158
Figure 13-2.1	Location map for each type of sheet pile	I -159
Figure 13-2.2	Construction procedure of tie-rod type steel sheet pile work	I -161
Figure 13-2.3	Cross-sectional map of the sheet pile method for each case (case $A - C$) (1/3	I -165
Figure 13-2.4	Cross sectional map of the sheet pile method for each case	
e	(case D - G) (2/3)	I -166
Figure 13-2.5	Cross sectional map of the sheet pile method for each case (case H - M) (3/3)	I -167
Figure 13-3.1	Standard cross-sectional map of wet stone pitching works	I -168
Figure 13-3.2	Standard cross-sectional map of gabion construction method	I -169
Figure 13-3.3	Diagram of stability calculation results of	T 1 60
	gabion construction method ······	I -169
Figure 14-1.1	Layout of ancillary road ·····	1-172
Figure 14-1.2	Layout of bridge	1-172
Figure 14-1.3	Sketch of acting point of the design load	1-173
Figure 14-1.4	Drawing of the design road alignment	1 -174
Figure 14-2.1	Schematic diagrams of ancillary bridges	1-175
Figure 15-1.1	Structure of gate leaf	1 -178
Figure 15-1.2	Height of double leaf gate	I -178
Figure 15-2.1	Rack gear type hoist	1 -181
Figure 15-2.2	Layout of hydraulic unit	1 -182
Figure 15-3.1	Conceptual diagram of control and operation	1 -184
Figure 15-3.2	Monitoring control system configuration diagram	1 -185
Figure 15-3.3	Minimum layout plan of regulator control room	1 -188
Figure 15-4.1	Outline drawing of an emergency generator	1 -194
Figure 15-5.1	Stoplog installation method for small regulators	I -201
Figure 15-5.2	Stoplog installation method for large regulators (upstream side)	I -201
Figure 15-5.3	Stoplog installation method for large regulators	I 201
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Figure 15 5 4	Lifting heam	I -201
Figure 15-5.4	Maximum baight of part of a stoplag for large regulators	I -201
Figure 15-5.5	Present situation of the construction site	I -202
Figure 16-1.1	Levent of control house	I -200
Figure 16-1.2	Elevation view of control house	1 -200
Figure 16-1.3	Elevation view of control house	I -200
Figure 16 2 1	Floor plan of control house	I -209
Figure 16-2.1	Layout of focal control house	I -211 I 212
Figure 16-2.2	Travelling loops of truck	I -212
Figure 16-2.5	L avout plan for Ibrahimia side	I -212
Figure 16-2.4	Study of company in and out mathed for stanlage	I -212
Figure 16-5.1	I event alon incide the steplace house	I -214
Figure 10-3.2	Layout plan inside the stoplogs house	I -215
Figure 17-1.1	Concernent for the second seco	I -210
Figure 17-2.1	Cross section of culvert	I -218
Figure 17-2.2	Hydraulic piping inside the culvert	I -218
Figure 17-2.3	Span arrangement in longitudinal direction	I -218
Figure 17-2.4	Combined load to the culvert	1 -219
Figure 18-3.1	Hanging method of gate (Small regulators)	I -223
Figure 18-3.2	Structure of gate guide of small scale regulators	I -223
Figure 18-5.1	Explanatory drawings for EL.(A) to EL.(D) ······	I -225
Figure 18-5.2	Canal bed elevation around the regulators	1 -225
Figure 19-3.1	Flow of examination of appropriate measure works	1 -233
Figure 20-1.1	Approach for groundwater simulation analysis	I -239
Figure 20-2.1	Model grid (regional model)	1 -240
Figure 20-2.2	Ground elevation of model area	1 -240
Figure 20-2.3	Boundary condition (MODFLOW PACKAGE)	1 -242
Figure 20-2.4	Land cover classification	1 -242
Figure 20-2.5	Distribution of observed permeability	1 -244
Figure 20-2.6	Permeability of each layer	I -244
Figure 20-2.7	Calibration point (monitoring well)	1 -246
Figure 20-2.8	Change in groundwater head and canal water level	1 -24/
Figure 20-2.9	Comparison between observation and calculation values	1 -250
Figure 20-2.10	(Case 10, current model on 27 July 2016)	I -251
Figure 20-3.1	Detailed model grid ·····	I -252
Figure 20-3.2	Groundwater head and flow vector (case 10)	I -253
Figure 20-4.1	Groundwater head and flow vector (case 11)	I -256
Figure 20-4.2	Groundwater head and flow vector (case 12)	I -257
Figure 20-4.3	Groundwater head and flow vector (case 13)	I -258
Figure 20-5.1	Groundwater rise (Case 11, Nm layer)	I -259
Figure 20-5.2	Groundwater rise (Case 12, Nm layer)	I -260
Figure 20-5.3	Groundwater rise (Case 13, Nm layer)	I -261
Figure 20-5.4	Area of shallow groundwater head (less than 3m from GL)	I -263

List of Tables

Table 1-1.1	Design discharge ······	I - 1
Table 1-1.2	Design water levels	· I - 2
Table 1-2.1	Contents of Egyptian code	· I - 4
Table 1-3.1	Outline of NDGRs	· I - 7
Table 2-2.1	Description of flood sediments	I - 9
Table 3-2.1	Result of calculation by non-uniform analysis	I -30
Table 4-2.1	Comparison of NDGRs' axis between 140m and 150m downstream of DGRs	I -34
Table 5-2.1	Size of gates for the two large scale regulators	I -37
Table 5-2.2	Size of gates for the three small scale regulators	I -37
Table 5-2.3	Comparison of discharge control between single and double leaf gate (1/2)	I -39
Table 5-2.4	Comparison of discharge control between single and double leaf gate (2/2)	I -40
Table 5-2.5	Comparison of hoist types for the large scale regulators	I -41
Table 5-2.6	Comparison of gate type for the small regulators	I -42
Table 5-2.7	Selection of hoist type ······	I -43
Table 6-1.1	Condition of hydraulic calculation	I -44
Table 6-1.2	Design of vents on the large scale regulators	I -45
Table 6-1.3	Number and width of vent for the large scale regulators (initial result) \cdot	I -46
Table 6-1.4	Number and width of vent for the large scale regulators (final result) \cdots	I -47
Table 6-2.1	Hydraulic conditions of downstream canals for the small scale regulators	I -48
Table 6-2.2	Comparison of width & number of vents for the small scale regulators (1/2)	I -50
Table 6-2.3	Comparison of width & number of vents for the small scale regulators (2/2)	I -51
Table 6-2.4	Vent width and numbers of the two small scale regulators	I -52
Table 6-2.5	Additional consideration on the two small scale regulators	I -53
Table 7-1.1	Elevation of apron around gate sill	I -54
Table 7-2.1	Gate height for each regulator	I -55
Table 8-1.1	Constant values for each method	I -57
Table 8-2.1	Comparison table of wall types at downstream apron (1/3)	I -64
Table 8-2.2	Comparison table of wall types at downstream apron (2/3)	I -65
Table 8-2.3	Comparison table of wall types at downstream apron (3/3)	I -66
Table 9-2.1	Length of downstream bed protection (new Bahr Yusef and Ibrahimia regulators)	I -69
Table 9-2.2	Length of downstream bed protection (new Badraman regulator)	I -69
Table 9-3.1	Flow velocity to determine the suitable riprap weight and scale	I -71
Table 9-3.2	Calculation result by Isbash method (Isbash 1936)	I -71
Table 9-3.3	Calculation result by US Geological Survey method (Blodgett 1981) \cdots	I -72
Table 9-3.4	Calculation result by USBR 1936	I -72
Table 9-3.5	Calculation result by Osama 1995	I -72
Table 9-3.6	Compositions of bed materials and purposes of installation	I -73
Table 9-3.7	Grain size distribution for bed protection materials	I -74
Table 10-1.1	Height of pier for each regulator	I -75

14010 11-1.1	Conditions of stability analysis for the large scale regulators	• I -78
Table 11-1-2	Inspection items for stability analysis	• I -79
Table 11-1.3	Bulk density	• I -79
Table 11-1.4	Coefficient of earth pressure	• I -79
Table 11-1.5	Gate weight	• I -79
Table 11-1.6	Bridge weight	• I -79
Table 11-1.7	Summary of the stability analysis	
	(Bahr Yusef and Ibrahimia regulators)	• I -88
Table 11-2.1	Conditions of stability analysis for the small scale regulators	• I -89
Table 11-2.2	Inspection items for stability analysis	• I -89
Table 11-2.3	Gate weight	• I -90
Table 11-2.4	Bridge weight	• I -90
Table 11-2.5	Summary of the stability analysis at the Badraman regulator (Badraman and Diroutiah canals)	• I -91
Table 11-2.6	Summary of the stability analysis (Abo Gabal regulator)	• I -92
Table 11-2.7	Summary of the stability analysis (Sahelyia regulator)	• I -92
Table 11-3.1	Allowable concrete stress (Egyptian code)	• I -93
Table 11-3-2	Shearing stress of concrete (Egyptian code)	• I -93
Table 11-3.3	Application to section of cast-in-place concrete	• I -93
Table 11-3.4	Allowable stress of sheet pile	• I -94
Table 11-3.5	Allowable stress intensity for reinforcing bar	• I -94
Table 11-3.6	Result of structural analysis of Bahr Yusef regulator	I -124
Table 11-3.7	Result of structural analysis of Ibrahimia regulator	I -125
Table 11-3.8	Result of structural analysis of Badraman regulator	I -126
Table 11-3.9	Result of structural analysis of Abo Gabal regulator	I -127
Table 11-3.10	Result of structural analysis of Sahelyia regulator	I -128
Table 12-1.1	Safety ratio for bearing capacity (Egyptian code)	I -130
Table 12-1.2	Shape factor of the foundation (Egyptian code)	I -131
Table 12-1.3	Summary of bearing capacity	I -134
Table 12-1.4	Results of the examination of bearing capacity	I -136
Table 12-1.5	Site conditions related to foundation treatment works	I -145
Table 12-1.6	Available soil improvement method and its evaluation	I -146
Table 12-1.7	Site conditions related to pile foundation works	I -146
Table 12-1.8	Available pile foundation method and its evaluation	I -147
Table 12-1.9	Comparison table of pile foundation	I -149
Table 12-2.1	Loading condition for pile design sourced by stability analysis	I -151
Table 12-2.2	Safety ratio for vertical bearing capacity and pull-out strength	I -151
Table 12-2.3	Ultimate bearing capacity per unit area of pile tip	I -152
Table 12-2.4	Surface friction per unit area	I -152
Table 12-2.5	Allowable stress of pile (Egyptian code)	I -154
Table 12-2.6	Necessary distance between piles	I -154
Table 12-3.1	Specifications of pile design at Bahr Yusef and Ibrahimia regulators	I -154
Table 12-3.2	Comparison table of economic pile specifications at Bahr Yusef and Ibrahimia regulators	I -155
Table 12-3.3	Pile bearing capacity according to Egyptian code	I -156

Table 12-3.4	Comparison between bearing capacity in Egyptian code and Japanese code	I -156
Table 12-3.5	Bearing capacity for target settlement	I -156
Table 13-2.1	Sectional performance of steel sheet piles	I -160
Table 13-2.2	Specifications of steel materials	I -160
Table 13-2.3	Result of the consideration for bank protection works (1/3)	I -162
Table 13-2.4	Result of the consideration for bank protection works (2/3)	I -163
Table 13-2.5	Result of the consideration for bank protection works (3/3)	I -164
Table 13-3.1	Comparative analyses of downstream revetment works $(1/2)$	I -170
Table 13-3.2	Comparative analyses of downstream revetment works $(2/2)$	I -171
Table 14-1.1	Design load for the ancillary road and bridge	I -173
Table 15-1.1	Design condition of gate facilities	I -177
Table 15-1.2	Allowable stress of structural steel ······	I -180
Table 15-1.3	Allowable stress of cast steel and carbon steel	I -181
Table 15-1.4	Allowable stress of joint steel	I -181
Table 15-2.1	Comparison between hydraulic hoisting systems	I -183
Table 15-3.1	Major status indication items	I -186
Table 15-3.2	Major fault indication items	I -186
Table 15-3.3	Components of remote control equipment	I -187
Table 15-3.4	List of information processing function	I -189
Table 15-4.1	Calculation of load capacity	I -190
Table 15-4.2	Components of power receiving equipment	I -190
Table 15-4.3	Objective load output for emergency generator	I -193
Table 15-4.4	Calculation of the capacity of emergency generator	I -193
Table 15-4.5	Necessary fuel tank capacity	I -194
Table 15-5.1	Design conditions of stoplogs	I -203
Table 15-5.2	Comparison of the small scale stoplogs	I -204
Table 15-5.3	Comparison of the large scale stoplogs	I -205
Table 16-1.1	Approximate area of rooms	I -208
Table 16-3.1	Size and quantity of stoplogs	I -213
Table 16-3.2	Comparison of carrying in/out method	I -213
Table 17-1.1	Types and specifications of water gauges	I -217
Table 17-2.1	Result of the structural calculation of box culvert	I -219
Table 18-1.1	Operational condition of gates	I -220
Table 18-1.2	Trial calculation result of gate openings	
	at each downstream water level ······	I -220
Table 18-3.1	Inspection classes and cycle	I -222
Table 18-3.2	Contents and cycle of maintenance	I -222
Table 18-4.1	Recommended storage period of maintenance record	I -224
Table 18-5.1	Design bed elevation of cofferdam works	I -224
Table 18-5.2	Management of canal bed elevation after the construction of NDGRs	I -225
Table 19-1.1	History of rehabilitation and partial renewal of DGRs	I -226
Table 19-2.1	Results of past surveys (1/3)	I -227
Table 19-2.2	Results of surveys in past years (2/3)	I -228
Table 19-2.3	Results of surveys in past years (3/3)	I -229

Table 19-2.4	Field survey results in Delta Barrage	I -230
Table 19-2.5	Photos of conservation measure cases (1/2)	I -231
Table 19-2.6	Photos of conservation measure cases (2/2)	I -232
Table 19-3.1	Recommendations for preservation measures for DGRs	I -234
Table 19-3.2	Recommendable survey	I -236
Table 20-2.1	Boundary conditions (BCs) of groundwater model	I -241
Table 20-2.2	Average permeability by depth	I -245
Table 20-2.3	Boundary condition and MODFLOW package	I -246
Table 20-2.4	Maximum/Minimum groundwater head and depth (Sep 2015 to Feb 2017)	I -247
Table 20-2.5	Calibration data (record of 13 monitoring wells on 27 July 2016)	I -248
Table 20-2.6	Calibration summary for aquifer coefficients	I -248
Table 20-2.7	Comparison between observation records and calculation values \cdots	I -249
Table 20-3.1	Summary of mass water balance in the model area	
	(case 10, current condition)	I -253
Table 20-4.1	Condition of simulation cases	I -254
Table 20-5.1	Comparison of the seepage control works	I -261

Volume I – DESIGN OF REGULATORS

1. Outline of Design

1-1 Design conditions

(1) Design discharge for each regulator

Maximum design discharge for NDGRs was decided at the 6th TAC meeting. Maximum design discharge at this stage should take into account not only previous discharge which was applied in the F/S stage, but also the future demand on irrigation water. Discharge of Ibrahimia regulator in NDGRs, is accordingly upgraded to 186m³/s from 161.6m³/s. All design discharges are shown on Table 1-1.1. Design discharges of diversion works provided by the Egyptian side were applied to the diversion works in the construction stage.

NDGR	Canal	Design Max. Discharge Qmax (m ³ /s)	Design Min. Discharge Qmin (m ³ /s)	Design Discharge for temporary works Qtem (m ³ /s)	Note
Ibrahimia Reg.	Ibrahimia	186	23.6	162	
Bahr Yusef Reg.	Bahr Yusef	227	33.1	185	
	Badraman	9	1.2	6	
Badraman Reg.	Diroutiah	12	1.7	10	
	Abo Gabal	7	0.9	2	
Abo Gabal Reg.	Irad Delgaw	9	1.3	6	
Sahelyia Reg.	Sahelyia	5	0.6	3.5	

|--|

(2) Design water level

"Unusual" and "normal" water levels should be taken into account in the design water level on the NDGRs as stipulated at the 6th TAC meeting as follows.

According to the 1962 drawings of the existing rehabilitation plan, a high water level (H.W.L) of 47.00m was shown at the upstream. As this water level was designed before the construction of the Aswan High Dam, Nile and canal waters were not controlled by the dam. Today, water levels are controlled and floods do not occur under normal conditions. However, the inoperative Ibrahimia intake at the upstream which causes over-inflow to the NDGRs, requires the evaluation of the design water level in emergency situations. Accordingly, WL 47.00mas design at High High Water Level (H.H.W.L) should be applied for the emergency case, and in addition, WL 46.30m as design at HWL should be applied.

CDWD of MWRI provided the conditions of the downstream water level, and design should comply with these water levels. In addition, since each cross section of the existing canals does not have the necessary flow capacity, the upgrading works should be conducted as a different project to achieve the provided water levels. Reference 1-1.1 shows the H-Q curve at an existing cross

Regulator name	Canal name	US.HHWL (m)	US.HWL (m)	US.LWL (m)	US.LLWL (m)	DS.HWL (m)
Ibrahimia Reg.	Ibrahimia	47.00	46.30	45.90	_	45.13
Bahr Yusef Reg.	Bahr Yusef	47.00	46.30	45.90	—	45.82
Badraman Reg.	Badraman	47.00	46.30	45.90	—	45.90
	Diroutiah	47.00	46.30	45.90	_	45.90
	Abo Gabal	47.00	46.30	45.90	44.30	45.90
Abo Gabal Reg.	Irad Delgaw	47.00	46.30	45.90	44.30	45.90
Sahelyia Reg.	Sahelyia	47.00	46.30	45.90	44.30	45.90

section of Bahr Yusef and Ibrahimia canals. Table 1-1.2 shows the full design water level of each canal.

Table 1-1.2 Design water levels

Note 1: Upstream water level shows at upstream of the existing DGRs

Note 2: US. LLWL is taken from the actual records for the past five years as the available water level at Abo Gabal and Sahelyia regulators after the winter closure. Refer to reference Figure 1-1.2.

*Reference 1-1.1 : H-Q curve at Bahr Yusef and Ibrahimia canal





※Reference 1-1.2 : Consideration of unusual upstream water level (US.LLWL)

The lowest upstream water level (US.LLWL) should be chosen from the five years record of just after the preparation period from 2011 to 2015 (see the graph below). As the result of the evaluation, US.LLWL should be determined as follows:



US.LLWL=44.30m (22th Jan 2015)

(3) Design of related facilities

Although no decision regarding the navigation lock and mini hydro power facilities was made at the F/S stage, after discussions between related Ministries, the Egyptian side decided that these facilities were unnecessary for the project.

a) Navigation lock

Neither navigation lock has been operated in the existing Bahr Yusef and Ibrahimia regulators in DGRs so far. Discussions at F/S stage deemed a navigation lock for the new Bahr Yusef regulator to be unnecessary, but encouraged the planning of the new Ibrahimia regulator.

At the 7th TAC meeting, discussions between MWRI and RTA concluded that no navigation locks need to be planned for the new Ibrahimia and the new Bahr Yusef regulators.

b) Mini hydro power generation

Mini hydro power generation was unable to generate the necessary electric power, due to the negative water level difference in F/S stage, and as such, the Egyptian side decided that that mini hydro power generation was unnecessary for the project. In this study, that conclusion was reviewed and agreed in the 6th TAC meeting. MWRI submitted an official letter stating that mini hydro power generators are infeasible and would not be constructed in NDGRs to MERE, the

authority in charge of hydro power generation in Egypt.

1-2 Reference code

In the Arab Republic of Egypt (hereinafter referred to as Egypt), all irrigation facilities constructed based on the project plan and detailed design under MWRI management are required to follow the Egyptian code.

The Egyptian code is the design criteria for water resources development and irrigation works, and is accountable to NWRC. The contents of the parts of the Egyptian code relevant to the project are shown below.

Egyptian Code	Chapter
Operation of the Irrigation and	1. Irrigation of the Agricultural Land
Drainage Network part 1	2. Drainage of the Agricultural Land
	3. Horizontal expansion
Operation of the Irrigation and	4. Water Resources Development
Drainage	5. Maintenance Work
Network part 2	6. Hydrology Torrents Management
	7. Survey Works
	1. Irrigation Networks Lining
	2. Water Installations Intersecting
	3. Outfalls
Civilian Facilities on Irrigation and	4. Weirs
Drainage part 1	5. Regulators (Barrage) and Gates
	6. Dams
	7. Sluice gates Navigation
	8. Hydroelectric Power Plants
	9. Pump Stations
Civilian Facilities on Irrigation and	10. Wells
Drainage part 2	11. Bridges
	12. Tunnels
	1. Pumps
	2. Internal Combustion Engines
	3. Transmission and Power rate
Irrigation and Drainage Mechanical	4. Valves and Gates
works	5. Mechanical, Chemical and Cathodic Protections
works	6. Selection and Testing of Materials
	7. Mechanical Equipment for Maintenance of Water Ways
	8. Advance for Irrigation Equipment
	9. Monitoring Water Quality in Streams Equipment
	1. Electric Stations
Irrigation and Drainage Electrical	2. Electric Transformers and Accessories
works	3. Keys, Electrical Connection and Electrical Fittings
	4. Circles and Control Devices in Electric Motors
Irrigation and Drainage Electrical	5. Terms Implementation of Electric Works
works	6. Power Supply Emergency Systems

Table 1-2.1 Contents of Egyptian code

Egyptian Code	Chapter
	7. Grounding
	8. Irrigation Equipment Powered by Electricity
	1. Natural Factor Affecting the Costal and Beach Areas
	2. Research Studies, Field work, Hydraulic Models and
Shore Protection Techniques	3. Facilities, Shore Protection Plan and its Impact on the
	4. Designer Protection
	5. Shore Protection and Maintenance Facilities

Adherence to the Egyptian code was given first priority in the design criteria applied at the basic design and the detailed design stages for NDGRs construction project. In the absence of a policy in the Egyptian code regarding an issue, Japanese design criteria in the field of the regulators and *Design Criteria for Irrigation and Drainage, Headworks* will be referred to.

The design criteria adopted for the study, is defined in chapter five "*Regulators (Barrage) and Gates in the Civilian Facilities on Irrigation and Drainage*." Part one of the chapter consists of following items:

5-1	Definition
5-2	Gate Types
5-3	Mutual affect between the Hydraulic Structure and Water Channel
5-4	Regulator Design
5-5	Gates
5-6	References

In the Japanese Criteria, the methodology for the design of the headworks is defined with great attention to theory and method. In the Egyptian code, the maximum velocity allowed at the vents is defined as follows with limited expansion and details.

Small scale regulators	1 - 1.5 m/sec
Large scale regulators (barrage)	1.5 - 2 m/sec
Barrage on Rivers	2.5 - 3.5 m/sec

To fill the gaps in the details left by the Egyptian code, the RGBS recommended the textbook *Part No. 2 Design of Hydraulic Structures, Spillways, Regulators and Barrage*, for design works.

Adherence to the Egyptian code was given first priority in defining the hydraulic dimensions at the Basic Study stage, the textbook only providing supplemental criteria.

1-3 Outline of facilities

Figure 1-3.1 and Table 1-3.1 show the outline of the NDGRs



Figure 1-3.1 General layout of NDGRs

Name of Regu	ulator	Data Yuraf	lle werk beer be	Badr	aman	AboG	Gabal	Osh shis	Bernarder
Name of Cana	al	Banr Yuser	Ibrahimia	Badraman	Diroutiah	AboGabal	Irad Delgaw	Sanelyia	Remarks
Design maxim	um discharge	227 m ³ /s	186 m ³ /s	9 m ³ /s	12 m ³ /s	7 m ³ /s	9 m ³ /s	5 m ³ /s	Total 455m ³ /s
Design minim	um discharge	33.1 m ³ /s	23.6 m ³ /s	1.2 m ³ /s	1.7 m ³ /s	0.9 m ³ /s	1.3 m ³ /s	0.6 m ³ /s	Total 62.4m ³ /s
Design U/S h	igh water level	EL46.30m	EL46.30m	EL46.30m	EL46.30m	EL46.30m	EL46.30m	EL46.30m	
Design U/S lo	w water level	EL45.90m	EL45.90m	EL45.90m	EL45.90m	EL45.90m	EL45.90m	EL45.90m	
Design D/S hi	gh water level	EL45.82m	EL45.13m	EL45.90m	EL45.90m	EL45.90m	EL45.90m	EL45.90m	
Width of vent		6.00m	6.00m	2.00m	2.00m	2.0	0m	2.00m	
Number of ver	nt	4	4	2	3	4	1	2	
Gate sill eleva	ition	EL40.00m	EL40.00m	EL43.90m	EL44.20m	EL43	.60m	EL43.00m	
Gate crest ele	vation	EL46.55m	EL46.55m	EL46.55m	EL46.55m	EL46	.55m	EL46.55m	
Total gate hei	ght	6.55m	6.55m	2.65m	2.35m	2.9	5m	3.55m	
	Main body	Cast-in-place RC pile	Cast-in-place RC pile	Raft foundation	Raft foundation	Raft fou	ndation	Raft foundation	
Foundation	Apron	Raft foundation	Raft foundation	Raft foundation	Raft foundation	Raft fou	ndation	Raft foundation	
	L-shape wall	Cast-in-place RC pile	Cast-in-place RC pile	-	-	-	-	-	1
Downstream	Туре	L-type retaining wall	L-type retaining wall	RC flume	RC flume	RC f	lume	RC flume	
apron	Length	44.25m	44.25m	23.35m	22.77m	23.8	37m	16.42m	Note(1)
Seepage cont	rol works	Steel sheet pile	Steel sheet pile	Steel sheet pile	Steel sheet pile	Steel sh	neet pile	Steel sheet pile	
		Riprap	Riprap	Riprap	Riprap				
Bed protection	n works	L=30.0m	L=30.0m	L=15.0m	L=15.0m	-	-	-	t : Thickness
	1	(D ₅₀ =0.40m,W ₅₀ =60kg,t=1.00m)	(D ₅₀ =0.40m,W ₅₀ =60kg,t=1.00m)	(D ₅₀ =0.20m,W ₅	₀ =10kg,t=0.50m)				Including gravel (0.10m)
	D/S	Cantilevered type/Brace type steel sheet pile wall	Cantilevered type/Brace type steel sheet pile wall	Cantilevered sheet pile	Cantilevered sheet pile	-	-	_	
Bank		Gabion wall	Gabion wall						
works	U/S	Brace type steel sheet pile wall	Cantilevered type/Brace type steel sheet pile	Cantilevered sheet pile	Cantilevered sheet pile	Brace type stee	l sheet pile wall	Brace type steel sheet	
		Wet stone pitching	Wet stone pitching	wali	waii			pile wali	
Bridge		RC, Total width=12.5m	RC, Total width=12.5m	RC,Total width=12.5m	RC,Total width=12.5m	RC,Total w	idth=6.0m	RC,Total width=6.0m	
	Туре	Double leaf Fixed wheel gate	Double leaf Fixed wheel gate	Single leaf Slide gate	Single leaf Slide gate	Single Slide	e leaf gate	Single leaf Slide gate	
	Hoist	Hydraulic cylinder	Hydraulic cylinder	Electric motor	Electric motor	Electric	c motor	Electric motor	
Gate facility	Operation speed	0.3 m/min	0.3 m/min	0.3 m/min	0.3 m/min	0.3 m	n/min	0.3 m/min	
	Material		Rolled stee	el & Stainless steel(Guid	de frame, bolt & nut, wh	eels)			
	Chamlana	1 set	1 set			2 sets			Note(2)
	Stopiogs	Height of one piec	ce=1.35m&1.20m		Height of one	e piece=0.95m&(0.85m		
Managana	fa ailite i	Remote control building: RC str	ructure, 2 floors (Stoplogs storag	e house is established t	ogether)				Location and the area is
management	racinity	Local control room: RC structure	e, 2 rooms (Bahr Yusef & Ibrahin	nia Regulator)					under study
Motor lovel as		2 sets	2 sets	2 sets	2 sets	3 s	ets	2 sets	Brocouro tumo
vvater ievel ga	auge	(U/S:1,D/S:1)	(U/S:1,D/S:1)	(U/S:1,D/S:1)	(U/S:1,D/S:1)	(U/S:1,	,D/S:2)	(U/S:1,D/S:1)	Fressure type
							-		

Table 1-3.1 Outline of NDGRs

(1) Length of downstream apron for small regulators shows the distance from a gate sill to the existing structure. Note: (2) One set means a pair of stoplogs for upstream and downstream. U/S:Upstream, D/S:Downstream

2. Topographic and Geological Outline

2-1 Topographic feature

The flood plain of the Nile has been formed by Nile sedimentation onto the eroded limestone plateau which was aggraded in early Eocene time. The flood plain is mainly composed of silt and sand, and is suitable for agriculture due to its fertility. According to an old map of the area (*Carte topographique de l'Égypte et de plusieurs parties des pays limitrophes*, 1826), Dirout El-Shareef city, which is 2.7km north of Dirout city, was situated along the original Bahr Yusef river (Figure 2-1.1 and Figure 2-1.2). This indicates that much excavation and reclamation work has been implemented around the target area in order to divert the water from the Ibrahimia canal into the Bahr Yusef river as Bahr Yusef canal.



Figure 2-1.1 Satellite picture (Dirout to Malawi)



Figure2-1.2 Antique map (1826, Dirout to Malawi) (Source: *Carte topographique de l'Égypte et de plusieurs parties des pays limitrophes*, 1826)

2-2 Geological feature

Geological structures around Dirout city feature an erosion valley striding over 15km to 20km beyond the river terrace developed over different geological times. Diluvium formation which formed the river terrace is consequently seen under the river Nile, but alluvium sediments is covered in the study area which is beside the current river Nile. The condition of Nile deposits depends on changes in hydraulic gradient caused by eustasy, and changes in the river course caused by tectonism (shown on Figure 2-2.1).

The geological field survey of the study area corresponds to the Neonile or Prenile description (Said 1993). Table 2-2.1 shows the features for those units.





Unit	Remarks (Stratigraphication and distribution)
Neonile	This river system is the current condition of the Nile (0.4Ma-present), and is categorized into 4 types of deposits, α , β , γ , and δ -Neonile considering the regression/transgression cycle. They are mainly composed of riverine (flood) deposits (silt and sand, and occasional gravel) and inter-fingered dune sand.
Prenile	It is mainly composed of two types of sand layers, one for cross-bedding riverine sand, and another for inter-bedding dune sand in the middle Pleistocene ($0.8 - 0.4$ Ma). The deposit from this river system includes mollusca and fauna which indicate that this river system is connected to Ethiopia (Said 1990). This river system conveyed massive amounts of sand on the Nile valley which resulted in considerably thick sand layer even in Upper Egypt.

Table 2-2.1 Description of flood sediments

2-3 Borehole logs

The location of borehole and borehole logs which relate the foundation properties for B/D stage are shown in the following figures. (See the *Field Survey Report* (April 2016) of the D/D study in regard with the detail information for the past boring surveys).

a) Location of the survey

The boring survey was carried out at fifteen borehole points in order to clarify the change in stratigraphy on the new axis, and the soil properties were determined through in-situ and laboratory tests. The results support the design of main regulators, navigation locks, piers, sheet piles, and all related structures in the construction of NDGRs. A location map for the boreholes is shown in Figure 2-3.1.



Figure 2-3.1 Location map of boreholes on NDGRs

b) Borehole logs

Figures 2-3.2 to 2-3.5 show the geological cross-sectional maps of the regulators and SPT values. Figures 2-3.6 to 2-3.19 show all 15 borehole logs on the new Bahr Yusef, Badraman, Diroutiah, and Ibrahimia regulators.

According to the borehole logs obtained in the survey, thick silt layer is overlain at the depth of 10m, changing from silt to sand with depth. Coarse facies intercalated with granule and pebble are dominant at the bottom of the boreholes. This upper silt may be correlated to γ -Neo-Nile (or δ -Neo-Nile) sub-stage, and the lower part of the sandy layer succession can be compared with a part of γ -Neo-Nile sequence¹ (or δ -Neo-Nile). It should be remarked that a loose backfill layer (containing mainly unconsolidated silt to clay, and traces of brick particles) exists under the new Bahr Yusef regulator. That backfill layer is classified into two layers, top and bottom, with an interbedded silt layer with a trace of shell fragments.

¹Sediment sequence: A succession of geologic events, processes, or layers, arranged in chronologic order to show their relative position and age with respect to geologic history as a whole. In the Dirout area in particular, sediment layer(s) indicate a transgressive deposit, consisting of low lying gravel overlain by a finer layer of sand/silt on the surface. This is influenced by past sedimentation in response to a seawater rise after the middle Pleistocene time.



Figure 2-3.2 Geological cross-sectional map (New Bahr Yusef regulator)



Figure 2-3.3 Geological cross-sectional map (New Badraman to Diroutiah regulators)



Figure 2-3.4 Geological cross-sectional map (New Ibrahimia regulator)

ne Ara	ab Re	publ	ic o	f Eyg .S	pt		Dore: Br	1-IN 1	201	5				Drille	d De	pth:	33 (r	nBG	L)	u -	
Drillir	ng Ca	ompa	any	Bor	ndok C	onsultant	Coordinates: 2	28369	2.26	6 : 30	5030	4.59		Bore	Dian	neter	: 101	.6 (r	nm)		
Drillir	ng Ma	etho	d:F	lotar	y Drilli	ng	Ground Elevat	ion: 4	48.1	2 (m/	AMS	L)		тосі	Eleva	tion:	Abde	laziz	Bond	dok (I	mAG
po	(9)	Ĺ)	3L)									1	ec)	(Pa)		Lab	orato	ory T	est	_	chire
Drilling Meth	Recovery (%	R.L. (m AMS	Depth (m BG	Graphic Log	Fines	Field So	Description of il Material	(blo	sws 9	SPT /300n 8	nm)	No. Blows of Steps	Permeability(cm/s	Elasity Modulus(N	qu(kg/cm²)	Wn(%2)	Gs(kg/cm ²)	N(m'fy), Mv(m'IMN), Co	GU: C(kg/cm?), @(')	DS: C(kg/cm?), @('), \	a S Borehole Stu
NCR		48 -	- 0	**		Fill (asphalt, st	ones, sand, silt)			contr.											
SPT		1.1	-2			Clay and silt, g	rey	4 ⁶	_			9.5°				-48 -	2.73				
SPT VCR		1.4						11		-		756				28	A 2.72				
SPT JDS		44-	-4					\square	25	-		THOMS			-4 <u>9</u> -	- 43 -	A 2.72		20.6		3
SPT VCR		1				Clay and silt, g	rey	-	27		-	anon		-	A (1.13)	45	a 2.74		0.08	-	
SPT		1.1.1	-6						30		-	anan				462	2.72				
		4.4					-	4	6			61010	A		3.2	23⊳	2.72				
JDS		40 -	-8			Silty clay, grey			21			enon			2.8	28 28	2.77		A 7/16.19		
		1914	-			4.0 A.		-	3			Horn			A (3.15	- 462 -	2.73		0131		
			-10			Silty day, grey				5 62		LASIST			49	48	A 2.72				
			-			granule, grey Sand some sil	t some day arev			58		13HADZI	. 1	1			2 2.61				
CR		36 -	-12 -			Sand and clay of granule, gre	, traces of silt, traces			1	1	100 10000	0.8		1 2 2 3		2.6				
ICR SPT		144	-			Sand, some sil	t, some clay, grey		8	-	-	3215150					4 C 20				
NCR SPT		114	- 14			Clayey sand, s	ome silt, grey		33	5		Still		1			62 24		-		
NCR SPT			- 16	0 0		Sand, some d traces of granu	ay, traces of silt, ile,		1	50		911					A 86 2.				
NCR SPT		32-	-	0.0		Sand, some sil grey	t, traces of granule,				1	100 .00	A PEA	1			A 67 2				
SPT		1	- 18			Sand, some si	t, some clay, grey		31	/		1.010					A				
SPT		44		0 0		Sand, some sil	t, traces of granule,			1	76	2128600					A 4				
SPT		28-	-20	0 0		ALAN.						100 000	-	-			A 2.63				
SPT		4	5	.0.0		Sand, some gr	anule, some silt, grey			61		15153128					2.71		- 11		
SPT		144	-22	0.0		Clayey sand, s	ome granule, grey	_	436	5		Alleria	A R R				A 2.64				
SPT ICR		19.1		.0.0		granule, grey	onie sit, some		31			1992					2.62				
SPT ICR		24-	-24			Gravel and sal	ome granule, grey	-			1	100 60 ¹⁶⁰¹					A 2.64				
SPT NCR		1.1.4				sampler)				_	- 4	100 ,0150		-							
SPT NCR		4	- 26			Sand, some gr	anure, some sin, grey	-	-		-	00 5050					A 2.66				
SPT VCR		4.4				Gand, some u	ay, inaces of sit, giey		-		1	NOR NORTH		(d = -4			A 2.65		* * * *		
		20 -	- 28			Sand, some sil	t, grey			- 4	75	134431					4 2.62				
		1.1				bellever to and a					-	100 18/9/50					A 2.61				
SPT ICR		î. Î. Î.	- 30			Sand, some cl	ay, some silt, grey	-	-	-	-	100 CHORD	-	-			A 2.63			-	
SPT ICR		1				Silty sand, gre	y				1	100 , BISTED					A 2.65				
		16-	- 32	.0.0		Silty sand, trac	es of granule, grey			-	4	100 5050					2.69		1000		
PI		4 4 A	- 24								1	100 4050					A 2.67				
			.34	-		Gran	hic Log	-					-		rilling	a Met	hod		-	-	
			Bric	ĸ	22	Sand(fill)	Silt	Silty	Cla	y		NCR: Non C	ore I	Drilling			AGR:	Aug	er Bor	ing	

Figure 2-3.5 Borehole log (BH-N1)

ne Ara	ING	publ	ic of	Eyg S	pt		Bore: BF	I-N2 12/23/2	015			10	Drille	d De	pth:	25.4	5 (ml	BGL)	IC,	
)rillin	ig Co	mpa	any:	Mis	r Ray	mond F.	Coordinates: 2	283755	: : : : : : : : : : : : : : : : : : :	05034	0		Bore	Dian	neter	: 101	.6 (n	nm)	GUY	
rittir	g wi	etno	a: R	otar	y Dhii I	ing	Ground Elevan	(ion: 4)	J.65 (r	NAMS	L)			leva	Lob		ssam	ont	GL)	Φ
Drilling Method	Recovery (%)	R.L. (m AMSL)	Depth (m BGL)	Graphic Log	Fines ତ ଜିଙ୍କି	Field I So	Description of il Material	(blo 8 8	SPT ws/300 9 8)mm)	No. Blows of Steps	Permeability(cm/sec)	Elasity Modulus (MPa	qu(kg/cm²)	Wn(%2)	Gs(kg/cm ²)	CV(m'1y), MV(m'1MN), Co	CU: C(kg/cm?), p(')	DS: C(kg(cm ³), p (³), v	e Sorehole Stuctu
	11	-						-												-1.
SPT ICR SPT		- - 40 -	-0			Fine to mediun silt,poorfy grad Fine sandy silt	n sand with trace of ed, yelowish brown	A ³			1.12 0.12									
		1.1.1	-2	ann.		Fine sand with Silty sand, yell	trace of silt	A ²			144									
			-4			fractured calca fragments,mica Silty day,lean, grey,trace mica	reous pebbles,shell medium stiff, dark	- 47			1.5M				ъ 362					
				× × ×		Clayey silt with grey).fractured Sandy silt, trac calcareous pet	trace of sand (dark calcareous pebbles e of fractured bles, trace of shells	A ⁷			arsta arsta									
ICR SPT ICR			0	X X X X X X		Sandy silt, trac calcareous peb	e of fractured bles,	3			144 144									
PT CR PT		32 — 		X		Top silty clay 3 bottorn 15 cm (<u>grey) traces of</u> Clayey silt, trac	0 cm (dark grey), Clayey Silt (very dark fine sand es of fine sand,	-6-			51.4 01.			+	A 42					
CR PT CR		1.1.1		X		Clayey silt, son calcareous pet	ne of red bricks and bles ne of red bricks and	A ¹²			THE									
		-	- 12	×		Clayey silt, trac	e of sand	5			125									
CR PT		28 -	0-1-4	X	1	Sandy silt, som pebbles, trace	e of calcareous of red bricks	2	2	-	70113									
CR PT		1.1.1	- 14			Coarse to med silt, trace of me	um sand traces of dium to fine sand		\$7	-	INITION .		14							
CR PT CR			- - - 16 -	0 0 0 0		Medium to fine trace of granule	sand, trace of silt,		34 42		91977 91977	۵ 36-4	26.2/40.4/> 1.0						a 0/29(1.5)	
PT CR PT			- - - 18 -	•		Fine sand ,son	ne of silt		26		13131A	40								
CR PT						Medium to fine	sand, some of silt	-	35	-	(Alters)	4 E	- 3 + 9			****	****		****	
JR PT		20-	- 20 -	.0.		Medium to fine trace of pebble	sand, trace of silt,	_	47		misse									
PT CR PT CR PT			- 22	0 0 0 0 0		Medium to fine trace of granule	sand, some of silt,		42		Landre Landre	∆ 1.8E-4		4 =====	6	****	+++		+)	
CR PT CR PT		16-	- -24 -			Medium to fine	sand, some of silt		44 46		1,11928									
			26		Ш	Grant	vic Log					-		rillie	n Mot	hod				-
			Brick	k	<u>88</u>	Sand(fill) Sand(granule)	Silt	Silty	Clay		NCR: Non C	ore D	rilling		<u>a wiet</u>	AGR:	Auge	er Bor	ing	

Figure 2-3.6 Borehole log (BH-N2)

RILL rillin rillin	ING Ig Co Ig Me	DE1 ompa	AIL any: d: R	S Misr otary	Rayı Drilli	nond F. ng	Drilling Date: 1 Coordinates: 2 Ground Elevat	2/18/ 8381 ion: 4	2018 5 12 (n	5 : 305 1AMS	037(L)	0		Drille Bore TOC E	d De Diam Eleva	pth: neter tion:	25 (n : 101 Tame	nBGL .6 (n er (m	_) im) AGL)		
8	(9)	()	(T)					Ĩ				1	ec)	Pa)		Lab	orato	ory Te	est		ture.
Drilling Meth	Recovery (9	B R.L. (m AMS	Depth (m BC	Graphic Log	Fines	Field I So	Description of il Material	(blo	S ows/: 9	PT 300mi 8 8	m)	No. Blows of Steps	Permeability(cm/s	Elasity Modulus(N	qu(kg/cm²)	Wn(%2)	Gs(kg/cm²)	OVIT TYJ. MVSTPTIMIN). CO	GU C(kg/cm ²), φ([*]	DS: C(kg(cm ²), \$(¹), ¹	a S Borehole Stu
								7													
PT CR		Top In	-0			Fine sandy silt, fine, dark grey, Fine sandy silt	loose to very loose, trace mice with fractured stone	4				2.202 Z.C.L		1							-0
CR PT		40 -	-2	××××		Clayey silt,lear	,loose, dark grey	40				ø				A 33.7					
CR PT	100		1.1.4	× × ×		Clayey silt, fat, Sany clay, lear	loose, dark grey 1. lean,loose, dark					4				A A 5.640.6					
PT CR	100	1-de de	-4			grey Silty sand, loos sample: grey a	e, dark grey (Shelby t top 95 cm and 5 cm	3				2410				- *		* * * *	8889		
PT DS		- 36 -	- 6			Fine sand with Silty day dark calcareous pet	silt / grey with some of //	\mathbb{A}				Q.									
DS PT	50					Fine sand, loos mica Silty clay dark calcareous pet	se, dark grey with grey with trace of obles(Bulk sample)		-		-	anto									
DR	100	and and	-8			Silty clay, trace calcareous pet Silty clay, trace	s of red bricks and bles s of red bricks and bles								A (2.04)	∆ 31.8	4 2.678	∆ 0.227/0,346			
PT		- 32-	- - -10			Top silty day 1 medium to fine Medium to fine	.15 m ,bottom 10 cm sand .some of silt sand, loose, dark	48				2000		0.958				0.61/			
CR		1.0				brown, some o	sand traces of silt		A31		-	THAT		5/61.9/> (
PT CR PT		- Andrews	- - 12			Wedian to me	Sanu, naces of sin		A ³⁴			anart .		15.						4)	
XR MT XR MT			- 14 			Coarse to med silf, poorly grac very dense, tra	lum sand, traces of ded, medium dense to ce mica		4 ²⁹			and the second								A 0/28.5(1	
R		0.1.0	- 16 	0.0		Coarse to med silt, trace of gra	ium sand traces of		4	2	-	1011125									
R T		- 24	- 18			Coarse to med silt	ium sand ,traces of		4	50		1623121									
R. T			-			Medium to fine	sand ,some of silt		2	Å ⁵²			4	4		***					
T R		100	- 20	0.0		Coarse to med silt Coarse to med	ium sand traces of	-	4 ⁸⁷		-	1 alland		6/> 1.01			-				
R				0.0		silt, trace of gra	anule				-	ANTHAN AND		17.8/46							
भ R भ		20-	- 22			Coarse to med silt	ium sand straces of		A35			1 alleria	4	2							
R T R		- Andrews	- 	0 0 0		Coarse to med silt, trace of me	ium sand ,traces of adium to granule		24 S			THOM			ee ea						
PT		16		2.22							-	Jan									
		10	26	14		Gran	nic Log	1		_				D	rilling	n Met	hod				

Figure 2-3.7 Borehole log (BH-N2')

DRILI Drillin Drillin	LING ng Ca ng Ma	DE DE omp	ic of FAIL any: d: R	f Eyg . S : Mis lotar	pt r Ray y Drill	mond F.	Drilling Date: Coordinates: Ground Eleva	12/31 2837 tion:	/20 74 38.1	15 : 30 8 (mA	5034 MSL	0	1	Drille Bore FOC E	d De Dian Eleva	pth: neter ition:	25.4 : 101 M. E:	5 (ml .6 (n ssam	BGL) nm) (mA	GL)	
Drilling Method	Recovery (%)	R.L. (m AMSL)	Depth (m BGL)	Graphic Log	Fines	Field [So	Description of Il Material	(b)	ows	SPT \$/300r } 8	nm)	No. Blows of Steps	Permeability(cm/sec)	Elasity Modulus(MPa)	qu(kg/cm²)	Lab (¿%)uM	Gs(kg/cm²)	ory To Sv(m/,m/w///////	cu: C(kg/cm²), q(°)	DS: C(kg/cm ²), \$(`), Y	L 8 Sorehole Stucture
SPT VCR SPT	43	42 38 34 30 22 22 18 14	-0 -2 -4 -6 -10 -12 -14 -16 -18 -20 -22 -22 -24 -22			Coarse to medi part, medium part, very losce limestone fragr timestone frag with sill, fractur stone fill (while Coarse to medi trace of granul trace of ractur trace of ractur trace of ractur trace of ractur sondy Silt (dart Sandy Silt (dart Silty day (undit Silty day (undit Silty day (undit Silty day (undit Silty day (undit Silty day (undit trace of shells Coarse to medi trace of medium coarse to medi trace of granule Fine sandy silt Medium to fine trace of granule Fine sandy silt	um sand at upper to fine sand at lower -loose, silt, ments(white), mixed a stone, fractured um sand, trace of silt e datone fill (white) oks sand, trace of silt sand, trace of silt sand, trace of silt sturbed sample) grey) Bottom: medium to whilmestone hells sand, some of silt trace of red stones um sand with silt um sand, trace of nule sand, some of silt (dark grey) sand, some of silt, sand, some of silt,				99					373	2675 2673	0.980/032/02.031/0333/03 92		0.0327.2(1.3) 0.0327.2(1.3)	

Figure 2-3.8 Borehole log (BH-N2A)

e Ara RILL Fillin Fillin	ING Ig Co g Me	DE1 DE1 mpatho	TAIL any: d: F	.S : Mis totar	rR 7D	ayr)rilli	nond F. ng	Drilling Date: 2 Coordinates: 2 Ground Elevat	1/5/2016 283794 tion: 39.	i ; 3 63 (n	05033 nAMS	0 L)	The second se	Drille Bore TOC I	d De Dian Eleva	epth: neter ation:	25.4 : 101 M. E	5 (ml I.6 (n ssam	BGL) nm) (mA	GL)	
Drilling Method	Recovery (%)	R.L. (m AMSL)	Depth (m BGL)	Graphic Log	Fir		Field Sc	Description of il Material	(blow 0 2 11111	SPT s/300 9 8	mm) 88	No. Blows of Steps	Permeability(cm/sec)	Elasity Modulus(MPa)	qu(kg/cm²)	Lab (2%)uM	Gs(kg/cm ²)	ovim'ny, Mwim'nww, co	cu: c(ks/cm?), ¢(")	DS: C(kg/cm²), φ('), γ	e Borehole Stucture
PT		- 42 - - - - -	-0				Silty sand		<u> </u>			192									-3
ICR SPT ICR SPT ICR SPT ICR		38	-2				Fill, limestone Medium to fine limestone frag	gravels sand, some of silt, ments	411 45 410												
SPT JDS SPT JCR SPT JCR SPT		34-	-4 - - - - - 6 -				Medium to fine fractured white Coarse to meo silf, trace of gra limestone Medium to fine limestone	sand, trace of silt simestone ium sand ,some of anule, fractured sand, fractured	4 ⁸			1946 1946 1946	100							0/29(1.4)	
ICR SPT ICR SPT ICR SPT ICR		30 -					Sandy silt (dar Sandy silt (dar dayey silt	k grey) k grey),seems of	13 16 13												
SPT ICR ICR ICR SPT ICR SPT			- - - - - - 14	× 0.0			Clayey silt, stif sand seam Sandy silt, sea Coarse sand ,t	f, intercalation of fine ms of clayey silt race of silt ,trace of	9 27			Brine Prine Prine				A 40.3					
ICR SPT ICR SPT ICR SPT ICR			- 16	0			granule Coarse sand ,t pebble Coarse sand ,t	race of silt , trace of		44	56	tinge serence								∆ 0/29.6(1.5)	
PT CR CR CR PT CR PT		The Leave	- 20	0.0.0.0.0			Medium sand , granule	trace of silt trace of	*	49	1	Parties Parties									-
ICR ICR ICR ICR ICR ICR ICR ICR		18	- 				Medium sand I silt	o fine sand ,trace of		4 56	70 68	NALE BELES POPOS POPOS									



Projec The N	t for lew D Regi ab Re	in De Cons Dirout ulator publi	truc Gro rs in ic of	f Eyg	of if pt		Borehol Bore: Bl	e Lo H-N:	ogg 2C	ging	R	ecord		Drillin Dime	ig Ho ensio	le n	9	SC	S C Ir	anyu onsu 1c.	ltants
DRILI Drillir Drillir	LING ng Ca ng Ma	DET ompa ethor	any: d: R	.S : Mis totar	r Ray y Drill	mond F. ing	Drilling Date: Coordinates: Ground Eleva	1/3/20 2837 tion:	015 76 38.1	: 30 7 (mAl	5041 MSL	0)		Drille Bore FOC I	d De Dian Eleva	pth: neter ation:	25.4 : 101 M. E	5 (ml I.6 (n ssam	BGL) nm) ı (mA	GL)	1
rilling Method	Recovery (%)	(:L. (m AMSL)	epth (m BGL)	sraphic Log	Fines	Field I So	Description of il Material	(b	ows	SPT 5/300n 2 8	nm)	No. Blows	rmeability(cm/sec)	sity Modulus(MPa)	lu(kg/cm²)	Lab (2%)uM	es(kg/cm ²)	CIVIL MARITY Co.	est (,)¢ (,)/s)	C(k@/cm?), @('), y	Borehole Stucture
		а 		0					ļ.	เปล้า		of Steps	Pe	Ela	a.		5	Ov(tr	on	DS;	GW Dept
PT CR PT CR PT CR CR CR CR CR	-	42 - - - - - - - - - - - - - - - - - - -	-02			Coarse to medi sill, some of sh Coarse to medi Medium to fine trace of shells, limestcene grav	ium sand, trace of ells ium sand, trace of silt sand, some of silt, sand, trace of silt, trace of red bricks, vels		19												
PT DS PT CR PT CR PT CR PT		34		× × × × ×		Fine silty sand	(dark grey)		26 19 25 25			800 800 800 1000					- 200				
CR PT CR PT CR PT CR PT		30		0.0.0.0.0		Medium to fine ,trace of granul	sand ,trace of silt e		431	40		52202 52202 10702								۵ 0/29.4(1.5)	
CR PT CR PT CR		26	- 14			Coarse to medi	ium sand, trace of silt	E	4	4G 3B 3B		in the second									-
CR PT CR PT CR CR	-	22	- - - - - - - - - - - - - - - - - - -	0.0.0		Medium to fine Coarse to medi silt, trace of gra	sand ,trace of silt ium sand, trace of inule			46	76	Labora 218541		 					 		
CR PT CR		1111		×××		Sandy silt (dark	(grey)		28			Thurst 100						•-••			
PT CR		18-	2			Medium to fine	sand, some of silt	-	3			10.									
PT CR			-22	•••		Coarse to medi	ium trace of silt	1	23			-1811S									
PT CR PT CR		111		0.0		Coarse to medi trace of granul	ium ,trace of silt e	-	1	40		111723									
PT CR PT		14 -	-24 - - - 26			Medium to fine	sand ,trace of silt			55		1912 11 11 11 11 11 11 11 11 11 11 11 11 1		-							
			20		r.i.l.	Graph	nic Log						Г	D	rillin	g Met	hod				1
			Bric Con Fill Gra Roc	k icrete vel ik		Sand(fill) Sand(granule) Sand(gravel) Sand(silt) Sand/Gravel	Silt Silt(brick) Silt(fill) Silt(sand)		y Cla y Cla y Cla y Cla y Cla	iy iy(brick iy(fill) iy(sand iy(stiff))))	NCR: Non C SPT: Stand UDS: Undis COR: Core I	ore D ard P turbe Drillin	orilling enetra d Sam g	tion T pling	est	AGR: BLR:	Aug Cable Water Water	er Bor e tool Level Level	ring s (Bail l (befo l (afte	ler) ore) r)

Figure 2-3.10 Borehole log (BH-N2C)

String Company: Misr Raymond F. Dring Company: Misr Raymond F. Drilling Company: Misr Raymond F. Goord Elevation: 36.3 (mAMSL) By Bring Company: Misr Raymond F. Goord Elevation: 36.3 (mAMSL) By Bring Company: Misr Raymond F. Field Doscription of Soil Material By Bring Company: Misr Raymond F. Field Doscription of Soil Material By Bring Company: Misr Raymond F. Field Doscription of Soil Material By Bring Company: Misr Raymond F. Field Doscription of Soil Material By Bring Company: Misr Raymond F. Field Doscription of Soil Material By Bring Company: Misr Raymond F. Field Doscription of Soil Material By Bring Company: Misr Raymond F. Field Doscription of Soil Material By Bring Company: Misr Raymond F. Concest one during the soil to a duri	ne Ar	Regi ab Re	pub	rs ir lic o TAU	f Eyg	pt			Bore: BH	-N	2D					1			nti	75 4	5 (m)	In	1C.	
Bin Ground Elevation: So 3 (mAMSL) TOC Elevation.dl Essan (mAGL) 98 <th>Drilli</th> <th></th> <th>omn</th> <th>anv</th> <th>Mis</th> <th>rR</th> <th>avr</th> <th>nond F.</th> <th>Coordinates: 2</th> <th>837</th> <th>95</th> <th>۰.</th> <th>3050</th> <th>)360</th> <th>0</th> <th></th> <th>Bore</th> <th>Diar</th> <th>pth: nete</th> <th>20.4 r: 10</th> <th>5 (m)</th> <th>nm)</th> <th>h.,</th> <th></th>	Drilli		omn	anv	Mis	rR	avr	nond F.	Coordinates: 2	837	95	۰.	3050)360	0		Bore	Diar	pth: nete	20.4 r: 10	5 (m)	nm)	h.,	
Str Spin Construction Field Description of Soil Material SPT (BlowS300mm) or R & Str Res Construction Str Str Str Str Str Str Str Str Str Str Str Str Str <th>Drilli</th> <th>ng Ma</th> <th>etho</th> <th>d: F</th> <th>lotar</th> <th>уE</th> <th>rilli</th> <th>ng</th> <th>Ground Elevat</th> <th>ion:</th> <th>39.</th> <th>3 (n</th> <th>NAM</th> <th>SL)</th> <th></th> <th></th> <th>roc I</th> <th>Eleva</th> <th>ation</th> <th>M. E</th> <th>ssam</th> <th>(mA</th> <th>GL)</th> <th></th>	Drilli	ng Ma	etho	d: F	lotar	уE	rilli	ng	Ground Elevat	ion:	39.	3 (n	NAM	SL)			roc I	Eleva	ation	M. E	ssam	(mA	GL)	
98 95 100	σ		0			Γ			Carlo and A and A and	T	-		-			6	ê		Lat	oorat	ory T	est		en
SPT 98 0 Fire sity and 1 0 SPT 98 0 Core to free intermine and, have of the trace of folling, frace wired 0 NR 98 0 Core to free intermine and, have of the trace of folling, frace wired 0 NR 0 Core to free intermine and, have of the trace of folling, frace wired 0 0 NR 0 Core to free intermine and, have of the trace of folling, frace wired 0 0 NR 0 Core to free intermine trace of the trace of site intermine and, have of the trace of site intermine and, have of the trace wire intermine and, have of the trace of site intermine and have of site the trace of s	Drilling Metho	Recovery (%	R.L. (m AMSI	Depth (m BGI	Graphic Log	Fil	nes s e	Field I So	Description of il Material	(b 0	low:	SP s/30 ¥ 5	T 10mr 3 8	n)	No. Blows of Steps	Permeability(cm/se	Elasity Modulus(MF	qu(kg/cm²)	VVn(%2)	Gs(kg/cm ²)	OV(m'YV). MV(m'IMN). Co	GU: C(kg/cm ²), q(°)	DS: C(kg/cm?), p(?), y	and Borehole Stuct
SPT 0 Fire sity send 1 1 1 SPT 0 Fire sity send 2 1 NCR SPT 0 Coase to medium send, trace of all three of site three of site three of all three of site three of all three of site three of all three of site three site three of s			-			4																H		-3
SPT 20 Fine sity sand 1 10 SPT 20 Fine sity sand 1 10 SPT 20 Coase to medum sand trace of a sit, medured 1 10 SPT 20 Status of site is, trace of a site, trace of a s			42-				_																	
SPT Coarse to medium sand, trace of all			-																					
SPT 0 Fine sety send 5 SPT Coarse to medium sand, trace of all tax of shell, frace of red limestone with statutes of all tax of shells, frace of red limestone with statutes of all tax of shells, frace of red limestone with statutes of all tax of shells, frace of red limestone small trace of all tax of shells, frace of red limestone small trace of all tax of shells, frace of red limestone, frace of shell, frace of all tax of shells, face of red limestone, frace of shell lim						Π				1					N									-
Series Series Coarse to modum sand. trace of series Series Carse to modum sand. trace of series Series Series Series Carse to modum sand. trace of series Carse to modum sand. trace of series Series <t< td=""><td>SPT</td><td></td><td></td><td>-0</td><td>11</td><td></td><td></td><td>Fine silty sand</td><td></td><td>-</td><td></td><td></td><td></td><td></td><td>O.V.</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></t<>	SPT			-0	11			Fine silty sand		-					O.V.									
CAX -2 Innstrine -2 COR -2 Carse to rendum send, trace of sit trace of shills, trace of neither pricks -2 COR Carse to rendum send, trace of sit trace of carbons -2 COR Carse to rendum send, trace of sit trace of carbons -2 COR Carse to rendum send, trace of sit trace of carbons -2 COR Carse to rendum send, trace of sit trace of carbons -2 COR Carse to rendum send, trace of tracture -2 COR Carse to rendum send, trace of tracture -2 COR Carse to rendum send, trace of tracture -2 COR Sandy sit -7 Corr to tract tracture -2 Corr to tract tract -2 Corr to tract tract tract -2 Corr to tract tract tract tract -2 Corr to tract tract tract -2 Corr to tract tract tract of sit -2 Corr to tract trace of sit -2	SPT		38-	L		H	Ħ	Coarse to med slit, trace of she	ium sand, trace of ells, fractured	4	F				243									
VCR	SPT			-2	14			Timestone Coarse to mod	um cand trace of	-		-			2314)	
VCR 4 Coarse to medium sand, trace of sit 3 4 UDS 54 4 Coarse to medium sand, trace of sit 4 VCR 8 Sit frace of sites to medium sand, trace of sit 7 3 VCR 8 Sit frace of sites to medium sand, trace of site 7 3 VCR 8 Site tage of site to medium sand, trace of site 7 3 VCR 8 Site tage of site to medium sand, trace of site 3 VCR 5 Sandy site 5 VCR 5 Sandy site 5 VCR Sandy site 5 5 VCR Coarse to medium sand, trace of site 5 VCR Coarse to medium sand, trace of site 5 VCR Coarse to medium sand, trace of site 5 VCR Coarse to medium sand, trace of site 5 VCR 26 14 Coarse to medium sand, trace of site VCR Coarse to medium sand, trace of site 5 VCR 20 Site tage of granule 5 VCR 22 Site tage of granule 5 VCR 22 Medium to fine sand, trace of site 5 VCR 20 Medium to fine sand, trace of site	SPT		4	F				silt, trace of shi bricks	ells, trace of red	46	-	-	-	-	2214									
UDS 34 -	NCR SPT		-	-4		+	+	Coarse to med silt, trace of rec	ium sand, trace of I bricks	-	3	-	-	-	sient)	
VCR 6 Wellum to fine sand, trace of silt 7 4 SPT 26 Carse to medium sand, trace of silt 4 VCR 10 Sandy all 4 SPT 10 Carse to medium sand, trace of silt 4 VCR 12 Carse to medium sand, trace of silt 4 VCR 12 Carse to medium sand, trace of silt 4 VCR 12 Carse to medium sand, trace of silt 4 VCR 14 Carse to medium sand, trace of silt 4 VCR 14 Carse to medium sand, trace of silt 4 VCR 14 Carse to medium sand, trace of silt 4 VCR 14 Carse to medium sand, trace of silt 4 VCR 14 Carse to final trace of silt 4 VCR 14 Carse to final trace of silt 4 VCR 16 Carse to final trace of silt 4 VCR 16 Carse to final trace of silt 4 VCR 16 Carse to final trace of silt 4 VCR 18 Y 4 4 VCR 18 Y 4 4 VCR 18 Y 4 4 VCR <td>JDS SPT</td> <td></td> <td>34 -</td> <td>ŀ</td> <td>11)</td> <td></td> <td>+</td> <td>Coarse to med silt, trace of shi</td> <td>ium sand, trace of ells, trace of red</td> <td>-</td> <td>16</td> <td>-</td> <td>-</td> <td>-</td> <td>6.6%</td> <td></td> <td>-</td> <td>-</td> <td></td> <td>-</td> <td></td> <td>-</td> <td></td> <td></td>	JDS SPT		34 -	ŀ	11)		+	Coarse to med silt, trace of shi	ium sand, trace of ells, trace of red	-	16	-	-	-	6.6%		-	-		-		-		
Ser Prick Prick Clayey sill at upper, silly clay at bottom 3 10 4 % SPT Sort Silly clay 7 10 4 % SPT Sort Sandy silt 4 % SPT Sort Sandy silt 4 % SPT Sort Coarse to medium sand, trace of silt 4 % SPT Coarse to medium sand, trace of silt 4 % SPT Coarse to medium sand, trace of silt 4 % SPT Coarse to medium sand, trace of silt 4 % SPT Coarse to medium sand, trace of silt 4 % SPT Coarse to medium sand, trace of silt 3 % SPT Coarse to medium sand, trace of silt 3 % SPT Coarse to medium sand, trace of silt 3 % VCR Silty sand 5 % SPT Coarse to resulum sand, trace of silt 3 % VCR Silty sand 5 %	NCR		-	-6			1	Medium to fine fractured limes	sand, some of silt,	-	7	-	_	_	5.814									
PP I Bottom 7 Pit Pit<	ICR			F	XXX			brick Clayey silt at u	oper, silty clay at	-	3		_		agui				िस					
SPT 30 4 St 4 St SPT 10 Sandy slit 11 4 St SPT 10 Sandy slit 5 4 St SRT 12 Coarse to medium sand, trace of slit, trace of slit 4 St SPT 26 Coarse to medium sand, trace of slit 4 St SPT 26 Coarse to medium sand, trace of slit 4 St SPT 26 Coarse to medium sand, trace of slit 4 St SPT 26 Coarse to medium sand, trace of slit 4 St SPT 26 Sity sand 4 St SPT 16 Sity sand 4 St SPT 22 Sity sand 5 St SPT 20 Medium to fine sand, trace of slity 4 St GR 22 St Medium to fine sand, trace of slity 4 St GR 22 St Medium to fine sand, trace of slity 4 St GR 22 St Medium to fine sand, trace of slity 4 St GR 22 St Medium to fine sand, trace of slity 4 St GR 22 St Medium to fine sand, trace of slity 4 St GR 22 St <td< td=""><td>SPT NCR</td><td></td><td></td><td>E.</td><td>XX</td><td></td><td></td><td>bottom</td><td></td><td>- /7</td><td></td><td></td><td></td><td></td><td>410.</td><td></td><td></td><td></td><td>A 37</td><td></td><td></td><td></td><td></td><td></td></td<>	SPT NCR			E.	XX			bottom		- /7					410.				A 37					
SPT 30 10 Sandy slit set set VCR Sandy slit set set set VCR 12 Sandy slit set set VCR Coarse to medium sand, trace of slit, set set set SPT Coarse to medium sand, trace of slit, set set set VCR Coarse to medium sand, trace of slit, set set set SPT Coarse to medium sand, trace of slit, set set set VCR Coarse to medium sand, trace of slit set set VCR Coarse to medium sand, trace of slit set set VCR Coarse to medium sand, trace of slit set set VCR Set Set set set VCR Set Sity send set set VCR Set set set </td <td>SPT VCR</td> <td></td> <td></td> <td>È</td> <td></td> <td>+</td> <td></td> <td>Silty clay</td> <td></td> <td>1</td> <td>1</td> <td></td> <td></td> <td></td> <td>-17. -24.</td> <td></td> <td></td> <td></td> <td>A 37.0</td> <td></td> <td></td> <td></td> <td></td> <td></td>	SPT VCR			È		+		Silty clay		1	1				-17. -24.				A 37.0					
SPT 10 Sandy slit 3 VGR 12 Sandy slit 3 VGR 12 Sandy slit 3 VGR 12 Sandy slit 3 VGR 26 Coarse to medium sand, trace of slit, 29 VGR Coarse to medium sand, trace of slit, 29 VGR Coarse to medium sand, trace of slit, 29 VGR SPT Coarse to medium sand, trace of slit, VGR Coarse to medium sand, trace of slit 42 VGR SIty trace of granule 43 VGR Table Sity trace of granule 3 VGR Sity trace of granule 3 VGR Sity sand 5 VGR <td>SPT</td> <td></td> <td>30-</td> <td>È.</td> <td>×></td> <td>P</td> <td></td> <td></td> <td></td> <td>-</td> <td>1</td> <td></td> <td></td> <td></td> <td>2</td> <td></td> <td></td> <td></td> <td>30.1</td> <td></td> <td></td> <td></td> <td></td> <td></td>	SPT		30-	È.	×>	P				-	1				2				30.1					
Correction Coarse to medium sand, trace of silt, trace of silt, trace of silt, trace of granule 28 VCR Coarse to medium sand, trace of silt, trace of silt, trace of granule 29 10% SPT 26 Coarse to medium sand, trace of silt, trace of silt, trace of granule 10% SPT 26 Coarse to medium sand, trace of silt 10% SPT 26 Coarse to medium sand, trace of silt 10% SPT 14 Coarse to medium sand, trace of silt 10% SPT 16 Coarse to medium sand, trace of silt 10% SPT 16 Silt, trace of granule 10% SPT 22 Silt, trace of granule 10% SPT 22 Silt, trace of silt 11% VCR Silt, trace of gravel 11% 11% SPT 22 Silt, trace of gravel 11% VCR 20 Medium to fine sand, trace of silty 11% VCR 22 Medium to fine sand, trace of silty 11% VCR 24 11% 11% SPT 18 11% 11% VCR 18 11% 11% SPT 18 11% 11% VCR 20 Medium to fine sand, trace of	SPT		-		×××			Sandy silt							1200 A									
NCR 12 - Coarse to medium sand, trace of silt, trace of silt, trace of tr	SPT			Ē	××					-					Lints									
NCR 26 Coarse to medium sand, trace of silt, 29 winth SPT Coarse to medium sand, trace of silt, 42 winth SPT Coarse to medium sand, trace of silt, 42 winth NCR 16 Silt, trace of granule 43 winth NCR 16 Silt, trace of silt 00 winth SPT 22 Silt, trace of silt 00 winth NCR 16 Silt sand, trace of silt 00 winth SPT 22 Silt sand Silt sand silt NCR SPT Silt sand, trace of silt 61 trace of silt NCR SPT Silt sand, trace of silt Silt sand silt sinth NCR SPT Silt sand, trace of silt Silt sinth Silt sinth NCR SPT Silt sand, trace of silt Silt sinth Silt sinth NCR SPT Silt sand, trace of silt Silt sinth Silt sinth NCR SPT Silt sand, trace of silt Silt sinth Silt sinth NCR SPT Silt sand, trace of silt Silt sinth Silt sinth NCR SPT Silt sinth Silt sinth Silt sinth SPT <t< td=""><td>SPT</td><td></td><td></td><td>-12</td><td></td><td>H</td><td>T.</td><td>silt, trace of silt</td><td>y day</td><td>-</td><td>425</td><td></td><td>-</td><td></td><td>outra</td><td></td><td></td><td></td><td></td><td></td><td>1-11</td><td></td><td></td><td></td></t<>	SPT			-12		H	T.	silt, trace of silt	y day	-	425		-		outra						1-11			
NCR 14 Coarse to medium sand, trace of silt 42 moth SPT 16 Silt, trace of granule 63 moth VCR 16 Silt, trace of silt 63 moth VCR 16 Silt, trace of silt 63 moth VCR 16 Silt, trace of silt 61 moth VCR Silt, trace of granule 61 moth VCR Set Set moth Set VCR Set Set Medium to fine sand, trace of silty Set VCR Set Set Set SP	SPT		- 26 -	-		╟	H	Coarse to med	ium sand, trace of silt,	-	29		-	-	Anants									
SPT UCR Medium sand, trace of sit 43	NCR SPT			-14		╟	\mathbb{H}	Coarse to med silt, trace of gra	ium sand, trace of inule	-	-	42	-	-	211125									
NCR 16 Coarse to medium sand, trace of silt, trace of granule SPT 22 18 Silt, trace of granule NCR 22 18 Fine sand, trace of silt 61 NCR 00 Medium to fine sand, trace of silty 61 NCR 20 Medium to fine sand, trace of silty 61 NCR 20 Medium to fine sand, trace of silty 61 NCR 20 Medium to fine sand, trace of silty 61 NCR 20 Medium to fine sand, trace of silty 61 NCR 20 Medium to fine sand, trace of silty 61 NCR 20 Medium to fine sand, trace of silty 61 NCR 22 Medium to fine sand, trace of silty 61 NCR 22 Medium to fine sand, trace of silty 61 NCR 22 Medium to fine sand, trace of silty 61 NCR 22 Medium to fine sand, trace of silty 61 NCR 24 Medium to fine sand, trace of silty 61 NCR 24 Medium to fine sand, trace of silty 61 NCR 24 Medium to fine sand, trace of silty 61 NCR 24 Medium to fine sand, trace of silty 61	SPT			ł	1	$\left \right $		Medium sand,	trace of silt	-	-	43	-	-	wind?	-	-	-				_		
SPT 22 38 Silty send 36 spits SPT 18 Fine sand, trace of silt 61 spits SPT Medium to fine sand, trace of silty 44 spits SPT 20 Medium to fine sand, trace of silty 44 SPT 20 Medium to fine sand, trace of silty 44 SPT 20 Medium to fine sand, trace of silty 36 SPT 20 Medium to fine sand, trace of silty 36 SPT 18 22 Medium to fine sand, trace of silty 36 SPT 18 22 Medium to fine sand, trace of silty 37 SPT 18 22 Medium to fine sand, trace of silty 37 SPT 22 Medium to fine sand, trace of silty 37 SPT 24 Medium to fine sand, trace of silt 36 SPT 24 Medium to fine sand, trace of silt 36 SPT 14 26 Medium to fine sand, trace of silt 36	NCR			- 16		1		Coarse to med silt, trace of gra	ium sand, trace of inule		-		60	_	Transt									
SPT 22	NCR		-	Ē	· · · ×			Silty sand		1		4	6	-	52355									
SPT Medium to fine sand, trace of silty 44 State VCR 20 Medium to fine sand, trace of silty 44 VCR 20 Medium to fine sand, trace of silty 54 VCR 20 Medium to fine sand, trace of silty 54 VCR 20 Medium to fine sand, trace of silty 54 VCR 22 Medium to fine sand, trace of silty 57 VCR 22 Medium to fine sand, trace of silty 57 VCR 22 Medium to fine sand, trace of silty 57 VCR 22 Medium to fine sand, trace of silty 57 VCR 22 Medium to fine sand, trace of silty 57 VCR 24 Medium to fine sand, trace of silt 56 VCR 24 Medium to fine sand, trace of silt 56 VCR 24 Medium to fine sand, trace of silt 50 VCR 24 Medium to fine sand, trace of silt 50 VCR 24 Medium to fine sand, trace of silt 50 VCR 26 Medium to fine sand, trace of silt 50	VCR		22-	-18	*			Fine sand trac	e of silt				61		volites								0	
SPT	SPT NCR			E				Medium to fine	sand, trace of silty		1	44			17.19								A 9.5(1.5	
SPT -20 -42 <td>SPT</td> <td></td> <td>-</td> <td>-</td> <td></td> <td></td> <td></td> <td>Medium to fine</td> <td>sand, trace of silty</td> <td></td> <td></td> <td>15</td> <td>4</td> <td></td> <td>101.00</td> <td></td> <td></td> <td></td> <td></td> <td></td> <td>- 44</td> <td></td> <td>0/2</td> <td></td>	SPT		-	-				Medium to fine	sand, trace of silty			15	4		101.00						- 44		0/2	
SPT 18 22 Medium to fine sand, trace of silty 57 state MCR 22 4 4 57 state SPT 22 4 4 57 state MCR 24 4 4 4 57 Medium to fine sand, trace of silty 57 state state Medium to fine sand, trace of silt 56 state state SPT 24 Medium to fine sand, trace of silt 53 state SPT 14 26 51 state	SPT			E 20	.0			clay	T.C.B. Control Man	-		5			150.00									
SPT CCR SPT C	SPT		18-	L	0 0		Ħ	Medium to fine day, trace of o	sand, trace of silty avel			1			TIP2 .						11			
ACR AS Astronomic SPT -24 Medium to fine sand, trace of silt 64 SPT -45 sparse 14 -26 -24	SPT			-22	0 0	t			37A)	-		1			1920124									
ICR -24 Medium to fine sand, trace of silt 64 spits ICR -24 -4 -4 spits ICR -26 -4 -4	NCR SPT		1	F		\parallel	++			-		45	+	-	191920									
NCR 251 807 ¹⁰ 14 26 11 11	ICR SPT			-24		╀	H	Medium to fine	sand, trace of silt	-	-		A ⁶⁴	-	18529:05									
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	.e 1			26		1								_						+	_			
Graphic Log Drilling Method			-	-			971	Graph	nic Log								₽	rillin	g Me	thod				

Figure 2-3.11 Borehole log (BH-N2D)

e Ara	ew D Regu b Re	lato publ	i Gra rs in ic ol	f Eyg	pl		Bore: BH	1-N3	3				Dime	ensio	n				onsu 1c.	itants
rillin	g Co g Me	ompa	any: d: R	: Mis totar	r Ray y Drill	mond F. ing	Coordinates: 2 Ground Elevat	283970 283970 tion: 39	o :: 0.7 (m	305040 AMSL)6 _)	E	Bore OC I	d De Dian Eleva	eptn: neter ation:	25.4 : 101 M. E	5 (mi I.6 (n ssam	BGL) nm) i (mA	GL)	
lethod	(%) K	AMSL)	(1981)	boŋ					SPT		- M	(cm/sec)	us(MPa)		Lab	orate	ory T ory T	est	۷.(۲)	Stucture
Drilling N	Recover	R.L. (m /	Depth (m	Graphic	Fines ₀ ଜ ≑	Field	Description of bil Material	(blov 8 0 11111	vs/30	0mm) 88	No. Blows of Steps	Permeability	Elasity Modu	qu(kg/cm²)	(2%)UM	Gs(kg/cm²)	Cv(m'ty), Mv(m'IN	GU: C(kg/cm ²)	DS: C(kg/cm ²), i	den Borehole
	ł	42									-									-2.
PT		وماد الدارجين	-0 -			Fill (rock fragn	nent,sand,silt)	A7			- sah						_			
PT DR PT		38-	- 2			Fill (dayey silt sand)	with rock fragment.	9			2 ¹⁰ 2				A 28.7				1 (((((((((((((((((((
PT CR PT DS		1.1.0.1.1	- 4 	× × ×		Fine sand, tra	ce of silt	20 			tall'					****				
DR PT CR CR PT		34	-6	× .×		Medium sand.	trace of silt	18			10 ¹⁰	2			line a					-
R PT R PT R PT CR		30							38 41		Inno Inno	∆ 3.6E-4								
PT CR PT CR PT		the first	- 12			Medium sand. stiff	trace of silt, becomes		41 39		anan Janan					1967		2 801		2
CR PT		26		0.0.		Medium sand, granule	trace of silt, trace of	_	47		1550 March	A 5.1E4								
PT		19	14 			Medium sand,	trace of silt		A4		, spath		A 8/-/4.803							
PT CR PT		r î date	- - 16 -			Modium sand, fine sand	trace of silt, trace of		41 46		10000 A		135.6							
DR PT DR PT		22	- - 18 - -			Medium sand,	trace of silt		47		160301	∆ 4.3E-4								
CR PT CR PT CR			-20 - - -	0.0.0		-			51 53	5	1782201 1888-99									
PT CR PT CR		11100	-22 - - - -24	0.0.0.0		- Coarse Sand,	granule ,trace of silt		5	7 65	Party Party									a.
11	81	1.1.1	1 - 1	0.0						72	TIGHT						-			

Figure 2-3.12 Borehole log (BH-N3)

Bit State Field Description of SPT (box/300mm)	e An RILI rillin rillin	ng Co ng Ma	DET DET ompa	AIL any: d: R	Eyg S Misi otary	n R	ayr rillii	nond F. ng	Drilling Date: 2 Coordinates: 2 Ground Elevat	2/1/201 84003 ion: 40	6 : 3).6 (m/	05039 \MSL	2)	C E T	Drille Bore TOC E	d De Dian Eleva	pth: neter ition:	24.4 : 10 ⁻ M. E	5 (ml 1.6 (n ssam	BGL) nm) (mA	GL)	
A4 File sord some of shells A GR File sord some of shells A GR File sly sond tace of shell A GR File sly sond tace of shell A GR File sly sond tace of shell B File File File File File File File File File File File File File File File File	Drilling Method	Recovery (%)	R.L. (m AMSL)	Depth (m BGL)	Graphic Log	Fir	ies on	Field So	Description of bil Material	(blo	SPT ws/300 9 8	mm)	No. Blows of Steps	Permeability(cm/sec)	Elasity Modulus(MPa)	qu(kg/cm²)	Lab (2%)UM	Gs(kg/cm ²)	ory To (NW/,W/W/W/) Co	cn: C(ks/cm/), q(")	DS: C(kg/cm3, p('), Y	e S Borehole Stucture
rr 40 -0 Fire sand some of shalls 3 45 45 rr -2			44																			-2
CR 4 Fine sand 6 4 DS 6 4 5 DS 6 77 7 Pr 6 77 7 Pr 7 7 7 CR 7 7 7 Pr 8 X Fine sand, trace of sit CR 7 7 7 Pr 8 X Fine sand, trace of sit CR 7 7 7 Pr 8 X Fine sand, trace of sit CR 7 8 9 CR 7 9 Pr 6 9 CR 7 9 Pr 9 9 CR 9 9 Pr 10 10 CR 9 9 Pr 14 Medium sand, trace of sit Pr 14 9 Pr 16 9 CR 16 9 Pr 16 9 Pr 16 9 Pr 16 9 CR 9 9 Pr 16 Pr 16	PT CR PT CR CR	-	40	-0 - - 				Fine sand .so	ne of shells I, trace of shells	4 ³			536 1217 1217			 					+	
CR -6 -7 CR -8 -7 CR -8 -7 CR -8 -7 CR -7 -7 CR <	CR SPT ICR SPT JDS SPT	-	36	- 4 				Fine sand		15 13 16			erte Get Gite									
PT 10 Medium sand, trace of silt, trace of 28 e e 4 PT 12 Medium sand, trace of silt 38 medium 4 PT 12 Medium sand, trace of silt 38 medium PT 14 Medium sand, trace of silt 38 medium PT 14 Medium sand, trace of silt 38 medium PT 14 Medium sand, trace of silt 38 medium PT 14 Medium sand, trace of silt 39 medium PT 16 Medium sand, trace of silt 39 medium PT 18 Medium sand, trace of silt 39 medium PT 18 Medium sand, trace of silt 39 medium PT 20 Medium sand, trace of silt 39 medium PT 20 Medium sand, trace of silt 39 medium PT 20 Medium sand, trace of silt 37 medium PT 20 Medium sand, trace of silt 37 medium PT 20 Medium sand, trace of silt 37 medium PT 22 Medium sand medium sand medium PT 2	PT CR PT CR PT CR PT CR			-6 - - - 8 -	× × × ×			Fine sand, tra	ce of silt		2		1966 1966 1966									
CR PT <	PT CR PT CR PT CR PT CR			10 	0.0			Medium sand, pebble Medium sand,	trace of silt, trace of trace of silt		41 41 38		in the second	4 1,2E-3								
R 24 Fine to medium sand, trace of silt 33 within 33 PT 18 Fine to medium sand, trace of silt 33 within 33 PT 18 Medium sand, trace of silt 33 within 33 PT 20 Medium sand, trace of silt 87 within PT 20 Medium sand, trace of silt 87 within PT 20 Medium sand, trace of silt.trace of pebble 44 within PT 22 Medium sand 44 within PT 22 Medium sand, trace of silt.trace of pebble 44 PT -22 Medium sand 44 PT -22 Medium sand 52 PT -24 Coarse sand 58 with	DR PT DR PT CR	-		- 				Medium to coa	arse sand, trace of silt		34 34 42		, 1999 , 1999 , 1999	A 9.2E.4	7/1.637							
Principal Medium sand, trace of silt Arr PT 20 Medium sand, trace of silt Ar PT 20 Medium sand, trace of silt Ar PT 22 Medium sand, trace of silt.trace of 43 PT 22 Medium sand 48 PT 22 Medium sand 48 PT 22 Medium to coarse sand, trace of silt. 52 PT 24 Coarse sand 58 PT 16 Coarse sand 58			24	- - - 18 -				Fine to mediur	n sand, trace of silt		39 39 44		unan anan unan		21.3/55.							
Image: starting of the starti	CR PT CR CR	-	20-	- 20 	0			Medium sand, Medium sand, pebble	trace of silt trace of		43		Lanna .		772							
	DR PT CR PT CR PT CR			-22 - - - - -24	0.0			Medium sand Medium to coa trace of granul Coarse sand	arse sand ,trace of silt, e		52 52		URANA URANA URANA		13/21.5/>1			 			 	

Figure 2-3.13 Borehole log (BH-N3')

Projec The N	t for 0 lew E Regi ab Re	Des Constr irout (ulators public	ruction Group (in of Eyg	of of gpt		Borehole Bore: BH	e Lo I-N	ogę 4	ging	R	ecord	1	Drillin Dim€	ig Ho ensio	ole n	9	5C	S C In	anyu onsu Ic.	ltants
DRILI Drillin Drillin	LING ng Ca ng Ma	DETA ompai othod	NLS ny: Boi : Manu	ndok C Ial She	consultant Il and Auger	Drilling Date: Coordinates: 2 Ground Elevat	11/12 2840(tion:	/201 35.8 49.1	15 8 : 30 14 (m	5038 AMS	88.81 SL)	1 E 1	Drille Bore FOC I	d De Dian Eleva	epth: neter ation:	30 (r : 101 :Abde	nBG I.6 (r elaziz	L) nm) : Bond	dok (r	mAGL
Drilling Method	Recovery (%)	R.L. (m AMSL)	Depth (m BGL) Graphic Log	Fines	Field E Soi	Description of I Material	(b)	ows	SPT /300r	nm)	No. Blows	Permeability(cm/sec)	Elasity Modulus(MPa)	qu(kg/cm²)	Lab (2%)uM	Gs(kg/cm ²)	ory T svim,tv); Wvim,twin); Ce	est (, , , , , , , , , , , , , , , , , , ,	3S: C(kg/cm ²), p(¹), v	Borehole Stucture
1		11	•		Fill (asphalt, sa	nd, silt, day)							1							
			2		Clay and silt, tra	aces of sand, grey	-	20							54	3 2.72				
AGR		46	4		Clayey silt, trac	es of sand, grey		26							A 35 30	A 4				
		111			Clay and silt, tra	aces of sand, grey	-	29						15 15	¢₿	A 2.74 2				
ŲDS			6		Silty day, grey			40	38					A A 11) 2.5	28 28	67 2.71		A 0.16/16.9		5.8
AGR UDS	100	42-	8		Silty clay, grey		+	4 ³¹						. △ 34) 2.1 (6.	33 35	4 2.73 2		A 21/15.2		
Ň		111	10		Sandy clayey si grey	It, traces of granule,	-	23				-		(3.5)	⊴8 ≼27	2.72 2.7		0		
		38-	(100-20-0 (100)-20-0 (100)-20-0		Silt and day, so granule, grey	me sand, traces of			39						- 24- 24-	2.72 88				
		1111	12 8-08-08-08 8-08-08-08-08 8-08-08-08-08 8-08-08-08-08 8-08-08-08-08 8-08-08-08-08		Sand and silt, s granule Clayey sandy s	ome clay, traces of It, traces of granule,			451						- 48	2.72 2.6				
		+	14		Sand, some cla of granule, grey	y, some silt, traces			63						48-	2.62 2.62				
		34-	16		 Clayey silt, grey Sand, some silt grey 	traces of granule,	1	A33	$\langle \ $			4		11	40	2.65				
		11	.0.	- -	Sand, some silt granule, grey	some clay, some			58			A 6.0E				2.68				
		1	18		grey	, traces of granule,	-		6							4 2.71				
		30-			Sand, some cla	y, some silt, grey	-			1	00					A 2.65				
BLR		+	20		Sand, traces of	silt, grey	-		_	-	100	_	-			2.62	-	-		
					Sand, traces of	granule, traces of				-	100					9 2.62				
		-	22 0		silt, grey	-)					00	A 2.5E-5				61 26				
		26-	24	••••	Sand, some gra grey	nule, traces of silt.					100					67 2.				
		-			Sand, traces of silt, grey	granule, traces of					00	58				32				
		1	.0.		Sand, some gra grey	nule, traces of silt.					100	9.16				32 2.				
		-	20 .0	• • •	Sand, traces of silt, grey	granule, traces of					100					32 20				
		22-	200		Sandy gravel, t	aces of silt, grey					00					4 2				
		ŧ	0	1	Gravelly sand,	some silt, grey					100					3.5				
		+	.0.		Sand, traces of granule, grey	silt, traces of					00					32 2.6				
		19										6.7E-4				2				
		-	adat:	229	Graph	ic Log						_	D	rillin	g Met	thod	<u>.</u>			
			oncrete	ALL N	Sand(IIII) Sand(granule) Sand(gravel)	Silt(brick)	Silt	y Cla	y(brick)	NCR: Non (SPT: Stand	ore D	rilling	tion T	Test	AGR: BLR:	Aug Cabl	er Bor e tools	ing s (Bail	er)
		E B	Bravel		Sand(silt)	Silt(sand)	Silt	y Cla	y(san	9	UDS: Undis COR: Core	turbe Drillin	d Sam g	pling		*	Water	Level	(befo	re)

Figure 2-3.14 Borehole log (BH-N4)

RILI rillir rillir	ING	DE DE omp	AIL any: d: R	⊑yg .S Bor tan	pt Idok C 7 Drilli	Consultant	Drilling Date: Coordinates:	Drilling Date: 11/12/2015 Coordinates: 284081.46 : 3050383.18 Ground Elevation: 48.62 (mAMSL)				Drilled Depth: 33 (mBGL) Bore Diameter: 101.6 (mm) TOC Elevation:Abdelaziz Bondok						dok (r	nAG
75	-	-	-								1	6		Lab	orato	ory Te	est		en
Drilling Metho	Recovery (%	R.L. (m AMSL	Depth (m BGI	Graphic Log	Fines	Field Sc	Description of il Material	(blow	SPT s/300mr 국 윤 윤	n)	Permeability(cm/see	Elasity Modulus(MP	qu(kg/cm²)	(2%)UA	Gs(kg/cm ²)	v(m'/y), Mv(m'/MN), Co	5u: C(kg/cm²), φ(°)	35: C(kg/cm ²), @(⁷), y	0 8 Borehole Stuct
ICR		48-	0	8		Fill				1.						0	0		Dep
CR PT CR PT CR PT CR PT CR PT CR PT CR PT CR PT CR PT CR PT CR PT CR PT		44				Clayey silt, gre	ÿ	20 22 26 22 26 22 26 22 26 22 20 20 20 20 20 20 20 20 20 20 20 20	2	2000 0 1000 0 0 1000 0 1000 0 1000 0 1000 0 000 0 0000 0 0000 0 0									5 U.
PT CR PT C C C C C C C C C C C C C C C C C C		36- -	12 12 Sand, some 14 16 Sand, trace			Sand, some sil	t, grey f silt, grey		29 51 54 58 58 58 58 58	- 200 - 200									
		28	-20 -22 -24 -24			Sand, traces o	fsilt, grey												
NCR SPT NCR SPT NCR SPT NCR SPT NCR SPT NCR SPT NCR SPT		20	- 28 - 30 - 32 - 32	0.0.0.0.0.0		Sand, traces o granule, grey	f silt, traces of			100 100 100									
			- 34						1							- ii			

Figure 2-3.15 Borehole log (BH-N4*)

Project for Construction of The New Dirout Group of Regulators in the Arab Republic of Eygpt							Borehole Bore: BH	Log I-N5	gin	g R	ecord	1	Drillin Dime	ig Ho ensio	le n	SC Sanyu Consultant Inc.					
DRILI Drillir Drillir	LING ng Co ng Mo	DE omp etho	TAIL any d: F	.S : Mis Rotan	r Ray ⁄ Drill	mond F. ing	Drilling Date: 1 Coordinates: 2 Ground Elevat	2/13/20 83870. ion: 43.)15 09 : 3(.58 (m)5016 AMS	33.25 SL)	1	Drille Bore FOC I	d De Dian Eleva	pth: neter ntion:	25.4 : 101 M. E	5 (ml 1.6 (n ssam	BGL) nm) ı (mA	GL)		
Drilling Method	Recovery (%)	R.L. (m AMSL)	Depth (m BGL)	Graphic Log	Fines	Field I Sc	Description of il Material	(blow	SPT rs/300 9 8	mm) 8 8	No. Blows of Steps	Permeability(cm/sec)	Elasity Modulus(MPa)	qu(kg/cm²)	Lab (2%)uM	Gs(kg/cm ²)	ory To	est (,)# '(,uo/stance) on control (,)	DS; C(kg/cm ²), φ(°), γ	a Sorehole Stucture	
SPT NCR COR BS SPT	42 42 42 42 42 42 42 4 4 4 4 4 4 4 4 4 4 4 4 4		y loose, fine, dark ron oxides, sediments ctured calcareous bulk sample) ium stiff, dark brown, raaments	1 43 425			100 AN				A 37.3		0.293			-1.					
COR SPT	73	38-				-do- (Core 1.1 Silty day with dark brown, tra	m) sand, medium stiff, aces of rock fragments	 23			mans			A (0.68)	A 30.3	2.677	0.25/0.577/				
SPT NCR SPT NCR SPT NCR		34-				Fine silty sand Medium to fine medium dense iron oxides, po	(dark grey) sand, dense to , light brown, trace ofly graded	4 ⁶			555 1997 1998 1998	р 3.76-4							0.01/27.5(1.4)		
NCR SPT NCR SPT NCR SPT NCR			- - - - - - - - - - - - - - - - - -			Coarse to med of silt Coarse to med silt	lium sand ,with some		42 49 59		- 1.110000 - 1.500000 - 1.600000 - 1.600000	ک 7.6E-4									
SPT ICR SPT ICR SPT	-	the second	14	0 0		Coarse to meo silt, trace of gra Coarse to meo	lium sand traces of anule		44		1911973 1911973 1911975										
CR PT CR PT CR	-	- 26 -	- 18	0		Joose-medium Coarse to med silt, traces of p Coarse to med	i dense, traces of silt ium sand traces of ebble ium sand .medium to		38		,anat	A 7.6E-4									
PT CR PT CR PT			- 20	0.0.0		granule, traces Coarse to meo Upper part: co ,some of silt, L medium sand t granule	i of silt lium sand ,some of silt arse to medium sand ower part coarse to races of silt, traces of		36		, Bille Julie Julie										
CR CR			- 22	0.0.d		Coarse to meo silt Coarse to meo silt, traces of g	lium sand traces of lium sand traces of ranule		47	70	, ener	۵ 5.5E-4	*								
ICR SPT	-		26			Coarse to meo silt	lium sand traces of	_	6		, BIRS			rillie	o Met	hed					
			Brid Cor Fill Gra Rod Sar Sar	k horete ivel sk hd hd(clas		<u>Grap</u> Sand(fill) Sand(granule) Sand(gravel) Sand(silt) Sand/Gravel	hic Log Slitt Slitt(brick) Slitt(fill) Slitt(sand)	Silty Ci Silty Ci Silty Ci Silty Ci	ay ay(bric ay(fill) ay(san ay(stiff	k) d))	NCR: Non C SPT: Stand UDS: Undis COR: Core I	ore D ard P turbe Drillin	D rilling enetra d Sam g	tion T	g Met est	AGR: BLR:	Auge Cable Water Water	er Bor e tool: Level Level	ing s (Bail) (befo (after	er) ire) r)	

Figure 2-3.16 Borehole log (BH-N5)

Drilling Drilling	Col	DET mpa thou	AIL any: d: R	S Misi otary	r R 7 D	ayn rillii	nond F. ng	Drilling Date: 1 Coordinates: 2 Ground Elevat	2/10 839	0/201 98.69 43.2	5 9 : 30 2 (m	5017 AMS	2 L)	E T	Drille Bore TOC I	d De Dian Eleva	pth: neter tion:	. 25.45 (mBGL) r: 101.6 (mm) r:M. Essam (mAGL)						
Drilling Method	Kecovery (%)	R.L. (m AMSL)	Depth (m BGL)	Graphic Log	Fir		Field I Sc	Description of oil Material		SPT (blows/300mm) 승 응 육 융 응 원 No. Blows of Steps			Permeability(cm/sec)	Elasity Modulus(MPa)	qu(kg/cm²)	Lab (2%)um	Gs(kg/cm ²)	ory Te	cu: C(kg/cm²), q(")	DS: C(kg/cm ³), #([^]), Y	▲ Borehole Stucture			
SPT GCR GCR SPT GCR GCR SPT GCR GCR GCR SPT GCR GCR GCR GCR GCR GCR GCR GCR		42	-0 -2 				Clayey silt locs ,sediments from Red Bricks, Fin pebblas Concrele Silty clay Silty sand (da fine sand (brow of calcareous Medium to fine and about 5 c contain granulic Medium to fine granule of granulic Medium to fine granule to med calation of silt fine coloured g coarse to med granule, traces Coarse to med silt, traces of granule, traces of granule, coarse to med silt, traces of granule, fine coloured g coarse to med granule, traces Coarse to med silt, traces of granule, traces Silt so the coloured g coarse to med granule, traces Coarse to med silt, traces of granule, traces	e, dark grey n canal intured calcareous intured calcareous intured calcareous into the second second mish yellow)-traces pebbles, trace of silt sand, some of silt sand, some of silt sand, some of silt sand, some of silt of the sand, sand, some of silt of the sand, some of silt, at lower horizon rese sand, some of silt, at lower horizon rese sand, some of inule um sand, inter ayer, thin layer of of silt um sand, some of of silt			42			51E4 23E4 15E3		231)	212	2674	0.4.10.2530.254		0295(1.5)			
NCR SPT NCR SPT NCR SPT NCR SPT NCR SPT NCR SPT		22	- 20 - 22 - 22 				Coarse to med	um sand traces of silt ium sand,traces of anule		4	51 51 42	71	19555	A 3.4E-4										

Figure 2-3.17 Borehole log (BH-N6)

ne Ara DRILI	Regulatoria Regula	ilator publi DET	AIL	f Eyg .S Mie	pt	mond F	Bore: BH	Bore: BH-A1 A Drilling Date: 2/10/2016 Coordinates: 283905 : 3050398						Drilled Depth: 33.45 (mBGL) Bore Diameter: 101.6 (mm)							
Drillir	ig Me	tho	d: F	lotar	y Drill	ing	Ground Elevat	ion: 48.2	36 (mAN	/ISL)	TOC Elevation:M. Essam (mAGL)										
pot	(%)	SL)	GL)								sec)	VPa)		Lab	orato	ory Te	*	licture			
Drilling Meth	Recovery (R.L. (m AM:	Depth (m B(Graphic Log	Fines	Field St	Description of oil Material	(blows	SPT /300mm) 8 8 ई) B_No. Blows of Steps	^D ermeability(cm/	Elasity Modulus(I	qu(kg/cm²)	(2%)UAN	Gs(kg/cm²)	v(m'ty), Mv(m'IMN), C	5u: С(kg/cm ²), ф('	ss: C(ke(cm?), #('),	S Borehole Stu		
PT CR	48 - 0 Fill (sand, si fragments)					Fill (sand, silt, fragments)	gravel,shall	8		200							2				
PT CR PT CR PT		1.4 1.4 1.4	-2			Silty clay, trac	Fill (sand silt, red bricks, rock fragments, calcareous pebbles) Silty day, traces of rock fragments			- 2 ⁹⁴⁶ - 1 ⁹⁴⁶											
OR	100	44 -	-4					7							110			+ = + +	3.		
T T	100		-6			Silty clay		14		- 101			۵ (2.55)	3⊳	A 2.38	0.12/0.252/0.333	م 0.28/19				
R	100	40	- 8			-		7		.0.			A (2.53)	Å 29			Ľ				
T	100	1.1.1	_ 			Ciltu day at 1	1 11 20 m fine cond at			- 59											
T	100	1.1.1				11.30-11.45 n	i-ii.30 m, fine sand at 1	26		6/10/19				Ξ	T		F				
R T R T T R		36				- Fine sand, tra	ces of silt	20 19		- 38 ⁶ - 3 ⁸¹⁴	Δ 2.5E-4						+===				
R R T T R		32 -	- 16					23 25	5 3												
		28	- 18 - 20 - 22			Fine to mediu	m sand, traces of silt	26	63 50 55	125 178022 18026 19126 1916 1916 1916 1916	A 1.3E-4							+			
T		1.1.1							45	NBC2C2											
		24	- 24 - - - - 26	0.0.0		Fine to mediu trace of granu	m sand, traces of silt, le		4 ⁵⁶	- 18292 - 18292 - 18292											
R T R		1.1.1		×		Fine silty sand	1	30		anoto					÷			+			
T R T R T		20	- 28 - - - 30	×		Fine to mediu	m sand, traces of silt		43 46	914 ,41955 ,85355											
1		1.1.1		0 0		Coarse to me silt trace of gr	dium sand, traces of anule	32		, energine		1.04									
		16 -	-	0.0		Fine to mediu granule, trace	m sand, traces of of silt		64	1411											
-			34			Gran	hic Log						rilling			-	_	-	-		

Figure 2-3.18 Borehole log (BH-A1A)

Regulators in e Arab Republic of Eygpt Brilling DetAlls Drilling Date								Bore: BH	-A1 B	I-A1 B					n 	22 (mPCL)							
rillin rillin	g Co g Ma	DE omp etho	any: d: F	. 5 Mis otar	r Ra y D	ayn rillir	nond F. ng	Coordinates: 2 Ground Elevati	713/2016 83856 ion: 49.18	: 30503 31 (mAN	95 1SL)	E	orille Bore OC E	d De Dian Eleva	pth: neter tion:	33 (r : 101 M.Ri	nBGI I.6 (n zk (m	L) nm) IAGL	-) IM) AGL)				
Q	-	()	î		1	1						()	(ie		Lab	orate	ory Te	est					
Drilling Metho	Recovery (%	R.L. (m AMS	Depth (m BG	Graphic Log	Fin o S	es 001	Field I Sc	SPT (blows/300mm) o 응 육 용 용 ^은 No. Blows			Permeability(cm/se	Elasity Modulus(MI	qu(kg/cm²)	VVn(%2)	Gs(kg/cm²)	CV(m ⁻⁷ /v), MV(m ⁻² /MN), Co	cu: C(kg/am²), φ(°)	DS: C(kg/cm ²), p(¹), y	G				
CR PT CR		48 -	_0	***		-	Clayey silt				Linh			A) (9)	∆ ∆ 5.5 25								
OR PT	39	1	-2	2		-	Silty clay, rock	fragment and gravel	5		100		a ŝi	3			57	,-	+ = =)				
	67		-4											A (2.27)	∆ 30.7	A 2.678	A 0.202/0.3						
2Ť		44 -				-			A ¹⁵		3618						0.12						
R	67	-	-6		╈	t	Stiff silty clay,r	ock fragment	≜ ¹⁶		ATTR												
R	73		-8																				
Τ		40 -	-		-	+	Silty day, rock	fragment at ton Fine	A ¹⁸		4 ⁸¹⁰						3/0.609	0.5		en l			
R T	18		-10			1	sand, trace of	silt at the bottom	A ⁹		250	-		-		2.6	A 0.15/0.21	0.08/2		-			
R T R		1	-12						A ¹⁸		Noto									-			
R		36 -		•••					19			A 1.9E-4											
R T		1	-14			T	Fine sand, trac	e of silt	æ ¹⁸		6 ⁸⁰ 10					1							
R T R			- 16						21		71012												
R		32-			$\left \right $	+			A38		1877°												
R PT		-	- 18 - -			Ī	Fine to mediun	n sand, trace of silt	3 ³⁴		, Hone												
R R			-20				7.000.000.000		36 40	6	Control 200	A 8 2E-4		_		_							
R		28-		.0		+	Fine to medium coarse sand ,tr	n sand, trace of ace of silt, pebble	436		Anno Anno												
RT			-22	0				(A) 40 4 (A) (A) (A)	4	2	121125									1			
R R			-24			-	Fine to mediun coarse sand, tr	n sand, trace of ace of silt	A 39	4	13/18/25												
R		24 -				T			40		1011123			_					0				
R		-	- 26						A10		121952									a.			
T R			-28		-	-	Fine to mediun	n sand, trace of silt		15	13101												
T R T		20-	-			T				48	1411												
R			-30							48 48	112325												
T			-32			+	coarse to medi	um sand, trace of silt,		278	16216			~ ~						-			
4D		16-	34				trace of granul-				301-		8	1		4							
					<u></u>		Grap	nic Log					D	rilling	a Met	hod	J.						

Figure 2-3.19 Borehole log (BH-A1B)

3. Hydraulic Dimensions and Calculation

3-1 Purpose

In order to clarify the flow capacity of the canal, a non-uniform flow analysis was applied under design conditions. Effective waterhead, is the difference between the upstream of the high water level (US.HWL) and the downstream of the high water level (DS.HWL).

In the evaluation of the analysis, the calculated water level at the end of the upstream must be lower than US.HWL under the conditions of the maximum discharge flow, with DS.HWL as the starting point for calculations. A water head shortage is found when US. HWL is calculated.

3-2 Hydraulic calculation (Non-uniform flow analysis)

(1) Method of analysis

Tracking the water surface in non-uniform flow is carried out by solving the basic equations of non-uniform flow, using the stepwise calculation method, or the graphical method. Calculations are carried out from a given point; toward the upstream side in the case of steady flow to the downstream side in the case of rapid flow.

Stepwise calculation method assumes the water depths at successive points from a given point, and the calculation proceeds verifying the energy by applying Bernoulli's theory. This method has many merits: (1) calculation can be carried out at any cross-section regardless of rate of flow, (2) losses other than those incurred by friction can be calculated. It is therefore the most widely used computerized method. By dividing the water channel into ideal calculation sections and applying boundary conditions at the nodes, the calculation is carried out to obtain the successive shape of the water surface so that Bernoulli's equation is satisfied in each section. Applying Bernoulli's equation to cross-sections I and II in Figure 3-2.1, the following equations are obtained.

$$h_{1} + \frac{\alpha \cdot Q^{2}}{2 g \cdot A_{1}^{2}} + z_{1} + h_{f} = h_{2} + \frac{\alpha \cdot Q^{2}}{2 g \cdot A_{2}^{2}} + z_{2}$$
$$h_{f} = \frac{Q^{2} \cdot l}{2} \left(\frac{n_{1}^{2}}{R_{1}^{4/3} A_{1}^{2}} + \frac{n_{2}^{2}}{R_{2}^{4/3} A_{2}^{2}} \right)$$



Figure 3-2.1 Explanatory drawing for non-uniform flow calculation

Where, z: Height from bedrock to bottom of water channel (m)

h: Water depth (m)

- Q: Discharge (m³/s)
- v: Flow velocity (Q/A) (m/s)
- *i* : Slope of the water channel bottom
- h_f : Water head loss produced at cross-sections I, II (m)
- ℓ : Slope length between cross-sections I to II (m)
- R: Hydraulic radius (m)
- A: Area of cross-section of water (m^2)
- n: Roughness coefficient
- g: Gravitational acceleration 9.8 (m/s²)
- α : Energy correction function

Subscripts 1, 2: indicate values at cross-sections 1 and 2 respectively.

When the energy at cross-section I is given, the water depth is calculated at cross-section II so that adding the hydraulic head loss between cross-sections I and II to the height of this energy line gives the height at cross-section II.

(2) Result of calculations

The result of required upstream-water level calculations by non-uniform analysis is shown on Table 3-2.1.

Reg.name	Debr Vueef	Ibrohimio	Badr	aman	Abo	Sahahria	
Canal name	Banr fuser	Ibranimia	Badraman	Diroutiah	Abo Gabal	Irad Delgaw	Saneryia
Qmax	227 m ³ /s	186 m³/s	9 m³/s	12 m³/s	7 m³/s	9 m³/s	5 m³/s
DS.HWL	45.82 m	45.13 m	45.90 m	45.90 m	45.90 m	45.90 m	45.90 m
Required US. water level (calculated WL)	46.00 m	45.22 m	45.96 m	45.95 m	45.94 m	45.95 m	45.93 m
US.HWL	< 46.30 m	< 46.30 m	< 46.30 m	< 46.30 m	< 46.30 m	< 46.30 m	< 46.30 m
Judgment	0.K	0.K	0.K	0.K	0.K	0.K	0.K

Table 3-2.1 Result of calculation by non-uniform analysis

4. Determining the Regulator Axis

4-1 Background related to determining the regulator axis

(1) Review of the regulators axis selection in the F/S stage

When the regulator axis was studied in F/S stage in 2010, there were two examination steps; namely, preliminary and detailed examinations.

1) 1st Step: Preliminary examination

In the beginning, the following three locations (plans) were compared.

- **Plan A**: The same location of the DGRs (rehabilitation of DGRs)
- Plan B: Upstream of DGRs (new construction)
- Plan C: Downstream of DGRs (new construction)

As the result of preliminary examination, NDRGs shall be constructed downstream of DGRs, which means that Plan C will be adopted.

2) 2nd Step: Detailed examination

In the detailed examination, layouts of the regulator axis were selected taking the following points into consideration:

- To secure enough space for the construction yard with due consideration given to the condition of site,
- To secure easy maintenance and effective operations as proper water diversion works (regulators),
- To mitigate negative impacts of the construction of NDGRs on the DGRs,
- To select locations for the new Sahelyia and Abo Gabal regulators that will solve the sedimentation issue.



Figure 4-1.1 Preliminary layout of NDGRs' axis





Figure 4-1.2 Layout of NDGRs' axis in the detailed examination stage

In the context of the above matters, the following three locations (plans) were compared.

- **Plan C-1**: This layout is approximately 100m downstream of DGRs, and the new layout of Sahelyia and Abo Gabal regulators is in front of each of the existing regulators.
- **Plan C-2**: This layout is approximately 140m downstream of DGRs, and the new layout of Sahelyia and Abo Gabal regulators is in front of each of the existing regulators.
Plan C-3: The layouts of NDGRs are scattered. The Bahr Yusef and Badraman regulators are approximately 600m downstream of DGRs, and Ibrahimia regulator is approximately 1,000m downstream of DGRs. The new layout of Sahelyia and Abo Gabal regulators is in front of each of the existing regulators.

The assessment symbols are as follows:

- •: advantage
- ×: disadvantage.

Plan C-1: 100m downstream of DGRs

- This plan has the advantage of having proper distribution functions as an integrated regulator, as well as the stability of the structure, and ease of construction.
- \times The temporary cofferdam touches DGRs, so the apron and navigation lock on DGRs need to be partially demolished before the construction of NDGRs.

Plan C-2: 140m downstream of DGRs (adopted)

- This plan has the advantage of having proper distribution functions as an integrated regulator, as well as structural stability, and ease of construction (same as Plan C-1).
- Additionally, the temporary cofferdam does not reach to the DGRs in order to construct the NDGRs. This plan preserves the DGRs as historical monuments.

Plan C-3: 600-1,000m downstream of DGRs

- Set further downstream from Plan C-2, this plan is 600m-1,000m downstream of DGRs and avoids densely-populated area.
- \times The maintenance bridge on each regulator is not continuous. Therefore, it takes extra time to reach each regulator, making it difficult to maintain NDGRs properly.
- × Gate operation could be a difficult to regulate discharge as new regulators are substantially away from diversion place of DGRs. Discharge will therefore not be controlled by regulator gates of NDGRs, but by the dischargeable capacity of DGRs vents. This causes unexpected backwater to move upstream of NDGRs.
- \times The low elevation 140m ahead of the downstream requires the building of an embankment along the canal from the NDGRs to DGRs against the raised water level, because of the expansion of the backwater area. This would increase costs and affect the surrounding area through possible seepage.
- 3) Conclusion of F/S stage

As a result of detailed examination, it was decided that NDGRs would be build 140m downstream of DGRs as confirmed by TAC on 30th March, 2010, thereby adopting Plan C-2.

(2) Request for supplemental examination at the Basic Design stage

During the study on the basic design stage, the Egyptian side requested that impacts on existing DGRs in the construction stage be avoided, and suggested a plan in which the wire axis be set 150m downstream from the existing DGRs. The D/D consultants agreed to conduct a supplemental examination of the plan above and compare between the 140m and 150m plans.

4-2 Location of regulator axis

As the result of these deliberations, NDGRs will be located 140m downstream of the existing DGRs, and Sahelyia and Abo Gabal regulators will be located in front of the existing ones. This is in conformity with the decision at F/S stage approved at the 6th TAC meeting.

(1) Effect on existing DGRs

Double sheet piles for the cofferdam could mitigate the negative impacts to the DGR foundations in the construction stage. The embedded length of this sheet pile shall be secured to the necessary length to avoid the influence of piping and seepage underneath the DGRs onto the construction yard. The following formula from the Japanese design criteria will be used for the examination to mitigate the negative impacts.

F=L1/h1 and $L2/h2 \ge Fs$

where,

- L1 and L2: Creep (seepage) length
- h1: Water depth
- h2: Difference length between water
- level and level of construction yard

F: Safety factor

Fs: Required safety factor





No negative impacts of piping and seepage were observed during construction in the four previous Japanese grant aid projects along the Bahr Yusef canal. The stability of the existing regulator was secure, including the exiting one located just beside the double sheet pile cofferdam.

Therefore, no negative impacts such as piping and seepage are expected. Monitoring instruments/devices that inspect the stability of DGRs, are expected to be installed at the construction stage.

(2) Impact on groundwater

Comparing the impact on groundwater between 140m D/S which was applied in F/S stage (Plan 1) and 150m D/S which was suggested in B/D stage (Plan 1), it was expected that the Plan 1 has an advantage due to smaller upstream pooled area which makes smaller impact on the groundwater.

(3) Result

Following the evaluation, Table 4-2.1 shows the general advantage of 140m axis to 150m axis.



Table 4-2.1 Comparison of NDGRs' axis between 140m and 150m downstream of DGRs

	The second	The second shall be also add a scheme second shall be set by a second state of the second sec
	- Two mosques shall be relocated to other areas to avoid impact by construction	- Two mosques shall be relocated to other areas to avoid impact by construction
	WORK.	WORK.
4 Impact on	- The residential area downstream of the right bank of the Bahr Yusef canal,	- The residential area downstream of the right bank of the Bahr Yusef canal,
4. Impact on	which is close to the Irrigation Department, may be affected by the temporary	which is close to the Irrigation Department, may be affected by the temporary
vicinity	cofferdam.	cofferdam. However, as the affected area is larger than that in plan 1, therefore
		increasing the construction costs.
	Point: 1	Point: 0
	Total point : 7	Total point : 4
	Recommended	Not Recommended
	- The DGRs building according to both plans yields similar hydraulic impact,	- The DGRs building according to both plans yields similar hydraulic impact,
5. Comprehensive	but the lesser effect of seepage in plan 1 gives it an advantage over plan 2, as	but the greater effect of seepage in plan 2 puts it at a disadvantage versus plan
evaluation	does the lower construction cost for protection works.	1, as do the higher construction cost for protection works.
	Recommending the adoption of plan 1 for construction works 140m	

1) Maximum point shall be 2 points in conformity with the number of plans.

2) No item shall be given more weight in order to evaluate fairly.

• Attached comparison tables



5. Weir Type

5-1 Determining weir type

Weirs are either of the fixed type constructed on the rock layer, or the floating type constructed on the permeable layer. In the project, since the geological conditions are mainly sand and clay, the floating type weirs should be used in the NDGRs.

In the design of floating type, it is important to maintain the stability of the foundation, and avoid the rising of piping and scouring at the canal bed.

5-2 Study of gate and hoist type

5-2-1 Size of target gates

Based on the results of hydraulic and structural design of weir body, the target gate facility sizes are as follows.

There are eight gates for the large scale regulators (Bahr Yusef and Ibrahimia regulators) and eleven for the small scale regulators (Sahelyia, Badraman and Abo Gabal regulators).

Name of regulator	Bahr Yusef	Ibrahimia		
Clear span	6.00m	6.00m		
Gate height	6.55m	6.55m		
Area of a leaf	39.3m ²	39.3m ²		
Gate sill elevation	EL40.00m	EL40.00m		
Gate crest elevation	EL46.55m	EL46.55m		
Number of gate	4	4		

Table 5-2.1 Size of gates for the two large scale regulators

Table 5-2.2 Size of g	gates for the three	small scale regulators
		-

Name of regulator	Sahelyia	Badraman		Badraman Abo Gabal	
Name of canal	Sahelyia	Diroutiah	Badraman	Irad Delgaw	Abo Gabal
Clear span	2.00m	2.00m	2.00m	2.00m	2.00m
Gate height	3.55m	2.35m	2.65m	2.95m	2.95m
Area of a leaf	7.10m ²	4.70m ²	5.30m ²	5.90m ²	5.90m ²
Gate sill elevation	EL43.00m	EL44.20m	EL43.90m	EL43.60m	EL43.60m
Gate crest elevation	EL46.55m	EL46.55m	EL46.55m	EL46.55m	EL46.55m
Number of gate	2	3	2	2	2

5-2-2 Large scale regulators

(1) Type of gate structure

Bahr Yusef and Ibrahimia regulator are the important facilities which control about 90% of the total discharge from all the DGRs though gate functions. Therefore, the appropriate selection of gate type significantly impacts the functioning of all the regulators and their future maintenance. Generally, gate

types are classified by: the movement of the gate, the structure of gate leaf, the form of discharge, the type of hoist, etc. The fixed wheel vertical lift gate is the most suitable for both regulators in terms of regulator scale, Japanese and Egyptian experience, reliability, etc.

Although a radial gate was selected for the Naga Hammadi Barrage (clear span 17m x height 13.5m x 7 gates) and Assiut Barrage (clear span 17m x height 9.6m x 8 gates) which are now under construction, they are constructed in the Nile River and their scale and functions are different from those of DGR. A fixed wheel gate was selected for the Ibrahimia head regulator (clear span 5m x height 5m x 9 gates) which was recently renovated.



Figure 5-2.1 Examples of gate facilities in Egypt

From left: Assiut Barrage (Radial gate), Ibrahimia head regulator (fixed wheel gate), El Dahab regulator (overflow double leaf gate) The four regulators constructed by Japanese grant aid project along the Bahr Yusef canal, have overflow double leaf gates. These consist of two leaves and can easily control discharge and water levels. This type of gate was expected to be selected for use on the Bahr Yusef and Ibrahimia regulators, as they utilize Japanese technology and comply with STEP.

The discharge flow features of the double leaf gate were compared to those of single leaf gate, under the design conditions of discharge and canal water level. Studies clarified that control by overflow or underflow volume was greater using double leaves, as was accuracy and stable water diversion. The decision to adopt a double leaf overflow gate was made in the 10th TAC meeting held on January 31and February 7, 2016.

(2) Hoist type

Wire-rope winding type hoisting equipment, widely used in Japan was used in the four regulators constructed in the Bahr Yusef canal by the Japanese grant aid project. On the other hand, the hydraulic cylinder type has become popular in Egypt and was used in projects like the Ibrahimia head regulators, the Naga Hammadi Barrage, and the new Assiut Barrage.

Therefore, three types of hoists can be used with a double leaf gate, (1) electric wire rope winding type, (2) hydraulic cylinder direct attached type, and (3) hydraulic cylinder wire rope winding type. Upon comparison, the hydraulic cylinder direct attached type was found to be the most suitable, especially for future ease of maintenance works and landscape, and was therefore selected for use in the 10th TAC meeting.

		Table 5-2	.3 Comparison of c	discharge control be	etween single and	double leaf gate (1	<u>/2)</u>	(1/2)
Descrio	tion	Single 1	Leaf-gate			Double Leaf-gate		
		(Under-fle	ow control)	(Over-flo	(Over-flow control)		(Orlfice-flow control)	
Schematic	Schematic drawing				v U.S. WL h v D.S. WL			
Structural	leature	1)The gate consists of one gate 1 supported by steel beams to resis 2)Thickness of gate leaf is const arrangement of main girder is van	eaf, and it has skin plate which is at the water pressure. ant from the bottom to the top, iable.	1)The gate consists of two gate le gate. Each gate leaf has skin plate beams to resist the water pressur 2)Cenerally, the water pressure a than the lower gate, therefore, the thirnner than that of the lower gate 3)The height of the upper gate can water head.	eaves, a lower gate and an upper e which is supported by steel e. acting on the upper leaf is smaller e thickness of the upper gate is e. n be designed within a half of	 The gate consists of two gate which is supported by steel bear 2)Generally, The water pressure thickness of the upper gate is this 	leaves, a lower gate and an upper ga ns to resist the water pressure. acting on the upper leaf is smaller uner than that of the lower gate.	tte. Each gate leaf has skin plate than the lower gate, therefore,
	General	1)Form of flow is classified in f depending on the water level. 2)Fluctuation of discharge for the larger than that of over flow type accurately is inferior to the over 3)High velocity of flow usually of abrasion of apron concrete.	ree flow and submerged flow e change of gate openings is . The ability to control discharge flow control. cccurs and this might cause	 Form of flow is classified in co overflow depending on the water Fluctuation of discharge for the smaller than that of under flow ty discharge is possible. Discharge from under flow is a purpose. 	omplete overflow and submerged level and opening. e change of gate openings is ope. High accurate control of also possible according to the	1)Fluctuation of discharge for th 2)Discharge from under flow is	te change of gate openings is large also possible according to the purp	r than that of over flow type. xxxe.
		Free outflow	Submerged flow	Complete overflow	Submerged overflow	Free orifice flow	Incomplete submerged orifice flow	Complete submerged orifice flow
Hadaadha faataar				h h h	h.j	m m		
Hydrawic feature	Form of flow	Q=CaB(2gh e) ^{1/2} Q:Discharge (m ³ /6) C:Coefficient of discharge a:Opening (m) B:Spanlength (m) h:Upstream water depth (m)	$Q=C_{I} aB(2gh_{s})^{1/2}$ Q:Discharge (m ³ /s) C_{I} :Coefficient of discharge a: Opening (m) B:Span length (m) $h_{S}: Upstream water depth (m)$	Q=CBh ^{3/2} Q:Discharge (m ³ /s) C:Coefficient of discharge B:Span length (m) h:Overflow depth (m)	$\begin{array}{l} Q=CBh_1(h_1-h_2)^{1/2}\\ \dot{Q}: \text{Discharge }(m^3/s)\\ C: Coefficient of discharge\\ B: Span length (m)\\ h_1, h_2: \text{ eff fig. (m)} \end{array}$	$\begin{array}{l} Q=2/3 CB(2g)^{1/2} (H_2^{-1/2} - H_1^{-1/2}) \\ Q: Discharge (m^3/s) \\ C: Ccefficient of discharge \\ B: Span length (m) \\ H_1, H_2; \ of. \ fig. (m) \end{array}$	$\begin{array}{l} Q=CaB(2gH)^{1/2}\\ Q: Discharge (m^2/s)\\ C: Coefficient of cischarge\\ a: Opening (m)\\ B: Span length (m)\\ H: of. fig. (m) \end{array}$	Q=CaB(2gH) ^{1/2} Q:Discharge (m ³ /s) C:Coefficient of discharge a:Opening (m) B:Span length (m) H:Water level difference (;
		•Discharge volume Q is the function of h_0 and a. •Minimum clearance for the opening (a) is 0.10m owing to self-exiting vibration (It occurs under the condition in smaller clearance than 0.10m).	 It is hard for the stable discharge control because C is affected by three variables (h 1, h 2 and a). It is also unclear in the demarcation between free and submerged outflow. 	• Discharge volume Q is the function of only one variable, overflow depth h; therefore, discharge control is the simplest to operate because it is hydraulically superior condition. • Besides, this method has the best accuracy in discharge control.	 Discharge volume Q is the function of h l and h z. It is clear in the demarcation between complete overflow and submerged overflow. 	* Discharge volume Q is the function of H_1 and H_2 (or H_7 and a). * Minimum clearance for gate opening a is 0.10m owing to self-exiting vibration (It occurs under the condition in smaller clearance than 0.10m).	*Discharge volume Q is the function of H (water depth from the downstream vena contracta and q). *It is irrational to calculate Q around the boundary between complete and incomplete submerged flow owing to the inconsistency in those equations	* Discharge volume Q is the function of H (difference in water level between H_1 and H_2 and a , which is relatively stat in this condition.

Single Leaf-gate			Double Leaf-gate			
Descr	lption	(Under-flow control)	(Over-flow control)	(Over-flow control) (Orfflee-flow control)		
	General verification results of hydraulic consideration	General verification results of hydraulic consideration in unit gate flow control (free outflow), over-flow control (complete overflow This figure also indicates that over-flow control (complete overflow in gate opening, which means the over-flow control is superior met (free outflow) is the has the biggest discharge volume change amon	length among three discharge control methods which are under-), and orifice-flow control (free orifice flow)). w) has smallest discharge volume charge, in response to the charge hod to the others in discharge volume control (Under-flow control g three methods).	Opening(acm)*Discharge(Qcm ¹ /s/m) 6.00		
Hydraulic feature	Verification results of bodynamic	Opening-Discharge (Under-flow control)	Opening: Discharge (Over flow control)	Opening-Discharge (Ortific :- flow control)		
hydraulic consideration in the case of the Bahr-Yusef Reg.	 It is not subject to gate opening and is always submerged flow owing to high downstream water level. Minimum discharge volume (at minimum gate clearance, 0.10m) is about 10m³/s. When the discharge volume is more than 150m³/s, difference in discharge volume by gate opening is stable. 	 Boundary between complete overflow and submerged flow is when the opening is 2,10m. Under the condition that the discharge volume is less than 110m³/s, over-flow is superior to under-flow in accurate discharge control. Discharge volume control with highest accuracy can be possible when over-flow control by upper leaf and under-flow control by lower leaf are properly applied depending on gate opening. 	•Orifice flow control has equivalent property to under-flow control •Under the condition that opening a is more than 1.90m, the solution in discharge volume is irrational. •This method has unstable water state in small opening condition. •Considering the conditions above, there is no merit to apply this method.			
1)Both hydraulic cylinder type and wire ro applicable. Hoisting equipment		1)Both hydraulic cylinder type and wire rope winding type are applicable.	1)Both hydraulic cylinder type and wire rope winding type are applicable. 2)In the case that hook type of gate is installed for upper leaf and combined with lower gate, one set of hoisting device is used. 3)Installing two sets of hoisting equipment can make gateposts shorter by shortening apparent gates height when they are fully open.	1)Both hydraulic cylinder type and wire rope winding type are applicable. 2)Two sets of hoisting devices are necessary to operate each leaf. 3)Installing two sets of hoisting equipment can make gateposts shorter by shortening apparent gates height when they are fully open.		
Maintenance Comprehensive Evaluation		1)Periodical inspection and maintenance are possible by lifting up the gates.	1)Periodical inspection and maintenance are possible by lifting up the gates. 2)The number of items to be inspected is larger than that of single leaf type.	 Periodical inspection and maintenance are possible by lifting up the gates. The number of items to be inspected is larger than that of single leaf type. 		
		Accurate discharge control and stable diversion to the seven directions of canals are the major required function of NDGRs. This type is inferior to over-flow control in this point.	Accurate discharge control and stable diversion to the seven directions of canals are the major required function of NDG Rs. This type is superior to other types in this point.	Accurate discharge control and stable diversion to the seven directions of canals are the major required function of NDG Rs. This type is inferior to over-flow control in this point.		
		Δ	۵	×		

		Wire rope winding type			Oil-hyo	draulic	cylinder		
		(Electric motor)		W	Wire rope winding type		Direct attached type		
Schematic drawing	Drum Reducing gear Brake Motor Baffle plate		Baffle plate		The second contract of		<u>1287</u> <u>34</u>		
General characteristics	 1)This type is widely used for any lifting heights and loads except a case that requires closing pressure. 2)There are several sub-styles with different combinations of wiring and number of drums. 3)In case double leaf gate, wiring and placement of hoisting devices become complicated. 4)It is impossible to push down the gate leaf by the force of hoist. 		 The gate leaf is operated by hydraulic cylinder through wirerope. It is possible to install the hydraulic cylinder in a remote place from the gate leaf. The structure of hoisting device is usually complicated. It is better not use this type for a gate of large lifting height and large load because of difficulties in terms of structure. It is impossible to push down the gate leaf by the force of hoist. 		 A hydraulic cylinder rod is attached directly to the leaf and the leaf is operated by pressurized oil. This type is widely used for high pressure gates. It is advantageous when the opening of the gate leaf must be strictly adjusted or when the hoisting device should be installed in a narrow space. Not only pulling up the gate leaf but also pushing down it is possible by the force of hoist. 		he leaf strictly arrow		
		Gate leaf (Rolled steel)			Gate leaf (Rolled steel)			Gate leaf (Rolled steel)	
	Gate leaf	Roller		Gate leaf	Roller		Gate leaf	Roller	
		Watertight rubber			Watertight rubber			Watertight rubber	
	Guide frame (Stainless	steel)		Guide frame (Stainless s	teel)		Guide frame (Stainless st	teel)	
		Sheave			Sheave			Hydraulic pump	
Main components of the facility		Brake			Wire rope			Valve	
		Wire rope			Hydraulic pump			Bearing of motor	-
	Hoisting davias	Matan		Hoisting davias	Welen		Heisting davias	Culinder (EUE)	
	Hoisting device	Motor		Hoisting device	Valve		Hoisting device	Cylinder (SUS)	
		Bearing of motor		_	Bearing of motor			Cylinder packing	
		Clutch			Cylinder (SUS)				
		Reduction gear			Cylinder packing				
Civil structure	Since baffle plate is required to protect wire rope and pier becomes higher.	uired at the both edges of the gate leaf d to avoid vibration of it, the height of	+	Since baffle plate is required at the both edges of the gate leaf to protect wire rope and to avoid vibration of it, the height of pier becomes higher. +		Baffle plate is not require because the cylinder rods high stiffness. For this re lowered and the structure	ed at the both edges of the gate leaf s are made of stainless steel and have asson, the height of pier can be is relatively simple.	++	
Discharge control	When double leaf gate t well as underflow contr	type is applied, overflow control as ol is possible.	+	When double leaf gate type is applied, overflow control as well as underflow control is possible. +		+	When double leaf gate type is applied, overflow control as well as underflow control is possible. +		+
Arrangement and space for hoist	Wide space is necessary to install the equipment. +		There is a flexibility of placement. ++		++	Since the number of hoisting parts is few, necessary space for installation is small.		+++	
Maintenance	1)Necessary inspection and maintenance items are largest. +		1)Necessary inspection and maintenance items are larger. 2)Oil leakage must be monitored and avoided. Maintenance of hydraulic oil as well as packing is very important. +		+	1)Compared with mechanical type, necessary inspection items are small. 2)Oil leakage must be monitored and avoided. Maintenance of hydraulic oil as well as packing is very important.		. +	
Landscape	High piers and complic	ated hoisting devices affect landscape.	+	The height of piers is higher than that of hydraulic cylinder ++		++	The height of pier is shortest and hoisting devices are ++		++
Approximate cost of hoisting device (Gate size;B=8m x H=6.55m)	2.1	Million USD/set	+	1.8	Million USD/set	++	1.5 Million USD/set +4		+++
Recommendation							Recomme	nded plan by JICA survey team	

Table 5-2.5 Comparison of hoist types for the large scale regulators

Note: +++:Excellent ++:Good +:Average

5-2-3 Small scale regulators

(1) Structural type of gate

Badraman, Sahelyia, and Abo Gabal regulators divert into two canals except for the Sahelyia regulator. Considering their design discharge, gate height and width are $10m^3/s$, 3.0m and 2.0 m respectively, those regulators are classified as a small gate group with less than $10m^2$ of gate leaf area. The type of large gate is mainly the slide gate and the bottom hinge flap gate. The former's gate leaf moves up and down, and the latter's is moved by rotating on its hinge

The double leaf gate could be used with the small regulator, but the lower accuracy of operation as a result of the small discharge excludes it as a suitable choice.

After considering the merits and demerits of both gates as shown in Table 5-2.6, the slide type gate was approved at the 11th TAC based on cost and ease of maintenance. The hinge flap gate type was better at operating the water levels and discharge volume, but was not recommended because it had not been used in Egypt before.

As for the number of spindles; the two spindles type was approved at the 22nd TAC meeting.

Gate type	Slide gate	Bottom hinge flap gate		
Hoist type	Rack gear type/Screw spindle type	Hydraulic cylinder type		
Schematic drawing	Rack spartelectric mator)	Hydraulic cylinder		
General characteristics	 Screw spindle or rack gear which are attached to the leaf and the leaf are operated mechanically. This type is not appropriate for large went or high lift gate from view points of structural stiffness and mechanical effectivity. 	1)The gate leaf bottom is fixed to the careal bed by means of a hinge. 2)Both sides (or one side)of a hinge pin at the bottom of the gate leaf are supported by torque. The driving force is transmitted through a rocker arm installed in the pier by an oil hydraulic cytinder.		
Discharge control	Underflow only	Overflow only More accurate discharge control is possible.		
Civil structure	 Since the gate leaf is lifted up vertically, high pier and slab to install the hoisting devices are necessary. High piers and boist will affect landscape a little. 	1) This type requires shorter piers and matches with current landscape.		
1)Maintenance works are easier than overflow gate because the gate leaf can b fully lifted up. 2Hoisting device is standardized and unitized in Japan. It is difficult to inspect inside of the device. 3)Labrication to the movable parts is the main maintenance work. 4)It is difficult to release the floating debris by gate operation.		 Oil leakage must be monitored and avoided. Since the gate leaf is always submerged, stop logs are required to inspect the gate leaf and seal parts. Floating debris can be removed easily by gate operation. Prevention of sediment flowing into carel is possible. 		
Rough cost ratio	1.0	2.0		
Total gate leaf area	51m ²	61m ²		
Conclusion	Recommended	Discharge controllability is superior, but this type is not common in Egypt and costly as well.		

Table 5-2.6 Comparison table of gate types for the small scale regulators

(2) Hoist type

The hoist type of slide gate is best suited for the rack gear type as it is simply built and therefore easier to maintain. Models that close by force or close by self-weight are also available. After considering the appropriate number of shafts connecting to the gate leaf with regard to the clear span width or horizontal to vertical ratio, the Egyptian government and the Design WG found two shafts were best at promoting high stability during operation.

		Hoist	type
Gate type	Scale of gate	Rack type	Wire rope winch type
	Small scale	0	Δ
Wheel gate	Medium scale	0	0
	Large scale	Δ	0
Slide gate		0	×

Table 5	-275	Selection	of	hoist	tvi	ne
Table J	-2.1 0	Jelection	UI.	noisi	ιy	μc

Note: \circ : Appropriate to use

 \times : Inappropriate to use

 Δ : Appropriate to use depending on occasions

Source: Guidelines on sluice gates (Japanese)

6. Width and Number of Vents

Discharge volume of NDGRs determines vent width and number. The Bahr Yusef and Ibrahimia regulators are defined as the large regulars and the Sahelyia, Badraman, and Abo Gabal regulators are defined as the small regulars.

6-1 Two large scale regulators

(1) Procedure of study

A comparative study on the various combinations of width to number of vents was carried out as follows.

a) Assumptions on width and number of vents

The width or the clear span length of vents for large regulators constructed on the main canal is generally 4-6m according to the Egyptian textbook, *Part No. 2 Design of Hydraulic Structures, Spillways, Regulators and Barrages.* A width of 8m was selected based on a feasibility study as well as the specifications of existing regulators along the Bahr Yusef canal like El Dahab regulator which was constructed by a Japanese grant aid projects. Therefore vents 4,5,6,7 and 8m in width were considered, and the number of vents adjusted accordingly. Given the importance of the Bahr Yusef and Ibrahimia canals, and the importance of distributing risk in the event that one of the gates fails to operate, as well as a discussion between the Egyptian government and the survey team at the 10th TAC meeting, the minimum number of vents was set at three.

b) Hydraulic analysis by non-uniform flow calculation

The capacity of assumed flow section against the design maximum flow discharge was verified by non-uniform calculations on the condition that all the gates of new regulators are fully opened. The starting water level just downstream of the new regulators was the maximum water level which the Water Distribution Directorate in RGBS was able to provide.

	Bahr Yusef regulators	Ibrahimia regulators		
Design discharge	227m ³ /s	186m ³ /s		
Water level at the starting point	45.82m	45.13m		
Design upstream water level	46.30m	46.30m		

Table 6-1.1 Conditions of hydraulic calculation

c) Hydraulic judgment

If the calculated water level upstream of existing regulators is below the design intake water level (46.30m), the cross section of the new regulators is assumed to be enough to discharge the design volume. In addition, some relevant conditions in the Egyptian code needed to be met. The conditions to be examined are as follows.

- Check 1 : Capacity of design discharge flow
 Calculated water level at the upstream of existing regulators≤WL.46.30m
- Check 2 : The maximum allowable velocity (Vr) through vents 2 V_{DS}<Vr < 3 V_{DS}

where, Vr: Velocity through vents (Vr =1.00-2.00 m/s)

V_{DS}: Velocity of channel downstream (m/s)

➢ Check 3 : Flow area

 $(A_{DS} - Are) / A_{DS} \le 40\%$

where, Are : Area of the water way through the openings (m²)

 A_{DS} : Area of the canal cross section downstream the structure (m²)

Check 4 : The maximum allowable heading-up

$$h = \frac{V_{US}^2}{2gC^2} \left(\left(\frac{A_{US}}{A_r}\right)^2 - 1 \right) \le 10 \ cm$$

where, V_{US} : Velocity in channel without regulator (m/s)

Aus: Cross section area of flow without regulator (m²)

- Ar: Regulator vent area (m²)
- C: Factor depends on the vent width
- g : Acceleration of gravity $(=9.8 \text{m/s}^2)$

d) Comprehensive evaluation

A comprehensive evaluation of the combinations of the number and width of vents which meet the aforementioned hydraulic requirements was made to judge economy, discharge controllability, ease of maintenance, etc.

The costs of major civil works and gate facilities were roughly estimated as part of the economic evaluation.

(2) Result of study

For the comparative study, three combination were used, namely, 5m in width with 5 vents, 6m in width with 4 vents, and 8m in width with 3 vents, for both the Bahr Yusef and Ibrahimia regulators.

8m width was found to be the most economical and superior size in reducing construction area because the fewer number of piers results in the smallest total regulators width. However, the large regulators constructed on the main canals in Egypt, are within the 4-6m range, as described in the textbook. The exceptions to this rule are the four regulators constructed through the Japanese grant aid projects. The RGBS requested that what was successfully used in the past, in terms of operability and maintenance, be repeated. Consequently, the 6m wide vent, which is the second most economical choice, was selected for the Bahr Yusef and Ibrahimia regulators at the 10th TAC meeting.

Table 6-1.3 shows the results of an initial comparative study in which the Egyptian code is ignored to review feasibility. Table 6-1.4 shows the final version of the comparison which was approved by TAC in discussions between the survey team and the Egyptian government. Table 6-1.2 shows the design of vents on the large regulator.

Table e Hz Beergh er verke en tre large regulatere						
	New Bahr Yusef	New Ibrahimia				
Vent width	6.00m	6.00m				
No. of vents	4 vents	4 vents				
Sill level	EL.40.00m	EL.40.00m				

Table 6-1.2 Design of vents on the large regulators

					-		1	2.5			1		
Wid	th of vent(m)		4.	00	5.	00	6.	00	7.	00	8.	00	
Tota	l gate height()	m)	6.	55	6.	55	6.	55	6,	55	6,	55	
	Hydraulic	Number of vent	7	.8	6	7	5	6	4	5	3	4	
	calculation	1 Judgement(\$46.30m)	40.32	40.40 Ausilable	40.31 Not amilable	40.50	40.31 Not available	40.29	40.32 Not appliable	40.30 Available	40.33 Not apilable	40.40 Areitable	
egulator		Judgement (140.50m)											
Bahr Yusef R	s	chematic drawing	1. W ^{4.00} 1.00 1.0 ^{4.00}		10 ^{5.00} 7.8 ^{1.00} 7.8 ^{1.00} 7.8 ¹					1.00 2.00 1.00 2.00 1.00 2.00 3.00 2.00 1.00 2.00 1.00 2.00 3.00			
		Total width (m)	51	.90	52	.60	52	.50	49	.00	43	.50	
		Number of vent	2	3	2	3	2	3	2	3	2	3	
	Hydraulic	Flow velocity(m/s)	4.01	2.67	3.21	2,14	2.67	1.78	2.29	1.52	2.00	1.34	
5	calculation	Judgement(≤3.0m/s)	Not available	Available	Not available	Available	Available	Available	Asailable	Available	Available	Available	
Ibrahimi	Schematic drawing			1 St 4	()0 ^{-1.0} 7.3 ²	8 7 8 7 8 7 8 7 8 7 8 7 8 7 8 7 8 7 8 7	2 10 ⁶ 4 00	55 5.50 7.60 5.50		8 30 30 30 30 50			
		Total width (m)	20	.40	23	.40	18	.50	20	.50	22	.50	
Disc	harge control	lability	Lo Discharge rate per gate operation of gate be	ow opening is so small that comes complicated.				_		\rightarrow	Hi Discharge rate per gate operation of gat	gh opening is so large that e becomes easy.	
Easi	ness of maint	enance works	Le Inspection and mainte	ow nance items are larger,	-	1 2 3					Hi Inspection and mainten	gh ance items are smaller.	
Easi	ness of const	ruction (*1)	Lo Switching of coffer construction perio	ow dam is required and d becomes longer.		10				÷	Hi Switching of cofferd construction perio	gh am is not required and d becomes shorter.	
Ecor	10my (*2)		La The quantities of gate fac larg	ow illities and civil works are ger.	IN SAME AREAS IN	-				\rightarrow	Hi The quantities of gate fac sma	gh ilities and civil works are iller.	
			Bahr Yusef	Ibrahimia	Bahr Yusef	Ibrahimia	Bahr Yusef	Ibrahimia	Bahr Yusef	Ibrahimia	Bahr Yusef	Ibrahimia	
Con	crete volume	of main body(m ³)	11,600	4,700	11,200	5,200	11,000	4,100	9,900	4,400	8,600	4,600	
Num	ber of foundation	tion piles	520	220	500	230	500	190	450	200	390	210	
Tota	l weight of ga	te facilities(ton)	570	220	580	250	550	190	490	200	420	210	
Cost	for major ci	vil works(Million USD)	6.9	2.9	6.7	3.1	6.6	2.5	5.9	2.6	5.2	2.8	
Cost	of gate facili	ties(Million USD)	13.1	4.9	12.2	5.3	11	3.7	9.5	3.8	8.1	4.1	
	Total co	st (Million USD)	20.0	7.8	18.9	8.4	17,6	6.2	15.4	6.4	13.3	6.9	
		(ratio)	25	7.8 38)	2 (1.	7.3 35)	23	3.8 18)	21 (1.	.8 08)	20	0.2 00)	
	Rec	ommendation			1						Recommended plan	by JICA survey team	

Table 6-1.3 Number and width of vents for the large scale regulators (initial results)

*1: This item is the evaluation of Barh Yusef Regulator only. Regarding Itrahimia Regulator, there is no wide difference.
 *2: This is the comparison of the total cost.

(a)Bał	nr Yusef Regulator	(Design discharge =	$227 \text{ m}^{3}/\text{s}$	Maximum downstre	am water level= 45.82m)
Width	of vent(m)	5.00	6.00	8.00	Remarks
Numbe	r of vents designed by Egyptian code	5	4	3	
ulic k	Number of vents	5	4	3	
drau		45.99	46.00	46.01	≤Normal water level(=46.30m)
Hy c	Required Upstream WL. (m)	OK	OK	OK	(Inflow head loss coefficient=0.2)
Selecte	ed number of vent	5	4	3	Minimum number =3 vents
Total w	vidth including piers (m)	38.0	35.5	33.0	
· Se	Concrete volume of main $body(m^3)$	8,200	7,500	6,600	
rox	Number of foundation piles	370	340	300	
App	Bridge surface area(m ²)	380	355	330	RC bridge,Effective width=10m
° Ø	Total weight of gate facilities(ton)	432	392	353	Stoplogs (1set=2pairs)included
	Major civil works(Million USD) (a)	5.2	4.7	4.2	Main body, foundation and bridge
ost	Gate facilities(Million USD) (b)	9.0	7.7	6.4	Manufacture and Installation, stoplogs included
ŭ	(a) + (b)	14.2	12.4	10.6	
	Ratio of cost	(1.15)	(1.00)	(0.85)	
	Conclusion		Selected		
(b)Ibr	ahimia Regulator	(Design discharge =	$186 \text{ m}^3/\text{s}$	Maximum downstre	am water level= 45.13m)
Width	of vent(m)	5.00	6.00	8.00	Remarks
Numbe	r of vents designed by Egyptian code	5	4	3	
ic.	Number of vent	5	1	2	

Table 6-1.4 Number and width of vents for the large scale regulators (final results)

(b)Ibra	himia Regulator	(Design discharge =	$186 \text{ m}^3/\text{s}$	Maximum downstre	eam water level= 45.13m)
Width o	of vent(m)	5.00	6.00	8.00	Remarks
Numbe	r of vents designed by Egyptian code	5	4	3	
ılic k	Number of vent	5	4	3	
'drau thec]	Demined Hastreen W/L (m)	45.22	45.22	45.22	≤Normal water level(=46.30m)
Hy c	Required Opstream w.L. (m)	ОК	OK	OK	(Inflow head loss coefficient=0.2)
Selecte	d number of vent	5	4	3	Minimum number = 3 vents
Total w	idth including piers (m)	38.0	35.5	33.0	
· se	Concrete volume of main $body(m^3)$	8,200	7,500	6,600	
orox	Number of foundation piles	370	340	300	
App	Bridge surface area (m^2)	380	355	330	RC bridge,Effective width=10m
` Ø	Total weight of gate facilities(ton)	432	392	353	Stoplogs (1set=2pairs)included
	Major civil works(Million USD) (a)	5.2	4.7	4.2	Main body, foundation and bridge
ost	Gate facilities(Million USD) (b)	9.0	7.7	6.4	Manufacture and Installation, stoplogs included
ŭ	(a) + (b)	14.2	12.4	10.6	
	Ratio of cost	(1.15)	(1.00)	(0.85)	
	Conclusion		Selected		
	Bahr Yusef + Ibrahimia (Million USD)	28.4	24.8	21.2	
	(Ratio)	(1.15)	(1.00)	(0.85)	

6-2 Three small scale regulators

(1) Procedure of study

The small regulators are those in Badraman, Sahelyia, and Abo Gabal. Badraman and Abo Gabal regulators divert into two canals each. In these regulators, the results of reasonable combinations of vent width and numbers are shown in the 'Result of study' section below.

As for the Sahelyia and Abo Gabal regulators, the consideration of additional new hydraulic conditions was requested by the Egyptian side. The results are shown in the 'Result of additional considerations' section below.

1) Cross section and hydraulic conditions of downstream canals

Hydraulic parameters of connecting downstream canals such as flow area and velocity are obtained by uniform flow calculation based on the topographic survey result.

Regulator Name		New Sahelyia	New Ba	draman	New Ab	o Gabal
Canal Name		Sahelyia	Diroutiah	Badraman	Irad Delgaw	Abo Gabal
Design discharge	(m ³ /s)	5.0	12.0	9.0	9.0	7.0
Water Level	(m)	45.90	45.90	45.90	45.90	45.90
Bed level	(m)	43.80	43.50	43.25	43.25	43.60
Water depth	(m)	2.10	2.40	2.65	2.65	2.30
Bed Width	(m)	6.00	9.00	5.00	5.00	6.00
Side slope 1:N		1.0	1.5	1.5	1.5	1.0
Flow area	(m ²)	17.01	30.24	23.78	23.78	19.09
Coefficient roughne	ss	0.030	0.030	0.030	0.030	0.030
Canal bed slop		0.00005	0.00007	0.00007	0.00007	0.00007
Mean flow velocity	(m/s)	0.30	0.40	0.39	0.39	0.37
Design cross see	ction	E45.00	<u>ВС-15.9</u> <u>ВС-15.9</u> <u>ВС-15.9</u> <u>ВС-15.9</u>	₩1-4520 H-2.65 <u>H-48.55</u> <u>H-48.55</u> <u>H-48.55</u>	W1-45.99 H=2.65 H=45.25 H=4.00	₩L=4590 H=230 <u>B=6.00</u>

Table 6-2.1 Hydraulic conditions of downstream canals for the small scale regulators

2) Assumptions on width and number of vents

According to the textbook, *Part No. 2 Design of Hydraulic Structures, Spillways, Regulators and Barrages*, the width of vents for small scale regulators constructed in branch canals is almost less than 3m. Therefore, the examined width was within 3m in a 50cm unit. Given the importance of distributing risk in the event that one of the gates fails to operate, as well as a discussion between the RGBS and the survey team at the 11th TAC meeting, two vents were proposed and a comparative study was carried out to examine the proposal.

3) Hydraulic evaluation

In addition to the flow capacity, the following requirements stipulated in Egyptian code must be met.

- Check 1 : Capacity of design discharge flow
 Calculated water level at the upstream of new regulators≤WL.46.30m
- > Check 2 : The maximum allowable velocity (Vr) through vents
 - $2 V_{DS} < Vr < 3 V_{DS}$

where, Vr: velocity through vents (Vr = 1.00-1.50 m/s)

V_{DS}: Velocity of channel downstream (m/s)

 Check 3 : Number of vents and total length of regulator between abutments B2= (0.6to1.0)x B1

Where, B1:Channel bed width (m), B2:Width between abutments of regulator (m)

Check 4 : The maximum allowable heading-up

$$h = \frac{V_{US}^{2}}{2gC^{2}} \left(\left(\frac{A_{US}}{A_{r}} \right)^{2} - 1 \right) \le 10 \ cm$$

or
$$h = \alpha \beta \frac{V_{DS}^{2}}{2g}$$

Where, V_{US}: Velocity in channel without regulator (m/s)

 A_{US} : Cross section area of flow without regulator (m²)

Ar: Regulator vent area (m²)

C:Factor depends on the vent width

 α : Contraction ratio, β :Coefficient depending on a shape of pier

V_{DS}: Velocity of channel downstream (m/s)

g:Acceleration of gravity $(=9.8 \text{m/s}^2)$

4) Comprehensive evaluation

A comprehensive evaluation of the combinations of the number and width of vents which meet the aforementioned hydraulic requirements was made to judge economy, discharge controllability, ease of maintenance, etc.

The costs of major civil works and gate facilities were roughly estimated as part of the economic evaluation.

(2) Result of study

A hydraulic examination and a comparison of rough cost estimates were carried out for the three following cases.

- i) Case 1A: Width of vent is composed of 1.5m and 2.5m
- ii) Case 1B: Width of vent is composed of 2.0m and 2.5m
- iii) Case 1C: Width of vent is 2.0m only

Table 6-2.2 summarizes the results for cases 1A, 1B, and 1C.

As there is no great difference in the construction costs in the three cases, case 1C was selected at the 12th TAC meeting, since it was the option where one stoplog was shared for all regulators during repair works.

			-			-		(1/2)
	1	Regulator Name	New Sahelyia	New Ba	draman	New Ab	o Gabal	Rough cost ratio
		Canal Name	Sahelyia	Diroutiah	Badraman	Irad Delgaw	Abo Gabal	&
	Des	ign discharge (m ³ /s)	5.0	12.0	9.0	9.0	7.0	Comments
		Width and number of vents	1.50m × 2Vents	2.50m × 2Vents	2.50m × 2Vents	2.50m × 2Vents	1.50m × 2Vents	
		Gate height	Hgate=2.30m	Hgate=2.65m	Hgate=2.25m	Hgate=2.45m	Hgate=2.45m	
		Flow area	Ar=4.95m ² (<5.61)	Ar=10.00m ² (>9.98)	Ar=8.00m ² (>7.83)	Ar=9.00m ² (>7.83)	Ar=5.40m ² (<6.30)	
		Velocity	Vr=1.01m/s (1.0 <vr<1.5)< td=""><td>Vr=1.20m/s (1.0<vr<1.5)< td=""><td>Vr=1.13m/s (1.0<vr<1.5)< td=""><td>Vr=1.00m/s (1.0<vr<1.5)< td=""><td>Vr=1.30m/s (1.0<vr<1.5)< td=""><td></td></vr<1.5)<></td></vr<1.5)<></td></vr<1.5)<></td></vr<1.5)<></td></vr<1.5)<>	Vr=1.20m/s (1.0 <vr<1.5)< td=""><td>Vr=1.13m/s (1.0<vr<1.5)< td=""><td>Vr=1.00m/s (1.0<vr<1.5)< td=""><td>Vr=1.30m/s (1.0<vr<1.5)< td=""><td></td></vr<1.5)<></td></vr<1.5)<></td></vr<1.5)<></td></vr<1.5)<>	Vr=1.13m/s (1.0 <vr<1.5)< td=""><td>Vr=1.00m/s (1.0<vr<1.5)< td=""><td>Vr=1.30m/s (1.0<vr<1.5)< td=""><td></td></vr<1.5)<></td></vr<1.5)<></td></vr<1.5)<>	Vr=1.00m/s (1.0 <vr<1.5)< td=""><td>Vr=1.30m/s (1.0<vr<1.5)< td=""><td></td></vr<1.5)<></td></vr<1.5)<>	Vr=1.30m/s (1.0 <vr<1.5)< td=""><td></td></vr<1.5)<>	
) II	Width ratio (B1: Canal B2:Regulator)	B2/B1=0.67 (0.6~1.0)	B2/B1=0.67 (0.6~1.0)	B2/B1=1.20 (0.6~1.0)	B2/B1=1.20 (0.6~1.0)	B2/B1=0.67 (0.6~1.0)	
	x 2.5	Heading up	h=9.6cm (<10cm)	h=9.9cm (<10cm)	h=9.0cm (<10cm)	h=6.8cm (<10cm)	h=15.5cm/ 0.6cm 💥	
	: 2 different width (1.5m Slide gate (underflow)	Cross section of regulator	1.501.50 1.00 .00 .12.47.50 .00 .12.47.50 .00 .12.47.50 .00 .12.47.50 .00 .00 .12.47.50 .00 .00 .12.47.50 .00 .00 .00 .00 .00 .00 .00	1.50, 2.50, 00 2.50, 1.50 EL.47.50 WIL 16.30 EL.46.55	1.50, 2.50, 00, 2.50, 1.50 → EL.47.50 WL #630 → EL.46.55 SC → EL.44.30	1.50, 2.50 0 2.50 ↓ 50, 2.50 0 EL.47.3 ₩1, 46.30 EL.47.3 ₩1, 46.30 EL.47.3 ₩1, 46.30 EL.47.3 ₩1, 46.30 EL.47.3 ₩1, 46.30 FL.47.3 W1, 16.30 FL.47.3 W1, 16.30 FL.47.3 W1, 16.30 FL.47.3 W1, 16.30 FL.47.3 W1, 16.30 FL.47.3 W1, 16.30 FL.47.3 FL.4	100 100 150 150 50 6.55 6.55 FL 44.0 Abo Gabal	-Most economical plan -2types of stoplogs are required (1.5mx2.45m, 2.5mx2.65m)
	EIA	Concrete volume of main body(m ³)	772.2	669.5	639.2	125	0.1	
	SAS	Bridge surface area(m ²)	-	100	100	-		
	Ŭ	Total gate leaf area(m2)	6.9	13.25	11.25	12.25	7.35	
		Civil works(Million USD)	0.28	0.31	0.30	0.4	6	Cost ratio=1.00
=		Gate facilities(Million USD)	0.08	0.15	0.13	0.14	0.09	
sctio		Stop logs (Million USD)			0.02			
ss se dato		Total (Million USD)			1.97			
ı cro regu		Width and number of vents	2.00m × 2Vents	2.50m × 2Vents	2.00m × 2Vents	2.00m × 2Vents	2.00m × 2Vents	
of		Gate height	Hgate=1.90m	Hgate=2.65m	Hgate=2.65m	Hgate=2.40m	Hgate=2.40m	
ă		Flow area	Ar=5.00m ² (<5.61)	Ar=10.00m ² (>9.98)	Ar=8.00m ² (>7.83)	Ar=7.00m ² (<7.83)	Ar=7.00m ² (>6.30)	
		Velocity	Vr=1.00m/s (1.0 <vr<1.5)< td=""><td>Vr=1.20m/s (1.0<vr<1.5)< td=""><td>Vr=1.13m/s (1.0<vr<1.5)< td=""><td>Vr=1.29m/s (1.0<vr<1.5)< td=""><td>Vr=1.00m/s (1.0<vr<1.5)< td=""><td></td></vr<1.5)<></td></vr<1.5)<></td></vr<1.5)<></td></vr<1.5)<></td></vr<1.5)<>	Vr=1.20m/s (1.0 <vr<1.5)< td=""><td>Vr=1.13m/s (1.0<vr<1.5)< td=""><td>Vr=1.29m/s (1.0<vr<1.5)< td=""><td>Vr=1.00m/s (1.0<vr<1.5)< td=""><td></td></vr<1.5)<></td></vr<1.5)<></td></vr<1.5)<></td></vr<1.5)<>	Vr=1.13m/s (1.0 <vr<1.5)< td=""><td>Vr=1.29m/s (1.0<vr<1.5)< td=""><td>Vr=1.00m/s (1.0<vr<1.5)< td=""><td></td></vr<1.5)<></td></vr<1.5)<></td></vr<1.5)<>	Vr=1.29m/s (1.0 <vr<1.5)< td=""><td>Vr=1.00m/s (1.0<vr<1.5)< td=""><td></td></vr<1.5)<></td></vr<1.5)<>	Vr=1.00m/s (1.0 <vr<1.5)< td=""><td></td></vr<1.5)<>	
	Ê	Width ratio (B1: Canal B2:Regulator)	B2/B1=0.83 (0.6~1.0)	B2/B1=0.67 (0.6~1.0)	B2/B1=1.00 (0.6~1.0)	B2/B1=1.00 (0.6~1.0)	B2/B1=0.83 (0.6~1.0)	
	(2.5	Heading up	h=7.2cm (<10cm)	h=9.9cm (<10cm)	h=9.0cm (<10cm)	h=12.0cm/ 0.7cm 💥	h=6.7cm (<10cm)	
	: 2 different width (2.0m) Slide gate (underflow)	Cross section of regulator	1.50,200,200,150 -0.00 EL.47.50 	1.50, 2.50, 0.00, 2.50, 1.50 EL.47.50 WL. 46.30 EL.43.90	2.00 2.00 1.50 EL.47.50 WH:46:50 EL.46.55 C	1.50, 2.00, 2.00 EL.47.50 EL.47.50 EL.44.15 Irad Delgaw	2.00 1.00 2.00 1.50 5.55	-Cost is almost same as CASE1A -2types of stoplogs are required (2.0mx2.65m, 2.5mx2.65m)
	EIB	Concrete volume of main body(m ³)	886.8	669.5	621.7	125	6.0	
	CAS	Bridge surface area(m ²)	-	100	87.5	-		
	-	Total gate leaf area(m2)	7.6	13.25	10.6	9.6	9.6	
		Civil works(Million USD)	0.33	0.31	0.29	0.4	6	Cost ratio=1.02
		Gate facilities(Million USD)	0.09	0.15	0.12	0.11	0.11	1
		Stop logs (Million USD)			0.02			
		Total (Million USD)			2.00			1

Note ; () requirement by Egyptian code %H

Exchange rate; \$1=JPY121.93

Heading up given by "h= $\alpha\beta V^2/2g$ "

	Regulator Name	New Sahelyia	New Ba	draman	New Ab	o Gabal	Rough cost ratio
	Canal Name	Sahelyia	Diroutiah	Badraman	Irad Delgaw	Abo Gabal	&
D	Design discharge (m ³ /s)	5.0	12.0	9.0	9.0	7.0	Comments
	Width and number of vents	2.00m × 2Vents	2.00m × 3Vents	2.00m × 2Vents	2.00m × 2Vents	2.00m × 2Vents	
	Gate height	Hgate=1.90m	Hgate=2.35m	Hgate=2.65m	Hgate=2.40m	Hgate=2.40m	
	Flow area	Ar=5.00m ² (<5.61)	Ar=10.20m ² (>9.98)	Ar=8.00m ² (>7.83)	Ar=7.00m ² (<7.83)	Ar=7.00m ² (>6.30)	
	Velocity	Vr=1.00m/s (1.0 <vr<1.5)< td=""><td>Vr=1.18m/s (1.0<vr<1.5)< td=""><td>Vr=1.13m/s (1.0<vr<1.5)< td=""><td>Vr=1.29m/s (1.0<vr<1.5)< td=""><td>Vr=1.00m/s (1.0<vr<1.5)< td=""><td></td></vr<1.5)<></td></vr<1.5)<></td></vr<1.5)<></td></vr<1.5)<></td></vr<1.5)<>	Vr=1.18m/s (1.0 <vr<1.5)< td=""><td>Vr=1.13m/s (1.0<vr<1.5)< td=""><td>Vr=1.29m/s (1.0<vr<1.5)< td=""><td>Vr=1.00m/s (1.0<vr<1.5)< td=""><td></td></vr<1.5)<></td></vr<1.5)<></td></vr<1.5)<></td></vr<1.5)<>	Vr=1.13m/s (1.0 <vr<1.5)< td=""><td>Vr=1.29m/s (1.0<vr<1.5)< td=""><td>Vr=1.00m/s (1.0<vr<1.5)< td=""><td></td></vr<1.5)<></td></vr<1.5)<></td></vr<1.5)<>	Vr=1.29m/s (1.0 <vr<1.5)< td=""><td>Vr=1.00m/s (1.0<vr<1.5)< td=""><td></td></vr<1.5)<></td></vr<1.5)<>	Vr=1.00m/s (1.0 <vr<1.5)< td=""><td></td></vr<1.5)<>	
	Width ratio (B1: Canal B2:Regulator)	B2/B1=0.83 (0.6~1.0)	B2/B1=0.89 (0.6~1.0)	B2/B1=1.00 (0.6~1.0)	B2/B1=1.00 (0.6~1.0)	B2/B1=0.83 (0.6~1.0)	Recommended plan
<u>n</u>	Heading up	h=7.2cm (<10cm)	h=9.5cm (<10cm)	h=9.0cm (<10cm)	h=12.0cm/ 0.7cm 💥	h=6.7cm (<10cm)	
El C: Uniform width (2 Slide gate (underflow)	Cross section of regulator	1.50 2.00 2.00 1.50 1.00 ∠EL.47.50 WE46.30 ∠EL.46.55 CEL.44.65	1.50 2.00 2.00 2.00 50 1.00 0 00 EL.47.50 ₩ -46.50 EL.46.55 EL.44.20	1,50,2,00,1,30, → (1,50,2,0,1,30,1,30,1,30,1,30,1,30,1,30,1,30	1.50, 2.00, 2.00 EL.47.50 WL.46.30 EL.41.15 Irad Delgaw	2.00 1.50 6.55 6.55 6.55 6.55 6.55 6.55 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7 7	-Cost is almost same as CASE -Stoplog is only one type (2.0mx2.65m)
ISE	Concrete volume of main body(m ³)	886.8	830.2	621.7	12:	56.0	
	Bridge surface area(m ²)	-	125.0	87.5		-	
	Total gate leaf area(m2)	7.6	14.1	10.6	9.6	9.6	
	Civil works(Million USD)	0.33	0.39	0.29	0.	46	Cost ratio=1.05
	Gate facilities(Million USD)	0.09	0.16	0.12	0.11	0.11	
	Stop logs (Million USD)			0.01			
	Total (Million USD)			2.07			1

Exchange rate; \$1=JPY121.93

I -51

(3) Result of additional considerations

The new hydraulic conditions provided by the Design Working Group on the two small regulators (Sahelyia and Abo Gabal regulators) are:

- a) To be a structure capable of taking minimum discharge from the hydraulic view,
- b) To be at the same apron level as the existing Sahelyia and Abo Gabal regulators.

As a result of the hydraulic evaluation and compliance with Egyptian code, the reasonable combinations of vent width, numbers, and sill levels are shown in Table 6-2.5. These results were approved by the meeting held shortly after the 19th TAC meeting.

The applied design of small regulators is shown in Table 6-2.4.

Regulator	Sahelyia	Badr	aman	Abo Gabal				
name								
Canal name	Sahelyia	Diroutiah	Badraman	Irad Delgaw	Abo Gabal			
Vent width	2.00m	2.00m	2.00m	2.00m	2.00m			
Nos of vent	2 vents	3 vents	2 vents	2 vents	2 vents			
Sill level	EL.43.00m	EL.44.20m	EL.43.90m	EL.43.60m	EL.43.60m			

Table 6-2.4 Vent width and numbers of the two small scale regulators

			Regulator Name					New Sa	ahelyia										N	ew Ab	o Gabal							
Canal Name								Sahe	elyia							Irad D	elgaw				Abo Gabal							
		14/	ath and much an africante		2	.00m ×	2Vents			1.50m×3	2Vents		2	.00m ×	2Vents		1	.50m ×	2Vents		2	2.00m ×	2Vents		1	.50m ×	2Vents	
		W	lath and number of vents		2Vents O)pen	1Vent C	lose	2Vents C	Open	1Vent C	lose	2Vents C	pen	1Vent C	lose	2Vents O	pen	1Vent C	lose	2Vents C	Open	1Vent C	lose	2Vents C)pen	1Vent C	lose
		A	pron lebel	EL. (m)				43.	00							43.	60							43.	60			
			Max. design discharge (m³/s)					5.	0							9.	0							7.	0			
			U.S.W.L.	(m)				46.	30							46.	30							46.	30			
			D.S.W.L.	(m)				45.	90							45.	90							45.	90			
~			Gate height	Hgate (m)				3.5	5							2.9	95							2.9	95			
ırge	Ę		Flow area	Ar (m ²)	11.60		5.80		8.70		4.35		9.20		4.60		6.90		3.45		9.20		4.60		6.90		3.45	
cha	gula		Velocity	Vr (m/s)	0.43		0.86		0.57		1.15		0.98		1.96		1.30		2.61		0.76		1.52		1.01		2.03	
dis	Re		Width	B2 (m)	5.00		2.00		4.00		1.50		5.00		2.00		4.00		1.50		5.00		2.00		4.00		1.50	
gn	_		Flow area	Ac (m ²)	16.56		16.56	6	16.56	i	16.56	6	23.40		23.40)	23.40		23.40)	19.09)	19.09	9	19.09		19.09)
esi	Cana		Velocity	Vc (m/s)	0.30		0.30		0.30		0.30		0.39		0.39		0.39		0.39		0.37		0.37		0.37		0.37	
o J	Width B1 (m)		B1 (m)	4.50		4.50	1	4.50		4.50		3.30		3.30		3.30		3.30		6.00		6.00		6.00		6.00		
Nay		Check 1	2 < Vr/Vc < 3	Vr / Vc	1.42	NG	2.83	ОК	1.89	NG	3.78	NG	2.50	OK	5.01	NG	3.34	NG	6.68	NG	2.06	ОК	4.12	NG	2.74	ОК	5.49	NG
-	code	CHECK I	Vr =1.00~1.50m/s	Vr	0.43	NG	0.86	NG	0.57	NG	1.15	OK	0.98	NG	1.96	NG	1.30	ОК	2.61	NG	0.76	NG	1.52	NG	1.01	OK	2.03	NG
	tian	Check 2	0.6 < B2/B1< 1.0	B2 /B1	1.11	NG	0.44	NG	0.89	ОК	0.33	NG	1.52	NG	0.61	OK	1.21	NG	0.45	NG	0.83	ОК	0.33	NG	0.67	ОК	0.25	NG
	Egyp	Chook 2	h=Vc²/(2gC²)×((Ac/Ar)²-1) ≦	≦ 10cm	0.73	ОК	5.03	ОК	1.84	ОК	9.48	OK	6.33	ОК	28.80	NG	12.16	NG	52.10	NG	3.43	ОК	16.83	NG	6.90	ОК	30.72	NG
		CHECK J	$h=\alpha \times \beta \times Vc^2/(2g) \leq 10cm$		0.18	ОК	0.40	ОК	0.29	OK	0.45	ОК	0.61	ОК	0.81	OK	0.71	ОК	0.86	ОК	0.47	ОК	0.69	ОК	0.58	ОК	0.74	OK
			Min. design discharge (m³/s)					0.	6							1.	3							0.	9			
			U.S.W.L.	(m)				44.	30							44.	30							44.	30			
			D.S.W.L.	(m)				44.	22							44.	08							44.	29			
~	fo		Flow area	Ar (m ²)	4.88		2.44		3.66		1.83		1.92		0.96		1.44		0.72		2.76		1.38		2.07		1.04	
lrge	gula		Velocity	Vr (m/s)	0.12		0.25		0.16		0.33		0.68		1.35		0.90		1.81		0.33		0.65		0.43		0.87	
cha	ž		Width	B2 (m)	5.00		2.00		4.00		1.50		5.00		2.00		4.00		1.50		5.00		2.00		4.00		1.50	
dis	_		Flow area	Ac (m ²)	3.76		3.76		3.76		3.76		5.98		5.98		5.98		5.98		4.63		4.63		4.63		4.63	
gu	Cana		Velocity	Vc (m/s)	0.16		0.16		0.16		0.16		0.24		0.24		0.24		0.24		0.19		0.19		0.19		0.19	
esi			Width	B1 (m)	4.50		4.50		4.50	-	4.50		3.30		3.30		3.30	_	3.30	_	6.00		6.00		6.00		6.00	,
Ч	æ	Check 1	2 < Vr/Vc < 3	Vr / Vc	0.75	NG	1.51	NG	1.01	NG	2.01	OK	2.84	OK	5.67	NG	3.78	NG	7.56	NG	1.68	NG	3.35	NG	2.24	OK	4.47	NG
Min	cod	oncon r	Vr =1.00~1.50m/s	Vr	0.12	NG	0.25	NG	0.16	NG	0.33	NG	0.68	NG	1.35	OK	0.90	NG	1.81	NG	0.33	NG	0.65	NG	0.43	NG	0.87	NG
	ptian	Check 2	0.6 < B2/B1< 1.0	B2 /B1	1.11	NG	0.44	NG	0.89	OK	0.33	NG	1.52	NG	0.61	OK	1.21	NG	0.45	NG	0.83	ОК	0.33	NG	0.67	ОК	0.25	NG
	Egyl	Check 3	h=Vc²/(2gC²)×((Ac/Ar)²-1) ≦	≦ 10cm	-0.08	OK	0.28	OK	0.01	ОК	0.65	OK	3.77	OK	16.36	NG	7.03	ОК	29.42	NG	0.52	ОК	2.94	ОК	1.15	ОК	5.45	OK
			$h=\alpha \times \beta \times Vc^{2}/(2g) \leq 10cm$		(0.05)	OK	0.06	OK	0.00	OK	0.09	OK	0.26	OK	0.32	OK	0.29	OK	0.33	OK	0.10	ОК	0.18	ОК	0.14	OK	0.19	OK
	Availa	ble water	level (Non-uniform flow)	≦44.30m	44.22	OK	44.23	OK	44.23	OK	44.24	OK	44.10	OK	44.20	OK	44.12	OK	44.33	NG	44.30	OK	44.31	NG	44.30	OK	44.33	NG
[Japanese code] 0.6≤ Intake velocity (Vi)≤1.0 Vi (m/s)					0.38	NG	0.76	OK	0.51	NG	1.01	NG	0.83	OK	1.67	NG	1.11	NG	2.22	NG	0.65	ОК	1.30	NG	0.86	OK	1.73	NG

Table 6-2.5 Additional considerations on the two small scale regulators

Final Report Volume I Design of Regulators

7. Elevation of Main Structures

7-1 Sill elevation of apron

The elevation for the top of apron under the gate is determined by the location of the new regulators. The current bed elevation of the canal is set to avoid sediment problems, as there are no plans for the construction of a new canal.

The locations of the new regulators are grouped into two types: one for Abo Gabal and Sahelyia regulators, which are constructed upstream of the DGRs at a right angle against the flow direction (TYPE1), and another for Bahr Yusef, Badraman, and Ibrahimia regulators which are constructed downstream of the DGRs (TYPE2).

In response to strong requests from the Egyptian side, the sill level of the Abo Gabal and Sahelyia regulators should be of a particular height capable of taking water under the conditions of LLWL upstream with mini-discharge (refer to Chapter 6-2 (3)). The apron-apart from the sill parts-should be the same elevation as the existing one. In addition, the sill level should be 1.0m higher than the apron level. During the maintenance works for removing sedimentation, the elevation excavated should be less than the apron elevation (EL 1: refer to Figure 7-1.1)

The elevation of the latter type of regulators is set 0.5m higher than the current elevation of the upstream canal bed to account for unexpected sediments. Table 7-1.1 shows elevation of apron around gate sill.

Location Type	Regulator	Current canal bed GL.(m)	Elevation of the apron: EL.1 (m) ^{*1}	Elevation for the apron on the gate section: EL.2 (m) ^{*1}
U.S. of	Abo Gabal	43.0±	42.75	43.60
(TYPE1)	Sahelyia	44.0m±	41.55	43.00
	Bahr Yusef	38.5~39.5	39.50	40.00
D.S of	Badraman	43.0±	43.40	43.90
(TYPE2)	Diroutiah	43.5±	43.70	44.20
	Ibrahimia	39.5±	39.50	40.00

Table 7-1.1 Elevation of apron around gate sill

*1 : refer to Figure 7-1.1





7-2 Gate top elevation and height

The top elevation of the gate is designed as EL.46.55m (Upstream Design High Water Level 46.30m + Free Board 0.25m).

- Upstream Design High Water Level: US.H.W.L.= 46.30m
- Free Board: Fb = 0.25m

(Egyptian Code "Vol.3. Chap.5 Regulators and Gates")

• Top Elevation of the gate: EL.3=US.H.W.L.46.30m+0.25m

= EL. 46.55m

The height of the gate is designed as the difference in elevation between the top of the gate and the apron on the gate section, as shown in Table 7-2.1.

Regulator	Top elevation of the gate EL.3	Elevation of the apron on the gate section EL.2	Gate height H (m)	Remarks
Bahr Yusef	46.55m	40.00m	6.55m	Double leaf
Ibrahimia	46.55m	40.00m	6.65m	Double leaf
Sahelyia	46.55m	43.00m	3.55m	Single leaf
Diroutiah	46.55m	44.20m	2.35m	Single leaf
Badraman	46.55m	43.90m	2.65m	Single leaf
Abo Gabal	46.55m	43.60m	2.95m	Single leaf

Table 7-2.1 Gate height for each regulator



Figure 7-2.1 Schematic drawing for top elevation of the gate and its height

7-3 Bottom elevation of gate when fully opened

Bottom elevation of the fully open gate is designed as EL.47.50m (Upstream Unusual High Water Level 47.00m + Free board 0.50m).

- Upstream Unusual High Water Level: US.H.H.W.L.= 47.00m
- Free Board: Fb = 0.50m

(Egyptian Code "Vol.3. Chap.5 Regulators and Gates")

• Bottom elevation of the fully open gate: EL.4 = US.H.H.W.L.47.00m + 0.50m = EL.47.50m

7-4 Elevation of downstream at the end of apron

As for the elevation at the end of the apron, the harmful effects of scoring should be considered to avoid damage to the apron and promote regulator longevity. Since the existing canal elevation at the downstream is higher than that at the design apron level, the long-term stability of the regulators and their safety from serious damage is ensured with flat apron design.

Accordingly, "EL 1" in Chapter 7-1" should be the downstream design apron level.

8. Design of Weir Body

8-1 Design of weir body

Since the foundation is composed of unconsolidated sand, silt, or clay, the regulator is of the 'floating' type. For this regulator type, the design of the length of the apron and the thickness of the regulator body complies with Egyptian Code "Vol.3. Chapter 5 Regulators and Gates" and *Part No.2 Design of Hydraulic Structures Spillways Regulators Barrage* as below.

(1) Length of downstream apron

Bligh's equation is applied to the length of the downstream apron, which is shown below.

$$Ls = 0.61 \times C \times \sqrt{H}$$

Where, Ls: Length of downstream apron (m)

C: Constant of Bligh equation

 \angle H: Maximum difference between upstream and downstream in water level (m)

(2) Creep length

In order to prevent piping, it is necessary to keep enough creep length along the foundation of the regulator. Required creep length is selected as the largest of the values calculated by Bligh's method and Lane's method

① Bligh's method

S' $\geq C \times \angle H$

Where, S': Creep length along the foundation of the regulator (m)

C: Constant of Bligh's equation

∠H: Maximum difference between upstream and downstream in water level (m)

② Lane's method

 $L' \ge C' \times \bigtriangleup H$

Where, L': Creep length along the foundation of the regulator (m)

C': Weighted Creep constant for Lane's method

∠H: Maximum difference between upstream and downstream in water level (m)

Geological feature	C : Bligh	C' : Lane
Fine sand	15	7
Heavy clay	4	1.8

Table 8-1.1 Constant values for each method

(3) Thickness of regulator body

The thickness of the middle and downstream apron is determined by the balance of uplift pressure under the apron.

$$t = 1.3 \times \frac{\angle H - Hf}{\gamma - 1} - \frac{Hu \times t0}{S + t0}$$

Where, t: Required thickness of apron at the calculation point (m)

 \angle H: Maximum difference between upstream and downstream in water level (m)

Hf: Head loss of the seepage water up to the calculation point (m)

 γ : Specific gravity of the material for apron (kN/m²)

1.3: Safety Factor

Hu: Height of the middle pier (m)

t0: Thickness of the middle pier (m)

S: Vent Width (m)

(4) Results

Figure 8-1.1 to 8-1.4 show the summary results of the hydraulic design to determine the dimensions of the apron and the regulator body. The dimensions of the apron of the new Sahelyia and Abo Gabal regulators are the same as those of the existing apron, as the new apron will be connected to the existing one.



Figure 8-1.1 Result of the hydraulic design for the length of apron and the thickness of the regulator body (Bahr Yusef regulator)



Figure 8-1.2 Result of the hydraulic design for the length of apron and the thickness of the regulator body (Ibrahimia regulator)



(1) Design creep length

 $\begin{array}{ll} \mbox{Horizontal creep length} & :\Sigma H {=} 27.70m \\ \mbox{Vertical creep length} & :\Sigma V {=} 2.50 {+} 1.5 {\times} 2 {+} 1.00 {+} 1.50 {\times} 2 {+} 2.50 {=} 13.00m \\ \mbox{Design creep length} & :\Sigma L {=} \Sigma V {+} \Sigma H {=} 40.70m \end{array}$

(2) Piping a) Bligh method : S' =C× Δ H=4×2.60=10.40m \leq S= Σ L=40.70m (OK) b) Lane method : L' =C' × Δ H=1.8×2.60=4.68m \leq L= Σ V+1/3 Σ H=13.00+1/3×27.70=22.23m (OK)

Figure 8-1.3 Result of the hydraulic design for the length of apron and the thickness of the regulator body (Diroutiah regulator)



Figure 8-1.4 Result of the hydraulic design for the length of apron and the thickness of the regulator body (Badraman regulator)

8-2 Design of downstream apron

The downstream apron should be designed for the protection of the bed in the large Bahr Yusef and Ibrahimia regulators, whose structures are separated into weir body and apron. The downstream aprons are 31.5m long at the bottom and are structured in a U-shape. Their shape is different from the weir body, with a middle pier on the bottom slab.

Although the Egyptian side requested a U-shaped structure, (a single body structure connected to two side walls and a bottom slab) an evaluation of structure and foundation types showed that the L-type structure of an L-type wall and an apron slab should be used. The foundation type selected should be of the pile foundation type in conformity with the regulators.

These decisions were approved by 22^{nd} TAC, and the comparisons and evaluations are shown in Table 8-2.1.

Туре	L type wall	T type wall	U type
			(Raft foundation and one body)
Structure design	100 Empary woks	1.50 1	
	/.50	Note: thickness of footing is 1.5m, same as the regulator apron. If it is over 2m, temporary double sheet pile will be unstable.	Note: thickness of footing is 1.5m, same as regulator footing. If it is over 2m, temporary double sheet pie will be unstable.
Stability of raft foundation	Safe stability is not secured because of substantial	Safe stability is secured as follows:	Safe stability is secured as follows:
• for land sliding	1) normal condition:	$F_{s}=1.606 > 1.5 \cdots OK$	2) offset of horizontal stress.
for eccentricity	$F_{S}=0.504 < 1.5 \cdots NG$ $e=1.256 > 1.250 = B/6 \cdots NG$	$c=0.773 < 1.083 = B/6 \cdot OK$	⇒Stable OK
	2) seismic condition:	$F_{s}=1.653 > 1.15 \cdots OK$	
	Fs-0.442 < 1.15 ·····NG	$e = 0.647 < 2.167 = B/3 \cdots OK$	
	$e = -0.688 < 2.500 = B/3 \cdots OK$		
	(No good)	(Good)	(Good)
Stability of bearing capacity of raft foundation	The actual stress to the ground is larger than the allowable bearing capacity because of the large eccentricity, so it is not used as the raft foundation . Measurements of foundation type: 1) normal condition: $q^- 68.53 \text{ kN/m2} > \text{range out} \cdots \text{NG}$ (6.85 tf/m2) 2) seismic condition: $q^= 82.84 \text{ kN/m2} > \text{range out} \cdots \text{NG}$ (8.28tf/m2)	The actual stress to the ground is larger than the allowable bearing capacity because of the great eccentricity, so it is not used as the raft foundation . Measurements of foundation type: 1) normal condition: $q=215.20 \text{ kN/m2} > \text{range out} \cdots \text{NG}$ (21.5tf/m2) 2) seismic condition: $q=239.49 \text{ kN/m2} > \text{range out} \cdots \text{NG}$ (23.95tf/m2)	The actual stress to the ground at Bahr Yusef is larger than the allowable bearing capacity, but at Ibrahimia it is within allowable bearing capacity. 1) normal condition: $q^{-50.18 \text{ kN/m2} > 49.16 \text{ kN/m2} \cdot \text{NG}}$ $\leq 91.48 \text{ kN/m2} \cdot \text{OK}}$ (5.02 tf/m2 > 4.92 tf/m2) (< 9.15 tf/m2) *: upper value: Bahr Yusef, lower value: Ibrahimia
	(No good)	(No good)	(Moderate)

Table 8-2.1 Comparison table of wall types at downstream apron (1/3)

r'=						
Туре		L type wall	T type wall		U type (Paft foundation and ana body)	
Structural stress Note) Available steel bar should be loss than a25mm in		 Following bar arrangement is applied. 1) Wall: φ 22@200mm 2) Footing: φ 25@200mm 	Following bar arrangement is applied. 1) Wall: φ 22@200mm 2) Footing: φ 25@200mm		 (Raft foundation and one body) Following bar arrangement is applied. 1) Wall: \$\phi 22@200mm\$ 2) Footing: \$\phi 25@100mm\$ 	
should be <u>less than $\varphi 25mm$</u> in the comparison table for marketability.		\Rightarrow Structural stress safety \rightarrow OK	\Rightarrow Structural stress safety \rightarrow OK		 ⇒Structural stress without safety →NG Note) Long footing is affected by strong moment especially at the center of footing. 	
		(Good)	(Go	od)	(No <u>s</u>	jood)
	B, H, d (mm)	1000, 1500, 1430	1000, 15	500, 1430	1000, 15	00, 1430
Wall	M (kN∙m)	377.19 (37.72tf · m)	377.19 (37.72tf·m)		376.66 (37.67tf·m)	
	N (kN)	0.00	0.00		0.00	
	S (kN)	165.19 (16.52tf•m)	165.19 (16.52tf•m)		183.82 (18.38tf·m)	
	Bar-arrange	φ 22@200mm	φ 22@200mm		φ 22@200mm	
	σ c / σ ca (N/mm2)	$2.05 < 9.50 \leftarrow OK$ (20.5kgf/cm2 < 95kgf/cm2)	2.05 < 9.50 ← OK (20.5kgf/cm2 < 95kgf/cm2)		2.15 < 9.50 ← OK (20.5kgf/cm2 < 95kgf/cm2)	
	σ s / σ sa (N/mm2)	144.64 < 200.0 ←OK (1446.4kgf/cm2 < 2000kgf/cm2)	$144.64 < 200.0 \leftarrow OK$ (1446.4kgf/cm2 < 2000kgf/cm2)		144.85 < 200.0 ←OK (1448.5kgf/cm2 < 2000kgf/cm2)	
	τ c / τ ca (N/mm2)	0.116 < 0.7 ←OK (1.16kgf/cm2 < 7.0kgf/cm2)	$0.116 < 0.7 \leftarrow OK$ (1.16kgf/cm2 < 7.0kgf/cm2)		0.129 < 0.7 ←OK (1.29kgf/cm2 < 7.0kgf/cm2)	
	B, H, d (mm)	1000, 1500, 1430	1000, 15	500, 1430	1000, 15	00, 1430
	M (k N∙m)	377.19 (37.72tf · m)	(Front footing) -92.65(9.27tf·m)	(Back footing) 377.19 (37.72tf·m)	(Edge of footing) 376.67(37.67tf·m)	(Center of footing) -6192.41(619.24tf·m)
	N (kN)	0.00	0.00	0.00	0.00	0.00
	S (kN)	205.68 (20.57tf · m)	181.61 (18.16tf•m)	183.69 (18.37tf•m)	796.257 (79.63tf•m)	0.00
	Bar-arrange	φ 25@200mm (Dia. comply with U type)	$\phi 25@200$ mm (Dia. comply with U type)	$\phi 25@200$ mm (Dia. comply with U type)	¢ 25@ 100mm	φ 25@ 100mm
Footing	σ c / σ ca (N/mm2)	$1.93 < 9.50 \leftarrow OK$ (19.3kgf/cm2 < 95kgf/cm2)	0.47 < 9.50 ←OK (4.7kgf/cm2 <95kgf/cm2)	1.93 < 9.50 ← OK (19.3kgf/cm2 <95kgf/cm2)	2.15 < 9.50 ←OK (21.5kgf/cm2 <95kgf/cm2)	24.07 > 9.50←NG (240.1kgf/cm2 >95kgf/cm2)
	σ s / σ sa (N/mm2)	111.77 < 200.0 ← OK (1117.7kgť/cm2 < 2000kgť/cm2)	27.45 < 200.0 ←OK (274.5kgf/cm2 < 2000kgf/cm2)	111.77 < 200.0 ←OK (1117.7kgf/cm2 < 2000kgf/cm2)	144.85 < 200.0 ←OK (1448.5kgf/cm2 < 2000kgf/cm2)	941.62 > 200.0←NG (9416.2kgf/cm2 > 2000kgf/cm2)
	τ c / τ ca (N/mm2)	0.144 < 0.7 < OK (1.44kgf/cm2 < 7.0kgf/cm2)	$0.127 < 0.7 \leftarrow OK \\ (1.3kgf/cm2 < 7.0kgf/cm2)$	$0.129 < 0.805 \leftarrow OK$ (1.3kgf/cm2 < 8.05kgf/cm2)	$0.557 < 0.7 \leftarrow OK$ (5.6kgf/cm2 < 7.0kgf/cm2)	

Table 8-2.2 Comparison table of wall types at downstream apron (2/3)

Туре	L type wall	T type wall	U type
			(Raft foundation and one body)
Impact on construction	No negative impact on the construction works, but (pile) foundation works are needed for stability.	The back footing causes adverse effects to the double sheet piles of the diversion works. Considering the necessary length of back footing, the diversion area is forced to become narrow and the flow velocity becomes high.	Due to the large steel bar volume, footing must be thicker, due to the long span footing. The deep digging required for the deep footing causes high stress to the sheet pile of the diversion works. The concrete needs careful casting to avoid temperature stress cracks if the footing is very thick. However, the thick footing causes excess weight to the allowable bearing capacity.
			515
	(Good)	(No good)	(No good)
General evaluation and	(Good) Raft foundation is not applied.	(No good) Raft foundation is not applied.	(No good) Raft foundation is not applied in Bahr Yusef.
General evaluation and possibility of raf foundation	(Good) Raft foundation is not applied. Suitable measurements of the foundation shall be made. L-type wall is the most reasonable wall type for the Babr Yusef and Ibrahimia regulators	(No good) Raft foundation is not applied. Even if the length of backward footing is secured by the required one, the diversion area in the construction stage cannot be secured at safe flow velocity.	(No good) Raft foundation is not applied in Bahr Yusef. Ibrahimia might be available for raft foundation from the viewpoint of bearing capacity, but large moment and stress act on the footing. To ensure regulator longevity, it should avoid this stressful structure.
General evaluation and possibility of raf foundation	(Good) Raft foundation is not applied. Suitable measurements of the foundation shall be made. L-type wall is the most reasonable wall type for the Bahr Yusef and Ibrahimia regulators.	(No good) Raft foundation is not applied. Even if the length of backward footing is secured by the required one, the diversion area in the construction stage cannot be secured at safe flow velocity. T-type wall is not the best type for the Bahr Yusef and Ibrahimia regulators.	(No good) Raft foundation is not applied in Bahr Yusef. Ibrahimia might be available for raft foundation from the viewpoint of bearing capacity, but large moment and stress act on the footing. To ensure regulator longevity, it should avoid this stressful structure. U-type is not the best type for the Bahr Yusef and Ibrahimia regulators.

Remarks: Buttress type cannot be applied under the condition of low bearing capacity. Buttress type is usually effective under the following conditions: 1) high stress acting

on a vertical wall 10m or higher, 2) high stress acting on backward footing due to the heavy weight of the embankment.

Table 8-2.3 Comparison table of wall types at downstream apron (3/3)

9. Design of Canal Bed Protection

9-1 Basic design concept

The purpose of the bed protection works is to protect the dissipation and the local scouring downstream due to the high flow velocity. In the basic concept of design, the high flow velocity is gradually dissipated by the friction acting on the bed protection until it is the same velocity as that downstream of the canal at the end of the bed protection. This assumes that flowing beyond the limit of sediment movement has continuity of sediment transport, and equilibrium of the canal bed is preserved.

9-2 Length of canal bed protection

(1) Applicable gate operation for the new Bahr Yusef and Ibrahimia regulators

Underflow (submerged flow) gate operation is necessary for the new Bahr Yusef regulator when large discharge is required (refer to the upper chart of Figure 9-2.1). On the other hand, overflow gate operations can be applied to the new Ibrahimia regulator in any case (refer to the lower chart of Figure 9-2.1).




(2) Type of hydraulic jump

The type of hydraulic jump which occurs just downstream of the gate is classified into three cases based on the relation between sequent depth (y2) and tailwater depth (y2') (refer to Figure 9-2.2).



The study of the bed protection should consider the flow state in the case of underflow operation, assuming garbage flushing maintenance takes place.

The result of the study of the relation between sequent depth and tailwater depth at each discharge volume is shown in Figure 9-2.3. The tailwater depth (y2') is always larger than the sequent depth (y2) at any discharge volume, which is classified in case 3 of Figure 9-2.2.



New Bahr Yusef regulator

New Ibrahimia regulator

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Figure 9-2.3 Relation between sequent depth (y2) and tailwater depth (y2') at each discharge
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The results indicate that flow state is classified as submerged flow, not exposed jet flow, or exposed hydraulic jump as in cases 1 and 2 in Figure 9-2.2.

(3) Determination of the length of bed protection

Judging from the abovementioned flow conditions just downstream of the gate, the energy for the

hydraulic jump is found to be completely dissipated in the area of the downstream apron for both new regulators (and the flow state after the apron section is considered steady).

Therefore, the length of the bed protection is designed more as a connection canal, not as an energy dissipater.

Following numerous experiences in Japan, the length of the apron of a connection canal is recommended to be three to five times the design water depth (H). Thus, considering safety, the length is designed to be 30m (5 times H) from the downstream apron of both new Bahr Yusef and Ibrahimia regulators.

Regulator	Downstream water level	Elevation of downstream apron	Design water depth	Length of bed protection
	DS.HWL	EL end	Н	$(3\sim 5 H)$ Applied
New Bahr Yusef	45.82 m	39.50 m	6.32 m	18.96~31.60m ⇒ 30.00m
regulator				
New Ibrahimia	45.13 m	39.50 m	5.63 m	16.89~28.15m ⇒ 30.00m
regulator				

Table 9-2.1 Length of downstream bed protection (new Bahr Yusef and Ibrahimia regulators)

(4) Determination of the length of the bed protection (New Badraman regulator)

As for the new Badraman regulator, the same method as that applied to the two large regulators is used. The new Badraman regulator (toward both Badraman and Ditoutiah canals) is designed to be 15m in length, as shown in Table 9-2-2.

Regulator	Downstream water level	Elevation of downstream apron	Design Length of bed protect water depth		d protection
	DS.HWL	EL end	Н	(3∼5 H)	Applied
New Badraman	45.90 m	43.40 m	2.50 m	7.50~12.50m	➡15.00m
New Ditoutiah	45.90 m	43.70 m	2.20 m	6.60~11.00m	➡15.00m

Table 9-2.2 Length of downstream bed protection (new Badraman regulator)

[Reference: Japanese design standard]





9-3 Stone size for the canal bed protection

(1) Applied formula

A large number of researchers in institutes have suggested various formulae to determine suitable riprap weight and size for certain flow states.

In this study, those riprap properties were calculated corresponding to the flow velocity using the following four formulae, which take into account the relatively gentle flow state.

Isbash method (Isbash 1936)

$$V = C \times \left[2 \times g \times \frac{\gamma \, s - \gamma \, w}{\gamma \, w} \right]^{0.5} \times (D_{50})^{0.50}$$
$$D_{50} = \left[\frac{8 \times W_{50}}{\pi \, \gamma \, s} \right]^{1/3}$$

Where,

V	:	Average flow velocity (ft/s)
С	:	C=1.20
g	:	Acceleration f gravity ($g=32.2$ ft/s ²)
$\gamma_{\rm s}$:	Weight of riprap ($\gamma_s = 137 \text{ lb/ft}^3$)
$\gamma_{\rm w}$:	Weight of water ($\gamma_{\rm w}$ =62.5 lb/ft ³)
D ₅₀	:	Average diameter of a riprap (ft)
W ₅₀	:	Average weight of a riprap (lb)

• U.S. Geological Survey method (Blodgett 1981)

$$D_{50} = 0.01 V^{2.44}$$

$$D_{50} = \left[\frac{8 \times W_{50}}{\pi \gamma}\right]^{1/3}$$

Where,

V	:	Average flow velocity (ft/s)
$\gamma_{\rm s}$:	Weight of riprap ($\gamma_s = 137 \text{ lb/ft}^3$)
D_{50}	:	Average diameter of a riprap (ft)
W_{50}	:	Average weight of a riprap (lb)

USBR 1936

$$D_{50} = (Vb / 3.88)^2$$

$$D_{50} = \left[\frac{8 \times W_{50}}{\pi \gamma}\right]^{1/3}$$

Where,

Vb:Near bed velocity at 0.9d (m/s) γ_s :Weight of riprap ($\gamma_s=2,200 \text{ kg/m}^3$) D_{50} :Average diameter of a riprap (m) W_{50} :Average weight of a riprap (kg)

Osama 1995

$$D_{50} = (Vb / 4.3)^2$$
$$D_{50} = \left[\frac{8 \times W_{50}}{\pi \gamma_{s}}\right]^{1/3}$$

Where,

Vb	:	Near bed velocity at 0.9d (m/s)
γ_{s}	:	Weight of riprap ($\gamma_s=2,200 \text{ kg/m}^3$)
D ₅₀	:	Average diameter of a riprap (m)
W_{50}	:	Average weight of a riprap (kg)

(2) The flow velocity of formula to determine suitable riprap weight and size

In order to determine the average weight and diameter of riprap, the velocity for riprap design is set as 1.5 to 2.0 times the flow velocity (V), considering the temporary increase in velocity during gate maintenance and variations between calculated and actual flow velocities in each canal.

	Discharge Flow area Flow velocity		Velocity for the r	iprap design				
	Qmax (m ³ /s)	A (m ²)	V (m/s)	(1.5∼2.0 V)	Applied			
Bahr Yusef	227	151.68	1.50	2.25~3.00	⇒2.50			
Ibrahimia	186	135.12	1.38	2.07~2.76	⇒2.50			
Badraman	9	10.00	0.90	1.35~1.80	➡1.50			
Diroutiah	12	13.20	0.91	1.37~1.82	➡1.50			

Table 9-3.1 Flow velocity to determine the suitable riprap weight and scale

(3) Determination of the average riprap weight and diameter

Tables 9-3.2 to 9-3.5 show the results of calculations for each flow velocity utilizing the above four formulae. There are some large differences among the riprap weights as determined by the recommended formula, but the riprap weights and sizes for the bed protection works on the downstream side of the regulators are as follows:

• Bahr Yusef, Ibrahimia	:	$D_{50} = 0.40 m$	$\mathbf{W}_{50} = 60 \ \mathbf{kg}$
• Badraman, Ditoutiah	:	$D_{50} = 0.20 m$	$W_{50} = 10 \text{ kg}$

Table 9-3.2 Calculation result b	y Isbash method	(Isbash 1936)

V	a	С	γs	γw	D	50	W	50
(m/s)	(ft/s)		(lb/ft ³)	(lb/ft ³)	(m)	(ft)	(kg)	(lb)
0.50	1.64	0.86	137	62.5	0.01	0.05	0.00	0.01
1.00	3.28	0.86	137	62.5	0.06	0.19	0.17	0.37
1.50	4.92	0.86	137	62.5	0.13	0.43	1.89	4.17
2.00	6.56	0.86	137	62.5	0.23	0.76	10.64	23.45
2.50	8.20	0.86	137	62.5	0.36	1.18	40.58	89.45
3.00	9.84	0.86	137	62.5	0.52	1.71	121.16	267.11

Va		γs	D ₅₀		W ₅₀	
(m/s)	(ft/s)	(lb/ft ³)	(m)	(ft)	(kg)	(lb)
0.50	1.64	137	0.01	0.03	0.00	0.00
1.00	3.28	137	0.06	0.18	0.15	0.32
1.50	4.92	137	0.15	0.49	2.84	6.26
2.00	6.56	137	0.30	0.99	23.32	51.41
2.50	8.20	137	0.52	1.70	119.43	263.30
3.00	9.84	137	0.81	2.65	453.65	1000.14

Table 9-3.3 Calculation result by U.S. Geological Survey method (Blodgett 1981)

Table 9-3.4 Calculation result by USBR 1936

Vb	γs	D ₅₀	W ₅₀
(m/s)	(kg/m ³)	(m)	(kg)
0.50	2,200	0.02	0.00
1.00	2,200	0.07	0.25
1.50	2,200	0.15	2.88
2.00	2,200	0.27	16.20
2.50	2,200	0.42	61.79
3.00	2,200	0.60	184.50

Table 9-3.5 Calculation result by Osama 1995

Vb	γs	D ₅₀	W ₅₀
(m/s)	(kg/m ³)	(m)	(kg)
0.50	2,200	0.01	0.00
1.00	2,200	0.05	0.14
1.50	2,200	0.12	1.56
2.00	2,200	0.22	8.74
2.50	2,200	0.34	33.35
3.00	2,200	0.49	99.58

(4) Design of bed protection

The stone scale and design should be a combination of "Geotextile sheets + stones as filter $(0.1 \sim 0.2m)$ + riprap stones $(2 \sim 3 \times D_{50})$ ", which have been approved at the joint 22^{nd} TAC meeting with MMG and DWG. The approved designs are as follows.



[Reference: Calculations of Stone Gravel Size Distribution]

The compositions of bed protection materials and the purpose of installation are shown in Table 9-3.6.

Material	Purpose of Installation	Remarks			
Riprap Stone	Installed to protect the dissipation and the local scouring downstream due to the high flow velocity.	Bahr Yusef and Ibrahimia Regulators: D ₅₀ =40 cm Badraman Regulator: D ₅₀ =20 cm			
Gravel (Crushed stone)	Installed as the cushion material with rubble to prevent the damage of the geotextile sheets.				
Geotextile sheet	Installed to prevent the suction of the present bed materials and control the degradation of the streambed.				
Present streambed material	_	Fine sand D_{15} =0.14 mm, D_{50} =0.23 mm, and D_{85} =0.37 mm			

Table 9-3.6 Compositions of bed materials and purposes of installation

The specifications of the stone materials used for the bed protection works are examined based on the "Standard Gravel Curve" as presented by HRI, Egypt.

The crushed stone installed under the riprap is intended to function as the cushion material. For that crushed stone, the hydraulic specifications are not required.

However, the crushed stone is required to have an effective grain size for piping to protect the suction from the riprap stones



Figure 9-3.2 Standard gravel size distribution of riprap stone (Source: HRI)

in order to keep long-term stability. Thus, the crushed stone size specifications should satisfy the following equation:



		Nev Ne	v Bahr Yusef R w Ibrahimia Ro	Reg. eg.	New Badraman Reg.			
		Riprap	Crushed stone	Remarks	Riprap	Crushed stone	Remarks	
D ₁₅	(=0.5D ₅₀)	20 cm	1.25 cm	20/5.0=4	10	1.25	10/5.0=2	
D ₅₀		40 cm	2.5 cm	< 5 (OK)	20	2.5	< 5 (OK)	
D ₈₅	(=2.0D ₅₀)	80 cm	5.0 cm	,	80	5.0	, ,	

Table 9-3.7	Grain size	distribution	for bed	protection	materials

Present bed materials under the downstream apron



Sieve	3 in.	2 in.	1.5 in.	1 in.	3/4 in.	1/2 in.	3/8 in.	no. 4	no. 10	по. 20	no. 40	no. 60	по. 100	no. 200
Size (mm)	75	50	37.5	25.0	19.0	12.5	9,50	4.75	2.00	0.85	0.425	0.25	0.15	0.075
% Passing	100	100	100	100	100	100	100	100.0	98.9	98.4	95.1	61.2	16.9	4.5
Effective Diameter (D ₁₀)				: 0.108 D ₃₀ (mm) : 0.180 D ₆₀ (mm) : 0.247					Uniformity coefficient (Cu) : 2.283					
Description : SP Coefficient of curvature (Cc) :						: 1.204								
% gravel		0.00		% sand	l	95.52		% silt	4.4	18	% clay	7	0.00	

Percent passing by weight	Gr	ain size (mm)	Remarks
15%	D ₁₅	0.139	
50%	D ₅₀	0.225	
85%	D ₈₅	0.373	

10. Design of Pier

10-1Height and thickness of pier

(1) Height of pier

The height of the pier is determined by the bottom elevation and the height of a fully opened gate (EL.4 and h respectively), height of free-board (Fb), and the thickness of the regulator top (t) shown in Table 10-1.1.

Elevation of the pier top EL.5 = the bottom elevation of fully opened gate (EL.4) + the height of fully opened gate(h) + Free board (Fb) + the thickness of the regulator top (t)

Where, the bottom elevation of fully opened gate (EL.4): refer to 7-3.

Height of fully opened gate (h): lower gate height for the double leaf gate

Free board (Fb): Room for the gate structure (such as spoiler and hook) and free space during reel-up, which is 1.0m for a large scale gate and 0.5m for a small scale gate

Regulator	Bottom elevation of the fully open gate: EL.4 (m)	Height of fully open gate: h (m)	Free board: Fb (m)	Thickness of top regulator: t (m)	Elevation of the pier top: EL.5 (m)
Bahr Yusef	47.50	3.40	1.00	0.60	52.50
Ibrahimia	47.50	3.40	1.00	0.60	52.50
Sahelyia	47.50	3.55	0.50	0.50	52.05
Diroutiah	47.50	2.35	0.50	0.50	50.85
Badraman	47.50	2.65	0.50	0.50	51.15
Abo Gabal	47.50	2.95	0.50	0.50	51.45

Table 10-1.1 Height of pier for each regulator



Figure 10-1.1 Schematic drawing of the elevation of the bottom of the fully opened gate (EL.4) and pier top (EL.5)

(2) Thickness of pier

The thickness of the pier should leave enough room for the groove, the transference of the load of the gate onto the pier body, and for ensuring structural stability.

Experiential regulations from the Egyptian Code "Vol.3. Chap.5 Regulators and Gates," require 1/4 to 1/3 of the vent width. Moreover, another experiential formula is shown below from the textbook *Part No.2 Design of Hydraulic Structures Spillways Regulators Barrage*.

 $tp = (0,25 \sim 0.35) \times S \ge 1.00m$

where, tp: Thickness of the pier (m) *Minimum pier thickness is 1.00m

S: Vent width (m)

Thickness of the piers for large scale regulators (Bahr Yusef and Ibrahimia) and small scale regulators (Sahelyia, Badraman, and Abo Gabal) is calculated as follows.

Large scale regulators S=6.00m: tp = $(0.25 \sim 0.35) \times 6.00 = 1.50 \text{m} \sim 2.10 \text{m}$

Small scale regulators S=2.00m: tp = $(0.25 \sim 0.35) \times 2.00 = 0.50 \text{ m} \sim 0.70 \text{ m} \Rightarrow \text{ tp} = 1.00 \text{ m}$

Regarding the gate (double roller gate with hydraulic cylinder) for large scale regulators, the guide wall is not designed to reduce the height of piers. In this case, larger room (2.40m×0.85m) is required for the blockout.





Figure 10-1.2 Schematic drawing for pier width

tp = 0.85m (blockout for the groove)×2+0.80m (effective pier material width and gallery)

$$= 2.50m$$
)

Thus, the thickness of the piers is 2.50m for large scale regulators and 1.00m for small scale regulators.

10-2 Design of the superstructure of pier

Operation space is designed on top of the piers, taking into account space for a rack which lifts/lowers gate, as well as space for conducting inspections. For large scale regulators (New Bahr Yusef and Ibrahimia), clearance for gate extraction was designed with the base frame of the hydraulic cylinder. In addition, a rail for the hoist crane was designed.

The superstructure of the piers (operation space) is shown in Figure 10-2.1.



