FINAL REPORT
ON
PRELIMINARY SMALL DAM DESIGN
OF
RECHARGE/FLOOD CONTROL PROJECT

FEBRUARY, 1980

JAPAN INTERNATIONAL COOPERATION AGENCY

FINAL REPORT
ON
PRELIMINARY SMALL DAM DESIGN
OF
RECHARGE/FLOOD CONTROL PROJECT

FEBRUARY, 1980

JAPAN INTERNATIONAL COOPERATION AGENCY

H.E. Ahmed Abdulla Salman
Deputy Minister
Ministry of Agriculture and Fisheries
United Arab Emirates

Re: Submission of the Final Report on Preliminary Small Dam Design of Recharge/ Flood Control Project

Dear Your Excellency

It is own great pleasure to submit herewith our Final Report on Preliminary Small Dam Design of "Recharge/Flood control Project in the U.A.E. We were dispatched to your country by the Government of Japan, through the Japan International Cooperation Agency (JICA) from January 30, 1980 to February 16, 1980 in order to assist the Ministry of Agriculture and Fisheries in Making up the preliminary and basic standard design of the Project.

In cooperation with personal of the Ministry of Agriculture and Fisheries, we made field trip in the proposed dam sites and accomplished our studys.

We would be much pleased if the report could contribute to the performance of "Recharge/Flood Control Project" and also to the development of water resources and agriculture in the U.A.E.

We would like to appreciate friendship and assistance extended to us and to Cope that the Project would come into reality we remain.

Very respectfully yours

March, 1980

Yoshimasa Isozaki
Dam Geologist

Akinori Masuda
Dam Design Expert

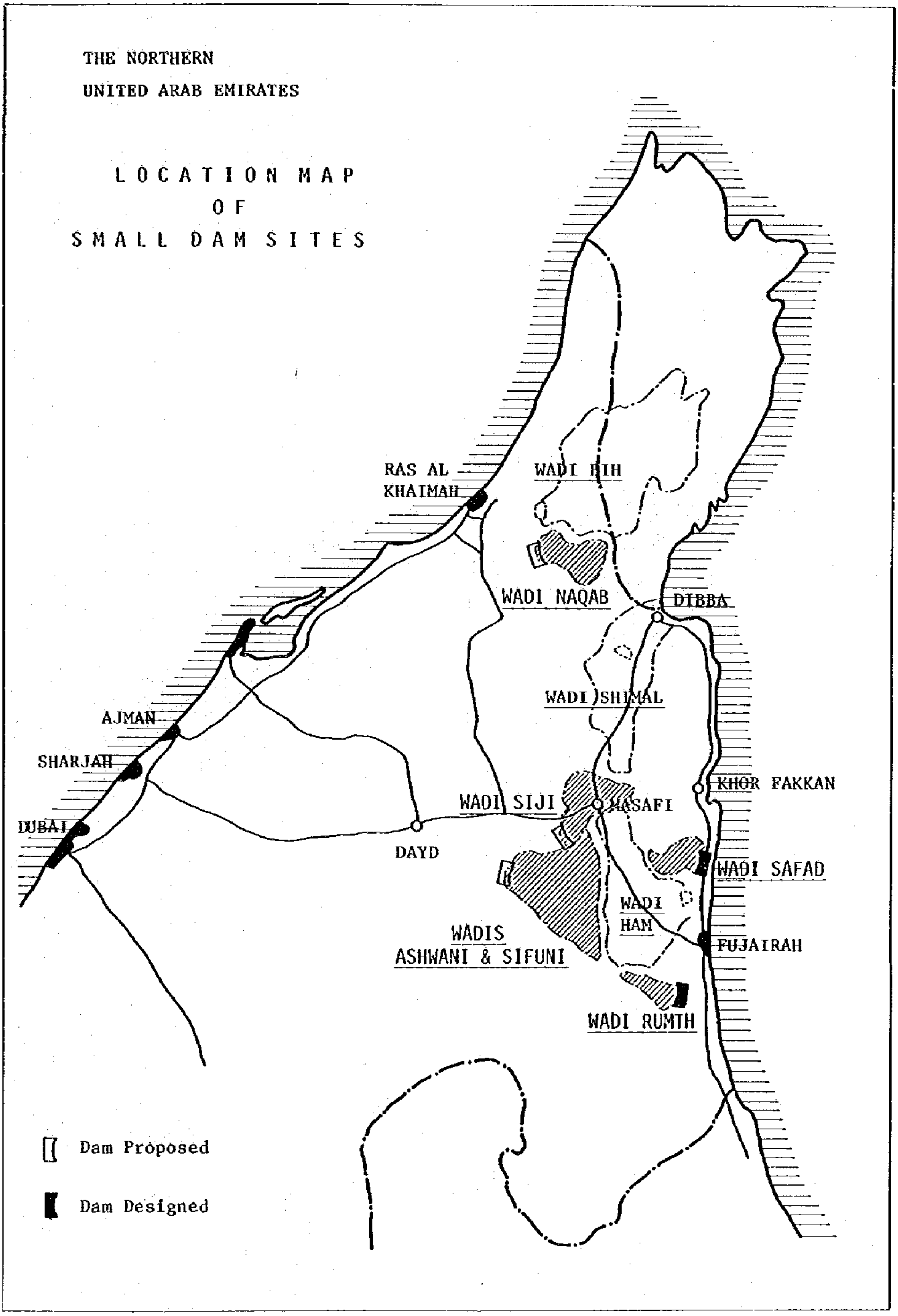
UNITED ARAB EMIRATES
MINISTRY OF AGRICULTURE & FISHERIES
SOIL & WATER DEPARTMENT

FINAL REPORT
ON
PRELIMINARY SMALL DAM DESIGN
OF
RECHARGE/FLOOD CONTROL PROJECT

JAPAN INTERNATIONAL COOPERATION AGENCY

SMALL DAM DESIGN TEAM

FEBRUARY, 1980


THE NORTHERN
UNITED ARAB EMIRATES
LOCATION MAP
OF
SMALL DAM SITES
RAS AL
KHAIMAH
WADI BIH
WADI NAQAB
DIBBA
AJMAN
WADI SHIMAL
SHARJAH
KHOR FAKKAN
WADI SIJI
MASAFI
DUBAI
DAYD
WADI SAFAD
WADI
HAM
WADIS
ASHWANI & SIFUNI
FUJAIRAH
WADI RUMTH
Dam Proposed
Dam Designed

Acknowledgment

Upon the request by the Ministry of Agriculture and Fisheries, U.A.E., we have investigated five small dam sites on wadies in the North-East part of the U.A.E. and we completed the preliminary designs of a diversion dam at Wadi Rumth and a small dam at Wadi Safad, staying in the U.A.E. from the 29th of January to the 16th of February 1980.

Although we had a very limited period to investigate the sites and to review the relevant information, and since all the necessary minimum data to complete detailed design were not available, we will report herein the results of our study, the designs and recommendations on the small dams on the wadies in a limited fashion. It is our great pleasure that our designing efforts could contribute to the performance of a "Recharge/Flood Control Project" as well as to the development of water resources and agriculture in U.A.E.

We would like to express our sincere apprecation to Mr. Obeid Karki, Director of Soil and Water Department, Ministry of Agriculture and Fisheries, U.A.E., and to those Officials of the Department listed hereinafter for their kindest cooperation and valuable guidance and suggestions during our survey trips and in the meetings held in Dubai.

Officials of Soil and Water Department

Dr. R.L. de Jong	Water Resources Advisor
Mr. Khalid Ataya	Deputy Director
Mr. Kurian	Hydrologist
Mr. Taissir Adlbi	Water Engineer

Feb. 1980

Yoshimasa Isozaki
Dam Geologist

Akinori Masuda
Dam Design Expert

SMALL DAM DESIGN TEAM OF JICA

CONTENTS

1. Progress and Outline of Project

1-1 Progress

Upon the request by the Ministry of Agriculture and Fisheries (M.A.F), U.A.E, the Government of Japan, through the Japan International Cooperation Agency (JICA), dispatched two Japanese dam design experts to the U.A.E in order to assist and to advise in the design of small dams, which are being planned by M.A.F, to be built on wadis located in the northern mountaines of the U.A.E in cooperation with expoerts of the U.A.E.

<Japanese experts>

Dr. YOSHIMASA ISOZAKI
Senior Engineering Geologist
Ministry of Agriculture, Forestry & Fishery, Japan

Mr. AKINORI MASUDA
Specialist Dam Engineering
Ministry of Agriculture, Forestry & Fishery, Japan

<U.A.E. experts>

Dr. R.L. de Jong
Water Resources Advisor

Mr. Kurian
Hydrologist

The study and design including site investigations of these proposed samll dams have been carried out by the team in accordance with the following schedule;

29, Jan., 80:	Arrival in Abu Dhabi
30, " " :	Open
31, " " :	Meeting in Japanese Embassy at Abu Dhabi Meeting in M.A.F Office at Dubai in attendance Mr. OBAID KARKI, Director, Soil and Water Department, M.A.E and Mr. K. MASUDA the Representative of Japanese Embassy. Preliminary briefing by M.A.F staff.

1, Feb., 80: Study and review of delivered technical documents.

2, " " : Meeting in M.A.F Office, Dubai for introduction to project, scope of work, arrangement of schedule etc. in attendance of Dr. R.L. De Jong. Water Resources Advisor, Mr. Kurea, Hydrologist of the M.A.F.

3, " " : Field trip to Wadi Naqab.

4, " " : " to Wadis Sifuni/Ashwani and Siji.

5, " " : " to Wadi Rumth and Wadi Safad.

6, " " :
7, " " : Planning and design at Khor Fakkan.
8, " " :
9, " " :

10, " " : Progress review meeting in attendance of Dr. De. Jong, Mr. Taiseer and Mr. Kurean.

11, " " : Field trip to Al Ain.

12, " " :
13, " " : Design & Report writing.

14, " " : Debriefing meeting in M.A.F Office Dubai submission of the draft design report.

15, " " : Open

16, " " : Debriefing meeting at Japanese Embassy.

17, " " : Departure to Japan.

1-2 Outline of the Project

The object of the project is requested from the U.A.E to identify suitable sites for recharge/flood control projects, and to have structures built on several wadis located in the northern mountains of the U.A.E., either by the Ministry or by an outside contractor. The following five locations were indicated to be studied and designed by the team.

Wadi Naqab
Wadi Sifuni/Ashwani
Wadi Siji
Wadi Rumth
Wadi Safad

The selection of dam site on each Wadi had already been made by M.A.F engineers and the results of some basic physiographic and hydrologic studies, listed below were given to the Japanese experts.

(1) Introduction Memorandam to Japanese Mission from Dr. De Jong.

(2) Work Plan of "Recharge/Flood Control Project".

(3) Tentative Program for the team.

(4) Location Maps of the Wadies.

(5) 1/25,000 Topo-Maps (6 sheets).

(6) Technical Data (Mainly Physiographic and Hydrological Data) for the Wadis.

(7) Design Drawings of proposed Dams at Wadis Bih and Ham.

(8) Report "Water Supply Augmentation for the United Arab Emirates" by U.S Department of the Interior Bureau of Reclamation, June 1979.

(9) Topo-Survey Drawings 1/100 for Proposed Dam Sites of Wadi Naqab, Wadis Sifuni/Ashwani, Wadi Rumth, Wadi Siji.

The objective of the Japanese expert as explained by M.A.F was, to develop a simple standard dam design, which can be easily modified so its can be used either as an overflow weir, a porous water retardation structure, or a diversion dyke.

And also explained by the M.A.E to prepare the technical specifications of main items for construction use.

In accordance with above objective and based on the data and informations delivered, 3 days of site visits to five Wadis as well as the following office studies have been performed.

As the result of these site investigations, and in line with M.A.F preference it was decided that the team would concentrate only on two dam sites located on the east coast: Wadi Rumth and Wadi Safad respectively.

The dam and diversion weir which were preliminarily designed by the team at this stage of project planning, are described in part 3 in this report.

2. Result of Field Survey

2-1 Wadi Naqab

Tentative damsite of Wadi Naqab, selected by M.A.F., is about 15 km south-east of the city of Ras Al Khaimah, just upstream from the point where Wadi Naqab emerges from the mountain front onto a gravel plain composed of the coalescing alluvial fan of the many wadis that flow westward from the mountains to the Arabian Gulf. Surface elevation at the damsite is about 85 m.a.m.s.l. It is the lowest practical damsite on Wadi Naqab.

Fig. 1 (a) shows an idealized cross section along the dam axis. The rock of the abutments is limestone and/or dolomite. Although a few small openings may follow bedding planes to considerable depth, they do not present any problems on bearing strength for a small dam. The wadi floor consists mainly of boulders and recent gravel, resting on a bed of compact older gravel. Their maximum depth at the damsite is not known.

The dam height, as intended, is limited to only about 3 ∿ 4 meters and it is restricted by habitation in upstream area. We would hardly expect that a dam of this magnitude would have any recharge effects of groundwater in the downstream area. Therefore, we recommend the consideration of a much large dam, of at least 10 m height, with a crest length of about 300 m.

2-2 Wadi Sifuni/Ashwani

The tentative damsite on Wadi Sifuni/Ashwani, selected by M.A.F., is about 25 km south-east of the city of Dayd, from this point Wadi Sifuni/Ashwani emerges into a gravel plain.

Fig. 1 (b) shows a schematic profile along the dam axis. The foundation of the dam abutments is formed by indurated older gravel bed. The Wadi floor consists of boulder to cobble sized recent gravel, resting on a former gravel bed.

The purpose of the dam is to temporalily retain the flood flows and permit the water to infiltrate into the wadi gravels. Whereas, it appears from superficial investigation that the wadi bed gravels may be too thin to provide substantial subsurface storage, it is recommended that no project at this site be implemended until more detailed site investigations is completed.

2-3 Wadi Siji

A dam as intended, on Wadi Siji about 2 km upstream of Siji village is considered technically feasible. A rockfill dam about 8 to 10 metres high and 70 to 80 metres long would create an inpounding reservoir of about 150,000 m^3 storage.

However, for the present purposes it will be necessary to clarify the hydrographical connection with the existing Siji dam about 2 km downstream of the proposed dam. Also some geological investigation into foundation conditions will be required to in sure stability.

Subject to completions of the recommended studies a suitable retardation structure could be designed and built in Wadi Siji.

2-4 Wadi Rumth

The damsite on Wadi Rumth, as intended, is about 6 km south-west of Kalba on the east slopes of the central mountains. Surface elevation at the damsite is about 60 m.a.m.s.l.

A fan spreding from the damsite to the coast forms the aquifer from which this coastal region takes most of its water. Recent large increases in abstraction from this aquifer has resulted in a dropping of the ground-water table and an increase of the salinity.

The Wadi Rumth Flood Detention Diversion Dam, as planned, would aid infiltration of flood water into the aquifer and provide some flood protection to the coastal region.

Details of the preliminary design are given in section 3-1.

2-5 Wadi Safad

The damsite on Wadi Safad, as intended, is about 2 km west of the east coast in the central mountains. Surface elevation at the damsite is about 80 m.a.m.s.l.

The foundation of the dam abutments is formed of compact hard basic plutonic rocks (Peridotites?) and the Wadi floor consists of boulder and cobble sized recent gravels.

As the dam has relatively steep abutments and a wide wadi floor, there is a suitable topography for spillway structures on the left abutment; a rock fill type dam is fitted to this site.

The Wadi Safad rock fill dam would create an impounding reservoir of about 70,000 CM storage with effective recharge of groundwater in the coastal' region.

Details of the preliminary design are given in section 3-2.

Table-1 Basic Technical Data for Five Small Dams

Parameters \ Wadis	Naqab	Ashwani Sifuni	Siji	Rumth	Safad
Drainage Area (km^2)	90.0	215.6	84.6	30.5	26.0
Time of Concentration (min.)	85.0	182.6	95.0	63.0	66.0
Intencity of Precipitation (cm/hr)	6.5	4.5	6.5	8.0	7.5
Peack Discharge (m^3/sec)	1,381 (2,910)	2,290	907	576	460
Specific Discharge (m^3/sec/km^2)	15.34 (32.33)	10.62	14.17	18.88	17.69
Annual Flow ($x10^3$ m^3)	1,461	4,678	1,760	759.5	668.2
Sediment Load (m^3/year/km^2)	170	154	178	194	198
Average Slope (I)	1/75	1/220	1/125	1/50	1/60
Dam Height (m)	4	2	8	5∿4	8∿10
Dam Length (m)	200	385	70	620	260
Approximate Storage Capacity (m^3)	50,000	100,000	150,000	-	70,000
Volume of Embankment (m^3)				16,000 (30,000) Excavation	55,000

2-6 Selection of Damsites

A) It may be said that the diversion weir and dam on those two wadies will be more effective to the object of the project than the other three project.

B) The damsites of these two wadis are more suitable for building a dam or diversion weir due to topographic condition than the others. Therefore, the construction costs of these two dams should be lower than those of the other three.

C) M.A.F expressed a survey preference for these two sites in response to requests by local people.

It was found that the topographic and geological conditions as well as the hydrological regime of each wadi were not clear. Since the schedule of the mission was too tight to study many details, these few unclear points or doubtful matters were left behind.

Nevertheless, the preliminary dam designs, an approximately 5 m high diversion dam on Wadi Rumth and an 8 ∿ 10 m high fill-type dam on Wadi Safad, have been made and details are shown in section 3 of this report.

Those preliminary designs should be followed by the final design, after collection of the results of detailed topographic surveys and other studies as recommended later.

The results of the studies made by the mission, the selection of two dams out of proposed five damsites for design, and the preliminary designs of the two, were discussed and reviewed with Dr. de Jong and Mr. Kurian at the progress meeting held in the M.A.F office on 10th Feb. 80 and the planning and the recommendation offered by the team were accepted basically by all personnel.

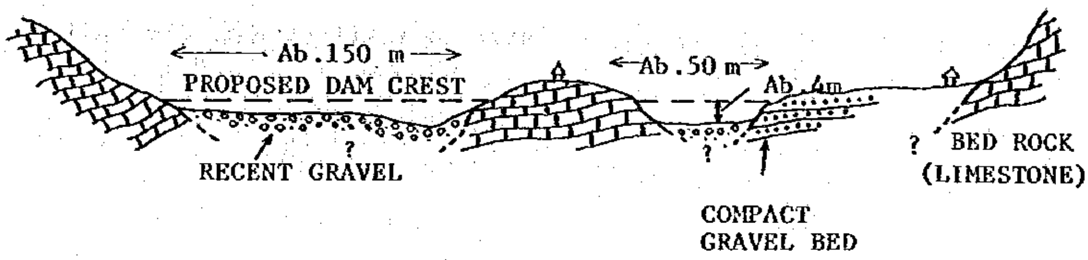


Fig-1 (A) WADI NAQAB DAMSITE

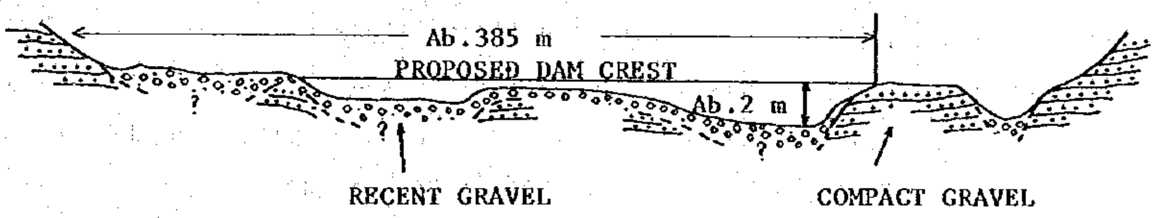


Fig-1 (B) WADI SIFUNI/ASHWANI DAMSITE

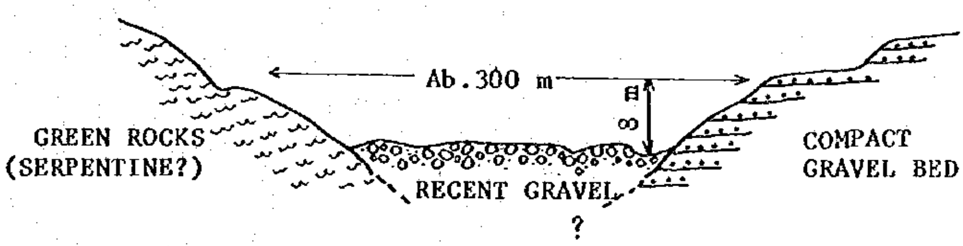


Fig-1 (C) WADI SIJI DAMSITE

3. Preliminary Design

3-1 Wadi Rumth Rock Fill Diversion Weir

The purpose of the proposed Wadi Rumth Dam is to divert the main flood-flows and to aid a greater volume of water to infiltrate in the wadi gravels.

Basic design data, proposed by the M.A.F, are given in Table-1 for the Wadi Rumth Dam.

A) Structural Data and Design Considerations.

Several diversion type structures were taken into consideration for Wadi Rumth. A preliminary appraisal design was prepared for a rockfill diversion dyke should be located as shown in Fig. 2 (A). The dyke would have a height of about 5m. There would be no spillway, as such, provided, but M.A.F may decide later, after gaining some experience with the project, to raise part of the dyke, and to leave the other part as an emergency relief spillway.

The dyke, as designed, would have a 1 : 2.5 upstream slope, a 1 : 2.0 downstream slope, and an about 1-m-deep cutoff wall. The dyke consists mainly of random gravels, excavated from the area upstream. Gravels for riprap should be hard and durable with good gradation containing no fines. Furthermore, the upstream slope is protected from scour and erosion by a gabion structure. (see Fig. 2 (B))

If the diversion dyke would be extende to the down stream small hill, it is possible that the greater volume of infiltrate water would be recharging the groundwater of northeast farmland.

Details of hydraulic calculation for wadi floor and of stability analysis of embankment are given in Appendix (A).

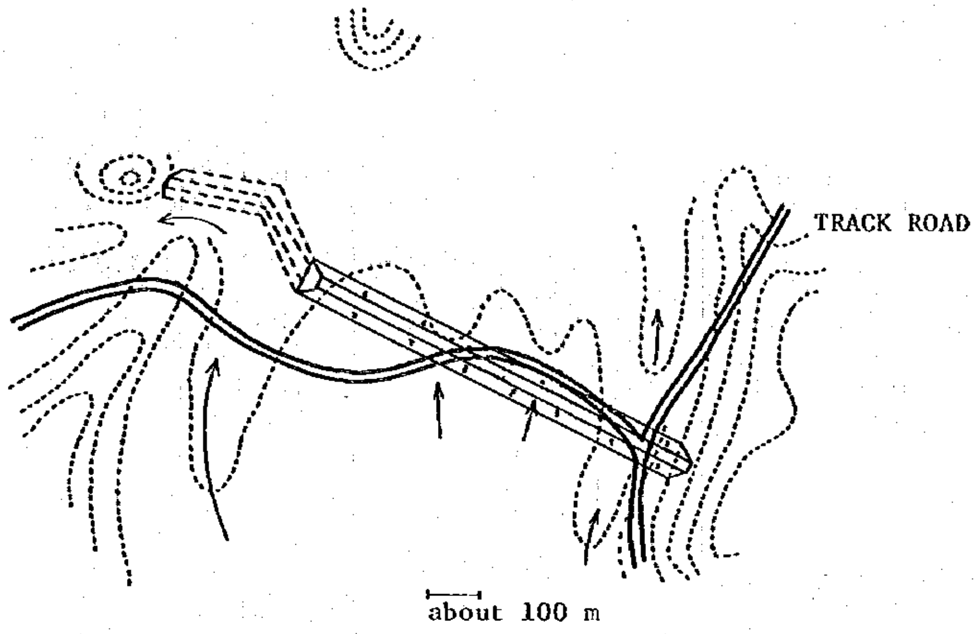


Fig-2 (A) LOCATION MAP OF WADI RAMUTH DIVERSION DAM

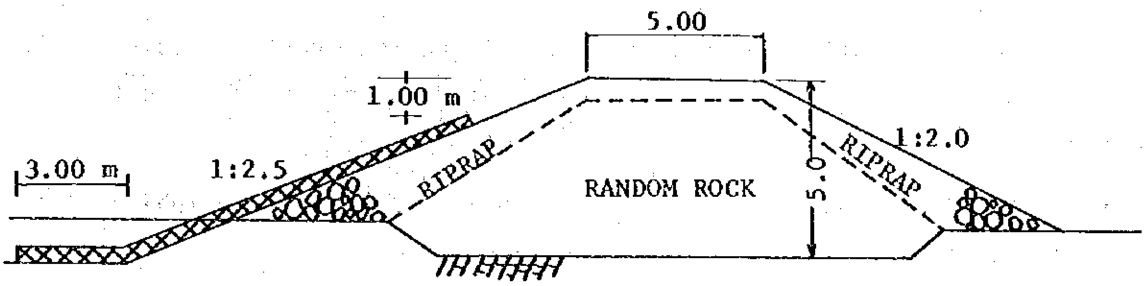


Fig-2 (B) STANDARD CROSS SECTION

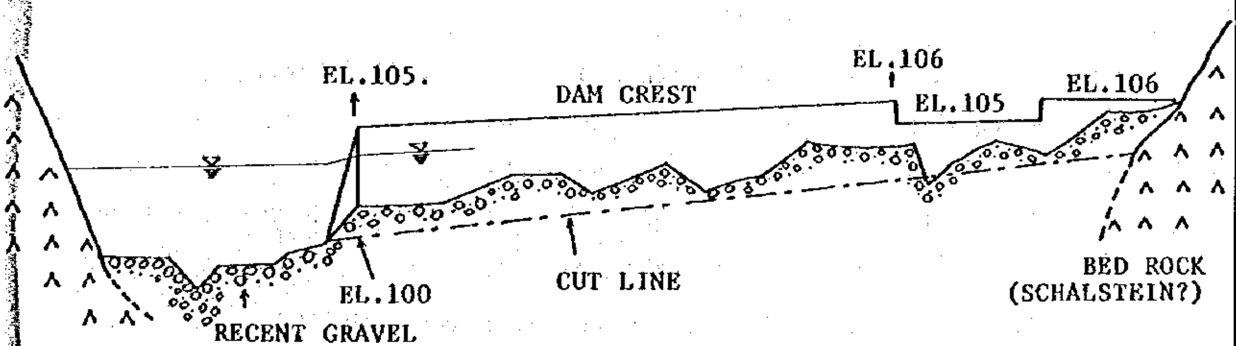


Fig-2 (C) LONGITUDINAL SECTION OF DIVERSION DYKE

B) Draft of the Technical Specification

Execution of Rock-fill:

	Random Zone	Riprap Zone
Maximum size of Materials	under 40 ∿ 50 cm	under 70 ∿ 100 cm
Placing Thickness	50 ∿ 60 cm	100 ∿ 120 cm
Placing Equipment	Bulldozer	Bulldozer
Compaction Equipment	Tire roller (30 ∿ 50 ton), Heavy Vibratory roller, or ab. 30 ton Bulldozer.	Bulldozer (ab. 30 ton)
Number of Passes for Compaction	about 4 ∿ 6	about 4

3-2 Wadi Safad Rock Fill Dam

The purpose of the proposed Wadi Safad Dam is to temporarily retain the floodflows and permit a greater volume of water to infiltrate into the wadi gravels.

Basic design data, mainly determinated by M.A.F, are given in Table-1 for the Wadi Safad Dam.

A) Structural Data and Design Considerations.

A preliminary appraisal design was prepared for a rockfill structure.

This structure, as proposed, would have a crest length of about 260 m, a maximum structural height of about 8 to 10 m, and contain about 55,000 m^3 of rock materials.

The dam, as proposed, would have a 1 : 2.5 upstream slope, a 1 : 2.0 downstream slope, and a 1 ∿ 2 m - deep cutoff wall. The centre core of the dam would be of semipervious materials 5 m wide at the top, 12 m wide at the bottom (Fig. 3). These dimensions were determined after a simple stability analysis (Appendix B).

It would have an ungated 38 m - wide spillway on the left abutment. The topography beyond the left abutment showed a possible low saddle as an alternate spillway.

The dimension of the spillway was set by routing the inflow design flood which has a peak flow of 460 m^3/sec. Details of the hydraulic calculation for the spillway structure are given in Appendix B.

A uncontrolled outlet pipes are provided to drain the reservoir below the level of the spillway. (See Ap-B-10) A solution for a passable road under dry-weather conditions needs to be included, in the basis of more detailed topography.

B) Draft of the Technical Specification

Construction of Embankment:

	Semi-Pervious	Random	Riprap
Top size of Materials	under 15 ∿ 20 cm	under 40 ∿ 50 cm	under 70 ∿ 100 cm
Placing thickness	about 25 ∿ 30 cm	about 50 ∿ 60 cm	about 100 ∿ 120 cm
Placing Equipment	Bulldozer	Bulldozer	Bulldozer
Compaction Equipment	Tire roller (20 ∿ 30 ton) or Heavy Vibratory roller	Tire roller (30 ∿ 5o ton) or Heavy Vibratory roller or about 30 ton Bull.	Bulldozer about 30 ton
Number of Passes for Compaction	about 6 ∿ 8	about 4 ∿ 6	about 4

Borrow area: It is recommended to make good use of the materials excavated from the reservoir area.

Dumped Riprap: Rocks for riprap shall be hard and durable with good gradation containing no fines. Rocks shall be dumped from the top of the embankment slope, and the riprap shall be placed and finished to specified lines and grades with bulldozer and the surface shall be dressed if necessary by hand, crane or other equipment.

Embankment of abatment: Embankment materials which touches to abutment and/or wall of spillway should be as fine as possible to prevent piping of water through the part.

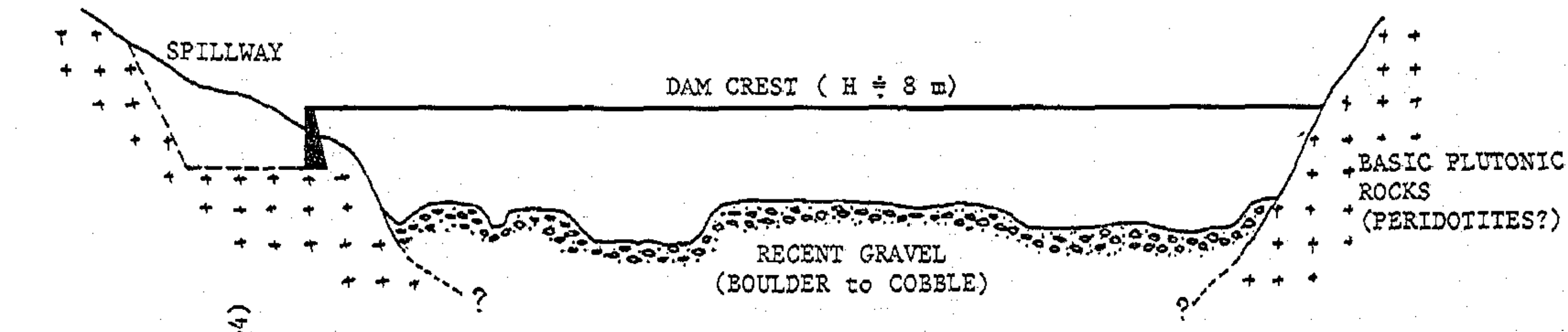
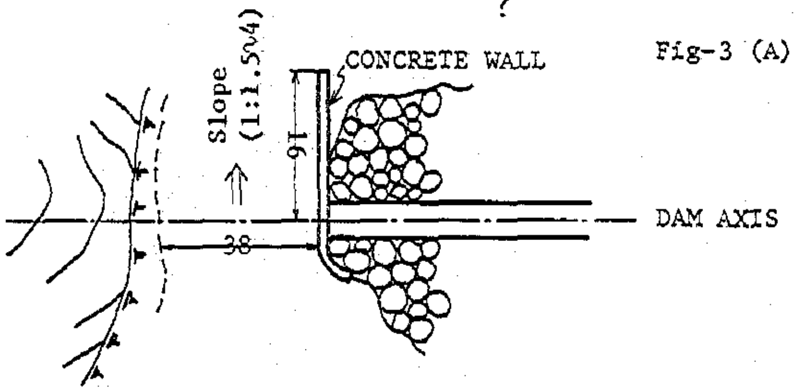
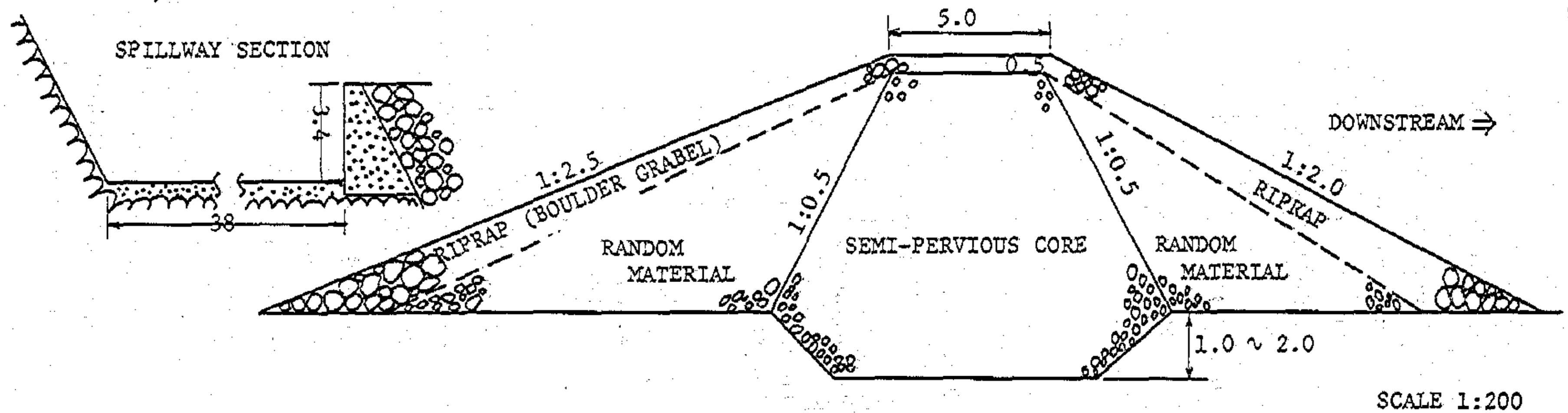


Fig-3 (A) SCHEMATIC PROFILE OF WADI SAFAD DAM

SCALE H ≑ 1/2,000
V ≑ 1/400





SCALE 1:200

DIMENSIONS GIVEN IN METERS.

Fig-3 (B) CROSS SECTION OF WADI SAFAD DAM

3-3 Restrictions on the Preliminary Dam Designs

A) The mission participated in this preliminary dam design for only for about two weeks from 31st Jan. to 16th Feb. 1980 including three days of site investigations. The time was very short, and therefore the results of this study are to be deemed very preliminary.

B) Based on the Ministry's representatives instructions, only the five dam sites mentioned below have been investigated and studied;

Wadi Naqab
Wadi Sifuni/Ashwani
Wadi Siji
Wadi Rumth
Wadi Safad

The damsites on each Wadi were identified in the field, and no additional selection of damsites was made.

C) The results of some basic physiographic and hydrologic studies were given to the team and this preliminary dam design has been executed based on those given data without any furhter studies or checks.

D) This preliminary dam design was made based on very rough eye measurements of the topography at the damsites, because it was found that there were some unclear points on the given 1/100 topographic drawings and sections.

E) Any kind of the feasibility studies, including positive or negative effects of recharge and/or flood control, have not made by the team.

F) The designs made for the dams of Wadi Rumth and Wadi Safad are to be considered as standard design. The detailed dimensions and elevations as well as the details of the structures have not been indicated, because some of the basic data, such as topographic maps of the damsites, and geological records were not yet completed. The final design of the dams should be made after getting those data.

4. Recommendations

4-1 For Wadi Rumth and Wadi Safad

The following notes for two dam sites are recommended as survey works and preparations of definitive plan in compliance with the preliminary design explaned in this report.

A) Survey works

Topographical map for the area of two proposed dam sites of Rumth and Safad should be prepared with scale 1 : 500 and 0.5 meter contour line on the map. And the Survey of Longitudinal profile along the dam's axis and for proposed center of spillway structure at Safad dam as well as survey of cross section along the profile surveying at dam axis and spillway.

B) Preparations of definitive plan

After the preparation of topographical map with the profile of ground surface, the definition plan of two dams could be prepared in compliance with the notices of preliminary design criteria as final design drawings, specifications for dam constructions with schedule, bill of quantities and management of dam construction at the site.

4-2 General recommendations

When any of these small dams are selected for construction, it is recommended that the following exploratory works and observations shall be performed in order to collect the most important data for the designings of future small dams.

(1) Installation of Rainfall Recorders in the Drainage Area of the Wadi.

(2) Installation of Runoff stations in the Wadi above the dams.

(3) Construction of Observation Wells in the benefited Areas for the Observation of the Groundwater level.

It would be recommendable to study the possibilities of construction of underground dams, in order to preserve the underground water, as well as erosion control works, drops and retarding levees for the purpose of retarding and recharging the peak flood discharges of the wadis, because,

(1) Suitable dam site might not always be found on some wadis.

(2) The underflow of some wadis also emptis into the sea in addition to the peak flood discharges.

It would be recommended that the water resources of wadis flowing to the eastern coast area between Dibba and Kalba should be developed prior to those of the wadis located at the Western side of the Oman mountains, because

(1) In case of the wadis located at the east coast area (hereinafter called "the east wadies"), the distance between the seashore and and the highest point of the alluvial fan of the wadis are extreamly short and these wadis also have steep slopes.

Therefore, the amount of discharge, not only in surface flow but also in underground flow being wasted to the sea is expected to be much bigger from the east wadis than from the wadis at the western side of the Oman mountains (hereinafter called "the west wadis") which are located very far from the seashore. At the same time, the damages caused by floods in the east wadis might be bigger than by those in the west wadis.

(2) The flood discharge of the west wadis, except for Wadi Bih and few wadis close by, could infiltrate naturally without having any structures taking into consideration the long distances between the location of the wadis and the seashore, even if the infiltration is not very effective.

APPENDIX A

WADI RUMTH DESIGN DATA

1. Situation; The river flows along left and right wadis separately.

Maximum discharge of the river are 576 m^3/sec (=Qp)

2. Plan; To divert the flow of the right wadi to the left wadi and bring the flood to the direction of Kalba to made the recharge increase.

For this purpose we design to excavation of artificial channel and a diversion dike.

2-1 Terms of design

° Suppose that there is discharge of 280 m^3/sec (=Q_R), that is 1/2 of max. discharge, along the right wadi in case of flood.

In this case one part of the flood water flows over a spillway which is on the diversion dike.

Here overflow discharge is Qout.

The agee part or crest of the spillway is protected by gabions (baskets filled with stones).

° Suppose that there is a discharge of 115 m^3/sec (=Q_L), that is 1/5 of max. discharge along the left wadi.

° Accordingly it is supposed that the discharge of

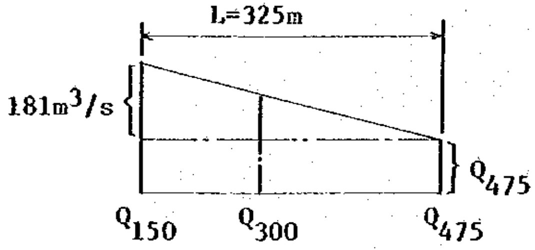
$$Q_H = Q_P - (Q_R + Q_L)$$
$$= 576 - (280 + 115) = 181 \text{ m}^3\text{/sec},$$

flow on the high water channel.

° Fig. 1 shows of above mentioned discharge.

° The planned longitudinal section of the embankment is on follow Fig. 2.

° Flood discharge at each main points.



$Q_{475} = (Q_R - Q_{out})$

$Q_{300} = (Q_R - Q_{out}) + \frac{181}{325} \times 175$

$Q_{150} = (Q_R - Q_{out}) + 181$

$Q_J = Q_{150} + Q_L$

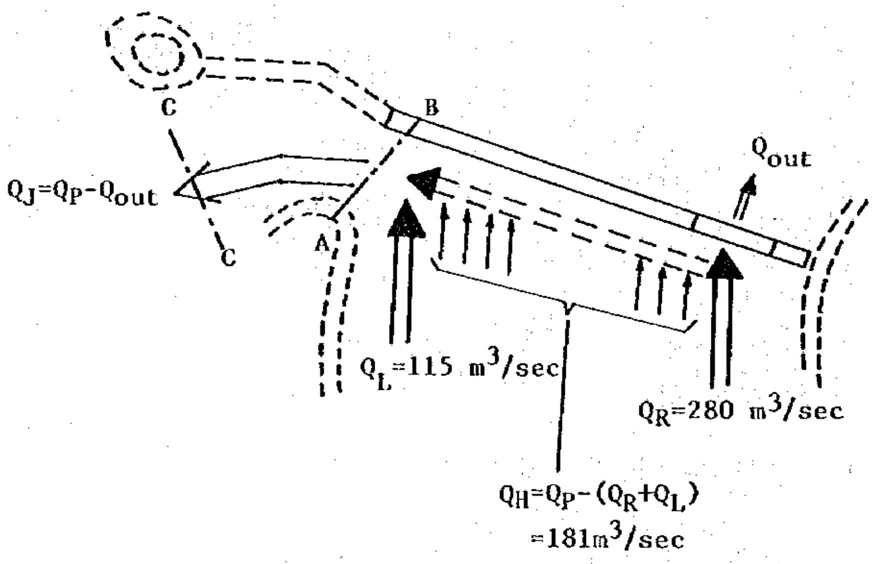


Fig-1 DISTRIBUTION GRAPH

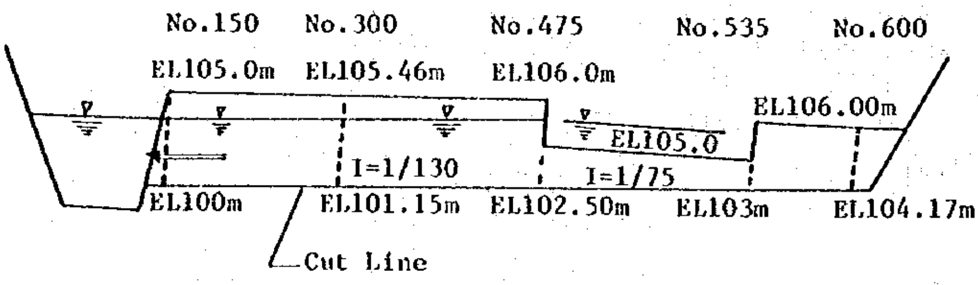


Fig-2 LONGITUDINAL SECTION

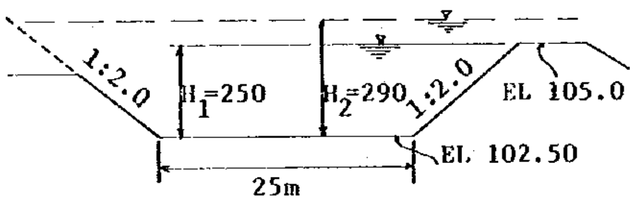
Table of each point

Point	Elevation of crest of dike	Elevation of bottom of channel	Width of bottom of channel	Designed discharge	
				m^3/sec	
No. 600	106^m	104.17^m	25^m		
No. 535 {	106	103.30	25		
	105	103.30	25	} $Q_R=280$	Qout=26 m^3/s
No. 475 {	105	102.50	25		
	106	102.50	25		
No. 300	105.46	101.15	32.5	351	
No. 150	105.00	100.00	40	435	
Confluent discharge				$Q_L=115$ $Q_J=550$	

2-2 Study of ability of channel to divert the flow to left wadi.

° Ability of the channel in case hydraulic gradient is supposed to be equal to channel slope.
(Manning formula is available)

$V=\frac{1}{n} \cdot R^{2/3} \cdot I^{1/2}$



n=0.05

No. 475 Section

$H_1=2.5m$

$P = 25^m + 2.236 \times 2.5 \times 2 = 36.18^m$

$A = \frac{25 \times 2 + 2.5 \times 2 \times 2}{2} \times 2.5 = 75\ m^2$

$R = A/P = 2.073m$

$V = \frac{1}{0.05} \times 2.073^{2/3} \times (\frac{1}{130})^{1/2}$

$= 2.85\ m/sec$

$Q = A.V = 214\ m^3/sec \quad < 280\ m^3/sec$

Here one part of the flood flows over the spillway.

$H_2=2.90m$

$P = 25 + 2.236 \times 2 \times 2.90 = 37.97m$

$A = \frac{25 \times 2 + 2.9 \times 2 \times 2}{2} \times 2.90 = 89.32m^2$

$R = A/P = 2.352$

$V = \frac{1}{0.05} \times 2.352^{2/3} \times (\frac{1}{130})^{1/2}$

$= 3.105$ m/sec

$Q = A.V = 277\ m^3/sec \fallingdotseq Q_R = 280\ m^3/sec$ OK

° Amount of discharge over spillway in case overflow depth is 0.40 meter

$Q = C.B.H^{3/2}$ Here $C=1.7$

$Qout = 1.7 \times 60 \times 0.4^{3/2}$

$\fallingdotseq 26\ m^3/sec$

° Accordingly designed discharge at each point is as follows.

$Q_{475} = 280 - 26 = 254\ m^3/sec$

$Q_{300} = 254 + 97 = 351$

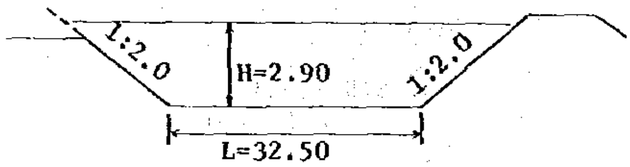
$Q_{150} = 254 + 181 = 435$

Q_J (discharge after confluency)

$= Q_{150} + Q_R$

$= 435 + 115 = 550\ m^3/sec$

No. 300 Section



$H=2.90m$

$P = 32.5 + 2.236 \times 2.9 \times 2$

$= 45.468m$

$A = \frac{32.5 \times 2 + 2.9 \times 2 \times 2}{2} \times 2.90 = 111.07\ m^2$

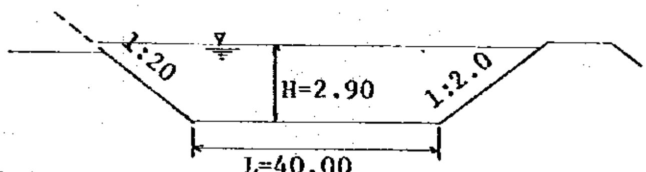
$R = A/P = 2.443m$

$V = \frac{1}{0.05} \times 2.443^{2/3} \times (\frac{1}{130})^{1/2}$

$= 3.182$ m/sec

$Q = A.V = 353\ m^3/sec \fallingdotseq 351\ m^3/sec$ OK

No. 150 Section



H=2.90m

$P = 40 + 2.236 \times 2.9 \times 2$

$= 52.968$

$A = \frac{40 \times 2 + 2.9 \times 2 \times 2}{2} \times 2.9$

$= 132.82 \ m^2$

$R = A/P = 2.507$

$V = \frac{1}{0.05} \times 2.507^{2/3} \times (\frac{1}{130})^{1/2}$

$= 3.236$

$Q = A.V = 430 \ m^3/sec \doteqdot 435 \ m^3/sec$ OK

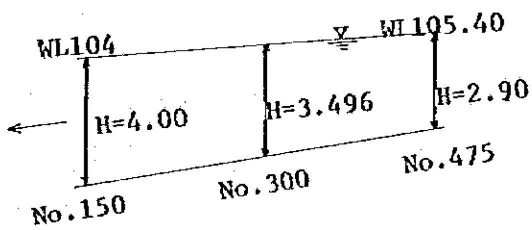
Check

Ability of the channel in case the following matters are supposed as

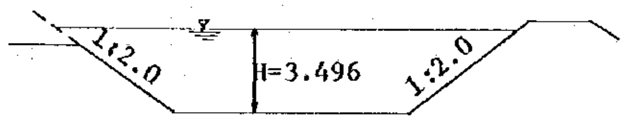
Water level at No. 475 is EL 105.40m

Water level at No. 150 is EL 104.00m

Hydraulic gradient is 1/232



No. 300 Section



H=3.496m

$P = 32.5 + 2.236 \times 3.496 \times 2$

$= 48.134 \ m^2$

$A = \frac{32.5 \times 2 + 3.496 \times 2 \times 2}{2} \times 3.496 = 138.06 \ m^2$

$R = A/P = 2.868$

$V = \frac{1}{0.05} \times 2.868^{2/3} \times (\frac{1}{232})^{1/2}$

$= 2.65$ m/sec

$Q = A.V = 364 \ m^3/sec > 323.04 \ m^3/sec$ OK

No. 150 Section

H=4.00m

$P = 40 + 2.236 \times 4.0 \times 2 = 57.888$ m

$A = \frac{40 \times 2 + 4.0 \times 2 \times 2}{2} \times 4.0 = 192$ m^2

$R = A/P = 3.316$ m

$V = \frac{1}{0.05} \times 3.316^{2/3} \times (\frac{1}{232})^{1/2}$

$= 2.919$

$Q = A.V = 560$ m^3/sec > 435 m^3/sec OK

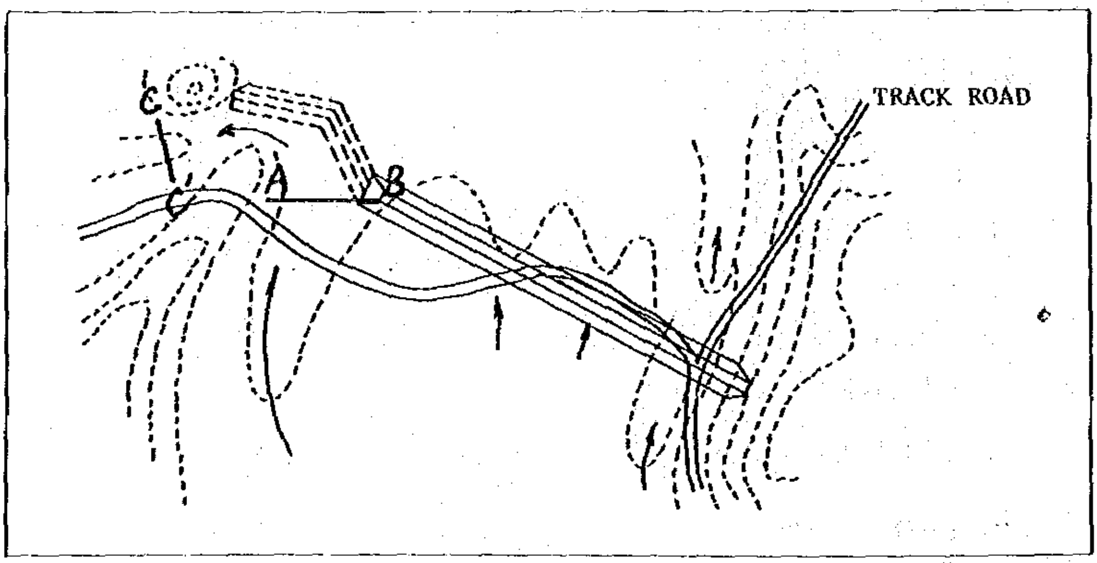
2-3 Design of the downstream of the confluency

° Slope of river of natural condition I = 1/50

Wadi is narrow and deep (width b=20∿30m) at the downstream of confluency (A∿B section).

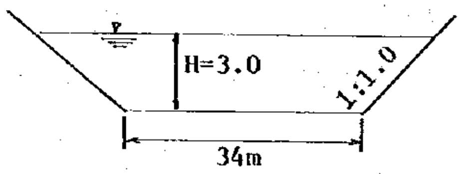
At the point C-C' section, however, wadi is broad and sharrow (width b=50∿60m).

The section of the diverted channel should be as follow to pass the discharge Q_J=550 m^3/sec safely.



° A ∿ B section

H=3.0m



$P = 34 + 1.414 \times 3 \times 2 = 42.484m$

$A = \frac{34 \times 2 + 3 \times 2}{2} \times 3.0 = 111\ m^2$

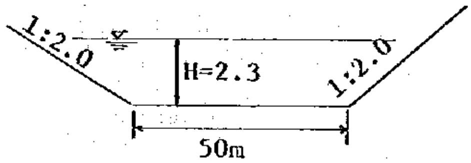
$R = A/P = 2.612m$

$V = \frac{1}{0.05} \times 2.612^{2/3} \times (\frac{1}{50})^{1/2}$

$= 5.368\ m^3/sec$

$Q = A.V = 5.368 \times 111 = 595\ m^3/sec > 550\ m^3/sec$ OK

° C - C' section



H=2.3m

b=50m

$P = 50 + 2.236 \times 2.3 \times 2 = 60.285m$

$A = \frac{50 \times 2 + 2.3 \times 2 \times 2}{2} \times 2.3 = 125.58m^2$

$R = A/P = 2.083m$

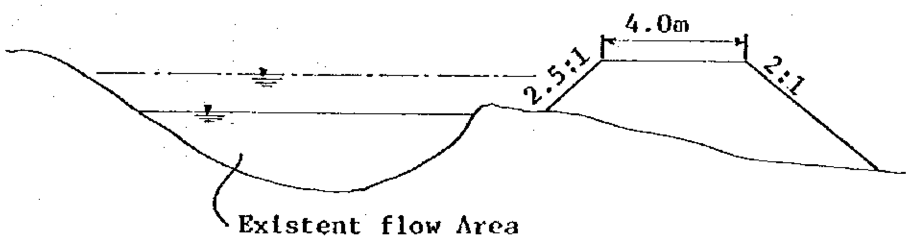
$V = \frac{1}{0.05} \times 2.083^{2/3} \times (\frac{1}{50})^{1/2}$

$= 4.61\ m/sec$

$Q = A.V = 125.58 \times 4.61 = 579\ m^3/sec > 550\ m^3/sec$

° These calculations show that the channel has enough capacity if the area of section of downstream of the confluency are 110 ∿ 130 m^2.

If the area are less than 110 ∿ 130 m^2, the following embanckment is necessary.



Topographic Survey Plans in Ramth

The following maps are necessary.

1. Topographic map of dam site of the contour distance 0.5 meter.

   Profile map through dam axis of the scale 1/200 ∿ 1/300.

   Cross section maps of a diverted dike and a diverted channel of the scale 1/200 ∿ 1/300 and point distance.

   Point distance 20 ∿ 30 meters.

Fig-3 RAMUTH DIVESION DAM AND CHANNEL $S = \frac{1}{200}$

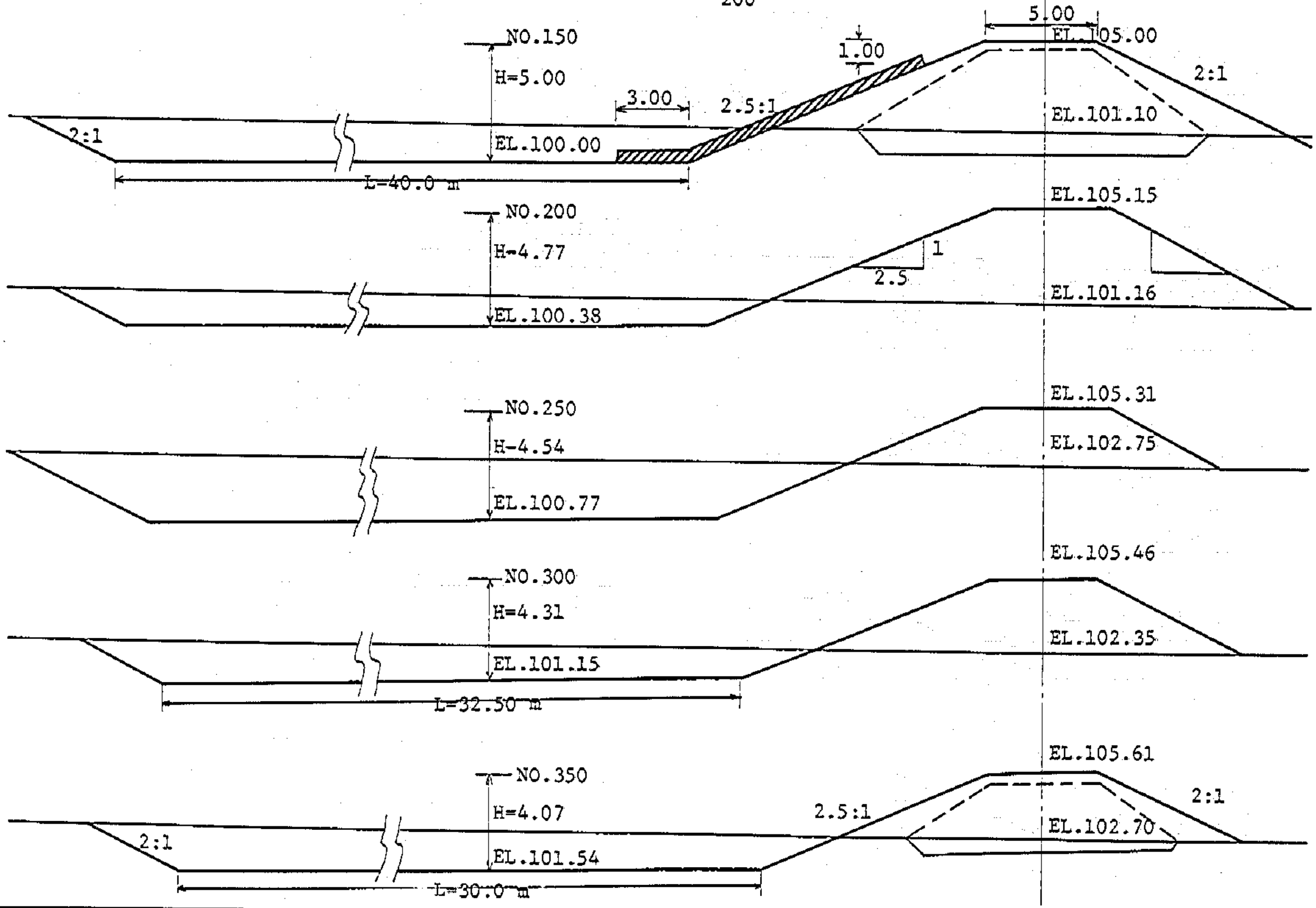
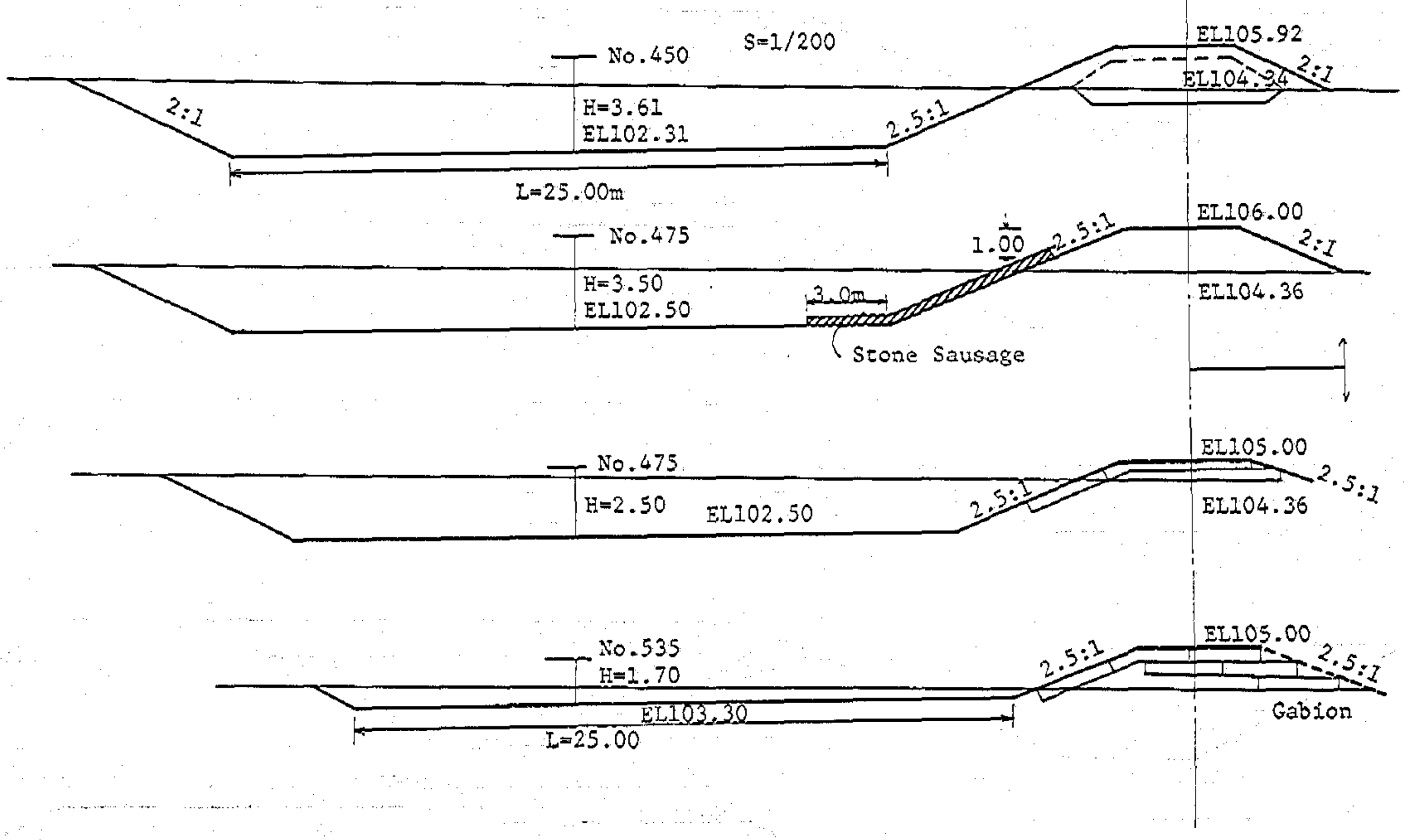
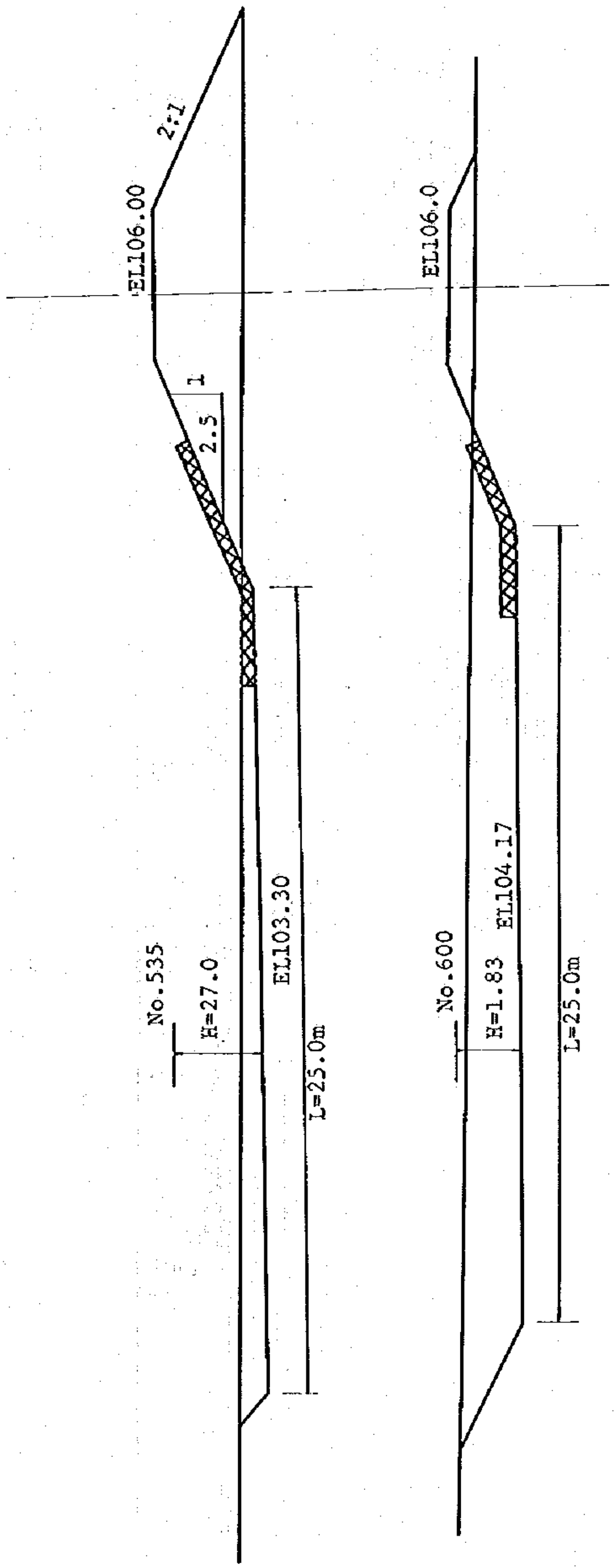


Fig-2


No.450
S=1/200
EL105.92
2:1
EL104.34
2:1
H=3.61
EL102.31
2.5:1
L=25.00m
EL106.00
No.475
1.00
2.5:1
2:1
H=3.50
EL102.50
3.0m
EL104.36
Stone Sausage
EL105.00
No.475
2.5:1
H=2.50
EL102.50
2.5:1
EL104.36
EL105.00
No.535
H=1.70
2.5:1
2.5:1
Gabion
EL103.30
L=25.00


2:1
EL106.00
1
2.5
No.535
H=27.0
EL103.30
L=25.0m
EL106.0
No.600
H=1.83
EL104.17
L=25.0m

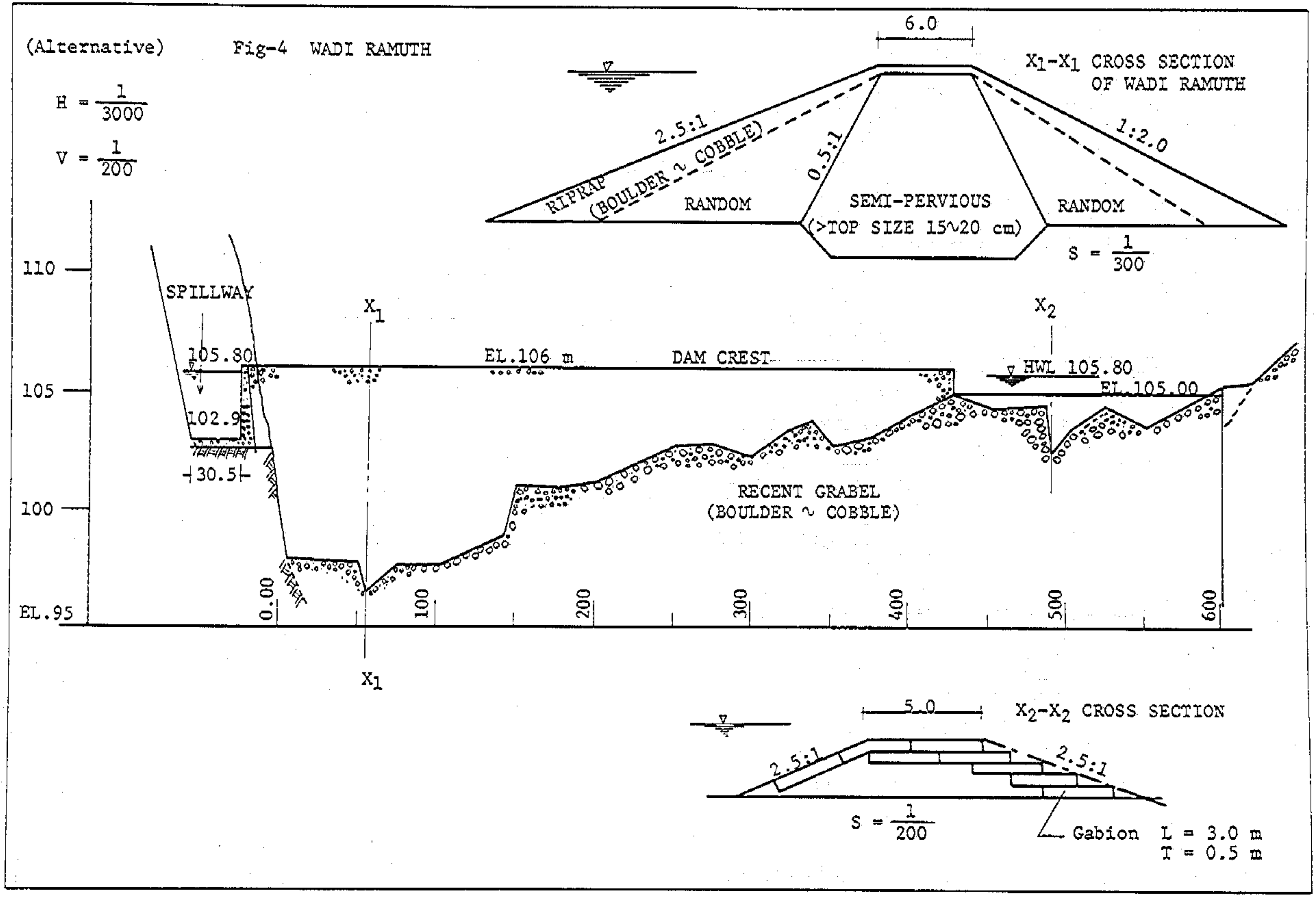
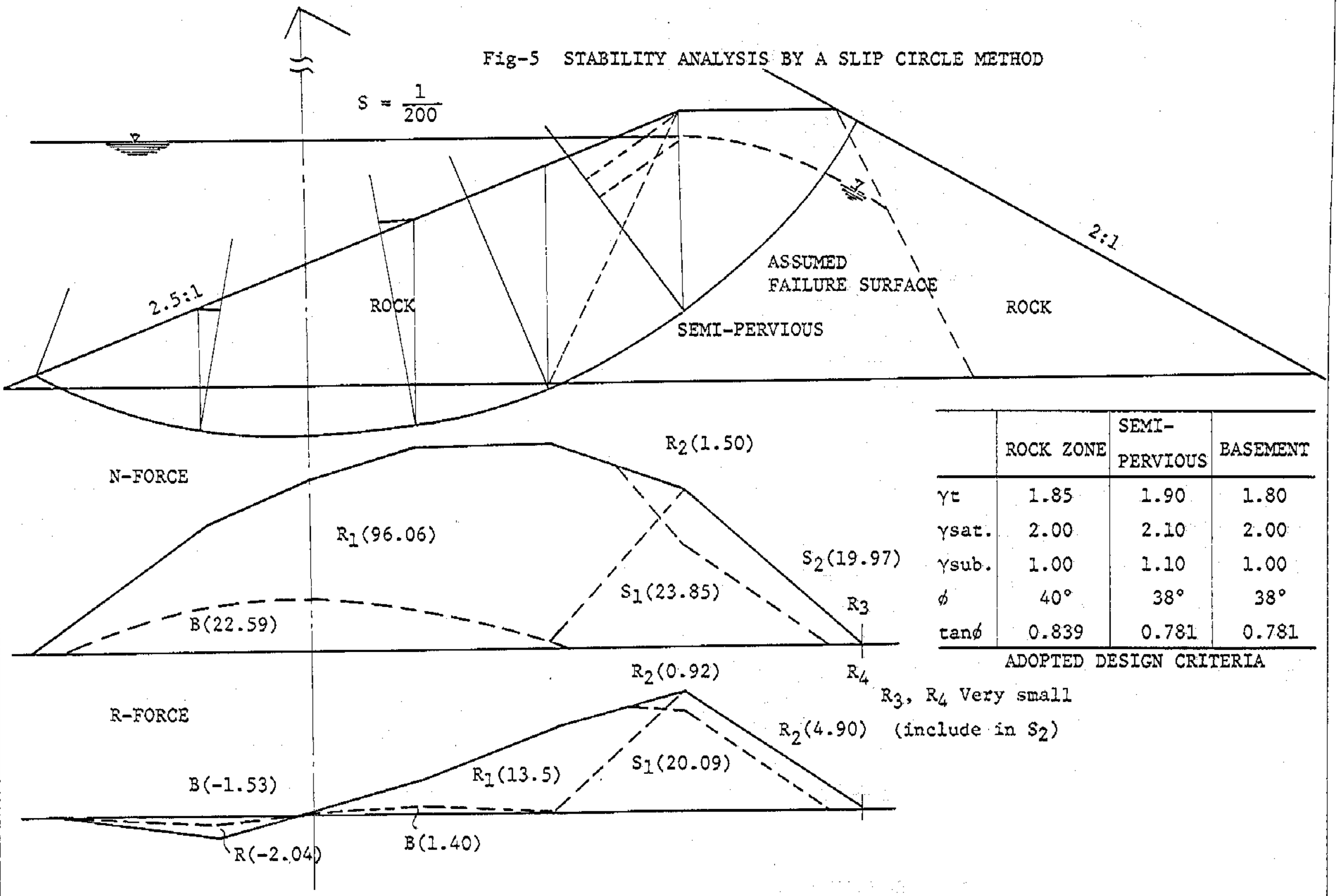


Fig-4 WADI RAMUTH

Fig-5 STABILITY ANALYSIS BY A SLIP CIRCLE METHOD



	ROCK ZONE	SEMI-PERVIOUS	BASEMENT
γt	1.85	1.90	1.80
$\gamma sat.$	2.00	2.10	2.00
$\gamma sub.$	1.00	1.10	1.00
ϕ	40°	38°	38°
$\tan\phi$	0.839	0.781	0.781

ADOPTED DESIGN CRITERIA

R_3, R_4 Very small (include in S_2)

(Alternative)

Fig. 5 Section Stability Analysis

TABLE

Materials	Normal force									Tangential force						
	N-U			Ne			ΣN	Tanϕ	ΣN·Tanϕ	T			Te			ΣT
	A	D	W	A	D·K	E_N				A	D	W	A	D·K	E_T	
	m^2	t/m^3	ton	m^2	t/m^3	ton	ton		ton	m^2	t/m^3	ton	m^2	t/m^3	ton	ton
R_1	96.06	1.00	96.06	19.82	2.0x0.1	3.96	N-U= 185.61			19.82	1.00	19.82	96.06	2.0x0.1	19.21	39.03
B	22.59	1.00	22.59	-0.13	2.0x0.1	-0.03				-0.13	1.00	-0.13	22.59	2.0x0.1	4.52	4.39
R_2	1.50	1.85	2.78	0.92	1.85x0.1	0.17	Ne= 9.27	0.781	137.72	0.92	1.85	1.70	1.50	1.85x0.1	0.28	1.98
S_1	23.85	1.10	26.24	20.09	2.10x0.1	4.24	ΣN= 176.34			20.09	1.10	22.10	23.85	2.10x0.1	5.01	27.11
S_2	19.97	1.90	37.94	4.90	1.90x0.1	0.93				4.90	1.90	9.31	19.97	1.90x0.1	3.79	13.10
Total									137.72							85.61

WHERE, A : Aria

D : Bulk density

W : Weight

Ne : $T \cdot K = E_N$

Te : $N \cdot K = E_T$

K : Seismicity Coefficient 0.1

$$F_S = \frac{\Sigma(N-U-Ne)\tan\phi}{\Sigma T} = \frac{137.72}{85.61} = 1.61$$

APPENDIX B

WADI SAFAD DESIGN DATA

$$SF = \frac{\tan \phi \, (1 - m \cdot \gamma \cdot k)}{m + \gamma \cdot k}$$

SF : Safety factor ≥ 1.2

m : $\tan \alpha = 1/x$

k : Seismicity coefficient $k = 0.1$

γ : $\gamma sat/\gamma sab$

ϕ : Angle of internal friction

Fig. 1

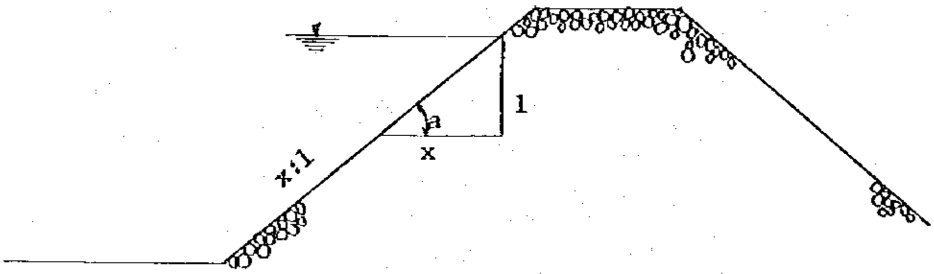


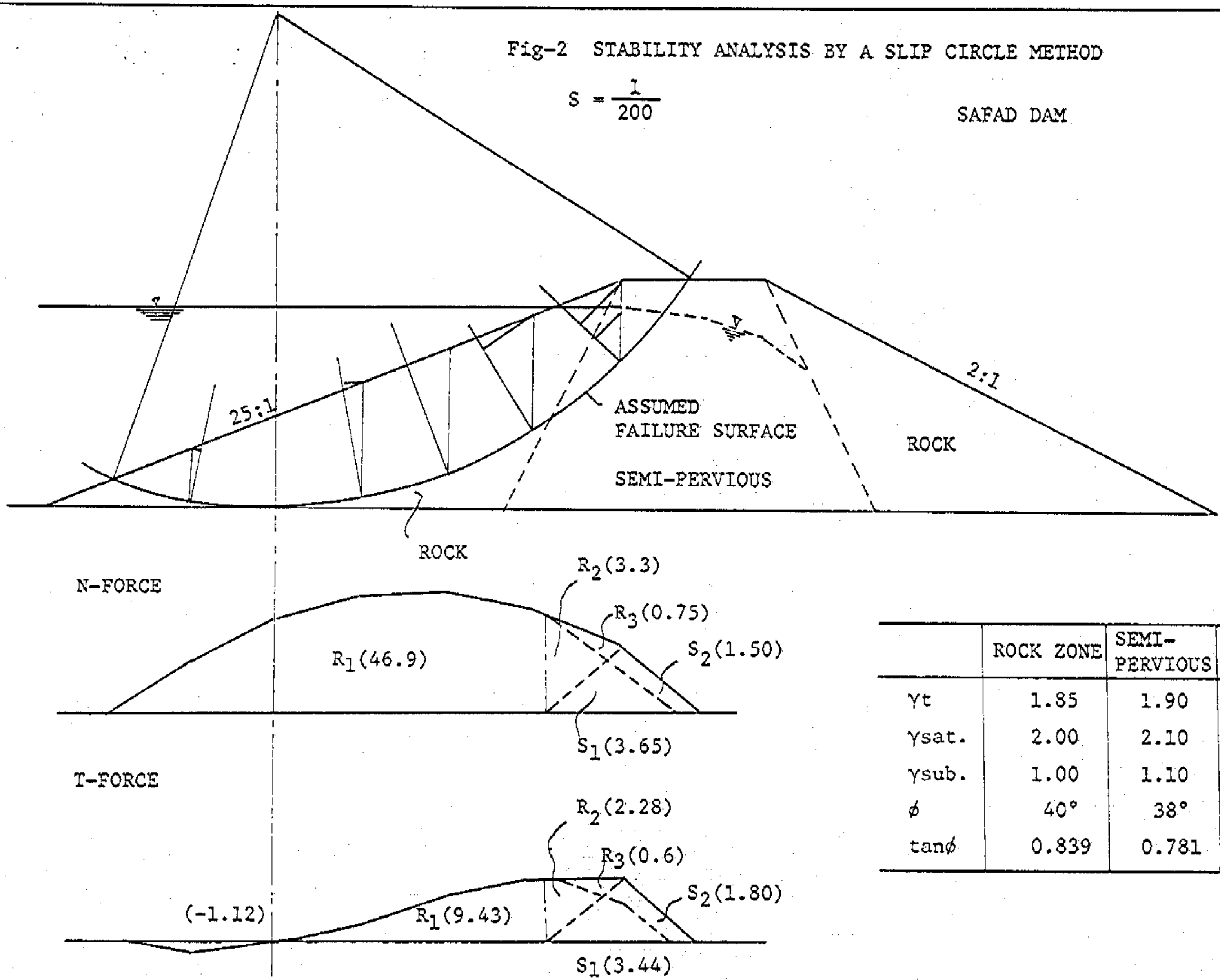
Table-1 Relations between ϕ and Slope

Portion		Submerged			Above Water Level
$\gamma = \gamma sat/\gamma sab$		2.1/1.1	2.0/1.0	1.9/0.9	$\gamma \equiv 1$
ϕ	m	SF	SF	SF	SF
38°	1/2.0	1.02	0.99		1.24
38°	1/2.2	1.11	1.09	1.06	1.35
38°	1/2.5	1.22	1.20	1.17	1.50
40°	1/2.0	1.10	1.08	1.06	1.33
40°	1/2.2	1.19	1.17	1.14	1.44
40°	1/2.5	1.31	1.29	1.26	1.61
42°	1/2.0	1.18	1.16	1.13	1.42
42°	1/2.2	1.27	1.25	1.22	1.55
42	1/2.5	1.40	1.38	1.35	1.73

Fig-2 STABILITY ANALYSIS BY A SLIP CIRCLE METHOD

$S = \frac{1}{200}$

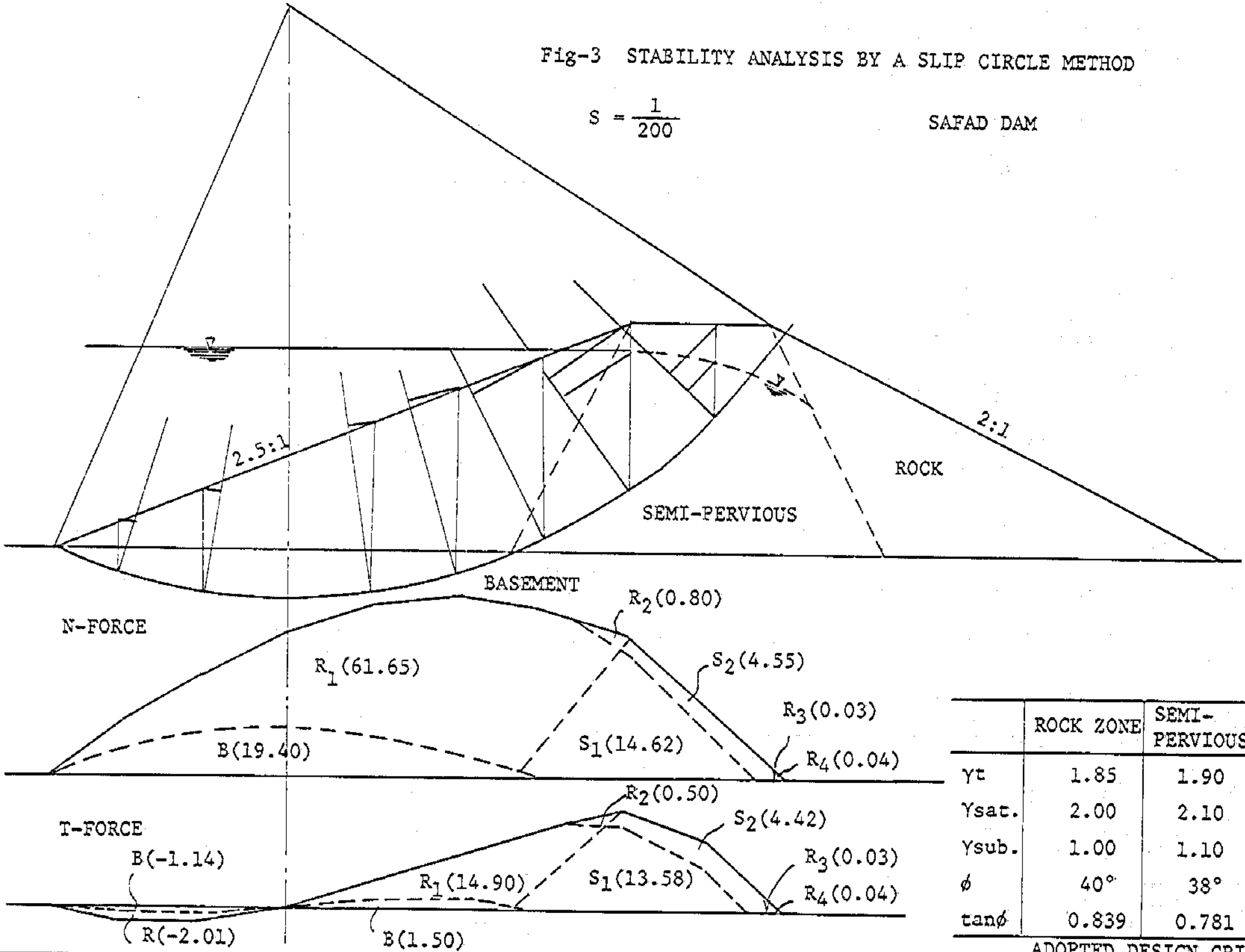
SAFAD DAM



	ROCK ZONE	SEMI-PERVIOUS	BASEMENT
γt	1.85	1.90	1.80
$\gamma sat.$	2.00	2.10	2.00
$\gamma sub.$	1.00	1.10	1.00
ϕ	40°	38°	38°
$\tan\phi$	0.839	0.781	0.781

Fig-3 STABILITY ANALYSIS BY A SLIP CIRCLE METHOD

$S = \frac{1}{200}$ SAFAD DAM



	ROCK ZONE	SEMI-PERVIOUS	BASEMENT
γt	1.85	1.90	1.80
γsat.	2.00	2.10	2.00
γsub.	1.00	1.10	1.00
ϕ	40°	38°	38°
tanϕ	0.839	0.781	0.781

ADOPTED DESIGN CRITERIA

Table-2 Section Stability Analysis

Safad Dam

Mate-rials	Normal force: N-U A	N-U D	N-U W	Ne A	Ne D·K	E_N	ΣN	Tanφ	ΣN·Tanφ	Tangential force: T A	T D	T W	Te A	Te D·K	E_T	ΣT
	m^2	t/m^3	ton	m^2	t/m^3	ton	ton		ton	m^2	t/m^3	ton		t/m^3	ton	ton
R_1	46.9	1.00	46.9	8.31	2.0x0.1	1.66	45.24	0.839	37.96	(9.43-1.12) 8.31	1.00	8.31	46.9	2.0x0.1	9.38	17.69
R_2	3.3	1.00	3.30	2.28	2.0x0.1	0.456	N-U= 11.56			2.28	1.00	2.28	3.3	2.0x0.1	0.66	2.94
R_3	0.75	1.85	1.39	0.60	1.85x0.1	0.111	Ne= 1.631	0.781	7.754	0.60	1.85	2.531	0.75	1.85x0.1	0.139	2.67
S_1	3.65	1.10	4.02	3.44	2.10x0.1	0.722				3.44	1.10	3.784	3.65	2.10x0.1	0.766	4.55
S_2	1.5	1.90	2.85	1.	1.90x0.1	0.342	ΣN= 9.929			1.80	1.90	3.42	1.50	1.90x0.1	0.285	3.705
Total									45.714							31.555

$$SF = \frac{\Sigma(N-U-Ne)\tan\phi}{\Sigma T}$$

$$= \frac{45.714}{31.555}$$

$$\doteqdot 1.45$$

Table-3 Section Stability Analysis

Safad Dam

Materials	Normal force									Tangential force						
	N-U			Ne			ΣN	Tanφ	ΣN·Tanφ	T			Te			ΣT
	A	D	W	A	D·K	E_N				A	D	W	A	D·K	E_T	
	m^2	t/m^3	ton	m^2	t/m^3	ton	ton		ton	m^2	t/m^3	ton	m^2	t/m^3	ton	ton
B_1	19.40	1.00	19.40	0.57	2.0x0.1	0.11	N-U= 107.31			0.57	1.00	0.57	19.40	2.0x0.1	3.88	4.45
R_1	61.65	1.00	61.65	12.89	2.0x0.1	2.58				12.89	1.00	12.89	61.65	2.0x0.1	12.33	25.22
S_1	14.62	1.10	16.08	13.58	2.1x0.1	2.85	Ne= 6.48	0.781	78.75	13.58	1.10	14.94	14.62	2.1x0.1	3.07	18.01
S_2	4.55	1.90	8.65	4.42	1.9x0.1	0.84				4.42	1.90	8.40	4.55	1.9x0.1	0.86	9.26
R_2	0.80	1.85	1.48	0.50	1.85x0.1	0.09	ΣN= 100.83			0.50	1.85	0.93	0.80	1.85x0.1	0.15	1.08
R_3	0.03	1.85	0.05	0.03	1.85x0.1	0.01				0.03	1.85	0.05	0.03	1.85x0.1	0.01	0.06
R_4	0.04	1.85	0.07	0.04	1.85x0.1	0.01	0.06	0.839	0.05	0.04	1.85	0.07	0.04	1.85x0.1	0.01	0.08
Total									78.80							58.16

$$SF = \frac{\Sigma(N-U-Ne)\tan\phi}{\Sigma T}$$

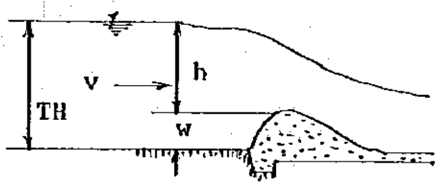
$$= \frac{78.80}{58.16}$$

$$= 1.35$$

Design Flood Discharge		$Q_D = 138\ m^3/sec.$	
Catastrophic Flood Discharge		$Q = 460\ m^3/sec.$	
Spillway Crest Length		$L = 38\ m$	
$Q = C \cdot L \cdot H^{3/2}$	$H < 1.50\ m$	Assume	$C = 2.0$
	$H \geqq 1.50$	Assume	$C = 2.0$
Overflow Depth	$H = 1.49$	$Q = 2.0 \times 38 \times 1.49^{3/2}$	
		$= 138.2\ m^3/sec. > 138\ m^3/sec.$ OK	
	$H = 3.25$	$Q = 2.1 \times 38 \times 3.25^{3/2}$	
		$= 467\ m^3/sec. > 460\ m^3/sec.$ OK	

1. Shape and Water Depth of Entrance Channel

$Q_D=138 m^3/sec.$

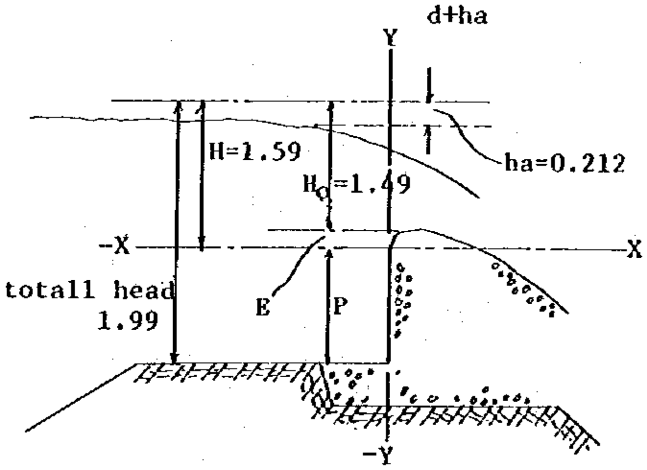


$W \geqq 1/5h$

$V \leqq 4\ m/sec.$

2. Shape of Overflow Section --------- $Q_D = 138\ m^3/sec.$

Entrance Channel	Total Head	1.99 m
	d	1.78
	$A = d \cdot L$	$1.78 \times 38 = 67.64\ m^2$
	$V = Q/A$	$138/67.64 = 2.04\ m/sec. < 4\ m$ OK
	$ha = V^2/2g$	$2.04^2/2x9.8 = 0.212$
	d+ha	$1.78 + 0.212 = 1.992$
		$\doteqdot$ T.H = 1.99 OK



Assume H_s = 1.59 m

ha/H_s = 0.212/1.59

= 0.133 m

E/Hs = 0.065 (from graph)

E = 0.065·Hs = 0.65 x 1.59

= 0.103 m

Ho = 1.49 m

∴ Ho + E = 1.49 + 0.103

= 1.593

≑ Assume H_s = 1.59 OK

P = 0.50 - E

0.397

From Table

E - Ymax

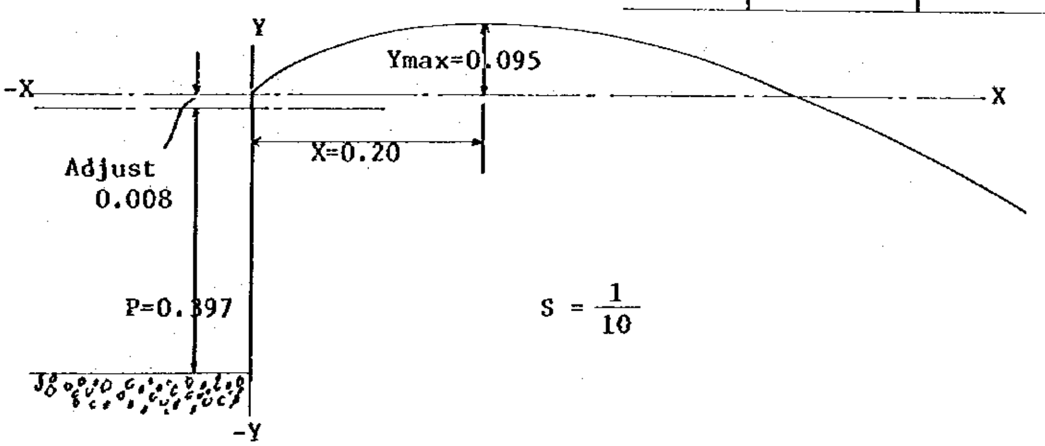
= 0.103-0.095
= 0.008

Shape of Crest

Table-4

Adopted ha/Hs = 0.14

X/Hs	Y/Hs	X	Y
0.000	0.00	0.00	0.00
0.05	0.0355	0.080	0.056
0.10	0.0520	0.159	0.083
0.15	0.0586	0.239	0.093
0.20	0.0599	0.318	0.095
0.25	0.0566	0.400	0.090
0.30	0.0503	0.477	0.080
0.35	0.0420	0.557	0.067
0.40	0.0303	0.636	0.048
0.45	0.0163	0.715	0.026
0.50	-0.0001	0.795	0
0.60	-0.043	0.954	-0.068
0.70	-0.091	1.113	-0.145
0.90	-0.216	1.431	-0.343
1.00	-0.290	1.590	-0.461
1.20	-0.463	1.908	-0.736
1.40	-.0.672	2.226	-1.068
1.80	-1.174	2.862	-1.867



S = $\frac{1}{10}$

3. Transition of Spillway

To design a transition of a spillway, the following have to be taken into consideration.

1) Water level transition shall be kept under a crest level.

2) Water in a transition shall flow without excessive turbulence.

4. Discharge Carrier (from the end of transition to a point from which water come back to natural flow)

In order to convey the flood water flowing down from the control structure, without hindrance, as well as securing the economy of construction works and stability of the structure, the discharge carrier of a spillway must be designed taking the following into consideration:

1) a plan with possible least curvatures be selected

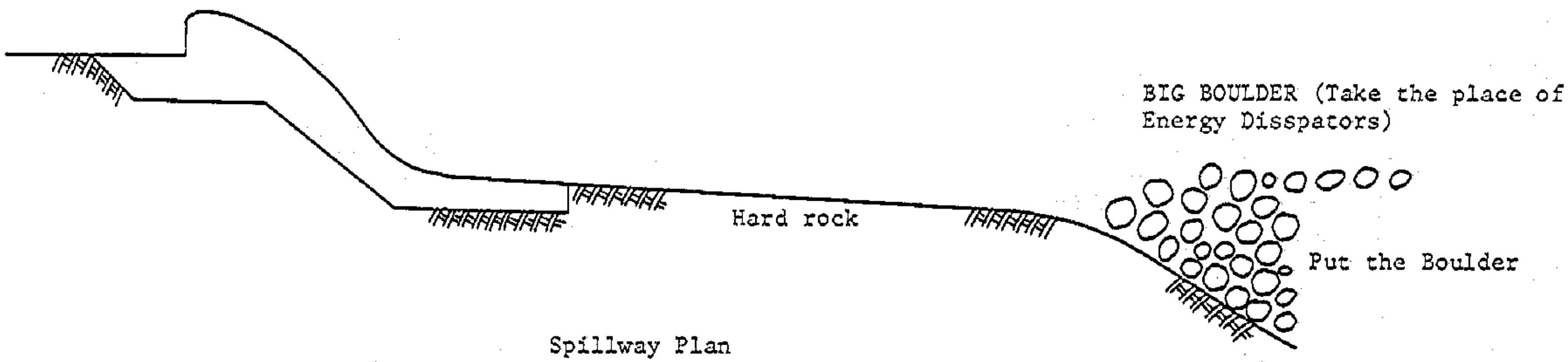
2) a rectangular cross-section be recommended for a discharge carrier, in general;

3) flatter slopes be usually assigned to the up-stream portion of a carrier and relatively steep slopes to the down-stream portion leading to energy dissipation.

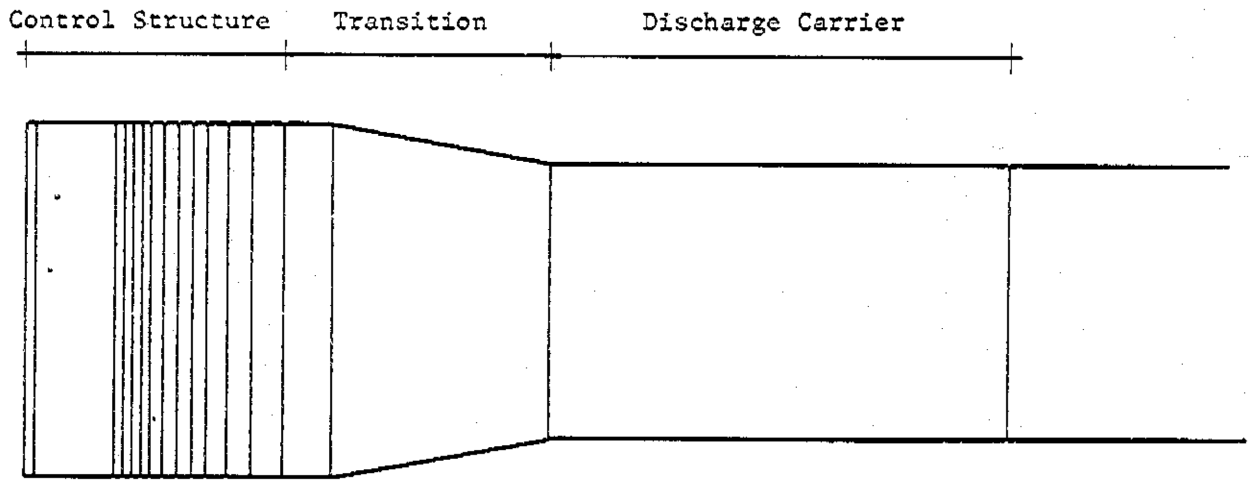
5. Energy Dissipators

An energy dissipator must be built at the down-stream end of a discharge carrier, in order to prevent erosion and scouring which may be caused by the high energy possessed by high velocity flow. As there are not any houses or agricultural lands as far as 2 kilometers downstream of the spillway, such energy disspating pond of concrete structure or sub-dam would not be necessary, but only a mount of big boulders would be sufficient against water energy.

Spillway Section (Tentative)

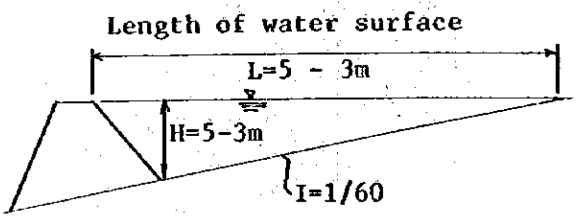


Spillway Plan



∘ Storage Capacity of Safad Dam

Suppose slope of river bed is 1/60, and mean width of the river are 260 ms.



In case H = 5.0 m, the storage capacity V

$$V = 5 \times 300 \times 1/2 \times 260$$
$$= 195{,}000\ m^3$$

In case H = 3.0 m

$$V = 3 \times 180 \times 1/2 \times 260$$
$$= 70{,}200\ m^3$$

Here the capacity is roughly supposed as 70,000 m^3

∘ Design of intake

Intake ability according to the dias of intake.

$$V = \sqrt{\frac{2 \cdot g \cdot H}{1 + fe + f' \frac{L}{R}}} = \sqrt{\frac{2 \cdot g \cdot H}{1 + fe + f \cdot \frac{L}{D}}}$$

fe : Coefficiency of intake loss of head 0.5

f : Coefficiency of friction loss of head

In case shape of intake is circular $f = \dfrac{12.704 \times n^2 \times g}{D^{1/3}}$

In case shape of intake is not circular $f' = \dfrac{n \cdot 2g}{R^{1/3}}$

In case the section is circular .... n = 0.015, g = 9.8 m/sec/sec.

ϕ 0.300 m $f = \dfrac{12.7 \times 0.015^2 \times 9.8}{0.3^{1/3}} = 0.04185$

ϕ 0.400 m $f = \dfrac{12.7 \times 0.015^2 \times 9.8}{0.4^{1/4}} = 0.03799$

ϕ 0.50 m $$f = \frac{12.7 \times 0.015^2 \times 9.8}{0.5^{1/3}} = 0.035379$$

In case the section is square

0.30 x 0.30 $$f' = \frac{0.015^2 \times 2 \times 9.8}{\left(\frac{0.3 \times 0.3}{0.3 \times 4}\right)^{1/3}} = 0.0104255$$

0.40 x 0.40 $$f' = \frac{0.015^2 \times 2 \times 9.8}{\left(\frac{0.4 \times 0.4}{0.4 \times 4}\right)^{1/3}} = 0.0095043$$

Discharge time in which the water surface changes from the highest to the lowest in case diameter of the

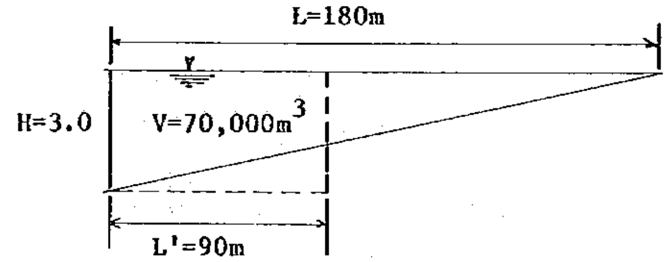
conduit ϕ = 0.4 m

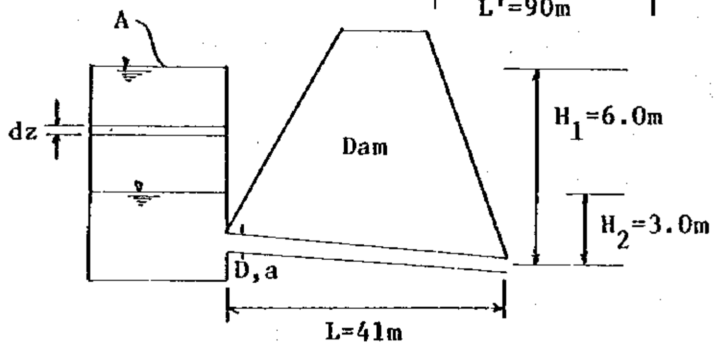
The calculation is done when the reservoir modelized the following Fig.

$L' = V \div (H \times b)$

$= 70,000 \div (3.0 \times 260)$

$\fallingdotseq 90$ m





Discharge time T

$$T = -\int_{H_1}^{H_2} \frac{A}{Q} \cdot dz$$

$$= \frac{2A \cdot \sqrt{1 + fe + f \cdot \frac{L}{D}}}{a \cdot \sqrt{2g}} (H_1^{1/2} - H_2^{1/2})$$

$$= \frac{2 \times 90 \times 260 \sqrt{1 + 0.5 + 0.03799 \times \frac{41}{0.4}}}{\frac{\pi}{4} \times 0.4^2 \times \sqrt{2 \times 9.8}} (\sqrt{6} - \sqrt{3})$$

$$= \frac{2 \times 90 \times 260 \times 2.322}{0.1256 \times 4.427} \times 0.7169$$

$= 140.119$ sec.

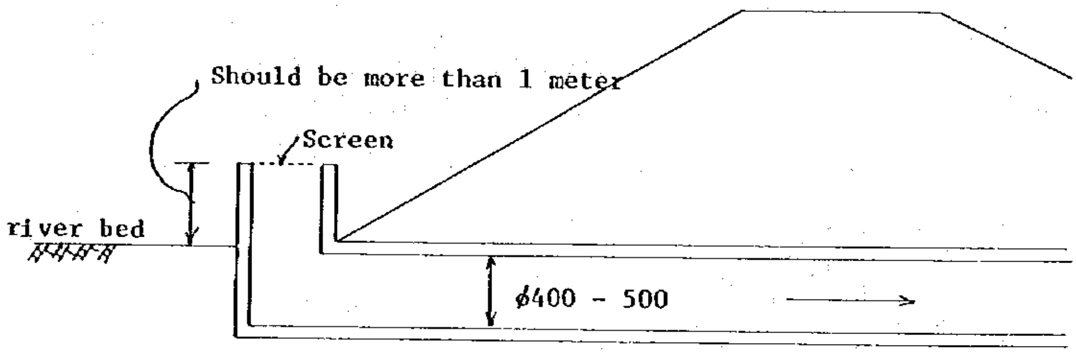
$\doteqdot$ 39 hours

Intake discharge (max.)

$$V = \sqrt{\frac{2 \cdot g \cdot H}{1 + fe + f \cdot \frac{L}{D}}} = \sqrt{\frac{2 \times 9.8 \times 6}{1 + 0.5 + 0.03799 \times \frac{41}{0.4}}} = 7.116 \text{ m/sec.}$$

$$Q = A \cdot V = \frac{\pi}{4} D^2 \times 7.116 = \frac{31.4}{4} \times 0.4^2 \times 7.116 = 0.893 \text{ m}^3\text{/sec.}$$

The shape of the intake should be made like the following figure to present the inflow of sands and gravels.



Topographic Survey Plans in the Area of Safad Dam

The following survey plans are necessary.

1. Maps of Topographic survey of the scale 1/1,000 ∿ 1/3,000 and contour distance 1.0 meter in the area of reservoir for the purpose of obtaining the storage capacity of Water.

2. Topographic maps of dam site and the area of spillway of the Scale 1/500 and contour distance 0.5 meter.

   Profile maps through dam axis (Cross section of the river) of the scale 1/200 ∿ 1/300.

   Cross section maps of the dam scale 1/200 ∿ 1/300 and point distance 20 ∿ 30 meters.

   Profile maps of the area of the spillway of the scale 1/200 ∿ 1/300.

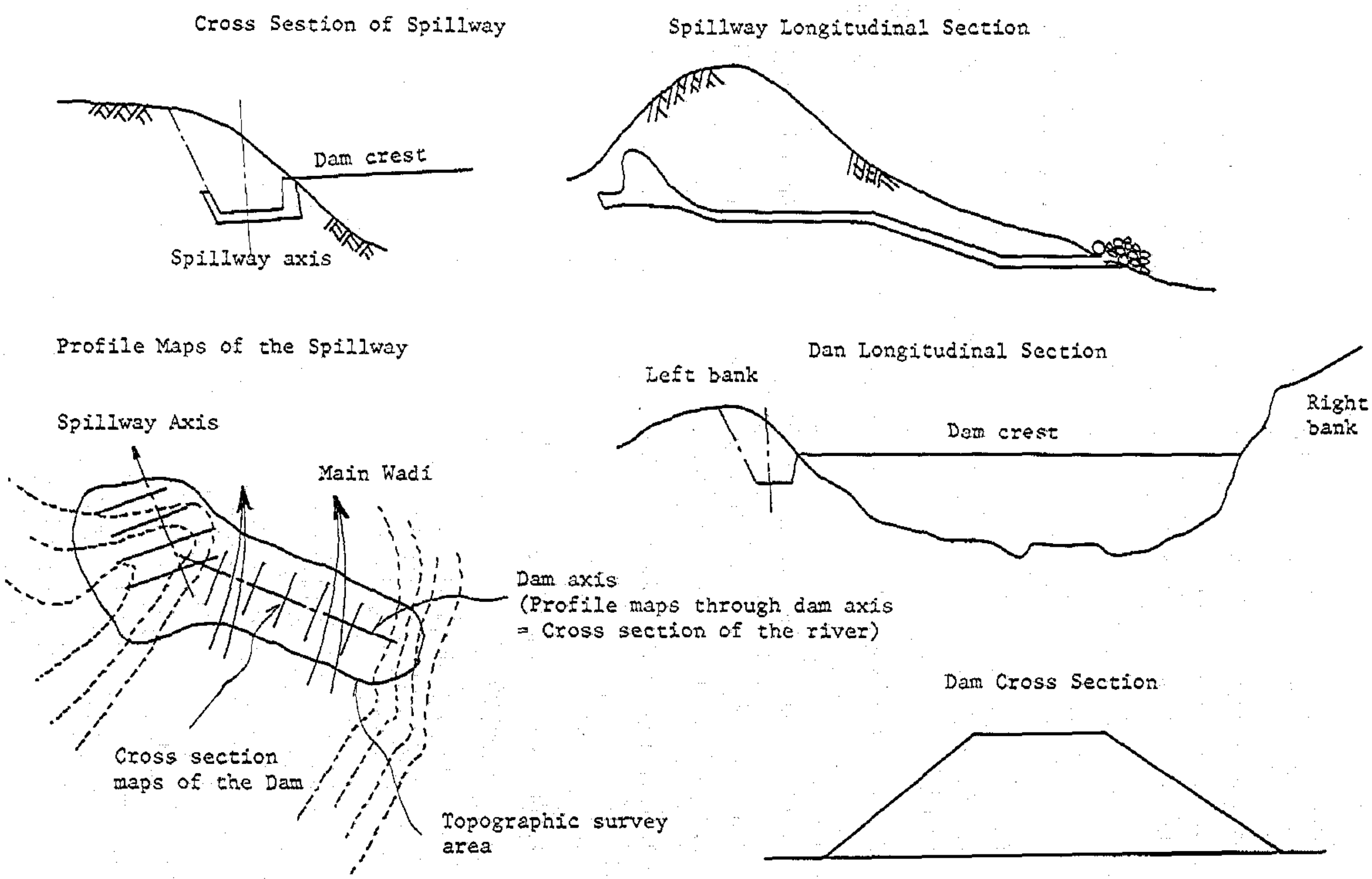
   Cross section maps of the area of the spillway of the scale 1/200 ∿ 1/300 and point distance 15 ∿ 20 meters.

   In case topography is much changeable, the point distnace should be shorter.

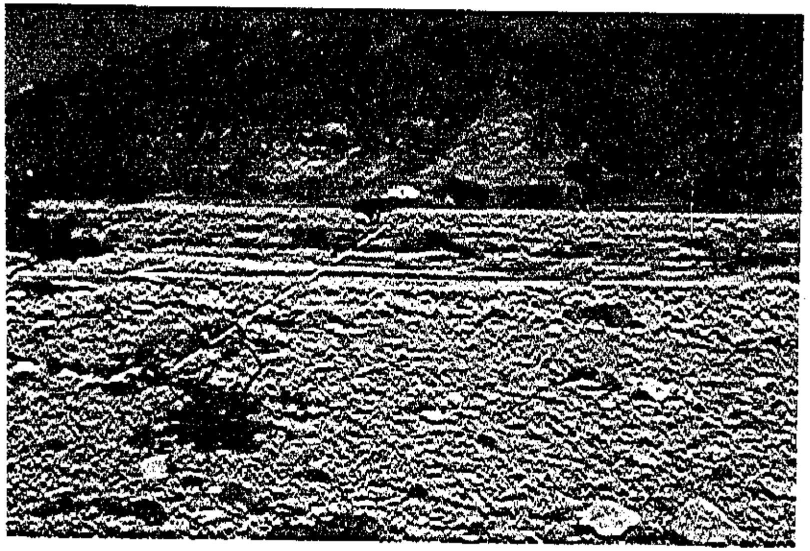
3. Profile map of the river of the scale 1/200 ∿ 1/300 and point distance 20 ∿ 30 meters.

   This map is not essential.

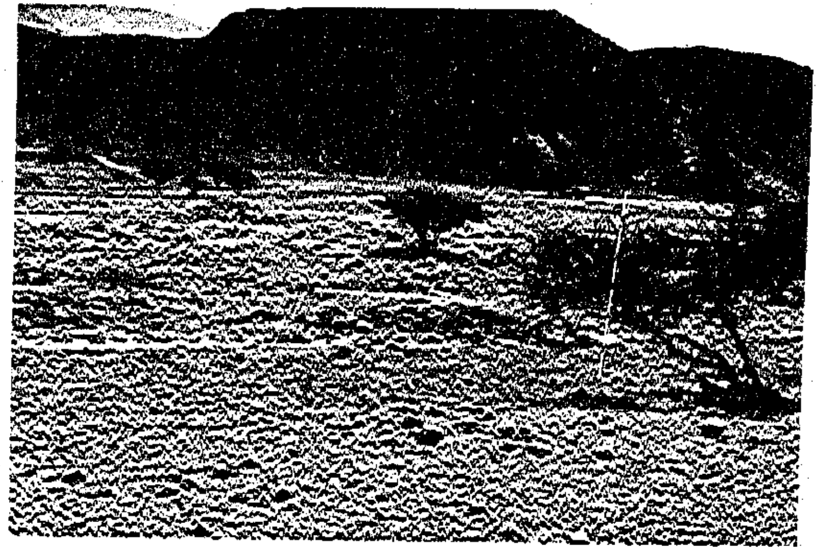
Wadi Safad Survey Method



WADI NAQAB (1)



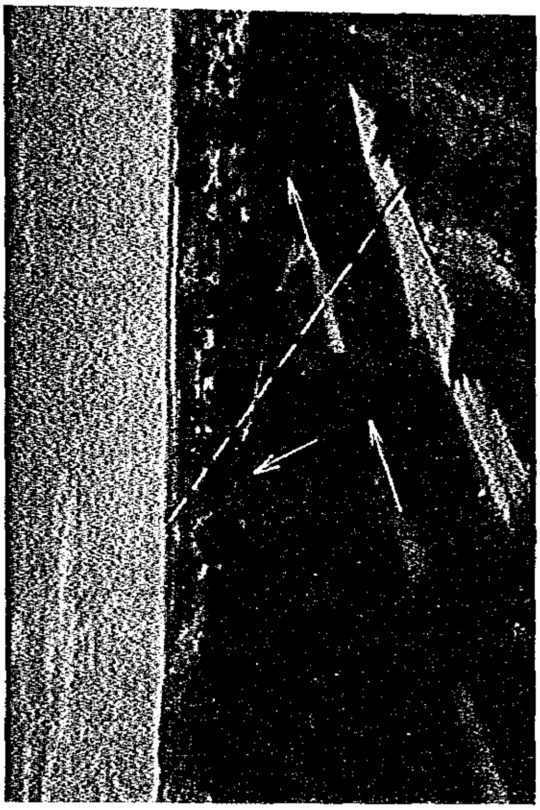
WADI NAQAB (2)



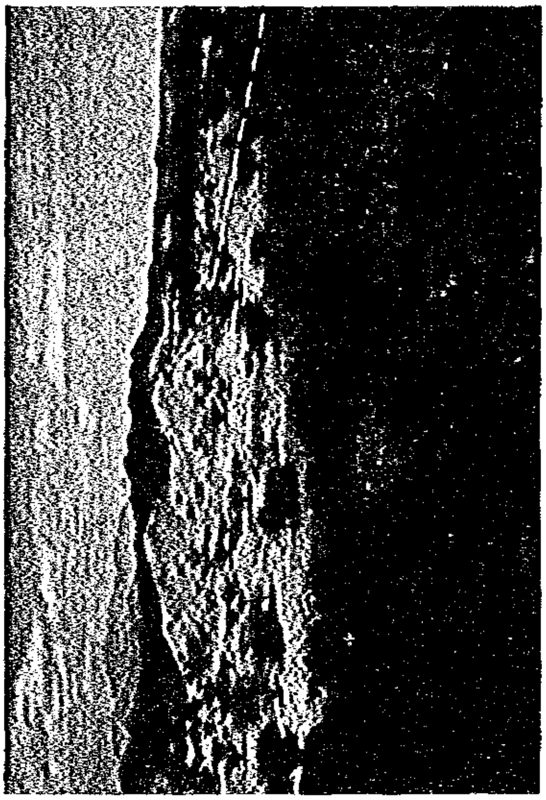
WADI SAFAD

WADI ASHWANI/SIFUNI

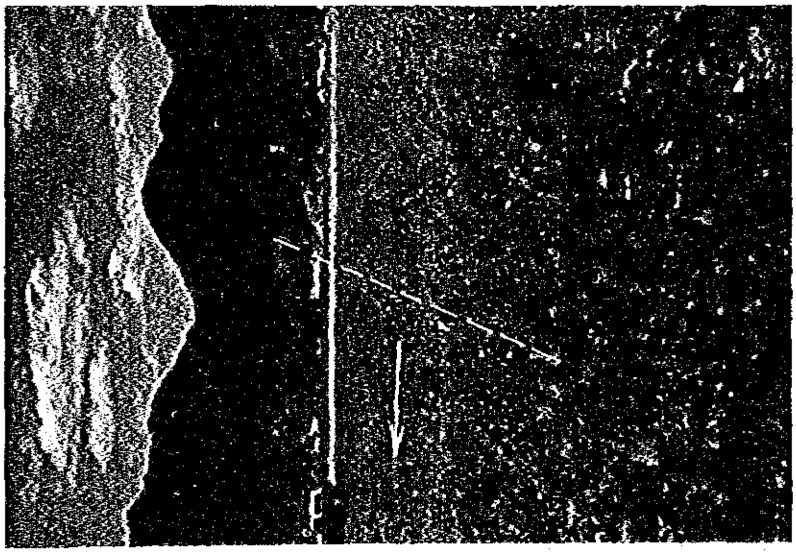
WADI RUMTH (1)



WADI RUMTH (2)



WADI SIJI



REFERENCES

RECHARGE/FLOOD CONTROL PROJECT

WORK PLAN

Note: The objective of the project is to identify suitable sizes for recharge/flood control projects, and to have structures built there, either by the Ministry or by an outside contractor. Various phases will overlap for various sites.

PHASE 1. PRELIMINARY SELECTION OF SITES

Scope:	On the basis of field visits a number of sites will be identified where topography and surface geology appear promising. Locations will be labelled on maps and photographs.
Manpower:	Adlby, Kurian, de Jong.
Timing:	October - December 1979
End Product:	Site descriptions, maps, photos

PHASE 2. PHYSIOGRAPHY

Scope:	A complete physiographic description will be made, on Data Bank form A2, of the drainage areas above the selected sites, based on map/photo study or field visits.
Manpower:	Kurian
Timing:	October 1979 - January 1980
End Product:	Completed forms A2

PHASE 3. HYDROLOGIC ASSESSMENT

Scope:	An analysis will be made of available data on rainfall and runoff to arrive at frequency curves for "Flood peaks" and "flood volumes", and sediment production will be estimated. If possible an FAO consultant will be called in to assist in developing frequency data for ungaged water-sheds.
Manpower:	Kurian, Consultant
Timing:	November 1979 - February 1980
End Product:	Frequency and production curves for floods and sediment loads.

PHASE 4. PROJECT CONCEPTULIZATION

Scope:	On the basis of 3 earlier phases the scope and nature of each project will be identified. This will include distribution of project components, description of each structure and its purpose, and qualitative identification of expected benefits.
Manpower:	de Jong
Timing:	November 1979 - February 1980
End Product:	Project descriptions for each wadi

PHASE 5. PRELIMINARY DESIGN

Scope:	This phase will quantify the project described in phase 4. This will require mapping of construction sites by a land surveyor, and an analysis of yield production and damage reduction for various sizes of structures. The preliminary design should clarify whether construction is to be done by the Ministry or by a Contractor.
Manpower:	Kurian, de Jong, Ministry surveyor
Timing:	November 1979 - March 1980
End Product:	Design sketches, storage vs. elevation curves, yield estimates, flood routing curves.

PHASE 6. FINAL DESIGN

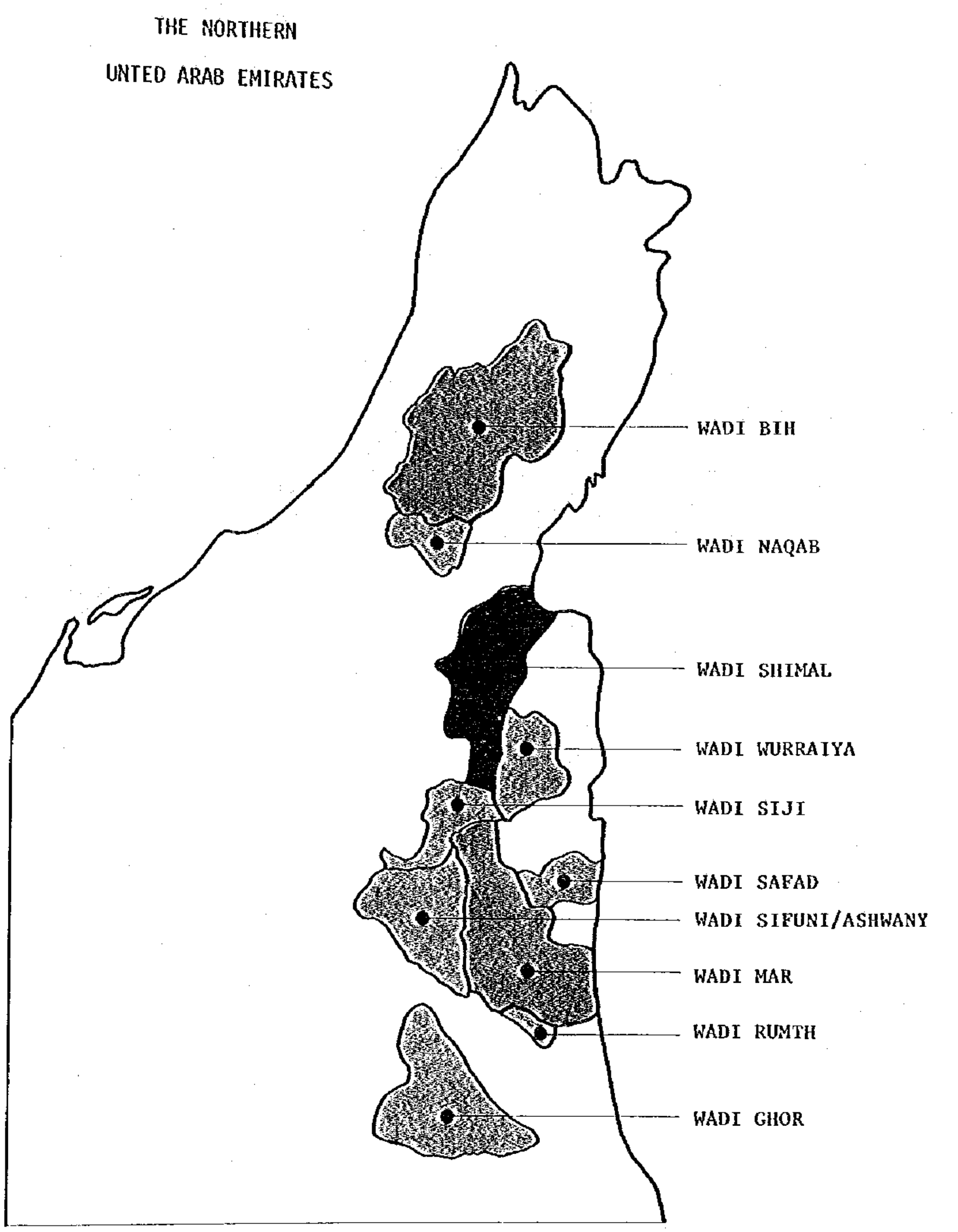
Scope:	The preliminary design should be finalized in a form ready for construction use. In case a Contractor will be involved Tender Documents will be required, including technical specifications. The presence of two Japanese design engineers will be utilized for this work.
Manpower:	Kurian, de Jong, Japanese engineers.
Timing:	November 1979 - April 1980
End Product:	Final design documents

PHASE 7. CONSTRUCTION

Scope:	The structures designed in Phase 6 will be built by the Ministry or a Contractor, under Ministry supervision. Final design drawings will be field corrected if necessary.
Manpower:	Ministry operators, or Contractor, Kurian
Timing:	January 1980 - August 1980
End Product:	Structures

PHASE 8. REPORTING

Scope:	For each wadi (project) a comprehensive report will be assembled, including the outputs of the earlier phases, and the corrected "as-built" drawings.
Manpower:	de Jong
Timing:	February 1980 - September 1980
End Product:	Final Reports



L O C A T I O N M A P R E C H A R G E B A S I N S

31 Jan. 1980

To: Dr. Isozaki, Mr. A. Masuda

From: Dr. R. de Jong

Subject: Assistance Mission - Small Dams

Mr. Obaid Karki, Director, Soil and Water Department, has asked me to provide some guidance and management to the Ministry's program to establish small dams on wadis where surplus surface water can be captured and put to a beneficial use.

Some time ago I prepared a work plan (copy attached), which is now being implemented, with necessary modifications as necessary. To date tentative sites have been selected on several wadis (see map attached) and for some of these sites other preparatory work has also been accomplished including: Physiographic descriptions, review of hydrologic records, topographic surveys. Some of this material is attached, other data will be made available to you.

The objective of your mission is to develop a simple standard dam design, which can be easily modified so it can be used either as an overflow weir, a porous water retardation structure, or a diversion dike. A few months ago I sketched out similar structures for Wadis Bih and Ham. Copies of the design drawings are attached.

It would be preferable if the proposed design would utilize almost exclusively local materials, since almost all other materials (cement, steel rod, wire baskets) have to be imported. It would also be preferable if the construction procedures could be kept simple enough so as to permit the Ministry to implement construction with its own, unskilled manpower, rather than by a outside contractor. In either case the Ministry will require detailed construction drawings; should you decide that construction be performed by a contractor, then the Ministry will also require a draft of the technical specifications, to accompany the drawings, for inclusion in Tender Documents.

Although you will be shown a few of the sites, I propose that you consider Wadi Sifuni/Aswani as your priority project. Most of the preliminary work for this site has been completed, and it is fairly close to Dubai.

It is the intent to develop individual Design Reports for each separate project, and during your stay here I will try to complete a draft of the Sifuni/Aswani report. Your work will be incorporated in each report.

For your work you will have available a meeting room in the Ministry (Second Floor), and desk space in my office (First Floor). A vehicle is available for field trips. Most of your contacts will be with Mr. Kurian, the Department's Hydrologist, who performed most of the preparatory work. Work areas in the Ministry are open for your use at all times.

Attached is a tentative program for your visit, which we can modify as time goes by.

I hope you will enjoy your visit to the U.A.E.

CC: Obaid Karki

PROGRAM

for

Japanese Dam Design Mission

(Dr. Yoshimasa Isozaki, Mr. Akinori Masuda)

Th	Jan	31:	11.30	Initial meeting, Director and staff, Water/Soil Dept.
			12.00	Introduction to project
Fr	Feb	1:		OPEN
Sa	"	2:	10.00	Introduction (ctd)
Su	"	3:		Field trip Wadi Sifuni/Aswani
Mo	"	4:		Design-Dubai
Tu	"	5:		Design-Dubai
We	"	6:		Field trip Wadi Naqub
Th	"	7:		Design-Dubai
Fr	"	8:		OPEN
Sa	"	9:		Design-Dubai
Su	"	10:	9.00	Progress review meeting with staff MAF
Mo	"	11:		Field trip ......
Tu	"	12:		Design-Dubai
We	"	13:		Design-Dubai
Th	"	14:	10.00	Debriefing MAF Dubai
Fr	"	15:		OPEN
Sa	"	16:	10.00	Debriefing Japanese Embassy, Abu Dhabi
Sun	"	17:		Departure JL 466 Abu Dhabi 0130 - Tokyo 2015

WATER RESOURCE DEVELOPMENT AT WADI'S OF ASHWANI AND SIFUNI, SIJI, SAFAD AND RUMTH

1. INTRODUCTION

Continued growth in demand for water is deplating the aquifers at a rapid pase, causing localized problems of saline intrusion and the drying up of some wells.

Preliminary observations have shown that some wadis appear to have sufficiant flows to justify construction of structures for groundwater recharge and thereby additional water development could be attaind. This would help to control flood flows and to increase infiltration into the ground.

Flood problems have been developing because of increased settlement in the flood plains.

The high-velocity, short-duration peak flows create gullies and ravines which make the flat cultivable land unfit for further cultivation. At the same time large quantities of water spreading over larger areas are going to waste due to evaporation. Infiltrated water stored up on the ground surface again lost by evaporation. Deep percolation is very rare because ground water levels are dropping gradually. The shallow acqifer systems of the gravel plains and desert foreland, which are the major groundwater reservoirs in the U.A.E, are now being heavily overdrawn. From the record of groundwater levels at Dhaid it can be seen that there was a decrease of 1.96 from march 1977 to Aug. 1979. Especially the Falaj flows are diminishing and as each area is mined, the water quality also locally deteriorates.

To limit further problems in the region, the Ministry of Agriculture and Fisheries of the United Arab Emirates intends to Develop projects which permit optimum utilization of the available water resources.

The main objectives of these projects is to carry out complete technical feasibility and design studies for collecting and conserving the waters from surface runoffs, including foundation material investigations, geological and hydrological analysis, and the preparation of designs specifications and cost estimates for construction.

The proposed works are expected to enhance recharge and to provide some flood protection.

All the four dam sites are in the northern part of the U.A.E. Wadi Ashwani and Sifuni and Siji are tributaries to the Wadi Lamhah which drains to the persian Gulf. Wadi Safad and Rumth drains to the Gulf of Oman in the vicinity of near by Fujairah and saff Kalbe.

The dam site at wadi Ashwani and Sifuni is located at down stream of the wadi Ashwani, sifuni junction. It is located 22 km from Dhaid town. The northen boundary of the drainage area is in common with the southern boundary of the drainage area of Siji catchment. The drainage area above the dam sites is 215.6 km^2. Elevations range from 200 m at the dam site 1050 m in the upper part of the basin. Its shape index worked out to be 2.09, from factor 0.36, Roundity factor 1.45 and compactness coefficient 2.26 average slope has been worked out to be 3.3% and drainage density is 1.69. Details physiographic characters has been worked out and enclosed.

The dam site at wadi Siji is located at the down stream of the gauging station. It is having a drainage area of 64 km^2. Elevation range from 230 m to 1124 meters. The shape index has been worked out to be 2.03. From factor 0.41 Rotundity factors, 1.95, compactness coefficient 1.32 and drainage density is 2.2. Detail physiographic characters has been worked out in the form of Data Bank.

Wadi Safad damsite is located 15 kms from Fujairah. The drainage area is 26 km^2. Elevations range from 55 meters to 846 meters. Shape index for the catchment is 1.78, from factor is 0.43. Rotundity Factor 1.93, compactness coefficient 1.22 average slope is 7.5%. Time of concentration is 66 minutes and drainage density is 1.48. Detail physiographic characters is enclosed in Data Bank form.

Wadi Rumth dam site is 8 km from saff Kalba. It has a drainage area of 30.5 km^2. Elevation range is 140 at the dam site to 1013 meters. Average slope is 8.3 percentage. Time of concentration is 63 minutes and drainage density is 1.5. Details are enclosed in the data Bank form.

UNITED ARAB EMIRATES
Ministry of Agriculture and Fisheries
P.O. Box 1509, Dubai

TEL:
TLX: 46590

PHYSIOGRAPHY

DATA BANK
FORM:A2

STATION IDENTIFICATION

1. NO:________ 2. NAME: Wadi Ashwani & Wadi Sifuni 3. AGENCY:________
4. COORDINATES:______N ______E 5. UTM:________

Geometry

5.	Size, A (Km^2)	215.6
6.	Average Width, W (Km)	95.7
7.	Average Length, L (Km)	10.5
8.	Basin Length along Main Stream, L_b (Km)	20.0
9.	Perimeter, P (Km)	64.0
10.	Perimeter of Equivalent Circle $Pc = 2\sqrt{\pi A}$ (Km)	28.3
11.	Shape Index, $SI = L_b^2 \div A$ (-)	2.08
12.	Form Factor, $FF = A \div L_b^2$ (-)	0.36
13.	Rotundity Factor, $RF = \pi L_b^2 \div 4A$ (-)	1.45
14.	Compactness Coefficient, $CC = P \div Pc$ (-)	2.26

Topography

15.	Elevation of Station	(m.a.s.l.)	260
16.	Maximum Elevation	(m.a.s.l.)	1050
17.	Mean Elevation	(m.a.s.l.)	
18.	Average Elevation	(m.a.s.l.)	625
19.	Maximum Relief	(m)	850
20.	Average Slope	(%)	3.3
21.	Lag Time	(hours) $Lg = C\,[(.168Ls \times Lca) \div \sqrt{S}\,]^x$	
22.	Time of Concentration	(mins.) $Tc = [.09195K^{0.77}]$ when $K = \sqrt{3 \div H}$	182.6

Drainage

23.	Number of Streams, N (-)	270
24.	Stream Density, $SD = N \div A$ (Km^{-2})	1.25
25.	Length of Main Stream, Ls (Km)	260
26.	Stream Order, SO (-)	
27.	Total Length of Streams, L_t (Km)	366
28.	Drainage Density, $DD = L_t \div A$ (Km^{-1})	1.60
29.	Stream Frequency, $SF = N \div A$ (Km^{-1})	
30.	Drainage Type (Dendritic 1, Trellis 2, Barbed 3, Complex 4, Parallel 5, Deranged 6, Radial 7, Rectangular 8)	4

WADI ASHWANI & WADI SIFUNI
Catchment Area & Tributeries)
Scale 1:100,000

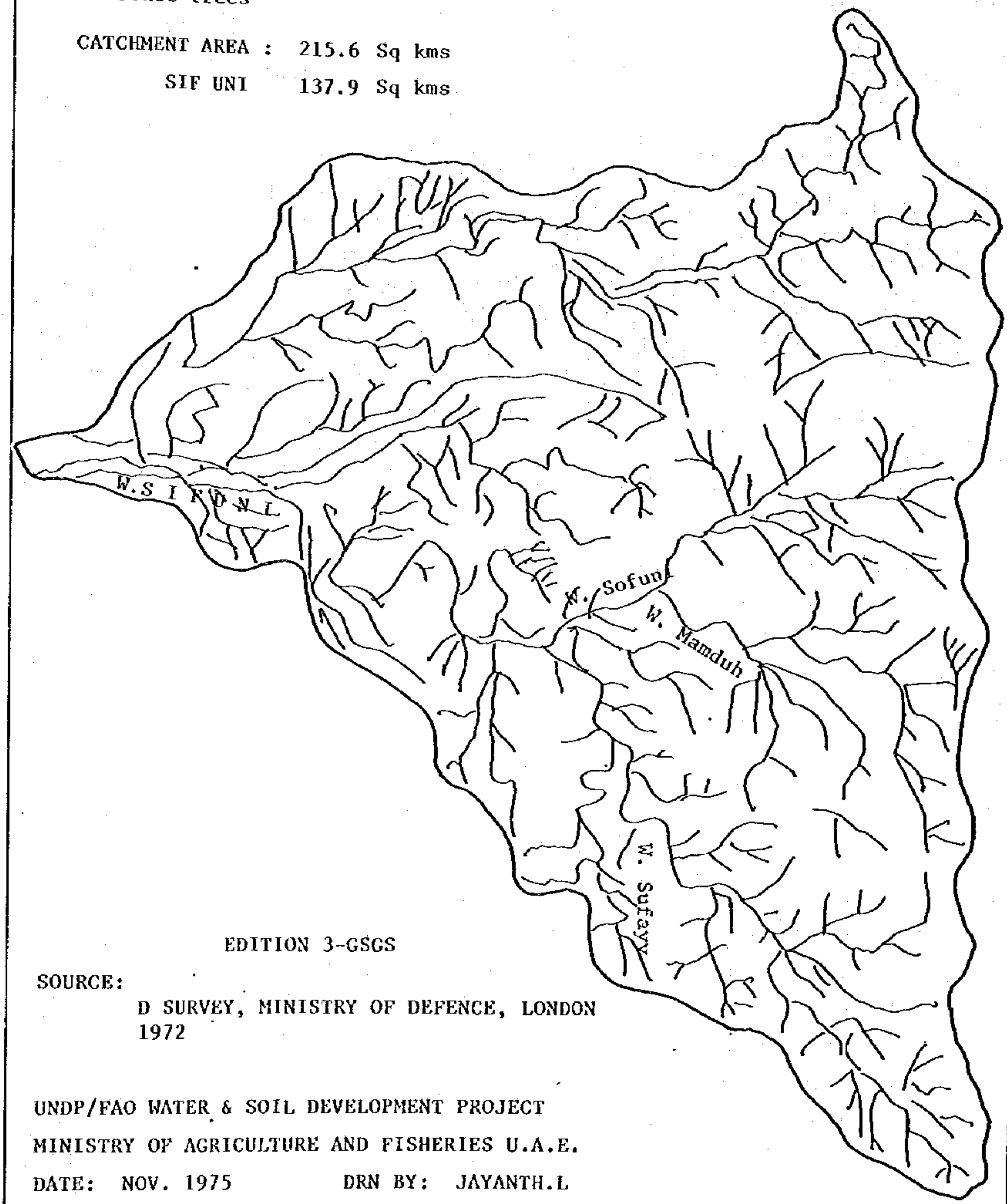
Wadi bed

Scattered cultivation

Dense trees

CATCHMENT AREA : 215.6 Sq kms

SIF UNI 137.9 Sq kms



EDITION 3-GSGS

SOURCE:

D SURVEY, MINISTRY OF DEFENCE, LONDON
1972

UNDP/FAO WATER & SOIL DEVELOPMENT PROJECT

MINISTRY OF AGRICULTURE AND FISHERIES U.A.E.

DATE: NOV. 1975 DRN BY: JAYANTH.L

UNITED ARAB EMIRATES
Ministry of Agriculture and Fisheries
P.O. Box 1509, Dubai

TEL:
TLX: 46590
STATION IDENTIFICATION

PHYSIOGRAPHY

DATA BANK
FORM: A2

1. NO:________ 2. NAME: SIJI CATCHMENT 3. AGENCY:________

4. COORDINATES: ____ N ____ E 5. UTM: ________

Geometry

5.	Size, A (Km^2)	6 4.0
6.	Average Width, W (Km)	6.2
7.	Average Length, L (Km)	1 1.6
8.	Basin Length along Main Stream, L_b (Km)	1 2.6
9.	Perimeter, P (Km)	3 7.5
10.	Perimeter of Equivalent Circle $Pc = 2 \pi A$ (Km)	2 8.4
11.	Shape Index, $SI = L_b^2 \div A$ (-)	2 0.3
12.	Form Factor, $FF = A \div L_b^2$ (-)	0.4 1
13.	Rotundity Factor, $RF = \pi L_b^2 \div 4A$ (-)	1.9 5
14.	Compactness Coefficient, $CC = P \div Pc$ (-)	1.3 2

Topography

15.	Elevation of Station	(m.a.s.l.)	2 3 0
16.	Maximum Elevation	(m.a.s.l.)	1 1 2 4
17.	Mean Elevation	(m.a.s.l.)	
18.	Average Elevation	(m.a.s.l.)	6 7 7
19.	Maximum Relief	(m)	8 9 4
20.	Average Slope	(%)	6.0
21.	Lag Time	(hours) $Lg = C\, [(.168Ls \times Lca) \div S]^x$	
22.	Time of Concentration	(mins.) $Tc = [.0195K^{0.77}]$ when $K = 3 \div H$	9 5

Drainage

23.	Number of Streams, N (-)	1 5 0
24.	Stream Density, $SD = N \div A$ (Km^{-2})	2.3 4
25.	Length of Main Stream, Ls (Km)	1 5
26.	Stream Order, SO (-)	
27.	Total Length of Streams, L_t (Km)	1 3 8
28.	Drainage Density, $DD = L_t \div A$ (Km^{-1})	2.2
29.	Stream Frequency, $SF = N \div A$ (Km^{-1})	
30.	Drainage Type (Dendritic 1, Trellis 2, Barbed 3, Complex 4, Parallel 5, Deranged 6, Radial 7, Rectangular 8)	4

WADI SIJI (Catchment Area & Tributeries)

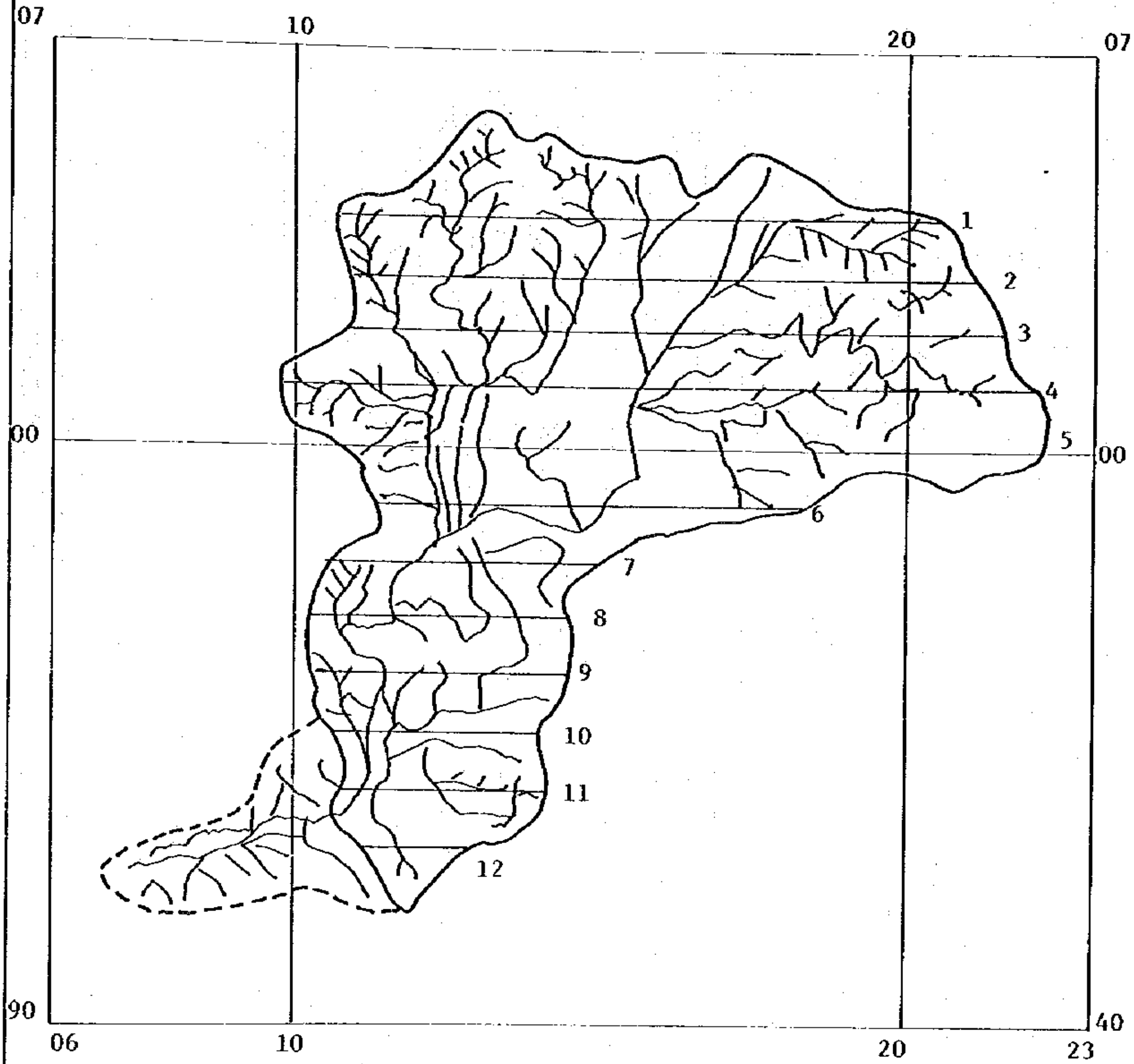
Scale 1:100,000

Wadi bed

Scattered cultivation

Dense trees

CATCHMENT ARE:: 67.6 Sq kms



EDITION 3-GSGS

SOURCE:

D SURVEY, MINISTRY OF DEFENCE, LONDON 1972

UNDP/FAO WATER & SOID DEVELOPMENT PROJECT

MINISTRY OF AGRICULTURE AND FISHERIES U.A.E.

DATE: NOV. 1975 DRN BY: JAYANTH.L

UNITED ARAB EMIRATES
Ministry of Agriculture and Fisheries
P.O. Box 1509, Dubai

TEL:
TLX: 46590
STATION IDENTIFICATION

PHYSOGRAPHY

DATA BANK
FORM: A2

1. NO:________ 2. NAME: WADI RUMTH ________ 3. AGENCY:________

4. COORDINATES:______ N ______ E 5. UTM:________

Geometry

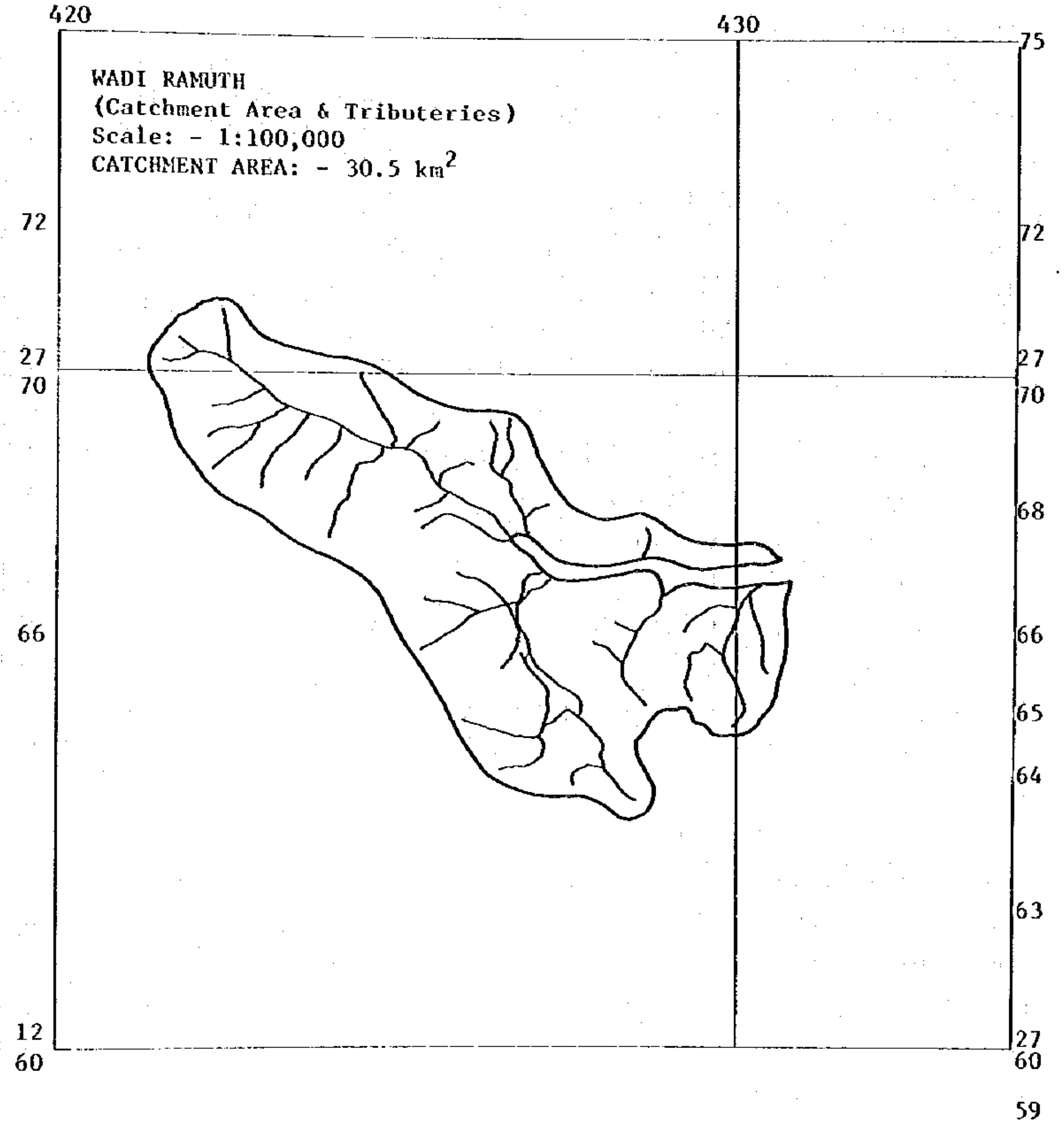
5.	Size, A (Km^2)	30.5
6.	Average Width, W (Km)	3.5
7.	Average Length, L (Km)	10.0
8.	Basin Length along Main Stream, L_b (Km)	10.2
9.	Perimeter, P (Km)	27.5
10.	Perimeter of Equivalent Circle $Pc = 2\sqrt{\pi A}$ (Km)	19.6
11.	Shape Index, $SI = L_b^2 \div A$ (-)	2.9
12.	Form Factor, $FF = A \div L_b^2$ (-)	0.33
13.	Rotundity Factor, $RF = \pi L_b^2 \div 4A$ (-)	2.7
14.	Compactness Coefficient, $CC = P \div Pc$ (-)	1.4

Topography

15.	Elevation of Station	(m.a.s.l.)	140
16.	Maximum Elevation	(m.a.s.l.)	1013
17.	Mean Elevation	(m.a.s.l.)	
18.	Average Elevation	(m.a.s.l.)	576.5
19.	Maximum Relief	(m)	873
20.	Average Slope	(%)	8.3
21.	Lag Time	(hours) $Lg = C\,[(.168Ls \times Lca) \div \sqrt{S}]^x$	
22.	Time of Concentration	(mins.) $Tc = [.0195K^{0.77}]$ when $K = \sqrt{3 \div H}$	63

Drainage

23.	Number of Streams, N (-)	35
24.	Stream Density, $SD = N \div A$ (Km^{-2})	1.15
25.	Length of Main Stream, Ls (Km)	10.5
26.	Stream Order, SO (-)	
27.	Total Length of Streams, L_t (Km)	45.4
28.	Drainage Density, $DD = L_t \div A$ (Km^{-1})	1.5
29.	Stream Frequency, $SF = N \div A$ (Km^{-1})	
30.	Drainage Type (Dendritic 1, Trellis 2, Barbed 3, Complex 4, Parallel 5, Deranged 6, Radial 7, Rectangular 8)	4


420
430
WADI RAMUTH
(Catchment Area & Tributeries)
Scale: - 1:100,000
CATCHMENT AREA: - 30.5 km2
75
72
72
27
70
27
70
68
66
66
65
64
63
12
60
27
60
59

UNITED ARAB EMIRATES
Ministry of Agriculture and Fisheries
P.O. Box 1509, Dubai

TEL:
TLX: 46590
STATION IDENTIFICATION

PHYSLOGRAPHY

DATA BANK
FORM: A2

1. NO:______ 2. NAME: WADI SAFAD 3. AGENCY:______

4. COORDINATES:____ N ____ E . UTM:______

Geometry

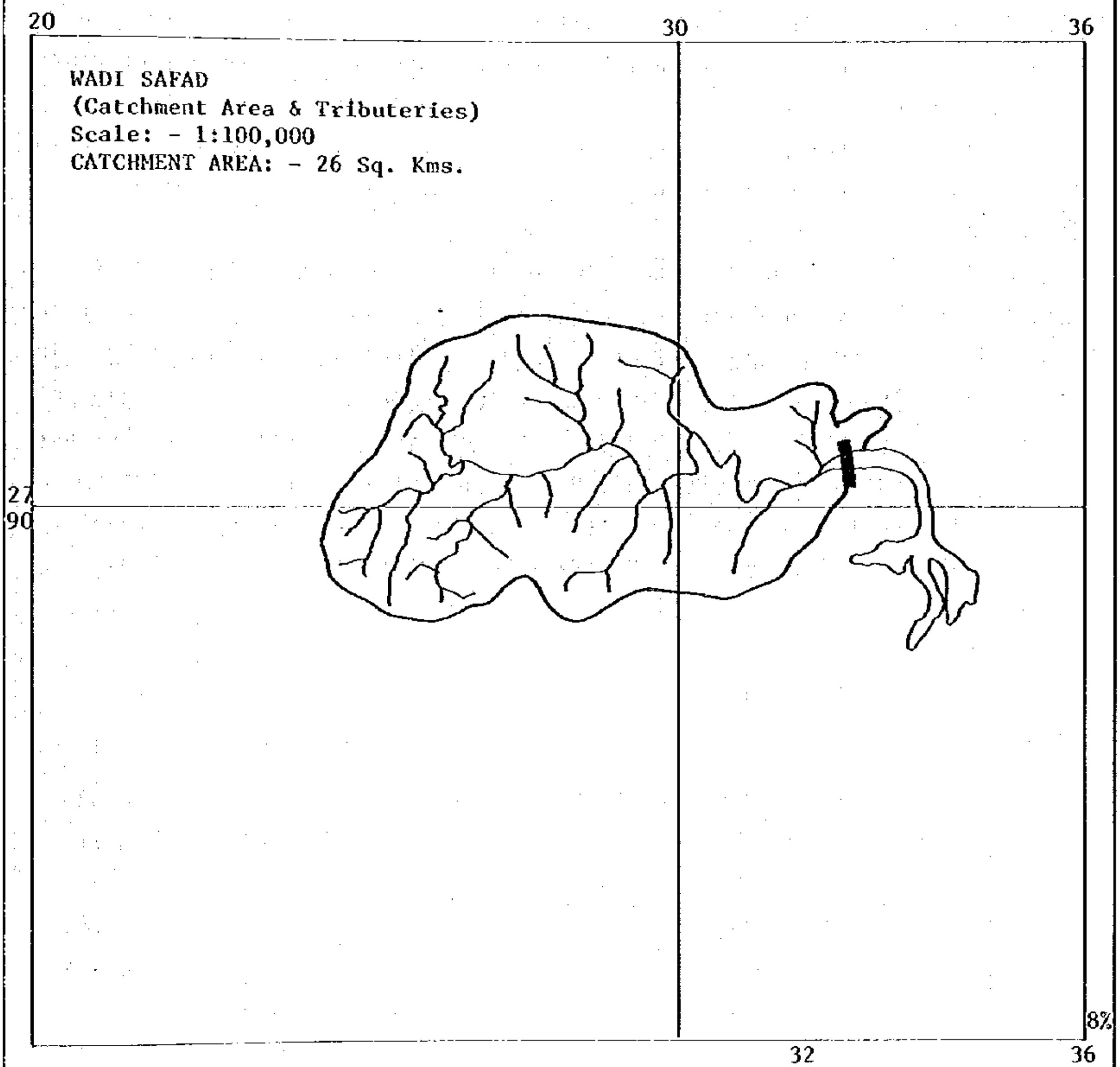
5.	Size, A (Km^2)	2 6.0
6.	Average Width, W (Km)	4.5
7.	Average Length, L (Km)	7.0
8.	Basin Length along Main Stream, L_b (Km)	8.0
9.	Perimeter, P (Km)	2 2.0
10.	Perimeter of Equivalent Circle $Pc = 2\sqrt{\pi A}$ (Km)	1 8.0
11.	Shape Index, $SI = L_b^2 \div A$ (-)	1.7 8
12.	Form Factor, $FF = A \div L_b^2$ (-)	
13.	Rotundity Factor, $RF = \pi L_b^2 \div 4A$ (-)	1.9 3
14.	Compactness Coefficient, $CC = P \div Pc$ (-)	1.2 2

Topography

15.	Elevation of Station	(m.a.s.l.)		5 5.0
16.	Maximum Elevation	(m.a.s.l.)		8 4 6
17.	Mean Elevation	(m.a.s.l.)		
18.	Average Elevation	(m.a.s.l.)		4 5 0.5
19.	Maximum Relief	(m)		7 9 1.0
20.	Average Slope	(%)		7.5
21.	Lag Time	(hours)	$Lg = C\,[(.168Ls \times Lca) \div \sqrt{S}]^x$	
22.	Time of Concentration	(mins.)	$Tc = [.0195K^{0.77}]$ when $K = \sqrt{3 \div H}$	6 6

Drainage

23.	Number of Streams, N (-)	3 1
24.	Stream Density, $SD = N \div A$ (Km^{-2})	1.1 9
25.	Length of Main Stream, Ls (Km)	1 0.5
26.	Stream Order, SO (-)	
27.	Total Length of Streams, L_t (Km)	3 8.6
28.	Drainage Density, $DD = L_t \div A$ (Km^{-1})	1.4 8
29.	Stream Frequency, $SF = N \div A$ (Km^{-1})	
30.	Drainage Type (Dendritic 1, Trellis 2, Barbed 3, Complex 4, Parallel 5, Deranged 6, Radial 7, Rectangular 8)	4


WADI SAFAD
(Catchment Area & Tributeries)
Scale: - 1:100,000
CATCHMENT AREA: - 26 Sq. Kms.
20
30
36
27
90
8%
32
36

DESIGN STORM DERIVATION

The Sharjah data shows that 50% of the rainfalls in December - January and about 70% in the 3 months period of Dec.: - Feb.: The annual rainfall for years averaged about 103 mm, for the 14yrs 82 mm for 12yrs 88 mm, for 6yrs 114 mm and for 2yrs 152 mm, the maximum rain has been 258 mm and minimum 0.3 mm. Most of the total annual rainfall generally occurs in about two storms, even in the wettest years. Rainfall is generally intense. A total fall of 107 mm was measured at Sharjah in 24 hours, a quantity in excess of the average annual rainfall at that station.

This short of intensity and variation can occur anywhere in Emirates and probably evenmore intense and variable in the ountains. The paucity of storms and their when occurence make for an inadequate, and undependable water supply and the intensity of the storms when they do occur, create short duration high peak flood flows, making economic development near the wadis a dangerous practics.

Few years rainfall data is too limited in area coverage and period of record to provide the basis for design storms derivation. Since adequate data for design storm derivation are not available for these Dam sites, the derivation here is based on probable maximum thunder storm precipitation for the desert region of similar condition (hydro-meterological brange of the U.S. National whether service Study used for derivation of the design thunder storm.) A probable maximum thunder storm precipitation value of 305 mm (12") for 2.59 km^2 (1 mile) was obtained, area reduction and time distribution factors were obtained too.

Factors for reducing probable maximum thunder storm precipitation from 2.59 km^2 to:-

DURATION (Hours)	485 Km^2	277 Km^2	215 Km^2	90 Km^2	64 Km^2	26 Km^2
$\frac{1}{2}$.	0.290	0.400	0.460	0.580	0.680	0.826
1.	0.360	0.480	0.538	0.655	0.679	0.714
2.	0.410	0.525	0.590	0.690	0.711	0.742
3.	0.450	0.560	0.615	0.725	0.748	0.782
4.	0.475	0.585	0.636	0.740	0.762	0.794
5.	0.495	0.605	0.655	0.755	0.776	0.807
6.	0.515	0.625	0.673	0.770	0.790	0.818

Factors applied to the 1 hour value of probable maximum thunder storm precipitation to get values for other duration as follows:-

Duration	Factor
$\frac{1}{4}$	0.43
$\frac{1}{2}$	0.70
1	1.0
2	1.27
3	1.44
4	1.54
5	1.63
6	1.70

The value of 305 mm for 1 hour for 2.59 Km^2 was reduced for area and distributed in time (up to a 6 hour duration) using the above factors.

INVENTORY OF WATER RESOURCES

Severe rainfall from thunderstorms can occur over the Arabian Gulf and the U.A.E. expecially in the mountainous region of the Musandum penisula. Such thunderstorm activity occurs primarily during the period from October to April in assosiation with cold fronts and line squalls moving from the north west across the warm waters of the Arabian Gulf. Very limited rainfall data for thunder storms in the mountainous area are available. How ever two severe thunder storm occurrences at Sharjah on the coast of the U.A.E. have been provided. A thunder storm at Sharjah on 23rd NOV.; 1957., produced 74.1 mm rainfall inabout 50 minutes. Another thunderstorm on 14th Nov.; 1954 produced about 56 mm in 45 minutes at Sharjah. During the summer 1956, 12.3 mm rainfall was observes at Sharjah even though it is quite unusual, it does demonstrate that summer rainfall can occur.

The resulting design thunderstorms for wadi Ashwani & Sifuni, Siji and Safad is given below.

Design thunder storm for Ashwani & Sifuni 215 Km^2 at damsite.

Duration (hours)	Precipitation depth (mm)	Hourly increments (mm)
$\frac{1}{2}$	111	71
1	182	64
2	246	48
3	294	30
4	324	27
5	350	24
6	374	

Design Thunder Storm for Siji Dam Site 64 Km^2

Duration (hours)	Precipitation Depth (mm)	Hourly Increments (mm)
½	127	204
1	204	68
2	271	52
3	323	31
4	353	31
5	380	28
6	404	25

Design Thunder Storm for Safad 26 Km^2

Duration (hours)	Precipitation Depth (mm)	Hourly Increments (mm)
½	131	
1	210	210
2	278	68
3	330	52
4	361	31
5	389	28
6	414	25

The intensity of the few rain storms that may be expected each year is more important as regards runoff than the total amount of precipitation.

Annual and Average Annual Rainfall Data for stations near Wadis Ashwani & Sifuni, Siji, Safad and Rumth. (mm) Given in Table down below.

	WADI ASHWANI & SIFUNI AREA		WADI SIJI AREA	WADI SAFAD AREA	
YEAR	MELEIHA	MASAFI	SIJI	KALBA	DIBBA
1965-66		72.3		50.1	50.6
67		67.3		21.8	20.8
68		106.6		110.0	88.9
69	135.6	181.2		123.7	166.0
70	58.78	31.29		68.2	60.3
71	3.9	20.5		20.6	16.3
72	171.6	195.5		266.2	199.2
73	65.4	83.2		20.2	93.7
74	8.6	41.0		23.4	11.9
75	134.6	325.5		144.1	72.4
76	260.5	357.1	334.5	265.8	195.4
77	133.9	264.0	244.6	241.8	246.5
78	69.9	197.9	68.1	78.2	96.6
79	58.1	103.0	77.4	78.6	90.4
14 yrs Avg: (66-79)		146.24		108.05	100.64
11 yrs Avg:	100.08	163.74		120.98	113.55
4 yrs Avg:	130.60	230.75	181.15	166.10	157.23
2 yrs Avg:	64.00	75.48	36.38	39.20	46.75

RAINFALL

1975-76	MASAFI	MELEIHA	SIJI	DIBBA	SIFUNI
February	130.8	97.7	165.5	92.6	-
March	43.5	46.8	54.0	27.7	-
April	61.5	55.5	60.0	74.1	-
August	78.5	9.3	50.0	4.0	71.5
1976-77					
October	84.0	0	54.5	0	7.2
November	2.5	0	30.8	0	20.6
January	57.4	35.0	-	175.6	-
February	37.6	36.6	42.0	17.2	0
March	52.0	3.3	1.7	15.5	0
April	40.8	30.8	19.3	24.1	84.2
1977-78					
February	63.8	45.3	54.0	22.4	-
March	-	0.7	-	22.9	-
August	56.6	13.7	-	0.2	-
September	-	-	-	-	4.0
1978-79					
March	51.0	45.7	62.8	64.2	62.0

Table ANNUAL AND AVERAGE ANNUAL RAINFALL DATA AT SHARJAH (mm)

YEAR	RAINFALL	YEAR	RAINFALL	YEAR	RAINFALL
1934/35	153.4	1950/51	33.1	1964/65	122.9
36	57.1	52	104.4	66	60.8
37	217.7	53	83.2	67	11.5
38	69.3	54	88.5	68	81.8
39	129.0	55	207.3	69	140.2
40	60.5	56	85.7	70	64.6
41	78.2	57	258.2	71	14.9
42	42.2	58	102.0	72	157.8
43	148.1	59	141.7	73	51.7
44	94.0	60	47.6	74	3.1
45	213.1	61	89.3	75	167.4
46	9.4	62	0.3	76	168.5*
47	58.2	63	227.9	77	134.7
49-50	NR	64	127.6	78	39.1
				79	49.2

	(mm)	(%)
40 yrs average (1934/35-1976/77)	102.8	100.00
14 yrs average (1975/76-1979)	81.8	79.6
12 yrs average (1965/66-1976/77)	88.1	85.7
11 yrs average (1966/67-1978/79)	90.1	87.6
6 yrs average (1971/72-1976/77)	113.9	110.8
4 yrs average (1975/76-1978/79)	97.9	95.2
2 yrs average (1975/76-1976/77)	151.6	147.5

Note: N.R. - No Record
* Practically Estimated

( ) - New Location (Dubai International Airport)

SURFACE WATER ESTIMATION (PEAK FLOW)

Water resource data and especially surface water data are very meager in the U.A.E. Different approaches have been tried to estimate the peak flow.

1. Rational Method:-

$$Q = \frac{CIA}{36}$$

When Q = Design peak run-off rate in cubic meters per second.

C = Run-off coefficient (0.85) was used for hilly land without any vegetation.

I = Maximum rate of rainfall in centimeters per hour over the entire area which may occur during the time of concentration (TC)

When TC= Time of concentration = $0.0195K^{.77}$

$K = \sqrt{L^3/H}$

L = Maximum length of flow in meters

H = Drop in meters

A = Area of the watershed

From 40 years of data available at Sharjah a thunderstorm of 74.1 mm of rainfall in about 50 minutes has been reported on 23rd Nov. 1957. Maximum one hour rainfall expected = 8.89 cm.

Time of concentration for Ashwani & Sifuni watershed has been worked out as 182.6 minutes from area of 215.6 km^2.

Value of I = 4.5 cm/hr (from graph)

Expected peak discharge from the catchment is 2290 m^3/sec

Wadi Siji has time of concentration of 95 minutes

Value of I = 6 cm/hr

Expected peak discharge from the catchment is 907 m^3/sec.

Wadi Safad has time of consentration of 66 minutes.

Value of I = 7.5 cm/hr

Expected peak discharge from the catchment is 460 m^3/sec.

Wadi Rumth has time of concentration of 63 minutes.

Value of I = 8 cm/hr

Expected peak discharge from the catchment is 576 m^3/sec.

It should be noted that run off estimated extrapolatid from sharjah rainfall data cannot have a high degree of reliability, because of different location and more over in U.A.E., located thunderstorms are very common.

2. BASED ON SURFACE RUN-OFF DATA OF WADIS:-

Flow data for wadi Siji and Sifuni for the hydrologic years of 1975 to 1979 is presented in the Table. Table shows wadi Siji had an average annual surface flow of 1681200 m^3 for the 4 years 1976 & 77 had above normal rainfall record and probably also had above normal run-off volumes. Using the average rainfall at Siji and to represent rainfall on wadi siji and average rainfall at Siji & Meleiha represent rainfall on the wadi Sifuni watershed, the run-off rate (percentage of rainfall showing up as measured stream flow) is 11.5% and at Siji it is 14.7%. Table shows the derivation of the estimated long term average annual run-off for wadi Siji & Sifuni. By using the average rainfall for 4yrs or 14 yrs of records at the station Masafi Siji & or 11 years at Meleiha and the equivalent period relationship to the 40 year record at Sharjah, a long term annual rainfall at the stations and on the watershed is obtained. Then by applying the run-off rate given in table to the long term basin rainfall, a long term unit run-off is derived. This unit run-off multiplied by the drainage area gives the long term run-off for the stream. As derived in the table the long term average annual flows are estimated to be 1760000 m^3 at wadi Siji dam site and 4678500 m^3 at wadi Ashwani & Sifuni.

Table ( ) also shows the derivation of the estimated long term average annual run-off for wadi Safad and Rumth. By using the average rainfall for the 14 years of record at station of Kalba & Dibba and the Equivelent period relationship to, the 40 years record at Sharjah, a long term annual rainfall at the dam site and on the watershed is obtained. Similarly run-off rate has been determined based on area and rainfall of the catchment as there is no flood measurement in the catchment. Thereby applying the run-off rate given in table to the long term basin rainfall, a long term unit run-off is derived. This unit run-off multiplied by the drainage area gives the long term run-off for the stream. As derived in the table the long term average annual flows are estimated to be 668200 m^3 for wadi Safad and 759500 m^3 for wadi RUMTH.

It should be noted, however that run-off estimates extrapolated few years of stream flow data cannot have a high degree of reliability, especially when it is further remembered that the Sharjah, rainfall data used to extend other recored data is itself not reliable for the years 1976 & 1977. The stations was discontinued in 1976 and relocated at Dubai International Airport in that year.

Surface Water Data For Wadi Siji 64 Km^2

Period	1000 m^3	mm	Basin Rainfall mm	Run-off rate %
1975-76				
February	1018.3	15.9	148.0	10.7
March	165.6	2.6	49.0	5.3
April	1247.4	19.5	61.0	32.0
August	341.9	5.3	64.0	8.3
Other	151.4	2.4	-	-
Total/avg:	2924.6	45.7	322.0	14.2
1976-77				
October	900.2	14.1	69.0	20.4
November	162.6	2.5	16.5	15.2
January	1054.8	16.5	116.5	14.2
February	321.3	5.0	40.0	12.5
March	119.5	1.9	27.70	6.9
April	356.1	5.6	30.0	18.6
May	358.6	5.6	-	-
Total/avg:	3273.1	51.2	299.7	17.1
1977/78				
February	164.0	2.6	27.0	9.6
March	49.0	0.8	12.0	7.0
Total/avg:	213.0	3.4	39.0	8.7
1978-79				
March	314.2	5.0	57.0	8.8
Total/Avg:	314.2	5.0	57.0	8.8
4 ys. Avg:	1681.2	26.3	179.4	14.7

SURFACE WATER DATA FOR WADI SIFUNI

Period	Wadi Sifuni 1000 m^3	138 Km^2 mm	Basin rainfall mm	Run-off Rate %
1975-76				
February	401.2	2.9	131.3	2.2
April	1490.4	10.8	63.0	17.0
August	1440.3	10.4	71.5	14.5
September	218.9	1.6	-	-
Total/Avg:	3550.8	25.7	265.8	9.7
1976-77				
October	635.9	4.6	30.6	14.9
November	256.0	1.9	25.7	7.4
January	709.3	5.1	46.0	11.1
February	88.1	0.64	39.0	1.6
March	14.2	0.1	6.8	1.5
April	903.7	6.5	51.75	12.6
Total/Avg:	2607.2	18.84	200.05	9.4
1977-78				
February	340.2	2.5	46.0	5.4
March	50.4	0.4	12.0	3.3
August	239.0	1.7	35.2	4.8
September	1.9	0.01	4.0	0.3
Total/Avg:	631.5	4.61	97.15	4.7
1978-79				
March	3098.7	22.4	62.4	35.9
Total/Avg:	3098.7	22.4	62.4	35.9

Table. Long Term Average Annual Run-off of Wadi Siji, Wadi Ashwani & Sifuni, Wadi Safad, and Wadi Rumth

Colum	1	2	3	4	5	6	7
Data Source	Table 1	Table	1÷2	Table		3x4	5x6
Rainfall Location	Avg: Rainfall of Record	Conversion Factor	Longterm Avg:Rainfall	Run-off Rate	Drainage Area	Long-Term Avg:Run-off	
	mm	%	mm	%	Km^2	mm	1,000 m^3
Masafi WADI SIJI	146.24	79.6	183.7	-	-	-	-
Siji	181.15	95.2	190.3	14.7	64	27.5	1,760.0
At Dam Site			187.0				
Meleihe	163.74	87.6	Wadi Sifuni & Ashwani	-	-	-	-
Siji	181.15	95.2	186.9 190.1	11.5	215.6	21.7	4,678.5
At Dam Site			188.5				
Kalba	108.05	79.6	Wadi Safad	-	-	-	-
Dibba	100.64	79.6	135.7 126.4	19.6	26.0	25.7	668.2
At Dam Site			131.05				
Kalba	108.05	79.6	Wadi Rumth	=	=	-	-
Dibba	100.64	79.6	135.7 126.4 131.05	19.0	30.5	24.9	759.5

SEDIMENT:

One of the problem in attempting to conserve surface water would be the sediment deposition that would take place in behind dams. The deposition if left accumulated would reduce the usable reservoir storage, and thereby the service functions of the projects. To maintain the project benefits, reservoir either must be built with extra capacity to store the volume of sediment or sediment accumulation must be regularly or periodically removed.

No records are available on the sediment louds of wadis in the U.A.E. A rough estimation can be done based on the formula $Qs=292.6A^{-0.12}$ when Qs is the sediment yield in m^3/year and A is the drainage area in sq Kms.

Bared on the above formula 64 Km^2 of area above the dam site would produce an average annual sediment load of 11369 m^3/year or a yield of 178 m^3/Km^2/yr.

Ashwani and Sifuni catchment with an area 216 Km^2 above the dam site would produce an average annual sediment load of 33023 m^3/year of a yield of 154 m^3/Km^2/yr.

Rumth catchment with an area of 30.5 Km^2 above the dam site would produce an average annual sediment load of 5922 m^3/yr or a yield of 194 m^3/Km^2/yr.

Similarly wadi safad catchment with an area of 26 Km^2 above the dam site would produce an average annual sediment load of 5146 m^3/yr or a yield of 198 m^3/Km^2/yr.

Most sediment is carried during the higher floods. Dam must be produce to in any given to handle sediment loads many times larger than the average volume.

Consideration should be given to investigate the feasibility of constructing sediment trap structures up stream of the proposed reservoir. The maintain reservoir capacity and project water yield, it will be essential for the sediment deposition to be removed from the reservoir area each year. The deposition will very greatly from year to year depending on the volume of the flood flows, but should average aoubt 11369 m^3/yr for Siji, 33023 m^3/yr for Ashwani and Sifuni 5922 m^3/yr Rumth and 5146 m^3/yr for wadi Safad. Manual, mechanical and hydraulic means of removal will need to be evaluated.

INFILTRATION

Infiltration tests reported on similar condition on a small area in the order of 0.25 m^3, making a 2 cm high around it and keeping it out with measured amounts of water until the time of infiltration rates appeared constant indicated infiltration rates on the higher more imprevious ground from about 0.6 to 5.0 m^3/m^2/day. Without any ring it is about 3 m^3/m^2/day.

An initial infiltration rates of 2 m^3/m^2/day appears reasonable to assume. This will be reduced by the accumulation of fine sediment in the reservoir but perhaps not completely.

The gravels of the wadis that are eroded by flash floods are continually providing a fresh infiltration surface. Nearly 40-50% of rainfall is infiltrated while flowing through the wadi for to Km length.

Infiltration in the reservoir area during floods would be then about m^3/day. After sedimentation the flood water be held until they clear and clean water released down stream for infltration. The down stream infiltration capability is estimated to be about 1.5 m^3/sec.

HYDROLOGIC DESIGN

Physical and hydrological factors indicated that a flood detension type rather than storage type structure was probably all that could be justified. So the main purpose of the proposed dams is to check the peak flood and permit a greater volume of water to infiltrat the wadi gravels. Its secondary purpose is to provide a measure of flood protection.

Because of the dearth of hydrologic data in the U.A.E. reservoir sizing on wadis is bared on two alternative approaches. One approach is to design a dam which would be capable of m^3/sec, and a flood volume of m^3.

The second apprach is to size the reservoir to conserve all or most of the out flow which occured during the year of available hydrologic data.

SIJI DAM

A dam with a spill way crest at elevation m would create a reservoir of cubic meters.

A m^3 capacity storage can be achieved with a structure height above streamed meters. Allowing for the fact that the hydrologic data is it not too firm, that the low pattern can occur, and that the reservoir sediment accumulation is highly variable and its regularity of removal is uncertain, the dam should be capable of storing to a depth of meters. This would result in a reservoir capacity of m^3.

ASHWANI & SIFUNI

A dam with a spill way crest at elevation m would create a reservoir of cubic meters.

A dam m^3 capacity storage can be achieved with a structure height above streamed meters. Allowing for the fact that the hydrologic data is not too firm, that the low pattern can occur, and that the reservoir sediment accumulation is highly variable and its regularity of removal is uncertain, the dam should be capable of storing to a depth of meters. This would result in a reservoir capacity of m^3.

WADI RUMTH

A dam with a spillway crest at elevation on would create a reservoir of cubic meters.

A m^3 capacity storage can be achieved with a structure height above streamed meters. The dam capable of storing to a depth of meters. This would result in a reservoir capacity of m^3.

WADI SAFAD

With a spillway crest at elevation m would create a reservoir of cubic meters.

A m^3 capacity storage can be achieved with a structure height above streamed meters. Allowing for the fact that the hydrologic data is not too firm, that the low pattern can occur, and that the reservoir sediment accumulation is heighly variable and its regularity of removal is uncertain, the dam should be capable of storming to a depth of meters. This would result in a reservoir capacity of m^3.

From preliminary observations and estimates in the basin, the initial infiltration rate in the reservoir area is estimated to be $2m^3$/day, with a total estimated storage in the aquifer under the Siji basin is m^3/day, Ashwani Sifuni basin is m^3/day, wadi Rumth basin is m^3/day, wadi Safad is m^3/day.

Some decreases in the infiltrate over the life of the reservoir is expected. This will be off set by releasing water from the out let to infiltrate in the channels down stream. Water in the storage will be released after settlement of the sediment is mostly complete.

Down stream from the dam, channel infiltration is reported to be maximum of 1.5 m^3/sec and an average can be considered 1.2 m^3/sec.

TOPOGRAPHIC MAPPING

Topographic mapping of dam sites has been done at a scale of 1:100 and a contour intarval of 1/2 meter (Reservoir to topography was available at a scale of 1:25,000 at a contour interval of 10 meters.

RESERVOIR TOPOGRAPHY

Topography of a scale 1:25,000 and 10 meters contour is included. This topography was made from arrival photography of a scale of 1:25,000 and photo identification points.

TYPE OF OPERATION

The reservoirs will be operated slowly for infiltration and incidental flood control at wadi Siji, Sifuni & Ashwani. But the wadis Safad and Rumth will be operated as storage dam. In the early years of the project, the gates will not be opend as infiltration through the basin will be rapid untill sedimentation reduces its efficiency. At that time the basin will be used for settling and clear water will be released down for infiltration.

STORAGE ALLOCATION

Reservoir storage is allocated to temporary retention for infiltration to ground water and flood control. Initial reservoir storage of Cubic meter is equal to secds of peak design flood flow for Siji, to for Ashwani & Sifuni, to for Safad, and to for Rumth.

Siji Dam split crest on the weir is recommended with a crest elevation of m for meters from left aboutment, a crest elevation of m for meters and a crest of m for last m left side of wadi, m for on from aboutment of right side wadi and m on meters. Total crest length is meters for wadi Siji.

ASHWANI & SIFUNI

Out lets are required to empty a fall reservoir in days at Siji controls should be adequate to relase as little as 1 cubic meters/second.

All releases made will be for infiltration to ground water. There will be no dead storage for Siji, Ashwani & Sifuni/Allowances should be made for suitable operation after sedimentation occurs.

PROPOSAL FOR WADI NAQAB WATER RESOURCE

(Introduction, Hydrologic, Hydraulic, Structural phase design criteria for the dam at Naqab)

Introduction:

Wadi Naqab appears to have sufficient waste cut flows to justify construction of some sort of ground water recharge facilities. Rapid growth in demand for water is deploting the aquifers at a rapid pace causing localized problems of salinity intrusion and desiccation of some wells in the near by area.

By the construction of dam in wadi surface, water development could be attained. This will help to retard flood flows and increase infiltration to the ground water recharge to establish a balance of central aquifers to its output.

Flood problems have been and are developing because of the growth of the settlement into the flood plains. This includes the growth around down stream of wadi Naqab.

Ground water levels are declining year after year. Shallow aquifer system of the gravel plains and desert foreland, which is the major ground water reservoir in UAE is now being heavily over drawn. Even the falaj flows are diminishing. As each area is mined, the water quality also locally deteriorate.

Waste outflow which actually can be conserved and converted to a new usable water supply will depend on the location and storage capacity of potential reservoirs.

Basin Descriptions

Wadi Naqab drains to the Arabian Gulf in the vicinity of Ras Al-khaima. It is located about 8 km south of Burairat dam site. The northern boundary of the drainage area is in common with the southern boundary of the drainage area of Burairat dam site. The drainage above wadi Naqab dam site 90 km^2. Elevation range from 84 m at the dam site to 1500 m in the upper part of the basin. Mountain forms steep topography with little vegetation coverage. The watershed area is compact having a Compactness coefficient of 1.34, Drainage density of 1.38, Stream density of 1.05 and having a perimeter of 44.5 kms. The water shed shape index is 1.93, form factor is 0.44 and Rotundity afactor is 1.65. Details of physiographic characters for the catchment has been worked out and given in Table I.

Inventory of Water Resources

Severe rainfall from thunder storms can occur over the Arabian Gulf and the UAE especially in the mountainous region of the Musandum peninsula. Such thunder storm activity occurs primarily during the period from October to April in association with cold fronts and line squalls moving from the northwest across the warm waters of the Arabian Gulf. Very limited rainfall data for thunder storms in the mountainous area are available. However, two severe thunderstorm occurences at Sharjah on the coast of the UAE have been provided. A thunder storm at Sharjah on 23rd November 1957, produced 74.1 mm rainfall in about 50 minutes. Another thunderstorm on 14th November 1954 produced about 56 mm in 45 minutes at Sharjah.

During the summer 1956, 12.3 mm rainfall was observed at Sharjah even though it is quite unusual, it does demonstrate that summer rainfall can occur.

Various Physiographic Characters of Wadi Naqab Catchments

S.NO.	Parameters	Formula used	Values
1.	Size of watershed	(A)	90 Km^2
2.	Average width	(W)	7 Kms
3.	Length of watershed parallel to the main mainstream	(Lb)	13.5 Kms
4.	Perimeter of watershed		44.5 Kms
5.	Shape index	L_b^2/A	1.93
6.	Length of mainstream	(L)	16.00 Kms
7.	Form factor	A/L_b^2	0.44
8.	Circumference of a circle of equal area (C.C.E.A.)		33.1 Km
9.	Compactness Coefficient	P/C.C.E.A.	1.34
10.	Maximum elevation		1,500 m
11.	Maximum relief		1,416 m
12.	Elevation at dam site		84 m
13.	Cumulative channel segment length		120.4 Kms
14.	Number of streams	(Ns)	91
15.	Drainage Density		1.38
16.	Stream Density		1.05
17.	Rotundity factor	$L_b^2/4A$	1.65
18.	Time of concentration	$Tc=0.0195K^{.77}$ $K=\sqrt{L_b^3/H}$	85 minutes
19.	Lag Time	$Lg=C\left[\frac{.168L\ .Lca}{\sqrt{S}}\right]^x$	= 1.65 hrs.

TABLE 1

Design Storm Derivation

A design thunderstorm which could be associated either with a winter type frontal situation or with a spring or fall tropical storm is considered appropriate for the dam site on the wadi Naqab. The Sharjah data shows that about 50% of the rain falls in December - January and about 70% in the 3 months period of Dec. - Feb. The annual rainfall for 40 years averaged about 103 mm, for 12 yrs 88 mm, for 6 yrs-114 mm and for 2 yrs-152 mm; the maximum rain has been 258 mm and minimum 0.3 mm. Most of the total annual rainfall generally occurs in about two storms, even in the wettest years. Rainfall is generally intense. A total fall of 107 mm was measured at Sharjah in 24 hours, a quantity in excess of the average annual rainfall at that station.

This sort of intensity and variation can occur anywhere in the Emirates and probably even more intense and variable in the mountains. The paucity of storms and their occurrence make for an inadequate, and undependable water supply and the intensity of the storms when they do occur, create short duration high peak flood flows, making economic development near the wadis a dangerous practice.

Few years rainfall data is too limited in area coverage and period of record to provide the basin for design storms derivation. Since adequate data for design storm derivation are not available for these dam sites, the derivation here is based on probable maximum thunderstorm, precipitation for the desert design & hy ro-meteorological branch of the U.S. National Wheather Service Study used for derivation of the design thunderstorm. A probable maximum thunderstorm precipitation value of 305 mm (12") for 2.59 km^2 (1 mile) was obtained from the map provided. Area reduction and time distribution factors were obtained too.

Factors for reducing probable maximum thunderstorm precipitation from 2.59 Km^2 (1 mile) to:-

TABLE 2

Duration	90 Km^2 (35 $mile^2$)
1/4	0.525
1/2	0.580
1	0.655
2	0.690
3	0.725
4	0.740
5	0.755
6	0.770

Factors applied to the 1 hour value of probable maximum thunder storm precipitation to get values for other duration are as follows:

TABLE 3

Duration	Factor
1/4	0.43
1/2	0.70
1	1.0
2	1.27
3	1.44
4	1.54
5	1.63
6	1.70

The value of 305 mm for 1 hour for 2.59 Km^2 was reduced for area and distributed in time (up to a 6 hour duration) using the above factors.

The resulting design thunderstorms for wadi Naqab are given below. Design thunderstorm for wadi Naqab. Dam site 90 Km^2 (Table 4)

Duration hours	Precipitation depth	Hourly increment
1/4	69 mm	
1/2	124	
1	200	200
2	267	67
3	318	51
4	348	30
5	378	27
6	399	24

The intensity of the few rain storms that may be expected each year is more important as regards run-off than the total amount of precipitation.

Annual and Average rainfall data for station near wadi Naqab

TABLE 5

Year	Burayrat	Dibba
1965/66		50.6
67		20.8
68		88.9
69		166.0
70		60.3
71		16.3
72	197.6	177.1
73	75.8	93.7
74	14.8	11.9
75	205.4	199.0
76	295.4	195.4
77	234.7	239.0
12 yrs average (66-67)		109.9
6 yrs average (72-77)	170.5	152.7
2 yrs average (76-77)	265.0	217.2

Average Annual Rainfall Data at Sharjah (TABLE 6)

40 yrs average (1934/35 - 1976/77)	102.8 mm	100.0%
12 yrs average	88.1 mm	85.7%
6 yrs average	113.9	110.8%
2 yrs average	151.6 mm	147.5%

SURFACE WATER ESTIMATION (PEAK FLOW)

Water resources data and especially surface water data are very meager in the U.A.E. Different approaches have been tried to estimate the peak flow.

1. Rational method:-

$$Q = \frac{CIA}{36}$$

where Q = Design peak run-off rate in cubic meters per second

C = Run-off coeff. (0.85) was used for hilly land without any vegetation

I = Maximum rate of rainfall in centimeters per hour over the entire area which may occur during the time of concentration (Tc)

Tc= Time of concentration = $0.019K^{.77}$ where K = L_b^3/H

L = Maximum length of flow in meters

H = Drop in meters

A = Area of the watershed = 90 Km^2

From 40 years of data available at Sharjah a thunderstorm of 74.1 mm of rainfall in about 50 minutes has been reported on 23rd Nov. 1957. Maximum one hour rainfall expected. Time of concentration for the watershed has been worked out as 85 minutes.

Value of I = 6.5 cm/hr (from graph)

Expected peak discharge from the catchment is 1381 m^3/secd, and total vl volume is (18700×10^3) m^3.

It should be noted that run-off estimated extrapolated from Sharjah rainfall data cannot have a high degree of reliability, because of different location and more over in U.A.E., localised thunderstorms are very common.

2. Based on two years surface run-off data of wadi Naqab:

Flow data for wadi Naqab for the hydrologic years of 1976 & 77 are presented in the Table 7.

Table 7 shows wadi Naqab had an average annual surface flow of 2,092,750 m^3, for the years. 1976 & 77 had above normal rainfall, based on long term Sharjah rainfall record and probably also had above normal run-off volumes. Using the two years average rainfall at Burayrat and Dibba to represent rainfall on the wadi Naqab watershed, the run-off rate (percentage of rainfall showing up as measured stream flow) is 11.48%.

Table 8 shows the derivation of the estimated long term average annual run-off for wadi Naqab. By using the average rainfall for the 6 or 12 years of record at the station of Burayrat & Dibba and the equivalent period relationship to the 40 year record at Sharjah, a long term annual rainfall at the stations and on the watershed is obtained. Then by applying the run-off rate given in table to the long term basin rainfall, a long term unit run-off is derived. This unit run-off multiplied by the drainage area gives the long term run-off for the stream.

As derived in the table the long term average annual flows are estimated to be 1,461,600 m^3 at wadi Naqab damsite.

It should be noted, however, that run-off estimates extrapolated from two years of stream flow data cannot have a high degree of reliability, especially when it is further remembered that the Sharjah rainfall data used to extend other record data is itself not reliable for the years 1976 & 1977. The station was discontinued in 1976 and relocated at Dubai International Airport in that year.

Table 7 - Surface water data for wadi Naqab:

Period	Wadi Naqab area-90 Km2		Basin * Rainfall	Run-off Rate
	1000 m	mm	mm	%
1975-76				
February	2038.7	22.65	122.5	18.5
March	147.1	1.63	43.0	8.0
April	1214.3	13.49	74.2	18.1
Other			5.2	
Total/Avg.	3400.10	39.56	245.4	16.0
1976-77				
January	742.0	8.24	82.7	9.96
April	43.4	0.48	42.8	1.12
Total/Avg.	785.4	8.72	125.5	6.95
2 yrs Avg.	2092.75	24.14	185.45	11.48

* = Average of Burayrat & Dibba

Table 8- Long term Average Run-off of wadi Naqab:

Column	1	2	3	4	5		6	7
Data surface Source	Table 5	Table 6	Table 5-6	Table 7	Table 1			
Rainfall location	Avg. rainfall record	Conversion factor	Long term Avg. rainfall	Run-off rate	Drainage area			Longterm Avg. Run-off
	mm	%	mm	%	km2	mm		1,000 m3
Burayrat	170.5	110.8	153.9					
Dibba	109.9	85.7	128.2					
At Dam site			141.2	11.5	90	16.24		1,461.6

3. By using Lag-time Dimensionless graph method:

The design thunderstorms were used in the determination of rainfall excess for the basin which were then utilized to construct hydrograph of maximum probable floods using the Lag-time dimensionless-graph method. This dimensionless graph represents surface run-off from steep terrain with no interflow.

Lag time (Lg) were calculated using the following formula:-

$$Lg = C \left[\frac{.168L \ .Lca}{\sqrt{S}} \right]$$

where L = Length of the longest watercourse from the Dam site to the drainage divide in kilometers.

Lca= Length of the watercourse from the dam site to the intersection of a perpendicular from the centroid of the basin to the stream aliment in kilometers.

S = Slope in meters per kilometer of the length

C = Constant (1.2)

X = Constant 0.33 was used

Basin characteristics for wadi Naqab:

Area 90 km^2	L = 16.0 km	Lca = 8 km
S = 80 m/km	$Fl = \frac{.168L. \ Lca}{S} = 2.63$	
Lag time	= 1.65 hours	Unit T time = 0.5 hours
Unit hydrograph peak	= 14.1 m^3/s	
Unit hydrograph volume= 90 x $10^3 m^3$.		

Unit duration were selected for each catchment equivalent to approx. 1/4 of the calculated lag time. From the foregoing, unit hydrograph were computed for the wadi Naqab and is given below. Peak discharge 2910 m^3/s, volume 32700 x $10^3 m^3$ for maximum probable flood (10,000 yrs flood) Peak discharge 485 m^3/s volume 4750 x $10^3 m^3$ for fifty year flood.

The design storm rainfall increment were arranged in the time sequences recommended, and the rainfall excesses were calculated. An assumed minimum loss rate of 2 mm per hour was used in these calculations. The rainfall excesses were applied to the unit hydrographs to give the inflow design floods. The plotted hydrographs along with a table of discharges for wadi Naqab are presented in a plate.

In determining an approximate frequency discharge curve, peak discharge and flood volumes were constructed using flood discharge and volume data measured during 1976 Feb - 23rd flood.

Peak discharges and volumes of the recorded floods were plotted against the catchment areas and the resulting points enveloped by a curve. It is estimated that the resulting curves, are based only 2 to 5 years data at best represent 10% probability of occuerance of a 10 year flood. There is little substantive date to support this assumption.

Wadi Naqab has no base flow only flood flows. Due to relatively lack of rainfall and run-off and the type and operation of the reservoir, routing of the design flood into empty reservoir with no recurring flood is recommended.

SEDIMENT:

One of the problems in attempting to conserve surface waters would be the sediment deposition that would take place in behind dams. The deposition if left accumulated, would reduce the usable reservoir storage, and thereby the service functions of the project. To maintain the project benefits, reservoir either must be built with extra capacity to store the volume of sediment or sediment accumulation must be regularly or periodically removed.

No records are available on the sediment loads of wadis in the UAE. A rough estimation can be done based on the formula

$$Qs = 292.6\ A^{-0.12}$$

where Qs is the sediment yield in m^3/year and A is the drainage area in km^2.)

Based on the above formula the 90 km^2 of area above the dam site would produce an average annual sediment load of 15300 m^3/year or a yield of 170 m^3/km^2/yr.

Most sediment is carried during the higher floods. Dam must be prepared to in any given to handle sediment loads many times larger than the average volume.

Consideration should be given to investigate the feasibility of constructing sediment trap structures upstream of the proposed reservoir.

To maintain reservoir capacity and project wateryield, it will be essential for the sediment deposition to be removed from the reservoir area each year. The deposition will vary greatly from year to year depending on the volume of the flood flows, but should average about 15,300 m^3/yr. Manual, mechanical and hydraulic means of removal will need to be evaluated.

INFILTRATION:

Infiltration tests reported on similar condition on a small area in the order of 0.25 m^3, making a 2 cm high like around it and keeping it out with measured amounts of water until the time of infiltration rates appeared constant indicated infiltration rates on the higher, more impervious ground from about 0.6 to 5.0 m^3/m^2/day. Without any ring it is about 3 m^3/m^2/day.

An initial infiltration rates of 2 m^3/m^2/day appears reasonable to assume. This will be reduced by the accumulation of fine sediment in the reservoir but perhaps not completely. (The gravels of the wadis that are eroded by flash floods are continually providing a fresh infiltration surface.) Nearly 40 - 50 % of rainfall is infiltered while flowing through the wadi for 17.5 km length.

Infiltration in the reservoir area during floods would be then about 200,000 m^3/day. After sedimentation the flood water be held until they clear, and clean water rebased downstream for infiltration. The downstream infiltration capability is estimated to be about 1.5 m^3/sec.

HYDROLOGIC DESIGN:

Physical and hydrological factors indicated that a flood detension type rather than storage type structure was probably all that could be justified. So the main purpose of the proposed wadi Naqab dam is to check the peak flood and permit a greater volume of water to infiltrate the wadi gravels. Its secondary purpose is to provide a measure of flood protection.

Because of the dearth of hydrologic data in the U.A.E., reservoir sizing on wadi Naqab is based on two alternative approaches. One approach is to design a dam which would be capable of 191 m^3/sec, and a flood volume of 18700 x $10^3 m^3$ or the 50 year flood was reported to have a peak flow of 485 m^3/s, and volume of 4750 x $10^3 m^3$.

The second approach is to size the reservoir to conserve all or most of the out flow which occured during the year of available hydrologic data.

A dam with a spillway crest at elevation 85 m would create a reservoir of 600,000 cubic meters. Since the dam is not going to be used as a storage structure, this capacity is quite sufficient.

A 8,000,000 m^3 capacity storage can be achieved with a structure height above streamed 5 meters. Allowing for the fact that the hydrologic data is not too firm, that the low pattern can occur, and that the reservoir sediment accumulation is highly variable and its regularity of removal is uncertain, the dam should be capable of storing to a depth of 4 meters. This would result in a reservoir capacity of 600,000 m^3.

From preliminary observations and estimates of gravels in the basin, the initial infiltration rate in the reservoir area is estimated at 2 $meter^3$/day, with a total estimated storage in the aquifer under the basin of 200,000 m^3/day. Some decreases in the infiltration rate over the life of the reservoir is expected. This will be offset by releasing water from the outlet to infiltrate in the channels down stream. Water in the storage will be released after settlement of the sediment is mostly complete.

Down stream from the dam, channel infiltration is reported to be maximum of about 2m^3/s and minimum of 1.2 m^3/s and an average can be considered 1.5 m^3/s.

The height of 5 meter is the maximum that can be built without flooding the houses constructed on the wadibed. Relocating the houses will be difficult and expensive as the houses are packka.

Topographic Mapping:

Topographic mapping of wadi Naqab dam site has been done at a scale of 1:100 and a counter interval of 1/2 meter (reservoir topography was available at a scale of 1:25,000 and a counter interval of 10 meters)

Reservoir Data:

Area-capacity:-

Elevation (m)	Area (m^3)	Cumulative volume (m^3)
80.5 to	0	0
85.0	150,000	600,000

Reservoir topography:

Topography of a scale 1:25,000 and 10 meter contour is included. This topography was made from aerial photography of a scale of 1:25,000 and photo identification points.

Type of Operation:-

The reservoir will be operated solely for infiltration and incidental flood control. Its operation will be unattended. In the early years of the project, the gates will not be opened as infiltration through the basin will be rapid untill sedimentation reduces its efficiency. At that time the basin will be used for settling and clear water will be released down for infiltration.

Storage Allocations:

Reservoir storage is allocated to temporary retention for infiltration to ground water and flood control. Initial reservoir storage of 600,000 cubic meters is equal to 410 secds of peak design flood flow.

Split crest on the weir is recommended with a crest elevation of 85.1 m for 20 meters from left aboutment, a crest elevation of 84.5 meter for 100 meters and a crest of 85 m for last 30 m on left side of wadi, 84.5 m for 50 meters from aboutment of right side wadi and 85 m on 80 meters.

Total crest length is 284 meters.

Out-lets:

Outlets are required to empty a full reservoir in 15 days. Controls should be adequate to release as little as 1 cubic meter/second.

All releases made will be for infiltration to ground water. There will be no dead storage. Allowances should be made for suitable operation after sedimentation occures.

Fluctuations:

The reservoir will empty within after any single storm.

Flood Control Operation:

There is no operation for flood control. Maximum permissible releases are not applicable. Spillways must be uncontrolled. The reservoir will be unattended.

Flood Impact:

Floods in the mountain wadis develops often to form a rolling wave. Since a high probability exists that the reservoir would be empty when a flood occurs, it is felt that the possibility of impact loads on the dam should be studied.

STRUCTURAL DATA & DESIGN CONSIDERATIONS:

From the economic point of view rock filled dam is recommended. The main purpose of the proposed rock filled dam is to check the flood flows and permit a greater volume of water to infiltratte the wadi gravels and for flood protection. The crest elevation would be at 85.0 meters. Since it is not a storage reservoir, the excess flood volumes would flow over the full length of 284m of the crest of the dam.

To provide stability riprap would be 1 meter cube, the upstream slope 3:1, the down stream slope 4:1 and a cut off 2 meter deep. The centre core of semi-previous material 3 m at top and 7 m at bottom would be stradded by 2 m thick beds of graded filter material. An out-let should be provided.

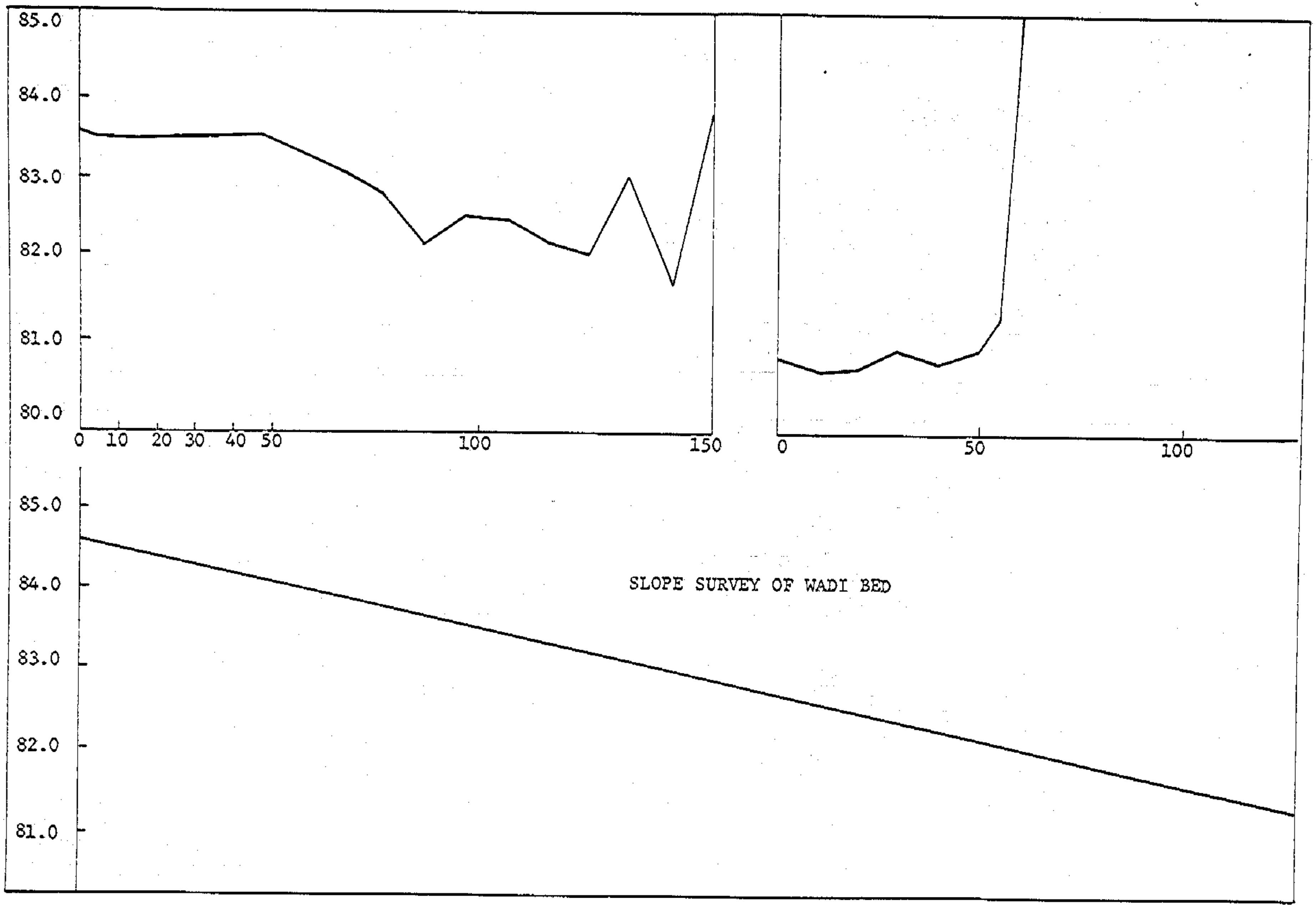
The structure as proposed will have a crest length of about 284 meter, a maximum structural height of about 5 meter.

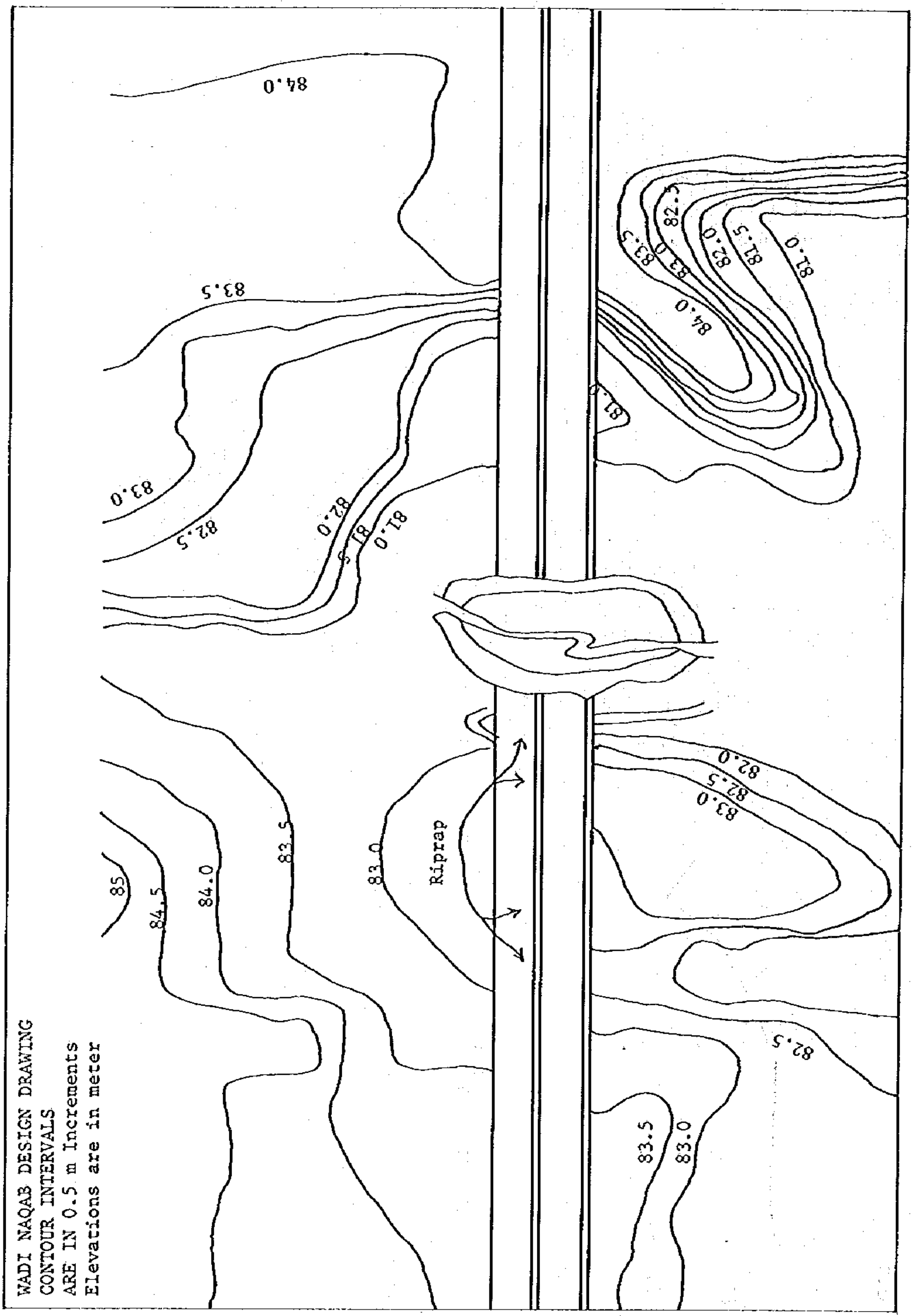
Material:

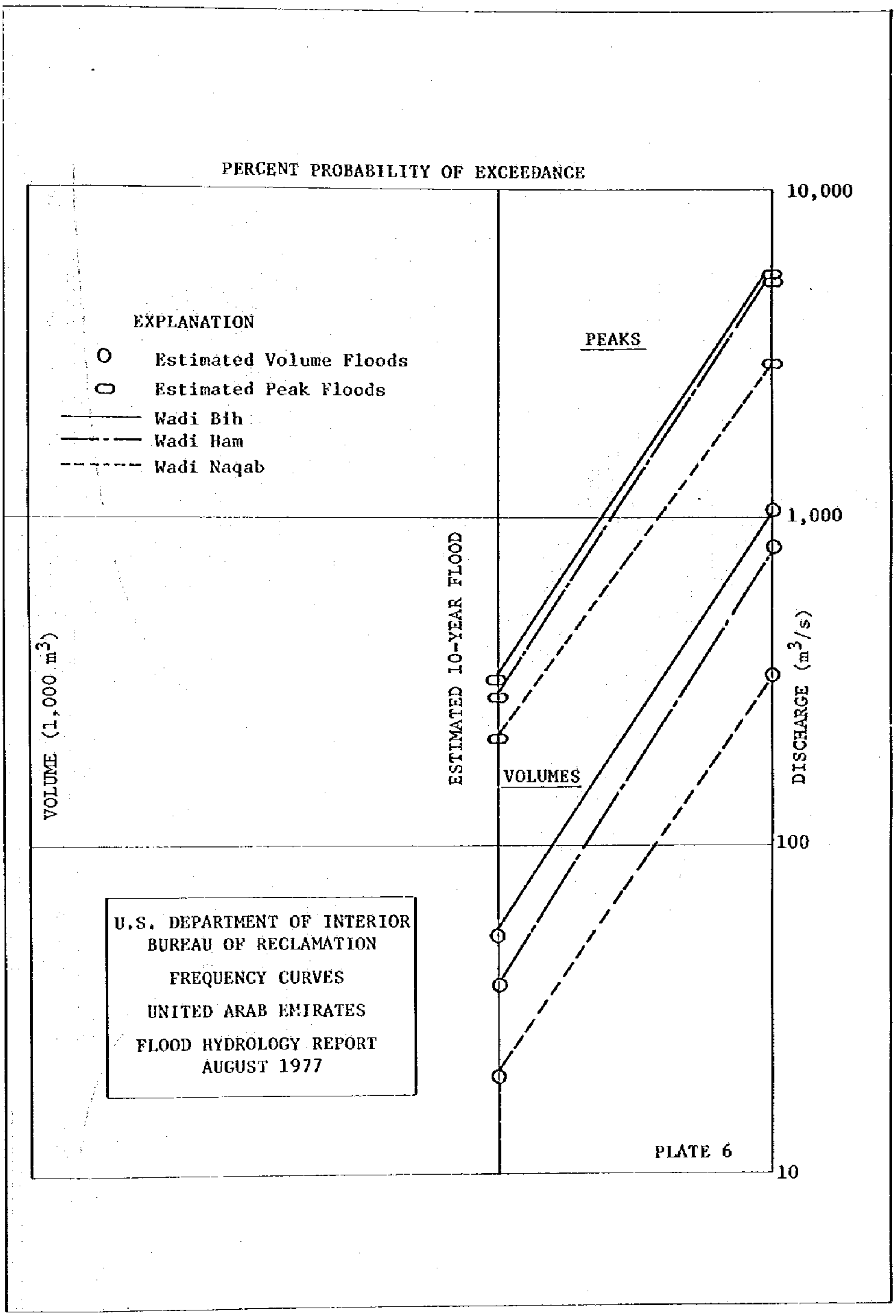
Rock fill, gabion fill, random fill can be had in abundance from the wadi gravels surrounding the site. Cobbles and bolders can best be obtained by scalping the surface in the vicinity of the weir site unless use is made of the gravel from which they are screemed.

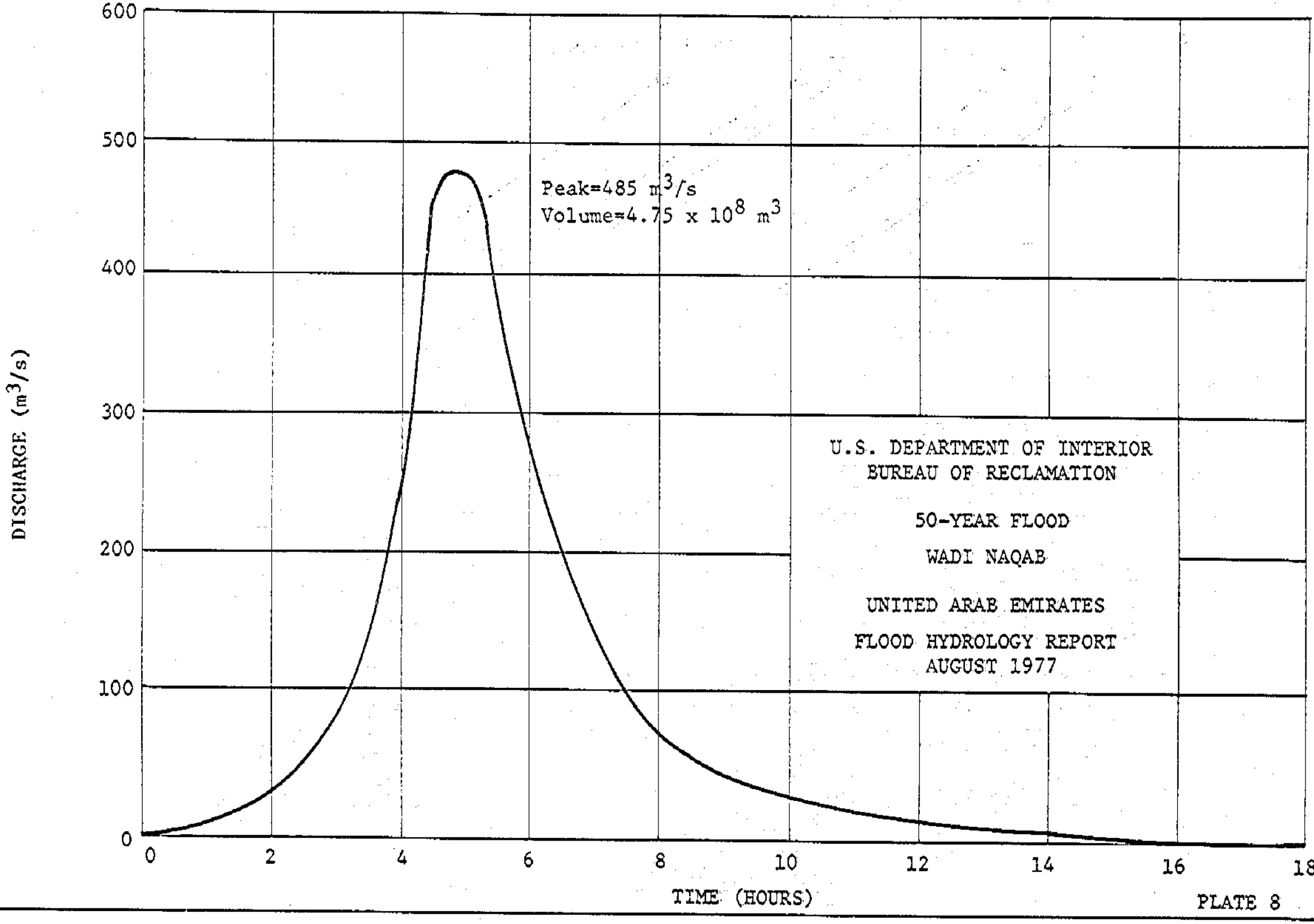
COST:

The construction cost for a wadi Naqab rock filled dam as detailed would be Dh. 7,636,000.00. Details of the cost estimates are given in Table 9. To obtain high degree of waste of surface of water, wadi flows need to be controlled at the different locations along the flow from their highest elevation. It is always better to control runoff from its original point. Simple inexpensive rock structures, Drop spillways of low head can be justified.


85.0
84.0
83.0
82.0
81.0
80.0
0
10
20
30
40
50
100
150
0
50
100
85.0
84.0
83.0
82.0
81.0
SLOPE SURVEY OF WADI BED

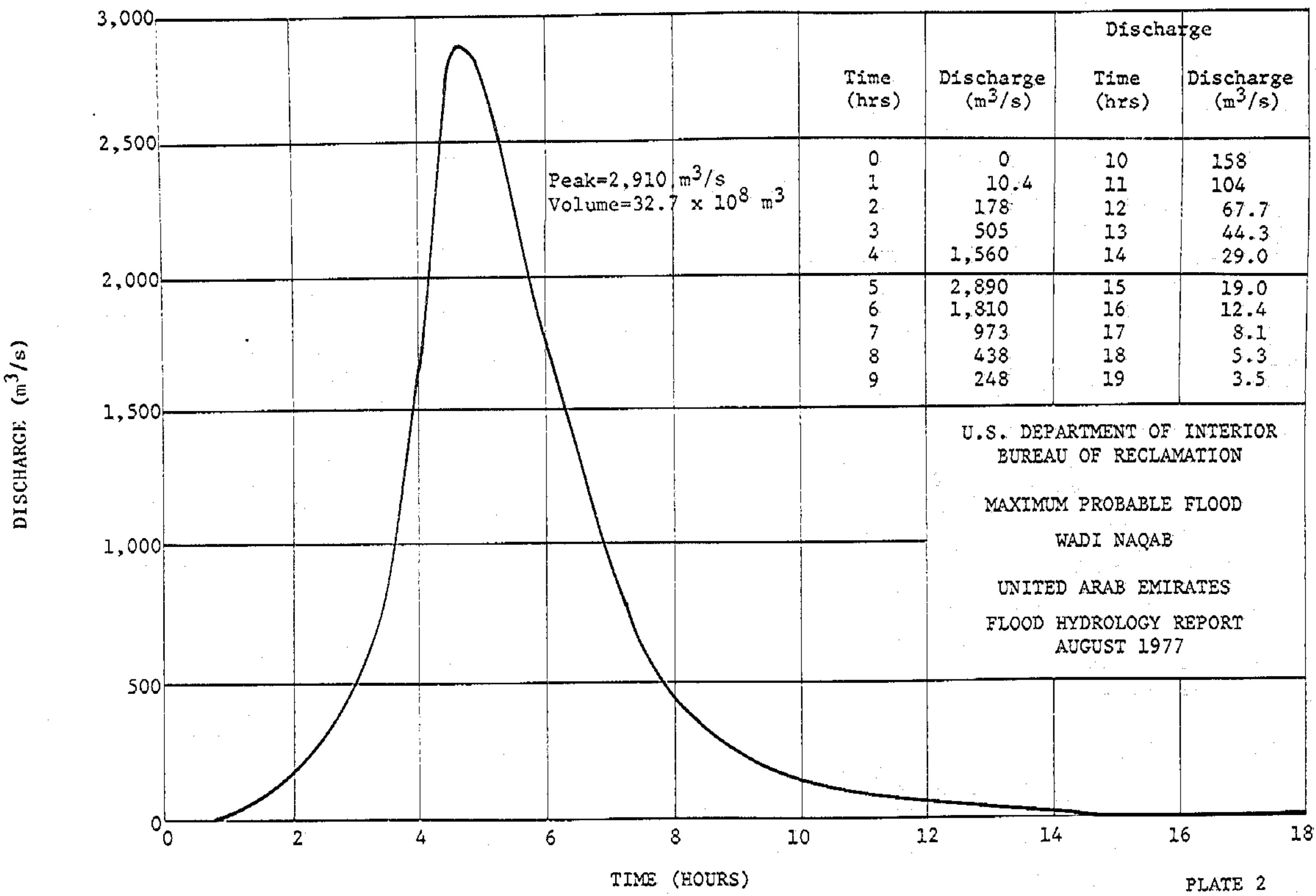

WADI NAQAB DESIGN DRAWING
CONTOUR INTERVALS
ARE IN 0.5 m Increments
Elevations are in meter
84.0
83.5
83.0
82.5
82.0
81.5
81.0
83.5
83.0
82.5
82.0
81.5
81.0
84.0
Riprap
85
84.5
84.0
83.5
83.0
83.0
82.5
82.0
82.5
83.5
83.0


PERCENT PROBABILITY OF EXCEEDANCE
10,000
1,000
100
10
EXPLANATION
Estimated Volume Floods
Estimated Peak Floods
Wadi Bih
Wadi Ham
Wadi Naqab
PEAKS
VOLUMES
ESTIMATED 10-YEAR FLOOD
VOLUME (1,000 m3)
DISCHARGE (m3/s)
U.S. DEPARTMENT OF INTERIOR
BUREAU OF RECLAMATION
FREQUENCY CURVES
UNITED ARAB EMIRATES
FLOOD HYDROLOGY REPORT
AUGUST 1977
PLATE 6



Peak=485 m3/s
Volume=4.75 x 108 m3
DISCHARGE (m3/s)
TIME (HOURS)
0
100
200
300
400
500
600
2
4
6
8
10
12
14
16
18
U.S. DEPARTMENT OF INTERIOR
BUREAU OF RECLAMATION
50-YEAR FLOOD
WADI NAQAB
UNITED ARAB EMIRATES
FLOOD HYDROLOGY REPORT
AUGUST 1977

PLATE 8



Discharge			
Time (hrs)	Discharge (m^3/s)	Time (hrs)	Discharge (m^3/s)
0	0	10	158
1	10.4	11	104
2	178	12	67.7
3	505	13	44.3
4	1,560	14	29.0
5	2,890	15	19.0
6	1,810	16	12.4
7	973	17	8.1
8	438	18	5.3
9	248	19	3.5

U.S. DEPARTMENT OF INTERIOR
BUREAU OF RECLAMATION

MAXIMUM PROBABLE FLOOD

WADI NAQAB

UNITED ARAB EMIRATES

FLOOD HYDROLOGY REPORT
AUGUST 1977

PLATE 2

JICA