The Kingdom of Saudi Arabia

The Ministry of Water and Electricity (MOWE)

THE STUDY ON MASTER PLAN

ON

RENEWABLE WATER RESOURCES DEVELOPMENT IN THE SOUTHWEST REGION

IN

THE KINGDOM OF SAUDI ARABIA

FINAL REPORT

(SUPPORTING REPORT)

J. SUB-CONTRACT SURVEYS

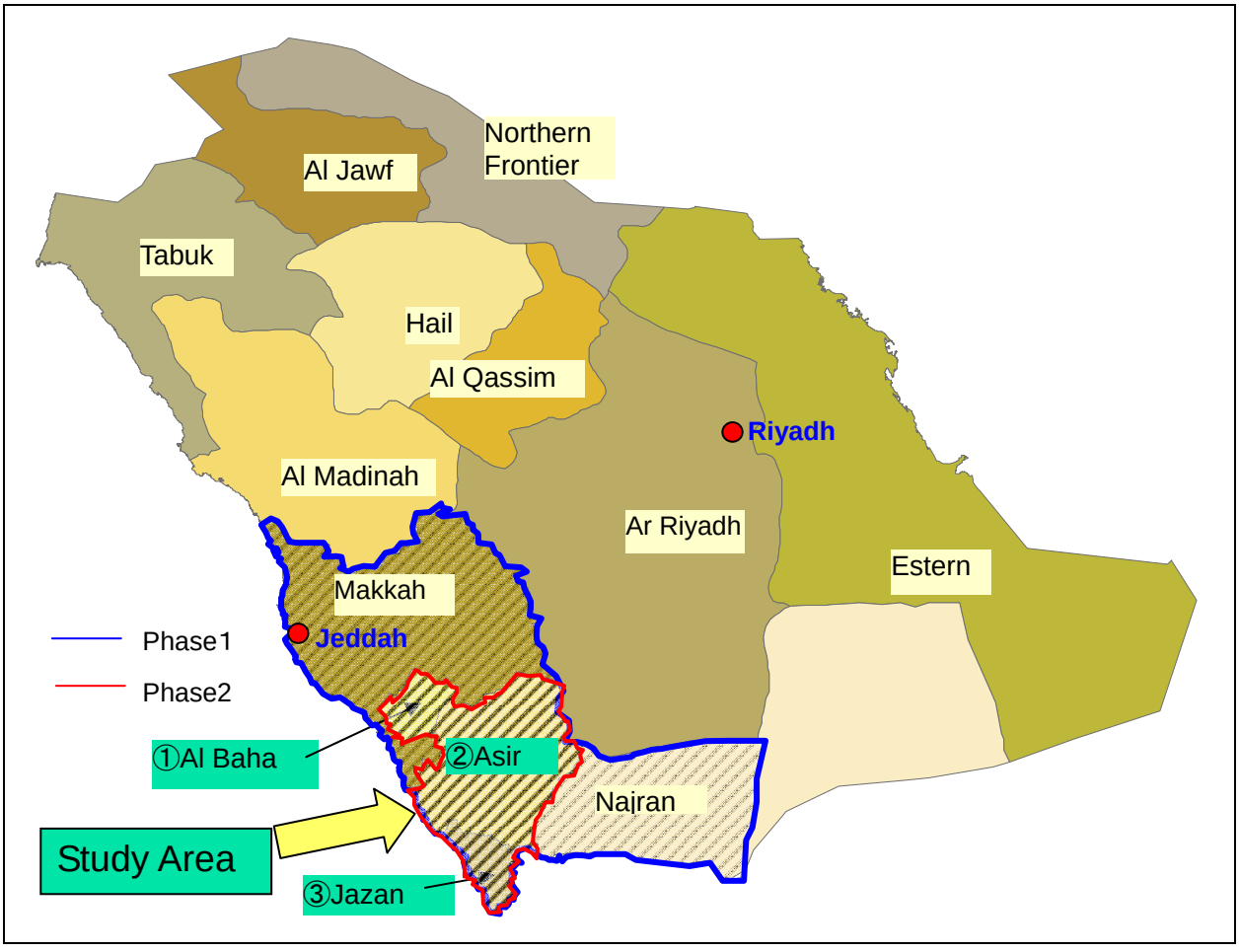
OCTOBER 2010

JAPAN INTERNATIONAL COOPERATION AGENCY

YACHIYO ENGINEERING CO., LTD.

SANYU CONSULTANTS INC.

The Kingdom of Saudi Arabia Location of Map



Final Report
Supporting Report (J)

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List of Abbreviations

Abbreviation and Acronym	English	Arabic (عربي)	Japanese (日本語)
BCM	Billion Cubic Meters	مليار متر مكعب	10 億立方メーター
CBD	Convention on Biological Diversity	اتفاقية التنوع البيولوجي	生物多様性保全条約
C/P	Counterpart	النظير	カウンターパート
EIA	Environment Impact Assessment	تقييم الأثر البيئي	環境アセスメント
ER	Effective Rainfall	الأمطار الفعالة	有効雨量
ET	Evapotranspiration	البخرنتح	蒸発散
FAO	Food and Agriculture Organization, United Nations	منظمة الأغذية والزراعة للأمم المتحدة	国連食料農業機関
GIS	Geographic Information System	نظام المعلومات الجغرافية	地理情報システム
GPS	Global Positioning System	نظام تحديد المواقع العالمي	グローバル・ポジショニング・システム
GDP	Gross Domestic Product	الانتاج المحلي الإجمالي	国内総生産
GDW	General Directorate of Water		地方水事務所
GNI	Gross National Income	الدخل القومي الإجمالي	国民総所得
GSMO	Grain Silos and Flour Mills Organization	صوامع الحبوب ومطاحن الدقيق	サイロ・製粉公団
GTZ	Deutsche Gesellschaft fur Technical Zusammenarbeit GmbH	الجمعية الألمانية للتعاون التقني المحدودة	ドイツ技術協力公社
IC/R	Inception Report	تقرير الإنشاء	インセプション・レポート
IEE	Initial Environmental Examination	الفحص البيئي الأولي	初期環境調査
IUCN	World Conversion Union	اتحاد التحويل العالمي	国際自然保護連合
IWPP	Independent Water and Power Project	المياه المستقلة وطاقة المشروع	独立水道・発電事業
IWRP	Integrated Water Resources Planning	التخطيط المتكامل للموارد المائية	総合水資源計画
JCCME	Japan Cooperation Center for Middle East	مركز التعاون الياباني للشرق الأوسط	財団法人中東協力センター
JICA	Japan International Cooperation Agency	الوكالة اليابانية للتعاون الدولي	独立行政法人国際協力機構
KSA	Kingdom of Saudi Arabia	المملكة العربية السعودية	サウジアラビア王国
LCD	Liter per Capita per Day	لتر للفرد يوميا	リッター/人/日
MAW	Ministry of Agriculture and Water	وزارة الزراعة والمياه	水・農業省
MEPA	Meteorology and Environment Protection Administration	ادارةالأرصاد الجوية و حماية البيئة	気象環境保護庁
MCM	Million Cubic Meters	مليون متر مكعب	100 万立方メーター
M/M	Minutes of Meeting	ملخص الاجتماع	会議の議事録
MMW	Million Megawatt	مليون ميغاوات	100 万メガワット
NAS	National Agriculture Strategy	استراتيجية الزراعة الوطنية	国家農業戦略
NGO	Non-Governmental Organization	المنظمات غير الحكومية	民間公益団体
NMS	National Mining Strategy	استراتيجية التعدين الوطنية	国家鉱業戦略
NSS	National Spatial Strategy	استراتيجية العمران الوطنية	国家特別戦略
NWC	National Water Company	شركة المياه الوطنية	国家水会社
MWS	National Water Strategy	الاستراتيجية الوطنية للمياه	国家水戦略
MOA	Ministry of Agriculture	وزارة الزراعة	農業省
MOEP	Ministry of Economy and Planning	وزارة الاقتصاد والتخطيط	国家経済計画省
MOF	Ministry of Finance	وزارة المالية	財務省
MOI	Ministry of Interior	وزارة الداخلية	内務省
MOMRA	Ministry of Municipal and Rural Affairs	وزارة الشؤون البلدية والقروية	地方自治省
MOWE	Ministry of Water and Electricity	وزارة المياه والكهرباء	水・電力省
M/P	Master Plan	الخطة الرئيسية	マスタープラン
MSR	Million Saudi Riyals	مليون ريال سعودي	100 万サウジリアル

Abbreviation and Acronym	English	Arabic (عربي)	Japanese (日本語)
NCWCD	National Commission for Wildlife Conservation and Development	اللجنة الوطنية لحماية و تطويرالحياة البرية	国立動物保護開発協会
NIA	National Irrigation Authority	السلطة الوطنية للري	国家灌漑局
PME	Presidency of Meteorology and Environment Protection	الرئاسة العامة للأرصاد وحماية البيئة	国家気象環境保護
P/O	Plan of Operation	خطة العمل	プラン オブ オペレーション
PPP	Public Private Partnership	شراكة القطاعين العام والخاص	官民連携
RWPC	Renewable Water Production Corporation	شركة إنتاج المياه المتجددة	再生可能水生産公社
REWLIP	Red Sea Water Lifeline Project	شريان الحياة للمياه البحر الأحمر المشروع	紅海水ライフライン事業
OJT	On the Job Training	التدريب المهني	研修
SAGIA	Governor Saudi Arabian General Investment Authority	محافظ الهيئة العامة للاستثمار العربي السعودي	サウジアラビア総合投資庁
SAMA	Saudi Arabian Monetary Agency	مؤسسة النقد العربي السعودي	サウジアラビア通貨庁
SAR	Saudi Arabian Riyal	الريال السعودي	サウジアラビアリアル
SCT	Supreme Council for Tourism	المجلس الأعلى للسياحة	最高観光委員会
SEA	Strategic Environment Assessment	التقييم البيئي الاستراتيجي	戦略的環境アセスメント
SGS	Saudi Geological Survey	هيئة المساحة الجيولوجية السعودية	サウジ地質調査
SOIETZ	Saudi Organization for Industrial Estates and Technology Zone	الهيئة السعودية للمدن الصناعية و للمنطقة التكنولوجية	サウジ産業国家技術団体
SR	Saudi Riyals	الريال السعودي	サウジリアル
STP	Strategic Transformation Plan	خطة التحول الاستراتيجي	戦略的転換計画
STP	Sewerage Treatment Plant	محطة معالجة الصرف الصحي	下水処理プラント
S/W	Scope of Works	العملنطاق	業務範囲
SWAT	Soil and Water Assessment Tool	أداة تقييم التربة والمياه	土壌水アセスメントツール
SWCC	Saline Water Conversion Corporation	المؤسسة العامة لتحلية المياه المالحة	海水淡水化公社
UFW	Unaccounted For Water	مياه غير محسوبة	無収水
UNDP	United Nations Development Programme	برنامج الأمم المتحدة للتنمية	国連開発計画
UN-ESCWA	United Nations Economic and Social Commission for Western Asia	اللجنة الاقتصادية والاجتماعية للأمم المتحدة لغربي آسيا	国連西アジア経済社会委員会
WB	The World Bank	البنك الدولي	世界銀行
WHO	World Health Organizations	منظمة الصحة العالمية للأمم المتحدة	世界保健機関
WMO	World Meteorological Organization	المنظمة العالمية للأرصاد الجوية	世界気象機関

J. SURVEY REPORTS BY SUB-CONTRACT

1. Survey by Sub-contract

To grasp the hydrological condition on surface runoff and sub-surface water in Wadi and groundwater level, hydrological surveys were done in the study area. The Initial environmental examination (IEE) was also conducted during the phase 2 study to recognize the richness and current conditions of the fauna, flora and water quality in the targeted areas as shown in Table 1-1.

Table 1-1 Outline of Survey by Sub-contract

Study Items	Consultant	Survey Area	Survey Description
Discharge in Wadi	Thobaity Office	Wadi Hirjab、Wadi Tabalah, Wadi Habawnah	Hydrological survey for discharge in three Wadis (Wadi Tabalah, Wadi Hirjab, Wadi Habawnah) for one year.
Sub-surface flow	Thobaity Office	Wadi Hirjab、Wadi Tabalah, Wadi Habawnah	Hydrological survey for groundwater level in three Wadis (Wadi Tabalah、Hirjab、Habawnah) for one year.
Groundwater in wells	Saudi Geo -physical	Selected 200 wells	Monitoring of groundwater level in selected 200 wells.
Initial Environmental Examination	Thobaity Office	Targeted study area or water resources development facilities	1) Recognize the richness and current conditions of the species of fauna and flora 2) Recognize the current water quality in selected water sources

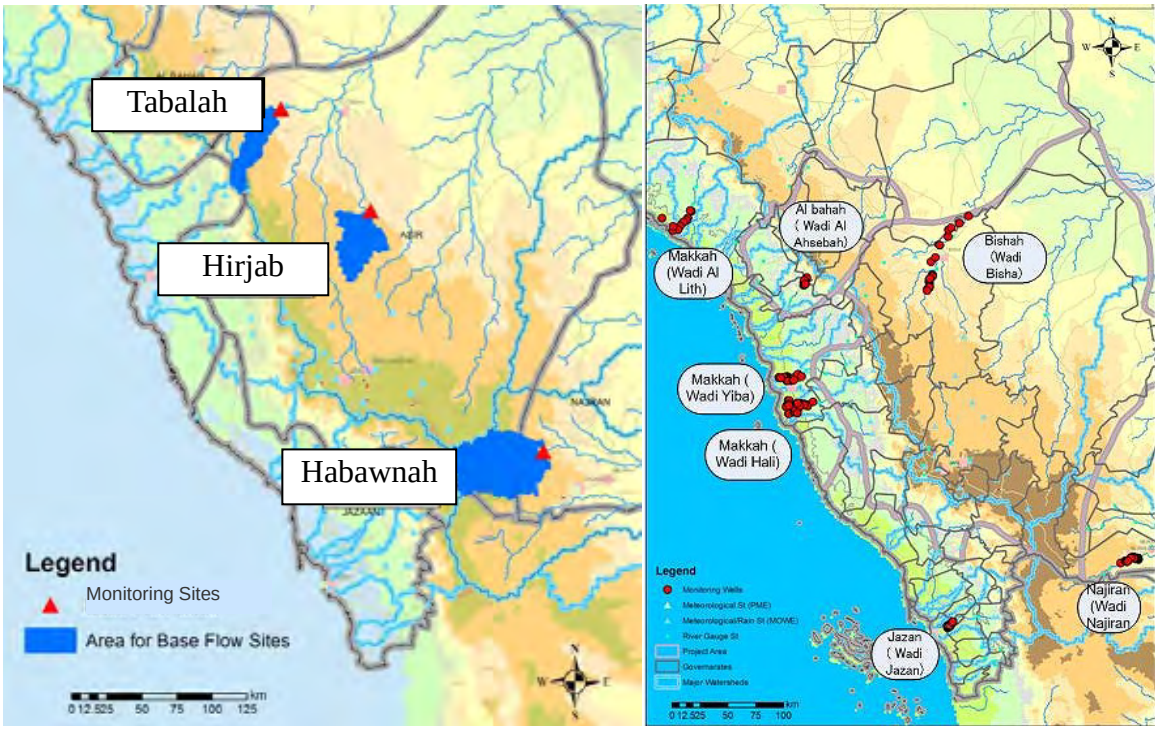


Figure 1-1 Location Map of Survey by Sub-contract

1.1 Runoff Discharge Survey

The renewable water resources are brought by rainfall. This includes surface water and sub-surface water in Wadis. For the analysis of water balance in Wadi, the monitoring station for surface flow and sub-surface flow should be re-installed in the same Wadi.

The purposes of the monitoring for runoff discharge are summarized as follows.

1) To grasp the relationship between rainfall and runoff (surface and sub-surface flow),
2) To estimate and evaluate the annual total runoff volume including runoff ratio and permeability coefficient,

For the selection of candidate sites for monitoring of runoff and sub-surface flow, the following aspects were taking into consideration.

1) The site where construction of facility such as dam etc. will be planned in the near future and monitoring station has not been installed.

2) Continuity of previous monitoring in 1980's.

During the past four months, the Study Team has obtained information on candidate of monitoring station through the interview to steering committee member of the Ministry of Water and Electricity (MOWE), and selected the candidate sites.

The Study Team selected planned dam site or Wadis monitored in 1980's suitable as the candidate of monitoring station at present as shown in Table 1-2 and Figure 1-1

Table 1-2 Outline of Candidate Wadis for Monitoring

Items	Hirjab Dam	Wadi Tabalah	Wadi Habawnah
Location of Sites (Long, & Lat.)	42 50 02 E 19 19 59 N	42 13 47.7E 20 00 24.3N	43 53 04.5E 17 46 10.5N
Region belonged	Asir	Asir	Najran
Width of Wadi	60- 80m (monitoring site)	300 m (at Bridge)	110 m (at Bridge)
Catchment Area (Km^2)	778 (at Dam Site)	1,900	4 ,930
Nearest City or Town	Samakh	Bisha	Habawnah
Remarks	Planned dam site by MOWE	Wadi Studies was executed in 1980's	Wadi Studies was executed in 1980's

1.2 Monitoring on Runoff in Wadis

Hydrological equipment for selected monitoring sites will be installed through the decision of the facility plan and detailed specification.

After the installation of monitoring equipment, the monitoring by the Study Team will commence and the technical transfer will be carried out to the counterpart staff.

Observation for above monitoring shall be carried out at the sites, and the monitoring period for water velocity shall be eight (8) months.

The outline of the monitoring plan in Wadi areas is shown in Table 1-3.

Table 1-3 Outline of Monitoring Plan in Wadi Areas

Item	Monitoring Method	Monitoring Equipment / Facilities	Remarks
1.Water Level (12 months)	Automatic recording	Automatic water level recorder	3 times a day as a frequency in case of staff gauge monitoring
	Manual reading of water level	Staff gauges	
2. Flow Velocity (8 months)	Measurement by current meter and manual measurement by using float	Current meter and floats	Parallel measurement shall be made in case of high water velocity

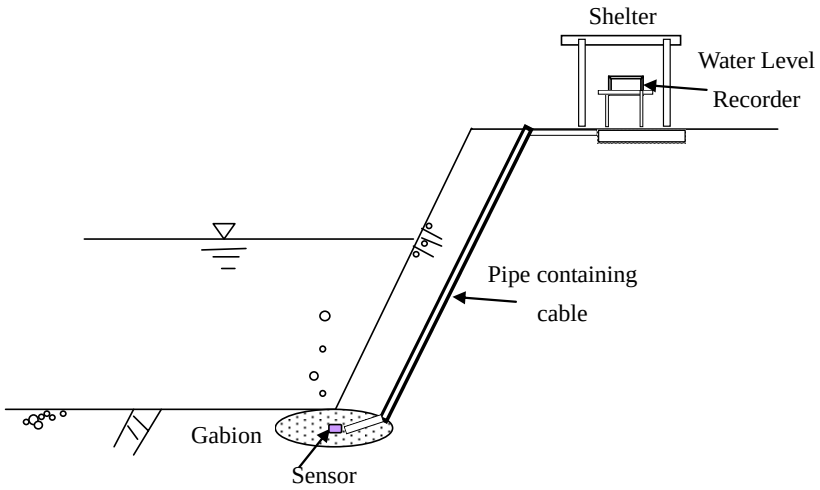


Figure 1-2 Image of Water level Monitoring Station

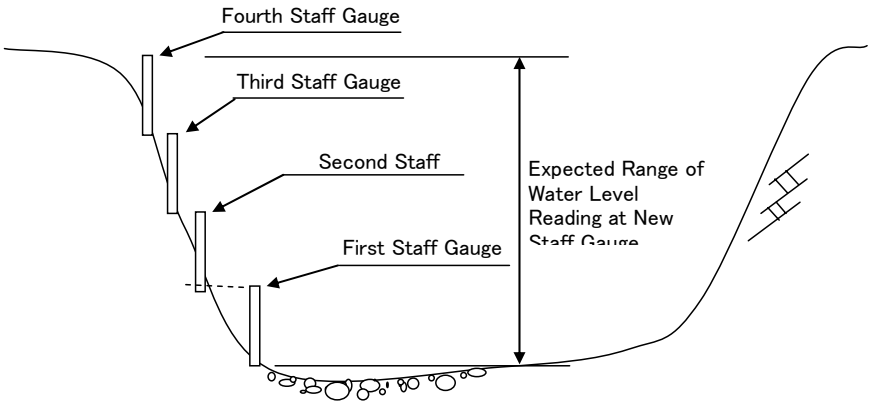


Figure 1-3 Schematic Diagram of New Staff Gauge Installation

In consideration of Hirjab Dam Site condition, it is not possible to use standard river gauging techniques to monitor current flow. Cableway gauging system will be adopted to measure flow velocity at Hirjab Dam Site. This system is a method of deploying a current meter across a river.

Upstream view

Downstream view

Figure 1-4 Photos of Wadi Hirjab (at Planned Dam Site)

Figure 1-5 Cableway Gauging System

1.3 Monitoring on Subsurface flow in Wadis

The survey aims at monitoring the intermediate runoff of the subsurface flow of Wadi in order to clarify the hydrological cycles consisting of the surface flood runoff, subsurface flow and groundwater infiltration and evapo-transpiration of Wadi basin.

Monitoring shall be carried out at three (3) sites, and a monitoring period shall be 12 months.

The following points will be taken into consideration to ensure the consistency with other observations of the surface discharge and groundwater level if it's located nearby.

- To select the same Wadi where the surface runoff monitoring is planned in the study for the grasp of the relationship between the surface runoff and the subsurface flow
- To select the linear sections which have neither deviation in flow direction nor the flow velocity distribution in longitudinal and cross-sectional profiles.
- To grasp the annual trend on the subsurface flow of Wadi through the analysis of the groundwater levels in neighboring wells of the Wadi

The outline of subsurface flow monitoring in Wadi areas is summarized as follows

Table 1-4 Outline of Monitoring on Subsurface Flow in Wadi

Monitoring Item	Method	Equipment/Facility	Remarks
1. wells L=25m,9 wells	Automatic water level recording	Wells & water level recorder	1 well (for monitoring) located in upstream and 2 wells (for test and monitoring) located downstream areas
2.Pump discharge	Pumping test	Pumping test equipment	Observed at testing well located in downstream

Observation of groundwater level shall be made once a month for one (1) year since the installation as well as maintenance work of the recorder. The automatic recording shall be adjusted at the interval of one (1) hour. Due to the calibration of the automatic data, monthly manual measurement shall be made by water-level meter.

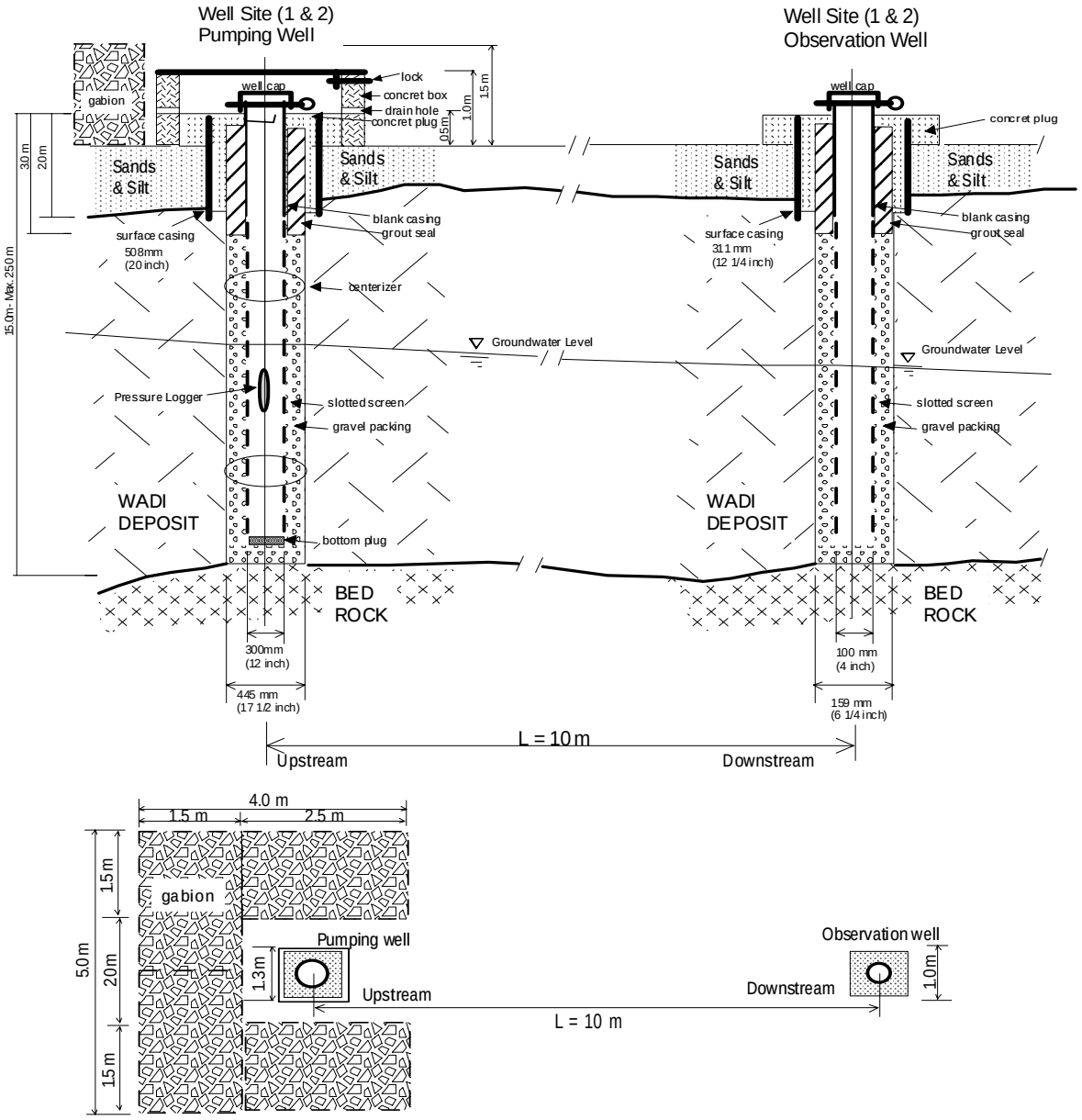


Figure 1-6 Typical Layout of Well Monitoring

1.4 Well Inventory and Survey

The Well Inventory and survey aims to clarify a current situation of existing observation wells and update the hydrogeological information for The Study on Master Plan on Renewable Water Resources Development in the Southwest Region in the Kingdom of Saudi Arabia.

The scope of the Works showing classification of phase I and II is as below:

1) Classification of well type (Phase I);
   To classify the MOWE's observation wells
2) Selection of wells observed in the Works (Phase I);
   To select 200 wells from MOWE's Observation Wells with reference previously obtained data and information before the field survey.
3) Design of Well Catalogue and Survey Form, and Compiling Those Forms (Phase I)
   To designate the form for the field survey with the consideration of existing form of well data or databases in MOWE
4) Field survey (Phase II);
   To conduct the field survey in accordance with flowing items,

a) Observing groundwater levels,
b) Water sampling and laboratory test and

5) Data verification (phase II);
To verify the survey data with on-site analysis during field survey.
6) Data entry;
To entry the surveyed data into CD (s) approved form by Engineer,

1.5 IEE Survey

The IEE Survey aims to clarify followings;

1) To collect the water level in selected observation wells/well fields
2) To recognize the richness and current conditions of the species of fauna and flora
3) To recognize the current water quality in selected water sources

The Study on Master Plan on Renewable Water Resources Development in the Southwest Region in the Kingdom of Saudi Arabia.

The Survey areas for the works are Al Baha Region, Asir Region and Jazan Region which locate at the south west of the Kingdom of the Saudi Arabia.

To assist the Study Team for conduction of Initial Environmental Examination (IEE), the scope of the Works is summarized as below:

1) Collection and arrangement of water level data in selected wells;
To identify water production in wells, monthly water level data over three (3) years shall be collected in selected well(s).
2) Collection and arrangement of water quality data in major water sources;
To identify current quality conditions in major water sources, water quality data shall be collected over one (1) year and arranged by the contractor.
3) Making an inventory for the endemic and endangered flora and fauna;
To make an inventory for the endemic and endangered flora and fauna inhabiting in three Regions.
4) Conducting interviews with authorized personnel;
To obtain information for the inhabiting area of endemic and endangered species, the contractor shall conduct interviews with three (3) persons who are well-recognized as ecological authorities..
5) Preparation of habitation map;
Based on the inventory and the interviews, the contractor shall prepare habitation maps describing the biological and ecological areas.

2. Survey Results

The survey results are shown as following parts.

2.1 Runoff Survey and Monitoring

(1) Location of Monitoring Stations

Monitoring Stations are installed to grasp of Wadi discharge in this study. The monitoring station sites are settled through the field survey and after consultation with MOWE.

The outline of three Wadis are summarized in Table 2-1. The locations of those monitoring stations in Three Wadis are shown in Figure 2-1.

Table 2-1 Outline of Three Wadis

Item	Hirjab Station	Tabalah Station	Habawnah Station
Region	Asir	Asir	Najran
Width of Wadi	80m (monitoring site)	290 m (at Bridge)	84 m (at Bridge)
Catchment Area (km^2)	594	1,039	1,000
Town in the neighborhood	Samakh	Bisha	Habawnah
Remarks	Planned Dam Site of MOWE	Monitoring was carried out in the 1980s.	Monitoring was carried out in the 1980s.

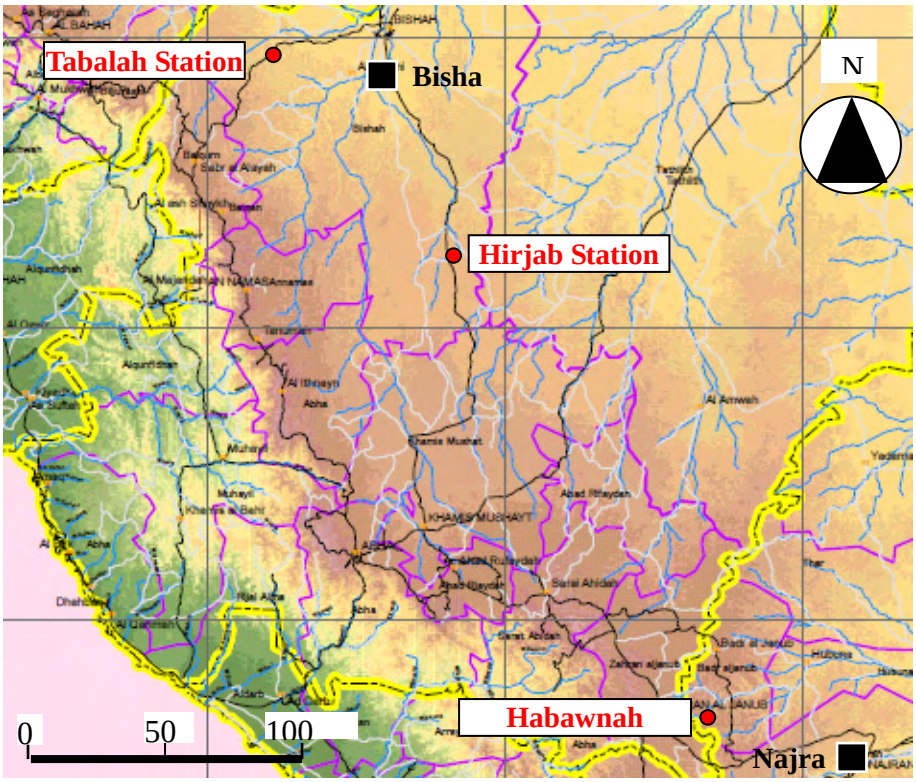


Figure 2-1 Location Map of Monitoring Stations

(2) Equipments of Monitoring Stations

Table 2-2 shows equipments installed in the three monitoring stations. Each of the equipments is shown in Photo-1～Photo-11.

Table 2-2 Equipments in the Three Stations

Station	Latitude	Longitude	Catchment Area (km^2)	Equipments
Hirjab	19° 19´59“N	42° 50´02“E	594	・Staff Gauges ・Water Level Recorder ・Cableway System
Tabalah	20° 00´24.3“N	42° 13´47.7“E	1,039	・Staff Gauges ・Water Level Recorder ・Portable Current-meter
Habawnah	17° 46´9.59“N	43° 53´45.76“E	1,000	・Staff Gauges ・Water Level Recorder ・Portable Current-meter

Photo-1 Staff Gauge (Hirjab)

Photo-2 Water Level Recorder (Hirjab)

Photo-3 Cableway System (Hirjab)

Photo-4 Cableway System (Hirjab)

Photo-5 Staff Gauge (Tabalah)

Photo-6 Staff Gauge on Pier (Tabalah)

Photo-7 Water Level Recorder (Tabalah)

Photo-8 Portable Current Meter (Tabalah)

Photo-9 Staff Gauge (Habawnah)

Photo-10 Water Level Recorder (Habawnah)

Photo-11 Portable Current Meter (Habawnah)

(3) Observed Floods (As of February 2009)

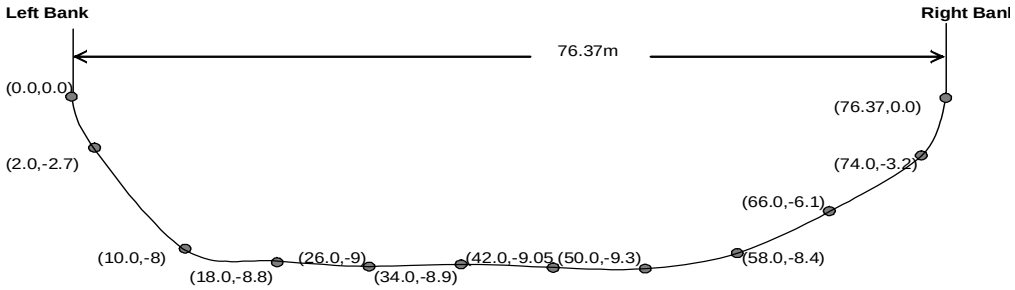
Since the monitoring started on June 2008, there occurred two floods at Hirjab Station and Tabalah Station, and one flood at Habawnah Station up to Februay 2009. Table 2-3 shows the discharge measurement.

Table 2-3 Discharge Measurement in the Three Stations

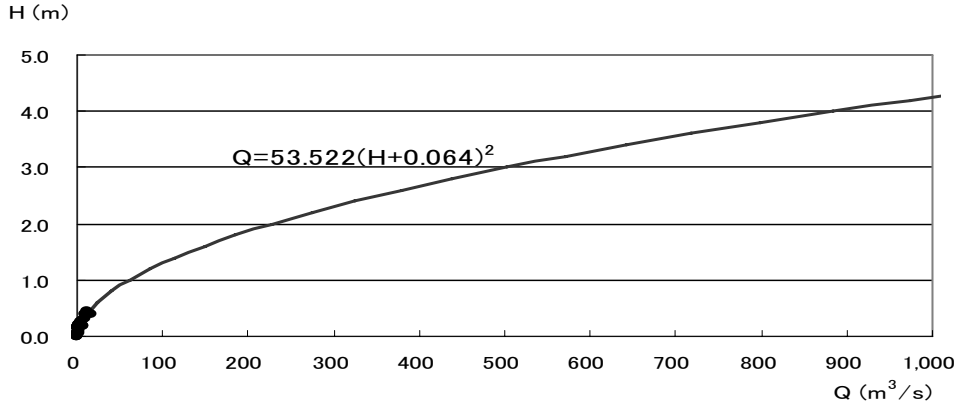
Station	Flooding Time	Observed Discharge (m^3/s)	Remarks
Hirjab	25 Oct. 2008 6:25p.m.～1:40a.m.(26 Oct.) 2 Nov. 2008 5:30p.m.～12:40a.m. (3 Nov.)	0.2～15.7 0.2～7.1	18 times carried out 12 times carried out
Tabalah	25 Oct. 2008 5:10a.m.～12:30p.m. 2 Nov. 2008 3:34p.m.～11:30a.m. (3 Nov.)	0.3～1.2 0.1～50.3	9 times carried out 19 times carried out
Habawnah	25 Oct. 2008 8:27p.m.～1:05a.m.(26 Oct.)	0.4～4.7	16 times carried out

Stage-Discharge Curve is obtained as below based on the observed flood data. The cross section and the stage-discharge curve of each stations are shown in Figure 2-2.

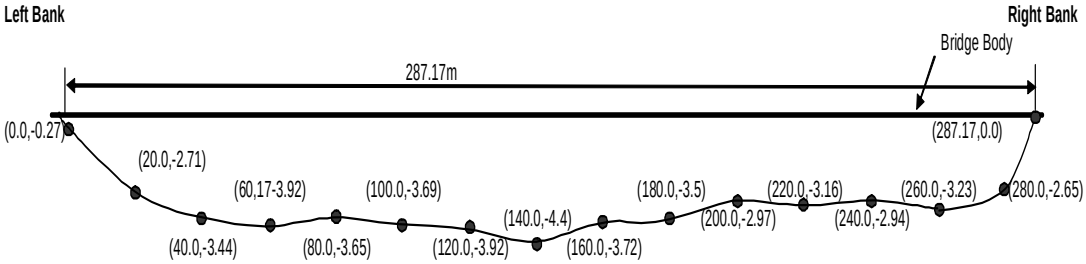
Station	Stage－Discharge Curve
Hirjab	$Q = 53.522 (H + 0.064)^2$
Tabalah	$Q = 56.923 (H + 0.017)^2$
Habawnah	$Q = 188.633 (H - 0.049)^2$



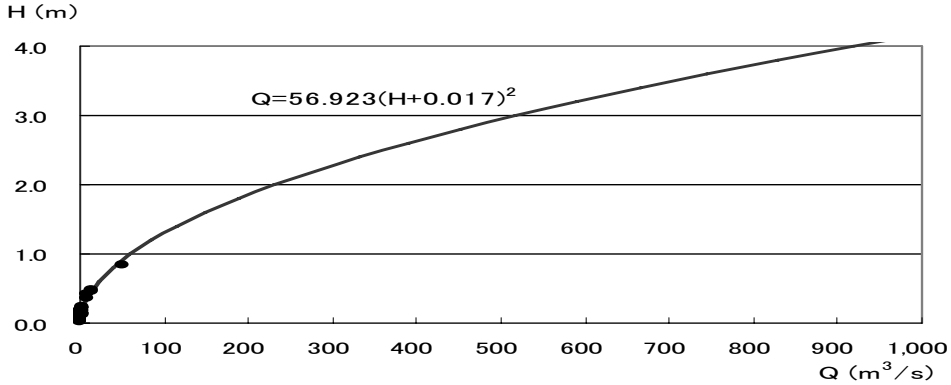
Cross Section（Hirjab）



Stage－Discharge Curve (Hirjab)

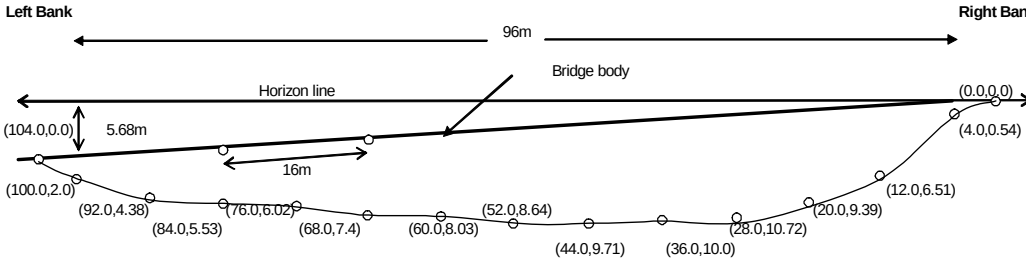


Cross Section (Tabalah)

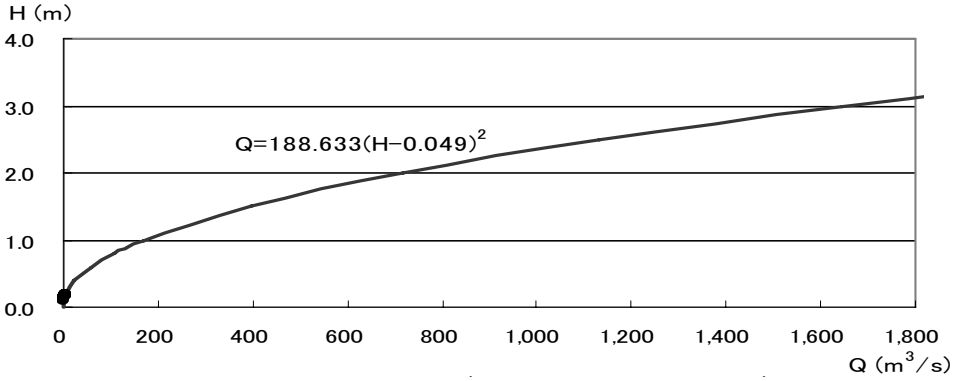


Stage－Discharge Curve (Tabalah)

Figure 2-2(1)　Cross Section and Satge-Discharge Curve (Hirjab, Tabalah)



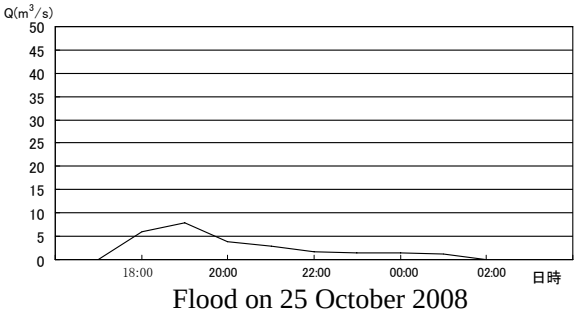
Cross Section(Habawnah)



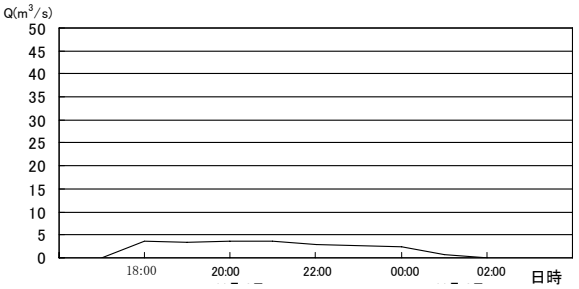
Stage－Discharge Curve(Habawnah)

Figure2-2(2) Cross Section and Satge-Discharge Curve (Habawnah)

The discharge of each stations can be obtained by converting from water level using the stage - discharge curve in Figure 2-3. Those discharge are shown in Figure 2-4 to Figure 2-5.



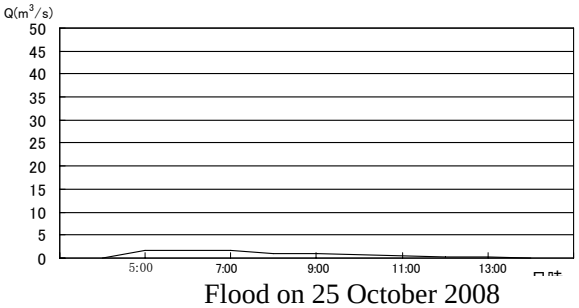
Flood on 25 October 2008



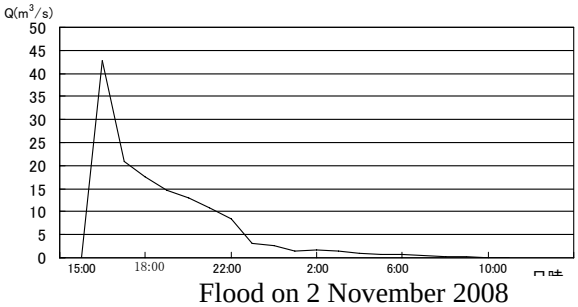
Flood on 2 November 2008

Hirjab

Figure 2-3 Observed Discharge (Hirjab)



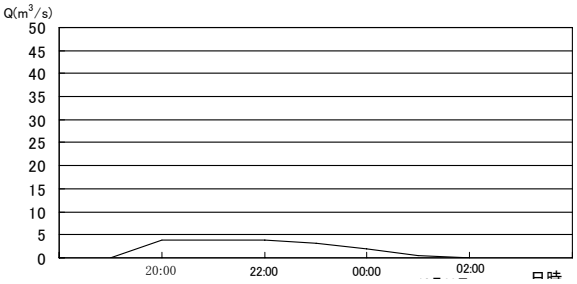
Flood on 25 October 2008



Flood on 2 November 2008

Tabalah

Figure 2-4 Observed Discharge (Tabalah)



Flood on 25 October 2008

Habawnah

Figure 2-5 Observed Discharge(Habawnah)

Table 2-4 shows the peak discharge observed at runoff station (B405,C.A.= 1,090km^2 ,Wadi Tabalah) which has same size of the catchment area. The observed discharge at Tabalah Station this time are neither big nor small.

Table 2-4 Observed Discharge at Runoff Station(B405)

No.	Occurrence Day	Qp (m^3/s)
1	1969 Jun. 30	58.0
2	1971 May 20	0.15
3	1973 May 3	14.7
4	1974 Mar. 23	78.0
5	1975 Apr. 3	570.0
6	1976 Mar. 21	44.4
7	1977 Oct. 24	23.5
8	1978 May 1	59.2
9	1979 Dec. 27	44.0
10	1980 Feb. 10	108.4
11	1981 Mar. 13	72.0
12	1982 Apr. 15	142.0
13	1983 Mar. 15	183.0
14	1984 Mar. 21	804.0

Sources: MOW.E

The observed discharge volume and runoff ratio to the neighborhood rainfall station data are shown in Table 2-5. The flow ratios at Tabalah Station indicate extraordinary numbers because of the rainfall data too small. This is caused by the inadequate rainfall data. The flow ratios for Hirjab Station and Habawnah Station show between 10 percent and 18 percent are rather higher than the observed data in wadis and dam sites shown in Table 2-6 and Table 2-7, but there is no major difference between them as shown in Figure2-6.

This time, they are just the results of the small 2 floods in 2008, and it is necessary to improve the accuracy by the accumulation of more data. Furthermore, there is still problem to grasp the appropriate mean rainfall over the basin with a few rainfall stations nearby.

Table 2-5 Observed Discharge Volume at 3 Stations

Station	C.A. (km^2)	Flood	Discharge Volume (1000m^3)	Rainfall (mm)	Flow Ratio (%)
Hirjab	594	Flood in 25 October 2008 Flood in 2 November 2008	2,258 1,995	39.0(24～25 Oct.) 30.0(1～2 Nov.)	9.7% 11.2%
Tabalah	1,039	Flood in 25 October 2008 Flood in 2 November 2008	745 12,292	2.2(24～25 Oct.) 2.4(1～2 Nov.)	32.6% 492.9%-
Habawnah	1,000	Flood in 25 October 2008	1,460	43.0(24～25 Oct.)	17.9%

Note） Rainfall Station：Hirjab; A103、Tabalah ; MET-03(GTZ)、Habawnah ; N001

Table 2-6 Flow Ratio in 5 Wadis

Wadi	Catchment Area (km^2)	Rainfall Amount (10^6m^3)	Discharge Volume (10^6m^3)	Flow Ratio (%)
Yiba	2,830	982.0	8.4	0.9
Al-Lith	3,079	583.2	2.3	0.4
Tabalah	1,900	346.7	9.6	2.8
Habawnah	4,930	695.7	8.4	1.2
Liyayah	456	134.6	4.3	3.2

Sources:Five Wadis Study Report (February, 1988)

Table 2-7 Flow Ratio at 13 Dam Sites

No.	Dam Site	Catchment Area (km^2)	Period	Mean Annual Rainfall (mm)	Mean Discharge Volume (10^6m^3)	Flow Ratio (%)
1	Rabigh Dam	3,456	1969-1985	98	83.34	24.6
2	Muruwai Dam	2,762	1966-1981	96	31.50	11.9
3	Al-Lith Dam	1,838	1984-1985	234	14.03	3.3
4	Ranyash Dam	4,379	1973-1982	201	88.76	10.1
5	Aqiq Dam	304	1967-1981	329	10.05	10.1
6	Tabalah Dam	863	1969-1984	267	12.04	5.2
7	Bisha (K.Fahd) Dam	7,600	1967-1981	269	101.43	5.0
8	Qanunah Dam	1,382	1971-1984	321	20.19	4.6
9	Hali Dam	4,843	1967-1985	375	95.62	5.3
10	Wadi Baysh Dam	4,600	1970-1985	391	74.48	4.1
11	Damad Dam	903	1970-1985	492	39.70	8.9
12	Qissi Dam	272	1970-1984	475	8.56	6.6
13	Sabya Dam	336	1970-1984	461	9.92	6.4

Sources:Final Report on each dam (1983-1987)

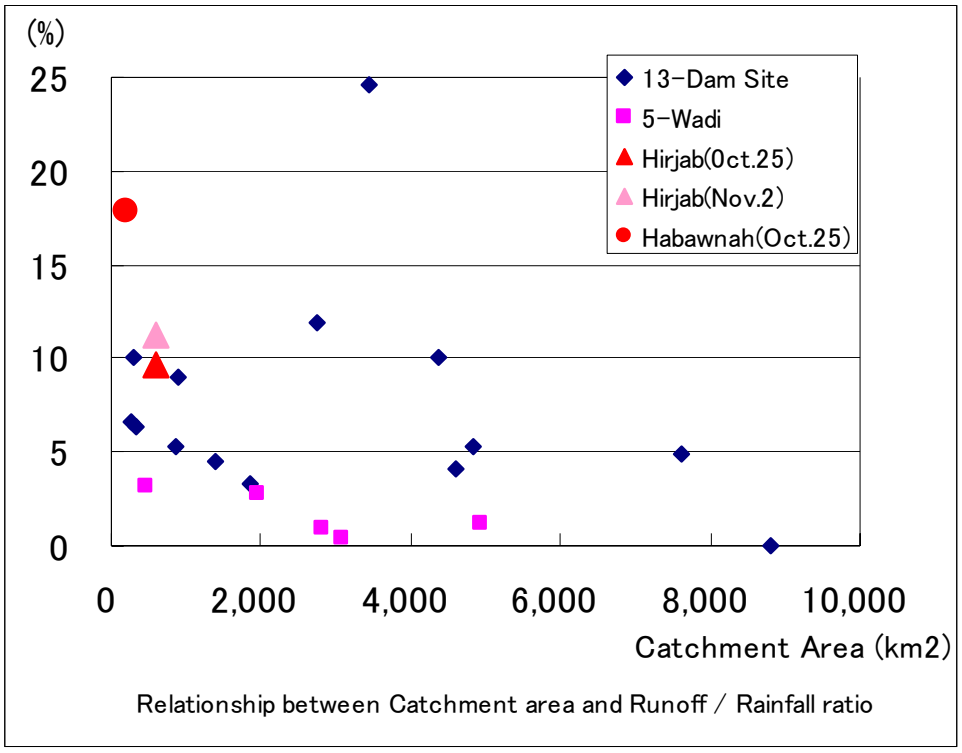


Figure 2-6 Observed Flow Ratio

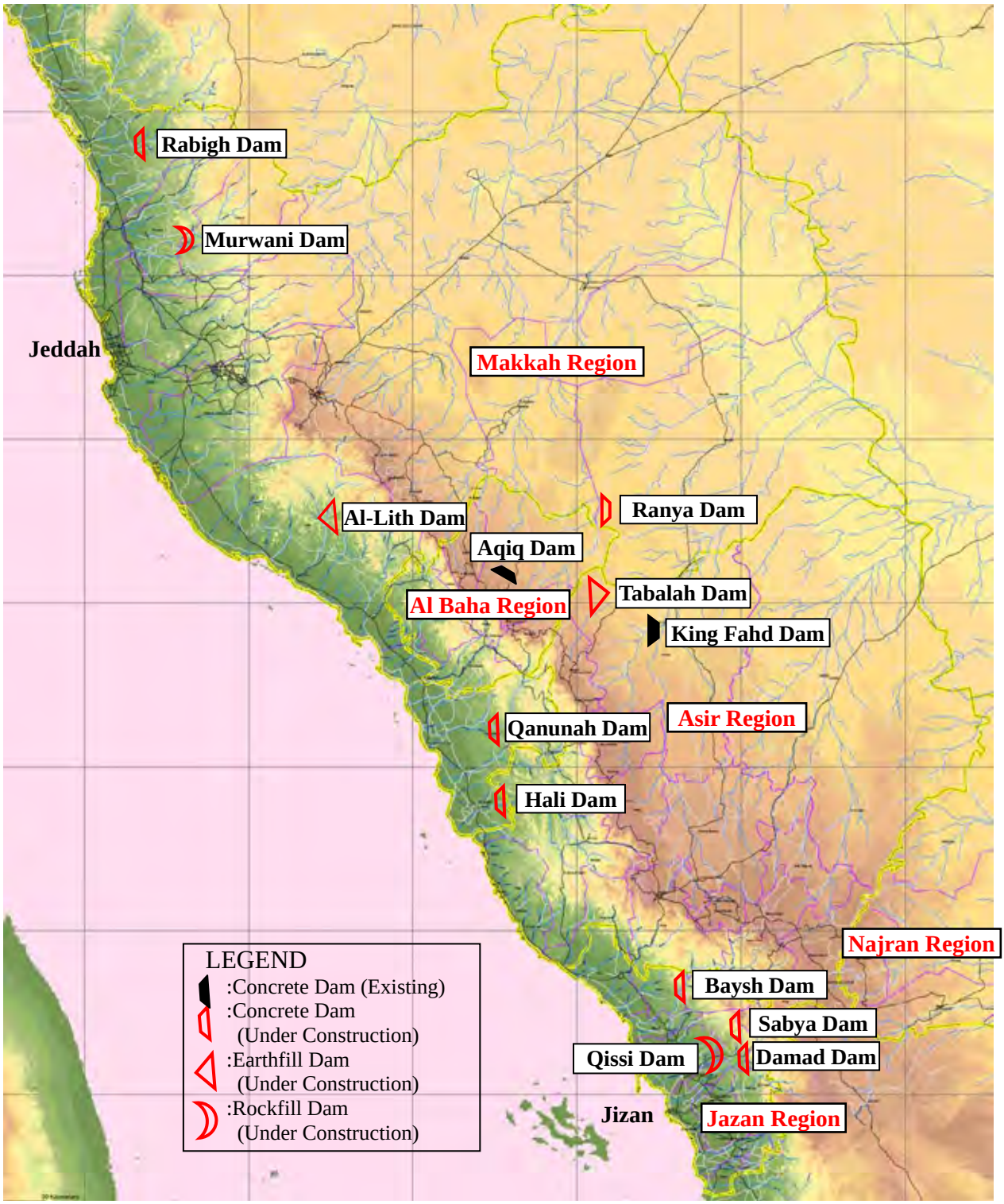


Figure 2-7 Location of 13 Dam Sites

2.2 Groundwater

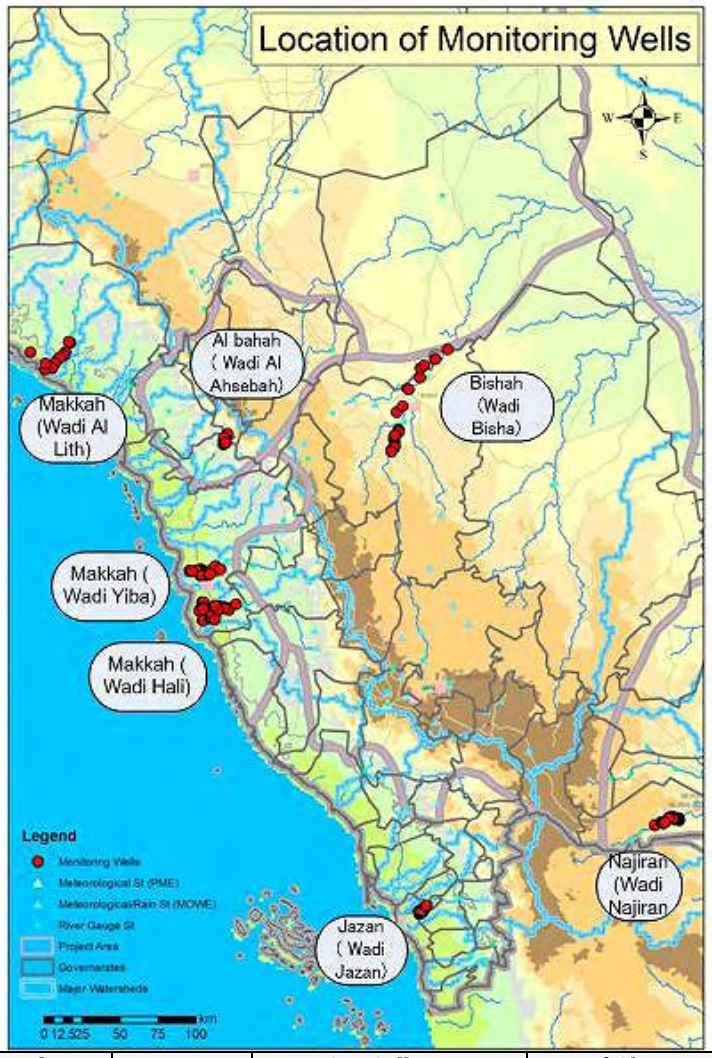
(1) Monitoring System

Observation wells had been constructed since the middle of 1960's, particularly for the monitoring of the groundwater level. By 1985, the Ministry of Agriculture and Water (MAW) had continued to expand the well system with individual project basis, and more than 300 wells have so far put in service for the project area. However, those records have not been maintained as registered data in MOWE database.

In the Study, location of observation well was newly re-organized from both MAW's list and Inventory survey.

The new observation wells were of 200 points located in groundwater utilizing areas for seven wadis as shown in Figure2-8.

Most of wells penetrate Recent wadi bed or river terrace which is composed of Alluvial or Pleistocene deposits.



Wadi	Region	Area/villages	No. of Observation
Al Ahseeba	Al Baha	Al Mukhwan	14
Al Lith	Makkah	Al lith/Omegah	13
Bisha	Asir	Bishah/Al Hazmi	35
Hali	Makkah	Al Qunfudan/Hali	33
Jazan	Jazan	Al Matery	45
Najran	Najran	Najran	38
Yiba	Makkah	Al Qunfudan /Al Gouz	22
		Total	200

Figure 2-8 Location Map of Monitoring Well

2.3 Well Inventory Survey

In order to review and update the hydrogeological database which is linked to the MOWE's observation network, the well inventory survey had begun May 2008. The survey has continued until April 2009 and survey output is of well catalogue, the water level measurements at every two months and water quality analysis in dry season (October 2008). The items of water inventory survey is composed of water level, EC and others as shown in Table2-8.

Table 2-8 Items of Water Sampling Survey and Water Quality

<water sampling survey>

· ID No.	· Latitude （D.D）	· Elevation （GPS, m）
· Name of Region	· Longitude （D.D）	· Elevation （SRTM, m）
· Agency	· Casing Detail (mm/inch)	· Dynamic Water Level （m）
· Name of District	· Total Depth (m)	· Aquifer （m）
· Name of Village	· Static Water Level （Depth,m）	· Purpose of well
· Name of Wadi	· Static Water Level （EL, m）	· Pumping Rate （lit/sec）
· Well No	· Static Water Level measured at (Date)	· Hours of Use （hr）

<water quality survey＞

Item of In-situ Test	Item of Laboratory Test		
＜field parameter＞	＜Hydro chemical＞	＜General＞	Cr(mg/l)
Odor	Ca(mg/l)	COD(mg/l)	Cd(mg/l)
Color	Mg(mg/l)	Hardness(mg/l)	As(ppb)
Turbidity(FTU)	Na(mg/l)	TDS(mg/l)	F(mg/l)
Temp(C)	K(mg/l)	＜Heavy Mineral＞	＜Biological＞
EC(uS/cm)	So4(mg/l)	Cyanide(mg/l)	Bacteria（CFU/100ml）
pH	Cl(mg/l)	Mercury(ppb)	Fecal_Coliform（CFU/100ml）
DO (%)	CO3(mg/l)	Cu(mg/l)	＜Environmental＞
Salinity（PSU）	HCO3(mg/l)	Fe(mg/l)	Foaming_Agent(mg/l)
Eh（mV）	NO3(mg/l)	Mn(mg/l)	Phenolic_Compound(mg/l)
	NO2(mg/l)	Zn(mg/l)	Organo_Phosphorus(mg/l)
	NH4(mg/l)	Pb(mg/l)	

2.4 Groundwater Level

As a rule, groundwater level was measured in early morning due to prevent well-interference from the existing wells. The summary of measurements (average, maximum, minimum value) is shown in Table 2-9. In Najran, groundwater level is deep as 40 m and more from the ground. While in other wadis, 20 to 30 m of depth are observed.

Table 2-9 Summary of Water Level Measurement

Wadis	Al Asheeba	Al Lith	Bisha	Hali	Jizan	Najran	Yiba
（No. of wells）	（14）	（13）	（35）	（33）	（45）	（38）	（22）
Average	19.4	19.1	26.2	26.4	29.8	42.1	23.1
Min. （m）	11.8	8.1	7.4	7.1	22.3	22.9	15.7
Max （m）	33.8	33.8	63.0	41.8	37.6	57.3	54.3

The spatial distribution, which is delineated by contour lines, reveals the water flows towards the center of wadi from the mountain. At convergences with tributaries, extruding/disturbance of contour lines is found as result of side-flow effects. In places nearby pumping wells, depression cones are also observed.

Near the coastal strip of Red sea, lying on the outlets of wadi Al Lith, Hali, Yiba and Jizan, the water level is lowered beneath the sea level. In Figure 2-9, groundwater contour of Al Lith, Najran are shown.

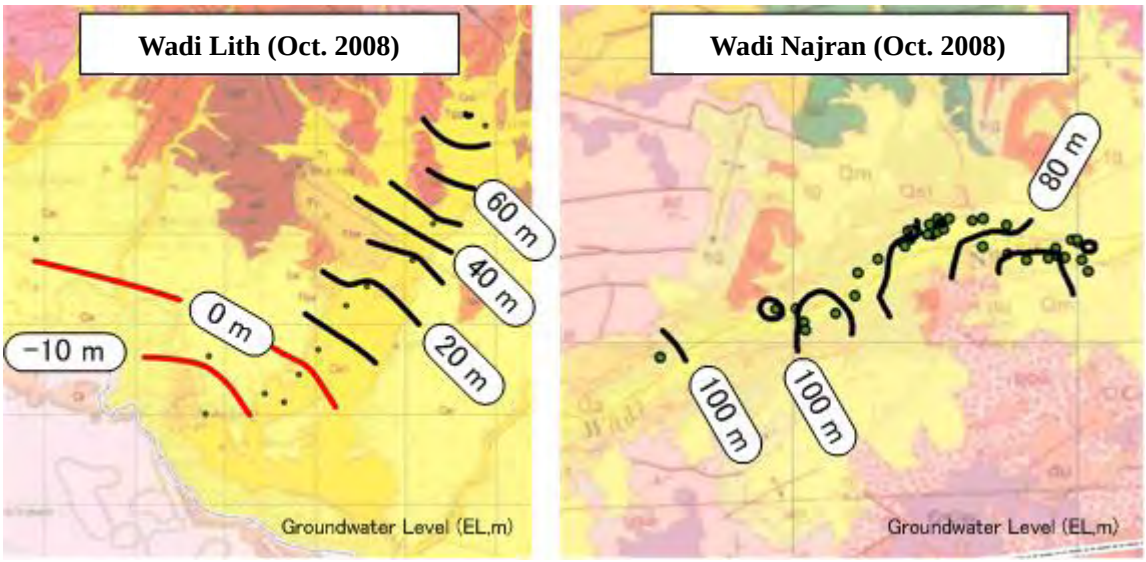


Figure 2-9 Groundwater Contour(Wadi Al Lith, Wadi Najran)

2.5 Water Sampling Survey

Along with the water level measurement, water-sampling survey was conducted, and field parameters (EC, pH and etc.) of water quality were observed as shown in Table 2-10.

Table 2-10 Summary of Water Sampling Survey

Wadi		Odor	Color	Turbidity	Temp.	EC	pH	DO	Salinity	EH
AL_AHSEEBA	Avg.	NO	NO	0.6	29.2	1,329	7.7	89.9	0.7	80.0
14 samples	Min	NO	NO	0.0	27.6	727	7.0	80.0	0.4	12.5
	Max	NO	NO	2.5	32.1	3,902	8.4	100.0	2.1	148.7
AL_LITH	Avg.	NO	NO	1.6	30.4	1,834	7.7	22.1	0.9	62.1
13 samples	Min	NO	NO	0.0	27.6	727	6.7	4.6	0.1	12.5
	Max	NO	NO	6.0	32.6	3,902	8.5	100.0	2.1	148.7
BISHA	Avg.	NO	NO	1.3	27.6	3,750	7.6	27.4	2.0	18.3
35 samples	Min	NO	NO	0.0	25.6	560	7.2	16.1	0.3	0.4
	Max	NO	NO	7.6	30.1	12,280	8.5	78.2	7.0	43.3
HALI	Avg.	NO	NO	1.8	27.2	2,263	7.7	17.8	1.2	57.4
33 samples	Min	NO	NO	0.0	24.0	983	7.2	0.0	0.6	9.1
	Max	NO	NO	5.9	34.0	7,785	8.2	31.7	4.3	107.3
JIZAN	Avg.	NO	NO	7.3	27.5	1,369	8.1	89.9	0.7	47.8
45 samples	Min	NO	NO	0.0	24.3	434	7.2	49.0	0.2	15.5
	Max	NO	NO	47.3	29.3	4,151	8.4	120.0	2.2	92.7
NAJRAN	Avg.	NO	NO	0.7	27.6	1,210	8.1	44.6	0.6	84.0
6 samples	Min	NO	NO	0.0	23.1	427	7.1	7.3	0.2	1.1
	Max	NO	NO	2.4	31.8	3,656	8.4	97.3	1.9	121.3
YIBA	Avg.	NO	NO	1.5	29.3	1,766	7.3	9.8	0.9	51.1
4 samples	Min	NO	NO	0.1	26.9	906	6.5	2.1	0.4	28.2
	Max	NO	NO	5.8	32.9	6,498	8.6	20.2	3.5	78.1

Note：Unit used in table refers to Table B.3-14 'Items of Water Sampling Survey and Water Quality'

EC of fresh water is 400 μS/cm while 12,000 μS/cm of brackish water. The average of EC is 1,500 to 2,000μS/cm in respective wadi, which is available quality for irrigation purpose. The fresh water indicating less than 1,000 μS/cm is only found in wadi channel and the upper stream, and its water quality is abruptly worsen as is far from wadi center and toward the downstream. In Bisha area, deterioration on water quality caused by excessive pumping is also suspected in the water sampling survey.

Highest turbidity is observed at Jazan by silt inclusions, and acidic water affected by hot springs is also observed at Al Lith and Yiba wadi. Other samples show in general pH 7.5 as weak alkaline. EC distribution of Wadi Bisha and Wadi Hali-Yiba are shown in Figure 2-10.

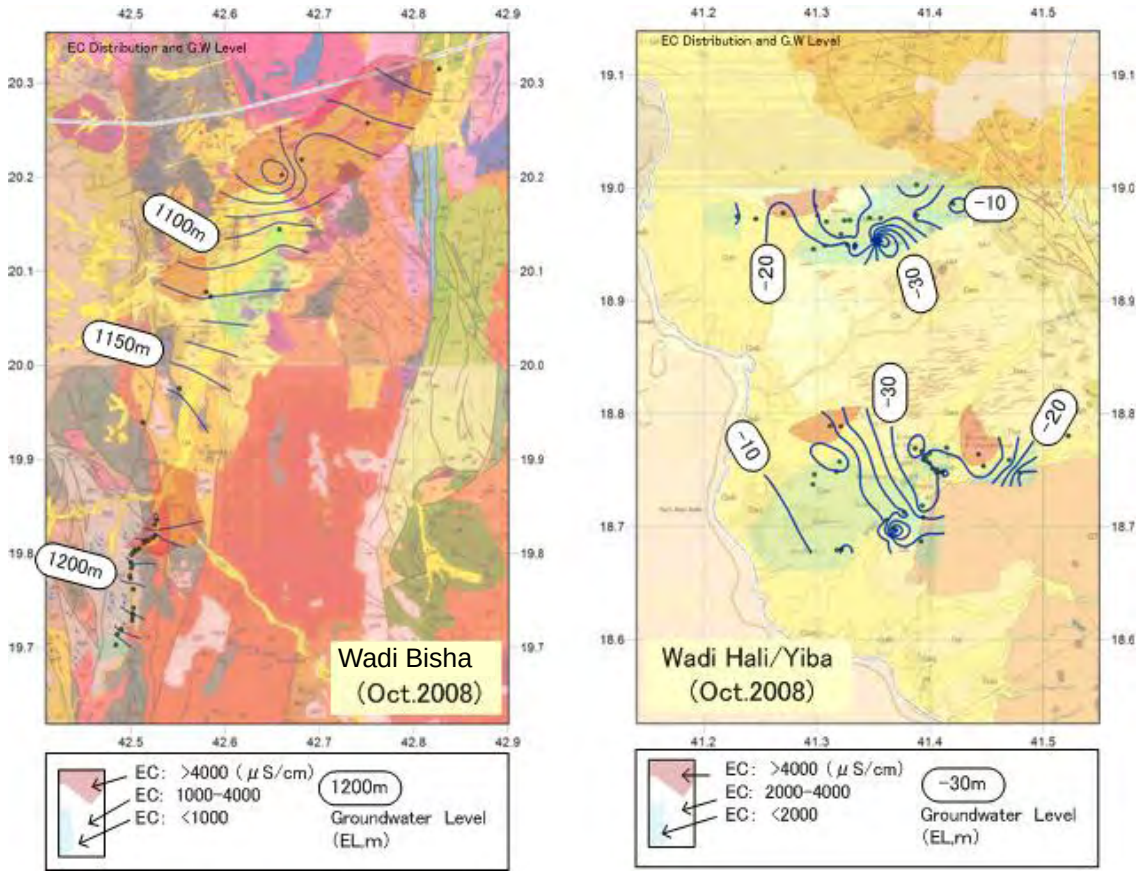


Figure 2-10 EC Distribution (Wadi Al Bisha, Wadi Hali-Yiba)

2.6 Water Quality (Laboratory) Test

Laboratory test was made for 200 samples (taken from observatory wells) with items of hydrochemistry, inorganic compound, heavy mineral, bacteria and environment. Summarized table is shown in Table 2-11(1)-(3).

Table 2-11(1) Summary of Water Quality Test

<Hydrochemistry>

Area		Ca	Mg	Na	K	SO4	Cl	CO3	HCO3	NO3	NO2	NH4
AL_AHSEEBA	Avg.	151.3	28.6	51.7	1.9	138.1	189.8	0.0	219.7	4.8	0.1	0.0
14 samples	Min	88.1	17.0	12.5	0.0	60.0	65.0	0.0	207.5	0.3	0.0	0.0
	Max	404.4	82.6	252.6	9.4	530.0	815.0	0.0	234.3	9.9	0.4	0.3
AL_LITH	Avg.	172.4	41.1	180.6	6.4	327.3	342.0	0.0	177.4	8.7	0.1	0.0
13 samples	Min	8.0	4.9	12.5	0.0	19.0	30.0	0.0	43.9	0.3	0.0	0.0
	Max	404.4	92.3	534.3	20.0	850.0	815.0	0.0	234.3	41.0	0.4	0.3
BISHA	Avg.	373.0	92.5	322.5	12.1	680.3	772.7	0.0	270.7	1.9	0.0	0.0
35 samples	Min	48.1	9.7	43.5	1.6	29.0	55.0	0.0	156.2	0.2	0.0	0.0
	Max	1401.5	340.0	890.3	33.3	1150.0	3900.0	0.0	356.3	9.7	0.1	0.2
HALI	Avg.	186.0	76.5	259.5	9.5	523.6	423.8	0.0	217.7	6.0	0.0	0.0
33 samples	Min	104.1	24.3	55.4	2.1	220.0	160.0	0.0	146.4	0.3	0.0	0.0
	Max	688.7	344.8	1273.8	47.6	2200.0	2000.0	0.0	258.7	96.0	0.3	0.4
JIZAN	Avg.	102.7	38.5	143.3	5.4	203.3	181.1	0.0	210.8	5.6	0.0	0.0
45 samples	Min	12.1	19.4	63.6	2.4	80.0	80.0	0.0	146.4	0.1	0.0	0.0
	Max	253.0	94.7	462.6	17.3	810.0	597.5	0.0	366.1	19.6	0.5	0.1
NAJRAN	Avg.	156.5	31.6	46.3	1.7	237.5	157.2	0.0	177.3	5.4	0.1	0.1
6 samples	Min	64.1	2.4	2.7	0.1	21.0	30.0	0.0	134.2	1.1	0.0	0.0
	Max	460.0	126.3	164.3	6.1	741.0	658.0	0.0	246.5	59.8	0.6	0.6
YIBA	Avg.	151.0	48.3	276.4	9.0	366.1	394.0	0.0	180.0	2.5	0.0	0.0
4 samples	Min	56.1	14.6	0.0	4.1	200.0	0.9	0.0	122.0	0.0	0.0	0.0
	Max	680.7	238.0	1110.7	36.6	880.0	2675.0	0.0	224.5	12.0	0.1	0.0

Note：Unit used in table refers to Table B.3-14 'Items of Water Sampling Survey and Water Quality'

Table 2-11(2) Summary of Water Quality Test

＜Inorganic Compound, Heavy Mineral＞

Area		Cyan	Hg	Cu	Fe	Mn	Zn	Pb	Cr	Cd	As	F
AL_AHSEEBA	Avg.	ND	<0.001	0.0	0.0	0.0	-	<0.01	0.0	<0.01	<1	0.6
14 samples	Min	ND	<0.001	0.0	0.0	0.0	0.1	<0.01	0.0	<0.01	<1	0.3
	Max	ND	<0.001	0.3	0.1	0.0	0.5	<0.01	0.0	<0.01	<1	0.9
AL_LITH	Avg.	ND	<0.001	0.0	0.0	0.0	-	<0.01	-	<0.01	3.6	1.9
13 samples	Min	ND	<0.001	0.0	0.0	0.0	0.1	<0.01	<0.01	<0.01	1.0	0.1
	Max	ND	<0.001	0.3	0.1	0.0	0.5	<0.01	0.0	<0.01	5.0	11.7
BISHA	Avg.	ND	<0.001	0.0	0.1	0.0	-	<0.01	0.0	<0.01	-	0.7
35 samples	Min	ND	<0.001	0.0	0.0	0.0	0.2	<0.01	0.0	<0.01	<1	0.1
	Max	ND	<0.001	0.1	0.4	0.1	0.2	<0.01	0.0	<0.01	1.0	1.2
HALI	Avg.	ND	<0.001	0.0	0.1	0.0	-	<0.01	0.0	<0.01	-	0.8
33 samples	Min	ND	<0.001	0.0	0.0	0.0	0.0	<0.01	0.0	<0.01	<1	0.2
	Max	ND	<0.001	0.1	1.5	0.2	0.4	<0.01	0.0	<0.01	9.0	2.1
JIZAN	Avg.	ND	<0.001	0.0	0.1	0.0	-	<0.01	0.0	<0.01	-	0.5
45 samples	Min	ND	<0.001	0.0	0.0	0.0	0.0	<0.01	0.0	<0.01	<1	0.2
	Max	ND	<0.001	0.1	0.8	0.1	0.0	<0.01	0.0	<0.01	3.0	0.9
NAJRAN	Avg.	ND	<0.001	0.0	0.2	0.0	-	-	0.0	<0.03	-	0.6
6 samples	Min	ND	<0.001	0.0	0.0	0.0	<0.01	<0.01	0.0	<0.04	<1	0.1
	Max	ND	<0.001	0.1	3.9	0.1	0.1	0.0	0.1	<0.05	17.0	2.2
YIBA	Avg.	ND	<0.001	0.0	0.1	0.0	-	-	0.0	<0.01	-	0.6
4 samples	Min	ND	<0.001	0.0	0.0	0.0	<0.01	<0.01	0.0	<0.01	<1	0.1
	Max	ND	<0.001	0.0	0.5	0.3	0.2	<0.02	0.0	<0.01	9.0	1.2

Note：Unit used in table refers to Table B.3-14 'Items of Water Sampling Survey and Water Quality'

Table 2-11(3) Summary of Water Quality Test

＜Bacteria and Environment＞

Area		COD	Bacteria	Fecal Coliform	Phenolic Compound	Organo Phosphorus	Hardness	TDS	Foaming Agent
AL_AHSEEBA	Avg.	27	925	ND	ND	0.0	496	803	-
14 samples	Min	24	300	ND	ND	0.0	300	497	Nil
	Max	36	1,200	ND	ND	0.0	1,350	2,348	2.0
AL_LITH	Avg.	39	567	ND	ND	0.0	602	1,289	-
13 samples	Min	9	200	ND	ND	0.0	40	138	Nil
	Max	158	1,200	ND	ND	0.0	1,350	2,634	2.0
BISHA	Avg.	35	724	-	ND	0.0	1,310	2,533	-
35 samples	Min	13	200	ND	ND	0.0	180	445	Nil
	Max	57	1,200	100.0	ND	0.1	4,840	7,821	1.0
HALI	Avg.	65	877	ND	ND	0.0	675	1,533	-
33 samples	Min	0	300	ND	ND	0.0	480	100	Nil
	Max	230	1,800	ND	ND	0.1	1,380	6,538	1.0
JAZAN	Avg.	28	784	ND	ND	0.0	421	963	-
45 samples	Min	21	200	ND	ND	0.0	220	538	Nil
	Max	50	1,200	ND	ND	0.0	1,020	2,620	2.0
NAJRAN	Avg.	30	650	ND	ND	0.0	518	821	-
6 samples	Min	21	200	ND	ND	0.0	180	273	Nil
	Max	75	1,200	ND	ND	0.0	1,700	2,283	2.0
YIBA	Avg.	35	507	ND	ND	0.0	601	1,432	-
4 samples	Min	10	200	ND	ND	0.0	220	734	Nil
	Max	46	900	ND	ND	0.0	2,680	5,697	1.5

Note：Unit used in table refers to Table B.3-14 'Items of Water Sampling Survey and Water Quality'

(1) Groundwater Type (Piper Diagram)

To identify the groundwater Type, Piper Diagram analysis was made (Figure 2-11).

The Piper program shows eight "standard" ions: 4 cations (Na, K, Ca, and Mg) and 4 anions (Cl, HCO3, CO3, SO4). Concentrations are translated to milli-equivalents per liter for plotting on the diagram. Besides, the concentration of TDS shows the size of circle. The following findings are obtained through the analysis.

The groundwater type is classified into two of Type I and Type V. Type I is indicated as Non-bicarbonate-Calcium chemical component and is common in hot spring or un-renewable water.

Type V is intermediate type of Type I and renewed water such as baseflow and river water originated from rainwater.

Type I is categorized as un-renewable water and common in Wadi Najran, Bisha and Hali.

Type V is regarded as a mixed water of river water, base flow water and un-renewable water. This is dominant type in Wadi Jizan, Al Lith, Yiba, Al Ahseeba.

In the coastal area, in particular Wadi Hali and Yiba, the chemical component of seawater (rich in Cl, Na+K) are included in both types of water.

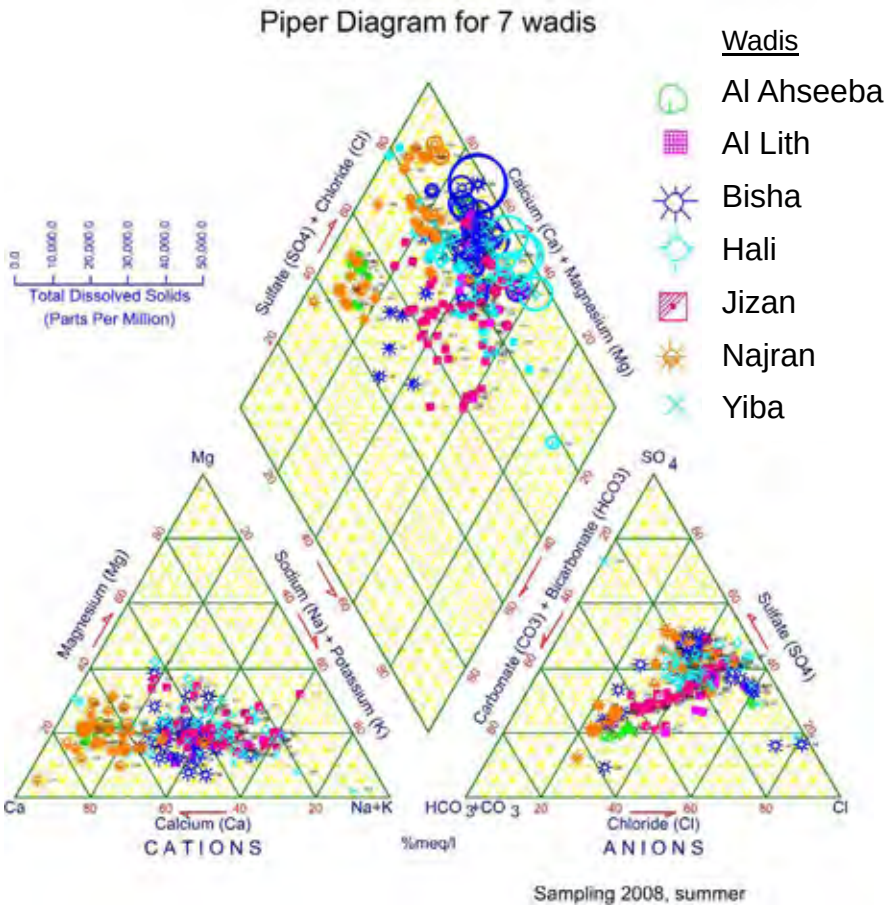


Figure 2-11 Groundwater Type (Piper Diagram)

(2) Water Quality Components in Wadis

For visualizing the changes of water quality, Stiff diagram is delineated. The stiff diagram has information (in any order) for eight "standard" ions: 4 cations (Na, K, Ca, and Mg) and 4 anions (Cl, HCO3, CO3, SO4). Concentrations are entered in parts per million (ppm) or milligrams per liter (mg/l); concentrations are translated to milli-equivalents per liter for plotting on the diagram. The Type I (Non-bicarbonate-Calcium type) is characterized by higher concentration of Ca at the left-middle. While for Type V shows squire shape. As well, contamination with seawater indicates high concentration of Cl at the right-low corner of diagram.

Figure2-12(right figure) shows the water quality changes along Wadi Yiba. At the upper stream, the Type V is dominant type which indicates the contamination with renewable water. Toward down stream, it turns into Type I and is mixed with seawater.

Figure 2-12 (left figure) represents Wadi Bisha. It includes fresh water at upper stream while un-renewable water categorized to Type I at down stream.

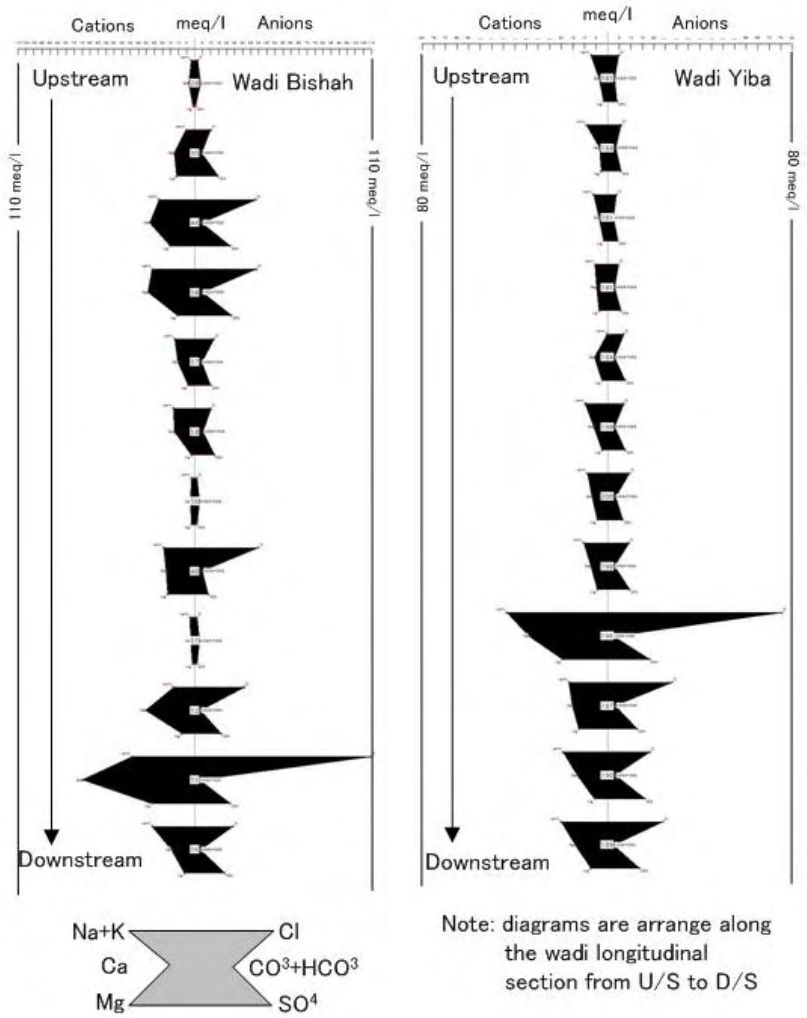


Figure 2-12 Changes of Water Quality in Wadi (Stiff Diagram)

(3) Drinking Water Quality

The renewal water source, replenished from rainwater and other surface sources are limited in its distribution in the study area, and most of them belong the Type I and V of un-renewable water, which is characterized by high contents of sodium, calcium, chloride and sulfide. Table 2-12(1)-(2) shows a correlation table which is examined by drinking water standard (MOWE). In the table, shaded part is hazardous concentration as potable water.

In most of wells, high EC is detected. Particularly half of samples taken from Wadi Al Lith, Bisha, Hali, Yiba indicate the higher than the standard's. As for the content of Na, K, Cl, SO4, the values also exceed those of the standard. Content of chloride measured in Wadi Bisha and Yiba shows 10 times of standard value. Coli form is detected in every samples and even fecal coliform is found out in Wadi Bisha's sample. If the water source is used in villages nearby, it must be disinfected beforehand in use.

The silt contamination is also found in the Wadi Jizan, Hali, Yiba, and those are higher than the standard. Nirtite content is also high in Wadi Hali and Najran, and the highest reaches several to 10 times of the standard. The fact means groundwater resource may be deteriorated from fertilizing, domestic sewerage and animal excrement.

The result of heavy minerals and inorganic test shows the ferric water (high contents of Fe and Mn) derived from basaltic lavas and fluoric water originated from granite rocks. As for other items, harmful components and high concentration are not found at the test dated on Oct, 2008.

Table 2-12(1) Summary of Water Quality Test

Area		Odor	Color	Turb	EC	TDS	pH	Ca	Mg	Na	SO4	Cl	NO3	NO2
AHSEEBA	Avg.	NO	NO	0.6	1,329	803	7.7	151.3	28.6	51.7	138.1	189.8	4.8	0.1
14 samples	Min	NO	NO	0.0	727	497	7.0	88.1	17.0	12.5	60.0	65.0	0.3	0.0
	Max	NO	NO	2.5	3,902	2,348	8.4	404.4	82.6	252.6	530.0	815.0	9.9	0.4
AL_LITH	Avg.	NO	NO	1.6	1,834	1,289	7.7	172.4	41.1	180.6	327.3	342.0	8.7	0.1
13 samples	Min	NO	NO	0.0	727	138	6.7	8.0	4.9	12.5	19.0	30.0	0.3	0.0
	Max	NO	NO	6.0	3,902	2,634	8.5	404.4	92.3	534.3	850.0	815.0	41.0	0.4
BISHA	Avg.	NO	NO	1.3	3,750	2,533	7.6	373.0	92.5	322.5	680.3	772.7	1.9	0.0
35 samples	Min	NO	NO	0.0	560	445	7.2	48.1	9.7	43.5	29.0	55.0	0.2	0.0
	Max	NO	NO	7.6	12,280	7,821	8.5	1401.5	340.0	890.3	1150.0	3900.0	9.7	0.1
HALI	Avg.	NO	NO	1.8	2,263	1,533	7.7	186.0	76.5	259.5	523.6	423.8	6.0	0.0
33 samples	Min	NO	NO	0.0	983	100	7.2	104.1	24.3	55.4	220.0	160.0	0.3	0.0
	Max	NO	NO	5.9	7,785	6,538	8.2	688.7	344.8	1273.8	2200.0	2000.0	96.0	0.3
JIZAN	Avg.	NO	NO	7.3	1,369	963	8.1	102.7	38.5	143.3	203.3	181.1	5.6	0.0
45 samples	Min	NO	NO	0.0	434	538	7.2	12.1	19.4	63.6	80.0	80.0	0.1	0.0
	Max	NO	NO	47.3	4,151	2,620	8.4	253.0	94.7	462.6	810.0	597.5	19.6	0.5
NAJRAN	Avg.	NO	NO	0.7	1,210	821	8.1	156.5	31.6	46.3	237.5	157.2	5.4	0.1
6 samples	Min	NO	NO	0.0	427	273	7.1	64.1	2.4	2.7	21.0	30.0	1.1	0.0
	Max	NO	NO	2.4	3,656	2,283	8.4	460.0	126.3	164.3	741.0	658.0	59.8	0.6
YIBA	Avg.	NO	NO	1.5	1,766	1,432	7.3	151.0	48.3	276.4	366.1	394.0	2.5	0.0
4 samples	Min	NO	NO	0.1	906	734	6.5	56.1	14.6	0.0	200.0	0.9	0.0	0.0
	Max	NO	NO	5.8	6,498	5,697	8.6	680.7	238.0	1110.7	880.0	2675.0	12.0	0.1
MOWE Water Standard for Drinking		NO	15	5.0	160-1600	100-1000	6.5-8.5	200	150	200	400	250	10	1

Note：Unit used in table refers to Table B.3-14 'Items of Water Sampling Survey and Water Quality'

Table 2-12(2) Summary of Water Quality Test

Area		F.Col	Cyan	Hg	Cu	Fe	Mn	Zn	Pb	Cr	Cd	As	F	Hard
AHSEEBA	Avg.	ND	ND	<0.001	0.0	0.0	0.0	-	<0.01	0.0	<0.01	<1	0.6	496
14 samples	Min	ND	ND	<0.001	0.0	0.0	0.0	0.1	<0.01	0.0	<0.01	<1	0.3	300
	Max	ND	ND	<0.001	0.3	0.1	0.0	0.5	<0.01	0.0	<0.01	<1	0.9	1,350
AL_LITH	Avg.	ND	ND	<0.001	0.0	0.0	0.0	-	<0.01	-	<0.01	3.6	1.9	602
13 samples	Min	ND	ND	<0.001	0.0	0.0	0.0	0.1	<0.01	<0.01	<0.01	1.0	0.1	40
	Max	ND	ND	<0.001	0.3	0.1	0.0	0.5	<0.01	0.0	<0.01	5.0	11.7	1,350
BISHA	Avg.	-	ND	<0.001	0.0	0.1	0.0	-	<0.01	0.0	<0.01	-	0.7	1,310
35 samples	Min	ND	ND	<0.001	0.0	0.0	0.0	0.2	<0.01	0.0	<0.01	<1	0.1	180
	Max	100.0	ND	<0.001	0.1	0.4	0.1	0.2	<0.01	0.0	<0.01	1.0	1.2	4,840
HALI	Avg.	ND	ND	<0.001	0.0	0.1	0.0	-	<0.01	0.0	<0.01	-	0.8	675
33 samples	Min	ND	ND	<0.001	0.0	0.0	0.0	0.0	<0.01	0.0	<0.01	<1	0.2	480
	Max	ND	ND	<0.001	0.1	1.5	0.2	0.4	<0.01	0.0	<0.01	9.0	2.1	1,380
JIZAN	Avg.	ND	ND	<0.001	0.0	0.1	0.0	-	<0.01	0.0	<0.01	-	0.5	421
45 samples	Min	ND	ND	<0.001	0.0	0.0	0.0	0.0	<0.01	0.0	<0.01	<1	0.2	220
	Max	ND	ND	<0.001	0.1	0.8	0.1	0.0	<0.01	0.0	<0.01	3.0	0.9	1,020
NAJRAN	Avg.	ND	ND	<0.001	0.0	0.2	0.0	-	-	0.0	<0.03	-	0.6	518
6 samples	Min	ND	ND	<0.001	0.0	0.0	0.0	<0.01	<0.01	0.0	<0.04	<1	0.1	180
	Max	ND	ND	<0.001	0.1	3.9	0.1	0.1	0.0	0.1	<0.05	17.0	2.2	1,700
YIBA	Avg.	ND	ND	<0.001	0.0	0.1	0.0	-	-	0.0	<0.01	-	0.6	601
4 samples	Min	ND	ND	<0.001	0.0	0.0	0.0	<0.01	<0.01	0.0	<0.01	<1	0.1	220
	Max	ND	ND	<0.001	0.0	0.5	0.3	0.2	<0.02	0.0	<0.01	9.0	1.2	2,680
MOWE Water Standard for Drinking		ND	0.005	0.001	1	0.3	0.1	2	0.05	0.05	0.005	50	0.6-1.7	500

Note：Unit used in table refers to Table B.3-14 'Items of Water Sampling Survey and Water Quality'

(4) Pumping Un-renewable Water

In the analysis of groundwater type by Piper Diagram, usage of un-renewable water source was suggested in every region (refer to sub-section 3.3.4 (1)). It is also supported by factual phenomena in field survey, such as,

- Groundwater quality degradation,
- Groundwater level lowering,

- Insufficient water amount for agricultural use,
- Not enough recovery of groundwater level and
- Seawater intrusion.

The groundwater obstacles listed above are seen with various forms extensively in five (5) regions and are MOWE's main enumeration which shall take immediate countermeasure for their solutions. Thus, the phenomena may be led by the over extraction beyond natural water replenishment from rainwater, and it gives clear evidence that supports the result of water type analysis which is pumping un-renewable resources. As well, SWAT output indicates that the renewable amount is less than present consumption of water in Jazan and Najran Regions (refer to sub-section 3.5).

However, with present water quality data, the further detail analysis of un-renewable water can not be progressed. It should take different approach to estimate the residence time of groundwater (age of water) and check up the storage of resources with time axis vs. demand.

Residence times can be estimated in two ways. The more common method relies on the principle of conservation of mass and assumes the amount of water in a given reservoir is roughly constant by which is applied by groundwater modeling involving both renewable and un-renewable resource. With this method, residence times are estimated by dividing the volume of the reservoir by the rate by which water either enters or exits the reservoir. An alternative method to estimate residence times, which is gaining in popularity for dating groundwater, is the use of isotopic techniques.

2.7 Base Flow Survey

In the study, three (3) base-flow observatories were installed. Two of them were located in Asir Region and other (1) was constructed in Najran Region, as shown below.

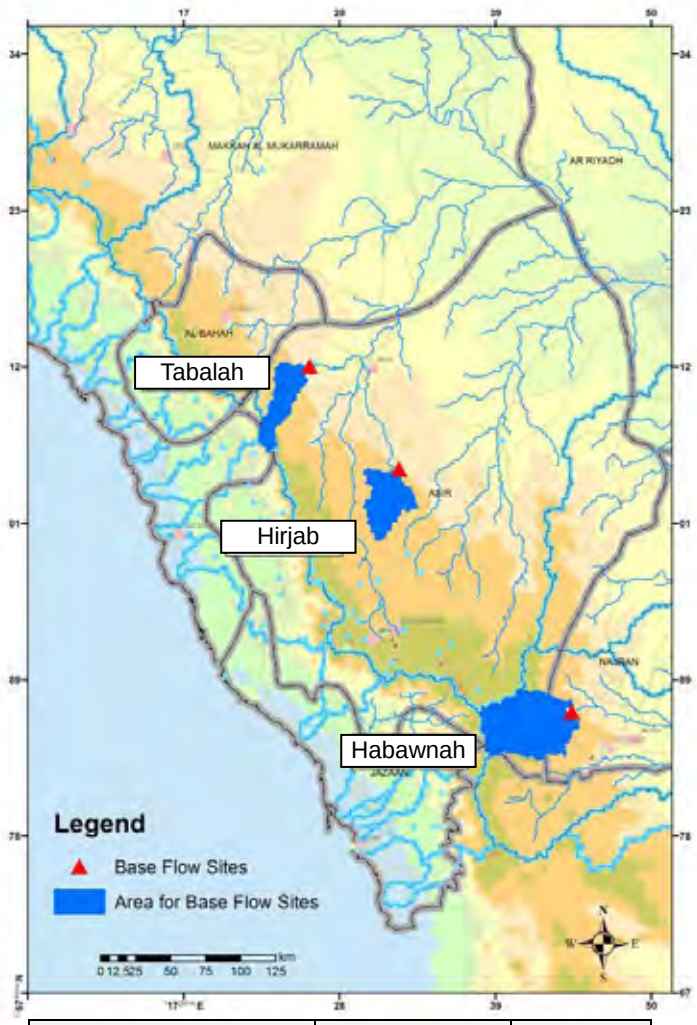
The observation period is one (1) year since July 2008, and half of observation had been completed by February 2009.

The method of the base flow estimation is

- Installing observation wells at upstream and downstream of measurement points in wadi,
- Measuring water levels at both points, and leveling wells' elevation to connect the both wells and calculate the hydrologic gradient of water table,
- Carrying out geophysical observation along wadi section to decide shape and thickness of aquifers,
- Obtaining transmissivity of aquifer by aquifer test, and calculating daily discharge at three sites.

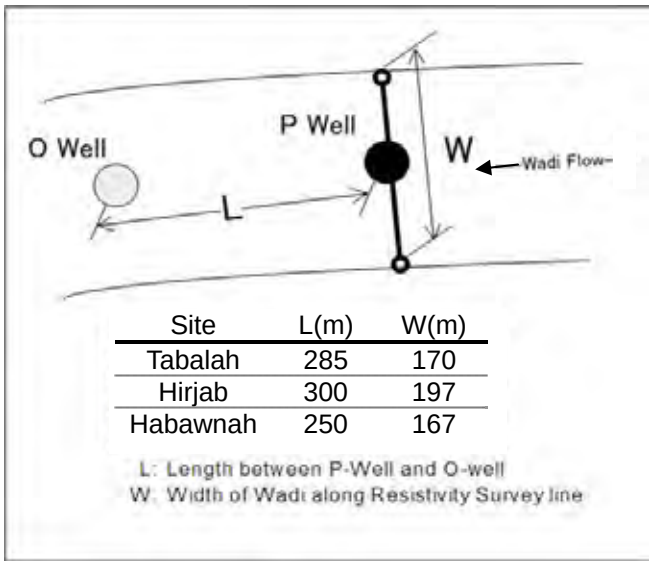
Upon above method, two (2) observation wells were constructed and geophysical survey was carried out, Figure B.3-39 shows the layout of base flow survey site.

On the wadi bed, pumping well (P-well) is settled at the upstream and observation well (Ob-well) located at downstream. Ob-well set at 250 m - 300 m far from P-well in order to maintain the accuracy on the measurement of hydraulic gradient in between wells. For the measurement of drawdown, P-well is used as mother (pumping) well while Ob-well is applied as child (observation) well. As for geophysical survey, the survey line crosses wadi section and passes at P-well. In Hirjab site and Habawnah site, the automatic recorders were installed in new drilled wells for the time-series measurement of the water level. In Tabalah site, due to using existing well for P-well, automatic recorder was installed, and manual measurement was instead made with monthly basis.



Wadi (states)	Co-ordinates (Lat/Lon,D.D)	Area (sqkm)
Tabalah（Asir）	17.79/44.00	1,030
Hirjab（Asir）	19.34/42.82	1,220
Habawnah（Najran）	19.99/42.20	2,620

Figure 2-13　Location of Base Flow Survey Site



Site	L(m)	W(m)
Tabalah	285	170
Hirjab	300	197
Habawnah	250	167

L: Length between P-Well and O-well
W: Width of Wadi along Resistivity Survey line

Figure 2-14　Layout of Base Flow Measurement Site

(1) Aquifer Test and Aquifer Coefficient

(a) Drilling

The wadi basement of Hirjab site is made up of Pre-Cambrian granite, while Habawnah site is of metamorphics. The depth of basement is 12 m at Hirjab while 20 m at Habawnah. The aquifer thickness at Hirjab is thus 6 m to 12 m and Habawnah's is 11m to 20m. The lithology of aquifer is mainly composed of sand and gravel and minor intercalation of silty - clay, In Figure 2-15, the well log is shown.

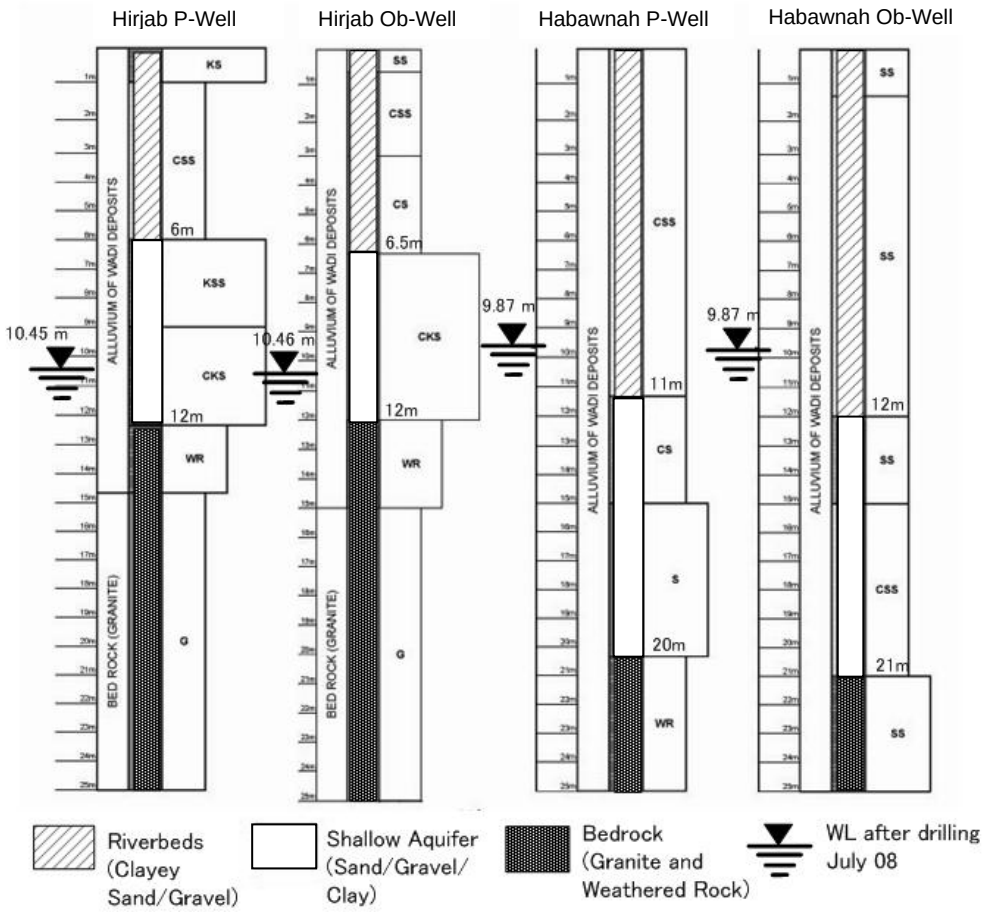


Figure 2-15 Well Logs

The water level measured after drilling (July 2008) was 10.45 m deep at Hirjab. It was only 1-2 m shallower than the basement. While at Habawnah, water level was 9.9 m and 11 m to 20 m of saturated zone was expected.

(b) Geophysical Survey (Resistivity Survey)

The vertical resistivity sounding (Schlumberger Method) was conducted up to 100 m deep along the wadi cross sections which traversed at P-well. Using smooth inversion analysis, the specific resistivity was calculated and the aquifer position was delineated through the correlation to drilling logs of P-well.

The resistivity pattern shows the clear contrast in resistivity which is low as 100 ohm-m at aquifer portion and inversely high more than 1,000 ohm-m at the surface layer and basement.

In Figure 2-16, cross section of aquifer is shown. The thickness of aquifer and shape of basement are as follows.

- 10 m at Hirjab site and 12 m at Tabalah site. The shape of basement is U-shaped with sight deeper at the center of wadi.
- Habawnah's basement is 25 m deep at the left bank, which is forms V-shaped valley.

The aquifer lies on the basement and characterized by silt intercalations. The aquifer is not uniformed aquifer but it consists of multi-aquifers divided into several layers of sand and gravel.

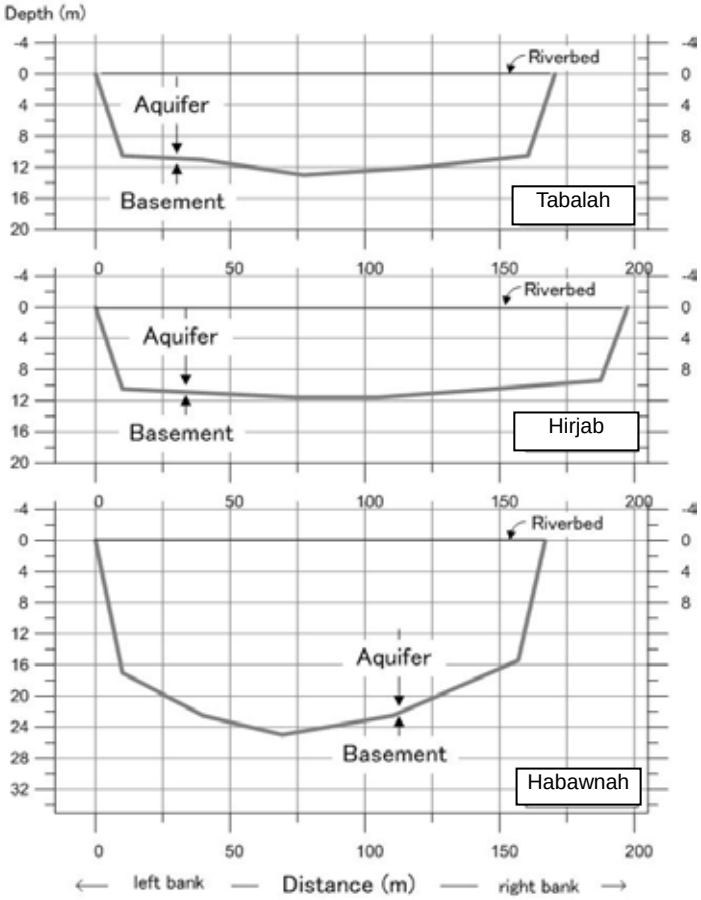


Figure 2-16 Thickness of Aquifer

(c) Aquifer Test

To obtain the aquifer coefficient, the aquifer test was completed at two sites of Hirjab and Habawnah. The test consisted of the continuous pumping test with constant rate and the recovery test. The test had begun after drilling in June 2008. It was the end of dry season being in the lowest level of groundwater through a hydrologic year. Thickness of saturated layer for the testing was thus very thin and not enough to acquire the aquifer coefficient. As well, the drawdown (displacement caused by pumping) was too little to measure it at observation well located 250 m far form pumping well. Considering the condition of measurement, the analysis was made with single well method only to acquire the Transmissivity.

As for Hirjab site, the testing section was not positioned within aquifer layer which was composed of pervious alluvium deposit but was located at semi-permeable layer below the proper aquifer position.

At Habawnah site, the testing was consistently done in proper aquifer from the beginning to the end of the test.

As for analysis, due to single well test with variable rate of pumping, the analysis was done in consideration of variable pumping rate as well as recovery response.

Consequently, the transmissivity was calculated with several kinds methods including Unconfined, Leaky-confined aquifers' solutions.

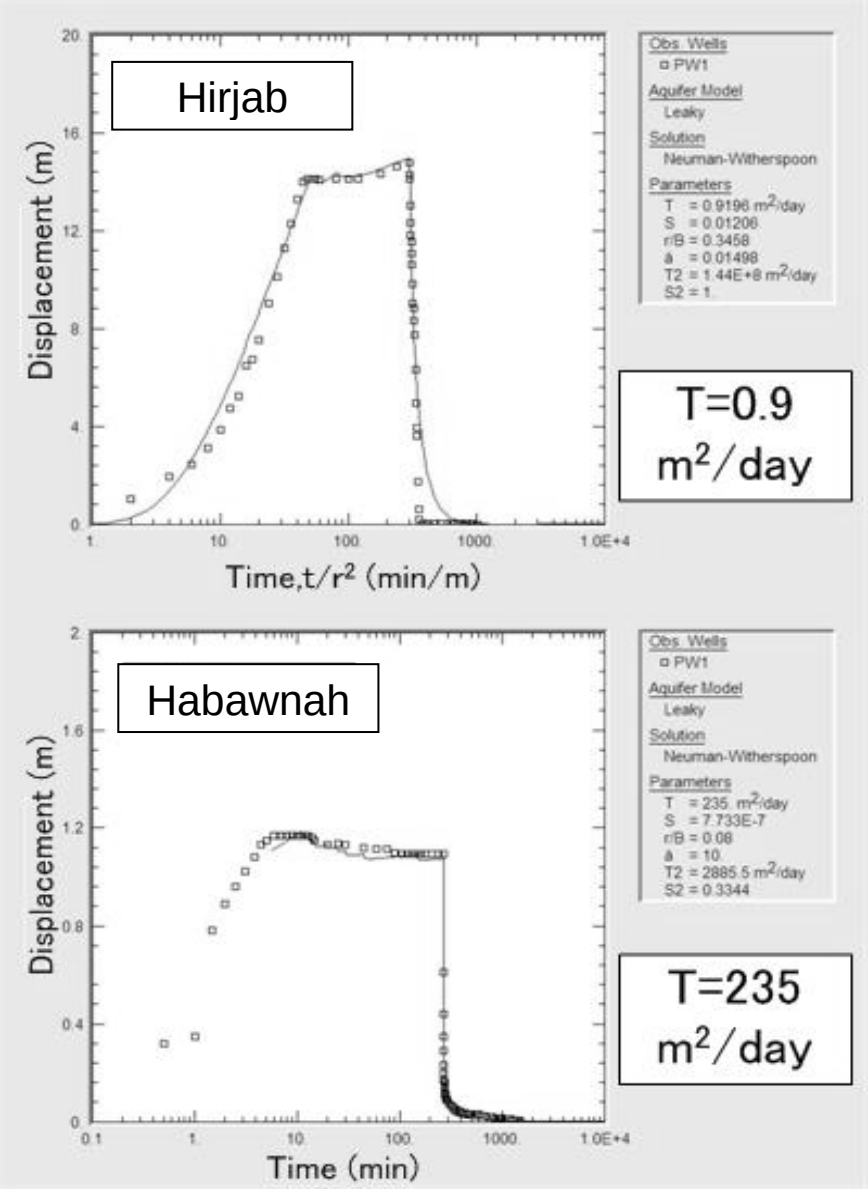


Figure 2-17 Analysis of Aquifer Test

In Table 2-13 , analytical result is shown. Transmissivity (T) = 0.9 to 1.0 m^2/day was taken from Hirjab's test and the range of 150 to 270 m^2/day was calculated form Habawnah's record. Among analytical methods applied, 'Neuman-Wetherspoon Methods (refer to Figure 2-17)' led best matching. Besides, with comparison to the existing results (refer to Table 2-14), Transmissivity (T) = 235 m^2/day is taken as input value for the estimation of the base flow calculation.

As well, a design value for Permeability (k), 8x10－3 cm/sec is calculated in a consideration of the 3-4 m of clean gravel, distinguished as net aquifer sections being half of total thickness of aquifer.

Table 2-13 Summary of Pumping Test

＜Hirjab＞		
Method	Transmissivity （T）	
Tartakovsky-Neuman	0.98	m^2/day
Neuman-Witherspoon	**0.92**	
＜Habawnah＞		
Method	Transmissivity （T）	
Tartakovsky-Neuman	267	m^2/day
Huntush	157	
Neuman-Witherspoon	**235**	

Table 2-14 Coefficient in Aquifers

Aquifer	Lithlogic Description	Thicness (m)	Total Depth (m)	Static Water Level (m)	Yield (lit/sec)	Trans-mmisivity	Stora-tivity	Total Dissolved Solids (mg/lit)	Locality
Alluvium	Gravel,Sand,Silt,etc.	10-100	-	-	5-50	1×10^{-3} to 1×10^{-1}	1×10^{-3} to 1×10^{-5}	-	-
Basalt	Basalt, etc.	40-70	-	-	-	-	-	-	-
Neogene	Sandy Marl & Sandy Limestone	-	±150	0-10	0.63-50	-	-	<1500	Coastal Belt
Minjur/ Druma	Sandstone and Some Shale	300 (Minjur) 100 (Druma)	±400	60-100	50			1400	Riyadh Area *1
			±1200	160-220	±50			1600	Sudair Area *1
			±900	150-180	±50			1800	Washem Area *1
			±1600	(+)	158	1×10^{-2} to	10^{-3}	2820	Kharj Area *1
			±590	(-)				4100	Ajlaj Area *1
WAJID	WAJID Sandstone, General, and Basement Erratics *1	400	±150	±20	9			1000-3000	West of Wadi Dawasir
			±250	(-)	16-126			±1000	East of Wadi Dawasir
			900-1200		4-13			±800	Southwestern Rub Al-Khali

Note *1: Hydraulic information of Minjur aquifer nearby the project area is not colleced so the reference value is shown in the table.

(d) Measurement of Groundwater Level

The observation of groundwater level had begun since July 2008. the measurement was made with automatic logger at five (5) minutes interval for 5 wells of Tabalah (P-well), Hirjab(P-Well, Ob-Well), Habawnah (P-Well, Ob-Well). Solely, Tabalah (Ob-well)'s measurement was done by monthly manual reading.

In Figure2-18, the result of measurement from Aug. 2008 to Jan. 2009 is shown. The groundwater level is indicated in depth above logger and following findings are taken.

- Habawnah site was suffered by the lowering groundwater level at the beginning of observation and groundwater level declined at rate of over 1 meter/month.
- However, after rainfall and surface discharge taken place on 25 Oct. 2008 to 1 Nov. 2008 The groundwater level turned to increase at every site.
- It indicated groundwater recharge which generally observed from 5 days later from wet day, particularly largest response for rainfall was on 25 and 26 Oct 2008 at Hirjab and Habawnah site.
- Groundwater recharge was thus recognized quickly within several days after wet day.
- However, rainfall was not large up to Jan 2009, and it once rose 0.2 to 0.5 m. But it again decreased after keeping high level for one month.

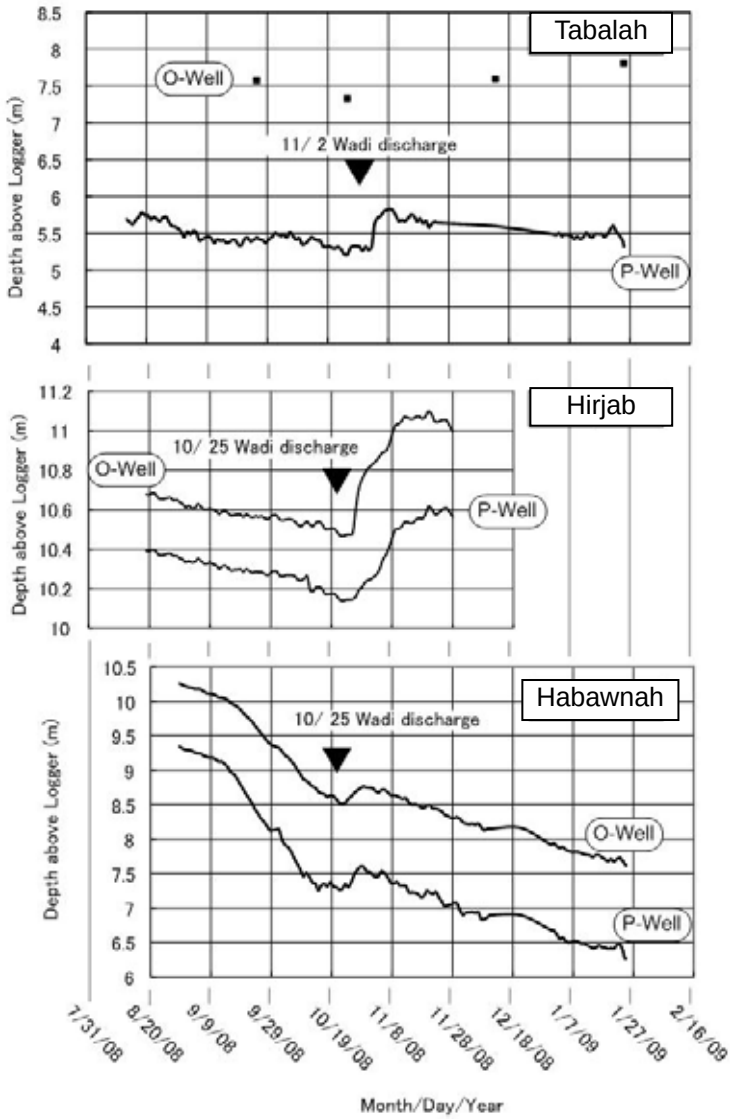


Figure 2-18 Groundwater Changes of Base Flow Stations

(e) Estimation of Wadi Base Flow

Estimation of base Flow was made with Darcy law.

Darcy law:

$Q = k \times \Delta h \times A$

Q: Discharge of wadi base Flow
k: Permeability
Δh: Hydraulic gradient
A: Section area (Sectional area for wadi aquifer)

Based on pumping test, the value of permeability (k) is 8 x 10-3 cm/sec. As well, Δh (hydraulic gradient) is taken form a slope from record, which is dividing difference of groundwater level between Ob-well and P-well by the distance of them. Furthermore, A (sectional area for wadi aquifer) is red from H-A curve which is plotted the depth to area of aquifer resulting in geophysical survey. Using these values of k, Δh and A, daily base Flow is calculated. In Figure2-19, daily discharge values of Hirjab and Habawnah site and monthly value of Tabalah site are shown.

< Hirjab Site>

In Hirjab site, the base Flow did not observed before 25 Oct. 2008 in the observation record. After rainfall on 25 Oct the groundwater recharge abruptly took place in the wadi, and the groundwater flow

has begun. Even though, flow amount did not exceed 20 m^3/day.

<Tabalah Site>

In Tabalah site, because of high pumpage from the existing wells nearby, the flowing rate was not much as 350 m^3/day. After wet day of 1st to 2nd Nov 2008 and succeeding surface discharge, the amount of base Flow increased to 430 m^3/day. However, its rate decreased again to 300 - 350 m^3/day as same level as being before rainfall within two (2) months.

＜Habawnah site>

Habawnah site behaves in the different way from other two sites. The interference from rainfall on 25 Oct was not observed. Even though, base Flow had increased since September. The area of Habawnah basin is large as 2,600 km^2 and its basin border extends to the highland peak of Hijaz mountains. Therefore, the August rainfall in the mountain area may affect the increment of base Flow since September. However, the rate did not exceed 300 to 350 m^3/day.

Rate of base Flow, as well as water level of three wadis is low yet during the survey, suggested by the result of base Flow survey. Its relationship to rainfall is however high and quick. It means a permeable condition of wadis has enough potential to recharge groundwater in to wadi bed when flood is caused. However, the scale of aquifer and exposed area may act as limited factor, by which are of narrow surface area, thin thickness and volume of aquifer etc. If the maximum rainfall, permeability and aquifer size were taken into account, the available amount of base Flow is estimated as 2000 to 6000 m3/day in the mountain wadis as large as 300 m in width.

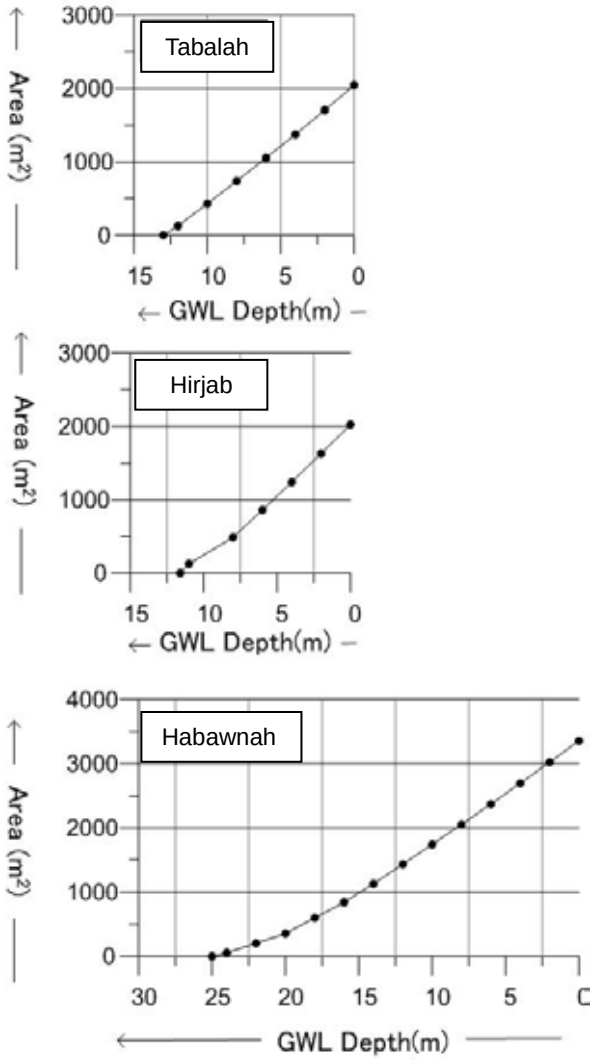


Figure 2-19 Cross section of Wajid Aquifer H-A Curve

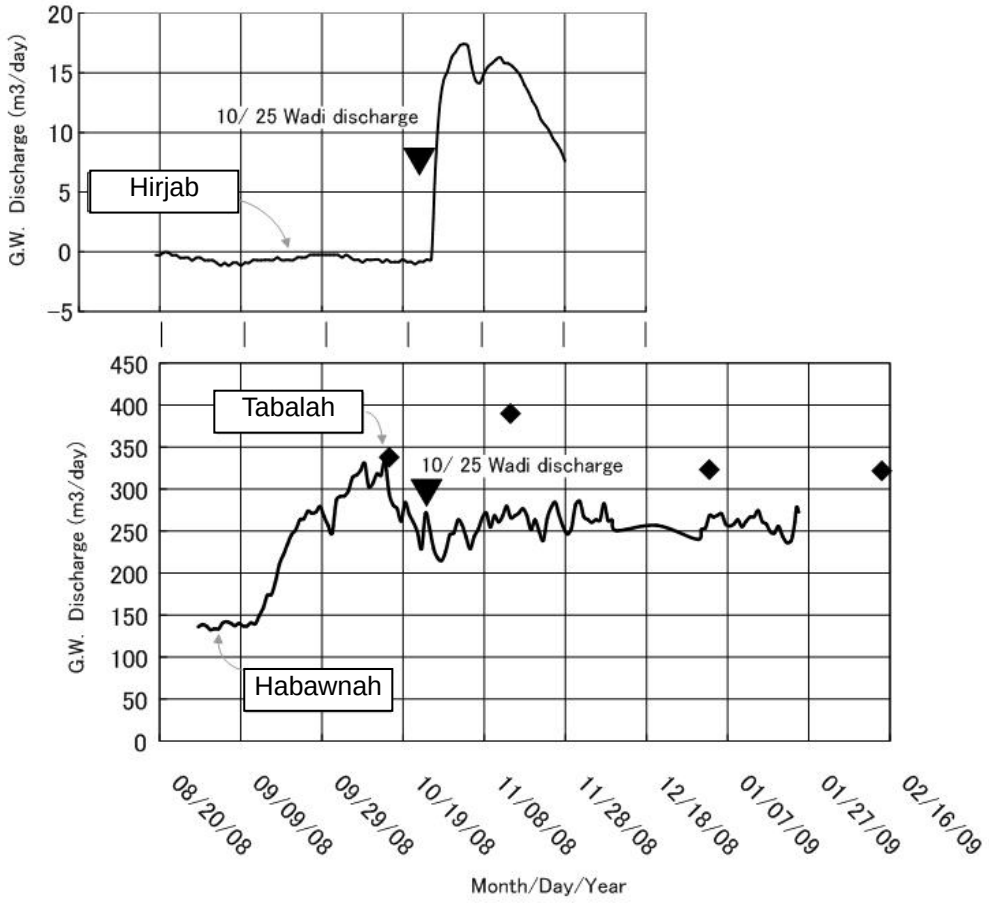


Figure 2-20 Discharge of Base Flow

3. Projection of the Impact of the Project

The master plan (M/P) consists of the following components;

- Integrated Water Resources Development and Management through utilization of the facilities (which have already existed, been under constructed and been under planning by the Kingdom.
- Construction of two new dams, pipelines and desalination plants

The first item, the integrated water resource development and management, itself does not adversely impact on the society and the environment. However, the second item, construction of new facilities, may affect on the society and the environment. Therefore, the following section will discuss the impact on the society and the environment owing to construction of the new dams, pipeline and desalination plant together with possible mitigation programmes and suggestion of further studies.

As a part of the activity of the M/P survey, a social and environmental consideration study at initial environmental examination (IEE) level was conducted. This study was conducted for (i) impact projection and evaluation on the social and natural environment and pollution by the execution of the M/P, and (ii) proposal of mitigation measures for adverse impacts. This study also examined the impacts of the M/P in a point of view of strategic environmental assessment (SEA). The social and environmental factors were set with referring to the JICA's environmental guidelines.

3.1 Projection of the Impact

(1) Dams

The M/P proposes two new dams namely (i) Hirjab dam located in the centre of Asir Region with the total capacity of 4,800,000 m3 and (ii) Ranyah dam located along the eastern border between Al Baha region adjacent to Asir Region with the total capacity of 213,800,000 m3.

In accordance to the laws and regulation, Environmental Impact Assessment (EIA) is compulsory for

any dam construction project. On the other hand, according to MOWE, there has been no record that the Kingdom has conducted any EIA for dam construction project.

MOWE conducted an environmental study for Hirjab dam and concluded that construction of dams does not give significant adverse impact on the environment. Since the study was conducted as a part of dam location selection process for dams in Asir Region, the study was not an official EIA. There has been no environmental study taken place for Ranyah dam.

Table3-1 ~ Table3-3 shows the result of the projection on social and natural environments and pollution. The following describes the main impacts anticipated to be caused by execution of the project at IEE level.

(a) Groundwater and Hydrological Condition

The planned sites for both dams locate on the existing wadi. Therefore, except flood season, there is no water flowing. Although no groundwater use is identified in the reservoir areas, there are small scale cultivated areas scattering in the downstream. It is possible groundwater may be utilized for agricultural activity in these lands.

Due to appearance of the dams, the water flown at flood occasions will be checked. Therefore, it is projected hydrological condition at flood occasion will be altered. Additionally, it is identified that wadi is one of the important recharging sources of groundwater. Therefore, appearance of the dams may impact on the groundwater recharges and levels.

(b) Water Quality

The planned sites for both dams locate on the existing wadi. Therefore, except flood season, there is no water flowing. The land use of the upstream for both dams is mainly barren land. There are no potential pollution sources such as industrial, commercial and agricultural land extends in the upper basins.

Due to scarcity of the river water in wadi, there has been no water quality survey conducted at the sites for the wadi water (i.e. inflow water).

Due to appearance of the dams, the water flown at flood occasions will be checked at the reservoir. Based on the calculation with the estimated annual inflow volume, the annual turnover rate for Hirjab dan is 3.5 and Ranyah dam is 0.5. In general, those dams with such low rate turnover rate tends to form thermocline in the reservoir. Therefore, it is possible the dams potentially cause cold and warm water discharges as well as high turbidity water discharge upon flood occasion. Additionally, if the inflow water is rich with phosphate and nitrogen, eutrophication may occur in the reservoir.

At this stage, there is difficulty to project the precise future phenomenon in the reservoir due to lack of water quality data. However, water quality of the areas may potentially alter due to appearance of the dams.

Table 3-1 Simplified Leopold Matrix for the Construction of Dams (Social Environment)

Item	Current Condition	Nature of Impact	Impact & Magnitude	Duration Phase
Involuntary Resettlement	No houses located at the dam and reservoir sites. According to the EIA report, 140 people live around Hirjab dam site whereas the number of residents at Ranyah dam site is unknown.	Since the precise locations as well as the muck disposal yard and quarry sites are not decided, it may cause adverse effects.	D	Construction Operation
Local Economy	Grazing and agriculture are the major local industry	Local employment opportunity increase during the construction phase.	B	Construction
		Appearance of reservoirs may attract tourism and enhance local economy	B	Operation
Land Use	Hirjab dam site is currently used for grazing. Ranyah dam site is mainly composed of barren land.	Some areas sink in the reservoir. However, such areas are small portion and the rest of the area have no negative impact	C	Operation
Local Community	140 people live around Hirjab dam site whereas the number of residents at Ranyah dam site is unknown.	There are few impacts on the community (split of the community) due to small scale of the proposing facilities.	C	-
Existing Infrastructure	There is no major infrastructure around the proposing project sites.	Any impacts due to execution of the proposing project are not expected.	C	-
Poor, Indigenous and ethnic people	There are no indigenous and ethnic people inhabiting the areas.	Any impacts due to execution of the proposing project are not expected.	C	-
Cultural Heritage	There is no cultural official heritage in the proposing project sites. However, there are some old houses extends along pipeline route.	The pipeline will not destruct the monuments. Therefore, the impact is considered as minor.	C	Construction Operation
Local Conflict	There is no conflict in the proposing project sites.	Any impacts due to execution of the proposing project are not expected.	C	-
Water Right	The M/P of the Study examines the water rights and allocations.	The execution of the M/P will give positive impact.	B	Operation
Sanitation	There is no major issue relating to sanitation due to little population.	Increase in water supply will improve local sanitation	B	-
Hazard & Infection	The HIV infection rate in the Kingdom is less than 0.01%.	Due to the Kingdom's strong policy on HIV, there is little impact foreseen for HIV infection among workers during the construction phase.	C	Construction

A~E indicates likely causing A:: significant favourable impact, B: slight favourable impact, C: no or little impact, D: slightly adverse impact and E: significant adverse impact

Table 3-2 Simplified Leopold Matrix for the Construction of Dams (Natural Environment)

Item	Current Condition	Nature of Impact	Impact & Magnitude	Duration Phase
Topography and Geology	There is no remarkable topography and geology.	Any impacts due to execution of the proposing project are not expected.	C	-
Soil Erosion	There is no information available on soil erosion in the proposing project sites.	Any impacts due to execution of the proposing project are not expected.	C	-
Groundwater	Groundwater is used in the downstream.	Due to change in the hydrology, the production rate of the groundwater in the downstream may alter.	E	Operation
Hydrological condition	Wadi runs the proposing project sites.	Due to change in the hydrology, the production rate of the groundwater in the downstream may alter.	E	Operation
Coastal Zone	Wadi running the proposing project sites flow toward inland (i.e. not toward coastal line)	Any impacts due to execution of the proposing project are not expected.	C	-
Flora and Fauna	Low biodiversity is expected due to scarce of vegetation in the areas. Currently, no information on flora and fauna is available in the proposing project sites.	Construction may lead to destruction of local flora and fauna community. Thus, it may affect on the local ecosystem.	D	Construction
		Appearance of reservoir may attract some fauna.	B	Operation
Meteorology	The areas belong to arid zone.	Any impacts due to execution of the proposing project are not expected.	C	-
Landscape	There is no landscape point near the proposing project sites.	Any impacts due to execution of the proposing project are not expected.	C	-
Global Warming	Raise of temperature is expected in accordance to the Fourth Assessment Report (AR4) by ICPP	Any impacts due to execution of the proposing project are not expected.	C	-

A~E indicates likely causing A:: significant favourable impact, B: slight favourable impact, C: no or little impact, D: slightly adverse impact and E: significant adverse impact

Table 3-3 Simplified Leopold Matrix for the Construction of Dams (Pollution)

Item	Current Condition	Nature of Impact	Impact & Magnitude	Duration Phase
Air Pollution	There is no information available on air pollution in the proposing project sites. However, since there is no source seen around the sites, significant air pollution is unlikely expected.	Generation of air pollution (SO2, NO2, etc) and dust may be expected during the construction due to mobilization of heavy equipments and construction work itself. However, there is no reception near the project site.	D	Construction
Water Pollution	No permanent water available at wadis in the proposing project sites. However, since there is no source seen around the sites, significant water pollution is unlikely expected.	Generation of high turbidity water is anticipated. However, there is no reception near the project site.	D	Construction
		Appearance of the reservoir may change water temperature and water quality. However, there is no reception near the project site.	E	Operation
Soil Contamination	Since there is no source seen around the sites, significant air contamination is unlikely expected.	Construction of dams will not lead to soil contamination.	C	-
Noise & Vibration	Since there is no source seen around the sites, significant noise and vibration contamination are unlikely expected.	Noise and vibration may occur due to heavy equipments and construction work itself. However, there is no reception near the project site.	D	Construction
Odour	Since there is no source seen around the sites, significant offensive odour is unlikely expected.	Construction of dams will not lead to generation of offensive odour.	C	-
Sediment	There is natural flow of sediments in wadi upon flooding.	Sediment is expected to be trapped at the reservoirs. However, MOWE considers these sediments may be effectively utilized as new topsoil.	D	Operation
Accident	There is no information on accident at the proposing project site.	Any impacts due to execution of the proposing project are not expected.	C	-

A~E indicates likely causing A:: significant favourable impact, B: slight favourable impact, C: no or little impact, D: slightly adverse impact and E: significant adverse impact

(2) Pipeline

The M/P consists of establishment of water distribution pipeline network with utilizing the existing, under construction and under planning pipelines. In addition to these pipelines, the Study Team proposed two new pipeline routes namely;

- Ras Mouhesan – Al Baha Line (approximately 100 km)
- Al Baha – Bisha / Al Alayah Line (approximately 180 km)

It is expected the construction facilities consist of pipelines and associated facilities such as booster pumps.

Since the pipelines are newly constructed and more than 50 km in length, environmental impact assessment (EIA) is required in accordance to the General Environmental Law and Rules for Implementation (2001).

Table 3-4 - 3-6 show the result of the projection on social and natural environments and pollution. The following describes the main impacts anticipated to be caused by execution of the project at IEE level.

(a) Flora and Fauna

The pipeline route between Ras Mouhesan and Al Baha lies approximately 20 km off in the southwest from the Jabal Shada protected area. Since there has been no biological surveys conducted, the flora and fauna inhabiting in the pipeline planning area is not known. However, the pipeline route is adjacent to the protected area and there is possibility that some similar environment may exist in the project site. In such occasion, some fauna may migrate to the area from the conservation zone. Despite uncertainty of the nature of the area, placement of the pipeline may potentially impact on the flora and fauna.

(b) Noise and Vibration

There have not been any noise and vibration survey conducted in the project site. Therefore, the noise and vibration level are not known. Pipeline itself does not generate noise and vibration. However, booster pump station which is required to pump the water to the mountain region is expected to be a source of noise and vibration. Since there are some villages and resident areas scattering around the project site, operation of the booster pump station may impact on the local environment.

Table 3-4 Simplified Leopold Matrix for the Construction of Pipelines (Social Environment)

Item	Current Condition	Nature of Impact	Impact & Magnitude	Duration Phase
Involuntary Resettlement	There are some towns and houses along the road. The precise routes of the pipelines have not been fixed.	Depending upon the routes of the pipelines, the lines may pass the housing areas and private owner's land.	D Unknown	Construction Operation
Local Economy	There are no large scale industrial and commercial areas along the proposing routes.	Construction works may lead to increase employment opportunities during the construction phase.	B	Construction
		Any impacts due to execution of the proposing project are not expected.	C	-
Land Use	The routes are along the existing roads.	Any impacts due to execution of the proposing project are not expected.	C	-
Local Community	There are some towns and houses scattering along the roads.	Any impacts such as split of local community due to execution of the proposing project are not expected.	C	-
Existing Infrastructure	There are some towns scattering along the roads.	Construction of water supply pipelines will contribute to improve local water supply networks	A	Operation
Poor, Indigenous and ethnic people	There are no indigenous and ethnic people inhabiting in the project sites.	Any impacts due to execution of the proposing project are not expected.	C	-
Cultural Heritage	There is no cultural heritage along the proposing routes.	Any impacts due to execution of the proposing project are not expected.	C	-
Local Conflict	There is no local conflict along the proposing routes.	Any impacts due to execution of the proposing project are not expected.	C	-
Water Right	The M/P of the Study examines the water rights and allocations.	The execution of the M/P will give positive impact.	A	Operation
Sanitation	There is no major issue relating to sanitation due to little population.	There is no major issue relating to sanitation due to little population.	C	-
Hazard & Infection	The HIV infection rate in the Kingdom is less than 0.01%.	Due to the Kingdom's strong policy on HIV, there is little impact foreseen for HIV infection among workers during the construction phase.	C	Construction

A~E indicates likely causing A:: significant favourable impact, B: slight favourable impact, C: no or little impact, D: slightly adverse impact and E: significant adverse impact

Table 3-5 Simplified Leopold Matrix for the Construction of Pipelines (Natural Environment)

Item	Current Condition	Nature of Impact	Impact & Magnitude	Duration Phase
Topography and Geology	The altitude of the proposing pipelines route consists of sea level till the top of Asir mountains.	The pipelines will be constructed on the surface on the ground along the existing roads. Thus, the impact on the topography and geology is considered as minor.	C	-
Soil Erosion	There is no information on soil erosion along the proposing project sites.	Construction of pipelines and booster pump stations will unlikely lead to soil erosion.	C	-
Groundwater	There is no information on groundwater along the proposing project sites.	The pipelines will be constructed on the surface on the ground or at a shallow depth. Therefore, the impact on the groundwater by the construction of pipelines is expected as minor.	C	-
Hydrological condition	There is no information on hydrology along the proposing project sites.	The proposing pipelines will be constructed along the existing roads. Therefore, the impact on the hydrological condition by the construction of pipelines is expected as minor.	C	-
Coastal Zone	Ras Mouhesan is a location along the coastal line. The area is barren land.	The proposing pipelines will unlikely impact on the coastal lines.	C	-
Flora and Fauna	There is Jabal Shada protected area extending on the route between Ras Mouhesan and Al Baha.	Since the protected areas and the adjacent areas, if the environment is similar, are rich with flora and fauna and there are some endemic and endangered species inhabiting in the area, construction works may affects on the behaviour on the creatures. Besides, placement on the pipelines on the surface of the ground may affects on migration of some small animals.	E	Construction
Meteorology	The areas belong to arid and semi-arid zone.	The proposing pipelines will not affect on the meteorology	C	-
Landscape	There is no landscape point near the proposing project sites.	Considering the scale of the pipelines, there will be minor impact on landscape	C	Operation
Global Warming	Raise of temperature is expected in accordance to the Fourth Assessment Report (AR4) by ICPP	It is expected there may be CO2 emitted from the booster pump stations. However, considering the capacity, there will be minor impact on global warming.	C	Operation

A~E indicates likely causing A:: significant favourable impact, B: slight favourable impact, C: no or little impact, D: slightly adverse impact and E: significant adverse impact

Table 3-6 Simplified Leopold Matrix for the Construction of Pipelines (Pollution)

Item	Current Condition	Nature of Impact	Impact & Magnitude	Duration Phase
Air Pollution	There is no information available on air pollution in the proposing project sites. However, since there is no source seen around the sites, significant air pollution is unlikely expected.	Heavy equipments during the construction emit pollutants. However, the impact is minor.	D	Construction
		It is expected there may be pollutants emitted from the booster pump stations. Considering the capacity, there will be minor impact on air pollution.	D	Operation
Water Pollution	There is no water along the proposing pipeline routes in most of the areas.	Generation of high turbidity water is anticipated. However, there is no reception near the project site.	D	Construction
		The pipelines carry water, therefore, there will be no soil contamination expected from leakage.	C	Operation
Soil Contamination	Since there is no source seen around the sites, significant air contamination is unlikely expected.	Construction activity is unlikely generate contamination.	C	Construction
		The pipelines carry water, therefore, there will be no soil contamination expected from leakage.	C	Operation
Noise & Vibration	Since there is no source seen around the sites, significant noise and vibration is unlikely expected.	Construction activity generates noise and vibration. Special attention in resident areas is necessary.	D	Construction
		The booster pumps generate noise and vibration.	E	Operation
Odour	Since there is no source seen around the sites, significant offensive odour is unlikely expected.	The proposing pipelines unlikely generate offensive odour.	C	-
Sediment	There are no sediments deposited along the pipeline routes.	The proposing pipelines will not generate sediments.	C	-
Accident	There is no information on accident at the proposing project site.	Any impacts due to execution of the proposing project are not expected.	C	-

A~E indicates likely causing A:: significant favourable impact, B: slight favourable impact, C: no or little impact, D: slightly adverse impact and E: significant adverse impact

(3) Desalination Plant

One unit of desalination plant is expected to be constructed in Ras Mouhesan and at the northern area of Jizan City.

It is expected the proposing facility consist of the main plant with reverse osmosis membrane method, intake and drainage culvert/pipelines and fuel storage tanks.

In accordance to the General Environmental Law and Rules for Implementation (2001), environmental impact assessment (EIA) is required for construction of all desalination plant.

Table 3-7 – 3-9 shows the result of the projection on social and natural environments and pollution. The following describes the main impacts anticipated to be caused by execution of the project at IEE level.

(a) Water Pollution

The desalination plant is planned to be constructed along the coastal zones. There has been no seawater quality survey conducted, thus the water quality in the surrounding sea is not known. The

plant intakes seawater and produces fresh water through separation of salt and fresh water by osmosis process. The separated salt water during the osmosis process is normally discharged into the sea as effluent. Yet, the recent academic studies revealed the effluent contains rather high concentration of salt and carbon dioxide than the ones in the sea. The exact impact of the brine water has been still under academic research and is not certain. The proposing facility is expected to generate similar brine water as effluent. Therefore, there may be some potential impact diffusing on aquatic biota and the marine environment.

(b) Pollution

The desalination plant is basically a factory to produce fresh water and consumes fuels. Therefore, the plant potentially emits air pollutants. However, such air pollution may be eased by introduction of anti air pollution devices. Additionally, there is no villages and residential areas in the adjacent area of the plant. Since there is no reception exists, the impact of the pollution may be limited.

Table 3-7 Simplified Leopold Matrix for the Construction of Desalination Plant (Social Environment)

Item	Current Condition	Nature of Impact	Impact & Magnitude	Duration Phase
Involuntary Resettlement	There is no resident area existing around the proposing construction site. The nearest town locates approximately 60 km in south.	Depending upon the location of the plant, it may locate in private owner's lands.	D	Construction Operation
Local Economy	There are no large scale industrial and commercial areas along the proposing sites.	Construction works may lead to increase employment opportunities during the construction phase.	B	Operation
		Operation of the plant may lead to increase employment opportunities of the local residents.	B	Operation
Land Use	The proposing area is barren land along coastal line.	Any impacts due to execution of the proposing project are not expected.	C	-
Local Community	The nearest resident area located approximately 60 km in south.	Any impacts such as split of local community due to execution of the proposing project are not expected.	C	-
Existing Infrastructure	There is no existing infrastructure near the proposing site.	Any impacts due to execution of the proposing project are not expected.	C	-
Poor, Indigenous and ethnic people	There are no indigenous and ethnic people inhabiting in the project site.	Any impacts due to execution of the proposing project are not expected.	C	-
Cultural Heritage	There is no cultural heritage along the proposing site.	Any impacts due to execution of the proposing project are not expected.	C	-
Local Conflict	There is no local resident in the proposing site.	Any impacts due to execution of the proposing project are not expected.	C	-
Water Right	The M/P of the Study examines the water rights and allocations.	The execution of the M/P will give positive impact.	A	Operation
Sanitation	There is no major issue relating to sanitation due to little population.	Improvement of water supply lead to improvement of sanitation	B	-
Hazard & Infection	The HIV infection rate in the Kingdom is less than 0.01%.	Due to the Kingdom's strong policy on HIV, there is little impact foreseen for HIV infection among workers during the construction phase.	C	Construction

A~E indicates likely causing A:: significant favourable impact, B: slight favourable impact, C: no or little impact, D: slightly adverse impact and E: significant adverse impact

Table 3-8 Simplified Leopold Matrix for the Construction of Desalination Plant (Natural Environment)

Item	Current Condition	Nature of Impact	Impact & Magnitude	Duration Phase
Topography and Geology	The proposing site is at the coastal line.	Considering the scale of the plant, the construction work unlikely impact on the topography and geology.	C	-
Soil Erosion	There is no information on soil erosion along the proposing project sites.	Construction of the proposing facility will unlikely impact on soil erosion.	C	-
Groundwater	There is no information on groundwater along the proposing project sites. However, since the location is along the coastal line, shallow water table and saline intrusion are expected.	The proposing project will not plan to intake or discharge into underground. Therefore, the impact due to the execution of the project is considered as minor.	C	-
Hydrological condition	There is no information on hydrology along the proposing project sites. The plant is located along the coastal line.	Considering the scale of the plant, the discharge from the plant will not effect on the oceanic currency.	D	Operation
Coastal Zone	Ras Mouhesan is a location along the coastal line. The area is barren land.	Considering the scale of the plant, the proposing plant will not significantly change the shape and nature of the coastal zone.	D	Construction
Flora and Fauna	There has no extensive investigation on both terrestrial and aquatic flora and fauna conditions.	Though the site is barren land, construction of the plant may impact on the local flora and fauna.	D	Construction
		It is known that the discharge water contains high concentration of CO2 and salt. Nevertheless the impact on the brine water is academically under still investigation, it is anticipated brine water may effect on the behaviour of aquatic flora and fauna.	E	Operation
Meteorology	The areas belong to arid and semi-arid zone.	The proposing plant will not affect on the meteorology	C	-
Landscape	There is no landscape point near the proposing project sites.	Considering the scale of the plant, there will be minor impact on landscape	C	Operation
Global Warming	The First National Communication of the Kingdom of Saudi Arabia (Presidency of Meteorology and Environment, 2005) pointed desalination plant is the third largest source of CO2 emission in the Kingdom in 1990.	It is expected there may be CO2 emitted from the plant due to combustion of fuel. However, considering the capacity as a plant, there will be minor impact on global warming.	C	Operation

A~E indicates likely causing A:: significant favourable impact, B: slight favourable impact, C: no or little impact, D: slightly adverse impact and E: significant adverse impact

Table 3-9 Simplified Leopold Matrix for the Construction of Desalination Plant (Pollution)

Item	Current Condition	Nature of Impact	Impact & Magnitude	Duration Phase
Air Pollution	There is no information available on air pollution in the proposing project sites. However, since there is no source seen around the sites, significant air pollution is unlikely expected.	Heavy equipments during the construction emit pollutants and appropriate measures are required.	D	Construction
		It is expected there may be pollutants emitted from the plant and appropriate measures are required.	D	Operation
Water Pollution	The proposing plant is located along the coastal line.	Generation of high turbidity water is anticipated during the construction phase.	D	Construction
		It is known that the discharge water contains high concentration of CO2 and salt. It is anticipated brine water may effect on the local oceanic water quality. However, such effect may be dismissed by mixing with the main oceanic currency.	E	Construction
Soil Contamination	Since there is no source seen around the sites, significant air contamination is unlikely expected.	Construction activity is unlikely generate contamination.	C	Construction
		Storage tanks for heavy oils may be equipped at the plant.	D	Operation
Noise & Vibration	Since there is no source seen around the sites, significant noise and vibration are unlikely expected.	Construction activity generates noise and vibration.	D	Construction
		The plant generates noise and vibration.	D	Operation
Odour	Since there is no source seen around the sites, significant offensive odour is unlikely expected.	The proposing plant unlikely generate offensive odour.	C	-
Sediment	There are no sediments deposited along the pipeline routes.	The proposing plant will not generate sediments.	C	-
Accident	There is no information on accident at the proposing project site.	Any impacts due to execution of the proposing project are not expected.	C	-

A~E indicates likely causing A:: significant favourable impact, B: slight favourable impact, C: no or little impact, D: slightly adverse impact and E: significant adverse impact

3.2 Mitigation Measures for Potential Adverse Impacts

(1) Mitigation Measures for Main Adverse Impacts

Table3-10 shows the mitigation measures for main adverse impacts for those items high or medium adverse impact projected.

Table 3-10 Mitigation Measures for Main Adverse Impacts

Item	Dam	Pipeline	Desalination	Possible Mitigation Measures
Involuntary Resettlement	D	D	D	Selection of detour pipeline route Mining the pipeline Compensation of the land
Groundwater	E	C	C	Appropriate recharge into the underground from dam site.
Hydrological condition	E	C	C	Appropriate discharge from dam site
Coastal Zone	C	C	D	Examination of minimization of land reform at the design stage
Flora and Fauna	D	E	E	Understanding of the biodiversity at the project sites through biodiversity study Selection of detour pipeline route from the protected and high biodiversity areas Mining the pipeline
Air Pollution	D	D	D	Sprinkling for dust Introduction of low air pollution type of heavy equipments Encouragement of appropriate operation of heavy equipments Examination of introduction of low air pollution types of facilities for booster pump stations and desalination plants
Water Pollution	E	D	E	Extension of effluent pipeline to the offshore for desalination plant Surface water discharge or introduction of selective intake facility for dam
Soil Contamination	C	C	D	Installation of appropriate storage facility for oils and liquids.
Noise & Vibration	D	E	D	Selection of appropriate site Compliance of the construction hours Install of noise barrier Selection of appropriate wall materials.
Sediments	D	C	C	Appropriate measures for prevention of sedimentation in the reservoir shall be examined in the detailed design stage.

A~E indicates likely causing A:: significant favourable impact, B: slight favourable impact, C: no or little impact, D: slightly adverse impact and E: significant adverse impact

(a) Involuntary Resettlement (Pipeline)

Since the concrete project sites for all components in the M/P have not been fixed at this stage, many unknown factors remain and magnitude of the impact is unpredictable. However, pipelines with the length of approximately 280 km in total may pass through some urban areas and private owner lands.

Primarily selection of detouring route for those areas should be considered. In case if detouring route is not economically, financially and environmentally feasible as well as appropriateness from engineering point of view, mining of the pipelines underground shall be selected as a mitigation measure. The compensation of the land shall be chosen as a last choice.

(b) Groundwater and Hydrological Condition (Dam)

Although there is no permanent water flow available at the dam sites, it is believed that the wadi functions as a source for groundwater recharge upon flood occasion. Therefore, construction of the dams obstacles these natural recharging and may lead to groundwater lowering at the downstream as well as natural flow in wadi.

In a part of the M/P, effective utilization of water in dam reservoir is examined. Under the current status, the groundwater recharge is limited to the flood occasion. In this examination, continuous flow regime of the wadi by controlled discharge from the stored water in the reservoirs was simulated. Controlled discharge from the reservoir to the downstream may enable permanent flow of water in wadi. If recharging wells are installed at the downstream of the dams under such condition, it is expected that discharging water from the dam continuously recharge groundwater at the present or

further level. Therefore, controlled discharge from the dam is recommended as a mitigation measure for improvement of groundwater and hydrological environment.

(c) Flora and Fauna (Pipeline)

It is expected that the pipeline between Ras Mouhesan and Al Baha with an approximately length of 100 km may pass the area adjacent to a protected area, Jabal Shada, located in the south of Al Baha city. This isolated mountain massif supports an exceptionally rich flora; with approximately 500 plant species recorded, including 63 key plant taxa including endemics and Afro-tropical relicts, it is the single site of highest botanical diversity known in Saudi Arabia. The exceptional floral diversity of Jabal Shada al- A'la, together with the presence of griffon vultures and endemic birds of the southwestern mountains and carnivores, including the rock fox, caracal, striped hyena, wolf, genet, and reportedly the Arabian leopard, makes this small protected area a unique treasure of biological diversity. Small communities on the mountain grow a distinctive variety of coffee and other crops in terraced fields.

The pipeline is expected to be placed in parallel to the existing road. A part of the pipeline route between Ras Mouhesan and Al Baha City passes the adjacent area of Jabal Shada Protected area. Since the behaviour of the resident fauna is not fully understood, prior to commencement of elaboration of countermeasures, it is recommended to conduct an intensive biodiversity survey. Key countermeasures considered at this stage are (i) Selection of detour route if mechanically, engineering point of view, financially and environmentally feasible, and (ii) Mining of the pipeline under the ground if any animal paths exist for their migration.

(d) Air Pollution (Dam, Pipelines and Desalination Plant)

It is expected that execution of construction works may generate temporary air pollution such as dust, NOx and SOx during the construction period. For reducing the impact of dust, the contractors shall comply the environmental protection and management including sprinkling water for reducing the generation of dust, encouragement of introduction of low pollution types of heavy equipments and appropriate operation of these equipments. Besides, operation of booster pump stations in pipelines and desalination plants may lead to cause of air pollution. For these facilities, introduction of low emission types of the facilities shall be examined during the detailed design stage.

(e) Water Pollution (Dam and Desalination Plant)

Appearance of reservoir is known to cause change in water quality including cold water discharge, eutrophication and high turbidity water discharge due to creation of a closed water area. Currently no water quality survey has conducted at both planned sites. Therefore, the precise impact of the water quality after appearance of the dam is not projected. However, construction of the dams possibly affects on the water quality. Therefore, an EIA study conducted during the feasibility study phase shall carefully examine the water quality of the dam sites. If significant adverse impact is expected, necessary countermeasures including installation of selective intake facility and its operation rule shall be examined.

The effluent from desalination plant contains high concentration of salt and carbon dioxide (CO_2). This effluent occurs due to the result of osmosis process. Recent academic researches indicate there may be potential impact of the brine water on the marine biology, especially benthos, aquatic plants, etc.

Despite the fact the precise impact on the aquatic environment is still under discussion in academic world, it may be necessary to conduct appropriate countermeasures as; (i) extensive aquatic biodiversity research prior to commencement of the project and understanding the environment, (ii) extension of discharge pipes till the offshore, where the current is strong enough for mixing and diluting the effluent, and (iii) introduction of reclaimed waste water into the effluent to dilute the concentration of the salt and CO_2.

(f) Soil Contamination (Desalination Plant)

It is expected that some oils for fuel may be stored at the desalination plant for its operation of the facility. Since storage of such liquids may become a potential source of contamination, appropriate

storage facility shall be designed and constructed.

(g) Noise and Vibration (Pipeline)

The pipeline itself will not generate noise and vibration. However, since the pipeline extend from the coastal line up to the top of the Asir Mountain with approximately 2,000 m in altitude, it is necessary to install a booster pump station before elevation. The pump station potentially becomes the source of noise and vibration.

The location of the booster pump station shall be at least 100 m off set from the residential area. The distance of 100 m reduces approximately 28 dB of power level owing to attenuation. Additionally, appropriate wall material for the architecture shall be considered.

(h) Sedimentation (Dam)

Sedimentation or accumulation of sediments in the reservoir is the common issue for dam. Although the rocks near the proposing dams are consolidated and generation of issue of sedimentation may be minor, appropriate sedimentation measures such as construction of sediment traps or sabo dam at the inflow of the reservoir, construction of selective intake facility, etc. shall be examined during the detailed design stage if sedimentation is forecasted based on the detailed topographical and geological surveys. Furthermore, the effective use of trapped sediments in the reservoir shall be studied.

(2) Mitigation Measures for Other Impacts

(a) Involuntary Resettlement (Dam and Desalination Plant)

The proposing project sites are barren land. There is no resident area at the sites. However, prior to commencement of the projects, the ownership of the land shall be inspected.

(b) Land Use (Dam)

According to the study for Hirjab Dam in the Environmental Impact Assessment for Asir Dams, the proposing area is utilized as a grazing area. Considering the nature of the land, it is estimated the land is not frequently used for grazing activity. However, the executing agency shall socialize with the local residents utilizing the area prior to the commencement of the project.

(c) Hazard and Infections, and Accident (Dam, Pipeline and Desalination Plant)

Conduction of construction works may lead to accident. Furthermore, construction works assemble a number of workers. The executing agency is strongly encouraged to put articles of safety and infection education in the contract document and supervise the contractor's activity.

(d) Landscape (Pipeline)

The proposing pipelines are placed in parallel to the existing roads. Considering the size of the pipelines, the impact of the landscape is minor in comparison to the existing roads. However, the executing agency shall put maximum effort to align the pipeline in match with the skylines.

(e) Global Warming (Pipeline and Desalination Plant)

The booster pump stations and the desalination plant itself become the source of emission of carbon dioxide (CO_2). In particular, desalination plant is categorized as one of the major source of green house gas in the Kingdom.

For mitigating the impact on global warming, the executing agency shall employ the recent pump and plant technology for minimizing the emission of carbon dioxide (CO_2).

(f) Flora and Fauna (Dam and Desalination Plant)

Since there has been no intensive flora and fauna studies conducted at the proposing project sites, the current status of the biodiversity condition is unknown. However, considering the proposing project sites are currently barren land and no particular vegetation group observed from satellite image and topographical maps, it is deemed the biodiversity in the sites are low. Nevertheless, although there is no protected area at the proposing project sites, special attentions shall be paid for flora and fauna. Upon the commencement of feasibility study, a survey for biodiversity shall be conducted. Based on

the key findings of the survey, further mitigation measures shall be elaborated.

(g) Air Pollution (Dam, Pipeline and Desalination Plant)

The proposing project sites are relatively isolated from the resident areas. At least, there are no concentrated resident areas in radius of 1 km around the sites for all components. Nevertheless, it is expected construction works may lead to emission of air pollutant such as gasses (SOx, NOx, CO, CO_2, etc) and dusts, it may be concluded there is no reception of the pollution and the impact of the environment is minor. Yet, considering the current raise of concern on the environment and protection of the natural environment, the contractors are encouraged to introduce low emission types of heavy machinery for conduction of construction works.

(h) Water Pollution (Pipeline and Desalination Plant)

During the construction works, high turbidity water may occur. The contractor shall set a sedimentation pond or equivalent device to settle the suspended particle in the effluent before discharge into the environment from the construction site. The executing agency shall monitor the contractor's measures.

(i) Noise and Vibration (Dam, Pipeline and Desalination Plant)

Construction works generate noise and vibration. Nevertheless each proposing project site except pipeline is off set from the resident areas, the executing agency shall maximum attention on generation of noise and vibration through encouraging the contractors to introduce low noise and vibration types of the heavy machinery. Such point shall be written in the contract document.