BASIC DESIGN STUDY REPORT
ON
THE PROJECT
FOR
THE TERAI GROUNDWATER DEVELOPMENT (Phase II)
IN
THE KINGDOM OF NEPAL

JULY 1988

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

In response to the request of His Majesty's Government of Nepal, the Government of Japan has decided to conduct a Basic Design Study on the Project for the Terai Groundwater Development (Phase II) and entrusted the study to the Japan International Cooperation Agency (JICA). JICA sent to Nepal a study team headed by Mr. Yoshiki MIYANISHI, Grant Aid Division, Economic Cooperation Bureau, Ministry of Foreign Affairs, from January 10 to March 24, 1988.

The team had discussions on the Project with the officials concerned of the Government of Nepal and conducted a field survey in the Terai plain of the Janakpur Zone. After the team returned to Japan, further studies were made and the present report has been prepared.

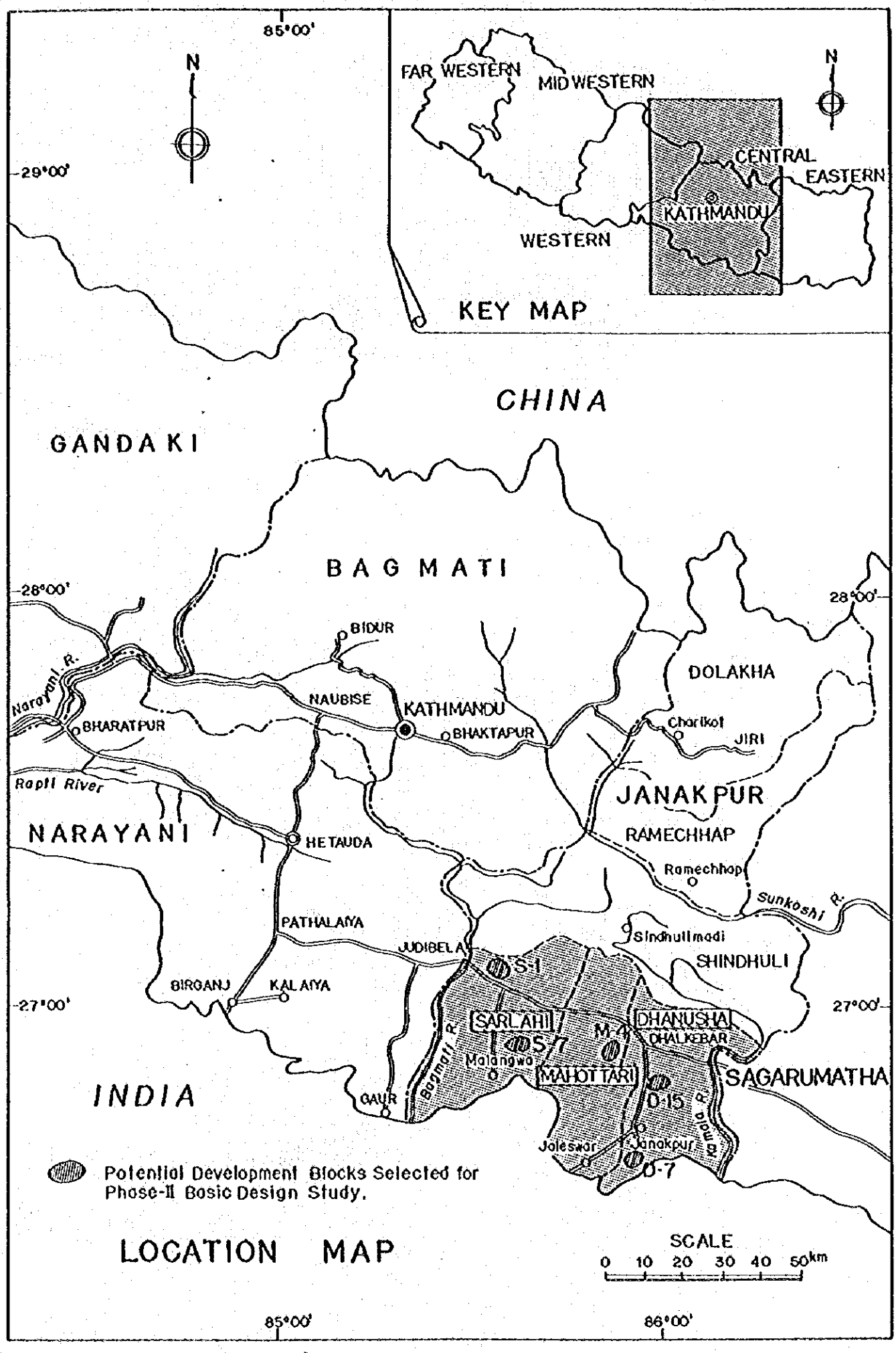
I hope that this report will be used as a reference for future development of deep tubewell irrigation in the Kingdom of Nepal and contribute to the promotion of friendly relations between the two countries.

I wish to express my deep appreciation to the officials concerned of His Majesty's Government of Nepal for their close cooperation extended to the team.

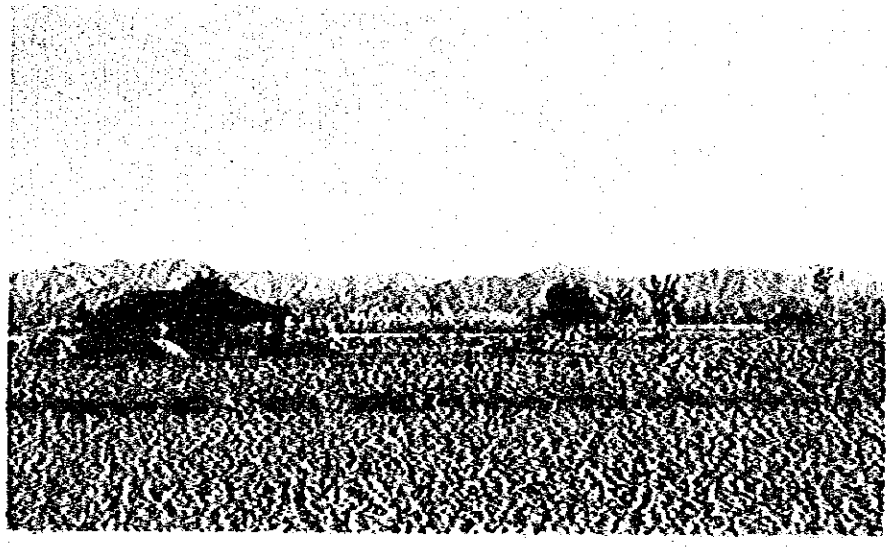
July, 1988

Kensuke Yanagiya

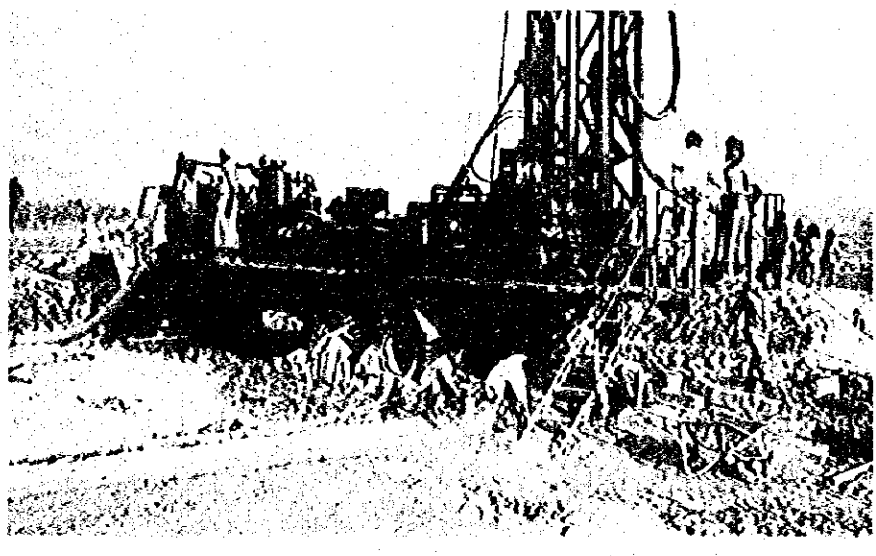
Kensuke Yanagiya
President
Japan International Cooperation Agency


85°00'
N
29°00'
FAR WESTERN
MID WESTERN
CENTRAL
EASTERN
KATHMANDU
WESTERN
KEY MAP
CHINA
GANDAKI
BAGMATI
28°00'
26°00'
BIDUR
Narayani R.
NAUBISE
KATHMANDU
BHARATPUR
BHAKTAPUR
DOLAKHA
Charikot
JIRI
Rapti River
JANAKPUR
NARAYANI
RAMECHHAP
HETAUDA
Ramechhap
Sunkoshi R.
PATHALAIYA
Sindhulimadi
JUDIBELA
SHINDHULI
S-1
BIRGANJ
KALAIYA
27°00'
SARLAHI
M-4
DHANUSHA
DHALKEBAR
Malangwa
MAHOTTARI
SAGARUMATHA
Bagmati R.
INDIA
GAUR
D-15
Janakpur
Jaleswar
D-7
Potential Development Blocks Selected for Phase-II Basic Design Study.
LOCATION MAP
SCALE
0 10 20 30 40 50km
85°00'
86°00'

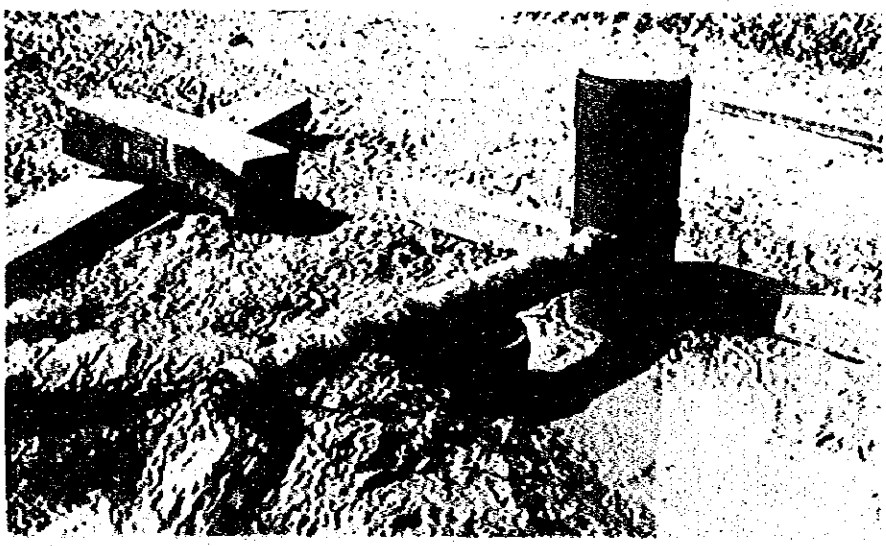
A view of development area in D-7 block



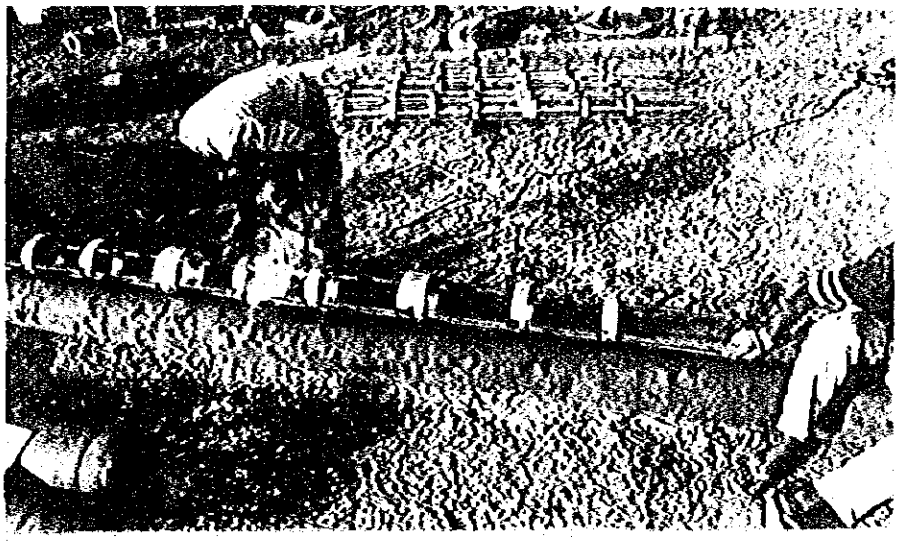
A view of development area in D-15 block



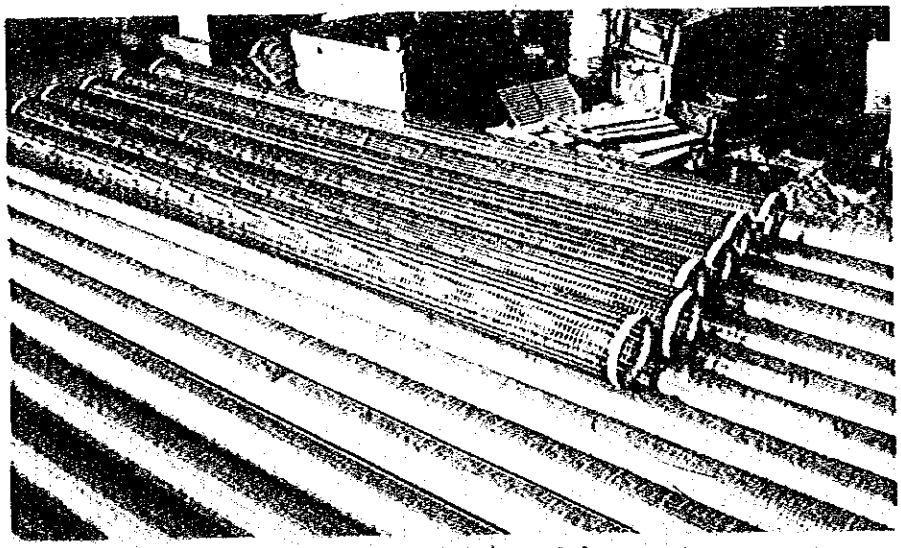
Drilling of test well D-7 (A) in D-7 block



Test well D-7 (A) constructed discharges an artesian of 20 l/sec.



Manufacturing of cages which are set inside existing Johnson type screens to reinforce the lateral compressive strength from 4.6 kg/cm^2 to 9.2 kg/cm^2.



Cages to be set inside existing Johnson type screens to reinforce the lateral compressive strength from 4.6 kg/cm^2 to 16 kg/cm^2 and rod based wire-wrapped screens newly sent from Japan.

SUMMARY

SUMMARY

His Majesty's Government of Nepal (HMGN) would like to expand irrigation by constructing considerable numbers of shallow tubewells and deep tubewells as one of the agricultural development programmed in the 7th Five-Year Development Plan. Shallow tubewell irrigation development has progressed relatively well since construction, operation and maintenance costs are low and drilling is easy. Deep tubewell irrigation development, however, has not progressed much because hydrogeological survey and drilling techniques are not yet established in Nepal and construction, operation and maintenance costs are high and not borne by the Government. Accordingly, HMGN requested the Government of Japan (GOJ) to provide grant aid cooperation for the Terai Groundwater Development Project, with the object of constructing 150 deep tubewells and the associated irrigation facilities to command about 3,000 ha of arable land, using equipment and materials provided under a KR-2 aid program in 1982 and 1983 for the construction of the deep tubewells and associated irrigation facilities in Janakpur zone.

In response to this request Japan International Cooperation Agency (JICA) sent a preliminary survey mission to Nepal from August 26 to September 19, 1986. The mission confirmed the details and significance of the Project envisaged by HMGN through the mission, and confirmed that implementation of the Project would be technically and economically viable. JICA then sent a basic design study mission (hereinafter referred to as "Phase-I mission") to Nepal from January 7 to March 6, 1987.

The Phase-I mission investigated the groundwater potential of the project area, made four (4) test borings, an inventory survey of the equipment and materials already provided, and a basic design. The basic design covered three (3) development blocks, D-7, M-4 and S-7, and the overall development of the Project, for construction of 115 deep tubewells and associated irrigation facilities to command about 4,600 ha in total in the

course of 4 years. It also confirmed that the vertical turbine pumps provided under the KR-2 aid would require deep tubewells with a yield of more than 25 l/sec to be economical in the Project.

However, in the Phase-I study the specification and size of the production tubewells and of the associated irrigation facilities could not be determined since pumping tests of the test tubewells could not be performed because the Johnson-type screens provided by the Nepalese side for the test tubewells collapsed owing to the insufficient collapse strength and the probable pump discharge in each development block could not be confirmed due to the shortage of the existing deep tubewells on which pumping tests could be carried out, insufficient numbers of electric sounding points, etc. No decision was taken, however, on how to reinforce the 8" Johnson-type screens (collapse strength: 4.6 kg/cm^2), which had failed in the test tubewells. Since these are vital issues on which the technical viability of the Project depends, it is judged that the preparation of a basic design for production tubewells and associated irrigation facilities applicable to all of 23 blocks would technically be difficult. Therefore, JICA sent the Basic Design Study Phase-II mission to Nepal from January 10 to March 24, 1988 in response to a request from HMGN for continuation of the Phase-I study which was given at an explanatory meeting on the draft basic design study report (Phase-I) held between the Phase-I mission and HMGN in June 1987.

The Phase-II mission presented an inception report and had a series of discussions with the Ministry of Agriculture (MOA) and Tubewell Irrigation, Agriculture, Training and Services Project (TIATSP); reviewed the probable pump discharge distribution in the project area; drilled 3 test tubewells (one in each of Blocks D-7, M-4 and S-7); did electric sounding in 5 blocks (D-7, D-15, M-4, S-1 and S-7); resurveyed the inventory of equipment and materials granted under the KR-2 aid for construction of deep tubewells and irrigation facilities; made

topographic surveys in 2 blocks (D-15 and S-1); reselected 23 blocks, collected data and information necessary for the basic design study; and surveyed present constraints and countermeasures required.

From the field surveys and investigations, the following facts were clarified and confirmed:

(1) The pump discharges of test tubewells D-7 and M-4 drilled this time were 40 l/sec at a pumping water level (P.W.L.) of 6 m and 20 l/sec at P.W.L. of 42 m, respectively, but in test tubewell S-7 drilled no good aquifer was observed;

(2) The natural water level of 2 tubewells drilled by the Mahottari Groundwater Project, Ministry of Water Resources about 3.5 km north and about 3 km southwest from test tubewell M-4 was 53 m (drilling depth: 119 m) and 14.6 m (drilling depth: 163 m) respectively, though the pumping results were not announced. This meant that the natural water level would be considerably lower than that of test tubewell M-4 (38 m) when M-4 block is shifted southwest from the original location, and the pump discharge of more than 25 l/sec could therefore be anticipated.

(3) The existing deep tubewell N-39 located at G.L. 550 feet (165 m) in S-1 block discharged a great quantity of sand and gravel at a discharge of more than 5-6 l/sec (P.W.L.: 66.2 m), but two (2) deep tubewells at the sugar factory constructed at G.L. 500 feet (150 m) in S-1 block were reported to have discharged 27 l/sec at P.W.L.: 19 m and 29 l/sec at P.W.L.: 19 m, respectively.

(4) The pump discharge of existing deep tubewell N-35 in the southern part and N-33 in the northern part of D-15 were 47 l/sec with a drawdown of 8.4 m, at

P.W.L.: 20.5 m and 19 l/sec with a drawdown of 3 m, respectively.

(5) The survey results mentioned above indicate that the hydrogeological structures in the project area change substantially from place to place, accordingly it is judged that the pump discharge estimated from the groundwater potential map prepared in the Phase-I study was unreliable and therefore not usable for the basic design of the Project.

The Phase-II mission reconfirmed the project components and discussed the development concept, implementation plan, etc. with TIATSP, one of the executing agency of the Project, and MOA, the other executing body and the superintendent ministry of the Project. However, no minutes of discussion, stipulating a basic development concept, implementation plan, etc. could be signed because the Japanese side could not accept the following 3 points insisted upon by the Nepalese side:

(1) If a Japanese contractor uses the drilling and construction equipment granted under the KR-2 aid and held by TIATSP at present in implementing the Project under general grant aid of the Japanese Government, the nominal charge would be payable to HMGN;

(2) If a deep tubewell constructed by a Japanese contractor is a dry or uneconomical well with a yield of less than 25 l/sec, HMGN will not issue a completion certificate, and there will be no payment for the said well. The contractor must redrill and complete an economical well with a yield of more than 25 l/sec at his own risk; and

(3) The objective blocks in the next survey and study shall be nine (9): S-1, S-2, S-10, M-4, M-12, M-13, D-13, D-14 and D-19. (In the judgement of the study

mission it may not be possible to construct economical production tubewells except in blocks M-4 and D-19.)

In view of the situation described above, it is judged that the Phase-II study should be worked out in the following manner:

(1) It will not be possible to implement the Project in line with the original overall development plan, which aimed to provide 115 production tubewells and associated irrigation facilities in 23 blocks over a period of 4 years, as worked out in the Phase-I study, since it would be too risky to construct production tubewells on the basis of the prospective pump discharge of each block without the confirmation of pumping tests on test tubewells. The implementation plan for the 23 blocks must therefore be worked out based on the basic design of the facilities which will be made after confirmation of probable pump discharge in each block by a test tubewell to be drilled in that same block in principle;

(2) The basic design of the production tubewells and associated irrigation facilities for blocks D-7 and D-15 is worked out because an economical pump discharge of more than 25 l/sec (with the existing vertical turbine pumps) may be confidently expected, on the basis of the pump discharges of existing deep tubewells tested;

(3) The basic design for M-4 block is not worked out since the development area of M-4 block has to be shifted southwest from its original location so as to ensure an economical pump discharge of 25 l/sec;

(4) No basic design for S-1 block is prepared because pump discharges of more than 6 l/sec could not be confirmed by the study mission in the field, though pumping test data showing yields of more than 25 l/sec at the

existing tubewells in S-1 block were given from the Nepalese side; and

(5) S-7 block is omitted from the objective blocks for development because no promising aquifer was found in drilling a test tubewell, and further investigation and study are not justified.

An outline of the basic design for the two blocks of D-7 and D-15 worked out in the Basic Design Study Phase-II is given below.

(1) Objective area:

- Naktajhij and Hariharpur panchayats (D-7 block) in Dhanusha district, Janakpur zone
- Basahiya panchayat (D-15 block) in Dhanusha district

(2) Net irrigable area:

Block	Hectarage (ha)
D-7	200
D-15	200
Total	400

(3) Production tubewells:

Block	D-7	D-15	
		Type A	Type B
Number of production tubewells*1	4+(1)	3+(1)	1
Static water level (m)	(artesian)	42	12
Designed pump discharge (l/sec)	40	40	40
Designed pumping water level (m)	9	50	20
Pump position (m)*2	25	57	35
Drill depth (m)	210	150	150
Casing depth (m)	200	140	140
Length of 14" casing (m)	30.0	60.0	42.0
Length of 8" casing (m)	120.0	42.0	66.0
Length of reinforced screen (m) 9.2 kg/cm^2	25.25	5.25	10.5	10.5
Length of reinforced screen (m) 16 kg/cm^2	10.5	21.0	21.0
Length of strengthened screen (m) 28 kg/cm^2	33.0	5.5	5.5
Pump to be installed	Existing 45 l/sec model vertical turbine pump		
Remodelling	None	*3	None
Improvement	Automatic engine stopper by water level detector attached to pump.		

Remarks:

*1: The number of production tubewells is five per block, and numbers in brackets denote test tubewells upgraded to production tubewells. One test tubewell in D-15 block has already been completed by TIATSP.

*2: Pump position designed to be at least 7 m below the designed pumping water level, taking into account the drawdown of the water level in the long term.

*3: Both pump shaft and column pipe for 4 vertical turbine pumps are extended from the original 40 m to 57 m.

(4) Irrigation facilities:

Block	D-7	D-15
Irrigation canal	8,610	6,910*1
Pump house	5	4
Operator hut	5	4
Baffle tank	5	4
Cattle pass	14	12
Road crossing (large)	1	3
Road crossing (small)	42	23
Turnout	70	56
Cross drain	23	11
Cross drain (large)	1	0
Corner box	32	15
Division box	5	7
Drop	2	6
Check plate	60	47

*1: Irrigation facilities of an irrigation unit in D-15 block are under construction by TIATSP as of end March 1988.

(5) Equipment and materials to be newly granted:

1) spare parts for drilling rigs and their mud pump
2) 17-1/2" and 14-3/4" tricone bits, hole openers, etc.
3) drilling mud such as bentonite, CMC, barite, etc.
4) strengthened rod base screens, conductor pipes, etc.
5) jetting nozzles and a mud cleaner for development and cleaning of production tubewells
6) DC engine welder and gas welder with cutting tools
7) high head-small discharge type submersible motor pump for pumping tests
8) parts and apparatus required for remodelling and improving existing vertical turbine pumps
9) some transportation equipment such as pick-up truck, self-loading truck, etc. and spare parts for existing transportation equipment and vehicles
10) spare parts for existing construction equipment
11) vehicles required for field survey and construction administration and supervision
12) others

(6) Implementation period of the Project:

The implementation period of the Project, including detailed design, selection of contractor, construction, etc. will be twelve (12) months after conclusion of exchange note (E/N) between GOJ and HMGN.

(7) Implementation system of the Project:

An executing agency of the Project will be TIATSP which is superintended by the Department of Agriculture, Ministry of Agriculture. Operation and maintenance of the constructed irrigation facilities including production tubewells and pumps will be conducted by TIATSP in collecting necessary water charges from water users' groups to be organized for each production tubewell and associated irrigation facilities.

Implementation of deep tubewell irrigation development in blocks D-7 and D-15 is expected to result not only in such direct effects as expansion of irrigable farm lands, increased cropping intensity and diversification of crops by perennial irrigation, increase of crop unit yields and agricultural production, and improvement of farmers' income and living standards resulting from the said effects, but also such indirect effects as improvement to the living environment, increased mutual cooperation between farmers, improved deep tubewell development technique, etc.

In development of blocks D-7 and D-15 under a general grant aid cooperation of GOJ, the cooperation of HMGN is vital, particularly in the following:

(1) in providing a Japanese contractor, free of charge, with the drilling and construction equipment and materials required by him out of those granted under the KR-2 aid;

(2) in taking over production tubewells constructed by the Japanese contractor and in issuing the necessary completion certificates to him, providing they are not dry wells;

(3) in providing construction sites and access roads as required by the Japanese contractor;

(4) in constructing branch earth canals branching off from main canals constructed under the Japanese grant aid; and

(5) in operating and maintaining the constructed facilities by organizing water users' groups and collecting water charges from the users' groups.

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CHAPTER 1. INTRODUCTION

CHAPTER 1. INTRODUCTION

His Majesty's Government of Nepal (HMGN) commenced the Japankpur Zone Agricultural Development Project (JADP) with grant aid and technical assistance from the Government of Japan (GOJ) in November 1971 to promote irrigated agriculture development in the non surface irrigation areas in the Terai plain within the Janakpur zone. This zone occupies the major part of the Central Development Region, and has already implemented various kinds of agricultural development projects to increase agricultural production, raise farmers' incomes and improve farmers' living standards. Among these projects, the shallow tubewell program (STWP) has made remarkable progress in the central belt of the Terai plain in the Janakpur zone and enabled irrigation of about 16,000 ha of arable lands by constructing some 2,646 shallow tubewells by May 1987, of which 2,307 have been successful (success percentage: 87%).

HMGN reorganized JADP into the Tubewell Irrigation, Agriculture, Training and Services Project (TIATSP) in January 1986 to accelerate groundwater irrigation projects in the Terai plain in the Janakpur zone. STWP has advanced smoothly under TIATSP and is expected to be continued in the future. On the other hand, the deep tubewell irrigation project (DTWIP), which was initiated in 1976 as one of JADP's projects and which had drilled 24 deep tubewells by 1984, constructed 39 deep tubewells (of which 15 were constructed by a Japanese contractor) in 1985 and 1986, using the drilling and construction equipment and materials provided under a KR-2 aid program of GOJ in 1982 and 1983, and was then taken over by TIATSP which drilled 18 deep tubewells in 1986/87 and planned to drill another 8 in 1987/88.

DTWIP has not progressed smoothly, however, since hydrogeological survey and deep tubewell construction techniques are not yet established in the country, and the huge construction costs of deep tubewells and the associated irrigation facilities

cannot be afforded. Moreover operation and maintenance of deep tubewell irrigation are difficult to ensure.

In light of the above, HMGN in April 1986 requested a grant aid cooperation in the Terai groundwater development project from GOJ with the aim of constructing 150 deep tubewells and associated irrigation facilities to command about 3,000 ha of arable land by using the drilling and construction equipment and materials granted under the 1982/83 KR-2 aid program. In this way it was hoped to accelerate DTWIP in a suitable area of the Terai plain in three (3) districts of the Janakpur zone: Dhanusha, Mahottari and Sarlahi. In response to this request, Japan International Cooperation Agency (JICA) sent a preliminary survey mission to Nepal from August 26 to September 19, 1986 to confirm the background, work components, executing system, organization and significance of the Project envisaged by HMGN. From the survey results the mission judged the Project would be technically and economically viable.

JICA then sent a Basic Design Study (hereinafter referred to as Phase-I study) mission to Nepal from January 7 to March 6, 1987. The mission carried out the surveys and investigations such as selection of the project area; an assessment of groundwater potential distribution in the project area; four (4) test borings on Dhalkewar-Jaleswar line; an inventory of the drilling and construction equipment and materials granted under the KR-2 aid in 1982 and 1983; siting of twenty-three (23) development blocks; topographic survey of the development areas in three (3) representative blocks (D-7, M-4, S-7); collection of data and information required for basic design of deep tubewells and irrigation facilities; and an assessment of present constraints and necessary countermeasures. The mission also had a series of discussions with TIATSP and the Ministry of Agriculture (MOA) of HMGN, the executing agencies of the Project on the project components and basic plan for implementation. In the Phase-I study, through the field survey and home analysis including an examination of the project components requested by HMGN, an overall plan for the Project was worked out and it was clarified

that the vertical turbine pumps granted under the KR-2 would require the production tubewells to have a yield of more than 25 l/sec for their economical use.

The following technical issues, however, were not settled in the Phase-I study even though they were vital to the technical feasibility of the Project:

(1) confirmation of the probable pump discharge of production tubewells to be constructed in each development block;

(2) determination of the size and specification of production tubewells and the associated irrigation facilities to be constructed;

(3) location of 15 development blocks excluding 8 priority blocks among the 23 blocks proposed; and

(4) determination of the measures required to reinforce the Johnson-type screens (horizontal compression strength: 4.6 kg/cm^2) which had been shown to have insufficient strength during the test borings.

In response to a request from HMGN for continuation of the basic design study Phase-I in June 1987, JICA despatched a further mission to Nepal, the basic design study Phase-II mission, headed by Mr. Yoshiki MIYANISHI, Grant Aid Division, Economic Cooperation Bureau, Ministry of Foreign Affairs from January 10 to March 24, 1988, to investigate and study five (5) development blocks (D-7, D-15, M-4, S-1, S-7). The Phase-II mission carried out such surveys and investigations as review of the groundwater potential distribution map of the project area; drilling of three (3) test tubewells (one each in D-7, M-4 and S-7); acceptability of reinforced Johnson-type screens (9.2 kg/cm^2 and 16 kg/cm^2) and strengthened rod based screen (28 kg/cm^2) to the test tubewells; made an inventory of the drilling and construction equipment and materials granted under

the KR-2 aid; topographic survey of the development areas in two (2) blocks (D-15 and S-1); resiting of twenty-three (23) blocks; collected data and information required for the basic design of the production tubewells and associated irrigation facilities, present constraints and necessary countermeasures to be taken for their implementation; and reconfirmed the project components and basic plan for implementation in a series of discussion held with TIATSP and MOA.

In the field surveys and investigations of the Phase-II study it was clarified that the overall development plan for twenty-three (23) blocks worked out in the Phase-I study could not be implemented unless the probable pump discharge in each block could be confirmed by test tubewell or pumping test of an existing deep tubewell in the same block, and that out of the five (5) blocks surveyed and investigated only two (2) blocks (D-7 and D-15) could be implemented, for the following reasons:

(1) in S-7 block no promising aquifer was observed;

(2) in M-4 block the confirmed pump discharge was only 20 l/sec at a pumping water level of 42 m and a drawdown of about 4 m;

(3) in S-1 block the pump discharge of the existing TIATSP deep tubewell was only 5 ~ 6 l/sec at a pumping water level of 66.2 m and a drawdown of about 18 m, although two (2) deep tubewells owned by a sugar factory yeilded 27 l/sec at a pumping water level of 19 m and a drawdown of about 5 m and 29 l/sec at a pumping water level of 19 m and a drawdown of about 5 m, according to a report available in the factory;

(4) in D-7 block the confirmed pump discharge was 40 l/sec at a pumping water level of 6 m and a drawdown of 6 m;

(5) in D-15 block the confirmed pump discharge of the existing TIATSP tubewell on the south side was 47 l/sec at a pumping water level of 20.5 m and a drawdown of about 8 m, and that of the existing TIATSP tubewell on the north side was 19 l/sec at a pumping water level of 45.1 m and a drawdown of about 3 m; and

(6) The facts mentioned above indicate that the hydrogeological structures in the project area change substantially from place to place, accordingly it is judged that the pump discharge estimated from the groundwater potential map prepared in the Phase-I study was unreliable and therefore not usable for the basic design of the Project.

However, after a series of discussions held between the study mission and MOA of HMGN based on the results of the field surveys and investigations in the Phase-II study, it was not possible to agree on a minutes of discussion stipulating a basic development concept, implementation plan, etc., for the Project, because Japanese side could not agree to the following 3 points insisted upon by the Nepali side:

(1) If a Japanese contractor uses the drilling and construction equipment granted under the KR-2 aid and held by TIATSP at present in implementing the Project under a general grant of the Japanese Government, a nominal charge would be collected by HMGN;

(2) If a deep tubewell constructed by a Japanese contractor is a dry well or uneconomical well with a yield of less than 25 l/sec, HMGN will not issue a completion certificate, resulting in no payment for the said well, and the contractor must redrill and complete an economical well with a yield of more than 25 l/sec at his own risk; and

(3) The objective blocks in the next survey and study shall be nine (9): S-1, S-2, S-10, M-4, M-12, M-13, D-13, D-14 and D-19. (In the judgement of the study mission, it may not be possible to construct economical production tubewells except in M-4 and D-19 blocks.)

The membership and itinerary of the Phase-II study mission, a list of Nepalese officials concerned, and a list of Nepalese counterparts to the mission are shown in an Attachment to this report.

This Basic Design Study Phase-II Report comprises project concept, basic design of production tubewells and associated irrigation facilities, implementation plan of blocks D-7 and D-15, evaluation of the Project, conclusions and recommendations, etc.

For ease of reference, the major differences between the Phase-I and Phase-II studies may be summarized as follows:

Work Item	Phase-I	Phase-II
1. Study blocks	30 blocks	5 blocks: D-7, D-15, M-4, S-1 and S-7
2. Drilling and testing of test wells	None. But, four (4) test borings were made on Dhalkewar-Jaleswar line in Dhanusha district	Three (3) test wells, one each in D-7, M-4 and S-7 blocks. Drilling in S-7 block was abandoned before casing because no promising aquifer was observed by electric logging.
3. Basic design of facilities	3 representative blocks of D-7, M-4 and S-7	2 blocks of D-15 and S-1
4. Overall plan	To construct 115 production wells and associated irrigation facilities in 23 blocks over 4 years	Not worked out

Work Item	Phase-I	Phase-II
5. Blocks to be constructed in 1st implementation year	5 blocks: D-7, M-4, S-7, D-15 and S-1	2 blocks: D-7 and D-15
6. Annual implementation plan	In and after 2nd year: 6 blocks	Not worked out

CHAPTER 2.

BACKGROUND OF THE PROJECT

CHAPTER 2. BACKGROUND OF THE PROJECT

2.1 National Economic and Agricultural Background

2.1.1 Land and Population

The Kingdom of Nepal is a land-locked country bordered by Tibet in the north and by India in the south. The area of the country is about 150,000 km^2. The annual rainfall is about 500 mm in the mountains and western part and is about 1,300 mm in the Terai Plain. The population is about 15,000,000 in 1981 and its annual growth rate is about 2.7% in the past ten years from 1971.

2.1.2 National Economy

The Gross Domestic Products (GDP) of Nepal in 1985/86 was about 45.3 billion Nepal Rupees (NRs.) in current price and its annual growth rate was about three percent in the past five years since 1980/81. The GDP per capita is estimated at about NRs.2,600 which is equivalent to US$175.

Nepal is an agricultural country, where the production of agriculture, forestry and fishery represents more than 60% of GDP and that of industry only 4.6%. About 90% of working population are engaged in agriculture, forestry and fishery.

2.1.3 National Development Plan

Nepal is in the third year of the Seventh Five Year Plan. The objectives of the Seventh Five Year Plan are (1) to accelerate increase of production, (2) to increase opportunities for productive employment, and (3) to meet the minimum basis needs of the people.

In the Seventh Five Year Plan, the first priority is given to agricultural sector. Then, the development of forest resources and land conservation are considered to be very important. In the sector of water resources development, several ideas are considered to connect it with economic development, that is development of transportation by electric power, construction of channel, etc.

The large scale industry is not recommended considering the geopolitical situation, potentiality of natural resources and small domestic market. Thus, the development of small scale industry is recommended. Besides, several plans such as boosting export, localizing implementation of rural development project, and reducing governmental interference and control to the private sectors are also considered.

The agricultural sector accounted more than 60% of GDP during the past five years, engaged about 90% of working population will be the biggest industry to support national economy. Thus the economic growth of Nepal greatly depends on the growth of agriculture. In the Seventh Five Year Plan, the target of production of major crops are settled as shown below.

	1984/85 (ton)	1988/89 (ton)	Rate of Increase (%)
Rice	2,733,000	3,400,000	124
Wheat	600,000	900,000	150
Maize	843,000	916,000	109
Sugarcane	500,000	800,000	160
Mustard	77,000	95,000	123
Tobacco	7,000	8,000	114
Potato	409,000	521,000	127

2.2 Present Status of Agriculture and Irrigation

1) Agriculture

The present land use in Nepal are summarized below.

Type of Land Use	Area (in million ha)	Percent of Total Area
Agriculture area	2.65	18.0
Forest area	5.53	37.6
Himali area	2.25	15.3
Grazing area	1.98	13.4
Water area	0.40	2.7
Habitation area and roads	0.10	0.7
Others (barren land, land slide, etc.)	1.80	12.3
Total	14.71	100.0

The recent production and cultivated area of major crops in Nepal are shown in Table 2-1.

About 1,970,000 or 90% of farm household are land owned farms out of 2,180,000 or total farm household in Nepal. The land owned farms cultivate about 2,300,000 ha which is of about 87% of total farm land. About 1,800,0000 or 82% of farm household manage less than 2 ha in each.

2) Irrigation

The irrigation of 340,000 ha has been developed till 1985. However, the actual irrigable area is assumed at only 100,000 ha because of lack of agricultural supporting activities and of operation and maintenance works.

Considering this, the extension of 235,500 ha of irrigation area is one of the most important target in the Seventh Five Year Plan as follows:

Description	Ministry of Water Resources	Ministry of Agriculture
On-going Projects	106,003 ha	
New Projects	29,490 ha	
Small Scale Irrigation		50,000 ha
Tubewell Irrigation		50,000 ha
Total	135,493 ha	100,000 ha

The distribution of 135,493 ha, proposed by the Ministry of Water Resources, is shown as follows by region and by topography, which indicates the priority is put on the central region where Janakpur zone belongs to.

Region	Terai Plan (ha)	Hill Area (ha)	Total (ha)
Eastern	39,235	2,385	41,620
Central	34,500	2,390	36,890
Western	8,666	5,227	13,893
Midwestern	5,500	1,560	7,060
Farwestern	10,950	3,480	14,430
Undecided	21,600	0	21,600
Total	120,451	15,042	135,493

The distributions of small scale irrigation area and tubewell irrigation area to be propelled by the Ministry of Agriculture are not clear though, the priority will be put on the on-going tubewell irrigation projects in Janakpur, Narayani and Lumbini zones in the Central region.

As for irrigation facilities, all the canals (from main canal to tertiary canal) are earthen canals, and smaller canals and ditches below tertiary are usually constructed by beneficiary farmers. Related structures such as barrages, diversion works, siphons, bridges, etc. are made with concrete and other structures are generally constructed by brick masonry.

2.3 Trend of Foreign Aid

Nepal has been taken seriously for economic cooperation by donor countries and agencies since 1951, an opening year of Nepal to foreign countries. Per capita aid receipts of Nepal is about 12 US dollars in 1984/85, which is the second rank position together with Bangladesh next to Sri Lanka (about 25 US dollars).

The yearly aid receipts of Nepal amounted to about 13 million US dollars during the first five year plan (1956 ~ 61) and after 1970, when donor systems by developed countries were strengthened and economic cooperations by international agencies became active, the aid amount has been increased rapidly, and reached 24 million US dollars in 1970, 175 million US dollars in 1982/83 and 186 million US dollars in 1984/85.

With progress of the economic cooperation, not only the increase of aid amount but also form of aid, allocation to aid sectors and member of donor countries have gradually transformed. As for the form of aid, both grant aid and technical cooperation are major forms for the initial aid stage though, in 1970s, in the cooperations by international agencies active percentage of loan to economic cooperation had increased, and reached 44 percent in 1980/81 and 56 percent in 1984/85. Regarding aid sector, road, electricity, agriculture and irrigation have been put importance on since the beginning of aid and that is not greatly changed today. However, the aid-receiving policy of Nepal was changed in and after 1977, and majority of aid has been allocated to the construction of rural roads connecting with trunk roads, village roads and the rehabilitation of existing roads in road sector and the construction of power distribution network in electricity sector and the construction of tertiary, quaternary canals and medium-small scale projects in irrigation sector. As for the member of donor countries, India, China and U.S.A. had occupied a big portion of the total aids (90% of the aid's amount) in the initial stage, however in 1970s the aid amount of China and

U.S.A. decreased and that of IDA, ADB, UN group and Japan increased largely. In 1982/83, IDA occupied 19% of total aid and ADB 18%, and in the bilateral aid, Japan occupied 14% of total aid and ranked for the first position, India 12% for the second and China 7% for the third.

With increase of aid amount, Nepal's capacity for absorbing foreign aid is coming to constraint in terms of lack of domestic fund, lack of manpower such as site engineers, supervisors, governmental staffs, etc. for project execution and increase of repayment following to the increase of loan portion. HMGN is therefore making effort to train manpower by financing to education and technical training projects and through the on-the-job training, etc.

2.4 The Request of HMGN on the Project

His Majesty's Government of Nepal (HMGN) requested the Government of Japan in April 1986 to provide the former with a grant aid to construct 150 deep tubewells and the respective irrigation facilities covering about 3,000 ha in total in the Terai Plain in Janakpur Zone using the equipment and materials granted under a KR-2 aid of the latter in 1982 and 1983.

The outline of the Project requested by HMGN for the grant aid mentioned above is summarized as follows.

1) Basic plan

(1) Objectives of project

- Extension of irrigation area
- Stable increase of agricultural products
- Increase of farmers' income
- Improvement of farmers' living standard and social welfare

(2) Project area

Terai Plain in Janakpur Zone

(3) Component of project

- Utilization of the deep tubewell construction equipment and materials provided under the KR-2 in 1982 and 1983

- Construction of 150 deep tubewells and their respective irrigation facilities covering about 3,000 ha of arable land in total

2) Development blocks

(1) Development blocks and their priority

- Number of development blocks: 30 blocks
- Gross area of one development block: 800 ha
- Number of development blocks by district and by priority are as follows:

District	Priority			Total
	1st	2nd	3rd	
Dhanusha	7	2	3	12
Mahottari	3	3	5	11
Sarlahi	5	0	2	7
Total	15	5	10	30

3) Groundwater development plan

(1) Deep tubewell plan

150 deep tubewells are to be constructed for 30 development blocks (5 tubewells for one development block).

(2) Equipment and materials plan

HMGN will provide drilling rigs, casing pipes, screen pipes etc. granted under KR-2.

4) Irrigation and drainage plan

(1) Principle

- Irrigable area to be covered by one deep tubewell is 20 ha on an average.

- Location of wells and layout of main canals are decided in the detailed design stage.

(2) Irrigation facilities

- Pump house
- Water supplying pipe
- Operator house
- Main canal and related structures

5) Administration

(1) Responsible government office: Department of Agriculture, Ministry of Agriculture

(2) Executive agency: TIATSP (Tubewell Irrigation Agriculture Training and Services Project)

2.5 Previous Studies

2.5.1 Preliminary Study by Japanese Government

The Government of Japan despatched a preliminary survey mission to Nepal from August 26th to September 19th in 1986. The mission conducted a field survey in Janakpur zone and had a series of discussion on the project with the officials concerned of the HMGN. The outline of the survey is as follows:

1) The agricultural policy of Nepal are based on the increase of food production and level up of farmer's living standard. In Terai Plain, development of shallow tubewell irrigation and deep tubewell irrigation are considered to be very effective and to be promoted rapidly. Therefore, this Terai Groundwater Development Project is under the necessity of being implemented and seems to be very effective.

2) The technical problems such as determination of well points and well depth and pumping discharge will be solved in the basic design study. The deep tubewell irrigation is being experienced successfully in Hardinath pilot farm and others. The project will be effectively implemented providing that a pumping discharge wold be more than 25 l/sec and operation and maintenance works would be made smoothly.

3) This project has enough technical soundness and economic viability for Japan's Grant Aid Project on condition that the following points are taken into consideration:

   (1) The deep tubewell irrigation will be made mainly for stable increase of rice and for expansion of cultivation area in the dry season. An unit irrigation will be of 1 l/sec/ha in the same way as in other irrigation projects in the Terai Plain.

(2) In the basic design study the hydrogeological condition will be investigated by test boring. A reasonable pumping discharge from the viewpoint of ground subsidence and a development method of low yield aquifer in the northern part will also be studied. An adequate design and development method of deep tubewell will be studied.

(3) Although this project is to be formulated on condition that the materials and equipment granted by a KR-2 of GOJ have to be utilized effectively, other materials and equipment will have to be provided additionally; namely submersible motor pumps for northern area, screen and pipes for deep aquifer in northern area.

Based on the above results of the survey, the preliminary survey mission recommended the basic design works as follows:

(1) To investigate and to identify the 30 blocks proposed by HMGN.

(2) To classify the 30 blocks into three to five types.

(3) To make basic design for representative block in every type.

(4) Test boring at three sites; namely one boring near East-West highway (150 m in depth), one boring in the northeast of Janakpur town (210 ~ 240 m in depth), one boring in the southwest of Janakpur town (210 ~ 240 m in depth).

(5) Inquiry of equipment and materials granted by a KR-2 of GOJ for construction of deep tubewells.

2.5.2 Phase-I Study

Based on the results of the preliminary survey, JICA despatched a basic design study mission (Phase-I study) from January 7th to March 6th in 1987.

The study mission investigated the hydrogeological conditions in the project area by 4 test borings and by pumping test of the existing deep tubewells, evaluated existing deep tubewell construction equipment and materials granted by the KR-2, determined 23 development blocks including topographical survey of 3 blocks, examined present constraints and their solutions, collected the data and information required for the basic design, and carried out the discussions with TIATSP (an executing agency of the Project) and the Ministry of Agriculture (a superintendence ministry of Project).

The main works carried out by Phase-I study mission in Nepal were as follows:

1) Explanation of Inception Report to and discussion with HMGN officials concerned;

2) Preparation of draft minutes of discussions between the mission and HMGN;

3) Collection and analyses of the data and information required for the basic design;

4) Site investigation to grasp the present condition of the project area;

5) Four numbers of test boring;

6) Topographic survey of three development blocks (D-7, M-4, S-7) and preparation of the topographical maps (scale 1/1,000); and

7) Confirmation and discussion on the scope of the project requested by HMGN.

Based on the results of the investigation and survey in Nepal mentioned above and the consecutive home analysis works in Japan, the Phase-I Study Team prepared a draft final of the basic design report, containing the scope and components of the Project, the basic design of the facilities, the implementation plan of the Project, the plan of the basic design study Phase-II, and the conclusion and recommendations. For the purpose of explaining the draft final report to and discussing with the officials concerned of HMGN about its contents, JICA sent a draft final explanation mission to Nepal from 29th May through 5th June in 1987.

The outline of the Project drafted in the Phase-I is as follows:

1) Overall plan

To construct 115 deep tubewells and irrigation facilities for 4,625 irrigable area by using equipment and materials granted by a KR-2 and to be newly procured.

2) Area to be developed

(1) 23 blocks out of 30 blocks requested by HMGN will be developed.

(2) Eight blocks of the 23 blocks were selected for first priority of the development.

3) Representative blocks for basic design

Three blocks (D-7, M-4, S-7) were selectedand basic design was made for those to estimate total cost of development for 23 blocks.

4) Groundwater development

(1) The project area seems to have a good potential of groundwater, judging from the hydrogeological conditions.

(2) Four types of standard well were designed for different hydrogeological condition.

	Depth of Casing (m)	Length of Casing (m)	Length of Screen (m)	Nos. of Tubewells
Type I	89	36	30	20
Type II	159	60	40	45
Type III	205	36	50	45
Type IV	205	48	50	5
Total				115

(3) The existing screen has to be reinforced and be used in the different manner as follows:

Depth (m)	Screen to be used	(kg/cm^2)
30 ~ 50	Existing screen	(4.6)
50 ~ 100	Existing screen, reinforced	(9.2)
100 ~ 150	Existing screen, reinforced	(16.0)
150 ~ 200	New rod based wire wrapped screen	(28.0)

(4) Quantity of equipment and materials, reinforcing existing screens, rod based screens to be purchased, spare parts for drilling rigs, etc. were estimated for 23 blocks.

5) Irrigation development

(1) The net irrigable area was estimated for 23 blocks.

Pumping Discharge (l/sec)	Nos. of Well	Irrigable area (ha)
25	5 (5)	125 (125)
30	35 (5)	1,050 (150)
40	35 (10)	1,400 (400)
50	30 (20)	1,500 (1,000)
55	10 (0)	550 (0)
Total	115 (40)	4,625 (1,675)

Figures in the brackets are those for eight blocks with first priority.

(2) The basic design was made for three blocks (D-7, M-4, S-7) and the results were applied to all of 23 blocks for estimation of the project cost.

6) Implementation program

(1) The development of 23 blocks, which consists of construction of 115 production wells and irrigation facilities for 4,625 ha will be implemented for four years.

(2) Scope of construction works
The scope of works to be covered under Japan's Grant Aid Program are outlined as follows:

- Construction of pump house and operator hut
- Construction of main irrigation canal and its related structures
- Construction of temporary access road, if necessary.

The major works to be undertaken by HMGN are outlined as follows:

- Land acquisition and land compensation required for construction works
- Construction of lateral canal and its related structures.

(3) Execution body for the project

Department of Agriculture of the Ministry of Agriculture

CHAPTER 3. THE PROJECT AREA

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3.1 General

3.1.1 Location and Access

The Janakpur zone in which the study area is included is located in the Central Development Region. It is bordered by China in north, India in south, Bagmati zone in north-west, Narayani zone in south-west, and Sagarmatha zone in east. The Janakpur zone widely classified into Himalayan ranges and adjacent hilly areas, and Terai Plain from the topographic point of view. The Janakpur zone is comprised of six districts. Out of six districts, the project area is comprised of three districts located in the Terai Plain i.e. Dhanusha, Mahottari and Sarlahi.

Of the five blocks in which the basic design was made, D-7 and D-15 blocks are located in Dhanusha district, M-4 in Mahottari, and S-1 and S-7 in Sarlahi. The total area of the three districts is about 3,441 km^2 and the gross area of the five block about 40 km^2.

Tubewell Irrigation Agriculture Training and Services Project Center (TIATSP Center) is situated about 19 km north from Janakpur. D-15 block is located about 3.5 km south from Dhalkewar, and D-7 block is located from 2.5 km south of Janakpur. M-4 block is located 5 km south of Lalgadh village on the East-West Highway. S-1 block is located in Hariwan village in Sarlahi district. S-7 block is located east of Malangwa.

The other blocks which have potential of development are summarized in Table 3-1 and are shown in Fig. 3-1.

3.1.2 Administration

The smallest administrative unit in Nepal is a village called "Panchayat" and there exist 68 Panchayats in Dhanusha district, 55 Panchayats in Mahottari district and 59 Panchayats in Sarlahi district. The Panchayats which belong to the five blocks are listed as follows:

Block	Panchayat
D-7	Basahiya
D-15	Naktajhij and Hariharpur
M-4	Kisannagar, Meghuath and Banarjhula
S-1	Hariwan
S-7	Bramhapuri

3.2 Socio-economy and Industry

3.2.1 Population

The present population and its density in the three districts estimated from the annual average growth rate of population (2.66%) in the census of 1981 are 1,193,000 and 350 per km^2 respectively, though the real figures will be over these estimates due to rapid flow of population in the recent years from the mountain area to the Terai Plain. The population of the five blocks are estimated as follows:

Block	Population
D-17	9,700
M-4	6,900
S-1	17,200
S-7	9,900
D-15	Data were not collected

3.2.2 Economy and Industry

The major industries in the project area are agriculture and agro-industry. The agricultural products are selfsufficient and some surplus products are shipped to Kathmandu or other major towns. Sugar mill, tobacco factory, rice mills and other small scale cottage industries are comparatively developed. As for the construction materials, there are about 10 brick factories in the project area, and almost all the construction materials such as cement, reinforcement bar, concrete pipe, timber, etc. can be purchased in Janakpur. However, the drilling materials such as bentonite, barite, CMC, etc. are of poor quality though those are available in Janakpur.

3.2.3 Infrastructure

1) Road

The East-West Highway runs from east to west in the northern part of the three districts along the foot of Churia hills. The highway branch goes southward from Dhalkewar in Dhanusha district to Jaleswar in Mahottari district and reaches to Indian border. Besides, a gravel paved road connecting Nawalpur and Malangwa runs southward in the central part of Sarlahi district, which is passable by vehicles in the rainy season, though the maintenance condition is not so good. Furthermore, four logging roads (unpaved) run from north to south crossing the highway, but there is no connecting road from east to west each other.

2) Air route

The regular flight is available between Kathmandu and Janakpur on every Sunday, Monday, Wednesday and Friday and takes 35 minutes. However, in rainy days, flights are often cancelled because of visual flying.

3) Railway

Janakpur-Janagar railway (52 km long) is utilized for import and export from and to India though, this will not become a transportation measure of the materials for the project implementation because of local line.

4) Electricity

There are two sources for the electricity utilized in Janakpur zone at present. One is bought from India (11 kV in Malangwa, Sarlahi district and 11 kV in Jaleswar, Mahottari district, supplying to Janakpur) and the other is generated by diesel generators in Janakpur (1,360 kW).

The transmission line (132 kV) along the highway between Biratnagar and Hetauda was completed in 1985, from which the electricity will be available for distribution in the near future. However, there is no plan on electric distribution in the project area at present and the granted diesel engine pumps have to be used for the Project. The utilization of electricity for the project's implementation will therefore be out of scope in this study.

5) Telecommunication

Telephone is available in Janakpur city, between Janakpur city and Kathmandu, and between TIATSP and Janakpur city though, the telecommunication network in the project area is not yet constructed. An international call is available at the central telephone office in Janakpur.

A wireless is installed between the TIATSP center and the liaison office set up in the agriculture department in Kathmandu.

6) Water supply

For domestic water, dug wells (10 - 20 meters in depth) shared by several families are generally used in the villages in the project area.

3.2.4 Agriculture and Irrigation

1) Agriculture

There are much difference in cultivation condition between the mountain area and the Terai Plain including three districts in Janakpur zone. The project area consisting of three districts, located in the Terai Plain, has a better condition for cultivation compared with the mountain area. The gross area, arable land and rate of arable land are 344,100 ha, 214,200 ha, and 62% respectively.

The present cropping pattern in the Terai Plain is usually mono-cropping of paddy or paddy-wheat in the paddy field, and in the upland field maize-oil seeds or maize-tobacco. The multi-crop index ranges from 150 to 180%.

The unit yield of paddy, wheat and maize is assumed at 2.0 ton/ha, 1.8 ton/ha, and 1.9 ton/ha, respectively.

2) Irrigation by surface water resources

National level irrigation projects in and around the project area, which use surface water resources, are (1) Bagmati irrigation project, (2) Kamla irrigation project, (3) Manusmara irrigation scheme. The total irrigable area envisaged by these projects are to be about 36,000 ha in the rainy season. However, the proposed five blocks (D-7, D-15, M-4, S-1 and S-7) are not included in the beneficial area of those projects.

3) Irrigation by groundwater

About 130 deep tubewells have been constructed and being used for irrigation in the Terai Plain. The irrigable area of these tubewells is located in the southwestern part of Sarlahi district, and from eastern part of Mahottari to western part of Dhanusha district. In the five blocks, deep tubewell has not been constructed till 1987. TIATSP constructed two tubewells in March, 1987. One is located in the D-15 and the other in the S-1. The pumping tests were made in this Phase II field survey and the results are shown in the following section 3.4.3.

In the central part of the three districts in the Terai Plain, approximately 2,300 shallow tubewells were constructed by May 1987. The yield is reported to be 7 to 15 l/sec/well and the total irrigation area is about 16,100 ha. In the D-15 block, several shallow tubewells are used for irrigation in southern part. In principle, the irrigable area by shallow tubewell is to be excluded from the deep tubewell development program.

3.3 Meteorology, Hydrology and Topography

1) Meteorology

The climate in the Terai Plain is clearly divided into both the rainy season (5 months, from the end of May to the beginning of October) and the dry season (7 months, from the Mid. October to the mid. May). More than 80% of the annual rainfall concentrate in the rainy season from June to September.

The meteorological data of Hardinath Farm located in the middle of Dhanusha district are given in the following table.

(Average in 1971-82)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total/ Average
Average Rainfall (mm)	11	12	14	44	89	231	377	285	160	63	5	4	1,295
Temperature (°C)													
Max.	23.6	26.0	32.5	37.2	36.6	34.7	32.5	32.7	32.4	31.8	29.8	25.1	
Min.	8.7	9.9	13.9	18.3	17.6	18.4	20.3	24.3	21.0	13.2	9.2	9.2	
Ave.	16.4	18.3	22.8	27.4	28.5	29.4	28.8	28.7	28.2	26.3	22.2	17.6	24.6
Humidity (%)	78	71	55	51	64	76	82	83	85	81	76	77	73
Sunshine (hr)	8.1	8.6	9.2	9.6	9.7	5.9	6.4	7.7	6.7	8.4	8.9	8.5	8.1
Wind Velocity (km/hr)	3.3	4.2	5.5	8.7	10.6	10.4	9.9	8.2	6.6	3.5	2.6	2.5	6.3
Evaporation (mm/day)	1.9	2.7	4.7	6.7	6.9	5.9	4.8	4.6	4.1	3.2	2.7	2.2	4.2

In the rainy season, vehicle traffic, construction of temporary access road, earthfilling of canal embankment, etc. are hardly possible. The construction period of the Project is therefore limited to 7 months from December to June of the next year. Especially in the middle and south of the project area, there are many mal-drainage fields where have stagnant water until November, which results in poor accessibility and difficult construction in November.

2) Hydrology

The major rivers in Janakpur zone are the Bagmati river, the Hardinath river, the Marha river, Jhim river, the Ratu river and the Kamala river. However, discharge records are available only for the Bagmati and the Kamala. The annual mean runoff of the Bagmati and Kamla rivers are 178 m^3/sec and 59 m^3/sec respectively. The discharge in the dry season decreases to 15 m^3/sec in the Bagmati river and to 1 m^3/sec in the Kamla river. Other rivers have only underground water even though in the rainy season except for flood time.

3) Topography

The Terai Plain in Janakpur zone, extending east-westward with a strip of about 30 km wide stretching the Indian border to south, forms a fan-like plain with very gentle slopes from the Churia Hill in north to the Indian border in south. The land ranges in elevation from about 210 m to 60 m.

From the topographical point of view, the Terai Plain is classified into the following four terraces (See Fig. 3-2).

I.	High terrace, about 50 m high fro the Bagmati or Kamala present riverbed, and Middle terrace, about 20 m high from the riverbed mentioned above,
II and III.	Lower terrace, about 6 to 7 m high from the above-mentioned riverbed,
III.	Present flood plain of the Bagmati and Kamala rivers.

The surface of the high and middle terrace is covered by lateritic soils with brown color and partly used as the materials of brick and pottery.

In the project area, there are many middle and small rivers flowing from north to south and the arable land is longitudinally dissected by those rivers.

3.4 Hydrogeology

3.4.1 General

Based on the results of investigation and analysis of existing data, the geological conditions in the project area is summarized as follows.

1) As shown in Fig. 3-2, the project area is bounded by the two large rivers, which are the Kamla river (catchment area: 1,550 km^2) in the easternmost end and the Bagmati river (CA: 2,700 km^2) in the westernmost end. However, in the project area, there exist only small streams such as the Ratu river (CA: 133 km^2), the Marha river (CA: 92 km^2) and the Lakhandei river (CA: 100 km^2) and other rivuletes.

2) The Churia hills which form catchment areas of the above-mentioned rivers except for Bagmati and Kamla rivers, are composed of Siwalik Formation (semiconsolidated sandstone, siltstone and conglomerate) in late tertiary pliocene to quaternary pleistocene age, and of unconsolidated sand and gravel formation in quaternary pleistocene age. The small rivers which flow out from Churia hills discharge much sand and gravel to the downstream catchment. On the other hand, catchment area of the Kamla river and the Bagmati river is mostly composed of well-consolidated hard rocks in tertiary age and pre-tertiary age. Thus the both rivers are stable and have small quantity of sands and gravels.

3) Topography of the plain in the project area can be classified into the flood plain of the Bagmati river, the lower terrace (middle basin of the Bagmati river and middle basin of the Kamla river), middle terrace and higher terrace along the foot area of the hill where the Ratu river flows, in ascending order. Further, the middle terrace can be subdivided into delta-like zone around Janakpur town, central zone around Hardinath and top zone of fan around Dhalkewar which respectively form small

scaled fan deposit at the foot line of small rivers, and a multi-fan deposit zone as a whole.

4) The contour lines in the middle terrace are in a tendency of bending southwards at a suddenly widened portion of the medium size rivers such as the Ratu river and the Marha river located in the central portion of the project area. All the surface water of the small rivers percolate into the riverbeds at the foot line of the hills except a flood season and spring out in the downstream area lower than 400 feet contour line, where many springs exist. The area downstream from the springs has always surface water through a year and many ponds are constructed. Groundwater table (the confined) of 50 m below the surface is concordant with the contour line of 500 feet.

5) In the delta-like zone of the middle terrace, south from Janakpur, all the rivers suddenly change narrow width and their course is stable. These facts indicate that all the rivers in the upstream area of the middle terrace above the contour line of 250 feet to 300 feet are unstable and change their course in the flood season, resulting in damages of their neighbouring area by floods containing much sands and gravels.

6) Subsurface geology in the delta-like zone consists generally of thick layers of fine sands, silts and clay (average thickness: 70 m), and cannot be developed for shallow tubewells. Although good artesian wells and springs exist along the middle to lower reach of the Ratu river, the distribution of the aquifer is considerably complicated, particularly a continuity of the aquifer from east to west is very poor.

7) The objective area for shallow tubewell development and major artesian area suitable for deep tubewell development locate in the central zone of the middle terrace. But, the hydrogeological structure in such areas is not homogeneous

and the aquifers change place to place, which are resulted from the development process of the aquifers along the old riverbeds in the geological ages.

8) In the northern area along the East-West Highway, the phreatic groundwater level is deeper than 20 m from the ground surface and at some places it is hardly possible to get domestic water. The contours of groundwater level are well corresponding with topographical relief.

9) The belt-like zone, where 7 to 17 l/sec is extractable by shallow tubewells, is distributed east-westward in the central part of the project area, and suited to shallow well irrigation.

10) The water temperature of the shallow wells ranges from 25 to 26°C in the northern area and 22 to 25°C in the southern area. The values of pH are in a range of 5.5-6.6 in the north and 7.0-7.4 in the south. It is found that the area with low pH extends along the Ratu river basin. The electric conductivity shows locally low value in the north, however significant characteristic is not found.

The conditions of deep groundwater can be guessed by the groundwater level contour, distribution of pH value of deep tubewells, the electric conductivity and water temperature as summarized below:

1) The groundwater level of deep tubewells in the northern project area along the East-West Highway lies 50 ~ 60 m below the ground. The groundwater level of shallow tubewells, standing approximately 20 m deep from ground surface in this area, is supposed to be the levels in the perched groundwater lying in the shallow subsurface. The groundwater level contour of deep tubewells generally corresponds with the present topographical contour line.

2) The pH value of deep tubewell water ranges from 6.1 to 7.8 showing higher than that of the shallow tubewell water. It is supposed that the rainfall percolated into the deep aquifer during long time. The distribution of pH values is 6.2-6.5 in the northern area, 7.1-7.8 in the southern area and the highest value is found near Jaleswar in the southern part of Mahottari district. The distribution of electric conductivity ranges 100 μ mho/cm in the northern area and 400 μ mho/cm in the southern area, and it is found that the low conductivity belt extends southward along the Ratu river basin.

3) The water temperatures are in the range of 25 to 27°C in the northern area, 24-25°C in the southern area, indicating that the deep groundwater flows in from and along the Ratu river.

From the data of the shallow and deep groundwater levels and qualities mentioned above, it is assumed that the deep groundwater of the project area is not recharged by flowing into east-westward from the deep groundwater underlying the Bagmati and the Kamala river basin but recharged by both north-south flow of groundwater and vertical percolation of rainfall.

The seasonal variation of groundwater table is assumed not so large in the project area (Appendix 5.1).

3.4.2 Potential of Groundwater

The potential of groundwater is assumed to be large in central area of Dhanusha district and western area of Sarlahi district and to be small in the south of Sarlahi and Mahottari districts and the area along with East-West highway as shown in Fig. 3-1. Fig. 3-1 has to be improved in the future by taking additional data into consideration. It is compelled to judge that the groundwater potential map prepared in the Phase-I is uneliable because the existing deep tubewell data based for the

map were not always trustworthy according to the investigation conducted this time.

3.4.3 Hydrogeological Condition in the Five Blocks

Based on the result of test drilling and electric resistivity test conducted in the Phase-II, the hydrogeological conditions in the five blocks are assumed as follows.

1) D-7 block

Classification	Depth (m)	Geology Facies	Resistivity (Ω-m)	Hydrogeologic Evaluation
Layer I	0~36	Alternation of clay (dominant) and sand	8~3,500	Dug wells are developed. Aquifer has low yield. Many ponds exist due to very poor drainage of clay.
Layer II	22~160	Mostly clay, partly sand & gravel sand are sandwiched.	12~54	Aquiculde.
Layer II'	25~63 60~90	Sand & gravel. Mostly sand.	78 ~ 250	This layer develops in Layer II in lentiform. It has discontinuity and has low potential of groundwater.
Layer III	110~160 or deeper	Sand & gravel. Mostly sand & clay are sandwiched.	48~200	Aquifer layers for deep well. Fine sand may be distributed where the resistivity is 100 Ω-m or less. Confined aquifer (artesian).

Layer III is inferred to be an aquifer for deep tubewells. Test tubewell of D-7(A) drilled in the Phase-II has an artesian discharge of 20 l/sec and a pump discharge of 41 l/sec (72 hours continuous test). This layer is evaluated to be a good aquifer. Geologic log and electric log are shown in Fig. 3-3, and yield logging is shown in Fig. 3-4.

2) D-15 block (Naktajhij, Hariharpur)

Classification	Depth (m)	Geology Facies	Resistivity (Ω-m)	Hydrogeologic Evaluation
Layer I	0~50	Mostly sand & gravel (with partly boulders). Thin layer of sand and clay is sandwiched.	41~2,700	Aquifer for shallow and dug wells.
Layer II	36~270	Alternation of sand, sand & gravel and clay. Clay is predominant in the 20cm of top.	63~100	Aquifer (sand & gravel, sand). Main aquifer of N-33well. The clay is to be aquiclude.
Layer II'	46~230	Sand & gravel and mostly sand (with partly boulders).	130~390	Aquifers for deep tubewell. If many boulders are contained, the drilling may be a little bit hard. This layer has poor continuity.
Layer III	190~540 or deeper	Sand & gravel and sand with boulders.	190~540	Aquifer. Clay is partly sandwiched in the top of the layer.

The layer II (II') is considered as an aquifer for deep tubewell. In the existing well of N-33 (depth: 113.5 m), screen was installed at the upper portion of the layer II. A 19 l/sec of pump discharge was confirmed by the pumping test. In order to obtain about 40 l/sec of the discharge, the proposed well has to be drilled deeper than 150 m.

From the hydrogeological viewpoint, it is recommendable to determine the location of wells in the southern part of Naktajhij Block and the western part of Hariharpur Block, in which the layer II' is distributed, and to drill deeper than 150 m so as to ensure a 40 l/sec of discharge.

3) M-4 block

Classification	Depth (m)	Geology Facies	Resistivity (Ω-m)	Hydrogeologic Evaluation
Layer I	20~30	Sand & gravel (mainly boulders). Fan deposits of the Ratu river.	58~43,500	Aquifer for dug well. Permeability of the layer is inferred to be in the range of 10^{-1} to 10^{0} cm/sec.
Layer II	20~300	Alternation of sand & gravel, sand and clay with partly boulders.	115~213	Aquifer for deep tubewell. Groundwater table is in 30m to 50m deep.
Layer III	210~320	Boulders with sand & gravel.	300~1,400	Aquifer.
Layer IV	240m or deeper	Clay or mudstone of Siwalik formation.	12~73	Aquiclude.

The layer II is considered to be an aquifer for deep tubewell. A 15 l/sec (91 hours continuous test) to 27 l/sec (12 hours continuous test) of pump discharge was confirmed at the test well M-4(A) drilled in the Phase-II. It is recommendable to shift location of wells from the original location determined in the Phase I to the south so as to ensure easy drilling works and 25 l/sec of pumping discharge: in the south area boulders become small and groundwater table shallow. Geologic and electric logs are shown in Fig. 3-5 and yield logging is shown in Fig. 3-6.

4) S-1 block

Classification	Depth (m)	Geology Facies	Resistivity (Ω-m)	Hydrogeologic Evaluation
Layer I	0~36	Mainly sand and sand & gravel. Thin clay layer is sandwiched.	20~420	Aquifer for shallow tubewells and dug wells.
Layer II	22~100	Mainly clay layer. Partly thin sand and gravel layers are sandwiched.	15~37	Aquiclude. It is thick in the center part of the block.
Layer III	32~220	Alternation of sand & gravel, sand and clay.	30~72	Aquifer (sand & gravel and sand) for deep tubewell. Aquiclude (clay). High resistivity value is observed in the western part of the block.
Layer IV	180 or deeper	The detail is unknown. Resistivity value indicates sand & gravel to sand layer or sandstone of Siwalik formation expands.	96~224	Maybe developed as aquifers for deep tubewells.

The layers III and IV are considered as the aquifers for deep tubewells. The layer III is a main aquifer of the existing well N-39. A 15 l/sec of pump discharge can be expected if production wells are drilled deeper than 150 m to 200 m in the area in elevation of 150 m where static water level is shallower than 40 m.

Only 6.1 l/sec of discharge was tested at the existing well (N-39; 165 m in elevation, static water level 48 m).

5) S-7 block

Classification	Depth (m)	Geology Facies	Resistivity (Ω-m)	Hydrogeologic Evaluation
Layer I	0~50	Fine to coarse sand layer (with clay sandwiched)	9~1,470	Aquifer for dug well. Low capacity of yield. Many ponds exist due to poor drainage of clay.
Layer II	13~260	Clay layer.	31~44	Aquiclude.
layer III	200~260	Mainly fine sand layer (or silty fine sand).	62~72	Aquifer seems to have a low capacity of yield because less than 100Ω-m of resistivity was observed.

The layer III is considered to be an aquifer for deep tubewell and is inferred the capacity of yield is low since the layer shows a low resistivity less than 100 Ω-m and is probably composed of the fine sand or silty fine sand layer. This block has to be excluded from the development because a good aquifer was not observed at the test well drilled till 260 m in the Phase-II. A geologic log and electric log are shown in Fig. 3-7.

3.4.4 Probable Pump Discharge in the Development Blocks

Based on the results of field investigation made in the Phase-II, the probable pump discharge in the five blocks (D-7, D-15, M-4, S-1 and S-7) and other blocks (S-4, S-9 and S-10) are assumed as follows.

1) D-7 block

(1) At the existing well (N-15) located at Sonapora, a 36.6 l/sec of discharge at 44.5 m of drawdown was confirmed by a continuous pumping test of six hours. However, the inflow of fine sand and drawdown was

remarkable, so it is assumed that gravel packing and cleaning work were not undertaken satisfactorily.

(2) At the test well D-7(A) drilled in the Phase-II, a 41.2 l/sec of discharge at 6 m of drawdown was examined. This well is an artesian well having a yield of 20 l/sec. A 60% of water seems to flow into from the screens set from 154 to 194 m in depth. No inflow of fine sand was observed during the pumping test. The analysis of pumping test is shown in Appendix 5.2.

(3) Accordingly, a 40 l/sec of probable pump discharge at 9 m drawdown can be expected.

2) D-15 block

(1) At the existing well (N-33) located in Naktajhij, a 19 l/sec of discharge at 3 m of drawdown was examined by a continuous pumping test of 7.5 hours with 45 m pumping water level. At another existing well (N-35) located in Mahendranagar, a 47 l/sec at 8 m of drawdown was confirmed by a nine hour-pumping test with 20.5 m pumping water level.

(2) The drawdown at N-33 was only 3 m so that a 40 l/sec of pump discharge with 7 to 8 m drawdown is probably assured, if new wells were constructed by modernized technology.

(3) Accordingly, a 40 l/sec of probable pump discharge at 7 to 8 m drawdown can be expected.

3) M-4 block

(1) At the test well M-4(A) drilled in the Phase-II, a 20 l/sec of discharge at 4 m of drawdown in 12 hours was examined with 42.0 m of pumping water level, and a

15 l/sec at 2 m drawdown in 72 hours was also examined with 40.0 m of pumping water level. A 60% of water seems to flow into from the screens set from 148 to 159 m in depth. The analysis of pumping test is shown in Appendix 5.2.

(2) The static water level of another well drilled by the Mahottari Groundwater Project is reported to be 14.6 m though the results of pumping test are not reported. This well is located at 3 km southwest fromhe M-4(A) and its depth is 163 m.

(3) The groundwater table of the test well is so low (38 m) that the discharge of more than 20 l/sec is not probable. However, in the area located southwest from the original M-4 block, the depth of groundwater is 3 m shallower and thus a 25 l/sec of pump discharge with 7 to 8 m of drawdown can be expected since the specific capacity of the aquifer is large (7 l/sec/m).

4) S-1 block

(1) At the existing well (N-39) located in Hariwan, inflow of many sand was observed at more than 5 l/sec of pump discharge with 18 m of drawdown (Natural groundwater table; 47.9 m and pumping water level; 66.2 m).

(2) An area lower than 150 m in elevation has to be selected so as to shallow groundwater table and thus to expect a 15 l/sec of probable pump discharge.

(3) It is hardly possible to judge the entire area of S-1 block has very poor groundwater potential, because two deep tubewells drilled by an Indian contractor in 1985 and being used in the sugar factory havethe following pumping rates and features:

No.	Depth (m)	Casing 12" (m)	Casing 6" (m)	Screen 6" (m)	Pumping Rate (l/sec)	Water level Static (m)	Water level Pumping (m)	Specific Capacity (l/sec/m)
2	90	0-25	25-60	19.5	27	13.8	19.2	5.2
3	81	0-24	24-60	18.0	29	14.4	19.2	6.0

Note: The present yield is not confirmed by a pumping test because the sugar factory has been run for 24 hours a day.

(4) However, in order to expect a probable discharge of more than 15 l/sec, it is vital to reselect the development area where the ground elevation is lower than 150 m and the groundwater level is 35 to 40 m. But, whether deep tubewell development shall be taken up or not should be judged from the results of a test tubewell to be drilled in the said area.

5) S-7 block

A test well was drilled up to 260 m in the north of the block, but no promising aquifer was found. So this block has to be omitted from the deep tubewell development.

6) S-9 block

(1) At the existing artesian well (N-37) located in Bhaktipur, a 57.6 l/sec of pump discharge at 22 m of drawdown was observed.

(2) A 50 l/sec of probable pump discharge can be expected.

7) S-4 block

At the existing well (J-22) located in Nawalpur near this block, a 25 l/sec of pump discharge at 4.8 m of drawdown was observed. A 25 l/sec of probable pump discharge can therefore be expected. The drawdown in the production wells could be lower than that of the existing well, since reinforced Johnson type screens and strengthened screens having larger opening

ratio than the slit screens set in the existing well will be installed.

8) S-10 block

(1) At the existing wells (S2 and S5) located near the block, a 27 to 29 l/sec of discharge were examined by small pumps installed.

(2) A 25 l/sec of probable pump discharge can be expected since this block is located in a promising groundwater potential area between Bagmati river basin and Lakhandhi river basin.

The present situation of existing tubewells (17 nos.) and test wells (2 nos.) for which pumping tests were made is summarized in Tables 3-2 and 3-3. The location of those wells is shown in Fig. 3-8.

3.5 Inventory of KR-2 Equipment and Materials

3.5.1 Present Situation

1) The equipment and materials are stored in two places, i.e. Nawalpur Horticulture Farm and TIATSP Center.

2) 14" and 8" casings are stored in Nawalpur. However, more than 30% of 14" casing are deformed in its screw due to the heavy weight of those highly piled up. Those deformed casings have to be connected by welding.

3) 8" screens are classified by a length of 5.25 m and 3.25 m and are stored mainly in Nawalpur.

4) Pipes and shafts for the pump are stored out-of-doors without any protection against rusting though they are in open worked wooden cases. The available quantity has been reduced year by year by heavy rusting. Presumably 20 to

30% of the pipes may have to be replaced or to be resuscitated by cleaning up of screw.

5) In the godowns of TIATSP center, spare parts for the drilling rigs, vehicles and construction equipment, etc. are stored, while out-of-doors in TIATSP center, the drilling rigs, well development tools, vehicles and construction equipment, etc. are parked. The pumps for production wells are stored both in and out-of-doors in TIATSP center.

6) Drilling rigs for deep tubewell construction are to be serviced, especially parts in the mud pumps and hydraulic systems are to be replaced. Also, the drilling tools in each rig are needed to be supplied because of wear and tear and/or inferior storing.

7) Of pipes for tubewell developing one-third of the total seem not to be usable due to the inferior storing after used. The rest is needed to clean up rust and corrosion.

8) Almost all the transportation equipment and the vehicles cannot start by themselves because of exhausted battery or no battery. Several of pick-up trucks cannot be used because of no stock of tire of 6.5 x 15 size in inch.

9) Gear boxes and engines of pumps for production wells are stored indoors. Pump bodies, shafts and pipes are stored outdoors in TIATSP center and in Nawalpur. Screws of the shafts and pipes are rusted and several pieces out of them are deformed. No problem is considered for the engines stored indoors.

3.5.2 Remained and Usable Quantity of the Equipment and Materials

The results of inventory survey of KR-2 equipment and materials for deep tubewell construction are quantified as shown in Table 3-4.

3.6 TIATSP

3.6.1 Project Activities

TIATSP (Tubewell Irrigation, Agriculture, Training and Services Project) was established in January 1986 in succession to JADP (Janakpur Zone Agriculture Development Project) which had been implemented from 1971 to July 1985 under the grant aid assistance and technical cooperation of the Government of Japan.

JADP, aiming at increasing farmers' income and improving living standard and social welfare through the various programs of increasing agricultural production, covers five districts out of six districts of Janakpur Zone (Mountain area of Dolakha was excluded) and implemented the following schemes.

(1) Construction of JADP center in Naktajhij (Main office, Library-cum-Lecture hall, Workshop, Store house, Dormitory for trainees, Quarters for staff, etc.)

(2) Construction of Agricultural Development Offices (one office in each of five districts)

(3) Training for agricultural extension workers, agricultural technicians, farmers, etc.

(4) Operation and management of Sindhuri Agriculture Farm

(5) Operation and management of Janakpur Horticulture Farm

(6) Operation and management of Hardinath Agriculture Farm

(7) Establishment and operation of Nawalpur Horticulture Center

(8) Implementation of Intensive Irrigation and Agriculture Program (IAP) (Irrigation scheme by nine deep tubewells)

(9) Implementation of Irrigated Model Farm (IMF)

(10) Shallow Tubewell Program (STWP)

(11) Deep Tubewell Irrigation Project (DTWIP)

Out of the above schemes, the groundwater irrigation programs of (8), (9) and (10) played the most important role for the agricultural development in the Terai Plain. And DTWIP of (11), by which a remarkable increase of irrigation area was expected, was started just before ending the cooperation period by the Government of Japan, but was suspended on the way because of constraints on finance, technique, materials, etc. and succeeded to TIATSP.

Under the background described above, main programs of TIATSP are set as follows.

(1) Promotion of Deep Tubewell Irrigation Project

(2) Continuation of Shallow Tubewell Program

(3) Construction of irrigation facilities for (1) and (2) above

(4) Extension of irrigated farming technique and training of farmers

(5) Establishment of water users' groups and water management organization

(6) Establishment of operation and maintenance system for irrigation facilities including pumps

(7) Acceleration of on-farm development

His Majesty's Government of Nepal expects Japan's grant aid and technical cooperation for the execution of all the programs except (2) above.

3.6.2 Annual Expenditure and Budget

According to a report of TIATSP, annual expenditures of JADP/TIATSP for the past three years and the budget for 1986/87 are as shown in Table 3-5.

A part of KR-2 counterparts fund (incomes by selling KR-2 materials) has been applied for more than 50% of the expenditures. From the year of 1985/86, when TIATSP was established, the expenditures for extension, training and drilling were increased more than two times, which indicate putting an emphasis on the drilling of deep and shallow tubewells.

3.6.3 Organization and Staffing

The present organization and staffing of TIATSP are the same to those of JADP, as shown in Fig. 3-9, and it seems to be hardly possible to manage the Terai Groundwater Development Project successfully and to operate and maintain the facilities after the completion. Therefore, it is indispensable to fill up the vacancies in each section and to increase the capable staff.

CHAPTER 4. PROJECT CONCEPT

CHAPTER 4. PROJECT CONCEPT

4.1 Objectives of the Project

The objectives of the Terai Groundwater Development Project are 1) to extend irrigated farm land, 2) to increase agricultural production, 3) to raise the incomes and living standards of farmers, 4) to upgrade technology of deep tubewell development, etc., by means of effective use of the drilling and construction equipment and materials granted by the KR-2.

The basic design study is therefore to prepare the basic design and implementation plan required for constructing a number of production tubewells and associated irrigation facilities using the equipment and materials provided by the KR-2 aid and to be newly provided under a general grant aid of GOJ to attain the objectives.

The following investigations and studies were conducted in the Phase-I in 1987:

(1) Test drilling at 4 sites;

(2) Pumping tests at 13 existing tubewells;

(3) Electric sounding at 135 points;

(4) Inventory of the equipment and materials granted by the KR-2;

(5) Selection of potential development blocks of 23;

(6) Topographic survey in the three representative blocks (D-7, M-4 and S-7);

(7) Preparation of an overall development plan for construction of 115 deep tubewells and associated irrigation facilities for 4,600 ha in four years; and

(8) Preparation of the basic design for three representative blocks.

In Phase-II, the following investigations were made in the field to prepare the basic design for the development of the five blocks (D-7, M-4, S-7, D-15 and S-1) planned in the Phase-I to be implemented in the first year:

(1) Drilling of three tubewells, one each in D-7, M-4 and S-7 blocks;

(2) Electric sounding in the 5 blocks for the purpose of siting production tubewells;

(3) Pumping tests at existing deep tubewells, for confirming probable pump discharge in the 5 blocks;

(4) Resurvey of the inventory of drilling and construction equipment and materials granted by the KR-2; and

(5) Topographic survey of development areas in D-15 and S-1 blocks.

4.2 Outline of the Plan Formulated in the Phase-II

4.2.1 Basic Conditions

The overall development plan drafted in the Phase-I cannot be implemented due to the following facts revealed in the Phase-II field work:

(1) No promising aquifer was observed in S-7 block;

(2) Only 20 l/sec of pump discharge was confirmed in M-4 block (pumping water level: 42 m, drawdown: 4 m);

(3) Only 5 to 6 l/sec of pump discharge was observed at an existing tubewell of TIATSP in S-1 block (pumping water level 66.2 m, drawdown 18 m), but 27 l/sec (19.2 m, 5 m) and 29 l/sec (19.2 m, 5 m) of pump discharge was reported at two wells of the sugar factory constructed in S-1 block;

(4) A 40 l/sec of discharge (pumping water level: 6 m, drawdown: 6 m) was confirmed in D-7 block;

(5) A 47 l/sec of discharge (pumping water level: 20.5 m, drawdown: 8 m) and 19 l/sec of discharge (45.1 m, 3 m) were confirmed in the south and north of D-15 block, respectively; and

(6) The facts mentioned above indicate that the hydrogeological structures in the project area change substantially from place to place, accordingly it is judged that the pump discharge estimated from the groundwater potential map prepared in the Phase-I study was unreliable and therefore not usable for the basic design of the Project.

The above findings revealed that the development plan would have to be made for each block after confirmation of a pump discharge of more than 25 l/sec. Accordingly, only two (D-7 and D-15) of the five blocks could be subjected to basic design work.

In M-4 block, re-selection and topographic survey of development areas are required. In S-1 block, drilling of a test tubewell, re-selection and topographic survey of develoment areas are required. Therefore, these two blocks could not be

subjected to basic design work, and S-7 block in which no promising aquifer exists is abandoned from the deep tubewell development.

4.2.2 Basic Concepts

1) Difference between Phase-I and Phase-II

The development plan formulated in Phase-II is quite different from that drafted in Phase-I. These are compared with each other in Table 4-1 and may be summarized as follows:

	Phase-I	Phase-II
1) Overall plan:	To construct 115 nos. of tubewells and irrigation facilities in 4,600 ha of 23 blocks in 4 years.	The overall plan is abandoned. The development plan has to be formulated for every block after confirmation of pump discharge.
2) Plan of production wells:	4 types of standard well are made and applied to 23 blocks.	A different type of well is applied to each block (D-7 and D-15).
3) Plan of irrigation:	A plan worked out for 3 blocks (D-7, M-4 and S-7) is applied to other 20 blocks.	An individual plan is made for each block (D-7 and D-15).
4) Basic design:	Made for 3 representative blocks (D-7, M-4 and S-7) and applied to other 20 blocks.	Made for D-7 and D-15.
5) Materials and equip. plan:	Mde for 23 blocks. New procurement is required. Existing turbine pumps are installed.	Made for D-7 and D-15 blocks. New procurement is required. Existing turbine pumps to be installed.
6) Implement-ation plan:	Made for 23 blocks. 5 blocks are selected for first year.	Made for D-7 and D-15 blocks.

2) Outline of the development plan

The development plan of D-7 and D-15 blocks were formulated as follows:

(1) D-7 block

i) Five production wells including a test tubewell will be constructed. The depth of each will be approximately 200 m. The pump discharge will be 40 l/sec for each well.

ii) Irrigation facilities for 200 ha (5 units) will be constructed. The facilities will consist of 5 pump houses, 5 operator huts, main canal of 8.6 km and related structures.

iii) A vertical turbine pump having a capacity of 45 l/sec granted by KR-2 will be installed in every well.

(2) D-15 block

i) Four production wells will be constructed. The depth of each well will be approximately 140 m. The pump discharge will be 40 l/sec. A fifth well has already been constructed by TIATSP.

ii) Irrigation facilities for 160 ha (4 units) will be constructed. The facilities will consist of 4 pump houses, 4 operator huts, main canal of 6.9 km and related structures. The fifth unit is being constructed by TIATSP.

iii) A vertical turbine pump having a capacity of 45 l/sec granted by KR-2 will be installed in every well. For 4 out of 5 pumps, pump shaft and discharge pipe will have to be expanded to 57 m.

The length of irrigation canal and the number of related structures are explained in the chapter 5 and are shown in Table 5-1. The pump houses and operator huts will be built with brick masonry. The roof and pump foundation will be made of concrete. The irrigation canal and its related structures will be made with brick masonry.

CHAPTER 5. BASIC DESIGN

CHAPTER 5. BASIC DESIGN

5.1 Basic Concept

A basic design is made for D-7 and D-15 blocks where more than 40 l/sec of pump discharge was confirmed and selection and topographic survey of the development areas were also completed. The basic design is made in accordance with the following basic concept.

(1) Production wells are designed in each development block due to different hydrogeological conditions between blocks.

(2) The standardization of structures is made as much as possible in the basic design such as pump station, main irrigation canal and the related structures to facilitate design and construction works and to shorten construction period.

(3) The local construction materials are used as much as possible to facilitate both construction of irrigation facilities and operation and maintenance of the facilities after construction.

(4) Considering the particular conditions in Nepal, the facilities are to be as simple as possible to reduce the construction costs.

5.2 Production Wells

5.2.1 Pumping Water Level and Design Yield

Based on the results of pumping test at test tubewells and existing tubewells, the pumping water level and design yield are determined as follows.

	D-7	D-15	
		Type A	Type B
Project Wells			
Static water level (m)	(Artesian)	42	12
Design yield (l/sec)	40	40	40
Design pumping water level (m)	9	50	20
Existing Wells			
Existing well	D-7A	N-15	N-33	N-35
Static water level (m)	self.	self.	42.1	12.1
Pump discharge (l/sec)	41.2	36.6	19	47
Pumping water level (m)	6.0	44.5	45.1	20.5

The design yield and pumping water level set for the two blocks in the above table are based on the following technical reasons.

1) D-7 block

(1) The result of the pumping test on D-7(A) test tube-well, i.e., pump discharge (yield), drawdown, etc., was adopted for the planning.

(2) More than 60% of pump discharge at D-7(A) (41 l/s, artesian, drawdown 6 m, specific capa. 6 l/s/m) flow into from screens set from 154 m to 193 m in depth.

(3) The hydrogeological structure in D-7 block is confirmed to be nearly same in the entire area by a geoelectric sounding.

(4) The result of the pumping test on the existing N-15 tubewell was not considered, because the tubewell had some technical problems such as use of 8" pipe based slit screens with a small opening ratio of less than 10%, discharging large quantity of sand and gravel during the pumping test, etc.

2) D-15 block

(1) The plan of the production tubewells in the southern part of the block is based on the result of the pumping test on the existing N-35 tubewell. The design yield is conservatively estimated, though the production tubewells may yield more than 40 l/sec because of the use of reinforced and strengthened Johnson type screens having larger opening ratio compared with the pipe based slit screens installed in N-35 tubewell.

(2) A design yield of 40 l/sec for the production tubewell in the northern part of the block is calculated from a drawdown of 8 m by employing a hydrologic formula, referring to the result of the pumping test on N-33 tubewell; 19 l/sec in a 3 m drawdown, though the planned production tubewell will have larger specific capacity than the existing one because of Johnson type screens to be installed.

(3) Although a geoelectric sounding shows the groundwater potential in the northern part is less than in the southern part, it is judged from a specific capacity of N-33 tubewell that the yield of 40 l/sec (drawdown: 8 m) in the northern part is surely possible.

5.2.2 Location of Production Wells

1) Numbers of wells

Five production wells will be constructed in each development block. The test tubewell drilled in D-7 block will be converted to a production well. The existing well (N-33) in D-15 block will be also converted to a production well. Accordingly, four production wells have to be constructed in each block in the implementation stage.

2) Basic condition of locating

The location of production wells in each development block is determined taking the following points into consideration.

(1) To fully use the results of electric sounding made in each block.

(2) Interval of tubewells

Based on the hydrogeological data of the existing tubewells, the influence circle of each tubewell is calculated to be 200 m and 1,000 m in minimum and maximum respectively, because the permeability coefficient and available discharge are widely different from place to place due to the difference in hydrogeological condition of aquifers. As for the existing tubewells, the minimum interval is 500 m among the independent tubewells in Malangwa, southern part of Sarlahi district, and on the other hand, 330 m in the linked tubewells in the IAP area incenter part of Mahottari district. Therefore, the interval of tubewells is determined to be more than 600 m based on the above facts. (The calculation is shown in Appendix 5.3.)

(3) A linked tubewell system is adopted as far as topographic condition allows, to secure equitable and even distribution of irrigation water for each farm.

(4) To minimize a temporary access road between existing farm road and tubewell proposed.

(5) To avoid physical obstructions on the access road such as river, irrigation and drainage canals, etc.

(6) To select higher place than irrigable area for tubewell location as far as hydrogeological conditions

allow, to enable irrigation water to be distributed by gravity.

(7) Protection of existing domestic-use shallow wells

In and around the villages in the two blocks there are many domestic-use shallow wells, utilizing phreatic water (or perched water) in the shallow aquifer, which are used by villagers for drinking and other domestic purposes. They are open wells with a depth of 10 to 20 m and their borehole is protected with precast concrete pipes or bricks to avoid their collapse. In this connection, when production tubewells are constructed, the existing domestic-use shallow wells should be protected from drawdown of their water table and their drying which are resulted from falling phreatic water in the shallow aquifer down to deeper aquifers. Therefore, the production tubewells to be constructed under this project, shall be protected by filling clay, cement, etc. between the casing pipes and the borehole surface down to 25 m depth to prevent the phreatic water from falling down to lower aquifers.

5.2.3 Standard of the Production Well

1) Design of production well

A pump housing is designed to be 14" in a diameter and its length is designed considering specific capacity of the aquifer and drawdown of the groundwater level in future. Based on the above conditions, the production wells are designed as summarized below.

	D-7	D-15	
		Type A	Type B
Static water level	Artesian	42 m	12 m
Specific capacity (l/s/m)	7.4	6.3	5.6
Design discharge (l/s)	40	40	40
Pumping water level	9 m	50 m	20 m
Pump position	25 m	57 m	32 m

Note: Pump position designed to be at least 7 m below the pumping water level, taking into account the drawdown of the water level in the long term.

2) Standard specifications of production wells

On condition that the KR-2 materials and equipment are utilized as much as possible, standard specifications of production well are tentatively determined as follows. The actual casing length will be decided during the construction.

Development Block	D-7	D-15	
		Type A	Type B
Drilling depth (diameter)	0-210m (17-1/2") or (14-3/4")	0-80 (17-1/2") 80-150 (14-3/4")	0-70 (17-1/2") 70-150 (14-3/4")
Thickness of aquifer	44 m	31.5 m	34 m
Casing depth	200 m	140 m	140 m
14" casing pipe	30 m	60 m	42 m
8" casing pipe	120.0 m	42.0 m	66.0 m
Reinforced screen 9.2 kg/cm^2	5.25 m (5.25m x 1 no.)	10.5 m (5.25m x 2 nos.)	10.5 m (5.25m x 2 nos.)
Reinforced screen 16 kg/cm^2	10.5 m (5.25m x 2 nos.)	21.0 m (5.25m x 4 nos)	21.0 m (5.25m x 4 nos.)
Rod based screen to be newly procured	33.0 m (5.5m x 6 nos.)	5.5 m (5.5m x 1 no.)	5.5 m (5.5 m x 1 no.)
Volume of gravel packing	20 m^3	13 m^3	14 m^3

<1: S.W.L., P.W.L. and pump location required for the determination of 14" casing pipe length are shown in the section 1) Design of production well.

5.2.4 Pumps in the Production Wells

Adaptability of two types of existing pump; granted under a KR-2 aid in 1983 to the design pumping water levels and design yields of the production tubewells for each block shown in the preceding section 5.2.3 was studied from pump capacity and fuel consumption points of view, and the following type of pump was selected to be installed in the production tubewells planned for each block.

Pumps to be Installed in Production Tubewells

Block	D-7	D-15
Pump to be applied	Existing vertical turbine pump (45 l/sec)	
Remodelling of pump unit	None	Out of 5, four units are to be remodelled in extending pump shaft and column pipe from the existing 40 m to 57 m.
Improvement to pump unit	An automatic water level detector, stopping pump engine automatically when the water reaches a dangerous level, is to be installed in each production tubewell.	

An extension of pump shaft and column pipe of 45 l/sec type turbine pump and installation of automatic water level detector to each production tubewell can be made at the site without serious difficulty.

Running cost of the pumps installed in the production tubewells planned respectively for each block is estimated as follows.

		D-7	D-15
Pump discharge (l/sec)		40	40
Irrigable area (ha)		40	40
Pump type		45 l/sec type	
Fuel consumption	(l/hr)	6.5	7.0
(1) Fuel cost	(Rs/hr)	52.0	56.0
(2) Lubricant cost	(Rs/hr)	5.2	5.6
(3) Operator cost	(Rs/hr)	2.5	2.5
(4) Pumping cost	(Rs/hr)	59.7	64.1
(5) Pumping cost	(Rs/l/ha)	1.5	1.6

5.2.5 Core Boring and Installation of Groundwater Level Monitors

Geological interpretation in each block has to be made from core samples, since the conventional one, which uses slime samples born by drilling rig, is not always same with exact geology of the drilled hole.

In order to confirm geological situations of each block and to install a groundwater level monitor or automatic water level recorder for long term measurement in each block, which is a prerequisite equipment to control pump discharge of production tubewells and their pump for long term without operation troubles, a core boring will be made in each block, apart from a test tubewell and be then used as an observation well after installing the groundwater level monitor.

However, seven units of drilling rig granted under the KR-2 aid, which are non-core type, are thoroughly occupied to drill both test tubewells and production tubewells.

For the purpose of both the core sampling and the observation well construction, the following equipment and materials will therefore be required:

(1) Wireline type core boring machine — 1 unit
(2) 2" or 4" casing pipes and screens — required quantity
(3) Automatic water level recorder for long term measurement — required quantity

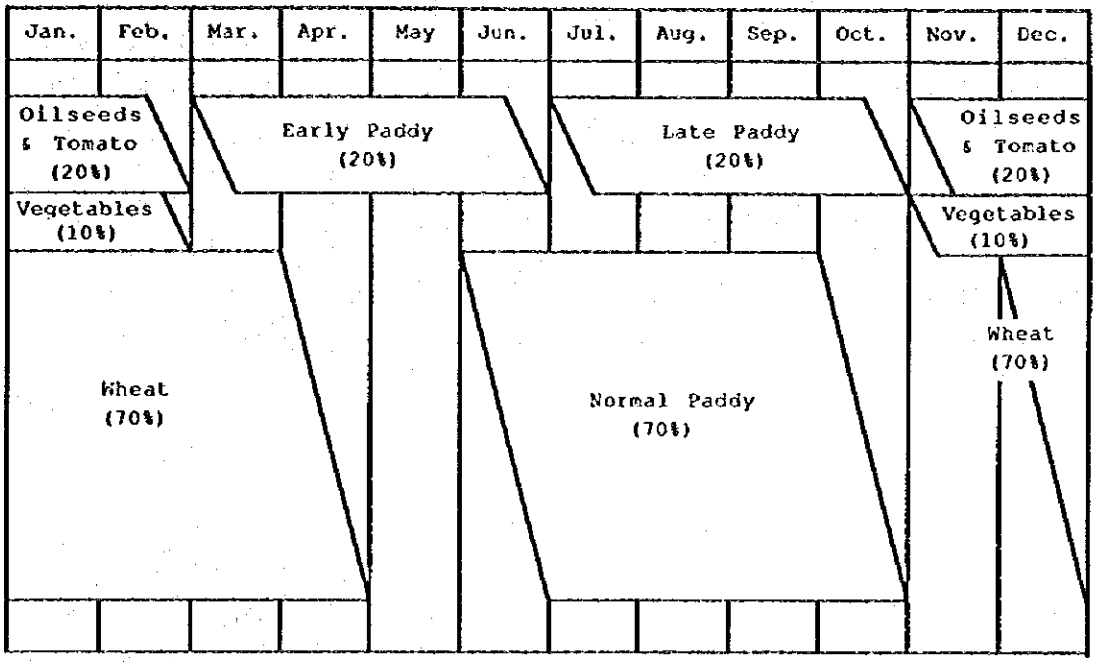
5.3 Irrigation Plan

5.3.1 Irrigation Water Requirement

1) Cropping pattern

The cropping pattern to be applied to the blocks D-7 and D-5 is proposed as shown below, considering that of the STWP being implemented by TIATSP.

Cropping Pattern



Note: Cropping Intensity: 210%

The above cropping pattern may be modified so as to meet the actual conditions of each block such as soil condition, available irrigation water, drainage condition, etc.

2) Irrigation water requirement

The evapotranspiration which is used for calculating the net irrigation water requirement is estimated applying the modified Penman method, because the measured data are not available in and around the project area. Based on the

estimated evapotranspiration, crop coefficient, percolation, puddling water requirement, effective rainfall and operation hours of pump (12 hrs/day), etc., the net irrigation water requirement is calculated. The gross irrigation water requirement at turnout structures for branch canal is calculated for each month considering the conveyance efficiency of 90% to the net requirement as shown below.

(Unit: l/sec/ha, 12 hours' irrigation)

Month	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
W. Req.	0.82	1.04	0.80	0.84	0.74	0.84	0.84	0.80	1.30	1.14	0.20	0.50

In D-7 and D-15 blocks, an unit water requirement of 1 l/sec/ha and a pump operation hour of 12 hours in a day are adopted based on the cropping pattern. The pump operation hour will be extended to 16-hours according to the increase of water requirement.

3) Irrigation method and design discharge

Irrigation water pumped up is distributed to farm by gravity through open channel. A rotation irrigation method is applied. An operation hour of pump is to be 12 hrs/day in the daytime. It will, however, be extended to 16 hrs/day during the peak irrigation period. Regulation pond is not constructed in this project because it requires a difficult leakage protection. A rotation interval is of 7 days (one week). Accordingly, an irrigation unit is divided into 7 or 14 rotation units. Irrigation water is distributed to a rotation unit through a turnout on a main canal.

A probable pump discharge of production well is applied to a design work of irrigation canals. The design discharge of the irrigation canal is to be constant from the beginning to the end of the main canal. The design discharge in each block is determined as follows:

Development block	Design discharge
D-7	40 l/sec
D-15	40 l/sec

5.3.2 Selection of Irrigable Area

Irrigable area is selected according to the following conditions:

(1) The arable land presently cultivated is to be selected.

(2) The land presently irrigated by shallow tubewell or deep tubewell, and the land to be irrigated by other projects are to be excluded.

(3) The land frequently inundated by rivers is to be excluded.

(4) Five production wells will be constructed in one development block.

(5) The production wells are to be located in the area selected in the preceding section 5.2.2. The irrigation water has to be distributed from the well to the field by gravity.

(6) One irrigation unit commanded by one production well belongs to one Panchayat. In addition, the number of Wards is to be as small as possible.

The results of selection are summarized as follows:

(1) D-7 block: A basic design was made in the Phase-I. It is revealed that the northern part could be irrigated by the tubewell (N-15) drilled by TIATSP after Phase-I study. Another irrigation area is

selected for substitution in the western part in the same Panchayat.

(2) D-15 block: The northern part is excluded from the selection due to low potential of groundwater. The southern part is also excluded since it has been developed by shallow tubewell.

Accordingly, the middle part in Naktajhij Panchayat is subjected to selection. Hariharpur Panchayat located east of the Naktajhij Panchayat is also included. Three production wells are selected in Naktajhij Panchayat and two in Hariharpur Panchayat.

An unit irrigation water requirement of 1 l/sec/ha is applied to estimate irrigable area in each block. The details of the irrigable area in blocks D-7 and D-15 are as follows.

Name of block	Pump discharge per production well (l/sec)	Irrigable area		
		(ha)	Panchayat	Ward No.
D-7	40	200	Basahiya	1, 2, 3, 5, 6, 7, 8A, 8B
D-15	40	200	Naktajhij	3, 4, 6A, 6B, 6C
			Hariharpur	2A, 2B, 2C
Total		400		

5.3.3 Layout of Irrigation Facilities

1) Facilities to be constructed

The following facilities are constructed in this project:

- Production well (deep tubewell)
- Pump house and operator hut
- Main irrigation canal and its related structures

The facilities of domestic water supply requires high cost for construction, operation and maintenance works. Considering the particular condition in the project area, a baffle tank equipped to the pump house and irrigation canals are enough for people taking domestic water. Accordingly, the domestic water supply facilities are not particularly constructed in this project.

Main irrigation canal is of open channel type made with bricks which results in cheap cost and easy maintenance. The main irrigation canal has a same flowing capacity from the beginning to the end points. Branch canals from main canal are of earthen type and are constructed by farmers.

The following related structures are constructed on the main canal:

- Turnout,
- Division box,
- Corner box,
- Drop,
- Road crossing,
- Cross drain,
- Cattle path, etc.

Construction of drainage canals, farm roads and inspection roads are not proposed in this project since land acquisition for those seems to be very difficult in Nepal. Operation and maintenance works can be made by walking on canal embankment. The existing farm roads can be used for transportation of agricultural inputs and outputs.

2) Layout of irrigation facilities

The following conditions are considered in planning the layout of irrigation facilities.

- A pump house is provided at the point of production well.

- An operator hut is provided apart from the pump house to avoid noise and vibration caused by the engine and pump.

- The irrigation canal system is so planned as to follow the topography in principle to decrease the embankment volume and as to follow the existing farm border as much as possible to reduce loss of land.

- Since a rotation irrigation method of seven days is applied, seven or fourteen turnout structures are provided and all the sub-units commanded by the respective turnouts are sized to be same.

- A drop structure is provided at the point where the topographic slope is steep and makes too high velocity in canal.

- A cross drain is provided on the natural drainage canal and stream to let flow pass under irrigation canal.

- A road crossing structure is provided for smooth traffic on the canal.

- A cattle pass is provided at proper interval to let livestock pass.

- A division box is provided at the point where two or three irrigation canals are branched out to facilitate water distribution.