GROUNDWATER MANAGEMENT PROJECT IN THE KATHMANDU VALLEY

FINAL REPORT

SUMMARY

JAPAN INTERNATIONAL COOPERATION AGENCY

HIS MAJESTY'S GOVERNMENT OF NEPAL
NEPAL WATER SUPPLY CORPORATION

GROUNDWATER MANAGEMENT PROJECT IN THE KATHMANDU VALLEY

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EXECUTIVE SUMMARY

NOVEMBER 1990

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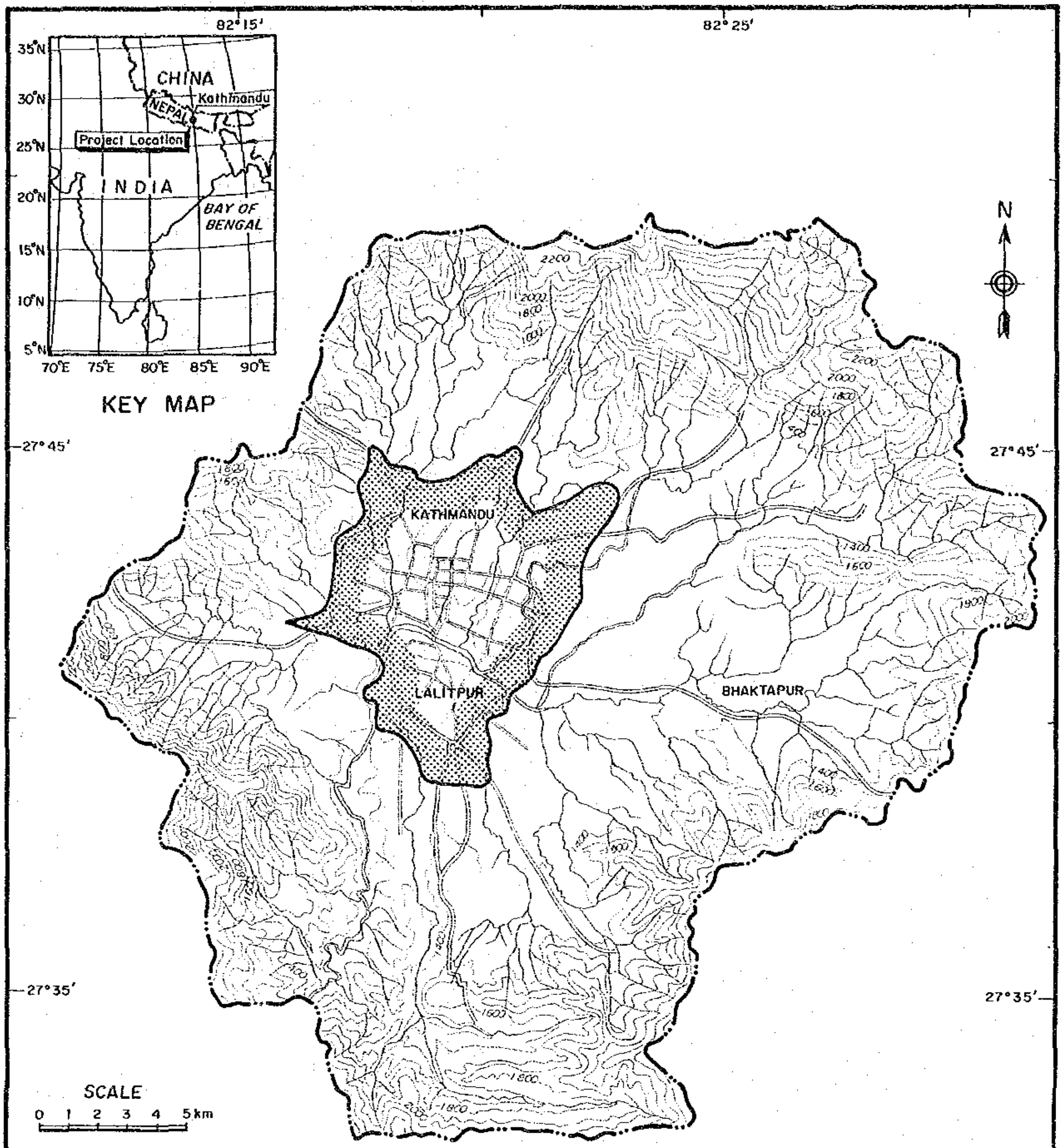


LEGEND

Study Area
(Boundary of the Kathmandu Valley Basin)

1 800 Contour Line at 100m Interval

River

Road

Objective Area for Water Demand Forecast
(Greater Kathmandu)

HIS MAJESTY'S GOVERNMENT OF NEPAL GROUND WATER MANAGEMENT PROJECT IN THE KATHMANDU VALLEY	LOCATION MAP
JAPAN INTERNATIONAL COOPERATION AGENCY	

SUMMARY

A. BACKGROUND

1. The study area is located in the whole Kathmandu valley. The floor is about 1,300 m above sea level and about 585 km^2 in area. The valley is almost fully utilized as agricultural land, with the paddy fields widely distributed over its floor. There are three cities in the valley, Kathmandu, Lalitpur (Patan) and Bhaktapur (Bhadgaon). The valley is populated by about one million (as of 1990) inhabitants, of whom 0.5 million are concentrated in these three cities. The objective area of projected water demand located in the central part of the Kathmandu valley which is composed of urban area of Kathmandu and Lalitpur. Kathmandu and Lalitpur are located side by side and function as one city which is called Greater Kathmandu. Its population is estimated 0.43 million (as of 1990). Kathmandu is the capital of the Kingdom of Nepal and the seat of government administration and all other activities.

2. The municipal water supply system of Greater Kathmandu has a history of more than 100 years, and many of the facilities are superannuated. The executive agency for water supply and sewerage is The Nepal Water Supply Corporation (NWSC) which belongs to The Ministry of Housing and Physical Planning (MHPP). This body was called The Water Supply and Sewerage Corporation (WSSC) before March 1990. In the early 1970's, deficiencies in the water supply became notable. To cope with the needs, a Master Plan was prepared in 1973 by UNDP. The First Project, Second Project and Third Project were executed successively under a loan from IBRD, and were completed in 1987. Their main achievements were construction of a number of reservoirs and transmission pipe lines, as well as 43 deep wells of which 30 wells are in use.

3. The water source before and for the IBRD's projects had been solely surface water. Groundwater was added in the projects. The quantity of water was thus increased to meet demand for the time being, but the quality of the well water was undesirable for the water supply. Since it contained a high percentage of ammonia, ferrous and manganese matters which caused complaints from consumers. Delivered well water has a reddish color, suspended matter and un unpleasant odor, all of which makes the well water unsuitable for the domestic use including drinking, cooking and washing. After a while such well water was mixed with surface water and sent to consumers. This improved the situation to some extent but there was no way to improve the quality and no countermeasures have been taken on this matter. Moreover water distribution to consumers is made by a "twice a day" system which has been practiced since the beginning and the rate of losses including leakage and those unaccounted for are very high.

4. It was stated in the 1973 Master Plan that the water resources of the valley would be exhausted by the year 2001, and it was necessary to search for water outside the valley. In line with in advice a study to find the best new source of water was made in 1989 by UNDP. As a result of this study, and a Melamchi Khola located to the north of the valley was selected and a feasibility study of the waterway tunnel is under way by UNDP. It is intended that water from that source will become available before 2001.

5. To cope with the increasing demand before 2001, it is also necessary to expand the water sources which are available inside the valley before 2001, as well as to establish a plan for water management before 2001. The government of Nepal accordingly requested the Government of Japan to provide technical cooperation on these matters. In response to this request, the Government of Japan organized, through The Japan International Cooperation Agency (JICA), the study team for The Groundwater Management Project in the Kathmandu valley (the study team). The study was commenced in January 1989 in close collaboration with NWSC. By November 1990, field work in the valley and office work in Tokyo had been completed in three phases each. Five reports, Inception, Progress 1, Progress 2, Interim Report and Draft Final Report were prepared and discussions with NWSC were made at each submission of these reports. This present report is a Final Report incorporating the Government's comments.

B PRESENT CONDITIONS

6. <u>Geography and hydrology</u>: The kingdom of Nepal has a territory of 147,181 km^2 and a population of about 18 million in 1990. The country is rectangular in shape and has four different topographic regions in the East-West direction. These are the Himalayas mountain range, Mahabharat mountain range, the Siwalik mountain range and the Terai plain which is the northern fringe of The Ganges alluvial plain. The Kathmandu valley is located to the south of the Mahabharat mountain range, and about 1/3 of the longitudinal side distant from the eastern side. The floor of the valley is situated at about 1,300 m elevation, whereas the surrounding mountains are about 3,000 m above sea level. There is only one drainage system, the Bagmati River which has many tributaries in the valley that are finally unified as a single river. Hence, there is only one outlet from the valley. The drainage area is 585 km^2 at Cobhar which is located close to the final outlet. The floor occupies 400 km^2. The Study Area of the present study coincides with the drainage basin of the Bagmati River. The annual precipitation is 1,300 mm on the floor and 3,000 mm on the slopes of surrounding mountains. The average precipitation over the drainage area is 1,912 mm. There are distinct rainy and dry seasons. The bulk of the annual precipitation, some 80%, falls in the rainy season which starts in June and lasts till September. Evaporation measured by pan is 3.7 mm/day. The annual total run-off of the Bagmati River at the outlet of the valley is estimated at 500 MCM.

7. <u>Land Use</u>: Of the drainage area, about 420 km^2 or 80% are used as agricultural land. Of this area, 220 km^2 are paddy fields and 90 km^2 are upland. About 7,600 ha in total are irrigated by surface flow. There are numerous irrigation systems which depend on the river water. As these irrigation systems are either old or incomplete, all of them have low irrigation efficiencies. In the dry season, only limited areas are irrigated because of decrease in the river flow. Maximum unit irrigation requirement is estimated at 1.2 l/s/ha which occur during the trans-planting period in June. If a master plan study is made to review and rehabilitate existing irrigation systems, it is evident that not only would the agricultural benefits be increase but also a surplus of river flow would be realized which would increase the water resource for municipal water supply.

8.<u>Geology</u>: The Kathmandu Valley is composed of two series of geological successions; one belonging to the Quaternary deposits which underlie the central part of the valley and overlie the basement rocks the other consisting of Precambrian to Devonian (Paleozoic Era) basement rocks surrounds the Valley. Many mountain ridges extend to the valley bottom from the surrounding mountains, implying that there are many buried ridges. The depth to the Precambrian bedrocks from the ground surface is confirmed to range from several tens of meters to more than 500 m. The thick quaternary deposits of central part of the Valley consists of lacustrine deposits and fluvial deposits. The lacustrine deposits are classified into three types which are arenaceous sediments, argillaceous sediments and intermediate types between these two.

9.<u>Present groundwater use</u>: About 60 tube wells were being operated in the valley at end of 1989, and the estimated annual groundwater abstractions from these wells reached around 14 million cubic meters. Of the 60 operating wells 28 belong to NWSC, however the production of NWSC wells amounts to over 80 % of total estimated abstractions from all the tube wells in the valley. About 30 spouts are used in Kathmandu and Lalitpur area for domestic supply to local people. The estimated yield of the largest scale spout varied between about 3 l/s in the dry season and 15 l/s in the rainy season. However, the quality of the spout water is poor as shown by the coliform count of from 50 to 250 per ml, and also the water has a much higher chloride ion content than water from deep well.

10.<u>Trend of groundwater level</u>: The static groundwater level in the Study Area has declined since commencement of the development of NWSC wells in the Third Project. This groundwater development has resulted in a progressive fall of about 10 meters in the water level during the past 4 years in the Manohara well field. This decline in groundwater level is serious since groundwater abstraction is growing significantly every year.

11.Water quality of groundwater: A high concentration of iron(Fe) in a range of 1 to 3 mg/l, ammonium(NH_4+) in a range of 0.05 to 6.5 mg/l, nitrogen(N) in a range of 0.1 to 4.8 mg/l and potassium permanganate ($KMnO_4$ Cons.)in the range of 3.9 to 16 mg/l are confirmed in most of NWSC tube wells in the valley. However ,such high concentrations of ions are not found in the surface water sources of NWSC.

12.Hydrogeology : Availability of groundwater recharge in the valley is controlled by the widespread distribution of lacustrine deposits interbedding the impermeable black clay which prevents easy access to the aquifers. In northern part of the valley, the upper deposits are composed of unconsolidated highly permeable materials which consist of micaceous quartz sand and gravel. These unconsolidated coarse sediments are as thick as 60 m and forms the main aquifer in the valley. The quality of the groundwater is characterized by low electrical conductivity such as 100 to 200 micro-simens/cm and the transmissivities of the aquifers range from 83 to 1,963 m^2/day.

13. In the central part of the valley,the upper deposits are composed of impermeable very thick (as thick as 200 m)stiff black clay accompanied by some lignite.Unconsolidated low permeable coarse sediments underlie this thick black clay. The quality of the groundwater is characterized by very high electrical conductivity, 1,000 micro-simens/cm in some wells located near Tripueswor. The transmissivities of these aquifers range from 32 to 960 m^2/day. Generally, water head pressure of this area is high, especially all deep gas wells are self-flowing. According to dating analysis, age of gas well water is about 28,000 years. This mean that the confined groundwater of the central area is probably non-rechargeable stagnant or "fossil" groundwater.

14. The southern part of the valley is characterized by a thick impermeable clay formation and basal gravel of low permeability. The aquifer is not well developed and is only recognized along the Bagmati river between Cobhar and Pharphing

15.Recharge : The main aquifer in the valley is a nearly isolated body surrounded and confined by lacustrine deposits. Therefore the flow of water in the aquifer is quite small as confirmed by water chronological analysis by C^{14} and Tritium. Average permeability of the aquitard in the main aquifer is estimated at 0.00033 m/day, or 12 cm/year.

16.Existing Water Works: There are eight (8) water supply systems managed by the NWSC in the valley for Kathmandu-Lalitpur (Greater Kathmandu) and two (2) systems for Bhaktapur. Of the former, the three (3) systems for Chapagaun, Dood Phokari and Lokhat use springs as the water source mainly to supply to villages around the cities.In the other systems, the water sources are surface water and/or groundwater, and the water is collected either at a treatment plant or reservoir, from where it is distributed to the cities. As a result of the

investigation, the available water sources for water supply in the valley can now be assumed to amount to 60,540 m^3/day from the surface water and for 55,620 m^3/day from groundwater, amounting to about 116,160 m^3/day. For the groundwater, however, because of the extreme drawdown caused by mutual interference due to the close proximity of many wells, in addition to such factors as facility repairs, electrical faults, etc., the actual abstraction of groundwater may be assumed to be much less than the above the mentioned value.

17. Water Quality: Chemical analyses of existing water resources during dry and rainy seasons have shown that the springs have stable water quality both in the dry and rainy seasons, neither is there any problem with river water as a resource for water supply, if appropriate treatment is applied, although its turbidity may increase immediately after rainfalls in the rainy season. However, groundwater, except for that from the Pharphing well field, contains very high levels of iron, manganese and ammonia, which exceed permissible levels as a water source for water supply. The currently practice of supplying groundwater without treatment results in additional problems.

18. Water Supply: Both surface water and groundwater from all sources, either remain untreated or after treatment through the treatment plants of each system, are stored in the distribution reservoirs, from where they are distributed to the cities through the intermittent supply approximately for three hours each in the morning and evening. The main distribution reservoirs for the Greater Kathmandu are the Balaju, Bansbari, Maharajganj, Mahankal Chaur and Shaibhu reservoirs. According to an analysis of their operation records of August 1989, the daily average supply amount from the above 5 reservoirs amounted to 61,155 m^3/day, of which surface water and groundwater amounted to 39,199 m^3/day and 21,956 m^3/day respectively.

19. Treatment Works: There are now five water treatment plants, at Balaju, Maharajganj, Sundarijal and Sundarighat for the Greater Kathmandu, and at Bansbari for the city of Bhaktapur. One of these, the Sundarighat water treatment plant used to take raw water from the Bagmati, but has recently been shut down because of heavily contaminated raw water due to the increased inflow of an urban sewer. The following describes both the facility and existing status of operating and maintaining each water treatment plant.

20. Balaju Treatment Plant: The Balaju treatment plant was constructed in 1961 to treat the surface water from springs at five locations within the Bisnumati basin. The design capacity is 10,900 m^3/day. When the turbidity of raw water is high, it is designed to add a coagulant to the raw water, but in practice no coagulant is added and the raw water is sent directly to the sedimentation basin. Because of imposing an excessive load on the filter basin and of insufficient coagulation, as well as inadequate washing, the filter media are too contaminated for satisfactory filtration. For disinfection, bleaching

powder is added, but as the quality of filtered water is bad, the residual chlorine is found to be about 0.1 ppm or less in the reservoir.

21.Maharajganj Treatment Plant: This treatment plant was constructed in 1960, and treats the surface water from such springs at Bisnumati and Shivapuri. The design capacity is 2,400 m^3/day.The sedimentation basin was demolished in 1987 due to severe water leakage, and the raw water is now flowing directly into the filter basin. For this reason and because of inadequate washing facilities, as well as the excessive load imposed on the filter basin, the filter media are substantially contaminated.For disinfection, bleaching powder is added, but because of the untreated groundwater flowing into the reservoir from the Bansbari reservoir, as well as the poor quality of the treated water, the residual chlorine is less than 0.1 ppm in the reservoir.

22. Sundarijal Treatment Plant: This treatment plant was constructed in 1966. The water resource for this treatment plant is Bagmati river water from the Sundarijal Dam which was constructed for the Sundarijal hydroelectric power plant. The design capacity is 19,600 m^3/day.When the turbidity of the raw water is high during the rainy season, both a coagulant (alum) and lime are added. But the rate of dosage of both the coagulant and lime is insufficient. The raw water, after the addition of chemicals, is mixed in the channel, then sent to the sedimentation basin. There are three filter basins, each being washed daily. Because the chemical dosage is insufficient and because the capacity of the back washing tank is not enough to continue the washing for a sufficient time, the filter media are contaminated. For disinfection, bleaching powder is added. After chlorination, water is supplied to villages along the transmission line, and then stored in the Mahankal Chaur reservoir.

23. Bansbari Treatment Plant: This treatment plant treats Mahadev Khola river water and supplies it to the city of Bhaktapur. The design capacity is 4,900 m^3/day, but because this plant is not provided with a chemical feeding facility, the raw water flows directly into the sedimentation basin without the addition of coagulant. Especially when the turbidity of the raw water is high during the rainy season, it remains unsettled in the sedimentation basin and flows directly into the filter basins. There are three filter basins. But, for lack of washing equipment, washing of filter materials is manually performed by removing them from the basins.For disinfection, bleaching powder is added to the reservoir. The residual chlorine was found to be about 0.1 ppm in the dry season, but less than 0.1 ppm in the rainy season.

24. Distribution System: Water is now being supplied intermittently to Greater Kathmandu and Bhaktapur from the reservoirs of each system for approximately three hours in the morning and evening. This hourly supply method has been employed ever since water supply commenced in the Kathmandu valley.On the other hand, villages around these cities are mostly situated along the transmission

lines from the water resources up to the reservoirs or treatment plants, through which water is supplied to them directly. The reservoirs were greatly increased in the capacity after the First and Second World Bank projects. The capacities of the reservoirs are now 24,500 m^3 and 5,600 m^3 serving Greater Kathmandu and Bhaktapur respectively.The reservoirs at Balaju, Maharajganj, etc. are now suffering from water leakage as a result of their deterioration. The Bansbari and Shaibhu reservoirs are both insufficient in capacity, causing overflows between the water supply hours.

25. Distribution Networks: Since the distribution networks in cities have been expanded in a disorderly way over a long period to keep pace with increasing demand, both new and old multiple pipelines have been laid under the same roads thus resulting in a very complex distribution system. Incomplete distribution systems also fail to maintain uniform water pressure, often causing water cuts at the ends of the pipelines. For this reason, water is supplied in distribution blocks by carefully operating the valves within the systems during the hours of water supply.The quality of water supplied right after starting the water supply and certain time thereafter was analyzed. Results show that the water quality right after starting the water supply contains very high levels of contaminating substances, which decrease as time goes on. This is attributable to the entry of such substances between supply times and flushing in the pipelines due to the sudden change in the flow velocity caused right after starting the water supply. This is a product of the intermittent water supply method.In this survey, on-site analysis of residual chlorine was made simultaneously upon sampling water. No residual chlorine was found, except from samples in the city of Lalitpur being supplied from the Shaibhu reservoir where the water quality is relatively good.These results indicate that if the water contains very high levels of ammonia, iron and manganese, but lacks residual chlorine, the inside of the distribution system becomes a favorable breeding environment for iron bacteria, nitro bacteria, etc.This results in increased chlorine consumption, as well as in deterioration of the water quality within the distribution pipes. Therefore, the current water quality can not kill pathogenic bacteria and causes the discharge of bacteria and colored water from taps.

26. Required Residual Chlorine and Anti-Corrosion: The level of residual chlorine to be maintained in the tap water must be sufficient to kill such pathogenic bacteria as those causing dysentery, typhoid, etc. Generally, this level has to be 0.1 ppm or upwards as free residual chlorine, while more than 0.2 ppm is necessary during epidemics or right after resuming the service after interruption of supply. Meanwhile for the anti-corrosion program, the past examples have shown that effective results were obtained when the pH was 7.5-8.0 and the Rangelier's index -1.0 or upwards. The Rangelier's index however was -1.50, -2.65 and 0.08 for the Balaju, Mahankal Chaur and Shaibhu systems, respectively. It may be deduced, therefore, that water supplied other than from the Shaibhu system are high corrosive.

C.DEMAND

27. Population Projections: The future populations of urban areas in the Kathmandu and Lalitpur Districts have been projected by many investigators for various projects since 1973. However, the population projections in previous studies vary widely. In the present study, a careful review is made on the two latest studies; by Proctor and Redfern(1984) and by Binnie and Partners(1988), and further a population projection was made by a different method from these studies to examine the large difference between their projections. The result of the present study together with the above-mentioned projections may be summarized as follows:

Studies	Urban Population (,000)			Average Annual Growth Rate (%)*		
	1981	1991	2001	1971-1981	1981-1991	1991-2001
(A)P & R, 1984	316	479	729	4.08	4.16	4.20
(B)B & P, 1988	316	593	958	4.08	6.29	4.80
(C)Present Study	315	486	734	4.08	4.34	4.12

*Exponential model
P & R: Proctor and Redfern
B & P: Binnie and Partners

As is obvious from the above table, that the population forecast in the present study (C) is close to that by Proctor & Redfern (A). The relatively high forecast of population by Binnie and Partners was due mainly to the high growth rate which was estimated from voter's lists for the period 1981-1986. However, since it is difficult to examine the reality of the above growth rate in course of the present study since it may have been influenced by social and political factors outside the scope of the study, the water demand study for urban areas of Kathmandu/Lalitpur, which is discussed in the succeeding paragraph, was carried out on the basis of the population projected in the present study.

28. Present Water Demand:In order to understand how the water supply is actually being used, a consumer survey was conducted during the 1st and 2nd field investigations. The number of samples were 52,246 for the first survey and 24,693 for the second survey respectively. In the first survey, the average consumption per connection, per capita consumption, number of consumers per connection, type of toilets, monthly average consumption, etc., were surveyed. The second survey covered the category of connections (functioning, metered, non-functioning metered and non-metered), category of use (domestic, commercial, industrial and institutional), number of consumers per connection, consumption per connection, etc. Through these surveys useful information was obtained which could not be obtained from the existing data. The original unit of consumption by use can be applied only to data on functioning metered connections, since the original

unit of consumption by use for nonfunctioning metered connections and non-metered connections was found to be respectively 1.10 and 1.77 times of that of functioning metered connections. The monthly consumption pattern was estimated from both the actual monthly consumption of functioning metered connections and the variation in average monthly temperature.

29. Planned water Supply Amount:Water demand projections for establishing the water supply plan up to the year 2001 as the planned water supply should thus be based on the following conditions:

(a) The population to be served is assumed to be that derived in the above mentioned population projection.

(b) Both the non-functioning metered connections and nonmetered connections are assumed to be improved at the rates of 40% in 1991, 20% in 1992 and 1993 and 10% in 1994 and 1995.

(c) For the per capita domestic consumption, an annual increase due to the popularization of cistern flush toilets is assumed to be 0.37 lcd, and the annual increase in the rate due to the livelihood level advancement is assumed to be 2.5%.

(d) The rate of water leakage is assumed to be improved in accordance with the implementation plan for rehabilitating the distribution system under IDA (20% in 1991, 15% in 1992 and 1993, and 10% in 1994 to 1998). The ultimate objective of the improvement is a saving of 25%.

D.OPTIMUM WATER MANAGEMENT PLAN

30.Criteria :Establishment of the plan for water supply facilities up to the year 2001 will be based on the following conditions:

(a) The development plan for the water supply facilities will consist of developing water sources to meet future water demand, constructing new facilities, and rehabilitating existing facilities to supply safe and potable water.

(b) The additional water resource from outside of the Kathmandu valley will become available after the year 2001 following completion of the water conveyance facilities from outside of the valley.

(c) In order to conserve groundwater resources, abstraction of groundwater will be reduced from the current production amount, and the level of the groundwater shall not be allowed to be lower than the yield computed by simulation.

(d) The increasing water demand up to 2001 shall be supplied from water resources within the valley. The groundwater resources are limited, so development of water resource must depend solely on surface water.

(e) In regard to the surface water development plan, all available surface water sources within the valley shall be examined and then determined.

(f) The available capacity of the surface water, which will be the sole source, will have a high level of monthly variation so the water supply facilities to be established shall coordinated with the planned monthly water supply.

(g) The groundwater shall, without exception, be treated with bio-filters to remove ammonia and iron.

(h) Disinfection equipment shall be expanded and established at all water treatment plants.

(i) The water supply area per system shall be established to minimize the effects upon the quality of water supplied at connections due to variation in the flow rate through the distribution system.

(j) The order of precedence of established schemes shall be decided through comparative examination of the many available implementation plans for improving both quality and quantity.

31. Mathematical Model Simulation on the main aquifer: The FEM mathematical model simulation reveals that

(a) The recharge source of the main aquifer is leakage water through aquitard deposit or squeezed from the aquitard deposit;

(b) The present rate of groundwater abstraction is twice as much as the available capacity. The abstraction should not exceed the critical abstraction amount of 15,000 m^3/day which is linked with conditions such as pump capacity, upper rim of the main aquifer, depth of strainers and well loss.

(c) Artificial groundwater abstraction will cause leakage (or squeeze) of water from upper layers, which may result in stable,or steady condition. But if the abstraction volume reaches or exceeds the critical capacity of 15,000 m^3/day, the pump efficiency will fall and several social problems such as subsidence will occur.

32. Optimum Operation: Optimum pump operation have been established by the Modified Simplex Method. The contributions of each well field will be:

(1)	Bansbari Well field	6,936 m^3/day	(44%)
(2)	Balaju Well field	1,000 m^3/day	(6%)
(3)	Gokarna/Manohara Well field	6,093 m^3/day	(39%)
(4)	Pharphing Well field	1,600 m^3/day	(10%)
	total	15,629 m^3/day	(100%)
		(15,000 m^3/day)	

33. Surface water development: A development plan for surface water in the valley has been formulated to meet the future water demand in Greater Kathmandu up to the year 2001 through exploitability study of all conceivable schemes. In the valley, there are some sixty Government-aided and local farmers' irrigation intakes and nine (9) NWSC's municipal water intakes, where river water is mostly used in the dry season. Therefore, the development plan has been made so as not to interfere with the present arrangements for water abstraction.

34. River water development: For effective use of net surplus river water, additional run-of-river type intake schemes are proposed on six rivers. In this study, two types of intake facilities are envisaged in consideration of site conditions and for ease of operation and maintenance: One is a ground-sill type for the three rivers Manohara, Dhobi Khola, and Lambagar Khola, and the other is a concrete weir type for the Balkhu Khola and Bisnumati river. In the Bagmati river, the existing low intake dam of the Sundarijal hydro-power plant could be used also for further water intake. Their planning rate of abstraction will vary seasonally up to 0.15 m^3/s at a maximum according to natural variations in available river water with proper reliability, say more than 80% dependability on average.

35. Storage reservoir schemes: Storage reservoir schemes have also been studied as the valley's own water source development. The Balkhu Khola. reservoir scheme, located to the west of Kirtipur, has the highest reservoir yield potential of 0.8 (m^3/s) and the highest storage efficiency (effective storage volume divided by dam volume) and appears to be economically superior. However, Bishnu Devi Temple which would be submerged after reservoir impounding is religiously important to local people. Unless this social problem can be solved in advance, this scheme's implementation would be impossible.The Nakhu Khola. dam scheme (at Tikabhairau, $Q=0.6m^3/s$) and Kodku Khola. dam scheme (at Baregau, $Q=0.3m^3/s$) with the Nakhu Khola. water transfer are expected to be attractive in view of their economical superiority and the absence of great technical constraints to their implementation, though compensation would have to be paid for agricultural land to be inundated.

36. Water Quality Improvement Plan :The groundwater has very high levels of ammonia, iron and manganese, and is not suitable as a source of water supply, if it remains untreated. Ammonia, iron and manganese are not necessarily directly injurious to the health, but they consume a great deal of the chlorine added for chlorination, and this creates the problem of reducing the residual chlorine enough so that it is sufficient for preventing the growth of water-borne disease organisms in the distribution system.

Although both iron and manganese can be treated by normal methods, such a high level of ammonia has never been treated in the field of waterworks.

There are several methods of treating ammonia, however, most of which are

very expensive and some may generate harmful byproducts such as triphenylmethane gas. Among these methods, an unprecedented experimental biological filtration method was tried out during the field investigation and resulted in excellent treatment effects and without the defers mentioned above. It is recommended, therefore, that groundwater in the valley be treated by this method.

A water quality improvement plan was therefore determined on the basis of a comprehensive treatment system for the groundwater consisting of bio-filtration, coagula-sedimentation and filtration for iron removal, and of a conventional treatment system for the surface water. The following describes the proposed water treatment plan for each system.

37. Balaju system:The water resource for this system consists of the existing surface water source (8,700 m^3/day) and a groundwater source in the Balaju well (600 m^3/day).

The existing Balaju treatment plant, where almost no output is assumed due to deterioration, is to be reconstructed to have a treatment capacity of 9,300 m^3/day. The existing distribution reservoir which has serious leakage shall also be rehabilitated. Treated water shall be stored in this distribution reservoir and then supplied (9,000 m^3/day) to consumers by gravity flow. The treated water of 4,300 m3/day from the Lambagar treatment plant will also be sent to this distribution reservoir and then into this system.

38. Lambagar system: The water source for this system will be the surface water to be taken in through a new run-of-river intake (14,300 m^3/day) from the Lambagar Khola (W105). A conventional water treatment plant (13,000 m^3/day) will be newly constructed for this system.

The treated water will be sent in part to the Balaju system and the remainder of some 8,300 m3/day shall be sent to a new distribution reservoir (2,400 m^3/day) through a new transmission pipeline. The water shall be supplied to consumers either by booster pumping system or by gravity flow.

39. Bansbari system: The water resource for this system will consist of the existing surface water source (2,100 m^3/day) of the existing Maharajganj treatment plant, surface water to be taken in through a new run-of-river intake (14,300 m^3/day) from the Bisnumati (W106), and the groundwater source of the Bansbari well field. The groundwater will first be pre-treated through bio-filters and then be treated through a new conventional water treatment plant (21,500 m3/day) together with the surface water. Of the treated water, 6,900 m^3/day will be supplied to the north area of the city of Kathmandu via the existing Bansbari reservoir (2,000 m^3) by gravity. The remaining water of 13,900 m^3/day will be sent into the Maharajganj system.

40. Maharajganj system: The existing water treatment plant will be demolished and the existing distribution reservoir (3,750 m^3) will be reconstructed to be supplied via a new water transmission pipeline from the new Bansbari treatment plant. 13,900 m^3/day will be supplied from the reservoir by gravity.

41. Mahankal Chaur system: The water source for this system consists of groundwater in the well fields of Gokarna, Manohara and Dhobi Khola, surface water in the Bagmati (W301) from the penstock of the Sundarijal hydroelectric power plant, and the surface water to be taken through a new run-of-river intake from the Dhobi Khola (W202).

The groundwater will first be pre-treated by bio-filters (18,600 m^3/day) to remove the high concentrations of both ammonia and iron and then will be treated in a new conventional water treatment plant (32,900 m^3/day) together with the surface water.

The treated water will be sent by pumps into the existing distribution reservoirs (9,000 m^3) and then be supplied to the central area of the city of Kathmandu.

42. Sundarijal system: The water treated in the existing water treatment plant is currently sent into the Mahankal Chaur reservoir but this will be diverted into the new Sundarijal system.

The existing Sundarijal water treatment plant will be reconstructed with a capacity of 20,600 m^3/day. The treated water will be sent to three water distribution reservoirs (1,850 m^3 x 2 basins and 1,550 m^3 x 1 basin) to be newly constructed in the water supply area to the east of the city of Kathmandu through the existing transmission pipeline into the Mahankal Chaur reservoir and a new transmission pipeline by which the water will then be supplied at a rate of 6,400 m^3/day, 6,400 m^3/day and 5,200 m^3/day.

43. Shaibhu system :The water source for this system consists of existing spring water and groundwater in the Pharphing well field. The water supply area is the city of Lalitpur. To ensure that water of 24,500 m^3/day shall be reliably supplied to consumers for 5 hours each in the morning and evening supply, a 4,500 m^3 distribution reservoir together with a distribution main shall be newly constructed, in addition to the existing distribution reservoir (2,700 m^3) and distribution main. Disinfection equipment shall also be newly constructed.

44. Manohara system: The water supply area is the southeast part of the city of Kathmandu. A conventional water treatment plant shall be newly constructed with the surface water source taken by a new run-of-river intake from the Manohara (W406). The treated water will be sent into two new water distribution reservoirs (1,850 m^3 each) within the water supply area from which 6,300 m^3/day

will be supplied to consumers by a booster pump system.

45. Balkhu system: The water supply area will be the southwest area of the city of Kathmandu. A conventional water treatment plant will be newly constructed for the surface water resource taken in through a new run-of-river intake from the Balkhu Khola (W802). The treated water will be sent into two new water distribution reservoirs (1,850 m^3 each) within the water supply area and 6,300 m^3/day will be supplied to consumers from one reservoir by gravity and the same quantity from the other reservoir by booster pump type.

46. Concept on Implementation Plan: In order to meet the water demand up to the year 2001 on both aspects of quality and quantity, the priority for establishment of each scheme of water supply facilities should be determined by the following conditions.

(a) The water supply to be increased by implementing the schemes shall balance the increase in water demand.

(b) No existing supply capacity will be disturbed.

(c) A scheme with a groundwater source that causes problems in terms of both water quality and quantity, shall in principle take precedence over all other systems, including the expansion of a new surface water source in the systems concerned.

(d) A scheme which will include refurbishment of an existing water treatment plant shall be quickly completed, including expansion with a new resource of surface water in the systems concerned.

(e) A new scheme with a completely new resource of surface water shall be implemented last.

(f) Through consideration shall be given to the workability and economy of the foregoing.

(g) Among the afore-mentioned surface water schemes, the storage dam schemes will not be needed before 2001. Hence these schemes are not taken up in this study, but proposed as an element to be considered when the plan after 2001 is studied.

47. Implementation Plan: As the result of comparative examination for many available implementation plans, the following implementation order is recommended:

Precedence	Scheme	Main objectives
1	Mahankal Chaur	Quality improvement of groundwater New treatment plant Development of surface water
2	Bansbari, Maharajganj	Quality improvement of groundwater New treatment plant Development of surface water Improvement of reservoir (Ban. only)
3	Shainbhu	Expansion of transmission pipeline and reservoir
4	Balaju	Renewal of existing treatment plant and reservoir
5	Lambagar	Development of surface water New reservoir, treatment plant and transmission pipeline
6	Sundarijal	Renewal of existing treatment plant New reservoir and transmission pipeline
7	Manohara	Development of surface water New treatment plant New transmission pipeline
8	Balkhu	Development of surface water New treatment plant New transmission pipeline

E.GROUNDWATER MANAGEMENT PLAN

48. Criteria

a) Groundwater resources in the valley should not be exhausted.

b) The critical groundwater yield shall be obtained by the optimization simulation, and abstraction of groundwater shall not be allowed to exceed the critical level.

c) During the dry season the potential of surface water sources of the valley does not satisfy the demand of water supply. Hence groundwater management will have to be carried out by a combination of well operation by standard production wells with due regard to conjunctive use.

d) Groundwater monitoring and subsidence monitoring is required to manage the groundwater

49. Groundwater Management Plan: The critical groundwater yield potential of existing NWSC wells (excluding Bhaktapur well field) for the groundwater management of the Kathmandu Valley is estimated at about 15,000 m^3/day with selected standard wells based on groundwater simulation methods. It is recommended that pump yields be controlled to avoid excessive drawdown.

50. Well Operation: Because, during the dry season the potential of surface water resources of the Kathmandu Valley does not satisfy the demand of water supply, groundwater management should be carried out by combination of well operation by standard production wells with due regard to conjunctive use. However, if the total amount of groundwater yield of the standard production wells does not meet the peak demand in the dry season (mainly April and May) then, supplementary groundwater pumping will be required not only from the standard wells but also from other production well during the dry season.

51. Conjunctive Use: In order to achieve conjunctive use, the existing NWSC production wells (excluding Bakutapur well field) have been classified into three groups, namely standard production wells, extra production wells and monitoring wells by a groundwater model simulation method. Twelve production wells have been selected as standard production wells for optimum groundwater management. Other production wells have been chosen as stand-by or extra wells to meet the shortage of surface water during the dry season. Therefore, during the rainy season standard operation pumping is to be carried out with standard production wells. In the dry season peak pumping operations after 1994 will be carried out by all production wells except monitoring wells, on condition that the annual discharge amounts of all NWSC production wells (excluding Bhaktapur well field) shall be controlled to be less than 15,000 m^3/day on a yearly average.

Peak operation forms an exception to the general operation rule. Therefore, careful groundwater monitoring is required to conserve the aquifer. In order to observe the groundwater level, three wells have been selected from NWSC wells and four JICA observation wells as a monitoring well for each well field.

52. Groundwater Monitoring: Monitoring methods include not only groundwater level monitoring, but also production monitoring, water quality monitoring, and subsidence monitoring. The information from these monitoring systems will indicate the time for improvement of future predictions before depletion of the aquifer. Also, the subsidence monitoring is important to preserve the Kathmandu Valley from subsidence.

F.PROJECT COST AND EVALUATION

53. Costs of Projects: For the purpose of determining the priority and for the provisional project evaluation, the projects' costs are estimated provisionally. The results are as follows; namely

Precedence	Project	Foreign Currency Portion	Local Currency Portion	Total
1	Mahankal Chaur	14,030	4,300	18,330
2	Bansbari, Maharajganj	11,599	3,816	15,417
3	Shaibhu	3,579	1,346	4,925
4	Balaju	4,271	973	5,244
5	Lanbagar	11,118	4,452	15,570
6	Sundarijal	11,118	4,452	15,570
7	Manohara	12,746	5,988	18,734
8	Balkhu	11,230	5,790	17,020
	Total	76,774	29,717	106,491

(Unit: US$ Thousand or equivalent)

54. Project Evaluation, Economic Analysis: The economic analysis has been made on the assumption that all the above mentioned eight schemes (projects) will be implemented so that the benefits and the costs of the eight projects may be treated together.

Tangible benefits will be: (1) those caused by the quantitative increase in the amount of water to be supplied and (2) those caused by the decrease in illness and epidemics owing to the improvement of water quality. The benefits will commence in the year following completion of the first projects and will grow to full benefits of US$ 4,115 million per year in year following full completion of the eight projects, namely in 2001. These full benefits will occur every year until 2023, and will disappear as the economic lives of the projects expire. The benefits will thus all disappear in 2031. In comparison of these benefits with the costs of the projects (construction cost and the OMR costs), the economic internal rate of return (EIRR) is estimated at 3.4 %.

55. Project Evaluation, Financial Analysis: On the assumption that all of the construction costs of the project will depend upon loans, the following model is assumed. Namely,(1) the rate of interest is 1 %, (2) the grace period is ten years, and (3) the repayment period is 30 years including the grace period. As to the income, two models are assumed, namely (1) 1.5 % of the house hold income and (2) about four times of the current tariff. In either case, the financial rate of internal rate of return (FIRR) is estimated at less than 2%. However, the loan will be fully refunded during the projects lives of 30 years until 2030, and the income will at all times be more than the relevant operation expenses.

56. Judgement: A municipal water supply project is normally accompanied by low value of internal rate of return (IRR). Nevertheless, implementation of this project provide safe and suitable drinking water to the inhabitants as a basic human needs. Moreover, Nepal is one of the countries whose gross domestic product (GDP) per capita is the lowest in the world. For these reasons, it is judged that these projects are viable.

G. CONCLUSION AND RECOMMENDATION

57. Conclusion: At present, groundwater in the valley is being pumped excessively. The amount pumped has to be decreased to the allowable amount by management. New water sources from surface water are available by the run-of-river method of $0.15m^3/s$ (or 12,600 m^3/day). In the initial stages of developing the surface water, an occasional shortage of water will occur.

58. As a new development, it is necessary to implement the eight projects proposed herewith one after the other so that all of them may be completed by 2001. The fundamental purpose of municipal water supply is to supply the quantities needed of safe and hygienic water containing the necessary amount of residual chlorine at the users' taps. So long as the groundwater of the valley is used, the obstacle to quality will be the high content of ammonia. In purifying the ammonia contained water, ammonia consumes about ten times the amount of chlorine as compared with purifying the same amount of ferrous and manganese contents. Moreover, it can originate matters which are harmful to the human body. Therefore, removal of ammonia is indispensable. Groundwater from which ammonia has been removed as well as surface water has then to be treated by the normal procedures of sterilization. To supply the water quantities only is not the way to achieve the fundamental requirements of supplying municipal water.

59. The eight projects proposed in this report are all needed, are technically possible, and are economically and financially viable. Therefore, all eight of the projects are worthy of implementation.

60. Recommendation 1: It is recommended that there be thorough management of groundwater. Without such management, it would be possible to exhaust the precious aquifer, and give rise social hazards associated with ground subsidence.

(1) Of the existing NWSC's wells, twelve wells have been selected as standard production wells and three wells as observation wells. The rest of the wells are to be reserved.

(2) In normal cases, pumping of groundwater will be made from the standard production wells only.

(3) At the end of the dry season, especially in April and May, when surface water runs short, the reserve wells may have to be operated. However, the pumped amount should not exceed 15,000 m^3/day on a yearly average.

(4) When water from outside the valley becomes available, certain water source will have to be found in place of the reserve wells in order to preserve the groundwater.

(5) Monitoring of the groundwater has to be made in order to preserve groundwater and to prevent ground subsidence.

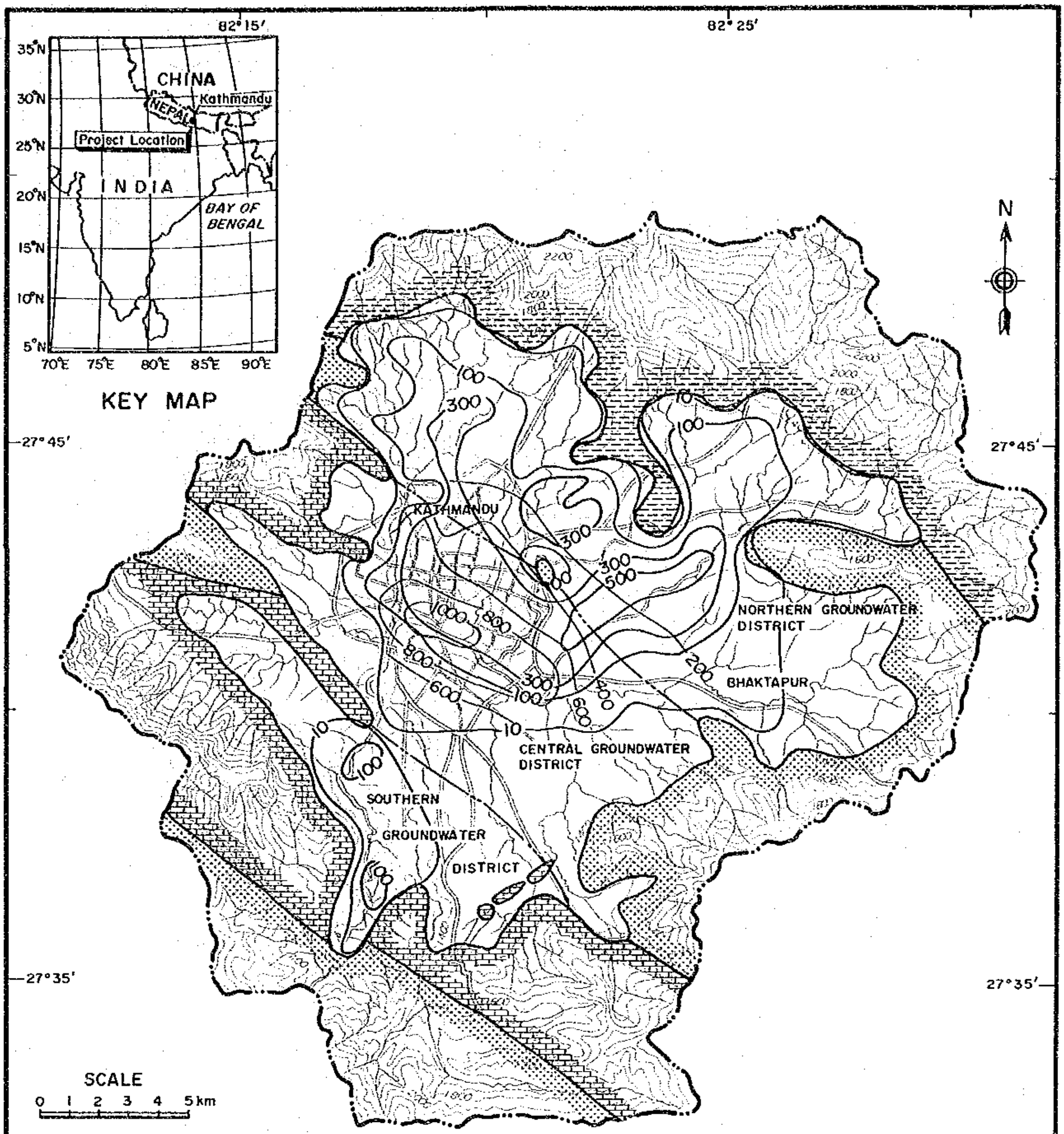
(6) Legal feature of groundwater of the Kathmandu valley should be defined in the near future as public water. Based on this, general legislation management/preservation including regulation of exploitation should be established.

61. Recommendation 2: The eight (8) projects proposed in this report,

1. Mahankal Chaur Project,
2. Bansbari and Maharajganj Project,
3. Shaibhu Project,
4. Balaju
5. Lambagar Project,
6. Sundarijal Project,
7. Manohara Project,
8. Balkhu Project

are to be implemented. It is, therefore, recommended that the necessary steps are taken for their implementations. The priority of implementation will follow the above-given precedence for technical reasons.

62. Recommendation 3: It may happen, even after water from outside the valley becomes available, that the surface water in the valley will run short by the end of the dry season, especially in April and May, and this may cause difficulty in maintaining the peak supplies. Accordingly, plans for storage dams for the valley are worthy of further studies.

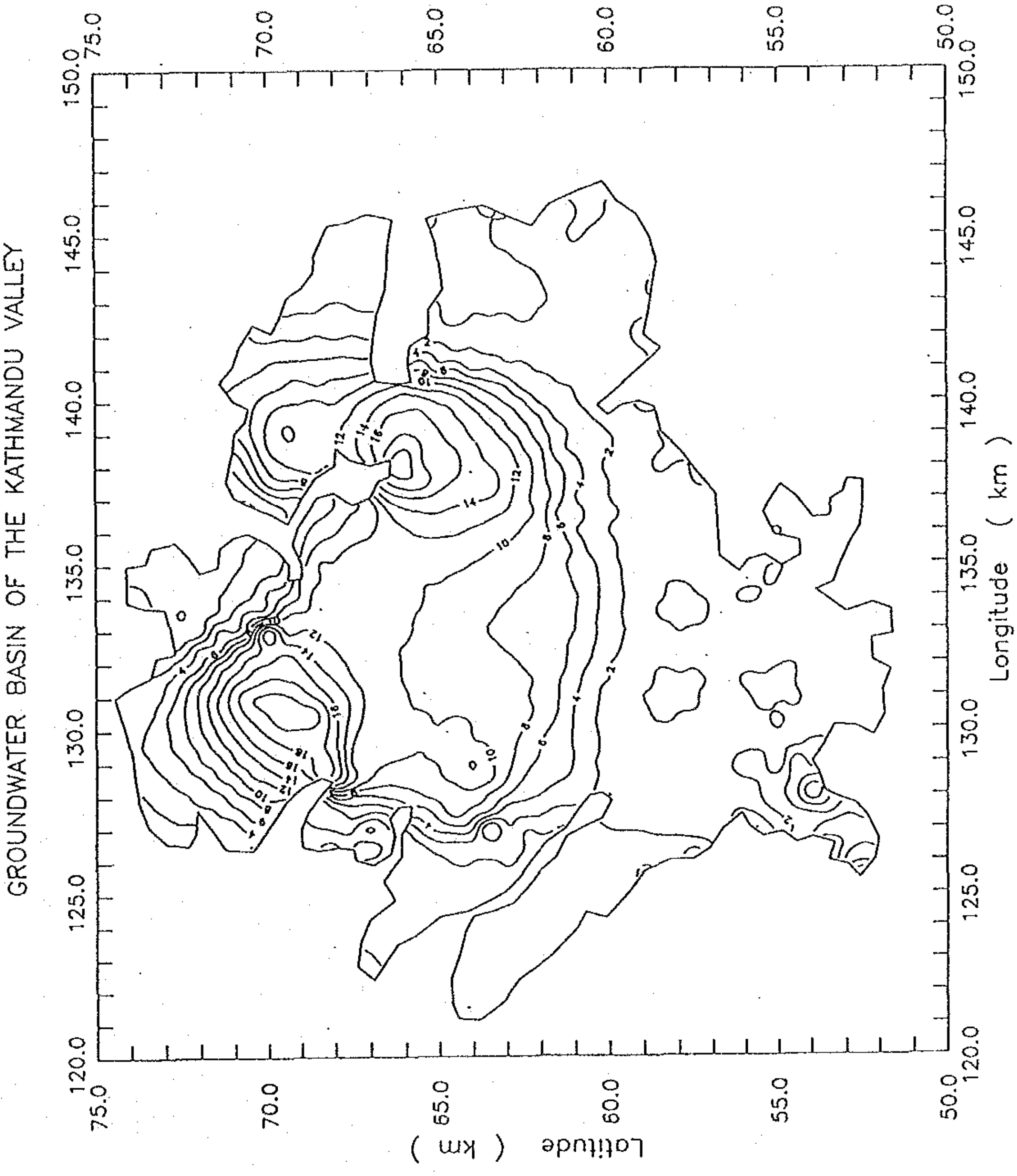


LEGEND

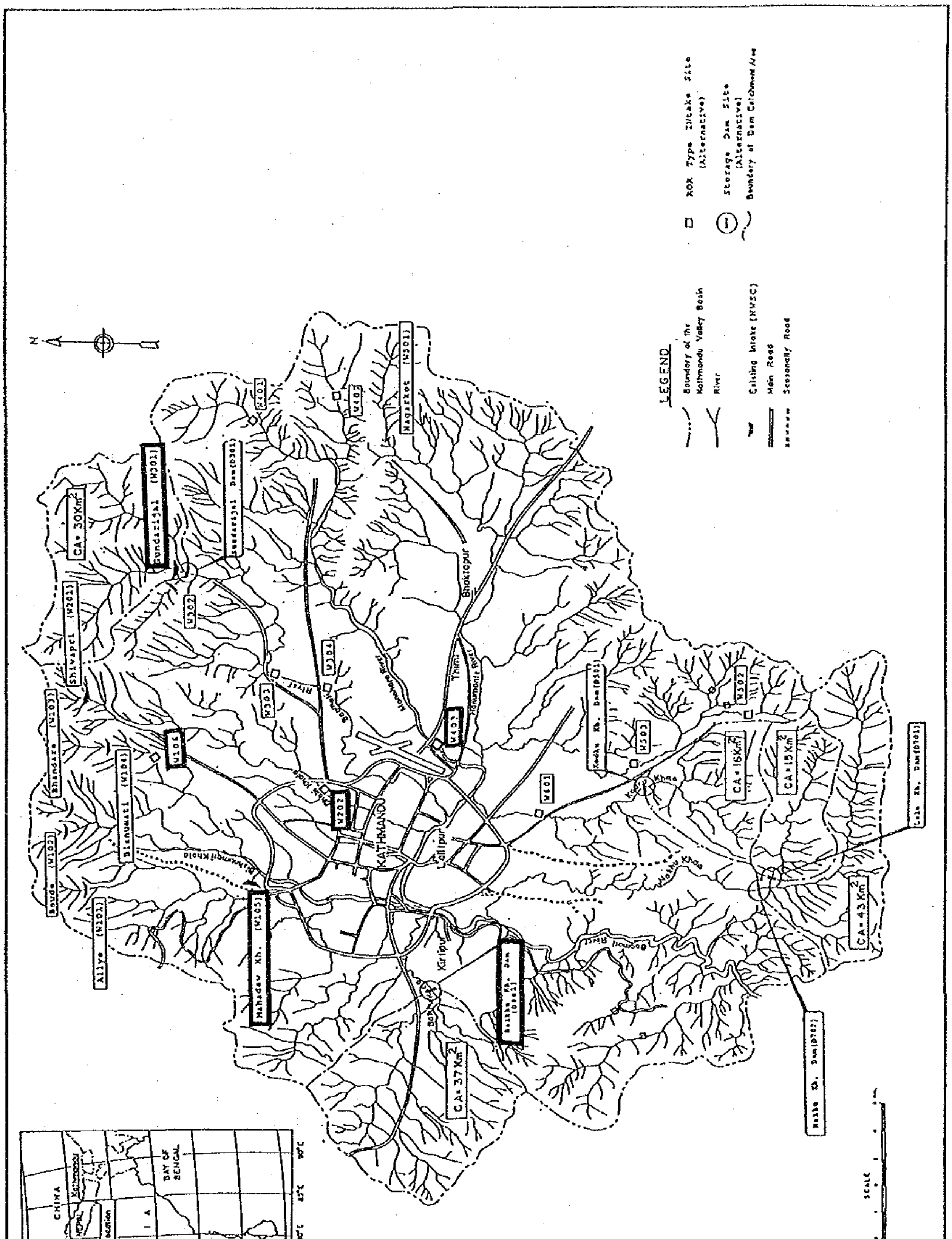
Hydrogeological Basement Rock
(Devonian - Precambrian)

- Chandrairi Formation — Crystalline Limestone, Quartzies
- Tistung Formation — Phyllites, Sandstone, Sandy Limestones
- Augen Gneisses, Banded Gneisses
- 200 EC Contur (MS/cm)
- 500 Iso Transmissivity Contour (m^2/day)
- River
- Contour Line at 100m Interval
- Boundary of the Kathmandu Valley Basin
- Groundwater District Boundary
- Road

HIS MAJESTY'S GOVERNMENT OF NEPAL GROUND WATER MANAGEMENT PROJECT IN THE KATHMANDU VALLEY	HYDROGEOLOGICAL MAP
JAPAN INTERNATIONAL COOPERATION AGENCY	

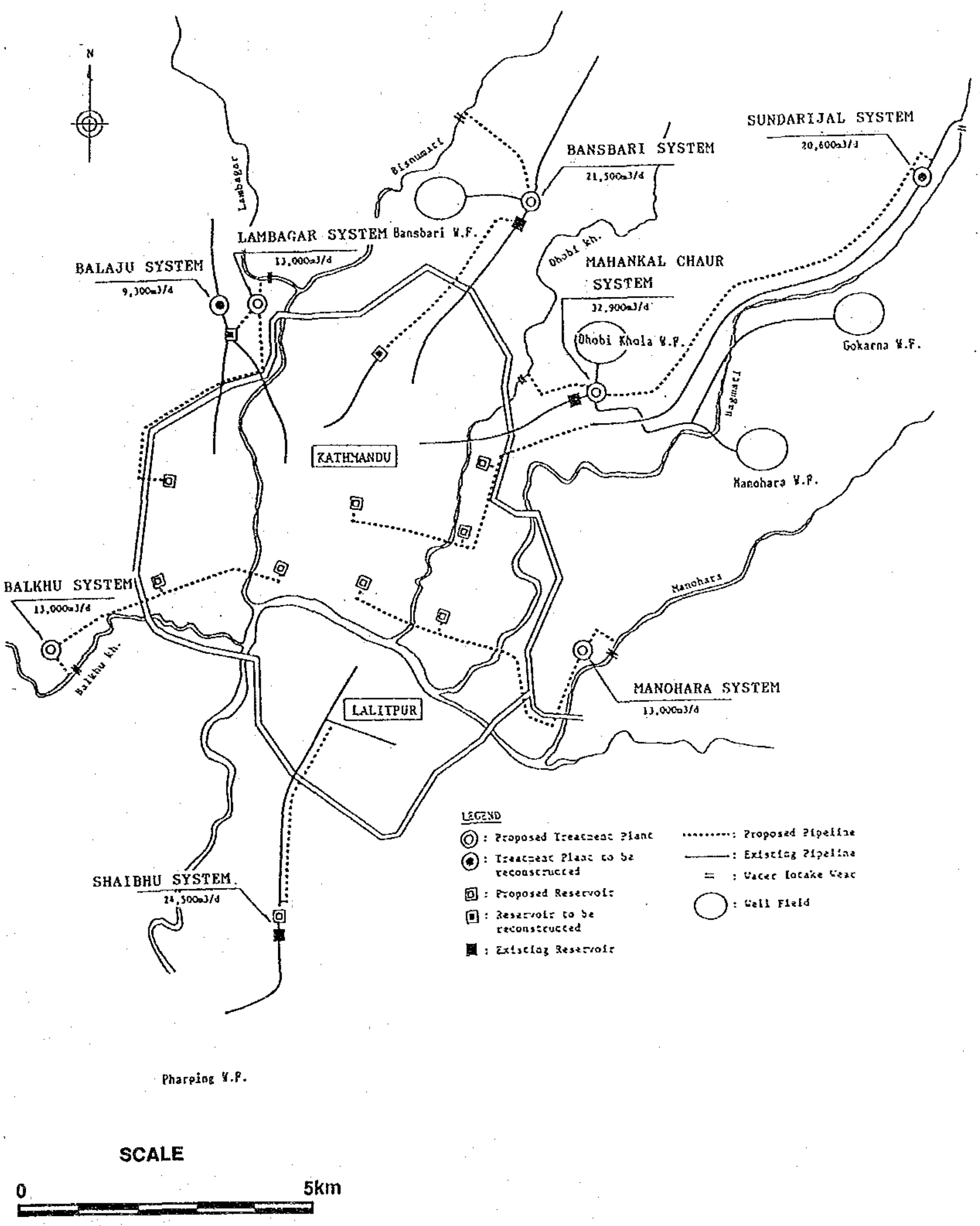


HIS MAJESTY'S GOVERNMENT OF NEPAL GROUND WATER MANAGEMENT PROJECT IN THE KATHMANDU VALLEY	DRAWDOWN OF GROUNDWATER LEVEL IN 1989
JAPAN INTERNATIONAL COOPERATION AGENCY	

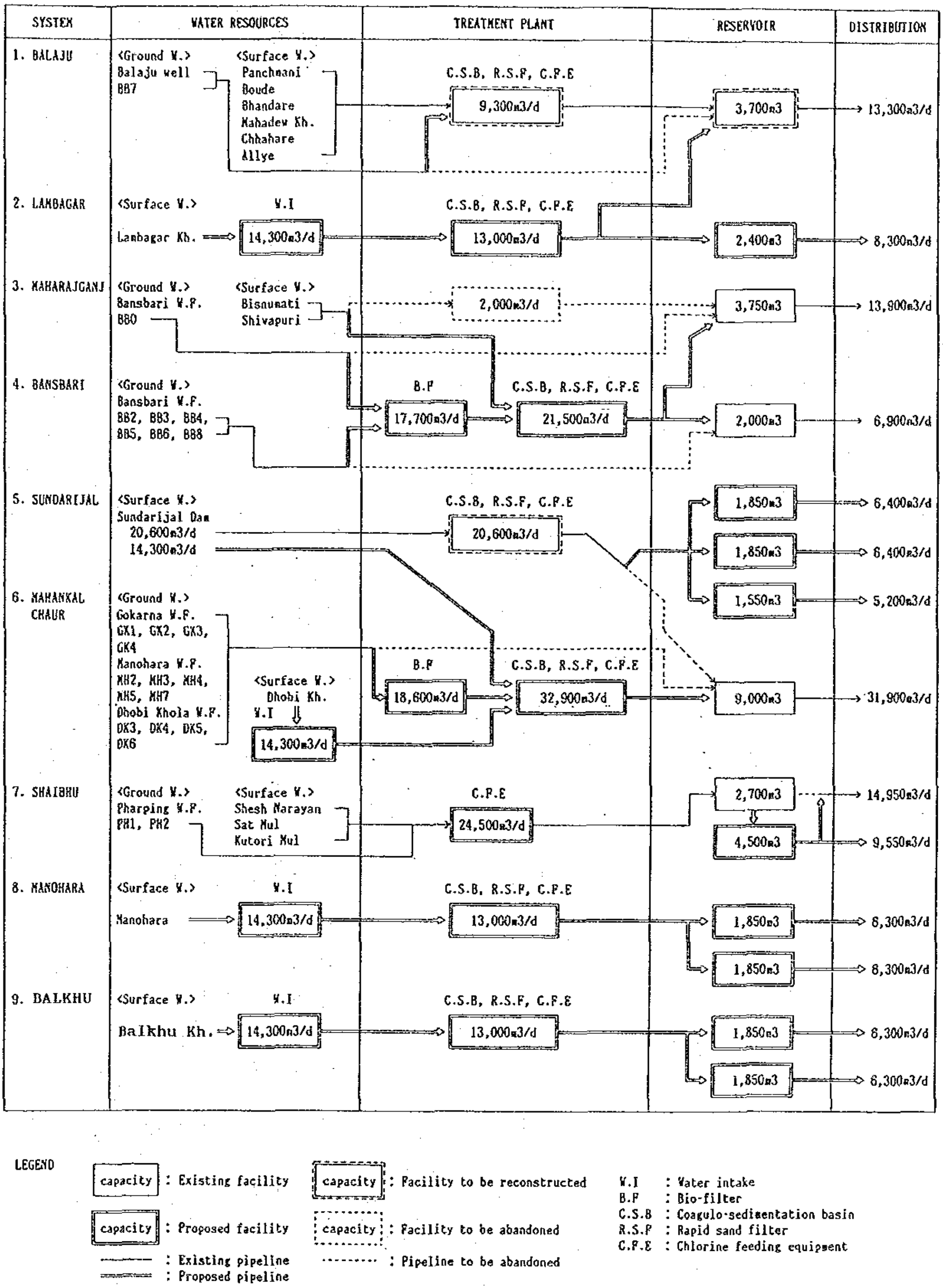


HIS MAJESTY'S GOVERNMENT OF NEPAL GROUND WATER MANAGEMENT PROJECT IN THE KATHMANDU VALLEY	LOCATION MAP OF EXISTING & ALTERNATIVE INTAKE SITES
JAPAN INTERNATIONAL COOPERATION AGENCY	

PROPOSED WATER SUPPLY SYSTEM



HIS MAJESTY'S GOVERNMENT OF NEPAL GROUND WATER MANAGEMENT PROJECT IN THE KATHMANDU VALLEY	LAYOUT OF PROPOSED WATER SUPPLY SYSTEM
JAPAN INTERNATIONAL COOPERATION AGENCY	



HIS MAJESTY'S GOVERNMENT OF NEPAL GROUND WATER MANAGEMENT PROJECT IN THE KATHMANDU VALLEY	EXISTING AND PROPOSED WATER SUPPLY SYSTEM
JAPAN INTERNATIONAL COOPERATION AGENCY	