DIRECTORATE GENERAL OF WATER RESOURCES,
MINISTRY OF PUBLIC WORKS

PUBLIC WORKS SERVICE, BALI PROVINCE

THE COMPREHENSIVE STUDY ON WATER RESOURCES DEVELOPMENT AND MANAGEMENT IN BALI PROVINCE IN THE REPUBLIC OF INDONESIA

FINAL REPORT

SUPPORTING REPORT

AUGUST, 2006

JAPAN INTERNATIONAL COOPERATION AGENCY

YACHIYO ENGINEERING CO., LTD.
NIPPON KOEI CO., LTD.

Exchange Rate

<Master Plan Study>

US$1.00 = RP9,260 = ¥106.97 Average of May 2004 - April 2005

<Feasibility Study>

US$1.00 = RP9,750 = ¥110.75 Average of Year 2005

PREFACE

In response to a request from the Government of Indonesia, the Government of Japan decided to conduct the comprehensive study on water resources development and management in Bali Province, and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA selected and dispatched a study team headed by Mr. Masatomo Watanabe of Yachiyo Engineering Co., Ltd. between September 2004 to June 2006.

The team held discussions with the officials concerned of the Government of Indonesia and conducted field surveys at the study area. Upon returning to Japan, the team conducted further studies and prepared this final report.

I hope that this report will contribute to the promotion of this project and to the enhancement of friendly relationship between our two countries.

Finally, I wish to express my sincere appreciation to the officials concerned of the Government of Indonesia for their close cooperation extended to the study.

August 2006

Akiyuki Matsumoto,
Vice President
Japan International Cooperation Agency

August 2006

Mr. Ariyuki Matsumoto
Vice President
Japan International Cooperation Agency
Tokyo, Japan

Dear Mr. Matsumoto

LETTER OF TRANSMITTAL

We are pleased to submit to you the final report of the Comprehensive Study on Water Resources Development and Management in Bali Province. The report has been prepared, taking into account the advices and suggestions of your Agency. Also included are the comments made by Directorate General of Water Resources (DGWR) under the Ministry of Public Works, and the Provincial Government of Bali.

In Indonesia, structural reform of the water resources sector (WATSAL) is being advanced, and a new water resources law has been established in 2004 in accordance with the principle of democracy, decentralization and transparency. The provinces and cities/regencies have been taking the initiative in implementing water resources development and management.

The Study was being implemented to compile a master plan for the comprehensive water resources development and management in Bali Province up to the target year of 2025 which consisted of Ayung Dam project, water supply project, flood control project, structural reform and capacity building, intending to achieve the sustainable development of local society and economy through the stable supply of safe water and reduction of flood damage. In the process of compilation of the master plan, stake holders' meetings were held, and opinions from stake holders' were incorporated widely.

The feasibility study of the priority project, consisting of Ayung dam project, water supply project (western system, central system and eastern system) in southern Bali Area and river improvement project selected in the master plan, has been implemented. Meanwhile, for the operation and maintenance of multiple Ayung dam and water supply facilities, the arrangement program for Dinas-PSDA (Water Resources Management Service Office) and Balai-PSDA (Water Resources Management Unit) including capacity building program have been proposed. It is expected that the stable water supply, mitigation of flood damage and management improvement and institutional strengthening shall be enhanced by implementing the above-mentioned project components.

We wish to take this opportunity to express our sincere gratitude to your Agency and the Ministry of Foreign Affairs. We also wish to express our deep gratitude to DGWR and the related organizations for the close cooperation and assistance extended to us during our study.

Very truly yours,

渡辺正和

Masatomo Watanabe
Team Leader
The Comprehensive Study on Water Resources Development and Management in Bali Province.

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FINAL REPORT
SUPPORTING REPORT

[A] SOCIO-ECONOMY

AUGUST 2006

JAPAN INTERNATIONAL COOPERATION AGENCY

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THE COMPREHENSIVE STUDY
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IN BALI PROVINCE IN THE REPUBLIC OF INDONESIA

SUPPORTING REPORT (A)
SOCIO-ECONOMY

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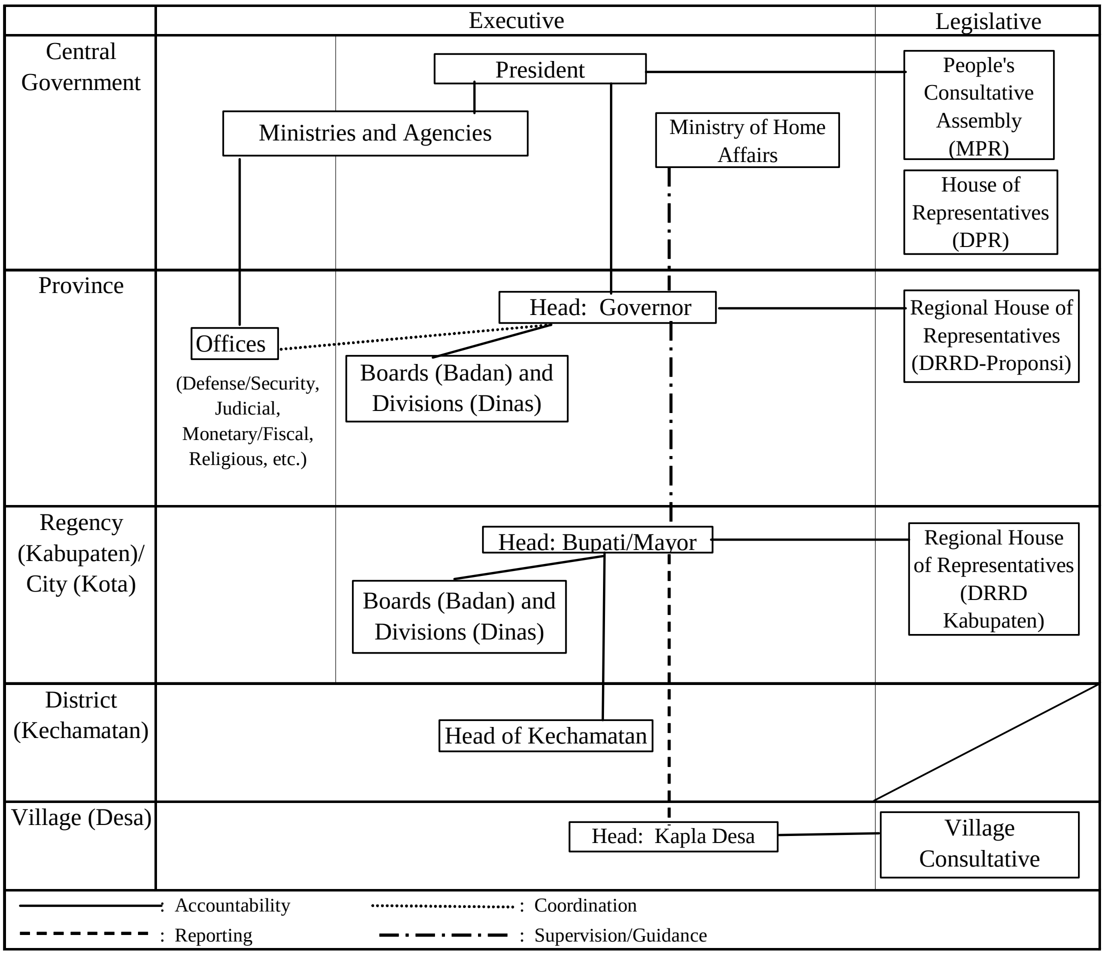
A-1 SOCIO-ECONOMY

A-1.1 Administrative Frame

GOI embarked on major decentralization initiatives in January 2001 that feature 1) decentralization (*desentralisasi*) rather than de-concentration (*dekonsentrasi)*, 2) the horizontal relationship between province and districts, where province is responsible for inter-district matters and overall coordination, and 3) the increasing role of the regional legislatures. A number of laws and regulations including the Law No.22/1999 on Regional Administration (amended by the Law No.32/2004) and the Law No.25/1999 on Fiscal Balance between the Center and the Regional Administration (amended by the Law No.33/2004) have been enacted to implement these and other aspects of decentralization. The structure of the government after the decentralization is depicted in Figure-A.1.



Sources: "Local Administration and Decentralization" (Chiho-gyosei to chiho-bunken), JICA, March 2001 (Chapter 2: Case Study on Indonesia) and the Law No.32-2004 on Regional Administration (unofficial English translation).

Figure-A.1 Government Structure in Indonesia After Decentralization

The regional autonomy under the new arrangement covers a broad range of fields except for foreign policy, defense and security, judiciary, monetary and fiscal policy, religions, and "other matters"*[1] that are under the purview of the central government. The governor of province is a representative of the central government and is responsible for de-concentrated functions of the central government and for providing supervision and guidance to district/city. In addition, the provincial government has authority in the field of administration which crosses district/city boundaries and the authority "in other specified fields of administration."*[2] However, as province is no longer superior to district/city

*[1] "Other matters" are listed as "macro-planning, fiscal equalization, public administration, economic institutions, human resources development, natural resources utilization, strategic technologies, conservation, and national standardization" (Article 7 of the Law No.22/1999).
*[2] Article 9 of the Law No.22/1999

and as the roles and responsibilities of province vis-à-vis those of district/city are not very clearly defined, the guidance and coordination functions of province have not been very effective in many cases.***[3]**

Bali Province includes eight regencies (*Kabupaten*) and one city (*Kotamadia*), and each regency/city has three (3) to ten (10) districts (*Kecamatan*). The study area covers all Bali Province (5,632.86km^2). See Table-A.1 and Figure-A.2.

Table-A.1 Regency (*Kabupaten*)/ City (*Kotamadia*) and District (Kecamatan) in Bali Province

Regency and District	Area (km^2)	Regency and District	Area (km^2)	Regency and District	Area (km^2)	Regency and District	Area (km^2)
JEMBRANA	858.26	BADUNG	398.29	KLUNGKUNG	316.38	BULELENG	1,333.59
Melaya	234.11	Kuta Selatan	100.48	Nusapenida	209.61	Gerokgak	408.30
Negara	188.37	Kuta	19.97	Banjarangkan	39.24	Seririt	157.98
Mendoyo	300.29	Kuta Utara	35.19	Klungkung	30.65	Busungbiu	106.99
Pekutatan	135.49	Mengwi	82.78	Dawan	36.88	Banjar	116.95
TABANAN	855.40	Abiansemal	67.48	BANGLI	531.30	Sukasada	182.88
Selemadeg	57.76	Petang	90.46	Susut	50.09	Buleleng	52.14
Selemadeg Barat	109.87	GIANYAR	367.96	Bangli	60.22	Sawan	89.17
Selemadeg Timur	65.70	Sukawati	53.78	Tembuku	49.21	Kubutambahan	120.92
Kerambitan	47.59	Blahbatuh	38.48	Kintamani	371.77	Tejakula	98.26
Tabanan	43.80	Gianyar	50.89	KARANGASEM	846.32	DENPASAR	125.36
Kediri	56.02	Tampaksiring	38.54	Rendang	110.82	Denpasar Selatan	45.38
Marga	44.26	Ubud	43.61	Sidemen	43.65	Denpasar Timur	34.67
Baturiti	108.71	Tegallalang	68.24	Manggis	77.35	Denpasar Barat	45.31
Penebel	144.17	Payangan	74.42	Karangasem	93.47		
Pupuan	179.44			Abang	135.14	TOTAL	5,632.86
				Bebandem	82.89		
				Selat	72.19		
				Kubu	230.82		

Source: 1) Area of Regency -Bali in Figures 2003, BPS of Bali Province, and 2) Area of District - Study Team based on the GIS data

Local governments are now given considerably larger fiscal resources to draw upon and greater authority over the use of the resources. By the end of 2002, local revenue and expenditure were more than three times of the pre-decentralization level. Total sub-national expenditure now makes up a little less than one-third of total government spending. But sub-national own-source revenue (*PAD*) is only about 7% of the total government revenue.***[4]** The rest are funded by the central government as transfers. The transfer is comprised of revenue sharing fund (*DBH*), general allocation fund (*DAU*), and special allocation fund (*DAK*). Each fund relies on different sources of revenue. *DAU* is by far the largest allocation by the central government and is a fiscal pillar of the regional autonomy.

A local government budget is referred to as *APBD*, which is jointly approved by the regional administration and *DPRD*. The *APBD* of district/city has two components: *APBD I* (the transfer from the province) and *APBD II* (the own budget). The budget of the central government is *APBN*. It must be noted that *APBN* finances capital development projects implemented at provincial and district/city levels. As it will be explained later, a majority of civil servants of the regional governments, especially in the arena of public works, are engaged in these centrally funded projects.

***[3]** The Law No.32/2004 intends to strengthen the role of province and lists the responsibilities of province (Article 13) as well as those of district/city (Article 14), but the ambiguity in the original law is basically left intact. It is expected that case-by-case approaches based on the capacities of the respective levels of local government will be pursued in different regions and sectors until clearer arrangements emerge.

***[4]** Blane D. Lewis, World Bank, "Indonesian Local Government Spending, Taxing and Saving: An Explanation of Pre and Post-Decentralization Fiscal Outcomes" (October 2004).

Figure-A.2 Administrative Division of Bali Province

A-2 POPULATION

Latest population census was carried out in 2000 as shown in Table-A.2. According to the census, 3.1 million people or 1.5% of the national population lives in Bali Province. Population growth rate during the period over the last decade was 1.3% showing a slight increase compared with the previous decade. Population density of Bali Province was 559 persons/km^2, which were five times larger than 109 persons/km^2 of the nation. Among eight regencies, Buleleng, Denpasar and Gianyar are the 3 largest populated regencies, and Denpasar is the extremely densely populated area.

Table-A.2 Actual Population and the Growth

Regions	Area (km^2)	Census Population (1,000 prs.)				% in Bali	Growth Rate		Density (prs./km^2)
		1971	1980	1990	2000		80-90	90-00	
Indonesia	1,890,754	119,208	147,490	179,379	206,265	-	2.0%	1.4%	109
Bali Province	5,632.86	2,119	2,470	2,777	3,147	100%	1.2%	1.3%	559
1. Jembrana	841.80	171	205	218	232	7%	0.6%	0.6%	275
2. Tabanan	839.33	329	343	350	376	12%	0.2%	0.7%	448
3. Badung	418.52	230	243	275	346	11%	1.2%	2.3%	826
4. Gianyar	368.00	272	306	337	393	12%	1.0%	1.6%	1,068
5. Klungkung	315.00	138	149	150	155	5%	0.1%	0.3%	493
6. Bangli	520.81	138	162	176	194	6%	0.9%	0.9%	372
7. Karangasem	849.54	267	314	343	361	11%	0.9%	0.5%	429
8. Buleleng	1,365.88	403	487	540	558	18%	1.0%	0.3%	409
9. Denpasar	123.98	171	261	388	532	17%	4.1%	3.2%	4,295

Source: 1) Web side of BPS of Indonesia, and 2) Bali in Figures 2003, BPS of Bali Province

A-3 GROSS REGIONAL DOMESTIC PRODUCT (GRDP)

Gross Regional Domestic Product (GRDP) of Bali Province was Rp.28.9trillion in 2004 as shown in Table-A.3 that accounts for 1.3% of the national Gross Domestic Product (GDP). GRDP grew stably at 4.6% in 2004 in spite of the bomb incident occurred in late 2002.

Agriculture is an important sector in Bali Province; however, the contribution to GRDP was only 21%. The largest contributor to GRDP was tertiary sector at 64% supported by the trade, hotel and restaurant activities that contributed around 30% in 2004. GRDP per capita of Bali Province was US$920 in 2004 that presents 80% of Indonesia. The growth rate of GRDP per capita in dollar bases was larger than that in Rupiah bases because of the Rupiah's recovery against US dollars over period of 2001 and 2004.

Table-A.3 GDP & GRDP at 2004 Constant Price

Unit: billion Rp.

Item		2001	2002	2003	2004	By Sector in 2004		
						Primary	Secondary	Tertiary
GDP and GRDP	Indonesia	2,001,252	2,088,818	2,190,664	2,303,031	24%	35%	41%
	Bali Prov.	25,917	26,750	27,704	28,984	21%	15%	64%
	% of Bali	1.3 %	1.3 %	1.3 %	1.3%	-	-	-
Growth Rate	Indonesia	3.5%	3.7%	4.1%	5.1%	0.5%	6.5%	7.0%
	Bali Prov.	3.4%	3.0%	3.6%	4.6%	3.7%	4.1%	5.1%

Note: Constant price is calculated by Study Team based on the data of statistical year book.
Source: 1) Indonesia; Statistical Year Book 2004, BPS of Indonesia, and 2) Bali; Bali in Figures 2004, BPS of Bali Province

Table-A.4 GDP & GRDP per Capita (Current Price)

Currency	Region	2001	2004	Annual Growth
Rupiah in thousands	Indonesia	8,080	10,641	9.6%
	Bali Province	6,369	8,531	10.2%
US$	Indonesia	780	1,150	13.8%
	Bali Province	610	920	14.5%
	% of Bali	79%	80 %	-

Note: The exchange rates of Table-3.11 are applied to convert Rupiah to US dollar.
Source: 1) Statistical Year Book 2004, BPS of Indonesia, and 2) Bali in Figures 2004, BPS of Bali Province

A-4 ECONOMIC SECTOR PROFILE

A-4.1 Agriculture

Agriculture is an important economic sector in Bali Province in terms of employment absorption power. About 40% of labor force in Bali Province engages in this sector. The features of agriculture products by regency are presented in Table-A.5. Paddy is cultivated mainly at Tabanan and Gianyar, vegetables at Tabanan, fruits at Bangli, and coffee at Klungkung and Karangasem.

Table-A.5 Agriculture Products by Regency in Bali

Items		Wetland Paddy	Maize	Cabbage	Tomato	Orange	Banana	Arabica Coffee
Year 1999 (ton)		850,350	108,572	55,750	42,504	46,964	51,812	5,394
Year 2003 (ton)		791,573	85,951	51,189	43,788	71,391	102,158	4,411
Share (%) in Bali Prov.	1. Jembrana	6%	2%	-	-	0.3%	24%	-
	2. Tabanan	26%	2%	68%	88%	1%	7%	3%
	3. Badung	15%	2%	1%	1%	25%	3%	6%
	4. Gianyar	21%	1%	0.2%	0.4%	0.5%	6%	4%
	5. Klungkung	4%	19%	-	1%	0.02%	2%	42%
	6. Bangli	3%	9%	24%	9%	65%	39%	6%
	7. Karangasem	7%	23%	-	1%	0.1%	0.1%	39%
	8. Buleleng	13%	43%	8%	0.1%	8%	18%	-
	9. Denpasar	4%	0.1%	-	-	0.02%	2%	-

Source: Bali in Figures 2003, BPS of Bali Province

A-4.2 Manufacturing Industry

The number of establishments and employment of manufacturing industry in Bali Province is shown in Table-A.6. It is obvious that the leading industries in Bali Province are characterized by 1) food and beverage, 2) textiles and leather, and 3) wood related.

Table-A.6 Number of Establishments and Employees of Manufacturing Industry

Classification of Manufacturing Industry	1999		2003		Output in Year 2002 (million Rp.)	
	Establish-ment	Employee	Establish-ment	Employee	Total	Employee
1. Food & Beverage	52	4,902	48	4,785	857,267	179.2
2. Textile & Leather	196	14,664	128	9,527	385,294	40.4
3. Wood & Furniture, Others	151	9,167	84	5,991	185,415	30.9
4. Publish & Printing	15	884	12	906	50,996	56.3
5. Rubber & Plastic	3	265	1	62	1,238	20.0
6. Other Non-Metallic	35	1,196	49	1,581	24,451	15.5
7. Fabricated Metal	15	1,574	11	827	14,139	17.1
Total	467	32,652	333	23,679	1,518,800	64.1

Source: Bali in Figures 2003, BPS of Bali Province

Table-A.7 shows the concentration of respective industries by regency that is; 1) food and beverage in Denpasar, 2) textile and leather in Denpasar and Badung, and 3) wood related in Gianyar. In total, most of the industries gather in Denpasar, Badung, Karangasem and Tabanan.

Table-A.7 Number of Establishments by Regency

Classification of Manufacturing Industry	Regency/City								
	JEM	TAB	BAD	GIA	KLU	BAN	KAR	BUL	DEN
1. Food & Beverage	9	6	3	3	1	0	4	1	21
2. Textile & Leather	2	11	34	14	10	0	4	0	53
3. Wood & Furniture, Others	3	10	10	42	0	4	3	0	12
4. Publish & Printing	0	0	1	0	0	0	0	1	10
5. Rubber & Plastic	1	0	0	0	0	0	0	0	0
6. Other Non-Metallic	2	3	1	1	1	0	37	3	1
7. Fabricated Metal	0	8	0	1	0	0	0	0	2
Total	17	38	49	61	12	4	48	5	99

Source: Bali in Figures 2003, BPS of Bali Province

A-4.3 Tourism

(1) Tourist

Tourism is a leading industry in Bali Province that largely depends on foreign tourists. The number of tourists arriving directly to Bali sharply dropped in 2003 caused by the bomb incident occurred in late 2002 as shown in Table-A.8. Although it is completely recovered in 2004 almost reaching 1.5 million and furthermore broke the record of 2000, the tourists decreased from October 2005 caused by bomb incident again.

Many visitors come to Bali on July, August and September; but it is unlikely that there is big seasonal difference of visitors.

Table-A.8 Foreign Visitors direct to Bali Province (1,000 persons)

Month	1999	2000	2001	2002	2003	2004	2005	Monthly Share
January	102	93	109	87	61	104	102	7%
February	105	104	99	96	67	84	101	7%
March	117	111	116	114	72	100	117	8%
April	104	110	117	105	54	111	116	8%
May	105	104	111	119	48	117	117	8%
June	120	122	129	131	81	132	136	9%
July	144	143	138	147	112	148	158	11%
August	146	144	145	161	116	156	157	11%
September	135	140	134	151	107	142	162	10%
October	104	130	97	81	97	128	81	8%
November	88	110	73	31	84	111	63	6%
December	86	102	89	63	94	125	n/a	7%
Total	1,356	1,413	1,357	1,286	993	**1,458**	1,310	100%

Source: Information of Bali Provincial Tourism Office

(2) Accommodations

The Table-A.9 shows number of hotels and rooms in Bali Province that gathers mostly in the two areas of Badung and Denpasar. Hotels and rooms increased respectively by 24% and 13% during 4 years; however, at present, there are no definite projects to develop new big classified hotel in Bali Province according to the Provincial Tourism Office.

Table-A.9 Number of Hotels and Rooms in Bali Province

Classification of Hotel	2000		2004	
	No. of Hotel	No. of Room	No. of Hotel	No. of Room
Classified Hotel	117	17,933	143	19,812
Non-classified Hotel and other accommodations	920	14,011	1,146	16,420
Total	1,037	31,944	1,289	36,232

Source: Information and Data from Bali Provincial Tourism Office

A-4.4 External Trade

External trade of Bali Province that includes both foreign trade and inter-provincial trade is presented in Table-A.10. The foreign trade balance shows constant surplus being supported by export of fish and fruit related products. Meanwhile, inter-provincial trade of Bali Province results continuously in negative balance.

Table-A.10 External Trade of Bali Province

Unit: million US$

Trade		2000	2001	2002	2003	2004
Foreign Trade	Export	278	250	242	228	237
	Import	28	23	35	51	29
	Balance	250	227	207	177	208
Inter-provincial Trade	From Bali	265	283	372	428	446
	To Bali	357	371	449	530	500
	Balance	-92	-89	-77	-102	-54

Note: Domestic Trade; estimated from Type of Expenditure of GRDP by Study Team
Source: Bali in Figures 2004, BPS of Bali Province

A-4.5 Inflation and Foreign Exchange Rate

Inflation rate of Denpasar is presented in Table-A.11. Although the inflation became stable in 2003 & 2004 for the first time after economic crises in 1997, it soared in 2005 caused by worldwide high energy prices.

Table-A.11 Inflation and Foreign Exchange Rate

Items	Area	2000	2001	2002	2003	2004	2005
Inflation	Indonesia [1]	9.35	12.55	10.03	5.06	6.40	17.11
	Denpasar	9.81	11.52	12.49	4.56	5.97	14.88[2]
Exchange Rate [3]	Rps./US$	9,595	10,400	8,940	8,465	9,290	9,830

Note: (1) Average rate of 43 cities, (2) yearly rate until October 2005, (3) Middle rate at the end of Year
Source: 1) Statistical Yearbook of Indonesia 2004, BPS of Indonesia, 2) Bali in Figures 2004, BPS of Bali Province, and 3) Web side of BPS Indonesia and Bali, and Central Bank

A-5 INFRASTRUCTURE

A-5.1 Road

Total length of the roads in Bali Province reaches 6,600 km as shown in Table-A.12.

Table-A.12 Length of Road by Status

Unit: km

Region	National Road	Provincial Road	Regency Road	Total	Share
Bali Province	406	847	5,391	6,644	100.0%
1. Jembrana	76	26	846	948	14.3%
2. Tabanan	67	119	860	1,047	15.7%
3. Badung	43	69	604	716	10.8%
4. Gianyar	27	104	558	689	10.4%
5. Klungkung	17	16	342	375	5.6%
6. Bangli	-	139	479	618	9.3%
7. Karangasem	6	208	410	624	9.4%
8. Buleleng	111	151	878	1,140	17.2%
9. Denpasar	59	14	414	487	7.3%

Source: Public Work Office of Bali Province

The road network in Bali Province is summarized below. A new artery road named "sunrise road" is now under construction at the east coastal region that will be connected the road to Pedang Bali of Karangasem. On the other hand, a new collector road named "sunset set road" is also under construction at the west coastal region.

< Artery Road Networks >

1) Gilimanuk - Padang Bai Route:
   - Gilimanuk – Soka - Brimgkit-Denpasar
   - Beringkit - Batuan,
   - Denpasar (Tohpati) – Gianyar-Padang Bai,
   - Denpasar (Tohpati) - Kusamba (Sunrise Road) - Padang Bai
2) Gilimanuk - Singaraja - Kubutambahan - Amed

< Collector Road Networks >

3) Antosari - Puputan - Busungbiu - Seririt Route
4) Soka - Kuta (Sunset Road)- Denpasar Route
5) Kubutambahan - Kimtamani - Bangli - Gianyar Route
6) Singaraja - bedugul – Beringkit Route

A-5.2 Electricity

(1) Electricity Infrastructures and Supply Potential

The operation of the electricity system in Bali Province is managed by the following five unit enterprises under National Electricity Limited Company (*PT. Perusahaan Listrik Negara/PLN*):

1) *PT. PLN-Distribusi Bali* manages the distribution of electricity supply including the service of adding new connection, adding power load, and repairing of electricity disturbance.
2) *PT. PLN-P3B* manages the transmission line of 150 kV in the inland of Bali, sea cables and main terminals.
3) *PT. Indonesia Power* conducts the operation and maintenance of electricity generator plants in Bali.
4) Rural Electricity Project (*Proyek Listrik Perdesaan*) manages the development of electricity facility in rural areas.
5) *PT. PLN-Proyek Induk Jawa Bali Nusra* manages the development of main transmission line, main terminal and main generator plant.

At present, there are five main electricity sources in Bali, such as *Jawa-Madura-Bali* (*JAMALI*) Interconnection System, Diesel Electricity Generator Plant (*Pusat Listrik Tenaga Diesel/PLTD*) in Gilimanuk, Gass Electricity Generator Plant (*Pusat Listrik Tenaga Gas/PLTG*) in Gilimanuk, *PLTD* and *PLTG* in Pesanggrahan, and *PLTG* in Pemaron. Present potential power generated by those sources and peak load demand in Bali is shown in Table-A.13.

Table-A.13 Present Electricity Sources and Supply Potential in Bali

Description	Unit	Production Capacity	Supply Potential
Total Potential Power	MW	-	516
a. Inside Bali	MW	452	316 (70% of Production)
- PLTD Gilimanuk (Diesel)	MW	50	
- PLTG Gilimanuk (Gas)	MW	100	
- PLTD Pesanggrahan (Diesel)	MW	78	
- PLTG Pesanggrahan (Gas)	MW	128	
- PLTG Pemaron (Gas)	MW	96	
b. From Jawa			
- JAMALI Interconnected System	MW	-	200
Peak Load Demand	MW	450	

Source: 1) Revised Spatial Plan of Bali Province 2003 - 2010 (Revisi Rencana Tata Ruang Wilayah Propinsi Bali 2003 – 2010), and 2) Information from Indonesia Power at Denpasar

Combining cycle of Pemaron gas electrical power plant, which is under construction at present and to be completed in 2006, can additionally produce 50 MW. Accordingly, total supply potential of Bali will be 551 MW (516 MW+50 MWx70%) in 2006.

(2) Demand and Supply Capacity of Electric Power

Basic tariff of the electricity in Bali is Rp.620.84/kWh at present. The largest electricity consumption is households sector, and is followed by commercial, public, and industrial sectors. The consumption amount of electricity by sector in 2003 is shown in Table-A.14.

The report of “General Planning on Regional Electricity in Bali, 2004” by BAPPEDA projects the future electric energy demand based on average annual growth rate of the provincial GRDP at the constant price in the period of 1993-2003, and the following three scenarios are introduced:

1) “Low Growth Scenario”, the average annual growth rate is assumed at 5.5%.
2) “Middle Growth Scenario”, the average annual growth rate is assumed at 6.0%.
3) “High Growth Scenario”, the average annual growth rate is assumed at 6.5%.

The projected demand of electric energy for household, commercial, public service, and industry in Bali is shown in Table-A.15.

Table-A.14 Electricity Consumption in Bali Province in 2003

Sector	Consumption	
	(GWh)	(%)
Household	761	45.5
Commercial	760	45.5
Public Service	77	4.6
Industry	74	4.4
Total	1,672	100.0

Source: Revised Spatial Plan of Bali Province 2003 - 2010

Table-A.15 Projected Demand of Electricity Energy in Bali (2003-2018)

Unit: GWh

Year	Household			Commercial			Public Service			Industry		
	Low	Middle	High	Low	Middle	High	Low	Middle	High	Low	Middle	High
2004	808	812	816	844	826	835	92	93	94	81	81	82
2008	1,310	1,341	1,373	1,250	1,286	1,339	146	151	157	104	108	112
2013	2,070	2,158	2,251	1,905	2,034	2,176	241	257	274	143	154	166
2018	2,874	3,050	3,238	2,768	3,034	3,323	378	414	452	197	221	246

Note: "Law", "Middle" and "High" show Low, Middle and High Growth Scenarios respectively.
Source: General Planning on Regional Electricity in Bali, 2004 (*Rencana Umum Ketenagalistrikan Daerah/RUKD, BAPPEDA-Propinsi Bali, 2004*)

Demand and supply capacity of electric power in Bali in the next 15 years are shown in Table-A.16. Crisis on the electricity supply in Bali is forecasted in 2006 looking at the total demand against the supply capacity.

Table-A.16 Demand and Supply Capacity of Electric Power in Bali in 2004-2018

Unit: MW

Description	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Peak Load	369	414	461	511	564	619	678	739	796	855	916	979	1,046	1,115	1,188
Reserved Margin (30% of the above)	111	124	138	153	169	186	203	222	239	256	275	294	314	335	356
Total Demand (A)	480	538	600	665	733	805	881	961	1,035	1,111	1,190	1,273	1,360	1,450	1,544
Total Installed Capacity	636	676	686	786	941	996	1,051	1,051	1,201	1,351	1,351	1,501	1,501	1,651	1,801
Supply Capacity (B) (85% of the above)	541	575	583	668	800	847	893	893	1,021	1,148	1,148	1,276	1,276	1,403	1,531
New Installed Capacity in Total	80	40	10	100	155	55	55	0	150	150	0	150	0	150	150
- Bedugul Geothermal Plant	-	-	10	-	55	55	55	-	-	-	-	-	-	-	-
- Pemaron Gas Plant	80	40	-	-	-	-	-	-	-	-	-	-	-	-	-
- New Generator Plant	-	-	-	100	100	-	-	-	150	150	-	150	-	150	150
Surplus of Power (B-A)	61	37	-17	3	67	42	12	-68	-14	37	-42	3	-84	-47	-13

Source: General Planning on Regional Electricity in Bali, 2004 (*Rencana Umum Ketenagalistrikan Daerah/RUKD, BAPPEDA-Propinsi Bali, 2004*)

(3) Development Plan of Electricity

The following several alternatives of development plans on electricity supply (see Table-A.16) have been planned in Bali to overcome the coming crisis.

1) To reduce the increasing rate of electricity consumption particularly for household and industry sectors. For instance, these sectors should provide their own generators.
2) To reduce the depreciation in distribution system.
3) To give opportunity to investors and communities to provide a small scale electricity power

generator, such as solar electricity, micro hydropower, and so on.

4) To maximize the existing electricity supply capacity.

5) To develop new energy sources utilizing hydropower, solar radiation, geotherm, and so on. There are several potential electricity sources that have not been developed yet at present, such as;

-Hydropower in Ayung River and Unda River that can produce 43.9 MW and 32.30 MW respectively. The possible hydropower development had been investigated by foreign grand aid such as JICA and ECU as shown in Table-A.17.

-Geothermal in Bedugul that can produce 200 MW, that is now under planning and investigation.

-Solar electrical power.

-Combining cycle of Pesanggrahan gas electrical power plant that can additionally produce 35 MW.

-Coal electrical power in Kubu Sub District.

Table-A.17 Potential Electrical Hydropower Plants in Bali

No	River	Location	Capacity (MW)	Remarks
1.	Ayung River	PLTA Sidan	23.00	The study was conducted by JICA in 1989.
		PLTA Selat	19.20	
		PLTA Buangga	1.70	
Total			43.90	
2.	Unda	PLTA Unda-1	13.10	The study was conducted by JICA in 1992.
		PLTA Unda-2	14.00	
		PLTA Unda-3	5.20	
Total			32.30	
3.	Several locations	PLTMH (23 location)	0.02 (Average)	Study was conducted by ECU.

Sources: PT. PLN (Persero)

A-6 LABOR FORCE AND MINIMUM WAGE

Labor force of Bali Province is shown in Table-A.18. The number of working labor forces in 2003 reached 1.76 million that was 3.7% increase compared with that in 1999. Description by economic sector shows that 40% of workers engaged in primary sector and tertiary sector, and 20% in secondary sector. In Karangasem, 60% of workers are engaged in primary sector; meanwhile 80% in tertiary sector in Denpasar. Unemployment rate of 2003 was 7.6% that shows a significant increase compared with 1.7% of 1999.

Table-A.18 Labor Force of Bali Province

Year	Regency	>age 10 years	Labor Force	Working	By Economic Sector (%)			Unemployment	
		1000 persons			Primary	Secondary	Tertiary	1000 persons	Rate (%)
1999	Total	2,517	1,766	1,703	(1) 32.9	(1) 22.8	(1) 44.3	63	1.7%
2003	1. Jembrana	204	136	122	38.8	19.7	41.5	15	10.9%
	2. Tabanan	340	243	225	47.0	21.6	31.4	17	7.1%
	3. Badung	336	225	206	26.6	21.8	51.6	20	8.9%
	4. Gianyar	352	236	217	25.1	39.9	35.0	19	8.0%
	5. Klungkung	142	102	97	53.8	12.1	34.1	5	4.9%
	6. Bangli	172	128	124	58.9	18.4	22.7	3	2.7%
	7. Karangasem	324	238	218	59.1	18.2	22.7	20	8.3%
	8. Buleleng	509	336	310	50.1	30.0	19.9	26	7.7%
	9. Denpasar	395	266	246	3.8	16.6	79.6	20	7.4%
	Total	2,774	1,910	1,765	38.7	20.3	41.0	145	7.6%

Note: (1) a ratio of the year 2000

Source: Bali in Figures 2000 and 2003, BPS of Bali Province

The minimum wage of workers was disclosed to the public every year. The last three years' minimum wage is shown in Table-A.19. The minimum wage of Bali Province is currently categorized into 6 grades. Badung is categorized at the highest grade in Bali Province. The level of Bali Province is counted as around 70% (Badung) to 60% (Others) of Jakarta.

Table-A.19 Minimum Wage

Region		2003	2004	2005	Increase
Jakarta		631,000	671,500	711,840	6.0%
Bali Province	1. Badung	430,000	469,000	506,500	8.0%
	2. Denpasar	427,500	465,000	500,000	7.5%
	3. Gianyar	423,000	446,265	475,000	6.4%
	4. Jembrana	417,500	432,650	455,300	5.2%
	5. Bangli	410,000	425,000	450,000	5.9%
	6. Others	410,000	425,000	447,500	5.3%

Source: Labor Office of Bali Province

A-7 POVERTY LINE

The population below the poverty line of Bali Province accounted for 6.9% of all provincial population in 2004 as shown in Table-A.20. However, it is obvious that its percentage is far smaller than 16.7% of Indonesia.

Table-A.20 Population below the Poverty Line

Region	Poverty Line (Rp.)			% of Population below the Poverty Line		
	2002	2003	2004	2002	2003	2004
Indonesia	-	-	-	18.2%	17.4%	16.7%
Urban	130,499	138,803	143,455	14.5%	13.6%	12.1%
Rural	96,512	105,888	108,725	21.1%	20.2%	20.1%
Bali Province	-	-	-	6.9%	7.3%	6.9%
Urban	145,650	158,415	158,639	5.7%	6.1%	5.1%
Rural	118,463	130,668	136,166	8.3%	8.5%	8.7%

Source: 1) Statistical Yearbook of Indonesia 2003 and 2004, BPS of Indonesia

On the other hand, according to the information of BPS of Bali Province, number of households below the poverty line accounts for 15.5% of total households in Bali Province as shown in Table-A.21. Regional features are summarized as follows; 1) slightly below 5% in southern areas of Bali Province, 2) just beyond 10% in western areas, and 3) absolutely high level in northern areas - 35% in Karangasem and 24% in Buleleng.

Table-A.21 Number of Households below the Poverty Line

Item	JEM	TAB	BAD	GIA	BAN	KLU	KAR	BUL	DEN
Households below Poverty Line 1)	7,069	11,369	4,001	6,473	10,449	6,948	32,328	36,171	3,639
% in the regency 2)	10.6%	11.3%	4.8%	7.8%	20.8%	19.4%	34.6%	24.3%	3.6%

Source: 1) Information from BPS Bali, and 2) Study Team by utilizing number of total household of respective regency that is presented in Bali in Figures 2005.

DIRECTORATE GENERAL OF WATER RESOURCES,
MINISTRY OF PUBLIC WORKS
PUBLIC WORKS SERVICE, BALI PROVINCE

THE COMPREHESIVE STUDY
ON
WATER RESOURCES DEVELOPMENT
AND MANAGEMENT IN BALI PROVINCE
IN
THE REPUBLIC OF INDONESIA

FINAL REPORT
SUPPORTING REPORT

[B] GEOLOGY

AUGUST 2006

JAPAN INTERNATIONAL COOPERATION AGENCY

YACHIYO ENGINEERING CO., LTD.
NIPPON KOEI CO., LTD.

THE COMPREHENSIVE STUDY ON WATER RESOURCES DEVELOPMENT AND MANAGEMENT IN BALI PROVINCE IN THE REPUBLIC OF INDONESIA

SUPPORTING REPORT (B) GEOLOGY

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B-1 Topography

B-1.1 General

Bali Island is topographically divided into two areas; northern and southern parts being separated by mountain ranges of 1,500 m to 3,000 m in altitude running in an east-west direction. The northern area has steep topography, while the southern part has relatively gentle slopes particularly below EL. 500 m, though the upper area is a little steeper(See Figure-1.1).

Rivers on the northern slopes sharply descend their altitude from highland to the coastal area and drain into the Bali Sea. Some alluvial fans are formed near the river mouths of the relatively large rivers such as Panarakan River and Saba River etc.

On the other hand, rivers on the southern slopes, including Ayung River, Oos River and Unda River etc., descend from highland on a steep gradient in the upper and middle reaches, being confined in deep V-shaped valley where both banks form steep topography of more than 40 degrees (red colored thin lines extending southward in Figure-4.1). The rivers flow from north to south with many bends reflecting the geological condition of the area, and finally drain into the Badung Strait or the Bali Strait. The tributaries of these rivers also show the similar river morphology. Thus, most of the river basins show complicated topographical feature.

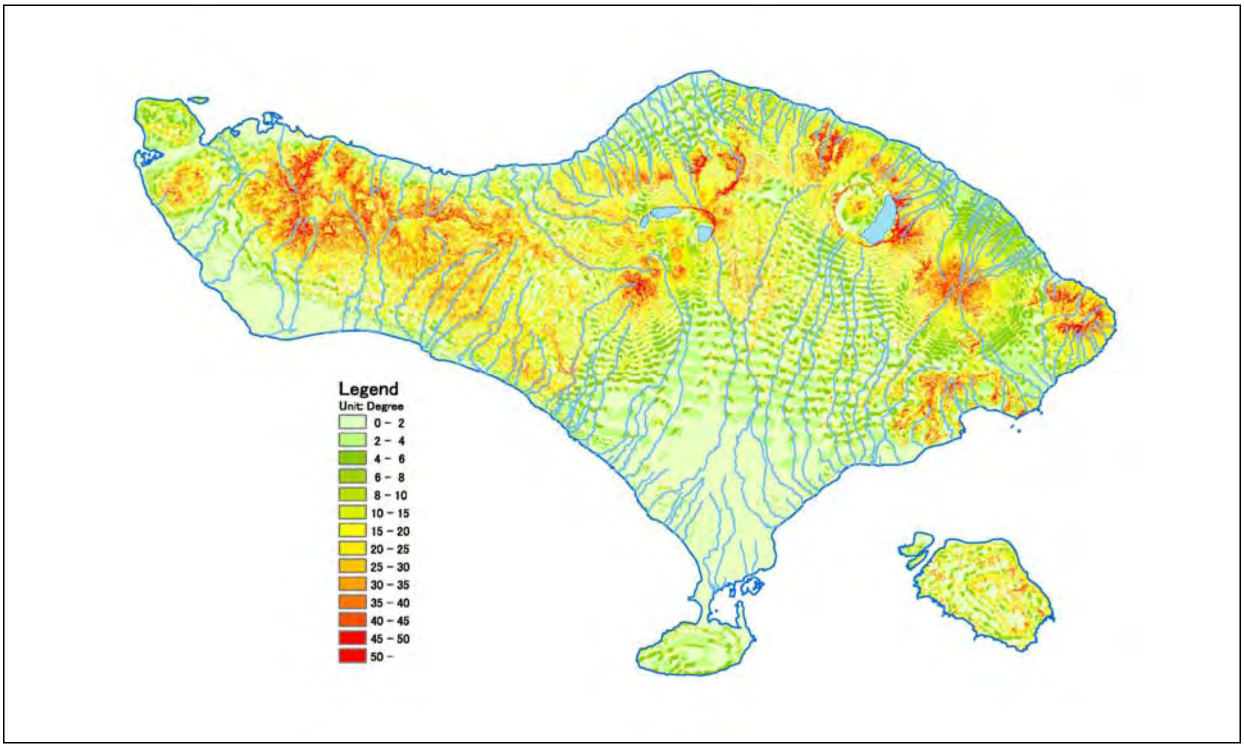


Figure-B.1 Slope Map of Bali Island

B-1.2 Project Area

(1) Ayung River

The Ayung River, catchment area of 302 km^2 and 62 km long, rises on the south slope of Mt. Batur and Mt. Mangu, forms a steep V-shape valley in pyroclastic flow deposits and flows southward straightly. The upstream basin is cultivated for the plantation or dryland, while its steep and deep valley remains natural forests. The relatively broaden downstream basin has many irrigation facilities and is cultivated for paddy fields. The Ayung River forms a small sandy delta at the east of Denpasar City and finally flows into Indian Ocean.

The Ayung Dam, which has the cathckment of 216 km^2 and the downstream area of 84 km^2, is proposed at narrowed Ayung River basin approximately 20 km north of Denpasar City.

Table-B.1 Topographic Characteristics of Ayung River Basin

Region	Upstream Area (Catchment Area)	Ayung Dam Site	Downstream Area
Mean river profile gradient	5%<	2-3%	<1%
Topography	Deep and steep V-shape valleys with 20-30 degrees inclined both bank terrains covered by volcanic ash.	More than 40 degrees inclined V-shape valleys of approx. 100 m in height and riverbed of 20 m in width. Both banks rise up to gently southward slopes.	Relatively broaden valleys with the riverbed of 20-30 m in width. Thin river deposits. Forming a small sandy delta at the river mouth.
Land use	A few irrigation facilities, cultivated for dryland and plantation	Natural forests in steep valleys Upland terrains for paddy and residence.	Many irrigation facilities Paddy fields, residence area, plantation

(2) Penet River

The Penet River, catchment area of 190 km^2 and 54 km long, rises on Danau Beratan Lake, forms a steep V-shape valley in pyroclastic flow deposits and flows southward straightly. The upstream basin is cultivated for the plantation or dryland, while its steep and deep valley remains natural forests. The downstream basin has many irrigation facilities and is cultivated for paddy fields. The Penet finally flows into Indian Ocean approximately 10 km west of Denpasar City.

A new water treatment facility is planned at approximately 1.5 km upstream from the estuary.

(3) Petanu River

The Petanu River, catchment area of 96 km^2 and 47 km long, rises on the south slope of Mt. Batur, forms a steep V-shape valley in pyroclastic flow deposits and flows southward straightly. The upstream basin is cultivated for the plantation or dryland, while its steep and deep valley remains natural forests. The downstream basin has many irrigation facilities and is cultivated for paddy fields. The Petanu finally flows into Indian Ocean approximately 10 km east of Denpasar City.

A new water treatment facility is planned at approximately one km upstream from the estuary.

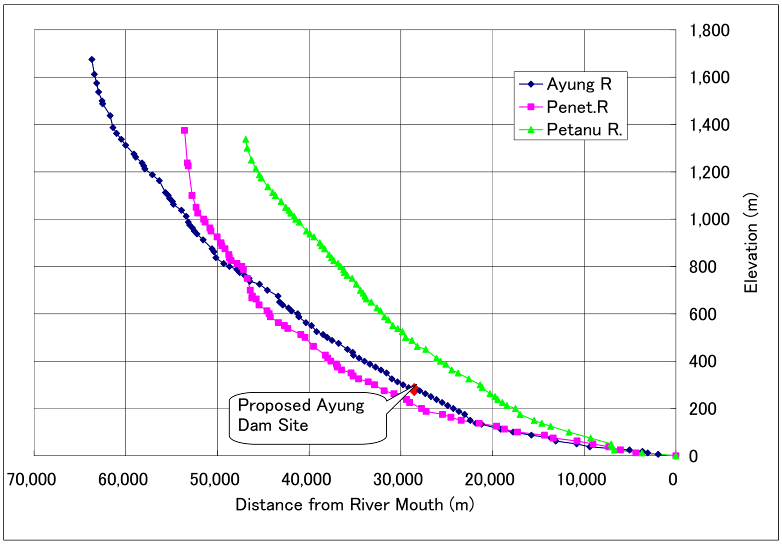


Figure-B.2 Distance-Elevation Curves of Project Rivers

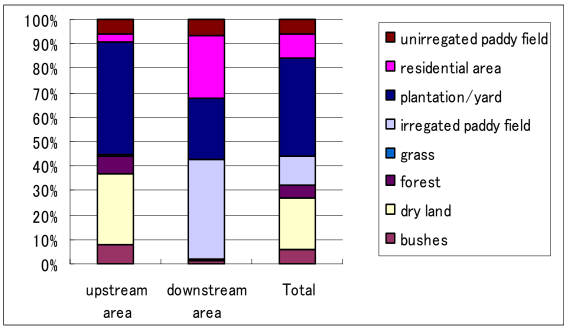


Figure-B. 3 Land Use of Ayung River Basin

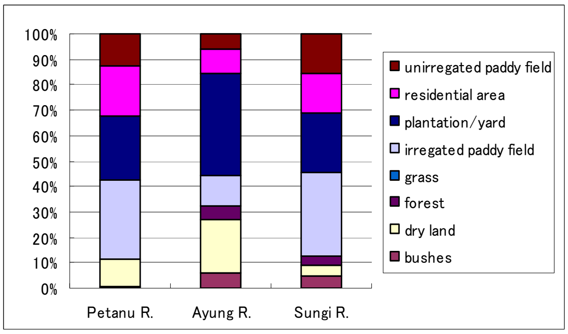


Figure-B. 4 Land Use of Project River Basin

B-1.3 Regional Geology

Bali island consists of Miocene to Pliocene volcanic products and marine sediment as basement rock, overlain by a thick pyroclastic flow, volcanic products and volcanic mudflow originated from intensive volcanic activities in Pleistocene to Holocene of Quaternary period. The stratigraphic unit of the study area can be described in Table-B.2, which is referred from "Reconnaissance Hydrogeological Map of Bali" with the scale of 1:250,000 published by the Geological Survey of Indonesia in 1972 (See Figure-B.5).

The exposure of basement rocks observed are the Ulakan Formation (volcanic breccia, lavas and tuff) of the oldest strata distributed in an area covering from the coast to mountain slopes up to EL. 500 m in the southeast, the Sorga Formation (sandstone) seen in limited areas from northwestern to northern coast, the Selatan Formation (limestone) forming Bukit Peninsula and Nusa Penida, the Parapatagung Formation (limestone, calcareous sandstone and marlstone) distributed in Prapatagung of west end of Bali, Palaki volacanics (lavas, volcanic breccia) and the Ash Formation (lavas, volcanic breccia and tuffs). Almost all of these strata of Tertiary age are covered by the Quaternary volcanic rocks.

The Lower Quaternary volcanic rocks are represented principally by Jembrana volcanics (lavas, volcanic breccia and tuffs) widely distributed in West Bali, volcanics of old Bujan-Bratan volcano and old Batur volcano, and Saraja volcanics. The Palasari Formation of Mid Quaternary age composed of sandstone, conglomerate and coral limestone covers the Jembrana Formation in south-west coastal area.

The Upper Quaternary volcanic rock covers the central and eastern region of Bali. Some mountains are still active. Mt. Batur and Mt. Agung are historically active volcanoes on the island. The 1994 eruption of Mt. Batur is the most recent, producing local ash falls, but many lavas have been produced during the last 150 years. A total of 23 magma-bearing eruptions (including 1994) of Mt. Batur have been officially recorded. Mt. Agung (3,142m) is a particularly hazardous volcano. Its most recent eruptive phase in 1963 was highly explosive and the debris flow deposits reached about 10 m in thickness on the north side of the mountain extending over an area of several square kilometers. More than 1,000 deaths were counted and many villages were destroyed.

Alluvial deposits are found in limited areas in coastal zone, around lakes and along the present river courses. Relatively large alluvium deposits are in the south of Denpasar, Perankac estuary and north-west coastal area of Bali.

The ordinary river water of the main river in Bali Island is relatively clear, and the volume of the suspended load including fine materials such as brown-colored laterite seems to be small, probably due to good conservation of the forests and high discharge of infiltration flow through pervious layers of the upper stream reaches. However, land denudation would be caused mainly of torrential rainfalls in rainy season.

Geological structures are characterized by fracture zones developed in NW-SE direction in the eastern part and NE-SW in the central part. Volcanoes are located along the zone formed by these fractures. The geological map indicates no existence of fault lines in the central part of island, but showing faults of NW-SE direction in the northeastern and eastern part and those of NE-SW/E-W directions in the western.

Table-B.2 Stratigraph of the Study Area

Period	Formation		Lithology	Locality	Aquifer/Groundwater	Yield Wells/Springs
Quaternary	Upper	Alluvium	alluvial sands, gravels, silts and clays	Sea coast, Banks of Buyan, Bratan Batur lakes	Generally good aquifer along north coast and south of Denpasar. Used for village wells in both regencies and many hotels in the south. Susceptible to saline intrusion.	Generally high permeability
		Subrecent volcanoes	Lavas, tuffs, Lahar, volcanic breccia, volcanic ash	Mt. Pohen, Mt.Sengayang, Mt.Lesong, Mt.Batukau, Mt.Agung and Mt.Batur	Variable aquifer, very widely distributed. Locally high potential in lowlands, limited in upland areas. Erratic well yields. Numerous springs.	Moderate to high permeability
		Buyan-Bratan and Batur tuffs and lahar deposits.	Tuffs, volcanic breccia, volcanic ash, lahar	The central part from north to south (the half of the island)		
	Lower	Palasari Formation	Sandstones, conglomerates, limestone grading to siltstones and shales.	Negara area (the south western part)	Good aquifer. Outcrop in Kabupaten Jembrana. May also exist at depth in south Bali, or be confused with the Prapatagung Formation	Generally high permeability in weathered conglomerate
		Seraya Volcanics	Volcanic rocks	Saraya (the extreme eastern part)	Generally poor aquifer with few springs. No water supply potential. Occurs widely in West Bali as the Jembrana Formation	Generally low permeability
		Volcanics of old Buyan-Buratan volcano and old Batur volcano	Volcanic rocks	The northern part		
		Jembrana Volcanics	Tuffs, breccias and lavas	The western part		
Tertiary	Pliocene	Asah Formation Pulaki Volcanics	Lavas, breccias and pumiceous tuffs	Some small stripe along the northern coast	Generally low to moderate permeability. (especially high in vesicular lava flows)	Generally low to moderate permeability
		Prapatagung Formations	Limestone, calcareous sandstones, tuffs, marls and shales.	The extreme western part	Outcrop in Prapatagung, west end of Bali. Good aquifer with large potential for development; over 200m thick in south Bali.	Moderate to high permeability. PDAM Denpasar wells; 91 l/s
		Selatan Formation	Limestone	Nusa Penida, Bukit Peninsula	Permeable aquifer in Bukit Batung and Nusa Penida. Extensive saline intrusion gives low water supply potential.	Moderate to high permeability
	Miocene	Sorga Formation	Tuffs, marls and sandstones	The small area in the north-western and western part	Generally low to moderate permeability	Generally low to moderate permeability
		Ulakan Formation	Tuffs, breccias and lavas	The south-eastern part	Poor aquifer with few springs. No water supply potential. Occurs in southwest area around Manggis	Low permeability

Sources:
1) CIDA (1993), Needs assessment and Assistance in the Preparation of Water Resources Management Plan Volume III,
2) The Geological Survey of Indonesia (1972), Reconnaissance Hydogeological Map 1:250.000, and
3) Simano (1992), Hydro-geomorphological characteristics in the volcanic island of Bali

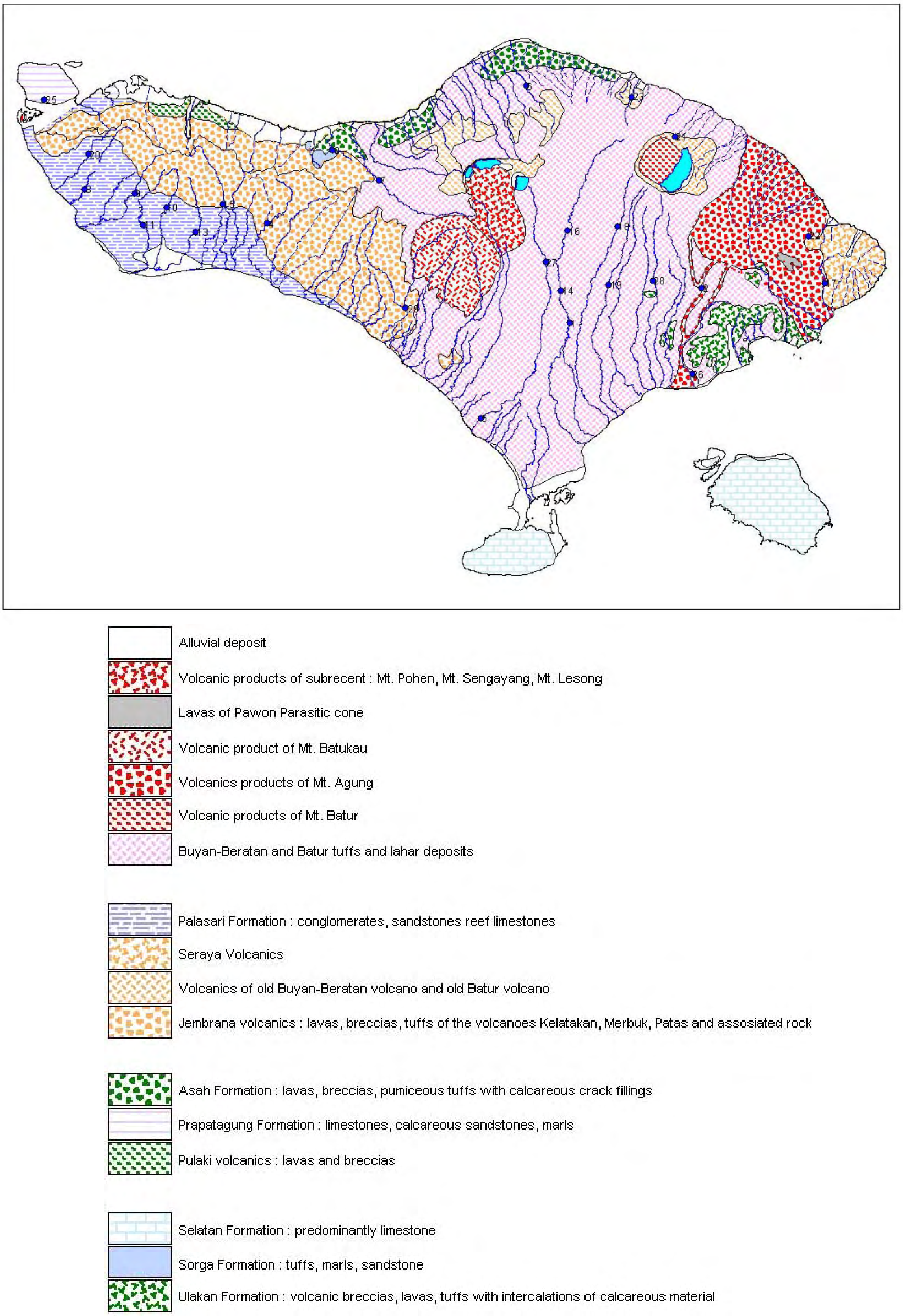


Figure-B.5 Regional Geological Map

B-2 Selection of Dam Site

B-2.1 Alternatives for Planned Dam Site

Three alternative dam sites of more than 10 M m^3 in storage capacity were proposed on the Ayung River from the confluence of the Ayung River and Siap River to its approximately 3 km downstream in the preliminary study based on 1:25,000 scale topographic maps.

The three sites, A, B and C in sequence from the upstream, were compared through the follow-up site investigations (See Figure-B.6).

B-2.2 Selection of Dam Site for Ayung Dam

C site is excluded due to its unsuitable social environmental impact, since the right bank of the C site was extensively developed for new hotel buildings.

Although no significant differences between A site and B site in topographic feature and economical efficiency, the plan of A site can minimize impacts of commercial rafting and has advantages of available topographic maps and geological data. A Chinese cemetery located on the left bank of A site is avoidable by the layout design of the proposed dam. Consequently A site has been selected as the optimum site.

The summary of the comparison is presented in Table-B.3.

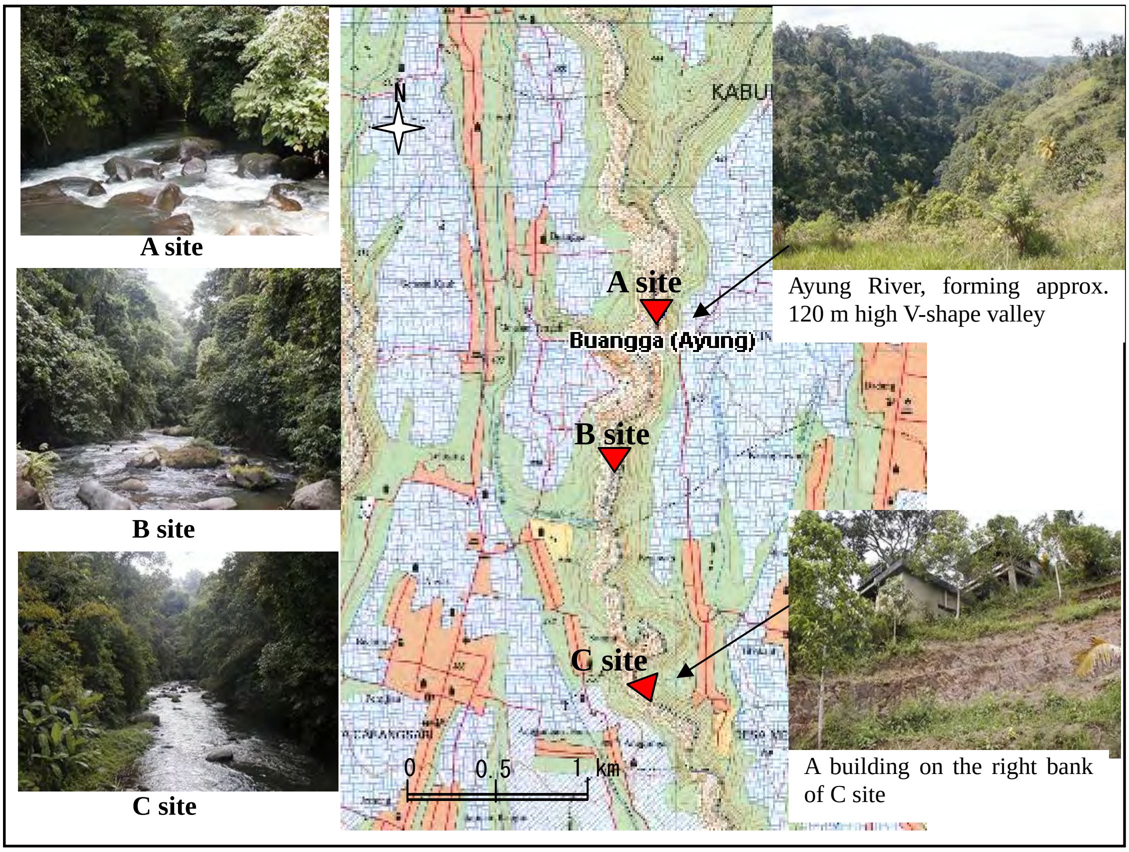
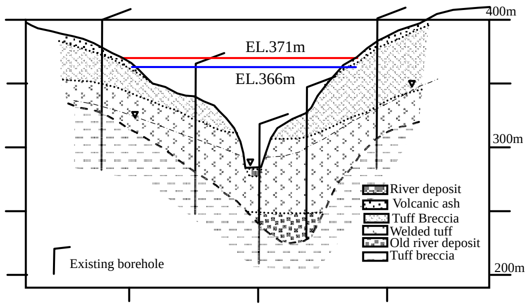
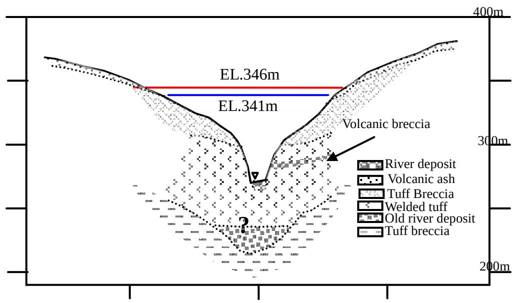
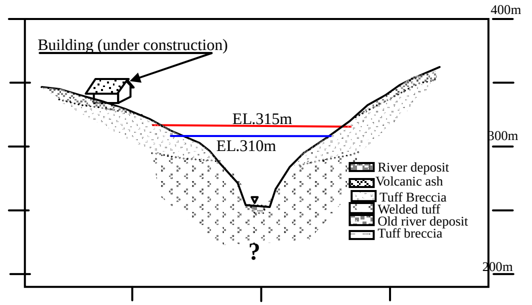


Figure-B.6 Location Map of Alternative Dam Sites

Table-B.3 Summary of Planned Alternative Dam Site Evaluation

Alternative Dam Site	A Site		B Site		C Site	
Schematic Profile of dam axis						
Dam Design	Storage Capacity 10,000,000 m^3 Effective Storage Capacity 9,000,000 m^3 Sediment Capacity 1,000,000 m^3 Normal Water Level 366.00 m Dam Top Level 371.00 m Foundation Level 305.00 m Dam Height 66 m (on the plug of 30 m high)		Storage Capacity 10,000,000 m^3 Effective Storage Capacity 9,000,000 m^3 Sediment Capacity 1,000,000 m^3 Normal Water Level 341.00 m Dam Top Level 346.00 m Foundation Level 279.00 m Dam Height 67 m (on the plug of 30 m high)		Storage Capacity 10,000,000 m^3 Effective Storage Capacity 9,000,000 m^3 Sediment Capacity 1,000,000 m^3 Normal Water Level 310.00 m Dam Top Level 315.00 m Foundation Level 263.00 m Dam Height 52 m (on the plug of 30 m high)	
Topology/Geology	EL. 390 m ~ <20°, EL. 340-390 m 30-40° EL. 280 m-340 m 50-60°, Riverbed 20 m wide Bedrock: Welded tuff: CH~CM class Tuff breccia: CL~CM class Riverbed: sand and gravel within 5 m thick A buried valley of old Ayung River is assumed.	F	EL. 390 m ~ <20°, EL. 300-390 m 30-40° EL. 270 m-300 m 50-60°, Riverbed 20 m wide Bedrock: Welded tuff: CH~CM class Tuff breccia: CL~CM class Riverbed: sand and gravel within 5 m thick A buried valley of old Ayung River is assumed.	F	EL. 350 m ~ <20°, EL. 300-350 m 30-40° (right bank: EL.320 m~ 20-30°), EL. 250 m-300 m 45-50°, Riverbed 20 m wide Bedrock: Welded tuff: CH~CM class Tuff breccia: CL~CM class Riverbed: sand and gravel within 5 m thick A buried valley of old Ayung River is assumed.	F
Social Aspects	No residence in proposed reservoir area Commercial rafting Chinese cemetery on the left bank	F~ P	No residence in proposed reservoir area A start point of commercial rafting and some facilities	F~ P	Buildings of hotel on the left bank Commercial rafting	U
Available Survey Data	Topographic map (1:5,000), 5 drilling holes（480 m）, 1 seismic line (500 m) and laboratory tests etc.	F	None	P	None	P
Conclusion	Fair		Fair-Poor		Unsuitable	

Note: Evaluation F: fair, P: poor or not recommended, U: unsuitable

B-3 Dam Plan for Ayung Dam

B-3.1 Topography and Geology

(1) Previous Study

The Ayung dam (Buangga dam) was studied feasibility as one scheme in the hydroelectric power development projects by Jica in 1989, when core-drilling, seismic refraction prospecting and laboratory tests were carried out. In the study, two alternative dam sites, the upstream site for a concrete gravity dam of 40m in height and the downstream site for a rock fill dam of 100m in height were compared. Additional geological investigation including core-drilling, electric resistance prospecting and laboratory tests were executed at the downstream site by PKSA in 2003, and a concrete gravity dam of 100m in height was designed.

Quantities of the existing survey carried out in Buangga dam (Ayung dam) are listed in Table-B.4.

Table-B.4 Existing Geological Survey

Survey Item	Quantities	Executing Office	Remarks
Feasibility study on Ayung Hydroelectric Power Development Project (1989)			
Mapping	20 ha, 1:1000 in scale	PLN	upstream and downstream site
Core drilling	4 holes, total 362m	PLN	upstream and downstream site
Seismic refraction prospecting	6 lines, total 2310 m	JICA	upstream and downstream site
Laboratory test			upstream and downstream site
Detail Design Ayung Multipurpose Dam, Payangan & Buangga - Bali (2003)			
Core drilling	5 holes, total 480m	PKSA	downstream site
Electric resistance prospecting	20 points	PKSA	downstream site
Test pit	4 pits	PKSA	downstream site
Trench cut	4 points	PKSA	downstream site
Laboratory test		PKSA	downstream site

(2) Topography

The Ayung River, forming a deep valley at the project area, runs southward.

The Siap River flows into the Ayung River at approximately 400m upstream of the proposed dam site.

The riverbed with 20m in width is at an elevation of approximately 280m at the proposed dam site and rises up to the tableland gently dipping southward of approximately 420m in elevation.

The inclinations of the both banks of 280-340 m, 340-390 m and 390-420m in elevation are 50-60 degrees, 30-40 degrees and 20 degrees respectively.

Figure-B.7 Proposed of Dam Site

(3) Geology of Ayung Dam Site

According to the previous study, the basement of the site is volcanic sandstone with gravel, volcanic breccia. The welded tuff flowed and deposited along the present river course, which was inferred from a particular geological structure confirmed by the results of the seismic prospecting.

The welded tuff is well cemented and forms 10-20 high cliffs along the river. On the both banks of the river the welded tuff is overlain by thick layers of pumiceous tuff and volcanic ash.

Pumiceous tuff and volcanic ash are moderately soft and easily eroded and small gullies are formed on the relatively gentle slopes of 340-390 m in elevation.

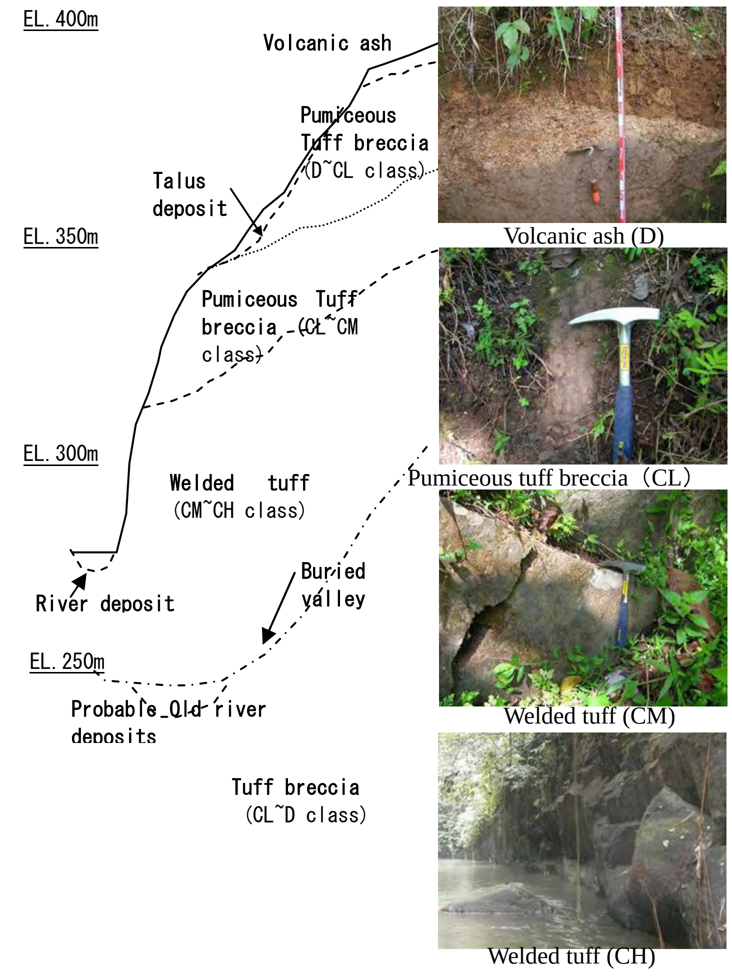
Talus deposits, less than 2m in thickness, are composed of sandy clay including some pumiceous fragments.

River deposits, less than 5m in thickness, are composed mainly of sand including some pebbles.

The stratigraphy of the Ayung dam site is shown in the following table.

Table-B.5 Stratigraphy of Proposed Ayung Dam Site

Schematic Profile



Geology	Characteristics*: hardness	Vp (km/s)	N value	Γt (t/m^3)	σ_c(t/m^2)	Es (t/m^2)	k (cm/s)	Thick-Ness (m)
River deposit: Grey, sand and gravel	Loose							<5
Talus deposit: Light brown soft gravels, sand and clay.	Loose							<2
Volcanic ash: Brown loam, and light-brown pumice	Very Soft, relatively compact and stable	0.3~ 0.5	5~10	1.4	3	3		1~2
Pumiceous tuff breccia: grey to light grey, including pumices, andesite, volcanic detritus and volcanic bomb, and sandy tuff matrix	Soft – moderately hard	0.7~ 0.8,	50<	1.5~	2	2,		30+/-
Welded tuff: Grey to purplish grey, including welded pumice fragments (0.5 cm thick, 2-3 cm long), Vertically variable facies and hardness. Low cemented welded tuff, High-cemented welded tuff, Lappli tuff of sandy tuff matrix, and andestic facies (at some places) occur in descendant order.	Hard – moderately hard	1.4~ 1.6 3.2~ 3.5		1.8 2.0	50~8 0 100~ 120	8 20		30+/-
Old river deposit: Grey, clayey(?) sand with cobbles of andesite	(Loose?)							20
Tuff breccia: Yellow brown to bluish-grey color, the breccias consists mainly of angular to subrounded fragments of 2 to 10 cm dia.	Moderately soft							40<

Source: JICA 1989 Feasibility study on Ayung Hydroelectric Power Development Project. The above engineering properties will be revised in the course of the study (Phase 3 study).

B-3.2 Geological Investigation

(1) Engineering Geology

(a) Rock Condition

The features and expectable physico-mechanical properties of the rock classes are shown in the following tables.

Table-B.6 Explanation of Rock Classes due to Drilling Core Conditions

Class	Outcrop Condition	Drilling Core Condition (expectable)
B	- The rock mass is solid. There is no opening joint and crack.	- Fresh and hard - Crack spacing larger than 50 cm - Cracks are closely adhered, no deterioration nor discoloration.
CH	- The rock mass is relatively solid. The rock forming minerals and grains undergo weathering except for quartz. The rock is contaminated by limonite etc.	- Relatively hard - Crack spacing about 30cm - Limonite adhered along cracks
CM	- The rock mass is somewhat soft. The rock forming minerals and grains are somewhat softened by weathering, expect for quartz.	- Somewhat soft - Crack spacing about 15 cm - Thin clay is sandwiched along the opening.
CL	- The rock is soft. The rock forming minerals and grains are softened by weathering.	- Soft rock fragments with clayey to sandy materials - Crack spacing smaller than 5 cm
D	- The rock mass is remarkably soft. The rock forming minerals and grains are softened by weathering.	- Clayey and sandy materials with soft rock fragments

Table-B.7 Expectable Physico-mechanical Properties for Each Rock Classes

Class	Modulus of Deformation (MPa)	Modulus of Elasticity (MPa)	Cohesion (MPa)	Int. Friction Angle (Degree)	P-wave Seismic Velocity (km/sec)
B	5,000	8,000	3.0	45+	4.0+
CH	3,000	5,000	2.2	40	4.0+
CM	1,000	2,000	1.5	35	4.0
CL	300	800	0.7	30	2.5
D	50	150	0.2	25	1.5

The bedrocks of the proposed dam site are composed of welded tuff classified into CH-CM class and tuff breccia classified into CL-CM class on the basis of a criteria developed by CRIEP (Tanaka, 1964) (See Figure-B.8).

Expected shear strength of each rock class is as follows:

CH class: $\tau 0 = 160$ tf/m^2
CM class: $\tau 0 = 80$ tf/m^2
CL class: $\tau 0 = 40$ tf/m^2

These engineering properties were estimated based on limited data of laboratory tests and naked observations of surface geological conditions. The above rock classification and engineering properties will be revised in the course of the geological investigation.

In-situ rock tests will be necessary to determine engineering properties in the detailed design study.

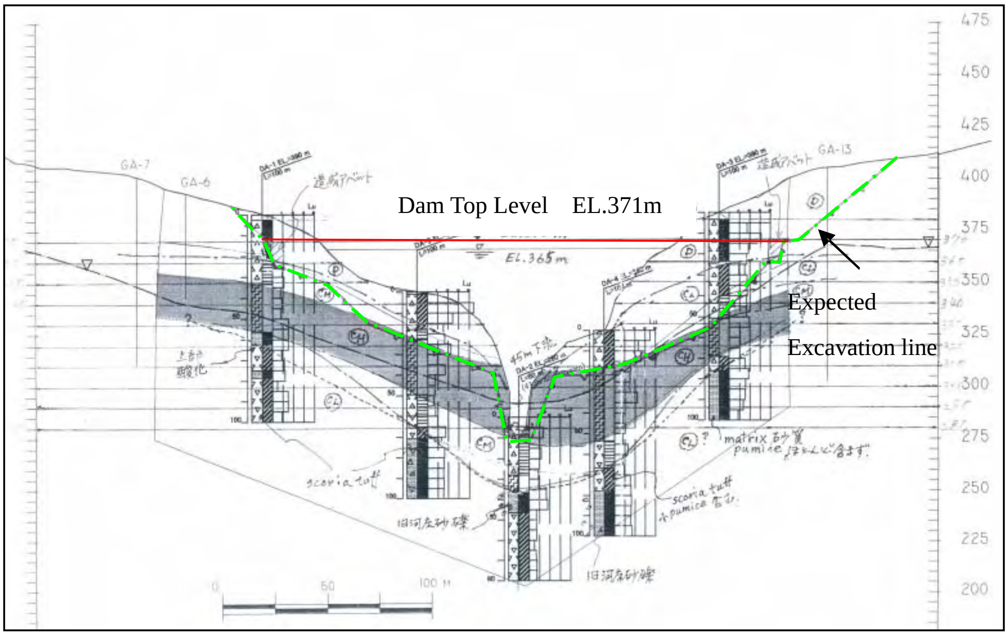


Figure-B.8 Geological Profile of proposed dam axis

(b) Permeability

According to previous study, permeability coefficient of the bedrocks shows the order of 10^{-5} to 10^{-4} cm/s.

Permeability of the dam site and ground water condition will be studied in the Phase 3 study.

(c) Reservoir Area

The Siap River, a main turbidity of the Ayung River, flows together at approximately 400 m upstream of the proposed dam site. The reservoir area forms a V-shaped and relatively straight valley extending N-S.

B-3.3 Construction Material

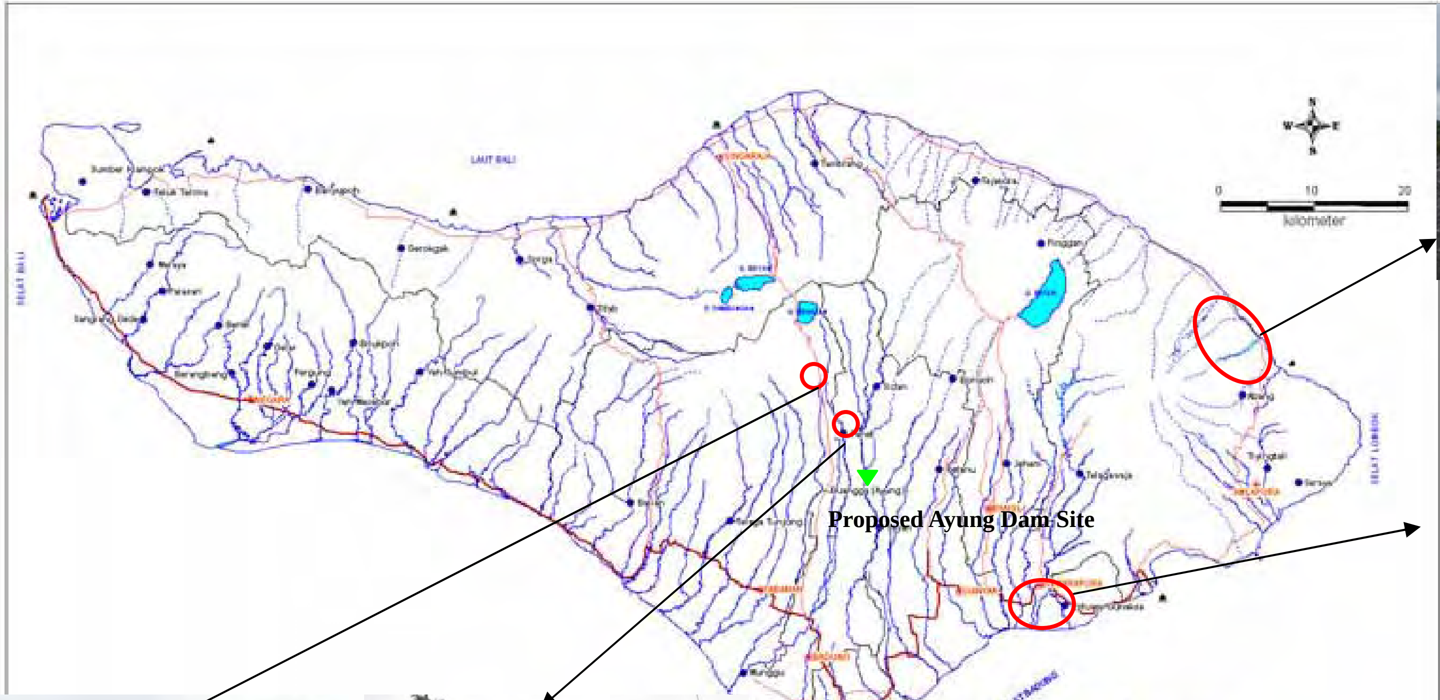
(1) Construction Material Resources

In the previous study (JICA1989), two alternative quarry sites, Bt. Payang site and Baturiti site, were proposed within 20 km from the proposed dam site (See Figure-B.9). Two core drillings were carried out in each quarry site.

Bt. Payang site and Baturiti site were environmentally unsuitable for exploitation of construction material resources based on field investigations in this phase, since either site was located in vicinity of residences and religious facilities.

River deposits of the Ayung River are insufficient in quantity for the material resources. Although usable sound rocks forming 20 m high cliffs occur along the riverbed, the exploitation for the quarry of reservoir area is economically handicapped, since 70-80 m thick soil covering the rocks has to be removed and considerable low-quality portions were contained in the sound rocks.

Procurement of the rock materials for the rock fill type dam of 100 m high is difficult in economical and environmental aspects. At the present moment, Karangasum site and Semarapuna site, which are located in approximately 60 km and 40 km from the dam site respectively, are economically considerable for material resources. A concrete gravity type dam is recommendable for the Ayung dam site in aspect of construction material procurement, since its required construction materials will be almost one to ten of required for rock fill type of same height and the transportation cost will be reduced.




Karangasem site


Semarapura site (Unda River)


Baturiti


Bt.Payung

Alternative Borrow area	Karangasem site	Semarapura site	Bt. Payung site	Baturiti site
Type of extraction	Fan deposit	Fan deposit	Rock quarry	Rock quarry
Material	Sand and gravel	Sand and gravel	Conglomerat e, dolerite	andesite
Transportation distance (km)	36	60+	7	16
Estimated Obtainable quantity (10^6 m^3)	indefinite	indefinite	42	1.7
Site condition	fair	fair	residence, temples	residences, temples
Conclusion	fair	fair	unsuitable	unsuitable

Figure-B.9 Location Map of Alternative Construction Material Sources

DIRECTORATE GENERAL OF WATER RESOURCES,
MINISTRY OF PUBLIC WORKS
PUBLIC WORKS SERVICE, BALI PROVINCE

THE COMPREHESIVE STUDY
ON
WATER RESOURCES DEVELOPMENT
AND MANAGEMENT IN BALI PROVINCE
IN
THE REPUBLIC OF INDONESIA

FINAL REPORT
SUPPORTING REPORT

[C] HYDROGEOLOGY AND GROUNDWATER

AUGUST 2006

JAPAN INTERNATIONAL COOPERATION AGENCY

YACHIYO ENGINEERING CO., LTD.
NIPPON KOEI CO., LTD.

THE COMPREHENSIVE STUDY
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SUPPORTING REPORT (C)
HYDROGEOLOGY AND GROUNDWATER

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C-1 HYDROGEOLOGICAL CONDITION

Several groundwater studies were previously carried out in Bali. The main ones containing drilling works of boreholes or wells were the following three projects, 1) Bali Groundwater (1977), 2) Southern Bali Groundwater Investigation (1985), and 3) North Bali Groundwater Irrigation and Water Supply Project (1995). In addition, there are three other main projects including the analysis of groundwater condition in Bali, namely 1) IUIDP Bali (1989), 2) Needs Assessment and Assistance in the Preparation of Water Resources Management Plan for Bali (1993), and 3) Master Plans Bali Water Supply (2000).

This report describes the hydrogeological condition of the study area based on the result of the field surveys and the inventory survey conducted by JICA Study Team, the analysis of the data provided by the counterpart of Indonesian side and the reports of the previous studies mentioned above.

C-1.1 Hydrologic Features of Formations

Figure-C.1 is the Reconnaissance Hydrogeological Map of Bali published by the Geological Survey of Indonesia in 1972.

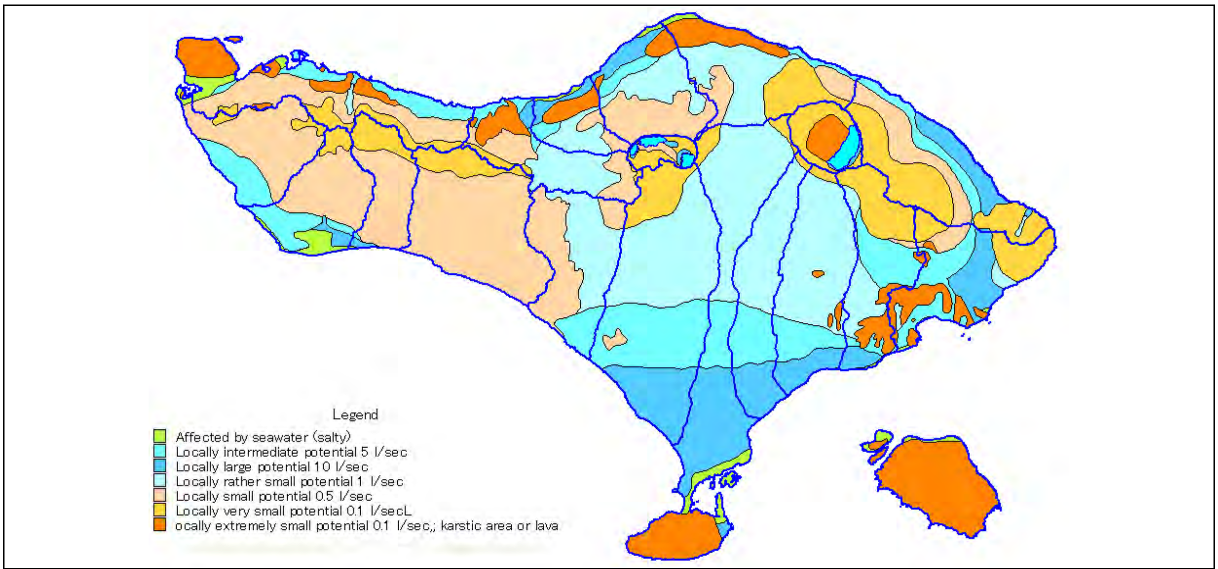


Figure-C.1 Reconnaissance Hydrogeological Map (1972)

Bali is the island covered by volcanic sediments except the west end of the island, which is Mount Prapatagung-Gilimanuk Area, and the south end of the island, which is Bukit Peninsula or Bualu Area, where limestone and calcareous stratums occur. The island of Nusa Penida is also formed by limestone.

Alluvium and young volcanic sediments are highly permeable. Lower Quaternary and Tertiary sediments have wide-ranging permeability due to the formation. Alluvial deposits are distributed in a narrow zone along the northern west coast, the coastal lowland area located in the south of Negara, and the southern seaside area of Denpasar. The formation has generally high permeability and groundwater has been exploited by dug wells and tube wells for villages in the area. The aquifer, however, is susceptible to saline intrusion.
Upper Quaternary volcanic products occur widely in the middle to eastern area of the island. The permeability of the formation varies from moderate to high. There are many production wells drilled in the area, especially in the terrace of southern Bali and the northeast coastal area. Palasari Formation of Lower Quaternary Sediments is distributed in the western area of Bali. Productive aquifers occur in the formation and have been developed for irrigation in Melaya and Negara, Kabupaten Jembrana.

Lower Quaternary Volcanic Rocks are distributed in the western central mountainous district, the parts of northern area and the east end region of the island. Although the formation has generally low permeability, the east end of the foot of Mount Seraya has relatively high permeability.

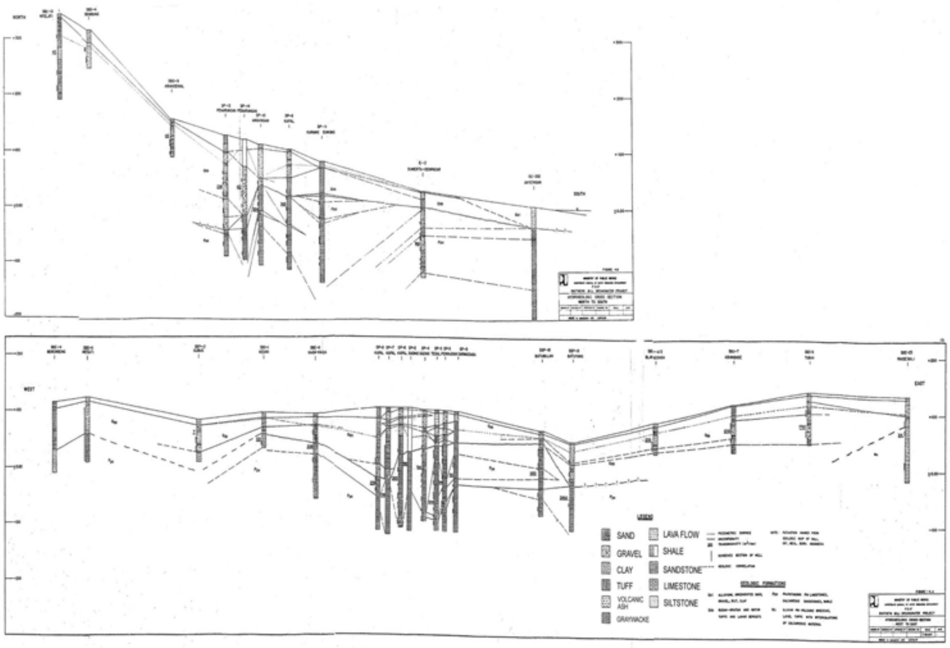
Tertiary Volcanic sediments are scattered in the northern area and in the hilly terrain around Manggis of Karangasem Regency. These volcanic formations are low permeable. There are another type of Tertiary Formations, namely Prapatagung Formation and Selatan Formation. They consist mainly of limestone and calcareous sediment. Prapatagung Formation occurs in the west end of the island, and Selatan Formation is distributed in the south end of the island and Nusa Penida. Productive aquifers, which are limited to fractures or solution channels, occur locally.

C-1.2 Borehole Lithology

Many exploratory boreholes and test wells were drilled for the previous groundwater studies. Based on the reports about drilling works, this section shows the borehole lithology of the main four areas, which are the southern Bali area, Negara area, the western part of Buleleng, and the northeast coastal area.

(1) Southern Bali

The project of Southern Bali Groundwater Investigation was carried out in 1985. More than 30 boreholes were drilled for the study and the two cross sections of the area were prepared in an east-west direction and in a north-south direction as shown in Figure-C.2. The maximum depth was about 150 meters at the borehole of SBE14 and SBP15, Ubud.



(Southern Bali Groundwater Investigation;1985)

Figure-C.2 Cross Section of Southern Bali

The area is mostly covered by the Upper Quaternary volcanic products consisting of volcanic sands, tuffs, breccias, agglomerates, lava and so on, which derived from Buyan-Buratan and Batur mountains. Although a drilling result showed the thickness varied from tens of meter to 145 meters, the total thickness actually must be hundreds of meters in the northward nearing the source of the materials. Limestone and calcareous rocks underlie the Quaternary volcanic products. The layer has been designated as Prapatagung Formation. Generally the permeability is moderate to high. The south of Denpasar, that is, the area from Sanur to Kuta, is covered by alluvial materials to a depth of ten to several tens of meters.

(2) Negara

11 test wells were constructed in Negara for the project named Bali Groundwater completed in 1977. The final report provided the lithology of boreholes, shown in Figure-C.3, with the lithology of another water supply well drilled up to 113 meters. The semi-consolidated Palasari Formation is widely distributed in the area. Productive aquifer occurs in the formation. The thickness is at least 80 meters or more. The borehole lithology shows the formation consists predominantly of sand and gravel intercalated with silt and clay. Thin alluvial deposits overlie Palasari Formation in the southern coastal area of Negara.

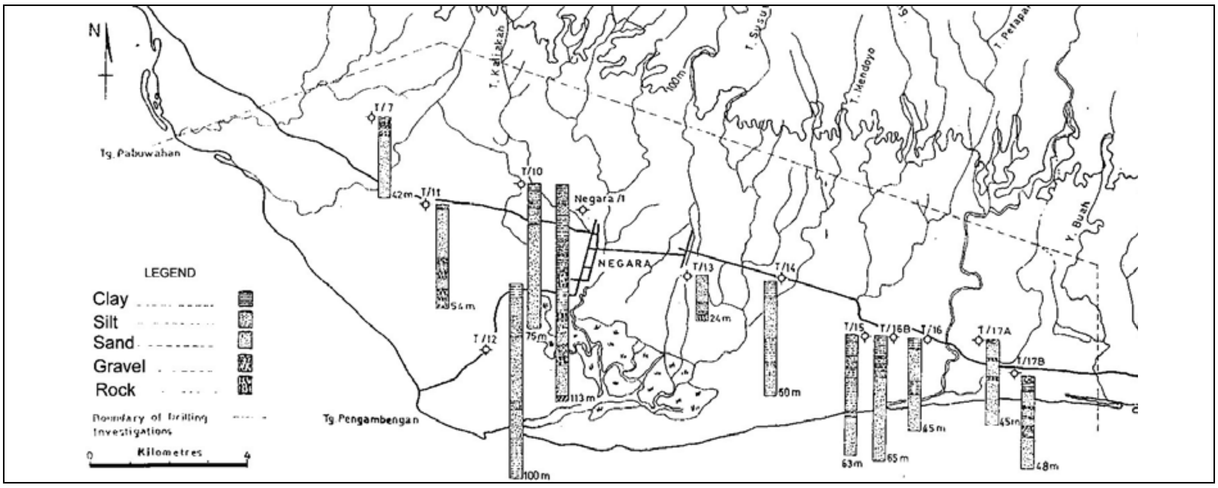


Figure-C.3 Negara: Lithology of Boreholes (Bali Groundwater, 1977)

(3) Western Part of Buleleng

The Bali Groundwater study drilled six boreholes with the depth from 14 to 120 meters in the area. The final report of the study has described that the constructed boreholes generally penetrated highly permeable layers, which consist of coarse sand and gravel, though these boreholes were located in a widespread area. The sand and gravel were interbedded with tuffaceous layer or consolidated tuff in places. A thesis (Gunaarsa, 2002) has summarized the groundwater condition of the area. The paper illustrated some profiles based on the drilling record of P2AT. The typical profile in the vicinity of Gerogak was shown in Figure-C.4.

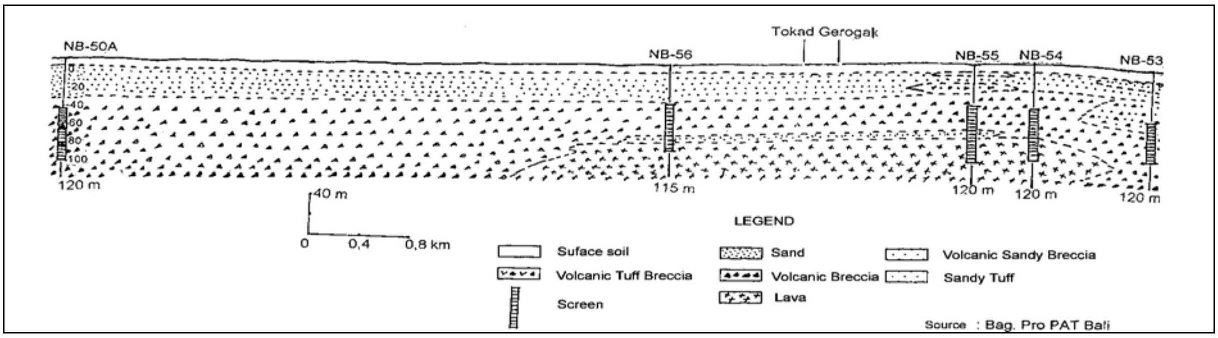


Figure-C.4 Western Buleleng : Lithology of Boreholes (Gunaarsa, 2002)

(4) Northeast Coastal Area

More than 30 production wells have been constructed during the project of North Bali Groundwater Irrigation and Water Supply, from 1993 to 1999. The project area is located between the villages of Pacung in Buleleng regency, and Tianyar in Karangasem Regency, which is approximately 30 km long. The depths of the wells range from about 50 to 70 meters. Groundwater occurs in the coastal alluvial formation that is composed of sands, gravels and conglomerates. Some boreholes reached the basement of the aquifer but others did not. Figure-C.5 shows the geological columns of the well of JLH08 and TBT28, which are located in the western area and the eastern area of the project respectively.

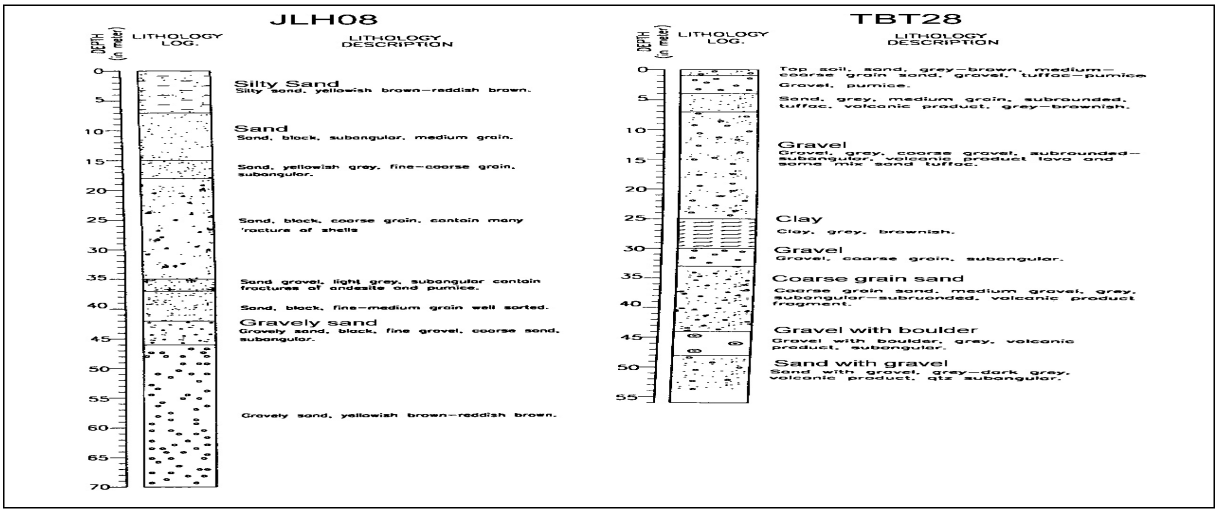


Figure-C.5 Northeast Coastal Area: Borehole Lithology (North Bali Project, 1995)

C-1.3 Aquifer Characteristics

P2AT has been taking a leading part for construction of production wells to exploit groundwater in Bali. On the basis of the well inventory provided P2AT and the data collected by JICA Study Team, aquifer characteristics are described in this section. A number of wells that have the data of pumping tests were tabulated in Table-C.1.

Table-C.1 Number of Wells

Regency/City	Number of Wells (The result of inventory survey)	Number of Wells with the data of pumping tests
JEMBRANA	100	73
BULELENG	107	77
KARANGASEM	64	40
TABANAN	16	16
GIANYAR	16	16
KULUNGKUNG	11	9
BADUNG	58	8
BANGLI	2	0
DENPASAR	31	0
Total	405	239

(1) Depth of Wells

There are 210 wells recorded the depths. The number of wells drilled up to 90 meters or less is almost 50% of the wells and about 80% of the wells were drilled up to 120 meters or less. The wells drilled to 50 meters were only 8%, as shown in Table-C.2. According to Figure-C.6 showing the distribution of well depth, relatively deeper wells have been constructed in the western part, Meraya and Negara, and the northwestern part, Gerokgak, though the depth of wells drilled in the southern area vary widely.

Table-C.2 Depth – Number of Wells

Depth of Well (m)	Number of Wells		Accumulative	
<40	6	2.9%	6	2.9%
40=< <50	11	5.2%	17	8.1%
50=< <60	26	12.4%	43	20.5%
60=< <70	19	9.0%	62	29.5%
70=< <80	25	11.9%	87	41.4%
80=< <90	23	11.0%	110	52.4%
90=< <100	19	9.0%	129	61.4%
100=< <110	28	13.3%	157	74.8%
110=< <120	15	7.1%	172	81.9%
120=< <130	13	6.2%	185	88.1%
130=< <140	8	3.8%	193	91.9%
140=< <150	12	5.7%	205	97.6%
150=<	5	2.4%	210	100.0%
Total	210	100.0%		

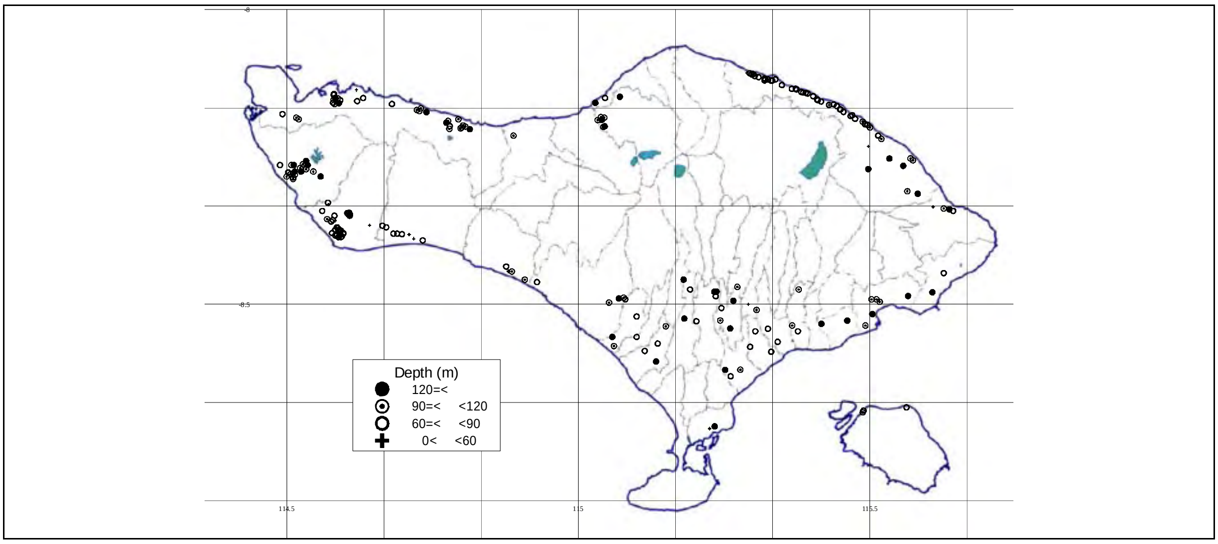
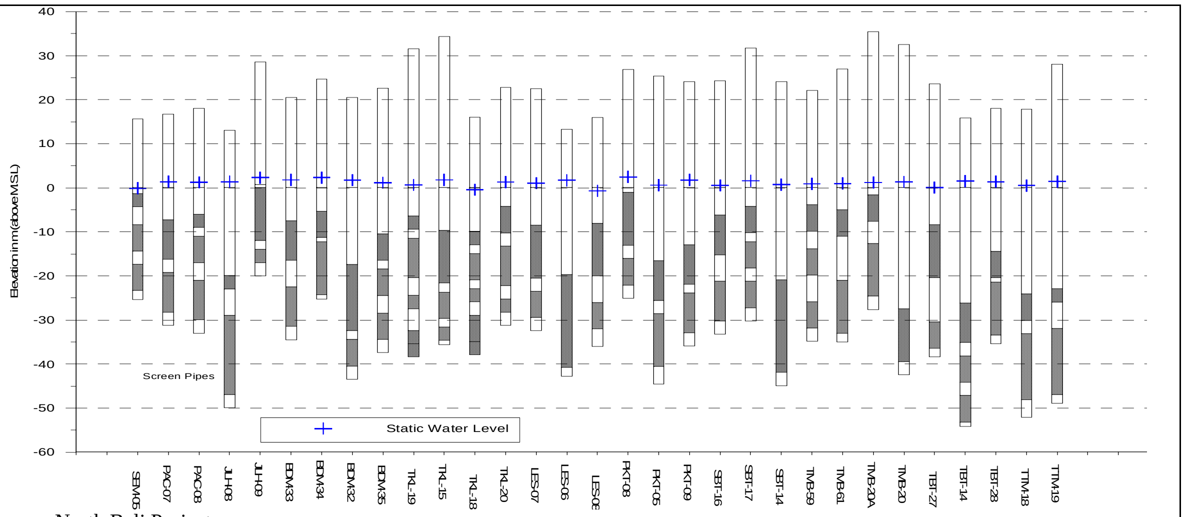


Figure-C.6 Distribution of Well Depth

Figure-C.7 shows the static water levels and the positions installed screen pipes in the wells constructed by North Bali Groundwater Irrigation and Water Supply Project, which was carried out in the northeast coastal area. The figure indicates a productive aquifer occurs below the sea level in the area.



Source: North Bali Project

Figure-C.7 Water Level and Screen Pipes Position of Production Wells

(2) Discharge Rate from Wells

211 wells were listed with the record of discharge rate at the pumping test as shown in Table-C.3. More than half of wells discharge 10 liters/sec and over of groundwater. And Figure-C.8 is the distribution map of well discharge, showing that the wells with the discharge of 20 liters/sec or more are mainly located in the western part of Jembrana and the northeastern coastal area.

Table-C.3 Discharge Rate of Wells

Discharge Rate (l/s)	Number of Wells		Accumulative	
<5	30	14.2%	30	14.2%
5=< <10	65	30.8%	95	45.0%
10=< <20	86	40.8%	181	85.8%
20=<	30	14.2%	211	100.0%
Total	211	100.0%		

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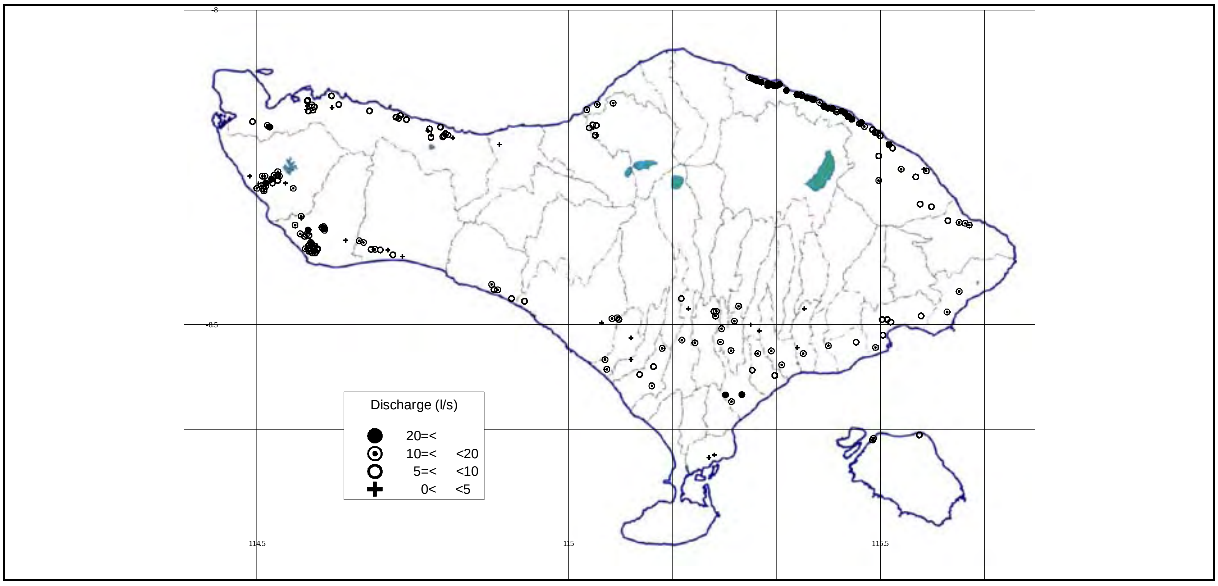

Figure-C.8 Distribution of Well Discharge

(3) Specific Capacity

Specific capacity is defined as the discharge rate of a well per unit of drawdown when the well is pumped, and is expressed in liters per second per meter (liters/sec/meter). The value of specific capacity can roughly suggest groundwater supply potential of a well or an aquifer as shown in Table-C.4.

Table-C.4 Comparison of transmissivity, specific capacity and well potential

Transmissivity (m2/day)			Specific Capacity (liters/sec/m)		Groundwater Supply Potential
	Irrigation	Good	100	Very high	Withdrawals of great regional importance
1000			10		
	Irrigation	Fair		High	Withdrawals of lesser regional importance
100			1		
	Irrigation	Poor		Intermediate	Withdrawals for local water supply
10	Domestic	Good	0.1		
	Domestic	Fair		Low	Smaller withdrawals for local water supply
1			0.01		
	Domestic	Poor		Very low	Withdrawals for local water supply with limited consumption
0.1			0.001		
	Domestic	Infeasible		Imperceptible	Sources for local water supply are difficult (if possible) to ensure

U.S. Bureau of Reclamation, Ground Water Manual, Krasny, Jiri. 1993. GROUND WATER. vol.31, no.2, pp.231

U.S. Department of Interior, Washington, 1977. (Kashef, A. Ismail, Groundwater Engineering, p.366)

Based on the recorded discharge rate and the drawdown, specific capacity of wells is calculated, and is shown in Table-C.5.

Table-C.5 Specific Capacity of Wells

Specific Capacity (liters/sec/meter)	Number of Wells		Accumulative		Groundwater supply potential
<0.1	7	3.3%	7	3.3%	Low
0.1=< <1	65	31.0%	72	34.3%	Intermediate
1=< <10	99	47.1%	171	81.4%	High
10=< <100	37	17.6%	208	99.0%	Very High
100=<	2	1.0%	210	100.0%	
Total	210	100.0%			

Specific capacity of almost half of wells ranges from 1 to 10 liters/sec/m. Groundwater supply potential of wells are generally intermediate to high in Bali. Figure-C.9 shows the distribution of the value of specific capacity. The figure indicates that.

- The southern Bali has moderate to high potential of groundwater supply in general.
- The coastal areas of the northeastern part, Kubu in Karangasem to Tejakula in Buleleng, and the western part, Gerokgak in Buleleng and Negara and Melaya in Jembrana, have generally high groundwater supply potential.

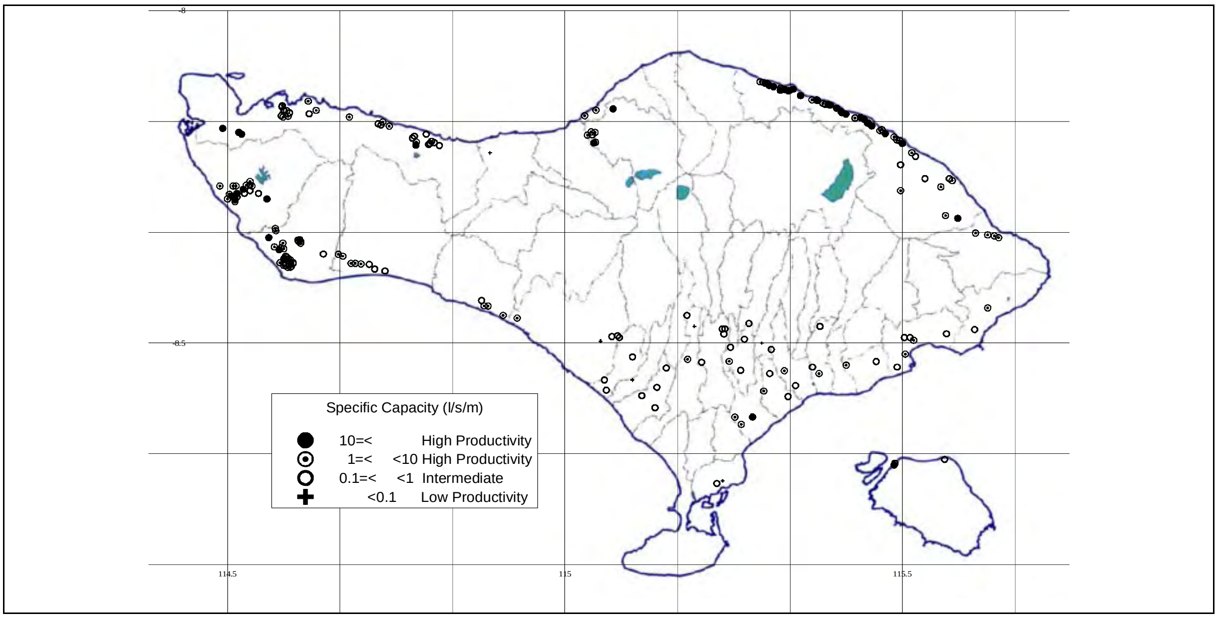

Figure-C.9 Distribution of Specific Capacity

(4) Transmissivity

Transmissivity is the flow in m^3/day through a section of aquifer 1 meter wide under a hydraulic gradient of unity. The value of transmissivity indicates groundwater supply potential of the aquifer as shown in Table-C.6. Transmissivity of 72 wells have been obtained by the analysis of pumping tests.

Table-C.6 Transmissivity of Wells

Transmissivity (m^3/day/m)	Number of Wells		Accumulative		Groundwater supply potential
<10	2	2.8%	2	2.8%	Low
10=< <100	18	25.0%	20	27.8%	Intermediate
100=< <1000	29	40.3%	49	68.1%	High
1000=<	23	31.9%	72	100.0%	Very High
Total	72	100.0%			

Naturally the ratio of wells classified with groundwater supply potential is approximately same as the result indicated by specific capacity. Figure-C.10 shows the distribution of transmissivity, and indicates the same pattern as Figure-C.9, although the western plain of Jembrana seems to have comparatively higher potential.

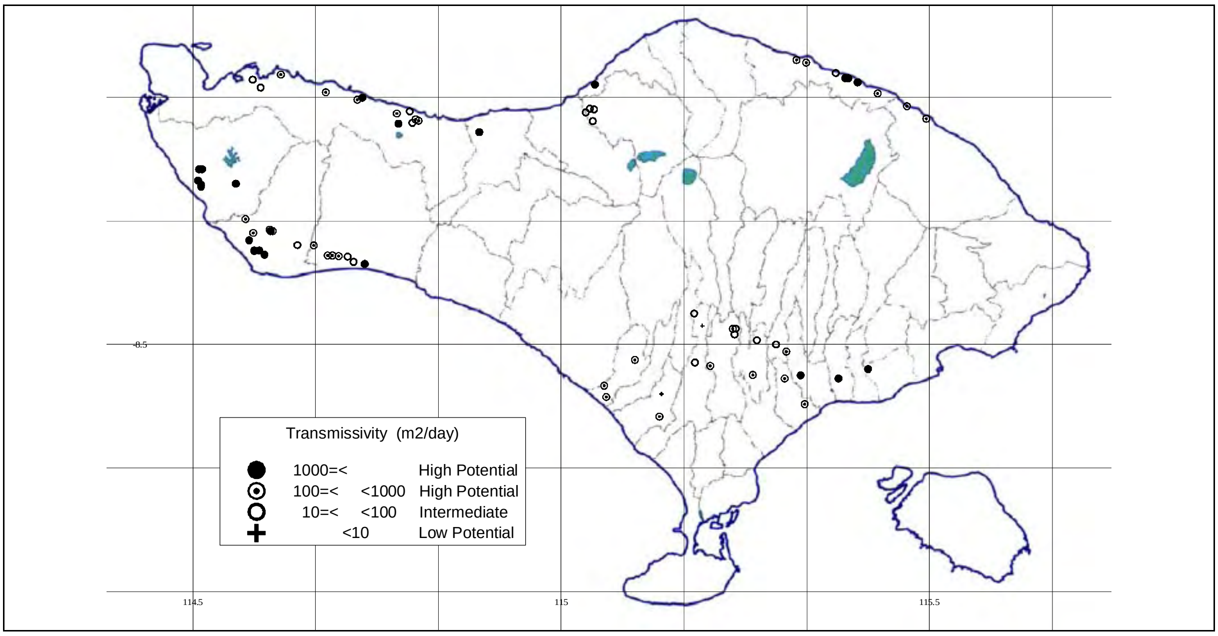

Figure-C.10 Distribution of Transmissivity

The values of transmissivity were plotted with the values of specific capacity, and the result is shown in Figure-C.11, which indicates transmissivity (T) can be represented by:

$$T\ (m^2/day) = (100 \sim 200) \times Sc(liters/sec/meter).$$

This equation may be useful to evaluate a transmissivity from the pumping rate and the drawdown.

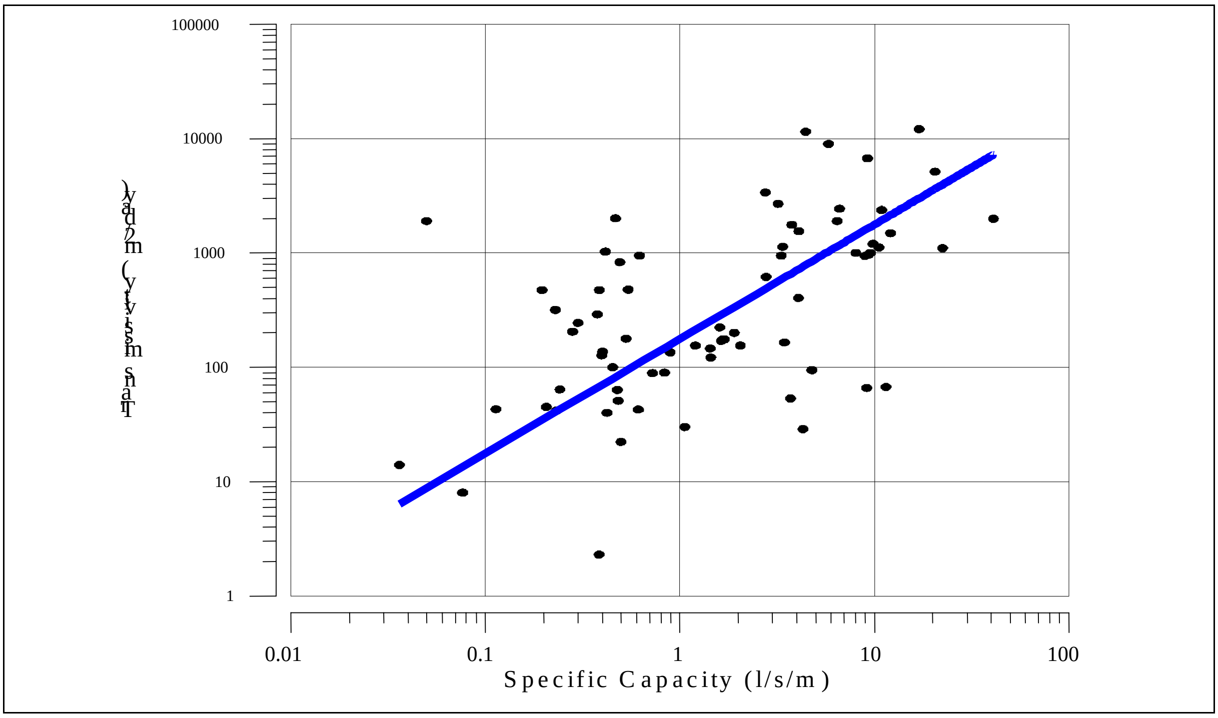

Figure-C.11 Specific Capacity-Transmissivity

(5) Hydraulic Conductivity

Hydraulic conductivity is the rate of flow through a unit cross section under a unit hydraulic gradient, which is the coefficient of permeability of a layer. Hydraulic conductivity, k, and transmissivity, T, are related to each other as follows:

$k = T/H$ where, H is the saturated thickness of the aquifer.

Practically hydraulic conductivity, k, is calculated with T obtained by the result of pumping test and Hs that is the total length of screen pipes installed into the well instead of the saturated thickness, H.

Table-C.7 Hydraulic Conductivity

m/day

10^4	10^3	10^2	10^1	1	10^{-1}	10^{-2}	10^{-3}	10^{-4}	10^{-5}

Relative permeability

Very high	High	Moderate	Low	Very low
Clean gravel	Clean sand and sand and gravel	Fine sand	Silt, clay, and mixtures of sand, silt, and clay	Massive clay
Vesicular and scorioceous basalt and covernous limestone and dolomite		Clean sandstone and fractured igneous and metamorphic rocks	Laminated sandstone, shale, and mudstone	Massive igneous and metamorphic rocks

after Kashef, A.I, GROUNDWATER ENGINEERING, 1987,
(U. S. Bureau of Reclamation, Ground Water Manual, U.S. Department of Interior, Washington, 1977.)

The values of hydraulic conductivity of 72 wells were calculated as tabulated below. Permeability of aquifer is mostly moderate in Bali. Figure-C.12 shows the distribution of hydraulic conductivity.

Table-C.8 Hydraulic Conductivity of Wells

Hydraulic Conductivity (m/day)	Number of Wells		Accumulative		Permeability
0.1=< <1	5	6.9%	5	6.9%	Moderate
1=< <10	22	30.6%	27	37.5%	
10=< <100	39	54.2%	66	91.7%	
100=<	6	8.3%	72	100.0%	High
Total	72	100.0%			

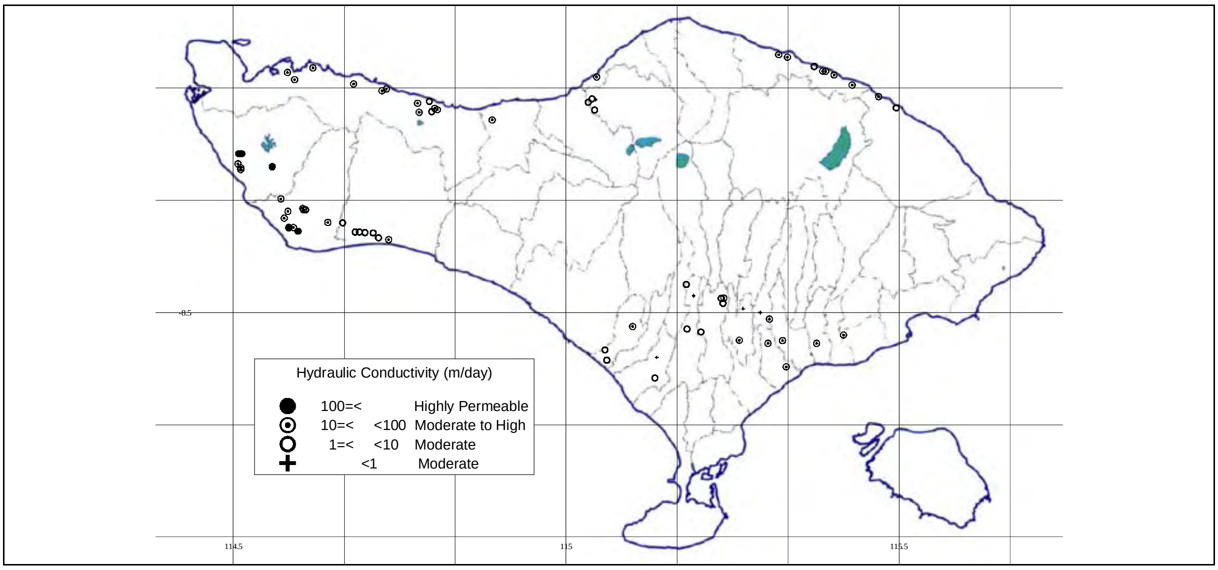

Figure-C.12 Distribution of Hydraulic Conductivity

The figure indicates that:

- The aquifer of western part of Jembrana is highly permeable in general.
- The northern coastal area in Buleleng and the area around Gianyar have relatively higher permeability.

C-1.4 Springs

The inventory survey conducted by the JICA Study Team listed the total of 1,273 springs in Bali. The yields of them range from less than one litre to several hundreds of litres per second. According to the result, there are 9 springs yielding 500 liters/sec or more, and 67 springs yield from 100 to less than 500 liters/sec. If you count springs with yield of a few liters per second, the inventory may be never completed. Table-C.9 summarizes the result of the inventory survey. Figure-C.13 shows the distribution of springs with the discharge of more than 10 liters/sec.

Table-C.9 List of Spring in Bali

Regency/City	Number of Springs	Number of Springs Yielding more than 10 liters/sec	Total Yield (liters/sec)	Average Yield (liters/sec)
Buleleng	327	79	5630	71.3
Karangasem	138	96	9808	102.2
Kulungkung (Nusa Penida)	9	5	522	104.4
Kulungkun	29	5	202	40.4
Gianyar	79	53	2981	56.2
Bangli	423	57	2736	48.0
Badung	30	7	1291	184.4
Tabanan	177	52	3808	73.2
Jembrana	61	5	85.1	17.0
Total	1273	359	27063	75.4

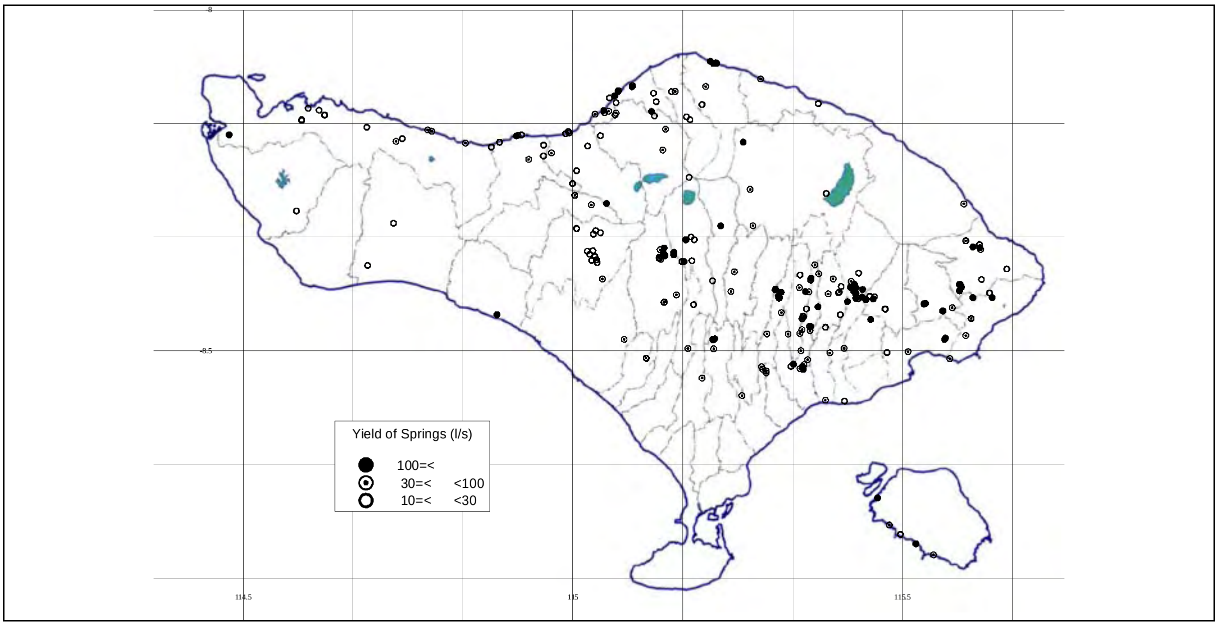

Figure-C.13 Distribution of Springs

The table shows that there are 359 springs yielding 10 liters/sec or more that are moderate to higher amount of discharge. The average yield of these springs is 75 liters/sec. In detail, there are 79 springs in Buleleng and 96 in Karangasem, where the most springs are located. The average yield in Beleleng and Karangasem are 71.3 and 102.2 liters/sec respectively. Karangasem has the larger yield springs than Buleleng dose. The southern Bali area, Gianyar, Bangli, Badun and Tabanan, has also the large yield of springs as shown in the table, though the number of springs is less. Some springs with large yield are located in Badung. In Nusa Penida, the recorded average is 104.4 liters/sec.

The figure shows that:

- There are many springs with moderate yield along the northwest coastal side. It is possible that groundwater yields under the sea in the northeast area.
- Springs with large yield of more than 100 liters/sec are mainly located in the middle to east area. Many of them particularly are on the mountain slopes of Mt. Pohen-Adeng and Mt. Agung.

In addition to the above, there are many springs with small yield of less than 10 liters/sec located in the southern mountain slope.

C-1.5 Groundwater Occurrence and Movement

(1) Bali Island

Fundamentally groundwater comes from rainfall in Bali. As described in the section of general climate, the annual rainfall increases with altitude in the island. It means that the most mountainous forestlands are the area that groundwater is recharged.

Rainfall infiltrates the ground surface or runs off a surface towards a stream channel, though some rainfall is intercepted by the vegetation cover and never reaches the ground. And some portion is lost as evapotranspiration. Anyhow, water reached the aquifer moves from a mountainous area to the foot of a mountain, while some of it discharges as springs. The map of piezometric surface provided by Southern Bali Groundwater Investigation (1985) showed the poezometric surface is almost parallel to the land surface. Therefore groundwater flows generally along the gradient of the land surface towards the coastline from the mountains.

(2) Nusa Penida

Seratan Formation consisting of stratified coral limestone forms the island of Nusa Penida. The formation is highly permeable in general. Therefore rainwater infiltrates to the formation and goes downward to the zone bearing groundwater immediately. The water table may be only 1 or 2 meters above sea level. Usually an aquifer or a fresh water reservoir forms a lens in shape keeping a balance with seawater in a permeable limestone island like Nusa Penida, and the thickness of the lens is generally thin. For example, the fresh water lens in Tonga Island in the South Pacific is the thickness of only 10 m or less. Of course, the island is composed of limestone. Exploitation of the groundwater should be planned not to break the fresh water lens, otherwise saline intrude soon.

C-2 GROUNDWATER RESOURCES

C-2.1 Groundwater Flow and Recharge

Groundwater flow (Q) through an aquifer is calculated by the following equation:

$$Q = kHWI$$

where k ; the hydraulic conductivity
H ; the saturated thickness of the aquifer
Transmissivity (T), may be substituted for kH, if it (T) is available as a result of pumping tests.
W ; the width of the aquifer through which groundwater flow occurs
I ; the hydraulic gradient

The estimated flow can be considered to approximately be a recharge to the aquifer. This approach was used by the previous studies that constructed boreholes and conducted the pumping tests, which were Bali Groundwater (1977), Southern Bali Groundwater Investigation (1985) and North Bali

Groundwater Irrigation and Water Supply Project (1995).
Bali Groundwater (1977) has calculated the groundwater flow of the 7 zones out of the 8 zones selected for the study. The 7 zones (Zone II - VIII) are shown in Figure-C.14. Southern Bali Groundwater Investigation (1985) has calculated the flow of the southern zones from the eastern part of Tabanan to the western part of Karangasem shown as S.B Zone 1-35 in Figure-C.14. North Bali Groundwater Irrigation Project (1995) constructed more than 30 wells in the area of zone VI in Bali Groundwater (1977). Based on the results of the pumping tests conducted by the project, they calculated the flow of each divided narrow zone in the zone VI.

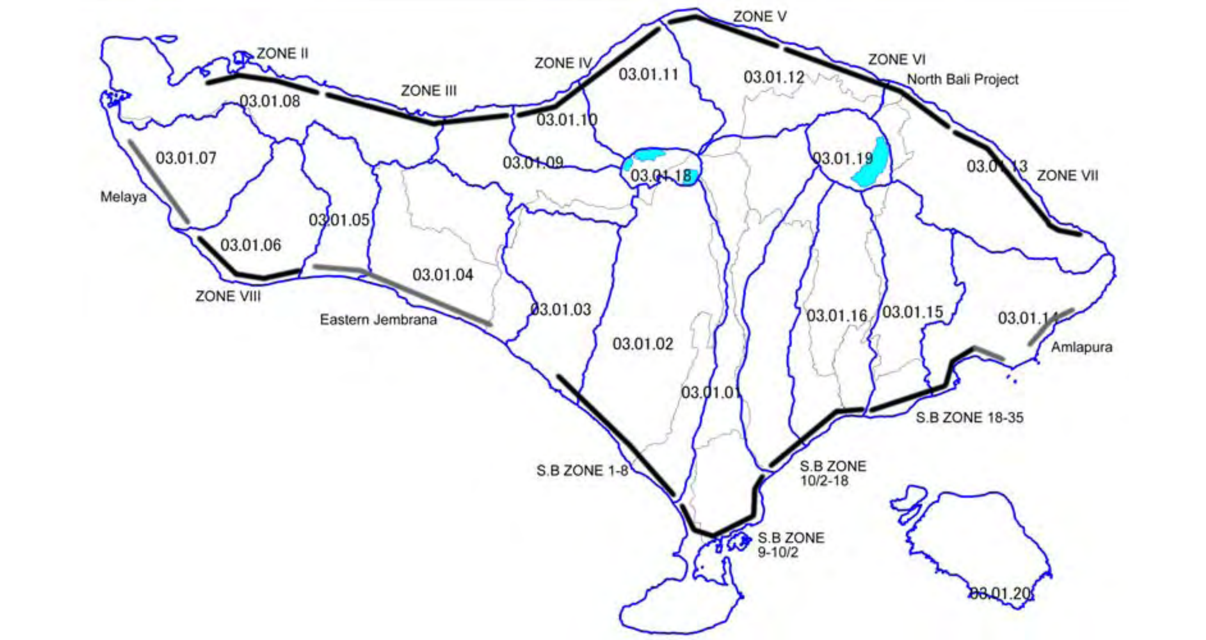

Figure-C.14 Zones for groundwater flow estimation

As shown in Figure-C.14, the zones of which the groundwater flow estimated covers almost entire Bali except some local areas, which are the plains of Melaya, the coastal plains of the eastern part of Jembrana, and the area around Amlapura. Groundwater flow is roughly calculated for these areas based on assumed values of transmissivity estimated by the values of specific capacity, which is explained in the subsection of 1.3. After reviewed the previous results, all of the estimated results were summarized in Table-C.10.

Another approach to estimate groundwater recharge is a water budget study or water balance analysis based on meteorological-hydrological data. To compare the groundwater flow with the total volume of precipitation in the main river basins contributing for the evaluated zones, the percentage of flow was calculated. The result is also shown in Table-C.10.

In addition to the above, IUIDP-Bali project (1989) adopted a different type of technique for the estimation of groundwater recharge. A “recharge coefficient” was determined for each geological formation using the base flows of 11 rivers. The volume of recharge to each regency was calculated with the recharge coefficient of the formation covered the regencies and the rainfall to the area. The IUIDP project recommended that 10% of the calculated recharge must be the exploitable limit, because some of the infiltrated water flow into streams and discharge as springs and then the rest is pumped from wells. Table-C.11 shows the revised result of IUIDP method with the latest data by JICA Study Team.

Table-C.10 Calculated Groundwater Flow

		Bali Groundwater (1977)							
Zone		Zone II	Zone III	Zone IV	Zone V	Zone VI		Zone VII	Zone VIII
Area Name		West Gerokgak	East G. to Sheririt	Shingaraja	Kubutanbahan	East Bulelen to Tianyar	North Bali Project (1995)	Tianyar to Amed	Negara
W	m	18000	24000	27000	5000	28000	29000	20000	22000
H	m		50	50					50
k	m/day		18	18					14
T	m2/day	200	900	900	450	880	(665)	880	700
I		0.018	0.007	0.007	0.01	0.006		0.006	0.005
Grounwater flow	m3/day	**64,800**	**151,200**	**170,100**	**22,500**	**147,840**	**81,816**	**105,600**	**77,000**
	m3/year	**23,652,000**	**55,188,000**	**62,086,500**	**8,212,500**	**53,961,600**	**29,862,749**	**38,544,000**	**28,105,000**
	MCM/y	**179.0**						**66.1**	**Jembrana**
Kabupaten		**Bleleng**						**Karangasem**	
Flow/Rainfall	%	14.2%	8.7%	9.1%	3.0%	11.0%	6.1%	9.0%	3.7%
Rainfall	m3/year	166,530,000	632,659,440	682,842,360	277,760,000	491,722,000		427,924,000	765,232,960
	mm	1365	1365 2096	1704 2005	1792	1792 1798		1798	2237
Area	km2	122	122 222.39	114.24 243.48	155	155 119		238	342.08
Sub-basin Name		a part of 03.01.08	part of 03.01.08 03.01.09	03.01.10 03.01.11	a part of 03.01.12	a part of 03.01.02 a part of 03.01.03		a part of 03.01.13	03.01.06

		Southern Bali Groundwater Investigation (1985)				JICA estimation			
Zone		Zone 1-8	Zone 9-10/2	Zone 10/2-18	Zone 19-35				
Area Name		Eastern Tabanan - Badung West	Denpasar	Giyanar-Klungkun west	Klungkun East-Manggis	Melaya	Eastern Jembrana (Mendoy, Pekutatan)	Amlapura	
W	m	30750	9500	37400	16800	12000	23000	6000	
H	m								
k	m/day								
T	m2/day	181	3000	300	51	2000	500	200	
I		0.0132	0.0092	0.0383	0.0461	0.005	0.01	0.03	**Total**
Grounwater flow	m3/day	**73,468**	**262,200**	**429,726**	**39,498**	**120,000**	**115,000**	**36,000**	**1,748,908**
	m3/year	**26,815,784**	**95,703,000**	**156,849,990**	**14,416,945**	**43,800,000**	**41,975,000**	**13,140,000**	**638,351,468**
	MCM/y	**26.8**	**95.7**	**156.8**		**113.9**			**638.4**
Kabupaten		**Tabanan**	**Badung/ Denpasar**	**Gianyar/Bangl i/Klungkun,**	**Karangasem**	**Jembrana**		**Karangasem**	
		(Reviced calcluration by JICA)							
Flow/Rainfall	%	1.2%	8.3%	11.5%	2.4%	11.4%	3.3%	4.2%	**6.2%**
Rainfall	m3/year	2,218,781,380	1,154,619,920	1,367,664,820	612,119,370	385,492,160	1,261,632,240	310,862,370	**10,264,121,020**
	mm	2450 2582	2078	2237 2337	1911 1629	1583	2360 - 2112	1911	
Area	km2	601.75 288.34	555.64	342.08 257.78	88 272.53	243.52	392.37 158.92	162.67	
Sub-basin Name		03.01.02 03.01.03	03.01.01	03.01.16 03.01.17	part of 03.01.14 03.01.15	03.01.07	03.01.04 03.01.05	a part of 03.01.14	

Table-C.11 Groundwater Recharge estimated by IUIDP approach

Kabupaten	Area	Rainfall	Recharge Coefficient	Recharge		Groundwater Exploitation Limit (10% of recharge)	
	(km^2)	(mm)		(mm)	(MCM/year)	(liters/sec)	(MCM/year)
Jembrana	858.26	1,970	0.21	413.7	355.1	1126	35.5
Tabanan	855.4	2,549	0.36	917.6	784.9	2489	78.5
Badung	398.29	2,078	0.41	852.0	339.3	1076	33.9
Denpasar	125.36	1,790	0.41	733.9	92.0	292	9.2
Gianyar	367.96	2,323	0.46	1,068.6	393.2	1247	39.3
Klungkung	106.77	1,763	0.3	528.9	56.5	179	5.6
Bangli	531.3	2,092	0.44	920.5	489.1	1551	48.9
Karangasem	846.32	1,810	0.43	778.3	658.7	2089	65.9
Buleleng	1333.59	1,834	0.27	495.2	660.4	2094	66.0
Nusa Penida	209.61	1,079	0.4	431.6	90.5	287	9.0
Total	5632.86	2,003			3,919.6	12,429	392.0

Revised by JICA

The same approaches (through flow and recharge coefficient) were applied to evaluate groundwater resources of each sub basin. The calculated result is shown in Table-C.12.

Table-C.12 Groundwater in Sub-Basins

No.	Sub-basin Code No.	Catchment Area (km^2)	Basin Average Rainfall Total		Ground-water Flow	Recharge coeffcient	Recharge	Groundwater Exploitation Limit (10%)
			(mm/year)	(MCM/year)	(MCM/year)		(MCM/year)	(MCM/year)
1	03.01.01	555.64	2,078	1,155	104.7	0.41	473.4	47.3
2	03.01.02	601.75	2,450	1,474	13.5	0.36	530.7	53.1
3	03.01.03	288.34	2,582	744	4.5	0.36	268.0	26.8
4	03.01.04	392.37	2,360	926	31.5	0.21	194.5	19.4
5	03.01.05	158.92	2,112	336	10.5	0.21	70.5	7.0
6	03.01.06	228.44	1,978	452	28.1	0.21	94.9	9.5
7	03.01.07	243.52	1,583	385	43.8	0.21	81.0	8.1
8	03.01.08	367.22	1,365	501	60.4	0.27	135.3	13.5
9	03.01.09	222.39	2,096	466	18.3	0.27	125.9	12.6
10	03.01.10	114.24	1,704	195	24.8	0.27	52.6	5.3
11	03.01.11	243.48	2,005	488	37.3	0.27	131.8	13.2
12	03.01.12	311.65	1,792	558	26.1	0.27	150.8	15.1
13	03.01.13	357.14	1,798	642	50.5	0.43	276.1	27.6
14	03.01.14	295.38	1,911	564	20.3	0.43	242.7	24.3
15	03.01.15	272.53	1,629	444	7.2	0.43	190.9	19.1
16	03.01.16	342.08	2,237	765	94.1	0.44	336.7	33.7
17	03.01.17	257.78	2,337	602	62.7	0.46	277.1	27.7
18	03.01.18	48.84	2,700	132	-	0.27	35.6	3.6
19	03.01.19	102.19	1,809	185	-	0.46	85.0	8.5
20	03.01.20	208.87	1,079	225	-	0.4	90.1	9.0
Total/Average		5,612.77	2,003	11,241	638.4		3843.6	384.4

The supposed aquifer widths and other factors for groundwater through flow analysis were based on the zones shown in Figure-C.14 and Table-C.10, which do not cover all coastline of Bali Island. Therefore, the total of the calculated figures may be less than the actual one. And the above total amount differs a little from the calculated total based on the area of each Kabupaten because some figures like aquifer width and recharge coefficient cannot accord completely. Anyway, the calculated groundwater potential is about 60% of the estimated flow in total.

C-2.2 Groundwater Use

(1) Deep Wells

Groundwater resources have been exploited by deep wells for irrigation, drinking water supply and other commercial use such as industries and hotels. The present condition of the groundwater use was summarized in Table-C.13.

Table-C.13 Present Groundwater Use

Regency/City	Pumping Rate from Tube Wells: Irrigation		PDAM		Others		Total
	(liters/sec)	(MCM/year)	(liters/sec)	(MCM/year)	(m^3/day)	(MCM/year)	(MCM/year)
Jembrana	357	11.3	139	4.4	7338	2.7	18.3
Tabanan	10	0.3	5	0.2	7257	2.7	3.1
Badung *	31	1.0	236	7.4	24107	8.8	17.2
Denpasar	0	0.0	350	11.0	25647	9.4	20.4
Gianyar	0	0.0	359.5	11.3	7120	2.6	13.9
Klungkung	0	0.0	5	0.2	2469	0.9	1.1
Bangli	0	0.0	0	0.0	764	0.3	0.3
Karangasem	113	3.6	69	2.2	2112	0.8	6.5
Buleleng	305	9.6	81.5	2.6	2035	0.7	12.9
Nusa Penida	0	0.0	5	0.2	-		0.2
Total	816	25.7	1,250	39.4	78,849	28.8	93.9

*: Badung includes PT.TB.

The values of pumping rate were estimated by the results of the inventory survey as well as the survey on water use and demand described in the supporting report concerned.

(2) Dug Wells

There are numerous dug wells used for domestic purpose. The extracted volume from the dug wells has not been recorded. Therefore, the amount was calculated based on per capita consumption of 60-80 liters/day and the ratio of people using dug wells. These values were estimated in the section of water use and demand. Table-C.14 shows the estimated result of extracted amount from dug wells.

Table-C.14 Extracted Amount of Dug Wells

Regency/City	Estimated Groundwater Use from Dug Wells	
	(m^3/day)	(MCM/year)
Jembrana	6,047	2.2
Tabanan	3,142	1.1
Badung	12,335	4.5
Denpasar	6,082	2.2
Gianyar	1,520	0.6
Klungkung	131	0.1
Bangli	424	0.2
Karangasem	882	0.3
Buleleng	11,181	4.1
Nusa Penida	201	0.1
Total	42,003	15.3

(3) Springs

Springs also have been widely used for irrigation, drinking water supply and others. The inventory survey conducted by JICA Study Team revealed the utilized amount of water from springs, which is summarized in Table-C.15.

Table-C.15 Utilized Volume of Springs

Regency/City	Yield		Abstracted Volume				
			Irrigation	PDAM	Others	Total	
	(liters/sec)	(MCM/year)	(liters/sec)	(liters/sec)	(liters/sec)	(liters/sec)	(MCM/year)
Jembrana	118.9	3.7	3.0	0.0	0.2	3.2	0.1
Tabanan	4148.6	130.8	832.5	1022.0	7.5	1862.0	58.7
Badung	1335.2	42.1	406.8	15.0	55.6	477.4	15.1
Denpasar		0.0				0.0	0.0
Gianyar	3051.9	96.2	80.0	393.0	1339.0	1812.0	57.1
Klungkung	263.1	8.3	0.0	78.8	56.6	135.4	4.3
Bangli	3393.4	107.0	517.0	131.3	43.4	691.7	21.8
Karangasem	9955.9	314.0	2357.7	183.2	1992.1	4533.0	143.0
Buleleng	6172.6	194.7	147.2	408.1	2378.8	2934.1	92.5
Nusa Penida	524.9	16.6	0.0	20.0	0.0	20.0	0.6
Total	28,964.5	913.4	4,344.2	2,251.4	5,873.2	12,468.8	393.2

C-2.3 Groundwater Development Potential

Groundwater development potential is considered to be the total groundwater flow from which the pumped volume of deep wells is deducted. The calculation of groundwater flow analysis does not count subsurface flows affected by dug wells and springs. First, the further development potential of dug wells and springs are described, and then the potential of exploitable groundwater by deep wells are explained.

(1) Dug Wells

Many dug wells have already been constructed in the locations where subsurface water may be extracted. Although the subsurface water is easy and cheap to use, excessive extraction certainly causes some problems such as the decline of the water table and the quality. The results of pumping tests of dug wells conducted by Bali Groundwater (1977) indicated that the potential of dug wells is suited to a very small-scale development. The potential of subsurface water is limited practically.

(2) Springs

The previous Table-C.15shows the yield of springs and the utilized amount from them. The rest can be calculated simply by deducting the utilized amount from the yield, which is shown in Table-C.16. However, once spring water comes out from subsurface, it flows directly into surface streams. Since most springs are located on the slopes of the mountain foot, the springs water is most likely diverted and used for irrigation on the way to downstream. The further use of springs may cause problems like a water shortage on the downstream area. Thus, not all of the calculated volume is usable, though the apparent amount is large. Consequently the expansion of spring use with a large scale is not recommendable except a particular case like Nusa Penida where it is difficult to exploit groundwater.

Table-C.16 Yield and Abstracted Volume of Springs

unit:MCM/year

Regency/City	Balance	Yield	Abstracted Volume
	A-B	A	B
Jembrana	3.7	3.7	0.1
Tabanan	72.1	130.8	58.7
Badung	27.1	42.1	15.1
Denpasar	0.0	0.0	0.0
Gianyar	39.1	96.2	57.1
Klungkung	4.0	8.3	4.3
Bangli	85.2	107.0	21.8
Karangasem	171.0	314.0	143.0
Buleleng	102.1	194.7	92.5
Nusa Penida	15.9	16.6	0.6
Total	520.2	913.4	393.2

(3) Deep Wells

(a) Groundwater Flow Approach

Groundwater development potential from deep wells can be estimated by the balance of the total groundwater flow and the discharge from wells at the present. Based on the results explained in the previous sections, Table-C.17 was provided to show the potential.

Table-C.17 Groundwater Development Potential

Unit:MCM/year

Regency/City	Potential	Groundwater Flow	Discharge from Wells	
	A-B	A	B	B/A
Jembrana	95.6	113.9	18.3	16.1%
Tabanan	23.7	26.8	3.1	11.7%
Badung	58.1	95.7	17.2	39.3%
Denpasar			20.4	
Gianyar	141.5	156.8	13.9	9.7%
Klungkung			1.1	
Bangli			0.3	
Karangasem	59.6	66.1	6.5	9.8%
Buleleng	166.1	179.0	12.9	7.2%
Nusa Penida	(0.2)		0.2	
Total	573.1	638.3	93.9	10.2%

Generally the volumes of water pumped from wells are around 10% of the groundwater flow, as shown in the above table. In Badun and Denpasar, however, almost 40% of the total flow has been already exploited. The further development should be carefully planned in the areas. And, naturally, it is noted that the excessive pumping from a coastal aquifer causes saline intrusion.

(b) Recharge Coefficient Approach (IUIDP method)

There was another approach conducted by IUIDP project, as explained in the sub section of 2.1. Based on the revised result in Table-C.11 and the analyzed data, another evaluation of the development potential was done. IUIDP project proposed the values equivalent 10% of the estimated recharge as the groundwater potential. Table-C.18 shows the calculated future development potential, which is calculated by deducting present exploited discharge from 10% of the estimated recharge.

Table-C.18 Groundwater Potential by IUIDP Approach

Regency/City	Potential (10% of recharge)	Present Discharge from Deep Wells		Future Development Potential	
	(MCM/year)	(MCM/year)	(liters/sec)	(MCM/year)	(liters/sec)
Jembrana	35.5	18.3	580	17.2	546
Tabanan	78.5	3.1	98	75.4	2391
Badung	33.9	17.2	545	16.7	531
Denpasar	9.2	20.4	647	-11.2	-355
Gianyar	39.3	13.9	441	25.4	806
Klungkung	5.7	1.1	35	4.6	144
Bangli	48.9	0.3	10	48.6	1541
Karangasem	65.9	6.5	206	59.4	1883
Buleleng	66	12.9	409	53.1	1685
Nusa Penida	9.1	0.2	6	*8.9	*281
Total	392	93.9	2978	298.1	9452

*: Development is not recommendable.

(c) Summary and Conclusions

Development potential was calculated by two approaches; 1) flow analysis and 2) revised IUIDP as shown in Table-C.19.

Table-C.19 Summarized Results

<table>
<tr><th rowspan="3">Regency/City</th><th colspan="5">Estimated Development Potential</th></tr>
<tr><th>Flow Analysis</th><th colspan="4">Revised IUIDP</th></tr>
<tr><th>(MCM/year)</th><th colspan="2">(MCM/year)</th><th colspan="2">(liters/sec)</th></tr>
<tr><td>Jembrana</td><td>95.6</td><td colspan="2">17.2</td><td colspan="2">546</td></tr>
<tr><td>Tabanan</td><td>23.7</td><td colspan="2">75.4</td><td colspan="2">2391</td></tr>
<tr><td>Badung</td><td rowspan="2">58.1</td><td>16.7</td><td rowspan="2">5.5</td><td>531</td><td rowspan="2">176</td></tr>
<tr><td>Denpasar</td><td>-11.2</td><td>-355</td></tr>
<tr><td>Gianyar</td><td rowspan="3">141.5</td><td>25.4</td><td rowspan="3">78.6</td><td>806</td><td rowspan="3">2491</td></tr>
<tr><td>Klungkung</td><td>4.6</td><td>144</td></tr>
<tr><td>Bangli</td><td>48.6</td><td>1541</td></tr>
<tr><td>Karangasem</td><td>59.6</td><td colspan="2">59.4</td><td colspan="2">1883</td></tr>
<tr><td>Buleleng</td><td>166.1</td><td colspan="2">53.1</td><td colspan="2">1685</td></tr>
<tr><td>Nusa Penida</td><td>-0.2</td><td colspan="2">*8.9</td><td colspan="2">*281</td></tr>
<tr><td>Total</td><td>573.1</td><td colspan="2">298.1</td><td colspan="2">9452</td></tr>
</table>

*: Development is not recommendable.

Table-C.19 shows the summarized results, which indicates follows:

- Tabanan has larger potential in revised IUIDP than the potential estimated by the flow analysis. There are many springs indicating a large recharge to this area and the geological condition is almost same as Badung and Gianyar. The result of flow analysis may be rather low.
- On the other hand, Jembrana and Buleleng have larger potential than the potential estimated by the revised IUIDP. Though these areas also have many springs and productive wells, the groundwater recharge and reserve areas of these regencies are relatively narrow. It is possible that the results of flow analysis may be over estimation.

- Even some potential is expected, the development by deep wells is practically difficult in Nusa Penida, because of very low water level and a risk of saline intrusion.

The report adopts the values obtained by the revised IUIDP method as the future groundwater potential of areas based on some points; 1) Flow analysis estimation may be doubted at the above described points, 2) The values by revised IUIDP are rather conservative estimate, and 3) have been used as a standard of groundwater potential in Bali.

The table above indicates simply the general potentialities of the areas. A detailed feasibility study is always necessary to make an actual plan for development.