JAPAN INTERNATIONAL COOPERATION AGENCY
THE GOVERNMENT OF THE REPUBLIC OF INDONESIA

THE STUDY ON FLOOD CONTROL AND WATER MANAGEMENT IN LIMBOTO-BOLANGO-BONE BASIN IN THE REPUBLIC OF INDONESIA

FINAL REPORT

VOLUME-III SUPPORTING REPORT: PART-A

EXISTING CONDITIONS

DECEMBER 2002

NIKKEN CONSULTANTS, INC.
AND
NIPPON KOEI CO., LTD.

THE STUDY ON FLOOD CONTROL AND WATER MANAGEMENT
IN
LIMBOTO-BOLANGO-BONE BASIN

FINAL REPORT

LIST OF REPORTS

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VOLUME-III SUPPORTING REPORT: PART- A EXISTING CONDITIONS

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GLOSSARY

(ENGLISH ABBREVIATION)

ADB	Badan Pembangunan Asia	Asian Development Bank
ASTM		American Standards for Testing Materials
BCR, B/C	Rasio Harga dan Keuntungan	Benefit Cost Ratio
BOD		Biochemical Oxygen Demand
CEA	Badan Pelaksana Kanada	Canadian Executing Agency
CIDA	Badan Penyandang Dana Kanada	Canadian International Development Agency
COD		Chemical Oxygen Demand
DD, D/D	Disain Teknis/Rencana Teknis	Detailed Design
DGWR	Direktorat Jenderal Sumber Daya Air	Directorate General of Water Resources
DGWRD	Direktorat Jenderal Pengairan	Dir. General of Water Resources Development
DO		Dissolved Oxygen
EIA	Analisa/Penelitian Lingkungan	Environmental Impact Assessment
EIRR	Tingkat Pengembalian Modal Internal Ekonomi	Economic Internal Rate of Return
FAO	Organisasi Pangan Dunia	Food and Agriculture Organization of the United Nations.
FS, F/S	Studi Kelayakan	Feasibility Study
FY	Tahun Anggaran	Fiscal Year
GDP	Produk Domestik Bruto	Gross Domestic Product
GIS	Sistem Informasi Geografi	Geographical Information System
GOI	Pemerintah Indonesia	Government of Indonesia
GPS	Penentuan Posisi Global	Global Positioning System
GRDP	Produk Domestik regional Bruto	Gross Regional Domestic Product
IBRD	Bank Dunia	International Bank for Reconstruction and Development (World Bank)
IEE		Initial Environmental Examination

JBIC		Japan Bank for International Cooperation (Former OECF)
JICA		Japan International Cooperation Agency
LAN	Jaringan Komputer Lokal	Local Area Network (Computer)
MCM	Juta Meter Kubik	Million Cubic Meters
MP, M/P	Rencana Induk	Master Plan
MSL	Tinggi Muka Air Laut Rata-rata	Mean Sea Level
NGO	Lembaga Swadaya Masyarakat	Non-Governmental Organization
NPV	Nilai Sekarang Neto	Net Present Value
O&M	Operasi dan Pemeliharaan	Operations and Maintenance
OECF	Badan Penyandang Dana Jepang	Overseas Economic Cooperation Fund (Japan), Now reorganized JBIC
OJT	Latihan di Lapangan	On-the-Job Training
PCM	Pertemuan Konsultasi Masyarakat	Public Consultation Meeting
R	Sungai	River
S/W		Scope of Works
TIU	Unit Pelaksana Teknis Dinas	Technical Implementation Unit
UNESCO	Badan Pendidikan, Ilmu Pengetahuan dan Kebudayaan, P.B.B	United Nations Educational, Scientific, and Cultural Organization
USAID	Badan Penyandang Dana Amerika Serikat	United States Agency for International Development
VAT		Value Added Tax
WATSAL	Wanita dalam Pembangunan	Water Sector Adjustment Loan
WID	Pengembangan Sumber Daya Air	Women in Development
WUA	Federasi Petani Pemakai Air	Water Users Association

(INDONESIAN ABBREVIATION)

AMDAL	Analisis mengenai Dampak Lingkungan	Environmental Impact Analysis
ANDAL	Analisis Dampak Lingkingan	Environment Impact Statement
APBD	Anggaran Pendapatan dan Belanja Daerah	Regional Income and Expenditure
APBN	Anggaran Pendapatan dan Belanja Nasional	National Income and Expenditure
Ass.	Asisten	Assistant
BAKORNAS PBP	Badan Koordinasi Nasional Penanggulangan Bencana dan Penanganan Pengungsian	National Coordination Board of Disaster and Evacuation
BAPEDAL	Badan Pengendali Dampak Lingkungan	Environmental Impact Management Board
BAPEDALDA	Badan Pengendali Dampak Lingkungan Daerah	Regional Environmental Impact Management Agency
Bappeda	Badan Perencanaan Pembangunan Daerah	Provincial Development Planning Board
Bappenas	Badan Perencanaan Pembangunan National	National Development Planning Board
Binlak	Pembinaan & Pelaksanaan	Construction Management
BMG	Badan Meteorologi dan Geofisika	Meteorological and Geophysical Institute
BPS	Badan Pusat Statistik	National Statistics Office
Bupati	Kepala Daerah Tingkat II/Kabupaten	Head of District (Regency)
CD, Cabdin	Cabang Dinas	Branch of Dinas
DATI I	Daerah Tingkat I	Regional Level I (Province)
DATI II	Daerah Tingkat II	Regional Level II (District)
DI	Daerah Irigasi	Irrigation Schemes
DinasPU, DPU	Dinas Pekerjaan Umum	Public Works Services
DIP	Daftar Isian Proyek	List of Project Budget
DPR	Dewan Perwakilan Rakyat	National Parliament
DPRD	Dewan Perwakilan Rakyat Daerah	Regional Parliament
DPU	Departemen Pekerjaan Umum	Ministry of Public Works

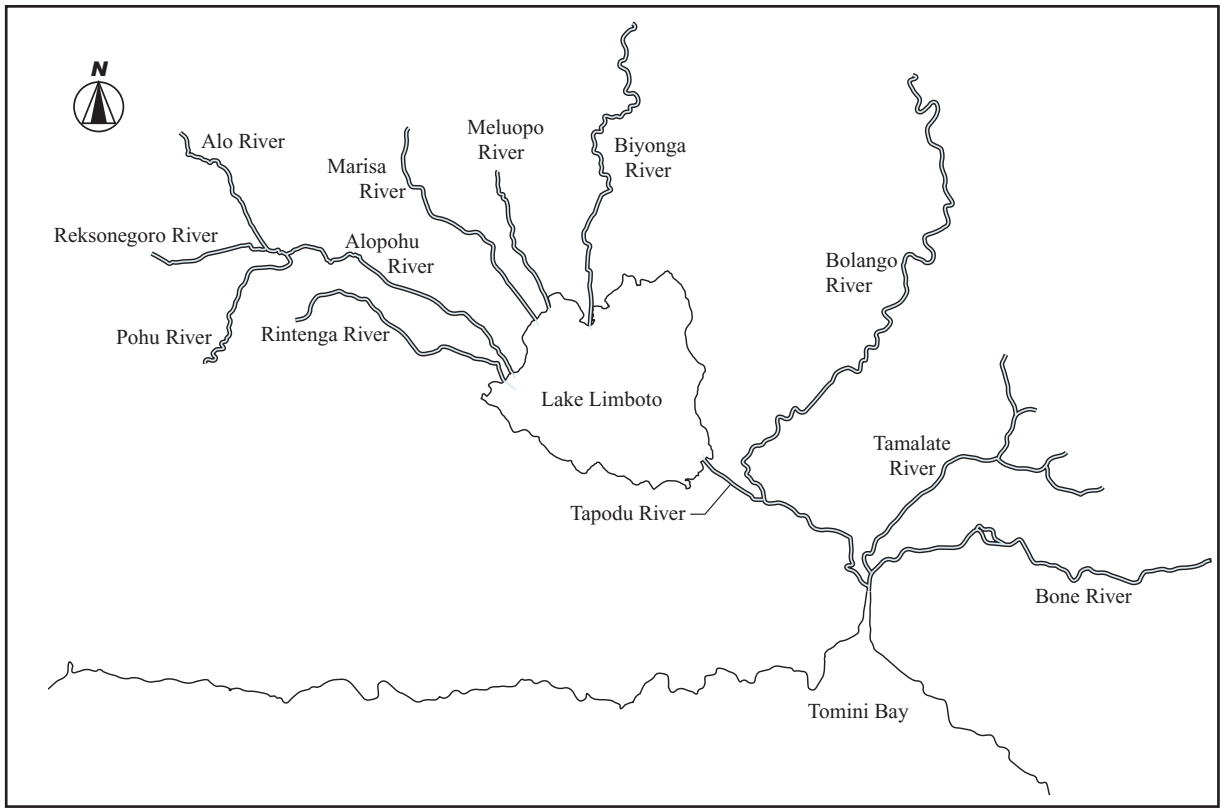
DPUP	Dinas Pekerjaan Umum Propinsi	Provincial Public Works Services
DTP	Dinas Tanaman Pangan	Office of Food Crops
Kanwil	Kantor Wilayah	Regional Office (of a Department)
Kaur	Kepala Urusan	Head of Sub Section
KDH	Kepala Daerah	Head of Regional Government
KDPP	Kepala Daerah Pengamatan Pengairan	Head of Water Resources Sub District
Kepmen	Keputusan Menteri	Minister's Decree
Keppres	Keputusan Presiden	Presidential Decree
KIMPRASWIL	Departemen Permukiman dan Prasarana Wilayah	Ministry of Settlement and Regional Infrastructure (MSRI)
KSDP	Kepala Sub Dinas Pengairan	Head of Provincial Water Resources Service
KTL	Kegiatan Tindak Lanjut	Follow-up Activity
KUD	Koperasi Unit Desa	Village Cooperative Unit
LBB	Limboto-Bolango-Bone	Limboto-Bolango-Bone
LSM	Lembaga Swadaya Masyarakat	Non-Governmental Organization
MONEV	Monitoring & Evaluasi	Monitoring & Evaluation
O&P	Operasi dan Pemeliharaan	Operations and Maintenance
P3A	Perkumpulan Petani Pemakai Air	Water Users' Association (WUA)
P3SU	Proyek Pembinaan Pengairan Sulawesi Utara	North Sulawesi Water Resources Institutional Development Project
PDAM	Perusahaan Daerah Air Minum	Regional Water Company
PDSA	Pengumpulan Data Sumber Air	Water Resources Data Collection
PEMDA	Pemerintah Daerah	Regional Government
PERDA	Peraturan Daerah	Regional Regulation
Pimpro	Pemimpin Proyek	Project Manager
Pinbagpro	Pemimpin Bagian Proyek	Sub Project Manager
PJP	Program Jangka Panjang	Long Term National Dev. Program
PLN	Perusahaan Listrik Negara	State Electricity Company
PPTPA	Panitia Pelaksanaan Tata Pengaturan Air	Basin Water Management Committee

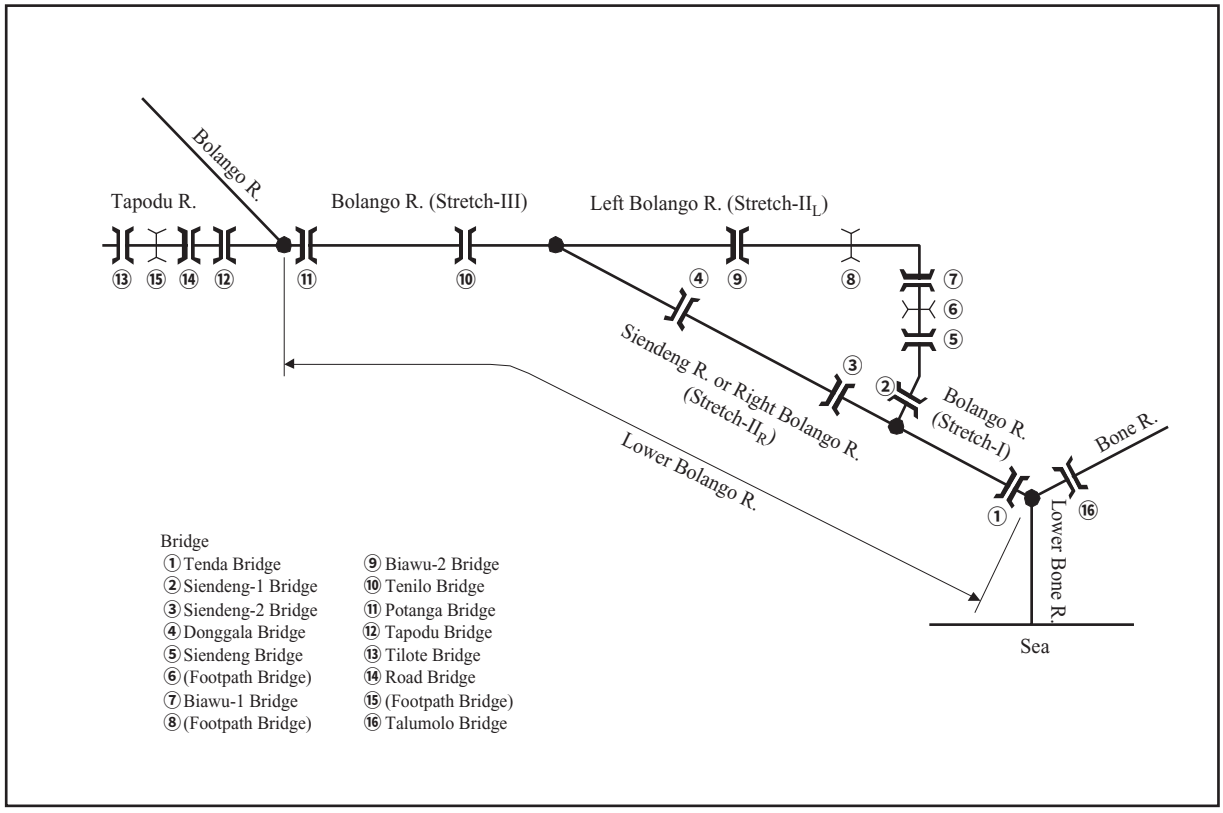
PSDA	Pengamanan Sumber Daya Air	Water Resources Conservation
PTPA	Panitia Tata Pengaturan Air	Provincial Water Resources Committee
PU	Pekerjaan Umum	Public Works
Puslitbang	Pusat Penelitian dan Pengembangan Pengairan PU	Institute of Hydraulic Engineering Center (Bandung)
PWS	Pengembangan Wilayah Sungai	River Basin Development
RKL	Rencana Pengelolaan Lingkungan	Environmental Management Plan
RPL	Rencana Pemantauan Lingkungan	Environmental Monitoring Plan
SATKORLAK PBP	Satuan Koordinasi Pelaksanaan Penanggulangan Bencana dan Penanganan Pengungsian	Implementation Coordination Unit of Disaster Mitigation and Evacuation
SATLAK PBP	Satuan Pelaksanaan Penanggulangan Bencana dan Penanganan Pengungsian	Implementation Unit of Disaster Mitigation and Evacuation
SDA	Sumber Daya Air	Water Resources
Sulut	Sulawesi Utara	North Sulawesi
Tkt. I	Tingkat I	Level I Administration (Province)
Tkt. II	Tingkat II	Level II Administration (Region)
UNSRAT	Universitas Sam Ratulangi	Sam Ratulangi University
UPTD	Unit Pelaksana Teknis Dinas	Technical Implementation Unit

(SOME INDONESIAN WORDS)

Desa	Village (rural area), The Lowest Administrative Unit, Headed by Kepala Desa or Kades who is elected by the residents
Kabupaten, Kab.	Administrative District Headed by Bupati (regency)
Kecamatan, Kec.	Administrative Sub District within the Kabupaten
Kelurahan	Village (urban area), The Lowest Administrative Unit, Headed by Lurah who is Appointed
Kota	Municipality, Administrative District Headed by the Walikotamadya
Kotamadya	Municipality, Administrative District Headed by the Walikotamadya
Propinsi	Province
Ribu	thousand = 1,000
Juta	million = 1,000,000
Milyar	billion =1,000,000,000
Trilyun	trillion = 1,000,000,000,000

NAME OF RIVER





A1. TOPOGRAPHY AND GEOLOGY

A1.1 Topography

(1) North Sulawesi

Sulawesi Island is the third largest in area of the Larger Sunda Islands, following Kalimantan, Sumatra islands, being entirely occupied by mountainous topography. The island consists of four narrow branches or arms, separated by deep gulfs and uniting in a central trunk, stretching in its typical outline of K.

The Sulawesi Island is surrounded by deep basis and troughs namely, the Sulawesi basin in the north, the Makassar trough in the west, Maluku and North Banda basins in the east, and South Banda (Flores) basin in the south. The Study Area of the Limboto–Bolango–Bone basin is located in the central part of north arm (the Minahassa Peninsula) of Sulawesi Island.

The Minahassa Peninsula stretches E-W direction in general, with its eastern end in NE-SW direction. The peninsula narrows down to 30km around Dondo Bay in the western end, and changes the trend to N-S direction toward Central Sulawesi.

Eastern part of the Minahassa Peninsula, trending NE–SW in direction, has active volcanoes extending onto Mindanao of the Philippine archipelago via Sangihe Islands. The central and western part of the Minahassa Peninsula has an E-W direction. The width of this section changes from 35km in the central to more than 100km in the western part. The whole of the Minahassa Peninsula is mountainous in general, except for sporadic coastal lands and some part of the area where a longitudinal depression stretches between the mountainous ranges of the north and those of the south coast. This longitudinal depression is observed also in the Study Area.

(2) Study Area

The Study Area is located in the central part of the Minahassa Peninsula covering total area of 2,700 km^2 consisting of three major basins such as Lake Limboto, Bolango River and Bone River basins. Topography of the Study Area is dominantly oriented in the E-W direction, bounded by the east-west oriented mountain ranges on the north and the south, and flat lowland plain in-between

The basins of Lake Limboto and the Bolango River are located in the western half of the Study Area and the Bone River basin in the eastern half of the area. All rivers flow dawn to the central lowland plain from mountainous area and finally empty into the Tomini Bay at southern most of the Gorontalo City.

The Biyonga, Alo, Molamahu, Pohu, Rintenga rivers are the main rivers flowing into Lake Limboto. The Bolango River, joining the outlet channel of Lake Limboto in the lower reaches, flows into the Bone River. The Bone River drains the eastern half of the LBB basin into the sea together with western half of the basin consisting of the Bolango River and Lake Limboto basins. These rivers are dissecting mountains and transporting sediments to lowland plains. It is assumed from the existence of unconsolidated lake deposits found in these basins that there used to be a large scale impounding reservoirs covering these basins. The Limboto Lake appears to be its remnant. The topography of the study area is shown in Figure A1.1.1.

A1.2 Geology

(1) North Sulawesi

Sulawesi appears to be formed by the collisions of two main crustal plates on the surface of the earth. The Australian plate is thrust westwards by sub-crustal magma currents, and it collides with the rigid Asian plate. The collisions were accompanied by considerable crust faulting and rotation of the fragments of the main plates. The Australian plate is being subducted beneath the Asian plate and it causes periodic rifting and separation of the fragments of the plate.

The North Sulawesi together with the South Sulawesi is split along the line of Makassar Strait from Asian plate of eastern Kalimantan due to the said tectonic process during the middle of Tertiary. According to the report prepared by Hamilton(1998), the North Sulawesi belongs to the Cretaceous subduction system. The oldest pre-Tertiary basement rocks of a complex of metamorphic and ultra basics are exposed in south western end of the North Sulawesi. Subsequently early-to-mid Tertiary volcanic rocks inter-bedded with sedimentary rocks are distributed covering the said basement rocks. Granite intrusions occurred in Middle and late Tertiary and they are widespread in the North Sulawesi closely associating mineralization.

Sandstones, volcanic conglomerates and thin beds of lime stones were formed in late Tertiary. They are mostly observed in the northern part of the North Sulawesi. Relatively less consolidated and gently dipping sedimentary strata called "Celebes Mollasse", which consists of conglomerates, quartz sandstones, shale, marls, coral lime stones are distributed mainly over granites and granitized rocks.

Volcanic rocks of andestic and/or dacitic composition were intruded through the above strata in early Quaternary and they formed the highest mountains in the region. Recent deposits of sands, gravels and coral reefs are distributed covering the said all strata. Stratigraphy of the area is described in Table A1.2.1.

(2) Study Area

Geology of the study area consists mainly of igneous, volcanic and sedimentary rocks of middle Tertiary to early Quaternary periods. Volcanic and sedimentary rocks formed prior to igneous intrusion are slightly to highly metamorphosed, and the original state of highly metamorphosed rocks are somehow undistinguishable. Some sedimentary rocks are granitized and metamorphosed. The strata of pre-Mid-Tertiary appear to form the basement rocks in study area. They consist of igneous rocks of granites and grano-diorites as well as metamorphosed rocks.

Sedimentary rocks of late Tertiary appear not to exist in the area. However, existence of crystallized state of lime stones indicates distribution of Tertiary sedimentary rocks prior to the latest volcanic event of early Quaternary. Sedimentary rocks of late Quaternary are distributed in the Study Area. They are composed of clay stone, sandstone, conglomerate and limestone.

Latest volcanic activities of early Quaternary formed the frame of the present topography in the study area. Andestic and dacitic lavas as well as agglomerates spread in high peaks of the area. Non-welded tuffs are also observed along the right bank of the Bone River.

Unconsolidated deposits of gravels and sands are widely distributed in the lowland of the basin. Talus and terrace deposits are also distributed in scarps of hilly and as well as mountainous areas covering the older formations. Geological map and schematic profile of the study area are shown in Figures A1.2.1 and A1.2.2, respectively.

A1.3 Geotechnical Conditions

Geological and geotechnical data obtained during the study period are reviewed and confirmed by the geological reconnaissance. Several dam-site data presented in the previous study reports were included among them. The dams proposed by the previous studies are located in the Bolango, Biyonga, Marisa, Alo and Molamahu rivers.

Core drillings were also carried out by the Study Team to obtain geotechnical information for possible dam and structure sites and lowland plain. The geotechnical conditions of the possible structure sites are described below in brief based on the previous study results and the core drilling data obtained by the Study Team.

(1) Dam Sites

Two dam sites, Toheti-Dehua dam along the Bolango River and Kayu-Merah dam along the Biyonga River have been selected for further flood control study, according to results of previous study by CIDA. These dam sites were selected for geological investigations during the Master Plan study period. Five (5) boreholes were drilled in each proposed dam site. Three (3) boreholes are allocated in dam axis and one (1) borehole each in the upstream and downstream sections as shown in Figure A1.3.1.

Toheti-Dehua Dam in Bolango River

The dam site is located on the Bolango River just downstream of the confluence with the Monglilo River. The river section of the dam site is relatively wide of nearly 300 m and the slopes of both abutments are moderately steep. Geological map and sections are shown in Figures A1.3.2 and A1.3.3 based on the results of drillings.

The basement rock is confirmed to be igneous rocks of granites, grano-diorites and hornfels and/or quartzite. The basement rock is covered with alluvial deposits of maximum thickness of around 35 m according to the drilling results. Top portion of the basement rock is moderately weathered and judged to be CL to CM in rock grade, and moderately large permeability of 5×10^{-4} cm/sec is recorded as the results of core drilling and permeability test performed for this study. Fresh state of the basement rock is sound enough of CM to CH in rock grade and permeability is quite low of 1.0×10^{-5} cm/sec according to the drilling results.

Kayu Merah Dam in Biyonga River

The dam site is located on the Biyonga River, at around 2 km upstream from the topographical boundary between the flood plain and mountainous area. Geological map and sections are shown in Figures A1.3.4 and A1.3.5 based on the results of drillings.

The slopes of abutments are moderately gently in both sides of the river, and river valley is relatively wide. The basement rock confirmed to be igneous rocks of Hornfels and dacite in the area. Basement rock is hard and compact and classified to be CM to CH in rock grade. Permeability of the foundation rock is low of 1×10^{-4} to 3×10^{-5} cm/sec as the result of permeability test. The basement rock is sound enough for dam foundation.

Other Dam Sites Discussed in Previous Studies

Marisa River: The dam site is located on the Olitabu River 1 km upstream from the junction between Olitabu and Buliyaa rivers, which both rivers are tributaries of the Marisa River. The dam site is situated near the village of Marisa. The slopes of both abutments are moderately gentle and the river terrace is relatively wide. The bedrocks appear to be composed of sedimentary rocks of mudstone alternating with sandstones, however, igneous and volcanic rocks underlying the sedimentary rocks are widely distributed nearby. The sedimentary rocks are relatively soft and highly weathered in general. Unconsolidated deposits, such as riverbed, terrace and talus deposits, are distributed covering the said rocks. The strength of the bedrocks and thickness of unconsolidated deposits shall be examined when the dam is planned.

Buhiyaa River: The dam site is located on the Buhiyaa River, around 500 m upstream from the topographic boundary between the lowland plain and hilly terrains. The slopes of both abutments are steep and they consist of coral lime stones. The lime stones of the bed rocks are massive and slightly weathered in dam site. No relatively large-scale cavities were observed in exposed rocks. The bedrock of lime stones appears to have enough strength for dam foundation, however seepage from the reservoir shall be assumed due to cavities which may exist in lime stones in general.

Molamahu River: The dam site is located on a tributary of the Molamahu River, where the topographic boundary between flood plains and hilly and mountainous areas. The

slopes of the abutments are steep and/or relatively steep in general, however terrace are formed along the river stream in height of around 10 m at places. The bedrock consists of coral lime stones underlying by sedimentary rocks, of which assumed to be sandstones and mudstones. The bedrocks are covered with terrace and present river deposits. The bedrock is relatively soft however it appears to have enough strength for 20 m high concrete structure proposed by CIDA. Coral lime stones of the bedrock have cavities observed in rock exposes. Foundation treatment will be needed as seepage through cavities is envisaged.

(2) Lowland Plain

Eight (8) boreholes were also drilled to confirm geotechnical conditions of lowland plain during the Master Plan study period. Locations of points A through H are indicated in the Figure A1.3.1. Results of drilling executed in the lowland plain are presented below by the points.

Point A: Point A is located in the lowland plain along Biyonga River at the north of Lake Limboto. Topographic boundary between lowland plain and hilly terrain is situated near the point A. Drilling hole was selected to place near the road. As a result of the drilling, recent deposits of around 4 m in thickness was confirmed to reach the foundation rock. The foundation rock of soft sandstone was confirmed in point A. N values of more than 50 were recorded below the depth of 4 m. Sound foundation can be obtained at depth of 4 m below ground surface.

Point B: Point B is located in northeast of Lake Limboto in between Bolango and Biyonga rivers, near topographical boundary between lowland plain and hilly terrain. Recent deposits of sandy gravels in thickness of a few meters were confirmed over base rock of volcanic. N-value of more than 30 was recorded in all section as a result of standard penetration tests, and it secures sound foundation for small structures.

Point C: Point C is located near Pilohayanga weir on Bolango River in northeast of Lake Limboto. Only river deposits of sandy gravels are confirmed in whole length of the borehole, therefore bedrock lays more than 15 m below the ground surface. N value of less than ten (10) is recorded in shallower portion of 3 m in thickness below the ground surface. N-value of ten (10) to thirty (30) are recorded at depth of below 3 m from ground surface. Attention shall be paid to foundation of structures in such poor geotechnical condition.

Point D: Point D is located near northern shore of Lake Limboto. Clay and loose unconsolidated fine to medium sand are distributed in shallower portion of the area, however sand is confirmed at depth of more than 6 m below ground surface. N values of more than 30 are recorded at depth of more than 10 m below ground surface. Relatively poor geotechnical condition is confirmed up to 5 m in depth.

Point E: Point E is located near northeast shore of Lake Limboto. No bedrock is confirmed up to 15 m in depth. Loose unconsolidated deposits of clay and fine to medium size of sand are confirmed in shallower and deeper portion of the borehole. Sandy deposits showing N value of more than 30 are distributed at depth between 7 to 10 m below ground surface. Relatively poor geotechnical condition is confirmed up to 5 m in depth.

Point F: Point F is located along Bolango River in the east of Lake Limboto. Irrigation canal exists near the drilling hole of this point. River deposits and/or deposits of flood plain are confirmed through drilling works. Bed rock of volcanic is also confirmed at depth more than 6 m below ground surface. N values of more than 50 are recorded in the bedrock layer. Relatively poor geotechnical condition is confirmed up to 5 m in depth, however sound foundation can be obtained in bedrock layer at depth of 6 m below ground surface.

Point G: Point G is located at outlet of Lake Limboto along southeast of the lake shoreline. Loose and moderately consolidated deposits of various size of sand are distributed there. Sandy gravel layer is encountered with intercalation of medium to coarse sand deposits throughout the drilling hole. Attention shall be paid to foundation of structures in such poor geotechnical condition.

Point H: Point H is located near center of Gorontalo city in the east of Lake Limboto. The area near point H is becoming residential area of Gorontalo city, though the point H is situated in the paddy field. Top soil of the paddy field is relatively loose and shows 14 in N value, however N values of more than 50 was recorded throughout the drilling hole except top soil of 6 m in thickness. Sound foundation for small structures can be obtained at depth of 3 m below the ground surface.

(3) Structure Sites

During the Feasibility Study period, core drillings were conducted by the Study Team at major structure sites to obtain geotechnical information on subsurface conditions of these structures. In addition, boring was conducted at the estuary of the Bone River to confirm the riverbed conditions which forms abrupt drop facing to the sea.

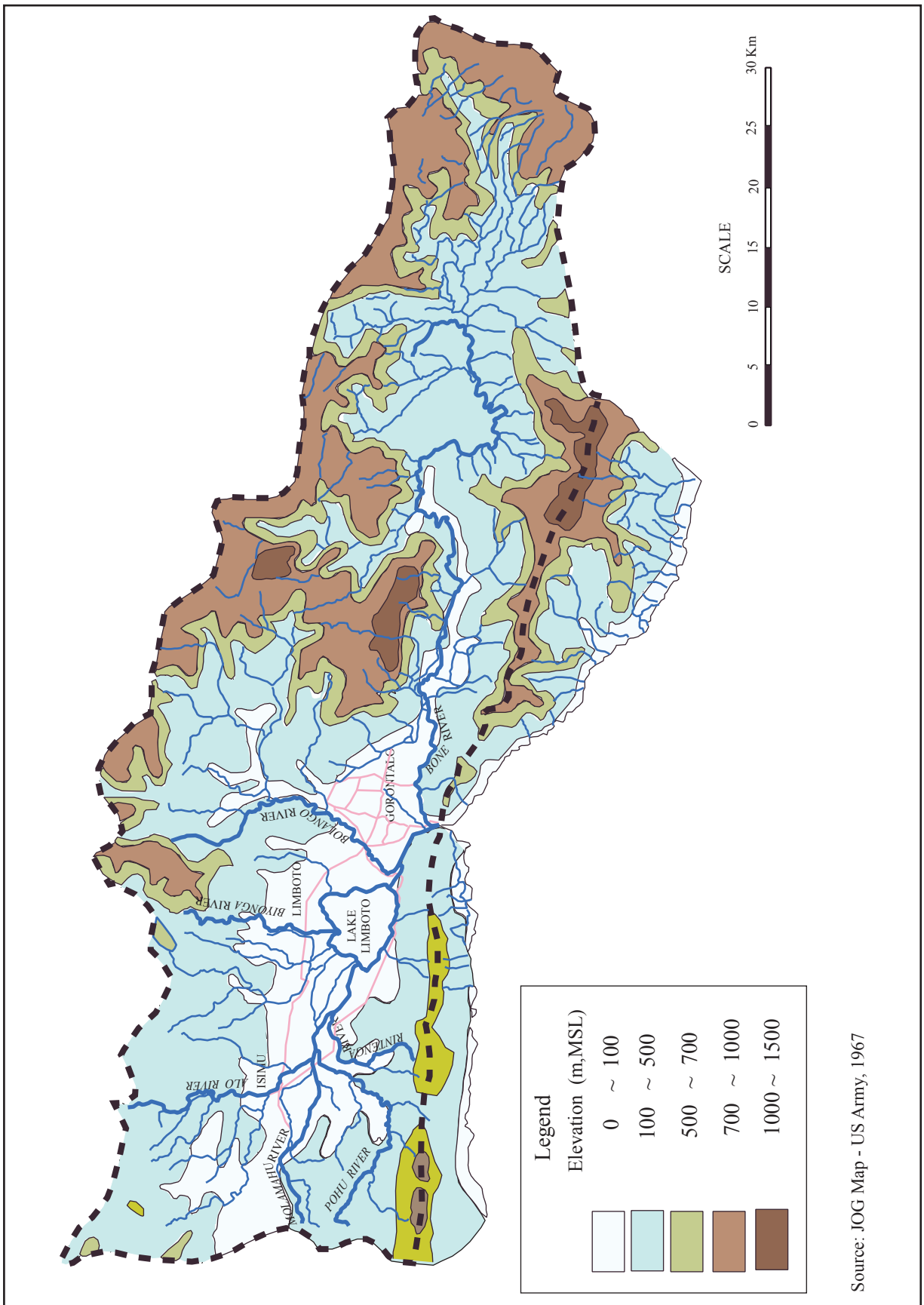
Tapodu Gate: Tapodu gate is located at around 1km downstream of the outlet of Lake Limboto. No base rock was confirmed according to the drilling works. However, recent deposits of sandy gravel are distributed in the river section. Sandy gravel layers of more than 30 in N value appear to have sufficient strength for foundation of the structures.

Tamalate Weir: Tamalate weir is planned to build in the inlet of Tamalate Floodway and recent deposits of sand and gravel are distributed around the area. No bedrock was confirmed through drilling works. However, outcrops of tuff breccia are observed around 200m west of the weir site. Base rock of the site appears to be the tuff breccia according to the site reconnaissance of the area.

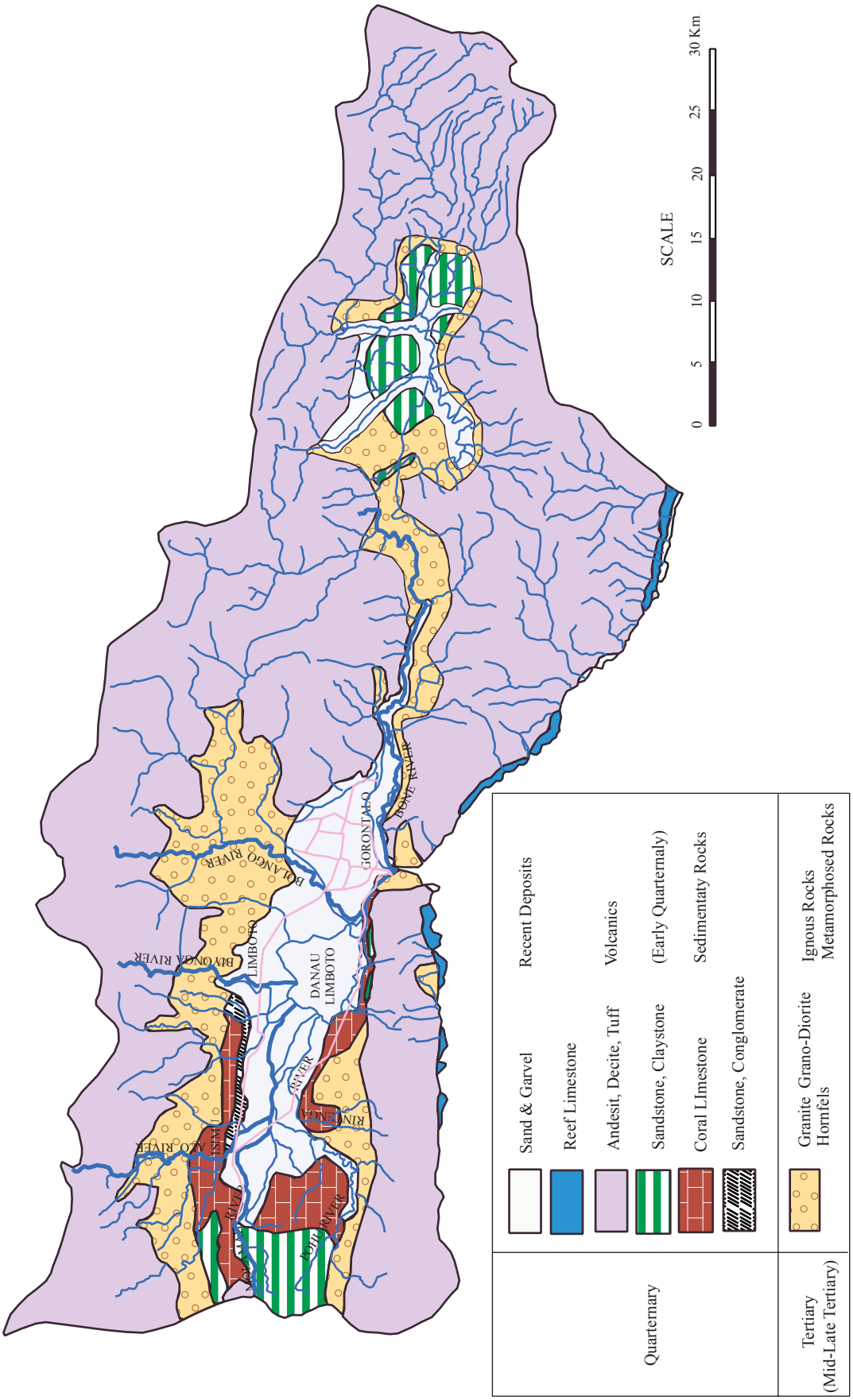
Estuary of Bone River: Borings were conducted at five (5) boreholes in the stretch from river mouth to confluence of the Bone and Bolango rivers. Out of the five, one borehole was extended to 15 m in depth. As a result, no bedrocks were confirmed at any boreholes. The riverbed of the Bone estuary is formed by thick sand and gravel sediments. The abrupt drop of riverbed at the sea front seems to be formed by river sediment and deep seabed like sediment deposition seen in dam reservoirs.

Table A1.2.1 GEOLOGICAL STRATIGRAPHY OF NORTH SULAWESI

CENOZOIC	Recent		Sand , Gravels , coral reefs
	Early Quaternary	Sedimentary rocks	Conglomerates , Quartz , sand-stones , Shale , Marls , Coral limestones (Celebes Molasse gently dipped)
	Early Quaternary	Volcanic rocks	Andestic and dacitic lavas , Tuffs in same composition
	Late Tertiary	Sedimentary rocks	Quartz sandstone , Silicified sandstone , Volcanic conglomerates Limestone (relatively thin)
	Mid-Late Tertiary	Igneous rocks	Granites , Granodiorites , Gabbros
	Middle Tertiary	Volcanic rocks	Lavas , Breccias , Agglomerates interbedded with sandstones , Siltstone , Shales and Limestones
	Early Tertiary	Volcanic rocks	Pillow lava , Tuff breccias Agglomerates interbedded with Sandstone , (Red) Shale , Limestone , greywacke , Tuff , Claystone, etc.
MESOZOIC	Cretaceous	Metamorphic complexes	Greenshist , Gneiss , Quartzite , Phyllites , Biotite-quartz schist, etc.



The Study on Flood Control and Water Management in Limboto-Bolango-Bone Basin in the Republic of Indonesia	**Figure A1.1.1**
Japan International Cooperation Agency	**TOPOGRAPHY OF STUDY AREA**

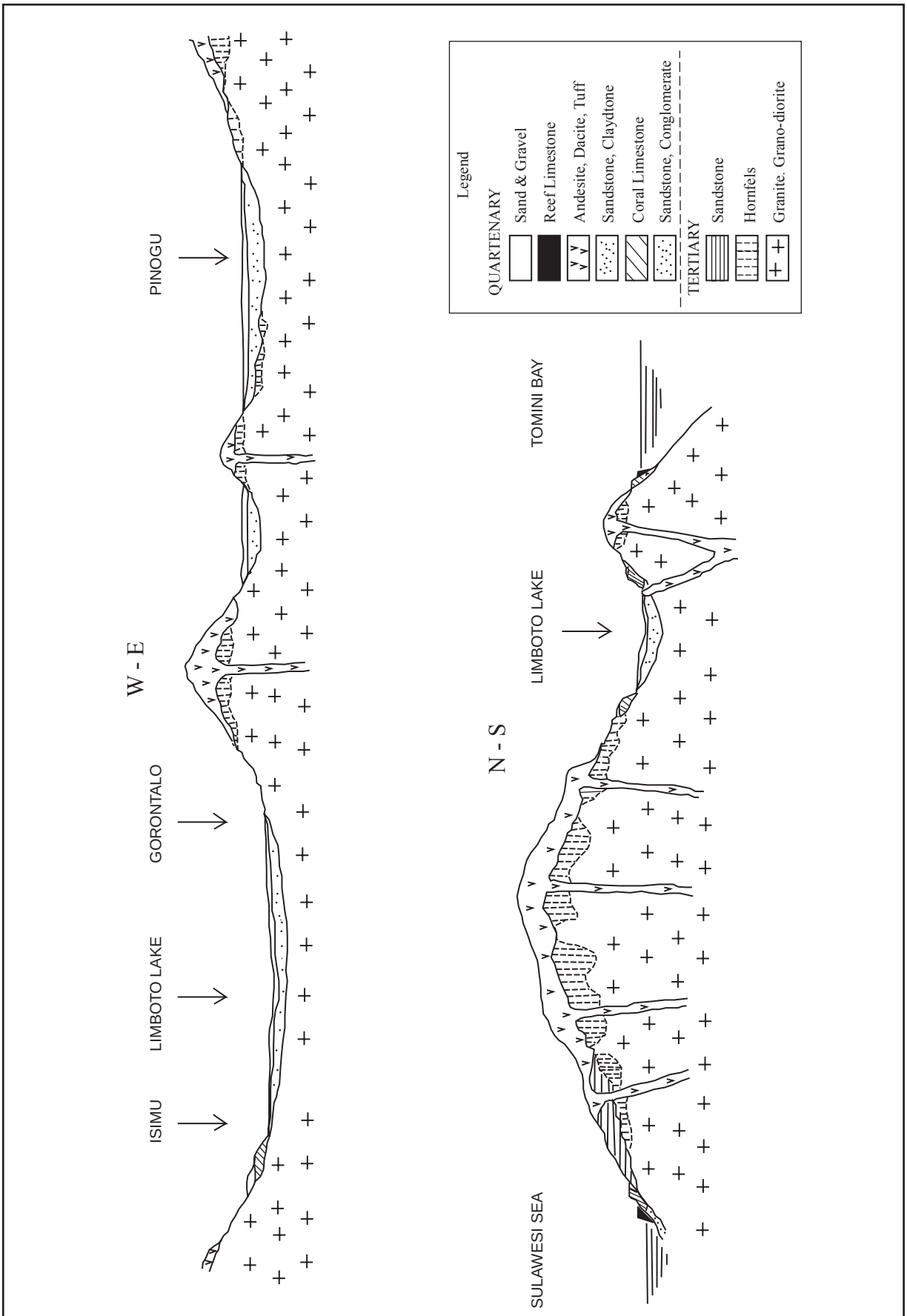


The Study on Flood Control and Water Management in Limboto-Bolango-Bone Basin in the Republic of Indonesia

Japan International Cooperation Agency

Figure A1.2.1

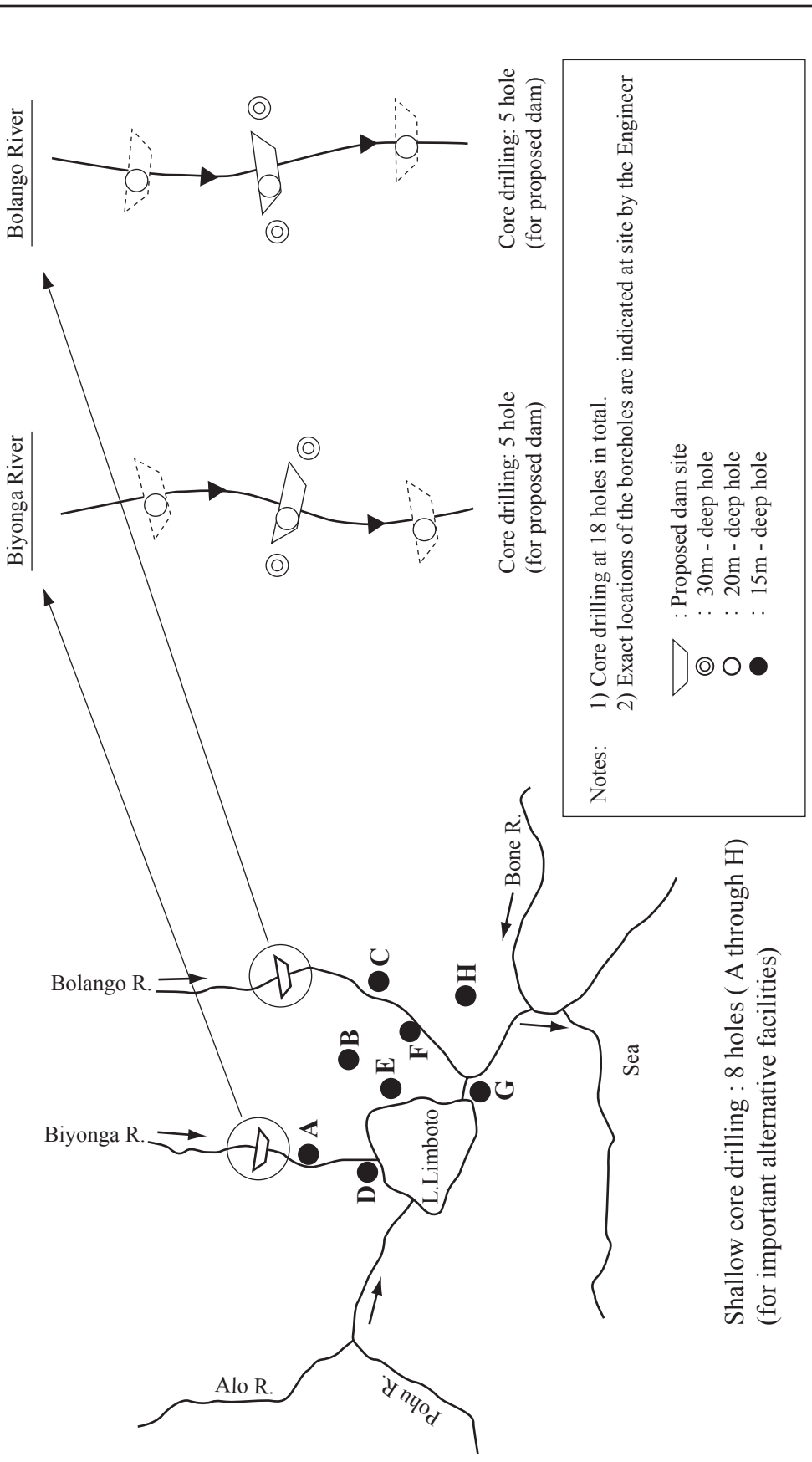
GEOLOGICAL MAP OF STUDY AREA



The Study on Flood Control and Water Management in Limboto-Bolango-Bone Basin in the Republic of Indonesia

Japan International Cooperation Agency

Figure A1.2.2
SCHEMATIC GEOLOGICAL PROFILE OF STUDY AREA



The Study on Flood Control and Water Management in Limboto-Bolango-Bone Basin in the Republic of Indonesia *Japan International Cooperation Agency*	**Figure A1.3.1** **LOCATION OF DRILLING HOLES** **(1/2 : M/P STAGE)**