JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

MINISTRY OF SETTLEMENT AND REGIONAL DEVELOPMENT
THE REPUBLIC OF INDONESIA

THE DETAILED DESIGN OF FLOOD CONTROL, URBAN DRAINAGE AND WATER RESOURCES DEVELOPMENT IN SEMARANG IN THE REPUBLIC OF INDONESIA

FINAL REPORT

COMPONENT B: JATIBARANG MULTIPURPOSE DAM CONSTRUCTION

VOLUME VII DATA BOOK

AUGUST 2000

CTI ENGINEERING CO INTERNATIONAL., LTD.
IN ASSOCIATION WITH
PACIFIC CONSULTANTS INTERNATIONAL
AND
PASCO INTERNATIONAL INC.

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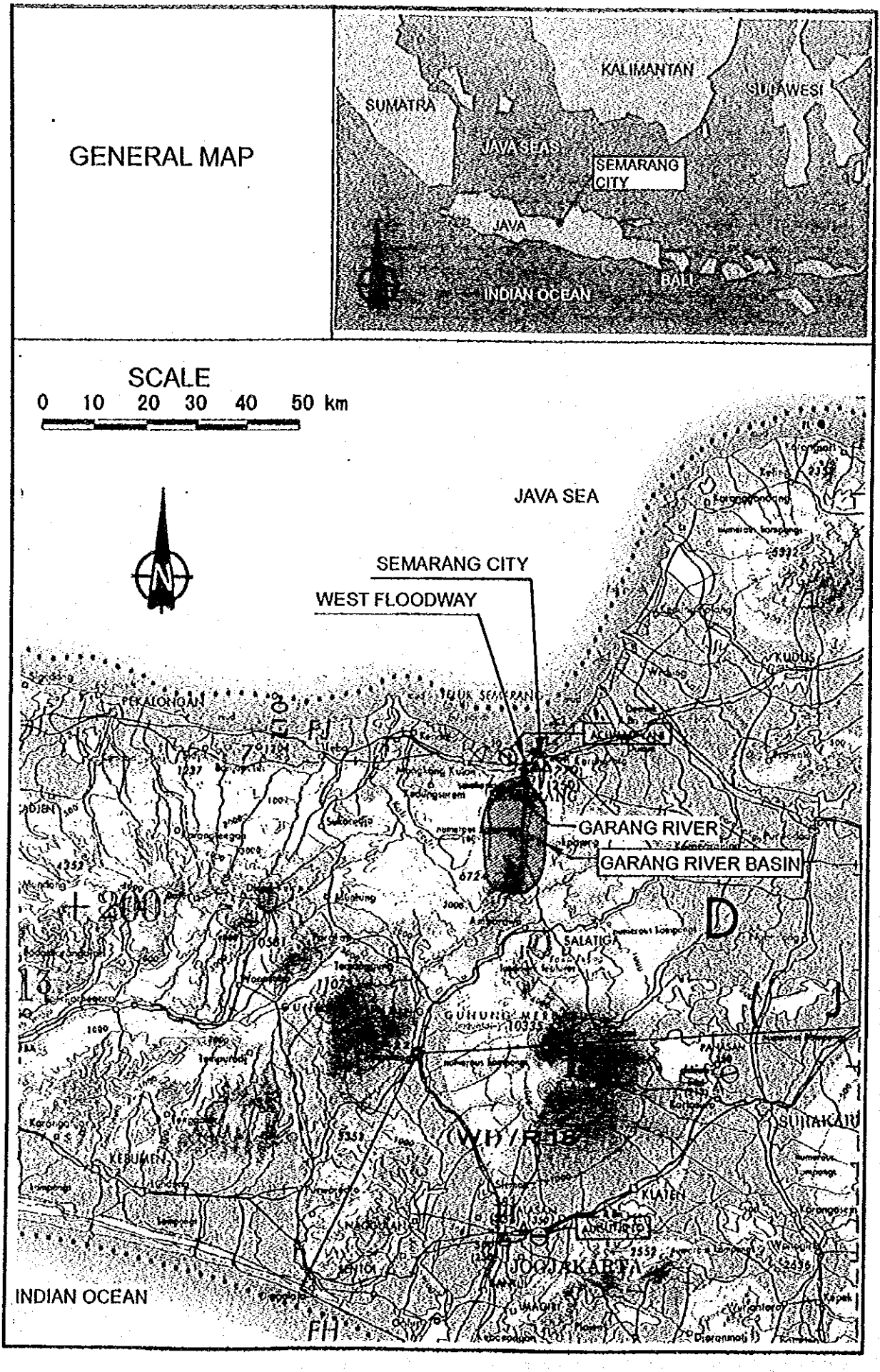
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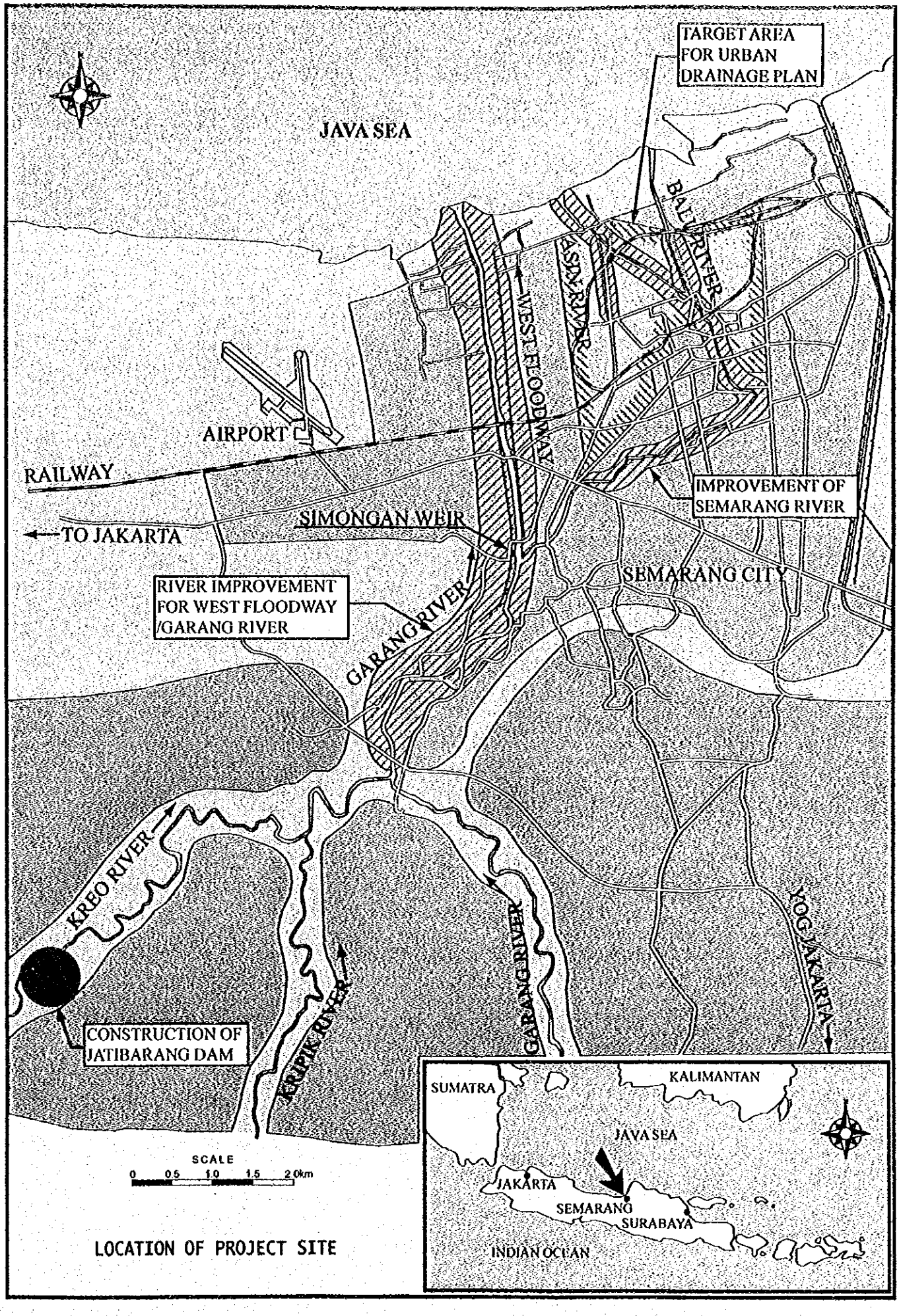

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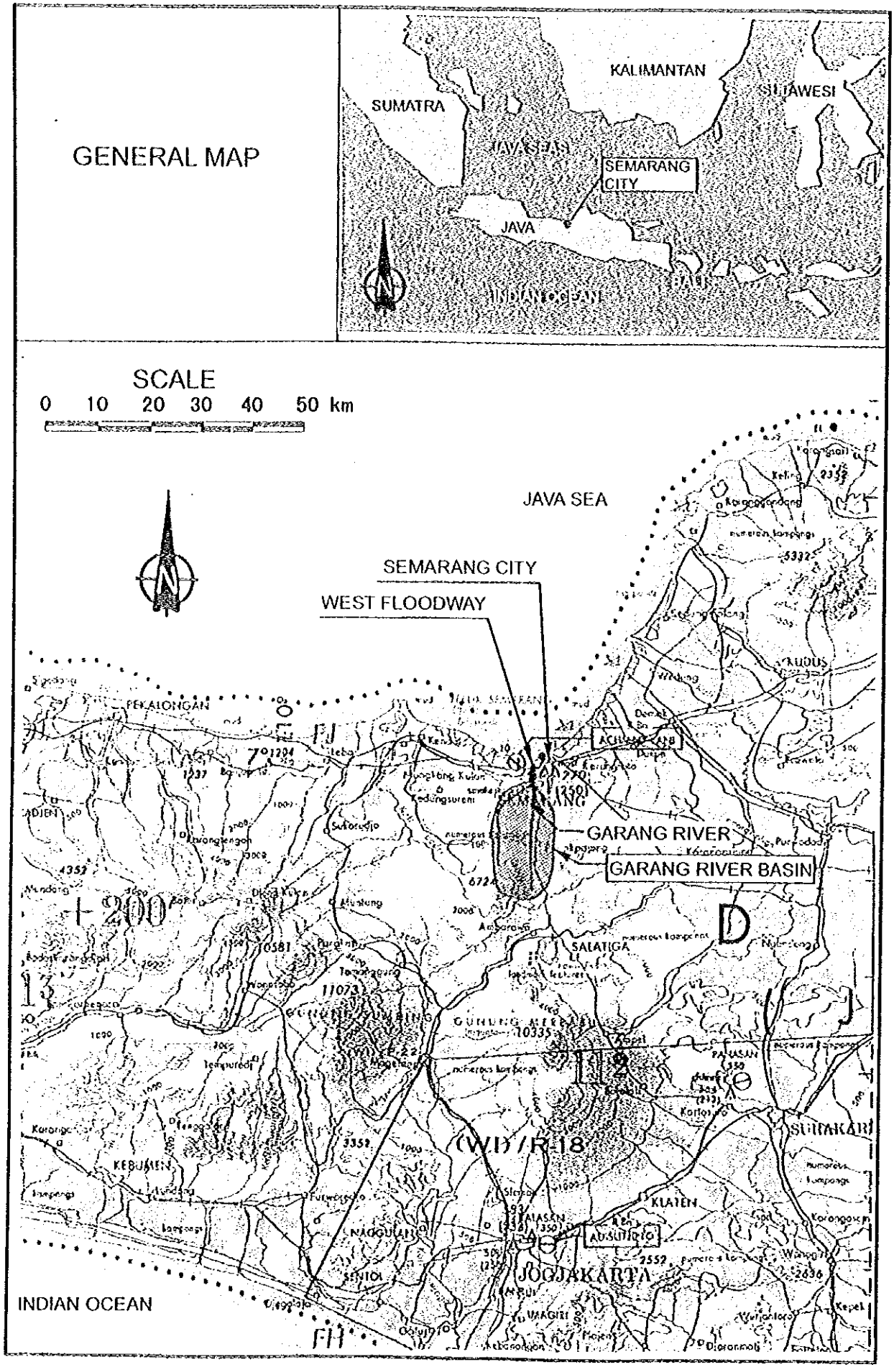
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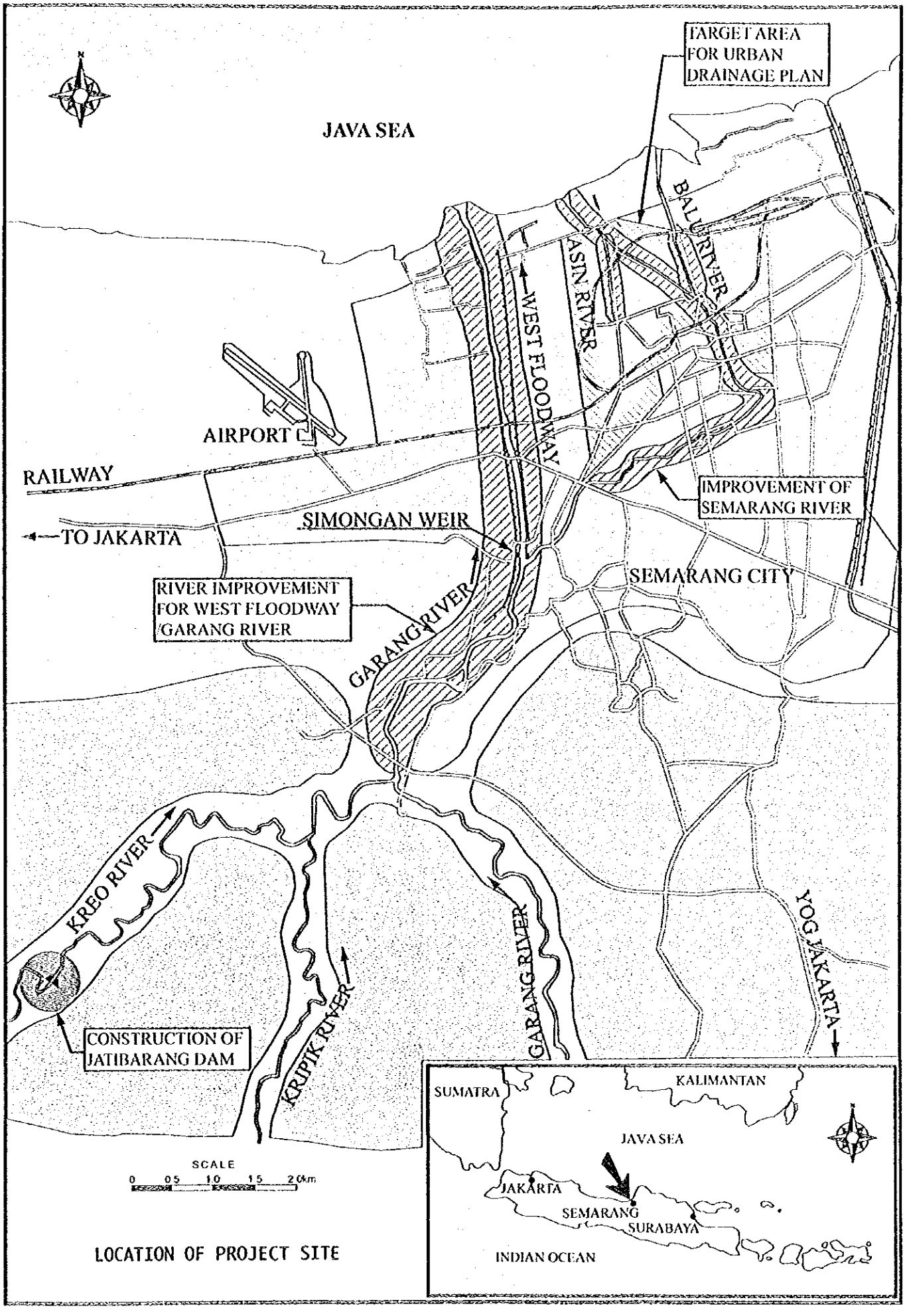

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VOL. VII DATA BOOK

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CHAPTER 1 PHOTOGRAMMETRIC MAPPING AND TOPOGRAPHIC SURVEY

1.1 Aerial Photography and Mapping

1.1.1 Aerial Photography

Aerial photography at a scale of 1:8,000 and covering approximately 64 line kilometer in total was started after obtaining permission from the Central Survey and Mapping ABRI (PUSSURTA ABRI).

The results of the aerial photography are as follows:

Total No. of Films	1 Roll
Total Flight Runs	12 Runs
Total Exposures	156 Photos
Overlap and Side Lap	55% and 35%

The aerial photography were taken by using Semarang Airport as a base, and processing of film and printing of aerial photos were done in Jakarta. The aerial photos were developed for mapping after checking navigation routes.

1.1.2 Uncontrolled Mosaic

Using aerial photographs that are newly taken at a scale 1:8,000 in 1997, uncontrolled mosaic photo at a scale of 1:10,000 was established for the area of 35 km^2 in total.

1.1.3 Photo Control Point Survey

Photo control point survey was conducted by Global Positioning System (GPS), and spirit leveling started from the photo control points and bench marks (BMs) for the above mentioned photogrammetry and the existing national control points and Tanda Tinggi Geodesi (TTGs).

(1) Control Point Survey

The control point survey by GPS was executed to determine the X and Y ordinates of a minimum two (2) existing control points to be used for the photogrammetric mapping, cross section survey, longitudinal profile and topographic survey. Final results of all photo control points by GPS are shown in Table 1.1.1

(2) Datum Coordinate

The Indonesian Government changed the surveying datum in 1997 from the Indonesia Datum 1974 (ID74) ellipsoid to the World Geodetic System in 1984 (WGS 84).

Two (2) existing GPS stations having the new Indonesian Datum, namely N1.0259 and N.0004, which were established by Badan Koordinasi Survey Dan Pemetaan Nasional (Bakosurtanal) in 1994, were chosen and applied as the X and Y geographical coordinates datum for this study by the JICA Study Team.

(3) GPS Observation

At least four (4) satellites were simultaneously observed for one hour for all the control points. In general, the base line lengths were planned between two (2) to five (5) kilometers.

(4) Post-processing

The post-processing was done using GPS survey software to obtain the best independent baseline solutions for all the GPS sessions. With the existing two stations (N1.0259, N.0004) fixed as the planimetric control on the modified WGS ellipsoid and the same stations serving as the vertical control for mean sea level height, the whole GPS network was constrained and adjusted by the GPS surveying software.

(5) Accuracy of GPS Survey

Accuracy of trigonometric closures for coordinates and height were checked to be less than 10 PPM (10/1,000,000) between the control points.

1.1.4 Leveling

Minor order leveling was executed to obtain the heights of control points necessary for the topographic survey, cross section survey and longitudinal profile survey.

Leveling survey was conducted by means of closed loops and double runs, and temporary bench marks were established at every 2 km interval on the leveling routes. Also temporary bench mark were established at 49 points in Semarang City. And a total distance of the leveling survey was approximately 105 km.

The leveling works are described below:

(1) Datum Height

Government bench marks obtained from the Mean Sea Level of Indonesia as established by Bakosurtanal are applied for the leveling survey.

(2) Checking of Government Bench Marks.

Before starting leveling survey, height of three government bench marks namely TTG446, TTG447, and TTG449 were checked by the local contractor.

Leveling Loops	Distance	Misclosure
TTG449 to TTG447	4.601 km	14 mm
TTG447 to TTG446	5.095 km	-201 mm

From the above, it was judged by the JICA Study Team that TTG446 shall be ignored because TTG446 had ground subsidence about 20 cm from 1983.

The JICA Study Team decided to use TTG447 as the bench mark for topographic survey river cross section survey and longitudinal profile survey in this project.

(3) Accuracy of Leveling

Any misclosure of leveling does not exceed 20 $\sqrt{S}$ between bench marks and/or control points (S: a single distance between bench marks in kilometer). And Standard division was 3.80 mm/km.

1.1.5 Field Verification

Using two (2) times enlarged aerial photographs, the key for interpretation required for plotting and cartography was done by verifying them in the field. The work quantity was 35 km^2 for mapping with the scale of 1:2,000 and 1 km^2 for mapping with the scale 1:1,000.

1.1.6 Aerial Triangulation

The implication and purpose of Aerial Triangulation work are to obtain the coordinates (X, Y, Z) of the aerial photo points necessary for the orientation process of each stereo model on the plotting instrument for the purpose of topographic map on the scale of 1:2,000 and 1:1,000 applying coordinates (X, Y, Z) of ground control points resulting from field measurement (GPS and leveling).

(1) Aerial Triangulation and Block Adjustment

The sequence of works to be carried out is as follows:

(a) Quantity

119 of aerial triangulation work was carried out and the quantity of models for each flight run was as follows:

Run Number	Number of Photo	Number of Model
Run 1 (Semarang Area)	10 PCs	9 Models
Run 2 (Semarang Area)	14 PCs	13 Models
Run 3 (Semarang Area)	13 PCs	12 Models
Run 4 (Semarang Area)	13 PCs	12 Models
Run 5 (Semarang Area)	13 PCs	12 Models
Run 6 (Semarang Area)	11 PCs	10 Models
Run 7 (Semarang Area)	18 PCs	17 Models
Run 8 (Semarang Area)	19 PCs	16 Models
Run 9 (Semarang Area)	17 PCs	6 Models
Run 11 (Ungaran Area)	9 PCs	6 Models
Run 12 (Ungaran Area)	9 PCs	6 Models
Total	**146 PCs**	**119 Models**

(b) Data Collection

All necessary data such as flight index, control point coordinate and calibration of the aerial photographic camera were collected.

(c) Planning

Preparation of aerial triangulation was carried out as follows:

Selection of the Aerial Photos

Total sheets of aerial photos for Ungaran Area : 12 models

Total sheets of the aerial photos for Semarang Area : 107 models

Control Point Selection

Total control points were 22, consisting of 5 horizontal and 17 vertical control points for aerial triangulation processing at Ungaran Area.

Total control points of 74, consisting of 21 horizontal and 53 vertical control points for aerial triangulation processing at Semarang area.

(d) Preparation

The preparation stages were carried out as follows:

Point selection and numbering

Pass points and tie points were selected within the triple overlap area with the circle notation on the index model.

Numbering system for aerial triangulation

Ex. Model number : 80011 *1*

Where:

8011 : First two digits show the number of flight run as shown and last two digits show the number of aero photographs.

1 : Tie point number

The horizontal and vertical control points were annotated on the index models as a square, and vertical control points were annotated as triangle.

The point selection and numbering were carried out on the 1:2,000 and 1:1,000 scale of aerial photographs by using mirror stereoscope.

(e) Point Transfer

The selected and control points on the diapositive film were marked an then transferred to adjacent diapositive film by using Wild PUG-4 instrument. This process was carried out until the last photo.

(f) Index Model

The index model on 1:50,000 scale, where all point numbers were plotted showing the relationship between each point, was produced.

(g) Measurement of Coordinates

Photo coordinates were observed and measured by using an analytical stereoplotter Leica SD-2000. All points including fiducial marks were measured.

(h) Adjustment

The final step of the aerial triangulation is the block adjustment using PATM-GPS software.

(i) Result

Block adjustment of Ungaran Area

Sigma Naught in the model system is as below.

Sigma naught for horizontal block = 21.064 micron

Sigma naught for vertical block = 14.773 micron

Weight root mean square values and check value of residual of Photogrammetric observations.

Model Points	RMS. (meter) Terrain system	RMS. (micron) Model system	CHV VXY/Z Model system
OBS X/Y	0.090	11.216	47.586
OBS z	0.063	7.888	23.664

Projection Center	RMS. (meter) Terrain system	RMS. (micron) Model system	CHV VXY/Z Model system
OBS X/Y	0.120	14.975	65.532
OBS z	0.094	11.750	73.658

Block adjustment of Semarang Area

Sigma Naught in the model system is as below.

Sigma naught for horizontal block = 18.890 micron

Sigma naught for vertical block = 20.353 micron

Weight root mean square values and check value of residual of Photogrammetric observations.

Model Points	RMS. (meter) Terrain system	RMS. (micron) Model system	CHV VXY/Z Model system
OBS X/Y	0.094	12.118	51.411
OBS z	0.080	10.273	30.820

Projection Center	RMS. (meter) Terrain system	RMS. (micron) Model system	CHV VXY/Z Model system
OBS X/Y	0.254	32.718	138.809
OBS z	0.130	13.292	39.875

(j) Equipment

The equipment used in Aerial Triangulation is as follows:

Steoroscope	2 units
Point transfer Wild PUG-4	1 unit
Analytical Stereoplotter Leica SD-2000	1 unit
Computer	1 unit
PATM-GPS Software	1 unit

1.1.7 Plotting and Editing

The implication and purpose of stereo plotting and editing work are drawing detailed and contour lines using aerial photo diapositives, which are placed on the plate holders of the stereo plotter instrument.

The sequence of the plotting and editing works are as follows:

(1) Data collection

All the following necessary data were collected and prepared for stereo plotting.

- Model index of aerial triangulation
- Print out of aerial triangulation adjustment
- Vertical control points and description on two (2) times enlarged aerial photographs
- Field identification on two (2) times enlarged aerial photograph.

(2) Planning

Preparation of stereo plotting was carried out as follows:

(a) Control sheets

Total control sheets of the stereo plotting topographic map are:

- 48 sheets for 1:2,000 scale of Semarang topographic map (including 4 sheet of sounding survey result);
- 4 sheets for 1:2,000 scale of Ungaran topographic map; and
- 26 sheets for 1:1,000 scale of channel topographic map.

(b) Models

Total models of stereo plotting are:

- 52 models for 1:2,000 scale of Semarang topographic map;

- 4 models for 1:2,000 scale of Ungaran topographic map; and
- 12 models for 1:1,000 scale of channel topographic map.

(c) Preparation of Control Sheets

Control sheers were produced by block adjustment result of aerial triangulation on polyester base material.

(d) Plotting

Plotting manuscript at the scale of 1:2,000 and 1:1,000 were produced from aerial photos at the scale of 1:8,000 by using second order precision plotter.

The sequence of the stereo plotting works are as follows:

- Inner Orientation;
- Relative Orientation;
- Absolute Orientation; and
- Plotting of details, spot height, vegetation boundary and contour lines.

Contour interval for intermediate contour line are 1 m both maps with the scale of 1:2,000 and 1:1,000.

Editing works was carried out on the plotting manuscript by compiling result of field identification, such as symbol annotation etc,.

(e) Result

The final manuscript was used for the fair drawing work and the number of sheets plotting manuscript are as below:

- 48 sheets plotting manuscript at scale of 1:2,000 for Semarang area (including 4 sheets of sounding survey result);
- 4 sheets plotting manuscript at scale of 1:2,000 for Ungaran area;
- 26 sheets plotting manuscript at scale of 1:1,000 for channel area..

(f) Equipment

The equipment used for plotting and editing are:

Computer	2 units
Roland Plotter	1 unit
Stereo Plotter, Wild A-8	2 units
Plotter Wild AG-1	1 unit
Stereo Plotter, Leica SD-2000	1 unit
Drafting Table	3 units

1.1.8 Fair Drawing

The implication and purpose of fair drawing work are drawing details using symbols and contour line with tracing method from the plotting manuscript and other additional data and information

The sequence of the fair drawing were carried out as follows:

(1) Data Collection

All necessary data were collected and prepared for fair drawing such as:

- Plotting manuscript;
- Vertical control points and description on two (2) times enlarged aerial photographs;
- Field identification result on two (2) times enlarged aerial photographs.

(2) Planning

Preparation for fair drawing were carried out as follows:

(a) Drawing sheets

Total sheets of fair drawing are 78 sheets, consisting of 48 sheets of Semarang map (including 4 sheets of sounding survey result) and 4 sheets of Ungaran map at the scale of 1:2,000, 26 sheets of map at scale of 1:1,000.

(b) Legend and Symbol

Legend, symbols and annotation used for the map are shown in Table 1.1.2.

(3) Preparation

The preparations were carried out as follows:

(a) Drawing sheets

Drawing sheets were made using computer PC on polyester base. The sheet's size is A1 (60 cm ~ 85 cm). Numbering system is as follows:

Sheet number 45 – *12*

Where:

45	=	Total sheets
12	=	Sheet number

(4) Fair Drawing

Fair drawing was carried out with tracing method using drafting pen and black ink from plotting manuscript at scale of 1:2,000 and 1:1,000.

Fair drawing works are as follows:

- Drawing details;
- Spot heights and counter lines;
- Symbols and annotations, on the map symbols must be matched to legend;
- Vegetation boundary.

Contour interval for intermediate contour lines are 1 m for map at scale of 1:2,000 and 1 m for map at scale of 1:1,000.

(5) Results

The final result of the fair drawing are:

- 48 sheets of topographic map at scale of 1:2,000 for Semarang area,
- 4 sheets of topographic map at scale of 1:2,000 for Ungaran area,
- 26 sheets of topographic map at scale of 1:1,000 for channel area,
- 48 sheets duplicate at scale of 1:2,000 for Semarang area,
- 4 sheets duplicate at scale of 1:2,000 for Ungaran area, and
- 26 sheets duplicate at scale of 1:1,000 for channel area.

The equipment used for the fair drawing works are:

- Computer : 2 units
- Roland plotter : 1 unit
- Drafting table : 9 units
- Drafting tools : 9 units

1.2 Ground Survey

1.2.1 River Longitudinal Profile and Cross-Section Survey

(1) Installation of Kilometer Post

Prior to the commencement of the river longitudinal profile survey, kilometer posts of wooden pegs were installed on the right and left banks of West Floodway, Garang,

Semarang, Asin and Baru rivers. When the location of a kilometer post is very close to such structures as bridges, water intake and water pipes, kilometer posts were shifted to the center line of these structures. The position of a kilometer post was decided by traverse method in the field.

(2) Longitudinal Profile Survey

The river longitudinal profile survey (the profile survey) by direct leveling was executed to obtain heights of kilometer posts for the river cross section survey and to prepare longitudinal profile sections. Leveling routes were formed by closed loops and double-runs. A total distance of the leveling survey covering West Floodway, Garang, Semarang, Asin and Baru rivers was 41 km.

The datum height was applied for the longitudinal profile survey including river cross section survey and auxiliary leveling. The heights of TTGs bench marks are applied to the kilometer posts by direct leveling.

All results of heights of kilometer posts by the profile survey, the deepest height of the river cross section survey, names of bridge and others were edited by Auto CAD system. The longitudinal profile sections at a horizontal scale of 1:2,000, 1:1,000 and vertical scale of 1:100 were prepared on the draft plotting paper sheets using the longitudinal profile data. Final longitudinal profile data for Jatibarang Damsite as shown in Table 1.1.3.

(3) River Cross Section Survey

Height and distance of slope changing points, road, channels, etc. along the cross section lines were measured by using a Total Station System, levels and Electric Distance Meter (EDM).

Water levels and depths of the rivers were measured using a survey rod, and the distance of these measured simultaneously. The bridges, irrigation intakes and water pipes of all rivers were also measured. A total number of cross sections surveyed are approximately 814.

(4) Checking of Longitudinal Profile

(a) The check results of differences in height closure between the kilometer posts did not exceed 20 $\sqrt{S}$ (S: length of single run in kilometer) as specified in the Technical Specifications.

(b) Checking of River Cross Sections

At the same kilometer posts checked above, river cross section lines were measured. The check results of height of these cross section line points did not exceed ± 50 mm and distance errors between the cross section line points are less than 1/300 as specified in the Technical Specifications.

Longitudinal profile and cross section were surveyed along Jatibarang Dam site and its reservoir area:

Jatibarang Dam Site and Reservoir Area

Work Item	Volume	Drawing		Remarks
		No. of Sheets	Scale	
Longitudinal Profile	6.049 km	3	H=1/2,000 V=1/100	Sheet Size: A1
Cross-section Survey	42 sections	42	H=1/200 V=1/200	Sheet Size: A1

1.3 Topographic Survey

Topographic survey was carried out for Jatibarang Damsite, Simongan weir, Asin Pumping Station, West and East Bandarharjo Pumping Station, West and East Bandarharjo Drainage Area, a bridge across Semarang River and a water gate at Baru River.

The work quantities carried out for Jatibarang Dam site are as follows:

Scale 1:500	Jatibarang Dam Site	15.0 ha
Scale 1:1,000	Jatibarang Dam Site	15.0 ha

CHAPTER 2 GEOLOGICAL AND SOIL MECHANICAL SURVEY AND INVESTIGATION

2.1 Work Method

All the Geological Survey work including the work plan, schedule, equipment and work method are carried out under the technical guidance and supervised by the Engineer.

Variation order and interruption of the work sometimes are ordered by the Engineer during the work period. It is executed based on the findings of the earlier stage investigation and also by conditions encountered as the work progress.

2.1.1 Core Drilling

(1) Common Boring (D=89 mm)

Common boring 89 mm of hole diameter are carried out at the dam site. The common boring is drilled by a rotary type of boring machine, with maximum capacity of more than 200 m deep.

Single core barrels with metal core bits are used for drilling in the soil or loose material, without water circulation while drilling. Double core barrels with diamond core bits are used for drilling in the common rock with good consolidation and well cemented. Triple core barrels with diamond bits are used for getting a good core recovery in the jointed and unwell cemented rock formations.

Water level in the bore holes are recorded during the drilling exploration, especially every morning before commencement of the work or every lugeon test execution.

The coordinate and elevation of each hole are surveyed by using Theodolite and water pass.

After the boring of each hole is completed, the upper holes will be filled up with cement grout of concentration of 1/1 in cement/water ratio in weight, by using the PVC pipe and marked with peg for future identification of the location.

Core samples of moisted soft rock are wrapped airtightly with transparent vinyl sheet before placing in a core box. Core boxes are made of galvanized steel plate. Each core box has grooves, each of, which has dimension to contain core samples for one

meter section. The part of no core recovery are left vacant in the grooves. Core samples taken from each hole are placed in order in core boxes showing the depth of coring clearly.

After placement in core boxes, the core are photographed and submitted to the Engineer.

Daily report is written and reported to the Engineer as weekly report, regarding work progress and all findings for each drilling unit every day. The following information are contained in the daily report.

- Date
- Location and the hole number
- Water level in the hole
- The time when each continuous drive of drilling is started, after descending empty core barrel to the bottom of the hole
- Time when each continuous drive of drilling is finish to lift the core barrel with core sample
- Progress in each continuous drive of drilling between the above times.
- Rate of drilling water flow in term of liter per minute which is pumped out of hole
- Description of subsurface rock conditions encountered, including the condition of return or loss of the injected water. The depth where a sudden loss of the injected water occurs, if any, is recorded accurately
- Model name of the drilling machine
- Diameter of hole
- Depth of casing
- Name of personnel in charge of the drilling

Drill logs are prepared for each hole in a logging form approved by the Engineer. The drill logs present continuous record of bore holes with at least 1/100 scale in vertical length. The drill log contains the following description:

- Name of the site
- Hole number
- Coordinate, elevation, and depth
- Inclination of hole
- Operation records: date, depth and diameter, model of drilling rig, ground water level, water loss, spring etc
- Record of coring: core recovery (recovered presented of core), RQD (Rock Quality Designation), etc
- Geological Description: rock name, color, columnar section, condition of weathering, fracturing and discontinuities, hardness, and all geological information obtained by careful observation of core sample
- Personal names of geologist who prepared the drill log and in charge of the drilling operation
- Other records: Lugeon test, standard penetration test with their locations and respective test results.

(2) Common Boring (D=66 mm)

The common boring (D=66 mm) are carried out at the dam site and reservoir areas. Rotary type drilling machines with maximum capacity of 150 m deep are used for common boring (D=66 mm).

Single core barrels with metal core bites without water circulation or dry method are used for drilling in the clay or loose material. While in the well cemented rock, drilling is done by double core barrel with diamond bits.

For getting a good core recovery or avoiding collapsed material in the bore holes, casing pipes of 86 mm up to 114 mm are used during the drilling exploration.

Work method for common boring is carried out by using the same method and procedure usually applied for common boring. The following works are done for common boring.

- Water level record during the drilling exploration
- Placing core samples in the galvanized steel boxes
- Core sample photographs
- Daily report
- Drill logs
- Etc.

2.1.2 Lugeon Test

Lugeon test is performed in the section of bore holes which are drilled through strata where packer can be set effectively and the hole side will not collapse without casing.

The lugeon test is made by 5 m stage in descending order by the use of packer. When the bore hole drilled 5 m into the bed, the hole is washed first by flushing water through injection pipe. The injection water quantity is observed until the injection rate of water nearly constant under the certain water pressure, that is kept constantly by controlling the return diversion flow.

During the ten minutes observation, the injection water quantity is recorded every minute. The observations in the same procedure are made in each stage of 5 m section, for eleven, different pressure, that is 1, 2, 3, 4, 6, 8, 10, 8, 6, 4 and 2 kg/cm^2 for one unit test or as directed by the Engineer.

After the test, the drill rod is inserted down to the bottom of the hole. If the rod does not reach to the original bottom, the depth will be noted.

If the pressure can not rise up to a certain maximum pressure under 100 liter/minute of injection rate because of much leakage from the test section, the test is done only for the attainable pressure.

The result of lugeon test is presented in coefficient of permeability and lugeon unit as calculated by the following formula:

- Lugeon unit (Lu)

$$Lu = Q/(H \times L)$$

Where:

Lu	:	Lugeon unit
Q	:	Injection rate of water (liter/minute)
L	:	Length of test section (cm)
H	:	Total Head applied at the middle part of the test section (cm) $H = Hp + Ho + Hf$

Where:

Hp	:	Pumping Pressure Presented in height or water head (cm)
Ho	:	Static head from the middle part of the test section to the level of the pressure gauge (cm). If the groundwater table is above the level of the test section, Ho is the distance of the groundwater table below the pressure gauge.
Hf	:	Friction loss corresponding to the length of the injection pipe at the injection rate (cm)

Daily report of the lugeon test is submitted to the engineer, regarding all finding, for each test every day. The following informations are contained in the daily report of lugeon test.

- Date
- Location and hole number
- Groundwater level
- Height of the pressure gauge measured from the neck of the hole
- Depth of the packer setting and the bottom of the hole as measured from the top of hole
- Diameter of hole
- Pumping pressure and the corresponding rate of water injection as observed every minute in the duration of test for 5 minutes
- Calculated lugeon unit
- Name of the personnel in charge.

2.1.3 Standard Penetration Test

Standard penetration test is carried out for evaluating the mechanical strength of the earth. The standard penetration test are performed especially at the reservoir area at 1 m interval of depth in the sections of boreholes which are drilled through unconsolidated deposits or as directed by the Engineer.

The tests are made in accordance with the specification by USBR that is presented in the Earth Manual. In advance of each test, drilling sludge and sediment in the bottom of the hole is removed.

The Raymond sampler connected with drill rod is inserted to the bottom of the hole, and driven for preliminary penetration of 15 cm by blow of hammer on the knocking block attached to the rod. After the above preliminary penetration of 15 cm, the test is started.

The sampler is driven 30 cm by the blow of the drive hammer freely dropped from 75 cm of height and the number of blows are recorded for every 10 cm of penetration.

In case that the penetration is less than 30 cm at 50 times of blow, the depth penetrations at 50 blows are recorded and the tests are finished.

The resulting of the standard penetration test is recorded on the daily report of the drilling, containing the following informations:

- Depth of test
- Number of blows for every 10 cm penetration
- Number of blows for 30 cm penetration (N-Value)

2.1.4 Trench Excavation

Trench excavations are carried out at the dam site and reservoir.

The work is done for excavation and back filling by manual labours.

Geological sketch are reported after opening the trench and contains the following information:

- Date
- Name of the site
- Trench number (code)
- Coordinate, elevation, depth, inclination
- Geological description = rock name, color, texture and structure of the rock, composition, condition of weathering, fracturing and discontinuities, hardness, and all geological information obtained by careful observation
- Personal in charge.

2.1.5 Adit Excavation

Dimension of adit is (2.0 m high x 1.5 m wide), and excavation by blasting method using damotine dynamite, anfo and electric detonator and by jack hammer Explosion storage is placed at Gunung Ungaran – Ungaran about 15 km from the Jatibarang Dam Project Site.

Portal entrance of the adit is protected by supporting of wooden column, and strengthened by retaining wall made by logs and sand sacks. Timbering system is used also for preventing roof caving and to maintain the adit safety especially at the geological weakness area.

A drainage system is performed at the floor of adit, about 20 cm x 20 cm, to keep the adit floor always in relatively dry conditions.

Temporarily lighting system is installed during adit excavation using small generator set and 20 or 40 watt of TL lamps.

Portal entrance of the adit and zones of loose material are excavated without explosive using the following equipment:

- Pickax
- Grub hoe
- Spade
- Jack hammer & compressor.

Blasting method for excavation of the adit is carried out in the hard rock condition. Boreholes pattern for blasting is shown in Fig. 2.1.1.

Damotin of 80% strength and manufactured by Dahana Indonesia is used for blasting. Cartridges dimension are 2 cm in diameter, 20 cm length and 200 gram weight. Charging volume is 0.6 kg of each hole with 1.2 – 1.3 m depth of pull.

Spoil bank as catching area of blasted rock hauled out of the adit is made by logs and reinforced using live trees grown near the adit entrance.

2.1.6 Test Pit Excavation

(1) Purpose

The objective of test pit excavation is to study the field geological condition of embankment materials, aggregate source, and to take sample for laboratory analysis.

(2) Method

The implementation of test pit is by digging up the soil layer manually until reaching hard rock/soil or target depth. In order to protect the wall collapse wooden cribbing is used.

(3) Equipment

The equipment for test pit consists of hoes, mattock, shovels, baskets, pick, ledder, ropes, portable water pump, etc.

2.1.7 In-situ Shearing Test

The in-situ rock shear test is carried out in the adit. The test spots as indicated in Fig. 2.1.2 is prepared under the technical guidance and supervised by the Engineer.

The base rock surface on which a concrete block is to be placed is finished 10 cm thickness with a hand chisel Roughness of the finished surface is ± 5 cm from the design level.

The base rock surface around concrete block with 15 cm in width is the same finish as the surface on which the block is to be placed Equipment for in-situ rock shear test is listed in Table 2.1.1.

All dial gauges are set on the test blocks as indicated in Fig. 2.1.4.

Loading and unloading speed of loading pattern is 2.5 T/min (0.69 kg/cm^2/min).

Once cycle of shearing load consists of loading for 5 minutes with loading speed of 1 T/min (0.27 kg/cm^2/min). The same load is kept for 5 minutes under the initial vertical load of 10 T and 25 ton. This loading cycle is repeated until the test block is broken.

2.1.8 Seismic Prospecting

(1) Theoretical Background

The refraction seismic were performed in order to obtain subsurface geotechnical data as a complement to direct site investigation techniques, especially for obtaining mechanical rock quality, such as physical and mechanical properties. The seismic theory is based on the physical principle that an elastic shock wave generated in a homogeneous material will travel as a function of the density and elastic modulus.

$$Vp = \sqrt{\frac{E(1-\sigma)}{d(1-2\sigma)(1+\sigma)}}$$

$$Vs = \sqrt{\frac{E\ 1}{d2(1+\sigma)}}$$

Where

E : Young's modulus of deformation
d : Density (gr/cm^3)
σ : Poisson's ratio

Theoretically, every rock has its own specific compressional and shear velocity for seismic waves to travel.

The types of seismic waves of particular interest are primary (P) and shear waves (S). The P and S waves are called "body" waves because they travel through inside material.

The Love and Rayleigh waves appear only at the surface. The P wave is a pressure wave (dilation). Its front wave consists of compression and dilation particle motion in the particle.

The velocity of the shear wave is less than of the P wave. The Love and Rayleigh waves are even slower.

By determining the velocities of the body waves and the density of the material one could evaluate the poisson's ratio, Dynamic Shear modulus, Dynamic Yaoung modulus, and the Dynamic Bulk Modulus.

The applicable equations are:

Poisson ratio $\sigma = \dfrac{(Vp/Vs)^2 - 2}{2(Vp/Vs)^2 - 2}$

Shear modulus $G = dVs^2$

$= d\,\dfrac{(3Vp^2 - 4Vs^2)}{3}\,pa$

Young modulus $E = Vs^2\,\dfrac{3(Vp/Vs)^2 - 4}{(Vp/Vs)^2 - 1}\,pa$

Bulk modulus $K = \dfrac{1}{3}\,\dfrac{E}{(1-2\sigma)}\,pa$

Where

Vp = Compressional velocity (m/s)
Vs = Shear velocity (m/s)
d = density (kg/m^3)

The static elasticity parameter can be calculated by using several formula:

$E_{stat} = 1.263 \cdot E_{dyn} - 29.5$ (King, 1983)
$E_{stat} = 0.69 \cdot E_{dyn} + 6.40$ (McCann & Entwille, 1982)
$E_{stat} = 0.64 \cdot E_{dyn} - 0.32$ (Eissa & Kazi, 1988)

These figures are linear and dynamic characteristic and need not always be identical to static modulus performances foundation material. Nevertheless, one can draw some useful conclusions from the study material, some of them can be proved by empirical data. Particularly, some low shear strength material (such as water) was a high confined compressive strength and correspondingly high P wave velocities. Therefore, shear wave determination is also often done.

(2) Field Procedure

The seismic investigation performed for Jatibarang Dam Project, Central Java consist of several works, data acquisition, data processing, geological correlation and interpretation.

A 1300 meter seismic line is conducted at the Dam site with 200 m penetration, consisting of 7 – 10 spread shots with maximum shot of 800 m. The lines are SD-01 of 800 m total length and SD-02 of 500 m total length.

At Quarry site, a 1700 meter seismic line is conducted with 60 m penetration, consisting of five (5) spread shots, they are:

- Line S-01, total length of 460 m
- Line S-02, total length of 340 m
- Line S-03, total length of 300 m
- Line S-04, total length of 300 m
- Line S-05, total length of 300 m

(3) Seismic Refraction Shooting

The Seismic Reciprocal Profiling is chosen to be conducted for seismic survey in this area. Each spread consists of 24 geophones and 5 to 10 shots/run. The geophones were spaced 5 meters each.

The shooting schedule for seismic profiling of seven to nine shots spread can be described as follows;

The seismic shots were distributed as follows; two shots were placed at both end of the seismic spread (forward, reverse), four shots were blasted at distance of ± 50 meters to 400 meters from each last end geophone. The other last shot was placed at the middle of spread (see the following figure).

The detail scopes of seismic investigation of Jatibarang Dam project are as follows:

Line	Total Spread	Total Length
Line SD – 01	8	800 meters
Line SD – 02	4.5	500 meters
Line S – 01	4	460 meters
Line S – 02	3	340 meters
Line S – 03	3	300 meters
Line S – 04	3	300 meters
Line S – 05	3	300 meters
Total	**28.5 spreads**	**3000 meters**

(4) Seismic Signal Generator

The explosive used for the investigation at Jatibarang Dam and quarry site is dynamite (Superdin) for refraction seismic of 125 kg weight. The superdin dynamite is commonly used for engineering purpose e.g.: seismic, adit, quarry etc.

2.1.9 Laboratory Test

(1) Laboratory Test of Samples from drilling core

Samples are taken from the drilling cores as directed by the Engineer.

After taking the samples from the core box, the space is filled and indicated with a wooden bar of the same length as the samples.

Laboratory tests and analysis are preformed in accordance with ASTM. The laboratory tests contain the following tests items:

- Physical properties test (including test of specific gravity, absorption ratio and effective porosity)
- Unconfined compression test.

(2) Laboratory Test for Construction Material

(i) Laboratory Test of Core Sample and Aggregate

The test is aimed to determine the physical and mechanical properties of rock and aggregate samples.

The laboratory test follows the standard method of ISRM and ASTM. The detail is available in the following table.

Item	Standard Method	Volume
Rock Samples		
Physical Properties	ISRM Doc No. 2, 1997	20
Unconfined Compressive Strength	ASTM D–2938 71.a.	20
Aggregate Samples		
Physical Properties	ISRM Doc No. 2, 1997	15
Petrography Observation	ASTM C 295	5
X-ray Examination	ASTM C 295	5
Alkalinity Chemical Reaction	ASTM C 227–90	3
Mortar Bar Test	ASTM C 227–90	9

(ii) Laboratory Test for Impervious and Semi-Pervious Material

- Purpose

The objective of the laboratory testing is to determine the physical and mechanical properties of soil samples

- Method

The laboratory test for soil sample followed the standard method of Japan Industrial Standard as can be seen below:

Standard Method of Laboratory Testing

Item	Standard Method
Fine Material	
Physical Property Test	
Moisture-Density Relation Test (D100 mm)	JIS A 1202, A 1203, A 1204
Permeability Test	JIS A 1210
	JIS A 1218

Item	Standard Method
Triaxial Compression, CU (D100mm)	
Coarse Material	
Physical Property Test	
	JIS A 1203, 1102, A 1204
Relative Density Test (D100 mm)	A 1109, A 1110
Triaxial Compression, CD (D100 mm)	JIS A 1210
Permeability Test	
	JIS A 1218
Mixed Material	
Physical Property Test	
	JIS A 1203, 1102, A 1204
Moisture-Density Relations Test (D100 mm)	A 1109, A 1110
Triaxial Compression, CU (D100 mm)	JIS a 1210

(iii) Laboratory Test for Pervious Material

The investigation at the proposed quarry site consists of rock sampling and large scale laboratory testing.

The quarry site is located about 30 km to the South of Semarang city and it belongs to Wringin Putih village, Klepu Sub-district, Ungaran Regency. The material at the quarry site, geologically, is Andesite rock of CM-CH class.

Rock Sampling

The rock sampling was executed by manual excavation at the private mining area, that was by using pick hammer, chisel, and crowbar.

After block samples has been accumulated, the samples were to be crushed in order to get specific size and weight as mentioned in the specification.

Large Scale Laboratory Test

- Objective

The large scale laboratory test is subjected to determine the physical properties and shearing strength of compacted rockfill material for the embankment of Jatibarang Dam. The large triaxial shear test was performed in order to eliminate some factors and difficulties which was occurred in the other large scale test.

- Scope of Test

The large scale laboratory test comprises of:

-	Physical Property	7 tests
-	Large Scale Relative Density Test (dia. 300 mm)	1 test
-	CD Triaxial Test (dia. 300 mm)	4 tests
-	Large Scale Permeability Test (dia. 300 mm)	3 tests

All the tests were carried out in the Mushashino doshitu chosa Co. Ltd. Technology Center, Saitama, JAPAN.

- Method

The large scale laboratory test was conducted according to the standard method of Japan Industrial Standard as can be seen in the following table:

Standard Method of Large Scale Laboratory Testing

Item	Standard Method
Particles size distribution of soil	JIS A 1204
Water content of soils	JIS A 1203
Specific Gravity and Absorption of Coarse Aggregates	JIS A 1110
CD Triaxial Test	JSF T 530, JSF T 531
Permeability of saturated soil	JIS A 1218

2.1.10 Loading Test in Borehole

The lateral loading test in borehole is subjected to determine the deformation modulus of the rock mass by applying the pressure to the wall of borehole and measuring the response of borehole's wall by inserting Elasmeter Sonde to the borehole.

Six (6) pressure cycles are to be adopted as stipulated at the specification unit to reach the maximum pressure of 100 kg/cm^2. The maximum pressure for each cycle will be maintained for at least at one (1) minute, and the deflection of borehole's wall will be recorded for every minute.

The E value is called the elastic coefficient of the ground. Assuming that the stress is elastic and the plane strain condition is satisfying in the direction of radius, the Elastic (E) and Deformation (D) Coefficients can be calculated by the following equation:

$$E, D = (1 + \gamma) R \times P / Wa \qquad (kg/sq.cm)$$

Where

γ = Poisson's ratio of the rock (0.3),
P = Total load on the wall of the borehole (kg/sq.cm),
R = Radius of the borehole at the test point (cm),
Wa = Average deflection of the wall (cm).

The details of borehole specification in Dam Site Area is given in the following table

- Equipment

The equipment used in the investigation consists of:

(i)	Rotary drilling machine	3 units
(ii)	Reciprocal Pressurized Water Pump	4 units
(iii)	In-situ test equipment	
	- Packer test TRIEFUS	4 sets
	- Horizontal Loading Test OYO Geologger 3030 Mark-2	1 set

2.1.11 In-situ Plate Loading Test

(1) Purpose

The plate load test is subjected to measures load deformation characteristics of rock mass especially to obtain modulus of elasticity and modulus of deformation.

(2) Method

The standard of the testing method is based on "A Guideline for the Testing Methods of Deferability and Shear Strength of In-situ Rock Masses" published by Japan Society of Civil Engineers.

(a) Test Block Preparation

The test location was set around the center of the adit, and detail position of plate load test is as follows:

Adit No.	Test No.	Depth from the entrance	Target Layer	Rock Classification
T–1	T.1–1	13.5	Conglomeratic Sandstone	CM – L
T–1	T.1–2	7.5	Fine Sandstone	CL – H
T–3–1	T.3–3–1	19	Tuffacious Sandstone	CL – L
T–3–2	T.3–3–2	11	Tuffacious Sandstone	CL – L
T–4–1	T.4–4–1	27	Sandstone	CL – H
T–4–2	T.4–4–2	21.5	Sandstone	CL – H

The rock surface of the test area was cut by jack hammer and loosened part were removed by chisels with dimension of 60 cm diameter and leveled surface of 30 cm diameter. The leveled surface had very small relief configuration.

The cut and leveled portion were photographed and sketched in order to record its geological condition. The 30 cm plate was placed on the tested rock surface.

The hydraulic jack was set on top of the loading plate. The plate reaction force for the jack was provided by the crown of the tunnel through column support.

Four transducers were mounted diagonally on top of the loading plate and one dial gauge was placed on the plate as show in the following figure:

(b) Loading Procedure

Six tests were carried out in this project. Each test includes 6 cycles of loading and unloading to reach the peak load of 30 kg/cm^2. The peak pressure of each

cycle was maintain for 5 minutes and the deflection reading is recorded for every minute.

(3) Equipment

(a) Equipment for cutting rock surface: chisel, jack hammer and hand rock drill (Boch hammer).

(b) Hydraulic Jack of which capacity of 100 tons and 30 cm diameter loading plate for applying normal force to the testing ground.

(c) Load cell to measure applied normal load.

(d) Transducers to measure settlement of the testing surface with accuracy of 0.002 mm.

(e) Data logger (10 channel) to record applied normal load and settlement of the tested rock surface.

(f) Dial gauge, stop watch, etc.

(4) Calculation and Result

The equation for the modulus of deformation is based on the elastic solution for rigid die pressed into the surface of semi-infinite isotropic elastic medium. The Elastic Modulus (E) and the Deformation Modulus (D) are calculated as follows:

$$E, D = (1 - \gamma^2) P / (2R - Wa)$$

Where:

γ	:	Poisson's ratio of the rock (0.3)
P	:	Total load on the rigid plate, (kgf)
R	:	Radius of the rigid plate, (15 cm)
Wa	:	Average deflection of the rigid plate, (cm)

2.2 Damsite

In the Phase 1 period, the study on the definitive plan of Jatibarang Multipurpose Dam was conducted as the concrete gravity type, which was a conclusion of the Feasibility Study, conducted in 1993. However, as a result of the geological survey conducted in the Phase 1 study period, it was concluded that the gravity type dam could not be applied for Jatibarang Multipurpose Dam because of the lack of the shear strength of the foundation rock then the dam type was changed to a rockfill type. Therefore the additional geological study of Jatibarang Multipurpose Dam for the type of rockfill dam is carried out in this study period.

The work items and quantities of geological survey at the dam in the study periods of Phase 1 and 2 are shown in the following table.

Study Period	Work Item	Work Quantities
Phase 1	Core Drilling (D=66mm)	24 holes, 1,669 m in total
	Lugeon Test in Borehole	18 holes, 245 times in total
	Trench Excavation	3 trenches, 648 m in total
	Adit Excavation	4 adits, 110 m in total
	In-situ Shearing Test	2 adits, 8 times in total
	Seismic Prospecting	2 lines, 1,300 m in total
	Laboratory Test of Core Sample	27 samples
Phase 2	Core Drilling (D=66mm)	8 holes, 535 m in total
	Lugeon Test in Borehole	3 holes, 52 times in total
	Loading Test in Borehole	2 holes, 20 times in total
	In-situ Plate Loading Test (at the existing adits)	3 adits, 6 times in total

The location map of the Geological Survey for the Dam site and Reservoir Area are shown in Fig. 2.2.1 and the location map for the Damsite are shown in Figure 2.2.2.

2.2.1 Core Drilling

The investigation items and work quantities of drilling work including the Lugeon-test and Loading Test in Borehole are as follows:

Stage	Hole No.	Hole Diameter (mm)	Ground Elevation (m)	Depth (m)	Lugeon-test (times)	Loading Test in Boreholes (times)	Coordinate	
							X	Y
Phase I	B-4	86	137.77	95	17		428,237.753	9,222,232.940
	B-5	86	88.57	100	18		428,304.925	9,222,232.535
	B-6	86	148.10	130	24		428,352.984	9,222,196.636
	B-7	66	90.42	70	13		428,257.687	9,222,170.483
	B-8	66	87.17	70	13		428,296.050	9,222,281.423
	B-9	66	170.99	90	15		428,090.750	9,222,307.094
	B-10	66	178.12	90	16		428,178.438	9,222,268.797
	B-11	66	188.91	100	17		428,491.528	9,222,133.311
	B-12	66	137.07	80	15		428,326.556	9,222,194.498
	B-13	66	148.47	80	14		428,374.956	9,222,255.730
	B-14	66	196.26	85	11		427,806.500	9,222,449.500
	B-15	66	185.75	60	9		428,597.783	9,221,889.908
	B-16	66	126.05	30			428,115.560	9,222,186.588
	B-17	66	131.45	40			428,335.838	9,222,467.660
	B-18	66	136.08	80	14		428,213.456	9,222,177.350
	B-19	66	147.48	80	14		428,324.282	9,222,132.942
	B-20	66	139.37	80	14		428,260.416	9,222,309.886
	B-21	66	92.96	20	3		428,208.826	9,222,060.330
	B-22	66	83.61	20	3		428,358.238	9,222,392.018
	B-23	66	158.15	40			428,157.131	9,222,227.643
	B-24	66	156.47	40			428,205.189	9,222,322.208
	B-25	66	122.56	81			428,309.834	9,222,405.566
	B-26	66	133.17	50			428,391.625	9,222,366.069
	B-27	66	136.65	88	15		428,150.248	9,222,084.714
Sub Total				1,669	245	0		

Stage	Hole No.	Hole Diameter (mm)	Ground Elevation (m)	Depth (m)	Lugeon-test (times)	Loading Test in Borcholes (times)	Coordinate	
							X	Y
Phase 2	B-28	66	128.774	115	19		428,218.310	9,222,152.634
	B-29	66	93.752	80	11		428,241.604	9,222,110.179
	B-30	66	134.949	125	22		428,290.243	9,222,122.153
	B-31	66	147.380	65			428,242.766	9,222,025.286
	B-32	66	171.143	85		15	428,399.885	9,222,172.417
	B-33	66	88.096	35		5	428,278.790	9,222,208.195
	B-34	66	100.958	10			428,103.083	9,222,162.478
	B-35	66	150.163	20			428,281.104	9,222,050.469
Sub Total				535	52	20		
Total				2,204	297	20		

All results of core drilling from Dam Site are shown in Photo Album, including the Lugeon Value for the corresponding depth.

2.2.2 Lugeon Test in Borehole

The investigation items and work quantities of Lugeon Test in Borehole are shown in sub Chapter 2.2.1 above.

Summary of the Lugeon Tests for the Damsite Area are shown in Table 2.2.1 (1/10) to Table 2.2.1(10/10).

2.2.3 Trench Excavation

The investigation items and work quantities of trench excavation work are as follows

Stage	Trench No.	Length (m)	Point	Coordinate		
				X	Y	Z
Phase 1	CL – R	114.00	Top	428,405.849	9,222,169.366	173.511
			Bottom	428,304.799	9,222,213.533	132.057
	CL – L	114.00	Top	428,181.099	9,222,267.601	178.274
			Bottom	428,256.721	9,222,234.548	124.999
	DS – R	101.00	Top	428,436.334	9,222,221.262	177.067
			Bottom	428,347.041	9,222,260.290	132.886
	DS – L	74.00	Top	428,219.069	9,222,318.524	152.164
			Bottom	428,283.962	9,222,290.161	119.217
	US – R	130.00	Top	428,421.585	9,222,097.009	187.136
			Bottom	428,305.765	9,222,147.633	137.300
	US – L	115.00	Top	428,155.442	9,222,213.575	151.007
			Bottom	428,238.037	9,222,177.473	120.646
Total		648.00				

The location map is shown in Figure 2.2.2.

2.2.4 Adit Excavation

The investigation items and work quantities of Adit excavation work are as follows:

Stage	Adit No.	Ground Elevation (m)	Length (m)	Shear-test (times)	Coordinate	
					X	Y
Phase 1	T – 1	92.745	20	8	428,269.507	9,222,209.610
	T – 2	117.865	30	0	428,262.655	9,222,231.955
	T – 3	140.029	30	4	428,236.147	9,222,243.540
	T – 4	138.967	30	0	428,333.837	9,222,200.843
Total			110	12		

The location map is shown in Figure 2.2.2.

2.2.5 In-situ Shearing Test

The investigation items and work quantities of in-situ shearing test are as follows:

Stage	Adit No.	Depth from the entrance (m)	Quantities		Remarks
			Rock Shear Test (point)	Block Shear Test (point)	
Phase 1	T – 1	5.5, 7.5, 11.5, 14.0	4	4	Left Bank
	T – 3	9.5, 14.0, 17.5, 21.5		4	Left Bank
Total			4	8	

The results of the in-situ rock shear test in adits are summarized in the Table 2.2.2 for result of shearing test and Table 2.2.3 for Elastic Modulus by Loading Test.

2.2.6 Seismic Prospecting

The investigation items and work quantities of Seismic Prospecting are as follows:

Stage	Location	Quantities (m)	Remarks
Phase 1	Dam Axis	800	
	Riverbed	500	
Total		1,300	

The geophysical campaign done at the Dam Site consists of 1300 meters refraction seismic lines, were distributed along two seismic lines as shown in Figure 2.2.3. There are two lines for 200 m penetration, they are Line SD-01 (Dam Axis) and Line SD-02 (Riverbed).

The result of investigation consists of T–X Graph and Seismic Section Line SD–01 and SD–02 as shown in Figure 2.2.4 and Figure 2.2.5 and Relation between Seismic velocity and lithology for line SD–01 and SD–02 as shown in Table 2.2.4 and Table 2.2.5.

2.2.7 Laboratory Test of Core Sample

The investigation items and work quantities of Laboratory Test of Core Sample at Dam Site are as follows:

Stage	Item		Quantities (samples)	Remarks
Phase I	Physical Property Test	Density, Absorption Ratio and Effective Porosity	27	
	Unconfined Compression Test		27	

The Rock Mechanical Properties Determination are shown in Table 2.2.6 and The Summary of Unconfined Compression Test is shown in Table 2.2.7.

2.2.8 Loading Test in Borehole

The investigation items and work quantities of Loading Test in Boreholes are shown in sub Chapter 2.2.1 above. The Summary of Loading Test in Boreholes is shown in Table 2.2.8.

2.2.9 In-situ Plate Loading Test

The investigation items and work quantities of in-situ plate loading test in Adits are as follows:

Stage	Adit No.	Depth from the entrance (m)	Quantities (point)	Remarks
Phase I	T – 1	7.5, 13.5	2	Left Bank
	T – 3	11.0, 19.0	2	Left Bank
	T – 4	21.5, 27.0	2	Right Bank
Total			6	

Summary of Plate Loading Test in Adits is shown in Table 2.2.9.

2.3 Reservoir Area

A saddle portion whose lowest elevation is EL. 161.69 m exists at the right bank of the reservoir. Since the creep length of the saddle portion at the Surcharge Water Surface (EL. 151.8 m) is about 150 m, leakage from the saddle portion can be presumed depending on the condition of the geology.

Gentle slopes and isolated hills are scattered at the right bank of the reservoir and the distribution of the alternate layers consist of some sedimentary rocks which cover bedrock of

siltstone is considered to be topographically irregular. There is a possibility that this irregularity of the topography was caused by landslide and the area has possibility to cause landslide after impounding water in the reservoir.

The same topography is recognized at the left bank of the reservoir. However, since bedrock of siltstone is outcropped over a wide area, it is judged that this area has low possibility of landslide.

Considering the above topographical conditions, geological survey with borings and excavation of trenches was conducted at the saddle portion and gentle slopes in the right bank of the reservoir.

The work items and quantities of geological survey in the reservoir area are shown in the following table.

Work Item	Work Quantities
Core Drilling (D=66 mm)	16 holes, 475 m in total
Lugeon Test in Bore Hole	5 holes, 28 times in total
Standard Penetration Test	11 holes, 310 times in total
Trench Excavation	7 trenches, 766 m in total

The locations of boreholes and trenches are shown in Fig. 2.2.1.

2.3.1 Core Drilling

The investigation items and work quantities of Drilling Work at Reservoir Area including the Lugeon Test and the Standard Penetration Test are as follows:

Hole No.	Hole Diameter (mm)	Ground Elevation (m)	Depth (m)	Lugeon -Test (times)	S.P.T* (times)	Coordinate	
						X	Y
RA – 1	66	165.94	30	5		428,575.699	9,221,554.590
RA – 2	66	176.36	35	6		428,534.944	9,221,471.492
RA – 3	66	163.78	30	5		428,624.547	9,221,654.218
RA – 4	66	181.96	40	7		428,709.088	9,221,827.654
RA – 5	66	166.99	30	5		428,670.089	9,221,747.091
RA – 6	66	146.72	20		20	428,538.689	9,221,684.341
RA – 7	66	150.33	20		20	428,764.492	9,221,668.156
RI – 1	66	165.43	30		30	428,428.009	9,221,519.380
RI – 2	66	153.79	20		20	428,407.231	9,221,658.000
RI – 3	66	150.33	30		30	428,491.635	9,221,501.728
RI – 4	66	170.19	30		30	428,508.559	9,221,568.052
RO – 1	66	187.34	30		30	428,672.370	9,221,450.722
RO – 2	66	162.34	30		30	428,673.241	9,221,551.054
RRD – 3	66	140.31	30		30	428,152.841	9,221,511.174
RRD – 4	66	143.95	30		30	428,117.302	9,221,605.982
RRD – 5	66	169.08	40		40	428,187.560	9,221,419.522
Total			475	28	310		

Note S.P.T* : Standard Penetration Test

The Drill Log from Reservoir Area including the Lugeon Value and the Standard Penetration Test Value are shown in the Photo Album.

2.3.2 Lugeon Test in Borehole

The investigation items and work quantities of the Lugeon Test in Borehole at Reservoir Area are shown in Sub Chapter 2.3.1 above.

Summary of Lugeon Test in Boreholes is shown in Table 2.3.1

2.3.3 Standard Penetration Test

The investigation items and work quantities of the Standard Penetration Test in Boreholes at Reservoir Area are shown in Sub Chapter 2.3.1 above. The N-values for each depth of test for each Drill Log are shown in the Photo Album

2.3.4 Trench Excavation

The investigation items and work quantities of trench excavation work at Reservoir Area are as follows:

Trench No.	Length (m)	Point	Coordinate		
			X	Y	Z
FS – 1	150	Northern end	428,566.9982	9,221,797.111	172.144
		Southern end	428,530.6103	9,221,654.48	149.151
FS – 2	52	Southern end	428,337.638	9,221,757.841	132.882
		Northern end	428,317.334	9,221,704.785	134.318
FS – 3	114	Northern end	428,806.734	9,221,813.545	163.703
		Southern end	428,822.211	9,221,673.55	146.599
SS – 1	130	Southern end	428,672.3695	9,221,450.722	187.338
		Northern end	428,673.459	9,221,576.233	158.264
SS – 2	150	Southern end	428,169.1204	9,221,468.199	163.945
		Northern end	428,117.3023	9,221,604.982	143.953
SS – 3	100	Southern end	428,420.5387	9,221,569.191	165.433
		Northern end	428,405.7176	9,221,668.096	153.791
SS – 4	70	Southern end	428,491.6352	9,221,501.728	180.824
		Northern end	428,508.56	9,221,568.053	170.545
Total	766				

The location of the trench excavations are shown in Figure 2.2.1