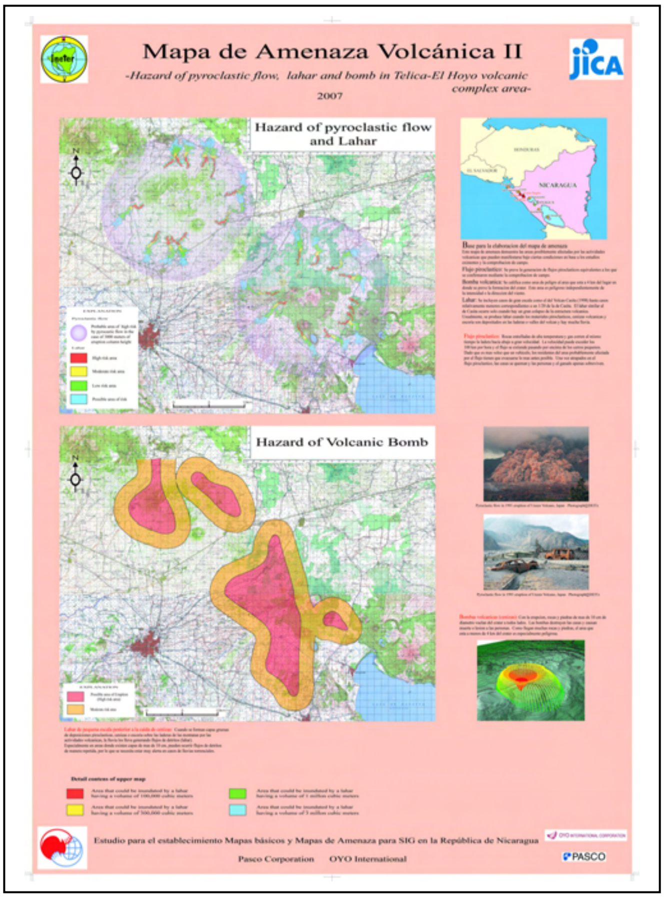

Figure 8-30 Pyroclastic Flow and Lahar (top) and Volcanic Bomb (bottom)

The photographs show the pyroclastic flow in Mt. Unzen (Japan) taken in 1991 (top) and damage caused by the pyroclastic flow (bottom).

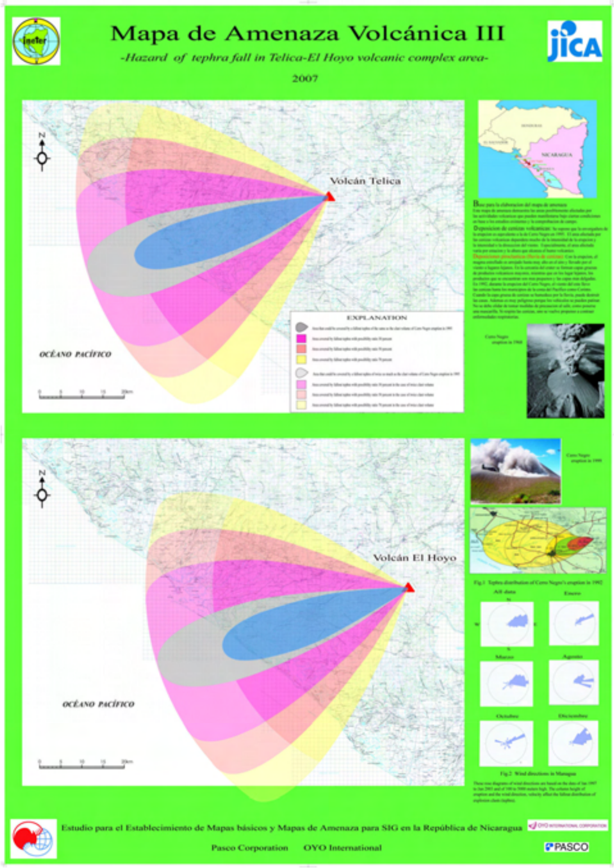

Figure 8-31 Different Eruption Locations (Tephra fall)

The photographs are eruption scenes of Cerro Negro in 1968 (top) and 1992 (bottom). The figure, below the photographs, shows the distribution map of actual tephra fall of Cerro Negro eruption in 1999.

The draft maps were prepared using Adobe Illustrator CS.

8-3 Flood

8-3-1 General

Figure 8-32 shows the general flow chart of flood analysis.

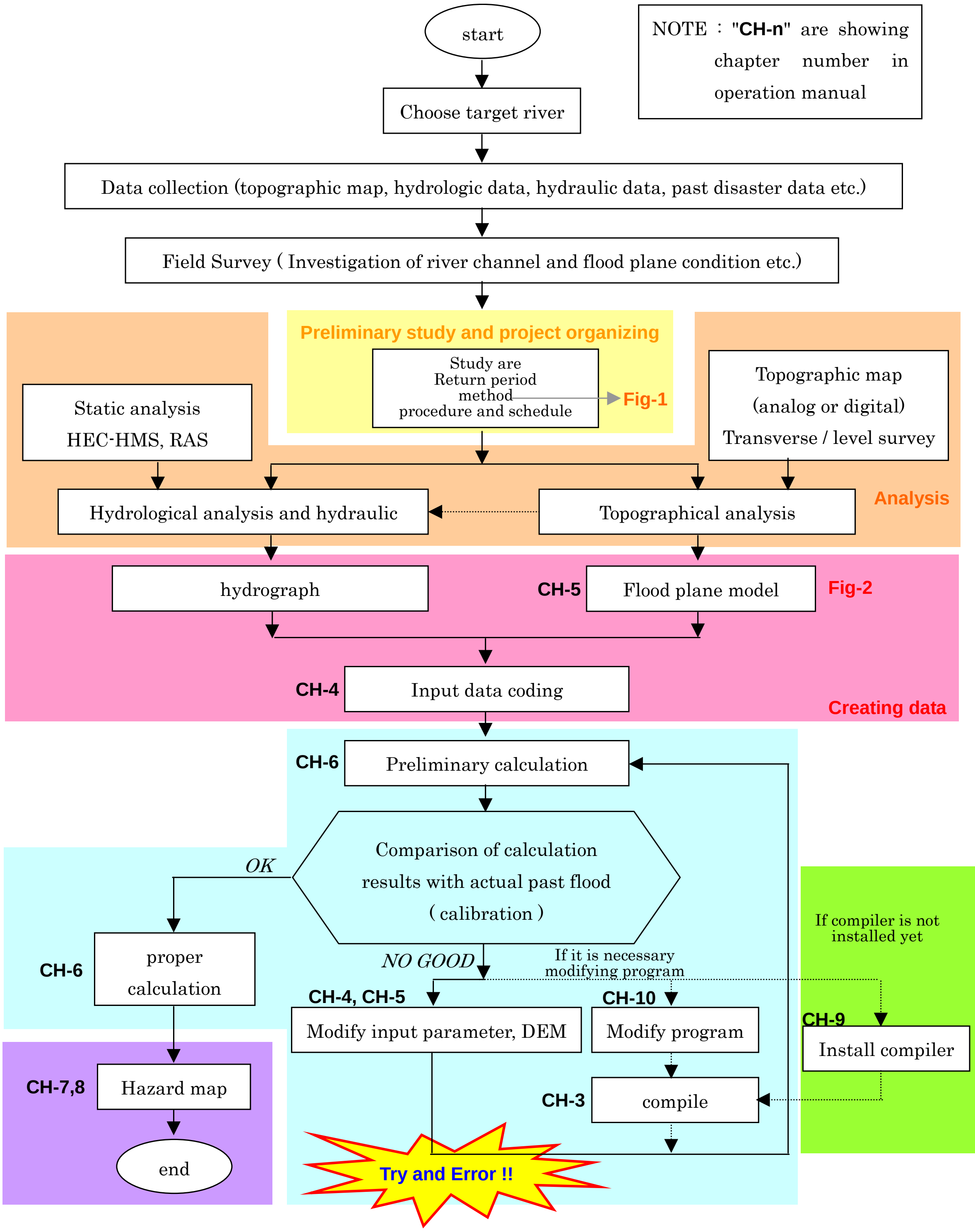

Figure 8-32 General Flow Chart of Flood Analysis

8-3-2 Landform Characteristics

(1) Landform characteristic

The upper region consists of volcanic products of Quarternary Period, and it is presenting the dissection landform of topographic infancy peculiar to the foot volcanic mountain. The upper part of the ridge, which forms a uniform line, presents the landform which inclines gently to the Pacific Ocean side (west side). The trough is deeply covered with the forest and land is less utilized.

From the mid-stream regions to the lower stream, a Tertiary deposit (Eocene - Miocene) is distributed, and a cuesta landform is present.

The down-stream region presents a gently-sloped-hilly-terrain form; each river flows to the east carving through a plateau. Most of the hilly terrain of a down-stream region is a cane field. When the cane grows high, it is difficult to interpret micro topography. The built-up area in Masachapa is located at the mouth-of-a-river, and residential units along the river densely occupied the area.

The topography and the outline of land use were shown using the section and ortho-photograph which were created from the topographic model (explained in the latter part of this section) created using 1:5000 topographic maps as an alternative approach to the aerial-photograph interpretation.

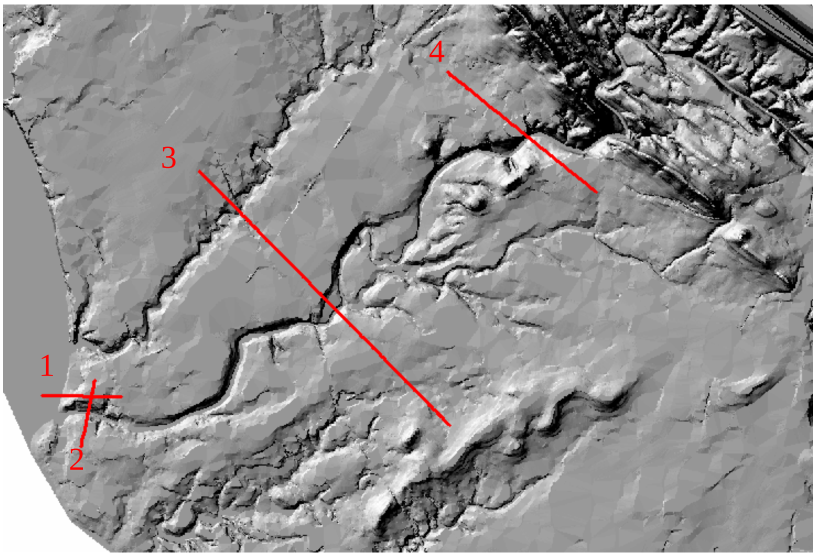

Figure 8-33 Shade Map of the Lower Part of the Maravilla River

Cross Section 1: Section of the Right Bank at the Mouth of a River from the Sea to Masachapa City

The built-up area has a height of about 10 m.

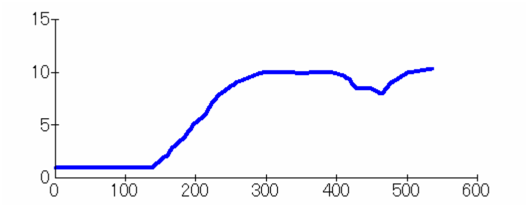

Figure 8-34 Section of Traverse Line 1

Figure 8-35 Lowest Stream and Masachapa City area

Cross Section 2: Traverse section right above the mouth of the river; A channel falls by 7-8m.

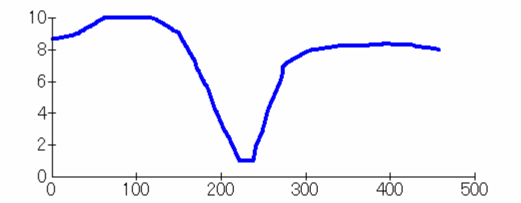

Figure 8-36 Section of Traverse Line 2

Cross Section 3: Near the intermediate point of the outlet and mouth of a river of a trough; The perimeter is a cane field. A channel falls by about 10m.

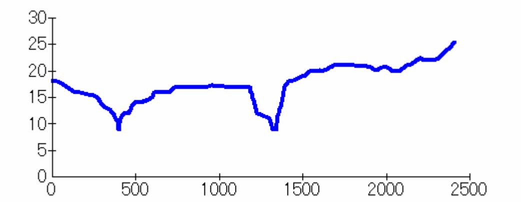

Figure 8-37 Section of Traverse Line 3

Figure 8-38 Hinterland of Masachapa City is a cane field.

Cross Section 4: Near the outlet of a trough; A channel is lower by 15 meters.

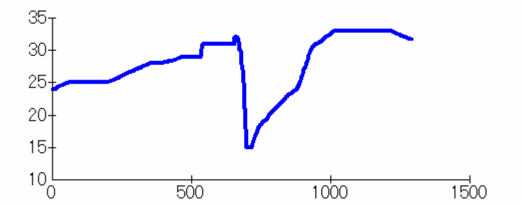

Figure 8-39 Section of Traverse Line 42

Figure 8-40 The hinterland of Masachapa City is a cane field.

The watershed characteristics measured from 1:50,000 topographic-map data is shown below.

- River name : La Maravilla river
- Drainage area : 64.91km^2
- Watercourse length : 29.8 km
- Valley length : 29.6 km
- Valley width : a maximum of 6.0km, an average of 2.7 km (the width of the part considered to be the average is measured)
- The highest altitude : 800m
- Average grade : 430/29800≒1 / 70 (altitude of the upper end which measured watercourse length 430 m)

- The watercourse length from the outlet of a trough to a mouth of a river and average grade : the altitude of 15m, 4800m of watercourse length, 1/320

(2) Field Identification

The field identification was conducted in the second and third work in Nicaragua. It carried out for the purpose of the Study Team mainly to grasp the river situations in Nicaragua.

During the fifth work in Nicaragua, in the first meeting (October 7, 2005), it was pointed out that there had been a report that a dam of Masachap City had been collapsed due to heavy rain. Since INETER did not have precise information, two persons, Mr. Isaias Montoya and Mr. Jamil Robleto both from INETER visited the site on October 12, the following week, to conduct the field identification. As a result, compared with the dry season, the water level was higher by one meter or more, and it became clear by the trace around a channel, or interview that there was a water-level rise of an about 2 m at the time of a flood last week. In the Masachapa dam, muddy water was flowing down from the floodgate to the maximum extent, and a submergence bridge was covered with water; however, abnormalities, such as collapse, were not recognized. It was concluded that it was a false report or misconception of its location. The volume of flow was small until the last field identification; therefore, the raise of the water level was not seen (Photo 8-2). On October 12, during the field identification, the outflow of from the dam was observed. It is to note that in Masachapa City, the submergence bridge, which crosses the Masachapa river, was covered with water. In the Masachapa dam, it was observed that water was flowing from all the section of the floodgate (Photo 8-3). According to an interview, it is a frequent phenomenon during the rainy season.

Photo 8-2 Masachapa Dam in the Dry Season

Photo 8-3 Masachapa Dam in the Rainy Season

8-3-3 Hydrological Statistics and Planned Scale

(1) Location map of hydro gauging station

The location map of the hydrology observatories near Masachapa is shown in Figure 8-41. Although the San Antonio observation station was the closest in the past, it was discontinued in 1981. The observatory, where data are obtained until recent years, is Julio Buitrago. The data until 2000 including rainfall by hour has been recorded. However, during the field identification, the observation station was not found as it seemed to be transferred to another location.

Thus, since a systematic observation of rainfall and discharge was not conducted in the watershed of the Maravilla River, the Study Team requested installation of a rain gauge and a flowmeter during the first work in Nicaragua. One rain gauge (Photo 8-4), and one a water/rain gauge (Photo 8-5 and Photo 8-6) were installed by INETER. Since it was installed recently, accumulation of data was not sufficient; the data could not be used for the hazard map preparation. However, it can be expected that the gauges will be able to accumulate sufficient data for future analyses and for disaster prevention activities. The water gauge was made to be a telemotor, and the data were sent to INETER of Managua through a satellite connection.

Photo 8-4 Rain Guage

Photo 8-5 Water Gauge

Photo 8-6 Rain Gauge and Telemeter

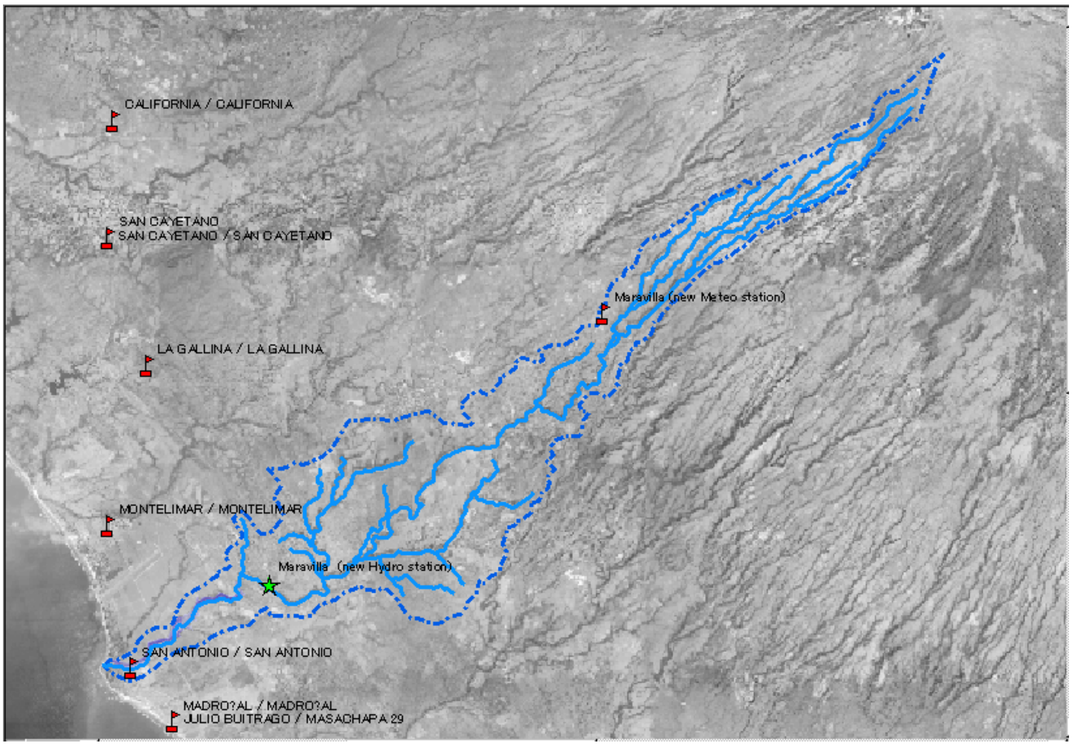

Figure 8-41 Hydrology Observatory near the Maravilla River

The asterisks show the newly installed water gauge and rain gauge which were indicated on Photo 4 and 5.

(2) Designed Rainfall

The return period of design rainfall considered the following situations in Nicaragua suggested by the counterpart, and four cases 25 years, 50 years, 100 years, and 200 were selected.

RETURN PERIOD BETWEEN 10 – 25 YEARS

They are used for the design of hydraulic and drainage works (small works) usually in urban zones. For example: bridges, fords, sewage disposals, small culverts, etc.

RETURN PERIOD BETWEEN 50 – 100 YEARS

They are used for the design of hydraulic and structural works with large extents/spread (Horizontal and vertical works) for example: homes, highways, bridges, etc.

RETURN PERIOD OF 200 YEARS.

It is used for the elaboration of Hydrologic Studies and it is considered the maximum period to elaborate which ever kind of design in the country, which is why periods longer than this one are not frequent.

(3) Statistic Analysis of Julio Buitrago

The hydrology observatory used for the analysis was set to the 680032 Julio Buitrago for its availability of rainfall by hour. The year maximum daily rainfall of the observatory is shown in Table 8-8.

Table 8-8 The Maximum daily rainfall of Julio Buitrago 680032 of the Year

	year	Max Daily
1	1987	192.0
2	1988	218.4
3	1989	148.2
4	1990	132.0
5	1991	170.4
6	1992	146.9
7	1993	112.5
8	1994	97.5
9	1995	180.7
10	1996	255.4
11	1997	95.0
12	1998	
13	1999	194.2
14	2000	231.6

Based on the data, another daily rainfall by return period was calculated using the log-normal probability paper by the Thomas plotting method. The plot is shown in Figure 8-42. This figure was created using the software provided during the OJT.

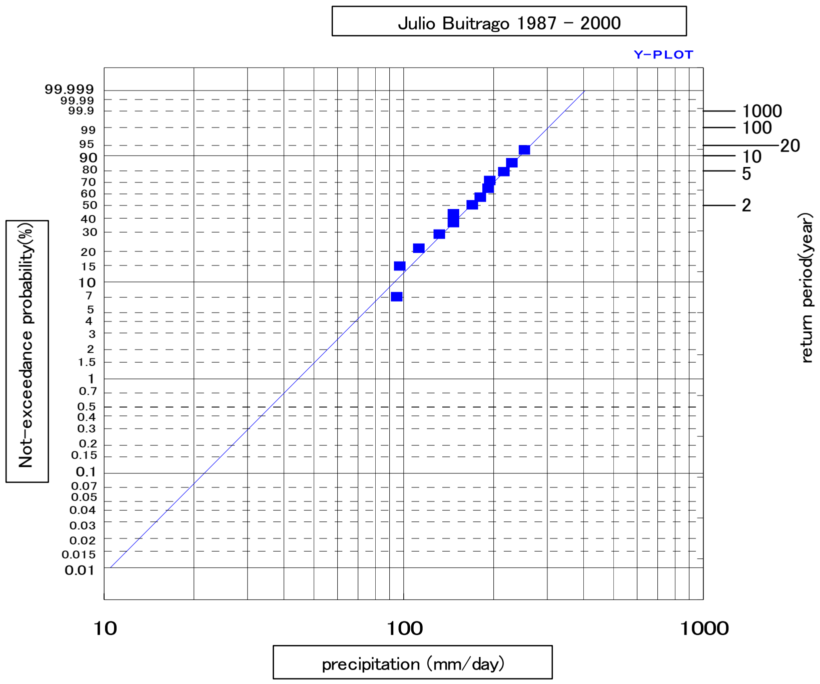

Figure 8-42 The Maximum Daily Rainfall Of A Year In 680032 Juliobuitrago Plotted To The Logarithmico-Normal Probability Paper

The daily rainfall by recurrence resulting from the diagrammatic chart is shown in Table 8-8. This table was created using the software offered in OJT.

Table 8-9 Daily Rainfall by Return Period

Return Period (year) 1/(1−P)	X
2	159.8
3	182.5
4	196.7
5	207.1
8	227.8
10	237.2
15	253.8
20	265.2
25	274.1
30	281.2
40	292.3
50	300.8
60	307.8
80	318.8
100	327.2
150	342.5
200	353.4
250	361.7
300	368.6
400	379.4
500	387.8

8-3-4 Hydrograph

(1) Hyetograph

Based on the daily rainfall according to the planned scale searched in the preceding chapter, the hyetograph of design rainfall (design rainfall) was calculated by the following steps.

1) Extract the rainfall pattern of the daily rainfall which serves as the maximum from the existing data on rainfall by hour. The rainfall pattern from 5:00 to 4:00 on the 30th on September 29, 2000 was adopted.

Table 8-10 Rainfall Record

	Sep-00 29-30
5	18.5
6	2.7
7	15.8
8	19.5
9	75.3
10	15.8
11	51.5
12	16.1
13	4.7
14	5.2
15	0.8
16	0.8
17	0.2
18	0.8
19	0.2
20	0.4
21	0.4
22	0.0
23	0.0
24	0.3
1	0.1
2	21.2
3	4.0
4	20.6
amount	274.9

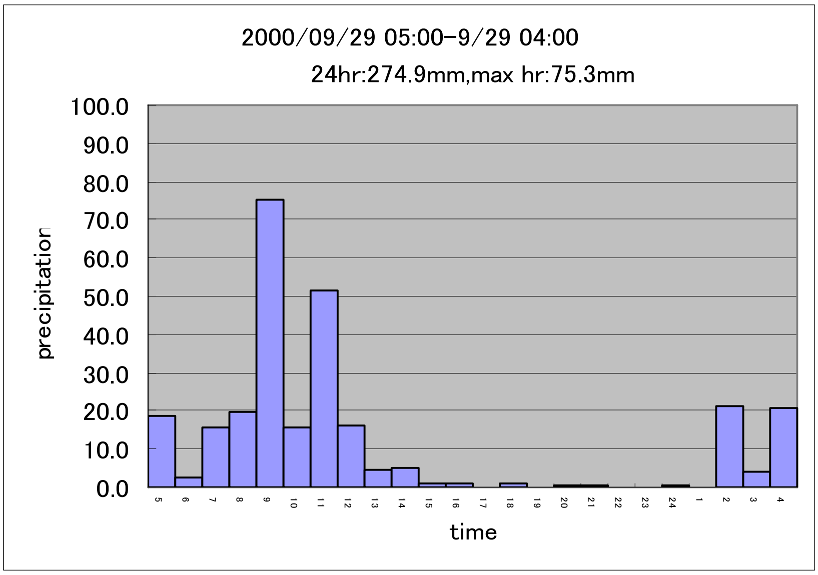

Figure 8-43 Hyetograph from Rainfall Record

2) Rainfall for each hour was extended by the ratio of the actual daily rainfall and each

planned scale.

Table 8-11 Design Rainfall

return period / hour	25	50	100	200
1	18.4	20.2	22.0	23.8
2	2.7	3.0	3.2	3.5
3	15.8	17.3	18.8	20.3
4	19.4	21.3	23.2	25.1
5	75.1	82.4	89.6	96.8
6	15.8	17.3	18.8	20.3
7	51.4	56.4	61.3	66.2
8	16.1	17.6	19.2	20.7
9	4.7	5.1	5.6	6.0
10	5.2	5.7	6.2	6.7
11	0.8	0.9	1.0	1.0
12	0.8	0.9	1.0	1.0
13	0.2	0.2	0.2	0.3
14	0.8	0.9	1.0	1.0
15	0.2	0.2	0.2	0.3
16	0.4	0.4	0.5	0.5
17	0.4	0.4	0.5	0.5
18	0.0	0.0	0.0	0.0
19	0.0	0.0	0.0	0.0
20	0.3	0.3	0.4	0.4
21	0.1	0.1	0.1	0.1
22	21.1	23.2	25.2	27.3
23	4.0	4.4	4.8	5.1
24	20.5	22.5	24.5	26.5
amount	274.1	300.8	327.2	353.4
expantion ratio	0.99709	1.094216	1.190251	1.285558

(2) Hydrograph

1) Establishing discharge time

For the precipitation to converted the precipitation to discharge, the effective rainfall was used. The effective rainfall was the sum of the rainfall within concentration time (time of concentration); that is the sum the outflow time from a slope face to a channel, and the flow time of a channel, and was calculated as follows from the configuration of a valley.

- Outflow time from a slope face to a channel : 30min
- Watercourse length : 29,000m
- Difference-in-elevation : 700m
- Average grade : 700/29000=1/41
- Mean velocity of flood flow: The value of Rziha was used. Since the average grade is steeper than 1/100, the value is set 3.5m^2/sec.
- The flow time of a channel: 29000/3.5=8285 sec=138 min
- Therefore, the time of concentration of a flood is 30+138=168≒180 min=3 hrs.

The effective rainfall turns to be the three-hour rainfall. Therefore, the mean value was calculated every three hours based on the hyetograph of past records, and the hyetograph of effective rainfall was created.

Table 8-12 Planned Hyetograph

return period / hour	25		50		100		200	
		R		R		R		R
1	18.4	12.3	20.2	13.5	22.0	14.7	23.8	15.9
2	2.7	12.3	3.0	13.5	3.2	14.7	3.5	15.9
3	15.8	12.3	17.3	13.5	18.8	14.7	20.3	15.9
4	19.4	36.8	21.3	40.3	23.2	43.9	25.1	47.4
5	75.1	36.8	82.4	40.3	89.6	43.9	96.8	47.4
6	15.8	36.8	17.3	40.3	18.8	43.9	20.3	47.4
7	51.4	24.0	56.4	26.4	61.3	28.7	66.2	31.0
8	16.1	24.0	17.6	26.4	19.2	28.7	20.7	31.0
9	4.7	24.0	5.1	26.4	5.6	28.7	6.0	31.0
10	5.2	2.3	5.7	2.5	6.2	2.7	6.7	2.9
11	0.8	2.3	0.9	2.5	1.0	2.7	1.0	2.9
12	0.8	2.3	0.9	2.5	1.0	2.7	1.0	2.9
13	0.2	0.4	0.2	0.4	0.2	0.5	0.3	0.5
14	0.8	0.4	0.9	0.4	1.0	0.5	1.0	0.5
15	0.2	0.4	0.2	0.4	0.2	0.5	0.3	0.5
16	0.4	0.3	0.4	0.3	0.5	0.3	0.5	0.3
17	0.4	0.3	0.4	0.3	0.5	0.3	0.5	0.3
18	0.0	0.3	0.0	0.3	0.0	0.3	0.0	0.3
19	0.0	0.1	0.0	0.1	0.0	0.2	0.0	0.2
20	0.3	0.1	0.3	0.1	0.4	0.2	0.4	0.2
21	0.1	0.1	0.1	0.1	0.1	0.2	0.1	0.2
22	21.1	15.2	23.2	16.7	25.2	18.2	27.3	19.6
23	4.0	15.2	4.4	16.7	4.8	18.2	5.1	19.6
24	20.5	15.2	22.5	16.7	24.5	18.2	26.5	19.6
amount	274.1	274.1	300.8	300.8	327.2	327.2	353.4	353.4

2) Rainfall-runoff Conversion

For the rainfall-runoff conversion the rational formula (rational formula) was used. In the following equation: Q (m^3/sec) represents the peak discharge; C is the run-off coefficient; I (mm/hr) is the effective rainfall intensity; and A is the drainage area.

$$Q = \frac{1}{3.6} CIA$$

Since the geology and the topography of a watershed were the mountainous landform of a Tertiary deposit, the ratio of run-off C was set to 0.7. The drainage area A was set to 2 64.9 km^2. The hydrograph of every return period is shown in Table 8-13.

return period / hour	25	50	100	200
1	152.0	167.2	182.1	197.0
2	152.0	167.2	182.1	197.0
3	152.0	167.2	182.1	197.0
4	454.4	499.7	544.4	588.7
5	454.4	499.7	544.4	588.7
6	454.4	499.7	544.4	588.7
7	297.0	326.7	355.9	384.9
8	297.0	326.7	355.9	384.9
9	297.0	326.7	355.9	384.9
10	27.9	30.7	33.5	36.2
11	27.9	30.7	33.5	36.2
12	27.9	30.7	33.5	36.2
13	4.9	5.4	5.9	6.4
14	4.9	5.4	5.9	6.4
15	4.9	5.4	5.9	6.4
16	3.3	3.6	3.9	4.3
17	3.3	3.6	3.9	4.3
18	3.3	3.6	3.9	4.3
19	1.6	1.8	2.0	2.1
20	1.6	1.8	2.0	2.1
21	1.6	1.8	2.0	2.1
22	188.2	206.9	225.5	243.8
23	188.2	206.9	225.5	243.8
24	188.2	206.9	225.5	243.8

Table 8-13 Hydrograph

The estimation method of the flood discharge shown is a simple approach used in Japan. It is because there are no data used for verification since the observational data of a discharge was not obtained. Therefore, a complex runoff-analysis model could not be developed for the Maravilla river. We decided to estimate by the simple approach. The approach to the run-off analysis, however, needs to be re-evaluated as the actual flood data are accumulated in Nicaragua.

8-3-5 Digital Elevation Model

(1) Topographic Data

The topographic-map data used for creation of a landform model are the 1/5,000 topographic map of the seashore part under the possession of the Bureau of Tourism (El Instituto Nicaraguense De Turismo, INTUR). The data were obtained during the information collection phase on Tsunami. The data were collected in the Masachapa perimeters, and turned out that the data can be utilized for the flood analysis. Therefore, we decided to create a topographic model using the data.

Data were in the dwg file format. They were imported to ArcView and converted to the shape file format. Since the contour lines had the height data, a three-dimensional landform model was created based on the data. Some errors of height were found at some parts of the data. When the model is actually used, a strict verification of the model is necessary. Only major errors were corrected for this time. As a result, the fine topography around a river with which these data are not expressed by 1/50,000 is expressed. Therefore, it was found that the data can be used for future flood analyses. The topographic data are shown in Figure 8-44.

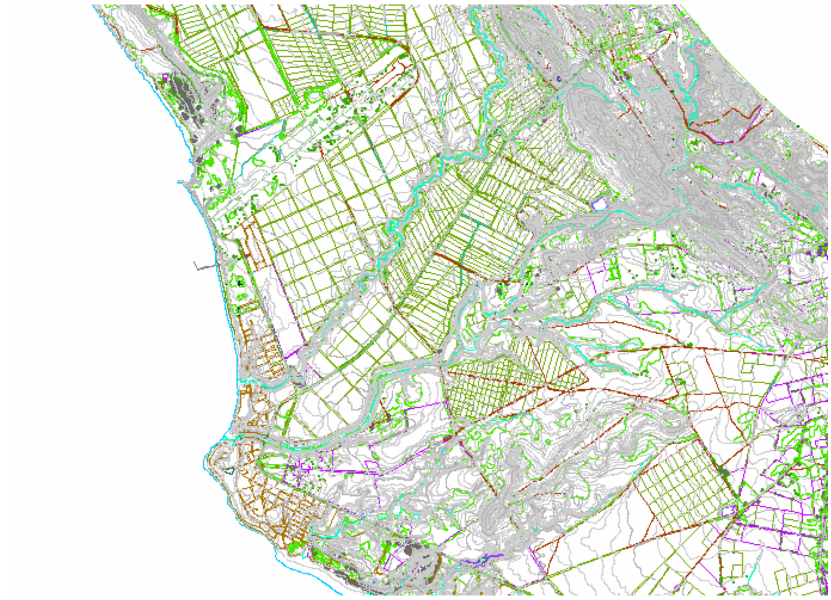

Figure 8-44 Map Showing Line Attributes in Colors from Topographic Mapping Data

TIN was created based on the contour line data, and DEM of 5m grid was further created from TIN. The hypsometric-tints figure created from this DEM is shown Figure 8-45, and the shade figure (hill shade map) is shown in Figure 8-46.

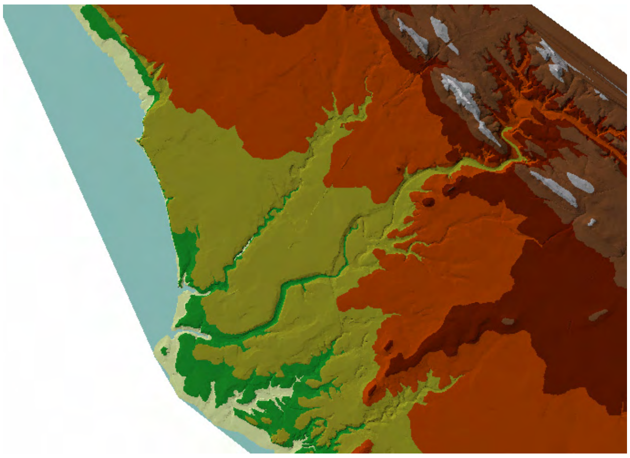

Figure 8-45 Elevation Classified in Colors Produced from TIN

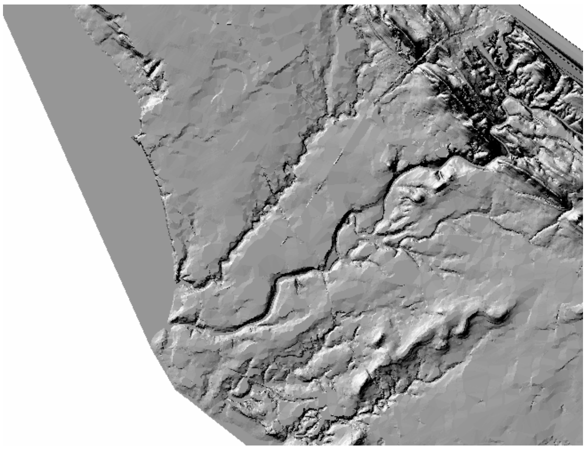

Figure 8-46 Hill Shade Map

(2) Flood Plane Model

A landform model with a 25 meter mesh was created from the DEM with a five-meter mesh; data files were created from the landform model. The direction and topography characteristic of the river were considered, and the topographic model set up as including the origin/datum and the area, to make the calculate efficiently. The series of work was conducted using the mesh generating tool of GIS.

The data of the topographic model were arrayed in accordance with the altitude data within the calculation range, the non-calculating rage (non-study area) and the boundary mesh numbers in the format that specified in the program. General text files were created. The detailed procedure is included in the operation manual. The created data were stored in CD and provided to the counterpart.

Figure 8-47 Creation of Elevation Model from Contour Lines

Fig-2 Creating flood plane model for 2 dimensional analysis

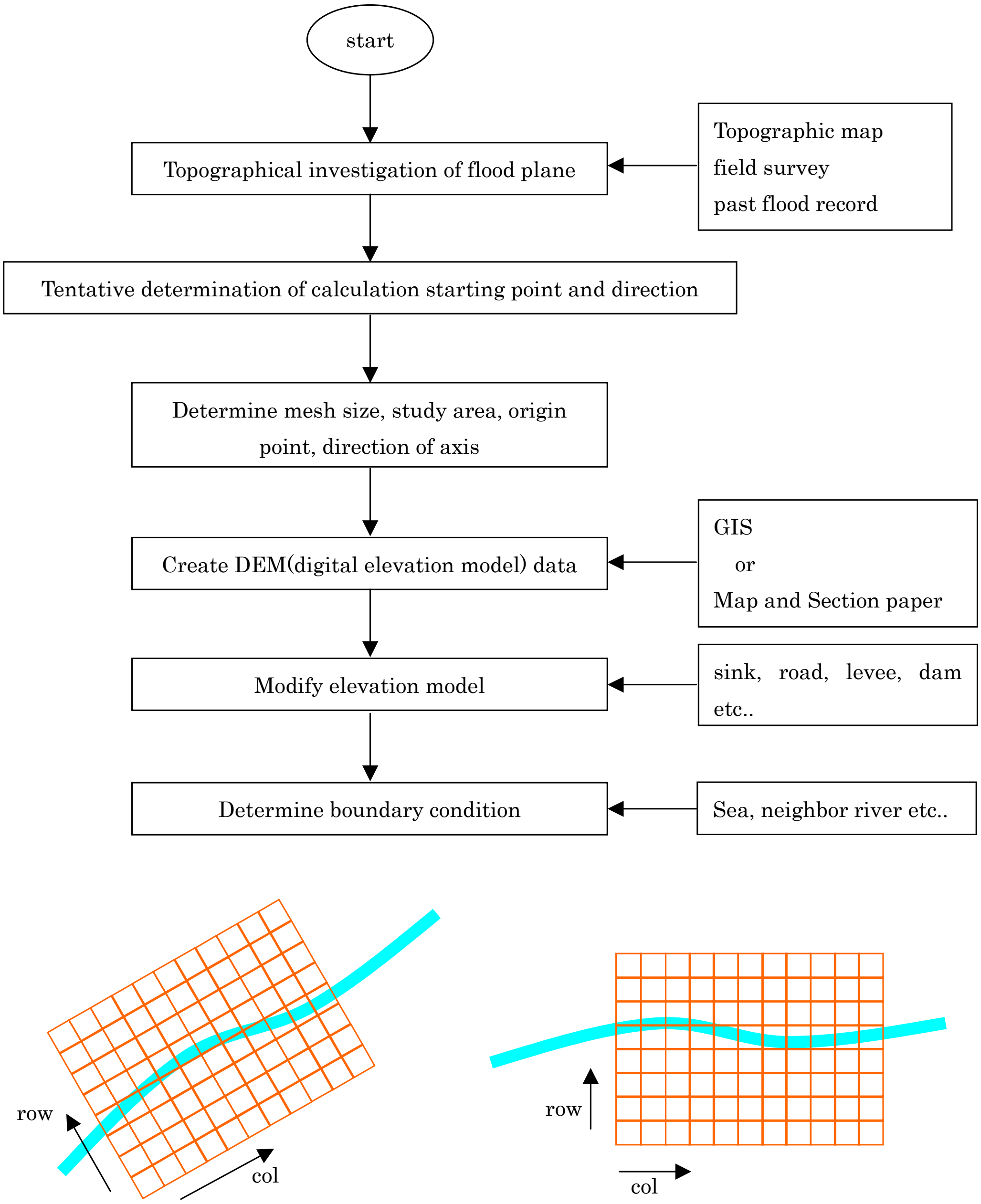

Figure 8-48 Flood Plane Modeling for Two Dimensional Analysis

8-3-6 Two-dimensional Simulation

(1) Two Dimensional Unsteady Flow Calculation--Basic Equations

$$\frac{\partial h}{\partial t}+\frac{\partial M}{\partial x}+\frac{\partial N}{\partial y}=0 \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (1)$$

$$\frac{\partial M}{\partial t}+\frac{\partial}{\partial x}uM+\frac{\partial}{\partial y}vM=-gh\frac{\partial H}{\partial x}-\frac{\tau_{xb}}{\rho} \cdots\cdots\cdots (2)$$

$$\frac{\partial N}{\partial t}+\frac{\partial}{\partial x}uN+\frac{\partial}{\partial y}vN=-gh\frac{\partial H}{\partial y}-\frac{\tau_{yb}}{\rho} \cdots\cdots\cdots (3)$$

u and v: The flow velocity averaged in the x direction and the depth direction of a y direction, respectively

h: Depth of water, M=uh, and N=vh : it is the discharge flux of a x direction and a y direction, respectively.

τ_{xb} and τ_{yb}: It is shearing stress of a x direction and a y direction which acts on a base, and when a Manning formula is used as a resistance rule, it is expressed as follows.

$$\tau_{xb} \text{ or } \tau_{yb} / \rho = gn^2 u \text{ or } v\sqrt{u^2+v^2}/h^{1/3} \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (4)$$

(2) Basic Equations to Difference Equations

As the calculation approach of the flood water in a land protected by dike, equations (1), (2) and (3) were differentiated. First, the (x, y, z) space is divided in lattice as in Figure 8-49; dependent variables M, N and h are arranged alternately. The lattice spacing is set for each direction Δx, Δy, and Δt. For differentiating, the suffixes i and j, which express a plane (x, y) location, were added to the lower right of the variables, and other suffix n is placed at the upper right side of the variable to show increments of time.

The continuous equation of (1) and dynamic equation of (2) to the x direction can be expanded as in the following equation. The dynamic equation for the y direction can be expanded in the same way.

Continuous Equation:

$$\frac{h^{n+3}_{i+1/2,j+1/2}-h^{n+3}_{i+1/2,j+1/2}}{2\triangle t}+\frac{M^{n+2}_{i+1,j+1/2}-M^{n+2}_{i,j+1/2}}{\triangle x}$$

$$+\frac{N^{n+2}_{i+1/2,j+1}-N^{n+2}_{i+1/2,j}}{\triangle y}=0 \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (5)$$

Equation of X direction:

$$\frac{M^{n+2}_{i,j+1/2}-M^{n}_{i,j+1/2}}{2\triangle t}=$$

$$-g\frac{(h^{n+2}_{i-1/2,j+1/2}+h^{n+1}_{i+1/2,j+1/2})(H^{n+1}_{i+1/2,j+1/2}-H^{n+1}_{i-1/2,j+1/2})}{2\triangle x}$$

$$- gn_{i,j+1/2}^{2} \frac{(M_{i,j+1/2}^{n} + M_{i,j+1/2}^{n+2})\sqrt{(u_{i,j+1/2}^{n})^{2} + (v_{i,j+1/2}^{n})^{2}}}{2\left[(h_{i-1/2,j+1/2}^{n+1} + h_{i+1/2,j+1/2}^{n+1})2\right]^{4/3}} \text{.....................(7)}$$

Thus:

$$u_{i,j+1/2}^{n} = 2M_{i,j+1/2}^{n+1} / \left(h_{i-1/2,j+1/2}^{n+1} + h_{i+1/2,j+1/2}^{n+1}\right) \text{......................................(8)}$$

Equation of Y direction:

$$\frac{N_{i+1/2,j}^{n+2} - N_{i+1/2,j}^{n}}{2\triangle t} =$$

$$- g \frac{(h_{i+1/2,j-1/2}^{n+1} + h_{i+1/2,j-1/2}^{n+1})(H_{i+1/2,j+1/2}^{n+1} - H_{i+1/2,j-1/2}^{n+1})}{2\triangle x}$$

$$- gn_{i+1/2,j}^{2} \frac{(N_{i+1/2,j}^{n} + N_{i+1/2,j}^{n+2})\sqrt{(u_{i+1/2,j}^{n})^{2} + (v_{i+1/2,j}^{n})^{2}}}{2\left[(h_{i+1/2,j+1/2}^{n+1} + h_{i+1/2,j-1/2}^{n+1})2\right]^{4/3}} \text{.....................(9)}$$

Thus:

$$u_{i+1/2,j+1/2}^{n} = 2N_{i,j+1/2}^{n+1} / \left(h_{i+1/2,j-1/2}^{n+1} + h_{i+1/2,j-1/2}^{n+1}\right) \text{......................................(10)}$$

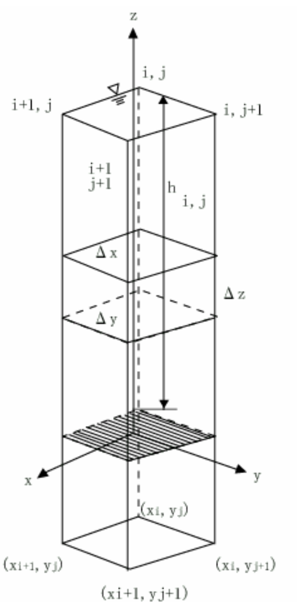

Figure 8-49 Volume Control

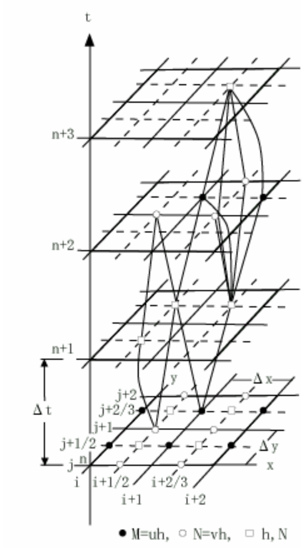

Figure 8-50 Placement of Variables on Difference Scheme

(3) Program

Following Figure 8-51 is the flow diagram.

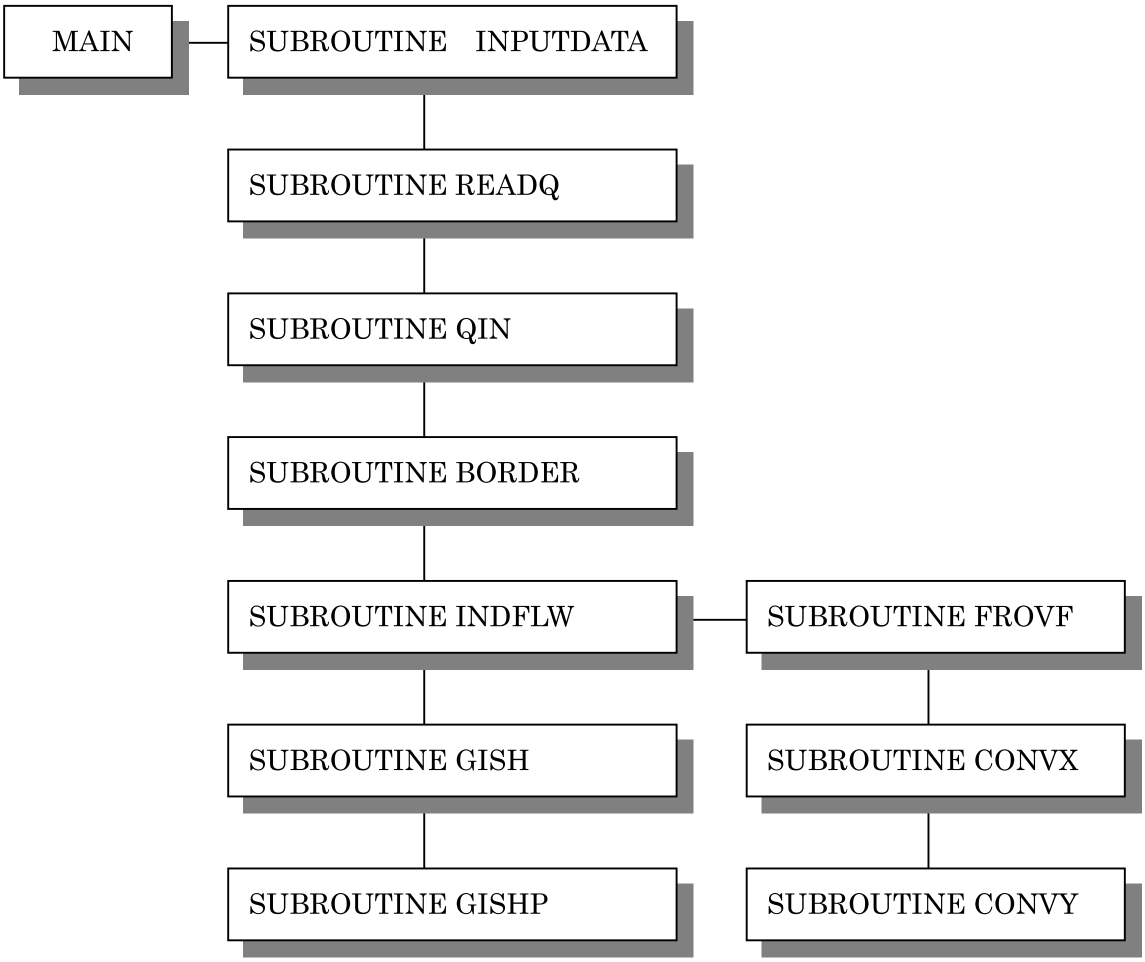

Figure 8-51 Process Flow of the Program

The simulation program, which was originally developed based on a commercially available program introduced in related books, used this time added improvement to the original application. The language is FORTRAN77. The compiler adopted WATCOM FORTRAN in consideration of its flexibility and availability. This compiler is downloadable for free from the website. The source code of the program is included at the end of the operation manual. With the compiler, the text file was stored in CD and submitted to the counterpart. ease refer to the explanatory material in CD and the operation manual for details.

(4) Calculation case and parameter

The four calculation cases of hydrograph are 25 years, 50 years, 100 years, and 200 years. All other conditions, such as topographic model and inflow point, are the same.

The inflow point was used as the channel of a mountain slope just before flowing into the flat ground. The inflow hydrographs are as in Table 8-14 and Figure 8-52. The sea level is set at 0.0m, and it is assumed that the water level is stable.

Table 8-14 Discharge for Every Return Period

return period / hour	25	50	100	200
1	152.0	167.2	182.1	197.0
2	152.0	167.2	182.1	197.0
3	152.0	167.2	182.1	197.0
4	454.4	499.7	544.4	588.7
5	454.4	499.7	544.4	588.7
6	454.4	499.7	544.4	588.7
7	297.0	326.7	355.9	384.9
8	297.0	326.7	355.9	384.9
9	297.0	326.7	355.9	384.9
10	27.9	30.7	33.5	36.2
11	27.9	30.7	33.5	36.2
12	27.9	30.7	33.5	36.2
13	4.9	5.4	5.9	6.4
14	4.9	5.4	5.9	6.4
15	4.9	5.4	5.9	6.4
16	3.3	3.6	3.9	4.3
17	3.3	3.6	3.9	4.3
18	3.3	3.6	3.9	4.3
19	1.6	1.8	2.0	2.1
20	1.6	1.8	2.0	2.1
21	1.6	1.8	2.0	2.1
22	188.2	206.9	225.5	243.8
23	188.2	206.9	225.5	243.8
24	188.2	206.9	225.5	243.8
amount	3387.9	3726.0	4059.6	4390.2

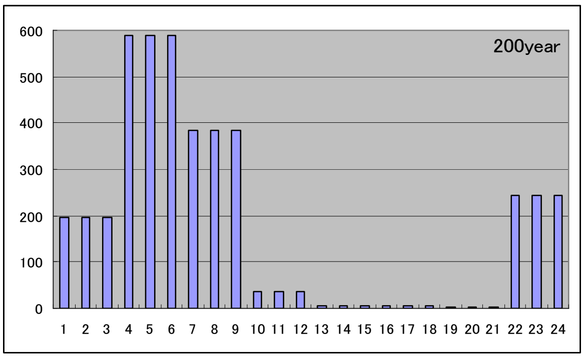

Figure 8-52 Hydrograph in Return Period 200 Years

The calculation conditions are described below. Details are included in the operation manual.

Topographic Model

- origin point : lower left corner (x-axis : west to east, y-axis : south to north)
- coordinates of origin point : x=552000, y=1301500 (coordinates system : WGS-1984,UTM zone16N)
- mesh size : x=25m, y=25m
- number of meshes : x=150, y=200, non-study area=3314meshes

Calculation condition

- coordinates of calculation starting mesh : x=171, y=119
- initial flow direction : to south
- calculation time interval : 0.25sec
- number of discharge values : 25
- continuance of each discharge : 3600sec (1hr)

(5) Results of Calculation

The results of the calculation showed that even a heavy rain in recurrence-interval 200 did not overflow largely. The flood flow was restricted around the channel. This was because the topography of the Maravilla river has a deep trough landform.

As for these calculation results, per-hour changes in depth of water, flow direction, flow velocity, and others were outputted to a file. The maximum depths of water were taken into GIS, and they were expressed onto ortho-photographs etc. For smooth operation of each work process, a tool (program), which operates on GIS, was developed and provided to the counterpart. The result, which used as the maximum depth of water, was shown in Figure 8-56. From Figure 8-53 to Figure 8-56 show the results with the maximum depths among the results of every return period. A slide show was created to show hourly changes of the calculation results using Microsoft PowerPoint. The changes of flood ranges over time were presented intelligibly. The presentation material was used in seminar presentations and in other occasions.

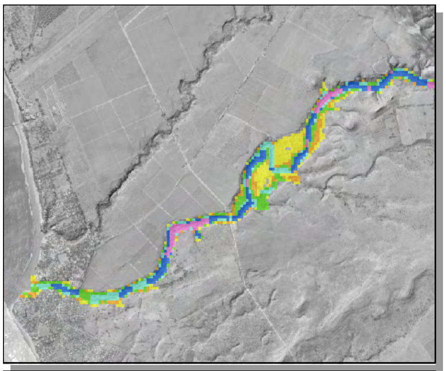

Figure 8-53 Return Period 25 Years

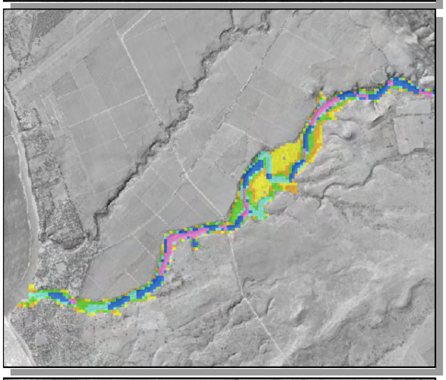

Figure 8-54 Return Period 50 Years

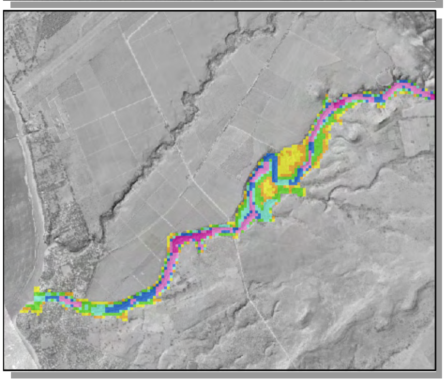

Figure 8-55 Return Period 100 Years