Supporting Report (C)

Natural Condition and
Landsliding Management Plan

PREPARATORY SURVEY
FOR
THE PROJECT ON DISASTER PREVENTION
AND
MITIGATION MEASURES FOR THE ITAJAI RIVER BASIN

FINAL REPORT

VOLUME III : SUPPORTING REPORT
ANNEX C : NATURAL CONDITION AND LANDSLIDE MANAGEMENT

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CHAPTER 1 INTRODUCTION

1.1 Coverage

The annex C describes the landslide/sediment discharge/flash flood management, and surface and subsurface condition of the Itajai River basin, which is related to water induced disasters. Water induced disaster includes flood, flash flood, landslide, and sediment discharge. The results of engineering geologic surveys are also described in this Annex C.

1.2 Constitution

1.2.1 General

The annex C is subdivided into 3 chapter groups of introduction, master plan, and feasibility study. Contents of each chapter are described as follows.

1.2.2 Introduction

‘Chapter 1 Introduction’ describes the coverage and composition of this Annex C.

1.2.3 Master Plan

‘Chapter 2 Regional Topography, Geology, Pedology, and Vegetation’ describe the surface and subsurface characters of the Itajai River basin.

‘Chapter 3 Status of Landslide and Sediment Discharge’ describes the status and restoration works of landslide, characteristics of landslide on each municipality, sediment balance evaluation, and risk assessment of landslide and sediment discharge.

‘Chapter 4 Needs and Basic Policy for Formulation of Master Plan for Landslide/Sediment Discharge/Flash Flood Management’ describes the approach, needs assessment results, and basic policy for the disaster management.

‘Chapter 5 Master Plan for Landslide/Sediment Discharge/Flashflood Management’ describes the non-structural measures of captioned disasters, structural measures for landside/sediment discharge and selection of structural measures for feasibility study.

1.2.4 Feasibility Study

‘Chapter 6 Engineering Geology on Selected Structural Measure Sites’ describes engineering geology of proposed structural measures sites.

‘Chapter 7 Feasibility Study of Structural Measure for Landslide/Sediment Discharge’ describes landslide type and selection of type of measure, criteria applied for the feasibility design, structural measures planning of 13 high priority slopes.

‘Chapter 8 Cost Estimate, Benefit Estimate, Cost Reduction Measures, Economic Evaluation of Master Plan for Landslide/Sediment Discharge/Flash Flood management’ describes cost estimate and economical feasibility assessment for the structural measures, and cost estimate for early warning system for landslide/flash flood.

‘Chapter 9 Implementation Plan of Master Plan for Landslide/Sediment Discharge/Flash flood’ describes implementation plan of structural measure for landslide/sediment discharge, and cost estimate for early warning system for landslide/sediment discharge.

‘Chapter 10 Conclusion and Recommendations’ describes them for landslide/sediment discharge/flash flood management.

CHAPTER 2 REGIONAL TOPOGRAPHY, GEOLOGY, AND VEGETATION

2.1 Topography

Figure 2.1.1 shows the location map of rivers, mountains and roads in the Itajai River basin, while Figure 2.1.2 shows the classification map of elevations.

The Itajai River Basin is surrounded by mountains with elevations varying from 200 to 1,750mm, except on the Atlantic Ocean side. The northeast boundary of the Itajai River basin is formed by the Jaragua Mountain Range, which is the watershed divide of the Luis Alves and the Benedito River sub-basins, with the highest point at an elevation of 986 m, located at the riverhead of the Benedito River, at the north end of Rio dos Cedros Municipality. The east-southeast boundary of the Itajai River basin is formed by the Geral Mountain Range, which is the watershed divide of Itajai do Norte, Itajai do Oeste and Itajai do Sul river sub-basins, with the highest point at an elevation of 1,752 m, at the southern end of Alfredo Wagner Municipality, at the riverheads of Itajai do Sul river. The southwest boundary of Itajai River basin is Tijucas Mountain Range, and the right bank of Itajai Mirim River.

On the right bank of Norte River and on the left bank of Timbo River, there is the Mar Mountain Range, with elevations above 800 m, in the northwest-southeast direction. The Mar Mountain Range is cut by Itajai-Acu river valley in the Apiuna Municipality perpendicularly. On the right bank side of Itajai-acu River, the Mar Mountain Range is apparently deviated in the upstream (southwest) direction at approximately the 15 km point. The Mar Mountain Range, on the right bank of the Itajai-acu River and the Itajai do Sul River, stretches out in the northwest-southeast direction, from Rio do Sul to Alfredo Wagner Municipality.

Between Itajai-Acu River and Itajai Mirim River, there is the Itajai Mountain Range, with elevations of more than 800 m, diverging perpendicularly from Mar Mountain Range in Lontras Municipality, stretching out at the south areas of Apiuna, Indaial, Blumenau and Gaspar Municipalities, in a northeast -southwest direction.

In the Ibirama Municipality, the Itajai-Acu River flows down, and its elevation is from 100 to 200 m and it meets with the Itajai Do Norte River. In Indaial Municipality it flows down to below 100 m elevation. Downstream from Blumenau Municipality, it meanders with an extremely gentle gradient flow across a flat alluvial plain, and flows into the Atlantic Ocean. From the Itajai-Acu River mouth in Itajai and Navegantes Municipalities until Ilhota and Gaspar Municipalities, the alluvial lowland spreads out from both banks. Along the Itajai Mirim River, alluvial lowland also spreads out from Itajai Municipality until Brusque and Guabiruba Municipalities. The width of this lowland is approximately 5 km in Gaspar Municipality, and approximately 3 km on the border between Itajai and Brusque Municipalities.

The prominent directions of valleys and mountain ranges are northwest-southeast (the direction of Itajai do Norte, Itajai do Oeste and Itajai do Sul Rivers), and northeast - southwest (the direction of Itajai-Acu River between Rio do Sul and Blumenau Municipalities, and of Itajai Mirim River between Presidente Nereu and Itajai Municipalities). The geological structures are in harmony with the prominent direction of surrounding valleys and mountain ranges. The northwest-southeast direction match the direction of the sedimentary rock distribution, and the northeast-southwest direction match the direction of faults and intrusive rocks.

Table 2.1.1 shows the area rate of altitude ranges in the whole Itajai river basin and in sub river basins.

Table 2.1.1 Area Rate of Altitude Ranges

Altitude range	Area rate of a elevation range (Area of a altitude range/basin area)							
	Whole Itajai River basin	Sub-Basin						
		Itajai do Norte	Itajai do Oeste	Itajaí do Sul	Benedito	Itajai-Acu	Itajai Mirim	Luis Alves
	15,111km^2	3,354km^2	3,015km^2	2,027km^2	1,496km^2	2,777km^2	1,679km^2	580km^2
Below 100m	11%	0%	0%	0%	8%	26%	26%	35%
100 to 500m	36%	23%	36%	19%	17%	50%	39%	63%
500 to 1000m	53%	77%	61%	75%	74%	24%	35%	2%
Above 1000m	1%	0%	4%	6%	1%	0%	0%	0%
Total	100%	100%	100%	100%	100%	100%	100%	100%

Source: JICA Survey Team

In whole Itajai River basin, area rate of altitude range below 100 m is approximately 11%; the range 500 m to 1000 m is predominately 53%; and the range above 1000 m does not reach 1%.

Figure 2.2.3 shows the surface gradient range distribution maps of Itajai River basin. Flat surfaces from 0 to 9 degrees are largely distributed throughout the Itajai River mouth area, and intermittently distributed on both banks of the river in the middle part. In general, hillsides have gentle gradients of 15 to 25 degrees. At the outlet of streams, there are small alluvial fans of 5 to 10 degrees gradient. Gradients with more than 25 degrees are distributed at the sides of streams, and just below part of the gentle mountain top slopes.

Table 2.1.2 shows the area rate per ground surface gradient range in the whole Itajai river basin and in sub-basins.

Table 2.1.2 Area Rate of Ground Surface Gradient Range

Ground surface gradient range (degrees)	Area rate of ground surface gradient range (Area of a ground surface gradient range/basin area)							
	Whole Itajai River Basin	Sub-basins						
		Itajai do Norte	Itajai do Oeste	Itajai do Sul	Benedito	Itajai-Acu	Itajai Mirim	Luis Alves
	15,111km^2	3,354km^2	3,015km^2	2,027km^2	1,496km^2	2,777km^2	1,679km^2	580km^2
0 to 5	24.4%	19.8%	30.3%	23.2%	25.6%	24.0%	20.6%	20.6%
5 to 10	30.5%	35.3%	33.5%	35.7%	30.4%	23.8%	23.0%	25.3%
10 to 15	20.3%	21.7%	17.5%	19.7%	19.3%	21.8%	20.5%	27.1%
15 to 20	13.0%	11.6%	9.8%	11.0%	12.8%	16.5%	17.4%	17.2%
20 to 25	7.1%	6.1%	5.2%	5.8%	7.6%	8.8%	11.4%	7.3%
25 to 30	3.2%	3.4%	2.4%	2.6%	3.2%	3.4%	5.1%	1.9%
30 to 35	1.2%	1.4%	1.0%	1.1%	0.9%	1.2%	1.6%	0.4%
35 to 40	0.4%	0.5%	0.4%	0.5%	0.2%	0.3%	0.3%	0.1%
40 to 45	0.1%	0.1%	0.1%	0.2%	0.0%	0.1%	0.0%	0.0%
40 to 50	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%
Above 50	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Total	100.0%	100.0%	100. 0%	100.0%	100.0%	100.0%	100.0%	100.0%

Source: JICA Survey Team

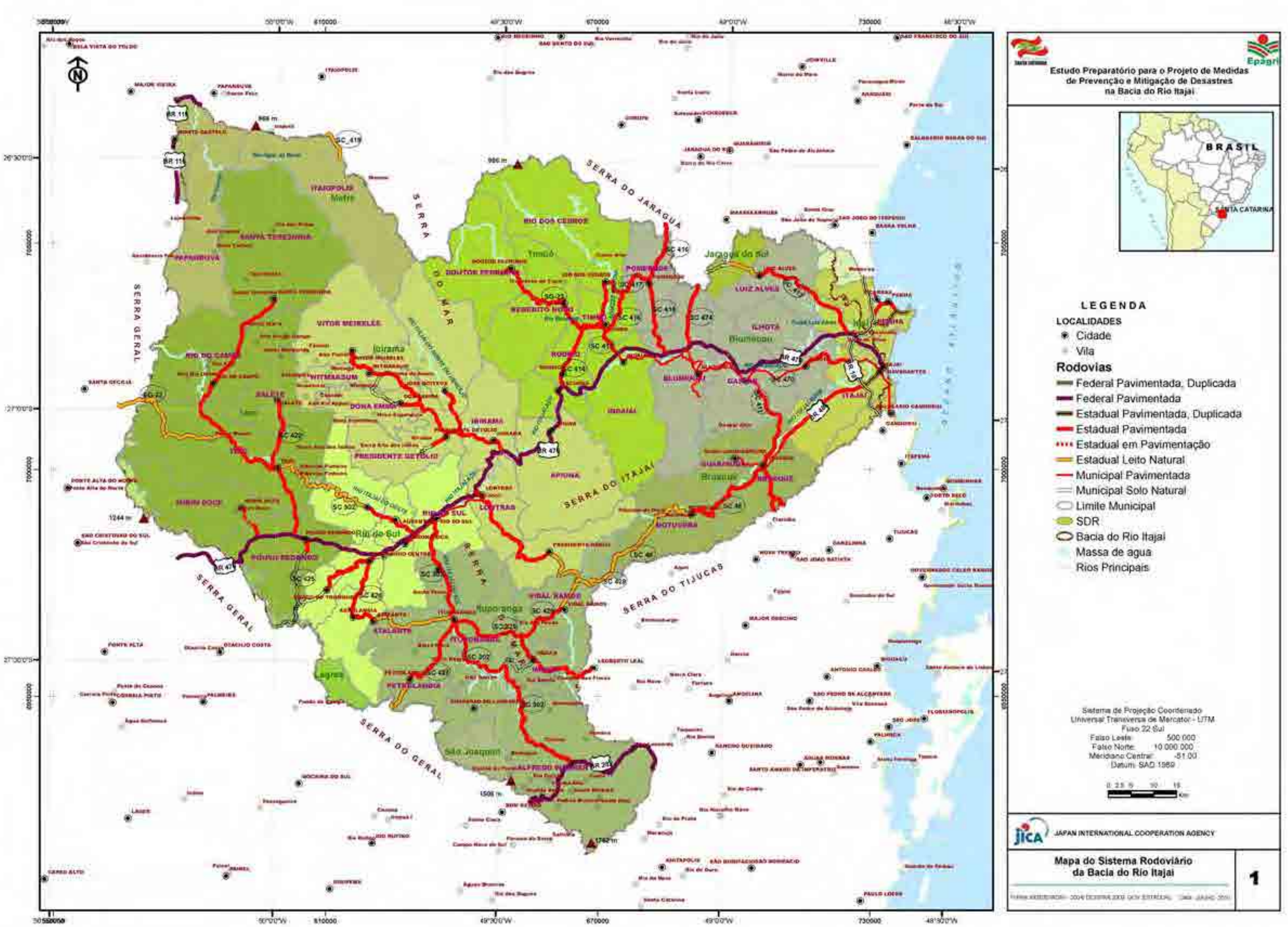


Figure 2.1.1 Location Map of Rivers, Mountain Ranges and Roads in Itajai River Basin

Source: Material edited by JICA Survey Team based on 2009 DEINFRA, MAPA RODOVIÀRIO DO ESTADO DE SANTA CATARINA

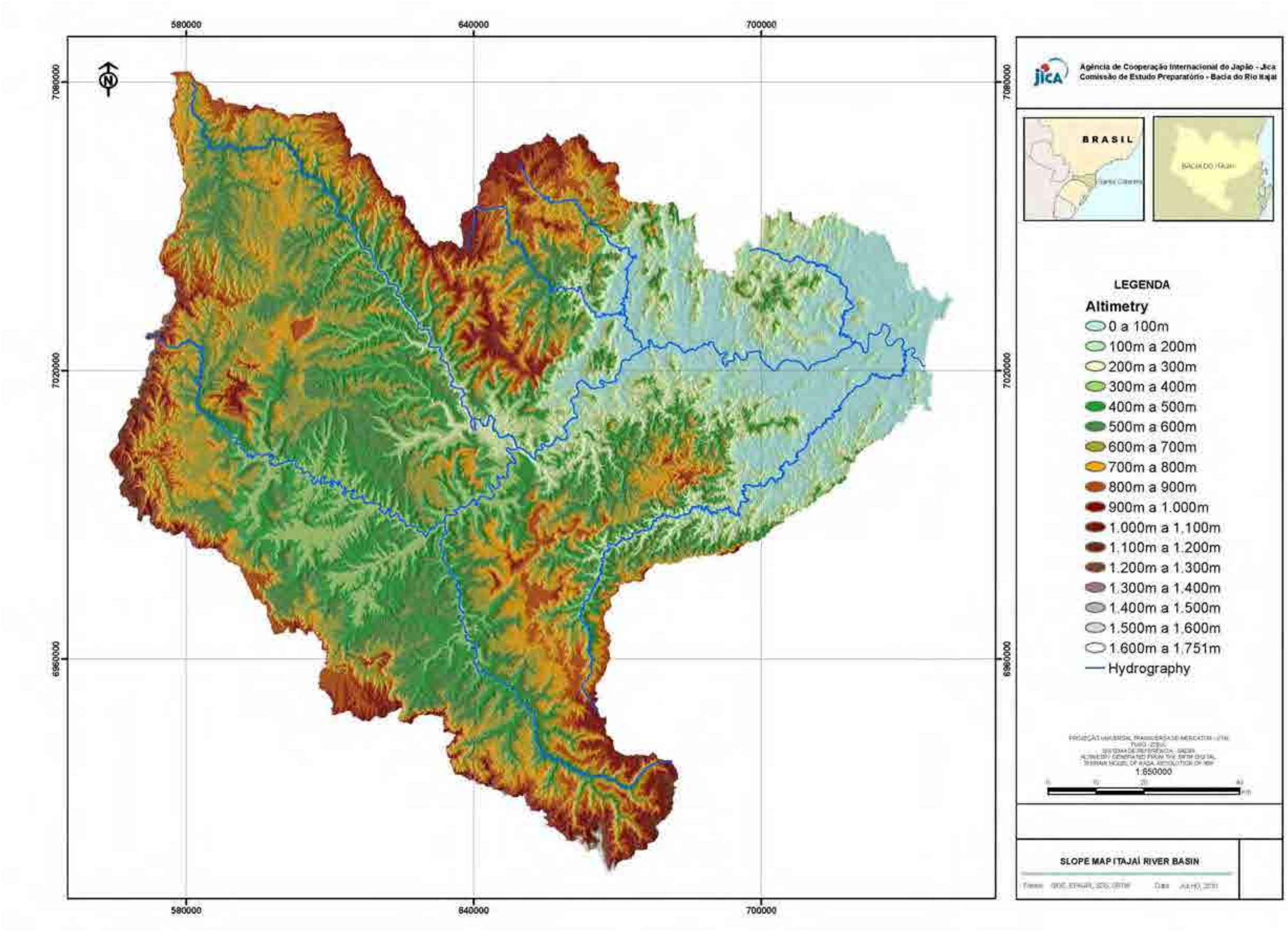


Figure 2.１.2 Map of Elevation Ranges of Itajai River Basin

Source: IBGE,EPAGRI,SDS,SRTM

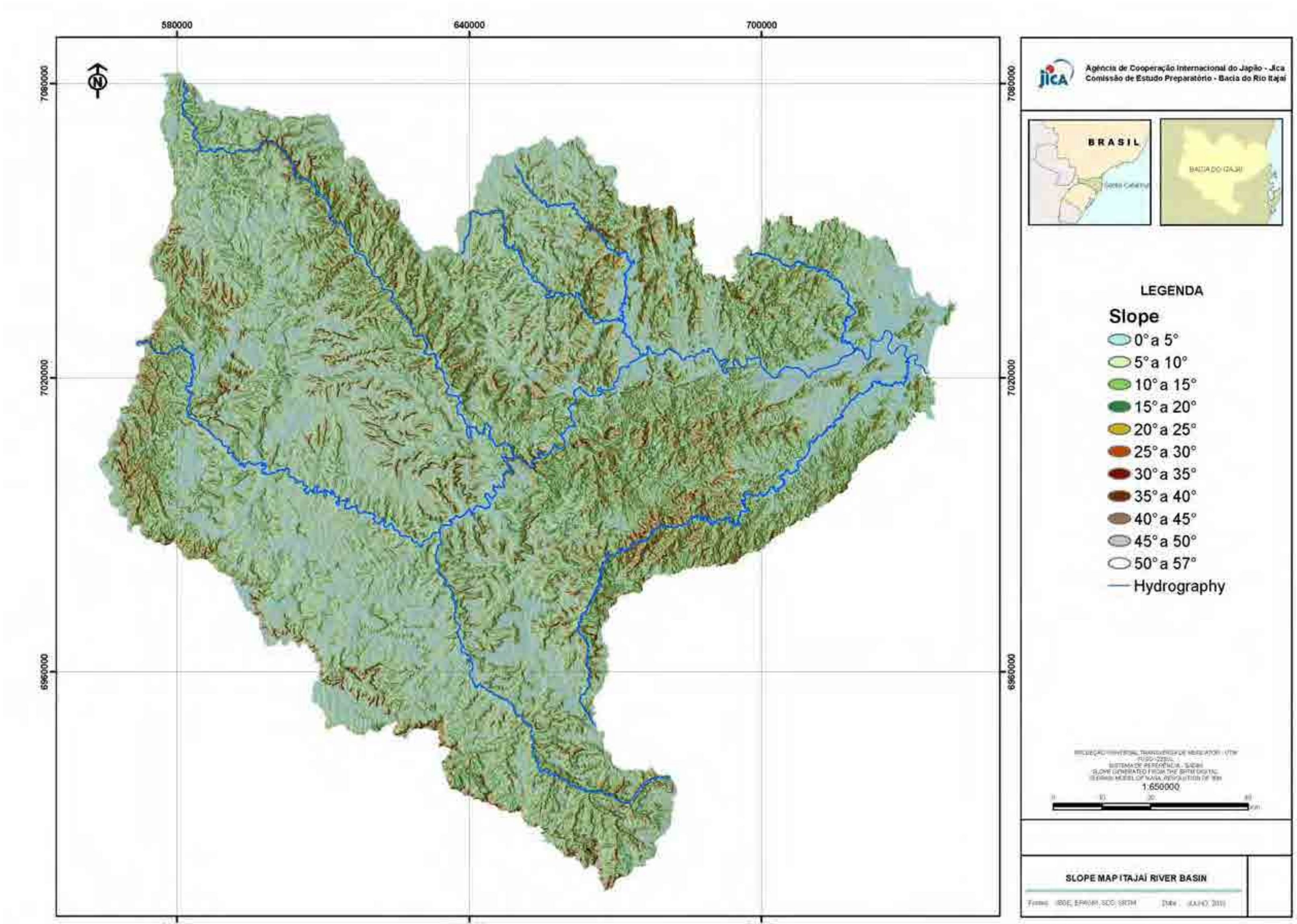


Figure 2. 1 **.3 Map of Gradient Ranges of the Itajai River Basin** Source: IBGE, EPAGRI, SDS, SRTM

Flatland with gradient of up to 5 degrees is in 24% of whole basin's total area, and ground with flat and gentle gradient of up to 10 degrees of 55% in it. On the other hand, areas with 40 degrees or more gradient specified APP (permanent protection area) do not exceed 0.1% of the whole basin's total area.

The trend of the ground surface gradient is generally the same in all sub-basins, but the percentages of flatland of 0 to 5 degrees of gradient are divided in the following three groups:

The percentage of flatland of 0 to 50 degrees of surface ground gradient is:

Quite big, 30%	Itajai do Oeste
Medium, from 23 to 26%	Itajai do Sul, Benedito, Itajai-Acu
Small, from 20 to 21%	Itajai do Norte, Itajai Mirim, Luis Alves

It influences the above situation that the Itajai do Oeste Basin is mainly composed of soft rock, relatively new and subject to erosion, which produce lots of sediment, causing large amounts of accumulation of sediments along the rivers, and the fact that Itajai Mirim and Luis Alves basins are composed of old and hard soil, little subject to erosion, which, produce relatively little sediment.

2.2 Geology

2.2.1 General

The geological map of Itajai River Basin and surrounding areas are presented in Figure 2.2.2, and the geological structure legend is presented in Figure 2.2.1. The corresponding stratigraphy is also presented in Table 2.2.1.

Itajai River basin is located at the east end of the so-called Parana sedimentary basin, which stretches out from Brazilian Mid-South to the northeast of Argentine, passing through the east region of Paraguay (the central portion is young geology , and as they stretch out to the periphery, geology become older) .

The geology of Itajai River Basin has the base from Archean to Proterozoic eons, which compose the stable continent of South-America, and above it, there are sedimentary rocks from the Paleozoic and Mesozoic eras, and in the upper layer, there are basaltic rocks run off in the Mesozoic era. Except for the alluvial portion that stretches out in the lowland of the Atlantic coast and the lowland of the banks of rivers, in general, the geology are old in the northeast region and young in the southwest region. In the upstream areas of the basin, there are rocks from the Paleozoic to Mesozoic eras. In the middle and lower portions, there are sedimentary rocks in the Paleozoic era, and metamorphic rocks from the Archean to Proterozoic eons. The distribution of geology in the basin of each tributary is shown in Table 2.2.2.

The fault system that stands out at the east side of Serra do Mar (downstream Itajai River) is the Northeast - Southwest system, at the maximum length of 60 km, which as good continuity. We also observe the North-Northeast - South - Southwest fault systems, with lengths of up to 20 km. At the west side of Mar Mountain Range (downstream Itajai River), the fault systems are relatively sparsely distributed. In addition to the Northeast -Southwest system, we also observe the North - Northwest South - Southeast system that continuously stretches out for 80 km along Itajai do Norte River, and for 40 km along Itajai do Sul River.

The geology of Itajai River basin is divided into four chronological orders from the most recent one:

1) Alluvial deposit in the Cenozoic era. It is largely distributed in the downstream

portion of the Itajai-Acu, Itajai Mirim and Luis Alves River basins, with depth lower than 30 m, and in the narrower areas along the upstream of Itajai-Acu river and other tributaries, with depth of up to 10 m.

2) Sedimentary and volcanic rocks in the Mesozoic era. These are distributed throughout the General Mountain Range, the eastern margin of Itajai River basin.

3) Sedimentary and volcanic rocks of the Paleozoic era. These are distributed at from the Mar Mountain Range which transverse the center of the Itajai River basin until eastern foot area of Geral Mountain Range.

4) Granulite, migmatite, metamorphic volcanic rocks, sedimentary rocks, intrusive rocks, and plutonic rocks of from Archean to Proterozoic eons. These are distributed in the eastern foot area of Mar Mountain Range (downstream area of the Itajai river basin).

2.2.2 Sub-river Basins of the Three Upstream Tributaries of Itajai-Acu River (Itajai do Norte, Itajai do Oeste, Itajai do Sul)

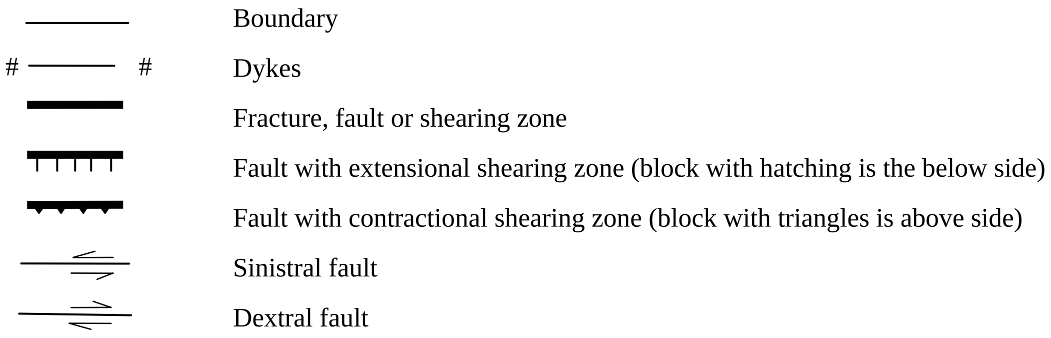
The geology of the three upstream tributaries of Itajai-Acu River in the west than Mar Mountain Range, sedimentary rocks from the Paleozoic to Mesozoic eras stand out (Itarare formation, Guata formation and Passa Dois formation).

In the lower elevation portions, there are sedimentary rocks from the Paleozoic and Mesozoic eras, mainly shale. These rocks are mainly constituted of marine sediment rocks, and are interstratified with fine sandstone.

In the portions with high elevations of General Mountain Range, which is the watershed of Itajai River basin, there are sedimentary rocks in the Mesozoic era. These are mudstone, sandstone, and are interstratified with siltstone and fine sandstone. They are characterized by the reducing environment of purple, pink and white color.

In the Itajai do Oeste River basin, there are basalts in the Mesozoic era.

The alluvial deposit is punctually distributed in the micro-basin along the Itajai-Acu River, between Rio do Sul and Lontras, and in Itajai do Oeste River and its tributaries. These alluvial deposits are generally composed of silty sand or sandy silt, and are interstratified by gravel layers. The alluvial deposits thicknesses are thought of be generally smaller than 10 m.



Source: Edited by JICA Study Team from CPRM Serviço Geológico do Brasil

Figure 2.2.1 Legend for the Geological Structure

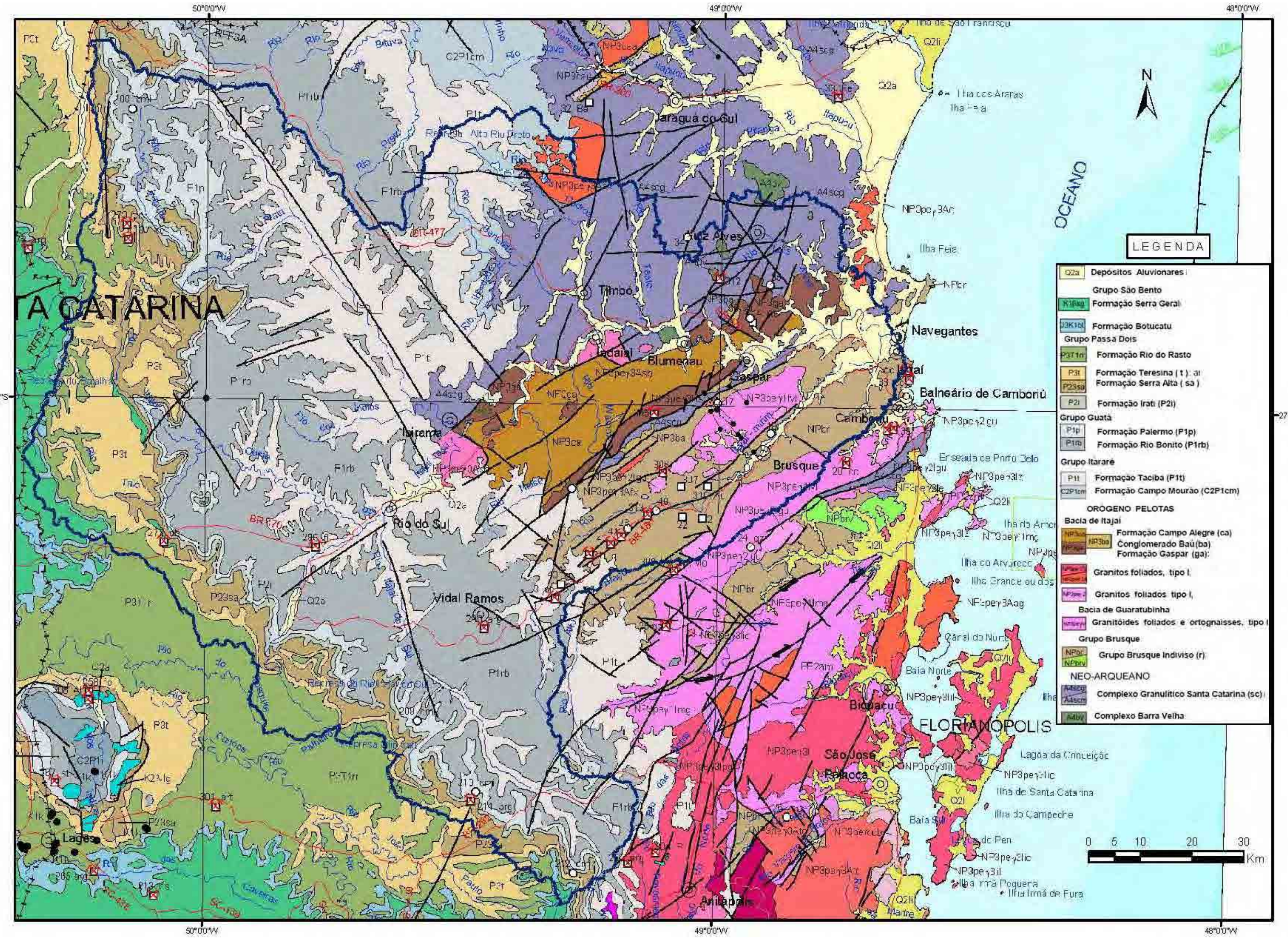


Figure 2.2.2 Geological Map of Itajai River Basin and Surroundings Source: CPRM -Serviço Geológico do Brasil

2.2.3 Sub-river Basins of Geology of the basins of Itajai-Acu, Benedito, Itajai Mirim, and Luis Alves

The geology distributed in this region, which is to the east of Mar Mountain Range, are described below in order from the old one as follows:

The Santa Catarina granulite complex of the Archean era (metamorphic rocks mainly composed of granulite) at the East side of Mar Mountain Range, at the North side of the Itajai-Acu river, which includes Benedito River basin and Luis Alves River basin.

The complex of Metamorphic rocks of the Brusque Group of the Proterozoic eon, and granite/orthogneiss with schistosity developed are distributed in the south of the Itajai-Acu River and the downstream from the Gaspar Municipality, in other words in the Itajai Mountain Range and the Itajai Mirim basin.

Non-metamorphic sedimentary rocks (Gaspar formation, Bau formation, Campo Alegre formation) in the Proterozoic eon are distributed from the north region of Itajai Mountain Range, and from Blumenau Municipality until the Luis Alves River basin.

Sedimentary rocks of Itarare strata group, and strata from the Paleozoic era and from Carboniferous to Permian period are found at the eastern side of Serra do Mar in Benedito river basin.

Alluvial sediments, to the east of Serra do Mar, are found along the main river and tributaries. The width of the alluvial layer distribution increases near Gaspar, in the main river, and near the meeting point of Luis Alves and Itajaí Mirim rivers, on the downstream side. Alluvial sediments are mainly composed of sandy silt or silty sand, intermingled with gravel layers. The thickness of sediments is generally close to 10 m. According to the location, basal rock outcrop is found in the river beds. River bed sediments are middle sized particle sand, containing rough particles. According to the results of foundation survey carried out by highway contractors, there is thick clay sedimentation containing organic matter in some portions.

Table 2.2.1 Geological Stratigraphy of Itajai River Basin

Era/ Eon	Period		10^6 years	Startigraphy		
Cenozoic	Quaternary	Holocen		Q2a	Alluvial Formation	Sand, quartz sand, gravel, silt, clay, locally peat
			0.01			
			1.75			
Mesozoic	Cretaceous			Sao Bento Group		
				K1βsg	Serra Geral Formation	Basalt, andesite, tholeiite; rhyolite and rhyodacite; intercalate layers of limestone and sandstone 135-129 Ma Ar-Ar
			135			
	Jurassic			J3klbt	Botucatu Formation	Fine to coarse reddish sandstone, well-rounded grains, stratified and / or cross-stratified, continental desert environment: eolian dune deposits
			203			
	Triassic			Passa Dois Group		
				P3T1rr	Rio do Rasto Formation	Mudstone and sandstone layers dominated by tabular or lenticular stretched, green or reddish siltstone, tabular, thin sandstone, purple, pink to white, tabular or lenticular; reducing environment, deltaic, lacustrine, wind and rare fluvial deposits.
			250			

Paleozoic	Permian		P3t	Teresina Formation	Mudstone, siltstone and sandstone, very fine, dark gray to greenish, tabular or lenticular geometry elongated lenses and limestone concretions; marine storms with the transitional (depths)
			P2i	Irati Formation	Shale, dark gray mudstone and siltstone; limestone, marl and bituminous shale with fossils of reptiles. Marine environment.
			Guata Group		
			P1p	Palermo Formation	Siltstone, sandy siltstone, sandstone, and shale, lenses of coarse sandstone and conglomerate with pebbles; gray to gray-green, yellowish when altered, shallow marine
			P1rb	Rio Bonito Formation	Arkose, siltstone and gray to dark gray carbonaceous, quartz-white sandstone, carbonaceous shale dark gray to black, charcoal, diamictite matrix carbons and marl; fluvial-deltaic environments, marine and coastal shelf.
			P23sa	Serra Alta Formation	Shale, siltstone and dark gray mudstone layers in tabular; marine environment at depths below the wave action
			ltarare Group		
			P1t	Taciba Formation	Sandstone, shale and cross lamination shale and sandstone; spores occur continental flora, marine and fluvial-deltaic glacial influence.
		295			
	Carboniferous		C2P1cm	Campo Mourao Formation	Fine to conglomeratic sandstone, shale and siltstone; occur spores ; continental environment braided fluvial to marine transgressive
Proterozoic		355			
	Neo-Proterozoic III	543	NP3ca	Campo Alegre Formation	Arkose, shale, siltstone and tuffite with mafic to intermediate volcanic
			NP3ba	Conglomerate Bau	Conglomerate and arkose
			NP3ga	Gaspar Formation	Polymict conglomerate, arkose and pelitic
			NP3peγ3	Granites	600-580 Ma U-Pb
			NP3peγ2	Granites	628 Ma U-Pb
			NP3peγ1	Granites and Orthogneiss	650-610 Ma U-Pb
			Grupo Brusque		
			NPbr	Brusque Group Undivided	Sericite schist and chloro-sericite schist with intercalations of quartzite; biotite-muscovite schist, quartz-mica schist and garnet-mica schist; metapelites, quartzite, mica schist with thin intercalations of metavolcanic calc-silicate acid; metamarls lenses, and metadolomite.
		650	NPbrv	Volcanic Unit	Interbedded mafic, tourmalinite and iron formation in quartzite, mica shale.
		2500			
Archean			A4scg	Santa Catarina Granulite Complex	granulitic orthogneiss with gneisses diorite, monzodiorite, monzonite, and syenite. granulitic pyroxenite, foliated granite, biotite-(hornblende) granodiorite orthogneiss and migmatite
			A4bV	Barra Velha Complex	metapyroxinite and metagabbro
		2800			

Arkose sandstone: 75% to 95% of quartz, particles of feldspar>fragments of rocks

Tuffite: Aquatic sedimentary rock in layers mainly composed of pyroclastic materials.

Calc-alkaline: Rich in calcium and poor in alkaline.

Rhythmite: Sediments in which thin layers of rough particle strata composed of fine sand and silt and fine particle strata composed of clay are cyclically repeated.

Granulite: Rock formed by the re-crystallization of big crystals in an agglomerate of small particles. It can appear as the result of rock fracturing during the re-crystallization action sequence.

Migmatite: Generic denomination of rock in which metamorphic rock and plutonic rock seem to be mixed looking with unaided eye. In general, these are rock in which the portions composed of crystalline schist or gneissic rocks (dark portions) and portions composed of granitic rocks (clear portions) are heterogeneously mixed.

Source: Edited by JICA Survey Team from CPRM: Serviço Geológico do Brasil

2.2.4 Geological Characteristics of Sub-river Basins

Table 2.2.2 shows the ratio of occupied areas per stratum in the sub river basins.

In the Itajai do Norte River basin, the sedimentary rocks of Mesozoic and Paleozoic eras represent 97% of the total. Guata Formation, of the relatively median sedimentation period, and the Itarare Formation, of an older period, are dominant.

In the Itajai do Oeste River basin, the sedimentary rocks of Mesozoic and Paleozoic eras represent 97% of the total. Compared with the river basins of Itajai do Norte and Itajai do Sul, this is the biggest ratio of relatively new sedimentary rocks, of the Mesozoic era, subject to erosion by weathering, and thus the sediment yield is also relatively big, also with a relatively big distribution of alluvial layer formed by the sedimentation. In some cases, crack rich volcanic rocks such as Basalt on the aquiclude soft sedimentary rocks, sometimes to be geological conditions of primary cause of landslide.

In the Itajai do Sul River basin, the sedimentary rocks of Mesozoic and Paleozoic eras represent approximate 100% of the total. It is predominantly distributed that the Guata Formation in the middle age from Mesozoic to Paleozoic eras.

In the Benedito River basin, the sedimentary rocks from Mesozoic to Paleozoic eras represent 61% of the total; older sedimentary rocks of Proterozoic eon represent 6%, and the oldest metamorphic rocks of the Archean era represent 30%.

In the Itajai-Acu River basin, the ratio of alluvial deposit is 13%, the biggest among the seven basins. The sedimentary rocks from Mesozoic and Paleozoic eras represent 18% of the total; the sedimentary rocks from Proterozoic era represent 31%, and the metamorphic rocks of the Achaean eon, the oldest one, 24%.

In the Itajai Mirim River basin, the sedimentary rocks from Mesozoic and Paleozoic eras represent 29% of the total; the metamorphic sedimentary rocks (Brusque Group) of the Proterozoic eon represent 47%.

In the Luis Alves river basin, the sedimentary rocks from the Mesozoic and Paleozoic eras represent 0%, and the metamorphic rock of the Archean eon is dominant with 73%.

Table 2.2.2 Area Ratio per Stratum

	Code and name of the stratum		Area ratio per stratum (area of stratum/ area of basin)							
			Whole Itajai River Basin	Sub-river basins						
				Itajai do Norte	Itajai do Oeste	Itajai do Sul	Benedito	Itajai-acu	Itajai Mirim	Luis Alves
			15,111 km^2	3,354 km^2	3,015 km^2	2,027 Km^2	1,496 km^2	2,777km^2	1,679 km^2	580 km^2
Cenozoic era										
	Q2o Alluvial Deposit		**4.2%**	**0.1%**	**0.8%**	**0.0%**	**3.4%**	**12.8%**	**7.3%**	**9,8%**
Mesozoic era	Sao Bento strata Group	K1βsg General Mountain Range Formation (volcanic rocks)	**0.4%**	**0.0%**	**1.9%**	**0.1%**	**0.0%**	**0.0%**	**0,0%**	**0.0%**
		J3klbt: Botucatu Formation (sedimentary rocks)	0.3%	0.0%	1.4%	0.5%	0.0%	0.0%	0,0%	0.0%
Paleozoic era	P3T1rr/P3t/P2i: Passa Dois Group (sedimentary rocks)		10.4%	7.7%	36.7%	9.9%	0.0%	0.0%	0.0%	0,0%
	P1p/P1rb/P23sa: Gosta Group (sedimentary rocks)		34.5%	51.6%	49.3%	74.2%	5.7%	4.5%	15.4%	0,0%
	P1t/C2P1cm: Itarare Group: (sedimentary rocks)		21.9%	37.8%	9.9%	15.4%	55.4%	13.0%	13.2%	0,0%
	Subtotal of sedimentary rocks from the Mesozoic and Paleozoic eras		**67.1%**	**97.0%**	**97.3%**	**99.9%**	**61.0%**	**17.5%**	**28.5%**	**0.0%**
Proterozoic eon	Np3ca: Campo Alegre Formations Np3ba: Bau Conglomerate Np3ga: Gaspar Formations (sedimentary rocks)		**7.2%**	**0.2%**	**0.0%**	**0.0%**	**6.0%**	**30.6%**	**0.0%**	**17,2%**
	Np3peγ1/ Np3peγ2/ Np3peγ3 Schist, granite, and orthogneiss		**3.8%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**9.7%**	**17.2%**	**0,0%**
	Brusque Group	NPbr: Metamorphic sedimentary rocks	**6.4%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**5.7%**	**47,0%**	**0.0%**
		NPbrv: volcanic rocks	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**	**0.0%**
Archean eon	A4scg: Santa Catarina granulite complex A4bV: Barra Velha complex (metamorphic rocks)		**10.9%**	**2.7%**	**0.0%**	**0.0%**	**29.6%**	**23.6%**	**0.0%**	**73.0%**
General			**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**

Source: Edited by JICA Study Team from based on information from CPRM Serviço Geológico do Brasil

2.3 Pedology

Figure 2.3.1 shows the map of soil classification of Itajai River basin. Table 2.3.1 presents a comparison between the soil classification of this map and the soil classification of institutions from the UN, USA and Japan.

Table 2.3.2 presents the Ratio of occupied area in the whole Itajaí River basin and the soil classification in each tributary basin. The characteristics of soil distribution in Itajaí River basin and in the basins of its tributaries are as follows:

The dominant soil type in Itajai River Basin is the Ordinary cambisols, occupying 43% of the whole area and mainly distributed in the middle altitude of the hillside. The second dominant soil type is the Leptosols occupying 26% of the total area, mainly found in the peak and in the watershed of the Itajai-acu River and tributaries. The third dominant is the Red-Yellow Acrisols, occupying 20% of the whole area, distributed from the hillside with elevation below 500 m until the banks of the Itajai-Acu River and tributaries.

(1) Itajai do Norte River basin has the same trend in the whole basin.

(2) In Itajai do Oeste River basin, the distribution ratio of Ordinary cambisols is quite big, occupying 56% of the whole area, and the distribution ratio of Red-Yellow Acrisols is small, occupying 6% of the whole area.

(3) In Itajai do Sul River Basin, the distribution ratio of Ordinary cambisols is the biggest one among the tributaries basins, occupying 61% of the whole area.

(4) In Benedito River Basin, the distribution ratio of Ordinary cambisols is quite big, occupying 56% of the whole area, and the distribution ratio of Leptosols is small in comparison with the other tributaries basins, only 2% of the whole area.

(5) In Itajai-Acu River basin, the distribution ratio of Leptosols is big, occupying 40% of the whole area, and this is the most dominant type of soil in the basin. The second place is occupied by the Red-Yellow Acrisols, occupying 24% of the whole area, and the third place is of the Ordinary cambisols, occupying 18% of the whole area.

(6) In Itajai Mirim River basin, the distribution of Leptosols is big, occupying 39% of the whole area, the most outstanding type of soil in the basin, showing the same trend of Itajai-Acu River basin.

(7) In Luis Alves River basin, the Red-yellow acrisols is predominant, occupying 63% of the whole area.

The characteristics of each soil are the following:

A: Agua (Water)

Rivers, lakes and swamps.

U: Urbano (Urban Area)

Distributed throughout the beach and is mainly composed of quartz particles.

PVA: Aregisso Vermelho-Amarelo (Red-Yellow Acrisols)

It develops in subtropical and tropical zones. The decomposition of vegetal remains is fast, and the humus layer of the upper part is thin. On the other hand, there is the eluviation of basic minerals and silicic acid due to the intense chemical weathering, forming an eroded stratum rich in ferric oxide and aluminum oxide, with a slightly high crystallization degree. If the oxidation degree of this part is high, soil becomes red, and if it is low, it becomes yellow. It is characterized by forming a film of deposited clay, which initially dispersed in the infiltrated water and moves to the pores of the soil. The soil particles are fine and difficult to become deposited, when dispersed in water.

CX: Cambissolos Haplico (Ordinary Cambisols), CH: Cambissolos Humico (Humic Cambisols)

It has a lack of clay, humus, soluble salts, iron and aluminum oxide. It develops a structure of fine fibrous soil structure. Since it contains soil structure of moderate porosity and in rich for efflorescence minerals, this soil is appropriate for agriculture. It is developed in temperate forests and subarctic zone. CX: Ordinary Cambisols is brownish yellow in the normal estate. CH: Humic Cambisols is humic and has the brown color.

EK: Espodossolo Humiluvico (Podzols Humic-elubial horizon)

They are formed and distributed in the coniferous forest under subarctic climate. They are formed in the upper humus accumulation layers (due to the low temperature, the decomposition of plant residue is not progressive, and the soil water containing organic acid infiltrates downward), and in the lower white-gray color layer (the basic minerals are eluviated by the organic acid, iron and aluminum bound to organic and move downward, and remaining sandy layer of silicic acid rich). Below the white-grey layer, the red and yellow layer is formed (accumulation layer of iron, etc.).

GX: Gleissolo Haplico (Ordinary Greysols)

The Ordinary greysols is formed in a water immersion environment, and with the lack of oxygen, and reducing character greying condition. The grey horizon or grey macules are formed with color varying from grey blue to grey green, as the result of iron reduction under fresh water.

LB: Latossolos Bruno (Ferralsols)

Ferralsols is the reddish yellow soil with strong chemical weathering under hot and pluvial climate in tropical rainforests and subtropical monsoon forests zones, the basic minerals and silica acid are leached, and reddish enriched high crystallinity horizon of the iron oxides and aluminum. The soil is rich in tubercles of these oxides, composing a porous and granular structure. Plant residues rapidly decompose, and the humus horizon development is very poor. That is why plants almost cannot absorb nutrients from the soil, limited to absorb nutrients from plant residues such as fallen leaves. Once trees are cut, the soil becomes hard or erodes, and the recuperation of the forest is generally difficult. In the past, this soil was also called laterite, but typical laterite is the product of weathering in the tertiary period, which solidified and transformed into rock with the drying up process, and thus shall be treated in a different from Ferralsols.

RY: Neossolos Fluvicos (Fluvisols)

Sand, clay and silt distributed in river beds and in flat land along the rivers.

RL: Neossolos Litolicos (Leptosols)

It has the characteristic of not forming perpendicular soil zone. Its matrix is non-solidified sediments and rocks, and it is basically not weathered chemically or alternated.

RQ: Neossolos Quartarenicos (Quartz Sand Marine)

It is distributed throughout the beach and is mainly composed of quartz particles.

NX: Nitossolos Haplico (Hapic Nitisols)   NV: Nitossolos Vermelho (Red Nitisols)

Nitisols is the red tropical soil, and is deeply distributed, highly permeable (porosity 50-60%). We observe moderate to strong horn-rimmed blocking structure, and when distributed in the slope, it easily collapses. The weight rate of clay is over 30%, and rich in kaolinite and halloysite. It is rich in Fe_2O_3, above 4%. Due to such characteristics, it is productive in terms of agriculture when compared to other tropical soils.

Table 2.3.1 Comparison between the Classification of the Soil Map of Itajai River Basin and the Soil Classification of Various Institutions

Portuguese			English		
Soil classification		SiBCS: Brazilian System of Soil Classification 2006	Soil Type	FAO Soil Type	EUA1991 Soil Taxonomy
Type of soil	Code				
Água	A		Water		
Urbano	U		Urban Area		
Argissolo Vermelho-Amarelo	PVA	Argissolo	Red-Yellow Acrisols	Acrisols Lixisols Alisols	Ultisols Oxisols
Cambissolos Haplico	CX	Cambissolos	Ordinary Cambisols	Cambisols	Inceptisols
Cambissolos Humico	CH		Humic Cambisols		
Espodossolo Humiluvico	EK	Espodossolo	Podzols Humic-elubial horizon	Podzols	Spodosols
Gleissolo Haplico	GX	Gleisso	Ordinary Greysols	Greysols	Entisols
Latossolos Bruno	LB	Latossolos	Ferralsols	Ferralsols	Oxisols
Neossolos Fluvicos	RY	Neossolos Fluvicos	Fluvisols	Fluvisols	Fluvents
Neossolos Litólicos	RL	Neossolos Litólicos	Leptosols	Leptosols	
Neossolos Quartarênicos	RQ	Neossolos Quartarênicos	Quartz Sand Marine	Arenosols	Quartziosamments
Nitossolos Haplico	NX	Nitossolos	Hapic Nitisols	Nitisols Lixisols Alisols	Utisols Oxisols Altisols
Nitossolos Vermelho	NV		Red Nitisols		

Source: Edited by JICA Survey Team based on Embrapa 2006 Brazilian System of Soil Classification

Table 2.3.2 Area Ratio of Soil Type

Soil symbol or name		Rate of occupied area (area of soil type/area of basin)							
Brazilian denomination	Symbol	Whole Itajai River Basin	Sub-river basins						
			Itajai do Norte	Itajai do Oeste	Itajai do Sul	Benedito.	Itajai-Acu,	Itajai Mirim	Luis Alves
		15,111 km^2	3,354 km^2	3,015 km^2	2,027 km^2	1,496 km^2	2,777km^2	1,679 km^2	580 km^2
Agua	A	0.8%	0.8%	0.0%	1.0%	1.2%	1.4%	1.1%	0.2%
Urbano	U	0.4%	0.1%	0.2%	0.3%	0.3%	1.2%	0.2%	0.0%
Argissolo Vermelho-Amarelo	PVA	20.3%	20.1%	5.9%	17.1%	27.9%	24.2%	22.4%	63.0%
Cambissolos Haplico	CX	42.8%	47.3%	56.2%	60.9%	55.7%	17.7%	29.6%	8.9%
Cambissolos Humico	CH	2.6%	0.2%	3.8%	9.1%	5.4%	0.0%	0.0%	0.0%
Espodossolo Humiluvico	EK	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Gleissolo Haplico	GX	6.4%	0.1%	7.6%	0.0%	7.1%	14.6%	7.9%	14.2%
Latossolos Bruno	LB	0.1%	0.4%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Neossolos Fluvicos	RY	0.1%	0.0%	0.0%	0.0%	0.0%	0.3%	0.1%	0.0%
Neossolos Litolicos	RL	25.6%	27.6%	26.2%	11.7%	1.6%	40.3%	38.6%	13.7%
Neossolos Quartarênicos	RQ	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.0%	0.0%
Nitossolos Haplico	NX	0.9%	3.5%	0.0%	0.0%	0.7%	0.0%	0.0%	0.0%
Nitossolos Vermelho	NV	0.0%	0.0%	0.1%	0.0%	0.0%	0.0%	0.0%	0.0%

Source: Edited by JICA Study Team based on Embrapa 2006 Brazilian System of Soil Classification

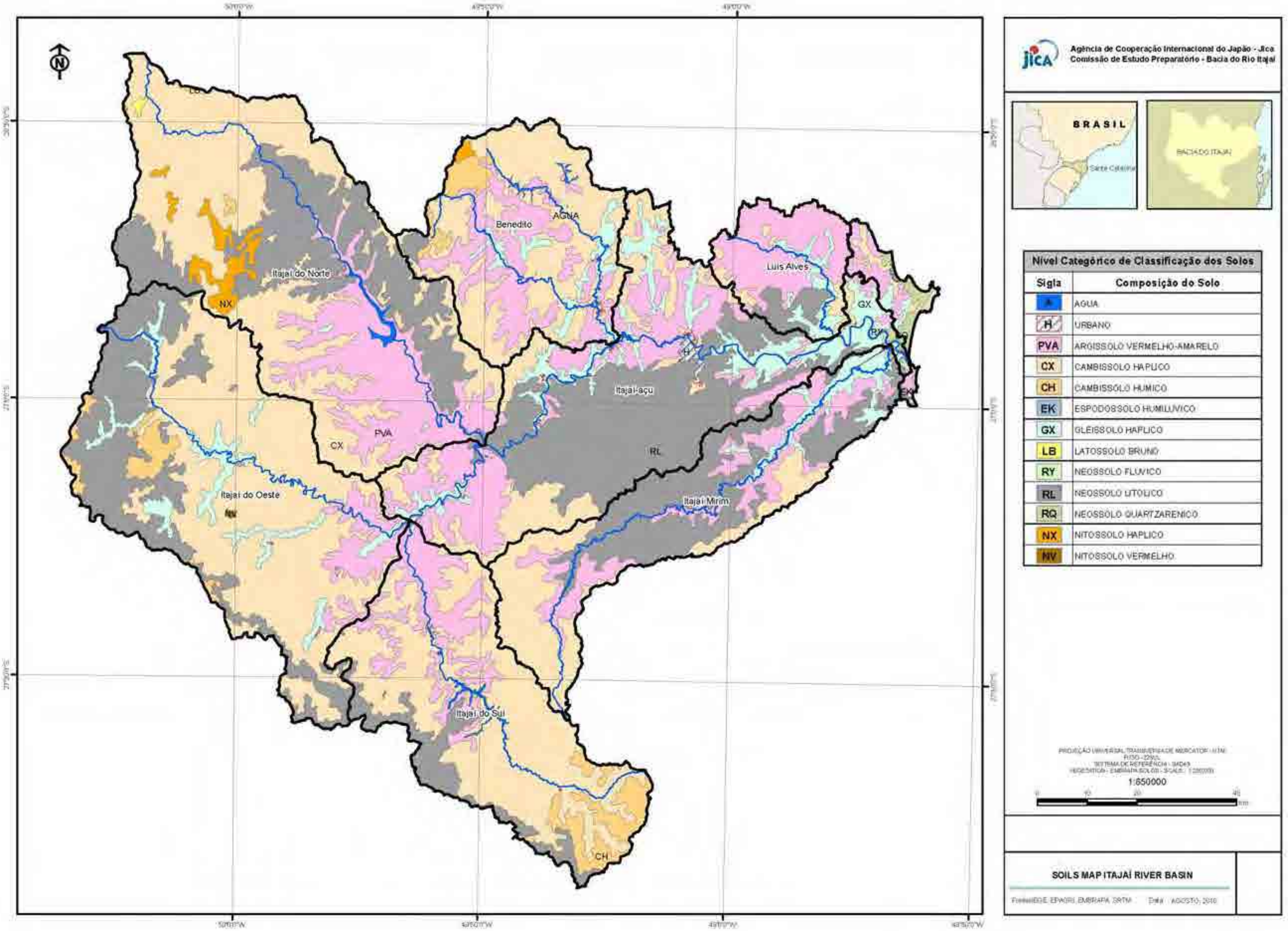


Figure 2.3.1 Soil Classification Map of Itajai River Basin Source: Embrapa Solos, 2004

2.4 Vegetation

Figure 2.4 below presents the vegetation classification in Itajai River basin. The definition for each vegetation type is presented according to the below Table 2.4.1.

Table 2.4.1 Nomenclature of Vegetation Type

Nomenclature	
Portuguese	English
Área urbana	Urban area
Corpos dágua	Water body
Campo e floresta subtropical perenifólia	Field and forest, subtropical evergreen
Campo subtropical	Subtropical Field
Fase campo subtropical	Phase field subtropical
Fase floresta subtropical perenifolia	Phase subtropical evergreen forests
Fase floresta tropical perenifolia de varzea	Phase lowland evergreen tropical rain forest
Floresta e campo subtropical	Subtropical forest and field
Floresta subtropical altimontana	Subtropical forest highland
Floresta subtropical perenifolia	Subtropical evergreen forest
Floresta tropical de restinga	Tropical sandbar
Floresta tropical de varzea	Lowland tropical forest
Floresta tropical perenifolia	Tropical forest evergreen
Floresta tropical perenifolia de várzea	Lowland evergreen tropical forest
Floresta tropical/subtropical perenifolia	Tropical subtropical evergreen forest
Floresta tropical/subtropical perenifolia de Varzea	Lowland tropical/subtropical forest

Source: Elaborated by JICA Survey Team, based on information from IBGE, EPAGRI, SDS, SRTM

Table 2.4.2 shows the area ratio occupied by vegetation type in the whole Itajai River basin and in the tributaries sub-basins.

The subtropical evergreen forest is the largest vegetation type in the whole basin, occupying 38% of the total area. The tropical subtropical evergreen forest is the second largest one, occupying 29%. The tropical evergreen forest is the third largest one, occupying 15% of the total area. These 3 types of vegetation represent more than 82% of the total basin.

In the sub-basins of Itajai do Norte, Itajai do Oeste and Itajai do Sul Rivers, which are located at West of Mar Mountain Range, the subtropical evergreen forests are predominate, corresponding to 52% to 63% of each river basin, the tropical evergreen forest occupied relatively small area, representing 1% to 9%.

At the East side of Mar mountain range and North side of Itajai-Acu River, the tropical evergreen forest occupies 33% of the whole Benedito River basin, and 72% of Luis Alves River basin.

At the East side of Mar Mountain Range and south of Itajai-Acu River basin, the tropical subtropical evergreen forest occupies very expressively, corresponding to 51% of the whole Itajai-Acu River basin, and 58% of the whole Itajai Mirim River basin.

Table 2.4.2 Area Ratio of Vegetation Type

Types of vegetation	Area ratio of vegetation type (Area of vegetation type / area of basin)							
Nomenclature in Brazil	Whole Itajai River basin	Sub-river basins						
		Itajai do Norte	Itajai do Oeste	Itajai do Sul	Benedito	Itajai-Acu	Itajai Mirim	Luis Alves
	15,111 km^2	3,354 Km^2	3,015 km^2	2,027 km^2	1,496 km^2	2,777 km^2	1,679 km^2	580 km^2
Área urbana	0.4%	0.1%	0.2%	0.3%	0.3%	1.2%	1.1%	0.0%
Corpos dágua	0.8%	0.8%	0.0%	1.0%	1.2%	1.4%	0.2%	0.2%
Campo e floresta subtropical perenifólia	0.5%	0.0%	0.0%	0.0%	5.4%	0.0%	0.0%	0.0%
Campo subtropical	0.2%	0.0%	0.0%	1.2%	0.0%	0.0%	0.0%	0.0%
Fase campo subtropical	0.4%	0.0%	0.0%	2.9%	0.0%	0.0%	0.0%	0.0%
Fase floresta subtropical perenifolia	4.1%	11.9%	6.1%	0.0%	0.0%	1.3%	0.0%	0.0%
Fase floresta tropical perenifolia de varzea	0.1%	0.0%	0.0%	0.0%	0.0%	0.3%	0.1%	0.0%
Floresta e campo subtropical	2.1%	2.4%	4.6%	4.4%	0.7%	0.0%	0.0%	0.0%
Floresta subtropical altimontana	2.4%	0.0%	4.4%	11.3%	0.0%	0.0%	0.0%	0.0%
Floresta subtropical perenifolia	38.3%	63.4%	59.1%	51.6%	24.5%	3.1%	18.7%	0.0%
Floresta tropical de restinga	0.0%	0.0%	0.0%	0.0%	0.0%	0.2%	0.0%	0.0%
Floresta tropical de varzea	0.3%	0.0%	0.0%	0.0%	1.6%	0.7%	0.0%	0.0%
Floresta tropical perenifolia	14.5%	8.5%	2.3%	0.6%	33.3%	25.5%	10.7%	71.8%
Floresta tropical perenifolia de varzea	6.2%	0.1%	4.1%	0.0%	7.4%	14.8%	11.1%	14.2%
Floresta tropical/subtropical perenifolia	28.9%	12.9%	15.6%	26.7%	25.5%	51.4%	58.0%	13.7%
Floresta tropical/subtropical perenifolia de Várzea	0.7%	0.0%	3.4%	0.0%	0.0%	0.0%	0.0%	00%

Source: Elaborated by JICA Study Team, based on information from IBGE, EPAGRI, SDS, SRTM

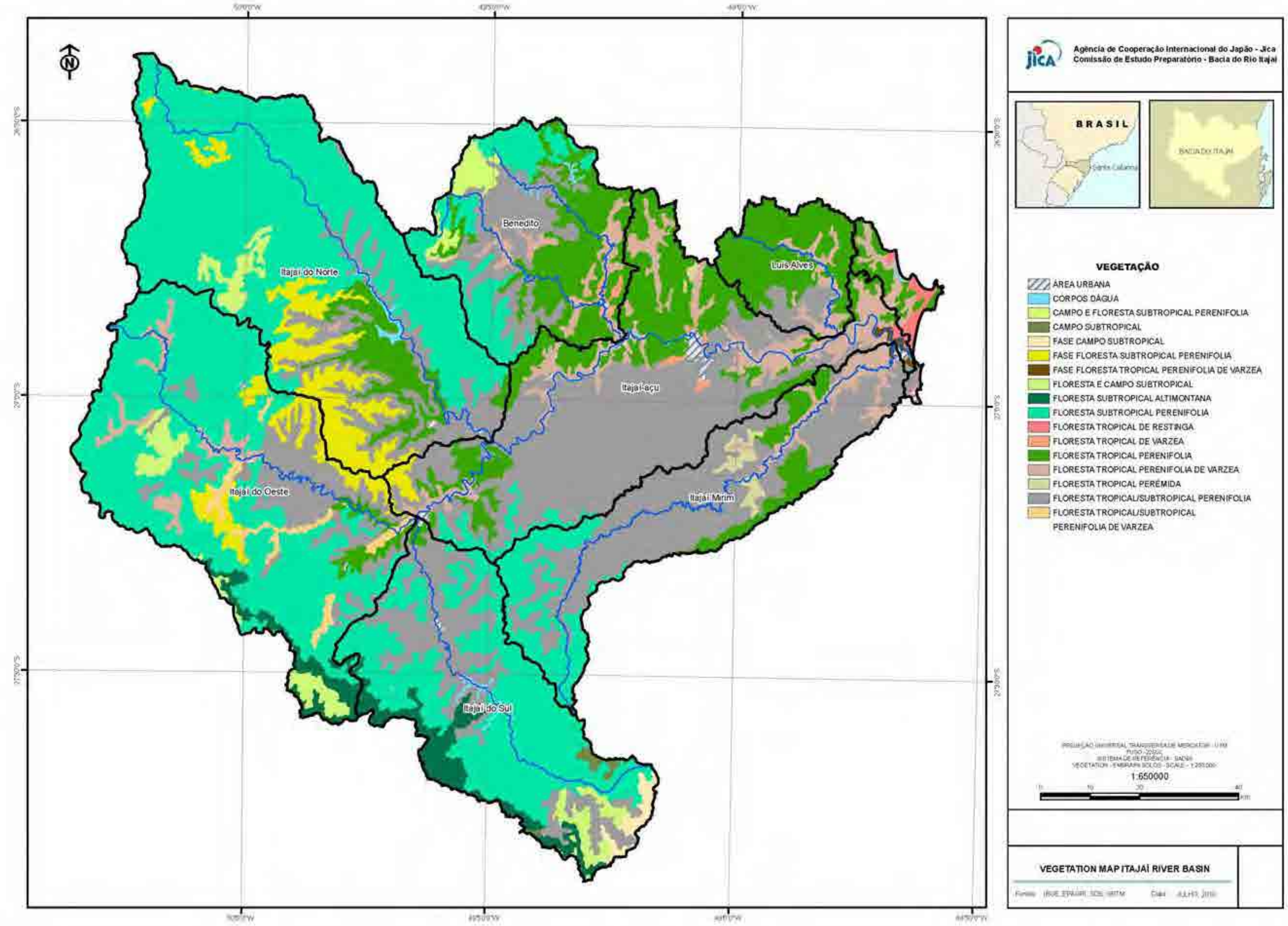


Figure 2.4.1 Classification Map of Itajai River Basin Vegetation Source: IBGE, EPAGRI, SDS, SRTM

CHAPTER 3 STATUS OF LANDSLIDE AND SEDIMENT DISCHARGE

3.1 Landslide

3.1.1 Status and Restoration Works

(1) History of landslide disasters over the years

The number of landslide events in Itajai River Basin, based on SC state Civil Defense information, is shown in Table 3.1.1. The data of landslide occurrence is available in 23 years, between 1980 and 2003. The number of landslides disasters was 185 in the whole State of Santa Catarina. While in Itajai River Basin, this number is 65, corresponding to 35% of the total in Itajai River Basin.

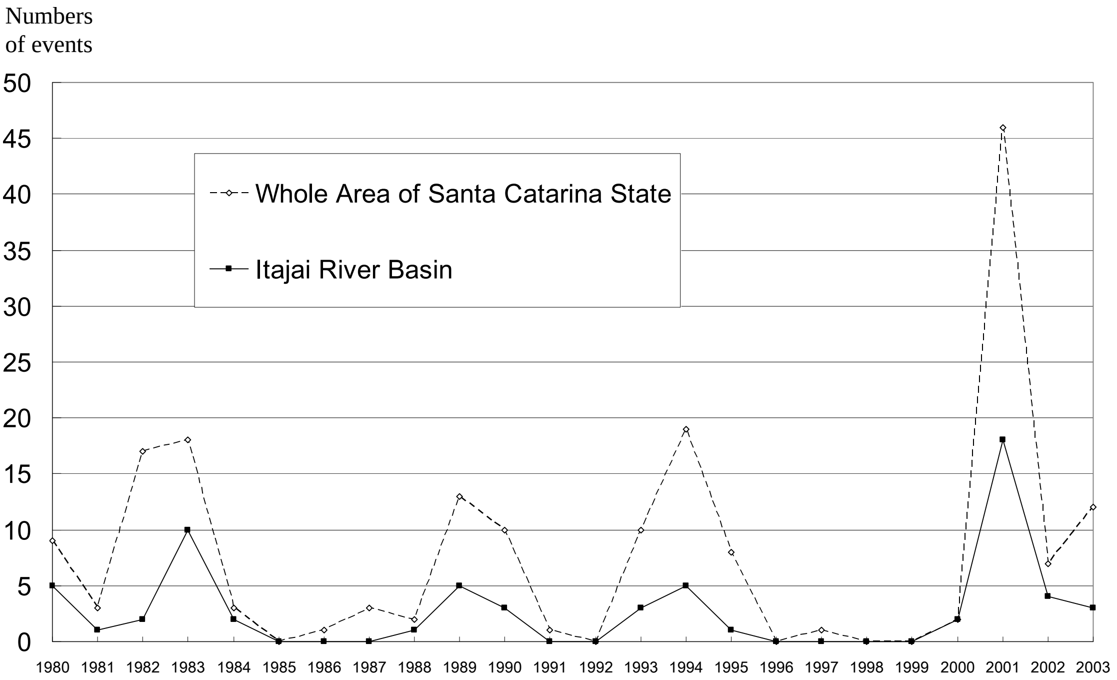


Figure 3.1.1 Changes of the AnualNumber of landslides in Santa Catarina State and in Itajai River Basin over the Years (1980 - 2003)

Table 3.1.1 shows the number of landslide occurrences in the State of Santa Catarina and in Itajai River basin, as well as the rainfall, areas and population.

The area rate of Itajai River basin is 16% of Santa Catarina State, and the number of landslide disasters per year in 1,000 km^2 is 0.85 events/1,000 km^2/year in the whole state, while in the Itajai River basin's figure is 1.9 events/1000 km^2/year, and 2.2 times bigger than the whole state, i.e., a relatively high level. Also, regarding the number of annual landslide disasters per million inhabitants, Santa Catarina State has 1.6 events/million inhabitants/year, while in Itajai River Basin's figure is 2.8 events/million inhabitants/year, 1.7 times bigger than the whole state. Itajai River basin as a relatively high population density, 68.4 inhabitants/km^2, against 51.2 inhabitants/km^2 in Santa Catarina State.

Table 3.1.1 Changes of the Annual number of landslides in Santa Catarina State and in Itajai River Basin (1980 - 2003)

	Year	Whole state of Santa Catarina	Itajai River Basin	Rate of Itajai River Basin to whole state of Santa Catarina	Maximum annual value of the soil water index (mm)				
					Rio do Campo	Ituporanga	Indaial	Blumenau	Itajai
Number of Landslide Disaster Events	1980	9	5	56%	-	-	-	-	-
	1981	3	1	33%	-	-	-	-	-
	1982	17	2	12%	-	-	-	-	-
	1983	18	10	56%	-	-	-	-	-
	1984	3	2	67%	-	-	-	-	-
	1985	0	0	-	-	-	-	-	-
	1986	1	0	0%	-	-	-	-	-
	1987	3	0	0%	-	-	-	-	113
	1988	2	1	50%	-	72	-	-	60
	1989	13	5	38%	-	99	-	-	123
	1990	10	3	30%	-	94	-	-	89
	1991	1	0	0%	-	88	96	-	79
	1992	0	0	-	-	101	131	-	131
	1993	10	3	30%	-	84	91	-	100
	1994	19	5	26%	-	91	99	-	117
	1995	8	1	13%	82	83	109	-	132
	1996	0	0	-	90	94	85	-	108
	1997	1	0	0%	101	109	117	113	98
	1998	0	0	-	119	81	97	111	136
	1999	0	0	-	95	86	100	81	184
	2000	2	2	100%	108	102	90	91	122
	2001	46	18	39%	132	104	154	103	121
	2002	7	4	57%	125	86	115	62	86
	2003	12	3	25%	113	93	87	102	167
	Total of 1980 - 2003	185	65	35%					
Area (1,000 km^2)		95	15	16%					
Population (thousand inhabitants) 1996		4,875	1,027	21%					

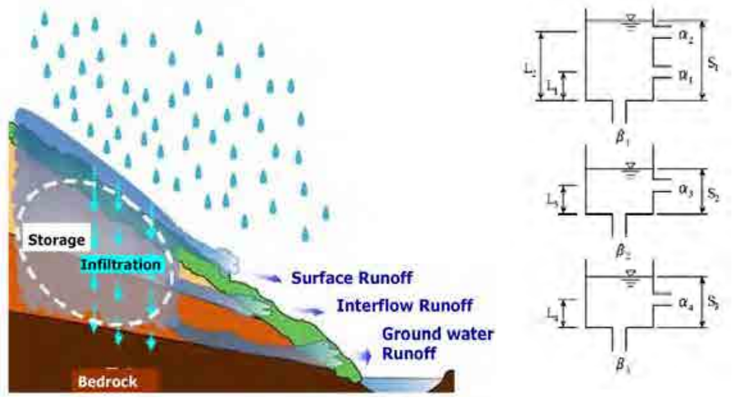
Source: Elaborated by JICA Study Team based on SC-Civil Defense information

(2) Relation between the soil water index and landslide disasters

Table 3.1.1 also shows the maximum annual values of soil water index (SWI): rainfall amount index that calculated by the rainfall amount per hour of past 30 day to reflect the amount of water in the soil.

The SWI used in the Meteorological Institute of Japan is estimated by the 3 story water tank model indicated as follows:

The maximum annual value of the soil water indexes were 132 mm (20 years return period) in Rio do Campo, in the northeast region of the basin, and 154 mm (30 years return period) in Indaial, in the center of the Basin. The landslide disasters in 2001 might occurred because of the heavy rainfalls of 20 -30 years return period.



Surface Tank and surface runoff

Surface Layer Tank and Interflow Runoff

Groundwater Layer Tank and Ground water Runoff

Parameters usually used in Japan for the alert of Landslide Disaster			
	Surface Tank	Surface Layer Tank	Underground water tank
Height Runoff Hole (mm)	L1 15 L2 60	L3 15	L4 15
Runoff Coefficient (mm/H)	A1 0.1 α2 0.15	α3 0.05	α4 0.01
Infiltration Coefficient (mm/H)	B1 0.1	β2 0.05	β3 0.01

Source: Translated by JICA Survey Team form Japan Metrological Agency in Japanese

Figure 3.1.2 Soil Water Indexes used for the Alert of Landslide Disasters

(3) Characteristics of landslide disasters caused by the rainfall of 2008

Table 3.1.2 presents the reports of disasters resulting from the extreme severe disaster of landslides and flood occurred during the November 2008 rainstorm. The 89 fatalities represent 0.09 % of the 103,602 persons who were evacuated, 0.13% of the 66,556 victims, and 0.61% of the 14,573 persons who lost their homes. In the official information, it is not specified if such victims were caused by flood or landslides. The Civil Defense of Santa Catarina says that 97% of deaths were caused by landslides. With regards to flood, people were evacuated by the existing alert system, escaping from death, but with regards to landslides, there were no alert system in place, and almost no evacuation was done, and this is probably the reason for the increase of injured person and fatalities.

Table 3.1.3 shows the situation of the soil water index in the November 2008 storm. The soil water index is calculated by the rainfall amount data provided by EPAGRI/CIRAM and of 5 stations of Itajai River Basin observed more than 10 years continuously (non-automatic recording, observation of accumulated rainfall in a gauge tank 2 to 3 times a day), and observed rainfall amount were divided by accumulated hours into hourly rainfall amount equally.

Figure 3.1.3 shows the area of soil water index (SWI), which is used for the landslide alert index in Japan, and the municipalities that declared emergency/calamity state in the November 2008 rainstorm. The houses destroyed and fatalities were only in the municipalities of emergency or calamity statement under November 2008 storm, were in area with peak SWI were above 145 mm of 20 years return period.

Table 3.1.2 Records of Victims due to Flood and Landslides in November 2008

	Population	Rate of victims	Evacuees	Victims	Victims who lost their homes	Injured Persons	Fatalities	Damaged buildings	Length of roads affected (km)
Benedito Novo	9,841	31%	102	712	210		2	191	576
Blumenau	292,972	35%		25,000	5,209	2,383	24	18,000	
Brusque	94,962	100%		8,000	1,200	66	1	1,220	120
Gaspar	52,428	100%		7,100	4,300	280	16	8,700	600
Ilhota	11,552	100%	3,500	3,500	1,300	67	26	406	
Itajai	163,218	100%	100,000	18,208	1,929	1,800	5	28,400	
Luis Alves	8,986	100%		3,232	239	41	10	220	40
Pomerode	25,261	1%		182	48		1	50	100
Rio dos Cedros	9,685	88%		595	96			283	300
Rodeio	10,773	5%		27	42		4	35	144
Timbo	33,326	2%						264	
	713,004		103,602	66,556	14,573	4,637	89	57,769	1,880

Source: AVADANs sent by the municipalities to the Civil Defense of Santa Catarina, on November 24 and 25, 2008.

Table3.1.3 Soil Water Index in 2008 Rain Storm

Municipalities of Rainfall Station	Station No.	Peak value of soil water index (SWI) during the November 2008 rainstorm	Return Period of SWI	Monitoring Period of rainfall amount utilized in the calculation for return period of SWI
Rio do Campo	639	37 mm	Less than one year	From 1995 to 2009 (15 years)
Ituporanga	191	43 mm	Less than one year	From 1988 to 2009 (22 years)
Indaial	167	145 mm	20 years	From 1991 to 2009 (19 years)
Blumenau	35	245 mm	60 years	From 1997 to 2009 (13 years)
Itajai	183	191 mm	30 years	From 1987 to 2009 (23 years)

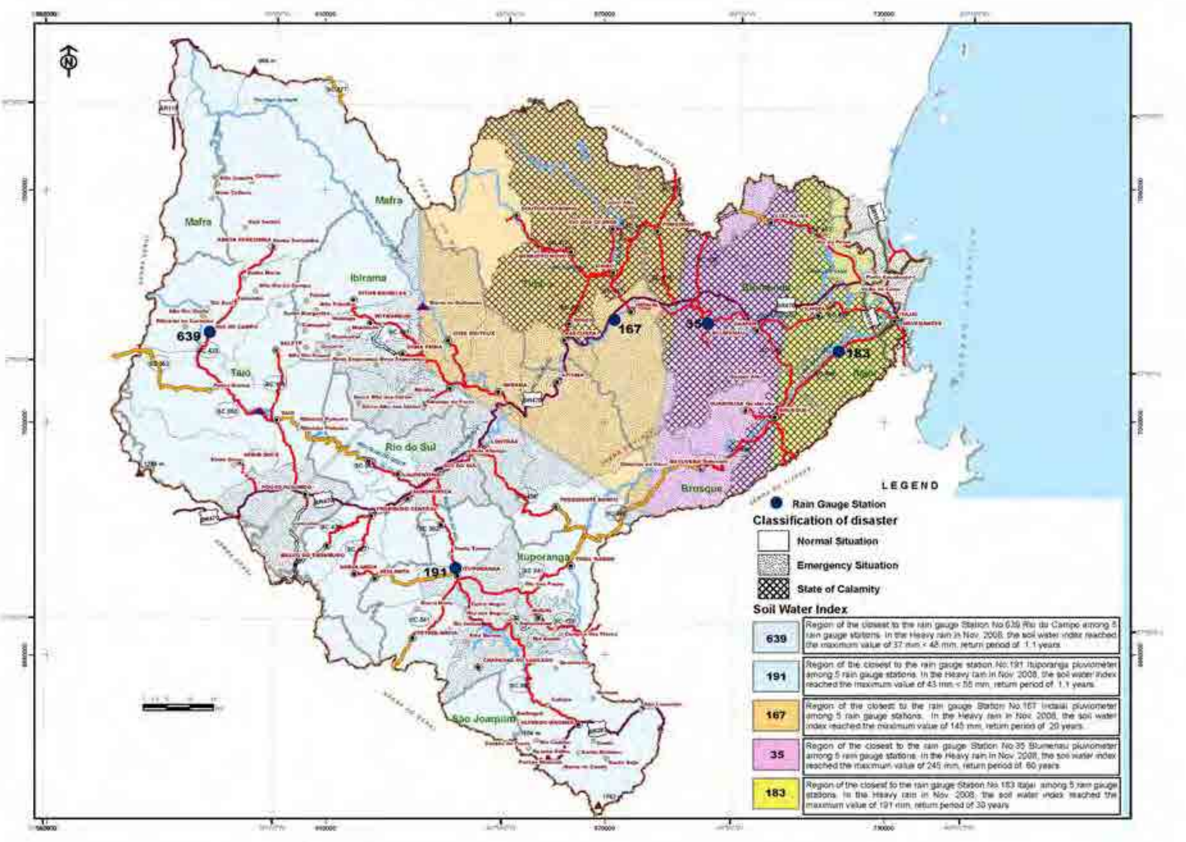
Source: JICA Survey Team

Figure 3.1.3 shows the area of soil water index (SWI), which is used for the landslide alert index in Japan, and the municipalities that declared emergency/calamity state in the November 2008 rainstorm. The houses destroyed and fatalities were only in the municipalities of emergency or calamity statement under November 2008 storm, were in area with peak SWI were above 145 mm of 20 years return period.

(4) Restoration Projects of landslide disasters of the November 2008 Rainstorm

The report released in November 2009, ‘Reconstrução Áreas afetadas Catástrofe Novembro / 2008’ described in lump sum about restoration projects for landslide and flood, because they can not be classified clearly. For emergency expenses of the Santa Catarina State was R$520 million for emergency evacuation, restoration works for damaged infrastructures.

Another of SC state restoration program, federal conducted the restoration program for landslide disasters on federal BR 470 highway. There was one site of whole width of road closure disaster and the other partial width road closure disasters; one of them was closure by rolling out boulder of 5 meter diameter. In Gaspar municipality, a gas explosion was occurred, because a landslide destroyed a gas pipe under the highway. The highway was reopened on 12th December 2011 by the emergency restoration works including earth removal and construction of temporary detour road. The total amount of restoration works for BR 470 highway was R$17 million.



Source: JICA Survey Team (The data sources is the Civil Defense-SC, EPAGRI/CIRAM)

Figure 3.1.3 Soil Water Index and Statement of Emergency / Calamity of November 2008 Rainstorm

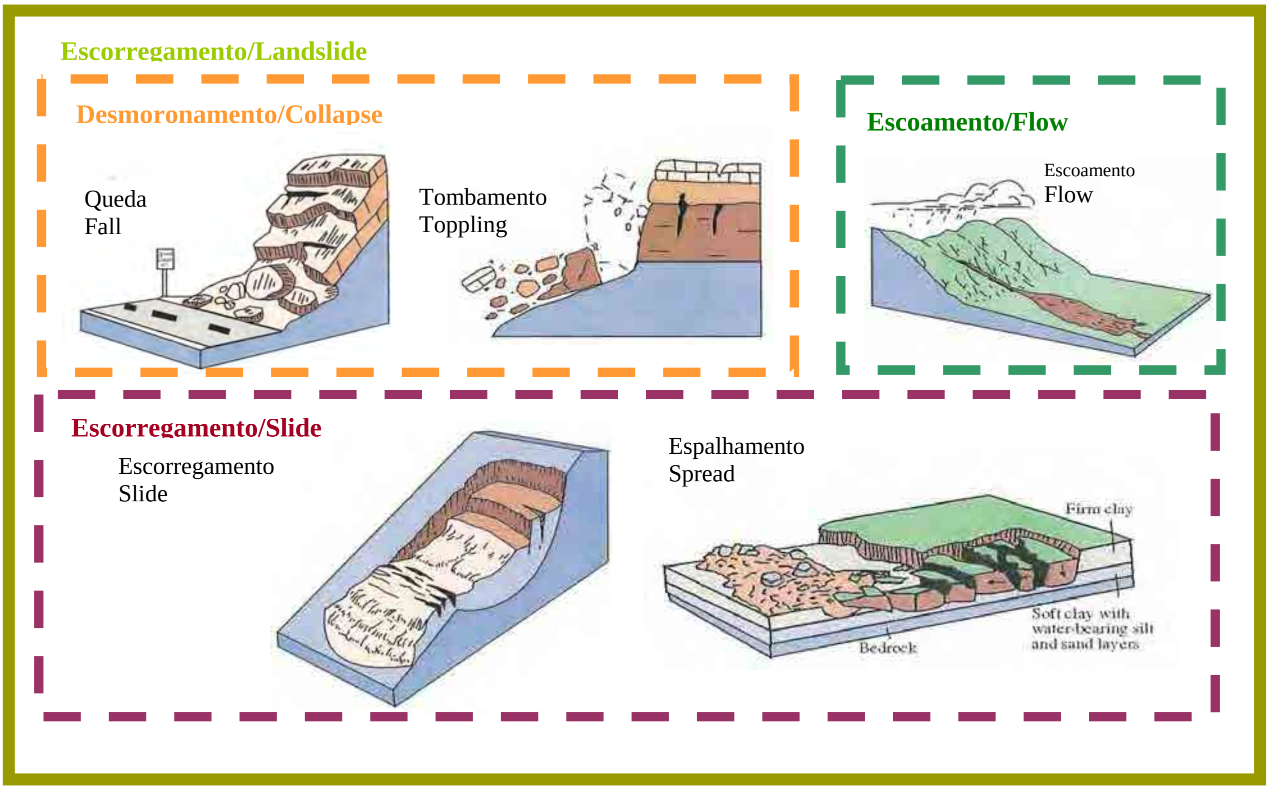
3.1.2 Landside Movement Types and Their Characteristics

(1) Generation Information

In Brazil, the expressions "*escorregamento*" and "*deslizamento*" are used with identical meaning, but in this study, the expression "*escorregamento*" (landslide) will be used following the Natural Disasters Atlas of Santa Catarina State of 2004.

The Varnes's classification of landside movement is well known in the world, which classifies into 5 types according to kinematic characters: Fall, Topple, Slide, Spread and Flow. In this study, we have unified fall and Topple into Collapse, and Slide and Spread into Slide, because the points for management are identical. The expression *escorregamento* will be used as landslide (broad meaning of all kinematic characters) and also as slide (restricted meaning for slide).

Table 3.1.4 shows the landslide classification according to movement and materials. The failure mechanism of landslide and the appropriate measures vary according to the types of landslide. In this study, we try to determine as much as possible the types of landslide for the appropriate landslide management. These types are not clearly defined. It is also same in the studied area that the existence of intermediate types, and the type of movement and materials might change during the movement process. For example, there is a case that in the beginning of the occurrence is a Collapse, after moving towards a torrent it became a Flow. And there is a case that the end of debris flow sediment is predominantly cobbles and boulders, but becomes sand and fine grained soils gradually to the upstream direction.



Source: Edited by JICA Survey Team based on Varnes 1982

Figure 3.1.4 Classification per Movement Type of Landslide

Table 3.1.4 Landslide Classification according to the Type of Movement and Material in this Study

Type of Movement	Type of Material		
	Bedrock	Engineering Soils	
		Predominantly Coarse	Predominantly Fine
Collapse (Fall, Topple)	Rock Collapse	Debris Collapse	Earth Collapse
Slide (slide, spread)	Rock Slide	Debris Slide	Landslide
Flow	-	Debris Flow	Earth Flow

Note: The term in parentheses is based on the classification of Dr. Varnes, 1978.

Source: Elaborated by JICA Survey Team

(2) Characteristics of the collapse

In this study, "collapse" indicates a phenomenon in which the soils and/or rocks that compose the slope fall or roll down in a relatively short time, due to the rainstorm or the earthquake. It is different from "slide" that the soil or rock mass slides slowly, or from "flow" that the soils that has accumulated or has fallen into the torrent during the rainstorm is flowing at once together with a great volume of water, because the disaster characteristics and appropriate control techniques are different.

This is the most common phenomenon in Itajai River Basin, and can cause victims due to a fast movement like as "flow". The collapse of fine grained residual soil of the surface is commonly recognized, due to the weakening by the rainstorm.

The collapse typically occurs in the red-yellow acrisols. It is formed by the deep weathering process by the sub-tropical climate, and can reach the depth over 10 m from the ground surface. It is divided into red soil (upper stratum) and yellow soil (lower stratum). This red soil has become into fine-grained soil completely by weathering, with remarkable deterioration of share strength under water content condition, the collapsed soil make the river muddy of reddish brown color, and the fine soil particles do not sediment easily, being carried into the sea (the sediments of Itajai River banks in the Blumenau City, are fine brown sand, with only fine reddish brown silt film of less than 1 mm thickness on the surface). The yellow soil has a relatively lowly weathering and remaining coarse soil particles, with somewhat relatively strong share strength.

In most of the slope collapse, only the red soil had collapsed, with a less than 1m thickness.

In the area where Itajai-Acu River cuts the Serra do Mar, the rock falls from the rocky slope. The relation between rainfall and the rock falls is not clear.

Source: DENIT office in Rio do Sul

Damages caused by the rainstorm of November 2008
BR 470, Km 44, in the municipality of Blumenau The yellow-reddish soil collapse completely closed the road.

Source: DENIT office in Rio do Sul

Damages caused by the rainstorm of November 2008
BR470, Km 41, in the municipality of Gaspar
The road, foundation of red soil, suddenly collapsed, causing the fall of vehicles trafficking there.

Source: DENIT office in Rio do Sul

Damages caused by the rainstorm of November 2008
BR470, in the municipality of Blumenau
A 5m diameter rock that was contained in the yellow-reddish soil fell on the road due to the weakening of the saturated soil.

Source: Provided by Civil Defense - Gaspar

Damages caused by the rainstorm of November 2008. A thin soil layer that was covering the base rock in the urban zone of the Gaspar municipality, in the state road SC470, collapsed from the boundary with the base rock. The collapsed soil covered the whole width of the road, getting to the ground floor of a gas station that was on the other side of the road.

Source: JICA Survey Team, May 26, 2010

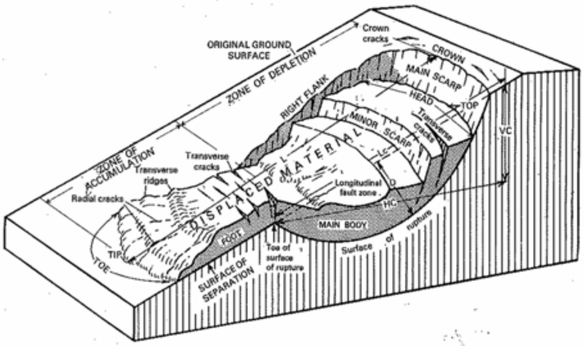
Site of a disaster prevention work in the municipal road of Blumenau, executed by DEINFRA. Collapse of the thin layer of yellow-reddish soil that covers the base rock.

Source: JICA Survey Team, May 08, 2010

Erosion in the yellow-reddish soil on cut slope in the municipality of Pomerode. It easily becomes deteriorate with the infiltration of water, becoming erosible.

(3) Characteristics of slide

Slide is a shearing skewness/displacement process that occurs inside one or various faces or thin layers, and its occurrence is progressive and destructive. The slide is a phenomenon of slow upper side mass movement on sliding surface, in large scale, with little disturbance of the movement mass, and most of the mass remains in the occurrence area. In the typical slide, which has a rotation sliding surface, the topographic characteristics presented in Figure 4.2.5 are observed.



Source: Varnes 1978

Figure 3.1.5 Rotation Slide Profile

In the case studies in Japan, the collapse depth is at most 2m, but the average length and the average depth of the slide can reach approximately 300m and 18m, respectively. While the collapse occurs more frequently in steep slope with more than 30 degrees of gradient, the slide occurs in moderate slope with 15 to 30 degrees of gradient.

As the slides occur in relatively deep subsurface to the collapses, it is a shearing phenomenon with little influence and/or time lag from the rainfall. The slide in the Pomerode Municipality in the Itajai River Basin, which became active at the end of August 2010, occurred with non-relation to the rainfall. The slide in the Benedito Novo Municipality, which formulated an approximately 5m high landslide scarp in December 2008, was caused, a month later, by the rainstorm of November 2008. The geological conditions of landslides prone in Itajai River Basin are as follows:

(1) Area of thick soil distribution, mainly red-yellow acrisols and/or ferralsols. The soils are subject to the deterioration of shear strength because of water absorption, facilitating the formation of sliding faces (Slopes of gentler than 30 degree, at the banks of Itajai-Acu River and tributaries).

(2) Area of distribution of soft muddy sedimentary rock (pelite) of the Mesozoic era, especially the region that volcanic rocks, such as basalt of the Serra Geral formation, overly the soft sedimentary rock. The muddy sedimentary soft rock being deteriorated due to the thin intrusive of lava and hot water that intruded along bedding plan. And the infiltrated fissure water dammed in the basalt is concentrated into springs, and they cause sliding surface. (Basins of rivers Itajai do Norte, Itajai do Oeste, and Itajai do Sul)

The slide of the yellow-reddish soil distribution area of the southwest region of Pomerode was activated at the end of August 2010 and has destroyed 2 houses near the hillside. The surrounding area of the two residences was a swamp until 25 years ago, and soft ground. The slide activated in the drought season. The slip surface is in red-yellow acrisols soil had been deteriorated over the years, and activated by slip surface to be below share strength.

Source: JICA Survey Team on September 14, 2010

Slide of the pelitic sedimentary rock distribution area of the Mesozoic era on the state road SC302, upstream the dam of Itajai do Oeste river, in the municipality of Taio. The road corresponds to the slide head, and at the left side of the photo there is the river, and in the hill at the right side we can observe the distribution of phyllite with water spring.

Source: JICA Survey Team on May 09, 2010

Slide in the area of Benedito Novo city hall. 5m high slide of the head side occurred with the yellow-reddish soil. Occurred in December, approximately one month after the rainstorm of November 2008.

Photo: provided by the Civil Defense - Benedito Novo

Photo taken in December 2008.

Road section between Luis Alves - Massaranduba of the state road SC413 in the municipality of Luis Alves. There is a sliding face within the yellow-reddish soil. In the rainstorm of November 2008, it completely obstructed the road. The sliding face is located a little above the road surface, and even now, a stretch 60m long along the road is advancing to the road. The total length, including the non-activated part, is 240m.

Photo: taken by JICA Study Team on May 24, 2010

(4) Characteristics of the flow

The flow, as the collapse, is characterized by the fact of causing huge damages to human lives, destroying houses and buildings, and demanding a long time and lots of money for the reconstruction.

The characteristics of disasters caused by the flow are due to the following characteristics:

A. Great velocity. In general, the flow of debris (which contain great amount of debris) comes down at 5 to 10m/second, and the land flow (with fewer debris, with smaller proportion of earth [sic]) comes down 10 to 20m/second.

B. It contains big rocks and tree trunks. Mainly at the end of the flow, there are big rocks of some meters of diameter and tree trunks, so that a great impact force is generated, destroying houses.

C. It occurs suddenly. The occurrence of the flow is sudden, with no visible warning signs.

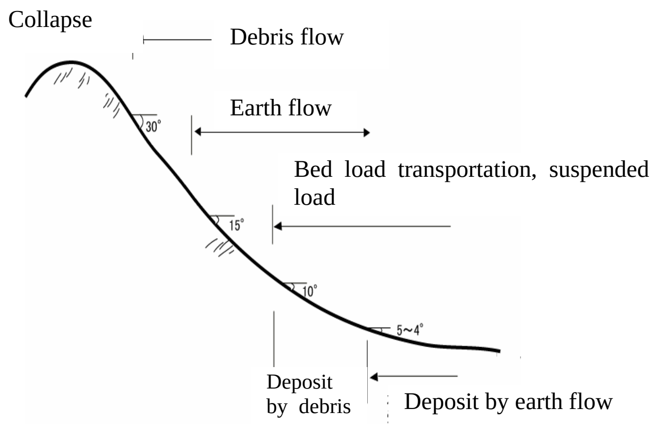


Figure 3.1.6 Relationship between Slope Gradient and Landslide/Sediment Movement and Sedimentation

Source: Eto, Ito and others: elaborated by JICA Study Team based on the collection of lectures and theses of the meeting for the presentation of the results of the study about the techniques of erosion and slide prevention

Figure 3.1.6 shows the relation between the slope movement/ sedimentation and the slope gradient.

Similarly, according to the report of the Civil Engineering Institute no. 157 of 1982, the sedimentation part of the flow (gradient before sedimentation) is above 2 degrees, being below 10 degrees in approximately 70% of the cases. In the field to be inundated at the exit of the current in which the occurrence of a flow is predicted, it is necessary to consider that, if the gradient is above 2 degrees, there is the risk of being impacted by the flow.

According to case studies in Japan, as illustrated in Table 3.1.6, the flow occurs relatively easily in regions with granite distribution (south of the municipalities of Gaspar, Blumenau and Indaial, south of Itajai Mirim river in the municipalities of Brusque and Botuvera) and metamorphic rocks distribution area (north of Luis Alves, Pomerode and Gaspar, part at the north of Itajai river of Blumenau, part at the north of Itajaí river, region of Benedito and Cedros Rivers sub-basins, center of Ibirama, etc.).

Table 3.1.5 Types of Rocks and Facility to Generate Flow

Type of rock	Number of flow cases A%		Proportion of the rocks distribution area %	Relative facility of flow occurrence according to the type of rock A/B
Granite rock	180	46.3%	13.3%	3.48
Metamorphic rock	36	9.3%	3.6%	2.54
Paleozoic sedimentary rock	38	9.8%	12.2%	0.80
Tertiary sedimentary rock	55	14.1%	18.9%	0.75
Tertiary and quaternary volcanic rock	50	12.9%	20.4%	0.63
Quaternary sedimentary rock	21	5.4%	20.7%	0.26
Mesozoic sedimentary rock	9	2.3%	9.3%	0.25
Igneous basic rock and intrusion ultra-mafic rock	-	-	1.6%	Less than 0.16
Total	389	100.0%	100.0%	

Source: Civil Engineering Institute Report no. 157 of 1982

Focus of the flow

Metamorphic gneissic rock is distributed in the current below the flow.

Part of flow sedimentation

Area affected by the flow caused by the rainstorm of November 2008 in the basin of Ribeirão Velha water head, in Blumenau. Five people have died because of it. Photo: taken by JICA Study Team on May 27, 2010

Area of potential risk that might be affected by the flow in Ribeirão Garcia basin, in Blumenau. There is a concentration of residences in the part of the current.

Photo: taken by JICA Study Team on May 27, 2010

Earth flow of November 2008 in the region of Ribeirão Pinheiro in the municipality of Benedito Novo; sand

Photo: provided by the Civil Defense - Benedito Novo

Earth flow occurred in November 2008 in Benedito Novo; there is a flow of yellow-reddish soil, but it also contains gneiss debris. It has intercepted Cunha river and temporarily formed a natural dam. At the back of the photo, below the dam, there is the municipality of Rio dos Cedros.

Photo: provided by the Civil Defense - Benedito Novo

Flow caused by the rainstorm of November 2008, at the hillside of Morro do Baú, in the municipality of Ilhota; it has a yellow-reddish soil base, and contains a great amount of 10-30 cm diameter rocks. The hillside of Morro do Baú was the place most affected by the landslide, with 27 deaths, a record number of Ilhota.

Photo: JICA Study Team in 2010

3.2.3 Characteristics of landslide risk of each municipality

A summary was made of the characteristics of the municipalities listed in this table and that recorded 3 or more cases of landslide in 23 years, from 1980 to 2003, according to information of the Santa Catarina Civil Defense; that had the state of emergency/calamity decreed in the rainstorms of November 2008, and that have stretches of roads subject o landslide, according to DEINFRA, after documental research and field research.

Table 4.2.6 Characteristics of Municipalities with High Landslide Risk

SDR	Municipality	Characteristics of landslide risk
SDR-Taio	Rio do Campo	There is intrusion of basalt in pelitic sedimentary rocks of the Mesozoic era, deteriorating the stratification face and forming the potential sliding face, facilitating the development of slides.
	Salete	
	Taio	Idem. With the water level alteration caused by Oeste dam, small scale landslides are verified intermittently in state road SC301.
SDR-Ibirama	Presi. Getúlio	Since it is formed of yellow-reddish soil as the result of eolic erosion of pelitic sedimentary rocks, the soil is fragile and favors the occurrence of slides. There are no major problems in state road SC421.
	Witmarsum	
SDR-Rio do Sul	Rio do Sul	There is intrusion of basalt in the pelitic sedimentary rocks of the Paleozoic era, with possible deterioration of the stratification face and the formation of potential the sliding face. There is landslide that provides flow to the area of concentration of residences. There are landslide problems in developments of approximately one hundred residences.
SDR-Timbó	Benedito Novo	There is a site with a large scale landslide besides the city hall. There is distribution of granites and metamorphic rocks, and the flow risk is relatively big. In the border between Benedito Novo and Rio dos Cedros, Cunha river was obstructed by the flow during the rainstorm of November 2008. In state Road SC416, there are points with risk of track collapse.
	Rio dos Cedros	It is an area of distribution of regional metamorphic rocks such as gneiss and granite, with risk of flow. Since there have been no reports of serious landslides before the rainstorm of November 2008, it is believed that the risk of catastrophe if there is intense rainfall of 20-years recurrence increases.
SDR-Blumenau	Blumenau	It is the area with the higher incidence of landslides in Santa Catarina. The major cause is the construction of houses in hillsides and in the region of the current. The problem is the construction of houses near dangerous currents and in hillsides with steep gradient. Even in smoother gradient hillsides, there are risks of landslide. In state road SC474, which goes towards north, with intense traffic, there is alteration resulting from land collapse and slide.
	Gaspar	There are many areas with hillside collapse risk in the state road SC486 and in the municipal Road, of residential areas collapse. There are alterations resulting from landslides in new housing developments located on hills. In the Gaspar-Luis Alves road, in the municipal road Gaspar-Blumenau and in the bypath of BR470 at the right bank of Itajaí river, there is a paving plan, but if measures regarding the hill are not taken, the obstruction of roads and damaging of paving works might happen, thus becoming a loss of money and efforts.
	Ilhota	With the rainstorm of November 2008, there were serious land collapses (slide/obstruction of rivers, flow) in the surroundings of Morro do Baú. In the affected locations, the recuperation of the vegetation is taking time, increasing the possibility of other slides, therefore it is necessary to promote the recuperation of the vegetation.
	Luis Alves	The risk of collapse and slide is higher in the Gaspar－Luis Alves Road and in the state road SC413, more in the north region than in the urban area. It is possible that measures against landslide should be necessary in the construction of the large scale residential complex currently under execution by the state government, with the fear that it might negatively affect aspects of inundation and landslide for increasing the rainstorm water flow.
	Pomerode	There are land collapses and slides (track slide) in the state road SC418, which goes towards north. There is a slide activated in August 2010, which is affecting residences and the printing facility.
SDR-Brusque	Brusque	The cut surface of the hillside of state road SC486 and of the municipal Road is steep and has no vegetation, with a major risk of collapse and landslide towards Itajaí Mirim River. There are many areas with landslide risk that might affect residences. There are landslides occurring in new housing developments located on hills.
	Botuverá	The hillside of state road SC486 is steep and has not vegetation, with a major risk of collapse and production of loose earth, which might fall down towards Itajaí Mirim River.
SDR-Itajaí	Itajaí	There is steep hillside collapsing at the edges of the plain. The hillside soil is mainly composed of yellow-reddish earth, which is easy to collapse.

Source: elaborated by JICA Study Team

The Itajai River basin with a catchment area of 15,221 km^2 locates in the center of the State of Santa Catarina in the southern part of Brazil. Riparian areas along the Itajai River and its tributaries have been suffering from flood damage due to repeating inundation. To cope with frequent flood damage along the Itajai River, flood control schemes such as flood control dam construction and river improvement works have been implemented since 1970s.

3.3 Sediment Discharge

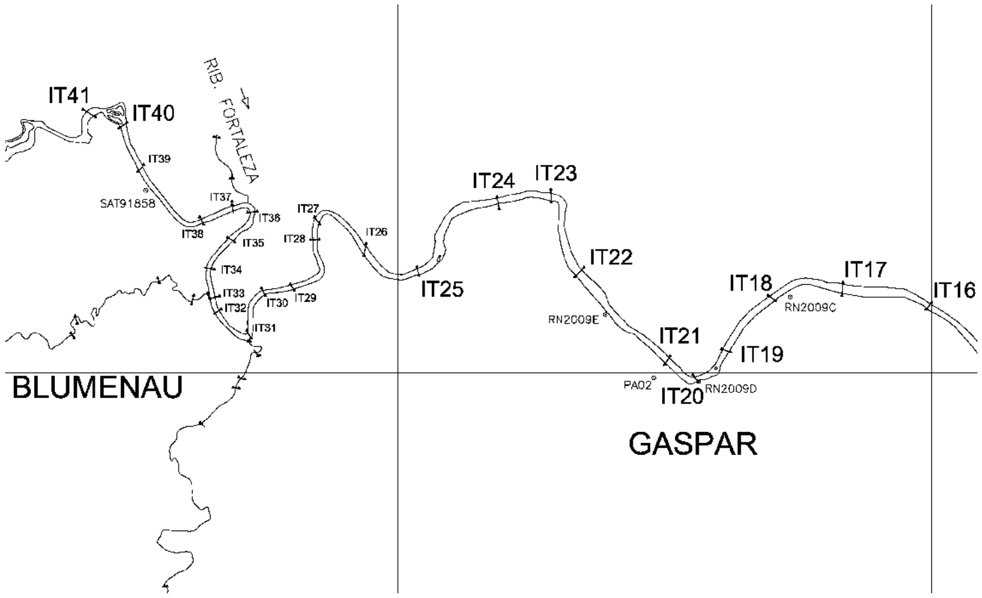
The comparison analysis of river cross sections, among past and this survey in 2010, are conducted to identify trends and changes in the bed of the Itajai River.

3.3.1 Status and Restoration Works

The situation of riverbed Itajai River was confirmed by site investigation and information corrected as follows;

1) Rocks are exposed at riverbed of Itajai River intermittently in upstream area from Blumenau City.
2) Sand extraction businesses are conducted from the river bed from Itajai-Acu River in downstream around Gaspar City, and Itajai Mirim River also. DNPM (Departamento Nacional de Produçao Mineral) allows 1,920,000 m^3 per year for sand extraction. The yearly volume divided by the catchment area, excluding the tributaries of Luiz Alves is equivalent to 0.13mm per year eroding velocity.
3) In Itajai Port, since 1988, jet- water dredging of annual 200-250 m^3 water volume has been conducted. The volume of dredging sediment has not been monitored. In 1970s, actual dredging volume was 50 thousand m3 per year, and altitude of riverbed was – 6.6 m. In 1980s, actual dredging volume was increase 840 thousand m3 per year, altitude of riverbed was – 8.0 m intentionally. The reason of dredging volume increase was considerably due to sediment from marine side by sea tide, but it was not quantified.

From the above, regarding upper reach of Blumenau, there is no trend of rising riverbed. In Itajai Acu River of downstream from Gaspar and Itajai Mirim River, commercial sand extraction is conducted, and the port of Itajai is also dredging, so it becomes difficult to make assessments of the riverbed by comparing topographic survey data. Therefore, analysis section of the Itajai Acu River was set between Gaspar and Blumenau. In Figure 3.7.1, the locations of target river section and the surveying cross sections are shown in.



Source: JICA Survey Team

Figure 3.3.1 River Section of Analysis Target

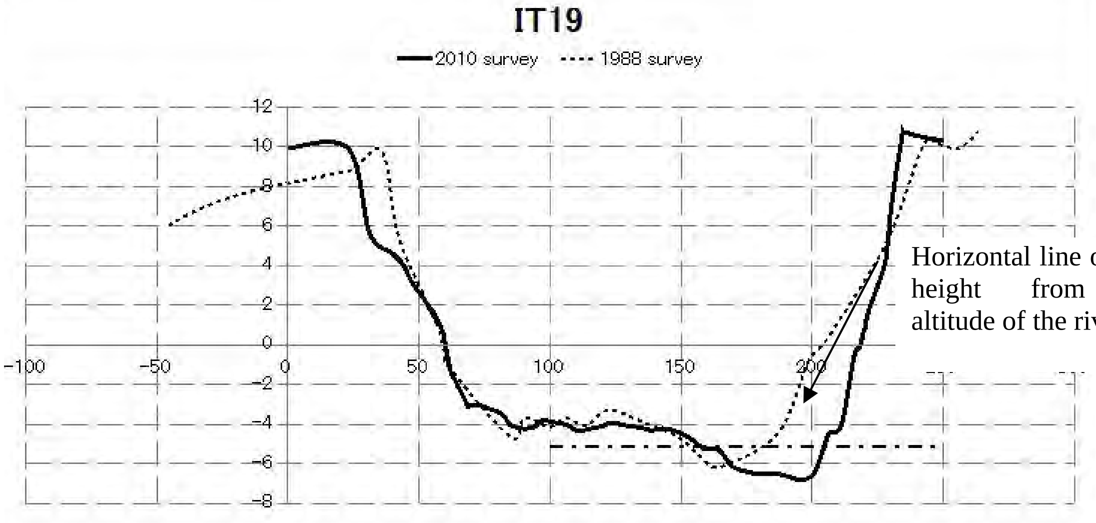
3.3.3 Method of Analysis

The trend of variation of the river bed is evaluated by the following equation;

$$\Delta H = \frac{\Delta A_u + \Delta A_d}{2 \cdot B}$$

Where ΔH : variation of the riverbed in the stretch (m)
B : average width of the river in the stretch (m)
ΔA_u : change in the upper section of the stretch (m^2)
ΔA_d : change in the lower section of the stretch (m^2)

The topographic survey data used to comparison of the section will be: The result of topographic survey conducted by the JICA Study in 1988 (Research for the flood control plan of the Itajaí River Basin - Feasibility Study (Plan of river improvement in Gaspar- Blumenau in January 1988) and the topographic survey result of this survey. The extension will be considered the stretch of 35 km in total, including Gaspar and Blumenau, shown in 3.3.2.



Horizontal line of the 1 m height from lowest altitude of the riverbed

Source: JICA Sturdy Team

Figure 3.7.2 Example of Analysis of Variance of the Riverbed

3.3.3 Result of Calculation

Table 3.3.1 shows the variation of the riverbed at each site. The width of the river is set as current width (verified in this survey). In general, the trend is riverbed erosion process. Looking at each site, erosion is greater in the stretch of downstream side of Gaspar City, considerately the effect of sand extraction from the riverbed. In the Blumenau City, stretch between the mouth of tributaries of Fortaleza and Garcia is no change or slight aggradations, less than 0.3 m, are recognized in river bed.

Table 3.3.1 Results of Calculation of Sedimentation

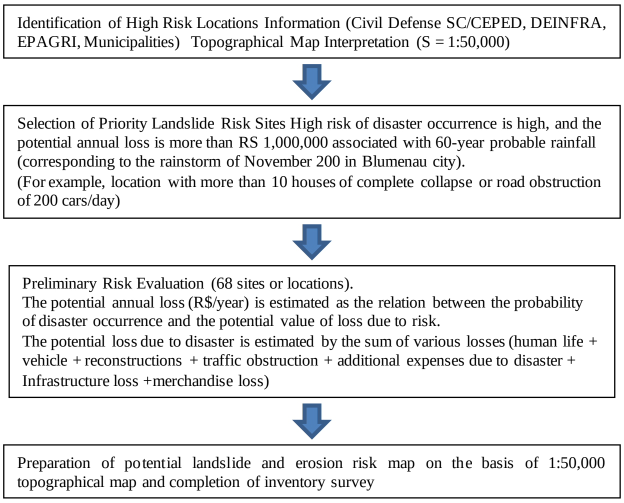
Survey Line No.	Municipality	Variation of the riverbed	Riverbed Variation + river bed aggradation - River bed lowering (m)	W (m)	Area change of upper end section of stretch (m^2)	Area change of lower end section of stretch (m^2)
IT16 a IT17	Gaspar	lowering	-0.8	220	235	128
IT17 a IT18			-1.0	225	235	235
IT18 a IT19			-0.7	208	37	235
IT19 a IT20		Slight lowering	-0.4	209	124	37
IT20 a IT21			-0.3	211	-6	124
IT21 a IT22			-0.1	257	39	-6
IT22 a IT23			-0.0	294	-18	39
IT23 a IT24	Blumenau		-0.2	256	130	-18
IT24 a IT25		lowering	-0.8	207	191	130
IT25 a IT26			-0.6	217	56	191
IT26 a IT27		Slight lowering	-0.3	216	73	56
IT27 a IT28		lowering	-0.6	170	139	73
IT28 a IT29			-0.7	159	99	139
IT29 a IT30		Slight lowering	-0.3	164	15	99
IT30 a IT31		Non variation	-0.0	177	-8	15
IT31 a IT32		Slight aggradation	+0,2	169	-44	-8
IT32 a IT33			+0.3	151	-35	-44
IT33 a IT34			+0.1	166	13	-35
IT34 a IT35		Non variation	0.0	188	-17	13
IT35 a IT36			0.0	203	28	-17
IT36 a IT37		Slight lowering	-0.1	191	-2	28
IT37 a IT38		Non variation	-0,0	159	10	-2
IT38 a IT39		Slight lowering	-0.2	170	48	10
IT39 a IT40			-0.3	221	100	48
IT40 a IT41		Non variation	-0.0	253	-79	100

Source: JICA Sourvey Team

3.4 Risk Assessment and Risk Mapping for Landslide and Sediment Discharge

3.4.1 Procedure of Risk Evaluation and Risk Mapping

The mapping and elevation of landslide risks is carried out according to the following procedure:



Identification of High Risk Locations Information (Civil Defense SC/CEPED, DEINFRA, EPAGRI, Municipalities) Topographical Map Interpretation (S = 1:50,000)

Selection of Priority Landslide Risk Sites High risk of disaster occurrence is high, and the potential annual loss is more than RS 1,000,000 associated with 60-year probable rainfall (corresponding to the rainstorm of November 200 in Blumenau city).

(For example, location with more than 10 houses of complete collapse or road obstruction of 200 cars/day)

Preliminary Risk Evaluation (68 sites or locations).

The potential annual loss (R$/year) is estimated as the relation between the probability of disaster occurrence and the potential value of loss due to risk.

The potential loss due to disaster is estimated by the sum of various losses (human life + vehicle + reconstructions + traffic obstruction + additional expenses due to disaster + Infrastructure loss +merchandise loss)

Preparation of potential landslide and erosion risk map on the basis of 1:50,000 topographical map and completion of inventory survey

Source: JICA Survey Team

Figure 3.4.1 Procedure of Evaluation and Mapping Landslide and Erosion Risks

Preparation of risk map is briefly described below and given in more detail in appendix report.

3.4.2 Identification of Potential Landslide Location

Potential landslide locations were identified as shown in Table 6.3.1, based on disaster records, site reconnaissance conducted in this study and topographical interpretations (1:50,000 topographical maps covering the study area, 1:25,000 topographical map of Ilhota city and aerial photos in 1978 and 1979). Totally 949 potential landslide locations were finally identified.

Table 3.4.1 Information Source of Landslide Disasters Records

Data source	Reports	Potential locations (949 sites)
Defesa Civil-CEPED	Response to the disaster occurred in Santa Catarina in 2008: evaluations during the disaster / University Center of Studies and Researches about Disasters,	932sites
Defesa Civil-CEPED	Disaster updated information added to the above-mentioned in Nonmember 2010	943sites
EPAGRI/CIRAM	COMPLEXO DO MORRO DO BAÙ Aerial survey of potential landslide areas	62sites
DEINFRA/DIOT	Landslide sites due to the rainstorm of November 2008	34 sites
JICA Survey Team (between April and November, 2008)	Site reconnaissance conducted in this study	68 sites

Source: JICA Survey Team

3.4.3 Selection of Priority Landslide Risk Site

A landslide site that has high potential of a landslide occurrence and damage of more than R$ one million potential annual loss at 60-year probable rainfall shall be selected as priority landslide risk site. The potential annual loss of over R$ one million as a rough guide is defined to be damage with complete collapse of more than 10 houses or complete closure of over 200 daily traffic volumes. Consequently, 68 priority landslide risk sites were selected for further study. They are 32 sites along SC State roads, 35 sites along the municipal roads city road, and 1 site around the Itajai port.

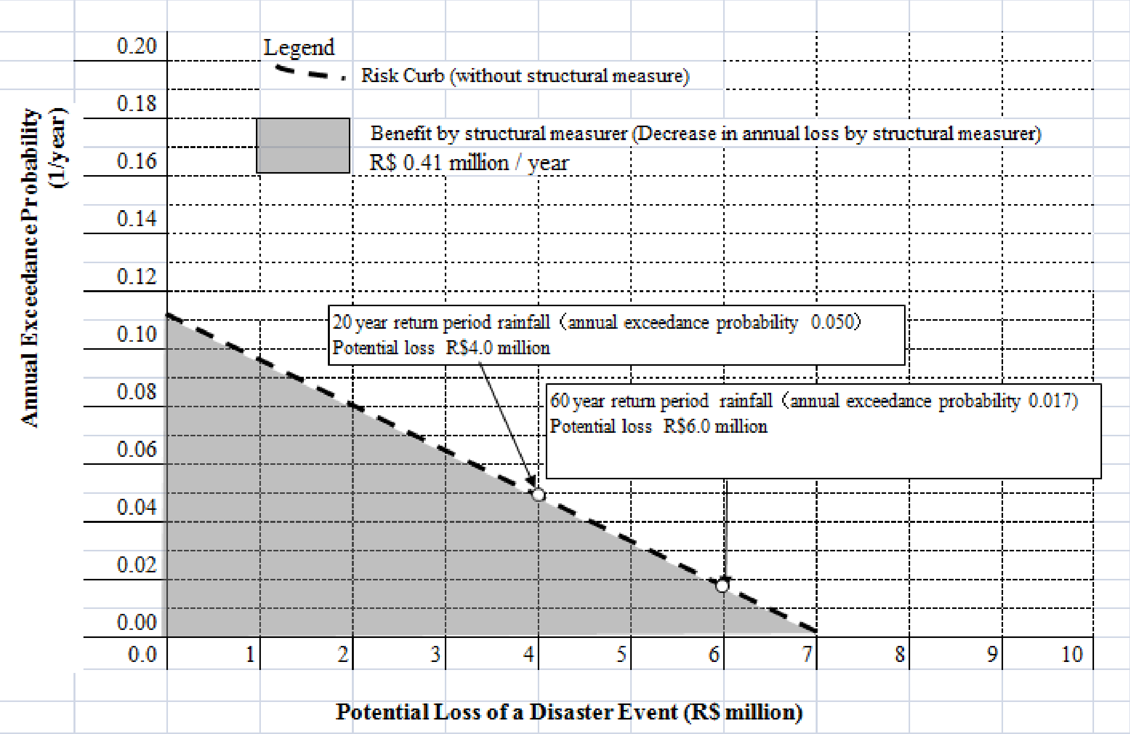
3.4.4 Calculation of Potential Annual Loss

For the selected 68 priority landslide risk sites, the risk was quantitatively evaluated in terms of potential annual loss. For the same landslide site, the scale of landslide disaster (sediment volume reaching target facilities, section length of affected roads, deposited sediment volume in port, etc.) depends upon the probability of landslide occurrence, scale of triggering factors such rainfall.

As shown in Figure 3.4.2, the potential annual loss (R$/year) calculated by using possibilities of non exceedance of landslide occurrences (vertical axis) and the potential loss (horizontal axis).

In the case of road damage, possibilities of non exceedance of landslide occurrences and the potential loss are first calculated and then the potential annual loss are done considering two kinds of damage scale, that is, complete closure and partial closure (one lane closure).

The possibility of non-exceedance of compete and partial closures was evaluated on the basis of the scale (volume) of landslide disaster similar to the rainstorm of November 2008, and the estimated probability of soil humidity index most close to landslide site. Calculation item and procedure are detailed in Appendix Report.



Source: JICA Survey Team

Figure 3.4.2 Risk Curve of Landslide Disaster and Example of Potential Annual Loss Calculation

The potential annual loss for the selected 68 priority landslide risk sites is shown in Table 6.3.2.

Table 3.4.2 Potential annual loss of the 68 priority landslide risk sites

Priority		South latitude			West longitude					Potential annual loss
	Location	G	M	S	G	M	S	SDR	City	R$ 10^3 / year
1	Itajai Port	26	53	56	48	40	7	Itajai	Itajai	9,000
2	SC 302 Taio-Passo Manso-5	27	1	45	50	8	18	Taio	Taio	1,255
3	SC470 Gaspar River Bank	26	55	2	48	58	37	Blumenau	Gaspar	1,095
4	Blumenau -Av Pres Casrelo Branco	26	55	7	49	3	58	Blumenau	Blumenau	1,021
5	SC418 Blumenau – Pomerode	26	51	32	49	9	18	Blumenau	Pomerode	989
6	SC474 Blumenau-Massaranduba 2	26	44	18	49	4	18	Blumenau	Blumenau	907
7	Gaspar - Luiz Alves, Gaspar 9	26	47	38	49	0	16	Blumenau	Gaspar	774
8	Gaspar - Luiz Alves, Luiz Alves 6	26	44	26	48	57	52	Blumenau	Luiz Alves	700
9	SC470 Gaspar Bypass	26	55	56	48	57	21	Blumenau	Gaspar	689
10	SC477 Benedito Novo – Dutor Pedrinho 1	26	46	50	49	25	6	Indaial	Benedito Novo	680
11	SC418 Pomerode - Jaraguá do Sul 1	26	40	29	49	8	35	Blumenau	Pomerode	651
12	Gaspar - Luiz Alves, Luiz Alves 4	26	46	38	48	59	31	Blumenau	Luiz Alves	629
13	SC474 Blumenau-Massaranduba 1	26	44	51	49	4	10	Blumenau	Blumenau	601
14	SC 302 Taio-Passo Manso 4	27	6	26	50	4	7	Taio	Taio	526
15	Gaspar - Luiz Alves, Luiz Alves 11	26	43	53	48	56	6	Blumenau	Luiz Alves	497
16	SC486 Brusque - Botuverá 13	27	10	41	49	2	5	Brusque	Botuverá	473
17	SC416 Timbó – Pomerode	26	45	32	49	13	52	Timbó	Timbó	443
18	SC486 Brusque - Botuverá 1	27	7	44	48	56	23	Brusque	Brusque	430
19	R. Alamedia Rio Branco, Blumenau	26	54	54	49	5	6	Blumenau	Blumenau	398

Priority		South latitude			West longitude					Potential annual loss
	Location	**G**	**M**	**S**	**G**	**M**	**S**	**SDR**	**City**	**R$ 10^3 / year**
20	Gaspar - Luiz Alves, Gaspar 2	26	48	59	49	1	11	Blumenau	Gaspar	384
21	Gaspar - Luiz Alves, Luiz Alves 7	26	44	13	48	57	22	Blumenau	Luiz Alves	380
22	Gaspar - Luiz Alves, Gaspar 1	26	49	5	49	1	9	Blumenau	Gaspar	379
23	Gaspar - Luiz Alves, Luiz Alves 3	26	46	54	48	59	41	Blumenau	Luiz Alves	372
24	Ponte Aldo P. de Andrade right bank	26	54	45	49	4	10	Blumenau	Blumenau	366
25	SC486 Brusque - Botuverá 3	27	9	5	48	58	50	Brusque	Brusque	344
26	SC486 Brusque - Botuverá 2	27	9	2	48	58	47	Brusque	Brusque	342
27	Gaspar - Luiz Alves, Gaspar 8	26	47	40	49	0	18	Blumenau	Gaspar	326
28	Gaspar - Luiz Alves, Gaspar 4	26	48	6	49	0	36	Blumenau	Gaspar	323
29	SC486 Brusque - Botuverá 9	27	9	31	48	59	24	Brusque	Botuverá	301
30	SC486 Brusque - Botuverá 7	27	9	20	48	59	10	Brusque	Brusque	298
31	Gaspar - Luiz Alves, Luiz Alves 2	26	46	57	48	59	42	Blumenau	Luiz Alves	278
32	Gaspar - Luiz Alves, Gaspar 7	26	47	48	49	0	20	Blumenau	Gaspar	276
33	Gaspar - Luiz Alves, Luiz Alves 1	26	47	10	48	59	47	Blumenau	Luiz Alves	271
34	Gaspar - Luiz Alves, Luiz Alves 5	26	45	3	48	58	34	Blumenau	Luiz Alves	271
35	Gaspar - Luiz Alves, Luiz Alves 8	26	44	4	48	56	56	Blumenau	Luiz Alves	270
36	SC486 Brusque - Botuverá 11	27	10	2	49	0	5	Brusque	Botuverá	260
37	SC486 Brusque - Botuverá 10	27	9	40	48	59	36	Brusque	Botuverá	260
38	Gaspar - Luiz Alves, Luiz Alves 10	26	44	1	48	56	30	Blumenau	Luiz Alves	227
39	SC486 Brusque - Botuverá 12	27	10	25	49	0	33	Brusque	Botuverá	221
40	SC486 Brusque - Botuverá 4	27	9	7	48	58	51	Brusque	Brusque	220
41	SC486 Brusque - Botuverá 6	27	9	18	48	59	7	Brusque	Brusque	220
42	SC486 Brusque - Botuverá 14	27	10	47	49	2	32	Brusque	Botuverá	220
43	SC486 Brusque - Botuverá 5	27	9	19	48	59	5	Brusque	Brusque	220
44	SC 302 Taio-Passo Manso 2	27	6	51	50	4	14	Taio	Taio	202
45	Gaspar - Luiz Alves, Gaspar 6	26	47	55	49	0	28	Blumenau	Gaspar	184
46	Gaspar - Luiz Alves, Gaspar 10	26	47	38	49	0	11	Blumenau	Gaspar	184
47	SC418 Pomerode - Jaraguá do Sul 2	26	39	38	49	8	39	Blumenau	Pomerode	184
48	Gaspar - Luiz Alves, Luiz Alves 12	26	43	45	48	55	58	Blumenau	Luiz Alves	184
49	Gaspar - Luiz Alves, Gaspar 3	26	48	42	49	1	5	Blumenau	Gaspar	184
50	SC413 Luiz Alves -Massaranduba 1	26	43	12	48	56	31	Blumenau	Luiz Alves	172
51	Gaspar - Blumenau 3	26	53	34	49	0	43	Blumenau	Gaspar	169
52	SC486 Brusque - Botuverá 8	27	9	25	48	59	16	Brusque	Botuverá	151
53	SC 302 Taio-Passo Manso 1	27	6	53	50	4	14	Taio	Taio	149
54	SC 302 Taio-Passo Manso 3	27	6	50	50	4	14	Taio	Taio	149
55	SC477 Benedito Novo – Dutor Pedrinho 2	26	46	3	49	26	13	Timbó	Benedito Novo	144
56	R. Bruno Hering, Blumenau	26	55	17	49	3	46	Blumenau	Blumenau	119
57	Gaspar - Luiz Alves, Luiz Alves 9	26	44	1	48	56	44	Blumenau	Luiz Alves	111
58	SC477 Benedito Novo – Dutor Pedrinho 3	26	47	3	49	21	54	Timbó	Benedito Novo	108
59	Gaspar - Luiz Alves, Gaspar 5	26	48	1	49	0	33	Blumenau	Gaspar	106
60	Bau	26	47	22	48	56	41	Blumenau	Ilhota	101
61	SC486 Brusque - Botuverá 15	27	9	46	48	59	45	Brusque	Brusque	78
62	Luiz Alves Municipality Road 1	26	43	33	48	57	31	Blumenau	Luiz Alves	67
63	SC413 Luiz Alves -Massaranduba 2	26	42	54	48	56	55	Blumenau	Luiz Alves	62
64	Luiz Alves Municipality Road 2	26	45	48	48	59	2	Blumenau	Luiz Alves	59
65	Brusque Municipality Road 1	27	7	43	48	53	53	Brusque	Brusque	56
66	Gaspar - Blumenau 2	26	53	48	49	2	19	Blumenau	Blumenau	55
67	Gaspar - Blumenau 1	26	53	42	49	2	20	Blumenau	Blumenau	55
68	Brusque Municipality Road 2	27	7	16	48	52	7	Brusque	Brusque	51

Source: JICA Survey Team

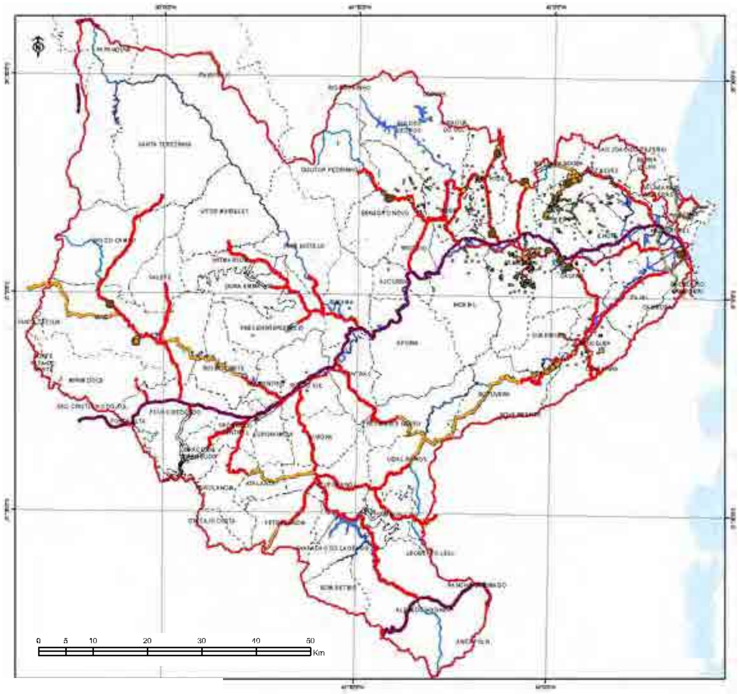
3.4.2 Risk mapping

Figure 3.4.3 shows the distribution of the priority landslide risk sites with different levels of the potential annual loss. F-6.3.4 gives an example of priority landslide risk maps. The base map is composed of 239 sheets with 1:30,000 Itajai topographical maps in A3 size. Each site has GIS information as listed below.

Table 3.4.3 Inventory Item of Landslide Risk Site

Regional number of landslide risk site (Map code + Serial number)
Location (longitude of latitude of central point of the target site)
SDR/Municipality
Type of Movement
Risk Area (Fall, Collapse, Movement, Runoff of mud, etc.)
Type of Geology, Soil, Vegetation
Classification of Elevations, Gradients

Source: JICA Survey Team



LEGENDA	Legend
Rodovias	**Road**
Federal Pavimentada, Duplicada	Federal paved roads, two lanes each way
Federal Pavimentada	Federal paved roads
Estadual Pavimentada, Duplicada	State paved roads, two lanes each way
Estadual Pavimentada	State paved road
Estadual em Pavimentação	State unpaved roads grave base
Estadual Leito Natural	State unpaved roads natural
Municipal Pavimentada	Municipality paved roads
Municipal Solo Natural	Municipality unpaved roads
Limites	**Boundary**
Bacia do Rio Itajaí	Itajai Basin
Municipios	Municipality
Hidrografia	Drainage
Massas de Água	Basin
Riscos (Perda de Potencial)	**Risk（Potential annual loss）**
● Baixo	Low level (less than 50,000 R$/year）
● Medio	Medium level （50,000～500,000 R$/year）
● Alto	High level (over 500,000 R$/year)

Source: JICA Survey Team

Figure 3.4.3 Maps of Priority Landslide Risk Site with Different Level of Potential Annual Loss

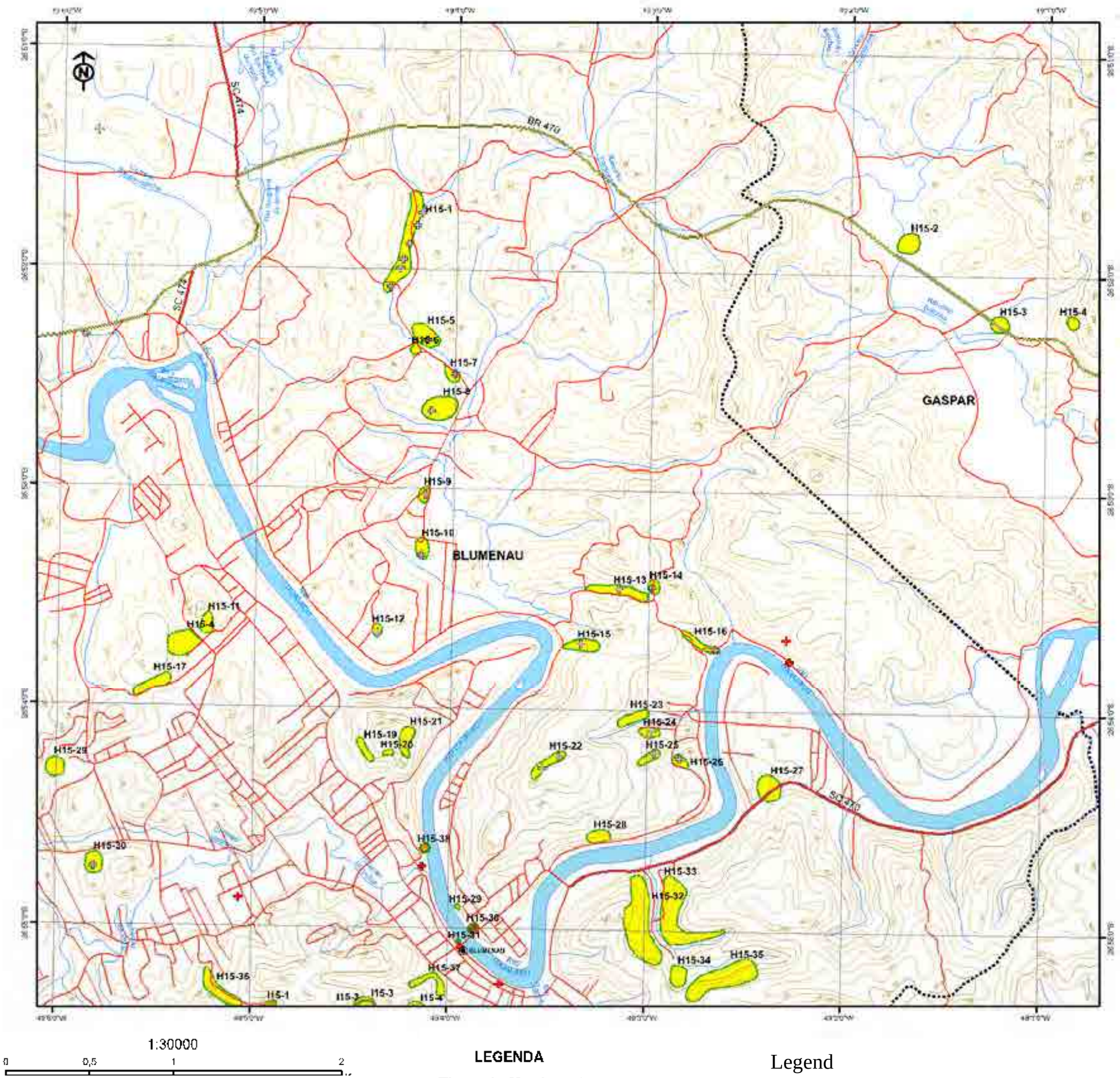
Table 3.4.2 Type of Movement of Landslides

Tipo de Movimento	NORMA BRASILEIRA ABNT (Associação Brasileira de Normas Técnicas) NBR (Número de referencia) 11682, Estabilidade de encostas @ABNT 2009	
	Terminologia dos tipos de movimento de massa Terminology of typys of movement of mass	Definision
Collapse (Desmoronamento) Fall/Rotation (Queda/ Rolamento) Gaspar 2008 	Fall/Rotation (Queda/ Rolamento)	Detachment of fragments of land of any size, falling from a height, in freefall, or any other type of motion and trajectory. (Desprendimento de fragmentos do terreno, de qualquer tamanho, que caem de certa altura, em queda livre ou com qualquer outra trajetória e tipo de movimento)
 Tombamento Luiz Alves 2010	Toppling (Tombamento)	Mass movement in the form of stumbling over that centers on base. (Movimento de massa em forma de báscula com eixo na base)
Escorregamento  Pomerode 2010	Landslide (Escorregamento)	Mass movement by movement on one or more surfaces. (Movimento de massa por deslocamento sobre uma ou mais superfícies)
 Escoamento Benedito Novo 2008	Flow (Escoamento)	Mass movement with fluid properties, slow or fast (running) (Movimento de massa com propriedades de fluido, lento ou rápido (corrida))

Fonte: Equipe de Estudos da JICA

In this study, the flow of more than 90% of water contents by volume is referred to as flash flood.

The priority locations identified which require measures are in number 68, being located on State Road 32 and 35 sites located in the municipal roads and the Port of Itajai.



Legend
Type of movement (possibility of damage)
Collapse
Collapse（Low）
Collapse（High）
Slide
Scarp（Low）
Scarp（High）
Displaced material（Low）
Displaced material（High）
Flow
Flow（Low）
Flow（High）
Risk（Potential annual loss）
Small（Less than 50,000 R$/year）
Medium（50,000 – 500,000 R$/year）
Large（Over 500,000 R$/year）
Priority landslide risk site
CEPED/Defesa Civil
Epagri/Ciram
JICA

Source: JICA Survey Team

Figure 3.4.4 Example of Priority Landslide Risk Mapping

CHAPTER 4 NEEDS AND BASIC POLICY FOR FORMULATION OF THE MASTER PLAN FOR LANDSLIDE MANAGEMENT

4.1 Principles and approach

4.1.1 Principle

In the formulation of the Master Plan for measures of landslide/sediment discharge/flash flood, three basic principles are considered:

(1) Installation of structural and non-structural measures;

Both of structural and non-structural measures are installed.

(2) Attentions given to genders and vulnerable persons for disasters;

Take care that benefit shall be equal opportunity for different social groups when studying disaster measures.

(3) Disaster measures for landslide disaster prevention from the global point of view with attention given to the natural and social environment;

The master plan of the disaster measures shall formulate to considering following view points

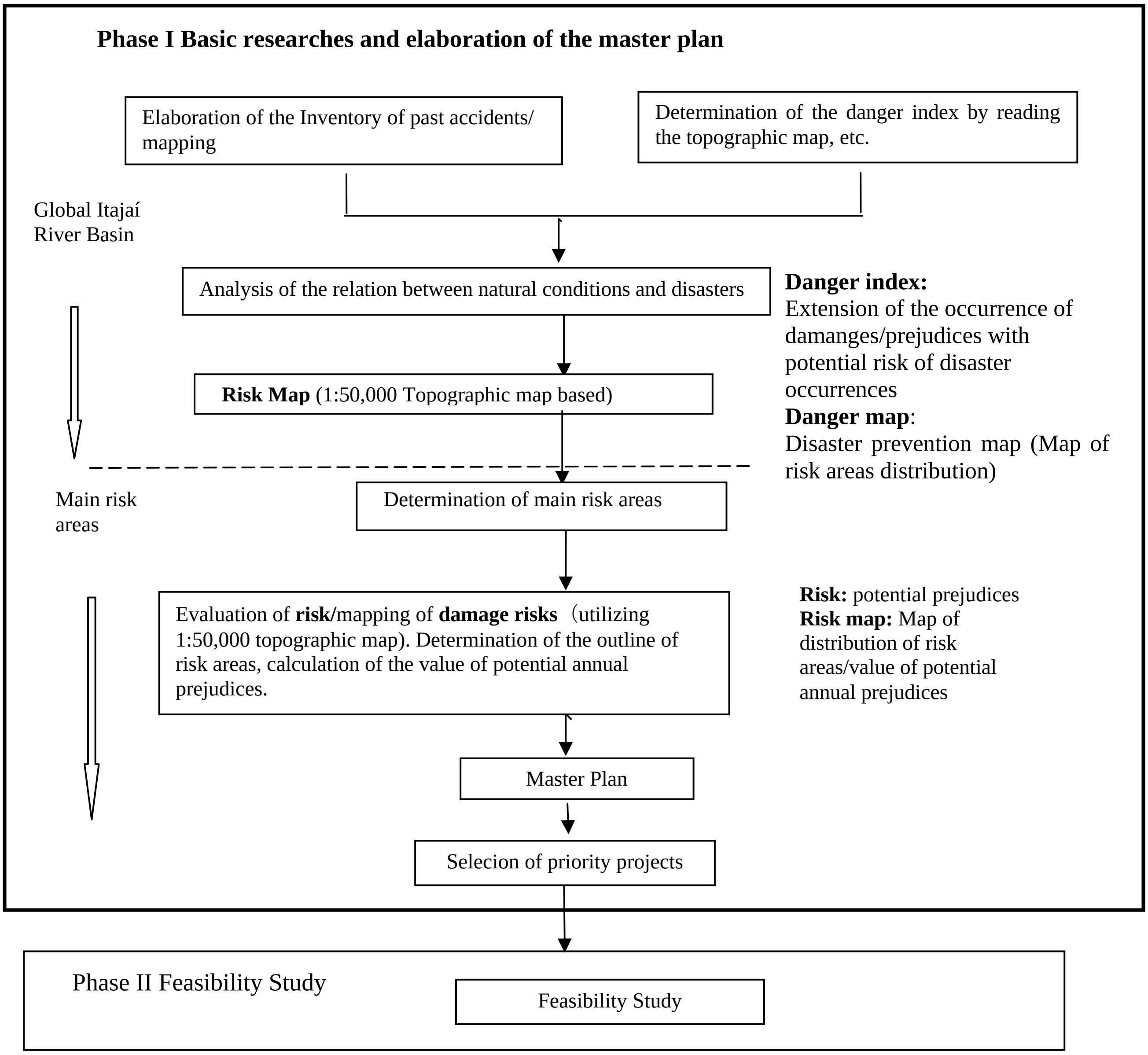
- Reducing the regional inequality of benefit and damages, as much as possible
- Maximizing the benefit of the whole Itajai River Basin.
- Taking care with the natural and social environment.

4.1.2 Approach

Figure 4.1.1 shows the flow of the study on measures for landslide/sediment discharge/

4.2 Needs related to the Mitigation of landslides.

Table 4.2.1 shows opinions of related entities about measures against landslide. We understand that residential zones are expanding towards hills, either to escape from inundation, or due to the population growth, thus increasing landslides. In places affected by landslide, there is the understanding that there are human factors, such as construction of residences in an irregular manner (cutting steep hills, living in floodable areas, poor drainage of water, etc.). The Civil Defenses of municipalities are requesting technical support and training about the manner to control landslides. The State Civil Defense and other entities also have similar opinions. DEINFRA understands that it is necessary to implement landslide preventive maintenance projects in state and municipal roads, as structural measures.



Source: JICA Study Team

Figure 4.2.1 Flow of the landslide disaster study

Table 4.2.1 Opinions and needs of related bodies about landslides

Control Bodies	Summary of opinions
（DNIT） National Department of Transports Infrastructure	• Regarding the federal highway BR-470, they think there is no need of landslide preventive maintenance (Rio do Sul administration office). • Regarding the federal highway BR282, administered by the federal government, they think there is no need of landslide preventive maintenance. BR-101, crossing the coast, in the Itajaí River Basin stretch, is privatized (office in Santa Catarina).
DEINFRA	• Supports the reconstruction of state and municipal roads affected by landslides. • There are many ways and points that need landslide preventive maintenance. • They have never executed a landslide preventive maintenance project in roads, and do not know how to plan it. • They would like to take part in the JICA preparatory study as a counterpart, to learn how to

	plan and to elaborate the landslide preventive maintenance project in roads. • As during the recuperation from 2008 disaster, the government of Santa Catarina State decided to include municipal roads as government works, it is possible that JICA support project might become a state government work (under the responsibility of DEINFRA), even being a preventive maintenance work of municipalities.
Civil Defense - SC	• The problem is the lack of geology specialists. In terms of training technicians, it should also be necessary in the fields of information and public health. • The irregular construction of residences in risk areas and the disagreements among provisions about land use in federal, state and municipal laws are increasing disasters. Currently, the landslide alert is given when rainfall reaches 200 mm/day, based on the CIRAM forecast. • Information from the National Institute of Spatial Researchers is not utilized. • It would be ideal to install automatic rainfall stations in each municipality to issue alerts about landslide, but they believe it is necessary to provide training to the Civil Defenses of municipalities. • The installation of automatic rainfall stations in the municipalities will be done with IDB funds, Program 5 (road improvement), and shall include 293 municipalities in the whole State of Santa Catarina. • It is desirable that structural measures are cheap.
UFSC (Federal University of Santa Catarina) CEPED	• Upon request from Santa Catarina Civil Defense Secretariat, the University is dispatching geology and civil engineering specialists to affected places for research purposes. • They will provide the most available information for JICA study. • They have proposed to Santa Catarina government to study the outsourcing of urban disaster prevention planning, but this was not accepted.
CIRAM	• It would be ideal if structural works were cheap, in view of the current situation of Brazil (director). • They are conducting a study to verify the inundation and landslide risk having as indicator the volume of rainfall at each three days.
Control Bodies	**Summary of opinions**
FURB CEOPS	• It is not providing landslide forecast or alert. • There is automatic rainfall station in 16 points of the Basin, which are owned by the Sustainable Development Secretariat, controlled by FURB, and storage the rainfall volume records of 15 minutes. • They consider necessary to implement the landslide forecast and alert system. • The Civil Defense Secretariats of municipalities, except for Blumenau, are little organized, and even if they install an automatic rainfall station in each municipality, it is unknown if they will be able to maintain and utilize them. • They have already conducted the study of the relation between landslide and rainfall volume, having as indicator the daily volume and the seven-day volume. The correlation was not good. • They would like to develop a model-project for structural measures against landslide of the steep hill beside the New Market gallery, in the urban zone of Blumenau. They would like to include from research and analysis to project and execution of structural works. They request the cooperation from Japan.
CPRM	• It will be necessary to update the disasters map done by the municipalities. • It will be necessary to deepen geologic and soil studies.
FATMA	• In 2002, the concept that hill with gradient above 45^{o} and the top of mountains (upper 1/3) are APP (Permanent Protection Area) was defined. There is no disagreement between federal and state laws. • Basically, constructions are not allowed in APP areas, but if they are public works, such as disaster prevention works, they shall be allowed.

State Planning Secretariat Urban Development Department	• The authorization for residential undertakings is provided by the municipality, for state, municipality or private works, but the environmental preservation control is conducted by FATMA. • They understand that it is necessary to take care to avoid new problems in the hills with the creation of new residential areas, and that the rainfall volume increase might increase inundation, being necessary to create rules to install torrent retention means in Itajaí River Basin, where there are flood problems. • Currently, there are no plans of new undertakings in the state sphere. • The Regional Development Secretariat (SDR) prioritizes the development, but the bottleneck is the lack of concern about natural disasters. In the regional development zoning, in general, the Regional Development Secretariat and the municipalities, which are developmentists, and the State, which is preservationist, have divergent opinions, with need to reach an agreement to solve the issue.
COHAB/SC	• In general, new housing undertakings are carried out as local government works in the municipalities that have engineers, such as Brusque and Rio do Sul, and as State works, in other municipalities. • The authorization for state works project, in the technical aspect, is provided by COHAB (in case of the municipality project, by the chief of the sector in charge for the project in the municipality). • The final authorization for the work execution is provided by the local mayor. • The environmental appraisal is done by FATMA. • They believe that the need of new housing undertakings in Itajaí River Basin is higher in the municipality of Blumenau. • In case of executing the works with Japanese loan, the execution of the work might be done by the municipality of Blumenau, which has a high technical level.
CREA	The Prefectures do not have resources for the adoption of landslide prevention structural measures in private residences, therefore, almost nothing was done about the landslides occurrences in the 2008 rainfall. With the partnerships between the Prefecture, CPRM and CREA, recuperation works in landslide areas of private residences are being done, optimizing the funds from private mining companies.

Source: JICA Study Team

In Table 4.2.2, the opinions and needs of each municipality regarding landslides are shown. The municipality of Blumenau is elaborating the landslide disaster map. In other municipalities, the geotechnical research with the exploration of each one of the locations affected by activated landslide, etc., is being conducted by university bodies such as CEPED, dispatched by Civil Defense/SC;

In the site of the landslide activated in August 2010, in the municipality of Pomerode, the landowner was making arrangements to do drains and civil works utilizing heavy machinery. In the municipality of Itajaí, there was a case of hillside cut and drain construction conducted as landslide prevention measure in residential areas, by initiative of the municipality. In the municipality of Benedito Novo, the erosion prevention work using *Petibá* grass is being conducted, under DEINFRA guidance. Both are relatively simple things, but the effect is also limited.

The municipalities mention the need to implement landslide prevention measures in roads of access to the water reservoir, and landslide prevention measures in residential areas.

Table 4.2.2 - Opinions and needs of each municipality regarding landslides

Control Bodies	Summary of opinions
Civil Defense of all municipalities	There is no landslide forecast and alert system. As for structural measures, they would like them to be done as State works.
Blumenau	There is the landslide fight manual, unified with the inundation one. The landslide risk map can be done in the webpage. The detailed research is ongoing (satellite images analysis + exploration). They have hope in the technical support from Japan. In landslide risk areas, there are various irregular residences. Even if they guide people to move from there, other persons come to live in the same place.
Gaspar	They have a map of places affected by November 2008 rainfall. They don´t know how to face landslides.
Ilhota	All cases of death resulting from November 2008 rainfall were caused by landslides in the Baú hill region. After the 2008 disaster, they are providing psychological counseling to the affected people. By suggestion of the psychologist, a leader was chosen for the community disaster prevention and the information network was formatted.
Luis Alves	The Gaspar/Blumenau road or the road connecting to Massaranduba is fragile, being necessary to adopt measures against landslide in these stretches. There is a concern about the collapse of the road connecting to the reservoir of piped water of the municipality.
Brusque	There are landslide problems in new residential undertakings also, and in some sites the work was interrupted.
Rio do Sul	They do not have knowhow of landslide fighting. They would like to make a course to lean with Japan.
Benedito Novo	They are trying to prevent erosion using *Petibá* grass (DEINFRA guidance). They don´t know how to deal with the landslide problem behind the prefecture building, which has a deep landslide face.
Timbó	There is lack of communication between the Civil Defense of municipalities.
Itajaí	In the municipality, there are many landslide risk areas. Some have developed fissure and high risk degree. Some of the existing measures (切土) are changed, perhaps due to lack of drain.
Rio dos Cedros	In November 2008, the river was blocked by landslide, creating a temporary natural reservoir. If this happens again, inundation might occur as the result of the breaking of the natural reservoir.
Pomerode	There is a landslide that appeared with the 2008 rainfall and was reactivated at the end of August 2010. The landowner built a superficial mortar drain, traditional drain made of intertwined bamboo and excavation with heavy machinery to change the direction of the landslide. He was helped by the research of CEPED.

Source: JICA Study Team

4.3 Basic policy for Landslide Management

4.3.1 General

In view of the basic principle of reducing at the most the distribution of facilities and losses among regions, and of maximizing the infrastructures of Itajaí River Basin as a whole, the fact is that this is the basin with the higher frequency of landslide occurrences in Santa Catarina, which risk extends to all the municipalities of the basin, and as the municipalities´ need there is the following basic policy:

- As non-structural measure, installation of the landslide forecast and alert system that encompasses the whole State of Santa Catarina.
- As structural measures, regarding the main infrastructure, the evaluation of risk of landslide risk points is done = the potential annual prejudice amount is calculated, and the priority projects are selected through the criterium of higher potential annual prejudice amount, also evaluating if its appropriate to select them as target projects for loan.
- The points of landslide risk in urban zones and in the locations of new housing undertakings of prefectures and of the State government will also be selected by the criterium of higher potential annual prejudice amount, being implemented as model undertaking of the municipality or of the state.

4.3.2 Non-structural measures

As non-structural measures, the landslide forecast and alert system using the "soil humidity indicator" will be installed.

(1) Objective of the landslide forecast and alert system:

Avoid human prejudices resulting from landsides.

(2) Scope of application of the landslide forecast and alert system:

It will encompass the whole State of Santa Catarina, utilizing automatic rainfall stations that will be provided to the 293 municipalities of the State, one for each municipality, so that facilities are enjoyed by the residents of all municipalities of Santa Catarina, and also by tourists going there.

(3) General information about the landslide forecast and alert system

The employees of the Civil Defense will monitor the automatic rainfall station and inform the mayor when the pre-defined rainfall index is reached. The mayor will issue the landslide alert to the municipal residents. The Civil Defense-SC will transmit the landslide information through radio and TV, and warning boards that DEINFRA will install in state roads. The residents and tourists can avoid going to school or to work, or to travel, in view of the landslide alert, and take refuge going through predetermined escape ways to determined locations (schools, churches, etc.) to protect themselves.

The storage of rainfall data and the establishment/updating of reference value for landslide alert will be done by CIRAM.

(2) Points of the landslide forecast and alert system that require attention:

Basically, the system will transmit information via common internet, and shall have low installation cost and facility of maintenance and control.

It shall be unified with the alert and evacuation transmission media of the inundation forecast and alert system.

The warning boards installed by DEINFRA in state roads shall provide, in addition to the disaster prevention alert, traffic safety information, information about works in the roads and traffic jams, and even during normality, provide facilities.

4.3.3 Structural Measures

(1) Selection of priority points for implementation of structural measures.

Priority points for the implementation of structural measures will be selected among various landslide risk areas, through the criteria of higher risk and equal benefits provided.

The risk/potential annual prejudice amount rate will be calculated in landslide risk points, in which the focus will be the main infrastructure and the urban zone, prioritizing the point with the higher score.

As the points related to the main infrastructure have higher public value, they will be selected as loan target projects.

As for structural measures of landslide risk points regarding the urban zone or new residential undertakings, model projects will be selected through the criteria of higher potential annual prejudice amount, studying the possibility of technical cooperation on the account of financing to structural measures.

(2) Project of structural measures related to the main infrastructure:

In federal roads BR470 and BR282, landslide preventive maintenance works were already executed, having low risk. DNIT also consider not necessary to execute new landslide preventive maintenance works.

In State roads, the landslide preventive maintenance works are still insufficient, with the existence of several landslide risk points. DEINFRA has also suggested the need of structural measures for landslide risk points. Concerning municipal roads, the need of structural measures for landslide risk points for the municipalities of Gaspar, Luis Alves and Brusque was suggested. After calculating the potential annual prejudice amount of these points, the priority points shall be selected to receive structural measures. Considering that the potential annual prejudice value reflects the importance of the road, a weighting factor shall not be applied for the fact that the road is state or municipal in the selection of priority points to receive structural measures. Even being a municipal road, the work might be executed as a project of the State, if the approval of the State House of Representatives is obtained, considering the background of the recuperation works of the 2008 catastrophe.

(3) Project of structural measures related to urban zones

In the municipalities of Rio do Sul, Benedito Novo and Blumenau there are active landslides related to the residential zone. In all the cases, the groundwater elimination work seems to be effective. In all municipalities, there is the landslide and land flow risk related to residential areas. Since in all of them the benefit is local and does not equitably cover the whole basin, it will not be included in the loan project or in the project object of the feasibility study.

CEOPS/FURB wishes the execution of the study, risk evaluation and model project of structural measures in the hill beside the New Market, one of the landslide risk points of the municipality of Blumenau. Concerning the structural measures against landslide in urban areas, the selection of higher risk areas as model project and technical cooperation on the account of the financing are proposed. The technical support shall include, study, planning of structural measures, evaluation of reasonability, in addition to the project and control of works execution.

(4) Project of structural measures against disasters related to new housing undertakings

There are cases of housing and industrial undertakings that are creating new landslide problems. It is necessary to enhance the technical standards regarding earthworks in steep land and, when executing the work, utilize open or close drains and a mean to regulate the water flow, to retain the torrent and also to contribute to fight inundation. The proposal is to select as model-project the higher risk areas among the ongoing or future undertakings, providing them with technical cooperation on the account of the financing. The technical support shall include study, evaluation of the land appropriateness for the undertaking, planning of structural measures, project and control of works execution.

CHAPTER 5 MASTER PLAN OF LANDSLIDE MANAGEMENT

5.1 Contents of Master Plan

Table 5.1.1 shows the contents of master plan to mitigate landslide, sediment yield, and flash floods. The master plan is consisted of the following two components; non-structural measures for landslide and flash flood and structural measures for landslide.

Table 5.1.1 Contents of Master Plan to Mitigate Landslide, Sediment Yield, and Flash Flood

Purpose	Measures	Description in the Master Plan
Avoidance of human lives loss	(1) Non-structural measures (Implementation of early warning systems for landslide and flash flood) a) Formulation of system for monitoring/repository of rainfall data and communication of warning information. b) Disaster education and drills to the persons in charge and residents for reliable evacuation.	Plan including cost estimation is prepared as a main measure project.
Reducing economic losses	(2) Structural measures for landslide Structural measures will be implemented from the priority sites which have high potential annual loss.	
	(3) Mitigation of sediment yield. Forestation of bare collapsed land, prevention of river-bank erosion by river bank forest will be promoted. Prevention of sediment yield will be secured by vegetation at structural measures sites for landslide.	Detailed plan is not formulated in the master plan; the issues are treated in watershed/ forest conservation plans.
	(4) Mitigation of flash flood Installation of discharge regulation facilities for rainfall runoff will be promoted in order to mitigate floods and flash floods.	Detailed plan is not formulated in the master plan; the issues are treated in regional planning.
	(5) Capacity building for structural measure and support for private self -reliant effort a) Capacity building for structural measure project b) Support for private self –reliant effort Disaster education and subsidy of official/private fund will be promoted for private sectors in order to reduce damage of private preservation objects which have low priority and potential annual losses.	The master plan describes necessity as political policy.

Source: JICA Survey Team

5.2 Non-structural Measures (Mitigation Plan of Landslide/Flash Flood)

5.2.1 Formulation of System for Monitoring/Repository of Rainfall Data and Communication of Warning Information

(1) Adaptation to the Whole SC State as Main Measure Project.

Non-structural measures will be installed to the whole SC State as a main measure project, because it is more practical than relocation from risk area. The reasons of installation to the whole SC state are follows;

i) Benefits by reduction of human lives losses are maximized in the whole SC State.

ii) Reducing human lives losses of travelers inside and outside of Itajai River basin in SC State.

iii) In case of Municipalities whose territories are extended both of inside/outside of Itajai River basin, the citizens are equally benefited both of residents living inside/outside of the

Itajai River basin.

(2) General and Monitoring of Rainfall

Early warning systems for landslide disaster and flash flood, which is described in section 9.2.3, will be implemented as follows;

Defesa Civil -SC conduct general management and official issue of the early warning.

Municipality governments order evacuation for residents and traffic regulation of municipality roads.

DEINFRA orders traffic regulation of SC state road.

SDRs order temporarily closed class, going-home, or staying at schools to school kids/students under the supervision of SDRs in case of attention/alert issue.

Firstly the early warning (information calling for attention) by rainfall index will be set as the kick off to increase awareness of disaster, secondary designation of houses for evacuation and roads for traffic regulation corresponding to warning, as shown in Figure 5.2.1.

Short Term

Setting of the early warning by rainfall index.

Municipality government promoted that self reliance evacuation of residents of risk areas in case of alert announcement, utilizing risk/hazard map which are prepared by this survey.

Municipality government inform the early warning and call for attention. When disaster phenomena progressing are recognized, they order evacuation and/or traffic regulation of road sections.

DEINFRA call for attention by utilizing the road information board along SC sate roads. When disaster phenomena progressing are recognized, DEINFRA order the traffic regulation of state road sections.

SDRs order temporarily closed class, going-home, or staying at schools school kids/students under the supervision of SDRs, in case of attention/alert announcement.

↓

Medium/Long Term Development (stepwise development in five to ten years)

Municipality government will prepare hazard maps of S=1:10,000, designate/inform risk areas/houses shall be evacuated when alert is issued, evacuation building, evacuation routes. Municipality also will designate disaster prone road sections of municipality roads which shall be ordered traffic regulation when alert is issued.

DEINFRA will designate disaster prone road sections of SC state roads which shall be ordered traffic regulation when alert is issued.

Municipality government/DEINFRA order traffic regulation when Defesa Civil-SC issue alert.

Source: JICA Survey Team

Figure 5.2.1 Instrument of Early Warning System of Landslide/Flash Flood and Stepwise Development

A automatic rain gauge will be installed to either municipality hall, Defesa Civil-municipality office, or office of CELESC. The gauges should be supplied by solar power in order not to lack of measuring data. The data will be transmitted to the data server of EPAGRI/CIRAM through GPRS (General Packet Ration Service) and VHS communication system of CELESC.

To avoid data lack due to transmission error of GPRS, the staffs of Defesa Civil- municipality should download the data from data logger and save to the computer once a week.

EPAGRI/CIRAM will calculate rainfall index criteria based on the exact data and forecasted data by WRF (Weather Research and Forecasting) model. When the rainfall is exceed to the rainfall index criteria, EPAGRI/CIRAM will announce through media and web sites and inform to Defesa Civil-SC, each SDR, Municipality. SDR announce attention/ alert to each school in the area, and Municipality government announce attention/ alert to the residents and travelers. Each municipality and DEINFRA announce early warning information by such as information boards along SC road and prepare for disaster.

(3) Setting of Attention/ Alert index criteria for Landslide and Flash Flood

Attention/ Alert index criteria will be decided based on a soil water index which is used in Japan and rainfall index which is studied by IPT (Instituto de Pesquisas Tecnológicas) in Sao Paulo State University. It is difficult to decide rainfall index criteria from the result of statistical analysis of rainfall index which is recorded at disaster occurrences, because there are no exact times of landslide and flash flood occurrence, and location of rainfall gauges are generally apart from disaster-occurrence points more than 10km.

Therefore an alert index is decided based on heavy rain of 10-year return period. Because, in Japan, 93 percent of landslide disaster mortality are happened under the conditions by maximum rainfall index in 10-years (based on 1991-2000 disaster occurrence excluding rock fall and disaster in construction sites).

While an attention index is decided based on heavy rain of 1.1-year return period for the purpose of preparation for state of alert, recognition for residents and training for the staffs.

The index criteria for attention/alert should be verified and revised by EPAGRI/CIRAM on every June (minimum rainfall month), based on accumulated rainfall and disaster occurrence data.

(4) Calculation of rainfall data and rainfall index, and issue/ announcement of attention/ alert

EPAGRI/CIRAM will estimate three-hour-later rainfall index by calculating current rainfall data and WRF data every 20 minutes. When the data is over rainfall index criteria, EPAGRI/CIRAM will announce by Internet and public media, such as television and radio. They should also report to the Mayor, Defesa-civil of related municipalities and Defesa civil-SC. The communication should be automatically conducted by text mail to mobile phone which previously registered by computer system.

Defesa Civil -SC will conduct official issue of attention/alert, announcement to corresponding municipalities, preparation for disaster.

Municipality government/Mayor will announce attention/alert to the residents by bulletin boards, telephone networks, church bells, and public relation vehicle, and call out staff for emergency. The method of information communication is as same as that of early warning system for floods).

Defesa Civil-SC, cooperation with DEINFRA and Municipalities, should announce attentions/ alerts to the target areas by advertising boards or bulletin boards at the major points of roadsides, and drive-inns in order to give information to the drivers. Commercial advertisement boards are effective for using as bulletin boards for attention/alert, by admitting from owners for emergency use. In case electric bulletin board, the boards are normally used for commercial advertisement or ordinary news, and are utilized for announcing attentions/alerts also.

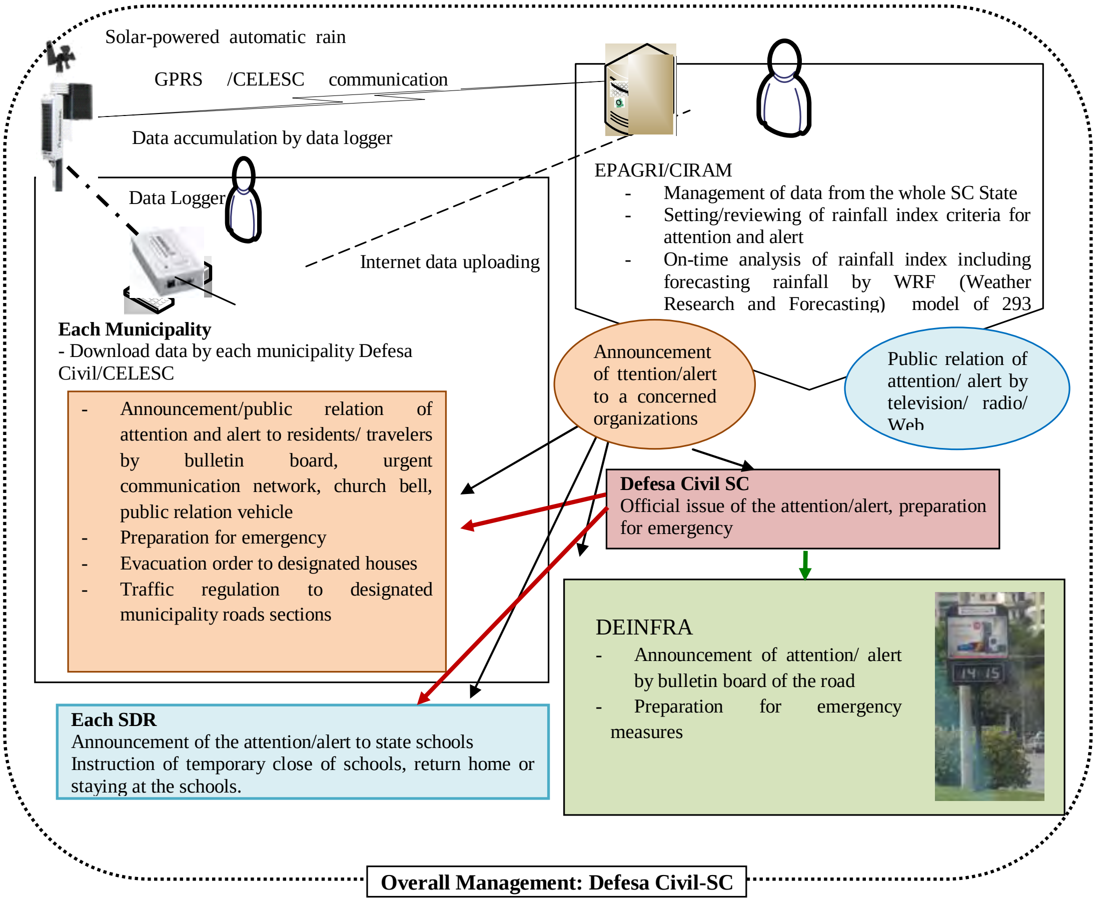
(5) Disaster Avoidance Activities

When attention is issued;

- SDR closes all state schools temporally and informs the students not to come to the schools. If the students are in the schools, instruct them to come back (or keep staying at the schools by situation). SDR also instructs all the offices to follow those actions.
- Road users hold back usage of roads in attention-issued areas by considering the attention.

When alert is issued;

- The residents, who live in risk areas which are designated in hazard maps, evacuate to designated evacuation sites (schools or churches) by designated evacuation routes.
- The Municipality and DEINFRA will order road traffic regulation of designated disaster-prone road sections in alert-issued areas when the alert is issued by Defesa Civil - SC.



Source: JICA Survey Team

Figure 5.2.2 Schematic Diagram for Early Warning System of Landslide and Flash Flood

5.2.2 Disaster Education and Evacuation Drills to the Persons Concerned and Residents

Defesa Civil of each municipality should give disaster education and evacuation drills to the persons concerned and residents to verify evacuation and communication of disaster information. Defesa Civil-SC should conduct disaster-related training to the staffs of Defesa Civil of each municipality.

The municipality should prepare a hazard map of S=1:10000 with the support of SC State and university. The hazard map contains risk sites, desirable evacuation routes and sites. After the hazard map is prepared and distributed, the municipality explains the contents of hazard map to the citizens and/or conducts fire drills to the residents who is living in a risk area.

The mayor orders to Defesa-Civil, firehouse and police to prepare evacuation sites for further alert state, announces to the residents and conduct patrols to the risk areas when the attention is issued. It is recommended for resident to evacuate to the evacuation sites as a evacuation drill even it is not a level for evacuation.

Teachers in state schools should order school kids/students to stay or return home and safety rout for return home depend on the safety of their homes. In case of staying, disaster education should be conducted to the school kids/students with hazard map and photographs of past disasters.

5.3 Structural Measures for Landslide

5.3.1 Priority and Plan of Structural Measures for Landslide

Structural measures will be conducted from priority sites which have higher potential annual loss, in order to prevent economic loss to be caused by landslide disasters.

Sixty-seven sites are selected as prioritized structural measure sites out of sixty-eight high risk sites excluding Itajai Port where continuous dredging might be appropriate. They are selected by landslide/sediment yield risk assessment and evaluated more than R$ 50,000 per year of potential annual loss. The risk sites selected are 33 state roads and 34 municipality roads.

According to the site investigation and interview with DNIT, restoration and rehabilitation of federal road had completed after heavy rain in 2008, there are no high risk sites in federal roads.

The structural measures for landslide are planned to secure half width road traffic against heavy rain level of the November 2008 (60-year return period). Type for measures will be selected by learning form existing measures of similar condition slopes (mainly the Federal road BR470), which have not full width road closure disaster events under 60 years heavy rain. It is also referred that technical norm in Brazil, NORMA BRASILEIRA ABNT (Associação Brasileira de Normas Técnicas), NBR (Número de referéncia) 11682, Estabilidade Encostas (Slope Stabilization).

The slope vegetation for each risk site is principal measure in order to mitigate sediment yield. Furthermore, trees should be planted in no-risk sites of falling tree in order to contribute to environmental improvement by carbon fix.

Table 5.3.1 Selection of Structural Measure Type by Landslide Situation

Type of Landslide	Location of hazard origin to preservation object	Applicable Slope Condition		Type of Structural Measurers Vegetation and drainage are applied to the whole sites
Collapse Desmoronamento	Mountainside slope	Stability by slope cutting is impossible.		Rock bolting, Anchoring
		There are possibilities of rock falls/collapses.		Removal of unstable rocks, foot protection works, rock catch fence, rock catch/covering net.
		Stability by slope cutting is possible	Slope height of 15 m or more	Removal of unstable soils（Slope cutting）, Reinforced earth for cutting slope
			Slope height of lower than 15 m	Removal of unstable soils（slope cutting）, vegetation net, gabion placing on slope foot.
	Valley side slope	Erosion has occurred, and might influence to road body collapse in the long term.		Embankment, piling, sheet piling, large block placing, gabion drainage along gully.
	Riverbank	River erosion has approached a preservation object, and/or cracks and subsidence are recognized.		Gabion revetment with cover soil, connecting concrete blocks with cover soil
Landslide Escorregamento	From mountainside to valley side slope	Assumed deep slide surface, high groundwater level.		Horizontal drainage drilling, gabion walls, steel pile working
	Mountainside	Assumed shallow slide surface, high groundwater level.		Closed conduit width open ditch, reinforced earth for cutting slope, gabion wall
	Road body to valley side slope	Assumed deep slide surface, low groundwater level.		Alternative study of steel pipe piling and light weight embankment
	Shallow road body slide	Shallow road slide of road body due to shoddy workmanship and/or poor drainage.		Rehabilitation of road body
Debris Flow Escoamento	Torrent of mountainside	Event history of debris flow disaster		Sediment trap works

Source: JICA Survey Team

Location and type of structural measures for selected 67 risk sites are shown in Table 5.3.2.

Table 5.3.2 Order of Priority and the Plan of Structure Measures for Landslides Disasters

Priority Order	**Place**	**Municipality**	**Road Management**	**Annual amount of potential damage (R$ x10^3/ year)**	**Type of disaster**	**Type of construction (slope protection with vegetation and drainage in all places)**
1	SC 302 Taio - Passo Manso-5	Taió	State road	1,255	Landslide (on the lane)	Horizontal drainage drilling, gabion retaining wall, pile work.
2	SC470 Gaspar Riverside	Gaspar	State road	1,095	Collapse (riverside & valley side)	Gabion retaining wall
3	Blumenau - Av Pres Casrelo Branco	Blumenau	Municipality road	1,021	Collapse (riverside)	Connecting concrete block, sheet piling
4	SC418 Blumenau - Pomerode	Pomerode	State road	989	Landslide (mountainside)	Closed conduit with open ditch, gabion retaining wall
5	SC474 Blumenau - Massaranduba 2	Blumenau	State road	907	Collapse (mountainside)	Cutting, slope reinforcement
6	Gaspar - Luiz Alves, Gaspar 9	Gaspar	Municipality road	774	Collapse (mountainside and riverside)	Cutting, slope reinforcement, Horizontal drainage drilling
7	Gaspar - Luiz Alves, Luiz Alves 6	Luis Alves	Municipality road	700	Collapse (mountainside)	Cutting, slope reinforcement
8	SC470 Gaspar Bypass	Gaspar	State road	689	Collapse (mountainside)	Cutting, slope reinforcement
9	SC477 Benedito Novo - Dutor Pedrinho 1	Benedito Novo	State road	680	Landslide (on the lane)	Alternative study of Light weight embankment and pile works.
10	SC418 Pomerode - Jaragua do Sul 1	Pomerode	State road	651	Lane collapse	Embankment with gabions at the bottom
11	Gaspar - Luiz Alves, Luiz Alves 4	Luis Alves	Municipality road	629	Landslide (mountainside)	Cutting, slope reinforcement
12	SC474 Blumenau - Massaranduba 1	Blumenau	State road	601	Collapse (mountainside)	Cutting, slope reinforcement
13	SC 302 Taio-Passo Manso 4	Taio	State road	526	Collapse (mountainside)	Cutting, slope reinforcement
14	Gaspar - Luiz Alves, Luis Alves 11	Luis Alves	Municipality road	497	Collapse (mountainside)	Cutting, slope reinforcement
15	SC486 Brusque - Botuverá 13	Botuverá	State road	473	Collapse (mountainside)	Cutting, slope reinforcement
16	SC416 Timbó - Pomerode	Timbó	State road	443	Landslide (mountainside)	Cutting, horizontal drainage drilling, gabion retaining wall
17	SC486 Brusque - Botuverá 1	Brusque	State road	430	Collapse (mountainside)	Cutting, slope reinforcement
18	R. Alamedia Rio Branco, Blumenau	Blumenau	Municipality road	398	Collapse (mountainside)	Cutting, slope reinforcement
19	Gaspar - Luiz Alves, Gaspar 2	Gaspar	Municipality road	384	Collapse (mountainside)	Cutting, slope reinforcement
20	Gaspar - Luiz Alves, Luis Alves 7	Luis Alves	Municipality road	380	Collapse (mountainside)	Cutting, slope reinforcement
21	Gaspar - Luiz Alves, Gaspar 1	Gaspar	Municipality road	379	Collapse (mountainside)	Cutting, Slope reinforcement
22	Gaspar - Luiz Alves, Luis Alves 3	Luis Alves	Municipality road	372	Collapse (mountainside)	Cutting, slope reinforcement
23	Ponte Aldo P. de Andrade - margem direita	Blumenau	Municipality road	366	Superficial landslide and lane sinking	Rehabilitation of road and pavement

Priority Order	Place	Municipality	Road Management	Annual amount of potential damage (R$ x10^3/ year)	Type of disaster	Type of construction (slope protection with vegetation and drainage in all places)
24	SC486 Brusque - Botuverá 3	Brusque	State road	344	Collapse (mountainside)	Cutting, slope reinforcement
25	SC486 Brusque - Botuverá 2	Brusque	State road	342	Collapse (mountainside)	Cutting, slope reinforcement
26	Gaspar - Luiz Alves, Gaspar 8	Gaspar	Municipality road	326	Collapse (mountainside)	Cutting, gabion retaining wall
27	Gaspar - Luiz Alves, Gaspar 4	Gaspar	Municipality road	323	Collapse (mountainside)	Cutting, slope reinforcement
28	SC486 Brusque - Botuverá 9	Botuverá	State road	301	Collapse (mountainside)	Cutting, slope reinforcement
29	SC486 Brusque - Botuverá 7	Brusque	State road	298	Collapse (mountainside)	Cutting, slope reinforcement
30	Gaspar - Luiz Alves, Luis Alves 2	Luis Alves	Municipality road	278	Collapse (mountainside)	Cutting, slope reinforcement
31	Gaspar - Luiz Alves, Gaspar 7	Gaspar	Municipality road	276	Collapse (mountainside)	Cutting, gabion retaining wall
32	Gaspar - Luiz Alves, Luis Alves 1	Luis Alves	Municipality road	271	Collapse (mountainside)	Cutting, slope reinforcement
33	Gaspar - Luis Alves, Luis Alves 5	Luis Alves	Municipality road	271	Collapse (mountainside)	Cutting, slope reinforcement
34	Gaspar - Luiz Alves, Luis Alves 8	Luis Alves	Municipality road	270	Collapse (mountainside)	Cutting, gabion retaining wall
35	SC486 Brusque - Botuverá 11	Botuverá	State road	260	Collapse (mountainside)	Cutting, slope reinforcement
36	SC486 Brusque - Botuverá 10	Botuverá	State road	260	Collapse (mountainside)	Cutting, slope reinforcement
37	Gaspar - Luiz Alves, Luis Alves 10	Luis Alves	Municipality road	227	Collapse (mountainside)	Cutting, slope reinforcement
38	SC486 Brusque - Botuverá 12	Botuverá	State road	221	Collapse (mountainside)	Cutting, slope reinforcement
39	SC486 Brusque - Botuverá 4	Brusque	State road	220	Collapse (mountainside)	Cutting, slope reinforcement
40	SC486 Brusque - Botuverá 6	Brusque	State road	220	Collapse (mountainside)	Cutting, slope reinforcement
41	SC486 Brusque - Botuverá 14	Botuverá	State road	220	Collapse (mountainside)	Cutting, slope reinforcement
42	SC486 Brusque - Botuverá 5	Brusque	State road	220	Collapse (mountainside)	Cutting, slope reinforcement
43	SC 302 Taio-Passo Manso 2	Taio	State road	202	Superficial landslide and lane sinking	Rehabilitation of road and Pavement
44	Gaspar - Luiz Alves, Gaspar 6	Gaspar	Municipality road	184	Collapse (mountainside)	Cutting, gabion retaining wall
45	Gaspar - Luiz Alves, Gaspar 10	Gaspar	Municipality road	184	Collapse (mountainside)	Cutting, gabion retaining wall
46	SC418 Pomerode - Jaraguá do Sul 2	Pomerode	State road	184	Collapse (mountainside)	Cutting, slope reinforcement
47	Gaspar - Luiz Alves, Luis Alves 12	Luiz Alves	Municipality road	184	Collapse (mountainside)	Cutting, slope reinforcement
48	Gaspar - Luiz Alves, Gaspar 3	Gaspar	Municipality road	184	Collapse (mountainside)	Cutting, slope reinforcement
49	SC413 Luiz Alves - Massaranduba 1	Luiz Alves	State road	172	Landslide (mountainside)	Horizontal drainage drilling, gabion retaining wall
50	Gaspar - Blumenau 3	Gaspar	Municipality road	169	Collapse (mountainside)	Cutting, slope reinforcement

Priority Order	Place	Municipality	Road Management	Annual amount of potential damage (R$ x10^3/ year)	Type of disaster	Type of construction (slope protection with vegetation and drainage in all places)
51	SC486 Brusque - Botuverá 8	Botuverá	State road	151	Collapse (mountainside)	Cutting, slope reinforcement
52	SC 302 Taio - Passo Manso 1	Taio	State road	149	Landslide superficial and lane sinking	Rehabilitation of road and pavement
53	SC 302 Taio - Passo Manso 3	Taio	State road	149	Landslide superficial and lane sinking	Rehabilitation of road and Pavement
54	SC477 Benedito Novo - Dutor Pedrinho 2	Benedito Novo	State road	144	Superficial landslide (mountainside)	Drain ditch and pavement
55	R. Bruno Hering, Blumenau	Blumenau	Municipality road	119	Debris flow	Gabion
56	Gaspar - Luiz Alves, Luiz Alves 9	Luiz Alves	Municipality road	111	Collapse (mountainside)	Cutting, slope reinforcement
57	SC477 Benedito Novo - Doutor Pedrinho 3	Benedito Novo	State road	108	Superficial landslide and lane sinking	Concrete block retaining wall
58	Gaspar - Luiz Alves, Gaspar 5	Gaspar	Municipality road	106	Collapse (mountainside)	Cutting, slope reinforcement
59	Baú	Ilhota	Municipality road	101	Debris flow	Gabion
60	SC486 Brusque - Botuverá 15	Brusque	State road	78	Collapse (mountainside)	Cutting, slope reinforcement
61	Luiz Alves Estrada municipal 1	Luiz Alves	Municipality road	67	Collapse (mountainside)	Cutting, Gabion
62	SC413 Luiz Alves -Massaranduba 2	Luiz Alves	State road	62	Collapse (mountainside)	Cutting, slope reinforcement
63	Luiz Alves Estrada municipal 2	Luiz Alves	Municipality road	59	Collapse (mountainside)	Removing unstable rock by explosion
64	Brusque Estrada municipal 1	Brusque	Municipality road	56	Collapse (mountainside)	Cutting, slope reinforcement
65	Gaspar - Blumenau 2	Blumenau	Municipality road	55	Collapse (mountainside)	Cutting, slope reinforcement
66	Gaspar - Blumenau 1	Blumenau	Municipality road	55	Collapse (valley side)	Gabion
67	Brusque Estrada municipal 2	Brusque	Municipality road	51	Collapse (mountainside)	Cutting, slope reinforcement

Note: Itajai Port which problem is sediment discharge is not included in this table. The table shows landslide risk sites only.

Source: JICA Survey team

5.4 Mitigation Measures for Sediment Yield

Mitigation measures for sediment yield are promoted as reforestation projects which mainly aim to watershed /forest conservation and carbon fix by planting tree. The mitigation measures of sediment yield are also applied for the structural measure sites for landslides. Because main purpose is watershed and forest conservation, detailed plan will not be made for sediment yield mitigation in this master plan.

In Itajai River basin, Itajai port is only one site of remarkable economical loss caused by riverbed aggradation. The annual amount of the potential loss due to sedimentation is R$ 9 million per year and it is estimated at R$ 19 per m^3 of sediments (see supporting report C).

It should be promoted that the mitigation measures of sediment yield in the whole basin by the reforestation of bared collapsed land and prevention of riverbank erosion by riparian forest. The main objective of these programs is to preserve the water resources and forestry resources, and it might contribute environment improvement such as climatic changes measures by the carbon fix of trees. The prioritized areas for mitigation of sediment yields is the Luiz Alves River where there is no significant sand extraction business, especially the Morro do Bau surrounding area where there are still remaining of many collapsed bare lands and debris along streams after the storm in November 2008 .

Sediment yield will be mitigated at sites of structure measures for landslide. Vegetation measures should be applied basically for bared road slopes. Trees should be planted in gentle slopes and/or valley side slopes of the road, where falling three risks are not expected, in order to contribute climate change measures by the carbon fix.

The sediment control dame, and/or sand pocket are not economical to reduce sediment discharge of the Itajai Port, due to the reasons below;

- The cost per volume of debris exclude works from sediment control facilities is almost equivalent to the potential loss per volume of sediment discharge at the Itajai Port.
- All of the sediments which taken by virtual sediment control facilities are not discharge into the Itajai Port originally, some of them might be taken by sand extraction business, some of them are sediment on flood plain and not discharge into the Itajai Port for a long time.

The river bed altitude of the river in the Itajai Port area was minus 5 meters in the past, and since 1980 a dredging work has been done in order to deepen the port and, nowadays the altitude is minus 14 meters in order to enable the port call of vessels. Therefore sedimentation is activated; sedimentation from marine side might be large amount also. If sediment discharge from river side is decreased by sediment yield mitigation, the sedimentation speed might not decrease simply, sedimentation from marine side might be increased and total sedimentation volume might be balanced at some extent.

The volume of sedimentation and the dredging volume in the Itajai Port have not monitored so far. After the monitoring of the sedimentation volume and the clarification of deposition mechanism, it would be desirable to adopt measures for sedimentation including the sediment from the marine.

5.5 Mitigation of Flash Flood

Measures for reducing flash floods are aiming to promote runoff regulation facilities for the purpose to reduce surface runoff.

The flash floods increase seriousness due to the reducing rainwater permeability by decreasing of forest with land development in mountainous area. Furthermore, it is recognized that are many housing areas in stream where no water in normal time. The issue shall be treated in city plan.

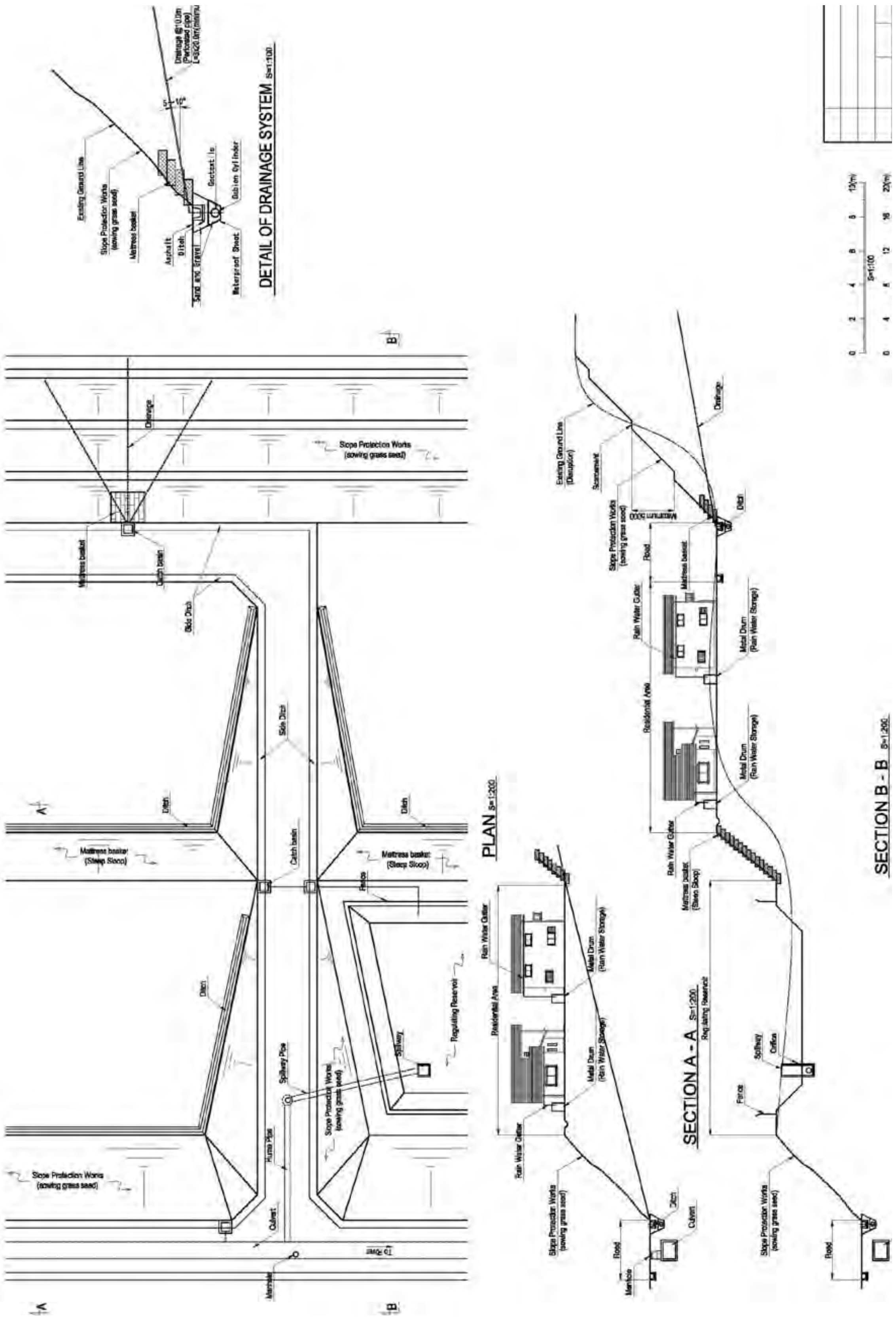


Figure 5.5.1 Example of Runoff Regulation Facilities by Reservoir

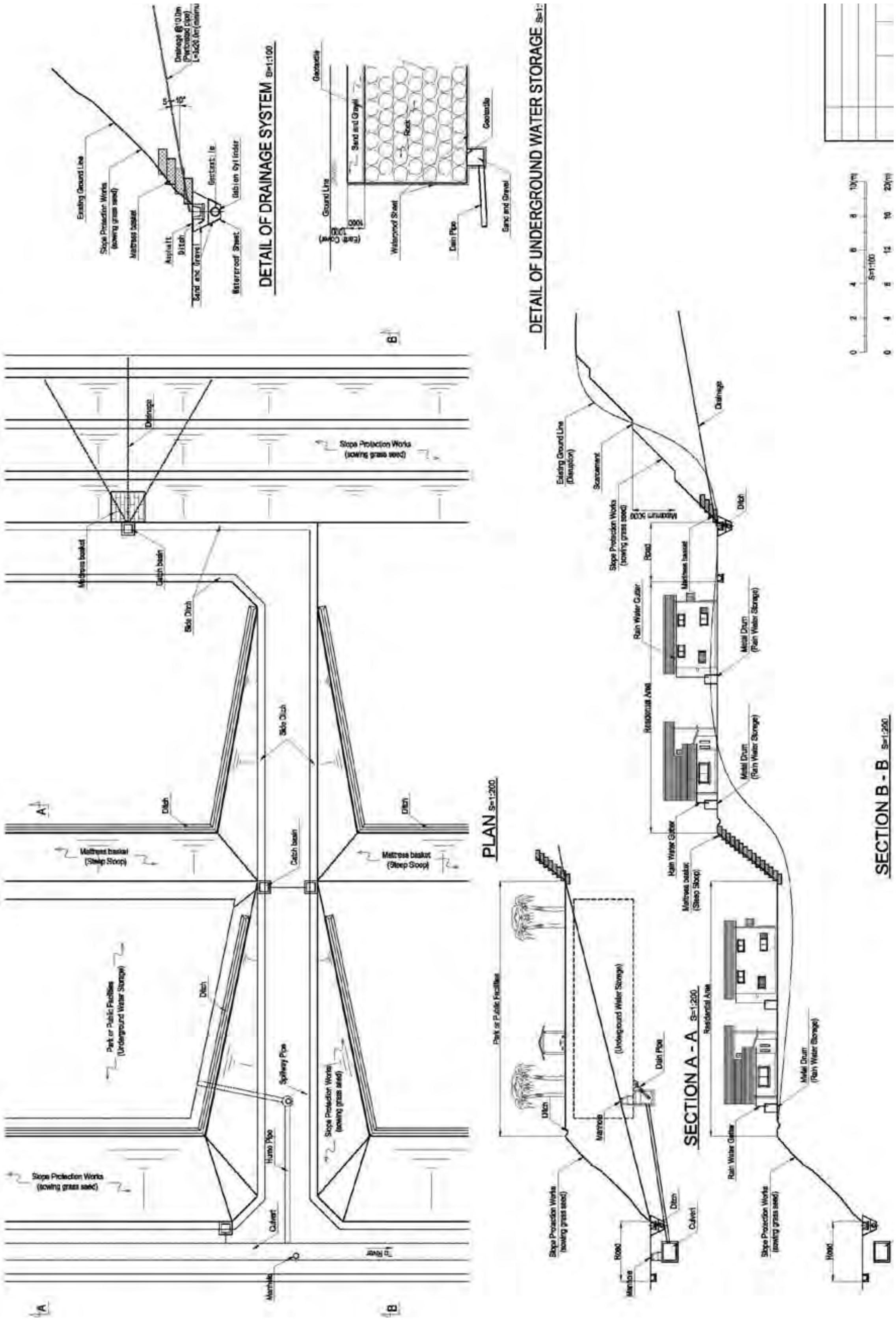


Figure 5.5.2 Example of Runoff Regulation Facilities by Underground Reservoir

5.6 Capacity Building for Structural Measure and Support for Private Self-reliant Effort

5.6.1 Capacity Building for Structural Measures

Land development by the State government is a disaster measure project to provide safe houses to the residents who are living in disaster risk area. Those land development should properly done not to cause further landslide disasters, flash flood and floods by increasing of surface runoff due to the land development. To tackle those problems, technical capacity development for land development shall be conducted.

Table 5.6.1 shows required techniques and measures for reducing disasters and sediment yield.

Table 5.6.1 Necessary Techniques and Plans to Mitigate Disasters of Landslide/Flash Flood and Sediment Yield

Technical Issues	Purpose and Objective	Recent condition	Measure
Installation of runoff regulation facilities for land development	To mitigate flash floods and floods by surface runoff increase due to land development	No technical standards	- Formulation of technical standards - Preparation of law to enable regal binding for new land development
Slope protection and slope stabilization	To stabilize slopes and protect slopes from erosion	Technical standards and methods for design review are available. The cases of instability of slopes and sedimentation are recognized. Drain ditch are not installed in some cases.	- Enhancement of design review to be conducted by State and Municipality. - Training of design engineers and construction engineers by the State government.
Disposal of waste soil	To protect sediment yield	FATEMA conducts legal instruction and management.	- Continuation of instructions and keeping laws and regulations

Source: JICA Survey Team

5.6.2 Support for Private Self-reliant Effort

Disaster education for such as simple measures will be conducted for private sectors in order to reduce damage of private construction objects which have low priority and potential annual losses with subsidy from official/private fund.

There are projects for structural measures funded by private mining company which was co-established by SC State, Municipality, Agency for institute of mining resources (CPRAM) and Association of engineers in SC State (CREA-SC), however those project cannot be applied to whole risk areas. It is recommended to promote disaster education for simple countermeasures such as drain ditches and support form official/ private funds.

5.7 Sustainable Maintenance

5.7.1 Maintenance of Structural Measures

The slope shall be maintain good condition by early remedy for damaged portions which find out by regular inspection and/or damage inspection just after heavy rain.

(1) Vegetation

If vegetation is not survival and/or bumped soils are eroded, vegetation base, such as wicker works, will be enhanced, and fertilizer will be added depend on the necessity. And then reforestation will be conducted by seeding or planting.

(2) Drainage

Repair of drainage works, and soil removal from drainage ditch and catch basin will be conducted. In case of clogging of horizontal drainage drilling, spouting water jet will be installed, and clogging are washed out until discharged water will be clean. The formulation reddish brown soil by iron bacterium, which is 60% of the cause of the clogging of drainage hole, can be controlled by cutting of oxygen supply.

Specifically, U-shaped pipe concatenating mouth of drainage hole is simple measure to cut off contact with air temporally.

(3) Slope protection works

Structural damage occurs generally due to strong wind, heavy rain disaster and aging. And unforeseen external force may cause deformation and collapse sometimes. Inspector shall pay attention not only slope protection works themselves, but also water situation in the surrounding. Measures against of cause of damage shall be done.

5.7.2 Maintenance for Landslide Flashflood Early Warning System

Defesa Civil-SC is responsible organization of the system. It is necessary to ensure the maintenance of equipment according to the budget of the system. Actually the maintenance will be conducted by each staff of related organization, and needs to be done other communication management.

(1) Automatic Rain gauge

In case of tipping bucket rain gauge, there may be trouble with the block of rainwater catchment by falling leaf etc. If rainfall is not recorded despite the rain, it is necessary to check the rainwater catchment and remove the blockage. For the sake of easy checking and maintenance, automatic rain gauges would be better to be installed on the office of municipality hall or Defesa-Civil of municipality.

(2) Communication facility, Computer, Computing System

The maintenance of communication facility, computer, computing system needs to be done as part of them of each related government organization.