4. IEE (Initial Environmental Examination)

16. The initial environmental examination in the proposed exploitation sites was carried out in accordance with JICA's guideline. For the proposed sites and the neighboring areas, possible negative impacts during and after exploitation were examined from a social and natural environmental standpoint and no serious negative impact is expected. Effluent quality and erosion during and after, and landscape after soil exploitation should be considered. Those potential environmental impacts are manageable by designing and implementing appropriate measures during exploitation. Reclamation after exploitation is included in the remediation cost estimates, covering the sites with original top soil or filling the sites with overburden waste and covering with clay and original top soil where required. The increase in truck traffic needed to haul material to the site could result in increased risks to the surrounding communities from dust and an increase in traffic accidents. All of those potential impacts should be addressed prior to implementing the remediation project.

5. Geological Survey for Limestone and Fossil Shell

17. The geology of Santa Catarina consists of the Precambrian strata as basement, the Gondowana strata, and overlaid basalt lava of Cretaceous age. The Precambrian strata, located in the eastern part of Santa Catarina, is made up of four domain rocks with different ages and geotectonic evolution as shown below:

	Age	Group	Lithology
i.	Early Proterozoic	Granitic rocks	
ii.	Early-middle Proterozoic	Itajai group	Conglomerate, sandstone
iii.	Late Proterozoic	Brusque complex	Sandstone, limestone
iv.	Archean	Granite-Gneiss complex	

18. The Brusque complex is of siliceous sandstone with intercalated limestone, generally striking in the NE-SW direction with westerly dip of approximately 80 degrees. As a whole, limestone here occurs as intercalated lenticular beds in various horizons with 10-50m in thickness and 50-300m in length. Most of them are metamorphosed and altered into dolomitic limestone. The limestone beds have been surveyed by DNPM in the Camboriu, Rio do Campo, Vidal Ramos and Botuvera districts. Currently only three quarries in the Botuvera district are in operation, however.

(a) Visit to quarries

19. A total of 30 intercalated limestone beds have been discovered by geologists and engineers of the quarries in the Botuvera district. Among them, three localities near Botuvera town are developed, quarrying different limestone beds independently. The current activity and its quarrying conditions are shown in Table F-7 and limestone quality is given in Table F-8.

(b) Quarries in Rio Grande do Sul

20. In Rio Grande do Sul, two quarries in Candiota, Sao Gabriel are operated by Cia Cimento Portland Gaucho to supply limestone to its own cement work in Pinheiro Machado, producing 600,000 tons per month. An intercalated limestone occurs in thick sandstone as a lenticular bed from 50 to 70m thick and is correlated to the Brusque Group of the Precambrian strata in Santa Catarina. The quality of limestone is shown inTable F-8.

(c) Fossil shell

21. The fossil shell bed of the quaternary strata is distributed in the coast area, and its thickness varies from 1 to 4 m, in which 20 to 40 % of fossil shells are contained. Currently two companies are producing soil neutralizers for agriculture use. The products and quality are shown in Table F-8.

TABLE F-7

CURRENT ACTIVE QUARRIES AND THEIR CONDITIONS

Company : Companhia de Cimento Portland Rio Branco

• Head office	Itajai, Santa Catarina
• Location of quarry	Ribeirao do Ouro, Botuvera 2.5km west of Botubvera town
• Deposits of limestone bed	Lenticular form Length of bed-Approximatery 200m Thickness- Approximately 20m
• Geologic structure	Homocline structure N45E65NW
• Workable reserves	9,400t (by data of DNPM)
• Face length for the quarrying	20m
• Face condition	Bad condition Interbeded sandstone and limestone approximetry 5m,separetry
• Production	100-200 tons / year
• Another facility	Non Transport the aggregate to Itajai by truck
• Other concession	1) Camboriu, Santa Catarina 2) Vidal Ramos (west of Botuvera district) Planning stage.

* Quarry of Botuvera currently carried out by contractor (Mineracao Areias Ltda)

Company: Calwer Mineracao Ltda

• Head office:	Estrada Geral Ribeirao do Ouro
• Location of quarry	Ribeirao do Ouro, Botuvera 1km west of Botuvera town
• Deposits of Limestone bed	Lenticular intercalated bed in thick sandstone bed Length-approximatly 300m width-approximatly 150m
• Geologic structure	Homocline structure N58E
• Workable reserves	2,000,000 ton
• Face length for quarrying	Approximatly 50m
• Mining condition	Excellent Contains intercalated thin claystone
• Products	100 tons (1995)
• Use	Neutrizer for soil improvement
• Facility	Crusher & Screen, Capacity:Max 400,000 tons /year
• Other concession	1) Vidal Ramos district

Company: Mineracao Rio do Ouro Ltda

• Head office	Estrada Geral s/n
• Location of quarry	Lageado, Botuvera 2.5km west of Botuvera towm
• Deposits of limestone bed	Contains intercalated thin sandstone Length-approximately 500m Thickness-Approximately 150m
• Geologic structure	Homocline N60E50NW
• Workable reserves	4,450,000 tons
• Face length	Approximately 50m
• Mining condition	Excellent Contains intercalated thin sandstone
• Products	128,430 tons (1995)
• Facility	Crusher & Screen, Capacity; 200,000 tons/year

TABLE F-8

QUALITY OF LIMESTONE AND FOSSIL SHELL

State	Santa Catrina	"	"	"	Rio Grande do Sul	"	Santa Catarina	"
Company*	C.C.P.R.B	"	Calwer	Rio do Ouro	C.C.P.G	"	CYSY	ICAM
Locality of quarry	Botuvera	(Vidal Ramos)**	Botuvera	Botuvera	Candiota	Sao Gabriel	Laguna	Jaguaruna
Raw Material	Limestone	Limestone	Dolomitic Ls	Dolomitic Ls	Limestone	Limestone	Fossil shell	Fossil shell
[Quality]								
Calcium carbonate(CaCo3)%	-	-	-	-	-	-	95.0	-
Calcium oxide(CaO) %	50.0	45.0	29.8	28.7	41.5	48.0	54.0	52.3
Magnesium oxide(MgO) %	2.1	1.0-2.0	20.8	21.4	4.5	4.5	0.32	-
Boron oxide(B2O3) %	-	-	-	-	-	-	0.056	-
Molybdenum(Mo)	-	-	-	-	-	-	(10ppm)	-
Zinc(Zn)	-	-	-	-	-	-	(13ppm)	-
Copper(Cu)	-	-	-	-	-	-	(7ppm)	-
Silicon Oxide(SiO2) %	-	-	-	-	15.0	8.5	3.0	-
Surfate %	-	-	-	-	-	-	1.5	-
PN	-	-	-	96.8	-	-	94.0	93.4
PRNT	-	-	-	81	-	-	75.0	69.0
[Size]								
>2mm	-	-	-	0.2		6-7inch	-	0
Passing 2mm	-	-	-	100	-	-	-	100
passing 0.84mm	-	-	-	93	-	-	-	70
Passing 0.30mm	-	-	-	67	-	-	-	50
Supply capacity								
Aggregates	-	-	60,000t/y	100,000t/y	-	-	-	-
Fine	-	-	200,000t/y		-	-	4,000t/m	-
Price(R$)	-	-	R$ 7.00?	R$ 7.00	-	-	R$64.00(fine) R$60.00(coarse)	R$ 55.00

*: C.C.P.R.B: Companhia de Cimento Portland Rio Blanco.
Calwer: Calwer Mineracao Ltda.
Rio do Ouro: Mineracao Rio do Ouro Ltda.
C.C.P.G: CIA Cimento Portland Gaucho.
CYSY: CYSY Mineracao Ltda.
Industria Catarinense: Industria Catarinense de Adubos e Mineracao Ltda
**: Planning stage

G VEGETATION AND MICROORGANISMS

1. Vegetation Survey

1.1 Objective

1. The objectives of vegetation survey are i.) to determine suitable plants for re-vegetation, that can tolerate the acidic conditions and meet the environmental conditions of the FS sites; and ii.) to identify natural vegetation (potential vegetation) which is supposed to grow in natural situations, to guide the restoration of natural vegetation, if required.

1.2 Methods

2. A physiognomic site survey in the four FS sites and their surrounding areas, including the existing re-vegetated areas was conducted to understand the current distribution of vegetation. Dominant species were described by the Ellenberg Dominance Index as shown below. Together with information from aerial photographs, vegetation maps were prepared.

Ellenberg Dominance Index

Dominance		Descriptions
5	---------	Coverage > 3/4
4	---------	Coverage 1/2 - 3/4
3	---------	Coverage 1/4 - 1/2
2	---------	Coverage 1/10 - 1/4
1	---------	Small number or small coverage
+	---------	rare
r	---------	very rare

1.3 Description of Site Conditions

3. The conditions of sampling areas are as follows:

(i.) Rocinha

R1 - Area with preserved forest located, upstream of the Rio Rocinha FS site, clayish soil not affected by coal mining;

R2 - Riparian forest on the banks of Rocinha River inside the reject deposit area;

R3 - An "island" with herbaceous species in clayey soil which was placed on the rejects; and

R4 - Arboreal-shrubby vegetation at initial secondary succession stage on a slope with undisturbed clay soil by the road side leading to the coal preparation plant. The surrounding area is used as a reject deposit.

(ii.) Carvao

S1 - Open pit mined area which has been abandoned for 13 years. Spontaneous secondary succession vegetation composed of herbaceous and arboreal species;

S2 - Area similar to S1, but with richer vegetation;

S3 - Area located near the inclined shaft of C.C.U. This area has not been open pit mined, has initial secondary succession on clayish soil;

S4 - Secondary forest on unmined clay soil;

S5 - Reject deposit area of C.C.U. The area was leveled with clay (70 cm); and

S6 - Sterile deposition area from open pit mine. Unreclaimed soil with eucalyptus and native sub-shrubby vegetation.

(iii.) Fiorita

F1 - Abandoned open pit mine area with herbaceous and shrubby vegetation at a secondary succession stage;

F2 - Sterile deposition area from open pit mine, covered by a thin clay layer on top soil on which eucalyptus were planted. It presents sub-shrubby vegetation by natural regeneration;

F3 - Clayish soil. Not mined. Probably an old plantation; and

F4 - Clayish undisturbed soil with secondary well-preserved forest.

(iv.) Capivari

E1 - Sandy and dry soil not affected by coal rejects;

E2 - Permanently wet land with peaty-sandy, undisturbed, uncontaminated soil; and

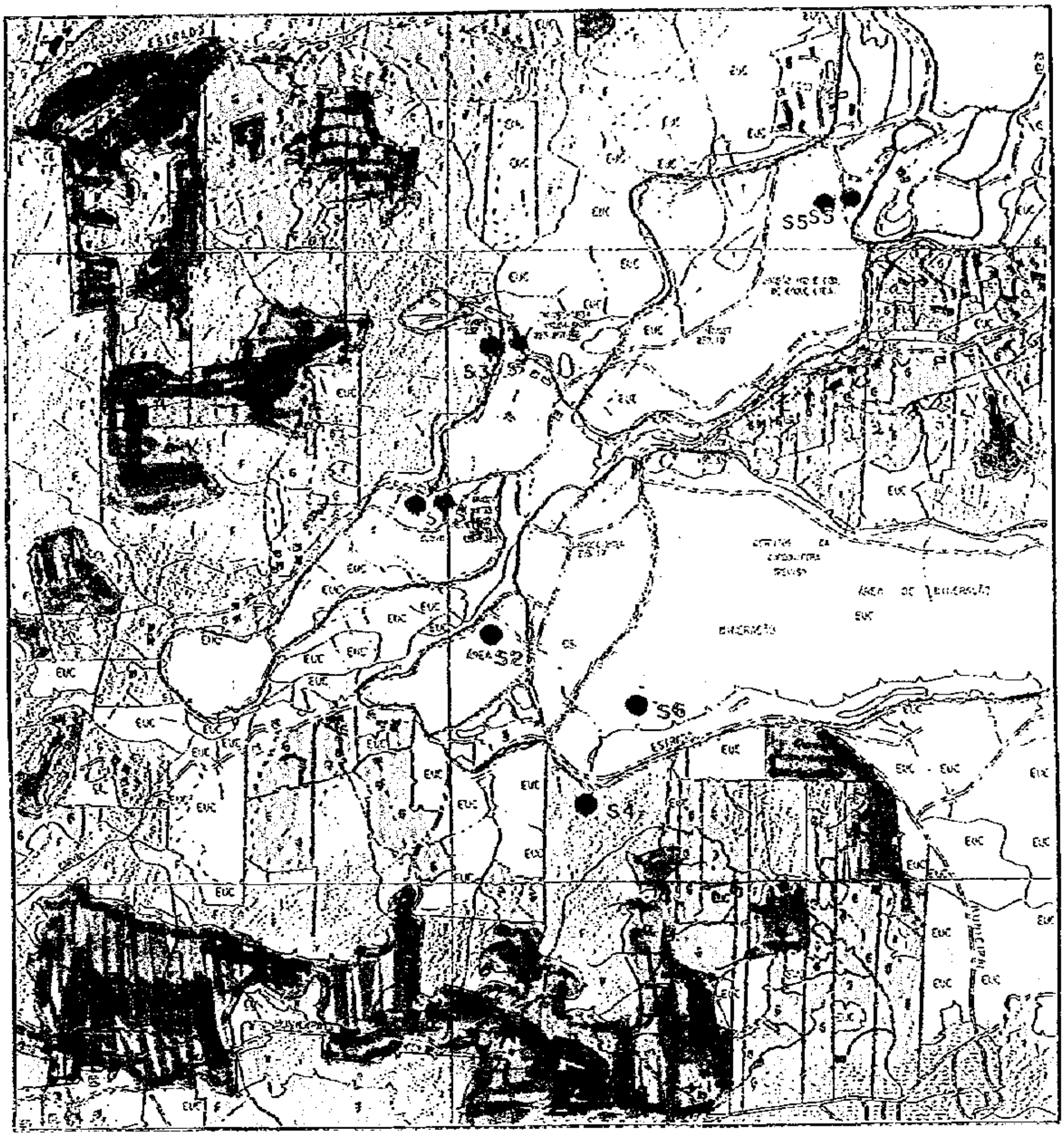
E3 - Narrow stretch of clayish soil (about 50 cm wide) placed on coal-mined rejects.

1.4 Results of Vegetation Survey

4. The existing and potential vegetation maps in the four FS sites and their surrounding areas are shown in Figures G-1(1/4) through G-1(4/4). An outline of the primary invaders (pioneer plants) is illustrated in Table G-1. In general, the sampling areas could be classified into the following five (5) types based on land use history:

- Type1: Undisturbed areas (natural vegetation): R1, S4; F4, E2;
- Type2: The areas where vegetation was mechanically removed but the soil has not been contaminated by the coal mine rejects: R4, F3, E1;
- Type3: Mined-out areas where the topsoil was recovered and re-vegetated. (Lower soils are contaminated by coal mine rejects.): F2, S5;
- Type4: Mined-out areas where the topsoil was recovered but not re-vegetated. (Lower soil are contaminated by coal mine rejects.): R2, R3, S1, S2, F1, E3; and
- Type5: Mined-out areas where the topsoil was ripped: S6.

5. In the Type 5 area, a growth rate of plants were low and species diversity were very poor. A growth rate of plants in the Type 4 area is higher than that of the Type 5 area, however, invaded plant species were mainly composed of herbaceous plants and the diversity is low. A relatively higher number of plants have immigrated to the Type 3 area compared with the Type 4 area. Topsoil recovering and re-vegetation may enhance the invasion of the native plants by increasing water holding capacity of the soil and preventing excessive rising of the soil temperature. The invaded species observed in the Type 3 area were almost similar to the native invaded speciesobserved in the undisturbed



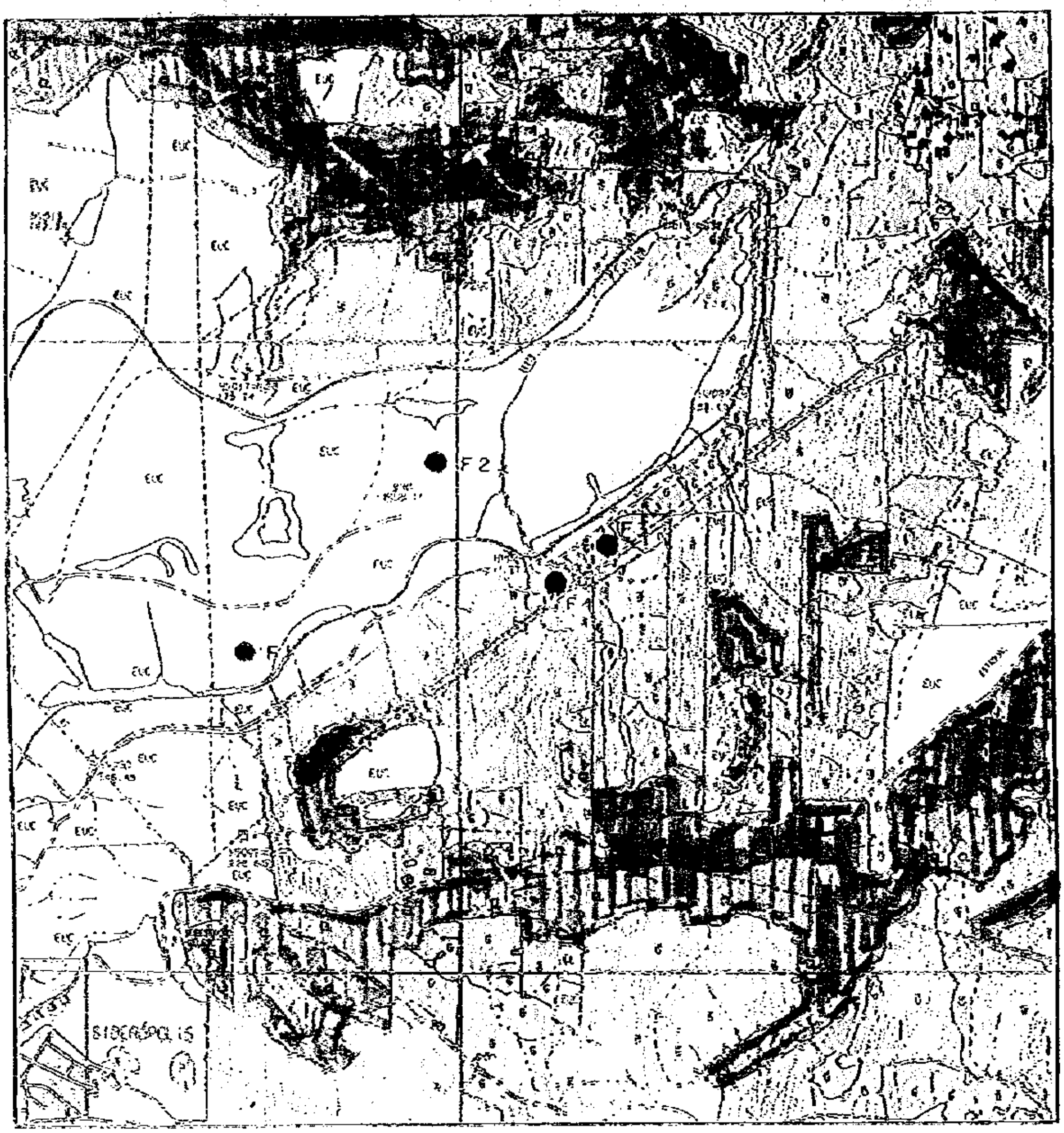
SCALE:1/20000

LEGEND

W, F	Wood, Forest
CANE, CL	Sugercane, Cultivation
O, G, EUC	Orchard, Grassland,Eucaript

FIGURE G-1(1/4)

EXISTING VEGETATION AND SAMPLING SITES IN FS SITE (ROCINHA)



SCALE:1/20000

LEGEND

W / F	Wood, Forest
CANE / C	Sugercane, Cultivation
O / G / EUC	Orchard, Grassland,Eucaript

FIGURE G-1(2/4)

EXISTING VEGETATION AND SAMPLING SITES IN FS SITE (CARVAO)

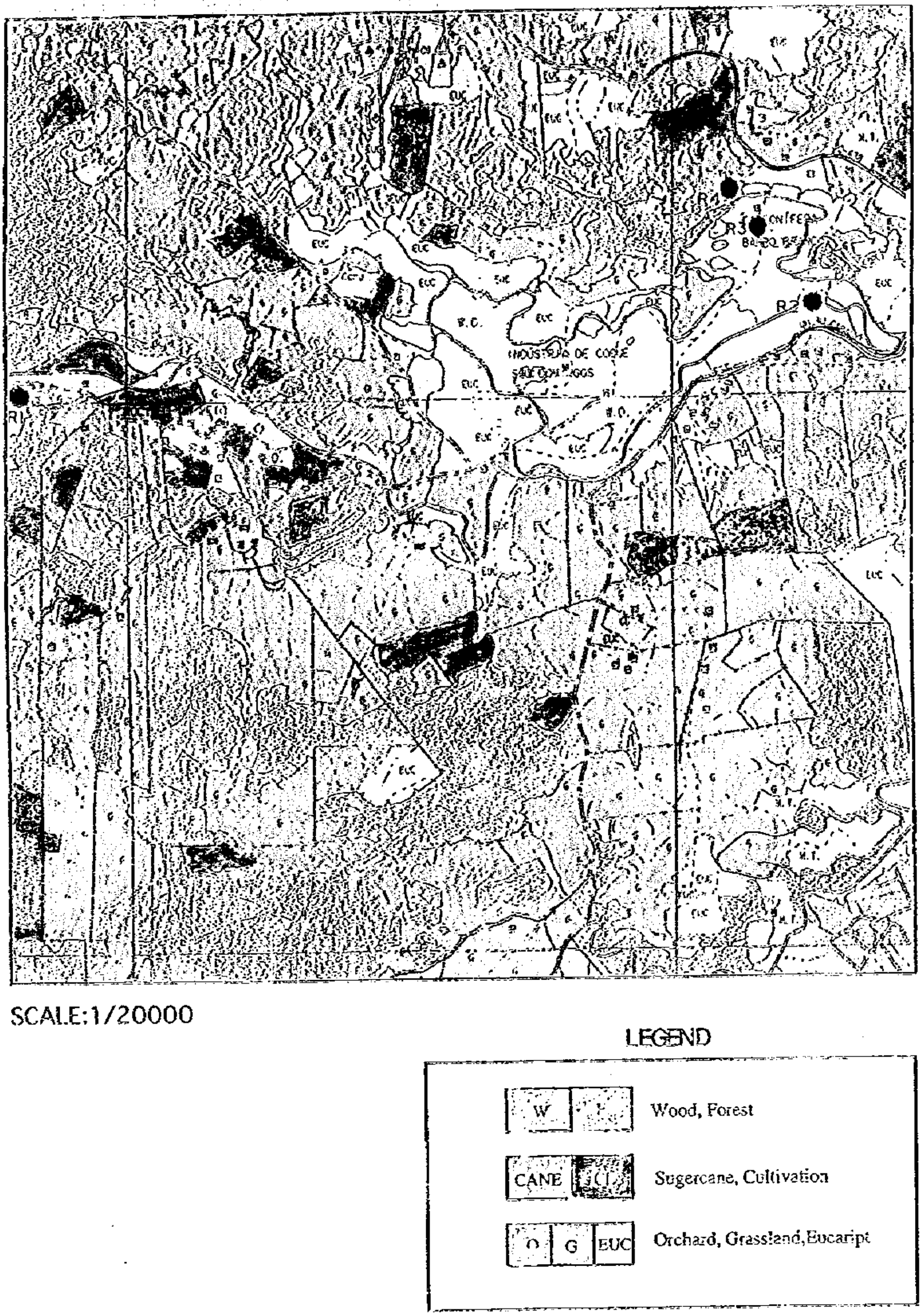
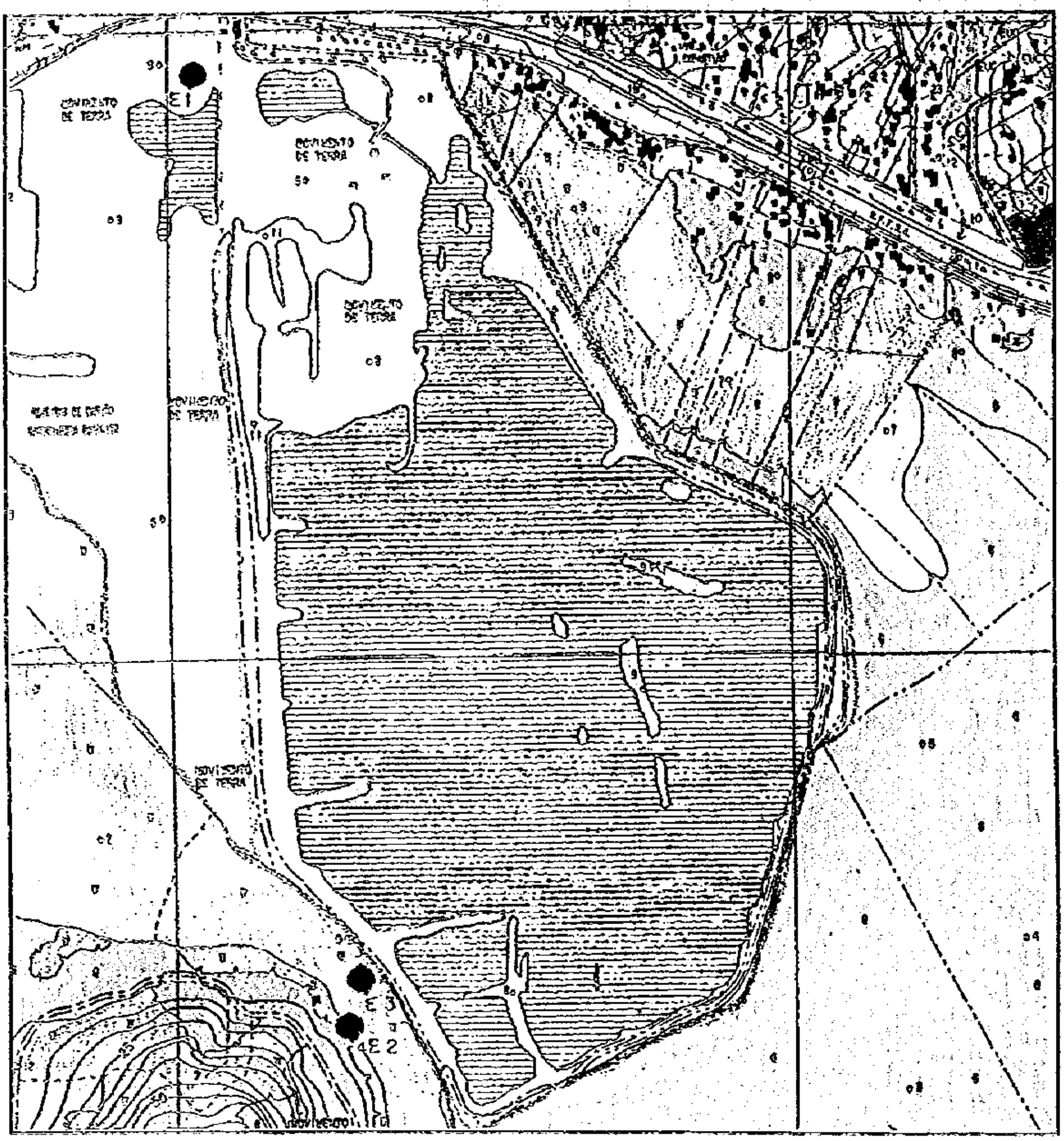


FIGURE G-1(3/4)

EXISTING VEGETATION AND SAMPLING SITES IN FS SITE (FIORITA)



SCALE:1/20000

LEGEND

W / F	Wood, Forest
CANE / CT	Sugercane, Cultivation
O / G / EUC	Orchard, Grassland,Eucaript

FIGURE G-1(4/4)

EXISTING VEGETATION AND SAMPLING SITES IN FS SITE (CAPIVARI)

TABLE G-1

PRIMARY PIONEERPLANTS IN THE FS SITES

No.	Family	Scientific name	Common name
1	Asteraceae	*Baccharis dracunculifolia*	Vassoura (broom)
2		*Eupatorium bupleurifolium*	Vassoura -do-campo
3		*Eupatorium intermedium*	eupatorio
4		*Eupatorium tremulum*	vassourao-do-brejo
5		*Vernonia Scorpioides*	erva-de-sao simao
6		*Vernonia tweediana*	assapeixe, chamarrita
7	Clethraceae	*Clethra scabra*	caujuja, carne-de-vaca
8	Cyperaceae	*Scirpus giganteus*	palha
9	Euphorbiaceae	*Alchomea triplinervia*	tanheiro, tapia-guacu
10		*Croton celtidifolius*	sangue-de-drago
11	Juncaceae	*Juncus sellowianus*	junco
12	Leguminosae	*Acacia meamsii*	acacia-negra, black wattle
13		*Mimosa Bimucronata*	marica, espinheiro, silva
14		*Mimosa scabrella*	bracatinga
15		*Senna multijuga*	aleluia
16	Melastomataceae	*Tibouchina sellowiana*	quaresmeira
17	Myrsinaceae	*Rapanea farruginea*	capororoca
18	Myrtaceae	*Psidium cattleyanum*	araca-amarelo, aracazeiro
19	Poaceae (Gramineae)	*Andropogon bicornis*	rabo-de-burro
20		*Andropogon leucostachyus*	capin-colchao
21		*Axonopus fissifolius*	grama-missioneira
22		*Axonopus obtusifolius*	grama-de-folha-larga
23		*Axonopus sp. (1)*	-
24		*Axonopus sp. (2)*	-
25		*Brachiaria sp.*	-
26		*Mellinis minutiflora*	capin-gordura
27		*Panicum hians*	pastinho tenro
28		*Paspalum pumilum*	grama-kikuio
29		*Rhynchelytrum repens*	capim-grafanhoto
30	Pteridaceae	*Pityrogramma calomelanos*	pitirograma-lindo-negra
31		*Pteridium aquilinum*	samambaia-das-taperas
32		*Trema micrantha*	grandiuva

area. Soil recovering and re-vegetation may be effective to rehabilitate the mined-out area. The Type 1 area shows the highest species diversity in all the subject areas.

1.5 Survey of the Existing Re-vegetated Areas

6. In order to collect data and information related to plants used for re-vegetation in southern Santa Catarina state, the following re-vegetated areas were surveyed, including interviews on the site:

- ⇨ Re-vegetation test areas: "Project M" by FATMA and "Project Itanema" by EPAGRI, UNESC and Carbonifera Treviso; and
- ⇨ Re-vegetated areas: Santana in Sidelópolis by Dalbo, a private company and *MINA PORTAO ITANEMA*.

7. In "Project M" and "Project Itanema", useful plants such as Eucalyptus (Eucalyptus saligna, Eucalyptus viminalis, Eucalyptus citriodora) and Pinus (Pinus Taeda, Pinus eliotis) were mainly selected for test planting. Plants of the family Leguminosae such as Mimosa scabrella (Bracatinga), Inga sessilis (Inga macaco), Inga marginata (Inga feijao) were also tested to determine their feasibility as re-vegetation species.

8. In the re-vegetated areas by private companies, grass species such as Brachiaria decumbens, Lolium multiflorum, Melinis minutiflora, Eragrostis curvula, Axnopus affinis and Axonopus obtusifolius were mainly planted. Woody plants such as Eucalyptus and Pinus were also selected as re-vegetation species. The species generally used in re-vegetated areas are shown in Table G-2. Those species have economic value. However, they should not be used for restoration of natural conditions. Also, the root of Eucalyptus penetrate deeply into the ground down to the aquifer, and they may penetrate the impervious soil cover systems prescribed for FS site remediation. Therefore, it would not be appropriate to use Eucalyptus or any other deep rooted species as a re-vegetation plant.

1.6 Selection of Re-Vegetation Species for Remediation

9. In cooperation with FUCRI, re-vegetation species were selected based on the following factors:

- Adaptability to the environment (Especially those that can tolerate acidic conditions);
- Availability of the plant;
- Improvement effects on the environment, including the ability to prevent erosion, flooding and landslides;
- Suitability for the land use purpose;
- Economic value; and
- Ecological importance.

10. The species which are good for re-vegetation given the local ecosystem are shown in Table G-3. Plants of the family Leguminosae, such as Mimosa bimocronat and Mimosa scabrella, are especially useful for soil fertilization since they have the ability to transmit nitrogen from the air to the

ground. Since the root of woody plants may grow too deep, they are not suitable for remediation of the FS sites which will be covered by impervious soil cover systems. Grass species which are shown in Table G-4 are good for the FS site re-vegetation.

TABLE G-2

PLANT SPECIES GENERALLY USED IN RE-VEGETATED AREAS

Scientific name	Common name	Hight (m)	Use	Price (US$)	Spacing*	Discription
Acacia meamsii	acacia-negra (black wattle)	8	Industrial (leather tannery) Timber Firewood	33 (/kg Seeds)	2×2	Native of Southeast Australia. Widely used for homogenous reforestation in the south of Brazil. It is used as a reforestation species due to its proved ability to adapt to mine disturbed areas.
Pinus taeda *Pinus eliotis*	Pinus	20-30	Timber	0.15-0.2 (/seedling)	2×2	Widely used for reforestation species because its not very demanding on soil nutrients and humidity.
Eucalipus saligna Eucalipus viminalis Eucalipus citriodora	Eucalliputo	20-30	Timber Firewood	0.15-0.2 (/seedling)	2×2	Widely used for reforestation species due to its proved ability to adapt to mine disturbed areas. But Eucaliput is not suitable as a revegetation plant because it sterilize the soil.

2×1.5m : 3,020 seedlings /ha

2×2m : 3,000 seedlings /ha

* The number of planted seedlings include 25% of dying individulals.

- : No commercial seeds available

TABLE G-3

RECOMMENDED PLANTS SUITABLE FOR REVEGETATION (WOODY PLANTS)

Scientific name	Common name	Hight (m)	Use	Price (US$)	Spacing (m)	Discription
Mimosa Bimucronata	marica (espinheiro,s ilva)	3-8	Timber Medicinal Apicule Plant Forage Plant Protective Planting	17 (/kg Seeds)	2×1.5	Suitable for soil improvement and in the erosion and flooding damages prevention due to its easy adaptability to wet and rocky grounds. In the studied area, it was found on humid soil and directly on coal mine sterile materials.
Mimosa scabrella	bracatinga	20	Timber Ornamental Apicule Plant Forage Plant Environmental Reforestation.	33 (/kg Seeds)	2×2	Suitable for soil preservation and for the reclaiming of disturbed grounds due to its capability to fertilize the soil by replenishing the biomass and the soil nutrients. Bracatinga occurs in low chemicallly fertile soils usually with pH from 3.5 to 5.5.
Senna multijuga	aleluia	3-5	Timber Ornamental Firewood industrial (resin, tannery)	32 (/kg Seeds)	2×2	Though it is not a very frequent and aboundant specie, it has adapted itself very well to the coal mines region. Appropriate for the reclaiming of bauxite mined areas and/or shale mine disturbed grounds.
Croton celtidifolius	sangue-de-drago	6	Firewood Other general uses.	15 (/kg Seeds)	2×2	It grows mainly in secondary formations belonging to initial and medium stages on natural revegetation. Used for reforestation at disturbed areas
Rapanea farruginea	capororoca	5-10	Timber Food Ornamental Firewood	-	No Data	Suitable for the reclaiming of disturbed ecosystems. Very important to achieve the succession reforestation by means of native species of the Atlantic Forest.
Trema micrantha	grandiuva	4-15	Timber, Medicinal Apicule Plant Forage Plant Firewood Charcoal	23 (/kg Seeds)	2×2	Due to its great ecological versatility, it is recommended for environmental reforestation, reclamation of coal-mine-eroded areas, for soil conservation and stabilization of sand dunes.
Psidium cattleyanum	araca-amarelo (aracazeiro)	3-10	Timber, Food Firewood Charcoal	23 (/kg Seeds)	2×2	Heliophyte specie which endures initial shading stage. This specie is essential to associated groves aimed at the reclaiming of disturbed areas for permanent preservation.
Alchomea triplinervia	tanheiro (tapia-guacu)	25	Charcoal and firewood. Apicule plant.	30 (/kg Seeds)	2×2	It is a fast developing specie which adapts itself to various soil types. Its fruit is suitable for Animal feeding.

2×1.5m : 3,020 seedlings /ha
2×2m : 3,000 seedlings /ha
* The number of planted seedlings include 25% of dying individulals.
- : No commercial seeds available

TABLE G-4

RECOMMENDED PLANTS SUITABLE FOR REVEGETATION (LAWN SPECIES)

Scientific name	Common name	Hight (cm)	Use	Price of Seeds (US$/kg)	Spacing	Discription
Brachiaria decumbens	-	-	Forage Plant	1.7-2.0	40kg/ha	It has been used for reclaiming coal mine disturbed areas of Project Itanema.
Brachiaria sp. (Brachiaria humidicola?)	-	-	Forage Plant	8.5	32kg/ha	It has been used for reclaiming coal mine disturbed areas of Carbonifera Urussanga at Santana. It was found expressively growing on clayish soil which covers coal reject piles.
Lolium Multiflorum	azesein	40-80	Forage Plant	No Data	30-40kg/ha	It has been used for reclaiming coal mine disturbed areas of Carbonifera Itanema and Project M (reclaimation project at Fiolita)
Eragrostis curvula	capin-choruas	20-50	Forage Plant	No Data	No Data	It is well adapted to the critical and depleted areas of the coal mine region.
Axonopus affinis	grama missioneira	20-50	Forage Plant	No Data	No Data	It is well adapted to the critical and depleted areas of the coal mine region.
Axonopus obtusfolius	grama-de-folha-larga	20-50	Forage Plant Ornamental	No Data	No Data	A. obtusifolius has been used for reclaiming coal mine disturbed areas of Carbonifera Urussanga at Santana.
Paspalum pumilum	grama-kikuio	15-60	Forage Plant	-	No Data	It is very useful regarding its potential to consolidate erosion prone terrain and to settle sand dunes.
Melinis minutiflora	capin-gordura	50-100	No Data	No Data	No Data	Native to Africa. It is largely distributed in practically all State of Santa Catarina. It is not very disseminated in the coal mines region. No records on its use in reforestation available
Andropogon leucostachyus	capin-colchao	40-80	mattress (stuffing in the country-side)	2.5	30kg/ha	No records on its use in reforestation.
Andropogon bicornis	rabo-de-burro	100-200	Medicinal Properties	-	No Data	It is well adapted to the critical and depleted areas of the coal mine region. No records on its use in reforestation available.
Rhynchelytrum repens	capim-grafanhoto	50-100	No Data	-	No Data	No records on its use in reforestation available.
Axonopus fissifolius	grama-missioneira	15-120	Ornamental	-	No Data	No records on its use in reforestation available. It would avoid soil erosion and provide constant grazing fields.

2. MICROORGANISMS

2.1 Numerical Survey of Microorganisms

11. Acid mine drainage (AMD) is generated by oxidation of pyrite contained in the coal seams. This reaction is catalyzed by iron bacteria (Thiobacillus ferooxidens) and sulfur-oxidizing bacteria (Thiobacillus thiooxidans). On the other hand, sulfate-reducing bacteria (Desulfovibrio, Desulfotomaculum) have an ability to facilitate water purification. As it is useful for understanding pollution mechanism and purification process to obtain information on the distribution of the microorganisms in the region, those living in ambient water were surveyed. At the same time, the techniques of cultivating and analyzing those organisms were transferred to the Brazilian counterparts.

2.2 Methods

12. Investigation of microorganisms living in ambient water were conducted during November in 1996 (Spring) and February in 1997 (Summer). The water was sampled at 22 locations including nine (9) from the FS sites, one (1) from a coal washing plant and twelve (12) from river flows. The number of bacteria (Iron bacteria and sulfate reducing bacteria) were estimated by the MPN (Most Probable Number) method. The sampling locations are shown in Figure G-2 and the description of sampling locations in Table G-5, respectively. The cultivation methods of bacteria are described below.

13. Iron bacteria:

i.) Culture medium
Silverman 9K medium was used for cultivation of iron bacteria. Ferrous sulfate ($FeSO_4 \cdot 7H_2O$) was added as an energy source.

ii.) Procedures

①. Five fermentation tube rows with three replications were arranged for each sampling point. (5 decimal series of sample dilution ×3 replications×sampling points). For example, 1 (sampling water), 0.1 (1/10 dilution), 10^{-2} (1/100 dilution), 10^{-3} (1/1,000 dilution) and 10^{-4} (1/10,000 dilution).

②. mm test tubes were used as fermentation tubes. The volumes of media were 9 ml for each tube. For comparative purposes, one uninoculated control was made for each set of inoculated tubes. Sample added water to each fermentation tube was inoculated through decimal series dilution.

③. The sample water was adequately shaken before the inoculation.

④. On the inoculation process, sterile pipettes were used for initial and subsequent transfers from each tube. After inoculation, each tube was closed with a cotton plug to provide ventilate low.

FIGURE G-2 SAMPLING LOCATION FOR BIO-CULTURING TEST

TABLE G-5(1/2)
SAMPLING LOCATION FOR BIO-CULTURING TEST (NOV.96)

Sampling Site		Kind of Bio-culturing test			Remarks
		Iron bacteria	Sulfur oxidizing bacteria	Sulfate reducing bacteria	
CARVAO	CR-1	O	O	O	Underground water
	CR-2	O	O	O	Settling pond water
	CR-3	O	O	O	Discharged water in mine waste
CAPIVARI	CP-1	O	-	-	Settling pond water
FIORITA	FR-1	O	-	-	Discharged water in mine waste
	FR-2	O	-	-	Pond water
ROCINHA	RO-1	O	-	-	Discharged water in mine waste
	RO-2	O	-	-	Settling pond water
	RO-3	O	-	-	Discharged water in mine waste
TOREVISO	TR-1	O	-	-	Settling pond water
RIO ARARANGUA	PA-1	O	O	-	Upper stream water of Rio Ararangua
	PA-6	O	O	-	Middle stream water of Rio Ararangua
	PA-8	O	O	-	Lower stream water of Rio Ararangua
RIO URUSANGA	PU-10	O	O	-	Upper stream water of Rio Urusanga
	PU-3	O	O	-	Middle stream water of Rio Urusanga
	PU-6	O	O	-	Lower stream water of Rio Urusanga
RIO TUBARAO	PT-1	O	O	-	Upper stream water of Rio Tubarao
	PT-4	O	O	-	Middle stream water of Rio Tubarao
	PT-8	O	O	-	Lower stream water of Rio Tubarao
RIO CRICIUMA	CM-1	-	-	O	River water of Rio Criciuma
&	SA-1	-	-	O	River water of Rio Sangao
RIO SANGAO	SA-2	-	-	O	River water of Rio Sangao

TABLE G-5(2/2)

SAMPLING LOCATION FOR BIO-CULTURING TEST (FEB.97)

Sampling Site		Kind of Bio-culturing test			Remarks
		Iron bacteria	Sulfur oxidizing bacteria	Sulfate reducing bacteria	
CARVAO	CR-1	O	O	O	Underground water
	CR-2	O	O	O	Settling pond water
	CR-3	O	O	O	Discharged water in mine waste
CAPIVARI	CP-1	O	-	O	Settling pond water
FIORITA	FR-1	O	-	O	Discharged water in mine waste
	FR-2	O	-	-	Pond water
ROCINHA	RO-1	O	-	O	Discharged water in mine waste
	RO-2	O	-	-	Settling pond water
	RO-3	O	-	-	Discharged water in mine waste
TOREVISO	TR-1	O	-	-	Settling pond water
RIO ARARANGUA	PA-1	O	O	-	Upper stream water of Rio Ararangua
	PA-6	O	O	-	Middle stream water of Rio Ararangua
	PA-8	O	O	-	Lower stream water of Rio Ararangua
RIO URUSANGA	PU-10	O	O	-	Upper stream water of Rio Urusanga
	PU-3	O	O	-	Middle stream water of Rio Urusanga
	PU-6	O	O	-	Lower stream water of Rio Urusanga
RIO TUBARAO	PT-1	O	O	-	Upper stream water of Rio Tubarao
	PT-4	O	O	-	Middle stream water of Rio Tubarao
	PT-8	O	O	-	Lower stream water of Rio Tubarao
RIO CRICIUMA	CM-1	-	-	O	River water of Rio Criciuma
&	SA-1	-	-	O	River water of Rio Sangao
RIO SANGAO	SA-2	-	-	O	River water of Rio Sangao

⑤. Inoculated tubes (and controls) were incubated at 30°C. Test tubes were shaken daily to keep the tube in aerobic conditions.

⑥. After the incubation period, the number of "iron bacteria positive" tubes were recorded in each dilution series. The positive tubes could be distinguished by browning as compared to the controls.

⑦. Bacterial density was estimated from the MPN table using the number of positive tubes in the dilution series.

14. Sulfur-oxidizing bacteria:

i.) Culture medium

Silverman 9K medium was used for cultivation of sulfur-oxidizing bacteria. Sodium thiosulfate ($Na_2S_2O_3 \cdot 5H_2O$) was added as an energy source.

ii.) Procedures

①. The arrangement of tube rows, dilution processes and MPN estimation processes was identical to those of the above "iron bacteria" experiment.

②. The tubes were incubated at 30°C under aerobic conditions.

③. The positive tubes could be distinguished by a decrease in pH from pH 4 to 2.

15. Sulfate-reducing bacteria:

i.) Culture medium

17-1 medium was used for cultivation of sulfate-reducing bacteria. Sodium thioglycolate ($C_2H_3NaO_2S$) was added as an energy source.

ii.) Procedures

①. The arrangement of tube rows, dilution processes and MPN estimation processes was almost the same as in the "iron bacteria" experiment. However, inoculated tubes were completely closed with aluminum films to create anaerobic conditions.

②. Inoculated tubes were incubated at 30°C under anaerobic and dark conditions.

③. The positive tubes could be distinguished by blackening in the medium as compared to uninoculated controls.

2.3 Result of Numerical Survey of Microorganisms

16. The results of bacterial tests in spring are shown in Table G-6. Iron bacteria were detected from all the locations and their number varies from each location. The number of iron bacteria tended to increase near the mining areas. However, a small amount of iron bacteria were detected in the upstream reaches of the rivers where no contamination by mine effluent exists. The number of iron bacteria showed higher value in the ponds located at Fiorita and Treviso. This result may suggest that the standing water which stores mine effluent, like a pond, acts as an aid in culturing the iron bacteria. Sulfate-reducing bacteria were mainly detected in the reaches of the Criciuma river eutrophicated

TABLE G-6

RESULT OF BIO-CULTURING TEST (NOV.96)

		pH	Temp. (℃)	MPN of bacteria (×10³/100ml) Iron	Sulfur-oxd.	Sulfate reducing	Remarks
CARVAO	CR-1	4.0	23	1.1	0	11	Underground water
	CR-2	3.0	28	44	0	6.1	Settling pond water
	CR-3	4.0	25	29	0	6.1	Discharged Water from the settling pond
CAPIVARI	CP-1	2.0	30	200	-	-	Settling pond water
FIORITA	FL-1	4.0	25	11,000	-	-	Discharged water in mine waste
	FL-2	4.0	25	430	-	-	Pond water
ROCINHA	RO-1	2.0	24	290	-	-	Discharged water in mine waste
	RO-2	3.0	28	290	-	-	Settling pond water
	RO-3	3.5	28	42	-	-	Discharged water in mine waste
TOREVISO	TR-1	2.0	32	>24,000	-	-	Settling pond water
RIO ARARANNOA	PA-1	6.0	18	1.1	0	-	Upper stream water
	PA-6	3.5	22	35	0	-	Middle stream water
	PA-8	4.0	24	28	0	-	Lower stream water
RIO URUSANGA	PU-10	6.0	22	7.2	0	-	Upper stream water
	PU-6	3.0	26	7.2	0	-	Middle stream water
	PU-3	4.0	26	290	0	-	Lower stream water
RIO TUBARAO	PT-1	7.0	25	1.5	0	-	Upper stream water
	PT-4	4.0	27	1.6	0	-	Middle stream water
	PT-8	5.0	25	1.1	0	-	Lower stream water
RIO CRICIUMA	CM-1	5.0	25	-	-	210	River water
&	CM-2	3.0	25	-	-	15	River water
RIO SANGAO	SA-1	3.0	25	-	-	15	River water

by the municipal sewage. However, small numbers of these bacteria were also detected from low pH water (3 - 4) at the Carvao sites and the Sangao river. This result may suggest that sulfate-reducing bacteria can exist under low pH conditions. Sulfur-oxidizing bacteria were not detected at any of the locations.

17. The results of bacterial tests in summer are shown in Table G-7. The number of bacteria in the summer season was smaller than those of spring season. This may result from the dilution and dispersion effects of microorganisms in ambient water caused by large and frequent rainfall in summer season. Sulfur oxidizing bacteria were also not found in any water sampled. Very low density of iron bacteria which generate AMD were found in upstream points of the FS site. However, higher density of bacteria were found in the site and downstream points. The mine-out area was recognized to be one of the source areas for an increase of iron bacteria concentrations. Sulfate-reducing bacteria were detected in river water. Sulfate-reducing bacteria are thought to be one potential biological resource for treating acid mine water under anaerobic conditions.

18. Investigation results of spring and summer seasons indicated that no sulfur-oxidizing bacteria were found but iron bacteria were found at all investigation points. A large number of iron bacteria were found in pond water within the FS sites. This result indicates that a water pond of abandoned open pit acts as a cultivation pond for iron bacteria. Sulfate-reducing bacteria were mainly found in river water which is polluted by urban sewerage. Low densities of sulfate-reducing bacteria were found in low pH water (pH : 3 to 4) within the FS sites. This result may indicate that sulfate-reducing bacteria could live in low pH water. Tests of microorganisms were conducted in Spring and Summer (February, 1997). However, it seems difficult to derive seasonal variations from the above test results.

2.4 Bacterial Treatment Test for Acid Mine Drainage

19. Iron bacteria and sulfur-oxidizing bacteria enhance an oxidation process from highly soluble Fe^{2+} to in-soluble Fe^{3+}. This effect can be utilized to remove iron from mine water by using a process of oxidation (under aerobic condition by aeration) and neutralization. Addition of carbon energy sources (vegetative cellulose such as fallen leaves, algae) under anaerobic conditions contributes a sedimentation of insoluble Fe^{3+} generated by a reduction process from Fe^{3+} to Fe^{2+}. The carbon energy sources have an ability to increase pH. As described above, microorganisms in mine water can be utilized for mine wastewater treatment. An appropriate utilization of microorganisms may lead to a large scale and inexpensive method of wastewater treatment. In order to study an application of microorganisms to AMD treatment, with the cooperation of FUCRI-UNESC, a laboratory-scale experiment for acid mine drainage treatment was conducted using iron bacteria and sulfate-reducing bacteria.

TABLE G-7

RESULT OF BIO-CULTURING TEST (FEB.97)

		pH	Temp. (℃)	MPN of bacteria (×10[2]/100ml) Iron	Sulfur-oxd.	Sulfate reducing	Remarks
CARVAO	CR-1	4.0	23	0.75	0	0	Underground water
	CR-2	3.0	25	35	0	0	Settling pond water
	CR-3	4.0	25.5	0.03	0	0.03	Discharged water in mine waste
CAPIVARI	CP-1	2.0	35	1.5	-	0.03	Settling pond water
FIORITA	FR-1	4.0	25	1.5	-	0.03	Discharged water in mine waste
	FR-2	4.0	25	20	-	-	Pond water
ROCINHA	RO-1	3.0	27	0.03	-	0.11	Discharged water in mine waste
	RO-2	2.0	32	0.11	-	-	Settling pond water
	RO-3	3.0	27	0.03	-	-	Discharged water in mine waste
TOREVISO	TR-1	3.0	27	11	-	-	Settling pond water
RIO ARARANNGA	PA-1	7.0	23	0.03	0	-	Upper stream water of Rio Ararangua
	PA-6	3.5	27	0.11	0	-	Middle stream water of Rio Ararangua
	PA-8	4.0	27.5	0.11	0	-	Lower stream water of Rio Ararangua
RIO URUSANGA	PU-10	7.0	23	0	0	-	Upper stream water of Rio Urusanga
	PU-3	3.0	26	0.2	0	-	Middle stream water of Rio Urusanga
	PU-6	4.0	29	0.2	0	-	Lower stream water of Rio Urusanga
RIO TUBARAO	PT-1	7.0	28	0	0	-	Upper stream water of Rio Tubarao
	PT-4	3.5	29.5	0.3	0	-	Middle stream water of Rio Tubarao
	PT-8	5.0	27	0.11	0	-	Lower stream water of Rio Tubarao
RIO CRICIUMA	CM-1	4.0	29	-	-	24	River water of Rio Criciuma
&	SA-1	3.0	29	-	-	0	River water of Rio Sangao
RIO SANGAO	SA-2	3.0	29	-	-	0	River water of Rio Sangao

2.5 Methods of Test

20. It is reported that iron bacteria are autotrophic bacteria and their metabolism is active under aerobic conditions. On the other hand, to facilitate the activity of sulfate-reducing bacteria on treatment, organic materials such as lactic acid were supplied under anaerobic conditions. pH of 4 to 7 and anaerobic conditions are needed to activate the sulfur reducing bacteria. This test was conducted under various conditions of pH and carbon energy sources. Inexpensive nutrient sources (river sediment of Ciciuma, dried cattle excrement) were investigated in this test. Water treatment effects of various carbon energy sources under pH 4 condition were compared based on the concentration of SO4 and T-Fe, which are parameters of water treatment effects. pH, ORP, electric conductivity and DO were also measured. Analysis of SO4 and T-Fe concentration were conducted by FUCRI. Figure G-3 shows contents of the experiment. Each test case is described below.

2.6 Test Cases

21. The test included the following two experiments using iron bacteria and sulfate-reducing bacteria.

i.) Iron bacteria (1 case)
Acid Mine Drainage (no pH adjustment)

ii.) Sulfate-reducing bacteria (6 cases)

Case 1 : Acid Mine Drainage + soil*[1] (Adjust pH)*[2]
Case 2 : Acid Mine Drainage + soil (Not adjust pH)
Case 3 : Acid Mine Drainage + Dried cattle excrement (Adjust pH)
Case 4 : Acid Mine Drainage + Dried cattle excrement (Not adjust pH)
Case 5 : Acid Mine Drainage + River sediment (Adjust pH)
Case 6 : Acid Mine Drainage + River sediment*[3] (Not adjust pH)

*[1] Sterilize the soil by autoclave at 120 °C for 15 min.
*[2] Use 1N-NaOH to adjust pH to 4.
*[3] River sediment of the will be collected from the Criciuma river.

Natural organic materials (dried cattle excrement or river sediment) were added as a energy source for sulfate-reducing bacteria in the acid mine drainage. Above Case 1 and Case 2 were tested as a control.

2.7 Analysis and Measuring Methods and Frequencies

22. Methods and frequencies for analysis are as follows ;

Items	Method	Frequency
pH	pH meter	
ORP	ORP meter	Every 2 or 3 days
DO	DO meter	
Conductivity	Conductivity meter	
Total Iron	Phenanthroline Method	Interval of 0, 10, 20 days
	Sulfate gravimetric method	

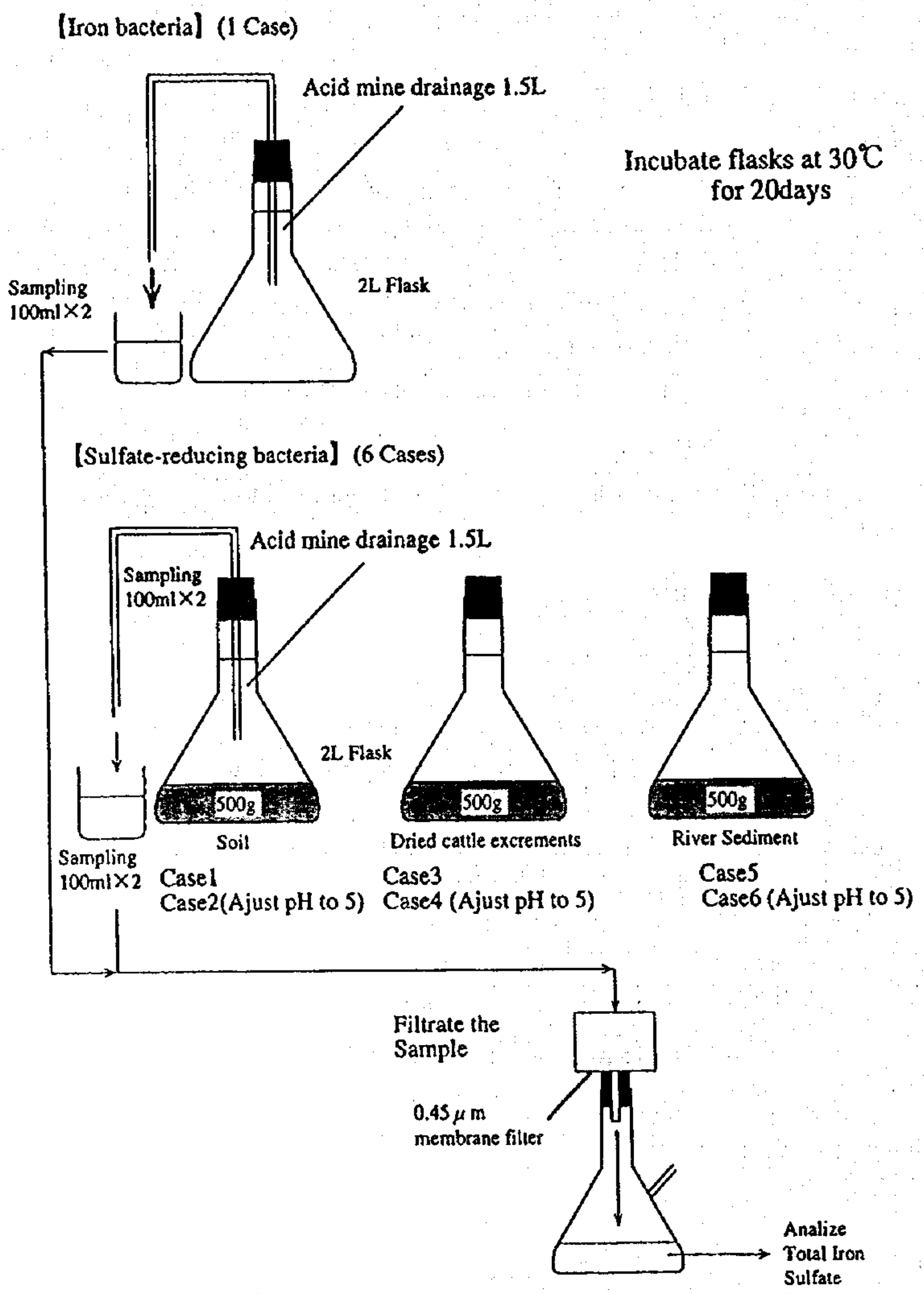


FIGURE G-3 BACTERIA TREATMENT TEST FOR ACID MINE DRAINAGE

23. Procedures are as follows:

i.) Iron bacteria (1 case)

①. The sample water from the pond of CAPIVARI was collected as a typical acid mine drainage.
②. The organic materials (300g) and the acid mine drainage (1.5L) were put into the 2L flask.
③. The iron bacteria which had been cultured (1week) was inoculated beforehand on the flask (30ml for each flasks).
④. The prepared flasks were incubated at 30°C under the aerobic conditions.
⑤. pH, DO, ORP and conductivity were measured every 2 or 3 days.
⑥. The two water samples (each of 100ml) from the flasks at intervals of 0, 10 and 20 days were collected after starting the test. $CaCO_3$ was added to the samples to sink Fe^{3+} ion.
⑦. The water samples were filtered using a 0.45 μ m membrane filter and then analyzed for the total iron and sulfate.

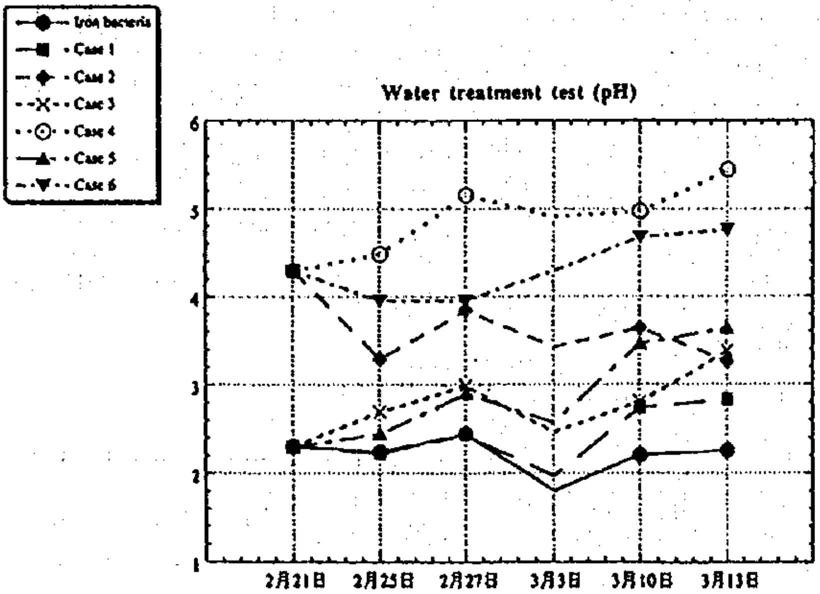
ii.) Sulfate-reducing bacteria (6 cases)

①. Acid mine drainage (1.5L) and organic materials (300g) were put into the 2L flask.
②. pH was adjusted to 4 using 1N-NaOH in pH adjust cases.
③. "Sulfate-reducing bacteria seed" was inoculated in the flask (30ml for each flasks).
④. Test flasks were closed with aluminum films to maintain anaerobic conditions.
⑤. Inoculated tubes were incubated at 30°C under anaerobic and dark conditions.
⑥. pH, DO, ORP, and conductivity were measured every 2 or 3 days.
⑦. The two water samples (each of 100ml) from the flasks at intervals of 0, 10 and 20 days were collected after starting the test.
⑧. The water samples were filtered using a 0.45 μ m membrane filter and then analyze for the total iron and sulfate.

2.8 Results of Experiment

24. Experiment results using test water inoculated with iron bacteria showed a trend toward lowering pH and water acidification. Experiment results using test water inoculated with sulfate-reducing bacteria showed a trend toward increasing pH and lowering ORP and DO (Figure G-4) in the water added sediment of Criciuma river and cattle excrement. Trend of iron bacteria and water purification were also observed. Concentrations of Fe and SO_4 were lowered over time not only in test waters containing iron bacteria but also in waters containing sulfate-reducing bacteria. Based on the results of this experiment, the bottom sediments from the river channel and cattle manure was recognized to be applicable for increasing sulfate-reducing bacteria numbers and to be effective for acid mine drainage treatment.

25. Based on the results described above, microorganisms treatment under anaerobic condition for multiplication of sulfate-reducing bacteria and addition of carbon energy sources such as sediment and cattle excrement. The low cost of sulfate-reducing bacteria treatment was one factor that makes this treatment method attractive for the regional remediation.



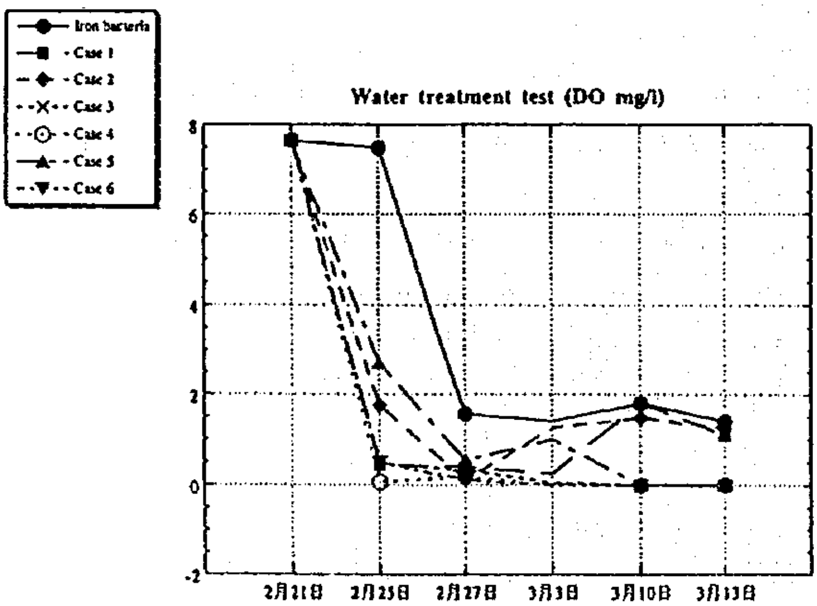
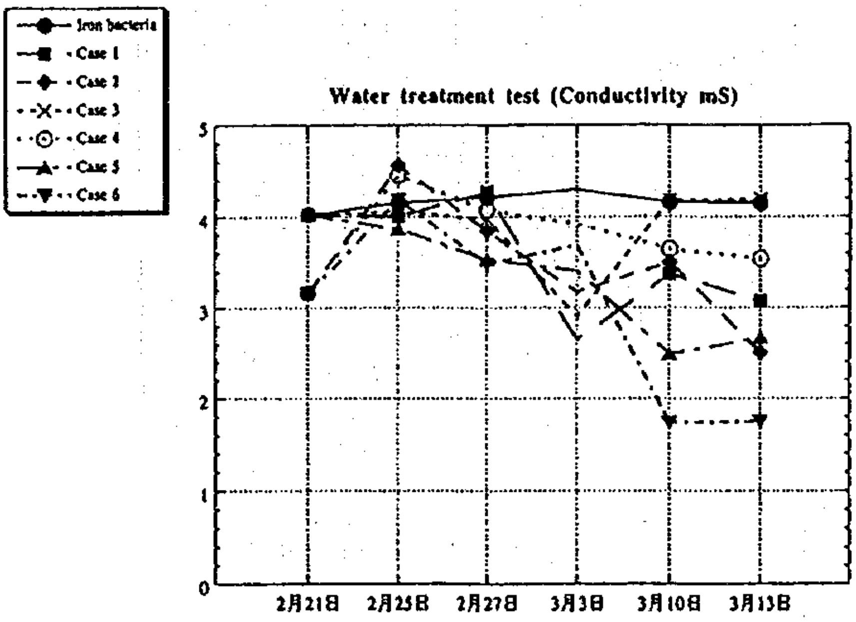


FIGURE G-4(1/3) RESULT OF THE BACTERIA TREATMENT TEST (PH, DO)



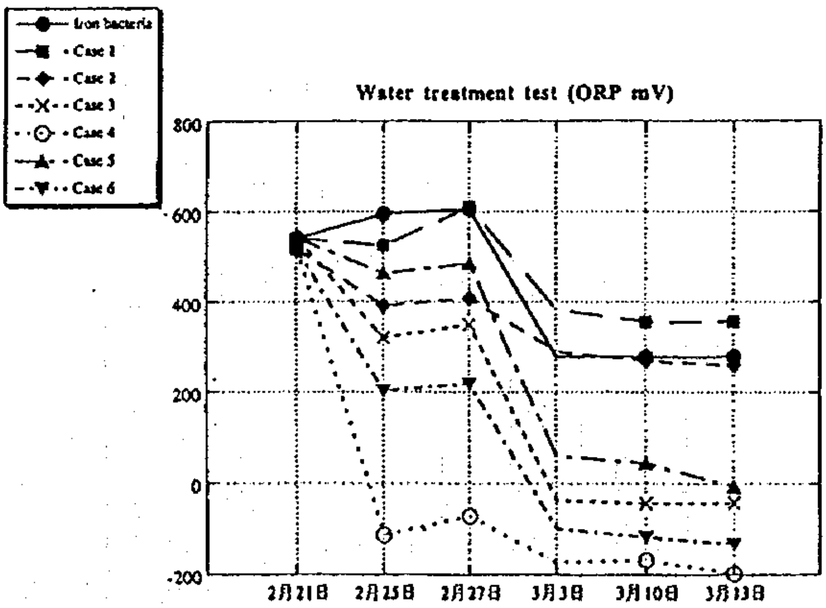


FIGURE G-4(2/3) RESULT OF THE BACTERIA TREATMENT TEST (CONDUCTIVITY, ORP)

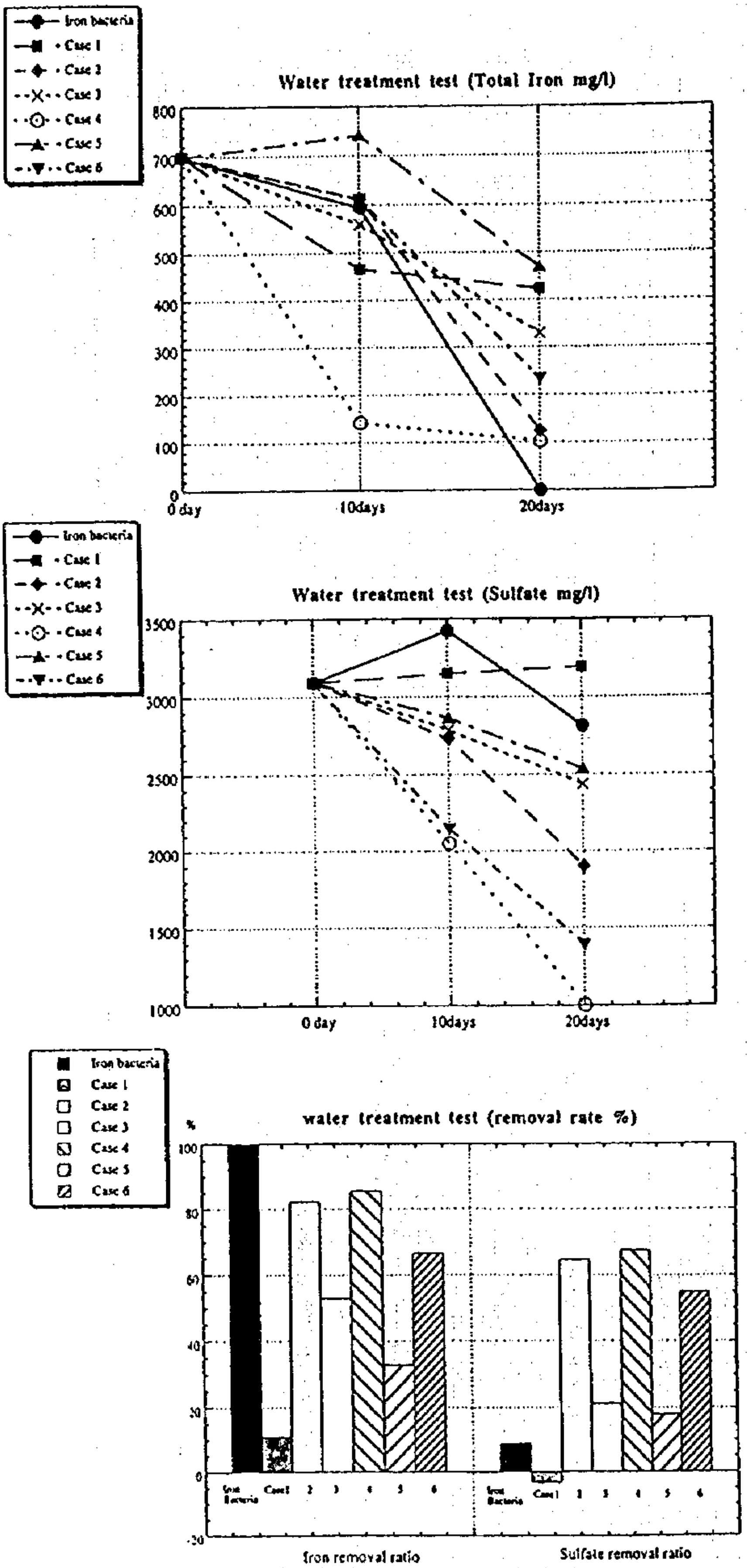


FIGURE G-4(3/3) RESULT OF THE BACTERIA TREATMENT TEST (TOTAL IRON, SULFATE)

H. UTILIZATION OF WASTE

1. Introduction

1. The main objective of the utilization of waste study is to search for possibilities of reducing pollution sources themselves. The study was based on interviews with concerned organizations in Brazil together with experience and lessons learned in Japan. The background of waste utilization activities in Japan are presented first, then the possibilities of waste utilization in Santa Catarina are discussed.

2. Waste Utilization in Japan

2.1 Background

2. The Chikuhou coal field was one of the leading regions in coal production, located along the Onga river in Fukuoka, Kyusyu, the southern island of Japan. It consists of 25 municipalities with a population of 485,000 living in an area of 984 km^2. Underground coal mining started around 1900 and at its peak more than 200 coal mines were being operated. The last coal mine was closed in the 1970s, due to competition with cheap imported oil and coal. During those decades of mining, waste from mines and washing plants were piled up in many places such as hilltops, hillsides, flat areas or valleys in pyramids or trapeziums. These landscapes were commonly seen in coal producing areas all over Japan.

3. There were houses, roads, rail ways, rivers or irrigation ponds around waste dumps, which caused landslides, dirty river water and rising river beds with heavy rains hurting people and damaging facilities. Occasionally, spontaneous combustion of coal remaining in waste occurred generating gas (CO) which poisoned people living nearby. The population demanded creation of new jobs for laid-off miners and solutions for pollution problems. The main difference with Santa Catarina's is the collapse of land and destruction of the irrigation system on a large scale as a result of underground mining. However, there is no acidic water problem in the river system since there is no pyrite in the coal seam.

4. The Ministry of International Trade and Industry of Japan (MITI) started a study on utilization of waste dumps as one of their regional development studies in 1960. The study included waste location of the dump sites, period of dumping, material, shape, etc. In the Fukuoka prefecture, the study found 624 dumps with accumulated waste amounting to 220 million m^3 over a territory equivalent to 14 km^2. To control pollution and also create new jobs, MITI began to address the problem of dangerous waste dumps in 1962 and continued for more than 10 years. At the end of March 1990, the remaining waste dumps decreased to 253 with 140 million m^3 of waste over a total area of 12.7 km^2. No dangerous dumps are left.

5. At first, from a standpoint of accident prevention, slope stabilization of waste dumps and/or relocation of waste were done, according to their level of dangerousness, while the concept of waste utilization was gradually introduced. In response to the economic expansion in the region as well as all over Japan at that time, a new highway and a railway for the bullet train were built using large amount of waste as construction materials. Coastal land reclamation for industrial use was also done. At the same time, the usefulness of the waste for cement manufacturing as argillaceous material was recognized. As a result, almost all the waste hauled out from the coal field was used for the above activity.

2.2 Waste Utilization in Japan

6. Various waste utilization techniques were tried and various testing methods were conducted in the past, including waste re-washing, material for cement production, coastal land reclamation, road construction material, lightweight aggregate, brick material, etc. as briefly discussed below:

(a) Waste re-washing

7. In the past, coal recovery from waste was a traditional small business in the region, and used simple equipment such as troughs with running water. Since this activity was not regulated, it polluted neighboring areas, making itself a nuisance to people living in the neighborhood. Like in Brazil, the mining law was not applicable to that business. As a result, a special act, "The Waste Re-Washing Business Act", was issued in 1958 to administer it. In 1965 a private company installed a conventional jig for waste re-washing. Since then, the business continues and at present two 50 t/h jigs are in operation in the region. At first, they washed nearby wastes but currently hauled them from remote waste dumps by truck, since the washing plant is not movable. Coal rich wastes had been exhausted already and, today, two coals of 3,300 and 4,500 kcal/kg are produced for caloric adjustment use at a coal fired power station. Washed waste amounts to 17 million tons so far and 1.4 million tons of coal have been recuperated since 1965.

(b) Raw material for cement

8. If final refuse after re-washing can be sold as raw material for cement production, more waste with less coal content would become profitable. At present, waste sold amounts to 7.2 million tons out of the washed waste of 17 million tons.

i) Raw materials:

- Raw materials for Portland cement are limestone, argillaceous material, silicic anhydrite, iron oxide, which are pulverized and blended into prescribed chemical composition before calcination in the rotary kiln. In the calcination process, they are turned into clinker. Finally, Portland cement is produced by blending clinker with gypsum. A typical raw material blend for one ton of Portland cement in Japan is as follows:

Clinker:	limestone	1,144 kg
	argillaceous material	228 kg
	silicic anhydrite	45 kg
	iron oxide	32 kg
Gypsum:		32 kg

- Main chemical components of clinker are CaO, SiO_2, Al_2O_3, Fe_2O_3. The most restricted harmful one in cement is MgO which can be found in limestone. More than 3.5 % of MgO in cement cause cracks in hardening concrete by expansive force and eventually structure collapse. MgO content is usually 0.8 to 2.5 % in Portland cement.

ii) Characteristics of favorable materials for cement production:

- Easy to pulverize
  Materials should be well pulverized to keep them in close contact with one another during chemical reactions. Hardness is unfavorable for pulverization and quartz (a very hard and chemically stable material) should be avoided as much as possible.

- Quick to react
  Synthetic reaction happens under half-melted state of blended materials. A source of SiO_2 should not be chemically stable quartz but other form of SiO_2 such as silicate, which is soft and quick to react.

- Rich in silicate

- Stable in ignition loss
  Changes in the amount of ignition loss cause lost control of materials component balance, which leads to bad quality cement.

- Others
  Materials should be provided as close as possible for stable supply and less transportation cast.

iii) Characteristics of waste in the Chikuhou coal field:
A typical waste consists of 45.8 % of SiO_2, 20.9 % of Al_2O_3, 3.0 % of CaO, 2.9 % of Fe_2O_3, 1.5 % of SO_3 and 0.4 % of MgO and its calorific value is 1,290 kcal/kg. It is rich in SiO_2 and Al_2O_3 and satisfies all the conditions required for cement material.

9. The remaining waste after recuperation of coal and cement material is hauled back to the waste dump which is reclaimed in a stable condition. Decrease in waste volume creates flat land, totaling 119 ha available for industry, university, industrial waste disposal, etc. Since progress in encouraging industry to come to the region is slow, most of the land has not been utilized yet.

(c) Coastal land reclamation

10. A coal mine agreed to undertake coastal land reclamation with a regional fishery association and, after obtaining governmental permit in 1955, started filling the sea with waste coming directly from the underground mine. The first step was to construct a bank, encircling the planned reclamation area with lumps of heading rock waste to avoid black water in the sea. After that, all kinds of waste were

dumped and filled inside. The total reclamation was 6.7 ha with 100,000 m^3 of waste. Waste in the Chikuhou coal field was hauled to the neighboring city about 30 km away from the waste dumps by truck for filling the sea. Prior to filling, an embankment was constructed in 1963. The amount of waste used for reclamation was 56.4 million m^3 and the reclaimed land totaled 640 ha. At present, the whole newly created land was used for factories.

(d) Road construction material

11. Prior to mass utilization for road construction material, a pilot road (width: 7.5 m, length: 125 m) was constructed, using conventional material and burned waste independently. Results revealed that a burned waste road was more economical and stronger than a conventional one. Since the limited access highway and the bullet train railway run through low and wet lands in the Chikuhou region, many parts of them are elevated roads, for which a large amount of ordinary waste was used. For subgrade material, burned waste was utilized.

12. As a result of the utilization of waste as construction material, many waste dumps became emptied and flat land, which was reclaimed for various uses, including housing, industrial areas, golf courses, etc. However, actual development was slow and only the most convenient places, e.g., those 'close to downtown' or 'having good transportation' were developed. Many areas still remain undeveloped.

(e) Construction materials (lightweight aggregate, brick, etc.)

13. Due to the gradual depletion of river sand and natural aggregate and given the rapid increase in high-rise construction in Japan, demand for lightweight aggregates was growing at that time. Research for artificial lightweight aggregate from coal mine waste started at many institutes and companies in 1960s. Because of the nature of the waste which is a random mixture of varying rocks, it was quite rare to find a stock pile accumulating only useful minerals and, due to scanty content of such minerals, it was difficult to separate them from waste. As a result, development on an industrial scale was rare.

14. Specific requirements for lightweight aggregate include: (i.) smooth and roundish surface; (ii.) little water absorptivity, i.e. less than 10 % after 24 hours; and (iii.) 60 to 100 kg/cm^2 of strength. Shale or clay with expansiveness can be a raw material and, after pulverizing and pelletizing them, they are calcined into lightweight aggregate.

(f) Refractory material

15. Before attention was focused on waste utilization, waste was burned to make chamotte for fire brick on a small scale. Chamotte was collected by hand. The amount of waste used for this purpose was limited.

3. Possibilities of Waste Utilization in Santa Catarina

16. The possibilities of waste utilization in Santa Catarina have been studied based on Santa Catarina's own research and activities together with our experiences in Japan. They include: (i.) waste re-washing; (ii.) cement raw materials; (iii.) fuel for fluidized bed combustion; (iv.) road construction material; and (v.) refractory material.

3.1 Waste Re-Washing

17. The study on the possibility of waste re-washing includes the following:

* Research for the existence of washable waste and recoverable coal; and
* Inspection of coal washing activities from a stand point of environmental protection for future operations.

(a) Re-washing possibilities

18. Coal production in Santa Catarina was concentrated on CPL (*carvão pre-lavado*, or pre-washed coal), which was sent to the preparation plant at Capivari for washing and separation between metallurgical coal and steam coal. Coal fines recuperation only started in 1973. Washery refuse before that time contains considerable amount of coal, which are sporadically located in the region, and coal recuperation are being operated in some areas. Five promising areas, where coal recuperation has never been carried out, were selected and two samples from each area were taken for preliminary analysis. Finally, from the result of the preliminary analyses, two typical areas were selected for washability tests to determine coal recovery rates.

(b) Preliminary analysis

19. The selected areas are Rocinha, Rio Fiorita, São Marcos, Rio America and Naspolini as shown in Table H-1 and Figures H-1 (1/2) & (2/2). The analytical parameters are size, weight percentage, moisture, ash and sulfur contents, carried out by SATC.

(c) Results of preliminary analysis

20. The characteristics of the sampled wastes are:

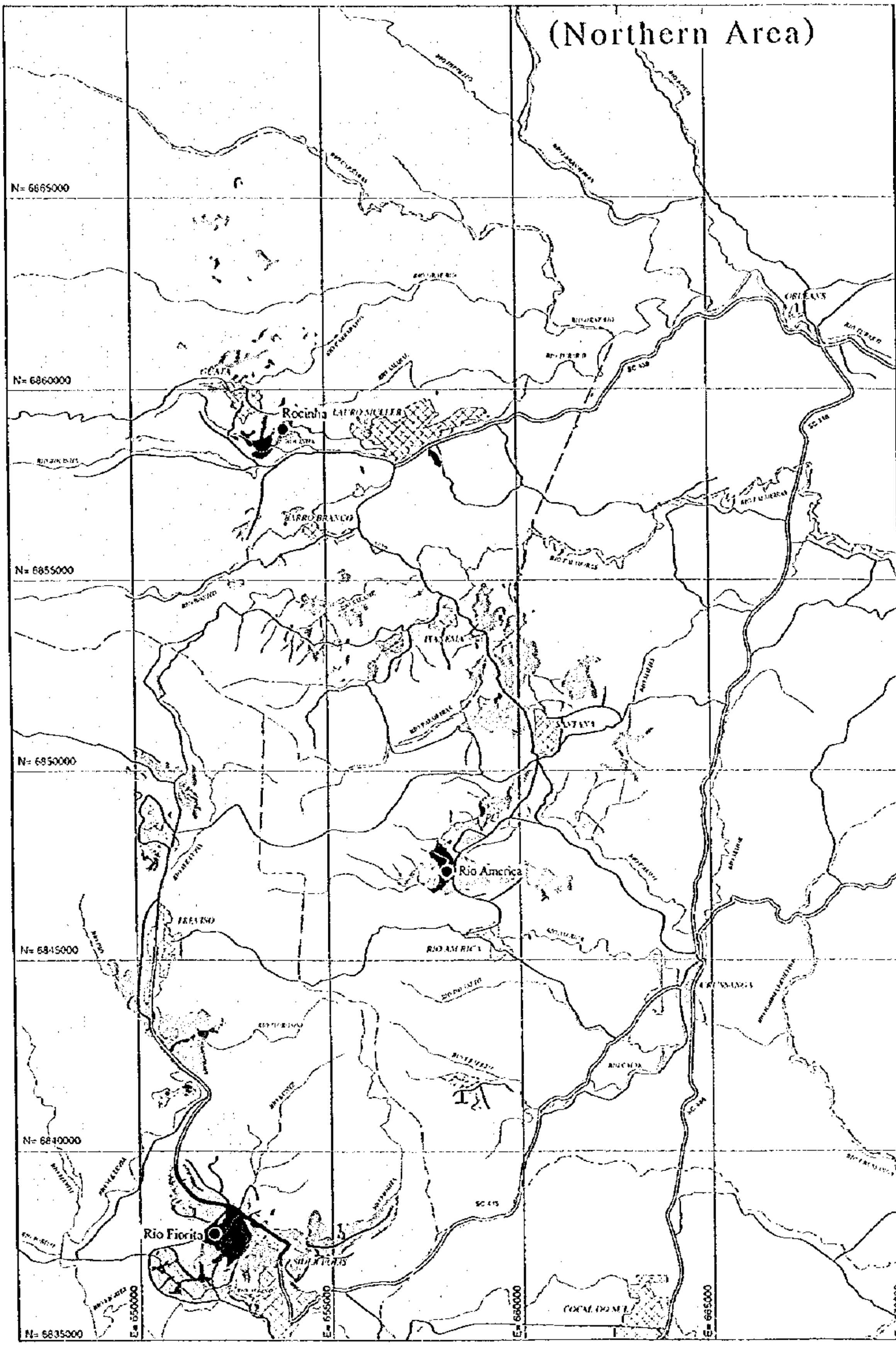
- About 70 % is more than 2.0 mm in size;
- More than 90 % is more than 1.65 in specific gravity;
- Ash content is more than 60 % (rich in SiO_2), and sulfur content varies; and
- Calorific value is between 800 and 1,500 kcal/kg.

Coal with relatively low calorific value can be recuperated from all the samples as shown on Table H-2. Rocihna and Naspolini were selected for further study.

TABLE H-1

REWASHABLE BLACK REJECT IN SANTA CATARINA

Municipality	Name of Areas	Status	Rewashable Area (ha)	Rewashable Volume (1,000m3)	Total Area (ha)	Total Volume (1,000m3)
Criciuma	Bairro Naspolini	Abandoned	31.0	1,426	31.0	1,426
	Mina Uniao	Abandoned			0.0	0
	Mina Uniao	Active	78.0	3,588	78.0	3,588
	Sao Marcos	Abandoned	24.0	1,104	24.0	1,104
	Sub-total		133.0	6,118	133.0	6,118
Icara	Minaracao	Active	8.8	405	8.8	405
	Sub-total		8.8	405	8.8	405
Lauro Muller	Lauro Muller	Active	8.0	368	8.0	368
	Rochinha		25.0	626	25.0	626
	Sub-total		33.0	994	33.0	994
Sideropolis	Campo Vila Funil	Active	56.0	2,576	56.0	2,576
	Lavador Rio Fiorita CO	Active	95.0	4,370	95.0	4,370
	Sub-total		151.0	6,946	151.0	6,946
Urussanga	Rio America	Active	132.2	6,081	132.2	6,081
	Sub-total		132.2	6,081	132.2	6,081
Total			458.0	20,544	458.0	20,544



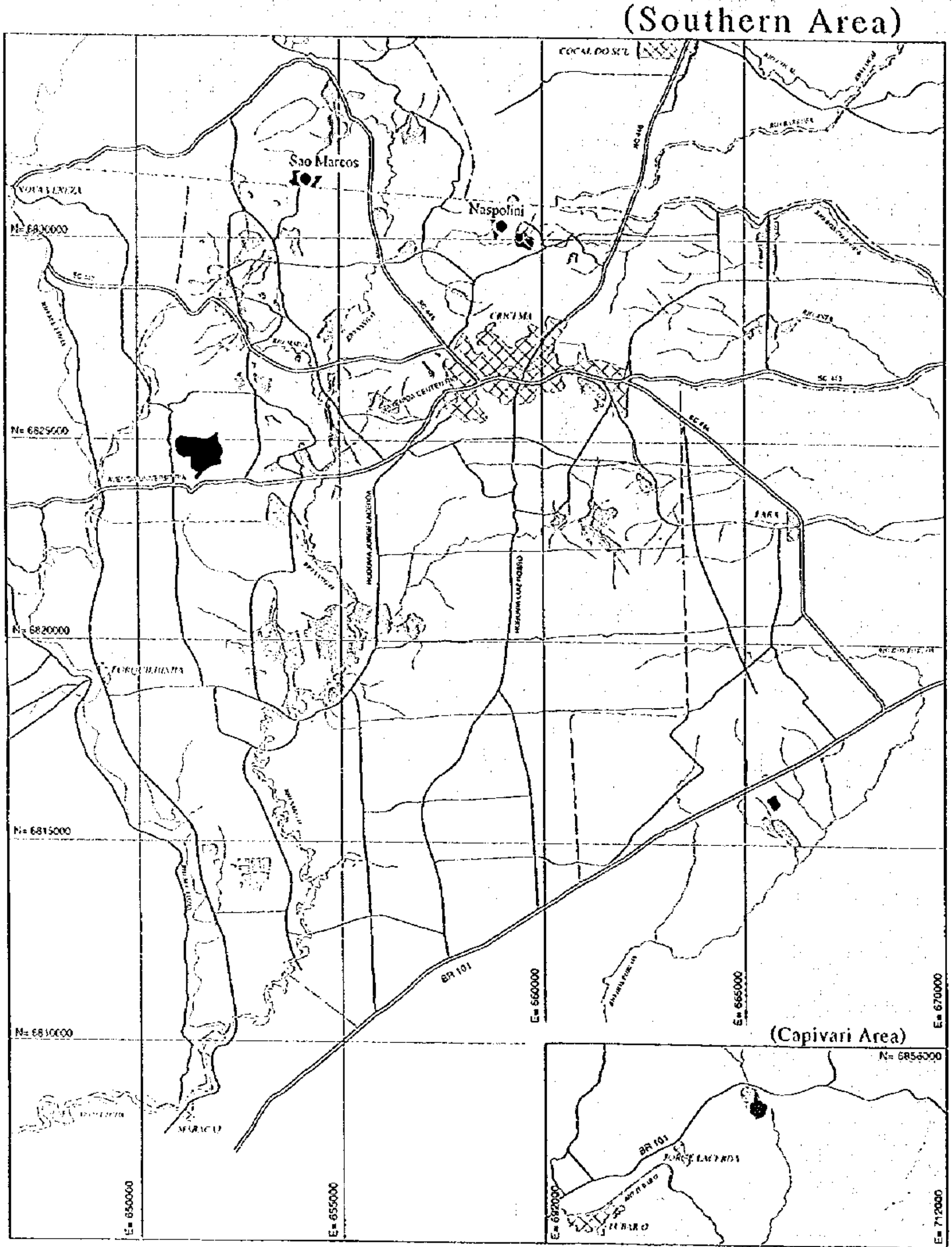
Legend:

- Black Reject(Rewashable)
- Pond
- Black Reject(Waste)
- Sampling Point
- Overburden Waste

FIGURE II-1(1/2) BLACK REJECT MAP

THE FEASIBILITY STUDY ON RECUPERATION OF MINED OUT AREAS IN SOUTH REGION OF SANTA CATARINA-REPUBLIC OF BRAZIL

JAPAN INTERNATIONAL COOPERATION AGENCY - JICA



Legend:

- Black Reject(Rewashable)
- Pond
- Black Reject(Waste)
- Sampling Point
- Overburden Waste

FIGURE II-1(2/2) BLACK REJECT MAP

THE FEASIBILITY STUDY ON RECUPERATION OF MINED OUT AREAS IN SOUTH REGION OF SANTA CATARINA-REPUBLIC OF BRAZIL

JAPAN INTERNATIONAL COOPERATION AGENCY - JICA

TABLE H-2

PRELIMINARY WASTE ANALYSIS IN SANTA CATARINA

1. Size Analysis (by SATC)

SIZE (mm)	RIO ROCINHA (1)	RIO ROCINHA (2)	RIO CARVAO (1)	RIO CARVAO (2)	NASPOLINI (1)	NASPOLINI (2)	SIDEROPOLIS (1)	SIDEROPOLIS (2)	SAO MARCOS (1)	SAO MARCOS (2)
>25.4	2.81	1.03	7.19	7.43	1.1	1.68	7.19	5.42	6.63	7.12
6.3	6.9	8.11	7.44	7.73	5.39	5.67	7.44	10.12	7.01	8.15
9.6	24.32	27.59	28.69	18.98	22.53	24	28.69	21.55	28.08	24.37
4.7	16.68	17.92	19.79	17.48	20.74	24.4	19.79	21.92	21.28	21.62
2.8	19.85	21.79	15.82	16.12	21.43	24.19	15.82	18.99	15.07	16.28
1	7.65	9.22	5.89	9.49	7.61	6.24	5.89	7.18	5.58	6.04
0.41	5.85	5.83	3.55	6.11	5.89	3.57	3.55	3.87	4.38	4.65
0.17	2.81	2.62	2.46	2.51	4.68	3.05	2.46	2.33	2.45	2.39
0.12	3.02	1.29	2.19	3.2	2.86	1.89	2.19	1.83	1.75	2.21
0.15	5.25	2.15	4.18	6.36	4.16	2.22	4.18	3	3.74	3.55
0.075	2.08	1.16	1.36	2.3	1.9	1.4	1.36	1.83	2.04	1.86
<0.075	2.78	1.29	1.44	2.29	1.71	1.69	1.44	1.96	1.99	1.76
TOTAL	100	100	100	100	100	100	100	100	100	100

2. Coal Analysis (by SATC)

WEIGHT(%)		RIO ROCINHA (1)	RIO ROCINHA (2)	RIO CARVAO (1)	RIO CARVAO (2)	NASPOLINI (1)	NASPOLINI (2)	SIDEROPOLIS (1)	SIDEROPOLIS (2)	SAO MARCOS (1)	SAO MARCOS (2)
<S.G 1.65		12.94	7.29	8.05	8.70	6.05	5.17	6.01	7.40	4.69	4.33
>S.G 1.65		87.06	92.71	91.95	91.30	93.95	94.83	93.99	92.60	95.31	95.67
TOTAL		100	100	100	100	100	100	100	100	100	100
MOISTURE	(%)	2.69	1.77	2.00	3.61	2.27	2.25	2.41	3.42	1.53	1.09
ASH	(%)	60.42	64.07	71.31	79.26	79.08	79.51	71.41	73.75	82.05	77.70
TOTAL SULFUR	(%)	6.75	7.99	5.10	0.58	2.35	1.39	3.43	2.58	1.11	1.09
YRITIC SULFUR	(%)	4.95	7.69	4.23	0.11	1.69	0.78	2.15	0.27	0.20	0.20

3. Ash Chemical Analysis (from ZETTA/IES report)

		Sample 1	Sample 2	Sample 3	Average	JAPAN
SiO2	(%)	54.65	56.72	58.06	56.48	45.80
Al2O3	(%)	31.09	33.31	34.45	32.95	20.90
Fe2O3	(%)	9.00	4.85	2.43	5.43	2.90
TiO2	(%)	2.04	2.27	2.27	2.19	
P2O5	(%)	0.36	0.09	0.06	0.17	
CaO	(%)	0.42	0.56	0.42	0.47	3.00
MgO	(%)	0.49	0.25	0.40	0.38	
Na2O	(%)	0.57	0.33	0.23	0.38	
K2O	(%)	1.20	1.45	1.17	1.27	
Others	(%)	0.18	0.17	0.53	0.29	
Total	(%)	100	100	100	100	

(d) **Washability test**

21. Washability test consists of a series of sink and float tests, identifying the relationship between clean coal recovery rate (yield) and ash content from the washability curve. Sink and float test determines the specific gravity constitution of coal by measuring weights of sink and float materials in varying heavy liquids, usually between 1.30 and 1.80 in specific gravity. Prior to the sink and float test, materials are sieved into different size groups, which are subjected to the tests. Since a subject is not ROM coal but washery refuse, the heavy liquids used were 1.50, 1.65 and 1.80 in specific gravity.

(e) **Results of test**

22. Tables H-3 and H-4 show the results of the waste sink and float test while Figures H-2 and H-3 show the washability curves. The coal (approximately 4,500 kcal/kg) recovery from waste ranged from 7 to 10% for the Rio Rocinha sample and 8 to 12% for the Naspolini sample. The near-density curve of the samples is comparatively flat so that actual coal recovery from the washing plant will be slightly lower than the test results. However, these yield ranges are in line with those obtained from interviews with actual operators (6 to 12%). As long as waste re-washing follows the current operation in the region, they are economically viable due to the same level of coal content.

(f) **Inspection of coal washing activities**

23. Prior to actual inspection, a preliminary study was carried out, which includes collecting and compiling public-issued information to understand the current situation and issues of washing. Currently 21 washing plants are operating for ROM coal washing and waste re-washing for coal sale or coke plant use, out of which 12 washing plants were inspected. (Tables H-5 and H-6)

24. Main equipment is jig and no heavy-media separation is used. For fine coal recuperation, cyclone, froth floatation, spiral or vibrating table separator is used. Jigs for ROM coal washing are relatively large scale, ranging from 250 to 650 tons/h. On the other hand, those for waste washing are less than 100 tons/h with simple wooden structures. ROM and waste washing produce, with a little exception, the same products, including CE-4,500 with 4,500 kcal/kg in calorific value for power plant, CE-5,400 for cement manufacturers and fine coal for cast metal coke. An average yield of ROM coal washing is 38.5 % in 1994 and higher than that of waste re-washing.

(g) **Issues and recommendations**

25. All the black wastes from which coal can be extracted are owned by private companies or individuals, who are already recuperating or plan to recover coal by using small-scale washing plants.These re-washable wastes are in 12 areas and their volumes are estimated at 20 million m^3 as shown in Table H-1, equivalent to almost 3 million tons of CE-4,500 coal. The waste re-washing

TABLE H-3

SINK AND FLOAT TEST (RIO ROCINHA)

TEST RESULTS (1) By SATC

Locality (Sampling)	: Rio Rocinha		
Seam	:	Grade of coal	: Waste material
Particle size (mm)	: Under 35 mm	Ash (%)	: 68.21
Mass of under 0.297 mm (%)	: 7.35	Ash content of under 0.297 mm (%)	:
Date of sampling	: 31/07/96	Date of test	: 14/08/96
Remark (S.G.Liquid)	: Tribromide Methane		

TEST RESULTS (2)

Specific gravity fraction (n)	Specific gravity	a Float Kg	a Float W(%)	(b) Ash content A(%)	(c) Cumulative mass up to middle point $V_{n}-(V_{n}/2)$	d ΣV	e ΣVA	(f) Float Cumulative mass ΣV	(g) Float Cumulative ash content $\Sigma VA/\Sigma V$	h Total ash (k) $-\Sigma VA$	(i) Sink mass $100-\Sigma V$	(j) Sink Ash content h/i
1	-1.25	0.00	0.0	0.00	0.0	0.00	0.00	0.0	0.00	6,334.27	100.0	63.34
2	1.25-1.50	0.44	1.5	21.85	0.7	32.05	32.05	1.5	21.85	6,302.22	98.5	63.96
3	1.50-1.65	1.89	6.3	39.20	4.6	246.96	279.01	7.8	35.92	6,055.26	92.2	65.65
4	1.65-1.80	3.72	12.4	49.18	14.0	609.83	888.84	20.2	44.07	5,445.43	79.8	68.21
5	+1.80	23.95	79.8	68.21	60.1	5,445.43	6,334.27	100.0	63.34			
	Total	30.00	100.0	63.34	100.0	(k)						

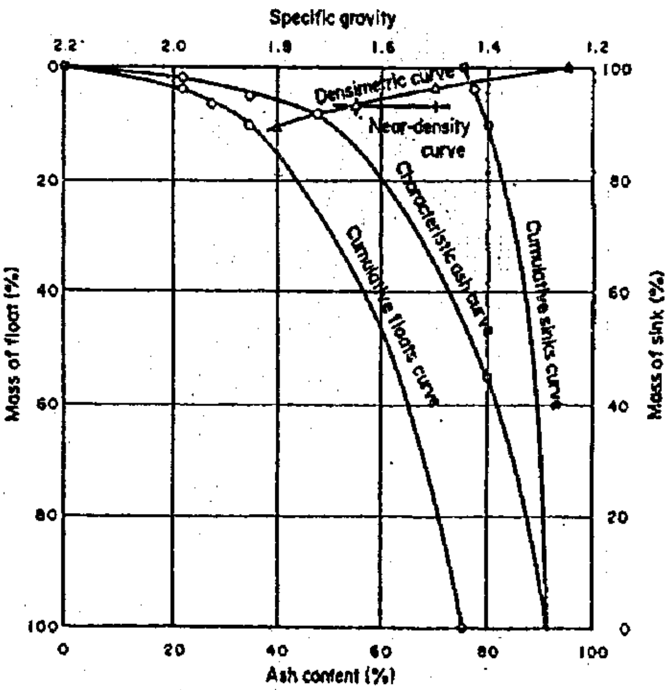


FIGURE H-2

WASHABILITY CURVES (RIO ROCINHA)

TABLE H-4

SINK AND FLOAT TEST (NASPOLINI)

TEST RESULTS (1) By SATC

Locality (Sampling)	: Naspolini			
Seam	:	Grade of coal		: Waste material
Particle size (mm)	: Under 35 mm	Ash	(%)	: 68.23
Mass of under 0.297 mm (%)	: 6.54	Ash content of under 0.297 mm	(%)	:
Date of sampling	: 31/07/96	Date of test		: 14/08/96
Remark (S.G.Liquid)	: Tribromide Methane			

TEST RESULTS (2)

		a		(b)	(c)	d	e	(f)	(g)	h	(i)	(j)
								Float		Total	Sink	
Specific gravity fraction	Specific gravity	Float		Ash content	Cumulative mass up to middle point	ΣW	ΣWA	Cumulative mass	Cumulative ash content	ash (k)	mass	Ash content
(n)		Kg	W(%)	A(%)	Y_n			ΣW	ΣWA/ΣW	-ΣWA	100-ΣW	h/i
1	-1.25	0.00	0.0	0.00	0.0	0.00	0.00	0.0	0.00	7,547.22	100.0	75.47
2.	1.25-1.50	1.13	3.8	21.88	1.9	82.41	82.41	3.8	21.88	7,464.81	96.2	77.57
3	1.50-1.65	0.85	2.8	34.31	5.2	97.21	179.63	6.6	27.22	7,367.59	93.4	78.81
4	1.65-1.80	1.10	3.7	47.61	8.4	174.57	354.20	10.3	34.50	7,193.02	89.7	80.16
5	+1.80	26.92	89.7	80.16	55.1	7,193.02	7,547.22	100.0	75.47			
	Total	30.00	100.0	75.47	100.0	(k)						

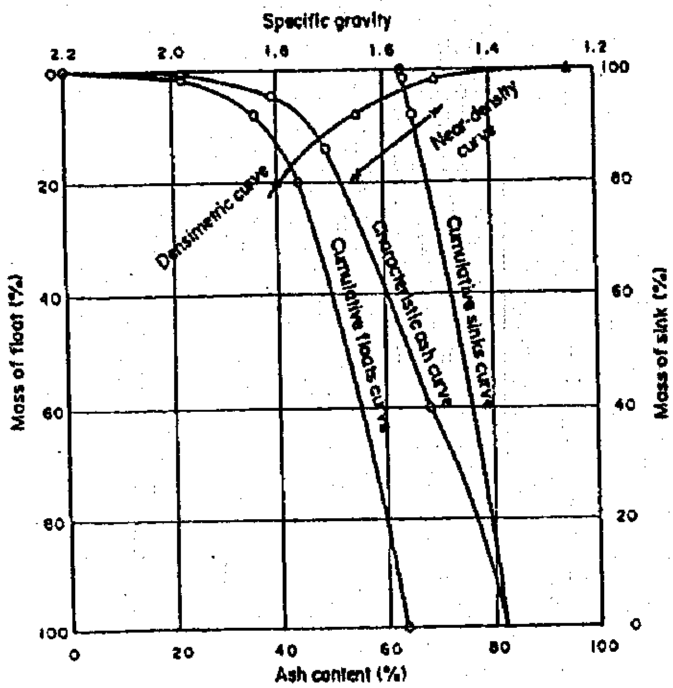


FIGURE H-3

WASHABILITY CORVES (NASPOLINI)

TABLE H-5(1/2)

LIST OF WASHING PLANTS

Location No.	Plant Name	Company	Municipality	Wash for	Capacity (t/h)	Washing Equipment	Note 1	Note 2
1	Guatá	Bez Birollo	Lauro Müller	ROM,Reject	30	Jig, Spirals	Active	Visited
2	Boa Vista	Carb. Barro Branco	Lauro Müller	ROM	110	Jig, Cyclones	Inactive	
3	São Domingos	São Domingos Ind. e Comércio de Coque Ltda.	Lauro Müller	Reject	60 x 2	2 Jigs	Active	Visited
4	Beneton	Beneton	Lauro Müller	ROM	na		Abandoned	
5	Rio Bonito	Carb. Barro Branco	Lauro Müller	ROM	na		Inactive	
6	Santa Rosa	Carb. Criciuma	Lauro Müller	ROM	na		Abandoned	
7	BC-8	Carb. Treviso S.A.	Urussanga	ROM	100	Jig, Cyclones, Shaking tables	Active	Visited
8	DBS	IBRAMIL	Urussanga	ROM	90	Jig	Inactive	
9	Rio Carvão	CCU	Urussanga	ROM	na		Abandoned	
10	3/Santana	CCU	Urussanga	Fine	120	Jig, Cyclones, Flotation	Active	
11	Coque Rio Deserto	Coque Rio Deserto	Urussanga	Fine	na	Shaking tables	Active	Visited
12	Rio Carvão	Carb. Treviso S.A.	Urussanga	ROM	na		Abandoned	
13	Rio America	COMIN E CIA	Urussanga	Reject	60	Jig	Active	Visited
14	Rio Deserto	CCU (& Rio Deserto)	Urussanga	ROM	71 + 41	2 Jigs, Cyclones, Shaking tables	Inactive	
15	Forquilha	COMIN E CIA (Treviso)	Siderópolis	ROM	50	Jig	Active	Visited
16	Esperança	Carb. Metropolitana S/A	Treviso	ROM	650	Jig, Cyclones, Flotation, Spiral	Active	Visited
17	Fontanella	Carb. Metropolitana S/A	Treviso	ROM	350	Jig, Cyclones, Spirals	Active	Visited
18	Siderópólis	COCALIT	Siderópolis	Reject	70 + 50	2 Jigs	Active	Visited
19	Rio Fiorita	Carb. Belluno LTDA.	Siderópolis	ROM	90	Jig	Active	
20	Poço 3	Henrique Salvaro (Sub. Belluno)	Siderópolis	Reject	40	Jig	Inactive	Visited
21	Ex-Patrimônio	COCALIT	Siderópolis	ROM	na		Abandoned	
22	São Geraldo	CCU (& Rio Deserto)	Siderópolis	ROM	250	Jig, Cyclones, Flotation, Shaking tables	Active	
23	None	COQUESUL	Criciúma	Fine	na	Shaking tables	Active	
24	None	INCOL	Criciúma	Fine	na	Jig, Shaking tables	Active	
25	None	CSN	Criciúma	ROM	na		Abandoned	
26	None	CSN	Criciúma	ROM	na		Abandoned	
27	None	CSN	Criciúma	ROM	na		Abandoned	
28	None	Carb. Criciúma	Criciúma	ROM	na		Abandoned	

TABLE H-5(2/2)

LIST OF WASHING PLANTS

Location No.	Plant Name	Company	Municipality	Wash for	Capacity (t/h)	Washing Equipment	Note 1	Note 2
29	São Marcos	Henrique Salvaro (Sub. Belluno)	Siderópolis	Reject	40	Jig	Active	Visited
30	Rio Maina	CIA. Carb. Catarinense	Criciúma	ROM	80	Jig, Flotation	Active	
31	Eng. Edison D.Montedo	Carb. Metropolitana S/A	Criciúma	Fine	350	Jig, Cyclones, Flotation	Active	
32	Santa Augusta	CCU	Siderópolis	ROM	na		Abandoned	
33	None	CBCA	Criciúma	ROM	na		Abandoned	
34	None	ICC (Ind. Coque Criciúma)	Criciúma	ROM	na		Abandoned	
35	Usina Mina A	Nova Prospera	Criciúma	ROM	600	2 Jigs, Cyclones, Flotation	Inactive	
36	Santa Libera	CBCA	Forquilhinha	ROM	500	Jig, Cyclones, Flotation, Shaking tables	Active	Visited
37	São Roque	ICC	Forquilhinha	Fine	na	Cyclones, Spirals, Flotation	Active	
38	Verdinho	Carb. Criciúma S.A	Forquilhinha	ROM	600	Jig, Cyclones, Spirals, Flotation	Active	Visited
39	Novo Horizonte	Carb. Barro Branco	Içara	Reject	40	Jig	Active	

TABLE H-6

LIST OF COKE PLANTS

Location No.	Plant Name	Company	Municipality	Note
1	Coque Rio Deserto	Coque Rio Deserto	Urussanga	Active
2	None	None	Urussanga	Active
3	Rio Fiorita	COCALIT	Siderópolis	Abandoned
4	Ex-Patrimônio	COCALIT	Siderópolis	Abandoned
5	None	COQUESUL	Criciúma	Active
6	None	INCOL	Criciúma	Active
7	None	ICC	Forquilhinha	Active
8	None	CBCA	Criciúma	Active

business could continue for 10 to 15 years, given current production. On the other hand, it is very difficult to control acidity within existing environmental standards while that business is going on. (See Annex Section II-A.) This is a dilemma for the people living in the region: what should come first, that activity which provides jobs and money or protection of the environment. For the time being, the only solution could be to make a gradual change in the situation in accordance with the progress of the region's remediation program.

3.2 Raw Material for Cement

26. Black waste of Santa Catarina are richer in SiO_2 and in Al_2O_3 than those of Japan as shown in Table H-2. It means that Santa Catarina's waste is better than the Japanese one for cement raw material, although this depends on the chemical components of the main raw material, i.e., limestone. To confirm these possibilities, a cement manufacturer was visited and it appears that CaO content in limestone is less than 50 % , i.e., too low to blend black waste with limestone, because it would be impossible to keep appropriate chemical components for cement calcination. Therefore, it is concluded that black reject in the region cannot be used for cement manufacturing unless high quality limestone is discovered in the vicinity of the Santa Catarina coal field.

3.3 Fuel for Fluidized Bed Combustion

27. Eletrobras's 2015 Plan projects the installation of 14 additional thermoelectric units of 145 MW each in Santa Catarina relying on the AFBC (atomospheric fluidized bed combustion) process and using ROM 2,800 coal. This would use an additional 13 million tons of coal/year. Although ROM coal burning does not, by itself, decrease the existing black waste, it would make ROM coal washing unnecessary, preventing further accumulation of washery refuse which is the culprit of water pollution.

28. Santa Catarina Electric Company (SELESC) has a plan to install a 125 MW fluidized bed combustion power unit. This would use 80,000 to 90,000 tons of coal/month, either CE-3,400 clean coal or ROM-3,000 coal extracted from the Bonito seam. They are also considering that black waste blending for fuel is an additional option in the SELESC project. Fuel types to be burned are still under study to determine the relationship between types of coal and amounts of limestone consumption in a fluidized bed furnace.

29. The fluidized bed power unit would use lower calorific coal than the current one of CE-4,500. Thus, blending of one ton of CE-4,500 coal with one ton of waste (1,000kcal/kg) makes two tons of coal with a calorific value of 2,750 kcal/kg which is almost equivalent to ROM-2,800. For this reason, the possibility of washing waste with less coal content would increase in spite of the fact that the price is lower due to the smaller calorific value and higher transportation costs as a result of the increase in the

volume to be hauled.

3.4 Road Construction Material (Black Waste)

30. Black waste has been used for road construction in Santa Catarina. So far, 106 km have been paved with it, using a volume of waste estimated at 40 million m^3. The material has advantageous characteristics for road paving, since it is easily compacted and road surface becomes similar to asphalt pavement. However, FATMA is currently prohibiting the use of black waste for road construction to prevent pollution source from spreading. In the past, FATMA allowed its use to expand the national road, BR101, around the Içara district on the condition that the waste should be placed above the ground water level and covered with clay.

31. The possibilities of generating acidic water caused from black waste road are: (i.) water penetration into a black waste road (generation by penetration); and (ii.) effluent on the surface of a black-waste-paved road (generation by contact). Concerning water penetration, compaction can make black waste into an impermeable layer. Actually, the existing black waste road in the Southern Santa Catarina region is compacted very well and no water saturation is observed. Second, concerning generation by contact, a recent study reveals that decrease in pH caused by pyrite takes place not in seconds but in days. It means that run-off water on the surface of road cannot generate acidic water. Black waste with pyrite was relocated and compacted layer by layer with about 25 cm in thickness each before compaction (e.g., in Japan). After that, the acidic water problem disappeared and later the compacted area was used for a part of municipality's road without any additional work.

32. Black waste is not necessarily stigmatized as pollution source and should not be prohibited. Rather, it is recommended that guidelines be established for road construction such as compaction method, drainage, ground water level limit, etc. Permeability test on compacted black waste is also recommended.

3.5 Construction Material (White Waste)

33. Overburden waste (white waste) stripped by dragline does not contain pyrite but a large amount of hard sandstone, suitable for foundation material such as elevated road construction. Aggregate can be easily produced by a crushing and screening plant, since rocks are already fractured.

34. At present, the expansion of National Road BR-101 between Garuva and Florianópolis in the Northern Santa Catarina (216 km) is under construction and is expected to be completed by September 1999. After that there would be another expansion of 300 km between Florianópolis and Osório in the Southern Santa Catarina and Rio Grande do Sul to be done over 30 months, for which DNER in Florianópolis is now preparing. The total amount of material such as aggregate, soil, etc. required for

the expansion, estimated at 12 million m^3, is equivalent to 5 % of total white waste existing in the region. It would be probably impossible to provide all the material required for the expansion from the waste dumps, since material price depends mainly on trucking cost. Active utilization of waste should be discussed among FATMA, DNPM, DNSR, or concerned institutions, specially with regard to the waste excavation business.

3.6 Refractory material

35. A private company, Ceramica Librelato Ltda, in the coal field region is producing 800 tons/ month of fire bricks from mining refuse for steel manufacture and domestic use, mostly for the São Paulo area. The material is argillaceous rock in the Barro Branco coal seam which is selectively extracted in the underground mine. However, it is not a recommended use of the waste as it is not possible to separate the material from the waste economically due to the present low price of 7 to 8 R$/ton and its scarce content in the waste dumps.

4. Conclusions and Recommendations

36. **Road construction material:** Both black and white waste could be used for road construction without any serious pollution problem and it is the most effective way to reduce the existing waste dumps. It is therefore recommended that active waste utilization guidelines be established, especially for black waste road construction guidelines and waste (black and white) exploitation guidelines through discussion with concerned organizations in the region in a view to preventing secondary pollution while creating new business.

37. **Waste re-washing:** Coal recuperation from waste seems economically attractive for the region. Coal recuperation has been estimated at more than R$ 100 million in total at current prices. However, re-washing companies are currently not taking any measures to protect the environment. Therefore, it is recommended that the true closed circuit system for washing plants, a parallel reclamation system for final refuse dump areas and effluent containment with impermeable settling ponds be gradually established in accordance with the progress of the regional remediation program as stated in Section II-A of Main Text.

38. **Fluidized bed combustion:** Fluidized bed combustion does not, in itself, reduce existing waste, but prevent further accumulation of black waste and reduces harmful gasses emission such as SOx and NOx. Therefore, it is recommended that new thermoelectric plants with this process be promoted and realized as scheduled from a standpoint of reducing pollution sources.

SECTION III
COST-BENEFIT STUDY

1. THE SETTING

1.1 THE ECONOMIC AND ADMINISTRATIVE SETTING

1. Southern Santa Catarina borders the Rio Grande do Sul, Brazil's southernmost state and is located at less than 500 kms from Uruguay. Administratively, the region regroups three associations of municipalities established during the 1970s and early 1980s: AMUREL (*Associação dos Municipios da Região de Laguna)*, representing the laguna area; AMREC (*Associação dos Municipios da Região Carbonifera*), representing the coal mining sub-region; and AMESC (*Associação dos Municipios do Extremo Sul Catarinense*), representing the southernmost part of the Santa Catarina state. Together, they comprise 43 municipalities with a total of 750,000 inhabitants (15% of the state's population) (1996 census) distributed over a territory of about 9,700 km^2 (10% of the state's total area). A map of Southern Santa Catarina with its 43 municipalities appears as Figure III-1.

2. The region is well endowed with mining and other natural resources. The soil is fertile and the population, mostly from European origin (Italians and Germans), is hard working. The education level is high, with about two thirds of the population having some high school education. The literacy rate approaches 100%. Last but not least, income is well distributed. Southern Santa Catarina can be proud to be ranked third in Santa Catarina (and among the top five regions in Brazil) in terms of income distribution.

3. The population, mostly urban (88%), is concentrated in a few relatively large cities. Criciúma, Ararranguá and Tubarão, the "capitals" of the three sub-regions account for more than 42% of the total population. During the 1980s, the region's population increased at an annual rage rate of 2.5%, which is about 30% higher than the state's average. AMREC grew the fastest (4.1%), spurred by the expansion of coal mining activities. Since then, population growth has significantly slowed down, averaging 1.2% per year from 1991 to 1996. Again, this was due to the special situation of AMREC whose population stagnated as a result of the crisis hitting the coal sector since 1990. In fact, the population of Lauro Müller, Nova Veneza and Urussanga, three major mining towns, decreased at an average rate of 0.85%, 0.79% and 0.29% per year, respectively.

4. The region is reputed for its ceramics titles and, until the late 1980s, was Brazil's main coal producer, meeting about 75% of the country's coal needs. Other industrial activities include garment

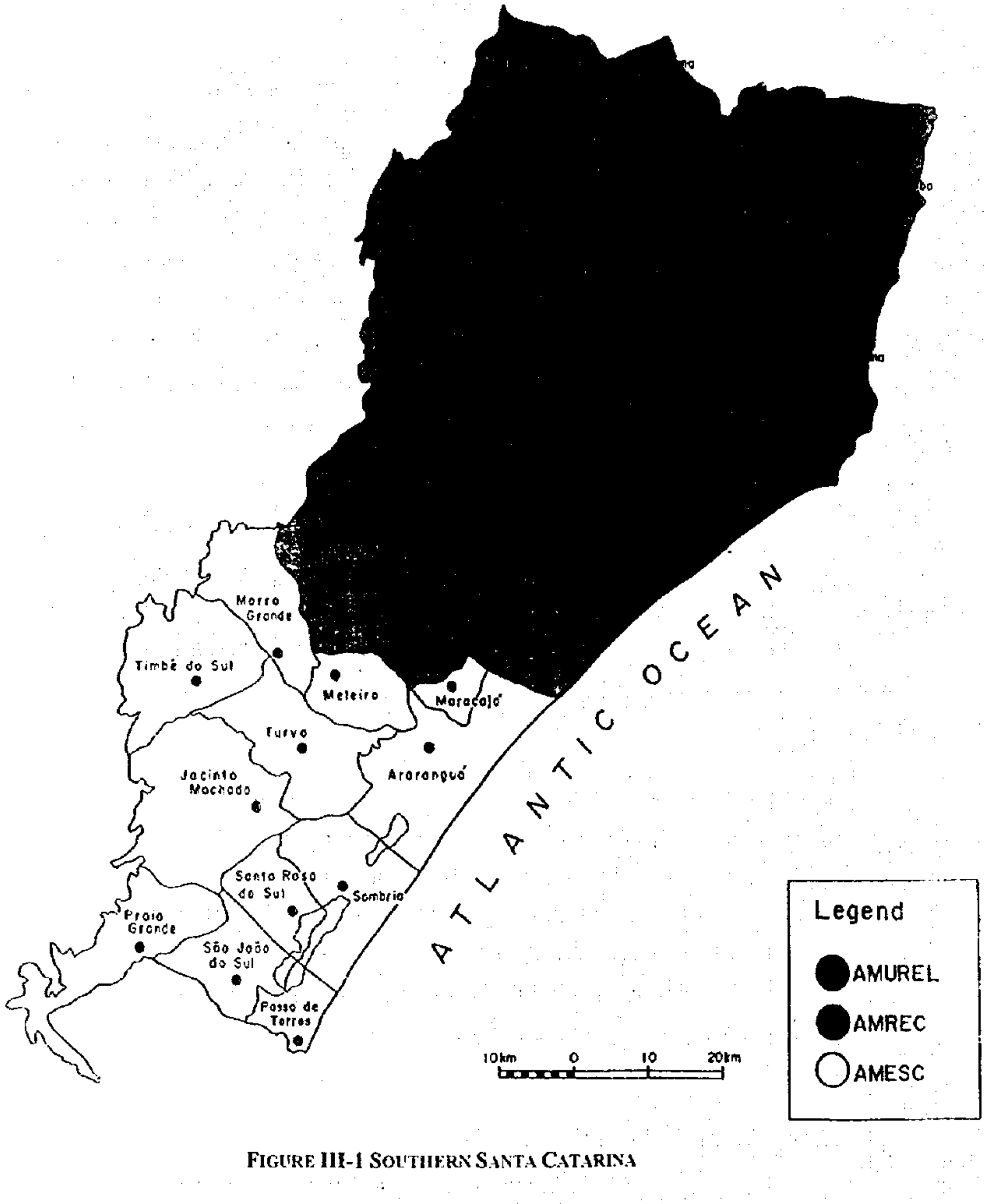
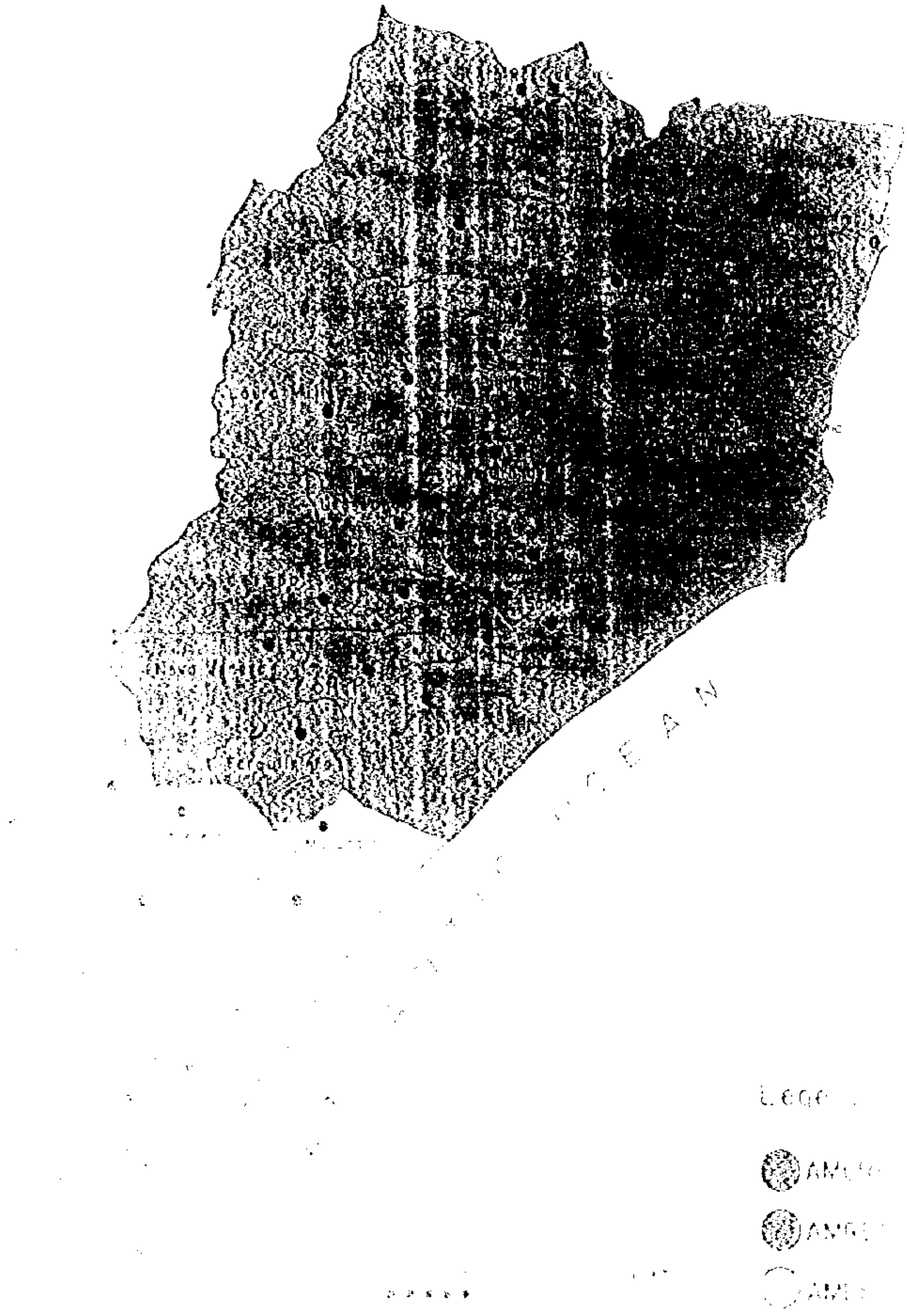


FIGURE III-1 SOUTHERN SANTA CATARINA



manufacturing, plastics, metal working, and furniture making. In the 1980s, industry, including mining, accounted for as much as a third of total value added generated by the region. Since then, its share has decreased to around 20% as a result of the coal mining crisis and difficulties in the ceramic and garment manufacturing sectors.

5. Agriculture is important in the region, accounting for as much as 20% of its GDP. The region is a major rice producer and exports agricultural products to other states. It is also well known for cattle raising and pig farming, a profitable but extremely polluting activity. Tourism is still negligible as an economic activity, but there is a large untapped potential, particularly for eco-tourism. Southern Santa Catarina also possesses a rich cultural heritage dating back to the European immigration of the 19th century. Many visit or tour the region as a pilgrimage to learn more about the place where their ancestors lived.

6. Despite these assets, southern Santa Catarina is among the poorer regions of the state, with a per-capita income estimated at $3,600/year, as compared to an average of $5,500/year for Santa Catarina as a whole. Economic progress is more expensive than elsewhere because of the high cost of water: As a result of the severe pollution of the main river basins and underground water due to coal exploitation over the last 50 years without regard for the environment, water for human consumption as well as for industrial, agricultural and commercial uses has to be imported.

7. The region is also yet to emerge from a deep economic depression brought about by a coal mining crisis when the Federal Government deregulated the sector in 1990, withdrew its price support and subsidies and allowed competition from imported coal and other sources of energy, such as petroleum. From a peak of 5 million tons in 1985, coal production decreased to about 2 million tons in 1994. Many small mining companies were forced to close down and the sector, which employed almost 11,000 workers in the mid-1980s and generated some other 30,000 jobs in related fields, only provided the livelihood for some 3,275 people in 1994. The sector now consists of six companies, some of which in critical financial condition.

1.2 RATIONALE FOR RECUPERATING MINED-OUT AREAS

8. Prospects for Santa Catarina's coal mining are relatively good. As a result of continued rapid economic growth in Brazil, energy demand is expected to remain high. Eletrosul is expanding its thermal electric complex at Jorge Lacerda by adding a fourth unit, while its 20-Year Development Plan (1995-2015) foresees the construction in Santa Catarina of three new units with a total installed capacity of 600 MW during 2000-2015. As a result, coal demand is expected to more than double from about 1.5 million tons in 1994 to more than 3 million tons in year 2000. World Bank projections also foresee a strengthening of coal prices, which are expected to increase to US$49/ton (US coal) in 2005 from their

level of US$39.4/ton in mid-1997.

9. Given the favorable price trends and some unavoidable restructuring[1], continued coal mining in Santa Catarina could be an economically viable proposition. However, without a parallel improvement of mining and environmental regulations and a substantial strengthening of FATMA's enforcement capability, the expected increase in coal mining activity is likely to result in an environmental disaster. It is therefore as important (or even more) to take the necessary actions to ensure that the mistakes of the past will not be repeated again. The recuperation of the mined-out areas must thus be seen as part of a greater effort aimed at improving the environmental management of coal mining in Santa Catarina.

2. DESCRIPTION OF THE PROBLEM AND QUANTIFICATION OF THE BENEFITS OF AN REMEDIATION PROGRAM

10. Both open cast and underground mining take place in Santa Catarina. Although open cast mining only represents 15% of the total coal produced in Santa Catarina today and is practically done by one company which possesses the necessary equipment for surface mining, this type of mining was prevalent until the mid-1980s and, together with the introduction of mechanized mining, was responsible for the destruction of vast areas.

11. Another aggravating factor is the relatively poor quality of the coal, which has a recovery rate of less than 35%. This means that for every ton extracted, only a maximum of 350 kgs of salable coal could be recovered, while the remaining 650 kgs end up as waste. Last but not least, environmental laws and regulations were vague and their enforcement weak, resulting in practically no reclamation of the mined land, thus making thousands of hectares unusable for any purpose. Compounding the problem is the high level of pyrite contained in the waste which has been infiltrating through over the years, contaminating most of the region' surface and ground water. The major consequences of coal mining pollution are described below.

2.1 LAND DEGRADATION

(a) LAND VALUE

(i) Magnitude of the Problem

12. Land degradation is mainly due to open cast mining, but coal transportation and, particularly, beneficiation also greatly contributed to the problem. Table III-1 shows the size and distribution of the

[1] Average production cost is high as a result of the large number of companies in the sector (they were more then twelve two years ago, producing less than 2 million tons of coal), which prevents economies of scale. There appears to be inefficiencies in some companies as well. Restructuring is bound to occur (and some is already taking place) as less efficient companies, squeezed by low prices and tougher competition, are forced to close down.

TABLE III-1

LAND DEGRADATION BY MUNICIPALITY (IN HECTARE AND PERCENTAGE)

Municipality	Affected Area: Open Cast Mining	Affected Area: Mined-out Ponds	Affected Area: Waste Deposits	Affected Area: Total	Total Municipal Area	Percent of Municipal Area
Capivari de Baixo	----	80	80	160	4,700	3.4
Criciúma	69	---	996	1,065	21,000	5.1
Forquilhinha	----	28	357	385	18,400	2.1
Içaca	----	---	45	45	31,560	0.1
Lauro Müller	420	5	204	628	26,700	2.4
Siderópolis	1,061	125	367	1,553	41,950	3.7
Urussanga	633	10	246	889	23,740	3.7
Total	2,182	248	2,295	4,725	184,180	2.6

Source: JICA Team, DNPM (*Departemento Nacional de Produção Mineral*); PBDEE (*Plano Básico de Desenvolvimento Ecológico-Econômico*) and NUPESE (*Núcleo de Pesquisas e Estudos Sócio-Econômicos*).

affected areas by municipality, as well as the source of pollution.

i) Size of the Polluted Land

13. The area polluted by coal mining is equivalent to 4,724 ha. In addition to Capivari de Baixo in AMUREL where the beneficiation plant was located and where most of the coal was washed for use at the Jorge Lacerda thermal power plant, all the AMREC municipalities, with the exception of Nova Veneza, are affected (Figure III-2). The total municipal area affected is 180,140 ha. in size and the polluted part is equivalent to 2.6% of the total. In the major mining municipalities, such as Criciúma, Urussanga and Sideropólis the proportion is much higher, amounting to 5.1%, and 3.7%, respectively.

14. As the method used in open cast mines was strip mining without any reclamation, this generated a "lunar landscape", with waste piles as high as 50 meters, making remediation difficult and expensive. In areas of "free dumping" (Fliorita) or where beneficiation plants were located (Capivari de Baixo), the soil is imbibed with layers of black reject 10 to 30 meters deep with extremely high pyrite content. Surface water in the vicinity has pH level as low as 2-3.

ii) Economic Classification of the Polluted Land

15. Table III-2 below shows that about 75% of the polluted land is classified as rural land with most of it suitable for agricultural use. The remaining 25% is considered urban land as defined by the laws or master plans of the affected municipalities (Figure III-3).

TABLE III-2

ECONOMIC CLASSIFICATION OF POLLUTED LAND
(IN HECTARES)

	Urban Area		Rural Area		
Municipality	Central	Peripheral	Agricultural	Industrial	TOTAL
Capavari de Baixo	---	----	----	160	160
Criciúma	57	659	183	165	1,065
Forquilhinha	---	----	112	272	385
Içaca	---	----	45	----	45
Lauro Müller	---	99	530	----	628
Sideropólis	---	280	792	----	1,071
Treviso	---	----	481	----	481
Urussanga	---	----	889	----	889
Total	57	1,037	3,032	598	4,724

Source: Southern Santa Catarina's municipalities land use records

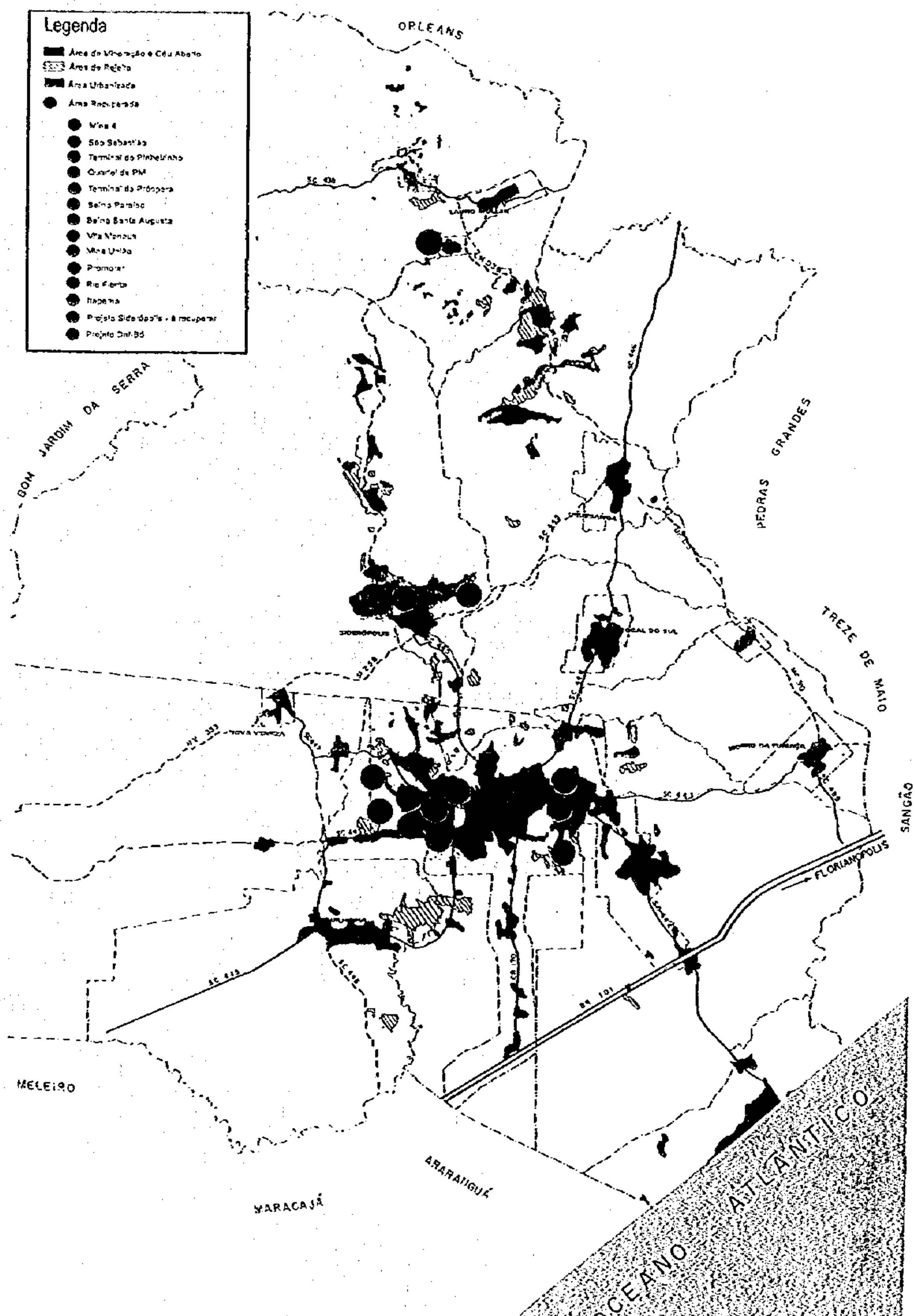


Figure III-2 Polluted Areas

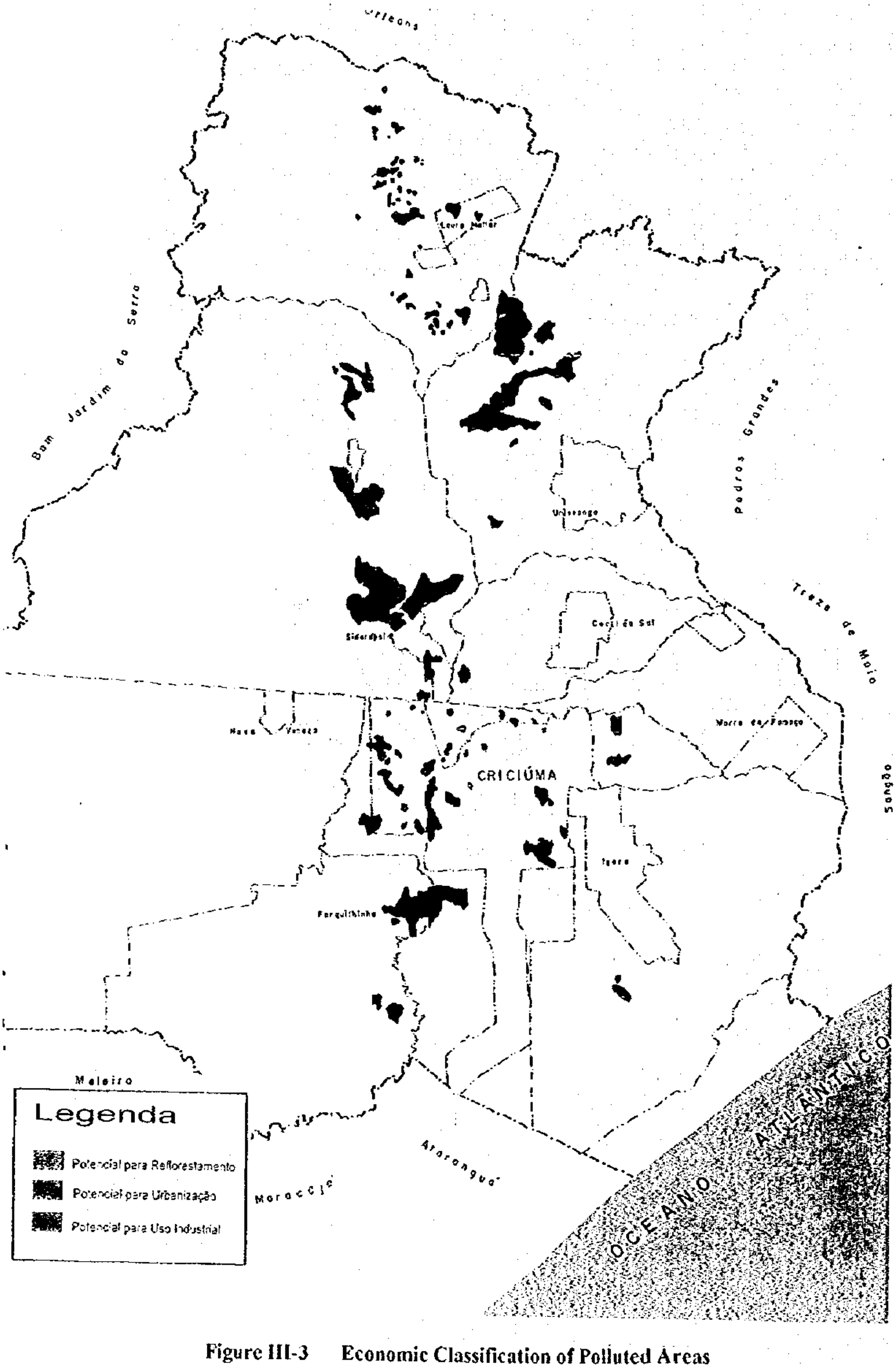


Figure III-3 Economic Classification of Polluted Areas

iii) Ownership of the Polluted Land

16. As shown on Table III-3 and Figure III-4, about 81% of the polluted land belong to private mining companies, while another 12% is owned by private individuals. Municipalities only hold 7%. This land ownership, together with the economic value of the polluted land resulting from its permissible uses according to municipal laws are determinants in the definition and adoption of a remedial strategy.

TABLE III-3

OWNERSHIP OF POLLUTED LAND
(IN HECTARES)

	Polluted Land (ha)	Polluted Land (%)
Private Individuals	566	12
Mining Companies [a]	3,818	81
Municipalities	340	7
Total	4,724	100

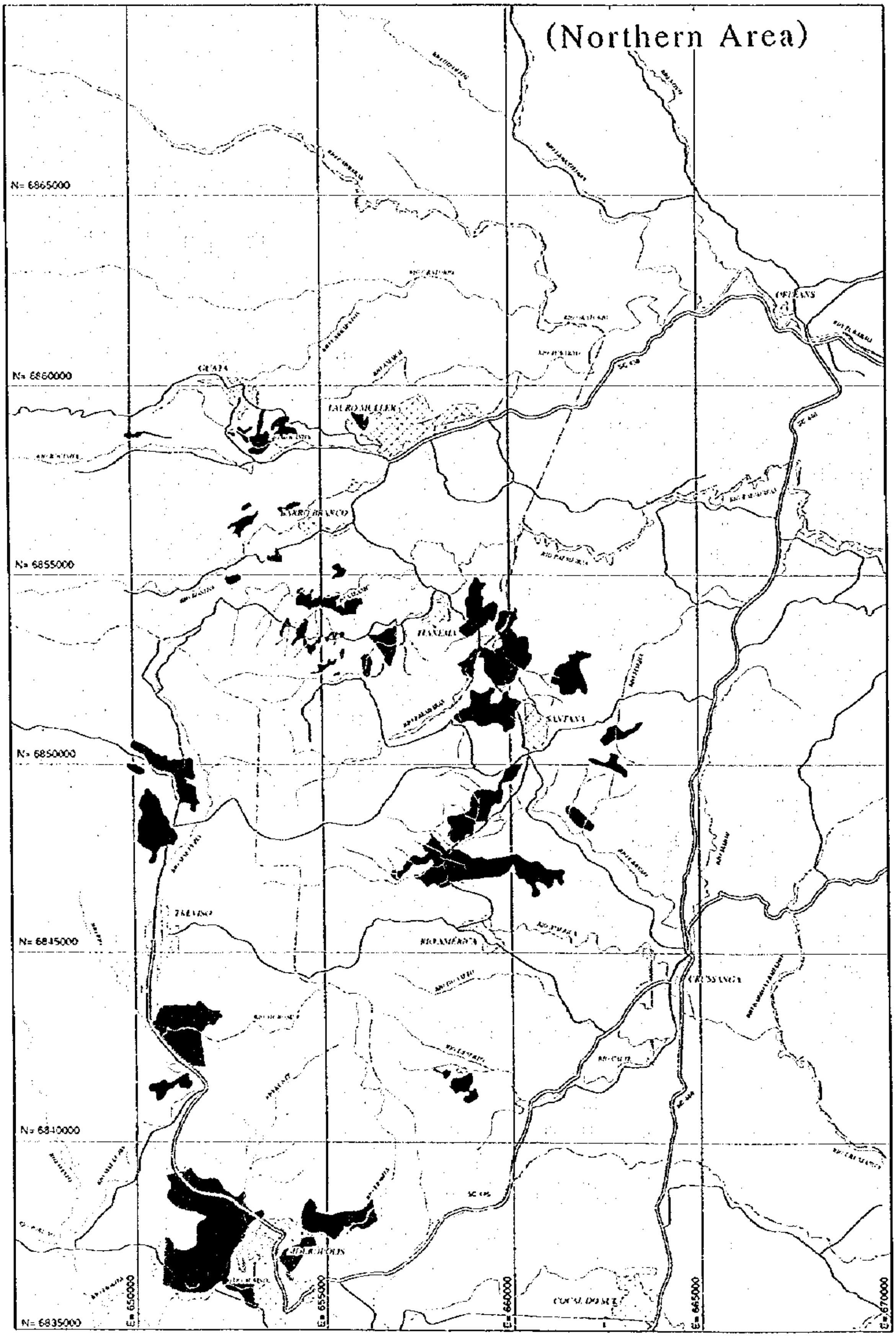
Source: JICA Study Team
[a] Including CSN (Companhia Siderúrgica Nacional)

(ii) Quantification of the Benefits

17. Potential permissible uses of the polluted land according to the affected municipalities' master plans and/or laws are shown in Figure III-5. Based on these indications, interviews have been conducted with selected municipalities and data on land prices collected from the region's two major real estate companies to estimate the market value of the land to be recuperated[2]. At present, the polluted land is worthless.

18. The results, based on the market value of good land in the immediate vicinity of the polluted land, are summarized in Table III-4 below, which show the minimum and maximum price for each category of land. Applying these prices would yield a potential benefit between R$77 million and R$191 million. Details of the calculations, as well as simulations based on different price series can be found in Annex 2 of this report.

[2] Data on administrative land prices (*valor venal*) have also been collected from the municipalities' cadastres. However, they are not used in the calculations of the benefits since they are administratively determined for tax purposes and do not reflect the real value of the land. These prices are kept in the project files and are available upon request.



Legend:

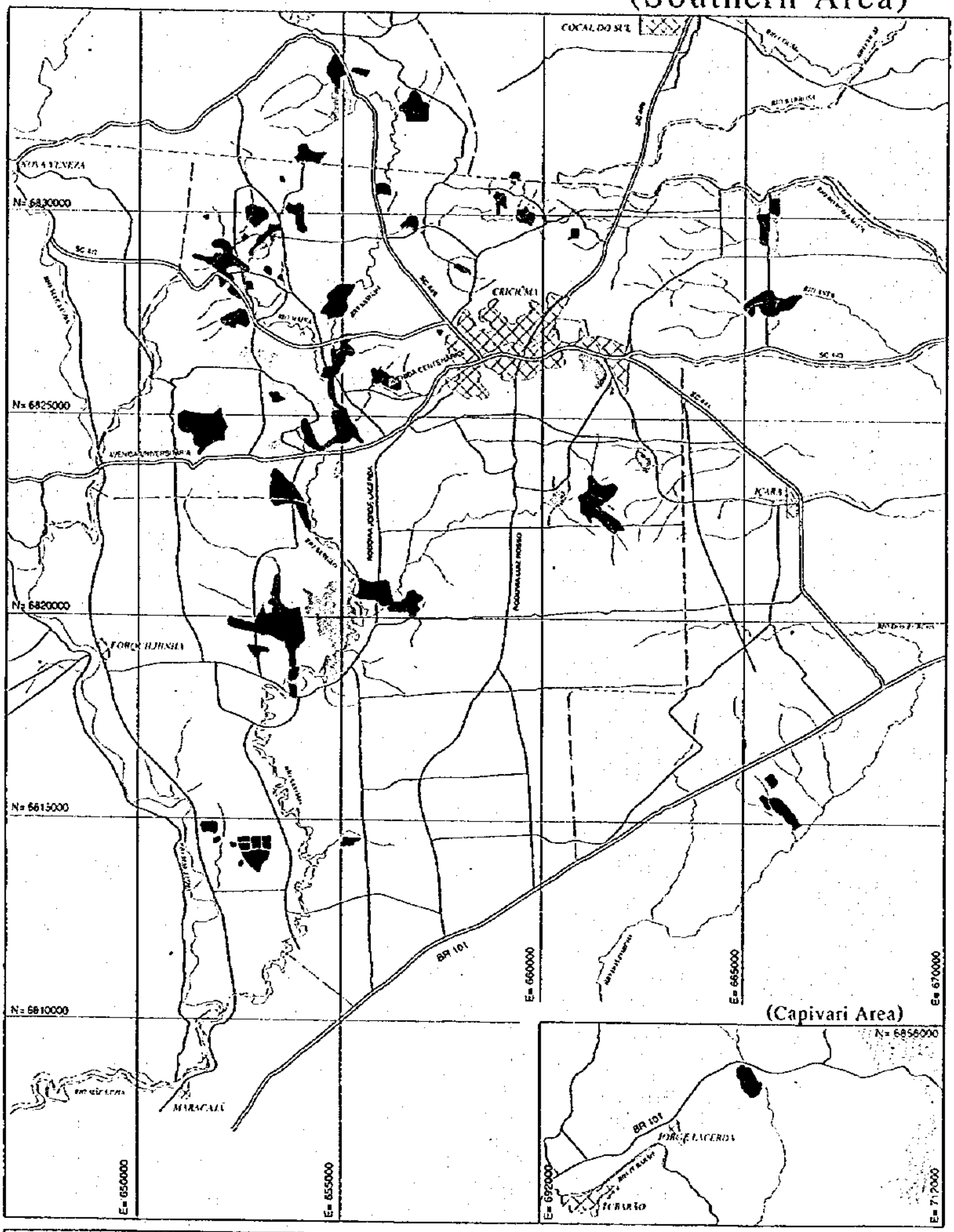
(dotted)	Private Individual	(dashed)	River
(black)	Private Company	(double line)	Road
(blank)	Public Land	(dash-dot)	Boundary of Municipalities
(black)	CSN(Cia Siderúgica Nacional)		

Figure III-4 (1/2) **Polluted Land Ownership**

THE FEASIBILITY STUDY ON RECUPERATION OF MINED OUT AREAS IN SOUTH REGION OF SANTA CATARINA-REPUBLIC OF BRAZIL

JAPAN INTERNATIONAL COOPERATION AGENCY - JICA

(Southern Area)



Legend:

- Private Indiuidual
- Private Company
- Public Land
- CSN(Cia.Siderúgica Nacional)
- River
- Road
- Boundary of Municipalities

Figure III-4 (2/2) **Polluted Land Ownership**

THE FEASIBILITY STUDY ON RECUPERATION OF MINED OUT AREAS IN SOUTH REGION OF SANTA CATARINA-REPUBLIC OF BRAZIL

JAPAN INTERNATIONAL COOPERATION AGENCY - JICA

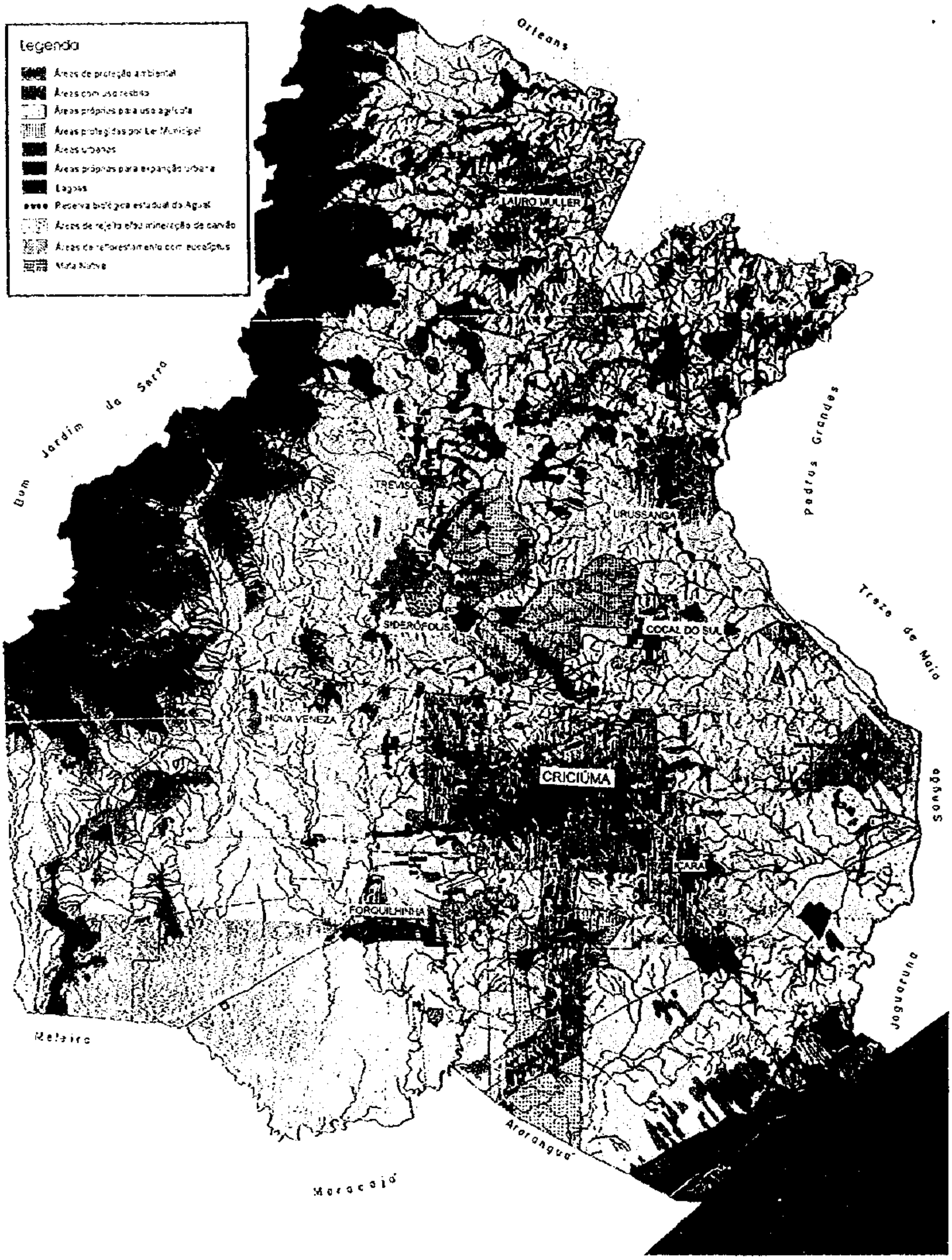


Figure III-5 Permissible Uses of Land in AMREC

TABLE III-4

MARKET VALUE OF THE LAND TO BE RECUPERATED
(IN HECTARE AND R$1000/HA)

Municipality	Urban Area						Rural Area					
	Central			Peripheral			Agriculture			Industrial		
	Ha	Max	Min	Ha	Max	Min	Ha	Max	Min	Ha	Max	Min
Capivari de Baixo	----	----	----	----	----	----	----	----	----	160	15.0	7.0
Criciúma	57	283.3	136.1	659	154.2	57.9	183	142.2	62.2	165	111.0	44.0
Forquilhinha	----	----	----	----	----	----	112	44.0	9.0	272	8.5	7.0
Içaca	----	----	----	----	----	----	45	12.0	5.0	----	----	----
Lauro Müller	----	----	----	99	22.0	3.4	530	4.3	2.3	----	----	----
Siderópolis	----	----	----	280	6.7	2.5	792	5.6	3.1	----	----	----
Treviso	----	----	----	----	----	----	481	5.6	3.1	----	----	----
Urussanga	----	----	----	----	----	----	889	6.1	2.9	----	----	----
Total (R$ million/ha)		(16.1)	(7.8)		(105.7)	(39.2)		(46.3)	(20.4)		(23.0)	(10.3)

Source: Southern Santa Catarina's Real Estate Agencies

Max Total: 191.1 R$ million
Min Total: 77.6 R$ million

(b) LAND USES

(i) Magnitude of the problem

19. Southern Santa Catarina is part of the *Floresta Ombrófila Densa (mata Atlântica)*, an ecological area characterized by dense forests and luxuriant vegetation in its western side (*Serra Geral*) and sandy beaches and lagoons along the coast. Many tree species grow in the *Serra Geral* side, from the *Tabebuia umbellate* and *Octea pulchella* types found in the low, flat and humid land stripes along waterways (*Sanga d' Areia* in the Sombio municipality) to the tall *Aspidosperma parvifolium* and *Alchomea triplinervia* striving in the hilly areas[3].

20. The indiscriminate exploitation of the area for timber in the 1950s and 1960s, coupled with intensive mining and agricultural activities, particularly the practice of slash-and-burn cultivation method, destroyed a large part of the forest cover. While small compared to the other factors, coal mining was nevertheless directly responsible for the destruction of 4,724 ha of this precious land. What remains of the original *Floresta Ombrofila Densa* is now under special protection from the Santa Catarina state.

21. The area is also habitat to a very rich and varied fauna, particularly in the *Serra Geral* where many varieties of vertebrates, reptiles and birds can be found. Mamal species include rondents such as the *Mus musculus e Rattus rattus*[4]. None of these species survived in the polluted areas.

(ii) Quantification of the Benefits

22. While many losses are irreversible and therefore not quantifiable, a monetary value can be estimated for the following environmental damages, which should be viewed as minimum benefits of a remediation program: (i) loss of forestry resources; (ii) loss of fauna and flora; and (iii) loss of the areas for recreational use.

i) Loss of Forestry Resources

23. The loss of forestry resources can be measured by the income foregone from the sale of timber and firewood resulting from a responsible exploitation of the area's forestry resources. This is a poor proxy as it does not take into account the loss of rare species with high scientific and economic value. It is nevertheless used to represent the absolute minimum benefit from recuperation.

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[3] For a more complete description of the forests and vegetation in the area, see Veloso & Klein: *"As Communidades e Associações Vegetais da Mata Pluvial no Sul doBrasil. I, II, III, IV, V, and VI"*. Sellowia, Itajaí.

[4] For a more complete description of the fauna in the area, see Dick and al: *"Estudos sobre o Impacto Ecológico da mineração e do beneficiamento do Carvão na Região Sul do Estado de Santa Catarina"*.

24. From Veloso & Klein (1963, 1968b) and information provided by timber companies in the region, an hectare can produce 180 m^3 of timber and 350 m^3 of firewood every seven years, since it takes about that time for the replanted trees to reach again the optimum cutting level (30 cm in diameter and 9 m in height). Timber sells for R$40/$m^3$ and firewood for R$5/$m^3$.

25. Given that after remediation, trees can be planted over about 2,182 ha (areas of overburden waste recuperated through covering them with clay), benefits from exploiting forestry resources are estimated at R$19.5 million every seven years.

ii) Loss of Fauna and Flora

26. A Willingness-To-Pay (WTP) study was conducted in six AMREC municipalities to assess the importance that the people living in the affected areas[5] give to the coal mining pollution problem and to learn more about their relative priorities with regard to the objectives of an eventual clean up operation. The detailed results of the study, its methodology, characteristics of the sample and coverage are given in Annex 3.

27. The results of the WTP study with regard to recuperation of fauna and flora will be used as a basis for quantifying the benefits of such an underaking. Indeed, past remediation experience in the Rio Grande do Sul state shows that proper remediation brings back most of the original vegetation cover, as well as some birds and animals living in the area before mining.

TABLE III-5

WILLINGNESS TO PAY FOR RECUPERATING THE LOSS OF FAUNA AND FLORA

Contribution (R$/month)	Capivari/ Criciúma	Lauro Müller/ Siderópolis	Treviso/ Urussanga	Total (No.)	Total (%)
1 to 5	185	99	156	440	40
5 to 10	46	20	26	92	8
10 to 15	16	7	6	29	3
15 and more	6	4	3	13	1
One workday	154	81	73	308	28
Nothing	89	97	39	225	20
No answer	----	3	2	5	neg
Total	496	100	305	1,112	100

Source: JICA Team's WTP study with the assistance of NUPESE

[5] The survey was not extended to people outside the affected areas in keeping with our strategy to take into account only unquestionable benefits, although it is perfectly conceivable that people living outside the affected areas would like to contribute because they believe this is an important problem which needs to be solved.

28. As shown on Table III-5 above, 79% of the people interviewed are willing to pay for the recuperation of the region's fauna and flora in mined-out areas. This is an extremely favorable percentage. Furthermore, the level of *monthly contribution* indicated is also very high (it is equivalent to about 2-3% of the interviwees' income) and shows the importance that the very people living in the affected areas attach to the problem.

29. Table III-6 below shows the results when the indicated contributions are applied to (i) the total population living in or near the affected areas; (ii) adult population; or (iii) family units.

TABLE III-6

VALUE OF THE RECUPERATION OF FAUNA AND FLORA TO THE PEOPLE LIVING IN THE AFFECTED AREAS

Contribution (R$/month)	Scenario I		Scenario II		Scenario III	
	Total Pop.	Average Value[a]	Adult Pop.	Average Value[a]	Family Units	Average Value[a]
1 to 5 [b]	75,704	2,725	43,407	1,563	19,166	690
5 to 10[b]	16,751	1,507	9,605	865	4,241	282
10 to 15[b]	4,237	635	2,430	365	1,072	161
More than 15 [c]	1,942	350	1,113	200	492	89
One workday [d]	84,621	4,062	48,520	2,329	21,424	1,028
Nothing	35,556	------	20,387	-------	9,002	------
No answer	1,854	----- -	1,063	-------	469	------
Total	22,0665	9,280	126,525	5,321	55,866	2,349

Source: JICA Team's WTP study with the assistance of NUPESE
a/ In thousands R$ per year.
b/ Taking a medium as multiplier.
c/ Taking 15 as the multiplier.
d/ R$4/day (minimum salary)

iii) Loss of Areas for recreational Use

30. The AMREC sub-region, with its many rivers, nice weather and beautiful landscape, offers many possibilities for tourism, as well as relaxation for its local population. Table III-7 and Figure III-6 below show the possible recreational uses of the polluted areas. Table III-8 gives the results of the calculations of the benefits using the same WTP approach as the loss of fauna and flora since many interviewees declared willing to contribute for that purpose.

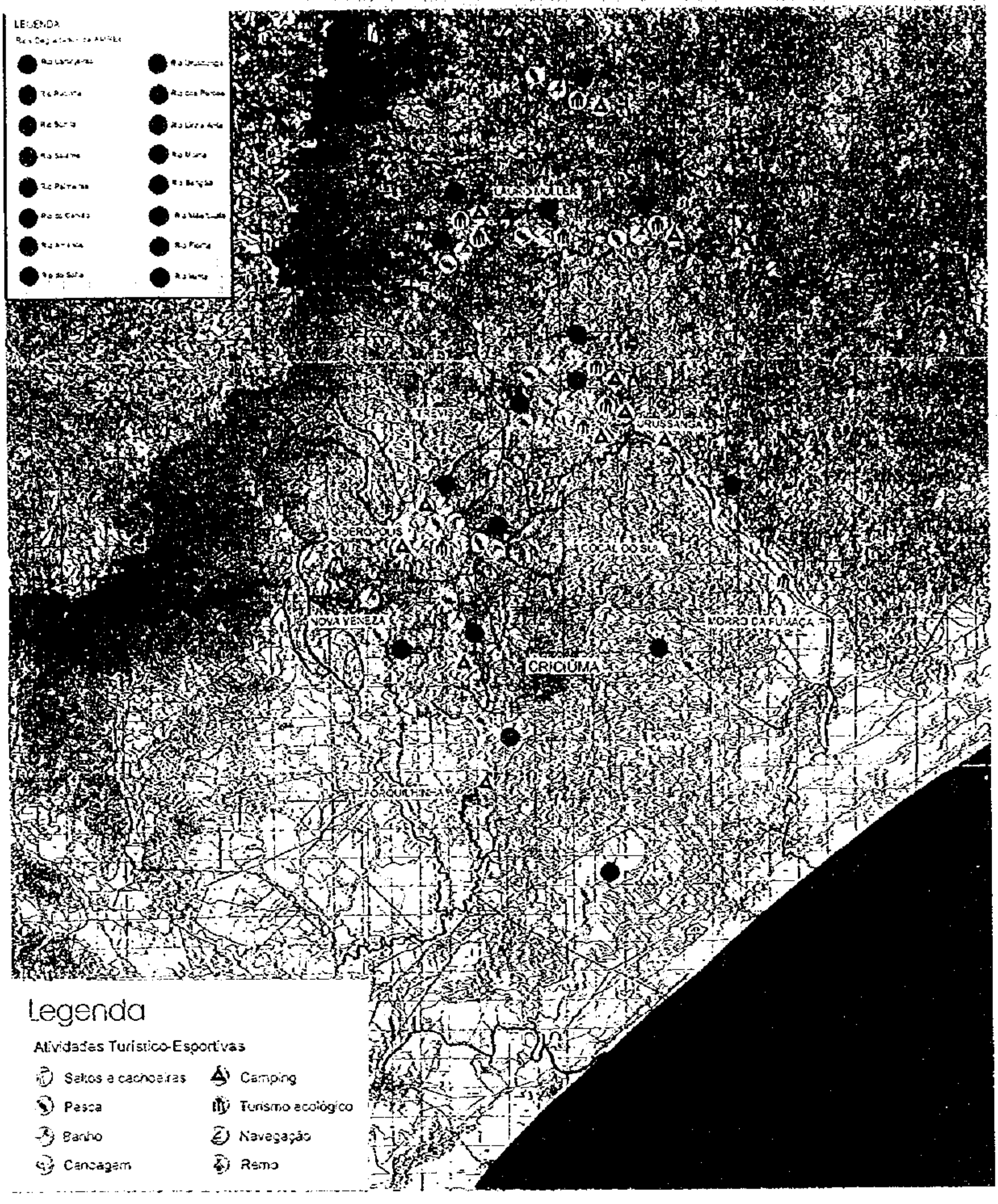

Figure III-6 Possible Recreational Uses of Polluted Land

TABLE III-7

POSSIBLE RECREATIONAL USES OF THE POLLUTED AREAS

	Fishing	Swimming	Canoeing	Camping	Eco-Tourism
Cocal do Sul	YES	YES	YES	NO	YES
Criciúma	YES	YES	YES	YES	YES
Forquilhinha	YES	YES	YES	YES	YES
Içara	YES	YES	YES	YES	YES
Lauro Müller	YES	YES	NO	YES	YES
M da Fumaça	YES	YES	NO	YES	YES
Nova Veneza	YES	YES	YES[a]	NO	YES
Siderópolis	YES	YES	YES	YES[b]	YES
Urussanga	YES	YES	YES	YES	YES

Source: NUPESE. [a] Also rowing. [b] Also water falls

TABLE III-8

VALUE OF RECUPERATING THE POLLUTED AREAS FOR RECREATIONAL USE TO THE PEOPLE LIVING IN THE AFFECTED AREAS

Contribution (R$/month)	Willingness to Pay (No.)	Willingness to Pay (%)	Scenario I Total Pop.	Scenario I Average Value[a]	Scenario II Adult Pop.	Scenario II Average Value[a]	Scenario III Family Units	Scenario III Average Value[a]
1 to 5	417	38	83,853	3,019	48,080	1,730	21,229	674
5 to 10	81	7	15,446	1,390	8,857	797	3,911	352
10 to 15	23	2	4,413	663	2,530	380	1,117	168
More than 15[b]	12	1	2,207	397	1,265	228	559	100
One workday[c]	323	29	63,993	3,072	36,692	1,761	16,201	778
Nothing	253	23	50,753	----	29,101	----	12,849	----
No answer	3	neg	----	----	----	----	----	----
Total			220,665	8,540	126,525	5,321	55,866	2,162

Source: JICA Team's WTP study with the assistance of NUPESE

[a] In thousands R$ per year.

[b] Taking 15 as the multiplier.

[c] R$4/day (minimum salary)

2.2 *WATER POLLUTION*

31. Perhaps even more important than land degradation is the pollution of surface and ground water resources as this has a tremendous negative impact on the region's economic growth and welfare of its people. Its many impacts are described below followed by an attempt to quantify the benefits of an eventual remediation.

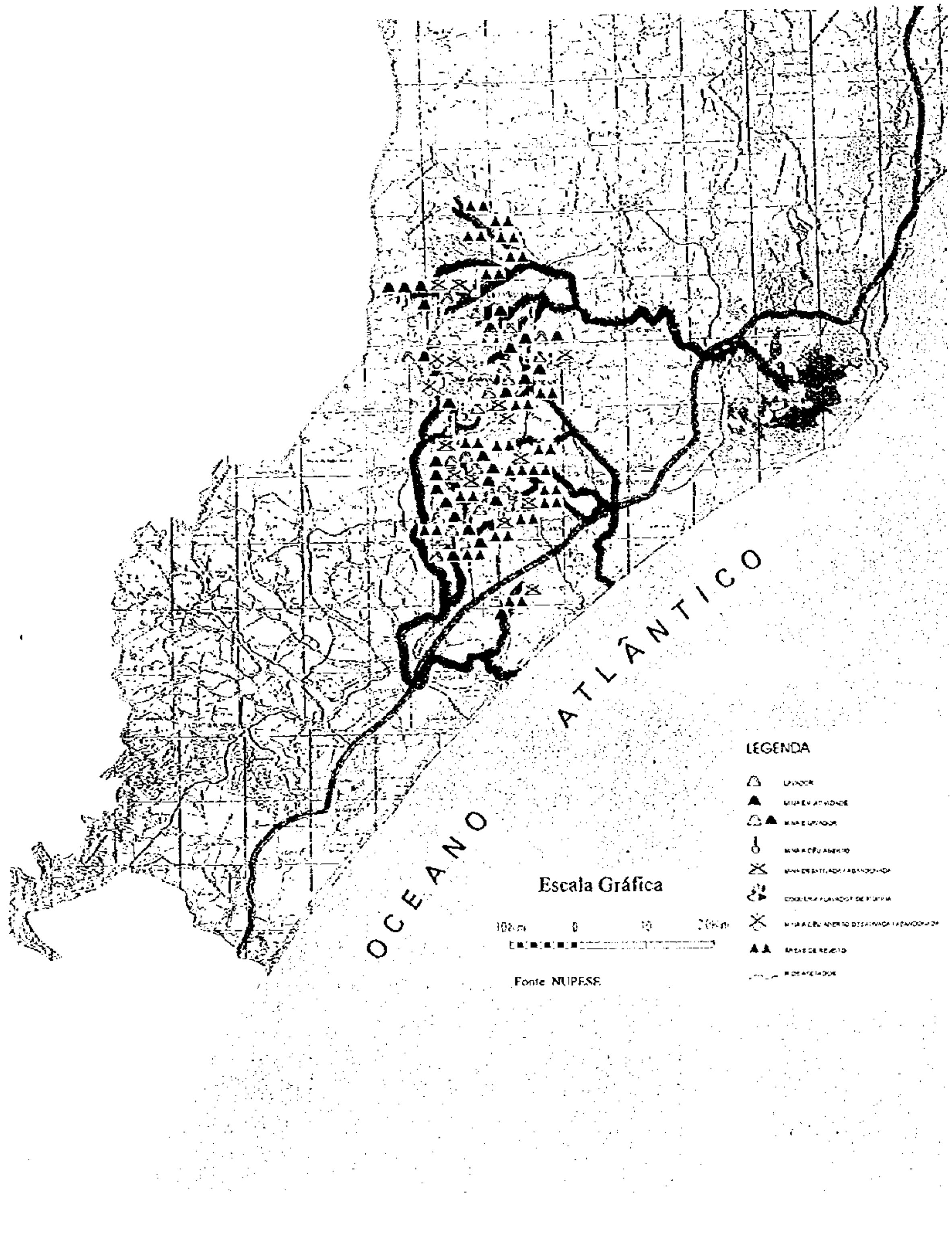

Figure III-7 Coal Pollution of the Region's River Basins