## T.5.1 The Abiotic Environment

### T.5.1.1 Geological characteristics

#### T.5.1.1.1 Introduction

The area in study is located in the western edge of the "Nicaraguan Depression", one of the four geographical-geomorphological provinces in which the country is divided. The mentioned depression is located in the western part of the country, it is a structural valley limited by two parallel coasts of the Pacific defects, and extendes from the northwest to the southwest from the Fonseca Gulf up to the border with Costa Rica .

The area is typically volcanic, in which a mainly explosive volcanism has occurred, accompanied, some times, by lava effusions. The recognized geological units, listed from the most ancient to the youngest are: Lavas of Apoyo, "Las Sierras" Group, Volcanic quaternary of Apoyo, Volcanic Quaternary of the Mombacho volcano and the Alluvial Quaternary.

**a. Lava of Apoyo**

The Lava of Apoyo are a group of the andesitic-balsatic lavas and tobaceous agglomerated profoundly meteorized, of presumable Plio-pleitocene age. The thickness of the meteorized zone is estimated at 10 m. The product of the meteorization is a very plastic clay with coloration from reddish brown to violet. These lavas flourish in the southwest edge of the lagoon of Apoyo and the northwest sector of the skirts of the Mombacho volcano.

**b. Las Sierras Group**

It includes the set of Plio-pleistocene age rocks, composed mainly of piroclasts from consolidated to moderately consolidated, deposited, in part, in shallow waters. Lithologically it is formed by fine and bulk tufas, tobaceous agglomerated, bulk and fine lapillis, volcanic ash, scoria and something of pumice, originated from the activity of the Plio-pleistocene volcanism of regional character.

**c. Volcanic Quaternary of Apoyo**

This includes the piroclastics rocks of the Superior Pleistocene age, from moderately consolidated to loose, that occupy a large part of the area. Lithologically it is formed of potent deposits of dacitic pumice with pinkinsh, that is yellowish and light gray in coloration. It contains ashes of bulk to fine granulometry, loose and balsatic-andesitic lithics, round and angular in shape. These deposits have a thickness exceeding 100 m in the proximity of the Caldera of Apoyo, its thickness decreases in the direction of Lake Nicaragua, underlined, in some cases, to the lavas of Apoyo, in other, to Las Sierras Group.

The upper part of the Volcanic Quaternary of Apoyo constitutes a stratum of pumice-dacitic ash, slightly pink in color, and locally predominant Talpuja. The thickness of the talpuja, observed in the natural cutting, is greater than 40 m.

**d. Volcanic Quaternary of the Mombacho**

Here the grouped lava flows and piroclasts originated by the Mombacho volcano. It consists of andesitic and balsatic lava flows, alternating with scoria and ash layers.

### c. Alluvial Quaternary Sediments

The alluvial sediments cover the plain of Tisma. They have originated from the accumulation of the volcanic materials transported by the numerous current that drain to the Mombacho volcano and the volcanic flatness. Lithologically, they consist of gravel, balsatic, andesitic and pumice character sands, silts and clays.

## T.5.1.1.2 Methodology

For the determination of the geological characteristics of the soil of San Jose de la Viuda, the following investigation were carried out:

- 7 stratographic perforations of 15 m deep, with control sample recovery, with a total depth of 105 m.
- Description of the stratographic composition of the perforation and control sample.
- Representative samples were taken of all the materials found in the control sample, classifying them using field methods by their color, plasticity, granulometry etc.
- Preparation of the stratographic column profile graphs.
- Preparation of the structural wegmentation graph.
- Analysis of the following parameters in 10 samples obtained from the upper and lower segments of the soil:
  - Water content
  - Granulometry
  - Volumetric Weight
  - Limits of Atterberg
  - Calculation of the Optimum Humidity for the compression
- Collection of 5 undisturbed samples of the upper segments of the soil.
- Direct cutting analysis of the five undisturbed samples.
- Five permeability tests for the soil absorption in the field (Infiltration).
- Measurement and report of the depth of the mirror of the ground water in each perforation.

### a. Stratographic Drillings

The stratographic drillings were carried out in a mechanized manner with the employment of an auto-transported conventional perforation machine, with a tower of 12 m of high, provided with a turntable. The perforation was carried out in the dry season with advances of 0.3 m every time, using sweeps of extension, 50 mm in diameter and draws - sample tubes of 100 mm and 1.5 m in length, designed for the extraction of soil kernel in a continuous manner.

The obtained control sample were deposited in wood boxes with a capacity for 5 m of each control sample. The description of the control sample was accomplished on-site and the determination of the materials were made visually with a magnifier, with

magnification factors by 10 and 20 and to the touch by field methods. Thereinafter, the samples were moved to the laboratory.

**b. Laboratory Analysis**

The laboratory analysis were conducted using to the following standard procedures:

| | |
|---|---|
| Water content | ASTM D 2216 |
| Granulometry | ASTM D 422 |
| Volumetric Weight | ASTM C 29 |
| Limits of Atterberg | ASTM D 423, D 424 |
| Classification USCS (Unified Soil Classification System) | ASTM D 3282 |
| Calculation of the optimum humidity for the compression | ASTM D 698 |

The samples for analysis were moved daily to the laboratory in sealed tubes and sealed with paraffin in order to preserve their natural characteristics. The first test carried out on each sample was the water content.

**b.1 Water Content**

The water content in the sediments was determined of two different forms:

1. In the material obtained from the deep levels of the drillings, the sediments were dehydrated at 105°C, to determine the water content in the pores and to 130°C, to determine the mineral water.
2. In the material obtained from the superficial undisturbed samples, the sediments were dehydrated at 105°C.

**b.2 Granulometry**

The granulometric composition of the sediments was determined mechanically, in the series of meshes ASTM AND 11 - 1970s, according to those withheld in the following meshsizes: 19, 9.51, 4.76, 2.38, 0.75, 0.5, 0.25, 0.15 and 0.074 mm.

**c. Other Trials**

- Collection of 5 undisturbed samples from the upper layer of the soil.
- Direct cross sectional tests in the five undisturbed samples. Procedure used was according to the standard ASTM D 3080 method, of the Soil Test device.
- Measurement of the permeability, and absorption of the soil (Infiltration). This was accomplished according to a standard procedure established for infiltration tests by the Sanitary Engineering Center R. A. Taft of Brazil.

The method consists of saturating and expanding soil through the careful filling of an excavation, with clean water, to a minimal depth of 30 cm to the bottom, maintaining the level, for at least 4 hours, through the gradual aggregate process of water, to determine the infiltration rate 24 hours after the water has been introduced, for the first time, in the excavation, through the measurement of the discouragement, for the last 30 minutes.

Measurement and report of the depth of the mirror of the ground water, in each perforation. The measurements were conducted by boring.

### T.5.1.1.3 Characteristic of the Subsoil

#### a. Stratigraphy

The stratigraphic description of each boring is shown below. The stratigraphic columns are presented in Chapter 8 of the Data Book: Volume V.

**Boring No.1**

Stratigraphic Description

0.00 - 1.45 m Medium clay plasticity (CL), low compressibility, with low adherence and light brown in color. Very cohesive soil in dry state, abundant roots and plant remains persent, in the first 0.3 m. Moderate quantity of isolated clasts of pumice and lithic fragments. Scarce volcanic glass medium. Granular structure, abundant pores.

1.46 - 2.20 m Sandy silt without plasticity, without adherence and pinky brown to reddish coloration. Slightly cohesive. Root remains are scarce. They are integrated by clasts of slightly rounded volcanic glass and crystalline (0.5 - 1.0 mm), in a translucent matrix of silt, product of the devitrification. Isolated clasts of pumice and lithic fragments. Medium granular structure.

2.21 - 3.75 m Silty sands without plasticity, without adherence and pink color to reddish. Without cohesion. The composition of the sand is fundamentally glassy clastic of slightly rounded and crystalline clasts (0.5 - 1.0 mm), in a translucent silt matrix, as a result of the devitrification. Isolated clasts of pumice and lithic fragments.

3.76 - 5.30 m Loose sands of bulk grain without plasticity, without adherence and fine grains. Slightly pinky gray in color. The sand is made of round lithic multicolor clasts of 2.0 to 3.0 mm and volcanic glass. Isolated clasts of pumice of up to 7 mm.

5.31 - 9.43 m Sand without plasticity (SM), without adherence and pink in color. Cohesive. It is made up of clasts of slightly rounded and crystalline volcanic glass (0.2 - 1.5 mm), in a translucent silt counterfoil, as a result of the devitrification.

4.44 - 10.00 m Bulk granular pumice, gravel size from 2.0 - 3.0 cm up to 5.0 - 6.0 cm, and light gray in color to white. The isolated clasts present flux structures.

10.00 - 15.00 m Loose clayey sands of bulk grain without plasticity, slightly adhesive. Brownish gray in color. The sand is made up exclusively of completely round multicolor lithic clasts of 2.0 - 3.0 mm. The last 50 cm were not recovered.

**Boring No.2**

Stratigraphic Description

0.00 - 1.78 m Organic clays of high plasticity (OH) and high adherence, very black in color. Non-cohesive soil in wet condition, abundant roots and plant

remains present in the first 0.5 m. Moderate quantity of isolated clasts of pumice and lithic fragments. Scarce volcanic glass. Without granular structure.

1.79 - 4.15 m Slightly plastic organic Silts, without adherence and obscure brown to black. Slightly cohesive. Root remains are scarce. Isolated clasts of pumice and lithic fragments.

4.16 - 6.50 m Loose sands of bulk grain without plasticity, without adherence and without fine grains. Slightly pink gray color. The sand is made up of round multicolor lithic clasts of 2.0 to 3.0 mm and volcanic glass.

6.51 - 9.00 m Sand without plasticity (SM), without adherence and of pink in color. Slightly cohesive. It is made up of clasts of semi-rounded and crystalline volcanic glass of 0.2 - 1.5 mm, in a translucent silt matrix, as a result of devitrification.

9.01 - 15.00 m Loose sands of bulk grain without plasticity, slightly cohesive. Brownish gray in color. The sand is made up exclusively of completely round multicolor lithic of 2.0 - 3.0 mm.

**Boring No.3**

Stratigraphic Description

0.0 - 0.53 m Plastic clay and without adherence, high compressibility (CH), very obscure brown coloration. Cohesive soil in dry condition, presents abundant roots and plant remains in the first 0.2 m. Median quantity of angular fragments of volcanic opaline glass of 2 - 3 mm and yellowish porous pumice. It can be observed clasts and multicolor lithic fragments. Angular structure.

0.54 - 1.30 m Sandy silts without plasticity, without adherence and pink in color. Slightly cohesive. They are made up of clasts of volcanic glass semi round and crystalline of 0.2 - 1.5 mm in a translucent silt matrix as a result of the devitrification. Present isolated clasts of pumice of gravel size (5 - 6 mm) and lithics fragments.

1.31 - 2.73 m Feeble plastic silty Sands, without adherence and pale pink in color. Cohesive. The composition of the sand is fundamentally a glassy of slightly round and crystalline clasts of 0.5 - 1.0 mm, in a translucent silt matrix, as a result of devitrification. Isolated clasts of pumice and lithics fragments.

2.74 - 5.30 m Loose sands of fine grain without plasticity, slightly cohesive. Brownish gray color. The sand is made up exclusively of completely round multicolor lithic clasts of 2.0 to 3.0 mm. Insertions of more clayey material of 10 - 15 cm of thickness. Toward the ground enrichment with granular pumice can be observed.

10.66 - 13.00 m Sands without plasticity (SM), without adherence and pink to reddish. Without cohesion. The composition of the sand is fundamentally glassy clastic of slightly round and crystalline clasts of 0.5 - 1.0 mm, in a scarce clayey matrix. Isolated clasts of pumice and lithic fragments.

13.01 - 15.00 m Loose sands of bulk grain (3 - 4 mm), without plasticity, slightly cohesive. Gray brownish in color. The sand is made up of pumice clasts and round multicolored lithic fragments of 2.0 to 3.0 mm with abundant fine grains.

**Boring No.4**

Stratigraphic Description

0.0 - 1.76 m High adherence silt, low compressibility (ML), grayish brown in color, very yellowish stained. Cohesive soil in wet condition, presents abundant roots and plant remains in the first 0.8 m. Scarce pumice clasts and lthic fragments. Granular structure.

1.77 - 3.80 m Slightly plastic organic silts, locally sandy, without adherence and very obscure gray color to black or brownish in color. Moderately cohesive. Present scarce root remains. Isolated clasts of pumice and lithic fragments.

3.81 - 4.80 m Loose grain sands middle to bulky (2 - 3 mm), without plasticity, without adherence. Reddish brown color. The sand is made up of round transparent glass clasts. Moderate quantities of clayey fine.

4.81 - 6.00 m Loose grain sands middle to bulk (2 - 3 mm), without plasticity, without adherence. Yellowish gray color to brownish. The sand is made up of round transparent glass clasts. Moderate quantities of clayey fine. Slightly plastic and cohesive.

6.01 - 10.00 m Loose sands (SM) of fine grain to middle (1 mm), without plasticity neither cohesion. Reddish brown in color. The sand is made up exclusively of completely round multicolor lithic clasts and scarce fragments of clear pumice of gravel size.

10.01 - 12.60 m Sands feebly cohesive of very fine grain, without plasticity. Yellowish gray color. The grains of the sand are slightly cemented by chemical silicate sediments as a result of the devitrification.

12.61 - 15.00 m Cohesive silty sands of very fine grain, little plasticity. Obscure gray in color. The grains of the sand are slightly cemented by chemical silicate sediments and silts, as a result of the devitrification.

**Boring No.5**

Stratigraphic Description

0.0 - 0.65 m Silt of high compressibility (MH) and high adherence, very black. Non-cohesive soil in saturated condition, presents abundant roots and plant remains in the first 0.3 m. Moderate quantity of isolated pumice clasts, lithic fragments and opaline chalcedony. Angular structure.

0.66 - 1.50 m Slightly plastic sandy clays, without adherence and charcoal gray to dark grayish in color. Slightly cohesive. Present scarce root remains. Isolated pumice Clasts and lithic fragments of seeding size.

1.51 - 3.90 m Feebly clayey loose sands of bulk grain without plasticity, without adherence and few fine grains. Reddish brown in color. The sand is made up of lithic multicolor round clasts of 2.0 to 3.0 mm and volcanic glass. Present a clayey intercalation between 2.90 - 3.30 m.

3.91 - 6.00 m Clayey sands feebly cohesive of fine grain ( 1 mm) without plasticity. Reddish brown in color. The sand is integrated by round multicolor lithic clasts and scarce fragments of clear pumice, gravel size.

6.01 - 10.30 m Cohesive silty sand (SM) of very fine grain, without plasticity. Dark gray in color. The grains of the sand are slightly cemented by chemical silicate sediments and silts, as a result of the devitrification.

10.31 - 14.70 m Loose sands of bulk grain, without plasticity, slightly cohesive. Reddish brown in color. The sand is made up exclusively by round multicolor lithic clasts of 2.0 to 3.0 mm. The segment presents clayey intercalations of sands at the depth of 11.60 - 12.00 m and 12.30 - 12.40 m.

14.71 - 15.00 m Sand feebly clayey, cohesive, of very fine grain, little plasticity. Dark gray color to gray greenish. The grains of the round sand are hardened by chemical sediments.

**Boring No.6**

Stratigraphic Description

0.00 - 2.95 m Organic clays of high plasticity and high adherence, very black in color. Non-cohesive soil, presents roots and plant remains in the first 0.4 m, humid. Moderate quantity of isolated pumice clasts, lithic fragments and opaline chalcedony. Granular structure.

2.96 - 5.50 m Plastic sandy silt and greasy to the touch, high adherence and clear brown in color. Slightly cohesive and humid. Presents scarce root remains. It can be observed also round fragments of pumice, lithic fragments and translucent glass less than 1 mm.

5.51 - 6.50 m Feebly clayey loose sand of bulk grain (3 - 4 mm), without plasticity, without adherence and abundant fine grains. Dry natural conditions. Brownish gray in color. The sand is made up of round multicolor lithic clasts of 2.0 to 3.0 mm and volcanic glass.

6.51 - 8.22 m Bulk loose grain sands (5 mm and gravely isolated clasts of up to 20 mm), without plasticity. Steel-like gray in color. The sand is made up of round multicolor lithic clasts and scarce fragments of light color pumice, gravel size.

8.23 - 10.60 m Silty sands without grain cohesion very fine, without plasticity. Clear pink color. The grains of the sand are slightly hardened by chemical silicate sediments and silts, as a result of the devitrification.

10.61 - 12.83 m Loose silty grain sands without plasticity, steel-like gray in color. The sand is made up exclusively by round multicolor lithic clasts of a

smaller size than 1 mm. The segment presents an intercalation bulky granular pumice of yellowish color between 12.30 and 12.82 m.

12.84 - 15.00 m Sand feebly clayey, cohesive, of middle to bulky grain, without plasticity. Gray color slightly brownish. The grains of lithic composition are completely round slightly cemented by chemical sediments.

**Boring No.7**

Stratigraphic Description

0.0 - 0.64 m Organic clayey soil of high plasticity and high adherence, very obscure brown in color, greasy to the touch. Slightly cohesive soil, humid, presents roots and plant remains in the first 0.2 m. Without clasts. Granular structure.

0.65 - 2.80 m Sandy Silt without plasticity neither adherence, of clear brown color to yellowish greenish. Slightly cohesive. Dry. Present scarce root remains. We can observe some round fragments of pumice lithic fragments and translucent glass, smaller than 1 mm.

2.81 - 4.00 m Clayey sands of bulk grain (2 - 3 mm), without plasticity, without adherence and abundant fine grains. Clear brown color, white spotted, as a result of lithic and/or pumice fragment alteration. The sand is composed of angular lithic clasts of greenish color and pumice fragments.

4.01 - 4.10 m Loose volcanic overage grain sand, graduated, with fine and bulky fragments ( 5 mm) isolated, of basaltic composition. Brownish gray in color.

4.11 - 7.30 m Grain sands middle to bulky (1 - 3 mm) with scarce gravelitic clasts of 5 - 7 mm, without cohesion, without plasticity. Humid. Yellowish brown color to brown reddish. The grains of the sand are composed of volcanic glass, lithic fragments and pumice, all round shaped.

7.31 - 10.00 m Sands feebly clayey of loose grain, without plasticity, non-greasy to the touch, slightly cohesive, in water saturation condition. Reddish brown in color. The sand is made up exclusively of round multicolor lithic clasts smaller than 1 mm and scarce pumice.

10.01 - 12.10 m Very fine grain cohesive sand (1 mm), without plasticity, reddish brown in color. Variable quantities of clasts of basaltic composition, completely round.

12.11 - 15.00 m Loose grain sands middle to bulk (2 - 3 mm), without plasticity, Brownish gray in color. Lithic composition. Round grains.

### T.5.1.1.4 Geotechnical Characteristic of the Subsoil

#### a. Water Content

The natural water content of the materials is shown in the table below.

Table T-7: Natural water content

| Drilling No. | Depth (m) | Material | Humidity (130 °C) | Humidity (105 °C) |
|---|---|---|---|---|
| 1 | 0.55 - 0.85 | Clay | | 10.7 |
| | 5.30 - 9.43 | Sand | 27.47 % | 26.74 % |
| 2 | 0.30 - 0.60 | Organic clay | | 27.9 |
| | 6.50 - 9.00 | Sand | 23.68 % | 21.42 % |
| 3 | 0.15 - 0.45 | Clay | | 12.1 |
| | 10.6 - 13.0 | Sand | 18.23 % | 15.48 % |
| 4 | 0.75 - 1.05 | Silt | | 21.1 |
| | 6.0 - 10.0 | Sand | 23.46 % | 23.00 % |
| 5 | 0.15 - 0.45 | Silt | | 10.9 |
| | 6.0 - 10.3 | Sand | 14.38 % | 14.34 % |

The percentages vary between a maximum of 27.9 %, in the organic clay from the Boring No. 2, between 0.3 and 0.6 m of depth and a minimum of 10.7 %, in the clay of the Boring No.1, between 0.5 and 0.8 m of depth. Under the saturation level of the underground waters, the natural humidity is variable between 15 and 27%.

The differences in the percentages of the water contents between following treatment at 105 °C and 130 °C, indicates the presence of water in the mineralogical composition of the materials in smaller proportions (Max. 2.75 %, Min. 0.03 %).

**b. Granulometric Composition**

The granulometric compositions of the sediments are shown in the table below.

The granulometric composition of the materials as a rule, corresponds to pelitic sediments of fine grain, with a light increase in the size of the grains in the depth of the sub - soil. The superficial layer corresponds to clays and silts with percentages preater than 60 %, that filter through a meshsize 0.074 mm and held smaller unfiltered ones about 20 %, with a meshsize 4.76 mm. Deeper sediments are exclusively psammitic, sands with smaller percentages of 40 % that filter through a 0.074 mm mesh and bigger unfiltered ones of 20 % through the mesh 1.0 mm.

Table T-8: Granulometric Composition

| Drilling No. | Depth | % that cross the mesh (mm) | | | | | | | | | | USCS Type |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 19.00 | 12.70 | 9.51 | 4.76 | 2.38 | 0.75 | 0.50 | 0.25 | 0.15 | 0.07 | |
| 1 | 0.5 - 0.8 | | | | 100 | 96 | 90 | 84 | 79 | 73 | 68 | CL |
| | 5.3 - 9.4 | | | 100 | 99 | 94 | 82 | 69 | 57 | 49 | 41 | SM |
| 2 | 0.3 - 0.6 | | | | 100 | 99 | 97 | 96 | 96 | 95 | 94 | OH |
| | 6.5 - 9.0 | | | | 100 | 98 | 85 | 70 | 57 | 45 | 37 | SM |
| 3 | 0.1 - 0.4 | | | | 100 | 99 | 93 | 89 | 81 | 79 | 76 | CH |
| | 10.6 - 13 | | | 100 | 95 | 87 | 75 | 62 | 52 | 42 | 36 | SM |
| 4 | 0.7 - 1.0 | | | | 100 | 94 | 80 | 73 | 69 | 58 | 54 | ML |
| | 6.0 - 10.0 | | | 100 | 98 | 92 | 79 | 62 | 49 | 38 | 33 | SM |
| 5 | 0.1 - 0.4 | | | | 100 | 100 | 97 | 95 | 90 | 88 | 86 | MH |
| | 6.0 - 10.3 | | | 100 | 91 | 81 | 67 | 52 | 42 | 34 | 29 | SM |

### c. Specific Gravity

The specific gravity of the sediments is shown in the table below. As it can be observed in the following table, the weight depends on the geological composition of the sediments:

- The sands and gray clayey sands from the deeper levels of the borings, present a volumetric loose dry weight greater than 1,200 kg/m$^3$.
- The brown and pink sands of the intermediate levels of the boring, present volumetric loose dry lower than 1,100 kg/m$^3$.
- The silts and organic clays present volumetric loose dry weight lower than 1,200 kg/m$^3$.

Table T-9: Volumetric loose dry weight

| Drilling No. | Depth (m) | Material | Specific Gravity ( kg/m$^3$) |
|---|---|---|---|
| 1 | 0.55 - 0.85 | Clay | 1.183 |
| | 5.30 - 9.43 | Pink sand | 1.079 |
| 2 | 0.30 - 0.60 | Organic clay | 623 |
| | 6.50 - 9.00 | Pink sand | 1.084 |
| 3 | 0.15 - 0.45 | Clay | 1.484 |
| | 10.6 - 13.0 | Pink sand | 1.100 |
| 4 | 0.75 - 1.05 | Silt | 907 |
| | 6.00 - 10.00 | Brown sand | 1.230 |
| 5 | 0.15 - 0.45 | Silt | 1.121 |
| | 6.0 - 10.3 | Gray silty sand | 1.340 |

### d. Limits of Atterberg and USCS Classification

The consistency limits and the classification USCS (Unified Soil Classification System) of the sediments are shown in Table T-10. From the results of the determination of the Atterberg limits, the presence of fine particle sediments of ML, CL type of low compressibility and MH, CH and OH type of high compressibility is evident in the surface layer. In the lower levels, the sediments are exclusively sandy, type SM, without plasticity.

Table T-10: Limits of Atterberg and USCS Classification

| Drilling No. | Depth | LL | IP | Type | Observation |
|---|---|---|---|---|---|
| 1 | 0.55 - 0.85 | 37 | 14 | CL | Light brown clay |
| | 5.30 - 9.43 | -- | NP | SM | Silty sand |
| 2 | 0.30 - 0.60 | 78 | 21 | OH | Black organic clay |
| | 6.50 - 9.00 | 28 | 3 | SM | Silty sand |
| 3 | 0.15 - 0.45 | 66 | 34 | CH | Dark brown clay |
| | 10.65 - 13.00 | -- | NP | SM | Silty sand |
| 4 | 0.75 - 1.05 | 44 | 4 | ML | Brown grayish silt |
| | 6.00 - 10.00 | -- | NP | SM | Silty sand |
| 5 | 0.15 - 0.45 | 62 | 29 | MH | Black silt |
| | 6.00 - 10.30 | -- | NP | SM | Silty sand |

### e. Optimum Moisture Content for the Compaction

The optimum moisture content for the compaction of the sediments is shown in Table T-11. This moisture content is highly variable and it depends on the geological quality of the sediments.

In the upper levels of the soil moisture content varies between a minimum of 21.8 %, for silt of high compression of the Boring No.5 to a depth between 0.15 and 0.45 m and a 51 % for the organic clay of the Boring No.2, at a depth between 0.3 and 0.6 m.

Table T-11: Optimum Moisture Content for the Compaction

| Drilling No. | Depth | Material | Optimum Moisture Content (%) | Maximum P.V.S. |
|---|---|---|---|---|
| 1 | 0.55 - 0.85 | Clay | 23 | 1.420 |
| | 5.30 - 9.43 | Sand | 31.5 | 1.480 |
| 2 | 0.30 - 0.60 | Organic clay | 55 | 938 |
| | 6.50 - 9.00 | Silt | 24.5 | 1.390 |
| 3 | 0.15 - 0.45 | Clay | 23 | 1.518 |
| | 10.65 - 13.00 | Sand | 19.6 | 1.450 |
| 4 | 0.75 - 1.05 | Silt | 48 | 1.107 |
| | 6.00 - 10.00 | Sand | 26.2 | 1.345 |
| 5 | 0.15 - 0.45 | Silt | 21.8 | 1.215 |
| | 6.00 - 10.30 | Sand | 20 | 1.390 |

### f. Results of the Direct Cross Section Trials

The results of the direct cross section trials of the sediments are shown in The samples were tested in their natural environment, that is to say, without pre-compaction and the test was carried out without drainage, with an axial load of 0.5, 1.0 and 2.0 kg/cm2.

The cohesion of the sediments under these conditions varied between 2.25 kg/cm2 in the clay with pumice clasts of Boring No.3 and 0.60 kg/cm2 in the silt of the Drilling No.4.

The internal friction angle is relatively high for this type of materials, varying between 18o for the organic clay of the Boring No.2 and 31.5o for the clay of the Drilling No.3.

Table T-12.

The samples were tested in their natural environment, that is to say, without pre-compaction and the test was carried out without drainage, with an axial load of 0.5, 1.0 and 2.0 kg/cm$^2$.

The cohesion of the sediments under these conditions varied between 2.25 kg/cm$^2$ in the clay with pumice clasts of Boring No.3 and 0.60 kg/cm$^2$ in the silt of the Drilling No.4.

The internal friction angle is relatively high for this type of materials, varying between 18° for the organic clay of the Boring No.2 and 31.5° for the clay of the Drilling No.3.

Table T-12: Results of the direct cross section trials

| Drilling No. | Depth | Material | Cohesion kg/cm$^2$ | Internal Friction Angle (Φ) |
|---|---|---|---|---|
| 1 | 0.55 - 0.85 | Clay | 1.00 | 21° |
| 2 | 0.30 - 0.60 | Organic clay | 0.63 | 34° |
| 3 | 0.15 - 0.45 | Clay | 2.25 | 28° |
| 4 | 0.75 - 1.05 | Silt | 0.60 | 28° |
| 5 | 0.15 - 0.45 | Silt | 1.45 | 28° |

### g. Results of the Infiltration Tests

The results of the infiltration tests in the sediments are shown in Table T-13.

Table T-13: Results of the infiltration tests

| Drilling No. | Depth (meter) | Material | Infiltration Rate | |
|---|---|---|---|---|
| | | | l/m$^2$/day | cm/sec |
| 1 | 0.55 - 0.85 | Clay | 27 | $3.12 \times 10^{-5}$ |
| 2 | 0.30 - 0.60 | Organic clay | 18 | $2.08 \times 10^{-5}$ |
| 3 | 0.15 - 0.45 | Clay | 70 | $8.10 \times 10^{-5}$ |
| 4 | 0.75 - 1.05 | Silt | 22 | $2.55 \times 10^{-5}$ |
| 5 | 0.15 - 0.45 | Silt | 53 | $6.13 \times 10^{-5}$ |

## T.5.1.2 Morphology of the Area

### T.5.1.2.1 Most Outstanding Geomorphological Features in the Landscape

**a. Volcanic Flatness**

The volcanic flatters extends east, northeast and to the north, with a gently sloping the terrain, from the skirts of the Caldera of Apoyo, up to Lake Nicaragua and the alluvial plain of Tisma. The flatness is conformed by a bulk accumulation of piroclasts, predominantly of pumice type expelled from the Caldera of Apoyo.

This geomorphologic feature, shows a slightly waved topography of low relief: in it, the erosion processes have originated from low relief hills. It is furrowed by a low density net of streams, some of which are and deep, of vertical walls. These streams collect the stormwater that fall in the northeastern and eastern side of the Caldera above mentioned and unload them in the lake of Nicaragua and in the flood zone of the plain of Tisma.

The prevailing drainage are parallel and sub-parallel. All the valleys are found in fresh conditions. From the lake and the plain of Tisma, the area ascends up to 100m above sea level, with a relatively low slope; the slope turns steeper, in the vicinity of the lagoon of Apoyo. The change from volcanic flatness to alluvial plain is gradual.

**b. Plain of Tisma**

This plain extends, with almost no slope, from the extreme south of the lagoon of Tisma, up to the lagoon of La Playuela. The plain sectors near the lake are swampy, due to low level of the terrain, to clayey soils present, to shallow underground water and to the existence of a sandy barrier (dunes), that separates the plain from the lake. The indicated barrier prevents that the waters flow directly in the lake.

**c. Lake of Nicaragua**

Lake Nicaragua constitutes the western boundary of the study area, it occupies the deepest part of the "Nicaraguan Depression". Its shape is approximately elliptical, its maximum dimensions are 163 km long and 74 km wide and covers a surface of 8,000 $km^2$. The surface of the water is at an approximate height of 31 meters above sea level.

**d. Caldera of Apoyo**

The Caldera of Apoyo is found approximately 5 km to the west of Granada. Structurally, it is an explosion caldera with subsequent collapse. It is almost round in shape with an approximate diameter of 5 km, its crater is occupied by the lagoon of the same name. The surface of the water is at 78 m above sea level. The interior walls of the caldera are almost vertical with a maximum height of approximately 220 m.

**e. Mombacho Volcano**

The Mombacho volcano is located about 8 km to the south of the Granada City. Structurally it is a stratum - volcano, whose maximum height reaches 1335 m above sea level. Today it is inactive. What is outstanding in the volcanic mountain mass is the lengthened depression that is found in the northeast flank, originated by the landslide of a rocky mass from a rocky promontory which can be seen as "fan-shaped" at the foot of the volcano. Such rocky promotory, in its prolongation toward the northeast inserts itself into Lake Nicaragua, forming more or less 380 islets (Isletas of Granada).

The volcano in its apex presents two small craters, located on the edge of the Caldera of more or less 2 km in diameter. At the foot of the northwest flank of the volcano, two small dross cones and three explosion craters can be seen, the latter set in a sole alignment.

#### T.5.1.2.2 Local Geomorphology

In San Jose de la Viuda, the western sectors are undulating and in the eastern sectors they are from flat to almost flat; the area is inclined, in general, toward the lake. Also, in this site, the deposits of pumice have a total thickness of a little more than 60 m and lie on moderately to fully consolidated piroclasts.

### T.5.1.3 Formation and type of soil

#### T.5.1.3.1 Introduction

Soils of the study area are immature development soils, that have been developed from most ancient ashes coming from eruptive periods of the Pleitocene epoch whose most important Piroclastics are constituted by acid pumice tufas, basic volcanic gaps and ashes deposited by river dragging.

The most important formation processes in the progressive evolution of these soils are the transformations and the colloid redistribution that have produced a strong illuvial of clays by falling movements, until forming a argillic horizon well-defined, by its reddish brown to reddish isolation defined and well structured. In the low plains, the degrading processes caused by hydromorphism, due to deficient drainage, have been the most important.

#### T.5.1.3.2 Methodology

For the determination of the type of soil in San Jose de la Viuda two "soil profiles" of 1,5 m deep were made, one at 250 m to the south of the estate (Profile No. 1) and the other at 350 m to the east of Profile No.1 (Profile No. 2).

Soil samples were taken from these profiles which were analyzed in the laboratory of the Agrarian National University (UNA), of Managua.

The methods and procedures utilized in the different determination were:

- Cationic Exchange Capacity (CIC), extraction with NaCl at 10% at pH 2.5, quantification of the ammonium by distillation and valuation.
- Interchangeable bases, extraction with ammonium acetate 1 at pH 7.0 and quantification by atomic absorption.
- The taxonomic criteria used in the classification are based on the classification system of the FAO, 1974.
- With respect to the analysis of the heavy metals, two equal samples to those analyzed in the laboratory of the UNA were sent to the Austrian laboratory "Osterreichisches Forschungs und Prufzentrum Arsenal - Geotechnisches Institut of Vienna, Austria" which specializes in the determination of heavy metals in water and soil.

### a. Methodology for the Heavy Metals Analysis

The determination of the analysis of: cadmium (Cd), lead (Pb), chromium (Cr), copper (Cu) and phosphorus (P), were conducted according to the methods of the Austrian norm ONORM L-1085. The metalic elements Cd, Pb, Cu and Cr were analyzed by spectromet of optical emission, with inductive coupling plasma (ICP-OES).

The arsenic (As) content was determined through spectrometry of atomic-hydric and mercury absorption, through a mercury analyzer (AAS - cold stream technique). The phosphorus content was determined by mass spectrometry with inductive coupling plasma (ICP - MS).

The pH of soil samples were measured electrochemically with an electrode, with a calcium chloride solution, (0.01 M), according to the ONORM - L - 1083 standard. For the detection of cyanide ($CN^-$) in solution it was extracted from the soil sample, with a solution of deionized water at a relationship of 1:10, for a period of 24 hours. The $CN^-$ was analyzed by spectra photometry from the filtered extract.

The determination of the $Cr^{+6}$ is based on a one hour lixiviation with $Na_2CO_3$ (0.28 M) and NaOH (0.5 M) at temperatures ranging from 90 - 95 °C. After centrifugaling the sample, the $Cr^{+6}$ was analyzed by ion solution spectrometry of optical emission with inductive coupling plasma (ICP - OES).

The determination of the organic part of the fixed phosphorus, was made by means of the difference in an incinerated soil sample and a non-incinerated one. The difference between the two analysis yields the content of the fixed organic phosphorus.

Through the incineration of the samples at 550 °C, the organic part of the phosphorus is freed to subsequently carry out extraction with $H_2SO_4$ (1 N), for a period of 16 hours. The non-incinerated sample was treated in the same manner. At the end of the extraction period, the samples were centrifuged and the phosphorus was determined in the solution through mass spectrometry with inductive coupling plasma.

## T.5.1.3.3 Taxonomy

These soils are characterized by presenting an Epipedo Molico, with a thickness no less than a third of the depth of Solum (A + B) and a horizon with base saturation higher than 80%, Argillic (Bt) well structured with colors that vary from reddish brown to dark red and presence of clay coating in the structural aggregates (Profile No.1).

The Type Argiaguolls, that correspond to the Mollisolls, which is badly drained develop in low hollow surfaces that are similar to the Argiutolls, as do their location on an angilic horizon moderately Hidromorphisized (Profile No.2), the types of soils are interrelated with the Low Humic Gley.

Based on the taxonomic concepts of the USA, Soil Taxonomy and its closest entity, the FAO identifies them as Luvic Kasstanozes (Profile No.1) and as Gleyie Phaeozms (Profile No. 2).

## T.5.1.3.4 Description of the Characteristics of the Soil

In the different horizons of the soil of the Profile No.1, these soils present a Cationic Exchange Capacity (CIC) range of 24, 21 to 23, being classified within the lower range that is between 16 to 24 CIC, by the sum of cations. Soils of the horizons of Profile No.2

present a CIC range of 35 to 37, being classified within the middle range that is between 24 to 40 CIC, by the sum of cations.

The percentage of bases saturation is very high, greater than 80% in both profiles and the organic matter content is greater than 2%; this is why they are classified as medium (2.0 to 4.0%). Their texture characteristics defines soils of Profile No.1 as clayey franc to clayey and all soils of the Profile No.2 as clayey.

### T.5.1.3.5 General Information of the Soil

The originating material is of recent sedimentary deposits, with a drainage class of 2 and 3, imperfectly drained to moderately drained (both profiles). When the profile was being described, in the adjacent horizons to the water table or phreatic layer was humid which showed up at 1.85 m, in Profile No.1 and 1.3 m, in Profile No.2. In a third observation, at about 150 m from Profile No. 2, in the zone close to the eastern boundary of the poultry farm with the large trees, the phreatic layer was found to be 30 cm deep.

The Profile No. 1 presents a greater clay accumulation in the horizons B, being the Solum (A + B), 60 cm deep with dark reddish brown coloration, with concretions of Plintita and water table.

The Profile No.2 is presented clayey in all its horizons, with brown reddish, black and gray colors with a hydromorphic process and water table. The total indication of the trace of minor elements in the levels of the soil, are presented in Table T-14.

Table T-14: Trace of minor elements in the soil levels

| ELEMENT | CONCENTRATION IN THE SOIL (ppm) | |
|---|---|---|
| | Lower Approximation | Usual Range |
| Cadmium (Cd) | 0.35 | 2.00-270 |
| Cobalt (Co) | 8.00 | 0.05-65.0 |
| Chromium (Cr) | 70.00 | 5.00 -15.0 |
| Iodine (I) | 5.00 | 0.10-25.0 |
| Molybdenum(Mo) | 1.2 | 0.10-40.0 |
| Lead (Pb) | 35.00 | 2.00-300 |

The results of the heavy metals concentration in soil, are shown in Table T-15.

Table T-15: Heavy Metal Concentrations in the Soil

| PARAMETER | UNIT | PROFILE No.1 | PROFILE No. 2 |
|---|---|---|---|
| pH | mg/kg | 5.8 | 7.4 |
| Cd | mg/kg | 0.2 | < 0.1 |
| Pb | mg/kg | 44 | 18 |
| Cu | mg/kg | 127 | 75 |
| As | mg/kg | 3 | 1 |
| P Total | mg/kg | 640 | 260 |
| Organic P | mg/kg | 150 | 40 |
| Cr | mg/kg | 7 | 5 |
| Cr +6 | mg/kg | 1 | 1 |
| Soluble CN - | mg/kg | < 0.1 | < 0.1 |
| Hg | mg/kg | < 0.05 | < 0.05 |

### T.5.1.3.6 Description of the Profiles

**Profile No.1:**

Slope: < 1%
Relief: Slightly flat
Height: 35 m above sea level
Drainage: Moderately drained
Current use: Grass land (grass)
Life Zone: Humid sub-tropical forest
Original Material: Recent sedimentary deposit
Date of description: 03/July/97
Described by: E. Mayorga E.
Location: 250 m south of the estate.

**Horizon -Depth:**

Ap **0 cm:** Dark reddish brown (5 YR 3/3) when wet and dark brown (7.5 YR 3/4) when dry, clayey texture (FA) with plintite gravel, angular block structures from moderate to slightly hard, adherent, adhesive Apc, friable when damp, with many pores, roots, abundant biological activity, sharp and flat limit and neutral pH 7.0.

**26 cm:** Dark Brown (7.5 YR 3/3) when wet and dark brown reddish (5YR 3/3) when dry, clayey texture, with abundant plintite gravel.

Btc Angular block structures of angle blocks, slightly plastic, slightly adherent, friable when wet. Slightly adherent, slightly hard, many pores, abundant roots, high biological activity, net and flat limit. pH 6.8 neutral.

**60 cm:** Very dark brown (10YR 2/2) when wet and dark reddish brown (5YR 3/4) when dry, clayey texture (A).

Bc Strong angular block structure, slightly adherent, slightly plastic, friable, slightly adhesive, slightly hard, abundant pores, few roots, net and flat limit, pH 6.7 slightly acidic.

**123 cm:** Dark reddish brown (5YR 3/4) when wet and grayish pink (7.5 YR 6/3) when dry, clayey texture Cb, angular block structure, moderate, plastic and adhesive.

**185 cm:** The phreatic layer appears.

**Profile No.2:**

Slope: < 1%
Height: Slightly flat
Increase: 35 m above sea level
Drainage: Imperfectly drained
Current use: Grass land (grass)
Life Zone: Sub - tropical humid forest
Originating Material: Recent sedimentary deposit
Date of description: 05/July /97
Described by: E. Mayorga E.
Location: 350 m to the east of profile No.1.

**Horizon -Depth:**

Ap **0 cm:** Dark reddish brown (5 YR 3/3) when wet and dark yellowish brown (10 YR 4/4) when dry, clayey texture (A).

Angle block structure, weak, adherent, slightly plastic, friable when wet, slightly hard when dry, many pores, many roots, sharp and flat limit, pH 6.2 neutral.

**16 cm:** Black (5YR 2.5/1) when wet and gray (10 YR 5/1) when dry, clayey texture (A).

Bg Angular block structure, moderate, slightly hard when dry, slightly adherent, very friable plastics, many pores, abundant roots, sharp and flat limit, pH 8.1 moderately alkaline.

**34 cm:** Gray (10 YR 4/1) when wet and light gray (5 YR 7/1) when dry, clayey texture (A).

B2g Angular block structures, medium, slightly hard when dry, very friable.

**34 cm:** When wet, adherent and plastic, many pores, abundant roots, sharp and undulating limit, pH 8.1 moderately alkaline, B21.

Cg **112 cm**: Weakly cemented extract, discontinuous and pisolitic.

**113 cm:** The phreatic layer appears.

**165 cm:** The stratum turns strongly solidified.

### T.5.1.4 Erosion and Sedimentation Processes

In San Jose de la Viuda, because the area is almost flat, with a short slope of 0.7%, leaning in general, towards the lake, there are no erosion or sedimentation processes.

### T.5.1.5 Stability of the Soil

The soil's stability was evident from the EIA on necessary items on 26/August/97 undertaken by Mr. Mauricio Lacayo of the MARENA.

### T.5.1.6 Topography of the Area

The Study carried out the topographic survey and the elaboration of the topographic map covered an area of approximately 200 ha that includes the San Jose de la Viuda site as well as all the property of Mr. William Gomez and Mr. Alberto Vasquez Gomez and the cooperative.

Listed below are the different activities that were accomplished throughout the land survey, the results are presented in Chapter 8 of the Data Book: Volume V.

**a. Topographic Survey of the Site**

- Planimetric survey of the Polygonal of the properties where the future sanitary landfill for Granada City will be built (minimal precision of the perimeter survey = 1: 5000).
- Installation of 10 bench marks (BM), connected to the three dimensions to the coming BM established by INETER, in the form of concrete landmarks.
- PI Installation on the dividing fences of the properties as well as in the changes of the direction of the Polygonal.
- Leveling Survey per grid (20 m by 20 m).

- Calculation of the planimetry by the D.O.M. system(analytical) with minimal precision as mentioned previously.
- Scale of the map: 1:2,500, contour lines 1 meter intervals indication in the map of all the existing infrastructure such as: houses, roads, drainage, riverbeds, banks, illegal solid waste dumps, electricity or telephone posts, dikes, water ways or other pipeline, etc.

**b. Route Survey**

- Topographic Survey of the route between the manhole where the sewer collector of the INAA deviates toward the oxidation lagoons, up to the construction site.
- Profile surveys every 20 meters with a total width of 60 meters in other words 30 meters on both sides of the road center.
- Preparation of a plan based on the surveyed profiles, with contour lines at 0.5 meter intervals and all the structures mentioned before.
- The precision of the leveling was of a minimum of 2 cm per km.
- Scale of the map = 1:1,000
- Installation of a BM with its respective reference to the side of the well

### T.5.1.7 Relief and Slope of the Land

At the San Jose de la Viuda site, the western sectors are undulating and the eastern sectors are flat or virtually flat, with a slope of 0.7%, leaning in general toward the lake.

### T.5.1.8 Natural - Surface Drainage Standards

Because the area proposed for the construction of the sanitary landfill is completely flat and even and soil is covered with a dense vegetation layer, the rainfall on this area immediately infiltrates the subsoil and then the phreatic mantle.

Even in the case of heavy rainfall, surface water currents are formed and therefore there are no riverbeds or creeks. The stream found in the western part of the property is about 200 meters long, but it is relatively flat and has no entry or exit points.

### T.5.1.9 Ground Water and Artificial Drainage Standards

The ground water flows from the west and hydraulic gradients vary between 0.0018 to 0.0057, from the side of the lagoon of Apoyo toward the Lake Nicaragua. In the study area, there are no artificial drainage channels.

### T.5.1.10 Quality of the Surface Water

For the determination of the quality of the surface water a sample from a stream, located southeast of the property ($W_1$) and another sample in the wetlands, located to the east of the property ($W_2$) were taken. The water in the stream remains stagnant; it is partially covered with algae and flows toward the lake when it rains.

The physico-chemical analyse that were conducted were Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), total Nitrogen, total Phosphorus, Chlorides,

pH and temperature. Furthermore, microbe analysis of total Coliform and Escherichia coli concentrations were also conducted.

The physico-chemical analyze were based on the "Analytic Guidelines of the Standardized Methods for Sewage and Potable Water Analyses (AWWA)". The results are shown in the table below.

From the results it can be observed that the surface water has a low concentration of organic matter, its pH is neutral and that its phosphate content is very low. Conversely it showed a high chloride concentration.

It also has contained coliforms and E. coli. which can be attributed to contamination by cattle and human excreta form the surrounding area.

Table T-16: Results of surface water analysis stream in SJV (07/July/1997)

| PARAMETER | Units | Concentration | |
|---|---|---|---|
| | | $W_1$ | $W_2$ |
| pH | | 7.46 | 7.53 |
| Temperature | °C | | |
| Biochemical Oxygen Demand (BOD) | mg/l | 5 | 3 |
| Chemical Oxygen Demand (COD) | mg/l | 36 | 20 |
| Kjeldahl Nitrogen (Norg + $NH_4$) | mg/l | n.e. | n.e. |
| Total Phosphates ($PO_4$) | mg/l | 1.26 | 1 |
| Chlorides ($Cl^-$) | mg/l | 173 | 168 |
| Total Coliform | NMP/100 ml | 1.8 E+03 | 4.5 E+03 |
| Escherichia Coli | NMP/100 ml | 1.3 E+02 | 1.4 E+02 |

### T.5.1.11 Ground Water Body

For the indication of the quality of the underground water, the analysis results of the well water of the Poultry Farm San Felipe is presented, which is located to the north of the San Jose de la Viuda site. Because of its proximity, it is considered that the water quality of of the wells at the property has the same characteristics as the ground water of the poultry farm.

The analysis of this sample was accomplished in the laboratory of the CIRA/UNAN and consist of physico-chemical and microbe analyses. The results are presented in Table T-17.

According to the report presented by CIRA, from a chemical /physical point of view, the analyzed water sample is considered fit for human consumption, due to the fact that all the analysis carried out are found to be within the limits established by the World Health Organization (WHO), for potable water. According to CAPRE, 1994, there must be no coliform bacteria of fecal origin in 100 ml of the sample under analysis in water for human consumption.

Table T-17: Results of Well Water Analysis of San Felipe Poultry Farm (26/Sep/1996)

| Parameter | Units | Concentration |
|---|---|---|
| Turbidity | UNT | 1.0 |
| pH | | 7.66 |
| Conductivity | /cm | 673.00 |
| Total dissolved solids | mg/l | 443.54 |
| Calcium | mg/l | 40.08 |
| Magnesium | mg/l | 9.72 |
| Sodium | mg/l | 84.80 |
| Potash | mg/l | 7.95 |
| Nitrates | mg/l | 9.56 |
| Nitrites | mg/l | 0.01 |
| Sulfates | mg/l | 22.87 |
| Chlorides | mg/l | 121.69 |
| Carbonates | mg/l | 10.08 |
| Bicarbonates | mg/l | 136.34 |
| Ionic Balance | | 0.29 |
| Total Hardness | mg/l | 139.90 |
| Total Alkalinity | mg/l | 128.90 |
| Phenolphthalein Alkalinity | mg/l | 8.37 |
| Silica | mg/l | 72.65 |
| Fluorides | mg/l | 0.45 |
| Total Iron | mg/l | 0.04 |
| Total Coliform | NMP/100 ml | 2.00 E+00 |
| Fecal coliform | NMP/100 ml | 1.00 E+00 |
| Fecal Streptococcis | NMP/100 ml | E+00 0.00 |

### T.5.1.12 Presence of the Ground Water

In the area of San Jose de la Viuda, the ground water is formed by runoff and stored in a fluvial - volcanic deposit, of quaternary age, constituted mainly by piroclasts. Within the fluvial - volcanic deposit, thick granulometric layers are found made up of lapilli, gravel and sand, all pumaceous in nature. The thickness of the granulometric layers range from about 0.91 m up to 29 m.

The high permeability of the pyroclastic material allows rapid penetration of stormwater through the layers.

### T.5.1.13 Air Quality

The determination of the air quality was made at 4 corners of the property, by measurement of air temperature, humidity, wind direction and speed, dust particles, odor intensity assessment and the concentration of the following gases: methane ($CH_4$), carbon dioxide ($CO_2$), ammonium ($NH_4$), methyl mercaptan ($CH_3SH$) and hydrogen sulfide ($H_2S$). All these measurements were carried out in a 15 hour period (from 5:00 a.m. to 8:00 p.m.), in each of the 4 points, at the same time noise and vibration measurements were taller.

The measurements of the air temperature, the humidity and the direction and speed of the wind were made by means of meteorological "Weather Monitor" equipment that monitors the climatic data installed at each 4 points. It also consisted of an anemometer

equipped with arms approximately 2 m high, to measure the direction and speed of the wind.

The quantification of the dust particles was made by placing, a stand on which a plastic bottle, 11 cm in diameter, was fixed at each corner. In this bottle the dust settled for a period of 7 days. At the end of this period the bottles were rinsed with distilled water and their content transferred to the Biomasa laboratory.

The quantification of dust particles was made using the suspended solids technique, dehudrated at 103 °C, according to the "standardized" methods for the analysis of potable water, sewage and residues". For the calculation, the surface area of the bottle interior and the expositor time were taken into account.

The odor intensity test was made at the Biomasa laboratory, in which air samples from each of the 4 corners were taken in "Zipploc" bags. Initially, a sample from each corner was given to 10 people who were to smell them and indicate whether the sensed any odor. When the 10 people indicated no odor whatsoever, it was deemed an necessary to dilute the odorants with clean air using activated charcoal to determine the olfactory sensitivity level of the 10 individuals.

The results of all these parameters are presented in the table below. The detail of the location of each point are as follows:

| | |
|---|---|
| Point 1: | Close to the property. |
| Point 2: | Northeast corner of the property. |
| Point 3: | Southeast Corner of the property. |
| Point 4: | Southern corner of the property. |

The gases $CH_4$, $NH_4$, $CH_3SH$ and $H_2S$ were not detected using the gas aspirator, meaning that their concentrations are below the detection limit. Also, it was not possible to determine any specific odorant. Similarly, the quantities of dust particles detected were negligible.

For the ait temperature values at point 1, the maximum value was recorded after 14 hours and the minimum value after 20 hours, when the last measurement was recorded. At point 2 the maximum value was recorded after 10 hours and the minimum after 20 hours. At point 3 the maximum value was after 14 hours and the minimum after 6 hours. At point 4 the maximum value was recorded after 9 hours and the minimum value after 6 hours. (see Chapter 8 of the Data Book: Volume V, for details). According to the characteristecs of the data, it is possible for the air temperature to continue decreasing after 20 hours.

The humidity of the air at point 1 reached a maximum after 20 hours and dropped to a minimum after 14 hours. At point 2 the maximum value was recorded after 8 hours and the minimum value after 12 hours. At point 3 the maximum was recorded after 6 hours and the minimum after 16 hours. At point 4 the maximum value was recorded after 6 hours and the minimum value after 20 hours.

At all the points the prevailing wind direction was from the east.

Table T-18: Results of the Air Quality

| Point | Temperature °C | | Humidity % | | Wind Direction | Wind speed m/s | | Settled dust mg/m²day | Odor Intensity | $CO_2$ | $CH_4$ | $NH_4$ | $CH_3SH$ | $H_2S$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Min. | Max. | Min. | Max. | | Min. | Max. | | | | | | | |
| 1 | 26 | 32 | 72 | 80 | East-West | 1.3 | 2.7 | 15 | ND | 400 | ND | ND | ND | ND |
| 2 | 26 | 35 | 64 | 80 | East-West | 0.4 | 1.3 | 30 | ND | 400 | ND | ND | ND | ND |
| 3 | 25 | 36 | 59 | 83 | East-West | 0.4 | 1.8 | 45 | ND | 400 | ND | ND | ND | ND |
| 4 | 24 | 33 | 62 | 86 | East-West | 0.9 | 3.1 | 15 | ND | 400 | ND | ND | ND | ND |
| 5 | NM | 35 | NM | NM | East-West | NM | NM | NM | ND | 400 | ND | ND | ND | ND |

ND: Not detected
NM: Not measured

### T.5.1.14 Intensity of the Noise and the Vibration

The noise and the vibration measurements were taken, concurrently, at made at the same time, in the 6 points that are detailed below: **Point 1:** Close to the property; **Point 2:** Northeast corner of the property; **Point 3:** Southeast corner of the property; **Point 4:** Southern corner of the property; **Point 5:** Entry to the property, close to the concrete ramp; **Point 6:** Granada City limits (in front of the Chico Tripa Grocery).

Measurements were taken for 10 minutes /every hour, for a period totaling 15 hours (from 5 a.m. to 8 p.m.). The RION Noise meter NL - 04 was used to measure the noise level and to measure the vibration the RION Vibration meter VM-52 was used.

#### T.5.1.14.1 Noise levels

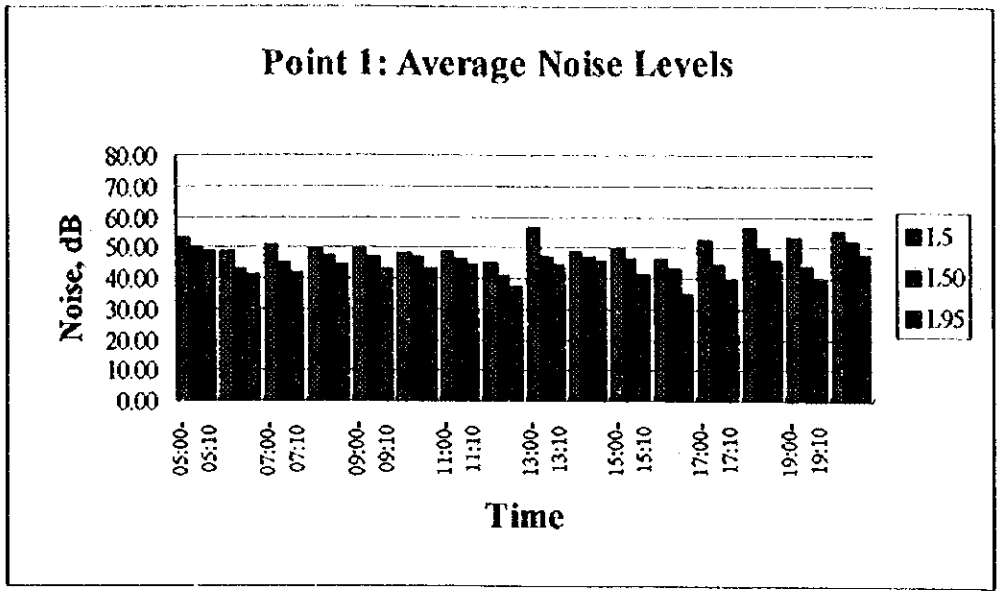
The figures $L_{95}$, $L_{50}$ and $L_5$ for the noise level, are shown in, and Figure T-4, Figure T-5 and Figure T-6 below.

$L_{95}$ measures the noise level which is exceeded by 95% during the measurement period and it is used as an indicator of background noise. The average figures of $L_{95}$ for points 1 to 6 were 43, 45, 44, 42, 44 and 53dB, respectively.

$L_{50}$ measures the noise level, which is exceeded by 50% during the measured period. The average figures of $L_{50}$ for points 1 to 6 were 46, 47, 49, 47, 49 and 60dB, respectively. These figures are less than the corresponding Japanese standard of 65 dB.

$L_5$ measures the noise level which is exceeded by 5% during the measured period and it can be used as an indicator of the upper limit of noise fluctuation, such as a passing vehicles. The average figures of $L_5$ for the points 1 to 6 were 51, 50, 54, 52, 55 and 70dB, respectively.

Due to the cattle ranch located near points 1 to 4, the noise levels are affected by the presence of cattle and their movement. At point 5 the noise levels are affected by the movement of people, animals and vehicles. Point 6 is the point where traffic of people, animals and vehicles is the highest, therefore this point is where the highest noise levels were recorded.



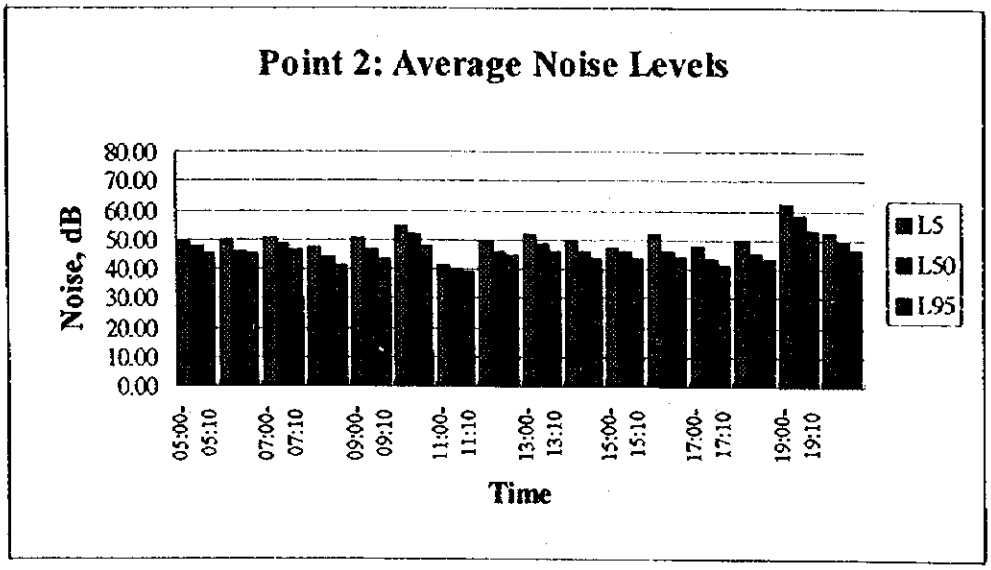
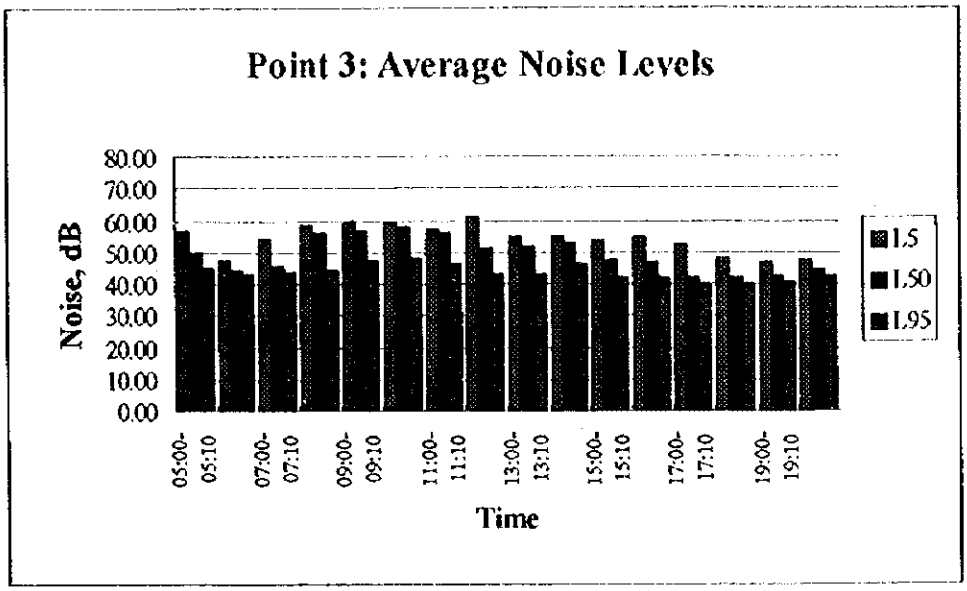




Figure T-4: Average Noise Levels (1)



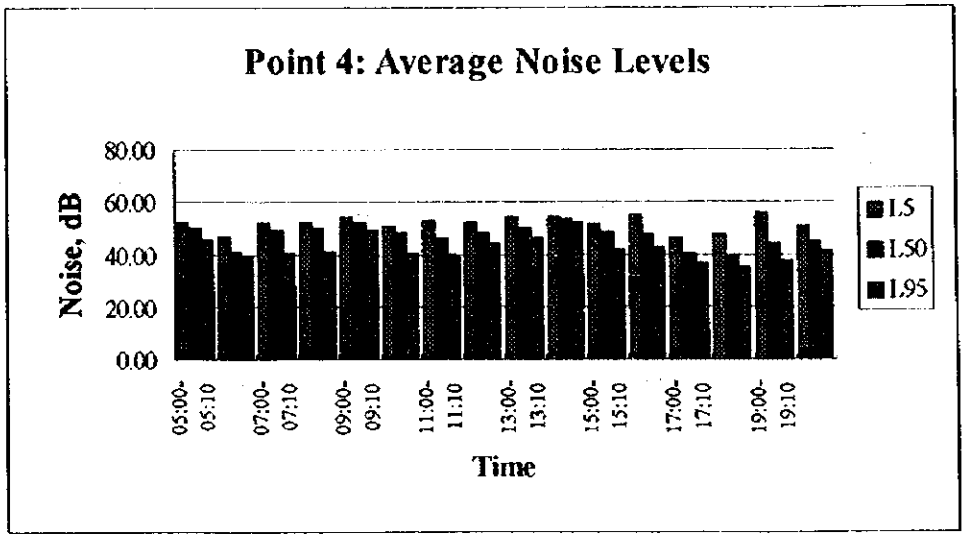
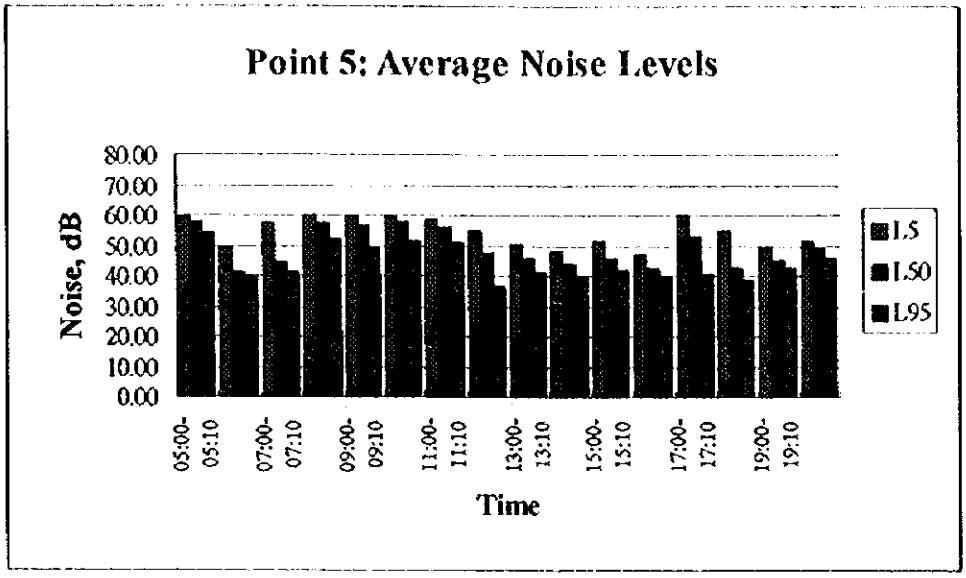




Figure T-5: Average Noise Levels (2)



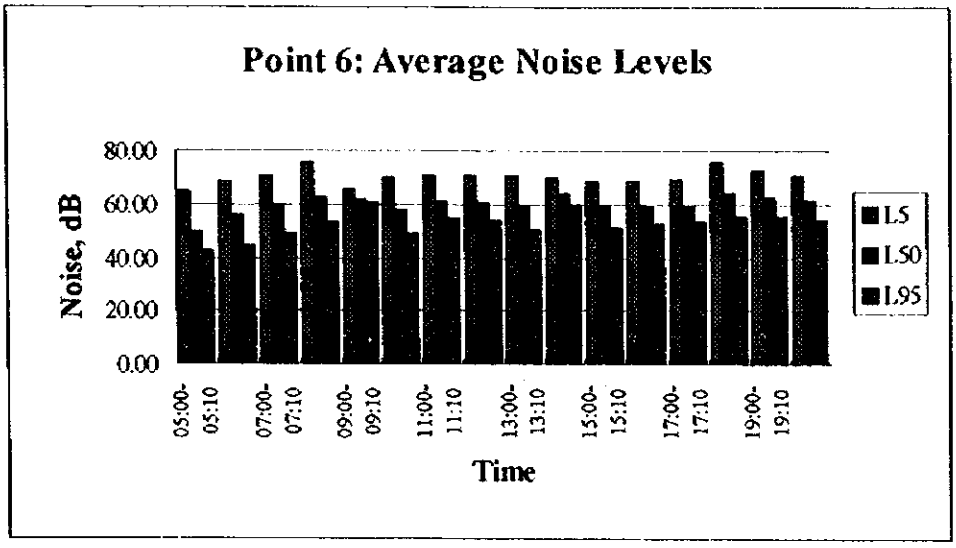




Figure T-6: Average Noise Levels (3)

### T.5.1.14.2 Vibration Levels

The vibration figures $L_{10}$ and $L_{50}$ are shown in Figure T-7, Figure T-8 and Figure T-9 that follow.

$L_{50}$ measures the vibration level which is exceeded by 50% in the measured period. The average figures measured in points 1 to 6 were 16, 15, 15, 15, 15 and 31dB , respectively. These figures are significantly less than the corresponding Japanese standard of 70 dB.

$L_{10}$ measures the vibration level which is exceeded by 10% in the measured period and it can be used as an indicator of the upper level of fluctuation, such as a passing vehicle on the highway. The average figures of $L_{10}$ for points 1 to 6 were 19, 18, 19, 16, 18, and 39dB, respectively.

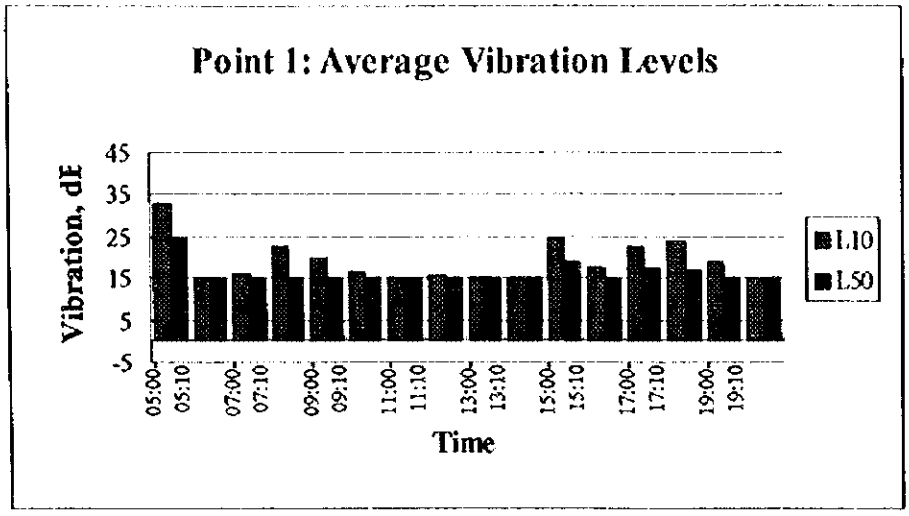
### T.5.1.15 Traffic Volume

The traffic volume survey was carried out in 15 hour periods (from 5:00 a.m. to 8:00 p.m.) at two points, along the Granada-Santa Rosa highway. Point 1 was located at the entrance Mr. Alberto Vasquez Gomez and the cooperatives', property close to the concrete ramp and point 2 at the Granada exit, opposite to the Chico Tripa Grocery crossroads.

At these points, the road is paved with soil and gravel, which is passable all year round, wide enough for two way traffic. In each point the vehicles on the outbound journey (from Granada to Santa Rosa) and the vehicles entering the city (from Santa Rosa to Granada), were numbered separately for each type of vehicles. Later on, the number of the different vehicle types were added in order to obtain the total number of vehicles passing each point. The results are presented in Figure T-10 overleaf.

From this survey it can be noted that at point 1, vehicle traffic is ranked in decreasing order, as (1) bicycles, (2) cars, (3) pickup trucks, (4) horse drawn carts and (5) trucks, and to a smaller degree (6) motorcycles and (7) minibuses.

At point 2, as with point 1, the most common type of vehicle on the road was the bicycle, followed by cars, pickup trucks, motorcycles, jeeps, horse drawn carts and trucks, and to a smaller degree minibuses, tractors and buses.



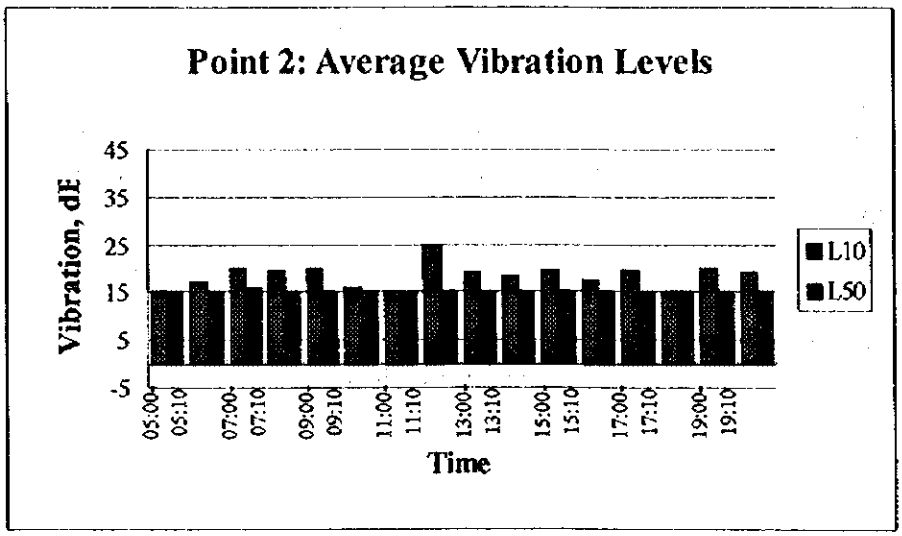
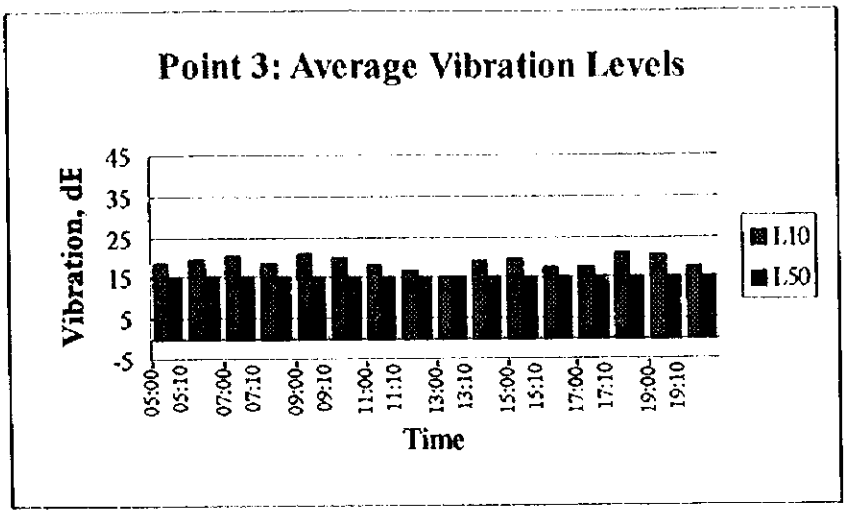




Figure T-7: Vibration Level Average (1)



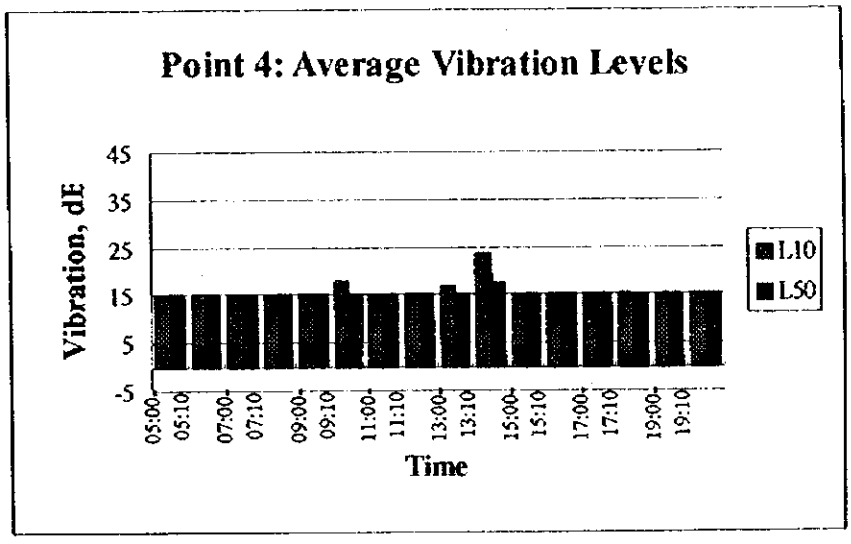
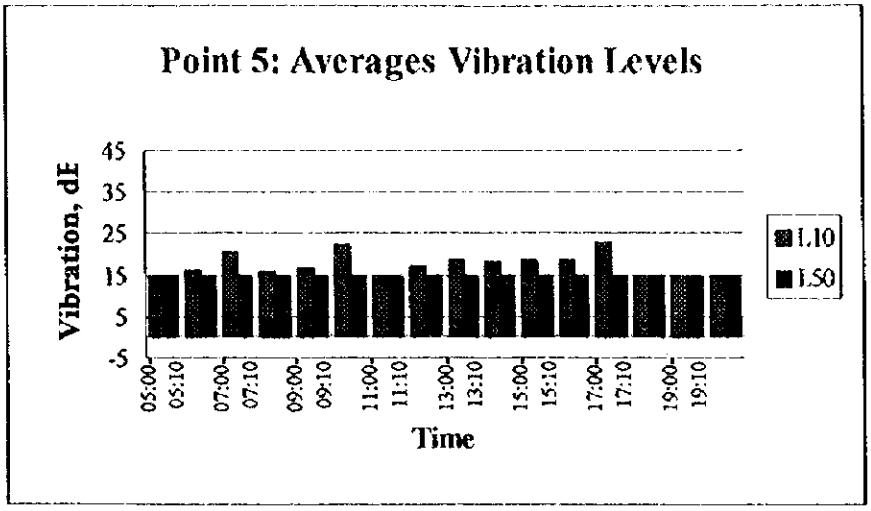




Figure T-8: Vibration Level Average (2)



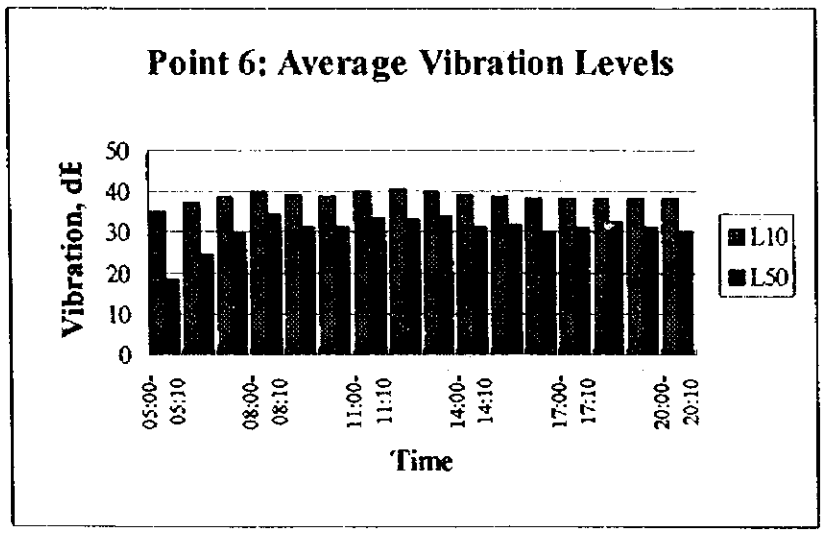
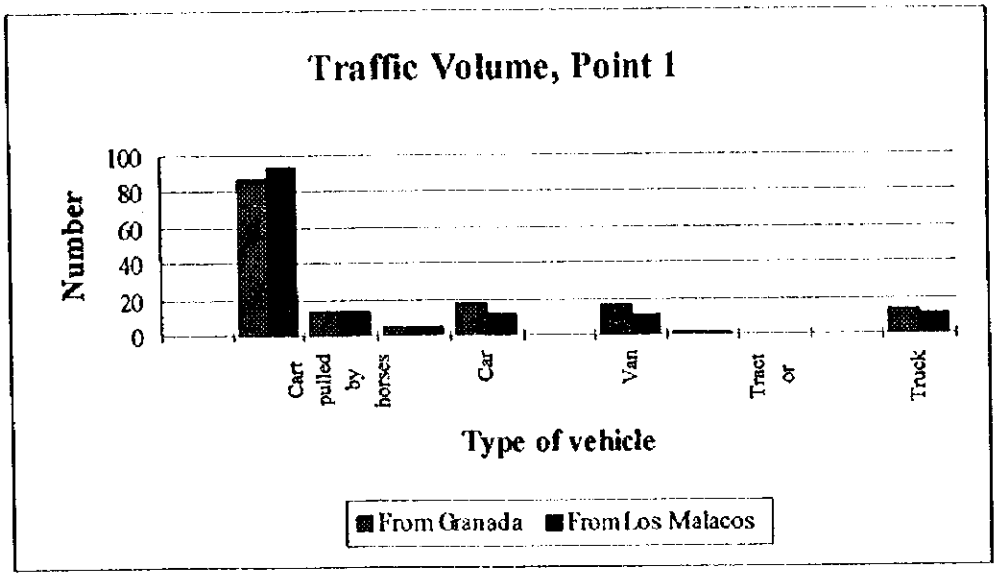




Figure T-9: Vibration Level Average (3)



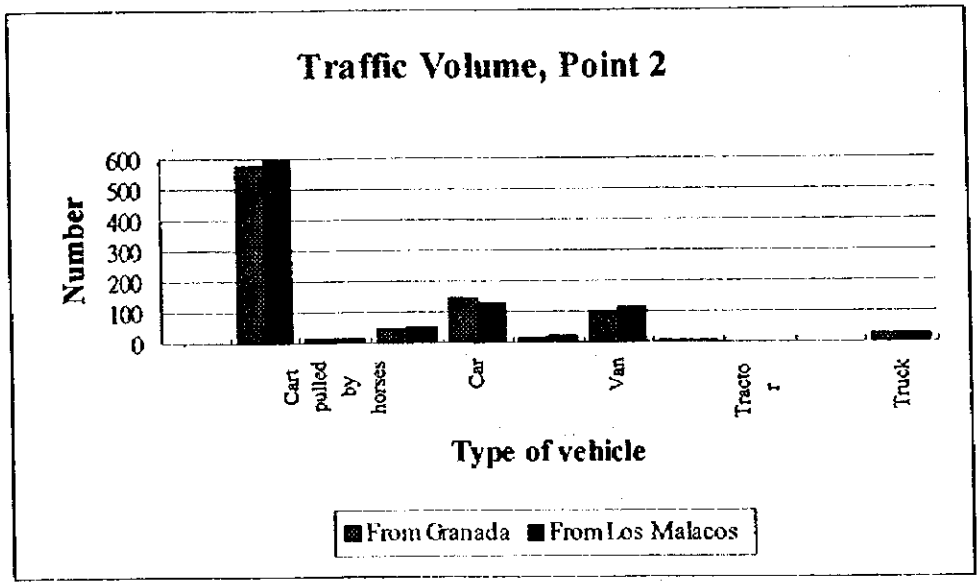




Figure T-10: Volume of Traffic

### T.5.1.16 Rainfall of the Influence Area

According to the 17 year rainfall data registered by INETER from 1969 to 1985, in Granada City, the annual average rainfall is 1,475 mm; the lowest value recorded was 1,000 mm in 1977 and the highest 1,919 mm in 1979.

Two different seasons are observed during the year, the rainy season (May - October), when approximately 96% of the total annual rainfall occurs and the dry season (November - April) in which brief, low intensity sporadic rainfall is registered. The annual rainfall varies notably from one year to another and even from one month to another with in the same year.

The months with the highest of greater rainfall are June, September and October. The driest months are December, January, February, March and April. November is a transition period between the rainy and dry seasons.

### T.5.1.17 Evaporation of the Influence Area

The total monthly evaporation registered by INETER, between 1969 to 1985, fluctuates between 150 mm (September) and 315 mm (April). The annual average evaporation is 2337 mm. In general, the evaporation rate peaks in March and April, and is the lowest in the September, October and November. (See data of INETER in Chapter 5 of Data Book: Volume V)

### T.5.1.18 Evapotranspiration of the Influence Area

There are no evapotranspiration data registered by INETER, at the Granada meteorological station.

### T.5.1.19 Wind Velocity and Direction

The estimated monthly average wind velocity vary between 0.7 m/sec (October) and 2.7 m/sec (February). The annual average velocity is estimated as 1.6 m/sec. The highest average wind velocities are recorded in February, March and April and are the lowest in October and November. The prevailing wind direction, all year is from the east.

## T.5.2 The Biotic Environment

### T.5.2.1 The Flora in the Area

#### T.5.2.1.1 Introduction

The study area is located four kilometers to the north of the city of Granada, exactly on the property known as San Jose de la Viuda. The flora survey was performed within a 1.5 kilometer radius from the center of the proposed landfill site.

The type of native vegetation in the area is of **Dry Tropical Forest (BTS: Bosque Tropical Seco)**, the deciduous trees shed their leaves during the dry season. The east of the area (toward the lake) is protected by a public forest with soils that are flooded temporarily, which allows the vegetation to maintain its leafage even during the dry season.

The principal economic activity of the area is cattle-raising, followed by chicken production and some fruit production by perennial cultivation (jocote *Spondias purpurea*, mangos *Mangifera indicates*, tamarind *Tamarindus indicates*, papaw *Meliccocus bijugatus*, tart lemons *Citrus aurantifolia*, and the barnanas *Musa spp.* (banana, plantain and filipito). At a smaller scale or experimental level corn *Zea Mays*, yuca *Manihot esculenta* and mung beans *Vigna radiata* are grown at El Carmen and sugar canes *Saccharum officinarum* at "San Jose de las Animas".

#### T.5.2.1.2 Methodology

The flora survey consisted of field investigations through out the study area for the identification of various habitats. The various species were identified in their national habitat; samples of flora which were found to be in full at the bloom time as well as species which were not possible to identify on-site were collected. The collected samples were registered, preserved and identified subsequently at the National Herbarium of Nicaragua, which is also the botanical depository that supports this study.

#### T.5.2.1.3 Ecosystems

In the study site three ecosystems can be determined:

- Arable and grazing land (pasture)
- Seasonal swamp with trees and shrubbery (grove).
- Marshland with low-lying vegetation (wetland or swamp).

**a. Arable and Grazing Land (Pasture)**

This ecosystem (i.e., arable land and pasture) occupies a little more than 70% of the total area and all the area proposed for the sanitary landfill is included. At present sorghum wheet *Sorghum X bicolor* is grown as fodder. This ecosystem in addition covers a small meadow to the east. All this area belongs to the property of San Jose de la Viuda.

Within this same ecosystem the following properties are also located to the North: Santa Rosa; San Ignacio; Las Mercedes; El Carmen; San Jose de las Animas and part of Santa Rita y Dolores. To the South, Las Porras and the West, La Porra and El Fortin are also located.

The principal economic activity in the area, is cattle-rearing, for the reason of natural pasture land management, with, the use of trees as fencing posts. Within the pasture land, there are various: fruit-bearing, timber yielding or "native" trees (see photos in Chapter 8 of the Data Book: Volume V).

Among the **native species** the following were identified:

Giant trees of: ceiba *Ceiba pentandra;* panama *Sterculia apetala;* espino de playa *Pithecellobium dulce;* coyol *Mexican Acrocomia;* guanacaste white *Albizia niopoides;* espavel *Anacardium excelsum;* anona *Annona reticulata;* jinocuabo *Bursera simaruba;* guarumo *Cecropia peltata;* papalon *Coccoloba caracasana;* poroporo *Cochlospermum vitifolium;* Laurel *Cordia alliodora;* jicaro sabanero *Crescentia alata;* guachipilin *American Diphysa;* black guanacaste *Enterolobium cyclocarpum;* talalate *Gyrocarpus americanus;* medlar *Manilkara chicle;* jaboncillo *Sapindus saponaria;* tempisque *Sideroxylon capiri;* acetuno *Simarouba amara;* huevo de chancho *Stemmadenia obovata;* palo de piojo *American Trichilia;* and cornizuelo *Acacia collinsii*.

Among the **native species** cultivated for their fruits, wood or for its aesthetic value, the following were identified:

Nancite *Byrsonima crassifolia;* papaya *Carica papaya;* laurel *Cordia alliodora;* tiguilote *Crdia dentata;* jicaro sabanero *Crescentia alata;* jicaro *Crescentia ujete;* madero negro *Gliricidia sepium;* guacimo de ternero *Guazuma ulmifolia;* guaicum *Guaiacum sanctum;* pitahaya *Hylocereus polyrhyzus;* mamey *American Mammea;* leucaena *Leucaena leucocephala;* yuca *Manihot esculenta;* mamon *Meliccocus bijugatus;* sapodilla *Pouteria mammosa;* guava *Psidium guajava;* spanish plum *Spondias purpurea;* mahogany *Swietenia humilis;* cortes *Tabebuia chrysantha;* and oak *Tabebuia rosea;* and cocoa *Theobroma cocoa*.

Among the **exotic/rare species** cultivated for their fruits, woods for its aesthetic value, the following were identified:

Nim *Azadirachta indicates;* Casuarina *Casuarina equisetifolia;* caimito *Chrysophyllum cainito;* tart lemon *Citrus aurantifolia;* sweet orange *Citrus sinensis;* coconuts *Coconut nucifera;* malinche *regal Delonix;* eucalyptus *Eucalyptus camaldulense;* rubber *Ficus elastica;* quinceanera *Jatropha hastata;* mango *Mangifera indicates;* bananas *Muse spp;* narciso *Nerium oleander;* Tamarind *Tamarindus indicates;*and almond *Terminalia catappa*.

Among the **species used as natural fencing** the following were identified:

Teonoste *Acanthocereus pentagonus;* spanish plum *Spondias purpurea;* jinocuabo *Bursera imaruba;* madero negro *Gliricidia sepium;* chilamate *Ficus morazaniana;* espino de playa *Pithecellobium dulce*.

Among the **herbaceous** were determined:

Yellow flower *honest Baltimora;* ledo *Amaranthus spinosus;* escoba dulce *Scoparia dulcis;* viborana *Asclepias curassavica; Blechum pyramidatum; Capraria biflora;* Chili pepper *Capsicum annum.; Cleome spinosa;* pegajosita *viscous Cleome;* quelite del fraile *Cnidoscolus aconitifolius;* achopaste *Cordia curassavica;* chischis *Crotalaria retusa; Croton lobatus;* pelotitas *Cucumis anguria;* zacate de gallina *Cynodon dactylon;* coyolillo *Cyperus rotundus; Desmodium spp.;* pringa mosca *Gronovia scandens;* cola de alacran *Heliotropium indicum;* guasquito *Lantana camara;* una de gato *Martynia annua;* manzanita *Momordica charantia;* verdolaga *Portulaca oleracea; Achyranthes aspera;* and *Rauvolfia tetraphylla*.

In the proposed landfill site area, all the properties are cattle ranches except for El Carmen farm. In all the properties, a high percentage of the pasture land is overgrown with weed (meadows). The following species are found in abundance on pasture land:

Gamba hay *Andropogon gallanus* and Estrella hay *Cynodon nlemfuensis;* followed by fodder sorghum forrajero *Sorghum X bicolor* and taiwanese hay *Pennisetum purpureum*.(see the photo in the Chapter 8 of Data Book: Volume V)

In the new sanitary landfill disposal site at San Jose de la Viuda, there is a total of 14 hectares of these different pastures. At the Santa Rosa and San Ignacio farms the meadows are mainly overgrown with yacate gamba *Andropogon gallanus*.

### b. Seasonal Swamp with Trees and Shrubbery

This area is located to the east of the landfill site area, and it is situated between the wetlands and the arable and grazing lands. In this zone seasonal floods occur. This habitat presents the characteristic of being the area which is found to be better preserved in relationship to the total area.

The surface vegetation is made up of woody species, most of which reach heights of up to 12 meters, especially the ceibas stands out with heights of up to 20 meters.

The following were identified as species abundant in the swamp: elequeme *Erytrina fusca* (the most common species), followed by the gigantic ceiba trees *Ceiba pentandra;* guanacaste *Enterolobium cyclocarpum;* tiguilote *Cordia dentata;* lagarto *Zanthoxylum sp.;* oak *Tabebuia rosea;* zapote de mico *Couroupita nicaraguense,* a **rare species**, and is the only kind of its genus found in Nicaragua in Nicaragua, genizaro *Albizia saman;* ojoche *Brosimum alicastrum*, panama *Sterculia apetala*, guacimo *Guazuma ulmifolia*, guarumo *Cecropia peltata;* espavel *Anacardium excelsum;* Jaboncillo *Sapindus saponaria;* in some sites with lot of regeneration, leucaena *Leucaena leucocephala;* papaturro *Coccoloba caracasana;* sweet orange *Citrus sinensis* (harvested), cocoa *Theobroma cocoa* (harvested); guava *Psidium guajava;* jicaro sabanero *Crescentia alata* and *Crescentia cujete* (haevested) acetuno *Simarouba amara;* spanish plum *Spondias purpurea;* jinocuabo *Bursera simaruba;* river almond-tree *Andira inermis;* anona de charco *Annona glabra;* chilamate *Ficus ovalis;* manzano *Crateva wall;* espino de playa *Pithecellobium dulce;* cornizuelo *Acacia collinsii;* palma *Eleais oleifera* (which was only observed in at San Jose de las Animas, although it is a native species to swampy zones), corozo *Scheelea rostrata* (the only species of this genus, also observed in the property of San Ignacio. This species is also a narive to swampy zones), quesillo or amapola *Malvaviscus arboreus;* aromo *cacia farnesiana* (see photos in Chapter 8 of the Data Book: Volume V)

Among the **herbaceous species** the following were observed:

Ave del paraiso *Heliconia latisphata;* pringa moya *Gronovia scandens;* coralillo *Rivina humilis;* escoba manga *Scoparia dulcis; Capraria biflora; Corchorus orinocensis;* zacate de gallina *Cynodon dactylon;* verdolaga *Portulacca oleracea;* yellow flower *Baltimora recfat; Crotalaria rugosa; Cleome spinosa; Cyperus articulatus; Ludwigia octovalvis; glaucous Canna* (this species is rare in Nicaragua but it is common within this area), *Lippia nodosa.; Kosteletskya pentasperma.; Boerhavia erecta; viscous Cleome* and *Cyperus articulatus*.

Growing on the stems of the trees, two species of climbing /trailing plants (gen. Araceae) were identified: *Monstera adansonii* and *Syngonium angustatum,* and on the branches, the hemiparasites of the genus Loranthaceae: *Struthanthus quercicola* and *Struthanthus orbicularis*.

The creek/riverbed that is located east of the in the farm of San Jose de la Viuda, is totally covered by the aquatic fern *Ceratopteris pteriodoides*. In this area and as well as in the area of the wetland, the cattle is left to graze.

### c. Marshlands with Low-lying Vegetation

The marshland, composed mainly of low-lying vegetation, is located within the influence area, to the east of the projected landfill area. This place is known by the locals as **El**

**Canal (The Channel)** and is located approximately one kilometer from the farmhouse San Jose de la Viuda up to about forty meters off the coast of Lake Nicaragua.

Within this ecosystem, the number of some dominant plant species prevails, and is ranked can be observed in the following from damp to wettest: (1) *Cyperus articulatus*, (2) *Thalia geniculata* and (3) *glaucous Canna*, also gramineous *Echinocloa cruspavonis; Oryza latifolia*, *Thalia geniculata*, *Brachiaria mutica* and *Thalia geniculata* can be found. In the most submerged part tule *Typha dominguense* followed by reeds *Phragmites australis* and bramble *Mimosa pigra*, and finally floating and covering the water surface, the water hyacinth *Echhornia crassipes*, water lettuce *Pistia stratiotes*, *Salvinia auriculata* and *Ceratopteris pteriodoides* (the later two species are ferns).

Some natural species of **espino de playa** *Pithecellobium dulce*, chichicaste *Cnidoscolus urens* (a herbaceous plant within urticating properties) *Ipomoea pesca-prae*, an herbaceous of *Crotalaria spp.* grown in the coastal area and on the sandy beach. It is common to observe the growth of (catapanza) *Passiflora foetida* and (manzanita) *Momordica charantia*.

Among those vegetation cultivated are coconut *Cocos nucifera* and almond *Terminalia catappa*.

Among the **herbaceous** present in the area the following species were identified: escoba lisa *Sida acuta*, bledo espinoso *Amaranthus spinosus*, quelite del fraile *Jatropha gossipiifolia*, pegajosita *Cleome viscosa*, guasquito *Lantana camara*, sorosi *Momordica charantia*, uña de gato *Martynia annua*, coyolillo *Cyperus rotundus* and *Cleome spinosa*.

#### T.5.2.1.4 Results of Flora Survey

A total of 69 florae families, comprising 130 genera with a total of 149 species were identified.

Three (3) ecosystems were determined and identified in the entire area:

- Arable and grazing land.
- Seasonal swamp with trees an shrubbery.
- Marshland with low-lying vegetation.

The arable and grazing land is the richest habitat for florae, therefore 107 species were identified; in the second place the seasonal swamp with trees and shrubbery has 64 species and in the last place the wetland with only 17 species. The differences in the number of species is because only the wetland plants are very robust and can adapt to the extremely hersh conditions of the marshland.

The large variety of species in the arable and meadow habitat is partly due to the introduction of natural species from other zones and of exotic species, especially among the ornamental and edible species, and also due to the environmental conditions in which development of those species is allowed.

Two individual species, which are locally rare but not endangered species, were found in the flora survey of the SJV site :

One specie is of the Lecythidaceae family bala de cañon *Couroupita nicaraguense*, and the another is of the Anacardiaceae family, espavel *Anacardium excelsum*. These species are common in other areas, but they are rare locally. Both species are located to the east of the farm house San Jose de la Viuda, the former in the seasonal swamp area and the latter in the meadow habitats.

Two more species of the Arecaceae or Palmae family exist. Each species was found to exist uniquely. These species are: *Elaeis oleifera* and *Scheelea rostrata*, the two are native to swampy areas. The former species was observed in the San Jose de las Animas Farm and the latter in the Santa Rosa Farm both in the seasonal swamp habitat with trees and shrubbery.

#### T.5.2.1.5 Conclusions of Flora Survey

**Within the area of research, which was the area of 1.5 km radius around the center of the project, no plant species in danger of extinction was found.**

It is considered that the project of a sanitary landfill with leachate control and treatment, daily soil covering over the waste disposed in cells and buffer zone of tall trees (e.g., eucalyptus), will not affect the local vegetation, because the chosen site is an area used presently for cultivation and the only matter at hand regarding vegetation is the cultivation itself and some weeds that normally grow on it.

On the other hand, it will be possible that some newer unique species may emerge if the soil cover material over the disposed waste are completely attired from the soils near the project site. A way of minimizing this effect is, to try to use the soil surrounding the landfill area to cover the disposed waste and not bring soil from distant places, because seeds of other species that would compete with the local species could be contained in the soil.

This project design proposing borrow pit for cover soil in the project site already paid attention to this matter and mitigated the problem.

#### T.5.2.1.6 References Used for the Flora Survey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### T.5.2.2 The Fauna In the Area

#### T.5.2.2.1 Introduction

This study was carried out in order to indicate the species of faunae that exist within a 1.5 km radius from the center of the future sanitary landfill site, to establish some criteria with respect to these components, and to view the effect this project could have on the ecosystem.

#### T.5.2.2.2 Methodology

The sampling and the observations were carried out from the 9th to the 12th of July at 3 points located within the property of San Jose de la Viuda and in the wetlands, next to the gravel road to Malacatoya. Furthermore, recognition in all the property above mentioned was executed as well as in the bordering properties. Because of the habits and differentiated use of the space on the part of the fauna, the methodology was variable.

**a. Birds**

Ornithological surveys were conducted in the morning from 5:30 am until 9:30 am and in the evening from 4:00 p.m. until 7:00 p.m.. Simultaneously 2 capture nets, 12 meters long and 2 meters wide were installed for the captivation of specimens. Counting of Zopilotes *Coragyps atratus* was carried out on Wednesday 9th of July and Saturday 12th of July in the surroundings of the wastewater disposal site of poultry farm San Felipe. Furthermore, the locals were interviewed to understand the presence of migrant birds in the different seasons of the year.

**b. Mammals**

During the night, traps for small-mammals were installed at 3 sampling sites. Night watches were simultaneously carried out in search of land mammals. In the case of bats a net was installed to capture and subsequently identify them. Also the locals were interviewed about the land mammals present in the area.

**c. Amphibians**

Daytime and night watches were made around 3 sampling points within the wetlands adjacent to the road to Malacatoya. Furthermore, interviews to the locals about the amphibians presence were made.

**d. Other**

Interviews to obtain information on other aspects such as the economic activities in the area and the existence of particular fauna species were carried out. Also, collections of mollusk shells for their identification were carried out.

#### T.5.2.2.3 Results

Through visual observation, 47 species of birds were identified, apart from capturing: 1 rodent, 4 chiropterans, 2 amphibians and a reptile. Also, 4 species of reptiles were seen. The inhabitants reported 1 additional species of bird, 8 mammals, 11 reptiles, 6 fishes (see the general list of fauna in Chapter 8 in the Data Book: Volume V).

The population of Zopilotes *Coragyps atratus* that currently inhabits the surroundings of the poultry farm San Felipe is estimated to number between 500 and 800. In the nocturnal and daytime tours no mammals were detected. Two types of mollusks in the tour were found, however, in the total research area 13 species of these animals were reported.

The birds species observed the most were: *Quiscalus mexicanus*, *Q. nicaraguensis*, *Crotophaga sulcirostris*; *Campylorhynchus rufinucha* and *Calocitta formosa*. On the other hand the most abundant species in the open swamp were: *Jacana spinoza* and *Casmerodius albus*. According to some inhabitants, the area of the swamp is used by some species which migrate locally at some time of the year. These species are: *Cairina moschata*, *Columbina Inca*, *Columbina talpacoti*, *Zenaida asiatica*, *Dendrocygna autumnalis*, *American Mycteria*. Furthermore the *Myiodynastes maculatus* was observed which is a species that migrates locally.

The inhabitants of the zone reiterated that many species of aquatic birds build their nests in the swampy area; such is the case of herons and ducks among others. They also pointed out that many birds such as the *Cairina moschata*, arrive for a certain period of the year and feed on seeds of wetland plants, others feed on mollusks which are very abundant in the swampy area. Among the mollusks, samples of *Pomacea flagelata* could be collected however, on other occasions other species have been collected in the same zone (see the mollusks list in Chapter 8 of the Data Book: Volume V).

The inhabitants pointed out the existence of Cuajipla (*Caiman crocodilus*) and black alligator (*Crocodilus acutus*) which are listed the categories managed by CITES (Convention on International Trade of Endangered Species). Furthermore they mentioned the Iguana population (*Iguana rhinolopha*) and the Gallego was observed (*Basilisk vittatus*) and *Mabuya unimarginata* which are commodities.

Some people indicated that in the fishing takes place in some parts of the swamp mainly for four species: guapote, mojarra, tilapia and barbudo (common names).

Concerning mosquitoes, the inhabitants indicate that only one species exists and that the number of these increases in the rainy season. In the days of the field research mosquitoes were not observed. On the other hand, large quantities of flies in the area of the farmhouse of the San Jose de la Viuda property were observed.

#### T.5.2.2.4 Discussion of Results

The distribution of the fauna in the area indicates that 3 types of habitats currently exist as a result of the human activity:

- cultivation and grazing land area
- seasonal swamp trees and shrubbery
- open wetlands with low-lying vegetation

During the sampling period 3 events, that elucidate the current status of the fauna within the area of interest, were observed:

1. In the first two sampling points, no chiropterans (bats), nor birds were captured by the installed nets.
2. Chiropterans in the seasonal swamp area were captured.
3. No mammals were observed during the daytime and nocturnal observation tours.

These events reveal that not many mammalian species live in the landfill project area. However, in the area of the wetland there is a large number of species of animals like, bats, fish, amphibians and mollusks that depend on the remainder of the seasonal swamp with tall and shrubs and of the open perennial swamp with low-lying vegetation.

By counting the Zopilotes *Coragyps atratus*, it was determined that between 500 and 800 live near the poultry farm San Felipe, however it is probable that the number of Zopilote could be larger since the inhabitants of the area indicated that in other occasions the number was much greater.

Traps to capture rats and smaller vermin were used. One roof rat *Rattus rattus* was captured near the poultry farm San Felipe.

#### T.5.2.2.5 Conclusions

**Within the area under research, which was a 1.5 km radius from the center of the project, no animal species was found in danger of extinction, upon execution the sanitary landfill construction.**

Within the research area, the part where there is currently cultivation and grazing land is the one that has less fauna abundance. The area of the open wetland of gramineous plants, trees and shrubs, makes up an ecosystem of abundant faunae.

### T.5.3 The Socio-economic Environment

#### T.5.3.1 Current Land Use

Land uses in the surrounding areas of the project site are mainly: cattle rearing and/or fallow agriculture. There is a little perennial harvesting of fruit trees, such as the spanish plum, mango, tamarind, papaw, tart lemon, banana, plantain and filipito. One specific economic activity in the surrounding area is the San Felipe poultry farm.

#### T.5.3.2 Current Utilization of the Ground Water Sources

In the property San Jose de la Viuda there are several wells, whose water is given to cattle for drinking and it is not consumed by the inhabitants, they assure the consumption of water brought from Granada City, as the contamination of the water wells in very likely.

In the San Felipe Poultry Farm there are two wells, which serve as a potable water source for the workers. Furthermore, the water of these wells is given to the chickens in growth stage and it is used for their plucking and washing in the slaughter process.

### T.5.3.3 Current Utilization of the Surface Waters

The surface water near the project site (i.e., wetland water) is not utilized for any specific economic activities. Meanwhile, the Lake Nicaragua is located to the east of the property, which is used by the population for their personal bathing. In the small village Kauloa, some people use its water for consumption. Furthermore, it is used as a resort by people who visit the city. On the other hand, certain properties and estates located on the border of the lake, use water of the lake for irrigation.

## T.6 Analysis of the Environmental Impacts

### T.6.1 Atmospheric pollution

Negative impact by atmospheric pollution will not be produced in the construction stage as well as the operation stage. This is because when the earth movement works take place, a water tanker will be used, which is equipped with a hose and sprinklers to control the dust. As for the operation stage, since a landfill gas removal facility will be installed, atmospheric pollution will be minimal as the structure of the sanitary landfill proposed prohibits open burning of waste disposed. On the other hand, due to the daily covering of the solid waste there will be no bad spreading.

### T.6.2 Dust Increase

There will be no dust increase either from the traffic of the waste collection vehicles, or from the sanitary landfill operation proposed (e.g., disposal, compaction and soil coverage), since the access road (from the city to the SJV site) will be paved. Likewise, the approach road in the site to the landfilling face will be gravel paved.

The pavement of the access road will be a positive impact for the neighboring zone, due to the reduction of the dust, noise and the vibration caused by the traffic on the road, etc. Furthermore, a water tanker will be used for dust control, when sanitary landfill operations are carried out in the site.

### T.6.3 Pollution Risk for the Subsoil and Ground Water Sources

Subsoil contamination by leachate will occur on the subsoil beneath the landfill cells dut to the absence of an impermeable liner. In view of lateral wide space of from landfill cells to the project site boundary, it is considered that subsoil contamination by leachate might be limited within the project site (i.e., inside the buffer zone boundary). Therefore, there will be no negative impact to the subsoil outside the project area.

There will be groundwater pollution. Groundwater contamination by leachate may start from the landfill cell area and be expanded in (mainly eastward) adjacent areas with dilution, due to groundwater gradient of 0.2 to 0.6% eastward.

Concentration level of groundwater contamination, being correlated with distance and time, (e.g., to what distance its influence reaches, increase/decrease of concentration in time passage) should be monitored by monitoring wells.

## T.6.4 Impacts Provoked by the Gaseous Emission of $CH_4$ and $CO_2$

There will be no negative impacts due to gaseous emissions in the zone, because the installation of a landfill gas removal facility will create the appropriate ventilation conditions to avoid the accumulation and possible explosion of the landfill gas (e.g., $CH_4$), as well as the underground lateral migration of the emissions, avoiding $CH_4$ to accumulate in confined spaces.

Meanwhile, $CO_2$ being 1.5 times heavier than the air, will sink and be vented out through the perforated leachate collection pipes which are laid at the bottom of the landfill cells. Hence, $CO_2$ accumulation in closed spaces will be avoided.

## T.6.5 Risks of human exposure to volatile chemicals and pathogenic microorganisms

In the sanitary landfill, with practices of daily soil coverage on disposed waste, human exposure to pathogenic microorganisms will be minimal and insignificant. Likewise, there will not be human exposure to volatile chemicals. To avoid personnel being affected, by pathogenis, workers will receive a supply of protective gear such as boots, gloves and masks, as well as toiletries, such as soap, for hand washing.

On the other hand, as hazardous industrial waste and/or hazardous/infectious medical waste (such as syringes) are not allowed to be disposed of at this landfill site, human exposure to volatile chemicals is not expected.

## T.6.6 Proliferation of Diseases Vectors

In the sanitary landfill, daily soil coverage on waste will be carried out and therefore, proliferation of disease transmitting vectors could substantially be controlled and avoided. Therefore, it is not expected that the sanitary landfill project would produce any impacts the poultry farm San Felipe due to disease vectors proliferation.

On the other hand, as for the San Felipe poultry farm, present activities and poor hygiene practices already attract some disease vectors (e.g., roof rats *Rattus rattus* are attracted to poultry feeds, Zopilotes *Coragyps atratus* are attracted to residues from fowl meat processing). (see pictures in Section 8.10 of Chapter 8 in the Data Book: Volume V)

Therefore, it is important to confirm that the **present environmental quality of the poultry farm** is such that some disease vectors are attracted to its unsanitary conditions.

## T.6.7 Fire Risks

Fires are not expected to be produced in the sanitary landfill, since the waste compaction and the daily soil covering on waste are methods that minimize the possibility of spontaneous fires occurrences.

## T.6.8 Impacts on the Flora and Fauna

With respect to the ecosystems in the project site (i.e., Cultivation and grazing land), the area where the sanitary landfill is projected is presently used for cattle rearing and no kind of flora and fauna in danger of extinction are found therein. Although surface vegetation of the project area will be removed at the construction period, since trees will

be planted as the buffer zone, there will be no negative impacts such as loss of florae. Likewise, there will be no negative impacts such as reduction in fauna.

With respect to the ecosystems in the forest and wetland area (i.e., Seasonal swamp with trees and shrubs, and Wetlands with low-lying vegetation), although the area makes up an ecosystem of abundant species, no florae and faunae in danger of extinction are found therein.

Furthermore, the forest and wetland area is beyond the reach of construction activities and as for landfill operation stages, a buffer zone of fast growing trees will protect the local ecosystem.

### T.6.9 Noise Impacts in the zone

The area bordering the sanitary landfill will not be influenced by the noise generated by the heavy machinery operating in the site, since with the construction of the buffer zone (fast growing trees, e.g., eucalyptus), the noise impact will be mitigated.

### T.6.10 Change in the Land Use

The impacts of land use changes will only be limited to the 40 hectares that will be developed for the SJV sanitary landfill project site (i.e., landfill area, area for treatment lagoons, borrow pit for cover soil, buffer zone, office etc.), as good sanitary landfill operation practices (e.g., daily soil coverage), environmental protection facilities (e.g., impermeable liner and leachate treatment lagoons), buffer zone with tall trees will limit the influence area to the 40 ha project area.

### T.6.11 Landscape Alterations

The 40 ha project site will suffer landscape alterations, however, the landfill shape and its operation will not be noticeable because of the buffer zone (plantation with fast growing trees) around the project site. It will be judged that the landscape alteration will not create negative impacts but rather a favorable scenic view.

The project site, after its service life and the closure process, will be used as an ecological park. It will further give a favorable landscape which will be accessible by citizens at that time.

### T.6.12 Damages to Archaeological and Paleontologic Points of Interest

Within and around the project site there are no archaeological and paleontologic points of interest.

### T.6.13 Changes to the Property Values

On the part of the land owners of the project site, there is a willingness to sell the necessary area. The negotiation of land purchase between the project proponent (i.e., Granada Municipality) and land owners will begin after the Environmental Permit (Permiso Ambiental) for the project is issued by MARENA, because it would be impractical to do so beforehand. This means that at the moment of the EIA elaboration it is difficult to predict whether the land price will increase due to the Environmental Permit given or not, and in that case how much it will cost.

Meanwhile, there will not be a negative impact on property value changes of the project neighboring areas, because the project will employ sufficient measures of environmental mitigation and furthermore, asphalt pavement on the access road will be beneficial to the neighboring land uses and to the users of the access road.

## T.7 Mitigation Measures

### T.7.1 Design of the Mitigation Measures

Some of the mitigation measures were already included in the conceptual design of the SJV landfill site project. Most of those measures are related to:

- security of the sanitary landfill.
- good sanitary practices of landfill operation.
- adequate functioning of facilities proposed in the project.
- monitoring of important parameters.

Table T-19 below summarizes the mitigation measures to be developed, in which it can be observed that some mitigation measures are common to several environmental factors.

On the other hand, an operation handbook will be prepared which will be given to all the staff of the landfill project, as well as to the managers and the corresponding authorities, before the operation stage begins, thereinafter it will be given to those new workers who are hired. In this handbook all daily activities will be described, as well as the actions to be taken in the event of emergencies, for example, breakdown of equipment, fires, accidents, etc.

## Table T-19: Mitigation Measures

| Activity | Description | Public Health | Hazards, Risks | Ground water | Flora & Fauna | Landscape, waste scatter | Air Pollution | Soil Contam. | Noise, Vibration |
|---|---|---|---|---|---|---|---|---|---|
| Security of the Project Site | Access Control (scavenger, etc.) | X | X | | | X | | | |
| | Fire Safety | X | X | | | | | | |
| Sanitary Practices of Landfill Operation, Adequate Functioning of Facilities | Fencing of the Site | X | X | | | X | | | |
| | Construction of Buffer Zone | | | | X | X | | | X |
| | Use of Compactor Trucks for Waste Collection | | | | | X | X | | X |
| | Inspection of Incoming Waste | X | X | | | | | | |
| | Waste Compaction and Daily Soil Coverage | X | X | | X | X | X | | |
| | Elimination of Stagnant Water | X | X | | X | | | | |
| | Waste Scatter Control | | | | | X | | | |
| | Tire Wash Basin and Washing Area for Vehicles | X | | | | X | X | | |
| | Preventive Maintenance of Vehicles and Equipment | | | | | | X | | X |
| | Access Road Asphalt Pavement, Gravel Approach Road | X | X | | | | X | | X |
| | Dust Control by Water Tanker | X | X | | | | X | | |
| | Surface Water Drainage | X | | X | X | | | X | |
| | Leachate Control by Daily Soil Coverage/Top Clay Liner | X | X | X | X | | | X | |
| | Control of Gaseous Emissions | X | X | | X | | X | | |
| | Closure of the Landfill Site | X | X | X | X | | X | X | |
| Compensatory Measures | Provision of water supply system to the project adjacent areas | X | | X | | | | | |
| Workers' Safety | Supply of Protection Equipment | X | X | | | | X | X | X |
| | Operation Manual | X | X | X | X | X | | | |
| Monitoring | Water Quality | X | | X | X | | | X | |
| | Air Quality | X | | | | | X | | |

Note: X marked means the mitigation measure will reduce the environmental impact for the indicated factor.

## T.7.2 Evaluation of the Efficiency of each Mitigation Measure

### T.7.2.1 Security of the Project Site

Access of unauthorized persons to the project site, including the firewood collectors will be fully restricted.

### T.7.2.2 Good Sanitary Practices of Landfill Operation, Adequate Functioning of Facilities

**a. Fencing of the Site**

The fencing of the site will not permit the access of unauthorized persons, thus protecting their health. Also, the light solid waste scattering out of the site will be avoided.

**b. Construction of the Buffer Zone (Tree Planting)**

With the plantation of trees the constant micro-climate of the area will be maintained, the landscape aesthetics will be preserved and the effects of the noise and vibration toward the surrounding areas will be minimal.

**c. Utilization of Compactor Trucks for Waste Collection**

With the utilization of compactor trucks, air pollution in the access road will be considerably reduced an to insignificant level, because the number of trips necessary for waste collection from the service areas to the site will be reduced by the employment of compactor trucks. There will be no diffusion of offensive odors, either.

**d. Inspection of the Incoming Waste**

With the inspection of the waste, disposal of hazardous, toxic, infectious or radioactive wastes will be restricted. With this, occupational health of the site workers and environmental settings therein and nearby (e.g., water quality of the lake, the wetland, ecology of present fauna and flora) will be protected.

**e. Waste Compaction and Daily Soil Coverage**

The waste will be extended and compressed into layers of about 30cm in order to achieve the optimum compaction in the area of the landfill, by a bulldozer. This work will be carried out repeatedly until a height of 3 m is reached. Each day a cell will be formed and covered with 10 - 15 cm of soil at the end of the day with a slope of 3:1. The material for the daily covering will be excavated from the on-site borrow pit designated within the site boundary.

The daily compaction of waste and soil covering over the disposed waste in the site will avoid the proliferation of disease transmitting vectors, thus public health is protected. Air pollution by foul odors will be avoided and scattering of the light solid waste at the boundaries will be avoided.

Therefore, daily soil coverage practices with the landfill gas removal facility and the buffer zone, will never cause adverse impacts on other environmental features (e.g., flora/fauna, agricultural production, poultry farm activities).

**f. Elimination of Stagnant Waters**

Stagnant water as a potential mosquito proliferation area will be eliminated by the site surface gradient and drainage designed and appropriate operational practices in the site, negative impacts on health by stagnant water will be reduced to nil. The only place with stagnant water that can not be avoided, will be the wash basin for the truck tires. However, vector proliferation therein will be avoided by periodical drain out of the water in the basin.

**g. Control of Waste Scattering**

With the mobile fence to be placed near the landfill face, the scatter of waste (e.g., plastic bags) out from the active cell will be restricted significantly. Furthermore, buffer zone with tall tree planting will restrict the scatter and finally the fence with mesh on the site boundary stops the scatter.

**h. Tire Wash Basin and Washing Area for Vehicles**

The tire washing basin will contribute to eliminate waste that could adhere to the tires which could make the access road (Granada-Santa Rosa) dirty and disperse bad odors along the road.

**i. Preventive Maintenance of Vehicles and Equipment**

With preventive maintenance of the waste collection vehicles and on-site equipment, the air pollution caused by inappropriate machine maintenance (e.g., smoke expel due to wrong operation of the injector pump, dirt in the air filters, etc.) will be avoided. Also, the noise increase caused by inappropriately maintained equipment will be avoided.

**j. Access Road Asphalt Pavement and Approach Road Gravel Pavement**

Asphalt pavement on the access road and gravel pavement and water sprinkling by a water tanker on approach road will significantly eliminate the air pollution caused by dust and it will contribute to the safety and health of the drivers, on-site workers and neighboring residents and others.

**k. Dust Control by Water Tanker**

Water sprinkling over dusty work site will eliminate the negative impacts of dust. Meanwhile, amount of water sprinkled will be controlled to an optimum level in order not to generate excessive leachate from the disposed waste.

**l. Surface Water Drainage**

The surface drainage system is designed to restrict the stormwater flowing to the active landfill cell in order to avoid increase of leachate generation. It is designed that the surface water originated from rainfalls on other than active cell will be separately gathered in a drainage channel and routed to the off-site area.

**m. Leachate Control by Daily Soil Coverage and Top Clay Liner**

Daily soil coverage over disposed waste will help reduce leachate generation by stormwater. Final clay coverage on a landfill cell (i.e., 60cm top clay liner) will significantly restrict leachate generation by stormwater. Consequently, it will contribute for a mitigation of groundwater contamination.

**n. Control of the Gaseous Emissions**

With the installation of the landfill gas removal facility (i.e., perforated chimneys), control on the ventilation will be created to avoid the impacts of gaseous emissions to public health and workers safety. The risk for methane to reach explosive levels and/or causing fire is eliminated by the gas removal facility and by the practices of daily soil coverage on disposed waste. On the other hand, enough space around the gas removal chimneys should be restricted as "off limits" in order to prevent the risk of burn for the on-site workers in case that the landfill gas chimney catches incidental fire.

**o. Final Coverage of the Site and Restoration of the Landscape**

The operation of a section (3.5 ha) of the landfill will be completed in 5 years. After the 5 years operation, the final covering will be placed on the section. Which will be: clay material of 60 cm thickness; and vegetation soil enough for the re-vegetation of the area. This final covering of the section will avoid the stormwater infiltration and in this manner the production of leachate in the section will be substantially restricted. Furthermore, the landscape with small size vegetation will be restored as an environmental setting.

### T.7.2.3 Compensatory Measures

**a. Provision of Water Supply System**

In view of the negative impacts of groundwater contamination by leachate, water supply system (INAA's water) should be provided to the project adjacent area, in order to secure safe potable water to the residents and industries near the project site. By doing so, negative impact of local ground water pollution can be compensated.

In practice, at first water supply system should be provided to the project area and project adjacent area when the project construction starts. And after landfilling works start, in case when monitoring wells detect symptom of groundwater contamination expansion and if it is envisaged the groundwater contamination may in the future expand outward the initial water supply area, water supply system should be expanded outward the area in advance. By monitoring groundwater and providing water supply system in advance, negative impacts of ground water contamination are compensated and controlled.

### T.7.2.4 Workers' Safety

**a. Supply of Protection Equipment**

Risk of catching diseases due to contact or inhalation of hazardous and/or infectious substances during the landfill operation will be avoided by the provision of the protection equipment. With these protection measures and practices, workers' safety and health will be protected.

**b. Operation Manual**

Provision and use of such manual will lead to protection of all environmental factors. The manual contains: principles of sanitary landfill works; restrictions regarding reception of waste materials; waste handling procedures in practice; operation and maintenance procedures; monitoring process; precautions to prevent negative impact on the environment; actions necessary in case of accident; etc.

### T.7.2.5 Monitoring

#### a. Water Quality

Since the landfill structure does not have bottom impermeable liner, groundwater contamination by leachate is envisaged.

Groundwater contamination by leachate may start from the landfill cell area and be expanded in (mainly eastward) adjacent areas with dilution, due to groundwater gradient of 0.2 to 0.6% eastward.

Behavior of groundwater contamination, in correlation with distance and time should be monitored at 6 monitoring wells and wetland. The monitoring should identify e.g.; to what distance contamination reaches; whether and how much the contaminated groundwater flow is captured at the wetland or goes straightly to the Lake Nicaragua; whether and how much the wetland's biodegradation capacity and toxicant removal/retention functions work.

The monitoring will give notice for taking necessary measures, in case any abnormal behavior is shown. In doing so, all environmental settings including human health will be protected.

#### b. Air Quality

By monitoring air quality, any necessary action to protect it can be implemented, in case altered concentrations of the control parameters are determined.

### T.7.3 Mitigation Effects

In view of the above clauses, it can be evident that, with construction and operation of the sanitary landfill, impacts which could not be mitigated are a few. They are: change of land use; **local groundwater contamination,** traffic volume increase on the access road due to waste collection vehicle; increase of noise levels.

Change of land use, which will be from present cattle breeding/agricultural production to landfill use, can limit its impact only for the project site by the buffer zone, planting native species of trees such as leucaena, eucalyptus and acacia, which happen to be fast growing kinds and give environmental integration to the site in a short period. After the project life, change of land use of the project site will give beneficial impacts to the city and citizens. The project site after the closure could give an environmental asset as ecological park and/or timber production from the buffer zone trees.

**As for local groundwater contamination, the impact will be compensated by providing water supply system to the project adjacent areas.**

In the event of traffic increase, the impact will be compensated with the asphalt pavement of the road. This will produce positive impacts: for the surrounding areas by reducing dust, noise and vibration; for the road users by giving a better road condition.

Increase of noise level around the site, will be muffled off with the plantation of trees around the area (buffer zone), preventing impact on surrounding areas.

### T.7.4 Occurrence of Impacts that cannot be Lessened

The increase of traffic on the area will take place from Monday trough Saturday, from 8:00 a.m. to 5:00 p.m. Assuming that 5 compactor trucks make 3 trips/day and 1 dump truck makes 4 trips/day in year 2001, the net traffic increase will be 19 trips/day on Monday to Saturday and it will count for about 13% increase to the present (year 1997) traffic at the entrance point to the project site. Such percentage represents a small negative impact on the traffic volume.

Modification of current land use will be during a 30 year span (which is also the useful life of the filling).

### T.7.5 Plan of the Project Closure

Once the useful life of the sanitary landfill is over (i.e., 5 years for one section), a final covering of the area will be carried out with 60 cm of clay, and vegetation soil over clay layer prepared for re-vegetation of the area. The site can have a future potential use in recreational purposes (such as ecological park) with or without planting more trees.

Meanwhile, monitoring of landfill gas generation after the project closure will be necessary until it is secured that the risk of landfill gas fire disappears. And enough space around the gas removal chimneys should be kept as restricted area of "off limits" when the project site is used for recreational purposes for the citizen.

## T.8 Environmental Management Program

### T.8.1 Monitoring Plan

In order to assure that the proposed mitigation measures work properly and to give notice for taking necessary measures (in case any abnormal behavior is shown), monitoring of environmental factors (e.g., groundwater quality) will have to be carried out.

#### T.8.1.1 Respective Impact Indicators

Periodical monitoring should be carried out for groundwater in 6 monitoring wells and the wetland water, since it is anticipated that leachate from the landfill may contaminate the local groundwater near the project site.

As mentioned previously, with the landfill operation at the project site, there will be noise increase caused by the traffic of the waste collection vehicles and the works of the heavy machinery in the site, which will be mitigated by the buffer zone. However, noise measurements will be implemented after installation of the buffer zone in order to verify whether the buffer zone mitigates increased noise to surrounding areas.

Although the landfill is designed to avoid lateral emissions of landfill gases (e.g., by gas removal facility), in order to verify the good functioning of the gas removal facilities, visual inspection of vegetation including count ups of survival percentage of the trees in buffer zone will be done.

### T.8.1.2 Results of the Measurements before the Beginning of the Project

The results of the measurements of the respective impact indicators such as air quality, noise levels, vibration, traffic, groundwater quality, water quality in the wetland, etc., are presented as the baseline of the present environmental settings. (see Chapter 8 of the Data Book: Volume V)

### T.8.1.3 Frequency of the Future Measurements of the Impact Indicators

Quality of: groundwater (6 monitoring wells) and wetland water should be monitored periodically in order to notify appropriate functioning of the environmental protection measures incorporated in the project and/or to suggest taking necessary measures (in case any abnormal behavior is shown).. With regard to monitoring items, Table T-20 lists parameters and the frequency to be surveyed.

Table T-20: Monitoring parameters

| Parameter | Groundwater and wetland |
|---|---|
| Color | once per week |
| pH | once per week |
| BOD | once per year |
| COD | once per year |
| SS | once per year |
| Electric conductivity | once per week |
| $NH_4$-N | once per year |
| $Cl^-$ | once per year |
| $SO_4$ | once per year |
| Fe | once per year |
| E. coli. | once per year |

### T.8.1.4 Sampling and Laboratory Analysis

The municipality will be in charge of the monitoring of those impact indicators, therefore it will be the municipality who will choose the laboratory or the institution that will make the samplings. Hence, the laboratory or the institution chosen will decide the techniques to be used for the sampling as well as for the analysis in the laboratory.

## T.8.2 Maintenance and Control of the Equipment

The preventive maintenance of the equipment (e.g., waste collection vehicles, heavy machinery at the landfill site, and a weigh bridge ), will be carried out once a week, in order to avoid the equipment to be damaged and thus affecting the operations in the landfill site. This maintenance will be carried out by staff of the maintenance shop of the Municipality.

## T.8.3 Cleansing and Maintenance Plan of the Facilities

The cleansing of the bordering areas to the sanitary landfill will be carried out once every other week, to avoid the growth of weeds. On the other hand, those facilities that require

structural maintenance (road surface, etc.) should be periodically inspected and repaired.

### T.8.4 Safety plans

The measures to be taken to protect the health of the on-site workers are already included as the mitigation measures of the project.

### T.8.5 Risk Control In Different Execution Stages of the Project

The control of accident risks for the workers, in the construction stage of the sanitary landfill project, will be the responsibility of the company contracted for the construction, who will have to inform the staff under its command about a security regulation.

For the operation stage, the measures to be taken to protect the health of the on-site workers are already included as the mitigation measures of the project.

Risk control after the site closure should ensure that the area around the gas removal facility (chimney) should be restricted as "off-limits" in view of a fire risk.

### T.8.6 Contingency Plans in Case of Emergencies

In the operation handbook that will be given to the workers, the measures to be taken will be indicated in the case of emergency. Furthermore, there will always be a vehicle available at the site in case it is necessary to take a worker to a hospital when having an accident, which is unlikely due to the safety measures that will be taken at the project site.

## T.9 Forecast of the Environmental Quality of the Influence Area

The environmental quality of the influence area is forecast for respective environmental items as follows:

- public health;
- hazards and risks (including exposure to volatile chemicals and pathogens);
- fire risks;
- air pollution including dust increase;
- gaseous emmision of $CH_4$ and $CO_2$
- Disease vectors
- soil and groundwater contamination;
- flora and fauna;
- landscape aesthetic;
- noise and vibration;
- archeologic and paleontologic points of interest; and
- economic activities including land use changes and land prices increase.

It is expected that due to the mitigation measures to be carried out in respective stage (i.e., construction, operation and closure and after closure stages) of the project, the environmental quality (other than "soil and groundwater contamination")during and after the project is maintained equal to the current conditions.

## T.10 Conclusion of EIA

### a. Outcome of EIA

SJV A New Municipal SW Disposal Site is planned with **level-2** (i.e., sanitary landfil with dike and daily soil covering without an impermeable liner). In order to minimize its impacts to the surrounding areas, various mitigation measures were formulated.

Although it is envisaged that the local groundwater contamination by leachate is probable, since the SJV project site (unlike La Joya site) does not have many groundwater users near or downstream the project site:

- **Provision of water supply system to the residents and industries near the project site will get rid of negative impact to the groundwater users.**

Meanwhile, as for the groundwater contamination impact to the Lake Nicaragua,

- **The impact will be estimated negligible, comparing "pollution load of leachate from the 3.5 ha landfill to the Lake by way of groundwater infiltration" and "total pollution load from the huge catchment area of the Lake Nicaragua by way of all surface drainage and groundwater inflow in the catchment area".**

Other negative impacts (e.g., occurrence of dust, vibration, noise, and increase of traffic volume) caused by the traffic of collection vehicles will be improved than it is now by the asphalt pavement of the present access road (Granada-Santa Rosa Road).

During the landfill operation period and after its closure, the landscape of the site is changed as landfill work involves topographical alteration. However, it can not be seen by the buffer zone, and after the landfill is completed, re-vegetation over the final covering of the landfill improve the landscape. Therefore, no negative impact of landscape alteration will be envisaged. Regarding the plan for land use after the closure, an ecological park construction is proposed by integrating surrounding natural resources such as a hill of about 7.5m formed by waste, existing wetland, forests, and Lake Nicaragua. This will bring not only environmental improvement, but also benefits for residents in the neighboring areas and all residents in Granada Municipality.

In the sanitary landfill, daily soil coverage on waste will be carried out and therefore, proliferation of disease transmitting vectors could substantially be controlled and avoided. Therefore, it is not expected that the sanitary landfill project produces impacts of disease vectors proliferation toward the poultry farm, San Felipe. On the other hand, as for the poultry farm, present activities and sanitation situation is already attracting some disease vectors (e.g., roof rats *Rattus rattus* are attracted by poultry feeds, Zopilotes *Coragyps atratus* are attracted by untreated residues from fowl meat processing).

The policy of prohibiting scavenging at the new disposal site will result in a loss of income and livelihood for scavengers and middlemen currently operating at La Joya disposal site, a decrease in the amount of waste materials recycled, and a little upset to the recycling system in the city. However, the negative impacts will be minor because the number of scavengers affected will be less than 30. Furthermore, it is recommended to promote recycling by segregation at the source in order to mitigate these negative impacts and also to improve the recycling rate.

**The important points regarding the positive impacts of the project are that present La Joya disposal site (although it is substantially improved by the pilot project) will be closed. Above all, since present La Joya disposal site is located upstream of the INAA's wells, which is the main water supply source in Granada City today, its closure and the shift to the new final disposal site, is urgent. Accordingly, the benefit brought from this plan is very high.**

**b. Getting an Environmental Permit**

As was stated in the EIA report, the negative impact brought by the implementation of SJV A New Municipal SW Disposal Site Development Project is within permissible level and minimal. On the other hand, there are numbers of positive impact for USE in Granada City, such as closure of the La Joya disposal site which has a high potential of giving serious negative impact to the city population through contamination of the ground water source. Therefore, the project shall be carried out based on the work process stated in the Implementation Plan. Granada Municipality, which is the proponent of SJV A New Municipal SW Disposal Site Development Project, needs to submit this EIA report and obtain an environmental permit in accordance with "EIA and Regulation to obtain an Environmental Permit (Decree No. 45-94)" in order to carry out the project promptly.

# ANNEX U

*Financial Analysis for the Sanitary Landfill (Level-2)*

## Contents



## List of Tables

# U Financial Analysis for the Sanitary Landfill (Level-2)

This examination is carried out to determine whether the Municipal SWM System Improvement Project can be sustainable for Granada City if a level-2 sanitary landfill is constructed.

## U.1 Preconditions

The preconditions (i.e. executing body, residual value, cut-off rate) used in the master plan will be adopted for this financial analysis. Except for the changes in the construction cost for the level-2 final disposal site, the investment plan will be as in the Master Plan. Namely, all vehicles required for solid waste management will be purchased and the MDO workshop will be improved in 2000. The additional investment for the purchase and renewal of collection vehicles after 2001 will be as stipulated in the Master Plan.

The improvement of the collection services will be carried out according to the Master Plan, hence improvement in the household collection system will be based on the said plan as well (see table below).

Table U-1: Preconditions in Collection Services Improvement

| Target Population | All households receiving the service |
|---|---|
| Refuse Collection Charge (RCC) | The refuse collection charges below is set according to service level:<br>High service charge (CCA): C$15/month/household<br>Ordinary service charge (CCB): C$10/month/household<br>Low service charge (PCA): C$5/month/household |
| Collection Rate | 82% |
| Collection Cost Rate | 5% |

The collection charge for other waste types shall be established according to the discharge volume, based on the beneficiary-pays-principle and in consideration of the required disposal cost which includes the depreciation costs and interest rate. In consideration of curtailments in the final disposal site expenses, the charges for other waste types were revised as shown in the table below.

Table U-2: Cost Comparison of Level-2 and Level-4 Projects

| | | Level 4 (A) | Level 2 (B) | B/A |
|---|---|---|---|---|
| Final disposal site construction cost (year 2000) (C$1,000) | | 38,589 | 15,344 | 0.398 |
| O&M cost (year 2005) (C$1,000) | | 477 | 451 | 0.945 |
| Cost including depreciation cost & interest rate (average annual cost in the period of 2001-2005) (C$1,000) | | 5,123 | 1,992 | 0.389 |
| Charges (C$/ton) | Collection & Disposal | 363 | 228 | 0.628 |
| | Disposal | 222 | 87 | 0.392 |

## U.2 Financial Case Studies of Level-2 Project and Comparison with the Case Studies of Level-4 Project

As in the financial analysis in the F/S of the level-4 project, three cases were conceptualized for the level-2 project regarding the two following items:

### a. Financial Source for Internal Investment for the Project Cost

| | |
|---|---|
| Case A | to acquire a loan for the total investment amount |
| Case B | to acquire grant aid to cover 90% of the investment for the construction of the final disposal site, procurement of landfill equipment and collection vehicles, and improvement of the MDO workshop in 2000. |
| Case C | to acquire grant aid to cover the entire investment for the construction of the final disposal site, procurement of landfill equipment and collection vehicles, and improvement of the MDO workshop in 2000. |

### b. Allocation of Funds for SWM from Municipal Budget

| | |
|---|---|
| Optimistic Scenario | assuming a budget allocation rate of 12% in 2005 by estimating a 6.7% growth in municipal taxes to incur a 0.2% annual increase in the current budget allocation rate of 10%. |
| Moderate Scenario | assuming that the present budget allocation rate of 10% is maintained in 2005 by estimating a 5.4% growth in municipal taxes. |
| Pessimistic Scenario | assuming a budget allocation rate of 8% in 2005 by estimating a 3.4% growth in municipal taxes that would annually reduce the present budget of 10% at an annual rate of 0.2%. |

The FIRR was calculated by combining the 3 cases presented in item (a) above and the 3 scenarios in item (b) [3×3=9 cases]. The results clearly indicate that even with C-3, which represents a pessimistic scenario in terms of revenues, the project is financially feasible as it was calculated to bring about an FIRR of 10.7%.

Table U-3: FIRR of Each Financial Case Study

| | | | Level 4 (A) | | Level 2 (B) | | B/A |
|---|---|---|---|---|---|---|---|
| | | | FIRR (%) | R/E | FIRR (%) | R/E | R/E |
| By Loan (full investment cost) | Optimistic | A-1 | n.a | 0.7291 | -0.4 | 0.9143 | 1.2540 |
| | Most Probable | A-2 | n.a | 0.7046 | n.a | 0.8499 | 1.2062 |
| | Pessimistic | A-3 | n.a | 0.5986 | n.a | 0.7088 | 1.1841 |
| Grant Aid (90% of investment for 2000) | Optimistic | B-1 | 16.4 | 1.2357 | 38.1 | 1.3819 | 1.1183 |
| | Most Probable | B-2 | 4.7 | 1.1280 | 13.7 | 1.2370 | 1.0966 |
| | Pessimistic | B-3 | -0.4 | 0.9875 | 4.7 | 1.0515 | 1.0648 |
| Grant Aid (entire investment for 2000) (excluding site acquisition cost) | Optimistic | C-1 | 37.4 | 1.2938 | 96.8 | 1.4315 | 1.1064 |
| | Most Probable | C-2 | 13.0 | 1.1766 | 31.5 | 1.2755 | 1.0841 |
| | Pessimistic | C-3 | 1.2 | 1.0391 | 10.7 | 1.0925 | 1.0514 |

Compared with Level 4, the table shows an overall improvement in revenues. The table also shows the following findings:

- If the total investment amount is to be covered by a loan (Cases A-1, A-2 and A-3), the project is seen to be financially infeasible, incurring an R/E of less than 1.
- If 90% of the investment amount for 2000 is to be covered by grant aid, the optimistic (B-1) and the most probable (B-2) scenarios show that revenues will exceed the estimated cut-off rate of 8.5%.
- If the entire investment amount for 2000 is to be covered by grant aid (excluding site acquisition cost), even if the forecast growth in municipal tax rate and the budget to be allocated for SWM services (C-3) is discouraging, the FIRR would still exceed the cut-off rate at 10.7%. However, the municipality of Granada has to adopt a special budgetary measure for the acquisition of a site for the new disposal site in SJV, as the land acquisition cost is excluded from the grant aid amount.

## U.3 Cash Flow and Statement of Profit and Loss

The cash flow and statement of profit and loss for C-3 were carried out as shown below. C-3 forecasts a pessimistic scenario in view of municipal tax growth rate and budget allocation for SWM, as it proposes covering the total investment cost (excluding site acquisition cost) for 2000 by grant aid, the joint billing of refuse collection (C$228/ton) and water supply charges, and C$87/ton charges on direct haulage waste.

Table U-4: Cash Flow and Profit/Loss Statement (Case C-3)

| Cash Flow (Case C-3) | | | | | | Unit: C$1,000 | |
|---|---|---|---|---|---|---|---|
| | | | | | | | Total |
| | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2000-2005 |
| a.1 Finance | | | | | | | |
| Grant | 23,173 | | | | | | 23,173 |
| Loan | 0 | 853 | 0 | 67 | 853 | 0 | 1,773 |
| GM Budget Allocation | 600 | | | | | | 600 |
| Total | 23,773 | 853 | 0 | 67 | 853 | 0 | 25,546 |
| a.2 Revenue | | | | | | | |
| Collection & Disposal | | 1,887 | 2,061 | 2,242 | 2,448 | 2,672 | 11,310 |
| Residential Area | | 1,309 | 1,449 | 1,604 | 1,776 | 1,966 | 8,103 |
| Commercial Area, etc. | | 578 | 612 | 638 | 672 | 706 | 3,206 |
| Self-haulage | | 74 | 74 | 74 | 77 | 77 | 376 |
| GM Budget Allocation | | 1,290 | 1,330 | 1,369 | 1,410 | 1,450 | 6,849 |
| Total | | 3,251 | 3,465 | 3,685 | 3,935 | 4,199 | 18,535 |
| Cash-in | 23,773 | 4,104 | 3,465 | 3,752 | 4,788 | 4,199 | 44,081 |
| b.1 Investment | 23,773 | 853 | 0 | 67 | 853 | 0 | 25,546 |
| b.2 Expenditure | | | | | | | |
| O&M Cost | | 2,322 | 2,498 | 2,502 | 2,508 | 2,683 | 12,513 |
| Interest | 0 | 4 | 9 | 9 | 13 | 18 | 53 |
| Fee Collection | | 65 | 72 | 80 | 89 | 98 | 405 |
| Total | 0 | 2,392 | 2,579 | 2,591 | 2,610 | 2,799 | 12,971 |
| Cash-out | 23,773 | 3,245 | 2,579 | 2,658 | 3,463 | 2,799 | 38,517 |
| c. Reserve | 0 | 859 | 1,745 | 2,839 | 4,164 | 5,564 | 5,564 |
| * Land Acquisition Cost | | | | | | | |

| Profit and Loss Statement (Case C-3) | | | | | | Unit: C$1,000 | |
|---|---|---|---|---|---|---|---|
| | | | | | | | Total |
| | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 | 2000-2005 |
| a. Revenue | | 3,251 | 3,465 | 3,685 | 3,935 | 4,199 | 18,535 |
| b. Cost | | | | | | | |
| b.1 Expenditure | 0 | 2,392 | 2,579 | 2,591 | 2,610 | 2,799 | 12,971 |
| b.2 Depreciation | | 0 | 110 | 110 | 110 | 219 | 548 |
| Cost Total | 0 | 2,392 | 2,689 | 2,701 | 2,720 | 3,018 | 13,519 |
| c. Profit and Loss | 0 | 859 | 776 | 984 | 1,215 | 1,181 | 5,016 |

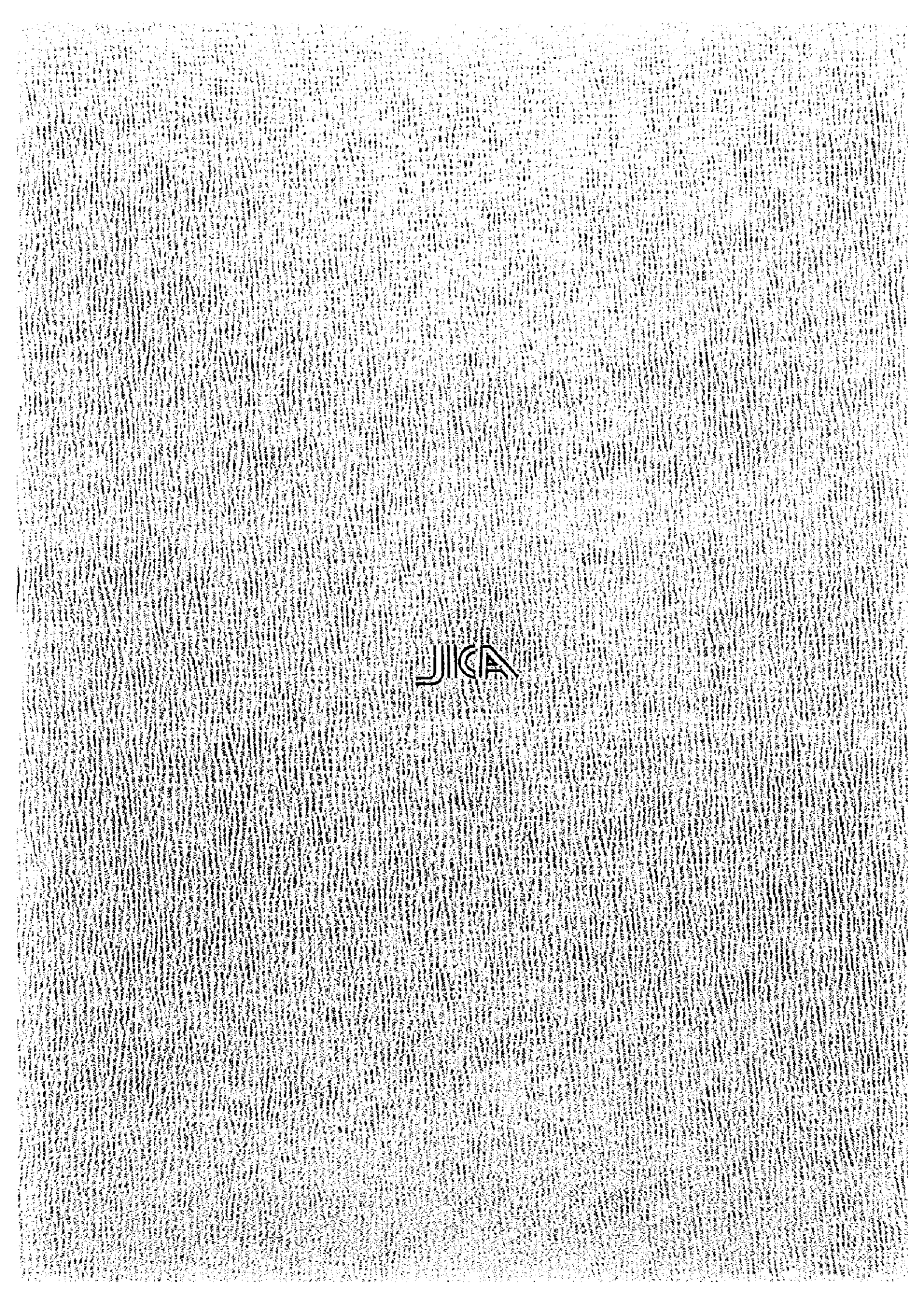
The statement of profit and loss shows positive results from 2001 and the accumulation of about C$5 million in the reserved fund to cover future expenses after 2006.

The investment for the extension of the sanitary landfill level 2 is estimated at C$2 million (C$8 million for a case of level 4) in 2005. The purchase of additional collection vehicles is considered feasible in this case. However, since C$12 million is required to cover the renewal costs for vehicles and heavy machinery in 2007, it is very important to achieve an increase in municipal tax growth rate and to improve the system (i.e. collection services, control of illegal dumping, etc.) till that time.

## U.4 Prerequisite to Make the Level-2 Project Financially Feasible

Table U-5: Prerequisite to Make the Level-2 Project Financially Feasible

| | |
|---|---|
| Municipal Tax Revenue | To secure an annual increase rate of at least 3.4% in the overall municipal taxes.<br>• secure an annual increase rate of 12.1% on vehicle tax revenue<br>• secure an annual increase rate of 14.6% on fixed property tax revenue<br>• to make, as much as possible, the assumed business income tax rate presented in the pessimistic scenario promising<br>• secure an annual tax increase of 5.4% for municipal services |
| Budget Allocated for SWM (%) | • to secure a budget allocation rate of at least more than 8% |
| Household Waste Collection Fee | • joint billing with water supply charges<br>• refuse collection charge according to service level:<br>high service charge: C$15/month/household<br>ordinary service charge: C$10/month/household<br>low service charge: C$5/month/household<br>• refuse collection fee collection rate: 82%<br>• refuse collection fee collection expenses: 5% of the waste collection charges will be paid to INAA |
| Other Waste Collection Fee | • As it is favorable to combine the collection fee with municipal taxes such as business tax, for efficient collection, collection shall be relegated to the municipal tax office as before.<br>• Refuse collection fee:<br>The refuse collection fee is set as follws based on waste volume: C$228/ton for waste collection and disposal, C$87/ton as waste disposal cost (directly transported by generators).<br>• Waste collection fee collection rate: 100% |
| Financial Source | • acquire grant aid to cover entire investment amount for • 2000 (excluding site acquisition cost).<br>• the municipality of Granada will adopt a special budgetary measure to provide the expenses required for site acquisition |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