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A GIS application for remote environmental surveillance in areas of petroleum exploration

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Abstract: this investigation is focused on the evaluation of land degradation and environmental and natural vulnerability for petroleum spills in the canto do amaro oil field area, located in the potiguar basin - rio grande do norte - brazil, through the use of a geographic information system (gis), associated to an environmental and socioeconomic database. the final objective is to subsidize the thematic cartographic basis for the elaboration of contingency plans in case of disasters in areas of petroleum exploration activities. the region is characterized by an intense intervention of antrophic activities, standing out more than 1.700 oil wells, dutes, storage and transport structures of gas and oil, ponds for stabilization and treatment of dejects, pumping and collecting stations, besides marine salt industry and wide areas with activities of shrimp farms. the study has the starting focal point on the geo-environmental monitoring of land degradation through the analysis of georeferenciated multi-temporal images of orbital sensors spot (2000 to 2004) and ikonos (2003), and aerial photos of low altitude. the methodology involved the mapping of the natural resources of the area using the sensor products that were classified through techniques of digital image processing (dip), associated to traditional techniques of field mapping, for production of thematic index maps in detail (1:25.000) and semi-detail (1:50.000) scales, containing information about geology, geomorfology, pedology, vegetation, land use and occupation, and environmental vulnerability to the occupation, as well as to petroliferous exploratory activity, seeking to determine which areas are more susceptible to degradation.

Key Word: Environmental Vulnerability; GIS; remote sensing.

1- Introduction

The Potiguar Basin – main area of petroleum exploration in Rio Grande do Norte State (Brazil) - is an area where in the last two decades Petrobrás (oil Brazilian company) increased considerably their exploratory activities, being the first national field producer of oil in land, and second if considered the production in land and sea. Associated to this activities was an expansion of all exploration infrastructure, increasing the number of wells (more than 3.600), only in the physical area of this project (www.petrobras.com.br) and, consequently, also increasing, it structure of transport of the oil and/or gas for dutes, starting from the new fields, besides the installation of the treatment ponds, places of effluents discard, and treatment of dejects and pumping stations.

Starting from the basic concepts that the disasters are resulting of the vulnerabilities and of the risks linked to the activities super or sub dimensioned, was establish the necessitate to develop a interdisciplinary research focused to the study of the physical-environmental conditions of the main risk areas, defining their vulnerabilities front to the risk to disasters of the exploratory system of oil and gas.

In this context, this proposal intended the evaluation of the environmental and natural vulnerability of this area, through geoprocessing techniques as the thematic cartography, database and Geographical information Systems (GIS), looking for to make available a support tool to the strategy and environmental planning for the exploration area of the Canto do Amaro (RN).

2- Location of the area

The study area is located in the northwest area of the State of Rio Grande do Norte (Brazil), in the municipal districts of Mossoró and distant 260km of Natal. (**Fig. 01**).

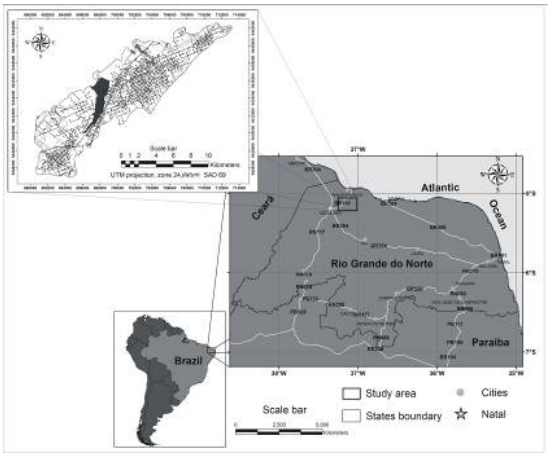

Fig. 01 - Location of the study area

3- Geo-environmental features

The Canto do Amaro field area has approximately 250 km2 were 32 hydro carbonates areas has been identified in depths that vary from 450 to 1000 meters. The main reservoir producing of oil of the field is the Zona Açu-MO2, belonging to the Açu Geological Formation (Cretaceous), possessing a medium depth of 460 meters. The oil found in Canto do Amaro presents API varying between 28^{o} and 44^{o} to depend on the producing area. The spacing among wells varies among 400 meters to 200 meters. Most of the wells has covering of 7 inches and double covering. The total production of the wells drains for 11 collector's stations and then for the central station of the Canto do Amaro. In the central station, part of the produced water is separate and treated in the station of effluents treatment and, to follow reinserted in injection wells that are part of the secondary recovery system that is applied in the Field. The remaining water, together with the oil, it is sent for the station of Treatment of Oil and Effluents in Guamaré (Petrobrás Strategic Plan). The separate water is treated for discard in the sea in agreement with the indexes and parameters allowed by the environmental legislation, and after treatment, the oil proceeds for the refineries through shape oil tankers.

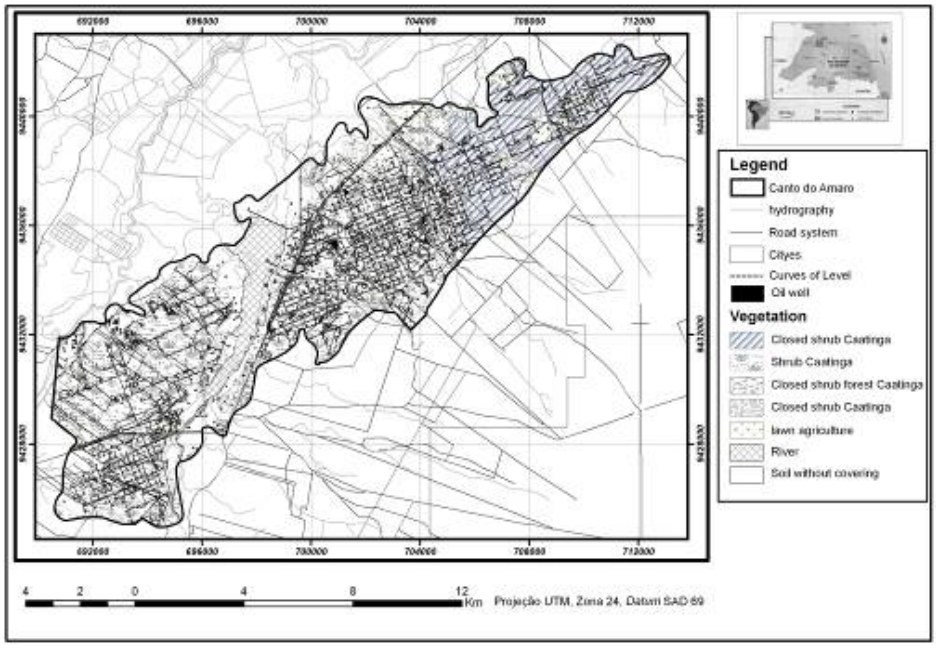

Fig. 02 - Map of the Vegetation

Vegetation: On the vegetation map (**Fig. 02**) it was used interpretation and classification of IKONOS II satellite images. After the interpretation of the images it was made the vetorization of the identified units of vegetation through computer screen. The vegetation of

the Savanna (caatinga) dominates the area of Canto do Amaro, that is formed by plants adapted to the hot and dry climate semi-arid or tropical and that survives with little water, getting to lose their leaves in the periods of larger drought. They present physiognomy that can distinguish in three types: (1) Arboreal Caatinga, (2) Closed Arbustive Caatinga, and (3) Caatinga Opened Arbustive, also denominated of Secondary Savanna.

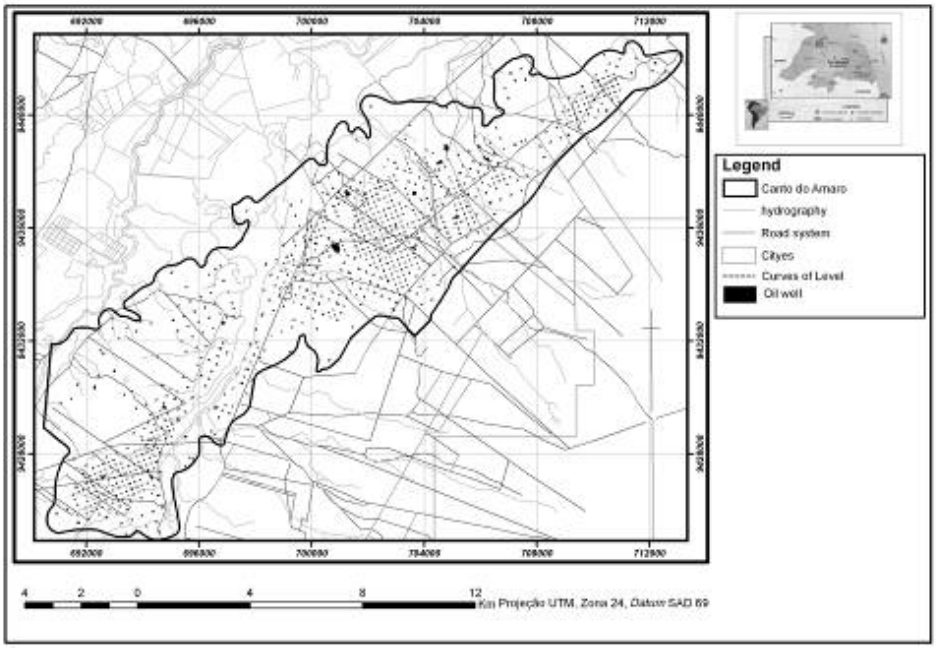

Fig. 03 - Hydrographic Map of the area

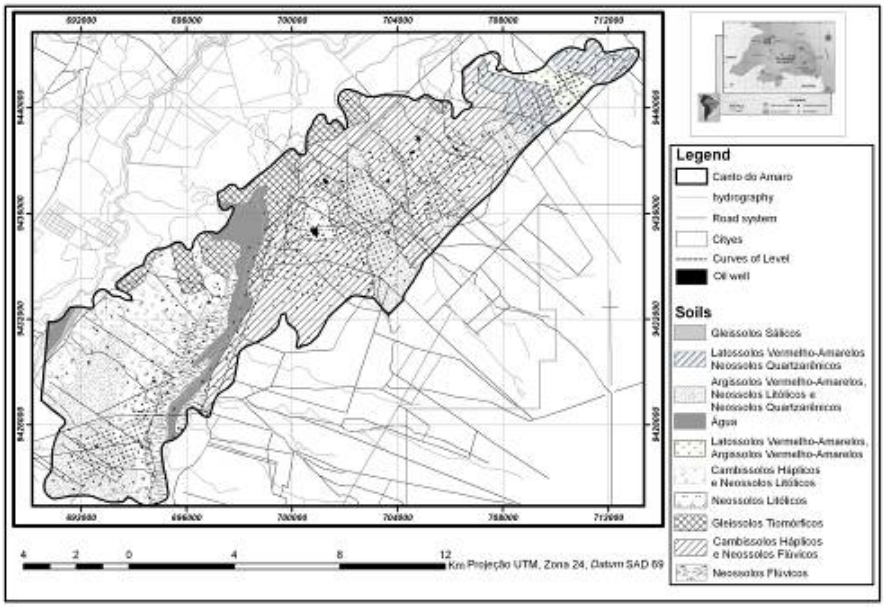

Fig. 04 - Map of the Soils Types

Hydrographic resources: The **figure 03** exhibits the hydrographic map of the area of the Canto do Amaro, which present their main drainages and their dams and existent ponds. For this map were used as base, the topographical map of SUDENE (1982) maps of Areia Branca and Mossoró, in 1:100.000 scale, from where were extracted the main drainages, that were

updated through images IKONOS II, with the mapping of new dams and ponds, as well as for the details of the drainages.

Soils: In the area of the Canto do Amaro eight types of soils were mapped (**Fig. 04**), according to the classification of EMBRAPA-CNPS (1999), the soils of the study area were identified as: (i) Latossolos Vermelho, (ii) Argissolos Vermelho Amarelos, (iii) Neossolos, (iv) Neossolos Litólicos, (v) Neossolos Quartzarênicos, (vi) Neossolos Flúvicos, (vii) Gleissolos Tiomórficos, and (viii) Cambissolos Háplicos.

Geomorphology: The geomorphologic modeling in the study area, is resulting from the geological evolution (regressions and sea transgressions) interacting with the dynamic action of the nature (climate, winds, tides, waves and sea currents) and with the antropic action.

The geomorphologic map of the Canto do Amaro (**Fig. 05**) was elaborated starting from the geomorphologic map of the Rio Grande do Norte State executed by the Project RADAMBRASIL (1981), in 1:1.000.000 scale, in studies developed by IDEMA (2002), and updated starting from the images of satellites IKONOS and field mapping control. It presents the following geomorphologic units: (i) fluvial-marine Plain (ii) Pediplan Surface, and (iii) Tabulate Forms.

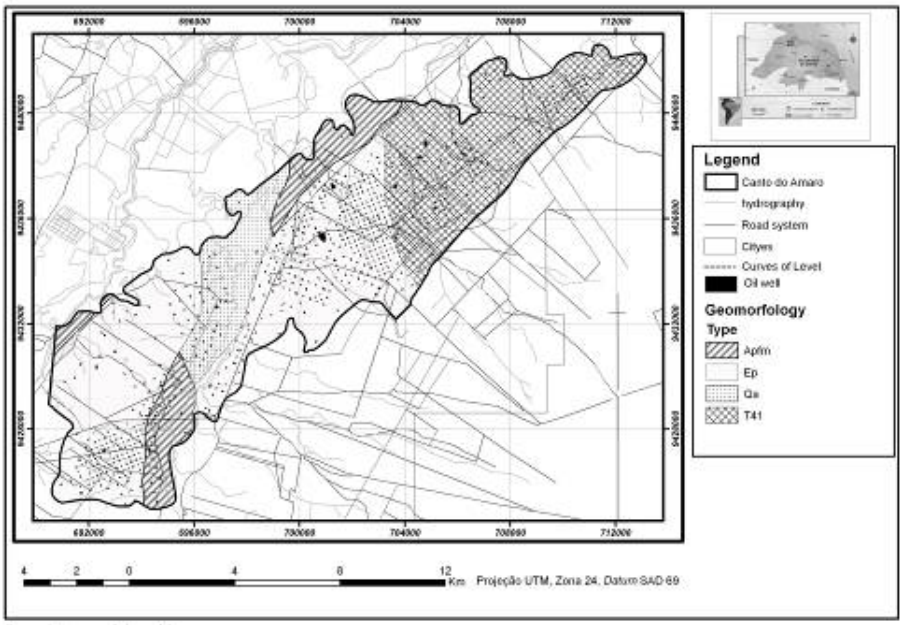

Fig. 05 – The Geomorphologic Map

Geology: The area is inserted in Potiguar Basin geological context, that possesses an area of 48.000km², being 21.500 km² correspond to the part emerged and 26.500 km² the platform and continental slope. As example of other marginal basins, the Potiguar Basin is resulting from the current efforts of the formation of Atlantic Ocean, whose process had beginning in Mesozoic, during the rupture of Gondwana, in Neocomiane. The Basin can be divided in four mega-sequences: Mega-Sequence Mesozoic Rift (Pendências Formation), Group of Sequences Transitional Mesozoic (Pescada and Alagamar Formations), Group of Mesozoic's Sequences Transgress Fluvial-marinas (Açu, Ponta do Mel, Ubarama and Jandaíra Formations) and Group of Mesozoic's Sequences Regressive Fluvial-marinas (Guamaré, Tibau and Barreiras Formations). Completing this last group of sequences is the Quaternary sediments.

The detailed geological map of the Canto do Amaro (**Fig. 06**) was elaborated starting from the compilation of existent data, interpretation of images of the satellites SPOT (1996) and IKONOS II (2003), and complemented and updated for field mapping works. It presents four main geological units: (i) Deposits of plains and tide channels, (ii) Paleocascalheiras, (iii) I Group Barreira (iv) Jandaíra Formation.

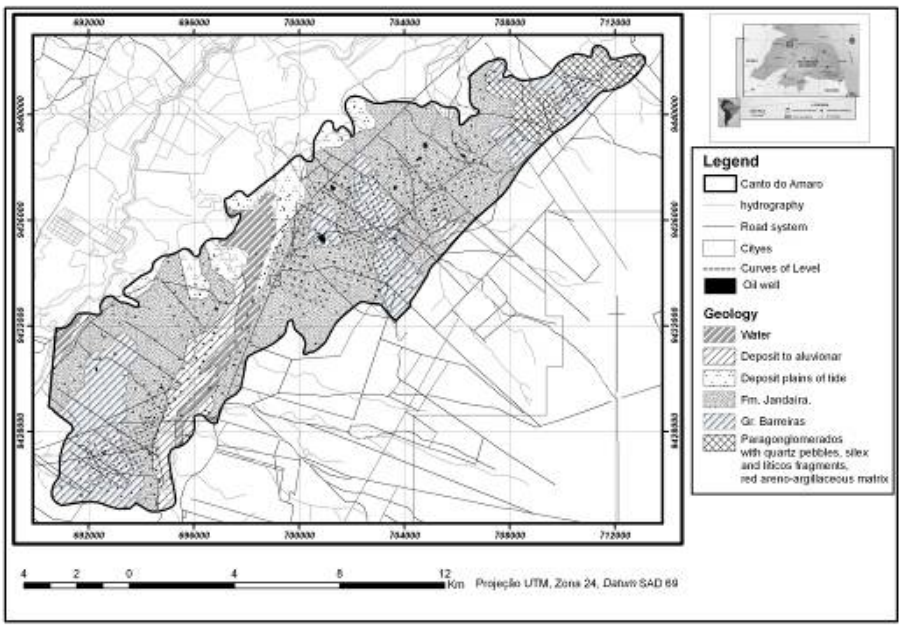

Fig. 06 - Geological Map of Canto do Amaro Field

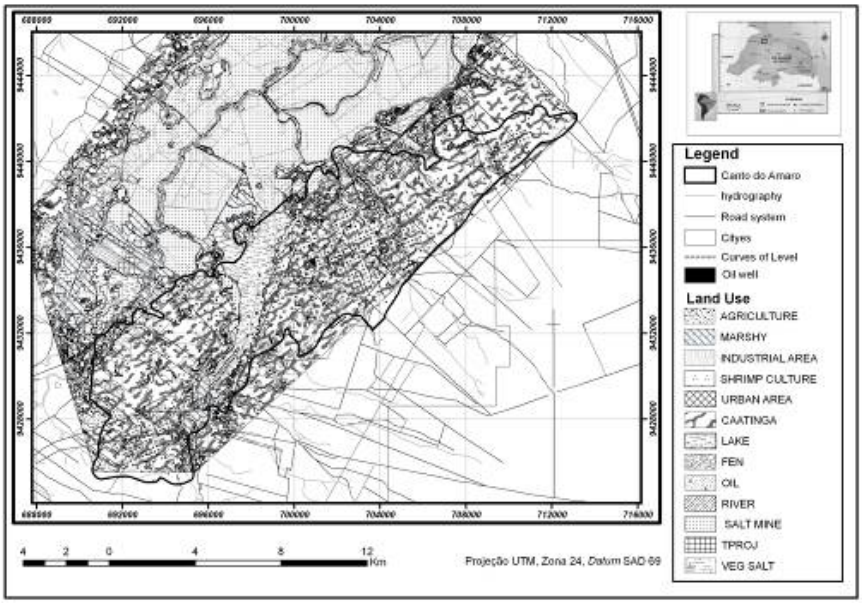

Fig. 07 – Land Use Map

Land use: In the elaboration of the land use map were used IKONOS 2003 satellite images. For the characterization of the types of land use the procedures adopted were contained in the "Technical Norms for Mapping Natural Resources through Remote Sensing" (INCRA, 1995) and in the "Technical Manual of Land Use" (IBGE, 1999). The limit of each class of land use including the road structure and drainages was interpreted and digitalized in the scale 1:2.000

direct in ArcGis over a base image. Starting from the visual interpretation, twelve use classes were identified (Table 1) and used to generated the Land Use map (**Fig. 07**).

Table 01 – Land Use Classes of the area of Canto do Amaro

Class	Area (ha)	Area (%)
Closed arboreal savanna	1772.23	38.96
Closed arboreal arbustive Savanna	317.47	6.98
Open arbustive Savanna	1008.36	22.17
Grassy, agricultural, pioneers	627.59	13.80
Exposed soil	297.94	6.55
Flooded Areas	199.39	4.38
Dam	99.84	2.19
Pond	4.63	0.10
Salines Industries	75.63	1.66
Coletor Station	14.05	0.31
Base of wells	120.06	2.64
Town	18.45	0.41
Total	**4555.17**	**100.00**

4- Remote Sensing

With the purpose of to extract information from the group of IKONOS images and to elaborate the thematic maps of the Canto do Amaro area, treatments of images were generated obtained by the transformation by main components starting from the four spectral bands (blue (1), green (2), red (3) and IVP (4)) of each image. Initially an image was generated containing the information of reflectance of the four bands in a single image, a process that is known as bands fusion, being afterwards this image processed by the analysis by main components (PCA). Finally, they were made the segmentations and supervised classifications, for the method of maxim Verisimilitude and of the Paving, starting from generated PCA, in the intention of identifying possible classes use and occupation of the soil. The definition of the classes or training samples were accomplished starting from preliminary observations done in field, as well as of identifiable features in the own image. The best obtained classification, for this part of the IKONOS image, was the one of maxim verisimilitude using 0,5 as an acceptance probability.

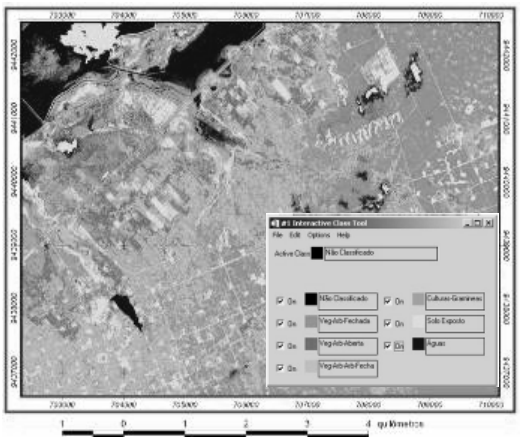

Fig. 08 Supervised classification Using Maxima Verisimilitude's Method, (acceptance 0,5) of Part of the Image IKONOS, Transformed by an PCA.

5- Natural and environmental vulnerability

The first stage of this work consisted of the individual analysis of each one of the information contained in the thematic maps. The group of all those information was integrated to generate and to store a georeferenciated data base with the software ArcGis, making possible a systematic analysis of each element of the thematic maps. On this sense the stored information can be managed to give the possibilities to the crossing of the maps and data that will results in the maps of Natural Vulnerability and Environmental Vulnerability.

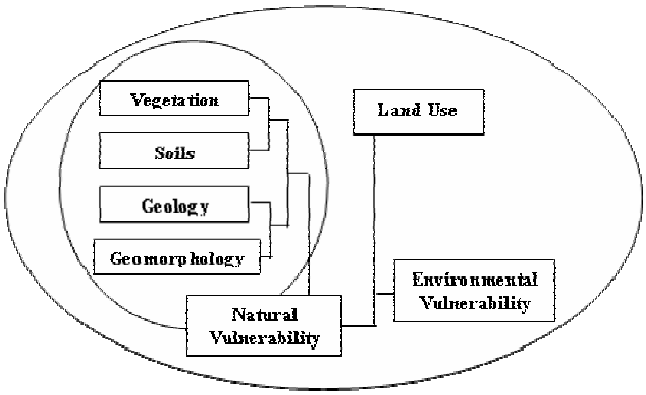

Fig. 09 – Methodology for generate the Natural and Environmental Vulnerability Maps

The map of natural vulnerability seeks to quantify its intensity and distribution in the area of the Canto do Amaro, and the environmental susceptibilities taken into account, the factors of the geomorphology, geology, vegetation and soils, and its stability in relation to the morphogenesis, and pedogenesis effects; while the map of environmental vulnerability refers to the susceptibilities of the environment to pressures anthropics. (**Fig 09**)

The integration of the thematic data was made according to a model modified from Barbosa (1997), Crepani et al, (1996) and Grigio (2003). The crossing of the maps was accomplished in the module Geoprocessing Wizard of the software ArcGis, that it makes possible the crossing among two maps. Firstly, the crossing was accomplished among the maps of geomorphologic units and of geology, and after among the maps of soils association and of vegetation. Soon afterwards, the two maps resulted of the previous crossings were crossed and the arithmetic average of the values of vulnerability of each class was calculated.

The result of the crossings of the thematic maps made possible the creation of the map of Natural Vulnerability (**Figure 10**). With base in the map of natural vulnerability and crossed with the Land Use Map (**Figure 07**), it took place a second crossing that resulted in the map of Environmental Vulnerability (**Figure 11**). The crossing of the maps was based on the concept of unit stability being considered the geodynamic analysis described by Tricart (1977).

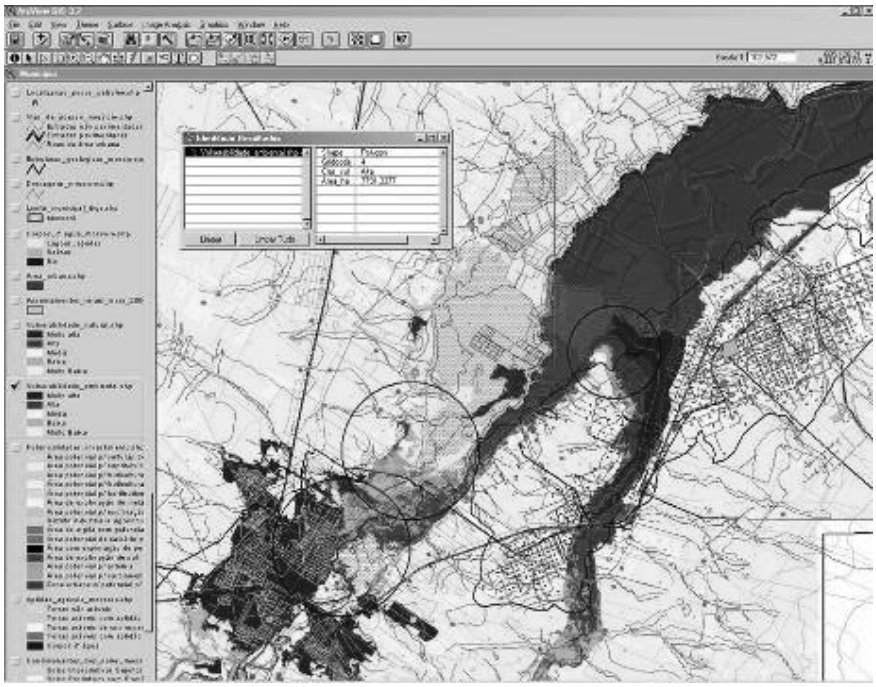

Fig. 10 – Map of Natural Vulnerability on the GIS System —

The Natural Vulnerability Map crossed with the Land Use Maps gives the Environmental Vulnerability Map, that the result can be seen in the **figure 11** that presents the map of the environmental vulnerabilities of the area.

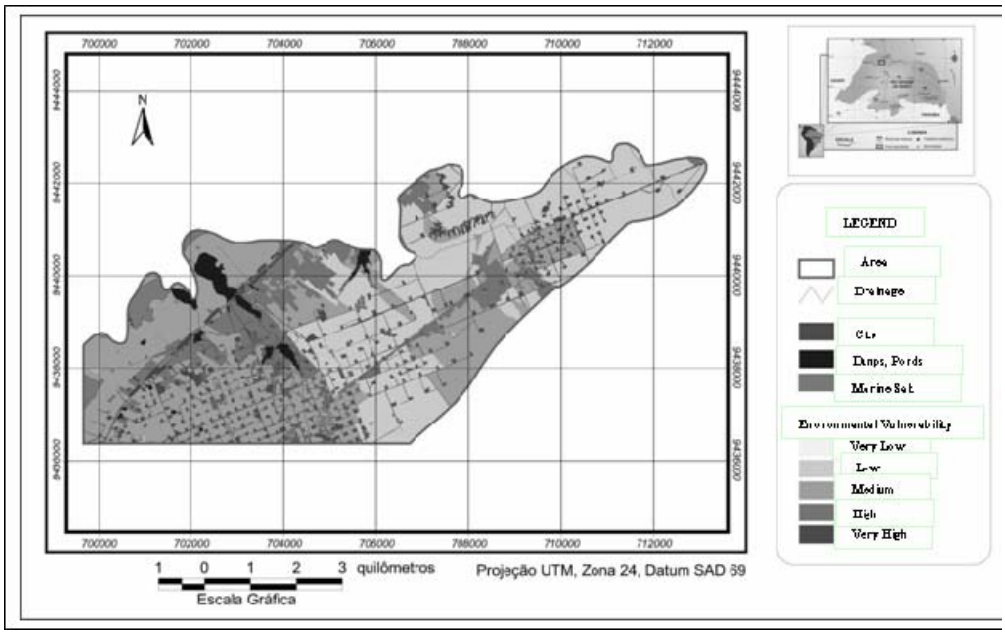

Fig. 11 – Detail of the Map of Environmental Vulnerability of Canto do Amaro

6- Conclusions

The map of natural and environmental vulnerability was possible to be elaborated in function of the existence of a digital georeferencied database which supplied the necessary thematic elements for the study. The analysis of the practical applications of environmental administration will allow to verify it adaptation to the local and regional conditions and to identify the difficulties, limitations and consequences of it implementation in the administration of the petroliferous area of the Canto do Amaro. It could also to contribute positively to the preservation of the environmental resources and prevention of accidents. The interpretative map can become prescriptive, indicating, besides the areas most environmental vulnerable, those more appropriate ones to the development of specific projects.

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