ブラジル連邦共和国

スアッペ臨海工業開発計画

資料No.10

BOOK I

DATA ON LOCAL PHYSICAL CONDITIONS

BOOK I

INDEX

1.0 CARACTERIZAÇÃO GENÉRICA DA ÁREA E DOS LEVANTAMENTOS EFETIVADOS

1.0 GENERIC CHARACTERIZATION OF THE AREA AND OF THE SURVEYS PERFORMED

The area chosen as the location of the Suape Port Industrial Complex extends along the coast to the south of Recife, from the mouth of the Jaboatão river to the Cupe land spit (Pontal de Cupe).

The coast along the area presents two strips with distinct characteristics, the first comprised of beaches from the mouth of the Jaboatão river to Santo Agostinho cape (Cabo de Santo Agostinho) and the other from the south of the cape to the proximity of Ponta do Cupe, characterized by a complex of lagoons separated from the open sea by an extensive chain of reefs.

Between the chain of reefs and Cabo de Santo Agostinho, a bar about 800 meters in length is formed and a lowering in the same permits the access of small craft to the lagoon complex.

This access is found near the mouths of the Massangana, Tatuoca, Ipojuca and Merepe rivers, and the first two are greatly influenced by the tides, which transforms them into veritable extensions of the ocean.

No beach formation can be found along the chain of reefs, except near Ponta do Cupe.

The most significant depths are found to the south of Cabo de Santo Agostinho, with isobaths basically taking an approximate NE-SW direction; in other words, depths increase towards Ponta do Cupe.

Close to the chain of reefs, in a stretch called the Suape basin (Bacia de Suape), isobaths of 13 and 14 meters are recorded, which gradually increase in depth towards the east, reaching 18 meters some 6 km from the coastline; however, at the Ponta do Cupe, similar isobaths are found at about 1.5 km.

In the area inside and contiguous to the chain of reefs, depths are significantly lesser, varying from 2 to 5 meters.

The reef formation, especially to the south of Cabo de Santo Agostinho, is that of a chain with trapezoidal cross-sections, having a base along the top that varies from 25 to 60 meters in width and slopes of approximately 1:3, on the inner as well as the outer face.

Before reaching the Ponta do Cupe, the chain of reefs disappears into the sand and reappears in an outcropping at the cited point, then extends to the vicinity of the 15-meter isobaths, some 1,000 meters from the coast, however with different geometric characteristics: no longer appearing as a chain but rather in a semicircular form and low, submerged.

The area considered for location of the port-related industrial activities covers approximately 300 km^2, including part of the counties of Cabo and Ipojuca.

The areas described, that is, the coastline stretches and the land behind them, underwent analysis of physical conditions in this volume. The surveys performed will be presented, beginning at the coast, in the following sequence:

- bathymetric and geophysical
- hydraulic and sedimentological
- geological
- of water resources
- climactic
- of vegetative cover

1.1 AEROPHOTOGRAMMETRIC SURVEYS

Based on 1:30,000 scale photos of the Department of Aeronautics, restitution work was performed at a scale of 1:10,000 to provide the basic elements for the development of studies.

The entire "legal" area, defined by Decree No. 2845 of the Government of the State of Pernambuco, underwent restitution as did the surrounding area considered to be of interest in developing studies of water supply.

For such, all the necessary topographic support was provided and reference levels transferred to the area of interest, based on the CNG network.

Upon suggestion by TRANSCON, DIPER authorized overflights of the entire area at a scale of 1:5,000 in order to permit restitution of specific areas at a scale of 1:1,000 for use in final design work.

The TRANSCON suggestion was based on the fact that aerial photographs of the region are difficult to obtain due to the frequency of rains and cloudy conditions.

This fact was confirmed in that, having lost the opportunity to fly during the summer, the photographs at 1:5,000 were unavailable at the time of preparation of the Master Plan.

Nevertheless, the material will be of great value in developing final designs, actually indispensable considering the magnitude of the undertaking.

1.2 PERFORMANCE OF BATHYMETRIC SURVEYS

The bathymetric and geophysical surveys were performed simultaneously.

An echo sounding machine was used, Raytheon's type DE-719, recording on electrosensitive paper and with a depth range of up to approximately 110 meters, on the metric scale, with an average precision of ± 10 cm.

Operating, in this case, in parallel with the geophysical surveying system, the two records exhibit identical time and position markings, which allows for exact correlation of depths.

All the depths designated on bathymetric charts refer to a single Level of Reduction (NR), independent of the level of tides at different times during the survey.

The results from use of the echo sounder were reduced to the level NR and the reductions were determined from variations on records from the tide recorder and by utilizing the datum levels read by observers on tide rods.

The surveys covered the area of the Suape basin and that of the mouth of the Ipojuca river, of the area that connects the two basins and by the Massangana, Tatuoca and Ipojuca rivers and the outer area between Cabo de Santo Agostinho and Ponta do Cupe, plus the open sea out to about 7 km.

1.3 PERFORMANCE OF GEOPHYSICAL SURVEYS

Under the title of geophysical surveying—as well as geophysical or seismic sounding or prospecting or acoustic profiling, terms which were used interchangeably—we find a research technique that utilizes acoustics and reflection to obtain data regarding the subsoil.

For this type of research, different types of equipment and performance systems were developed, covering a wide range of applications.

Basically, the method is the same for all: impulses of acoustic energy are emitted in the direction of or transmitted through an area or a volume of a particular material or materials of interest.

The reflected impulses are captured, amplified as necessary, filtered and continuously registered on strips of electro-sensitive paper to be analyzed or interpreted for information which can describe the nature of the materials and the distance to the interfaces between different materials which caused the reflections.

The actual quality of registered data, assuming the use of suitable equipment, depends primarily upon the existence of horizons, or interfaces, between different materials in the subsoil that are capable of reflecting acoustic energy.

Furthermore, differences in the conditions or composition of soils, the degree of solidification, as well as the temperature and water content, also exercise appreciable influence on the reflection properties of the soils and, therefore, on the quality of the registered data.

At Suape, the conditions of materials found proved extremely varied, not readily defined for both this area and for other coastal areas.

Beginning with the water, there are variations from zero to twenty meters in depth, from fresh to salt, and also in temperature, especially at the bottom which is at times composed of organic sediment with absorbing properties and at other times of tightly joined coralligenous sand that forms a compact barrier capable of reflecting acoustic energy.

It was therefore necessary to select the type of equipment best suited to the described conditions, which would be able to generate and emit acoustic impulses that could penetrate thick sedimentary deposits up to a reasonable depth, uniting this capacity with that of showing good results, or detailed records, also of the relatively thin layers of deposits found near the surface, an important consideration in the present studies.

While some systems appear ideal for certain applications, these same systems can manifest relatively little or no usefulness in others.

At the start of the work, the properties of the soil were as yet unknown and simple caution demanded that more than one type of equipment be used. Thus, during the first days (actual tests and surveys) another type of acoustical tool was kept as a stand-by, in case the results of the first did not prove satisfactory.

The equipment adopted was an integrated system, with balanced and calibrated components, which basically included:

- Group (bank) of rectifiers/capacitors, with floats—300 W/sec, 3.5 kV

- Acoustic impulse emitter - transducer, with floats

Level of power:	100-300 W/sec
Duration of impulse:	0.2 milliseconds
Acoustic level:	95-107 db
Spectrum:	400 Hz - 14 kHz
Frequency:	2-6 impulses/sec

- Dynamic hydrophones, encapsuled and self-floating

Sensitivity:	103 db
Spectrum:	100 Hz - 10 kHz

Both the impulse emitter and the hydrophones are towed by craft.

- High power sound amplifier and wide range filter, electronic

- Continuous recorder/register for electrosensitive paper, incorporating a time marking device, a tripped control for the emitter, sound amplifier and multiple filters to eliminate unwanted noises

- Diesel electric generator group, 7.5 kW, 110 V, 60 Hz

- Electric (gasol) generator group, 1.5 kW, 110 V. 60 Hz

- Batteries and accumulators of various types

1.4 PERFORMANCE OF GEOLOGICAL SURVEYS

The area studied covers about 300 km^2, bound on the north by the Jaboatão river, on the south by a line that joins Ponta do Cupe with the city of Ipojuca, on the east by the Atlantic Ocean and on the west by a line that follows the PE-060 highway at a distance of about 3 km.

The purpose of geological mapping is to provide elements needed to carry out the Master Plan for the Suape Industrial Complex, thus defining the problems that must initially be confronted in occupying the land, in infrastructure construction work and, finally, suggesting some solutions for these problems.

First, geological mapping was performed based on 1:30,000 scale aerial photographs that were taken by FAB (the Brazilian Air Force) in 1970 and on local inspections by land and over-flight. Once data were gathered, preliminary photointerpretation was revised which resulted in the general geological map presented herein.

This mapping provided the first indications of the possible technical feasibility of the excavated port solution, and recommended geotechnical reconnaissance which could better define the sedimentary areas to the south of Cabo de Santo Agostinho, primarily, as well as substantiate the interpretation of geophysical surveys of the ocean area.

Later, detailed field reconnaissance was performed, with the support of geophysical investigation (on the land area as well as in the water), percussion and rotary drilling in preselected locations and, further, jet-probes of the ocean bottom.

The results of geophysical and geotechnical surveys thus permitted sounder confirmation of geological maps that presented alternative port concepts for the excavated port solution and a definition of the urbanization concept, together with other pertinent factors.

The excavated port solution was then investigated in terms of analyzing the technical feasibility of establishing canals with natural banks; such investigation, considering the preliminary routes of canals and maneuvering basins, made necessary a geotechnical drilling program with a greater density and more accurate tests to establish the basic characteristics of canals and basins, types of margin protection work, operating structures and the other elements in terms of soil mechanics for the purpose of project development.

1.5 WATER RESOURCES

The general hydrological diagnosis of the region was made for future water supply, sewage and rainwater drainage systems design.

The diagnosis consisted of the survey of local water resources and hydrographic mapping of the area. The area included the surface and subsurface waters in the Suape area of influence.

A hydrometric program was also developed to support hydrological studies of the Pirapama river, in the tributary area of Matapagipe. TRANSCOM has six pluviometric stations in operation in the Pirapama river basin, collecting data to supplement specific hydrological studies.

The geographic scope of the studies performed basically includes the river basins of the Pirapama (the control area above the Engenho Matapagipe station) and the Ipojuca (the control area above the Primavera or Engenho Tabocas station). This area can be determined approximately by the 8°10' and 8°30' parallels and the 35°00' and 37°00' meridians. The area of hydrogeological investigation was limited to formations which presented aquiferous possibilities, corresponding to sedimentary areas resulting from contact with crystallin, situated between the 8°27'48" and 8°16'57" parallels and the 34°55'00" and 35°03'45" meridians.

The conclusions of the study, which was performed at a regional hydrological level and was of a pioneering nature, should be used as orientation in proceeding with complementary studies for dimensioning specific designs.

The objective established at first was to study the surface source of the Pirapama river, in the tributary area of Engenho Matapagipe, which is already part of a final design nat must be revised. As for the Ipojuca river basin, the objective was to study the flooding problems in the area.

The findings of these studies and the possibility of developing industries with high water consumption rates pointed out the need to widen the scope of the surveys.

The studies were supported by hydrological data furnished by the Hydrology Division of SUDENE. The results of observations made by the SUDENE fluviometric stations, in Primavera and Engenho Maranhão, on the Ipojuca river, served as correlation with the Pirapama river. The stretch between these stations, on the Ipojuca, represents a physiographical zone similar to the controlled zone, on the Pirapama river in Matapagipe, despite the fact that the basic drainage of the cited stretch of the Ipojuca is augmented by a small amount of infiltration coming from the part of the basin situated in the agrestic zone, above Primavera.

Later studies of hydrological characteristics of the soil-vegetation complex also provided evidence of the similarity between conditions of the region and of the basins near the Goitá and Tapacurá rivers, on which series of hydrometric data have previously been obtained. However, the Tapacurá basin no longer permits parallel observations because of the reservoir that now exists there.

A summary analysis of the already existing design for the Matapagipe dam recommended that the design be restudied for modification, in view of the factors not available at that time, basically:

- Height of the dam established too low to avoid flooding a plant railroad, not yet built, a fact that limited greatly the regulating capacity of the reservoir and impeded the control of floods.

- Deficiency still in the geotechnological study.

- The need to revise hydrological studies for the design in view of the new information now in existence, and of other information which may soon become available, providing greater economization for the design.

Field and office work, with available aerial photographs and aerophotogrammetric restitutions, made possible a preview into aspects of the capture and future supply of water to areas of the Suape complex for consumption. The favorable technical flexibility became evident of some day integrating the two systems, Pirapama and Ipojuca, which constitute the primary sources of water for Suape. Such integration would be accomplished by an operational reservoir located on the Massangana river and nearby streams, which by means of small repressions would receive water from the Pirapama as well as the Ipojuca, besides being able to count on a small contribution from the Massangana river itself.

2.0 LEVANTAMENTOS BATIMÉTRICOS E GEOFÍSICOS

2.0 BATHYMETRIC AND GEOPHYSICAL SURVEYS

2.1 TOPOGRAPHIC SUPPORT

Topographic services consisted of implementing a third order triangulation network in the area between Cabo de Santo Agostinho and Ponta do Cupe; employing open polygons that correspond to the margins of the Suape basin and of the Massangana, Tatuoca and Ipojuca rivers and, finally, locating and levelling the tidal rod and the vertices.

Triangulation operations were repeated at least three times.

The polygons were established with double-distance readings, forward and backwards, and with bi-supplementary horizontal angles.

Levelling was performed in the classical meth.d, with the first and second levellings done in the same direction, equal to counterlevelling.

Four vertices were located and concrete markers were set, following one line alone which corresponds approximately to the longitudinal axis of the line of reefs, with an azimuth at 23° 34'58" NE and a length of 4,811 meters between the vertices of Recife-1 and Recife-8.

Twenty vertices were located on land and concrete markers set, named as per the respective regions.

Following are descriptions of the topographic support points utilized, their location and characterization. Some were integrated in the support network "a posteriori" for the restitution at 1:10,000, based on the CNG network and therefore also marked with the labels used by AERODATA.

E-O, Marégrafo - R.N.-21 AERODATA concrete marker in a rock named Pedra da Preguiça, very close to the tide recorder, beside two babaçu palm trees.

E-3, Suape: concrete marker, containing a metal disk, inscription Hidroport Est.-E-3, Alt. + 3,316, located on the elevated part to the NW of Suape beach.

E-7, "A" of the base: concrete pillar (1.20m), containing a metal disk, no inscription, with two intersecting axes at 90° defining the vertex, located on the elevated part of the point at Suape beach.

E-8, "B" of the base (PP-72 AERODATA): concrete pillar (1.20m), containing a metal disk, no inscription, with two intersecting axes at 90° defining the vertex, located to the SW of the point at Suape beach, between palms.

Areia Preta, R-O: Encal origin, concrete pillar, containing a metal disk, with two intersecting axes at 90° defining the vertex, located on the elevated part of the beach on the right hand margin of the mouth of the Tatuoca river, a little to the E of a bunch of palms.

Franceses: Encal origin, concrete pillar, containing a metal disk, with two intersecting axes at 90° defining the vertex, located on the beach with the same name.

Outeiro Alto: concrete pillar, containing a metal disk, no inscription, with two intersecting axes at 90° defining the vertex, located on the elevated part at the extreme south of Outeiro Alto beach.

Banquinhos: concrete pillar, containing a metal disk, no inscription, with two intersecting axes at 90° defining the vertex, located on the elevated part of the Banquinhos point, SW of Outeiro Alto beach, near fishermen's houses (Sr. Sebastião Cabral de Souza).

Concórdia: concrete pillar, containing a metal disk, no inscription, with two intersecting axes at 90° defining the vertex, located on the left hand margin of the mouth of the Ipojuca river, approximately 200m from the Banquinhos vertex.

Ipojuca: concrete pillar, no inscription, with two intersecting axes at 90° defining the vertex, located at the top of a sand wall at Gamboa beach.

Muro Alto: concrete pillar, no inscription, with two intersecting axes at 90° defining the vertex, located at Gamboa beach on top of a sand wall and to the south of the Ipojuca vertex.

Decca: concrete pillar, containing a metal disk, no inscription, with two intersecting axes at 90° defining the vertex, located at the slope of the hill to the north of Suape beach.

Forte de N. Srã. de Nazaré: Encal origin, concrete marker set between rocks on the wall of the fort by the same name, containing a metal disk with a definition of the vertex.

Farol: DHN marker.

Cupe: DHN marker.

Recife-1: concrete marker, located among the rocks on the reef, located approximately 100m from the sandbar, on the extreme north of the reef line.

All markers on reefs have as the central point a plastic tube cemented into the marker itself.

Recife-3: concrete marker, located among the rocks on the reef, approximately 300m to the south of a ship's hull on the reefs, almost "in front" of the Franceses point.

Recife-5: concrete marker, located among the rocks on the reef, located near the small sandbar and "in front" of Outeiro Alto beach.

Recife-8: concrete marker, set among the rocks of the reef, located "in front" of the mouth of the Ipojuca river.

(The Recife-1, 3, 5 and 8 markers obey the same alignment.)

Recife-10: concrete marker, set among the rocks of the reef, located "in front" of Gamboa beach and the Muro Alto vertex.

All other vertices pertaining to the support polygons are wooden stakes sunk in the ground with a small identification stake alongside.

Following are the UTM plane coordinates of the points of topographic support:

1) Farol de Santo Agostinho	(DHN)	N. =	9.075.948,90
		E. =	285.701,92
2) Cupe	(DHN)	N. =	9.064.254,94
		E. =	281.738,53
3) Forte Nazaré	(Encal)	N. =	9.075.162,68
		E. =	285.976,35
4) Franceses	(Encal)	N. =	9.073.917,53
		E. =	284.669,40
5) Areia Preta	(Encal)	N. =	9.073.003,03
		E. =	283.944,08
6) Marégrafo — E-0	(HP)	N. =	9.075.314,00
		E. =	285.313,45
7) Suape — E-3	(HP)	N. =	9.075.544,11
		E. =	284.834,50
8) Pontal — E-8	(HP)	N. =	9.074.487,41
		E. =	28[illegible].514,55

9) E-7	(HP)	N.	=	9.074.775,06
		E.	=	284.546,50
10) Recife-1	(HP)	N.	=	9.074.468,33
		E.	=	285.743,30
11) Recife-3	(HP)	N.	=	9.073.203,82
		E.	=	285.191,24
12) Outeiro Alto	(HP)	N.	=	9.072.612,62
		E.	=	284.548,24
13) Recife-5	(HP)	N.	=	9.071.560,78
		E.	=	284.648,46
14) Banquinhos	(HP)	N.	=	9.070.528,64
		E.	=	283.482,70
15) Recife-8	(HP)	N.	=	9.069.995,00
		E.	=	283.790,54
16) Ipojuca	(HP)	N.	=	9.069.134,00
		E.	=	283.021,78
17) Recife-10	(HP)	N.	=	9.068.976,27
		E.	=	283.345,60
18) Muro Alto	(HP)	N.	=	9.068.718,93
		E.	=	282.970,46
19) Decca	(HP)	N.	=	9.075.686,18
		E.	=	285.172,64
20) Ponto "O"		N.	=	9.078.318,456
		E.	=	286.710,219

OBS:

1) The "Concórdia" point was determined by stadimetry and does not have UTM plane coordinates.

2) The azimuth of the reef line, according to vertices "Recife-1" and "Recife-2", is 23°34'58" NE.

3) Considering the performance of hydrographic work, implementation of the triangulation network followed the third order level.

For the purpose of supporting hydrographic surveys, one tide recorder and 26 tide gauges and limnometers were located in the areas inside the reef chain, supported by a network of Level References (RNs) appropriately positioned.

Based on the altitudes transferred from the city of Cabo to the Suape area, a network of RNs was established to support the tide recorder, tide gauges and limnometers. These RNs were established on wooden stakes, with concrete markers used only in strategic positions when necessary.

These are:

HIDROPORT's RN.0 that coincides with the vertex E-O belonging to HIDROPORT and with AERODATA's RN 21;

Galheta GN;

HIDROPORT's E-7 and E-8, with whose vertices E-8 coincides with AERODATA'S PP72;

RO, the point of a HIDROPORT polygon and coinciding with the point called Areia Preta, left by Encal from previous surveys;

Francês vertex, from the HIDROPORT triangulation and coinciding with Encal's Francês point;

Forte de Nazaré vertex, from the HIDROPORT triangulation network, also coinciding with the Encal Forte point;

Outeiro Alto vertex from the HIDROPORT triangulation network;

Banquinhos vertex, from the HIDROPORT triangulation network;

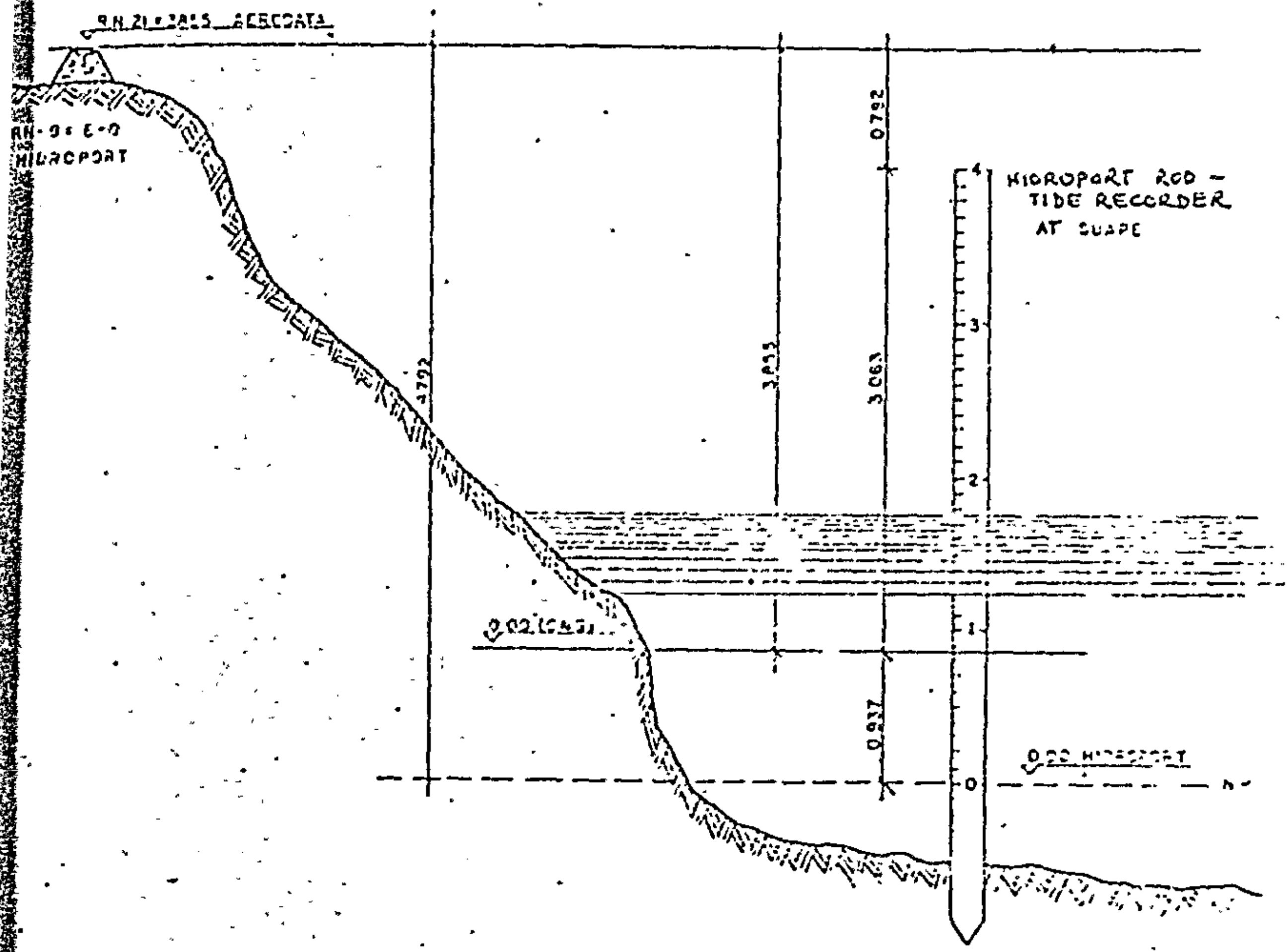
Concórdia vertex located near Banquinhos, obtained by taqueometry and not part of the HIDROPORT triangulation network; set merely for operational purposes;

Ipojuca vertex, from the HIDROPORT triangulation network;

Muro Alto vertex, from the HIDROPORT triangulation network.

Another point worthy of mention is the Cupe RN, which consists of a concrete marker with a bronze DHN plaque and served as a polygonal vertex for AERODATA and as support for the hydrographic survey performed by HIDROPORT.

A weekly tide recorder, type HI, model S, was placed in the Suape basin, near Cabo de Santo Agostinho, between the fort at Pontal de Nazaré and the Suape beach in a location known as Pedra da Preguiça. Its temporary installation was on wooden stakes, covered and protected from the weather.



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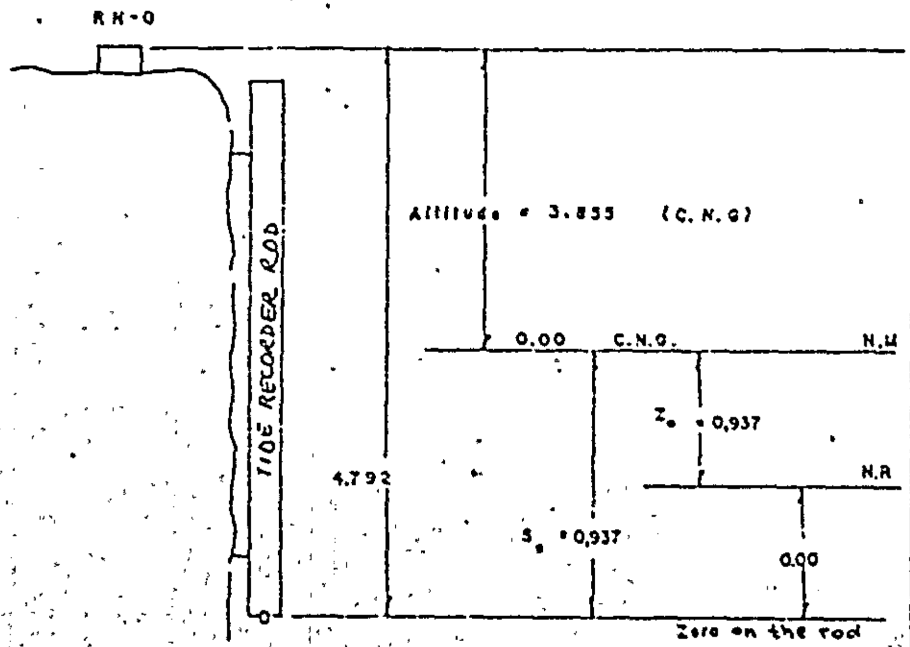
DE PERNAMBUCO

COMPLEXO INDUSTRIAL DE SUAPE

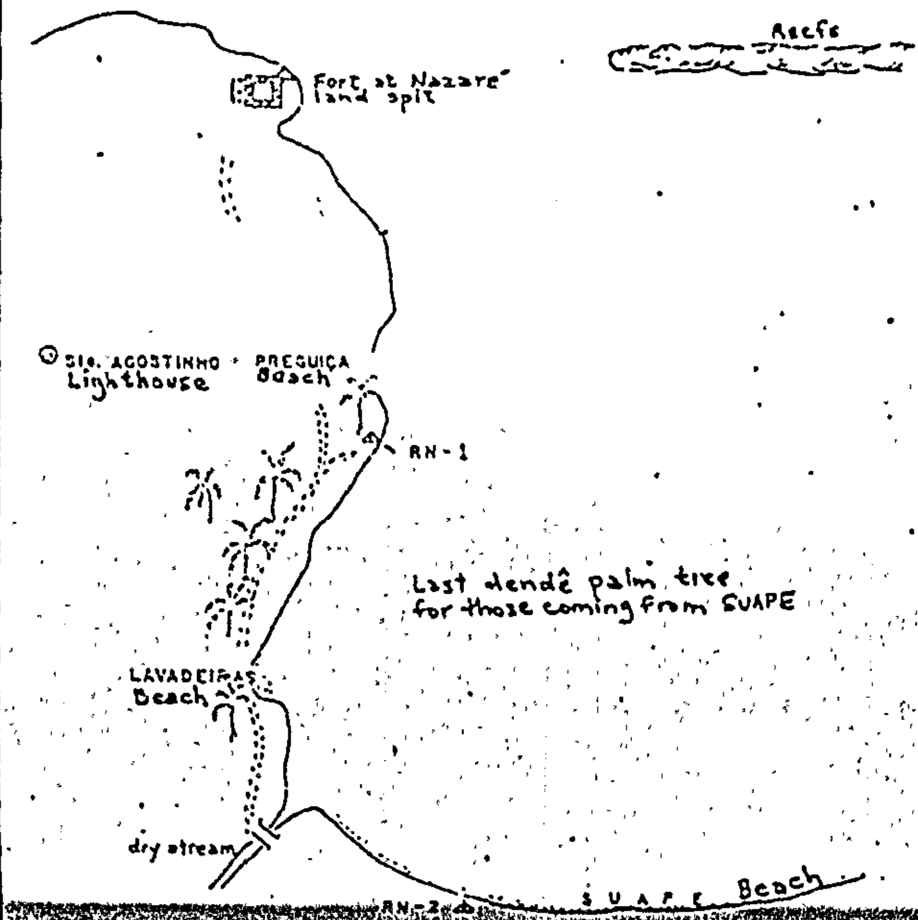
CALIBRATION
TIDE RECORDER ROD
SKETCH

TRANSCON SA

DIAGRAM



LAYOUT



OBSERVATIONS

People who know the area (residents)

MANOEL MARIANO

GILDO

diper

COMPLEXO INDUSTRIAL DE SUAPE

TIDE RECORDING STATION LOG

F – – /

Station: SUAPE (Cabo de Sto. AGOSTINHO) State: PERNAMBUCO Locale : SUAPE

Survey – Map Nº 930 Team : HIDROPORT Year: 1974

Geographic coordinates

Lat.

Long.

Fuse.

Tide recorder: HIDROLOGIA – Weekly model (HI – model 5)

Zero on tide recorder 0 cm from zero on the rod A (TIDE RECORDER)

Description of tide rods

Rod A (of TIDE RECORDER)

4-meter wooden rod, with centimeter graduations, attached to one of the stakes supporting the station structure

Description of level references

RN ·0
BASE OF PYRAMID IN CEMENT OVER STONE SLAB CONTAINING A METAL DISK WITH THE INSCRIPTION – HIDROPORT – RN Nº 0
ALT. 3.8559

TECHNICAL FILE

Received on:

Reference documents:

People involved in assembly
PRISTA – LUIZ – ROBERTO – ARMANDO – WALOIR – ANTONIO CARLOS and four other divers

Head of team: LUIZ Date:

diper

COMPLEXO INDUSTRIAL DE SUAPE

DESCRIPTION OF TIDE RECORDING STATION

TRANSCON SA

A rigid PVC tube, 200mm in diameter, was used as a regulating pit, buried in the bottom with one opening 7mm in diameter, situated approximately at the -0.30m mark on the tide rod, attached to one of the stakes. The tide recorder findings are referenced to the zero mark on this rod which, in turn, is gauged with the RN-1 HIDROPORT (RN-21 AERODATA). The zero mark on the rod can be found 4.792m below the RN, whose datum line is at 3.855m, as shown in the drawings. Tide recorder station forms were filled out, according to DHN (Diretoria de Hidrografia e Navegação da Marinha—the Navy's Office of Hydrography and Navigation) regulations.

As a result, tide charts are obtained weekly and serve as reference for widely varied services and studies being performed or to be performed in the Suape area.

The Level of Reduction (NR) for soundings was obtained by transfer from Recife to Suape, Galheta and Cupe, utilizing the methodology indicated by the DHN to do so which consists of simultaneous comparison of the tide at a location with a known NR and one to be established, continuously, during a time period encompassing four tide low points, on the occasion of spring tides. The NR values obtained are as follows:

Suape (tide recorder): 0.937m below the CNG zero and 0.008m above the zero on the tide recorder rod.

Galheta: NR situated 0.13m above the zero on the Galheta rod and 1.062m below the CNG zero, transferred to the location by AERODATA.

Cupe: NR situated 0.09m below the zero on the Cupe rod and 1.038m below the CNG zero transferred by AERODATA.

The correlation of the level reference (RN) and reduction levels (NR) between Recife and Suape can be found at the end of this section.

For the transfer of NR and reduction or reference of hydrographic services, 25 tide gauges and limnometers were installed, besides the previously cited tide recorder, and were related to the mentioned RNs and these latter to the local polygons or triangulation network.

The tide gauges and limnometers are indicated below:

Galheta (G)	1
Suape (S-1 and S-2)	2
Massangana (M-1 to M-7)	7
Tatuoca (T-1 and T-7)	7
Franceses (F)	1
Outeiro Alto (OA)	1
Banquinhos (B)	1
Manē Velho (MV)	1
Ipojuca (I)	1
Merepe (ME)	1
Ponto do Sītio (PS)	1
Cupe (C)	1

The tide gauges and limnometers are related to nearby RNs and these to local polygons or the triangulation network.

Comparison is shown in diagrams for each rod together with one plan which indicates the location of all the RNs and another the altitudes of each.

To transfer the NR, simultaneous and uninterrupted readings were taken in Recife, on the Suape and Galheta tide recorder rod, on the 23rd, 24th and 25th of January, 1974, at spring tide, during the new moon; and on the 6th, 7th and 8th of February, 1974, in Recife, on the Suape and Galheta tide recorder rod, at spring tide, during the full moon.

With these readings, it was possible to obtain the data needed for the NR transfer from Recife to Suape, Galheta and Cupe, indispensable to the reduction of bathymetric and geophysical soundings in the Suape area.

The transfer calculations and the NR values in the locations mentioned are presented at the end of this section.

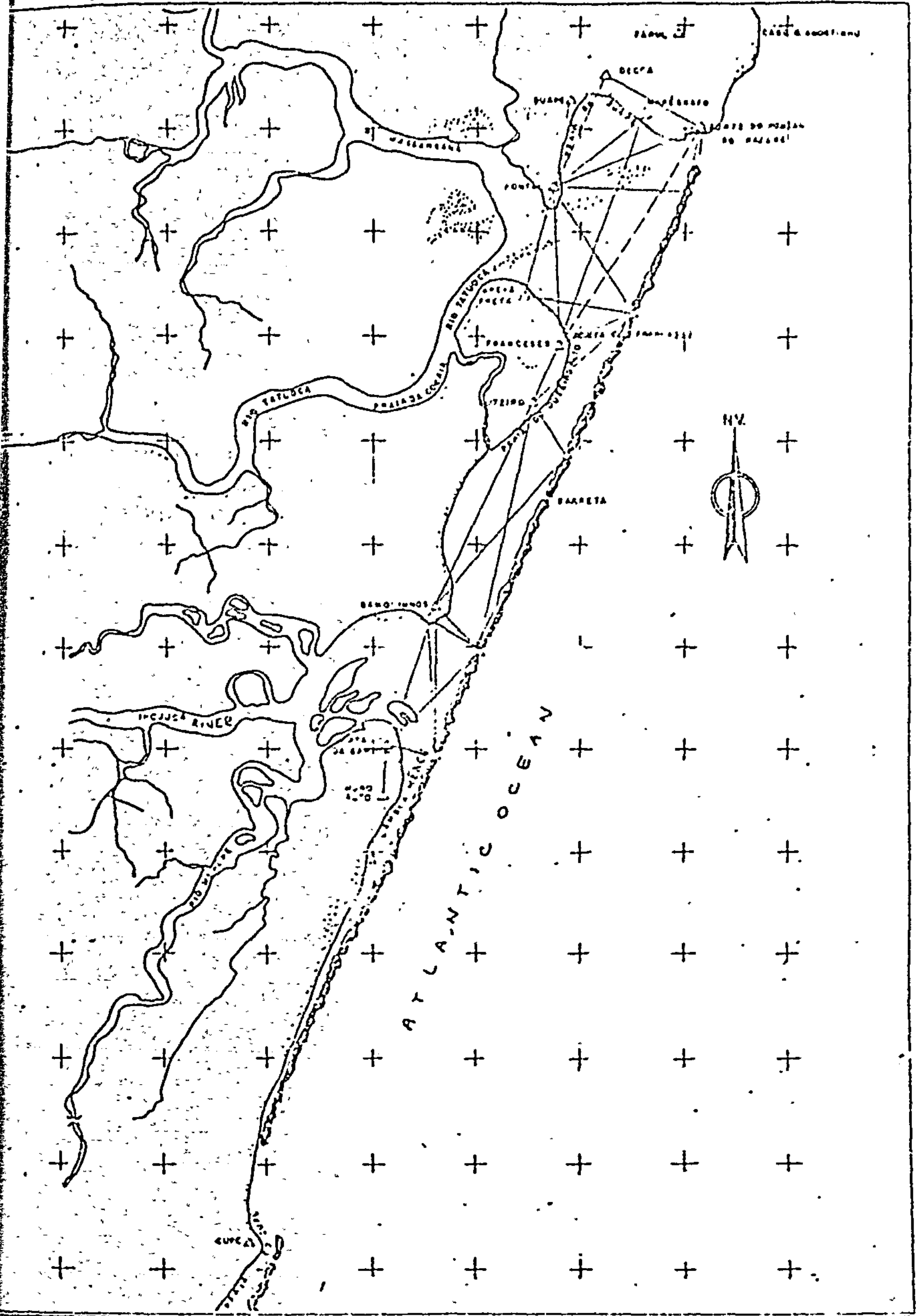
Finally, the electronic method was utilized for positioning the craft along the lines followed in the ocean, which offers excellent reliability at any time, as well as accurate, practical and rapid operation.

The equipment utilized was the Trisponder Survey System, type 202-A, manufactured by DECCA Survey Limited.

The system involves three stations, minimum, one mobile—the interrogator, mounted aboard the craft—and two, three or even four remote response units, on land, in locations with visible geodesic markers.

The positions of markers are those previously determined by the topographic support described before.

The interrogator station emits short-range microwave signals, alternately, in the direction of response stations. The time elapsed for this interrogation is detected and translated into the distance in meters existing in a given moment between the craft and the stations, calculated and registered (plotted) continuously, permitting a faithful reproduction of the lines travelled.



diper

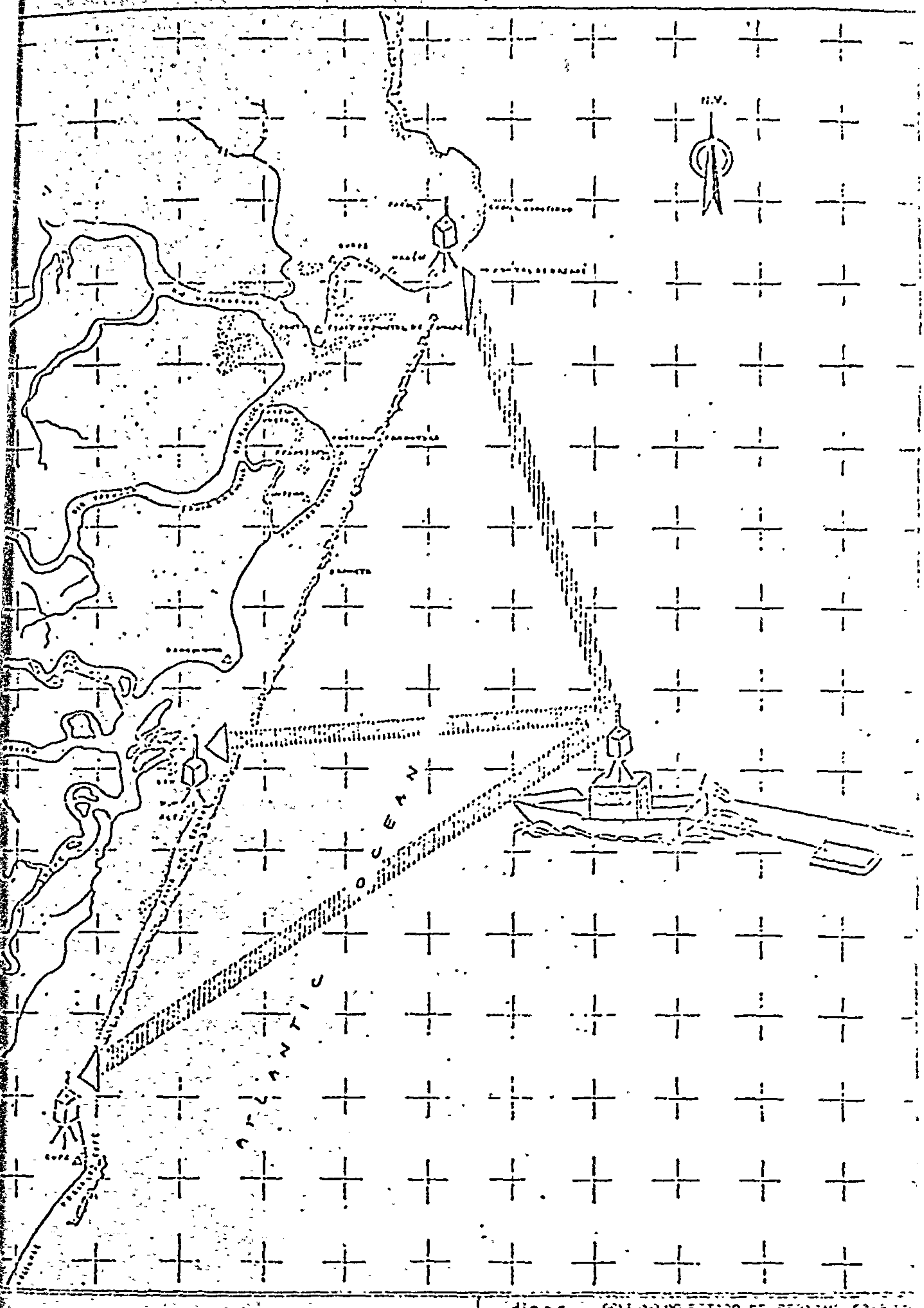
GOVERNO DO ESTADO DE PERNAMBUCO
COMPANHIA DE DESENVOLVIMENTO INDUSTRIAL
DE PERNAMBUCO

COMPLEXO INDUSTRIAL DE SUAPE

TRIANGULATION NETWORK

TRANSCON SA

1:30.000



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ELECTRONIC POSITIONING LAYOUT

COPY

HIDROPORT - Estudos e Projetos Ltda.

LP - 082/73 Rio de Janeiro, December 18, 1973

DIRECTOR OF HYDROGRAPHY AND NAVIGATION
D.H.N.
Ilha Fiscal
Rio de Janeiro

As HIDROPORT - Estudos e Projetos Ltda was authorized by you on December 11 of this year to perform surveys of a hydrographic nature on stretches of the Pernambuco coastline, near Cabo de Sto Agostinho, we hereby request the data below needed to perform the services:

a) Level of Reduction adopted by the DHN for soundings performed between Cabo de Sto. Agostinho and Pontal de Cupe;
b) Data on the closest RNs;
c) Copy of the logs that contain the stretch of coastline cited in "a"; and
d) Confirmation that the coordinates and azimuths below are correct:

Sto. Agostinho lighthouse

Lat =	02°21'16"954 S	N =	9.075,948,90
Long =	034°36'45"328 W	E =	286.701,92

Cupe vertex

Lat =	08°27'36"872 S	N =	9.064.254,94
Long =	054°58'56"771 W	E =	281.738,53

Jordão vertex

Lat =	08°08'13"347 S	N =	9.0100.028,91
Long =	034°56'28"784 W	E =	286.091,15

Cupe azimuth vertex - Sto. Agostinho lighthouse - Jordão vertex Az = 181°12'19"00

Cupe azimuth vertex - Sto. Agostinho lighthouse Az = 199°00'46"00

We anxiously await the above information and thank you in advance for your attention to this matter.

HIDROPORT - Estudos e Projetos Ltda.

s/

OFFICE OF HYDROGRAPHY AND NAVIGATION
DEPARTMENT OF THE NAVY

Rio de Janeiro, __ December 1974

ER/10

COPY

No. 0003 (DHN-10)
CLÁUDIO VESPA DE GUANABARA
MANAGER, HIDROPORT, ESTUDOS E PROJETOS LTDA.
RUA MEXICO, 111/1702
RIO DE JANEIRO, GB.

Dear Sir,

I was requested by the Director of Hydrography and Navigation to forward the data solicited in your letter No. 082/73, as mentioned below:

a) The Level of Reference (RN) closest is the bronze pin, 5/8", set in a pillar 10" in diameter, with 3" of height, situated on the breakwater 267 feet to the SSW of the W corner of the Picão lighthouse. In the concrete is the inscription "18-8-1948-7º D";

b) The Average Level (NM) is located at 275 cm below the Level of Reference (RN) described.

The Level of Reduction is 114 cm below the Average Level (NM);

c) The geographical coordinates of the Sto. Agostinho lighthouse and the Cupe and Jordão vertices are hereby confirmed.

OFFICE OF HYDROGRAPHY AND NAVIGATION
DEPARTMENT OF THE NAVY - ILHA FISCAL - GB/RJ

OFFICE OF HYDROGRAPHY AND NAVIGATION
DEPARTMENT OF THE NAVY

COPY

ILHA FISCAL RIO DE JANEIRO
BRASIL

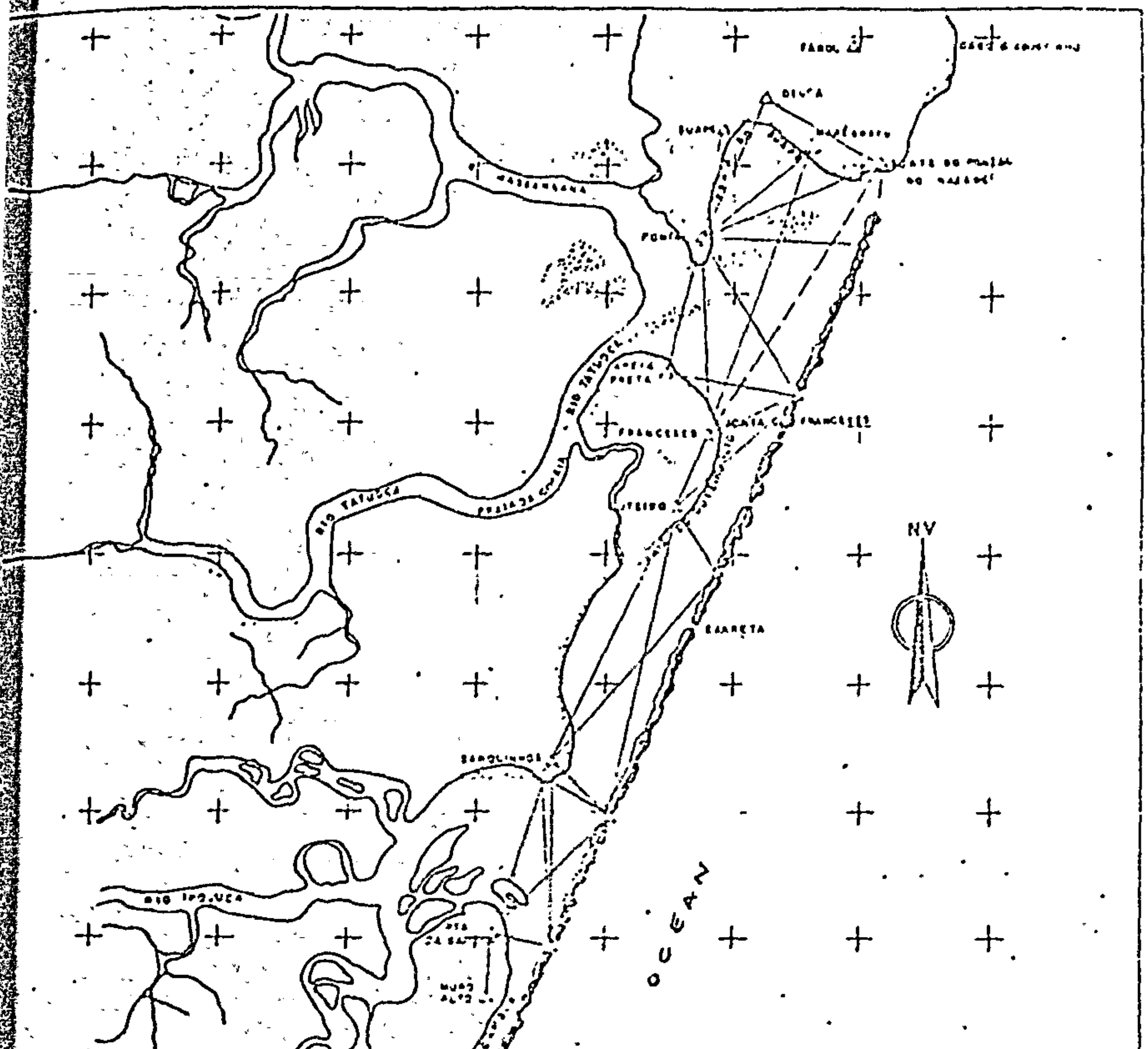
(Continuation of Letter No. 0008 (DHN-10) dated 7 January 1974, from the OFFICE OF HYDROGRAPHY AND NAVIGATION..

The logsheets for the area can only be supplied in the beginning of February, in virtue of the work presently underway, which makes access to the logsheet files impossible.

Cordially,

FERNANDO MENDONÇA DA COSTA FREITAS

VICE DIRECTOR OF HYDROGRAPHY AND NAVIGATION



diper

GOVERNO DO ESTADO DE PERNAMBUCO
COMPANHIA DE DESENVOLVIMENTO INDUSTRIAL DE PERNAMBUCO

COMPLEXO INDUSTRIAL DE SUAPE

TRIANGULATION NETWORK

TRANSCON SA

ALTITUDES FURNISHED BY AERODATA

Markers	Altitudes	Observations
RN-5	+ 8.237.7	Obelisk at the mill Massangana – PE-60
RN-6	+ 7.797.3	PE-60
RN-7	+ 11.741.8	PE-60
RN-8	10.578.2	PE-60
RN-9	7.315.5	PE-60
RN-10	3.489.1	PE-60
RN-11	2.153.7	Nossa Senhora do Ó
RN-Cupe	6.977.1	DHN Marker
V. Forte	+ 11.393.8	Aerodata datum level (Nazaré fort)
RN-Pontal	+ 2.420	Suape land spit
RN-20	+ 5.146	Suape medical station
RN-21	+ 3.855	E-O (Tide recorder)
RN-Gaibu	+ 44.225	Cabo-Suape road

ALTITUDES USED BY HIDROPORT

Markers	Altitudes	Observations
RN-5	+ 8.237	Obelisk at Massangana mill
RN-Cupe	+ 5.977	DHN point
V. Forte	+ 11.323	Vertex at Nazaré fort
RN-Pontal	+ 2.420	Suape land spit
RN-20	+ 5.140	
RN-21	+ 3.055	= E-O (RP)-Tide recorder RN O =
RN-Gaibu	+ 4.422	
RN-Galheta	+ 2.307	Galheta beach
RN-T1	+ 2.365	Tatuoca river source
RN-M7	+ 1.597	Massangana mill

SUAPE BEACH POLYGON AND MASSANGANA POLYGON ESTABLISHED BY HIDROPORT

Markers	Altitudes	Observations
E-0	+ 3.655	Tide recorder = RN 0
E-1	+ 5.320	
E-2	+ 6.059	
E-3	+ 3.318	RN-S1
E-4	+ 3.245	
E-5	+ 3.240	RN-S2
E-6	+ 2.679	
E-7	+ 2.720	Land spit
E-8	+ 2.779	Land spit
E-9	+ 1.913	
E-10	+ 1.813	
E-11	+ 1.800	
E-12	+ 1.767	
E-13	+ 2.041	
E-14	+ 2.060	RN - M1
		Next to M1 rod
E-15	+ 2.173	
E-16	+ 1.916	
E-17	+ 1.530	
E-18	+ 1.757	
E-19	+ 1.230	
RN-M2	+ 1.576	Next to M2 rod
E-20	+ 3.659	
E-21	+ 4.553	
E- 22	+ 4.353	
E-23	+ 4.028	
E-24	+ 3.489	
E-25	+ 3.280	
E-26	+ 1.172	
E-27	+ 1.431	
RN-M3	+ 1.570	Next to M3 rod
E-28	+ 0.655	
E-29	− 0.579	
E-30	+ 1.128	
E-31	+ 1.346	
E-32	+ 1.156	
E-33	+ 2.814	
E-34	+ 3.193	
E-35	+ 6.618	
E-36	+ 0.415	
RN-M4	+ 1.144	Next to M4 rod
E-37	+ 3.270	Sugar port
E-38	+ 0.604	
E-39	+ 2.178	
E-40	+ 3.470	
E-41	+ 4.247	
E-42	+ 1.551	
E-43	+ 1.354	
E-44	+ 1.031	
E-45	+ 1.299	
E-46	+ 1.378	
E-47	+ 3.261	Cobras island
E-48	+ 3.213	
E-49	+ 1.250	RN-M5

TATUOCA RIVER POLYGON

ESTABLISHED BY HIDROPORT

Markers	Altitudes	Observations
R-0	+ 2.532	Areia Preta
R-1	+ 1.956	Next to T1 rod
R-2	+ 0.938	
R-3	+ 1.135	
R-4	+ 1.169	
R-5	+ 1.207	
R-6	+ 0.701	
R-7	+ 0.823	
R-8	+ 0.313	
R-9	+ 0.715	
R-10	+ 1.246	
R-11	+ 0.911	
R-12	+ 1.011	
R-13	+ 1.209	
RN-T2	+ 0.603	Next to T2 rod
R-14	+ 0.659	
R-15	+ 1.458	
R-16	+ 1.106	
R-17	+ 0.8[illegible]3	
R-18	+ 0.521	
R-19	+ 0.457	
R-20	+ 0.093	
R-21	+ 0.203	
R-22	+ 0.312	
R-23	+ 1.265	
R-24	+ 1.271	
R-25	+ 1.480	Right hand margin
R-26	+ 2.020	Left hand margin to R-46
R-27	+ 0.724	
RN-T3	+ 0.942	Next to T3 rod
R-28	+ 0.674	
R-29	+ 1.074	

Markers	Altitudes	Observations
R-30	+ 1.475	
R-31	+ 1.112	
R-32	+ 1.134	
R-33	+ 1.078	
R-34	+ 1.390	
R-35	+ 2.118	
R-36	+ 0.960	
R-37	+ 1.194	
R-38	+ 1.076	
R-39	+ 1.180	
RN-T4	+ 1.056	Next to T4 rod
R-40	+ 1.334	
R-41	+ 1.468	
R-42	+ 1.242	
R-43	+ 1.208	
R-44	+ 2.484	
RN-T5	+ 2.115	Next to T5 rod
R-45	+ 1.756	
R-46	+ 1.150	Next to T6 rod
V. Franceses	+ 3.132	
RN-F	+ 2.024	Next to F rod
RN-OA	+ 0.601	
V. Conquinhos	+ 3.535	
V. Concórdia	+ 2.694	RN-B
V. Ipojuca	+ 7.257	
V. Muro-Alto	+ 7.994	
RN-Ps	+ 1.717	Not necessary
RN-ME	+ 0.878	
RN-I	+ 1.615	
RN-MV	+ 1.793	
V. Forte	+ 11.293	
V. Outeiro Alto	+ 3.994	

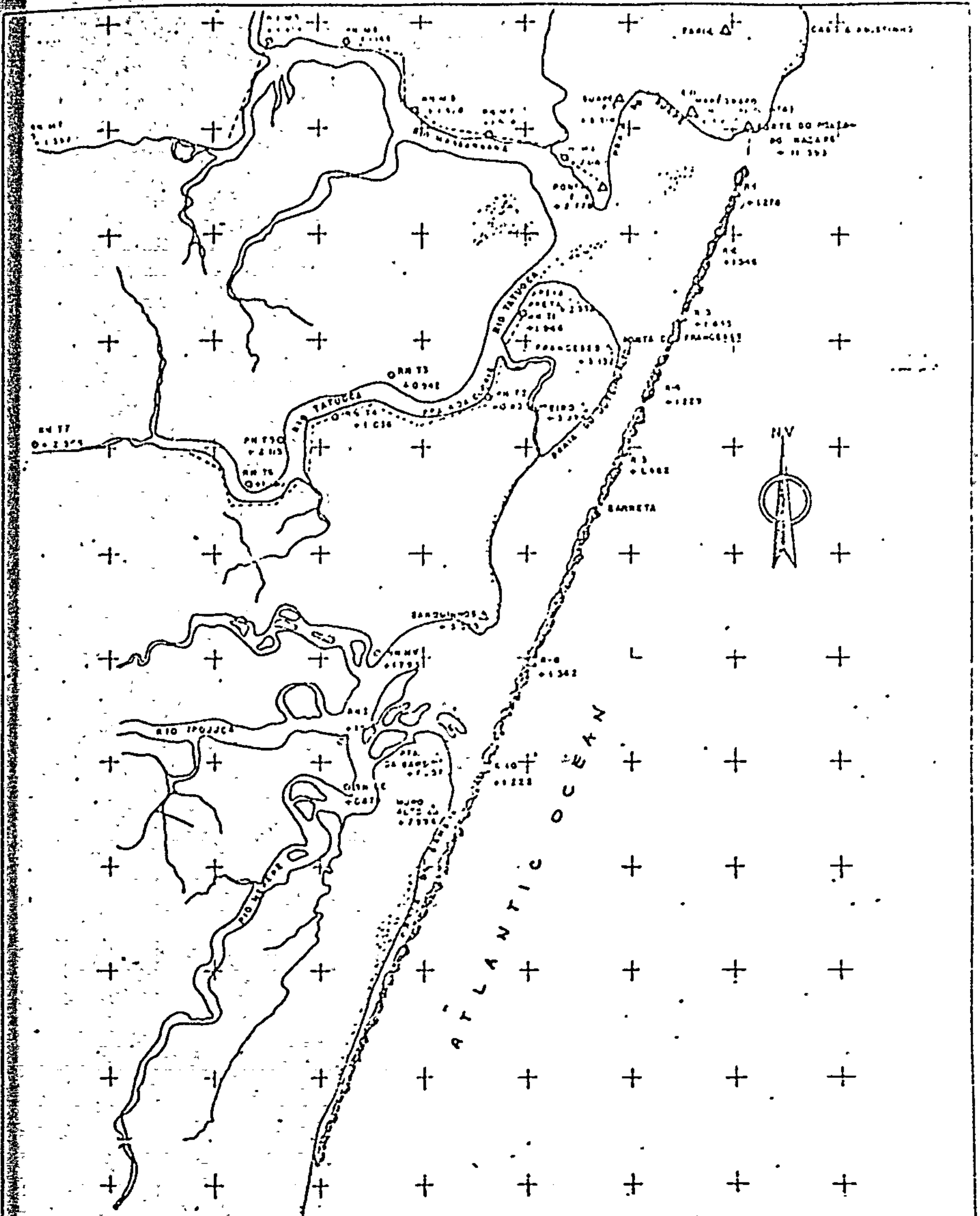
Obs: V signifies vertices in concrete markers

LEVELLING OF THE CHAIN OF REEFS

PERFORMED BY HIDROPORT

Markers	Altitudes	Observations
Recife-1		Marker
Recife-1	+ 1.278	Base
Recife-2	+ 1.546	
Recife-3	+ 1.835	Marker
Recife-3	+ 1.532	Base
Recife-4	+ 1.229	
Recife-5	+ 1.462	Marker
Recife-5	+ 1.131	Base
Recife-6		
Recife-7		
Recife-8	+ 1.362	Marker
Recife-8	+ 1.031	Base
Recife-10	+ 1.222	Marker
Recife-10	+ 0.932	Base

Obs: The numbering of Recife 1 - 8 approximates the cross-sections of reefs



diper

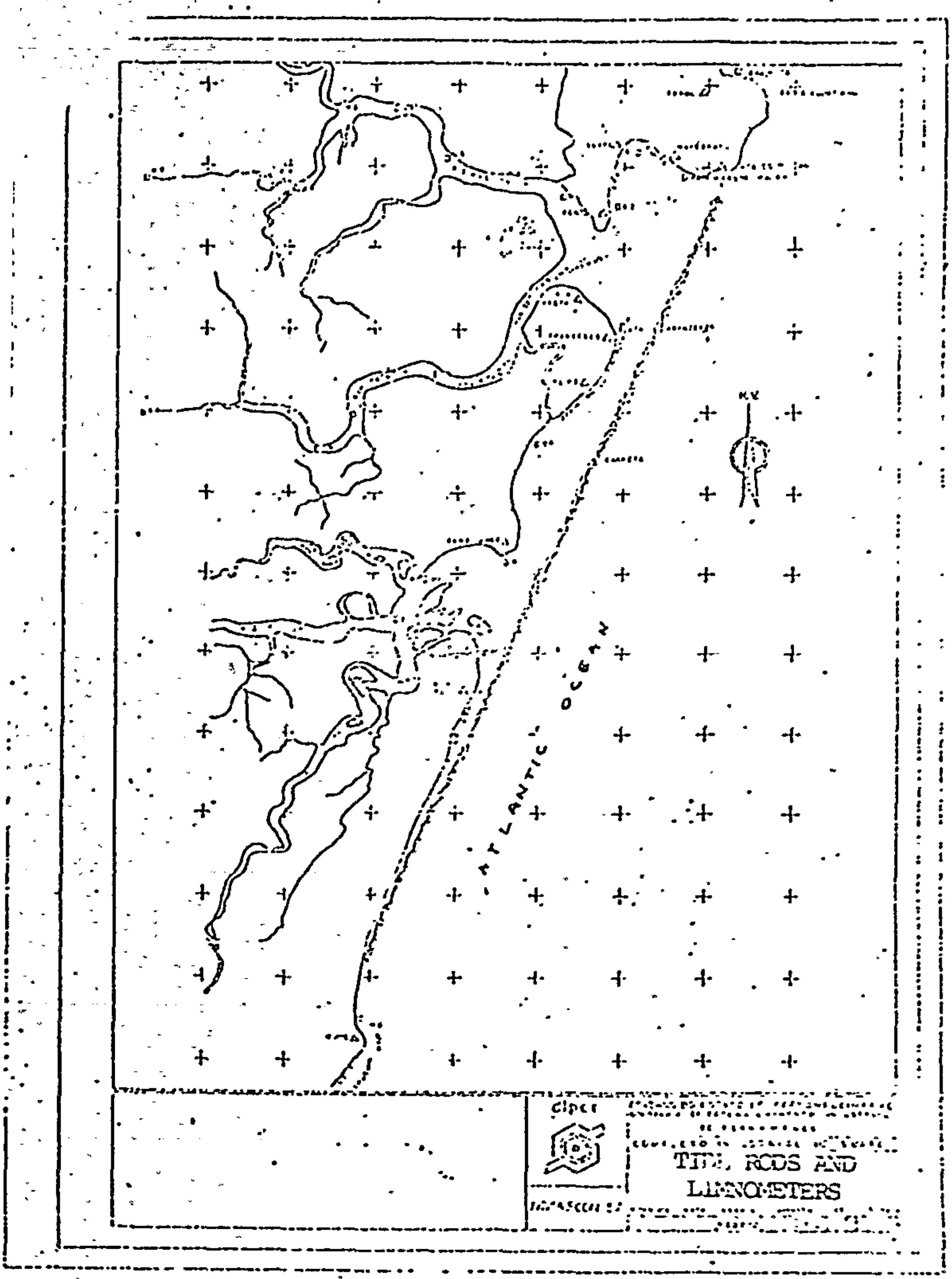
GOVERNO DO ESTADO DE PERNAMBUCO
COMPANHIA DE DESENVOLVIMENTO INDUSTRIAL DE PERNAMBUCO

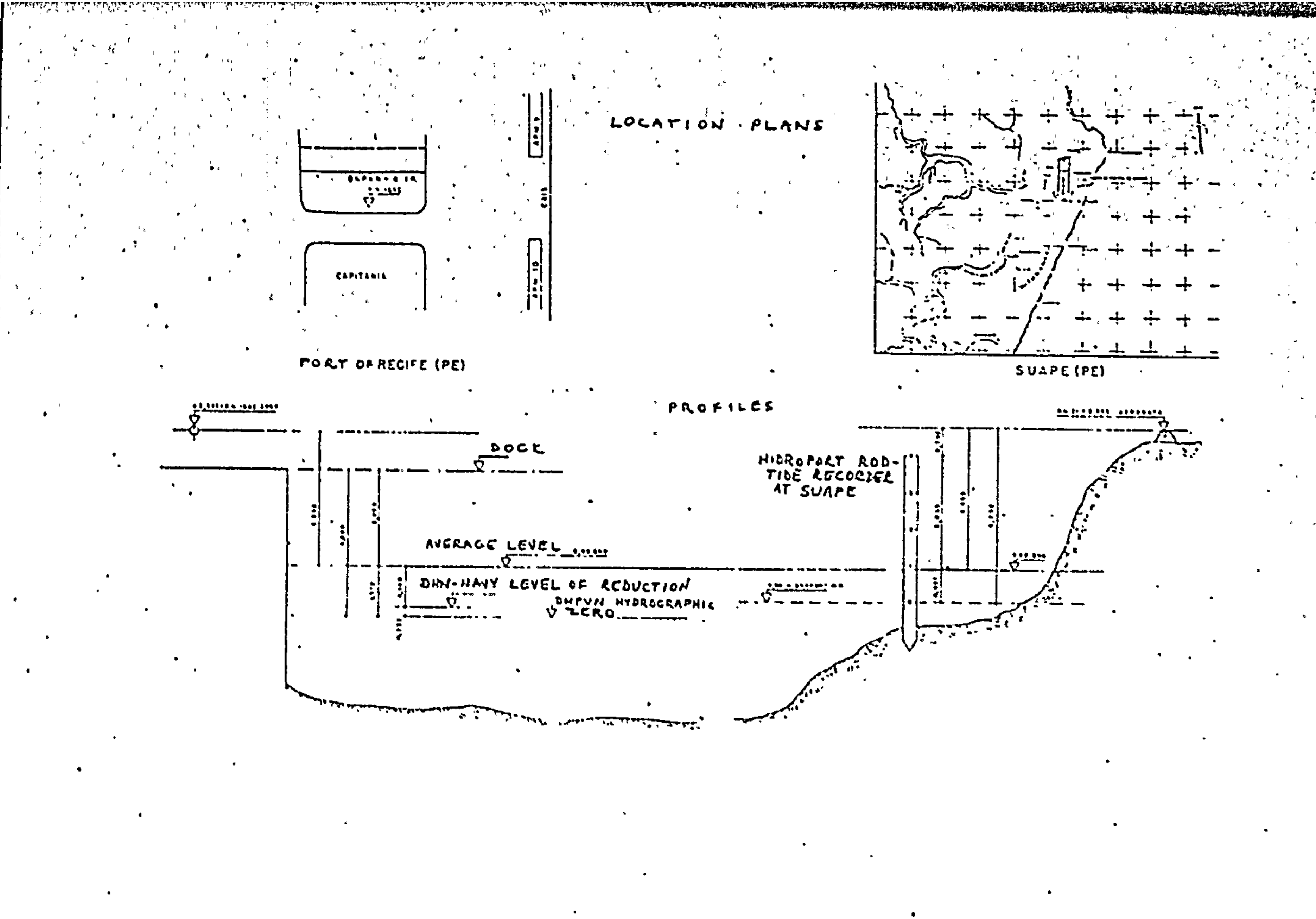
COMPLEXO INDUSTRIAL DE SUAPE

NETWORK OF RNs

TRANSCON SA

1:5000


ATLANTIC OCEAN
CIPCI
TIDE RODS AND
LIMNOMETERS



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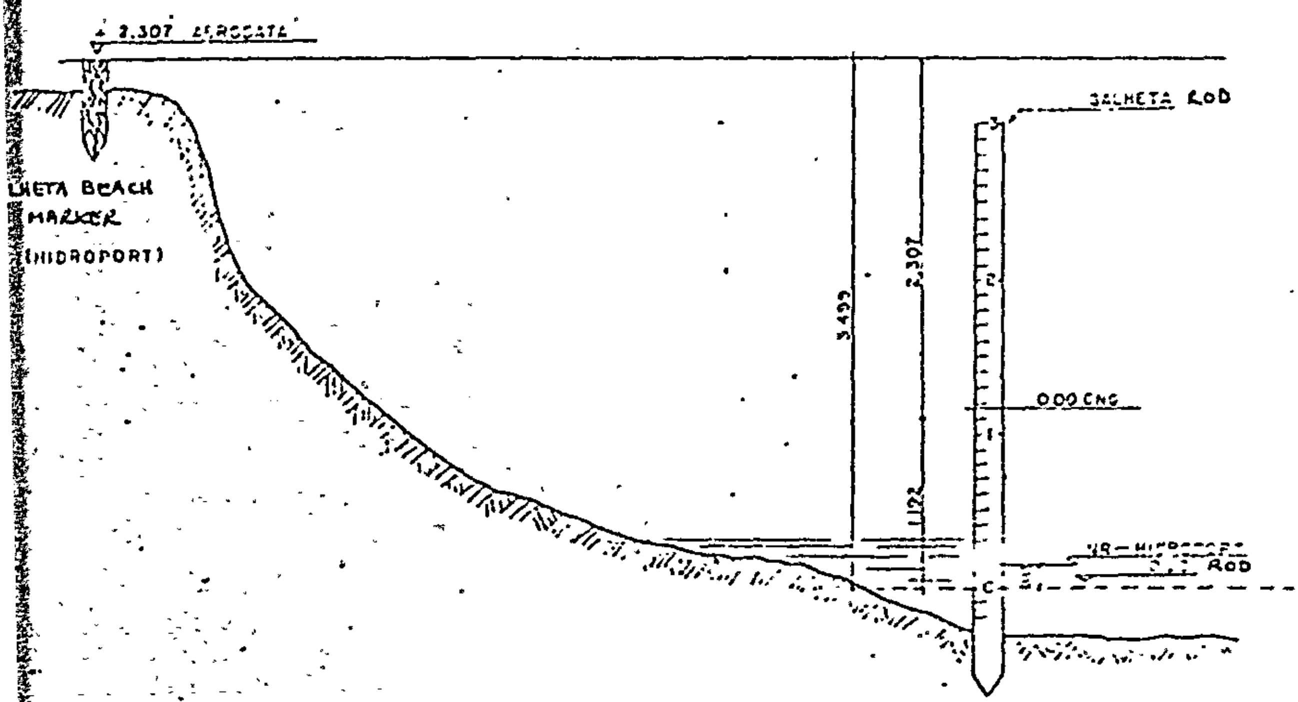
TRANSCON S.A.

GOVERNO DO ESTADO DE PERNAMBUCO
COMPLEXO INDUSTRIAL DE SUAPE

LEVEL REFERENCES
RECIFE - SUAPE



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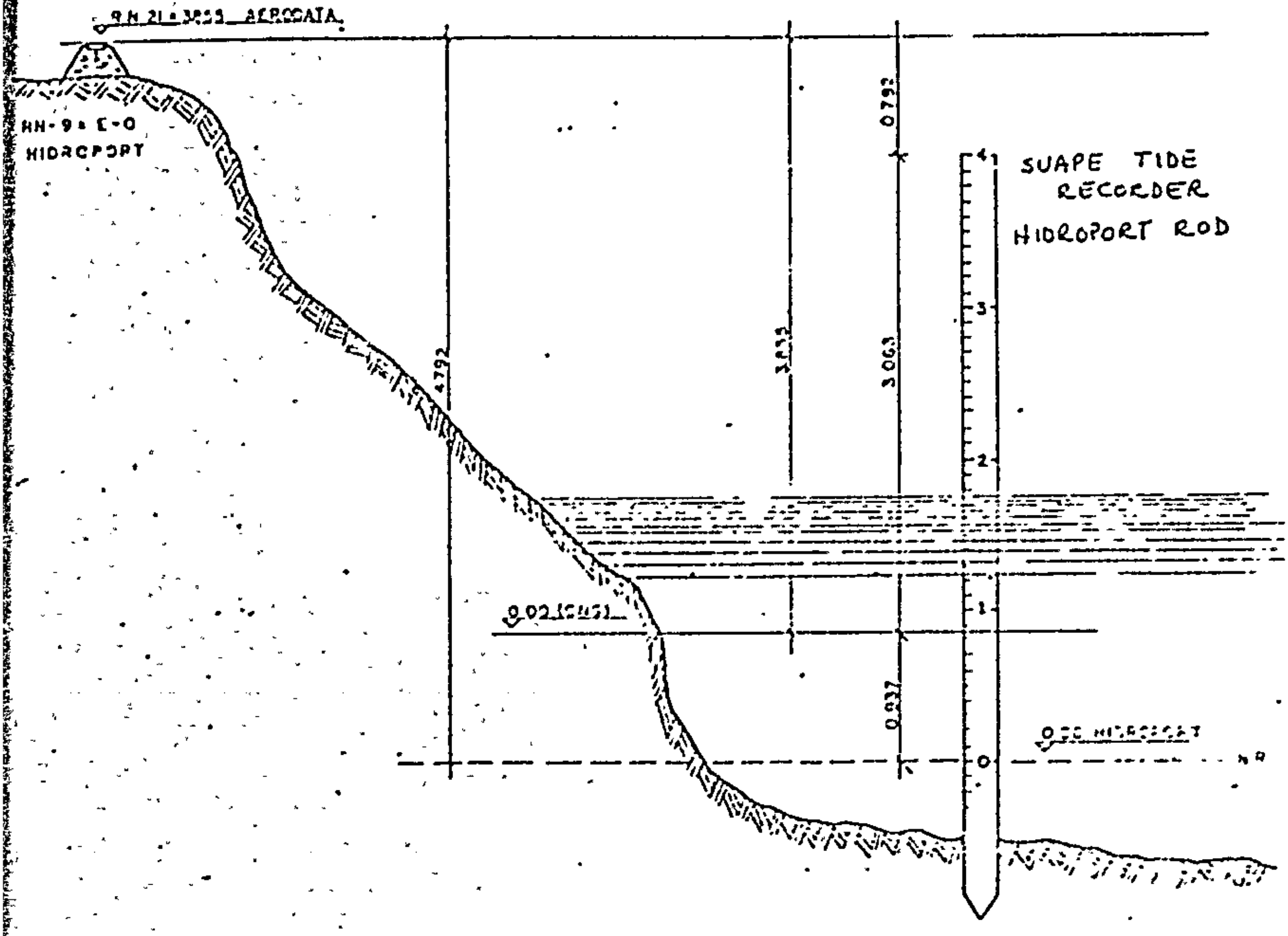
TRANSCON SA

COMPANHIA DE DESENVOLVIMENTO INDUSTRIAL DE PERNAMBUCO

COMPLEXO INDUSTRIAL DE SUAPE

CALIBRATION
GALHETA ROD
SKETCH



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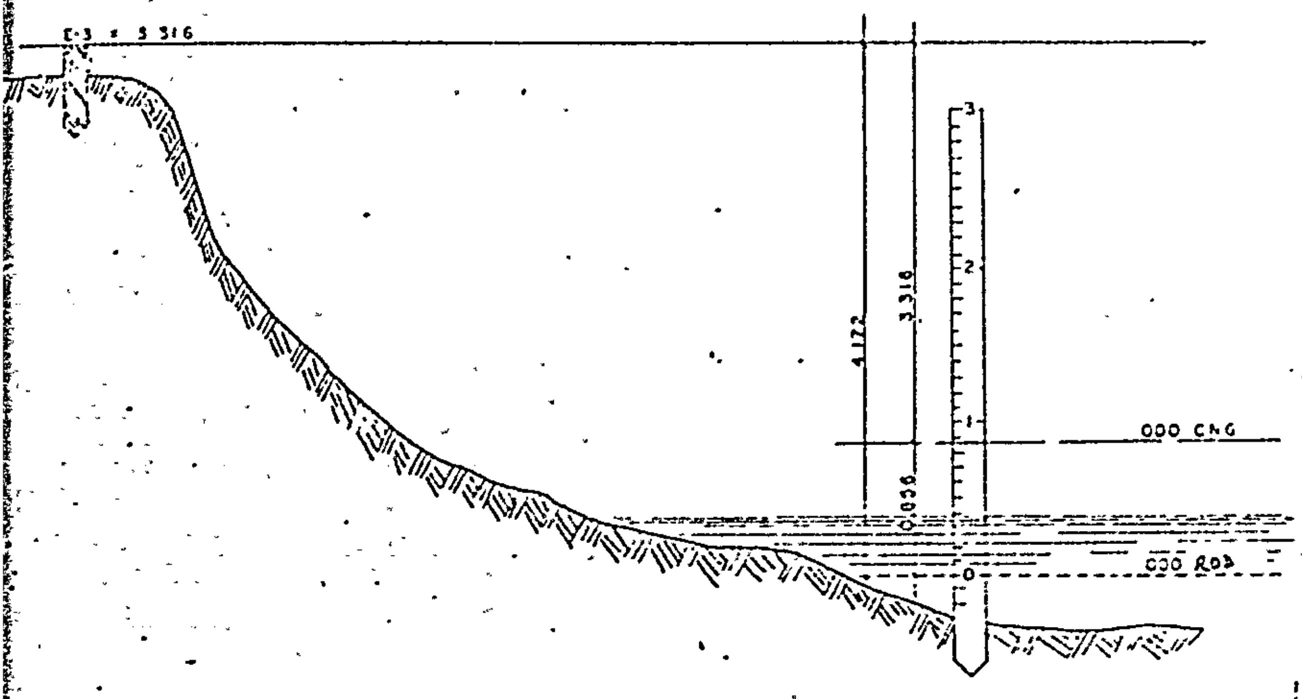
TRANSCON SA

GOVERNO DO ESTADO DE PERNAMBUCO
COMPANHIA DE DESENVOLVIMENTO INDUSTRIAL DE PERNAMBUCO

COMPLEXO INDUSTRIAL DE SUAPE

SUAPE TIDE RECORDER
ROD INSTALLATIONS
SKETCH



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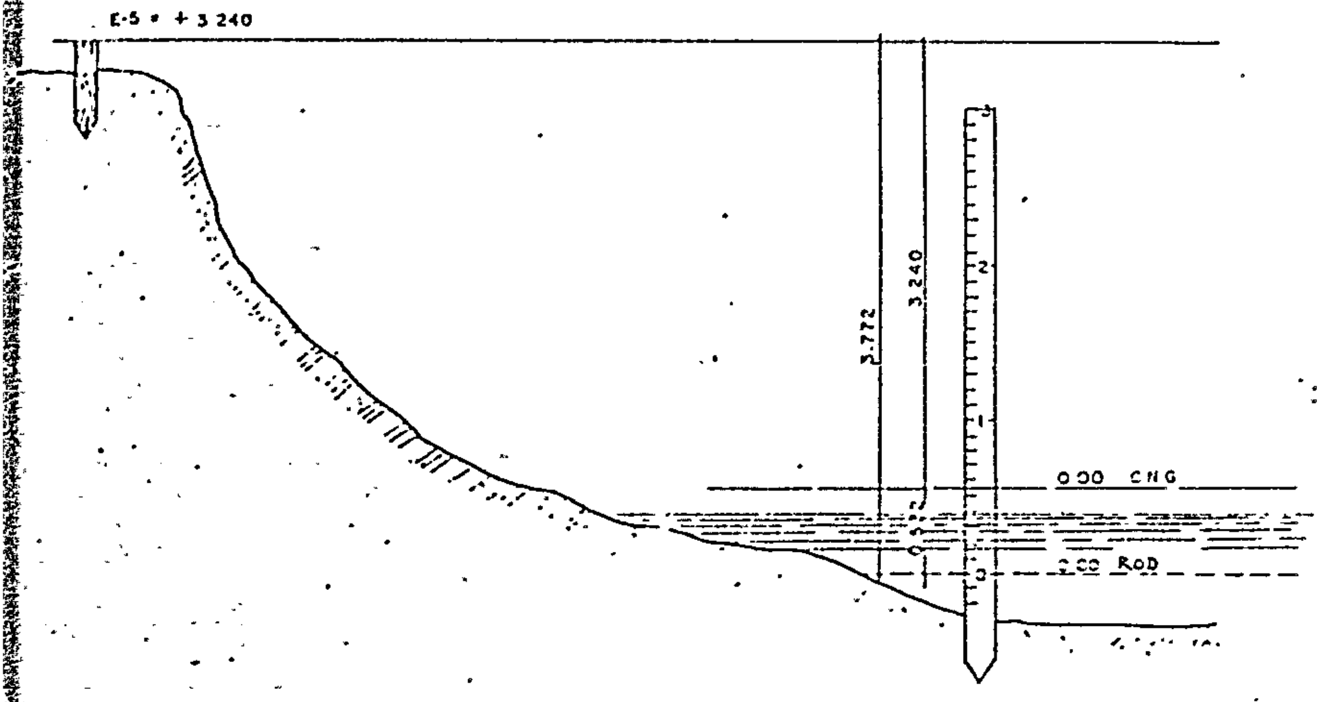
GOVERNO DO ESTADO DE PERNAMBUCO-FPAC
COMPANHIA DE DESENVOLVIMENTO INDUSTRIAL
DE PERNAMBUCO

COMPLEXO INDUSTRIAL DE SUAPE

CALIBRATION
S-1 ROD
SKETCH

TRANSCON SA



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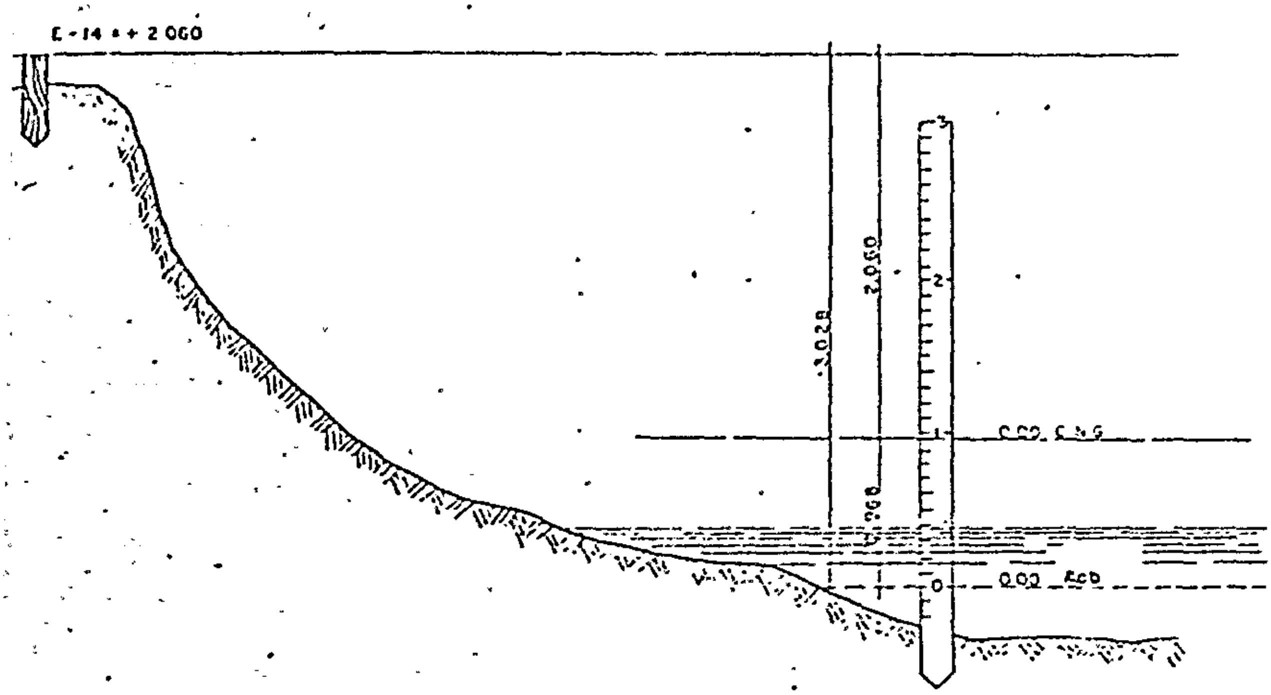
GOVERNO DO ESTADO DE PERNAMBUCO
COMPANHIA DE DESENVOLVIMENTO INDUSTRIAL DE PERNAMBUCO

COMPLEXO INDUSTRIAL DE SUAPE

CALIBRATION S-2 ROD SKETCH

TRANSCON SA



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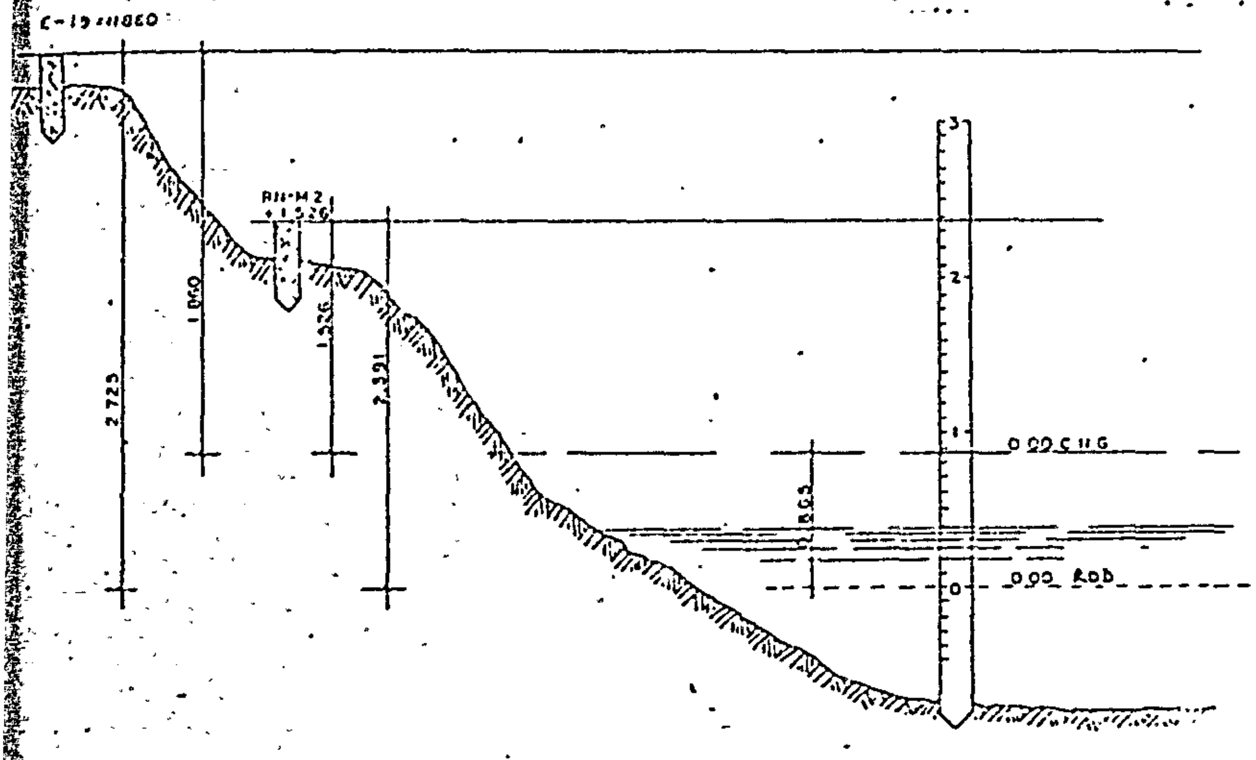
COMPLEXO INDUSTRIAL DE SUAPE

CALIBRATION M-1 ROD
SKETCH

TRANSCON SA



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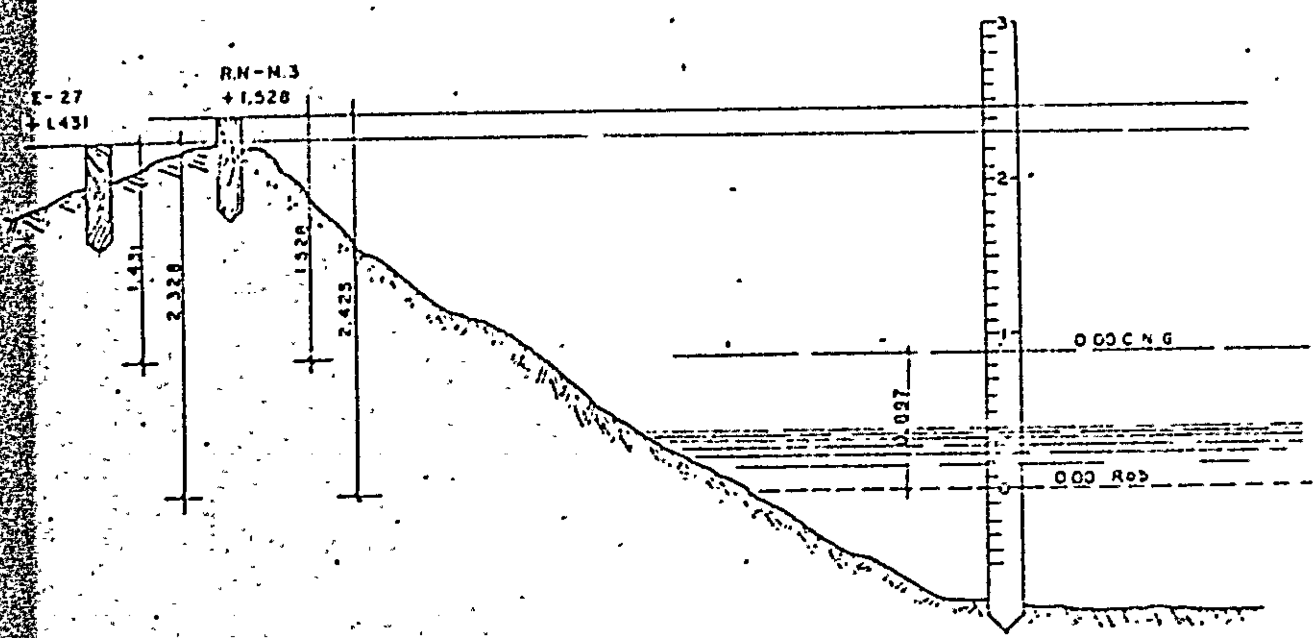
GOVERNO DO ESTADO DE PERNAMBUCO
COMPANHIA DE DESENVOLVIMENTO INDUSTRIAL DE PERNAMBUCO

COMPLEXO INDUSTRIAL DE SUAPE

CALIBRATION M-2 ROD SKETCH

TRANSCON SA



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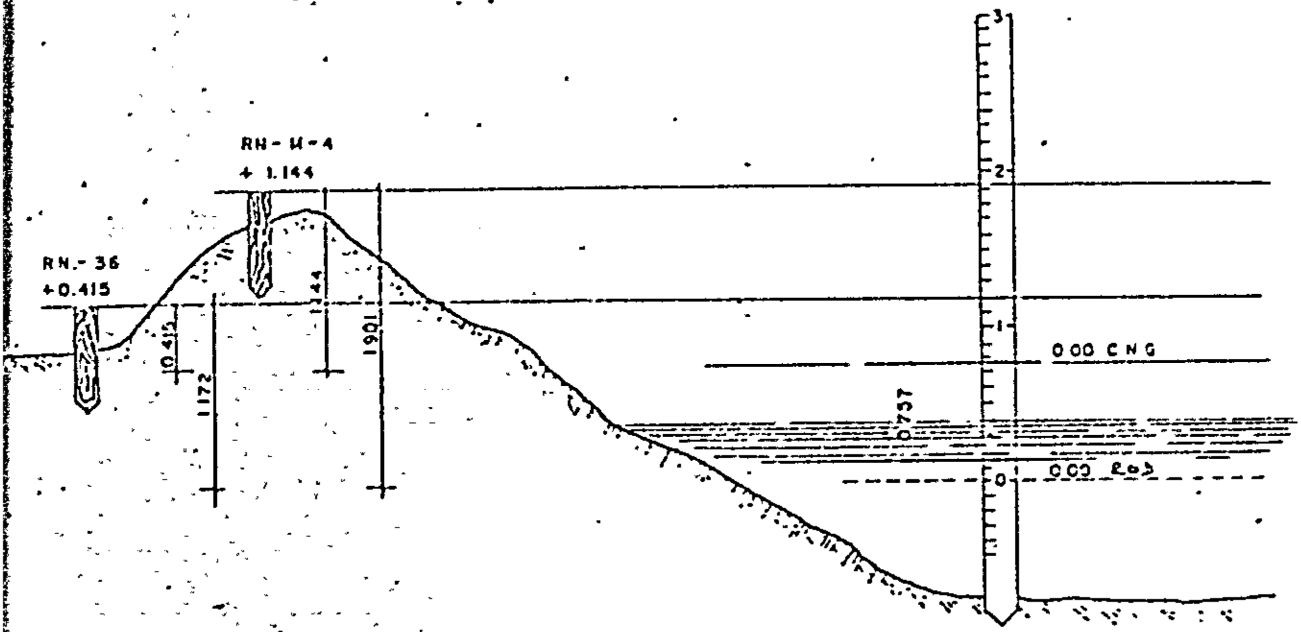
GOVERNO DO ESTADO DE PERNAMBUCO-PPAC
COMPANHIA DE DESENVOLVIMENTO INDUSTRIAL
DE PERNAMBUCO

COMPLEXO INDUSTRIAL DE SUAPE

CALIBRATION M-3 ROD
SKETCH

TRANSCON SA



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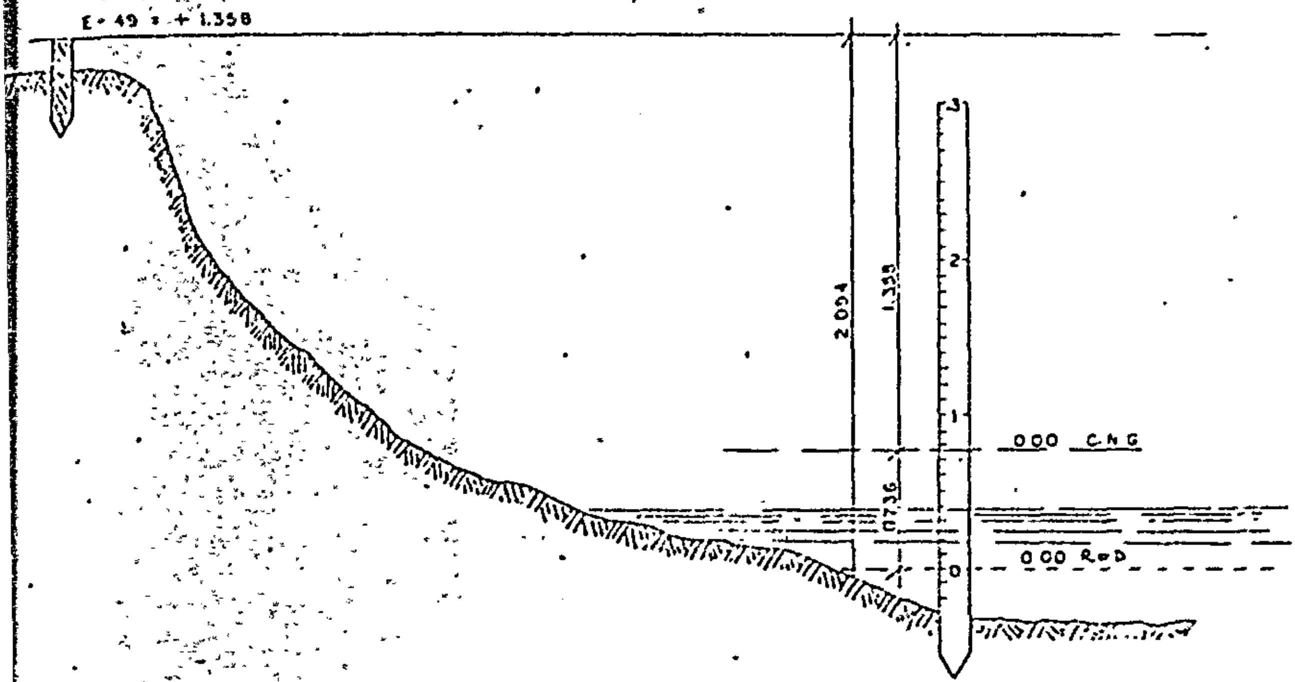
GOVERNO DO ESTADO DE PERNAMBUCO
COMPANHIA DE DESENVOLVIMENTO INDUSTRIAL DE PERNAMBUCO

COMPLEXO INDUSTRIAL DE SUAPE

CALIBRATION N-4 RCD SKETCH

TRANSCON SA



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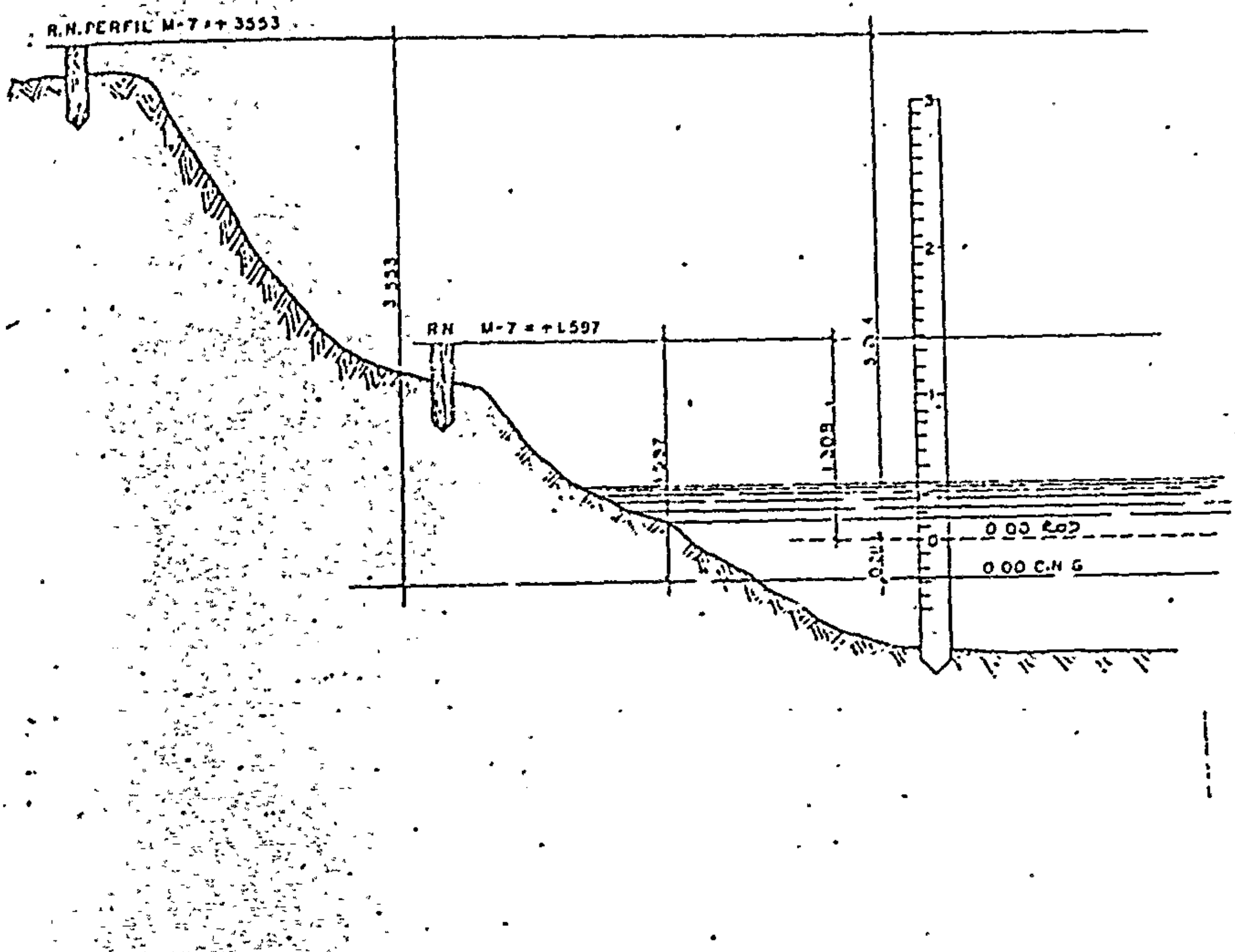
GOVERNO DO ESTADO DE PERNAMBUCO

COMPLEXO INDUSTRIAL DE SUAPE

CALIBRATION N-5 ROD
SKETCH

TRANSCON-SA



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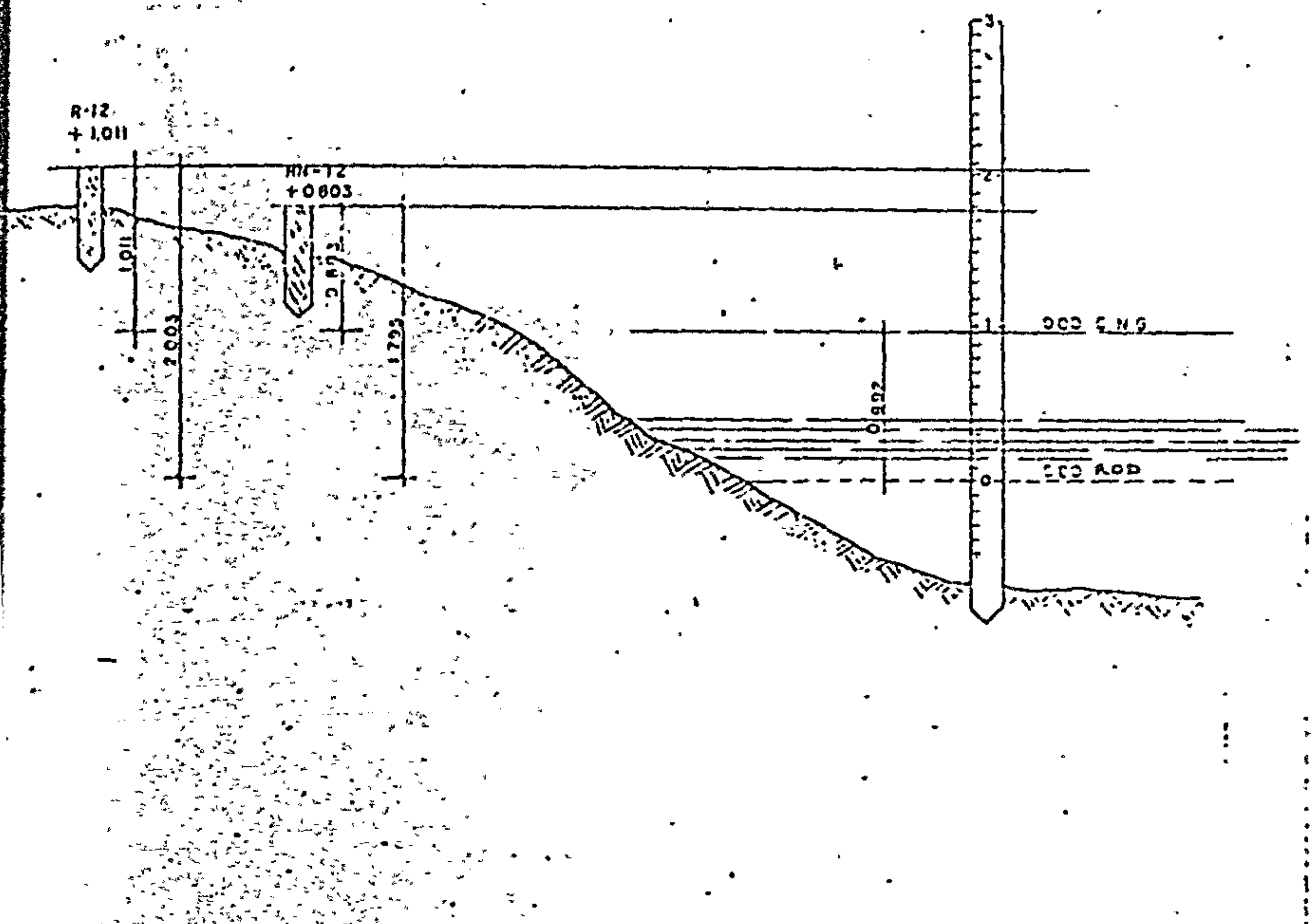
COMPLEXO INDUSTRIAL DE SUAPE

CALIBRATION M-7 ROD
SKETCH

TRANSCON SA

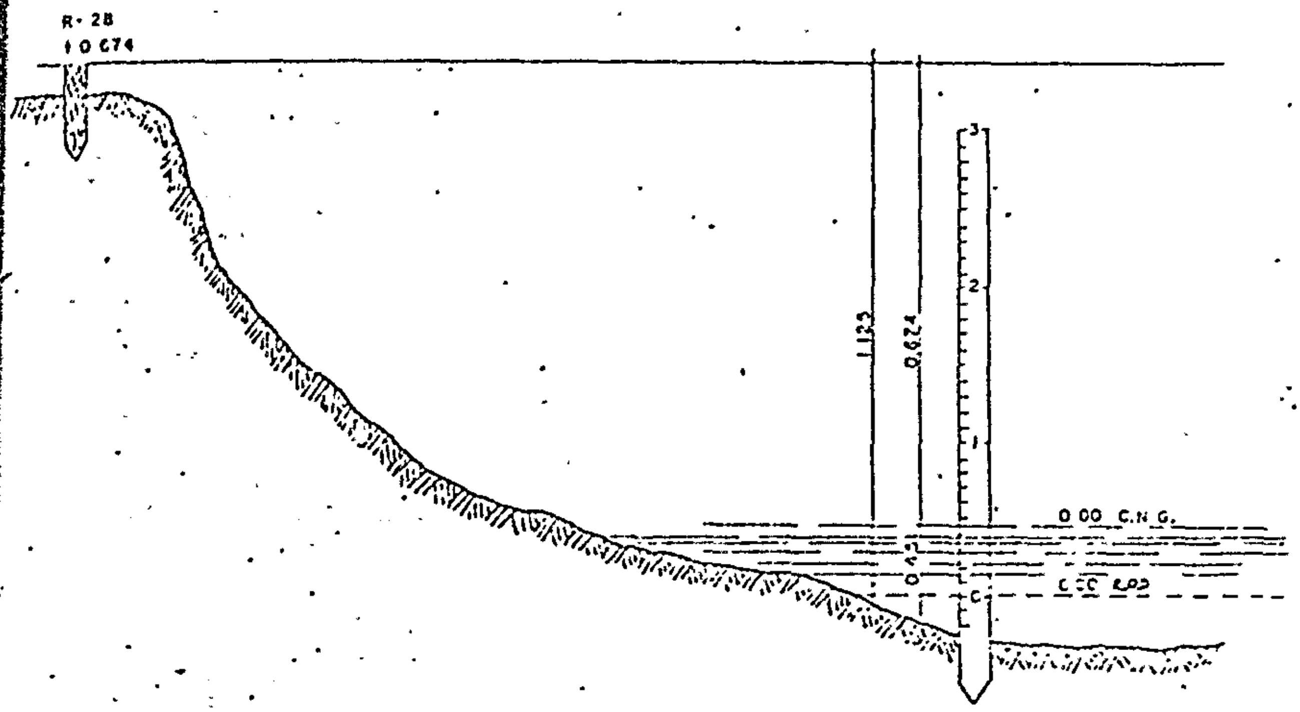


diper

COMPLEXO INDUSTRIAL DE SUAPE

CALIBRATION T-2 ROD
SKETCH

TRANSCON SA



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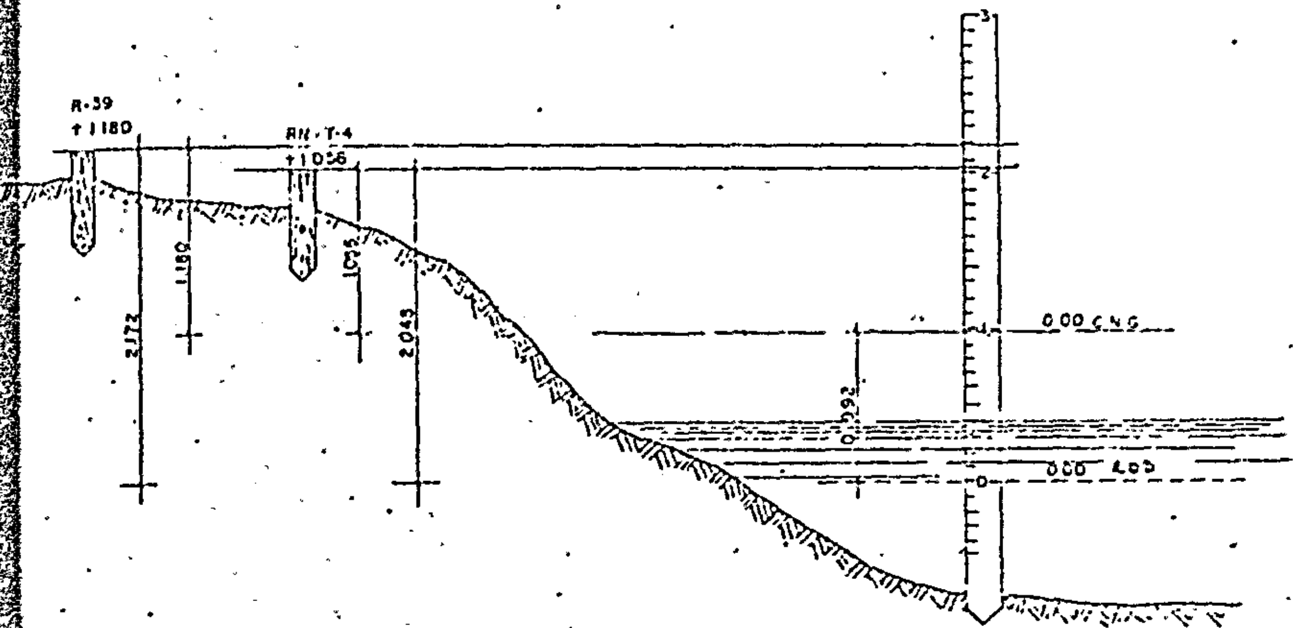
GOVERNO DO ESTADO DE PERNAMBUCO

DE PERNAMBUCO

COMPLEXO INDUSTRIAL DE SUAPE

CALIBRATION T-3 ROD SKETCH

TRANSCON SA

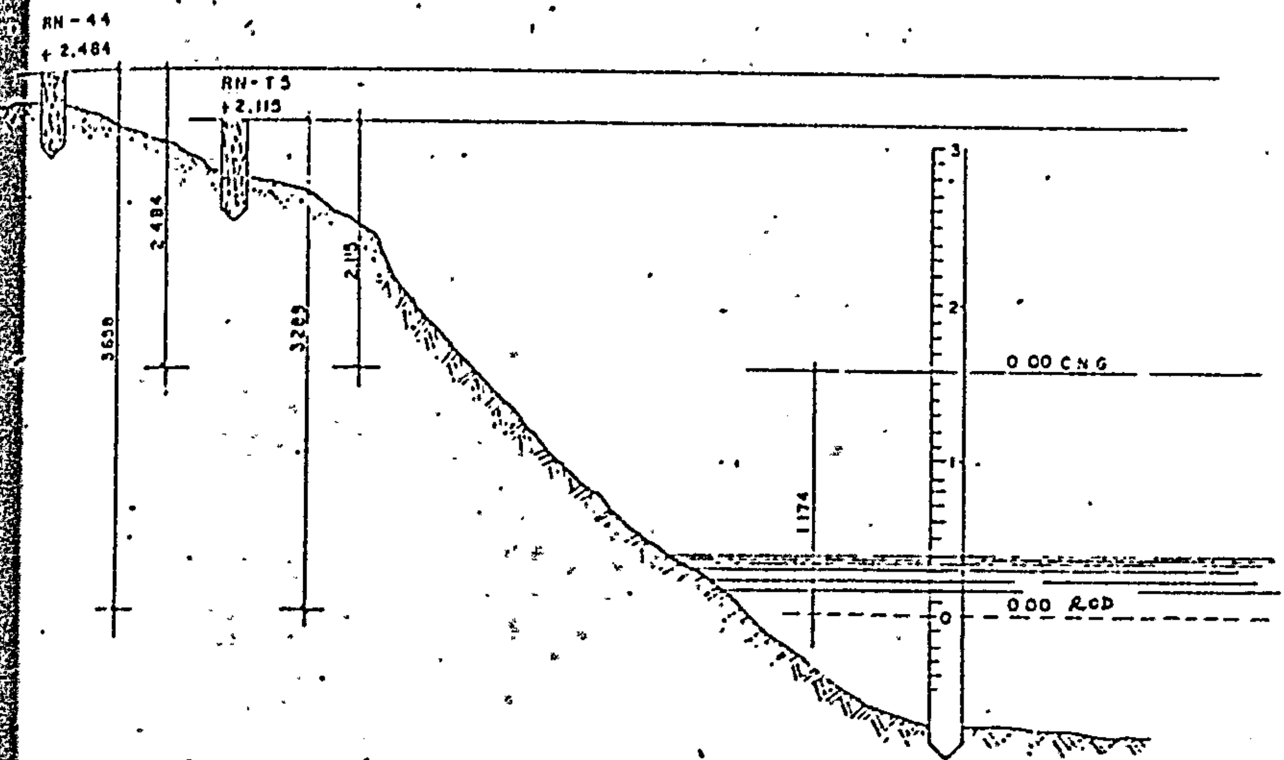


diper

COMPLEXO INDUSTRIAL DE SUAPE

CALIBRATION T-4 ROD
SKETCH

TRANSCON SA



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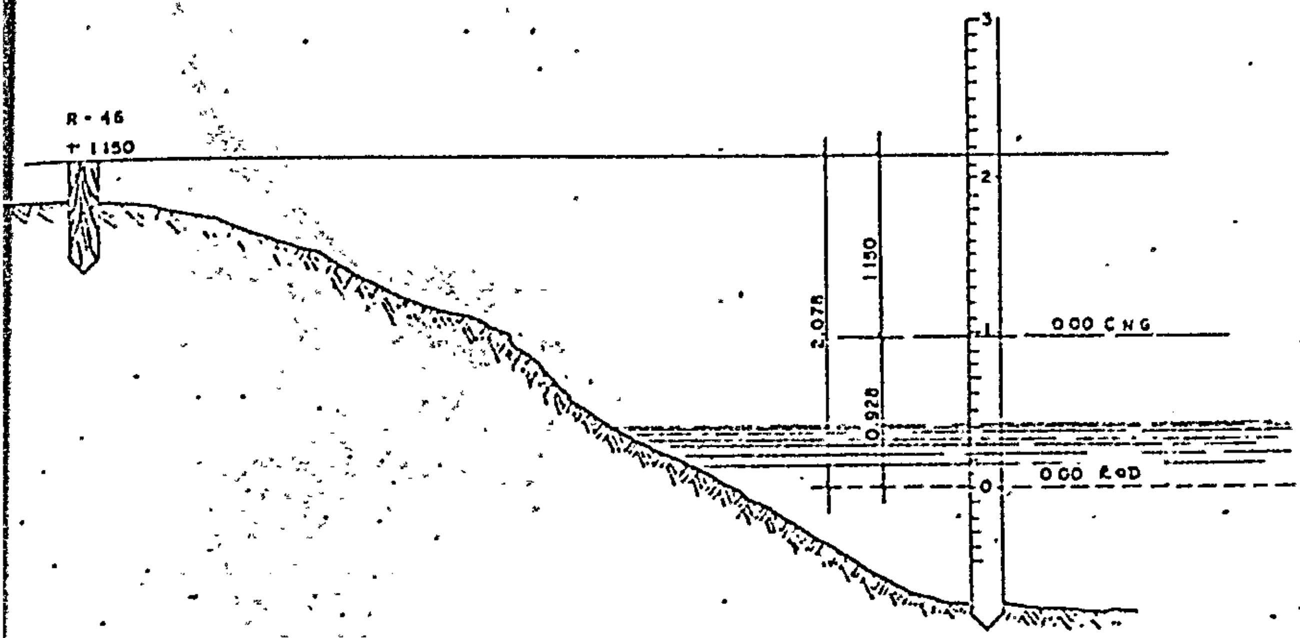
DE PERNAMBUCO

COMPLEXO INDUSTRIAL DE SUAPE

CALIBRATION T-5 ROD
SKETCH

TRANSCON SA



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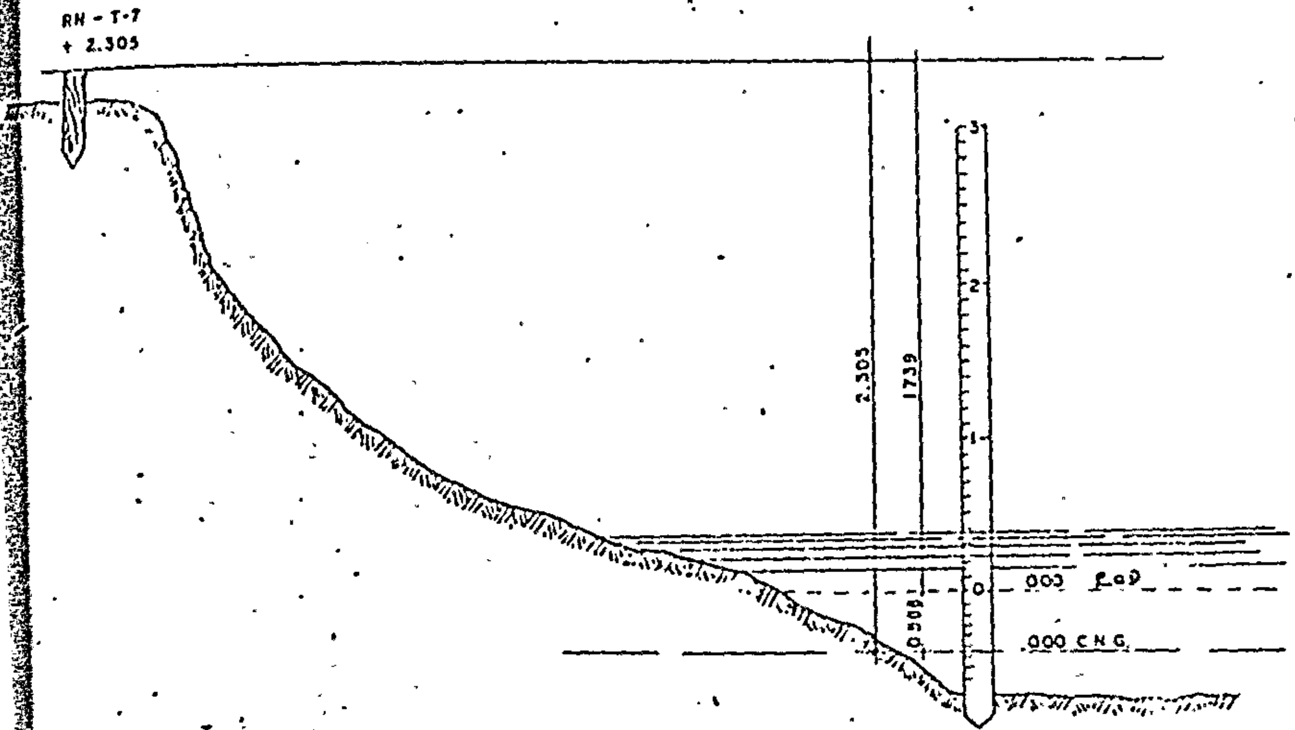
TRANSCON SA

CALIBRATION T-6 ROD
SKETCH



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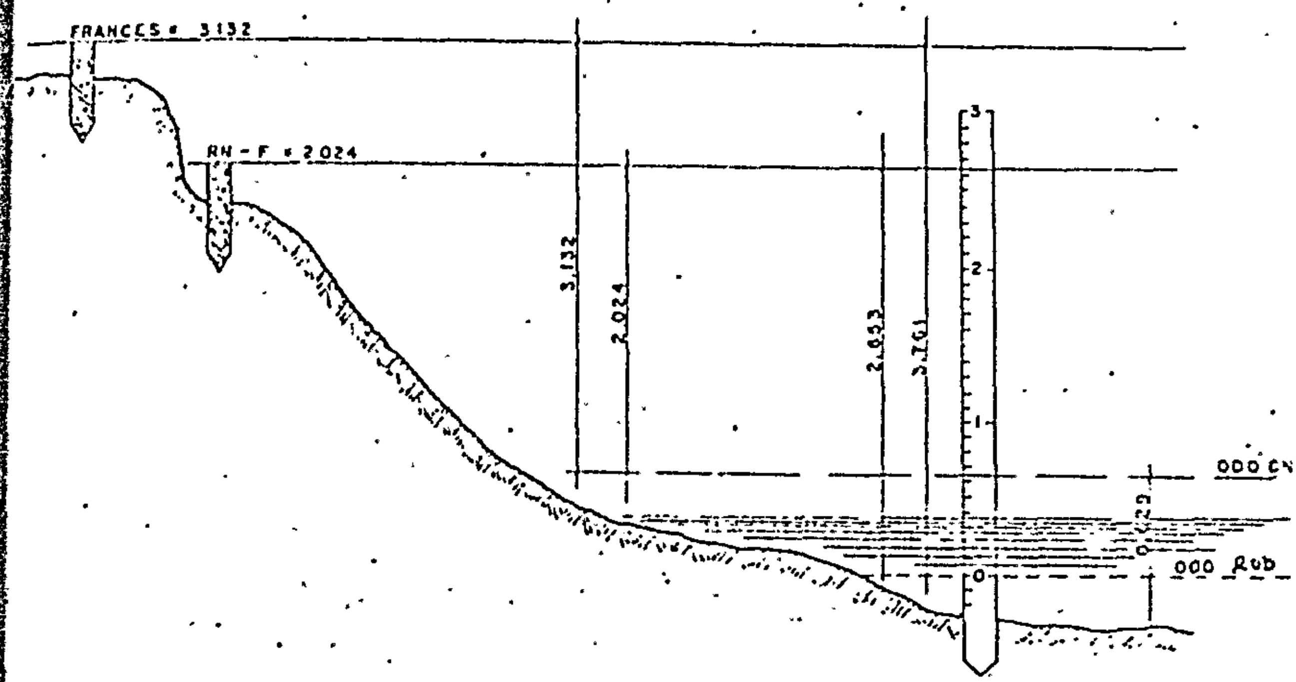
GOVERNO DO ESTADO DE PERNAMBUCO
COMPANHIA DE DESENVOLVIMENTO INDUSTRIAL DE PERNAMBUCO

COMPLEXO INDUSTRIAL DE SUAPE

CALIBRATION T-7 ROD SKETCH

TRANSCON SA



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TRANSCON SA

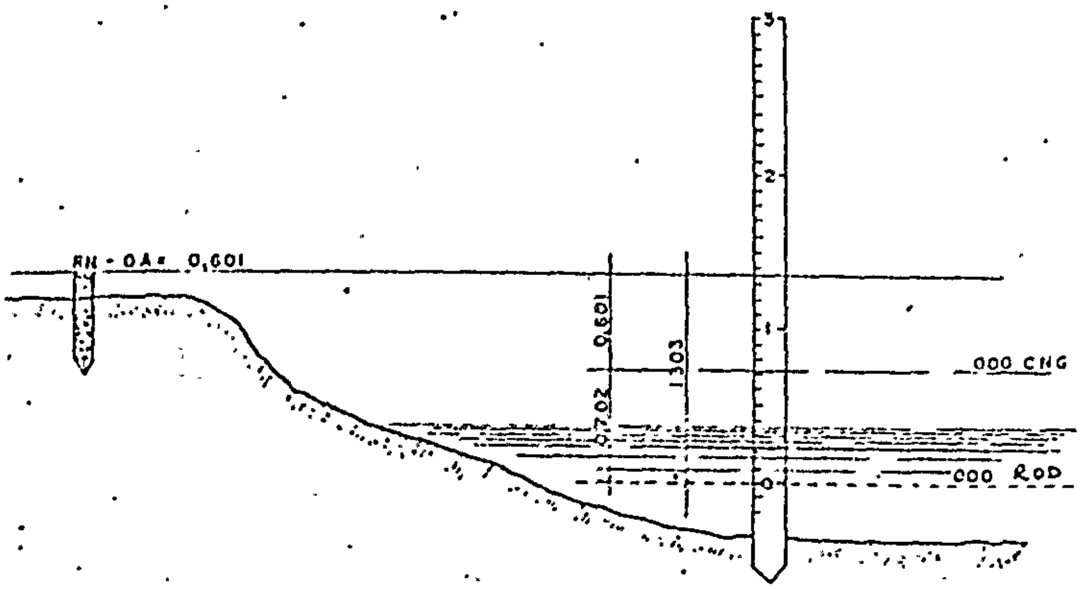
GOVERNO DO ESTADO DE PERNAMBUCO-PRAC
COMPANHIA DE DESENVOLVIMENTO INDUSTRIAL
DE PERNAMBUCO

COMPLEXO INDUSTRIAL DE SUAPE

CALIBRATION FRANCÊS ROD
SKETCH

desenhista	data	escala		verificado	nº	folha

/73



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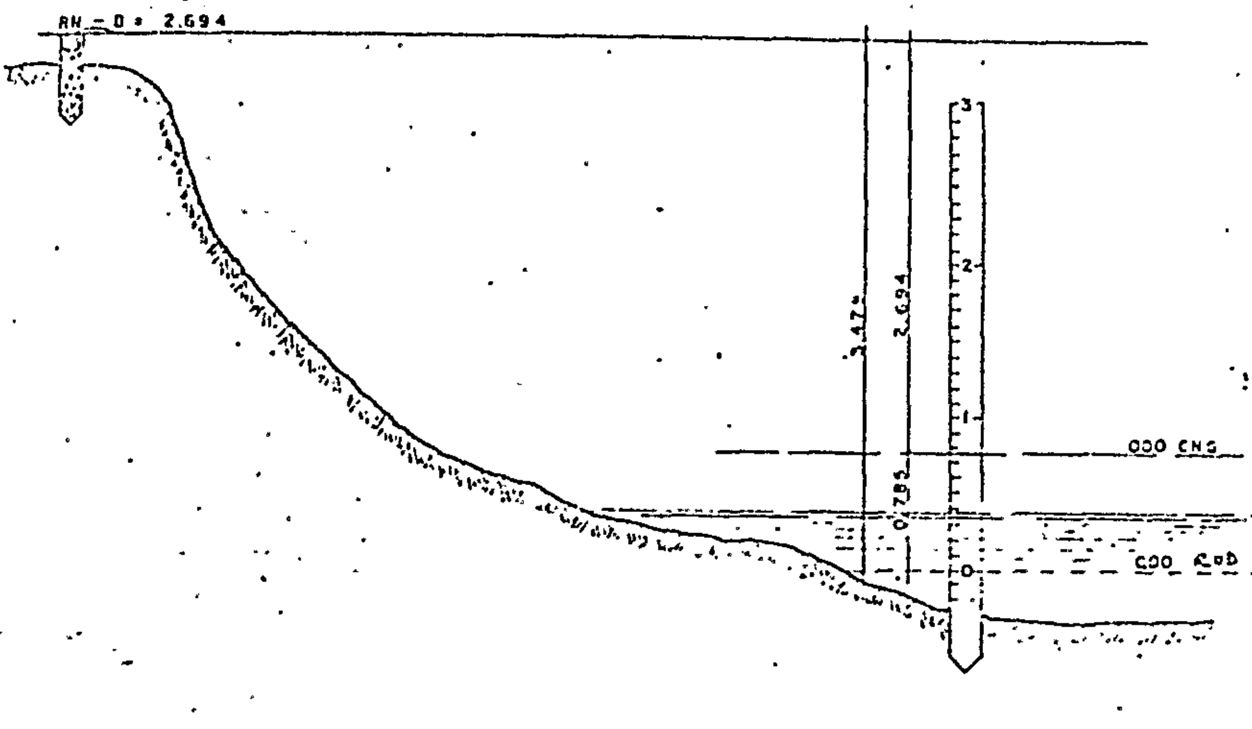
GOVERNO DO ESTADO DE PERNAMBUCO-COMPANHIA DE DESENVOLVIMENTO INDUSTRIAL DE PERNAMBUCO

COMPLEXO INDUSTRIAL DE SUAPE

CALIBRATION
OUTEIRO ALTO ROD
SKETCH

TRANSCON SA

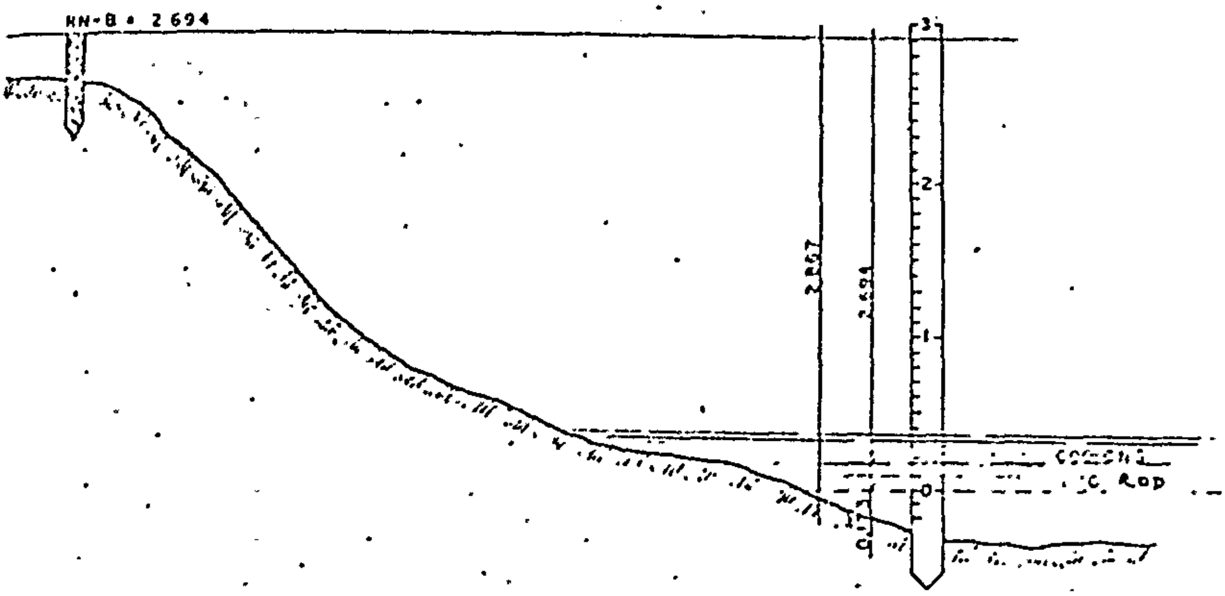


DATA: 9/2/74

diper

CALIBRATION
BANCUINHOS ROD
SKETCH

TRANSCON S/A



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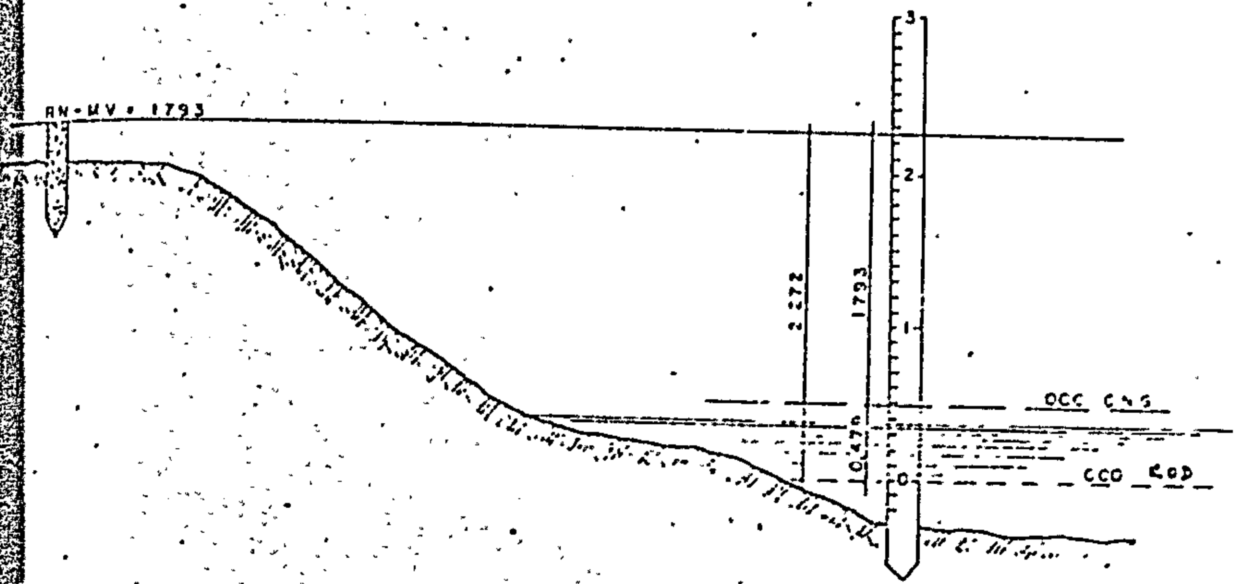
dipor

TRANSCON S.A

GOVERNO DO ESTADO DE PERNAMBUCO
COMPANHIA DE DESENVOLVIMENTO INDUSTRIAL DE PERNAMBUCO

COMPLEXO INDUSTRIAL DE SUAPE

CALIBRATION
BANQUINHOS ROD
SKETCH



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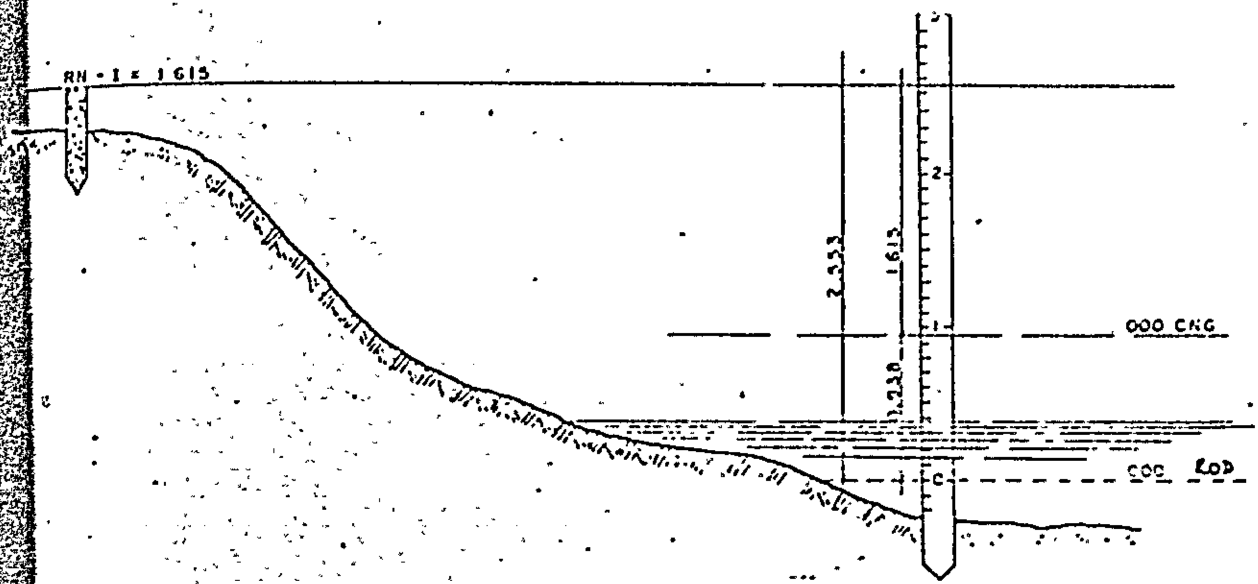
TRANSCON SA

GOVERNO DO ESTADO DE PERNAMBUCO
COMPANHIA DE DESENVOLVIMENTO INDUSTRIAL DE PERNAMBUCO

COMPLEXO INDUSTRIAL DE SUAPE

CALIBRATION
MANÉ VELHO ROD
SKETCH



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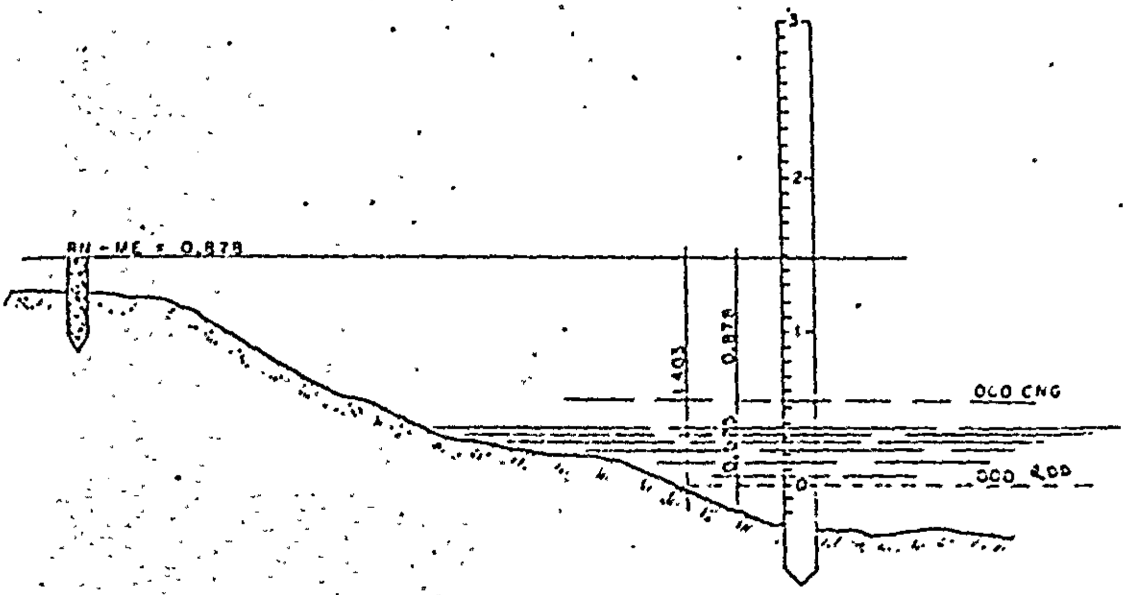
GOVERNO DO ESTADO DE PERNAMBUCO
COMPANHIA DE DESENVOLVIMENTO INDUSTRIAL
DE PERNAMBUCO

COMPLEXO INDUSTRIAL DE SUAPE

CALIBRATION
IPOJUCA ROD
SKETCH

TRANSCON SA



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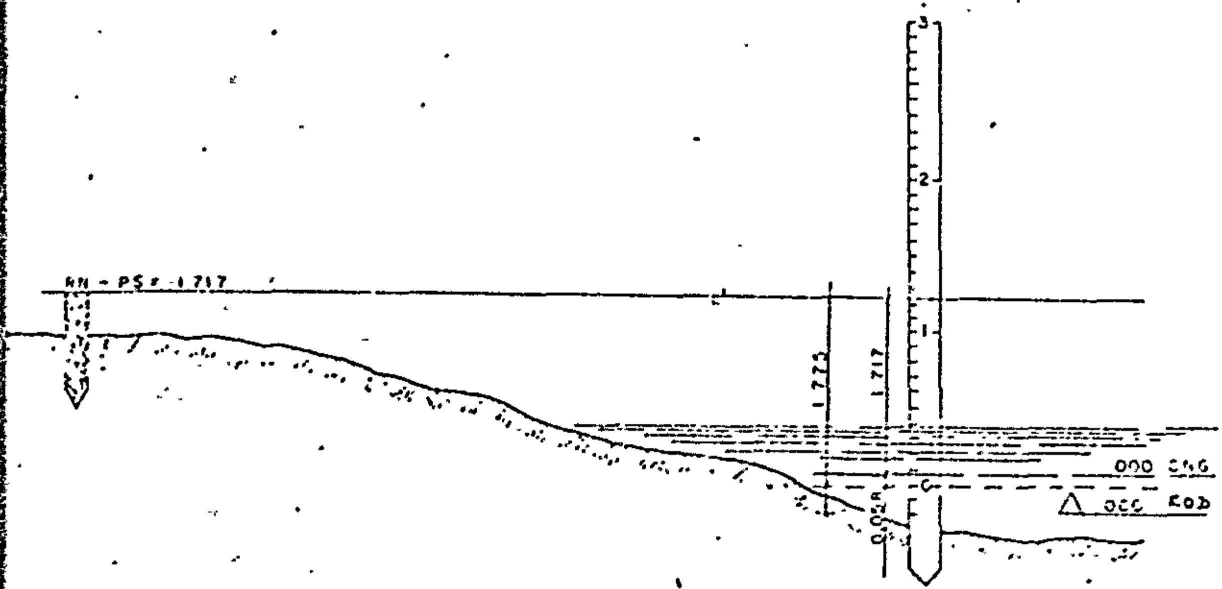
GOVERNO DO ESTADO DE PERNAMBUCO
COMPANHIA DE DESENVOLVIMENTO INDUSTRIAL
DE PERNAMBUCO

COMPLEXO INDUSTRIAL DE SUAPE

CALIBRATION
MEREPE: ROD
SKETCH

TRANSCON



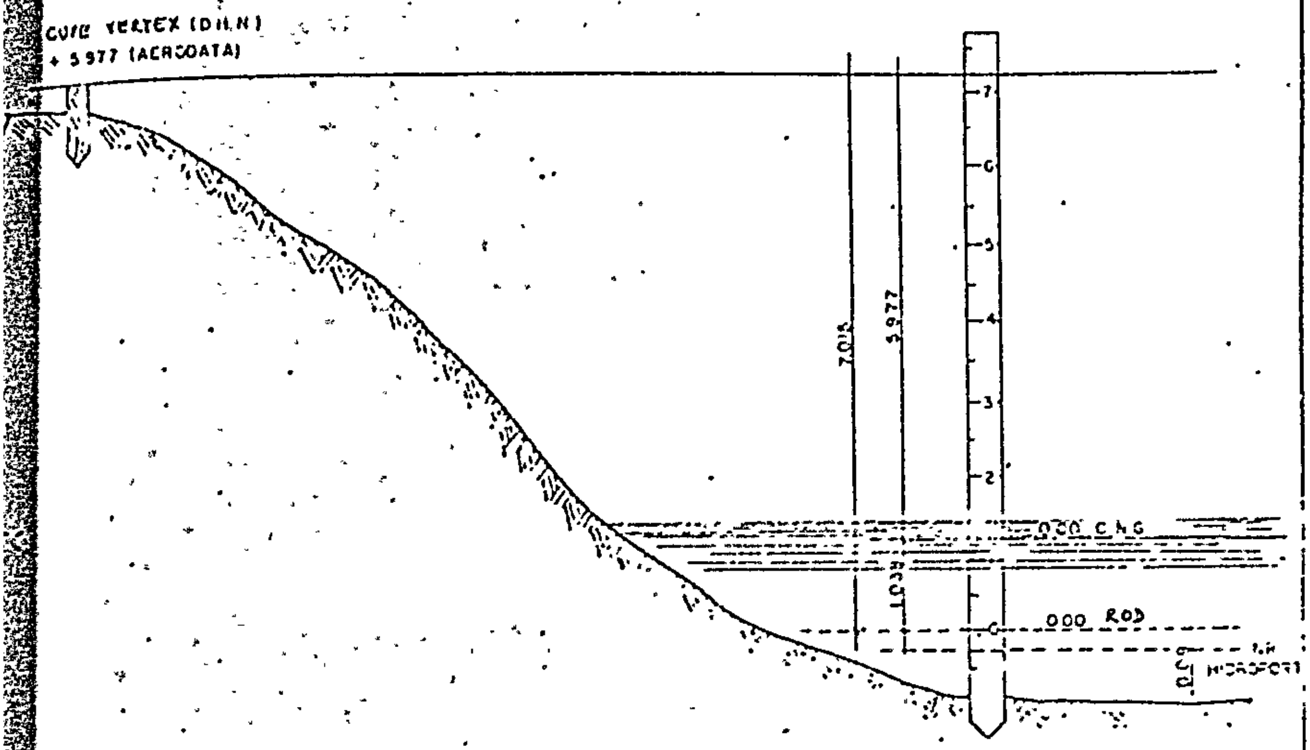
diper

DE PERNAMBUCO

COMPLEXO INDUSTRIAL DE SUAPE

CALIBRATION
SITIO POINT ROD
SKETCH

TRANSCON SA



diper

TRANSCON SA

GOVERNO DO ESTADO DE PERNAMBUCO
COMPANHIA DE DESENVOLVIMENTO INDUSTRIAL DE PERNAMBUCO

COMPLEXO INDUSTRIAL DE SUAPE

CALIBRATION
CUPE ROD
SKETCH

Tide with semi-daily preponderance

	Reference Stat: RECIFE					Secondary St: SUAPE				
	heights above the NR			contribs for		heights above zero on rod			contribs for	
	H.W.	L.W.	fator	H.Ws.	L.Ws.	H.W.	L.W.	fator	H.Ws.	L.Ws.
a		0.37	1		0.37		0.35	1		0.35
b	2.27		1	2.27		2.00		1	2.00	
c		0.27	3		0.81		0.40	3		1.20
d	2.47		2	4.94		2.30		2	4.60	
e		0.32	3		0.96		0.29	3		0.87
f	2.27		1	2.27		2.18		1	2.18	
g		0.42	1		0.42		0.34	1		0.34
Sum of contributions				9.48	2.56				8.78	2.76
M.H.W. and M.L.W.				2.37	0.32				2.195	0.345

H = 2.05   Z = 1.34   h = 1.85   a = 1.27

H = M.H.W. obs. − M.L.W. obs.   M.H.W. obs. = sum of contribs of H.W ÷ 4

Z = $\frac{1}{2}$ (M.H.W. obs. + M.L.W. obs.)   M.L.W. obs. = sum of contribs of L.W. ÷ 8

NR calculation at secondary station

(A) When T.S.M.L at reference station is known

M.H.W.S. = 2.18 m

M.L.W.S. = 0.10 m

A = 1.14 m

$$d = a - (Z - A) - A\frac{h}{H}$$

$$= 1.27 - (1.34 - 1.14) - \frac{1.14 \times 1.85}{2.05}$$

= 0.04 m above zero on rod

(B) When T.S.M.L. at reference station is unknown

$$d = a - \frac{Z\,h}{H} = \_\_\_\_\_\_ =$$

= m above zero on rod

calculated by:

conferred by:

DATE: 23 to 25/1/74

diper

GOVERNO DO ESTADO DE PERNAMBUCO
COMPANHIA DE DESENVOLVIMENTO INDUSTRIAL DE PERNAMBUCO

COMPLEXO INDUSTRIAL DE SUAPE

TRANSFER OF LEVEL OF REDUCTION

TRANSCON SA

Tide with semi-daily preponderance

	Reference Stat: RECIFE					Secondary St: GALHETA				
	heights above the NR			contribs for		heights above zero on rod			contribs for	
	H.W.	L.W.	fator	H.Ws.	L.Ws.	H.W.	L.W.	fator	H.Ws	L.Ws.
a		0.37	1		0.37		0.50	1		0.50
b	2.27		1	2.27		2.40		1	2.40	
c		0.27	3		0.81		0.50	3		1.50
d	2.47		2	4.94		2.53		2	5.06	
e		0.32	3		0.96		0.35	3		1.05
f	2.27		1	2.27		2.40		1	2.40	
g		0.42			0.42		0.55	1		0.55
Sum of contributions				9.48	2.56				9.86	3.60
M.H.W. and M.L.W.				2.37	0.32				2.46	0.45

H = 205　　h = 2.01
Z = 134　　a = 1.45

H = M.H.W. obs. − M.L.W. obs.　　M.H.W. obs. = sum of contribs of H.W ÷ 4

Z = $\frac{1}{2}$ (M.H.W. obs. + M.L.W. obs.)　　M.L.W. obs. = sum of contribs of L.W. ÷ 6

NR calculation at secondary station

(A) When T.S.M.L. at reference station is known

M. H. W. S : 2.18 m
M. L. W. S : 0.10 m

A = 1.14 m

$d = a - (Z - A) - A \frac{h}{H}$

$= 1.45 - (1.34 - 1.14) - \frac{1.14 \times 2.01}{2.05}$

NR = 0.13 m above zero on rod

(B) When T.S.M.L. at reference station is unknown

$d = a - \frac{Z\,h}{H} = \_\_\_\_\_\_\_\_ =$

= m above zero on rod

calculated by:
conferred by:

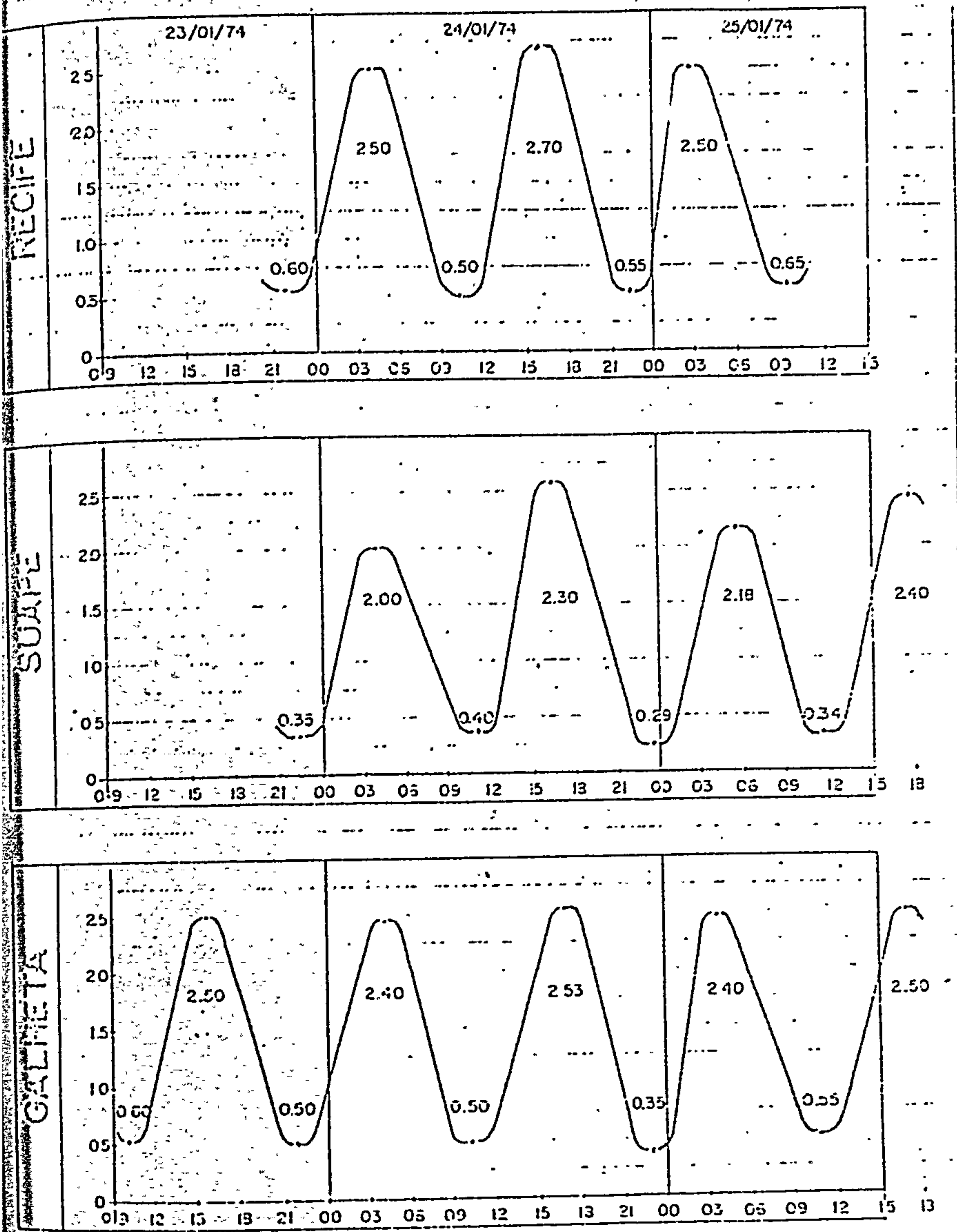
DATE: 23 to 25/1/74

diper

GOVERNO DO ESTADO DE PERNAMBUCO - FPAC
COMPANHIA DE DESENVOLVIMENTO INDUSTRIAL DE PERNAMBUCO
COMPLEXO INDUSTRIAL DE SUAPE

TRANSFER OF LEVEL OF REDUCTION

TRANSCON SA



diper

GOVERNO DO ESTADO DE PERNAMBUCO
COMPANHIA DE DESENVOLVIMENTO INDUSTRIAL DE PERNAMBUCO

COMPLEXO INDUSTRIAL DE SUAPE

TRANSFER OF
LEVEL OF REDUCTION

TRANSCON SA

Tide with semi-daily preponderance

	Reference Stat: RECIFE					Secondary Stat: SUAPE				
	heights above the NR			contribs for		heights above zero on rod			contribs for	
	H.W.	L.W.	fator	H.Ws.	L.Ws.	H W	L.W.	fator	H Ws	L Ws
a		0.32	1		0.32		0.11	1		0.11
b	2.72		1	2.72		2.70		1	2.70	
c		0.22	3		0.66		0.27	3		0.81
d	2.77		2	5.54		2.75		2	5.50	
e		0.25	3		0.75		0.22	3		0.66
f	2.62		1	2.62		2.75		1	2.75	
g		0.17	1		0.17		0.25	1		0.25
Sum of contributions				10.88	1.90				10.95	1.83
M.H.W. and M.L.W.				2.72	0.23				2.73	0.22

H = 2.49 h = 2.51

Z = 1.47 a = 1.47

H = M.H.W. obs. − M.L.W. obs. M.H.W. obs. = sum of contribs of H W − 4

$Z = \frac{1}{2}$ (M.H.W. obs + M.L.W. obs) M.L.W. obs. = sum of contribs of L.W − 8

NR calculation at secondary station

(A) When T.S.M.L. at reference station is known

M.H.W. S : 2.18 m

M.L.W. S : 0.10 m

A = 1.14 m

$d = a - (Z - A) - A\frac{h}{H}$

$= 1.47 - (1.44 - 1.14) - \frac{1.14 \times 2.51}{2.49}$

= 0.008 m above zero on rod

(B) When T.S.M.L. at reference station is unknown

$d = a - \frac{Z\,h}{H} =$ ______ =

= m above zero on rod

calculated by:

conferred by:

DATE: 6,7(8/2/74

diper

TRANSCON SA

GOVERNO DO ESTADO DE PERNAMBUCO-PRIC
COMPANHIA DE DESENVOLVIMENTO INDUSTRIAL DE PERNAMBUCO

COMPLEXO INDUSTRIAL DE SUAPE

TRANSFER OF LEVEL OF REDUCTION

Tide with semi-daily preponderance

	Reference Stat: RECIFE					Secondary Stat: CUPE				
	heights above the NR			contribs for		heights above zero on rod			contribs for	
	H.W.	L.W.	fator	H.Ws.	L.Ws.	H.W.	L.W.	fator	H.Ws.	L.Ws.
a		0.32	1		0.32		0.12	1		0.12
b	2.72		1	2.72		2.70		1	2.70	
c		0.22	3		0.66		0.18	3		0.54
d	2.77		2	5.54		2.70		2	5.40	
e		0.25	3		0.75		0.10	3		0.30
f	2.62		1	2.62		2.75		1	2.75	
g		0.17	1		0.17		0.10	1		0.10
Sum of contributions				10.88	1.90				10.85	1.06
M.H.W. and M.L.W.				2.37	0.23				2.71	0.13

H = 2.49
Z = 1.47

h = 2.58
a = 1.42

H = M.H.W. obs. − M.L.W. obs.

M.H.W. obs. = sum of contribs of H.W ÷ 4

$Z = \frac{1}{2}$ (M.H.W. obs. + M.L.W. obs.)

M.L.W. obs = sum of contribs of L.W. ÷ 8

NR calculation at secondary station

(A) When T.S.M.L. at reference station is known

M. H. W. S : 2.18 m
M. L. W. S. : 0.10 m

A = 1.14 m

$$d = a - (Z - A) - A\frac{h}{H}$$

$$= 1.42 - (1.47 - 1.14) - \frac{1.14 \times 2.58}{2.49}$$

= 0.09 m above zero on rod

(B) When T.S.M.L. at reference station is unknown

$$d = a - \frac{Zh}{H} = \_\_\_\_\_\_ =$$

= m above zero on rod

calculated by:
conferred by:

DATE: 6,7 (8/2/74

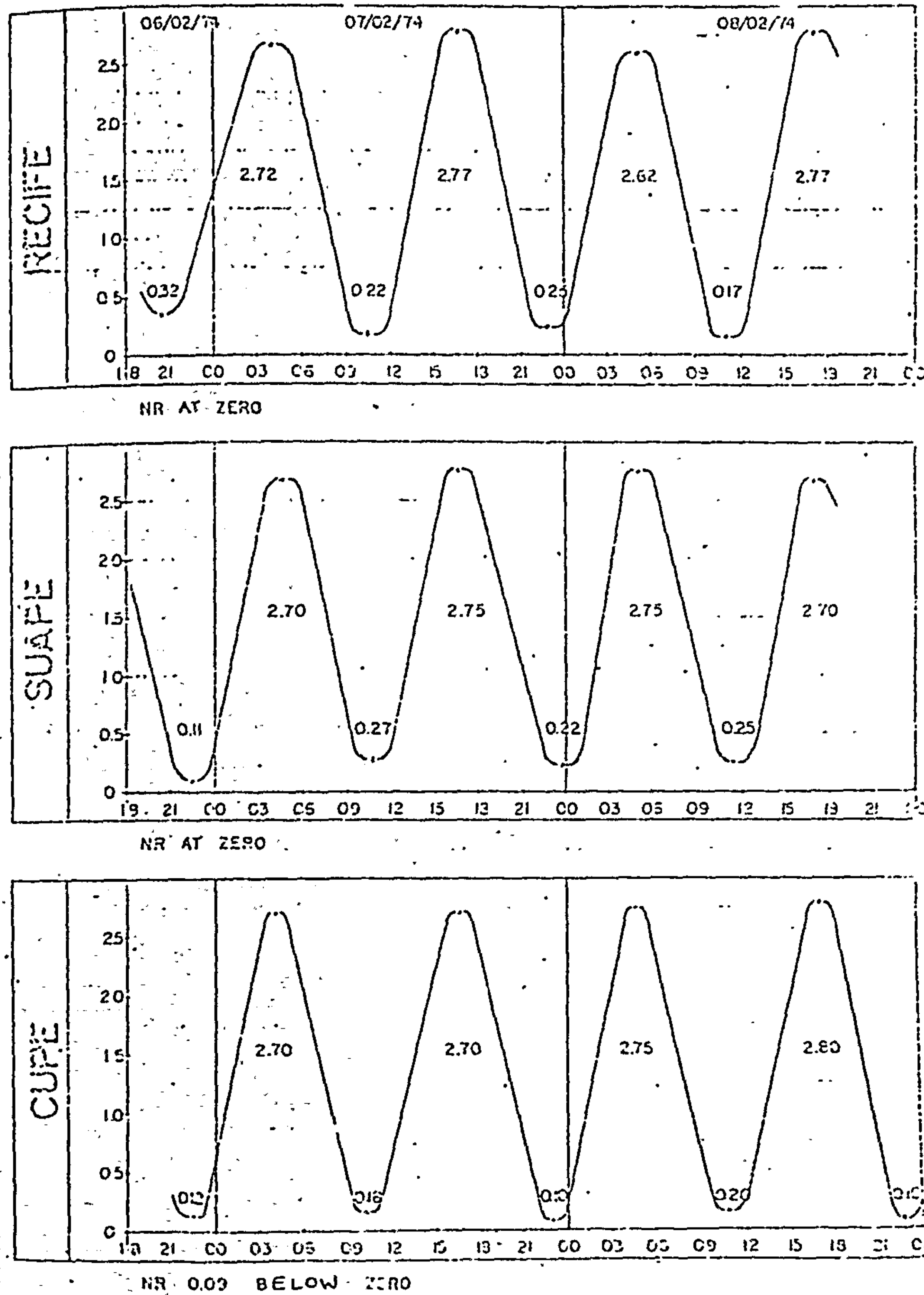
diper

TRANSCON SA

GOVERNO DO ESTADO DE PERNAMBUCO
COMPANHIA DE DESENVOLVIMENTO INDUSTRIAL
DE PERNAMBUCO

COMPLEXO INDUSTRIAL DE SUAPE

TRANSFER OF
LEVEL OF REDUCTION



diper

GOVERNO DO ESTADO DE PERNAMBUCO
COMPANHIA DE DESENVOLVIMENTO INDUSTRIAL DE PERNAMBUCO

COMPLEXO INDUSTRIAL

TRANSFER OF
LEVEL OF REDUCTION

TRANSCON SA

2.2 BATHYMETRIC SURVEYS

The bathymetric surveys covered the areas of interest previously selected with a degree of densification capable of permitting consideration of the port concept and furnishing elements for calculating the volumes of dredgeable materials, with the necessary approximation to the level of the Master Plan.

The bottom of the inner area, composed mostly of sedimentary materials, never appeared to be deeper than 10m. This depth is found at only one point, where the waters are turbulent at the confluence of the Massangana and Tatuoca rivers.

All the rivers present shallow banks, with only one drainage ditch which reaches -7 to 8m on the Massangana, -4 to 5m on the Tatuoca and -3 to 4m on the Ipojuca.

The Suape basin is cut by a series of canals, with a depression of 1.5 to 4m along the reefs as well, created by the river currents and/or the tides.

At the extreme end of the sandbar, between the reef formation and the cape, are isobaths between -6 and 10m which, as they rapidly deepen in the direction of the open sea, reach a depth of 14m at a distance of only 100m.

In the outer area, the depths increase gradually in a southeast direction, reaching an isobath of 19m at about 6,400m from the sandbar and at 1,800m from the Ponta do Cupe.

Generally, the isobaths follow a SW-NE direction.

A depression is noted that causes the consideration of a natural channel with minimum depths of 17m, in a SE-NW direction, to the mouth of the sandbar.

Another significant characteristic of the bottom, in the outer area, is an ample pit to the south of Cupe characterized by an isobath of 20m at a distance of 2,000m from the coast, 22m at 3,000m and 23m at about 6,000m.

In an approximately easterly direction, starting from the Ponta do Cupe, an isobath of 30m is found 17 km out to sea and about 21 km in the same direction starting from the reefs of the Suape basin.

In an approximately NW-SE direction, starting from near Cabo de Santo Agostinho, reconnaissance work was performed of the bottom to a depth of 110m, situated only somewhat more than 30 km, observing a more accentuated downslope starting at 28 km, approximately. At about 17 km, the reconnaissance detected a slight elevation, with minimum depths of 26m.

The volume of drawings presents the results of the bathymetric surveys.

2.3 GEOPHYSICAL SURVEYS

For better characterization of the results of the geophysical survey, the area was divided into four parts:

- the inner area, comprised of the Suape basin and the Massangana, Tatuoca and Ipojuca rivers;
- the chain of reefs;
- Cabo de Santo Agostinho (Santo Agostinho cape);
- the outer area or open sea.

Following is an analysis of the results of each area, with the characteristics of the most significant sections in regards to the port concept and its respective positions being presented in the volume of drawings.

The records, duly catalogued, will be available for consultation in a single volume, in the possession of TRANSCON until the conclusion of design work, since reproduction of the same would not present satisfactory results.

ANALYSIS OF THE INNER AREA

a SUAPE BASIN

In this basin, according to the interpreter, records vary between good, fair and poor.

The good quality records, showing a well-defined rock, are of the area near the banks of Cabo de Santo Agostinho, at river mouths and deep parts, not near the reefs.

The fair and poor records are found near the sand banks and alongside the reefs, and are due to the weakening of acoustic impulses, caused by these materials.

The mapping of rock is obtained with a good safety margin due to good penetration of energy in this basin.

The depths of the rock vary from 11m, near Cabo de Santo Agostinho, to 70m on the reefs, with the remainder of the points in the basin having varying depths from 35 to 60m.

The materials existing and found in the basin, seen from top to bottom, are the following:

> A layer of sand, varying from 3 to 30 meters, followed by a layer of clay, oscillating from 0 to 24m, continuing with another layer of sand varying from 0 to 50 meters, followed by rock.
>
> Observation: These data were concluded from geological profiles. They are representative of a sectioning shown on geological-geophysical profiles found in the respective volumes of drawings.

It should be noted that not all these layers exist, as some areas contain no clay at all.

There are also lateral extensions of the reefs up to around 30 meters from the outcrop, with a width varying from 0 to 4 meters.

b MASSANGANA RIVER

The records obtained are of good quality.

Mapping of the rock, in the section where sounding was applied, is highly reliable, having given a result identical to that obtained by rotary drilling. The depths of rock decrease, beginning in the estuary at 50 meters and reaching about 6 meters up the river in the surveyed part.

The materials found are the following, in vertical order from top to bottom: a layer of sand varying from 5 to 25 meters, a layer of clay between 0 and 25 meters, followed by another layer of sand between 6 and 20 meters and, afterwards, rock.

This is valid for the section between the estuary and point 21 on line B.

Between points 22 on line B and 254 on line E, we find the following vertical arrangement: sand with a thickness of 0 to 20 meters and a sandy-clayey rock varying in thickness between 0 and 13 meters, followed by a base.

Between the points 251 and 254 on line E, there is a layer made up of sand and clay with a thickness of some 3m above the base.

In the section 244 to 251 of line E, there is a layer of clayey sand about 3 meters thick, followed by sandy-clayey rock with a thickness that varies between 1 and 7 meters, then followed immediately by the base. In the final section of the sounding lines, at the head of the river, there is a layer consisting of sand and clay about 3m thick over the base. These data are relative to the sectioning shown in the cited geological-geophysical profile.

c TATUOCA RIVER

Good quality records were obtained, with high reliability in interpretation of the base.

The depth of the base decreases, varying from 45 meters in the estuary to 16 meters at the head of the river.

The materials existing, in a vertical manner from top to bottom, are: a layer of sand with a variable thickness from 3 to 12 meters, followed by a layer of clay with a thickness from 0 to 15 meters and, again, a layer of sand between 4 and 30 meters, situated on top of the base.

In the section where clay is not found, the sand is the only layer, with a thickness of 35m, on top of the base.

These data are representative of the sectioning shown by the cited geological-geophysical profile.

d IPOJUCA RIVER

The geophysical records obtained are of good to poor quality.

Along the river, the records are good; however, they decline in quality near the reefs.

The depth of the base decreases, varying from 70m in the estuary to 40m at the head of the river, at the last points surveyed.

The description of the materials that exist, vertically from top to bottom, is as follows: a layer of sand with varying thickness from 7 to 10m, followed by a layer of clay varying from 4 to 11m, and having a new layer of sand 40m thick.

These data refer to the sectioning shown by the geological-geophysical profile.

CHAIN OF REEFS

The reefs, as confirmed by Mabesoone, are formations of calcareous sandstone, having its origin in the cementation or union of quartzous sands by carbonatic fragments, which was confirmed up to the level reached by the sounding work performed on the chain.

The geophysical records near the reefs are of low reliability due to the weakening of the acoustic impulses due to lateral extensions of the reefs, which extend up to 30m in the inner area and 80m in the outer.

In the vicinity of the reefs, the depth of the base varies from 16m near Cabo de Santo Agostinho to 70m in the Ipojuca estuary and to 40m on Cupe beach.

This reef is near a geological fault, responsible for the present coastline configuration.

The transverse section was determined through dives at eight points, as indicated in the illustration at the end of this item, and this section shows gradual banks on the order of 1:3 as can be seen in the drawing in the respective volume.

CABO DE SANTO AGOSTINHO

The records near this point are very important, as they show the base and permit correlation of this to the inner and outer areas, also pointing to its disappearance due to the non-penetration of energy in the sections where reefs are superimposed.

The records near the cape are of a good quality and offer sure interpretation of layers until the base is reached.

The depth of the base near the cape varies between 12 and 20m and gives the impression that the contact between the cape granite and the base, which is pre-Cambrian, is abrupt.

ANALYSIS OF THE OUTER AREA

This area extends from Cabo de Santo Agostinho to the Cupe beach, for about 7 km (seven kilometers) towards the open sea, beginning at the reefs.

The records obtained are of good quality, except near the reef for the reasons previously established.

Also, in the zones where faults are found, the quality of records decreases.

Although the outer area is identical to the inner in terms of tectonics, a large number of faults was found, taking into consideration the greater extension of the former.

Physiographically, it was found that the base deepens progressively towards open sea. It was observed, however, that in virtue of the series of faults that are parallel to the reefs, the base returns at each fault to a lesser depth and later deepens once again, until it reaches another fault.

Four extensive faults were found in this area, parallel to the reefs, reasonably equidistant, with the first being in the vicinity of the chain.

Others of lesser extension appear perpendicular to these faults.

Zones with reefs were found in the outer area but they are not large and are sparse.

However, at Cupe beach, up to part of Gamboa beach, near the coast a reef zone appears with a thickness of up to 9m.

The lesser depths of the base appear near Cabo de Santo Agostinho, at nearly 17m (seventeen meters). The remaining depths oscillate between 25 (twenty five) and 50m (fifty meters), reaching 70m (seventy meters) over the reef, in front of Suape beach.

Based on the jet probe drill holes and, also, extrapolation of the data on the inner area, it was noted that the materials above the base are dredgeable, with the exception of reef areas. Dredging, in certain zones, will be more difficult due to the degree of compaction of the existing materials.

The predominant material is sand, with the upper part made up of sand and the remains of shells and coralligenous sand-corals.

CONCLUSIONS

1- In general, records are of good quality and permit mapping of the base with a safe margin of reliability.

2- The depth of the base in the inner area varies from 70m (seventy meters) near the reefs to 6m (six meters) on the last part of the Massangana river surveyed.

3- The materials found, sand and clay, are dredgeable in the parts surveyed by geophysics, with the exception of the reefs.

4- The depth of the base in the outer area oscillates between 25 (twenty five) and 50m (fifty meters) with points, however, between 17 (seventeen) and 70m (seventy meters).

5- The pre-Cambrian base outcrops in a NW direction, that is, perpendicular to the reefs, however, quite distant and on dry land. This base is cut by a series of faults parallel to the reef.

6- Between Cupe and Gamboa beaches, reefs are found along the coast that are some 9m (nine meters) thick.

7- With the exception of the part surveyed up the Massangana river, it is feasible to consider dredging all the other parts.

8- The observations and conclusions noted herein will be presented in a greater degree of detail upon incorporation of supplementary data.

9- As per the aspect of dredging, the Suape Industrial complex can be considered preliminarily feasible, within the limitations up the Massangana river.

2.4 GEOLOGICAL INTERPRETATION

STRATIGRAPHY

An almost constant relation of the sedimentary layers existing over the base was proved by percussion and rotary drill holes. The base, a rock column, is presented considering only the rocks encountered in the researched area and not the regional geology. The sequence obeyed the order in which the rocks were formed (stratigraphically):

Rock	Age
Gneissic-granitic base	pre-Cambrian
Arkosic sandstone	
Chalcosodic granite	
Alkaline plutonics	
Barreiras series	tertiary
Alluvionary sequence and reefs	recent quaternary

Here the base includes all the "hard" rocks found in the area such as gneiss, arkosic sandstone, granitic stock and alkaline plutonics. The portion considered dredgeable was divided into its predominant characteristics: sand, clay, sandy clay, coralligenous sand and clayey-sandy sediments of the Barreiras series.

THE INNER AREA

The Massangana river, upstream, presents a thin superficial clayey-sandy cover at the confluence of the Algodoais stream (Riacho Algodoais) with the Massangana. There the base is about 6 meters below the surface, with a lowering of the same in a northwest direction near drill hole No. 13 (with approximately 25m of tertiary sediments) and a later rise up to about 8m, near drill hole No. 5. This depression, which is quite sudden, could have been caused by an ancient fault that resulted in a valley and was later covered over by tertiary and recent sediments. The direction of the valley is SSW-NNE and seems to reach at least to drill hole No. 6 (with 25m of quaternary sediment). From point 13, headed in a northwest direction, there is a visible rise in the base up to an outcrop, although there is a very thick layer of exomorphic rock. In the case of drill holes No. 9 and 10, there was exomorphism through 5m.

Downstream from the confluence of Algodoais stream with the Massangana river to about 2 km below, there is sand, the Barreiras series and the base, superimposed, the total varying from the initial 6m to 24m at this point where the Barreira series occurrence ends and where the last advance of the Cenozoic ocean must have reached, for from there to the mouth of the river a sequence of sandy (marine) layers are recorded with thick clayey layers (fluvial) which dictate the dominance of one ambience over the other during the eras of quaternary sedimentation.

The change of sandy clay to sand and surface clay took the form of a graduation in material content, due to the ebb and flow of the tides.

In the more internal parts of the area, out of the reach of the tides, there is a layer over the sediment which is clayey, with a great deal of organic material, product of decomposition of the same by vegetation and soil moisture.

In the Tatuoca river, whose minimum datum level for its base is about 5.5m at drill hole No. 4, from 50m at its mouth, its order of layers is still: base, sand, clay layer and surface sand. This river also presents a large paleochannel structure, filled with sand.

The Ipojuca river was considered along with the Suape basin, for its surveyed area is very small and all this region has the same stratigraphy, or rather, base, sand, clay and surface sand, with variation only in thickness. The base is found at great depths in almost its entire extension, with datum levels increasing somewhat in the direction of the reefs and decreasing suddenly when nearing Cabo de Santo Agostinho. The layers taper off in thickness at that point until they disappear, thus the conclusion that all the sediment was deposited over a basin which was bound, to the north, by the granite of the cape.

Perfect outcrops appear at Cabo de Santo Agostinho, where the layers of the Barreiras series are found over the granite. This stretches into the sea to about 300 to 500m, but the downslope is very sharp, dropping until merging with the pre-Cambrian base.

OUTER AREA

Separated from Suape bay by the chain of reefs, this region varies in surface stratigraphy with a thin layer of sand largely containing the remains of shells and corals covering the entire outer area.

According to the drill holes bored in this area, by jet probe, this layer of sand was extremely hard. Where the jet penetrated the layer, a base layer of sand was encountered and penetration was limited. However, according to geophysical records, the entire area between the base and the coralligenous sand was mapped as sand.

The relief of the base appeared very cut up in this area due to paleoerosive and tectonic effects.

As for the reefs, they are barely penetrable by sound and, therefore, easily identifiable by seismic means; they were shown to be only on the surface, always over a layer of sand.

According to profiles made by the diving team, there are parts along the chain that measure over 100m and the geophysical instrumentation detected its "skirts" on various occasions. The drill holes above the reef, near Cabo de Santo Agostinho, came up with average widths of 3m. Geophysical interpretation showed thicknesses of up to 9m near Cupe.

The existence of subterranean reef chains was not proved, except at the entrance to the sandbar where they are eroded and somewhat covered over with sand. On the inner as well as the outer part, all the reefs outcrop soon after the surface layer of sand, whether appearing above sea level or not.

STRUCTURAL GEOLOGY

INNER AREA

With the exception of the faults found in those parts where sedimentary metamorphic and igneous (from pre-Cambrian to tertiary) rock occur, faults whose main direction is SSW-NNE, approximately parallel to the present reef line, and which follow the faults that dictate the northeastern coastline of Brazil, there is a depression near drill hole No. 13, in the same direction as the regional fault, which could indicate a fault whose eastern block rose and western fell, but with a probable small rejection. The rocks at drill hole No. 12 presented visible signs of fracturing, which can be used as the near boundary of this fault.

OUTER AREA

The entire base near the reef chain, within the bay, is found at depths varying from 50 to 70m.

The datum levels are sharply diminished, crossing the reefs towards the sea for about 20 to 30m. This "cliff" also follows the SSW-NNE direction of the regional faults. The sudden change in datum levels is due to a large fault, which dictated the coastline at this point and consequently caused the reefs, in the quaternary, following the coastline. In this fault, the western part sank and the eastern part rose. This latter, in turn, begins to sink gradually to about 45m, 3 km out to sea from the reefs, and turns suddenly to the east at levels of up to 20m, indicating the presence of another parallel fault, in the SSW-NNE direction.

Almost all the faults are normal, with rare cases of superimposition.

There are also lesser faults, running approximately SSE-NNW, or rather, perpendicular to the principal direction.

These are all plotted on the base map under the symbol Fa, only at the points where detected by the geophysical survey.

As referred to previously, the relief of the base appears very cut up, with various paleochannels and a greatly eroded ex-surface, with sparse drops up to 17m deep, although most commonly with elevations of up to 20m. Many of these are caused by faults in the base.

LITHOLOGY

Some macroscopic characteristics of each lithological type found in the area are presented below. The problems most probably encountered upon dredging are also mentioned.

a GRANITE

Found to form Cabo de Santo Agostinho and spreading suddenly towards the sea to merge with the gneissic base, its state of decomposition reaches about 5m, mixing with overlaying sediment of the Barreiras series. It is a very stable area, for there are no great fractures nor faults cutting it, in that it is newer than the regional faults; this is confirmed by the fact that the granite cuts the fault parallel to the reefs, rather than the fault extending itself over the granite.

A dike that crosses this granite has a maximum width of 10m of rhyolitic and alkaline rocks.

b GNEISS

Found in drill hole No. 10 in a semi-fresh state, at a depth of 14m, with an exomorphic layer of 5m over fresh rock, for the entire zone up the rivers this indicates the presence of a gneissic base at shallow depths, until it outcrops to the northwest, although always with an exomorphic cover.

c ARKOSIC SANDSTONE

This is found in drill hole No. 12 in a fresh state, somewhat fractured, at a depth of 10m, stratigraphically above the base and below the Barreiras series. It contains many angular sandstone fragments, indicative of the presence of a fault. This rock is cut by chloritized igneous dikes.

d ALKALINE IGNEOUS ROCKS

These exist in the form of dikes, cutting the granite of the cape. A trachyte forms a dike on the edge of the cape, in Suape bay, outcropping right below Nazaré fort, and seems to continue on Suape beach where there is an outcrop of green clayey rock, quite decomposed. This occurrence can only be seen at low tide. In drill hole No. 12, the arkosic sandstone is cut by a greenish igneous vein which is clayey and somewhat exomorphized.

Regarding the dredging of the described rocks, only the exo-morphic covers can be removed, in that the rocks in their fresh state can only be separated by means of blasting.

e BARREIRAS SERIES

These are tertiary clayey-sandy sediments, of a reddish color, with almost horizontal layering, which outcrop in all parts of the project. The base layer of this series is an oligonitic conglomerate, whose pebbles are quartz, well polished and up to 5 cm in size. Its thickness is 1 meter, being quite visible at Cabo de Santo Agostinho, at the granite-Barreiras contact. This same conglomerate is found in the outcroppings at Suape beach, already quite decomposed. On the beach, it outcrops for some 150m in the direction of Cabo-Pontal. The layer is dredgeable, but with some difficulty.

f CLAY

This appears generally in the form of a layer, a bit sandy and quite compacted, which causes it to mold to applied pressure. It is typical clay of fluvial origin, dredgeable with some difficulty.

g SAND

This is quartzous, in layers formed in marine ambience, with great variation in grain size from place to place, consisting of large amounts of shell remains and well-polished grains; usually its layers do not have graded-bedding, but rather the entire grain size gamut is intermixed, one with another, showing the inconstancy of the forming agent. The layer is easily dredgeable as it is quite disaggregated.

h SANDY CLAY

Found on the flats flooded over by the rivers, its mixed composition is due to the ebb and flow of the tides. It contains a layer that is generally thin, easily separable, with a great amount of organic matter, enclosing some more sandy or clayey areas. It is easily dredgeable.

i CORALLIGENOUS SAND

Quartzous material, containing a great amount of shell and coral remains, it covers the entire outer area with a thin layer which at times is joined by means of a calciferous material, although separatable with little difficulty since this hard layer does not exceed 10 cm in width; all the rest is easily dredgeable.

j SANDSTONE

Quartzous rock, whose rounded grains were joined by siliceous remobilization, its maximum thickness is about 4m and it is found often to be separated. It appears on Tatuoca island, in layer form, dipping to the west where it is deeper and outcropping at the confluence of the Massangana and Tatuoca rivers. Other occurrences were detected by drill holes, as in drill hole No. 6, but with negligible lengths and thicknesses. Within the Massangana river (in its channel), sandstone does not appear in its subsurface as it must have been eroded by the river channel. Its dredging would not be advised as its removal would probably entail blasting.

k REEFS

Sandstone body with calciferous cementation, very hard, containing polished quartz pebbles, shell remains, crossed stratifications, etc., it generally is tubular in form.

Its present state is one of erosion, noted by the channels that are being created in its surface by water and wear caused by water in the existing fractures, causing separation of large pieces.

Besides the chain parallel to the coast, near Cupe and Gamboa beaches, various isolated reef bodies can be found as plotted on the base map under the symbol R. These reach nearly 2 km to sea from the Pontal de Cupe and were detected by the geophysical survey.

In the drill holes made in the reefs, a sandy layer was found underneath that was very difficult to penetrate by percussion drilling. It shows cementation by leaching of calciferous material of the reefs and, possibly, compaction by the weight of the reef. This cementing indicates that dredging over the reefs would be somewhat difficult.

JET-PROBE RESEARCH IN THE CANAS STREAM

Considering the channel route alternative for the preliminary port concept between the Tatuoca and Barreiras islands, through the Canas stream, a series of jet-probe tests were performed in order to permit, still of a very primary nature, the characterization of places with greater or lesser difficulty for dredging in that area, as well as assistance in directing the geotechnical drilling program along the cited route.

As for the reconnaissance performed, positioning of drill holes was related to characteristic points in the nearby area, with large markings on trees located along the banks; these trees were, most often, used as support bases and were painted to permit later recognition due to the difficulty in establishing topographic support in the area which is extremely marshy.

All the drill holes have samples of the various materials of which they are composed. However, as could be expected, they are extremely deformed and have a high water content, primarily those which are more clayey, due to the jet-probe sampling mechanism itself.

In drill hole No. 1, the jet-probe was unable to penetrate as it hit a resistant sheet of sandstone. Therefore a transversal profile was made by the mouth of the river until Barreiro island was reached, in order to verify the continuity of this rock. From these data, where the sandstone appears right at the surface of the river bed, and relating it to the drill holes, it was easily established by extrapolation that a layer of friable sediment lay beneath this sandstone.

From drill hole No. 1 to 10, no great problems were encountered except for No. 5, 7 and 9 where the hole ended, not because of impossible penetration but rather of other difficulties, such as tide changes, etc. Thus, it is likely that greater thicknesses of friable sediment lay beyond the end of these drill holes, as was indicated in the geological profile further on where the end was impenetrable, simply for purposes of correlation.

In drill hole No. 10, because sandstone was found at about 5 meters from the zero level, further research was decided upon, also by jet-probe, in order to verify the horizontal extension of the outcropping, as was established. Various drill holes were made but only four resulted in reliable samples. In the areas away from the occurrence, the jet penetrated between 6 and 9 meters without finding any resistance.

Drill holes No. 11 and 12 were also not ended because of impenetrability, for the same reasons explained previously. From there to drill hole No. 15, there were no problems.

Of the fifteen drill holes, the only ones that showed the impenetrable material to be sandstone were No. 1 and 10; in the others the nature of the impenetrable material is unknown, and could be sandstone or base rock. A correlation of the type of this rock can be found in the comments that appear with the geological profiles which follow.

The stratigraphy of the area remains unalterable, with many layers of sand as well as clays resting directly on the base or interspersed with clay or vice-versa.

Up river there is a homogenization of layers, or rather, from drill hole No. 11 to No. 15, only a thick layer of silty clay appears over the impenetrable material, to the surface.

Based on the observations made from the previous drilling, it was possible to extrapolate, in the drill holes that proved impenetrable in sandstone, some thicknesses of clayey-sandy sediments underneath.

There is a concentration of clayey-sandy material with organic matter in the more marshy areas, forming the more recent sediments; treated as humus, it is easily removed by dredging.

All of the materials found, from drill hole No. 1 to No. 15, can be dredged easily with the exception of the sandstone that presents thicknesses from 1 to 5 meters; it is unlikely that the sandstone will be found greatly exomorphized and disaggregated.

Another factor to be observed is the non-occurrence of the Barreiras series in this area of the Canas stream, as it ends, almost abruptly, at Barreiros island.

SANDSTONE	SANDY CLAY WITH ORGANIC REMAINS
SILTY CLAY	FINE-TO-AVERAGE SAND
SANDY CLAY	THICK-TO-AVERAGE SAND
WATER	BARREIRAS SERIES
IMPENETRABLE	EXOMORPHIZED ROCK
HUMUS	END OF DRILL HOLE

VERTICAL SCALE 1:500	CHANGE OF FACIES
HORIZONTAL SC 1:50,000	LACK OF LITHOGRAPHICAL CORRELATION
F_S - DRILL HOLES	PROBABLE CORRELATION
F - JET-PROBE HOLES	LITHOLOGICAL CORRELATION
A A' GEOLOGICAL PROFILES	PROBABLE FAULT

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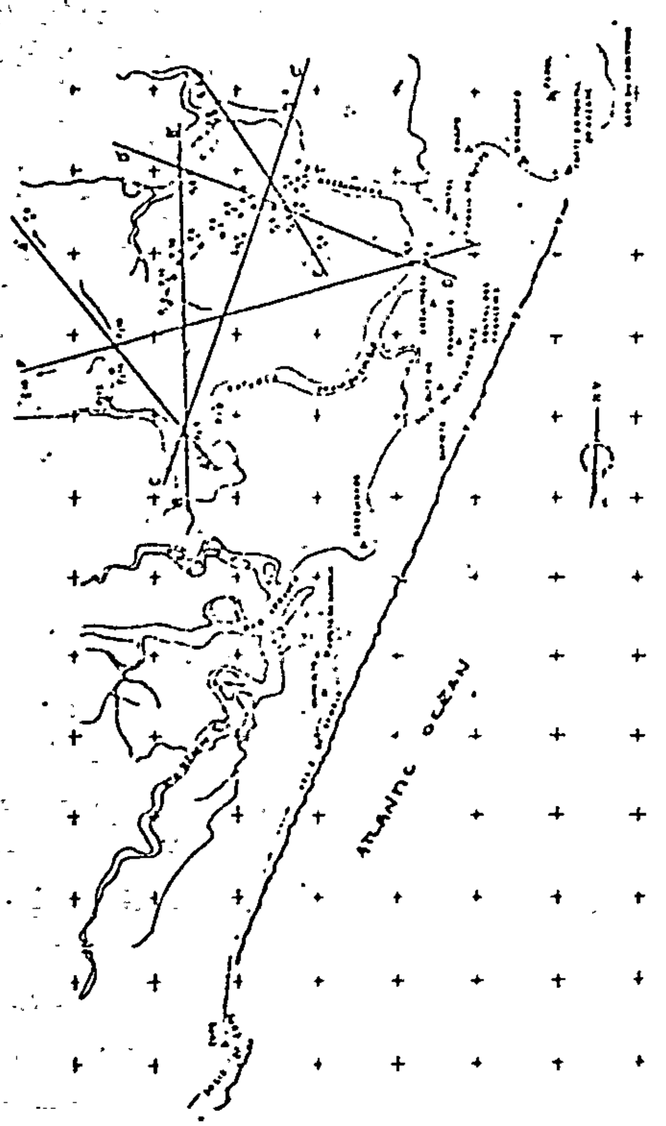
COMPANHIA DE DESENVOLVIMENTO INDUSTRIAL DE PERNAMBUCO

COMPLEXO INDUSTRIAL DE SUAPE

KEY FOR
GEOLOGICAL PROFILES



JET-PROBE DRILL HOLES

DRILL HOLES

PROFILE LINES

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DE PERNAMBUCO

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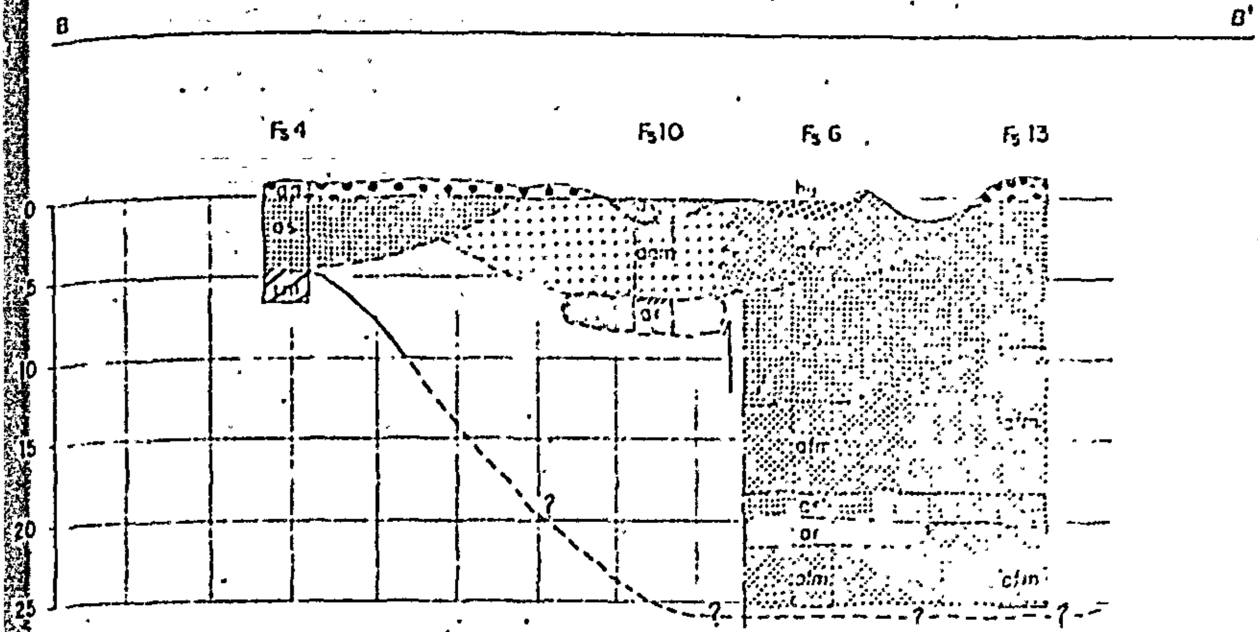
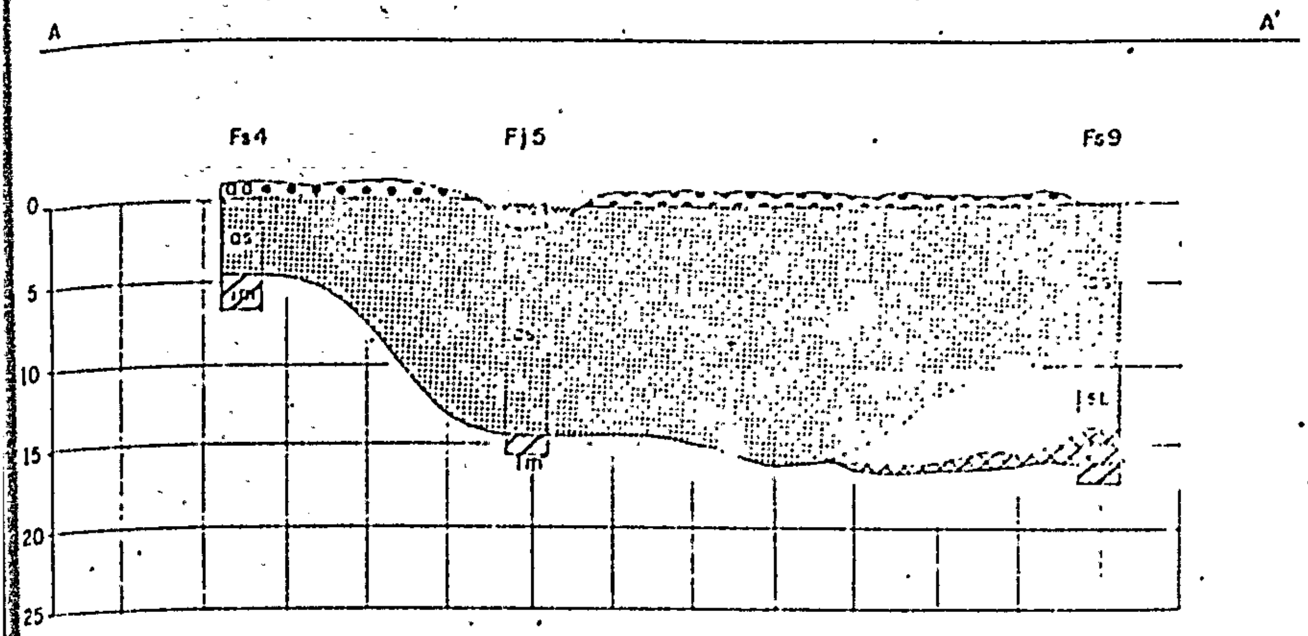
POSITION MAP OF GEOLOGICAL PROFILES



OBSERVATIONS

If friable sedimentary material is sought beneath the sandstone in drill hole No. 10, a layer should be found of the thickness of that in drill hole No. 6, where the sandstone seems to have been dislocated by reactivation of ancient faults. This motion could have caused a mixture of those sediments found with the active part of the fault.

diper TRANSCONSA	GOVERNO DO ESTADO DE PERNAMBUCO - PRAC COMPANHIA DE DESENVOLVIMENTO INDUSTRIAL DE PERNAMBUCO COMPLEXO INDUSTRIAL DE SUAPE GEOLOGICAL PROFILES	



OBSERVATIONS

The impenetrable material of drill hole No. 4 is argillite and of No. 9 is gneiss. Because of the overall agreement of drill holes No. 4 and 15, this impenetrable material should also be argillite.

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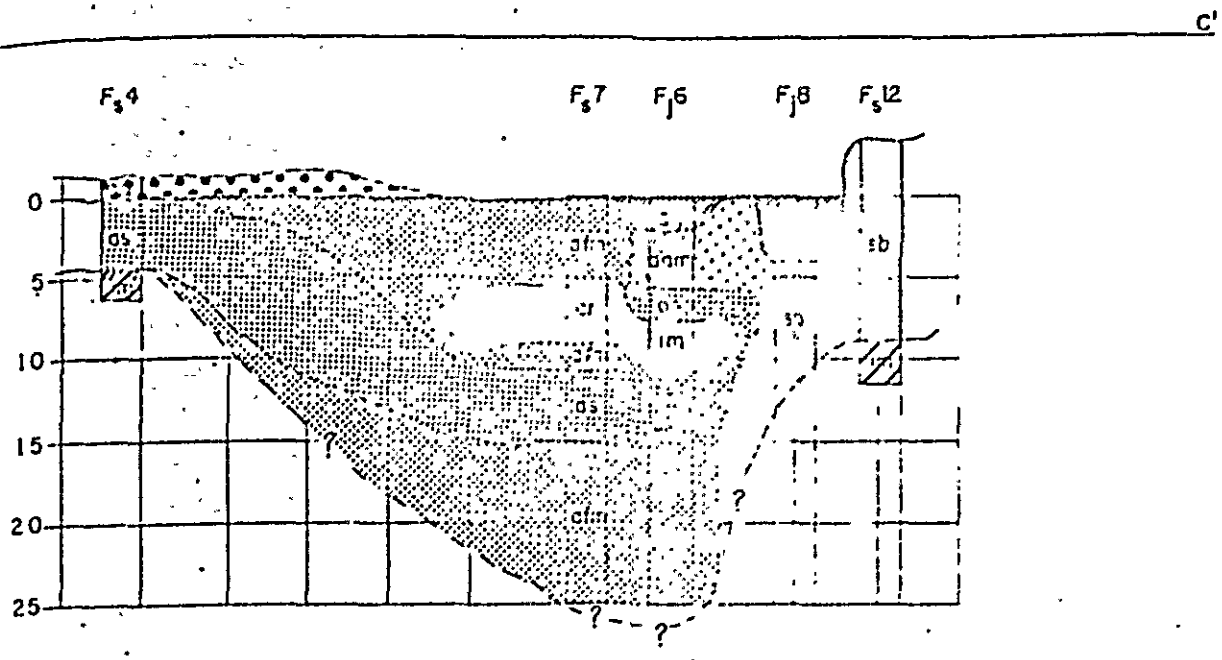
GOVERNO DO ESTADO DE PERNAMBUCO - PRAC
COMPANHIA DE DESENVOLVIMENTO INDUSTRIAL DE PERNAMBUCO

COMPLEXO INDUSTRIAL DE SUAPE

GEOLOGICAL PROFILES



OBSERVATIONS

If the impenetrable layer of drill hole No. 6 is interpreted as sandstone, there will surely be a friable sediment layer down to the real base, which will not be the case should the impenetrable layer concur rather with drill holes No. 4 and 12, as argillites and arkosics.

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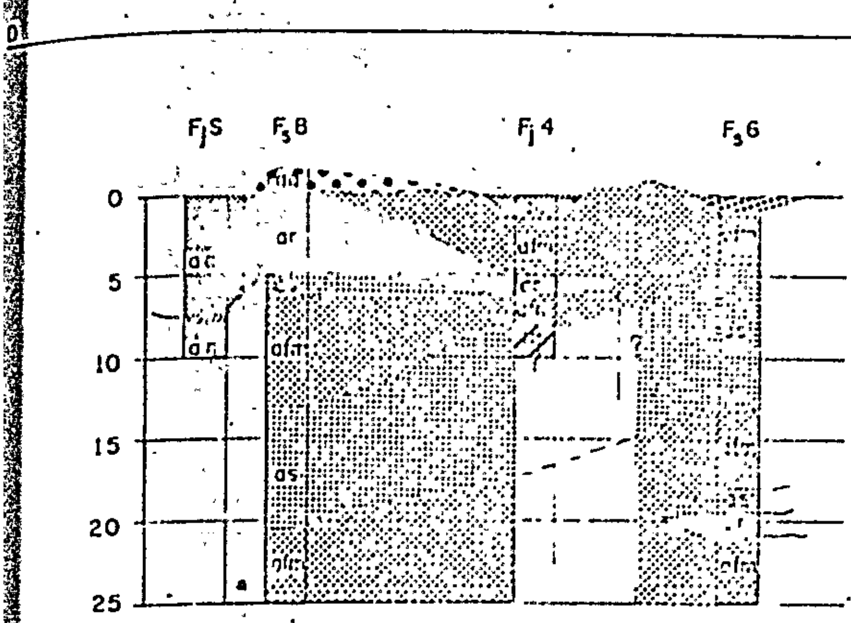
GOVERNO DO ESTADO DE PERNAMBUCO - PRAC

COMPLEXO INDUSTRIAL DE SUAPE

GEOLOGICAL PROFILES



OBSERVATIONS

There are two ways of interpreting this profile:

1) where there are two laters of sandstone, one in drill holes S to 4 and the other in drill hole No. 5, which would correspond to having no interruption in the upper and lower sediment layers.

2) where there is a fault equal to that of profile B-B', which would dislocate the sandstone layer and in that case there would be no correlation between the layers of drill holes No. 8 and 6.

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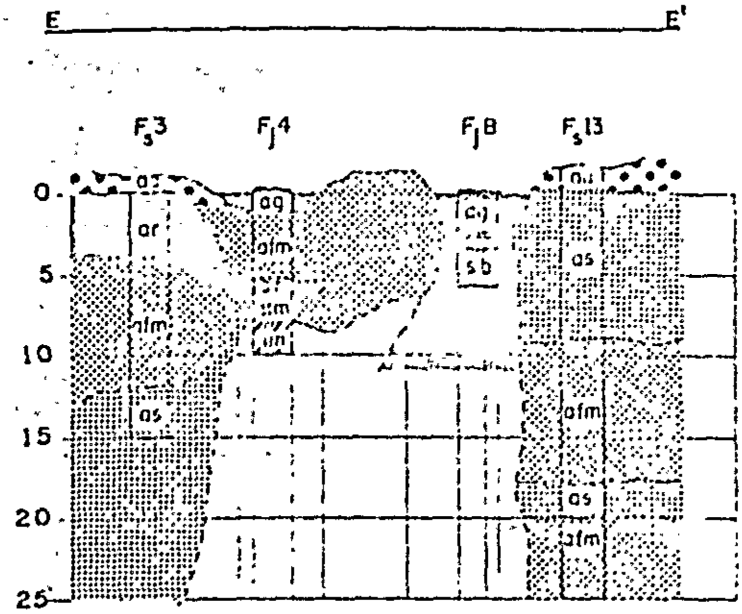
GEOLOGICAL PROFILES



OBSERVATIONS

Drill hole B appears only to have the Barreiras series in this profile, that is, one extension alone covered by quaternary sandy-clayey sediment.

In drill hole No. 4, regarding the impenetrable matter, since a thin layer of sand is found beneath the sandstone, it is not likely that more sandstone will be found underneath; furthermore, since there are no quaternary alluvial layers in drill hole B the impenetrable matter can be extrapolated for drill hole No. 4 as Barreiras series, which is impenetrable by jet-probe. This still permits a dredgeable layer before reaching the base.

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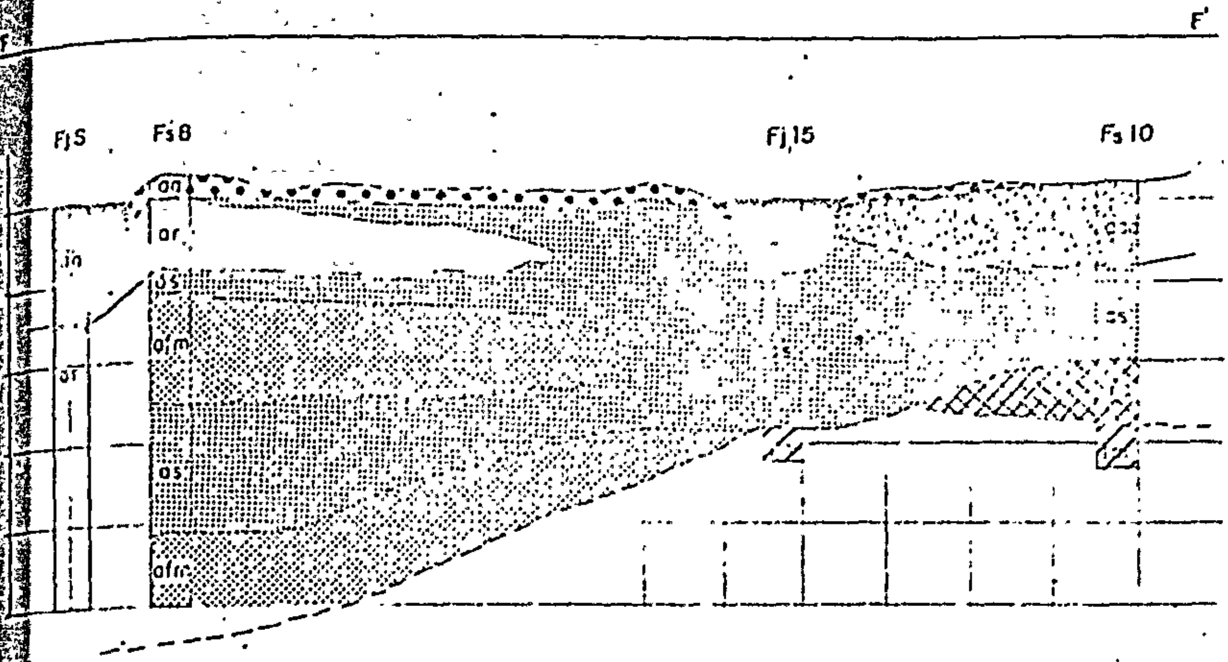
		GEOLOGICAL PROFILES
	TRANSCON S.A.	



OBSERVATIONS

In drill hole S the sandstone that outcrops at the river bottom appears to be the base of the layer of sandstone also found in drill hole No. 8; this should not be any thicker, and should have the same sediment sequence as drill hole No. 8, underneath.

In drill hole No. 15, the most easily correlated impenetrable matter is argillite (see profile A-A').

CONCLUSIONS AND RECOMMENDATIONS

In the case of dredging and rectification of the Massangana river, the following should be observed:

- The layer of sandstone that occurs on Tatuoca Island, and its lateral continuation, since this layer does not appear under the river bed in geophysical profiles. Ways of circumventing this sandstone should be studied to avoid blasting (see the block diagram in the respective volume of drawings).

- The continuity of the depression found in drill hole No. 13, since the other drill holes presented some sort of agreement in terms of depth of the base (see the block diagram in the respective volume of drawings). A network of drill holes, more closely spaced, or other on-land geophysical means can be utilized to determined such continuity.

In the case of dredging, the materials that present little difficulty in removal are sand, sandy-clay and coralligenous sand, while the materials in the Barreiras series and the clayey layers present greater difficulty due to the great aggregation of components of these sediments.

The areas where the Barreiras series and igneous and metamorphic rock can be found are very stable for construction of industrial structures as long as faults in the same are made known.

In the case of landfill of marshy areas, only sandy layers should be measured and utilized, primarily those in the Suape bay and the Ipojuca river that present good thickness. Those from the outer area can also be used, including or not the coralligenous sand that is found above the sand layer.

TOMO I - 3.0

ROLO DA I-3/4 PRA I-3/8

3.0 HYDRAULIC AND SEDIMENT SURVEYS

3.0 HYDRAULIC AND SEDIMENTATION SURVEYS

3.1 CHARACTERISTICS OF THE WAVES OFF THE PERNAMBUCO SHORE

The Sea and Swell charts of the U.S. Navy are based on observations collected on boardship, at depths that can be considered as infinite, for practically all present periods.

From compari-ons of informations taken from the Charts, registering the waves during a whole year at some points off the Brazilian shore, it was noted that the general schedule furnishe by these was confirmed by the records, taking into consideration the inherent limitations of the same, which show that:

- the Charts give no information about the period of the waves;

- the heights of the waves are classified simply as "high", "medium" and "low" both for swell and sea. In the charts that show the percentual distribution of both in polar coordinates, shown at the end of this item, the limits of classes according to the height of the waves are determined;

- the directions of the incidence of the waves are grouped according to the eight fundamental directions (N, NE, E, Se S, SW, W and NW), and the visual observation of their directions, at a given depth, make it possible to define them with an error of $\pm$ 5%;

- the fact that these waves were observed at practically infinite depths means that these waves had not yet refracted. As a consequence of the refraction phenomenon, the angles of attack at shallower depths will be less than offshore, since the crests of the waves will have a tendency to become parallel to the shoreline as they propagate themselves along decreasing depths. Offshore, with a general alignment from SW to NE, the waves that come, at great depths, from the South, seem to originate in the SE at depths of about 20 m or less. Besides, the shoaling phenomenon causes them to grow larger, or to increase as they get nearer the shore.

The information obtained from the Charts for the zone where the Pernambucan coast lies are condensed in the four graphs presented at the end of the item, in the shape of polar coordinates, and shows the percentage of occurence of swell and sea for the eight fundamental directions in relation to the total of available information. These graphs show:

- The distribution within these directions, regardless of heights (Graph 2-X)

- The distribution of observations of high swells and seas (Graph 2-X)

- The distribution of swells and seas of medium height (Graph 2-X)

- The distribuion of low swells an seas (Graph

Graph 2-X shows that the highest percentage of occurence of swell (52,0%) and sea (58,5%) originate from the SE. The E direction follows, with 26,2% for swell and 24,6% for sea. From the NE, only 3,7% of swell and 1,6% of sea. From the S, we have 5,2% of swell and 7,6% of seas.

The " direction" of the waves, mentioned above, is that of the local winds that generated them. Chart 2-X shows that the shape indicated for sea is the same as that shown for swell. It can be stated, therefore, that unlike in the south of Brazil, there are no great differences between the direction of the winds and that of the swell. Graph 2-X leads to the belief that the swell that reaches the shores of Pernambuco comes from comparatively near-by generating zones.

As can be seen on graph 2-X, the high swell comes mainly from the SE (5,0%), and little from the E (0,9%). The high seas come also mainly from the SE (2,7%) and a little from the S. No high swell comes from N., NE., and S. , and no high seas from the N. or NE. This last fact shows that the summer seas, at the time when winds from the N.E. prevail, are generally low.

Graph 2-X shows that- also for swells and seas of medium height, the maximums of occurence are associated with the direction coming from the SE. The Eastern direction comes next. There is no swell of medium height coming from the N or NE.

It is still from the direction originating in the SE that occur the maximums of low swells and seas. Next come the directions E, NE (for low swell) and S.

The four graphs mentioned refer to the year as a whole. During the gathering of data for the charts, so that they could be traced, some symptoms of seasonal variations were found, but they are not shown on the charts. These symptoms are:

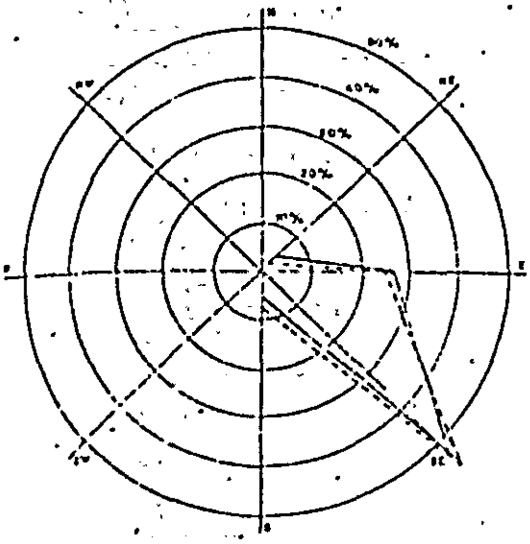
- the months during which most high swells and seas occur are those of late autumn ad winter in the southern hemisphere (from May to September);

- the seas and swells coming from the S are only noted from May to September;

- seas and swells coming from the NE appear only from November to March (summer in the southern hemisphere).

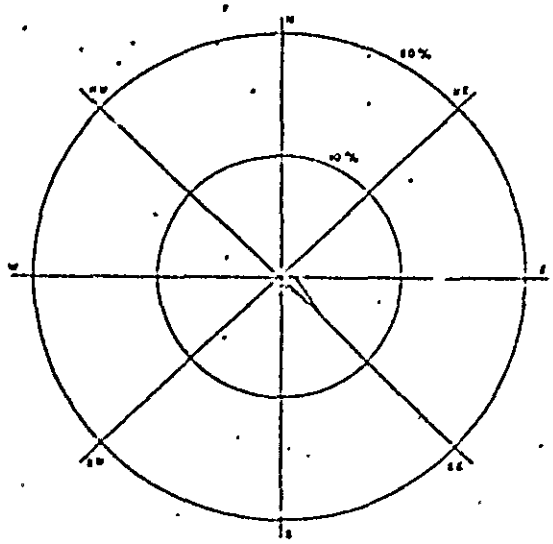
Considering the general alignment of the shore and the occurence of seas mainly from the SE and E, the conclusion is reached that, where the morphology of the shore is favourable to the instauration of coastal transport, there will be transport in both directions, because the seas from the SE produce it to the NE, and those from the E to the SW, but the dominating transport will be to the NE, since the main occurences of swells and seas come from the SE.

The results of this analysis of the data from the Sea and Swell Charts do not suppress the need for records of the seas from observations of at least one yea's duration, when they can be compared. The experiences of these comparisons, carried out by the Special Consultant of TRANSCOM for Coastal Engineering, in Tramandaí, Aracaju and Paranaguá were highly successful, within the already mentioned limitations of the Charts.



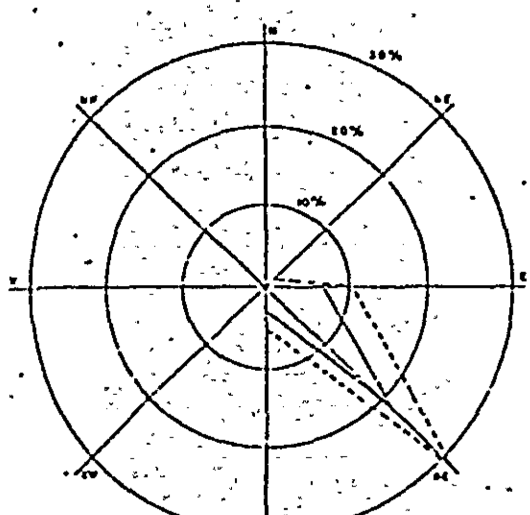
*-Occurence of swell regardless of height
*-Occurence of seas

escala - 0,6 cm por 10%



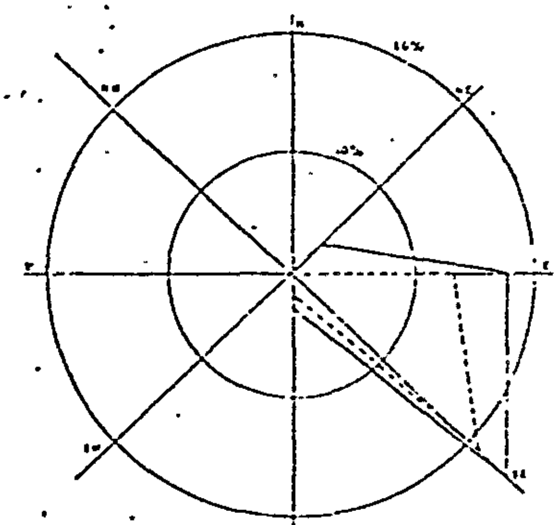
*-Occurence of high swell
*-Occurence of high seas

escala - 1,55cm por 10%



*-Occurence of medium swell
*-Occurence of medium seas

escala - 1,05cm por 10%



*-Occurence of swell
*-Occurence of low seas

escala - 1,55 cm por 10%

*FONTE

SEA AND SWELL CHARTS FOR THE SOUTH ATLANTIC OCEAN US NAVY HIDROGRAPHIC OFFICE.

diper

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COMPLEXO INDUSTRIAL

DISTRIBUTION OF THE FREQUENCY OF WAVES BY TYPES AND DIRECTION OF APPROACH

TOMO I - 30

3.2 MEASUREMENTS OF CURRENTS AND SAMPLINGOF SUSPENDED SOLIDS

In the area outside the reef barrier, currents were measured on the surface and 7 m below, using floats, at 8 points about 300 m offshore, from Boto Beach, to the North, to Porto de Galinhas Beach to the South, in the case of both incomingand outgoing tides.

In the inner area of the reef barrier, current measurements were carried out on the surface. Water samples were collected for the determination of suspended solid matter, in 14 points of the Suape bay. The current measurements were made on two occasions at each point: one during incoming tide, the other at the time of the outgoing tide.

The points of measurements of the currents are shown at the end of this item, as are the results obtained.

Other measurments of currents were made in a similar way in the rivers Massangana and Tatuoca, cloes to Ponta dos Franceses and to Ponta dos Banquinhos, as subsidiary elements for the estimation of the flows of the pprivers and the penetration of tides.

The currents observed on the littoral are all of very low intensity. Average values of 0,06 m on the surface, and 0.03 m in depth were noted, showing they are apparently generated by the wind.

No predominance of any one direction could be noted at any of the eight points were measurments were taken.

As a conclusion, it can be atated that the offshore current, during the days the measurments were taken, had no significant value, and may be considered as inexistent.

A condensation of the measurements of the currents is shown below.

Conversely to the currents observed on the outside, the currents within the reef line show currents with an intensity of close to 1 m/s, generated by the tides.

The higher values are found in the mouths of the rivers Tatuoca (0,93 m/s) and Massangana (0,85 m/s) at the time of the outgoing tide, when an inversion of the current could be noted at high tide or low tide.

The currents in the inside part are stronger in the natural canals that wind about sandbanks.

The ebb and the flow of the waters of the Massangana and Tatuoca rivers are through a canal that connect their mouths with the natural basin close to Cabo de Santo Agostinho, with the shape of an arc of a circle, the concavity of which is turned towards the Bay of Suape, and having, on its inner banks, sandbanks that are uncovered at low tide.

The waters of the Ipojuca and Merepe basins flow through a canal, parallel to the line of reefs, communicating with the sea through the little bar (with high current speeds, the difference in level between the level of the waters in the inner and the outer parts being remarkable) and in part through the natural bar. There is also, at the southern end of the reef line a communication with the sea at high tides, calle the "waterfall", at the site called Muro Alto.

There is a significant quantity of suspended solids, as the results of analyses show, and these are, for the greater part, grains of quarzxwith a maximum diameter varying between 60 and 400 μ and aggloemrates of clay, silt and vegetable fibers.

CURRENTS

(speed in m/s)

Positions			Incoming						Outgoing					
Point Nº	Approximate Coordinates		Surface			Depth			Surface			Depth		
	N	E	Data	Azimuth	Veloc.	Data	Azimuth	Veloc.	Data	Azimuth	Veloc.	Data	Azimuth	Veloc.
01	9.080.230	283.440	24/01/74	280º	0,04	24/01/74	62º	0,02	18/01/74	183º	0,03	18/01/74	213º	0,07
02	9.077.340	285.880	24/01/74	205º	0,03	24/01/74	58º	0,01	18/01/74	28º	0,03	18/01/74	50º	0,02
03	9.073.030	283.040	24/01/74	250º	0,05	24/01/74	33º	0,02	18/01/74	72º	0,05	18/01/74	43º	0,02
04	9.072.700	285.310	24/01/74	235º	0,06	24/01/74	270º	0,03	18/01/74	80º	0,07	18/01/74	283º	0,02
05	9.070.100	284.270	18/01/74	28º	0,07	18/01/74	28º	0,07	24/01/74	93º	0,03	24/01/74	38º	0,05
06	9.065.010	282.150	18/01/74	342º	0,09	18/01/74	245º	0,04	24/01/74	233º	0,08	24/01/74	163º	0,03
07	9.064.140	282.210	18/01/74	330º	0,20	18/01/74	342º	0,05	24/01/74	148º	0,03	24/01/74	333º	0,04
08	9.062.030	280.930	18/01/74	308º	0,05	—	—	—	24/01/74	138º	0,05	24/01/74	343º	0,02

3.3 PENETRATION OF THE SEA, FLOW OF THE RIVERS AND SUSPENDED SOLIDS

SURVEYS CARRIED OUT

On the 8th of February, 1974, during the full moon syzygy tides, between 06.00 and 18.00 hours, simultaneous readings were taken every half hour at all the limnometers of the rivers Tatuoca and Massangana, with the use of explosive rockets to guarantee the simultaneity of readings. Water samples were also collected on the surface and at half depth, close to each rod at 06.00, 12.00, 15.00 and 18.oo hours.

Transverse sections of the rivers Massangana (M-1 and M-7)and of the river Tatuoca (T-1 and T-7) were surveyed, and the currents were meaaured every hour at these sites, on the surface.

On the 9th of February, 1974, also in the period between 06.00 and 18.00 hours, tide gauges S-1, S-2 , F, OA, B, MV, I, ME and PS were read simultaneously every half hour. Surface currents were observed in the vicinity of Ponta dos Franceses, Ponta dos Banquinhos, at the mouth of the river Ipojuca and at the mouth of the river Merepe. Samples of water were also collected for the determination of suspended solids and salinity, both on the surface and at half-depth at all the points of the tide gauges, at 06.00, 09.00,12.00, 15.00 and 18.00 hours, samples F-P9, F-P12, F-P15 and F-P18 (Franceses, depth of 9, 12, 15 and 18 hours respectively), I-P9, I-P12, I-P15 and I-p18 (Ipojuca, depth of 9, 12, 15 and 18 hours respectively). The other, not analyzed, were deposited at the TRANSCON office in Recife.

The results obtained are shown at the end of this item.

PENETRATION OF THE SEA IN SUPAS

From the information obtained, especially as a result of the observations made on the 23rd, 24th, and 25th of January 1974 and those of the 6th, 7th and 8th of February 1974 in Recife, Suape, Galheta and Cupe, with the possibility of drawing the following conclusions in relation with the tides in Suape:

- Amplitude

  The amplitudes of the tides in Suape are less than those of Recife anc Cupe, reaching differences of up to 15 cm at the time of the syzygies.

- Phase

  The tides in Suape occur with variable delays that may reach up to 15 minutes (in the syzygies) in relation to Cupe and 60 minutes in relation to Galheta. The delays, at the time of the syzygies, are:

  - In relation to Cupe:
    At high tides - delay of 10 to 30 minutes
    At low tides - delays of 30 to 50 minutes

  - In relation to Galheta:
    At high tides: delay of 20 to 30 minutes
    At low tides - delays of 30 to 60 minutes

  - In relation to Recife,:
    smaller delays than those in relation to Cupe, probably not in excess of 30 minutes.

- High tide and low tide levels (PM and BM)
  The readings on tide measuring rods, with a rough sea, are restricted by 5 or 10 cm in their precision, depending upon the capacity of the surveyor to obtain successive and immediate measurements of the maximum and minimum values

in the successive and various seas that reach it, to record an average of averages. Therefore, it is difficult, during the analysis, to detect differences of this order, between the inner and outer tides. However, the observations mademake it possible to say ath, at the time of syzygies, the levels of the low tides at Suape are higher than those of Recife by 5 to 8 cm, and those of high tides are lower by 2 to 7 cm.

PENETRATION OF THE SEA FROM SUAPE TO THE IPOJUCA

As can be seen on the tide graphs of th 9th of February 1974, the syzygy tide propagates itself in the inner sea from Suape to the Ipojuca, with the approximate delays shown below:

30 minutes at Ponta dos Franceses
60 minutes at the Ponta dos Banquinhos
90 minutes at the mouth of the Ipojuca.

As regards amplitudes, it can be seen that there is a reduction of about 25 cm in the amplitude between Suape and Cupe. Between Suape and Ponta dos Franceses, the difference is 10 cm, in the syzygy.

- Levels

Comparing the tide graphs of the Tidological Station and those of the Ipojuca, of February 9, 1974, it can be seen that the level of low tide in the Ipojuca is the one that is responsible for the reduction in amplitude. This level is 25 cm higher, approximately that that of the Tidological Station, while that of the high tide is approximately the same.

Salinity

Through the analyses of suspended material and salinity, it can be seen taht while close to Ponta dos Franceses oceanic salinty values are found during a full cycle of tides, the same does not occur at the mouth of the Ipojuca, where the latter falls to value of 1/3 of the normal maritime salinity, at the time of the low tide at the syzygy and during the dry season.

PENETRATION OF THE SEA IN THE RIVERS MASSANGANA AND TATUOCA

Tides

oncerning the retardation suffered by the tide along the rivers Massangana and Tatuoca, it is noticeable that the river Tatuoca offers more restriction to the penetration of the tide than does the river Massangana. The tables that follow show the hours of the occurence of high tide and low tide on the 8th of February, 1974, at various limnometers along the rivers Massangana and Tatuoca, and were built on the basis of the tide graphs obtained from the readings taken on the measuring rods mentioned above:

River Massangana

	Suape	M-1	M-3	M-5	M-7
Low Tide	11.30	11.30	11.45	11.45	11.00 to 11.45
High Tide	17.00	17.30	17.45	18.00	18.30

River Tatuoca

	Suape	T-3	T-5	T-6	T-7
Low Tide	11.30	12.00	12.30	12.30	11.30 to 14.30
High Tide	17.00	18.30	18.30	18.30	18.30

It can be seen that, in the inner marshland area, the hours of occurence of high tide is the same in both rivers, being an hour and a half later than in Suape. At low tide, this coincidence of hours does not occur, and, while the difference in the Massangana is only about 15 minutes, it reaches one hour in the Tatuoca.

At Fazenda Massangana, Limnometer M-7, the river is unrestrained in the period between 11.00 and 15.00 hours, which shows that it is restrained during almost 8 hours of the 12 hour cycle of the syzygy tide, which shows that the reiver is affected when the tide reaches 1/3 of its height approximately, that is, elevation 1.00 m on the rod of the tide gauge, or altitude 0 at the Suape C.N.G., although this does not mean that only the points at level zero are affected, since the elevation of the level of the sea hampers the flow of the rivers, and the effect of the restraint will be felt at higher levels. The tide chart of Limnometer T-7 shows that at this point, the effect of the zero tide in Suape affects the river at level 0,37 m at Fazenda Massangana. If this difference should be approximately maintained, it is to be expected that the sea, that reaches the 1,60 m or 1.70 m levels (CNG) in Suape, might affect the whole region below elevation 2.00 m (CNG).

Amplitude

Regarding the amplitudes of the tide in the rivers Massangana and Tatuoca, they are approximately the same as those at Suape, since it is an ample and low region, and the differences found in the readings of the limnometers of these rivers should be attributed more to inaccuracies on the part of the observers tha to an actual variation in the amplitude, that was 2,35 m in the syzygy tide of February 28, 1974.

Salinity

Although the samples collected in the river Tatuoaca have not been analyzed, it can be safely stated, considering the results of inspections made on the spot, where it was noted that the fresh water contributions are so small, that the river Tatuoca is actually a sea horn where the tidal currents are felt over all its extension.

The river Massangana had part of its samples analyzed, and it has been found that at its mouth, the oceanic salinity is maintained during the complete cycle of a syzygy tide, while at limnometer M-6, it falls as much as 12,88% at the time of low tide. Limnometer M-6 is in the middle of an area of marshlands, and it is to be expected that the same should occur over the whole of this area. Ater the marshland area, the Massangana river flows on firm grounds and shows actual river characteristics, its flow at Fazenda Massangana not being inverted at the syzygy tides, it is not affected by the salinity of the sea.

FLOWS OF THE RIVERS AND SUSPENDED SOLIDS IN SAME

A comparison of the flow at the mouths of the rivers and in an upstream section where the influencde of the tide does not cause a reversal of the flow, will gove an idea of the contribution in fresh water and of the importance of the rivers Massangana and Tatuoca either as rivers or sea horns, in the region under study. Thus, it can be seen that, while at the mouth of the Massangana, during a half flood, the flows are about 500 m^3/sec, upstre: ., at the Fazenda Massangana (February 8, 1974), it is barely in excess of 5 m^3/sec.

In the Tatuoca, the flow at the mouth is in the vivinity of 200 m^3/sec, also at half tide at syzygy. The flow upestream has no signification, since upon observing the transverse profile of section T-7, and knowing the place, it is noted that it is a low and comparatively flat region. where flows only a trickle of water that is never fresh, at low tides.

The comparison of the flows of the Massangana and the Tatuoca can also give an idea of the relative sizes of their basins, in the area of the port prjcct. Thus, it can be said that these basins are in a relation of 2:5, the Massangana basin being the larger one.

Besides, it should also be noted that, at the times of high tides, these basins are probably interconnected.

Suspended Solids

Regarding suspended solids, at the mouth of the Massangana, it can be seen that they are abou 20 mg/1. Considering a flow of 500 m^3/sec, there will be a back and forth movement, at the mouth of the Massangana, at half tide, of 36 tons per hour of suspended solids.

These suspend solids are for the greater part grains of quartz the size of clay and silt.

SAMPLES FROM THE BOTTOM

All the samples from the bottom were collected by a diver, who endeavoured to collect the most representative material in the region.

The samples of the outer area were collected on two lines, parallel to the reef barrier and at a distance of between 300 and 500 m. from the reefs and at points on this line 1.000 m apart, as shown of the situation plant.

In the Suape basin, there were 14 points of collection that were referenced 1.201 to 1.214. while in the Massangana and Tatuoca basins they were collected at 7 points, close to the limnometers and having the same identification numbers.

From Ponta dos Franceses to the South samples were collected in the same alignment as the profile of the reefs, and the deepest part of the channel' and the were identified through the symbology adopted for the profiles R-4, R-5, R-6, R-7, R-8 and R-10).

In the Ipojuca Pasin, three sanples were collected: "B" close to the canal, in the vicinity of Ponta dos Banquinhos "I" at the mouth of the river Ipojuca and "ME" at the mouth of the Merepe. The results of the granulometric analyses are at the end of the annex. They will be used for guidance durin studies on scale models and with radioactive tracers.

3.5 STUDY WITH RADIOACTIVE TRACERS

In order to characterize solid transport along the coast, studies are under way with radioactive tracers, within the series called "Extended Studies in Nature".

The projected undertakings include:

i The measuring off the bottom sediment, along the reef barrier, in the winter regimen.

ii The measurement of sediment transpot, along the barrier, in the summer regimen

iii The sutdy of the bottom sediment in the region of the port, withinh the reef line.

iv The collection, interpretation and analysis of hydraulic data about the characteristics of waves and currents.

The radioisotope laboratory of the Instituto de Pesquisas Radioativas in Belo Horizonte was entrusted with the performance of the work with radioactive tracers. The hydraulic measurements were the responsibility of the Instituto Nacional de Pesquisas Hidroviárias (INPH) of the Departamento Nacional de Portos e Vias Navegáveis.

Below is the results of the part of the study already completed.

An injection was made of 500 g of ground glass, marked with iridium 192, with the same granulometry as the botom material, with an activity of 2,4 curies, on June 28,1974, in the offing of the reef line. The following day, a preliminary detection was carried out, the first detection being performed on July 7. The analysis of the data obtained showed a small displacement of the material towards the Northeast, parallelly to the reef line. The application of the "balance Method for Tracers" provided a flow of bottom material of about 0,4 tons per linear meter per day.

Considering these results, a second coampaign of measurements was planned for the second half of August and was carried out on the 22nd and 23rd days of that month, being analyzed separately in order to check the repetitiveness of the results obtained.

As in the first campaign, the results showed a little dispalcement of the material in the direction of the Northeast, along the reef line.

The analysis through the method above showed, for the period between the injection and new detections, an average flow of 90 kilogs per linear meter per day.

While the work with tracers was under way, data were collected regarding the characteristics of the waves and currents, by the team of the Instituto Nacional de Pesquisas Hidroviárias, Dpartamento Nacional de Portos e Vias Navegáveis (DNPVN), to be later correlated with the data provided by the use of radioisotopes.

3.5.1 CONSIDERATIONS ON THE WORKING METHODS WITH RADIOACTIVE TRACERS

Working with tracers consist essentially in:

1. Markimg with a radioisotope a representative sample of the bottom material.

2. Deposit it at the site to be studied;

3. Follow its subsequent displacement, through a radiation detector towed by a boat. Another method is the simulation of the bottom material by ground glass of the same shape, granulometry and density as the sediment to be studied, containing an activable matter (iridium, gold, scandium)

The position of the boat that transports the tracer is obtained, at predetermnide intervals, through a network of transits or by radio-location.

A detection consists in the coverage of all the area through which the radioactive material has scattered through parallel trajectories relating each instantaneous position of the sea lead with the count it has obtained.

A series of detections, eparated by intervals that vary between days and months represents a complete programme.

THE METHODS FOR THE ANALYSIS OF DATA

Prior Corrections

i correction of the bottom noise.

The bottom always shows some natural radioactivity, which is higher in the case of slime than in the case of sand, and that is measured before the injection of the tracer.

The value of the noise at the bottom in each point is subtracted from the count obtained during detection at that point.

ii Correction of the radioactive reduction

Every isotope has a characteristic and constant half-life. Half-life is defined as the time necessary for a given activity to be reduced to half its initial value. Among the most common racers, iridium-192 has a half-life of 74.4 days and gold-198 of 2,7 days.

The correciton of the radioactive reduction is made through the expression:

$$A = Ao\ e^{-\frac{In2.t}{T}}$$

where

A is the remaining activity after the lapse of time t

Ao is the activity on the day chose as time origin (the day of injection or of the first detection)

T is the half-life

iii Corrections of the variations in the speed of the boat

The method of analysis that is to be used assumes that the boat performs the detection at a constant speed. Since this does not happen in practice, all counts are adjusted for a boat speed of i m/s, and the value of the count on a given stretch is multiplied by the speed of the boat on that stretch.

iv Correction of the inclination of the detection lines

It is obviously impossible to construct parallel trajectories to the movement of the boat during detection, in spite of the navigation corrections which are constantly being made during the carrying out of the proceedings. To correct this situation, a direction is defined, to be parallel to the largest possible number of the boat's trajectories. The deviations from the trajectory on each stretch are corrected by the multiplication of the count there obtained times the cosine of the angle between the stretch and the previously defined direction.

All the corrections above are made on a Hewlett-Packard programmable calculator, fed by perforated tape. The calculations programs were established by the Isotope Laboratory.

After these corrections are made, all the counts oı a given line of detection are added up, and the value thus obtained is used in the cinstruction of the transport diagram that will be defined later.

The Isocount Curves

These curves are a system for the presentation of experimental results that allow an easy visualization of the displacement of the material. They are obtained by marking on the map of the area under study each point at which a count was effected and correlating this point with the counting rate there obtained.

The oints with the same rate of count are then joined by a continuous line.

In spite of their showing clearly the area covered by the radioactive material and the preferential direction of displacment, the isocount curves give little quantitative information.

Transport Diagram

The theoretical direction of transport is defined as the direction perpendiclar to the mean detection trajectory executed by the boat. The mean trajectory is defined by the application of the method of minimum squares to the various courses of the boat.

The transport diagram is constructed correlating the corrected count of each line with the position given by the intersection of the line with the theoretical transport direction. By joining the points thus obtaine through a continuous line, the diagram transport is obtained, the area of which furnishes value N of the total count detected. The transport diagram shows clearly the regions of concentration of activity and are used for the calculation of the flow of solids at the bottom.

The "tracer balancing method", defined in Annex I, makes it possible to calculate the average depth of transport E, from value N of the total count detected.

Calculation of solid flow

The calculation programmes which are used at present also make it possible to determine, from experimental data, the position of the center of gravity of the radioactive cloud.

Dividing the distance between the centers of gravity of successive clouds by the time lapsed between the detections, the average speed of displacement of the cloud, Vm , is obtaines. For the first detecon, the average speed is calculated from the distance between its center of gravity and the point of injection.

The bottom solid flow Q is calculated by:

$$Q = p\ L\ VmE$$

where Vm and E have already been defined, p is the apparent density of the bottom material, and L the width of the region covered by the transport.

Resuming:

i. the area of the transport diagram gives the value of N

ii the application of the tracer balancing method" makes it possible to calculate, from valu N, theaverage depth of transport E.

iii the successive positions of the center of gravity of the cloud make it possible to calculate the average speed of the transport, Vm

iv the solid flow is calculated by adopting, in general, a value L = 1m applied in Q = PLVmE

3.5.2 FIRST DETECTION CAMPAIGN

The first campaign in Suape began on the 15th of June, 1974 and was terminated on July 11.

The radioactive material was 500 g of ground glass, marked with iridium-192 and irradiated in the Ezeiza reactor, of the Argentinian National Commission for Atomic Energy. The granulometry of the injected material (fig. 3.5-I) was the average of the bottom samples collected at about 500 m North of the interruption in the reef line known as Barreta.

The detections were made with metal sled (fig 3.5-II) that carried a scintillation probe. The sledge was tied to a steel cable ad towed by the boat over the bottom. Its launching and recovery were made with a motorized winch mounted on the stern of the boat. The boat was the "São Pedro", one of the lobster-fishing fleet of Nortepseca, S.A., almost 12 m long at the waterline, with a beam of 3 m; the cabin was adapted for the studies, a table having been built for the positioning and a rack for the installation of the electronic equipment.

The following equipment was used:

- SRAT, type SP33 scintillation detectors witha sodium iodine crystal 1" x 1 1/4", enclosed in a watertight protection.

- Hewlett-Packard 5021L impulse counter, crystal time basis.

- Moseley graphic recoreders - Hewlett-Packard 7100 BM

- Raytheon Echosounder, with recorder.

These devices were fed by a Honda generator of 1500W, with a gasoline engine, with a control panel that included a voltemeter and a fequency meter.

The positioning of the boat was effected, at intervals of 30 s by a battery of transits. The position was noted on a map in the canin of the boat, thus allowing a quick correction of deviations from the route.

The communications between the boat and the transits were made through portable radio transceivers, Tokay or Evadin, operating on 27 MHz with an output of 5W.

Parallelly to the work with tracers, the INPH team made measurements of the direction, the amplitude and the frequency of the waves, and of the direction and speed of the currents. A Neyrpic wave gauge and a Mecabdier current meter, both recording, were used, besides a non recording current meter for measurements in depth. The methodology for the collecting of hydraulic data will be shown in detail in a separate report, to be presented at the end of the measurement campaign.

The fisrt week of work was dedicated to the adaptation of the boat for the lauching of the wave recording gauge with the installation of a winch and the change of the location of the launching davit. The whole week was rainy, preventing the access to the Suape by land.

On June 23, the first launching of the current recording meter and of the wave recording gauge took place. The following days were dedicated to a careful survey of the natural bottom noise, that is rather variable, and even shows rather active anomalies. The towing of the sled on the bottom presented a few problems, due to the existence of stones. The results of the bottom noise survey, presented in the shape of isocount lines, are shown in the figure (3.5-III)

The injection of the radioactive tracer was performed on the 28th of June, at the point shown in figure 3.5-IV.

The handling of the material had been taken care of in Belo Horizonte, and consisted in:

i. Opening of the transport shield;

ii opening of the irradiation flask;

iii transfer of the radioisotope to the irradiation container;

iv homogeneization of the radioisotope: the container is spun y a motor for 40 minutes.

v measuring of the aliquotas of the radioisotope for the calibration of the injected activity, and for the checking of the homogeneity.

All of the homogeneization process is carried out with the flask in the transport shield, from which it is only removed at the moment of injection. At this moment, the injector (fig. 3.5-V) is placed on the transport shield, and a locking system fixes the injection container to the injector. This container, hanging from the same davit used for the launching of the wave recording gauge, is rotated over the side of the ship and sunk to the bottom. The moment it touches the bottom, a lever opens the injection container and the radioisotope is deposited. The whole of the operation was successfully carried out.

The injection was made at the point of Cartesian coordinatesX = 3109m and Y = 1081m, in the reference system that has as an axes arigin the Fort of Nazaré, and whos axis OX is formed by the line that connects the base of the fort to the base of Outeiro Alto. It was performed at 16.05 hours, in a quiet sea, with waves from the South, at the beginning of the outgoing tide period.

On the following day, June 29, the "positioning" detection was made, with the purpose of checking whether there was a great scattering of the tracer at the time of injection. It was found that the radioisotope was circumscribed practically to the point of injection.

The following week was characterized by a strong and persistent SE wind, squalls of more than 30 miles having been recorded. The condition of the sea and the rainy weather prevented new successful detections, in spite of various efforts.

The first detection was carried out on July 7, with little swell, waves from the S and wind from the E.

It was noted that the scattering of the material had been small, and it was thus possible to carry out a good detection during a single day's work.

Considering the small movement recorded, it was decided that the second detection should be performes one month later, or say, around the middle of August. During this period, the gathering of hydraulic data would proceed.

3.5.3 AN ANANLYSIS OF THE EXPERIMENTAL DATA OF THE FIRST CAMPAIGN

During the detection, the following observations were noted:

i. The angles given by the transits indicating the position of the boat were noted every 30 seconds.

ii The counts that correspond to the route covered by the boat, printed every 5,8 second.

iii The depths of the stretch, recorded continuously.

These data were transferred to a perforated tape, through a teletype. This tape was fed to a calculator that made all the corrections previously mentioned and provided the data for the establishment of the isoconcentration curves and the transport diagram. The bottom noise corresponding to each line of detection was obtained from Fig. 3.5-III.

The isoconcentration curves for the July 7 detection are shown in Figure 6. This figure shows that the existing movement in towards the Northeast, and parallel to the line of reefs. The cloud was 400 meters long and about 130 m wide nine days after injection. The region of high activity covers almost 150 m from the point of injection, no count being recorded to the south of it. The activity recorded at the point of injection was very high, in excess of 80.000 counts per second.

Figure 3.5-VII shows a situation plan of the work site, indicating the region covered by the radioactive cloud, as well as the direction of its displacement.

The transport diagram is shown in Figu.e 8. It shows clearly the concentration of the activity in the region of the injection, the pricipal region of activity bring concentrated within about 60 m.

The data used for the construction of the transport diagram, that are the intersection of a navigation line with the theoretical transport direction, and the total count detected on the line, make it possible to calculate the balance of the radioactive material in the working region. For the detection of the 7th of July, a value of $N = 4.73 \times 10^7 c/s \times m^2$ was obtained.

As shown in annex 1, the value of N is used for the calculation of the average transport thickness, using the expression:

$$\frac{\alpha N}{\beta f_0 A} = \frac{1 - e^{-\alpha E}}{E} .$$

α e f_0 are coefficients, determined in the laboratory, which refer to the response of the detection device to a uniformly distributed activity, situated at various depths. For sounding device 4, used in this detection, the values are:

$$\alpha = -0{,}144\ m^{-1}$$

$$f_0 = 54{,}9\ c/s/\mu Ci/m^2$$

β is a function of the distribution in depth of the radioactive material. Assuming that the material will be deposited uniformly from the surface to the limiting region of the movement, coefficient B has the value $\beta = 1$.

Injected activity A was obtained by the direct calibration of samples obtained of the irradiated material, during the preparation of the injection.

On June 28, date of the injection, the existing activity was

$$A = 2{,}40 \times 10^6\ \mu ci$$

Replacing these values in the first member of the expression (3.1), we have:

$$\frac{1 - e^{-\alpha E}}{E} = 0{,}052$$

The value of E, calculated by successive iterations is:

$$E = 0{,}18\ m$$

The calculation program also establishes the center of the radioactive cloud.

For this detection, the coordinates of the center of gravity, in the system of axes defined above are:

$$X_G = 3099\ m$$

$Y_G = 1086$ m

The distance between the injection point and the center of gravity, calculated from its Cartesian coordinates is 11 m. The displacement speed, 8,9 days after the injection and the detection, will be 1,23m/day.

Therefore, the solid flow of the bottom, given by expression:

$$Q = p \, Vm \, L \, E$$

will be

$$Q = 1,65 \times 1,23 \times 1 \times oi8 = 0,37 \text{ t/m/day}$$

The solid flow of the bottom is therefore of almost 400 kg per linear meter and per day, in the NE direction, in the summer regimen.

This result was obtained from data referring to a single detection, and should be confirmed by results from subsequent measurements. Besides, the ,easurements of the injected activity are being checked, and this might alter the results to a value of 300 kg per linear meter per day.

3.5.4 CONCLUSIONS REGARDING THE FIRST DETECTION CAMPAIGN IN THE WINTER REGIMEN

The first detection made in Suape showed that the material from the bottom showed a slight displacement toward the NE, parallelly to the reef line. The calculations of the solid flow from the bottom defined a value of about 0,4 tons per linear meter and per day.

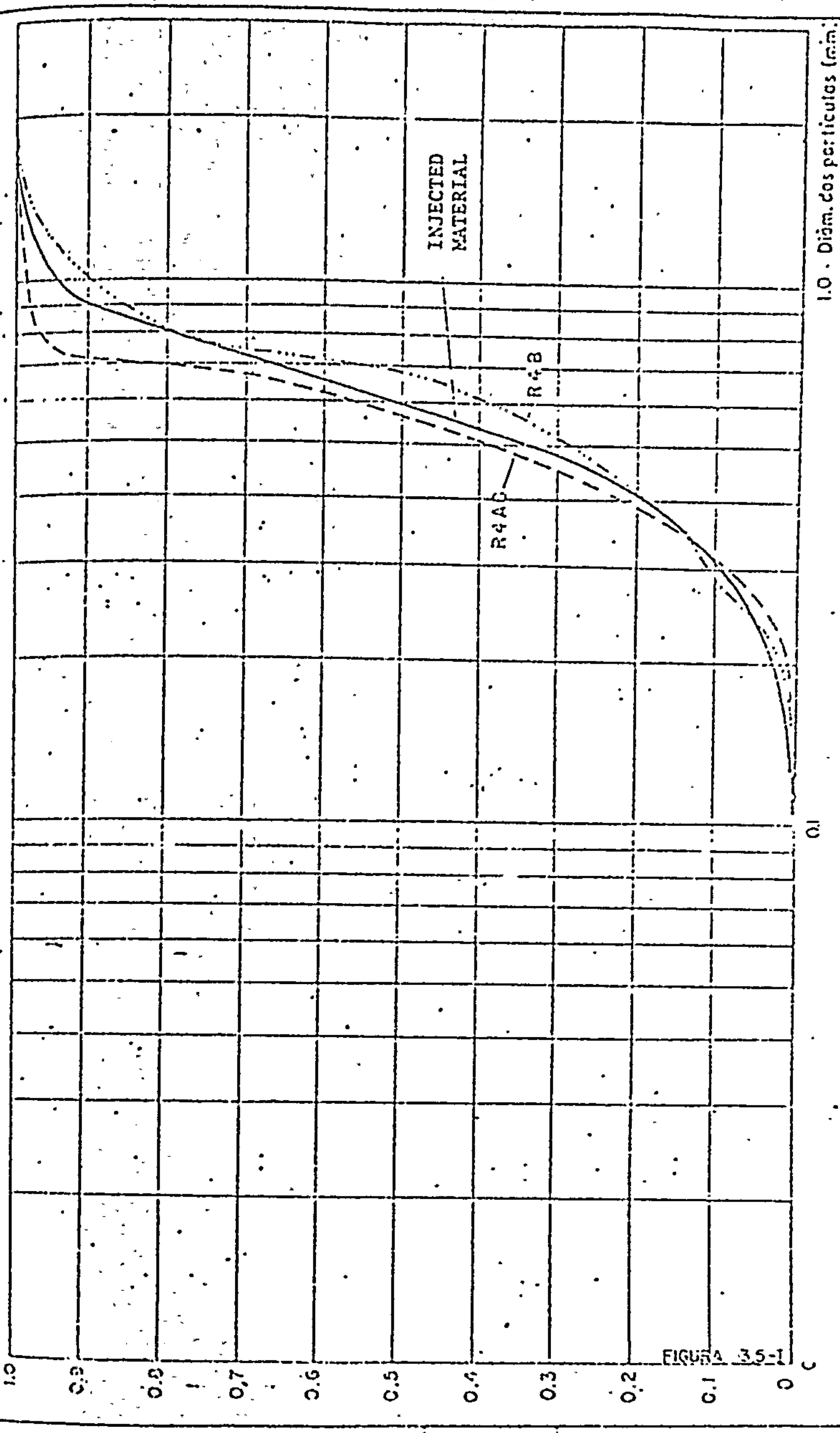


FIGURA 3.5-1

SOURCE - IPR

NO SCALE

Dimensions in millimeters

diper

TRANSCON SA

COMPLEXO INDUSTRIAL DE SUAPE

GRANULOMETRY OF THE INJECTED MATERIAL

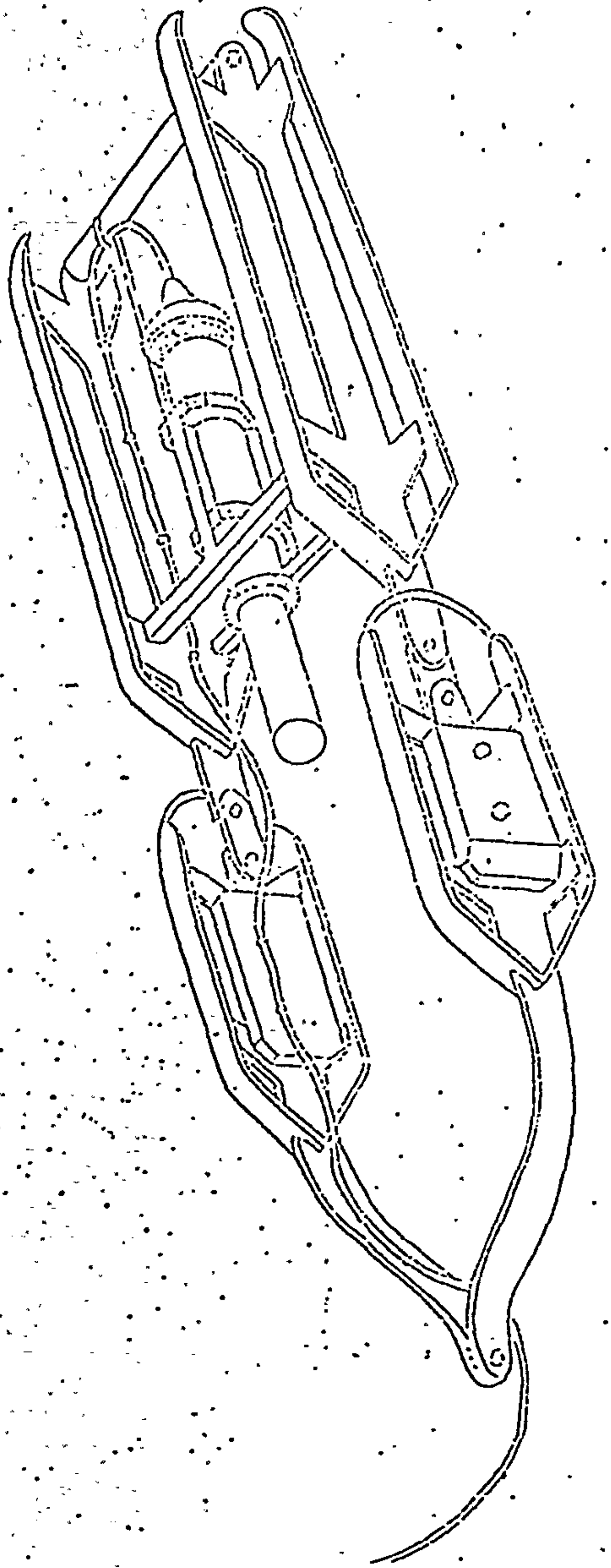


FIGURA 3.5 II

SOURCE - IPR
NO SCALE
DIMENSIONS IN MILLIMETERS

diper

TRANSCON S.A.

GOVERNO DO ESTADO DE PERNAMBUCO
COMPLEXO INDUSTRIAL DE SUAPE

SLEDGE AND SOUNDING DEVICE

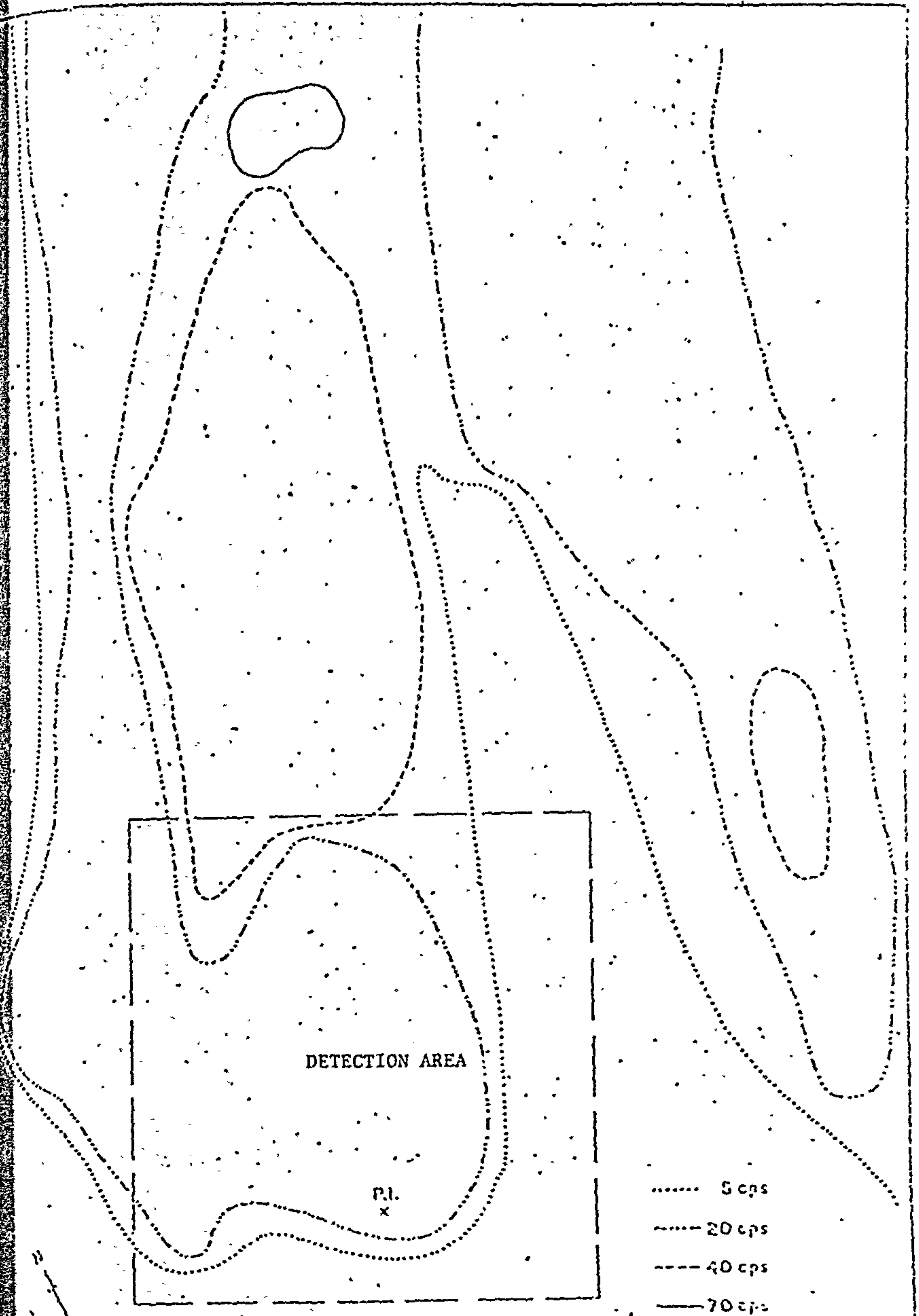


FIG:3-5-III

ISOCOUNT CURVES: NATURAL BOTTOM NOISE

COMPLEXO INDUSTRIAL DE SUAPE

ESCALA GRÁFICA

0 10 50 100 m

diper

TRANSCON S.A.

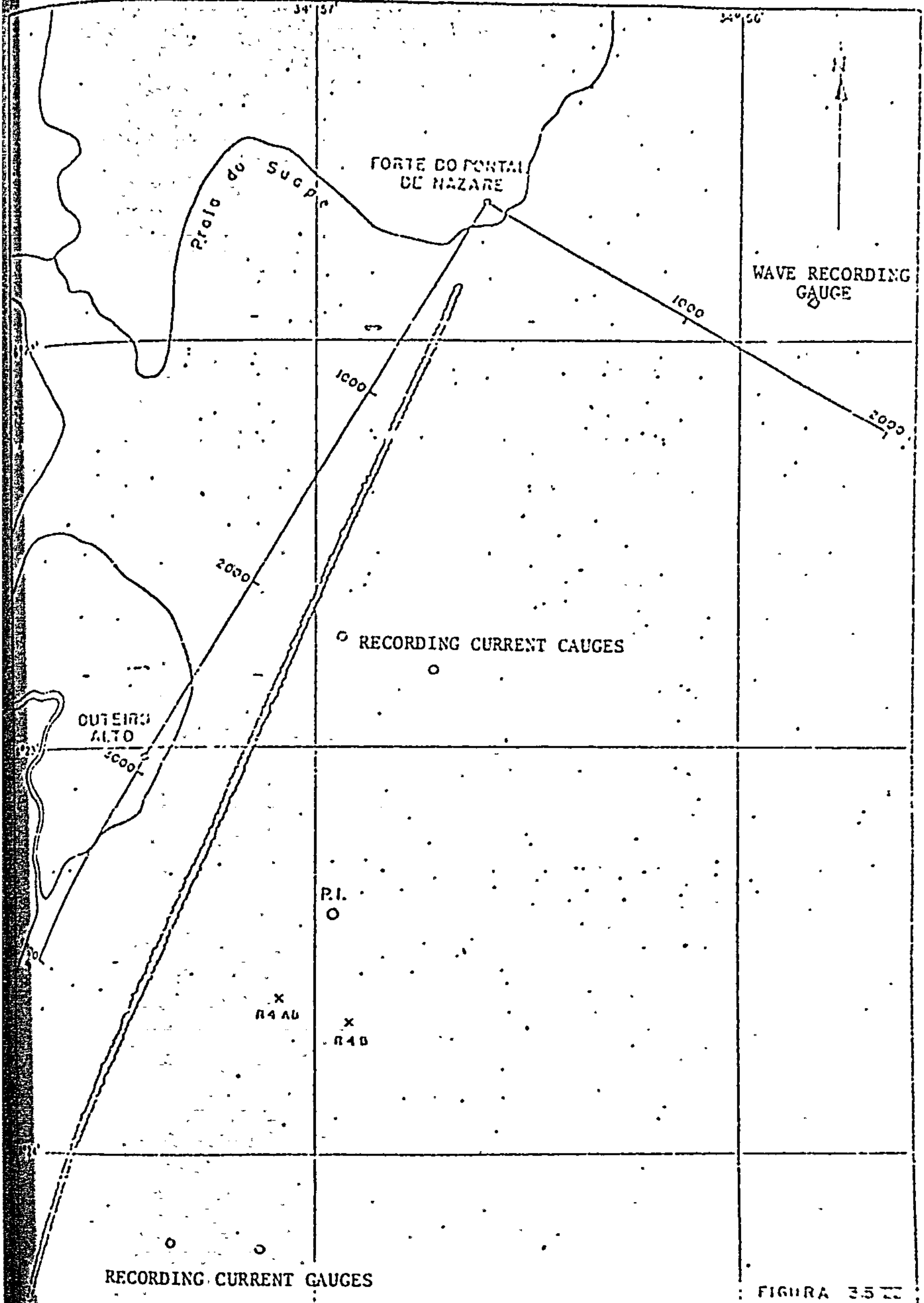


FIGURA 3.5

FONTE – IPR

ESCALA GRÁFICA

dipar

TRANSCON S.A.

COMPLEXO INDUSTRIAL DE SUAPE

LOCATION OF THE INJECTION POINT

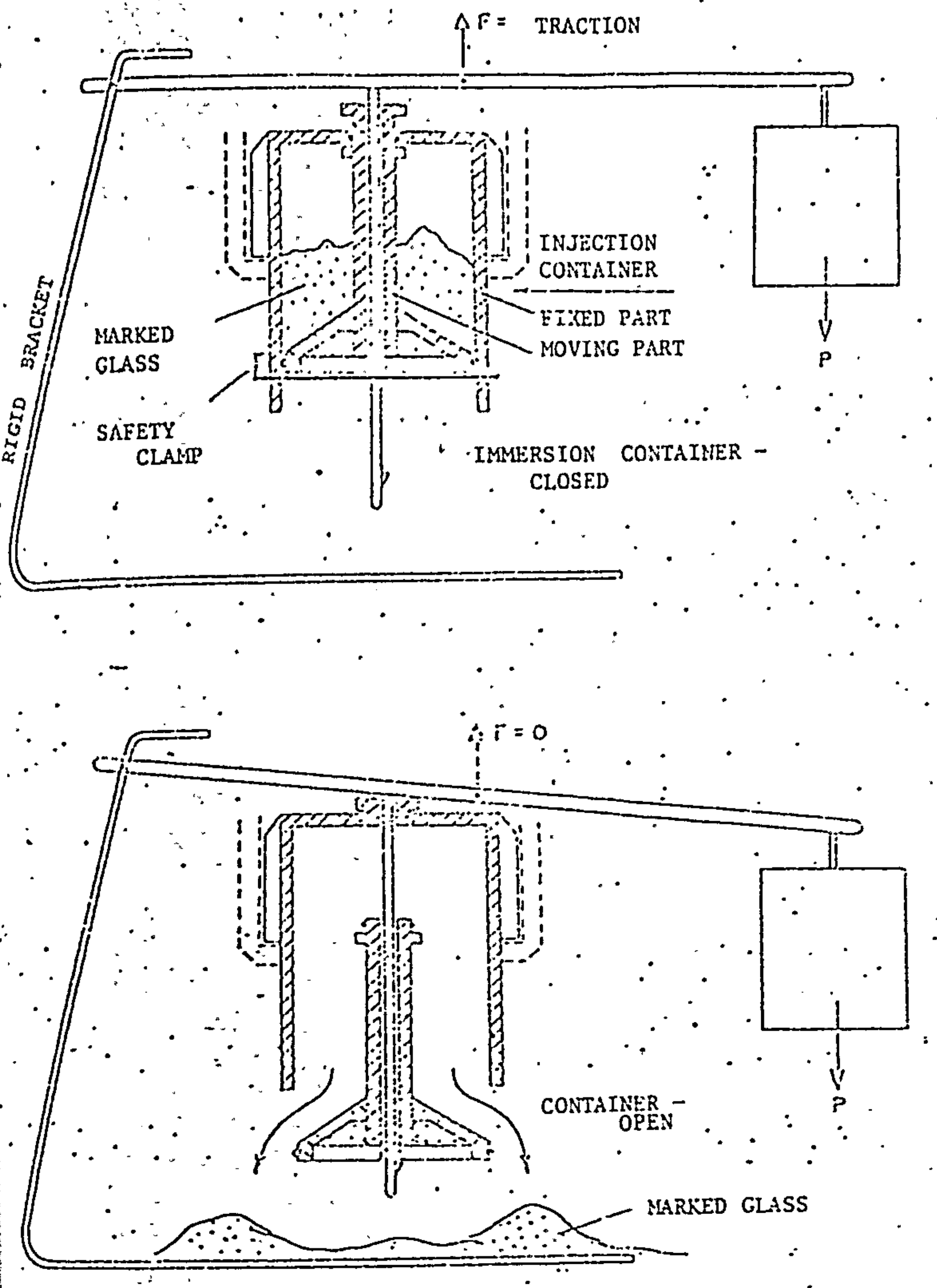


FIGURA 35

SOURCE - IPR

NO SCALE

DIMENSIONS IN MILLIMETERS

diper

TRANSCON S.A.

COMPLEXO INDUSTRIAL DE SUAPE

INJECTOR

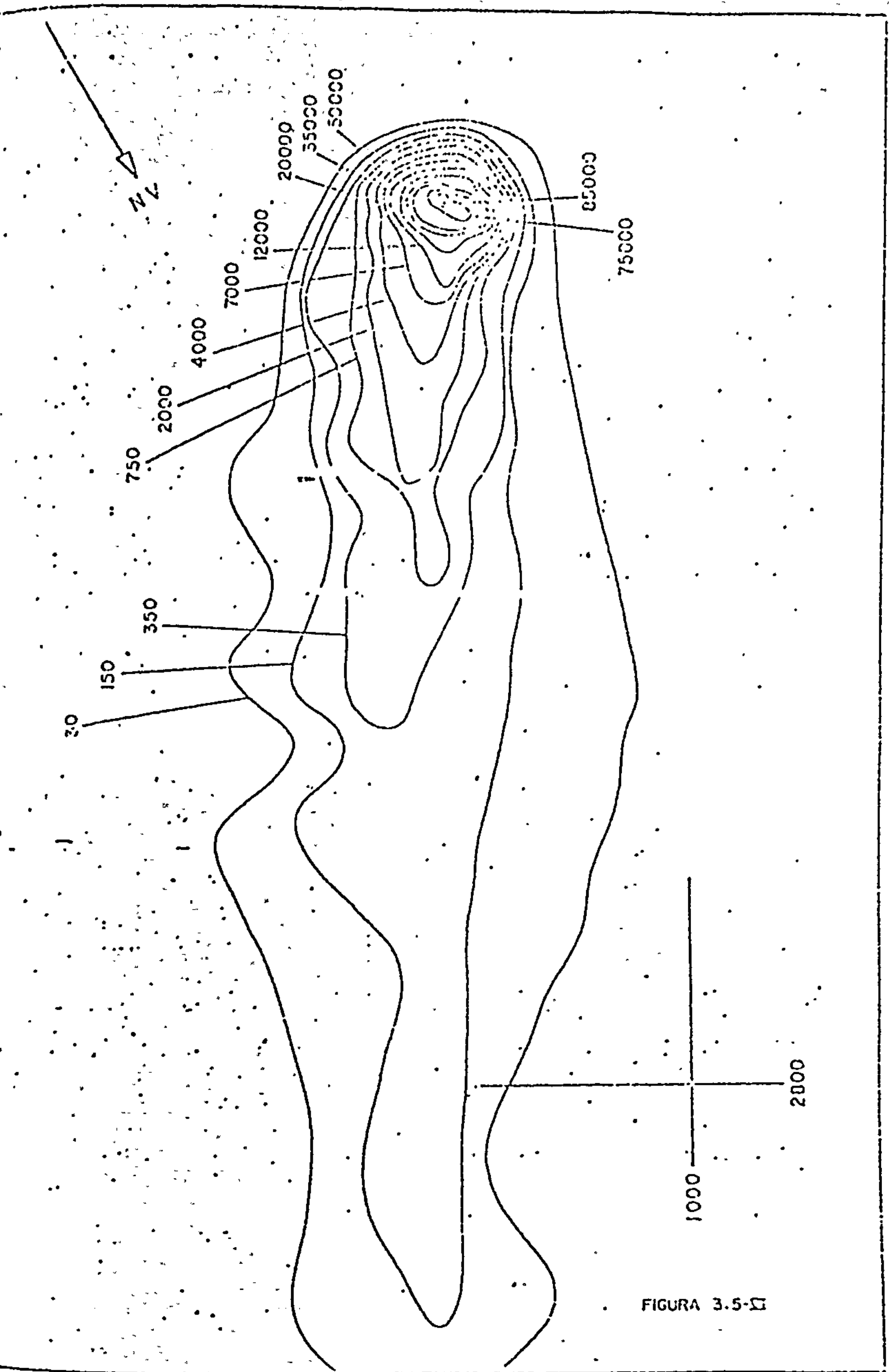


FIGURA 3.5-VI

ESCALA GRÁFICA
0 10 50 100 m

diper

TRANSCON S.A.

COMPLEXO INDUSTRIAL DE SUAPE

ISOCOUNT CURVES
DETECTION OF JULY 7,1974

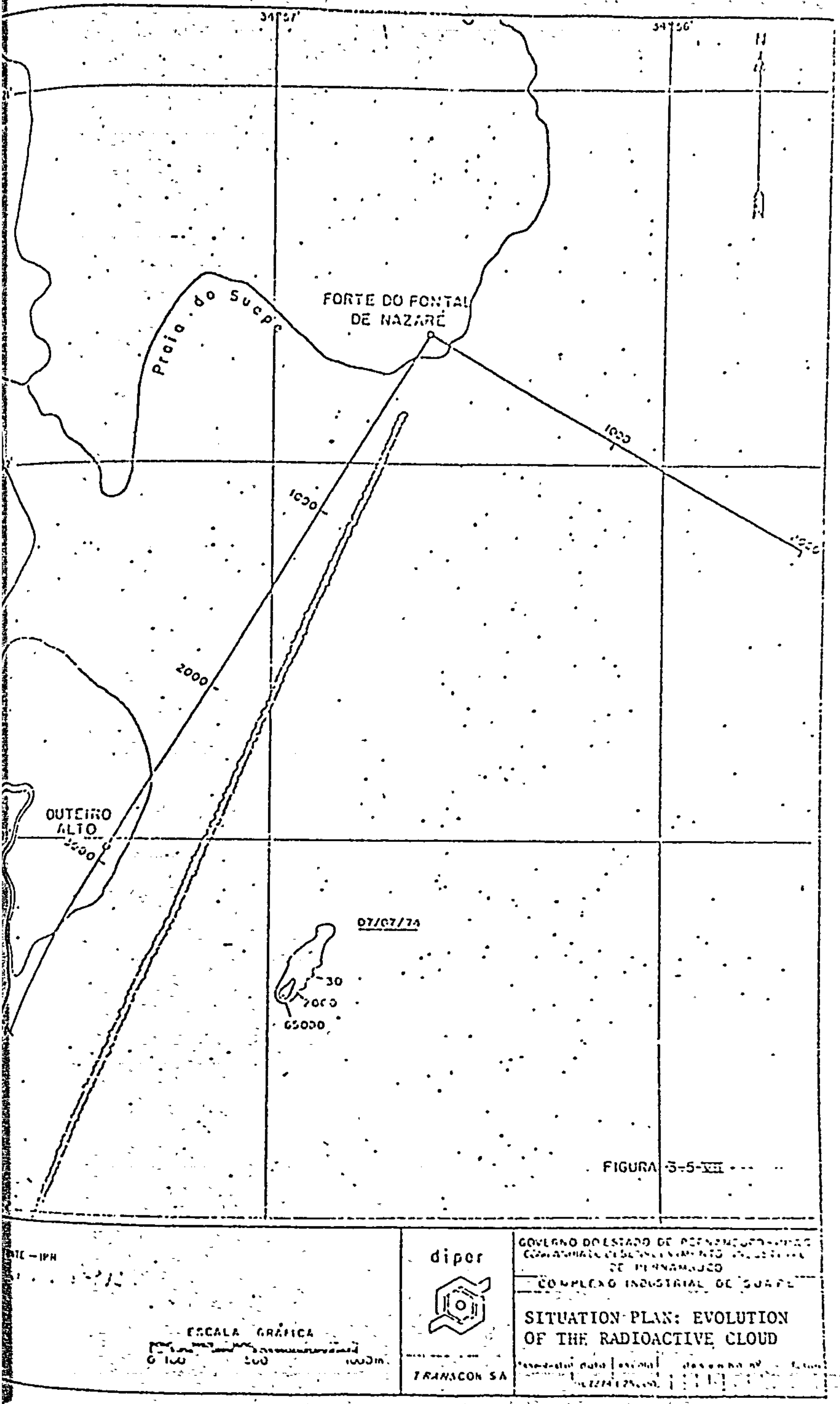


FIGURA 3-5-XII

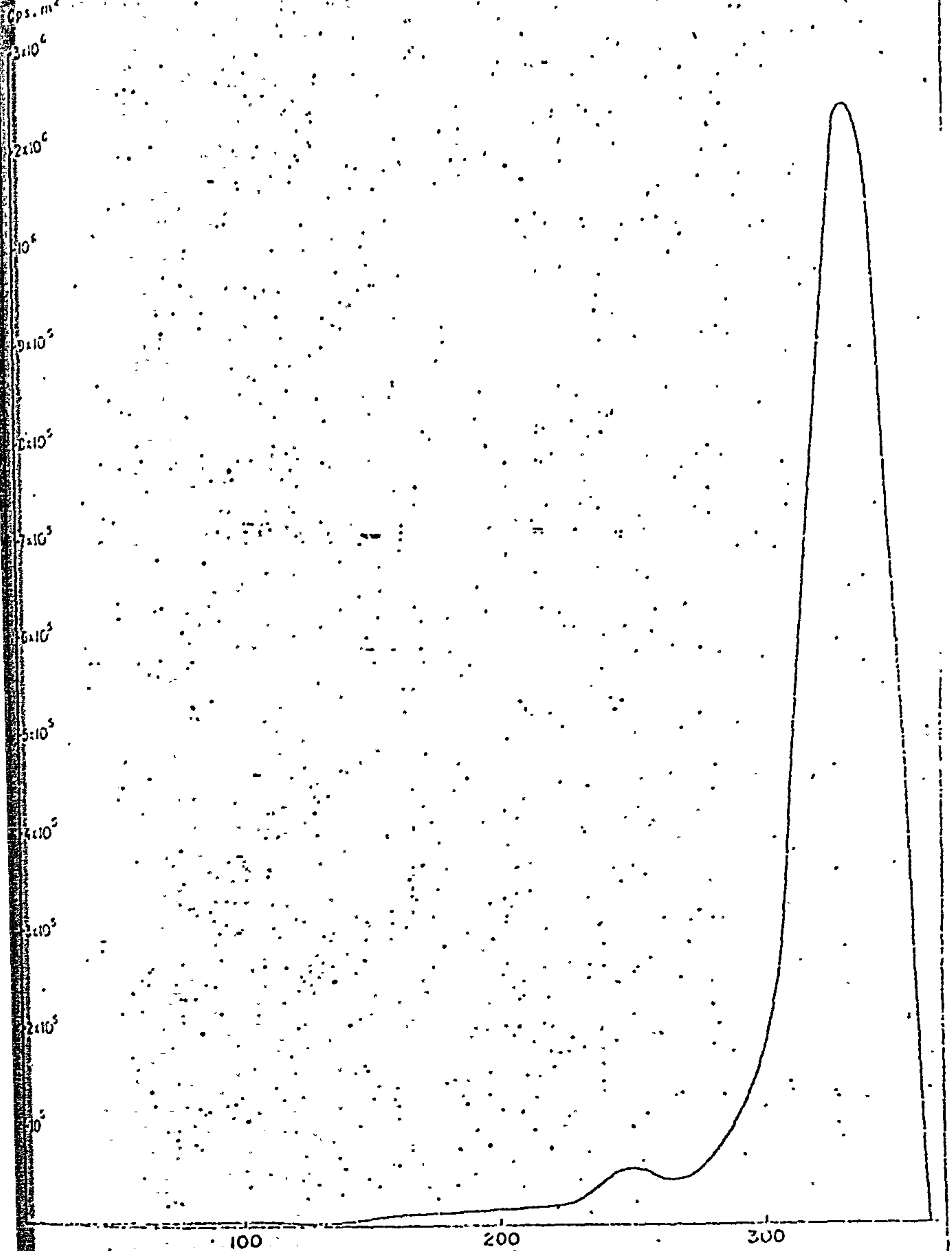


FIGURA 3.5

SOURCE - IPR
NO SCALE
DIMENSIONS IN MILLIMETERS

dipor

TRANSCON S.A.

GOVERNO DO ESTADO DE PERNAMBUCO

COMPLEXO INDUSTRIAL DE SUAPE

TRANSPORT DIAGRAM
DETECTION OF 7 July 1974

3.5.5 SECOND DETECTION CAMPAIGN

PRELIMINARY CONSIDERATIONS

Due to the time lapsed since the injection, it was necessary to correct the decay of the radioactive material injected, using a correction factor of 1,685, corresponding to 56 days.

Another correction ids due to the difference between the response of the sounding device on the bay considered as the time origin and the days of the detections. This factor, obaqned from thetables for the daily calibration of the device, was 0,882.

All the count data obtained during the detections were multiplied by these factors.

The corrections of the speed variations of the boat and of the inclination of the detection line were carried out point by point, through a calculation program established for the programmable Hewlett-Packard 9820A calculator, as before.

The results obtained were used in the establishment of the isocount curvws and of the transport diagrams.

FIELDWORK

The second detection campaign in the SUape was carried out between the 17th and the 29th of August 1974

A scintillation sound was dragged over the bottom of the region under study, attached to a sled towed by a boat. This was again the São Pedro, a lobster fishing boat, 12 meters long, adapted for the radioactive and hydraulic measurement campaign.

The equipment used was the same as the one in the previous detection:

- SRAT scintillation detectors
- Hewlett-Packard impulse counter.
- Hewlett-Packard graphic recorder
- Hewlett-Packard printer
- Honda gasoline generator

The positioning of the boat was done through a series of transits, using for bases the fort of Nazaré and Outeiro Alto, and giving the position every 30 seconds. The positions were plotted on a map in the boat's cabin, allowing quick corrections of the route.

The communications between the boat and the transits was through portable Tokay transceivers.

Also during this campaign, measurements of the amplitude and period of the waves (Neyrpic recording wave gauge) were made, as well as measurements of currents (Mecabolier current recording gauge)) and measurements of the direction of the waves at a constant depth (observation by transit).

Thes data are being analysed, and will be presented as results of the work.

In this campaign, two dtetctions were carried out:

- on August 22nd, with a SE (160º) swell, 1,5 and 2 m. high, with a SE wind.
- on August 23rd, with a rough sea, SE (160º to 165º) swell, and S wind.

Satisfactory results were obtained in both cases, the radioactive cloud having been covered with about 20 lines, separated by distances varying between 50 m and 10 m.

A first observation, made during the detections, was that the radioactive material had undergone only a small displacement, staying in approximately the same position as before.

3.5.6 AN ANALYSIS OF THE EXPERIMENTAL DATA OF THE SECOND CAMPAIGN

THE DETECTION OF AUGUST 22nd

The isocount curves that correspond to the detection of August 22 are shown in figure 3.5-IX. The displacement of the cloud is still towards the NE, parallelly to the line of the reefs, as demonstrated in figure 3.5-X.

The length of the cloud was 400 m, and its width 120 m, almost 55 days after injection.

The high activity region was still concentrated close to the point of incetion. As in the previous time, no activity appears at the South of the injection point,, showing that the small existing movement is Northwards.

The transport diagram that corresponds to this detection is shown in figure 3.5-XI, and shows clearly a concentration of activity of about 70 m, in the region of the injection.

The area of the transport diagram furnishes the total count recuperated during the detection, that is, the balance of the count rates. The value of N that corresponds to this detection is:

The Cartesian reference system id used, the axis OX passing by the bases of the Nazaré Fort and of Outeiro Alto, it origin being at the base of the Nazaré Fort.

The coordinates of the point of injection, taken as the origin in this study, are:

$$X_I = 3109 \text{ m}$$

$$Y_I = 1081 \text{ m}$$

The distance between these points is 22 m. Since, between the injection and the detection, 55 days elapsed, the average speed of the cloud is:

$$Vm = o,40 \text{ m/days}$$

The solid flow of the bottom, between the day of the injection and that of this detection is calculated by:

$Q = p\ Vm\ L\ E$, giving the value, for $L = 1$ m,

$$Q = 0,09 \text{ t/m/day.}$$

THE DETECTION OF AUGUST 23rd

Regarding this detection, the corresponding isoconcentration curves are in figure 3.5-XII; the displacement in relation to the shore in figure 3.5XIII and the transport diagram in figure 3.5-XIV.

The isoconcentration curves have the same orientation as the previous ones, the material moving parallelly to the reef.

The length of the cloud is 350 m and its width, 110 m, the larger part of the material being in the vicinity of the injection point.

This information id confirmed by the transport diagram, the area of which furnishes a value

$$N = 6{,}0 \times 10^7 \ c/s \times m^2$$

The values of the parameters for for this detection, for which another sound was used, are:

$$\alpha = 0{,}144 \ cm^{-1}$$

$$fo = 54{,}9 \ c/s/uCi/m^2$$

$$N = 6{,}0 \times 10^7 \ c/s \times m^2$$

$$A = 2{,}4 \times 10^6 \ uCi$$

$$\beta = 1.$$

Therefore,

$$\frac{\alpha N}{\beta \ fo \ A} = 6{,}55 \times 10^{-2}$$

From this value, we obtain:

$$E = 0{,}13 \ m$$

The coordinates of the center of gravity of this detection are:

$$X_G = 3.090 \ m$$

$$Y_G = 1.090 \ m$$

The distance between the center of gravity and the point of injection is 21 m. Since 56 days elapsed between the time of injection and that of detection, the average speed of the cloud is:

$$Vm = 0,37 \text{ m/day}$$

The value of the solid flow on the bottom will then be:

$$Q = 0,079 \text{ t/m/day}$$

or close to 80 kg per linear meter per day.

The solid flow of the bottom between the detections of July 7 and August 23 can also be calculated. The distance between the centers of gravity of the two detections is x = 9,2 m. If we ca E_1 and E^2 the average transport thicknesses that correspond to each of the detections, (0,18 m and 0,13 m), the total solid flow between them can be calculated by:

$$Q_1 = p \times \frac{E_1 + E_2}{2} L = 2,35 \text{ t/m}$$

Since 47 days elapsed between the detections, the flow per linear meter and per day will be 50 kg. The order of magnitude is therefore confirmed.

3.5.7 CONCLUSIONS RELATING TO THE SECOND DETECTION CAMPAIGN IN THE WINTER REGIMEN

During this measurement campaign, two independent detections were carried out, yielding concurrent results.

The displacement of the bottom material continues small, and proceeds northward, parallelly to the reefs.

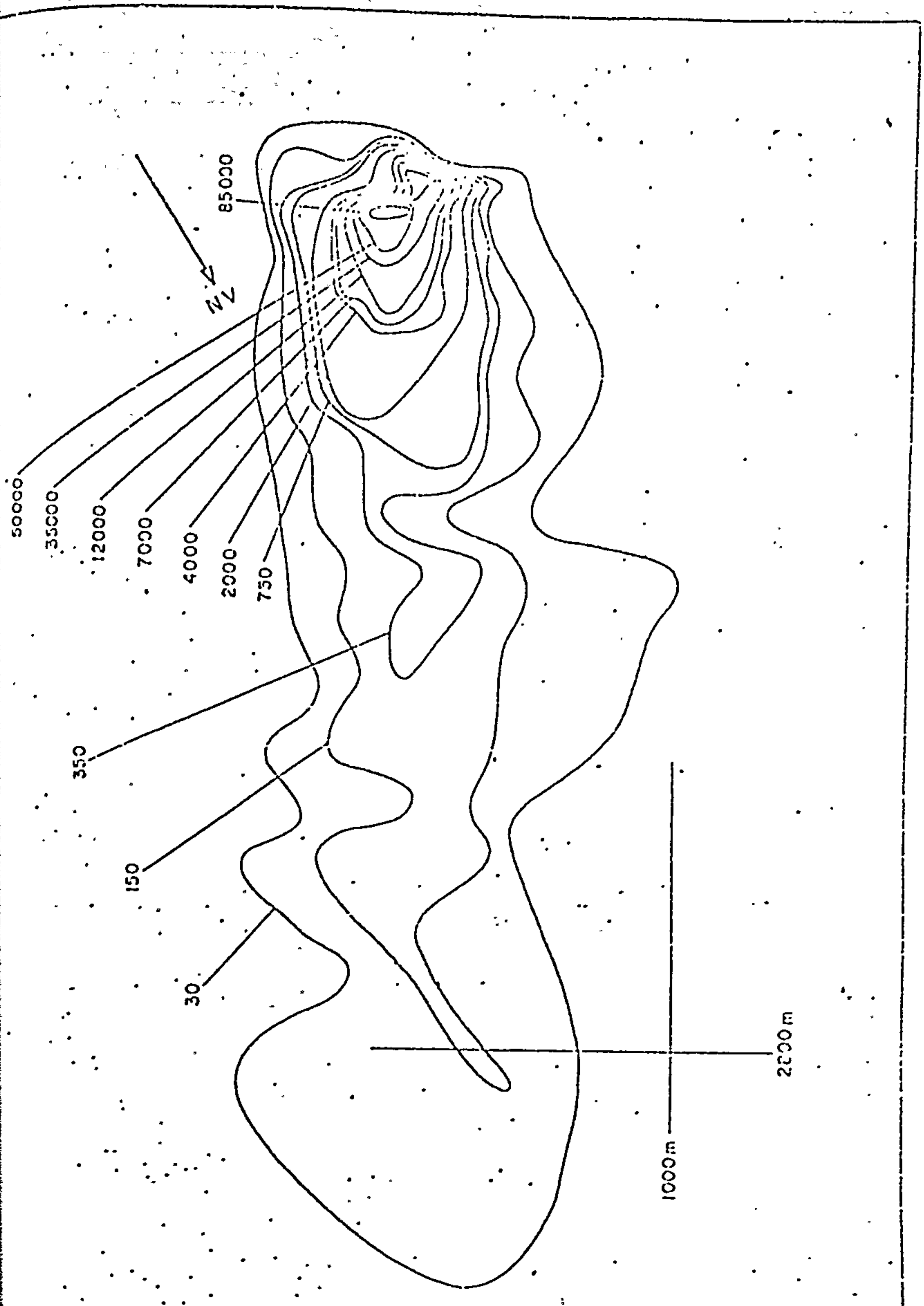
The value found for the flows is lower than that of the detection of July 7, principally because it was possible to better localize the most active region. The results now obtained should be close to the actual value of the solid displacement by dragging which, however, is small.

During the detection of August 22, an average solid flow of 90 kg per linear meter and per day was found, between the day of the injection and the day of the detection.

In relation to the detection of August 23, the average flow, during the 56 days taht elapsed since the injection of the tracer, was 80 kg per linear meter and per day.

Between the detections of July 7 and August 23, the average flow was 50 kg/m/day.

Considering the results obtained so far, it can be stated that the displacement of the bottom material by dragging, in the offing of the reef barrier, at a depth of 14 m, takes place in a northward direction, parallelly to the barrier, and its order of magnitude may be quantified at 100 kg per linear meter per day.



Data in counts per second

FIG: 3.5-IX

dipor

ESCALA GRÁFICA

0 10 50 100 m

TRANSCON S.A.

COMPLEXO INDUSTRIAL DE SUAPE

ISOCOUNT CURVES
DETECTION OF JULY 22,1974

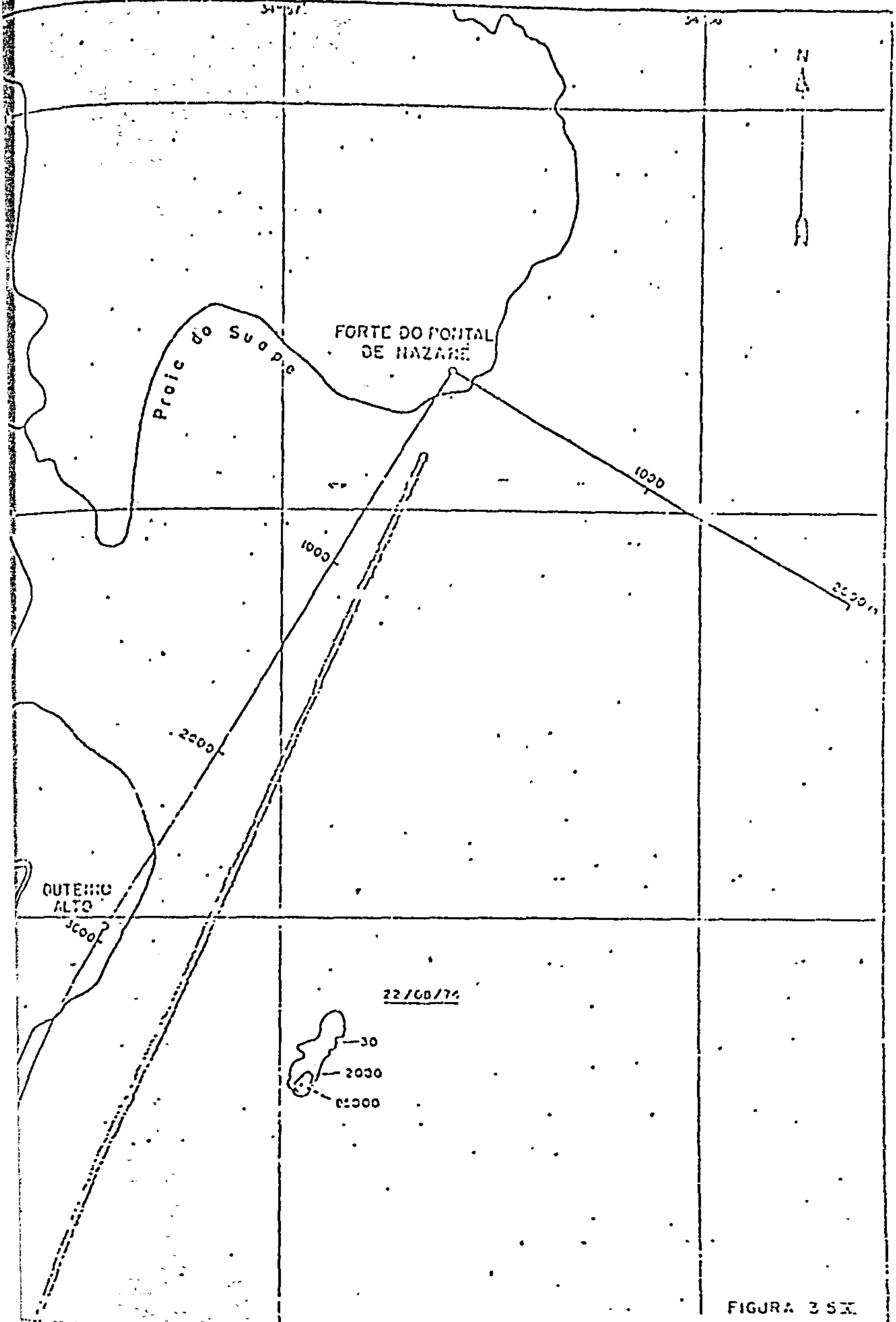


FIGURA 3 SX

dipor

FRANSCON S.A.

COMPLEXO INDUSTRIAL DE SUAPE

SITUATION PLAN
EVOLUTION OF THE RADIOACTIVE CLOUD

ESCALA GRÁFICA
0 100 500 1000 m

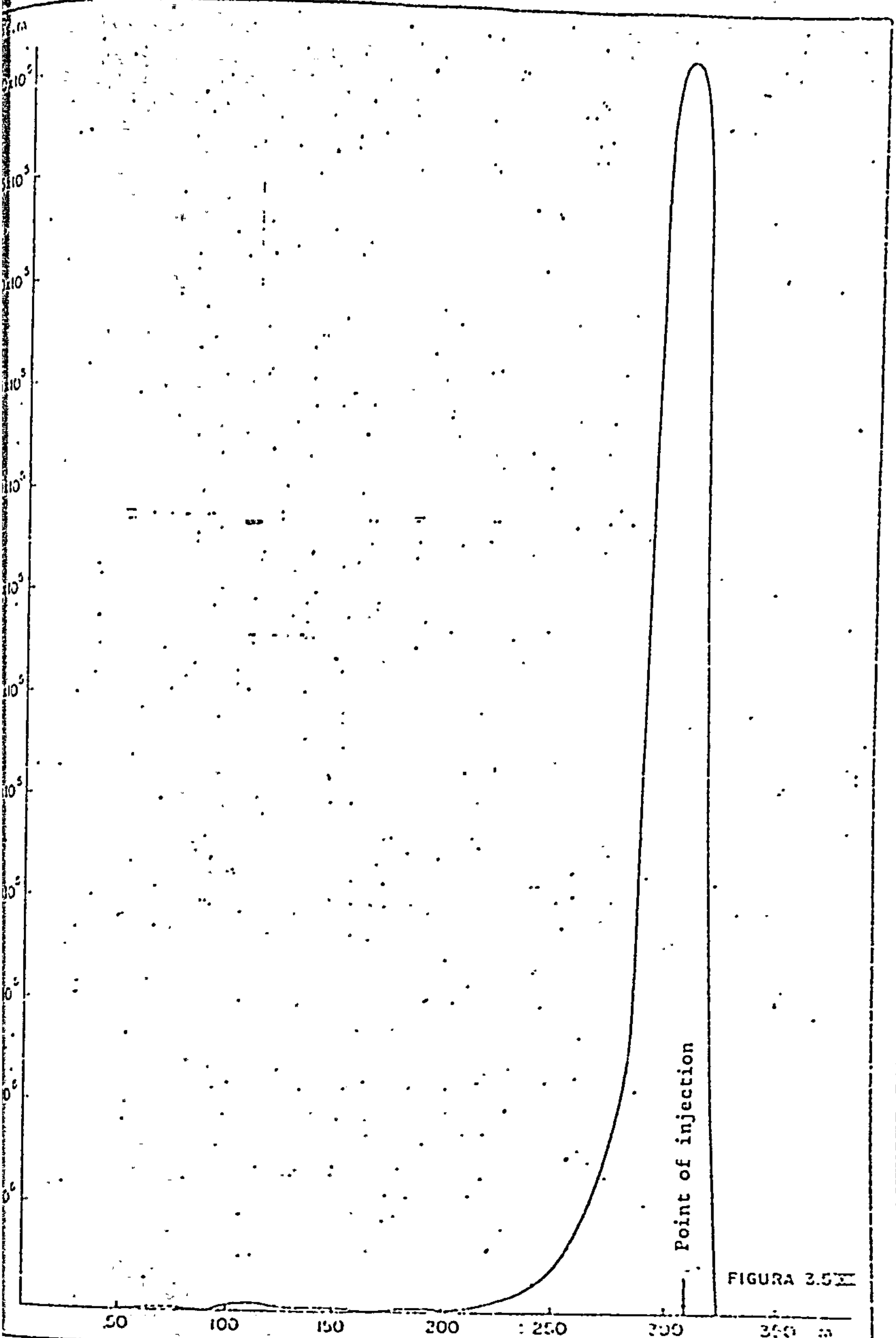
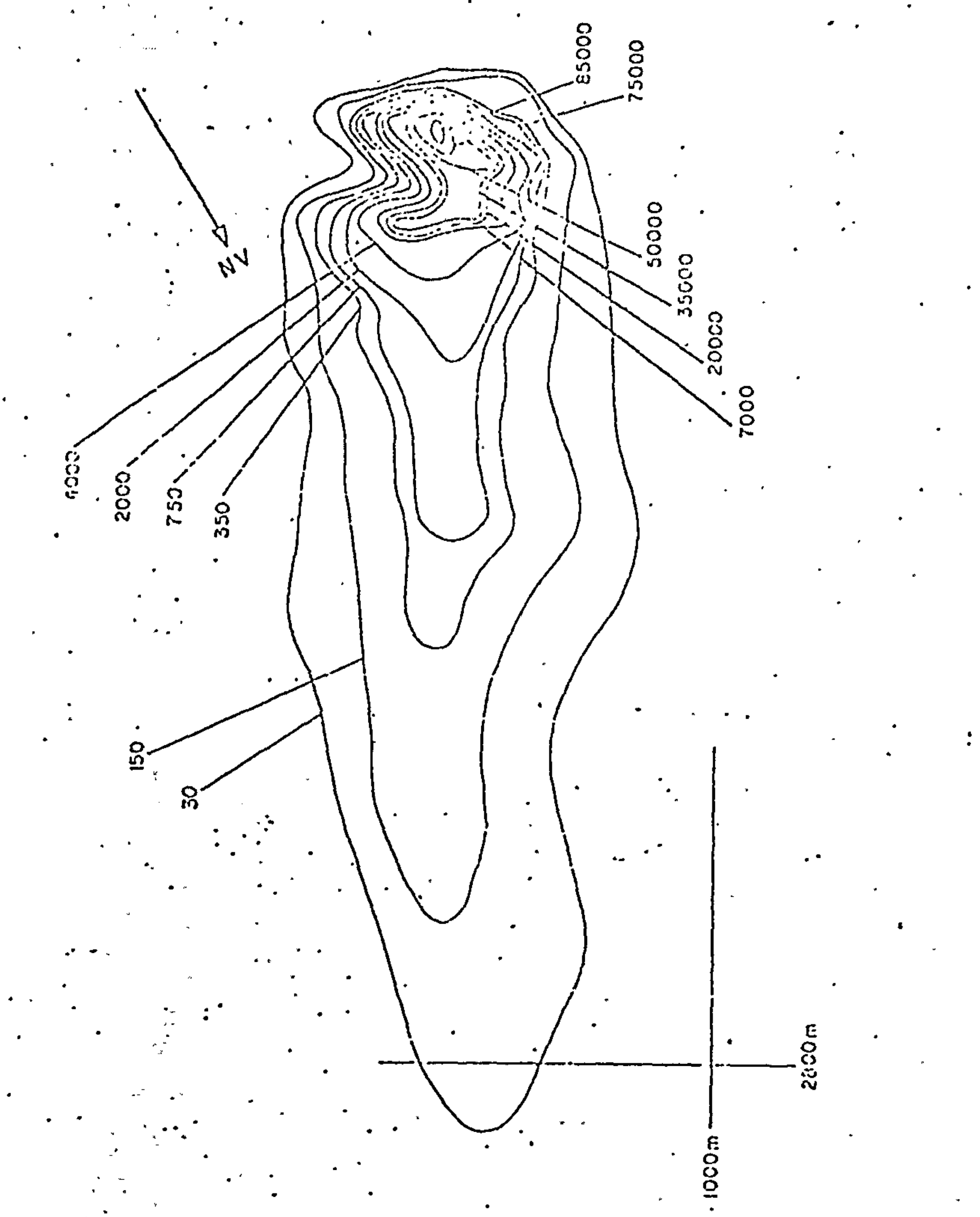


FIGURA 3.5

ESCALA …ÕES EM METRO	dipor TRANSCON S.A	DE PERNAMBUCO COMPLEXO INDUSTRIAL DE SUAPE TRANSPORT DIAGRAM DETECTION OF AUGUST 22, 1974



Data in counts per second

FIGURA 35

FONTE – IPR

ESCALA GRÁFICA

0 10 50 100m

dipor

TRANSCON S.A.

DE PERNAMBUCO

COMPLEXO INDUSTRIAL DE SUAPE

ISOCOUNT CURVES

DETECTION OF AUGUST 23, 1974

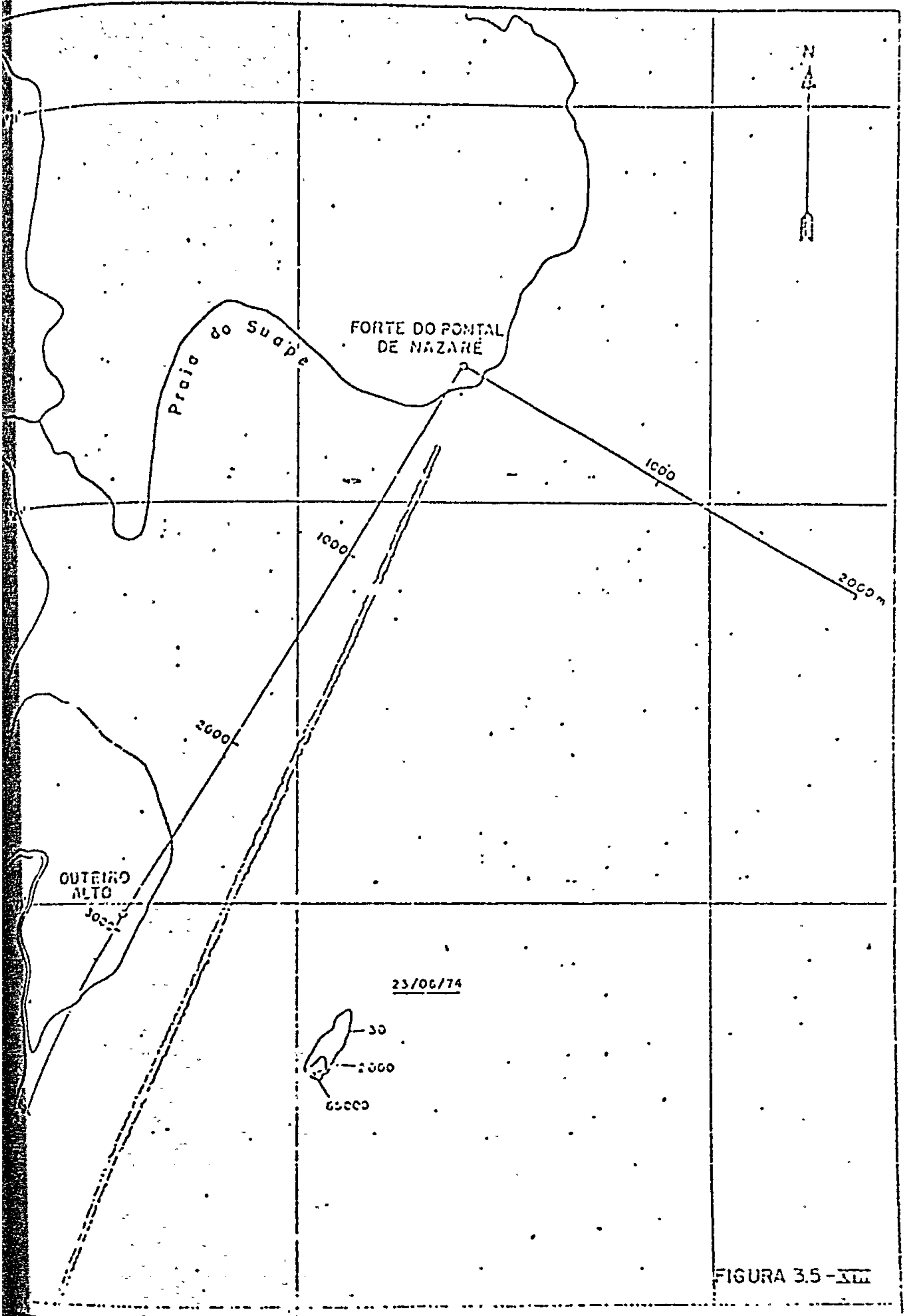


FIGURA 3.5 - XIII

ESCALA GRÁFICA
0 100 500 1000m

dipor

TRANSCON S.A.

GOVERNO DO ESTADO DE PERNAMBUCO

DE PERNAMBUCO

COMPLEXO INDUSTRIAL DE SUAPE

SITUATION PLAN - EVOLUTION OF THE RADIOACTIVE CLOUD

FIGURA 3.5-XXX

ESCALA

DIMENSÕES EM MILIMETRO

diper

TRANSCON S.A.

COMPLEXO INDUSTRIAL DE SUAPE

TRANSPORT DIAGRAM
DETECTION OF 23 AUGUST 1974

ANNEX TO ITEM 3.5

THE BALANCE METHOD OF RADIOACTIVE TRACERS

INTRODUCTION

The determination of the maximum flow of moving material at the bottom of a river or of the sea is a complex problem. As a solution, the use of radioactive tracers has shown rather satisfactory results, and its use is increasin in several countries.

Working with tracers consists essentially in marking with a radioactive tracer a representative sample of the moving material on the bottom, and following its evolution through a radiation detector towed by a boat. Another alternative is the simulation of the bot· m material with ground glass, in the necessary granulometry, adding an activable material (iridium, gold, tantalum etc.)

The position of the ship that carries the detector is obtained, at preestablished intervals, through a network of transite, with sextants or with a radio-location equipment.

In spite of this apparent simplicity, each part of the work must be thoroughly studied and planned, because of the differnces between them, that rbing deep alterations in the way of dealing with them.

The method described above is a typical example of integration in space, since, in each detection, there is an attempt at establishing the complete distribution of the material that lies on the bottom. A series of detections, separated by intervals that vary between days and months, represents a complete job.

The determination of the centers of gravity of the successive detections makes it possible to determine the average speed V_m of the solid transport, within a preestablished time interval. The maximum flow is then calculated, using the expression:

$$Q = p\ l\ V_m\ E$$

where:

Q = maximum flow in tons/day

p = specific mass of the sediment in tons/m^3

l = width of the transport, in meters

V_m = average speed in m/day

E = thickness of the moving layer in meters.

Therefore, this method requires the knowledge of thickne E of the moving layer. This thickness can be established by :

- samplings made inside the radioactive cloud
- considerations on the mode of transport (wrinkles, dunes) obtained from ultrasonic soundings
- using the method of tracer balance.

Each method has its advantages and presents its problems, and all are generally complementary to each other. The balance method can be used directly on the data obtained during the detections of radioactive material, starting from assumptions - based on the results of experiments - about the probable distribution in depth of the tracer.

Before studying the balance method, it is necessary to stress the improtance of hydraulic data for the analysis and the interpretation of the results. The work with tracers, in spite of the fact that it can be carried out over a period of various months, furnishes informations that are limited in time. The extrapolation of the information obtained for longer periods and the global interpretation of the results of each job require the knowledge of complete hydrologic data about the region under study.

The existence of these data condition the validity of the results obtained from radioactive tracers.

THE BALANCE METHOD OF COUNT RATES

PRINCIPLE

the balance method of the count rates is based on a simple idea. Let us assume that the detection of two radioactive clouds is being carried out, each of these clouds transporting the same activity A, one being much more deeply buried than the other. The deeper a tracer layer, the least counts it provides for a sound that passes over it, as a consequence of the higher absorption suffered by the radiation, and of a less favourable detection geometry. Therefore, it can be derived that a given curve of isoactivity (v.g. 500 c/s) will cover a larger area in the case of the shallower layer. Therefore, a relation must exist between the thickness of the moving layer E and the total number of counts that can be detected $\iiint n\,ds$. We call balance of the count rates the calulation of the value N of this integer, from the isocount (or isoactivity) curves.

$$N = \iiint n\,ds$$

Let us assume that the detector is calibrated, that is, that we know its response f to a unitary activity buried at depth z

$$F = f(z)$$

At a determine spot of the radioactive cloud the count rate n will be:

$$n = \int_0^e f(z)\, C(z)\, dz, \qquad (2)$$

where C(z) is the activity per unit of volume at the point considered, at depth z. Expression (2) gives the relation that existe between the thickness of the radioactive cloud at the point, and the measured count rate.

N can be calculated by

$$N = \iiint_S n\, ds = \iiint_V f(z)\, C(x,y,z)\, dx\, dy\, dz \qquad (3)$$

Let us call T(z) the actual ativity in all the cloud in the layer at depth <u>z</u>

$$N = \int_0^E f(z) dz \iint C(x,y)\, dx\, dy$$

$$N = \int_0^E f(z)\; T(z)\, dz, \qquad (4)$$

where E is the thickness of the moving layer.

Let us now consider the shape that the response of the sounder may take in the case of a unitary activity f(z).

Generally, f(z) has an exponential form

$$f = f_0\, e^{-\alpha z} \qquad (5)$$

This expression is determined by calibration, in the laboratory, burying sources of unitary activity at various depths z, and establishing the response of the sounding device for each of these configurations.

Carrying expression (5) into expression (4), we have:

$$N = \iiint n\, ds = \int_0^E T(z)\; f_0\; e^{-\alpha z}\, dz$$

$$N = 5,9 \times 10^7 \text{ c/s} \times m^2$$

The highest recuperation encountered in this detection, compared to the results the 7th of July is due to the fact that a line of detection was obtained which was very close to the point of injection. The exact definition of the maximum value of a count is a difficult problem, in the case of concentrated activity, for a difference of a few meters in a navigation line strongly alters the counts obtained. The value of N is used to calculate the theoretical average transport thickness, using the expression:

$$\frac{\alpha N}{\beta \, fo \, A} = \frac{1 - e^{-\alpha E}}{E}$$

The values of these parameters, in the present case, are:

$$\alpha = 0,147 \text{ cm}^{-1}$$

$$fo = 56,2 \text{ c/s / uCi / m}^2$$

$$A = 2,4 \times 10^6 \text{ uCi}$$

$$\beta = 1$$

Therefore, the first member of the expression has a value of $6,43 \times 10^{-2}$. In order to obtain the same value for the second member, we shall have E = 0,13 m.

The coordinates of the centers of gravity of the clouds, obtained from the calculation program are:

$$X_G = 3090 \text{ m}$$

$$Y_G = 1092 \text{ m}$$

This can be written;

$$N = \Gamma_M \int_0^E f_o\, e^{-\alpha z}\, dz = \Gamma_M \frac{f_o}{\alpha} (1 - e^{-\alpha E}) \qquad (6)$$

Γ_M which is a function of Γ_M and of f(z) is the equivalent uniform concentration that, spread in the same thickness E, would give the same count rate as real repartition $\Gamma(z)$.

$$\Gamma_M = \frac{\int_0^E \Gamma(z)\, f(z)\, dz}{\int_0^E f(z)\, dz} \qquad (7)$$

This value of Γ_M is generally different from average concentration Γ_m

$$\Gamma_m = \frac{\int_0^E \Gamma(z)\, dz}{\int_0^E dz} = \frac{A}{E} \qquad (8)$$

Let us make:

$$\beta = \frac{\Gamma_M}{\Gamma_m} \qquad (9)$$

The value of B can be calculated if we base assumptions on the law Γ_M since the response of sound f(z) has already been determined experimentally. Generally, various possibilities are tested, assuming the tracer will spread.

4.0 LEVANTAMENTOS GEOLÓGICOS

4.0 GEOLOGICAL SURVEYS

4.1 GEOMORPHOLOGY

Three very distinct topographic levels are observed, all related to the rocks in the region.

The highest of these levels is represented by pre-Cambrian gneisses, whose altitudes vary between 100m and 150m. As was clearly noted by R. Q. Cobra, the altitudes decrease in a north-south direction, forming a planed surface that dips in this direction.

The second level is formed by tertiary hills (sedimentary and effusive rocks) whose average altitudes vary between 40m and 80m.

The coastal plains and alluvial deposits of the Ipojuca, Pirapama and Jaboatão rivers form the third level, whose average levels vary around 5m.

The pre-Cambrian rocks that occur to the west of the area appear deeply dissected, forming a series of somewhat rounded hills with a thin soil layer. Their limits, to the east, with cretaceous and tertiary rocks are sharp, and this contact is evidenced by large faults where the crystalline block rose in relation to the block of sedimentary and effusive rocks.

The Ipojuca river valley is located in a tectonic pit, or graben, that was entirely silted up by sedimentary deposits from this water flow. The faulty bluffs on either side of the valley explain the extension of this alluvial plain included in the crystalline.

In the area where sedimentary and vulcanic rocks are found, from the tertiary and cretaceous age, the morphology is characterized by a succession of low hills which have relatively steep slopes.

The cape conglomerate (Conglomerado do Cabo) forms a tremendous number of hills, all small (average diameter less than 200m), densely cut up, creating a series of small crests distributed randomly. The arkosic sandstones and the siltites and the sandstones from the Barreiras formation are located at levels higher than the conglomerate. Its slopes are steeper, although less choppy, which indicates its greater susceptibility to erosive agents. The vulcanic rocks have rounded forms, are very steep and cut up.

Corresponding to the shape presented by the quaternary formations are the alluvial plains of the Ipojuca, Pirapama and Jaboatão rivers, all in tectonic depressions, and the coastal plain. This plain consists of, initially, extensive sandy chains along the coast that bound all the beaches from Recife to the south of this area. With the protection of these sand banks, the ocean invades the plains systematically and creates the extensive mangrove swamps that are found in the region. Of noteworthy interest is the development of these sand banks at the mouths of the Jaboatão and Ipojuca rivers (this last presently showing evidence of the action of breakers and winds perpendicular to the line of beaches).

The more important promontories are Ponta das Pedras Pretas and Cabo de Santo Agostinho (approximately 70m high). From this cape to the south of Ponta de Cupe, there is a line of calcitic sandstone reefs. This line joins the beach to the north of Cupe and forms the point by that name.

Other lines of reefs appear near the beach at Gaibu (between Cabo de Santo Agostinho and Ponta das Pedras Pretas) and, somewhat further out, out from the Jaboatão sand bank.

4.2 GENERAL GEOLOGY

STRATIGRAPHIC COLUMN

Based on the geological studies performed in the region, the following geological column was established for the area:

Age	Grouping	Lithology
Quaternary	Fluvial Deposits	Clayey-silty and sandy alluviums
	Marine Deposits	Quartzous sands and mangrove swamps (organic clays
Tertiary	Barreiras Formation	Siltite and sandstone intermixed in fine layers
	Cabo Arkosics	Arkosic sandstone
Tertiary or Cretaceous	Vulcanic Rocks	Basalt, trachyte, trachytic quartz and rhyolites
	Santo Agostinho Granite	Calcium-alkaline granite
	Cabo Conglomerate	Conglomerate with arkosic cement
Pre-Cambrian	Undivided Crystallin	Gneissic granite, metamorphized to a high degree (migmatites)

By means of percussion and rotary drill holes, an order of almost constant sedimentary layers, in general terms, was determined above the base. This second column of rocks is presented considering only those rocks found in the area under study and not in the regional geology. The sequence obeys the order of formation of the rocks (stratigraphically):

Rock	Age
Gneissic-granitic base	Pre-Cambrian
Arkosic sandstone	
Chalcosodic granite	
Alkaline plutonics	

Barreiras series	Tertiary
Alluvial sequence and reefs	Recent-Quaternary

QUATERNARY

The quaternary deposits were divided into fluvial and marine, considering the different behavior demonstrated from an Engineering point of view. The lithology described in the geological column and presented on the 1:30,000 map refers to surface occurrences. In total, these formations should reveal a sequence of clayey and sandy layers, alternately, down to the base. The reefs are calcitic sandstone rich in shell fragments.

Clay

Generally in layer form, somewhat sandy, quite compacted, which causes it to shape itself to any pressure applied to it. Typical fluvial clay. Dredgeable with some difficulty.

Sand

Quartzous, layers formed in marine environments with a wide variety of grain size, from place to place, with a large amount of shell remains and well-polished grains. Layers generally do not present graded bedding, but rather have the full gamut of grain size mixed together, showing the inconstancy of the forming agent. Easily dredgeable layer due to its disaggregate condition.

Sandy Clay

Found on the flooded plains along the rivers and whose mixed composition is due to the ebb and flow of tides. Generally a thin layer, easily separable, with alot of organic matter, surrounding more sandy or clayey parts. Easily dredgeable.

Coralligenous Sand

Quartzous material containing many remains of shells and coral, that extends along the entire outer area in a fine layer, at times cemented by a calciferous material, but not difficult to separate in that the hard layer does not exceed 10 cm in thickness and the rest is easily dredgeable.

Sandstone

Quartzous rock whose rounded grains were cemented by siliceous remobilization. Its maximum thickness is around 4m, often found separated. Occurs on Tatuoca Island, in the form of a layer, dipping to the west, where it is deeper, and outcrops at the confluence of the Massangana and Tatuoca rivers. Other occurrences were detected by drill holes, such as at No. 6, but with negligible extensions and thicknesses. Within the Massangana river (in its channel), sandstone is not found on the subsurface, as it was most probably eroded by the water flow. Its dredging should be avoided as it is only possible through blasting.

TERTIARY

Barreiras Formation

Composed of horizontal stratifications of silty, clayey and sandy layers. The rocks are only slightly lithified and very susceptible to erosion, which causes the formation of great vertical walls, which in turn caused the formation to be called Barreiras, or barricades.

These are sandy-clayey tertiary segments, reddish in color, with almost horizontal layers that outcrop all over the project area. The base layer of this series is an oligonitic conglomerate whose pebbles are quartz, well polished and up to 5 cm in size. Its thickness is one meter and is clearly visible at Cabo de Santo Agostinho, at the granite-Barreiras contact. This same conglomerate is observed at outcroppings at Suape beach, already quite decomposed. On the beach, it outcrops for about 150m in the direction of Cabo Pontal. Dredgeable layer, but with some difficulty.

Cabo Arkosics

Composed of feldspathic sandstone. A deep change caused the feldspars to transform entirely into kalinite, creating essentially clayey-sandy soil.

Found in drill hole No. 12 in a fresh state, somewhat fractured, at a depth of 10m, stratigraphically above the base and below the Barreiras series. Contains many angular sandstone fragments, which indicates the presence of a fault. This rock is cut by chloritized igneous dikes.

TERTIARY OR CRETACEOUS

Vulcanic Rocks

Various types of vulcanic rocks appear in the area: basalt, trachyte, trachytic quartz, andesite and rhyolite.

The order of contacts, where superimposing of one rock over another can be seen, shows evidence of progressing vulcanism, beginning with the effusion of base rocks (basalt) and ending with acidic rocks (trachytic quartz and rhyolite).

Andesite (not shown on the map) occupies small areas and, in general, forms reduced dikes and sills on sedimentary and crystalline rocks.

Alkaline igneous rocks appear as dikes, cutting the granite of the cape. Trachyte forms a dike on the edge of the cape, at Suape beach, outcropping right below Nazaré fort, and appears to continue on Suape beach where there is an outcropping of a green clayey rock, quite decomposed. This occurrence is only seen at low tide. At drill hole No. 12, it appears cutting the arkosic sandstone as a greenish, clayey, somewhat altered igneous vein.

Regarding the dredging of the above mentioned rocks, only the exomorphic layers can be removed, since the rocks in their fresh state can only be separated by blasting.

Cabo Conglomerate

This is an arkosic conglomerate composed of rounded blocks and granite pebbles, gneisses and schists. The probable origin is separation of a crystalline complex along the fault line that defines the rock groupings.

Santo Agostinho Granite

Cabo de Santo Agostinho is a calco-alkaline granitic stock, with approximately one kilometer of radius. Superimposed on this is the Barreiras formation alone, with makes it difficult to determine its age by correlation. Studies performed and cited by R. Q. Cobra indicate that this age is somewhere around 90 million years, and its intrusion would have occurred concurrently with the acid phase of vulcanism.

Its layer of decomposition reaches about 5m and becomes confused with the sediments above the Barreiras series. The area is extremely stable due to the absence of diaclases and faults of any large scale because the area is younger than the regional faulting. This fact was confirmed in that the granite cuts the fault parallel to the reefs and does not extend under the fault.

cutting this granite, there are dikes with a maximum width of 10 meters composed of rhyolites and alkalines.

PRE-CAMBRIAN

The pre-Cambrian is represented in the region along the entire western boundary of the area and is composed of highly metamorphized rock: gneiss, granite, feldspathic schist, etc. This is the area where the greatest number of tectonic disturbances occur, in which the faults resulted in shearing forces in a NW-SE direction.

Gneiss - Found in drill hole No. 16, in a semi-fresh state, at a depth of 14m, having an exomorphic layer of 5m over the fresh rock, indicating the presence of gneissic rock at shallow depths in the entire zone up the rivers, until it outcrops in the northwest, although always with an exomorphic layer.

GEOLOGICAL EVOLUTION

After the slight lifting of the crystalline shield, a long period of alteration and erosion took place until the Mesozoic. In this era, large scale tectonic movements lowered the block closest to the coast, creating the conditions for the cape conglomerate, formed by pebbles and boulders of crystalline origin.

New tectonic movements, associated with vulcanism, developed in the area. Vulcanism begins with base and effusive character, evolving gradually to acid and explosive. Correlations cited by R. Q. Cobra (1960) associate the final vulcanism with the intrusion of Santo Agostinho granite (geochronological studies establish an age of 90 million years and trace elements correlate the granite with rhyolite in the region).

At the end of this phase, new sedimentation conditions were implanted, permitting the deposition of the Cabo arkosic, which by the distribution of samples consider the hypothesis of having covered the region.

After a short period of alteration and erosion, the deposition of the Barreiras formation begins. This formation, of a continental nature, probably covered the area, preserving the arkosic from total destruction.

Presently, the erosive processes are concentrated in the older areas, taking the materials for deposit on the extensive outer plains.

1.3 STRUCTURAL GEOLOGY

INNER AREA

With the exception of faults found in areas with sedimentary, metamorphic and igneous rocks (from the tertiary to the pre-Cambrian), whose main direction is SSW-NNE, approximately parallel to the present line of reefs and following the faults that determine the northeast coast of Brazil, there is a depression near drill hole No. 13 with the same direction as regional faults and which can indicate a fault whose east block rose and west block fell, but with probable small rejection. The rocks found in drill hole 12 present visible signs of fracture, which can be used as the near boundary of this fault.

OUTER AREA

The entire base near the reef chain, within the bay, is found at depths varying from 50 to 70m.

The datum levels are sharply diminished, crossing the reefs towards the sea for about 20 to 30m. This "cliff" also follows the SSW-NNE direction of the regional faults. The sudden change in datum levels is due to a large fault, which dictated the coastline at this point and consequently caused the reefs, in the quaternary, following the coastline. In this fault, the western part sank and the eastern part rose. This latter, in turn, begins to sink gradually to about 45m, 3 km out to sea from the reefs, and turns suddenly to the east at levels of up to 20m, indicating the presence of another parallel fault, in the SSW-NNE direction.

Almost all the faults are normal, with rare cases of superimposition.

There are also lesser faults, running approximately SSE-NNW, or rather, perpendicular to the principal direction.

Faults are plotted on the base map under the symbol Fa, only at the points where detected by the geophysical survey. As referred to previously, the relief of the base appears very cut up, with various paleochannels and a greatly eroded ex-surface, with sparse drops up to 17m deep, although most commonly with elevations of up to 20m. Many of these are caused by faults in the base.

GEOTECHNOLOGICAL ASPECTS

Areas with occurrences of ancient formations (tertiary and before) can presently be occupied with few problems. This is not so for all areas where quaternary deposits occur, as these areas would need to undergo costly recuperation work first.

Even in the quaternary areas, where outcropping sediments are sandy, soft layers of organic clay are found at greater depths which do not offer much security for foundations. The occupation of low areas should consider the possibility of recuperation of these regions according to the solutions adopted for the remainder of the structures. During construction of an excavated port, for example, the use of materials extracted during dredging can greatly reduce the cost of recuperation in marshy areas.

RECONNAISSANCE OF THE INNER AREA

The Massangana river, upstream, presents a thin superficial clayey-sandy cover (see the geological profile of the Massangana river) at the confluence of the Algodiais stream (Riacho Algodoais) with the Massangana. There the base is about 6 meters below the surface, with a lowering of the same in a northwest direction near drill hole No. 13 (with approximately

25m of tertiary sediments) and a later rise up to about 8m, near drill hole No. 5. This depression, which is quite sudden, could have been caused by an ancient fault that resulted in a valley and was later covered over by tertiary and recent sediments. The direction of the valley is SSW-NNE and seems to reach at least to drill hole No. 6 (with 25m of quaternary sediment). From point 13, headed in a northwest direction, there is a visible rise in the base up to an outcrop, although there is a very thick layer of exomorphic rock. In the case of drill holes No. 9 and 10, there was exomorphism through 5m.

Downstream from the confluence of Algodoais stream with the Massangana river to about 2 km below, there is a superimposition of sand, Barreiras series and base, whose total thickness varies from 6m to 24m. This point, where the Barreiras series occurrence ends, must have been the last advance of the Cenozoic ocean for from there to the mouth of the river a sequence of sandy (marine) layers is recorded with thick clayey layers (fluvial) which dictate the dominance of one ambience over the other during the eras of quaternary sedimentation.

The change of sandy-clay facets to sand and surface clay took the form of a graduation in material content, due to the ebb and flow of the tides.

In the more internal parts of the area, out of the reach of the tides, there is a layer over the sediment which is clayey, with a great deal of organic material, product of decomposition of the vegetation.

In the Tatuoca river, whose base datum level runs from 5.5m at drill hole No. 4 to 50m at its mouth, its order of layers is still: base, sand, layers of clay and surface sand. This river also presents a large paleochannel structure, filled with sand.

Ipojuca river will be considered along with the Suape basin, its surveyed area is very small and all this region has same stratigraphy (or rather, base, sand, clay and surface d), varying only in thickness. The base is found at great pths in almost its entire extension, with datum levels creasing somewhat in the direction of the reefs and decreasing ddenly when nearing Cabo de Santo Agostinho. The layers taper f in thickness at that point until they disappear, thus the nclusion that all the sediment was deposited over a basin ich was bound, to the north, by the granite of the cape.

rfect outcrops appear at Cabo de Santo Agostinho, where the yers of the Barreiras series are found over the granite. is stretches into the sea to about 300 to 500m, and the wnslope is very sharp, dropping until merging with the e-Cambrian base.

CONNAISSANCE OF THE OUTER AREA

parated from Suape bay by the chain of reefs, this region ries in surface stratigraphy with a thin layer of sand rgely made up of the remains of shells and coral covering e entire outer area.

cording to the drill holes bored in this area, by jet probe, is layer of sand was extremely hard. Where the jet penerated the layer, a base layer of sand was encountered and netration was limited. According to geophysical records, e entire area between the base and the coralligenous sand s mapped as sand.

e relief of the base appeared very cut up in this area due o paleoerosive and tectonic effects.

e excavated port alternative considers, in the first place, e use of the line of reefs as natural piers.

essone (1964) in his work "Origin and Age of the Sandstone efs of Pernambuco" presents a detailed description of their position, grain size, correlations, etc. His description tates that the thickness of this rock is about 3 to 4 meters, ying directly upon the sand of the ocean bottom.

ese considerations were, in part, confirmed by the studies veloped.

e reefs allow very little penetration of sound and are erefore easily identifiable in the seismic soundings that owed them only on the surface, always above a layer of sand.

e profiles made by the diving team showed widths of over 00m in the chain and the geophysical instrumentation detected s "skirts" on various occasions, besides the parts that are sible under the ocean. The drill holes above the reef, near o de Santo Agostinho, registered averages of 3m and geo-ysical interpretation allowed thicknesses of up to 9m to be asured near Cupe.

e existence of subterranean reef chains was not proved, cept at the entrance to the sandbar where they are eroded d somewhat covered over with sand. In the inner as well s the outer area, all the reefs outcrop soon after the rface layer of sand, whether appearing above sea level or t.

e reef is a sandstone body with calciferous cementation, ry hard, containing polished quartz pebbles, shell remains, ossed stratifications, etc. It is generally tubular in

...pe. Its present state is one of erosion, noted by the ...nnels that are being created in its surface by water and ...r caused by water that provokes separation of large blocks.

...ides the chain parallel to the coast, near Cupe and Gamboa ...ch, various isolated reef bodies can be found as plotted ...the base map under the symbol R. These reach nearly 2 km ...sea from the Cupe land spit and were detected by the ...physical survey.

...the drill holes made in the reefs, a sandy layer was ...nd underneath that was very difficult to penetrate by ...cussion drilling. It shows cementation by leaching of ...iferous material of the reefs and, possibly, compaction ...the weight of the reef. This cementing indicates that ...dging over the reefs would be somewhat difficult.

...ENTS

...materials of the Barreiras series and the clayey layers ...ld be harder to dredge since there is a great degree of ...regation among the components of these sediments.

...the areas where the Barreiras series and igneous and ...amorphic rocks appear, there is stability for construction ...industrial structures as long as any faults in these rocks ...e detected. Should it be desirable to construct over the ...ndy and clayey areas, detailed studies with surface sampling ...uld be undertaken to characterize the degree of resistance ...these layers if submitted to extremely heavy structures; ...s is especially so for clay layers, which are tremendously ...stic and can cause disastrous consequences if their physical ...racteristics are not geotechnically interpreted. The same ...uld be done to determine the incline of the banks of ...dging channels since there are inserts of different ...erials.

the case of landfill of marshy areas, only sandy layers uld be measured and utilized, primarily those in the Suape and the Ipojuca river that present good thicknesses. Those m the outer area can also be used, including or not the alligenous sand that is found above the sand layer.

uld removal or conservation of the chain of reefs be of terest, it should be noted that since it lies above a layer sand the simple dredging of sand along its edges and base ld cause its undermining and it would fall.

the outer area, due to the existence of many parallel and pendicular faults (in relation to the reefs), all plans r any structure should be carefully located so that they do t coincide with these weakened zones. Thus, a seismic finement of this area is suggested to detect other lesser ults, should there be any plans for installing some port ructure; the same should be done in the inner area where e industrial complex will be installed.

the Cupe area and adjacent, a study should be performed to ify the feasibility of utilizing, or not, the reefs that e found there to support small port structures since these efs are located away from the coast.

CESS AND INNER ROUTES

e construction of access routes will have, as the greatest oblem, the foundation of landfills at mangrove crossings. nsidering the variation of thicknesses and physical racteristics that these sediments normally present, ividual and specific construction solutions can be expected r each stretch of the crossing.

other problem to be faced, which is more easily resolved, the stability of the slopes of cuts performed in areas with Barreiras formation and Cabo arkosic rocks. These lithological combinations appear "in natura" with a strong propensity to erosion which, acting on the slopes, destroys the stability of the same.

CONSTRUCTION MATERIALS

Due to the grand scale of the work involved in the Suape Industrial Complex, it becomes necessary to locate great volumes of sand and stone for concrete.

The proximity of crystallin and the existence of vulcanic rock in the entire region assure the supply of stone for the construction work. Large quarries exist to the west of Carvalhos bridge (Ponte dos Carvalhos) that furnish crystalline rock and the Algodoais quarry furnishes rhyolite. This last outcrops in an area of about 1.5 km^2.

Sands can be removed from the alluviums of the Ipojuca, Pirapama and Jaboatão rivers, all of which will need washing before use.

The sands along the beaches and near the canals suffer the influence of the ocean water. Their salinity could increase the alkalinity of the concrete and cause undesirable reactions with the aggregate; therefore the use of these sands is not indicated for construction material.

CONCLUSIONS OF INTEREST TO THE PORT CONCEPT

the possibility of constructing an excavated port, the of reefs as natural piers should be considered promising. In building the docking structure, the existing fault under sediment, up the Massangana approximately 3 km from its mouth, should be used if possible. The location of this fault, in the field, will prolong the line established on the geological map which separates the Barreiras formation from the Cabo Arkosic.

The continuity of the fault was detected by geophysical studies and surveys, located in the different blocks. The western block rose in relation to the eastern block, leaving the crystalline base closer to the surface in the former. Location of the industrial structures and the dock over the western block would reduce the problems of foundations and dredging will be facilitated by the greater depth of the base in the eastern block.

4.5 PRELIMINARY EVALUATION OF THE STABILITY OF CANAL BANKS

This part attempts to evaluate the stability of canal banks, in a preliminary fashion, in order to offer a forecast of the possibility of assuming natural banks for the canals used in the excavated port solution.

Some considerations of a qualitative nature of the problem are presented, conditioned by the geological formations crossed, as well as geotechnical research undertaken with a spaced network of about 450m along the port canals needed for the overall project.

Such research, as confirmed by the indicated characteristics, will serve as the basis for final engineering designs in the port area, with the network tightening when possible for the purpose of and in the specific locations of respective designs.

MAJOR GEOLOGY IN THE AREA OF INTEREST

The area of interest is understood to be that crossed by the line of canals, furnished by the port concept and finally reproduced.

In the geological survey it is noted that the area is bound by the Massangana river-Canas stream to the north, the Ipojuca river to the south, the line of reefs to the east, and the dominant elevations in the region to the west. The area is largely covered with quaternary formations (sand and mangrove swamps). The Barreiras series surfaces in many sub-areas.

The crystalline rocks, which form the base in the zone, are generally beneath the Barreiras formation; the notable exception is the outcropping of Cabo de Santo Agostinho and vicinity.

The more obvious tectonic traces of the region consist of faults, with an approximate NW-SE direction, with the two most notable located under the line of reefs and crossing the vast mangrove swamp area in the course of the Massangana river. The surface of the base in faulty areas ascends from the coast to the interior, and from the line of the Ipojuca river to the Massangana river. The Ipojuca river, in turn, flows over sediments deposited in a tectonic pit. Seismic sounding detected the base generally between datum levels of -20 and -27m. Near the faults further to the west, the base was found at far lesser depths (5 to 10m).

GEOTECHNICAL CHARACTERISTICS OF SEDIMENTARY FORMATIONS IN THE ZONE OF INTEREST

Reefs and Coralligenous Sand

These are formed by calcitic sandstone. The only available indication of their mechanical properties is the percentage of recuperation obtained in percussion drilling already performed during the preliminary phase; information of a geological nature seems to indicate that this formation should present mechanical characteristics of rock that is resistant to simple compression of 500 kg/cm^2.

Seismic sounding detected great blocks of reef in various areas adjacent to reefs found above average sea level, but these were submerged and resulted from partial degradation of the original formation.

In general, the thickness of reef banks is about 3 meters.

The ocean bottom in the zone close to the area of interest presents a layer 3 to 4m thick of partially cemented coralligenous sand lying directly on sand. This last sandy layer with an extremely varied thickness (2 to 30m) sits directly ove the crystallin base (profiles 22A and 22B of the seismic ounding). Quantitative data on the mechanical properties of he layer of coralligenous sand are not available.

n the bay within the line of reefs, the layer of coralligenous nd was not detected, but rather (and only very close to the eefs) submerged blocks of reef.

Sand

he sands of the area of interest appear in various aspects n terms of geotechnical characteristics. Average to thick ands predominate, however, in the interior of the area.

ercussion drilling already performed shows fluffy surface ayers followed by horizons with average and strong cementation. hese appear to be alluvial horizons cemented by ferrous oxide at comes from surface sandy horizons. This formation was etected by drilling performed on Tatuoca Island in drill holes 3, F7 and F8 and can be observed along the right hand argin of the Massangana river outcropping above the level of e water. In these places, the thickness of the hardened ayers varies from 2 to 4 meters and in the percussion illing presented indexes of resistance to penetration (SPT) ual to compacted sand, highly compacted sand. Drill hole 11 also showed a cemented sub-surface layer.

e geological map defines the zones of sand.

ngrove Swamps

e drilling performed (6, 9 and 10) showed surface layers very soft organic clay, with variable thicknesses (one to meters). The available geological map defines the surface the mangrove swamp zone. Peat formations were found in the to upper course of the Massangana (10).

The very soft surface clays are made up of materials still in the process of condensing and usually present a sensitivity of 4, that is, its resistance when flattened down to 25% of the original value.

Subsoil of the Area

This appears in the form of layers, alternated, at times silty and at others sandy.

Rotary drilling, core samples of which are available, present siltite and argillite in various degrees of lithification: inserts of soft black clay can be found between more or less hardened layers.

Percussion drilling showed clayey and sandy layers with varying consistency and compaction. However, layers of rigid clay and medium compact sand predominate. Drill holes No. 3, 7 and 8 showed the existence, in the subsoil of Tatuoca Island, of soft clay layers; in drill hole No. 7 between datum levels -10m and -15m and in drill holes No. 3 and 8 between datum levels -15m and -22m.

In two groups of drill holes there was a certain amount of agreement in the succession of layers: the first constituted by drill holes No. 6 and 13, the second by drill holes No. 3 and 8. The great distances between one hole and another did not allow definitive statements at this time regarding such continuities.

Percussion drilling already performed in the interior of the area where the feasibility of an excavated port was examined shows the following important aspects:

(a) Drill hole No. 11, in the middle of the main maneuvering basin, did not present a layer of soft clay:

b) The same drill hole (11) showed a layer of sandstone 3m thick at a level of -20m;

c) Drill holes No. 3, 7 and 8 showed that the subsurface sandstone (Bir horizon of podzol soil?) in these locations has the same resistance to dynamic penetration (SPT) as compacted sand;

d) The same holes showed a layer of soft clay, with varying thickness, between the datum levels of -10 and -22m;

e) Drill holes No. 6, 9 and 10 showed that the surface layers of very soft organic clay with thicknesses between one and eight meters, situated in the inner mangrove swamps over rigid and compacted layers;

f) The rotary drilling logs must be examined for a first evaluation of the horizon that was impenetrable by percussion, detected under the rigid and compacted layers cited at the end of the previous item;

g) The geological and geophysical surveys, as well as the results of percussion drilling and of local inspection, brought out the following preliminary conclusions regarding the study of interior canal excavation:

i) Considering the first findings from drilling on Tatuoca Island, the submerged slopes with normal inclines (1:4) present precarious stability. This was already proved by the first stability analyses.

ii) The mangrove swamps that are covered by typical, but ..., vegetation, with 5 to 10 cm root diameters, can present reasonable difficulty for their use, besides the vegetation: the material to be dredged is of poor quality for landfill in areas to be recuperated.

STUDY OF THE STABILITY OF CANAL BANKS - SIMPLIFIED BISHOP METHOD

Stability analysis was performed on a computer utilizing the simplified Bishop method. The subsoil profile used was based on the seismic sounding profile obtained along the Massangana River, near its mouth at Suape bay.

objective of the analysis undertaken was to provide the itial indicators for the development of preliminary designs canals, considering the reconnaissance performed by that . A more accurate study of the subsoil will be necessary further detailing of the preliminary designs.

depths were tested: 20 and 17.5m (measured from the rage water level), three bank inclines (1:3, 1:5 and 1:10) three resistant coverings for the clayey layer:

$c = 1\ t/m^2$	$\phi = 0°$	(soft clay)
$c = 5\ t/m^2$	$\phi = 0°$	(medium clay)
$c = 1\ t/m^2$	$\phi = 17.5°$	(clay, covering of effective pressure)

first coverings refer to possible resistant values for ck requests, and the last serves for a first evaluation of avior, over time, of banks. Evidently, these data serve y an auxiliary purpose in the first evaluation of safety fficients of the banks.

ults Obtained from the Numeric Analysis

method utilized to determine the safety coefficient was simplified Bishop method. This method supposes the rupture of faces to be circular.

results obtained are presented in the drawings that appear tem 11.5. As could be expected, the clayey layer always luenced the position of the critical circle (corresponding he lowest safety coefficient). The critical circle was icated for each case in the cited drawings.

table below presents the safety coefficients considered mum for the network of centers tested:

INCLINE OF THE BANK	WATER AT 20m			WATER AT 17.5m		
	(1)	(2)	(3)	(1)	(2)	(3)
1:3	0.23	1.13	-	0.26	1.36	1.40
1:5	0.34	1.24	-	0.35	1.45	1.73
1:10	0.60	1.69	-	-	-	-

(1) For the layer of clay with covering: S = 1 t/m^2 (soft clay)
(2) For the layer of clay with covering: S = 5 t/m^2 (medium clay)
(3) For the layer of clay with covering: S = 1 + p'tan 17.5º

[Ve]rification was not made with the third covering for water at 20m due to the fact that the first two presented low values for [s]afety coefficients.

[Ve]rification was not made at the 1:10 incline, for water at 17.5 meters, as this alternative was removed due to the [gr]eat volume of excavation which would restrict the useful [ar]ea too much.

[As] can be seen, the existence of a soft layer of clay always [ca]used low safety coefficients which, formally, prohobited the [so]lution of canals with natural side slopes.

[Fo]r the simplified geometric conformation adopted, the existence [of] clayey layers with minimum cohesion values of 5 t/m^2, even [fo]r banks of 1:3, brought the safety coefficients to the level [ad]opted for similar construction projects.

[Ad]ditional Considerations about the Stability Analysis of Banks

[Th]e above results, although presenting values with approximations [to] the hundredth, should not be transposed for simplistic [con]siderations to the real situation in question. The precision [re]ached in calculating the safety coefficient has some condi-[ti]oning factors, the more important of which are:

- the values of the resistance coverings;
- the shape of the surface rupture;
- the succession and geometry of the massif layers.

this first approximation, resistance coverings were estimated the succession and geometry of layers (inferred from the smic soundings) were simplified. The shape of the surface ture was assumed to be circular.

ter approximations can be obtained in later phases of study, ough densification of the network of drill holes, and by ing undeformed samples and other tests. Other methods of lysis which utilize different forms of surface rupture, h as those of Jambu and Chugaev, can be used. There will some uncertainty, however, prior to actual construction. s uncertainty results essentially from possible geological ations not detected by studies, as careful as they may be: ll discontinuities, resulting from ancient slides, fine or her thin layers of fine saturated sand, etc.

lowing the numerous indications that exist in similar cases large scale projects, precautions should be taken for struction in stretches which, submitted to instrumentation control, provide additional data for the completion of k within the safety and economic conditions established.

clusions

ictly for the hypotheses on which the first estimates of e stability are based, the following conclusions are drawn:

The excavation of normal slopes for the depths of and 17.5m is not feasible when dealing with soft clay esion 1.0 t/m^2);

The use of normal slopes is feasible (1:3 and 1:5) or clayey layers with a minimum cohesion of 5 t/m^2 and coverings ith the effective pressures adopted in this study;

c) The increased knowledge and understanding of the ubsoil along the port canals will permit the evaluation of tability in the areas in contact with all the canals that make the overall project for the purpose of the final design;

d) In any case, the final design will accompany the actual rformance of work, at which time careful observation should made of the stretches excavated. These observations will mplement the data obtained in previous phases and will indicate y necessary adjustments to design items, providing more tailed orientation in slope stability and the need for and type protection of the margins.

TOMO I

5.0

5.0 SURVEY OF HYDRIC RESOURCES

5.0 SURVEY OF HYDRIC RESOURCES

5.1 GENERAL

The present study reinforces the studies made for the Suape Industrial Complex, in order to determine the Hydric Resources of the region and the Hydrographic Mapping of the originally proposed area.

It is a pioneering study in the Suape area, at the REGIONAL HYDROLOGY level, with a character of basic elements, and, although it soes not represent by itself elements for specific projects, it appears as an ample general hydrologic diagnosis of the tributary basins that interests not only the Suape Industrial Copmlex, but also the whole of the so called "Zona da Mata Pernambucana".

As has been said in the chapter about the hydrometric campaign, the results that are part of the present diagnosis can be tranferred, by analogy, to the above-mentioned "Zona da Mata", whose hydrological characteristics are similar to those of the region now being studied, where the lack of data or values of observations or measurements is only too well known.

As previously mentioned, the global object of the studies in this report is the preparation of a "hydrologic diagnosis" of the region, intended for the preliminary projects and the future projects for the supply of water and disposal of sewer and storm waters that will be necessary for the substructure of the CI. The result is the conclusions and recommendations that follow the analysis of the results thus obtained, that will orientate the development of hydric projects and complementary studies.

Such a study includes the superficial and underground waters of the Suape zone of indluence. Parallelly, a hydrometric campaign was carried out during the months of February to September to suppor the hydrological studies of the water-courses liable to be utilized as a source of water supply, or whose floodscould prove harmful to the installations, buildings or industrial and harbour establisments in the future.

The geographical scope of the studies that were undertaken include basically the basins of the rivers Pirapama (control area upstream from Engenho Maranhão) and Tabatinga-Massangana.

This area can be limited, approximately by parallels 8º 10' and 8º 30' and meridians 35º 00 and 37º 00.

The area for hydrogeological investigation was evidently limited to the formations that show aquiferous poddibilities, corresponding to sedimentary areas starting in contact with the crysatlline, and situated between parallels 8º 27' 48" and the meridians 34º 55' 00" and 35º 03' 45".

5.2 SUMMARY AND RECOMMENDATIONS

5.2.1 AVAILABLE SOURCES

Th preliminary studies undertaken in the area showed that the following water resources, shown in the map of illustration 5.1, were the best suited for use by the Suape Industrial Complex.

1 RIVER GURJAÚ

This river is an affluent of the Pirapama, downstream from the town of Cabo, and one of the main sources of supply for the city of Recife.

The hydrographic basin of this river, up to the dam used for the supply of Recife, has a contributing area of about 114 km^2, and its estimated regulated flow should be of about 115.000 m^3 per day.

This source contributes to the water supply of Recife on the basis of about 65.000 m^3 per day, thus leaving an excess of about 55.000 m^3 per day that could be used by the Suape Complex, if not utilized immediately by Recife.

2 RIVER PIRAPAMA

The river Pirapama is one of the main watercourses in the area, with a contributing basin, together with the basin of its affluent Manoel Gonçalved, of 336 km^2, at the height of the possible dam site at the widening at Engenho Matapagipe, in the county of Cabo.

The Pirapama originates in Chão dos Pintos, in the neighbourhood of the village of Serra Grande, at an altitude of about 500 m. From the spring to the widening, it has an extension of 63 km, and shows a form factor of 0,09.

This river could offer a regulated flow of about 340.000 m^3 minimum per day.

During the period of observation of six months during this year (1974) a minimum discharge of 2,800 m^3/sec was registerd in February, and a discharge of 66,080 m^3/sec in July.

The proximity of this basin with that of the river Gurjaũ, as well as the existing topographical conditions, offer an easy transposition at the same level of the water from this basin through the affluent Manoel Gonçalves to the basin of the Gurjaũ (downstream from its dam) by the Cafofo stream, or even, with a small amount oi pumping, through the next effluent upstream of the Cafofo stream going directly to the existing dam.

The transposition of the waters of the river Pirapama to the basin of the river Gurjaũ would have the advantage of the integration of both basins, and the utilization of the treatment st·tion, or of a simple expansion of the etation that is already operating in Gurjaũ. Th operation of the Pirapama dam in Matapagipe would also be a regulating agent for the floods of this river, minimizing their effect in the lower areas of the Cabo Industrial zone.

h regulated water reserve can be used for the direct supply of the Suape Complex, although farther away, or it can reinforce the other sources that are closer from the c nsuming cneters, choosing whichever solution may prove more economical.

Th reiver Pirapama can also be utilized slightly downstream from the confluence of the Utinga de Cima (Pavão), close to the town of Charneca, with a small dam at the approximate elevation of 30 m, as a reinforcement of the supply of the Suape Industrial Complex or of Cabo. This reservoir can have its useful capacity increase once the river has a regulated flow.

Further exploitation of the river Pirapama will be possible, using the site of an old dam, close to the city of Cabo, slightly upstream from the Rhodia Industry. Although this use is of limited capacity. "as the water flows", it can be improved if the river flow is regulated. It can only be used for limited consumption, such as a reinforcement to the supply of the city of Cabo and nearby industries.

3 RIVER MASSANGANA

The river Massangana has as affluents the rivers Tabatinga and Gangari. The rivers Boa Esperança and Utinga de Baixo form the river Tabatinga, which, as the rivers Pirajã and Bita, was in the past a contributor of the river Ipojuca, but, dammed and diverted, it now integrates the basin of the Massangana.

The rivers Boa Esperança and Utinga de Baixo show favourable conditions for damming at high elevations (70 m), between Engenho Tabatinga and Engenho Utinga de Baixo, and their origins are located in the directions and proximity of the rivers Pirapama and Ipojuca, respectively.

The hydrographic basin of these two interconnected sources is of about 16 km^2 at the widening downstream from Engenho Utinga de Baixo, which would be the equivalent to a regulated flow of about 16.000 m^3/day, induced from studies made in other areas; yet, the few discharge measurements taken so far in both these rivers lead us to much higher discharges, of over 30.000 m^3 per day.

The use of these two reivers as exclusive sources for the supply of the Suape Industrial Complex would demand that it should be complemented after a short time with water pumped from the Pirapama ou Ipojuca basins.

The rivers Pirajã and Bita are interconnected at present in a weir upstream from Engenho Pindorama. This weir could be improved, increasing the level of the water to elevation 45.

The hydrographic basin of theses two streams at the site of the dam is about 20 km^2 and could contribute with a flow of 36.000 m^3 per day.

Th river Bita originates near the river Ipojuca in such a position that it would be easy to receive a reinforcement a reinforcement from the waters of this river, either by direct pumping or by pumping and canal to the treatment station.

The reservoirs of the rivers Boa Esperança-Utinga de Baixo, with their water level at elevation 75 m could divert their water to the Pirajã stream by a spillway located upstream from Engenho Andarepe, supplementing, when necessary, the capacity of the rivers Pirajã-Bita reservoir, thus increasing the flow for the supply of the Suape Industrial Complex.

The diversion of these affluents is also intended to reduce the discharge of the Massangana river into the industrial area, improving the conditions of this river in time of floods.

4 RIVER IPOJUCA

This river is one of the largedt in the State, with a basin of 3.539 km^2 , besides being the longest. It springd between theSerra das Porteiras and the Serra das Guaibas at an altitude of approximately 800 m, having a length of 245 km and a form factor of 0,05. Once regulated, its discharge will be of about 1.000.000 m^3 per day. This river crosses the industrial area and flows into the port area, and it could be dammed up in favourable conditions at about 20 km from the consumption area. However, it can become a valuable source for the reinforcement of industrial use, once industries with a large consumption are establihed in the Suape, although the quality of its water shows seasonal variations.

Tle low, lagoonal areas of Suape and Merepe have so far acted as natural reservoirs as natural reservoirs for the floods of this river. With the increase in value created for the lands of the Suape land, a solution is imperative so that the flood discharges do not each this area.

These flows are the basis for the study of several solutions for the ironing out of the floods and diversions.

Whichever solution is adopted, it may improve greatly the reinforcement of the water supply, either by a transposition of basins from the river Ipojuca to the Rio Bita, or directly through the area that is crossed. The regulation of the river Ipojuca, together with the contention of the floods, has its effects on the protection of the port, at the time it is executed, havin as a by-product the reinforcement of the water supply.

UNDERGROUD WATER

The initial object of this study is to make an approximate estimate of the possibilities of exploiting the underground water resources in the area of the future Industril and Port Complex of Suape.

It merely represent a preliminary diagnosis of the hydric underground resources that are liable to be exploited, and more detailed studies will be necessary.

The underground waters of the tubular wells that already exist at the North of the Suape Complex show reasonable specific capacity.

Underground water was revealed by the preliminary hydrogeological studies, with the possibility of their exploitation through the use of Tubular Wells for a specific utilization in limited areas, or consumption emergencies.

The two wells already drilled in the cuty of Nossa Senhora do Ó, close to, and Sout of the Complex, produced 100 m^3/hour and 140 m^3/hour, at depths of 63 and 80 m. respectively, a static level of 8,30 m and 8.00 m and a dynamic level of 17,80 m and 18,30 m. The cost of the water produced by those wells was estimated at Cr$ 0,110 per m^3 (Price in April 1974).

North of the Complex, several wells were drilled in the industrial area of Jaboatão, along highway BR-101.

These wells are farther away from Suape and have a lower output than those of Nossa Senhora do Ó. Their depth varies between 80 m and 100 m, with a flow of 6 m^3/hour and 18 m^3/hour, the static level varying as much as 5 m in surge, and the dynamic level netween 2 m and 56 m.

In he neighbourhood of the city of Cabo (CERMIC factory), therefore close to the Suape Complex, a well was drilled to 150 m, with negative results, without the crystalline base having been reached. In the face of such factors, an investigation of the possibilities of the aquifer in the area under study must be undertaken, instead of generalizing the results obtained in other areas.

5.2.2 - Quality of the water

A campaign for the collection of water samples was undertaken in strategic sites, shown in the illustration (IV-2-43) close to the places of use or to the polluting centers, to obtain a better knowledge of the qualities of the water sources that are of interest to the Complex. Local, as well as seasonal factors, alter the quality of the water. However, analyses performed in 1967, 1968 and the beinning of 1974, in the rivers Pirapama and Ipojuca lead to believe that the waters from these sources will not present any major diificulties for their treatment, with physical, chemical and bacteriological characteristics acceptable by international standards (results attached). The high iron content of these bodies, and of sodium chloride in the river Ipojuca can probably be corrected.

The analysesperformed are shown in table IV-2-01, in the certificates of analyses Nº 30/74 t0 41/74, 68/74, 407/74 to 415/74, 448/74 to 456/74, 477/74 and bulletins 151/74 to 153/74.

The underground waters from the tubular wells that already esxisted North of the complex show physical and chemical qualities within potability standard. For the wells that are closer, located at the South, in the city of Nossa Senhora do Ó, thei protection must be provided before they are analysed, so that superficial waters do not interfere and lead to dubious results. In the area that is to be settled, the pioneer wells to be installed will give an opportunity to learn about the quality of the aquifers.

5.2.3 Medical and Sanitary Investigations of the Nearby Areas and the Areas that are to be Settled

Through the investigations made and the medical and sanitary research in the State of Pernambuco's Zona da Mata, a heavy incidence of intestinal parasites was noted, reflecting the sanitary conditions of the region that are the result of the social and economic level of its population.

The low sanitary leve, in itself, is a limiting factor of productivity, and, therefore of the work efficiency in this area. The studies concerning these aspects will also be considered as a protection of the investments to be made in the region of the Complex.

In the town of Escada, close to the Suape Complex, out of a total of 214 persons examined in 1971, only 3,7% showed negative results as regards helminths and protozoans. Among these parasitic infections, ancylostoma accounted for 69,6% and schistosomia for 32,8%.

In the town of São Lourenço da Mata, during the sa,e period, out of 556 persons examined, 4,5% showed negative results, while 57,9% were psoitive for ancylostoma and 59,2% were positive for schistosomia.

An investigation for the diagnosis of the medical and sanitary conditions will therefore be necessary in this area, to determine the infection rate of both humans and forest mammals, the existing sanitary facilities, the intermediate hosts, especially the type of mollusks that exist in the region, in order to take the necessary adequate measures for the controle of these parasitic illnesses, and, especially of schisomia.

As a preliminary measure, the persons affected will have to be conveniently treated, or withdrawn from the area, and a sorting out will have to be performed upon arrival for the recruiting of the new arrivals, eliminating those who are carriers, as well as the foci of contamination found in nature, thus breaking up the transmission chain.A survey of triatoma, responsible for the transmission of Chagas' disease was carried out in the towns of Cabo and Ipojuca, by SUCA (Superintendência da Campanha), with a total inspection of all the houses included in both the city and rural zones, no carrying species having been found.

Malaria, which took a heavy toll in such damp regionsno longer exists in the cities of Cabo and Ipojuca. SUCAM indicates that the latest reported case of malaria was in 1969, and the patient, who came from the State of Maranhão was immediately submitted to a specific treatment.

5.2.4 Continuation of Hydrogeological Studies

A continuation of more detailed studies is recommended, in order to obtain a better definition of the Cabo Formation aquifer, that shows possibilities as an eventual supplier of future communities for the residence of workmen or light industries with a low water consumption at points where this source could be exploited. It is also necessary to mention that the use of wells may be a solution to water supply at the beginning of the future works of the Complex.

As a guide for a works program intended for the definition of the underground hydric sources available, and of the most convenient system for its utilization under an economic point of view, the following is recommended:

a) the definition, from the litho-stratigraphic aspect of the spatial behaviour of the identified auiferous unit (variation in "facies, higher frequency of psammites and psaphites, confining units) and their relationship to other geological elements of the region: intrusions, faults, geological sequence etc.

b) Determination of the hydrogeological behaviour (flows, gradients) and it relationship to the other hydrogeological units (drainage, confinements etc.).

c) determination of the average parameters that characterize the aquifer (T, S and K) and the chemical behaviour of the water.

d) from the above elements, define the optimum exploitation flow and the distance between wells, so that great interferences between wells can be avoided.

e) define as well the most recommendable areas and systems for exploitation, under every respect.

The items recommended above represents the minimum of what has to be done so as to have satidfactory technical information on which an opinion can be based, concerning the level of water supply that the aquifer of the Cabo Formation can provide for the Suape Industrial Complex.

5.2.5 Continuation of the Hydrometric Campaign

The hydrometric campaign which was undertaken by Transcom is developing normally, with intensive measurements of the discharges in 14 fluviometric stations installed on the rivers Ipojuca, Pirapama, Massangana and on the main affluents of the last two, as well as observations at 6 pluviometric stsaions, one pluviometric station (engenho Matas) and a limnographic station (Engenho Matapagipe).

There is no doubt that the registrations of this campaign are reaching results that are far more comprehensive than would be the mere knowledge of the surface water resources that interest the Port and Industrial Complex of Suape. Actually, the results of the studies which are being made can be extrapolated for all the so called "Zona da Mata" of Pernambuco.

Organs like COMPESA, DNOS and others, either public or private, used empirical formulae imported from other regions, for lack of regional data, whenever they had to dimension hydraulic undertakings, and the results were not always satisfactory.

It should be mentioned that in other States, like São Paulo, Minas Gerais, Rio Grande do Sul etc., the governments keep up systematic observations of hydrometric data, for better knowlege and rationalization of their hydric resources.

Therefore, the continuation of the present campaign is recommended, and it will be maintained at least until the month of September of the coming year, when one more hydrological year will be completed in the region (October to September).

5.3 HYDROGRAPHIC MAPPING

Below are shown the characteristic elements of the hydrologic conditions, of the soils, of the vegetal and hydrological surveys of the area that interests the Complex, in order to identify the supply sources and the hydric potentials, and besides to subsidize the projects for longitudinal and transverse draining of the roads, city planning and the zones that may be built.

The mapping consists of the representation through cartograms of informations relative to climatology, pluviometry, soil characteristics, vegetal and hydrolgological surveys that speak for themselves and need no comments.

5.3.1 CLIMATOLOGIC AND PLUVIOMETRIC MAPPING

The climatologic and pluviometric mapping was intended for the supply of data for use in the various sectors of applied hydrology involved in the project whether in the study of resevoirs, or in the dimensioning of drainage works in streets, highways or railroads.

The report on hydrological studies, presented in chapter 4, gives sufficient details about this topic, regarding the survey of available data, the complementation and operation of stations, data analysis, methodology and criticism of the results.

These results are presented in the guise of maps and illustrations that stress:

- The site of pluviometric and fluviometric ststions used;

- the observation period for each pluviometric station, noting that for most stations only data for the 1963-1971 period are available;

- the accumulated differential curves for the pluviometric stations of Escada and Vitória de Santo Antão, for which data are available covering the period from 1920 to 1971;

- the period of availability of pluviometric data from the Primavera station, on the river Ipojuca, the Engenho Bela Rosa, on the river Tapacura, and Engenho Sítio on the river Coitá, and the period of availability of evaporimetric and thermometric data of the stations of Curado, in Recife and Engenho Tabocas, in Primavera, Ipojuca Basin;

- the longitudinal profiles of the rivers Ipojuca and Pirapama, with extensions of 245 km and 63 km, where average slopes of 0,0033 m/m and 0,0117 m/m respectively are observed;

- the behaviour of pluviometric data before and after homogeneiation;

- the histograms for average monthly rains referring to the stations located in the Ipojuca basin;

- the average monthly isohyets, noting that the highest average pluviometric precipitations occur in the Primavera region, in the Ipojuca basin;

- the average annual isohyets;

- the isolines of average temperatures, average minima and average maxima, the annual averages of relative humidity and the annual evaporation averages;

- the areas of influence of every pluviometric station, determined by the Thiessen process.

- the fluctuations of the average monthly rains in the basins of the Ipojuca and Pirapama.

5.3.2 MAPPING OF THE SOIL CHARACTERISTICS AND OF THE VEGETAL COVERING.

The mapping of the characteristics of the soils and the vegetal covering was aimed primarily ar rhe determination of the flow coefficient to be used in the drainage works. The methodolgy used was that of the Hydrolgy Guide for Use in Watershed Planning, of the National Engineering Handbook, Section 4, Hydrology Supplement A, VS Department of Agriculture, Soil Conservation Service (Illustrations 5.2 and 5.3).

The maps were obtained from both field and office studies, through intensive studies of photo-interpretation and local information, or photo-ground correlations. Over 130 stereographic pairs were examined, 1.120 km were covered in the field, more than 285 boreholes were drilled and an approximate area of over 1.200 km^2 was mapped.

The photographs that were examined, to the scale of 1:30.000 were take by the photogrammetric squadron of the FAB (Brazilian Air Force) on normal panchromatic film, at the beginning of 1970.

After a preliminary examination of the photographs, field trips were undertaken, correlating the photo-ground standards, examining the vegetation to check present conditions (1974), determining the superficial structures by boring and by touch, and establishing a preliminary mapping legend.

Subsequently, the final photo-interpretation zas carried out with the reduction of the overlaps and the transposition of satins to a map to the scale of 1:100.000, and the final legends wereprepared with the soil characteristics and those of the vegetal covering as shown on the maps.

5.3.3 DRAINAGE CURVES

The maps provide the necessary elements for the use of the following table, where the "numbers of the CN curve" are determined for each hydrological soil-vegetation combination; should several combinations occur in the contributing basin, the final "CN" will be the weighted average of the partial "CN" 's

After the detemination of the final "CN", the curve makes possible the finding, on the basis of the parameters, Actual Rain and the number of the curve, the Effective Rain, that is the part that will drain.

The "CN's" of the graph correspond to data from previous rainfalls (during the 5 preceding days) included within the limits of 35 mm to 53 mm, at the stage of growing vegetation.

The data provided by the Escada station, during a period of observation of 53 years show, as an average of the previous rains in this period, 33 mm (very close to the lower limit of the condition shown on the graph).

MISCELLANEOUS SOIL-VEGETATION HYDROLOGICAL COMBINATIONS
NUMBERS OF THE FLOW CURVES

Use of the Soil and Covering	Treatment and Method	Conditions for Infiltration	Hydrologic group of the soil			
			A	B	C	D
1) Naked or undisturbed Soil	SR		77	86	91	94
2) Cultivation in Rows	SR	Bad	72	81	88	91
	SR	Good	67	78	85	89
	C	Bad	70	79	84	88
	C	Good	65	75	82	86
	C&T	Bad	66	74	80	82
	C&T	Good	62	71	78	81
3) Small cereals	SR	Bad	65	76	84	88
	SR	Good	63	75	83	87
	C	Bad	63	74	82	85
	C	Good	61	73	81	84
	C&T	Bad	61	72	79	82
	C&T	Good	59	70	78	81
4) Vegetables or Pasture in rotation	SR	Bad	66	77	85	89
	SR	Good	58	72	81	85
	C	Bad	64	75	83	85
	C	Good	55	69	78	83
	C&T	Bad	63	73	80	83
	C&T	Good	51	67	76	80
5) Pasture or dense grass		Bad	68	79	86	89
		Regular	49	69	79	84
		Good	39	61	74	80
	C	Bad	47	67	81	88
	C	Regular	25	59	75	83
	C	Good	6	35	70	79
6) Low Pasture		Normal	30	58	71	78
7) Woods (Isolated Thickets)		Bad	45	66	77	83
		Regular	36	60	73	79
		Bad	25	55	70	77
8) Bare and worn out earth			59	74	82	86
9) Roads			72	82	87	89
			74	34	90	92

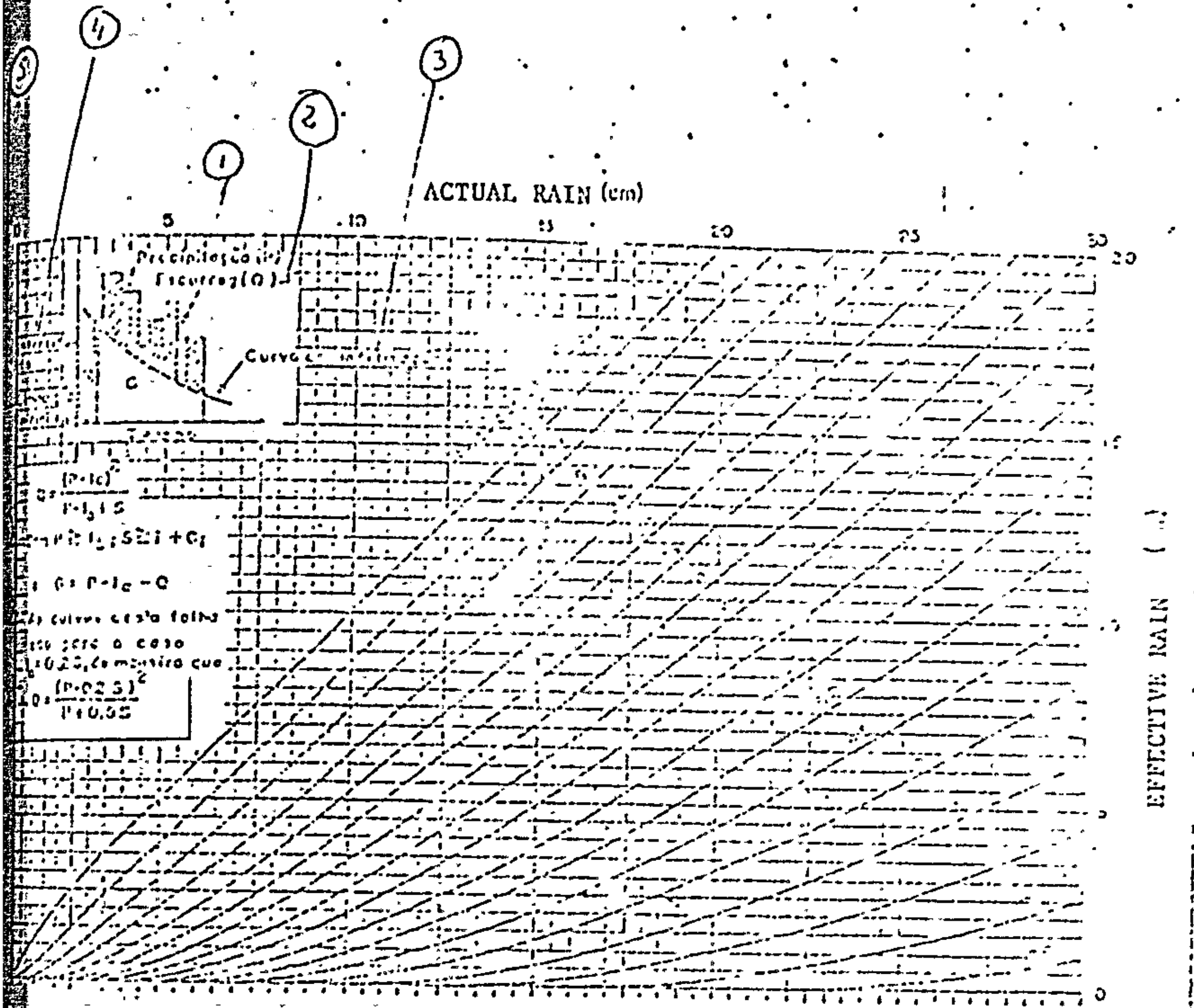
SOURCE: U.S. Soil Conservation Service

SR = Straight Rows

T = Terracing

C = By Contour Curves

C & T = Contour and Terracing



- Precipitation
- Flow
- Infiltration curve
- Intensity
- Initial Reduction
- With
- The curves on this sheet are for
- So that

diper

RAIN CURVE

5.4 STUDIES OF SUPERFICIAL HYDROLOGY

5.4.1 EXISTING DATA

Very few hydrological data have been directly observed in the basins that interest the projects for the Industrial and Port Complex of Suape. Only very few station have data gathered over a long observation period, and even that information is insufficient to characterize the average monthly and annual rains in the basins.

Therefore, all data that could in any way contribute toward the studies were taken into consideration.

The data thus compiled were submitted to several degrees of analysis, and only those that were used are being presented.

The hydrological data used were obtained form the Hydrology Division of SUDENE.

The illustrative map 5.IV shows the location of the pluviometric and fluviometric stations.

A PLUVIOMETRIC DATA

Considering the need to establish a relationship between the rains and the defluents, a survey was made of existing pluviometric data, and it was noted that, though desirable, the series for long periods only existed for a number of stations that was insufficient to charcaterize the actual conditions of the distribution of rainfalls over the basins.

As can be seen in illustration 5.V, most of the stations only have data for the 1963-1971 period.

An attempt was then made to investigate the series that corresponded to this period, in order to verify whetherthey represented reasonably critical conditions for the utilizations of the hydric resources of the basins. For this purpose, graphs were drawn of the accumulated differential curves of the pluviometric stations of Escada and Vitória de Santo Antão, shown in illustrations 5.VI and 5.VII, for which are available data over a longer period of observation.

Taking into consideration the fact that these stations should represent the global tendencies of rainfalls over the basins, the period from 1963 to 1973 can be considered quite critical from the point of view of the incidence of rainfalls, and, consequently of the production of defluents. Therefore, the pluviometric series covered by the hydrological years (October/September) 1962/63 to 1971/72 were adopted.

The stations considered for the determination of the average rainfalls are the ones below:

Cabo	Ipojuca
Escada	Primavera
Amaraji	Vitória de Santo Antão
Barra de Guabiraba	Gravatá
São Joaquim do Monte	Bezerros
Barriguda	São Caetano
Cachoeirinha	Tacaimbó
Belo Jardim	Sapo Queimado
Sanharó	Salobro
Poção	Alagoinha
Cimbres	Arcoverde
São Sebastião do Umbuzeiro	Henrique Dias

B FLUVIOMETRIC DATA

Within the basins under study, there is only one station on the Ipojuca, in Primavera with sufficient data for the determination of correlations rainfalls - defluents. In the Pirapama basin, no fluviometric station existed.

The Consultant installed a fluviometric station in the vivinity of Engenho Matapagipe, and on the river Manoel Gonçalves (Rua D'Agua), reactivated one station installed by SUDENE in 1971 at Engenho Maranhão (river Ipojuca) that was inoperative; and another two on the Boa Esperança stream and on the river Utinga de Baixo.

For purposes of correlation researches with the basins of the area, the fluviometric data of the stations of Bela Rosa, on the river Tapacurá, and Engenho Sítio on the river Hoitã were also considered.

Illustration 5.VIII shows the period for which data are available ine the three above-mentioned stations, and the tables 5/1, 5/2 and 5/3 show the average monthly and annual defluents.

C EVAPORIMETRIC AND THERMOMETRIC DATA

The existing data were compiled from the available information from the evaporimetric stations of Curado, in Recife, and Engenho Tabocas, in Primavera. The periods of availability for these data is shown in illustration 5.V, and its monthly and annual values are shown in tables 5/4, 5/5 and 5/6.

D MAPPING DATA

For the determination of the drainage areas, in the sections studied and in the preparation of isoyet maps and those of the areas of influence of the pluviometric stations over the basins, the maps used were the IBGE to the scale of 1:250.000 and the SGE to the scale of 1:25.000.

5.4.2 CHARACTERISTICS OF THE LARGEST BASINS

The largest basins in the area are those of the rivers Ipojuca and Pirapama.

The Ipojuca basin originates between the Serra das Porteiras and the

Serra das Guaribas, in the county of Arcoverde-PE, at an approximate altitude of 800 m, and that of the Pirapama in Chão dos Pintos, in the vicinity of the village of Serra Grande, at an altitude of about 500 m.

Their areas are respectively 3.603 km^2 upstream from the city of Ipojuca, and 347 km^2 upstream from the site of the dam of Matapagipe.

Both rivers flow in a West-East direction, the Ipojuca having a total length of 245 km and the Pirapama, of 63 km.

Their average slopes are 0.oo33 m/m for the Ipojuca, and 0.0117 m/m for the Pirapama. Illustrations 5.IX and 5.X show, respectively, the lingitudinal profiles of the rivers Ipojuca and Pirapama.

The Ipojuca basin is characterized by the predominance of length over width, showing a form factor of 0.05, while the Pirapama basin, although also elongated, shows a much higher factor, that is 0.09.

5.4.3 CLIMATE

The Pirapama basin, the smaller basins studied and the lower part of the Ipojuca basin are located in the Pernambucan Zona da Mata, where the climate is considered warm-humid, with an annual average temperature of 23ºC and an annual average relative humidity of 83%. The upper part of the Ipojuca basin lies in the Zona do Agreste, where the climate is classified as smi-arid, with an annual average temperature of 27ºC and an annual average relative humidity of 75%.

The average annual rainfall for the larger basins is 1469 mm, for the Pirapama, adn 882mm for the Ipojuca basin. As shown in illustrations 5.XVIII and 5.XXX of the isoyets network, the rainfalls in the Ipojuca basin generally decreas as they get farther from the littoral, and as a result the general average is much lower than that of the

Pirapama and of the other smaller basins, although the highest pluviometric indices in the State occur in the lower part of the basin of the Ipojuca.

Illustrations 5.XXXI to 5.XXXV show the isolines of avarage temperatures, average minimums and average maximums, annually, the average annual relative humidity and the annual average evaporation for the region under study.

The data used for the preapration of the above-mentioned isoline maps were taken from "Normas Climatológicas da Área da SUDENE", detrmined as the result of an agreement between SUDENE and the Ministry of Agriculture.

The correlation between the monthly evaporation, the monthly rainfall and the average temperature of the month, prepared by the Olinda station and representative of the coastal zone, and by the Nazaré da mata station, representative of the Penambucan Mata, shown in illustrations 5.XXXIX and 5.XL respectively, show a high degree of correlation (correlation coefficient of 0,96), from which it can be inferred that, for every homogeneous zone, the data provided by a single evaporimetric station and by various stations equipped only with a pluviometer make it possible to deduce with a reasonable degree of certainty the monthly evaporation for each of those pluvio-themometric station.

5.4.4 RATE OF RAINFALL

CHECKING AND ADJUSTMENT OF DATA

The gaps in the pluviometric data for the period considered were filled and were submitted to a homogeneity check before being used for this study.

For the homogeneity check, the process of accumulative lines was used.

Illustrations 5.XI and 5.XVI show, respectively, the behaviour of the data before and after homogeneization, and tables 5.VIII to 5.XXXII show the value of these data after they have been adjusted.

ANNUAL DISTRIBUTION OF RAINFALLS

Illustration 5.XVII shows the average monthly distribution of rainfalls at the stations considered for the period between October 1962 and September 1971.

This illustration shows that the average patterns of annual distribution of the rainfalls are quite different.

GEOGRAPHICAL DISTRIBUTION OF RAINFALLS

Illustrations 5.XVIII to 5.XXX show the geographical distribution of the average monthly and annual rainfalls in the basins of the area for the period considered.

These illustrations show that the average monthly and annual values diminish as one gets farther from the coast.

AVERAGE ANNUAL RAINFALLS

The average annual rainfalls were determined by the Thiessen process.

Illustration 5.XXXVI shows the area of influence of each station and tables 5 XXXIII and 5.XXXIV show the annual and monthly rainfalls on the larger basins and their average monthly and annual values.

FLUCTUATION OF RAINFALLS

Illustrations 5.XXXVII and 5.XXXVIII show the fluctuation of the average monthly rainfalls on the larger basins of the Ipojuca and

Pirapama, upstream respectively of the city of Ipojuca and the Matapagipe dam.

FREQUENCY AND DURATION.

Studies for the forecast of rainfalls of one day's duration were made, with the use of various statistical methods, for the Escada station where the statistical series for the rains over 53 years are available, and which is a representative station of the area.

The following table sums up the results that were obtained:

TIME OF RECURRENCE YEARS	STATISTICAL METHODS			
	Hazen (1930)	Pearson III (1967)	Gumbel (1958)	Chow (1964)
5	106	102	107	106
20	145	149	153	145
100	186	202	204	183
1000	241	274	277	235
10000	297	344	349	265

Note: Height of rainfall in millimeters for one day's duration

Of the four methods used, Gumbel's method was adopted, considering the good correlation of the actual data with the line of external probability of Gumbel, as shown in illustration 5.XLI.

In illustration 5.XLII of the project rainfalls, the lines of height of the rainfall were considered as HERSHFIELD and WILSON's probability, in relation to duration, for the various times of recurrence, with the data provided by Gumbel's series and the characteristics of the zone for the duration of one hour, and also for 6 minutes (1/10 hour).

5.4.5 FLUVIAL REGIMEN

The data that are being gathered in the stations installed and operated by the Consultant, and the use of the readings of water level measurements made at a station operated by SUDENE on the river Tabatinga make it possible to characterize with some accuracy the fluvisl regimen of the basins that interest the Suape project, excepting the river Ipojuca that, due to its size,its shape, and to the diversity of the climates of the physiographic regions it crosses, cannot be compared to the other basins of the region. However, for the river Ipojuca, observations carried out by SUDENE and the Consultant make it possible to reach a few conclusions about its regimen.

The studies that are under way, both in the field and in the office, aim at establishing, with a higher grade of certainty, the following characteristic elements of the basins:

- efficiency
- basic flow
- project flood

The elements presented in the nest sub-sections represent estimates made with the closest approximation allowed by the available data.

The results contained in those sub-sections are being adjusted as new data of the hydrometric campaign are studied and analysed.

A EFFICIENCY OF THE HYDROGRAPHIC BASINS

The results obtained through the data available at present show that the small basins of the Zona da Mata have an average efficiency that varies between 35 and 45%, for average rainfalls of 1.800 to 2.200 mm per year.

For basins with average rainfalls of 1.400 to 1.800 mm/year, the efficiency varies between 25 and 35%.

Finally, for the middle and upper Ipojuca (Zona do Agreste), where the average rainfall is between 600 and 1.000 mm, the efficiency varies between 10 and 15%.

B BASIC FLOW

The driest period in the region occurs in January and February and, therefore, only during that phase can the basic discharges for the year be known.

With this object in viez, systematic measurements are being made, in order to follow the variations in discharges from the period of rains until the basic flow is reached, during the various months of the dry season.

Theknowledge of the basic flow is extremely important for the best use of surface water, especially in the definition of the modular utilizations.

Preliminary calculations indicate the following values for the basic flow of the rivers Ipojuca, Pirapama and Massangana:

Ipojuca (engenho Tabocas)	1,5 m^3/s
- Ipojuca (Engenho Maranhão)	3.0 m^3/s
- Pirapama (Engenho Matapagipe).	2,0 m^3/s
- Massangana (Engenho Tabatinga)	o,3 m^3/s

C PROJECT FLOODS

The project floods were calculated by the triangular hydrogram synthetic method, for periods of recurrence of 100 years, and shows the following values:

River Pirapama (Engenho Matapagipe)	
River Ipojuca (Engenho Tabocas)	800 m^3/s
River Ipojuca (Engenho Maranhão)	1.100 m^3/s
River Bita (Dam site)	240 m^3/s
River Utinga de Baixo (Dam Site)	86 m^3/s
River Algodoais (at projected railroad)	100 m^3/s
River Jasmim (at projected railroad)	40 m^3/s
River Prego (at projected railroad)	85 m^3/s
River Massangana (area included between Utinga dam and the projected railroad	150 m^3/s

5.5 HIDROMETRIC STUDIES

In order to carry out the survey of the hydric resources for the supply of the Suape Industrial Complex, TRANSCON maintains permanently in the region a team of four hydrometrits, under the orientation of a hydrological engineer. This team has the following equipment:

1 Adequate aluminium boat
1 Outboard Motor
2 Reels
2 Measuring winches - on board
2 Phones
2 Rods for measurement of fords
1 Calculator
4 Levels
1 Staff

Besides this equipment, the team also have at their disposal a Jeep, adapted for carryng the boat and miscellaneous equipment.

Illustration 5.XLIV shows on the map of the region the extension of the hydrometric network operated by TRANSCON.

5.5.1 PLUVIOMETRY

TRANSCON installed and operates in the basin of the river Pirapama 6 "Ville de Paris" type stainless steel pluviometers (one already existed in the basin) and one IH pluviograph.

The pluviometers are mounted on sucupira wood rafters, in order to make possible a perfect levelling ov the openings, which stand 1,50 m above the ground. Each pluviometric station fas two measuring glasses, graduated in millimeters, on of 25 mm and the other 7 mm.

These pluviometric stations were installed at predetermined sites, so that each can represent the precipitations of every 60 km of the basin.

In each of these stations, TRANSCON has an operator to take the daily readings. These observers are inspected every fortnight.

Table 5.XXXV shows a synopsis of the installation data of the pluviometric stations operated by TRANSCOM.

5.5.2 FLUVIOMETRY

The fluviometric studies were started in the basin of the river Pirapama, wit the installation of two fluviometric stations: one, on the main river and the other on its affluent, called Manoel Gonçalves Stream. These stations were given the names of the site on which they stand, that are, respectively:

Nº1 Engenho Matagipe (Pirapama) Fluviometric Station
Nº2 Rua D'Água (Manoel Gonçalves Fluviometric Station

A FEATURES OF THE ENGENHO MATAGIPE STATION - F.1

The installation of this station was completed by TRANSCON on January 1, 1974. It is located on the west bank of the river Pirapama and drains an area of 347 km^2. The installations include:

- Section for measurement from the ground
- Section for measurements from a boat
- IH Limnograph
- Limnometric station
- Level reference

In the section for the measurements from a boat, pieces of sucupira wood were anchored in concrete bases, at a distance from each bank, to which is fixed a 1/4" steel cable, 100 m long, which is also tied to the boat.

The limnograph is 6 meters from the level of low waters, and it was necessary to move 40 m^3 of earth for its installation.

The limnometric section consist of staggered rows of adequate rods, graduated centimeter by centimeter, attached to wooden props, with the following distribution:

1st. row	- readings from	0 to 100 cm
2nd row	- readings from	100 to 200 cm
3rd row	- readings from	200 to 300 cm
4th row	- readings from	300 to 400 cm
5th row	- readings from	400 to 500 cm.

For control of the altimetric position,a level refernce was installed, and it was determined in relation to the zero of the rod, the elevation of which is 6.079 m.

B FEATURES OF THE RUA D'ÁGUA STATION - F.2

The Rua d'Água station was installed by TRANSCON on February 16, 1974. It is located under the wooden bridge that stand close to the hamlet that bears the same name. It corresponds to a drained area of 57,69 km^2 of the hydrographic basin of the Manoel Gonçalves Stream. The installations include:

- Section for measurement from the ground
- Section for measurement from the bridge
- Limnometric section
- Level reference.

The measuring sections are 50 m away from each other and the banks were cleared of all the waterside vegetation at the time of the installation.

The limnometric station has staggered rows of graduated rods, graduated centimeter by centimeter:

1st row - Readings from 100 to 200 cm

2nd row - readings from 200 to 300 cm
3rd row - readings from 400 to 500 cm

The control of the altimetric position is m. le through a level reference established in relation to the rods, the eleveation of which is 6.254 m.

C FEATURES OF ENGENHO MARANHÃO STATION

In the Ipojuca basin, TRANSCON uses a fluviometric station installed by SUDENE in 1971, to complement previous observations.

This station is located at Engenho Maranhão, and drains an area of 3.195 km^2.

Transcon rigged up a 1/4" steel cable, 120 m long, joining both banks, to make possible measurements from a boat.

This station was reactivated by TRANSCON on February 22, 1974

D FLUVIOMETRIC STATION F.4 - BOA ESPERANÇA STREAM (UPSTREAM)

Features of the fluvial basin

The Boa Esperança stream is, together with river Utinga de Baixo, the originator of the river Tabatinga, that, in its turn, takes the name of Massangana after crossin the ranch of the same name. Its drainage area, upstream from the station is 1,8 km^2, according to a planimetry based on the 1:25.000 map prepared by SUDENE. It should be mentioned that on the above-mentioned map, the Boa Esperança stream is shown under the name of Utinga de Baixo, while it is actually the river that passes close to the Engenho Utinga de Baixo that it is known under that name.

Features of the Station

The Station was installed by TRANSCOM, for the account of DIPER, on

June 2, 1974, and includes a limnometric section and a measuring section.

Situation of the Limnometric Station

The Limnometric Section, located on the left bank, is formed by 2 rows of wooden measuring rods, 1 meter each, graduated centimeter by centimeter, attached to wooden props.

Level Reference

For the control of the altimetric position of the rows, a level reference was establishe, the elevation of which was determined in relation to the zero of the rods.

E .PLUVIOMETRIC STATION F.5 - BOA ESPERANÇA STREAM (DOWNSTREAM)

Features of the Fluvia Basin

The fluvial basin of this station is the same as that of station F.4 and its drainage area, upstream from the stationis of 5,5 km^2, according to a planimetry based on the 1:25.000 map prepared by SUDENE.

Features of the Station

The station was installed by TRANSCON, in the service of DIPER, on May, 26, 1974, and includes a limnometric section and a measuring section.

Situation of the Limnometric Station

The limnometricststion is located on the left bank and includes 2 rows of wooden rods, one meter each, graduated centimeter by centimeter, attached to wooden props.

Level Reference

For the control of the altimetric position of the rod, a level reference was determined, the elevation of which refers to the zero of the rods.

F FLUVIOMETRIC STATION F.6 - RIVER UTINGA DE BAIXO AT ENGENHO UTINGA DE BAIXO

Features of the Fluvial Basin

The river Utinga de Baixo, as was mentioned in the description of the fluvial basin of station F.4, is one of the originators of the river Tabatinga. This river flos close to Engenho Utinga de Baixo, and, for this reason, it is known in the region uder the same name, although this name does not show on the 1:25.000 map prepared by SUDENE. Its drainage area, upstream from the station is 13.0 km^2, according to a planimetry based on the above-mentioned map.

Features of thb Station

The station was installed by TRANSCOM, in the service of DIPER, on May 26, 1974, and includes a limnometric section and a measuring section.

Situation of the Limnometric Section

The Limnometric section is located on the right bank, and includes 3 rows of wodden rods, one meter high each, graduated centimeter by centimeter, and attached to wooden props.

Level reference

For the altimetric control of rows, a level refernce was established, the elevation of which was determined in relation to the zero of the rods

G FLUVIOMETRIC STATION F.7 - RIVER UTINGA DE BAIXO AT ENGENHO TABATINGA

Features of the Fluvial Basin

The river Utinga, at the site of this station, drains a 15.7 km^2 area.

Features of the Station

The station was installed by TRANSCON, in the sevice of DIPER, on May 25, 1974, and includes one limnometric section and a measuring station.

Situation of the Station

The limnometric station is located on the right bank, and includes two rows of wooden measuring rods, one meter each, graduated centimeter by centimeter, attached to wooden props.

Level reference

A level reference was established for altimetric control, the levation of which was determined in relation to the zero of the rods.

H OTHER STATIONS CONSIDERED

The data of the fluviometric station of Engenho Tabocas, on the river Ipojuca were also included in this report, since they are of grat interest for the hydrological sudies of this vale. This station is maintained and operated by SUDENE.

The data from the Station of Engenho Maranhão corresponding to the period during which it was maintained and operated by SUDENE were also included.

Table 5.36 sums up the general feature of each station.

5.5.3

PRESENTATION OF THE RESULTS

A PLUVIOMETRIC DATA

Appendix A shows the daily data for the operating pluviometric stations.

5.5.4 LIMNOMETRIC DATA

Appendix B shows the daily limnometric readings of the operating fluviometric stations.

5.5.5 DISCHARGE MEASUREMENTS

The discharge measurements and calculations made amounted to 164, distributed as follows:

F-1 – Matapagipe Station	61
F-2 – Rua D'Água Station	48
F-3 – Engenho Maranhão Station	15
F-4 – Boa Esperança Station (upstream)	10
F-5 – Boa Esperança Station (Downstream)	6
F-6 – Utinga de Baixo Station Station (upstream) at Utinga de Baixo Engenho	14
F-7 – Utinga de Baixo Station (downstream) at Engenho Tabatinga.	10

The summing up of the measurements are presented in Appendix B of this report (Tables 5/176 to 5/188)

5.5.6 ANALYSIS OF THE OBSERVED DATA

Calibration curves

On the basis of the measurements effected to date, it has been possible to establish the elevation-discharge curves for the operating fluviometric stations, except the two stations of the Boa Esperança stream, installed more recently, and where the measurements carried out so far are not sufficient to define those curves. Illustrations 5 XLV to 5VLIX show the curves that were drawn and the average daily and monthly discharges of the above-mentioned stations and those of Engenho Tabocas, maintained and operated by SUDENE, as mentioned previously in another part of this report.

Considering tha small number of measurements of the discharges used in the tracing of the calibration curves of the Rio Utinga de Biaxo stations, the data shown in this report may undergo certain alteration when, as measurements continue, the calibration curves are better defined.

Limnograms

Illustratios 5.L to 5.XXXII show the limnogram traced on the basis of the plotting of daily readings of the operating fluviometric stations. The limnogram furnished by the Matapagipe station are being used for the determination of the discharges in the project for the Matapagipe dam.

5.6 HYDROGEOLOGICAL STUDIES

5.6.1 METHODOLOGY

The study included a stage of field work (preceded by an interpretation of photographs of the area), followed by laboratory work (chemical analysis of the water), and office work (interpretation of the results).

While work proceeded in the field, consideration was given yo the precariousness of information and data about the deeper geological formations in the area. Actually, only two of the wells that were surveyed had a depth of between 60 and 80 meters (this, incidentally, not representing the maximum thickness of the sediments), while the others were less than 10 meters deep.

Thus, after the survey of the water points - the hydric inventory of the region - the well that showed the best constructive features was chosen for a pumping trial.

5.6.2 PHYSIOGRAPHIC ASPECTS

A CLIMATE

The area studied is characterized by a regimen of rainfalls that is rather intensive - 1500 to 2000 mm/year - distributed practically over all the months of the year, with a predominance in the period from March to August. Th temperatures are generally high, with an annual average of 23ºC, and maximum and minimum annual averages of 24ºC and 22ºC respectively.

The relative humidity is also high, the annual average being in excess of 80%. The prevailing winds are from the South-East, with East-North-East variations, constituents of the Equtorial Atlantic front.

Evapotranspiration has not been calculated as yet for the area under study, but, considering the similarity as far as other characteristics are concerned with those of the city of Recife, approximate values of 1700 mm and 1100 mm should be expected for the actual and potential evapotranspiration (annual average), respectively.

The type of climate that shows the characteristics mentioned is Koeppen's As, that is, tropical humid. In Gaussen's bioclimatic classification, the sub-dry Mediterranean or Northeastern could be established, with a variation toward Equatorial to the South of the area, with a xerothermic index between 0 and 40. Finally, in Martonne's classification, the area fits in the aridity indices 40 to 50.

B HYDROGRAPHY

The principal river in the region studied os the Ipojuca, with an extensive hydrographic basin, originating in the county of Belo Jardim in the interior of the State, and having an extension of almost 250 km. Other small rivers and streams drain the region, but have very limited extensions. Among them is the river Massangana.

The lower course is the part that characterizes the hydrographic network, with permanent regimen, and high lateral erosion, causing the formation of wandering meanders that make the river bed wind its way through the alluvial plain.

The network is irregular and dendritic, presenting a general alignment that follows the E-W direction.

C MORPHOLOGY

Morphologically, fundamental difference occur following the E-W direction, that is from the coast towards the interior, and also along the coast, following the approximate direction N-S.

Three planes of different altitudes exist in the E-W profile, the highest being represented by the little modulated pre-cambrian surface, with elevations varyying between 100 and 140 m. A zone of scattered hills from the base, crystalline, follow, that are in an advanced dtage of dessication, with elevations varying between 40 and 60 m. Also included in this mrophological aspect are depoists from the Cabo formation, and, at an almost identical elevation, but under the guise of mesas instead of hills, appear the deposits of the Barreiras Group. Finally, we have the low plains, represented by the alluvional, colluvional, eolian and maritime deposits, with a maximum elevation of 5 m.

In the N-S direction, we have two exyensive coastal plains: the first, outside the limits of this study, to the North, originates in Prazeres and extending as far as Camaçari, and the second is limited to the North by Cabo de Santo Agostinho, extending to the South further than the limit of the area - Suape-Nossa Senhora do Õ plain. These two plains are separated by a strip with a greater intensity of intrusive rocks that reached high elevations and culminated with the granite of Cabo Santo Agostinho.

D VEGETATION

In the region that was formerly covered by a dense tropical forest - Mata Atlântica - only a few residual spots are left of this vegetation, in the highest regions, in places not touched as yet by economic exploitation, with a dominance of semiperemnifolian species.

It should also be noted that this forest was destroyed to give place to the cultivation of sugar-cane, that is well developed in the whole area.

In the lower lands, exposed to the influence of the tides, the typical marshland vegetation grows on a large scale.

5.6.3 GEOLOGY OF THE AREA

The studies about the geology of the region were begun by Branner (19o2), Morais (1928 and Kleidler (1949), but the first geological mapping was undertaken by Cobra R. Q. in 1959, published in Bulletin Nº 142 of the D.N.P.M. in 1967. In 1968, Costa W.D., Coutinho P.N. and Rebouças A.C. carried out for SUDENE and D.S.E. (the State's Sanitation Department) a geological and hydrogeologica study of all the metropolitan area of Recife, including the towns of Cabo and Jaboatão to the South. In 1968, Seniors of the Geology course of the Federal University of Recife (Maciel, Cantarelli, Cotrim, Braga, Crasto and Pedrosa Junior) made detailed studies in sedimentology, petrography, and geophysics in part of that coastal area.

With theses studies as a basis, ebsides personal work, Professors Mello A.A. and Siqueira L.P. of the Insituto de Geociências of the FEderal University of Pernambuco made the "Geological Survey of the Coastal Strip South of Pernambuco" (Levantamento Geológico da Faixa Costeira Sul de Pernambuco", in 1972, as yet unpublished.

A LITHO-STRATIGRAPHIC UNITS

The coastal strip at the South of Pernambuco is marked by the presence of crystalline, crystallophylian and sedimentary rocks chronolitho-stratigraphically distributed according to the following table:

AGE		GROUP	FORMATION	LITHOLOGY
QUARTERNARY	Holo	discrepany		Alluvions and dunes
	Pleist	BARREIRAS	Potengi Macaiba R. Morno Guararapes	Sandy-clay sediments
TERTIARY	Plioc.			
	Miocen			
CRETACEOUS		discrepancy		AGGLOMERATE RHYOLITE TRACHYTE BASALT and ANDESITE CABO GRANITE W/O AG
				CALCAREOUS ROCK
			CABO	CONGLOMERATE and ARKOSIC
PRE-CAMBRIAN		discrepancy		Granites, Migmatites and gneisses

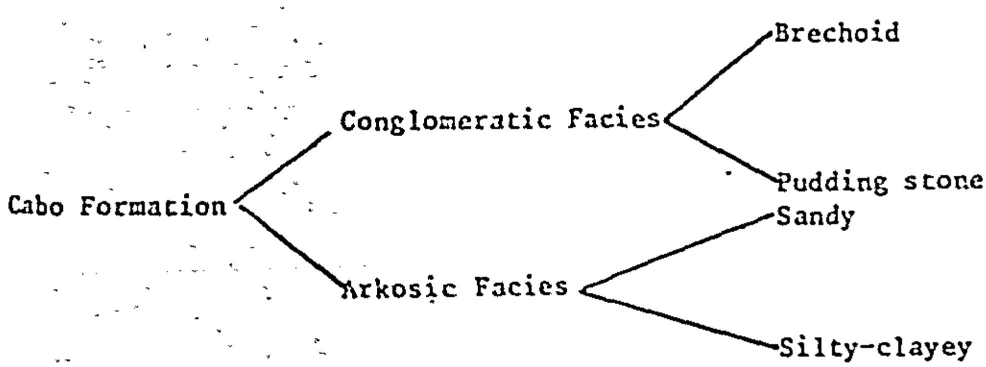
The petrographic description will be made starting with the oldest in each unit, as follows:

a) BASE ROCKS

There exists a predominance of granites with a coarse granulation, porphyroid, with crystals of miccrocline, alcaline feldspar, besides quartz and biotite. Although there is a predominance of granites, grano diorites, siorites and migmatites of miscellaneous types appear (genisses rarely occur).

b) CABO FORMATION

This sedimentary formation shows a sizable granulometric complexity, appearing under the form even of psephytes, and it is possible to schematize this variation in the following form:



Actually, under the form of a conglomerate, this formation is found to be brechoid in certain places, in contact with the base slope that acts as a shield, and that probably provided its constituent elements. Farther form the bas, in the horizontal direction, it occurs under the form of pudding stone, with rounded or semi-rounded pebbles, rarely angualar.

The composition of the pebbles and blocks (that may reach one meter in diameter) is as arule granitic, gneissic or migmatic, and the matrix is arkosic with a predominance of feldspars, generally decomposed, mica and quartz. The width of the emergence strip is around 100 m for the brechoid, 3 km for the pudding-stone or actual conglomerate.

The sandy arkosic facies is more restricted in area, but there is no accurate information about its lateral extension. It is formed by sandy coarse sediments for its larger part, of granitic decomposition, with a predominance of fresh, semi-modified or kaolinized feldspars and quartz. Theu are generally compacted and show light colours, in the ranges of white, yellow, green and purple.

The arkosic silty-clayey facies is less freauent, and has a reddish brown colour, with shiny spots due to the presence of mica.

The total thickness of the formation is estimated at between 150 and 200 m. The transition from the conglomeratic facies to the arkosic is almost always gradational and interdigitated in a lateral direction. Generally speaking, we have a conglomeratic layer at the base and another at the top, interlaid with an arkosic layer.

As for the origin, it has been much discussed, clear evidences of creeping on the slopes of the faults being visible (for instance, the chasm).

However, a colluvionary deposit would not have a conglomeratic aspect with rounded pebbles and blocks , almost 1 m in diameter. On the other hand, a transport of the mud and flow type could not be justified due to the impossibility of the available transport system to carry blocks of such a size, as well as because of the degree of rounding up that exists, and that is incompatible with what it would undergo in a mud current, because of its high viscosity. It is most probable that the slope of the fault was formed on a former coast line, submitting the newly formed deposit to a reworking from the sea, with the fromation of cliffs. With the gradual withdrawal of the sea - of which traces are still visible - the reworked blocks were scattered along the abrasion platform with a gradational interdigitated variation.

c) LIMESTONES

They appear in small quantity in a small emergence close to Suape Cocaia beach) and farther South, outside the map area, at Engenho Cameleira. This limestone has a high contents of MgO, it is compact and finely crystallized, and contains fossils in certain locations. According to Beorlen, these limestones are either Albian orTuronian.

d) MAGAMATIC ROCKS

These rocks occur in both the basic and the acid type, and in the extrusive or intrusive shapes.

Stratigraphically, the basic character occurres before the acid one, starting with Basalat and Andesite, passing through the intermediate stage of trachyte and quartz-trachyte, and ending with the eminently acid riolite.

d_1) CABO DE SANTO AGOSTINHO GRANITE

Its appearance is limited to the Santo Agostinho promontory, and shows an interesting feature that distinguishes it from the surrounding ones. It is magmatic, anorogenic and of the createceous age (determined by Cordani through radioactive methods).

Its texture is hypidiomorphic or porphyritic (varying from one site to anotehr), containing orthoclase, quartz and oligoclase and occasionnall a sodic amphibole (Riebeckite).

d_2) BASALTS AND ANDESITE

They occur mainly under the extrusive form, vith little dissemination, and occasionnally in the intrusive dike form.

The chemical alteration of these rocks on the surface produces a characteristi clayey soil of a brownis colour - massapê - that is very fertile.

The macroscopic composition of the basalt is an aphanitic mass, in which are small crystals of olivine - a prophyritic texture, while plagioclase crystals dominate in andesite.

Microscopically, plagioclase and pyroxene (augite) crystals are observed.

d_3) TRACHYTES, QUARTZ TRACHYTES

They appear both in the extrusive form (flows) as in the intrusive one (silts and dikes), and constitute one of the most frequent magmatic rocks in the region. Their texture is also very variable, the aphanitic, porphyritic and vesicular types appearing.

There is an evidence of the occurrence of trachyte flows in different phases, with erosion or fault surfaces separating these flows.

These rocks often show great alterations, with various colours (purple, brown, grey and yellow) difficulting their classification and the identification of its mineral components.

Microscopically, sanidine crystals in an aphanitic mass are visible in ht types of prophyritic texture. Also identifiable are aegirine, augite o riebeckite in the trachytes and quartz in the quatz-trachytes.

d_4) RHYOLITES

Occur in small emergences at the Engenho Algodoais, under the intrusive shape of a dike; they show a pqrphyritic microlitic texture and are lineolate snaidine and quartz crystals, being microsopically identified.

Biotite, albanite, ferrous oxyde and zircon (in small quantities) are also visible under the microscope.

e) BARREIRAS GROUP

In the shape of intensely cut-up tables, or of isolated hills, sandy-clay sediments, called Bareeiras, or Barreiras Group, occur, and, according to scholars (Beurlen, Mabessone, Bigarela, Campos etc.), constitute a formation complex.

This group can be subdivided into the following formations:

- Potengi
- Macaiba
- Riacho Morno
- Guararapes

Of these formations, only the two lower ones appear on the Pernambucan coast, the lower one - Guararapes Formation- being the one that characterizes the Southern zone now under study.

Granulometrically, it is made up of sands, silts and clays, with eventual horizons of clayey to sub-clayey flints,quartz or feldspar.

The colour of this material is generally yellowish and reddish with purple or violet shades.

The probable origin of those Barreiras is probably a mud and sand flow, in torrential proportions, that happende at the end of the Miocene and Pliocene Tertiary and the beginning of the Pleistocene Qaurtenary.

f) - RECENT SEDIMENTS

These occur in the extensive plains and are represented by sands and alluvial clays, besides themarshlad deposits, the dune and beach sand.

B) STRUCTURES

The dominant tectonic style in the region is one of fractures, causing gravity and directional faults.

The faults that came from pushes have an E-W direction (as a continuation of the Pernambucan lineament) being displaced by a system of directional rejection faults in a NE-SW direction with a tendency for N-S.

These faults which should be correlated with thos of the crystalline shield in the Northeast, with the same orientation, are all pre-cambrian, although they underwent reactivations during the Mesozoic in hte Cretaceous.

These tectonic reactivations suffered another type of stress, that produced tensions instead of compressions, which caused a gravity fault with the descent of some blocks in relation to others. These reactivation movements took place more than once during the Cretaceous, but there is strong evidence that at the beginning of that period - Albian or Aptia - a great fault occurred, producing a slope in the older advanced coastline, that gave birth to the Cabo formation, counting with the reworking by the seaof the blocks and stones that fell along the slope of the fault.

Subsequently, during the medium and higher Cretaceous, there was an orogenic paroxysm which caused the rise through the planes of the fault that were more widely open in this tectonic phase of lavas, basic at first and acid later (a characteristic of any orogenesis). Thus were formed the basalts and andesites (basic) at the beginning of the orogenic phase, continuing with the trachytes and quartz-trachytes (neutral) and ending with the rhyolite (acid).

This fractures structure produces "horst" and "graben" that got to command the subsequent regime of deposits. As a reflection of this situation, we shall find both in the Recife sedimentary basin and in the South, sunken zones, filled by cretaceous and cenozoic sediments and higher zones with small sedimentary coverings.

These structures must be carefully studied, for they may offer exceptional possibilitied for the storage of water, or may cause the confining of fossil waters with a high salt contents.

The structure of sedimentary rocks, outside from the aspects already analysed show a structure with little perturbance generally, sub-horizontal with slight dips eastward.

5.6.4 ANALYSIS OF THE GEOLOGY AIMING AT HYDROGEOLOGY

An examination of the available geological information about the area makes it possible to present considerations directly related to the hydrogeological conditioning, as follows.

a - the highst frequency of flow emergences and of intrusions occurs in a stretch included between the sediments of the Cabo Formation ad the Barreiras Group. A certain subordination in two directions of semicontinuous emergences can be observed, the main one, approximately N-S starting at the Engenho Bela Vista, to the East of the City of Cabo, ending in Engenho Mercês, to the East of the town of Ipojuca. The other, less obvious, approximately E-W, passing by the Cape of Santo Agostinho.

Besides tehse inetrmittent faults, there are isolated inexpressive emergences in Itapuama (trachytes), in the very crystalline base (rhyolite) close to Ipojuca and at Engenho Baco, West of the city of Nossa Senhora do Ő (agglomerate).

It is normal to admit that the known emergences do not indicate all the intrusions that exist in the area, snd it should be hoped, on the other hand, that the areas where thesemagmatites are predominnant the same intrusions should occur, still covered by more recent sediments. As a consequence, the area that corresponds to the Suape-Nossa Senhora do Ő plain shows little probability of containing intrusions, ad this fact, when confirmed, will increase the value of the aquifers that exist there, and make the drilling of wells maor favourable.

b - PETROBRAS geologist F. Ponte, studying the spatial distribution and the present cut up residual forms of the sediments of the Barreiras Group reached the conclusion that the preserved barren tablelands were an indication of structural heights of the substratum. In the area under study, informations show that the substratum on which these sediments rest in discrepancy with erosion is represented by the Cabo formation or by the system of intrusive rocks mentioned above.

By the exmination on a geological map the sptial distribution of the Barreiras Group,, it can be seen that it occupies a wide area, almost continuously, in the shape of a partially preserved tableland that extends to the North pf the river Massangana, and is repeated to the South of the Nossa Senhora do Ő plain, yet with less E-W extension.

There is countless evidence of tectonic type reactivations if the crystallin substratum along all the sea coast of the Northeast..
In the specific case of the area under study, the interesting reactivations

are the ones that occurred during the depositing of the sediments of the Cabo formation, that cause an increase in the thickness of this formation. A proof of this fact is the presence of a conglomeratic horizon over arkosic arenites and clayey siltites.

Cinsidering F. Ponte's conclusion for the area valid, and also taking into consideration the above-mentioned evidence, one is led to admit that the area occupied by the Suape-Nossa Senhora do Ó plain should correspond to a sinking of the Barreiras substratum,that, ultimately, corresponds to a larger sinking of the very crystalline basis, making it possible that the Cabo formation may have greater thickness.

However, the assumption that the preservation of the sediments in Barreiras may have been the result of an intervening obstacle to the water courses that came from the West, should not be discarded. In this case, the thickness of the sediments of the Cabo formation should not be different from the one that is liable to be found in the area of the Suape-Nossa Senhora do Ó plain.

However, the elements analysed here, taken as a whole, lead to the more logical conclusion taht the Suape-Nossa Senhora do Ó plain shows better possibilities of the thickening of the sedimentary package and, therefore, it might show better hydro geological conditions.

c - the sedimentation process of the Cabo formation and field studies show that, from Eat to West, from the contact with the crystalline base, there is a gradation of the sediments, from conglomerates (blocks and large flints) to silty clay, passing through arkosic arenites, coarse and fine, , and conglomerates.

There is therefore a variation in the facies from West to East, that provides a natural selection, making rather difficuk klt and inaccurate the superficial individualization of thes tqo facies: conglomerate and arkosic (see geological map in illustration 5.xxxIV).

This gradational variation, also interdigitated, occurs both horizontally and verticallyconstituting a double discontinuity - in space and in time. Due to this fact, a lithological variation of great intensity, laterally and vertically, sould be expected, and this makes the aquifer rather heterogeneous.

The granulometric analysis of 6 surface samples of arkosic arenites of the Cabo formation, as per table below, shows that as an average, after elimination of the discrepant values, sand shows the highest percentage (62%), followed by clay (23%) and silt (8%), showing the treatment of an excellent aquifer from a lithological point of view.

Nº	Gravel	Sand	Silt.	Clay	ϕ_{25}	ϕ_{50}	ϕ_{75}	CCφ	Sφ
2	7,25	59,95	7,80	25,00	-0,20	0,95	8,50	4,4	3,2
3	0,10	58,00	19,24	22,66	1,25	3,00	8,00	3,4	1,6
4	6,60	54,30	9,10	21,00	0.25	1,55	6,60	3,3	1,9
5	2,30	68,85	9,85	19,00	0,20	1,49	6,25	3,3	1,7
6	8,35	71,20	1,45	19,00	-0,10	1,09	3,75	1,3	3,8
8	0,00	8,20	61,08	30,72	4,95	5,75	0,0		0,0

Source: Levantamento Geológico da Faixa Costeira Sul de Pernambuco; Mello,A.A e Siqueira, L.P.)

5.6.5 LOCAL HYDROGEOLOGY

A) BASIC ELEMENTS - SURVEY OF THE WATER POINTS

Even though they do no representthe total existing in the work area, the water points surveyed, 41 in number, çermitted a good definition of the hydrogeological behaviour.

Table 5.6/1 attached shows a synopsis of the data obtained, listing depth, elevation, static level, diameter, besides the localization and miscellaneous observations about the quality of the water (taste) and the seasonal variations of the water level.

The 41 points, plotted on the map, are distributed among the various geological formations, and can be situated as follows:

a) Contained in the Cabo Formatio - 4 water holes (Nº 23,24,25 and 26), 7 (seven) springs (Nº 15, 27, 28, 29, 30, 31, 32); 3 (three) tubular wells (Nº 2,3 and 28-A), the last one with a depth of only 10m;

b) contained in sand and alluvion, 13 (thirteen) water holes (Nº 1, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 16, 17, 18, 19, 20 21 and 22)

c) contained in the sediments of the Barreiras Group, 2 (two) springs (Nº 33 and 36), both in contact with intrusions, 4(four) water holes (Nº 34, 35, 37, and 40) and two auger drillings Nº 38 and 39.

Nine (9) collections of water samples were made for chemical analyses the results of which are shown in Table 5-6/2 below.

All the waterholes surveyed are located on the geological and pizometric maps, the latter also showing the elevations of the ground surface and those of the static level.

The only deep wells that exist in the region under study that deserve special mention are located in the city of Nossa Senhora do Ó. These two wells (water points Nº 02 and 03) are about 2o meters apart, and they were drilled by DPNM (Departamento Nacional da Produção Mineral) under the responsibility of geologist Paulo Celestion, and thei technical data are as follows:

REFERENCE	2/70-11S	1/70-11S
Depth	80.00 m	63,0 m
NOLD filters, ∅ 6"	21,0 m	13,0 m
Position of filters	50-71 m	49-62 m
Aquifer used	27 m	15 m
Position of aquifers	48-75 m	48-63 m

Denomination of Aquifer | Cabo Formation Arksic Arenite

LITHOLOGIC PROFILE		
Sand from continental and alluvial beaches	0-31 m	0-27 m
Fluvial Clays	31-48 m	27-48 m
Arkosic Arenites	48-75	48-63
FLOW	140 m^3/h	100 m^3/h
Static Level	8,3 m	6,0 m
Dynamic Level	17,8 m	15,3 m

Remarks: 1 - The aquifer used is an arenite, medium to coarse, generally not very clayey, with conglomeratic horizons, locally badly selected, and reddis to brown in colour. Intercalations of sandy clay exist.

2 - Although close together, the wells do not use the same thicness of aquifer or filters, this being the reason why they show different specific capacity and dynamic level; however, it we divide the specific capacities by the respective thickness of the aquifers used, we can see that the values thus obtained are practically identical: 0,46 and 0,48 m^3/h/m/m/, indicating the uniformity of behaviour of the aquifer.

We show hereafter the water holes and the technical data of both Nossa Senhora do Ó wells.

SURVEY OF THE WATER POINTS

Nº REF.	Type (*)	DEPTH (m)	DIAMETER (m/")	ELEVATION (m)	N.E. (m)	PIEZOMETRIC ELEVATION (m)	LOCATION	REMARKS
01	o	4,60	2,00	4,00	2,82	1,18	Vila Usina Salgado	Dry in summer
02	⌖	63,00	6"	6,50	4,50	2,00	Cidade N.Sra. do Ó	To be installed
03	⌖	60,00	6"	6,50	4,50	2,00	" " " " "	" " "
04	d	-	4,00	2,00	3,11	-1,11	Faz. Marepe	Brackish Water
05	o	-	1,00	2,00	0,30	1,70	" "	Fresh Water
06	o	2,00	2,00	1,00	0,85	0,15	" "	Polluted Fresh Water
07	o	1,30	1,00	1,00	0,37	0,63	" "	Fresh Water [illegible]
08	o	1,50	1,10	1,00	0,60	0,40	" "	" "
09	o	2,00	0,43	1,00	0,80	0,20	Faz.Mario Papa	0,5 m lower in Summer
10	o	1,50	3,00	1,00	0,60	0,40	" " "	
11	o	2,00	0,85	1,00	0,50	0,50	" " "	Potable Water

SURVEY OF THE WATER POINTS (cont.)

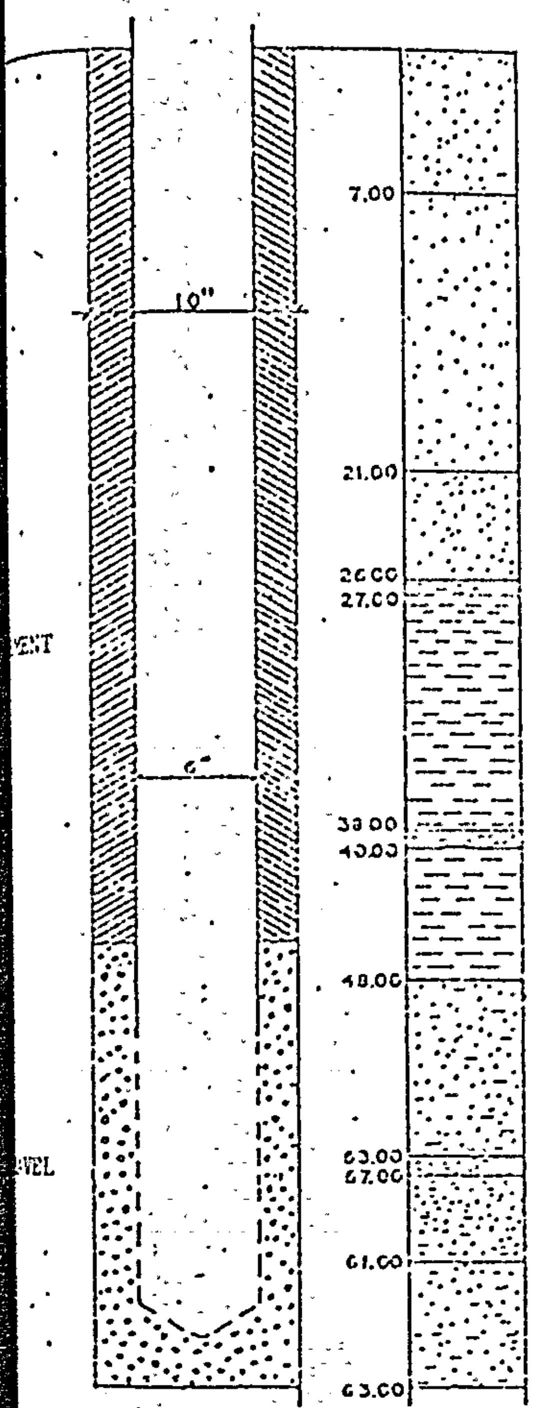
Nº REF.	TYPE (*)	DEPTH (m)	DIAMETER (m/")	ELEVATION (m)	N.E. (m)	PIEZOMETRIC ELEVATION (m)	LOCATION	REMARKS
12	o	2,50	0,86	1,00	1,10	-0,10	Faz.Merepe	
13	o	2,00	0,90	4,00	0,86	3,14	Usina Salgado	Level falls slightly in Summer
14	o	1,00	0,80	4,00	0,60	3,40	" "	Fresh water; dries in Summer
15	o	0,88	0,60	4,00	0,00	4,00	" "	Does not dry up
16	o	5,00	1,00	6,00	1,00	5,00	Engenho Mercês	Level falls much im Summer
17	o	2,50	1,00	3,00	1,50	1,50	Praia de Cocaia	
18	o	2,50	1,00	2,00	1,50	0,5	" " "	
19	o	2,50	1,00	2,00	1,50	0,5	" " "	Chalybeate water
20	o	2,50	1,00	2,00	?	?	" " "	" "
21	o	2,50	1,50	4,00	?	?	" " "	" "
22	o	?	?	4,00	?	?	" " "	" "

SURVEY OF WATER POINTS (Cont.)

Nº REF.	TYPE (*)	DEPTH (m)	DIAMETER (m/")	ELE-VATION (m)	N.E. (m)	PIEZOMETRIC ELEVATION (m)	LOCATION	REMARKS
23	o	10,00	2,50	10,00	0,00	10,00	Engº Mercês	Fresh Water
24	o	1,60	1,20	10,00	0,00	10,00	Engº Massangana	" "
25	o	?	1,00	6,00	0,00	6,00	" "	" "
26	o	2,00	0,40	8,00	0,00	8,00	" "	Fresh Water
27	o'	--	--	4,00	0,00	4,00	Usina Salgado	Fresh Water
28	o'	--	--	25,00	0,00	25,00	Engº Massangana	
28A	-+-	10,00	6"	20,00	--	?	" "	Fresh Water
29	o'	---	--	25,00	--	25,00	" "	Fresh Water
30	o'	---	--	10,00	--	10,00	" "	Fresh Water
31	o'	---	--	10,00	--	10,00	" "	Fresh Water
32	o'	---	--	10,00	--	10,00	" "	Fresh Water

Nº.	TYPE (*)	DEPTH (m)	DIAMETER (m/")	ELEVATION (m)	N.E. (M)	PIEZOMETRIC ELEVATION (m)	LOCATION	REMARKS
33	♂	-	-	2,00	-	2,00	Sitio Ant.Gomes	
34	o	1,30	1,00	3,00	0,80	2,20	Suape	
35	o	1,90	1,00	3,00	0,00	3,00	Suape	Hard rock at bottom
36	♂	-	-	5,00	-	5,00	Gaibu	Contato Barreira / Gr.
37	o	0,90	1,00	5,00	0,20	4,80	Estr.Gaibu-Suape	Fresh Water
38	-o-	6,50	-	3,00	2,50	0,50	Praia Itapuama	
39	-o-	6,50	?	3,00	2,50	0,50	Praia Itapuama	
40	o	2,00	1,00	5,00	0,00	5,00	Praia Itapuama	Fresh Water
								-o- = Tubular Well
							(*) LEGEND OF WATER POINTS	o = Water Hole
								♂ = SPRING

SIZE OF WELL	LITHOLOGY	LITHOLOGICAL DESCRIPTION



MEDIUM SAND, WHITE COLOUR

MEDIUM SAND, DARK COLOUR

MEDIUM TO COARSE SAND, WHITISH

SANDY CLAY, CREAM COLOURED

GRAY CLAY

MEDIUM TO COARSE ARENITE LITTLE CLAYEY

GRAY CLAY

COARSE ARENITE, LITTLE CLAYEY

COARSE ARENITE TO LITTLE CLAYEY CONGLOMER.

MEDIUM ARENITE, LITTLE CLAYEY

MEDIUM ARENITE, CLAYEY, REDDISH

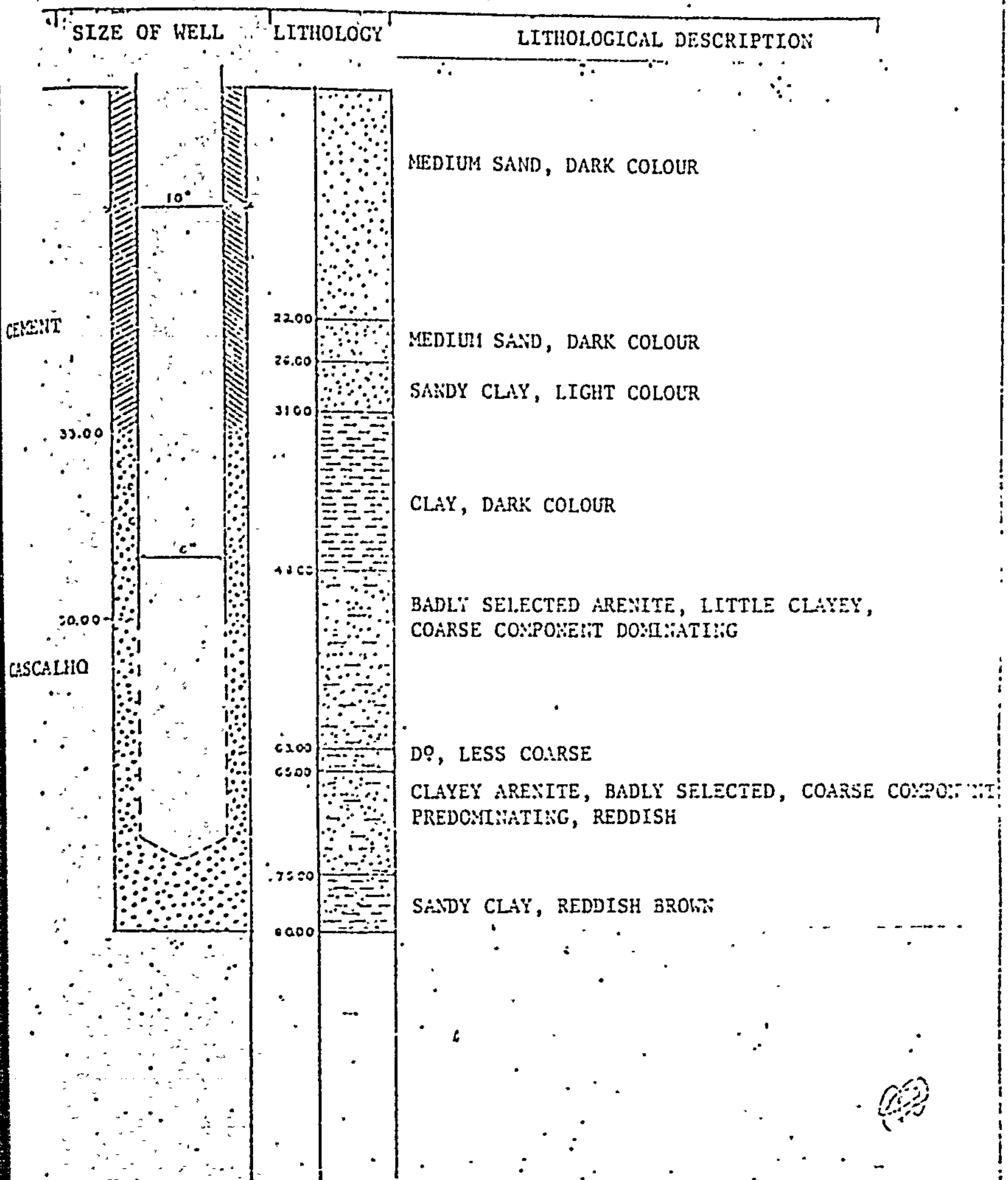
...O 2/70 - 115
...AL NOSSA SENHORA DO "O"
...ÍPIO IPOJUCA ESTADO: PE
...ESTÁTICO: 8,20 m DINÂMICO: 17,00 m
...: D.N.P.M.

dipor

TRANSCON S.A.

COMPLEXO INDUSTRIAL ...

HYDROGEOLOGY SECTION



...O 1/70 - HS ...: NOSSA SENHORA DO "O" ...: IPOJUCA — ESTADO: PE ...: SANEPE ... ESTÁTICO: 0,00 m — DINÂMICO: 15,30 ...: 150 000 L/H ...: D. N. P. N.	dipor TRANSCON S.A.	COMPLEXO INDUSTRIAL ... SEÇÃO DE HIDRO...

B BIEZOMETRIC MAPPING

On the basis of the elements provided by the survey of the water points, and more specifically of the static level elevation, the preparation of an isopiezometric contours was mad possible for the surface of the free auifer. (illustration IV-2-73)

The lowest isopiezometric curve considered for this map was the 1,0 m curve, and the highest, the 10,0 m curve. The lowest curve is close to the line that limits the Suape-Nossa Senhora do Ó sedimentary plain.

Various conclusions can be drawn from this map:

- The general flow is in the direction of the Ocean

- In the cut up zones or in the narrow vales in the sedimentary package of the Cabo Formation, the flow is to the interior of the vale from its slopes.

- Although not defined numerically, the hydraulic gradient of the underground waters is much higher in the occidental part of the plain, on the foothils that limit it.

- There exists an underground watershed - shown on the isopiezometric map - in the region of Cabo de Sanct Agostinho as far as the city of Cabo. From this watershed, the watershed the waters drain towards the NE and SE, respectively, the highland of Barreiras and the Suape-Nossa Senhora do Ó plain.

It must be mentioned that the isopiezometric map shown was based on the topographical map of the Serviço Geográfico do Exército (Army Geographical Service), to the scale of 1:25.000, with contour curves for every 10 m, besides scattered reference points.

C IDENTIFICATION, TYPIFICATION AND CHARACTERIZATION OF THE AQUIFERS

According to the information that is available at present, three aquiferous complexes can be identified in the area that interests the Suape Industrial Complex, two being free and one confined.

In sratigraphic order, they are:

a) The free aquifer from the alluvions, dunes, and non-confined part of the Cabo Formation;

b(Th aquifer from the plio pleistocene sediments of the Barreiras Group,

- The confined aquiferous of the Cabo Formation.

Considering the hydrogeologic characteristics of each aquifer, on the basis of the field data, we can establish an order of importance for these aquifers, and this criterion will orient their description.

The confined aquifer of the Cabo Formation is therefore the most important in the region, its confinement being provided by the clayey alluvions from the rivers (principally the river Ipojuca), as shown by the profiles of the Nossa Senhora do Ó wells, or by Barreiras Group sediments, or by igneous flows, and, finally, by the pelitic sediments of the formation itself.

For the perfect undestanding of this aquiferous unit, it is necessary to know the mechanism of the respective sedimentary formation.

As previously mentioned, the sediments of the Cabo Formation have their probable origin in the slope of a fault, the direc-ion of which is approximately parallel to the coast, the colluvial product being the result of the crumbling of blocks along the plan of the fault and their being reworked by the sea and redeposited alonga gradational and interdigitated contact, with a diminishing granulometry from East to West.

Subsequently to teh reworking by the sea, the rivers still acted toward the scattering of these sediments, especially the least coarse.

In the area under study, the river Ipojuca is the one that played the role of main coadjuvant of the sea, and according to evidence, ut flowed into the sea in the guise of a delta, fanning out the sediments it carried, especially the psammitic ones. Upon the subsequent recession of the coastline, this delta was silted up by more recent poligenic sediments, covering even the canals that should probably have been formed within the delta.

This probable paleogeographic evolution gave birth to favourable hydrogeological cinditions in the region that is at present represented by theSuape Nossa Senhora do Ó sedimentary plain, since, besides the interdigitations of the depoistion regimen of the Cabo Formation, from where arose alternate beds of fine and coarse sediments,the deltaic formation probably actuated as well under two respects: producing the confinement of the underlying aquifer through its clayey sediments, and increasin the porosity of the free aquiferous, through the canals of deposition of the coarse sediments in the delata itself.

As regards the thicness of the cretaceous sedimentary package, the surface data, as mentioned previously lead to an estimate of 150 to 200 m, that needs to be determined accurately with the help of geophysics, with the support of stratigraphic drilling.

A well drilled by T,Janer & Cº close to the city of Cabo (CERMIC works) was sunk to a depth of 150 m, alwys in the conglomerate, however without reaching the crystalline base, and its result was negative in termos of flow. This information in no way invalidates the imortance of the aquifer, since the site of the well, besides being considered of little transport, is very heterogeneous, and therefore without selection. On the other hand, the main characteristic of the Cabo Formation aquifer is its sandy arkosic facies.

To conclude, the estimate for the thickness may be considered valid, and, once confirmed or exceeded, it will increase significantly the present importance of this aquiferous complex.

The genetic behaviour of the hydrogeologic complex under study leads to the conclusion that the recharging of the aquifer is mainly provided by the infiltration of rainwater in the emergence region of the Cabo Formation, along an irregular strip, 5 km wide, situated to the West, at the occidental limit of the cretacic sedimentary basin. Besides, in the area under study, the river Ipojuca itself, with a permanent flow (in its lower course); as well as the Massangana and others, upon crossing the formation, represent a recharging factor of great value.

On the other hand, upon examination of the punctual information of the elevation of the piezometric level of this aquifer, for the only sandy stratum crossed in Nossa Senhora do Ó, and the surface hydrostatic elevation of the free aquiferous on the same place, it can be seen that, in rounded numers, the first is equal to 2 m and the second is equal to 3 m, which means that a large part of the basin must enjoy a natural downward drainage, thus allowing tee confined aquifer to receive a contribution from the free aquifer.

Thus, we reach the conclusion that the aquifer that was analysed has three recharging sources: direct rainwater infiltration, infiltration of the flowing water of the rivers, and the drainage of the free aquifer.

In accordance with oral information gathered from the owners of the wells and water holes, (the working period did not allow seasonal observations), the difference in level observed in the highest weirs (elevation 10 m) located in the sediments of the Cabo Formation, is of about 2 m, and this variation diminishes graduallyfor the lower elevations. Taking as a basis the spring with the lowest elevation that exists in the Cabo Formation,, and the same piezometric reference noted in the east in the Nossa Senhora do Ó wells, it can be seen that the underground flow of the aquifer is in the direction of the sea.

The second aquiferous unit in order of importance is free, and it is represented lithologically by the alluvial deposits of shallow depth and by the continental sand deposits (dunes) and those of the beaches.

The lithological profile of well 2/70-11S of Nossa Senhora do Ó reflects faithfully the complete sequence of this higher sedimentary package, where we see in the upper part a 7m layer of medium sand, white in colour (dunes), and, below, a layer of dark coloured medium sand, followed by whitish nedium to coarse sand (alluvion), forming a total 26 m thick, with. at the base, a thick layer of clay.

Correlating all the elements provided by the piezometric map with other data obtained in the field, it was deduced that:

- during the period of rainfalls, the rivers, and especially the Ipojuca) feed this aquifer;

- The elevations that bound the Suape-Nossa Senhora do Ó plain to the West, especially those represented by the sediments of the Cabo Formation, constitute a recharging element, and therefore elevate thesurface of the phreatic;

- As a consequence of the fact mentioned above, and in the present state of knowledge, it is believed convenient to include the underground water, non-confined, of the Cabo Formation into this aquiferous unit;

- Due to its topographical situation, this aquifer is vulnerable to the influence of the advance of the high tides (superficial salinization) and, locally the surface of the ground water blends with the marshes that, in final analysis, are its natural outlet to the East.

- The recharge of this aquifer is provided not only by the infiltration of the permanent watercourses that, in its turn, are also fed by the ressurgences of the Cabo Formation, but also by direct infiltrations from the precipitations. It can also be assumed that in determined areas, there should be an upward drainage from the underlying confined aquifer.

- The flows demanded from the water holes in use at present are very restricted, and oral information shows a considerable annual amplitude in the oscillation of the hydrostatic surface, of over 2 m in certain places.

- The hydrometric parameters of this aquifer have not been determines, considering its limited importance, and the lack of installations.

As a consequence of the above, it is inferred that only under very special conditions, both restricted and localized, could this aquifer be used to attend any significant demand for water in that region.

The third aquiferous unit was individualized North of the river Massangana, and it is fundamentally represented by the sediments of the Barreiras Group that constitute extensive cut-up mesas, cut by thalwegs in a general E-W direction.

Geological evidence shows that the flow should occur eastward, a fact that is consfirmed by the resurgences (springs) that exist along the coast..

It was decided to individualize this aquifer because, as a whole, the phreatic surface proves to be much higher than in the preceding unit.

The Barreiras sediments lie on the intrusions and on the Cabo Formation, and should, according to indications, show a predominance of the former. In this case, this aquifer would be in suspension.

Anyhow, it is quite viable that ths aquifer should represent a recharge element for the others.

The rocks of the Barreiras Group, is spite of being disposed along a vast extension of the seashore of Brasil have no tradition as aquifers, their effective poritity and permeability being generally very poor.

The recharge of this aquifer is provided only by the percentage of the atmospheric precipitation that infiltrates.

An analysis of the complex of these aquiferous units identified in the area leads to the conclusion that the confined aquifer is the one that has the largest continuous area and is best suited for use, from an economic point of view, although it should be mentioned that there exist preferntial areas for its utilization through tubular wells. In the first place, is a region included in the Suape-Nossa Senhora do Ó plain, the perfect insulation of the overlying free aquifer, and, in second place, in a much less favourable condition, in the first thalweg that exists North of Cabo de Santo Agostinho, inclided between the mesas of the Bareeiras Group.

In this last mentioned place, the indication has a acharacter of investigation, and depends on the interest and the demand of the Suape Industrial Complex.

A priori, the possibility of a large scale water supply from the aquifer of the Barreiras Group should be excluded.

D - HYDROCHEMICAL CHARACTERISTICS OF THE AQUIFERS

The 9 (nine chemical analyses carried out on the water collected in different spots among those mentioned in the survey are distributed in the following way in relation to the aquifers studied:

a) free and confined, originating from the Cabo Formation:

- samole nº 02 = tubular well 2/70-11S, situated in Nossa Senhora do Ó
- Sample Nº 27 = spring of the Usina Salgado
- Sample Nº 28-A = 10 m. deep tubular well at Engenho Massangana
- Sample Nº 23 = waterhole of Engenho Mercês

b) Originating from Barreiras Group

- Sample Nº 23 = spring at the Sítio Antônio Gomes
- Sample Nº 36 = spring in Gaibú

c) originating from dunes and alluvions

- Sample Nº 17 = Waterhole in Cocaí
- Sample Nº 01 = Waterhole of Usina Salgado
- Sample Nº 01 = Cupe Waterhole

The chemical composition of these waters is shown in table IV-2 below

The analyses of the waters of the Cabo formation show that they are slightly acid and generaaly with little mineralization. Actually, theindication of traces of ammonia does not preclude its use as drinking water, but it should be used cautiously and bacteriological analyses should be made. Besides, the results shown do not necessarily imply a bacteriological pollution of the aquifer, since the conditions in which samples are collected for a chemical analysis do not include the specialized technique used for the case of bacteriological analyses. On the other hand, since the well had been out of use for a long time, and in precarious safety conditions, some superficial contamination was to be expected, even artificially provoked. Only after several days of constant use of the well water through pumping, and using the proper technique for the collection, could the water be examined bacteriologically with any accuracy.

The analysis of the well of Nossa Senhora do Ó shows quantitative values that are higher than the average for the tested aquifer, and this leads to the supposition that it was not properly insulated from the free aquiferous during its construction. Even so, except for the indication of nitrates, the water is within the acceptable potableness standards. It should be remebered that the city of Nossa Senhora do Ó has no sewers network. It should also be considered that the presence of nitrates is allowed within certain limits, and that in the region under study there is intensive cultivation of sugar-cane,, with the use of fertilizers in the soil.

The analyses of the waters of the Barreiras Group show very little mineralization and relative acidity, with traces of nitrate and ammonia.

The waters from the dunes and alluvions are the most mineralized of all, though they are still within the aceeptable potableness limits. It is recognized, however, that this aquifer is the most vulnerable to pollution by man, and in places by the advance of the sea. the pH can be considered neutral. The water collected in CUpe shows indices that are outside the average, and it is considered slightly brackish by its users.

The presence of nitrite and nitrate is also noted, and this may represent a certain danger for human consumption without due bacteriological control..

The examination of the results obtained as a whole through the analyses is remarkable by the generalized indication of traces of nitrates and ammonia, and secondarily of nitrite, suggesting that the cause could be the lack of sanitary protection and the artificial fertilizing of the soil.

As for salinity, the quality of the waters of the region is generally very good, a slight restriction should only be made regarding the pH of certain samples which are slitly agressive (corrosive) because of their acidity: samoles 33 and 36, and, to a lesser degree, 23 and 28-A. As for the basic character, only one sample showed a value over 8, and that was Nº 4. As a rule the waters of the region may be considered normal as far as chemical characteristics are concerned.

We show below the result of the chemical analyses of the waters of the Suape region and its surroundings.

A) In Cabo Formation

PLACE	ORIGIN	Nº REF.	pH	CONDUT (mho)	CLORIDO (mg/l)	Ca+Mg (mg/l)	Na+K (mg/l)	NITRATE	NITRITE	AMMONIA
N.Sra. do Ó	Tub. Well	02	7,8	2.500	200,7	79,0	101,4	Traços	Absent	Absenta
Us.Salgado	Spring	27	5,9	92	22,0	2,4	12,6	Traços	Absent:	Absent:
Eng.Massangana	Tub. Well	28-A	6,8	167	19,0	12,2	21,2	Presen.	Absent	Traços
Eng.Mercês	Weir	23	5,9	70	15,0	3,5	5,0	Absent	Absent	Traços
B) In Barreiras Group										
St. Ant.Gomes	Spring	33	5,3	72	25,0	11,0	6,9	Traços	Absente	Traços
Gaibu	Spring	36	5,7	96	23,0	11,0	10,6	Traços	Absent	Absent:
C) In the dunes and alluvions										
Us.Salgado	Weir	01	7,0	220	22,0	11,4	30,9	Absent:	Absent:	Absente
Cupe	Weir	04	8,1	816	129,0	75,7	105,4	Presen.	Presen.	Absente
Jonal	Weir	17	6,5	123	14,0	3,3	5,0	Traços	Traços	Ausence

E. PUMPING TEST

TEST CONDITIONS

During a trial, it was discovered that Nº 1 well was obstructed above its static level, and for this reason, the reduction and recuperation measurement were performed only on well Nº 2.

The pumping system used was the airlift, using an ATLAS COPCO compressor with an injector at a depth of 59 m. Air injection was trough a pipe of 1 inch, external diameter and the return pipe was 3 inch.

The test was carried out in two stages:

MEASUREMENTS	1st STAGE			2nd STAGE		
	DAY/MONTH	TIME	DURATION	DAY/MONTH	TIME	DURATION
PUMPING	24/02	15:00	36hs	26/02	22:00	26hs.
RECUPERATION	26/02	03:00	19hs	---	---	---

First Stage

The flow was constant from the 5th minute, and was 60 m^3/h.

The tables attached show the measurements of the fall in level and the recuperation, corrected in relation to ground level. The first measurements of the fall in level (1, 2 and 4 minutes)were impaired because of a flow back of water through the 6 inch tube, and in the tracing of the curve because of a limitation of the number of logarithmic cycles on the paper, only the measurements after 10 minutes were plotted.

The points obtained showed a comparatively normal distribution, and

and the probavle existence of a frontier of lower permeability cold be noted after pumping for k5 hours.

It is smpossible to determine the distance of this frontier because of the impossibility of determining the storage coefficient (the well under observation had not been used).

Second Stage

The flow was constant from the seventh minute. For the same reasons as above, it was impossible to make the first minute measurements.

The fall of level curve was plotted from the 10th minute because of the limitation in cycles of the paper, besides the fact that the first points wdre impaired by the return of the water through the 6 inch tube.

The points show the same alignment condition found in the first stage, and the almost perfect superposition of the two curves of level reduction should be noted.

In this second tes also, there is an indication of a horizon of lower permeability.

The conditions in which the test was carried out in the second stage were similar to those of the first stage, and the flow was also of 60 m^3/h. However, the stabilization time of the dynamic level was lower in the second test than in the first, 26 and 36 hours, respectively.

PUMPING TEST OF THE NOSSA SENHORA DO Ó WELL

1st STAGE

PUMPED WELL

DATE	HOUR	MINUTES ACCUM.	MINUTES AVER.	D.L. (m)	REDUCTIONS	REMARKS
24/02/74	15:00					
		1	1			S.L. = 4.00 m
		2	1			
		3	1	5,44	1,44	FLOW = 60 m^3/h
		4	1			
		5	1	5,42	1,42	Flow stabilized as of
		7	2	5,75	1,75	the 5th minute
		9	2	5,77	1,77	
		11	2	5,79	1,79	-Flow measurements
		13	2	5,80	1,80	from a 220 l. drum
		15	2	5,85	1,85	
		20	5	5,96	1,96	
		25	5	5,96	1,96	
		30	5	6,06	2,06	- Depth of Injector: 53 m.
		40	10	6,15	2,15	
		50	10	6,25	2,25	
		60	10	6,32	2,32	- Pumping System: Air-lift
		70	10	6,39	2,39	
		80	10	6,44	2,44	
		90	10	6,51	2,51	
		110	20	6,61	2,61	
		130	20	6,71	2,71	
		150	20	6,80	2,80	
	18:00	180	30	6,94	2,94	
		210	30	7,05	3,05	
		240	30	7,14	3,14	
	20:00	300	60	7,33	3,33	
		360	60	7,52	3,52	
		420	60	7,70	3,70	
		480	60	7,86	3,86	
	24:00	540	60	8,01	4,01	
25/2/74		600	60	8,13	4,13	Owner: SANEPE
	02:00	660	60	8,28	4,28	DRILLED by DPNM
		720	60	8,38	4,38	
		780	60	8,45	4,45	
		840	60	8,60	4,60	
	06:00	900	60	8,74	4,74	
		960	60	8,67	4,67	
		1020	60	8,90	4,90	
		1080	60	9,01	5,01	
		1140	60	9,20	5,20	
		1200	60	9,36	5,36	

PUMPING TEST OF THE NOSSA SENHORA DO Ó WELL

REDUCTION

1st. Stage (Cont.)

PUMPED WELL

DATE	HOUR	MINUTES ACCUM.	MINUTES AVER.	D.L. (m)	REDUCTION	REMARKS
	12:00	1260	60	9,48	5,48	
		1320	60	9,54	5,54	
		1380	60	9,68	5,68	
		1410	30	9,72	5,72	
		1440	30	9,84	5,84	
		1470	30	9,81	5,81	
		1500	30	9,90	5,90	
		1530	30	9,90	5,90	
		1560	30	9,92	5,92	
		1590	30	9,97	5,97	
	18:00	1620	30	10,02	6,02	
		1650	30	10,05	6,05	
		1680	30	10,09	6,09	
		1710	30	10,17	6,17	
	20:00	1740	30	10,17	6,17	
		1770	30	10,20	6,20	
	21:00	1800	30	10,28	6,28	
		1830	30	10,32	6,32	
		1860	30	10,33	6,33	
		1890	30	10,38	6,38	
		1920	30	10,41	6,41	
		1950	30	10,47	6,47	
	24:00	1980	30	10,51	6,51	
		2010	30	10,54	6,54	
	01:00	2040	30	10,58	6,58	
		2070	30	10,62	6,62	
	02:00	2100	30	10,68	6,68	
		2130	30	10,70	6,70	
	03:00	2160	30	10,74	6,74	

PUMPING TEST OF THE NOSSA SENHORA DO Ó WELL

RECUPERATION

1st STAGE

PUMPED WELL

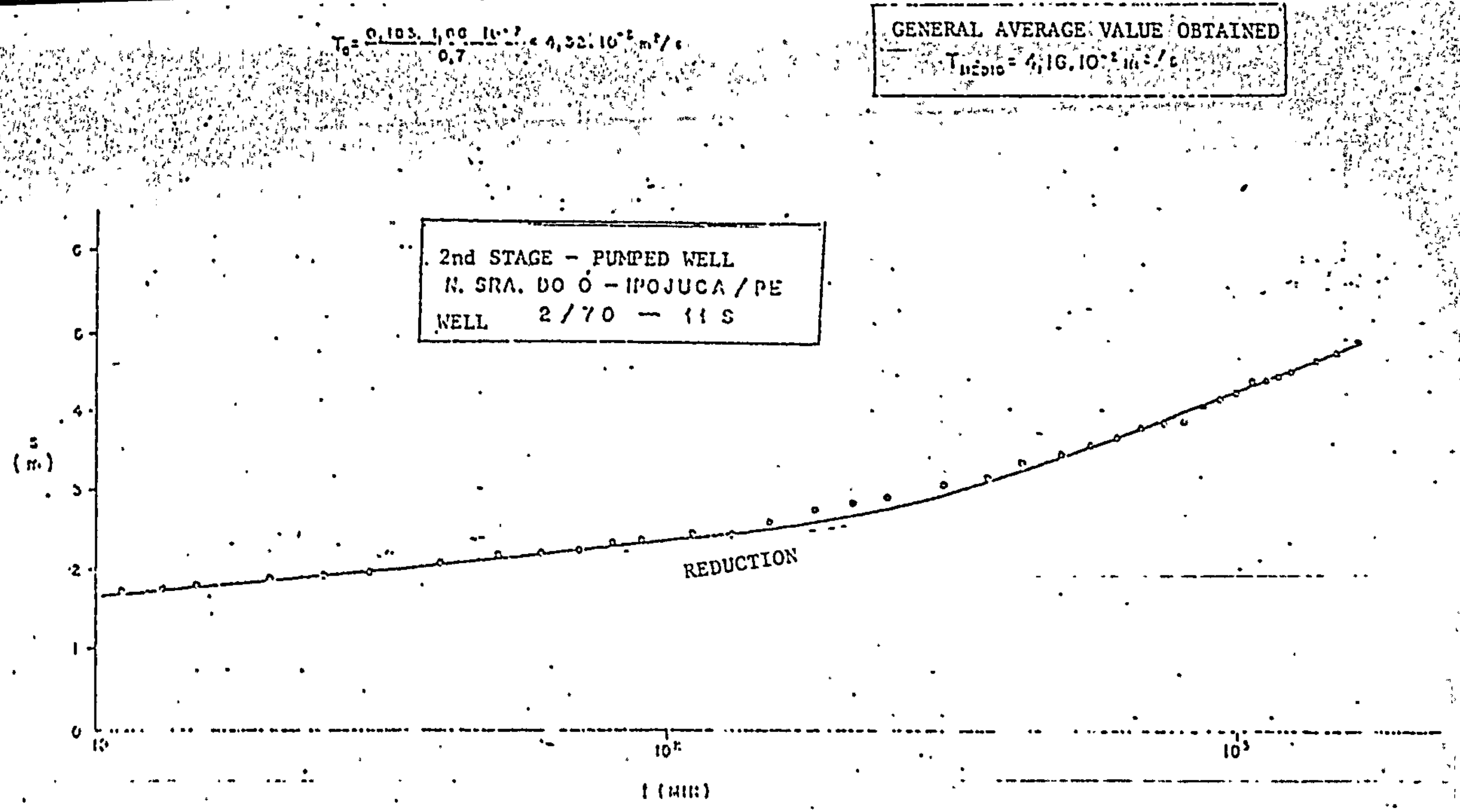
DATE	HOUR	MINUTES		$\frac{tb}{ti}$ + 1	RESIDUAL REDUCTION s - s'	REMARKS
		ACCUM.	MEASURED			
26/02/74	03:00	1	1	2.161,0	5,42	PUMPING TIME:
		2	1	1.081,0	5,35	tb =2.160 min.
		3	1	721,0	5,31	
		4	1	541,0	5,30	D.L.: 10,74 m
		5	1	433,0	5,26	
		7	2	309,5	5,20	S.L.: 4,00 m
		9	2	241,0	5,17	
		11	2	197,3	5,12	
		13	2	167,1	5,09	
		15	2	145,4	5,07	
		20	5	109,0	5,03	
		25	5	87,4	4,98	
		30	5	73,0	4,93	
		40	10	55,0	4,86	
		50	10	44,0	4,78	
	04:00	60	10	37,0	4,73	
		70	10	31,8	4,67	
		80	10	28,0	4,61	
		90	10	25,0	4,58	
		110	20	20,6	4,49	
		130	20	17,6	4,42	
		150	20	15,4	4,37	
	06:00	180	30	13,0	4,29	
		210	30	11,2	4,24	
		240	30	10,0	4,13	
		300	60	8,2	3,96	
		360	60	7,0	3,79	
		420	60	6,3	3,62	
		480	60	5,5	3,57	
		540	60	5,0	3,50	
	13:00	600	60	4,6	3,46	
		660	60	4,2	3,39	
		720	60	4,0	3,33	
		780	60	3,7	3,27	
		840	60	3,5	3,23	
		900	60	3,4	3,19	
		960	60	3,2	3,12	
		1020	60	3,1	3,07	
	21:00	1080	60	3,0	3,03	
	22:00	1140	60	2,8	3,00	

PUMPIMG TEST OF THE NOSSA SENHORA DO Ó WELL

2nd STAGE

PUMPED WELL

DATE	HOUR	MINUTES		D.L. (m)	REDUCTION (m)	REMARKS
		ACCUM:	AVERAGE			
26.07/74	22:00	1	1	8,32	1,32	
		2	1	8,32	1,32	This stage was carried out in the same conditions as the first.
		3	1	8,32	1,32	
		4	1	8,29	1,29	
		5	1	8,24	1,24	
		7	2	8,64	1,64	
		9	2	8,73	1,73	
		11	2	8,73	1,73	The pumping was started with a residual reduction of 3 m.
		13	2	8,76	1,76	
		15	2	8,79	1,79	
		20	5	8,86	1,86	
		25	5	8,90	1,90	
		30	5	8,94	1,94	
		40	10	9,04	2,04	
		50	10	9,16	2,16	
	23:00	60	10	9,18	2,18	
		70	10	9,23	2,23	
		80	10	9,32	2,32	
	23:30	90	10	9,35	2,35	
		110	20	9,44	2,44	
27/02/74		130	20	9,46	2,46	
	00:30	150	20	9,59	2,59	
		180	30	9,74	2,74	
		210	30	9,83	2,83	
		240	30	9,90	2,90	
		300	60	10,05	3,05	
		360	60	10,18	3,18	
		420	60	10,33	3,33	
	06:00	480	60	10,46	3,46	
		540	60	10,58	3,58	
		600	60	10,66	3,66	
		660	60	10,75	3,75	
		720	60	10,83	3,83	
		780	60	10,85	3,85	
	12:00	840	60	11,04	4,04	
		900	60	11,12	4,12	
		960	60	11,21	4,21	
		1020	60	11,38	4,38	
		1080	60	11,42	4,42	
		1140	60	11,44	4,44	
	18:00	1200	60	11,50	4,50	
		1320	120	11,65	4,65	
		1440	120	11,77	4,77	
	24:00	1560	120	11,90	4,90	



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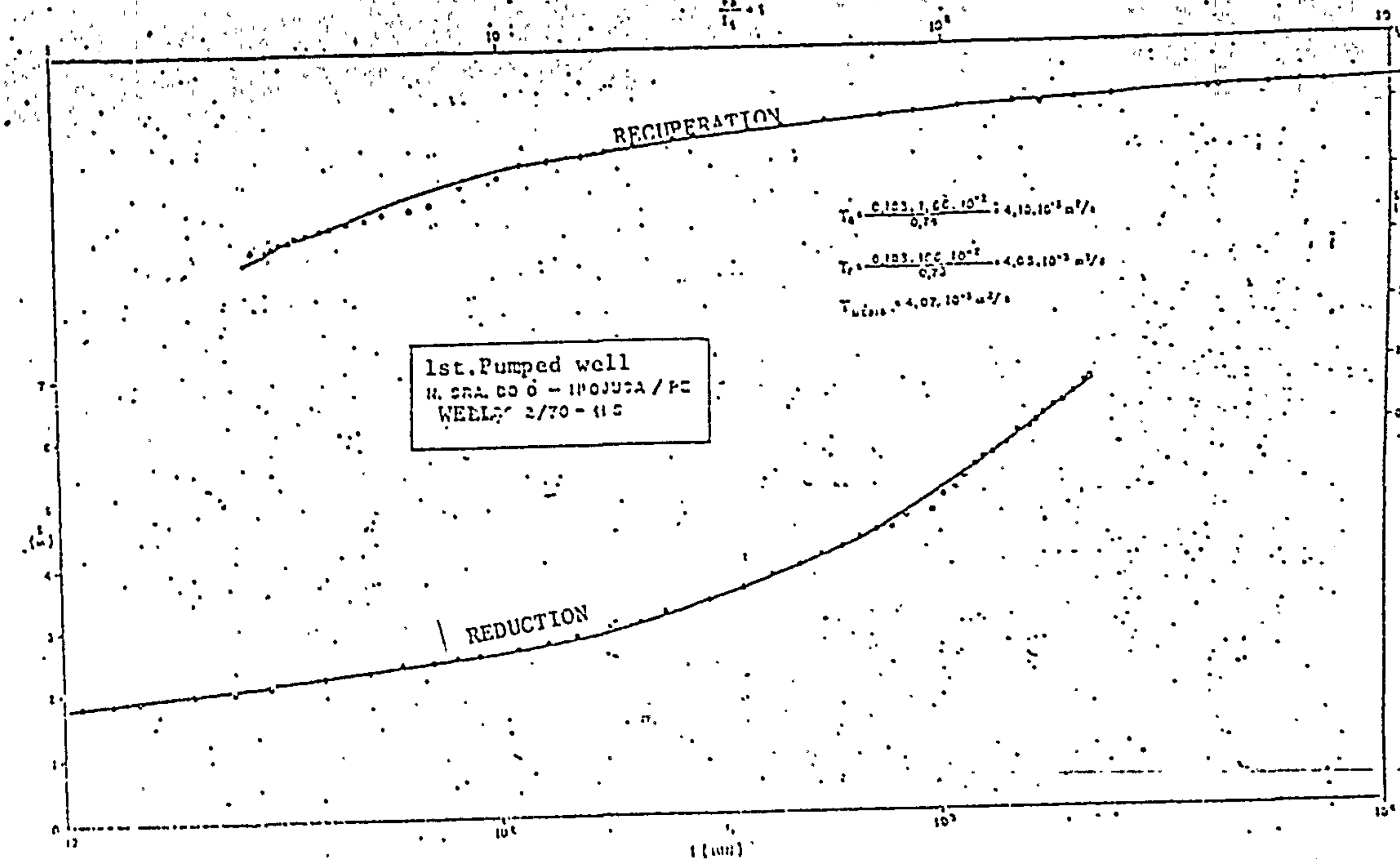
TRANSCON S.A.

GOVERNO DO ESTADO DE PERNAMBUCO

DE PERNAMBUCO

COMPLEXO INDUSTRIAL DE SUAPE



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COMPLEXO INDUSTRIAL DE SUAPE

F HYDRODYNAMIC CHARACTERISTICS OF THE AQUIFERS

a) Coefficient of transmissivity - T

The fall and recuperation curves (figs. IV-3 and IV.4) of the two stages of the pumping made it possible to estimate the coefficient of transmissivity using Jacob's method, equivalent to $4,16.10^{-3} m^2/s$.

b) Coefficient of Permeability

An analysis of the profile of both wells showed that the aquifer that was used is confined from above by an aquaclude at 48 m, and from below by another horizon, semi-confining, (aquitard) situated at 75 m.

The total thickness of the aquifer, as far as can be told due to the limited knowledge of the regions stratigraphic column, is therefore 75 - 48 = 27 m. (If the aquifer is thicker, the aquitard situates between 75 and 80 m is an intercalation).

Therefore, the well used is, in these conditions, partially penetrating.

Considering the 27 m thickness, the average permeability of the aquifer is of average $K = 1,5.10^{-4} m/s$

G DETERMINATION OF THE LOSS OF LOAD OF THE WELL

The lowering due to the loss of load, in the case of a partially penetrating well is given by:

$$\left(h_{2b} - h_w = \frac{Q\,p}{4\pi K} \frac{2}{h_s} \cdot \ln \frac{\pi h_s}{2r_w} + \frac{0,2}{b} \right)$$

where:

$h_{2b} - h_w$ = Lowering
Q_p = flow = $1{,}66.10^{-2}$ m^3/s
h_s = penetrated thickness of the aquifer = 15 m
b = thickness of the aquifer = 27 m
$2\ r_w$ = diameter of covering = 0,15

The value obtained was $h_{2b} - h_w = 6{,}64$ m

The measured lowering being 6,74 m, the actual loss of load is only 0,1 m, corresponding to 1,5%, which shows that the well was very well developed.

H   Production capacity of the well

a)   Partially penetrating well

Since the base of the confining layer is situated at 48 m, this will be the limit of the pumping chamber.

To be exploited by airlift (direct injection into the covering), the maximum lowering will be 27 m (ND = 31 m), and, for exploitation with an immersion pump, the maximum lowering will be 39 m ND = 43 m). In the latter case, the pumping chamber would need to have a diameter larger than the diameter of the well.

Let us see the flows that could those of the isolated, partially penetrating well, for these lowerings, through the use of the equation:

$$Q_p = \frac{4 \Pi K}{\frac{2}{h_s} \ln \frac{\Pi h_s}{2r_\omega} + \frac{0{,}2}{b}} (h_{2b} - h_\omega)$$

in which we already know the symbols

For $h_{2b} - h = 27$ m:

$$Q_p = \frac{4.3,14.1,5.10^{-4}}{\frac{2}{15} \ln \frac{3,14.15}{0,15} + \frac{0,2}{27}} \cdot 27$$

$Q_p = 6{,}58.10^{-2}$ m^3/s or

$Q_p = 236$ m^3/h.

Para $h_{2b} - h_w = 39$ m, we should have

$Q_p = 9{,}5.10^{-2}$ m^3/s,

$Q_p = 342$ m^3/h

If we admit a sfatey margin of about 10%, we could adopt:

$$Q_p\ (27) = 200\ m^3/h$$

$$Q_p\ (39) = 300\ m^3/h.$$

b) Totally penetrating well

If the pumped well had completely crossed the aquifer, the flow would be higher than the one obtained. The following formula allows the definition of what the flow would be:

$$Q = \frac{(b/_{hs}.\ \ln \pi\ hs/\ 2r_\omega) + 0{,}10 + \ln (r_o/\ 2b)}{\ln (r_o/r_\omega)} \times Q_p$$

Where:

Q = flow of the totally penetrating well
Q_p = flow of the partially penetrating well = $1,66.10^{-2}$ m^3/s
$2r_w$ = diameter of the well = o,15 m
r_o = influence radius = 300 m (adopted)
b = Thickness of the confined aquifer (drilled = 27 m
h_s = thickness of the aquifer = 15 m

By the subsitution of values, we get:

$$Q = \frac{27/15 \times 2,303 \times 10 \frac{3,14 \times 15}{0,15} + 0,10 + 2,303}{2,303 \times \ln \frac{150}{0,15}} \times \ln \frac{300}{54} \times 1,66.10^{-2}$$

$$Q = 1,75 \times 1,66.10^{-2} = 2,9.10^{-2}\ m^3/s, \text{ ou}$$

$$Q = 104,0\ m^3/h.$$

Considering the above result, and the test flow for a partially penetrating well, we reach the conclusion that in order to transform the flow of the latter into that of the former, that is from partially to totally penetrating, it is sufficient to multiply the flow by 1,75.

Thus, in the case of the well under study, and for a lowering of 27 and 39 m., respectively, we should have, when totally penetrating:

$Q_{(27)}$	= 350 m^3/h
$Q_{(39)}$	= 525 m^3/h

I ANALYSIS OF THE RESULTS

The final conclusion of the pumping test is that, on the basis of the available information, and for the conditions of the city of Nossa Senhora do Ó, it is pssible to build wells that supply flows of 300 to 500 m^3/h.

This result admits the following restrictions:

- The curves of level reduction showed the existence of frontiers with a lower permeability, which implies lowerings greater than those obtained for a longer pumping time;

- After pumping for 36 hours, the well had not yet reached the stsionary regimen;

- All the mathematical development was based on the assumption theat the aquifer is both intensive and homogeneous and that only one well would be operated. For the exploitation of a set of wells, it would be necessary to undertake further and more detailed studies about the interferences produced by the reduction cone of a well upon the others, that is its area of influence.

- The recharging water is very close to the possible exploitation area

- As was mentioned in the chapter concerned with the chemistry of the water, the Nossa Senhora do Ó well must have impounded some water from the free aquiferous, due to bad insulation during construction. This fact causes an increase in the pumped flow, the results obtained being thus higher than the actual ones.

Even considering these restrictions, the preliminary results obtained suggest that there is an appreciable hydric reserve in the ground of the region of Nossa Senhora do Ó, that should be studied in more detail, including the area that is of interest to Suape Complex.

Even though the appreciable low determined by mathematical calculation, based on the determined hydrodynamic parameters might not be exploited in the context of a set of wells, and that it should be restricted to, say, 150m^3/h per well; we shall still have a very low unit price for the m^3, as we shall see later.

5.6.6 COST OF THE WATER FROM THE WELLS

Considering:

- an average depth of 80 m
- the present costs of drilling and studies,
- a flow oh 150 m^3/h per well,
- a lithologic sequence of the Nossa Senhora do Ō wells (approximately)
- a pumping schedule of 12/24 hours,
- a useful life of 20 years,
- that the exploitation should be by an electric immersion pump,
- that the recommended materials should be used,

we shall have the following costs for the well:

A - COSTS REFERRING TO THE WELL (INCLUDING INSTALLATION AND TECHNICAL FOLLOWING

a) Drilling

In 20" ∅	48,0 m x Cr$ 600.00	Cr$ 28.800,00
In 11 1/2" ∅	32,0 m x Cr$ 450,00	Cr$ 14.400,00

b) Lining

In patent iron pipe 12" ø = 49 m x Cr$ 550,00	Cr$ 26.950,00
In galvanized pipe 6" ø = 8 m x Cr$ 250,00	Cr$ 2.000,00
In 6" ø NOLD stainless filter = 27 m x Cr$ 2.000,00	Cr$ 54.000,00
Cost of placing lining. 35%	Cr$ 29.032,00

c) Pre-Filter

1,5 m^3 x 500,00	Cr$ 750,00

d) Cement

190 bags at Cr$ 60,00	Cr$ 11.400,00

e) Development

24 hours at Cr$ 250,00	Cr$ 6.000,00

f)

Flow Test

48 hours at Cr$ 250,00	Cr$ 12.000,00
g) Miscellaneous expenses	Cr$ 13.200,00
h) Pump, installed	Cr$ 100.000,00
i) Hydrodynamic study and technical supervision	Cr$ 20.000,00

365(days) x 20 (years) x 12 (hours of pumping) x 150 m^3/h) =
$13,14.10^6 m^3$/20 years, The cost of the cubic meter of water shall be:

$$\frac{31,85.10^4}{13,14.10^6} = \text{Cr\$}0,024/m^3$$

B COST OF PUMP OPERATION

The hourly operating cost of the pump is indicated by

$$\frac{\text{Flow x head x 0,746 x cost of Kwh}}{\text{3960 x efficiency of the pump and efficiency of the motor}}$$

Flow 150 m^3/h or 660 gpm
Head: 60 m = 196.8 feet
Efficiency of the pump = 70%
Efficiency of the motor = 90%
Cost of Kwh

$$\frac{660,196,8 \times 0,746.\ 0,1}{3.690 \times o,7 \times 0,9} =$$

For 150 m^3/h, the cost of operation of the pump is Cr$ 0,034/m^3

C COST OF MAINTENANCE OF THE PUMP

Assuming that the annual conservation cost of the pump is equivalent to 10% of the cost of the pump installed, that is Cr$ 10.000,00, this represents Cr$ 0,015/m^3 for annual flow of 657.000 m^3.

D COST OF THE PUMP OPERATOR

Assuming that the pump will be operated by an employee whose monthly salary (including all expenses) should be equivalent to Cr$ 2.000,00, this expense increases the cost of the cubic meter by Cr$ 0,037.

E TOTAL COST OF THE CUBIC METER OF WATER

- Equipped well	Cr$	0,024
- Operation of pump (power)	Cr$	0,034
- Maintenance of pump	Cr$	0,015
- Operation of pump)operator)	Cr$	0,110

The approximate cost of the cubic meter of water from the standard well studied is equivalent to Cr 0.11 (11 centavos)

As has already been seen, the value obtained for a cubic meter refers to water from a well similar to those that exist in Nossa Senhora d Ó.

It is obvious that the cost of the water from a well taht reaches a depth of say, twicw as deep as the one examined will not rise in the same proportion as the depth of the well.

It can be seen that the construction and installation of the well under study represents barely 21% of the cost of the cubic meter of water, proving that the fixed expenses get diluted according to the time of use of the system of impoundment.

On the other hand, and always within that condition, the increase in cost will certainly be lessened through a higher flow and by less significan reductions in level.

TOMO I - 6.0

FÔLHA SEGUINTE A 1-6/6 NÃO ESTÁ NUMERADA
OU DA 1-6/10 PRA 1-6/13

6.0 - ANALYSIS OF THE CLIMATIC ELEMENTS

6.0 ANALYSIS OF THE CLIMATIC ELEMENTS

6.1 PURPOSES OF THE STUDIES

The present analysis corresponds to an attempt at a closer approximation to the local climatic conditions, with their individualizations, through a rhythmical analysis and that of the various types of climate that might exert an influence on the regional ecology. For this reason, among available data, we preferred to select the most recent and complete series, referring to the data of the village of Curado in the 1967 to 1972 period.

The preoccupation with the genetic order prevailed, starting from the zonal circulation to reach the cellular, with th intention of characterizing the chains or types of weather regulated by the regional atmospheric circulation. However, the monthly data were not completely left aside, or even the very "climatological norm" for the period between 1931 and 1960, that served as a starting point for the comparison and correlation of the behaviour of the elements of the climate during the considered period, through the notion of rhythm.

6.2 BEHAVIOUR OF THE CLIMATIC ELEMENTS

6.2.1 REGIONAL ATMOSPHERIC CIRCULATION

The region of Recife is all year round under the predominance of the Equatorial Atlantic Mass, according to the studies of Adalberto Serra and Leandro Ratisbonna.

This mass is constituted by the trade winds from the Southeast and the East, originating in the high pressure of the hot and humid region of the South Atlantic (semi-fixed anticyclone).

The Equatorial Atlantic Mass is composed by two separate currents: a lower current, rather cool and humid (cool, because it is "old" polar air, and humid because it originates over the ocean, and thus absorbs a great oceanic evaporation that is accelerated by a strong surface wind), and another, higher, very hot and dry because of the stron temperature inversion that separates it from the first (superficial), not allowing that both should mix, the vapour remaining concentrated in the superficial current, and the lower the altitude, the higher the tenperature.

When both currents reach the oriental shore of the Northeast, the thermal discontinuity that was rising and weakening, descends rapidly, permitting the violent ascension of the two layers of trade winds. The first, being almost saturated, cools off according to the humid adiabatic gradient, provoking a fall in the temperature at the higher altitudes and a strong superficial instability that produces continuous rainfalls of the littoral. This occurs more frequently during the winter months, when the Equatorial Atlantic Mass covers a major part of Brazil, and in the autumn, when this Mass suffers an interference from the air originating from the Intertropical Front (FIT) that attains at that time of the year it southernmost position on the Brazilian coast.

Having crossed the littoral in the direction of the interior, after the mountainous barrier of Borborema, the hot and dry air of the second current descends, originating a high pressure cell, with a higher frequency in the Spring and Summer months.

Therefore, the constant actuation of the Equatorial Atlantic Mass, in its lower current, is responsible for the rhythmic regularity of the region's climatological elements and for the pluvial regimen. This regularity is, at times, disturbed by the repercussion of the Intertropical Frontand, very rarely, by the repercussions of the Atlantic Polar Front brought by the migratory polar anticyclone, and on those occasions appear slight deformations in theclimatic elements and in the pluviometric quantitatives.

6.2.2 TEMPERATURE - PRESSURE BINOMIAL

The temperature and pressure being physical properties of the atmosphere, and the region being permanently uner the control of the Equatorial Atlantic Mass, of well defines properties, it is obvious that the degree of variation of these elements over the months will be kept to a minimum.

The average annual temperature of the region, in the period considered, (1967-1972) was 25,4ºC, the month of february being the hottest with a compensated average of 26,9ºC, yet quite similar to the other Summer months, since the amplitude of the variation was always less than o,6ºC. Generally speaking, the average temperature of the Summer months is between 26ºC and 27ºC, this last values only having been exceeded in January and February 1967.

Similarly, the degree of variation in the winter months is small, almost 1ºC, showing sometimes July, sometimes August to be the least hot month, with average temperatures descending to 23,8ºC.

In the winter, these compensated average temperatures are between 23,4ºC (july i167) and 25,2ºC (September 1972)

In the intermediate stations, the autumn months show temperatures comparable to those of the winter months, because of the concentration of the rains in this oeriod, the values being between 23,7ºC and 26,4ºC, while in the Spring, these values range between 23,4ºC and 27,1ºC.

What can be noticed, therefore, is a small ampiltude in annual variation that is alzays less than 4ºC, even in the contrastin seasons.

These high average temperatures are a constant of the coastal region of Pernambuco, end they emphasize the rather cadenced rhythm with a minimum alternance between the hotter and less hot months.

Similarly, the average maximum and minimum values(average of the maximums and average of the minimums) obey to a rather uniform rhythmic command, even to the degree of variation. The annual value of the average of themaximums, 29,1ºC, rises to 30,5ºC in February, going down to 27,3ºC in July, while the average of the minimums, tha is 21,9ºC varies between 22.8ºC in March (February 22,7ºC) and 20,7ºC in August showing a smaller reduction in thevariation amplitude.

In the same way the absolute maximum values, although they are always above 30ºC, do not exceed 32,7ºC, while the absolute minimums range between 17,1ºC and 20,1ºC, the lowest values occurring frequently in August.

Normally, it can be seen that during 8 months of the year, the values included between the average of the maximums and the absolute maximums are higher than 30ºC (January-June and November-December), but only rarely do they exceed 32ºC, as was the case in February 1969 (32,6ºC).

The year 1969 is particularly noticeable for showing a set of these values above 30ºC, something that could be explained by the fact that it was a characteristically dry year for the region.

Such facts show clearly the uniformity of actuation of the dominating atmospheric system (Atlantic Equatorial) with a predominance of Southeast and East winds, guaranteeing coolness and a temperature uniformity to the region of Recife, situated at a latitude of 8º from the Equator.

This remarkable rhythmic regularity of the temperature of the air, obviously, is repeated with the same synchronism in the behaviour of the atmospheric pressure. that is, in average figures, of 1011,1 mb all through the year. This value falls to 1009.2 mb in March, rising to 1013.7 mb in July and August, demonstrating a certain constancy in barometric value of the center of action of thesemi-fixed anticyclone of the South Atlantic, the original source of the Atlantic Equatorial Mass.

The seasonal distribution below condenses in a very clear way the beahviour of the binomial of the physical properties of the atmosphere: temperature and pressure.

PERNAMBUCO - SEASONAL DISTRIBUTION OF PRESSURE AND TEMPERATURE

SEASONS	PRESSURE (mb)	AVERAGE MAXIMUMS (º C)	AVERAGE MINIMUMS (º C)	COMPENS. AVERAGE (º C)	ABSOLUTE MAXIMUMS (º C)	ABSOLUTE MINIMUMS (º C)
SUMMER	1009.3	30º2	22º7	26º6	32º6	19º7
AUTUMN	1010.8	28º6	22º2	25º1	32º1	18º7
WINTER	1013.6	28º0	21º1	24º1	32º7	17º1
SPRING	1010.8	29º8	21º8	25º7	32º0	18º3

6.2.3 INSOLATION, NEBULOSITY, EVAPORATION, HUMIDITY AND PRECIPITATION

The average annual insolation id Recife, in the period between 1967 and 1972 was 2.805,4 hours, while the nebulosity reache 6,2, the evaporation attained 1.221,6 mm, the relative humidity stood at 79,5% and precipitaion totalled 2.278,9 mm, with the following distribution over the seasons:

SEASONS	INSOLATION (h ..)	NEBULOSITY (0 - 10)	EVAPORATION (mm)	HUMIDITY (%)	PRECIPITATION (mm)
SUMMER	711.9	5.9	326.7	77	420.6
AUTUMN	597.3	6.9	188.4	86	1096.5
WINTER	652.8	6.5	277.5	81	646.2
SPRING	843.4	5.5	429.0	74	115.6

This shows that the larger number of hours of insolation is concentrated in the spring and in the summer, exactly at the time when rainfalls increase and when nebulosity is least, the sky remaining covered between 5,5 qnd 5,9 parts, due to the greater displacement of the center of action of the semi-fixed anticyclone in the direction of the ocean.

Conversely, when this center of action comes closer to the continent (autumn winter), there is an accentuation of the condensation process through the ascension of the trade winds. The sky shows from 6,9 to 6,5 parts covered. Rainfalls are frequent and, consequently, there is a sharp reduction of the insolation hours to 597,3 hours in the autumn and 652,8 in the winter.

Evaporation and relative humidity follow rigorously the same rhythm, imposed by insolation and nebulosity. Thus, the maximum values (in millimeters) for evaporation occur in the spring (429.0 mm) and summer (326,7 mm) when the hours of insolation are at their highest and the incursions of the east wind qre at their lowest, this being reflected directly by the low relative humidity that settle between 74% respectively. The lowest evaporation values appear in the autumn, (188,4 mm) and in the winter (277,5 mm), the relative humidity rising to 86% and 81%.

Since it could not be otherwise, considering the elements described, the average distribution of rainfalls varies in the same ratio as those climatic components during the seasons. Thus, we can see that 77% of the rains of the region are concentrated in the months of the autumn and the winter.

GRAPH

MONTHLY VARIATION IN THE RHYTM OF THE CLIMATIC ELEMENTS

COASTAL REGION OF PERNAMBUCO

1) - Precipitation

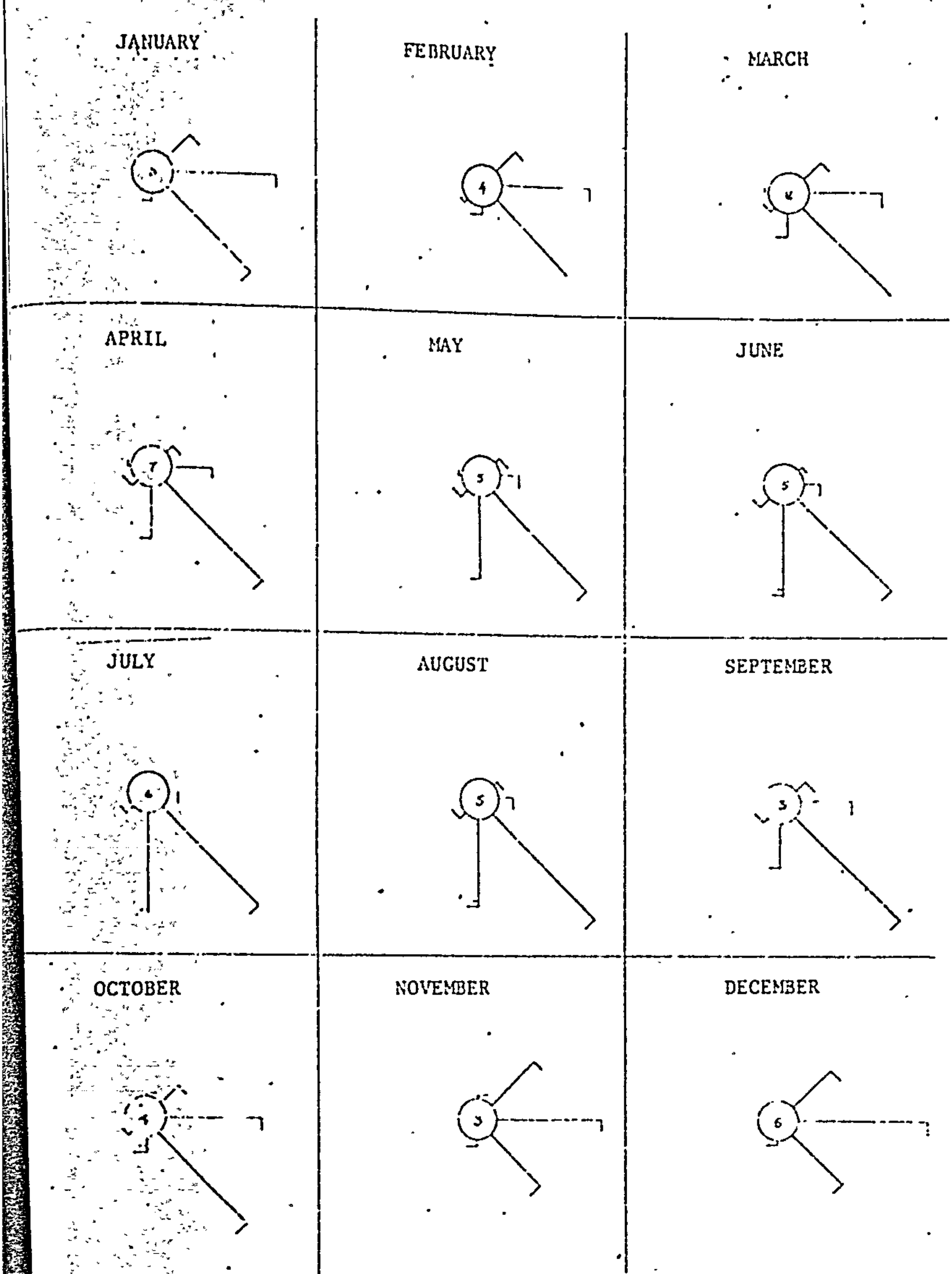
2) - Temperature

3) - Evaporation

4 - Insolation

5) - Relative humidity

6) - Pressure



0 10 20 30 40 50 100%

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MONTHLY REPARTITION OF THE WINDS

The medium height of rainfalls during the period 1967-1972 was 2.278.9 mm, varying between 2.046,6 mm in 1972 and 2.912,0 mm in 1970 (not considering the year 1968 for lack of data in the month of February).

The months with most rainfalls alternate between March, April, May, June and July, this period extendig at times into August, as was the case in 1970, when we had the month with most rains in the period, with 626.0 mm.

The dry period shows more regularity, the months of October, November and December proving to be the driest, with rainfalls below 60 mm per month, that may frequently be as low as 10 mm in the month of October, as happened in 1967, 1968 and 1972.

This dry period (below 60 mm) is either expected for September (1967) or may extend to January (1967 to 1972) and February (1969 and 1971), but it never exceeds 4 months.

Finally, if we intend to compare the meteorological data included between 1967 and 1972 with "normal" data for the 1931 to 1960 period, although the rhytmic identity between the elements and a better characterization of both the rainy period and the dry period, there is a certain differentiation of values, which is at times significant. This comes from the excessive abuse of averages that characterize the climatological "normals" and greatly disguise the values.

6.2.4 WINDS

The mere observation of the monthly distribution of wind in Recife graph seems to prove clearly the predominance of actuation of the system constituted by the Atlantic Equatorial Mass.

The predominance of the winds originating from the southeast is quite significant and is responsible for 44.9% of the total frequency, followed by the east winds that participate with 23,3%.

The actuation of the southeast winds, during 10 months of the year, is in excess of 40%, even reaching 50% to 55% in the months that correspond to the autums and winter. only during the months of November and Dexember, when the Semi-Fixed Anticyclone starts to recede away from the land, does the frequency fall for 28%, being replaced by the east winds which are felt significantly until March, when an increase of the participation of winds originating in the south is felt, when the latter start dividing the frequency with the southeast wind until the month of August, when its participation starts diminishing until it practically disappeas in December.

The participation of the south wind in the autumn and wither months seems to be a consequence of the great approach towards the contient of the South Atlantic Semi-Fixed Anticyclone which, whirling counter-clockwise, causes the change of the flux from southeast to south, more than the effect of polar invasions carried by the Migrating Polar Anticyclone, since it is cinfirmed by SERRA and MONTEIRO that only rarely, in exceptional conditions, does the Polar Front reach the latitude of Recife, although its indirect effects may make themselves felt even wehn the Polar front atuates on the coast of Bahia.

The participation of the northeast and southwest is insignificant, and the period of lull is also short.

The speed is quite uniform, keeping predominantly between 2 and 4 meters per second. This value is only exceeded by the south wind, in the winter months, when it may reach the speed of 4,6 m/second.

Generally speaking, the speed of the wind in the region increases during the autumn and wither months, due to the approach of the center of positive action of the Semi-fixed Anticyclone towards the continent, that, attending the stronger attraction of the continental depressive area, causes an increas in the speed of the wind.

Succinctly, the distribution of the anemometric observations in Recife, during the period 1931 to 1960 showed the following:

Direction	Frequency	%	Speed (m/sec)
SE	492	44.9	3,2
E	255	23,3	2,8
S	177	16,2	3,7
NE	87	7,9	2,7
C	59	5,3	-,-
SW	21	1,9	2,6
W	3	0,3	1,9
N	2	0,2	4,3

6.3 DEFINITION OF CLIMATIC DYNAMICS

6.3.1 The regional circulation and the Subsystems

As was already mentioned, the coastal region of the State of Pernambuco is, during the whole of the year, under the predominance of a single cell, represented by the South Atlantic Semi-Fixed Anticyclone, the original source of the Atlantic Equatorial Mass, with very well defined physical characteristics.

This circulation, while predominant and uniform, is at times disturbed by the indirect action of the polar flux, when the latter displaces the Polar Front to the level of the Bahia coastline. This disturbance is more noticeable at certain periods of the autumn and winter, when appears, close to the shore, a strip of lull, originating from the convergence of the northeast and southwest trade winds. This is the moment when rainfalls are heavier in the region.

However, the great oscillations that happen in the system are associated to the migratory movement of the Anticyclone over the seasons of the year, either approaching, or receding from, the shore, conjugated with the latitudinal mobility, which determines an alternation in the predominant direction of the winds that suffer a torsion from Southeast to East.

It is as a consequence of thispatterned and little disturbed circulation that we decided in our analysis, to adopt a methodological treatment at the level of 'subsystems' determined by the frequency of the winds and conjugated with the overcast which, in last resort, reflect the regional peculiarities and atmospheric phenomena.

This habitual sucession of peculiarities and phenomena constitute actual "chains" that will be te source of the differnt types of weather.

Thus, we were able to identify, through a daily rhythmical analysis, during the years 1970-1972, the subsystems below that, through its peculiarities, both physical and individual, and through the physical phenomena that they determine, constitute actual "type of weather chains".

6.3.2 Subsystems Identified in the Region

a) Southeastern Atlantic Equatorial Anticyclone

This is the subsystem with the highest frequency in all the seasons of the year, and the one that is responsible for the great pluviometric qauntitatives of the region, especially in the autumn an winter, when its participation is more significant, and always in excess of 72% while not reaching 84,8%.

The temperatures that result from the actuation of the subsystem of the Southeast are high, only eventually falling below 20ºC (24 hours C.G.T.), or exceeding 30ºC (18 hours CGT) either in the rainy season, or in the dry season, while the temperature of 12 hours C.G.T. appears on a rather uniform rhythm, standing between 25ºC and 29ºC according to the season of the year and the overcast.

As a result of these uniformly high temperatures, low pressures appear, oscillating between 1010 and 1013 mb in summer, autumn and spring, rising to 1015 and 1016 mb in the winter.

The insolation varies as function of the overcast and the duration of the rainfalls, but, generally, it is of about 6 to 9 hours a day, reaching higher values in the spring and summer months, which determines an evaporation in excess of 5 mm perday during those seasons, falling to 2 and 3 mm in the autumn and winter.

Consequently this evaporation will have its refelctions on the realtive humidity which is always in excess of 75%-80% in the two first observations, reaching 90% and even 95% at the end of the period.

The replacement of this subsystem by that of the East and of the convergence of winds(most characteristic situation) is forecast by a reduction in the speed of the wind, the sky shows an overcast of more than 7/10, causing a reduction in the insolation and an increase in the percentage value of relative humidity, refleted in an oscillation of the temperature of between 2ºC and 3ºC less, causing a tendency for an increase of atmospheric pressure.

The modification for the southern and northeastern system is followed by an increase in the speed of the wind, while the temperature, for the southern subsystem shows an oscillation, for less of 3ºC to 4ºC, the sky is almost totally overcast, reflecting an increase in relative humidity and an increase in atmospheric pressure; for the notheastern subsystem, the sign is a paralyzation of the wind at the end of the period, followed by a sudden increas in speed. In this case, there is a slight increas in temperature due to the clearing of the sky and to the reduction of the relative humidity, causing the increase in the insolation hours, and causing a tendency for the reduction of the atmospheric pressure.

b) Eastern Atlantic Equatorial Anticyclone

This subsystem is determined by thedisplacement of the semi-fixed anticyclone in the direction of the ocean, from the beginning of spring to the end of summer.

The temperatures at 12 hours C.G.T. are higher than in the previous system, and are more regularly distributed between 26ºC and 28ºC, frequently attaining 30ºC in the spring and summer. Only rarely do the minimums dall to 22ºC, while the maximum values often reach 30ºC and 32ºC, but only rarely do they exceed the last value.

Together with these high temperatures, there is an almost uniform low pressure, between 1010 and lol2 mb, and this rhythm is only raslightly disturbed in winter, when the values settle at lol3 and 1014 mb.

This high and uniform temperature is caused by the number of hours of insolation, almost always in excess of 6 hours a day, and frequently attaining 9 or 11 consecutive hours,, which will cause an evaporation of between 3 and 5 mm a day, reflecting the degree of humidity in the atmosphere, between 80%-90%, and even 95% at the end of the period.

The eastern subsystem, although deriving from the previous one, is responsible for an insignificant quantity of rain, a fact that seems to have an explanation in the greater distance from the center of action at the time the subsystem is most active (spring - summer).

The alteration in the actuation of the Eastern Subsystem is most often caused by the Southeastern Subsystems and the convergence of the winds.

In the first case, hours before its installation, the wind stops suddenly, and increases in speed the next day. Although the sky may remain partially overcast, the relative humidity usually diminishes, while the atmospheric pressure oscillates with a tendency to increase. The temperature, on the other hand, shows only a small oscillation of 1ºC or 2ºC, as a result of the increase in the number of hours of insolation.

With the approach of the Subsystem with Convergence, the speed of the wind abates gradually until the lull appears. The sky is overcast, which prevents solar radiation, and the temperature falls from 2ºC to 3ºC.

The relative humidity increases greatly, causing heavy rains, while the rpessure is rather irregular.

c) Southern Atlantic Equatorial Anticyclone

We identify this subsystem through the higher predominance of southern wids, either originating from the istallation of the center of action of the semi-fixed anticyclone close to the continent, more often in the autumn and winter, or from the indirect actuation of the flux that originates from the migratory polar anticyclone, when it dynamizes the polar front as far as the coast of Bahia.

Its presence is connected with a high plusviosity that reflects the reduction in the number of hours of insolation, that only occasionnally exceed 9 hours a day, thus causing a slight decline in the temperature at 12 hours, to 26ºC, while the extremes stand between 20ºC and 22ºC (24 hours C.G.T.) and 28ºC and 30ºC (18 hours C.G.T.)

Atmospheric pressure may reach up to 1016 mb, but usually, and very constantly, it stands at 1010 and 1012 mb.

Evaporation is slight, ranging between 2mm qnd 3mm, due to the high relative humidity of between 80% and 95%, which most often turns into rain.

The first assumption already has been described,, while the second and the third are followed by an alteration in the speed of the winds and an excessive overcast, causing a reduction in the number of hours of insolation. The temperature shows higher variations, that frequently reach 5ºC, while the relative humidity and atmospheric pressure remain high.

d) Northeastern Atlantic Equatorial Anticyclone

In the spring, at the start of the migratory movement of the center of action of the semi-fixed Atlantic anticyclone towards the ocean, the northeast winds, originating from the Northern Equatorial Mass reach constantly the oriental shore of Brazil, originating a subsystem that is rather characteristic, although it does not disturb to any sppreciable extent the isobaric cinformation delineated by the Atlantic Equatorial Mass, especially since the winds are of low intensity, with a speed that is always below 2 meters per second, due to the great identity in barometric value between the two centers of action, North Equatorial and Atlantic Equatorial.

It is under the action of this system that we shall find the highest temperatures in the region, the values for 12 hours easily reach

28ºC and 29ºC and the extremes are between 23ºC and 32ºC, establishing a low atmospheric pressure (1010-1012 mb) and an insolation that is almost alzays in excess of 9 hours. This fact, however, does not increase much the value of the evaporation, that rarely excedd 6 hours, bringing a low relative humidity, almos always below 80%, and the consequent reduction in pluviosity that only occurs when the northeast wind stops blowing, or when the penetration of the southeast starts, but always at the end of the period.

The replacement of the northeast subsystem alternates either with that of the southeast or with that of the east, but rarely with that of Convergence of the winds.

In the first two situations, the effects are practically identical: the wind grows from moderate to strong, the temperature shows a slight oscillation, with a tendency to increas, which is reflected by the higher number of hours of insolation allowed by the smaller degree of nebulosity. The relative humidity and the atmospheric pressure fall at times in a significant manner, making the rains disappear.

The opposite happens at the time of the exchange with the northeastern Subsystems, and with the convergence of the winds.

e) Equatorial Anticyclone with Convergence of the Winds

The great distance between the center of action and the continent at certain times of the autumn and summer favours a convergence of trade winds from both hemispheres, resulting in a zone of lull close to the shore. This happens after 2 successive frontal passages in the south of Brazil, that reach low latitudes.

The result of this fact is the occurreme of rainfalls that may reach great heights, as happened on August 11, 1970 when 335.8 mm fell in barely 24 hours.

Therefore, such a subsystem is characterized by the absence of winds, which should provoke an increase in temperature. However this does not occur, because the constancy of the pluviosity prevents an isolation of more than 6 hours a day.

Thus, it is under the action of this subsystem that we find the lowest temperatures, either at 12 hours C.G.T. (22ºC-25ºC) or at 18 hours C.G.T. (26ºC to 28ºC), or at 24 hours CGT (20ºC-22ºC), noting a slight break in the rather symmetric rhythm of the preceding subsystems.

However, this reduction in the temperature is not followed by an increase in the atmospheric pressure, which remains, with great regularity, between 1010 and 1012 mb.

The reduction in temperature, together with the absence of wind and the excessive relative humidity of 80% to 95% are responsible for the evaporation rate, almost always below 2mm under the action of the Subsystem with Convergence of the Winds.

As for the mutations undergone by this subsystem, they should be considered the opposite of those decribed when we referred to the preceding subsystems.

6.3.3 ANNUAL RELATIONSHIP BETWEEN THE SUBSYSTEMS ASSOCIATED WITH PLUVIOSITY IN THE COASTAL REGION OF PERNAMBUCO

SUBSYSTEMS	1970				1972			
	Freq	%	Rains	%	Freq	%	Rains	%
A.E.A. de Sudeste	225	69,9	1.821,1	62,4	247	67,5	1.186,7	58,0
A.E.A. de Este	58	15,9	200,5	6,9	48	13,1	66,7	3,3
A.E.A. de Nordeste	23	6,2	27,5	0,9	30	8,2	29,6	1,4
A.E.A. de Sul	17	4,7	321,8	11,1	8	2,2	87,9	4,3
A.E.A. com Convergência de Ventos	12	3,3	541,1	18,7	33	9,0	675,7	33,0
T O T A L	365	100,0	2.912,0	100,0	366	100,0	2.046,6	100,0

6.3.4 SEASONAL RELATIONSHIP BETWEEN THE SUBSYSTEMS

<u>Summer</u>

SUBSYSTEMS	1970				1972			
	Freq	%	Rains	%	Freq	%	Rains	%
A.E.A. de Sudeste	61	67,8	243.5	47,9	66	72,5	87.5	33,7
A.E.A. de Este	22	24,4	133.4	29,3	5	5,5	14.4	5,5
A.E.A. de Nordeste	–	–	–	–	5	5,5	1.7	0,6
A.E.A. de Sul	–	–	–	–	2	2,2	24.4	9,4
A.E.A. com Convergência de Ventos	7	7,8	113.0	23,2	13	14,3	132.0	50,8
T O T A L	90	100,0	489.9	100,0	91	100,0	260.0	100,0

Autumn

SUBSYSTEMS	1 9 7 0				1 9 7 2			
	Freq	%	Rains	%	Freq	%	Rains	%
A.E.A. de Sudeste	77	84,6	857.5	74,6	66	72,5	503.3	51,1
A.E.A. de Este	1	1,1	8.0	0,6	5	5,5	9.4	0,9
A.E.A. de Nordeste	-	-	-	-	-	-	-	-
A.E.A. de Sul	11	12,1	209.3	18,2	6	6,6	63.5	6,4
A.E.A. com Convergência de Ventos	2	2,2	75.4	6,6	14	15,4	408,9	41,6
T O T A L	91	100,0	1150.7	100,0	91	100,0	985.1	100,0

Winter

SUBSYSTEMS	1 9 7 0				1 9 7 2			
	Freq	%	Rains	%	Freq	%	Rains	%
A.E.A. de Sudeste	78	84,8	704.6	58,7	69	75,0	512.6	75,4
A.E.A. de Este	5	5,4	32.6	2,6	14	15,2	30.9	4,5
A.E.A. de Nordeste	-	-	-	-	3	3,3	2.3	0,3
A.E.A. de Sul	6	6,5	112.0	9,3	-	-	-	-
A.E.A. com Convergência de Ventos	3	3,3	352.7	29,4	6	6,5	134.8	19,8
T O T A L	92	100,0	1.201.9	100,0	92	100,0	680.6	100,0

Spring

SUBSYSTEMS	1970				1972			
	Freq	%	Rains	%	Freq	%	Rains	%
A.E.A. de Sudeste	39	42,4	15.5	22,5	46	50,0	83.3	68,8
A.E.A. de Este	30	32,6	26.5	38.0	24	26,0	12.0	10,0
A.E.A. de Nordeste	23	25,0	27.5	39.5	22	24,0	25.6	21,2
A.E.A. de Sul	-	-	-	-	-	-	-	-
A.E.A. com Convergência de Ventos	-	-	-	-	-	-	-	-
TOTAL	92	100,0	69.5	100.0	92	100,0	120.9	100,0

SOURCE - Maps of meteorological observations and synoptic surface maps, 12 hour C.G.T. - Serviço de Meteorologia - Ministério da Agricultura

6.3.5 COMPARATIVE AND SEASONAL BALANCE OF THE PARTICIPATION OF THE SUBSYSTEMS AND OF THE SUCCESSION OF THE TYPES OF WEATHER ASSOCIATED WITH PLUVIOSITY

The comparative balance of the years 1970-1972 shows clearly the diversification of the pluviometric totals in the period under consideration.

The predominance of the southeast susystem was absolute, with a participation of 69,9% and 67,5%, respectively of the regional circulation.

It can also be seen that more than 50% of the rains over the years that were analyzed were under the responsibility of said system

This large participation of the Southeast subsystem, with peculiar physical characetristics that were already described, is present, at time in a relative manner, at other times in an absolute manner, all along all seasons, with a small excess in favour of 1972 against 1972 in the autumn-winter rainy season.

The frequency, that reaches in the spring 42.4% (1970) and 50,0% (1972) increases as the seasons of the year follow each other, until the percentage of 84,8% and 75,0% is reached in both winters. An almost identical fact repeats itself with the rains, their greater of smaller intensity depending on the longer or shorter duration of the period of installation of the subsystem.

The highest actuation rates correspond to two rainy seasons autumn-winter when the above-mentioned subsystem was present in 84.6% and 84.8% of the total circulation in 1970, this participation falling to 78.5% and 75,0% in 1970

On the other hand, the average duration of the actuation of the southeastern subsystem over the region was 3 to 5 consecutive days in 1970, and on certain occasions in the autumn-winter, we shall see it actuating for 6, 15, 16 and even 26 days uninterruptedly, (from August 31 to September 25, 1970) providing rather similar atmospheric conditions, and giving the idea od a regular "types of weather" chain.

In 1972, the stability of this subsystem rarely exceeded a period of actuation of 10 consecutive days, holding out more regularly for 3 or 4 days, after which it was replaced by another subsystem.

This longer persistenc explains clearly the 1.562.1 mm of rain in the autumn-winter of 1970, against the 1.015.9 mm in the same period of 1972

Therefore, the pluviometric quantitatives are proved to increase in a direct ratio of the numeber of days of persistency of the subsystem in the region. The longer the period it is dominant, the larger the total of rains.

Conversely, in the spring-summer the higher participation of the southeastern subsystem was in 1972. Although the larger participation is connected to the summer of 1972 (72,5%) against the summer of

1970 (67,8%), it is in that year that the greates number of days of persistency was noted in the region, often 7, 10, 11 consecutive days, in contrast with 1972, when only exceptionally did this domination exceed 6 days, which explains again the high pluviometric quantitatives of that season in comparison with the subsequent year.

The east subsystem, originating in the displacement of the semifixed anticyclone away from the continent, acted with higher intensity in 1971, when it made itself felt with 15,9% as against 13,1% in 1972.

Normally its frequency is significant in the spring months, diminishing in the summer until it practically disappears in the autumn, when it is replaced by the southeast subsystem.

Its domination rarely exceed 3 days, even in the spring when its participation is higher (32,6% and 26,0%, respectively), waning either in the autumn winter direction, as happened in 1970 (1,1% and 5,4%), or in the summer autumn direction, as in 1972 (5,5% and 5,5%).

The rains are practically absent from this subsystem. Those are rather weak precipitations that only occur at the end of the period, when the degree of humidity in the air increases. Their most important heights are recorded in the summer, but they are insignificant when compared to the preceding subsystem, since they do not exceed 11% of the annual total under its repsonsibility.

The northeast subsystem appears in the regional circulation almost exclusively in the spring (25% and 24% respectively of the seasonal circulation) when the northeast trade winds reach the east coast of Brazil, even though they are rather weakened.

It annual percentage did not exceed 1,4% in 1972, and 6,2 in 1970 when it was detected in spring, while in the preceding year, in spite of the reduction in frequency, it was only absent in winter.

Its main characteristic is high temperatures and an almost complete absence of rains, that do not even reach the 30mm per year index.

The time of persistency varied between 1 and 3 days, except in the spring of 1972 (10h to 22nd of December), where it stationed for 13 consecutive days, originating an impressive uniformity in the behaviour of the meteorological elements.

The participation of the south subsystem was insignificant - 4,7% and 2,2% in 1972 - and typical of the autumn-winter months, when it reached percentages of 12,1% and 6,5% in 1970, and barely 6,6% in the autumn of 1972. Its presence causes rains through the very fact of being constituted by winds from higher latitudes, therefore with lower temperatures, that, when contacting the warmer region, cause an elevation of the relative humidity, an increas in nebulosity and the occurrence of rainfalls, as was the case in 1970 when 11,i% of the rains (321,8 mm) were under its responsibility and 1972 with 4,3%, corresponding to 87,9 mm.

The major disruption in the rhythm of the climatic elements is associated with this system, in spite of its short period of actuation, that only occasionnally exceeded 24 hours.

As for the subsystem with the convergence of the winds, to which is also cinnected the genetic mechanism of the rains, its participation was slight, and it was more especially noted in 1972, when it participated in 9% of the circulation, as against 3,3% in 1970. Such percentages, even though rather small in general terms, contributed significantly with 18,7% and 33% of the total of the rains in the periods, that is 541,1 mm and 675,7 mm respectively.

The highest frequency of this susbsystem is felt in the summer-autumn, but with a rather significant difference between two years. While in 1970 7 and 2 frequencies are recorded, respectively, in 1972, they increased to 13 and 14, which caused a considerable increase in the pluviometric totals.

The predominance of this subsystem over the region is short, scarcely exceeding 48 hours, except in the period from April 26 to April 30, 1972 when it persisted for five consecutive days, causing the high pluviometric quantitative of 217,7 mm, that is more than 20% of the rainfall in the three autumn months.

6.4 CHARACTERIZATION OF THE CLIMATIC TYPE

The coastal region of Pernambuco has a sui generis type of climate, with high temperature al year round. There are two rainy seasons (autmn-winter) and two dry seasons, one more accented and characteristic (spring) and the other less rigorous and rather irregular (summer).

This climatic type, described by Professor Lusia Maria Cavalcanti Bernades as "Humid Tropical Climate with Autumn-Winter Rains" (As' in W. Koppen's terminology), originates in a unique and typical atmospheric circulation under the responsibility of the anticyclonic cell of the South Atlantic, with very well defined physical characteristics, that generates a chain of types of of weather that follow, and alternate with, each other in the various seasons of the year, yet always led by the southeast Subsystem, whatever the period. This subsystem is frequently replaced by that of the East or the Northeast, and, on a smaller scale, by the Subsystems with the Convergence of the Winds and of the South, that give continuity to the sequence, and, obviously to thenotion of rhythm, making it possible to perceive the various combinations of climatic elements between themselves, and to identify the relationships with the other elements of the local geographical picture.

The apparently uniform features of the atmospheric dynamics in this part of the country had already been understood clearly by Strahler, when he classified the oriental shore of the Northeast as under "the Predominance of the Humid Coastal Climate Exposed to the Tropical Sea Masses".

As for the Subsystems, we can say, briefly, that each one of them, with its well defined individual features, represent actual chains of types of weather in which can be noted clearly a perfect syntony of climatic elements, the constituents of which are very close and produce similar effects.

The larger or smaller participation of the subsystems detected in in a direct ratio of the greater or smaller distance of the semi-fixed South Atlantic aticyclone from the continent.

In the years when it is closest, as was the case in 1970, the duration of the period of actuation of the Southeast Subsystem os longer, and as a consequence, the pluviometric totals are higher. Conversely, when the distance is greater, as in 1972, the participation of this subsystem is less, in contradiction with the participation of the East subsystem, which causes a reduction in the pluviosity totals.

Therefore, the Subsystems of the Southeast, with convergence of the winds, and of the South generate rains, and were responsible, during the years covered by this analysis, for 92,2% and 95,3% respectively of the pluviometric totals of the region, while the East and Northeast subsystems are connected with a type of typically dry weather during which the rains have little signification, being below 7,8% and 4,7%, and not exceeding 100 mm per year.

7.0 - LEVANTAMENTO DA COBERTURA VEGETAL

7.0 SURVEY OF VEGETATIVE COVER

7.1 DISTRIBUTION OF AREAS

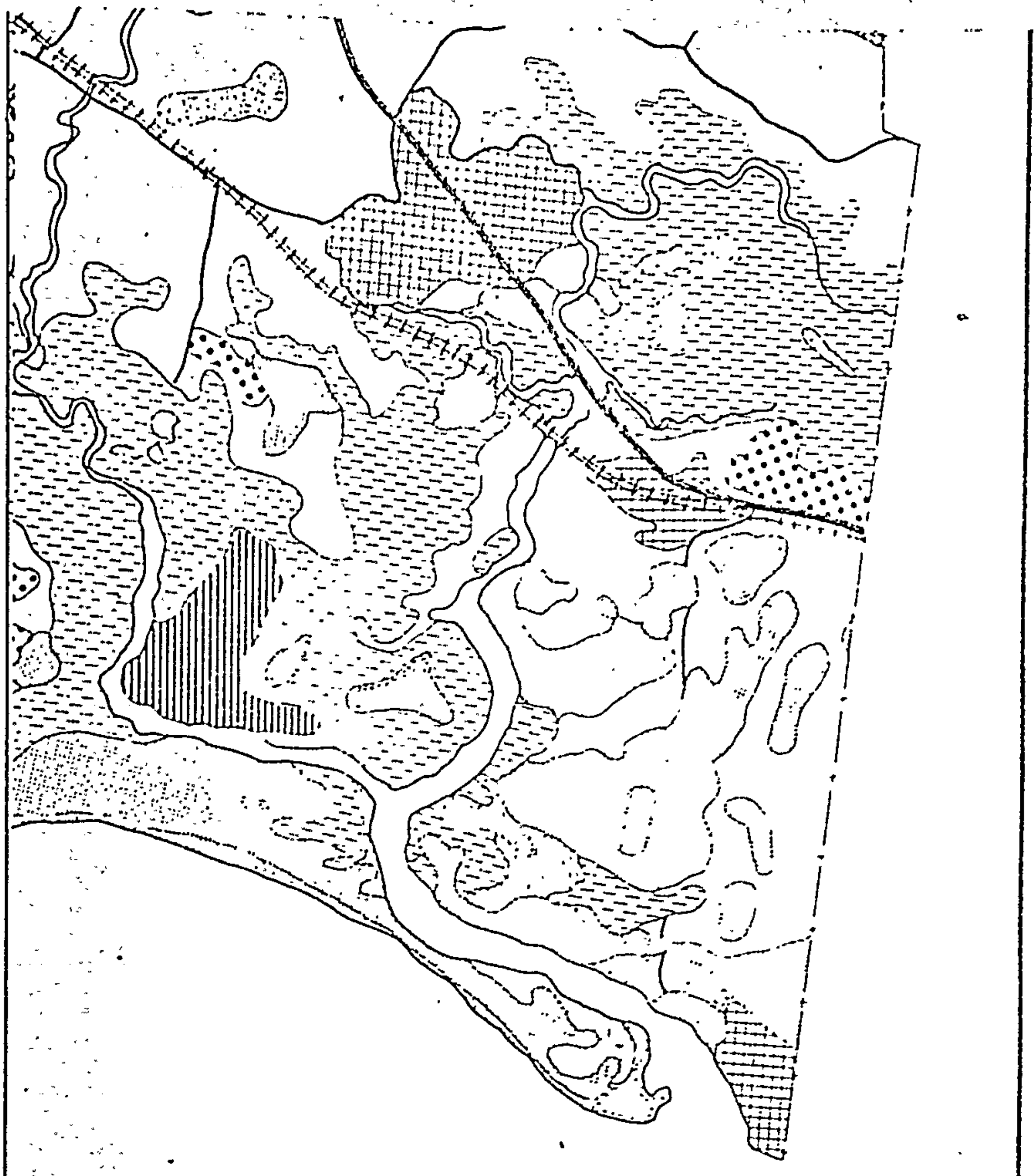
By means of the analysis of available aerophotogrammetric surveys, as well as through direct research, it was possible to identify the forest cover encountered in the region. From this data, other elements of the landscape were identified in order to form the following table:

LISTING	AREA KM^2	%
URBAN ZONE	7.21	2.48
MANGROVE SWAMPS	39.15	13.49
BEACHES	13.16	4.19
RESIDUAL WOODS	37.81	13.02
In high, well drained zones	9.00	3.10
In receding, well drained zones	3.96	1.36
In low, poorly drained zones	1.46	0.50
On sandy and rocky soil in ondulated landscapes	19.69	6.85
On sandy soil in dunes	3.50	1.21
COCOS NUCIFERA AND OTHERS	17.88	60.67
Cocos nucifera	17.46	6.01
Unidentified palms and trees (by photo)	0.42	0.14
SUGAR CANE	174.92	60.67
TOTAL	290.13	100.00

OBS: Areas were estimated with an approximate error of 2.5%.

The following inserted map summarizes the results transcribed.

The conceptualization of the units identified follows.



GOVERNO DO ESTADO DE PERNAMBUCO - PRAC
COMPANHIA DE DESENVOLVIMENTO INDUSTRIAL DE PERNAMBUCO

COMPLEXO INDUSTRIAL DE SUAPE

ANALYSIS OF VEGETATIVE COVER

data	escala	desenho nº	folha

7.2 COMPOSITION OF THE UNITS IDENTIFIED

RESIDUAL WOODS IN HIGH, WELL DRAINED ZONES

Consists of all the vegetative formations that are still conserved or which have not suffered noticeable alteration due to man, as observed in photographs.

These formations occupy the ample areas of ondulated zones where sugar cane is planted. Traditionally, these areas are not cultivated.

Given the long time that farmers have occupied the area and due to the population density, these areas are periodically stripped, it is supposed, in order to obtain building materials and/or firewood. Therefore, it is deduced that the original forest composition of these areas was far different from that found there now.

RESIDUAL WOODS IN HIGH, WELL DRAINED RECEDING ZONES

This type of vegetation is similar to the previous; however, the destruction wrought by man can clearly be seen in aerial photographs as these areas have been incorporated in sugar cultivation.

RESIDUAL WOODS IN POORLY DRAINED ZONES

Formed by vegetative masses associated to the principal waterways. As these occupy flat areas that could be utilized for irrigated sugar cane cultivation, they were almost totally devastated, leaving very little of the original vegetation.

RESIDUAL WOODS ON SANDY SOIL IN COASTAL DUNES

Located in the zones that appear in the flats that become covered with water, with mangroves or along the seashore.

In general, they are the remains of the original coastal vegetation, distinct from the mangrove swamps in regards to salinity, which were substituted by planting COCOS NUCIFERA in almost the entire area.

COCOS NUCIFERA

Includes the commercial planting of this palm located on the coastal dunes or on sandy zones with relatively good drainage, within the areas covered at high tide. These planted areas are increasing, as can be noted upon confirming the data on the photos in the field: the area occupied is presently larger, on certain sides, than when the photo was taken (in 1969).

In the area of the Suape land spit and the Suape beach, it was noted that the ocean is invading the sand and also destroying existing palms. The fort that was constructed at the time of the Dutch invasion, which still exists at the Suape land spit, was once on dry land and today is surrounded by water.

It was impossible to clarify the causes of this phenomenon in this work.

PALMS AND TREES NOT IDENTIFIED IN THE PHOTO

These are small areas generally occupied by planted trees or palms.

It was observed in the field that part of this vegetation, located on the rock slope, probably resulted from seeds carried by the wind or birds.

SUGAR CANE

This area, from an agricultural standpoint, is a one-product region, sugar cane, which supplies the mills in the region.

Besides sugar cane, some insignificant planting was observed on small pieces of property, such as manioc and corn.

7.3 GENERAL CHARACTERIZATION

The preceding identification verifies the predominance of sugar cane, which occupies somewhat more than 60 percent of the area, followed by mangrove swamps at 13 percent.

Once must point out the presence of the COCOS NUCIFERA which is characteristic of the area and confers great natural beauty, along with the residual woods on sandy and rocky soil, on undulated landscape, completed by the beaches.

Analysis of the above distribution confirms the still small participation of an urban zone which, together with the predominance of sugar cane, permits identification of the area as typically rural. This is accentuated by the existence of vast mangrove swamps and the significant presence of the typical vegetation in the remaining natural areas.