

GEO TEST

Geological Consultants

**GEOLOGICAL AND
HYDRO-GEOLOGICAL
STUDY
FORM D-I
PROJECT:
WEST ESTERILLOS
CONDOMINIUMS AND
VILLAS.
PARRITA, PUNTARENAS.**

Requested by: TECNOCONTROL S.A.

JULY 2007.

1. Professional Responsibility Document

The contents of the geological and hydro-geological studies that are set forth in this report are the responsibility of Roberto Protti Q., a geology consultant from the Geotest S.A. company.

Credential No. 64, Geologists' Association of Costa Rica

SETENA Registration No. 001-96.

Specialties registered with the Geologists' Association of Costa Rica: **Hydro-geology** (La Gaceta official journal, No. 231, November 30, 2005).

Specialties registered with the Geologists' Association of Costa Rica: **Geotechnics** (La Gaceta official journal, No. 23.1 November 30, 2005).

Roberto Protti Q.

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3. Summary of results and technical conclusions

The geological and hydro-geological contents of this report are for the "Villas and Condominiums" project to be developed in West Esterillos, the Canton of Parrita, in the Province of Puntarenas.

Geology

The area where this project is located is made up a rocky bedrock from the Tertiary Age that is co-related to the Punta Judas Formation. In this case, there are some fractured and altered shales and siltstones on the surface of reddish plastic lateritic clays with very low permeability.

The types of surface coverage include in situ alterations of the rocks in the bedrock in most of the plot and deposits for a fluvial-marine source with fine grains (sand and silt) with little relative thickness. They are located on the southern end of the property.

The thickness of the coverage types with lateritic alteration present on most of the property is some 5 to 6 meters according to the geo-technical probes performed by the

Tecnocontrol S.A. company for this project. Meanwhile, toward the south end of the property where there are sand deposits of a marine-fluvial origin, the thickness ranges between 3 and 5 meters. The aforementioned data pertain to the results of probes, however, in the project area and specially toward the north end on the boundary with the coastal highway, alteration thicknesses were seen that are thicker than the indicated thicknesses. The local geological structure is characterized by the presence of secondary folding and faulting zones; however, due to the scarcity of rocky outcrops, it is impossible to define the local structure precisely. The land in this project has good drainage, however, there are areas in the center of the project that are flooded like swamps with poor drainage.

Hydro-geology.

The saturation level under the project site is located at variable depths according to the land's morphology. In most of these, the indicated level is located some 10 meters deep and pertains to a local saturation level within the developed aquitard units in the sedimentary rocks.

In this case, it is a local aquifer-aquitard with low potential within the fractured, altered sedimentary rocks.

The hydro-geological parameters for the altered sedimentary rock units are: Permeability: $k = 0.17 \text{ m/d}$ (see attached calculation sheets).

Porosity $p = 0.3$.

Hydraulic gradient $i = 20/270 = 0.07$.

The aquifer vulnerability for the sedimentary rock units in most of the project is A.V.I. = 0.20, which pertains to low vulnerability under contamination.

The transit time for percolation in the non-saturated areas is $T = 18$ days. The minimum flow distance for the gradient so the percolated water is disinfected (for $T = 70$ days) is $D = 2$ to 3 meters.

This project should have a waste water treatment plant to minimize the risk of contamination due to percolation of the waste water, especially in the low parts in the southern area of the project.

Geo-morphology and natural threats.

The general relief for the land on the project is rolling with hills with convex hillsides with a low slope to the south and southwest.

These lands do not show any conditions that would give rise to the threat of seasonal flooding since they are located outside the area of influence for any fluvial system that is able to generate this type of condition. However, there is a swampy zone toward the west that may be caused by the poor drainage conditions in this sector.

The natural hillsides show good stability conditions; however, specific slope and excavation stability analyses should be run once they have been designed to verify their long-term stability.

In terms of seismic risk, according to the Costa Rican Seismic Code, the project area is located in seismic zone III with a type S1 soil profile so the value of $A_e = 0.30$ should be used for actual peak acceleration for the structural design of civil work.

Introduction.

This document presents the geological and hydro-geological support contents for Form D1 for the "Condominiums and Villas" project located in West Esterillos, in the canton of Parrita, the Province of Puntarenas.

This project is the property of Villas y Condominios S.A. and its location is shown on the map on sheet 1 in the appendix to this report.

This study was performed by the Geotest S.A. consulting firm at the request of Tecnocontrol S.A. This report includes a description of the local geological conditions and the hydro-geological analysis in terms of the risk of aquifer contamination that may be caused by operating a residential project on the analyzed land.

These studies have encompassed the full property and its surroundings up to a distance of 1,000 meters around it.

Sheet 1 attached in the appendix shows the location of the project area based on the "HERRADURA" and "PARRITA" cartographic sheets at a scale of 1:50,000. Sheet 2 includes the project area's geological and hydro-geological maps.

The appendix also includes a copy of the survey for the property being researched.

5. Surface and sub-soil geological units.

Stratigraphy.

The area where this project will be developed is located in the West Esterillos sector between the indicated location and the south coastal highway, as shown on the location map on sheet 1 attached in the appendix to this report.

This region, as shown on sheet 2 of the geological map, is made up of a rocky bedrock from the Miocene age that is co-related to the Punta Judas Formation, which is made up of shale and siltstone that are well stratified. The thickness of this rocky unit exceeds hundreds of meters.

These rocks outcrop profusely along the coastline between West Esterillos and Punta Judas in the area of the current marine abrasion platform. Meanwhile, the outcroppings inland are scarce and the rocks show a major thickness with a lateritic type alteration occurring on site.

The types of surface coverage in the project area are predominantly lateritic clays of a reddish color, from moderate to high plasticity with a thickness that exceeds 8 meters.

Toward the south sector of the property, in the areas around West Esterillos, the types of surface coverage are non-consolidated deposits of a marine fluvial original, mostly fine loamy sand whose thickness ranges between 5 and 8 meters.

surface coverage of lahar-type deposits made up blocks of variable sized rock that are moderately altered, encrusted in a moderately consolidated clayey silt with low relative permeability.

The thickness of the lahar-type surface coverage at the site range between 10 and 30 meters.

The map of lithological units on site on the project land is shown on sheet 3, which was prepared based on the property survey. The map indicates the area where there are lateritic alterations in the area of the non-consolidated marine fluvial deposits toward the south end and the approximate location of a flooded area toward the west end.

Hydro-geology.

Sheet 2 of the map has included the project area's hydro-geological characteristics and the location of the drilling registered in the official files (Senara) in the area in question.

Likewise, during the field reconnaissance, the hydro-geographic information was recorded for the surface as shown on the aforementioned sheet.

Most of the wells located in the area on sheet 2 have a low potential aquifer saturation level between the bedrock and the water flow reported for the wells in question that range between 0.25 and 2.0 l/s in a non-balanced regimen. In other words, this is an aquitard and/or free aquifer (phreatic) type unit with low relative permeability and with residual lateritic type clays with low permeability.

Table A shows the basic information for the drilling used as a source of information during this research based on the information contained in the Senara drilling files.

TABLE A: LIST OF REGISTERED WELLS 1,000 KM AROUND THE PROJECT SITE

WELL No.	OWNER	DEPTH	AQUIF	Depth N. SAT (m)
HE-37	Inv. Cotsco	40	Sediment Bedrock	8-10
HE-38	Inv. Cotsco	40	Sediment Bedrock	8-10
PAT-7	W. Mora	41	Sediment Bedrock	7
HE-13	F. Mora	20	Sediment Bedrock	1
HE-14	F. Quesada	n.d.	n.d.	n.d.
ILG-815	La Cruz del Sur	n.d	n.d	n.d

n.d. = no data for well.

ILG: Illegal well (Senara)

Table B describes the stratigraphic hydro-geological profile for most of the project land as it was defined in the field work during the research.

TABLE B: SITE STRATIGRAPHIC PROFILE

SECTION	DESCRTITON
0.10 to 10 m.	Plastic reddish lateritic clay. K = 0.17 m/d.
10 to > 100 m.	Bedrock with fine fracture sedimentary rocks, of low permeability

The materials in the surface alteration coverage on the bedrock are reddish lateritic clays from moderate to high plasticity. The consistency is soft to medium according to the permeability testing for variable loads performed on these materials (see basic data and calculation sheet in the appendix). The permeability is $k = 0.17 \text{ m/d}$ ($2.05 \times 10^{-4} \text{ cm/s}$).

These soils in general are type CL-CH according to the Unified Soil Classification System. Soils (U.S.C.S.)

The hydro-geological map for the area of interest is shown on sheet 2 where the location of the registered wells is indicated up to a distance on the order of 1 kilometer from the project site. The hydraulic gradient was determined based on the probable location in the natural discharge area for the water contained in the sedimentary rock unit that drains southeast toward the Aserradero Estuary. The gradient in question is $i = 20/270 = 0.07$.

The aquifer contamination risk analysis for this project was performed using the Morris and Foster (2000) vulnerability analysis methodology, which includes the following facets:

- Types of aquifer present in the sub-soil.
- Depth of the saturation levels.
- Type and thickness of the surface coverage.

The basic concepts involved in this type of risk analysis contain the probability that the aquifers in the sub-soil are contaminated in concentrations above the acceptable limits. There are two fundamental concepts involved in the evaluation, i.e.:

- The **load and type of contamination** that is or will be applied to the sub-soil as a consequence of human activity; in this case, the possible percolation of waste water coming from domestic sources.
- The **vulnerability of the aquifer or aquifers**, which depends on the characteristics of the sub-soil where the contaminating load will be applied.

This case was analyzed on the project site within the context of the criteria, i.e., the phreatic aquifer with a clayey coverage on bedrock with very low permeability found among the shale and siltstone units in the Punta Judas Formation.

In this case, according to the indicated methodology, the assessments of the vulnerability parameters are the following:

- Aquifer type: phreatic (non-confined) coverage: value **G = 0.6**.
Coverage phytology: Residual clayey soil: value **O = 0.4**
- Depth to the saturation level: 5-10 m: value **G = 0.8**

Aquifer Vulnerability Index Value **A.V.I. = G x O x D = 0.6 x 0.4 x 0.8 = 0.2 = low vulnerability to contamination.**

What is deduced from the application of the previously mentioned methodology is that constructing and operating this project posits a **threat of contamination that is low to null** for the aquifers present in the sub-soil. Nevertheless, given the project's proximity to surface bodies of water that are sensitive to contamination, a treatment plant should be built for the waste water. The purpose is to minimize the risk of any direct discharge of untreated waters into those bodies of water, especially toward the Aserradero Estuary that is located some 200 meters southeast of the project site (see sheet 3).

When there is direct seepage by untreated water, the transit time for percolation through the non-saturated area was calculated to be $T = b \times p / k = 10 \times 0.3 / 0.17 = T = 18 \text{ days}$.

This time is insufficient for the water to be sterilized by percolation if there is any seepage due to any possible failures of the treatment plant. Nevertheless, the minimum flow distance to the benefit of the gradient in the saturated area required for such a disinfection to occur (for a transit time of 70 days) is $D = T \times k \times i / p = 52 \times 0.17 \times 0.07 / 0.3 = D = 2.0 \text{ m.}$, i.e., a flow distance is required on the order of 2.0 meters to the benefit of the gradient inside the saturated area for natural sterilization to occur

for the water being percolated so the possible risk of contamination in this case is practically non-existent.

6. Relevant geo-morphological data.

The general relief for the land on the project is rolling with hills with convex hillsides with a low slope to the south and southwest.

In general, this relief is caused by combined processes involving erosion and on site alteration of the sedimentary rocks that make up the ground's sub-soil.

This land does not show any conditions that would give rise to the threat of seasonal flooding since it is located outside the area of influence for any fluvial system that is able to generate this type of condition. However, there is a swampy area toward the west that may be caused by the poor drainage conditions in this sector.

The natural hillsides show good stability conditions; however, specific slope and excavation stability analyses should be run again once they have been designed to verify their long-term stability.

Natural threats

As indicated previously, this lands does not lie within the area of influence for seasonal flooding by any body of water, i.e., it is not subject to the risk of flooding.

The natural hillsides have gentle slopes and there was no evidence of massive instability of the hillsides that could affect the project work.

In terms of seismic risk, according to the Costa Rican Seismic Code, the project is located in seismic zone III with an S1 soil type profile so the value of $A_e = 0.30$ for actual peak acceleration should be used for the civil work structural design.

7. Summary of results and conclusions.

The main conclusions reached from the studies performed on the land in the project where the "Condominiums and Villas" project will be developed in West Esterillos in Parrita are:

- The area in question is made up of sedimentary rocks from the Miocene age that are co-related to the Punta Judas Formation.
- The types of surface coverage are predominantly on site lateritic alterations of a reddish color with moderate to high plasticity, type CL-CH. The thickness is on the order of 8 to 10 meters toward the south end of the land. The types of surface coverage are non-consolidated deposits of a marine fluvial origin made of sand and silt with a maximum thickness on the order of 6 meters.
- The saturation level underground on the project is located at a depth on the order of 10 meters. A phreatic aquitard unit has developed with low aquifer potential in the sedimentary rocks in the bedrock. The materials in the types of surface coverage and up to a depth on the order of 10 meters have a permeability of $k = 0.17$ m/d.
- The Aquifer Vulnerability Index (A.V.I.) for the units of sedimentary rocks under the alteration coverage is $A.V.I. = 0.20$, which corresponds to low vulnerability to contamination.
- A recommendation has been made for this project to have a waste water treatment plant so that, under normal operating conditions there should be no contaminants discharged that may percolate into the sub-soil.

- In case of any possible problems with operating the treatment plant that would allow direct percolation of waste water into the sub-soil, a distance is required in the form of a 2.0 meter gradient under the site where the percolation occurs for the percolating water to be naturally sterilized.
- The land on this project is not subject to short-period of return geological risks such as flooding or hillside or slope instability. According to the Costa Rican Seismic Code, the project area is located in seismic zone III with an S1 soil type profile so the structural design of the work with a peak actual acceleration value of $A_3 = 0.30$ minimizes the seismic risk for the project's civil work.

8. Study degree of uncertainty and scope.

The stratigraphy for the project land has been defined for depths much higher than the depths that are relevant for the type of project intended to be developed, i.e., residential units with low coverage density.

In that regard, there is no uncertainty of relevance in relation to the local stratigraphy.

The permeability of the surface coverage materials was measured during permeability testing for variable loads (see appendix) so there is no uncertainty that arises in relation to the hydro-geological parameters for the sub-soil materials.

9. Bibliographic Reference.

Geotest S.A. File of technical reports for the Central Pacific region.

Moms and Foster, 2000: "Assessment of groundwater pollution risk".

Senara: file with basic drilling data.

10. Appendix.

Sheet 1: location map.

Sheet 2: hydro-geological map.

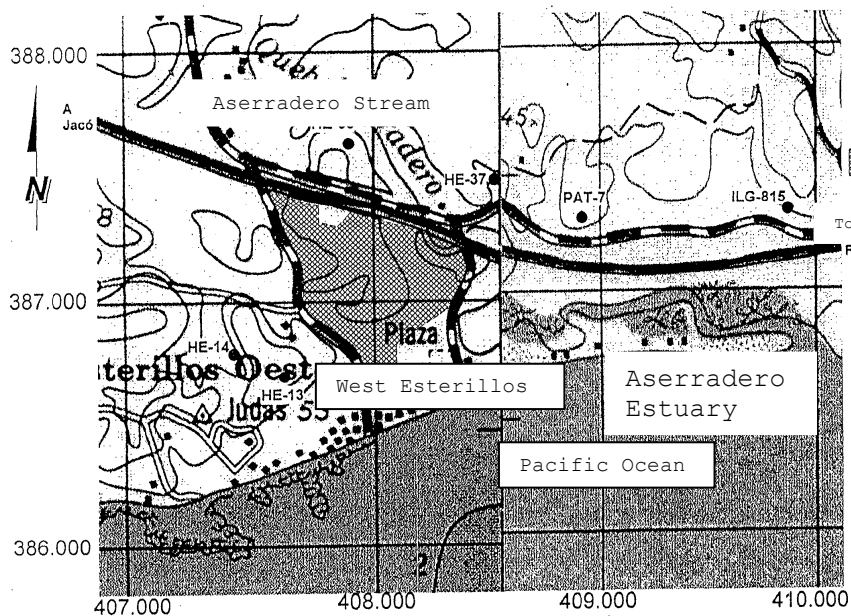
Sheet 3: site lithological map.

Basic data and calculation sheets for testing variable load permeability.

Copy of survey.

Roberto Protti Q. Geology
Consultant

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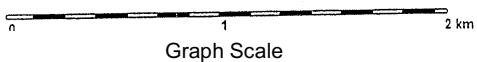
SYMBOL KEY

PAT-7 ● Registered Well (Senara)

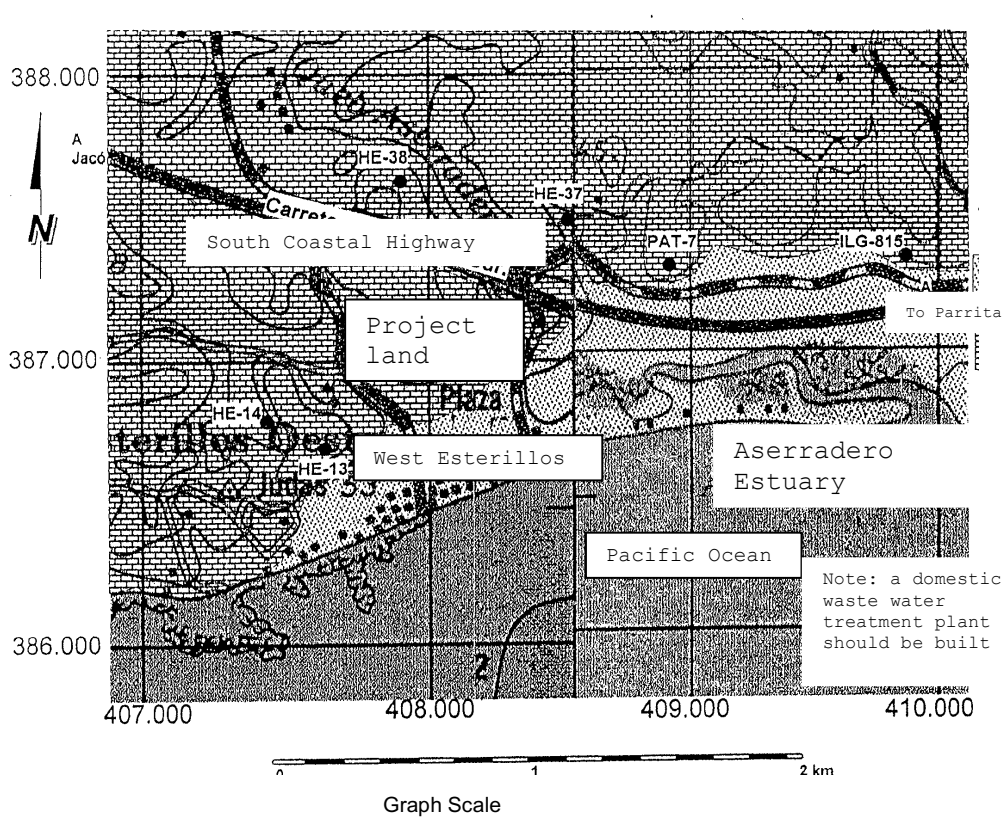
ILG-815 ● Legal Well (Senara)

 Project land (approximate)

Project:
VILLAS AND CONDOMINIUMS
Owner:
VILLAS Y CONDOMINIOS S.A.
Consultant:
TecnoControl S.A.
GEOTEST
Resp. Prof.:
Roberto Protti Q.
Geologist
Contents:
GENERAL LOCATION MAP
Scale Date / Illegible /
Indicated July 2007



Note: Base map: "Herradura" "Parrita"
scale 1:50,000



SYMBOL KEY

- PAT-7 ● Registered Well (Senara)
- ILG-815 ● Legal Well (Senara)
- Project land (approximate)
- [Stippled Pattern] Colluvial, alluvial, deposits, and marine flow. Non-consolidated sediments
- [Brick Pattern] Local bedrock, Shale and siltstone. Punta Judas Formation Low permeability rocks

HYDRO-GEOLOGICAL PARAMETERS

- coverage permeability $k = 0.17 \text{ m/d}$.
- Aquifer vulnerability index $AVI = 0.2$
- Low vulnerability to contamination

Project:

VILLAS AND CONDOMINIUMS

Owner:

VILLAS Y CONDOMINIOS S.A.

Consultant:

TecnoControl S.A.

GEOTEST

Resp. Prof.:

Roberto Protti Q.

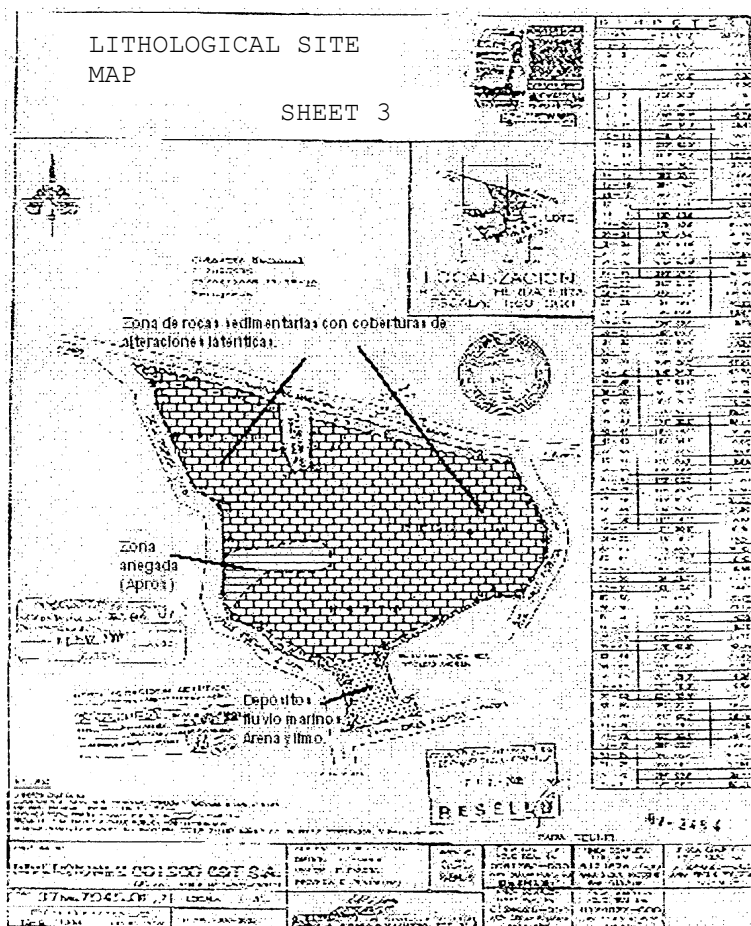
Geologist

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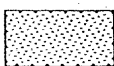
GENERAL LOCATION MAP

Scale Date / Illegible /
Indicated July 2007

Note: Base map: "Herradura" "Parrita"
scale 1:50,000



LEGEND



Coverage types with marine fluvial deposits. Sand and silt, relatively thin.



Punta Judas Formation. Shale & siltstone altered to reddish lateritic clay

Resp. Prof.
Roberto Protti
Geologist

GEOTEST S.A.
BASE SHEET FOR VARIABLE LOAD PERMEABILITY TESTING

	DATE	June 2007
BASE DATA:	PROJECT	Villas & Condo
Drill No.: P-2	LOCATION	West Esterillos
DRILLING DEPTH	1.00 m	
DRILLING DIAMETER	10.10 cm	Lat: 387350
DIAMETER: CASING:	10.10 cm	Long. 407800

H1 (cm)	H2 (cm)	T (seg)	d h (cm)	ki (cm/s)	ki (m/d)
37.50	35.30	600	1.0623	2.9E-04	2.51E-01
43.20	41.10	600	1.0511	2.4E-04	2.07E-01
39.30	37.50	600	1.0480	2.3E-04	1.95E-01
46.60	44.50	600	1.0472	2.2E-04	1.92E-01
41.10	39.30	600	1.0458	2.2E-04	1.86E-01
44.50	42.60	600	1.0446	2.1E-04	1.81 E-01
47.80	45.80	600	1.0437	2.1E-04	1.78E-01

Layer tested: Lateritic clay

Graph B

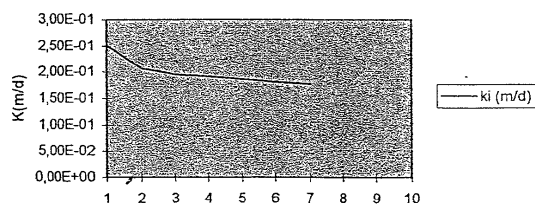
Prepared: R. Protti

Calculation: R. Protti

$$K = \frac{3.1416 \cdot D \cdot \ln(H1/H2)}{11 \cdot (t)}$$

CASE: OPEN BASE IN UNIFORM SOIL

VARIABLE LOAD PERMEABILITY



TEST

ASYNTHOTIC VALUE = k = 1.78E-01 m/d
k = 2.05E-04 cm/s

GEOTEST S.A.
BASE SHEET FOR VARIABLE LOAD PERMEABILITY TESTING

	DATE	June 2007
BASE DATA:	PROJECT	Villas & Condo
Drill No.: P-2	LOCATION	West Esterillos
DRILLING DEPTH	1.00 m	
DRILLING DIAMETER	10.10 cm	Lat: 386850
DIAMETER: CASING:	10.10 cm	Long. 408100

H1 (cm)	H2 (cm)	T (seg)	d h (cm)	ki (cm/s)	ki (m/d)
37.40	32.20	60	1.1615	7.2E-03	6.22E+00
29.70	27.20	60	1.0919	4.2E-03	3.65E+00
32.20	29.70	60	1.0842	3.9E-03	3.36E+00
37.30	34.70	60	1.0749	3.5E-03	3.00E+00
42.70	39.90	60	1.0702	3.3E-03	2.82E+00
39.90	37.30	60	1.0697	3.2E-03	2.80E+00
45.30	42.70	60	1.0609	2.8E-03	2.46E+00

Layer tested: Sand, marine fluvial deposit

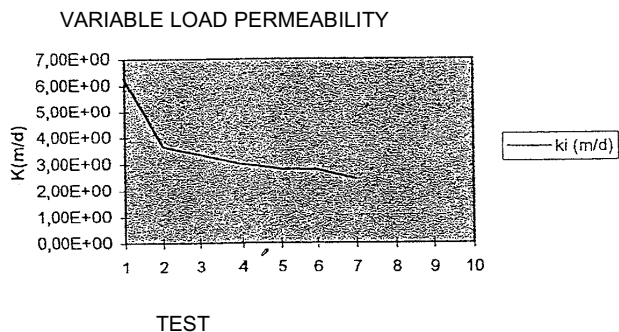
Graph A

Prepared: R. Protti

Calculation: R. Protti

$$K = \frac{3.1416 \cdot D \cdot \ln(H1/H2)}{11 \cdot (t)}$$

CASE: OPEN BASE IN UNIFORM SOIL



ASYNTHOTIC VALUE = k = 2.46E+00 m/d
k = 2.84E-03 cm/s

