CONSTRUCTION ROADS AND HIGHWAYS ON PEAT

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LECTURE TOPICS

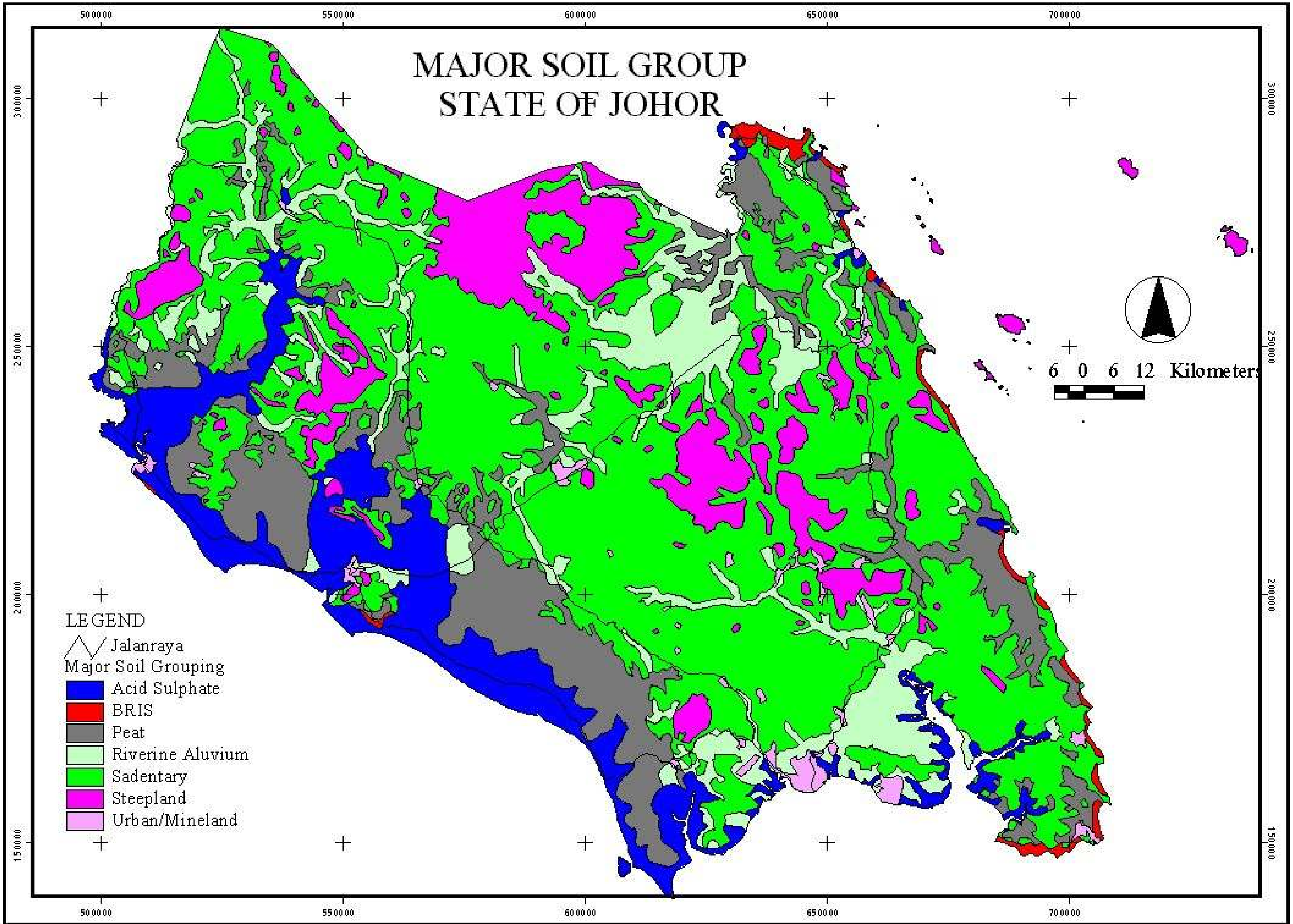
- Occurrence and distribution
- Types and classifications
- Properties
- Soil Investigations
- Stability
- Settlement
- Methods of placing fills
- Case histories
- Decomposition’
- Role of peat swamps in Global warming

DISTRIBUTION OF PEAT and PEATY ORGANIC SOILS

PENINSULAR MALAYSIA

- Near KLIA airport – about 4 m deep peat.
- Air Itam – Kulai, Johore – 4 to 7 m deep peat but can be as deep as 12 m in isolated areas
- Putra Jaya – organic soils can extend to 15 m
- Trengganu – as deep as 4 to 5 m with soft clay beneath
- Batang Berjuntai

SOIL MAP JOHORE



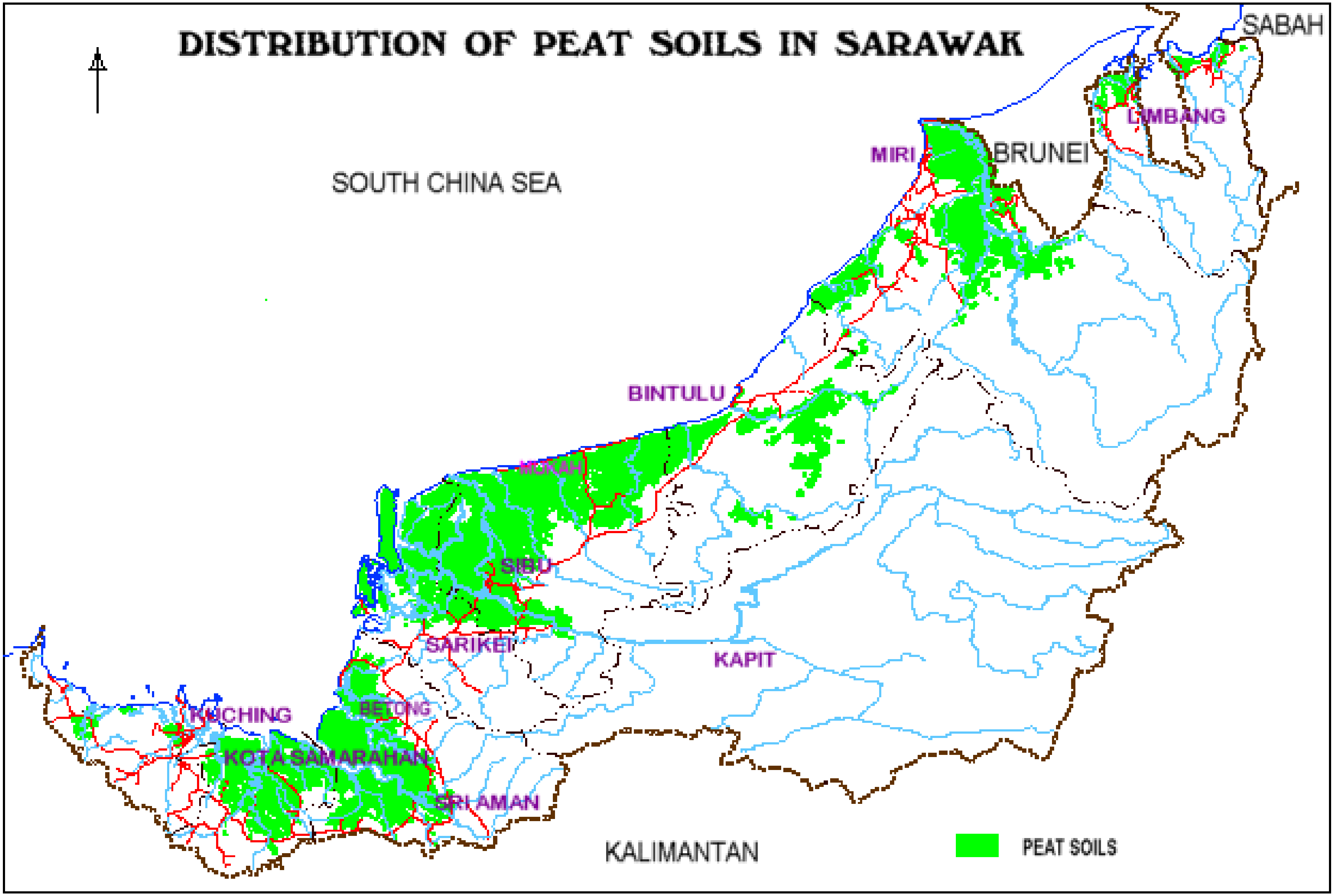
SARAWAK

SIGNIFICANT EXTENT OF PEAT

Some Examples

- SIBU TOWN – KNOWN TO BE AS DEEP AS 17 M
- BATU KAWA – 3 TO 6 M OVER SOFT CLAY OR LIMESTONE
- PETRA JAYA – UP TO 7 M WITH SOFT CLAY BENEATH
- BALINGIAN – UP TO ABOUT 6 M WITH SOFT CLAY BENEATH
- MATANG –UP TO ABOUT 5 M WITH SOFT CLAY BENEATH'
- LIMBANG AREA
- MIRI – BEHIND CANADA HILL

PEAT MAP OF SARAWAK



WORLD PEAT DISTRIBUTION

Canada	1,500,000sq km	18%
USSR	1,500,000sq km	
USA	600,000 sq km	10%
Indonesia	170,000 sq km	14%
Finland	100,000 sq km	34%
Sweden	70,000 sq km	20%
China	42,000 sq km	
Norway	30,000 sq km	10%
Malaysia	25,000 sq km	
Germany	16,000 sq km	
Brazil	15,000 sq km	
Ireland	14,000 sq km	
Uganda	14,000 sq km	
Poland	13,000 sq km	

World wide peat distribution

Falklands	12,000 sq km	
Chile	11,000 sq km	
Zambia	11,000 sq km	
26 other countries	220 to 10,000 sq km	
Scotland		10%
15 other countries		1 to 99%

PEAT . FORMS

Two forms that characterize the deposition of peat:

- Valley peat which are flat and layered with river deposits;
- Basin peat which forms domes that can be up to 15 m high –also reported in Ireland and UK
- In Peninsular Malaysia the peat appears to be valley peat whereas both forms of peat are found in Sarawak.

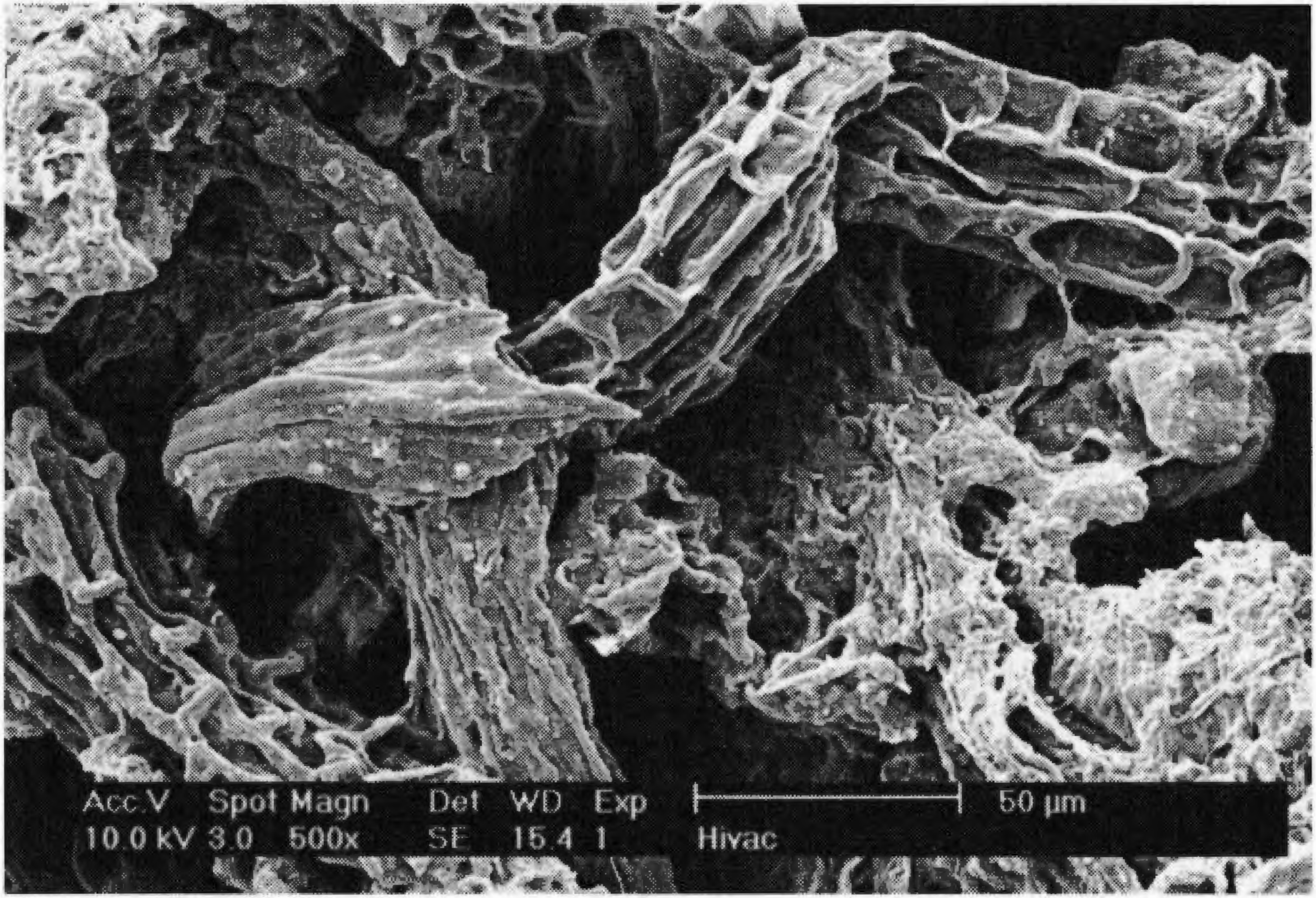
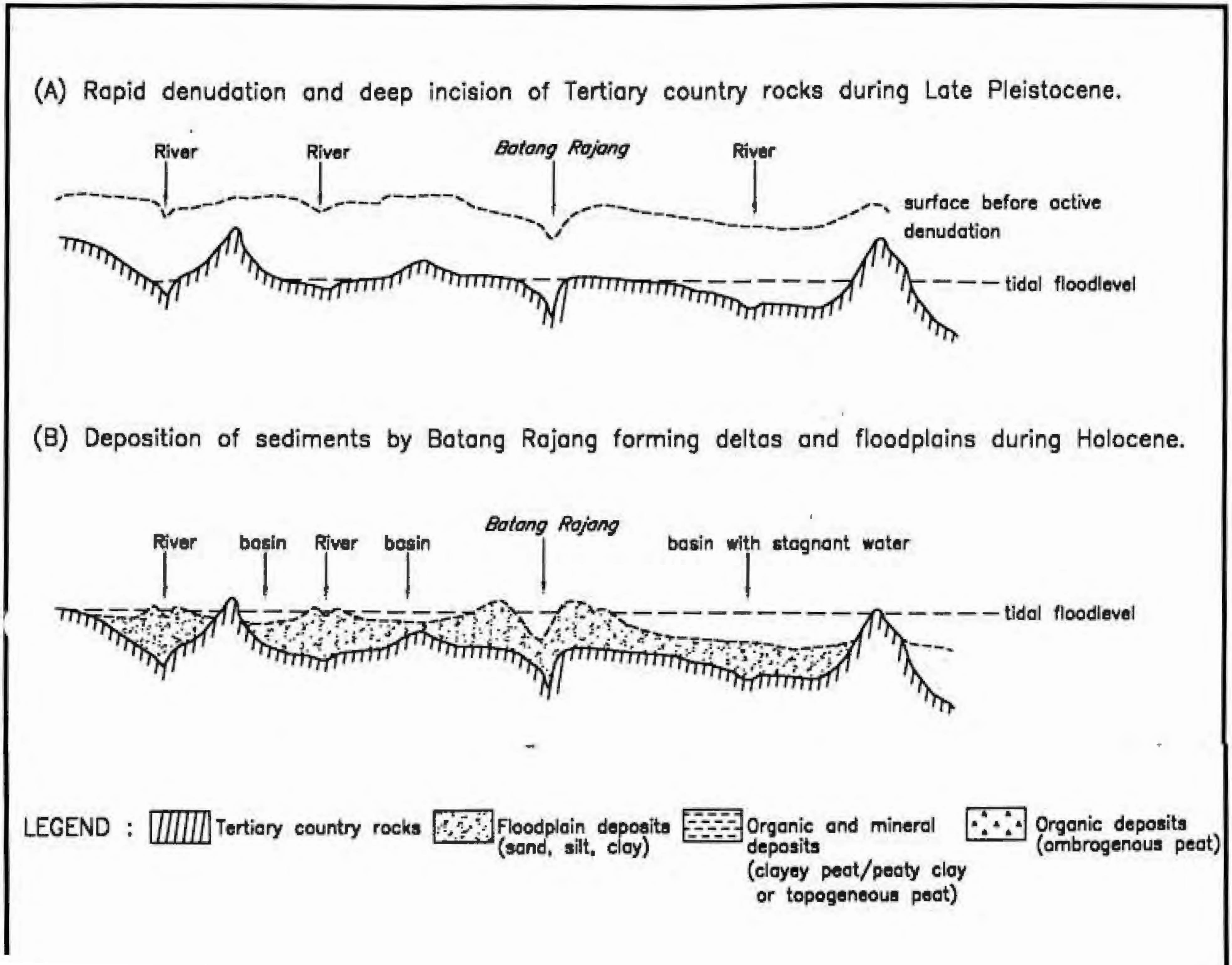


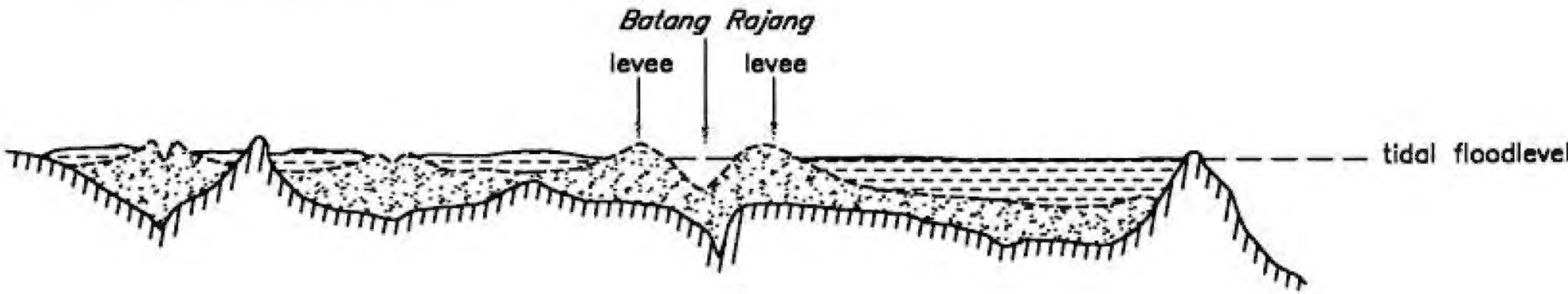
Fig. 5. Scanning electron microphotograph of horizontal section of James Bay peat showing fabric with very large macropores

GEOLOGICAL FORMATION MODEL
for
BATANG RAJANG PEAT

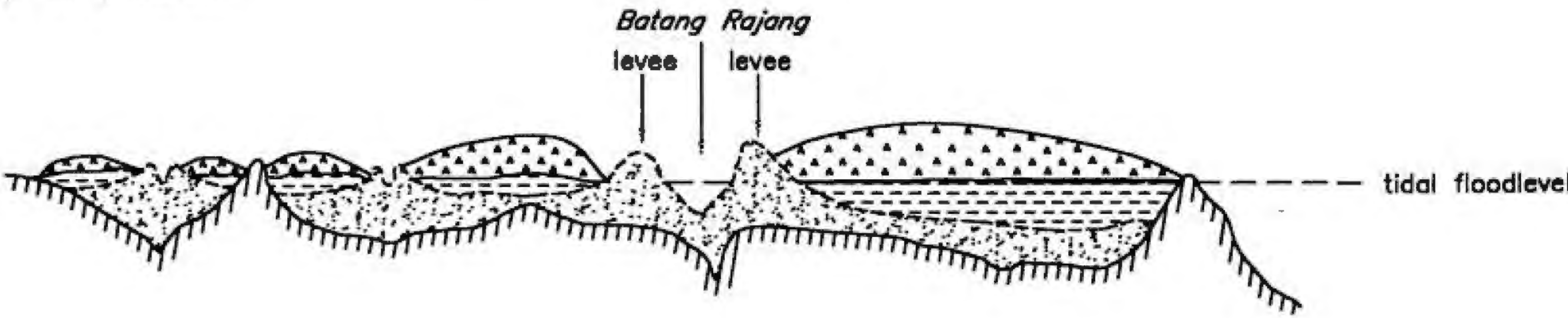
from Lam Sia Keng


(A) Rapid denudation and deep incision of Tertiary country rocks during Late Pleistocene.
River
River
Batang Rajang
River
surface before active denudation
tidal floodlevel
(B) Deposition of sediments by Batang Rajang forming deltas and floodplains during Holocene.
River
basin
River
basin
Batang Rajang
basin with stagnant water
tidal floodlevel
LEGEND :
Tertiary country rocks
Floodplain deposits (sand, silt, clay)
Organic and mineral deposits (clayey peat/peaty clay or topogeneous peat)
Organic deposits (ambrogenous peat)

(C) Accumalation of organic and mineral deposits (peaty clay / clayey peat) in basins betweer levees and isolated hills.



(D) Accumulation of organic matters only (ombrogenous peat) in basins above tidal floodlevel ıp to present.



LEGEND : Tertiary country rocks; Floodplain deposits (sand, silt, clay); Organic and mineral deposits (clayey peat/peaty clay or topogeneous peat); Organic deposits (ombrogenous pe

PEAT CLASSIFICATION

PEAT MAIN TYPES

Peat is derived from plants and can be very fibrous. As the degree of humification# increases, the peat becomes less and less fibrous until it is transformed into an amorphous* mass without any discernable structures.

 # Convert plant remains to humus

** Without a clearly defined shape*

IMPORTANT BASIC PROPERTIES FOR PEAT CLASSIFICATION

- Natural moisture content (%)
- Ash content (%) = 100 – Organic content
- Ignition loss (%) close to the value of the organic content.

When peat burnt organic content becomes CO_2, the ash left is reflective of soil content.

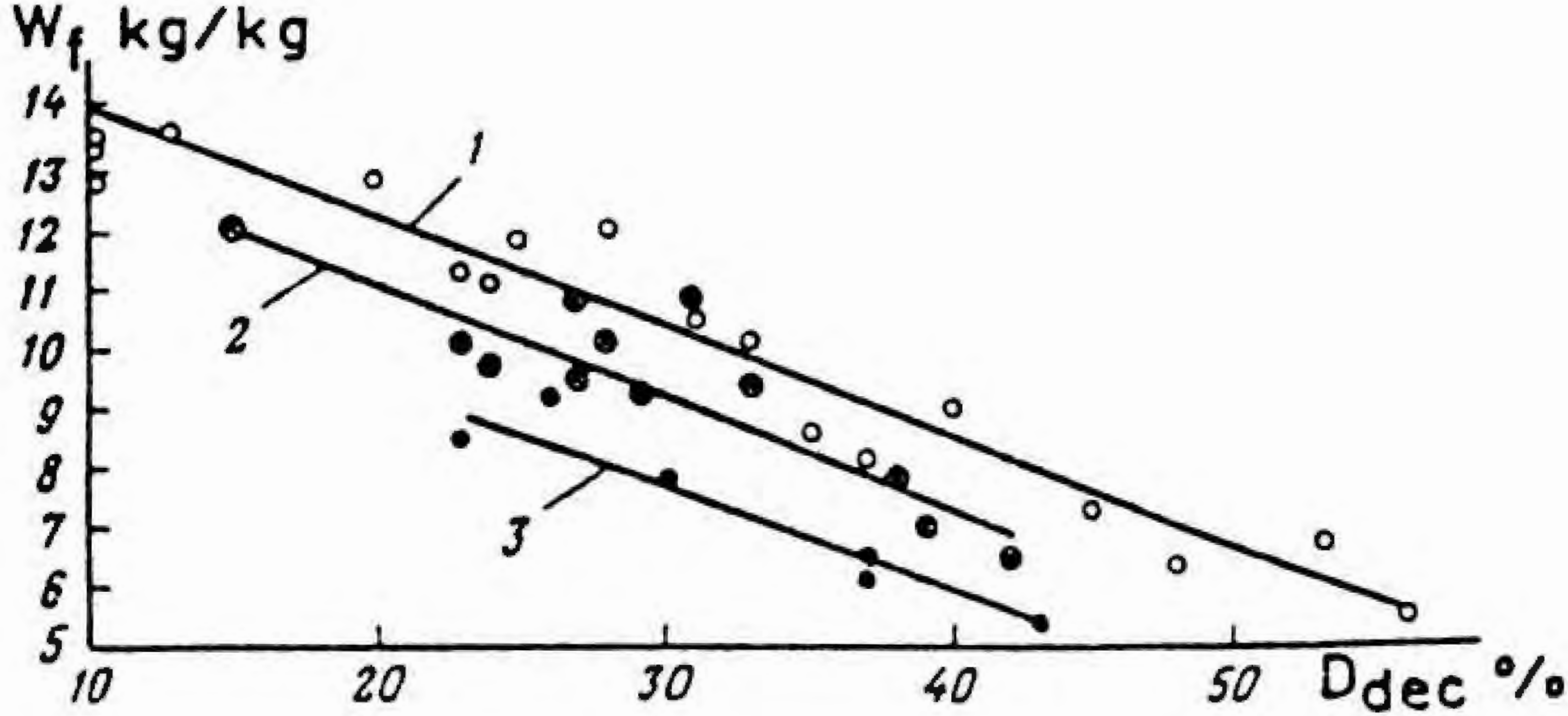


Fig. 2: Water content vs. degree of decomposition. (1) bog peat, (2) transition peat, (3) fen peat. From Amaryan (1993).

PEAT CLASSIFICATION

Von Post System
(Best known –more for agricultural purposes

Based on botanical components, degree of humification, water content, fine and coarse fibre content.

10 grades H1 to H10.

Von Post System

H1	Completely un-decomposed. Releases clear water. Plant remains easily identifiable. No amorphous material present.
H2	Almost completely un-decomposed peat which releases clear or yellowish water. Plant remains easily identifiable. No amorphous material present.
H3	Very slightly decomposed peat which releases very muddy brown water but for which no peat passed between fingers. Plant remains still identifiable and no amorphous material present.
H4	Slightly decomposed peat which releases very muddy dark water. No peat passes between fingers but the plant remains are slightly pasty and have lost some of the identifiable features.

Von Post System

H5	Moderately decomposed peat which releases very muddy water with also a very small amount of amorphous granular peat escaping between fingers. The structure of plant remains is quite indistinct, although it is still possible to identify certain features. The residue is strongly pasty.
H6	Moderately strongly decomposed peat with a very indistinct plant structure. When squeezed, about 1/3 of the peat escapes between the fingers. The residue is strongly pasty but shows the plant structure more distinctly than before squeezing.
H7	Strongly decomposed peat. Contains a lot of amorphous material with very faintly recognizable plant structure. When squeezed about 1/2 of the peat escapes between fingers. The water, if any released, is very dark and almost pasty.

Von Post System

H8	Very strongly decomposed peat with a large quantity of amorphous material and very dry indistinct plant structure. When squeezed about 2/3 of the peat escapes between the fingers. A small quantity of pasty water may be released. The plant material remaining in the hand consists of residues such as roots and fibres that resist decomposition.
H9	Practically fully decomposed peat in which there is hardly any recognizable plant structure. When squeezed almost all of the peat escapes between fingers as a fairly uniform paste.
H10	Completely decomposed peat with no discernable plant structure. When squeezed all the wet peat escapes between the fingers.

French and North American based on Mangan

Organic components	Von Post degree of humification	Qualifying terms	Symbol
PEAT		Fibric or fibrous	Pt
	H1 to H3	Hemic or Moderately decomposed (semi fibrous)	f
	H4 – H6	Sapric or Amorphous	h
	H7 – H10		a
ORGANIC SOIL			O

Landva (classification for engineering purpose)

Ash content (less ash means higher organic content)	Description
0 to 20 %	Peat. Pt. SG < 1.7. SG < 1.7. NMC > 500 %. Fibre content > 50 %. H1 to H8
20 to 40 %	Peaty Organic Soil. PtO. SG = 1.7 to 3.0. NMC = 150 – 800%. Fibre content < 50 %. H8 to H10
40 to 95 %	Organic soils. O. NMC = 100 to 500 %. Fibre content insignificant .LL > 50 %
95 to 99 %	Soils with Organic content. CO, MO. SG > 2.4. NMC< 100%. LL< 50 %

Landva – Ash content versus moisture content

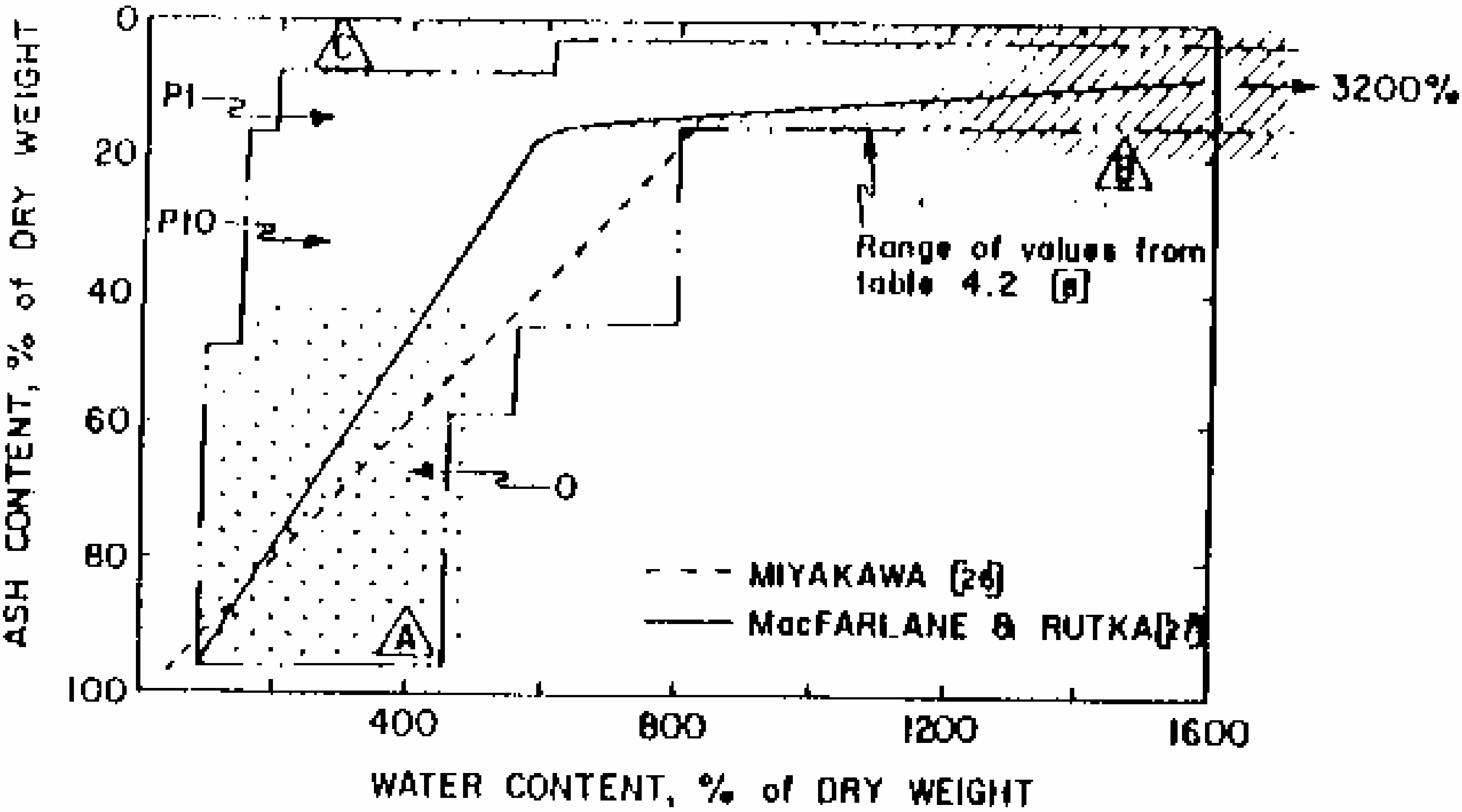


FIG. 2—*Relationship between ash content and water content.*

LOCAL DESCRIPTION (SARAWAK)

- Tai and Lee (Sibu Conference, 2002)

- Wong King Min (Sibu Conference, 2002)

Tai and Lee (2002)

Adopted the common terms Ombrogeneous or Fibrous Peats as distinct from Topogeneous and Amorphous Peats (from Lam)

Ombrogeneous or fibrous peat (deposited above flood levels)

- Mc = 300 to 2000 %.
- Bulk density = 1.1 to 1.4 mg /m3.
- pH = 3 to 5
- Pile up of slightly to moderately decomposed, loose tree trunks, branches, leaves, roots, fruits and other vegetable remains.
- Overlay Topogeneous or Amorphous peat

Tai and Lee (2002)

Topogeneous or amorphous peat.

- Mc = 100 to 300 %
- Bulk density = 1.3 to 1.6 mg /m3
- pH = 3 to 5
- Clayey peat. Slightly to moderately decomposed leaves, reeds and wood with clastic sediments; usually more compact with layered structure
- Deposited under flood conditions below the fibrous peat zone

Wong Kin Min (2002)

NMC 70 to 200%	Organic clays with density greater than 10 kg /m3. pH = 5to 7.
200 to 600 %	Completely to moderately decomposed peat. Ash content = 10 – 50 %. pH = 5 to 7.5
600 to 1200%	Partially to moderately decomposed peat. Ash content 5 – 18 %. High fibre content. pH = 3.5 to 5
> 1200 %	Un-decomposed to partially decomposed peat. Acidic

PEAT PROPERTIES

Basic Peat Properties

- Ash content = 100 – Organic content
- Ignition loss close to the value of the organic content.
- There can be much confusion from the different classification schemes. It is better to just think in terms of the natural moisture content of peat since, in any case, the moisture content is correlated to a variety of properties.

BASIC PROPERTIES

GENERAL.

- Much published data internationally relating peat properties to natural moisture content, ash content (100-organic content), ignition loss (very close to organic content)
- Pity little such correlations from Malaysia. Some collection of Sarawak correlations by Wong Kin Min (2002)

ARE QUALITATIVE DESCRIPTIONS NECESSARY IF IT IS POSSIBLE TO RELATE ESSENTIAL ENGINEERING CHARACTERISTICS TO

- Natural moisture content
- Organic content
- Ash content

?

SETTLEMENT

S_∞ = primary consolidation + secondary consolidation

$$S_\infty = (Cc / (1 + e_0))\, H \, \text{Log}\, (1 + \Delta p/p_0')$$

$$+ C_\alpha \, H \log (t / t_p)$$

BASIC PROPERTIES FOR SETTLEMENT ESTIMATES

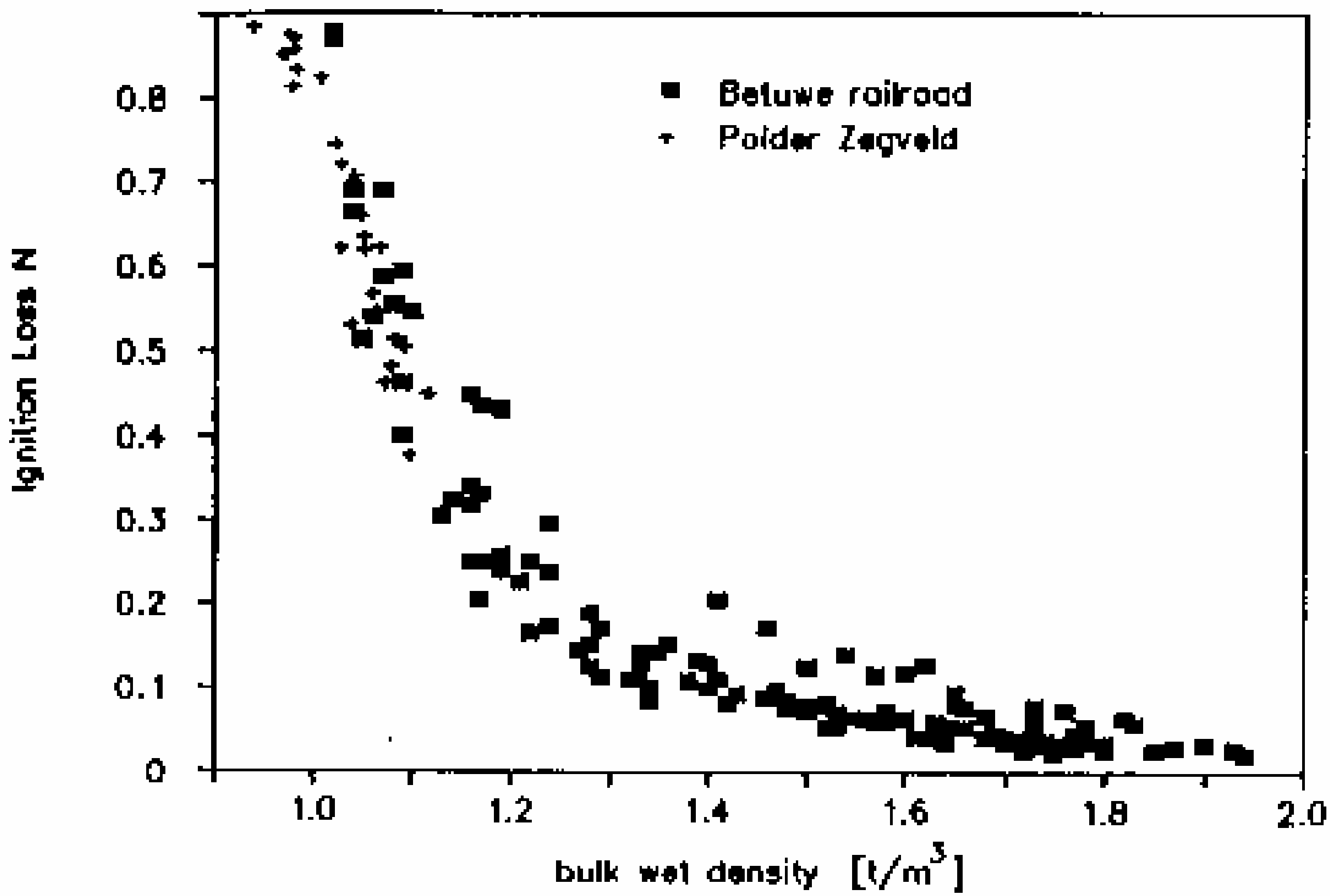
Bulk density range from 1.0 to 1.9 tons / m3.

Bulk density + ground water >>>>> po’ – effective overburden pressure

Lower bulk density related to higher organic content (higher ignition loss)

Ignition loss >>>>> bulk density >>>>> po’

BULK DENSITY – IGNITION LOSS



: Correlation of wet bulk density and ignition loss for Dutch organic soils

SPECIFIC GRAVITY

Specific gravity well related to ash content.

SG values range from 1.4 to 2.4.

Lower SG values are for higher organic contents

Ash content >>>>>>SG >>>>>>> bulk density >>>>>> effective overburden pressure po’

S.G. – ASH CONTENT

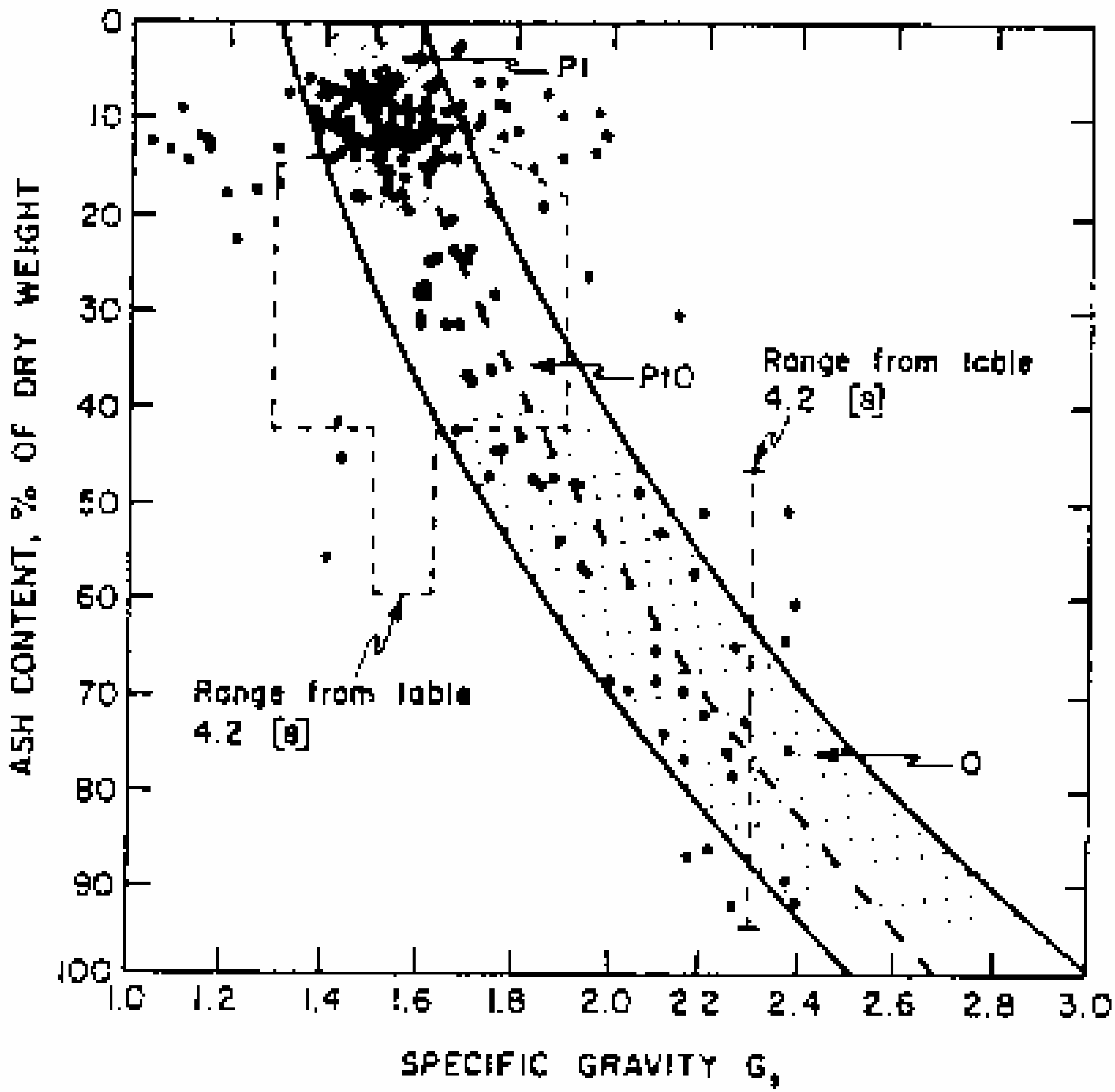


FIG. 3—*Relationship between ash content and specific gravity. Individual points from Refs 10 and 14*

$$S_\infty = (C_c / (1 + e_0))\, H \,\mathrm{Log}\,(1 + \Delta p/p_0') + C_\alpha H \log (t / t_p)$$

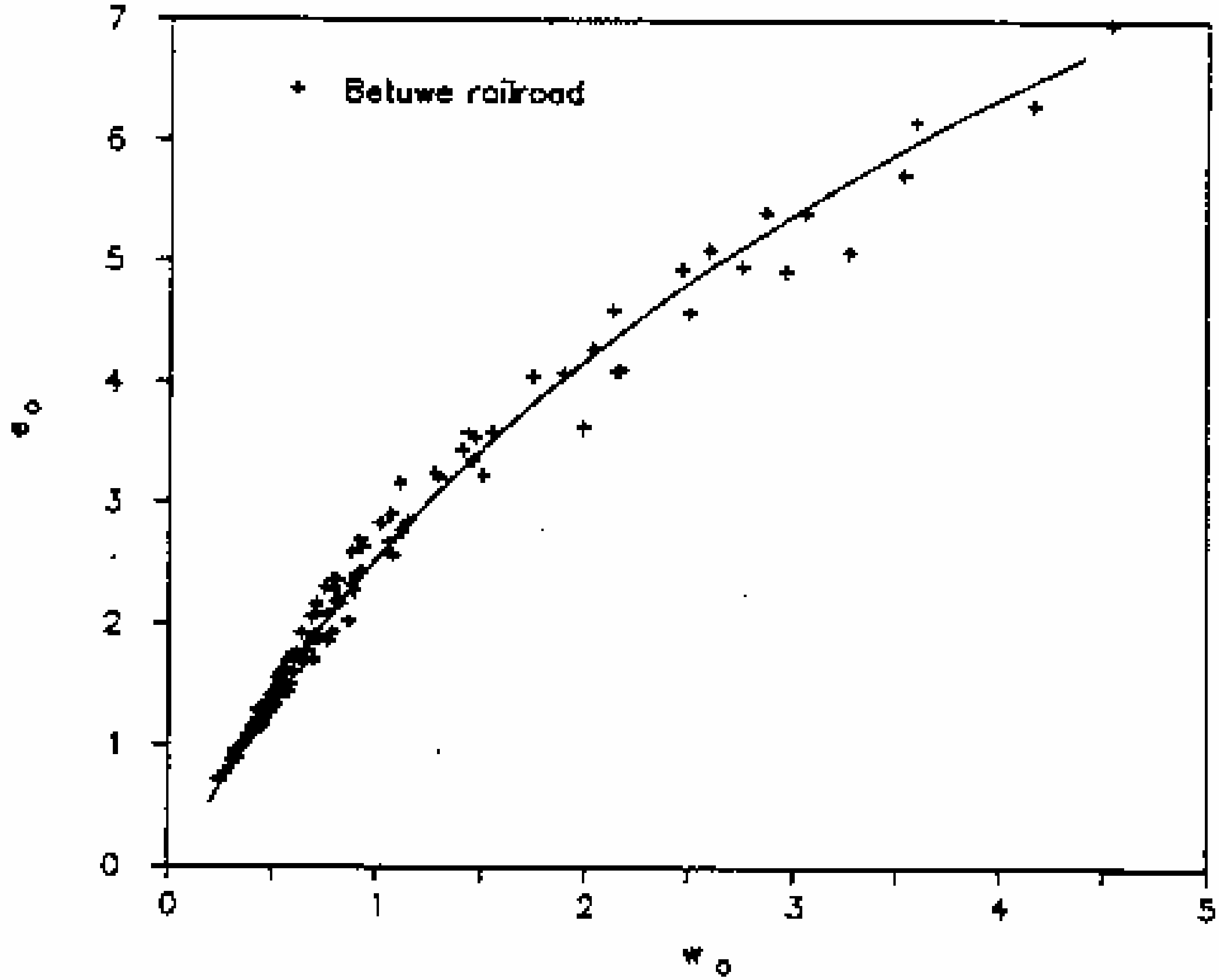
Know p_o'

VOID RATIO AND COMPRESSIBILITY

Natural moisture content >>>>>>>>initial void ration e0 (Dutch correlations)

Natural moisture content >>>>>> compressibility index Cc (Mesri)

PEAT. Initial void ratio - NMC



. 7: Correlation of initial water content and voids ratio for Dutch organic soils

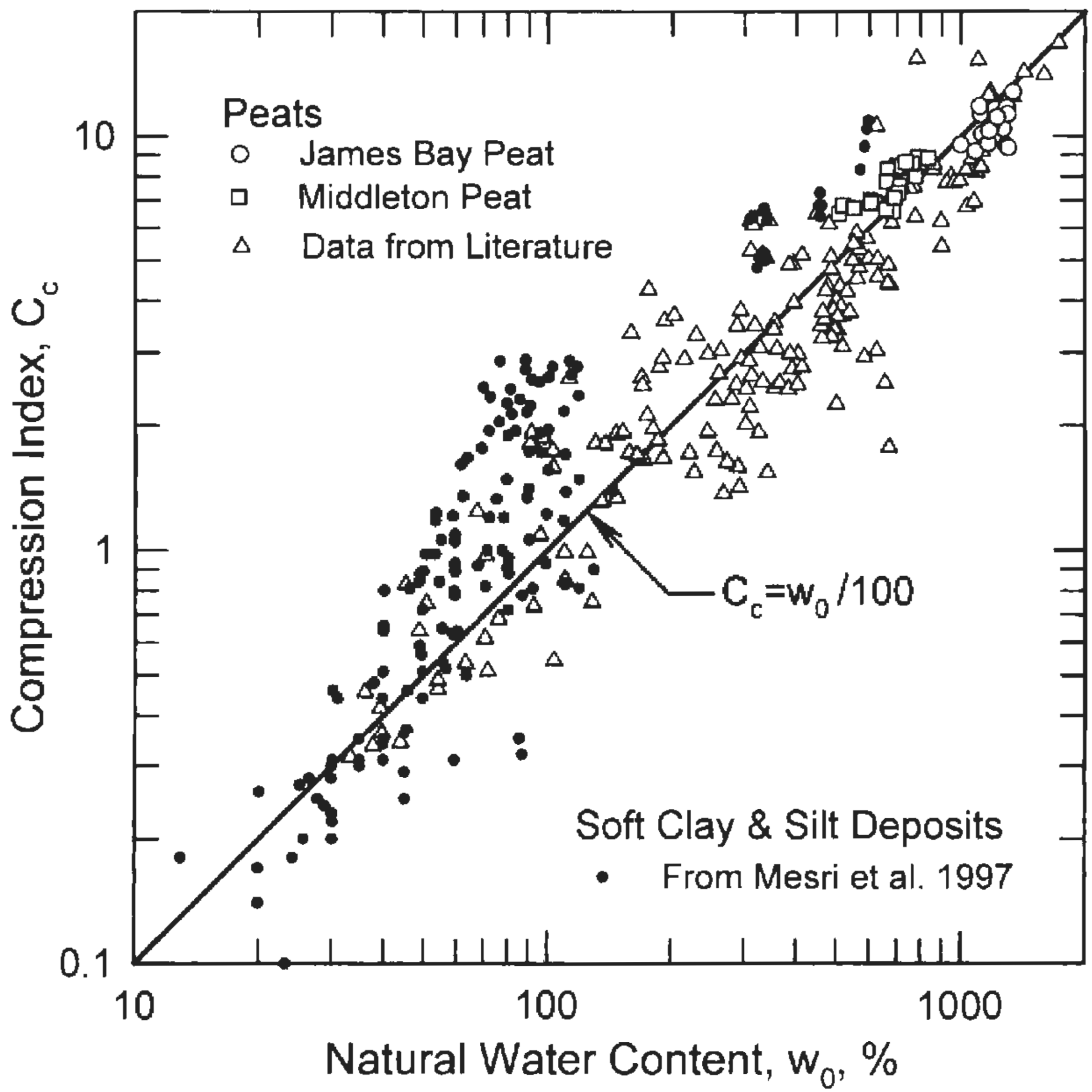


Fig. 10. Empirical correlation between compression index, C_c, and natural water content, w_o, for peats as well as soft clay and silt deposits

$$S_\infty = \left(C_c / (1 + e_0)\right) H \, \mathrm{Log}\,(1 + \Delta p / p_0')$$

$$+ \, C_\alpha H \log (t / t_p)$$

Know p_0' from organic content and ignition loss

Know $C_c / (1+e_0)$ from natural moisture content

H = peat thickness

Δp = applied pressure

Therefore can estimate primary consolidation settlement

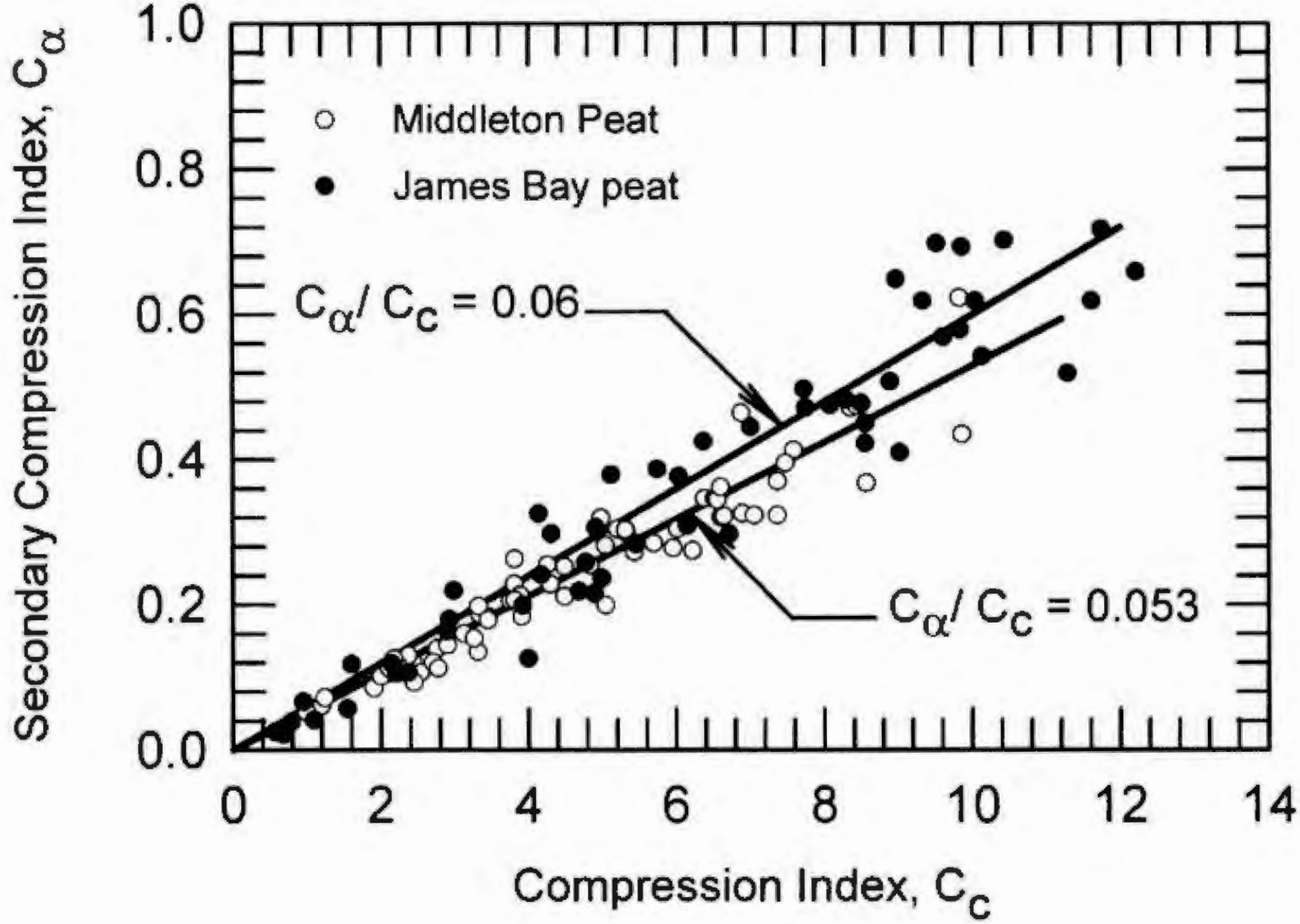


Fig. 12. Secondary compression index, C_α, versus compression index, C_c, for Middleton and James Bay peats

Cα – coeeficient secondary consolidation

Cc>>>>>>>>> Cα (from Mesri)

$$S_\infty = (C_c / (1 + e_0))\ H \log (1 + \Delta p/p_0')$$

$$+ C_\alpha\ H \log (t / t_p)$$

H =peat thickness

tp = time for end of primary consolidation

Therefore can estimate secondary consolidation and total settlement S_∞

PEAT. Settlement parameters

PRIMARY CONSOLIDATION

- Bulk density related to Ignition Loss. Therefore po' can be estimated.
- Initial void ratio (eo) related to Natural moisture content
- Cc (compressibility index) related to natural moisture content
- Therefore can obtain Cc / (1 + eo) from natural moisture content

PEAT. Settlement parameters

Coefficient of secondary consolidation C_α related to Cc

Therefore from natural moisture content, organic content or ignition loss, all the settlement parameters can be obtained.

PEAT. Void ratio and permeability

Void ratio changes on application of load.

Void ratio related to coefficient of permeability

K range from 10-6 to 10-11 m / sec. Peat is not so permeable.

Therefore can estimate Cv from k at different pressures

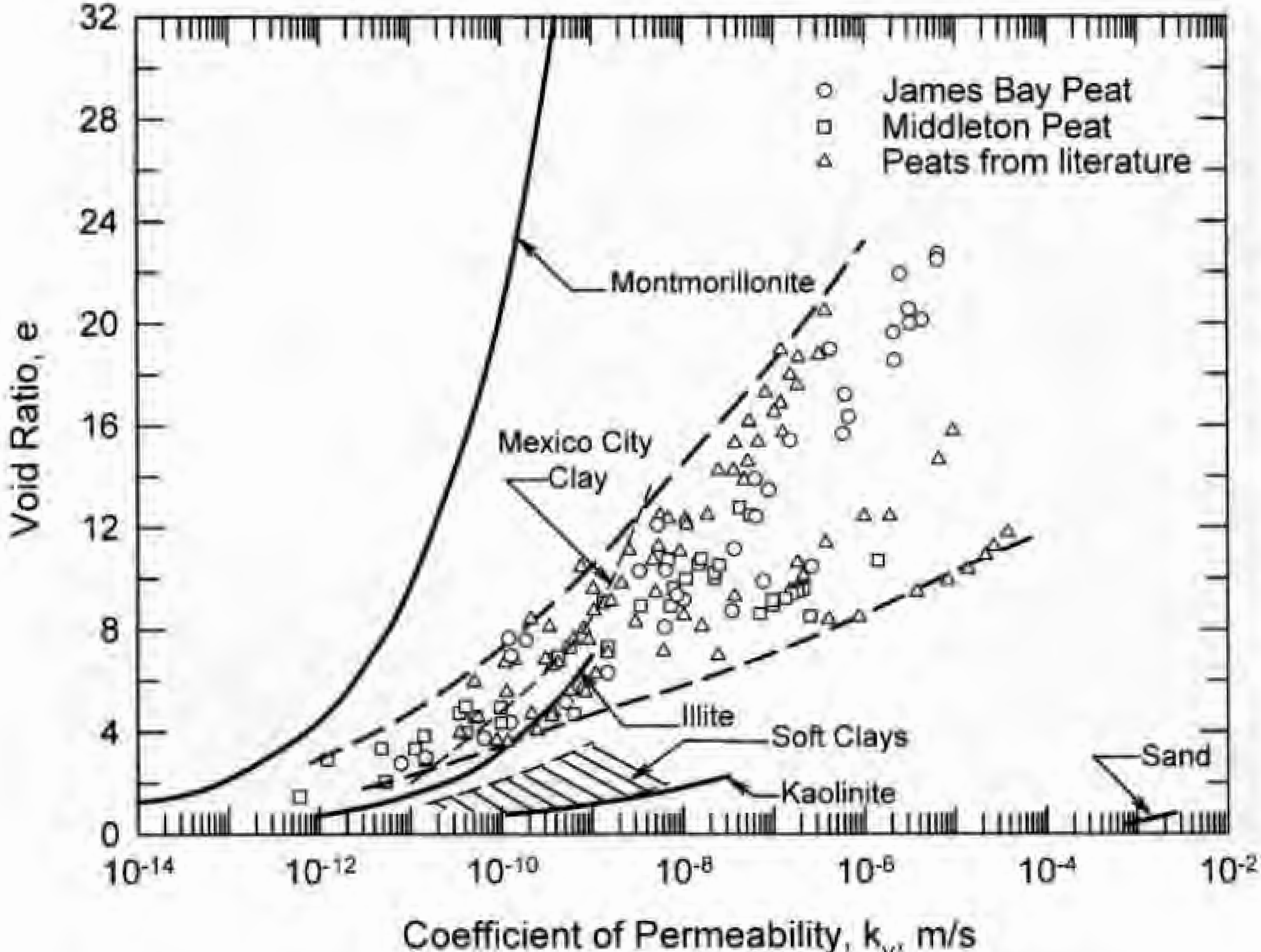


Fig. 2. Data on coefficient of permeability, k_v, of fibrous peats within frame of reference of permeability data for sodium clay minerals, soft clay deposits, including Mexico City clay, and clean sand

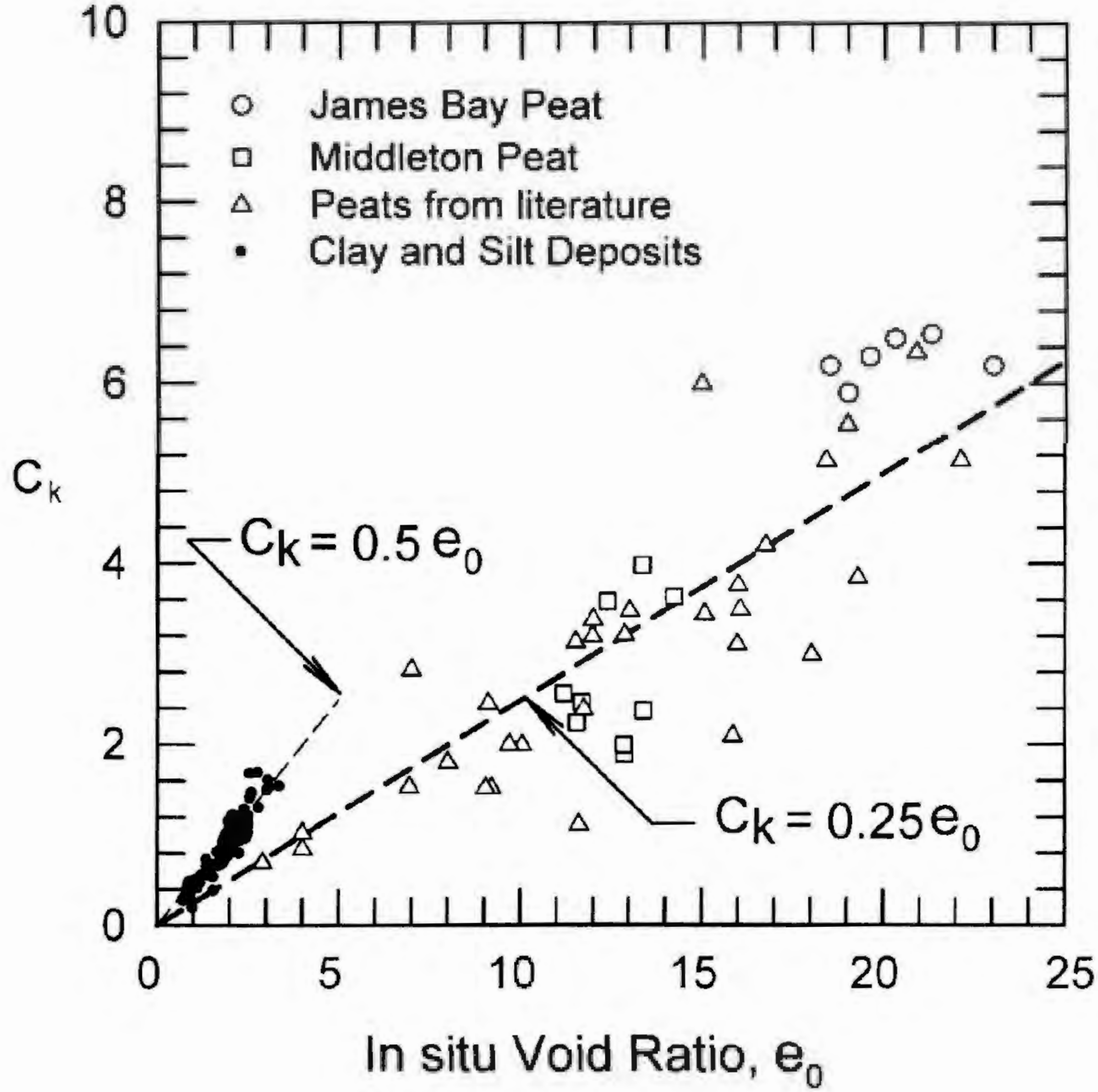


Fig. 3. Relationship between $C_k = \Delta e / \Delta \log k_v$ and in situ void ratio, e_o, for fibrous peats compared to that of soft clay and silt deposits

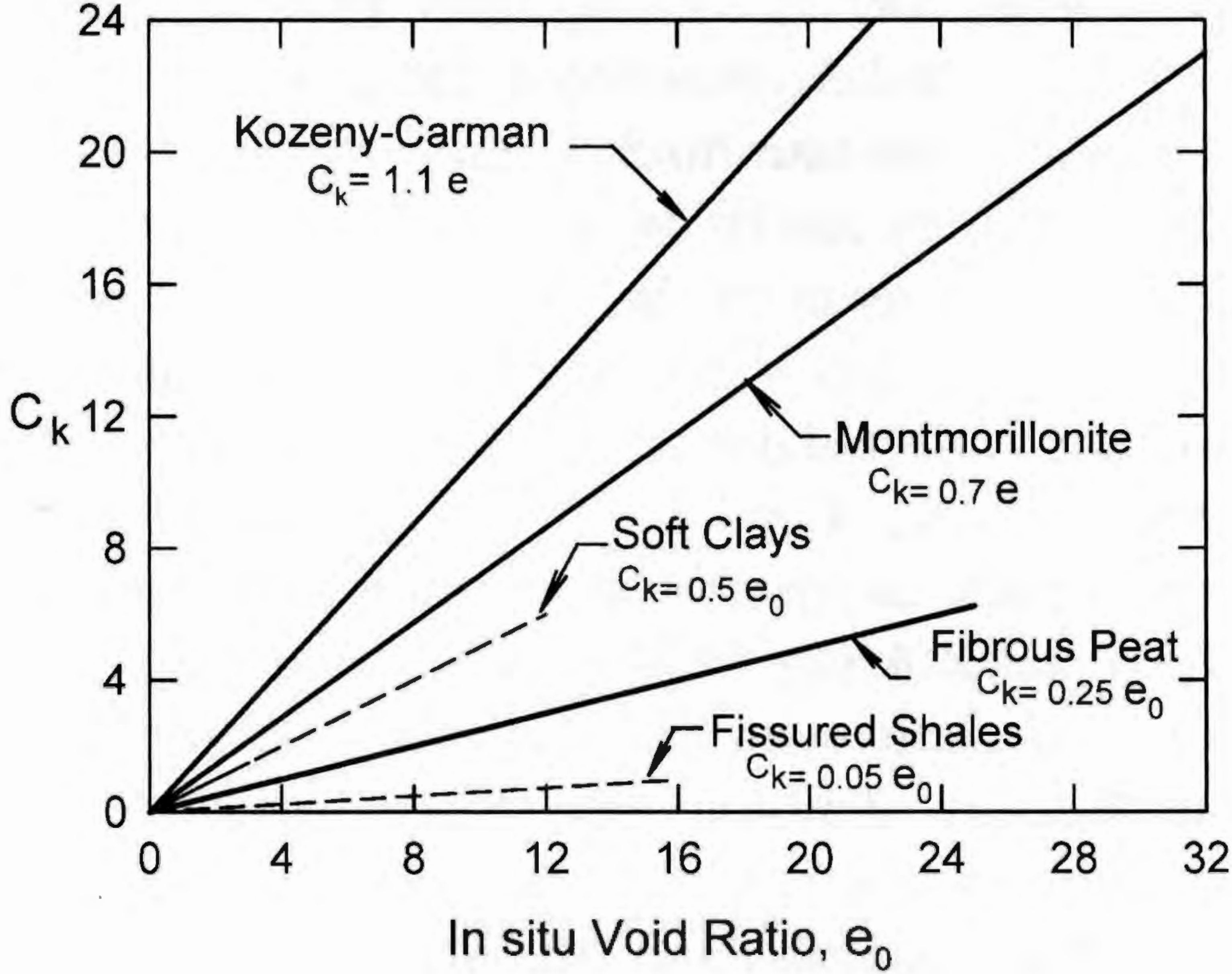


Fig. 4. Explanation of magnitude of C_k/e or C_k/e_o in terms of fiv
materials with different pore-size distribution

PEAT. BASIC STRENGTH PROPERTIES

PEAT. Strength properties

Undrained shear strength:

- Cu very low < 10 kPa for fibrous peat.
- Not possible to use vane shear tests because of fibres
- Piezocones useful for profiling only. Cone resistance < 100 kPa
- Mckintosh useful for shallow peat. MP = 5 to 10 blows / 300 mm for peat less than 3 m thick. Wong Kin Ming (2002) show MP of about 40 for peat depth of 7.0 m – Careful when interpreting Mckintosh probes

Peat . Undrained shear strength

- Difficult to measure
- Field vane shear tests not reliable especially for high fibre content – can result in abnormally high strength values
- Difficult to obtain undisturbed samples for laboratory strength tests.
- Landva concluded that vanes and cone penetrometers of little use.

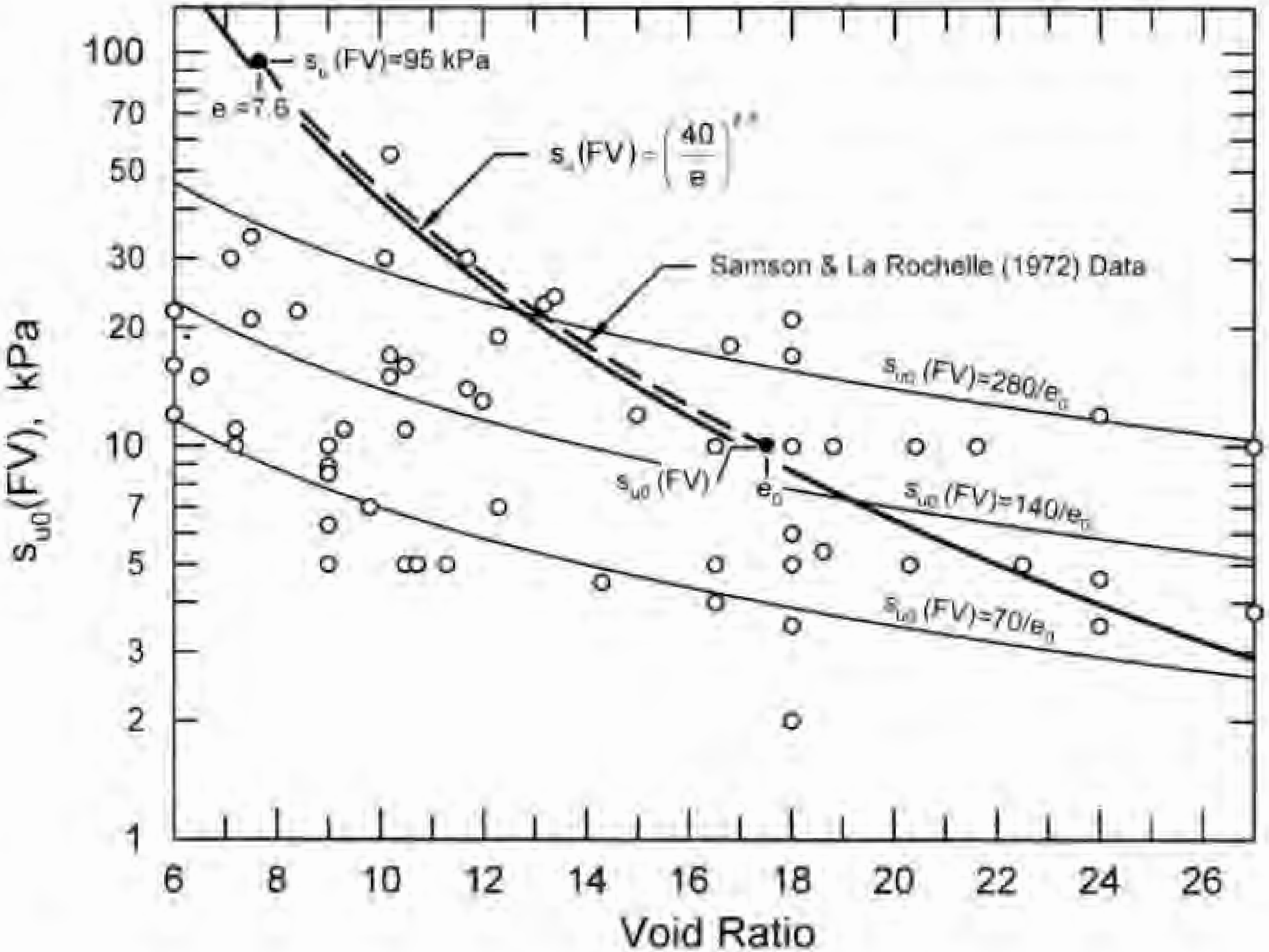


Fig. 20. Undrained shear strength of surficial fibrous peat deposits, from field vane test, s_u(FV), summarized in terms of in situ void ratio, as well as s_u(FV) versus e according to Eq. (13), together with preloading data of Samson and La Rochelle (1972)

Peat Effective / drained strength parameters

PEAT. Effective and drained strength

Usually very high friction angles compared to soft clay due to interlocking and stretching of the fibres.

CIU triaxial tests give

- Batu Kawa Road – Phi’ = 40 to 42 degrees
- Dutch peat - Phi’ = 35 to 52 degrees
- Soft clay typically –Phi’ = 24 degrees

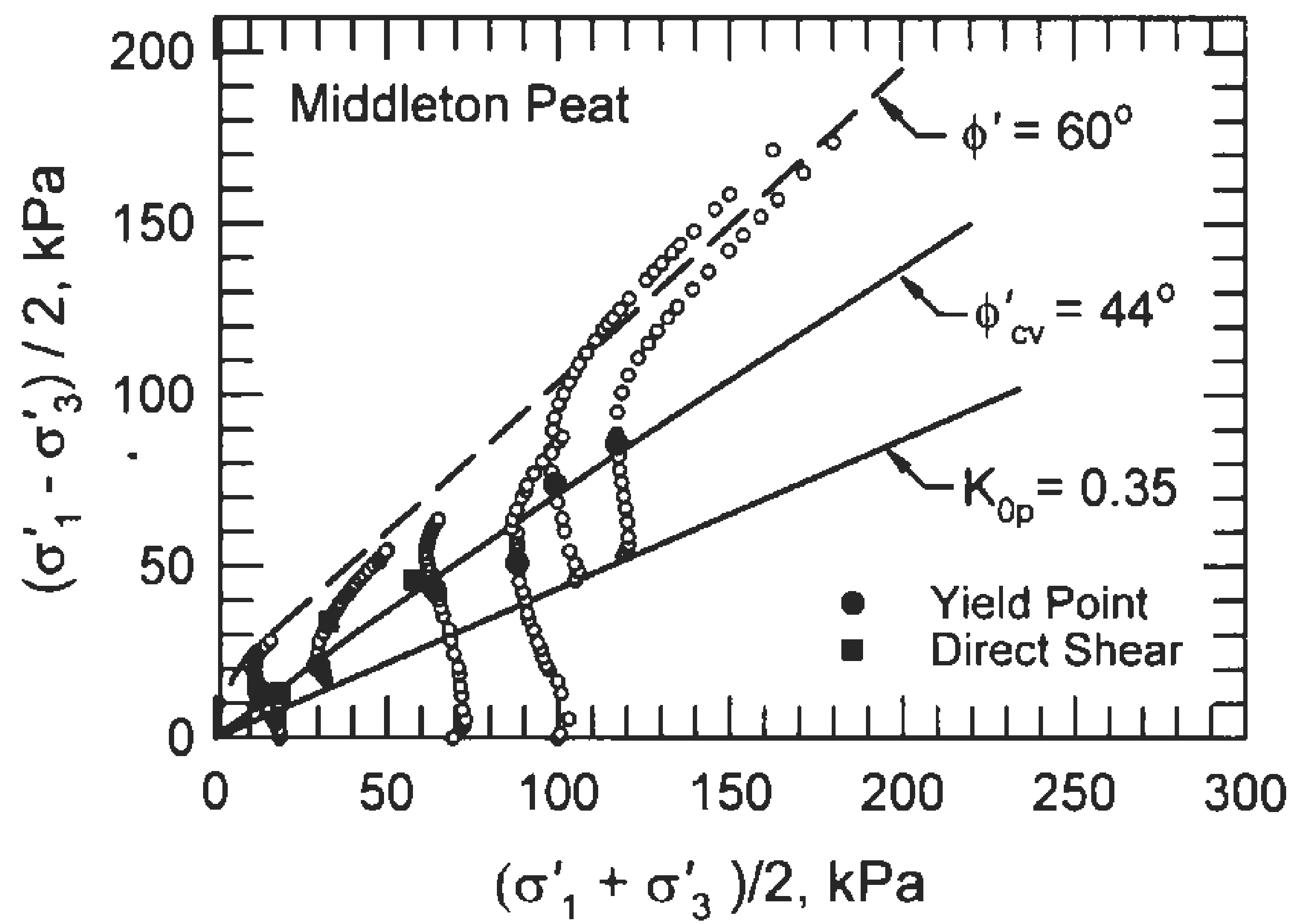


Fig. 17. Effective stress paths of Middleton peat specimens consolidated under equal all-around pressure or under laterally constrained condition and then subjected to undrained axial compression, and peak shear strength versus effective normal stress σ_n' from three drained direct shear tests

Table 5. Friction Angle of Fibrous Peats from Triaxial Compression Tests on Vertical Specimens

Source	Peat	w_o (%)	ϕ' (degrees)
Adams (1961)	Muskeg	375–430	50–60
Adams (1965)	Moose River	330–600	48
Ozden et al. (1970)	Muskeg	800	46
Tsushima et al. (1977)	Muck	—	52–60
Yasuhara and Takenaka (1977)	Omono	—	50–60
Tsushima et al. (1982)	Muck	—	51
Edil and Dhowian (1981) and Edil and Wang (2000)	Middleton	500–600	57
	Portage	600	54
Landva and LaRochelle (1983)	Escuminac	1,240–1,380	40–50
Marachi et al. (1983)	San Joaquin	200–500	44
Yamaguchi et al. (1985a,c,d)	Ohmiya	960–1,190	51–55
	Urawa	980–1,260	53
Ajlouni (2000)	Middleton	510–850	60

Friction angle – Irish peat

Author	Φ' (degrees)
Farrel and Hebib	55 degrees for NMC of 1200 to 1400%
Sodha	36 degrees for NMC of 710% 43 degrees for NMC of 575%
Hanrahan - backcalculation	C' = 5.5 to 6.1 kPa Φ' = 36.6 to 43.5 degrees

PEAT. Strength increase

The increase in strength with effective pressure is much higher for peat than soft clay

- Soft clay cu/po' = 0.25 typically
- Peat cu/po' = 0.54 to 0.72

The higher ratios are for the higher organic content. The interlocking of fibres give very high drained strength; same reason for the higher φ'

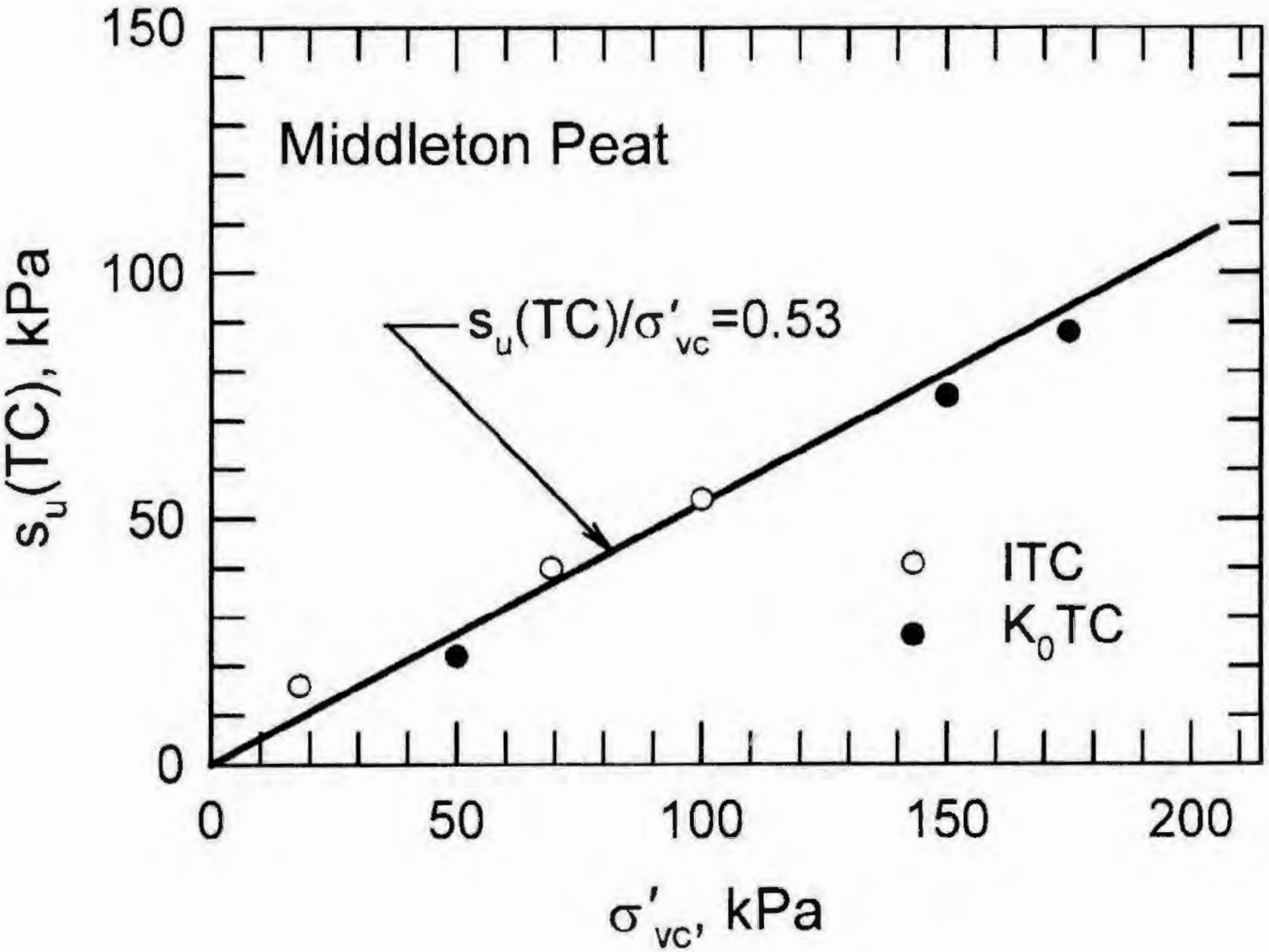


Fig. 19. Relationship between undrained shear strength from compression mode of shear defined at phase transformation yield point, s_u(TC), and vertical consolidation pressure, σ'_v, for Middleton peat

Table 6. $s_u(\text{TC})/\sigma'_{vc}$ of Fibrous Peats

Source	Peat	w_o (%)	$s_u(\text{TC})/\sigma'_{vc}$
Moran et al. (1958)	Antioch, Algiers	230–1,000	0.48–0.60
Lea and Brawner (1959)	Burnaby	400–1,200	0.47–0.58
Adams (1965)	Moose River	330–600	0.68
Forrest and MacFarlane (1969)	Ottawa	900–1,200	0.50
Yasuhara and Takenaka (1977)	Omono	—	0.54
Tsushima et al. (1977)	—	—	0.52–0.54
Dhowian (1978) and Edil and Wang (2000)	Middleton	500–600	0.55–0.75
	Portage	600	0.70
Yamaguchi et al. (1985a,c,d)	Ohmiya	960–1,190	0.55
	Urawa	980–1,260	0.52
Den Haan (1997)	—	—	0.54–0.78
Ajlouni (2000)	Middleton	510–850	0.53[a]

[a]Defined at phase transformation yield point.

Cu/p0’

Author	Cu / p0’
Carlsten (Ireland)	0.4 to 0.55 (from CIU triaxial)
Edil (US)	0.4 to 0.8 (from CIU triaxial) 0.3 to 1.5 (from vanes)
Landva and la Rochelle	1.23
Hazawa	0.45

IMPLICATIONS OF HIGH φ’ , HIGH Cu/p’ and HIGH Cv

- Certainty of appreciable gain in strength
- Encourages stage construction for construction of high embankments

OTHER PEAT PROPERTIES

OTHER PEAT PROPERTIES

- Cold
- Acidic
- Oxygen free environment
- Bacteria immobilized
- Mummifies / preserves dead bodies
- 2300 year old bodies have been recovered form European peat during peat mining

NCIENT HUMAN REMAINS (2300 YEARS OLD) UNEARTHED FROM EUROPEAN PEAT SWAMPS (BBC)

SOIL INVESTIGATIONS IN PEAT

Soil Investigations

Landva : *For fibrous peat, small scale tests such as vanes and cone penetrometers of little use.*

Vane shear tests meaningless – fibres are torn rather than sheared, Likely to completely over-estimate the shear strength.

PEAT. Soil Investigations

(i) Difficulty in obtaining undisturbed samples of peat especially for higher organic content

(ii) Strategy is to obtain disturbed samples (use peat augers) and carry out:

- Natural moisture content;
- Ignition loss;
- Organic content;
- Ash content

PEAT. Soil Investigation

With the basic properties use published correlations to :

- Obtain consolidation parameters for settlement estimates.
- Obtain strength parameters at different stages of embankment construction from consolidation up to that stage.

NECESSARY to obtain properties of soft clay beneath peat.

- Vane shear strength;
- Consolidation parameters;

PEAT. Soil Investigation

NOTES

- Careful about boreholes. Inexperienced driller can record absence of peat
- Use peat augers on a grid pattern
- Use Mckintosh probes on a grid pattern(shallow peat)
- Boreholes and piezocones for profiling
- Local knowledge

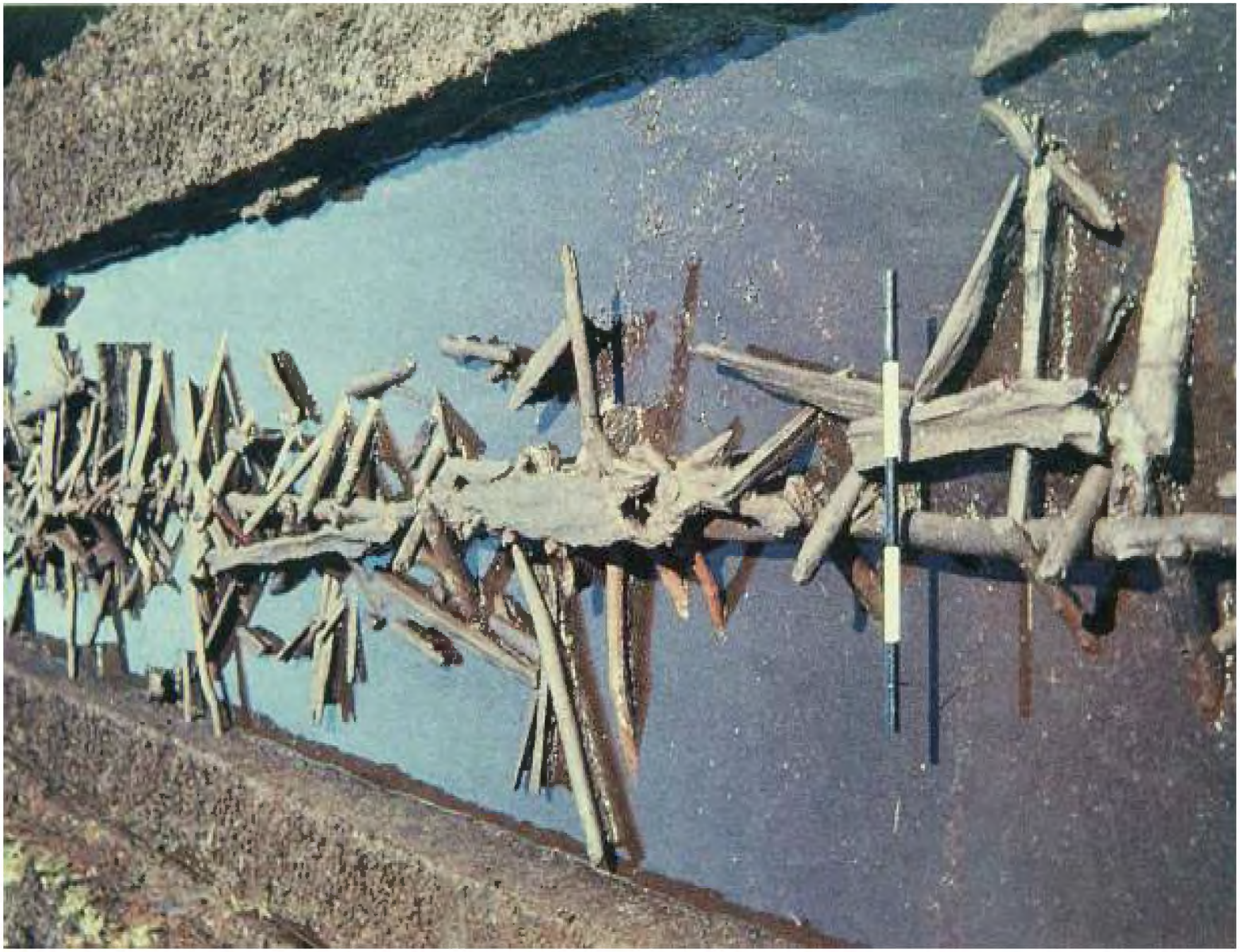
CONSTRUCTION ON PEAT

ANCIENT HISTORY

HOW ANCIENT MAN CROSSED PEAT SWAMPS

FROM ARCHEOLOGICAL FINDINGS

AT SOMERSET, SOUTHERN ENGLAND



MEDIEVAL TIMES

Corduroy Roads

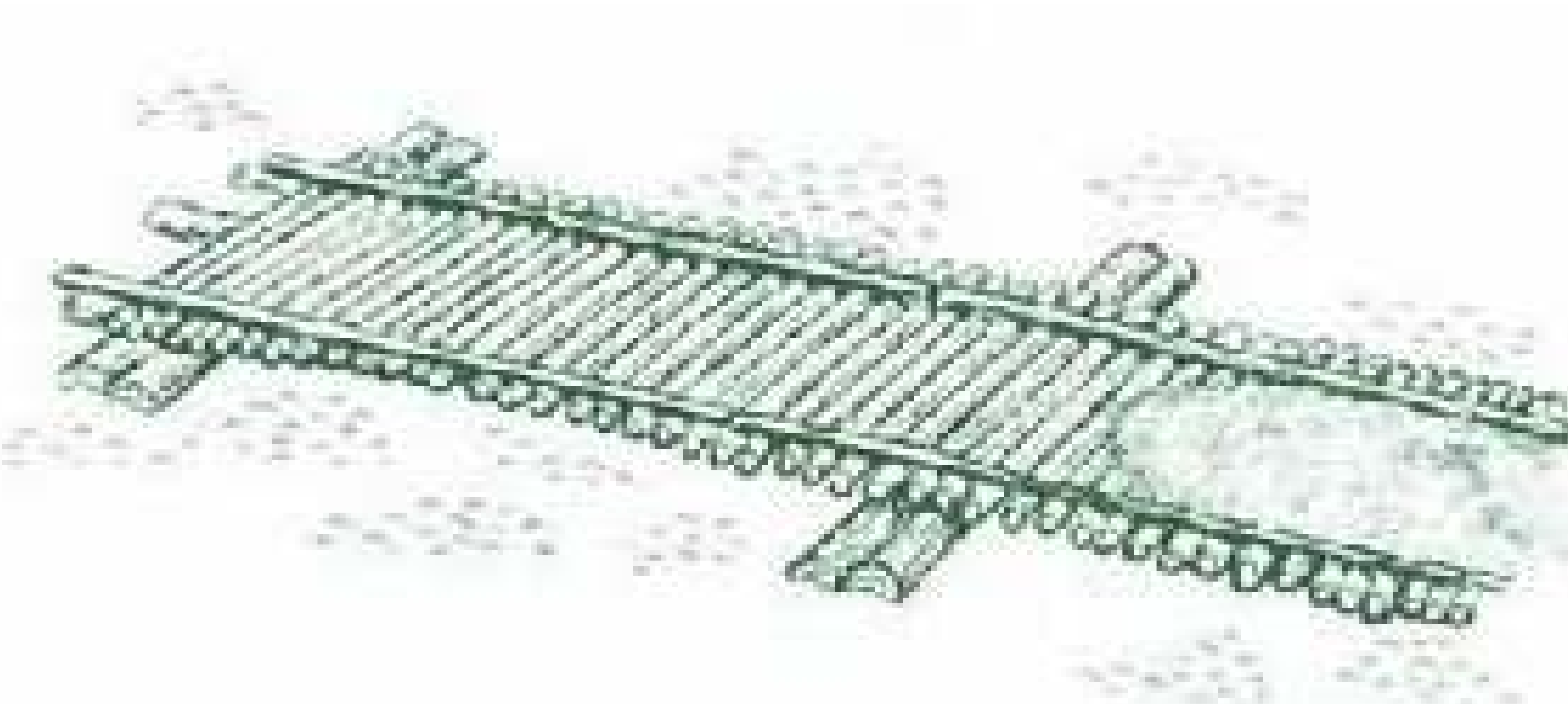
Discovery in UK of roads from Roman days.

Roads dated at between 900 to 1020AD

MEDIEVAL WOODEN TRACK, WALES, 900 TO 1020 AD

CROSSING SWAMP ON CORDUROY ROAD, UK 1815

CORDUROY ROAD
Earliest 4000BC (Glastonbury UK) to 20th Century



CORDUROY ROAD.UNION ARMY. AMERICAN CIVIL WAR

CORDUROY ROAD

WORLD WAR II

Extensively used by German Army during invasion of Russia

According to Antony Bevar author of "STALINGRAD"

"In some places, where no birch trunks came to hand to make corduroy roads, the corpses of Russian dead were used instead as planks."

MALAYSIA 1970 TO 1980s

EARLY ROAD CONSTRUCTION ON PEAT

- Modern earthworks equipment
- End tip approach
- Brute force
- Not a lot of thinking
- No past history then

PEAT . Filling over Peat

PLACING FILL OVER PEAT

- Very , very important consideration
- Peat swampy and inaccessible except to light equipment. Often soil inv equipment has to access on timber planks
- End tipping will cause mud waves, severe lateral movements, loss of fill as fill mixed with peat. Volume of fill loss can be immense.
- Excavators known to have sunk into peat

Planks for soil investigation, Machap, Johore

Plate 1 **Timber matting required for drilling rig access during site investigation**

PEAT. Uncontrolled filling

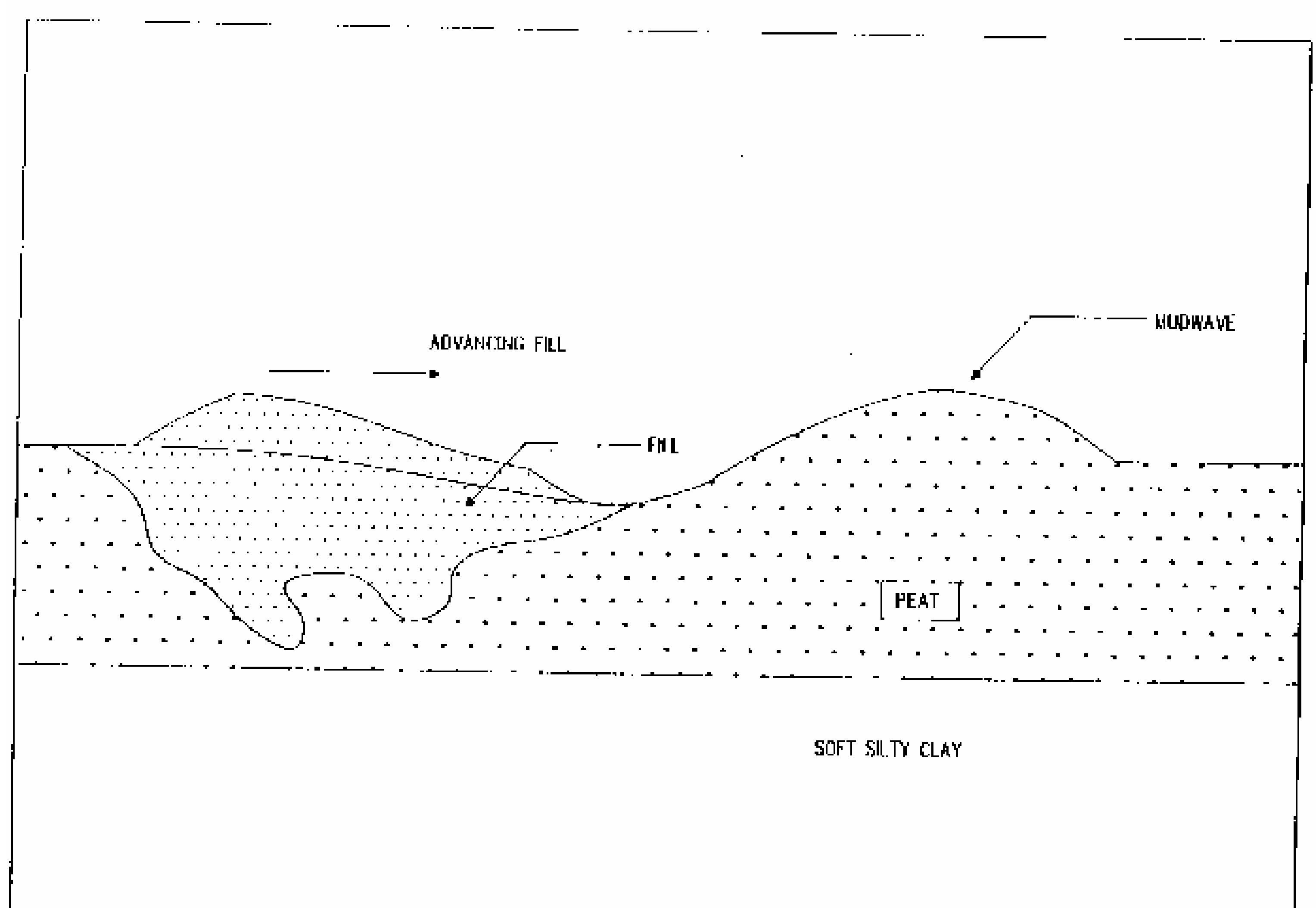


FIG. 11 -- DISPLACEMENT OF PEAT DUE TO FILL PLACEMENT

PEAT. Uncontrolled Filling
Air Baloi Road, Johore

PEAT. Uncontrolled filling Air Baloi Road, Johore

CONTROLLED FILL PLACEMENT ON PEAT

AN ABSOLUTE NECESSITY

Methods to ensure stable fill placement

Drain the peat to lower ground water table by 0.5m to 1.0m. Enable access by light earthworks equipment and placement of fill in dry conditions in thin layers.

Timber matting.

Geotextile bamboo fascine mattress.

PEAT. Filling in dry conditions

- Critical to start with site drainage and lower ground water by about 1.0 m.
- Achieve drainage by a network of drains and allow peat to drain for several weeks
- Drain construction slow. Progressive deepening. Maybe ½ metre each increment then allow drainage for few weeks then next increment.
- Peat fibres will then interlock and stretch under load like a thick geotextile cushion (high φ)

PEAT. Filling in dry condition

- If gravity drainage not possible , will need to pump.
- When peat surface is well drained, place first layer of less than 0.5 m using light track dozers.
- Tree trunks or timber waste from site clearance will be useful to help form the access.

PEAT . Drainage

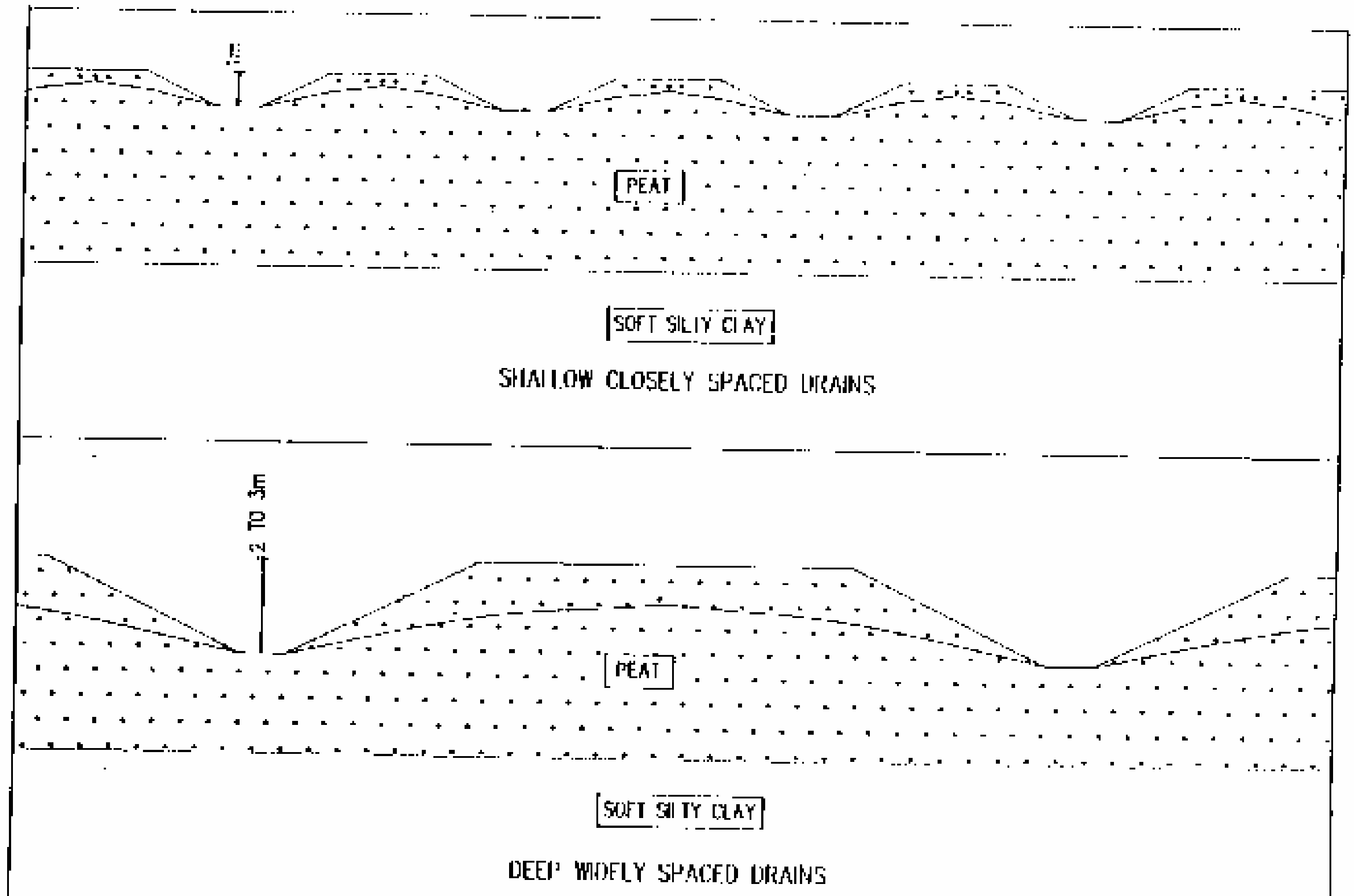


FIG. 13 – LOWERING OF WATER TABLE BY SURFACE DRAINS

PEAT. Large Areal Drainage by DID (Johore)

PEAT. Large Area Drainage by DID (Johore)

PEAT. Drainage due to dewatering for peat excavation (Machap)

PEAT. Timber matting

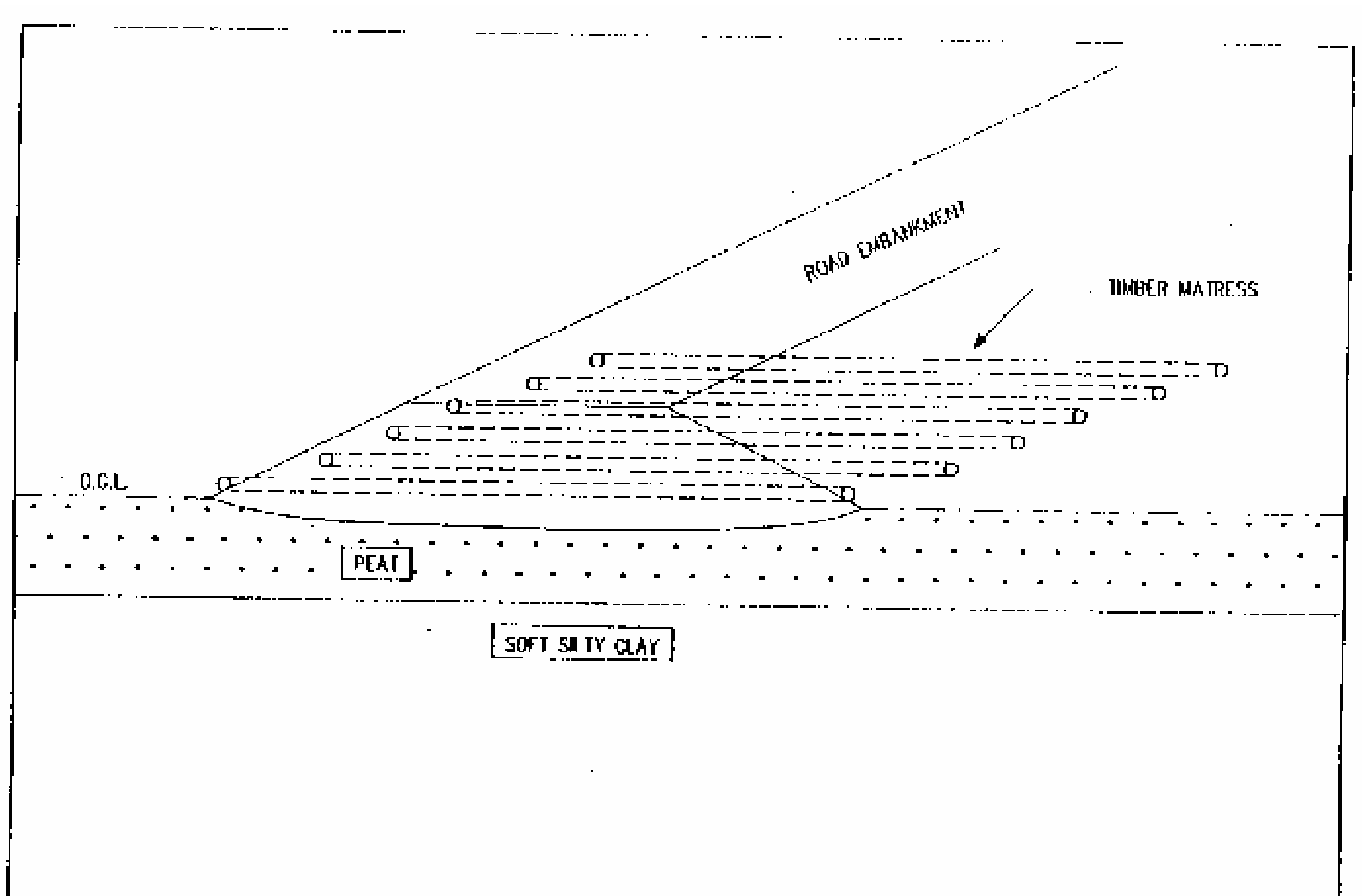


FIG. 12 ROAD EMBANKMENT ON TIMBER MATTRESS

PEAT. Geotextile bamboo Fascine

- Local innovation originally developed for filling over disused mining slime ponds (see Toh, Chee, Lee, Wee)
- First used in Sarawak for peat at Petra Jaya Boulevard and Petra Jaya ring road
- Bamboo frame tied by wire to provide stiffness and access
- Highly extensible geotextile to stretch without tearing and contain mudwave ahead of the fill.

PEAT.Geotextile – bamboo fascine

- Geotextile must have high permeability to enable dissipation of pore pressures
- First layer of fill about 500 mm must be sand to enable pore pressures to be dissipated
- Significant mud waves can form if low permeability soil used as first layer fill
- Use when not possible to drain low lying peat areas

PEAT. Geotextile bamboo fascine

PEAT. Geotextile bamboo fascine

Geotextile bamboo fascine

Geotextile Bamboo Fascine

Geotextile Bamboo fascine

Geotextile Bamboo Fascine

Geotextile bamboo fascine

Geotextile bamboo fascine

Geotextile Bamboo fascine

PEAT. Hydraulic sand filling

Good way of filling over peat because the sand can be placed by pumping in thin lifts and spread over a wide area.

No need to drain the peat and no need for timber matting or geotextile bamboo fascine.

Was used successfully for the Matang Highway, Kuching

Peat Swamp . Matang

Peat Matang. Hydraulic sand fill

Peat. Matang. Hydraulic sand fill

Peat. Matang. Hydraulic sand fill

Peat. Matang. Hydraulic sand fill

Peat. Matang. Hydraulic sand fill

Peat. Matang. Hydraulic sand fill

Peat. Matang. Hydraulic sand fill

Peat. Matang. Hydraulic sand fill

CASE HISTORIES

PEAT. CASE HISTORIES

- Miri Bypass road – Stage construction of road embankment
- MJ City. Batu Kawa (First phase) filling with surcharge
- Oya-Balingian Road
- Matang Highway (hydraulic sand fill + preload)
- Sylhet road (Bangladesh) – Stage construction with geotextile reinforcement
- Khoo and Yam. Pagoh
- Peat replacement (Air Itam to Johor Baru NORTH SOUTH Expressway)
- Sibu floating road

Embankment stability (repeat important points)

Very low initial Cu < 10 kPa will give rise to filling and stability problems if embankment built too rapidly

Punch type bearing capacity due to high ratio of embankment to foundation stiffness

High Cu/p' of 0.5 to 0.8 and high friction angle favours stage construction. Rest periods between lifts to enable gain in strength to take place. The gain in strength comes quickly from the more rapid pore pressure dissipation especially in the early stages.

PEAT. Embankment stability (repeat important points)

CARE

Soft clay often found beneath peat. If peat is relatively thin, slip circle extends into soft clay, and stability not governed by peat but by soft clay.

Examples of Stage construction in case histories.

PEAT. Settlement (repeat important points)

Estimates of peat settlement made in the same manner as for soft clay except that:

$C_c/(1 + e_o) = 0.4$ to 0.5 (higher than clay)

C_α contributes to long term settlement.

Experience shows that from use of above parameters with $c_v = 5$ sq m per year, fairly good estimate of settlement can be made.

PEAT. Settlement (from measurements)

Commonly significant settlement occur during the building up of the embankment.

Settlement can be up to between 50 to 65 % of the peat thickness.

Longer term settlement influenced more by the consolidation of the underlying soft clay.

Extra earthworks must be envisaged and allowed for.

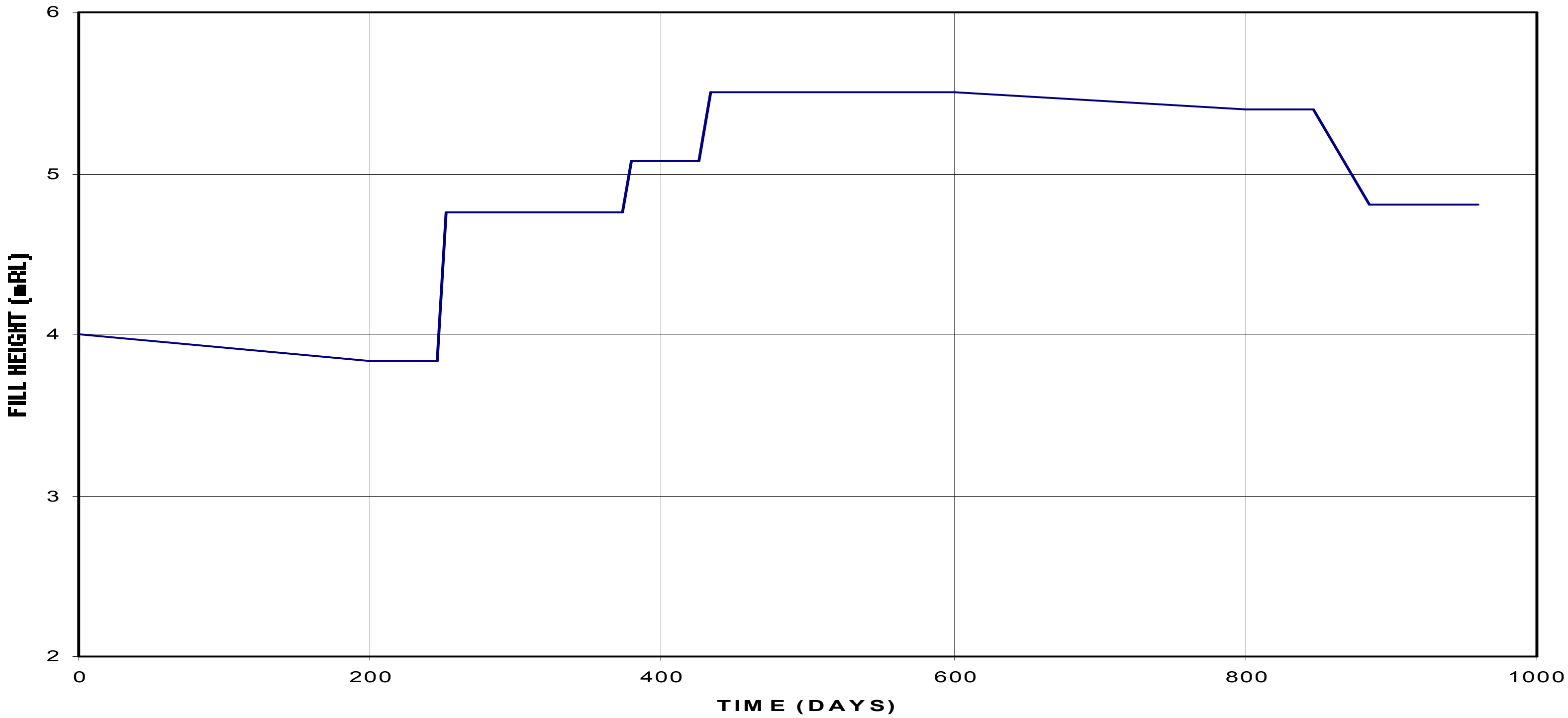
Settlement of peat addressed in case histories

PEAT CASE HISTORY.

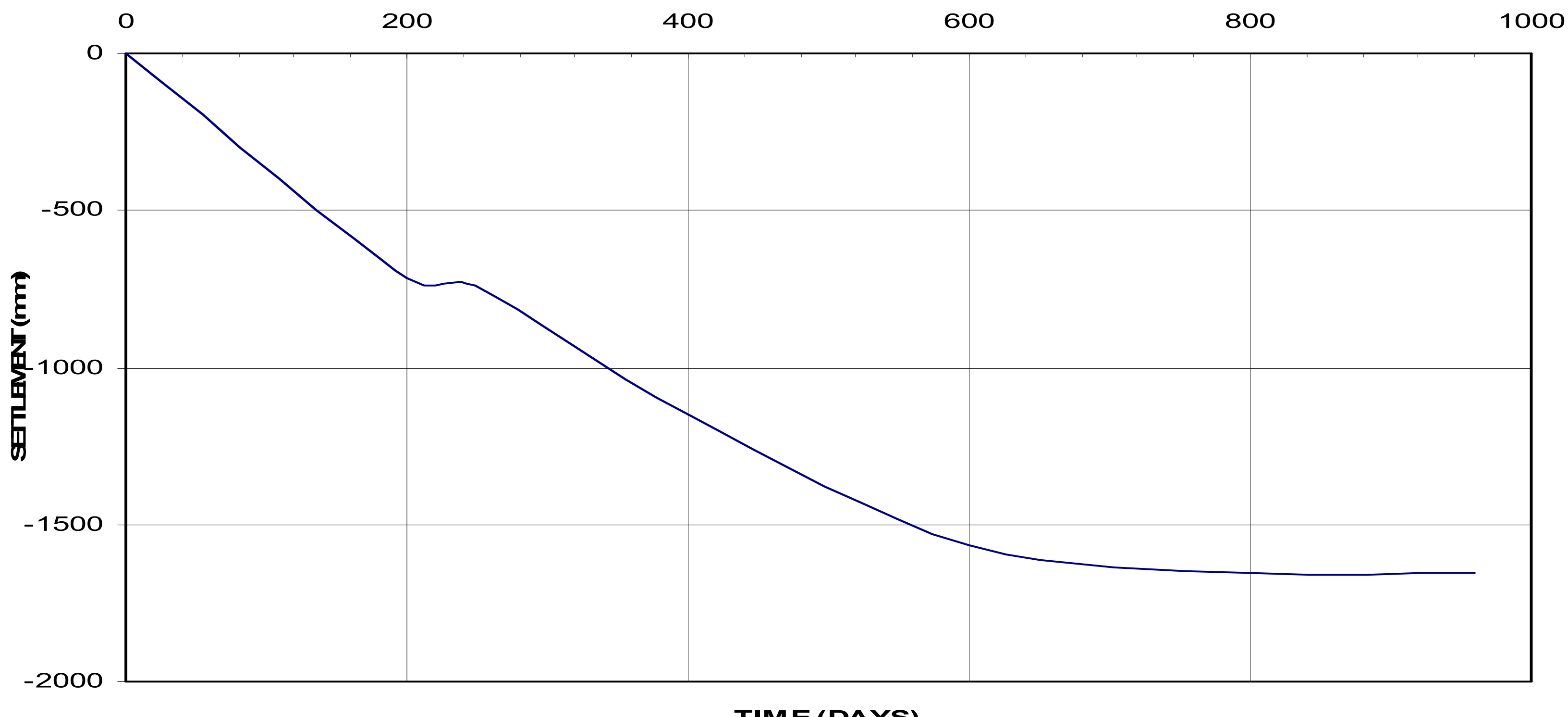
MIRI BY PASS ROAD

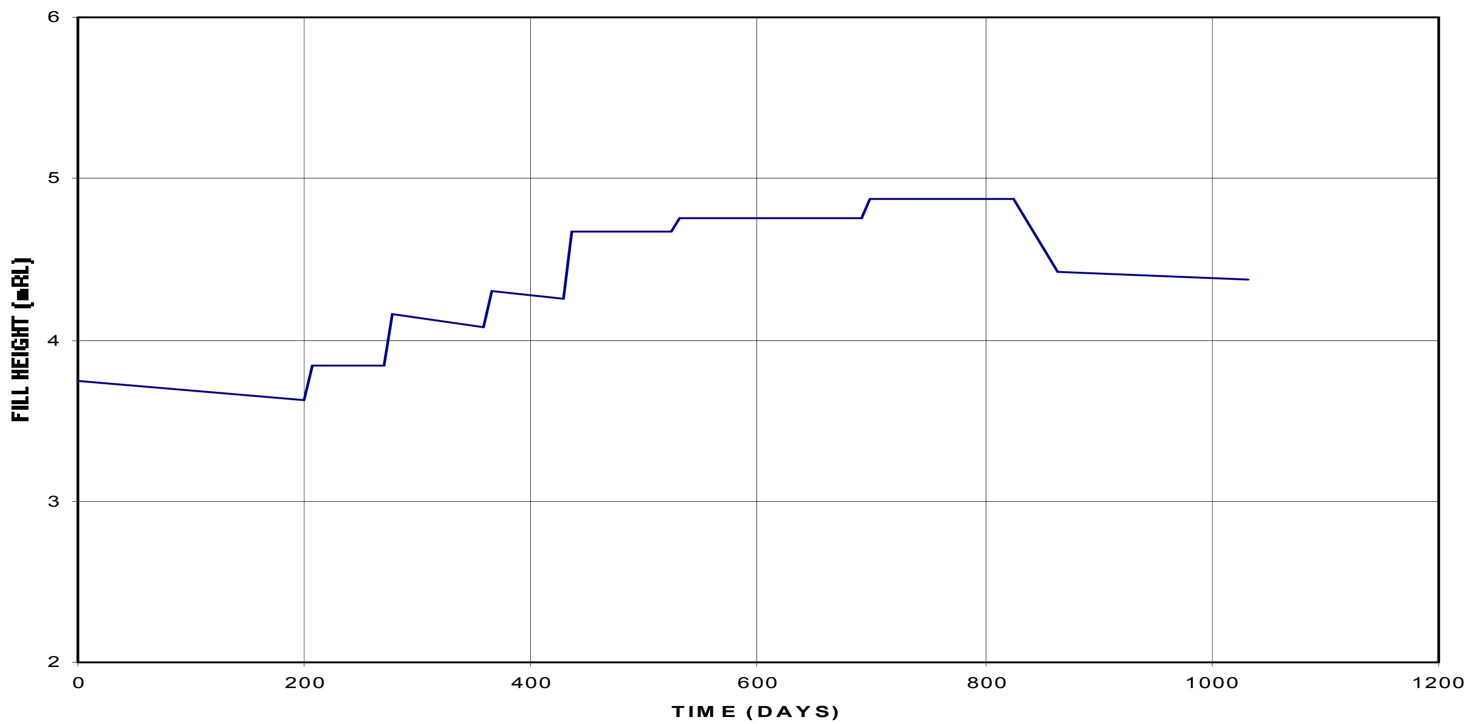
MIRI BY PASS ROAD

SP 2	3 m peat 3 – 18 m soft clay	S = 1.7 m
SP 4	1.5 m peat 1.5 – 19 m soft clay	S = 1.05 m
SP 6	1.2 m peat 1.2 – 8.5 m soft clay	S = 0.8 m

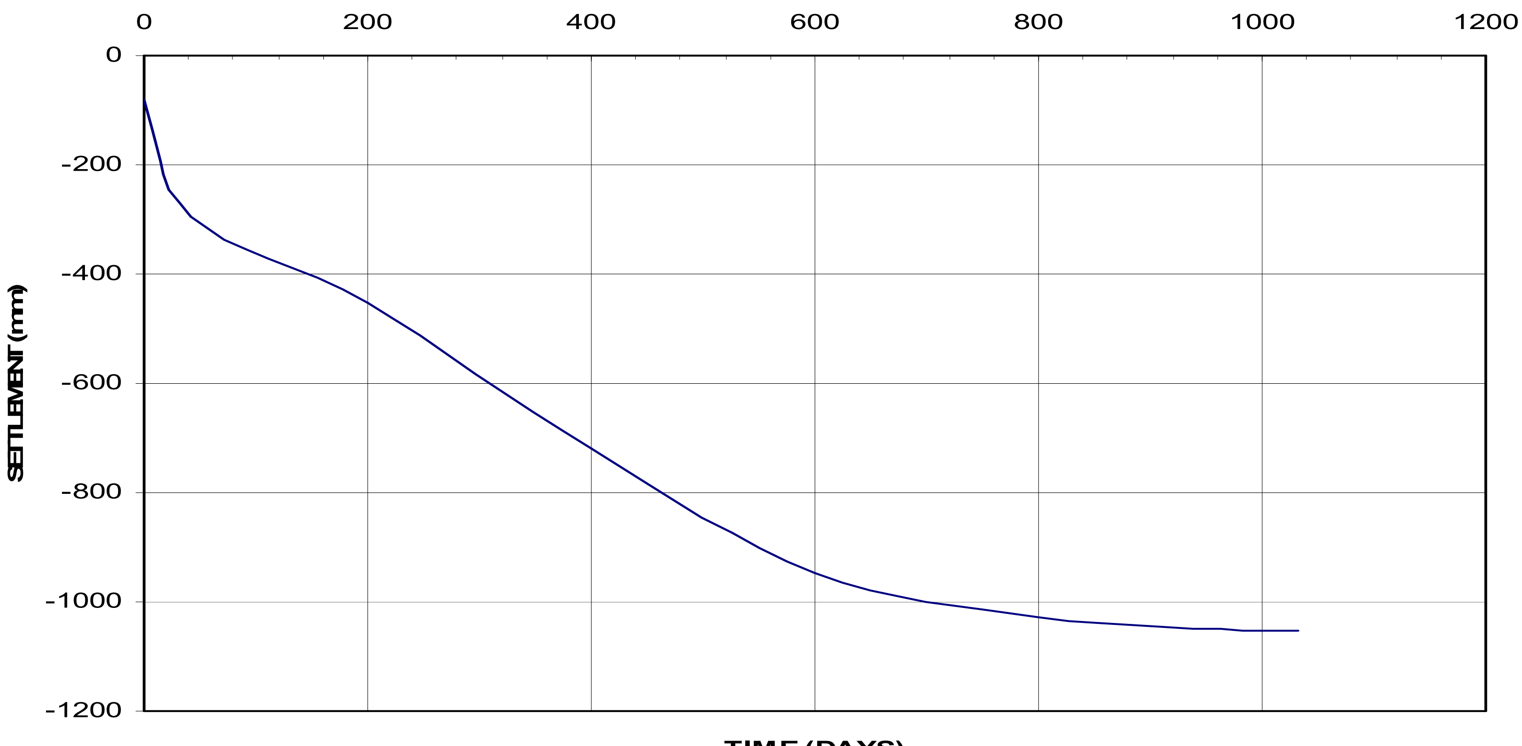


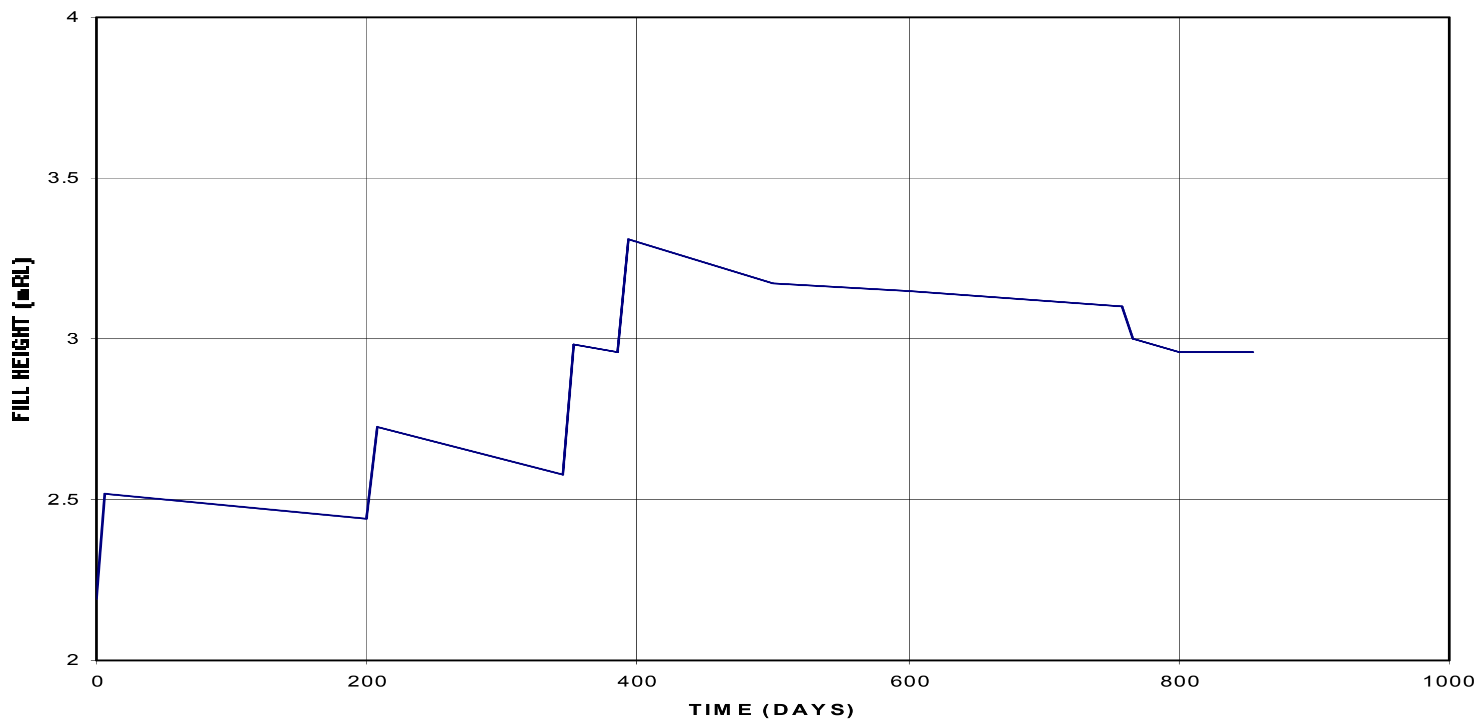
SP2 @ CH2+700 Road 1



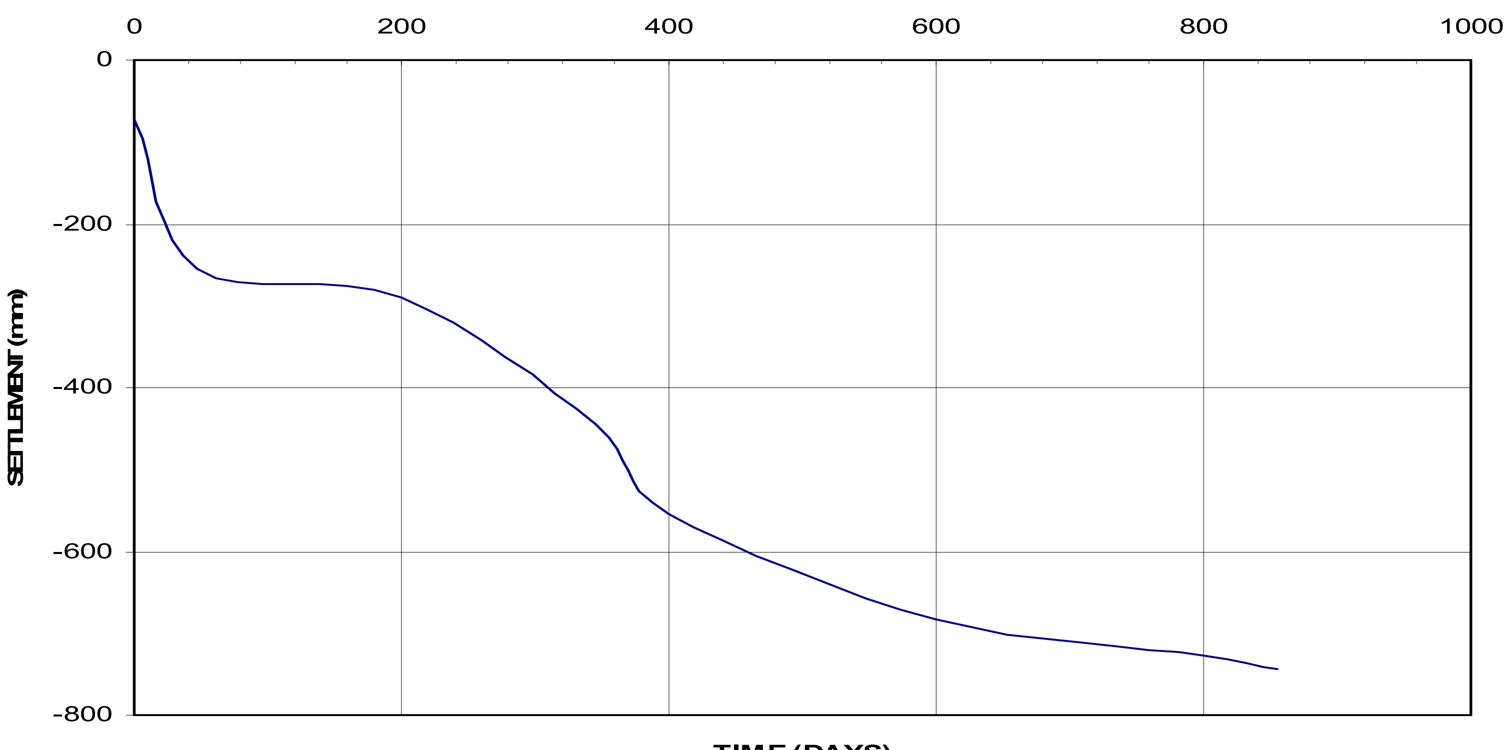


SP4 @ CH3+310 Road 1





SP6 @ CH4+265 Road 1



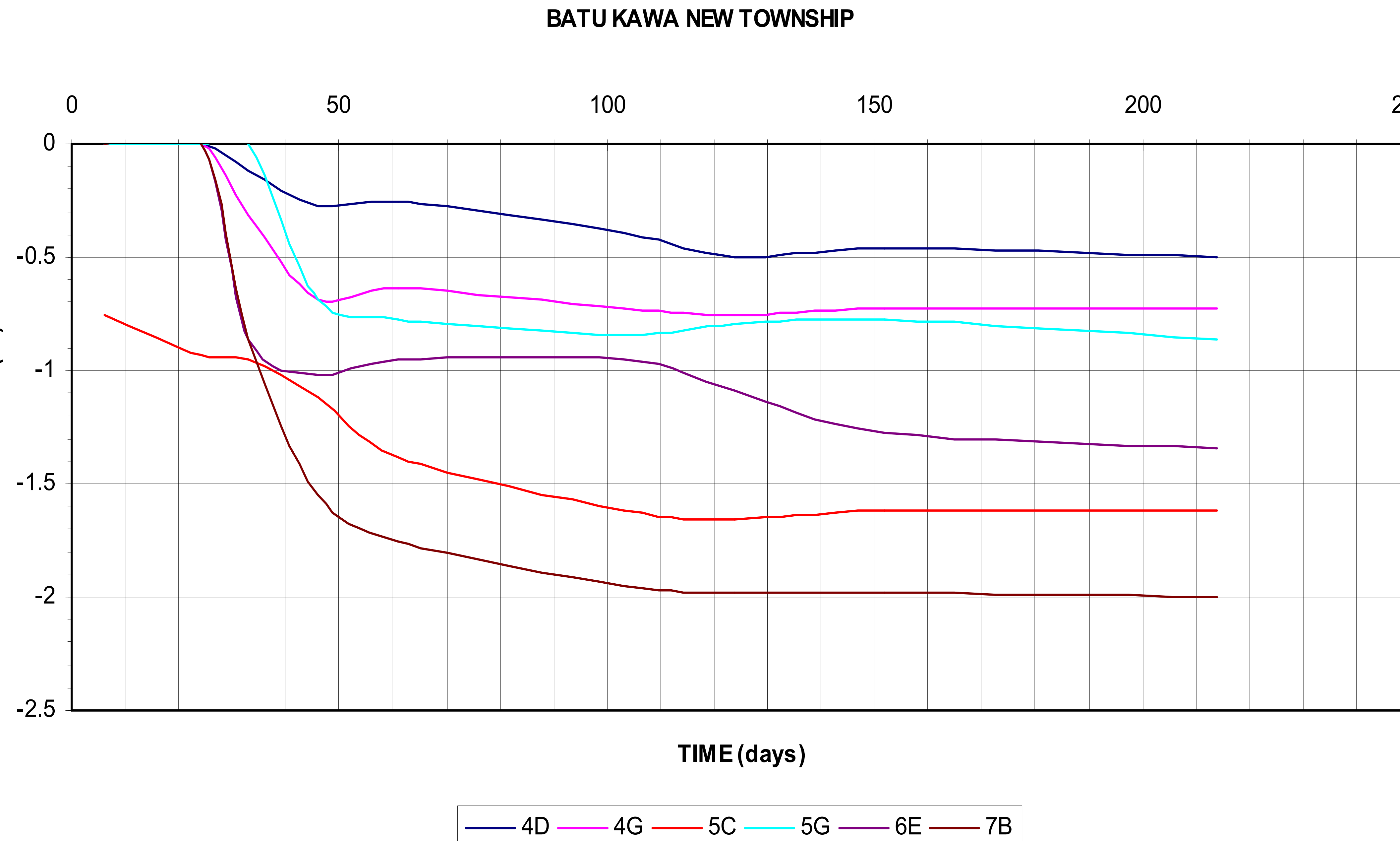
MJ CITY BATU KAWA

4 to 6 m peat over limestone

Surcharge over 200 days

Settlement up to 2 m

MJ CITY. BATU KAWA

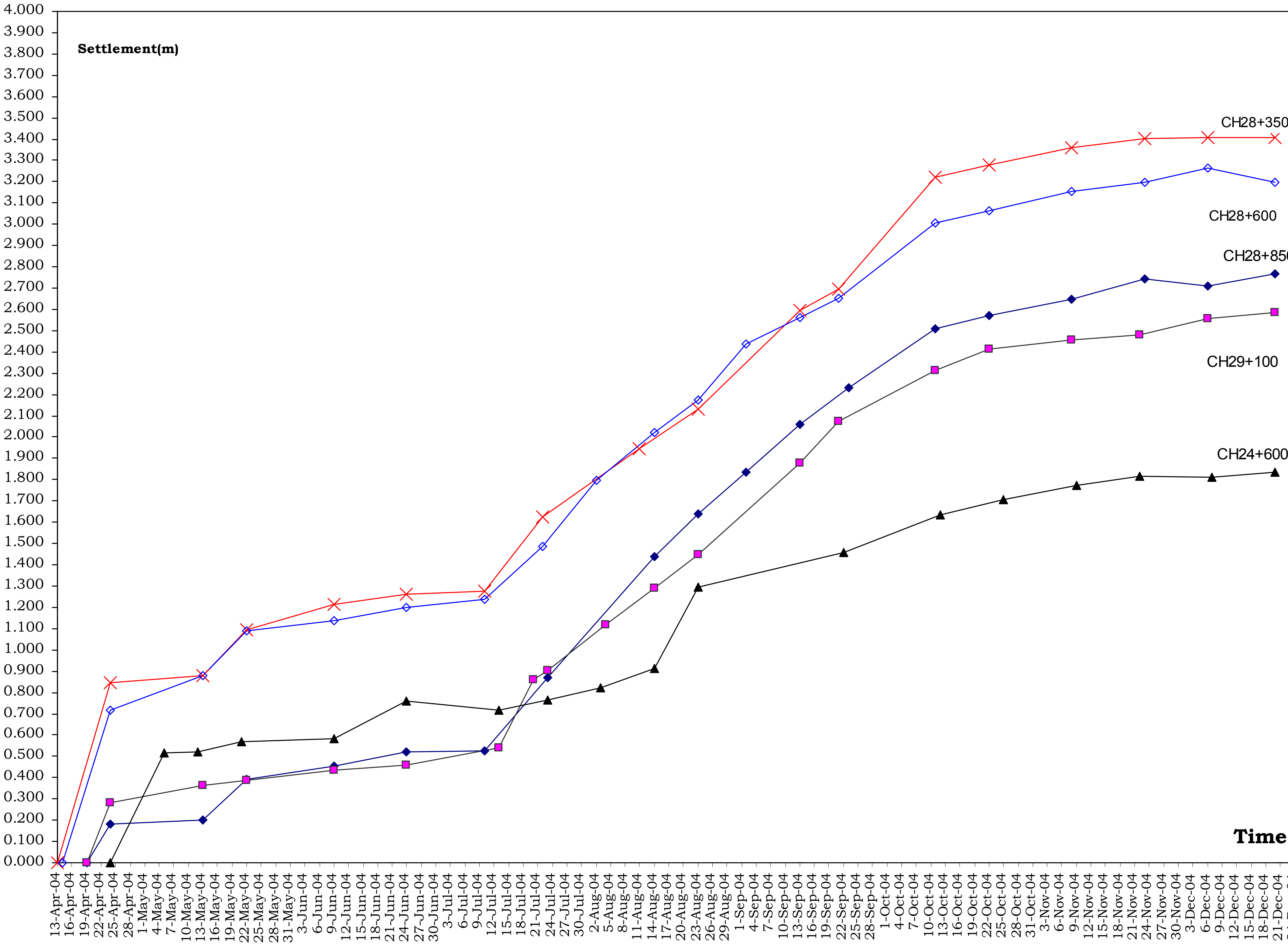


OYA BALINGIAN ROAD

PEAT DEPTH UP TO ABOUT 5.5 M

SURCHARGE FOR ABOUT 9 MONTHS

MEASURED SETTLEMENT S UPTO 3.9 M



Settlement(m)
4.000
3.900
3.800
3.700
3.600
3.500
3.400
3.300
3.200
3.100
3.000
2.900
2.800
2.700
2.600
2.500
2.400
2.300
2.200
2.100
2.000
1.900
1.800
1.700
1.600
1.500
1.400
1.300
1.200
1.100
1.000
0.900
0.800
0.700
0.600
0.500
0.400
0.300
0.200
0.100
0.000
CH28+350
CH28+600
CH28+850
CH29+100
CH24+600
Time
13-Apr-04
16-Apr-04
19-Apr-04
22-Apr-04
25-Apr-04
28-Apr-04
1-May-04
4-May-04
7-May-04
10-May-04
13-May-04
16-May-04
19-May-04
22-May-04
25-May-04
28-May-04
31-May-04
3-Jun-04
6-Jun-04
9-Jun-04
12-Jun-04
15-Jun-04
18-Jun-04
21-Jun-04
24-Jun-04
27-Jun-04
30-Jun-04
3-Jul-04
6-Jul-04
9-Jul-04
12-Jul-04
15-Jul-04
18-Jul-04
21-Jul-04
24-Jul-04
27-Jul-04
30-Jul-04
2-Aug-04
5-Aug-04
8-Aug-04
11-Aug-04
14-Aug-04
17-Aug-04
20-Aug-04
23-Aug-04
26-Aug-04
29-Aug-04
1-Sep-04
4-Sep-04
7-Sep-04
10-Sep-04
13-Sep-04
16-Sep-04
19-Sep-04
22-Sep-04
25-Sep-04
28-Sep-04
1-Oct-04
4-Oct-04
7-Oct-04
10-Oct-04
13-Oct-04
16-Oct-04
19-Oct-04
22-Oct-04
25-Oct-04
28-Oct-04
31-Oct-04
3-Nov-04
6-Nov-04
9-Nov-04
12-Nov-04
15-Nov-04
18-Nov-04
21-Nov-04
24-Nov-04
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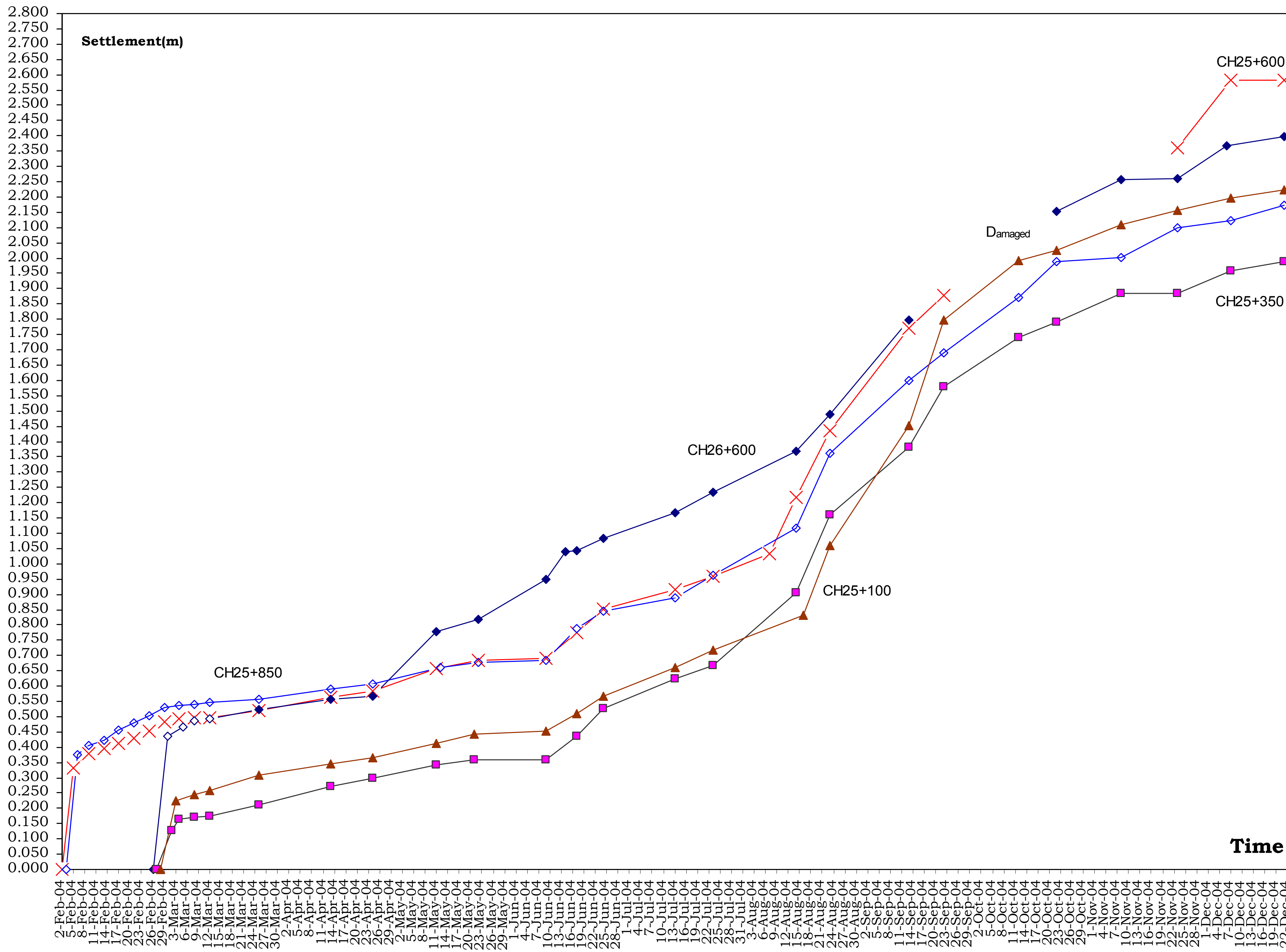
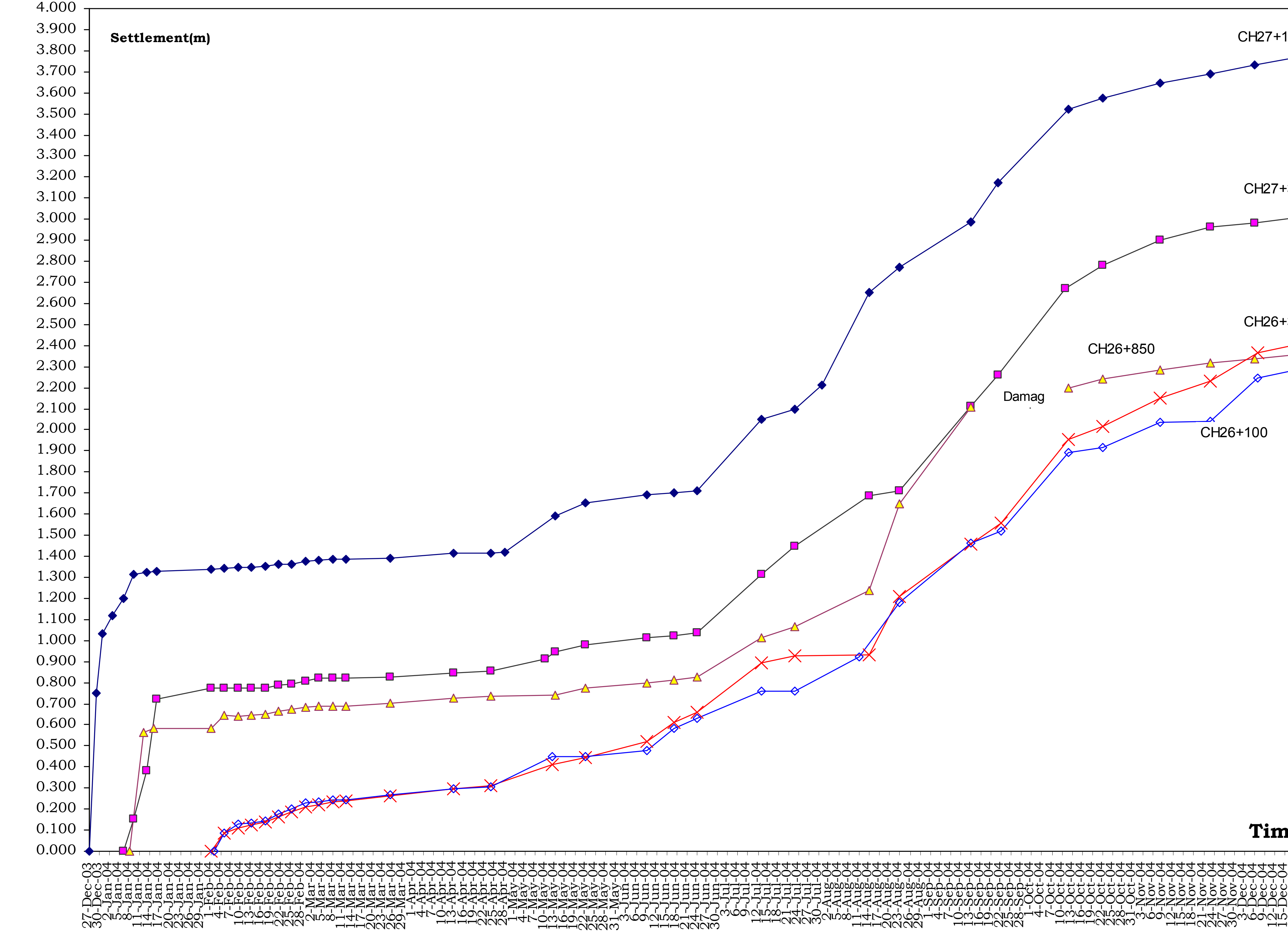
15-Dec-04
18-Dec-04
21-Dec-04



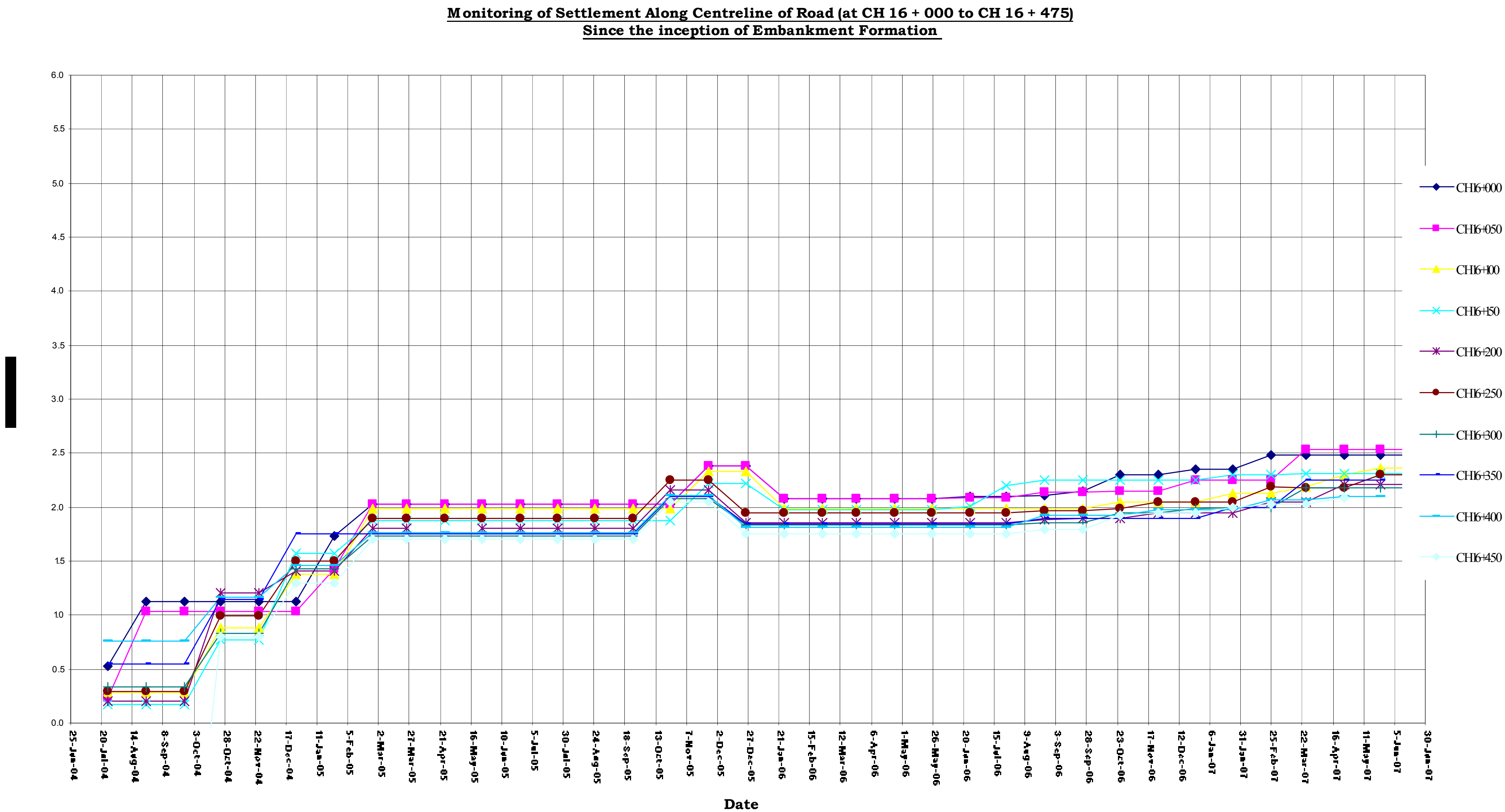
Settlement(m)
CH25+600
Damaged
CH26+600
CH25+850
CH25+100
CH25+350
Time


Settlement(m)
CH27+1
CH27+
CH26+
CH26+850
Damag
CH26+100
Tim

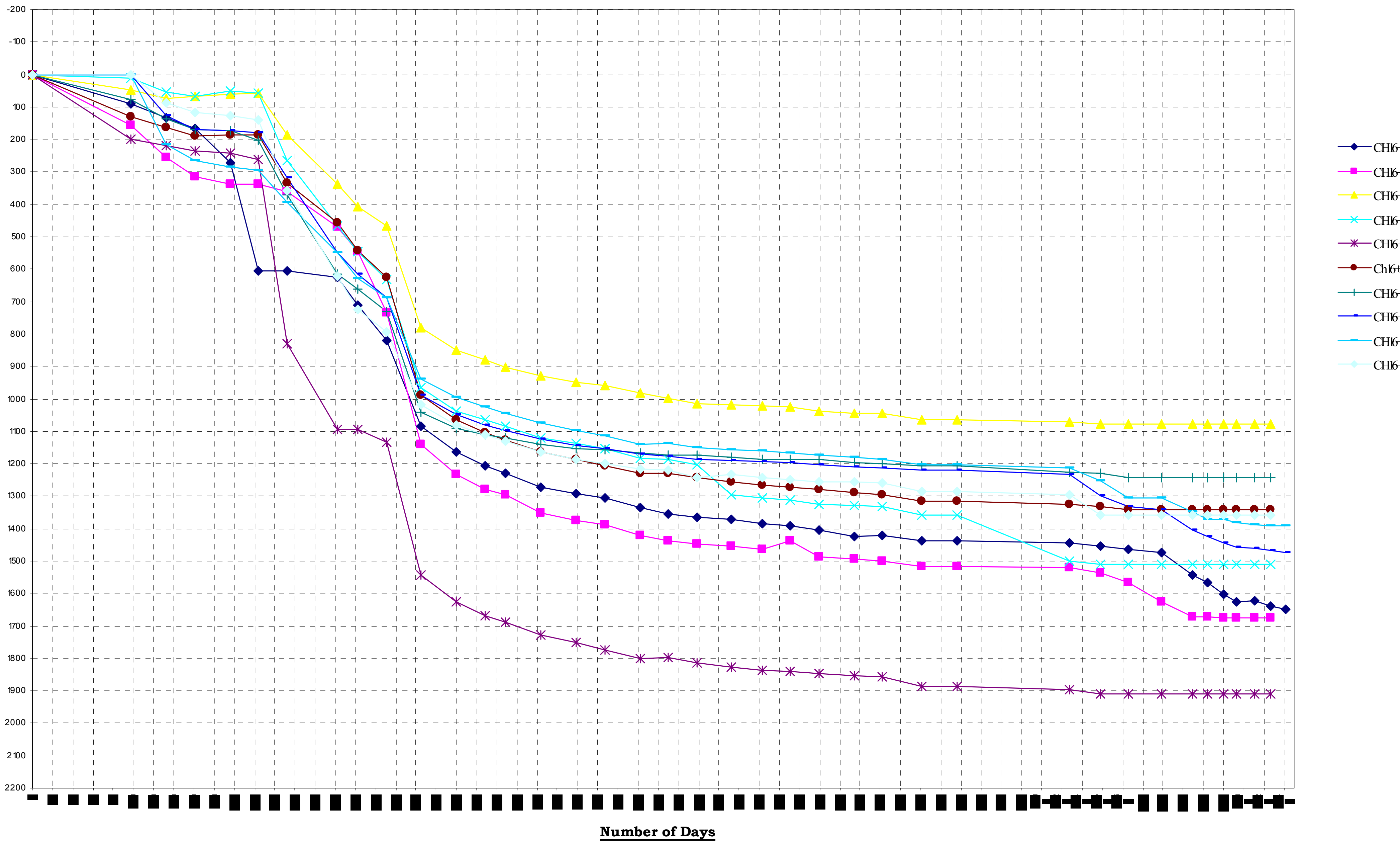
MATANG HIGHWAY KUCHING

- PEAT THICKNESS UP TO 6 M
- SOFT CLAY BENEATH
- MEASURED SETTLEMENT LOW SINCE HYDRAULIC FILLING MEABS SETTLEMENT GAUGE INSTALLED ONLY AFTER AT LEAST 1.0 M FILL IN PLACE

Matang Highway



MATANG HIGHWAY



PEAT CASE HISTORY. SYHLET ROAD , BANGLADESH

- About 200 km North of Dhaka
- 0 to 4 m Peaty organic clay in places with 4m to 8 m soft clay beneath.
- Some places no peat only soft clay.
- Embankment up to 8 m high
- Stage construction to mitigate post construction settlement with gain in strength and geotextile reinforcements for stability

PEAT. SYLHET

- Fill placed over 1 year with rest periods.
- 1.0 to 1.8 m settlement in soft clay
- 2.4 m settlement in peat
- Roc PEC high tensile geotextile reinforcement
- Geotextile bamboo for access.

SYLHET, BANGLADESH

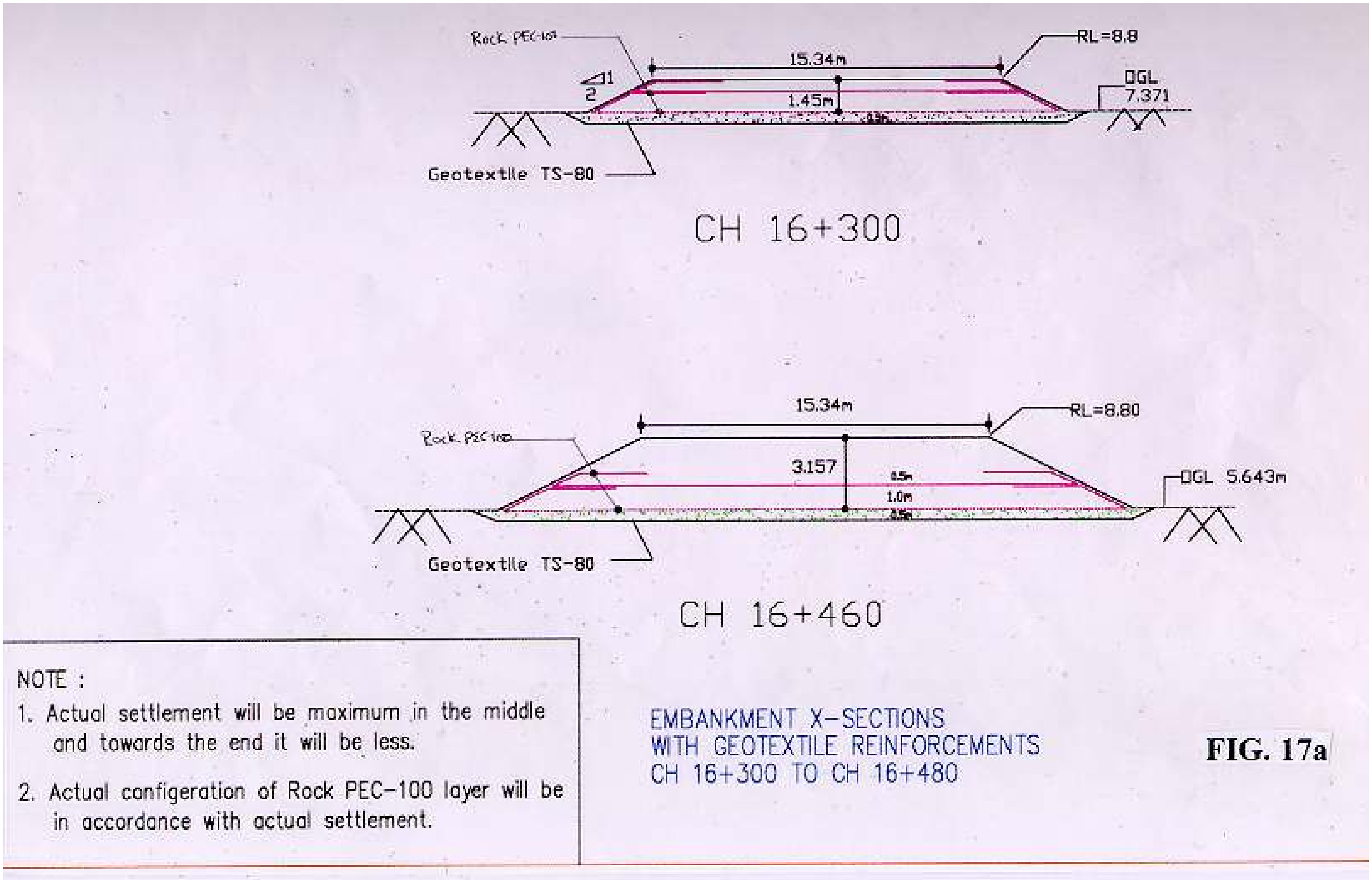
SYLHET, BANGLADESH

SYLHET, BANGLADESH

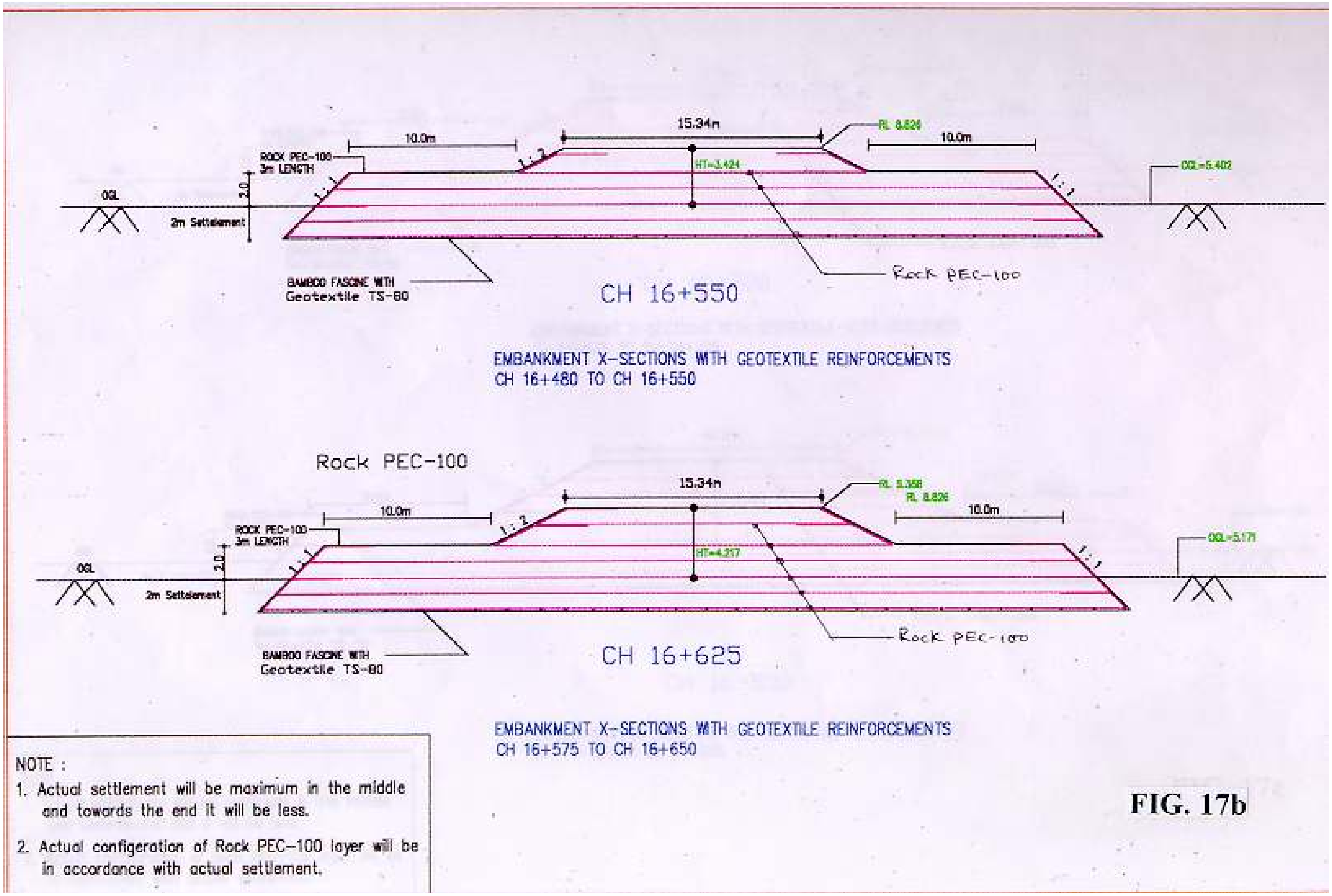
SYLHET, BANGLADESH

SYLHET, BANGLADESH

Geotextile reinforced embankment



Geotextile reinforced embankment



Geotextile reinforced embankment

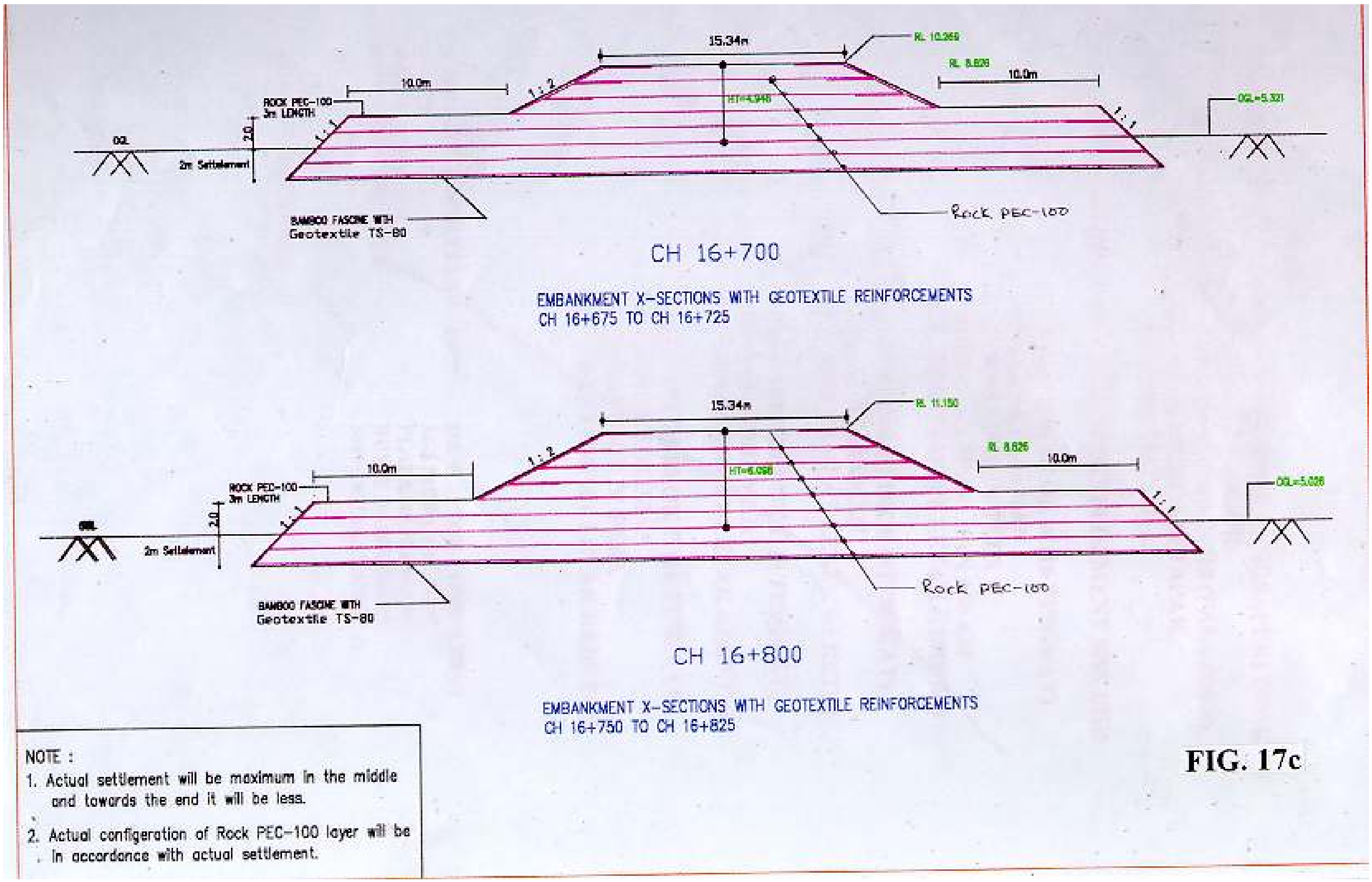


FIG. 17c

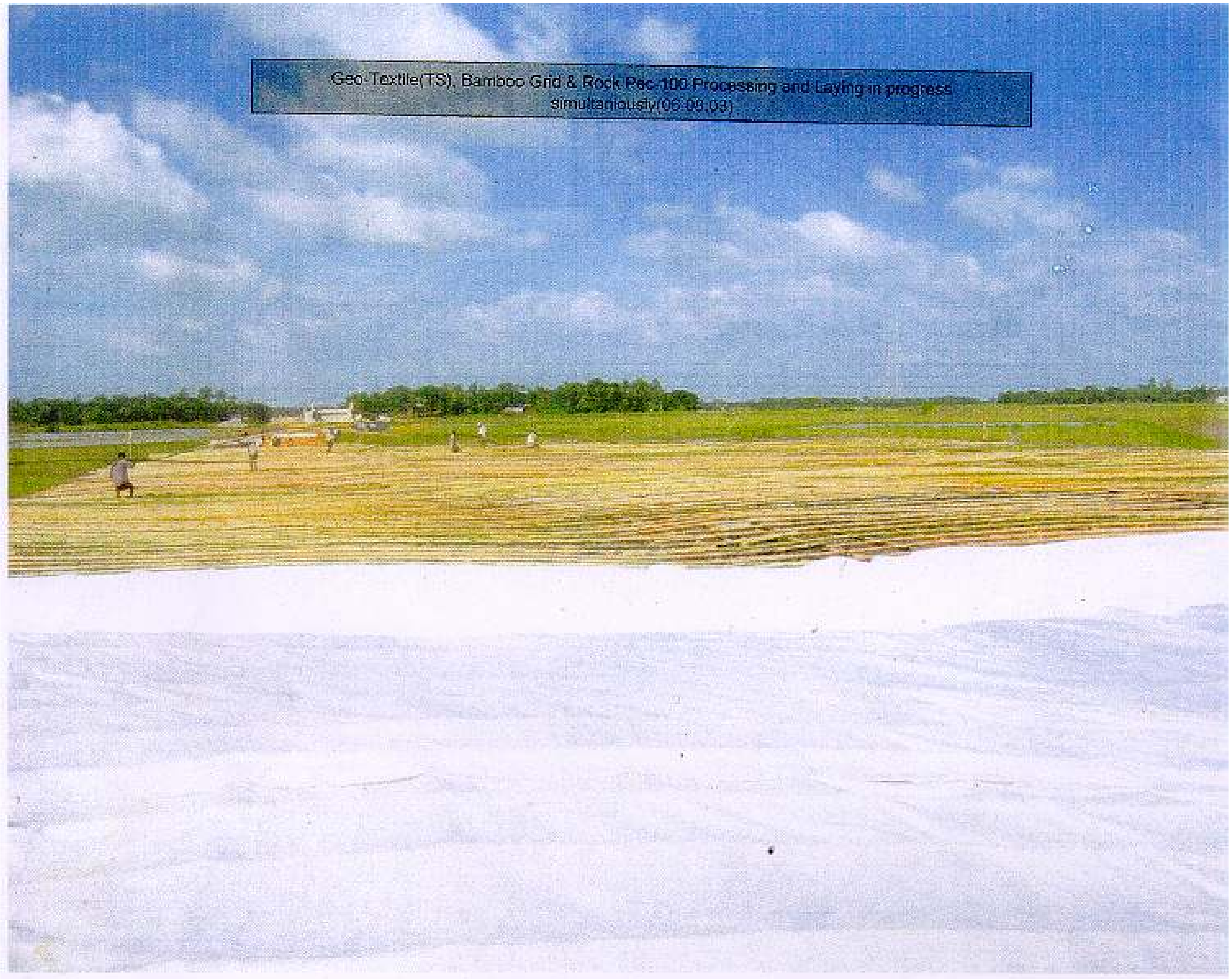
SYLHET, BANGLADESH

SYLHET, BANGLADESH

SYLHET, BANGLADESH

SYLHET, BANGLADESH

Sylhet. Geotextile and bamboo



SYLHET, BANGLADESH

Sylhet. Rock PEC geotextile reinforcement

SYLHET, BANGLADESH

SYLHET, BANGLADESH

SYLHET, BANGLADESH

Sylhet. Reinforced embankment

Syhlet. Reinforced embankment

Geotextile reinforced embankment

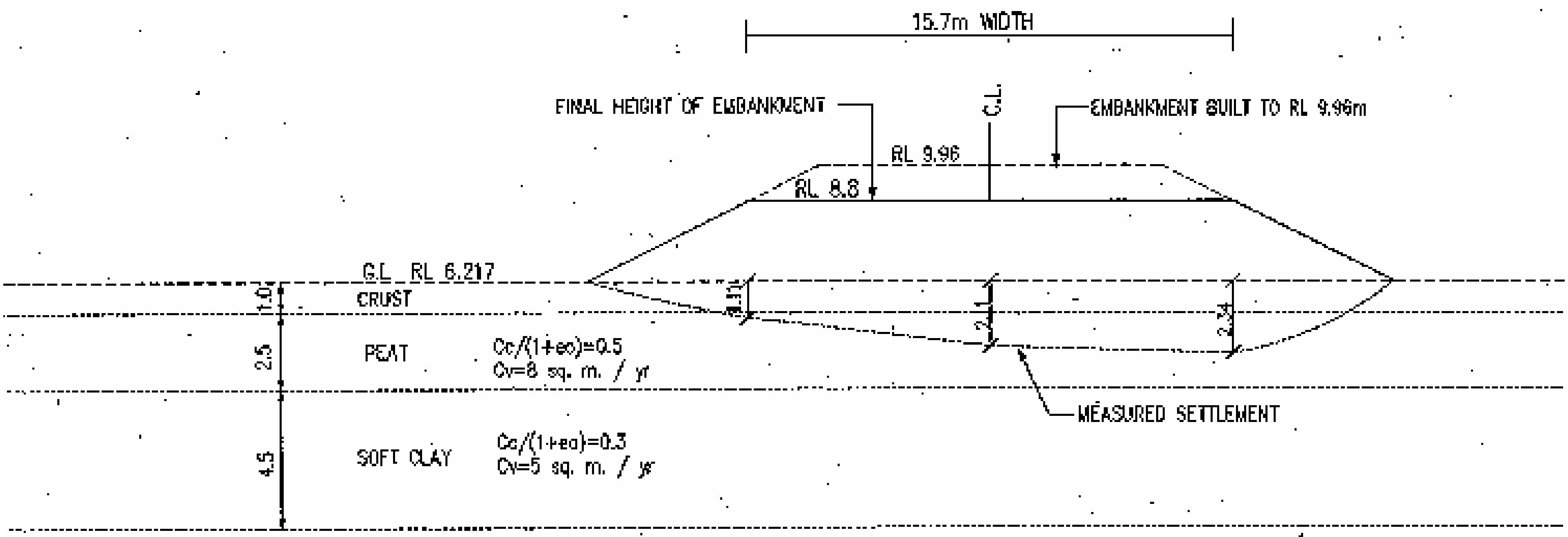


FIG. 4 – BACKCALCULATED PARAMETERS AT CH 16+460

Geotextile reinforced embankment Stage construction

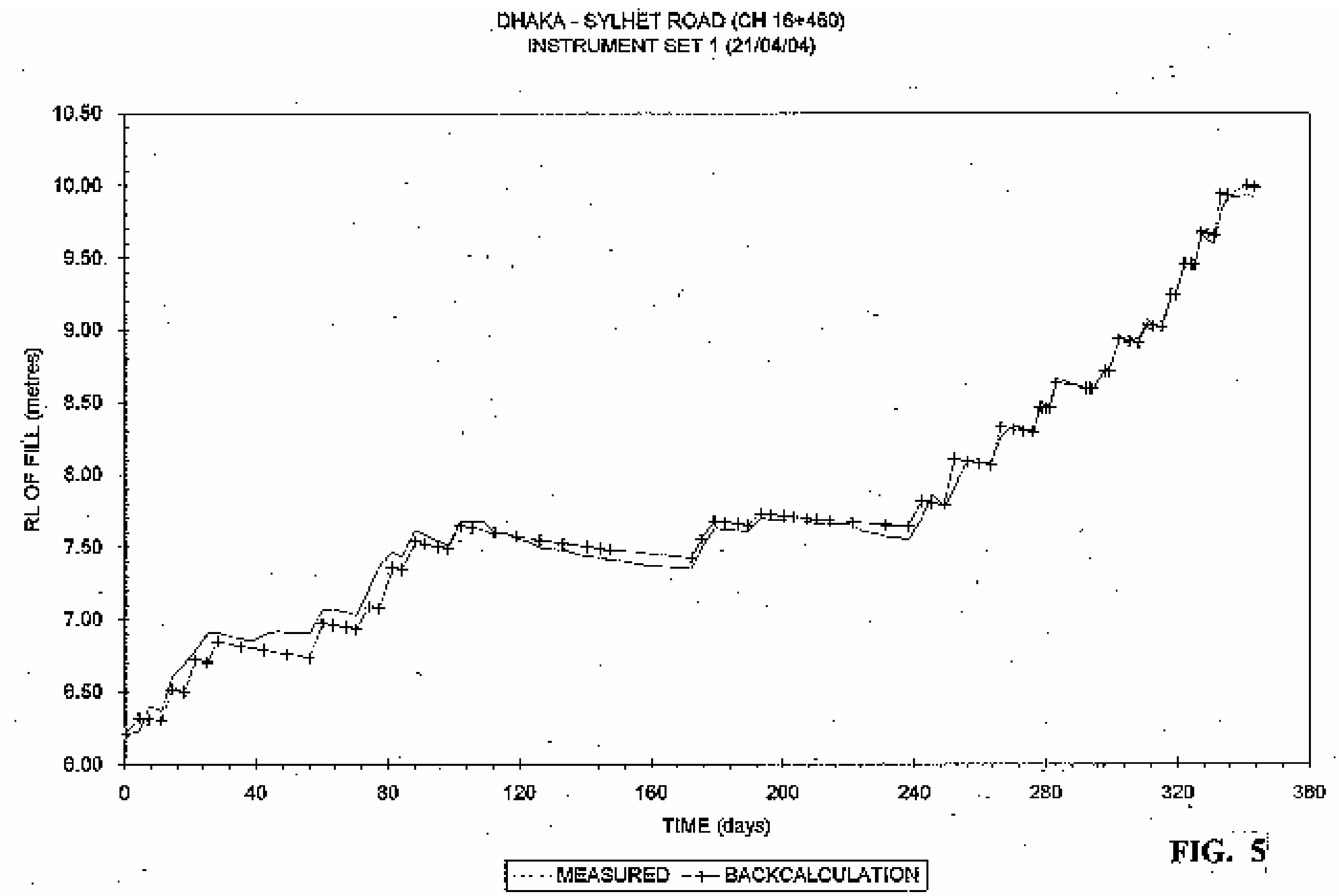


FIG. 5

Geotextile reinforced embankment. Settlement

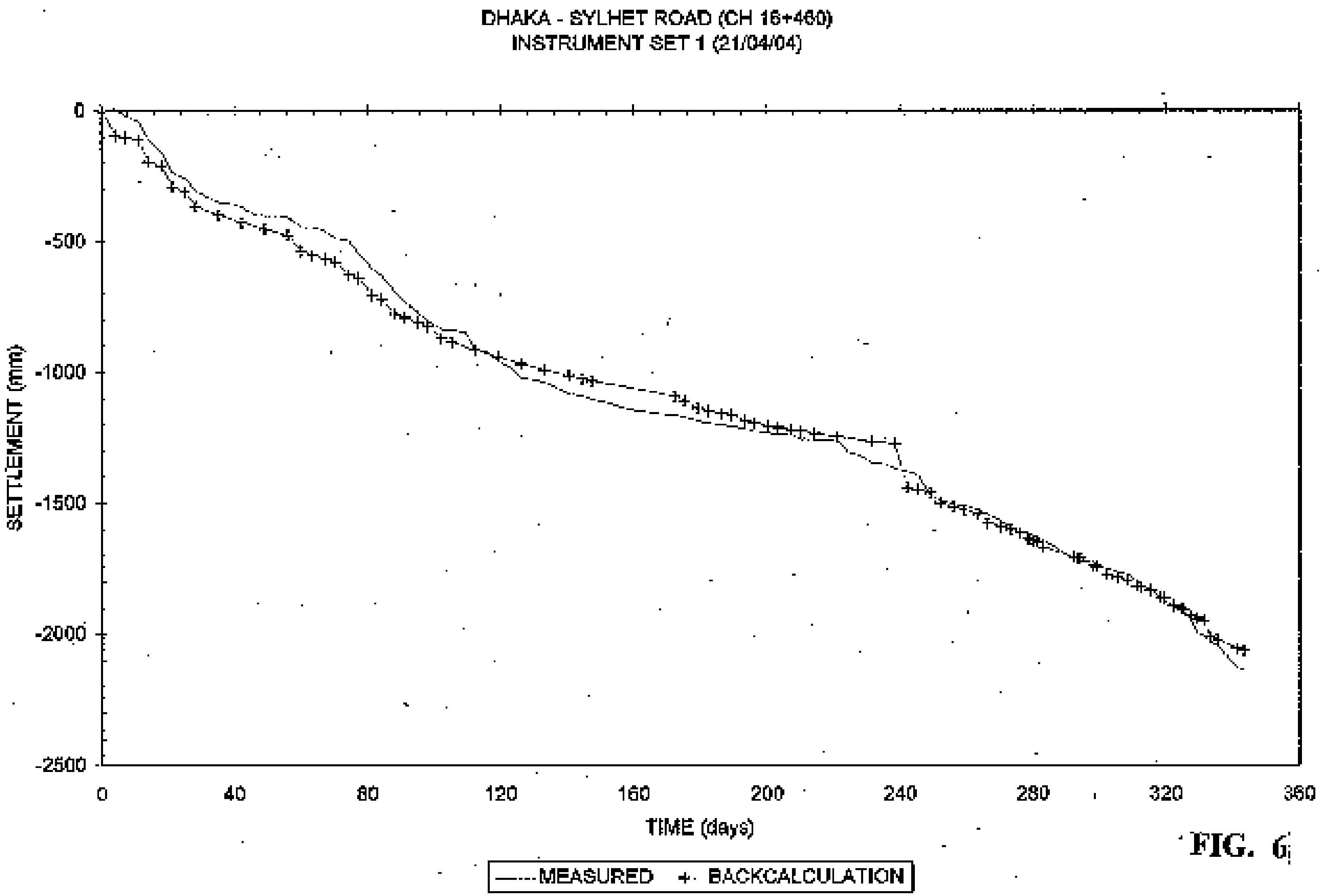
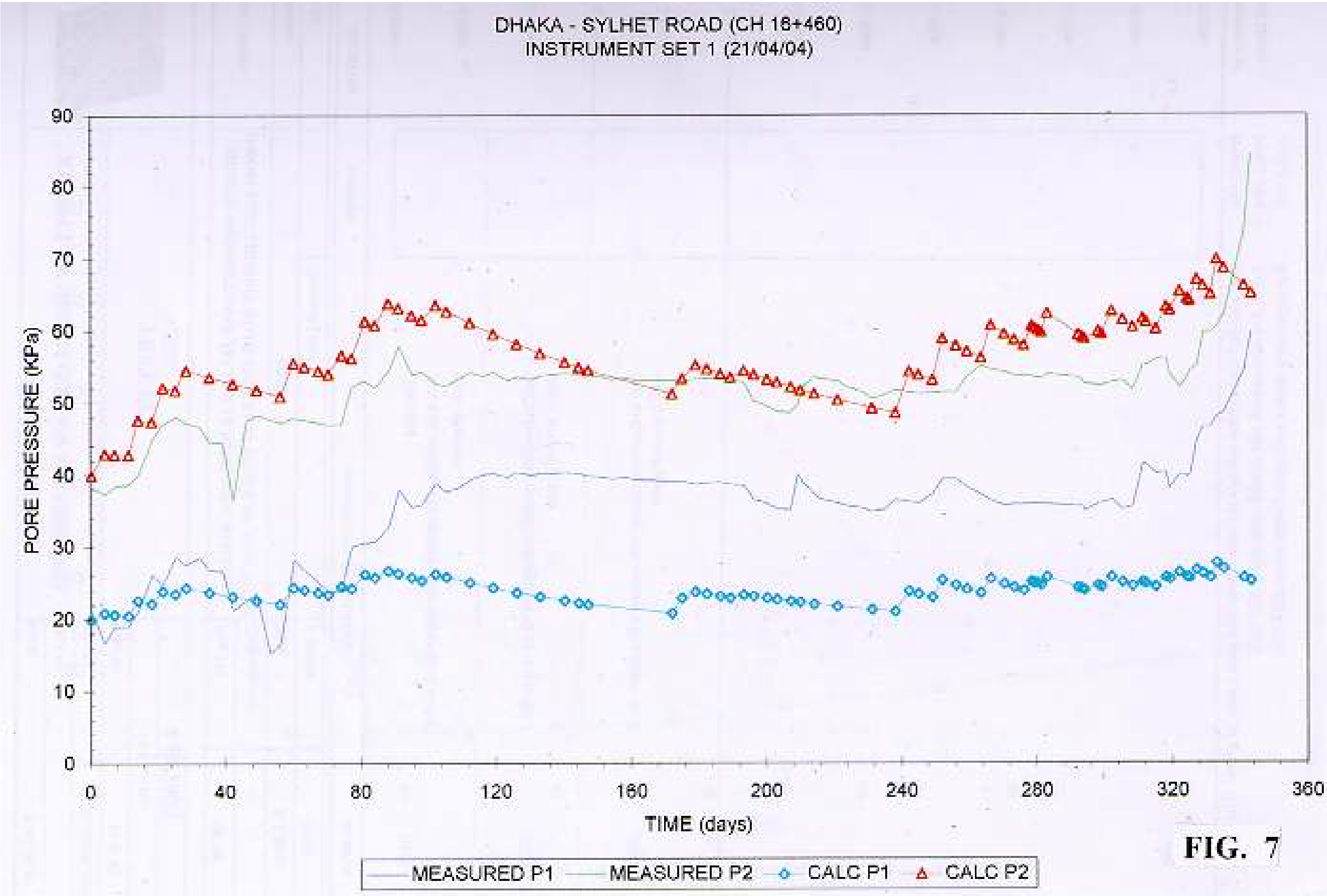


FIG. 6

Geotextile reinforced embankment. Piezometers



Gain in strength

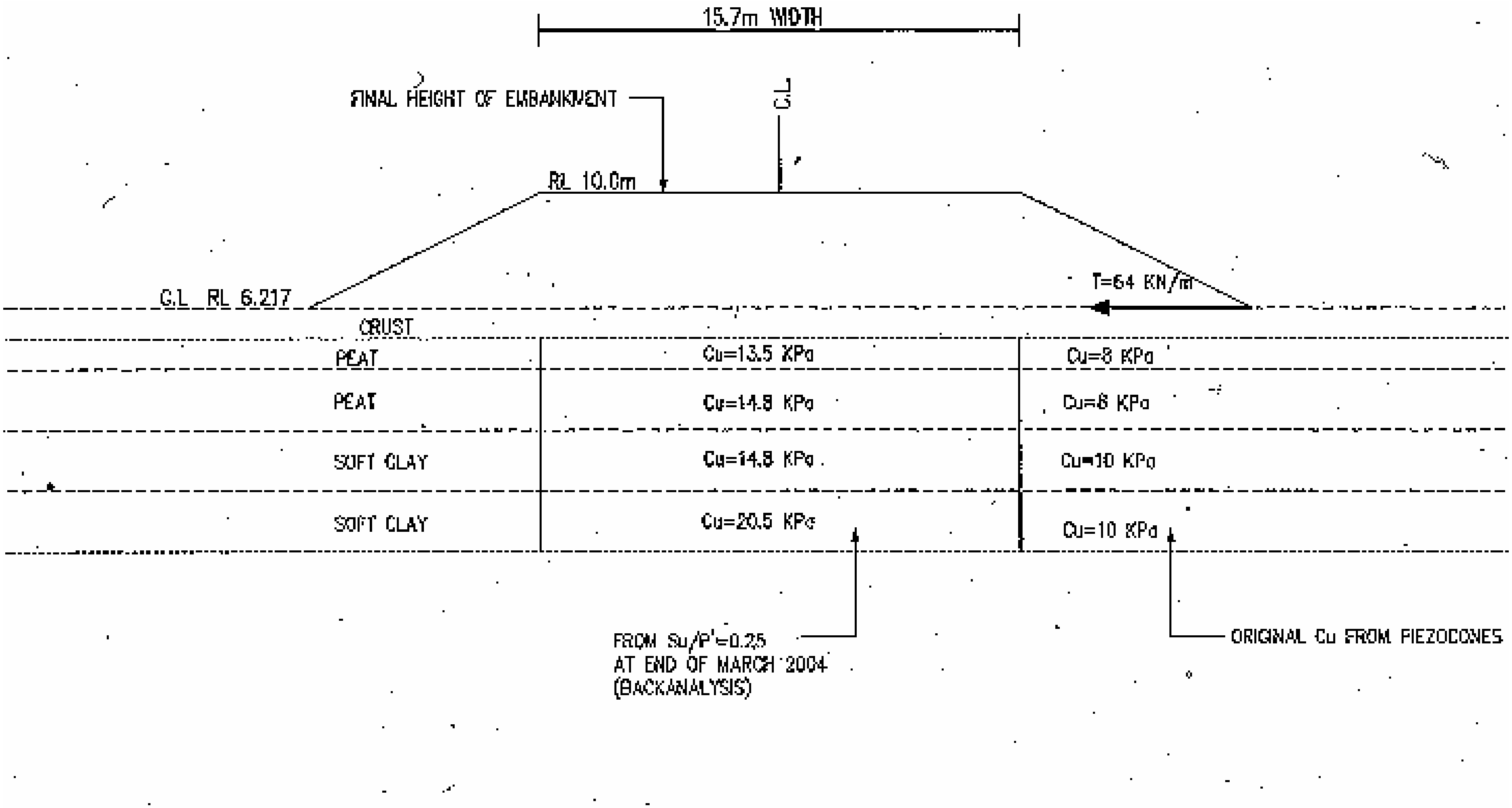


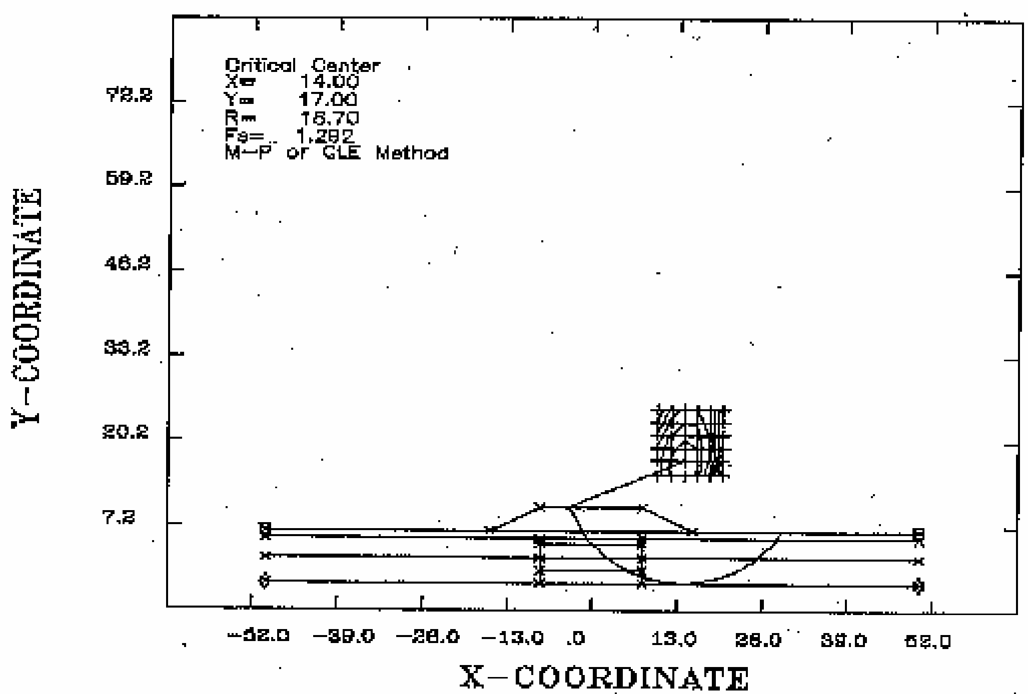
FIG. 9

Stability analysis. Reinforcement and gain in strength

DHAKA SYLHET ROAD CH 16+460

1 28.04.04

WITH GAIN IN STRENGTH AT 30/03/04 (T OF 64 KN/m)



UNIT WEIGHT	COHESION	PHI	DESCRIPTION
19.00	10.00	30.00	COMPACTED FILL
18.00	10.00	30.00	CRUST
12.00	8.00	.00	PEAT
12.00	13.60	.00	PEAT (1)
12.00	14.80	.00	PEAT (2)
14.00	10.00	.00	SOFT CLAY
14.00	14.80	.00	SOFT CLAY (1)
14.00	20.50	.00	SOFT CLAY (2)
-1.00	.00	.00	BASE OF PROBLEM

File name : DK6A.SET

FIG. 10

Embankment buildup

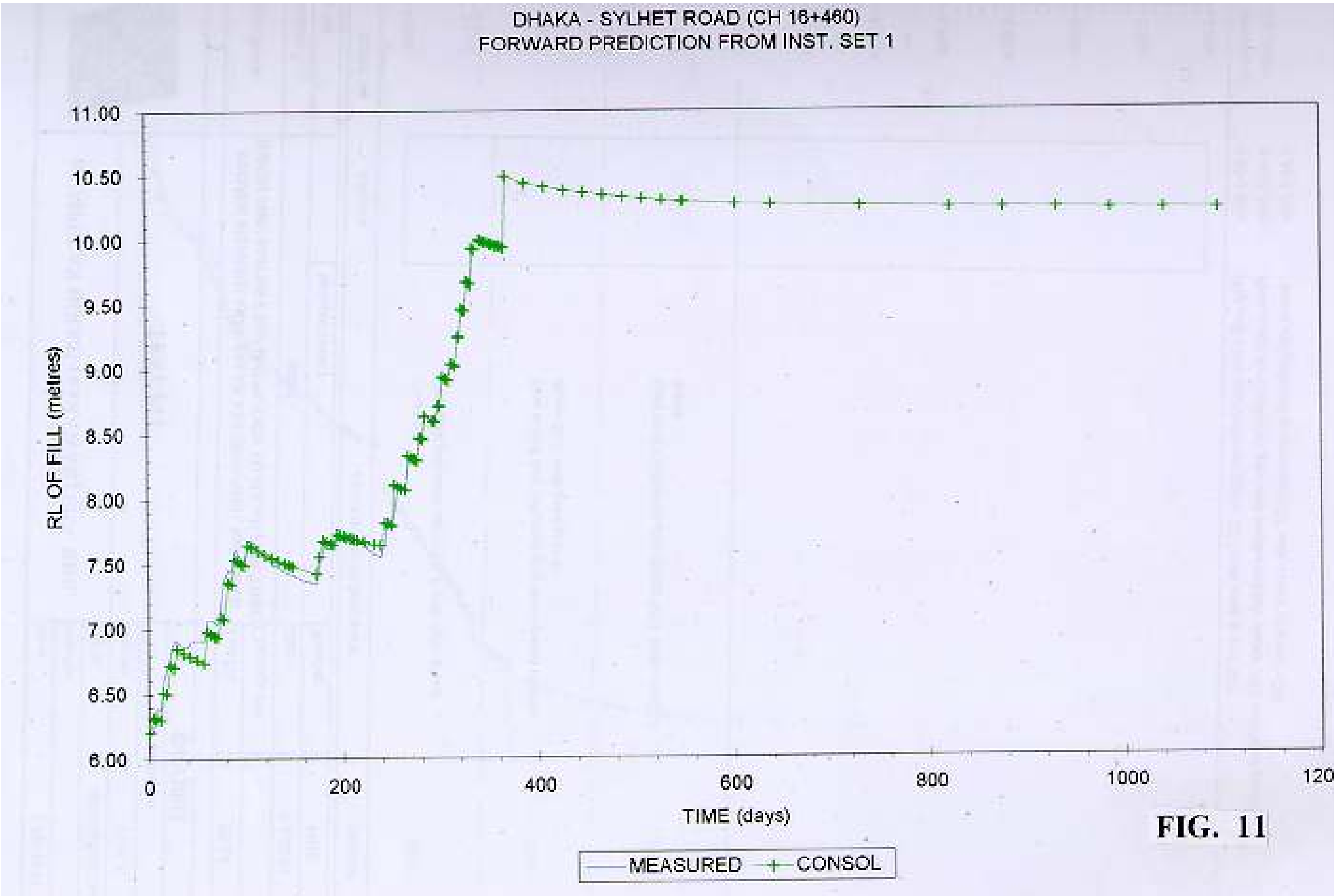


FIG. 11

Long term settlement

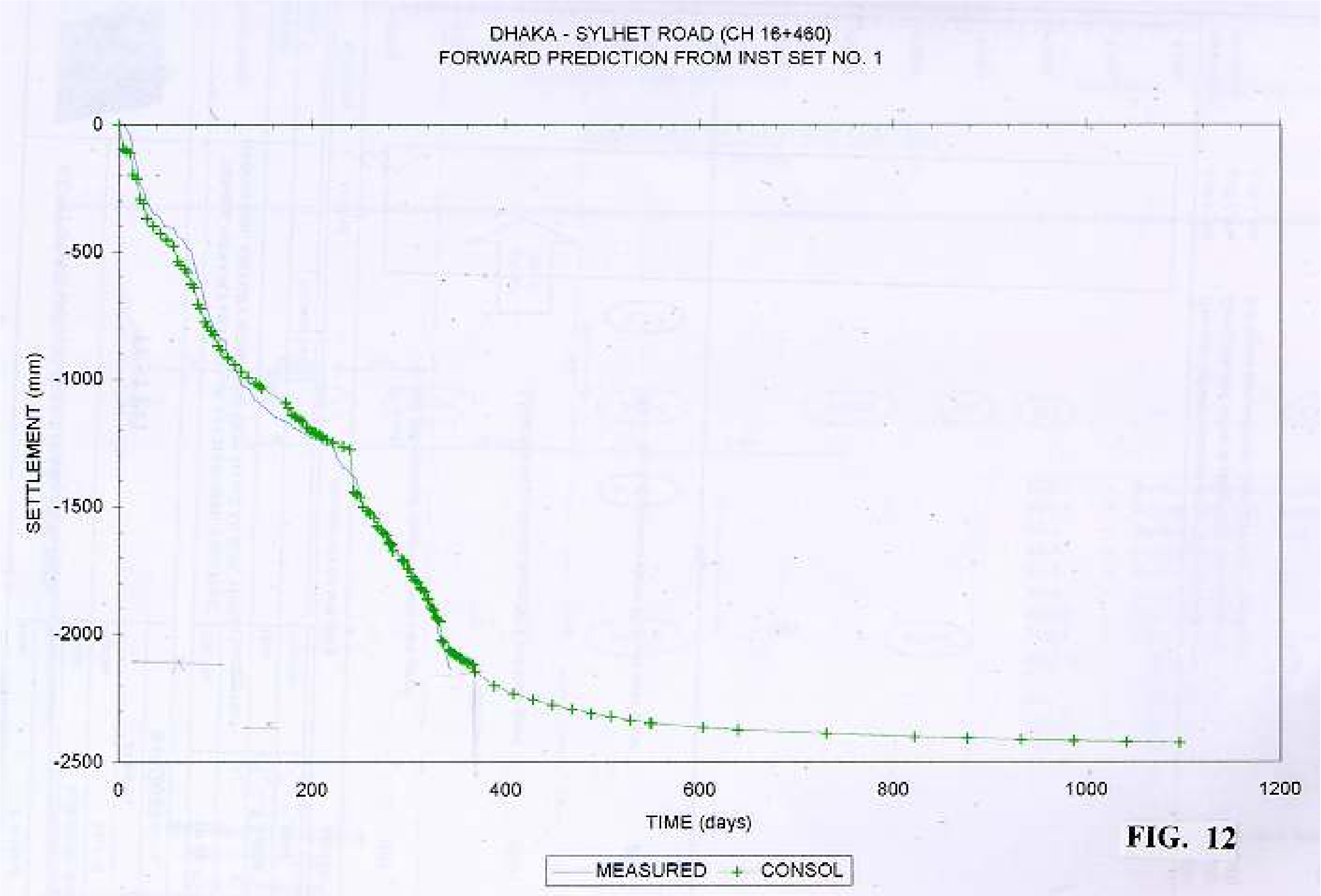


FIG. 12

Geotextile reinforced embankment

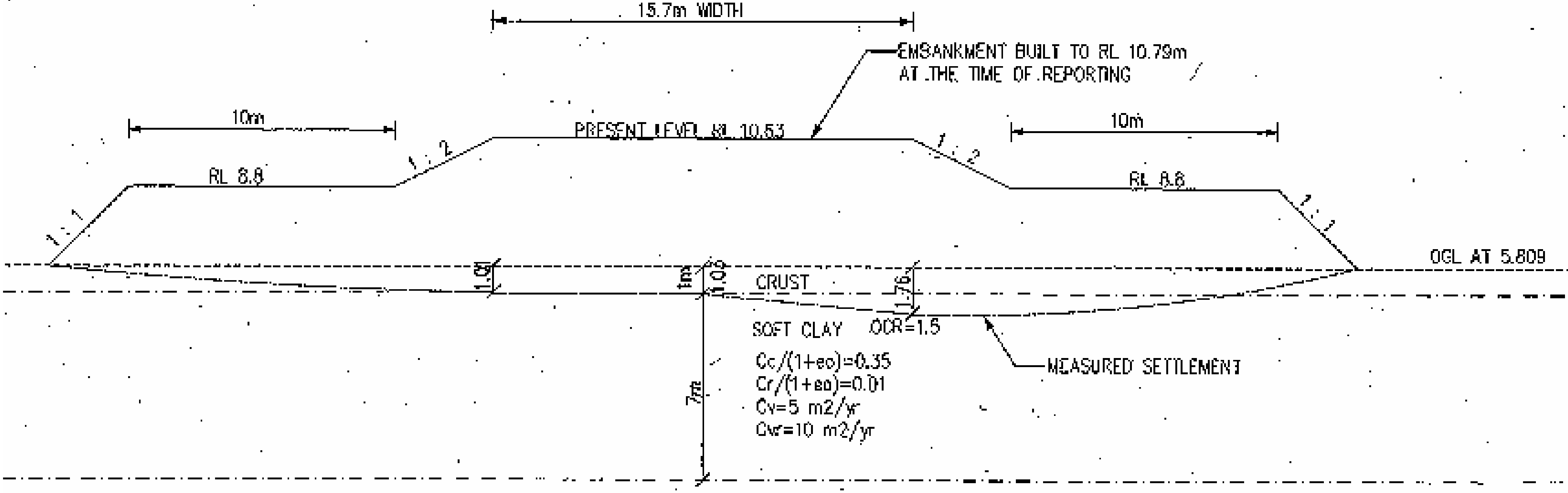
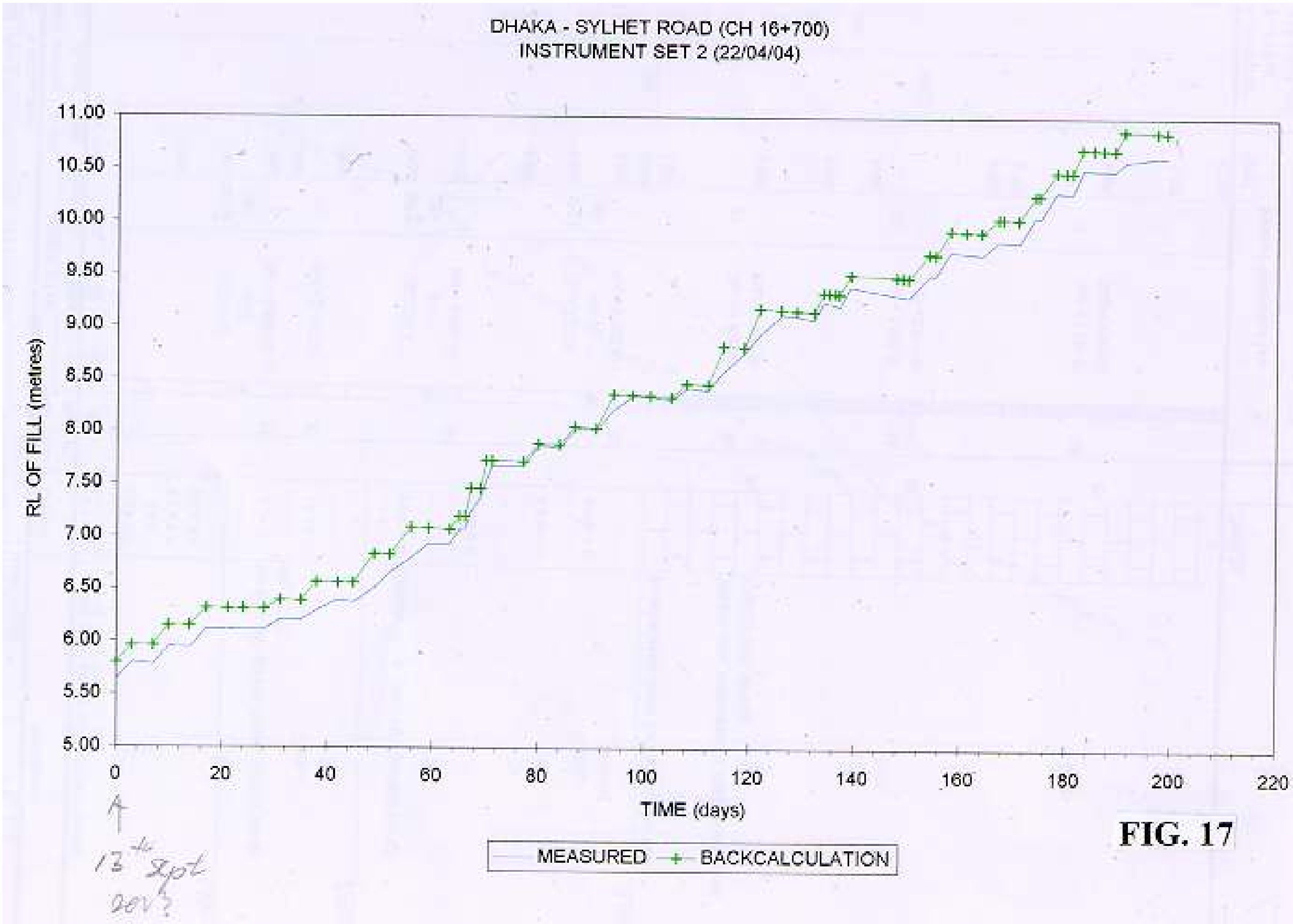


FIG. 16 – BACK CALCULATED PARAMETERS AT INSTRUMENTATION SET NO. 2 (CH 16+700) – CPT 700 CONDITION

SCALE :– 1 : 200

Stage construction



Settlement

FIG. 18

Stability parameters

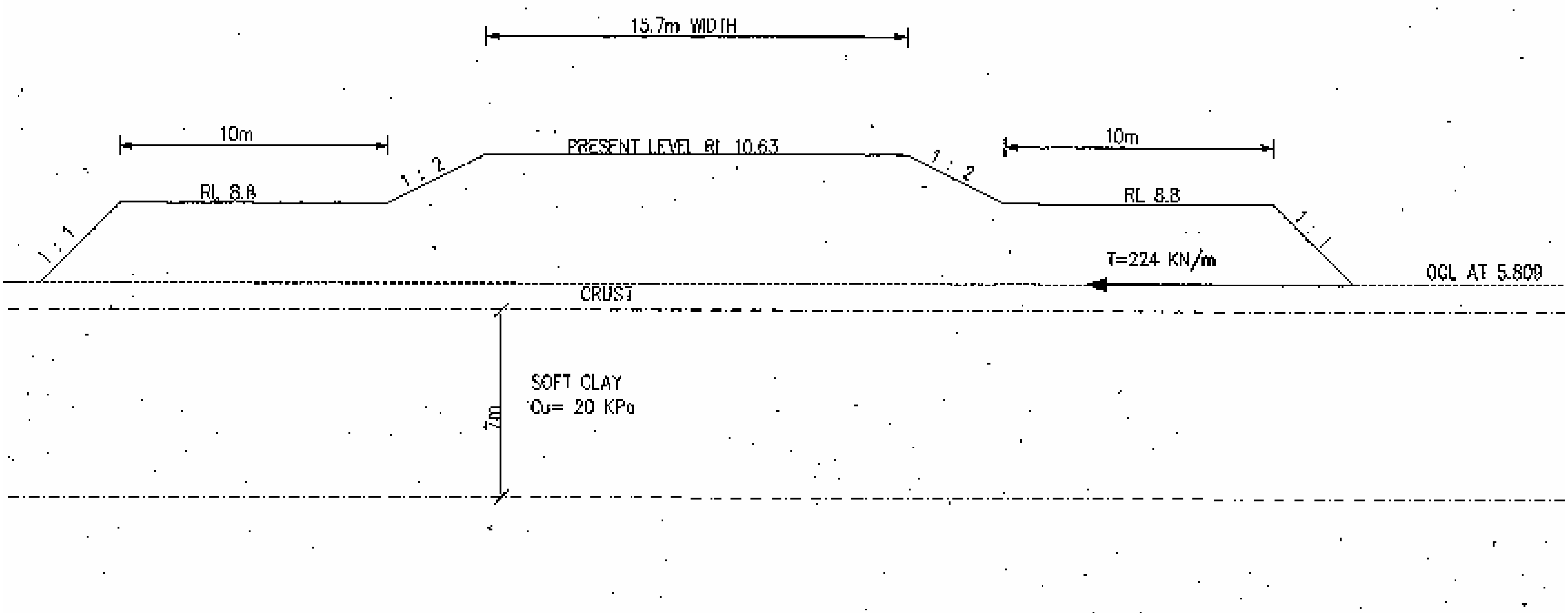


FIG. 21

Stability analysis with reinforcement

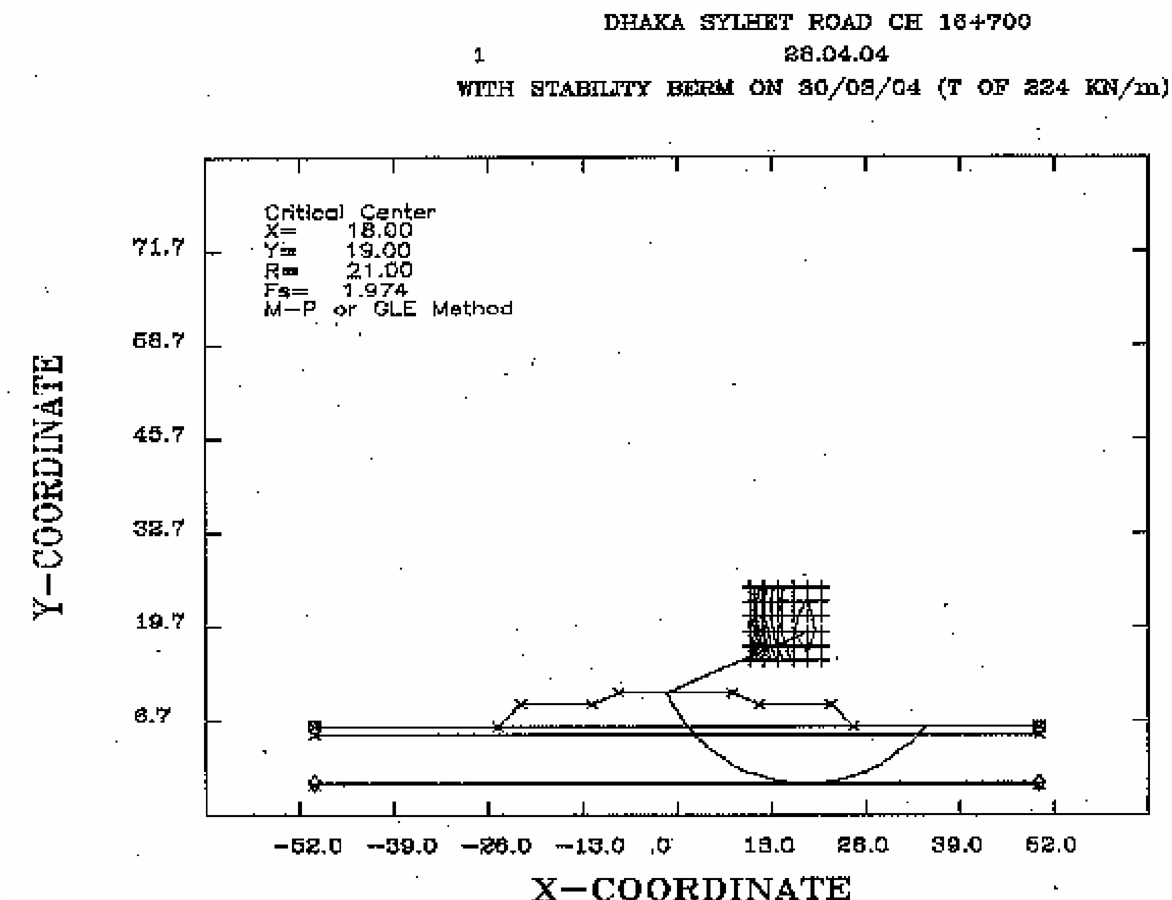


FIG. 22

UNIT WEIGHT	COHESION	PHI	DESCRIPTION
19.00	10.00	30.00	COMPACTED FILL
18.00	10.00	30.00	CRUST
15.00	20.00	.00	SOFT CLAY
–1.00	.00	.00	BASE OF PROBLEM

File name : DK69.SET

Embankment construction

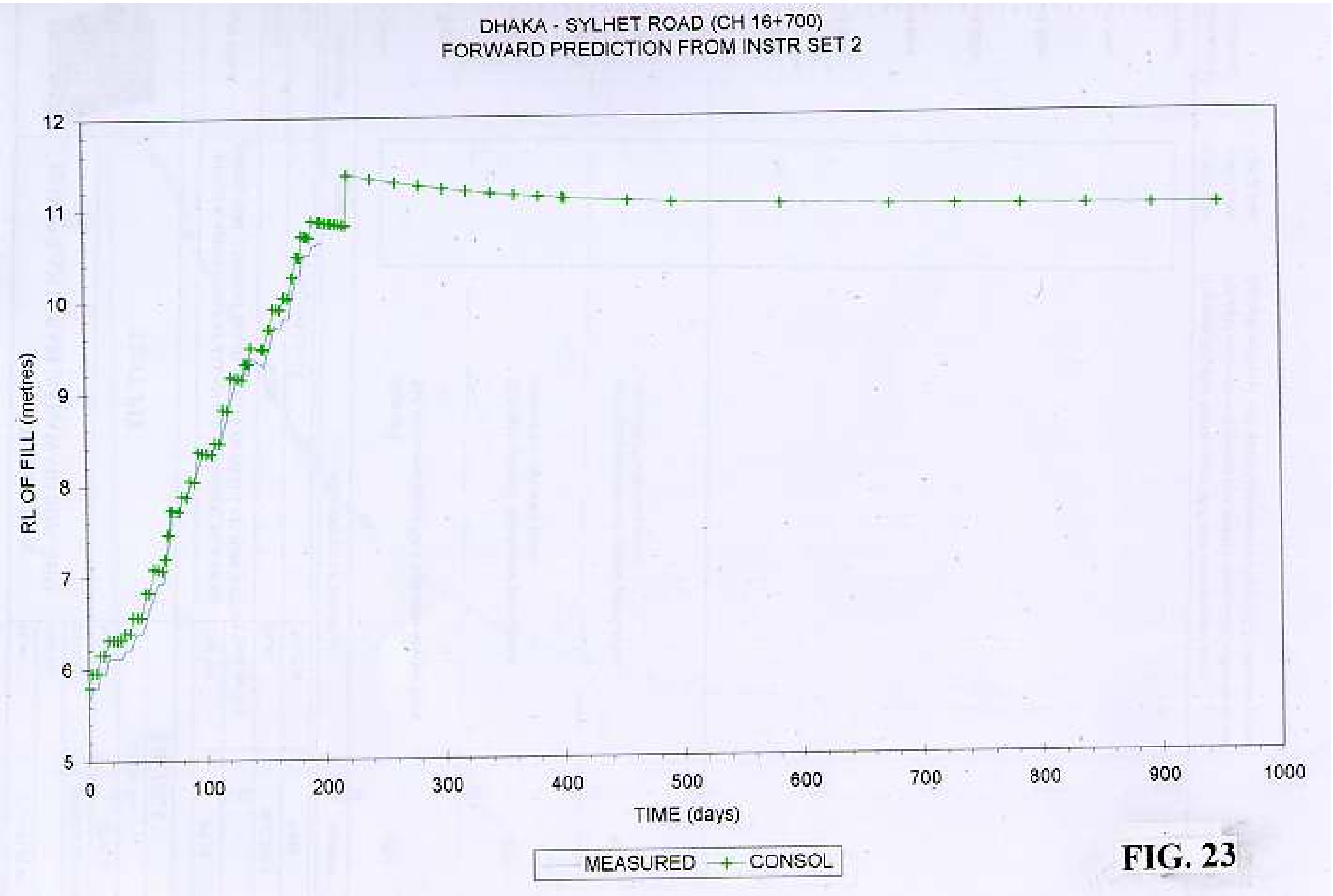


FIG. 23

EMBANKMENT ON PEAT
Khoo Kim Poh and Yam Seng Lam (PLB Conference 1990).

- 5m high embankment on 2 m peat by stage construction and surcharge
- Pagoh to Bukit Sulong Road diversion

Khoo and Yam

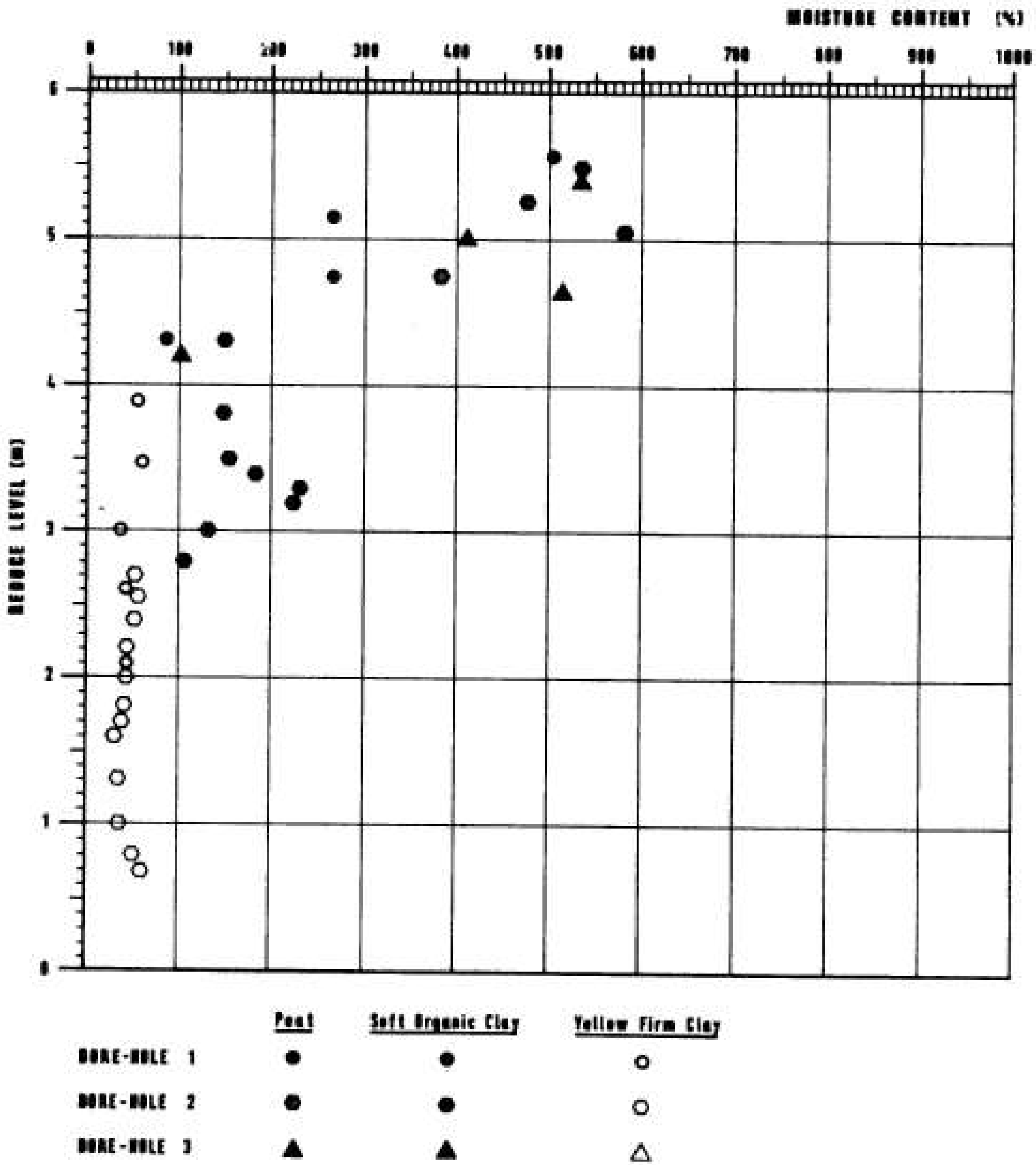


Figure 2 **Plot of moisture content versus reduced level**

Khoo and Yam

- 1.4 to 1.7 m thick peat . NMC 300 to 600%.
- 0.4 to 1.6 m very soft organic clay with pieces of decayed wood . NMC 150 to 200%
- 1.8 m soft to firm clay. NMC of 50%.

Khoo and Yam

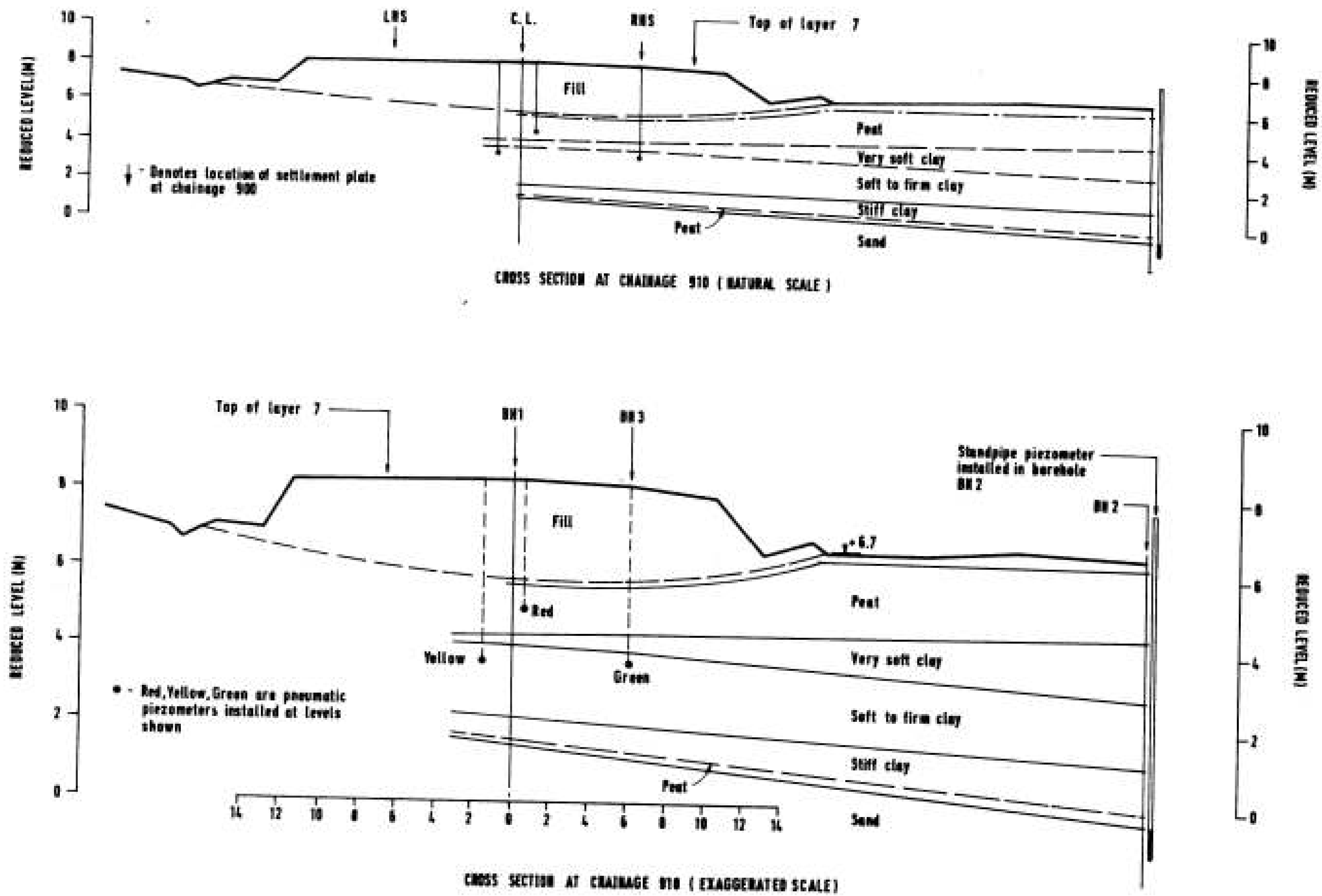


Figure 1 **Cross-section at chainage 0 + 910**

Khoo and Yam

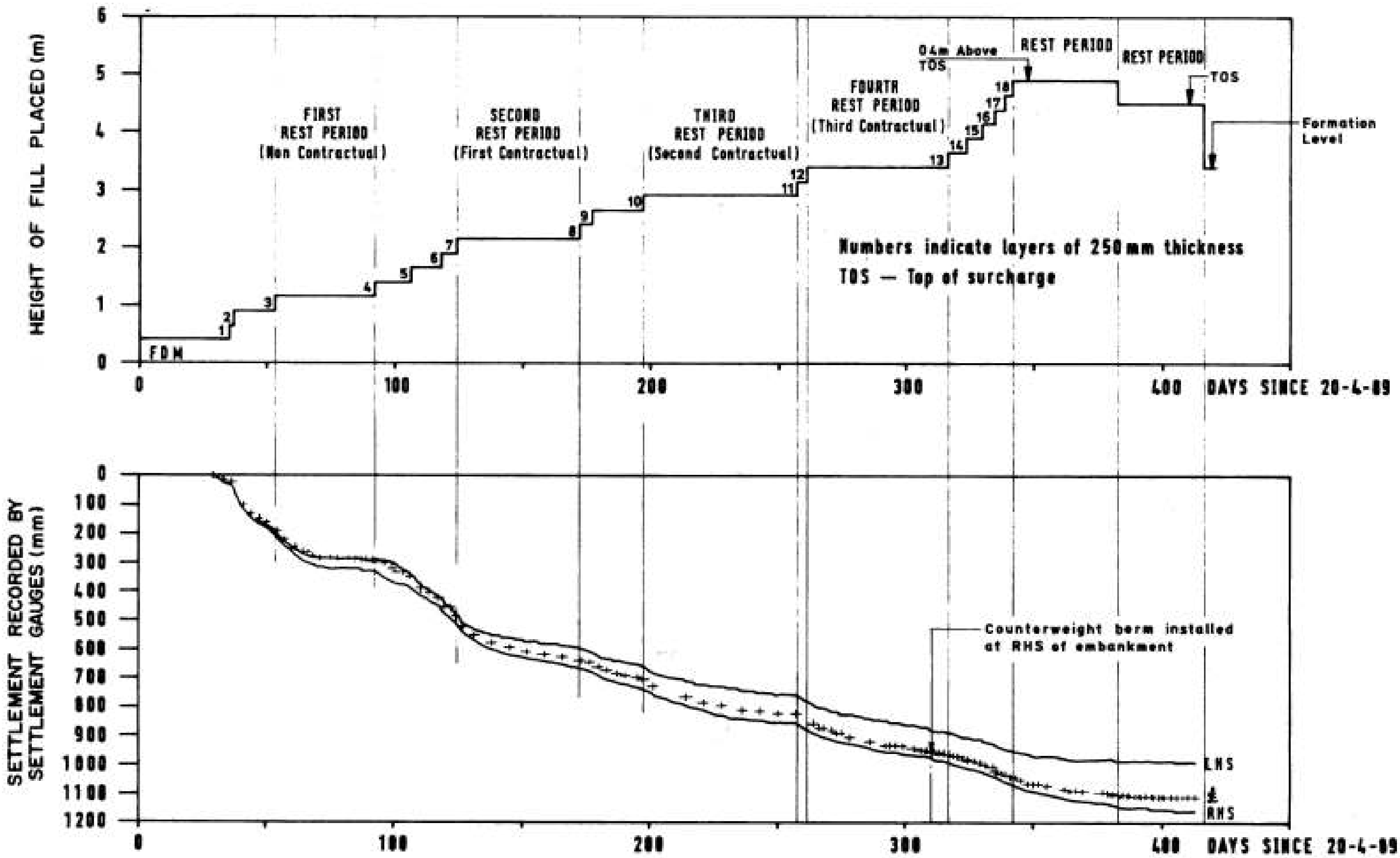


Figure 3 Settlement behaviour at chainage 0 + 900

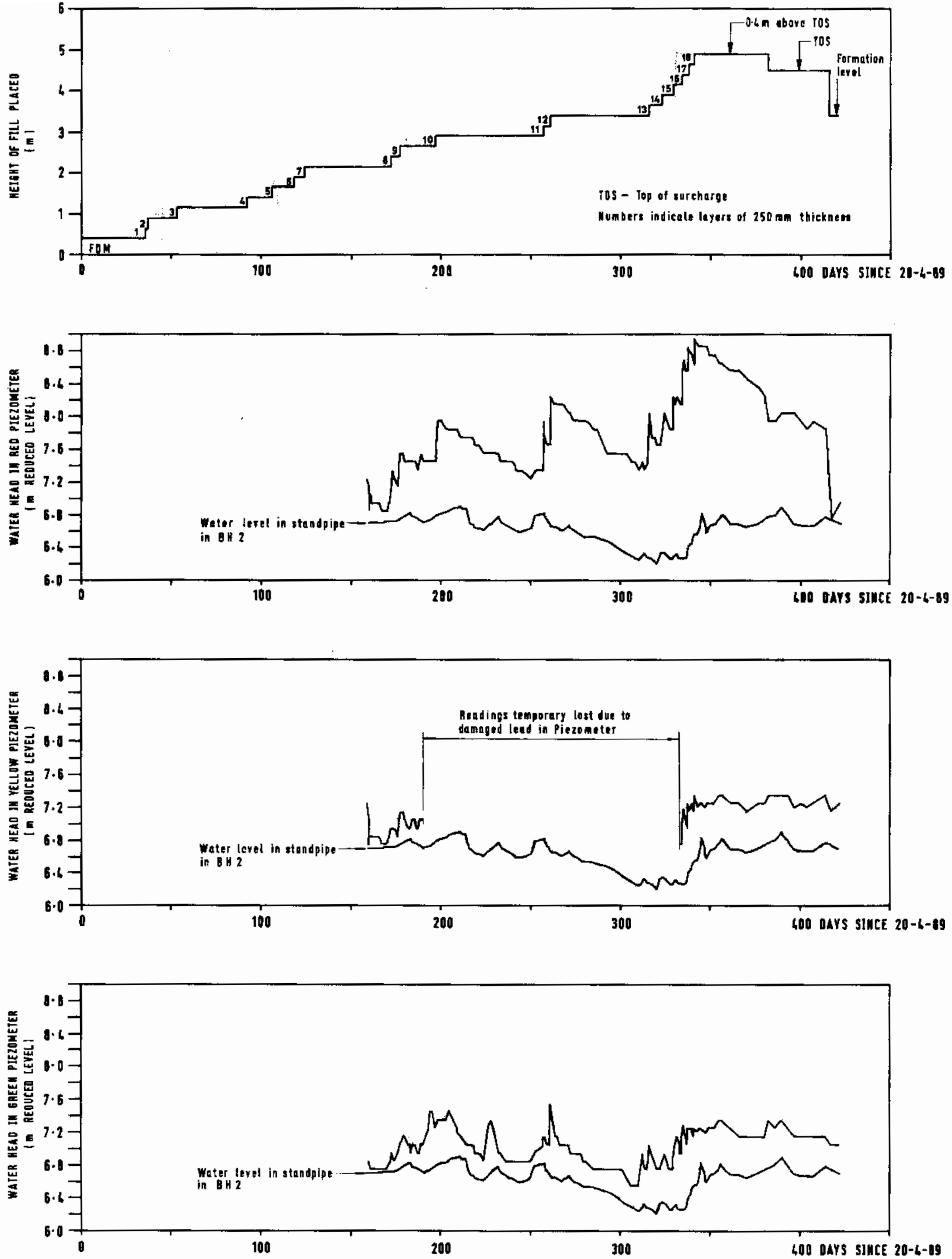


Figure 4 Response of piezometers at chainage 8+210

PEAT EXCAVATION CASE HISTORY

MACHAP TO AIR HITAM – 30 km of peat

NORTH SOUTH EXPRESSWAY

PEAT GENERALLY ABOUT 6 M

LOCALIZED AREAS UP TO 12 M

DEWATERING, COMPLETE REMOVAL, REPLACE WITH COMPACTED FILL

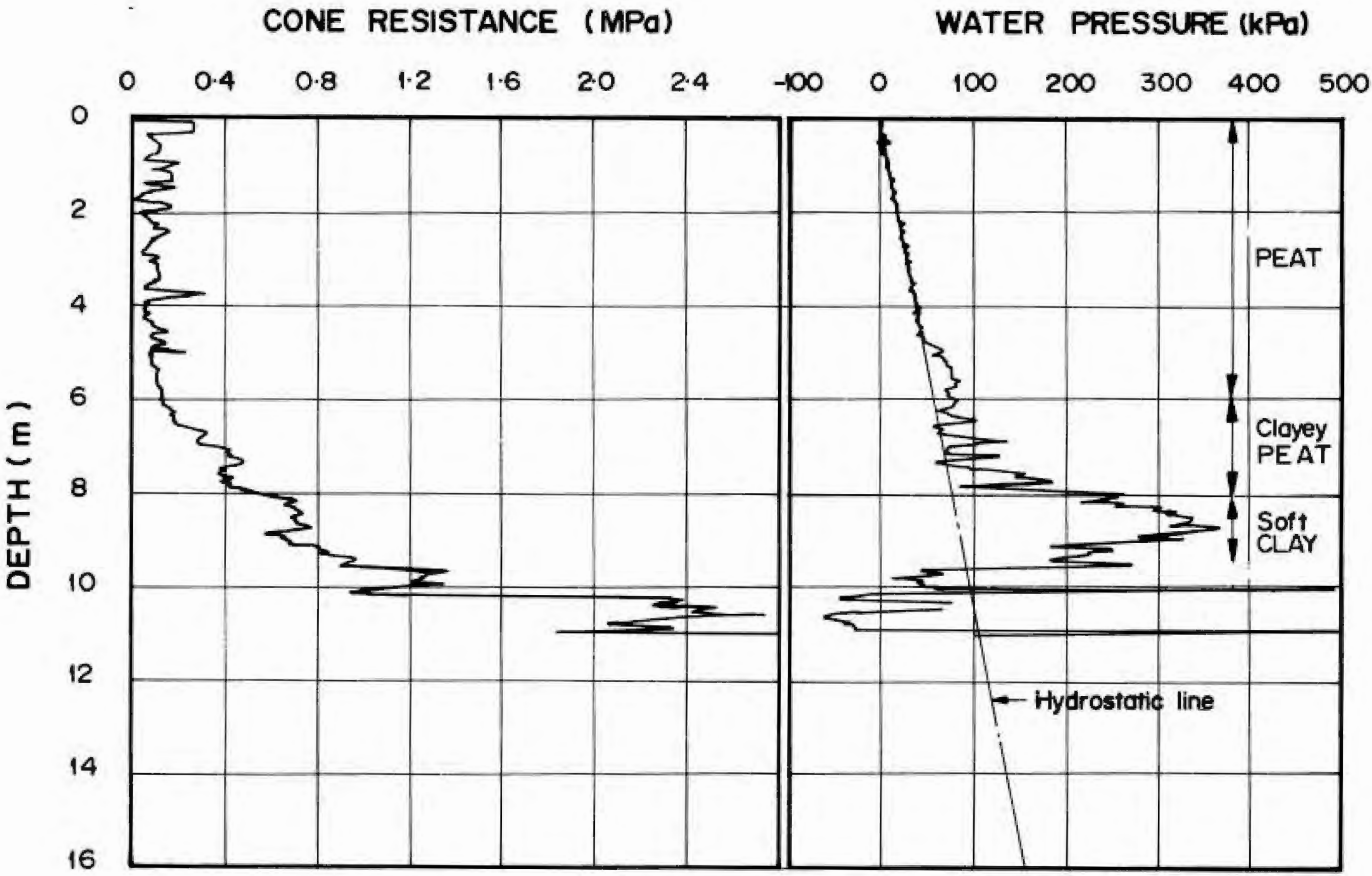


Figure 1 Typical piezocone profile

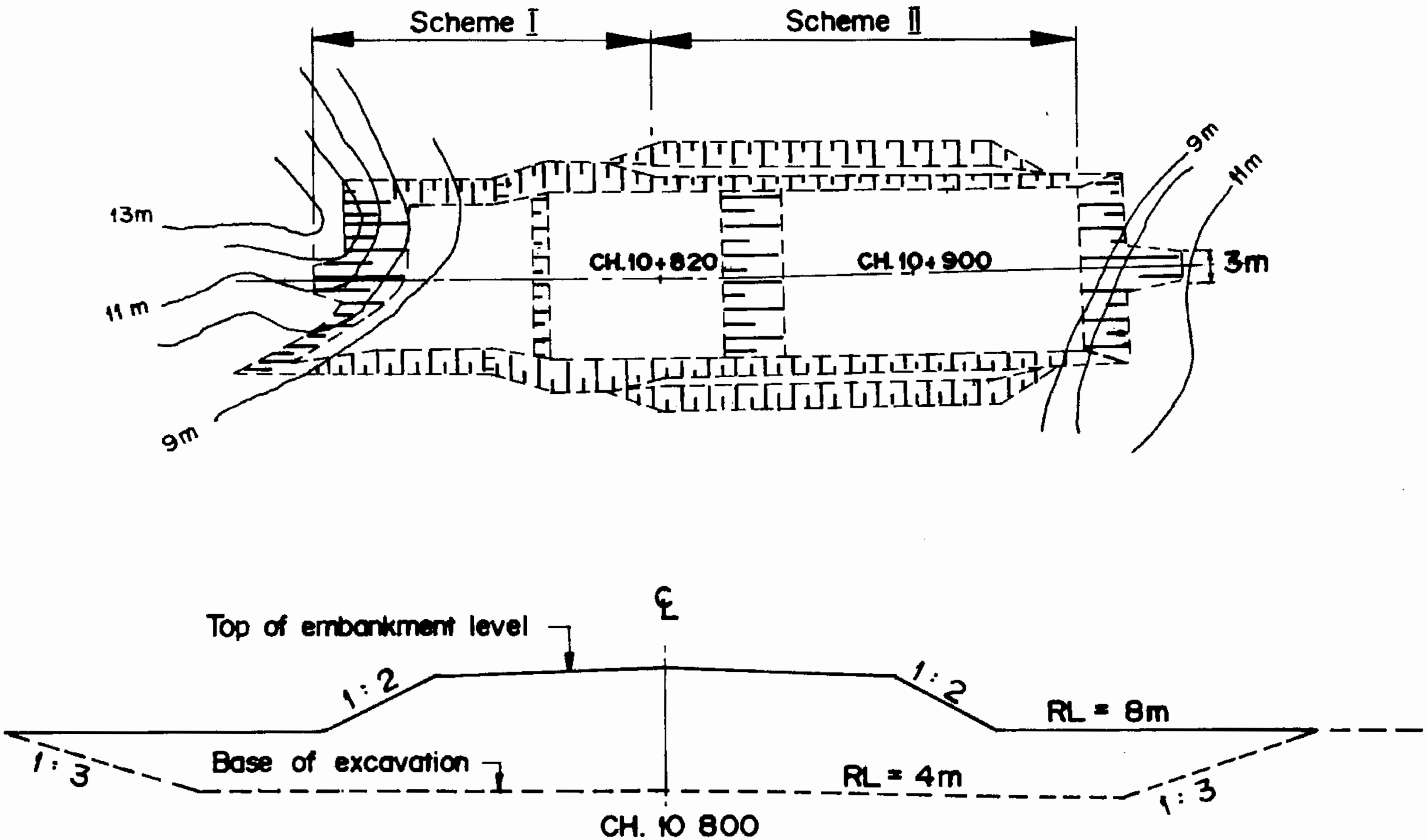
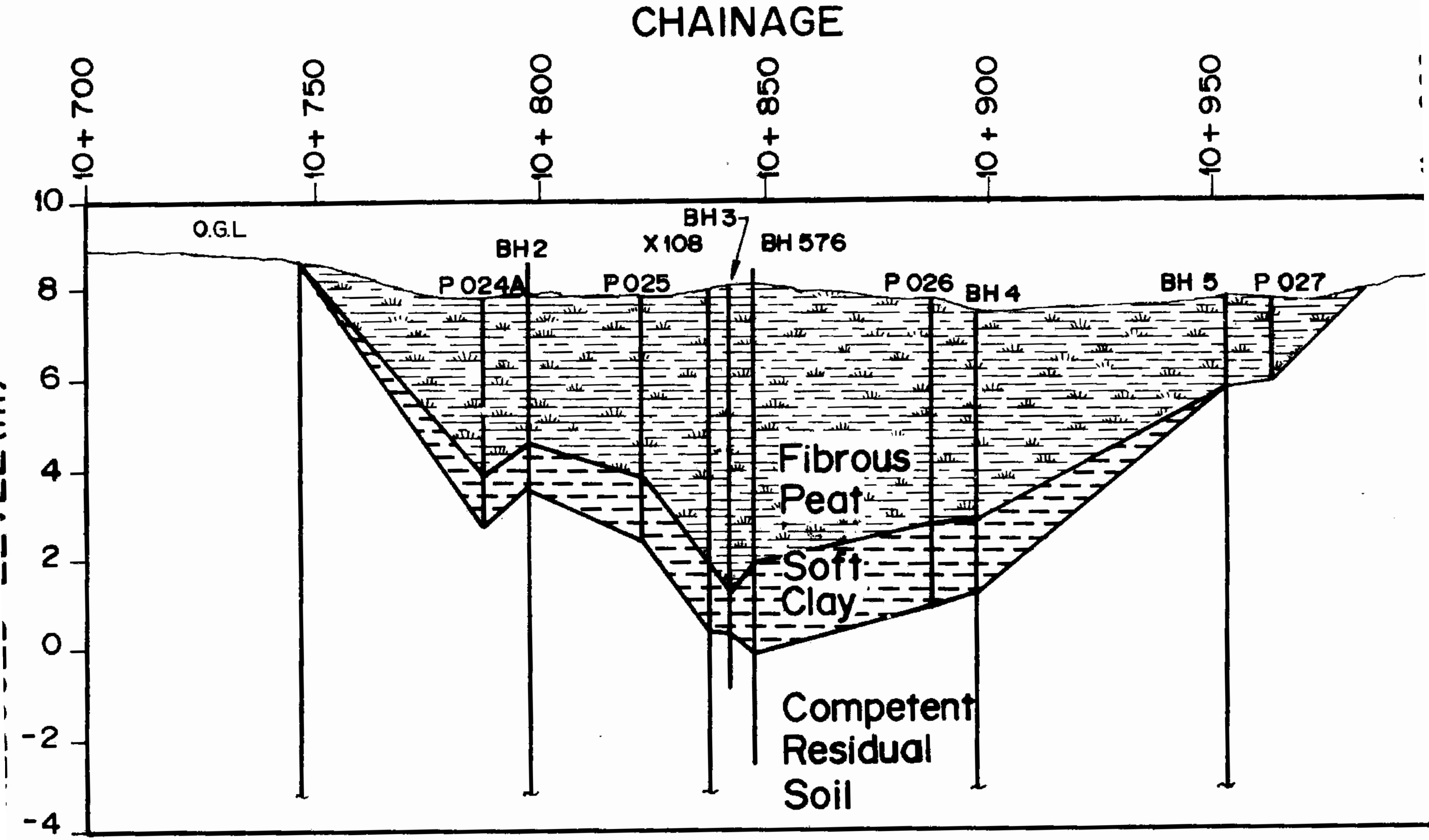
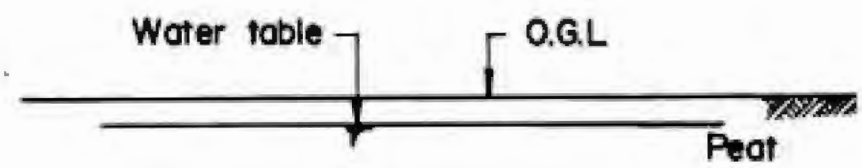


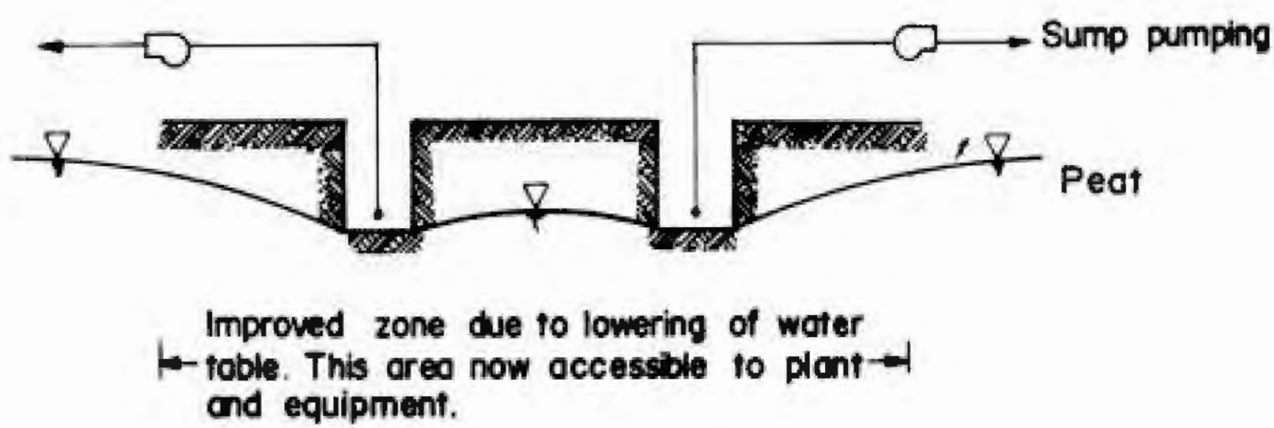
Figure 3 Originally intended extent of excavation and replacement



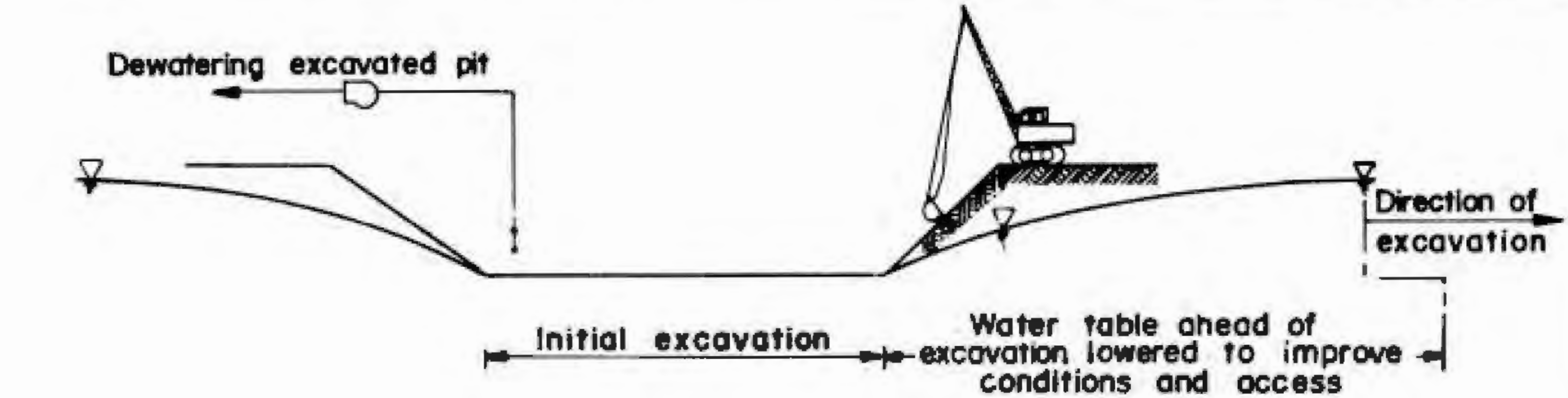
igure 2 Subsurface profile at the trial site



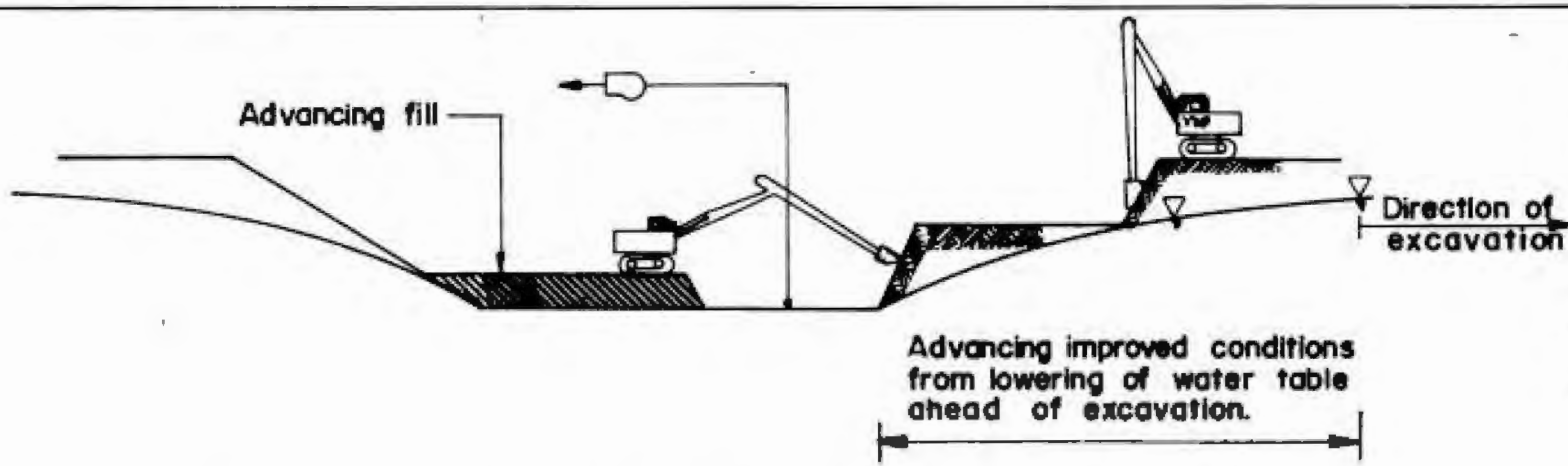
1. ORIGINAL WATER TABLE CONDITIONS, INACCESSIBLE TO PLANT AND EQUIPMENT



2. INITIAL DEWATERING OF LIMITED AREA TO ENABLE ACCESS BY EXCAVATION PLANT FOR INITIAL EXCAVATION.



3. INITIAL EXCAVATION AND LOWERING OF WATER TABLE AROUND EXCAVATED PIT.



4 ADVANCING EXCAVATION WITH ADVANCING IMPROVED CONDITIONS AHEAD OF EXCAVATION.

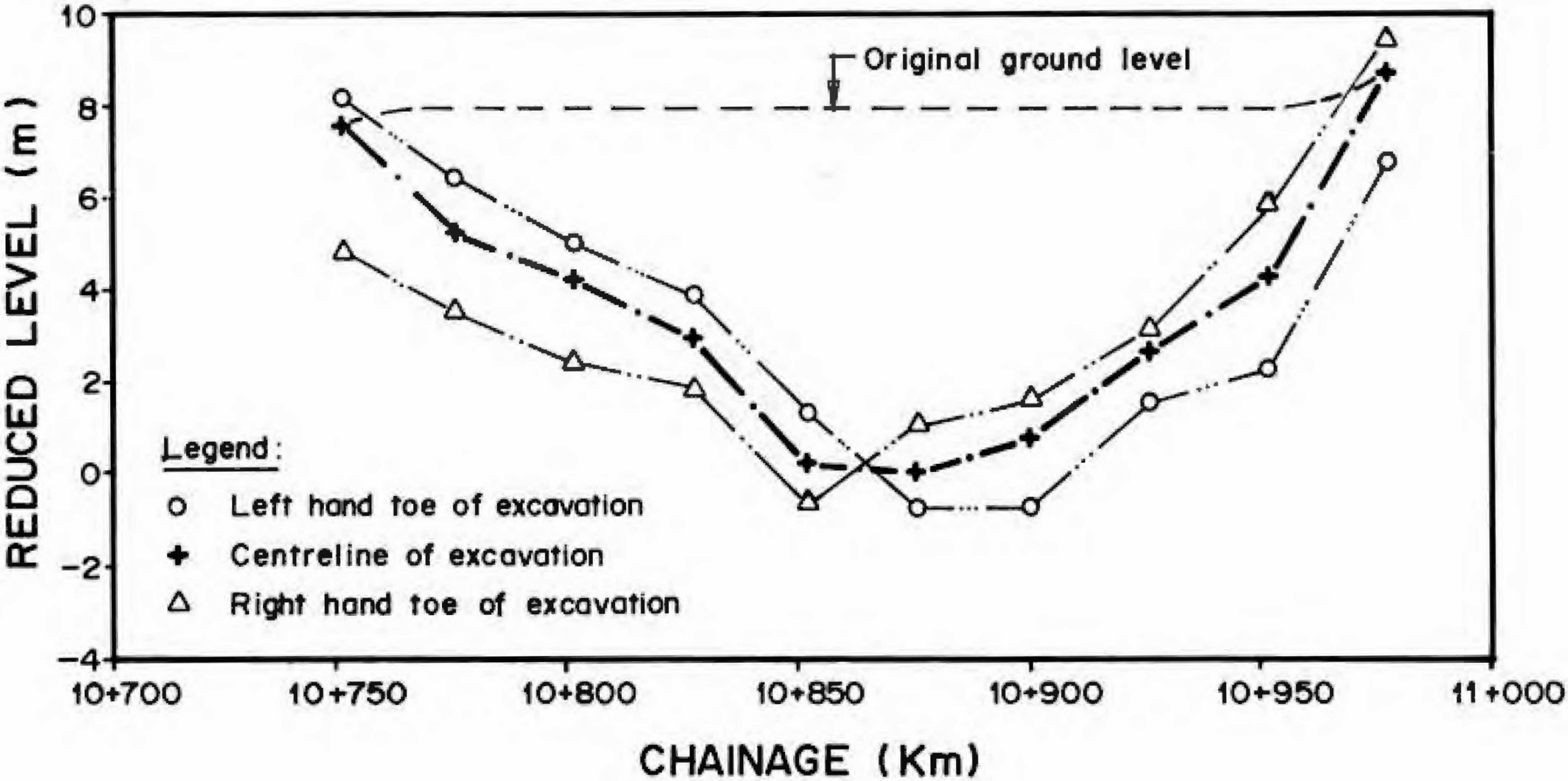


Figure 9 Final excavation levels

Maximum daily volume = 5 Million gallons
= 19 million litres

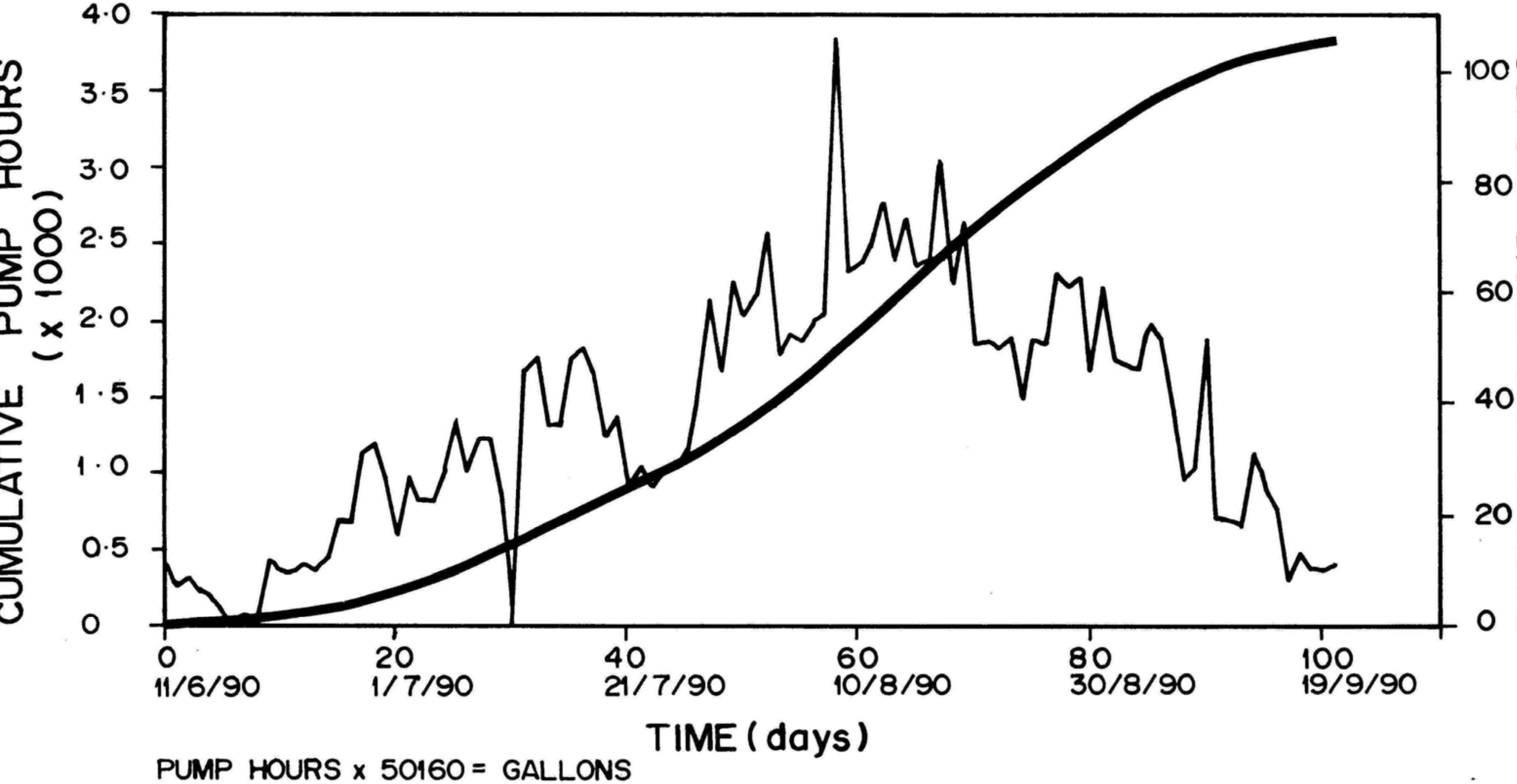


Figure 10 Daily and cumulative pump hours

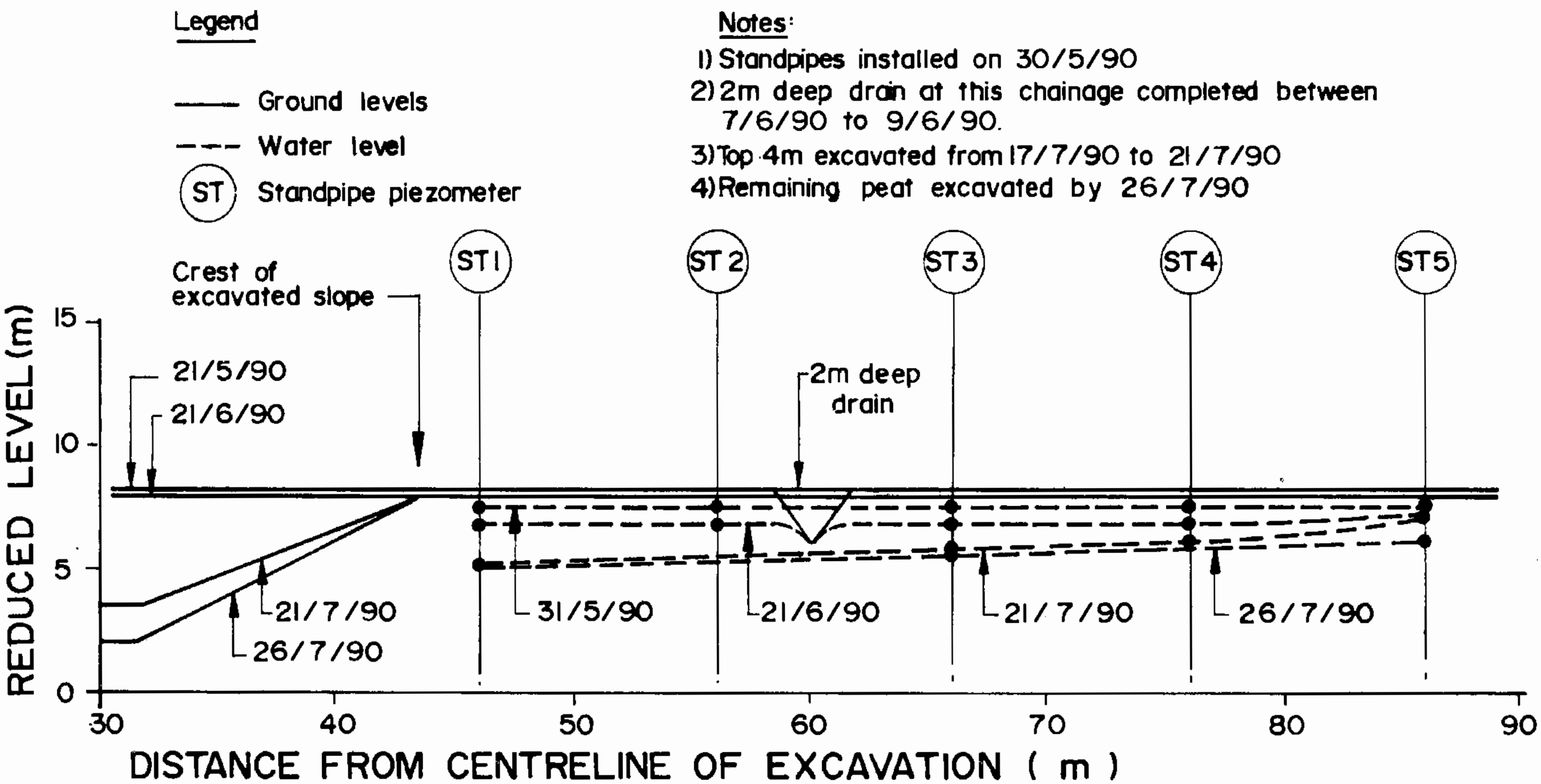
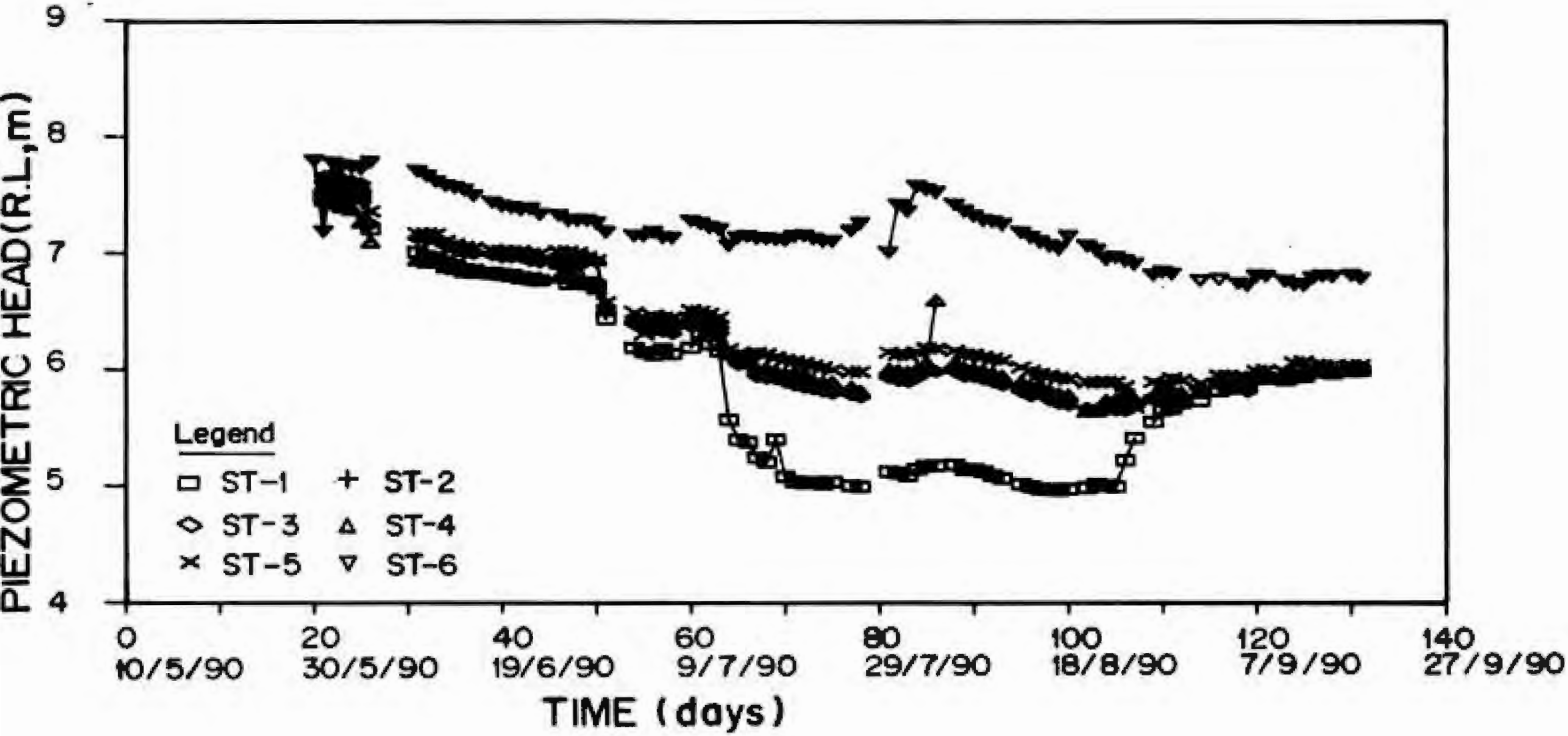


Figure 6 Monitored phreatic surfaces at chainage 10+870



igure 7 Standpipe piezometer records at chainage 10+870

Machap. Peat excavation

Machap. Peat excavation

Machap. Peat excavation

Machap. Peat excavation

Machap. Peat excavation

Machap. Peat excavation

Machap. Peat excavation

Machap. Peat excavation

Machap. Peat excavation

Machap. Peat replacement

Machap. Peat Replacement

Machap. Peat replacement

PEAT CASE HISTORY
SIBU POLYSTYRENE ROAD

Joint full scale project between Dr C T Toh Consultant and Sibu Municipal Council

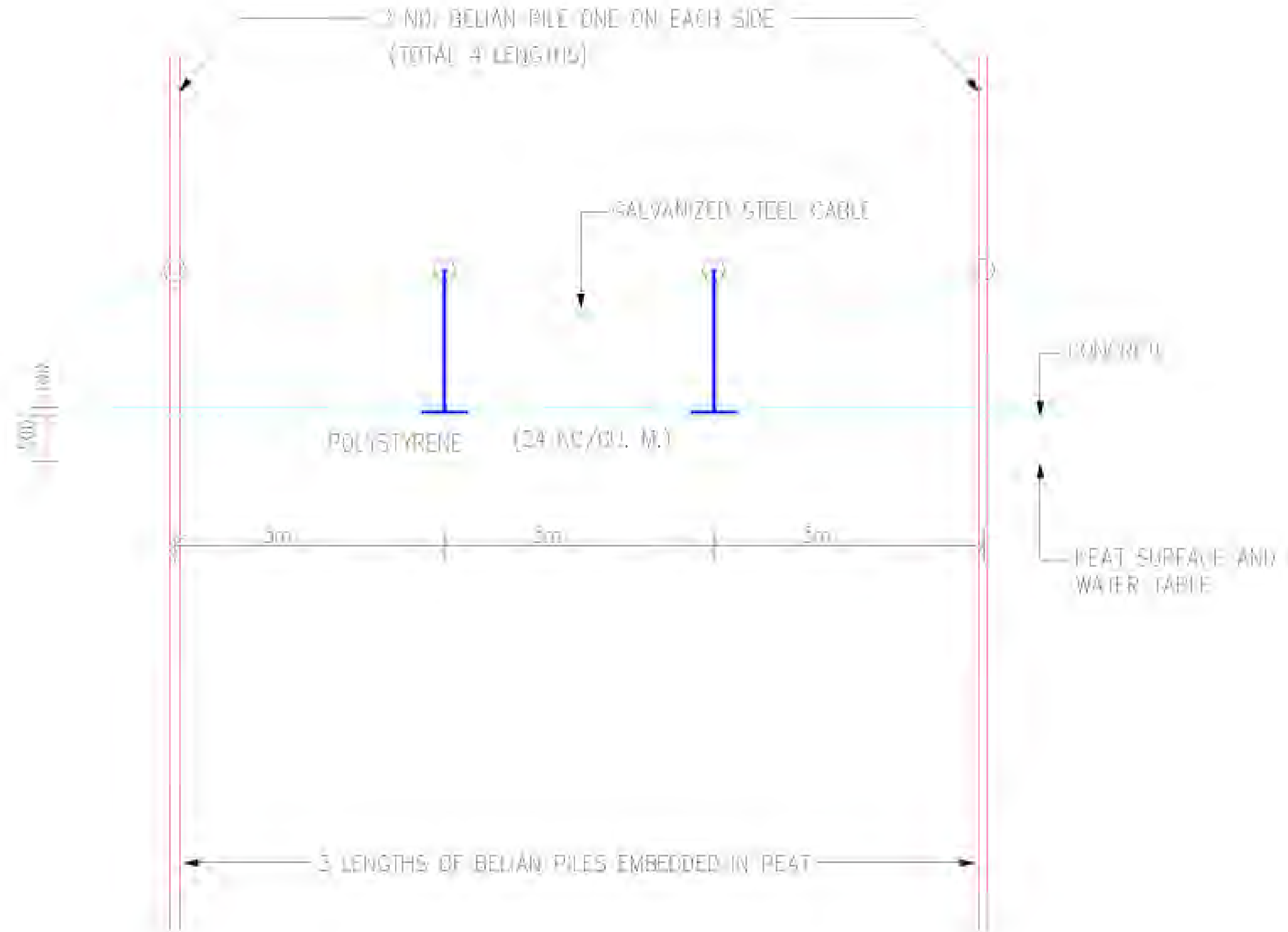
Located in the resettlement area of Sibu where the peat depth exceeds 20 m.

Flood prone area

Long term settlement of normal roads had resulted in high maintenance costs to councils

Sibu Polystyrene Walkway

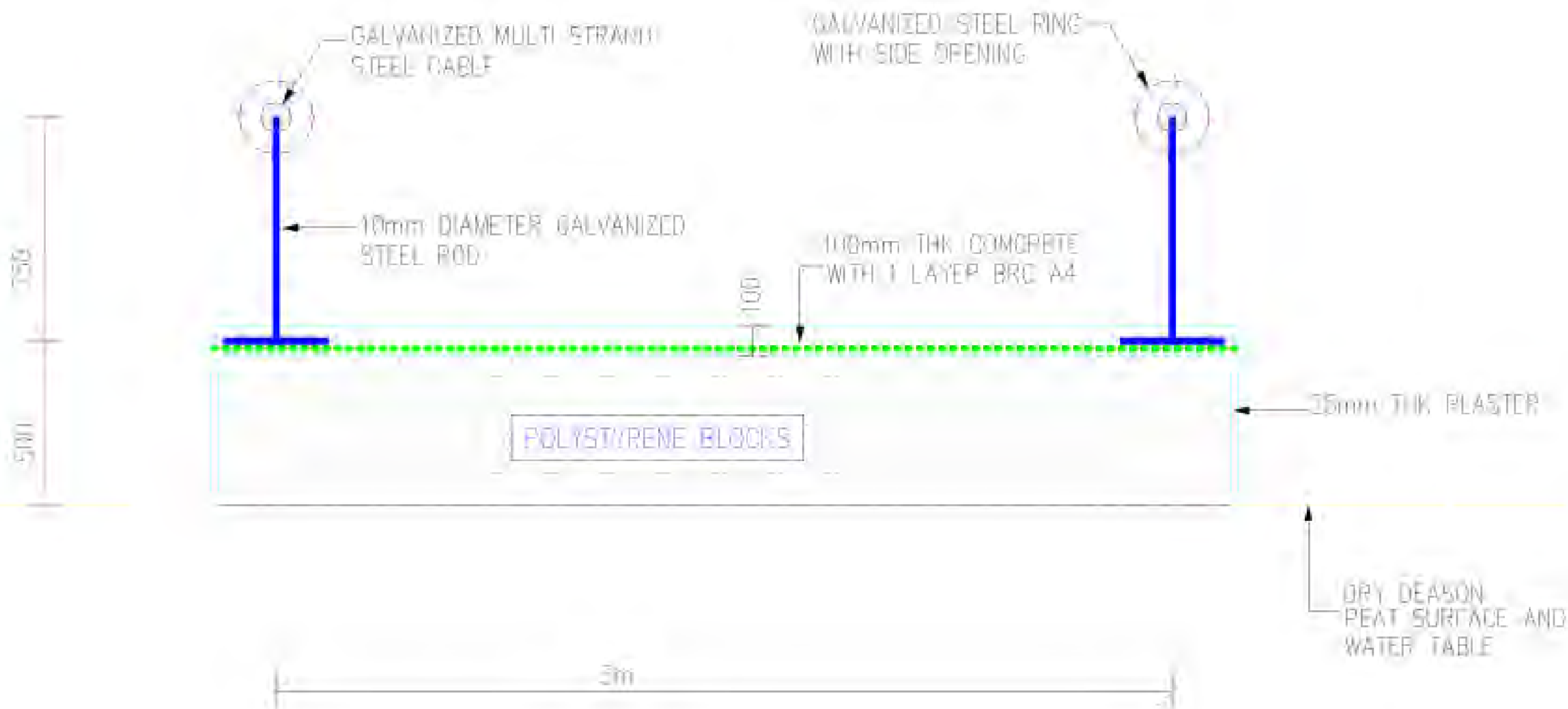
- Idea was to construct a floating road like floating jetty
- Use polystyrene blocks and confine movements due to flooding only in the vertical direction. This is by connecting the polystyrene blocks to cables to belian piles at regular intervals
- Polystyrene covered by 100 mm thick lean concrete with BRC



PROPOSED POLYSTYRENE WALKWAY ON PEAT (LONG SECTION)

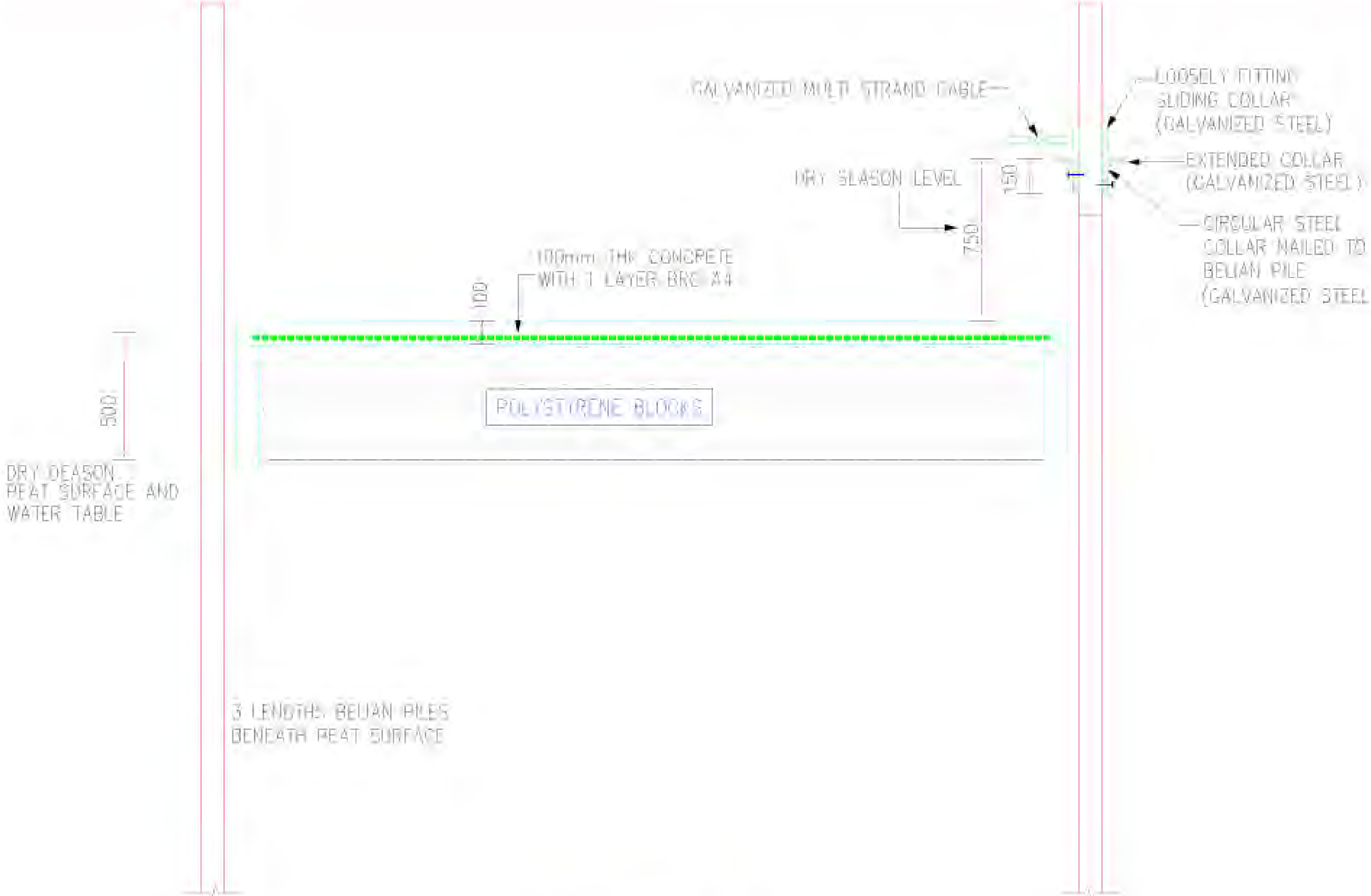
(RESETTLEMENT AREA, SIBU)

SCALE : 1 : [illegible]



SECTION A–A

SCALE : 1 : 25



SECTION B-B

SCALE :- 1 : 25

Sibu Polystyrene walkway

Sibu Polystyrene walkway

SIBU POLYSTYRENE WALKWAY

Sibu Polystyrene walkway

Sibu Polystyrene Walkway

Sibu Polystyrene walkway

Sibu Polystyrene walkway

Sibu Polystyrene walkway

Sibu polystyrene walkway

Sibu Polystyrene walkway

SIBU POLYSTYRENE WALKWAY

SIBU POLYSTYRENE WALKWAY

SIBU POLYSTRYRENE WALKWAY

SIBU POLYSTYRENE WALKWAY

Settlement of peat after drainage due to decomposition

SETTLEMENT OF DRAINED PEATLAND

- Drainage of peat results in decomposition of the peat above ground water.

>>>>>Lowering of the ground level and higher ground water relative to peat surface;

- Agriculture requires dry ground and therefore continuous deepening of surface drains and continuous lowering of ground water;

>>> Continuous decomposition of peat above ground water

>>> Continuous lowering (settlement) of peat surface due to decomposition

SETTLEMENT OF DRAINED PEAT GROUND

The average rate of lowering of the peat surface in Sarawak is about:

- 100 mm per year for fibrous peat;
- 50 mm per year for amorphous peat.

Therefore a 3 m peat layer will disappear in about 30 year unless surface drainage becomes impossible.

SETTLEMENT OF DRAINED PEAT

New Zealand records of settlement of reclaimed peat swamp for agricultural / horticultural purposes since 1924 showed:

- Ground subsidence / peat thickness reduction of up to 60 mm per year.
- Higher subsidence for deeper peat areas.

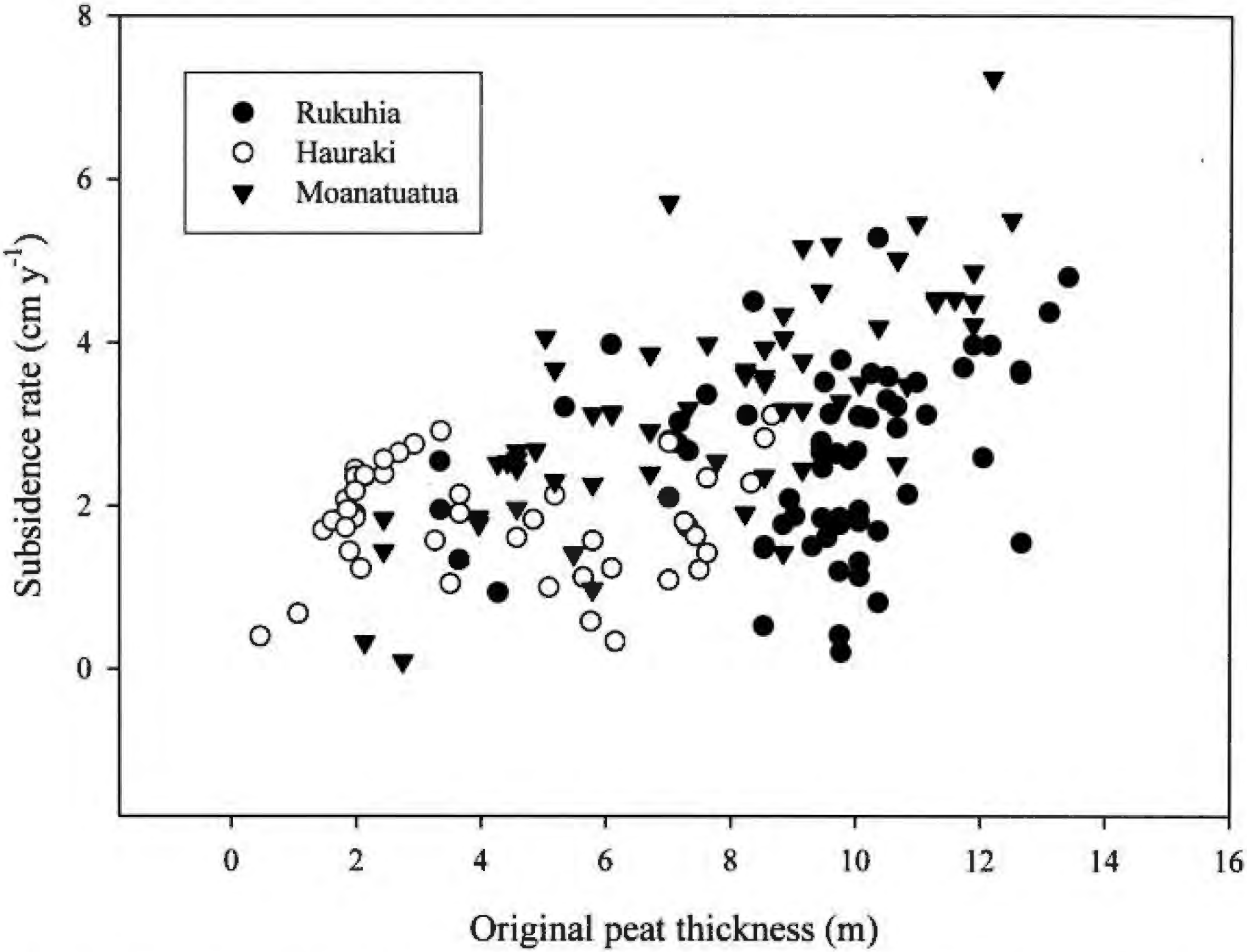


Figure 3: Subsidence rate of peat following conversion at Rukuhia, Hauraki (data from McLeod et al. 2003), and Moanatuatua (data from McKenzie and McLeod, 2002) in relation to original peat thickness.

SETTLEMENT OF DRAINED PEAT GROUND

Implications on stabilized road.

- The surrounding peat level will be lowered at a rate higher than the post construction settlement if design criteria of post construction settlement of road too strict.
- Culverts will not function within a few years.

SETTLEMENT OF DRAINED PEAT GROUND

- There is therefore a need to re-look the design criteria for settlement of roads in peat area if there will be agriculture in surrounding areas.

- If the settlement criteria is too strict, the surrounding ground will , in the long run, be lower than the embankment toe level.

- Culverts will cease to function in a short while.

PEAT AND THE ENVIRONMENT, CARBON STORAGE/RELEASE AND CLIMATE CHANGE

CARBON STORAGE AND CARBON RELEASE

WHEN PEAT IS SODDEN >>> CARBON LOCKED INSIDE.

WHEN EXPOSED TO WIND AND SUN, THE PEAT WILL DRY OUT >>> *TRANFORMATION* FROM AN ABSORBER OF CARBON TO A MASSIVE SOURCE OF CARBON

PEAT SWAMP CARBON STORAGE

- CLEARING PEAT SWAMP RESULTS IN GREATER SUSCEPTIBILITY TO PEAT FIRES.
- HAZE IN S. E. ASIA DUE LARGELY TO PEAT FIRES.
- RESULTS IN RELEASE OF CARBON DIOXIDE TO ATMOSPHERE
- ADDS TO GLOBAL WARMING

1007 FIRES IN SOUTH EAST ASIA

- Estimated 2.67 billion tons of greenhouse CO_2 released through burning of peat in SE Asia in 1997.

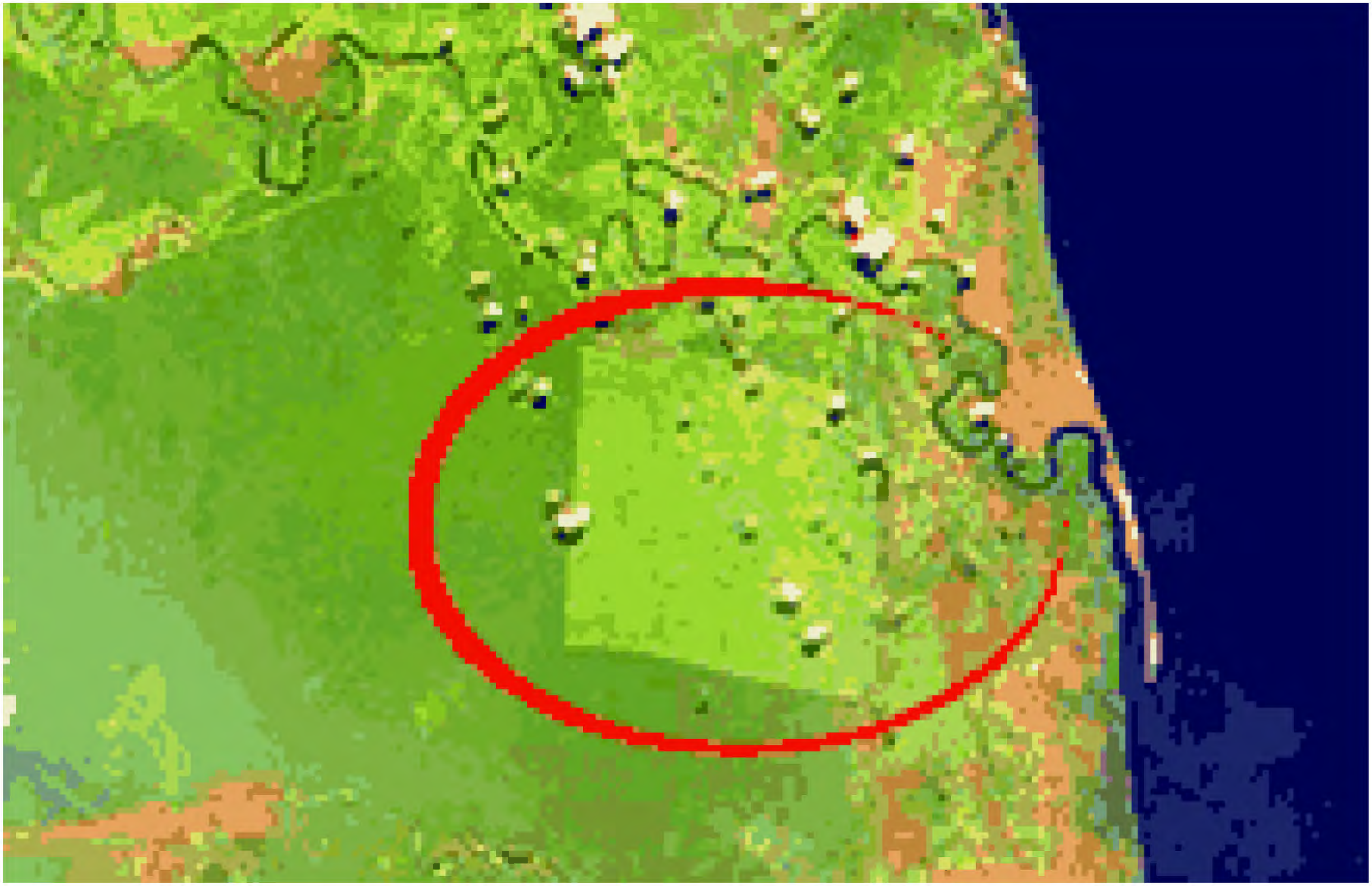
- This is about 40% of 1 year of global fossil fuel combustion.

RELEASE OF CO2 TO ATMOSPHERE

- PEAT FIRES IN SOUTH EAST ASIA ADDS SIGNIFICANTLY TO GLOBAL WARMING
- BIG FEARS IS GLOBAL WARMING THAWS FROZEN SIBERIAN PEAT>>> GREAT RELEASE OF CO2 TO ATMOSPHERE>>>>> ACCELERATES GLOBAL WARMING

ILLEGALLOGGING OF PEAT SWAMP

- Satellite photo of illegal logging in peat swamp of Tengganu from MalaysiaKini



INDONESIAN PEAT FOREST FIRE(from BBC)

PEAT FIRE (from BBC)

NATURAL INHABITANTS
PROBOSCIS MONKEY

Proboscis monkey

- Endemic in mangrove and peat swamps of Borneo
- Climbs trees
- Web feet for swimming
- Voracious sexual appetite

DESTRUCTION PEAT SWAMPS WILL DESTROY BIO - DIVERSITY

END OF LECTURE

THANK YOU