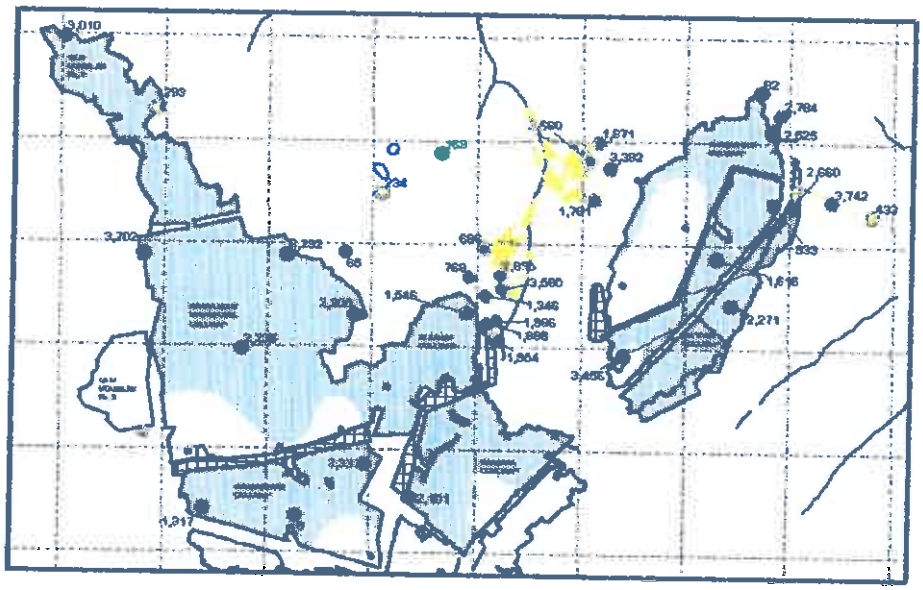
WQM/01/00

Water Quality
Management Series

OLIFANTS RIVER CATCHMENT

BLESBOKSPRUIT CATCHMENT GEOHYDROLOGICAL REPORT for Acid Mine Drainage Collection and Conveyance System for Abandoned Mines



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DOCUMENT INDEX

This document is one of a series of reports compiled which addresses the Water Quality Management in the Blesbokspruit Catchment. The following documents precede this report:

1. Department of Water Affairs and Forestry, No. 1383/350/1/W, June 1990 Olifants River Catchment, Ferrobank, Report on Water Pollution Mitigation and Rehabilitation at T & DB Collieries.

2. Department of Water Affairs and Forestry, No. 2938/1023/1/E, May 1995. Geohydrological Assessment of Old Mine Workings in the Blesbokspruit Catchment.

3. Department of Water Affairs and Forestry, No. WQ/B104/03/01/96, March 1997. Preliminary design report for Acid Mine Drainage Collection and Conveyance Systems for Abandoned Mines in the Blesbokspruit Catchment.

4. Department of Water Affairs and Forestry, WQM/01/00, February 2000. Blesbokspruit Catchment - Geohydrological Report for Acid Mine Drainage Collection and Conveyance System for Abandoned Mines.

APPROVAL

TITLE	:	Blesbokspruit Catchment - Geohydrological Report for Acid Mine Drainage Collection and Conveyance System for Abandoned Mines.
LEAD CONSULTANTS	:	Goba Moahloli & Associates and Keeve Steyn Incorporated
SPECIALIST CONSULTANTS	:	Jasper Muller Associates CC
AUTHORS	:	J.L. Muller and L.J. Botha
PROJECT NAME	:	Proposed Water Pollution Control Works at Abandoned Coal Mines in the Witbank and Ermelo Districts - Phase 2B.
REPORT STATUS	:	Final
CLIENT	:	Department of Water Affairs and Forestry
DWA&F REPORT NO	:	WQM/01/00
DWA&F FILE NO	:	16/4/B104/3
JMA REPORT REF	:	JMA/10138/03/99
DATE	:	February 2000
Approved for JMA	:	Jasper L. Muller Managing Director JMA
Approved for GMA-KSI	:	P J le Roux Director KSI
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EXECUTIVE SUMMARY

Jasper Muller Associates (JMA) was appointed as sub-consultant to GMA-KSI, to perform a geohydrological investigation in the Blesbokspruit catchment. The terms of reference of the investigation were as follows:

- Investigate the current ground water situation in the following mines:

  - Old Douglas No.2 Colliery
  - Middelburg Steam Coal and Coke (including Station Colliery)
  - Coronation Colliery
  - Witbank Colliery
  - Tavistock Colliery
  - Uitspan Colliery

  with the aim to assess:

  - Current flooding status
  - Ground water quality distribution

  and to understand:

  - The hydraulic response subject to recharge and discharge. In this regard an attempt must be made to compile a ground water model which could quantify and predict the seepage and decant flow rates, as well as the potential remedial impact of surface rehabilitation.

- Investigate the physical and hydraulic control of the seepage occurrences at three sites - later extended to include a fourth site.

- Provide a monitoring system for future monitoring and management of the situation.

The terms of reference was compiled to support the following overall DWAF objectives for the Brugspruit/Blesbokspruit catchments:

- To confirm the contribution of the Blesbokspruit catchment.

- To identify other alternative remediation options for the Blesbokspruit catchment, such as for instance:

  - Mine de-watering/water level manipulation.
  - Surface rehabilitation/filling of depressions.
  - Mining of the residual coal.
  - Elimination of other sources contributing to the hydraulic loading of the mined out areas.

- From these alternative options, a combined effort between JMA, GMA-KSI and DWAF must eventually deliver the selection of the most appropriate option to address the water pollution emanating from the Blesbokspruit catchment.

The investigation by JMA comprised the following actions:

- Gather, review and collate existing information.
- Conduct a reconnaissance walk-over survey.
- Conduct a magnetic survey.
- Site and drill 45 new boreholes.
- Perform geohydrological profiling.
- Survey all boreholes for X, Y and collar Z.
- Do EC profiling and sampling horizon selection.
- Perform stratified sampling.
- Analyze water samples for macro chemistry and selected micro variables.
- Perform Acid/Base tests.
- Measure ground water and mine water levels.
- Perform permeability (slug) testing on holes outside mine workings.
- Code and computerize data.
- Collate data and compile information sets.
- Interpret and evaluate the data and information.
- Compile a report, discussing the current situation, the modeling of the water balance, also giving proposals for management and monitoring, as well as conclusions and recommendations.

The following conclusions were reached:

- Quantitative information on the extent of flooding, as well as the water quality distribution in the underground and rehabilitated open-cast mines in the Blesbokspruit catchment, was generated during the field work phase of this investigation.

- The boreholes drilled outside the perimeters of the mined areas, did not only generate sufficient information to perform a quantitative geohydrological description of the aquifers in the area, but furthermore facilitated a detailed assessment of the physical and hydraulic controls of the seepage occurrences.

- During the study a quantitative water balance model was developed. The development of this model resulted in a fundamental understanding of the components and dynamics of the mine water/ground water balance in the Blesbokspruit catchment. The model could be quantified to such a degree that simulation of the observed flows could be modeled satisfactorily. However, further calibration will be required for the model to be used for management purposes.

- In order to facilitate refinement and calibration of the water balance in the Blesbokspruit catchment, monitoring of the components of the water balance will be necessary. A comprehensive mine water and ground water monitoring infrastructure was commissioned during this investigation and detailed proposals for future monitoring are given in the report.

- It can further be concluded that the results obtained during this investigation, go a long way not only in confirming the contribution of the Blesbokspruit to the Klipspruit water quality situation, but also in creating an understanding of the dynamics of the situation (fluctuations in flow volumes and quality).

- It further clearly demonstrated the available options, and their relative potential efficiency, for management of the situation.

The report concludes with the following recommendations:

- It is recommended that the IWQS update their July 1996 report, N/B 100/RMQ0996 to check the impact of the Brugspruit treatment works on water quality in the Klipspruit so as also to reflect the relative pollution contribution of the Blesbokspruit.

- That the monitoring program as proposed, be implemented as a matter of urgency.

- That, subject to generation of the data as proposed in the monitoring program, the water balance model be calibrated after a 12 month monitoring period.

- That no additional management and/or collection facilities be commissioned, without taking cognizance of the findings of this report, and assessing their potential impact on the mine water/ground water balance in the Blesbokspruit catchment.

- Once the model is calibrated, the available options for remediation should be considered as possible solutions to the problem. A workshop to address this aspect is recommended. Possible options which can be considered for further investigation, are:

  - Additional evapotranspiration
  - Rehabilitation of subsidence
  - Opencast mining of the area
  - Treatment of the water

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APPENDICES

1. INTRODUCTION

Mining activities on the No.1 and No.2 coal seams in the Blesbokspruit and Brugspruit catchments, started some 100 years ago. Although some mining activities of fringe coal took place between the mid-1970's and mid-1990's, underground mining ceased in the late 1940's and early 1950's.

Severe residual environmental problems, including acid mine drainage (AMD) and underground fires resulting from spontaneous combustion, are currently experienced at some of these old defunct mines in the Witbank area. Several investigations related to the collection and conveyance of the AMD in the Brugspruit and Blesbokspruit catchments have been conducted since the early 1990's. However, a lack of quantitative geohydrological information, to support detailed ground water balance and hydro-chemical response calculations, have always restricted the understanding of the dynamics of the AMD and fire situations, to conceptual model levels.

In a report compiled by GMA-KSI for the Department of Water affairs and Forestry during 1997 (Preliminary Design Report for Acid Mine Drainage Collection and Conveyance Systems for Abandoned Mines in the Blesbokspruit Catchment), it was recommended that a quantitative geohydrological investigation be performed to describe the ground water dynamics related to mine flooding and AMD discharge from the mines.

JMA was contacted in this regard by Mr Paul Le Roux of KSI in July 1996. A sequence of actions, comprising a field inspection, followed by a JMA cost estimate, dated August 1996, and a revised JMA cost estimate dated 23 September 1997, resulted in a letter of appointment from KSI to JMA, dated 27 May 1998, in which KSI informed JMA that the latter cost estimate was approved with the following changes:

- JMA 1998 fees and tariffs to be applicable.
- Drilling to be done by the DWAF Drilling Division.

2. TERMS OF REFERENCE

Based on discussions held between DWAF, KSI and JMA, it was agreed that JMA should perform a geohydrological investigation that should:

- Investigate the current ground water situation in the following mines:
  - Old Douglas No.2 Colliery
  - Middelburg Steam Coal and Coke (including Station Colliery)
  - Coronation Colliery

- Witbank Colliery
- Tavistock Colliery
- Uitspan Colliery

with the aim to assess:

- Current flooding status
- Ground water quality distribution

and to understand:

- The hydraulic response subject to recharge and discharge. In this regard an attempt must be made to compile a ground water model which could quantify and predict the seepage and decant flow rates, as well as the potential remedial impact of surface rehabilitation.

- Investigate the physical and hydraulic control of the seepage occurrences at three sites - later extended to include a fourth site.

- Provide a monitoring system for future monitoring and management of the situation.

The terms of reference was compiled to support the following overall DWAF objectives for the Brugspruit/Blesbokspruit catchments:

- To confirm the contribution of the Blesbokspruit catchment.

- To identify other alternative remediation options for the Blesbokspruit catchment, such as for instance:
  - Mine de-watering/water level manipulation.
  - Surface rehabilitation/filling of depressions.
  - Mining of the residual coal.
  - Elimination of other sources contributing to the hydraulic loading of the mined out areas.

- From these alternative options, a combined effort between JMA, GMA-KSI and DWAF must eventually deliver the selection of the most appropriate option to address the water pollution emanating from the Blesbokspruit catchment.

- To eliminate some of the problems experienced in the Brugspruit catchment (e.g. ground water pollution due to apparent ineffective collection system).

All the above should optimize:

- The rehabilitation of the Blesbokspruit and the Klipspruit to an acceptable water quality.
- Removal of the threat to human health associated with the potable use of water.
- The restoration of the irrigation potential of the water.
- The restoration of the natural aquatic ecosystem.

3. PROJECT APPROACH

In order to facilitate fulfillment of the stated terms of reference, it was realized from the outset that accurate, and if possible, quantitative descriptions, relating to the following, would have to be generated:

- Physical/hydraulic/hydro-chemical attributes of the historical mining operations, including:
  - Lateral extent of mining
  - Compartmentalization (inter-connectivity).
  - Coal seam elevation.
  - Topography.
  - Pillar stability - subsidence areas.
  - Hot spots (burning coal).
  - Hydraulic response.
  - Geochemical response.
  - Recharge.
  - Discharge.
- Physical/hydraulic/hydro-chemical attributes of the ground water zone. Relevant aspects are:
  - Host rock composition.
  - Lateral aquifer boundaries/preferential flow zones.
  - Aquifer thickness/depth of weathering.
  - Hydraulic conductivity.
  - Yielding capacity.
  - Porosity.
  - Recharge.
  - Ground water flow.

- Ground water hydro-chemistry as it relates to:
  - Background ground water.
  - Seepage water.
  - Mine water.
  - Ground water in pillars.

- A dynamic ground water balance model, comprising the following:

  - Identification of ground water balance components.
  - Quantification of ground water balance components.
  - Inter-active water balance calculation to facilitate water balance management optimization.
  - Salt load calculation required for catchment management purposes.

4. ACTIONS PERFORMED

In order to give fulfillment to the stated terms of reference, the following actions were performed:

4.1 Gather, review and collate existing information

A wealth of existing information exists for the study area. The following reports were used extensively:

- Olifants River Catchment, Ferrobank. Report on water pollution mitigation and rehabilitation at Transvaal and Delagoa Bay Mine (T & DB). Wates & Wagner Report No. 1383/350/1/W, June 1990.
- Water Quality Management Series: Olifants river catchment. Geohydrological assessment of old mine workings in the Blesbokspruit catchment. DWAF (WMB) Report No. 2938/1023/1/E.
- Water Quality Management Series: Olifants river catchment. Blesbokspruit catchment preliminary design report for Acid Mine Drainage Collection and Conveyance System for Abandoned Mines. DWAF (GMA-KSI) Report No. WQ/B104/03/01/96.

Relevant information contained in these reports pertain to:

- Mining related information.
- Conceptual geohydrological model.
- The nature of AMD.
- Detailed descriptions of the geomorphology, climate and geology.
- Different types of surface subsidence.
- Environmental impacts.
- Chemical processes.

In addition to the above, the following information sources were used to obtain data/information relevant to the study:

- Digital, mining related information from Keeve Steyn Consulting Engineers and Project Managers.
- DWAF flow, water quality and rainfall records for the study area.
- Surface Water Resources of South Africa 1990. WRC Report No. 298.
- 1:50 000 Digital aireal photograph obtained from the Chief Directorate Surveys and Mapping.
- Mining related information from the Department Mineral and Energy Affairs.
- Aireal, heat sensitivity, photographs taken by Mr. Tom Furstenburg for the Department Mineral and Energy Affairs.
- Geohydrological information from the National Ground Water data base.
- Internet search.

However, the integrity of certain data/information, especially that related to the extent of mining, as well as that applicable to the No.2 Coal seam floor contours, is questionable. Although JMA spent a lot of time and effort in trying to optimize this information, severe deficiencies still exist in certain instances.

During the information collation process, existing information was scrutinized for possible errors and corrected as far as other information sources and newly generated information permitted.

4.2 Conduct a reconnaissance walk-over survey

The main objectives of the reconnaissance survey, were to accurately map surface seepage, surface subsidence, extent of underground fires, and the extent of tree growth in the Blesbokspruit catchment. The location of the study area, where the reconnaissance survey was conducted, is shown on FIGURE 1 - APPENDIX I.

The following comments have relevance to field observations made during this initial survey:

- Seepage apparently occur were bedding planes cut the topography, below the flood level of totally flooded underground sections, as well as from decant points at the opencast sections.
- No dolerite outcrops were observed at any of the seepage areas.
- Numerous depressions have been formed as a result of pillar failure. These are considered to be potential enhanced recharge areas. Water can be seen at the bottom of some of these depressions.
- Smoke from underground fires, was observed.

- Areas of tree growth, especially blue-gum and black wattle. Due to their evaporative potential, these trees are considered to be potential discharge components of the water balance.

The mapped seepage areas, together with other relevant existing information, is shown on FIGURE 2 - APPENDIX I.

4.3 Conduct a magnetic survey

Despite fairly extensive magnetic traversing at all four main seepage spots, no magnetic anomalies which could possibly indicate dolerite intrusion presence, were observed. No magnetic evidence, indicating a possible dolerite related structural control of the seepage occurrences, could be found.

4.4 Site and drill 45 new boreholes

The total number of 45 boreholes sited and drilled, is made up as follows:

- 18 Boreholes penetrated the underground workings.
- 7 Boreholes intended to penetrate the underground workings, actually penetrated pillars.
- 2 Boreholes penetrated rehabilitated open-cast areas.
- 18 Boreholes were drilled outside the extent of mining to investigate the physical and hydraulic attributes of the four seepage areas.

Boreholes into the mine workings, were drilled at a diameter of 203 *mm* with an air percussion rig, to a depth corresponding with the floor of the No.2 Coal Seam. Holes were stabilized with 160 *mm* diameter solid and/or perforated 3 *mm* steel casing. Holes were finished with cement collar blocks, steel caps and locks.

The boreholes at the seepage spots, were drilled to depths varying between 18 m and 42 m. These holes were drilled to penetrate both the No.2 and No.1 Coal seams. They were also stabilized with solid and /or perforated steel casing through the weathered horizons.

The localities of the newly drilled boreholes, together with other relevant information, are shown on FIGURE 3 - APPENDIX I.

The borehole construction specifications are shown on the borehole profile plots attached as APPENDIX II.

4.5 Perform geohydrological profiling

A JMA geotechnician performed continuous geohydrological profiling during drilling. All the information generated is contained in the geohydrological site reports, and plotted on the borehole profile plots, both information sets of which are attached as APPENDIX II.

4.6 Survey all boreholes for X, Y and collar Z

All new and existing boreholes, were surveyed accurately for X, Y and Z coordinates. These surveyed borehole coordinates are also given on the site reports and on the borehole profile plots attached as APPENDIX II.

4.7 Do EC profiling and sampling horizon selection

In order to facilitate stratified sampling, all boreholes which recorded water levels, were EC profiled. The EC profiles, together with the selected sampling horizons, are shown on the borehole profile plots attached as APPENDIX II.

4.8 Perform stratified sampling

Stratified sampling was performed at the pre-determined sampling horizons, using a high integrity grab sampler. The selected sampling depths are indicated on the hydro-chemistry reports - APPENDIX III.

4.9 Analyze water samples

The 37 water samples taken, were submitted to WATERLAB RESEARCH and analyzed for the following water quality variables:

pH, EC, TDS, Ca, Mg, Na, K, Total Alkalinity, Si, F, Cl, SO_4, NO_3, Fe & Mn.

The results obtained from the laboratory, were computerized into HYDROCOM. Hydro-chemistry compliance reports were printed and are attached as APPENDIX III.

4.10 Perform Acid/Base tests

Selected formation samples were taken during the drilling programme. 15 Samples were submitted to WATERLAB RESEARCH for Acid/Base tests. The results are attached as APPENDIX IV.

4.11 Measure ground water and mine water levels

Ground water and mine water levels were taken on three occasions during the course of the project. A water level report, and time dependant hydrographs, are attached as APPENDIX V.

4.12 Perform permeability (slug) testing on holes outside mine workings

Slug tests were performed on boreholes which did not penetrate the mine workings. The resulting hydraulic conductivity values will be discussed in the text.

4.13 Code and computerize data

All generated information was coded and computerized into the HYDROCOM data base. Electronic files were converted to the format of National Ground Water Data Base, and submitted to DWAF - Division Geohydrology.

4.14 Collate data and compile information sets

CAD and GIS technologies were used to collate data and to compile information required to give fulfillment to the stated terms of reference. The following information sets, some of which were already referenced, are attached as APPENDICES to this report.

- APPENDIX I : FIGURES AND TABLES
- APPENDIX II : BOREHOLE SITE REPORTS AND PROFILE PLOTS
- APPENDIX III : HYDRO-CHEMISTRY RESULTS
- APPENDIX IV : ACID BASE TEST RESULTS
- APPENDIX V : GROUND WATER LEVEL AND MINE WATER LEVEL REPORT AND HYDROGRAPHS
- APPENDIX VI : GEOLOGICAL CROSS SECTIONS
- APPENDIX VII : HYDROCHEMICAL IMAGING
- APPENDIX VIII : PHOTOGRAPHS
- APPENDIX IX : ASSESSMENT OF WATER BALANCE AND WATER BALANCE COMPONENTS

4.15 Interpret and evaluate the data and information

Interpretation and evaluation of data and information were focused to give effect to the stated terms of reference:

- Investigate the current ground water situation in the listed abandoned mines, with the aim to assess the current flooding status and the ground water quality distribution, and to understand the hydraulic response subject to recharge and discharge. In this regard an attempt was made to compile a ground water model which could quantify and predict the seepage and decant flow rates, as well as the potential remedial impact of surface rehabilitation.

- Investigate the physical and hydraulic control of the seepage occurrences at three sites - later extended to include a fourth site.

- Provide a monitoring system for future monitoring and management of the situation.

4.16 Compile report

The project report contains the following sections:

- Introduction
- Terms of Reference
- Project Approach
- Actions Performed
- Description of the Current Ground Water Situation
- Geohydrological Impact Assessment - Water Balance Model
- Ground Water Management Measures
- Monitoring Proposals
- Conclusions
- Recommendations

5. DESCRIPTION OF THE CURRENT GROUND WATER SITUATION

The description of the current ground water situation will focus on the following aspects:

- Physical aquifer characteristics.
- Hydraulic aquifer characteristics.
- Hydro-chemical aquifer characteristics.

Although referred to as a ground water description, the discussion will also encompass aspects closely related to the geohydrology, such as the water situation (flooding and quality status) in the abandoned mines, as well as the surface seepage emanating from the mines into the Blesbokspruit.

5.1 Physical Aquifer Characteristics

The physical aquifer description is based on information obtained from previous reports, as well as on information generated during the drilling program, summarized in TABLE 1 - APPENDIX I.

5.1.1 Aquifer types

The aquifers in the study area, show typical geological and geohydrological characteristics of hard rock type aquifers. In view of the geological setting (Karoo), this is to be expected.

Two main aquifer zones exist within the hard rock aquifer. The main attributes of these two zones are summarized as:

- Shallow, weathered, largely unconfined, aquifer zone: This is the zone that plays the most important role in ground water movement in the study area. It is weathered to an average depth of 12,5 *m*, and stretches from surface right down to the base of the No.1 coal seam. Although residual clays are observed in the upper-most part of this shallow zone aquifer, their distribution are non-continuous, varying in thickness between 0 and 2 *m* thick. A shallow perched aquifer, usually found at the top of weathered zone Karoo aquifers, does therefore not exist over the entire area, It is only developed intermittently, depending on the presence and extent of the clays. Where it is developed, it appears that it only becomes saturated during events of high rainfall, or when saturated due to discharges from the underground and open cast mining areas.

- Deeper, largely confined, aquifer zone: The geology of this zone, which underlies the shallow weathered zone aquifer, is described as fresh. Fractures are much less common, have smaller apertures, and are less continuous. In comparison with the shallow weathered zone aquifer, described above, the volumes of ground water that can potentially flow through this zone is insignificant by comparison. This zone primarily exists below the No.1 coal seam.

5.1.2 Aquifer Host Rock Composition

The general geology consists mainly of sandstones and shales belonging to the Ecca Group (Karoo Sequence). Underlying these are tillites/diamictites of the Dwyka group, which represent the base of the Karoo sequence. Important to note that the coal seams mined here, were deposited right at the fringe of the Karoo basin.

Being located right at the edge of the Karoo basin, dolerite intrusions are not as common as in the remainder of the Witbank coal fields. The current information (borehole logs, magnetic survey and walk over survey) suggests the existence of only two dolerite dykes in the Uitspan Colliery area. They appear to tie up and are orientated in a SW-NE direction, striking from borehole BSG-PB39 to borehole BSG-UB42 (these boreholes did not intersect the dykes). Data gathered from the DWA&F ground water data base, indicate two groups of boreholes which intersected dolerite (see FIGURE 2 - APPENDIX I for these borehole localities):

- Boreholes 00058 & 00059, situated approximately 1 *km* to the east of Old Douglas No.2 Colliery, intersected 10 *m* of dolerite at a depth of 30 *m*.
- Boreholes 00045 & 00046, situated approximately 1,5 *km* to the south-east of Uitspan Colliery, intersected 14 *m* and 20 *m* dolerite, at depths of 62 *m* and 57 *m*, respectively.

Although dolerite intrusions do occur in the study area, no magnetic anomalies were found at the four investigated seepage spots. Dolerite intrusions are therefore not believed to have any control over the seepage occurrences. More about the structural control of seepage in section 5.2.6.

However, the distribution of the No.1 and No.2 coal seams, apparently do play a significant role in seepage occurrence. Wates and Wagner previously reported that the thickness of the No.2 seam varies between 1 *m* and 6 *m*, with an average thickness of 5 *m*, while the No.1 seam, which is generally poorly developed, varies in thickness between a few *cm* to 3 *m*. The parting thickness between the two seams also vary between 1 *m* and 3 *m*.

The No.2 coal seam lies between 0 and 22 *m* deep, and has been mined underground as shallow as 10 *m* deep. In shallow areas the coal was mined opencast. The No.1 coal seam was apparently not extensively mined.

The available information on the distribution of the coal seams is not of high integrity. A number of sources were consulted for information on the No.2 coal seam floor elevation. The fact that the floor contours available for the different mines did not correlate well, as well as the fact that percussion drilling was used in this study, which made detailed logging of the different coal seam elevations very difficult, complicated detailed mapping of the extent and geometry of the No.2 seam floor contours. A combination of existing and newly generated information was eventually used to compile the No.2 coal seam floor elevation contour map, attached as FIGURE 4 - APPENDIX I.

Bearing in mind the possible in-accuracies in the No.2 coal seam floor distribution, the following observations can nevertheless be made:

- The regional dip in the No.2 coal floor elevation is from south to north.
- The highest No.2 coal seam floor elevations are observed in Witbank Colliery.
- The known seepage spots are all associated with the lowest observed floor elevations, suggesting that gravitational flow do play a governing role with regard to water movement within the mines, as well as with related seepage from the mines.
- Subject to the above, the north-western tip of Old Douglas No.2 Colliery, seems to be indicated as a potential seepage locality.

5.1.3 Lateral Extent of Aquifers

With regard to the delineation of lateral aquifer boundaries, a distinction is usually made between two generic boundary types:

- Physical boundaries
- Hydraulic boundaries

Although information on dolerite occurrences in the area is limited, the information which was generated at the seepage spots, do indicate a restricted presence of significant dolerite intrusions in the study area, which could act as catchment/aquifer boundaries. In view of the above, it was therefore decided to follow the conservative approach for this impact assessment, by selecting hydraulic boundaries where applicable.

The hydraulic boundaries proposed/selected are indicated on FIGURE 5 - APPENDIX I. The following observations are important:

- The olive green lines depict surface water catchment boundaries, which are usually interpreted as ground water no-flow boundaries. However, in this specific instance, the mines which contribute to the seepage in the Blesbokspruit, straddle the surface water divide. Subject to the observed floor elevations in the mines, and the control of that on the mine water flow patterns and seepage, it follows that the actual hydraulic boundaries for the mine water/seepage water balance, coincide with the mine perimeters and not the catchment boundary.

- The cyan lines depict the surface streams which are interpreted as ground water discharge boundaries. All these boundaries could be prone to ground water impact originating from the mines.

- The brown lines, represent lateral no-flow boundaries, and are selected subject to anticipated ground water flow directions (perpendicular to the surface topography). No mine related impacts are anticipated beyond these boundaries.

5.1.4 Aquifer Thickness

The following APPENDICES have relevance to this discussion:

- APPENDIX II : Borehole site reports and profile plots.
- APPENDIX V : Ground water level report.
- APPENDIX VI : Geological cross sections.

As stated in SECTION 5.1.1, the aquifer is divided into two distinct, horizontal aquifer zones:

- The shallow weathered zone aquifer.
- The deeper aquifer.

For the purposes of the present study, all discussions have relevance to the shallow weathered zone aquifer only. All mining activities and associated lateral ground water movement and pollutant migration, will occur in this aquifer zone. Due to the very low hydraulic aquifer properties of the deeper lying aquifer, its contribution to, and interaction with the shallow aquifer is considered negligible.

Geohydrological information was generated in two catchments:

- Blesbokspruit catchment
- Catchment B11J

Two aspects are important when describing the aquifer thickness:

- Depth of weathering.
- Depth to ground water.

5.1.4.1 Depth of Weathering

The weathering depths summarized in the following table, were calculated from all boreholes, except for boreholes BSG-RB1 and BSG-RB16, which have been drilled into rehabilitated open cast areas:

TABLE 5.1.4.1(A)
Depth of Weathering (*m*)

	Blesbokspruit catchment	Catchment B11J	Both catchments
Min	3,00 *m*	6,00 *m*	3,00 *m*
Max	>21,00 *m*	>31,00 *m*	>31,00 *m*
Avg	11,00 *m*	17,50 *m*	12,17 *m*

A thematic map of the weathering depths observed at the boreholes was compiled and is attached as FIGURE 6 - APPENDIX I.

The following important comments have relevance:

- 80 % of all boreholes have weathering depths of between 6 *m* and 24 *m*.
- 6 Boreholes (BSG-B18, BSG-B19, BSG-B20, BSG-PB25, BSG-UB27 and BSG-UB28) are weathered for the total depth to which they have been drilled. All 6 boreholes were drilled to the floor of the No. 2 coal seam.
- One third of the remaining boreholes were drilled to the floor of the No. 2 coal seam. None of these are weathered to that depth.
- Only five boreholes were drilled to depths greater than the No. 2 seam floor horizon.

- It has been noted during the field survey that the seepage do occur on the contact of the coal seam. A photograph showing ground water seeping on the coal seam contact, is attached as PHOTO 12 - APPENDIX VIII.
- Boreholes in the Eastern catchment (B11J) indicate much deeper weathering than was observed for the remainder of the Blesbokspruit area.
- No definite correlation exists between the weathering depths of boreholes and the topographical elevation.

5.1.4.2 Depth to Ground Water

The top of the unsaturated zone is defined by the original ground surface, while the bottom is defined by the water table, which represents a non-fixed (time dependant) boundary. Because ground water levels vary according to rainfall and pressure heads of infiltration sources, the unsaturated zone thickness is therefore defined at a particular point in time, and also subject to the distance from infiltration sources. To date, three water level monitoring runs have been completed and the results are attached as APPENDIX V.

Maps depicting the depth to the ground water level and ground water level elevations, were compiled ane are attached as FIGURE 7 and FIGURE 8 - APPENDIX I, respectively.

The following comments have relevance:

- All ground water levels in the mined areas are representative of the flooding status of the relevant mine. Subject to this it is assumed that the aquifers overlying non-flooded mining areas, are unsaturated.
- For all practical purposes, a shallow perched aquifer, is not considered to play a major role in pollutant migration from the mines.
- A definite influence is observed on ground water levels in close proximity to flooded mining areas.
- No definite correlation exists between the depth to ground water and the weathering depths of boreholes.

- Ground water levels are a function of:
  - Recharge.
  - Discharge.
  - Ground water flow.
  - Underground fires. This is considered as an important water level control mechanism, as fires may be continuously active for long periods.

The depth to ground water levels, for areas not affected by mining activities are summarized in the following TABLE:

TABLE 5.1.4.2(A)
Depth to Ground Water Level (*m*)
(Areas not Affected by Mining)

	Blesbokspruit catchment	Catchment B11J	Both catchments
Min	2,13 *m*	9,82 *m*	2,13 *m*
Max	7,51 *m*	17,58 *m*	17,58 *m*
Avg	4,24 *m*	13,7 *m*	6,13 *m*

5.1.4.3 Saturated Zone

The thickness of the saturated zone for the shallow weathered zone aquifer, is defined by the water table at the top and the depth of weathering at the bottom. FIGURE 9 - APPENDIX I indicates the saturation and flooding status as observed in all boreholes that were drilled to the No. 2 coal seam floor horizon (within and outside mining perimeters).

Based on available information, the following TABLE summarizes the thickness of the saturated zone outside of the mining area:

TABLE 5.1.4.3(A)
Aquifer Saturated Thickness (*m*)
(Outside Mining Perimeter)

	Blesbokspruit catchment	Catchment B11J	Both catchments
Min	0,76 *m*	3,15 *m*	0,76 *m*
Max	18,54 *m*	21,18 *m*	21,18 *m*
Avg	7,22 *m*	12,04 *m*	7,89 *m*

For calculation purposes the thickness of the saturated zone is taken as 7,22 *m* and 12,04 *m*, for the two catchments respectively.

NOTE that in calculations where the depth of rehabilitated material is relevant, a value of 10 *m* is used.

5.1.5 Flooding Status of the Mines

An accurate qualitative assessment of the current flooding status of the mines, is supported by the available information. The extent of the mined areas where water is present on the mine floor, is indicated on most of the FIGURES attached as APPENDIX I. The stacked bar charts shown at the borehole localities on FIGURE 9 - APPENDIX I, furthermore give an indication of the depth of water observed in the boreholes which penetrated the mines.

It is obvious from the information given on FIGURE 9, that with the exception of restricted areas in the Middelburg Steam Coal Colliery, Coronation Colliery, Witbank Colliery, Uitspan Colliery and Tavistock Colliery, the largest part of the No.2 coal seam floor is flooded with water.

The mine floor in Station Colliery is fully flooded.

Although an indication of the depth of flooding is given by the information on FIGURE 9 - APPENDIX I, the uncertainties related to the No.2 coal seam floor elevation distribution, prevents accurate calculations of the extent of full saturation within the mine workings.

5.2 Hydraulic Aquifer Characteristics

The discussion on hydraulic aquifer characteristics will focus on the shallow weathered zone aquifer. All pertinent geohydrological data is summarized in TABLE 1 - APPENDIX I.

5.2.1 Aquifer Hydraulic Conductivity

In order to quantify the aquifer hydraulic conductivity, which is a critical parameter with regard to ground water pollution migration, slug tests were performed on the newly drilled boreholes and evaluated to calculate a representative value.

Obviously, these tests could only be performed on boreholes not drilled into the underground workings. The calculated hydraulic conductivity values are shown at the borehole localities in FIGURE 10 - APPENDIX I, and are summarized in TABLE 5.2.1(A).

TABLE 5.2.1(A)
Calculated Hydraulic Conductivity (*m/day*)
(Outside Mining Perimeter)

	Hydraulic Conductivity (*m/day*)
Arithmetic mean	0.409
Median	0.081
Harmonic mean	0.026
Geometric mean	0.103
Average of Harmonic and Geometric mean	0.060
Chosen for calculation purposes	0.060 - 0.080

The following comments have relevance:

- Although there is a difference in the physical aquifer characteristics of the Blesbokspruit and B11J catchments, the hydraulic characteristics of the catchments seemsto be very similar. Therefore a representative hydraulic conductivity is chosen for the whole study area.

- The generally accepted approach which assumes the representative hydraulic conductivity for a specific aquifer in fractured aquifer environments, to be bounded by the harmonic and geometric means, as is the case for Karoo aquifers, has been successfully applied in previous modeling studies in the area.

- The deeper aquifer zone underlying the shallow weathered zone aquifer is considered to be of low potential.

- No definite correlation exists between the hydraulic conductivity, the ground water level distribution, or the depth of weathering.

NOTE that in calculations where the hydraulic conductivity is relevant, a value of 10 *m/day* is assumed for rehabilitated open-cast areas. (A value of 30 *m/day* was measured in borehole BGM-RB16 while borehole BSG-RB1 is artesian and could therefore not be tested. Both boreholes are situated in extremely loose material).

5.2.2 Aquifer Yielding Capacity

The blow yield information generated during commissioning of the monitoring boreholes, are shown on FIGURE 11 - APPENDIX I. The borehole site reports and profile plots, attached as APPENDIX II, also have relevance in the following discussion on the borehole yields:

- 25 Boreholes drilled in the mined area:
  - Not relevant to this discussion.
- 2 Boreholes drilled into rehabilitated opencast areas:
  - Values of 2,3 *l/s* and 5,5 *l/s* were measured in boreholes BSG-RB1 and BSG-RB16 respectively. Both boreholes have been drilled into extremely loose material.
- 18 Boreholes drilled into areas where no mining activities took place:
  - An average yield of 0,44 *l/s* was measured.
  - Yields vary between 0,01 *l/s* and 3,0 *l/s*.
- No definite relation is observed between borehole yield, hydraulic conductivity, ground water level, depth of water strike and depth of weathering.
- Water strike depths vary between 5 *m* and 24 *m*, with the first water strike occurring at an average depth of 10,3 *m*.
- Bearing in mind that a second water strike may often not be observed due to the presence of water flowing from the first water strike, the following comments also have relevance:
  - A second major water strike was only recorded 3 times.
  - Only one water strike (in borehole BSG-B12) was noted to be deeper than the No. 2 coal seam floor.
  - The large variation in yields is typical of fractured hard rock aquifers.

5.2.3 Aquifer Porosity

The porosity within the study area will be variable as a function of:

- the composition of the host rock
- the weathering status of the host rock
- areas where open cast mining had taken place
- nature of surface subsidence for undermined areas

To date no tests were performed in this specific area to quantify the aquifer porosity. However, based upon porosity tests done previously on borehole cores, by JMA, the estimated ranges for porosity values in the shallow weathered zone aquifer and the deeper zone aquifer, are given in TABLE 5.2.3(A).

TABLE 5.2.3(A)
Ranges for Porosity (%)

Aquifer zone	Minimum	Maximum
Shallow weathered zone aquifer	5%	10%
Deeper aquifer	1%	5%
Rehabilitated open cast areas	20%	35%

The porosity values for rehabilitated open cast areas, are influenced by the sorting and the bulking factor of the spoils, as well as to what extent the spoils were compacted.

5.2.4 Aquifer Storativity

Aquifer storativity is a function of porosity, more correctly the "drainable porosity", which is a defined as the volume of water that can be drained from a unit volume of rock under a unit gradient. The proposed aquifer storativity values, obtained from literature and from JMA experience in similar geological/geohydrological settings, are given in TABLE 5.2.4(A).

TABLE 5.2.4(A)
Ranges for Storativity

Aquifer zone	Minimum	Maximum
Shallow weathered zone aquifer	0.05	0.10
Deeper aquifer	0.01	0.05
Rehabilitated open cast areas	0.20	0.30

5.2.5 Aquifer Recharge

The volume of rainfall that can potentially recharge to the aquifer, is mainly a function of:

- topographic gradient
- degree of surface subsidence
- rainfall distribution and intensity
- soil characteristics, including compaction
- vegetative cover
- aquifer type

It is realistic to assume that the annual rainfall recharge to the shallow weathered zone aquifer, will be in the order of the values given in TABLE 5.2.5(A).

TABLE 5.2.4(A)
Ranges for Recharge (% of MAP)

Surface condition	Minimum	Maximum	Average
Undisturbed areas	2%	4%	3%
Rehabilitated areas	10%	20%	15%
Areas of surface subsidence	10%	90%	50%

A distinction can be made between areas of moderate and severe surface subsidence. JMA submits that the best method to optimize the recharge on areas of surface subsidence would be through application of the inverse approach, during compilation and simulation of the water balance.

5.2.6 Ground Water Flow/Seepage Flow

An assessment of ground water flow patterns within especially the shallow weathered zone aquifer, is of critical importance. The main ground water pollution migration mechanism relates to convection, implying that ground water flow will be the primary governing parameter for pollutant migration and pollution plume formation.

The ground water flow direction map attached as FIGURE 12 - APPENDIX I, indicates the direction of ground water flow and was compiled subject to the following:

- observed ground water level elevations in boreholes
- flooding status of the underground mines

- using the Bayesian approach which relates ground water level elevation to topography
- taking cognizance of the effect of:
  - infiltration from discard dumps
  - drainage into the underground mine workings
  - possible vertical hydraulic pressure from the underground workings
- observations made throughout this report, relating to:
  - the Blesbokspruit will act as a discharge boundary
  - surface water divides will act as ground water no-flow boundaries
  - no indication could be found that dyke contacts in the area act as preferential flow zones
  - hydro-chemistry results as discussed in **section 5.3.**

In summary, the general ground water flow directions, are largely topographically controlled and are:

- from south to north
- towards the Blesbokspruit stream
- towards the east in the case of the B11J catchment
- away from the surface catchment boundaries

With specific reference to the seepage occurrences, the ground water flow patterns support the localities of seepage.

5.3 Hydro-Chemical Aquifer Description

Ground water and mine water hydro-chemistry data was gathered during the current study, while surface water hydro-chemistry has been monitored by DWAF on a continuous basis since 1994. The available data was used to assess:

- the current quality status of the mine water
- the current quality status of the ground water in the neighboring aquifer
- the ground water hydraulics of the aquifer
- the current and future impacts of the underground and open cast mines on the Blesbokspruit

5.3.1 Current Mine Water and Ground Water Quality Status

The hydro-chemistry data generated from boreholes during the geohydrological investigation, representing both mine water and ground water, is attached as APPENDIX III. The results contained in this APPENDIX represent compliance reports, evaluated against the SA Drinking Water Standard.

The following FIGURES, attached as APPENDIX I, were compiled from the data:

- FIGURE 13: Current pH values observed at monitoring boreholes.
- FIGURE 14: Current EC values observed at monitoring boreholes (*mS/m*).
- FIGURE 15: Current SO_4 concentrations observed at monitoring boreholes (*mg/l*).
- FIGURE 16: Current Fe concentrations observed at monitoring boreholes (*mg/l*).
- FIGURE 17: Stiff diagrams of major cations and anions at boreholes, representing all information shown on the Piper diagram.

Hydro-chemical imaging was also performed for the analyzed samples. The resulting Piper and Durov diagrams, are attached as APPENDIX VII.

Perusal of the compliance reports and the maps depicted in FIGURES 13 to 16, indicate the following:

- A general exceedence of maximum acceptable values in terms of the SA Drinking Water Standard, for pH, EC, Ca, SO_4, F, Fe and Mn, is obvious in both the mine water and ground water.

- It is suspected that other heavy metals, that have not been analyzed for, are also in solution at elevated concentrations, at the low pH levels.

- Whereas the attenuation effect is obvious for the pH, EC and SO_4 data, it is not the case for Fe, suggesting that Fe should not be used in assessing the extent of the ground water pollution plumes.

The stiff diagrams, shown at borehole localities in FIGURE 17 - APPENDIX I, can be used to assess the polluted status of a specific borehole. A stiff diagram comprise the following:

- The diagram consists of 6 nodes (represented by the *meq/l* of Ca, Mg, Na+K, Cl+NO_3, SO_4 and Total Alkalinity), which are all joined by a continuous line. Three fixed, horizontal axes and one vertical axis, in the center of the diagram, are utilized. Two nodes plot on each horizontal axis - one cation to the left and one anion to the right of the vertical axis in the center. The relative plot positions of nodes vary as a distance from the vertical center axis, depending on its concentration in *meq/l*.

- Similar to Piper diagrams, the cations, *meq/l*, are shown on the left:

Parameter	Plot axis on Piper, cation triangle (left triangle)	Plot position in Stiff diagram (left halve of diagram)
Ca	Bottom-left	Bottom
Mg	Top	Center
Na+K	Bottom-right	Top

- And similar to Piper diagrams, the anions, *meq/l*, are shown on the right:

Parameter	Plot axis on Piper, anion triangle (right triangle)	Plot position in Stiff diagram (right halve of diagram)
$Cl + NO_3$	Bottom-right	Bottom
SO_4	Top	Center
T.Alk	Bottom-left	Top

Note that all stiff diagrams have a predefined height, but vary in terms of their width to the left and the right.

- The diagrams should be viewed together with the hydro-chemical images attached as APPENDIX VII. In a Piper diagram, the relative plot positions are shown in relation to each other. However, the total salt concentrations are not indicated. On the other hand, the stiff diagram indicates the total salt concentration by virtue of its area.

- Stiff diagrams provide an easy way to visualize the extent of the pollution in the aquifer, as the shape of the diagram is an indication of the type of pollution. Polluted and unpolluted ground water types are easily observed:

  - The highest TDS concentrations (polluted ground water) are indicated by the stiff diagrams that cover the biggest area, the reason being that higher cation and anion concentrations increase the size of a specific diagram to the left and right respectively.
  - Similarly, unpolluted ground water is indicated by "thin" stiff diagrams.

– The macro chemistry elements which are dominant, are easily observed, especially SO_4, which is indicative of the degree to which different boreholes are polluted.

Assessment of the Piper and Durov plots, yielded the following relevant observations:

- The hydro-chemical image observed for the mine water, clearly indicate Ca as the dominant cation and SO_4 as the dominant anion.
- Interestingly, only four of the six boreholes which intersected pillars in the mine, also shown this hydro-chemical image. The two holes with different hydro-chemical images, are, however, located in pillars present in areas where extensive flooding is not observed.
- The varying images observed for the ground water plume monitoring boreholes, can be explained in terms of borehole localities relative to sources of mine water pollution, as well as the observed ground water flow patterns.

5.3.2 Interpretation of Ground Water Hydraulics/Dynamics using Hydro-chemistry

Using the information attached in APPENDIX III (Hydro-chemistry Compliance Reports), APPENDIX I (FIGURES 13 to17), APPENDIX VII (Hydro-chemical Imaging), and with reference to the discussion of the physical and hydraulic aquifer characteristics, the following can be stated:

- The difference in ground water qualities observed in boreholes close to, and further away from seepage areas, confirm that migration of contaminated ground water is mainly occurring in the areas where seepage is observed. This is confirmed, both hydro-chemically and hydraulically, as ground water on the periphery of the seepage zones are less polluted than in the seepage areas, as is clearly illustrated by the stiff diagrams in FIGURE 17 - APPENDIX I.
- Ground water qualities improve with distance from the old mine workings. This is attributable to attenuation due to dilution, a phenomenon inherent to ground water pollution plume dynamics.

- Unpolluted boreholes outside the mining perimeter, can be explained in terms of the observed ground water flow directions, and their distance from and relative locality to, the flooded mining sections.

- The only dolerite dyke observed in the area, which is situated in the Uitspan and Tavistok areas, does not appear to have an effect on the water quality distribution, and therefore the hydraulics in the area.

- Four sets of boreholes were drilled to assess the pollutant migration routes away from the mining areas and specifically to understand the ground water hydraulics governing the seepage areas:

  - In a north-easterly direction away from Middelburg Steam Coal Colliery, three boreholes were drilled. The boreholes situated closest and furthest away from the mine, are unpolluted, whilst the intermediate borehole indicate some pollution. This intermediate borehole has a significantly higher hydraulic conductivity compared to the other two, suggesting its location on a possible preferential flow path.
  - In a north-easterly direction away from Station Colliery, seven boreholes were drilled. Because of the polluted seepage water flowing on surface, no clear trend can be explained..
  - In a westerly direction away from Tavistock Colliery, four boreholes were drilled. Because of the polluted seepage water flowing on surface, no clear trend can be explained.
  - In an easterly direction away from Uitspan Colliery, three boreholes were drilled. A definite improving trend is observed in the direction away from Uitspan Colliery - attenuation phenomenon.

6. GEOHYDROLOGICAL IMPACT ASSESSMENT

During performance of geohydrolgical impact assessments, two overriding components are addressed generically:

- What impact does the activity have on the availability of ground water/surface water in the catchment.

- What impact does the activity have on the quality of ground water/surface water in the catchment.

However, subject to the terms of reference of this study, the impact assessment to be performed will focus primarily on the quality related aspects, and the water balance governing the migration and discharge of pollutants into the Blesbokspruit.

In the following sections, the relevant impact components will be discussed synoptically, with specific reference to their extent of manifestation as well as their migration and discharge mechanisms. The components of the governing water balance will be discussed while an attempt will be made to quantify the input and output components of the water balance.

6.1 Identification of Relevant Impact Components

The following impact components have been identified as applicable to this specific study:

- Water quality deterioration within the abandoned mines.
- Formation of ground water pollution plumes.
- Ground water base flow interaction of these plumes directly with the Blesbokspruit.
- Surface seepage of polluted water emanating from the mines, into the Blesbokspruit.

6.2 Description of Impacts

6.2.1 Water Quality Deterioration in Mines

The extent of water quality deterioration within the abandoned mines in the study area, has been discussed in section 5.3.1

Water quality deterioration in the defunct mines in the Blesbokspruit is a natural process. Triggered by the availability of oxygen (higher oxygen levels is possible in areas of surface subsidence), pyrite oxidation takes place. As a result, sulphuric acid and dissolved ferric and ferrous salts are produced. The process is catalyzed by microbial action. Currently the water quality in all the Blesbokspruit mines show very low pH levels (2,3 to 4,2) and very high SO_4 and Fe concentrations, see FIGURES 13 to 16 - APPENDIX I.

The water quality deterioration in the mines manifest as the following related impacts:

- Ground water pollution plumes.
- Ground water base flow into the Blesbokspruit.
- Surface seepage into the Blesbokspruit.

6.2.2 Formation of Ground Water Pollution Plumes

Ground water plumes establish as a result of pollutant migration through the ground water regime, which primarily occurs as a result of convection (dispersion and diffusion play minor roles in this instance). The direction and velocity of ground water flow will therefore determine the lateral extent of pollution plumes, and the rate of movement of pollutants within these plumes, respectively.

The following parameters discussed in section 5. of this report will therefore govern the formation and extent of ground water pollution plumes in the Blesbokspruit catchment:

- hydraulic gradients (determined by mine flooding levels and ground water levels)
- hydraulic conductivity values
- porosity values

Using the quantitative information pertaining to the above, as discussed in section 5., the extent of the ground water pollution plume(s), as originating from the abandoned mines in the Blesbokspruit catchment, is shown on FIGURE 1 - APPENDIX IX.

It should be stated that the front perimeter of the plume(s) was not verified with ground water quality data, as no boreholes were drilled to specifically investigate the front extent of the plume(s), in areas not affected by surface seepage. However, in the areas of surface seepage, quantitative ground water quality information was generated, and used to verify the extent of the plume(s).

6.2.3 Ground Water Base Flow into the Blesbokspruit

The zones of polluted and un-polluted base flow interaction with the Blesbokspruit, are indicated on FIGURE 1 - APPENDIX IX. Of specific importance is the total volume of, both polluted and unpolluted ground water base flow, that contribute to the flow at the downstream monitoring weir B1H032.

Base flow from shallow weathered zone aquifers into surface streams is a well known phenomenon. The actual flux volumes can be quantified, using the following parameters quantified in section 5. of this report:

- ground water gradient
- hydraulic conductivity
- flux face area - depth of weathering * length of base flow zone

6.2.4 Surface Seepage into the Blesbokspruit

Significant surface seepage of AMD originating from the abandoned mines in the Blesbokspruit catchment, occurs at three seepage spots (the two spots north-east of Station Colliery, are actually one seepage occurrence).

The three seepage spots will be referred to as:

- north-east of Station Colliery
- west of Tavistock Colliery
- east of Uitspan Colliery - into eastern catchment

A fourth area, north-east of Middelburg Steam Coal Colliery was also investigated.

The surface seepage of AMD into the Blesbokspruit catchment, occurring at the first two seepage spots listed, is measured at 3 monitoring weirs (Weir-11, Weir-12 and Weir-13).

JMA submits that the seepage is controlled by the following mechanisms:

- surface topography
- No.2 seam coal floor elevation
- coal seam and coal seam contacts.
- hydraulic conductivity of the aquifer, including areas of high hydraulic conductivity as a result of open cast mining.
- flooding status of the different mines.

In order to investigate the seepage mechanisms, a number of boreholes were drilled to investigate the physical and hydraulic characteristics of the shallow weathered zone aquifer in the four areas listed above. The data generated was used to compile 6 geohydrological cross sections. A map indicating the localities of the cross section lines, is attached as FIGURE 1 in APPENIDIX VI. The actual cross sections are also attached in APPENDIX VI (Cross sections A-A' through F-F').

The following comments have relevance:

- Cross section A-A', clearly illustrate the influence of the following controlling mechanisms on the seepage observed at the seepage spot north-east of Station Colliery, and also why no seepage is currently observed to the west from Tavistock colliery along the upper reaches of the Blesbokspruit:

- flooding status of the mines
- No.2 seam floor elevation distribution
- coal seam and coal seam contacts
- topography
- open-cast mining

- Cross section B-B' indicates why seepage is not observed to the north-east of Middelburg Steam Coal Colliery:

  - The No.2 coal seam pinches out completely between the perimeter of the mine and the Blesbokspruit.
  - The weathering depth profile is shallower than the No.2 coal seam horizon.
  - A ground water gradient exists towards the mine from borehole BSG-B8, thus implying that ground water is entering the mine through its north-eastern perimeter.
  - The ground water quality information suggests that some preferential flow do exist towards borehole BSG-B9, where the No.2 coal seam was intersected again. It is possible that the No.2 seam do continue and that borehole BSG-B8 was just drilled beyond the sub-outcrop.

- Cross section C-C' illustrates the situation at the seepage spot to the west of Tavistock Colliery:

  - Although the No.2 coal seam pinches out, the seepage appears to be associated with this horizon - possibly on the coal seam outcrop.
  - The weathering profile observed in the area, suggests that a significant contaminated base flow component could enter the Blesbokspruit as ground water seepage, additional to the observed surface seepage
  - The mine is not flooded to a high level. Should the water level in the mine increase, a significant increase in seepage can be expected.

- Cross section D-D' illustrates the situation at the seepage to the east of Uitspan Colliery:

  - The seepage is obviously related to the flooding in Tavistock and Uitspan Collieries and the No.2 coal seam horizon. The backfilling of the mini-pit from which fringe coal was mined, resulted in an enhanced permeability, and created ideal conditions for decant of ground/mine water at this point.

- The weathering depth profile is shallower than the No.2 coal seam horizon.

- Cross section E-E' illustrates the situation to the north-east of Station Colliery, across the Blesbokspruit, towards the seepage spot to the west of Tavistock Colliery:

  - The extensive seepage observed in the area north-east of Station Colliery appears to be related to decant from the rehabilitated open pit, as well as migration on the No.2 coal seam horizon.
  - Furthermore, the weathering profile observed in the area, suggests that a significant contaminated base flow component could enter the Blesbokspruit as ground water seepage, additional to the observed surface seepage.

- Cross section F-F' was generated on the request of DWAF to illustrate the possible correlation of the seepage controlling features on either side of the Blesbokspruit at the seepage area to the west of Tavistock Colliery. Although the geological information was sparse, the following is important:

  - The seepage observed at BSG-B10 is of a good quality and represent un-contaminated seepage, the sub-surface component of which will report to the Blesbokspruit as un-contaminated base flow.
  - Furthermore, the weathering profile observed in the area, suggests that a significant contaminated base flow component could enter the Blesbokspruit as ground water seepage, additional to the observed surface seepage.
  - The ground water levels on either side suggest that the Blesbokspruit will in fact act as a discharge boundary for ground water base flow. Seepage is therefore unlikely to move underneath the river to outcrop on the other side.

6.3 Quantification of Impacts

The impact assessment to be performed, must facilitate quantification of two discharge components of the ground water balance, namely base flow and seepage into the Blesbokspruit, through utilization of an easily measured controlling mechanism, such as e.g. rainfall.

The impact assessment should further facilitate utilization of the water balance model to perform a sensitivity analyses on the various impact components, and should also be able to model various scenarios which may be conceptualized during compilation and design of future remedial/rehabilitation measures.

In order for the impact assessment to fulfill all these requirements, it follows logically that the mechanism which control and influence the impacts, should be understood. The mechanism referred to above, which governs the seepage of surface and ground water in the Blesbokspruit catchment, is the combined mine water/ground water balance. This water balance has different components, all with different attributes (different characteristics and different extent).

The following components of the water balance, are believed to govern the seepage situation at Blesbokspruit:

- Recharge from rainfall on undisturbed areas, including areas that have been well rehabilitated and compacted - gain.
- Recharge from rainfall on areas of moderate subsidence - gain.
- Recharge from rainfall on areas of severe subsidence - gain.
- Recharge from rainfall on areas of rehabilitated open cast mining - gain.
- Lateral ground water flow towards the underground areas - gain.
- Lateral ground water flow away from the flooded underground areas - loss.
- Evapotranspiration from trees - loss.

The in-balance in the 7 components listed above, manifests as the discharge component seepage. A certain percentage of the lateral ground water flow away from the mines, will also join the Blesbokspruit, either as clean or contaminated base flow.

A schematic diagram, depicting the various components of the water balance, is attached FIGURE 2 - APPENDIX IX.

6.3.1 Impact Assessment Methodology

The objective to be obtained is a ground water balance which would balance all the water balance components, to give the resulting seepage and ground water base flow impact on the Blesbokspruit.

In order to solve all the components of the mine water/ground water balance, the following methodology was followed:

- All 5 hydrological units of the Blesbokspruit mines were considered:

  - Uitspan Colliery
  - Tavistock Colliery
  - Old Douglas No.2 Colliery
  - The combination of Middelburg Steam and Coal, Station and Witbank Collieries
  - Coronation Colliery

- Using the accurately quantified aquifer characteristics, all ground water inflow and outflow components were computed.
- Recharge on areas of no subsidence was considered to be in the order of 3% of MAP and not optimized in the water balance.
- The 5 hydrological units were, systematically, evaluated separately in terms of the 7 impact components (4 unknown components and 3 components which were already quantified). This methodology presented itself because not all 7 impact components act on the water balances of all 5 hydrological units. The impact components acting on the different hydrological units, are summarized in TABLE 6.3.1(A).

TABLE 6.3.1(A)
Impact Component Summary

Hydrological unit	Impact components						
	Recharge from rainfall on areas				Lateral ground water flow		Evapotranspiration
	undisturbed	moderate subsidence	severe subsidence	open cast mining	towards the underground areas	away from flooded underground	Evapotranspiration from trees
Uitspan	Yes			Yes		Yes	Yes
Tavistock	Yes	Yes		Yes		Yes	Yes
Old Douglas No.2	Yes	Yes	Yes			Yes	Yes
Middelburg Steam, Station and Witbank	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Coronation	Yes		Yes	Yes		Yes	Yes

- This methodology facilitated compilation of a number of equations and their solution.
- Systematic solving of all the equations, resulted in the unknown impact components being quantified.
- Verification was achieved through application of the solved unknowns to the equations of the other hydrological units.

6.3.2 Data Used

A wealth of quantitative data either existed or was generated during this study, including the following:

- Flow and water quality measurements taken by DWAF at Weirs-11,12 & 13, as well as at weir B1H032.
- Rainfall data obtained from the SA Weather Bureau.
- Newly generated geohydrological information.

Flow measurements

The following TABLE lists seepage volumes as measured at three V-notch weirs (see the location of these weirs on FIGURE 2 - APPENDIX I):

TABLE 6.3.2(A)
Measured Seepage Volumes at Weirs 11,12 & 13

V-notch number	Average flow (m^3/d)	Min-Max flow (m^3/d)	Mines contributing to flow
11 [*]	536	102 - 1141	Middelburg Steam Coal, Station & Witbank
12 [*]	31	3 - 110	
13	30	7 - 107	Tavistok
East of Uitspan fringe coal workings	26 (estimated by JMA)	No continuous measurements are available	Uitspan

[*] The numbers of weirs 11 and 12, have been switched on FIGURE 2 to accommodate a comment by Mr Paul le Roux. Note that weir 11 corresponds to the "old" weir 12 and weir 12 to the "old" weir 11, as used in previous reports and maps.

The average monthly flow measurements are shown on FIGURE 3 - APPENDIX IX. Unfortunately, the monitoring weirs do not measure the total seepage volumes. Based on field observations, and subject to the

estimated average annual evaporative potential, the following adjustment to the measurements are proposed:

TABLE 6.3.2(B)
Adjusted Seepage Volumes at Weirs 11,12 & 13

V-notch number	Average flow: Measured (m^3/d)	Flow Adjustment (%)	Average flow: Adjusted range (m^3/d)	Mines contributing to flow
11	536	2 - 5	546 - 563	Middelburg Steam Coal, Station & Witbank
12	31	10 - 25	34 - 38	
13	30	100 - 150	60 - 75	Tavistok
East of Uitspan	26	10 - 15		Uitspan

The adjusted values are based on less than 20% of the potential rainfall deficit (MAP - MAE), multiplied by the areas of visible seepage or no vegetative growth.

It should be noted that the flows measured at downstream weir B1H032, are more than double the total flow measured at Weirs-11,12 & 13 (see FIGURE 2 - APPENDIX I for the positions of these weirs). The following TABLE summarizes the flow measurements from weir B1H032.

TABLE 6.3.2(C)
Measured Flow Volumes at Weir B1H032

Date	Flow (m^3/d)
Jan 1998	2480
Feb 1998	3960
Mar 1998	1395
Apr 1998	1245
May 1998	1079
Jun 1998	1090
Jul 1998	1208

The current flow from the Uitspan Colliery is estimated at approximately 0,3 *l/s*.

Rainfall/Recharge

Monthly rainfall data, as measured at station 515382, was used. The rainfall data was analysed with a method known as the Cumulative Rainfall Departures (CRD) method to determine how the current flow measurements, which is a function of the ground water levels within the mines, would relate to the measured seepage volumes during wet and dry rainfall cycles. In FIGURE 4 - APPENDIX IX, the flow rates as at Weirs-11,12 & 13 (measured and adjusted), are compared to the CRD.

The excellent correlation is an indication of the hydraulic control that rainfall recharge has on the seepage volumes.

Water quality

Water qualities are measured at Weir B1H032. As can be expected, water quality will improve during times of higher rainfall and deteriorate during low flow periods. The correlation between the EC-values and SO_4-concentrations, as compared to the measured flow at Weirs-11,12 & 13, shown in FIGURE 5 - APPENDIX IX, is an indication of the effective mixing that takes place in the underground mines, also supporting the observed relationship between rainfall and seepage volumes.

Areas

The different areas which have a bearing on the water balance, were calculated and are summarized in TABLE 1 - APPENDIX IX.

Evapotranspiration from the trees

Most trees in the area are either blue-gum or black-wattle. Both are known for their high evapotranspiration potential. This value was optimized as a component of the water balance.

Aquifer hydraulics

All parameters active in Darcy's Law, are believed to have been well defined and quantified (section 5. of this report).

The ground water base flow was computed, using Darcy's law:

$$Q = k * A * i,$$

where k = hydraulic conductivity,
A = the cross-section through which water will flow (weathering depth x length of flow boundary), and
i = hydraulic gradient.

6.3.3 Scenarios

Although the compiled water balance model do facilitate the simulation of various scenarios, scenario modeling falls outside the terms of reference of this report. Suffice to say that once the model has been calibrated, it will support simulation of a large variety of scenarios.

Even at this stage it is possible to use the model to obtain an indication of the relative contribution of the various components of the water balance, which will enable strategic decision taking on matters pertain to rehabilitation/remediation approach, e.g. rehabilitation of open-cast areas, rehabilitation of subsidence areas and/or enhancement of evapotranspiration, etc.

6.3.4 Results

The resulting contributions of the different water balance components were optimized according to the methodology discussed in section 6.3.1. The results obtained are summarized in TABLE 6.3.4(A).

TABLE 6.3.4(A)
Contributions of the Different Water Balance Components
(Expressed as % of MAP)

Water Balance Component	Magnitude	Comment
Recharge from rainfall on undisturbed areas, including areas that have been well rehabilitated and compacted.	3%	A value of 4% is assumed for the compacted/ rehabilitated area at Uitspan Colliery
Recharge from rainfall on areas of moderate subsidence.	8%	This value could be much higher
Recharge from rainfall on areas of severe subsidence.	24%	This value could be much higher
Recharge from rainfall on areas of rehabilitated open cast mining.	15%	Value is well optimized
Lateral ground water flow towards the underground areas.	Flux calculated	Quantified individually using Darcy's law
Lateral ground water flow away from the flooded underground areas.	Flux calculated	Quantified individually using Darcy's law
Evapotranspiration from trees.	Flux calculated	This value used is a first order estimate

With regard to optimization of the various components of the water balance, expressed as percentages of the MAP, the following comments have relevance:

- The average recharge to the water balance, when all the components are added up, calculates to 4 % of the MAP. JMA submits that this appears to be on the low side, especially in view of the fact that the flows observed at weir B1H032, are considerable higher than the cumulative flows at the three weirs 11, 12 & 13.

- The contribution of the areas of moderate and severe subsidence is probably underestimated.

The simulated flow volumes, compared with the measured and adjusted flow volumes, are shown as bar charts on FIGURE 6 - APPENDIX IX.

The following observations have relevance:

- The simulated flows are equal to, or greater than, the observed flows at the three weirs 11, 12 & 13.

- However, the cumulative flows are significantly lower than that observed at weir B1H032, indicating that the full ground water impact is not measured at weirs 11, 12 & 13. The calculated base flows do, however, not cover the deficit, therefore suggesting inefficient capturing of seepage at weirs 11, 12 & 13.

- All this supports the JMA opinion that the average recharge of 4 % of the MAP is an underestimate.

The relative contribution from the different recharge and discharge components of the water balance, are shown on the pie charts attached as FIGURES 7 and 8 - APPENDIX IX, respectively.

With regard to the recharge components (FIGURE 7), the following is important:

- Even if underestimated, the subsidence contribution accounts for more than 60 % of the recharge water balance, clearly indicating the impact of subsidence on the total mine water make.

With regard to the recharge components (FIGURE 7), the following is important:

- Although the evapotranspiration was largely optimized through the inverse approach, its relative contribution to the water balance discharge, is obvious.

A comparison of areas of the different zones/areas contributing to the water balance, is given in TABLE 1 - APPENDIX IX, and depicted graphically on the pie charts in the same TABLE. The following is important:

- Despite the fact that subsidence occurs over less than 35 % of the area, its contribution to the water balance recharge is more than 60 %.

7. GROUND WATER MANAGEMENT MEASURES

Detailed proposals for possible management measures falls outside the scope of the current investigation. However, the following aspects are worthwhile mentioning:

- Open-cast mining and subsequent rehabilitation as a means to management of underground fires, should be done with great circumspection. The seepage observed at some of the rehabilitated open-cast workings, bears testimony to the possible enhancement of decant from the flooded underground sections. Good

compaction of rehabilitated spoils, and possibly even the installment of seals where the open-cast interact with underground workings, should be considered.

- Compartmentalizing of some of the mines which was performed in the past, appears to be effective.

- The results of the water balance modeling indicate that minimization of recharge in the subsidence areas, will carry the most benefit to the seepage discharge situation. This becomes even more significant if the notion that this component was underestimated, is in actual fact true.

- The current water levels in the mines are lower than the optimal levels suggested in an earlier report, for fire control purposes. De-watering of the mines to minimize seepage is seen as a high risk solution.

- Seepage collection systems should be installed at the base of the shallow weathered zone and/or the floor of the No. and No.2 coal seams, whichever is located at the lowest elevation, if they are to be optimally efficient. This implies that topographical considerations will play an important role in the selection of these facilities.

- Minimization of ground water base flow can best be achieved through minimization of flooding levels in the mines, bearing in mind of course that this will enhance to possibility for underground fires.

8. MONITORING PROPOSALS

Calibration of the water balance for the Blesbokspruit catchment is of critical importance. It follows logically that continued monitoring of the measurable components of the water balance must continue on a regular basis:

- Local rainfall measurements must be taken on a daily basis.

- Monitoring of the flows and qualities from weirs 11, 12 and 13 must continue. An effort should be made to make these measurements as representative of the total seepage discharges as possible.

- A monitoring infrastructure must be commissioned to measure the seepage discharge (flow and quality) east of Uitspan Colliery, into the eastern catchment.

- Monitoring of flows and qualities past weir B1H032 must continue.

- AMD flow should be monitored in the Blesbokspruit at the Verena Road bridge immediately downstream from weirs 11 and 12.

- The measuring of ground water levels and water temperatures, in all accessible boreholes, must be done on a monthly basis. Water qualities must be determined on an annual basis. Samples must be analyzed for macro chemistry and selected micro elements to facilitate hydro-chemical imaging. A monitoring field form for ground water monitoring, including a list of water quality variables to be analyzed for, is attached as APPENDIX X.

- A surface survey to map the extent of surface subsidence and tree growth, must be performed on an annual basis.

- All generated data and information should be stored in a structured data base for subsequent assessment and interpretation.

9. CONCLUSIONS

With reference to the stated terms of reference, the following conclusions can be reached:

- Quantitative information on the extent of flooding, as well as the water quality distribution in the underground and rehabilitated open-cast mines in the Blesbokspruit catchment, was generated during the field work phase of this investigation.

- The boreholes drilled outside the perimeters of the mined areas, did not only generate sufficient information to perform a quantitative geohydrological description of the aquifers in the area, but furthermore facilitated a detailed assessment of the physical and hydraulic controls of the seepage occurrences.

- During the study a quantitative water balance model was developed. The development of this model resulted in a fundamental understanding of the components and dynamics of the mine water/ground water balance in the Blesbokspruit catchment. The model could be quantified to such a degree that simulation of the observed flows could be modeled satisfactorily. However, further calibration will be required for the model to be used for management purposes.

- In order to facilitate refinement and calibration of the water balance in the Blesbokspruit catchment, monitoring of the components of the water balance will be necessary. A comprehensive mine water and ground water monitoring infrastructure was commissioned during this investigation and detailed proposals for future monitoring are given in the report.

- It can further be concluded that the results obtained during this investigation, go a long way not only in confirming the contribution of the Blesbokspruit to the Klipspruit water quality situation, but also in creating an understanding of the dynamics of the situation (fluctuations in flow volumes and quality).

- It further clearly demonstrated the available options, and their relative potential efficiency, for management of the situation.

10. RECOMMENDATIONS

In order to optimize the knowledge generated during the study, the following actions are recommended:

- It is recommended that the IWQS update their July 1996 report, N/B 100/RMQ0996 to check the impact of the Brugspruit treatment works on water quality in the Klipspruit so as also to reflect the relative pollution contribution of the Blesbokspruit.

- That the monitoring program as proposed, be implemented as a matter of urgency.

- That, subject to generation of the data as proposed in the monitoring program, the water balance model be calibrated after a 12 month monitoring period.

- That no additional management and/or collection facilities be commissioned, without taking cognizance of the findings of this report, and assessing their potential impact on the mine water/ground water balance in the Blesbokspruit catchment.

- Once the model is calibrated, the available options for remediation should be considered as possible solutions to the problem. A workshop to address this aspect is recommended. Possible options which can be considered for further investigation, are:

  - Additional evapotranspiration
  - Rehabilitation of subsidence
  - Opencast mining of the area
  - Treatment of the water

Respectfully submitted

Jasper L. Muller (Pr.Sci.Nat.)

Louis J. Botha (Pr.Sci.Nat.)

PROJEK/JM1439

APPENDIX I

FIGURES AND TABLES

FIGURE 2

Site layout showing boreholes on DWAF database, V-notch monitoring localities and newly drilled boreholes.

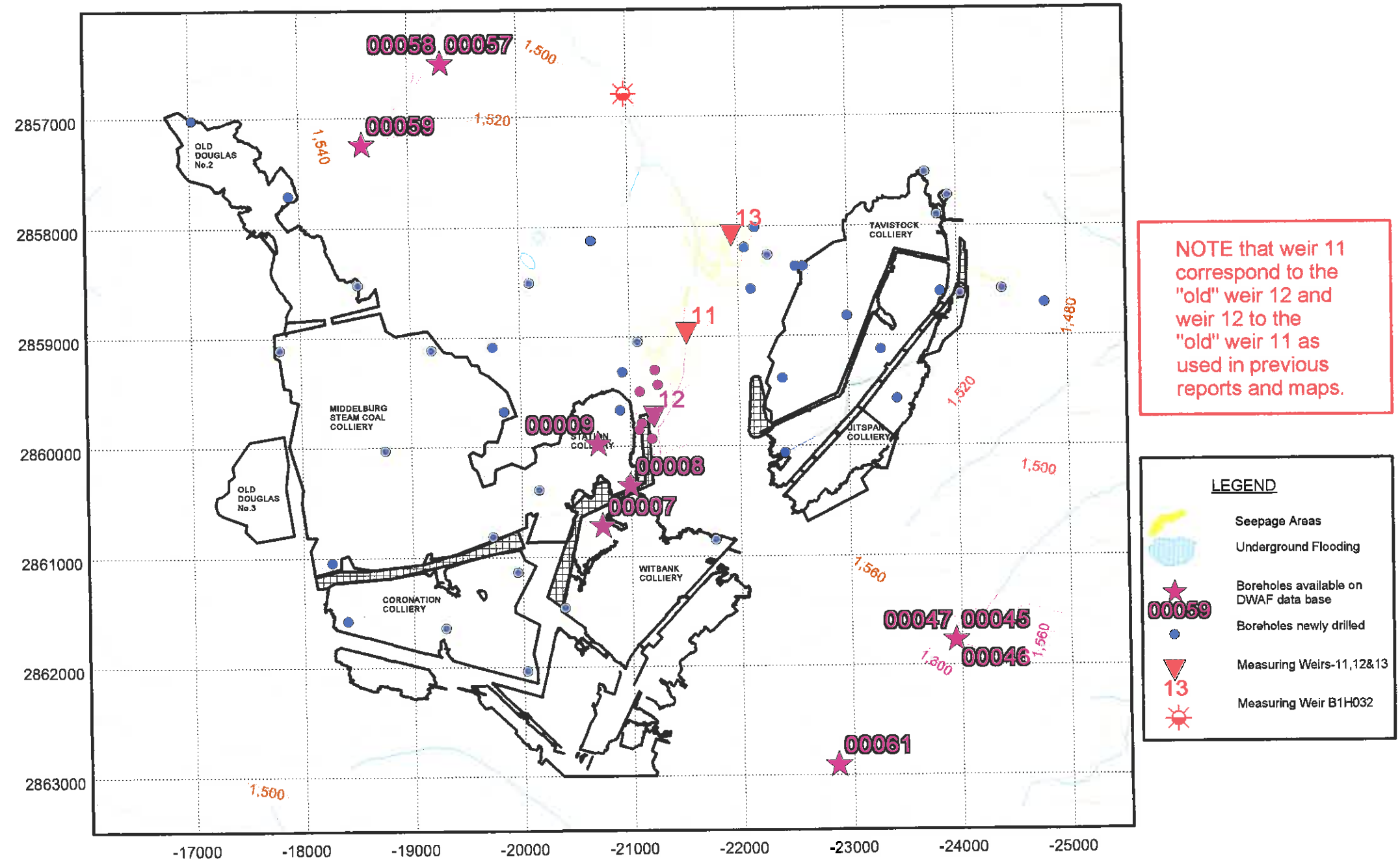


FIGURE 4

Interpreted No 2. Coal floor contours, also showing ground water level elevations (mamsl).

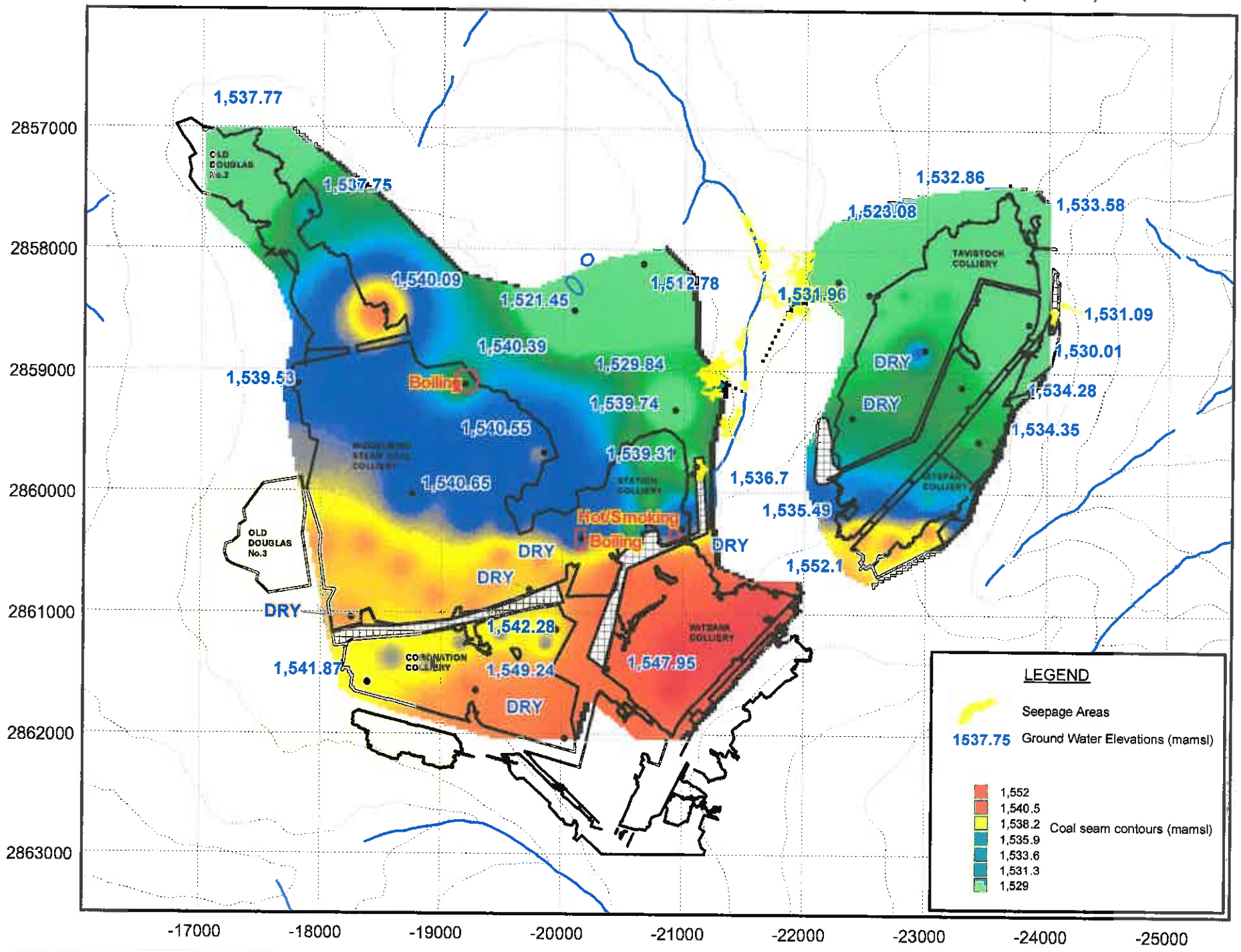


FIGURE 5

Delineation of lateral aquifer boundaries.

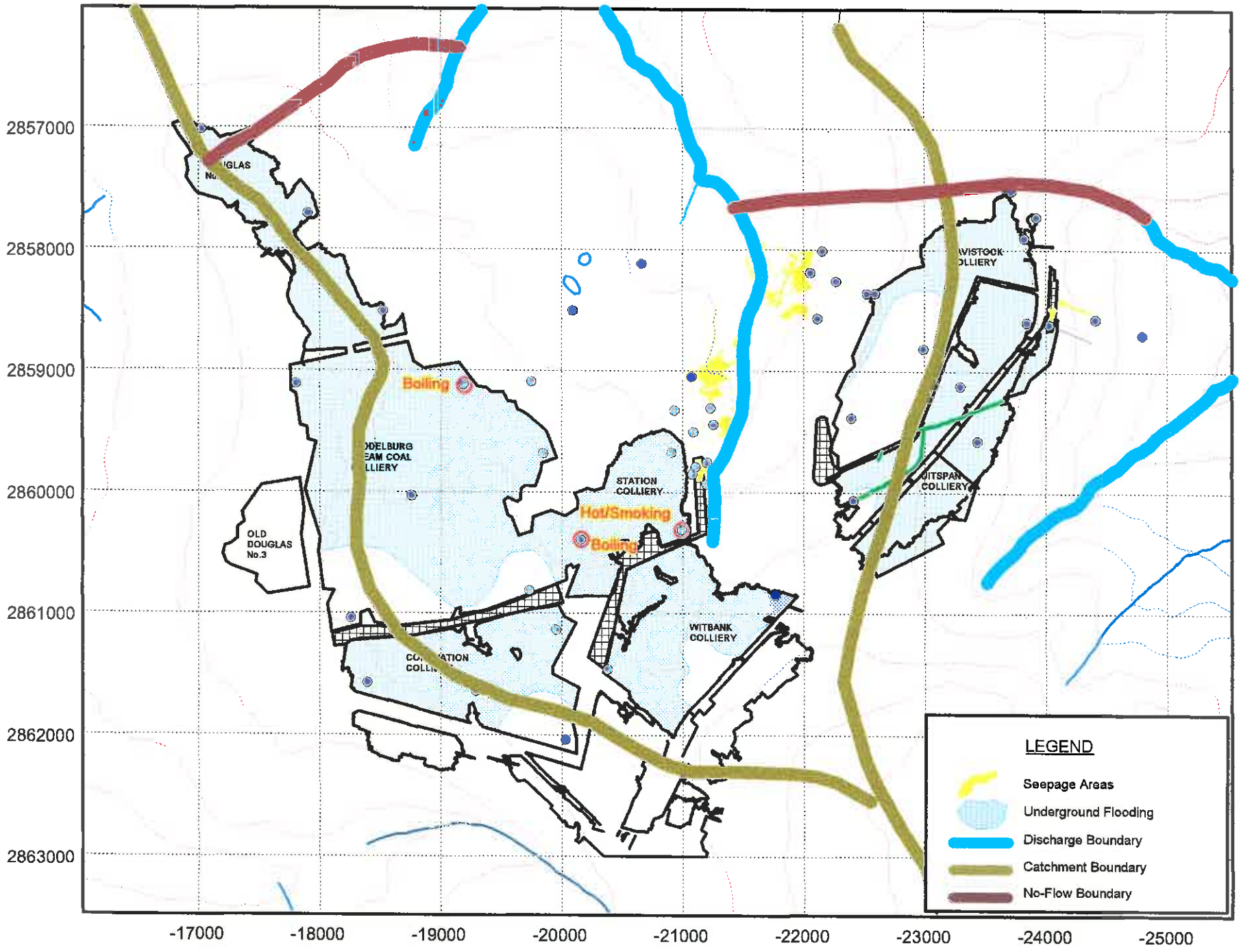


FIGURE 6

Thematic map of depth of weathering as observed from geological borehole logs (m).

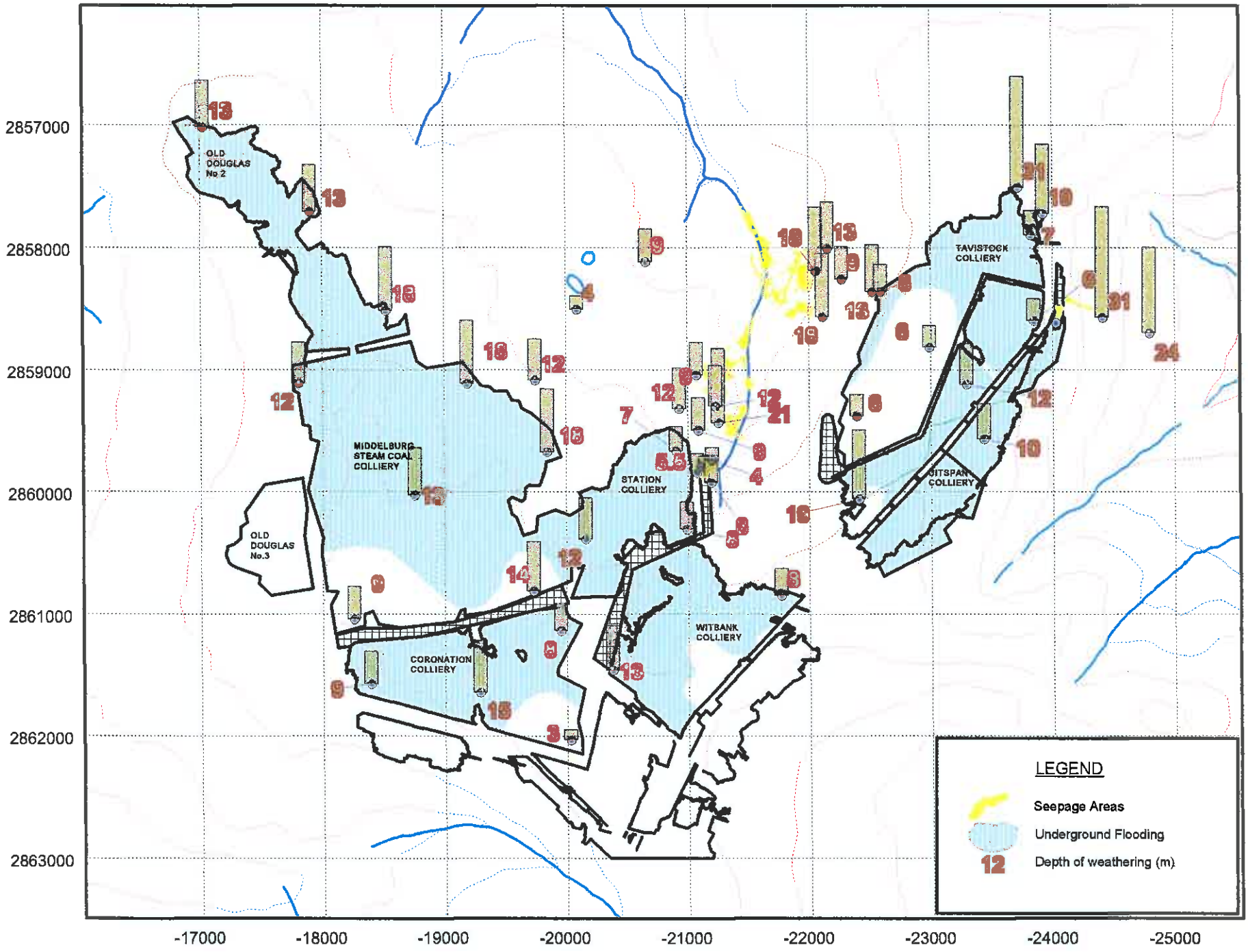


FIGURE 7

Depths to ground water level (m).

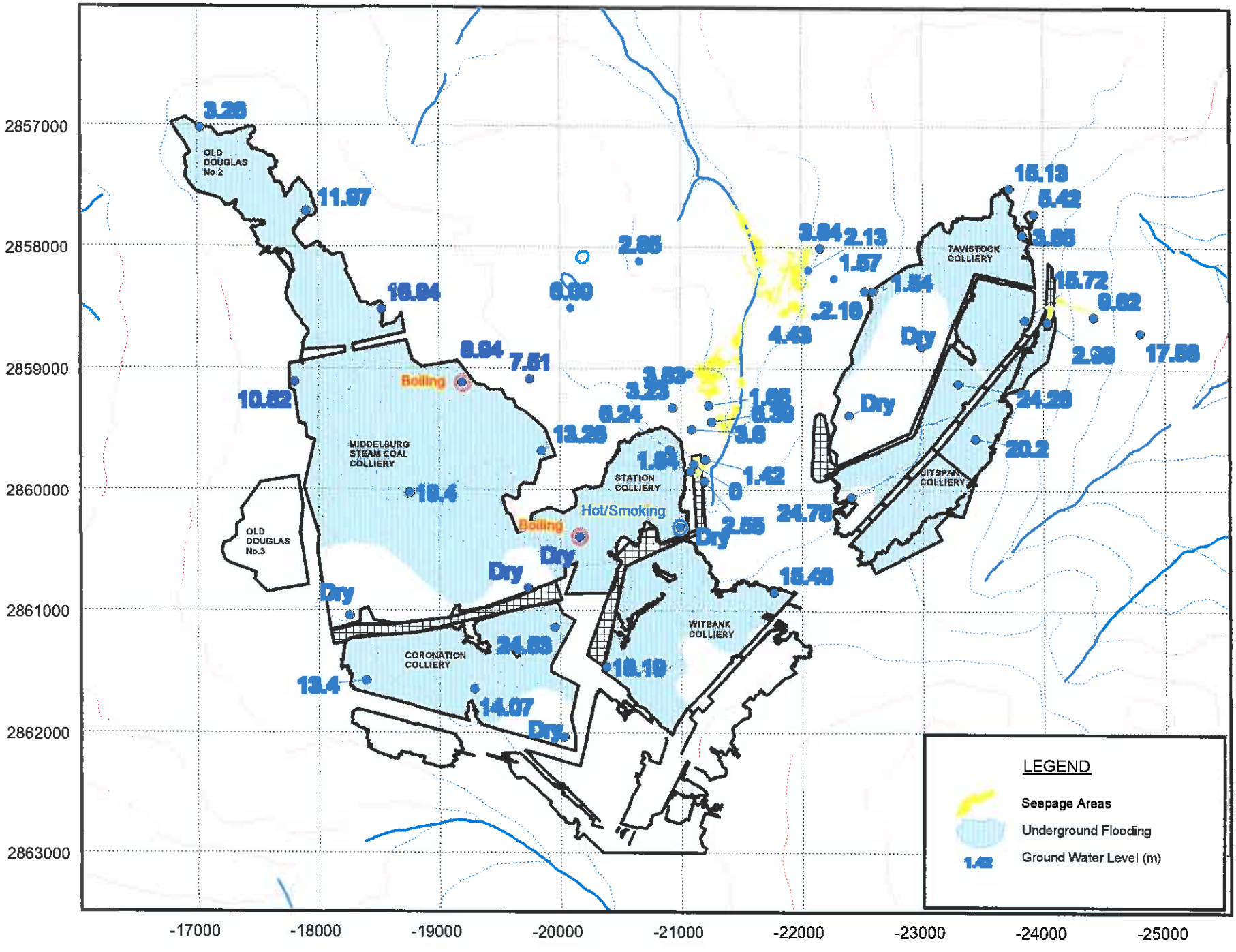


FIGURE 8

Ground water level elevations (mamsl).

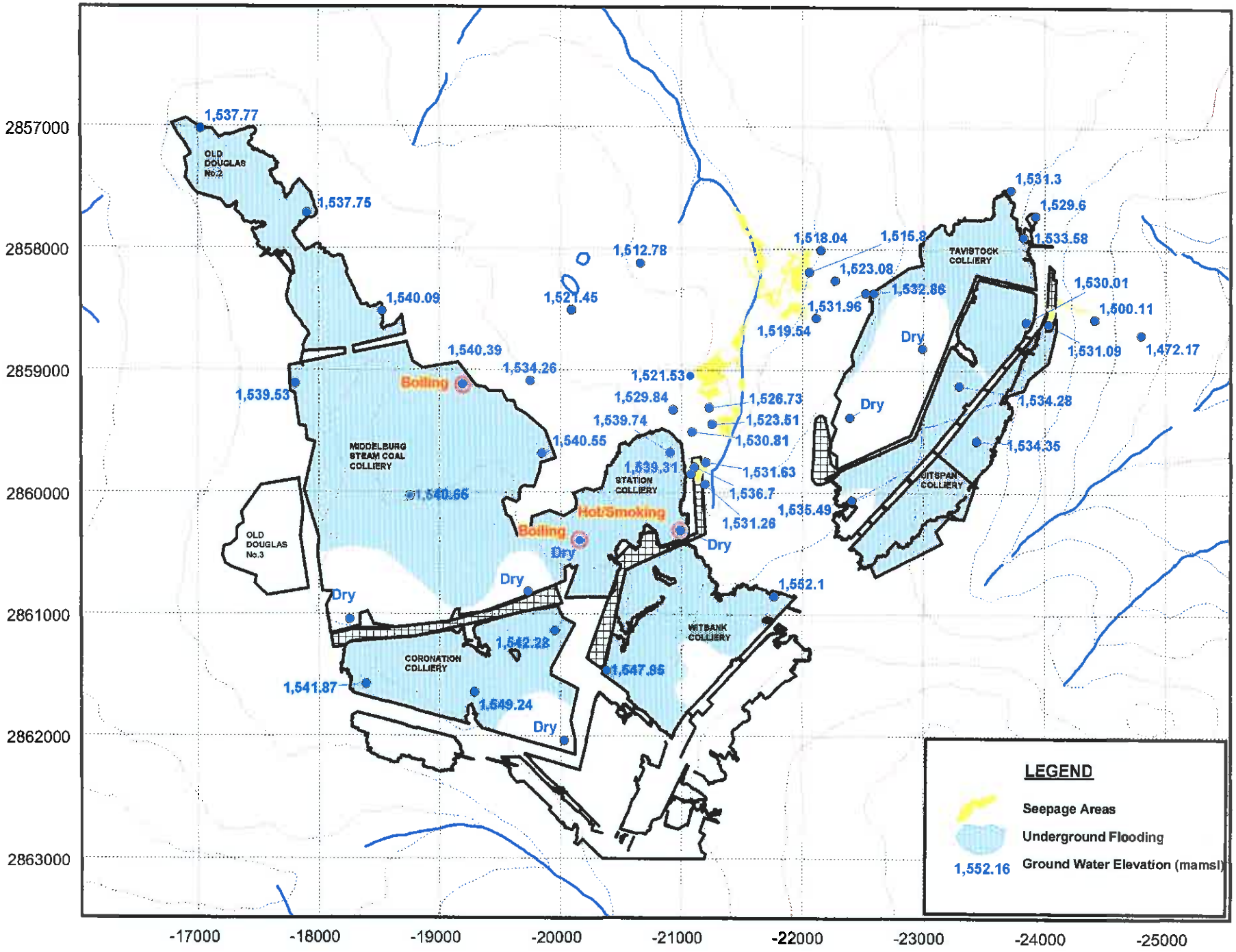


FIGURE 9

Thematic map of Saturation/Flooding status, showing holes that were drilled to the No. 2 coal seam floor (mamsl).

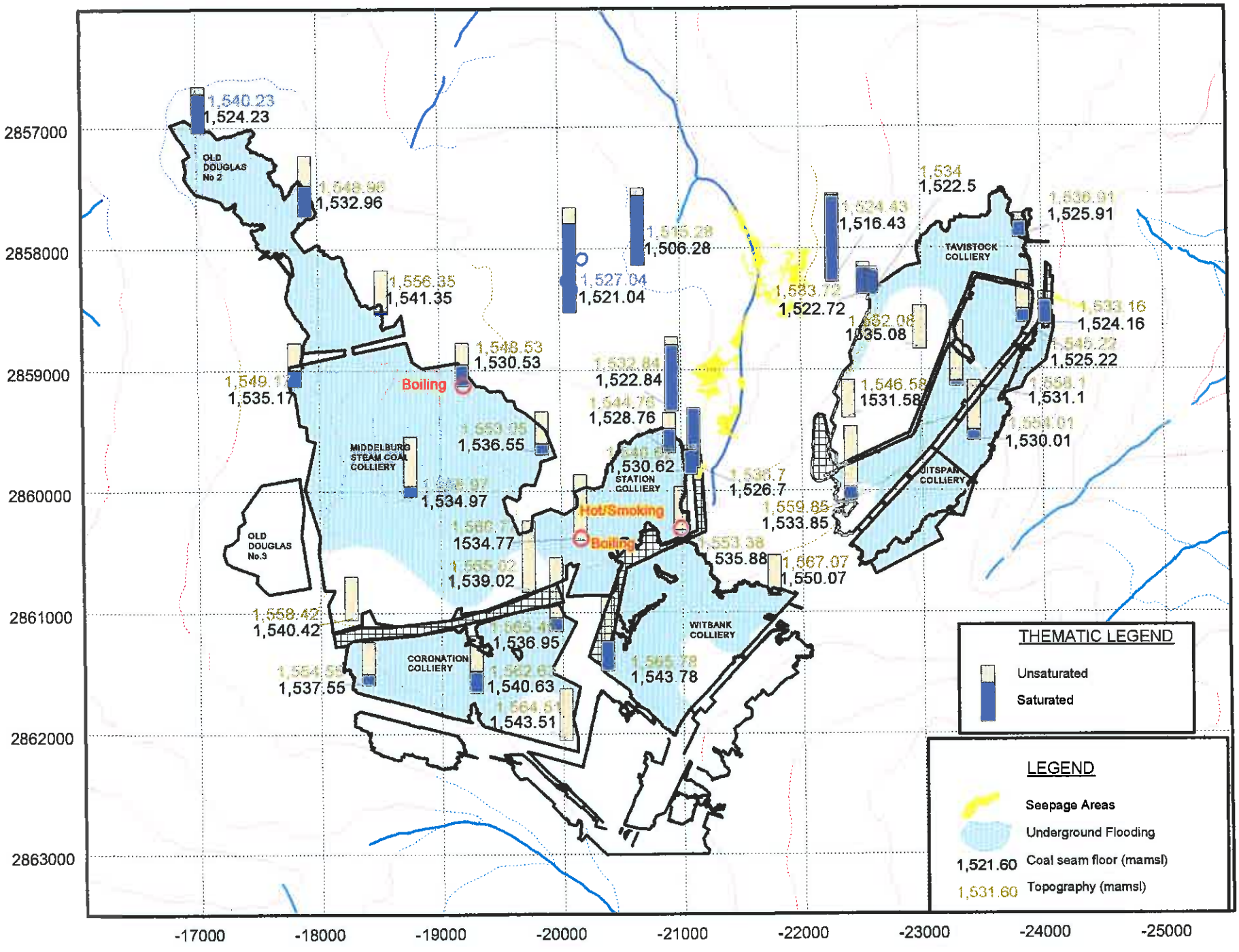


FIGURE 10

Hydraulic conductivity values calculated from slug tests (m/d). Thematic mapping excludes values observed in rehabilitated areas.

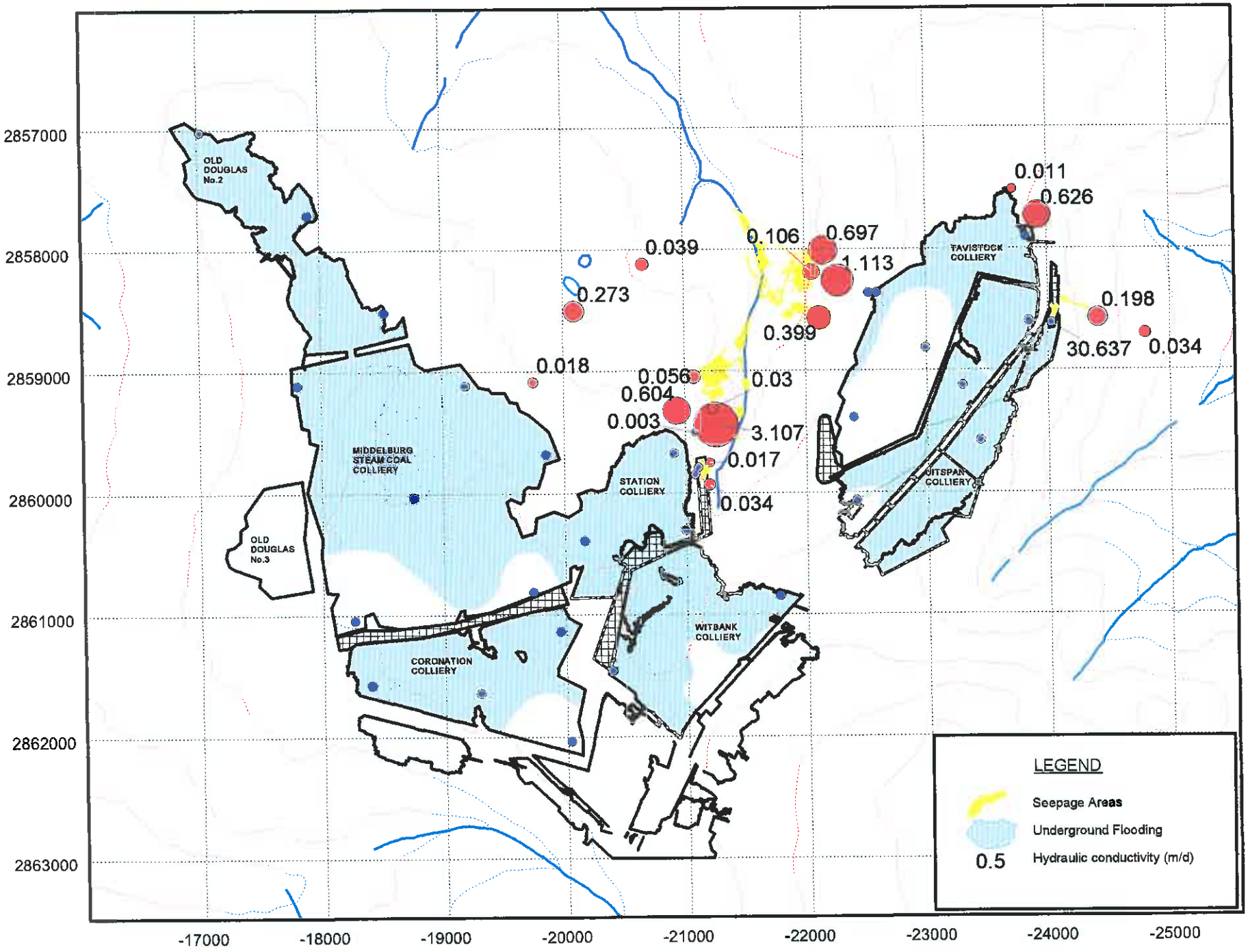


FIGURE 11

Borehole blow yields measured during drilling (l/s). Thematic mapping excludes values observed in rehabilitated or underground areas.

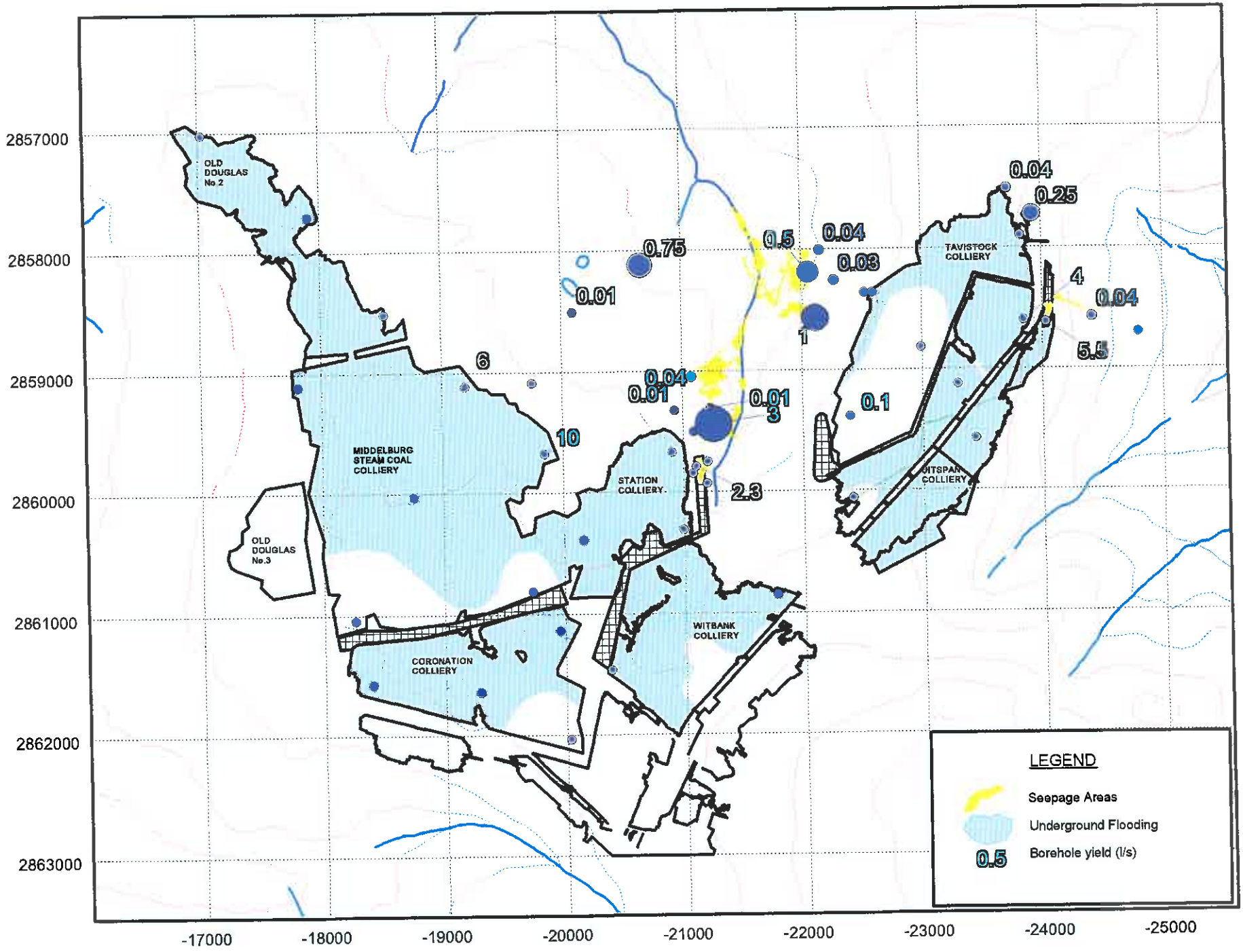


FIGURE 13

Current pH values observed at monitoring boreholes.

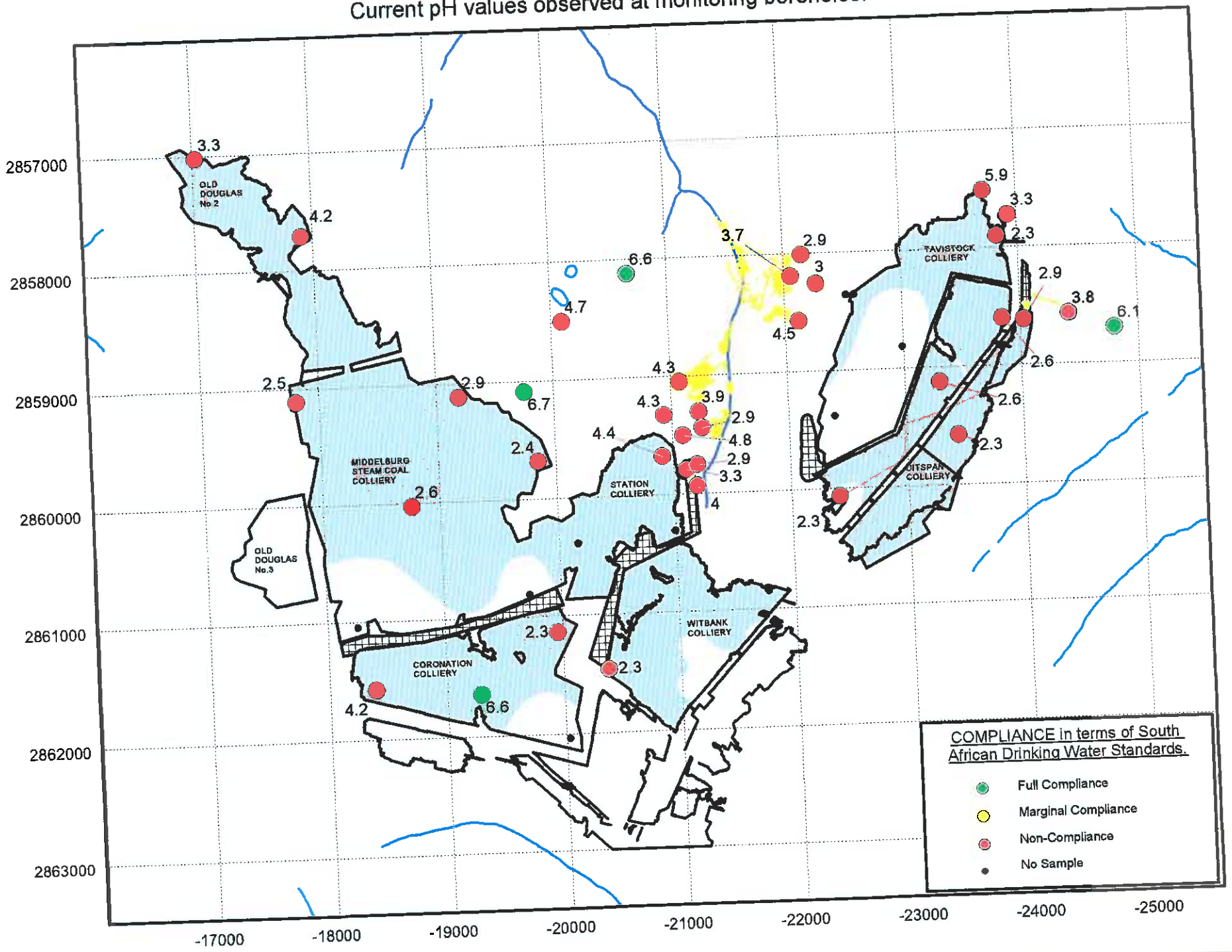
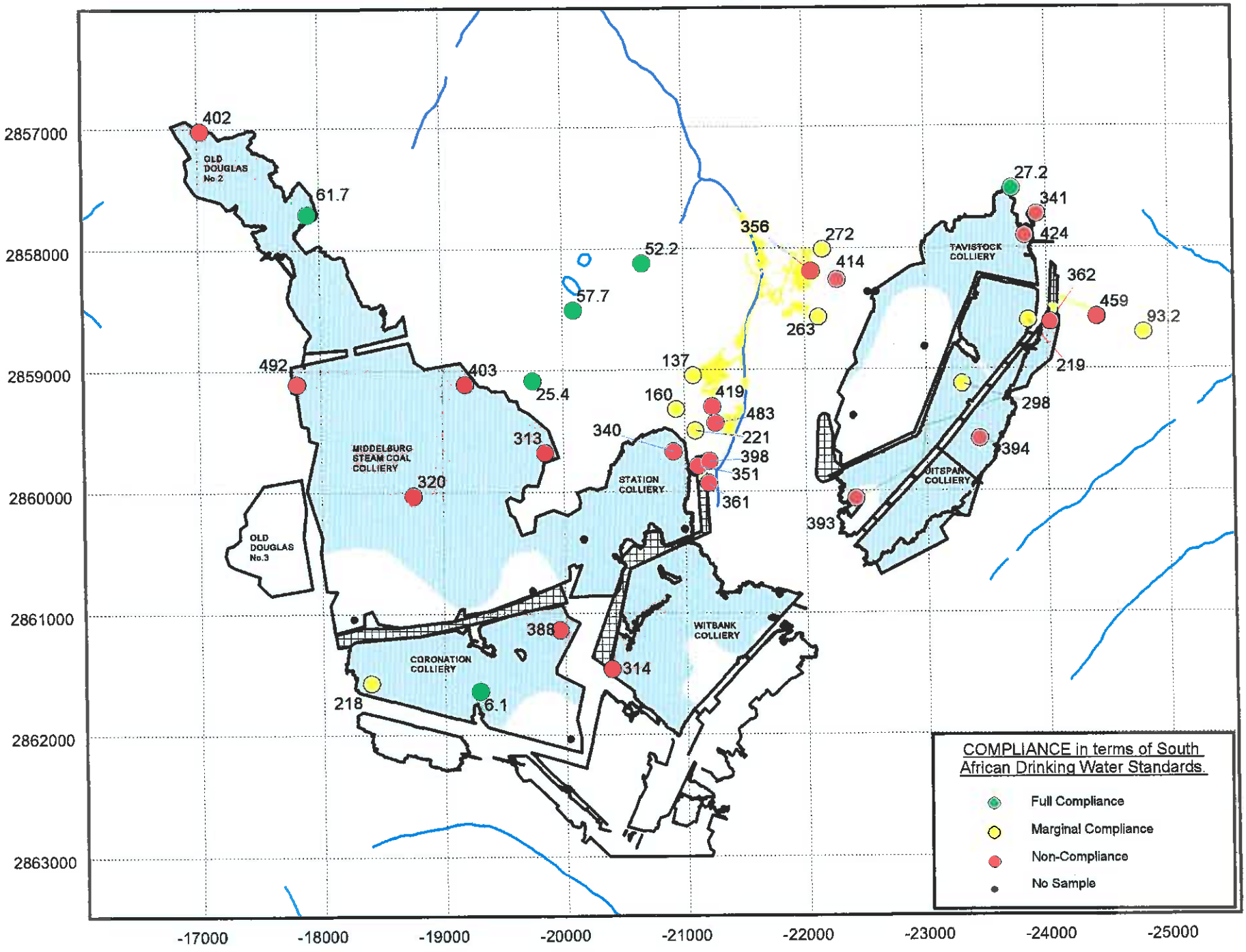


FIGURE 14

Current EC values observed at monitoring boreholes (mS/m).



Site-ID : 2529CC00032 Nr on Map : BSG-UB32

* HydroGraph * Borehole log : DWA BLESBOKSPRUIT

Coordinates : -18255.32 (E-W) 2861042.88 (N-S) 1558.42 (Ground elevation) Date Plotted: Feb 15 1999

m amsl

1558.

1550.

1540.

Geology

Sandstone: reddish brown; very weathered;

Sandstone: fine to medium grained; white; weathered;

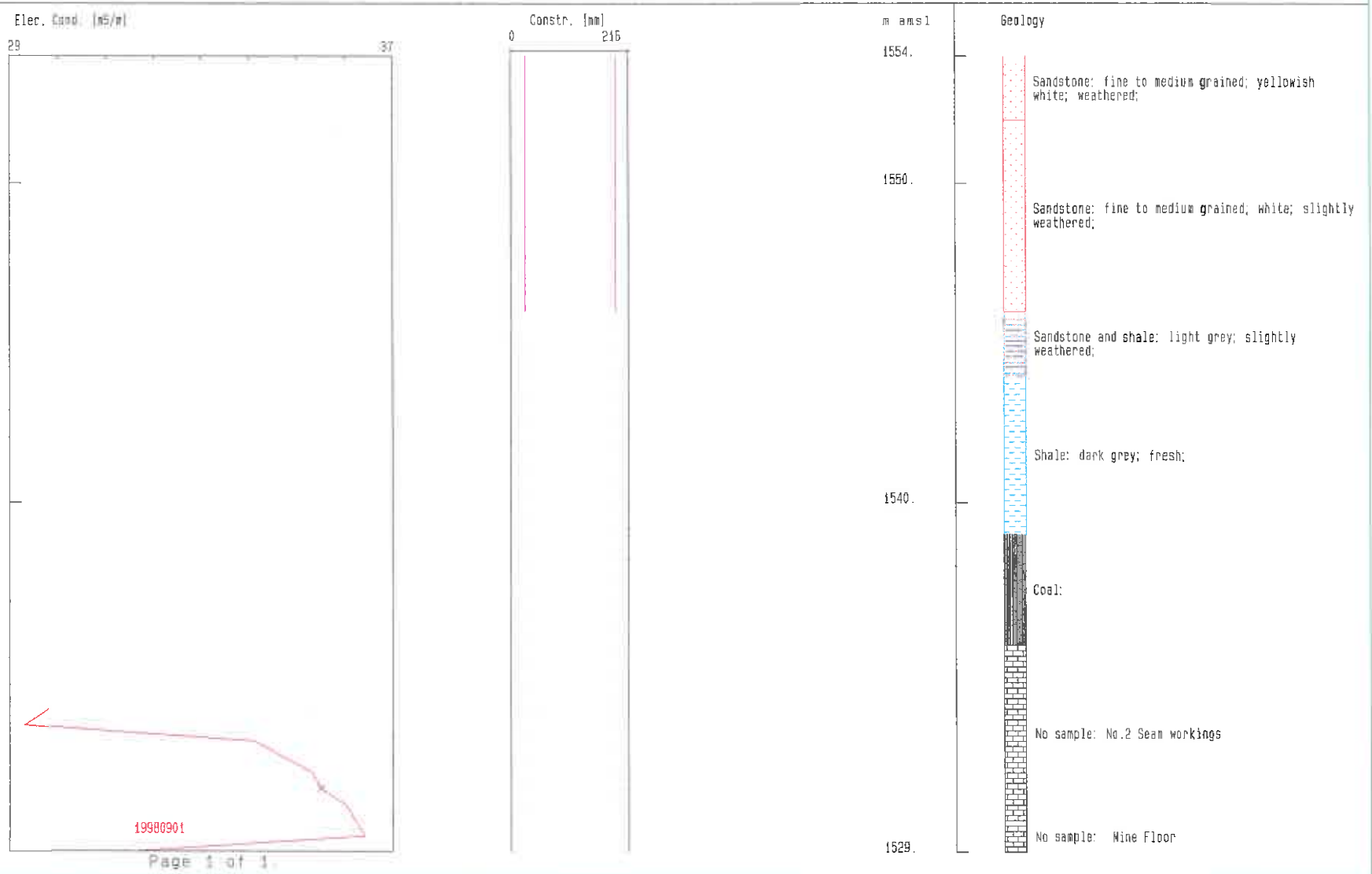
No sample: Caving.

No sample: Caving, No 2 Seam Workings.

Site-ID : 2529CC00045 Nr on Map : BSG-UB45

* HydroGraph * Borehole log : DWA BLESBOKSPRUIT

Coordinates : -23435.31(E-W) 2859573.32(N-S) 1554.01(Ground elevation) Date Plotted: Sep 21 1998



Site name : DWA - BLESBOKSPRUIT : BSG-UB34
Notes :

Site ID: 2529CC00034 Number on map: BSG-UB34

E-W coordinate : -19952.21 N-S coordinate : 2861136.71
Ground Elevation: 1565.45 mamsl Collar Height: 0.68 m
Depth of Casing: 30.00 m Diameter of Hole: 165 mm
Logged by: Date Drilled: 19980729

Depth (m) from	to	Thickness (m)	Description
Geology			
0.00	2.00	2.00	SOIL : reddish brown; very weathered. And sandstone. Slightly moist.
2.00	3.00	1.00	SANDSTONE : coarse grained; yellowish white; very weathered. Slightly moist.
3.00	8.00	5.00	SANDSTONE : fine to medium grained; white; slightly weathered. Moist.
8.00	15.00	7.00	SANDSTONE AND SHALE : light grey; fresh. Dry.
15.00	22.00	7.00	SHALE : dark grey; fresh; carbonaceous. Dry.
22.00	25.00	3.00	COAL : fresh. And carbonaceaous shale.
25.00	28.50	3.50	NO SAMPLE : No.2 Seam workings
28.50	30.00	1.50	NO SAMPLE : Mine Floor.
Geohydrology			
(no information.)			

Site name : DWA - BLESBOKSPRUIT : BSG-UB33
Notes :

Site ID: 2529CC00033
Number on map: BSG-UB33

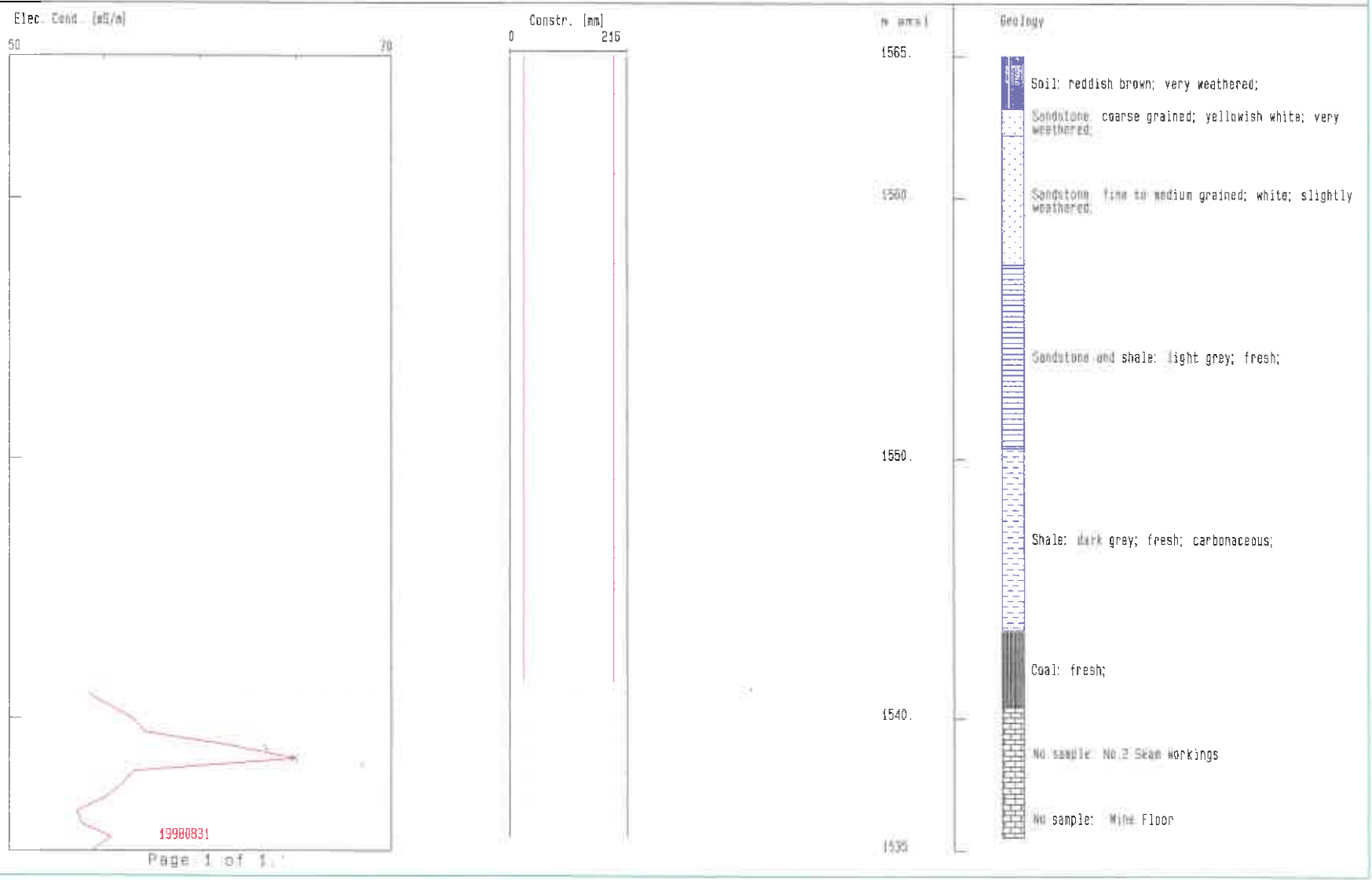
E-W coordinate : -18391.03
N-S coordinate : 2861576.57
Ground Elevation: 1554.55 mamsl
Collar Height: 0.36 m
Depth of Casing: 18.00 m
Diameter of Hole: 165 mm
Logged by:
Date Drilled: 19980728

Depth (m) from	to	Thickness (m)	Description
Geology			
0.00	1.00	1.00	SANDSTONE : reddish brown; very weathered. Dry.
1.00	2.00	1.00	SANDSTONE : coarse grained; white; weathered.
2.00	7.00	5.00	SANDSTONE : coarse grained; reddish brown; weathered. Dry.
7.00	9.00	2.00	SANDSTONE AND SHALE : dark grey; slightly weathered. Dry.
9.00	12.00	3.00	SHALE : dark grey. Dry.
12.00	17.00	5.00	NO SAMPLE : No 2 Seam Workings
17.00	17.50	0.50	NO SAMPLE : Mine floor.
Geohydrology			
(no information.)			

Site-ID : 2529CC00034 Nr on Map : BSG-UB34

* HydroGraph * Borehole log : DWA BLESBOKSPRUIT

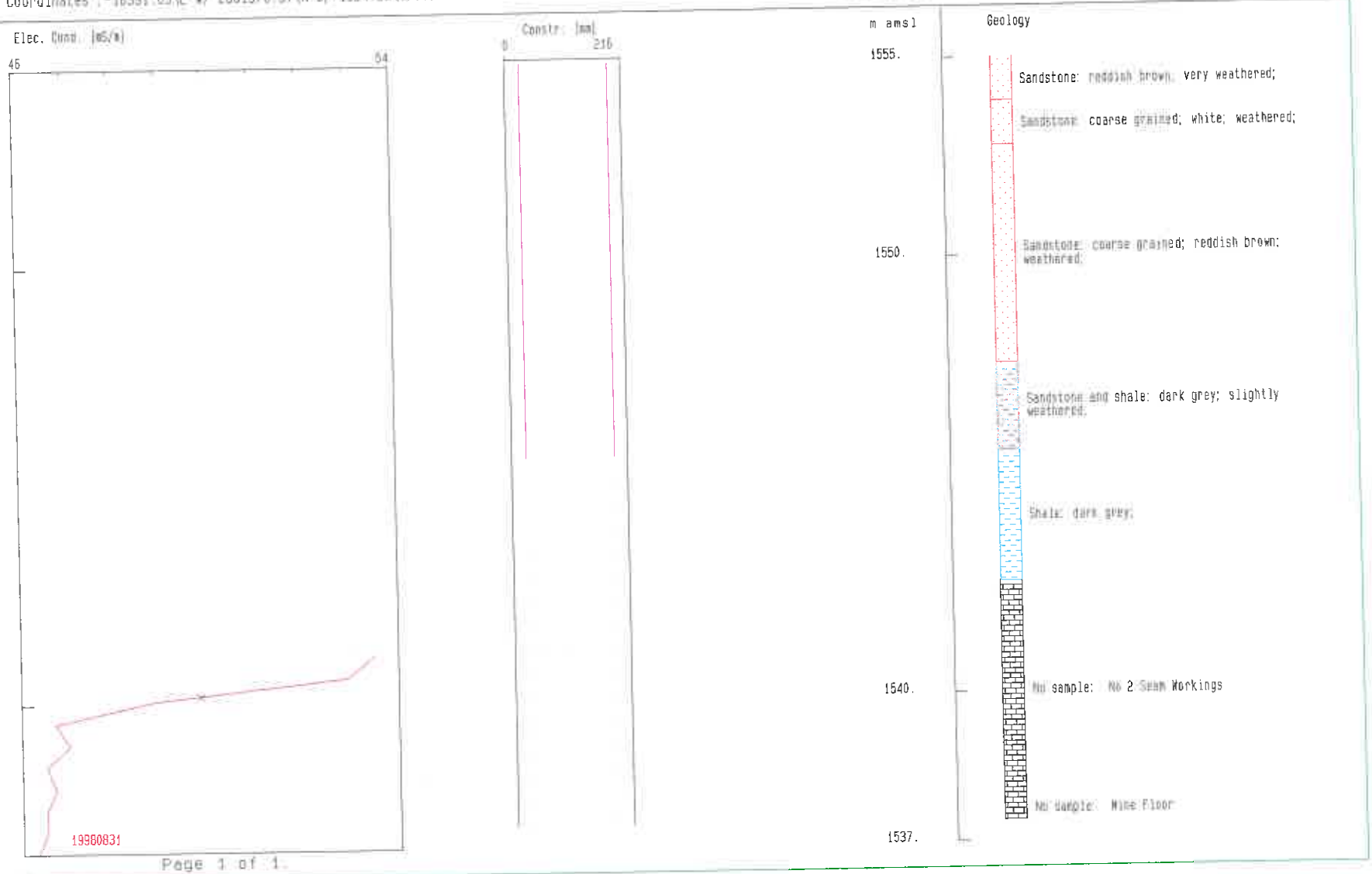
Coordinates :-19952.21 (E-W) 2861135.71 (N-S) 1565.45 (Ground elevation) Date Plotted: Sep 17 1998



Site-ID : 2529CC00033 Nr on Map : BSG-UB33

* HydroGraph * Borehole log : DWA BLESBOKSPRUIT

Coordinates : -18391.03(E-W) 2861576.57(N-S) 1554.55(Ground elevation) Date Plotted: Feb 15 1999



Site name : DWA - BLESBOKSPRUIT : BSG-UB36
Notes :

Site ID: 2529CC00036 Number on map: BSG-UB36

E-W coordinate : -20027.89 N-S coordinate : 2862038.26
Ground Elevation: 1564.51 mamsl Collar Height: 0.47 m
Depth of Casing: 21.00 m Diameter of Hole: 165 mm
Logged by: Date Drilled: 19980728

Depth (m) from	to	Thickness (m)	Description

Geology

0.00	3.00	3.00	SANDSTONE : fine to coarse grained; yellowish white. Dry.
3.00	7.00	4.00	NO SAMPLE : Caving.
7.00	9.00	2.00	SANDSTONE : fine to medium grained; yellowish white; slightly weathered. Dry.
9.00	21.00	12.00	NO SAMPLE : Caving, No 2 Seam Workings.

Geohydrology

(no information.)

Site name : DWA - BLESBOKSPRUIT : BSG-UB32
Notes :

Site ID: 2529CC00032
Number on map: BSG-UB32

E-W coordinate : -18255.32
N-S coordinate : 2861042.88
Ground Elevation: 1558.42 mamsl
Collar Height: 0.42 m
Depth of Casing: 18.00 m
Diameter of Hole: 165 mm
Logged by:
Date Drilled: 19980728

Depth (m) from	to	Thickness (m)	Description
Geology			
0.00	2.00	2.00	SANDSTONE : reddish brown; very weathered. Slightly clayey. Slightly moist.
2.00	7.00	5.00	SANDSTONE : fine to medium grained; white; weathered. Dry.
7.00	9.00	2.00	NO SAMPLE : Caving
9.00	18.00	9.00	NO SAMPLE : Caving, No 2 Seam Workings.

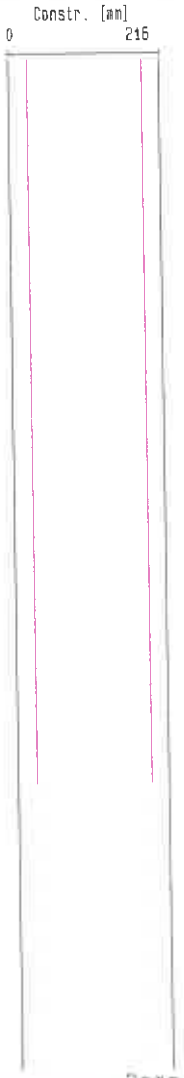
Geohydrology

(no information.)

Site-ID : 2529CC00036 Nr on Map : BSG-UB36

* HydroGraph * Borehole log : DWA BLESBOKSPRUIT

Coordinates : -20027.89 (E-W) 2862038.26 (N-S) 1564.51 (Ground elevation) Date Plotted: Feb 22 1999



m amsl

1565.

1560.

1550.

1544.

Geology

Sandstone: fine to coarse grained; yellowish white;

No sample: Caving

Sandstone: fine to medium grained; yellowish white; slightly weathered;

No sample: Caving, No 2 Seam Workings

Site name : DWA - BLESBOKSPRUIT : BSG-UB38
Notes :

Site ID: 2529CC00038
Number on map: BSG-UB38

E-W coordinate : -21765.40
N-S coordinate : 2860848.32
Ground Elevation: 1567.07 mamsl
Collar Height: 0.49 m
Depth of Casing: 18.00 m
Diameter of Hole: 165 mm
Logged by:
Date Drilled: 19980730

Depth (m) from	to	Thickness (m)	Description
Geology			
0.00	4.00	4.00	SANDSTONE : fine to coarse grained; light brown; very weathered. Dry.
4.00	6.00	2.00	SANDSTONE : fine to coarse grained; very weathered; clayey. Seepage water 6m.
6.00	7.00	1.00	SANDSTONE : fine to medium grained; weathered. Dry.
7.00	8.00	1.00	SILTSTONE : purple brown; slightly weathered. Dry.
8.00	10.00	2.00	SHALE : black; fresh; carbonaceous. Dry.
10.00	12.00	2.00	SHALE : black; fresh; carbonaceous. Dry.
12.00	13.00	1.00	COAL :
13.00	17.00	4.00	NO SAMPLE : No 2 Seam Workings

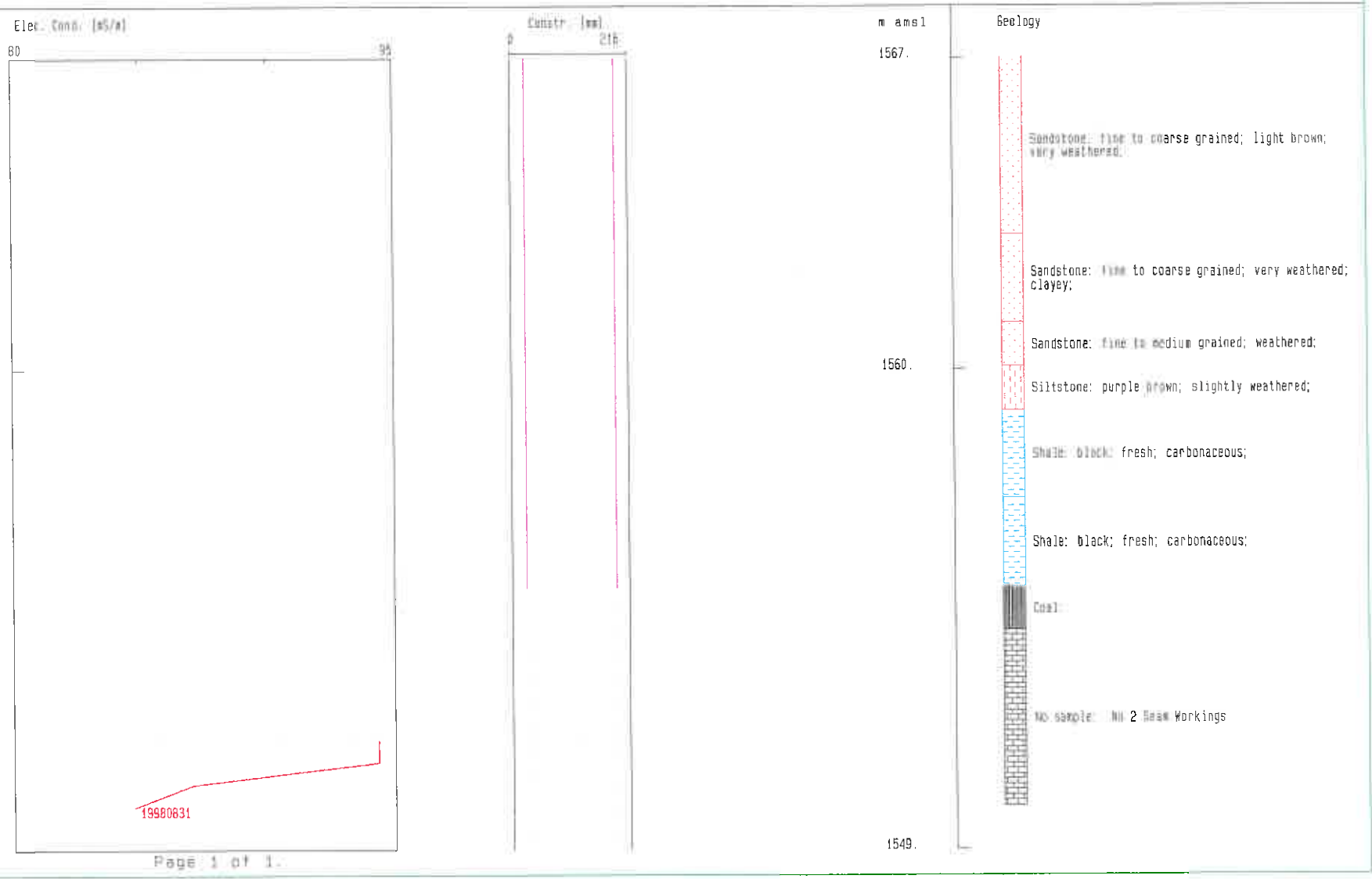
Geohydrology

(no information.)

Site-ID : 2529CC00038 Nr on Map : BSG-UB3B

* HydroGraph * Borehole log : DWA BLESBOKSPRUIT

Coordinates : -21765.40 (E-W) 2860848.32 (N-S) 1567.07 (Ground elevation) Date Plotted: Sep 21 1998



Site name : DWA - BLESBOKSPRUIT : BSG-UB40
Notes :

Site ID: 2529CC00040	Number on map: BSG-UB40
E-W coordinate : -22391.24	N-S coordinate : 2859382.78
Ground Elevation: 1546.58 mamsl	Collar Height: 0.49 m
Depth of Casing: 15.00 m	Diameter of Hole: 165 mm
Logged by: JMA	Date Drilled: 19980804

Depth (m) from	to	Thickness (m)	Description
Geology			
0.00	1.00	1.00	SANDSTONE : medium grained; reddish white; very weathered. Dry.
1.00	4.00	3.00	SANDSTONE : fine to coarse grained; white; slightly weathered. Dry.
4.00	6.00	2.00	SHALE AND SILTSTONE : purple red; slightly weathered. Slightly moist.
6.00	7.00	1.00	SHALE : black; carbonaceous; fresh. Very slightly moist.
7.00	11.00	4.00	SHALE : dark grey; fresh. Moist, wet at 10m.
11.00	15.00	4.00	NO SAMPLE : No 2 Seam workings
Geohydrology			
9.00	10.00	1.00	0.01 L/sec (estimated). According to JMA Geotechnician

Site name : DWA - BLESBOKSPRUIT : BSG-UB42
Notes :

Site ID: 2529CC00042 Number on map: BSG-UB42

E-W coordinate : -23293.43 N-S coordinate : 2859122.51
Ground Elevation: 1558.10 mamsl Collar Height: 0.46 m
Depth of Casing: 28.00 m Diameter of Hole: 165 mm
Logged by: Date Drilled: 19980803

Depth (m) from	to	Thickness (m)	Description

Geology

0.00	3.00	3.00	SILTSTONE : yellowish brown; very weathered. And sandstone. Dry.
3.00	5.00	2.00	SHALE : yellowish brown. Dry.
5.00	9.00	4.00	SHALE AND SILTSTONE : yellowish brown; slightly weathered. Dry.
9.00	12.00	3.00	SANDSTONE : fine to coarse grained; white; slightly weathered. Dry.
12.00	16.00	4.00	SANDSTONE : fine to medium grained; light grey; fresh. Dry.
16.00	18.00	2.00	SANDSTONE AND SHALE : grey; fresh. Dry.
18.00	22.00	4.00	SHALE : fresh. Dark grey to black. Dry.
22.00	24.00	2.00	COAL : black; fresh. And carbonaceous shale. Dry.
24.00	27.00	3.00	NO SAMPLE : No 2 Seam workings

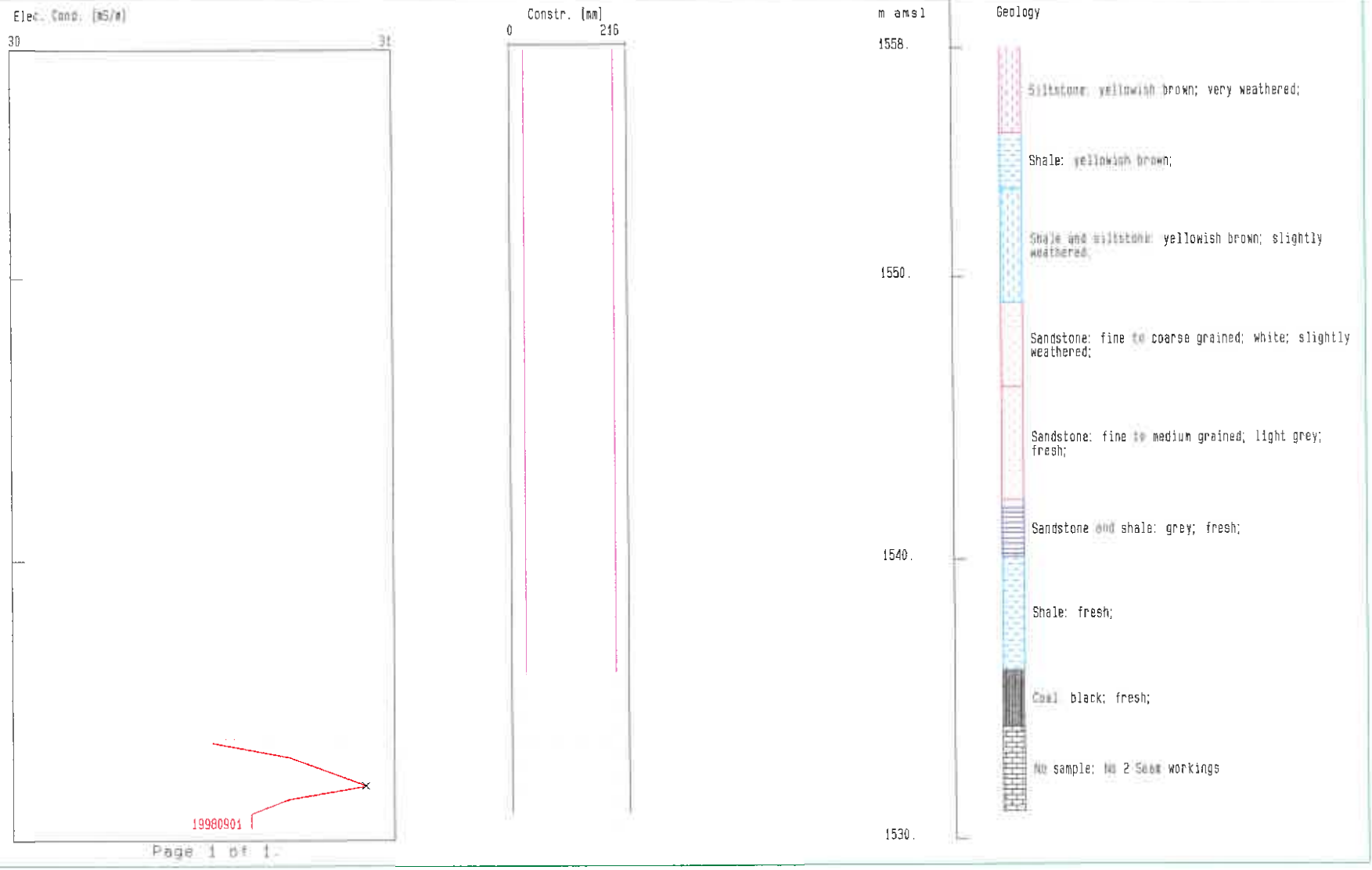
Geohydrology

(no information.)

Site-ID : 2529CC00042 Nr on Map : BSG-UB42

* HydroGraph * Borehole log : DWA BLESBOKSPRUIT

Coordinates : -23293.43 (E-W) 2859122.51 (N-S) 1558.10 (Ground elevation) Date Plotted: Sep 14 1998



Site name : DWA - BLESBOKSPRUIT : BSG-UB41
Notes :

Site ID: 2529CC00041 Number on map: BSG-UB41

E-W coordinate : -22988.80 N-S coordinate : 2858816.29
Ground Elevation: 1552.08 mamsl Collar Height: 0.40 m
Depth of Casing: 18.00 m Diameter of Hole: 165 mm
Logged by: Date Drilled: 19980803

Depth (m) from	to	Thickness (m)	Description

Geology

0.00	1.00	1.00	SOIL : reddish brown; very weathered. Highly weathered sandstone. Dry.
1.00	3.00	2.00	SANDSTONE : fine to medium grained; yellowish white; weathered. Slightly moist.
3.00	6.00	3.00	SANDSTONE : yellowish white; slightly weathered. Slightly moist.
6.00	12.00	6.00	SANDSTONE : fine to medium grained; white. Dry.
12.00	17.00	5.00	NO SAMPLE : No 2 Seam workings
17.00	18.00	1.00	NO SAMPLE : Mine Floor.

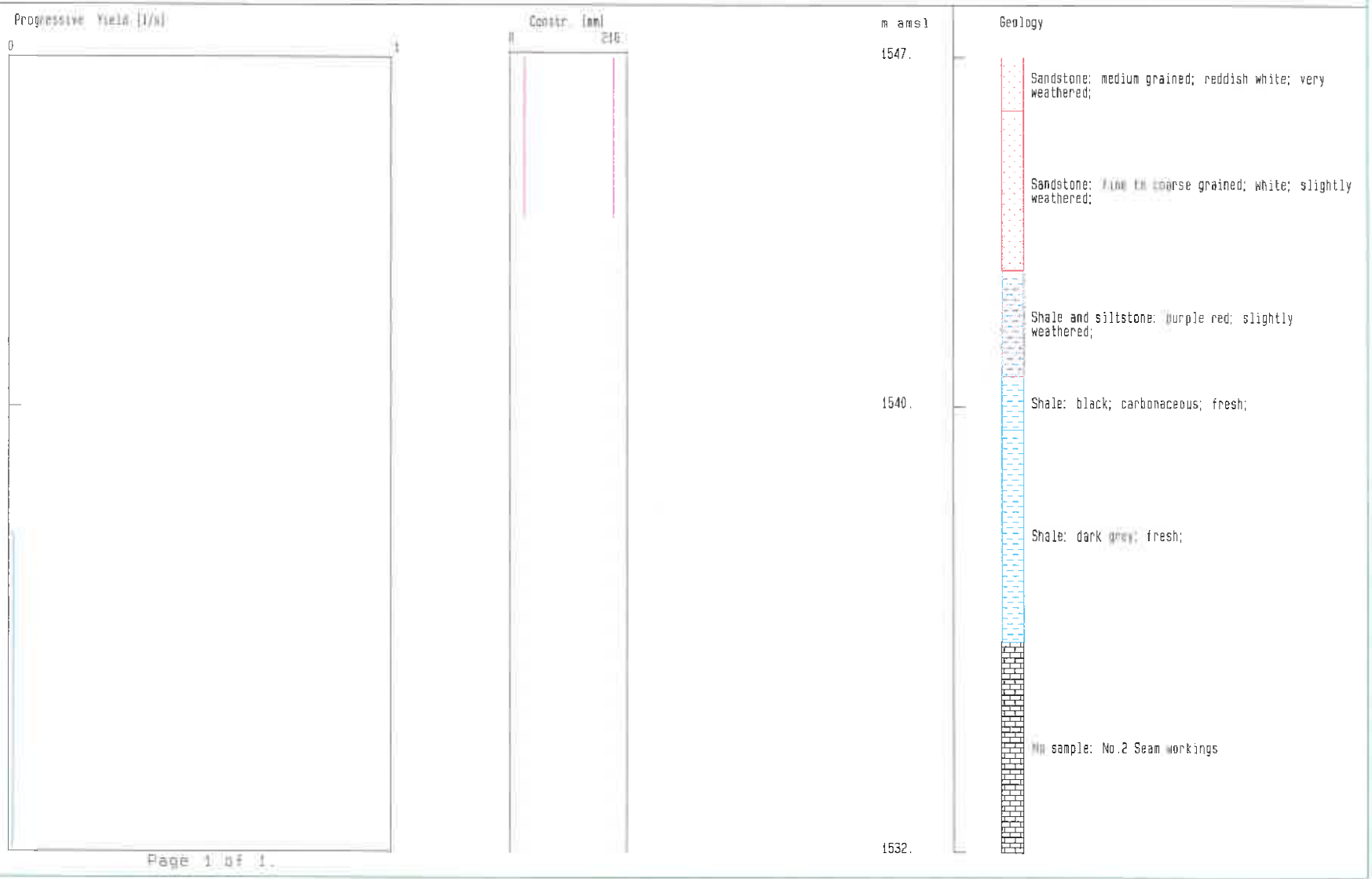
Geohydrology

(no information.)

Site-ID : 2529CC00040 Nr on Map : BSG-UB40

* HydroGraph * Borehole log : DWA BLESBOKSPRUIT

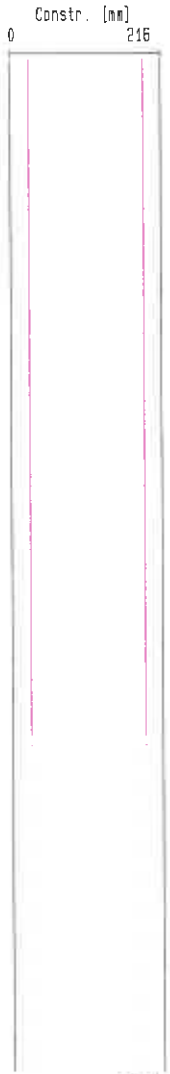
Coordinates : -22391.24(E-W) 2859382.78(N-S) 1546.58(Ground elevation) Date Plotted: Feb 15 1999



Site-ID : 2529CC00041 Nr on Map : BSG-UB41

* HydroGraph * Borehole log : OWA BLESBOKSPRUIT

Coordinates : -22988.80 (E-W) 2858816.29 (N-S) 1552.08 (Ground elevation) Date Plotted: Sep 21 1998



m amsl

1552.

1550.

1540.

1534.

Geology

Soil: reddish brown; very weathered;

Sandstone: fine to medium grained; yellowish white; weathered;

Sandstone: yellowish white; slightly weathered;

Sandstone: fine to medium grained; white;

No sample: No.2 Seam workings

No sample: Mine Floor

Site name : DWA - BLESBOKSPRUIT : BSG-UB43
Notes :

Site ID: 2529CC00043
Number on map: BSG-UB43

E-W coordinate : -23823.18
N-S coordinate : 2857897.75
Ground Elevation: 1536.91 mamsl
Collar Height: 0.52 m
Depth of Casing: 12.00 m
Diameter of Hole: 165 mm
Logged by:
Date Drilled: 19980804

Depth (m) from	to	Thickness (m)	Description
Geology			
0.00	5.00	5.00	OVERBURDEN :
5.00	6.00	1.00	SHALE : yellowish red; very weathered. Slightly moist.
6.00	7.00	1.00	SHALE : slightly weathered; carbonaceous. Grey to black. Wet.
7.00	11.00	4.00	NO SAMPLE : No 2 Seam workings
Geohydrology			
(no information.)			

Site-ID : 2529CC00043 Nr on Map : BSG-UB43

* HydroGraph * Borehole log : OWA BLESBOKSPRUIT

Coordinates : -23823.18 (E-W) 2857897.75 (N-S) 1536.91 (Ground elevation) Date Plotted: Sep 14 1998

Site name : DWA - BLESBOKSPRUIT : BSG-UB44
Notes :

Site ID: 2529CC00044 Number on map: BSG-UB44

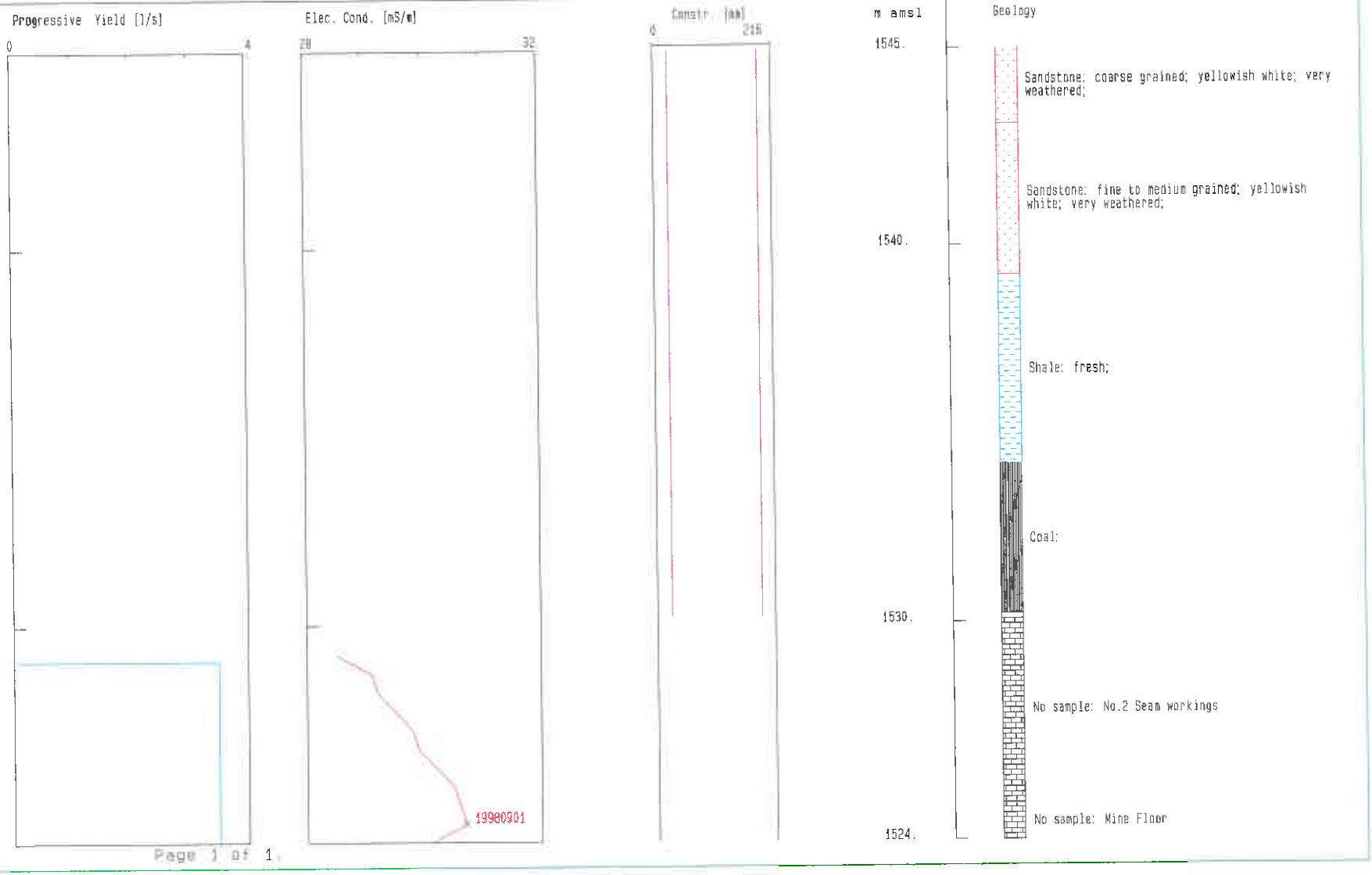
E-W coordinate : -23844.34 N-S coordinate : 2858597.63
Ground Elevation: 1545.22 mamsl Collar Height: 0.51 m
Depth of Casing: 21.00 m Diameter of Hole: 165 mm
Logged by: JMA Date Drilled: 19980804

Depth (m) from	to	Thickness (m)	Description
Geology			
0.00	2.00	2.00	SANDSTONE : coarse grained; yellowish white; very weathered. Slightly moist.
2.00	6.00	4.00	SANDSTONE : fine to medium grained; yellowish white; very weathered. Seepage water at 6m.
6.00	11.00	5.00	SHALE : fresh. Very slightly moist. Seepage water at 11m.
11.00	15.00	4.00	COAL : And fresh carbonaceous shale.
15.00	20.00	5.00	NO SAMPLE : No 2 Seam workings
20.00	21.00	1.00	NO SAMPLE : Mine Floor.
Geohydrology			
16.00	20.00	4.00	4.00 L/sec (estimated). According to JMA Geotechnician

Site-ID : 2529CC00044 Nr on Map : BSG-UB44

* HydroGraph * Borehole log : DWA BLESBOKSPRUIT

Coordinates : -23844.34 (E-W) 2858597.63 (N-S) 1545.22 (Ground elevation) Date Plotted: Sep 21 1998



Site name : DWA - BLESBOKSPRUIT : BSG-UB45
Notes :

Site ID: 2529CC00045
Number on map: BSG-UB45

E-W coordinate : -23435.31
N-S coordinate : 2859573.32
Ground Elevation: 1554.01 mamsl
Collar Height: 0.54 m
Depth of Casing: 24.00 m
Diameter of Hole: 165 mm
Logged by:
Date Drilled: 19980804

Geology

Depth from (m)	Depth to (m)	Thickness (m)	Description
0.00	2.00	2.00	SANDSTONE : fine to medium grained; yellowish white; weathered. Dry.
2.00	8.00	6.00	SANDSTONE : fine to medium grained; white; slightly weathered. Dry.
8.00	10.00	2.00	SANDSTONE AND SHALE : light grey; slightly weathered. Slightly moist.
10.00	15.00	5.00	SHALE : dark grey; fresh. Very slightly moist.
15.00	18.50	3.50	COAL : Dry.
18.50	24.00	5.50	NO SAMPLE : No 2 Seam workings
24.00	25.00	1.00	NO SAMPLE : Mine Floor.

Geohydrology

(no information.)

FIGURE 15

Current SO_4 concentrations observed at monitoring boreholes (mg/l).

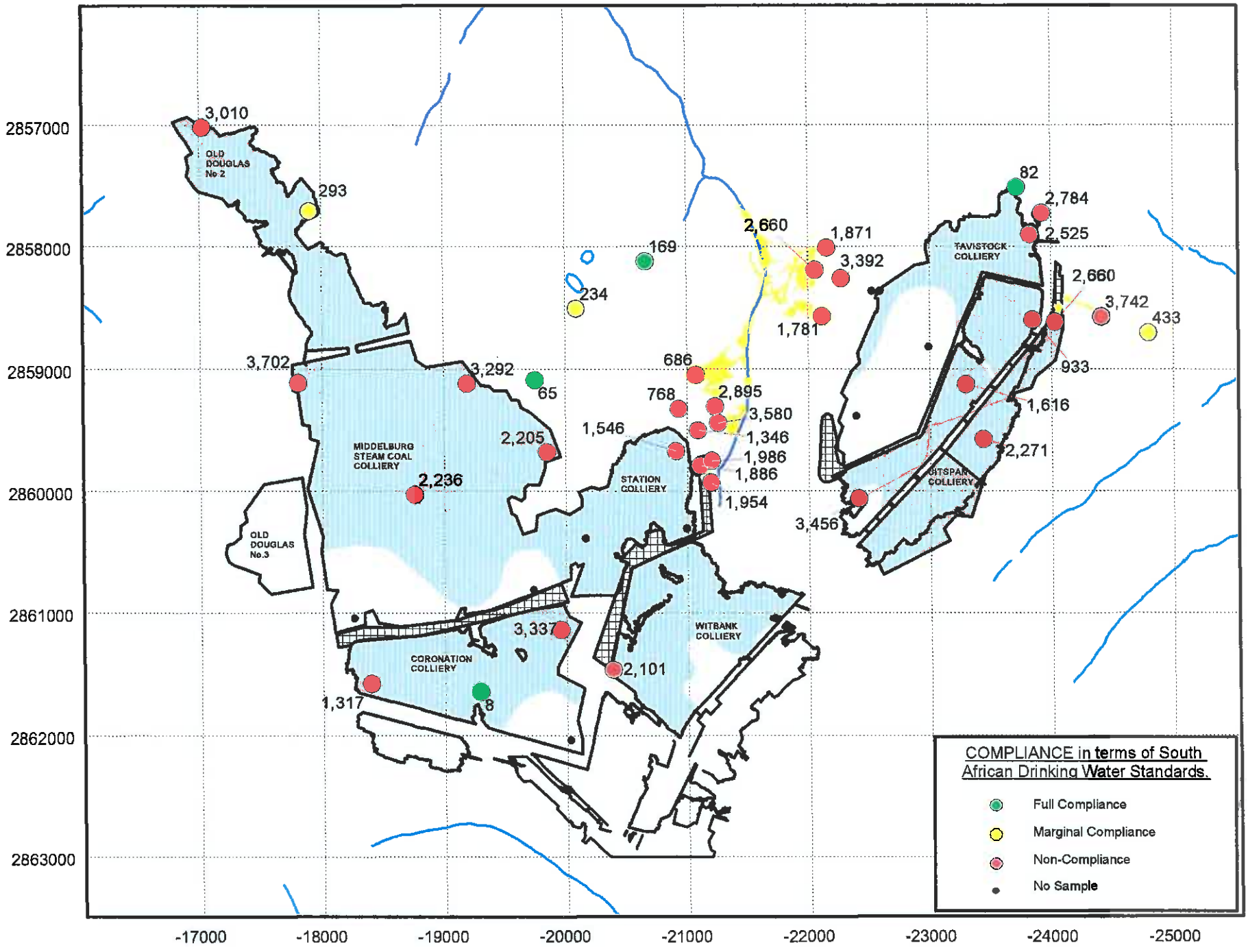


FIGURE 16

Current Fe concentrations observed at monitoring boreholes (mg/l).

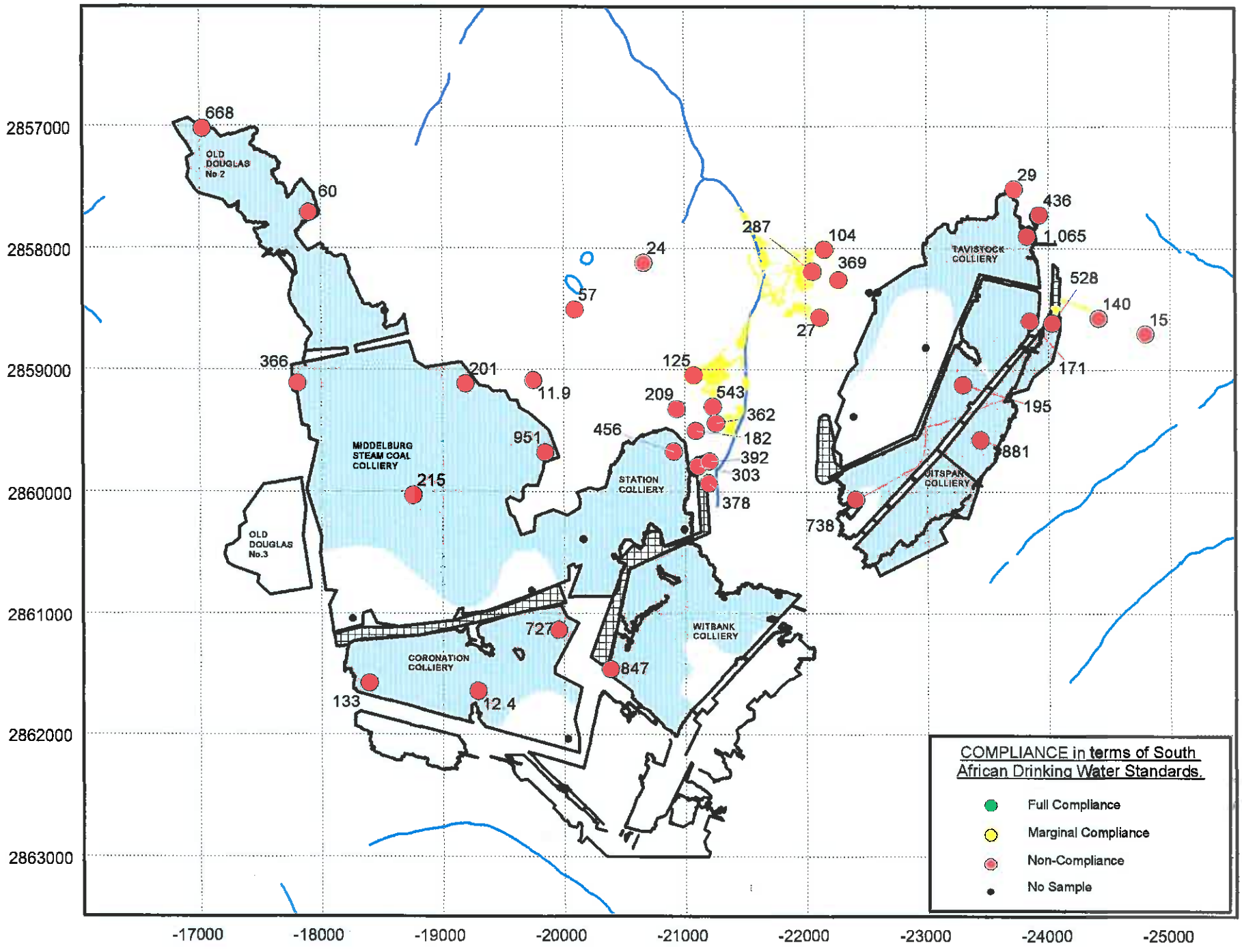


FIGURE 17

Stiff diagrams, showing the relation between major cation and anion concentrations in meq/l

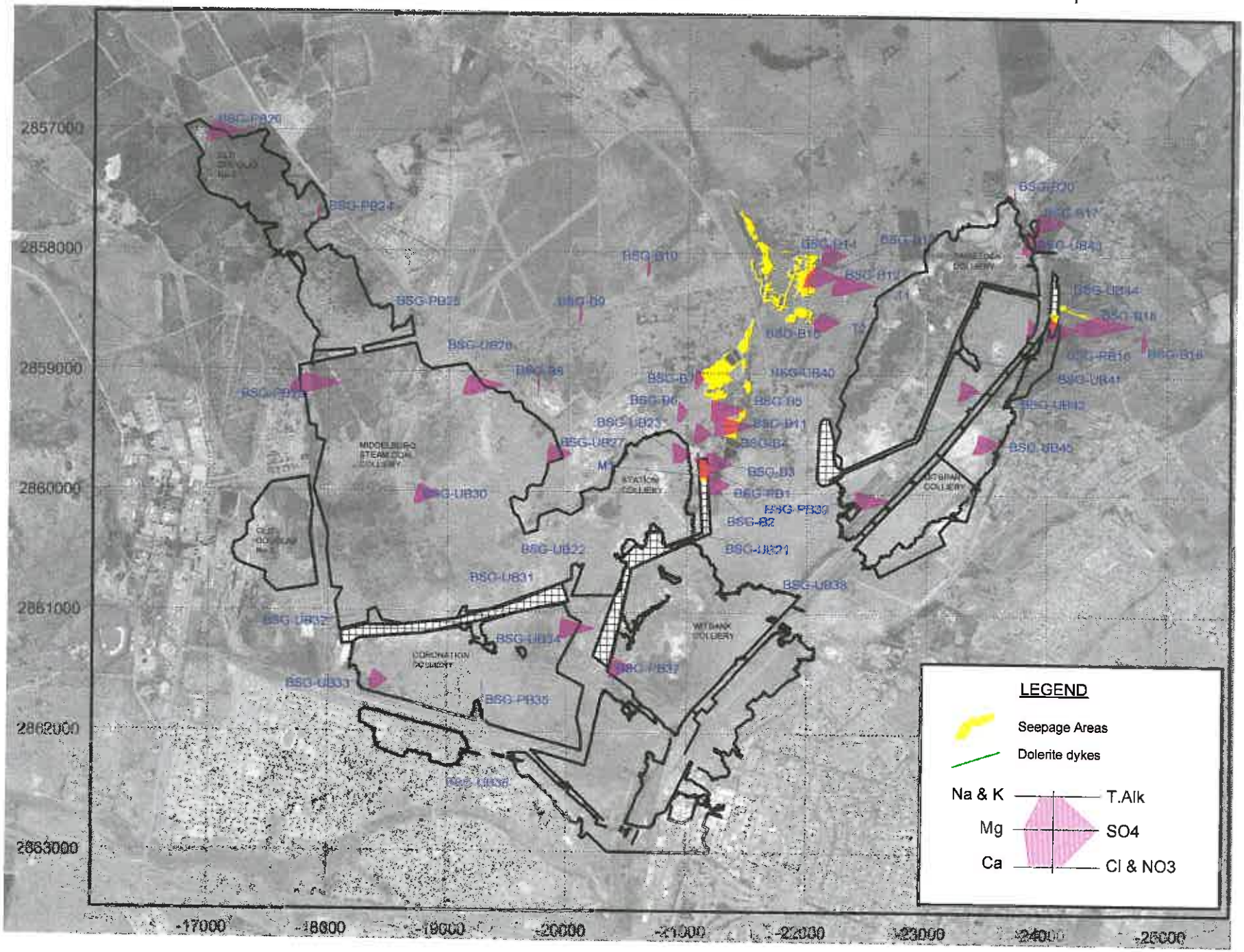


TABLE 1: PERTINENT GEOHYDROLOGICAL INFORMATION

Site_Id	BH_NO	Y	X	Z	COLLAR (m)	DEPTH (m)	water level Aug1998 (m)	water level Oct1998 (m)	water level Jan1999 (m)	Water Level Elevation (mamsl)	Floor (mamsl)	Weathering (m)	Yield (l/s)	Strike (m)	Overburden (m)	Holed	Hydraulic Conductivity (m/d)	Comment
2529CC00001	BSG-RB1	21103.49	-2859788.96	1536.70	2.04	24.00	0	2.7	0	1536.70	1526.70	0.00	2.30	5.5-20				2 SEAM FRINGE
2529CC00002	BSG-B2	21192.57	-2859828.69	1533.81	0.47	18.00	2.55	2.44	2.27	1531.26		6.00			0.00		0.034	NO. 1 SEAM
2529CC00003	BSG-B3	21198.77	-2859749.35	1533.05	0.00	24.00	1.42	1.26	1.14	1531.63		4.00			2.00		0.017	NO. 1 AND 2 S
2529CC00004	BSG-B4	21086.32	-2859500.00	1534.03	0.38	33.00	3.6		2.85	1530.81		9.00			7.00		0.003	NO COAL SEAM
2529CC00005	BSG-B5	21227.53	-2859303.41	1528.08	0.30	30.00	1.65	1.19	1.06	1526.73		12.00	0.01	6-7	1.00		0.030	NO COAL SEAM
2529CC00006	BSG-B6	20929.35	-2859322.17	1532.84	0.23	30.00	3.23		2.88	1529.84	1522.84	12.00	0.01	8-9	2.00		0.604	NO. 1 AND 2 S
2529CC00007	BSG-B7	21072.12	-2859044.98	1524.69	0.67	30.00	3.83	3.57	2.03	1521.53		9.00	0.04	14-15	0.00		0.056	NO COAL SEAM
2529CC00008	BSG-B8	19747.86	-2859087.66	1541.36	0.41	30.00	7.51		4.67	1534.26		12.00			0.00		0.018	NO. 1 SEAM
2529CC00009	BSG-B9	20090.43	-2858504.50	1527.04	0.50	42.00	6.09	6.12	4.31	1521.45	1521.04	4.00	0.01	6-9	0.00		0.273	NO. 1 AND 2 S
2529CC00010	BSG-B10	20659.73	-2858117.99	1515.28	0.35	30.00	2.85	2.78	0	1512.78	1506.28	9.00	0.75	5-9	2.00		0.039	NO. 1 AND 2 S
2529CC00011	BSG-B11	21252.06	-2859438.09	1529.30	0.60	24.00	6.39	5.48	4.59	1523.51		21.00	3.00	13&21	0.00		3.107	NO COAL SEAM
2529CC00012	BSG-B12	22269.76	-2858257.96	1524.43	0.22	36.00	1.57		0.89	1523.08	1516.43	9.00	0.03	19-21	1.00		1.113	NO. 1 AND 2 S
2529CC00013	BSG-B13	22056.62	-2858187.90	1517.45	0.48	31.00	2.13	2.17	1.56	1515.80		18.00	0.50	10&15	1.00		0.106	NO COAL SEAM
2529CC00014	BSG-B14	22153.03	-2858007.53	1521.46	0.42	30.00	3.84	3.81	3.2	1518.04		13.00	0.04	7-8	1.00		0.697	NO. 1 SEAM
2529CC00015	BSG-B15	22112.99	-2858567.21	1523.36	0.61	30.00	4.43	4.95	3.33	1519.54		18.00	1.00	14-18	1.00		0.399	NO COAL SEAM
2529CC00016	BSG-RB16	24028.24	-2858814.53	1533.16	0.46	13.00	2.99	2.92	1.39	1531.09	1524.16	0.00	5.50	0-9			30.637	2 SEAM FRINGE
2529CC00017	BSG-B17	23922.78	-2857722.88	1533.90	0.56	19.00	5.42	5.16	4.75	1529.60		19.00	0.25	8-13	1.00		0.626	NO COAL SEAM
2529CC00018	BSG-B18	24410.26	-2858572.53	1509.26	0.67	31.00	9.82	10.9	9.31	1500.11		31.00	0.04	20-22	12.00		0.198	NO COAL SEAM
2529CC00019	BSG-B19	24795.67	-2858701.33	1489.41	0.34	24.00	17.58	14.6	14.18	1472.17		24.00			1.00		0.034	NO COAL SEAM
2529CC00020	BSG-B20	23716.95	-2857510.40	1545.93	0.50	31.00	15.13	8.55	14.32	1531.30		31.00	0.04	21-24	0.00		0.011	NO. 1 AND 2 S
2529CC00024	BSG-PB24	17900.68	-2857705.54	1548.96	0.38	24.00	11.97	12	11.53	1537.75	1532.96	13.00			2.00			
2529CC00025	BSG-PB25	18523.51	-2858515.48	1556.35	0.34	18.00	16.94	16.81	16.52	1540.09	1541.35	18.00			1.00			
2529CC00026	BSG-PB26	17022.92	-2857017.06	1540.23	0.40	19.00	3.26	3.22	2.91	1537.77	1524.23	13.00			1.00			
2529CC00029	BSG-PB29	17803.71	-2859110.92	1549.17	0.44	17.00	10.52	10.58	10.52	1539.53	1535.17	12.00			1.00			
2529CC00035	BSG-PB35	19288.16	-2861644.19	1562.63	0.68	23.00	14.07	14.12	14.3	1549.24	1540.63	15.00			0.00			
2529CC00037	BSG-PB37	20378.05	-2861461.72	1565.78	0.36	30.00	18.19		18.24	1547.95	1543.78	13.00			0.00			
2529CC00039	BSG-PB39	22407.62	-2860059.90	1559.85	0.42	30.00	24.78	24.56	24.06	1535.49	1533.85	19.00			1.00			
2529CC00021	BSG-UB21	20989.88	-2860306.69	1553.38	0.45	18.00					1535.88	8.00			1.00	YES		HOT SMOKING
2529CC00022	BSG-UB22	20157.31	-2860388.99	1560.77	0.73	26.50			23.05		1534.77	12.00			1.00	YES		BOILING
2529CC00023	BSG-UB23	20904.07	-2859669.80	1544.76	0.61	16.00	6.24	6.53	7.35	1539.74	1528.76	7.00			1.00	YES		
2529CC00027	BSG-UB27	19844.49	-2859679.41	1553.05	0.38	18.00	13.26	13.41	13.49	1540.56	1536.56	18.00	10.00	14-16.5	2.00	YES		
2529CC00028	BSG-UB28	19189.00	-2859114.83	1548.53	0.40	18.00	8.94	9.88	8.97	1540.39	1530.53	18.00	6.00	13-16	1.00	YES		BOILING
2529CC00030	BSG-UB30	18754.94	-2860027.90	1558.97	0.54	24.00	19.4	19.56	20.59	1540.65	1534.97	13.00			2.00	YES		
2529CC00031	BSG-UB31	19730.07	-2860811.94	1565.02	0.41	29.00					1539.02	14.00			0.00	YES		
2529CC00032	BSG-UB32	18255.32	-2861042.88	1558.42	0.42	18.00					1540.42	9.00			0.00	YES		
2529CC00033	BSG-UB33	18391.03	-2861576.57	1554.55	0.36	17.50	13.4		13.41	1541.87	1537.55	9.00			0.00	YES		
2529CC00034	BSG-UB34	19952.21	-2861136.71	1565.45	0.68	30.00	24.53	24.72	24.72	1542.28	1536.95	8.00			1.00	YES		
2529CC00036	BSG-UB36	20027.89	-2862038.26	1564.51	0.47	21.00					1543.51	3.00			0.00	YES		plakkershut nou bo-oor
2529CC00038	BSG-UB38	21765.40	-2860848.32	1567.07	0.49	17.00	15.46	13.58	11.85	1552.10	1550.07	8.00			0.00	YES		
2529CC00040	BSG-UB40	22391.24	-2859382.77	1546.58	0.49	15.00					1531.58	6.00	0.01	6-10	0.00	YES		
2529CC00041	BSG-UB41	22988.80	-2858816.29	1552.08	0.40	18.00					1535.08	6.00			1.00	YES		
2529CC00042	BSG-UB42	23293.42	-2859122.51	1558.10	0.46	27.00	24.28	24.55	24.5	1534.28	1531.10	12.00			0.00	YES		
2529CC00043	BSG-UB43	23823.18	-2857897.75	1536.91	0.52	11.00	3.85	4	3.92	1533.58	1525.91	7.00			5.00	YES		
2529CC00044	BSG-UB44	23844.34	-2858597.62	1545.22	0.51	21.00	15.72	11.66	11.81	1530.01	1525.22	6.00	4.00	6&11	0.00	YES		
2529CC00045	BSG-UB45	23435.31	-2859573.32	1554.01	0.54	25.00	20.2	20.43	20.37	1534.35	1530.01	10.00			0.00	YES		
	M1	21077.73	-2859847.12	1540.62	0.23	12.00		1.64?		1539.31	1530.62	5.50		5.5	1.00			Old borehole
	T1	22590.00	-2858360.00	1534.00	0.20	12.00		2.16?		1532.86	1522.50	8.00		8	1.00	YES		Old borehole
	T2	22522.71	-2858361.49	1533.72	0.20	13.00				1531.96	1522.72	13.00		7.6	2.00			Old borehole

APPENDIX II

BOREHOLE SITE REPORTS
AND
PROFILE PLOTS

FOR

UNDERGROUND BOREHOLES
PILLAR BOREHOLES
PLUME MONITORING BOREHOLES

UNDERGROUND BOREHOLES

Site name : DWA - BLESBOKSPRUIT : BSG-UB21
Notes :

Site ID: 2529CC00021	Number on map: BSG-UB21
E-W coordinate : -20989.88	N-S coordinate : 2860306.69
Ground Elevation: 1553.38 mamsl	Collar Height: 0.45 m
Depth of Casing: 18.00 m	Diameter of Hole: 165 mm
Logged by:	Date Drilled: 19980731

Depth (m) from	to	Thickness (m)	Description
Geology			
0.00	1.00	1.00	OVERBURDEN : Coal rubble.
1.00	2.00	1.00	SANDSTONE : medium to coarse grained; reddish brown; very weathered. Slightly moist.
2.00	5.00	3.00	SANDSTONE : fine to medium grained; yellowish white; very weathered. Slightly moist.
5.00	6.00	1.00	SAND AND SILT : yellowish brown; very weathered. Slightly moist.
6.00	8.00	2.00	SANDSTONE AND SHALE : weathered; carbonaceous. Dry.
8.00	14.00	6.00	SANDSTONE AND SHALE : fresh. Dry.
14.00	17.50	3.50	NO SAMPLE : No.2 Seam Workings
17.50	18.00	0.50	SANDSTONE AND SHALE : fresh.

Geohydrology

(no information.)

Site-ID : 2529CC00021 Nr on Map : BSG-UB21

* HydroGraph * Borehole log : DWA BLESBOKSPRUIT

Coordinates : -20989.88 (E-W) 2860306.69 (N-S) 1553.38 (Ground elevation) Date Plotted: Feb 19 1999

m amsl	Geology
1553.	Overburden:
	Sandstone: medium to coarse grained; reddish brown; very weathered;
1550.	Sandstone: fine to medium grained; yellowish white; very weathered;
	Sand and silt: yellowish brown; very weathered;
	Sandstone and shale: weathered; carbonaceous;
	Sandstone and shale: fresh;
1540.	No sample: No.2 Seam Workings
1535.	Sandstone and shale: fresh;

Site name : DWA - BLESBOKSPRUIT : BSG-UB22
Notes :

Site ID: 2529CC00022
Number on map: BSG-UB22

E-W coordinate : -20157.32
N-S coordinate : 2860388.99
Ground Elevation: 1560.77 mamsl
Collar Height: 0.73 m
Depth of Casing: 21.00 m
Diameter of Hole: 165 mm
Logged by:
Date Drilled: 19980731

Geology

Depth from (m)	to (m)	Thickness (m)	Description
0.00	1.00	1.00	SAND : yellowish red. Dry.
1.00	3.00	2.00	SANDSTONE : fine to coarse grained; reddish brown; very weathered. Slightly moist.
3.00	4.00	1.00	SANDSTONE : fine to coarse grained; light brown; very weathered. Dry.
4.00	6.00	2.00	SANDSTONE : coarse grained; brownish white; very weathered. Dry.
6.00	11.00	5.00	SANDSTONE AND SHALE : greyish white; slightly weathered. Slightly moist.
11.00	12.00	1.00	SANDSTONE : medium to coarse grained; brown; slightly weathered. Moist.
12.00	22.00	10.00	SANDSTONE AND SHALE : dark grey. Dry.
22.00	26.00	4.00	NO SAMPLE : No 2 Seam Workings
26.00	26.50	0.50	NO SAMPLE : Mine Floor

Geohydrology

(no information.)

Site-ID : 2529CC00022 Nr on Map : BSG-UB22

* HydroGraph * Borehole log : DWA BLESBOKSPRUIT

Coordinates : -20157.32 (E-W) 2860388.99 (N-S) 1560.77 (Ground elevation) Date Plotted: Feb 15 1999

m amsl	Geology
1561.	
1560.	Sand: yellowish red;
	Sandstone: fine to coarse grained; reddish brown; very weathered;
	Sandstone: fine to coarse grained; light brown; very weathered;
	Sandstone: coarse grained; brownish white; very weathered;
	Sandstone and shale: greyish white; slightly weathered;
1550.	Sandstone: medium to coarse grained; brown; slightly weathered;
	Sandstone and shale: dark grey;
1540.	
	No sample: No 2 Seam Workings
1534.	No sample: No 2 Seam Workings

Site name : DWA - BLESBOKSPRUIT : BSG-UB23
Notes :

Site ID: 2529CC00023
Number on map: BSG-UB23

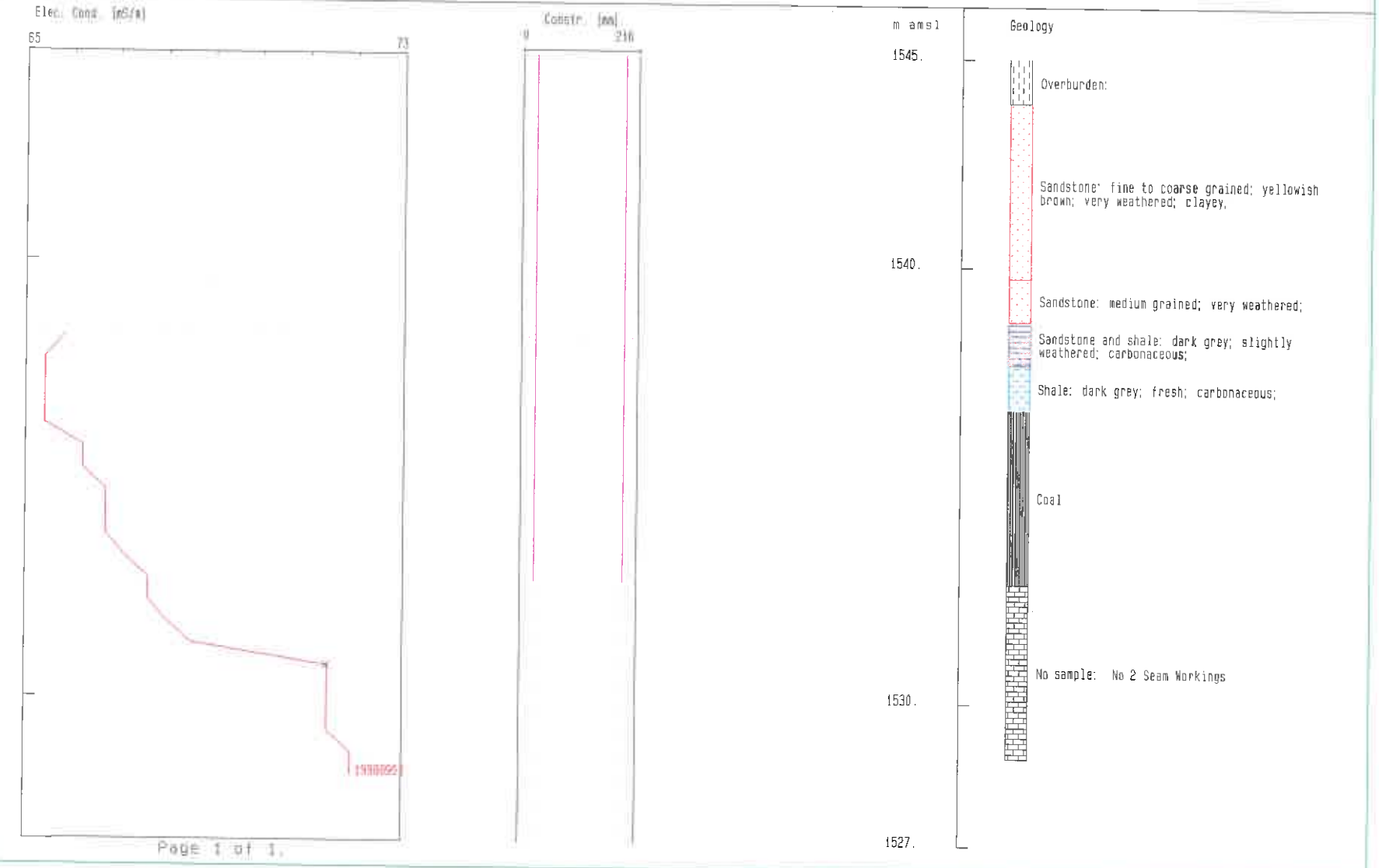
E-W coordinate : -20904.07
N-S coordinate : 2859669.80
Ground Elevation: 1544.76 mamsl
Collar Height: 0.61 m
Depth of Casing: 18.00 m
Diameter of Hole: 165 mm
Logged by:
Date Drilled: 19980722

Depth (m) from	to	Thickness (m)	Description
Geology			
0.00	1.00	1.00	OVERBURDEN : Coal rubble.
1.00	5.00	4.00	SANDSTONE : fine to coarse grained; yellowish brown; very weathered; clayey. Very moist.
5.00	6.00	1.00	SANDSTONE : medium grained; very weathered.
6.00	7.00	1.00	SANDSTONE AND SHALE : dark grey; slightly weathered; carbonaceous. Dry.
7.00	8.00	1.00	SHALE : dark grey; fresh; carbonaceous.
8.00	12.00	4.00	COAL
12.00	16.00	4.00	NO SAMPLE : No 2 Seam Workings
Geohydrology			
(no information.)			

Site-ID : 2529CC00023 Nr on Map : BSG-UB23

* HydroGraph * Borehole log : DWA BLESBOKSPRUIT

Coordinates : -20904.07 (E-W) 2859669.80 (N-S) 1544.76 (Ground elevation) Date Plotted: Sep 17 1998



Site name : DWA - BLESBOKSPRUIT : BSG-UB27
Notes :

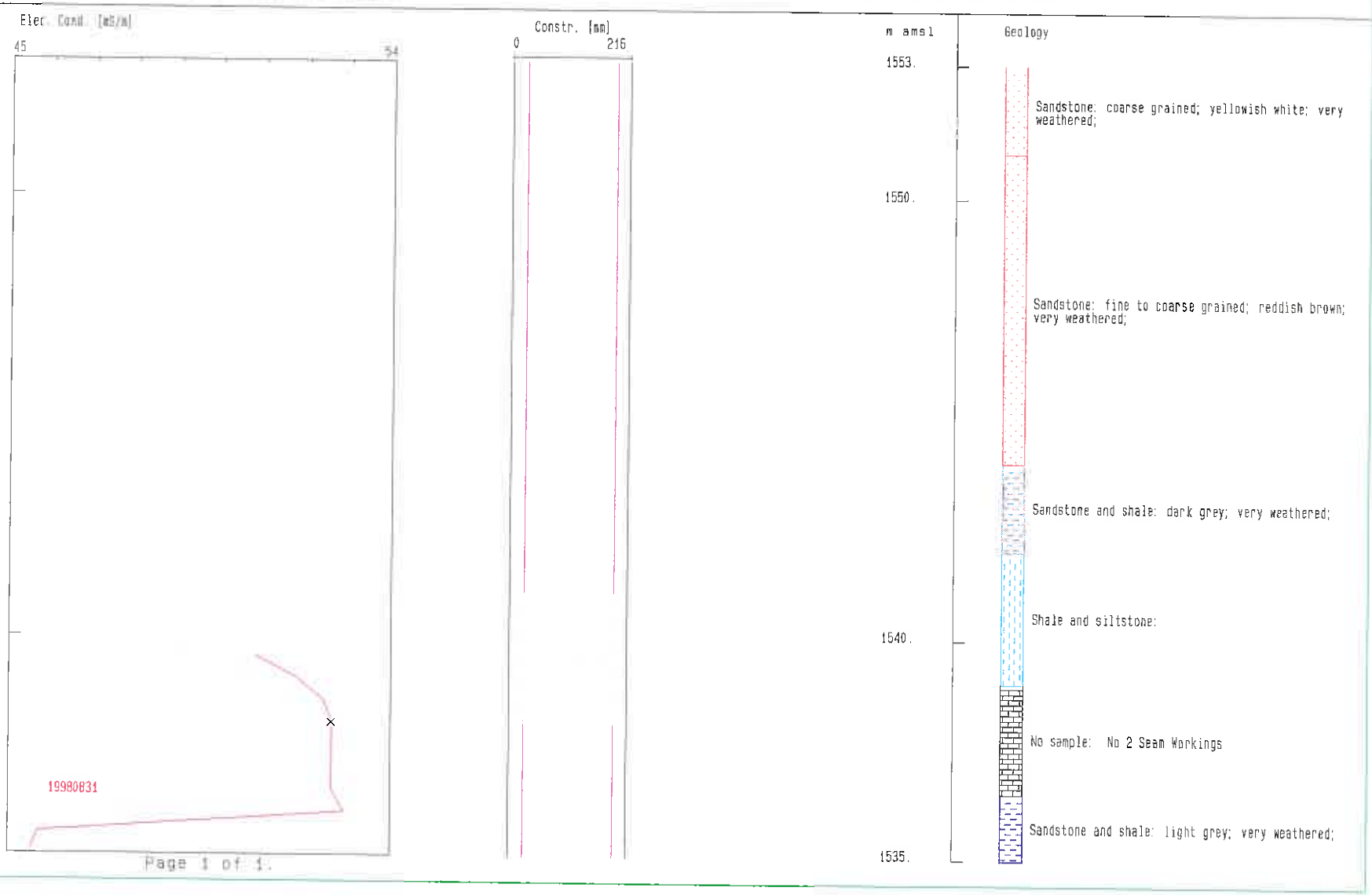
Site ID: 2529CC00027	Number on map: BSG-UB27
E-W coordinate : -19844.49	N-S coordinate : 2859679.41
Ground Elevation: 1553.05 mamsl	Collar Height: 0.38 m
Depth of Casing: 18.00 m	Diameter of Hole: 165 mm
Logged by:	Date Drilled: 19980727

Depth from (m)	to (m)	Thickness (m)	Description
Geology			
0.00	2.00	2.00	SANDSTONE : coarse grained; yellowish white; very weathered. Slightly moist.
2.00	9.00	7.00	SANDSTONE : fine to coarse grained; reddish brown; very weathered. Moist.
9.00	11.00	2.00	SANDSTONE AND SHALE : dark grey; very weathered. Moist.
11.00	14.00	3.00	SHALE AND SILTSTONE : Thin layer of coal at 13m. Poor samples because of mud.
14.00	16.50	2.50	NO SAMPLE : No 2 Seam Workings
16.50	18.00	1.50	SANDSTONE AND SHALE : light grey; very weathered.
Geohydrology			
14.00	16.50	2.50	10.00 L/sec (estimated). According to JMA geotechnician

Site-ID : 2529CC00027 Nr on Map : BSG-UB27

* HydroGraph * Borehole log : OWA BLESBOKSPRUIT

Coordinates : -19844.49 (E-W) 2859079.41 (N-S) 1553.05 (Ground elevation) Date Plotted: Feb 19 1999



Site name : DWA - BLESBOKSPRUIT : BSG-UB28
Notes :

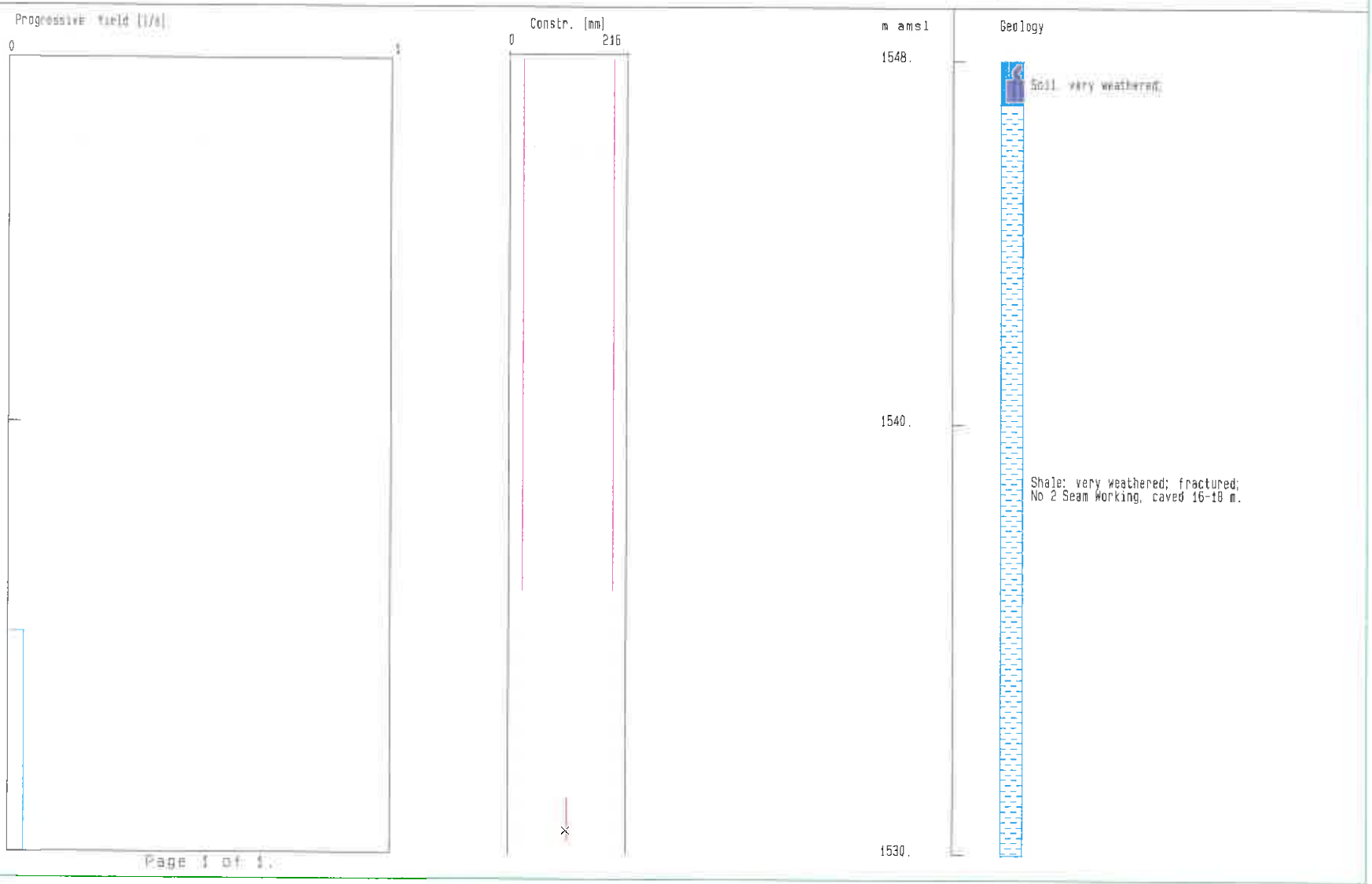
Site ID: 2529CC00028	Number on map: BSG-UB28
E-W coordinate : -19189.00	N-S coordinate : 2859114.83
Ground Elevation: 1548.23 mamsl	Collar Height: 0.40 m
Depth of Casing: 18.00 m	Diameter of Hole: 165 mm
Logged by: JMA	Date Drilled: 19980727

Depth (m) from	to	Thickness (m)	Description
Geology			
0.00	1.00	1.00	SOIL : very weathered. Soil with shale. Dry.
1.00	18.00	17.00	SHALE : very weathered; fractured. No 2 Seam Working caved 16-18 m.
Geohydrology			
13.00	16.00	3.00	6.00 L/sec (estimated). According to JMA Geotechnician

Site-ID : 2529CC00028 Nr on Map : BSG-UB28

* HydroGraph * Borehole log : DWA BLESBOKSPRUIT

Coordinates : -19189.00 (E-W) 2859114.83 (N-S) 1548.23 (Ground elevation) Date Plotted: Sep 17 1998



Site name : DWA - BLESBOKSPRUIT : BSG-UB30
Notes :

Site ID: 2529CC00030	Number on map: BSG-UB30
E-W coordinate : -18754.94	N-S coordinate : 2860027.90
Ground Elevation: 1558.97 mamsl	Collar Height: 0.54 m
Depth of Casing: 24.00 m	Diameter of Hole: 165 mm
Logged by:	Date Drilled: 19980728

Depth (m) from	to	Thickness (m)	Description

Geology

0.00	2.00	2.00	SOIL : fine to medium grained; yellowish brown. Dry.
2.00	6.00	4.00	SANDSTONE : fine to coarse grained; reddish brown; very weathered. Dry.
6.00	11.00	5.00	SANDSTONE : fine to medium grained; white; very weathered. Dry.
11.00	13.00	2.00	SANDSTONE AND SHALE : grey; slightly weathered. Dry.
13.00	17.00	4.00	SHALE : fresh; carbonaceous. Dry.
17.00	19.00	2.00	COAL : and carbonaceous shale; dry.
19.00	24.00	5.00	NO SAMPLE : No 2 Seam Workings

Geohydrology

(no information.)

Site-ID : 2529CC00030 Nr on Map : BSG-UB30

* HydroGraph * Borehole log : DWA BLESBOKSPRUIT

Coordinates : -18754.94 (E-W) 2860027.90 (N-S) 1558.97 (Ground elevation) Date Plotted: Feb 16 1999

Site name : DWA - BLESKBOKSPRUIT : BSG-UB31
Notes :

Site ID: 2529CC00031 Number on map: BSG-UB31

E-W coordinate : -19730.07 N-S coordinate : 2860811.94
Ground Elevation: 1565.02 mamsl Collar Height: 0.41 m
Depth of Casing: 29.00 m Diameter of Hole: 165 mm
Logged by: Date Drilled: 19980727

Depth (m) from	to	Thickness (m)	Description

Geology

0.00	2.00	2.00	SANDSTONE : medium to coarse grained; yellowish brown; very weathered. Moist.
2.00	4.00	2.00	SANDSTONE : medium grained; light brown; very weathered. Moist.
4.00	8.00	4.00	SANDSTONE : fine to medium grained; yellowish white; very weathered. Moist.
8.00	9.00	1.00	SANDSTONE AND SHALE : dark grey. Slightly moist.
9.00	14.00	5.00	SANDSTONE AND SHALE : light grey; slightly weathered. Dry.
14.00	20.00	6.00	SANDSTONE AND SHALE : dark grey; fresh. Dry.
20.00	23.00	3.00	SHALE : dark grey; fresh; carbonaceous. Dry.
23.00	25.00	2.00	COAL :
25.00	26.00	1.00	NO SAMPLE : No 2 Seam Workings
26.00	29.00	3.00	NO SAMPLE : Mine Floor.

Geohydrology

(no information.)

Site-ID : 2529CC00031 Nr on Map : BSG-UB31

* HydroGraph * Borehole log : DWA BLESBOKSPRUIT

Coordinates :-19730.07(E-W) 2860811.94(N-S) 1565.02(Ground elevation) Date Plotted: Sep 14 1998

m amsl

1565.

1560.

1550.

1540.

1536.

Geology

Sandstone: medium to coarse grained; yellowish brown; very weathered;

Sandstone: medium grained; light brown; very weathered;

Sandstone: fine to medium grained; yellowish white; very weathered;

Sandstone and shale: dark grey;

Sandstone and shale: light grey; slightly weathered;

Sandstone and shale: dark grey; fresh;

Shale: dark grey; fresh; carbonaceous;

Coal:

No sample: No 2 Seam Workings

No sample: Mine Floor

PILLAR BOREHOLES

Site name : DWA - BLESBOKSPRUIT : BSG-PB24
Notes :

Site ID: 2529CC00024 Number on map: BSG-PB24

E-W coordinate : -17900.68 N-S coordinate : 2857705.55
Ground Elevation: 1548.96 mamsl Collar Height: 0.38 m
Depth of Casing: 24.00 m Diameter of Hole: 165 mm
Logged by: Date Drilled: 19980723

Depth (m) from	to	Thickness (m)	Description
Geology			
0.00	2.00	2.00	SOIL : very weathered; clayey. Slightly moist.
2.00	11.00	9.00	SHALE : yellowish white; weathered. Slightly moist.
11.00	13.00	2.00	SANDSTONE AND SHALE : dark grey; slightly weathered. Slightly moist.
13.00	13.50	0.50	SHALE : dark grey; carbonaceous.
13.50	16.00	2.50	COAL : black. No 2 & 1 Seam.
16.00	18.00	2.00	SANDSTONE AND SHALE : dark grey; fresh; carbonaceous.
18.00	24.00	6.00	SANDSTONE AND SHALE : light grey; fresh. Dry.

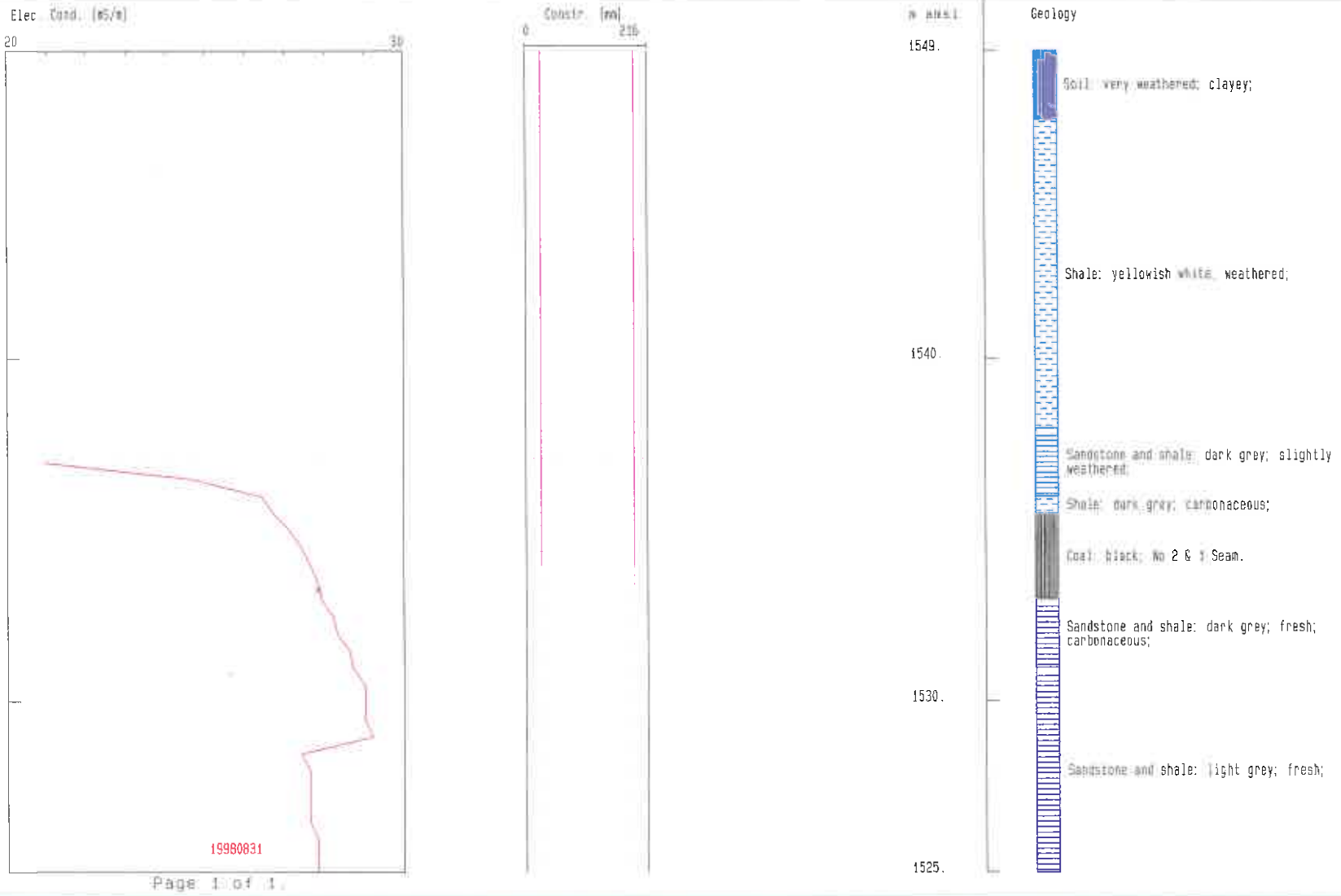
Geohydrology

(no information.)

Site-ID : 2529CC00024 Nr on Map : BSG-PB24

* HydroGraph * Borehole log : DWA BLESBOKSPRUIT

Coordinates :-17900.68(E-W) 2857705.55(N-S) 1548.96(Ground elevation) Date Plotted: Sep 17 1998



Site name : DWA - BLESBOKSPRUIT : BSG-PB25
Notes :

Site ID: 2529CC00025 Number on map: BSG-PB25

E-W coordinate : -18523.52 N-S coordinate : 2858515.49
Ground Elevation: 1556.35 mamsl Collar Height: 0.34 m
Depth of Casing: 18.00 m Diameter of Hole: 165 mm
Logged by: Date Drilled: 19980723

Depth (m) from	to	Thickness (m)	Description

Geology

0.00	1.00	1.00	SOIL : reddish brown. And highly weathered sandstone.
1.00	2.00	1.00	SANDSTONE : very weathered. Slightly moist.
2.00	7.00	5.00	SANDSTONE AND SHALE : yellowish brown; very weathered. Slightly moist.
7.00	8.00	1.00	SILTSTONE : Highly weathered; purple brown. Slightly moist.
8.00	11.00	3.00	SILTSTONE : Weathered, well fractured; purple brown. Slightly moist.
11.00	15.00	4.00	COAL : Weathered and slightly moist on 1 metre. No 2 & 1 Seam.
15.00	18.00	3.00	SANDSTONE AND SHALE : light grey; slightly weathered. Dry.

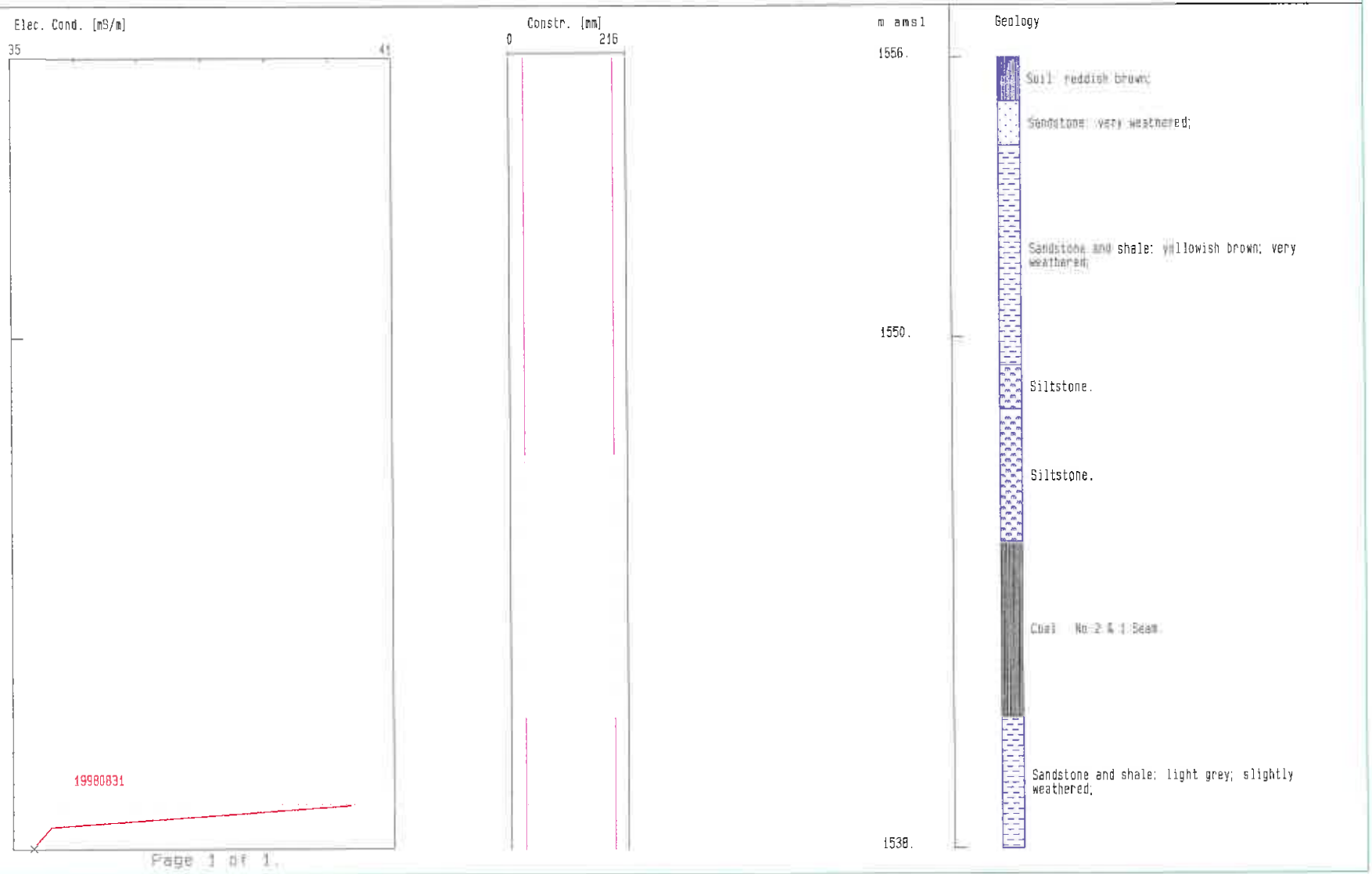
Geohydrology

(no information.)

Site-ID : 2529CC00025 Nr on Map : BSG-PB25

* HydroGraph * Borehole log : DWA BLESBOKSPRUIT

Coordinates : -18523.52 (E-W) 2858515.49 (N-S) 1556.35 (Ground elevation) Date Plotted: Sep 10 1998



Site name : DWA - BLESBOKSPRUIT : BSG-PB26
Notes :

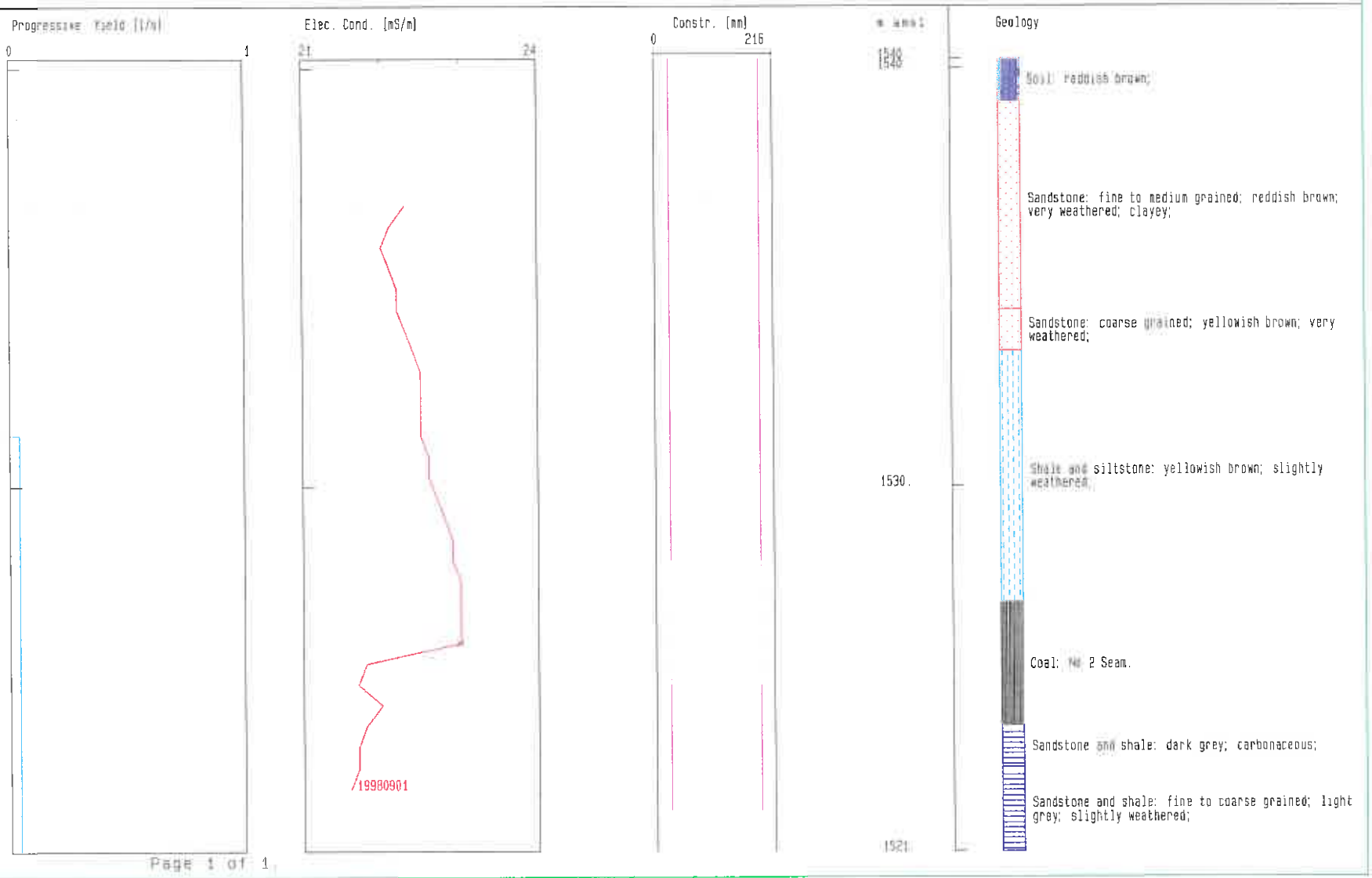
Site ID: 2529CC00026
Number on map: BSG-PB26
E-W coordinate : -17022.92
N-S coordinate : 2857017.06
Ground Elevation: 1540.23 mamsl
Collar Height: 0.27 m
Depth of Casing: 18.00 m
Diameter of Hole: 165 mm
Logged by: JMA
Date Drilled: 19980724

Depth (m) from	to	Thickness (m)	Description
Geology			
0.00	1.00	1.00	SOIL : reddish brown. Dry.
1.00	6.00	5.00	SANDSTONE : fine to medium grained; reddish brown; very weathered; clayey. Moist.
6.00	7.00	1.00	SANDSTONE : coarse grained; yellowish brown; very weathered. Slightly moist.
7.00	13.00	6.00	SHALE AND SILTSTONE : yellowish brown; slightly weathered. Moist.
13.00	16.00	3.00	COAL : No 2 Seam.
16.00	17.00	1.00	SANDSTONE AND SHALE : dark grey; carbonaceous.
17.00	19.00	2.00	SANDSTONE AND SHALE : fine to coarse grained; light grey; slightly weathered.
Geohydrology			
9.00	13.00	4.00	0.04 L/sec (estimated). According to JMA Geotechnician

Site-ID : 2529CC00026 Nr on Map : BSG-PB26

* HydroGraph * Borehole log : DWA BLESBOKSPRUIT

Coordinates : -17022.92 (E-W) 2857017.06 (N-S) 1540.23 (Ground elevation) Date Plotted: Sep 09 1998



Site name : DWA - BLESBOKSPRUIT : BSG-PB29
Notes :

Site ID: 2529CC00029
Number on map: BSG-PB29

E-W coordinate : -17803.71
N-S coordinate : 2859110.92
Ground Elevation: 1549.17 mamsl
Collar Height: 0.44 m
Depth of Casing: 18.00 m
Diameter of Hole: 165 mm
Logged by:
Date Drilled: 19980728

Depth (m) from	to	Thickness (m)	Description
Geology			
0.00	1.00	1.00	SOIL : very weathered. Soil and sandstone.
1.00	4.00	3.00	SANDSTONE : fine to coarse grained; reddish brown; very weathered. Clayey, slightly moist.
4.00	8.00	4.00	SHALE : pinkish brown; very weathered. Dry.
8.00	9.00	1.00	SILTSTONE : purple brown. Dry.
9.00	12.00	3.00	SHALE AND SILTSTONE : light grey; slightly weathered. Dry.
12.00	13.00	1.00	SHALE : dark grey; fresh; carbonaceous. Dry.
13.00	14.00	1.00	COAL : No 2 & 1 Seam.
14.00	17.00	3.00	SANDSTONE AND SHALE : light grey; fresh. Dry.

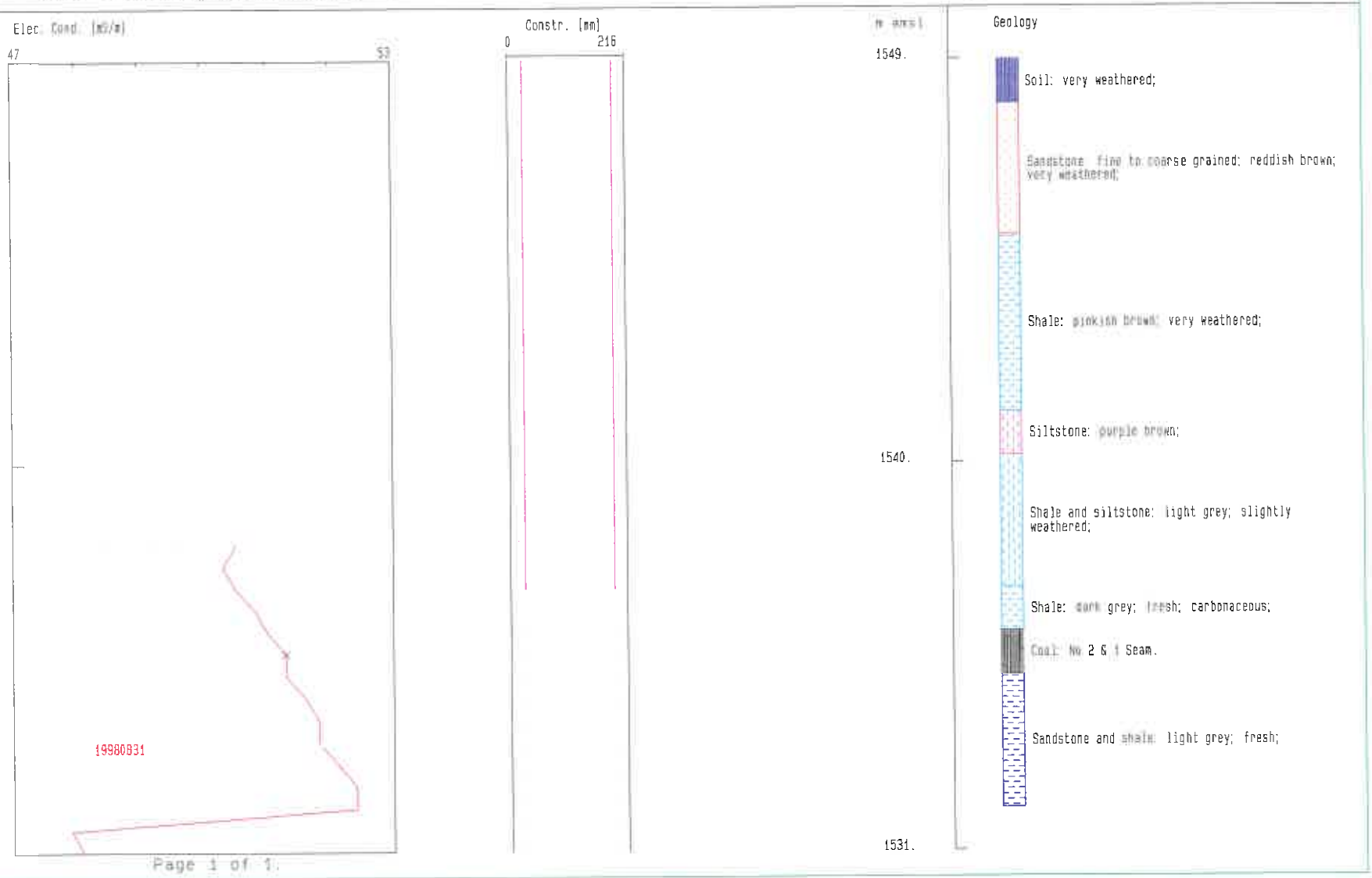
Geohydrology

(no information.)

Site-ID : 2529CC00029 Nr on Map : BSG-PB29

* HydroGraph * Borehole log : DWA BLESBOKSPRUIT

Coordinates : -17803.71 (E-W) 2859110.92 (N-S) 1549.17 (Ground elevation) Date Plotted: Feb 16 1999



Site name : DWA - BLESBOKSPRUIT : BSG-PB35
Notes :

Site ID: 2529CC00035
Number on map: BSG-PB35

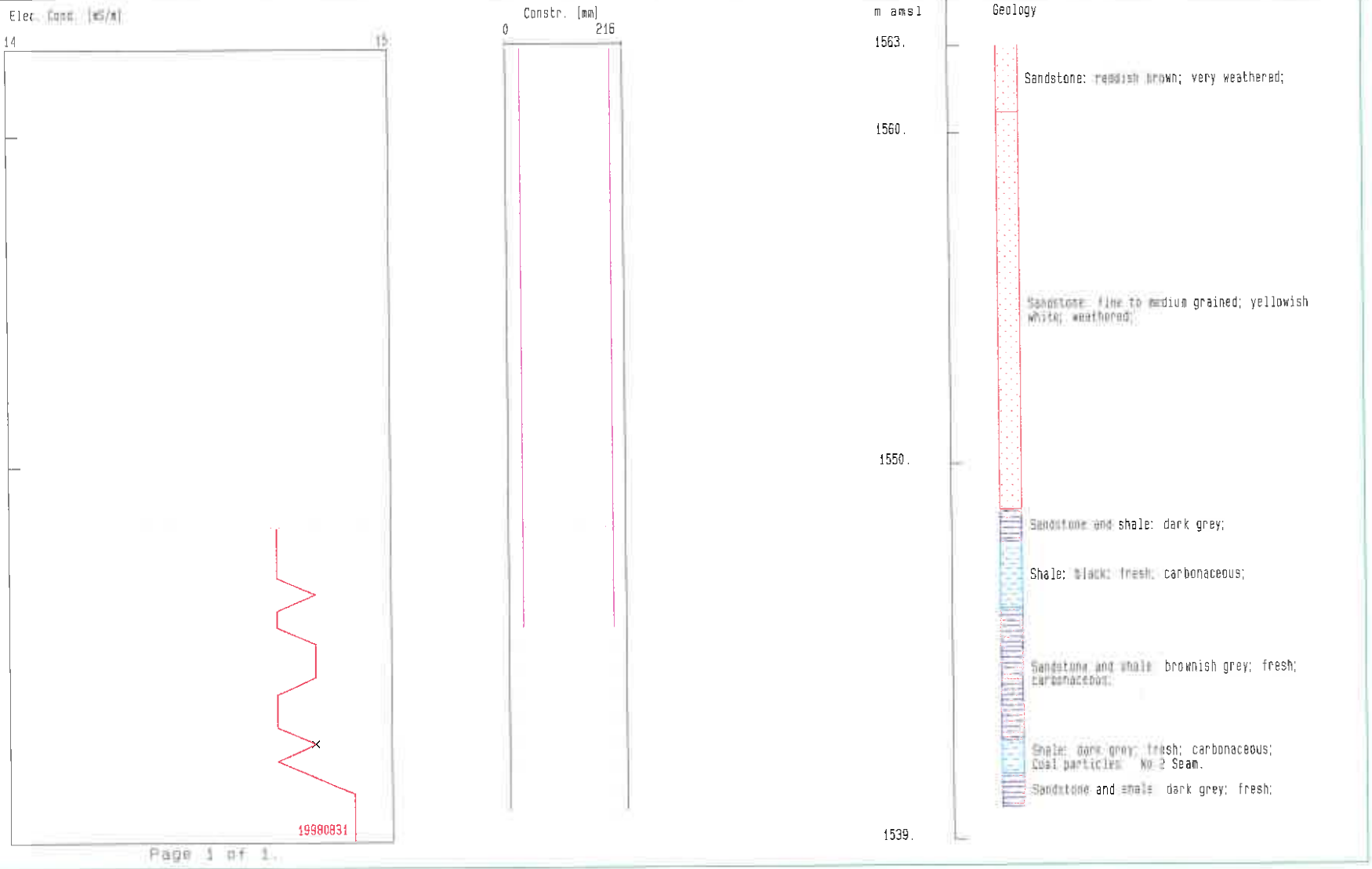
E-W coordinate : -19288.16
N-S coordinate : 2861644.19
Ground Elevation: 1562.63 mamsl
Collar Height: 0.68 m
Depth of Casing: 23.50 m
Diameter of Hole: 165 mm
Logged by:
Date Drilled: 19980728

Depth (m) from	to	Thickness (m)	Description
Geology			
0.00	2.00	2.00	SANDSTONE : reddish brown; very weathered. Dry.
2.00	14.00	12.00	SANDSTONE : fine to medium grained; yellowish white; weathered. Dry.
14.00	15.00	1.00	SANDSTONE AND SHALE : dark grey. Dry.
15.00	17.00	2.00	SHALE : black; fresh; carbonaceous.
17.00	21.00	4.00	SANDSTONE AND SHALE : brownish grey; fresh; carbonaceous. Dry.
21.00	22.00	1.00	SHALE : dark grey; fresh; carbonaceous. Dry. Coal particles. No 2 Seam.
22.00	23.00	1.00	SANDSTONE AND SHALE : dark grey; fresh. Dry.
Geohydrology			
(no information.)			

Site-ID : 2529CC00035 Nr on Map : BSG-PB35

* HydroGraph * Borehole log : DWA BLESBOKSPRUIT

Coordinates : -19288.16(E-W) 2861644.19(N-S) 1562.63(Ground elevation) Date Plotted: Sep 17 1998



Site name : DWA - BLESBOKSPRUIT : BSG-PB37
Notes :

Site ID: 2529CC00037
Number on map: BSG-PB37

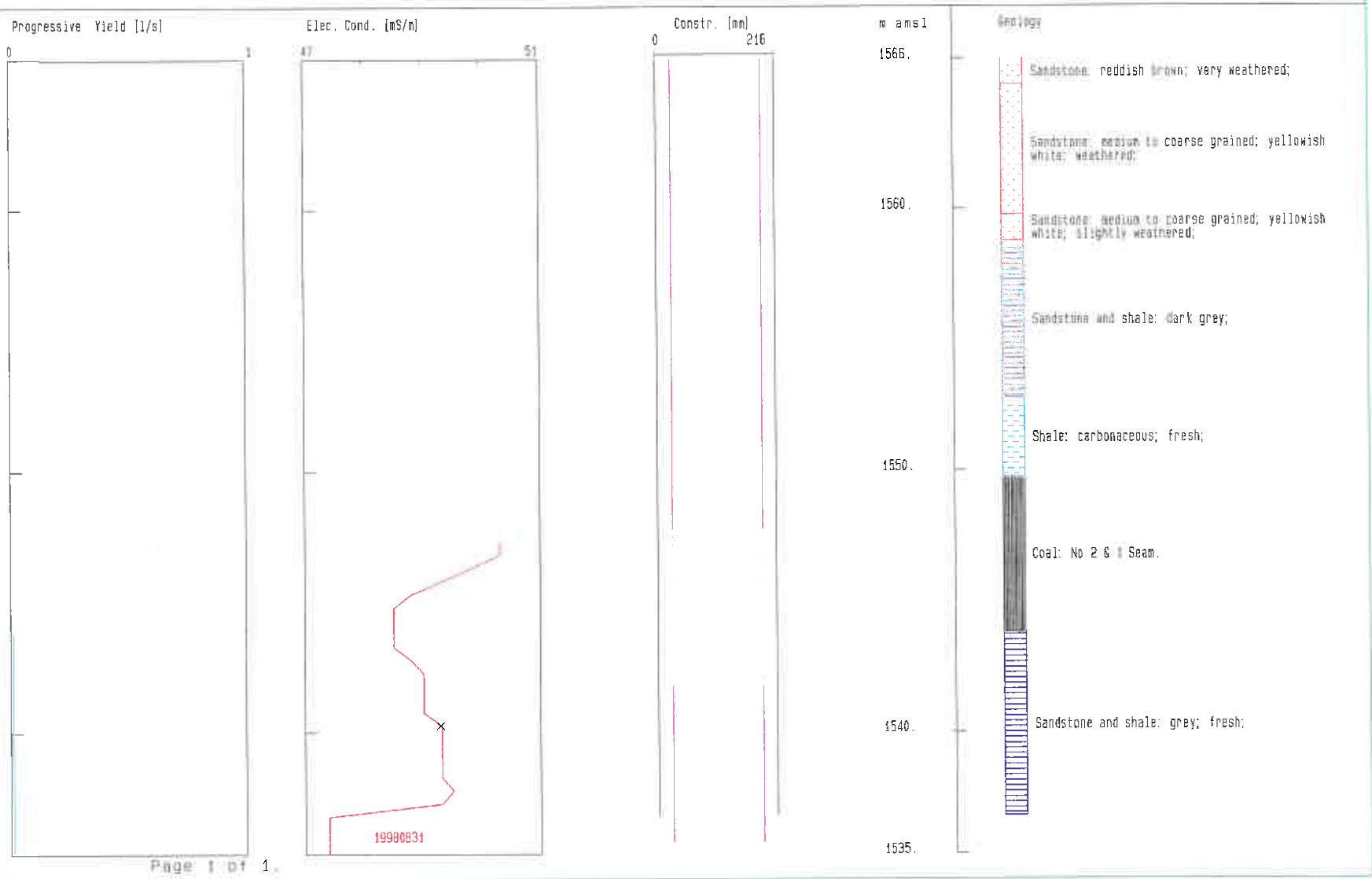
E-W coordinate : -20378.05
N-S coordinate : 2861461.72
Ground Elevation: 1565.78 mamsl
Collar Height: 0.36 m
Depth of Casing: 30.00 m
Diameter of Hole: 165 mm
Logged by: JMA
Date Drilled: 19980729

Depth (m) from	to	Thickness (m)	Description
Geology			
0.00	1.00	1.00	SANDSTONE : reddish brown; very weathered. Slightly moist.
1.00	6.00	5.00	SANDSTONE : medium to coarse grained; yellowish white; weathered. Slightly moist.
6.00	7.00	1.00	SANDSTONE : medium to coarse grained; yellowish white; slightly weathered.
7.00	13.00	6.00	SANDSTONE AND SHALE : dark grey.
13.00	16.00	3.00	SHALE : carbonaceous; fresh.
16.00	22.00	6.00	COAL : No 2 & 1 Seam.
22.00	29.00	7.00	SANDSTONE AND SHALE : grey; fresh. Seepage water from 25m.
Geohydrology			
22.00	29.00	7.00	0.01 L/sec (estimated). According to JMA Geotechnician

Site-ID : 2529CC00037 Nr on Map : BSG-PB37

* HydroGraph * Borehole log : DWA BLESBOKSPRUIT

Coordinates : -20378.05 (E-W) 2861461.72 (N-S) 1565.78 (Ground elevation) Date Plotted: Sep 21 1998



Site name : DWA - BLESBOKSPRUIT - BSG-PB39
Notes :

Site ID: 2529CC00039
Number on map: BSG-PB39
E-W coordinate : -22407.62
N-S coordinate : 2860059.90
Ground Elevation: 1559.85 mamsl
Collar Height: 0.42 m
Depth of Casing: 30.00 m
Diameter of Hole: 165 mm
Logged by:
Date Drilled: 19980731

Depth (m) from	to	Thickness (m)	Description
Geology			
0.00	1.00	1.00	SOIL : reddish brown. And highly weathered sandstone. Dry.
1.00	3.00	2.00	SANDSTONE AND SHALE : yellowish brown; very weathered. Dry.
3.00	4.00	1.00	SANDSTONE : fine to medium grained; yellowish white; very weathered. Dry.
4.00	9.00	5.00	SANDSTONE : fine to coarse grained; yellowish white; weathered. Dry.
9.00	13.00	4.00	SANDSTONE : fine to medium grained; yellowish brown; weathered. Slightly moist.
13.00	19.00	6.00	SHALE : dark grey; slightly weathered; carbonaceous. Slightly moist.
19.00	26.00	7.00	COAL : black. No 2 Seam.
26.00	27.00	1.00	SANDSTONE AND SHALE : dark grey; fresh. Dry.
27.00	28.00	1.00	COAL : And fresh sandstone and shale - dark grey to black. Dry. No 1 Seam.
28.00	30.00	2.00	SANDSTONE AND SHALE : dark grey. Dry.

Geohydrology

(no information.)

Site name : DWA - BLESBOKSPRUIT : BSG-B19
Notes :

Site ID: 2529CC00019 Number on map: BSG-B19

E-W coordinate : -24795.87 N-S coordinate : 2858701.33
Ground Elevation: 1489.41 mamsl Collar Height: 0.34 m
Depth of Casing: 24.00 m Diameter of Hole: 165 mm
Logged by: Date Drilled: 19980731

Depth (m) from	to	Thickness (m)	Description

Geology

0.00	1.00	1.00	SOIL : fine to medium grained; very weathered. Soil and sandstone. Moist.
1.00	5.00	4.00	SANDSTONE AND SHALE : fine grained; yellowish brown; very weathered. Slightly moist.
5.00	7.00	2.00	SANDSTONE AND SHALE : fine grained; reddish brown; very weathered. Moist.
7.00	10.00	3.00	SANDSTONE : fine grained; brown; very weathered; clayey. Moist.
10.00	18.00	8.00	SILTSTONE : purple; slightly weathered; clayey. Moist.
18.00	21.00	3.00	TILLITE : very fractured; weathered. Slightly moist.
21.00	24.00	3.00	TILLITE : slightly weathered; fresh.

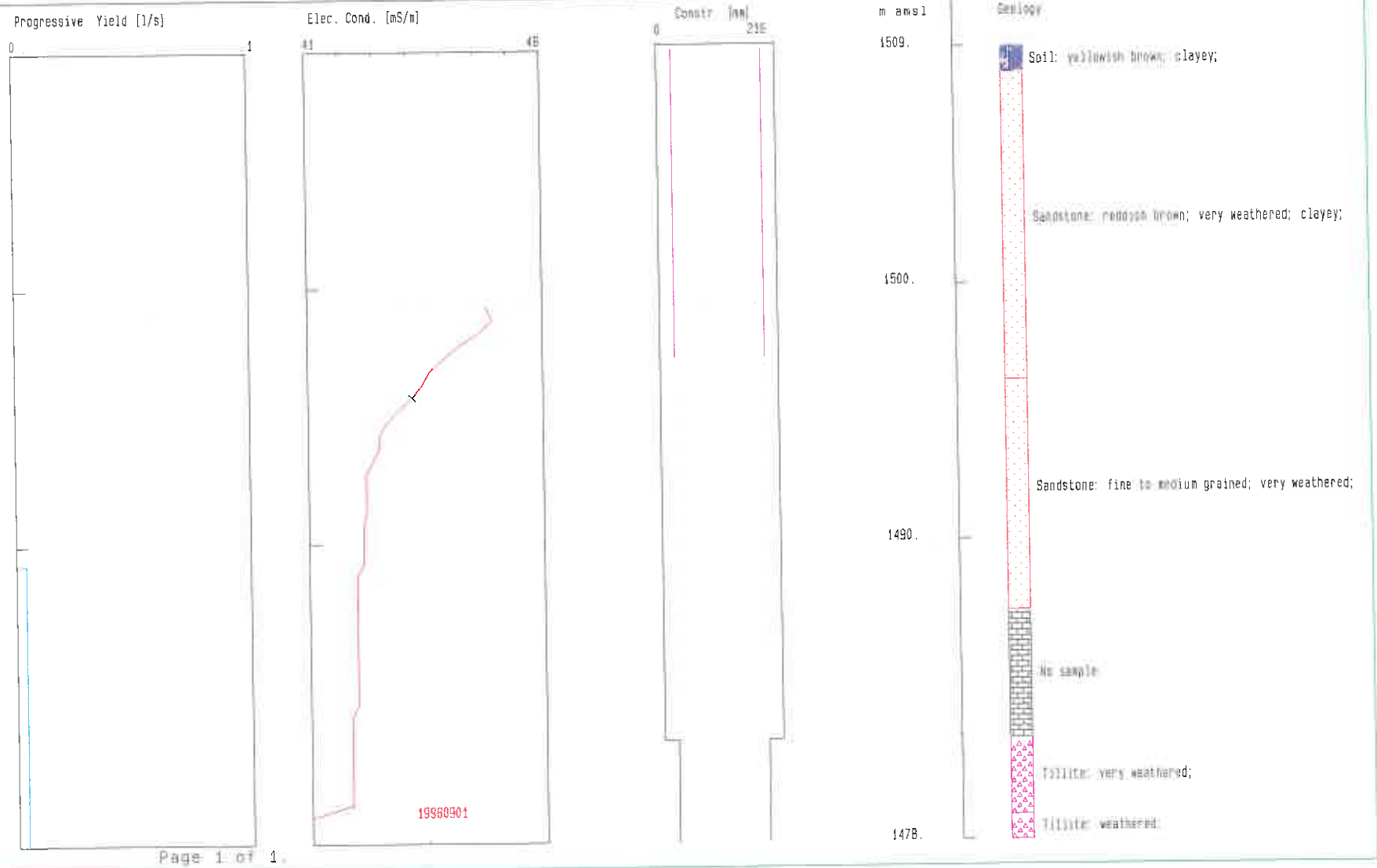
Geohydrology

(no information.)

Site-ID : 2529CC00018 Nr on Map : BSG-B18

* HydroGraph * Borehole log : DWA BLESBOKSPRUIT

Coordinates : -24410.26(E-W) 2858572.53(N-S) 1509.26(Ground elevation) Date Plotted: Sep 08 1998



Site name : DWA - BLESBOKSPRUIT : BSG-B17
Notes :

Site ID: 2529CC00017
Number on map: BSG-B17
E-W coordinate : -23922.78
N-S coordinate : 2857722.88
Ground Elevation: 1533.90 mamsl
Collar Height: 0.56 m
Depth of Casing: 15.00 m
Diameter of Hole: 165 mm
Logged by: JMA
Date Drilled: 19980721

Depth (m) from	to	Thickness (m)	Description
Geology			
0.00	1.00	1.00	SOIL : very weathered; clayey. Soil and sandstone. Moist.
1.00	2.00	1.00	SANDSTONE : fine to medium grained; reddish brown; very weathered; clayey. Moist.
2.00	3.00	1.00	SANDSTONE : fine to medium grained; very weathered; clayey. Moist.
3.00	7.00	4.00	SANDSTONE : fine to medium grained; very weathered; clayey. Moist.
7.00	13.00	6.00	SANDSTONE : fine to medium grained; very weathered.
13.00	14.00	1.00	SANDSTONE AND SHALE : very weathered.
14.00	19.00	5.00	SANDSTONE : fine to medium grained. Tillite layer starts at 19m.
Geohydrology			
8.00	13.00	5.00	0.25 L/sec (estimated). According to JMA Geotechnician

Site-ID 2529CC00017 Nr on Map : BSG-B17

* HydroGraph * Borehole log : DWA BLESBOKSPRUIT

Coordinates : -23922.78 (E-W) 2857722.88 (N-S) 1533.90 (Ground elevation) Date Plotted: Sep 16 1998

Site name : DWA - BLESBOKSPRUIT : BSG-18
Notes :

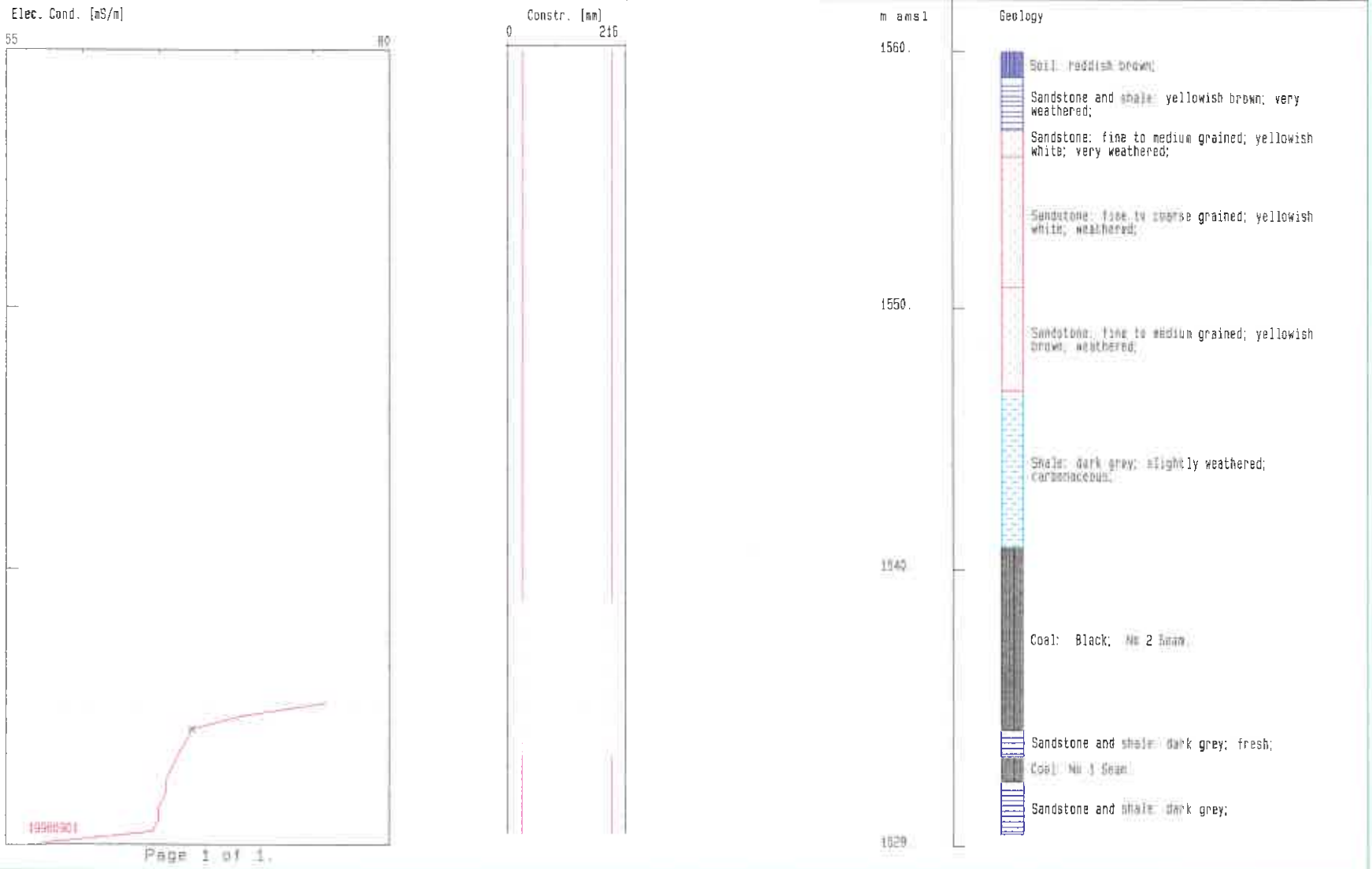
Site ID: 2529CC00018	Number on map: BSG-B18
E-W coordinate : -24410.26	N-S coordinate : 2858572.53
Ground Elevation: 1509.26 mamsl	Collar Height: 0.67 m
Depth of Casing: 27.00 m	Diameter of Hole: 165 mm
Logged by: JMA	Date Drilled: 19980721

Depth (m) from	to	Thickness (m)	Description
Geology			
0.00	1.00	1.00	SOIL : yellowish brown; clayey. Moist.
1.00	13.00	12.00	SANDSTONE : reddish brown; very weathered; clayey. Moist.
13.00	22.00	9.00	SANDSTONE : fine to medium grained; very weathered. Moist at 19m.
22.00	27.00	5.00	NO SAMPLE :
27.00	30.00	3.00	TILLITE : very weathered.
30.00	31.00	1.00	TILLITE : weathered.
Geohydrology			
20.00	22.00	2.00	0.04 L/sec (estimated). According to JMA Geotechnician

Site-ID : 2529CC00039 Nr on Map : BSG-P839

* HydroGraph * Borehole log : DWA BLESBOKSPRUIT

Coordinates : -22407.62(E-W) 2860859.90(N-S) 1559.65(Ground elevation) Date Plotted: Sep 21 1998



PLUME MONITORING BOREHOLES

Site name : DWA BLESBOKSPRUIT : BOREHOLE NO. BSG-RB1
Notes :

Site ID: 2529CC00001
Number on map: BSG-RB1

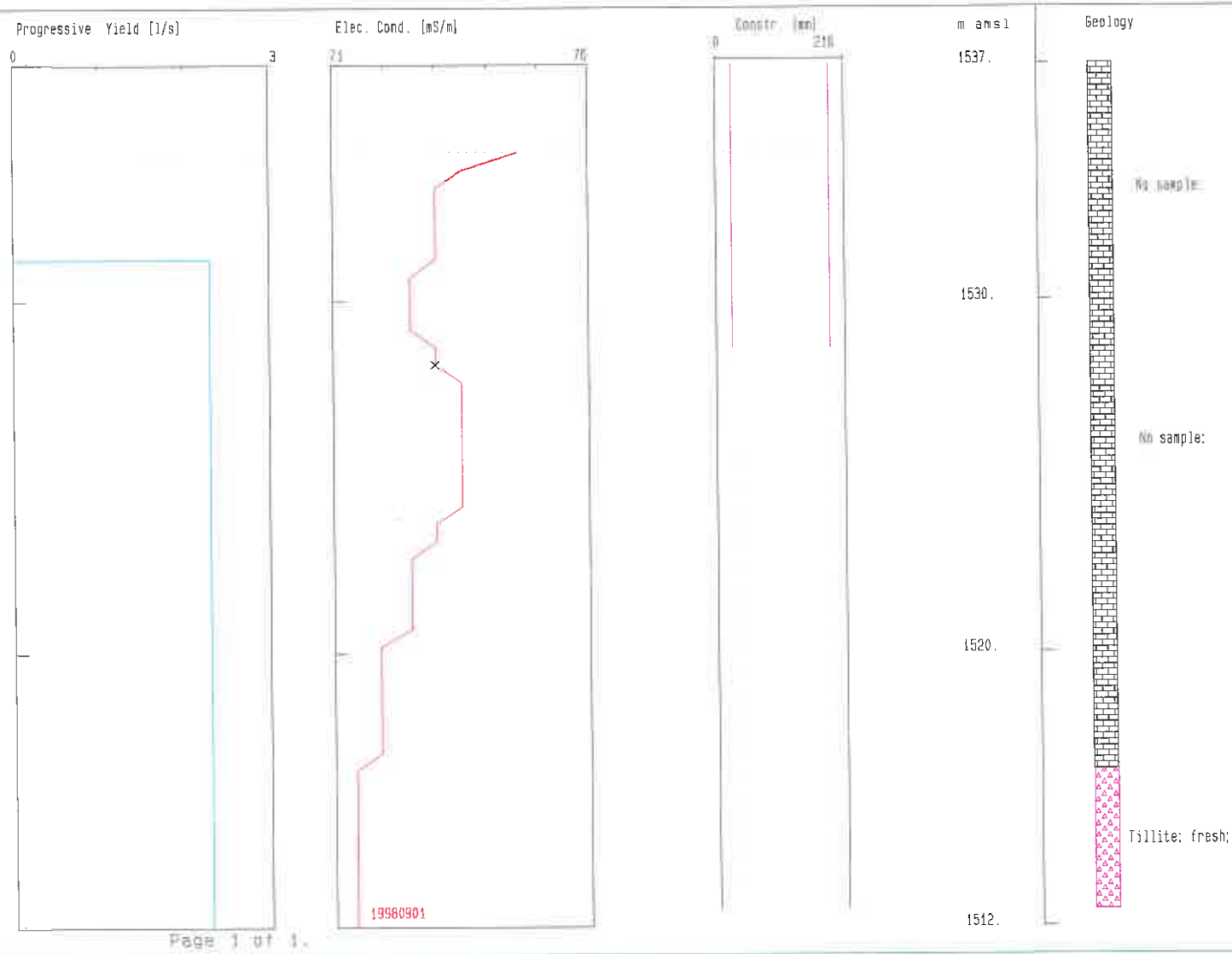
E-W coordinate : -21103.49
N-S coordinate : 2859788.96
Ground Elevation: 1536.70 mamsl
Collar Height: 2.04 m
Depth of Casing: 24.00 m
Diameter of Hole: 165 mm
Logged by: JMA
Date Drilled: 19980713

Depth (m) from	to	Thickness (m)	Description
Geology			
0.00	10.00	10.00	NO SAMPLE : Backfill: Sandstone and shale. Waterstrike at 5.5m
10.00	20.00	10.00	NO SAMPLE : Pitfloor.
20.00	24.00	4.00	TILLITE : fresh.
Geohydrology			
5.50	20.00	14.50	2.30 L/sec (estimated). According to JMA Geotechnician

Site-ID : 2529CC00001 Nr on Map : BSG-RB1

* HydroGraph * Borehole log : DWA BLESBOKSPRUIT

Coordinates : -21103.49 (E-W) 2859788.96 (N-S) 1536.70 (Ground elevation) Date Plotted: Sep 07 1998



Site name : DWA - BLESBOKSPRUIT : BSG-B2
Notes :

Site ID: 2529CC00002 Number on map: BSG-B2

E-W coordinate : -21192.57 N-S coordinate : 2859928.69
Ground Elevation: 1533.81 mamsl Collar Height: 0.47 m
Depth of Casing: 9.00 m Diameter of Hole: 165 mm
Logged by: Date Drilled: 19980713

Depth (m) from	to	Thickness (m)	Description
Geology			
0.00	1.00	1.00	SANDSTONE : brown; very weathered. Moist.
1.00	3.00	2.00	SANDSTONE : brown; very weathered; clayey. Moist.
3.00	4.00	1.00	SANDSTONE : yellowish brown; very weathered; clayey. Moist.
4.00	5.00	1.00	SANDSTONE : yellowish brown; very weathered; clayey. Moist. Coal layers.
5.00	6.00	1.00	COAL : No 1 Seam greyish black; slightly weathered. Carbonaceous shale.
6.00	8.00	2.00	SANDSTONE : fine to medium grained; light grey; slightly weathered. Slightly moist.
8.00	13.00	5.00	SANDSTONE : light grey; fresh. Slightly moist.
13.00	18.00	5.00	TILLITE : fresh.

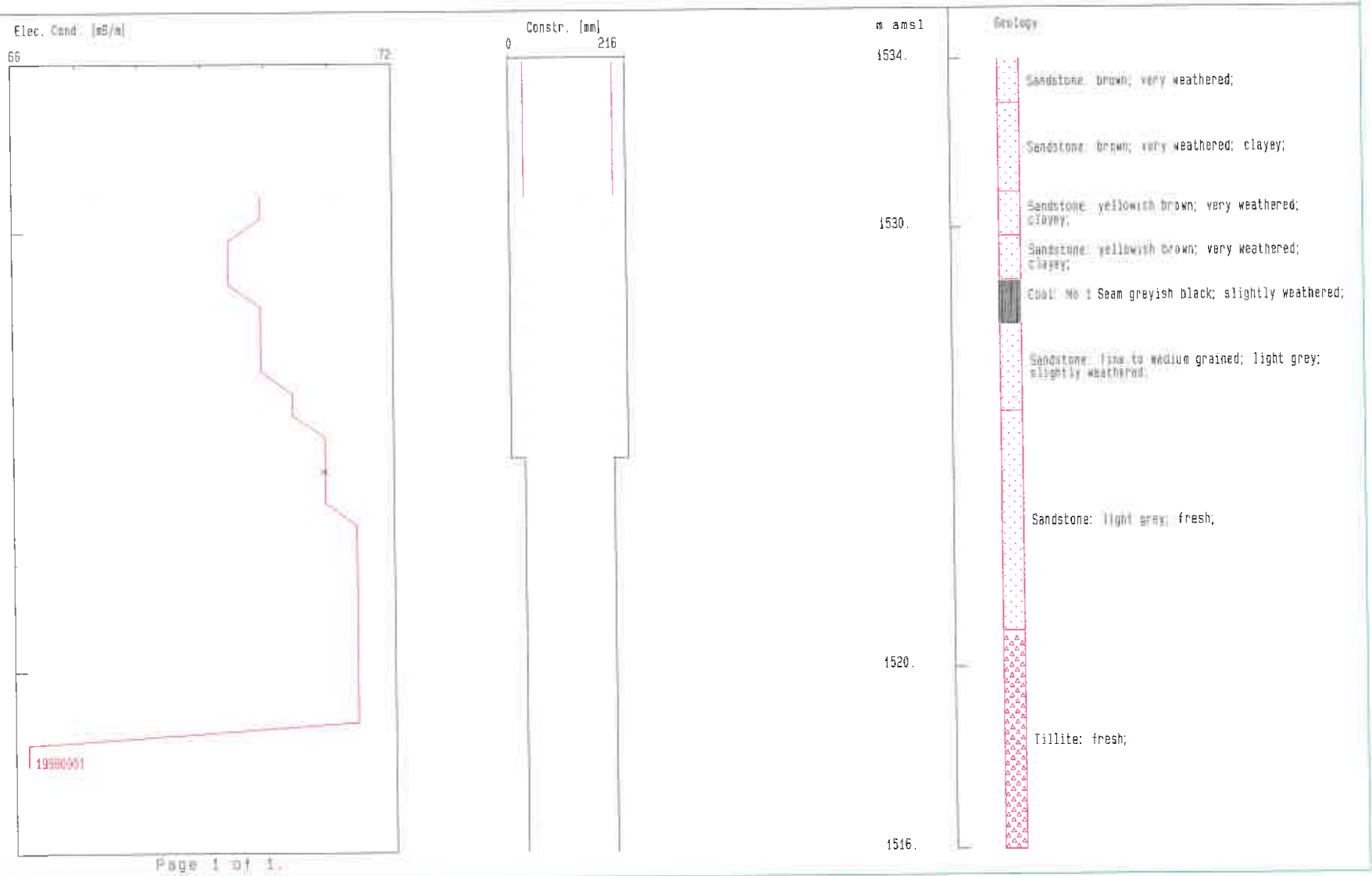
Geohydrology

(no information.)

Site-ID : 2529CC00002 Nr on Map : BSG-B2

* HydroGraph * Borehole log : DWA BLESBOKSPRUIT

Coordinates : 21192.57 (E-W) 2859928.69 (N-S) 1533.81 (Ground elevation) Date Plotted: Sep 07 1998



Site name : DWA - BLESBOKSPRUIT : BSG-B3
Notes :

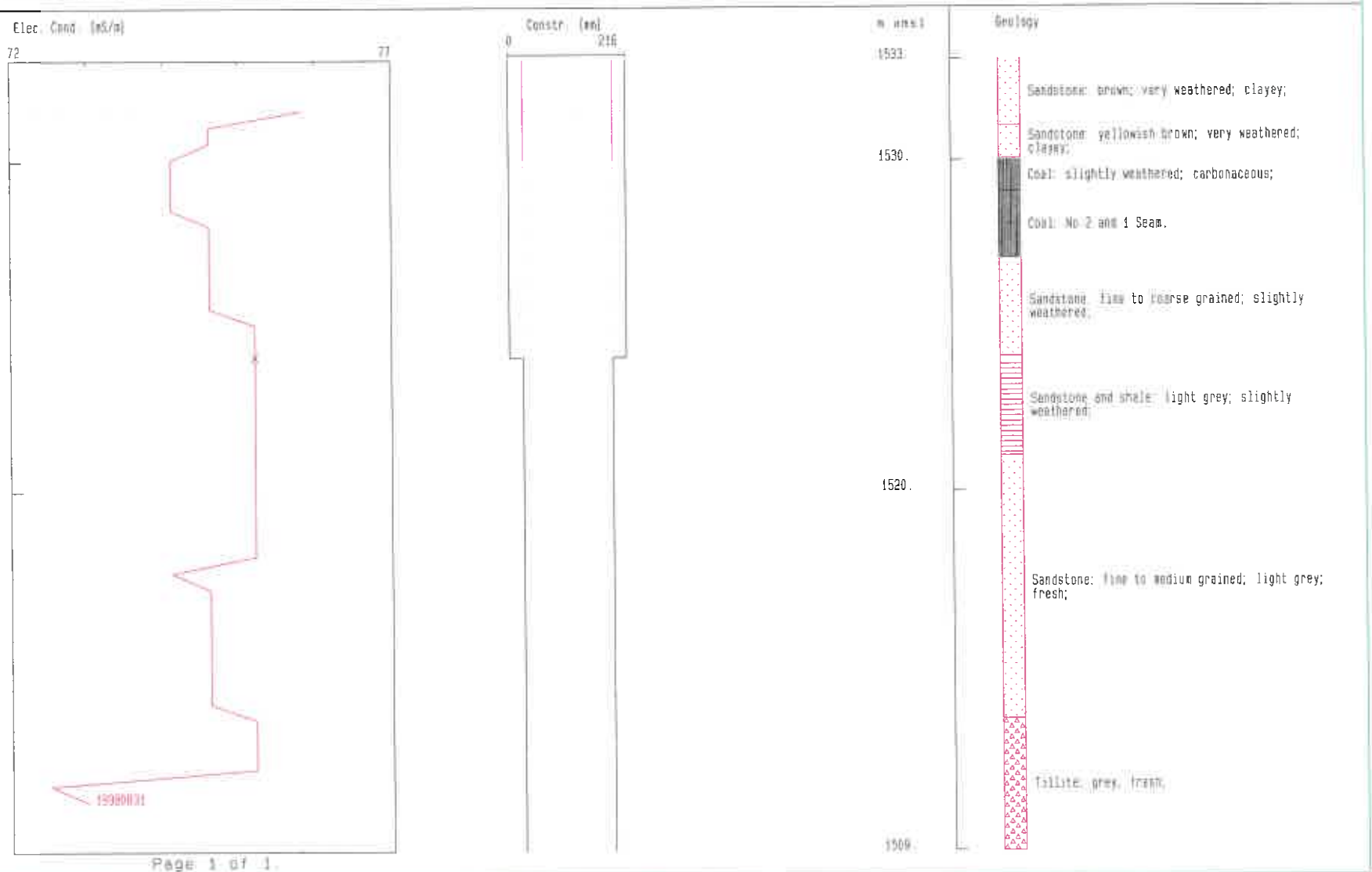
Site ID: 2529CC00003	Number on map: BSG-B3
E-W coordinate : -21198.77	N-S coordinate : 2859749.35
Ground Elevation: 1533.05 mamsl	Collar Height: 0.56 m
Depth of Casing: 9.00 m	Diameter of Hole: 165 mm
Logged by:	Date Drilled: 19980713

Depth (m) from	to	Thickness (m)	Description
Geology			
0.00	2.00	2.00	SANDSTONE : brown; very weathered; clayey. Moist.
2.00	3.00	1.00	SANDSTONE : yellowish brown; very weathered; clayey. Moist.
3.00	4.00	1.00	COAL : slightly weathered; carbonaceous.
4.00	6.00	2.00	COAL : No 2 & 1 Seam
6.00	9.00	3.00	SANDSTONE : fine to coarse grained; slightly weathered. Slightly moist.
9.00	12.00	3.00	SANDSTONE AND SHALE : light grey; slightly weathered. Slightly moist.
12.00	20.00	8.00	SANDSTONE : fine to medium grained; light grey; fresh. Dry.
20.00	24.00	4.00	TILLITE : grey; fresh.
Geohydrology			
(no information.)			

Site-ID : 2529CC00003 Nr on Map : BSG-B3

× HydroGraph × Borehole log : DWA BLESBOKSPRUIT

Coordinates : -21198.77(E-W) 2859749.35(N-S) 1533.05(Ground elevation) Date Plotted: Sep 07 1998



Site name : DWA - BLESBOKSPRUIT : BSG-B4
Notes :

Site ID: 2529CC00004
Number on map: BSG-B4
E-W coordinate : -21086.32
N-S coordinate : 2859500.00
Ground Elevation: 1534.03 mamsl
Collar Height: 0.38 m
Depth of Casing: 9.00 m
Diameter of Hole: 165 mm
Logged by:
Date Drilled: 19980715

Depth (m) from	to	Thickness (m)	Description
Geology			
0.00	7.00	7.00	CLAY : reddish brown. Moist.
7.00	9.00	2.00	SANDSTONE : fine to medium grained; very weathered. Moist.
9.00	19.00	10.00	SANDSTONE AND SHALE : dark grey; fresh. Dry.
19.00	32.00	13.00	SANDSTONE AND SHALE : light grey. Dry.
32.00	33.00	1.00	TILLITE : fresh. Dry.

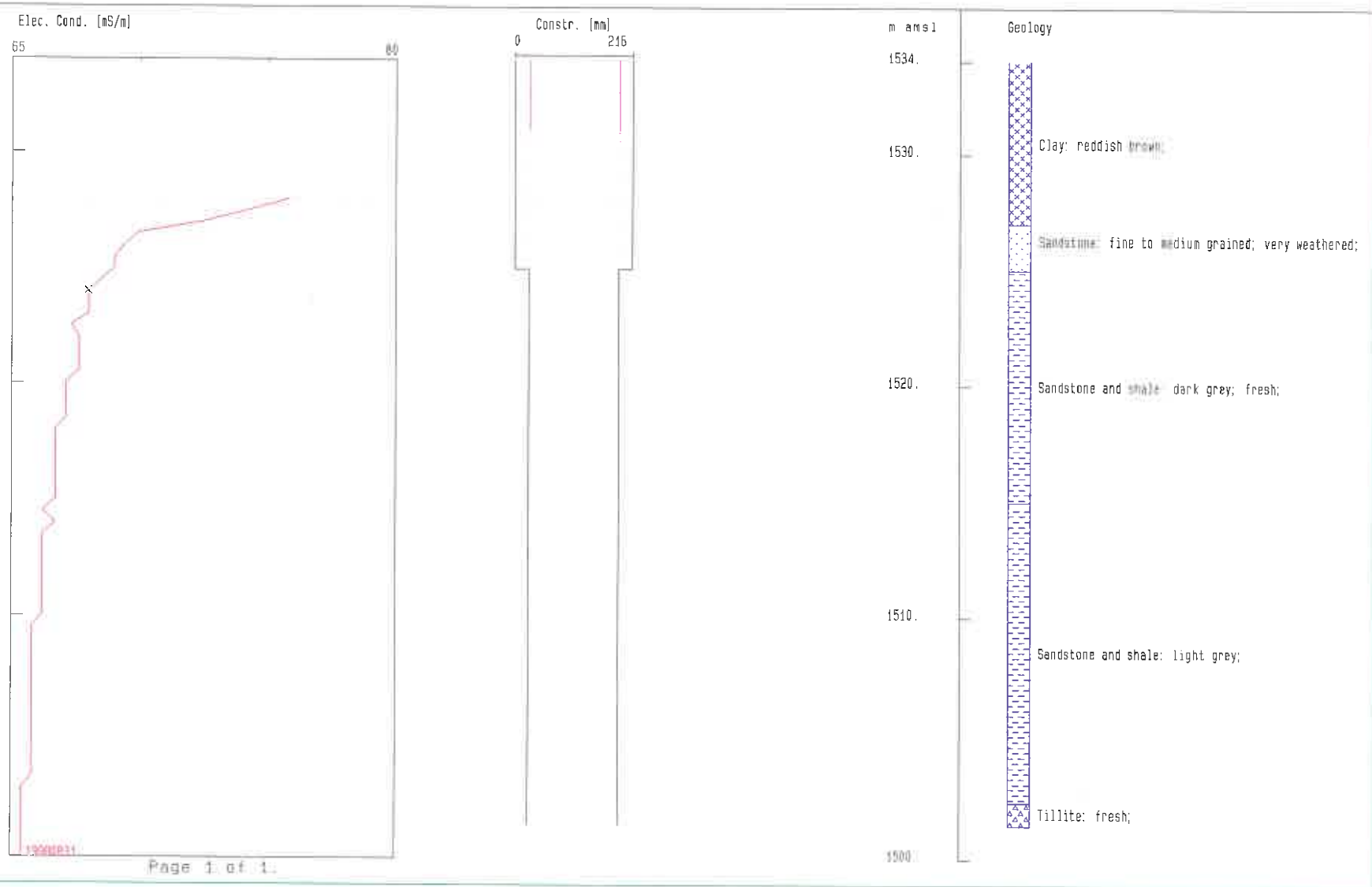
Geohydrology

(no information.)

Site-ID : 2529CC00004 Nr on Map : BSG-B4

* HydroGraph * Borehole log : DWA BLESBOKSPRUIT

Coordinates :-21086.32(E-W) 2859500.00(N-S) 1534.03(Ground elevation) Date Plotted: Feb 11 1999



Site name : DWA - BLESBOKSPRUIT : BSG-B5
Notes :

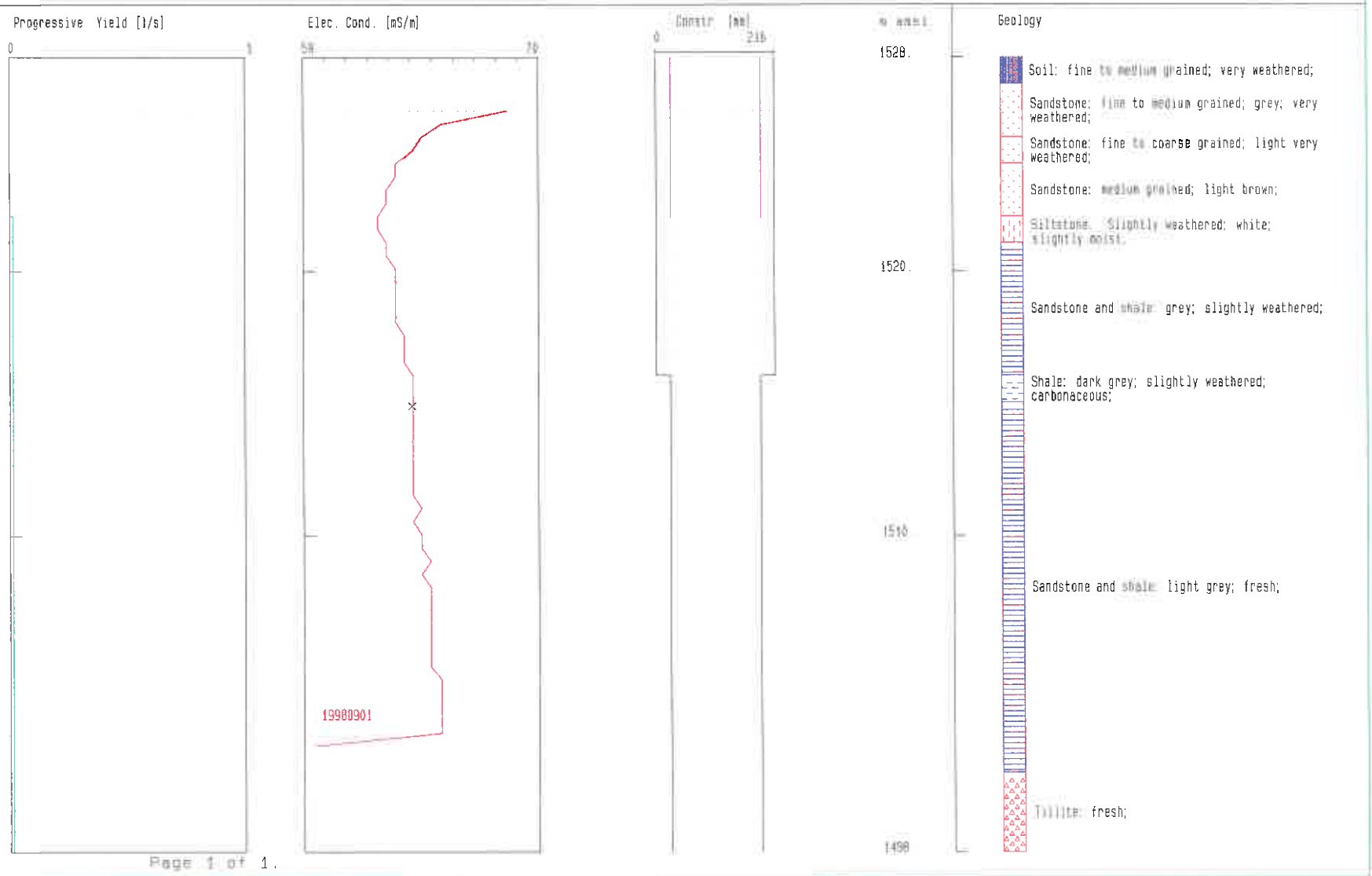
Site ID: 2529CC00005	Number on map: BSG-B5
E-W coordinate : -21227.53	N-S coordinate : 2859303.41
Ground Elevation: 1528.08 mamsl	Collar Height: 0.30 m
Depth of Casing: 12.00 m	Diameter of Hole: 165 mm
Logged by: JMA	Date Drilled: 19980714

Depth (m) from	to	Thickness (m)	Description
Geology			
0.00	1.00	1.00	SOIL : fine to medium grained; very weathered. Soil and sandstone. Moist.
1.00	3.00	2.00	SANDSTONE : fine to medium grained; grey; very weathered. Moist.
3.00	4.00	1.00	SANDSTONE : fine to coarse grained; light very weathered. Moist.
4.00	6.00	2.00	SANDSTONE : medium grained; light brown. Moist.
6.00	7.00	1.00	SILTSTONE : Slightly weathered; white; slightly moist.
7.00	12.00	5.00	SANDSTONE AND SHALE : grey; slightly weathered. Slightly moist.
12.00	13.00	1.00	SHALE : dark grey; slightly weathered; carbonaceous. Dry.
13.00	27.00	14.00	SANDSTONE AND SHALE : light grey; fresh.
27.00	30.00	3.00	TILLITE : fresh. Red siltstone 30m.
Geohydrology			
6.00	7.00	1.00	0.01 L/sec (estimated). According to JMA Geotechnician

Site-ID : 2529CC00005 Nr on Map : BSG-B5

* HydroGraph * Borehole log : DWA BLESBOKSPRUIT

Coordinates : -21227.53 (E-W) 2859303.41 (N-S) 1528.08 (Ground elevation) Date Plotted: Sep 07 1998



Site name : DWA - BLESBOKSPRUIT : BSG-B6
Notes :

Site ID: 2529CC00006
Number on map: BSG-B6

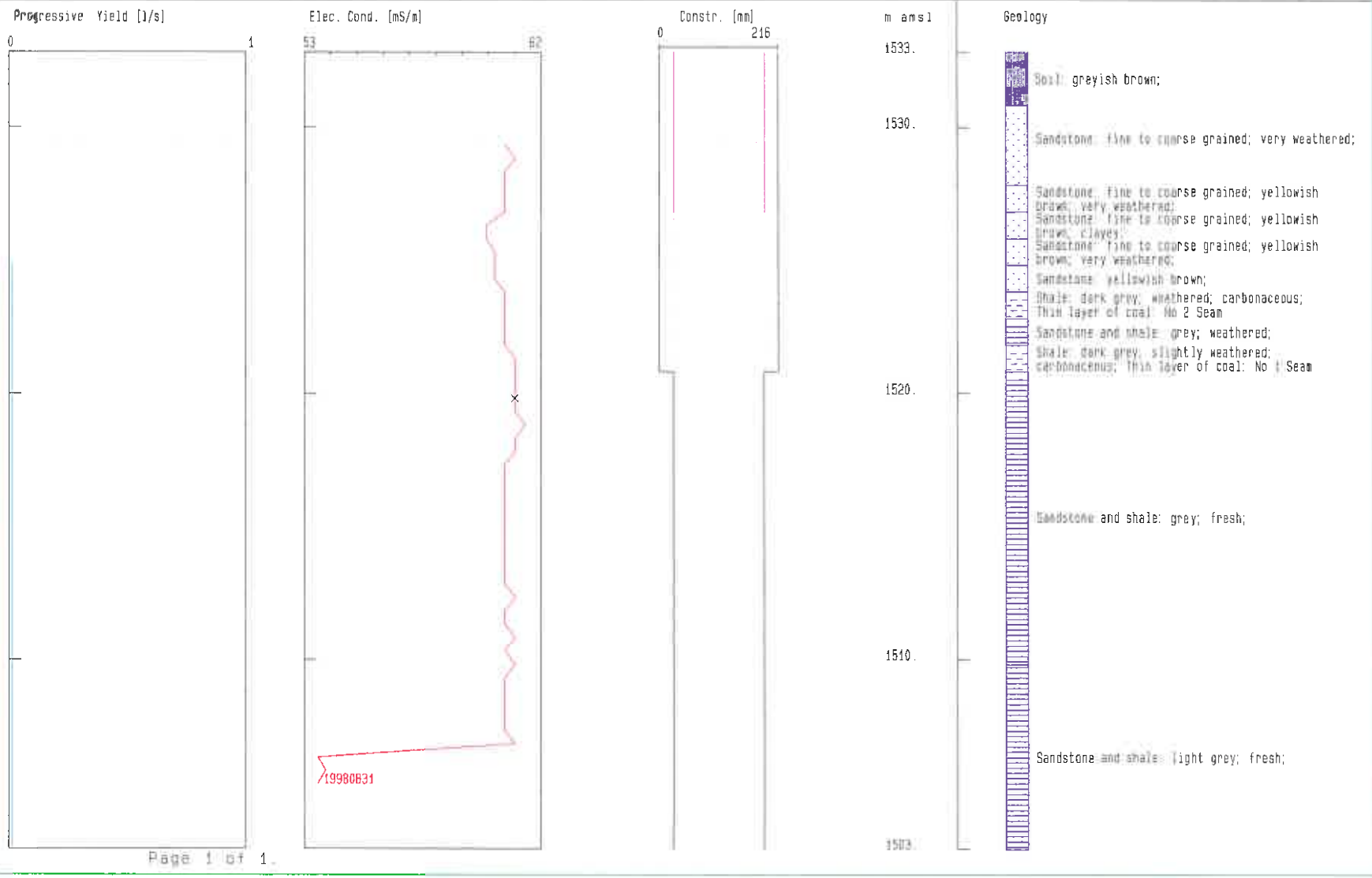
E-W coordinate : -20929.35
N-S coordinate : 2859322.17
Ground Elevation: 1532.84 mamsl
Collar Height: 0.23 m
Depth of Casing: 12.00 m
Diameter of Hole: 165 mm
Logged by: JMA
Date Drilled: 19980714

Depth (m) from	to	Thickness (m)	Description
Geology			
0.00	2.00	2.00	SOIL : greyish brown. Soil and sandstone. Slightly moist.
2.00	5.00	3.00	SANDSTONE : fine to coarse grained; very weathered. Clayey.
5.00	6.00	1.00	SANDSTONE : fine to coarse grained; yellowish brown; very weathered. Moist.
6.00	7.00	1.00	SANDSTONE : fine to coarse grained; yellowish brown; clayey. Red siltstone. Moist.
7.00	8.00	1.00	SANDSTONE : fine to coarse grained; yellowish brown; very weathered. Red siltstone. Moist.
8.00	9.00	1.00	SANDSTONE : yellowish brown. Siltstone/sandstone.
9.00	10.00	1.00	SHALE : dark grey; weathered; carbonaceous. Slightly moist. Thin layer of coal, No 2 Seam.
10.00	11.00	1.00	SANDSTONE AND SHALE : grey; weathered. Very slightly moist.
11.00	12.00	1.00	SHALE : dark grey; slightly weathered; carbonaceous. Thin layer coal, No 1 Seam.
12.00	23.00	11.00	SANDSTONE AND SHALE : grey; fresh. Dry.
23.00	30.00	7.00	SANDSTONE AND SHALE : light grey; fresh. Dry.
Geohydrology			
8.00	9.00	1.00	0.01 L/sec (estimated). According to JMA Geotechnician

Site-ID : 2529CC00006 Nr on Map : BSG-B6

* HydroGraph * Borehole log : DWA BLESBOKSPRUIT

Coordinates : -20929.35 (E-W) 2859322.17 (N-S) 1532.84 (Ground elevation) Date Plotted: Sep 07 1998



Site name : DWA - BLESBOKSPRUIT : BSG-B7
Notes :

Site ID: 2529CC00007 Number on map: BSG-B7

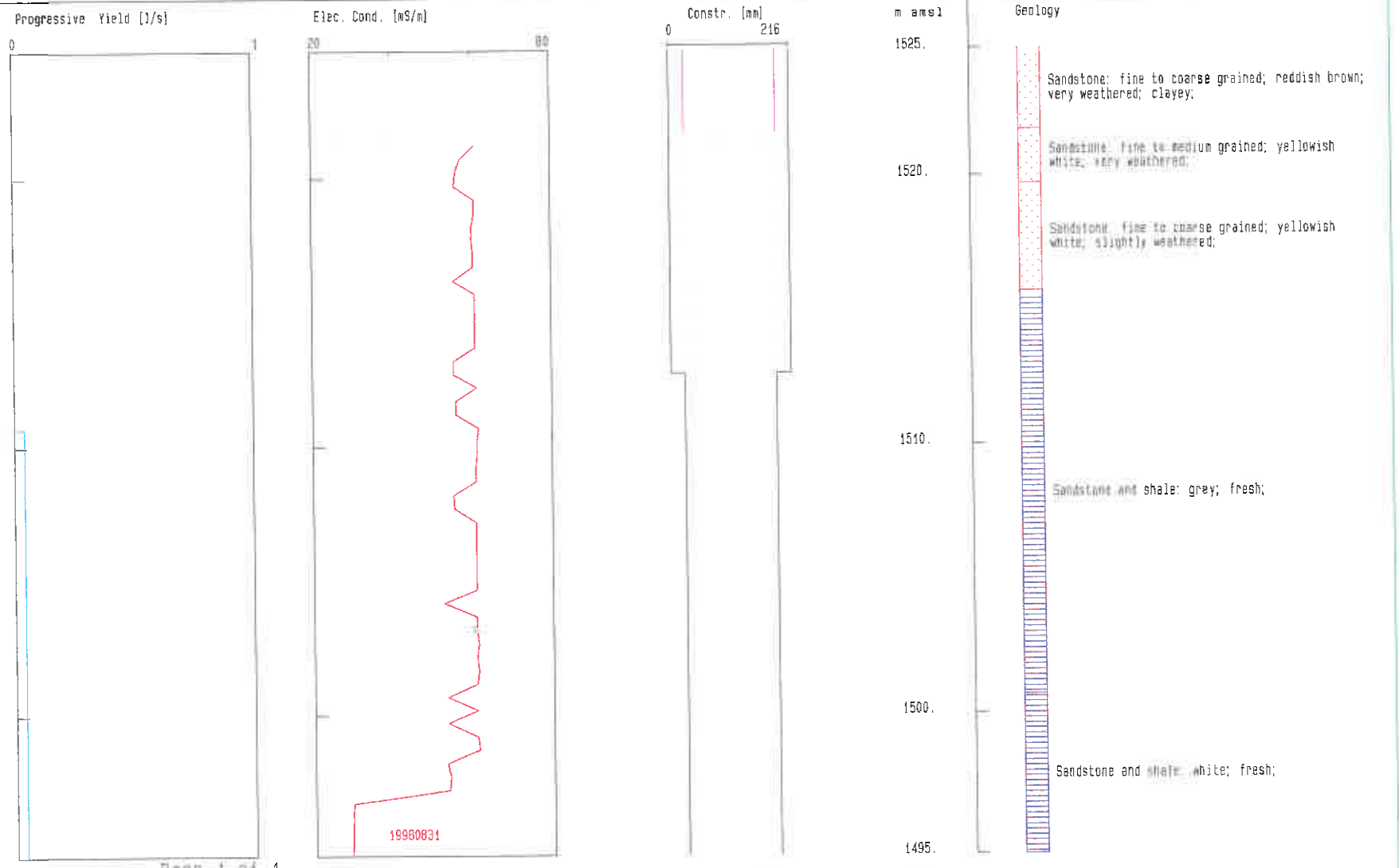
E-W coordinate : -21072.12 N-S coordinate : 2859044.98
Ground Elevation: 1524.69 mamsl Collar Height: 0.67 m
Depth of Casing: 12.00 m Diameter of Hole: 165 mm
Logged by: JMA Date Drilled: 19980714

Depth (m) from	to	Thickness (m)	Description
Geology			
0.00	3.00	3.00	SANDSTONE : fine to coarse grained; reddish brown; very weathered; clayey. Moist.
3.00	5.00	2.00	SANDSTONE : fine to medium grained; yellowish white; very weathered. Moist.
5.00	9.00	4.00	SANDSTONE : fine to coarse grained; yellowish white; slightly weathered. Moist.
9.00	24.00	15.00	SANDSTONE AND SHALE : grey; fresh. Seepage water at 14m, yield <0.1l/s.
24.00	30.00	6.00	SANDSTONE AND SHALE : white; fresh.
Geohydrology			
14.00	15.00	1.00	0.04 L/sec (estimated). According to JMA Geotechnician

Site-ID : 2529CC00007 Nr on Map : BSG-B7

* HydroGraph * Borehole log : DWA BLESBOKSPRUIT

Coordinates : -21072.12 (E-W) 2859044.98 (N-S) 1524.69 (Ground elevation) Date Plotted: Sep 08 1998



Site name : DWA - BLESBOKSPRUIT : BSG-B8
Notes :

Site ID: 2529CC00008 Number on map: BSG-B8

E-W coordinate : -19747.86 N-S coordinate : 2859087.68
Ground Elevation: 1541.36 mamsl Collar Height: 0.41 m
Depth of Casing: 12.00 m Diameter of Hole: 165 mm
Logged by: Date Drilled: 19980715

Depth (m) from	to	Thickness (m)	Description

Geology

0.00	2.00	2.00	SANDSTONE : coarse grained; reddish brown; very weathered. Moist.
2.00	6.00	4.00	SANDSTONE : fine to medium grained; yellowish brown; very weathered.
6.00	7.00	1.00	SANDSTONE AND SHALE : very weathered. Chips of fine coal, No 1 Seam. Slightly moist.
7.00	8.00	1.00	SANDSTONE : coarse grained; light very weathered. Slightly moist.
8.00	12.00	4.00	SANDSTONE AND SHALE : grey; slightly weathered. Dry.
12.00	13.00	1.00	SANDSTONE : fine to medium grained; light yellow; fresh. Dry.
13.00	25.00	12.00	SANDSTONE AND SHALE : grey; fresh. Dry.
25.00	28.00	3.00	SANDSTONE AND SHALE : light grey; fresh. Dry.
28.00	30.00	2.00	TILLITE : fresh. Dry.

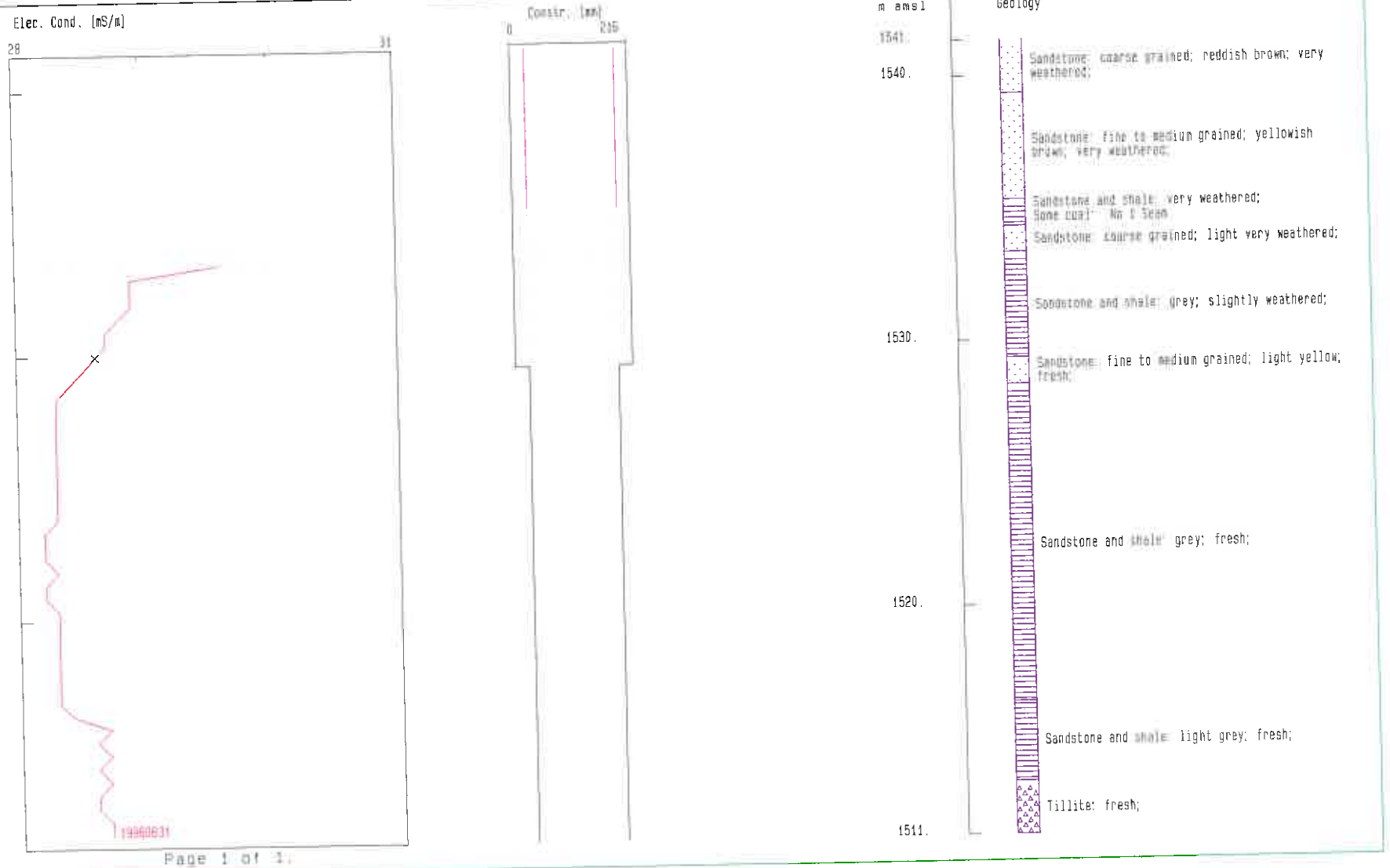
Geohydrology

(no information.)

Site-ID : 2529CC00008 Nr on Map : BSG-B8

* HydroGraph * Borehole log : DWA BLESBOKSPRUIT

Coordinates : -19747.86 (E-W) 2859087.68 (N-S) 1541.36 (Ground elevation) Date Plotted: Sep 14 1998



Site name : DWA - BLESBOKSPRUIT : BSG-B9
Notes :

Site ID: 2529CC00009 Number on map: BSG-B9

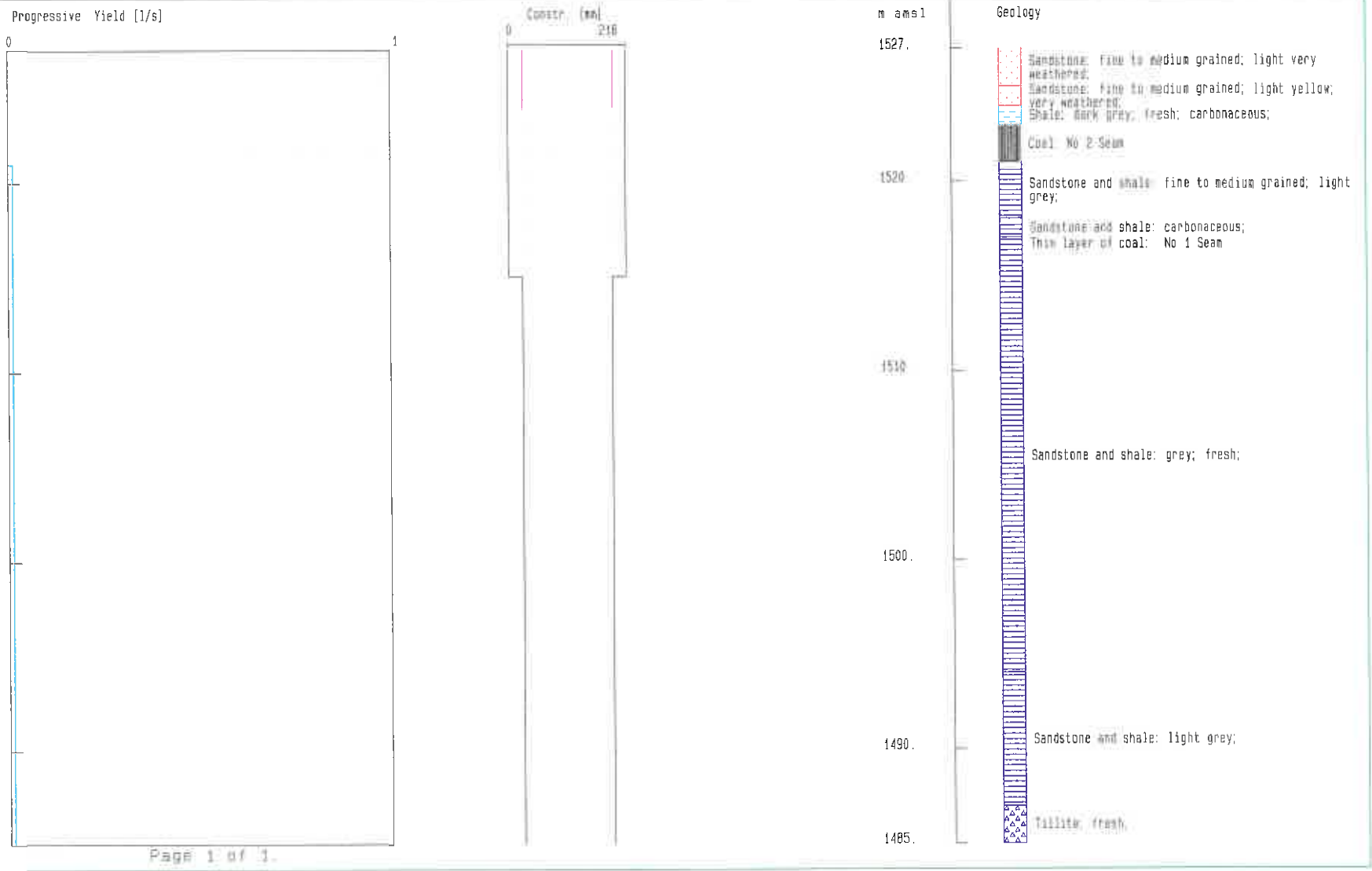
E-W coordinate : -20090.43 N-S coordinate : 2858504.50
Ground Elevation: 1527.04 mamsl Collar Height: 0.50 m
Depth of Casing: 12.00 m Diameter of Hole: 165 mm
Logged by: JMA Date Drilled: 19980715

Depth (m) from	to	Thickness (m)	Description
Geology			
0.00	2.00	2.00	SANDSTONE : fine to medium grained; light very weathered. Slightly moist.
2.00	3.00	1.00	SANDSTONE : fine to medium grained; light yellow; very weathered. Slightly moist.
3.00	4.00	1.00	SHALE : dark grey; fresh; carbonaceous. Coal seam starts.
4.00	6.00	2.00	COAL : No 2 Seam
6.00	9.00	3.00	SANDSTONE AND SHALE : fine to medium grained; light grey. Slightly moist.
9.00	10.00	1.00	SANDSTONE AND SHALE : carbonaceous. Thin layer of coal, No 1 Seam.
10.00	33.00	23.00	SANDSTONE AND SHALE : grey; fresh. Dry.
33.00	40.00	7.00	SANDSTONE AND SHALE : light grey. Dry.
40.00	42.00	2.00	TILLITE : fresh.
Geohydrology			
6.00	9.00	3.00	0.01 L/sec (estimated). According to JMA Geotechnician

Site-ID : 2529CC00009 Nr on Map : BSG-B9

* HydroGraph * Borehole log : DWA BLESBOKSPRUIT

Coordinates : -20090.43 (E-W) 2858504.50 (N-S) 1527.04 (Ground elevation) Date Plotted: Sep 07 1998



Site name : DWA - BLESBOKSPRUIT : BSG-B10
Notes :

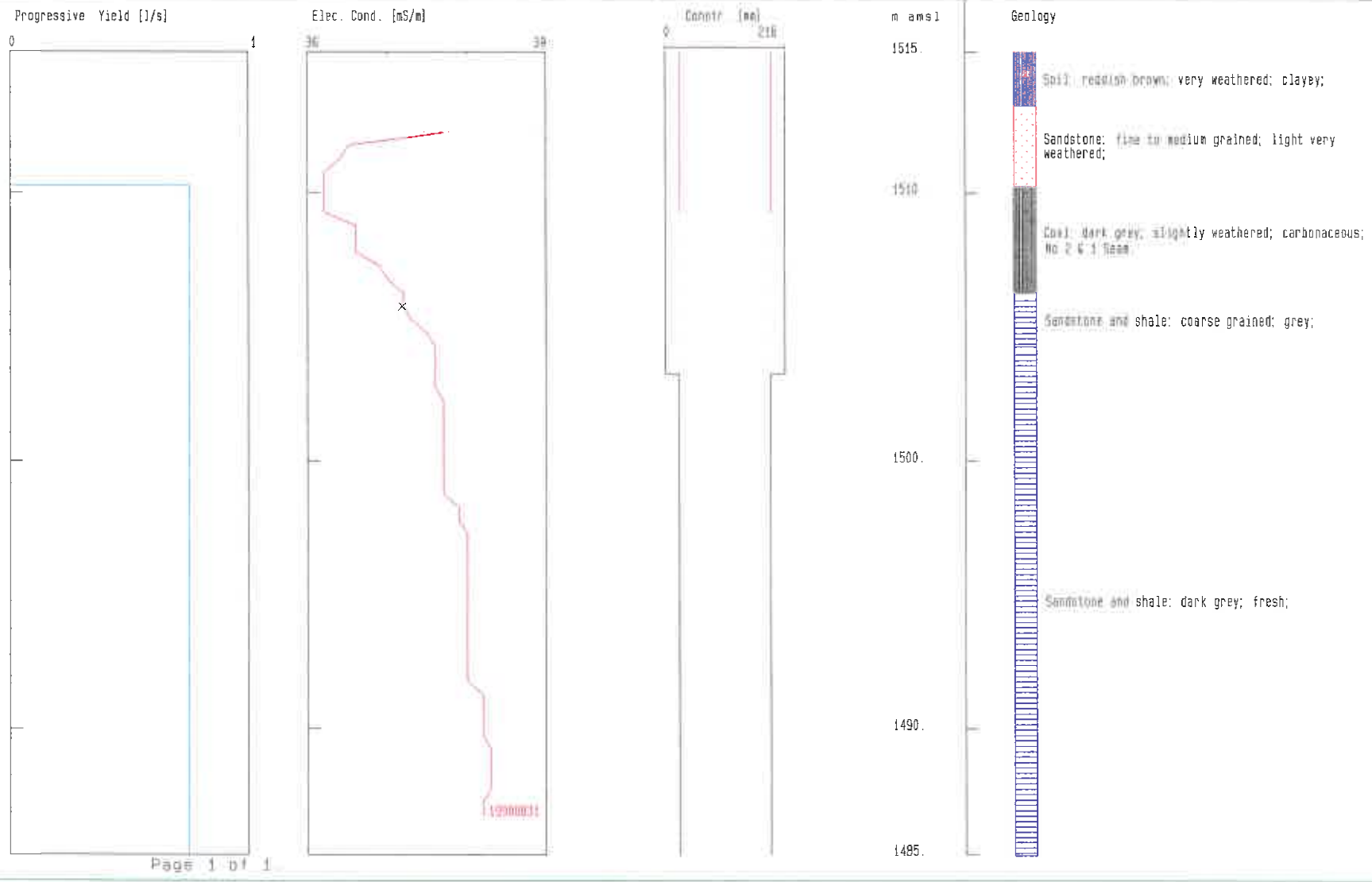
Site ID: 2529CC00010	Number on map: BSG-B10
E-W coordinate : -20659.73	N-S coordinate : 2858117.99
Ground Elevation: 1515.28 mamsl	Collar Height: 0.35 m
Depth of Casing: 12.00 m	Diameter of Hole: 165 mm
Logged by: JMA	Date Drilled: 19980715

Depth (m) from	to	Thickness (m)	Description
Geology			
0.00	2.00	2.00	SOIL : reddish brown; very weathered; clayey. Moist.
2.00	5.00	3.00	SANDSTONE : fine to medium grained; light very weathered. Moist.
5.00	9.00	4.00	COAL : dark grey; slightly weathered; carbonaceous. With shale. No 2 & 1 seam.
9.00	11.00	2.00	SANDSTONE AND SHALE : coarse grained; grey.
11.00	30.00	19.00	SANDSTONE AND SHALE : dark grey; fresh.
Geohydrology			
5.00	9.00	4.00	0.75 L/sec (estimated). According to JMA Geotechnician

Site-ID : 2529CC00010 Nr on Map : BSG-B10

* HydroGraph * Borehole log : DWA BLESBOKSPRUIT

Coordinates :-20659.73(E-W) 2858117.99(N-S) 1515.28(Ground elevation) Date Plotted: Sep 08 1998



Site name : DWA - BLESBOKSPRUIT : BSG-B11
Notes :

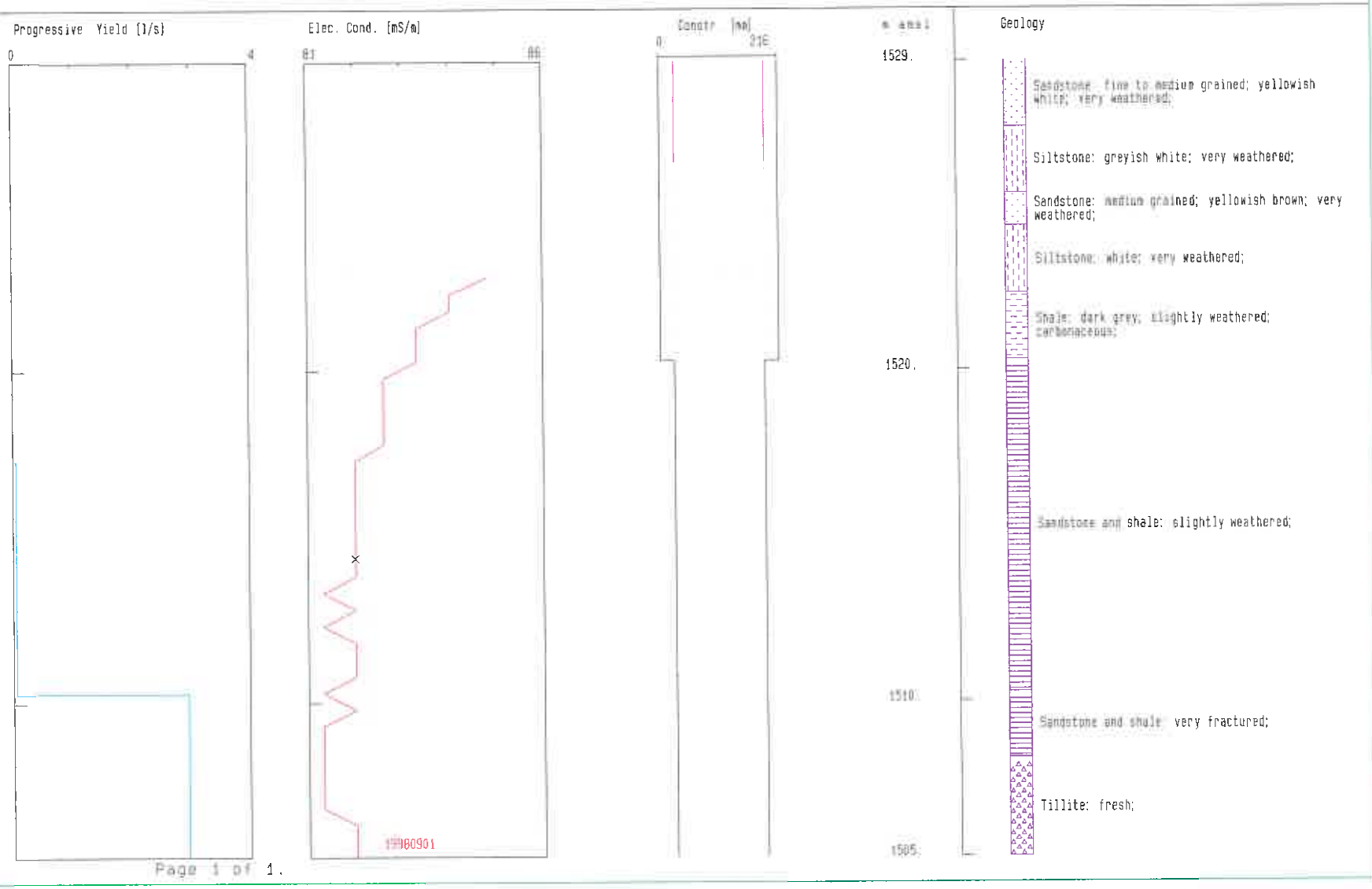
Site ID: 2529CC00011	Number on map: BSG-B11
E-W coordinate : -21252.06	N-S coordinate : 2859438.09
Ground Elevation: 1529.30 mamsl	Collar Height: 0.60 m
Depth of Casing: 9.00 m	Diameter of Hole: 165 mm
Logged by: JMA	Date Drilled: 19980714

Depth (m) from	to	Thickness (m)	Description
Geology			
0.00	2.00	2.00	SANDSTONE : fine to medium grained; yellowish white; very weathered. Moist.
2.00	4.00	2.00	SILTSTONE : greyish white; very weathered. Moist.
4.00	5.00	1.00	SANDSTONE : medium grained; yellowish brown; very weathered. Moist.
5.00	7.00	2.00	SILTSTONE : white; very weathered. Moist.
7.00	9.00	2.00	SHALE : dark grey; slightly weathered; carbonaceous. Slightly moist.
9.00	19.00	10.00	SANDSTONE AND SHALE : slightly weathered.
19.00	21.00	2.00	SANDSTONE AND SHALE : very fractured.
21.00	24.00	3.00	TILLITE : fresh.
Geohydrology			
12.00	13.00	1.00	0.04 L/sec (estimated). According to JMA Geotechnician
19.00	21.00	2.00	2.96 L/sec (estimated). According to JMA Geotechnician

Site-ID : 2529CC00011 Nr on Map : BSG-B11

* HydroGraph * Borehole log : DWA BLESBOKSPRUIT

Coordinates : -21252.06 (E-W) 2859438.09 (N-S) 1529.30 (Ground elevation) Date Plotted: Sep 08 1998



Site name : DWA - BLESBOKSPRUIT : BSG-B12
Notes :

Site ID: 2529CC00012 Number on map: BSG-B12

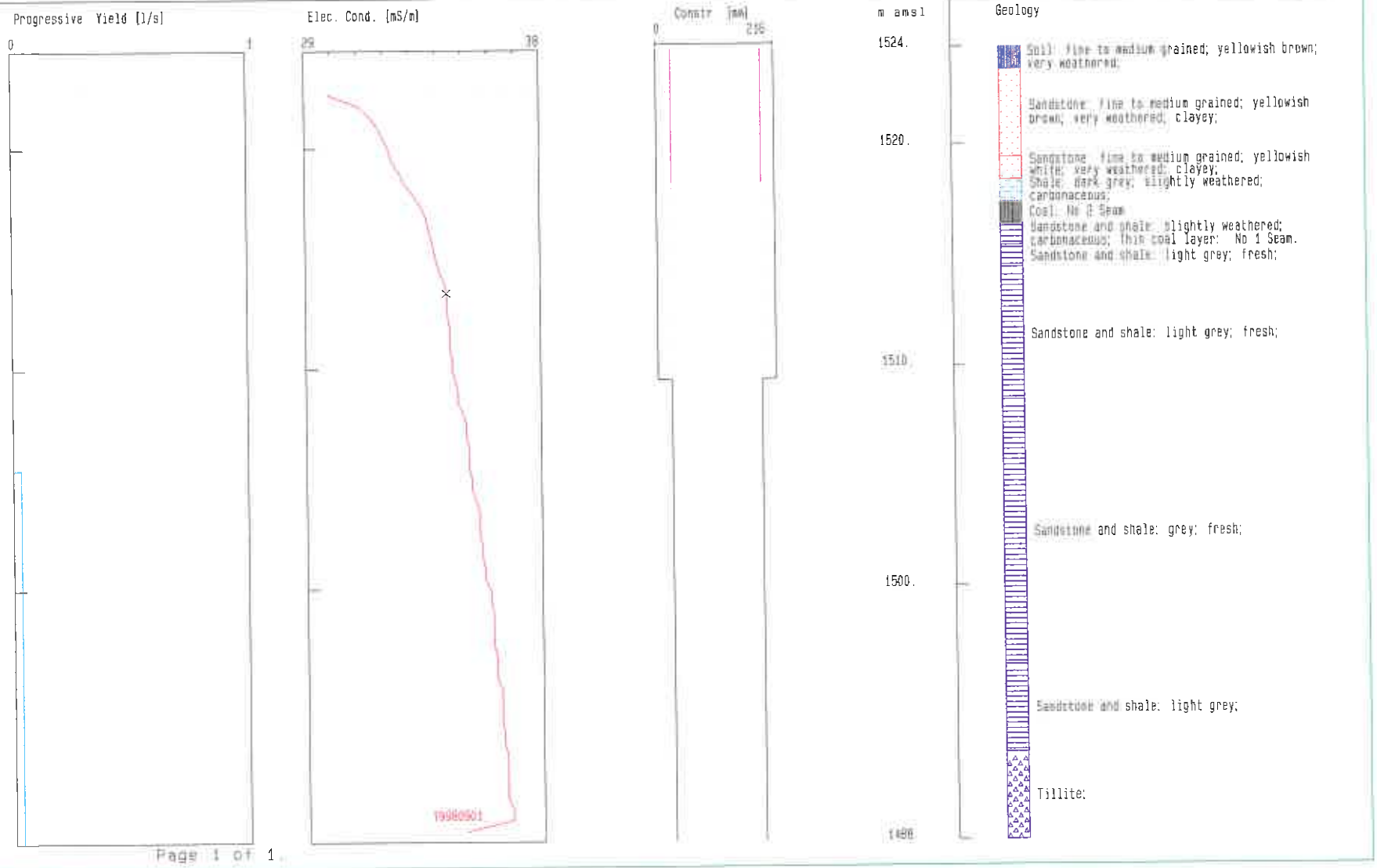
E-W coordinate : -22269.76 N-S coordinate : 2858257.96
Ground Elevation: 1524.43 mamsl Collar Height: 0.22 m
Depth of Casing: 15.00 m Diameter of Hole: 165 mm
Logged by: JMA Date Drilled: 19980716

Depth (m) from	to	Thickness (m)	Description
Geology			
0.00	1.00	1.00	SOIL : fine to medium grained; yellowish brown; very weathered. Soil with sandstone. Moist.
1.00	5.00	4.00	SANDSTONE : fine to medium grained; yellowish brown; very weathered; clayey. Moist.
5.00	6.00	1.00	SANDSTONE : fine to medium grained; yellowish white; very weathered; clayey. Moist.
6.00	7.00	1.00	SHALE : dark grey; slightly weathered; carbonaceous. Coal layer.
7.00	8.00	1.00	COAL : No 2 Seam
8.00	9.00	1.00	SANDSTONE AND SHALE : slightly weathered; carbonaceous. Slightly moist.
9.00	10.00	1.00	SANDSTONE AND SHALE : light grey; fresh. Thin layer of coal: No 1 Seam.
10.00	16.00	6.00	SANDSTONE AND SHALE : light grey; fresh. Dry.
16.00	28.00	12.00	SANDSTONE AND SHALE : grey; fresh.
28.00	32.00	4.00	SANDSTONE AND SHALE : light grey.
32.00	36.00	4.00	TILLITE :
Geohydrology			
19.00	20.00	1.00	0.03 L/sec (estimated). According to JMA Geotechnician

Site-ID : 2529CC00012 Nr on Map : BSG-B12

* HydroGraph * Borehole log : DWA BLESBOKSPRUIT

Coordinates : -22269.76 (E-W) 2858257.96 (N-S) 1524.43 (Ground elevation) Date Plotted: Sep 08 1998



Site name : DWA - BLESBOKSPRUIT : BSG-B13
Notes :

Site ID: 2529CC00013
Number on map: BSG-B13

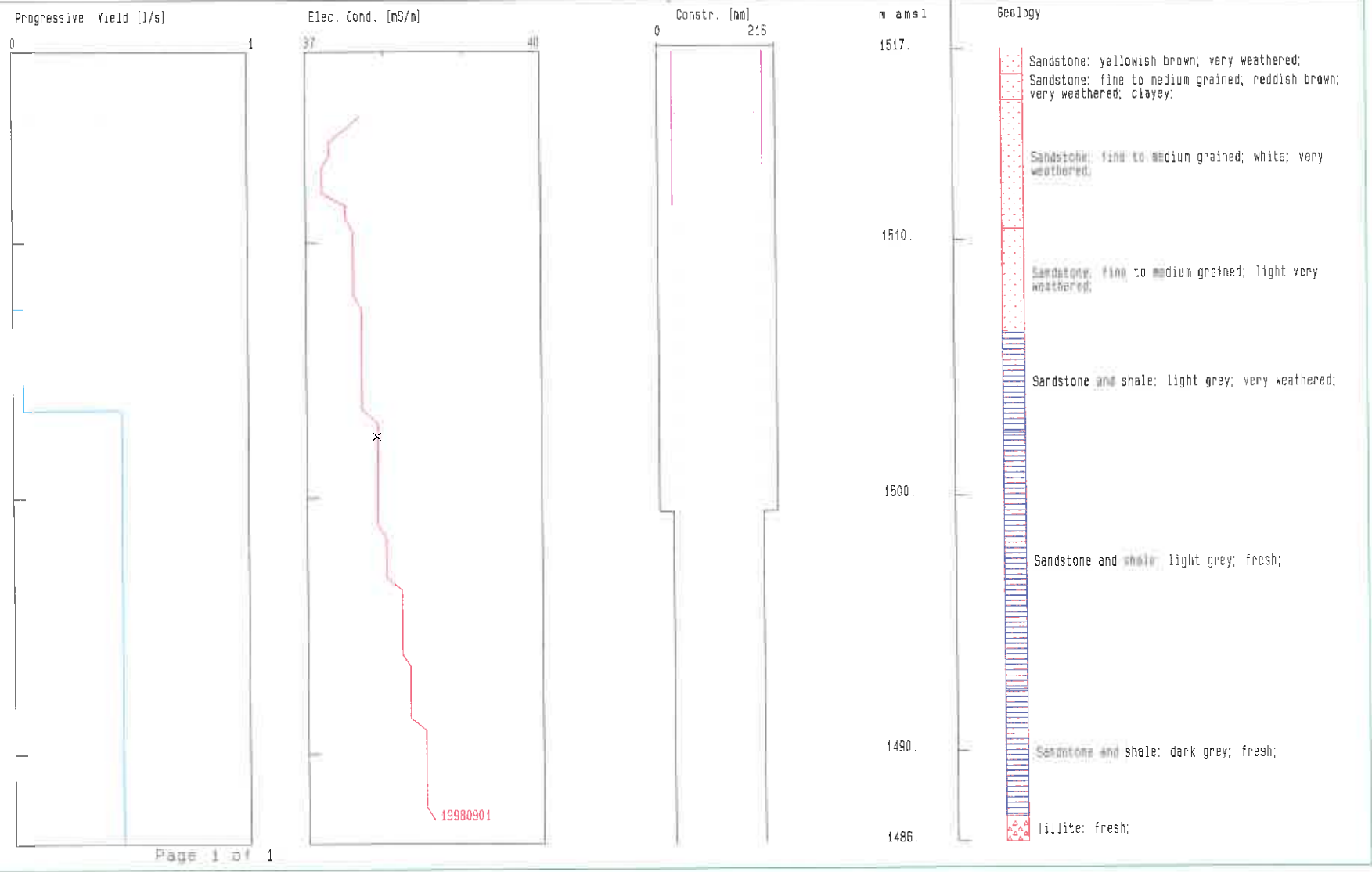
E-W coordinate : -22056.62
N-S coordinate : 2858187.91
Ground Elevation: 1517.45 mamsl
Collar Height: 0.48 m
Depth of Casing: 18.00 m
Diameter of Hole: 165 mm
Logged by: JMA
Date Drilled: 19980720

Depth (m) from	to	Thickness (m)	Description
Geology			
0.00	1.00	1.00	SANDSTONE : yellowish brown; very weathered. Moist.
1.00	2.00	1.00	SANDSTONE : fine to medium grained; reddish brown; very weathered; clayey. Moist.
2.00	7.00	5.00	SANDSTONE : fine to medium grained; white; very weathered. Slightly moist.
7.00	11.00	4.00	SANDSTONE : fine to medium grained; light very weathered.
11.00	15.00	4.00	SANDSTONE AND SHALE : light grey; very weathered.
15.00	25.00	10.00	SANDSTONE AND SHALE : light grey; fresh. Slightly fractured at 18m.
25.00	30.00	5.00	SANDSTONE AND SHALE : dark grey; fresh.
30.00	31.00	1.00	TILLITE : fresh.
Geohydrology			
10.00	14.00	4.00	0.04 L/sec (estimated). According to JMA Geotechnician
14.00	15.00	1.00	0.46 L/sec (estimated). According to JMA Geotechnician

Site-ID : 2529CC00013 Nr on Map : BSG-B13

* HydroGraph * Borehole log : DWA BLESBOKSPRUIT

Coordinates : -22056.62 (E-W) 2858187.91 (N-S) 1517.45 (Ground elevation) Date Plotted: Sep 14 1998



Site name : DWA - BLESBOKSPRUIT : BSG-B14
Notes :

Site ID: 2529CC00014
Number on map: BSG-B14

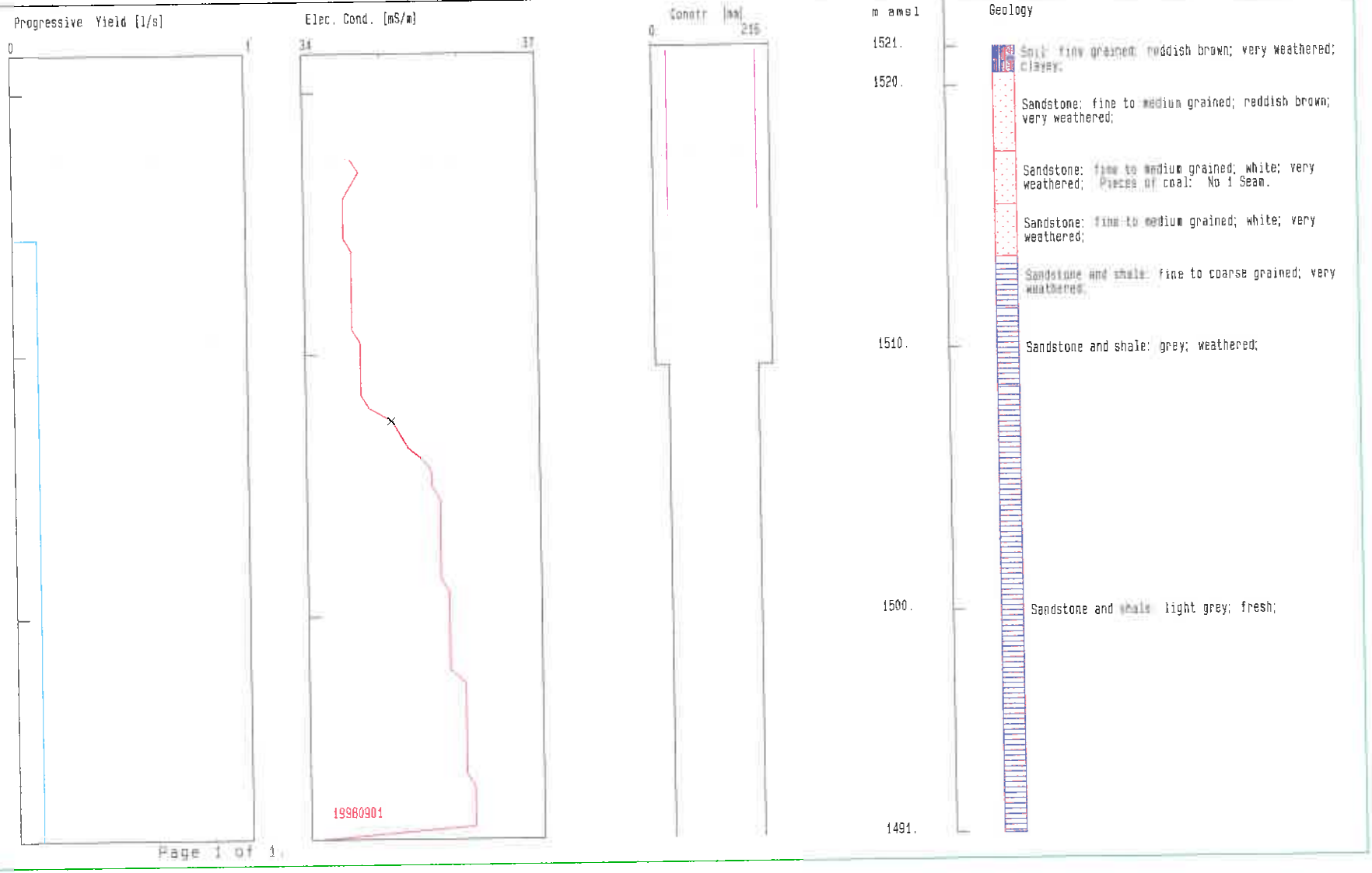
E-W coordinate : -22153.03
N-S coordinate : 2858007.53
Ground Elevation: 1521.46 mamsl
Collar Height: 0.42 m
Depth of Casing: 12.00 m
Diameter of Hole: 165 mm
Logged by: JMA
Date Drilled: 19980714

Depth (m) from	to	Thickness (m)	Description
Geology			
0.00	1.00	1.00	SOIL : fine grained; reddish brown; very weathered; clayey. Soil with sandstone. Moist.
1.00	4.00	3.00	SANDSTONE : fine to medium grained; reddish brown; very weathered. Moist.
4.00	6.00	2.00	SANDSTONE : fine to medium grained; white; very weathered.
6.00	8.00	2.00	SANDSTONE : fine to medium grained; white; very weathered. Clay with pieces of weathered coal. Moist. No 1 Seam.
8.00	10.00	2.00	SANDSTONE AND SHALE : fine to coarse grained; very weathered.
10.00	13.00	3.00	SANDSTONE AND SHALE : grey; weathered.
13.00	30.00	17.00	SANDSTONE AND SHALE : light grey; fresh.
Geohydrology			
7.00	8.00	1.00	0.10 L/sec (estimated). According to JMA Geotechnician

Site-ID : 2529CC00014 Nr on Map : BSG-B14

* HydroGraph * Borehole log : DWA BLESBOKSPRUIT

Coordinates : -22153.03 (E-W) 2858007.53 (N-S) 1521.46 (Ground elevation) Date Plotted: Sep 09 1998



Site name : DWA - BLESBOKSPRUIT : BSG-B15
Notes :

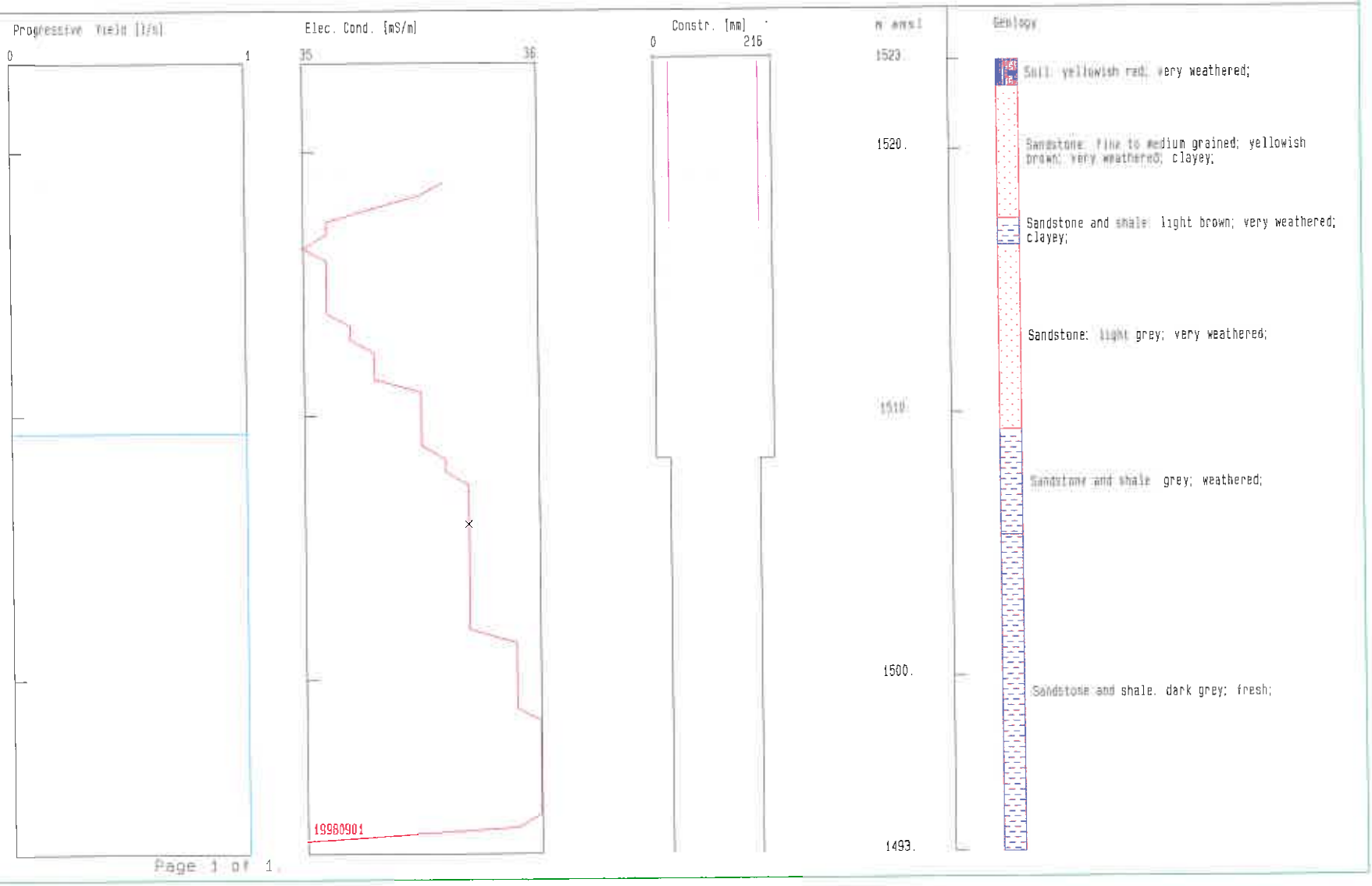
Site ID: 2529CC00015
Number on map: BSG-B15
E-W coordinate : -22112.99
N-S coordinate : 2858567.21
Ground Elevation: 1523.36 mamsl
Collar Height: 0.61 m
Depth of Casing: 9.00 m
Diameter of Hole: 165 mm
Logged by: JMA
Date Drilled: 19980731

Depth (m) from	to	Thickness (m)	Description
Geology			
0.00	1.00	1.00	SOIL : yellowish red; very weathered. Soil with sandstone. Slightly moist.
1.00	6.00	5.00	SANDSTONE : fine to medium grained; yellowish brown; very weathered; clayey. Moist.
6.00	7.00	1.00	SANDSTONE AND SHALE : light brown; very weathered; clayey. Moist.
7.00	14.00	7.00	SANDSTONE : light grey; very weathered.
14.00	18.00	4.00	SANDSTONE AND SHALE : grey; weathered.
18.00	30.00	12.00	SANDSTONE AND SHALE : dark grey; fresh. Tillite formation at 30m.
Geohydrology			
14.00	18.00	4.00	1.00 L/sec (estimated). According to JMA Geotechnician

Site-ID : 2529CC00015 Nr on Map : BSG-B15

* HydroGraph * Borehole log : DWA BLESBOKSPRUIT

Coordinates : -22112.99 (E-W) 2858567.21 (N-S) 1523.36 (Ground elevation) Date Plotted: Feb 12 1999



Site name : DWA - BLESBOKSPRUIT : BSG-RB16
Notes :

Site ID: 2529CC00016
Number on map: BSG-RB16

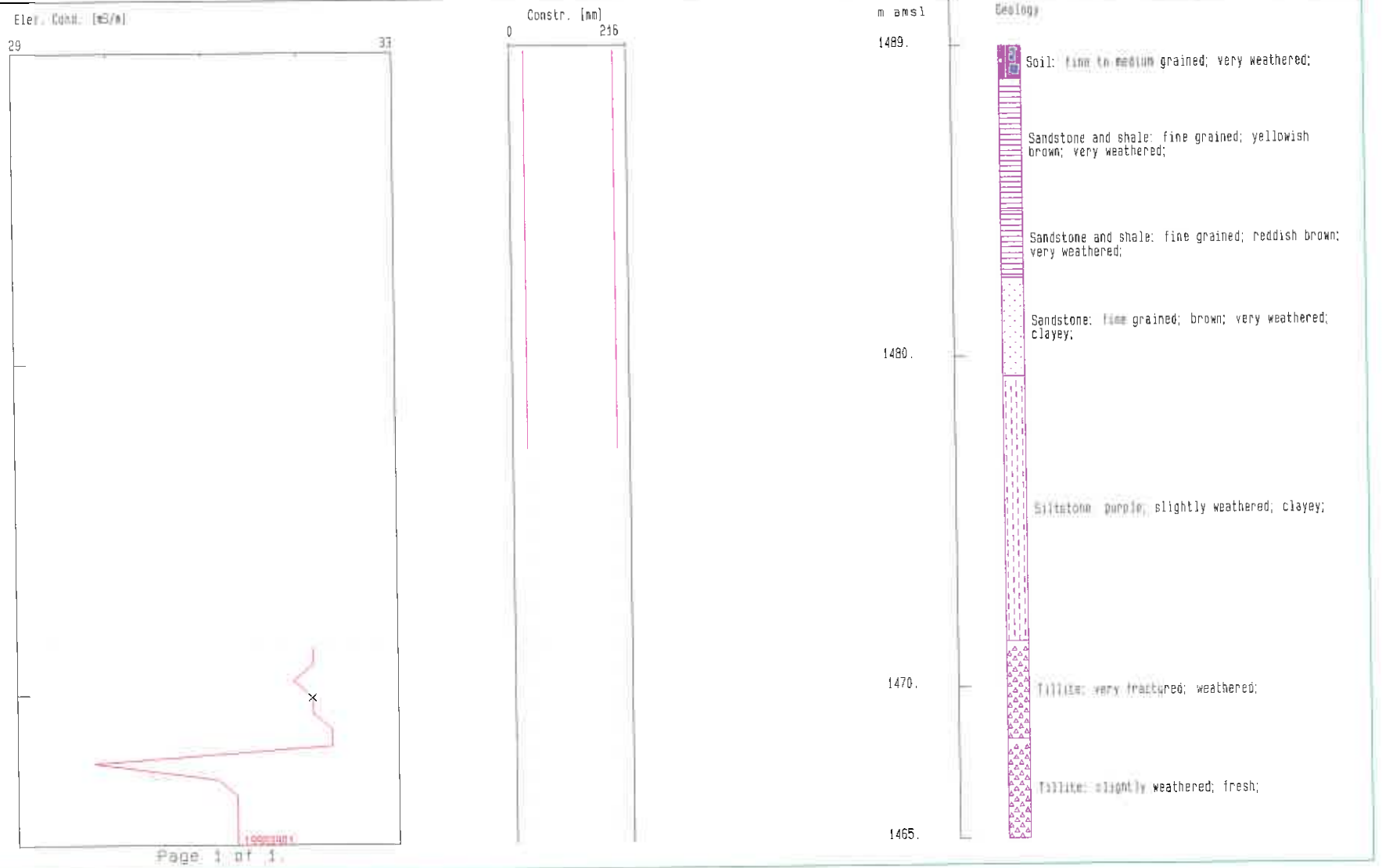
E-W coordinate : -24028.25
N-S coordinate : 2858614.53
Ground Elevation: 1533.16 mamsl
Collar Height: 0.46 m
Depth of Casing: 12.00 m
Diameter of Hole: 165 mm
Logged by: JMA
Date Drilled: 19980720

Depth (m) from	to	Thickness (m)	Description
Geology			
0.00	9.00	9.00	NO SAMPLE : Backfill.
9.00	11.00	2.00	SANDSTONE AND SHALE : dark grey; slightly weathered. Pit floor.
11.00	13.00	2.00	SANDSTONE AND SHALE : coarse grained; light grey; slightly weathered; fresh.
Geohydrology			
3.00	7.00	4.00	5.50 L/sec (estimated). According to JMA Geotechnician

Site-ID : 2529CC00019 Nr on Map : BSG-B19

* HydroGraph * Borehole log : DWA BLESBOKSPRUIT

Coordinates : -24795.87(E-W) 2858701.33(N-S) 1489.41(Ground elevation) Date Plotted: Sep 16 1998



Site name : DWA - BLESBOKSPRUIT : BSG-B20
Notes :

Site ID: 2529CC00020
Number on map: BSG-B20

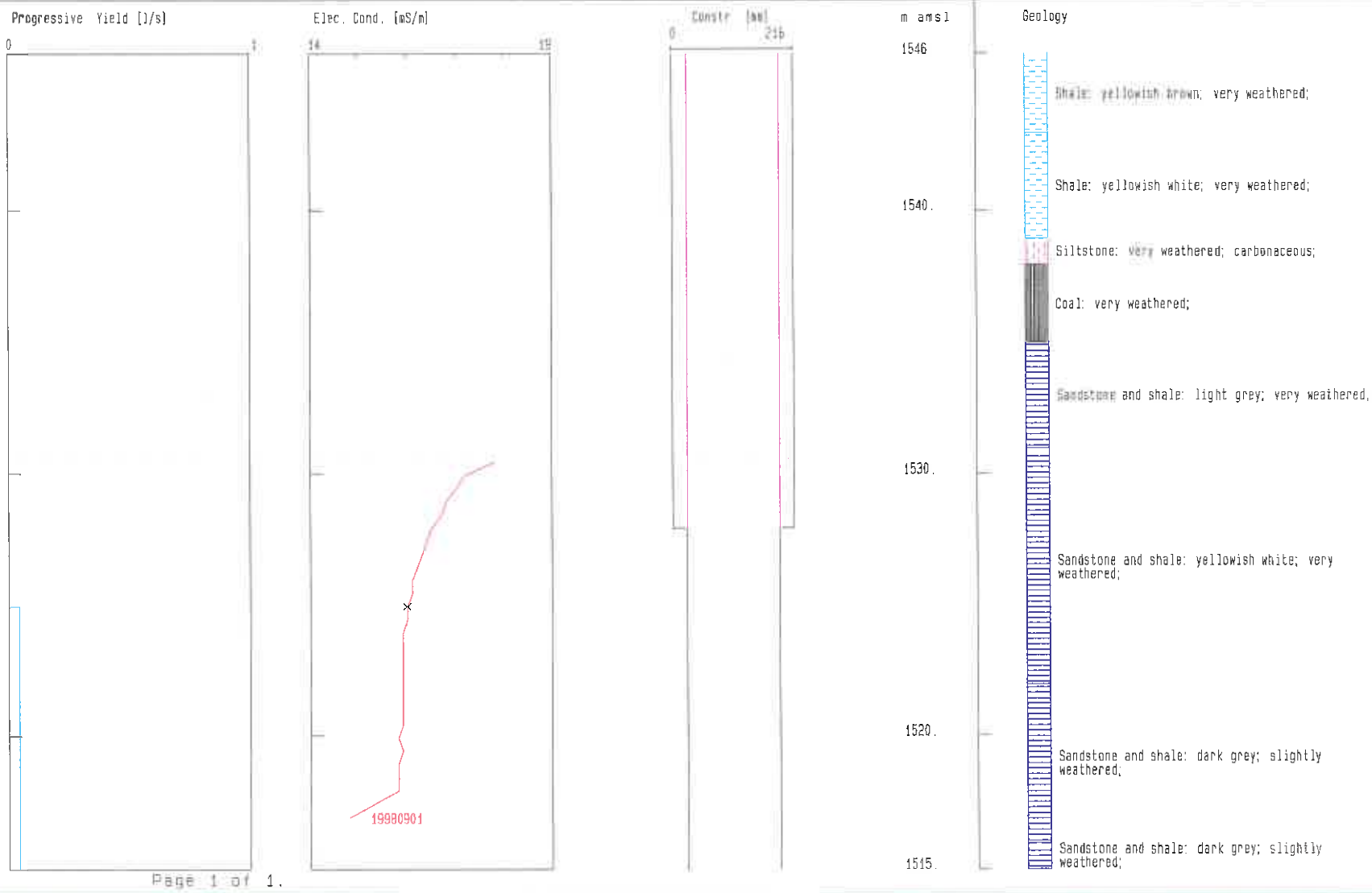
E-W coordinate : -23716.95
N-S coordinate : 2857510.40
Ground Elevation: 1545.93 mamsl
Collar Height: 0.50 m
Depth of Casing: 26.00 m
Diameter of Hole: 165 mm
Logged by: JMA
Date Drilled: 19980722

Depth (m) from	to	Thickness (m)	Description
Geology			
0.00	3.00	3.00	SHALE : yellowish brown; very weathered. Dry.
3.00	7.00	4.00	SHALE : yellowish white; very weathered. Dry.
7.00	8.00	1.00	SILTSTONE : very weathered; carbonaceous. Slightly moist.
8.00	11.00	3.00	COAL : very weathered. Fine, slightly moist. No 2 & 1 seam.
11.00	15.00	4.00	SANDSTONE AND SHALE : light grey; very weathered. Slightly moist. Carbonaceous shale.
15.00	24.00	9.00	SANDSTONE AND SHALE : yellowish white; very weathered.
24.00	30.00	6.00	SANDSTONE AND SHALE : dark grey; slightly weathered. Dry.
30.00	31.00	1.00	SANDSTONE AND SHALE : dark grey; slightly weathered. Dry. Tillite particles.
Geohydrology			
21.00	24.00	3.00	0.04 L/sec measured by notch (v- or u-notch). According to JMA Geotechnician

Site-ID : 2529CC00020 Nr on Map : BSG-B20

* HydroGraph * Borehole log : DWA BLESBOKSPRUIT

Coordinates : -23716.95 (E-W) 2857510.40 (N-S) 1545.93 (Ground elevation) Date Plotted: Sep 16 1998



APPENDIX III

HYDRO-CHEMISTRY RESULTS

Number on map		BSG-B1	BSG-B2	BSG-B3	BSG-B4	BSG-B5	BSG-B6
Sample date		19980901	19980831	19980831	19980831	19980901	19980831
Sample time		0845	1635	1620	1650	1215	1455
Depth of sample	(m)	9.000	6.000	9.000	10.000	13.000	10.000
Analytical laboratory		WATERLAB	WATERLAB	WATERLAB	WATERLAB	WATERLAB	WATERLAB
pH		3.30▼	4.00▼	2.90▼	4.80▼	3.90▼	4.30▼
Electrical conductivity	(mS/m)	351.0▲	361.0▲	398.0▲	221.0↑	419.0▲	160.0↑
Total dissolved solids	(mg/L)	3255	3560	3590	2105	4960	1335
Calcium	(mg/L)	99	207▲	96	235▲	187↑	96
Magnesium	(mg/L)	48	85↑	54	93↑	105▲	44
Sodium	(mg/L)	271↑	214↑	254↑	78	179↑	64
Potassium	(mg/L)	8.4	36.0	9.4	15.9	21.0	9.3
Silicon	(mg/L)	0.2	0.9	0.1	1.6	0.6	2.7
Total alkalinity	(mg/L)	4	4	4	4	4	4
Chloride	(mg/L)	359↑	330↑	318↑	88	269↑	108
Sulphate	(mg/L)	1886▲	1954▲	1986▲	1346▲	2895▲	768▲
Nitrate as nitrogen	(mg/L)	0.4	0.6	0.5	0.4	0.3	1.8
Fluoride	(mg/L)	13.0▲	14.0▲	14.0▲	12.0▲	16.0▲	9.2▲
Iron (total)	(mg/L)	303.000▲	378.000▲	392.000▲	182.000▲	543.000▲	209.000▲
Manganese	(mg/L)	9.370▲	11.000▲	9.610▲	5.480▲	21.000▲	8.870▲
Ion-balance error	(%)	-22.00▼	-10.13▼	-18.89▼	-2.21	-19.34▼	-1.25

Selected standard : SA drinking water- humans

▲ = Exceeds max acceptable value ↓ = Below min guideline value

↑ = Exceeds max guideline value ▼ = Below min acceptable value

< = Below detection limit

Number on map		BSG-B7	BSG-B8	BSG-B9	BSG-B9	BSG-B10	BSG-B11
Sample date		19980831	19980831	19980831	19980831	19980831	19980831
Sample time		1520	0835	1400	1405	1435	1605
Depth of sample	(m)	14.000	12.000	10.000	36.000	9.000	14.000
Analytical laboratory		WATERLAB	WATERLAB	WATERLAB	WATERLAB	WATERLAB	WATERLAB
pH		4.30▼	6.70	5.00▼	4.70▼	6.60	2.90▼
Electrical conductivity	(mS/m)	137.0↑	25.4	58.3	57.7	52.2	483.0▲
Total dissolved solids	(mg/L)	1255	142	402	416	320	5450
Calcium	(mg/L)	98	15	32	33	38	183↑
Magnesium	(mg/L)	47	8	15	16	19	90↑
Sodium	(mg/L)	25	13	22	24	26	242↑
Potassium	(mg/L)	10.7	8.0	4.3	4.1	13.0	8.2
Silicon	(mg/L)	1.0	9.8	6.9	8.0	1.0	0.1
Total alkalinity	(mg/L)	4	25	4	4	30	4
Chloride	(mg/L)	34	21	37	37	39	330↑
Sulphate	(mg/L)	686▲	65	252↑	234↑	169	3580▲
Nitrate as nitrogen	(mg/L)	0.5	1.3	0.8	0.8	0.4	1.0
Fluoride	(mg/L)	10.0▲	1.1↑	1.9▲	2.0▲	1.2↑	18.0▲
Iron (total)	(mg/L)	125.000▲	11.900▲	57.000▲	57.000▲	24.000▲	362.000▲
Manganese	(mg/L)	17.000▲	0.660↑	3.440▲	3.420▲	1.310▲	20.000▲
Ion-balance error	(%)	-2.15	0.59	-3.68	0.96	4.68	-34.92▼

Selected standard : SA drinking water- humans

▲ = Exceeds max acceptable value ↓ = Below min guideline value

↑ = Exceeds max guideline value ▼ = Below min acceptable value

< = Below detection limit

Number on map		BSG-B12	BSG-B13	BSG-B14	BSG-B15	BSG-B16	BSG-B17
Sample date		19980901	19980901	19980901	19980901	19980901	19980901
Sample time		1230	1350	1410	1425	1605	1515
Depth of sample	(m)	10.000	15.000	14.000	17.000	4.000	6.500
Analytical laboratory		WATERLAB	WATERLAB	WATERLAB	WATERLAB	WATERLAB	WATERLAB
pH		3.00▼	3.70▼	2.90▼	4.50▼	2.90▼	3.30▼
Electrical conductivity	(mS/m)	414.0▲	356.0▲	272.0↑	263.0↑	362.0▲	341.0▲
Total dissolved solids	(mg/L)	4746	4080	2768	2738	3822	4298
Calcium	(mg/L)	388▲	503▲	242▲	291▲	301▲	245▲
Magnesium	(mg/L)	219▲	235▲	129▲	226▲	64	87↑
Sodium	(mg/L)	35	24	21	20	52	37
Potassium	(mg/L)	10.8	35.0	12.8	38.0	7.1	4.7
Silicon	(mg/L)	0.4	0.7	35.0	1.7	0.2	0.2
Total alkalinity	(mg/L)	4	4	4	4	4	4
Chloride	(mg/L)	24	15	17	17	50	24
Sulphate	(mg/L)	3392▲	2660▲	1871▲	1781▲	2660▲	2784▲
Nitrate as nitrogen	(mg/L)	0.1	0.1	0.1	0.1	0.1	0.1
Fluoride	(mg/L)	14.0▲	12.0▲	13.0▲	11.0▲	13.0▲	14.0▲
Iron (total)	(mg/L)	369.000▲	287.000▲	104.000▲	27.000▲	528.000▲	436.000▲
Manganese	(mg/L)	38.000▲	19.000▲	30.000▲	22.000▲	16.000▲	23.000▲
Ion-balance error	(%)	-14.57▼	0.73	-16.61▼	-1.99	-15.37▼	-22.57▼

Selected standard : SA drinking water- humans

▲ = Exceeds max acceptable value ↓ = Below min guideline value

↑ = Exceeds max guideline value ▼ = Below min acceptable value

< = Below detection limit

Number on map		BSG-B18	BSG-B19	BSG-B20	BSG-UB23	BSG-UB24	BSG-UB26
Sample date		19980901	19980901	19980901	19980901	19980831	19980901
Sample time		1620	1645	1520	1130	0815	0930
Depth of sample	(m)	13.000	22.500	21.000	14.000	16.000	14.000
Analytical laboratory		WATERLAB	WATERLAB	WATERLAB	WATERLAB	WATERLAB	WATERLAB
pH		3.80▼	6.10	5.90↓	4.40▼	4.20▼	3.30▼
Electrical conductivity	(mS/m)	459.0▲	93.2↑	27.2	340.0▲	61.7	402.0▲
Total dissolved solids	(mg/L)	5928	720	160	3158	472	4800
Calcium	(mg/L)	671▲	84	13	138	30	355▲
Magnesium	(mg/L)	592▲	56	10	56	25	133▲
Sodium	(mg/L)	42	20	8	225↑	10	34
Potassium	(mg/L)	28.0	6.4	15.8	7.4	9.8	15.5
Silicon	(mg/L)	0.3	7.7	7.7	0.4	0.1	0.1
Total alkalinity	(mg/L)	4	20	15	4	4	4
Chloride	(mg/L)	24	11	11	330↑	12	22
Sulphate	(mg/L)	3742▲	433↑	82	1546▲	293↑	3010▲
Nitrate as nitrogen	(mg/L)	0.1	1.7	0.1	0.2	0.4	0.3
Fluoride	(mg/L)	17.0▲	1.5↑	1.1↑	12.0▲	1.3↑	14.0▲
Iron (total)	(mg/L)	140.000▲	15.000▲	29.000▲	456.000▲	60.000▲	668.000▲
Manganese	(mg/L)	136.000▲	0.636↑	1.960▲	23.000▲	4.320▲	44.000▲
Ion-balance error	(%)	8.69↑	2.31	16.63▲	-4.43	-0.53	-6.71↓

Selected standard : SA drinking water- humans

▲ = Exceeds max acceptable value ↓ = Below min guideline value

↑ = Exceeds max guideline value ▼ = Below min acceptable value

< = Below detection limit

Number on map		BSG-UB27	BSG-UB28	BSG-UB29	BSG-UB30	BSG-UB33	BSG-UB34
Sample date		19980831	19980831	19980831	19980831	19980831	19980831
Sample time		0900	1345	0950	0930	1020	1330
Depth of sample	(m)	15.000	18.000	14.000	21.000	14.500	27.000
Analytical laboratory		WATERLAB	WATERLAB	WATERLAB	WATERLAB	WATERLAB	WATERLAB
pH		2.40▼	2.90▼	2.50▼	2.60▼	4.20▼	2.30▼
Electrical conductivity	(mS/m)	313.0▲	403.0▲	492.0▲	320.0▲	218.0↑	388.0▲
Total dissolved solids	(mg/L)	2976	4732	5148	3104	2060	4868
Calcium	(mg/L)	92	384▲	686▲	206▲	225▲	94
Magnesium	(mg/L)	54	176▲	359▲	86↑	130▲	45
Sodium	(mg/L)	10	56	26	27	38	23
Potassium	(mg/L)	12.0	19.0	21.0	5.6	19.4	3.4
Silicon	(mg/L)	0.1	0.1	0.1	0.1	6.3	0.1
Total alkalinity	(mg/L)	4	4	4	4	4	4
Chloride	(mg/L)	4	7	7	7	15	5
Sulphate	(mg/L)	2205▲	3292▲	3702▲	2236▲	1317▲	3337▲
Nitrate as nitrogen	(mg/L)	0.5	2.7	0.6	0.5	24.0▲	0.4
Fluoride	(mg/L)	9.1▲	15.0▲	11.0▲	13.0▲	11.0▲	13.0▲
Iron (total)	(mg/L)	951.000▲	201.000▲	366.000▲	215.000▲	133.000▲	727.000▲
Manganese	(mg/L)	14.200▲	22.000▲	13.800▲	14.200▲	24.000▲	5.270▲
Ion-balance error	(%)	-2.48	-22.06▼	0.69	-27.75▼	-0.84	-32.70▼

Selected standard : SA drinking water- humans

▲ = Exceeds max acceptable value ↓ = Below min guideline value

↑ = Exceeds max guideline value ▼ = Below min acceptable value

< = Below detection limit

Number on map		BSG-UB35	BSG-UB37	BSG-UB39	BSG-UB42	BSG-UB43	BSG-UB44
Sample date		19980831	19980831	19980901	19980901	19980901	19980901
Sample time		1130	1200	1500	1555	1530	1545
Depth of sample	(m)	22.000	25.000	26.000	26.000	9.000	19.000
Analytical laboratory		WATERLAB	WATERLAB	WATERLAB		WATERLAB	WATERLAB
pH		6.60	2.30▼	2.30▼	2.60▼	2.30▼	2.60▼
Electrical conductivity	(mS/m)	6.1	314.0▲	393.0▲	298.0↑	424.0▲	219.0↑
Total dissolved solids	(mg/L)	38	2758	4604	2244	4930	1298
Calcium	(mg/L)	3	174↑	31	222▲	290▲	154↑
Magnesium	(mg/L)	2	33	8	58	95↑	34
Sodium	(mg/L)	2	27	59	79	56	41
Potassium	(mg/L)	5.2	9.8	6.9	9.5	5.6	6.6
Silicon	(mg/L)	1.0	0.1	0.1	0.3	0.1	1.9
Total alkalinity	(mg/L)	10	4	4	4	4	4
Chloride	(mg/L)	7	4	71	87	16	33
Sulphate	(mg/L)	8	2101▲	3456▲	1616▲	2525▲	933▲
Nitrate as nitrogen	(mg/L)	0.3	0.5	0.3	0.4	0.6	0.4
Fluoride	(mg/L)	1.0	8.9▲	11.0▲	12.0▲	14.0▲	8.6▲
Iron (total)	(mg/L)	12.400▲	847.000▲	738.000▲	195.000▲	1065.000▲	171.000▲
Manganese	(mg/L)	0.319↑	8.810▲	0.588↑	12.500▲	31.000▲	7.040▲
Ion-balance error	(%)	21.62▲	-1.09	-40.77▼	-15.47▼	8.69↑	-5.29↓

Selected standard : SA drinking water- humans

▲ = Exceeds max acceptable value ↓ = Below min guideline value

↑ = Exceeds max guideline value ▼ = Below min acceptable value

< = Below detection limit

Number on map		BSG-UB45
Sample date		19980901
Sample time		1655
Depth of sample	(m)	23.000
Analytical laboratory		WATERLAB
pH		2.30▼
Electrical conductivity	(mS/m)	394.0▲
Total dissolved solids	(mg/L)	3684
Calcium	(mg/L)	305▲
Magnesium	(mg/L)	66
Sodium	(mg/L)	53
Potassium	(mg/L)	14.0
Silicon	(mg/L)	0.1
Total alkalinity	(mg/L)	4
Chloride	(mg/L)	34
Sulphate	(mg/L)	2271▲
Nitrate as nitrogen	(mg/L)	0.5
Fluoride	(mg/L)	13.0▲
Iron (total)	(mg/L)	881.000▲
Manganese	(mg/L)	14.800▲
Ion-balance error	(%)	6.09↑

Selected standard : SA drinking water- humans

▲ = Exceeds max acceptable value ↓ = Below min guideline value

↑ = Exceeds max guideline value ▼ = Below min acceptable value

< = Below detection limit

Waterlab Research (Edms) Bpk/(Pty) Ltd
(Reg No/No 83/09165/07)

WATERLAB

CERTIFICATE OF ANALYSIS

PROJECT NO: 4020 **REPORT NO:** 1862
SAMPLES NO: 0023-0037 **DATE:** 09/08/98

ATTENTION: Mr. L. van der Walt : Jasper Muller & Associates

Sample	Paste pH	Fizz Rating	Total S(%)	Acid Generation Potential (AP) CaCO3 (kg/t)	Neutr. Potential (NP) CaCO3 (kg/t)	Netto Neutr. Potential (NNP) CaCO3 (kg/t)	AP:NP Ratio	Rock Type
BSG-B3 3m (1)	4.5	None	0.015	0.47	-29.50	-29.97	1 : 3+	III
BSG-B3 4m (2)	5.0	None	0.569	17.78	-24.50	-42.28	1 : 1.4	II
BSG-B3 7m (1)	6.0	None	0.050	1.56	-22.00	-23.56	1: 3+	III
BSG-B9 3m (1)	5.6	None	0.001	0.03	-23.25	-23.28	1 : 3+	III
BSG-B9 5m (2)	5.3	None	0.502	15.69	-27.00	-42.69	1 : 1.7	II
BSG-B9 7m (1)	5.1	None	0.101	3.16	-23.25	-26.41	1 : 3+	III
BSG-B10 5m (1)	6.2	None	0.001	0.03	-24.50	-24.53	1 : 3+	III

(1) : Skalie/Sandsteen (2) : Steenkool

Signed.....
L.P.D. de Wet (PhD), Snr. Environmental Scientist

Waterlab Research (Edms) Bpk/(Pty) Ltd
(Reg No/No 83/09165/07)

WATERLAB

CERTIFICATE OF ANALYSIS

PROJECT NO: 4020
SAMPLES NO: 0023-0037

REPORT NO: 1862
DATE: 09/08/98

ATTENTION: Mr. L. van der Walt : Jasper Muller & Associates

Sample	Paste pH	Fizz Rating	Total S (%)	Acid Generation Potential (AP) CaCO3 (kg/t)	Neutr. Potential (NP) CaCO3 (kg/t)	Nett Neutr. Potential (NNP) CaCO3 (kg/t)	AP:NP Ratio	Rock Type
BSG-B10 8m (2)	5.5	None	0.282	8.81	-25.75	-34.56	1 : 2.9	II
BSG-B10 11m (1)	5.9	None	0.099	3.09	-25.75	-28.84	1 : 3+	III
BSG-B12 6m (1)	5.3	None	0.008	0.25	-25.75	-26.00	1 : 3+	III
BSG-B12 8m (2)	4.2	None	0.119	3.72	-34.50	-38.22	1 : 3+	III
BSG-B12 11m (1)	5.5	None	0.333	10.41	-25.75	-36.16	1 : 2.5	II
BSG-B20 7m (1)	5.3	None	0.001	0.03	-28.25	-28.28	1 : 3+	III
BSG-B20 11m (2)	5.1	None	0.005	0.16	-38.25	-38.41	1 : 3+	III
BSG-B20 12m (1)	5.7	None	0.001	0.03	-27.00	-27.03	1 : 3+	III

(1) : Skalie/Sandsteen (2) : Steenkool

Signed.....
L.P.D. de Wet (PhD), Snr. Environmental Scientist

APPENDIX : TERMINOLOGY AND ROCK CLASSIFICATION

TERMINOLOGY (SYNONYMS)

- Acid Generation Potential (AP) ; *Syn*: Maximum Potential Acidity (MPA)
  Method: Total S(%) (Leco Analyzer) x 31.25

- Neutralization Potential (NP) ; *Syn:* Gross Neutralization Potential (GNP) ; *Syn*: Acid Neutralization Capacity (ANC)
  Method: Fizz Test ; Acid-Base Titration (Sobek & Modified Sobek (Lawrence) Methods)

- Nett Neutralization Potential (NNP) ; *Syn:* Nett Acid Production Potential (NAPP)
  Calculation: NNP = NP – AP ; NAPP = ANC - MPA

ROCK CLASSIFICATION

TYPE I	Potentially Acid Forming	Total S(%) > 0.25% and AP:NP ratio 1:1 or less
TYPE II	Intermediate	Total S(%) > 0.25% and AP:NP ratio 1:3 or less
TYPE III	Non-Acid Forming	Total S(%) < 0.25% and AP:NP ratio 1:3 or greater

REFERENCES

Lawrence, R.W. & Wang, Y. 1997. ***Determination of Neutralization Potential in the Prediction of Acid Rock Drainage***. Proc. 4th International Conference on Acid Rock Drainage. Vancouver. BC. pp. 449 – 464.

Sobek, A.A., Schuller, W.A., Freeman, J.R. & Smith, R.M. 1978. ***Field and laboratory methods applicable to overburdens and minesoils***. EPA-600/2-78-054. USEPA. Cincinnati. Ohio.

Environment Australia. 1997. ***Managing Sulphidic Mine Wastes and Acid Drainage***.

APPENDIX V

GROUND WATER LEVEL
AND
MINE WATER LEVEL
REPORT
AND
HYDROGRAPHS

HydroBase * WATER-LEVEL REPORT * DATE : 2 September 1998
Generated for : DWA BLESBOKSPRUIT

Site id	Date	Time	Water level (m)	Water-level Elevation (mamsl)	Number on map	Piezo nr.
2529CC00001	19980827	08h45	0.00	1538.74	BSG-RB1	0
2529CC00001	19981028	13h35	2.70	1536.04	BSG-RB1	0
2529CC00001	19990114	16h30	0.00	1538.74	BSG-RB1	0
2529CC00002	19980825	08h50	2.55	1531.73	BSG-B2	0
2529CC00002	19981028	13h40	2.44	1531.84	BSG-B2	0
2529CC00002	19990114	16h15	2.27	1532.01	BSG-B2	0
2529CC00003	19980825	08h55	1.42	1532.19	BSG-B3	0
2529CC00003	19981028	13h46	1.26	1532.35	BSG-B3	0
2529CC00003	19990114	16h05	1.14	1532.47	BSG-B3	0
2529CC00004	19980825	09h00	3.60	1530.81	BSG-B4	0
2529CC00004	19990114	16h35	2.85	1531.56	BSG-B4	0
2529CC00005	19980827	09h05	1.65	1526.73	BSG-B5	0
2529CC00005	19981028	14h05	1.19	1527.19	BSG-B5	0
2529CC00005	19990114	15h50	1.06	1527.32	BSG-B5	0
2529CC00006	19980825	10h00	3.23	1529.84	BSG-B6	0
2529CC00006	19990114	15h15	2.88	1530.19	BSG-B6	0
2529CC00007	19980825	10h05	3.83	1521.53	BSG-B7	0
2529CC00007	19981028	14h25	3.57	1521.79	BSG-B7	0
2529CC00007	19990114	15h30	2.03	1523.33	BSG-B7	0
2529CC00008	19980825	10h10	7.51	1534.26	BSG-B8	0
2529CC00008	19990114	13h55	4.67	1537.10	BSG-B8	0
2529CC00009	19980825	10h15	6.09	1521.45	BSG-B9	0
2529CC00009	19981028	14h30	6.12	1521.42	BSG-B9	0
2529CC00009	19990114	14h20	4.31	1523.23	BSG-B9	0
2529CC00010	19980825	10h20	2.85	1512.78	BSG-B10	0
2529CC00010	19981028	14h39	2.78	1512.85	BSG-B10	0
2529CC00010	19990114	14h50	0.00	1515.63	BSG-B10	0
2529CC00011	19980825	10h30	6.39	1523.51	BSG-B11	0
2529CC00011	19981028	13h56	5.48	1524.42	BSG-B11	0
2529CC00011	19990114	15h55	4.59	1525.31	BSG-B11	0
2529CC00012	19980825	10h35	1.57	1523.08	BSG-B12	0
2529CC00012	19990115	12h50	0.89	1523.76	BSG-B12	0
2529CC00013	19980825	10h30	2.13	1515.80	BSG-B13	0

Site id	Date	Time	Water level (m)	Water-level Elevation (mamsl)	Number on map	Piezo nr.
2529CC00013	19981028	09h51	2.17	1515.76	BSG-B13	0
2529CC00013	19990115	13h05	1.56	1516.37	BSG-B13	0
2529CC00014	19980825	10h35	3.84	1518.04	BSG-B14	0
2529CC00014	19981028	10h02	3.81	1518.07	BSG-B14	0
2529CC00014	19990115	13h10	3.20	1518.68	BSG-B14	0
2529CC00015	19980825	11h00	4.43	1519.54	BSG-B15	0
2529CC00015	19981028	09h28	4.95	1519.02	BSG-B15	0
2529CC00015	19990115	15h20	3.33	1520.64	BSG-B15	0
2529CC00016	19980827	11h05	2.99	1530.63	BSG-RB16	0
2529CC00016	19981028	11h31	2.92	1530.70	BSG-RB16	0
2529CC00016	19990115	14h45	1.39	1532.23	BSG-RB16	0
2529CC00017	19980827	11h10	5.42	1529.04	BSG-B17	0
2529CC00017	19981028	10h25	5.16	1529.30	BSG-B17	0
2529CC00017	19990115	13h25	4.75	1529.71	BSG-B17	0
2529CC00018	19980827	11h15	9.82	1500.11	BSG-B18	0
2529CC00018	19981028	11h45	10.90	1499.03	BSG-B18	0
2529CC00018	19990115	14h00	9.31	1500.62	BSG-B18	0
2529CC00019	19980827	11h20	17.58	1472.17	BSG-B19	0
2529CC00019	19981028	11h20	14.60	1475.15	BSG-B19	0
2529CC00019	19990115	14h10	14.18	1475.57	BSG-B19	0
2529CC00020	19980827	11h30	15.13	1531.30	BSG-B20	0
2529CC00020	19981028	10h15	8.55	1537.88	BSG-B20	0
2529CC00020	19990115	13h20	14.32	1532.11	BSG-B20	0
2529CC00022	19990115	12h15	23.05	1538.45	BSG-UB22	0
2529CC00023	19980827	11h50	6.24	1539.13	BSG-UB23	0
2529CC00023	19981028	14h14	6.53	1538.84	BSG-UB23	0
2529CC00023	19990115	11h35	7.35	1538.02	BSG-UB23	0
2529CC00024	19980825	11h55	11.97	1537.37	BSG-PB24	0
2529CC00024	19981028	15h24	12.00	1537.34	BSG-PB24	0
2529CC00024	19990114	12h15	11.53	1537.81	BSG-PB24	0
2529CC00025	19980825	12h05	16.94	1539.75	BSG-PB25	0
2529CC00025	19981028	15h35	16.81	1539.88	BSG-PB25	0
2529CC00025	19990114	13h00	16.52	1540.17	BSG-PB25	0

Site id	Date	Time	Water level (m)	Water-level Elevation (mamsl)	Number on map	Piezo nr.
2529CC00026	19980825	12h15	3.26	1537.24	BSG-PB26	0
2529CC00026	19981028	15h09	3.22	1537.28	BSG-PB26	0
2529CC00026	19990114	11h40	2.91	1537.59	BSG-PB26	0
2529CC00027	19980825	12h30	13.26	1540.17	BSG-UB27	0
2529CC00027	19981028	08h09	13.41	1540.02	BSG-UB27	0
2529CC00027	19990114	11h35	13.49	1539.94	BSG-UB27	0
2529CC00028	19980825	12h35	8.94	1539.69	BSG-UB28	0
2529CC00028	19981028	09h10	9.88	1538.75	BSG-UB28	0
2529CC00028	19990114	13h35	8.97	1539.66	BSG-UB28	0
2529CC00029	19980825	12h45	10.52	1539.09	BSG-PB29	0
2529CC00029	19981029	09h31	10.58	1539.03	BSG-PB29	0
2529CC00029	19990115	09h05	10.52	1539.09	BSG-PB29	0
2529CC00030	19980825	12h55	19.40	1540.11	BSG-UB30	0
2529CC00030	19981029	10h00	19.56	1539.95	BSG-UB30	0
2529CC00030	19990115	11h10	20.59	1538.92	BSG-UB30	0
2529CC00033	19980825	13h20	13.40	1541.51	BSG-UB33	0
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2529CC00034	19980825	13h30	24.53	1541.60	BSG-UB34	0
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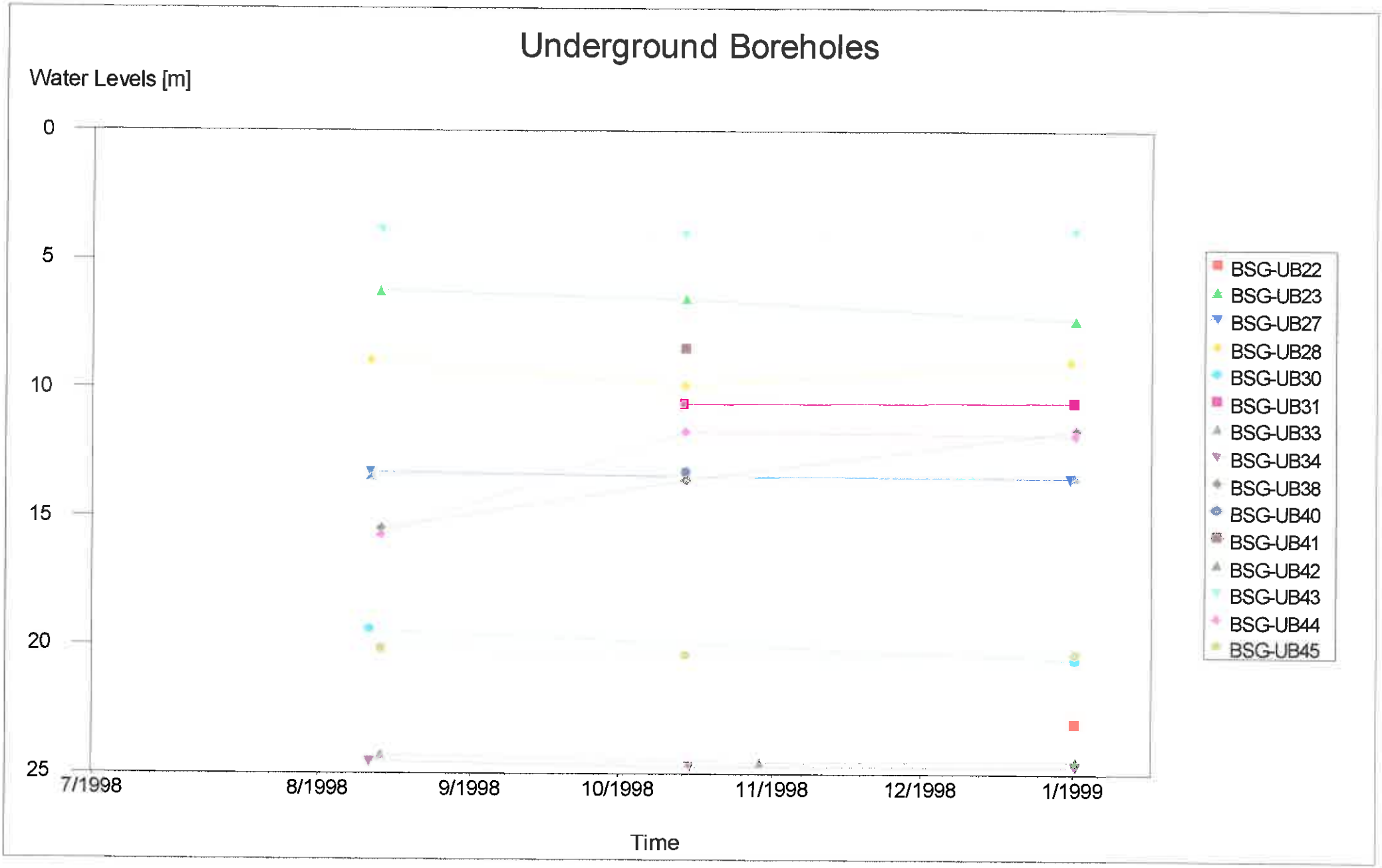
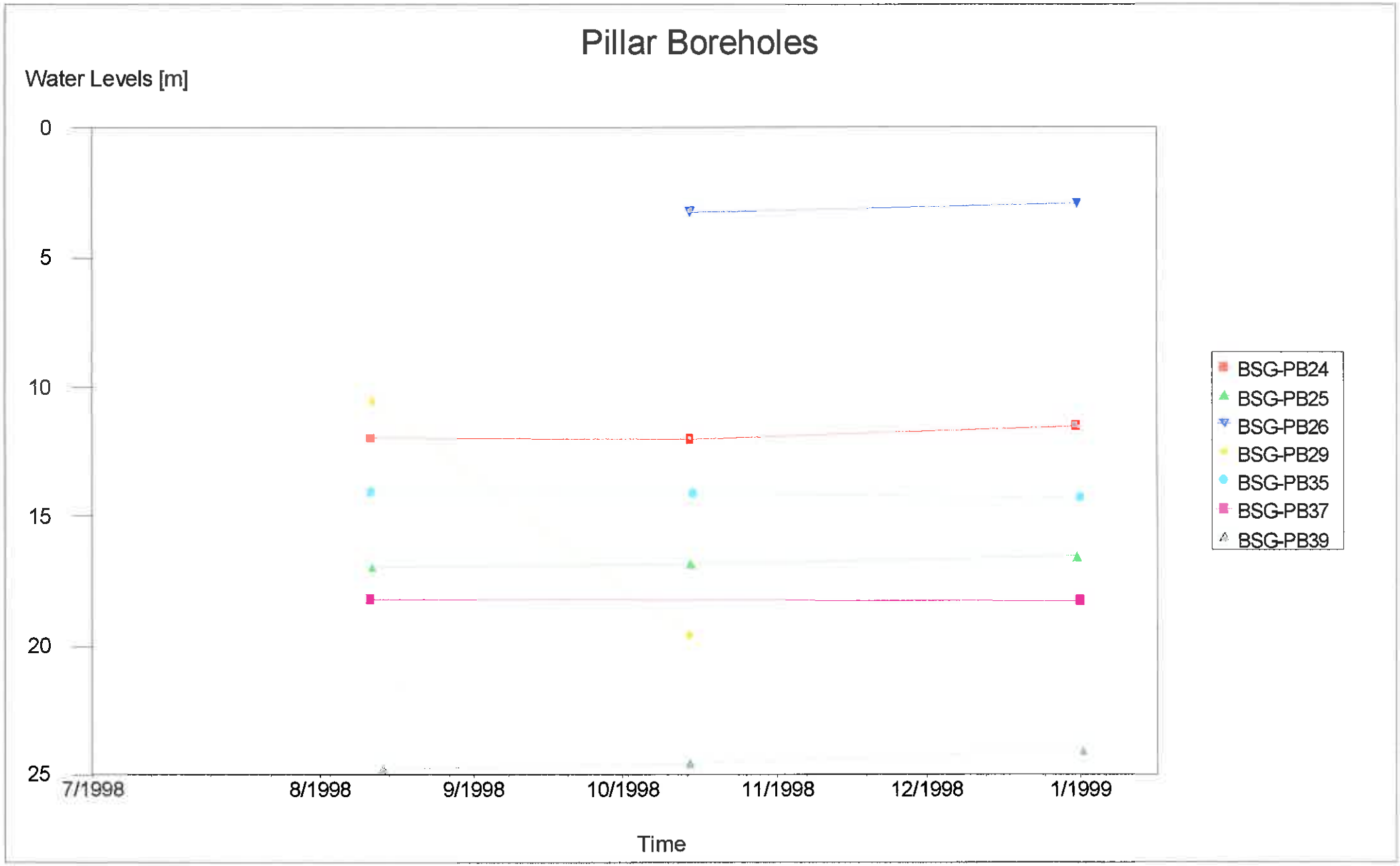
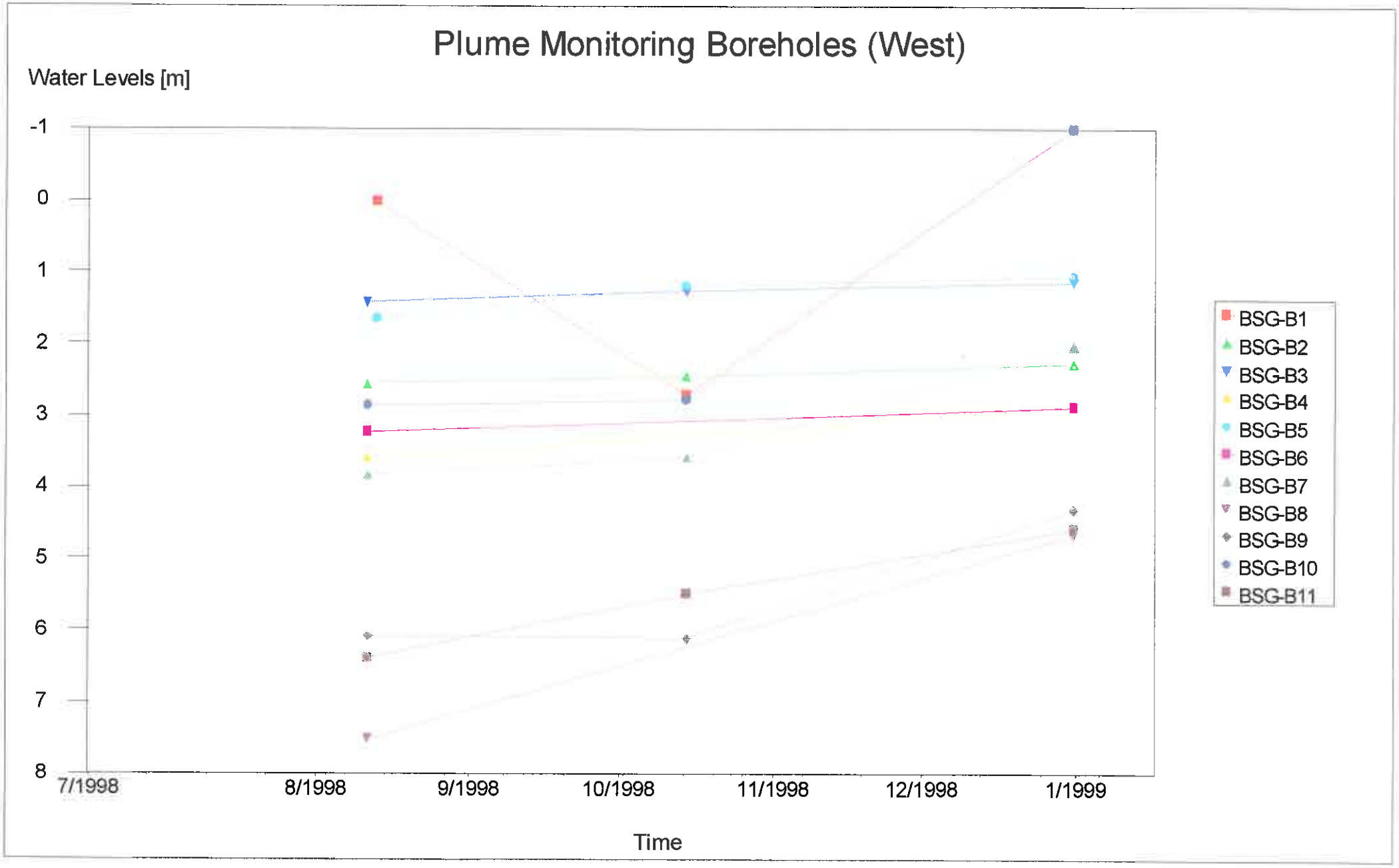
2529CC00034	19990115	10h50	24.72	1541.41	BSG-UB34	0
2529CC00035	19980825	13h35	14.07	1549.24	BSG-PB35	0
2529CC00035	19981029	07h34	14.12	1549.19	BSG-PB35	0
2529CC00035	19990115	10h10	14.30	1549.01	BSG-PB35	0
2529CC00037	19980825	14h00	18.19	1547.95	BSG-PB37	0
2529CC00037	19990115	10h30	18.24	1547.90	BSG-PB37	0
2529CC00038	19980827	15h00	15.46	1552.10	BSG-UB38	0
2529CC00038	19981028	12h44	13.58	1553.98	BSG-UB38	0
2529CC00038	19990115	15h45	11.65	1555.91	BSG-UB38	0
2529CC00039	19980827	15h10	24.78	1535.49	BSG-PB39	0
2529CC00039	19981028	12h33	24.56	1535.71	BSG-PB39	0
2529CC00039	19990115	15h00	24.06	1536.21	BSG-PB39	0
2529CC00042	19980827	15h35	24.28	1534.28	BSG-UB42	0
2529CC00042	19981112	14h05	24.55	1534.01	BSG-UB42	0

Site id	Date	Time	Water level (m)	Water-level Elevation (mamsl)	Number on map	Piezo nr.
2529CC00042	19990115	14h35	24.50	1534.06	BSG-UB42	0
2529CC00043	19980827	15h50	3.85	1533.58	BSG-UB43	0
2529CC00043	19981028	10h36	4.00	1533.43	BSG-UB43	0
2529CC00043	19990115	13h30	3.92	1533.51	BSG-UB43	0
2529CC00044	19980827	16h00	15.72	1530.01	BSG-UB44	0
2529CC00044	19981028	10h46	11.66	1534.07	BSG-UB44	0
2529CC00044	19990115	13h45	11.81	1533.92	BSG-UB44	0
2529CC00045	19980827	16h10	20.20	1534.35	BSG-UB45	0
2529CC00045	19981028	11h08	20.43	1534.12	BSG-UB45	0
2529CC00045	19990115	14h20	20.37	1534.18	BSG-UB45	0
2529CC00104	19981005	15h00	20.98	1579.66	BH-I	0


Underground Boreholes
Water Levels [m]
0
5
10
15
20
25
7/1998
8/1998
9/1998
10/1998
11/1998
12/1998
1/1999
Time
BSG-UB22
BSG-UB23
BSG-UB27
BSG-UB28
BSG-UB30
BSG-UB31
BSG-UB33
BSG-UB34
BSG-UB38
BSG-UB40
BSG-UB41
BSG-UB42
BSG-UB43
BSG-UB44
BSG-UB45


Pillar Boreholes
Water Levels [m]
0
5
10
15
20
25
7/1998
8/1998
9/1998
10/1998
11/1998
12/1998
1/1999
Time
BSG-PB24
BSG-PB25
BSG-PB26
BSG-PB29
BSG-PB35
BSG-PB37
BSG-PB39


Plume Monitoring Boreholes (West)
Water Levels [m]
-1
0
1
2
3
4
5
6
7
8
7/1998
8/1998
9/1998
10/1998
11/1998
12/1998
1/1999
Time
BSG-B1
BSG-B2
BSG-B3
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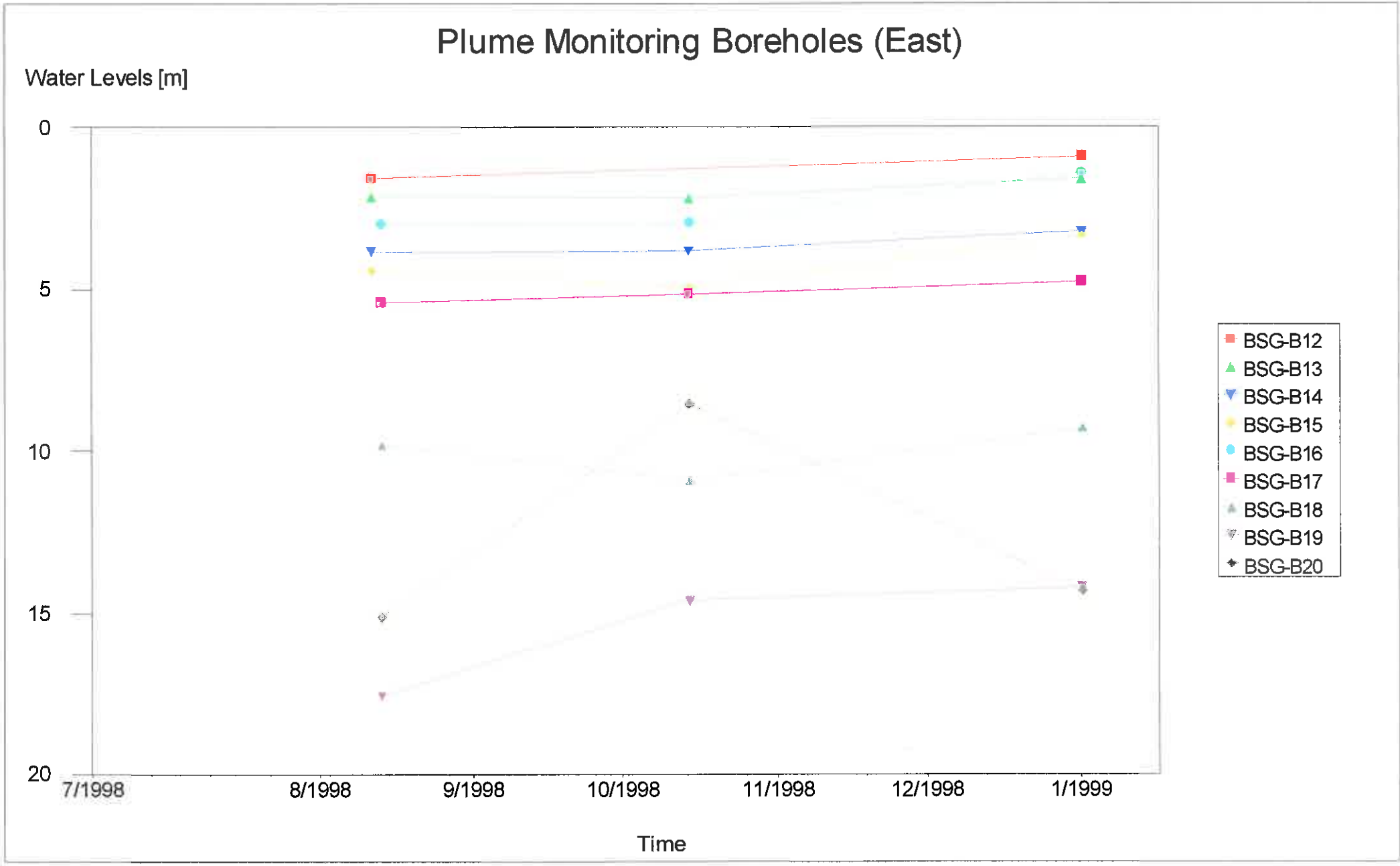
BSG-B8
BSG-B9
BSG-B10
BSG-B11


Plume Monitoring Boreholes (East)
Water Levels [m]
0
5
10
15
20
7/1998
8/1998
9/1998
10/1998
11/1998
12/1998
1/1999
Time
BSG-B12
BSG-B13
BSG-B14
BSG-B15
BSG-B16
BSG-B17
BSG-B18
BSG-B19
BSG-B20

APPENDIX VI

GEOHYDROLOGICAL CROSS SECTIONS

FIGURE 1:Positions of cross-section lines

Cross-section A - A'

Cross-section B - B'

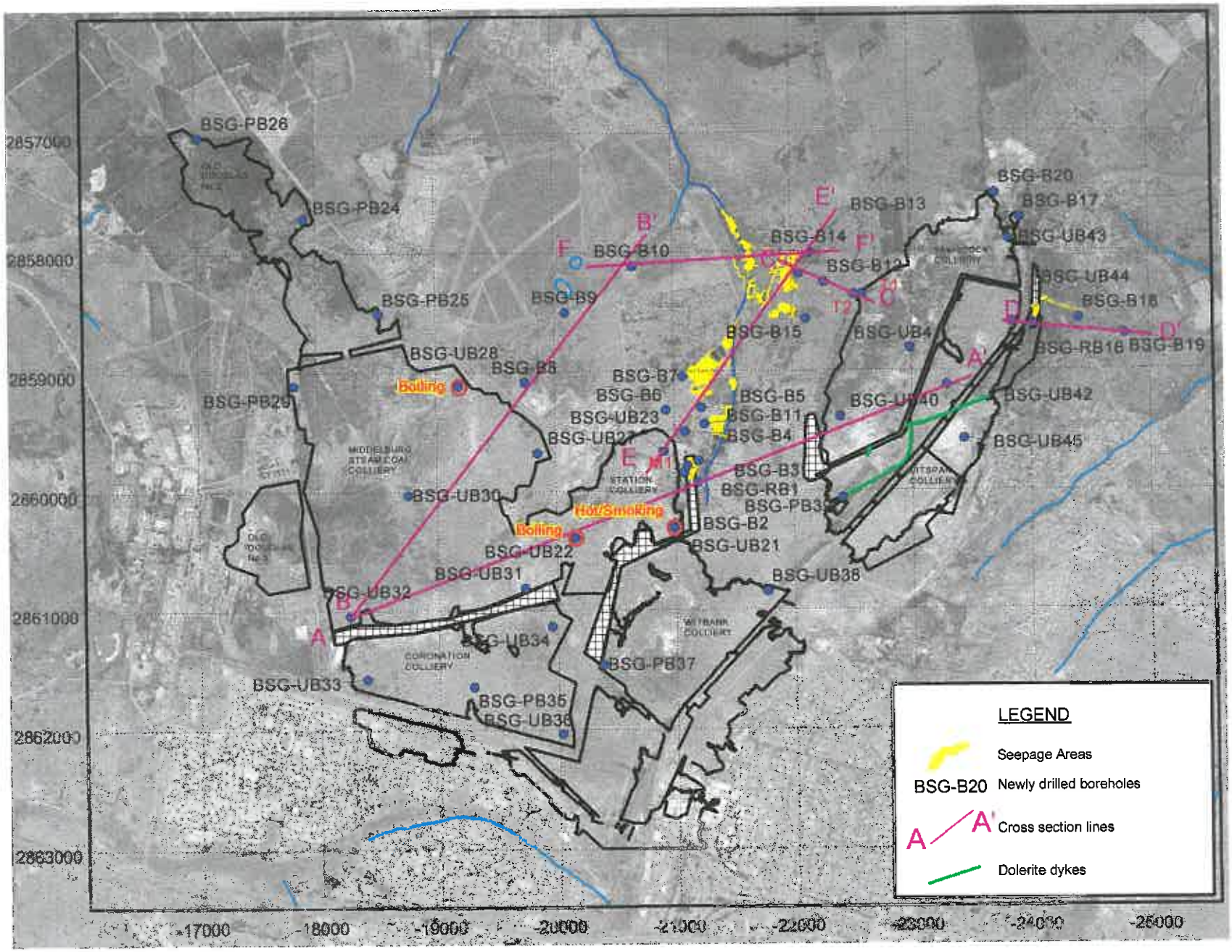
Cross-section C - C'

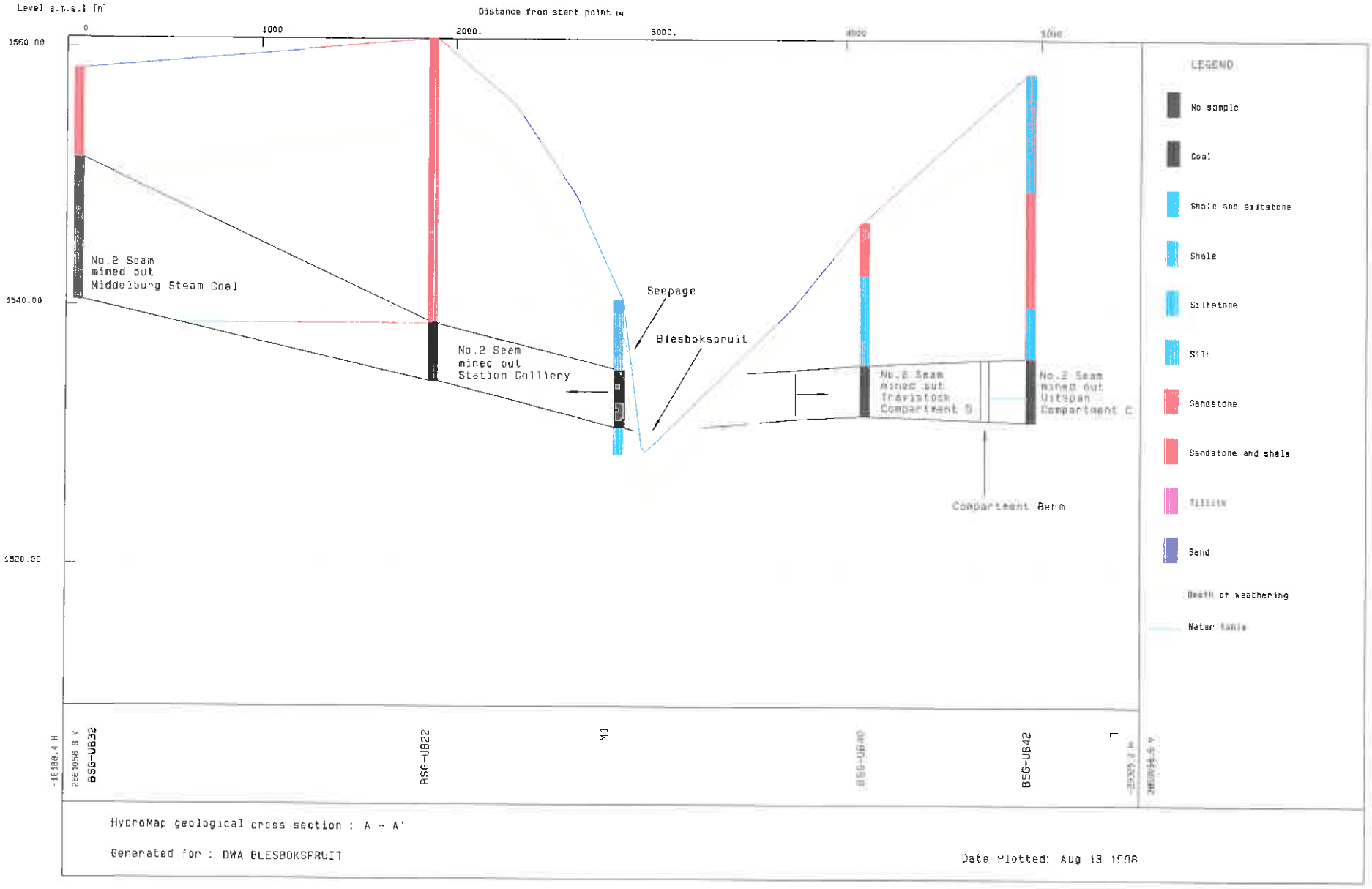
Cross-section D - D'

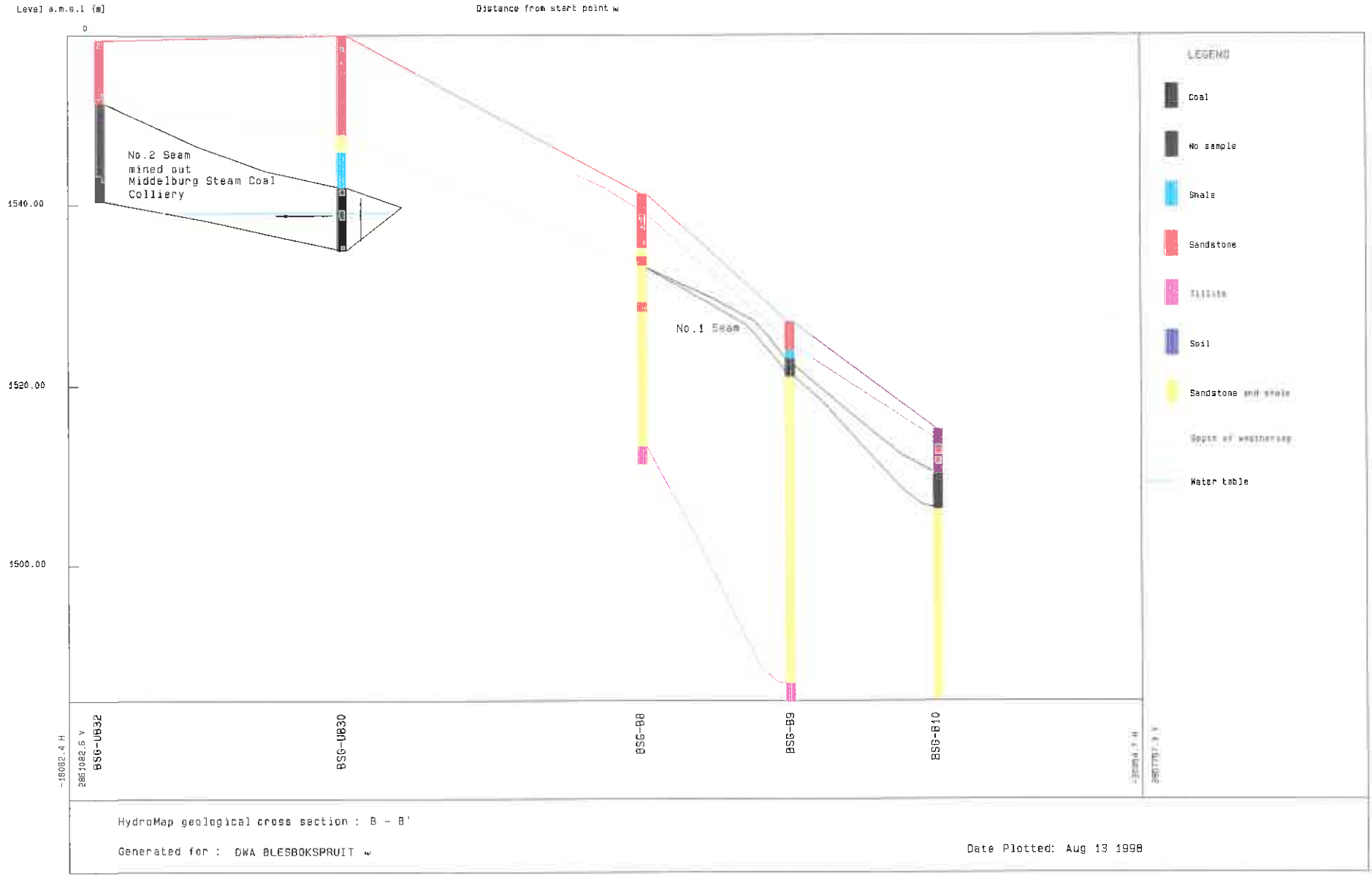
Cross-section E - E'

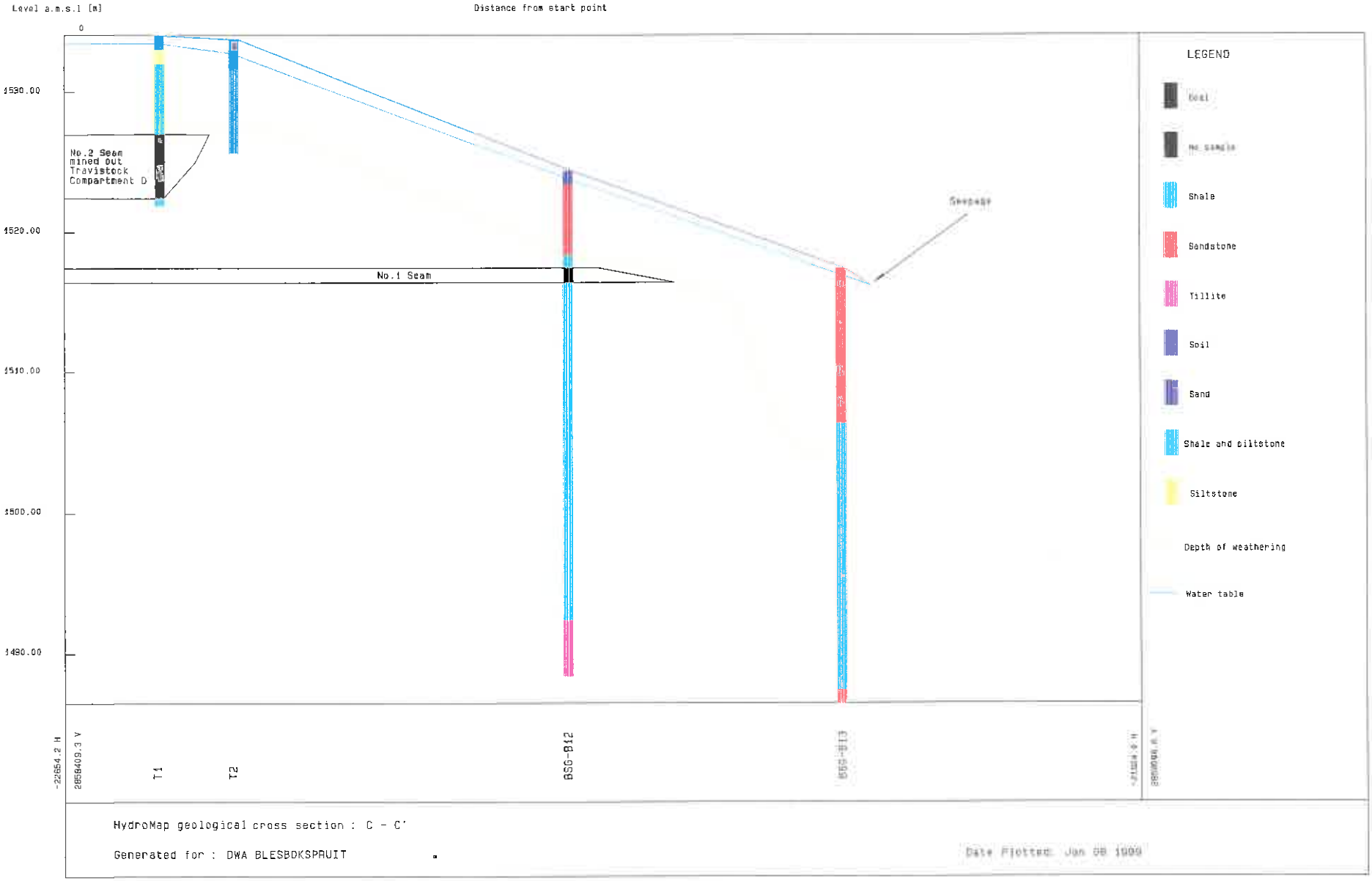
Cross-section F - F'

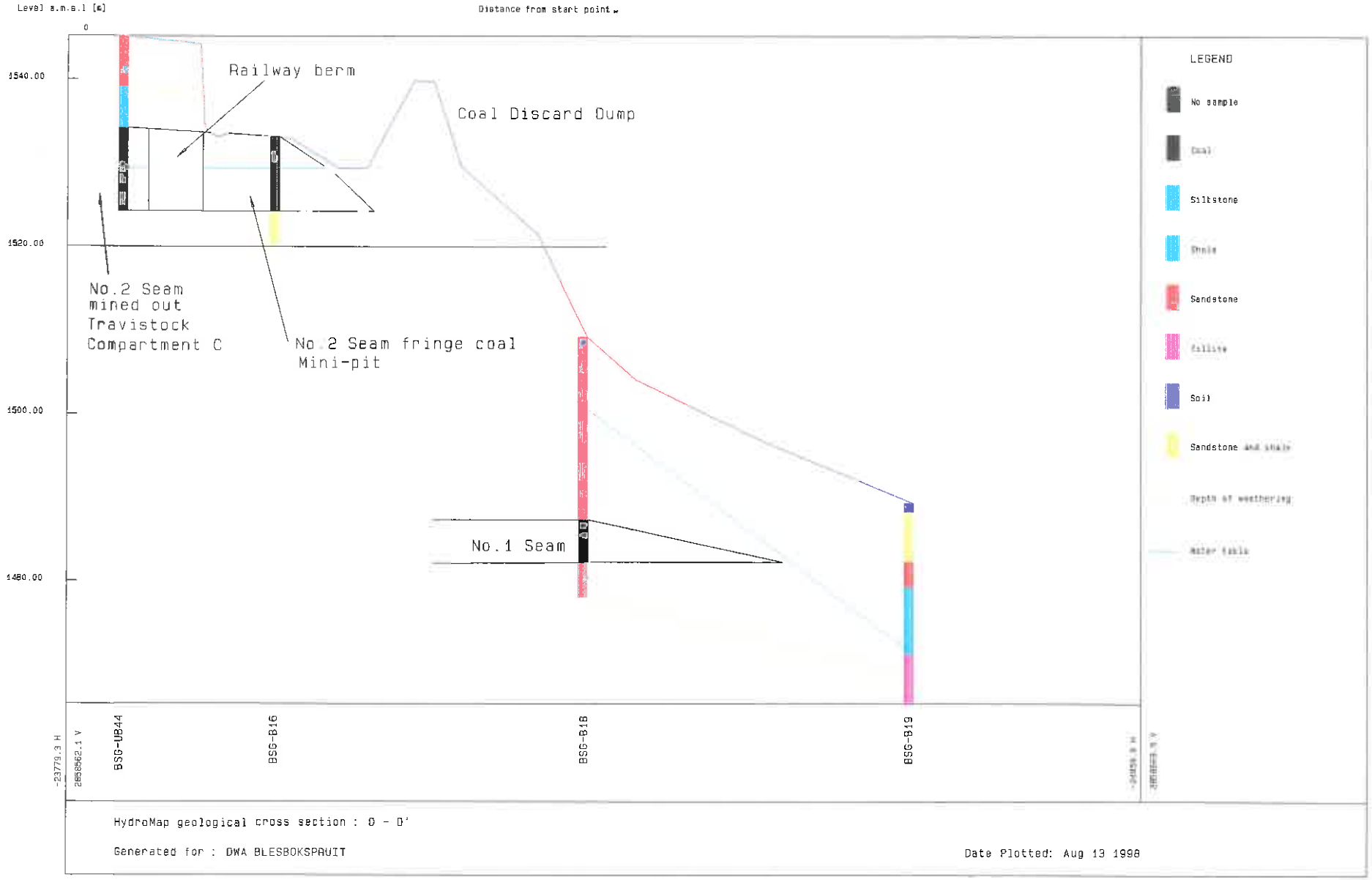
FIGURE 1
Positions of cross section lines.

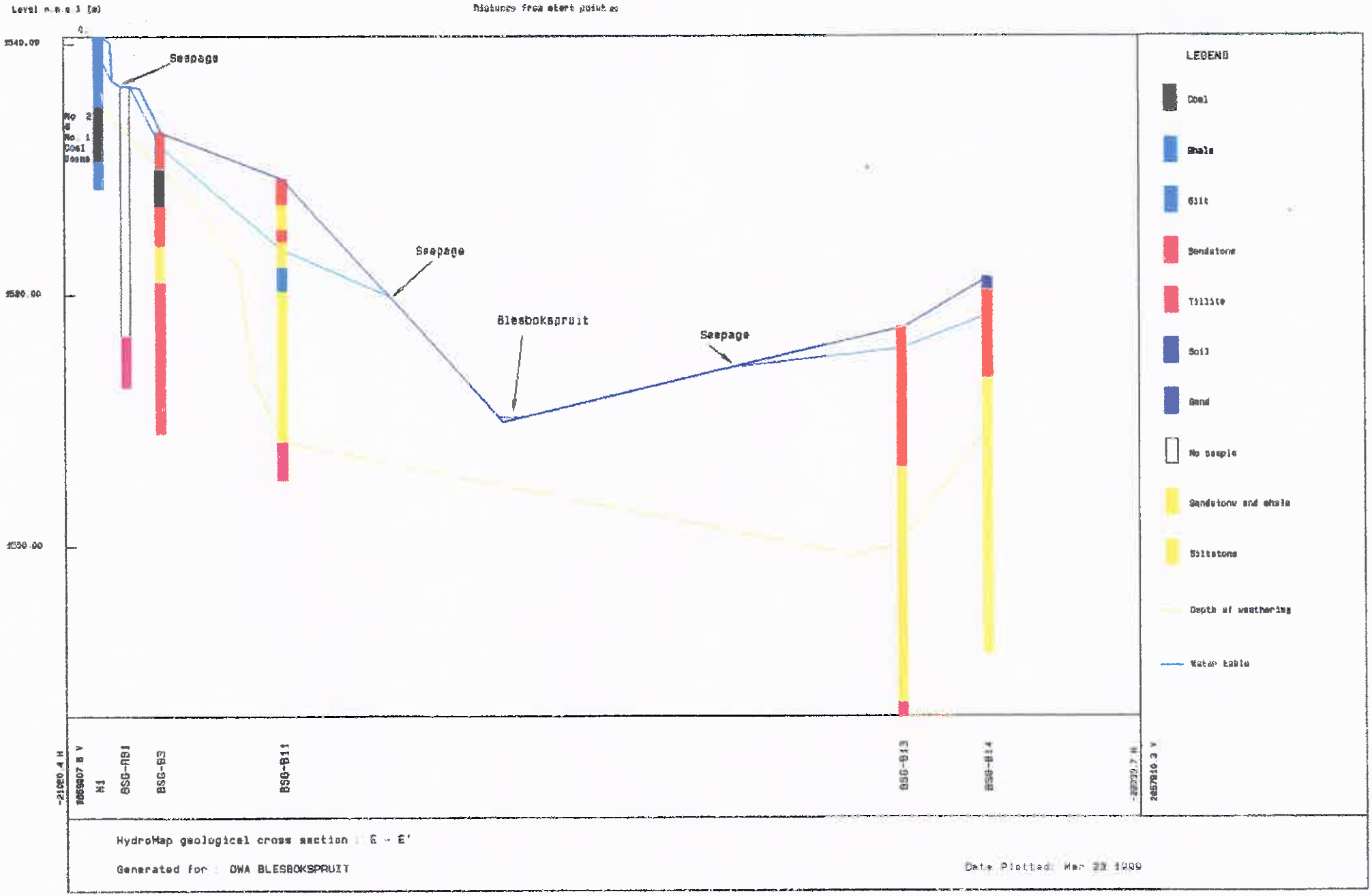


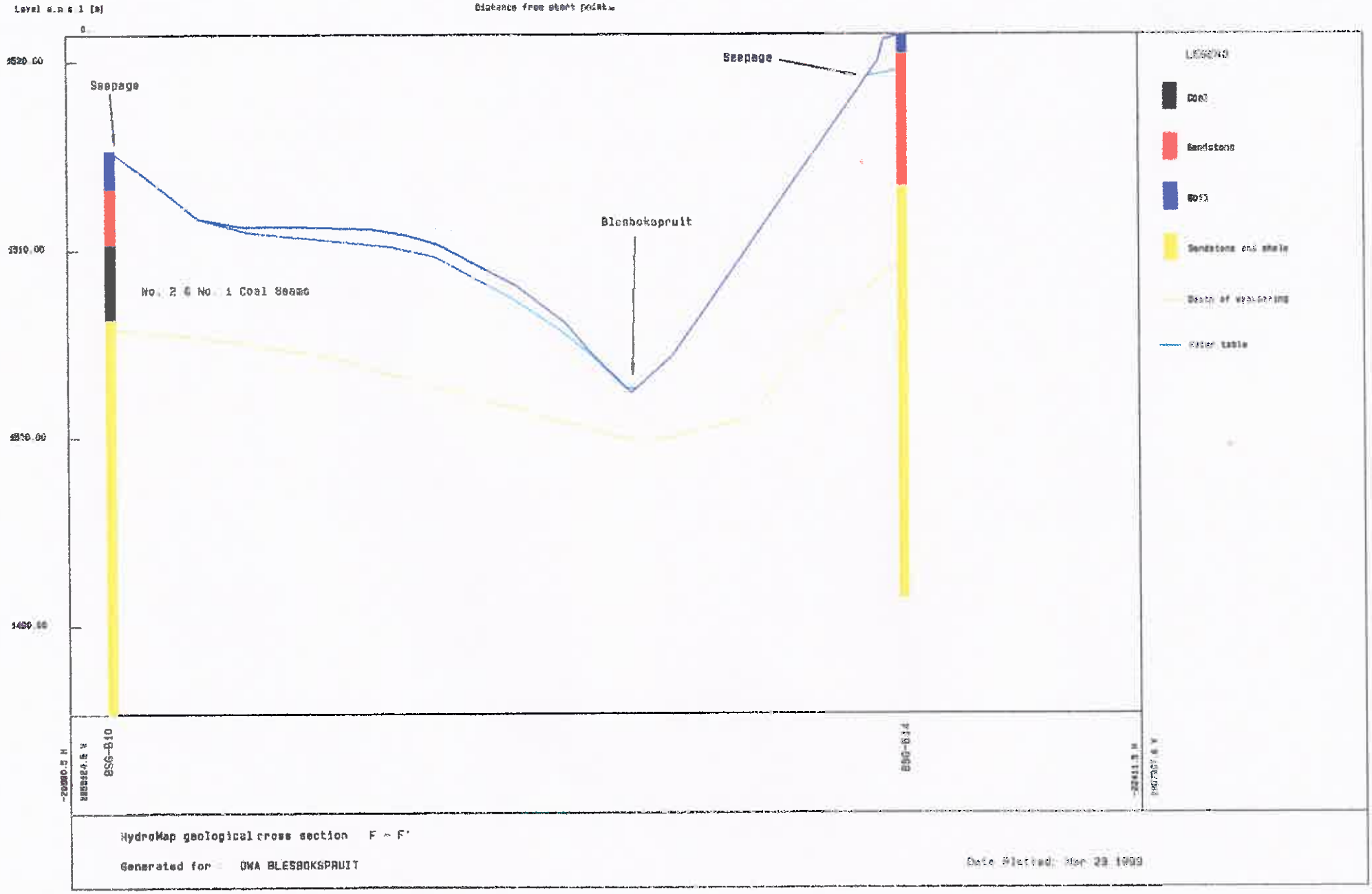

Level a.m.s.l [m]
Distance from start point (m
0
1000
2000.
3000.
4000
5000
1560.00
1540.00
1520.00
No.2 Seam
mined out
Middelburg Steam Coal
No.2 Seam
mined out
Station Colliery
Seepage
Blesbokspruit
No.2 Seam
mined out
Travistock
Compartment B
No.2 Seam
mined out
Uitspan
Compartment C
Compartment Berm
BSG-UB32
BSG-UB22
M1
BSG-UB40
BSG-UB42
LEGEND
No sample
Coal
Shale and siltstone
Shale
Siltstone
Silt
Sandstone
Sandstone and shale
Tillite
Sand
Depth of weathering
Water table
HydroMap geological cross section : A - A'
Generated for : DWA BLESBOKSPRUIT
Date Plotted: Aug 13 1998


Level a.m.s.l (m)
Distance from start point m
0
1540.00
1520.00
1500.00
No.2 Seam
mined out
Middelburg Steam Coal
Colliery
No.1 Seam
LEGEND
Coal
No sample
Shale
Sandstone
Tillite
Soil
Sandstone and shale
Water table
BSG-UB32
BSG-UB30
BSG-B8
BSG-B9
BSG-B10
HydroMap geological cross section : B - B'
Generated for : DWA BLESBOKSPRUIT m
Date Plotted: Aug 13 1998


Level a.m.s.l [m]
Distance from start point
0
1530.00
1520.00
1510.00
1500.00
1490.00
No.2 Seam
mined out
Travistock
Compartment D
No.1 Seam
Seepage
LEGEND
Coal
No sample
Shale
Sandstone
Tillite
Soil
Sand
Shale and siltstone
Siltstone
Depth of weathering
Water table
-22654.2 H
2858409.3 V
T1
T2
BSG-B12
BSG-B13
HydroMap geological cross section : C - C'
Generated for : DWA BLESBOKSPRUIT
Date Plotted: Jan 08 1999


Level a.m.s.l [m]
Distance from start point
0
1540.00
1520.00
1500.00
1480.00
Railway berm
Coal Discard Dump
No.2 Seam
mined out
Travistock
Compartment C
No.2 Seam fringe coal
Mini-pit
No.1 Seam
BSG-UB44
BSG-B16
BSG-B18
BSG-B19
LEGEND
No sample
Coal
Siltstone
Shale
Sandstone
Silica
Soil
Sandstone and shale
Depth of weathering
Water table
HydroMap geological cross section : B - B'
Generated for : DWA BLESBOKSPRUIT
Date Plotted: Aug 13 1998


Level m.a.s.l (m)
Distance from start point (m)
1540.00
1530.00
1520.00
Seepage
Seepage
Blesbokspruit
Seepage
No. 2
No. 1
Coal
Seams
BSG-RB1
BSG-B3
BSG-B11
BSG-B13
BSG-B14
LEGEND
Coal
Shale
Silt
Sandstone
Tillite
Soil
Sand
No sample
Sandstone and shale
Siltstone
Depth of weathering
Water table
HydroMap geological cross section : E - E'
Generated for : OWA BLESBOKSPRUIT
Date Plotted: Mar 23 1999


Level a.m.s.l. (m)
Distance from start point
1520.00
1510.00
1500.00
1490.00
Seepage
Seepage
Blesbokspruit
No. 2 & No. 1 Coal Seams
BSG-B10
BSG-B14
Coal
Sandstone
Shale
Sandstone and shale
Depth of weathering
Water table
HydroMap geological cross section F - F'
Generated for DWA BLESBOKSPRUIT
Date Plotted: Mar 28 1999

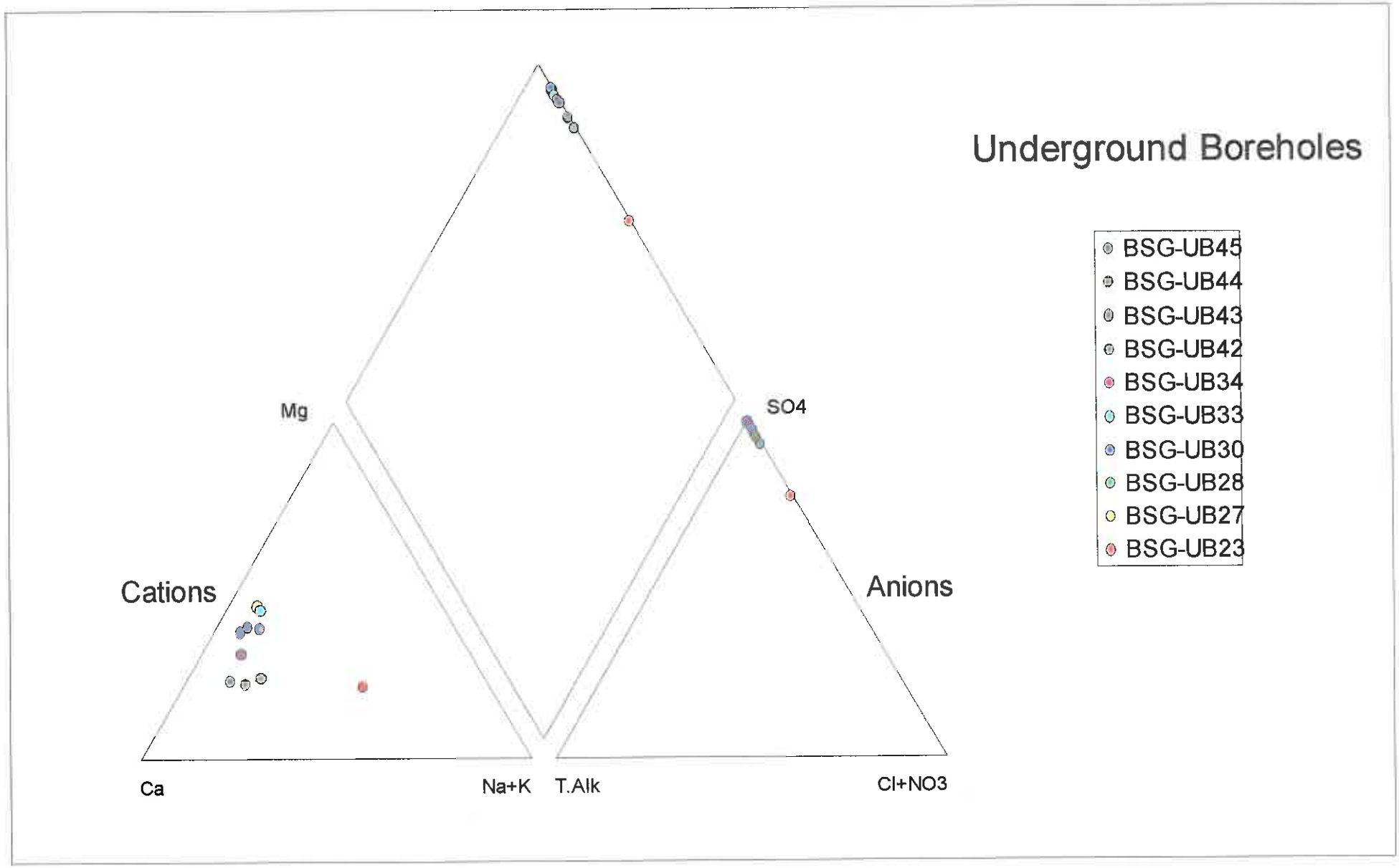
APPENDIX VII

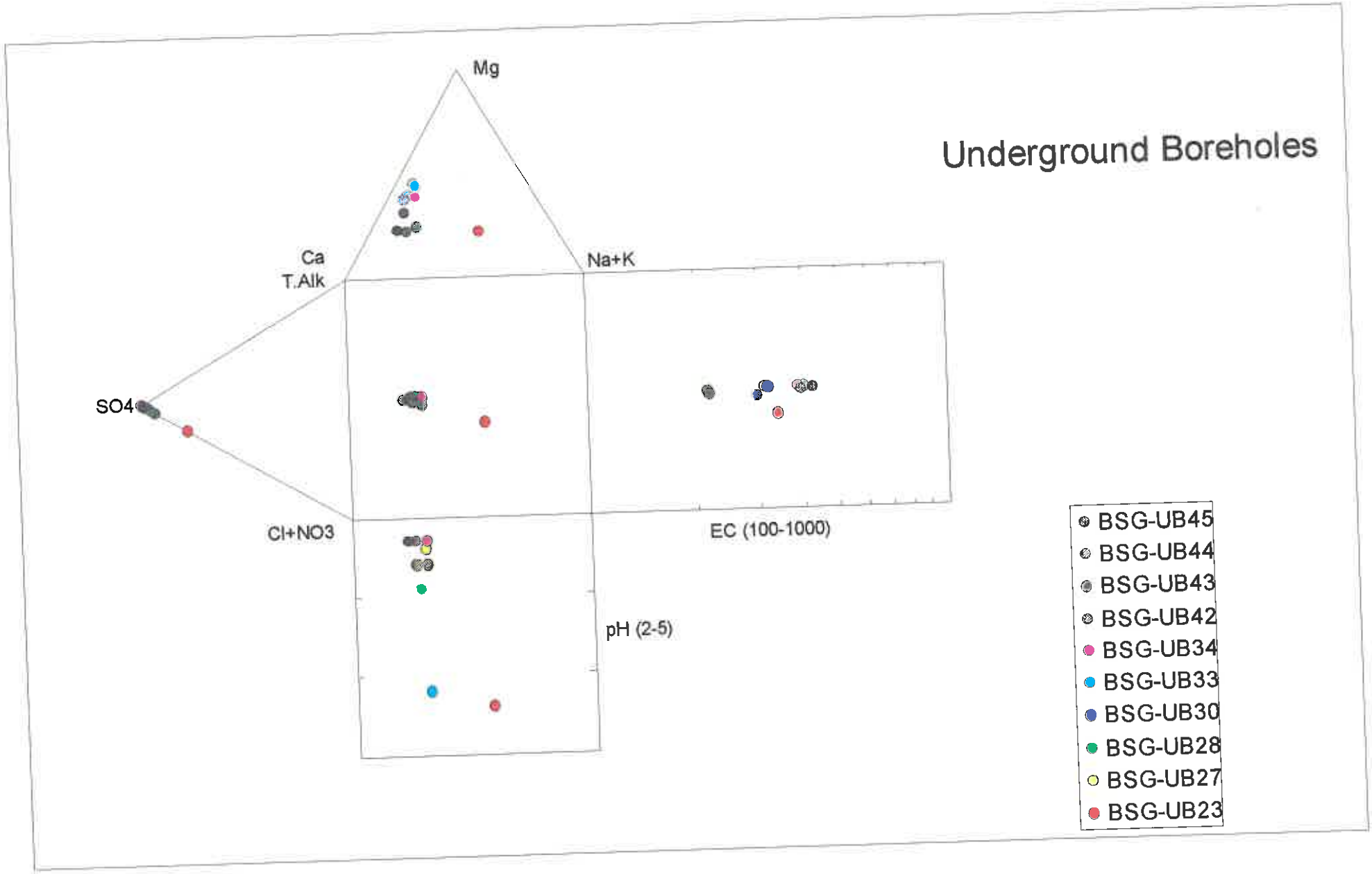
HYDROCHEMICAL IMAGING
(PIPER, DUROV & EXPANDED DUROV PLOTS)

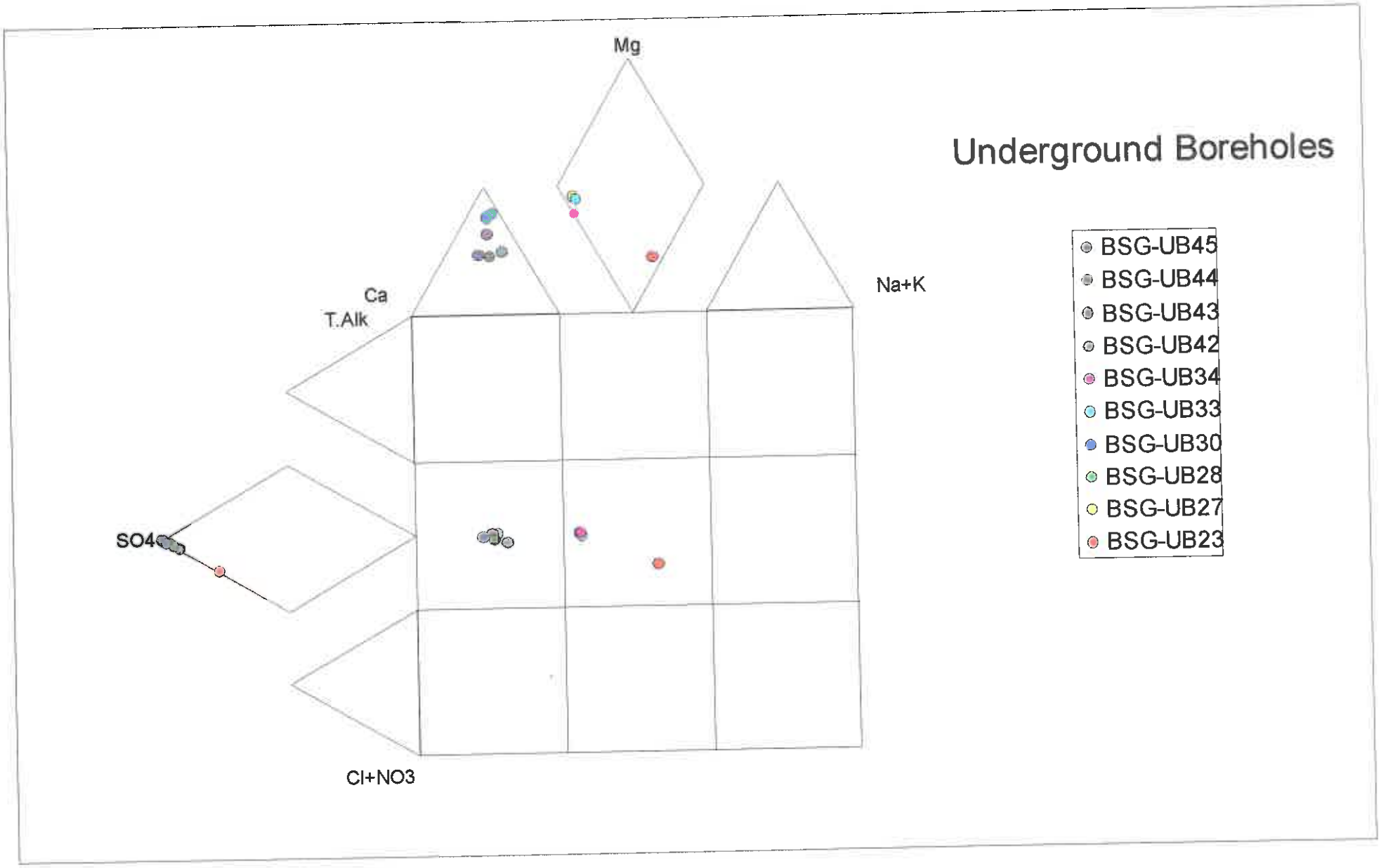
FOR

UNDERGROUND BOREHOLES
PILLAR BOREHOLES
PLUME MONITORING BOREHOLES

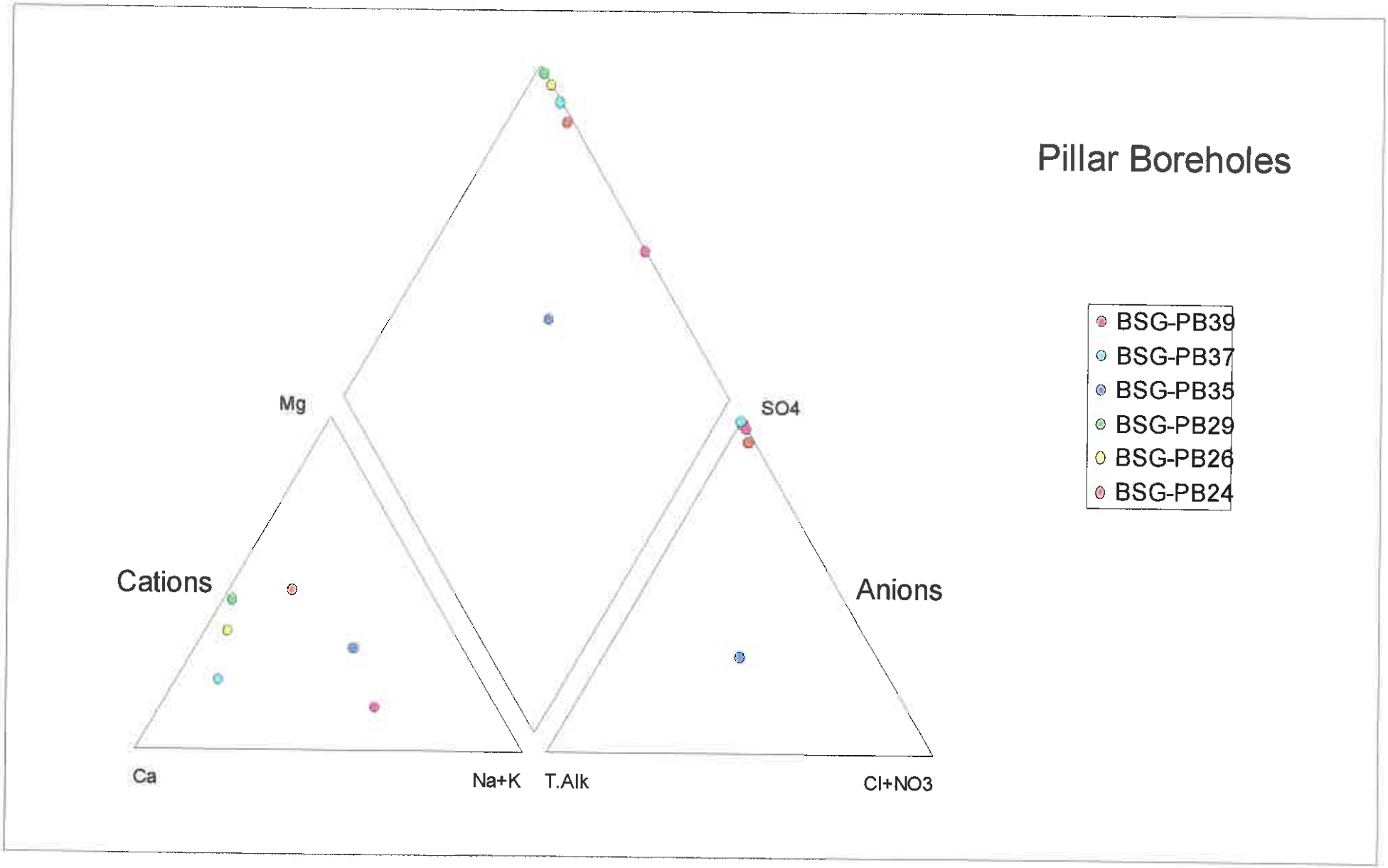
UNDERGROUND BOREHOLES

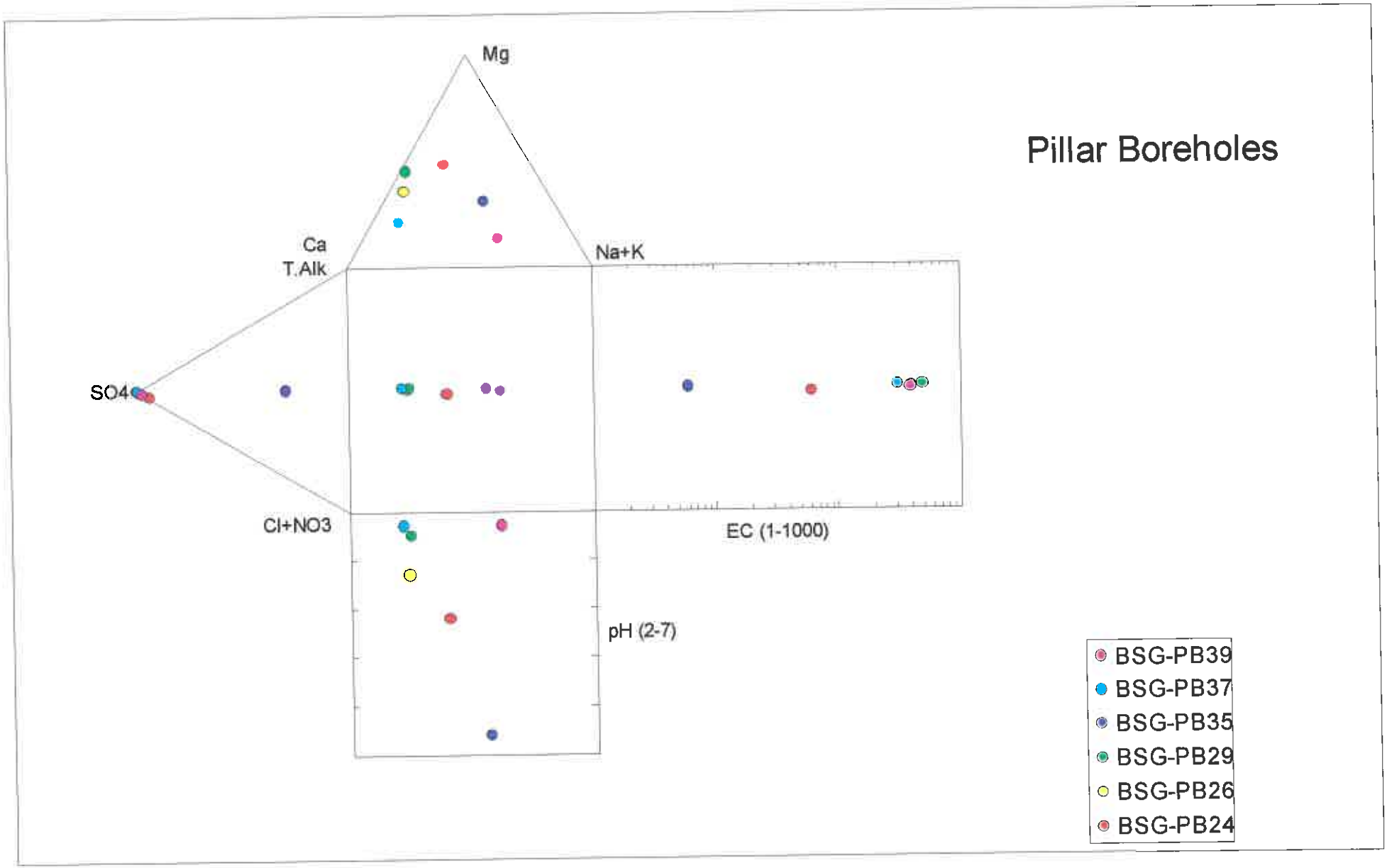

Underground Boreholes
BSG-UB45
BSG-UB44
BSG-UB43
BSG-UB42
BSG-UB34
BSG-UB33
BSG-UB30
BSG-UB28
BSG-UB27
BSG-UB23
Mg
SO4
Cations
Anions
Ca
Na+K
T.Alk
Cl+NO3

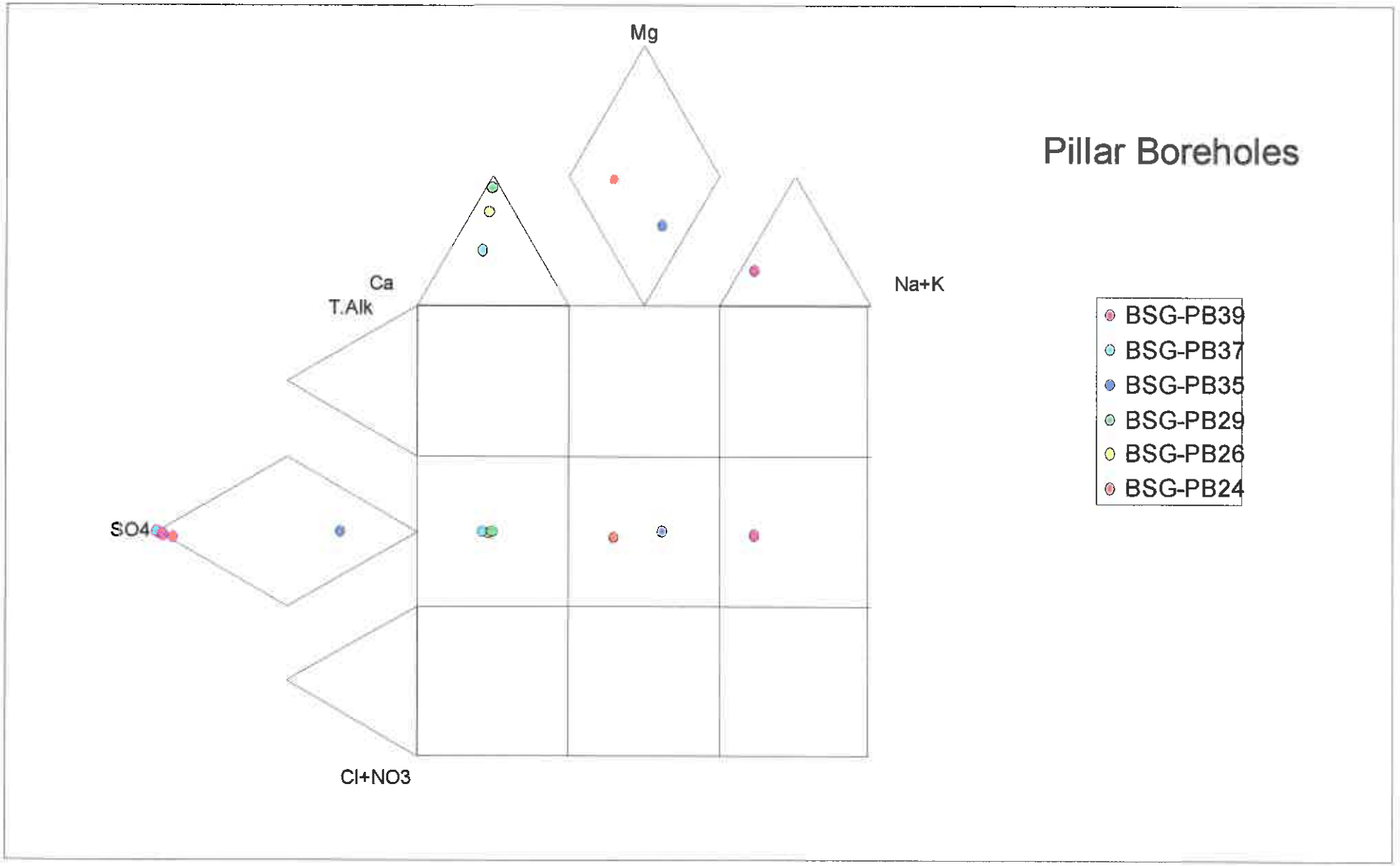

Underground Boreholes
Mg
Ca
T.Alk
Na+K
SO4
Cl+NO3
EC (100-1000)
pH (2-5)
BSG-UB45
BSG-UB44
BSG-UB43
BSG-UB42
BSG-UB34
BSG-UB33
BSG-UB30
BSG-UB28
BSG-UB27
BSG-UB23


Mg
Ca
T.Alk
Na+K
SO4
Cl+NO3
Underground Boreholes
BSG-UB45
BSG-UB44
BSG-UB43
BSG-UB42
BSG-UB34
BSG-UB33
BSG-UB30
BSG-UB28
BSG-UB27
BSG-UB23

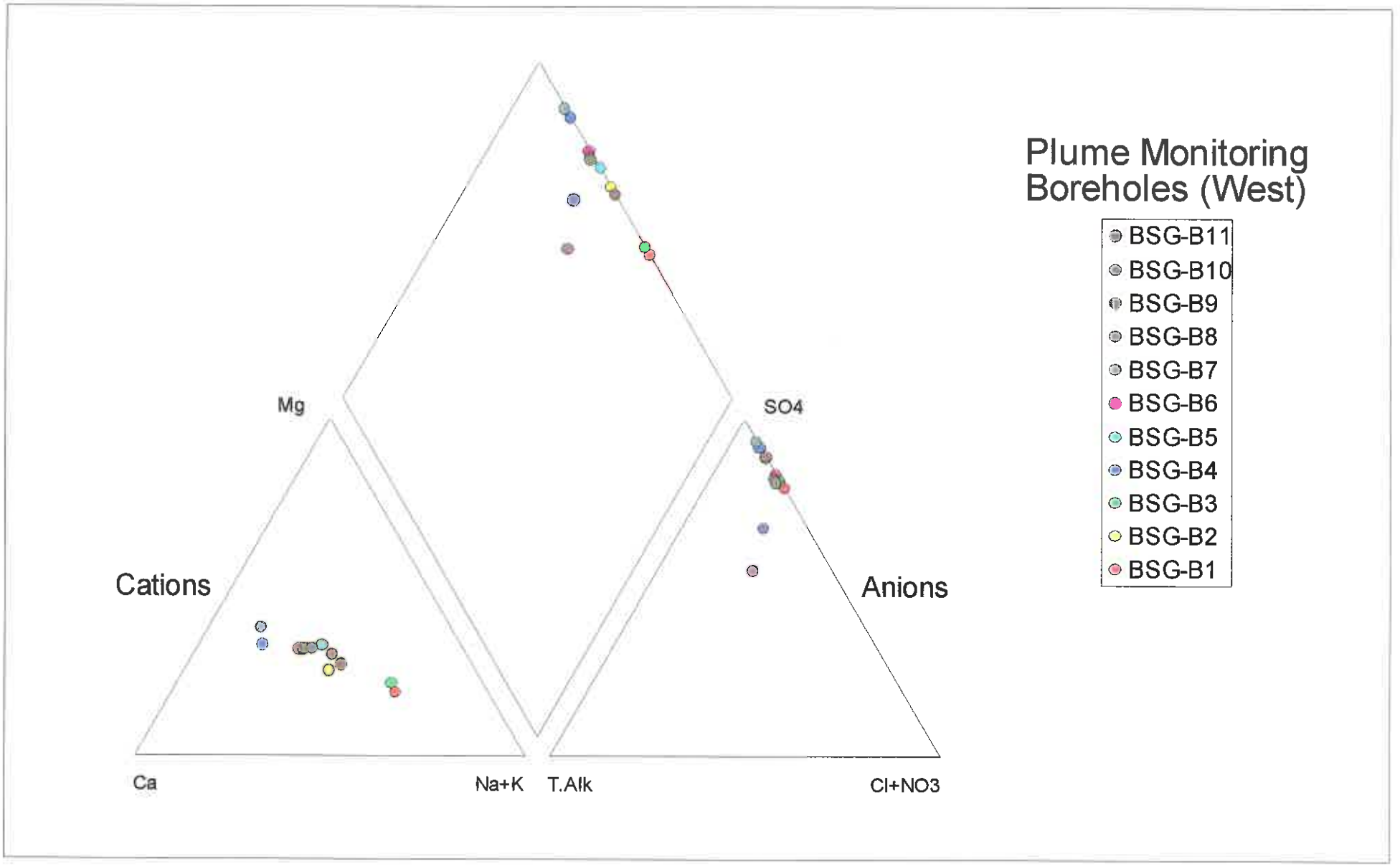
PILLAR BOREHOLES

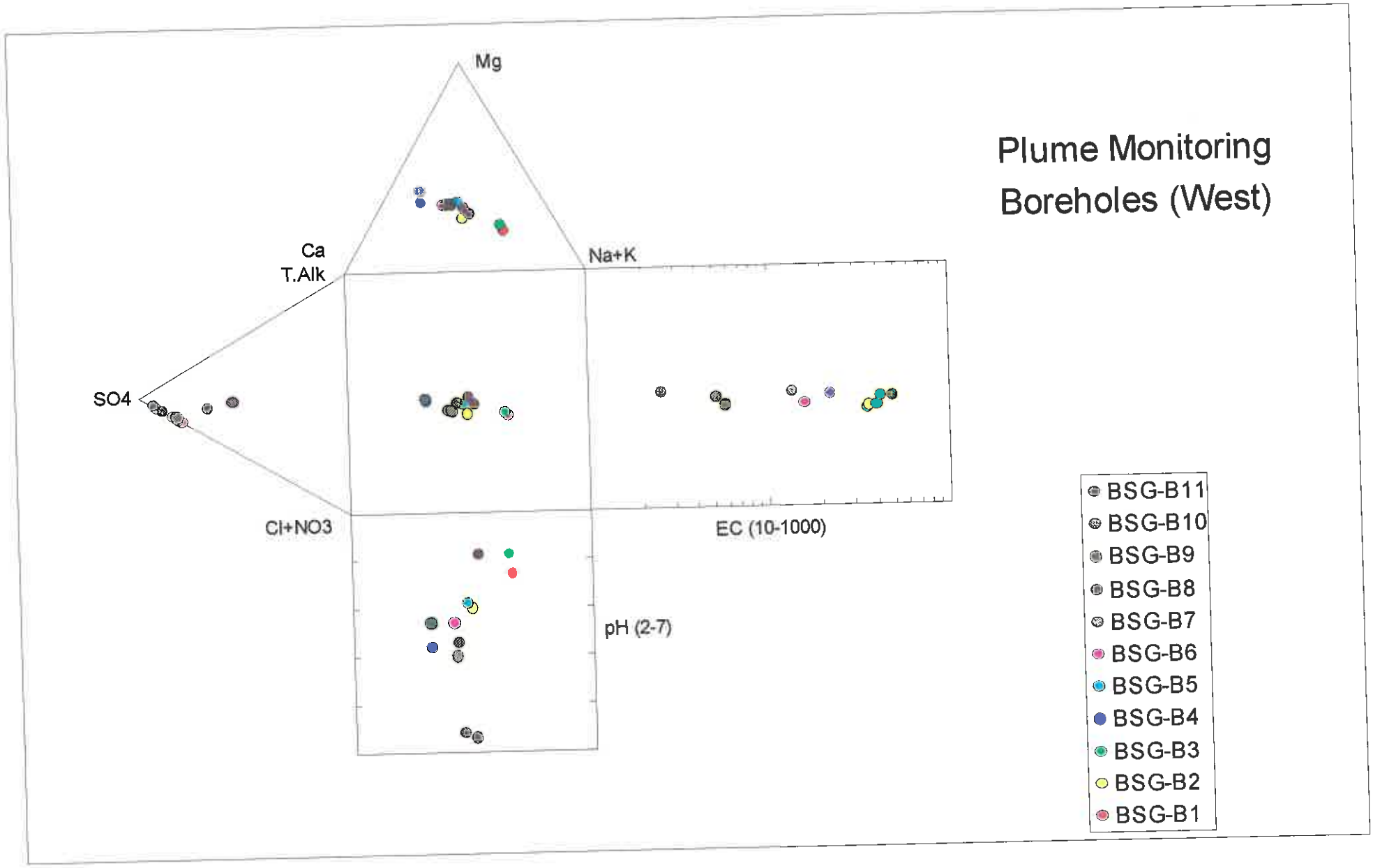

Pillar Boreholes
BSG-PB39
BSG-PB37
BSG-PB35
BSG-PB29
BSG-PB26
BSG-PB24
Mg
SO4
Cations
Anions
Ca
Na+K
T.Alk
Cl+NO3

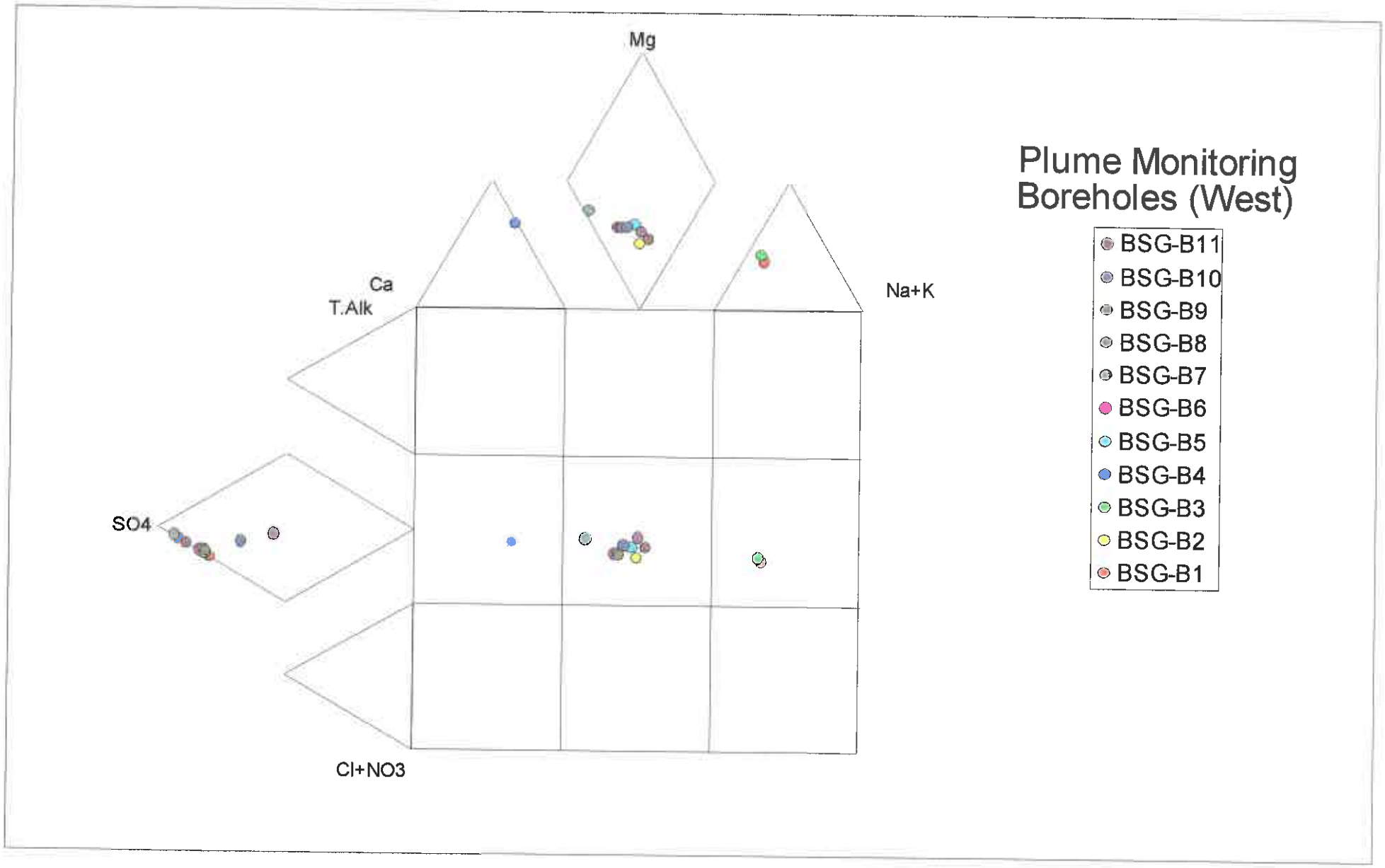

Pillar Boreholes
Mg
Ca
T.Alk
Na+K
SO4
Cl+NO3
EC (1-1000)
pH (2-7)
BSG-PB39
BSG-PB37
BSG-PB35
BSG-PB29
BSG-PB26
BSG-PB24

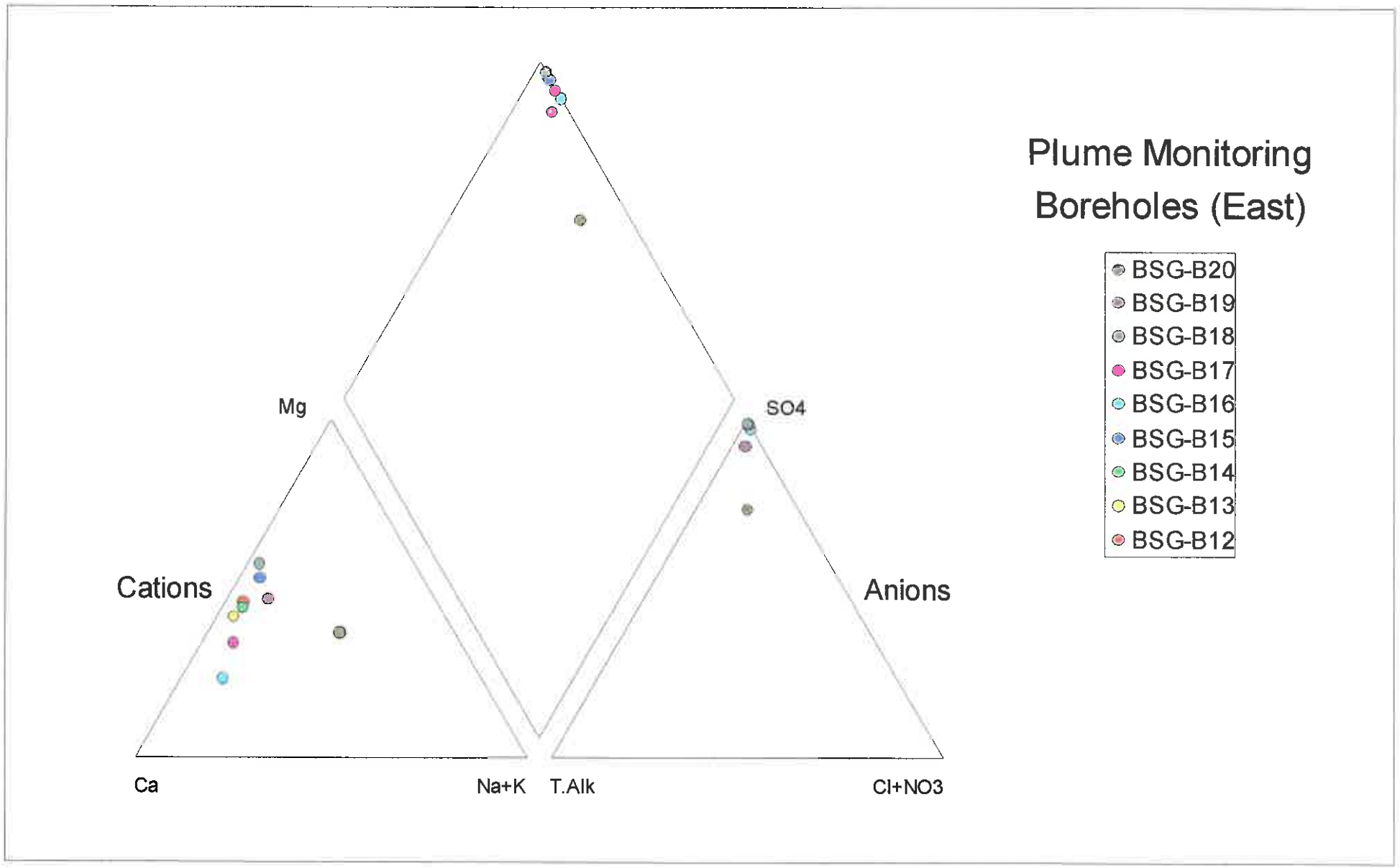

Mg
Ca
T.Alk
Na+K
SO4
Cl+NO3
Pillar Boreholes
BSG-PB39
BSG-PB37
BSG-PB35
BSG-PB29
BSG-PB26
BSG-PB24

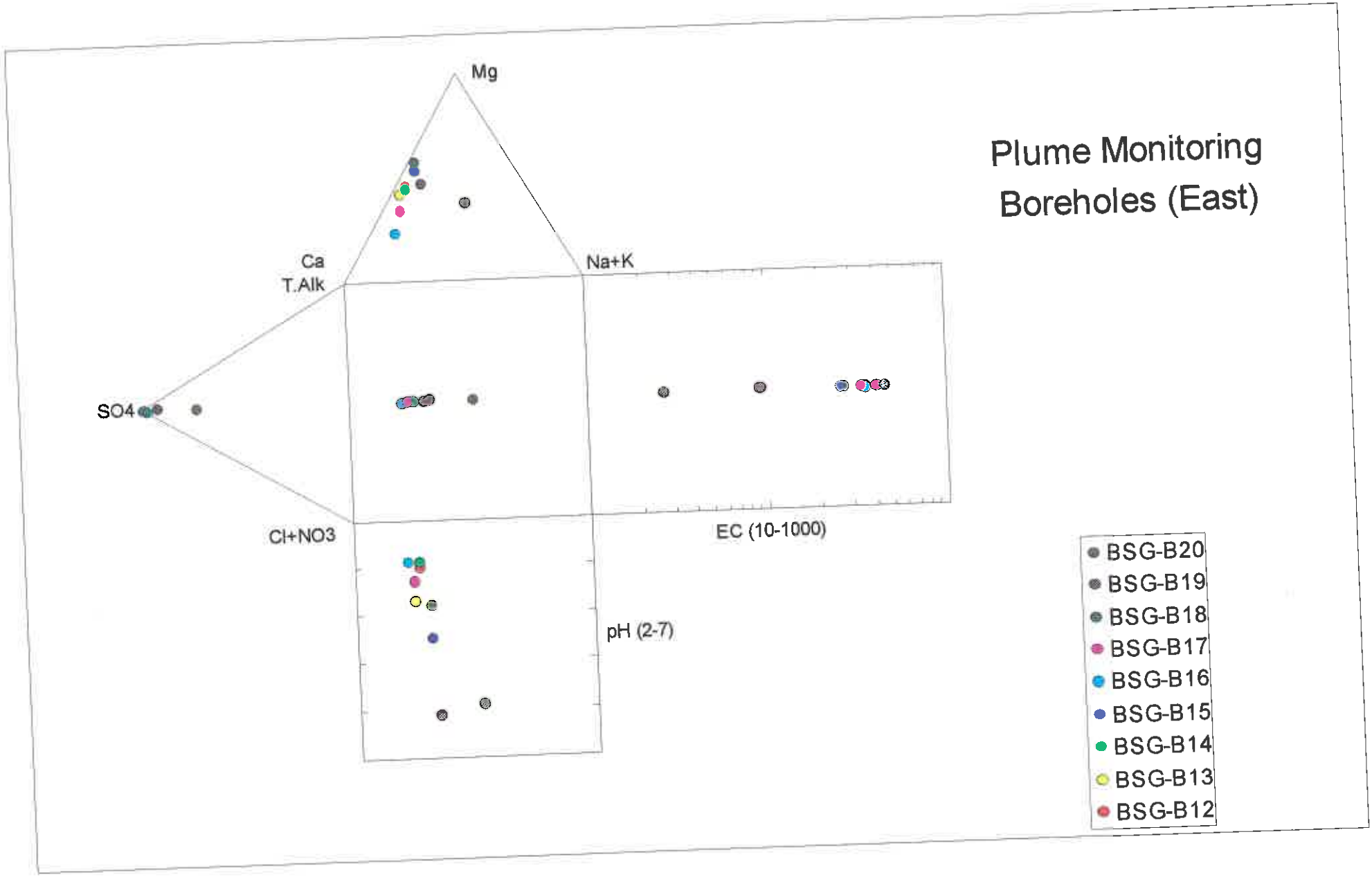
PLUME MONITORING BOREHOLES

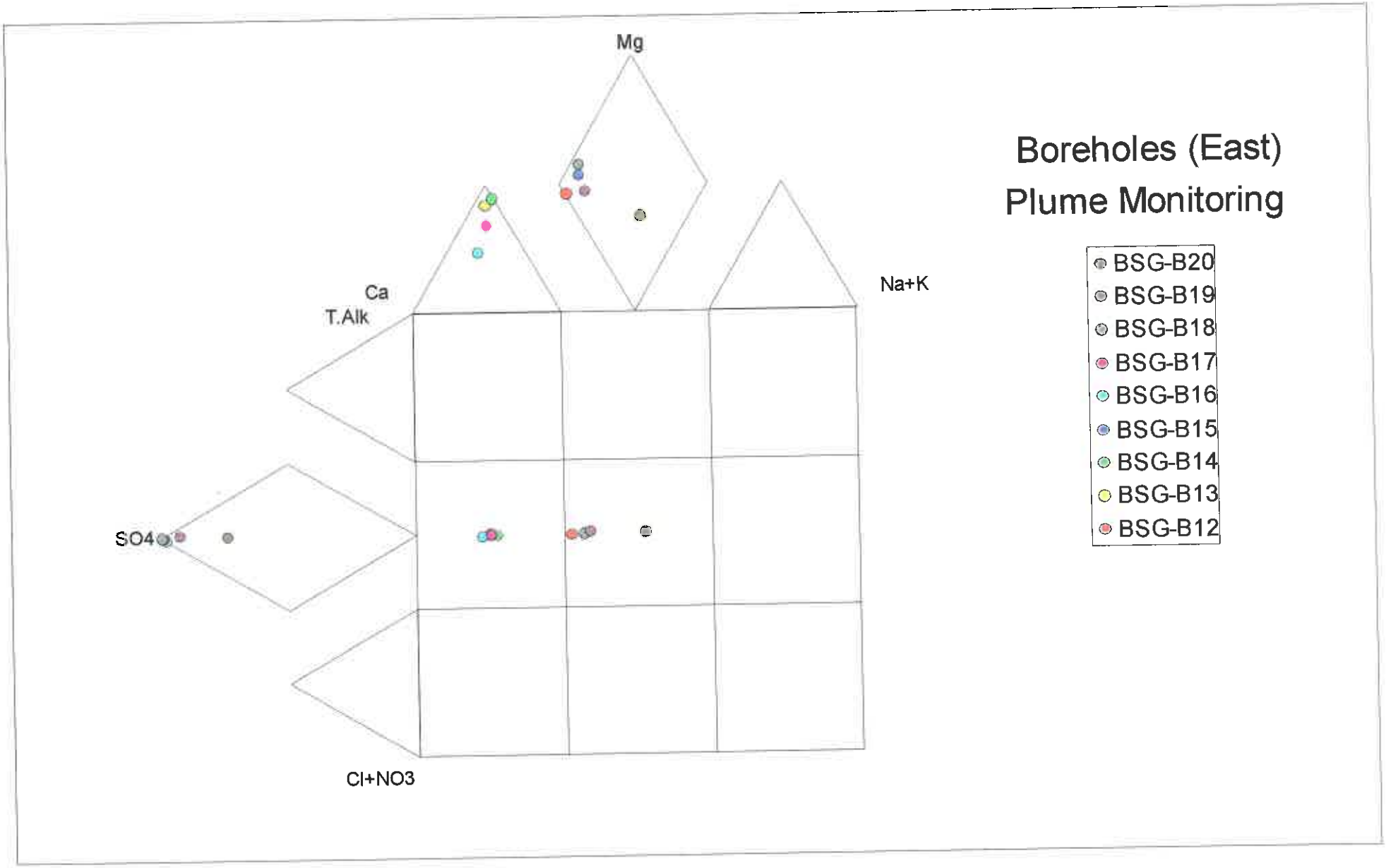

Plume Monitoring Boreholes (West)
BSG-B11
BSG-B10
BSG-B9
BSG-B8
BSG-B7
BSG-B6
BSG-B5
BSG-B4
BSG-B3
BSG-B2
BSG-B1
Mg
SO4
Cations
Anions
Ca
Na+K
T.Alk
Cl+NO3


Plume Monitoring
Boreholes (West)
Mg
Ca
T.Alk
Na+K
SO4
Cl+NO3
EC (10-1000)
pH (2-7)
BSG-B11
BSG-B10
BSG-B9
BSG-B8
BSG-B7
BSG-B6
BSG-B5
BSG-B4
BSG-B3
BSG-B2
BSG-B1


Mg
Ca
T.Alk
Na+K
SO4
Cl+NO3
Plume Monitoring Boreholes (West)
BSG-B11
BSG-B10
BSG-B9
BSG-B8
BSG-B7
BSG-B6
BSG-B5
BSG-B4
BSG-B3
BSG-B2
BSG-B1


Plume Monitoring
Boreholes (East)
BSG-B20
BSG-B19
BSG-B18
BSG-B17
BSG-B16
BSG-B15
BSG-B14
BSG-B13
BSG-B12
Mg
SO4
Cations
Anions
Ca
Na+K
T.Alk
Cl+NO3


Plume Monitoring
Boreholes (East)
Mg
Ca
T.Alk
Na+K
SO4
Cl+NO3
EC (10-1000)
pH (2-7)
BSG-B20
BSG-B19
BSG-B18
BSG-B17
BSG-B16
BSG-B15
BSG-B14
BSG-B13
BSG-B12


Mg
Ca
T.Alk
Na+K
SO4
Cl+NO3
Boreholes (East)
Plume Monitoring
BSG-B20
BSG-B19
BSG-B18
BSG-B17
BSG-B16
BSG-B15
BSG-B14
BSG-B13
BSG-B12

APPENDIX VIII

PHOTOGRAPHS

Photo 1: An example of underground fires as a result of spontaneous combustion

Photo 2: Water ponding at Uitspan (fringe coal mining activities east of railway line).

Photo 3: Water run-off at Uitspan (fringe coal mining activities east of railway line).

Position and direction in which photos were taken.

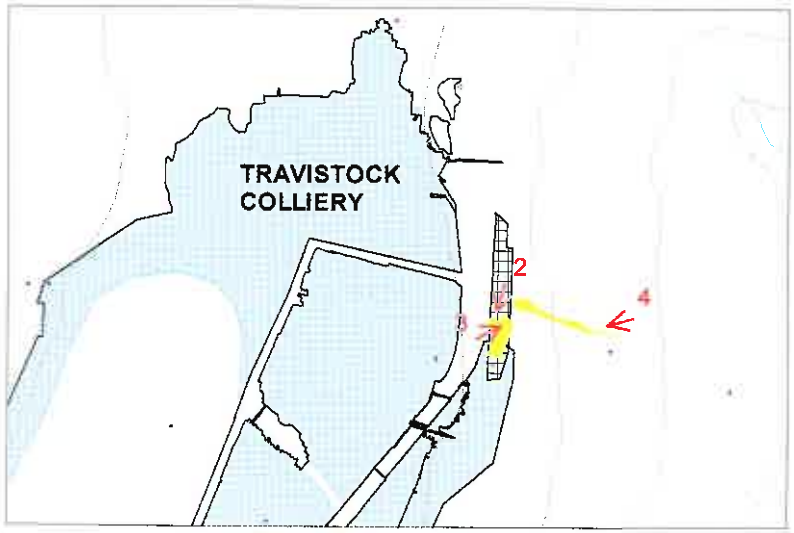


Photo 4: Water run-off from site at Uitspan (approximately 0,3 l/s).

Photo 5: Seepage west of the Blesbokspruit. Note borehole BSG-RB1 in the background.

Photo 6: Seepage east of the Blesbokspruit. Flow from this area is partial measured at measuring weir 13.

Position and direction in which photos were taken.

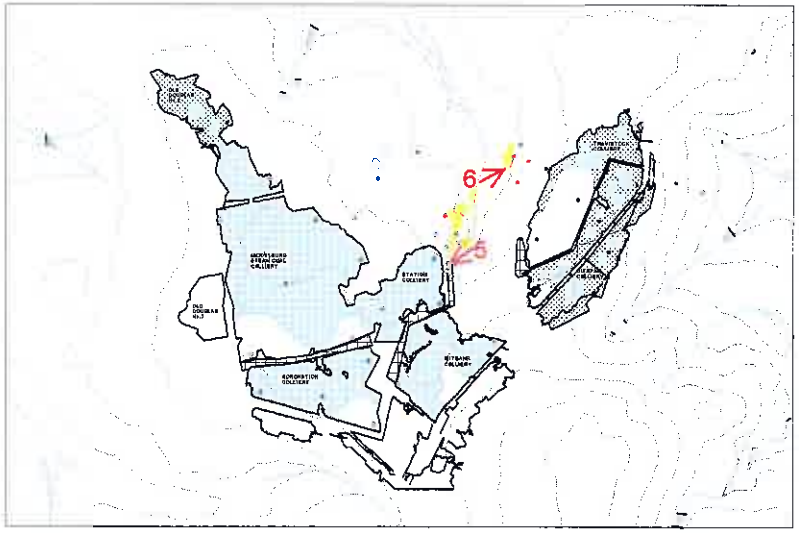


Photo 7: An example of the formation of cracks due to pillar failure.

Photo 8: An example of the formation of surface subsidence due to pillar failure.

Position and direction in which photos were taken.

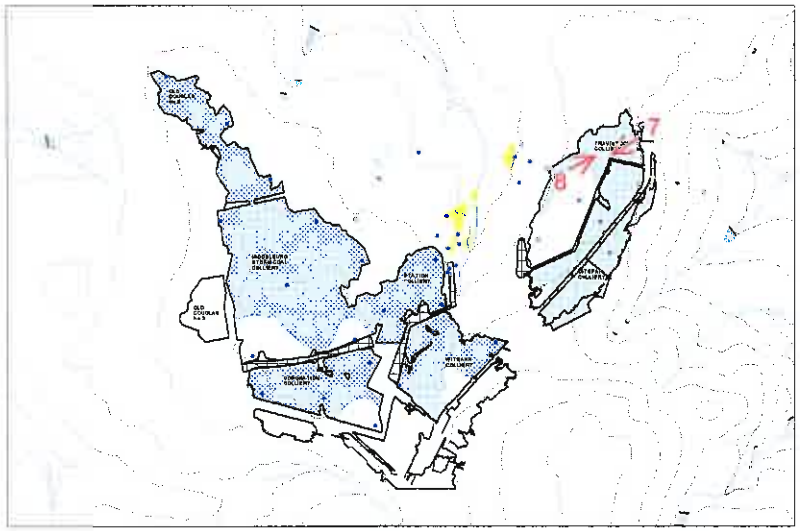


Photo 9: Water suddenly disappeared from this dam.

Position and direction in which photos were taken.

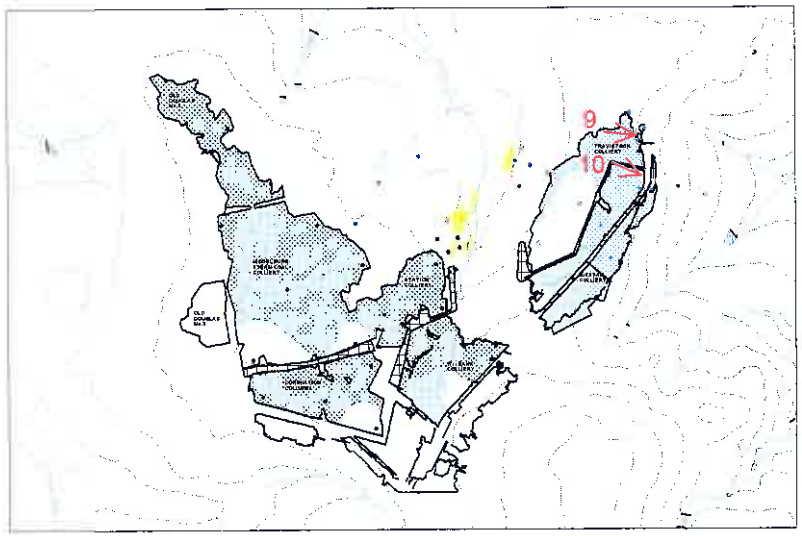
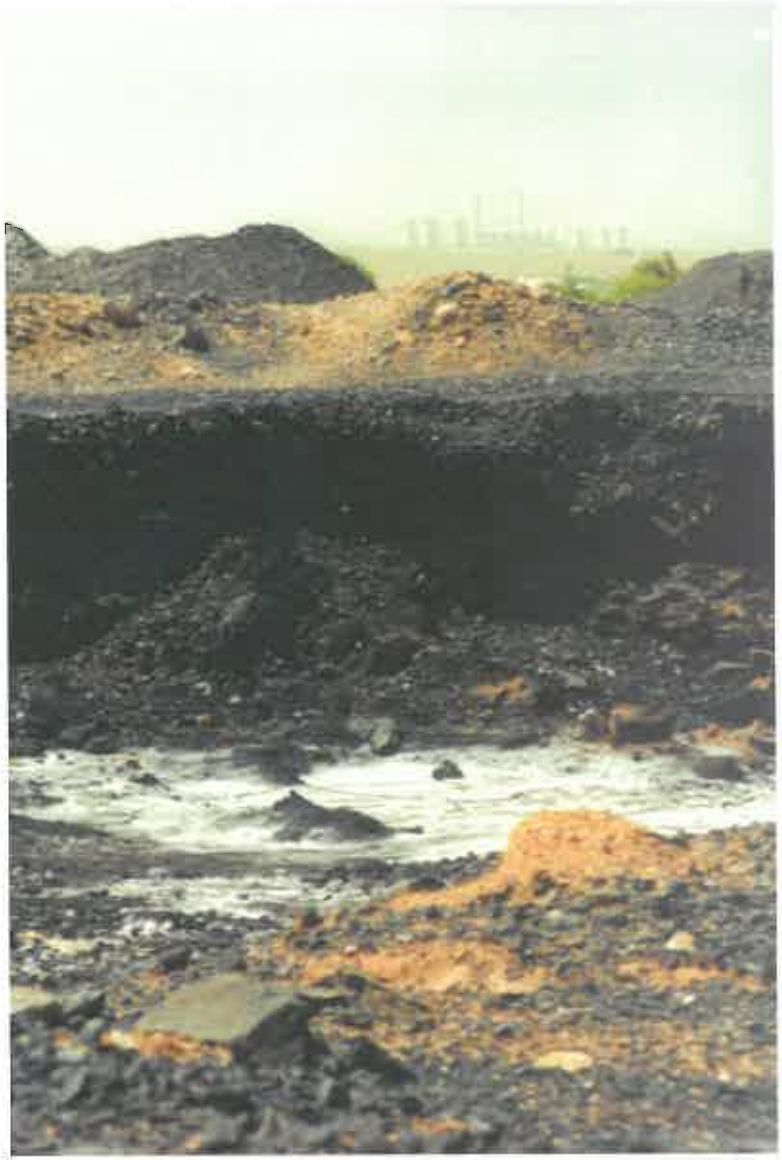


Photo 10: Fringe coal mining activities, showing power station in distance.



Phot 11: An example of an old adit to the underground workings.

Position and direction in which photos were taken.

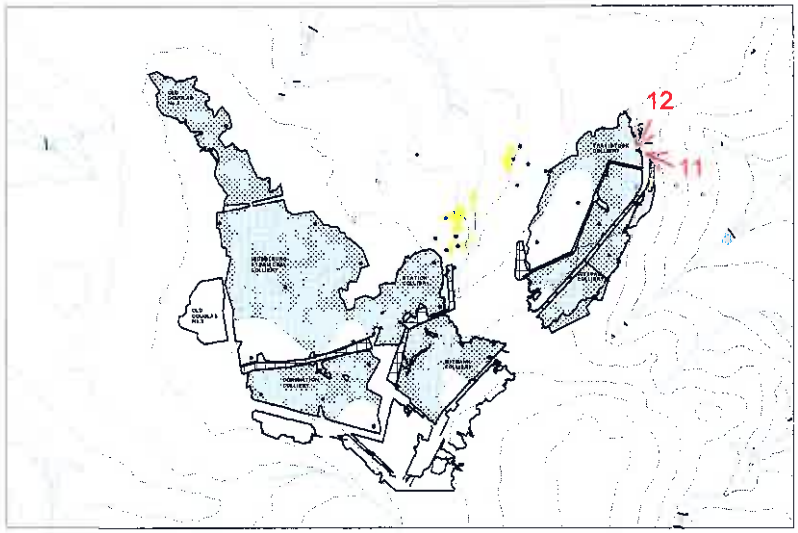


Photo 12: Seepage from adit on the No. 2 coal seam floor.

APPENDIX IX

ASSESSMENT OF WATER BALANCE
AND
WATER BALANCE COMPONENTS

FIGURE 1

Ground water pollution plume and areas of base flow interaction with the Blesbokspruit.

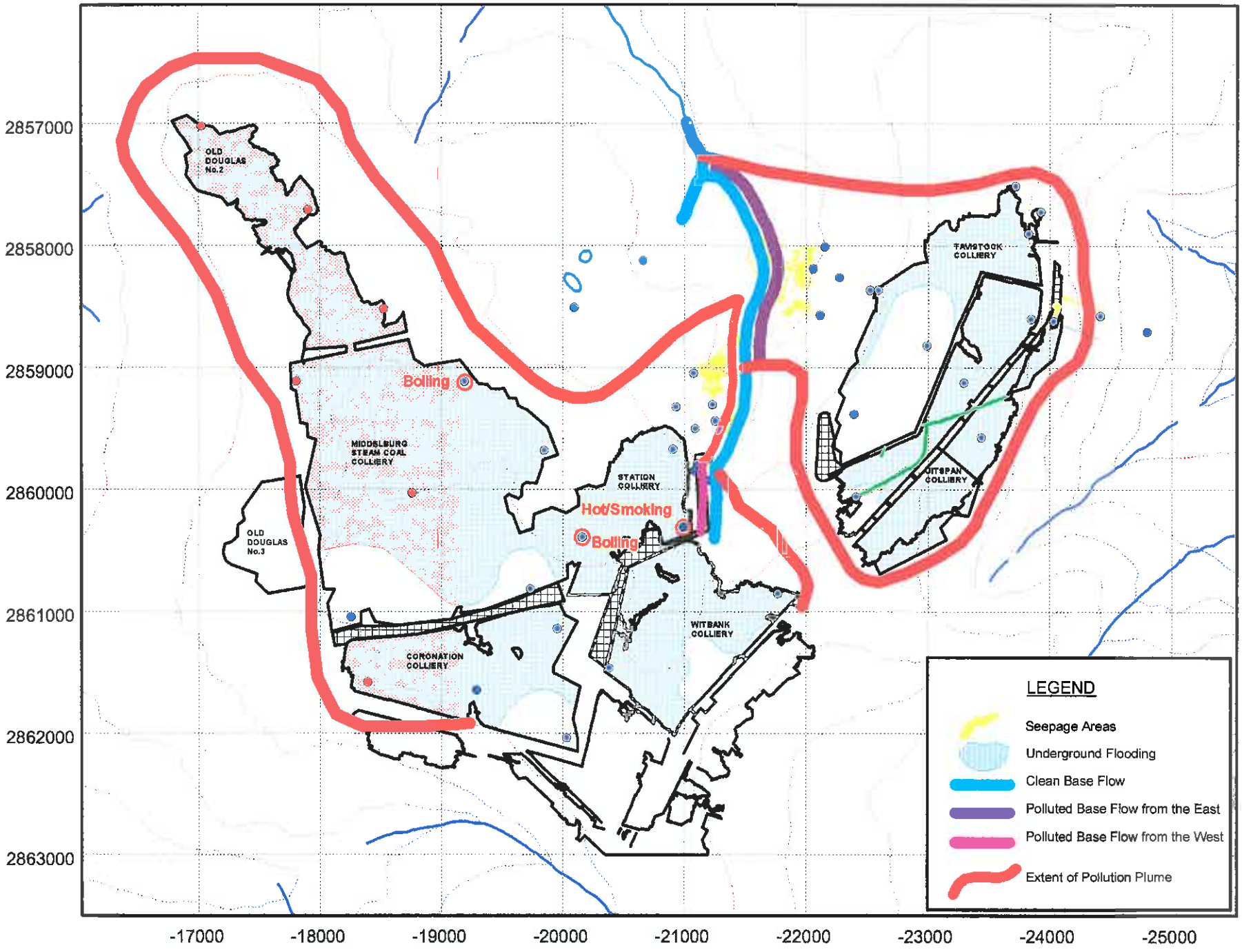


FIGURE 2

Schematic diagram of water balance components.

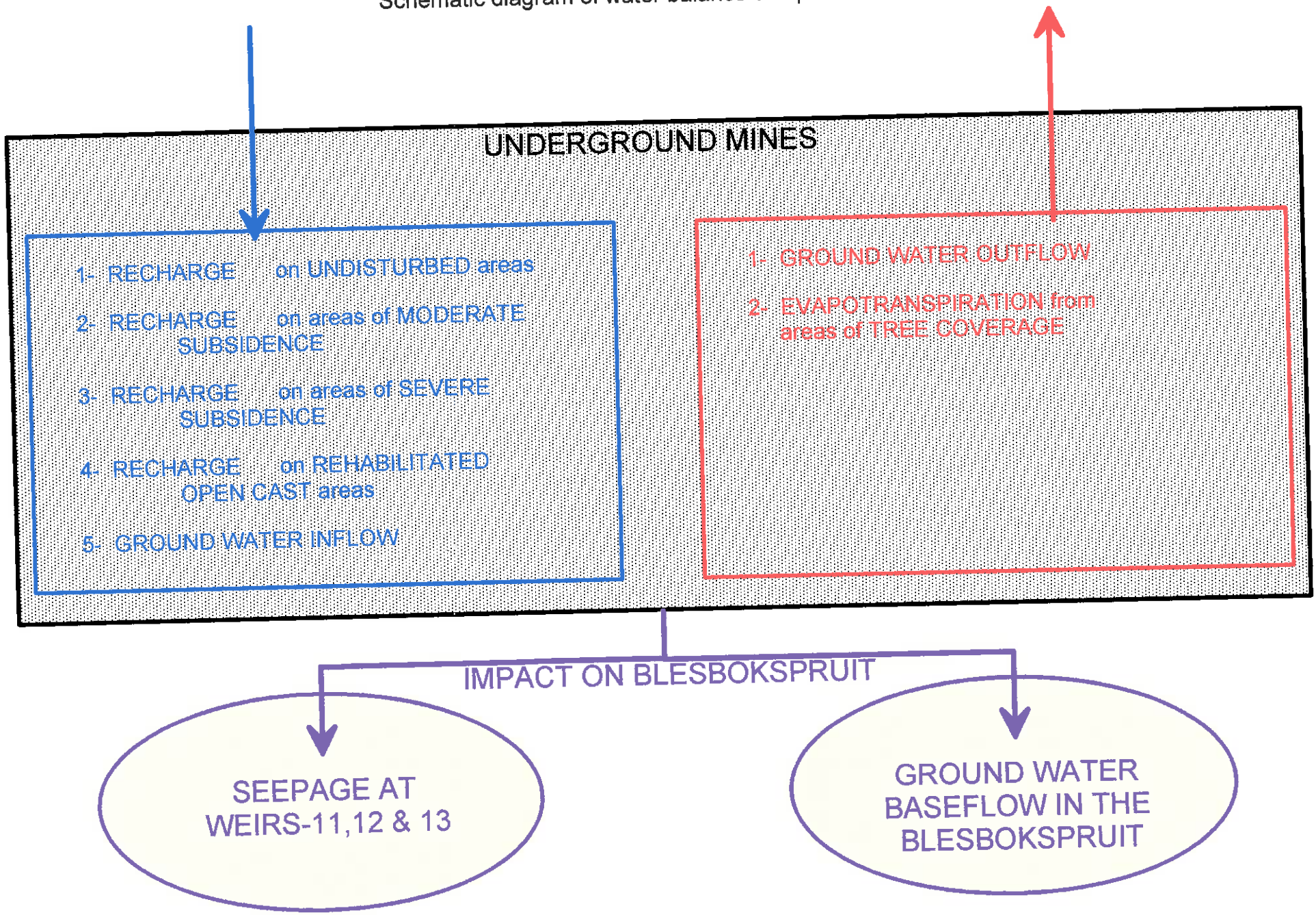


FIGURE 3: Flow measurements (m3/d) at different monitoring localities

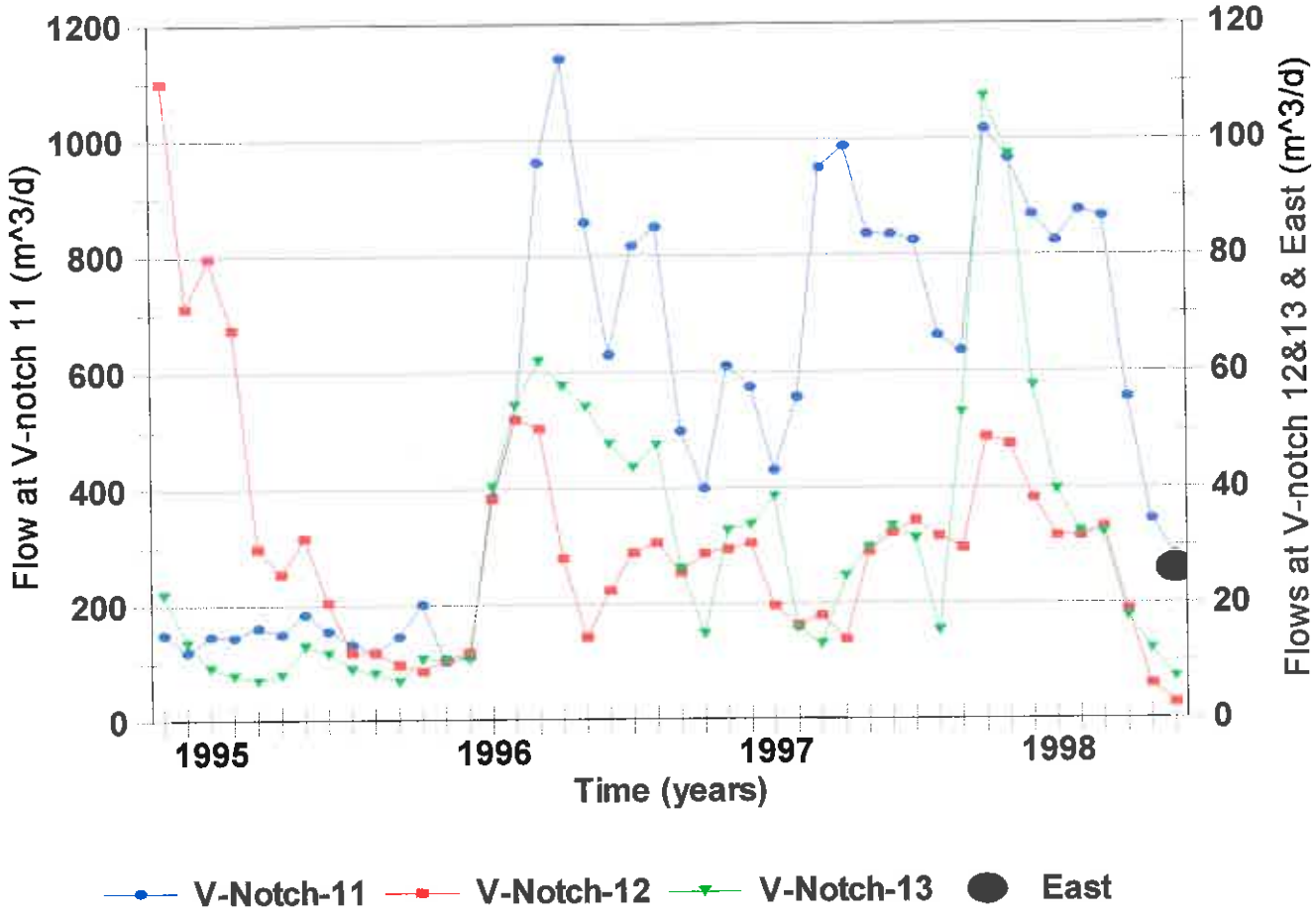
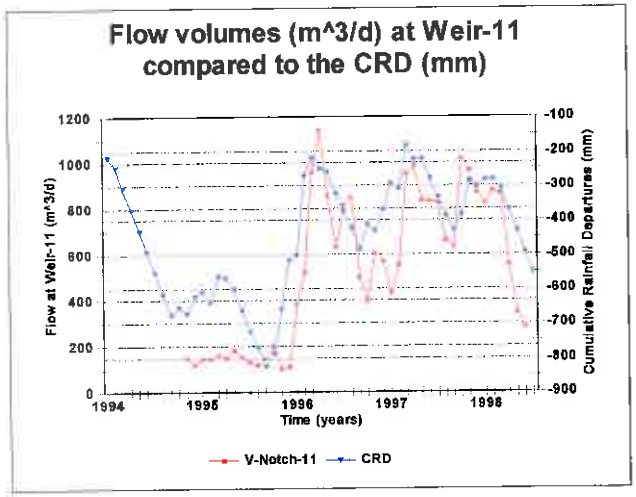
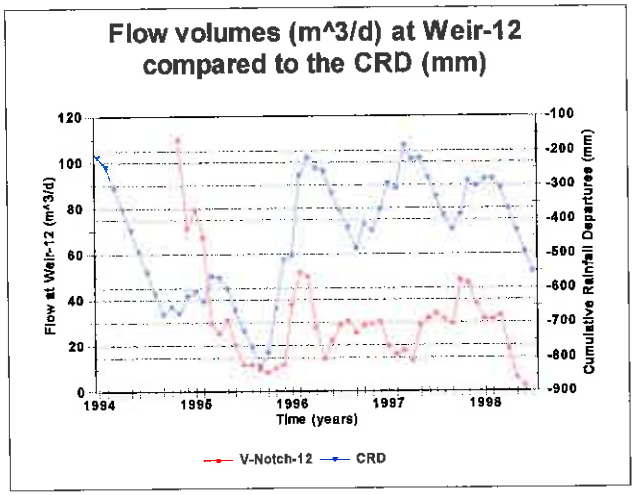
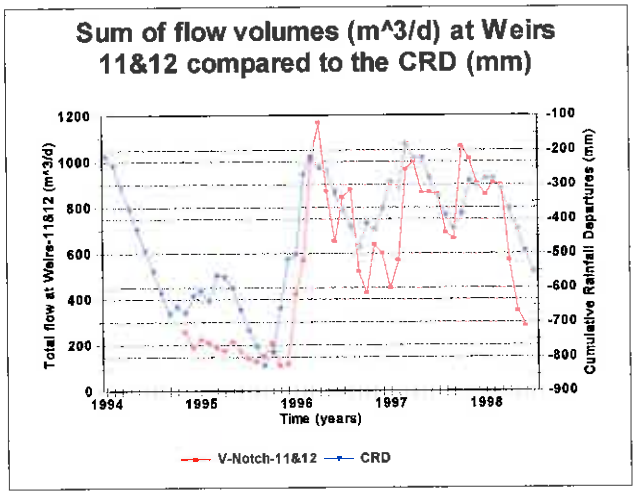
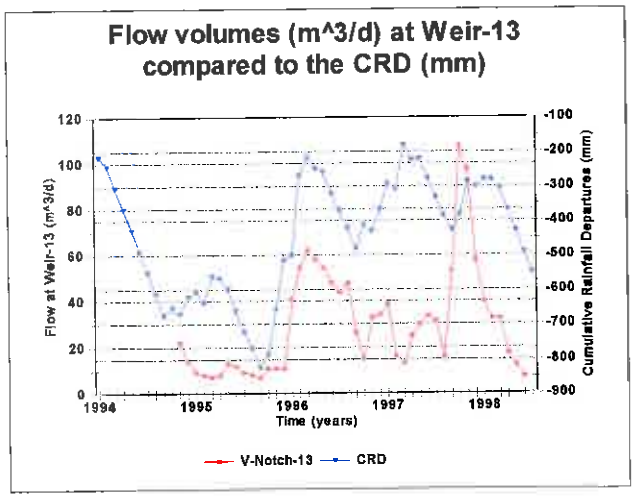


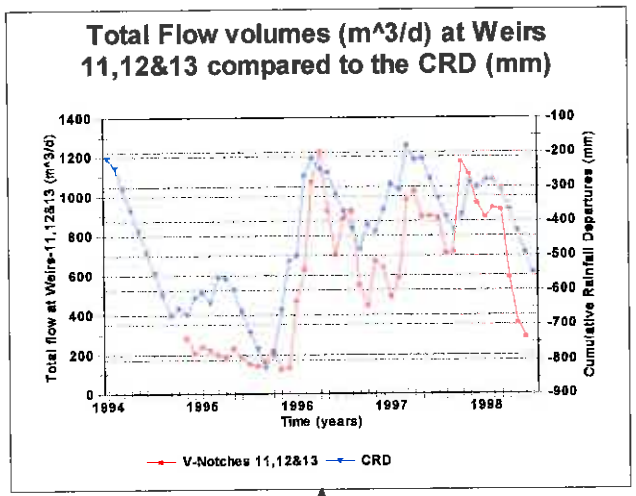
FIGURE 4
Comparison of flow measurements at monitoring weirs to Cumulative Rainfall Departures











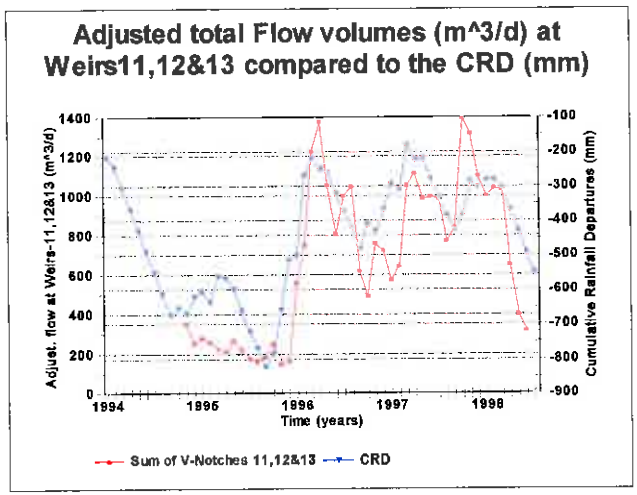


FIGURE 6 Comparison between observed and simulated flows at measuring Weirs

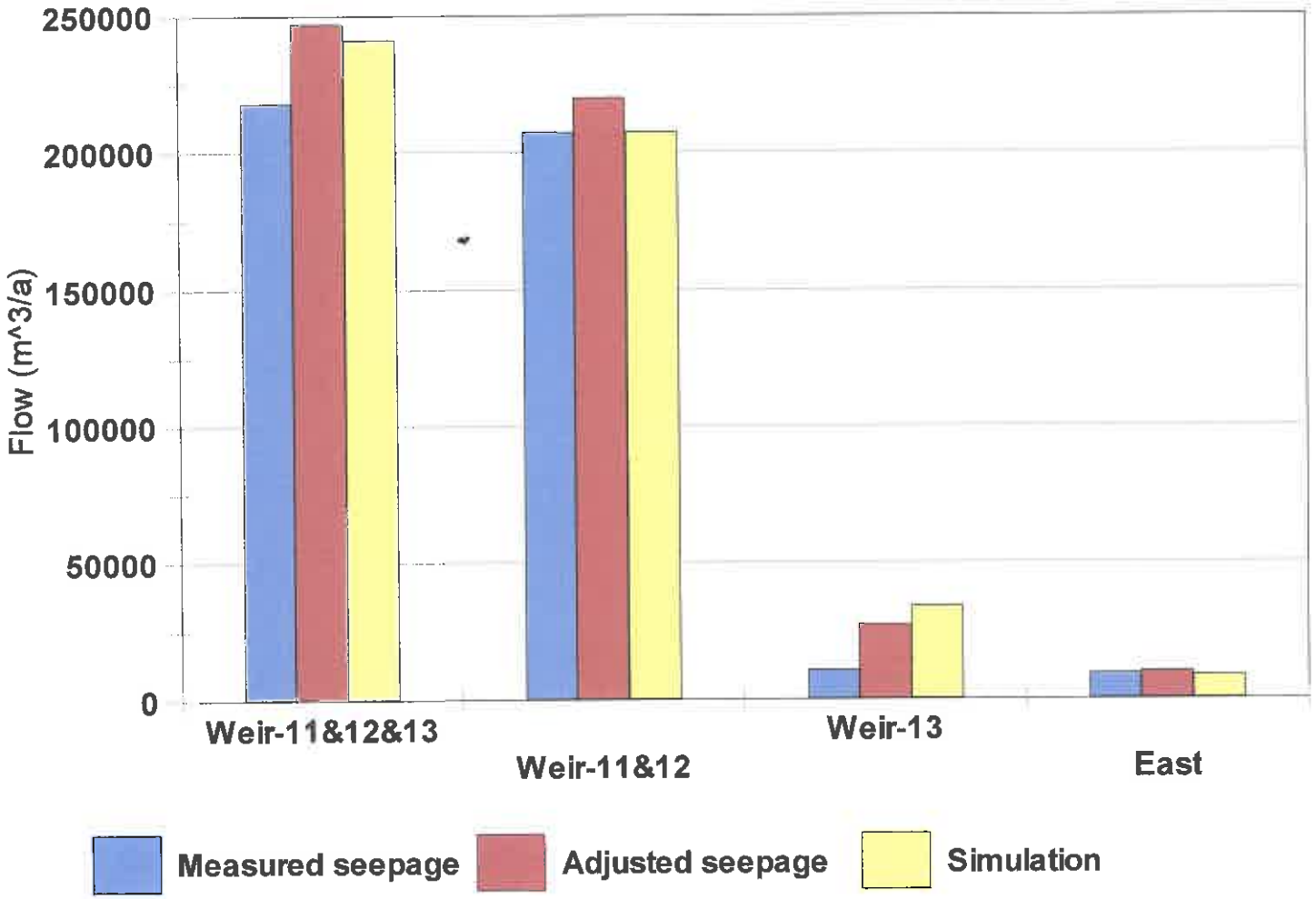


FIGURE 5: EC & SO4 plotted vs. Total Flow at Weirs (m^3/d)

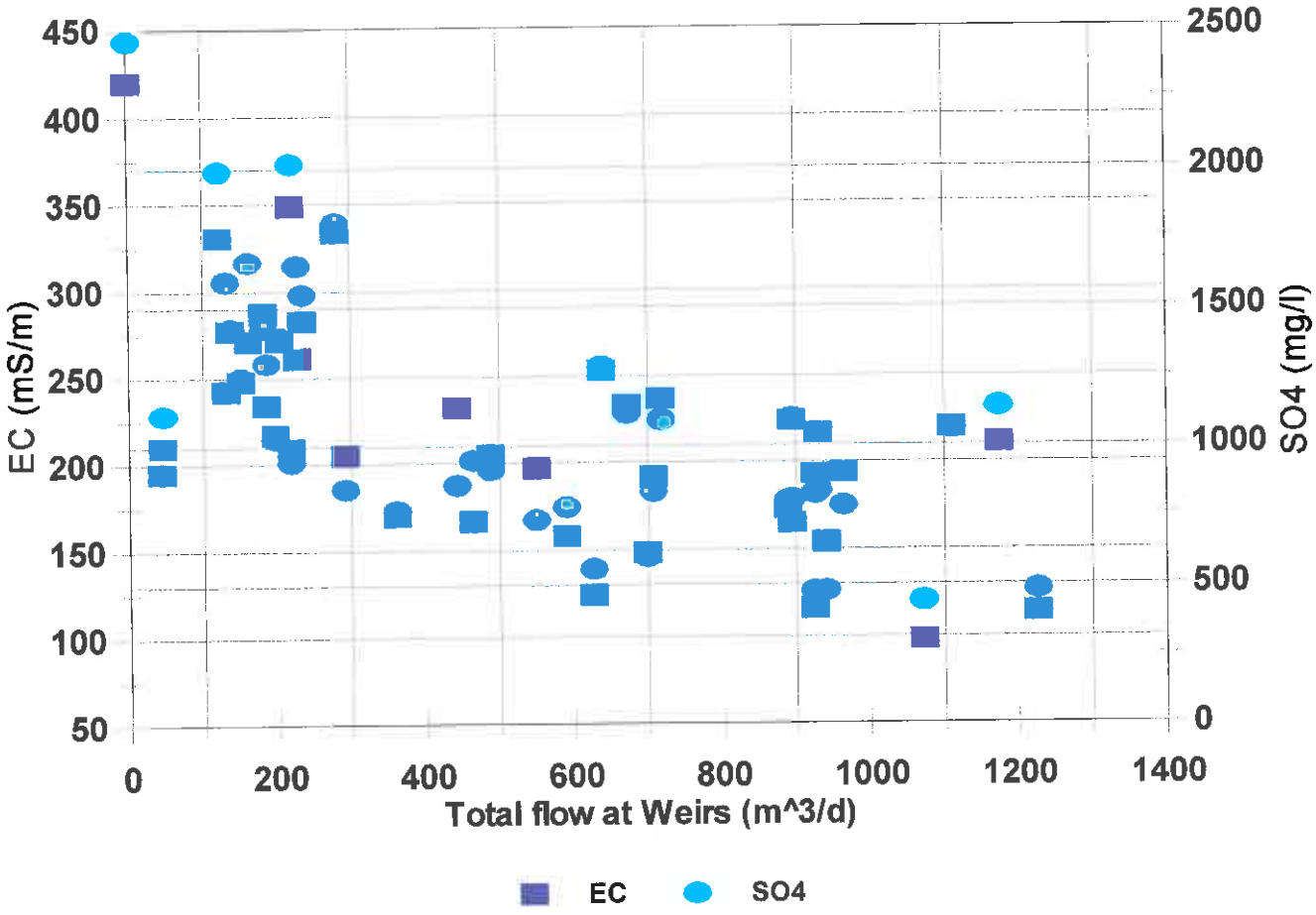


FIGURE 7: Relative contribution from different recharge components:

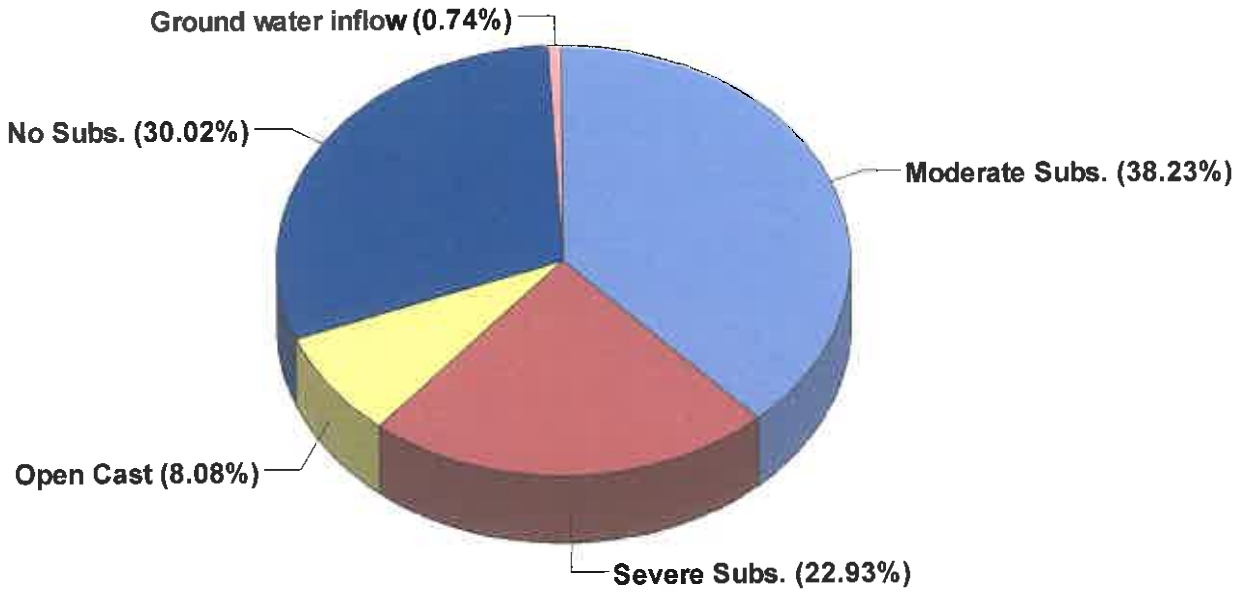


FIGURE 8: Relative contribution from different discharge components

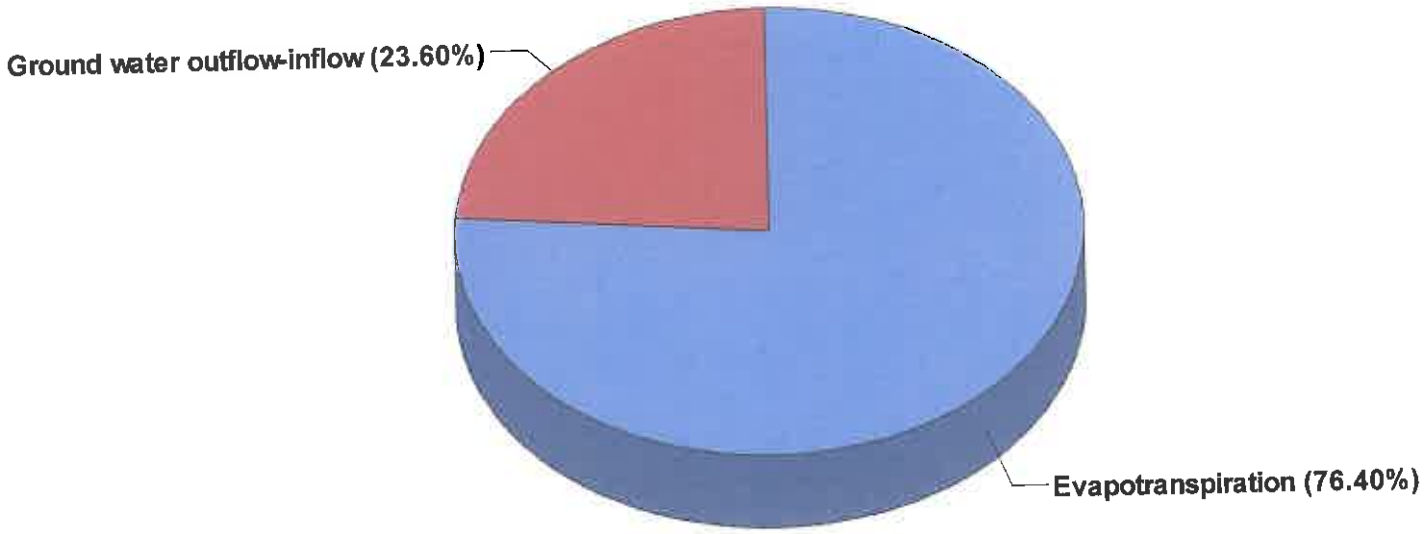


TABLE 1. SUMMARIZING TABLE OF PERTINENT AREAL INFORMATION OF THE WATER BALANCE.

Colliery	Area (x 10^6 m^2)							
	Trees	Subsidence			Burning Coal	Mining		Flooded
		Moderate	Severe	NO		Open Cast	Under ground	
Uitspan	107000			843000		29000	843000	843000
Tavistock	835000	926000		1474000		57000	2400000	1420000
Witbank	55000			1286000		209000	1286000	1102000
Coronation	70000		456000	832000	92000	183000	1380000	1180000
Middelburg Steam Coal & Station	750000	1435000	472000	2184000	649000		4740000	4053000
Old Douglas No.2	580000	499000	150000	451000			1100000	1100000
SUM	2.397E+06	2.860E+06	1.078E+06	7.070E+06	7.410E+05	4.780E+05	1.175E+07	9.698E+06