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Nitrate Responses in Groundwater under Grassland Dairy Agriculture

Volume II of II
Appendices

Presented in fulfilment
of the requirements for the degree of
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by

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APPENDICES **Page**

APPENDIX A

This appendix provides details of each reviewed nitrate leaching model and of documented successes of specific applications: a table outlining model application, required model inputs and expected outputs accompanies the discussion of each model. A table of contents for this appendix is provided overleaf.

Catchment scale agronomic modelling was also reviewed due to its relevance in regard to the broader issues of modelling nutrient mobilisation within an integrated hydrological resource, e.g. the Water Framework Directive (EC, 2000). Six catchment modelling approaches from the literature, listed in section 3.8.4.5, are presented: model applications are discussed, data requirements are tabulated and conclusions are drawn regarding both surface and groundwater simulations. Catchment and national scale modelling will require the use of geographical information systems (GIS) and so information regarding using GIS to link nitrate leaching models is presented in also presented in this Appendix. Many of the modelling applications reviewed referenced other models. In particular, the hydrological model TOPMODEL (Beven & Kirby, 1979; Quinn & Beven, 1993) and river basin model SWAT (Arnold *et al.*, 1993; 1994; 1997) were mentioned widely in the literature concerning modelling at the catchment- or larger-scale. It is for this reason that a subsection this appendix also presents these and other relevant hydrological and river basin models.

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1. MODELLING PROCEDURE

Guidelines for modelling and reviews of terms exist (NRC, 1993; ASTM, 1994; CAMASE, 1995). A myriad of terms describes the steps required in a modelling procedure. Conceptualisation, development, sensitivity analysis, calibration, validation are steps along the way to model implementation. Data acquisition is the first step and should be considered distinct from data validation and formatting. Karanjac (pers. comm., 2000) suggests that a model can be applied as a prognostic tool only after a number of steps. In short, create a GWIS (Ground Water Information System), develop the conceptual model, select appropriate GUI (Graphical User Interface) and software, and then model development ends with calibration on a specific set of field data.

1.1. Conceptualisation

A conceptual model must represent the real system adequately through simplification (Addiscott, 1993), but it should include the most pertinent processes. Models represent approximations (i.e. simulations) of the actual processes, interactions and energy exchanges in the real world (Shaffer, 1995), they are an abstraction of reality (Bredehoeft, 1999). Defining the system and its boundaries, and recognising the assumptions that can be made, leads directly to the selection of an appropriate model (Peck *et al.*, 1988) [the term 'model' meaning the set of appropriately constrained governing equations].

The biggest problem in modelling grassland systems is accurately describing the nitrogen input resulting from the mineralisation of soil organic matter and biological fixation of atmospheric N by grassland micro-organisms (Sapek & Sapek, 1993). Linkage between the unsaturated and saturated zones can be achieved by defining loading rates into the groundwater by regression analysis using measured field data for nitrogen fertilisation and leaching as a function of soil type and land use (CEC, 1991).

A key parameter input is the total amount of nitrate applied by farmers for each land unit and how much residual nitrate remains from previous years (Van Herpe *et al.*, 2000). Thus any map of land cover is a map of nitrate available to leaching before the onset of the winter leaching period. At the mapping unit scale, models should include the most pertinent water flow, solute partitioning and solute transformation routines, but also make provisions for preferential flow and have the capability to vary input parameters using a truly stochastic approach (Inskeep, 1996).

1.2. Model Development

Model development entails the selection and derivation of the mathematical equations, empirical formulae or statistical relationships that are deemed to adequately represent the system and the processes occurring, and the programming and presentation of results, this is the model. The literature provides much detail regarding groundwater flow and solute transport equations, their derivation and application to saturated flow modelling (e.g. van der Heijde & Elnaway, 1993; McIntosh, 1994). Development of model equations and components then highlights the data requirements.

Many have reviewed model development with particular attention to nitrate leaching (e.g., Addiscott 1993; Addiscott *et al.*, 1995; Feyen *et al.*, 1998; MAFF, 1999; Stockdale 1999).

1.3. Sensitivity Analysis

Running the model a number of times and repeatedly changing a particular input parameter value helps to determine the sensitivity of the model to that one component; this sensitivity analysis should be repeated for each model parameter (CAMASE, 1995). A sensitivity analysis should be carried out on a grossly calibrated model before attempting to 'fine-tune' the calibration, in order to provide direction (Anderson & Woesner, 1992). The ratio of the change in the output to that of the parameter provides a simple measure of sensitivity; ratios appreciably greater or less than unity suggest sensitivity and insensitivity respectively (Addiscott, 1993).

1.4. Calibration

Model calibration is the term used to describe the 'tweaking' of model parameters and equations until the differences between model predictions and field observations are within an expected range. Calibration and reliability in groundwater modelling is a topic extensively researched and discussed within the framework of the ModelCARE conferences (e.g., Kovar, 1990) organised by the International Association of Hydrological Sciences (IAHS).

1.5. Validation

Model validation is an independent test, and can only be accomplished by applying the model to other similar type-areas, which have suitable data available, and if there is a match between predictions and the observed data this contributes to model validation (Hopstaken & Ruijgh, 1994). Split-sample testing procedures, where the dataset is divided (either in space or time), with a portion of the data used for calibration and the remainder used for validation is also acknowledged

(NRC, 1991). Donnigan & Rao (1990) explore the inter-related issues of model selection, application, and validation, with particular emphasis on the model testing and validation procedures. They discuss technical issues that should be considered in model validation procedures, including the following:

- Variability in observed data, both input and output, must be recognized and its impact must be considered.
- Parameter estimation procedures must be well-defined and accepted.
- Benchmark data sets are needed for field testing and model validation
- Performance and acceptance criteria for model validation must be defined.

Model validation is an ongoing process and Hopstaken & Ruijgh (1994) suggest that the *curriculum vitae* of a model determines the level of validation. Others believe groundwater models can never be truly validated (Kazmann, 1987; Konikow & Bredehoeft, 1992; NRC, 1993). Attention is drawn to the potential problems associated with data used for model validation.

2. MODELLING SUBSURFACE ZONES

2.1. ROOT ZONE MODELS

2.1.1. NCYCLE (Scholefield et al, 1991)

This field scale model calculates N transformations and losses from grazed grassland through full description of the nitrogen cycle. The windows based format is user friendly and accessible for all familiar with agriculture. It was designed for grassland grazed by beef cattle but options are available for dairy or no grazing (cutting only) systems. It is a steady state, mass balance, static simulation model whose output accounts for local soil texture, fertilizer application rate, weather (temperature), sward and grazing management characteristics, each of which must be selected by the user. The sub-models in the simulation are based on results from ten long-term field experiments conducted at IGER (UK) and partly from other published information describing nitrogen cycling for UK conditions (Falloon *et al.*, 1999). The publication in which the model is described (Scholefield *et al.*, 1991) provides useful numerical rates for each component of the N cycle. For example, of the total amount of nitrate determined to be available for loss below the root zone – 10% is assigned as potentially dentrified and 90% available for leaching (for a sandy soil). Other useful combinations are provided in the document, which are valuable for any nitrate leaching model development. Output is the annual nitrate loading of NO3-N available to leaching loss below the grass root-zone from individual pasture fields. The peak NO3-N concentration is also suggested (usually associated with the first 25mm drainage, from the experimental plots at North Wyke – where the model was developed). The graphing tool, in the windows version, and its associated underlying data table allows the user to observe the effects of changing input parameters on certain parts of the nitrogen cycle. NCYCLE is one of the components of the MAGPIE (Lord & Anthony, 2000) local, catchment and national scale modelling strategy developed by the ADAS/MAFF consortium (UK). NCYCLE (IRELAND) is currently under development, under the direction of some of the original NCYLE (UK) team, and should be available at the end of 2004 from TEAGASC, Johnstown Castle, Wexford.

<table>
<tr><td colspan="3">MODEL NCYCLE</td><td colspan="2">AUTHOR Scholefield <i>et al.</i> (1991) UK</td></tr>
<tr><td colspan="3">MODEL TYPE Steady state mass balance static simulation</td><td colspan="2">SCALE Field</td></tr>
<tr><td colspan="5">APPLICATION Predicts average annual NO_3^- loading of water draining from the root zone of individual pasture fields.</td></tr>
<tr><td>PROCESSES</td><td>INPUT PARAMETERS</td><td>MODEL OUTPUTS</td><td>MISCELLANEOUS</td><td>REQ'D</td></tr>
<tr><td>-Calculates Nitrogen transformations and losses from grazed grassland.
- The difference between N inputs to soil mineral pool and plant uptake is partitioned to denitrification and leaching with respect to soil texture.
-Submodels in this simulation derived from experiments at IGER and published information representing effects of relationships that govern flow of N in agricultural systems.</td><td>-Set site parameters;
Fertiliser rate,
Grazing management,
Soil type (Organic matter content, texture, drainage status),
Sward type,
Climate zones governing mineralisation rates and excess rainfall amounts. The UK is designated as two zones.
[the above parameters allow the model equations to calculate soil mineral N and consequent fluxes of nitrogen, through the N cycle]</td><td>-Fluxes to each component of the nitrogen cycle.
-Results presented as a dynamic display.
-Graphical representations of losses to volatilisation, denitrification &leaching.
-Graphs and data tables of nitrogen cycle component's quantities according to fertilisation rate.
-Output results may be varied by user, with immediate recalculation of the model.</td><td>The program calculates soil mineral N from soil organic matter content.
Model calculations based on extensive agricultural research field trials across the UK.
NCYCLE is a good screening tool for nitrate leaching potential with respect to climate, soil and management factors.
NCYLE is a component of MAGPIE (Lord & Anthony, 2000), the UK national modelling strategy for nitrate leaching.
NCYCLE expanded to NCATCH for catchment scale (Scholefield & Rodda, 1992).</td><td>-IBM PC
-Minimum 386 SX
-Win. 3.1</td></tr>
</table>

2.1.2. NLEAP (Shaffer *et al.*, 1991)

NLEAP combines basic information concerning on-farm management practices, soils and climate and then translates the results into projected N budgets and nitrate leaching below the root zone and to groundwater supplies and estimates the potential off site effects of leaching (USDA, 1996b). Developed by the USDA to provide a rapid method of determining potential nitrate leaching associated with agricultural practices.

The model has three levels of analysis to determine leaching potential: an annual, monthly or event-by-event analysis. The annual screening may be used to indicate a potential for nitrate leaching. The monthly and event analysis may be used to demonstrate the effect of alternate management strategies on reducing nitrate leaching (Follet *et al.*, 1991).

The processes included in the model include movement of water and nitrate, crop uptake, ammonia volatilisation, mineralisation of soil organic matter, denitrification, nitrification & mineralisation/immobilisation associated with crop residues, manures and other organic wastes (Shaffer *et al.*, 1991).

The program uses data entry screens with pop-up data selection and online help menus. Internal model checking verifies data type and range; errors are identified and highlighted. Validation testing on fifty plus sites across ten US states has proven that the model can predict residual soil nitrate and nitrate leaching within an acceptable range (for US conditions). Regionalised USDA farm management, soils and climate databases facilitate easy application of this model for US sites.

This field scale model has been successfully applied to farm and regional scale with use of GIS (Shaffer, 1995; Saporito & Lanyon, 1998). The recently developed national scale, Scottish NIRAMS model successfully adapted NLEAP to describe N leaching and integrated the model into a GIS system to provide good predictions of nitrate loss to surface waters in ungauged Scottish catchments (Dunn *et al.*, 2003a & b).

<table>
<tr><td colspan="3">**MODEL** NLEAP</td><td colspan="2">**AUTHOR** Shaffer *et al.*, 1991</td></tr>
<tr><td colspan="3">**MODEL TYPE** Process orientated, root zone, screening analysis tool.</td><td colspan="2">**SCALE** Field to Regional. (in conjunction with GIS).</td></tr>
<tr><td colspan="5">**APPLICATION** Calculates nitrate leaching indices for agricultural areas as a function of soils, management & climate.</td></tr>
<tr><td>**PROCESSES**</td><td>**INPUT PARAMETERS**</td><td>**MODEL OUTPUTS**</td><td>**MISCELLANEOUS**</td><td>**REQ'D**</td></tr>
<tr><td rowspan="3">-Processes simulated include movement of water and nitrate, crop uptake, denitrification, volatilisation, nitrification, mineralisation & immobilisation.
-Area weighted Soil & Weather Factors are calculated for each field based on the distribution of soils.
-This screening procedure uses a simplified annual water & nitrogen budget to give only a general estimate of potential nitrate leaching.</td><td rowspan="3">-N balance for field.
-Winter & summer rainfall.
-Soil Weather Factor.
-Soil bulk density.
-Rooting depth.
-Soil hydraulic group.
-Specify management type.
[soil, climate and management data required to run the model are traditionally obtained from databases compiled by the USDA for particular regions in the US]</td><td rowspan="3">-Monthly and annual drainage volume.
-Nitrate leached.
-Residual N in soil.
-The soil N balance (input) in conjunction with a management factor (based on excess of N and the SWF) yields the NLEAP leaching index.</td><td rowspan="3">-Primarily a US validated and calibrated tool whose simplicity is intricate with the extensive USDA soil databases.
-Khakural & Roberts (1993) found NLEAP to simulate total leaching loss well.
-Shaffer (1995) reports successful application at farm and regional scales using GIS.
-Saporito & Lanyon (1998) used NLEAP successfully at farm scale.
-Dunn *et al.* (2003a & b) employ NLEAP in national scale Scottish risk assessment model (NIRAMS).
-USDA (1996b) notes that the model has not yet been developed for organic soils.</td><td>IBM PC</td></tr>
<tr><td>**Time Step**</td></tr>
<tr><td>-3 levels of analysis; annual, monthly, event by event.</td></tr>
</table>

2.1.3. RZWQM (USDA- Agricultural Research Service, 1992, 1995, 1999)

The Root Zone Water Quality Model (RZWQM) is a process-based research simulation model designed to simulate soil water and solute movement to predict runoff and leaching of nutrients and pesticides. The hydrologic response, and thereby potential for surface- or groundwater contamination, for different crop-management scenarios may be evaluated using RZWQM. Hanson (1999) recently outlined his calibration of RZWQM. For a unit area of an agricultural field, over multiple years, crop development and the movement of water, nutrients and pesticides is simulated through the root zone. Solute movement from the root zone to the water table can also be examined (DeCoursey *et al.*, 1992).

Daily weather data, soil profile descriptions, plant growth, nutrient inputs and residues, and management practices amount to the input data required for the simulation. The model includes components for management practices, pesticide degradation dynamics, nutrient cycling and hydrology. It is also necessary to provide break point rainfall information.

The model was designed for daily and hourly simulations, but long-term simulation (100+ years) is possible. Recent modifications to the model (Ahuja et al, 1999) include capabilities to simulate rapid transport of surface applied chemicals through macropores to deeper depths and the preferential transport of chemicals within the soil matrix via mobile-immobile zones. Simulation of water table fluctuations and tile drain conditions is currently underway by the USDA (Kanwar, 1999)

The model has been validated for many Management System Evaluation Areas [MSEA] (Watts *et al.*, 1999).

<table>
<tr><td colspan="3">MODEL RZWQM</td><td colspan="2">AUTHOR United States Department of Agriculture-ARS (1992, 1995, 1999)</td></tr>
<tr><td colspan="3">MODEL TYPE Process based, research, deterministic, one dimensional</td><td colspan="2">SCALE Field – point scale, one dimensional model</td></tr>
<tr><td colspan="5">APPLICATION Comprehensive simulation of biological, chemical, physical and hydrological processes within and below the root zone to predict runoff and leaching (pesticides and nutrients) for alternative management scenarios.</td></tr>
<tr><td>PROCESSES</td><td>INPUT PARAMETERS</td><td>MODEL OUTPUTS</td><td>MISCELLANEOUS</td><td>REQ’D</td></tr>
<tr><td rowspan="3">-The model includes components for management practices, pesticide dynamics, nutrient cycling and hydrology.
-Evaluates potential for surface and groundwater contamination for alternative crop systems.</td><td rowspan="3">Minimum
-Break point RF data for simulation period.
-Daily RF, temperature, wind speed, radiation, relative humidity.
-Soil horizon delineation by depth. Soil horizon physical properties: bulk density, particle size distribution, soil hydraulics.
-Initial conditions must be defined for each horizon; water contents, pH & CEC, temperature, nutrient information (mineral nitrate and ammonia) & soil carbon pools.
-Agricultural management information.</td><td rowspan="3">-Transport and fate of water controlled processes.
-Soil water redistribution.
-Chemical transport.
-Infiltration and runoff.
-Pesticide wash-off.
-Soil heat dynamics.
-Evapotranspiration and transpiration.
-Plant N uptake.
-Crop yield.</td><td rowspan="3">-Essentially this is a crop simulation tool with specific emphasis on pesticide dynamics for US applications.
-The model has been validated for many Management System Evaluation Areas [MSEA] (Watts <i>et al.</i>, 1999).
-RZWQM has been used for grassland simulations in a limited way but does not have a detailed mechanistic grass growth model (Ahuja, pers. comm., 2000).
-Solute movement from the root zone to the water table can also be examined (DeCoursey <i>et al.</i>, 1992).
-Ahuja <i>et al.</i> (1999) details capabilities to simulate macropore preferential transport of chemicals within the soil matrix.</td><td>-IBM PC</td></tr>
<tr><td>TimeStep</td></tr>
<tr><td>-Hour
-Day
-Long term (100 years plus)</td></tr>
</table>

2.1.4. CREAMS (Knisel *et al.*, 1980)

CREAMS is a USDA field scale model for evaluating runoff, erosion and transport of sediment bound nutrients, and chemical transport through percolation from agricultural soils. It is a model developed specifically to evaluate effects of different management strategies rather than an absolute predictor of nitrate leaching (Leonard *et al.*, 1987).

This models has four components – hydrology, erosion/sediment yield, nutrient and pesticide transformation and transport. Required model inputs are precipitation, radiation, temperature and management information (land use, agricultural practices, plant nutrient contents, fertiliser and pesticide usage). The preferred time step for data entry is hourly and although the model can simulate events it was not designed for this purpose, but for continuous simulations from 2-50 years. There are two hydrological options: the SCS curve number is used if only daily rainfall information is available but if hourly rainfall is available, an infiltration-based model can be used for runoff simulation. Water movement is modelled using a simple capacity approach with vertical flow occurring when a model soil layer exceeds field capacity. The author (Knisel, 1980) cites the relative simplicity and few model input requirements as model usage incentives. Dunn (1994) contradicts Knisel's claims, describing CREAMS as a non-user-friendly model that requires careful attention to its sensitivity to the particular agricultural application under investigation. The model has been extensively used and validated in the US (Leonard *et al.*, 1987). Svetlosanov & Knissel (1982) detail an EU evaluation involving six countries.

Several models use equations developed for the CREAMS model: GLEAMS (Leonard *et al.*, 1987), SWAT (Arnold *et al.*, 1993) and SWIM (Krysanova, 1996). A CEC (1991) evaluation of nitrate leaching models rejected CREAMS in the first screening, based on model structure, the described nitrogen processes and the unsuitability of the model to realise the specific project objectives. Subsequently, Rekolainen & Posch (1993) successfully modified the model to suit Finnish conditions. Sapek & Sapek (1993) used CREAMS, with good agreement, for observations in a permanent grassland system. While they recommend its use for grassland systems they noted difficulties in accurately defining N input from mineralisation of organic matter and N fixation by grassland microorganisms.

<table>
<tr><td colspan="3">MODEL CREAMS</td><td colspan="2">AUTHOR Knisel <i>et al.</i> (1980)</td></tr>
<tr><td colspan="3">MODEL TYPE One dimensional, deterministic, layered soil.</td><td colspan="2">SCALE Point-field scale.</td></tr>
<tr><td colspan="5">APPLICATION Scenario tool, long term simulation of different agricultural management scenarios.</td></tr>
<tr><td>PROCESSES</td><td>INPUT PARAMETERS</td><td>MODEL OUTPUTS</td><td>MISCELLANEOUS</td><td>REQ'D</td></tr>
<tr><td rowspan="3">-Mineralisation, nitrification and denitrification considered.
-Two hydrologic solution techniques considered.
-Essentially a soil erosion, sediment yield and concentration model with percolation capabilities.
-Intermediate output files from hydrologic and erosion submodels form input for chemistry component of the model.</td><td rowspan="3">-Climatic data; hourly precipitation, radiation and temperature (daily data also accepted). Wind speed & dew point temperature.
-Soils characterisation & water retention capacity.
-N sources; inorganic fertiliser and rainfall deposition.
-Management information; land use, agricultural practices, plant nutrient contents, fertiliser and pesticide usage.</td><td rowspan="3">-Evapotranspiration.
-Surface runoff volumes.
-Erosion mass and transport of sediment bound nutrients.
-Chemical transport (dissolved and absorbed) through percolation.
-Plant nutrient mass at end of simulation.</td><td rowspan="3">-Widely validated in the US (Leonard <i>et al.</i>, 1987).
-Stetlosanov & Knissel (1982) detail a EU evaluation involving six countries.
-Design documentation states simple model data inputs but in reality the model is as data-hungry as any process based model, differing from DAISY only in less C & N inputs required for the plant/crop.
-Dunn (1994) describes CREAMS as a non-user-friendly model which requires careful attention to the sensitivity of the model to the particular agricultural application under investigation. 87).
-Sapek & Sapek (1993) found CREAMS suitable for grassland systems.</td><td>-IBM PC
-DOS/UNIX
-large output files require large storage hard disk.</td></tr>
<tr><td>Time Step</td></tr>
<tr><td>-2-50 years.
-event simulation possible but not advised.</td></tr>
</table>

2.1.5. Other Root Zone Models

These models are not relevant for Irish application because they are US models that rely heavily on specific format us databases.

2.1.5.1. EPIC (Williams *et al.*, 1983)

The Erosion/Productivity Impact Calculator model (EPIC) was developed by the USDA. This root-zone, field scale model is not described in full detail here for a variety of reasons. The model is relevant for arable ecosystems. Also, in the course of an EU modelling review (CEC, 1991) it was concluded that EPIC was not suitable for groundwater influenced soils or capillary rise situations. Many functional models assume constant bottom boundary conditions like free drainage. This makes their use unsuitable in different hydrogeological conditions.

However, for relevant sites within the CEC (1991) evaluation, EPIC performed well. One particularly important finding was that output variables of EPIC react only in a very limited way to changes in input variables.

Engelke and Fabrewitz (1991a & b) suggest good possibilities for EPIC in regional modelling due to short time taken for simulation and the simple equation structure of the model. They also report the input parameters as easily obtained yet extensive. A comprehensive description of climatic, soil and agricultural management and plant response characteristics is required to run this model. Of all the models reviewed only DAISY and EPIC consider immobilisation explicitly but EPIC does not consider the carbon cycle. The climatic inputs are the driving force of the model with a capacity-type approach to water movement in soil layers being the most dynamic variable of the model (Engelke and Fabrewitz, 1991b).

Outputs from this model are: water movement volumes (surface and leaching); nutrient loss in runoff and leachate (both soluble and attached) and an erosion assessment. Pesticide loss for selected pesticides may also be simulated (USDA, 1997).

2.1.5.2. AGNPS (Young *et al.*, 1987, 1989)

This model simulates sediment and nutrient transport from agricultural watersheds for single storm events. The watershed is divide in grid format, each cell having twenty-two inputs. There are essentially six categories: watershed (catchment); topographic; surface water features; soils/subsoils; land use/cover and point sources contributing to watershed flow and nutrient loadings.

Soluble nitrogen and phosphorus is partitioned, in the course of the simulation, between surface runoff and infiltration. Both soluble and sediment bound N and p is determined (USDA, 1997). The model relies heavily on US soil databases and the model equations are based on the CREAMS model (Knisel *et al.*, 1980).

The output data from AGNPS simulations may be presented for each cell in detail or as a summary for the watershed. These outputs relate to the basic components of the model; hydrology [runoff & peak flow], sediment/erosion and nutrient dynamics [nitrogen, phosphorus and Chemical Oxygen Demand] (Kang & Bartholic, 1994).

<table>
<tr><td colspan="3">MODEL AGNPS</td><td colspan="2">AUTHOR Young <i>et al.</i> (1987, 1989).</td></tr>
<tr><td colspan="3">MODEL TYPE Management-scenario tool</td><td colspan="2">SCALE Watershed (up to 20,000ha)</td></tr>
<tr><td colspan="5">APPLICATION Single-event, surface water.</td></tr>
<tr><td>PROCESSES</td><td>INPUT PARAMETERS</td><td>MODEL OUTPUTS</td><td>MISCELLANEOUS</td><td>REQ’D</td></tr>
<tr><td rowspan="3">-Soluble & sediment N & P simulated.
-Soluble N & P partitioned between surface runoff and infiltration.
-COD and nutrients transported from diffuse & point sources.
-Main components are; hydrology, sediment transport and nutrient dynamics.</td><td rowspan="3">-Hydrology: RF, US Soil Curve Number (yields soil type and hydraulic characteristics from database), runoff volume/watershed length.
-Erosion & sediment transportation results from Universal Soil Loss Equation model USLE.
-Nutrient transport: chemical data adapted from CREAMS, COD from US literature, point source flow rates and N, P & COD concentrations must be specified.</td><td rowspan="3">-Peak flow.
-Sediment yields
-Nutrient concentration in catchment surface waters per grid cell or as catchment summary.</td><td rowspan="3">-USDA model.
-Continuous simulation not an option (USDA, 1997).
-Young <i>et al.</i> (1989) developed the model because ANSWERS (Beasley, 1977; Beasley <i>et al.</i>, 1980) and SWRRB (Arnold <i>et al.</i>, 1990) are for smaller catchments only.
-Relies heavily on US soil databases. Successful running of this type of USDA model in Ireland would require extensive soil investigations or inferences.</td><td>-Desktop PC</td></tr>
<tr><td>Time Step</td></tr>
<tr><td></td></tr>
</table>

2.2. UNSATURATED ZONE MODELS

2.2.1. LEACHN (Wagenet & Hutson, 1992)

LEACHN belongs to the LEACHM suite, referring to several versions of a simulation model, which utilise similar numerical solution schemes to simulate water and chemical movement. The model can be applied to unsaturated or partially saturated soils to a depth of approximately two meters, to describe N and P transport and transformations (Hutson, pers. comm., 2000).

LEACHN is a heavily mechanistic model: evapotranspiration, water flow, solute movement, sources and sinks chemistry (degradation, transformation, volatilisation, microbial growth), leaf and root growth, temperature and solute adsorption by plants, each have individual subroutines. The model has a modular basis with the main program initilising variables to call subroutines to perform mass balance. Like other detailed process based models, such as DAISY (Hansen *et al.*, 1991), the cycling of carbon is central to the simulation. Mineralisation rate constants relate the C:N ratios to transformations of organic carbon, which is split into three transformation pathways; soil humus, biomass and carbon dioxide. Nitrification and denitrification rate constants comprise the simulation of inorganic N. Ammonia volatilisation is not simulated but described by a first-order kinetics equation, which is a function of a rate constant. Model users can chose the way water flow is simulated: the Richard's convection-dispersion equation, a mobile/immobile tipping bucket approach adopted from Addiscott and Whitmore (1991) or a steady state or interflow condition with uniform water content. An evaluation and comparison of the Richard's and tipping bucket water flow options found that both methods adequately simulated and predicted nitrate leaching below 1.2m depth (Jabro *et al.*, 1995).
The LEACHM suite of models are intended for point or field scale application and, as such, are not intended for long-term scenario simulation but for one growing season (Leonard *et al.*, 1987). Mulqueen *et al.* (1999) concluded that the LEACHN model performed well in an Irish application evaluating NO_3-N leaching. Jabro *et al.* (1993) validated LEACHN in the field. LEACHN was linked with a GIS to simulate N flows on two US dairy farms (Hutson and Wagenet, 1996). Integration with GIS, to model on a regional scale, has been achieved (Petach *et al.*, 1991; Shaffer, 1995; Hutson *et al.*, 1996). However, the intensity or resolution of input data requirements are reported to make such a detailed mechanistic model unrealistic for large area applications (Petach *et al.*, 1991; Inskeep *et al.*, 1996).

MODEL LEACHN

AUTHOR Wagenet & Hutson (1989) Hutson & Wagenet (1991) USA/AUS.

MODEL TYPE Mechanistic deterministic.

SCALE Field and laboratory scale

APPLICATION Simulates water and N and P transport and transformations to below the root zone to a depth of approximately 2m.

PROCESSES	**INPUT PARAMETERS**	**MODEL OUTPUTS**	**MISCELLANEOUS**	**REQ'D**
-Solute movement is simulated by differentiating the solute flux with depth and adding a source, or subtracting a sink, of the solute. -Finite difference technique used to solve differential equations. -Heat flow simulation is included allowing adjustment of rate constants according to temperature and water content of the soil. -Model requires input descriptions of soil N, P and Organic Carbon pools.	-Agricultural: N fertiliser and manure rates; crop and N uptake and crop residue data. -Climate: daily rain and irrigation; weekly mean temperature and pan evaporation -Soil: bulk density, particle size distribution, initial C, N; NH_4-N and NO_3-N contents; initial soil water content; water retentivity parameters; saturated hydraulic conductivity; dispersivity, profile depth and depth to water table. -Partitioning coefficients and rate constants for mineralisation, nitrification, denitrification & volatilisation.	-Mass balance of water and N & P contents, including amounts currently in the profile. --Cumulative totals of water contents, solute concentrations and fluxes. -Summary of root density, water and solute uptake by plants. - Breakthrough curves listing cumulative time, pore volume and leachate concentrations at selected drainage increments.	-Large data needs, serious errors reported if attempt to use analysis deeper than the root zone (NRC, 1993). -Johnson *et al.* (1999) report that for a LEACHN modelling application, laboratory derived rate constants and hydraulic properties did not simulate field conditions well. -In terms of preferential flow, Inskeep *et al.* (1996) report poor model performance but Jabro *et al.* (1994) show adequate simulation results when infiltration rates are distributed. -Petach *et al.* (1991) suggest use of simpler model for catchment scales, and GIS applications. The intensity of input parameters required is not realistic for larger geographic applications (Inskeep *et al.* (1996).	IBM

2.2.2. SLIM (Addiscott & Whitmore, 1991)

The Solute Leaching Intermediate Model, SLIM, is a single program written in standard FORTRAN 77 which simulates nitrate and water flow from the top 90 cm of the soil profile. It is a physically based (functional) deterministic management model that can also be used with the option of inputs presented as distributions rather than single values.

Water flow is simulated with a mobile/immobile component for each layer and a tipping bucket approach describing migration downwards through each designated soil layer. Rainfall is split into aliquots to simulate matrix flow rather than flow in a structured soil (immobile/mobile water principal). The leaching model expresses the proportion of soil nitrate leached as a function of drainage density and it can be applied to many soils and land use scenarios for any *a proiri* distribution of nitrate in the soil (Van Herpe *et al.*, 2002).

The model is applied to *leaching seasons,* after the harvest period, assuming the residual soil nitrate continuously decreases during the leaching season and is reset again at the onset of the next leaching season (Van Herpe *et al.*, 2002). The main outputs are solutes in defined layers, total amount and concentration of solute leached, total amount of soil water retained and lost.

The authors of this model acknowledge that SLIM does not conform with classical soil-water theory but does provide a simple and clearly defined description of how solutes are leached from the soil. The model has the clear advantage of easily derived input parameters from existing soil survey information; soil aggregate size, structure, percentage clay, particle size distribution, volumetric water contents. This may not be such a clear advantage in Ireland where soil physical descriptions are generally not included in soil survey information. Addiscott and Bland (1988) show that variability of SLIM's parameters are not overly sensitive so as to hamper model performance. This was confirmed by the production of the SLIMMER algorithm relating drainage losses and nitrate leaching to a single curve for soils in entire UK (Lord & Anthony, 1999). Modelling strategies using the Minimum Information Requirement approach (Quinn *et al.*, 1999; Van Herpe et.al., 2002) have employed SLIM as the soil nitrate leaching component with success. Jabro et. al. (1994) validated SLIM's accurate simulation of field conditions.

<table>
<tr><td colspan="3">MODEL SLIM</td><td colspan="2">AUTHOR Addiscott & Whitmore (1987, 1991) UK</td></tr>
<tr><td colspan="3">MODEL TYPE Functional, deterministic, physically based.</td><td colspan="2">SCALE Field, unsaturated zone. Catchment (employing GIS).</td></tr>
<tr><td colspan="5">APPLICATION Considers solute and water added at surface, calculates movement through soil layers vertically downward</td></tr>
<tr><td>PROCESSES</td><td>INPUT PARAMETERS</td><td>MODEL OUTPUTS</td><td>MISCELLANEOUS</td><td>REQ'D</td></tr>
<tr><td>-Simulates the ranges of N export, vertically, from the top 90cm of the soil profile.
-The model divides the soil profile into layers within which water and solute is partitioned into mobile and immobile categories. Saturation of the top layer of soil defines a third category of water: by-pass flow.
-Leaching component of the model operates in four stages.
-Retention, advection & dispersion drainage considered.</td><td>-Rainfall and evaporation data. Rainfall is split into aliquots to simulate matrix flow rather than flow in a structured soil (immobile/mobile water principal).
-Model considers water with associated solute concentration to be applied at the surface layer.
-The model's rate and capacity parameters are derived from soil survey information, soil aggregate size, structure, percentage clay, Particle Size Distribution, volumetric water contents.</td><td>-Amount and concentration of solute leached from each layer.
-Solute concentration retained within each specified layer.
-Soil water contents and volumes leached for each layer.</td><td>-Incorporated into national UK NO_3^- modelling strategy MAGPIE (Lord & Anthony, 1999). SLIMMER algorithm developed for model inputs, applicable to all UK soil types.
-SLIM is the N model used within a Minimum Information Requirement (MIR) modelling approach validated for UK (Quinn <i>et al.</i>,1996) & Belgian (van Herpe <i>et al.</i>, 2002) catchments.
-Variability in input parameters shown not to seriously hamper model performance (Addiscott & Whitmore, 1991).
-Vinten & Redman (1990) successfully calibrated and validated SLIM for a clay loam soil.
-Seventeen input parameters per run (Rodda <i>et al.</i>, 1995).</td><td>-PC</td></tr>
</table>

2.2.3. DAISY (Hansen *et al.*, 1990)

A one dimensional, physically based root zone model which simulates crop production, soil water and nitrogen dynamics under various agricultural management practices. The simulation considers processes involving water, heat, carbon and nitrogen. Nitrogen is considered added to the system in various forms: fertilisation, different types of animal manures, deposition or plant residues.

The hydrological processes considered in DAISY include snow components, interception of precipitation, evaporation, infiltration, water uptake by plant roots, transportation and vertical movement of water in the soil profile. Vertical flow in the unsaturated zone is solved using the one dimensional Richards equation. Daisy uses a flux boundary, a fixed groundwater level or a file of groundwater levels as the lower boundary condition (Stychen & Storm, 1993).

DAISY's description of the nitrogen cycle is comprehensive. Mineralisation is determined by the turnover of three organic matter (OM) subpools [fresh/added, microbial and humus] and is described in a complex way. The overall result of all OM turnover is net mineralisation which may be positive [ammonium is released] or negative [ammonium/nitrate is immobilised] (CEC, 1991). Nitrification depends on soil temperature and soil water status and is described by first order kinetics. Soil temperature, soil water status and oxygen content govern denitrification. Nitrogen uptake by plants is determined as the nitrate flux to the root surface, controlled by mass flow and diffusion, which in turn depend on the concentration around the roots (Stychen & Storm, 1993). There are also soil temperature and crop growth models within DAISY.

Nielson *et al.* (1991) used this model successfully at catchment scale by assigning percentage land use categories and associated agricultural parameters in conjunction with census data and farm surveys. Stychen & Storm (1993) successfully integrated DAISY and a fully distributed hydrological catchment model (MIKE SHE, Danish Hydraulic Institute, 1993) for simulation of nitrate movement from application on the field to its occurrence in surface- and groundwater.

<table>
<tr><td colspan="3">MODEL DAISY</td><td colspan="2">AUTHOR Hansen <i>et al.</i> (1990) Denmark</td></tr>
<tr><td colspan="3">MODEL TYPE Complex, mechanistic, soil plant model</td><td colspan="2">SCALE Plot, field. Catchment (employing GIS).</td></tr>
<tr><td colspan="5">APPLICATION Unsaturated Zone. Most suitable for arable ecosystems including animals. When applied to catchments all farming systems considered.</td></tr>
<tr><th>PROCESSES</th><th>INPUT PARAMETERS</th><th>MODEL OUTPUTS</th><th>MISCELLANEOUS</th><th>REQ'D</th></tr>
<tr><td rowspan="3">-Water, heat, carbon and nitrogen processes considered.
-Water flow in the unsaturated zone is simulated by a numerical solution to Richards equation.
-Soil is divided into five layers each characterised by its own physical properties.
-Heavy emphasis on soil organic matter processes.
-Model requires complete description of soil hydraulic properties.</td><td rowspan="3">-Daily weather data.
-Detailed soil data including temperature and initial water, clay, nitrogen and carbon contents (totals, ratios, partitioning for each layer).
-Soil moisture characteristics and saturated hydraulic conductivity for each horizon.
-Crop management information, plant growth parameters, harvesting, residues, etc.
-Inorganic and organic applications (timing, rates, type, N & C contents). N deposition.</td><td rowspan="3">-Final soil carbon, nitrogen nitrate, ammonia and biomass data for each soil layer.
-Soil water and temperature dynamics.
-Nitrate leaching.
-N gross mineralisation.
-N immobilisation.
-N loss by denitrification.
-Plant information (leaf area index, root depth).</td><td rowspan="3">-Data hungry model
-Calibrated with measurements of soil moisture or tension, or both, as well as nitrate concentrations in soil moisture.
-Nielsen <i>et al.</i> (1991) further developed DAISY for regional scale nitrate leaching study.
-Model usage needs a proper initialisation period to stabilise the more dynamic parts regarding soil N and water (Nielsen <i>et al.</i> 91).
-Styczen and Storm (1993) successfully developed a model system for the evaluation of nitrate loads and movement in a catchment using Daisy and MIKE SHE.</td><td>IBM PC</td></tr>
<tr><td>Time Step</td></tr>
<tr><td>-Hours
-Output in days</td></tr>
</table>

2.2.4. SOIL - SOILN (Johnsson *et al.*,1987, Jansson, 1991)

The SOILN model was designed to simulate transport and transformations of nitrogen in soils and its uptake by plants. It was designed by one of the authors of the SOIL model, on which SOILN is dependent. SOIL is a water and heat model, based on two coupled differential equations derived from Darcy's and Fouriers laws, for a one dimensional layered soil profile (Bergstrom and Jarvis, 1991). The SOIL model uses standard meteorological data as driving variables in addition to key soil and plant properties such as soil water release characteristic (water content/water retention), hydraulic conductivity function, root distribution and leaf area development. This model is reported to also simulate groundwater flow (Bergstrom and Jarvis, 1991). The outputs from the SOIL model form some of the inputs to the SOILN model.

SOILN requires information on all N inputs: atmospheric deposition (calculated from the nitrogen concentration of collected rainfall), fertiliser N and manure applications. The model works on the principle of balance of receipt and loss of soil nitrogen. Nitrogen pools are added to by mineralisation of litter and humus, nitrification, fertilisation and deposition and those pools are depleted by plant uptake, immobilisation to litter, leaching and denitrification. Soils are divided into layers in order to account for the vertical distribution of soil properties affecting the processes simulated. All biological processes, defined by the given heat and water conditions, are simulated in order to infer the available nitrogen for loss to the environment. Rate constants and response functions must be defined in order to simulate the transformations of nitrogen. Organic nitrogen is divided into three pools – litter, humus and faeces. Mineralisation of humus to ammonium is assumed to be a first order rate process. The litter and faeces pools, also first order rate processes, are linked to pools of carbon to control mineralisation and immobilisation rates. Specific mineralisation constants and abiotic response functions govern these processes.

Bergstrom and Jarvis's (1991) long-term simulation with SOILN emphasised the importance of crop uptake as a major sink for nitrogen. With no fertiliser input, humus and litter stores of organic nitrogen were found to be profoundly depleted in the first few years and leaching losses were recorded of the same order of magnitude as the loss by denitrification.

<table>
<tr><td colspan="3">**MODEL** SOIL – SOILN</td><td colspan="2">**AUTHOR** Johnsson *et al.* (1987), Jansson (1991)</td></tr>
<tr><td colspan="3">**MODEL TYPE** Mechanistic, 1D layered soil profile model</td><td colspan="2">**SCALE** Field & catchment (in conjunction with GIS)</td></tr>
<tr><td colspan="5">**APPLICATION** Simulation model for nitrogen conditions in soils. Principally developed for arable land. However, due to many extensions developers claim it is applicable to any soils independent of plant cover (Jansson, 1996).</td></tr>
<tr><td>**PROCESSES**</td><td>**INPUT PARAMETERS**</td><td>**MODEL OUTPUTS**</td><td>**MISCELLANEOUS**</td><td>**REQ’D**</td></tr>
<tr><td rowspan="3">-The SOIL model (Johnsson *et al.*, 1987) provides driving variables for the SOILN model.
-Processes include: mineralisation of humus; min./immob. of C & N fractions; nitrification; denitrification; NO_3^- leaching, and plant uptake.
-Organic N is treated as 3 pools: humus, litter, faeces.
-Nitrate transport is calculated as the product of water flow between two given soil layers & the concentration of nitrate in the originating layer.
-Ammonium is assumed to be immobile in the soil profile.</td><td rowspan="3">-The water & heat model, SOIL, uses standard meteorological data but also requires knowledge of key soil and plant properties (see text).
-Driving variables for SOILN include runoff and infiltration characteristics, water flow between layers, soil water content and temperature for each layer & drainage flow.
-Then, SOILN requires all N inputs to the system: fertiliser, manure and atmospheric deposition.
-Rate constants & response functions are set to describe all the transformations of the N cycle with respect to 3 organic pools defined in model</td><td rowspan="3">-N balance.
-Harvested nitrogen.
-NO_3 leachate concentration.
-Drain discharge.
-NO_3 concentrations in drainage outflow.</td><td rowspan="3">-Bergstrom & Jarvis (1991) sometimes found a 100% discrepancy between field and simulation results, which they attributed to macropore flow or partitioning errors. However, overall longterm mean yearly losses were estimated well (Arable application).
-Arheimer & Brandt (1999) used SOILN as part of a large catchment modelling strategy. SOILN adequately represented NO_3 leaching from the root zone under arable, pasture & forest. Results were then input into a dynamic model of N transport for the southern region of Sweeden.
-Jansson (1996) reports the model to be fully validated.</td><td>-IBM PC
-DOS OS
-5MB</td></tr>
<tr><td>**TIME STEP**</td></tr>
<tr><td>-minutes
-years</td></tr>
</table>

2.2.5. RENLEM (Kragt & de Vries, 1987, Kragt & Hack-ten Broeke, 1991a & b)

RENLEM, **R**egional **N**itrate **L**eaching **M**odel, is a deterministic steady state nitrate-leaching model using relatively simple concepts for processes like mineralisation, volatilisation, nitrification and denitrification. Immobilisation is not considered. This model is less rigorous in regard to detailed mathematical description of the processes with the overall result of less accuracy but greater usability for many different scenarios, quickly and with relative ease (Rodda, 1993).

The model was developed for calculation of the long-term regional effects of various nitrate management scenarios for an average hydrological year. RENLEM is a policy/decision-making tool that gives results accurate to within one order of magnitude which is accurate enough to provide a quick overview of the situation. Two periods of calculation are considered– summer (growing season) and winter (leaching period). There is no hydrology component, as in many Dutch nitrogen models an external water balance must be used.

The soil is divided into two layers: the root zone and a layer below the root zone. Complete mixing is assumed to take place in each soil layer. The bottom boundary can either be the groundwater level or a specific sampling depth within the unsaturated zone (Kragt *et al.*, 1990). Inputs to RENLEM comprise soil data, fertiliser and manure application data, crop details and averaged hydrological data. Nitrate leaching is calculated by multiplying nitrate concentration leaving the root zone (obtained by process transformations and moisture contents) by precipitation surplus.

It is assumed that there is no change in soil N storage in that, on an annual basis, all added organic N is mineralised. This assumption implies a soil system at equilibrium, which rarely happens. However, as the intended application of the model is a long-term management strategy tool the assumption was considered valid. As would be expected, the model performs best when there is very little change in soil storage (Kragt & Hack-ten Broeke, 1991). A CEC (1991) evaluation calibrated and validated RENLEM for six dataset watersheds (UK & EU) and concluded that the model has a tendancy to underestimate nitrate leaching. The model has been proven to predict nitrate leaching on a regional basis, for Dutch conditions (Kragt & Hack-ten Broeke, 1991).

MODEL RENLEM

AUTHOR Kragt & de Vries (1987), Kragt & Hack-ten Broeke (1991)

MODEL TYPE Scenario tool. Deterministic, steady state.

SCALE Regional

APPLICATION Long-term, regional effects of various nitrate management scenarios for average hydrological year. No qualitative simulation of amount of nitrate leached. External water balance model must be employed.

PROCESSES	**INPUT PARAMETERS**	**MODEL OUTPUTS**	**MISCELLANEOUS**	**REQUIREMENTS**
-Volatilisation assumed a linear function of applied manure. -Mineralisation assumed in equilibrium with added organic N, in each year. -Nitrification assumed complete in each year. -Denitrification described in the most complex way (a function of moisture, C, pH, bulk density and temperature). -Immobilisation not considered.	-Soil data: bulk density, pH, and organic matter. -N applications in fertiliser and manure (quantity, C & N content). N deposition. -Crop uptake, & rooting. -Farm management data (grazing). -Average hydrological data (uses half year average moisture content and net precipitation surplus for two simulation periods – summer & winter).	-N balance terms per season per soil layer (two considered). -Average N concentrations in soil water.	-Model performs best when there is very little change in soil storage (Kragt & Hack-ten Broeke, 1991). -A CEC (1991) evaluation calibrated and validated RENLEM for six dataset watersheds (UK & EU) and concluded that the model has a tendancy to underestimate nitrate leaching. -The model has been proven to predict nitrate leaching on a regional basis (Kragt & Hack-ten Broeke, 1991).	-

2.2.6. Other Models: Unsaturated -Saturated Zone Models

Two mechanistic models ANIMO (Berghuijs *et al.*, 1985 & Ritjema *et al.*, 1995) and SWMS_2D (Simunek *et al.* (1994, 1996) consider nutrient transformations and transport through the unsaturated zone to the saturated zone. However, those models do not simulate flow and transport within the groundwater body. Models can contain equations for user-defined simulation of flow in the unsaturated and saturated zones, they are referred to as coupled saturated-unsaturated zone models.

2.2.6.1. ANIMO (Berghuijs *et al.*, 1985, Ritjema *et al.*, 1995)

ANIMO dynamically simulates the carbon, nitrogen and phosphorus cycles, and their interactions, in unsaturated and saturated soil systems. Optimal simulation of the phosphorus cycle was achieved in the later versions of the model. (Kroes & Roelsma, 1998). The model was developed to analyse the leaching of nitrogen, from the soils of grassland fields, to groundwater and surface waters as influenced by fertiliser strategy, water management and land use. There is no hydrological component in the model; an extended water balance is an input requirement of ANIMO. Hackten-Broeke (2000) employed SWACROP to find water fluxes required for ANIMO simulations of nitrate leaching from dairy farming in the Netherlands. Given details of water fluxes, ANIMO calculates solute fluxes. The model system is a based on a multi-layer one dimensional soil column. The user specifies the number of soil layers up to a maximum of 100. The upper boundary is the soil surface, the lower boundary is the depth of the local groundwater flow and the lateral boundary is defined by the surface water system. Main processes included in the model are crop uptake, denitrification related to anaerobiosis and decomposing organic matter, mineralisation and immobilisation, oxygen and temperature distribution in the soil, nitrification, desorption and adsorption. All the processes are deemed to be strongly affected by soil moisture (external water balance model) pH (input parameter), oxygen supply, soil temperature (simulated by ANIMO) and the decompostion of organic matter (Hackten-Broeke, 2000). Model nitrogen inputs include; fertiliser and manure applications, volatilisation rates for each application, atmospheric deposition of N, and N supply through crop residues and excreta from cattle. Runoff, discharge to different surface water systems and leaching to groundwater are outputs of the model (Roelsma, 2000). This model was developed in the Netherlands, where they have predominantly sandy soils with a shallow water table (often less than one metre below ground level). It is quite important to note that this models' application has only been successfully validated in hydrogeological conditions quite different to our own.

<table>
<tr><td colspan="2">MODEL ANIMO</td><td colspan="3">AUTHOR Berghuijs <i>et al.</i> (1985), Ritjema <i>et al.</i> (1995)</td></tr>
<tr><td colspan="2">MODEL TYPE Dynamic deterministic, mechanistic.</td><td colspan="3">SCALE Plot, field, regional, catchment.</td></tr>
<tr><td colspan="5">APPLICATION Unsaturated and saturated soils. Quantitative evaluation of nitrate leaching below root zone. Pseudo 2D.</td></tr>
<tr><td>PROCESSES</td><td>INPUT PARAMETERS</td><td>MODEL OUTPUTS</td><td>MISCELLANEOUS</td><td>REQ’D</td></tr>
<tr><td rowspan="3">-External hydrology model must be used (eg. SWATRE).
-Describes almost complete nitrogen cycle in the soil in combination with the carbon cycle. Considers transformations and relationships between mineralisation, immobilisation, aeration, denitrification, plant uptake and adsorption
-Soil temperature and organic matter (four pools) considered.
-Assumes complete mixing of solutes in each layer.</td><td rowspan="3">-Daily/weekly climatic data.
-Water balance.
-Soil physical properties: clay content; organic matter; PSD; bulk density; diffusion coefficient for oxygen in soil and five temperature parameters.
-Soil chemical properties: pH; nitrogen & carbon content; sorption coefficient and rates.
-Management data: fertiliser management (amounts, types, C/N ratios, time, etc.); crop data (management, uptake & residues).
-N deposition, nitrate and ammonia concentrations in groundwater. Specify initial and boundary conditions.</td><td rowspan="3">-All terms of complete balances of the soil – water-crop system: total nitrogen; carbon & nitrate content; ammonium content, total mineral nitrogen; ortho P; organic P.
-Nitrate leaching.
-Soil temperature dynamics.
-Mineralisation and denitrification rates.
-Detail relating to different organic matter pools.</td><td rowspan="3">-Valid for crop and grassland.
-Better predictions for N leaching when (a) both mineral and organic N considered & (b) N shortage in the system (Ritjema <i>et al.</i>, 1991).
-Jansen <i>et al.</i> (1991) conclude that ANIMO is a useful nitrate leaching scenario tool but is limited by quality of input data.
-Performed satisfactorily in EU model evaluation, neither over- nor underestimating nitrate leaching but better performance for arable rather than grassland application (CEC, 1991).</td><td>IBM PC</td></tr>
<tr><td>TIME SCALE</td></tr>
<tr><td>-Days, weeks and monthly inputs.
-Long & short time range.</td></tr>
</table>

2.2.6.2. SWMS_2D (Simunek *et al.*, 1994, 1996)

This USDA model varies from most others in that it does not assume homogenous, isotropic soil conditions over a uniform simulation area. The simulation area may have irregular boundaries, non-uniform soils and an arbitrary degree of local anisotropy. Water and solute transport is simulated in a two-or three-dimensional (SWMS_3D, Simunek *et al.*, 1995) variably saturated media.

Water movement is solved numerically using Richards' equation for saturated-unsaturated water flow and the convection-dispersion equation is applied to solving solute transport (USDA, 1994). Solute and water flow may occur in the vertical, horizontal or three-dimensional plane in order to attempt to represent field conditions. Water tables and flux boundaries, e.g. nodal drains, can be included in the simulation.

The model, as with most others, requires the user to specify and define layers (say 10cm each). Data is then input for each layer, describing physical and hydraulic characteristics, nitrate concentrations and water contents at the start and end of simulation period. Climatic information (global net radiation, air temperature, relative humidity, precipitation, wind speed, wind direction & soil temperature) and initial boundary conditions (water table, drain locations) must be supplied.

Although the model was developed in 1994, only recent field applications can be found in the literature. DeVos *et al.* (2000) concludes that SWMS_2D is a useful tool for evaluation of relative effects of management practices to reduce N leaching. In their application, the model was calibrated for water flow taking into account N production in the topsoil. Macroscopic soil heterogeneity was described using the soil hydraulic characteristics for different soil layers. The results were good. Charnock *et al.* (2000) detail the successful interaction of SWMS_2D within a GIS environment.

<table>
<tr><td colspan="3">MODEL SWMS_2D</td><td colspan="2">AUTHOR Simunek <i>et al.</i> (1994, 1996)</td></tr>
<tr><td colspan="3">MODEL TYPE 2D process based, variably saturated model.</td><td colspan="2">SCALE Field scale.</td></tr>
<tr><td colspan="5">APPLICATION Saturated & unsaturated zones, model developed to improve on the usual 1D-homogeneous simulation models. Simulates practices, not absolute N leached.</td></tr>
<tr><td>PROCESSES</td><td>INPUT PARAMETERS</td><td>MODEL OUTPUTS</td><td>MISCELLANEOUS</td><td>REQ'D</td></tr>
<tr><td>-The model is based on two dimensional, transient Darcian water flow and the convection-dispersion of solute in the combined saturated–unsaturated zones.
-Unsaturated, partially or fully saturated applications.</td><td>-Soil profile descriptions by layer (% clay, OM, CEC).
-Soil hydraulic characteristics by layer (water retention, hydraulic conductivity [K], saturated K)
-Nitrate concentration and volumetric water contents in the soil profile at user chosen interval (say 10cm) at the start and end of simulation period.
-Global net radiation, air temperature, relative humidity, precipitation, wind speed, wind direction & soil temperature.
-Initial boundary conditions (water table, drain locations).</td><td>-Groundwater levels.
-Drain discharge rates.
-Associated nitrate concentrations.</td><td>-A USDA model.
-Simulation areas may have non-uniform soils with irregular boundaries and an arbitrary degree of local anisotropy.
-DeVos <i>et al.</i> (2000) concludes that SWMS_2D is a useful tool for evaluation of relative effects of management practices to reduce N leaching. In their application, the model was calibrated for water flow taking into account N production in the topsoil. Macroscopic soil heterogeneity was described using the soil hydraulic characteristics for different soil layers. The results were good.
-Charnock <i>et al.</i> (2000) detail the interaction of SWMS_2D within a GIS environment.
-SWMS_3D is also available (Simunek <i>et al.</i> 1995).</td><td>-IBM PC</td></tr>
</table>

2.3. SATURATED ZONE MODELS

2.3.1. Styczen & Storm (1993)

Styczen & Storm (1993) simulated water and nitrate transportation on a regional scale using DAISY (Hansen *et al.*, 1990) in combination with MIKE SHE (Danish Hydraulic Institute, 1993; Storm *et al.*, 1990). Their task was to evaluate the effects of changes in agricultural practice and land-use on water quality in groundwater and rivers in a 425 Km^2 Danish catchment. MIKE SHE accounted for the occurrence of catchment water and DAISY provided a detailed process-based description of the fate of nitrogen in the soil. The two models were run sequentially in order to provide a comprehensive three-dimensional, deterministic modelling system. A 500 x 500m grid was used with a 5cm vertical division in the upper soil profile and 40cm in the lower unsaturated zone. A 5m vertical layer structure was employed in the aquifer as a constant thickness for three-dimensional saturated flow simulation. The simulation sequence followed was as follows (Styczen & Storm, 1993):

1) MIKE SHE is calibrated for groundwater heads and surface runoff volumes, at catchment scale, in order to ensure that it is a correct simulation of the temporal and spatial recharge to groundwater.

2) N cycle dynamics are simulated with DAISY for all combinations of agricultural management practices in the catchment. Data mostly derived from literature and local agricultural advisors.

3) Results from 2) are distributed across the MIKE SHE grid.

4) MIKE SHE is re-generated using DAISY outputs for crop status parameters (another DAISY output) to ensure full compatibility in the recharge volumes for the two models.

The input data required for this modelling approach fell into the following classes: a) weather; b) topography; c) soils; d) hydrogeology, and e) land-use management.

Good correlation was obtained between observed and simulated groundwater heads (for the hydrological model MIKE SHE). Site-specific validation of the DAISY simulations was not possible because the data sets were statistically derived but parallel research teams, for plots within the catchment, found the DAISY model to perform well (*in* Stychen & Storm, 1993). The range of groundwater nitrate concentrations was comparable for simulations and observations under different land use areas. The spatial and vertical distribution of nitrate loading in the catchment is reported to have been successfully simulated by the combination of DAISY and MIKE SHE.

The 5m deep aquifer layer simulation allowed examination of the behaviour of nitrate in aquifer systems. As expected, a deep unsaturated zone was found to dampen the influence of soil nitrate loads on groundwater nitrate concentrations. A high water table manifested itself with large fluctuations in groundwater nitrate concentrations. Both measurements and simulations show that the groundwater layer just above the reduced zone has particularly high nitrate concentrations. Approximately half of the nitrate leaching from the root zone was found to be denitrified at the redoxcline (the zone where groundwater condition changes from oxidised to reduced).

Comparisons between observed and simulated surface water nitrate concentrations highlighted the models underestimation of the role of denitrification in wetland areas along river systems [estimated to be as much as 50-75% of the simulated addition (Brüsch and Nielsen, 1990)].

The modelling system employed by Styczen & Storm (1993) is reported to be of use to both research scientists, for trend analysis, and policy makes, for land-use changes. The large database requirements were easily met using published process rates, agricultural annuals, available environmental databases and local expert knowledge from agricultural advisors. However, management of these databases and the process orientated models requires substantial resource commitment.

<table>
<tr><td colspan="4">MODEL APPROACH DAISY & MIKE SHE</td><td colspan="2">AUTHOR Styczen & Storm (1993)</td></tr>
<tr><td colspan="6">APPLICATION Simulation of water and nitrate transportation at a regional scale using DAISY (Hansen <i>et al.</i>, 1990) in combination with MIKE SHE (Danish Hydraulic Institute, 1993; Storm <i>et al.</i>, 1990) to evaluate the effects of changes in agricultural practice and land-use on water quality in groundwater and rivers in a large Danish catchment.</td></tr>
<tr><td>PROCESSES</td><td>INPUT PARAMETERS</td><td>MODEL OUTPUTS</td><td colspan="2">MISCELLANEOUS</td><td>REQ’D</td></tr>
<tr><td rowspan="3">-See descriptions of DAISY & MIKE SHE in text.
-The flow of water and solutes in the catchment is obtained by solving the governing equations of overland and channel flow, for unsaturated and saturated conditions, using FDM.
-The FDM water velocities allowed solute transport to be solved using the appropriate advection-dispersion equations.</td><td rowspan="3">-As for DAISY & MIKE SHE.
-Digitised 1:50 000 scale maps of topography, stream systems and point sources.
-Agricultural data sets required for DAISY simulations were derived statistically.</td><td rowspan="3">-Catchment water balance.
-Evaluation of nitrate loads and movement in the catchment, both spatially and temporally.
-Groundwater and surface water nitrate concentrations.</td><td colspan="2" rowspan="3">-The modelling system is reported to be of use to both research scientists, for trend analysis, and policy makes, for land-use changes.
-The large database requirements were easily met using published process rates, agricultural annuals, available environmental databases and local expert knowledge from agricultural advisors.
-The two models were run sequentially (see text for details).
-The spatial and vertical distribution of nitrate loading in the catchment was successfully captured by the combination of DAISY and MIKE SHE.
-The system usefully highlighted the behaviour of nitrate in aquifer systems.
-Denitrification in wetland areas along river systems was a significant sink in the river nitrate loadings.</td><td></td></tr>
<tr><td>Time-Step</td></tr>
<tr><td></td></tr>
</table>

2.3.2. Lassere *et al.* (1999)

This French study linked a nitrogen flux model (AgriFlux) to a GIS-integrated aquifer transport model. AgriFlux (Banton & Laroque, 1997) is a mechanistic stochastic model in which spatial distribution is considered. There are water flux (HYDRIFLUX) and nitrogen cycle (AGRI) components to the process model which quantify fluxes leaving the root zone.

The aquifer transport model, written in the Pascal language, considers pure advection only. The overall approach is based on simpler hydrogeological principles than the classical advection-dispersion model. Preferential/bypass flow, hydrodynamic dispersion and adsorption/desorption are not considered and this may be disadvantageous.

As many maps, as parameters needed by the models, must be created for the GIS: hydraulic conductivity, high and low piezometric water levels, initial groundwater nitrate concentrations, water and nitrate fluxes from the root-zone, hydraulic gradients and flow directions. The GIS employed is a raster based system, IDRISI (Eastman, 1997), developed in the US. External vector GIS maps are appropriated and converted to raster model i.e. the fragmentation of maps into series of user defined pixel sizes, each pixel having a numerical value. A raster file is the series of numerical values read by the GIS-linked model. The system then translates all the parameter maps into files that are read automatically by the model before running. IDRISI subroutines facilitate the input of modelling data in homogeneous zones or point data that requires interpolation to areal representations. Employing a GIS facilitates large numbers of points, with a spatial reference and parameter values assigned to each point. Use of MODFLOW, previous to the GIS model, was necessary to get the spatial distribution of hydraulic conductivity. The AgriFlux model outputs', simulated water and nitrate fluxes from the root zone, were applied in the GIS transport model as groundwater recharge. The study team deemed this an acceptable approach as it was a shallow water table situation, at-5–20m below ground level. The model output from the Lassere *et al.* (1999) approach is the distribution of nitrate in the aquifer. The study successfully validated their approach with a more comprehensive, labour intensive model– the MODFLOW-MT3D package (Groundwater Modelling Software, US Department of Defence), and recorded results that compared well with their own simulations. MODFLOW is a USGS groundwater flow model. MT3D (Zheng, 1990) is a groundwater contaminant transport model (see section 2.3.5).

<table>
<tr><td colspan="3">MODEL Modelling Approach for Groundwater Contaminant Simulation.</td><td>AUTHOR Lassere <i>et al.</i> (1999)</td></tr>
<tr><td colspan="3">MODEL TYPE GIS-integrated aquifer transport model.</td><td>SCALE Catchment</td></tr>
<tr><td colspan="4">APPLICATION Determination of the distribution of nitrate in an aquifer.</td></tr>
<tr><td>INPUT PARAMETERS</td><td>MODEL OUTPUT</td><td>MODELLING PROCEDURE</td><td>REQ’D</td></tr>
<tr><td>-Model inputs for – AgriFlux: a mechanistic stochastic Ncycle model (Banton & Laroque, 1997) & the water balance model HYDRIFLUX.
- As many maps, as parameters needed by the models, must be created for the GIS (see text).
-Inverse modelling using MODFLOW (USGS) provides spatial distribution of K & porosity.</td><td>-The AgriFlux model outputs, simulated water and nitrate fluxes from the root zone, were applied in the GIS transport model as groundwater recharge. The study team deemed this an acceptable approach as it was a shallow water table situation, at-5–20m below ground level.
-The model output is the distribution of nitrate in the aquifer.</td><td>-A 1ha grid spacing was employed for a 20 km^2 watershed.
-Piezometric levels and nitrate concentrations collected for two years (bimonthly) along with soils and cultivation data (data for the AgriFlux model). Vadose zone transfer time must be determined (groundwater reaction times).
-N transformation rates, obtained from international scientific literature, used in AgriFlux to determine fluxes leaving the root-zone.
-MODFLOW applied to the area – inverse modelling to get hydraulic conductivity and porosity distribution by fitting to observed groundwater heads.
-As many maps as parameters, needed by the models, were created: hydraulic conductivity, high and low piezometric water levels, initial groundwater nitrate concentrations, water and nitrate fluxes from the root-zone, hydraulic gradients and flow directions. Pedologic maps gave soil characteristics for the modelling (porosity, saturated hydraulic conductivity, field capacity, wilting point and particle size distribution). The maps are then applied to a specially written advection transport model within a GIS.
-Validations with a more comprehensive model – the MODFLOW-MT3D package recorded simulation results that compared well with the simpler approach.</td><td>-IBM PC</td></tr>
</table>

2.3.3. GLEAMS (Leonard *et al.*, 1987, Knisel, 1993)

The Groundwater Loading Effects of Agricultural Management System (GLEAMS) is a continuous field-scale model that was developed as an extension of the CREAMS model, Essentially, GLEAMS is a one dimensional, deterministic and physically based model that simulates runoff, percolation, N and pesticide leaching, erosion and sedimentation with a daily time-step. The model consists of a single computer program of interactive processes. Separate hydrological, erosion runoff, erosion and transport of sediment bound nutrients, and chemical transport output files are maintained based on CREAMS. Soils data are input by horizon (with seven computational layers) and the model distributes values for porosity, water retention characteristics and organic matter into the appropriate computational layer. It is a tool for comparative analysis of management factors in association with soil properties and climate. GLEAMS can be used to assess the effect of farm level management decisions on water quality as application rates, methods and timing can be altered to account for agricultural systems.

GLEAMS determines the impact of management scenarios on water quality constituents leaving the root-zone and therefore the title 'groundwater' is misleading. Model evaluations (Leonard *et al.*, 1987; USDA, 1996a) present no evidence of simulation of nutrient transport below the root-zone to groundwater. Leonard *et al.* (1996) details the developments of GLEAMS according to 'worldwide' usage of the pesticide model compartment with suitable adjustments according to recent findings of pesticide behaviour. GLEAMS has been used to assess nitrogen losses (Yoon *et al.*, 1994; Wu *et al.*, 1997; Bakhsh *et al.*, 2000) and to simulate nitrate leaching (Wu *et al.*, 1996). The latter stochastically applied GLEAMS within a GIS environment and obtained simulation results similar to those observed from suction lysimeter data. Garnier *et al.* (1998) used GLEAMS in conjunction with a GIS, to assess different strategies for the disposal of animal waste in a region, and found it to be a model with 'huge' data needs. He concluded that the tool is one suitable for comparative analysis rather than an absolute predictor in space and time. In the same fashion De Paz & Ramos (2002) linked GLEAMS with a GIS to evaluate the risk of nitrate pollution in a Mediterranean area and found it to be a complex model that requires much data and parameters but works well for determining relative *potential risk* of groundwater nitrate pollution. Vieaux *et al.* (1998) applied GLEAMS in conjunction with GIS to delineate wellhead protection areas. There is no summary table for GLEAMS in this review because other approaches are deemed more relevant.

2.3.4. DRASTIC (Aller *et al.*, 1987)

DRASTIC is an empirical approach developed by the US EPA. This standardised rating system evaluates aquifers for relative pollution potential using hydrologic characteristics. It provides a method for creating maps used to evaluate the relative vulnerability of an aquifer's water table to contamination. A grid covers the land surface area, over the aquifer. A DRASTIC index is created for each grid square. DRASTIC maps can then be used for policy decisions regarding nutrient vulnerable areas overlying unconfined aquifers. Essentially this is a screening analysis tool that identifies problematic areas warranting further investigation (US EPA, 1992). The name DRASTIC is derived from the seven factors that compose the 'DRASTIC rating': **D**epth to water; **R**echarge; **A**quifer media**,** **S**oils; **T**opography; **I**mpact of vadose zone; hydraulic **C**onductivity. The parameters, combine geological, hydrological, geomorphologic & meteorological conditions, to relate an aquifer to the nature of its recharge. Each parameter is rated, according to significance, to create a general vulnerability map. Further weightings may be employed to emphasise areas of agricultural land or, potentially, point sources. A DRASTIC index is calculated by adding the products of the rating and weighting of each specified factor (Rosen, 1994):

DRASTIC index = **D**r**D**w + **R**r**R**w + **A**r**A**w + **S**r**S**w + **T**r**T**w + **I**r**I**w + **C**r**C**w.

The higher the index, the greater the relative pollution potential. A low pollution potential need not mean that it is free from groundwater contamination but it is less susceptible to contamination compared to sites with high DRASTIC index (Hart, 1999). A systematic review of DRASTIC, questioned the usefulness of such a qualitative methodology (Rosen, 1994). Two national US monitoring programmes (EPA, 1992; Holden *et al.*, 1992) found that there was little association between contamination by agricultural chemicals and DRASTIC scores, for their particular investigations, indicating that individual DARSTIC parameters were poorly correlated with contamination (NRC, 1993). This lack of association may be attributed to either poor model performance or the intrinsic problems in attempting to relate model predictions with observed groundwater quality from abstraction points.

The NRC (1993) report seems to have prompted modified applications of this model. Composite use of DRASTIC and agricultural indices yielded results comparable with field observations in Isreal (Secunda *et al.*, 1998). Lynch *et al.* (1997) presented a South African national application, (theoretical) not validated. A GIS environment easily facilitates the models grid and layer structure of analysis for data processing and display. Engel *et al.*, (1996) modified DRASTIC, to include additional data layers describing land use and fertiliser applications, on a grid basis, within an ARC/INFO GIS environment. These modifications were found to increase the accuracy of model performance. Zhang *et al.* (1996a & b) developed aquifer sensitivity maps using DRASTIC, within a GIS mapping environment, and numerical modelling methods. These types of maps are used for prioritising areas that require apecial attention due to potential groundwater contamination. Fuest *et al.* (1998) applied DRASTIC, with mixed success, using spatially referenced environmental data (land use, stocking rates, soils types, a Digital Elevation Model and climatic data) stored within a GIS. Mc Lay *et al.* (2001) compared three approaches (dominant land use at or surrounding groundwater sampling sites, topsoil properties which reflect N cycling and the DRASTC risk assessment model) and found that DRASTIC gave the best correlation with actual groundwater nitrate concentrations. DRASTIC is a model, like most US EPA models, easily applied in the US due to extensive environmental database availability.

Mc Lay *et al.* (2001) compared three approaches (dominant land use at or surrounding groundwater sampling sites, topsoil properties which reflect N cycling and the DRASTC risk assessment model) and found that DRASTIC gave the best correlation with actual groundwater nitrate concentrations. They suggest that models such as DRASTIC that assess the risk of solute leaching to groundwater at a site, perhaps with a land managemnt index included, are more useful for predicting areas for more intensive monitoring of groundwater.

<table>
<tr><td colspan="3">MODEL DRASTIC</td><td colspan="2">AUTHOR Aller <i>et al.</i> (1987)</td></tr>
<tr><td colspan="3">MODEL TYPE Screening analysis tool for qualitative analysis</td><td colspan="2">SCALE >4 Km2 (100 acres), Regional, National.</td></tr>
<tr><td colspan="5">APPLICATION It provides a method for creating maps used to evaluate the relative vulnerability of an aquifers' water table to contamination. DRASTIC maps can then be used for policy decisions regarding nutrient vulnerable areas.</td></tr>
<tr><th>PROCESSES</th><th>INPUT PARAMETERS</th><th>MODEL OUTPUTS</th><th>MISCELLANEOUS</th><th>REQ'D</th></tr>
<tr><td rowspan="3">-Seven factors comprise the 'DRASTIC rating': Depth to water; Recharge; Aquifer media, Soils; Topography; Impact; hydraulic Conductivity.
-The parameters, combine geological, hydrological, geomorphologic & meteorological conditions, to relate an aquifer to the nature of its recharge.
-Each parameter is rated and weighted to provide mapped output of potential for aquifer contamination.</td><td rowspan="3">-D = Depth to water.
-R = Recharge.
-A = Aquifer media.
-S = Soils.
-T = Topography.
-I = Impact of vadose zone.
-C = hydraulic Conductivity.</td><td rowspan="3">-DRASTIC index
-Intrinsic vulnerability maps for the aquifers land surface area.
-Specific vulnerability maps concerning agricultural contamination risks</td><td rowspan="3">-The higher the index, the greater the relative pollution potential.
-Including additional agricultural information, within a GIS environment, has been proven to yield more realistic results (Navular, 1996: Secunda <i>et al.</i>, 1998). A DEM and agricultural data improves model performance.
-DRASTIC has been successfully applied in Europe (Lobo-Ferreira & Oliveira, 1997), Asia (Kim & Hann, 1999), the middle east (Secunda <i>et al.</i>, 1998), extensively in the US (US EPA, 1992) and other countries.</td><td>-IBM PC
-GIS</td></tr>
<tr><td>TIME-STEP</td></tr>
<tr><td>-Map output, not predictive simulation.</td></tr>
</table>

2.3.5. MODFLOW (Harbaugh and McDonald, 1996) & MT3D (Zheng, 1990)

MODFLOW is a three-dimensional finite-difference ground-water flow model developed by the US GS. The modular structure allows easy modification to adapt the code for a particular application. The program was constructed in the early 1980's and has continually evolved with the development of many related packages and programs simulating groundwater flow. MODFLOW is widely used worldwide

MODFLOW is designed to simulate aquifer systems in which: 1) Saturated-flow conditions exist; 2) Darcy's Law applies; 3) The density of groundwater is constant, and; 4) The principal directions of horizontal hydraulic conductivity or transmissivity do not vary within the system. When the above conditions are met MODFLOW can simulate a wide variety of hydrologic features and processes such as rivers, streams, drains, springs, wells, evapotranspiration and recharge from precipitation.

Steady-state and transient flow, in an irregularly shaped flow system, can be simulated. Aquifer layers can be confined, unconfined or a combination of both. The groundwater flow equation is solved using the finite-difference approximation where an aquifer system is divided into blocks by a grid (variably spaced both horizontally and vertically). Some grids hold depth information which modifies the depth representation so that layers can follow the surfaces of the geological layers. The grid of blocks is organised by rows, columns and layers, and each block is called a "cell". Several solvers are provided for solving the grid associated matrix problem. Mass balances are computed for each time step and as a cumulative volume for each source and type of discharge.

Model Inputs - For each "cell" within the aquifer system, the user must specify initial conditions and hydraulic properties. In addition, the user specifies stresses such as wells, rivers, and other inflow and outflow features.

Model Outputs – MODFLOW uses the input to construct and solve equations of groundwater flow in the aquifer system. The primary output is head (groundwater level) at every cell in the aquifer system (except for head-input data cells) at time-step intervals. In addition to heads, MODFLOW computes the water budget for the entire aquifer system (listing inflows to and outflows from the aquifer system for all hydrologic features) and flow rates for each model cell. Computed water levels for individual cells can be compared with measured water levels, from wells at corresponding locations, to determine model error and thereby adjust model input values to reduce the model error (the process of calibration). Inverse modelling, a more formal approach to calibration, and automatic parameter estimation are features of the MODFLOWP code (Hill, 1992). Model output includes the estimation of parameters and statistics relating to the parameter estimates (used to quantify the reliability of the resulting model).

Many studies require information such as the average rate of movement of groundwater and contaminants or the recharge and capture areas of wells, springs and streams. Although MODFLOW does not compute this information directly, simulation provides basic information needed for such analysis. MODPATH is a post-processing program for MODFLOW which estimates flow paths and times of travel in groundwater systems. Particles can be tracked forward from starting locations or backwards to map where they came from.

MOC3D is a solute-transport program (based on a particle-tracking method) integrated with MODFLOW and has the ability to calculate changes in concentration of a single solute as affected by processes of advection, dispersion, diffusion, fluid sources, decay and retardation. In addition to the input data requirements of MODFLOW, the user must also define porosity, thickness, dispersivity, initial concentrations and source-concentrations.
Model output includes the calculated concentration distribution in space and time.
MODFLOW works on many different computer systems ranging from personal computers to super computers. The code has been used on UNIX-based computers and DOS-based 386 or greater computers, having a math coprocessor and 4MB of memory. All of the above-mentioned programs are available from the USGS at no cost at http://water.usgs.gov/software/. Data input instructions and theory are well documented at http://water.usgs.gov/pubs/

<table>
<tr><td colspan="3">MODEL MT3D</td><td colspan="2">AUTHOR Zheng (1990)</td></tr>
<tr><td colspan="3">MODEL TYPE Contaminant Transport in the Saturated Zone.</td><td colspan="2">SCALE Aquifer.</td></tr>
<tr><td colspan="5">APPLICATION Simulation of advection, dispersion and chemical reactions of contaminants in groundwater systems. Interfaces with MODFLOW for groundwater flow component.</td></tr>
<tr><td>PROCESSES</td><td>INPUT PARAMETERS</td><td>MODEL OUTPUTS</td><td>MISCELLANEOUS</td><td>REQ'D</td></tr>
<tr><td>-Utilises a comprehensive set of solution options; hybrid method of analysis and particle tracking and FDM, to simulate contaminant transport, MODFLOW flow rate must be provided.
-Handles a variety of discretisation schemes and boundary conditions.</td><td>VERY DETAILED hydrogeological characterisation required</td><td>- contaminant transport</td><td>-Public domain code.
Inappropriate model for policy making wrt to Nitrates directive</td><td>Desktop PC</td></tr>
</table>

2.3.6. RAM (ESI, 2000)

The RAM model (ESI, 2000) is a 'customisable quantitative decision tool for risk-based groundwater assessment and decision-making'. Although the model was developed, under the remit of environmental protection, for assessing risks to groundwater from brownfield redevelopment the framework is appropriate for application in determining risk of NO_3^- contamination of groundwater from dairy farming. RAM was designed using the latest Environment Agency (UK) methodologies for contaminated land.

The greatest advantage of the RAM model is the Windows based framework that allows the conceptual model to be created easily within Microsoft Excel. 'Black box' modelling is overcome and the model integrates all subsurface zones and so avoids awkward linkage issues that would arise if three separate subsurface zone models had been chosen. Also, model development includes automatic audit trail and in that way Quality Assurance is facilitated. There are four 'tiers' built into RAM, with a built in link between all tiers. 'Tier One' requires description of the soil zone and the identification of contaminants (nitrates for this application but any contaminant can be modelled, e.g. ammonium is also relevant in this study). 'Tier Two' considers dilution, 'Tier Three' considers dilution and attenuation and the simulation can end there. Further, a 'Tier Four' assessment can be created in which a full dilution, advection, dispersion, retardation simulation is possible. 'Tier Four' incorporates a unique semi-analytical model designed to represent detailed site-specific cases where multiple sources, pathway sections and receptors can be evaluated without compromising on the conceptual model involved. Not only can the hydrogeology of the karstified environment be adequately described but also different spatial zones on a farm, and their associated loading differences, can be created within the simulation framework.

RAM's data input requirements are substantially less than those of any other model reviewed and are also more available for extension of this model for application for Nitrate Directive policy-making on a national scale. The software utilises the familiar Microsoft Excel environment, with standard editing and calculation facilities, which ensures great model transferability and ease of use. Both deterministic or stochastic simulations are possible. When a stochastic simulation is chosen, Monte Carlo uncertainty analysis is a feature of associated software that has already integrated with RAM.

MODEL RAM

AUTHOR Environmental Simulations International

MODEL TYPE Customisable quantitative decision tool for risk-based groundwater assessment

SCALE Hydrogeological units defined by user

APPLICATION Risk of breaching groundwater regulations quantitatively defined (stochastic and deterministic assessment possible)

PROCESSES	**INPUT PARAMETERS**	**MODEL OUTPUTS**	**MISCELLANEOUS**	**REQ'D**
--User defines sources, pathways and targets. - User can specify level of simulation required. -Available processes: no processes, advection, dispersion, dilution, and retardation. -Different processes can be chosen for each hydrogeological pathway specified. -User defined final target can be surface or groundwater (either monitoring or abstraction borehole) and user can specify appropriate processes in target also.	-External water balance. -External contaminant source loads or concentrations. -Pathway hydrogeological parameters (area, thickness, hydraulic conductivity, hydraulic gradient, porosity, velocity and tortuosity). - Contaminant name and Quality standard (i.e. Nitrates Directive MAC 11.3mg/l). Attenuation parameters if applicable. -Pathways data (specify transport processes, define travel distance, nixing depth, mixing width, dispersivity, dilution flow rate).	-Annual simulation is the smallest time-step available. - Results correspond to user-specified parameter values in simulation data sheets. -Solute concentration retained within each specified pathway. -Concentrations in target. -All outputs are highlighted as either conforming with or breaching specified quality objective (e.g. 11.3 mg/l NO3-N). -User friendly format: if a significant input parameter is omitted, there is no output from the model.	-User specifies simulation 'timeslice' in years (i.e. future scenarios based on either constant or declining contaminant sources). -Developed specifically for UK Environment Agency Risk Assessment Remedial Targets Methodology. -Employs 'source-pathway-target' risk model. Principles enshrined in GSI groundwater vulnerability assessment methodology. -Monte Carlo analysis allows evaluation of risk to user specified confidence levels.	-Desk-top PC. -Operates within Microsoft EXCEL program.

3. CATCHMENT SCALE MODLELLING

3.1. Introduction

There is a need to investigate threats to water quality from nitrate contamination at the scale that the threats are presented; that is catchment and regional scale. Catchment scale modelling is the only option for systematic analysis of the effects of changes in management practices or the effects of new policy on water quality. 'Catchment' is a term commonly used in hydrological modelling to define a topographic delineation of the area contributing water, from precipitation, to a water body. Catchment boundaries can be inferred from topographic maps. For surface waters a catchment can be plotted with a line along highest elevations encompassing the surface water system, the reaches of rivers are the guides. Surface and groundwaters should be considered a combined interactive resource, however groundwater catchments are harder to delineate under Irish hydrogeological conditions. The EC Water Framework Directive (EC, 2000) places emphasis evaluating all waters contributing to river sub-basins and catchments.

Models for nitrate management at the catchment scale need to be able to predict nitrate concentrations at the catchment outlet for various scenarios (Van Herpe *et al.*, 1999). The most important changes in soil nitrate storage can be evaluated using simulation routines for percentage change in agricultural management practices or rainfall amounts (MAFF, 1999).

Distributed catchment modelling is a means of relating land use to associated water quality. A distributed model is one in which the spatial distribution of the important catchment characteristics is taken into account in the model. Only a spatially distributed model can identify "hotspots" (Heathwaite, 2001). Once a degree of confidence in a distributed model is developed it can be used to generate outputs for an unlimited number of different scenarios of catchment, soil, topography and land use types which can be used to check other approaches using empirical equations (Bruen, pers. comm., 2000).

3.2. Dynamics Of Nitrate Loss At Catchment Scale

Complex field scale models must be represented by simple functional relationships if they are to be utilised effectively at larger scales (Van Herpe *et al.*, 1999). It has been demonstrated in the literature that simple field scale dynamics of nitrate losses are closely related to the N losses seen at the catchment scale (e.g., Quinn *et al.*, 1999; Lord & Anthony, 2000), both UK research teams using similar approaches. They developed a relationship to link the volume of water draining from the soil directly to the nitrate loss from that soil, thereby constructing a model that can predict soil drainage losses of nitrate for any point in the landscape. The difficulties of tracing model parameter uncertainties and their effects indicate that a model dependent upon fewer parameters is more justifiable at the catchment scale than a complex modelling approach (Van Herpe *et al.*, 2002).

Addiscott & Mirza (1998) conclude that the intrinsic variability of the soil is only one of the factors that has to be considered at catchment or regional scale. At those scales, land-use is likely to be the dominant source of variability in the loss of contaminants such as nitrate and phosphate. In this case, they suggest that simulating land use effects is essentially a data-handling exercise that has to involve the use of GIS with models for N turnover and leaching in what is essentially a decision-support system (Addiscott & Mirza, 1998). The data handling facilities should provide parameters for different crops and soil types together with information about farming operations. The above theory probably aided the development of the UK decision support system MAGPIE (Lord & Anthony, 2000) which combines arable and pasture models with GIS data handling capabilities and a front end graphical user interface (GUI). Conclusions arising from the development of MAGPIE included the observation that farming types and practices are often regionally driven. Essentially, grassland agriculture was found in areas conducive to good grass growth and that the choice of crop combinations grown on arable farms was often dictated by local soil and weather suitability. This, in some ways, contradicts Addiscott & Mirza's (1998) hypotheses of land-use variability being a dominant variability factor in catchment nutrient loss.

Simulating nitrate behaviour in catchment waters is most usually attempted using an established water flow model with an added N component. Surface water applications dominate the scientific literature. The following discussion considers studies of nitrate loss to surface and groundwater. The surface water studies are included because they are relevant in the sense that the approaches used have been validated. Also, it should be possible to modify the surface water approaches for groundwater application, if required, by the expansion of the balance of hydrological and agricultural loading terms.

3.3. Catchment Modelling Applications

3.3.1. Jordan *et al.* (1994)

This application employed a GIS system to layer physical, climatic and antropogenic characteristics of a catchment in a PC database with spatial processing and display facilities, offering scope for relating information derived from a number of sources. This interestingly simple overlay method approach was applied to surface water catchments to predict and map nitrate loads and concentrations in leachate, on a 10 x 10 Km grid, for the whole of Northern Ireland. Quantitative nitrate leaching results were obtained without the use of a nitrogen model.

A digital base map of Northern Ireland, at 1:125 000 scale, was the foundation of the approach with the centroid of each grid square referenced on the OS map. The GIS system was raster based with area themes, that is to say each grid had one parameter value but overlaying the maps gave aggregate values (raster themes). The data needs included farm and population census data and physical and physiochemical climatic information.

The methodology was facilitated by the relatively simple spatial distribution of agricultural types in Northern Ireland – crops make up only 6% of the total agricultural area. There, the nitrogen applied as fertiliser is essentially used to produce grass which, in turn, is used only for cattle production. Therefore, the livestock census yielded animal numbers per $10km^2$ grid-square, which were then converted to *Dairy Cow Equivalents* (DCE). This data was then used to infer and distribute the total fertiliser N used per grid-square. Other N sources considered in the GIS map layers were N deposited in rainfall and nitrate from sewerage (septic tanks were neglected as it's contribution was deemed negligible with respect to the three main N sources considered). In essence, daily effective rainfall data in combination with agricultural census information yielded nitrate concentrations as a ratio of load to flow.

The GIS simulations were proven for flow rates from catchment outlets. Reasonable agreement was obtained between observed and predicted surface water flows, loads and concentrations. This approach is open to development by the addition of a groundwater flow and transport model. The nitrate and water fluxes could be applied as the groundwater recharge as demonstrated by Lassere *et al.* (1999) and Wuttke *et al.* (1991).

<table>
<tr><td colspan="3">MODEL Modelling Approach for Surface Water Nitrate Simulation.</td><td colspan="2">AUTHOR Jordan <i>et al.</i> (1994)</td></tr>
<tr><td colspan="3">MODEL TYPE GIS based model utilising layers of data and empirical relationships.</td><td colspan="2">SCALE Catchment</td></tr>
<tr><td colspan="5">APPLICATION Determination of the surface water flows and nitrate loads and concentrations without the use of a nitrogen model.</td></tr>
<tr><td>INPUT S</td><td>OUTPUTS</td><td colspan="2">MODELLING PROCEDURE</td><td>REQ'D</td></tr>
<tr><td rowspan="3">-Digitised OS map 1:125 000 scale.
-Farm census information.
-Human population data.
-Physical (quantity) and physiochemical (quality) climatic information.
[This approach is open to development by the addition of a groundwater flow and transport model]</td><td rowspan="3">-Surface water flows.
-Nitrate loadings.
-Nitrate concentrations.</td><td colspan="2" rowspan="3">-The modelling procedure used empirical relationships in three steps:
N sources are quantified, per grid square;
N_{fert}– inferred from livestock numbers to DCE's per grid square.
N_{Dep} – N concentration weighted annual mean x rainfall amount x area.
N_{Sewer} – (9.1g N/p/d x number of people (p) x 365)/10^6 [t N/yr/].
Therefore, $\mathbf{N}_{\mathbf{Total}} = (0.15 \text{ x } N_{fert}) + N_{Dep} + N_{Sewer}$ [t N/yr]
It was assumed that nitrate leached was 15% of N applied (simulation results intimated that 19-25% was a more accurate representation of the rate of nitrate leaching).
Flow (W) from each grid cell was calculated as:
$\mathbf{W} = [(RF - PEt) \text{ x land area}] / 100$ [10^6 l/yr]
Results showed good correlation between observed and simulated flow.
The nitrate concentration lost from each grid square was calculated from the above as:
$\mathbf{N}_{\mathbf{Conc}} = (\mathbf{N}_{\mathbf{Total}} \text{ x } 1000) / \mathbf{W}$ [mg N/l]
-Fair correlation between predicted and observed surface water nitrate concentrations.</td><td>-IBM PC</td></tr>
<tr><td>Time-Step</td></tr>
<tr><td></td></tr>
</table>

3.3.2. MAGPIE (Lord & Anthony, 2000)

MAGPIE is a metamodel, **M**odelling **AG**ricultural **P**ollution and **I**nteractions with the **E**nvironment, which acts as a 'Policy Decision Support System' (PDSS). The system was developed by UK research (ADAS) and governmental (MAFF) agencies as a method of estimating nitrate exports to groundwater and surface water catchments, on a national scale. The system was found to give estimates of mean annual flow and nitrate loads for agricultural catchments that closely matched measured data (Lord & Anthony, 2000). The system operates at two scales: field scale for detailed simulations and catchment scale for policy related scenario testing.

The MAGPIE modelling system integrates a national database, at 1 km^2 grid resolution, with nitrate leaching models. The databases contain the following information (the sources of data):

- Crops grown & livestock numbers (MAFF annual agricultural census);
- Land use types (satellite imagery, 1989);
- Climate (Met. Office data at 40 x 40 km resolution, interpolated to 1 km^2);
- Soil physical properties (Soil Survey and Land Research Centre- dominant soil associations for each km^2).
- Other agricultural management data, such as, fertiliser & manure usage, crop yields, nutrient offtakes, are described with respect to land cover type classified (MAFF advisors & literature data).

The modelling strategy was to run a large number of mechanistic simulations, with complex field-scale models, to derive simplified relationships (algorithms) for typical management and land type scenarios (essentially many different combinations of database components). No single detailed field-model was optimal for all land uses and processes. Nitrate loss from grassland was evaluated using NCYCLE (Scholefield *et al.*, 1991). NITCAT (Lord, 1992) was employed for nitrate loss from all crops and manures. MANNER (Chambers *et al.*, 1999) described the fate of manure nitrogen. SUNDIAL (Smith et al, 1996) simulated nitrate loss from arable systems. SLIM (Addiscott & Whitmore, 1991) and The Burns model (Burns 1974) were used to examine the process of nitrate movement within soils, and hence developed the SLIMMER algorithm. Modelled output from SLIM, for all the soil types, was found to approximate to a single curve and this SLIMMER algorithm captured the essence of the leaching process while avoiding the need for detailed daily weather data and lengthy model runs (Lord & Anthony, 2000). Water balance terms were solved the UK Meteorological Office's evapotranspiration model, MORECS (Thompson *et al.*, 1991).

For the catchment scale, there were three main stages of development:

1) field scale models yielded coefficients,
2) adjustments were made for soil and climatic regions and then,
3) the time-course of nitrate concentrations in catchment waters was incorporated.

Stages 1) and 2), above, merely quantify the nitrate load leaving agricultural land. Daily river nitrate concentrations were simulated by adding mixing and delay effects, point source data, abstraction rates and temperature-dependent river processes affecting nutrient concentrations.

MAGPIE's developers took an approach to national losses of nitrate from grasslands similar to that of Jordan *et al.*'s (1994) dairy cow equivalents. As there is such a large range of fertiliser N application rates associated with grassland, livestock stocking rates were used to dictate fertiliser usage and manures deposited and applied. The NCYCLE model (Scholefield *et al.*, 1991) was used to estimate the loss/head of livestock.

Applying MAGPIE nationally (Lord & Anthony, 2000), it was found that for any given crop and management system – there are consistent risk areas across the UK (substantiated by the reality that farmers choose crops and management systems according to local conditions, soils and climatic suitability). Areas of intensive livestock showed the highest nitrate losses, with housed pig and poultry units resulting in large localised losses. Upland areas (low stocking and fertiliser rates) acted to reduce modelled nitrate concentrations in a catchment, even with areas of intensive agriculture downstream in fertile river valleys. Climatic effects were evident, modelled river concentrations in the east were lower, which correlates with national monitoring observations (lower rainfall in the east is a contributing factor). Results of simulations with MAGPIE were shown to provide an accurate simulation of peak river nitrate concentrations, the pattern of over-winter flow and river concentration trends, which is no mean feat for a model.

<table>
<tr><td colspan="3">MODEL MAGPIE</td><td colspan="2">AUTHOR Lord & Anthony (2000)</td></tr>
<tr><td colspan="3">MODEL TYPE Policy Decision Support System (PDSS).</td><td colspan="2">SCALE Field-Catchment-National.</td></tr>
<tr><td colspan="5">APPLICATION The PDSS provides an interface to national environment database with embedded process-based field models.</td></tr>
<tr><td>COMPONENTS</td><td>MODEL STAGES</td><td>MODEL OUTPUTS</td><td>MISCELLANEOUS</td><td>REQ'D</td></tr>
<tr><td rowspan="3">1. –National environment database, including information on long-term mean climate, soil attributes, land usage and agricultural management information.
2. -Many embedded process based models*: NCYCLE, NITCAT, MANNER, SLIM, SUNDIAL.
3. –Simplified algorithms derived, from 1 & 2 above, for user simulations.</td><td rowspan="3">-Field Scale – Potential nitrate loss from soil, in a sufficiently wet period, is calculated using the ouputs from detailed process based models, in the form of simplified algorithms.
-Adjustments are made for user specified study site location (concerning climate & soil type).
-Factors included account for the modification between agricultural loading leaving the soil and consequent concentrations in catchment waters.</td><td rowspan="3">-NO_3-N concentrations in the soil profile.
- NO_3-N loss by leaching from agricultural land.
-Peak river nitrate concentrations.
-Pattern of over-winter flow and river concentration trends.
-Scenario testing for Nitrate Sensitive Area and Nitrate Vulnerable Zone policy decisions.</td><td rowspan="3">-Tailor made for UK national investigation (Lord & Anthony, 2000).
-Incorporates all tested UK nitrate models.
-Results validated for surface water flows and concentrations.
-Groundwater simulation presented but validation or commentary missing from documentation.
-River time-series flow and quality data required for model validation.
-MORECS* water balance model used to calculate periods of winter drainage.</td><td>-Pentium PC.
-CD installation</td></tr>
<tr><td>Time-step</td></tr>
<tr><td>-Daily peaks and seasonal patterns simulated.</td></tr>
</table>

*= See text for full reference

3.3.3. INCA (Whitehead *et al.*, 1998)

INCA was developed for assessing multiple sources of nitrogen in catchments. It is process based and uses mass balance and reaction kinetic equations to simulate the principal mechanisms operating. Mineralisation, nitrification, denitrification, immobilisation, plant uptake and nitrogen fixation are modelled. Model documentation claims both surface soil zones and groundwater zones are simulated together with leaching of water into the river system (AERC, 2000). The land phase and river channels are modelled so that a semi-distributed description of oxidised and reduced nitrogen across the catchment can be obtained.

INCA is a daily simulation model with built in hydrological mass balance equations. Daily time series of model outputs at any reach boundary can be obtained and compared with observed data. Other outputs include statistical summaries, distribution graphs of water quality and profiles down the river system. In addition, it is possible to evaluate scenarios of environmental change to assess impacts on flow, loads and water quality (e.g. changing climate patterns or agricultural practice).

Six different land uses; forest, arable, surface vegetation (grazed or fertilised) and moorland can be designated for simulation. Sources of nitrogen can be from atmospheric deposition, point sources such as sewage discharges, distributed sources such as agricultural fertilisers or from natural organic sources of nitrogen. Nitrogen loads from different land uses and information on annual and daily fluxes can be calculated.

INCA was developed for research applications: in experimental plot studies; to evaluate nitrogen balance in catchments and river systems; or to explore catchment dynamics, groundwater/surface water interactions, processes controlling nitrogen behaviour and environmental change issues.

<table>
<tr><td colspan="3">MODEL INCA</td><td colspan="2">AUTHOR Whitehead <i>et al.</i> (1998)</td></tr>
<tr><td colspan="3">MODEL TYPE Process based using mass balance and reaction kinetic equations</td><td colspan="2">SCALE Catchment</td></tr>
<tr><td colspan="5">APPLICATION Assesses multiple sources of nitrogen in catchments. The land and river channels are modelled so that a semi-distributed description of oxidised and reduced nitrogen across the catchment can be obtained.</td></tr>
<tr><td>PROCESSES</td><td>MODEL INPUTS</td><td>MODEL OUTPUTS</td><td>MISCELLANEOUS</td><td>REQ'D</td></tr>
<tr><td>-Modelled processes include mineralisation, nitrification, denitrification, immobilisation, plant uptake and nitrogen fixation.
-Both surface soil zones and groundwater zones are simulated together with leaching of water to the river system.
-Windows based user interface with embedded hydrological & mass balance equations.
-Iterative, teaching tool enables evaluation of N dynamics/processes and GW/SW interactions.</td><td>-</td><td>-Enables user to calculate nitrogen loads from different land uses and information on daily fluxes.
-Daily time series of model outputs at any reach boundary can be obtained and compared with observed data.</td><td>-Six different land uses may be simulated; forest, arable, surface vegetation (grazed or fertilised) and moorland.
-Sources of nitrogen can be from atmospheric deposition, point sources, diffuse sources such as agricultural fertilisers or from natural organic sources such as manures.
-Impact of different land use scenarios on flow, loads and water quality can be evaluated.
-Forms part of the SEAL project; a catchment approach to vulnerability mapping and scenario analysis for sludge disposal, different sludge types, nutrient saturation thresholds and hydrological conditions (Heathwaite <i>et al.</i>, 2001).</td><td>-PC</td></tr>
</table>

3.3.4. NCATCH (Scholefield & Rodda, 1991)

NCATCH predicts the annual nitrate loading of rivers draining grassland catchments and attempts to predict the peak and average concentrations of nitrate in drainage water. The model contains subroutines for processing input data for many fields and for outputting area weighted averages of nitrate loss from whole grassland catchments. It is a development of the field scale NCYCLE (Scholefield et al, 1991) to give a semi-distributed catchment scale management model. NCATCH does not simulate groundwater concentrations.

NCATCH uses empirical relationships to predict maximum nitrate concentrations in drainage water from different soil structural categories. The sub-model that calculates the supply and transport of soil nitrate is sensitive to annual patterns of weather through classification based on the maximum soil moisture deficit (SMD). Although the model aims to provide a tool capable of predicting river nitrate concentrations, there is no simulation for transformations of the calculated load between the root zone and the flowing river. Hence, simulations of nitrate loading compare well with observations in the subsoil but surface water concentration simulations consistently overestimate (Rodda, 1993). The actual model output is an area weighted average NO_3^- concentration in water draining below the root zone but Rodda (1993) tried to match model output with observed river concentrations. Many improvements were suggested Rodda (1993): the areal nature should be changed to field unit scale; variable leaching potentials need to be accounted for, and groundwater components to classify initial groundwater nitrate concentrations need to be included. Furthermore, it is a grassland catchment model when few catchments have single land use. Therefore, inclusion of models to simulate other agricultural land uses is necessary. Cropper *et al.* (1996) describes an empirical approach to predicting nitrate leached to surface water from catchments of mixed land use by combining NCYCLE for pastures (Scholefield *et al.*, 1991) with SUNDIAL for arable land (Smith *et al.*, 1996) in combination with a UK database of soil haydraulic characteristics.

NCATCH is a good scenario tool, rather than an absolute predictor. It is likely that the model is lacking, otherwise it may have been employed in some fashion by the ADAS/MAFF consortium which developed MAGPIE (Lord & Anthony, 2000), of which NCYCLE is an element.

MODEL NCATCH

AUTHOR Rodda (1993), UK

MODEL TYPE Semi-distributed version of field scale NCYCLE

SCALE Catchment

APPLICATION Predicts annual nitrate loadings of rivers draining grassland catchments, also gives peak & average concentrations of nitrate in drainage water.

PROCESSES	INPUT PARAMETERS	MODEL OUTPUTS	MISCELLANEOUS	REQ'D
- Modified NCYCLE to simulate N loss at catchment scale. - Includes routines for temporal weather conditions; temperature and moisture changes, differences in rainfall affecting amounts of nitrate leached - Regression equations for maximum nitrate concentrations in the leachate and proportions of potentially leachable nitrate. - Hydrogeology submodel added to allow variable leaching rates in the catchment.	-As for NCYCLE -Hydrogeological information	-Annual nitrate loading to river. -Area weighted averages of nitrate concentration in water leaching below the root zone. -File output lists ; kg N leached /ha., kg N leached /field, cumulative total N leached for entire catchment.	-The average nitrate concentration is obtained by dividing the calculated load by the drainage volume. -Good simulation results for loading only. Consistent overestimation of maximum and average surface water nitrate concentrations. -No account for changes in nitrate concentration between root zone and river.	-IBM PC

3.3.5. Van Herpe *et al.* (1998; 1999; 2002)

Research by this author and his associates has concentrated on the quantification of nitrate concentrations, in rural river basins, originating form diffuse sources. Their methodology combines a hydrological part, TOPMODEL (Quinn & Beven, 1993), and a nitrate transport module. Van Herpe *et al.* (1999) presents the application of their conceptual model to two catchments in the UK and Belgium, having approximate areas of 100 km^2. Details of the model components are documented in Van Herpe *et al.* (1998). The results of the hydrological model are used to control the different functions of the nitrate transport module. A dynamic transfer function was developed in order to transform the output of the nitrate-leaching model into river nitrate concentrations (Van Herpe *et al.*, 1999). Comparison with field data showed reliable simulation results. The transfer function is based on the "flushing hypothesis" (Hornberger *et al.*, 1994; Creed *et al.*, 1996), postulating a relationship between river nitrate concentrations and the extent to which the catchment is saturated. The flushing hypothesis states that when a catchment is a potential source of nitrogen, the release of nitrogen to adjacent waters increases exponentially as the soil saturation deficit decreases (Van Herpe *et al.*, 1999). Decline in the catchment saturation deficit, or the corresponding rise in the groundwater table, is deemed proportional to increases in baseflow nitrate concentrations, according to their transfer function. The transfer function used is not exponential but depends on the variations in groundwater recharge. Van Herpe *et al.* (1999) describes groundwater components in their application of TOPMODEL.

Van Herpe *et al.* (2002) presented two applications, improvements to the earlier model, for studying the hydrological mobilisation of nutrients at the catchment scale using TOPMODEL and the principles of the Minimum Information Requirement approach (MIR). In the first instance, a low-parameter lumped version of the simplified TOPMODEL (Quinn & Beven, 1993) used statistical representations of land units to approximate to a nutrient input index for a digital elevation model. This resulted in a lumped N export that simulated well the spatial and temporal fluxes of nitrate inputs and losses in the study catchments surface waters. In the second application, there was a full implementation, in a semi-spatially distributed fashion, of TOPMODEL (Quinn & Beven, 1993) with an added nitrogen-leaching component, the SLIM model (Addiscott & Whitmore, 1991). This second model distributes the soil moisture and nutrient activity, based on topography, to differentiate zones of vertical leaching and zones of surface flushing. In this way, policy can be tailored for different risk areas in any catchment. Simulation results showed good agreement with catchment observations of temporal variability of nitrate concentrations at catchment outlet and the spatial variability of soil moisture and soil nitrate concentrations.

3.3.6. Arheimer & Brandt (1998)

Arheimer & Brandt (1998) designed the HBV-N model, using the Scandanavian hydrological HBV model (Bergstrom, 1976; Lindstrom *et al.*, 1997) in conjunction with nitrogen routines for prediction of riverine N. It is a dynamic, continuous, semi-distributed, conceptual approach. This very detailed approach to catchment analysis links process based models to a comprehensive hydrological model within a GIS. The scale of the study required multi agency co-operation and extensive monitoring data for calibration and validation. Data from over three and a half thousand sub-basins, with average areas of 35 Km^2, formed some part of the modelling process: design/development, calibration/fitting and validation/testing.

The GIS handled geographic information regarding land use and management, physiography, meteorology, hydrology, soil types, land cover, point sources and environmental monitoring (empirical time-series data from national and regional monitoring programmes - hydrometrical and hydrochemical data from rivers, groundwaters and lakes). Catchment boundaries were inferred from topographic maps. Groundwater divides were assumed to follow surface water catchment boundaries since most of Sweeden has a thin till-soil layer over bedrock.

In the nitrogen routine, process models such as SOILN (Johnsson *et al.*, 1987, Jansson, 1991) calculated nitrate leakage concentrations for more than five hundred types of arable fields and pastures. Each sub-basin was then assigned representative crop areas and fertiliser patterns in order to compute leakage concentrations for soil types and agricultural regions. Calculations were made from the root zone to determine transport in groundwater, rivers and lakes within sub-basins, which are integrated into larger river systems. Transport of N load from land in addition to transformations and residence times in surface and groundwaters are considered in the HBV-N model.

Overall, the model was validated 'with acceptable performance' for riverine-N transport. However, it was concluded that even more detailed databases describing catchment characteristics were required at local scales. This highlights the reliance of heavily mechanistic, process based, approaches on quality of input data. The simplified approach of Jordan *et al.* (1994) achieved similarly accurate results without the use of detailed process models.

3.3.7. Hydrological & River Basin Models

Many of the modelling applications reviewed referenced other models. In particular, the hydrological model TOPMODEL (Beven & Kirby, 1979; Quinn & Beven, 1993) and river basin model SWAT (Arnold *et al.*, 1993; 1994; 1997) is mentioned widely in the literature concerning modelling at the catchment- or larger scale. It is for this reason that this section presents hydrological and river basin models.

3.3.7.1. Hydrological Models

3.3.7.1.1. TOPMODEL (Beven & Kirby, 1979) (Quinn & Beven, 1993)

TOPMODEL is a hydrological model with a variable structure that facilitates its application to different surface water systems. It has been extended with a nitrate transport module extensively discussed in the literature (Van Herpe *et al.*, 1998; 1999; 2000).

This quasi-physical model simulates catchment hydrology using a simplified relationship between topography and flow generation. Catchment water discharge (1-10,000 km^2 at 5-50m resolution) and spatial soil water saturation patterns are predicted based on climatic time-series data (rainfall and evapotranspiration) and the catchment Digital Elevation Model (DEM). TOPMODEL assumes a simple relationship between catchment deficit and local water table levels, in which the controlling factor is topography (Van Herpe *et al.*, 1999). Essentially, TOPMODEL combines a series of soil moisture stores and a function for routing water from the soil to the outlet of the catchment. Soil parameters are not required as a direct input to the model (Quinn *et al.*, 1999). However, soil information is needed in order to establish water table or infer soil moisture contents. Successful model performance relies heavily on correct estimation of evaporation (Van Herpe et al, 2002). Surface runoff is a function of variably saturated areas on the topography and subsurface flow is described using a simple exponential function of soil water content. Channel routing and overland flow (infiltration excess) are quantified in the model output. The length of the simulation period depends on the duration of climatic data available to the simulation. Model users suggest an hourly time-step in order to represent surface runoff peaks (Quinn & Beven, 1993).

Van Herpe *et al.* (2000) summarises model assumptions as follows: 1) saturated hydraulic conductivity varies with depth; 2) the water table gradients can be approximated by local topographic slope, and 3) the steady state flux is achieved within the modelling time step.
The full TOPMODEL version (Beven & Kirkby, 1979) uses a topographic function to determine the position of the water table and the zones of saturation and excess runoff. The full model is complex and was simplified, for future use, by Quinn & Beven (1993). Quinn *et al.* (1996) detail the re-conceptualisation of the model that is necessary for land areas with extensive under drainage. Van Herpe *et al.* (1999) describes groundwater components in their application of TOPMODEL.

<table>
<tr><td colspan="3">MODEL TOPMODEL</td><td colspan="2">AUTHOR (Beven & Kirby, 1979) (Quinn & Beven, 1993)</td></tr>
<tr><td colspan="3">MODEL TYPE Quasi-physical catchment hydrology model</td><td colspan="2">SCALE 1-10,000 km^2 at 5-50m resolution</td></tr>
<tr><td colspan="5">APPLICATION Predicts nitrate concentrations in discharge and spatial soil water saturation patterns based on climatic time-series data (rainfall and evapotranspiration) and the catchment DEM</td></tr>
<tr><td>PROCESSES</td><td>INPUT PARAMETERS</td><td>MODEL OUTPUTS</td><td>MISCELLANEOUS</td><td>REQ'D</td></tr>
<tr><td>-The catchment storage deficit and local water table controlled by the topography.
-The degree of wetness in the catchment is correlated with the location with the water table (and saturated areas).
-Essentially, TOPMODEL combines a series of soil moisture stores and a function for routing water from the soil to the outlet of the catchment.</td><td>-Daily rainfall and evapotranspiration time-series.
-Digital elevation Model (DEM).
-Historic discharge data at catchment outlet.</td><td>-Simulated future discharge at catchment outlet and associated nitrate concentrations.
-Soil water saturation patterns and nitrate concentrations.</td><td>-Requires high quality DEM.
-Model performance depends on the quality of climatic input data.
-Soil parameters are not required as a direct input to the model (Quinn <i>et al.</i>, 1999). However, soil information is needed in order to establish water table or infer soil moisture contents.
-Van Herpe <i>et al.</i> (2000) incorporated the nitrate leaching model SLIM (Addiscott & Whitmore, 1991).</td><td>-Arbitrary PC/OS with a minimum amount of RAM and disc space.</td></tr>
</table>

3.3.7.1.2. MIKE SHE (Danish Hydraulic Institute, 1993; Storm *et al.*, 1990)

A finite difference method (FDM) fully distributed hydrological-catchment model. The MIKE SHE approach is an extension of SHE (Abbot *et al.*, 1986 [1 & 2]), the European Hydrological System model.

A network of squares, in the horizontal direction, represents the variation in catchment characteristics and climate. The climatic data in the driving force of the model, an approach expected from hydrologists. Each topographic square is further divided in the vertical direction, using layers to describe variations in the soil profile and the groundwater aquifer. Richard's equation simulates the vertical flow in the unsaturated zone for each square independently. Soil columns then link the three dimensional groundwater flow system to the two dimensional flow system for overland flow (Styczen & storm, 1993). Lateral unsaturated flow between the soil columns is neglected, being regarded as an insignificant phenomenon under natural conditions. The (finite difference) grid squares are the links of the simulation, with the surface water channel system running along the boundaries of the grid. At each link the river receives lateral groundwater and overland inflow from adjacent squares.

<table>
<tr><td colspan="2">MODEL MIKE SHE</td><td colspan="3">AUTHOR Danish Hydrological Institute (1993), Storm <i>et al.</i> (1990)</td></tr>
<tr><td colspan="2">MODEL TYPE FDM, fully distributed hydrological model.</td><td colspan="3">SCALE Catchment.</td></tr>
<tr><td colspan="5">APPLICATION Climatic data acts as the driving force of this catchment hydrology model to yield groundwater heads, runoff volumes and surface water discharges.</td></tr>
<tr><td>PROCESSES</td><td>INPUT PARAMETERS</td><td>MODEL OUTPUTS</td><td>MISCELLANEOUS</td><td>REQ'D</td></tr>
<tr><td>-A network of squares, in the horizontal direction, represents the variation in catchment characteristics and climate.
-Vertical layer definition for soils and groundwater body.
-Richard's equation simulates the vertical flow in the unsaturated zone for each square independently.
-Soil columns then link the three dimensional groundwater flow system to the two dimensional flow system for overland flow (Styczen & storm, 1993).</td><td>-Climatic: precipitation, temperature, potential E_T.
-Catchment: topography, drainage pattern, stream geometry, and roughness coefficients.
-Soils: spatial distribution, soil hydraulic conditions for each layer, texture, % OM.
-Hydrogeology: groundwater table data, geological layers and associated hydraulic properties, possible location of redoxcline and extraction point details</td><td>-Overland and channel flow.
-Groundwater heads.</td><td>-Long term simulation, scenario tool. Provides annual results.
-Requires historic catchment hydrological data for calibration.
-Styczen & Storm (1993) simulated water and nitrate transportation at a regional scale using DAISY (Hansen <i>et al.</i>, 1990) in combination with MIKE SHE.</td><td>-IBM PC</td></tr>
</table>

3.3.7.2. River Basin Models

3.3.7.2.1. SWRRB (Arnold *et al.*, 1990; 1991)

The Simulator for Water Resources in Rural Basins, developed by USDA-ARS, aims to simulate hydrologic, sediment, nutrient and pesticide transport in large, complex basins. Modifying other USDA models such as CREAMS, GLEAMS and the Modified Universal Soil Loss Equation (MUSLE), again, contributed to the development of this model. Thorsen *et al.* (2001) define SWRRB as a conceptual model. SWRRB is no longer under development as it has been incorporated into the SWAT model. Readers are therefore referred to the description of SWAT, which modified several of SWRRB's modules within a GIS environment for large scale application.

3.3.7.2.2. SWAT (Arnolds *et al.*, 1993 & 1994)

The Soil Water Assessment Tool is a three-dimensional river basin or catchment scale model also developed by the Agricultural Research Service (ARS) department of the USDA. Developed to predict the impact of land management practices on water, sediment and agricultural chemical yields in large, complex basins with varying soils, land use and management conditions over long periods of time [1-100 years] (Arnold *et al.*, 1997). The model developers advise against SWAT's use for single events.

SWAT builds on many models developed within the USDA-ARS such as CREAMS (Knisel, 1980), GLEAMS (Leonard *et al.*, 1987), EPIC (Williams *et al.*, 1983) and SWRRB (Arnold *et al.*, 1990).

The water balance equation forms the basis of SWAT. Soil water is modelled using a capacity-cascade approach. The catchment under investigation is divided into homogeneous parts; each part is then analysed on its own as well as its interaction with the whole. Srinivason & Arnold (1993) integrated SWAT with a GIS interface to successfully extract spatially distributed parameters for a given sub-basin map.

Extensive, readily available US soils and climatic databases provide the information used to calculate runoff or infiltration, sediment yield and chemical transport outputs. The spatial resolution of data available, and the spatial heterogeneity of soil characteristics, in Ireland would hinder successful application of the model. So far, SWAT is only feasible for US applications with readily available databases to supply large input data requirements. Krysanova *et al.* (1996) based their own model SWIM on SWAT. However, the German SWIM adaptation is only suitable for larger catchments than found in Ireland. The emphasis of the model is transport of sediment to surface waters, which makes it more relevant to the phosphorus issue.

<table>
<tr><td colspan="3">**MODEL** SWAT</td><td colspan="2">**AUTHOR** Arnolds *et al.*, (1993 & 1994)</td></tr>
<tr><td colspan="3">**MODEL TYPE** Continuous (1-100 year) management, scenario tool.</td><td colspan="2">**SCALE** River basin, catchment up to 100 miles^2</td></tr>
<tr><td colspan="5">**APPLICATION** Can be applied to ungauged catchments to examine effects of climate and management changes on water, sediment and agricultural chemical yields.</td></tr>
<tr><td>**PROCESSES**</td><td>**INPUT PARAMETERS**</td><td>**MODEL OUTPUTS**</td><td>**MISCELLANEOUS**</td><td>**REQ’D**</td></tr>
<tr><td>-Based on the water balance equation.
-Builds on CREAMS (Knisel, 1980), GLEAMS (Leonard *et al.*, 1987), EPIC (Williams *et al.*, 1983) and SWRRB (Arnold *et al.*, 1990).
-Uses US soils and Climatic databases (for example, SCS curve number generates runoff volume).
-Capacity-cascade soil water model.</td><td>-Soil type, texture, depth, hydrological classification (supplied by databases in US applications)
-Climatic data .</td><td>-Runoff volume.
-Sediment yield.
-River water quality.
-Pollutant transport.</td><td>-So far, the complex input data requirements are set-up to use specific US databases.
- Srinivasan & Arnold (1993) integrated SWAT with a GIS interface to successfully extract spatially distributed parameters for a given sub-basin map.
- Krysanova *et al.* (1996) based their own model SWIM on SWAT, however, this German adaptation is only suitable for larger catchments than found on this island.
-The emphasis of the model is transport of sediment to surface waters which makes it more relevant to the Phosphorus issue.</td><td></td></tr>
</table>

3.3.7.2.3. SWIM (Krysanova *et al.*, 1996, 1998)

SWIM (Soil & Water Integrated Model) is a development of SWAT (Arnold *et al.*, 1993) by German researchers for European application. It is a continuous-time, spatially distributed river basin model (100-20 000 Km^2) simulating hydrology, vegetation, erosion and nutrients (N & P). The model has a daily time-step and represents a coupling of a hydrological process model to nutrient cycling, crop and erosion sub-models. Direct application of SWAT to the German study was not possible (Krysanova *et al.*, 1996) because of SWAT's connection to US databases (soil, weather and crop parameters). However, the hydrology submodel and GIS interface was taken from SWAT and combined with MATSALU (Krysanova *et al.*, 1989), which provided spatial disaggregation schemes and nutrient models. SWIM was developed to be transferable to other large basins in Europe and has been extensively validated in a number of mesoscale basins in Germany (Krysanova *et al.*, 1998).

The model requires a Digital Elevation Model, and associated land usage and characterisation information held within a GIS (ARC/INFO or GRASS). This is similar to the TOPMODEL approach (Quinn & Beven, 1993, Van Herpe et al, 2002) but SWIM becomes more mechanistic in that there are detailed hydrological, nutrient, crop and erosion submodules within it. The hydrological processes are considered to have four control volumes within the soil column: the soil surface, the root zone, the shallow aquifer, and the deep aquifer. The soil column is analysed by layer (maximum of ten). The soil column water-balance includes precipitation, surface runoff, evapotranspiration, percolation and subsurface runoff. The shallow aquifer water balance includes groundwater recharge, capillary rise, lateral flow and percolation to the deep aquifer.

The nutrient module gives comprehensive consideration of many forms of nitrogen (stable, active, organic, plant residue), phosphorus (labile, active, stable, mineral/organic, plant) and also the soil nitrate-nitrogen. Each possible flow and transport mechanism of nutrients, in and out of the system, is detailed and described in the model documentation (Krysanova *et al.*, 1996). However, in application of the model to two different catchments (575 km^2 and 1504 km^2), the nutrient submodel is referred to as robust: where the flow chart of nutrients is kept as simple as possible, but includes the main pools of nutrients and flows between them (Krysanova *et al.*, 1999). They conclude that SWIM is an appropriate model yielding successful results with modest data requirements (three-four basic digital maps, climate data and regional soils and crop information). However, they caution that model results should not be interpreted as exact positions, rather as an indicator of possible trends and qualitative differences.

As expected with a model this mechanistic, Krysanova *et al.* (1999) caution that understanding of the code and interrelations between different processes is a prerequisite for successful applications. The model will not run as a black box.

MODEL SWIM

AUTHOR Krysanova *et al.* (1996, 1998).

MODEL TYPE Continuous, spatially distributed river basin, management model. Process based.

SCALE 100-20 000 Km^2 catchments, Regional.

APPLICATION For use in analysis of the impact of climatic and land-use changes on catchment hydrology and water quality

PROCESSES	**INPUT PARAMETERS**	**MODEL OUTPUTS**	**MISCELLANEOUS**	**REQ'D**
-Coupling of a hydrological process model to nutrient cycling, crop and erosion sub-models. -The nitrogen module includes pools of NO$_3$-N in soil, active and stable organic N in soil and fresh organic matter. -Nitrogen flows described include mineralisation, fertilisation, plant uptake, loss by surface and lateral subsurface flows, leaching to groundwater, erosion loss and denitrification.	-Daily climatic data (precipitation, air temperature, solar readitation). -Historic river water quality and hydrological data at river outlet. River geometry. --A GIS system is required with a DEM [sub-basin maps must be created in advance], land use and crop factors, soil map, groundwater water table map and point sources of pollution identified. -Soil database: depth, PSD, bulk density, porosity, water holding capacity, field capacity, organic N & C contents, saturated hydraulic conductivity.	-A water and nutrient balance is calculated for every hydrotope (disconnected units in the sub-basins which have the same land use and soil type). -The outputs from the hydrotopes are used to calculate the sub-basin output. -Routing procedures, to account for transmission losses, are applied to extrapolate catchment outlet values from the sub-basin outputs. -All flows described yield simulation results.	-SWIM's hydrology submodel and GIS interface was taken from SWAT (Arnold *et al.*, 1993) and combined with MATSALU (Krysanova *et al.*, 1989), which provided spatial disaggregation schemes and nutrient models. -Solute in runoff, leaching and interflow are estimated as the products of the volume of water and the average nitrate concentrations leaving any of the four hydrological control volumes of the model. The hydrology model has been extensively validated for German applications, the nutrient submodule less so (Krysanova *et al.*, 1998, 1999).	

3.3.8. Discussion - Catchment Scale Simulations

Model complexity and parameter uncertainty are cited as the key issues when simulating nutrient mobilisation at the catchment scale (Van Herpe *et al.*, 2002; Stockdale, 1999; NRC, 1993). The conundrum of complex physical (mechanistic) models versus simple empirical models is an ongoing debate. Ultimately, confidence in any catchment modelling approach is dependent upon the confidence in the input parameters and justification of these parameters. The uncertainty in input parameters may be quite high due to natural heterogeneity and especially if the datasets are statistically derived. Any uncertainty at the input stage travels through to the final model output. A model with a simple structure allows the error associated with the input parameters to be transferred to the model output in a simple and unambiguous way (Van Herpe et al, 2002). In this way, an uncertainty estimate may be presented alongside model simulation results to highlight confidence in the method. Thorsen *et al.* (2001) modelled nitrate leaching to aquifers at catchment scale and analysed how uncertainty in input data propagates to model output. Interestingly, they stressed that all uncertainty discussions should clearly state the scale of model application because large uncertainties were to be expected at point/grid scales but these uncertainties were vastly reduced in simulated concentrations at aquifer/catchment level.

A suggestion for an ideal future modelling approach, from users of simple model structures (Quinn *et al.*, 2000; Van Herpe *et al.*, 2002), is to develop a simple hydrological model based on a soils parameter (Thorsen *et al.*, 2001, suggest soil texture) and a number of flow control parameters derived directly from baseflow measurements. Others suggest that optimally predicting solute transport at mapping unit scales would combine a minimal set of the most pertinent water flow, solute partitioning and solute transformation routines, with possible provisions for preferential flow and capabilities to vary input parameters using *ad hoc* or a truly stochastic approach (Inskeep *et al.*, 1996).

3.3.8.1. Catchment Simulations - Surface Water Approaches

National Hydrological Institutes have sustained the constant development of surface water modelling approaches. Long-term time series information regarding flow and quality, available for most countries surface waters, is crucial for model development.

TOPMODEL (Beven & Kirkby, 1979; Quinn & Beven, 1993) [Appendix A] was the hydrological model employed with the N model SLIM (Addiscott & Whitmore, 1991) for national and catchment surface water simulations by Quinn *et al.* (1993) and Van Herpe *et al.* (2000).

Arheimer & Brandt (1998) used the Scandanavian hydrological HBV model (Bergstrom, 1976; Lindstrom *et al.*, 1997) in conjunction with nitrogen routines for prediction of riverine N, thereby developing the HBV-N model. Their very detailed approach to catchment analysis links process based models to a hydrological model within a GIS. It is a dynamic, continuous, and semi-distributed conceptual model. They concluded that more detailed databases describing catchment characteristics were required at local scales. This highlights the reliance of heavily mechanistic, process based, approaches on quality of input data. The simplified approach of Jordan *et al.* (1994) achieved similarly accurate results without the use of detailed process models.

Arheimer (1998) concludes that although the measure of agricultural activity in a catchment is linked to nitrate concentrations (in stream waters) several natural physiographic and hydrometeorological conditions act together to make catchments more or less susceptible to terrestrial leackage. The work of Van Herpe et al (2000) then becomes pertinent, land use management modelling with consideration of topography enables agriculture policy to be adapted to site-specific conditions, with less intensive cultivation in sensitive areas.

Some approaches to modelling N transport at catchment scale determine gross load lost only and simple mixing in surface flow (e.g. Jordan *et al.*, 1994; Rodda, *et al.*, 1993) with no other transformations considered, such as activity between the root zone and the appearance in catchment waters (Arheimer, 1998). Interestingly, of the two approaches just mentioned Jordan et al's. (1994) was simpler, involved no process based model, and yielded much more accurate results than Rodda's (1993) attempt to validate a semi-distributed, land unit N-loss, model with surface water concentrations. The findings of Stychen & Storm (1993) may explain why Roddas validation attempts encountered difficulties.

Some of the existing models for studying catchment pollution are physically based, but none are fully integrated models for flow and transport (Birkinshaw and Ewen, 2000). Arheimer (1998) concludes that for large-scale model application the two dominant processes, controlling temporal N concentration variability are hydrological pathways and biogeochemical transformations in the aquatic system. Thus, these two dynamic processes are recommended for inclusion in any model, as well as accounting for the spatial variability of potential N losses.

The hydrological model SHE (Abbott et.al, 1986) was developed jointly by Danish, British and French hydrological institutes with the intention of providing solutions in water resources studies, where problems arising from conjunctive use need to be solved (Querner, 1997). SHE is a physically based distributed catchment modelling system. SHETRAN, a PC development of SHE, is an advanced physically based, spatially distributed integrated catchment modelling system. The physical basis allows a link between the simulations and the physical property measurements. Implementation of SHETRAN, for Irish application with respect to P in surface water catchments, is a task currently engaging a UCD project group under joint Teagasc and EPA stewardship.

Recent advances in physically based spatially distributed surface water modelling have avoided over-simplification of the problem (Birkinshaw and Ewen, 2000, Van Herpe et al, 2002, Lord & Anthony, 2000). Minimum Information Requirement (MIR) models have been proposed for catchment scale modelling (Anthony *et al.*, 1996; Quinn *et al.*, 1999, 1999; & Van Herpe et al, 2002). Others employ the technique without explicitly mentioning MIR (Styczen & Storm, 1993; Lord & Anthony, 2000; Krysanova *et al.*, 1999). MIR models depend upon fewer input parameters and have a simpler model structure than physically based (mechanistic) models. Hence, the interacting effects of parameter uncertainties is more easily analysed and traced (Van Herpe et al, 2002). A certain level of complexity is maintained by MIR models in order to ensure the outputs are sensitive to the *key* environmental parameters that are variable in time and space (Van Herpe *et al.*, 1999). Effective rainfall, land-use patterns (inferring fertiliser usage and initial soil nitrate conditions) and topographical information (Digital Elevation Model/digitised OS maps) within a GIS environment are usually the key components of the MIR approach.
Other approaches to modelling nitrate in surface water catchments include: CATCHN (Cooper *et al.*, 1994), NCATCH (Rodda *et al.*, 1995), SWAT (Arnold *et al.*, 1993, 1994, 1997) and SWIM (Krysanova *et al.*, 1996, 1998). Analysis of the models SWAT and SWIM is not fully relevant to this project.

3.3.8.2. Catchment Simulations - Groundwater Approaches

For groundwater simulations, when contaminant transport is the issue, a contaminant loading must be calculated previous to flow simulations. Point- and field-scale nitrogen models can be used to determine nutrient loading leaving the root zone. This loading is then usually applied as a recharge rate with a given contaminant concentration (e.g. Lasserre *et al.*, 1999; Jordan *et al.*, 1994). Transport of the concentration with flow must be simulated with a contaminant transport model. Saturated contaminant transport modelling without accounting for dispersion is simply particle tracking simulating advective transport (e.g. MODPATH). This is a common approach in the environmental industry because of its expediency and the usual lack of data to support more sophisticated fate-and-transport analysis. Whitehead (1990) discusses modelling nitrate from agriculture into public water supplies and classifies four methodologies: time series approaches; lumped conceptual models; distributed models and river quality models.

Integration of surface water and groundwater (unsaturated and saturated zone) models is necessary to model the effect of changes at a regional scale. Advances in computer technology support combining specific application models for an integrated analysis of catchment water quality. Implementation of the Water Framework directive will require consideration of the combined surface and groundwater resources in a catchment.

Lassere *et al.* (1999) used GIS to link an N model and a groundwater flow model. Observations and predictions of nitrate concentrations in groundwater matched well. Wendland *et al.* (1998) combined submodels, within a GIS environment, relating to nitrogen balance, groundwater recharge, groundwater flow and nitrate degradation to form a comprehensive model describing the flow of nitrate in the soil and groundwater of Germany. The model was not constructed to calculate actual concentrations in space and time, but to provide comparative analysis of potential nitrate hazard areas. They used their model on a supraregional scale to evaluate the impact of various nitrogen reduction strategies on the nitrate pollution of soil and groundwater in Germany. Wuttke *et al.* (1991) made partial use of GIS to complete an agro-ecosytem model, employing EPIC as the N model. Poor validation of their predicted results would suggest that it is better to use an established groundwater flow model (e.g. MODFLOW) rather than attempt a complex approach tailor-made for a particular system. Styczen and Storm (1993) achieved an integrated approach with the DAISY/MIKE-SHE modelling approach which successfully modelled catchment loads and surface and groundwater nitrate concentrations.

Only recently have integrated surface and groundwater models appeared in the literature (Styczen and Storm, 1993; Birkinshaw and Ewen, 2000; Whitehead *et al.*, 1998). The INCA model (Whitehead *et al.*, 1998) simulates both surface soil and groundwater zones together, with the leaching of water into the river system. INCA assesses multiple sources of nitrogen in catchments to give outputs as daily or annual loads and water quality fluxes. It was designed as an interactive tool for exploring catchment dynamics, groundwater/surface water interactions, nitrogen control processes and land-use scenario evaluation. While this model has a surface water emphasis, it does consider groundwater characterisation in a catchment. There is no evidence of INCA being applied to groundwater research as yet. INCA forms part of the current UK SEAL project which aims to develop a spatially sensitive, sustainable sludge management protocol without detriment to the environment and receiving water quality (Heathwaite, 2001).

The SHETRAN system for a river catchment and groundwater simulation (Birkinshaw and Ewen, 2000b) has been described. The model is capable of simulating nitrate transport in groundwater (Ewen *et al.*, 2000). A nitrogen transformation model, NITS, has been developed and integrated into the SHETRAN system (Birkinshaw and Ewen, 2000). This gives SHETRAN the capability, the developers claim, to simulate flow in perched, unconfined, confined and unsaturated systems with the associated leaching and transport of nitrate through the subsurface and ultimate discharge into surface waters and through river networks. The subsurface is represented as a fully three-dimensional variably saturated heterogeneous medium. Preferential flow and nitrate transport is allowed for using a dynamic region and dead space approach. A validation test for the full SHETRAN system for a river catchment is described in Birkinshaw and Ewen (2000b). A SHETRAN groundwater flow model for karst hydrogeological conditions has been developed and applied (Adams & Parkin, 2001).

4. LINKING THE UNSATURATED AND SATURATED ZONES

4.1. Linkage Methodologies

A comprehensive review (Mull & Pfingsten, 1991a) regarding methods for linking the unsaturated and saturated zones, for the purpose of groundwater-nitrate modelling identifies three possibilities: (a) direct coupling of detailed process-based models, (b) black box approach, (c) regression approach. Each of these linkage methodologies is discussed below with particular emphasis on recent research concerning modelling nitrate loss from agriculture to the water environment. These possibilities are discussed as follows.

4.1.1. Direct coupling or coupling of detailed process-based models

Realistically this would be achieved with the use of GIS technology. The land surface is divided to create volumes extending down from the land surface through to the aquifer (e.g. Lassere *et al.*, 1999). These volumes represent homogeneous sections where information is provided for model parameters (such as water-table depth, soil type, permeability, land use, fertilisation and N cycle parameters). The advice is to choose larger grid surface areas in accordance with the resolution of available data (Lord *et al.*, 1993). Process based model runs, for each soil column, results in estimations of the nitrate leaving the unsaturated zone. Transfer functions can be employed between the boundary of the unsaturated and saturated zones to obtain nitrate loading to the aquifer (Mull & Pfingsten, 1991a; Lassere *et al.*, 1999; Lord & Anthony, 2000). A groundwater flow and transport model then uses the pre-determined groundwater loading.

4.1.2. Black box approaches

These methods employ the results of empirical determinations (rough calculation) of the nitrate input into the aquifer from the land surface using available land use, fertiliser usage and soils data. Knowledge of the recharge rate and historical observations of groundwater aquifer concentrations is required because empirical values for loading are mostly obtained from observations in the field from piezometers and lysimeters. This type of approach is valid for large scale groundwater modelling and should incorporate the thickness of the unsaturated zone as an indicator for the time delay and biochemical process activity between application of nitrogen and arrival of nitrates in the groundwater body (Mull & Pfingsten, 1991a).

4.1.3. Regression approaches

Simple relationships derived between nitrogen application and nitrate loading based on experimental data. A sensitivity analysis is carried out on an established (tested and validated) model to identify the most significant parameters. By running multiple runs of variable data sets regression equations are obtained. This methodology results is a stable, reliable model with computational speed (Mull & Pfingsten, 1991a). In the MAGPIE (Lord & Anthony, 2000) modelling strategy (UK national approach) the SLIM soil nitrate model (Addiscott & Whitmore,

1991) yielded the SLIMMER algorithm relating drainage losses and nitrate leaching to a single curve for soils in entire UK.

4.2. Linkage Of Agronomic Models With Gis

4.2.1. Introduction

Strategies employing GIS environments are most common at this stage in the evolution of nutrient loss to water environments' research. Modelling the movement of nitrates, through the vadose zone, to groundwater is a spatial problem well suited for the coupling of a suitable model with a GIS (Corwin et.al, 1997). The UK national nitrate modelling strategy MAGPIE (Lord & Anthony, 2000); Northern Irish approach (Jordan *et al.*, 1994); Irish national P modelling (Daly et. al., 2002) and European approaches to modelling nitrate loss to groundwater (Lassere *et al.*, 1999; Wuttke *et al.*, 1991; Styczen & Storm, 1993; Arheimer & Brandt, 1998; Wendland *et al.*, 1998; de Paz & Ramos, 2002) all employ GIS in some degree of complexity for either surface or groundwater application. Figure 1 shows an example of how GLEAMS was used within a GIS environment.

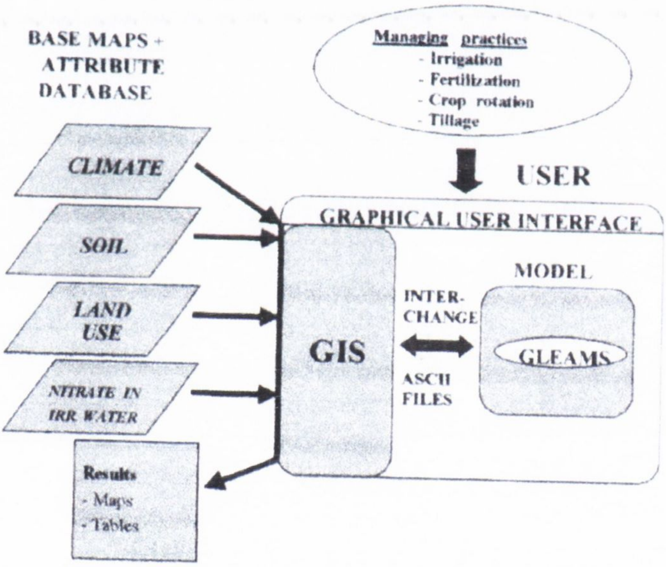


Figure 1 Schematic for the coupling of GLEAMS to a GIS (de Paz & Ramos, 2002).

The application of GIS to the modelling of non-point source pollutants (NPS) in the unsaturated zone has been comprehensively reviewed. Corwin & Wagenet (1996) provide an introduction and review of modelling NPS in the unsaturated zone with GIS. Corwin *et al.* (1999) overview advanced technologies for measurement and modelling of NPS pollution in the unsaturated zone and subsurface waters.

The next step in this field will be the full exploitation of Digital Elevation Model's (DEM's), employed within a GIS environment. Consideration of topography allows differentiation of source and sink areas (Van Herpe *et al.*, 2002). Use of DEM"s highlight that not all areas in a catchment have equal risk of contributing nutrients to receiving waters, as highlighted by Heathwaite *et al.* (2001). A topographic model component is necessary when the purpose of nutrient modelling is policy driven. There is a need for policy to be topographically related with respect to buffer zones and wetland areas (Van Herpe *et al.*, 2002).

4.2.2. Interfacing Agronomic models

Hartkamp *et al.* (1999) reviewed the interfacing of GIS with agronomic modelling and considers the diverse terminology in use, programming approaches, issues of data and scale, and existing applications. *Linking* is defined as merely passing input and output between a GIS and a model, *combining* is defined as automatic data exchange and GIS tool functions, and *integrating* is defined as embedding a model in a GIS or *vice versa*. They suggest that a major challenge in linking GIS to models lies in developing systems that handle spatial processes by implying interactions among spatial units.

Different 'environmental subsystems' can be identified within any catchment, e.g. groundwater flow, soil moisture movement, agricultural management. To evaluate a catchment as a whole, using Geographical Information Systems (GIS), two different approaches exist (Lasserre *et al.*, 1999): models linked with a GIS and models developed within a GIS. The simpler approach is advocated (Charnock *et al.*, 1996; Hiscock *et al.*, 1995; Elgy *et al.*, 1993; Fedra, 1993; Harris *et al.*, 1993; Petach *et al.*, 1991) where existing models are used and each model is linked into the GIS separately using a network of communicating programs. The linkage allows each model to be applied to the data just as any other GIS function (Fedra, 1993). Thereby, the GIS provides channels of communication between the models and allows them to be combined together for more sophistication and complex analysis (Hartkamp, 1999). The GIS and linked-models have no direct connection and information transfer is assumed by input-output routines added to the model (Lassere *et al.*, 1999).

Charnock *et al.* (1996) describes a system to link several one-dimensional soil and crop nutrient transport models within a GIS. The models employed within the GRASS GIS system (Shapiro *et al.*, 1993) were various existing one dimensional soil and crop models, such as SWATRE and SWIMS-2D, and the USGS groundwater flow model MODFLOW. A digitised topographic map, with a defined grid, allowed application of the model to homogenous areas. The input parameters are represented as rasters that vary across the landscape, such as saturated conductivity of a particular horizon, depth of a particular horizon *etc.* Then the process/transport model run is executed; a translation program samples the rasters at a point and writes the input file for the appropriate grid definition. It was concluded by Charnock *et al.* (1996) that sophistication of the model components themselves is less of a limitation, with respect to simulation accuracy and applicability to decision making, than data availability and quality or capability to calibrate the approach.

Fedra (1993) highlights the importance of the translation programme between different layers of a GIS. Different levels of integration range from *simple*, using the GIS for writing the model input and the presentation of model output, to *closely integrated systems*, where user interfaces are created and expert knowledge based systems are developed, and a special model is created. An example of such a *closely integrated system* is the HYDRA DECISION SUPPORT SYSTEM (Ireland, 1995), which involved a very complex development and manpower intensive methodology to characterise catchment waters.

The other option, development of the model directly within the GIS, is limited by the simplicity required in model formulation and restrictions in calculation possibilities, because GIS is reported to have difficulty with temporal resolution (Hiscock *et al.*, 1995). On the other hand, considering heavily mechanistic models can create data collection and model validation problems, simpler models may be more suitable. Oloufa *et al.* (1995) and McKinney & Tsai (1996) are reported to be among the few authors who have successfully developed models within a GIS that provide quantitative results (*in* Lassere *et al.*, 1999).

4.2.3. GIS Utilisation in the Literature

Charnock et al (1996) outlines linking one-dimensional soil and water models to a groundwater flow model within a GIS. A digitised topographic map, with a defined grid, allows application of the model to homogenous areas. The input parameters are represented as rasters that vary across the landscape, such as saturated conductivity of a particular horizon, depth of a particular horizon *etc*. Then the process/transport model run is executed; a translation program samples the rasters at a point and writes the input file for the appropriate grid definition.

The MAGPIE approach (Lord & Anthony, 2000) successfully employed an extensive array of mechanistic models to derive simpler relationships, fronted by a user friendly graphical user interface (GUI), thereby employing both the coupling of models and use of empirical relationships to provide a qualitative management tool. More general soil models are reported to be more useful for coupling with groundwater models due to the diffuse nature of nitrate inputs and transport within the aquifer (Mull & Pfingsten, 1991a).

In catchment simulations the integration of solute and hydrological models will encounter the problem of disparity of scale and time-steps, this has been discussed with some detail in the literature (CEC, 1991; Rodda *et al.*, 1995; Quinn *et al.*, 1999; Addiscott & Mirza, 1998). Models for the unsaturated zone consider one-dimensional vertical flow and are run with a high resolution in space and time, with spatial resolutions of metres or less. Groundwater models are multi-dimensional, cover far larger areas and have larger simulation time-steps (Refsgaard *et al.*, 1999). Therefore, the results of more general soil models, accounting for regional nitrate inputs, are more useful for coupling with groundwater models. Mull & Pfingsten (1991a) proposed a method for handling a more "regional soil model" acting as an input for a groundwater model with lower linkage difficulties than with conventional process based models, figure 2.

Linking GIS and simulation models at a technical level does not guarantee improved understanding or better prediction (Burrough, 1996). Hartkamp *et al.* (1999) observes that both GIS and simulation models have been developed with their own conventions, procedures and limitations. However, the growing need to place point scale model outputs in a spatial and long-term perspective has encouraged GIS use in agronomic and environmental research (Hartkamp, 1999). GIS allows storage, manipulation, analysis and visualisation of spatial data on a desktop PC with unprecedented ease by users who are not GIS programmers (Stoorvogel, 1995). There is a fear that if GIS interfaces become too easy to use, understanding the systems basic concepts and limitations will be neglected and that calibration, validation and error analysis will be overlooked in the absence of this understanding (Burrough, 1996). This fear is frequently aired in the hydrogeological modelling community also.

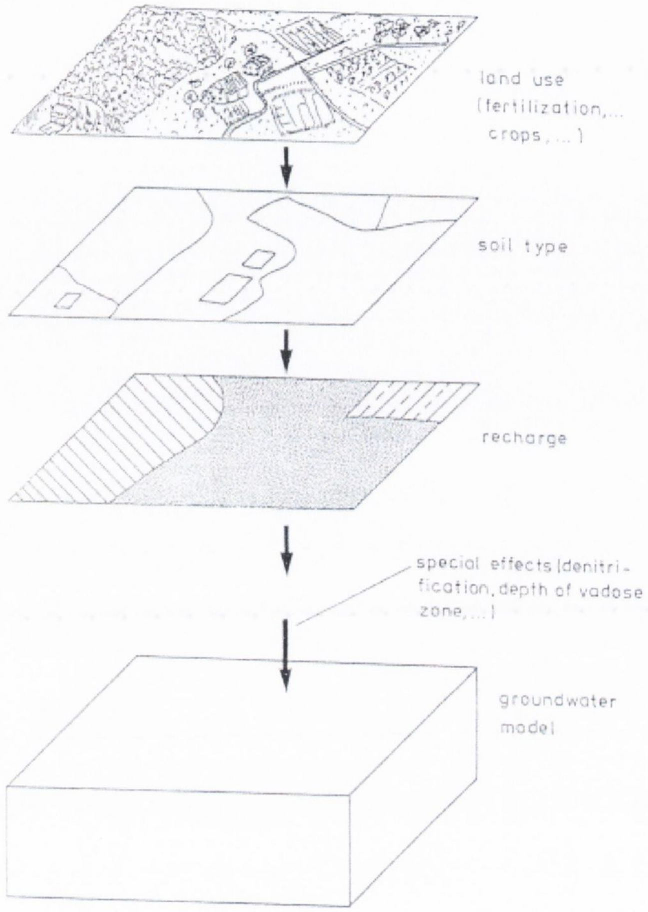


Figure 2 Proposal for linking a 'regional soil model' to modelling nitrate transport in groundwater with low linkage problems (Mull & Pfingsten, 1991a).

Lassere *et al.* (1999) linked an established N cycle model and a groundwater flow model within a GIS environment. Observations and predictions of nitrate concentrations in groundwater matched well. Wuttke *et al.* (1991) made partial use of GIS to complete an agro-ecosytem model, employing EPIC as the N model. Jordan *et al.* (1994) used a GIS to predict and map nitrate loads and concentrations in leachate without the use of a process model. The results of their simplistic approach were successfully validated by river system monitoring results.

The GSI groundwater protection schemes, delineated for specific counties, rely on a GIS environment (www.gsi.ie). Ireland's only national scale nutrient model (for riverine P concentrations) is built within a GIS system (Daly *et al.*, 2002).

APPENDIX B – BOREHOLE LOGS – CURTIN'S FARM

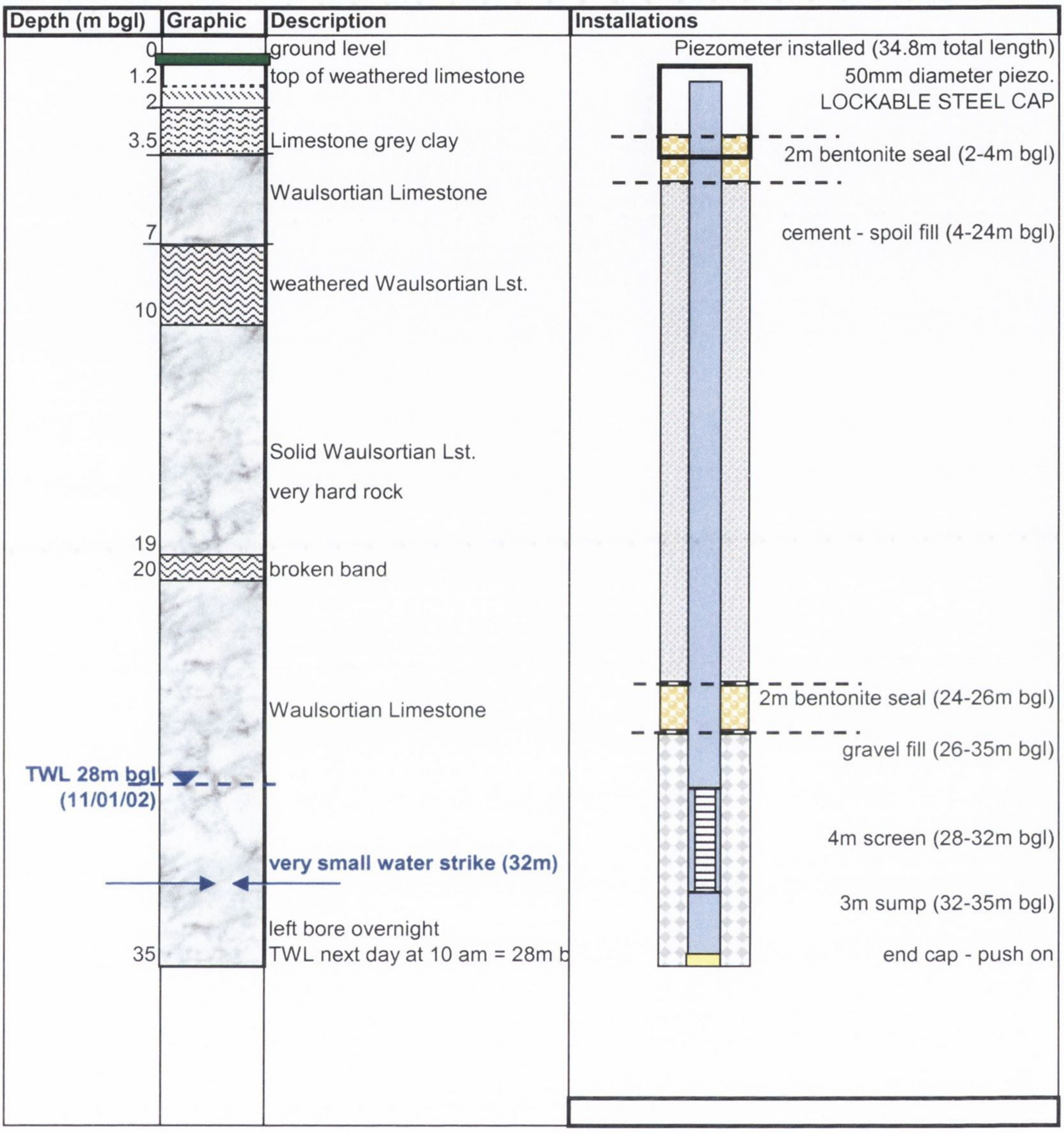
I created the borehole logs provided in this appendix from notes taken while supervising drilling of boreholes on Curtin's farm. The project bore identification (e.g. BHC.1) is provided at the upper right hand of each borehole log sheet. Firstly, logs are presented for all successful groundwater monitoring piezometers (see chapter five, Figure 5.2 for all drilling locations and borehole identifiers). Then, borehole logs for all failed boreholes (i.e. no water-strike) are presented. At the end of this appendix (pages 468-473) borehole log notes are provided for BHC.3 and BHC.8. A geologist investigating mineral deposits in the region supplied these logs; the company drilled these two bores at Curtin's farm.

The bore number refers to the chronological order of drilling and installation (e.g. BHC.1 was the 13th hole drilled and so the borehole log shows bore number 13 in the notes at the top right hand side of the sheet). The plot in which the borehole was installed (e.g. BHC.1 was installed in plot 15BLUE – see chapter five, Figure 5.14 for plot identifiers) and the ground elevation are also provided.

The page is split in two – the left hand side column shows the bedrock stratigraphy and the right hand column details piezometer configuration; location of screened interval and bentonite seals.

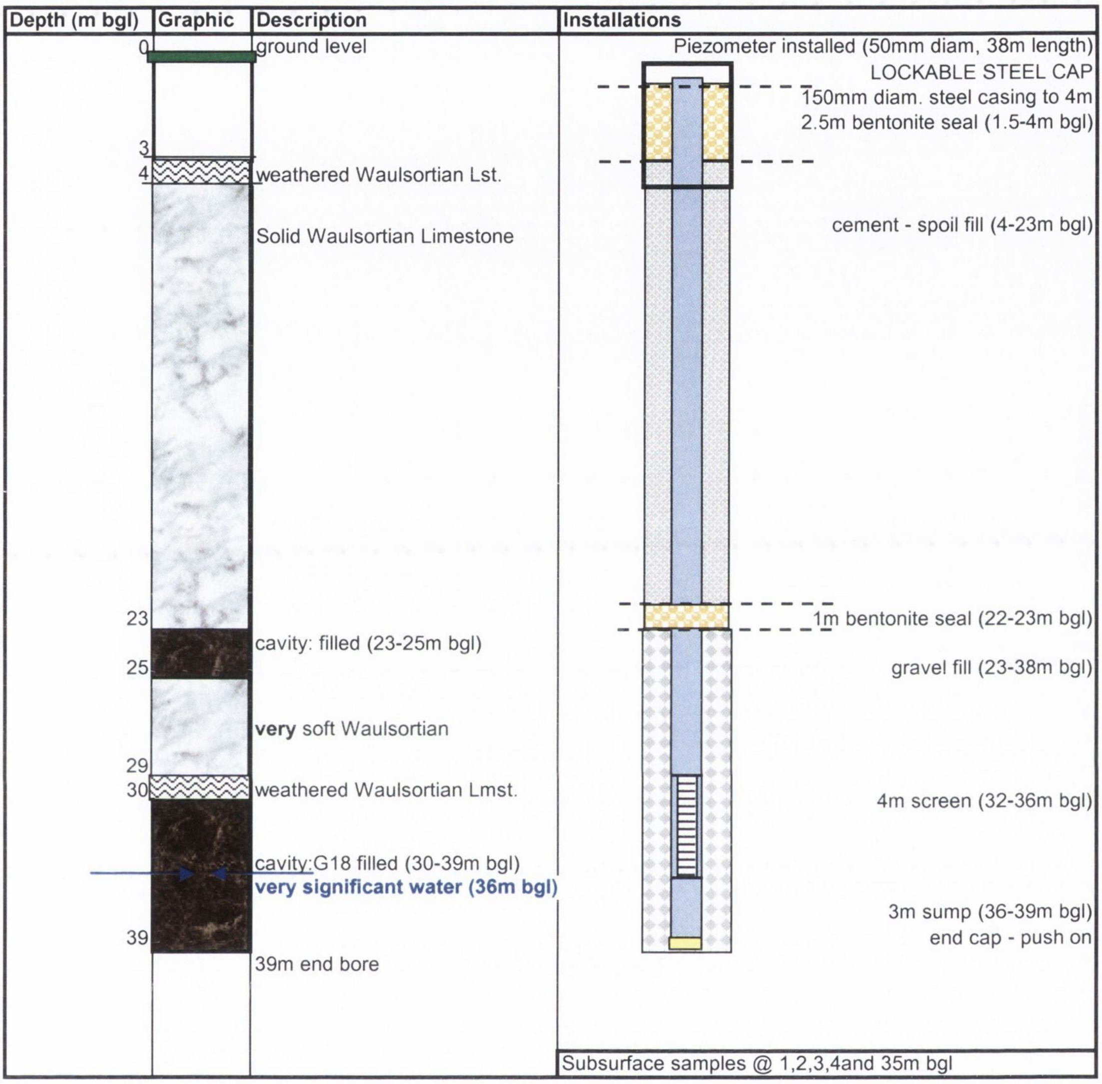
Page 1 of 1
Study: Curtins Farm
Logged by: P. Bartley
Driller: Emlyn Davies Drilling Co.
150mm borehole

Project bore I.D: BHC.1
bore number 13
Curtins plot number 15BLUE
date drilled: 11/01/02
Ground Elevation = 55.81m AOD



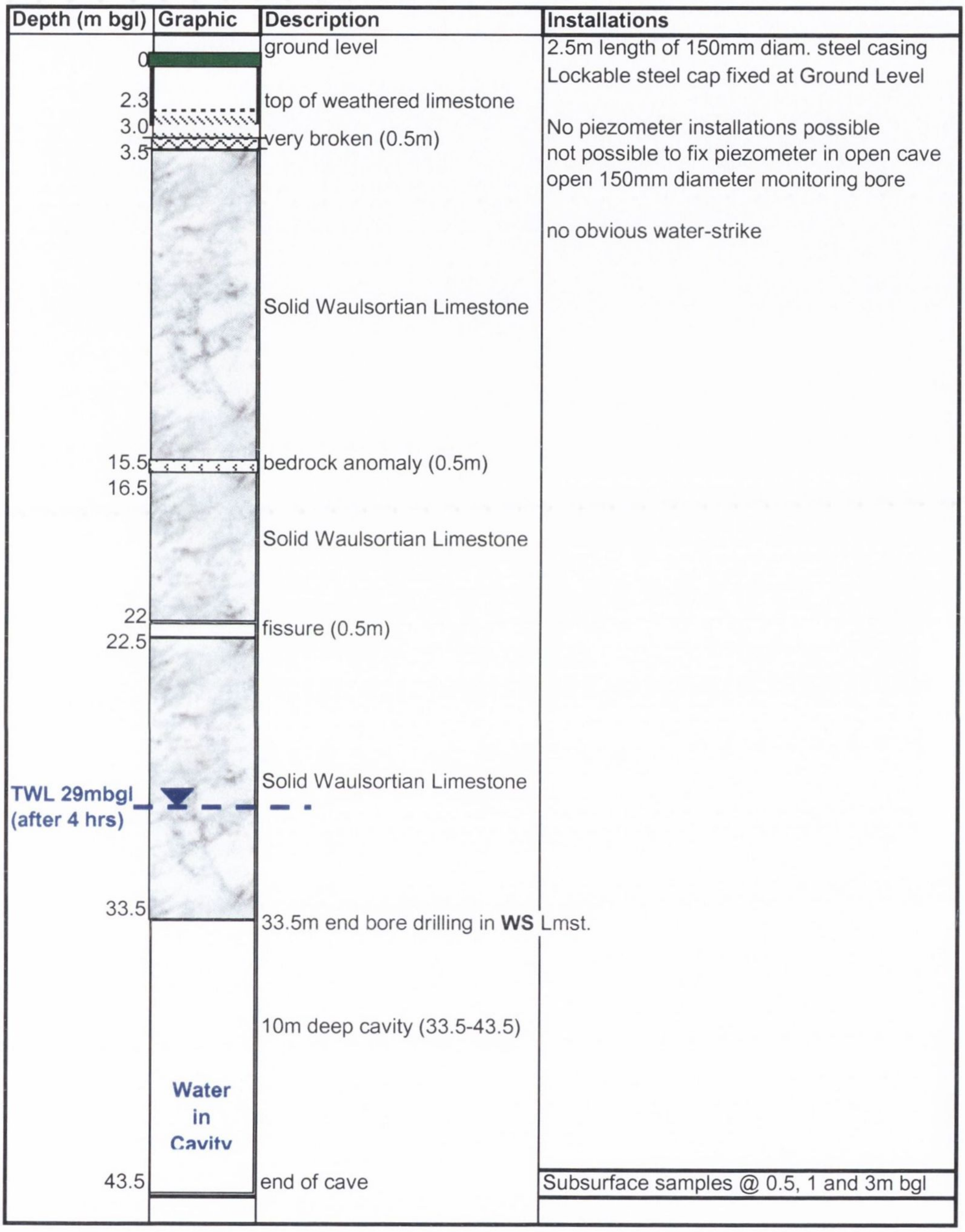
Page 1 of 1
Study: Curtins Farm
Logged by: P. Bartley
Driller: Leo O'Sullivan Drilling Co.
150mm borehole

Project bore I.D: BHC.2
bore number 9
Curtins plot number 17BLUE
date drilled: 29/08/01
Ground Elevation = 53.9m AOD



Page 1 of 1
Study: Curtins Farm
Logged by: P. Bartley
Driller: Dunnes of Mallow

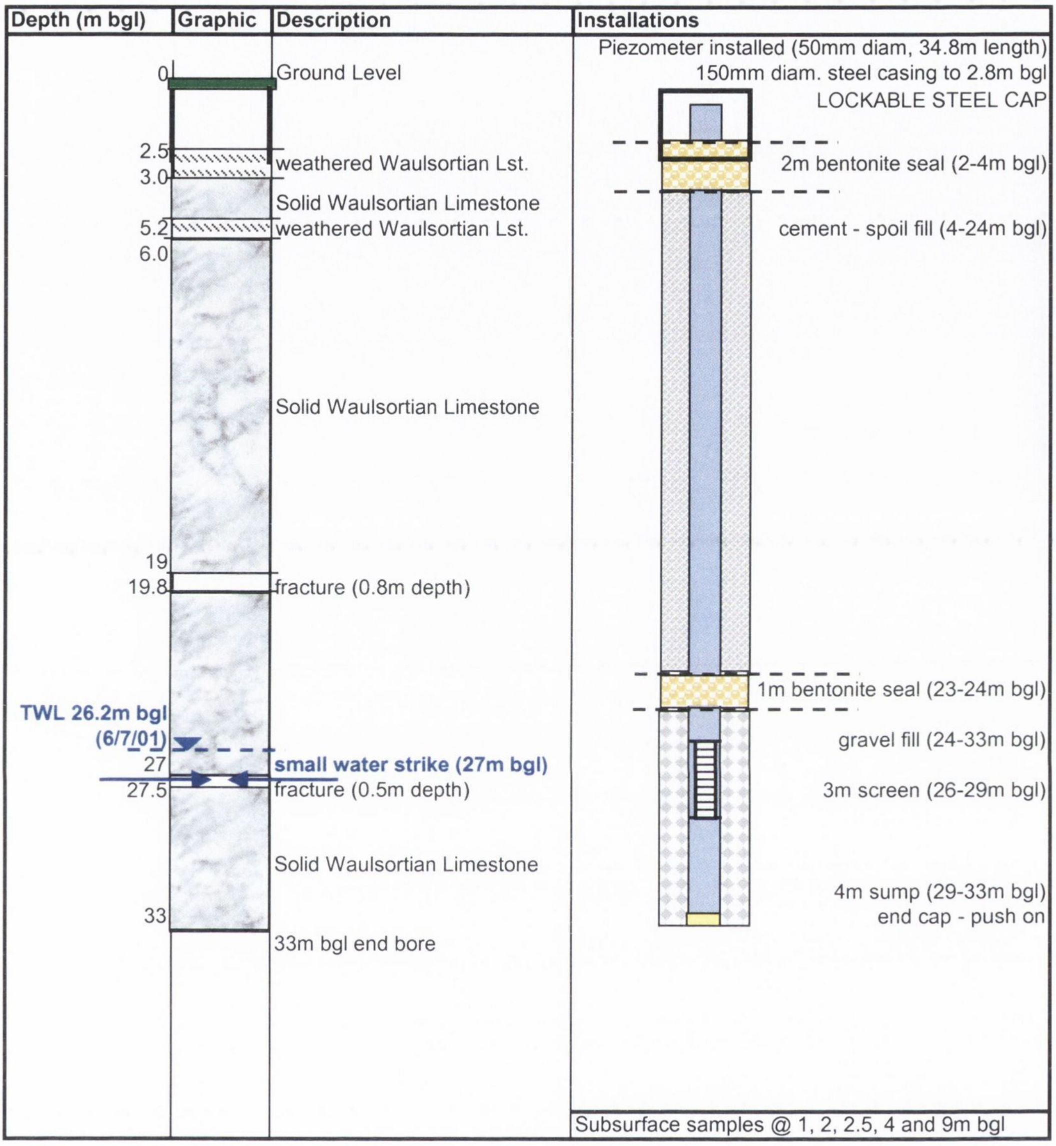
Project bore I.D: BHC.4
bore number 6
Curtins plot number 11RED
date drilled: 13/7/01
Ground Elevation: 54.06m AOD



Depth (m bgl)	Graphic	Description	Installations
0		ground level	2.5m length of 150mm diam. steel casing Lockable steel cap fixed at Ground Level
2.3		top of weathered limestone	
3.0			No piezometer installations possible not possible to fix piezometer in open cave open 150mm diameter monitoring bore
3.5		very broken (0.5m)	
			no obvious water-strike
		Solid Waulsortian Limestone	
15.5		bedrock anomaly (0.5m)	
16.5			
		Solid Waulsortian Limestone	
22		fissure (0.5m)	
22.5			
		Solid Waulsortian Limestone	
TWL 29mbgl (after 4 hrs)			
33.5		33.5m end bore drilling in **WS** Lmst.	
		10m deep cavity (33.5-43.5)	
	Water in Cavity		
43.5		end of cave	Subsurface samples @ 0.5, 1 and 3m bgl

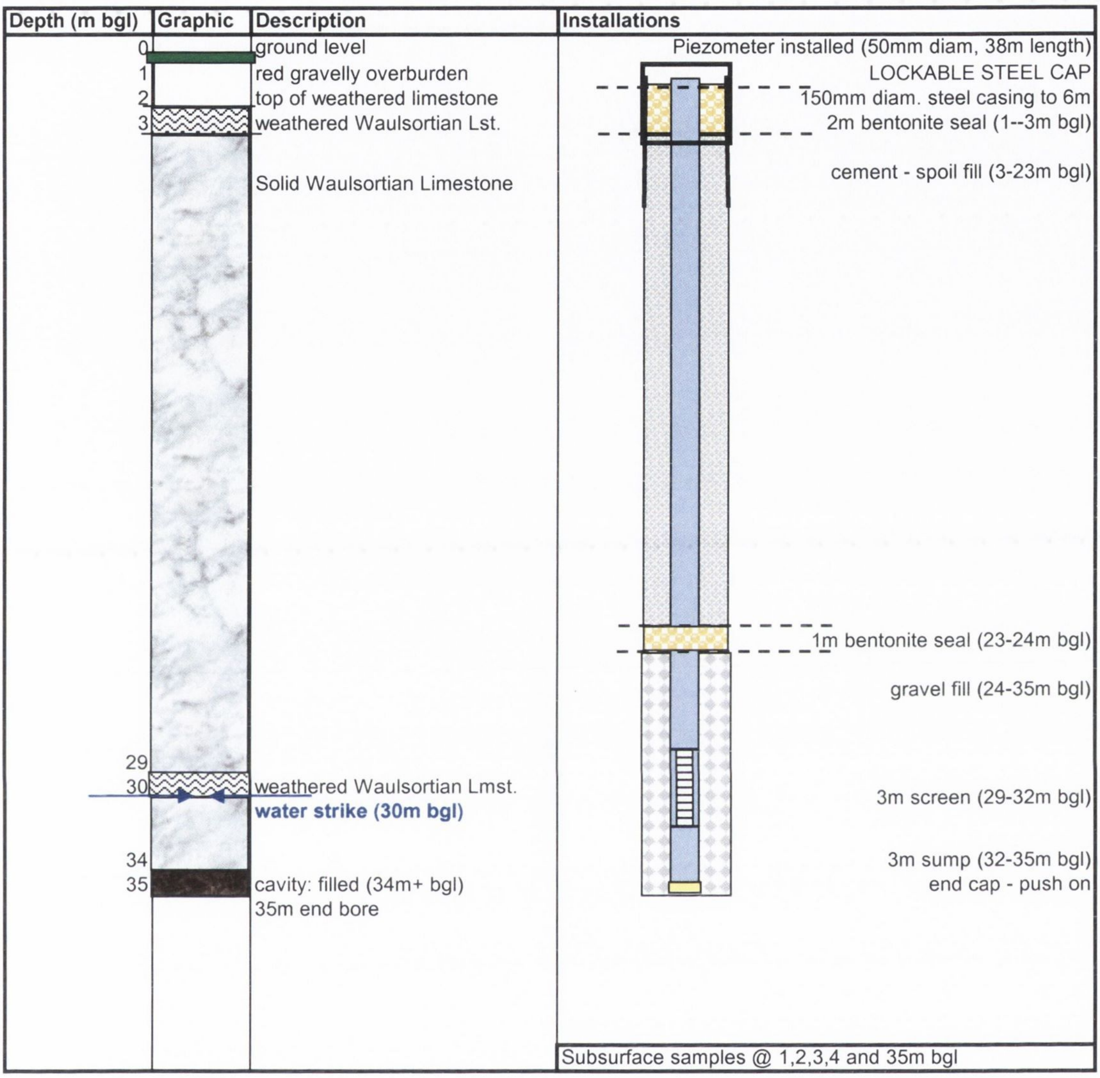
Page 1 of 1
Study: Curtins Farm
Logged by: P. Bartley
Driller: Dunnes of Mallow
150mm borehole

Project bore I.D: BHC.5
bore number 4
Curtins plot number: NUIG EXPERIMENTAL PLOT
date drilled: 5/7/01
Ground Elevation = 51.78m AOD



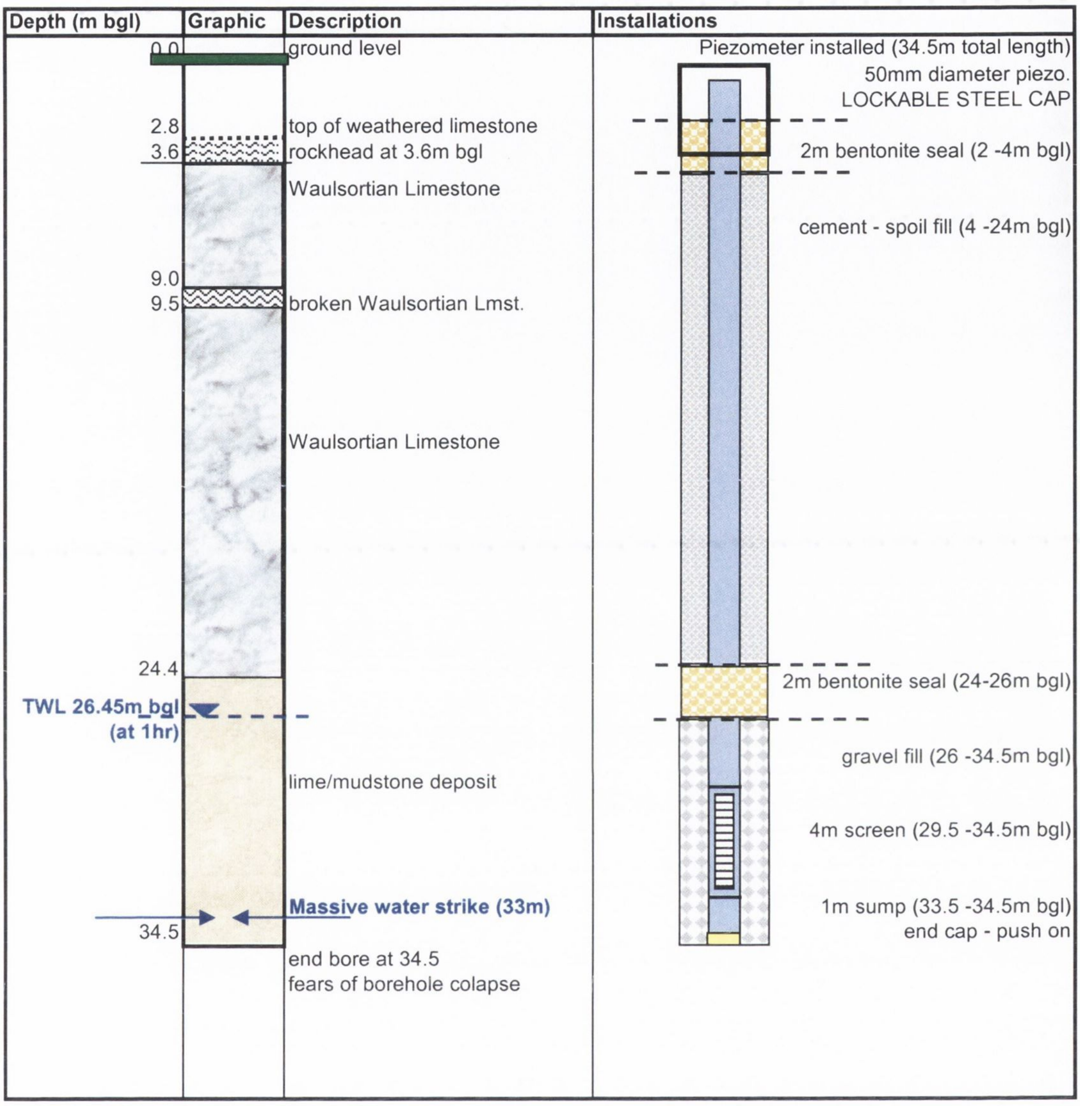
Page 1 of 1
Study: Curtins Farm
Logged by: P. Bartley
Driller: Leo O'Sullivan Drilling Co.
150mm borehole

Project bore I.D: BHC.7
bore number 8
Curtins plot number 12BLUE
date drilled: 29/08/01
Ground Elevation = 53.9m AOD



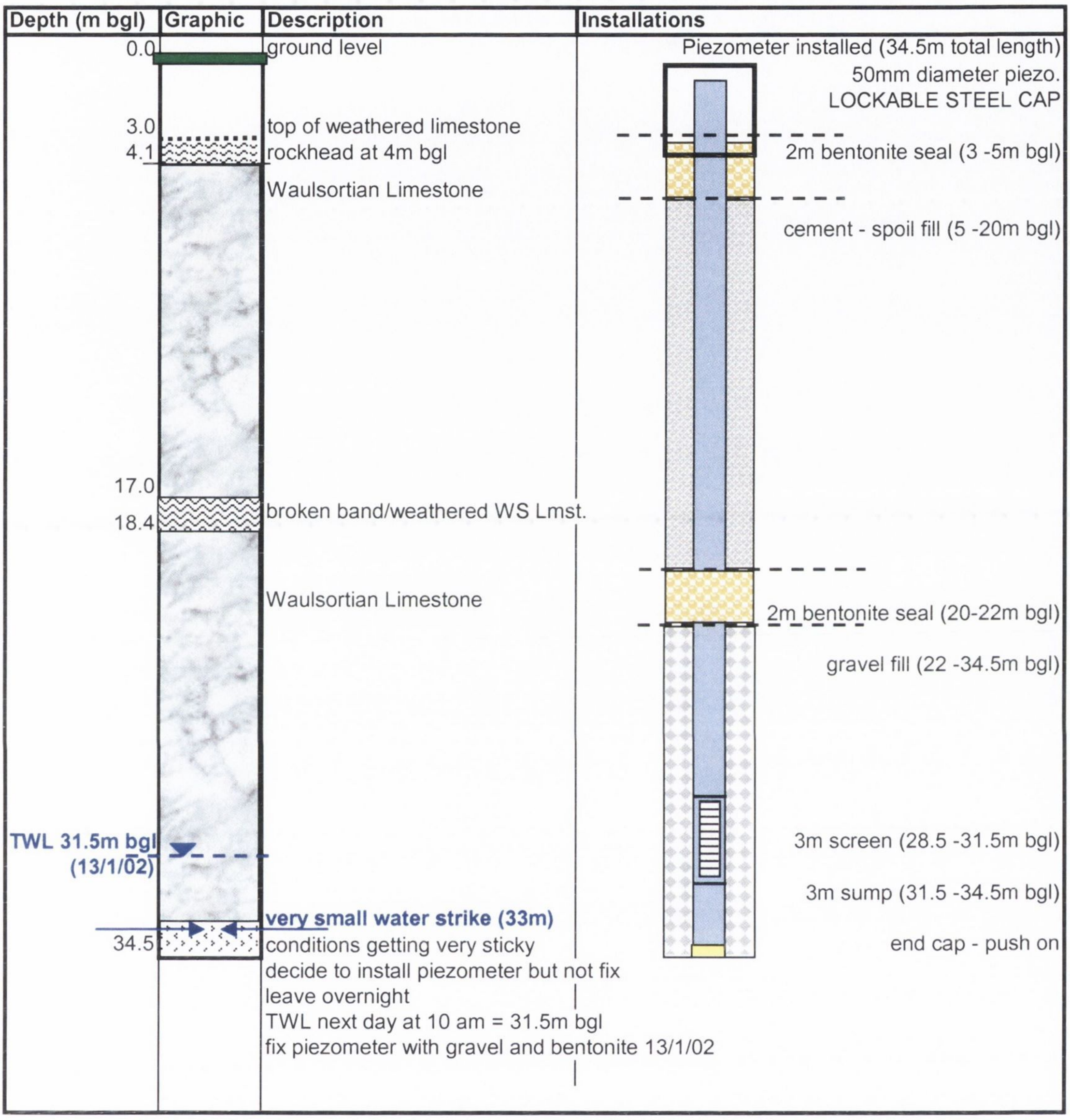
Page 1 of 1
Study: Curtins Farm
Logged by: P. Bartley
Driller: Emlyn Davies Drilling Co.
150mm borehole

Project bore I.D: BHC.9
bore number 15
Curtins plot number 3BLUE
date drilled: 13/01/02
Ground Elevation = 54.66m AOD



Page 1 of 1
Study: Curtins Farm
Logged by: P. Bartley
Driller: Emlyn Davies Drilling Co.
150mm borehole

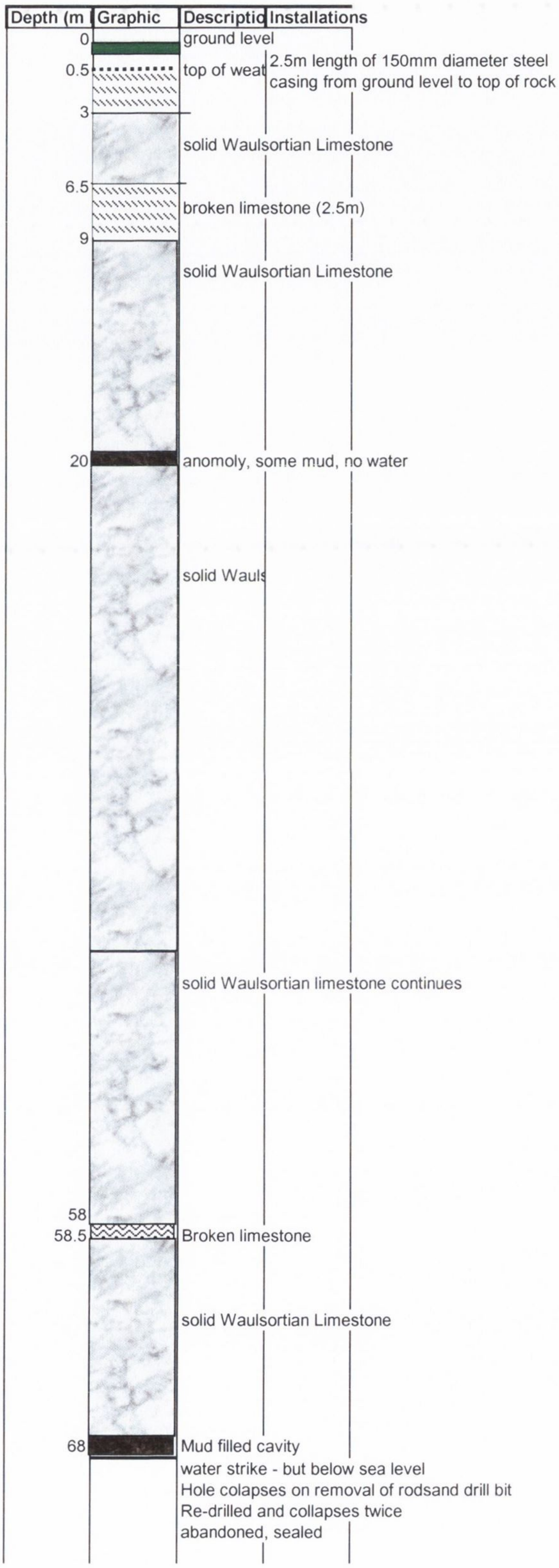
Project bore I.D: BHC.10
bore number 14
Curtins plot number 6BLUE
date drilled: 12/01/02
Ground Elevation = 57.23m AOD



Page 1 of 2
Study: Curtins Farm
Logged by: P. Bartley

Driller: Dunnes of Mallow
150mm borehole

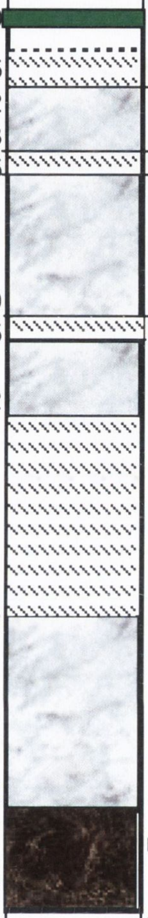
Project bore I.D: F1
bore number 2
Curtins plot number 14YELLOW
date drilled: 21/6/01



Depth (m	Graphic	Descriptio	Installations
0		ground level	
0.5		top of weat	2.5m length of 150mm diameter steel casing from ground level to top of rock
3		solid Waulsortian Limestone	
6.5		broken limestone (2.5m)	
9		solid Waulsortian Limestone	
20		anomoly, some mud, no water	
		solid Wauls	
		solid Waulsortian limestone continues	
58			
58.5		Broken limestone	
		solid Waulsortian Limestone	
68		Mud filled cavity water strike - but below sea level Hole colapses on removal of rodsand drill bit Re-drilled and collapses twice abandoned, sealed	

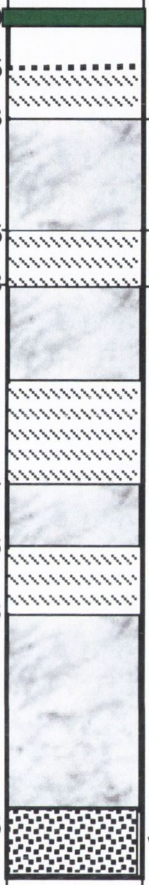
Page 1 of 1
Study: Curtins Farm
Logged by: P. Bartley
Driller: Dunnes of Mallow

Project bore I.D: F2
bore number 1
Curtins plot number 14BLUE
date drilled: 29/6/01

Depth (m bgl)	**Graphic**	**Description**	**Installations**
		ground level	
0			10m length of 150mm diameter steel casing from ground level to top of rock
1.5		top of weathered limestone	
2 3		solid Waulsortian Limestone	
3.5		broken limestone (0.5m)	
		solid Waulsortian Limestone	
9 9.5		broken limestone (0.5m)	
12		solid Waulsortian Limestone	
		broken limestone (6m)	
18			
22		mud bank, no water strike	
27			
		Driller unable to make further progress Mud compacting only drilling rig not powerful enough hole abandoned	
		Subsoil samples @ 0.5, 3, 22 and 25m bgl	

Page 1 of 1
Study: Curtins Farm
Logged by: P. Bartley
Driller: Dunnes of Mallow

Project bore I.D: F3
bore number 1
Curtins plot number 14BLUE
date drilled: 20/6/01

Depth (m bgl)	**Graphic**	**Description**	**Installations**
0		ground level	1.5m length of 150mm diameter steel casing from ground level to top of rock
1.5		top of weathered limestone	
3		solid Waulsortian Limestone	
6.5		broken limestone (1.5m)	
8		solid Waulsortian Limestone	
11		broken limestone (3m)	
14		solid Waulsortian Limestone	
16		broken limestone (2m)	
18			
24.5		weathered limestone	
		Driller unable to make further progress with drill bit, abandoned hole	
			Subsoil samples @ 0.5 and 1m bgl

Page 1 of 1
Study: Curtins Farm
Logged by: P. Bartley
Driller: Dunnes of Mallow

Project bore I.D: F4
bore number 7
Curtins plot number 19BLUE
date drilled: 2/8/01
Ground Elevation: 53.98m AOD

Depth (m bgl)	Graphic	Description	Installations
0.0		Ground Level	
			No water strike - no piezometer installed
		top of weathered limestone	no installations possible
2.5		rockhead	compressor breaks down at end of bor
			two-week repair
		Waulsortian Limestone	then drilling rig breaks down
			one-week repair delay
6.5			on removal of rods, hole has cemented up
		weathered Waulsortian Lmst.	rig not powerful enough
			driller discharged from contract
10.5			
		open fracture (2m)	
12.5			
		solid Waulsortian Limestone	
37		weathered limestone	
37.5			
40			
		no returns at all from bore (40-50m bgl)	
50			
		no water-strike, hole abandoned	
			Subsoil samples @ 0.5 and 1m bgl

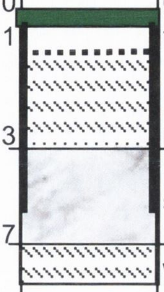
Page 1 of 1
Study: Curtins Farm
Logged by: P. Bartley
Driller: Dunnes of Mallow

Project bore I.D: F5
bore number 5
Curtins plot number 11BLUE
date drilled: 9/7/01
Ground Elevation: 52.9m AOD

Depth (m bgl)	**Graphic**	**Description**	**Installations**
		Ground Level	
0			No water strike - no piezometer installed
4.5		top of weathered limestone	
4.9		Waulsortian Limestone	
5.5			
6.0		fissure (5.5-6.0m bgl)	
		solid Waulsortian Limestone	
33.5		weathered limestone	
34.0			
51		no water-strike, hole abandoned	
			Subsoil samples @ 0.5, 1 and 2m bgl

Page 1 of 1
Study: Curtins Farm
Logged by: P. Bartley
Driller: Leo O'Sullivan
Bore Diameter: 200mm to 6m, 150mm from 6m to 24m bgl

Project bore I.D: F6
bore number 11
Curtins plot number 2BLUE
date drilled: 30/8/01

Depth (m bgl)	Graphic	Description	Installations
0		ground level	
1		top of weathered limestone	6m length of 150mm diameter steel casing from ground level to top of rock
3		rockhead at 3m	
		solid Waulsortian Limestone	
7		weathered limestone at 7m	
		Drill-bit is making contact with rock but no spoils returned from hole Driller experiences real difficulty retracting drill-bit and rods Driller refuses to progress, hole abandoned	
			Subsoil samples @ 0.5m bgl

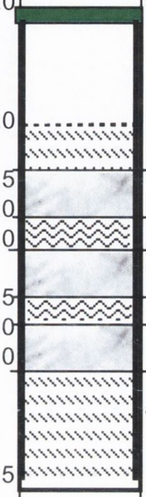
Page 1 of 1
Study: Curtins Farm
Logged by: P. Bartley
Driller: Leo O'Sullivan
Bore Diameter: 200mm to 6m depth, 150mm diameter from 6-24m bgl

Project bore I.D: F7
bore number 10
Curtins plot number 1RED
date drilled: 30/8/01

Depth (m bgl)	Graphic	Description	Installations
0.0		ground level	
1.0		top of weathered limestone at 1m bgl	15.5m length of 150mm diameter steel casing from ground level to top of rock
2.0		rockhead at 2m bgl	
		solid Waulsortian Limestone	
22			
24		weathered limestone/cavern	
		end bore at 24m bgl no spoils returned from the hole for two metres Driller unable to make any depth progress despite half hour drilling Driller refuses to progress, hole abandoned at 24m bgl	
			Subsoil samples @ 1, 2, 3 and 4m bgl

Page 1 of 1
Study: Curtins Farm
Logged by: P. Bartley
Driller: Leo O'Sullivan
Bore Diameter: 200mm to 15.5m, 150mm thereafter

Project bore I.D: F8
bore number 12
Curtins plot number 6YELLOW
date drilled:30/8/01

Depth (m bgl)	Graphic	Description	Installations
0.0		ground level	15.5m length of 150mm diameter steel casing from ground level to top of rock
4.0		top of weathered limestone at 4m bgl	
		rockhead at 5.5m bgl	
5.5			
7.0		solid Waulsortian Limestone	
8.0		broken Waulsortian Limestone	
		solid Waulsortian Limestone	
9.5		broken Waulsortian Limestone	
10.0			
12.0		solid Waulsortian Limestone	
		weathered Waulsortian Lime-mudstone	
15.5		15.5 m steel lining	
		16m bgl end bore (3 hours to drill 3m in weathered, gritty limestone)	
		lining starts to rotate, slip, now inclined	
		Driller not interested in drilling more holes	
		Driller decides that there is too much risk and not enough progress	
			Subsoil samples @ 1, 2, 3 and 4m bgl

The following pages detail the borehole logs for BHC.3 and BHC.8, which were supplied by the geologist supervising drilling at these locations.

#01-3626-01 100868.9N 181411.8E, ✓Their 71-50m AOD NOT!

GEOLOGICAL CORE LOGGING SHEET

MINORCO

Page .1. of ..3.. **Area:** CLOTTIN'S FORT

Logged by: DDC

Sect:
Plan:

Scale 1: 100

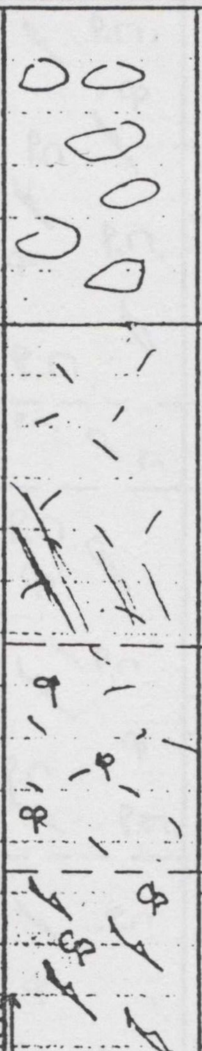
Driller: Andy LaPuzzo
12/02/01

Angle: -50 **Bearing:** 360°
E:
N:
Z:

Survey					
Depth	Angle	Bear.	Depth	Angle	Bear.

BHC.3

Notes
NOTE; BEDDING DIPS NOT CORRECTED TO B.H. ORIENTATION.



BOX # / TAG	TCR (%)	RQD (%)	Depth	Structure Description	ACA	Lithology Description	Depth	Sph	Gal	Pyrite	Sample
						ORS + LMC +/- LST OB. ~ ? TILL?					
3	100%	100%				3m. ROCKHEAD WAULSORTIAN MUDBANK COMPLEX UNDR; PORCELLANEOUS BIOMIC'S					
5.5				Fe-STAINED BEDDING) e 75° TO C.A. re DRILLING DOWN DIP.							
	100%	100%				6.1 CHAOTIC, FELTY-FIBROUS BRY-RICH DARK BIOMIC					
8.5						8.3 START OF STROM. CAVITIES.					
				SEVERAL Fe-STAINED, ROUGH JOINT DIPS N.E. B_STR 45-60° → 095 B_STR 25-40° → 085 B_STR 45-60° → 135/140	9.6 9.8 9.9	CHAOTIC STROMATACTOID CAVITIES					
	100%	95%	STRIKE SLIP? ▽	B_LAM 40/45° → 160 B_STR 25° → 160	10.5 10.75	10.15 10.5 10.6 CAVITY FILLED BY 1-3cm ROTTEN, MILKY DOL FOLLOWED BY COARSE, CLEAR WHITE CALCITE.					
11.5			STRIKE SLIP? ▽	B_STR 25/30° → 250/285	11.15						
				B.LAM 60 → 180 B.STR 35/40 → 220/235	11.45 11.6						
				B_STR 45° → 165	12.25	OCCASIONAL MINOR PATCHES OF DOLOMITE ~<5%.					
	100%	100%		B.STR 40° → 160 B.STR 45/50° → 160 B.STR 30/35° → 180	12.6 12.7 12.8 ORIENTATED CORE						
14.5											
	100%	98%		ZONE OF SUB-VERT (80°) ROUGH, Fe STAINED JOINTS + WHITE DOG TOOTH SPAR. POOR GROUND CONDITIONS.	15.55						
17.5					17.7	17.45 ST START OF PINK-RED MOTTLED STROM. BIOMIC'S + MIC (R) F.					
	100%					RED-LT PINK MOTTLED STROM. LMC.					

Overburden	O_OB	10 Middle Agrascast	BR_MA	134 Crinoids	W_EN	230 Oolites	S_OO	330 Zone of transitional Alteration	L_FEA	430
Undifferentiated weathered rock	O_WR	20 Lower Agrascast	BR_LA	135 Disseminated Sulphides	W_DS	240 Argillaceous calcite	S_AO	380 Pink Plug Dolomite (>80cm)	L_PO	470
Supra-reef	BR	100 Crosspatrick	BR_C	130 Veins / Stringer Sulphides	W_VS	250 Disseminated Sulphides	S_DS	340 Significant fault zone	F_FZ	500
Durrow	BR_D	110 Upper Crosspatrick	BR_UC	132 Massive Sulphide	W_MS	260 Vein / Stringer Sulphides	S_VS	350 Fault zone with sulphides	F_DS	540
Upper Durrow	BR_UD	112 Lower Crosspatrick	BR_LC	140 Lower Transition Unit	W_LTU	270 Massive Sulphide	S_MS	360 Large Cavity (.30cm)	F_CAV	510
Middle Durrow	BR_MD	114 Waulsortian	W	150 Lower Limestone Lens	W_LLL	280 Sub-ABL Shales	S_LLS	370 Weathering obscures lithology	F_WTO	530
Lower Durrow	BR_LD	116 Upper Transition Unit	W_UTU	200 Sub-Waulsortian	S	290 SMD	L_SMD	400 0-10 degree fault	F_10	610
Agrascast	BR_A	120 Dolomitised Biomicrite	W_BM	210 Nodular Micrite	S_NM	300 Hydrothermal Dolomite	L_HD	410 0-10 degree bedding	B_10	710
Upper Agrascast	BR_UA	122 Wavy Laminated Facies	W_WL	220 ABL	S_ABL	310 WMD - well developed	L_WMD	420		

GEOLOGICAL CORE LOGGING SHEET

MINORCO

Page 2 of 3 Area: CASTLE'S FARM

Logged by:

Sect:

Plan:

Scale 1:

Angle:

Bearing:

E:

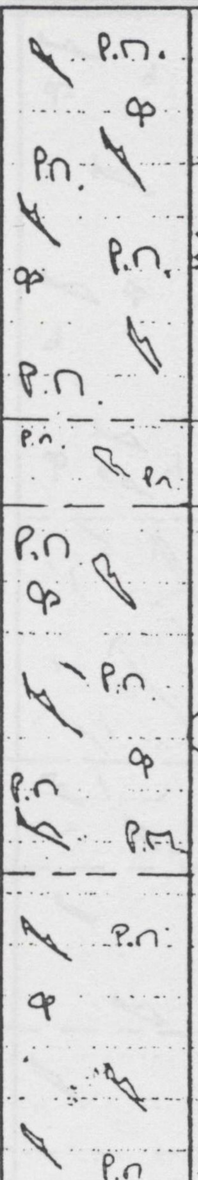
N:

Z:

Survey					
Depth	Angle	Bear.	Depth	Angle	Bear.

Notes

BHC.3



TAG	TCR (%)	RQD (%)	Depth	Structure Description	ACA	Lithology Description	Depth	Sph	Gal	Pyrite	Sample
20.5	100%	85%	NOTE: SAMPLE P.M. V'S NON-P.M. IS THERE A DIFF?	(2) SUBVERTICAL, E-STRIKING/N-... SAND-CLAY FILLED JOINT	21.2 21.5	MOD-INTENSE PINK MOTTLED ± FELTY, STRON-RICH BIOMIC'S. NOTE: IMPORTANCE OF GAMMA JOINTS ETC. NOT LITHOLOGY. 1Y. TEXTURALLY REF. ② OF FINE(R) MIC ?MORE NUCLEATION SITES?					
23.5	100%	100%				23.9 WEAK PINK MOTTLING. 24.7 MODERATE TO INTENSE PINK MOTTLED STRON + BRY RICH BIOMICRITES. (CF. BY S.MIXED P.DOL VEINLETS.)					
26.5	100%	87%	27.7	SUBVERTICAL, E-STRIKING JOINT – PREDOMINANTLY DIPS TO NTH.	27.7	28.3 WEAK PINK MOTTLED LMC					
29.5	100%	90%	NOTE: CHANGE IN STRIKE? DUE TO BAR BEING UNABLE TO RIGHT ITSELF PRIOR TO GAMSIT, INSUFFICIENT FALL.		30.6						
32.5	100%	100%	[AVE. GENTLE @ 20° TO C.A.?] BEDS DIP 1Y TO NTH @ 40-75°	B_LAG 50-65° → 015 B_STR 65° → 065 B_STR 60° → 355 B_STR 30/45° → 065 B_STR 30 → 255 B_STR 40/45 → 040 B_LAG 75 → 005 B_STR 40 → 345/350 B_STR 40-65° → 005/010 B_STR 50/65 → 315	32.4 32.55 33.5 33.9 34.25 34.5 35 35.15 35.35 36.45	35.4 'UNALTERED', FELTY-FIBROUS; ENCRINAL RICH BIOMICRITES.					
35.5	100%	95%		B_STC 45° → 360 B_STC 50° → 290 B_STC 70° → 300°	36.85 37.1 37.45	38.1 GRADATIONAL BDY					
38.5	100%	83%		SUB-VERTICAL FRACTURE		PART. DOL. FIBROUS STRON BIOMICS → C.10-15%.					

[illegible]	O_OB	100	Middle Aghmacart	BR_MA	124	Encrinite	W_EN	230	Oolites	S_OO	330 Zone of Intense Alteration
[illegible]	O_WR	200	Lower Aghmacart	BR_LA	126	Disseminated Sulphides	W_DS	240	Argillaceous salts	S_AO	330 Pink Plug Dolomite (>50cm)
[illegible]	SR	100	Crosspatrick	BR_C	130	Vein / Stringer Sulphides	W_VS	250	Disseminated Sulphides	S_DS	340 Significant fault zone
[illegible]	BR_D	110	Upper Crosspatrick	BR_UC	132	Massive Sulphide	W_MS	260	Vein / Stringer Sulphides	S_VS	350 Fault zone with sulphides
[illegible]	BR_UD	112	Lower Crosspatrick	BR_LC	134	Lower Transition Unit	W_LTU	270	Massive Sulphide	S_MS	360 Large Cavity (>30cm)
[illegible]	BR_MD	114	Waulsortian	W	190	Lower Limestone Lens	W_LLL	280	Sub-ABL Breccias	S_LLS	370 Weathering obscures lithology
[illegible]	BR_LD	116	Upper Transition Unit	W_UTU	200	Sub-Waulsortian	S	290	DMB	L_[illegible]	400 0-10 degree fault
[illegible]	BR_A	120	Oolitised Biomicrite	W_[illegible]	210	Nodular Micrite	S_HD	300	Hydrothermal Dolomite	L_HO	410 0-10 degree bedding
[illegible]	BR_UA	122	Wavy Laminated Facies	W_WL	220	ABL	S_ABL	310	VMB - well developed	L_WMB	420

GARAGE – [illegible] --

LC JARVIS

E-MAIL EDJA EYARROW@ANGLOAMERICAN.CO...

469

→ D. [illegible]

+ 6?? 684145?

GEOLOGICAL CORE LOGGING SHEET

MINORCO

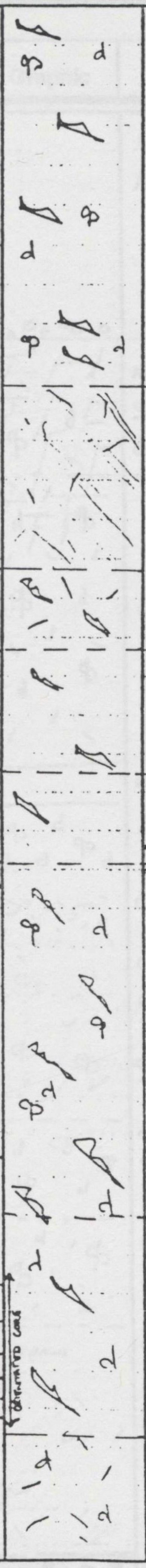
Page 3 of 3
Area:
Logged by:
Sect:
Plan:
Scale 1:

Angle:
Bearing:
E:
N:
Z:

Survey					
Depth	Angle	Bear.	Depth	Angle	Bear.

Notes
BHC.3

TAG	TCR (%)	RQD (%)	Depth	Structure Description	ACA	Lithology Description	Depth	Sph	Gal	Pyrite	Sample
	100%	83%		DIPS c. 50-65° (? TO N ??)		OCCASIONAL MINOR PRCT. DOL- SYNTAXING ~5% OR LESS.					
41.5	100%	100%									
44.5	100%	97%				44.8 ZONE TO STEEP ~70-80° TO C.A. LAMINATED BIOMICRITES; MINOR LITHOLOGY					
47.5	100%	100%		KP_MS SAMPLES	47.15 48.15 49.7 50.9	47.15 FELTY-CHAOTIC STROM CAVITIES - MINOR LITHOLOGY 48.15 ! ZONE OF V. SECTORIAL PRE. SPAR. CMTS. EARLY CT. CEMENT. AT. COULD BE DOL OR LITHO !? TOO FINE CRYST TO TELL. PROB LITHO ← 49.7 ? MINOR PREC, FINE Sph. AS SYNTAXITES + LINING CAVITIES - SP. HABIT ETC.					
50.5	100%	50%		VERTICAL; RANDOM; IRREGULAR FE-STAINED (FES=1) JOINT.	51.02	FIBROUS-FELTY BIOMICRITES; CHAOTIC STROM RICH +/- MINOR DOL + LITHOLOGY					
53.5	100%	93%		BEDDING PAR-DOM. DIPS N @ ≈ 50/55°. BEDDING 60° → 360° B-DR LNG 60/65° → 355°	54.5	DOL ↑ ▽ 55.1					
56.5	100%	97%	DEBATABLE	? B-STR 40 → 020 ? B-DR LNG 60/70° → 030 B-STR 35 → 325 B-STR+DR LNG 70° → 360 B-LNG 55/60 → 030	56.4 56.9 57.3 57.6 57.9 58.15 ORIENTATED CORE	PARTIALLY DOLOMITISED CAVITY RICH BIOMICRITES + DR: 35/40%. 58.35 PART. DOL BIOMICS ~40%					
59.5			22/02/91	INFORMED SAM I WISHED TO TURN RIG ABOUT + DRILL TO S @ -75°							



Overburden	O_OB	100 Middle Aghmacart	BR_MA	124 Encrinite	W_BO	230 Oolites	S_OO	330 Zone of ironstone alteration	L_PEA	430
Undifferentiated weathered rock	O_WR	200 Lower Aghmacart	BR_LA	126 Disseminated Sulphides	W_DS	240 Argillaceous oolite	S_AO	380 Post Plug Dolomite (>50cm)	L_PD	470
Tops-out	BR	100 Crosspatrick	BR_C	130 Vein / Stringer Sulphides	W_VS	250 Disseminated Sulphides	S_DS	340 Significant fault zone	F_FZ	500
Durrow	BR_D	110 Upper Crosspatrick	BR_UC	132 Massive Sulphides	W_MS	260 Vein / Stringer Sulphides	S_VS	360 Fault zone with sulphides	F_DS	540
Upper Durrow	BR_UD	112 Lower Crosspatrick	BR_LC	134 Lower Transition Unit	W_LTU	270 Massive Sulphides	S_MS	360 Large Cavity (.30cm)	F_CAV	610
Middle Durrow	BR_MD	114 Waulsortian	W	160 Lower Limestone Lens	W_LLL	300 Sub-ABL Shales	S_LLS	370 Weathering obscures lithology	F_WTD	630
Lower Durrow	BR_LD	116 Upper Transition Unit	W_UTU	200 Sub-Waulsortian	S	370 MMS	L_SMB	400 0-10 degree fault	F_10	610
Aghmacart	BR_A	120 Dolomitised Biomicrite	W_BM	210 Modular Micrite	S_NM	300 Hydrothermal Dolomite	L_HD	410 0-10 degree bedding	B_10	710
Upper Aghmacart	BR_UA	122 Wavy Laminated Packes	W_WL	220 ABL	S_ABL	310 WMB - well developed	L_WMB	430		

152067

470

01-3626-03 101146.1 181526.4E

GEOLOGICAL CORE LOGGING SHEET

BHC.8 **ANGLO AMERICAN**

1 of ~~4~~ 3 **Area:** CURTINS FARM

Logged by: CMC

Sect:
Plan:

Scale 1: 100

A.L **Angle:** -80 **Bearing:** 180

26/04/01 **E:**

01/05/01 **N:**

322.2 M. **Z:** . .

Survey					
Depth	Angle	Bear.	Depth	Angle	Bear.
10	-79	195.6			

Notes
dips not corrected for c.a
DIPS MEASURES RELATIVE TO SHORT CORE AXIS.

TAG	TCR (%)	RQD (%)	Depth	Structure Description	ACA	Lithology Graphic	Lithology Description	Depth	Sph	Gal	Pyrite	Sample

Overburden.
Minor Waulsortian fragments

2.90

V. broken ground
Superficial Weathering
rounded weathered fragments

Felty Fibrous dolomitised 'WMC'
Spar bands.
Dol. >50 (~65%)
light grey-buff dolomite

(140)

5.40 — MAST → 70 ⊥ → c.a

7.10 b-str 55 ⊥ → c.a

(202)

8.15 b-str 50 → 160° (spar band)

8.20

WMC Homogenous → Bionic with minor str.

9.10

9.3 — —
Fractured broken ground.
Dissolution of Lime st

Increase in buff brown dol. — good development. Felty fibrous by Bionic.

10.2 — —

Calcite brecciation
↓ Full Porcelyn Brec. texture
Cavities → 60% CAL → 40% DOL

(164)

Re xstallised - homogenising WMC. to light pastel-blue grey limestone with brecciated bands

40

15.0

Patchy Grainstone with re xstallised and dolomitised areas d < 25%.

(283)

↑ General steep dipping fabric in grainstone

orientation looks to be reversed

No evidence for Structure above or below.

14.2

Felty fibrous, part dol (buff-grey) by. bionic

100

13.6 St. vy soft
0.15
(N 0.)

TRANS

Homog - Pure, re xstalls

(245)

Brec. whispy bionic → later X cutting re xstld with bionic clast (Bx) + CAL CAVS

17.4

↳ Shearing of clasts

Whispy sino - steep dipping

100

16.55 b-udp - 60 ⊥ → c.a 135°

16.90 s.lam - 45 → 50°
17.25 St.str 45 → c.a (grainstone)
b-lag 45 → 130°

Grainstone.

Pale dol —

- rept dol

- str

infill

Stain.

01-3626-03

GEOLOGICAL CORE LOGGING SHEET

BHC-8 ANGLO AMERICAN

2 of ~~?~~ 3 Area: CURTINS FARM

Logged by: CMC

Sect:
Plan:

Scale 1: 100

A.L Angle: -80 Bearing: 120

[illegible].04.01 E:

[illegible].05.01 N:

322.2 m Z:

Survey						Notes
Depth	Angle	Bear.	Depth	Angle	Bear.	

TCR (%)	RQD (%)	Depth	Structure Description	ACA	Lithology Description	Depth	Sph	Gal	Pyrite	Sample
					Continuation.					
					Partially homog. biomic + pore bals					
					CAL Bx whispy veinlets & full homog					
					areas.					
					Fabric orientations vary.					
					25-40% dol!					
				23.??	(Increasingly Elastic - whisps. almost varies blear-)					
		24.8	b-avg str _ 45->c.a							
		24.95	b-str _ 35->c.a							
					↓ increase in homog of rock.					
		[illegible]	b-log 45->c.a		Increase in clasts - minor crinoidal Grainstone					
					Grades into Fibrous bag. rck					
					+ patches of V. whispy Fabric					
		25.8	b-str 45->c.a (180°)							
		25.[illegible]	↓ 30-40 ->H.A. whisps 80 ⊥-> [illegible] 65°->c.a ->165°							
	(Debatable)	29.90	b-log 35-40//->c.a->165°		homogenous Grainstone and					
		30.0	vein (dom calcite)	30						
		31.	series of veinlets 80% Dol-Gran Bx - 30-50° //->c.a ->065 L 075 [illegible]		Veined Bx. Increase in buff dol >85%.	See Bali	(T.S)			
		31.4	VEINED -> Full Dol + small X cutting CAL veins		Much veining - Full dolo of rock with X cutting CAL veins					
		32			Felty Fibrous fabric - overprinted calcite [illegible] of dolostone					
			vein - 70 ⊥->c.a ->280			1 UNIT?				
					Felty Fibrous, bag. Biomic					
		[illegible]	Sheet spar ->65 ⊥->c.a-170		+ whispy fabric					
		32.75	[illegible] 45°->170.							
					↑60% buff dol ↓<25% buff dol					
		34.6	Series of veinlets 0.5-1cm [illegible] 30-70 ⊥->c.a 140-190 DOL/CAL 50/50							
		[illegible]	->160		Increase in CAL fabric					
		[illegible]	sheet spar - 60 ⊥->c.a - 170		↑ in whispy fabric					
					Sheet Spa					
					Felty Fibrous. bag WMC Biomic					
					patchy sheet spar					
		[illegible]	b-str 45° ⊥ ->175°							
		[illegible]	b-str 50 ⊥ ->165°		Crinoid + bag stems					
	(debatable)	[illegible]	b-str 40-50 ⊥ ->155°							

1-3626 - 03

GEOLOGICAL CORE LOGGING SHEET

BHC.8

ANGLO AMERICAN

3 of ~~4~~ 3 **Area:** CURTINS FARM

Logged by: CMC

Sect:
Plan:

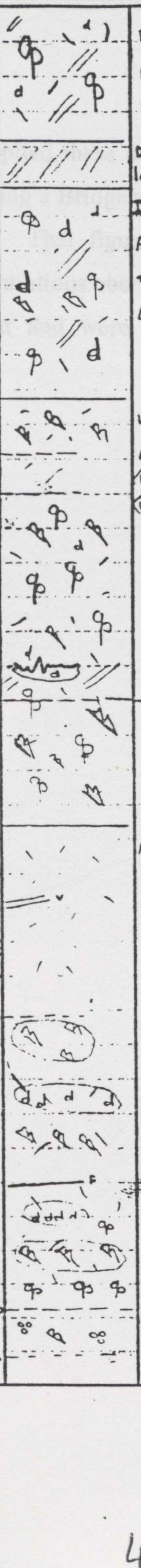
Scale 1: 100

Angle: -80
Bearing: 180
E: 0401
N: 05.01
Z: 322.2 m

Survey						Notes
Depth	Angle	Bear.	Depth	Angle	Bear.	

TCR (%)	RQD (%)	Depth	Structure Description	ACA
		40.85	b_sty 45-50°⊥ -> 160°	
	(245)			
	100	42.25	b-ssp - 60⊥ -> c.a	
		42.33	b-ssp - 60-65⊥ -> c.a	42.??
		43.??	b-st _ 55-60⊥ h -> 005 (orotuned ford sugd ?)	
	206	43.70	b-str - 60⊥ -> 005 (steep sheet spar)	
		(dependable) 44.00	b-st _ 45-50⊥ -> 170°	
		44.? 44.??	BG 44.55 b-str _ 40⊥ 175 44.68 " _ 45⊥ 150 44.85 " _ 40⊥ 175 44.70 " _ 40 ⊥ 160	44.75
	100	45.50	b-str 40⊥ -> c.a	45.6
		46.5	H.4.ST 80⊥ -> c.a	
	(228)			
				47.8
		48.50	b-lag 45⊥ -> 010°	
		48.55	b-lag 40 ⊥ -> 005	
	100	48.55	b-str 30 ⊥ -> 145°	
		48.60	b-str 60 ⊥ -> 160°	
		48.6	b-str 45-50 ⊥ -> 155°	
		49.5	Buff dol ? ? -b// sty	
		49.?	b-ssp - 60⊥ -> 140°	
	(290)	50	Buff dol -> sty/fracture	50.30
	100	51.60	b-str 60 ⊥ -> 170	
		51.75	b-str 40 ⊥ -> 180	51.9
	(238)	51.85	vein buff clay(?) + green org. 60 ⊥ -> 175°	
		53.70	b-ssp 50⊥ -> 175°	53.??
	100	54.70	buff clay? striatic (?)	
				56.25
		56.50	b-lag 50°⊥ -> 180°	
		56.55	b-lag 50⊥ -> 170°	
		57.20	F_40->120(?) slicken lines	
		57.30	b-str 60⊥ -> 155°	
		57.14	b-lag 55⊥ -> 150°	
		57.70	b-ssp 45⊥ -> 170°	
		57.80	b-lag 65 ⊥ -> 1??	58.70
		59.??	b-str 45-50⊥ -> 150	59.0

Lithology



Description

50-55%
Felly Fibros, buff dolo, bay reef
patchy sheet spar - bedding // sty
(3mm amplitude) — diag. sty

Decrease in buff dol
Increase in white grey sheet spar

~~Increase~~ in buff dolomite
Felly Fibros, by Bianc + patchy sheet spar
tractor reezes blue dendro - from Reef
Dol 50%

White-blue (venus Blau)
Decrease in sheet spar
(High sheet spar)
(Low sheet spar)
Increase in buff dol - 40%
Felly Fibros by Bianc with patch area
of bry-rich unit
Med-~~dark~~ blue Bianc + white dog-spar
cav. infills
Dol < 25% - 35?
Dol < 25
Med-dark blue - less Dol
↑ in spar cav, bry. rich WMC

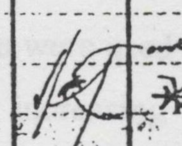
Paler limestone, ↓ in dol < 25?
light blue grey colour

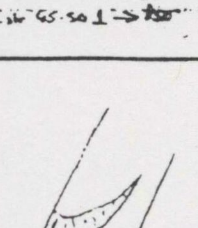
(bry rich area ? bar

<25% dol (some patch buff dol)
Patchy bry rich portings
Pale grey blue (purple tinge, Mauve) Bianic
More Felly & Fibros toward Bar

Partial Granoline dol < 5%
minor bay fronds.

Depth	Sph	Gal	Pyrite	Sample





APPENDIX C

DOWNING'S BRIDGE PUBLIC SUPPLY BOREHOLE

HYDROCHEMICAL DATA 1999-2003

(Cork County Council, 1998, 2003)

Cork County Council supplied these data. They concern groundwater nitrate concentrations abstracted from the Downing's Bridge public supply borehole. These data were used to create Figure 4.6, chapter four. That figure demonstrates the continuously increasing trend in groundwater nitrate concentrations observed in the last twenty years. Data were supplied in the NO_3 concentration format and were converted, by myself, to the NO_3-N concentration equivalent.

Downing's Bridge Public Supply Borehole

	Groundwater			Groundwater	
Date (d/m/y)	NO3 (mg/l)	NO3-N (mg/l)	Date (d/m/y)	NO3	NO3-N (mg/l)
10/11/1983	9.7	2.2	08/02/1999	36.2	8.2
28/11/1983	12.0	2.7	02/03/1999	34.7	7.8
29/11/1983	14.0	3.2	07/04/1999	37.2	8.4
30/11/1983	12.0	2.7	12/05/1999	32.8	7.4
01/12/1983	22.0	5.0	09/07/1999	41.3	9.3
01/12/1983	26.6	6.0	07/09/1999	40.1	9.1
02/04/1991	33.8	7.6	03/11/1999	27.3	6.2
19/11/1991	62.3	14.1	03/02/2000	40.9	9.2
27/05/1992	35.6	8.0	10/04/2000	39.5	8.9
20/07/1992	36.9	8.3	31/05/2000	39.0	8.8
30/03/1993	71.2	16.1	04/09/2000	40.5	9.2
29/07/1993	31.2	7.0	23/10/2000	37.9	8.6
09/02/1994	40.3	9.1	27/11/2000	39.6	8.9
06/07/1994	37.7	8.5	31/01/2001	38.7	8.7
14/09/1994	38.6	8.7	22/02/2001	44.4	10.0
14/03/1995	40.7	9.2	29/03/2001	45.2	10.2
24/05/1995	40.8	9.2	17/04/2001	44.7	10.1
10/07/1995	53.0	12.0	21/05/2001	43.8	9.9
05/02/1996	39.1	8.8	21/06/2001	45.9	10.4
24/06/1996	35.7	8.1	23/07/2001	43.7	9.9
12/12/1996	48.0	10.8	21/08/2001	45.7	10.3
02/02/1996	42.0	9.5	27/09/2001	47.4	10.7
03/03/1996	41.0	9.3	22/10/2001	46.1	10.4
04/04/1996	45.0	10.2	22/11/2001	44.8	10.1
06/06/1996	40.0	9.0	17/12/2001	47.8	10.8
08/08/1996	45.0	10.2	28/01/2002	46.0	10.4
09/09/1996	40.0	9.0	12/03/2002	45.1	10.2
10/10/1996	42.0	9.5	29/04/2002	43.0	9.7
11/11/1996	44.0	9.9	29/07/2002	42.8	9.7
12/12/1996	46.0	10.4	20/08/2002	40.3	9.1
10/01/1997	43.0	9.7	12/09/2002	40.1	9.1
02/02/1997	49.0	11.1	30/10/2002	44.7	10.1
04/04/1997	46.0	10.4	29/11/2002	44.4	10.0
12/12/1997	46.5	10.5	13/03/2003	47.2	10.7
02/02/1998	43.0	9.7	07/04/2003	29.5	6.7
06/06/1998	44.0	9.9	20/05/2003	47.0	10.6
12/12/1998	45.0	10.2	08/07/2003	45.0	10.2
18/01/1999	32.1	7.3	06/08/2003	31.0	7.0
			11/09/2003	42.4	9.6
			09/10/2003	41.7	9.4

APPENDIX D

National Federation of Group Water Schemes
Summary Report on Samples of Raw Untreated Groundwater Data
November 2000 – November 2001

The National Federation of Group Water Schemes supplied this report on regional groundwater quality. The report is prepared each year based on monthly sampling for a range of physical and hydrochemical parameters. A map showing sampling locations was also provided and is included in this appendix. In my work, only the groundwater nitrate concentrations were used to generate a regional characterisation of groundwater nitrate status at the beginning of installation and monitoring at Curtin's farm. These data were used to create Figure 4.7, chapter four (see section 4.2.9).

National Federation of Group Water Schemes
Society Ltd.
Knockboy, Lissarda, Co. Cork *Tel:* (021) 7336691 *Fax:* (021) 7336691

22 – 10 - 03

Dear Pamela,

Find enclosed the map of Cork North as promised long ago.

The Scheme are as follows;

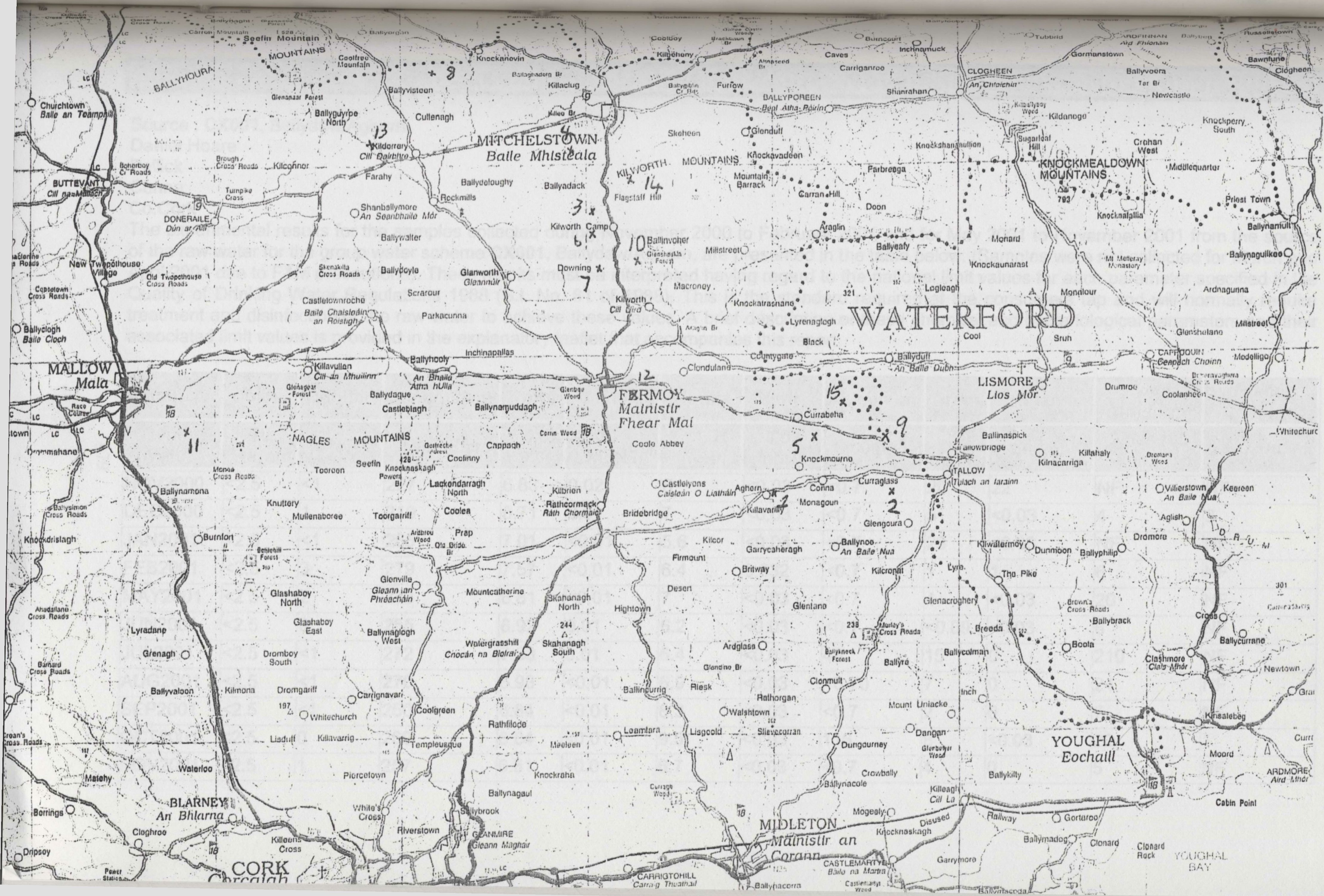
1. Aghern/Baldaw
2. Curraglass
3. Caherdrinny
4. Carriganleigh/Ballykerney
5. Clashaganniv
6. Curraghalla
7. Downing
8. Graigue
9. Kilcornan
10. Kilally
11. Knoppoge
12. Strawhall
13. Tankardstown
14. Turbeigh
15. Waterpark

Hope this is helpful

Send me the executive summary of your thesis when you have it finished. I look forward to reading it.

Yours Sincerely

David N. Murphy



Seefin Mountain
BALLYHOURA MOUNTAINS
Churchtown
Baile an Teampaill
Buttevant
Cill na Mallach
Doneraile
Dún ar Aill
New Twopothouse Village
Ballyclogh
Baile Cloch
MALLOW
Mala
NAGLES MOUNTAINS
Knockanevin
Kildorrery
Cill Dairbhre
MITCHELSTOWN
Baile Mhisteala
Kilworth Camp
Glanworth
Gleannúir
Kilworth
Cill Uird
Ballyhooly
Castlelyons
Caisleán Ó Liatháin
Rathcormack
Ráth Chormaic
FERMOY
Mainistir Fhear Maí
KILWORTH MOUNTAINS
Ballyporeen
Béal Átha Póirín
CLOGHEEN
An Chloichín
KNOCKMEALDOWN MOUNTAINS
Ballyduff
An Baile Dubh
WATERFORD
LISMORE
Lios Mór
Cappoquin
Ceapach Choinn
TALLOW
Tulach an Iarainn
Conna
Villierstown
An Baile Nua
YOUGHAL
Eochaill
MIDLETON
Mainistir an Corann
BLARNEY
An Bhlarna
CORK
Corcaigh
GLANMIRE
Gleann Maghair
Carrigtohill
Carraig Thuathail
Castlemartyr
Baile na Martra
Ardmore
Aird Mhór
Youghal Bay
13
8
4
3
14
61
7
10
12
15
9
5
11
1
2

Summary Report on Samples of Raw Untreated Water, November 2000 to November 2001

Source : **CX001**, Ballydaw/Aghern
Daniel Hoare
Pellick
Conna
Co.Cork

The experimental results for the samples collected during November 2000 to February 2001 and for May 2001 to November 2001 from the source of the raw water for the group water scheme **CX001**, Ballydaw/Aghern, are presented in the table below. (Samples were not collected for March and April 2001 due to F&M precautions). These results must be interpreted having regard to the national limit values for each parameter specified in the Quality of Drinking Water Regulations 1988 (S.I. No. 81 of 1988). This is the standard required at the consumers tap and will normally require treatment and disinfection of the raw water to achieve these values. A brief description of these chemical and bacteriological parameters and their associated limit values is provided in the explanatory leaflet that accompanies this report.

Parameter	Colour	Turbidity	Conductivity	pH	Ammonia	Nitrate	Nitrite	Aluminium	Iron	Manganese	Total Coliform	Faecal Coliform
Limit Value	**20 Hazen**	**4 NTU**	**1500 µS/cm**	**6.0 to 9.0**	**0.23 mgN/l**	**11.3 mgN/l**	**0.03 mgN/l**	**200 µg/l**	**200 µg/l**	**50 µg/l**	**0 per 100 ml**	**0 per 100 ml**
NOV2000	<2.5	<1	227	6.83	0.02	5	<0.03	<0.7	20	22	NF	NF
DEC2000	<2.5	1	210	6.71	0.01	7	<0.03	<0.7	5	<0.03	4	3
JAN2001	<2.5	<1	265	7.01	<0.01	5.6	<0.03	<0.7	23	<0.03	NF	NF
FEB2001	<2.5	3	279	7.57	<0.01	6.4	0.032	<0.7	1	1	6	NF
MAY2001	<2.5	2	273	6.81	<0.01	7	<0.03	<0.7	4	<0.03	20	NF
JUN2001	<2.5	0	255	6.92	0.01	6.2	<0.03	<0.7	<0.09	<0.03	6	NF
JUL2001	<2.5	<1	272	7.33	0.01	6.4	<0.03	48	15	0	210	NF
AUG2001	<2.5	<1	270	6.98	<0.01	6.9	<0.03	<0.70	7	0	24	NF
SEP2001	<2.5	<1	250	6.84	<0.01	8.3	<0.03	<0.7	2	0	7	NF
OCT2001	<2.5	0	269	6.84	<0.01	9.5	<0.03	116	8	<0.03	22	1
NOV2001	<2.5	1	257	6.81	<0.01	6.7	<0.03	<0.7	4	0	5	NF

Summary Report on Samples of Raw Untreated Water, November 2000 to November 2001

Source : **CX002**, Blackpool/Curraglass
Rose Hickey
Curraglass
Mallow
Co.Cork

The experimental results for the samples collected during November 2000 to February 2001 and for May 2001 to November 2001 from the source of the raw water for the group water scheme **CX002**, Blackpool/Curraglass, are presented in the table below. (Samples were not collected for March and April 2001 due to F&M precautions). These results must be interpreted having regard to the national limit values for each parameter specified in the Quality of Drinking Water Regulations 1988 (S.I. No. 81 of 1988). This is the standard required at the consumers tap and will normally require treatment and disinfection of the raw water to achieve these values. A brief description of these chemical and bacteriological parameters and their associated limit values is provided in the explanatory leaflet that accompanies this report.

Parameter	Colour	Turbidity	Conductivity	pH	Ammonia	Nitrate	Nitrite	Aluminium	Iron	Manganese	Total Coliform	Faecal Coliform
Limit Value	**20 Hazen**	**4 NTU**	**1500 µS/cm**	**6.0 to 9.0**	**0.23 mgN/l**	**11.3 mgN/l**	**0.03 mgN/l**	**200 µg/l**	**200 µg/l**	**50 µg/l**	**0 per 100 ml**	**0 per 100 ml**
NOV2000	<2.5	1	211	6.61	0.02	6.5	<0.03	<0.7	19	22	NF	NF
DEC2000	<2.5	<1	222	6.69	<0.01	10	<0.03	<0.7	8	<0.03	NF	NF
JAN2001	<2.5	<1	277	7.18	<0.01	6.4	<0.03	<0.7	9	<0.03	2	NF
FEB2001	<2.5	0	364	7.9	<0.01	5.3	<0.03	<0.7	1	1	NF	NF
MAY2001	<2.5	1	254	6.45	<0.01	4.9	<0.03	<0.7	212	<0.03	NF	NF
JUN2001	<2.5	2	243	6.61	0.02	5.8	<0.03	<0.7	1185	20	NF	
JUL2001	<2.5	<1	255	6.75	0.02	6	<0.03	88	11	0	2	1
AUG2001	<2.5	<1	267	7.6	<0.01	5.2	<0.03	<0.70	327	4	NF	NF
SEP2001	<2.5	<1	243	6.6	<0.01	7.2	<0.03	<0.7	2	0	NF	NF
OCT2001	<2.5	0	256	6.62	<0.01	6.2	<0.03	77	112	<0.03	2	NF
NOV2001	<2.5	1	245	6.77	<0.01	5.9	<0.03	<0.7	25	2	NF	NF

Summary Report on Samples of Raw Untreated Water, November 2000 to November 2001

Source : **CX003**, Caherdrinny
Ned Roche
Caherdrinny
Kilworth
Co Cork

The experimental results for the samples collected during November 2000 to February 2001 and for May 2001 to November 2001 from the source of the raw water for the group water scheme **CX003**, Caherdrinny, are presented in the table below. (Samples were not collected for March and April 2001 due to F&M precautions). These results must be interpreted having regard to the national limit values for each parameter specified in the Quality of Drinking Water Regulations 1988 (S.I. No. 81 of 1988). This is the standard required at the consumers tap and will normally require treatment and disinfection of the raw water to achieve these values. A brief description of these chemical and bacteriological parameters and their associated limit values is provided in the explanatory leaflet that accompanies this report.

Parameter	**Colour**	**Turbidity**	**Conductivity**	**pH**	**Ammonia**	**Nitrate**	**Nitrite**	**Aluminium**	**Iron**	**Manganese**	**Total Coliform**	**Faecal Coliform**
Limit Value	**20 Hazen**	**4 NTU**	**1500 µS/cm**	**6.0 to 9.0**	**0.23 mgN/l**	**11.3 mgN/l**	**0.03 mgN/l**	**200 µg/l**	**200 µg/l**	**50 µg/l**	**0 per 100 ml**	**0 per 100 ml**
MAY2001	<2.5	1	148.2	5.67	<0.01	3.7	<0.03	<0.7	361	<0.03	4	NF
JUN2001	<2.5	0	168.2	6.32	<0.01	3.5	<0.03	<0.7	14	1	3	NF
JUL2001	<2.5	<1	144.1	6.1	<0.01	3.5	<0.03	54	25	2	13	NF
AUG2001	<2.5	<1	285	7.03	<0.01	4.6	<0.03	<0.70	25	3	1	NF
SEP2001	<2.5	<1	283	6.73	<0.01	5.6	<0.03	74	<0.09	0	NF	NF
OCT2001	<2.5	0	291	6.76	<0.01	3.4	<0.03	101	610	0	10	NF

Summary Report on Samples of Raw Untreated Water, November 2000 to November 2001

Source : **CX004A**, Carriganleigh/Ballykerney A
John Roche
Ballykerney
Mitchelstown
Co.Cork

The experimental results for the samples collected during November 2000 to February 2001 and for May 2001 to November 2001 from the source of the raw water for the group water scheme **CX004A**, Carriganleigh/Ballykerney A, are presented in the table below. (Samples were not collected for March and April 2001 due to F&M precautions). These results must be interpreted having regard to the national limit values for each parameter specified in the Quality of Drinking Water Regulations 1988 (S.I. No. 81 of 1988). This is the standard required at the consumers tap and will normally require treatment and disinfection of the raw water to achieve these values. A brief description of these chemical and bacteriological parameters and their associated limit values is provided in the explanatory leaflet that accompanies this report.

Parameter	Colour	Turbidity	Conductivity	pH	Ammonia	Nitrate	Nitrite	Aluminium	Iron	Manganese	Total Coliform	Faecal Coliform
Limit Value	**20 Hazen**	**4 NTU**	**1500 µS/cm**	**6.0 to 9.0**	**0.23 mgN/l**	**11.3 mgN/l**	**0.03 mgN/l**	**200 µg/l**	**200 µg/l**	**50 µg/l**	**0 per 100 ml**	**0 per 100 ml**
NOV2000	<2.5	<1	427	7.54	0.02	2.2	<0.03	<0.7	11	22	NF	NF
DEC2000	<2.5	<1	435	7.69	0.01	1.2	<0.03	<0.7	16	<0.03	NF	NF
JAN2001	<2.5	<1	517	7.77	<0.01	1.5	<0.03	<0.7	12	<0.03	1	NF
FEB2001	<2.5							<0.7	0	<0.03		
MAY2001	<2.5	<1	170	7.28	0.01	1.8	<0.03	<0.7	<0.09	<0.03	NF	NF
JUN2001	<2.5	0	460	7.42	<0.01	2	<0.03	<0.7	7	4	NF	NF
JUL2001	<2.5	<1	488	7.6	<0.01	1.3	<0.03	107	<0.09	<0.03	NF	NF
AUG2001	<2.5	<1	516	7.51	0.01	2.6	<0.03	<0.70	14	0	NF	NF
SEP2001	<2.5	<1	474	7.82	<0.01	3.1	<0.03	87	0	0	NF	NF
OCT2001	<2.5	0	507	7.47	<0.01	2.1	<0.03	70	1178	1	NF	NF
NOV2001	<2.5	<1	485	7.6	0.01	2.5	<0.03	<0.7	<0.09	<0.03	NF	NF

Summary Report on Samples of Raw Untreated Water, November 2000 to November 2001

Source : **CX004B**, Carriganleigh/Ballykerney B
John Roche
Ballykerney
Mitchelstown
Co.Cork

The experimental results for the samples collected during November 2000 to February 2001 and for May 2001 to November 2001 from the source of the raw water for the group water scheme **CX004B**, Carriganleigh/Ballykerney B, are presented in the table below. (Samples were not collected for March and April 2001 due to F&M precautions). These results must be interpreted having regard to the national limit values for each parameter specified in the Quality of Drinking Water Regulations 1988 (S.I. No. 81 of 1988). This is the standard required at the consumers tap and will normally require treatment and disinfection of the raw water to achieve these values. A brief description of these chemical and bacteriological parameters and their associated limit values is provided in the explanatory leaflet that accompanies this report.

Parameter	Colour	Turbidity	Conductivity	pH	Ammonia	Nitrate	Nitrite	Aluminium	Iron	Manganese	Total Coliform	Faecal Coliform
Limit Value	20 Hazen	4 NTU	1500 µS/cm	6.0 to 9.0	0.23 mgN/l	11.3 mgN/l	0.03 mgN/l	200 µg/l	200 µg/l	50 µg/l	0 per 100 ml	0 per 100 ml
NOV2000	<2.5	<1	425	7.52	0.02	2.4	<0.03	<0.7	21	22	NF	NF
DEC2000	<2.5	<1	433	7.6	<0.01	1.8	<0.03	<0.7	<0.09	<0.03	NF	NF
JAN2001	<2.5	2	498	7.64	<0.01	1.7	<0.03	<0.7	8	<0.03	NF	NF
FEB2001	<2.5	3	508	7.91	<0.01	2.8	<0.03	<0.7	4	1	NF	NF
MAY2001	<2.5	1	505	7.34	<0.01	1.8	<0.03	<0.7	<0.09	54	NF	NF
JUN2001	<2.5	0	466	7.40	0.01	6.2	<0.03	<0.7	2	<0.03	NF	NF
JUL2001	<2.5	<1	512	7.6	<0.01	2.2	<0.03	93	6	<0.03	NF	NF
AUG2001	<2.5	<1	515	7.34	0.01	2.5	<0.03	<0.70	1	0	NF	NF
SEP2001	<2.5	2	462	7.95	<0.01	3.3	<0.03	67	0	0	NF	NF
OCT2001	<2.5	0	495	7.49	<0.01	2.4	<0.03	110	82	1	34	NF
NOV2001	<2.5	2	489	7.62	0.01	2.8	<0.03	<0.7	<0.09	<0.03	NF	NF

Summary Report on Samples of Raw Untreated Water, November 2000 to November 2001

Source : **CX005**, Clasaganniv
Tom Roche
Clashaganniv
Conna
Co.Cork

The experimental results for the samples collected during November 2000 to February 2001 and for May 2001 to November 2001 from the source of the raw water for the group water scheme **CX005**, Clasaganniv, are presented in the table below. (Samples were not collected for March and April 2001 due to F&M precautions). These results must be interpreted having regard to the national limit values for each parameter specified in the Quality of Drinking Water Regulations 1988 (S.I. No. 81 of 1988). This is the standard required at the consumers tap and will normally require treatment and disinfection of the raw water to achieve these values. A brief description of these chemical and bacteriological parameters and their associated limit values is provided in the explanatory leaflet that accompanies this report.

Parameter	**Colour**	**Turbidity**	**Conductivity**	**pH**	**Ammonia**	**Nitrate**	**Nitrite**	**Aluminium**	**Iron**	**Manganese**	**Total Coliform**	**Faecal Coliform**
Limit Value	**20 Hazen**	**4 NTU**	**1500 µS/cm**	**6.0 to 9.0**	**0.23 mgN/l**	**11.3 mgN/l**	**0.03 mgN/l**	**200 µg/l**	**200 µg/l**	**50 µg/l**	**0 per 100 ml**	**0 per 100 ml**
NOV2000	<2.5	<1	226	6.42	0.02	8.2	<0.03	<0.7	13	22	1	NF
DEC2000	<2.5	<1	236	6.32	<0.01	4.8	<0.03	<0.7	12	<0.03	NF	NF
JAN2001	<2.5	<1	259	6.86	<0.01	6	<0.03	<0.7	12	<0.03	7	NF
FEB2001	<2.5	0	292	7.44	<0.01	6.2	<0.03	<0.7	<0.09	1	17	NF
MAY2001	<2.5	<1	264	6.14	<0.01	6	<0.03	<0.7	<0.09	<0.03	NF	NF
JUN2001	<2.5	0	248	6.37	<0.01	5.8	<0.03	<0.7	<0.09	0	NF	NF
JUL2001	<2.5	<1	280	6.65	0.01	6.2	<0.03	80	11	0	15	NF
AUG2001	<2.5	<1	263	6.41	<0.01	6	0.066	<0.70	6	1	2	NF
SEP2001	<2.5	<1	238	6.15	<0.01	3	<0.03	<0.7	<0.09	0	4	NF
OCT2001	<2.5	0	257	6.44	0.01	2.8	<0.03	102	<0.09	0	28	NF
NOV2001	<2.5	1	245	6.38	<0.01	6.1	<0.03	<0.7	<0.09	0	40	NF

Summary Report on Samples of Raw Untreated Water, November 2000 to November 2001

Source : **CX006**, Curraghalla
Michael Casey
Curraghalla
Kilworth
Co.Cork

The experimental results for the samples collected during November 2000 to February 2001 and for May 2001 to November 2001 from the source of the raw water for the group water scheme **CX006**, Curraghalla, are presented in the table below. (Samples were not collected for March and April 2001 due to F&M precautions). These results must be interpreted having regard to the national limit values for each parameter specified in the Quality of Drinking Water Regulations 1988 (S.I. No. 81 of 1988). This is the standard required at the consumers tap and will normally require treatment and disinfection of the raw water to achieve these values. A brief description of these chemical and bacteriological parameters and their associated limit values is provided in the explanatory leaflet that accompanies this report.

Parameter	Colour	Turbidity	Conductivity	pH	Ammonia	Nitrate	Nitrite	Aluminium	Iron	Manganese	Total Coliform	Faecal Coliform
Limit Value	**20 Hazen**	**4 NTU**	**1500 µS/cm**	**6.0 to 9.0**	**0.23 mgN/l**	**11.3 mgN/l**	**0.03 mgN/l**	**200 µg/l**	**200 µg/l**	**50 µg/l**	**0 per 100 ml**	**0 per 100 ml**
NOV2000	<2.5	<1	267	6.8	0.02	4.7	<0.03	<0.7	18	22	NF	NF
DEC2000	<2.5	<1	262	6.76	0.01	4.1	<0.03	<0.7	5	<0.03	6	NF
JAN2001	<2.5	<1	300	7.39	<0.01	4.9	<0.03	<0.7	8	<0.03	NF	NF
FEB2001	<2.5	0	351	8.1	<0.01	5.5	<0.03	<0.7	0	1	NF	NF
MAY2001	<2.5	10	307	6.84	<0.01	2.6	<0.03	<0.7	<0.09	<0.03	86	NF
JUN2001	<2.5	0	300	7.07	<0.01	5	<0.03	<0.7	40	0	3	NF
JUL2001	<2.5	<1	330	7.35	<0.01	5.4	<0.03	115	<0.09	<0.03	12	NF
AUG2001	<2.5	<1	323	8.11	<0.01	5	<0.03	<0.70	0	0	7	NF
SEP2001	<2.5	<1	296	6.74	<0.01	6.7	<0.03	<0.7	<0.09	<0.03	NF	NF
OCT2001	<2.5	0	316	6.85	<0.01	2.8	<0.03	74	7	<0.03	33	NF
NOV2001	<2.5	1	266	6.76	<0.01	6.5	<0.03	<0.7	<0.09	<0.03	NF	NF

Summary Report on Samples of Raw Untreated Water, November 2000 to November 2001

Source : **CX008**, Downing
Eugene Roche
Downing
Kilworth
Co.Cork

The experimental results for the samples collected during November 2000 to February 2001 and for May 2001 to November 2001 from the source of the raw water for the group water scheme **CX008**, Downing, are presented in the table below. (Samples were not collected for March and April 2001 due to F&M precautions). These results must be interpreted having regard to the national limit values for each parameter specified in the Quality of Drinking Water Regulations 1988 (S.I. No. 81 of 1988). This is the standard required at the consumers tap and will normally require treatment and disinfection of the raw water to achieve these values. A brief description of these chemical and bacteriological parameters and their associated limit values is provided in the explanatory leaflet that accompanies this report.

Parameter	**Colour**	**Turbidity**	**Conductivity**	**pH**	**Ammonia**	**Nitrate**	**Nitrite**	**Aluminium**	**Iron**	**Manganese**	**Total Coliform**	**Faecal Coliform**
Limit Value	**20 Hazen**	**4 NTU**	**1500 µS/cm**	**6.0 to 9.0**	**0.23 mgN/l**	**11.3 mgN/l**	**0.03 mgN/l**	**200 µg/l**	**200 µg/l**	**50 µg/l**	**0 per 100 ml**	**0 per 100 ml**
MAY2001	<2.5	<1	286	6.36	0.01	4.8	<0.03	<0.7	<0.09	<0.03	13	NF
JUN2001	<2.5	0	226	6.57	0.01	6.5	<0.03	<0.7	<0.09	<0.03	2	NF
AUG2001	<2.5	<1	242	8.01	<0.01	5.1	<0.03	<0.70	1	0	11	NF
SEP2001	<2.5	<1	219	6.35	<0.01	7.2	<0.03	<0.7	<0.09	0	11	NF
OCT2001	<2.5	0	239	6.39	0.01	4.1	<0.03	112	<0.09	0	71	NF
NOV2001	<2.5	1	206	6.35	<0.01	4	<0.03	<0.7	<0.09	0	5	NF

Summary Report on Samples of Raw Untreated Water, November 2000 to November 2001

Source : **CX009**, Graigue
Keiran O'Connor
Cullenagh
Kildorrery
Co.Cork

The experimental results for the samples collected during November 2000 to February 2001 and for May 2001 to November 2001 from the source of the raw water for the group water scheme **CX009**, Graigue, are presented in the table below. (Samples were not collected for March and April 2001 due to F&M precautions). These results must be interpreted having regard to the national limit values for each parameter specified in the Quality of Drinking Water Regulations 1988 (S.I. No. 81 of 1988). This is the standard required at the consumers tap and will normally require treatment and disinfection of the raw water to achieve these values. A brief description of these chemical and bacteriological parameters and their associated limit values is provided in the explanatory leaflet that accompanies this report.

Parameter	**Colour**	**Turbidity**	**Conductivity**	**pH**	**Ammonia**	**Nitrate**	**Nitrite**	**Aluminium**	**Iron**	**Manganese**	**Total Coliform**	**Faecal Coliform**
Limit Value	**20 Hazen**	**4 NTU**	**1500 µS/cm**	**6.0 to 9.0**	**0.23 mgN/l**	**11.3 mgN/l**	**0.03 mgN/l**	**200 µg/l**	**200 µg/l**	**50 µg/l**	**0 per 100 ml**	**0 per 100 ml**
DEC2000	<2.5	<1	176.2	6.12	0.05	3.6	<0.03	<0.7	12	<0.03	NF	NF
JAN2001	<2.5	<1	531	8.14	<0.01	3.7	<0.03	<0.7	2	6	2	NF
FEB2001	<2.5	0	165.6	6.85	0.03	3.4	<0.03	<0.7	1	98	NF	NF
MAY2001	<2.5	<1	188.9	5.68	<0.01	3.6	<0.03	<0.7	<0.09	69	18	11
JUN2001	<2.5	0	190	5.71	<0.01	3.9	<0.03	86	2	93	32	NF
JUL2001	<2.5	<1	175.2	6.07	0.01	3.8	<0.03	63	<0.09	85	54	NF
AUG2001	<2.5	<1	173.6	6	0.01	3	<0.03	<0.70	1	90	NF	NF
SEP2001	<2.5	<1	199.4	6.56	<0.01	5.4	<0.03	99	8	106	5	NF
OCT2001	<2.5	0	177.2	5.91	<0.01	2.1	<0.03	114	<0.09	152	1	NF
NOV2001	<2.5	2	199.6	6.02	<0.01	4.1	<0.03	<0.7	<0.09	137	NF	NF

Summary Report on Samples of Raw Untreated Water, November 2000 to November 2001

Source : **CX010**, Kilcoran
Patrick Ahern
Shanbeg
Ballyduff
Co.Cork

The experimental results for the samples collected during November 2000 to February 2001 and for May 2001 to November 2001 from the source of the raw water for the group water scheme **CX010**, Kilcoran, are presented in the table below. (Samples were not collected for March and April 2001 due to F&M precautions). These results must be interpreted having regard to the national limit values for each parameter specified in the Quality of Drinking Water Regulations 1988 (S.I. No. 81 of 1988). This is the standard required at the consumers tap and will normally require treatment and disinfection of the raw water to achieve these values. A brief description of these chemical and bacteriological parameters and their associated limit values is provided in the explanatory leaflet that accompanies this report.

Parameter	Colour	Turbidity	Conductivity	pH	Ammonia	Nitrate	Nitrite	Aluminium	Iron	Manganese	Total Coliform	Faecal Coliform
Limit Value	**20 Hazen**	**4 NTU**	**1500 µS/cm**	**6.0 to 9.0**	**0.23 mgN/l**	**11.3 mgN/l**	**0.03 mgN/l**	**200 µg/l**	**200 µg/l**	**50 µg/l**	**0 per 100 ml**	**0 per 100 ml**
NOV2000	<2.5	<1	219	6.08	0.02	5.8	<0.03	<0.7	97	24	2	NF
DEC2000	<2.5	<1	206	5.98	<0.01	7	<0.03	<0.7	5	<0.03	NF	NF
JAN2001	<2.5	<1	252	6.3	<0.01	9.6	<0.03	<0.7	14	<0.03	NF	NF
FEB2001	<2.5	1	271	6.51	<0.01	8	0.161	<0.7	1	2	NF	NF
MAY2001	<2.5	<1	266	6.11	<0.01	5	<0.03	<0.7	<0.09	<0.03	1	NF
JUN2001	<2.5	0	253	6.36	0.01	9.7	<0.03	<0.7	<0.09	<0.03	NF	NF
JUL2001	<2.5	<1	271	6.41	0.04	9.5	<0.03	101	42	0	2	NF
AUG2001	<2.5	<1	271	8.01	<0.01	9.3	0.032	<0.70	8	0	NF	NF
SEP2001	<2.5	<1	242	6.15	<0.01	13.1	<0.03	<0.7	2	0	NF	NF
OCT2001	<2.5	0	261	6.24	<0.01	5.8	<0.03	109	21	0	5	NF
NOV2001	2.5	1	253	6.2	<0.01	10.1	<0.03	<0.7	<0.09	0	8	NF

Summary Report on Samples of Raw Untreated Water, November 2000 to November 2001

Source : **CX011**, Killally
Jim Nash
Killally
Kilworth
Co.Cork

The experimental results for the samples collected during November 2000 to February 2001 and for May 2001 to November 2001 from the source of the raw water for the group water scheme **CX011**, Killally, are presented in the table below. (Samples were not collected for March and April 2001 due to F&M precautions). These results must be interpreted having regard to the national limit values for each parameter specified in the Quality of Drinking Water Regulations 1988 (S.I. No. 81 of 1988). This is the standard required at the consumers tap and will normally require treatment and disinfection of the raw water to achieve these values. A brief description of these chemical and bacteriological parameters and their associated limit values is provided in the explanatory leaflet that accompanies this report.

Parameter	Colour	Turbidity	Conductivity	pH	Ammonia	Nitrate	Nitrite	Aluminium	Iron	Manganese	Total Coliform	Faecal Coliform
Limit Value	**20 Hazen**	**4 NTU**	**1500 µS/cm**	**6.0 to 9.0**	**0.23 mgN/l**	**11.3 mgN/l**	**0.03 mgN/l**	**200 µg/l**	**200 µg/l**	**50 µg/l**	**0 per 100 ml**	**0 per 100 ml**
NOV2000	<2.5	<1	125	610	0.02	3.1	<0.03	<0.7	16	22	NF	NF
DEC2000	<2.5	<1	133	6.18	<0.01	2.4	<0.03	<0.7	0	<0.03	NF	NF
JAN2001	<2.5	<1	111.1	6.87	<0.01	3.3	<0.03	<0.7	12	<0.03	NF	NF
FEB2001	<2.5	0	121.9	7.57	<0.01	3.1	<0.03	<0.7	2	4	NF	NF
MAY2001	<2.5	2	161	6.01	<0.01	1.9	<0.03	<0.7	<0.09	2	NF	NF
JUN2001	<2.5	1	134.9	6.12	0.02	2.8	<0.03	<0.7	28	<0.03	5	NF
JUL2001	<2.5	<1	136.2	6.38	<0.01	2.6	<0.03	95	<0.09	0	2	NF
AUG2001	<2.5	<1	155.3	7.03	0.01	3.2	<0.03	<0.70	1	1	3	NF
OCT2001	<2.5	0	145.7	6.34	<0.01	5.1	<0.03	37	<0.09	1	19	NF
NOV2001	<2.5	<1	142	6.18	<0.01	6.8	<0.03	<0.7	<0.09	1	1	NF

Summary Report on Samples of Raw Untreated Water, November 2000 to November 2001

Source : **CX012**, Knoppoge
Patrick Owens
Knoppoge
Mallow
Co.Cork

The experimental results for the samples collected during November 2000 to February 2001 and for May 2001 to November 2001 from the source of the raw water for the group water scheme **CX012**, Knoppoge, are presented in the table below. (Samples were not collected for March and April 2001 due to F&M precautions). These results must be interpreted having regard to the national limit values for each parameter specified in the Quality of Drinking Water Regulations 1988 (S.I. No. 81 of 1988). This is the standard required at the consumers tap and will normally require treatment and disinfection of the raw water to achieve these values. A brief description of these chemical and bacteriological parameters and their associated limit values is provided in the explanatory leaflet that accompanies this report.

Parameter	Colour	Turbidity	Conductivity	pH	Ammonia	Nitrate	Nitrite	Aluminium	Iron	Manganese	Total Coliform	Faecal Coliform
Limit Value	**20 Hazen**	**4 NTU**	**1500 µS/cm**	**6.0 to 9.0**	**0.23 mgN/l**	**11.3 mgN/l**	**0.03 mgN/l**	**200 µg/l**	**200 µg/l**	**50 µg/l**	**0 per 100 ml**	**0 per 100 ml**
JAN2001	<2.5	<1	394	7.46	<0.01	2.5	<0.03	<0.7	11	2	NF	NF
FEB2001	<2.5	1	426	8.42	<0.01	1.9	<0.03	<0.7	1	65	NF	NF
MAY2001	<2.5	<1	396	6.25	0.01	2.2	<0.03	<0.7	<0.09	8	10	2
JUN2001	<2.5	1	344	6.75	<0.01	2.2	<0.03	101	<0.09	76	26	11
JUL2001	<2.5	<1	375	6.84	0.01	3.6	<0.03	117	<0.09	30	11	4
AUG2001	<2.5	<1	409	6.89	<0.01	3.6	<0.03	<0.70	<0.090	44	7	1
SEP2001	<2.5	5	373	6.85	<0.01	3.9	<0.03	61	<0.09	110	7	NF
OCT2001	2.5	<1	381	5.66	<0.01	1.6	<0.03	124	25	163	7	2
NOV2001	10	4	381	6.88	<0.01	3.7	<0.03	27	16	432	5	NF

Summary Report on Samples of Raw Untreated Water, November 2000 to November 2001

Source : **CX013**, Strawhall
Mary Ryan
Strawhall
Fermoy
Co.Cork

The experimental results for the samples collected during November 2000 to February 2001 and for May 2001 to November 2001 from the source of the raw water for the group water scheme **CX013**, Strawhall, are presented in the table below. (Samples were not collected for March and April 2001 due to F&M precautions). These results must be interpreted having regard to the national limit values for each parameter specified in the Quality of Drinking Water Regulations 1988 (S.I. No. 81 of 1988). This is the standard required at the consumers tap and will normally require treatment and disinfection of the raw water to achieve these values. A brief description of these chemical and bacteriological parameters and their associated limit values is provided in the explanatory leaflet that accompanies this report.

Parameter	Colour	Turbidity	Conductivity	pH	Ammonia	Nitrate	Nitrite	Aluminium	Iron	Manganese	Total Coliform	Faecal Coliform
Limit Value	**20 Hazen**	**4 NTU**	**1500 µS/cm**	**6.0 to 9.0**	**0.23 mgN/l**	**11.3 mgN/l**	**0.03 mgN/l**	**200 µg/l**	**200 µg/l**	**50 µg/l**	**0 per 100 ml**	**0 per 100 ml**
MAY2001	<2.5	<1	243	6.61	<0.01	3	<0.03	<0.7	29	0	NF	NF
JUN2001	<2.5	0	243	6.53	0.01	4.9	<0.03	<0.7	19	<0.03	NF	NF
JUL2001	<2.5	<1	272	6.83	0.01	5.1	<0.03	136	5	0	2	NF
AUG2001	<2.5	<1	283	7.1	<0.01	5.6	<0.03	0	35	1	NF	NF
SEP2001	<2.5	<1	255	6.39	<0.01	5.2	<0.03	<0.7	26	0	NF	NF
OCT2001	<2.5	0	264	6.37	0.01	4.1	<0.03	113	64	1	16	1
NOV2001	2.5	2	250	6.59	<0.01	5.9	<0.03	<0.7	58	0	8	NF

Summary Report on Samples of Raw Untreated Water, November 2000 to November 2001

Source : **CX014**, Tankardstown/Ballyguyroe
John Hunter
Tankardstown
Kildorrery
Co.Cork

The experimental results for the samples collected during November 2000 to February 2001 and for May 2001 to November 2001 from the source of the raw water for the group water scheme **CX014**, Tankardstown/Ballyguyroe, are presented in the table below. (Samples were not collected for March and April 2001 due to F&M precautions). These results must be interpreted having regard to the national limit values for each parameter specified in the Quality of Drinking Water Regulations 1988 (S.I. No. 81 of 1988). This is the standard required at the consumers tap and will normally require treatment and disinfection of the raw water to achieve these values. A brief description of these chemical and bacteriological parameters and their associated limit values is provided in the explanatory leaflet that accompanies this report.

Parameter	Colour	Turbidity	Conductivity	pH	Ammonia	Nitrate	Nitrite	Aluminium	Iron	Manganese	Total Coliform	Faecal Coliform
Limit Value	**20 Hazen**	**4 NTU**	**1500 µS/cm**	**6.0 to 9.0**	**0.23 mgN/l**	**11.3 mgN/l**	**0.03 mgN/l**	**200 µg/l**	**200 µg/l**	**50 µg/l**	**0 per 100 ml**	**0 per 100 ml**
NOV2000	<2.5	0	477	7.47	<0.01	3.4	<0.03				5	NF
DEC2000	<2.5	<1	466	7.54	0.05	2.6	<0.03	<0.7	5	<0.03	NF	NF
JAN2001	<2.5	<1	149	6.94	<0.01	3.7	<0.03	<0.7	20	67	NF	NF
FEB2001	<2.5	0	572	8.54	<0.01	2.6	<0.03	<0.7	1	5	2	NF
MAY2001	<2.5	<1	542	7.22	<0.01	3.7	<0.03	<0.7	<0.09	<0.03	4	NF
JUN2001	<2.5	<1	485	7.48	<0.01	4	<0.03	92	<0.09	<0.03	5	NF
JUL2001	<2.5	<1	504	7.34	0.01	4.9	<0.03	75	<0.09	<0.03	770	10
AUG2001	2.5	<1	547	7.41	0.01	6.1	<0.03	<0.70	0	0	16	1
SEP2001	<2.5	2	510	7.68	<0.01	5.6	<0.03	46	<0.09	0	10	NF
OCT2001	<2.5	0	526	7.44	0.01	3.7	<0.03	111	<0.09	<0.03	113	NF
NOV2001	<2.5	1	512	7.47	0.02	4.5	<0.03	<0.7	<0.09	0	NF	NF

Summary Report on Samples of Raw Untreated Water, November 2000 to November 2001

Source : **CX015**, Turbeigh
Eugene Sheehan
Turbeigh
Mitchelstown
Co.Cork

The experimental results for the samples collected during November 2000 to February 2001 and for May 2001 to November 2001 from the source of the raw water for the group water scheme **CX015**, Turbeigh, are presented in the table below. (Samples were not collected for March and April 2001 due to F&M precautions). These results must be interpreted having regard to the national limit values for each parameter specified in the Quality of Drinking Water Regulations 1988 (S.I. No. 81 of 1988). This is the standard required at the consumers tap and will normally require treatment and disinfection of the raw water to achieve these values. A brief description of these chemical and bacteriological parameters and their associated limit values is provided in the explanatory leaflet that accompanies this report.

Parameter	**Colour**	**Turbidity**	**Conductivity**	**pH**	**Ammonia**	**Nitrate**	**Nitrite**	**Aluminium**	**Iron**	**Manganese**	**Total Coliform**	**Faecal Coliform**
Limit Value	**20 Hazen**	**4 NTU**	**1500 µS/cm**	**6.0 to 9.0**	**0.23 mgN/l**	**11.3 mgN/l**	**0.03 mgN/l**	**200 µg/l**	**200 µg/l**	**50 µg/l**	**0 per 100 ml**	**0 per 100 ml**
JAN2001	<2.5	<1	93.3	7.63	<0.01	4	<0.03	<0.7	103	<0.03	NF	NF
FEB2001	<2.5	0	185.1	7.5	<0.01	5	<0.03	<0.7	0	21	NF	NF
MAY2001	<2.5	<1	125.5	7.63	0.01	3.7	<0.03	<0.7	<0.09	7	NF	NF
JUN2001	<2.5	0	120.8	6.02	<0.01	5.1	<0.03	<0.7	<0.09	21	NF	NF
JUL2001	<2.5	<1	302	6.25	<0.01	4	<0.03	<0.7	<0.09	0	34	15
JUL2001	<2.5	<1	426	7.2	0.01	5.6	<0.03	103	10	0	1	NF
AUG2001	<2.5	<1	152.2	7.13	<0.01	5.4	<0.03	<0.70	1	3	NF	NF
SEP2001	<2.5	1	142.3	5.76	<0.01	6.9	<0.03	102	4	5	NF	NF
OCT2001	<2.5	0	140.9	5.5	<0.01	4.5	<0.03	110	<0.09	6	2419	NF
NOV2001	<2.5	1	169.6	5.82	0.01	6.8	<0.03	<0.7	<0.09	19	NF	NF

Summary Report on Samples of Raw Untreated Water, November 2000 to November 2001

Source : **CX016**, Waterpark
David Feeney
Coolbawn
Fermoy
Co.Cork

The experimental results for the samples collected during November 2000 to February 2001 and for May 2001 to November 2001 from the source of the raw water for the group water scheme **CX016**, Waterpark, are presented in the table below. (Samples were not collected for March and April 2001 due to F&M precautions). These results must be interpreted having regard to the national limit values for each parameter specified in the Quality of Drinking Water Regulations 1988 (S.I. No. 81 of 1988). This is the standard required at the consumers tap and will normally require treatment and disinfection of the raw water to achieve these values. A brief description of these chemical and bacteriological parameters and their associated limit values is provided in the explanatory leaflet that accompanies this report.

Parameter	**Colour**	**Turbidity**	**Conductivity**	**pH**	**Ammonia**	**Nitrate**	**Nitrite**	**Aluminium**	**Iron**	**Manganese**	**Total Coliform**	**Faecal Coliform**
Limit Value	**20 Hazen**	**4 NTU**	**1500 µS/cm**	**6.0 to 9.0**	**0.23 mgN/l**	**11.3 mgN/l**	**0.03 mgN/l**	**200 µg/l**	**200 µg/l**	**50 µg/l**	**0 per 100 ml**	**0 per 100 ml**
NOV2000	<2.5	<1	167	5.8	0.02	7.4	<0.03	46	197	31	NF	NF
DEC2000	<2.5	<1	192	5.94	<0.01	4.4	<0.03	13	118	<0.03	4	NF
JAN2001	<2.5	<1	154.7	6.02	<0.01	6.4	<0.03	<0.7	40	<0.03	122	NF
FEB2001	<2.5	0	304	7.55	<0.01	6.8	0.045	<0.7	4	8	NF	NF
MAY2001	<2.5	<1	194	5.57	<0.01	6	<0.03	<0.7	2	<0.03	2	NF
JUN2001	<2.5	0	170.8	5.75	0.01	7.4	<0.03	<0.7	<0.09	4	NF	NF
JUL2001	<2.5	2	482	7.2	<0.01	1.3	<0.03	<0.7	<0.09	0	NF	NF
AUG2001	<2.5	<1	182.4	7.36	<0.01	6.6	0.046	11	<0.090	5	2	NF
SEP2001	<2.5	<1	169.9	5.7	<0.01	7.6	<0.03	<0.7	<0.09	5	NF	NF
OCT2001	<2.5	0	168.8	5.8	0.01	3.2	<0.03	106	20	6	4	NF
NOV2001	<2.5	4	192	5.83	<0.01	7.2	<0.03	<0.7	98	8	24	NF

Summary Report on Samples of Raw Untreated Water, November 2000 to November 2001

Source : **CX017**,

The experimental results for the samples collected during November 2000 to February 2001 and for May 2001 to November 2001 from the source of the raw water for the group water scheme **CX017**, are presented in the table below. (Samples were not collected for March and April 2001 due to F&M precautions). These results must be interpreted having regard to the national limit values for each parameter specified in the Quality of Drinking Water Regulations 1988 (S.I. No. 81 of 1988). This is the standard required at the consumers tap and will normally require treatment and disinfection of the raw water to achieve these values. A brief description of these chemical and bacteriological parameters and their associated limit values is provided in the explanatory leaflet that accompanies this report.

Parameter	Colour	Turbidity	Conductivity	pH	Ammonia	Nitrate	Nitrite	Aluminium	Iron	Manganese	Total Coliform	Faecal Coliform
Limit Value	**20 Hazen**	**4 NTU**	**1500 µS/cm**	**6.0 to 9.0**	**0.23 mgN/l**	**11.3 mgN/l**	**0.03 mgN/l**	**200 µg/l**	**200 µg/l**	**50 µg/l**	**0 per 100 ml**	**0 per 100 ml**
AUG2001	5	13	396	7.15	<0.01	8.2	<0.03	<0.7	4	1	NF	NF
SEP2001	<2.5	16	387	7.25	<0.01	2.5	<0.03	97	<0.09	0	NF	NF
OCT2001	<2.5	1	426	7.17	<0.01	5.2	<0.03	56	<0.09	<0.03	2	NF
NOV2001	<2.5	3	404	7.31	0.01	3.1	<0.03	<0.7	0	0	1	NF

Summary Report on Samples of Raw Untreated Water, November 2000 to November 2001

Source : **CX018**,

The experimental results for the samples collected during November 2000 to February 2001 and for May 2001 to November 2001 from the source of the raw water for the group water scheme **CX018**, are presented in the table below. (Samples were not collected for March and April 2001 due to F&M precautions). These results must be interpreted having regard to the national limit values for each parameter specified in the Quality of Drinking Water Regulations 1988 (S.I. No. 81 of 1988). This is the standard required at the consumers tap and will normally require treatment and disinfection of the raw water to achieve these values. A brief description of these chemical and bacteriological parameters and their associated limit values is provided in the explanatory leaflet that accompanies this report.

Parameter	Colour	Turbidity	Conductivity	pH	Ammonia	Nitrate	Nitrite	Aluminium	Iron	Manganese	Total Coliform	Faecal Coliform
Limit Value	**20 Hazen**	**4 NTU**	**1500 µS/cm**	**6.0 to 9.0**	**0.23 mgN/l**	**11.3 mgN/l**	**0.03 mgN/l**	**200 µg/l**	**200 µg/l**	**50 µg/l**	**0 per 100 ml**	**0 per 100 ml**
AUG2001	<2.5	3	285	6.46	<0.01	7.9	<0.03	<0.70	<0.090	0	54	43
SEP2001	<2.5	<1	261	6.41	<0.01	10.8	<0.03	<0.7	3	0	27	NF
OCT2001	<2.5	0	270	6.37	0.01	1.2	<0.03	44	<0.09	0	29	3
NOV2001	<2.5	1	261	6.45	<0.01	8.3	<0.03	<0.7	<0.09	0	86	NF

APPENDIX E

Johnstown Castle Study: Ancillary Information

The material contained in this appendix concerns my investigations at Johnstown Castle, county Wexford. The study was outlined in chapter four, section 4.3.

1 Borehole design, Drilling & Instrumentation

In order to attempt to investigate nitrate leaching from soil to groundwater piezometer installations were designed so that each site houses three piezometers arranged to target: just below the winter water-table (A), the soil rock interface (B), and a depth ~5m into bedrock (C). Each piezometer was 50mm diameter, internal screw, flush treaded, thermoplastic casing with a 0.5m long, horizontally slotted, bottom capped, screen. Each screen was clothed with a geo-textile sock, gravel packed in a 150mm borehole, isolated using a 1m bentonite seal and filled to ground level with a cement slurry fill.

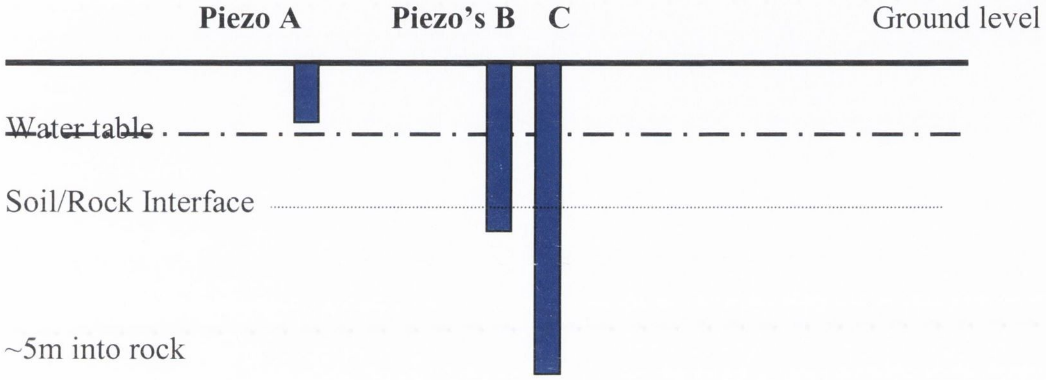


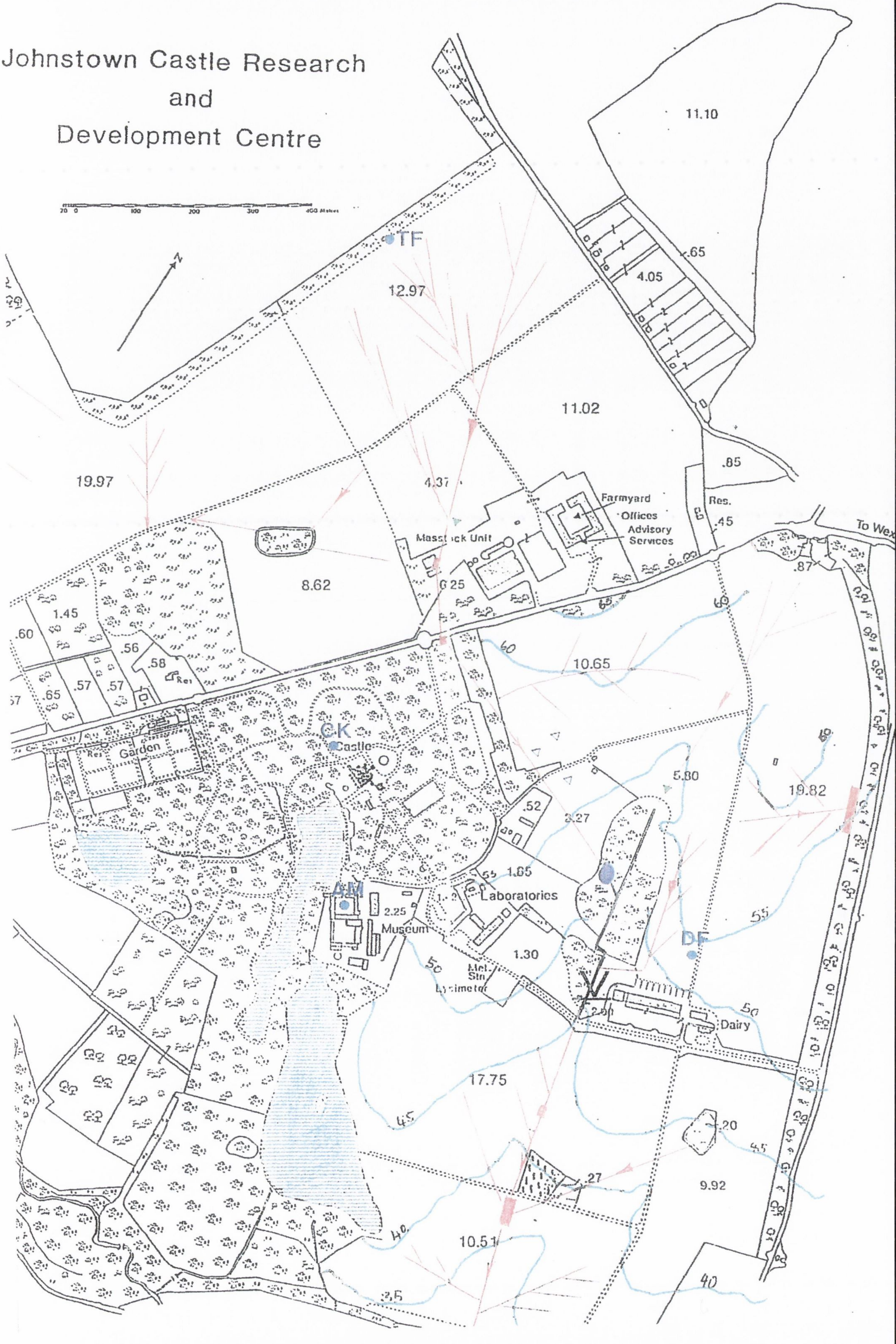
Figure 6.45 Schematic representation of piezometer configuration at each study site.

Generally, at each drilling location two 150mm boreholes were drilled. The first bore was drilled approximately 5m into rock using the compressed drilling method, the depth to rock was noted and two piezometers installed, the first to target deeper groundwater and the second at the soil-rock interface, they were isolated using bentonite pellets and cement and spoil backfill. Then, at a distance of approximately three metres, a second bore was drilled to approximately 2m below the then winter water table using hollow stem auger (HSA) and a single piezometer installed to target the top of the water-table. The HSA allows soil samples (disturbed) to be taken for discrete layers for chemical and physical analysis.

2 Groundwater Monitoring

A groundwater-monitoring programme commenced in February 1998. Groundwater samples were obtained from the piezometers using dedicated Wattera hand pumps, which allowed sample collection from the screened area at the base of each piezometer. Duplicate field samples are returned to the laboratory within 2 hours of sampling for further physical analysis and promptly refrigerated. Nitrate analysis was carried out, within 24 hours of sample collection.

Johnstown Castle Research and Development Centre



Chemical analysis results of field duplicates 1999:2000 (MAX,AVERAGE and MIN)																										
range 1999&2000		two year average				*=unfiltered																				
		temp (o	pH	D.O	Cond. u	P*	P	TON*	TON	NO3	NH4N*	NH4N	Fe*	Cl	Ca	Mg	Na	K	SO4	CaCO3	HCO3	Mn*	Cu	Zn	Fe	Mn
DF1	A (7m)																									
Max		13.0	7.9	10.1	691	0.24	<0.005	1.00	1.10	4.42	0.15	0.09	3.42	41.3	160.1	25.1	25.5	2.9	26.5	394.0	480.7	0.03	0.01	<0.01	0.02	0.02
AV		11.4	7.2	7.0	647	0.06	<0.005	0.74	0.79	3.27	<0.1	<0.1	0.79	39.1	94.0	17.2	22.0	1.5	18.6	288.7	352.2	0.02	0.01	<0.01	0.01	0.01
Min		10.0	6.8	5.5	635	0.01	<0.005	0.50	0.50	2.21	<0.1	0.04	0.05	21.8	78.5	14.4	19.8	1.2	11.0	251.0	306.2	0.01	<0.01	<0.01	<0.01	<0.01
DF2	A (6.5m)																									
MAX		14.0	7.7	9.6	729	0.13	0.007	2.40	2.50	10.62	0.29	0.32	3.65	40.7	126.0	18.6	22.7	4.1	24.0	373.0	455.1	0.87	0.03	0.02	4.00	2.00
AVERAGE		11.6	7.2	3.7	690	0.03	<0.005	1.55	1.76	6.84	<0.1	<0.1	0.47	36.3	101.9	17.1	21.4	2.8	17.1	313.9	383.0	0.31	0.02	0.02	1.45	0.59
MIN		9.3	6.8	1.7	640	0.00	<0.005	0.10	0.75	0.44	0.04	0.03	0.02	17.1	88.2	15.4	20.0	2.1	9.8	279.0	340.4	0.03	0.01	<0.01	<0.01	0.13
DF2	B (12m)																									
MAX		14.9	13.7	11.4	673	0.11	0.020	4.05	4.15	17.92	0.24	0.14	0.26	53.0	260.9	24.2	43.0	63.5	57.0	307.0	374.5	0.15	0.01	<0.01	0.01	0.12
AVERAGE		11.8	9.0	3.7	597	0.03	0.007	3.24	3.20	14.33	<0.1	<0.1	0.05	42.3	104.8	14.7	21.8	4.1	19.4	225.8	271.7	0.07	<0.01	<0.01	<0.1	0.11
MIN		9.4	6.9	0.8	340	<0.005	<0.005	2.65	1.85	11.73	0.01	0.02	<0.01	34.5	24.3	0.1	17.5	1.3	1.5	90.0	109.8	0.01	<0.01	<0.01	<0.01	0.11
DF2	C (16.5m)																									
MAX		14.0	9.4	11.2	692	0.20	0.038	3.70	3.85	16.37	0.11	0.10	0.82	47.3	107.5	32.9	40.7	15.6	88.0	285.0	347.7	0.26	0.01	<0.01	<0.01	0.05
AVERAGE		11.5	7.5	3.7	619	0.05	0.023	2.67	2.75	11.97	<0.1	<0.1	0.17	31.9	61.7	27.9	28.4	3.2	42.7	242.8	296.9	0.06	<0.01	<0.01	<0.01	0.02
MIN		7.9	7.0	1.1	564	<0.005	<0.005	1.65	1.15	7.74	0.11	0.02	<0.01	15.4	50.1	13.9	21.8	2.0	17.0	215.0	262.3	<0.01	<0.01	<0.01	<0.01	<0.01
DF3	A (6m)																									
MAX		14.0	9.0	12.2	722	0.23	0.050	1.95	1.95	8.63	0.20	0.10	3.61	31.1	120.5	20.3	28.1	4.1	48.0	337.0	411.1	0.245	0.04	0.03	<0.01	0.03
AVERAGE		11.9	7.3	3.7	635	0.06	0.029	0.86	0.82	3.81	<0.1	<0.1	0.71	27.2	90.4	16.9	22.4	2.4	20.6	292.4	358.6	<0.01	0.01	0.01	<0.01	0.02
MIN		8.8	4.7	1.0	605	0.03	<0.005	0.25	<0.3	1.11	0.03	0.01	0.04	0.0	78.8	14.0	17.9	1.2	9.8	255.0	311.1	<0.01	<0.01	<0.01	<0.01	0.01
DF3	B (12m)																									
MAX		14.0	8.8	12.2	685	0.08	0.010	1.40	1.15	5.97	0.10	0.16	2.22	32.3	112.7	21.8	42.1	4.6	52.0	323.0	394.1	0.50	0.02	0.01	<0.1	0.44
AVERAGE		11.8	7.4	2.8	626	0.03	<0.005	<0.3	<0.3	<1.3	<0.1	<0.1	0.39	29.5	78.4	18.5	28.0	3.3	23.1	283.2	345.5	0.30	0.01	<0.01	<0.01	0.30
MIN		9.8	6.9	0.9	604	0.00	0.002	<0.3	<0.3	<1.3	<0.1	<0.1	<0.01	26.1	59.0	12.2	19.6	2.6	10.5	251.3	306.6	0.08	<0.01	<0.01	0.01	0.18
DF3	C (17m)																									
MAX		14.0	8.7	11.1	630	0.06	0.100	<0.3	<0.3	<1.3	<0.3	0.10	1.43	34.3	80.5	24.6	28.4	5.1	25.5	524.0	639.3	0.81	0.01	0.01	<0.01	0.83
AVERAGE		11.8	7.4	2.5	592	0.02	0.008	<0.3	<0.3	<1.3	<0.1	<0.1	0.26	29.8	70.2	21.4	24.2	3.9	16.6	284.3	346.8	0.39	<0.01	<0.01	<0.01	0.58
MIN		9.4	6.8	0.9	576	0.00	0.002	<0.005	<0.3	<1.3	<0.1	0.08	<0.01	12.0	63.7	19.0	22.9	3.1	12.0	241.0	294.0	0.15	<0.01	<0.01	<0.01	0.44
ORG 2	A (6.5m)																									
MAX		13.9	8.6	9.8	720	0.33	0.059	<0.3	<0.3	6.40	0.13	0.10	4.35	29.9	166.3	23.2	39.6	5.7	46.0	381.0	464.8	0.30	0.01	0.02	0.03	0.45
AVERAGE		11.4	7.3	3.3	672	0.06	0.009	<0.3	<0.3	1.20	<0.1	<0.1	0.89	26.6	100.2	15.8	24.2	3.1	29.7	319.9	390.3	0.21	<0.01	0.01	0.01	0.13
MIN		7.0	3.7	0.9	350	0.00	0.002	<0.005	<0.3	<1.3	0.02	0.03	0.03	13.4	44.5	7.9	10.5	1.5	16.3	195.0	237.9	0.03	<0.01	<0.01	<0.01	0.02
ORG 2	B (11m)																									
MAX		13.1	8.1	11.3	700	0.38	<0.005	1.80	5.10	7.96	0.18	0.20	4.35	33.3	185.6	28.9	34.6	5.6	38.0	405.0	494.1	0.20	0.02	0.02	0.02	0.23
AVERAGE		11.7	7.3	3.5	677	0.06	<0.005	0.85	1.11	3.78	<0.1	<0.1	0.78	29.1	104.3	15.6	24.5	2.0	30.5	312.2	380.9	0.07	0.01	0.02	0.02	0.11
MIN		9.7	6.9	0.5	649	<0.005	<0.005	0.25	0.25	1.11	<0.1	0.06	0.02	19.7	85.9	12.4	21.0	1.1	14.0	264.0	322.1	0.02	0.01	0.01	0.01	0.07
ORG 2	C (15m)																									
MAX		13.9	7.9	12.4	698	0.26	<0.1	2.95	3.20	13.05	<0.1	0.11	5.31	35.6	117.0	16.1	26.9	3.9	35.0	393.0	479.5	0.19	0.01	0.02	0.01	0.03
AVERAGE		11.7	7.2	4.2	638	0.05	<0.005	2.36	2.40	10.45	<0.1	<0.1	0.74	31.5	90.6	14.2	25.6	2.0	27.4	275.0	335.5	0.05	<0.01	0.02	0.01	0.02
MIN		9.2	6.8	1.5	602	<0.005	<0.005	1.95	1.60	8.63	<0.1	<0.1	0.11	16.3	77.4	12.8	23.1	1.3	11.3	227.9	278.0	0.01	<0.01	<0.01	<0.01	<0.01
ORG 1	A (9.5m)																									
MAX		15.6	8.0	11.4	765	0.10	0.012	7.35	5.40	32.52	0.24	0.15	5.03	27.9	168.1	30.0	28.6	5.3	52.0	395.0	481.9	0.08	0.02	0.02	0.01	0.02
AVERAGE		11.6	7.4	8.7	661	0.04	0.006	2.08	2.31	9.22	<0.1	0.09	0.88	22.1	101.1	17.2	20.5	3.2	30.4	291.6	355.7	0.03	0.01	0.01	<0.01	<0.01
MIN		9.4	6.9	6.5	455	0.00	0.001	0.25	0.30	1.11	<0.1	0.03	0.06	13.8	59.0	9.1	14.9	1.5	17.0	217.5	265.4	<0.01	<0.01	<0.01	<0.01	<0.01
ORG 1	B (12m)	?validity max/mins with only winter (3 months) water in this well???																								
MAX		10.3	7.0	7.2	519	0.03	<0.005	3.95	4.00	17.48	<0.1	<0.1	0.50	29.2	115.6	11.4	17.5	2.0				0.02				
AVERAGE		10.1	6.9	7.0	515	0.03	<0.005	3.58	3.53	15.86	<0.1	<0.1	0.35	22.9	85.5	10.7	16.9	1.8				0.01				
MIN		10.0	6.9	6.7	511	0.03	<0.005	3.30	3.20	14.60	<0.1	<0.1	0.09	12.4	63.8	9.8	15.8	1.6				0.01				
ORG 1	C (16.6m)																									
MAX		13.6	8.0	12.6	596	0.043	0.005	6.2	6.4	27.4	<0.1	0.1	1.83	33.0	109.7	12.6	22.2	3.8	20.5	264.0	322.1	0.07	<0.01	0.01	<0.01	0.00
VERAGE		11.5	7.3	6.4	498	0.018	<0.005	4.8	4.7	21.2	<0.1	<0.1	0.39	27.8	73.5	10.3	17.9	1.7	14.0	204.5	249.5	0.02	<0.01	<0.01	<0.01	
MIN		5.2	6.9	3.5	442	0.002	<0.005	3.1	3.1	13.5	<0.1	<0.1	0.02	13.5	60.8	8.9	8.6	1.2	9.5	164.0	200.1	0.01	<0.01	<0.01	<0.01	0.00

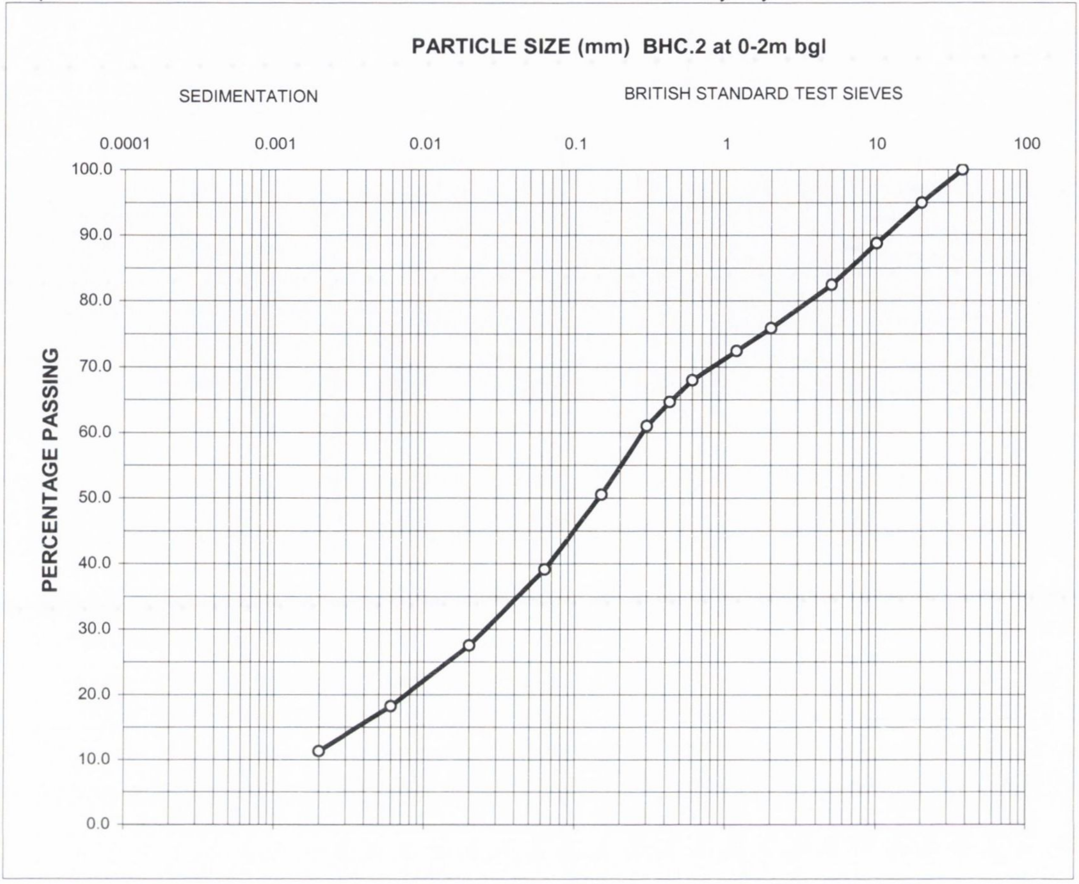
APPENDIX F

Curtin's Farm Particle Size Distribution Charts (BS 1377 1990)

Wet sieve analysis following B.S. 1377 (1990) was carried out on 25 subsoil samples collected during borehole drilling. The samples were collected at 0.5m intervals from the spoils of borehole drilling at ten different locations. Further laboratory analysis was carried out on a representative subset of all samples: pipette analysis (sedimentation tests), also described in B.S. 1377 (1990), allowed further differentiation of the actual proportions of silt and clay. Sedimentation tests were carried out on samples taken from 1m-depth bgl. Full results of the particle soil analysis, the associated subsoil grading curves and classification of soil types are presented in this Appendix.

PARTICLE SIZE DISTRIBUTION CHART

Sample No	Curtins, Fermoy
Bore 9 - **BHC.2**	17/10/2001
Depth 0 - 2m	Gravelly silty SAND



B.S. sieve size	% Passing
37.5	100.0
20	95.0
10	88.8
5	82.4
2	75.9
1.18	72.4
0.6	68.0
0.425	64.7
0.3	61.0
0.15	50.6
0.063	39.2
0.02	27.5
0.006	18.2
0.002	11.3

Soil Fraction	Total %	**BHC.2 at 0-2m**
Cobbles	0.0	
Gravel	24.1	
Sand	36.7	
Silt	27.8	
Clay	11.3	

Gravelly silty SAND

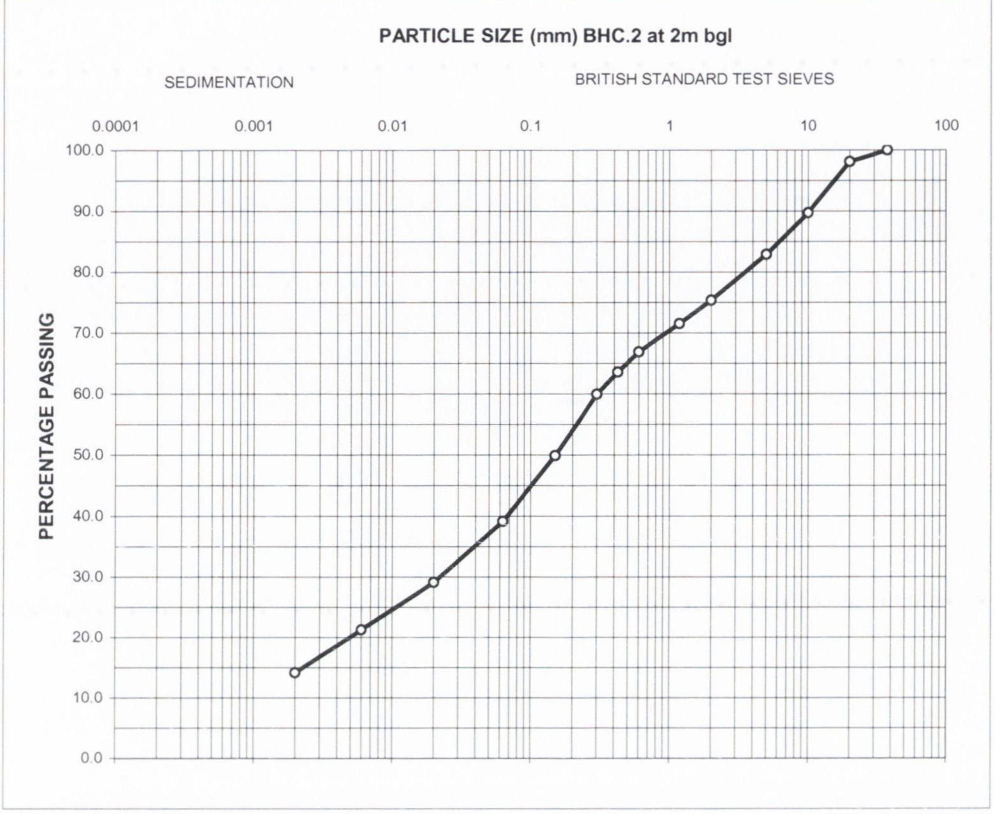
Wet Sieve Analysis B.S. 1377 1990 Clause 9.2
Pipette analysis B.S.1377 1990 clause 9.4

GEOTECHNICAL LABORATORIES,
TRINITY COLLEGE,
DUBLIN.2.

PARTICLE SIZE DISTRIBUTION CHART

Sample No.
Bore 9 - BHC.2
Depth 2.0m

Curtins, Fermoy
17/10/2001
Very gravelly silty SAND



B.S. sieve size	% Passing
37.5	100.0
20	98.1
10	89.8
5	82.9
2	75.4
1.18	71.5
0.6	66.9
0.425	63.6
0.3	59.9
0.15	49.9
0.063	39.2
0.02	29.1
0.006	21.3
0.002	14.1

Soil Fraction	Total %	BHC.2 - 2m
Cobbles	0.0	
Gravel	24.6	
Sand	36.2	
Silt	25.0	
Clay	14.1	

Very gravelly silty SAND

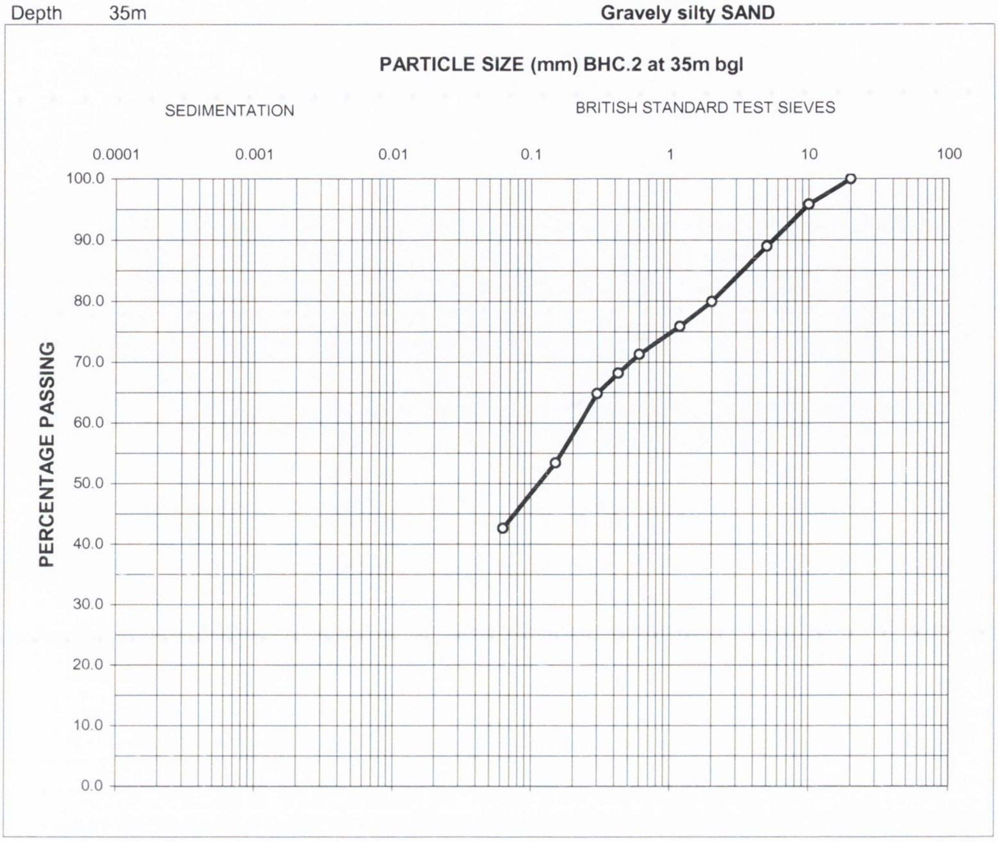
Wet Sieve Analysis B.S. 1377 1990 Clause 9.2
Pipette analysis B.S.1377 1990 clause 9.4

GEOTECHNICAL LABORATORIES,
TRINITY COLLEGE,
DUBLIN.2.

PARTICLE SIZE DISTRIBUTION CHART

Sample No.
Bore 9 - **BHC.2**
Depth 35m

Curtins, Fermoy
17/10/2001
Gravely silty SAND



B.S. sieve size	% Passing	Soil Fraction	Total %	**BHC.2 at 35m**
		Cobbles	0.0	
37.5	100.0	Gravel	20.1	
20	100.0			
10	95.8	Sand	37.3	
5	89.0			
2	79.9	Silt & Clay	42.6	
1.18	75.9			
0.6	71.3	**Gravely silty SAND**		
0.425	68.2			
0.3	64.8			
0.15	53.4			
0.063	42.6			

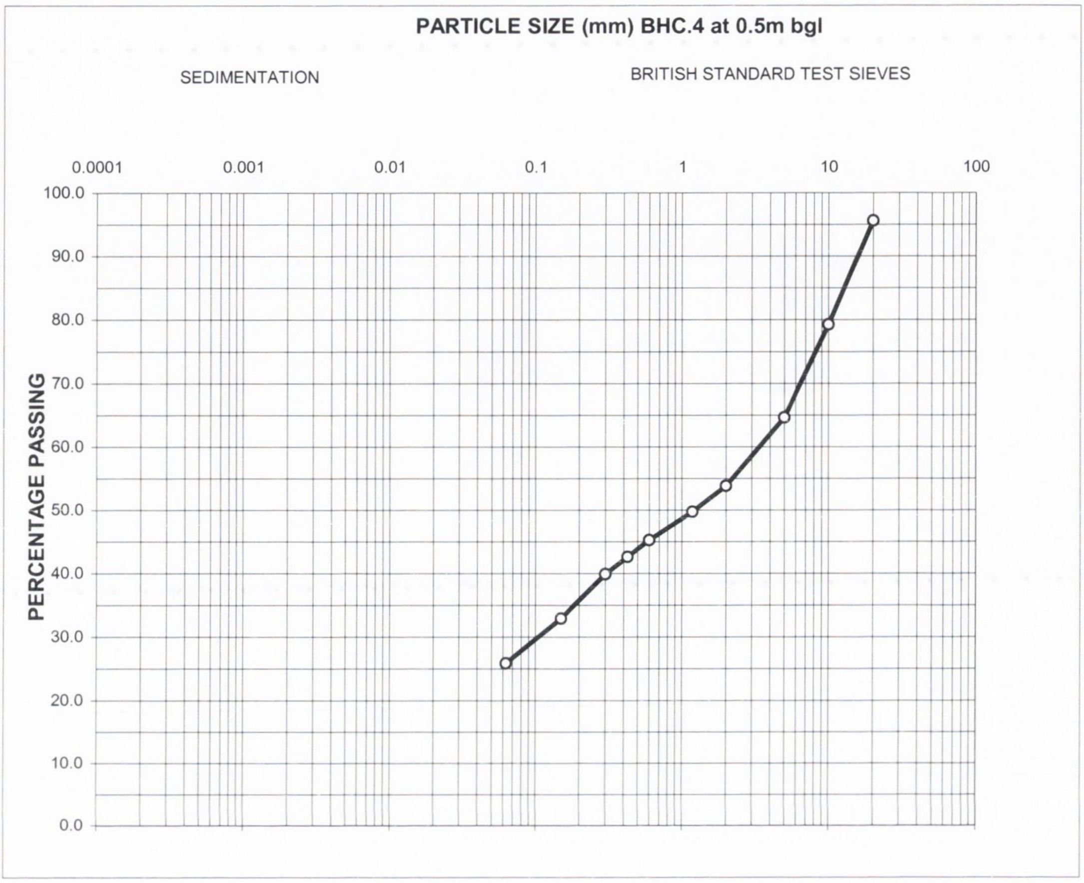
Wet Sieve Analysis B.S. 1377 1990 Clause 9.2
Pipette analysis B.S.1377 1990 clause 9.4

GEOTECHNICAL LABORATORIES,
TRINITY COLLEGE,
DUBLIN.2.

PARTICLE SIZE DISTRIBUTION CHART

Sample No.
Bore 6 **BHC.4**
Depth 0.5m

Curtins
Date 17.10.01
Brown silty sandy GRAVEL



B.S. sieve size	% Passing
37.5	100.0
20	95.6
10	79.3
5	64.6
2	53.8
1.18	49.8
0.6	45.3
0.425	42.6
0.3	39.9
0.15	32.9
0.063	25.9

Soil Fraction	Total %	**BHC.4 0-0.5m**
Cobbles	0.0	
Gravel	46.2	
Sand	28.0	
Silt/Clay	25.9	

Brown silty sandy GRAVEL

Wet Sieve Analysis B.S. 1377 1990 Clause 9.2

GEOTECHNICAL LABORATORIES,
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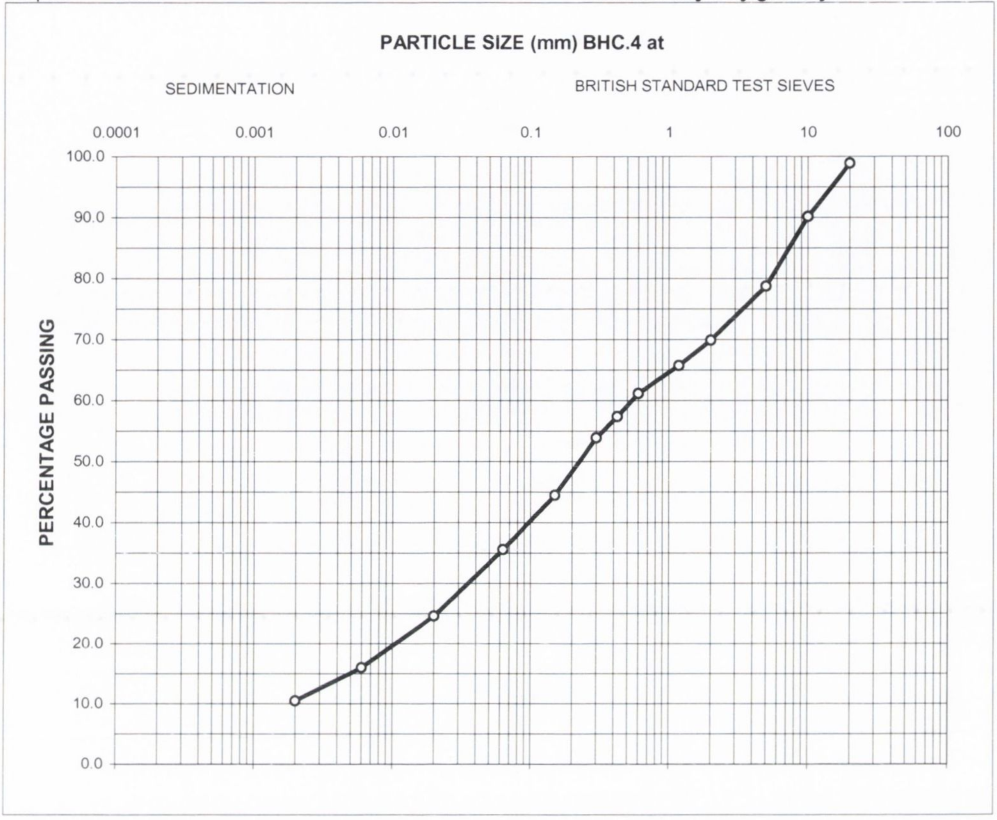
DUBLIN.2.

PARTICLE SIZE DISTRIBUTION CHART

Sample No.
Bore 6 - BHC.4
Depth 1.0m

Curtins, Fermoy
17/10/2001
Brown silty very gravelly SAND



B.S. sieve size	% Passing	Soil Fraction	Total %	**BHC.4 at 1m**
		Cobbles	0.0	
37.5	100.0	Gravel	30.1	
20	98.9			
10	90.1	Sand	34.4	
5	78.7			
2	69.9	Silt	25.1	
1.18	65.7			
0.6	61.1	Clay	10.5	
0.425	57.4			
0.3	53.9			
0.15	44.4	Brown silty very gravelly SAND		
0.063	35.6			
0.02	24.6			
0.006	16.0			
0.002	10.5			

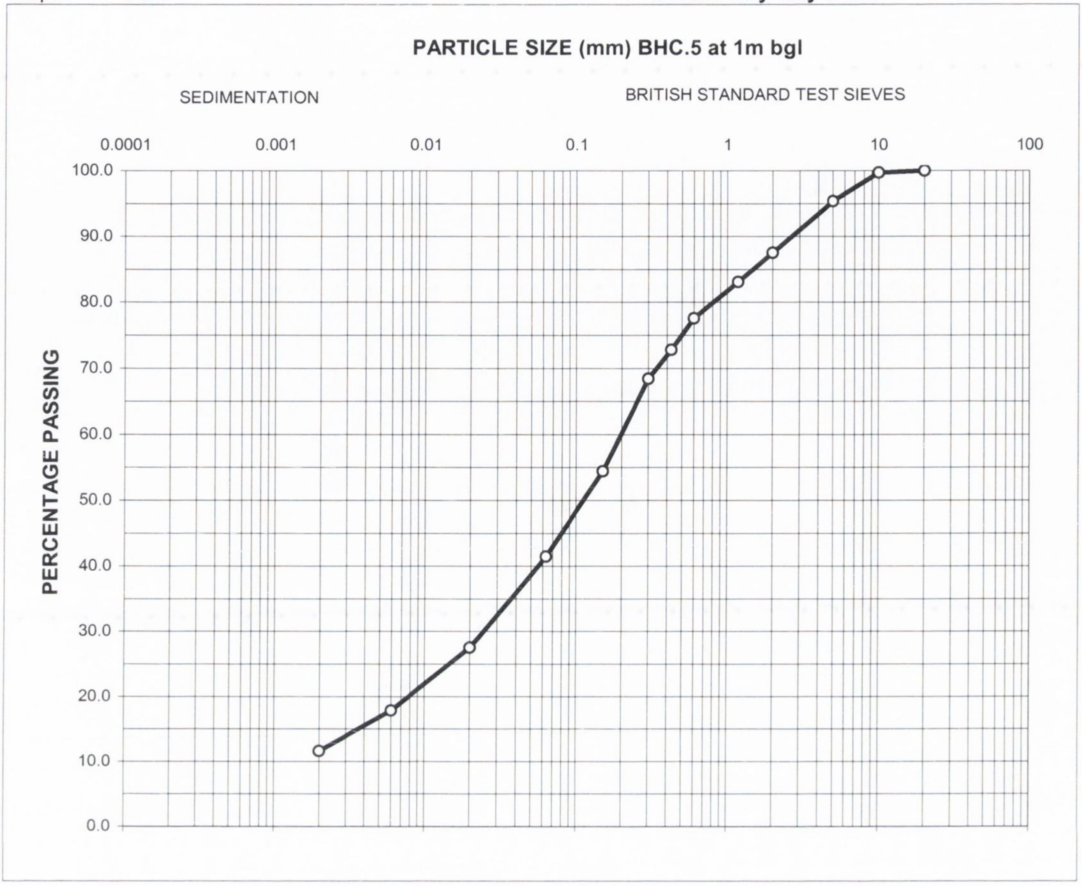
Wet Sieve Analysis B.S. 1377 1990 Clause 9.2
Pipette analysis B.S.1377 1990 clause 9.4

GEOTECHNICAL LABORATORIES,
TRINITY COLLEGE,
DUBLIN.2.

PARTICLE SIZE DISTRIBUTION CHART

Sample No. Bh.4
Bore 4 - BHC.5
Depth 1.0m

Curtins, Fermoy
17/10/2001
Brown very silty SAND



B.S. sieve size	% Passing	Soil Fraction	Total %	**BHC. 5 at 1m**
		Cobbles	0.0	
37.5	100.0	Gravel	12.5	
20	100.0			
10	99.7	Sand	46.1	
5	95.4			
2	87.5	Silt	29.9	
1.18	83.1			
0.6	77.6	Clay	11.6	
0.425	72.8			
0.3	68.4	Brown very silty SAND		
0.15	54.4			
0.063	41.5			
0.02	27.5			
0.006	17.9			
0.002	11.6			

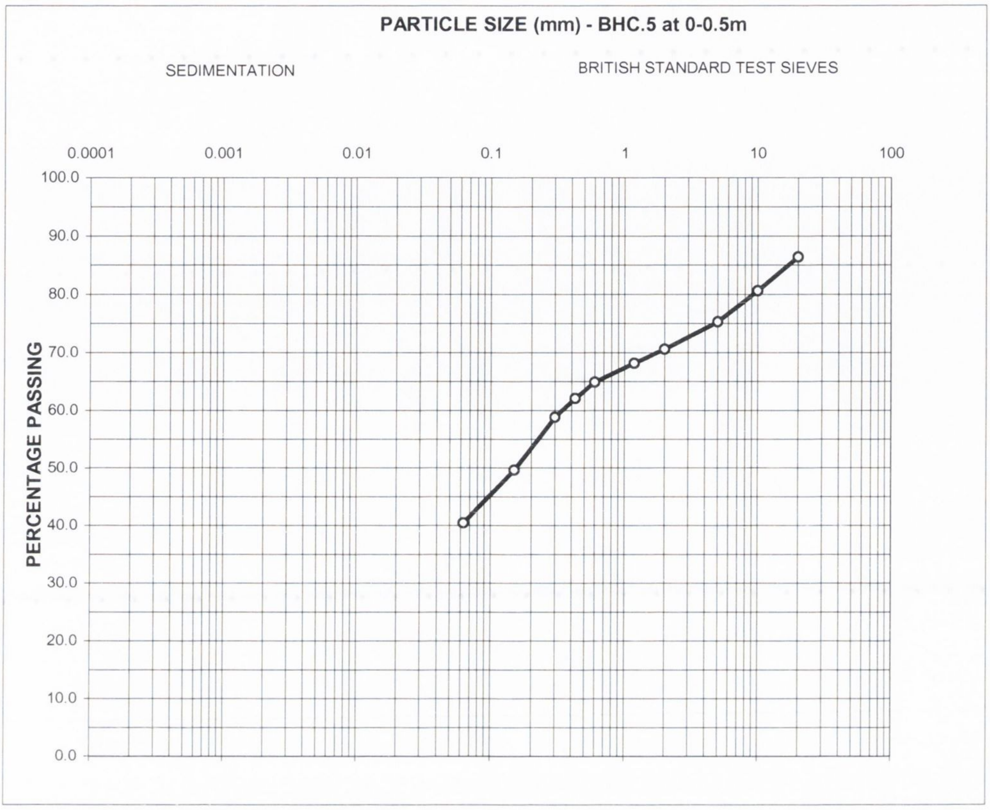
Wet Sieve Analysis B.S. 1377 1990 Clause 9.2
Pipette analysis B.S.1377 1990 clause 9.4

GEOTECHNICAL LABORATORIES,
TRINITY COLLEGE,
DUBLIN.2.

PARTICLE SIZE DISTRIBUTION CHART

Sample No.
Bore 4 - **BHC.5**
Depth 2m

Curtins
Date 17.10.01
Brown silty gravelly SAND



B.S. sieve size	% Passing
37.5	100.0
20	86.4
10	80.6
5	75.3
2	70.6
1.18	68.2
0.6	64.9
0.425	62.1
0.3	58.8
0.15	49.6
0.063	40.5

Soil Fraction	Total %	BHC.5 - 2m
Cobbles	0.0	
Gravel	29.4	
Sand	30.1	
Silt/Clay	40.5	

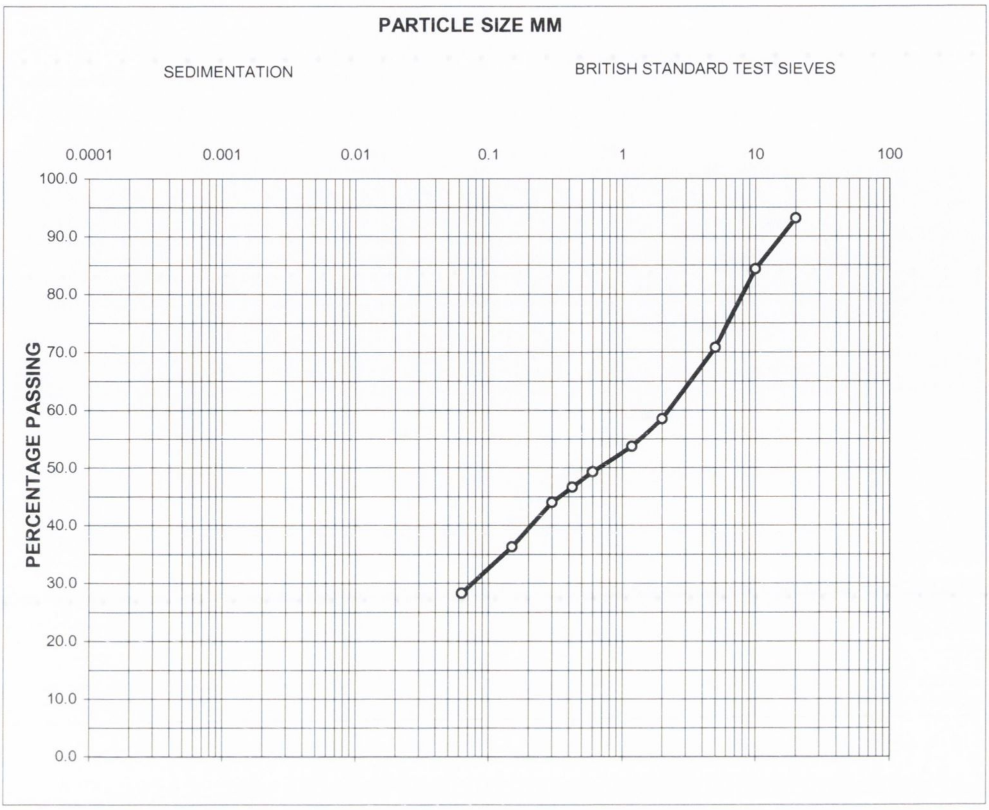
Brown silty gravelly SAND

Wet Sieve Analysis B.S. 1377 1990 Clause 9.2

GEOTECHNICAL LABORATORIES,
TRINITY COLLEGE,
DUBLIN.2.

PARTICLE SIZE DISTRIBUTION CHART

Sample No.	Curtins
Bore 4 **(BHC.5)**	Date 17.10.01
Depth 2.5m	**Brown sandy GRAVEL**



B.S. sieve size	% Passing
37.5	100.0
20	93.1
10	84.4
5	70.8
2	58.5
1.18	53.7
0.6	49.3
0.425	46.7
0.3	44.0
0.15	36.3
0.063	28.3

Soil Fraction	Total %	**BHC.5 - 2.5m**
Cobbles	0.0	
Gravel	41.5	
Sand	30.2	
Silt/Clay	28.3	

Brown sandy GRAVEL

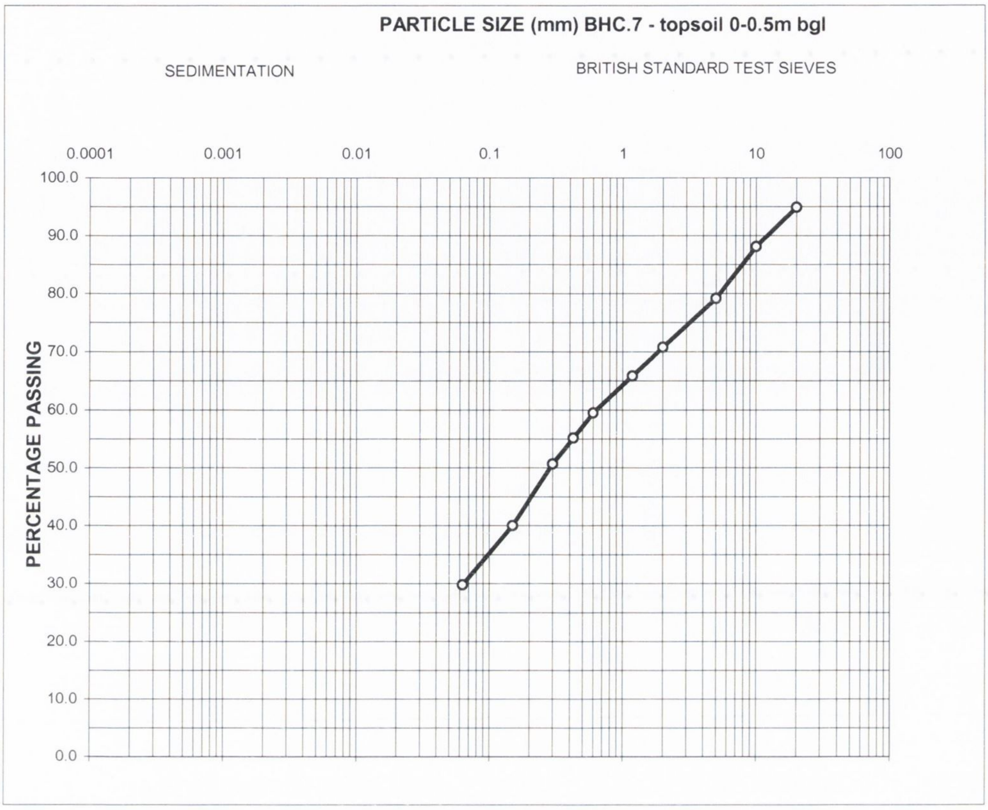
Brown silty/clayey very gravelly SAND

Wet Sieve Analysis B.S. 1377 1990 Clause 9.2

GEOTECHNICAL LABORATORIES,
TRINITY COLLEGE,
DUBLIN.2.

PARTICLE SIZE DISTRIBUTION CHART

Sample No.	Curtins, Fermoy
Bore 8 - **BHC.7**	Date 17.10.01
Depth topsoil <0.5m	**Brown silty gravelly SAND**



B.S. sieve size	% Passing	Soil Fraction	Total %	**BHC.7 - topsoil**
		Cobbles	0.0	
37.5	100.0	Gravel	29.2	
20	94.9			
10	88.1	Sand	41.0	
5	79.1			
2	70.8	Silt/Clay	29.8	
1.18	65.8			
0.6	59.5	**Brown silty gravelly SAND**		
0.425	55.2			
0.3	50.7			
0.15	40.0			
0.063	29.8			

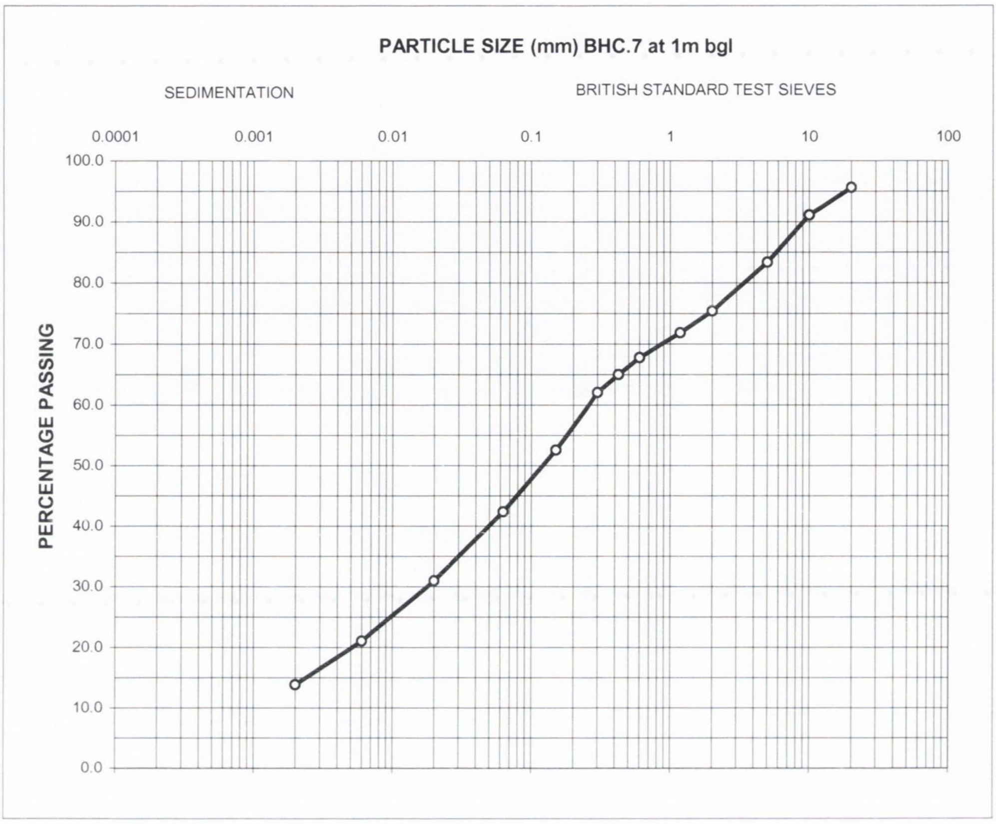
Wet Sieve Analysis B.S. 1377 1990 Clause 9.2

GEOTECHNICAL LABORATORIES,
TRINITY COLLEGE,
DUBLIN.2.

PARTICLE SIZE DISTRIBUTION CHART

Sample No.
Bore 8 - BHC.7
Depth 1.0m

Curtins, Fermoy
17/10/2001
Gravelly silty SAND



B.S. sieve size	% Passing
37.5	100.0
20	95.6
10	91.1
5	83.4
2	75.4
1.18	71.9
0.6	67.8
0.425	65.0
0.3	62.1
0.15	52.6
0.063	42.3
0.02	30.9
0.006	21.1
0.002	13.8

Soil Fraction	Total % BH8 -1m
Cobbles	
Gravel	24.6
Sand	33.1
Silt	28.5
Clay	13.8

Gravelly silty SAND

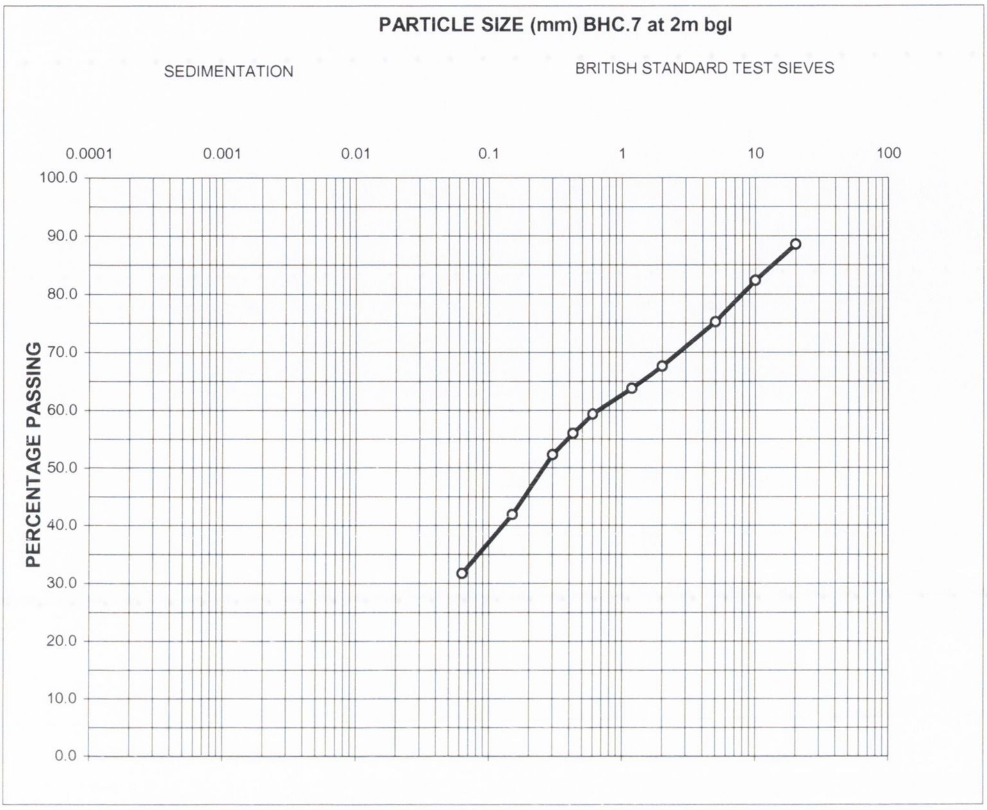
Wet Sieve Analysis B.S. 1377 1990 Clause 9.2
Pipette analysis B.S.1377 1990 clause 9.4

GEOTECHNICAL LABORATORIES,
TRINITY COLLEGE,
DUBLIN.2.

PARTICLE SIZE DISTRIBUTION CHART

Sample No.
Bore 8 - **BHC.7**
Depth 2m

Curtins, Fermoy
Date 17.10.01
Brown silty very gravelly SAND



B.S. sieve size	% Passing
37.5	100.0
20	88.5
10	82.4
5	75.3
2	67.6
1.18	63.8
0.6	59.3
0.425	56.0
0.3	52.3
0.15	41.9
0.063	31.7

Soil Fraction	Total %	BHC.7 at 2m
Cobbles	0.0	
Gravel	32.4	
Sand	35.9	
Silt/Clay	31.7	

Brown silty very gravelly SAND

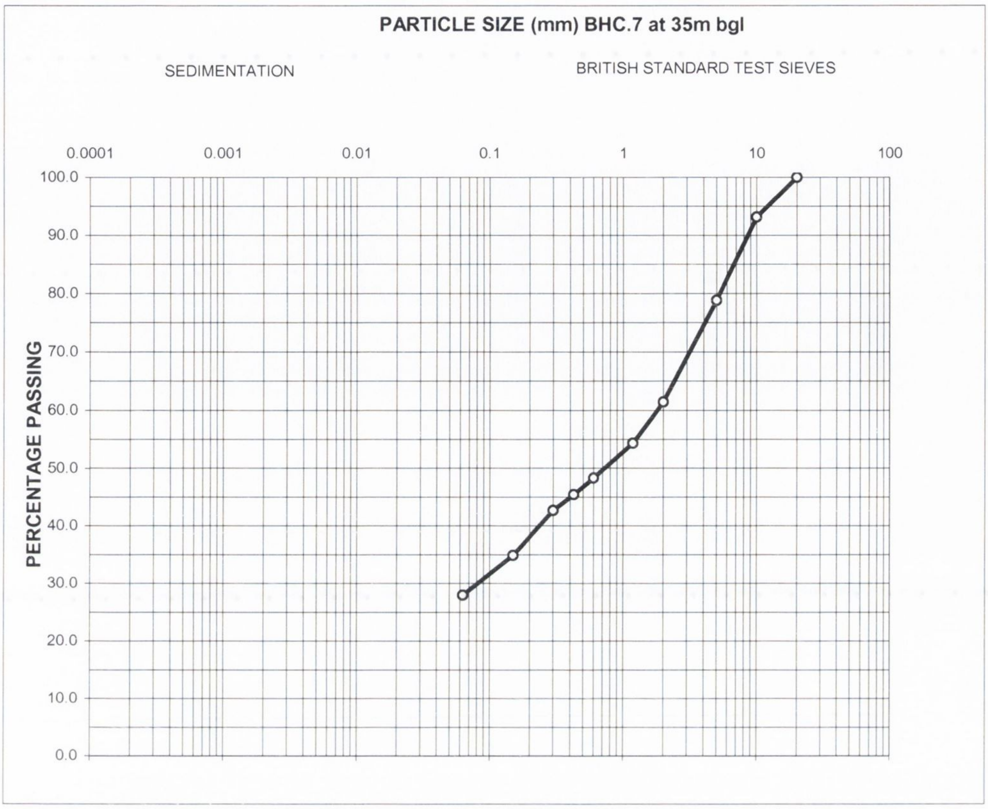
Wet Sieve Analysis B.S. 1377 1990 Clause 9.2

GEOTECHNICAL LABORATORIES,
TRINITY COLLEGE,
DUBLIN.2.

PARTICLE SIZE DISTRIBUTION CHART

Sample No.
Bore 8 - **BHC.7**
Depth 35m

Curtins, Fermoy
Date 17.10.01
Brown silty very sandy GRAVEL



B.S. sieve size	% Passing
37.5	100.0
20	100.0
10	93.1
5	78.8
2	61.4
1.18	54.4
0.6	48.3
0.425	45.4
0.3	42.7
0.15	34.9
0.063	28.0

Soil Fraction	Total %	**BHC.7 -35m**
Cobbles	0.0	
Gravel	38.6	
Sand	33.4	
Silt/Clay	28.0	

Brown silty very sandy GRAVEL

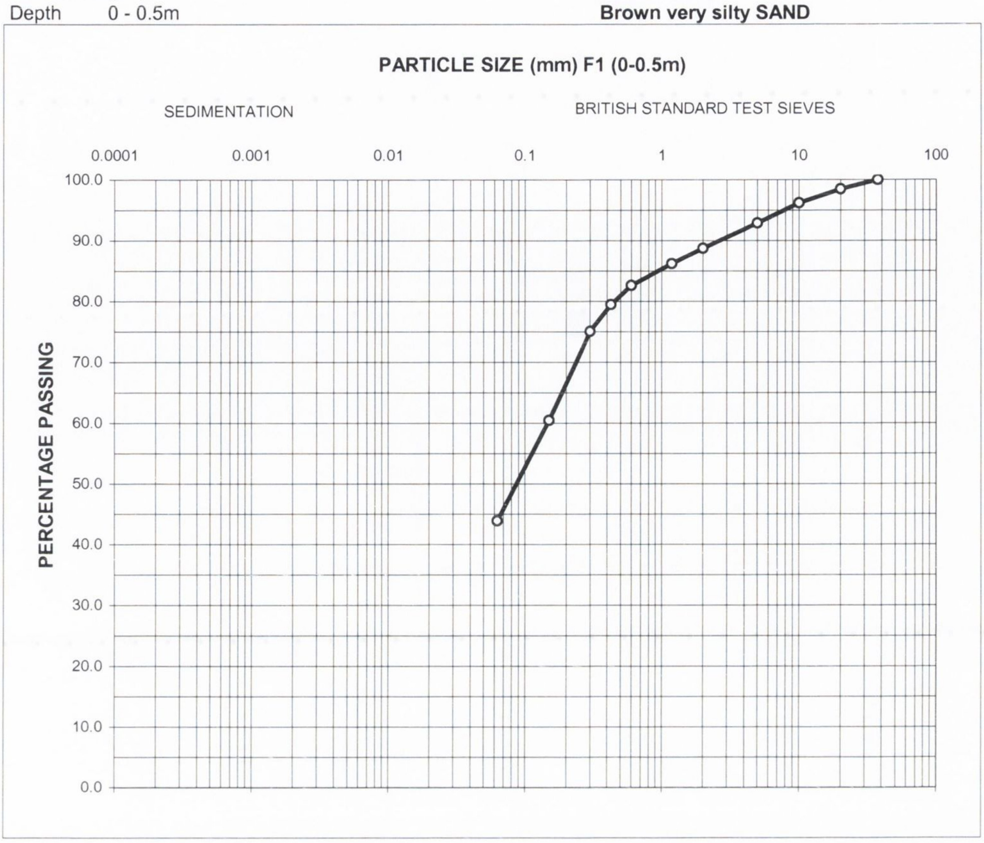
Wet Sieve Analysis B.S. 1377 1990 Clause 9.2

GEOTECHNICAL LABORATORIES,
TRINITY COLLEGE,
DUBLIN.2.

PARTICLE SIZE DISTRIBUTION CHART

Sample No. 2
Borehole 2 (F1)
Depth 0 - 0.5m

Curtins farm, Fermoy
Date 17-10-01
Brown very silty SAND



B.S. sieve size	% Passing
37.5	100.0
20	98.5
10	96.2
5	92.9
2	88.7
1.18	86.2
0.6	82.6
0.425	79.5
0.3	75.1
0.15	60.5
0.063	43.9

Soil Fraction	Total %	**F1 (0-0.5m)**
Cobbles	0.0	
Gravel	11.3	
Sand	44.8	
Silt/clay	43.9	

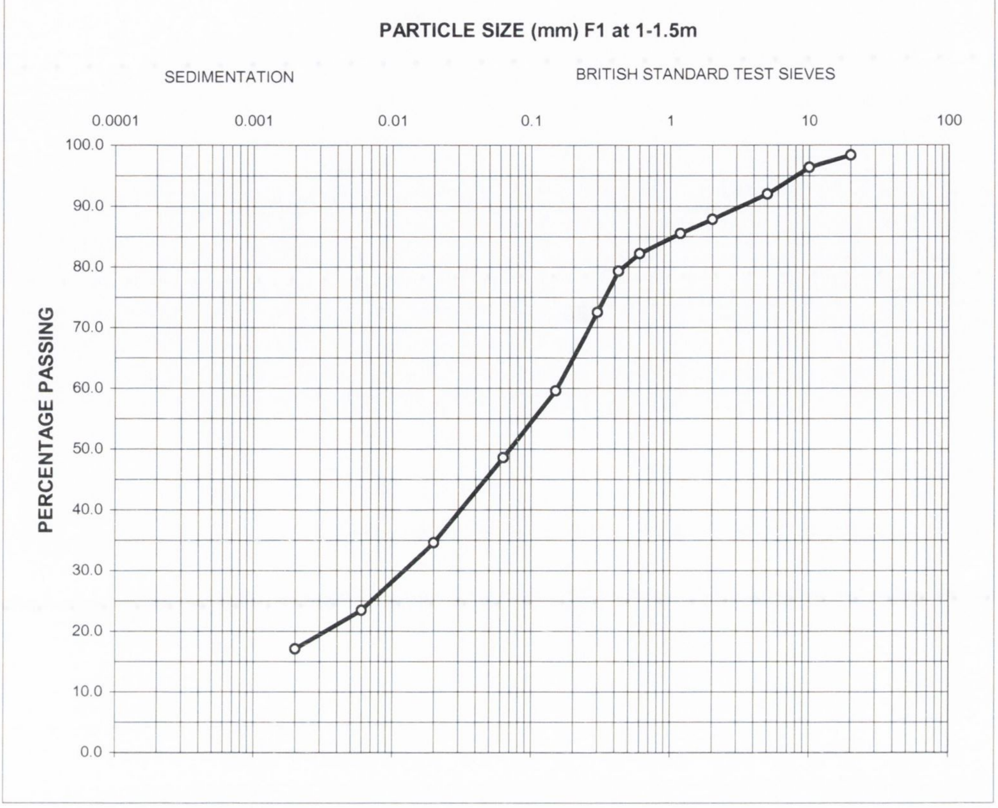
Brown very silty SAND

Wet Sieve Analysis B.S. 1377 1990 Clause 9.2

GEOTECHNICAL LABORATORIES,
TRINITY COLLEGE,
DUBLIN.2.

PARTICLE SIZE DISTRIBUTION CHART

Sample No.	Curtins, Fermoy
Bore 2 - F1	17/10/2001
Depth 1 - 1.5m	**Brown very silty SAND**



B.S. sieve size	% Passing
37.5	100.0
20	98.3
10	96.4
5	92.0
2	87.8
1.18	85.5
0.6	82.2
0.425	79.3
0.3	72.5
0.15	59.6
0.063	48.6
0.02	34.6
0.006	23.5
0.002	17.1

Soil Fraction	Total %	**F1 at 1-1.5m**
Cobbles	0.0	
Gravel	12.2	
Sand	39.3	
Silt	31.5	
Clay	17.1	

Brown very silty SAND

Wet Sieve Analysis B.S. 1377 1990 Clause 9.2
Pipette analysis B.S.1377 1990 clause 9.4

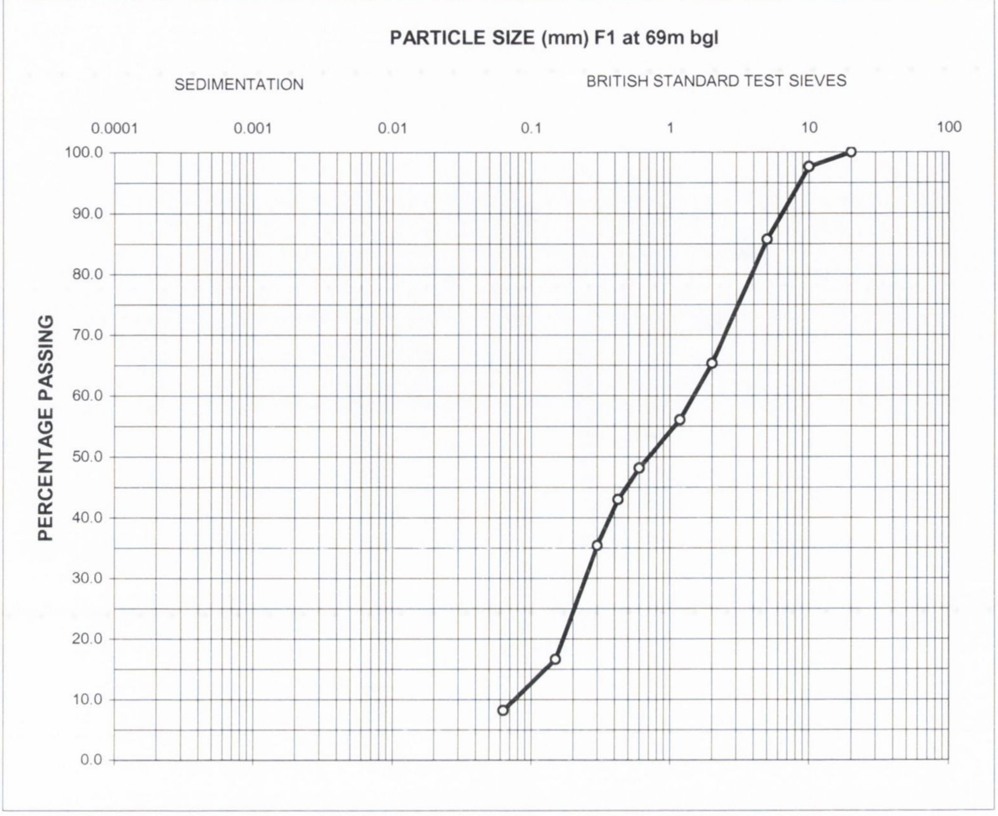
GEOTECHNICAL LABORATORIES,
TRINITY COLLEGE,
DUBLIN.2.

PARTICLE SIZE DISTRIBUTION CHART

Sample No. Bore 2 - **F1**

Depth 69m

Curtins, Fermoy
17-Oct-01
Brown very gravelly SAND



B.S. sieve size	% Passing
20	100.0
10	97.6
5	85.7
2	65.3
1.18	56.1
0.6	48.2
0.425	43.0
0.3	35.4
0.15	16.6
0.063	8.2

Soil Fraction	Total %	**F1 - 69m**
Cobbles	0.0	
Gravel	34.7	
Sand	57.1	
Silt/Clay	8.2	

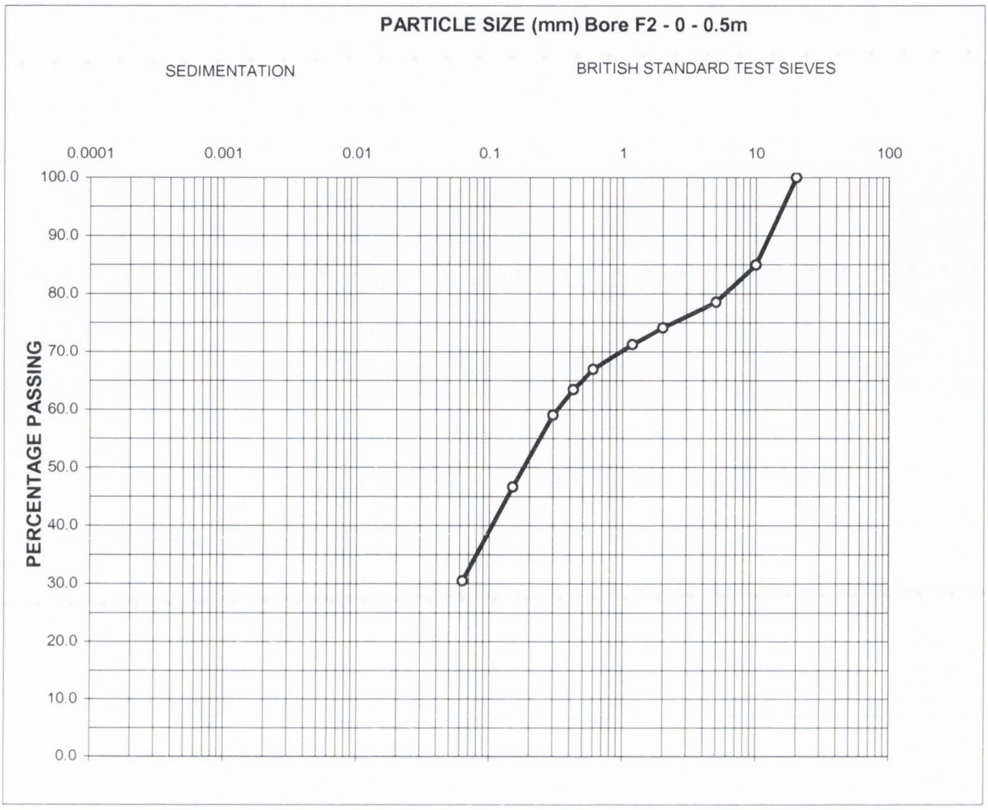
Brown very gravelly SAND

Wet Sieve Analysis B.S. 1377 1990 Clause 9.2
Pipette analysis B.S.1377 1990 clause 9.4

GEOTECHNICAL LABORATORIES,
TRINITY COLLEGE,
DUBLIN.2.

PARTICLE SIZE DISTRIBUTION CHART

Sample No.		Curtins, Fermoy
Bore 1 - **F2**		Date 17.10.01
Sample Depth	**0.0 - 0.5m.**	**Brown very gravelly SAND**



B.S. sieve size	% Passing
20	100.0
10	84.9
5	78.5
2	74.1
1.18	71.3
0.6	67.0
0.425	63.4
0.3	59.1
0.15	46.6
0.063	30.5

Soil Fraction	Total %	**F2 (0-0.5)**
Cobbles	0.0	
Gravel	25.9	
Sand	43.6	
Silt/Clay	30.5	

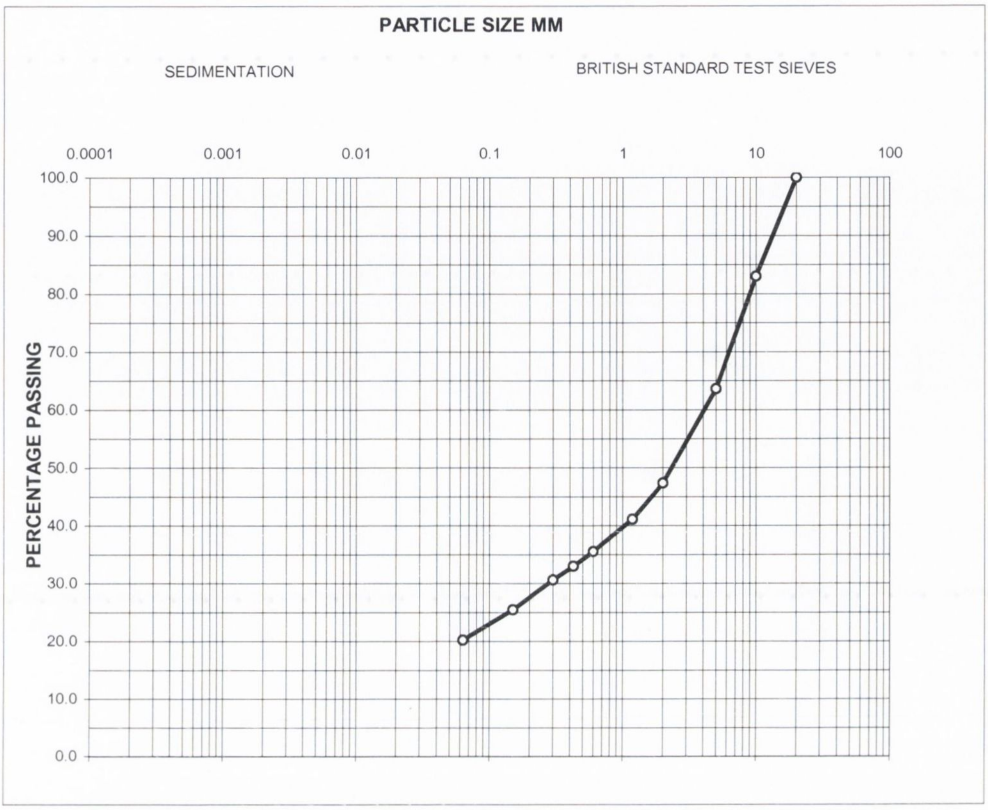
Brown very gravelly SAND

Wet Sieve Analysis B.S. 1377 1990 Clause 9.2

GEOTECHNICAL LABORATORIES,
TRINITY COLLEGE,
DUBLIN.2.

PARTICLE SIZE DISTRIBUTION CHART

Sample No.	Curtins
Bore 3 **F3**	Date 17.10.01
Depth 0.0 - 0.5m.	**Brown sandy GRAVEL**



B.S. sieve size	% Passing	Soil Fraction	Total %	F3 0-0.5m
		Cobbles	0.0	
		Gravel	52.6	
20	100.0			
10	83.0	Sand	27.1	
5	63.6			
2	47.4	Silt/Clay	20.2	
1.18	41.1			
0.6	35.6			
0.425	33.0	Brown sandy GRAVEL		
0.3	30.6			
0.15	25.5			
0.063	20.2			

Wet Sieve Analysis B.S. 1377 1990 Clause 9.2

GEOTECHNICAL LABORATORIES,
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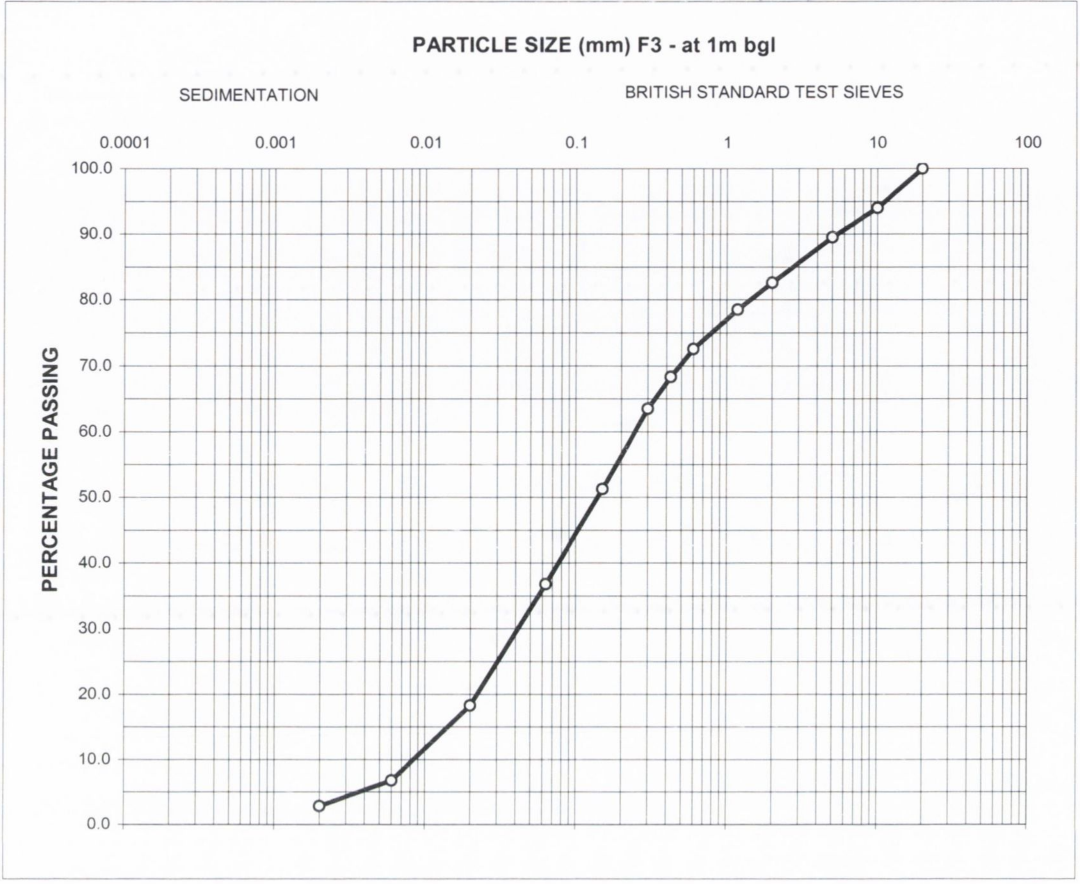
DUBLIN.2.

PARTICLE SIZE DISTRIBUTION CHART

Sample No.
Bore3 - F3
Depth 1.0m

Curtins, Fermoy
17/10/2001
Brown very silty SAND



B.S. sieve size	% Passing	Soil Fraction	Total %	**F3 at 1m**
		Cobbles	0.0	
37.5	100.0	Gravel	17.4	
20	100.0			
10	94.0	Sand	45.8	
5	89.5			
2	82.6	Silt	34.0	
1.18	78.5			
0.6	72.6	Clay	2.8	
0.425	68.3			
0.3	63.5			
0.15	51.3	Brown very silty SAND		
0.063	36.8			
0.02	18.3			
0.006	6.8			
0.002	2.8			

Wet Sieve Analysis B.S. 1377 1990 Clause 9.2
Pipette analysis B.S.1377 1990 clause 9.4

GEOTECHNICAL LABORATORIES,
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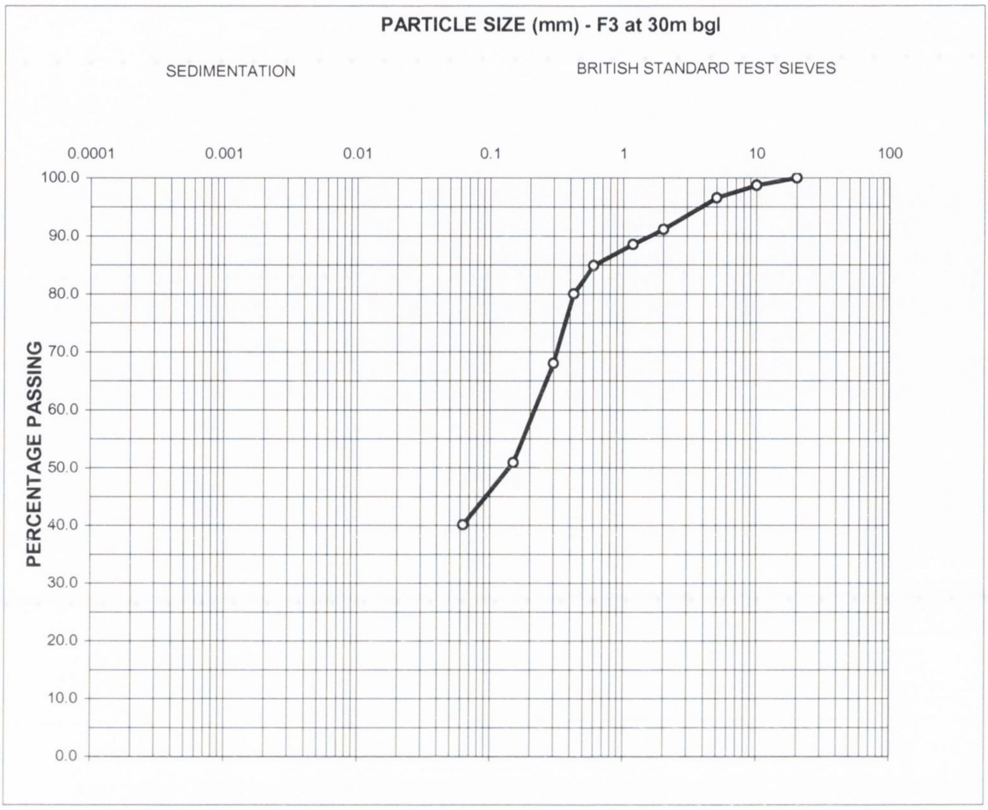
PARTICLE SIZE DISTRIBUTION CHART

Sample No.	Curtins Farm, Fermoy
Bore 3 **(F3)**	Date 17.10.01
Depth 27m	**Silty SAND**



B.S. sieve size	% Passing
20	100.0
10	98.7
5	96.6
2	91.2
1.18	88.5
0.6	84.9
0.425	80.0
0.3	68.1
0.15	50.9
0.063	40.1

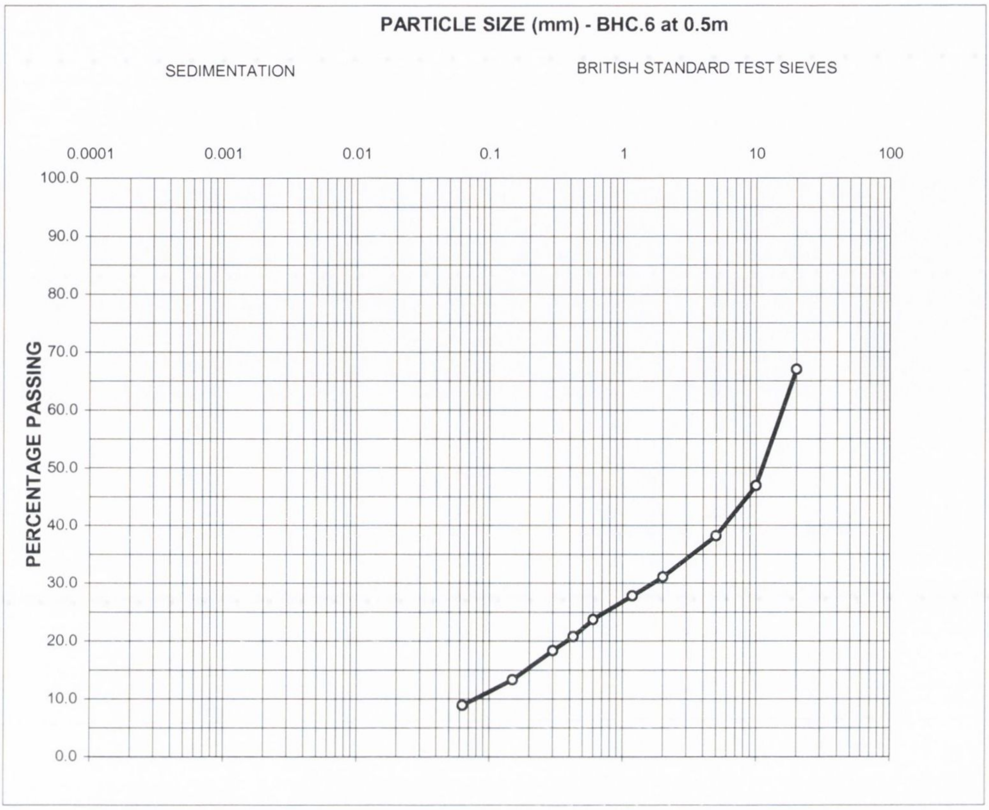
Soil Fraction	Total %	**F3** - 30m
Cobbles	0.0	
Gravel	8.8	
Sand	51.0	
Silt/Clay	40.1	
Silty SAND		

Wet Sieve Analysis B.S. 1377 1990 Clause 9.2

GEOTECHNICAL LABORATORIES,
TRINITY COLLEGE,
DUBLIN.2.

PARTICLE SIZE DISTRIBUTION CHART

Sample No.	Curtins
Bore 5 - **F5**	Date 17.10.01
Depth 0.5m	**Brown sandy GRAVEL**



B.S. sieve size	% Passing	Soil Fraction	Total %	**F5 0-0.5m**
		Cobbles	0.0	
37.5	100.0	Gravel	68.9	
20	67.0			
10	46.9	Sand	22.2	
5	38.2			
2	31.1	Silt/Clay	8.9	
1.18	27.8			
0.6	23.7	Brown sandy GRAVEL		
0.425	20.8			
0.3	18.4			
0.15	13.3			
0.063	8.9			

Wet Sieve Analysis B.S. 1377 1990 Clause 9.2

GEOTECHNICAL LABORATORIES,
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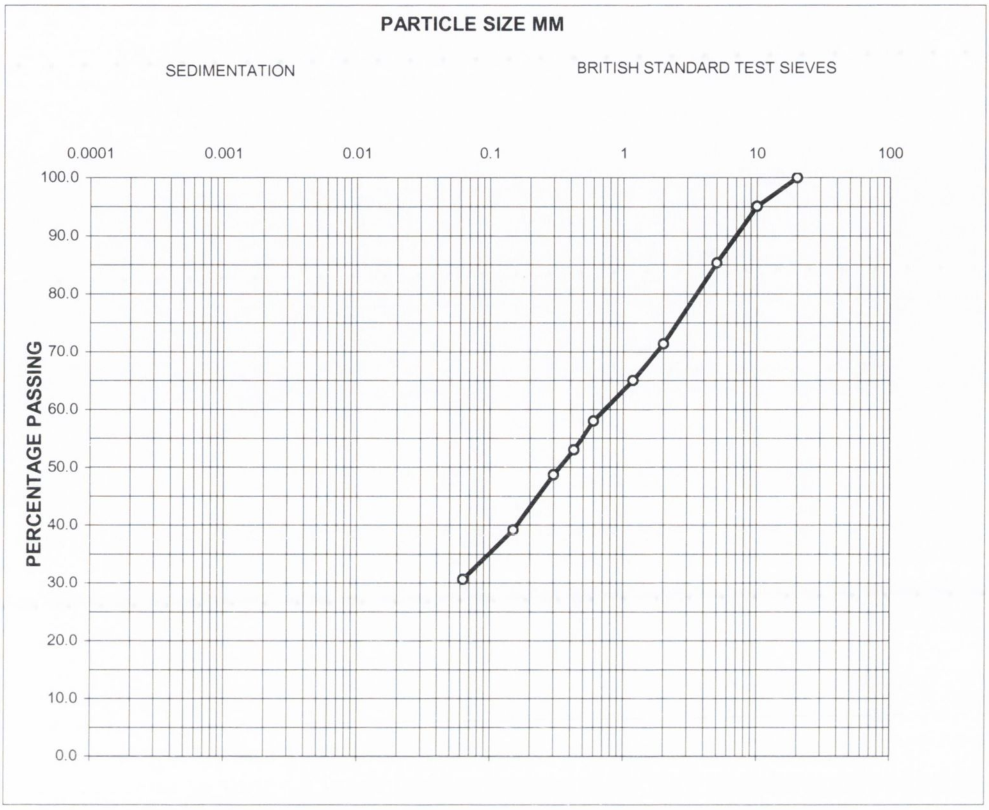
DUBLIN.2.

PARTICLE SIZE DISTRIBUTION CHART

Sample No.
Bore 5 - **F5**
Depth 1m

Curtins
Date 17.10.01
Brown silty gravelly SAND



B.S. sieve size	% Passing
37.5	100.0
20	100.0
10	95.1
5	85.3
2	71.4
1.18	65.0
0.6	58.0
0.425	53.0
0.3	48.7
0.15	39.2
0.063	30.6

Soil Fraction	Total %	**F5- 1m**
Cobbles	0.0	
Gravel	28.6	
Sand	40.8	
Silt/Clay	30.6	

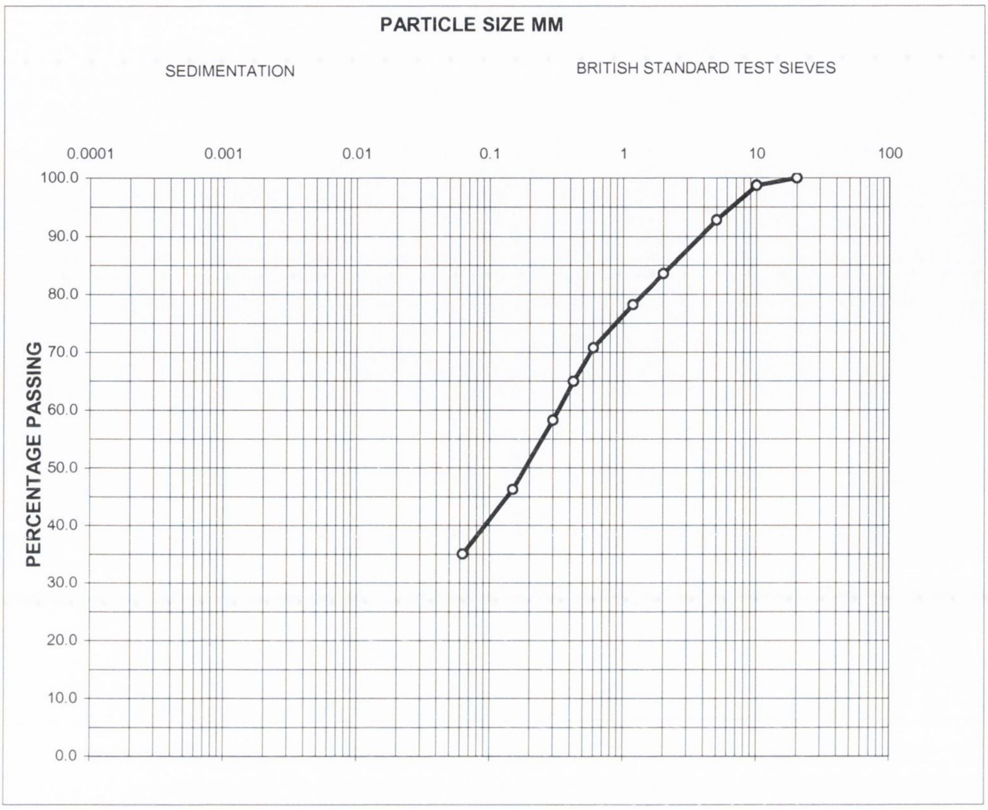
Brown silty gravelly SAND

Wet Sieve Analysis B.S. 1377 1990 Clause 9.2

GEOTECHNICAL LABORATORIES,
TRINITY COLLEGE,
DUBLIN.2.

PARTICLE SIZE DISTRIBUTION CHART

Sample No.	Curtins, Fermoy
Bore 5 -**F5**	Date 17.10.01
Depth 2m	**Brown silty SAND**



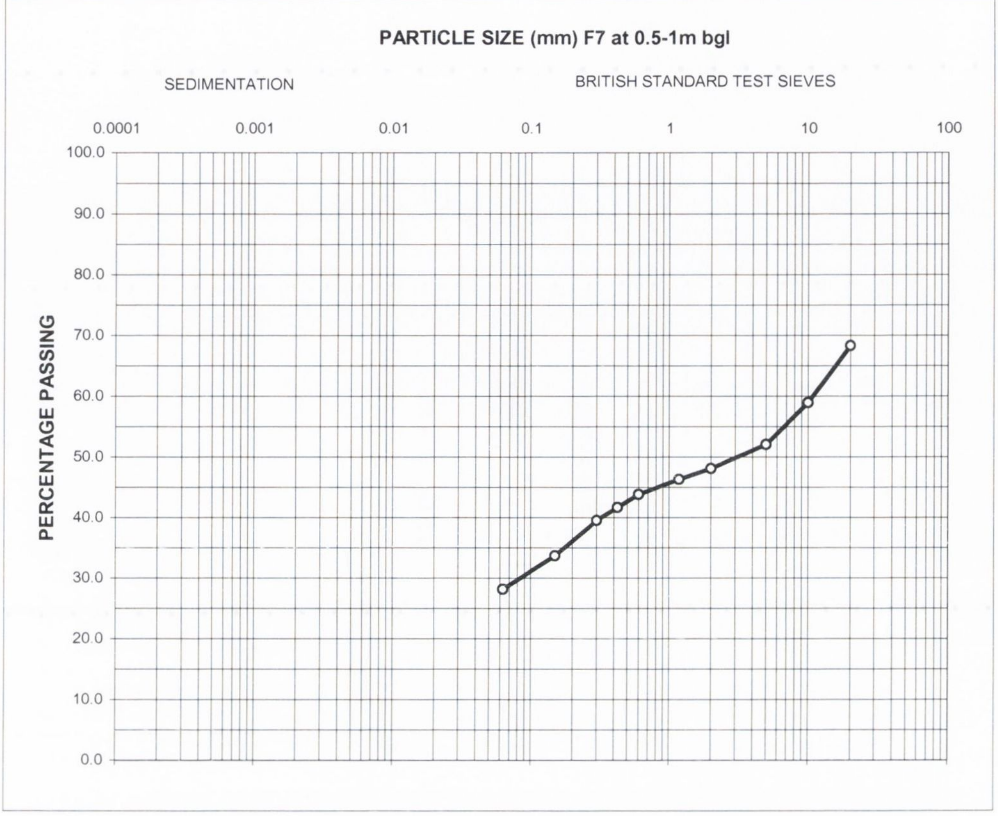
B.S. sieve size	% Passing	Soil Fraction	Total %	**F5 -2m**
		Cobbles	0.0	
37.5	100.0	Gravel	16.4	
20	100.0			
10	98.7	Sand	48.6	
5	92.8			
2	83.6	Silt/Clay	35.0	
1.18	78.2			
0.6	70.7			
0.425	64.9	**Brown silty SAND**		
0.3	58.3			
0.15	46.3			
0.063	35.0			

Wet Sieve Analysis B.S. 1377 1990 Clause 9.2

GEOTECHNICAL LABORATORIES,
TRINITY COLLEGE,
DUBLIN.2.

PARTICLE SIZE DISTRIBUTION CHART

Sample No.	Curtins Farm, Fermoy
Bore 11 - F7	17/10/2001
Depth 0.5 - 1m	**Brown sandy GRAVEL**



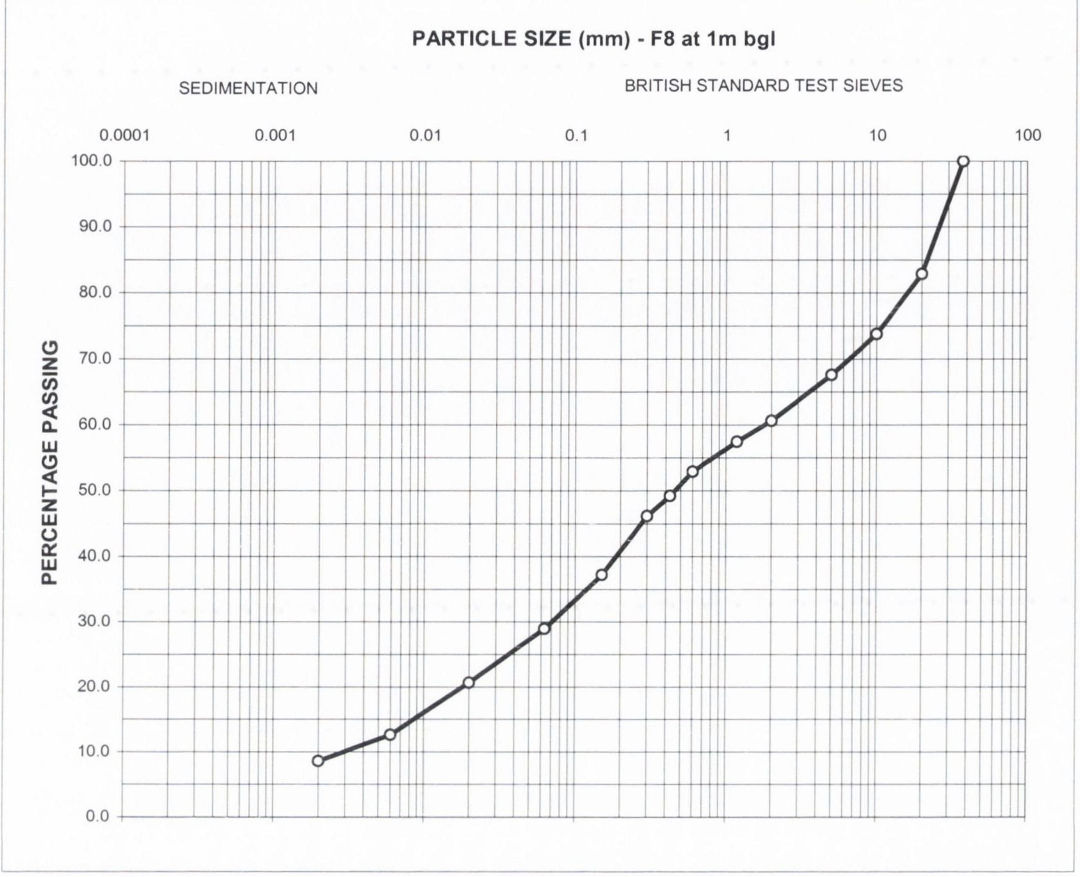
B.S. sieve size	% Passing	Soil Fraction	Total %	**F7 at 0.5-1m**
		Cobbles	0.0	
37.5	100.0	Gravel	51.9	
20	68.3			
10	59.0	Sand	19.9	
5	52.1			
2	48.1	Silt & Clay	28.2	
1.18	46.3			
0.6	43.9			
0.425	41.7	**Brown sandy GRAVEL**		
0.3	39.5			
0.15	33.7			
0.063	28.2			

Wet Sieve Analysis B.S. 1377 1990 Clause 9.2
Pipette analysis B.S.1377 1990 clause 9.4

GEOTECHNICAL LABORATORIES,
TRINITY COLLEGE,
DUBLIN.2.

PARTICLE SIZE DISTRIBUTION CHART

Sample No.	Curtins Farm, Fermoy
Bore 12 - **F8**	17/10/2001
Depth 1m	**Brown sandy GRAVEL**



B.S. sieve size	% Passing
37.5	100.0
20	82.9
10	73.8
5	67.6
2	60.6
1.18	57.5
0.6	52.9
0.425	49.2
0.3	46.2
0.15	37.2
0.063	28.9
0.02	20.7
0.006	12.6
0.002	8.6

Soil Fraction	Total %	**F8 -1m**
Cobbles	0.0	
Gravel	39.4	
Sand	31.7	
Silt	20.4	
Clay	8.6	

Brown sandy GRAVEL

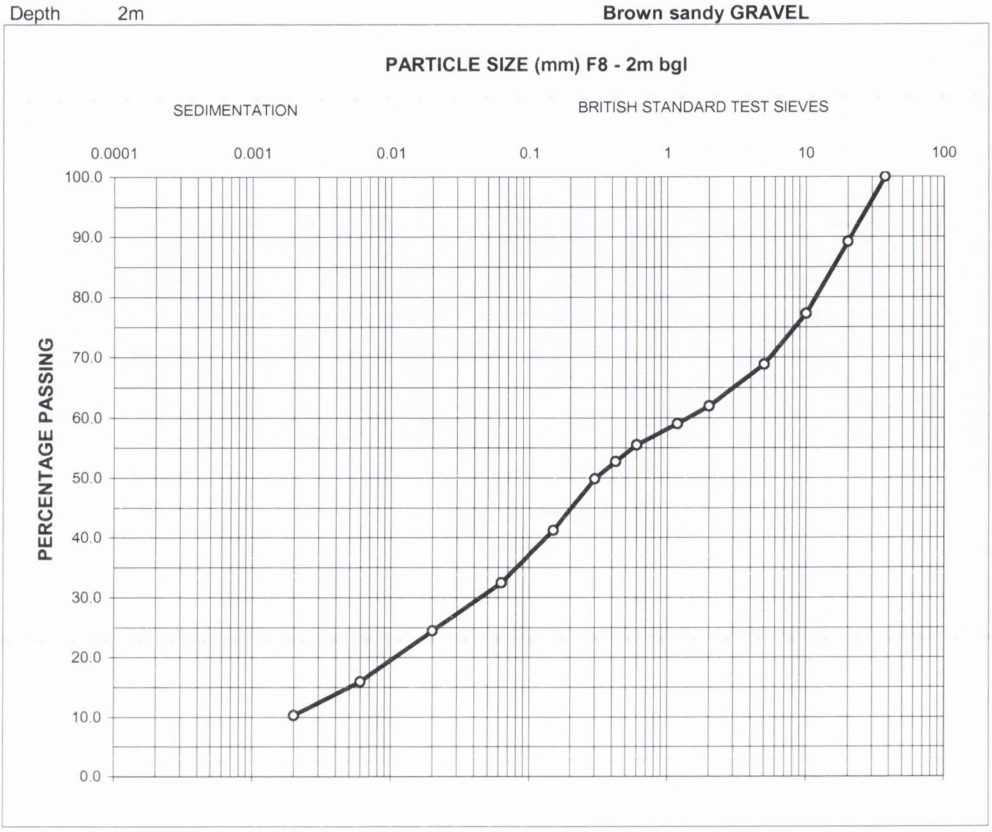
Wet Sieve Analysis B.S. 1377 1990 Clause 9.2
Pipette analysis B.S.1377 1990 clause 9.4

GEOTECHNICAL LABORATORIES,
TRINITY COLLEGE,
DUBLIN.2.

PARTICLE SIZE DISTRIBUTION CHART

Sample No.
Bore 12 F8
Depth 2m

Curtins Farm, Fermoy
17/10/2001
Brown sandy GRAVEL



B.S. sieve size	% Passing
37.5	100.0
20	89.2
10	77.3
5	68.8
2	61.9
1.18	59.0
0.6	55.5
0.425	52.7
0.3	49.9
0.15	41.3
0.063	32.5
0.02	24.4
0.006	15.9
0.002	10.3

Soil Fraction	Total %	**F8 - 2m**
Cobbles	0.0	
Gravel	38.1	
Sand	29.5	
Silt	22.2	
Clay	10.3	

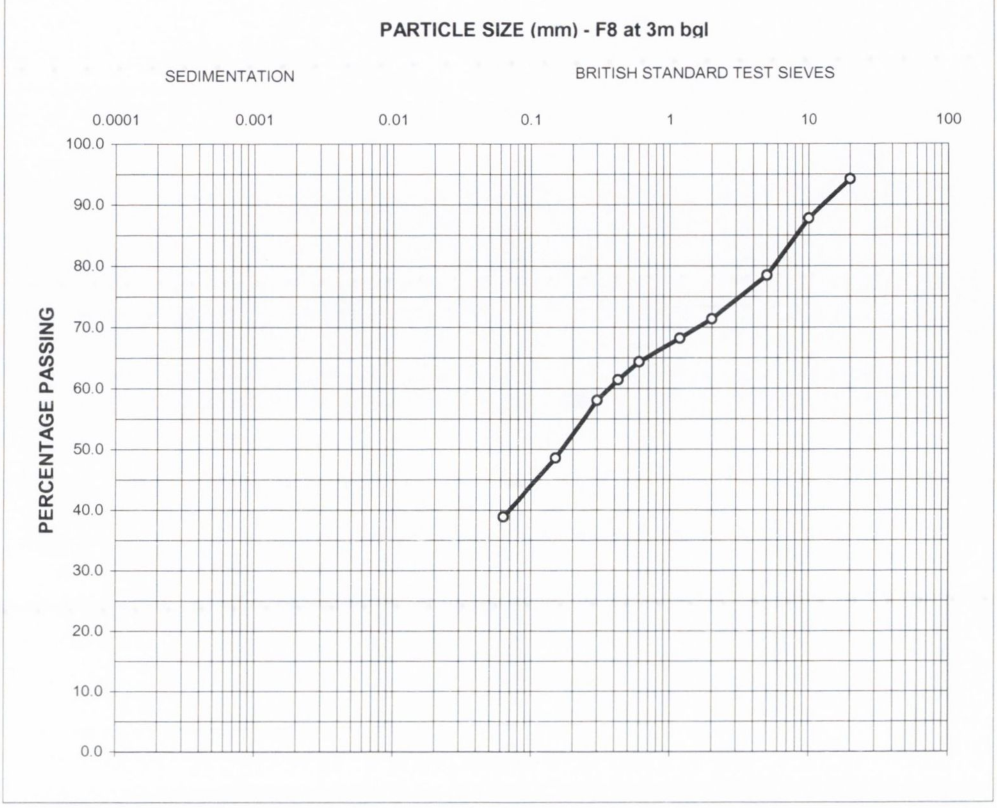
Brown sandy GRAVEL

Wet Sieve Analysis B.S. 1377 1990 Clause 9.2
Pipette analysis B.S.1377 1990 clause 9.4

GEOTECHNICAL LABORATORIES,
TRINITY COLLEGE,
DUBLIN.2.

Particle Size Distribution Chart

Sample No	Curtins Farm, Fermoy
Bore 12 - F8	17/10/2001
Depth 2-3m	**Brown gravelly silty SAND**



B.S. sieve size	% Passing
37.5	100.0
20	94.2
10	87.8
5	78.5
2	71.3
1.18	68.2
0.6	64.4
0.425	61.4
0.3	58.1
0.15	48.6
0.063	38.9

Soil Fraction	Total %	**F8 (2-3m)**
Cobbles	0.0	
Gravel	28.7	
Sand	32.5	
Silt & Clay	38.9	

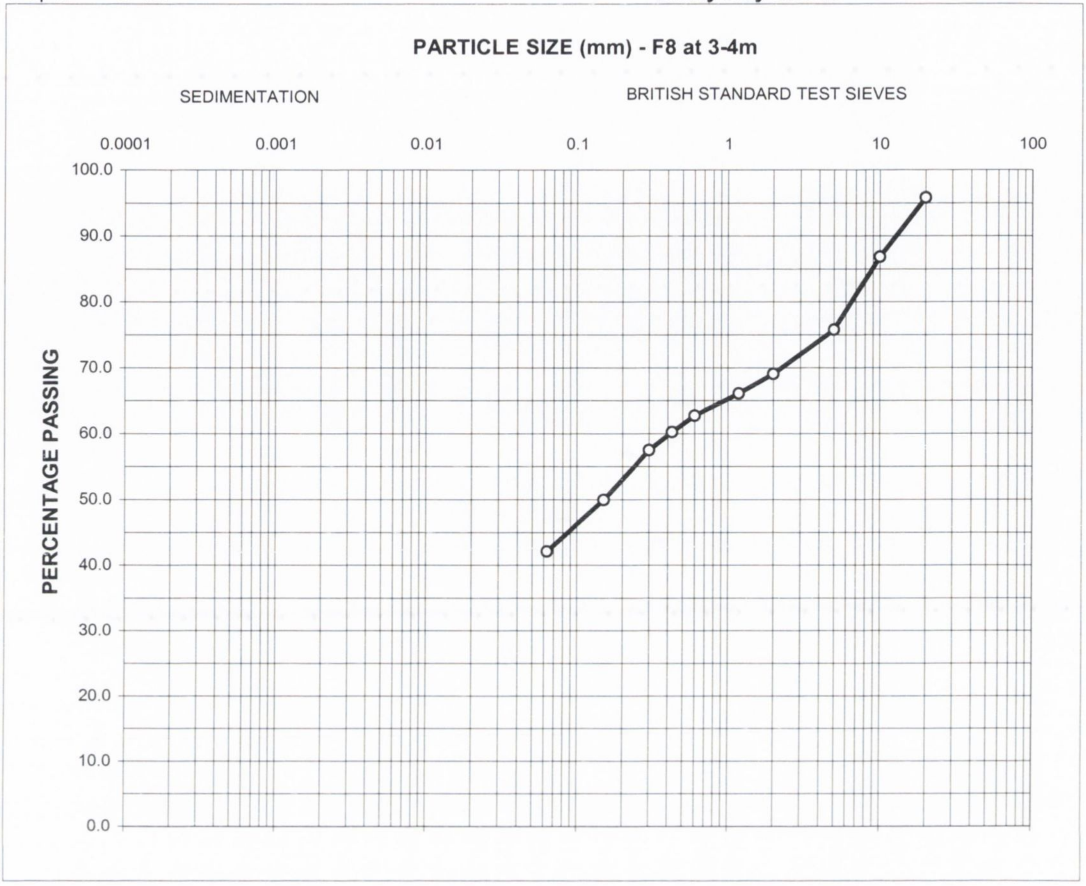
Brown gravelly silty SAND

Wet Sieve Analysis B.S. 1377 1990 Clause 9.2
Pipette analysis B.S.1377 1990 clause 9.4

GEOTECHNICAL LABORATORIES,
TRINITY COLLEGE,
DUBLIN.2.

PARTICLE SIZE DISTRIBUTION CHART

Sample No. Bh.12	Curtins, Fermoy
Bore 12 - F8	17/10/2001
Depth 3-4m	**Sandy silty Gravel**



B.S. sieve size	% Passing
37.5	100.0
20	95.8
10	86.8
5	75.8
2	69.0
1.18	66.1
0.6	62.7
0.425	60.3
0.3	57.5
0.15	50.0
0.063	42.1

Soil Fraction	Total %	**F8 3-4m** Epikarst
Cobbles	0.0	
Gravel	31.0	
Sand	26.9	
Silt & Clay	42.1	

Sandy silty Gravel

Wet Sieve Analysis B.S. 1377 1990 Clause 9.2
Pipette analysis B.S.1377 1990 clause 9.4

GEOTECHNICAL LABORATORIES,
TRINITY COLLEGE,
DUBLIN.2.

Appendix G

Soil & Subsoil Hydraulic Conductivity

Soil hydraulic conductivity was investigated in five farm plots in which piezometers were located. In each plot four bores were drilled using the 'Giddings' drilling rig. Each bore targeted a specific 0.5m depth interval. Results for K_{sat} were presented in chapter six, section 6.1.1. The investigation and analyses methodologies were presented in chapter five, section 5.2.1.2. During the testing period the watertable was approximately 25m below ground level.

Data in this appendix are presented to show the graphical analysis for each bore in a plot followed by the data sheet for the test period. Piezometer identifier and Curtin's farm plot number identify the graphs and data sheets (see chapter five, Figure 5.14 for plot and piezometer locations).

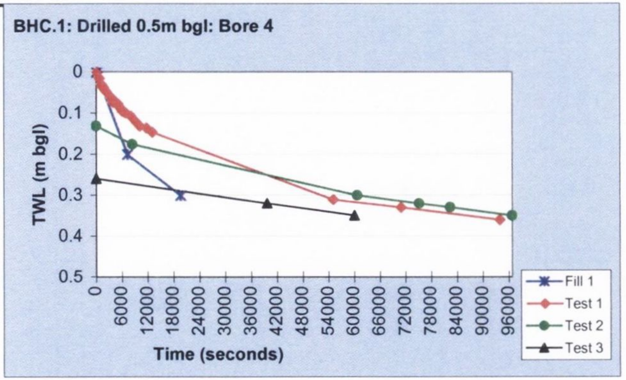
The data are organised as follows:

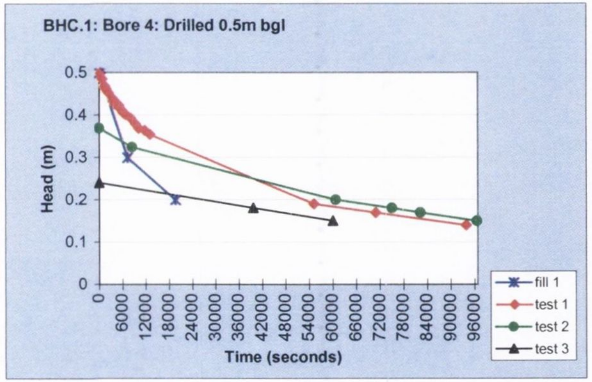
Test Location	Piezometer	Page Number
Plot – 15 BLUE (two cut silage & grazing)	BHC.1	528 – 534
Plot – 17 BLUE (grazing only)	BHC.2	535 – 542
Plot – NUIG experimental plot	BHC.5	543 – 550
Plot – 12 BLUE (dirty water & grazing)	BHC.7	544 – 560
Plot – 3 BLUE (one cut silage & grazing)	BHC.9	561 - 570

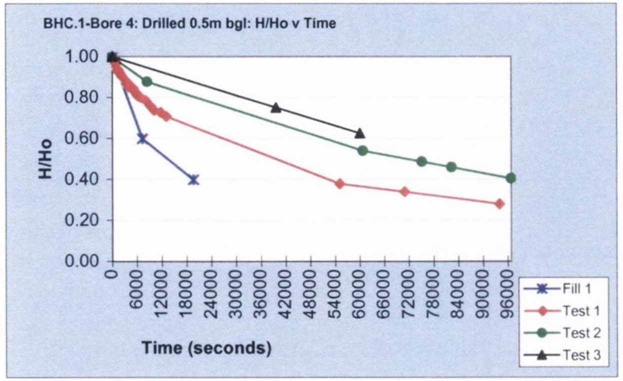
NOTE

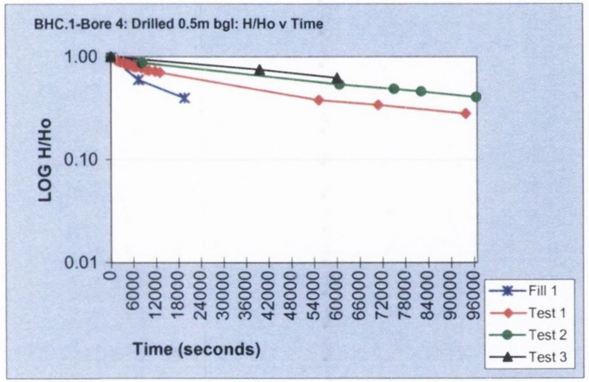
IN THE FOLLOWING PAGES K (m/day) SIGNIFIES K_{sat} AS REFERRED TO IN VOLUME ONE OF THIS THESIS.

PLOT 15BLUE


BHC.1: Drilled 0.5m bgl: Bore 4


BHC.1: Bore 4: Drilled 0.5m bgl


BHC.1-Bore 4: Drilled 0.5m bgl: H/Ho v Time


BHC.1-Bore 4: Drilled 0.5m bgl: H/Ho v Time

BHC.1 Bore 1 Drillled 0.5m bgl

K (m/day)		Initial head(m)
0.0761415	fill 1 of 3	0.5
0.012091	test 1	0.5
0.0123619	test 2	0.23
0.0137509	test 3	0.095

0.0127 m/day saturated K value for 0-0.5m bgl

(2 fills prior to three tests)

BHC.1 plot - Bore 4 - drilled to 0.5m bgl

BHC.1 plot				
K	0.013 m/day	0.009 m/day	0.319 m/day	1.05 m/day
Bore Depth	0.5m bgl	1m bgl	1.5m bgl	2m bgl

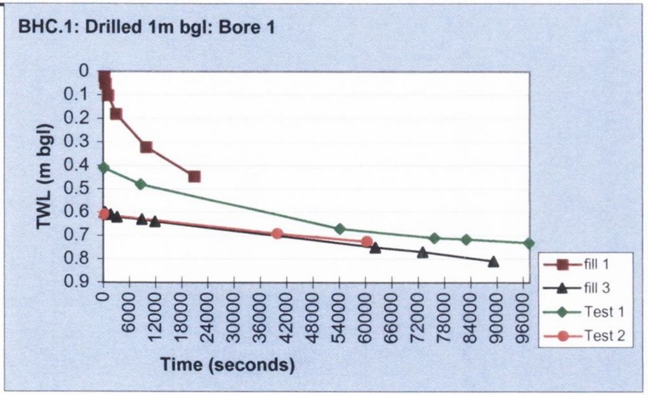
PLOT 15BLUE

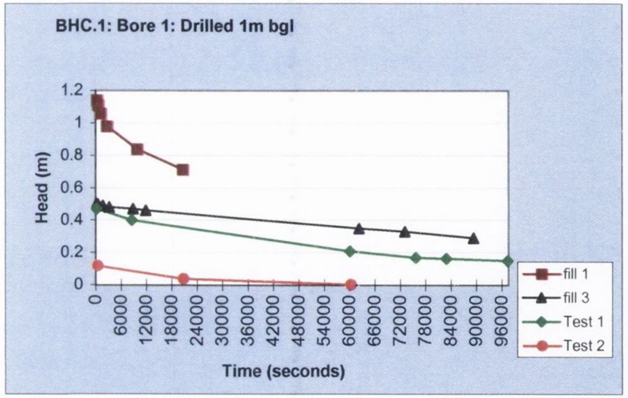
BHC.1 bore 4 - 0.5m TD

	head h (m)	**head h (m)**	**head h (m)**	**head h (m)**
time (secs)	fill 1	test 1	test 2	test 3
0	0.5	0.5	0.37	0.24
480		0.486		
1080		0.47		
1320		0.464		
1440		0.464		
1800		0.457		
2100		0.453		
3360		0.438		
3660		0.428		
4200		0.427		
4800		0.424		
5280		0.415		
5640		0.41		
5760		0.408		
5880		0.406		
6240		0.404		
6600		0.402		
7200	0.3			
7800		0.394		
8400			0.325	
9000		0.38		
9840		0.37		
11400		0.365		
12780		0.355		
19500	0.2			
39600				0.18
54780		0.19		
60000				0.15
60600			0.2	
70560		0.17		
75000			0.18	
82200			0.17	
93600		0.14		
96600			0.15	
K (cm/sec)	8.81267E-05	1.39943E-05	1.43078E-05	1.59153E-05
K (m/day)	0.076141486	0.012091033	0.012361903	0.013750854
	fill 1	test 1	test 2	test 3
Initial head(m)	0.5	0.5	0.23	0.095

K = 1.15*r*(((log(ho+0.5r))-(log(ht+0.5r))/(t-to)) **(cm/seconds)**

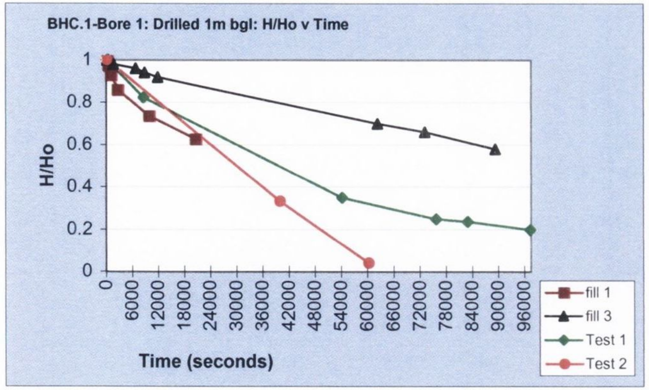
PLOT 15BLUE

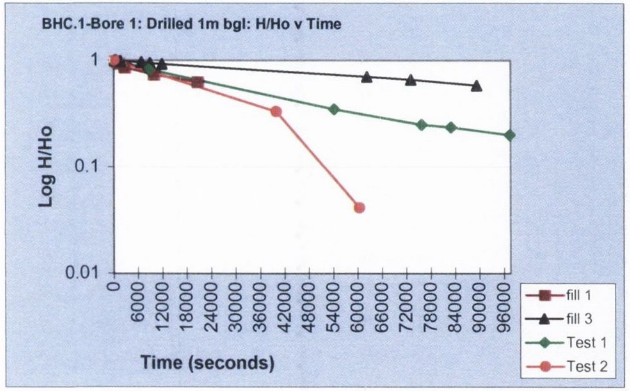

BHC.1: Drilled 1m bgl: Bore 1


BHC.1: Bore 1: Drilled 1m bgl

K = 0.0086 m/day

	K (m/day)	Head (m)
Fill 1	0.0383	1.14
Fill 3	0.0089	0.5
Test 1	0.0089	0.47
Test 2	0.0080	0.27


BHC.1-Bore 1: Drilled 1m bgl: H/Ho v Time


BHC.1-Bore 1: Drilled 1m bgl: H/Ho v Time

BHC.1 plot

K	0.013 m/day	0.009 m/day	0.319 m/day	1.05 m/day
Bore Depth	0.5m bgl	1m bgl	1.5m bgl	2m bgl

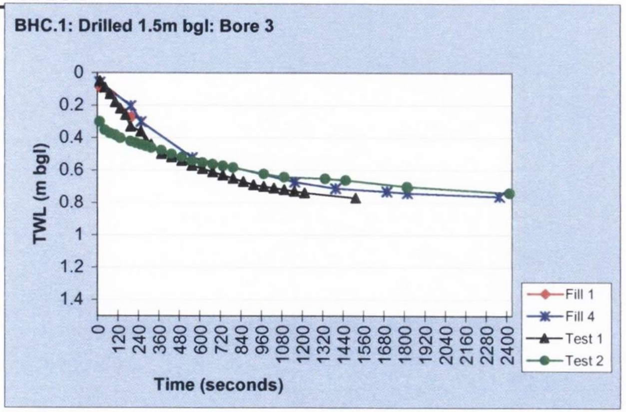
PLOT 15BLUE

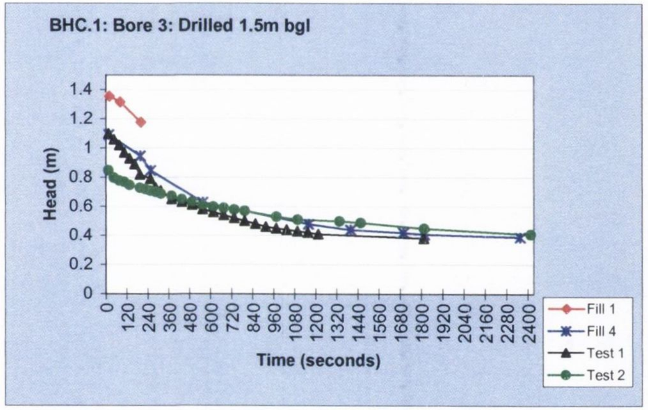
BHC.1 bore 1 - 1.16 TD

	head h (m)	head h (m)	head h (m)	head h (m)
time (secs)	**fill 1**	**fill 3**	**Test 1**	**Test 2**
0	1.14	0.5	0.47	0.27
300	1.11	0.5		
840	1.06			
900		0.5		
1500		0.49		
1920		0.49		
2580	0.98			
3000		0.48		
6600		0.48		
8400			0.4	
8700		0.47		
9780	0.84			
9900		0.47		
11700		0.46		
20580	0.715			0.19
39600				
54000				
60000			0.21	0.155
62100		0.35		
72900		0.33		
75600			0.17	
82800			0.165	
89100		0.29		
97200			0.15	
K (cm/sec)	4.4295E-05	1.031E-05	1.0287E-05	9.2398E-06
K (m/day)	0.03827062	0.00890819	0.00888806	0.00798321
	fill 1	**fill 3**	**Test 1**	**Test 2**
Initial head(m)	1.14	0.5	0.47	0.27

K = 1.15*r*(((log(ho+0.5r))-(log(ht+0.5r))/(t-to)) **(cm/second)**

PLOT 15BLUE

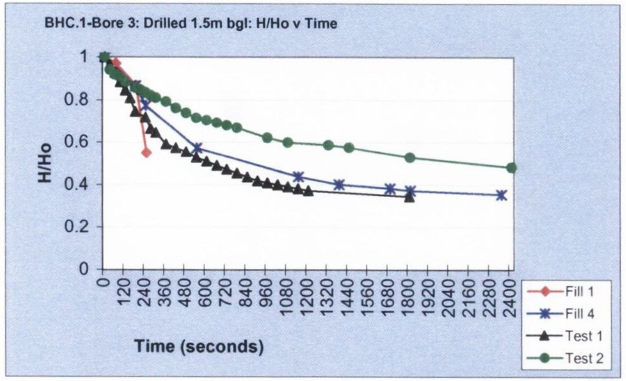

BHC.1: Drilled 1.5m bgl: Bore 3

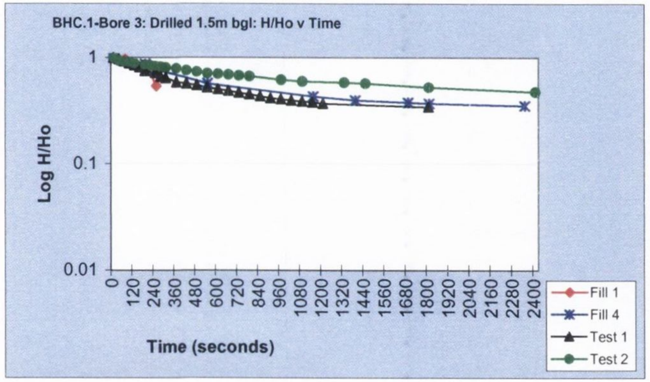

BHC.1: Bore 3: Drilled 1.5m bgl

BHC.1 bore 3- 1.5m

K (m/day)		Initial head(m)
0.1084981	fill 1	1.36
0.319	fill 4	0.875
0.316	test 1	0.71
0.322	test 2	0.43

K=0.319 m/day


BHC.1-Bore 3: Drilled 1.5m bgl: H/Ho v Time


BHC.1-Bore 3: Drilled 1.5m bgl: H/Ho v Time

BHC.1 - Bore 3 - drilled 1.45m bgl

BHC.1 plot

K	0.013 m/day	0.009 m/day	0.319 m/day	1.05 m/day
Bore Depth	0.5m bgl	1m bgl	1.5m bgl	2m bgl

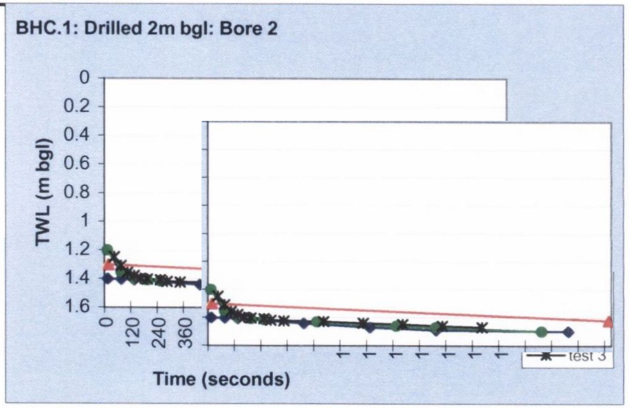
PLOT 15BLUE

BHC.1 bore 3: 1.5m deep

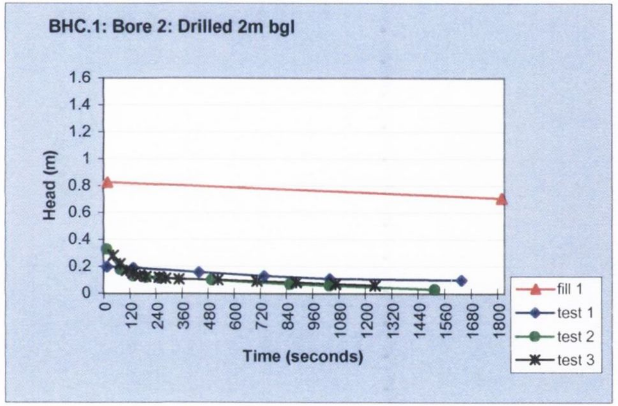
	head h (m)	head h (m)	head h (m)	head h (m)	head h (m)
time (secs)	**fill 1**	**fill 3**	**fill 4**	**test 1**	**test 2**
0	1.36	0.65	1.095	1.1	0.85
30				1.06	0.8
60	1.32			1.02	0.78
90				0.97	0.77
120		0.23		0.93	0.75
150				0.89	
180	1.18	0.225	0.95	0.82	0.73
210					0.72
240			0.85	0.79	0.71
270		0.22		0.73	0.7
300				0.71	0.69
360		0.22		0.65	0.675
420				0.63	0.65
480				0.61	0.63
540			0.63	0.58	0.61
600				0.56	0.6
660		0.22		0.54	0.59
720				0.52	0.58
780				0.5	0.57
840				0.48	
900				0.46	
960				0.45	0.53
1020				0.44	
1080				0.43	0.51
1140			0.48	0.42	
1200				0.41	
1320					0.5
1380			0.44		
1440					0.49
1560		0.22			
1680			0.42		
1800			0.41	0.38	0.45
2340			0.39		
2940			0.39		
8100	0.75				
18900	0.68				
K (cm/sec)	0.000125576	6.307E-05	0.00036963	0.0003655	0.000373159
K (m/day)	0.10849807	0.0544916	0.31936333	0.31579526	0.322409533
	fill 1	**fill 3**	**fill 4**	**test 1**	**test 2**
Initial head(m)	1.36	0.65	0.875	0.71	0.43

K = 1.15*r*(((log(ho+0.5r))-(log(ht+0.5r))/(t-to)) **(cm/second)**

PLOT 15BLUE



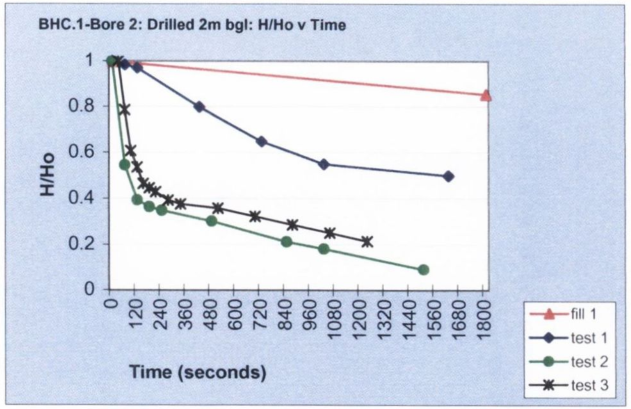
BHC.1: Drilled 2m bgl: Bore 2



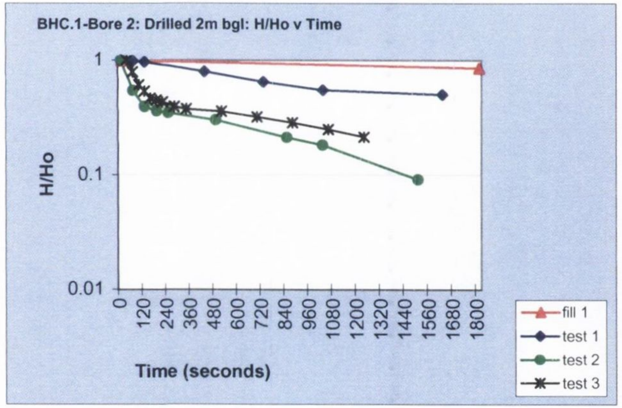
BHC.1: Bore 2: Drilled 2m bgl

BHC.1 bore 2: Drilled 2m bgl		
K (m/day)		Initial head(m)
0.17512814	fill 1	0.83
0.93616431	Test 1	0.2
1.29603167	Test 2	0.33
0.9195491	Test 3	1.2

K (m/day) 1.05058169



BHC.1-Bore 2: Drilled 2m bgl: H/Ho v Time



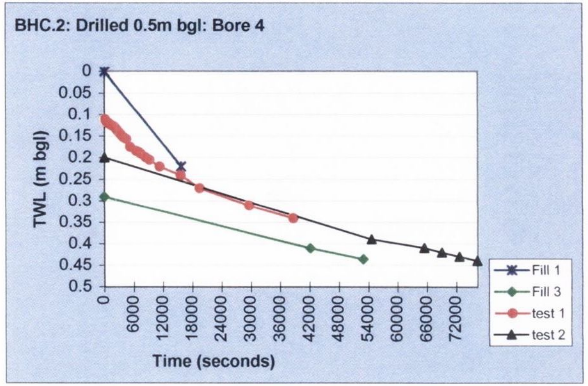
BHC.1-Bore 2: Drilled 2m bgl: H/Ho v Time

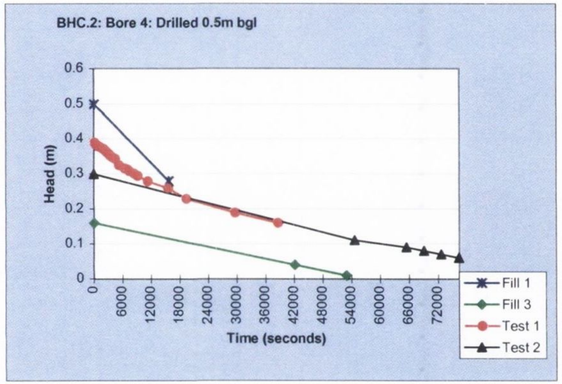
BHC.1 - bore 2: Drilled 2m bgl

BHC.1 plot				
K	0.013 m/day	0.009 m/day	0.319 m/day	1.05 m/day
Bore Depth	0.5m bgl	1m bgl	1.45m bgl	2m bgl

PLOT 15BLUE

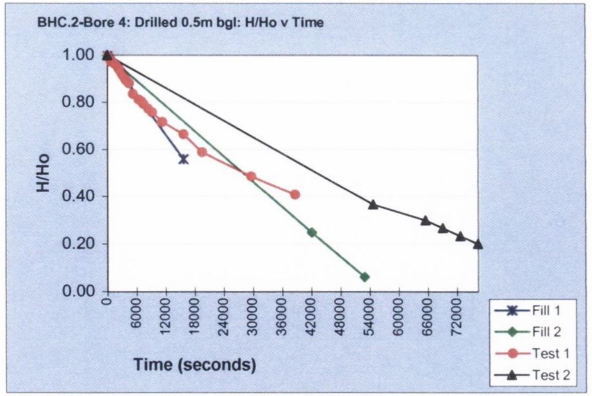
PLOT 17 BLUE

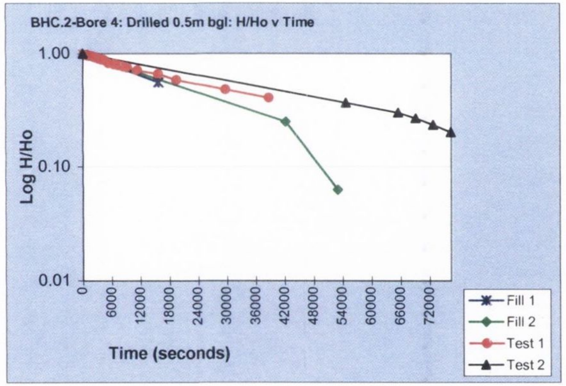




K = 0.034 m/day

	K (m/day)	Head (m)
Fill 1	0.061	0.5
Fill 3	0.059	0.16
Test 1	0.033	0.39
Test 2	0.035	0.3





BHC.2 - Bore 4- Drilled to 0.5m bgl

Drilled	0.5m bgl	1m bgl	1.5m bgl	2 m bgl
K	0.034 m/day	0.085 m/day	0.013 m/day	0.038 m/day

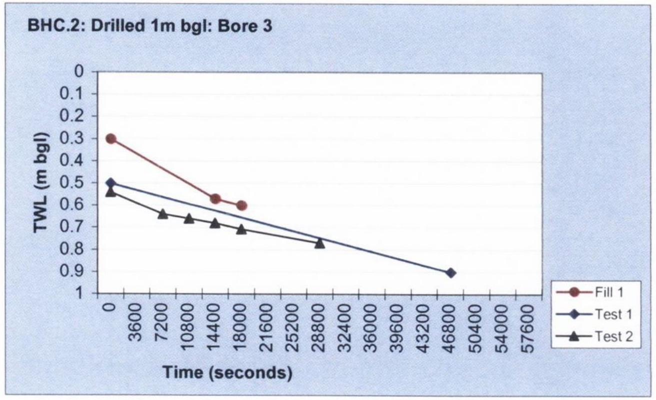
PLOT 17BLUE

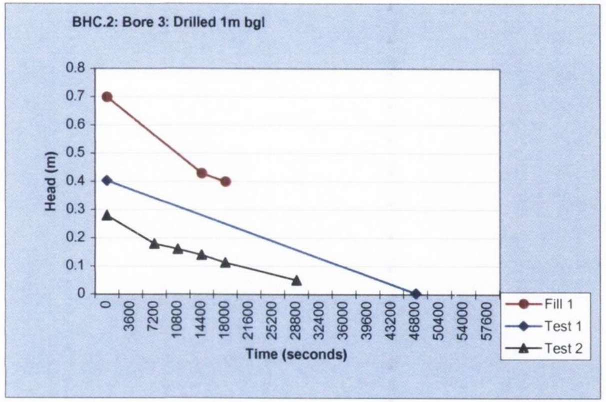
BHC.2 bore 4: 0.5m TD

	head h (m)	head h (m)	head h (m)	head h (m)
time (secs)	**Fill 1**	**Fill 3**	**Test 1**	**Test 2**
0	0.5	0.16	0.39	0.3
240			0.385	
300			0.384	
420			0.383	
480			0.3825	
540			0.382	
600			0.381	
660			0.38	
900			0.379	
960			0.3785	
1020			0.378	
1500			0.375	
1800			0.373	
2100			0.369	
2400			0.365	
2700			0.361	
3000			0.357	
3300			0.353	
3600			0.349	
4020			0.346	
4260			0.344	
5040			0.326	
6240			0.317	
6840			0.314	
7200			0.31	
8220			0.302	
9000			0.296	
11100			0.28	
15420			0.26	
15600	0.28			
19260			0.23	
29400			0.19	
38400			0.16	
42000		0.04		
52800		0.01		
54600				0.11
65400				0.09
69000				0.08
72600				0.07
76200				0.06
K (cm/sec)	7.04396E-05	6.77935E-05	3.84105E-05	4.08124E-05
K (m/day)	0.060859806	0.058573567	0.033186677	0.035261946
	Fill 1	**Fill 3**	**test 1**	**test 2**
Initial head(m)	0.5	0.16	0.39	0.3

K = 1.15*r*(((log(ho+0.5r))-(log(ht+0.5r))/(t-to)) **(cm/seconds)**

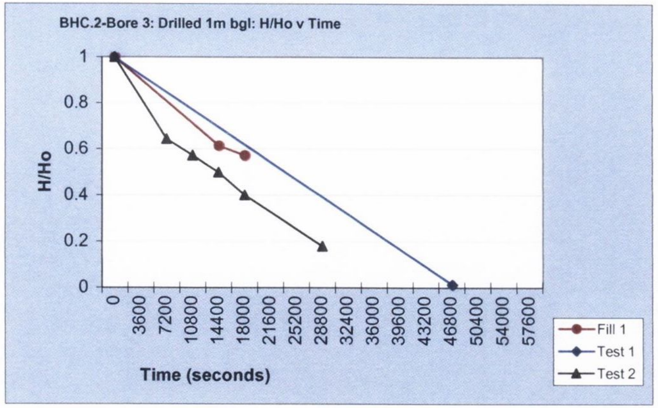
PLOT 17BLUE

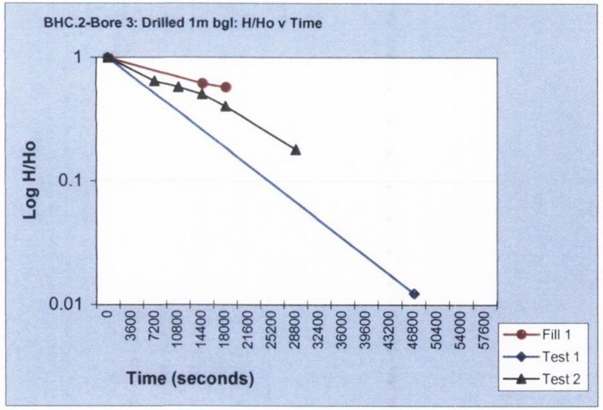

BHC.2: Drilled 1m bgl: Bore 3


BHC.2: Bore 3: Drilled 1m bgl

K = 0.085 m/day

	K (m/day)	Head (m)
Fill 1	0.055	0.7
Test 1	0.083	0.405
Test 2	0.086	0.28


BHC.2-Bore 3: Drilled 1m bgl: H/Ho v Time


BHC.2-Bore 3: Drilled 1m bgl: H/Ho v Time

BHC.2 - Bore 3- Drilled to 1m bgl

Drilled	0.5m bgl	1m bgl	1.5m bgl	2 m bgl
K	0.034 m/day	0.085 m/day	0.013 m/day	0.038 m/day

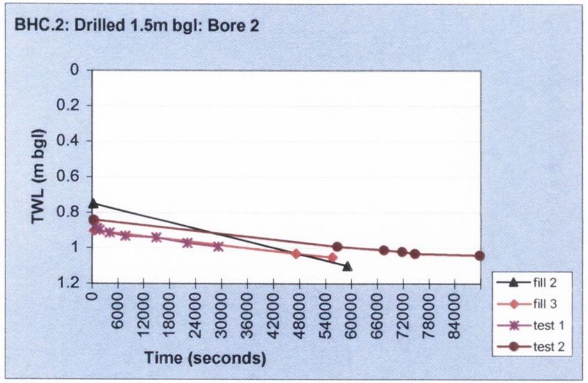
Plot 17BLUE

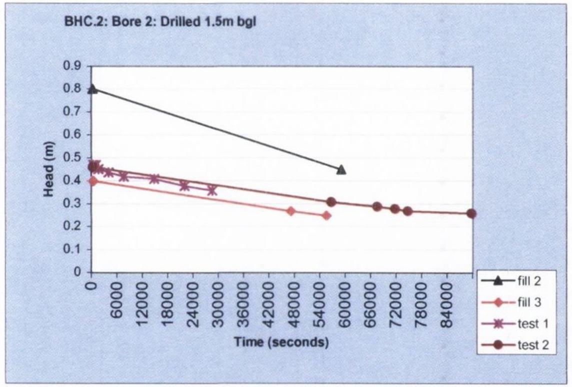
BHC.2 bore 3: 1m bgl

	head h (m)	head h (m)	head h (m)	head h (m)	head h (m)
time (secs)	**fill 1**	**fill 2**	**fill 3**	**Test 1**	**Test 2**
0	0.7	0.7	0.405	0.315	0.28
3360					
5160					
5520					
8100					0.18
9120					
11700					0.16
12720					
14400	0.43				
15300					0.14
15960	0.4				
17520					
18900					0.112
27120					
29700					0.05
36000					
43200					
48000			0.005		
51300				0.005	
54000					
58500		0.05			
K (cm/sec)	6.34E-05	7.514E-05	0.0001124	9.649E-05	9.9421E-05
K (m/day)	0.0547748	0.0649219	0.0971435	0.0833635	0.08589948
	fill 1	**fill 2**	**fill 3**	**Test 1**	**Test 2**
Initial head(m)	0.7	0.7	0.405	0.315	0.28

K = 1.15*r*(((log(ho+0.5r))-(log(ht+0.5r))/(t-to)) **(cm/seconds)**

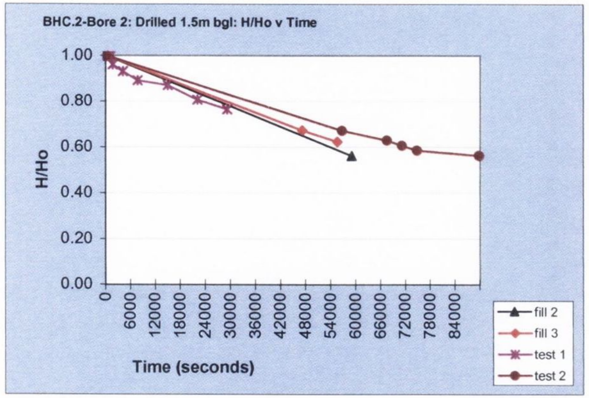
PLOT 17Blue

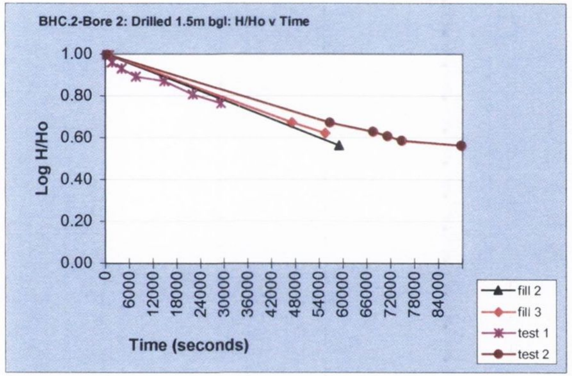




K = 0.013 m/day

	K (m/day)	Head (m)
Fill 2	0.0163	0.8
Fill 3	0.0147	0.4
Test 1	0.0130	0.17
Test 2	0.0124	0.46





BHC.2 - Bore 2- Drilled to 1.55m bgl

Drilled	0.5m bgl	1m bgl	1.5m bgl	2 m bgl
K	0.034 m/day	0.085 m/day	0.013 m/day	0.038 m/day

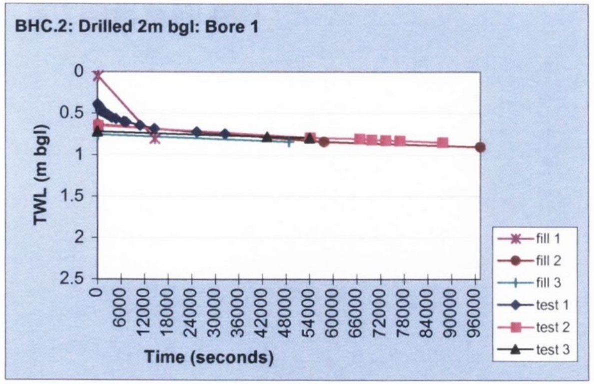
PLOT 17BLUE

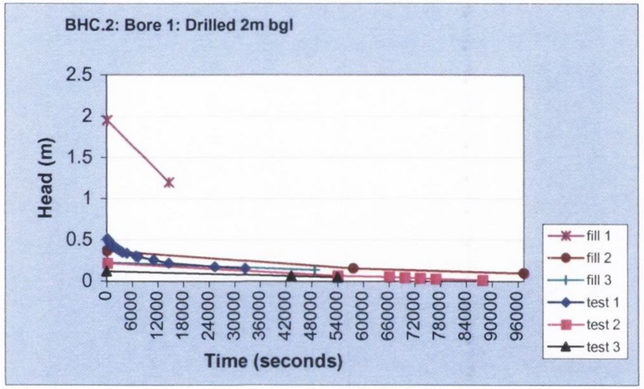
BHC.2 bore 2: 1.5m TD

	head h (m)	head h (m)	head h (m)	head h (m)
time (secs)	**fill 2**	**fill 3**	**test 1**	**test 2**
0	0.8	0.4	0.47	0.46
60			0.47	
120			0.467	
180			0.465	
600			0.46	
900			0.458	
1080			0.455	
1260			0.452	
1440			0.451	
3600			0.438	
7200			0.42	
14400			0.41	
21600			0.38	
28680			0.36	
46800		0.27		
55200		0.25		
56700				0.31
58800	0.45			
67500				0.29
71100				0.28
74700				0.27
89100				0.26
132300				0.2
143100				0.18
K (cm/sec)	1.891E-05	1.6995E-05	1.503E-05	1.434E-05
K (m/day)	0.016338	0.01468363	0.0129843	0.0123904
	fill 2	**fill 3**	**test 1**	**test 2**
Initial head(m)	0.8	0.4	0.17	0.46

K = 1.15*r*(((log(ho+0.5r))-(log(ht+0.5r))/(t-to)) **(cm/seconds)**

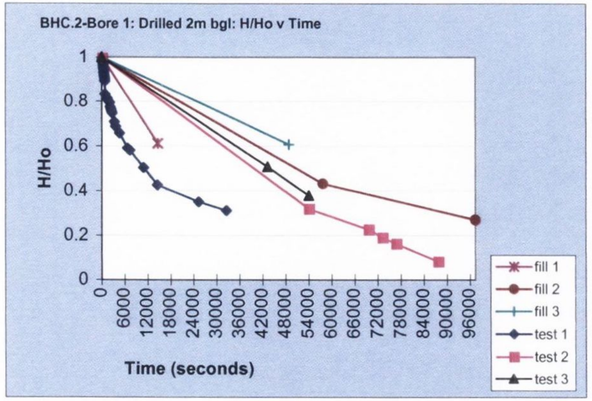
PLOT 17Blue

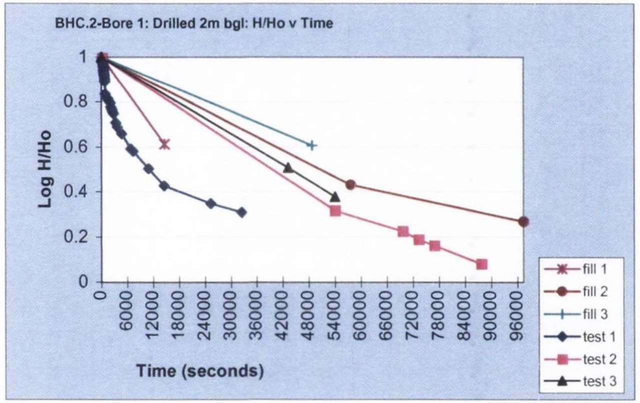




K= 0.038 m/day

	K (m/day)	Head (m)
fill 1	0.065	1.95
fill 2	0.023	0.37
fill 3	0.018	0.23
test 1	0.039	0.52
test 2	0.036	0.22
test 3	0.038	0.12





BHC.2 - Bore 1- Drilled to 2m bgl

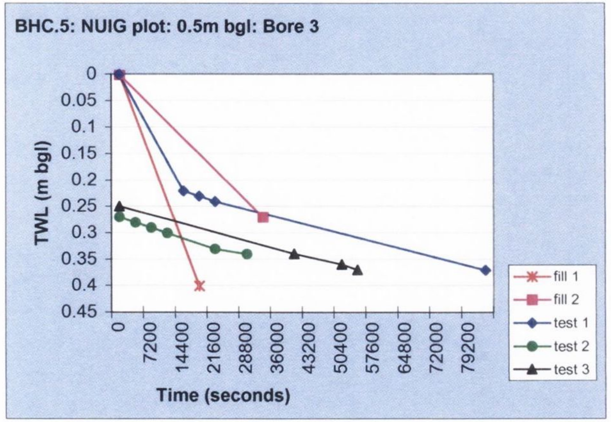
BHC.2

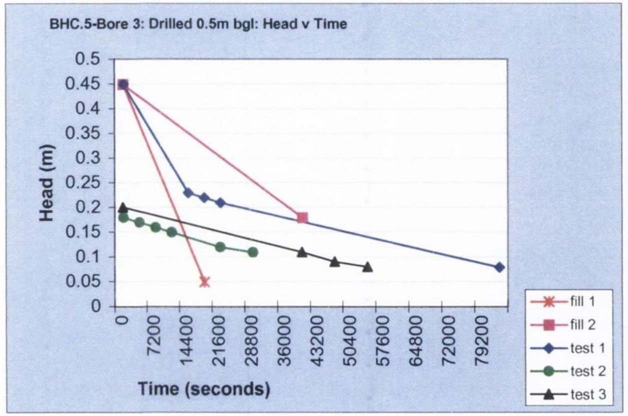
Drilled	0.5m bgl	1m bgl	1.5m bgl	2 m bgl
K (m/day)	0.034 m/day	0.085 m/day	0.013 m/day	0.038 m/day

PLOT 17BLUE

	BHC2 bore 1 - 2m bgl					
	head h (m)	**head h (m)**	**head h (m)**	**head h (m)**	**head h (m)**	**head h (m)**
time (secs)	**fill 1**	**fill 2**	**fill 3**	**test 1**	**test 2**	**test 3**
0	1.954	0.37	0.23	0.515	0.22	0.122
60				0.51		
120				0.505		
180				0.5		
240				0.495		
300				0.49		
360				0.485		
420				0.48		
480				0.475		
540				0.47		
600				0.465		
660				0.46		
720				0.43		
1320				0.42		
1500				0.415		
1860				0.41		
2040				0.4		
2220				0.395		
2400				0.39		
2580				0.385		
3120				0.365		
3480				0.355		
4500				0.34		
6600				0.305		
7140				0.3		
10740				0.26		
14340				0.22		
14400	1.2					
25140				0.18		
32340				0.16		
43200						0.062
48600			0.14			
54000					0.07	0.046
57600		0.16				
66000					0.06	
69600					0.05	
73200					0.042	
76800					0.036	
87600					0.018	
97200		0.1				
K (cm/sec)	7.498E-05	2.692E-05	2.038E-05	4.54623E-05	4.2204E-05	4.3684E-05
K (m/day)	0.0647852	0.0232624	0.0176095	0.039279406	0.03646404	0.03774278
	fill 1	**fill 2**	**fill 3**	**test 1**	**test 2**	**test 3**
Initial head(m)	1.954	0.37	0.23	0.515	0.22	0.122

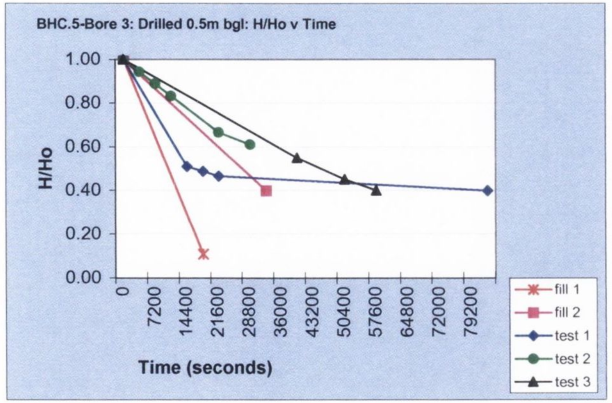
K = 1.15*r*(((log(ho+0.5r))-(log(ht+0.5r))/(t-to)) **(cm/seconds)**

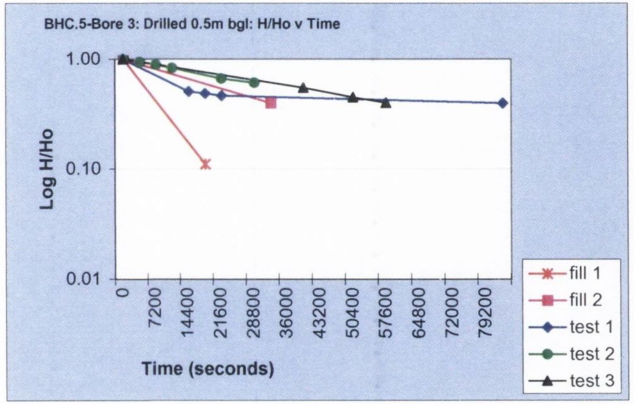




K = 0.034 m/day

	K (m/d)	Head (m)
Fill 1	0.183	0.45
Fill 2	0.046	0.45
Test 1	0.035	0.45
Test 2	0.030	0.1
Test 3	0.037	0.2





NUIG Plot - Bore 3- drilled to 0.5m bgl

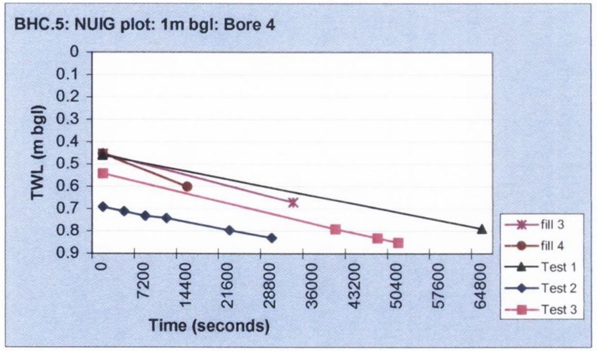
NUIG plot				
Drilled	0.5 m bgl	1 m bgl	1.5 m bgl	2 m bgl
K (m/day)	0.034	0.080	0.069	0.068

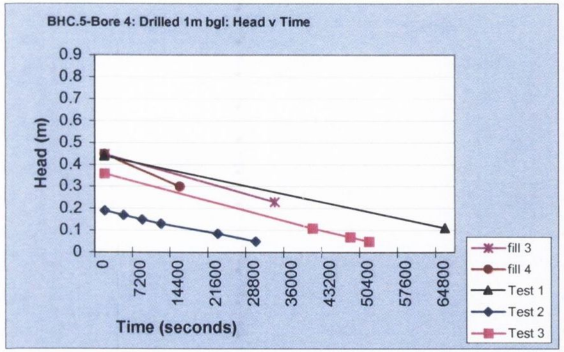
NUIG plot

NUIG bore3: 0.5m bgl

	head h (m)	head h (m)	head h (m)	head h (m)	head h (m)
time (secs)	fill 1	fill 2	test 1	test 2	test 3
0	0.45	0.45	0.45	0.18	0.2
3600				0.17	
7200				0.16	
10800					
16200			0.23		
17400			0.22		
18000	0.05			0.15	
19500			0.21		
21600				0.12	
28800				0.11	
32400		0.18			
41400					0.11
49200					0.09
52800					0.08
82800			0.08		
K (cm/s)	2.1134E-04	5.2682E-05	4.0487E-05	3.4866E-05	4.2343E-05
K (m/d)	**0.1826**	**0.0455**	**0.0350**	**0.0301**	**0.0366**
	fill 1	**fill 2**	**test 1**	**test 2**	**test 3**
Initial head (m)	0.45	0.45	0.45	0.1	0.2

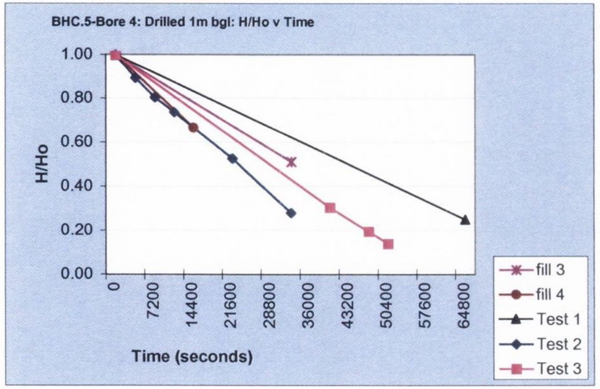
K = 1.15*r*(((log(ho+0.5r))-(log(ht+0.5r))/(t-to)) **(cm/seconds)**

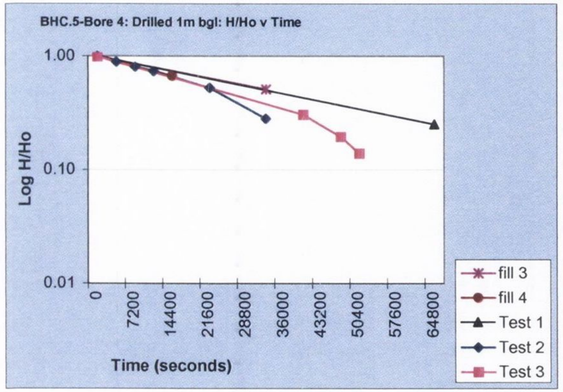

BHC.5: NUIG plot: 1m bgl: Bore 4


BHC.5-Bore 4: Drilled 1m bgl: Head v Time

K = 0.08 m/day
for subsurface zone: 0.6 - 1m bgl

	K (m/d)	Head (m)
Fill 3	0.034	0.45
Fill 4	0.041	0.45
Test 1	0.033	0.44
Test 2	0.079	0.19
Test 3	0.081	0.36


BHC.5-Bore 4: Drilled 1m bgl: H/Ho v Time


BHC.5-Bore 4: Drilled 1m bgl: H/Ho v Time

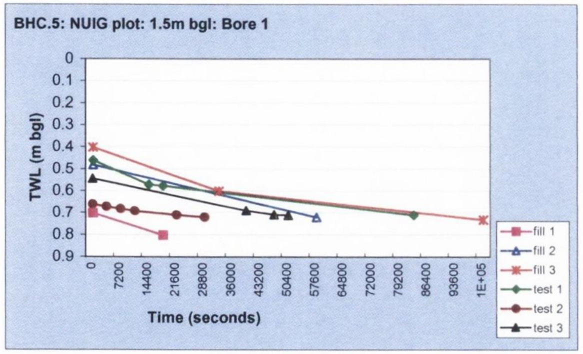
NUIG Plot - Bore 4- drilled to 1m bgl

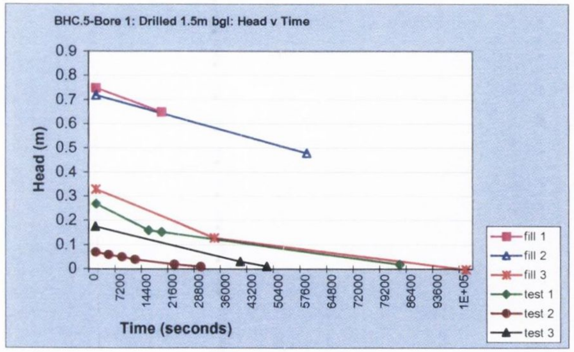
NUIG plot				
Drilled	0.5 m bgl	1 m bgl	1.5 m bgl	2 m bgl
K (m/day)	0.034	0.080	0.069	0.068

NUIG bore 4: 1m bgl BHC.5

	head h (m)	head h (m)	head h (m)	head h (m)	head h (m)
ime (secs)	Fill 3	fill 4	Test 1	Test 2	Test 3
0	0.45	0.45	0.44	0.19	0.36
2100			0.41		
3600				0.17	
7200				0.15	
10800				0.14	
16200		0.3			
21600				0.085	
28800				0.05	
32400	0.23				
39600					0.11
49200					0.07
52800					0.05
65100			0.11		
K (cm/s)	3.8924E-05	4.7405E-05	3.7934E-05	9.1750E-05	9.3689E-05
K (m/d)	0.0336	0.0410	0.032775	0.079272	0.080947
	fill 3	fill 4	Test 1	Test 2	Test 3
l head (m)	0.45	0.45	0.44	0.19	0.36

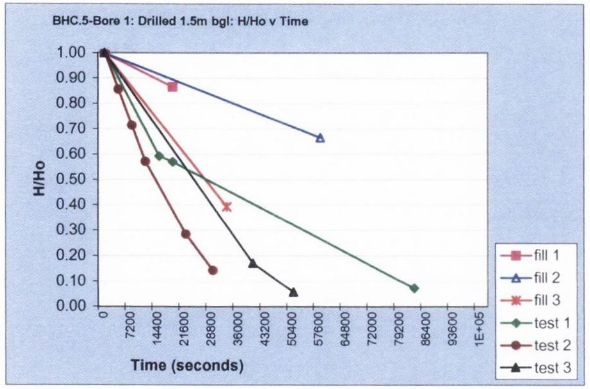
K = 1.15*r*(((log(ho+0.5r))-(log(ht+0.5r))/(t-to)) **(cm/seconds)**

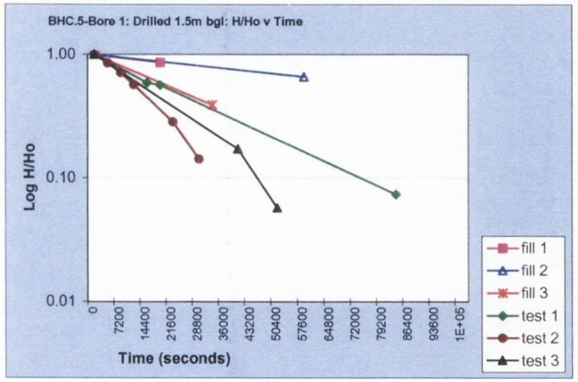




K = 0.069 m/day

	K (m/day)	Head (m)
Fill 1	0.013	1
Fill 2	0.012	0.72
Fill 3	0.045	0.33
Test 1	0.039	0.27
Test 2	0.069	0.07
Test 3	0.069	0.175



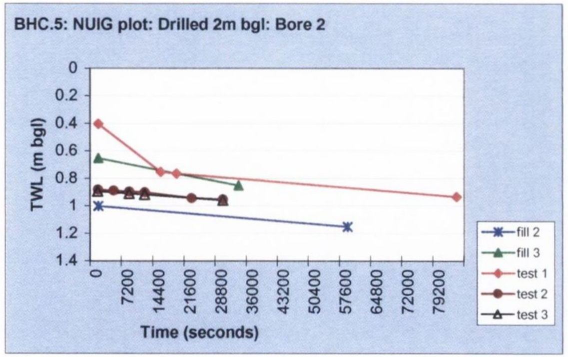


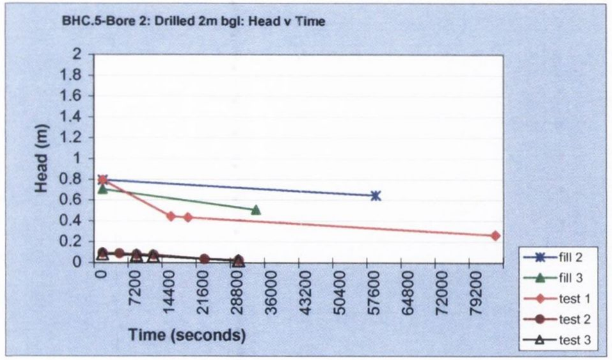
NUIG Plot - Bore 1- drilled to 1.5m bgl

NUIG plot				
Drilled	0.5 m bgl	1 m bgl	1.5 m bgl	2 m bgl
K (m/day)	0.034	0.080	0.069	0.068

NUIG bore1 (1.5m bgl)

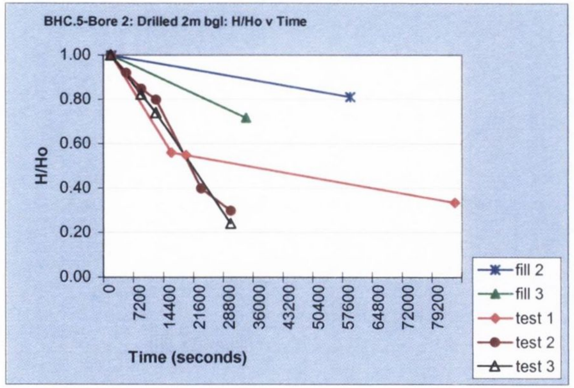
	head h (m)	head h (m)	head h (m)	head h (m)	head h (m)	head h (m)
time (secs)	Fill 1	Fill 2	Fill 3	Test 1	Test 2	Test 3
0	0.75	0.72	0.33	0.27	0.07	0.175
3600					0.06	
7200					0.05	
10800					0.04	
14400				0.16		
18000	0.65			0.154		
19500				0.15		
21600					0.02	
28800					0.01	
32400			0.13			
39600						0.03
46800						0.01
50400						
57600		0.48				
61200						
82800				0.02		
100800			0			
K (cm/s)	1.544E-05	1.36E-05	5.224E-05	4.566E-05	7.982E-05	7.99E-05
K (m/d)	0.0133398	0.0117481	0.0451385	0.0394545	0.0689662	0.0690351
	Fill 1	Fill 2	Fill 3	Test 1	Test 2	Test 3
Initial head (m)	**0.75**	**0.72**	**0.33**	**0.27**	**0.07**	**0.175**

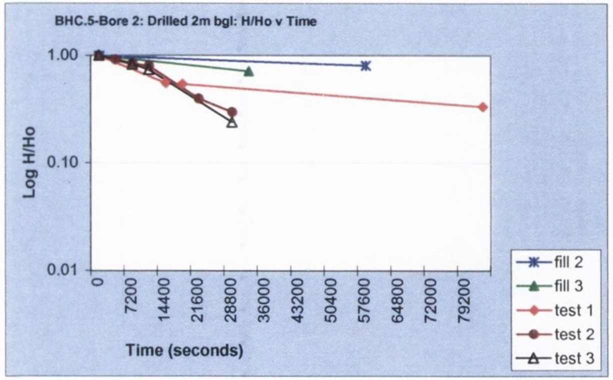




K= 0.068 m/day

	K (m/d)	Head (m)
Fill 2	0.006	0.8
Fill 3	0.018	0.7
Test 1	0.054	0.8
Test 2	0.069	0.1
Test 3	0.067	0.085





NUIG Plot - Bore 2- drilled to 2m bgl

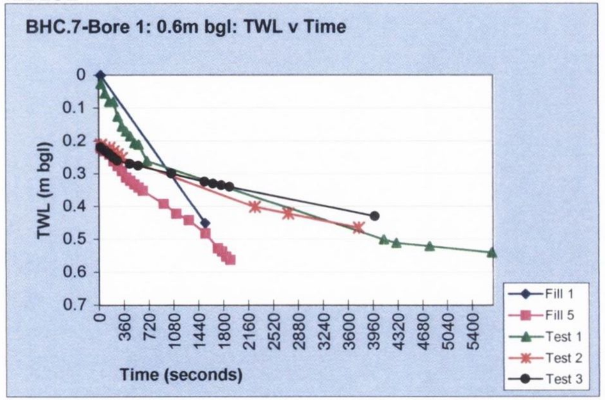
NUIG plot				
Drilled	0.5 m bgl	1 m bgl	1.5 m bgl	2 m bgl
K (m/day)	0.034	0.080	0.069	0.068

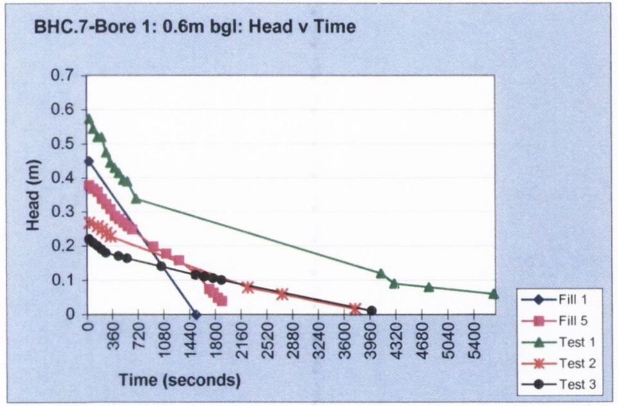
NUIG bore2: 2m bgl

	head h (m)	**head h (m)**	**head h (m)**	**head h (m)**	**head h (m)**
time (secs)	**fill 2**	**fill 3**	**test 1**	**test 2**	**test 3**
0	0.8	0.71	0.8	0.1	0.085
3600				0.092	
7200				0.085	0.07
10800				0.0800	0.063
14400			0.45		
18000			0.44		
19500			0.42		
21600				0.04	
28800				0.03	0.02
32400		0.51			
39600					
57600	0.65				
82800			0.27		
K (cm/s)	7.4323E-06	2.0933E-05	6.2728E-05	8.0291E-05	7.8021E-05
K (m/d)	**0.0064**	**0.0181**	**0.0542**	**0.0694**	**0.0674**
ial head (m)	0.8	0.71	0.8	0.1	0.085
	fill 2	**fill 3**	**test 1**	**test 2**	**test 3**

K = $1.15*r*(((log(ho+0.5r))-(log(ht+0.5r))/(t-to))$ **(cm/seconds)**

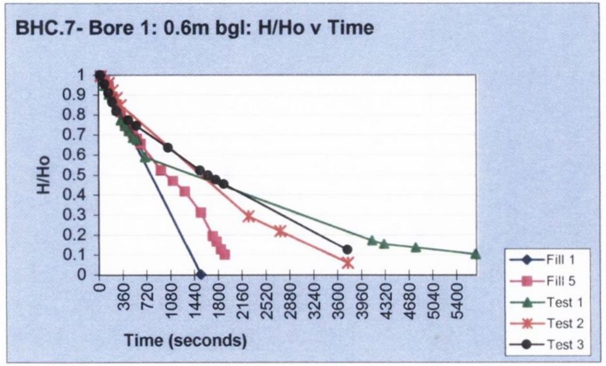
Plot 12BLUE

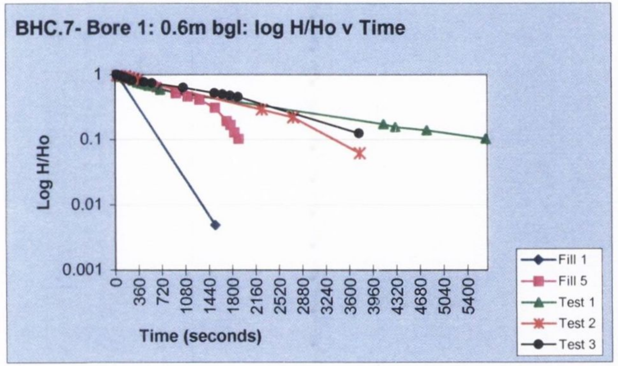

BHC.7-Bore 1: 0.6m bgl: TWL v Time


BHC.7-Bore 1: 0.6m bgl: Head v Time

K = 0.57 m/day
at 0.2 - 0.6m bgl

	K (m/d)	Head (m)
Fill 1	3.308	0.45
Fill 5	1.570	0.38
Test 1	0.481	0.58
Test 2	0.720	0.27
Test 3	0.504	0.22


BHC.7- Bore 1: 0.6m bgl: H/Ho v Time


BHC.7- Bore 1: 0.6m bgl: log H/Ho v Time

Saturated Hydraulic Conductivity calculated using Ritzema's formula (1994) for Auger Hole method

BHC.7
Plot 12BLUE

BHC.7

Depth	0.6m bgl	1m bgl	1.3m bgl	1.5m bgl	2m bgl
K	0.57 m/day	0.166 m/day	0.047 m/day	0.044m/day	2.2 m/day

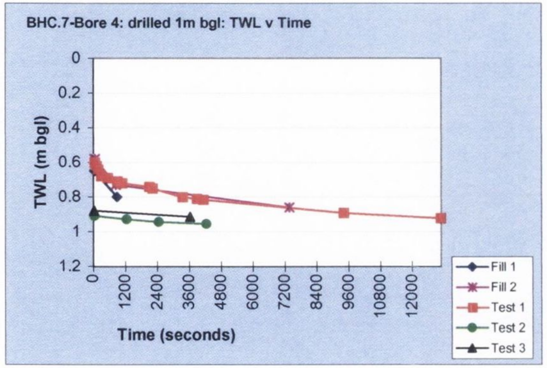
Plot 12BLUE

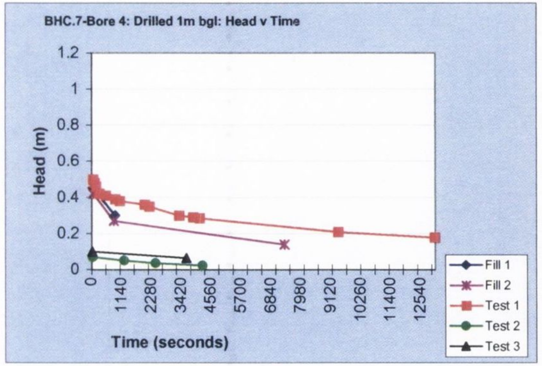
BHC.7 bore 1: 0.6m TD

BHC.7 bore1	**head h (m)**	**head h (m)**	**head h (m)**	**head h (m)**	**head h (m)**
time (secs)	**Fill 1**	**Fill 5**	**Test 1**	**Test 2**	**Test 3**
0	0.45	0.38	0.575	0.27	0.22
30			0.56		
60		0.37	0.545		0.21
120		0.36	0.52	0.26	0.20
180		0.34	0.52	0.25	0.19
240		0.325	0.475	0.24	0.18
300		0.31	0.445	0.23	
360		0.29	0.43		
420		0.28	0.415		0.17
480		0.27	0.395		
540		0.26	0.39		0.16
600		0.25			
660			0.34		
900		0.2			
1020					0.14
1080		0.18			
1260		0.16			
1500	0	0.12			0.12
1620					0.11
1680		0.075			
1740		0.065			0.11
1800		0.05			
1860		0.04			0.10
2220				0.08	
2700				0.06	
3720				0.017	
3960					0.01
4080			0.12		
4260			0.09		
4740			0.08		
5640			0.06		
K (cm/s)	0.003828429	0.001817026	0.000556665	0.00083605	0.000583379
K (m/d)	3.307762285	1.569910708	0.480958413	0.72234761	0.504039593
	fill 1	**Fill 5**	**Test 1**	**Test 2**	**Test 3**
Initial head(m)	0.45	0.38	0.575	0.27	0.22

K = 1.15*r*(((log(ho+0.5r))-(log(ht+0.5r))/(t-to)) **(cm/seconds)**

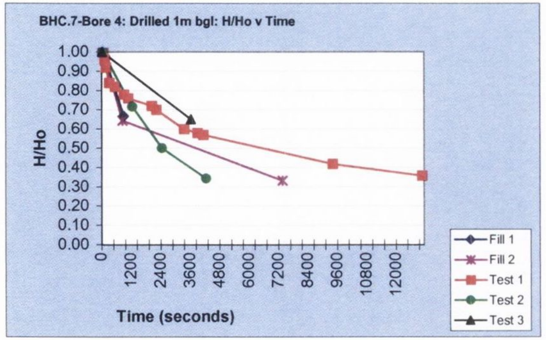
Plot 12BLUE

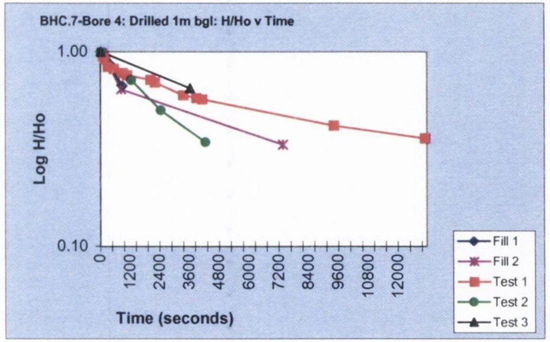




K =0.166 m/day
at 0.6 - 1m bgl

	K (m/d)	Head (m)
Fill 1	0.69568	0.45
Fill 2	0.21079	0.42
Test 1	0.15311	0.5
Test 2	0.19728	0.07
Test 3	0.14836	0.1





Saturated Hydraulic Conductivity calculated using Ritzema's formula (1994) for Auger Hole method

BHC.7
Plot 12BLUE

Drilled	0.5m bgl	1m bgl	1.3m bgl	1.5m bgl	2m bgl
K	0.57 m/day	0.166 m/day	0.047 m/day	0.044 m/day	2.2 m/day

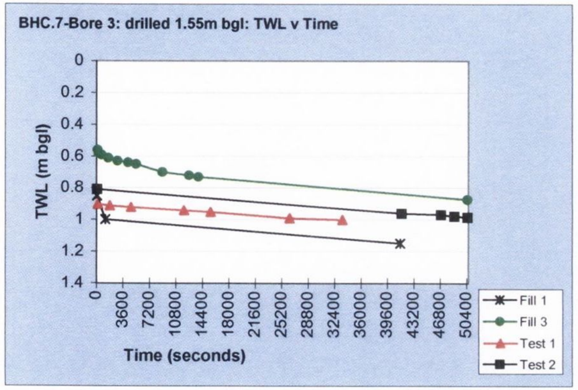
Plot 12BLUE

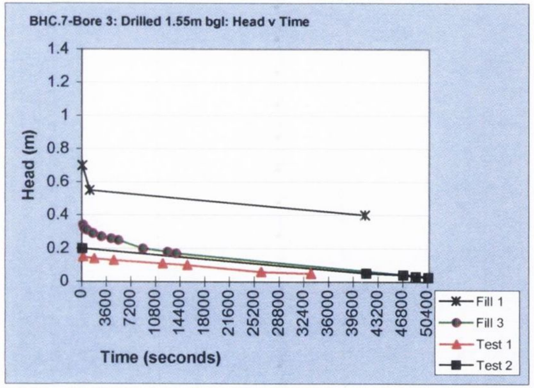
BHC.7 bore 4: 1m TD

	head h (m)	head h (m)	head h (m)	head h (m)	head h (m)
time (secs)	**Fill 1**	**Fill 2**	**Test 1**	**Test 2**	**Test 3**
0	0.45	0.42	0.5	0.07	0.1
60			0.48		
120			0.46		
240			0.42		
480			0.41		
780		0.27			
840	0.3		0.39		
1020			0.38		
1200				0.05	
1980			0.36		
2160			0.35		
2400				0.035	
2700					
3300			0.3		
3600					0.065
3840			0.29		
4080			0.285		
4200				0.024	
4500					
5700					
7320		0.14			
7800				0.002	
9360			0.21		
13020			0.18		
14220			0.17		
K (cm/s)	0.00080518	0.00024397	0.000177209	0.00022833	0.000171715
K (m/d)	0.69567685	0.21079268	0.153108521	0.19727885	0.148362065
	Fill 1	**Fill 2**	**Test 1**	**Test 2**	**Test 3**
Initial head(m)	0.45	0.42	0.5	0.07	0.1

K = 1.15*r*(((log(ho+0.5r))-(log(ht+0.5r))/(t-to)) **(cm/seconds)**

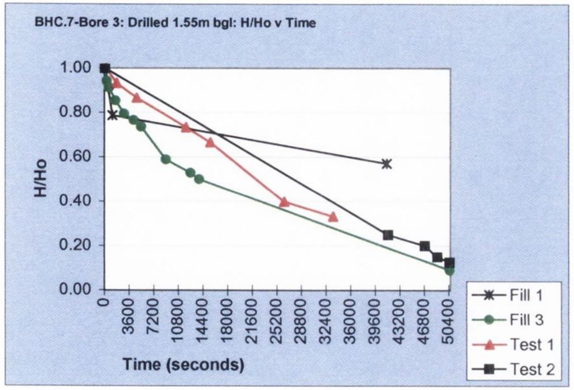
Plot 12 BLUE

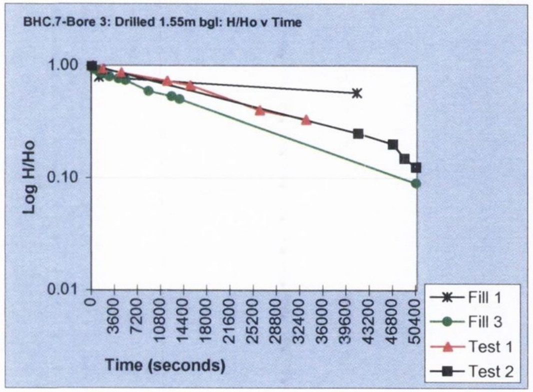

BHC.7-Bore 3: drilled 1.55m bgl: TWL v Time


BHC.7-Bore 3: Drilled 1.55m bgl: Head v Time

K = 0.044 m/day

	K (m/d)	Head (m)
Fill 1	0.020	1
Fill 3	0.057	0.34
Test 1	0.040	0.15
Test 2	0.047	0.2


BHC.7-Bore 3: Drilled 1.55m bgl: H/Ho v Time


BHC.7-Bore 3: Drilled 1.55m bgl: H/Ho v Time

Saturated Hydraulic Conductivity calculated using Ritzema's formula (1994) for Auger Hole method

BHC.7
Plot 12BLUE

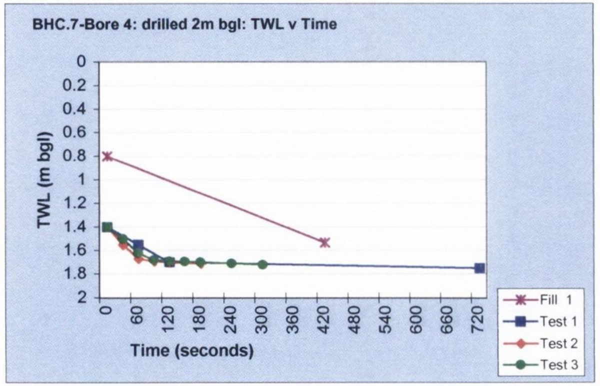
Drilled	0.5m bgl	1m bgl	1.3m bgl	1.5m bgl	2m bgl
K	0.57 m/day	0.166 m/day	0.047 m/day	0.044 m/day	2.2 m/day

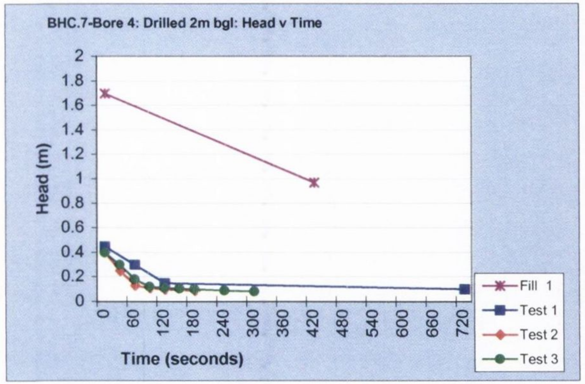
Plot 12BLUE

BHC.7 bore 3: 1.55m TD				
	head h (m)	**head h (m)**	**head h (m)**	**head h (m)**
time (secs)	**Fill 1**	**Fill 3**	**Test 1**	**Test 2**
0	0.7	0.34	0.15	0.2
60		0.33		
180		0.32		
540		0.31		
1080	0.55			
1440		0.29		
1620			0.14	
1710		0.28		
2700		0.27		
4140		0.26		
4500			0.13	
5220		0.25		
7200				
8820		0.2		
11700			0.11	
12420		0.18		
13680		0.17		
15300			0.1	
26100			0.06	
33300			0.05	
41220	0.4			
41400				0.05
46800				0.04
48600				0.03
50400		0.029		0.025
K (cm/s)	2.29631E-05	6.65655E-05	4.67521E-05	5.47239E-05
K (m/d)	0.019840157	0.057512632	0.040393815	0.047281453
	Fill 1	**Fill 3**	**Test 1**	**Test 2**
Initial head(m)	0.7	0.34	0.15	0.2

K = 1.15*r*(((log(ho+0.5r))-(log(ht+0.5r))/(t-to)) **(cm/seconds)**

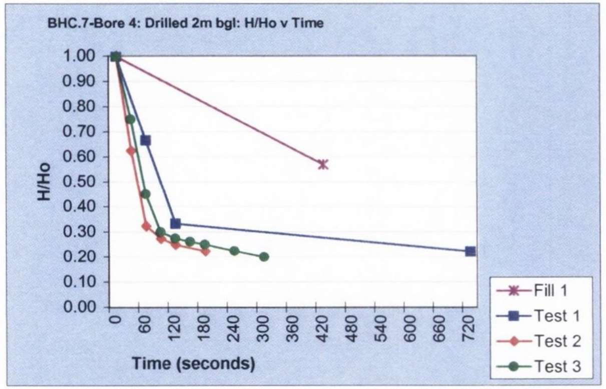
Plot 12BLUE

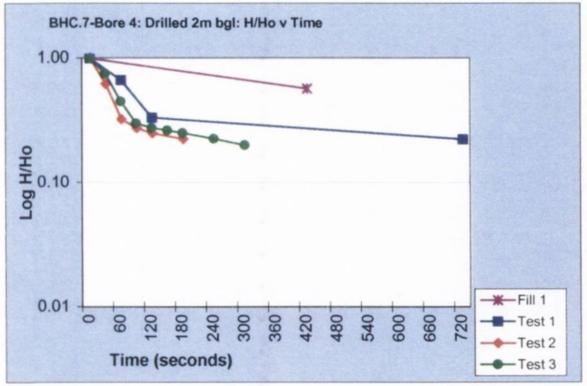




K = 2.2 m/day

	K (m/d)	Head (m)
Fill 1 of 5	1.99	1.7
Test 1	2.27	0.45
Test 2	2.24	0.4
Test 3	2.15	0.4





Saturated Hydraulic Conductivity calculated using Ritzema's formula (1994) for Auger Hole method

BHC.7
Plot 12BLUE

Drilled	0.5m bgl	1m bgl	1.3m bgl	1.5m bgl	2m bgl
K	0.57 m/day	0.166 m/day	0.047 m/day	0.044 m/day	2.2 m/day

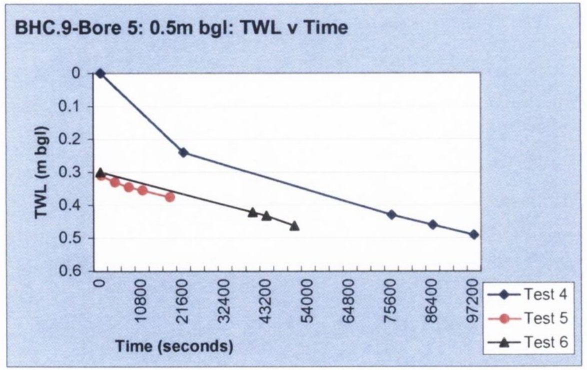
Plot 12BLUE

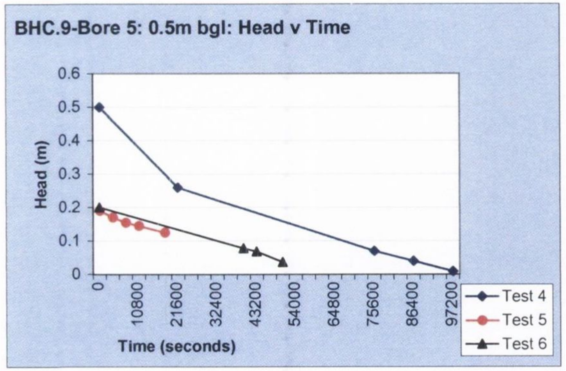
BHC.7 - Bore 4: Drilled 2m bgl				
	head h (m)	head h (m)	head h (m)	head h (m)
time (secs)	Fill 1	Test 1	Test 2	Test 3
0	1.7	0.45	0.4	0.4
30			0.25	0.3
45			0.17	
60		0.3	0.13	0.18
90			0.11	0.12
120		0.15	0.1	0.11
150				0.105
180			0.09	0.1
240				0.09
300				0.08
420	0.97			
720		0.1		
780		0.09		
1200		0.08		
3600		0.07		
4080		0.05		
4320		0.04		
4680		0.03		
K (cm/s)	0.002303447	0.00263275	0.0025914	0.0024855
K (m/d)	1.990177831	2.27469744	2.2389602	2.14746786
	Fill 1 of 5	**Test 1**	**Test 2**	**Test 3**
Initial head(m)	1.7	0.45	0.4	0.4

dropping 50mm/sec (~3m/hr during pretests no. 2 and 3)

K = 1.15*r*(((log(ho+0.5r))-(log(ht+0.5r))/(t-to)) **(cm/seconds)**

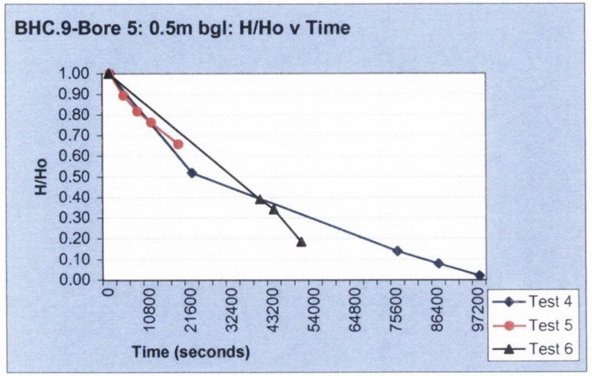
Plot 3BLUE

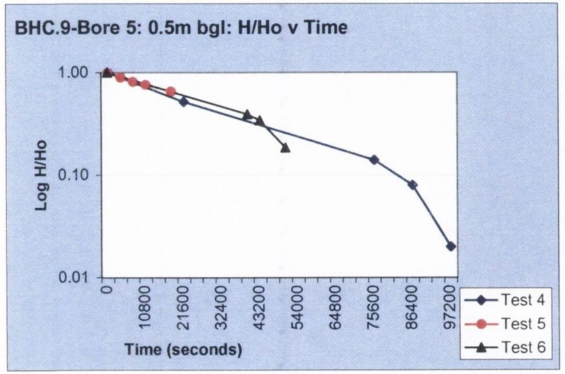

BHC.9-Bore 5: 0.5m bgl: TWL v Time


BHC.9-Bore 5: 0.5m bgl: Head v Time

K= 0.042 m/day
at 0.5m bgl

	K (m/day)	Head (m)
Test 4	0.041	0.5
Test 5	0.034	0.19
Test 6	0.052	0.2


BHC.9-Bore 5: 0.5m bgl: H/Ho v Time


BHC.9-Bore 5: 0.5m bgl: H/Ho v Time

Saturated Hydraulic Conductivity calculated using Ritzema's formula (1994) for Auger Hole method

BHC.9

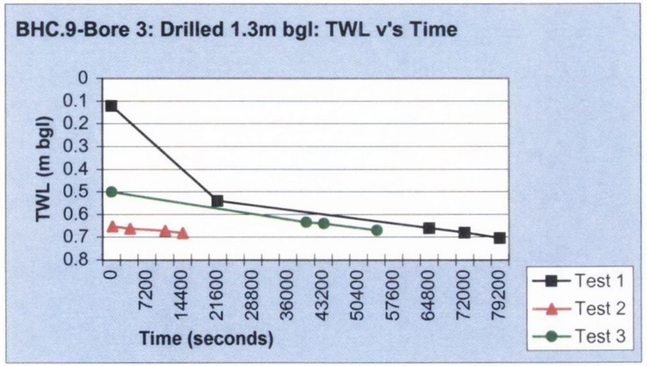
Depth	0.5m bgl	1m bgl	1.2m bgl	1.3m bgl	2.2m bgl
K	0.042 m/day	0.015 m/day	0.62 m/day	0.041 m/day	11.24 m/day

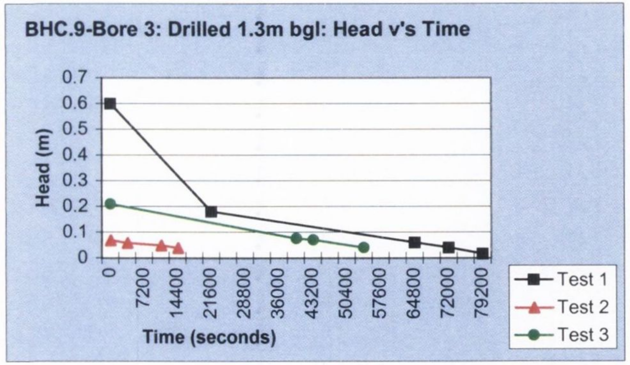
Plot 3BLUE

BHC.9 bore 5: 0.5m bgl			
BHC.9 - bore 5	head h (m)	head h (m)	head h (m)
time (secs)	Test 4	Test 5	Test 6
0	0.5	0.19	0.2
600		0.18	
3000		0.175	
3600		0.17	
7200		0.155	
10800		0.145	
18000		0.125	
21600	0.26		
39600			0.078
43200			0.068
50400			0.037
75600	0.07		
86400	0.04		
97200	0.01		
K (cm/s)	4.74912E-05	3.91445E-05	5.97277E-05
K (m/d)	0.041032416	0.033820851	0.051604718
	Test 4	**Test 5**	**Test 6**
Initial head(m)	0.5	0.19	0.2

K = 1.15*r*(((log(ho+0.5r))-(log(ht+0.5r))/(t-to)) **(cm/seconds)**

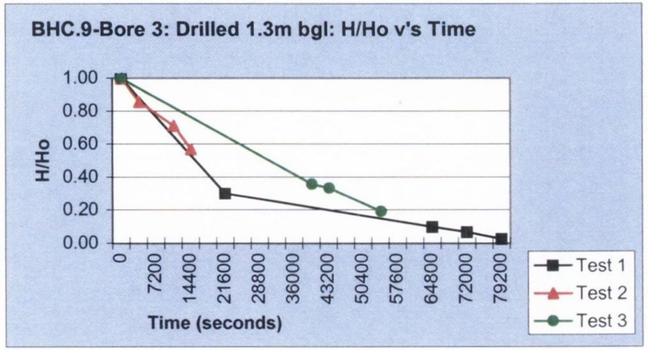
Plot 3BLUE

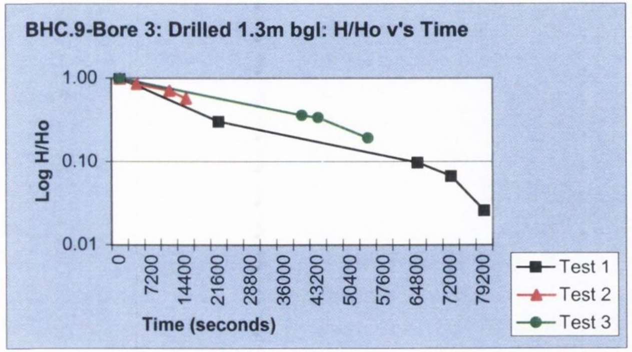




K = 0.041 m/day
at 1.3m bgl

	K (m/d)	Head (m)
Test 1	0.041	0.62
Test 2	0.040	0.07
Test 3	0.043	0.21





Saturated Hydraulic Conductivity calculated using Ritzema's formula (1994) for Auger Hole method

BHC.9

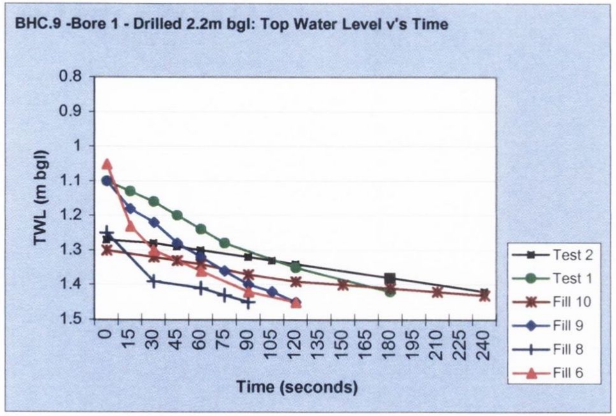
Depth	0.5m bgl	1m bgl	1.2m bgl	1.3m bgl	2.2m bgl
K	0.042 m/day	0.015 m/day	0.62 m/day	0.041 m/day	11.24 m/day

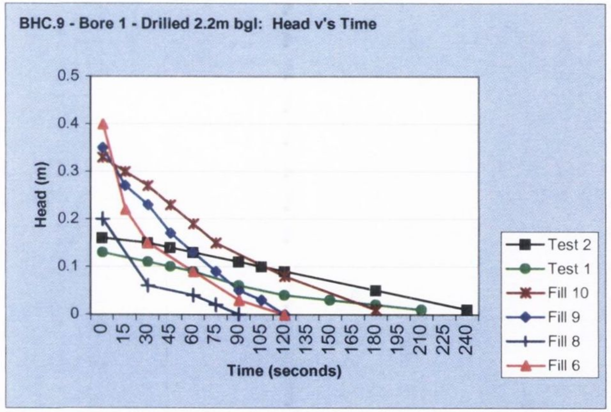
Plot 3BLUE

BHC.9 bore 3: 1.3m bgl			
BHC.9 bore 3	**head h (m)**	**head h (m)**	**head h (m)**
time (secs)	**Test 1**	**Test 2**	**Test 3**
0	0.6	0.07	0.21
3600		0.06	
10800		0.05	
14400		0.04	
21600	0.18		
39600			0.075
43200			0.07
54000			0.04
64800	0.06		
72000	0.04		
79200	0.016		
K (cm/s)	4.77231E-05	4.64875E-05	4.97121E-05
K (m/d)	0.041232724	0.040165165	0.042951237
	Test 1	**Test 2**	**Test 3**
Initial head(m)	0.62	0.07	0.21

K = 1.15*r*(((log(ho+0.5r))-(log(ht+0.5r))/(t-to)) **(cm/seconds)**

Plot 3BLUE

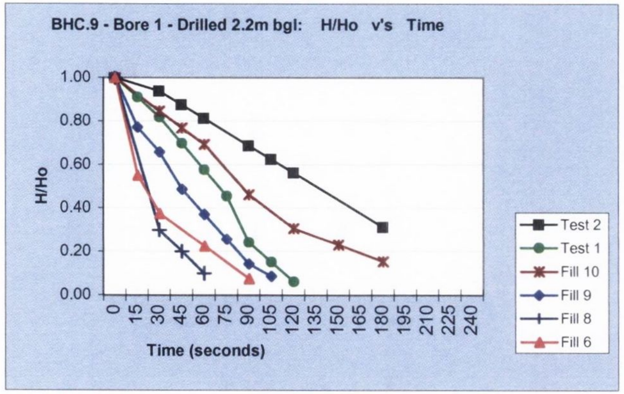

BHC.9 -Bore 1 - Drilled 2.2m bgl: Top Water Level v's Time

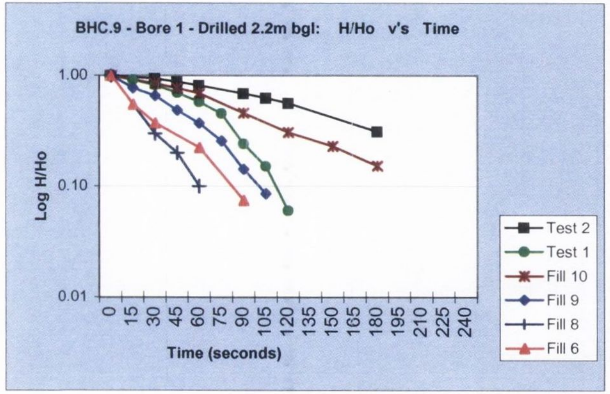

BHC.9 - Bore 1 - Drilled 2.2m bgl: Head v's Time

K= 11.24 m/day

at 2m bgl

	K (m/day)	head (m)
Test 2	11.71	0.16
Test 1	10.76	0.13
Fill 10	16.00	0.33
Fill 9	29.43	0.35
Fill 8	33.49	0.2
Fill 6	34.15	0.4


BHC.9 - Bore 1 - Drilled 2.2m bgl: H/Ho v's Time


BHC.9 - Bore 1 - Drilled 2.2m bgl: H/Ho v's Time

Saturated Hydraulic Conductivity calculated using Ritzema's formula (1994) for Auger Hole method

BHC.9

Depth	0.5m bgl	1m bgl	1.2m bgl	1.3m bgl	2.2m bgl
K	0.042 m/day	0.015 m/day	0.62 m/day	0.041 m/day	11.24 m/day

sand layer at 2m

Plot 3BLUE

BHC.9 bore 1: 2.2m bgl							
to calc K	HEAD (m)	HEAD (m)	HEAD (m)	HEAD (m)	HEAD (m)	HEAD (m)	HEAD (m)
seconds	***Test 12***	***Test 11***	***Test 10***	***Test 9***	***Test 8***	***Test 7***	***Test 6***
0	0.16	0.13	0.33	0.35	0.2	0.2	0.4
15			0.3	0.27		0.18	0.22
30	0.15	0.11	0.27	0.23	0.06	0.1	0.15
45	0.14	0.1	0.23	0.17		0.06	
60	0.13	0.09	0.19	0.13	0.04	0.03	0.09
75			0.15	0.09	0.02	0	
90	0.11	0.06		0.05	0		0.03
105	0.1			0.03			
120	0.09	0.04	0.08	0			0
150		0.03					
180	0.05	0.02	0.01				
210		0.01					
240	0.01						
K (cm/s)	0.013557856	0.012453	0.018513	0.03406161	0.03876017	0.04432636	0.03671613
K (m/d)	11.71398791	10.7595	15.99552	29.4292309	33.4887905	38.2979772	31.7227369
	Test 2	***Test 1***	***Fill 10***	***Fill 9***	***Fill 8***	***Fill 7***	***Fill 6***
Initial head(m)	0.16	0.13	0.33	0.35	0.2	0.2	0.4

test 6 takes place after 60 litres added in an afternoon

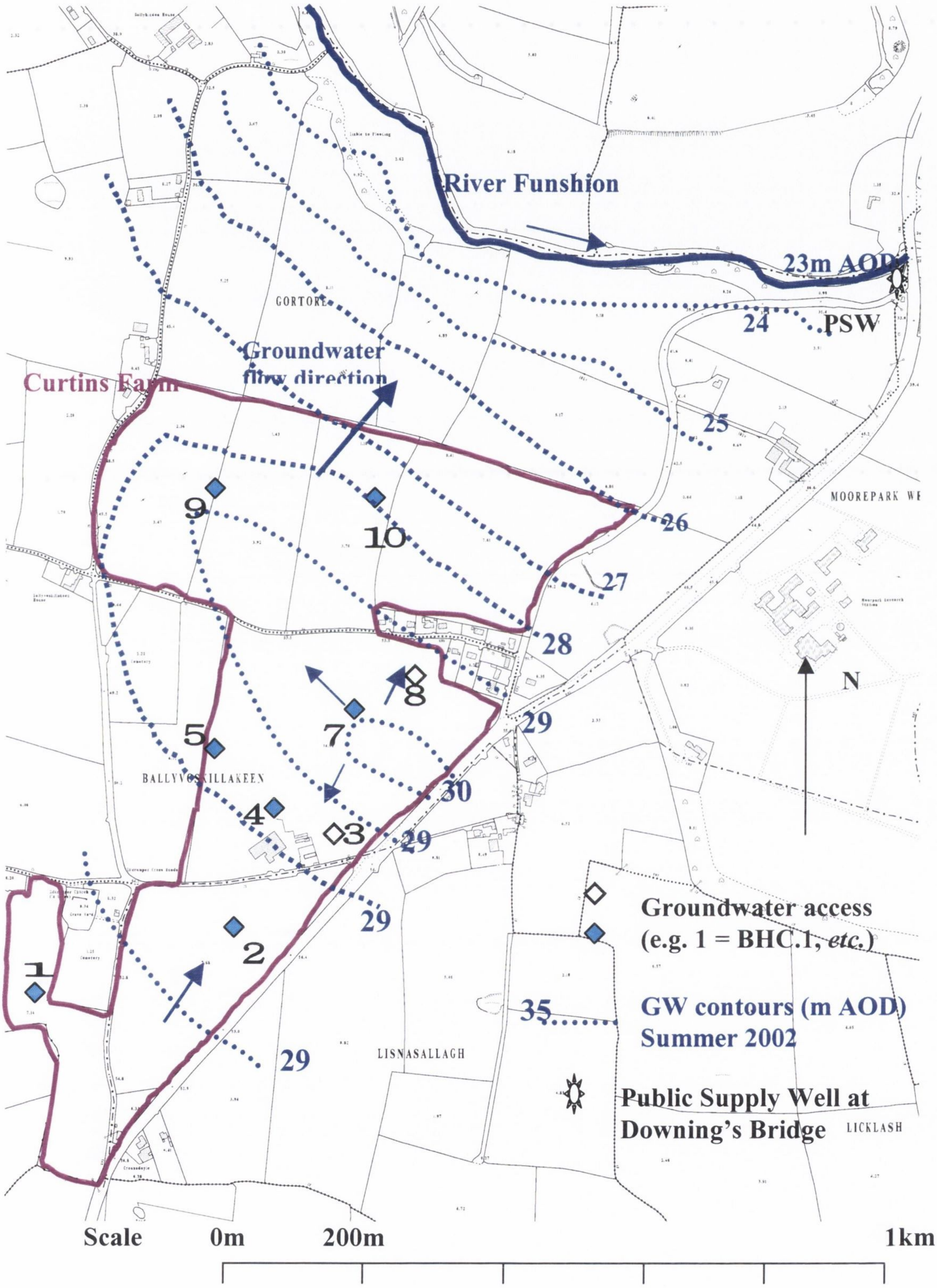
Appendix H

Curtin's Farm Water Table Elevation Maps

Using borehole-surface elevation data, borehole water level data and stage data from the OPW gauging station at Downing's Bridge, water table elevation maps were constructed. Raw data pertaining to field observations of water level and consequent conversion to water level elevations are contained in Appendix J, as is the magnitude of water level change between each monitoring event.

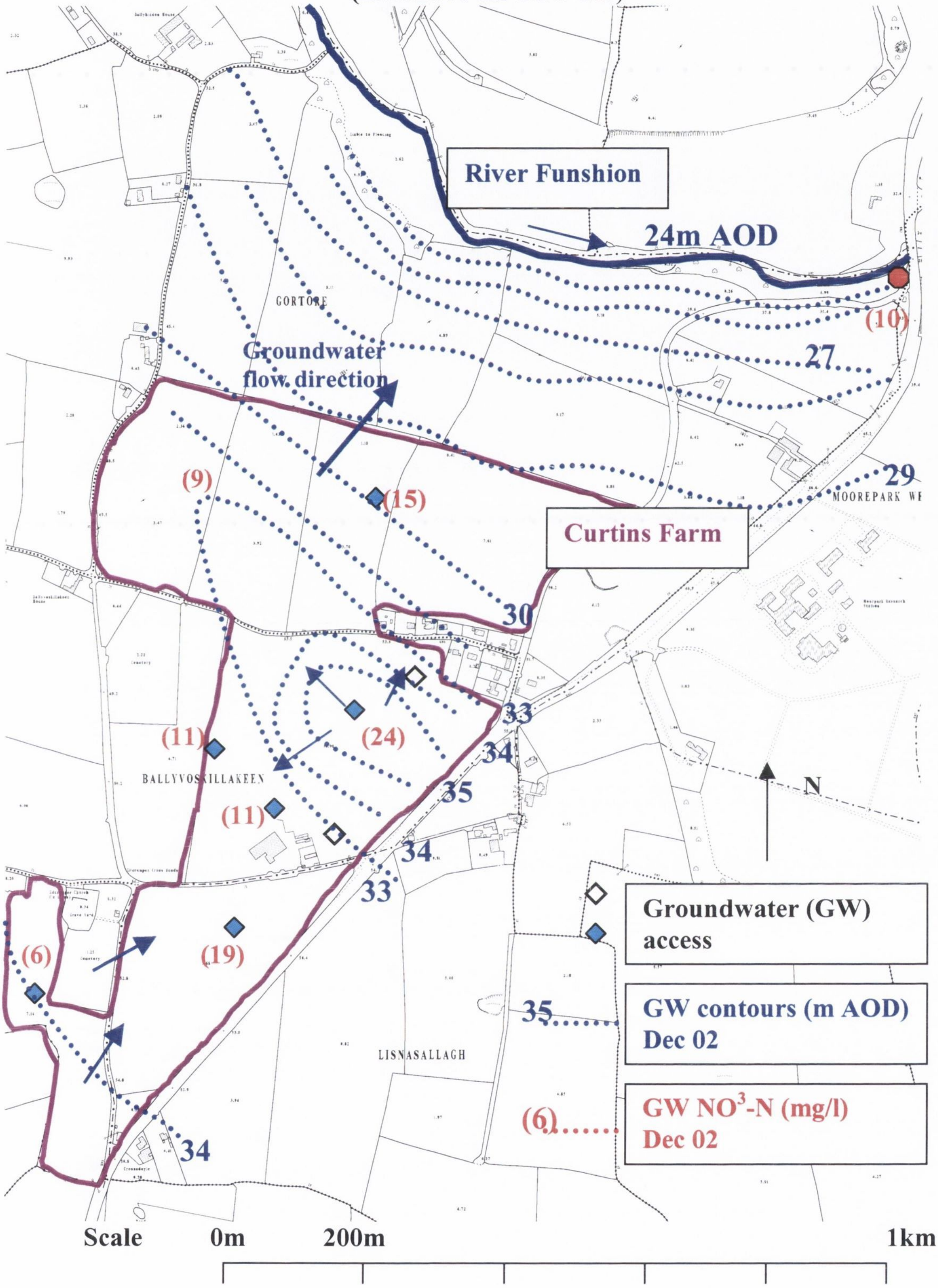
Borehole Locations (BHC.) & Water Table Elevations – Summer 2002

EPA 2000-LS-2.3.3 M1 (Groundwater)

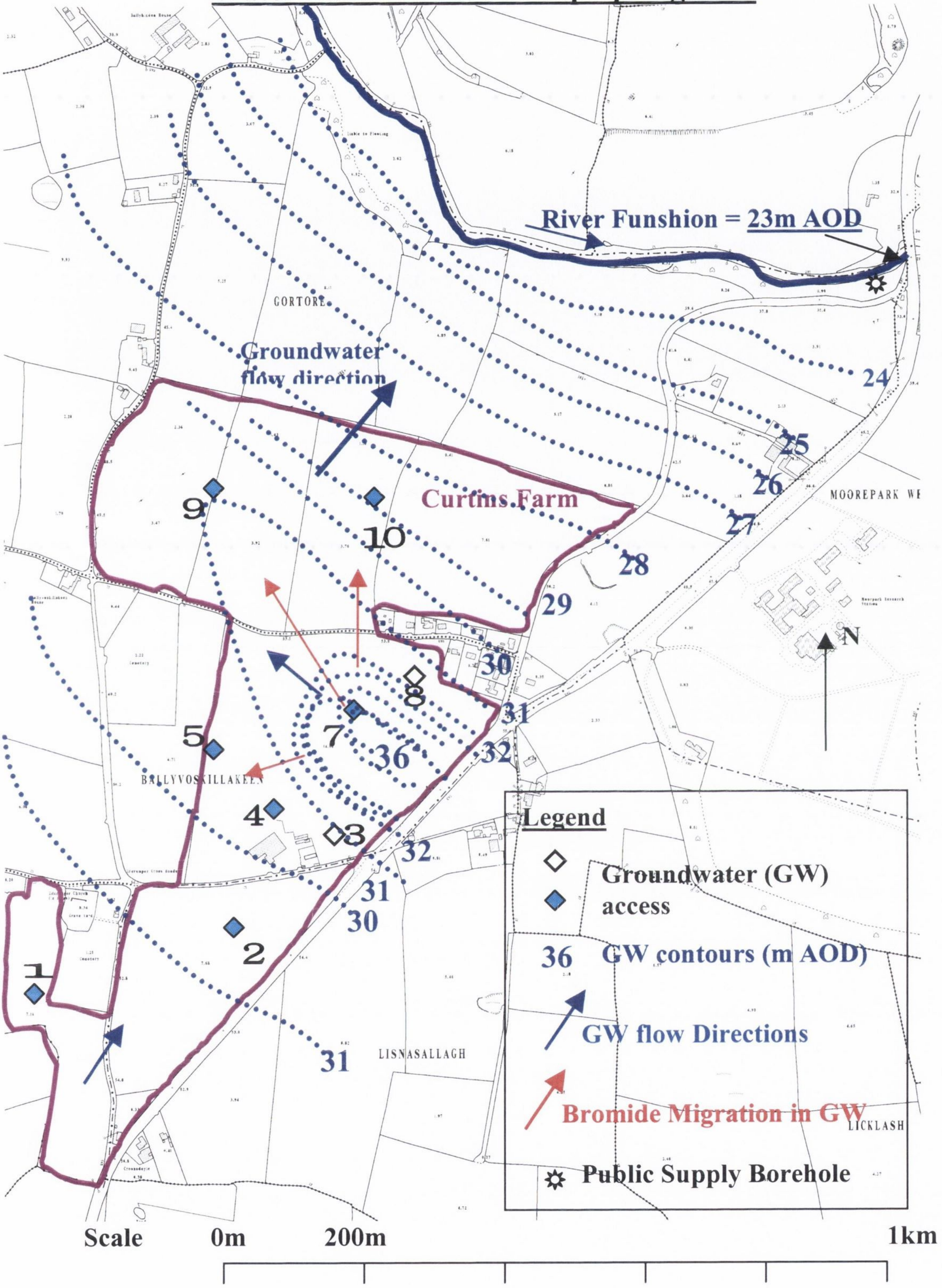


DECEMBER 2002 – Water Table Elevations & Groundwater Nitrate (mg/l)

(EPA 2000-LS-2.3.3 M1)

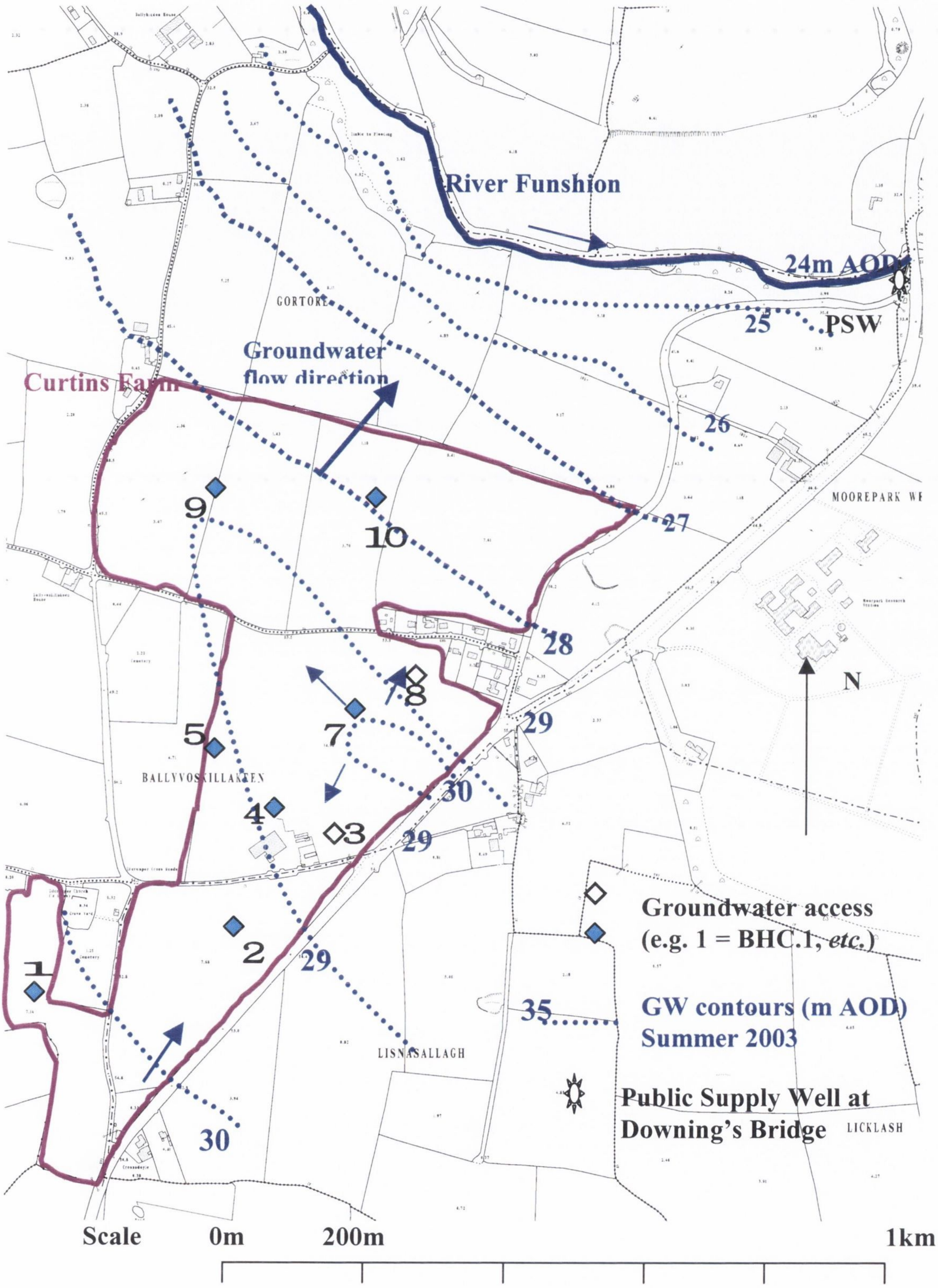


Water Table Elevation Map Spring 2003



Borehole Locations (BHC.) & Water Table Elevations – Summer 2003

EPA 2000-LS-2.3.3 M1 (Groundwater)



Appendix I

Aquifer Hydraulic Conductivity

Groundwater hydraulic conductivity was investigated in each of the operational piezometers. This appendix contains response graphs and calculation details. The investigation and analyses methodologies were presented in chapter five, section 5.2.2.1. Results for K were presented in chapter six, section 6.2.1. During the testing period the watertable was approximately 28m below ground level.

The data sheets in this appendix are presented as follows:

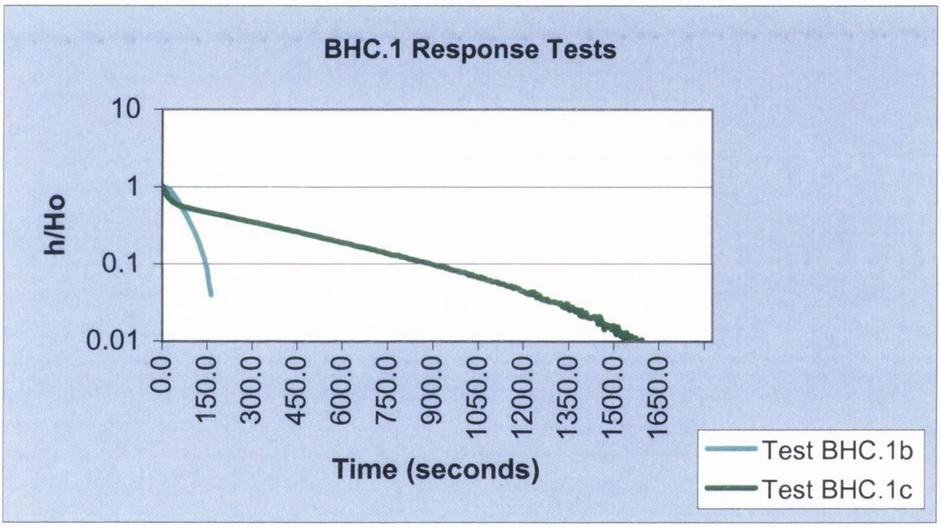
	To
t BHC.1b	160 seconds
t BHC.1c	240 seconds

ng Hvorslevs equation as presented in Freeze & Cherry (1979); at Head ratio 0.37, To=10 seconds
L/R>8

K = [(R^2.ln(L/R))/(2L.To)]

where R = 50mm = 0.05m
and L = 3m
Therefore L/R = 60
To= 160 seconds for test BHC.1b
To= 240 seconds for test BHC.1c

refore, for BHC.1b:	excel formula	**1.06624E-05 m/s**	**0.921228 m/day**
for BHC1c:	excel formula	**7.10824E-06 m/s**	**0.614152 m/day**
		K =	**0.76769 m/day**
		K =	~10^0 m/day



	To
Test BHC.2a	5 seconds
Test BHC.2b	6 seconds

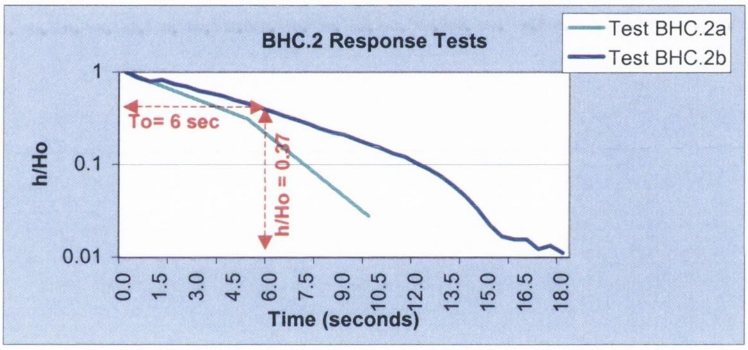
(a)

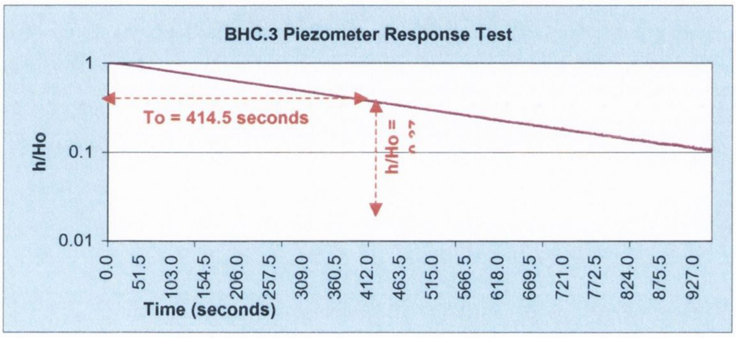
Using Hvorslevs equation as presented in Freeze & Cherry (1979); at Head ratio 0.37
For L/R>8

K = [(R^2.ln(L/R))/(2L.To)]

where R = 50mm = 0.05m
and L = 3m
Therefore L/R = 60
To= 6 seconds and To = 4.5 seconds

Therefore, for BHC.2a:	excel formula	**0.0003412**	**m/s**	**29.47928**	**m/day**
And, for BHC.2b:	excel formula	**0.0002843**	**m/s**	**24.56607**	**m/day**
			K =	**27.02267**	**m/day**





(a)

Using Hvorslevs equation as presented in Freeze & Cherry (1979); at Head ratio 0.37, To=414.5 seconds
For L/R>8

K = [(R^2.ln(L/R))/(2L.To)]

where R = 50mm = 0.05m
and L = 3m
Therefore L/R = 60
To= 414.5 seconds = 414.5/86400 = 0.0047975 days

Therefore, for BHC.3: K = [(0.0025xln(60))/(2x3x0.0047975)] = 0.3556 m/day = 10^-1 m/d
excel formula **4.11575E-06 m/s** **0.3556 m/day**

(b)

Using Hvorslevs methodology as presented by Schwartz and Zhang (2003): chose values t1, H1 and t2, H2 off semi log graph

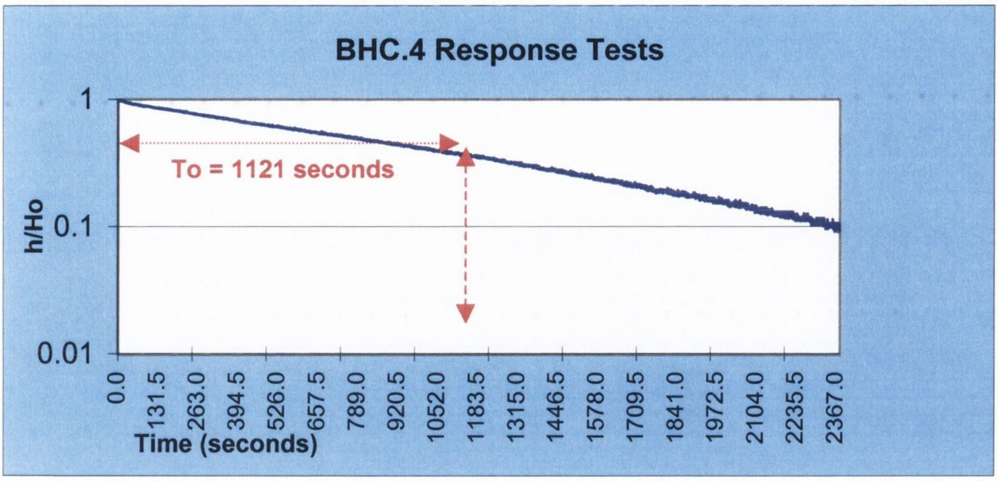
K = (R^2/2L(t2-t1).[ln(L/R)].[ln(H1/H2)]

where R = 0.05m
L = 3m
L/R = 60
H1 = 0.770742358 at t1 = 115 seconds
H2 = 0.316593886 at t2 = 480.5 seconds

Therefore, repeating calculation for BHC.9: K = ((0.0025)/(2x3x(480.5-115)).[ln(60)].[ln(0.770742358/0.316593886)]

K = 4.15285E-06 m/s
for Piezo BHC.3 **K=** 0.358806126 m/day

same result for two methods ~10^-1 m/d

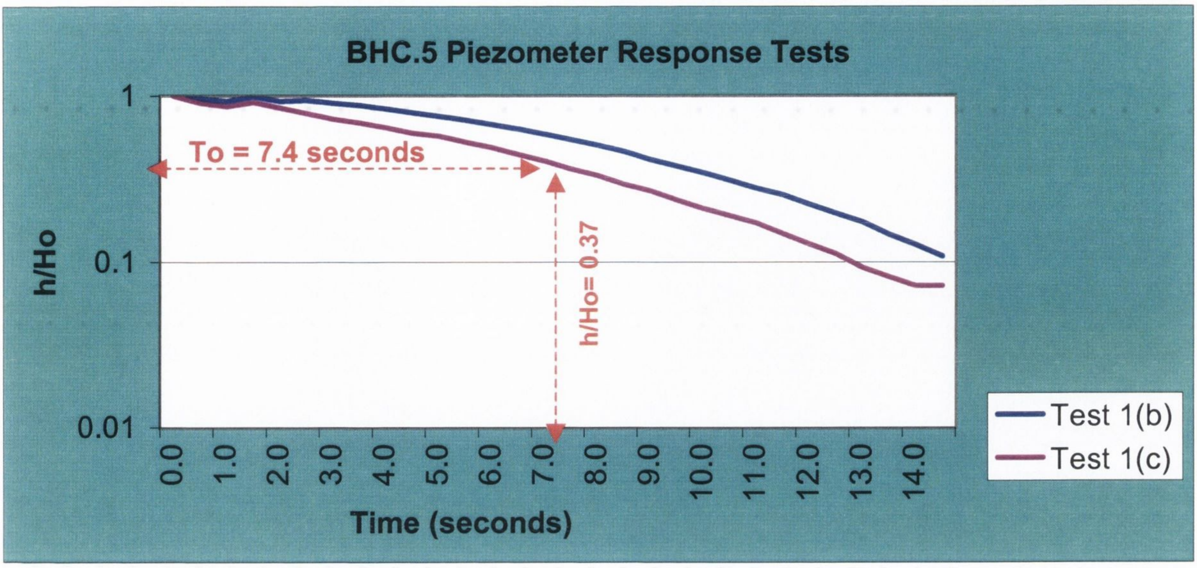


Using Hvorslevs equation as presented in Freeze & Cherry (1979); at Head ratio 0.37, To=10 seconds
For L/R>8

K = [(R^2.ln(L/R))/(2L.To)]

where R = 50mm = 0.05m
and L = 3m
Therefore L/R = 60
To= 1121 seconds = 1121/86400 = 0.0129745 days

Therefore, for BHC.4: K = [(0.0025xln(60))/(2x3x0.0129745)] = 0.1314865 m/day = 10^ -1 m/d
excel formula **1.52183E-06 m/s** **0.131487 m/day**



(a)

Using Hvorslevs equation as presented in Freeze & Cherry (1979); at Head ratio 0.37
For L/R>8

K = [(R^2.ln(L/R))/(2L.To)]

where R = 50mm = 0.05m
and L = 3m
Therefore L/R = 60
Two tests: To = 9.4 seconds for test BHC.5b
To = 7.4 seconds for test BHC.5c

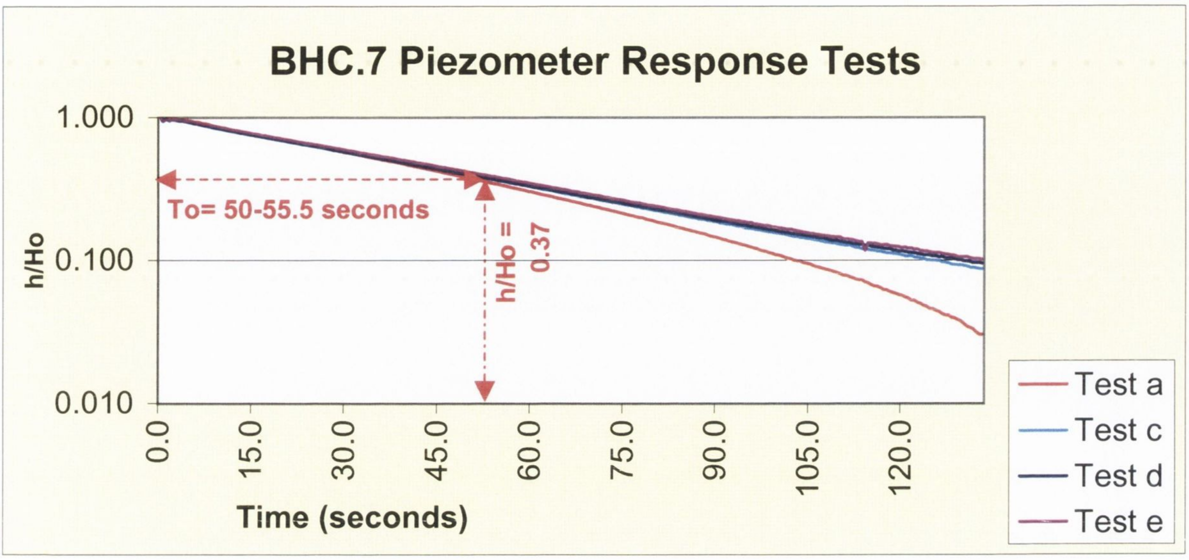
9.4 seconds= 9.4/86400=0.0001088 days
7.4 seconds= 7.4/86400=0.0000856 days

Therefore, for BHC.5b: K = [(0.0025xln(60))/(2x3x0.0001088)] = 15.68 m/day = 10^1 m/d
excel formula **0.000181 m/s** **15.68047 m/day**

And, for BHC.5c: K = [(0.0025xln(60))/(2x3x0.0000856)] = 19.92 m/day = 10^1 m/d
excel formula **0.000231 m/s** **19.91843 m/day**

Average K 17.80 ~10^1 m/d

Summary BHC.5 groundwater K tests		
Test 1	K= 16m/da	K~ 10^1 m/d
Test 2	K= 20m/da	K~ 10^1 m/d



	Test a	**Test c**	**Test d**	**Test e**
To (seconds)	50	53	53.5	55.5

Using Hvorslevs equation as presented in Freeze & Cherry (1979); at Head ratio 0.37, To=

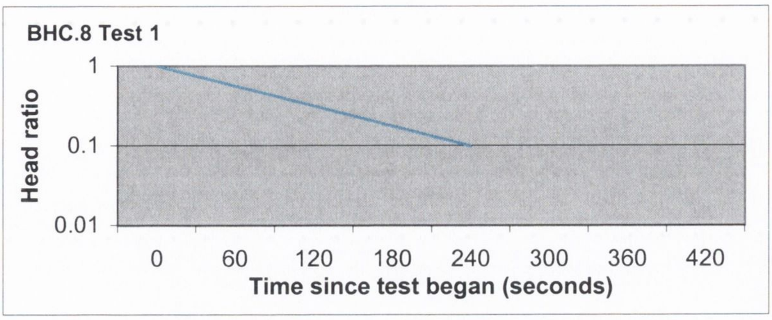
For L/R>8

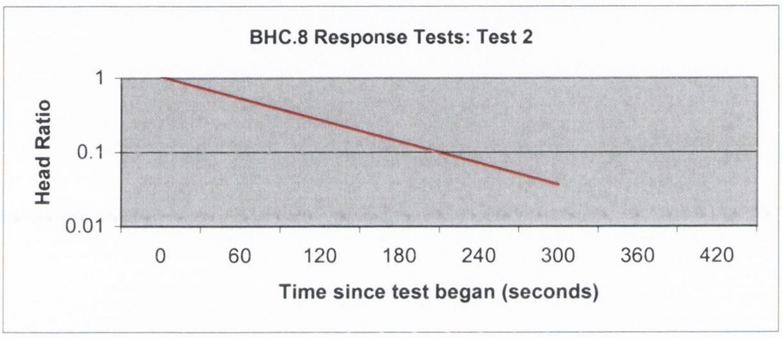
K = [(R^2.ln(L/R))/(2L.To)]

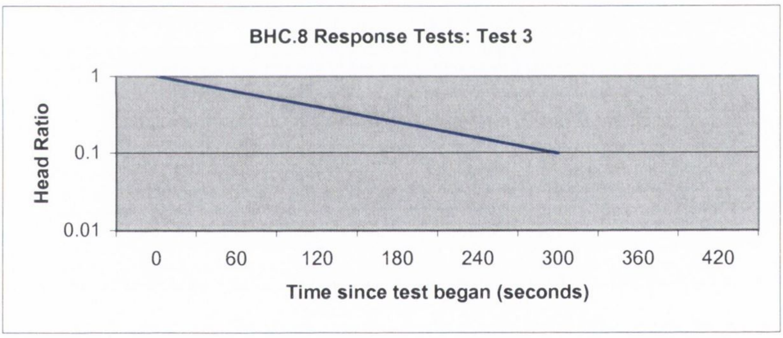
where R = 50mm = 0.05m
and L = 3m
Therefore L/R = 60

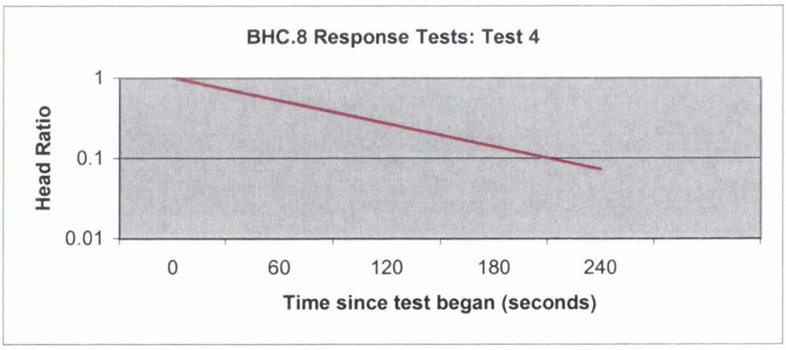
	SECONDS			
Therefore, for BHC.7a:	To = 50	excel formula	3.41195E-05 m/s	2.9 m/day
Therefore, for BHC.7c:	To = 53		3.21882E-05 m/s	2.8 m/day
Therefore, for BHC.7d:	To = 53.5		3.18874E-05 m/s	2.8 m/day
Therefore, for BHC.7e:	To = 55.5		3.07383E-05 m/s	2.7 m/day
				2.8 m/day

BHC.8 Groundwater Hydraulic Conductivity Analyses









	K1	K2	K3	k4
m/second	1.65081E-05	1.89E-05	1.32E-05	1.88E-05
m/day	1.42629833	1.637183	1.13943	1.620782

1.455923 K (m/day)
Average

K calculations

Using Hvorslevs equation as presented in Freeze & Cherry (1979); at Head ratio 0.37
For L/R>8

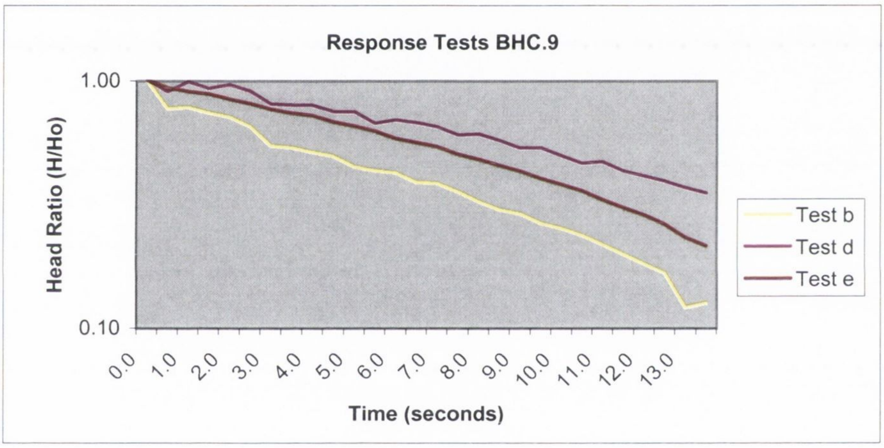
K = [(R^2.ln(L/R))/(2L.To)]

where R = 50mm = 0.05m
and L = 3m
Therefore L/R = 60
To= 10 seconds = 10/86400 = 0.0001157 days

Therefore, for BHC.9: **K = [(0.0025xln(60))/(2x3x0.0001157)] = 14.7 m/day = 10^1 m/d**
excel formula **0.000171 m/s** **14.73984 m/day**

	Test b	Test d	Test e
To (seconds)	7.25	13	10
K (m/sec)	0.000235	0.000131	0.000171
K (m/day)	20.3	11.3	14.7

15.5 K (m/day)



Appendix J

Curtin's Farm Groundwater Level Monitoring Results

Raw data pertaining to field observations of water level and consequent conversion to water level elevations are contained in Appendix J, as is the magnitude of water level change between each monitoring event.

Dipped Groundwater Level in Each Piezometer For Each Monitoring Occasion

	BHC.1 (m bgl)	BHC.2 (m bgl)	BHC.3 (m bgl)	BHC.4 (m bgl)	BHC.5 (m bgl)	BHC.7 (m bgl)	BHC.8 (m bgl)	BHC.9 (m bgl)	BHC.10 (m bgl)
11-Jul-01	x	x			26.29	x			
13-Jul-01	x	x		29.1	26.35	x			
24-Jul-01	x	x	27.94	28.64	26.47	x	30.48	x	x
3-Aug-01	x	x	28.73	28.77	26.6	x	30.56	x	x
20-Aug-01	x	x	29.26			x	30.62		
21-Aug-01	x	x	28.2	28.83	26.66	x	30.59		
3-Sep-01	x	28.65	26.5	29.02	26.85	28.5	30.77	x	x
1-Oct-01	x	28.8	28.69	29.09	26.99	28.58	30.72		
1-Nov-01	x	27.82	27.6	27.8	26.13	26.72	29.95	x	x
19-Nov-01	x	27.99	27.8	28.19	26.32	27.32	30.15	x	x
5-Dec-01	x	27.33	26.8	26.98	25.32	22.62	28.63	x	x
18-Jan-02	27.02	26.27	25.81	26.91	24.92	23.6	28.79	26.07	29.71
5-Feb-02	19.64	18.86		19.98	18.02	13.74	19.68	20.71	26.49
18-Feb-02	19.58	18.98	18.5	21.33	19.48	17.94	25.54	22.22	27.84
11-Mar-02	22.25	21.55	21.24	23.57	21.62	20.43	27.05	23.76	28.54
26-Mar-02	23.65	22.93	22.54	24.6	22.62	21.42	27.74	24.5	28.97
4-Apr-02	24.32	23.64	23.3	25.25	23.22	22.43	28.22	24.92	29.17
9-Apr-02	24.85	24.14	23.87	25.66	23.62	23.67	25.57	25.25	29.38
17-Apr-02	25.57	24.84	24.44	26.22	24.16	24.41	28.91	25.62	29.6
23-Apr-02	25.99	25.27	25.02		24.44	24.8	29.09	25.79	29.61
30-Apr-02	26.36	25.59	25.21	26.4	24.62	25.1	29.12	25.89	29.56
8-May-02	26.5	25.8	25.55	26.8	24.71	24.78	29.25	25.96	29.71
23-May-02	26.61	25.87	25.5	26.6	24.56	24.3	29.01	25.77	29.47
4-Jun-02	24.97	24.29	23.82	25.37	23.34	20.81	28.04	24.89	29.01
19-Jun-02	25.47	24.72	24.34	25.86	23.84	23.97		25.25	29.2
28-Jun-02	25.85	25.11	24.79	26.25	24.21	23.75	28.82	25.6	29.5
4-Jul-02	26.19	25.4	25.13	26.54	24.49	24.5		25.79	29.57
16-Jul-02	26.9	26.12	25.89	27.06	25.02	25.53	29.48	26.2	29.79
15-Aug-02	28.06	27.34	27.16	26.97	25.89	26.99	30.04	26.78	30.03
19-Sep-02	28.96	28.29	28.14	28.73	26.59	28.14	30.62	27.31	30.5
24-Oct-02	29.25	28.44	28.02	28.45	26.53	27.19	30.45	27.2	30.31
21-Nov-02	25.9	25.03	23.8	25.2	23.27	23.1	24.38	24.38	28.64
29-Nov-02	21.15	20.33		19.85	18.77	13.14	21.1	21.1	26.48
5-Dec-02	20.6	19.86	19.13	21.79	19.78	16.99	25.41	22.26	27.63
10-Dec-02	20.9	20.21	19.7	22.3	20.37	18.45	26.2	22.82	28.19
16-Jan-03	22.13	21.5	21.11	23.6	21.66	20.84	27.14	23.84	28.66
23-Jan-03	22.37	21.61	21.07	23.25	21.3	18.5	26.58	23.5	28.41
28-Jan-03						19.84			
29-Jan-03	22.61	21.9	21.43	23.7	21.76	19.98	27.1	23.9	28.65
31-Jan-03	22.8	22.05				20.6	27.25		
2-Feb-03	22.95	21.23	21.7	24.1	22.09	20.9	27.35	24.12	28.79
4-Feb-03	23.05	22.34	21.8	24.17	22.18	21.07	27.35	24.16	28.75
6-Feb-03						21.08	27.44		
8-Feb-03	23.32	22.62	22.13	24.34	22.34	20.99	27.45	24.29	28.85
10-Feb-03	23.48	22.72	22.17	24.43	22.41	21.01	27.5	24.32	28.82
12-Feb-03	23.57	22.78	22.3	24.38	22.4	20.42	27.43	24.29	28.81
14-Feb-03	23.57	22.81	22.2	24.37	22.37	20.18	27.4	24.27	28.8
16-Feb-03	23.65	22.9	22.33	24.5	22.48	20.45	27.52	24.35	28.87
20-Feb-03	23.87	23.11	22.64	24.77	22.76	21.43		24.59	29.01
22-Feb-03	24.03		22.81	24.95	22.9	21.82	27.95	24.71	29.1
24-Feb-03	24.2	23.45	23.02	25.1	23.07	22.22	28.08	24.83	29.18
26-Feb-03	24.37	23.65	23.15	25.27	23.21	22.52	28.3	24.97	29.23
28-Feb-03	24.5	23.73	22.95	25.4	23.32	22.85	28.2*	25	29.2
3-Mar-03	24.53	23.72	23.12	25.15	23.12	21.63	27.95*?	24.79	29.06
5-Mar-03	24.52	23.74	23.13	25.1	23.07	21.25	27.86	24.76	29.02
10-Mar-03	24.2	23.4	22.55	24.65	22.61	19.81	27.4	24.35	28.57
12-Mar-03	23.58	22.85		23.8	21.76	17.95	26.59	23.66	28.2
19-Mar-03	23.15	22.46	21.9	24.11	22.1	20.2	27.24	24.04	28.67
25-Mar-03	23.55	22.89	22.47	25.62	22.62	21.89	27.74	24.49	28.98
2-Apr-03	24.4	23.67	23.33	25.35	23.32	23.19	28.3	25.02	29.3
9-Apr-03	25.15	24.4	24.11	25.95	23.89	24.1	28.7	25.42	29.5
16-Apr-03	25.75	25.02	24.7	26.37	24.29	24.58	28.98	25.67	29.6
25-Apr-03	26.05	25.53	24.76	26.77	24.65	25.2	29.06	25.9	29.67
30-Apr-04	26.45	25.68	25.35	26.69	24.64	24.68	29.14	25.94	29.7
6-May-03	25.55	24.73	23.77	25.05	23.14	19.15	27.51	24.59	28.8
16-May-03	25.15	24.42	23.98	25.74	23.66	22.43	28.4	25.18	29.25
22-May-03	25.5	24.78	24.4	26.07	23.02	23.65	28.71	25.44	29.4
5-Jun-03	26.45	25.7	25.4	26.8	24.7	25.05	29.22	25.93	29.68
19-Jun-03	26.15	25.4	24.97	26.35	24.3	23.2	28.85	25.62	29.46
1-Jul-03	26.75	25.92	25.58	26.72	24.8	24.85	29.2	25.81	29.64
13-Aug-03	28.37	27.54	27.34	28.03	26.03	27.25	30.22	26.91	30.23
2-Sep-03	29	28.07	27.92	28.48	26.45	28.86	30.53	27.21	30.45
(m bgl)									
MAX	29.25	28.44	28.14	28.73	26.59	28.14	30.62	27.31	30.5
MIN	19.58	18.86	18.5	19.85	18.02	13.14	19.68	20.71	26.48
RANGE	9.67	9.58	9.64	8.88	8.57	15	10.94	6.6	4.02

Piezometric Groundwater Elevations

Rise (+) or fall (-) in piezometer groundwater levels between sampling occasions (metres)

	Ground Level	55.81m AOD		53.88m AOD		53.2m AOD		54.059m AOD		51.775m AOD		53.896m AOD		54.767m AOD		54.66m AOD		57.23m AOD	
		BHC.1	BHC.1	BHC.2	BHC.2	BHC.3	BHC.3	BHC.4	BHC.4	BHC.5	BHC.5	BHC.7	BHC.7	BHC.8	BHC.8	BHC.9	BHC.9	BHC.10	BHC.10
	Date	(m AOD)	+/- (m)	(m AOD)	+/- (m)	(m AOD)	+/- (m)	(m AOD)	+/- (m)	(m AOD)	+/- (m)	(m AOD)	+/- (m)	(m AOD)	+/- (m)	(m AOD)	+/- (m)	(m AOD)	+/- (m)
	11-Jul-01									25.51									
	13-Jul-01							25		25.45	-0.06								
	24-Jul-01					25.26		25.46	0.46	25.33	-0.12			24.32					
	3-Aug-01					24.47	-0.79	25.33	-0.13	25.2	-0.13			24.24	-0.08				
	20-Aug-01					23.94	-0.53							24.18	-0.06				
	21-Aug-01							25.27	-0.06	25.14	-0.06			24.21	0.03				
	3-Sep-01			25.25		26.7		25.08	-0.19	24.95	-0.19	25.4		24.03	-0.18				
	1-Oct-01			25.1	-0.15	24.51	-2.19	25.01	-0.07	24.81	-0.14	25.32	-0.08	24.08	0.05				
	1-Nov-01			26.08	0.98	25.6	1.09	26.3	1.29	25.67	0.86	27.18	1.86	24.85	0.77				
	19-Nov-01			25.91	-0.17	25.4	-0.2	25.91	-0.39	25.48	-0.19	26.58	-0.6	24.65	-0.2				
	5-Dec-01			26.57	0.66	26.4	1	27.12	1.21	26.48	1	31.28	4.7	26.17	1.52				
	18-Jan-02	28.78		27.63	1.06	27.39	0.99	27.19	0.07	26.88	0.4	30.3	-0.98	26.01	-0.16	28.63			
	5-Feb-02	36.16	7.38	35.04	7.41			34.12	6.93	33.78	6.9	40.16	9.86	35.12	9.11	33.99	5.36	30.71	
	18-Feb-02	36.22	0.06	34.92	-0.12	34.7	7.31	32.77	-1.35	32.32	-1.46	35.96	-4.2	29.26	-5.86	32.48	-1.51	29.36	-1.35
	11-Mar-02	33.55	-2.67	32.35	-2.57	31.96	-2.74	30.53	-2.24	30.18	-2.14	33.47	-2.49	27.75	-1.51	30.94	-1.54	28.66	-0.7
	26-Mar-02	32.15	-1.4	30.97	-1.38	30.66	-1.3	29.5	-1.03	29.18	-1	32.48	-0.99	27.06	-0.69	30.2	-0.74	28.23	-0.43
	4-Apr-02	31.48	-0.67	30.26	-0.71	29.9	-0.76	28.85	-0.65	28.58	-0.6	31.47	-1.01	26.58	-0.48	29.78	-0.42	28.03	-0.2
	9-Apr-02	30.95	-0.53	29.76	-0.5	29.33	-0.57	28.44	-0.41	28.18	-0.4	30.23	-1.24	26.23	-0.35	29.45	-0.33	27.82	-0.21
	17-Apr-02	30.23	-0.72	29.06	-0.7	28.76	-0.57	27.88	-0.56	27.64	-0.54	29.49	-0.74	25.89	-0.34	29.08	-0.37	27.6	-0.22
	23-Apr-02	29.81	-0.42	28.63	-0.43	28.18	-0.58			27.36	-0.28	29.1	-0.39	25.71	-0.18	28.91	-0.17	27.59	-0.01
	30-Apr-02	29.44	-0.37	28.31	-0.32	27.99	-0.19	27.7	-0.18	27.18	-0.18	28.8	-0.3	25.68	-0.03	28.81	-0.1	27.64	0.05
	8-May-02	29.3	-0.14	28.1	-0.21	27.65	-0.34	27.3	-0.4	27.09	-0.09	29.12	0.32	25.55	-0.13	28.74	-0.07	27.49	-0.15
	23-May-02	29.19	-0.11	28.03	-0.07	27.7	0.05	27.5	0.2	27.24	0.15	29.6	0.48	25.79	0.24	28.93	0.19	27.73	0.24
	4-Jun-02	30.83	1.64	29.61	1.58	29.38	1.68	28.73	1.23	28.46	1.22	33.09	3.49	26.76	0.97	29.81	0.88	28.19	0.46
	19-Jun-02	30.33	-0.5	29.18	-0.43	28.86	-0.52	28.24	-0.49	27.96	-0.5	29.93	-3.16			29.45	-0.36	28	-0.19
	28-Jun-02	29.95	-0.38	28.79	-0.39	28.41	-0.45	27.85	-0.39	27.59	-0.37	30.15	0.22	25.98		29.1	-0.35	27.7	-0.3
	4-Jul-02	29.61	-0.34	28.5	-0.29	28.07	-0.34	27.56	-0.29	27.31	-0.28	29.48	-0.67			28.91	-0.19	27.63	-0.07
	16-Jul-02	28.9	-0.71	27.78	-0.72	27.31	-0.76	27.04	-0.52	26.78	-0.53	28.37	-1.11	25.32	-0.66	28.5	-0.41	27.41	-0.22
	15-Aug-02	27.74	-1.16	26.56	-1.22	26.04	-1.27	27.13	0.09	25.91	-0.87	26.91	-1.46	24.76	-0.56	27.92	-0.58	27.17	-0.24
	19-Sep-02	26.84	-0.9	25.61	-0.95	25.06	-0.98	25.37	-1.76	25.21	-0.7	25.76	-1.15	24.18	-0.58	27.39	-0.53	26.7	-0.47
	24-Oct-02	26.55	-0.29	25.46	-0.15	25.18	0.12	25.65	0.28	25.27	0.06	26.71	0.95	24.35	0.17	27.5	0.11	26.89	0.19
	21-Nov-02	29.9	3.35	28.87	3.41	29.4	4.22	28.9	3.25	28.53	3.26	30.8	4.09	30.42	6.07	30.32	2.82	28.56	1.67
	29-Nov-02	34.65	4.75	33.57	4.7			34.25	5.35	33.03	4.5	40.76	9.96	33.7	3.28	33.6	3.28	30.72	2.16
	5-Dec-02	35.2	0.55	34.04	0.47	34.07	4.67	32.31	-1.94	32.02	-1.01	36.91	-3.85	29.39	-4.31	32.44	-1.16	29.57	-1.15
	10-Dec-02	34.9	-0.3	33.69	-0.35	33.5	-0.57	31.8	-0.51	31.43	-0.59	35.45	-1.46	28.6	-0.79	31.88	-0.56	29.01	-0.56
	16-Jan-03	33.67	-1.23	32.4	-1.29	32.09	-1.41	30.5	-1.3	30.14	-1.29	33.06	-2.39	27.66	-0.94	30.86	-1.02	28.54	-0.47
	23-Jan-03	33.43	-0.24	32.29	-0.11	32.13	0.04	30.85	0.35	30.5	0.36	35.4	2.34	28.22	0.56	31.2	0.34	28.79	0.25
	28-Jan-03	1										34.06	Br Appl.>>						
	29-Jan-03	33.19										33.92	-0.14	27.7					
	31-Jan-03	33	-0.19	31.85								33.3	-0.62	27.55	-0.15				
	2-Feb-03	32.85	-0.15	31.67	-0.18	31.5		30		29.71		33	-0.3	27.45	-0.1	30.58		28.41	
	4-Feb-03	32.75	-0.1	31.56	-0.11	31.4	-0.1	29.93	-0.07	29.62	-0.09	32.83	-0.17	27.45	0	30.54	-0.04	28.45	0.04
	6-Feb-03	1										32.82	-0.01	27.36	-0.09				
	8-Feb-03	32.48	-0.27	31.28	-0.28	31.07	-0.33	29.76	-0.17	29.46	-0.16	32.91	0.09	27.35	-0.01	30.41		28.35	
BHC.7	10-Feb-03	32.32	-0.16	31.18	-0.1	31.03	-0.04	29.67	-0.09	29.39	-0.07	32.89	-0.02	27.3	-0.05	30.38	-0.03	28.38	0.03
Br first arriva	12-Feb-03	32.23	-0.09	31.12	-0.06	30.9	-0.13	29.72	0.05	29.4	0.01	33.48	0.59	27.37	0.07	30.41	0.03	28.39	0.01
	14-Feb-03	32.23	0	31.09	-0.03	31	0.1	29.73	0.01	29.43	0.03	33.72	0.24	27.4	0.03	30.43	0.02	28.4	0.01
	16-Feb-03	32.15	-0.08	31	-0.09	30.87	-0.13	29.6	-0.13	29.32	-0.11	33.45	-0.27	27.28	-0.12	30.35	-0.08	28.33	-0.07
	20-Feb-03	31.93	-0.22	30.79	-0.21	30.56	-0.31	29.33	-0.27	29.04	-0.28	32.47	-0.98			30.11	-0.24	28.19	-0.14
	22-Feb-03	31.77	-0.16			30.39	-0.17	29.15	-0.18	28.9	-0.14	32.08	-0.39	26.85		29.99	-0.12	28.1	-0.09
	24-Feb-03	31.6	-0.17	30.45		30.18	-0.21	29	-0.15	28.73	-0.17	31.68	-0.4	26.72	-0.13	29.87	-0.12	28.02	-0.08
	26-Feb-03	31.43	-0.17	30.25	-0.2	30.05	-0.13	28.83	-0.17	28.59	-0.14	31.38	-0.3	26.5	-0.22	29.73	-0.14	27.97	-0.05
	28-Feb-03	31.3	-0.13	30.17	-0.08	30.25	0.2	28.7	-0.13	28.48	-0.11	31.05	-0.33			29.7	-0.03	28	0.03
	3-Mar-03	31.27	-0.03	30.18	0.01	30.08	-0.17	28.95	0.25	28.68	0.2	32.27	1.22			29.91	0.21	28.14	0.14
	5-Mar-03	31.28	0.01	30.16	-0.02	30.07	-0.01	29	0.05	28.73	0.05	32.65	0.38	26.94		29.94	0.03	28.18	0.04
	10-Mar-03	31.6	0.32	30.5	0.34	30.65	0.58	29.45	0.45	29.19	0.46	34.09	1.44	27.4	0.46	30.35	0.41	28.63	0.45
	12-Mar-03	32.22	0.62	31.05	0.55			30.3	0.85	30.04	0.85	35.95	1.86	28.21	0.81	31.04	0.69	29	0.37
	19-Mar-03	32.65	0.43	31.44	0.39	31.3		29.99	-0.31	29.7	-0.34	33.7	-2.25	27.56	-0.65	30.66	-0.38	28.53	-0.47
	25-Mar-03	32.25	-0.4	31.01	-0.43	30.73	-0.57	28.48	-1.51	29.18	-0.52	32.01	-1.69	27.06	-0.5	30.21	-0.45	28.22	-0.31
	2-Apr-03	31.4	-0.85	30.23	-0.78	29.87	-0.86	28.75	0.27	28.48	-0.7	30.71	-1.3	26.5	-0.56	29.68	-0.53	27.9	-0.32
	9-Apr-03	30.65	-0.75	29.5	-0.73	29.09	-0.78	28.15	-0.6	27.91	-0.57	29.8	-0.91	26.1	-0.4	29.28	-0.4	27.7	-0.2
	16-Apr-03	30.05	-0.6	28.88	-0.62	28.5	-0.59	27.73	-0.42	27.51	-0.4	29.32	-0.48	25.82	-0.28	29.03	-0.25	27.6	-0.1
	25-Apr-03	29.75	-0.3	28.37	-0.51	28.44	-0.06	27.33	-0.4	27.15	-0.36	28.7	-0.62	25.74	-0.08	28.8	-0.23	27.53	-0.07
	30-Apr-04	29.35	-0.4	28.22	-0.15	27.85	-0.59	27.41	0.08	27.16	0.01	29.22	0.52	25.66	-0.08	28.76	-0.04	27.5	-0.03
	6-May-03	30.25	0.9	29.17	0.95	29.43	1.58	29.05	1.64	28.66	1.5	34.75	5.53	27.29	1.63	30.11	1.35	28.4	0.9
	16-May-03	30.65	0.4	29.48	0.31	29.22	-0.21	28.36	-0.69	28.14	-0.52	31.47	-3.28	26.4	-0.89	29.52	-0.59	27.95	-0.45
	22-May-03	30.3	-0.35	29.12	-0.36	28.8	-0.42	28.03	-0.33	28.78	0.64	30.25	-1.22	26.09	-0.31	29.26	-0.26	27.8	-0.15
	5-Jun-03	29.35	-0.95	28.2	-0.92	27.8	-1	27.3	-0.73	27.1	-1.68	28.85	-1.4	25.58	-0.51	28.77	-0.49	27.52	-0.28
	19-Jun-03	29.65	0.3	28.5	0.3	28.23	0.43	27.75	0.45	27.5	0.4	30.7	1.85	25.95	0.37	29.08	0.31	27.74	0.22
	1-Jul-03	29.05	-0.6	27.98	-0.52	27.62	-0.61	27.38	-0.37	27	-0.5	29.05	-1.65	25.6	-0.35	28.89	-0.19	27.56	-0.18
	13-Aug-03	27.43	-1.62	26.36	-1.62	25.86	-1.76	26.07	-1.31	25.77	-1.23	26.65	-2.4	24.58	-1.02	27.79	-1.1	26.97	-0.59
	2-Sep-03	26.8	-0.63	25.83	-0.53	25.28	-0.58	25.62	-0.45	25.35	-0.42	25.04	-1.61	24.27	-0.31	27.49	-0.3	26.75	-0.22

REALLY BAD STORMS on weekend previous to the 5/2/02 then fairly dry in the two weeks up to 18/2/02

Appendix K

Curtin's Farm Groundwater Datalogger Records

Three OTT 'Orphimedes' dataloggers were installed. Piezometers BHC.2, BHC.7 and BHC.9 were the piezometers selected for instrumentation. Selected datalogger records are presented in this appendix. The full dataset is too lengthy, but is available.

BHC.2 datalogger record

BHC.2	Interval	Date	WL (daily average)	BHC.2	Interval	Date	WL (daily average)	BHC.2	Interval	Date	WL (daily average)	BHC.2	Interval	Date	WL (daily average)	BHC.2	Interval	Date	WL (daily average)
	Q	17/04/2002	24.84		Q	01/08/2002	26.88		Q	01/12/2002	19.70		Q	05/03/2003	23.72		H	22/06/2003	25.54
	Q	18/04/2002	24.90		Q	02/08/2002	26.91		Q	02/12/2002	19.73		Q	05/03/2003	23.73		H	23/06/2003	25.60
	Q	19/04/2002	24.99		Q	03/08/2002	26.94		Q	03/12/2002	19.78		Q	06/03/2003	23.73		H	24/06/2003	25.66
	Q	20/04/2002	25.07		Q	04/08/2002	26.98		Q	04/12/2002	19.72		Q	07/03/2003	23.68		H	25/06/2003	25.71
	Q	21/04/2002	25.12		Q	05/08/2002	27.00		Q	05/12/2002	19.41		Q	08/03/2003	23.62		H	26/06/2003	25.76
	Q	22/04/2002	25.19		Q	06/08/2002	27.04		Q	05/12/2002	18.57		Q	09/03/2003	23.53		H	27/06/2003	25.82
	Q	23/04/2002	25.25		Q	07/08/2002	27.08		Q	06/12/2002	19.04		Q	10/03/2003	23.44		H	28/06/2003	25.87
	Q	23/04/2002	25.43		Q	08/08/2002	27.10		Q	07/12/2002	19.18		Q	10/03/2003	23.44		H	29/06/2003	25.91
	Q	23/04/2002	25.28		Q	09/08/2002	27.11		Q	08/12/2002	19.27		Q	10/03/2003	23.33		H	30/06/2003	25.87
	Q	23/04/2002	25.30		Q	10/08/2002	27.14		Q	09/12/2002	19.31		Q	11/03/2003	23.13		H	01/07/2003	25.91
	Q	24/04/2002	25.34		Q	11/08/2002	27.18		Q	10/12/2002	19.33		Q	12/03/2003	22.93		H	01/07/2003	25.91
	Q	25/04/2002	25.41		Q	12/08/2002	27.22		Q	10/12/2002	20.31		Q	13/03/2003	22.84		H	01/07/2003	25.91
	Q	26/04/2002	25.47		Q	13/08/2002	27.25		Q	11/12/2002	20.37		Q	12/03/2003	22.81		H	02/07/2003	25.91
	Q	27/04/2002	25.52		Q	14/08/2002	27.28		Q	12/12/2002	20.37		Q	13/03/2003	22.69		H	03/07/2003	25.91
	Q	28/04/2002	25.56		Q	15/08/2002	27.30		Q	13/12/2002	20.39		Q	14/03/2003	22.55		H	04/07/2003	25.91
	Q	29/04/2002	25.60		Q	15/08/2002	27.30		Q	14/12/2002	20.37		Q	15/03/2003	22.48		H	05/07/2003	25.91
	Q	30/04/2002	25.60		Q	15/08/2002	27.34		Q	15/12/2002	20.44		Q	16/03/2003	22.44		H	06/07/2003	25.91
	Q	01/05/2002	25.64		Q	16/08/2002	27.36		Q	16/12/2002	20.47		Q	17/03/2003	22.43		H	07/07/2003	25.91
	Q	02/05/2002	25.68		Q	17/08/2002	27.39		Q	17/12/2002	20.42		Q	18/03/2003	22.44		H	08/07/2003	25.91
	Q	03/05/2002	25.70		Q	18/08/2002	27.42		Q	18/12/2002	20.30		Q	19/03/2003	22.48		H	09/07/2003	25.91
	Q	04/05/2002	25.72		Q	19/08/2002	27.46		Q	19/12/2002	20.31		Q	20/03/2003	22.51		H	10/07/2003	25.91
	Q	05/05/2002	25.74		Q	20/08/2002	27.49		Q	20/12/2002	20.36		Q	21/03/2003	22.56		H	11/07/2003	25.91
	Q	06/05/2002	25.76		Q	21/08/2002	27.52		Q	21/12/2002	20.40		Q	22/03/2003	22.62		H	12/07/2003	25.91
	Q	07/05/2002	25.77		Q	22/08/2002	27.56		Q	22/12/2002	20.50		Q	23/03/2003	22.70		H	13/07/2003	25.91
	Q	08/05/2002	25.78		Q	23/08/2002	27.59		Q	23/12/2002	20.51		Q	24/03/2003	22.78		H	14/07/2003	25.91
	Q	09/05/2002	25.80		Q	24/08/2002	27.62		Q	24/12/2002	20.57		Q	25/03/2003	22.87		H	15/07/2003	25.91
	Q	10/05/2002	25.82		Q	25/08/2002	27.65		Q	25/12/2002	20.52		Q	26/03/2003	22.96		H	16/07/2003	25.91
	Q	11/05/2002	25.85		Q	26/08/2002	27.68		Q	26/12/2002	20.54		Q	27/03/2003	23.05		H	17/07/2003	25.91
	Q	12/05/2002	25.88		Q	27/08/2002	27.71		Q	27/12/2002	20.64		Q	28/03/2003	23.14		H	18/07/2003	25.91
	Q	13/05/2002	25.84		Q	28/08/2002	27.74		Q	28/12/2002	20.60		Q	29/03/2003	23.25		H	19/07/2003	25.91
	Q	14/05/2002	25.88		Q	29/08/2002	27.77		Q	29/12/2002	20.53		Q	30/03/2003	23.36		H	20/07/2003	25.91
	Q	15/05/2002	25.93		Q	30/08/2002	27.79		Q	30/12/2002	20.54		Q	31/03/2003	23.47		H	21/07/2003	25.91
	Q	16/05/2002	25.96		Q	31/08/2002	27.83		Q	31/12/2002	20.49		Q	01/04/2003	23.56		H	22/07/2003	25.91
	Q	17/05/2002	25.97		Q	01/09/2002	27.86		Q	01/01/2003	20.48		Q	02/04/2003	23.64		H	23/07/2003	25.91
	Q	18/05/2002	26.01		Q	02/09/2002	27.88		Q	02/01/2003	20.64		Q	02/04/2003	23.64		H	24/07/2003	25.91
	Q	19/05/2002	26.05		Q	03/09/2002	27.90		Q	03/01/2003	20.59		H	02/04/2003	23.70		H	25/07/2003	25.91
	Q	20/05/2002	26.01		Q	04/09/2002	27.93		Q	04/01/2003	20.48		H	03/04/2003	23.78		H	26/07/2003	25.91
	Q	21/05/2002	25.98		Q	05/09/2002	27.96		Q	05/01/2003	20.42		H	04/04/2003	23.89		H	26/07/2003	25.91
	Q	22/05/2002	25.90		Q	06/09/2002	27.98		Q	06/01/2003	20.39		H	05/04/2003	23.99		H	26/07/2003	26.97
	Q	23/05/2002	25.86		Q	07/09/2002	28.01		Q	07/01/2003	20.40		H	06/04/2003	24.09		H	27/07/2003	26.97
	Q	23/05/2002	25.87		Q	08/09/2002	28.03		Q	08/01/2003	20.44		H	07/04/2003	24.19		H	28/07/2003	26.97
	Q	24/05/2002	25.79		Q	09/09/2002	28.06		Q	09/01/2003	20.39		H	08/04/2003	24.29		H	29/07/2003	26.97
	Q	25/05/2002	25.71		Q	10/09/2002	28.08		Q	10/01/2003	20.26		H	09/04/2003	24.37		H	30/07/2003	26.97
	Q	26/05/2002	25.61		Q	11/09/2002	28.10		Q	11/01/2003	20.22		H	09/04/2003	24.45		H	31/07/2003	26.97
	Q	27/05/2002	25.47		Q	12/09/2002	28.12		Q	12/01/2003	20.22		H	10/04/2003	24.51		H	01/08/2003	26.97
	Q	28/05/2002	25.27		Q	13/09/2002	28.15		Q	13/01/2003	20.25		H	11/04/2003	24.61		H	02/08/2003	26.97
	Q	29/05/2002	25.04		Q	14/09/2002	28.17		Q	14/01/2003	20.24		H	12/04/2003	24.71		H	03/08/2003	26.97
	Q	30/05/2002	24.81		Q	15/09/2002	28.19		Q	15/01/2003	20.36		H	13/04/2003	24.79		H	04/08/2003	26.97
	Q	31/05/2002	24.65		Q	16/09/2002	28.21		Q	16/01/2003	20.36		H	14/04/2003	24.80		H	05/08/2003	26.97
	Q	01/06/2002	24.52		Q	17/09/2002	28.22		Q	17/01/2003	20.23		H	15/04/2003	24.90		H	06/08/2003	26.97
	Q	02/06/2002	24.42		Q	18/09/2002	28.24		Q	18/01/2003	20.68		H	16/04/2003	24.99		H	07/08/2003	26.97
	Q	03/06/2002	24.34		Q	19/09/2002	28.26		Q	19/01/2003	20.71		H	16/04/2003	25.00		H	08/08/2003	26.97
	Q	04/06/2002	24.30		Q	19/09/2002	28.29		Q	20/01/2003	20.72		H	17/04/2003	25.09		H	09/08/2003	26.97
	Q	05/06/2002	24.26		Q	20/09/2002	28.30		Q	21/01/2003	20.80		H	18/04/2003	25.17		H	10/08/2003	26.97
	Q	04/06/2002	24.25		Q	21/09/2002	28.32		Q	22/01/2003	20.77		H	19/04/2003	25.25		H	11/08/2003	26.97
	Q	05/06/2002	24.25		Q	22/09/2002	28.34		Q	23/01/2003	20.38		H	20/04/2003	25.32		H	12/08/2003	26.97
	Q	06/06/2002	24.25		Q	23/09/2002	28.35		Q	23/01/2003	20.40		H	21/04/2003	25.39		H	13/08/2003	26.97
	Q	07/06/2002	24.26		Q	24/09/2002	28.37		Q	24/01/2003	24.04		H	22/04/2003	25.48		H	13/08/2003	27.25
	Q	08/06/2002	24.28		Q	25/09/2002	28.39		Q	25/01/2003	24.01		H	23/04/2003	25.55		H	14/08/2003	27.55
	Q	09/06/2002	24.26		Q	26/09/2002	28.41		Q	26/01/2003	23.97		H	24/04/2003	25.60		H	15/08/2003	27.59
	Q	10/06/2002	24.30		Q	27/09/2002	28.43		Q	27/01/2003	23.97		H	25/04/2003	25.58		H	16/08/2003	27.62
	Q	11/06/2002	24.35		Q	28/09/2002	28.45		Q	28/01/2003	23.91		H	25/04/2003	25.58		H	17/08/2003	27.64
	Q	12/06/2002	24.40		Q	29/09/2002	28.47		Q	29/01/2003	23.95		H	25/04/2003	25.53		H	18/08/2003	27.67
	Q	13/06/2002	24.46		Q	30/09/2002	28.48		Q	30/01/2003	25.56		H	26/04/2003	25.56		H	19/08/2003	27.70
	Q	14/06/2002	24.50		Q	01/10/2002	28.49		Q	31/01/2003	23.80		H	27/04/2003	25.61		H	20/08/2003	27.73
	Q	15/06/2002	24.55		Q	02/10/2002	28.50		Q	31/01/2003	21.54		H	28/04/2003	25.62		H	21/08/2003	27.75
	Q	16/06/2002	24.59		Q	03/10/2002	28.51		Q	01/02/2003	21.47		H	29/04/2003	25.66		H	22/08/2003	27.78
	Q	17/06/2002	24.58		Q	04/10/2002	28.52		Q	02/02/2003	21.50		H	29/04/2003	26.36		H	23/08/2003	27.81
	Q	18/06/2002	24.64		Q	05/10/2002	28.54		Q	02/02/2003	22.04		H	30/04/2003	26.31		H	24/08/2003	27.83
	Q	19/06/2002	24.68		Q	06/10/2002	28.55		Q	03/02/2003	22.80		H	01/05/2003	26.29		H	25/08/2003	27.86
	Q	19/06/2002	24.68		Q	07/10/2002	28.56		Q	03/02/2003	22.81		H	01/05/2003	25.37		H	26/08/2003	27.88
	Q	19/06/2002	24.71		Q	08/10/2002	28.56		Q	03/02/2003	22.89		H	02/05/2003	24.71		H	27/08/2003	27.91
	Q	20/06/2002	24.72		Q	09/10/2002	28.56		Q	04/02/2003	23.05		H	03/05/2003	24.77		H	28/08/2003	27.93
	Q	21/06/2002	24.75		Q	10/10/2002	28.57		Q	04/02/2003	22.70		H	04/05/2003	24.66		H	29/08/2003	27.96
	Q	22/06/2002	24.78		Q	11/10/2002	28.57		Q	05/02/2003	22.43		H	05/05/2003	24.20		H	30/08/2003	27.98
	Q	23/06/2002	24.83		Q	12/10/2002	28.58		Q	06/02/2003	22.42		H	06/05/2003	23.84		H	31/08/2003	28.01
	Q	24/06/2002	24.88		Q	13/10/2002	28.59		Q	07/02/2003	22.48		H	16/05/2003	24.41		H	01/09/2003	28.03
	Q	25/06/2002	24.93		Q	14/10/2002	28.60		Q	08/02/2003	22.48		H	17/05/2003	24.45		H	02/09/2003	28.05
	Q	26/06/2002	24.97		Q	15/10/2002	28.61		Q	08/02/2003	21.55		H	18/05/2003	24.50				
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	Q	28/06/2002	25.08		Q	17/10/2002	28.64		Q	10/02/2003	21.50		H	20/05/2003	24.63				
	Q	29/06/2002	25.13		Q	18/10/2002	28.65		Q	10/02/2003	21.50		H	21/05/2003	24.70				
	Q	30/06/2002	25.17		Q	19/10/2002	28.67		Q	10/02/2003	23.77		H	22/05/2003	24.75				
	Q	01/07/2002	25.21		Q	20/10/2002	28.64		Q	11/02/2003	24.08		H	22/05/2003	24.75				
	Q	02/07/2002	25.26		Q	21/10/2002	28.49		Q	12/02/2003	24.23		H	22/05/2003	24.80				
	Q	03/07/2002	25.32		Q	22/10/2002	28.41		Q	13/02/2003	25.45		H	23/05/2003	24.85				
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	Q	04/07/2002	25.43		Q	24/10/2002	28.39		Q	15/02/2003	25.53		H	26/05/2003	25.07				
	Q	05/07/2002	25.46		Q	25/10/2002	28.30		Q	14/02/2003	22.77		H	27/05/2003	25.14				
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	Q	07/07/2002	25.59		Q	27/10/2002	28.05		Q	16/02/2003	22.77		H	29/05/2003	25.26				
	Q	08/07/2002	25.63		Q	28/10/2002	27.90		Q	16/02/2003	22.77		H	30/05/2003	25.33				
	Q	09/07/2002	25.68		Q	29/10/2002	27.64		Q	16/02/2003	22.82		H	31/05/2003	25.40				
	Q	10/07/2002	25.75		Q	30/10/2002	27.29		Q	17/02/2003	22.85		H	01/06/2003	25.45				
	Q	11/07/2002	25.81		Q	31/10/2002	27.05		Q	18/02/2003	22.90		H	02/06/2003	25.52				
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	Q	13/07/2002	25.94		Q	02/11/2002	26.77		Q	20/02/2003	23.06		H	04/06/2003	25.62				
	Q	14/07/2002	26.00		Q	03/11/2002	26.60		Q	20/02/2003	23.07		H	05/06/2003	25.68				
	Q	15/07/2002	26.05		Q	04/11/2002	26.39		Q	21/02/2003	23.14		H	05/06/2003	25.67				
	Q	16/07/2002	26.10		Q	05/11/2002	26.19		Q	22/02/2003	23.19		H	06/06/2003	25.56				
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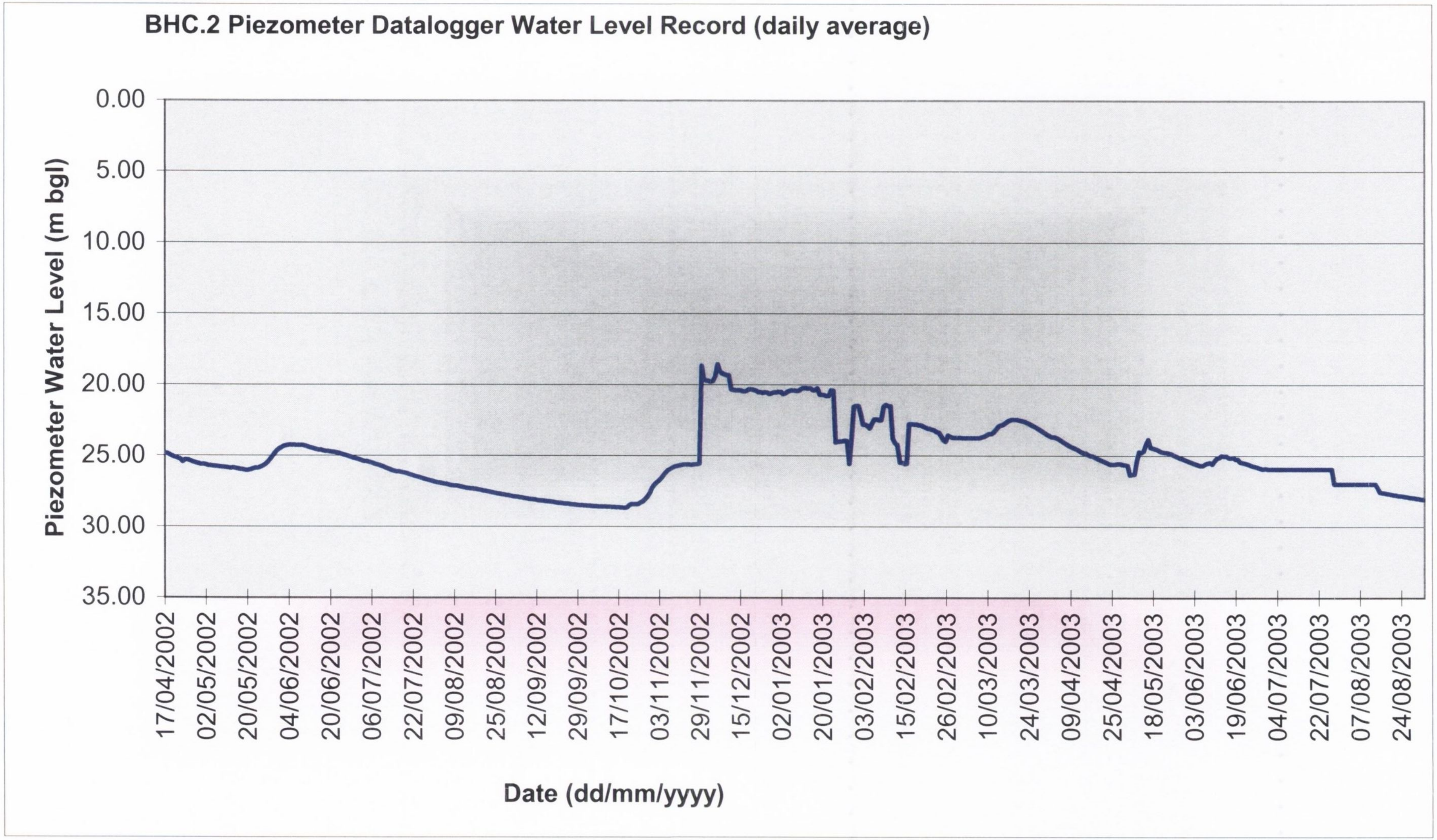
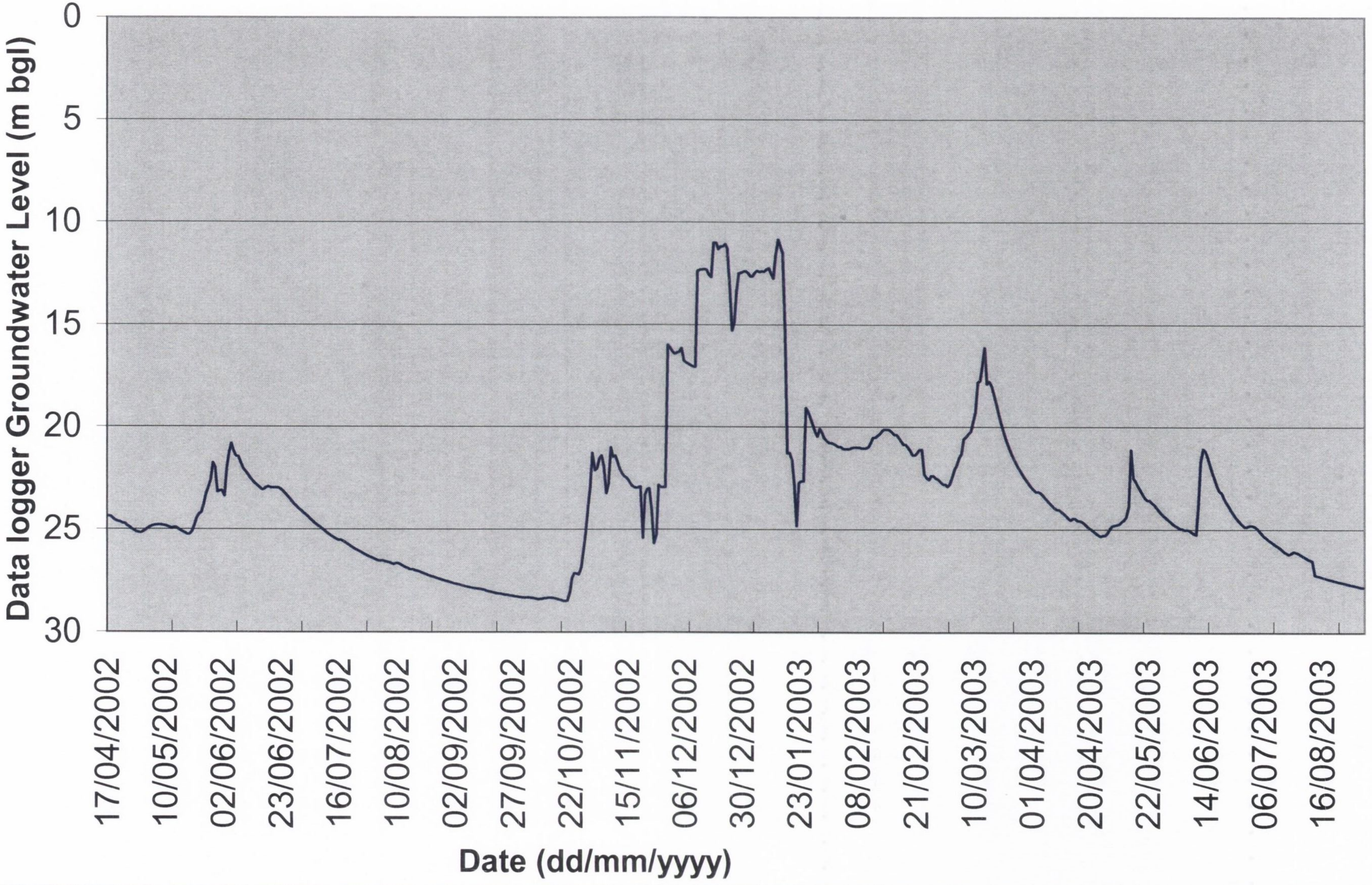
	Q	16/07/2002	26.13		Q	07/11/2002	25.93		Q	24/02/2003	23.35		H	08/06/2003	25.46				
	Q	17/07/2002	26.16		Q	08/11/2002	25.84		Q	24/02/2003	23.59		H	09/06/2003	25.58				
	Q	18/07/2002	26.21		Q	09/11/2002	25.78		Q	25/02/2003	23.87		H	10/06/2003	25.32				
	Q	19/07/2002	26.26		Q	10/11/2002	25.73		Q	26/02/2003	23.99		H	11/06/2003	25.15				
	Q	20/07/2002	26.32		Q	11/11/2002	25.71		Q	26/02/2003	23.54		H	12/06/2003	25.10				
	Q	21/07/2002	26.37		Q	12/11/2002	25.67		Q	27/02/2003	23.63		H	13/06/2003	24.99				
	Q	22/07/2002	26.42		Q	13/11/2002	25.64		Q	28/02/2003	23.71		H	14/06/2003	25.02				
	Q	23/07/2002	26.47		Q	14/11/2002	25.61		Q	28/02/2003	23.71		H	15/06/2003	24.99				
	Q	24/07/2002	26.52		Q	15/11/2002	25.61		Q	28/02/2003	23.70		H	16/06/2003	25.10				
	Q	25/07/2002	26.57		Q	16/11/2002	25.62		Q	01/03/2003	23.70		H	17/06/2003	25.15				
	Q	26/07/2002	26.62		Q	17/11/2002	25.63		Q	02/03/2003	23.72		H	18/06/2003	25.10				
	Q	27/07/2002	26.67		Q	18/11/2002	25.62		Q	03/03/2003	23.72		H	19/06/2003	25.22				
	Q	28/07/2002	26.71		Q	19/11/2002	25.59		Q	03/03/2003	23.72		H	19/06/2003	25.22				
	Q	29/07/2002	26.76		Q	20/11/2002	25.55		Q	03/03/2003	23.73		H	19/06/2003	25.42				
	Q	30/07/2002	26.80		Q	29/11/2002	18.66		Q	04/03/2003	23.72		H	20/06/2003	25.46				
	Q	31/07/2002	26.84		Q	30/11/2002	19.66		Q	05/03/2003	23.72		H	21/06/2003	25.50				



BHC.2 Piezometer Datalogger Water Level Record (daily average)

BHC.7: Daily average Datalogger Readings



Appendix L

Johnstown Castle Water Analysis Laboratory Methods for Nutrient Analysis

The following pages relate the details for nutrient analysis on the KONELAB autoanalyser, which was used to analyse groundwater samples from Curtin's farm. Further details regarding methods of analysis for other parameters investigated are available from the laboratory at the Teagasc, Johnstown Castle, Environmental Research centre.

Labmedics
THE WAY FORWARD

Nitrate -N

Application Notes

For the measurement of Nitrate in potable, surface, saline and waste waters

Principle

Nitrate is reduced to Nitrite with hydrazine sulfate. Nitrite ions so produced and those originally present are determined by diazotisation with sulphanilamide and coupling with N-(1-naphthyl)-ethylenediamine dihydrochloride. The colored azo-dye is measured at 540 nm.

This reaction measures Total Oxidised Nitrogen. Nitrate is determined by subtracting Nitrite from T.O.N

Stock Solutions

Stock Nitrate Standard –1000 mg/L

Dissolve 7.215 g of dried Potassium Nitrate [KNO_3] in 1000mL of distilled water

Copper Sulfate Solution

Dissolve 2.28 g $CuSO_4.5H20$ in 1000mL of distilled water.

Working Solutions

Reagent 1

Dissolve 0.8 g Sodium Hydroxide [NaOH] in 100 mL of distilled water. Prepare daily

Reagent 2 (Reductant)

Dissolve 0.219 g of Hydrazine sulfate $N_2H_4.H_2SO_4$ in 400 ml of distilled water. Add 5 mL of stock copper sulfate solution and make up to 500 ml with distilled water. Prepare freshly as required.

Reagent 3 (Color reagent as in Nitrite)

Carefully add ~~200~~ 50ml of conc. Phosphoric acid[HP_3O_4] to 500 ml of distilled water. Add ~~10~~ 5 g of sulphanilamide and dissolve completely before adding .25 ~~0.8~~ g N-(1-naphthyl)-ethylenediamine dihydrochloride. Dilute to 1000ml with distilled water , store in an amber bottle in a refrigerator.

Standard solutions

Prepare standard solutions in the required analytical range.
e.g. 0, 2, 4, 6, 8, 10 mg/l

Konelab

Ammonia-N

Application Notes

For the measurement of Ammonia in potable, surface, saline and waste waters

Principle

Ammonia reacts with **Salicylate and Dichloroisocyanurate in the presence of sodium nitroprusside to form a blue color that is proportional to the amount of Ammonia present. The color produced is measured at 660nm**

Working Solutions

Sodium Salicylate solution (Rgt 1)

Dissolve 65 g. of Sodium Salicylate [$C_7H_5O_3Na$] and 65 g. tri-Sodium Citrate [$C_6H_5Na_3O_7.2H_2O$] in 400 mL ammonia free water, adjust to pH less than 8.0 if necessary with 0.4% Nitric Acid. Add 0.49 g. of Sodium Nitroprusside [$Na_2[Fe(CN)_5NO].2H_2O$], dissolve and make up to 500 mL with ammonia free water.

D.I.C. solution (Rgt 2)

Dissove 16 g. Sodium Hydroxide [$NaOH$] in 250 ml of ammonia free water. Cool and add 1.0 g. of Sodium Dichloroisocyanurate [$Cl_2Na(NCO)_3.2H_2O$], dissolve and make up to 500 mL with ammonia free deionised water

Standard Ammonia solutions –1000mg/L as N

Dissolve 3.819 g of dried Ammonium chloride [NH_4Cl] in 1000ml of ammonia free water

Prepare standard solutions in the required analytical range.
e.g. 0, 0.2, 0.4, 0.6, 0.8, 1.0 mg/l

Konelab

Labmedics
THE WAY FORWARD

Nitrite - N

Application Notes

For the measurement of Nitrite in potable, surface and waste waters

Principle

Nitrite ions, when reacted with a reagent containing sulphanilamide and N-(1-naphthyl)-ethylenediamine dihydrochloride produce a highly colored azo dye that is measured photometrically at 540 nm

Stock Solutions

Stock Nitrite standard – 200 mg/L as N
Dissolve 0.986 g of dried sodium nitrite [$NaNO_2$] in 1000 ml of distilled water.

Working Solutions

Color Reagent
Carefully add 200ml of conc. Phosphoric acid[HP_3O_4] to 500 ml of distilled water. Add 10 g of sulphanilamide and dissolve completely before adding 0.8 g N-(1-naphthyl)-ethylenediamine dihydrochloride. Dilute to 1000ml with distilled water , store in an amber bottle in a refrigerator.

Standard solutions
Prepare standard solutions in the required analytical range.
e.g. 0, 0.02, 0.04, 0.08, 0.16, 0.02 mg/l

Labmedics

o-Phosphate

Application Notes

For the measurement of orthophosphate in potable, surface, saline and waste waters

Principle

Orthophosphate reacts with ammonium molybdate and antimony potassium tartrate under acidic conditions to form a complex which, when reduced with ascorbic acid, produces an intense blue color which is measured photometrically at 880 nm. (or at 660 nm.). The absorbance is proportionate to the amount of orthophosphate in the sample

Stock Solutions

Antimony potassium tartrate solution
Dissolve 0.3 g $K(SbO)C_4H_4O_6.{}^1/_2H_2O$ in 50 mL distilled water and dilute to 100mL . Store in a dark bottle and refrigerate.
Ammonium molybdate
Dissolve 4.0 g $(NH_4)_6Mo_7O_{24}.4H_2O$ in 100ml of distilled water. Store in a plastic container.
Dilute Sulphuric acid
Very slowly add 140 ml of conc H_2SO_4 to 1000 ml of distilled water. Cool
Ascorbic Acid solution
Dissolve 1.76 g ascorbic acid in 100 mL distilled water. This solution is stable for 5 days when refrigerated.
Standard Phosphate solution – 1000 mg/L as P
Dissolve 4.3936 g anhydrous K_2PO_4 in 1000mL of distilled water

Working Solutions

Reagent 1
Add 75 ml of stock Ammonium Molybdate to 250 ml of dilute Sulphuric acid. Add 25ml of stock Antimony Potassium Tartrate to this mixture.
Reagent 2
Stock Ascorbic acid solution.

Mix 28 ml of Reagent 1 with 12 ml of Reagent 2. – Prepare daily

Standard solutions
Prepare standard solutions in the required analytical range.
e g. 0, 0.02, 0.04, 0.08, 0.12, 0.16, 0:02 mg/l

Konelab

Appendix M

Interim Guideline Values (IGV) for Groundwater Characterisation

The following page is taken from the EPA 'Towards Setting Guidelines Values for the Protection of Groundwater in Ireland' (2003a) document.

Table 3.1: Interim Guideline Values for Characterisation List of Parameters

PARAMETER	*List I or List II*	*Drinking Water Standards (units)*	*GSI Trigger Values*	*EQSs for Surface Waters*	***Interim Guideline Value***	*Source of Interim GVs*
CORE PARAMETERS or NATURAL SUBSTANCES						
Physicochemical-Microbiological						
Coliforms (faecal)		0 counts per 100ml	0 counts per 100ml		**0 counts per 100ml**	B, I
Coliforms (total))		0 counts per 100ml	0 counts per 100ml		**0 counts per 100ml**	B, I
Electrical Conductivity		1500 µS/cm		1000µS/cm	**1000µS/cm**	K
Temperature		25^{0}C			**25^{0}C**	B
TOC		*No abnormal change*			***No abnormal change***	-
Colour					*No abnormal change*	A
pH (pH units)		≥ 6.5 and ≤ 9.5			**≥ 6.5 and ≤ 9.5**	A
Inorganic						
Alkalinity					***No abnormal change***	-
Ammonia (as ammonium)	*II*	0.30 mg/l	0.15 mg/l	0.02 NH3	**0.15 mg/l**	I
Bicarbonate		*No abnormal change*			***No abnormal change***	-
Calcium		200 mg/l			**200 mg/l**	B
Carbonate		*No abnormal change*			***No abnormal change***	-
Chloride		250 mg/l	30 mg/l	250 mg/l	**30 mg/l**	I
Dissolved Oxygen		*No abnormal change*			***No abnormal change***	-
Hardness (as $CaCO_3$)		200 mg/l			**200 mg/l**	G
Iron		0.2 mg/l		1.0 mg/l	**0.2 mg/l**	A
Magnesium		50 mg/l			**50 mg/l**	B
Manganese		0.05 mg/l		0.3 mg/l	**0.05 mg/l**	A
Nitrate (as NO_3)		50 mg/l	25 mg/l	50 mg/l	**25 mg/l**	I
Nitrite (as NO_2)	*II*	0.1 mg/l		0.2 mg/l	**0.1 mg/l**	A
Orthophosphate		0.03 mg/l			**0.03 mg/l**	F
Potassium		12 mg/l	5 mg/l		**5 mg/l**	I
Sodium		150 mg/l			**150 mg/l**	B
Sulphate mg/l		250 mg/l		200 mg/l	**200 mg/l**	K
Metals						
Aluminium		0.2 mg/l		0.2 mg/l	**0.2 mg/l**	A, K
Arsenic and its compounds	*II*	0.01 mg/l		0.025mg/l $^{\#}$	**0.01 mg/l**	A
Boron	*II*	1.0 mg/l		2.0 mg/l	**1.0 mg/l**	A
Cadmium and its compounds	**I**	0.005 mg/l		0.005 mg/l	**0.005 mg/l**	A, K
Chromium and its compounds	*II*	0.05 mg/l		0.03 mg/l $^{\#}$	**0.03 mg/l** $^{\#}$	J
Copper and its compounds	*II*	2.0 mg/l		0.03 mg/l $^{\#}$	**0.03 mg/l** $^{\#}$	J
Mercury and its compounds	***I***	0.001 mg/l		0.001 mg/l	**0.001 mg/l**	A, K
Nickel and its compounds	*II*	0.02 mg/l		0.05 mg/l $^{\#}$	**0.02 mg/l**	A
Zinc and its compounds	*II*	5.0 mg/l		0.1 mg/l $^{\#}$	**0.1 mg/l** $^{\#}$	J
Organics						
TON mg/l		*No abnormal change*			***No abnormal change***	-
Total Hydrocarbons to include mineral oil by GC** mg/l	*I*	0.01 mg/l		0.01 mg/l	**0.01 mg/l**	B, K

** TPH by Gas Chromatography: This analysis can serve as a 'catch-all' and will present results for the general term 'Gasoline Range Organics' and the separate 'BTEX' parameters including MTBE. 'Diesel Range Organics' (DRO) should also be specified in order to determine mineral oil concentration.

Appendix N

Ceramic Cup Details

Supplied by M. Ryan, Teagasc, Johnstown Castle

Protocol for " Effects of Agricultural Practices on nitrate Leaching" 2000-LS-2.3-M2
FARM SCALE

Plots to be fertilised with 350 kg N per hectare and designated to be grazed by 2.47 cows per hectare which will be fed 500 kg concentrate per head will be located at Curtin's farm. From these, three plots will be selected for insertion of 8 ceramic cups per plot at I m deep. The Giddings soil coring machine will be employed to assist in placing the cups at the appropriate depth.

In selected plots (3) of other treatments a similar procedure will be followed. The other treatments will be; Plots that will receive fertiliser N plus slurry and will be cut for silage once in May-June followed by grazing until the end of the grazing season.

Plots that will receive fertiliser N plus slurry and will be cut twice (May-June and July-August) for silage followed by grazing until the end of the grazing season.

Plots that will receive fertiliser N plus dirty water from the dairy and will be grazed by cows all year round.

Once the ceramic cups are installed in a zig-zag pattern in the plots, the connecting tubing will be led underground to the electric fence area of each plot where the collecting flasks will be located, overground. Electrified wires will protect the flasks from interference by cows. Suction, 50 k Pa, will be applied to the ceramic cups in test trials, once installed, provided there is free soil moisture to collect.
The first experimental leaching results are expected from recharge in autumn 2001.

Soil water samples collected will be analysed for nitrate and ammonium concentrations on a KONELAB auto-analyser. The start and finish dates of soil water sampling and the load removed per hectare will be determined using the soil hydrology information and flux measurements carried out by J. Mulqueen in the Soil Investigation work package. Advice on the soil water sampling methodology has been sought from D.Scholefield, IGER, N.Wyke, UK.

The sealed ceramic cups with tubing have been assembled at Johnstown Castle. Cups are round-bottomed, straight necked, 80 mm long with 22 mm outer diameter and 14 mm inner diameter.
To make the tube connections to the glass ware and to seal these connections, a bung 14 mm outer diameter, 8 mm inner diameter is introduced into the cup via tubing having 8mm outer diameter, 5 mm inner diameter which carries the final tubing of 4mm diameter inserted into it. Finally the assembled cup is sealed with glue.

Soil water will be extracted from the soil using hand pumps to supply a vacuum of 50 k Pa. The hand-pumps are supplied by Soil Moisture Corporation, USA.

The amount of N fertiliser spread throughout the year will be monitored for each experimental plot, using information supplied by the herd manager. The N input, coming from slurry applied to the silage plots, will be assessed by sampling the slurry prior to spreading, analysing for nitrate, ammonium and total N concentrations and determining the rate of land-spreading of slurry.

Similarly for dirty water, 5 samples per week from the holding tanks combined with determination of the rate of spreading, using a timer on the pump and volume output gauge, will give an estimate of the rate of N added to the plots. Sampling of the sludge removed may be necessary together with an estimate of rate of spread. Samples will be acidified (.06 ml/30 ml) and stored/transported at 0-4d C.

The intake of N by cows will be determined, based on established DM intake rates and grass sampling for N content prior to grazing; export rates onto grass plots will be estimated by using retention equations for the particular yield group. Partitioning to urine and dung will be achieved using established values.

NCYCLE will use some of the data being generated together with historic data. Final requirements for this aspect awaits the meeting in September.

Appendix O

K Br to Br Equivalent Calculations

A surface applied bromide tracing experiment was successfully executed in the course of these investigations. This appendix contains calculations showing the areal application rate of bromide, bromide concentration in the irrigated water and the depth of irrigation. All analyses results from the subsoil and groundwater monitoring programme are contained in Appendix S.

Bromide mass in KBr$^-$ form.

	Ion	**Atomic weight**
	Br	79.904
	K	39.0983
Sum		119.0023g (1M KBr$^-$)

119.0023g = 100% of the weight

K: therefore 39.0983/119.0023 = 32.86% of the KBr$^-$ mass is potassium (K)

Br$^-$: and 79.904/119.0023 = 67.14% of the KBr$^-$ mass is bromide (Br$^-$)

So for the piezometer grid of 110m^2 (0.011ha):

12kg of KBr$^-$ was applied over 0.011ha = 1090.9 kg ha^{-1} KBr$^-$

= 1090.9 x 67.14% Br$^-$ = 732.4 kg ha^{-1} as Br$^-$

Concentration of Irrigation

1kg KBr$^-$ dissolved in 10 litres water = 10^6 mg/10 litres

= 10^5 mg/l

= 10,000 mg/l * 67% Br

= 67, 000 mg/l Br at ground level

For the irrigation depth calculation:

For the grid-area around BHC.7: 120litres = 0.12 m^3 /110 m^2 = 1.09mm depth

For each of the squares above the cups: 10litres = 0.01 m^3 /9 m^2 = 1.1mm depth

Appendix P

Meteorological Data – Curtin's Farm

Daily effective rainfall was determined using data from the Met Eireann weather station at Moorepark, the FAO evapotranspiration model (FAO, 1998) and soil moisture deficit accounting (Aslyng, 1965). The methodologies used and the results obtained were outlined in chapter five, section 5.5.1.

- This appendix contains a step by step guide to the FAO (1998) equations (Page 604).

- Calculated daily data meteorological balance data are presented for each year as follows:

Year	**Pages**
2000	605 - 610
2001	611 – 615
2002	617 – 622
2003	623 – 626 (partial record)

- In addition, summary meteorological data are presented (pages 627 – 629).

APPENDIX

Meteorological Modelling: Steps in calculation of Eto using FAO guide (1998)

CALCULATION IS SET UP IN EXCEL

Follow columns starting at 'Entry 1'

Altitude (z) =	34m AOD, weather station		note box 11 pg 67
Latitude =	52° 07' 60"	52	
Lat radians=	0.9098925	Therefore φ = 0.909893	

Entry 1	Step 12	Step 23	Step 34	Step 45
date	Δ/[Δ + γ(1 + 0.34∗u2)]	RHmean	N	Rn
		%	hrs	MJ/m2/day
Entry 2	Step 13	Step 24	Step 35	Step 46
T max	[Δ+γ(1+0.34*u2)]	J	Rs	Rn
°C		(day no.)	MJ/m2/day	mm/day
Entry 3	Step 14	Step 25	Step 36	Step 47
T min	[900/Tmean+273)]u2	dr	Rso	G day
°C		rad	MJ/m2/day	MJ/m2/day
Entry 4	Step 15	Step 26	Step 37	Step 48
T mean	e°(Tmax)	φ	Rs/Rso	0.408 *(Rn -G)
°C	kPa	rad		MJ/m2/day
Entry 5	Step 16	Step 27	Step 38	Solution
sunshine	e°(Tmin)	(2*π/365)*J	Rns	ET o
hours	kPa		MJ/m2/day	mm/day
Entry 6	Step 17	Step 28	Step 39	
uZ	es	[(2*π/365)*J-1.39]	σTmax,K4	
m/s	kPa		MJ/m2/day	
Step 7	Step 18	Step 29	Step 40	
u2	Tdew~Tmin	SIN[(2*π/365)*J-1.39]	σTmin,K4	
m/s	°C		MJ/m2/day	
Step 8	Step 19	Step 30	Step 41	
Δ	ea	δ	(σTmax,K4+σTmin,K4)/2	
kPa/°C	kPa	rad	MJ/m2/day	
Step 9	Step 20	Step 31	Step 42	
P	es-ea	ωs	(0.34-0.14sqrt(ea))	
kPa	kPa			
Step 10	Step 21	Step 32	Step 43	
γ	RHmax	Ra	(1.35 * Rs/Rso - 0.35)	
kPa/°C	%	MJ/m2/day		
Step 11	Step 22	Step 33	Step 44	
(1+0.34*u2)	RHmin	Ra	Rnl	
m/s	%	mm/day	MJ/m2/day	

Meteorological balance		DAILY DATA						Weekly Totals (mm/week) for each week ending on a Wednesday		
2000		meas.	calc.	calc.	calc.	mm/d				
	DATE	RF mm/d	Eto (mm/d)	SMD (mm)	Et (mm/d)	Effective RF	DATE	RF	Et	Eff. RF
	1/1/00	0.0	0.3	0	0.3	0.0	1/1/00			
	2/1/00	1.2	0.9	0.0	0.9	0.3	2/1/00			
	3/1/00	6.3	0.6	0.0	0.6	5.7	3/1/00			
	4/1/00	1.5	0.9	0.0	0.9	0.6	4/1/00			
wed	5/1/00	7.7	0.8	0.0	0.8	6.9	5/1/00	9.0	2.7	6.6
	6/1/00	0.0	0.4	0.4	0.4	0.0	6/1/00			
	7/1/00	1.6	0.4	0.0	0.4	0.8	7/1/00			
	8/1/00	0.0	0.4	0.4	0.4	0.0	8/1/00			
	9/1/00	0.4	0.5	0.6	0.5	0.0	9/1/00			
	10/1/00	4.4	0.9	0.0	0.9	2.9	10/1/00			
	11/1/00	17.1	0.5	0.0	0.5	16.6	11/1/00			
wed	12/1/00	4.8	0.0	0.0	0.0	4.8	12/1/00	31.2	4.0	27.2
	13/01/00	0.4	0.4	0.0	0.4	0.0	13/01/00			
	14/01/00	0.0	0.2	0.2	0.2	0.0	14/01/00			
	15/01/00	0.0	0.4	0.6	0.4	0.0	15/01/00			
	16/01/00	0.0	0.4	1.0	0.4	0.0	16/01/00			
	17/01/00	0.0	0.6	1.6	0.6	0.0	17/01/00			
	18/01/00	0.0	0.3	1.9	0.3	0.0	18/01/00			
wed	19/01/00	0.0	0.1	2.0	0.1	0.0	19/01/00	5.2	2.3	4.8
	20/01/00	1.1	0.4	1.3	0.4	0.0	20/01/00			
	21/01/00	0.0	0.5	1.8	0.5	0.0	21/01/00			
	22/01/00	0.0	0.6	2.4	0.6	0.0	22/01/00			
	23/01/00	0.0	0.3	2.7	0.3	0.0	23/01/00			
	24/01/00	0.0	0.3	3.0	0.3	0.0	24/01/00			
	25/01/00	0.0	0.3	3.2	0.3	0.0	25/01/00			
wed	26/01/00	0.0	0.0	3.2	0.0	0.0	26/01/00	1.1	2.4	0.0
	27/01/00	0.7	0.8	3.3	0.8	0.0	27/01/00			
	28/01/00	2.2	1.6	2.7	1.6	0.0	28/01/00			
	29/01/00	1.0	0.9	2.6	0.9	0.0	29/01/00			
	30/01/00	0.6	0.4	2.4	0.4	0.0	30/01/00			
	31/01/00	0.5	0.3	2.2	0.3	0.0	31/01/00			
	1/2/00	2.4	0.4	0.3	0.4	0.0	1/2/00			
wed	2/2/00	1.9	0.7	0.0	0.7	0.9	2/2/00	7.4	4.4	0.0
	3/2/00	1.5	0.9	0.0	0.9	0.6	3/2/00			
	4/2/00	0.0	0.7	0.7	0.7	0.0	4/2/00			
	5/2/00	1.8	0.5	0.0	0.5	0.7	5/2/00			
	6/2/00	6.8	0.9	0.0	0.9	5.9	6/2/00			
	7/2/00	3.2	1.2	0.0	1.2	2.0	7/2/00			
	8/2/00	0.6	0.4	0.0	0.4	0.2	8/2/00			
wed	9/2/00	10.1	1.3	0.0	1.3	8.8	9/2/00	15.8	5.2	10.4
	10/2/00	0.5	0.4	0.0	0.4	0.1	10/2/00			
	11/2/00	11.6	1.2	0.0	1.2	10.4	11/2/00			
	12/2/00	0.4	0.5	0.1	0.5	0.0	12/2/00			
	13/02/00	6.8	1.1	0.0	1.1	5.5	13/02/00			
	14/02/00	1.4	1.2	0.0	1.2	0.2	14/02/00			
	15/02/00	6.7	0.7	0.0	0.7	6.0	15/02/00			
wed	16/02/00	1.5	0.7	0.0	0.7	0.8	16/02/00	37.5	6.5	31.0
	17/02/00	1.5	1.3	0.0	1.3	0.2	17/02/00			
	18/02/00	0.8	0.9	0.1	0.9	0.0	18/02/00			
	19/02/00	0.0	0.6	0.7	0.6	0.0	19/02/00			
	20/02/00	7.8	1.0	0.0	1.0	6.1	20/02/00			
	21/02/00	0.6	1.0	0.4	1.0	0.0	21/02/00			
	22/02/00	0.7	0.9	0.6	0.9	0.0	22/02/00			
wed	23/02/00	1.8	1.1	0.0	1.1	0.1	23/02/00	12.9	6.5	7.1
	24/02/00	1.9	0.6	0.0	0.6	1.3	24/02/00			
	25/02/00	0.4	1.2	0.8	1.2	0.0	25/02/00			
	26/02/00	12.1	1.5	0.0	1.5	9.8	26/02/00			
	27/02/00	1.9	0.5	0.0	0.5	1.4	27/02/00			
	28/02/00	2.2	1.0	0.0	1.0	1.2	28/02/00			
	29/02/00	3.5	0.9	0.0	0.9	2.6	29/02/00			
wed	1/3/00	0.0	1.0	1.0	1.0	0.0	1/3/00	23.8	6.8	16.4
	2/3/00	7.7	1.6	0.0	1.6	5.1	2/3/00			

Meteorological balance		DAILY DATA						Weekly Totals (mm/week)		
		meas.	calc.	calc.	calc.	mm/d		for each week ending on a Wednesday		
	DATE	RF mm/d	Eto (mm/d)	SMD (mm)	Et (mm/d)	Effective RF	DATE			
	3/3/00	0.0	1.1	1.1	1.1	0.0	3/3/00	**RF**	**Et**	**Eff. RF**
	4/3/00	0.0	1.0	2.0	1.0	0.0	4/3/00			
	5/3/00	0.0	1.0	3.1	1.0	0.0	5/3/00			
	6/3/00	4.3	1.7	0.5	1.7	0.0	6/3/00			
	7/3/00	0.4	1.2	1.3	1.2	0.0	7/3/00			
wed	8/3/00	0.0	1.2	2.5	1.2	0.0	8/3/00	12.4	8.6	5.1
	9/3/00	0.0	0.8	3.3	0.8	0.0	9/3/00			
	10/3/00	0.0	1.7	5.0	1.7	0.0	10/3/00			
	11/3/00	0.0	1.0	6.0	1.0	0.0	11/3/00			
	12/3/00	0.0	1.2	7.1	1.2	0.0	12/3/00			
	13/03/00	2.3	1.1	5.9	1.1	0.0	13/03/00			
	14/03/00	0.0	1.0	6.9	1.0	0.0	14/03/00			
wed	15/03/00	0.0	1.0	7.9	1.0	0.0	15/03/00	2.3	7.9	0.0
	16/03/00	0.0	0.9	8.8	0.9	0.0	16/03/00			
	17/03/00	0.0	0.8	9.6	0.8	0.0	17/03/00			
	18/03/00	0.0	0.9	10.5	0.9	0.0	18/03/00			
	19/03/00	0.0	1.3	11.8	1.3	0.0	19/03/00			
	20/03/00	0.0	1.1	12.9	1.1	0.0	20/03/00			
	21/03/00	0.0	0.8	13.7	0.8	0.0	21/03/00			
wed	22/03/00	2.7	1.3	12.3	1.3	0.0	22/03/00	0.0	6.8	0.0
	23/03/00	3.2	1.5	10.6	1.5	0.0	23/03/00			
	24/03/00	1.3	1.4	10.7	1.4	0.0	24/03/00			
	25/03/00	2.6	1.6	9.7	1.6	0.0	25/03/00			
	26/03/00	0.1	1.7	11.3	1.7	0.0	26/03/00			
	27/03/00	0.0	1.9	13.3	1.9	0.0	27/03/00			
	28/03/00	0.0	1.5	14.8	1.5	0.0	28/03/00			
wed	29/03/00	0.0	1.9	16.7	1.9	0.0	29/03/00	9.9	11.0	0.0
	30/03/00	0.0	1.6	18.3	1.6	0.0	30/03/00			
	31/03/00	3.4	1.5	16.4	1.5	0.0	31/03/00			
	1/4/00	15.9	1.2	1.7	1.2	0.0	1/4/00			
	2/4/00	0.0	1.7	3.4	1.7	0.0	2/4/00			
	3/4/00	0.0	1.3	4.7	1.3	0.0	3/4/00			
	4/4/00	0.0	1.7	6.4	1.7	0.0	4/4/00			
wed	5/4/00	0.0	1.8	8.2	1.8	0.0	5/4/00	19.3	11.0	0.0
	6/4/00	0.0	2.0	10.2	2.0	0.0	6/4/00			
	7/4/00	0.0	1.3	11.5	1.3	0.0	7/4/00			
	8/4/00	0.0	2.3	13.9	2.3	0.0	8/4/00			
	9/4/00	0.0	2.1	15.9	2.1	0.0	9/4/00			
	10/4/00	3.3	1.7	14.4	1.7	0.0	10/4/00			
	11/4/00	0.8	1.7	15.3	1.7	0.0	11/4/00			
wed	12/4/00	0.0	1.4	16.7	1.4	0.0	12/4/00	4.1	12.9	0.0
	13/04/00	1.7	1.5	16.5	1.5	0.0	13/04/00			
	14/04/00	0.0	1.9	18.4	1.9	0.0	14/04/00			
	15/04/00	1.8	1.9	18.5	1.9	0.0	15/04/00			
	16/04/00	11.3	1.6	8.8	1.6	0.0	16/04/00			
	17/04/00	1.7	1.7	8.8	1.7	0.0	17/04/00			
	18/04/00	0.0	2.5	11.3	2.5	0.0	18/04/00			
wed	19/04/00	4.8	1.8	8.3	1.8	0.0	19/04/00	16.5	12.5	0.0
	20/04/00	3.7	1.8	6.4	1.8	0.0	20/04/00			
	21/04/00	0.5	2.4	8.2	2.4	0.0	21/04/00			
	22/04/00	1.5	2.1	8.8	2.1	0.0	22/04/00			
	23/04/00	1.5	2.3	9.6	2.3	0.0	23/04/00			
	24/04/00	2.4	1.8	8.9	1.8	0.0	24/04/00			
	25/04/00	0.0	1.2	10.1	1.2	0.0	25/04/00			
wed	26/04/00	0.3	1.5	11.3	1.5	0.0	26/04/00	14.4	13.2	0.0
	27/04/00	0.0	1.4	12.7	1.4	0.0	27/04/00			
	28/04/00	0.0	1.5	14.1	1.5	0.0	28/04/00			
	29/04/00	0.0	2.7	16.8	2.7	0.0	29/04/00			
	30/04/00	0.0	2.6	19.4	2.6	0.0	30/04/00			
	1/5/00	0.0	3.1	22.5	3.1	0.0	1/5/00			
	2/5/00	0.0	3.7	26.2	3.7	0.0	2/5/00			
wed	3/5/00	0.0	**3.8**	**30.0**	**3.8**	0.0	3/5/00	0.3	16.4	0.0

Meteorological balance			DAILY DATA					Weekly Totals (mm/week)		
		meas.	calc.	calc.	calc.	mm/d		for each week ending on a Wednesday		
	DATE	RF mm/d	Eto (mm/d)	SMD (mm)	Et (mm/d)	Effective RF	DATE			
	4/5/00	0.0	2.5	32.5	2.5	0.0	4/5/00	RF	Et	Eff. RF
	5/5/00	0.0	2.1	34.5	2.1	0.0	5/5/00			
	6/5/00	0.0	3.4	37.8	3.3	0.0	6/5/00			
	7/5/00	3.9	3.1	36.8	2.9	0.0	7/5/00			
	8/5/00	0.0	3.3	39.8	3.0	0.0	8/5/00			
	9/5/00	0.0	3.6	43.0	3.2	0.0	9/5/00			
wed	10/5/00	0.2	4.1	46.3	3.5	0.0	10/5/00	3.9	20.6	0.0
	11/5/00	0.5	2.1	47.5	1.7	0.0	11/5/00			
	12/5/00	0.8	1.6	48.0	1.3	0.0	12/5/00			
	13/05/00	0.3	2.4	49.6	1.9	0.0	13/05/00			
	14/05/00	0.6	2.9	51.3	2.3	0.0	14/05/00			
	15/05/00	8.7	3.3	45.1	2.5	0.0	15/05/00			
	16/05/00	23.6	2.2	23.3	1.8	0.0	16/05/00			
wed	17/05/00	2.2	1.8	23.0	1.8	0.0	17/05/00	34.7	15.1	0.0
	18/05/00	0.0	2.5	25.5	2.5	0.0	18/05/00			
	19/05/00	0.0	2.1	27.6	2.1	0.0	19/05/00			
	20/05/00	0.0	2.2	29.8	2.2	0.0	20/05/00			
	21/05/00	5.6	2.7	26.9	2.7	0.0	21/05/00			
	22/05/00	8.6	2.8	21.0	2.8	0.0	22/05/00			
	23/05/00	0.0	2.9	23.9	2.9	0.0	23/05/00			
wed	24/05/00	3.3	3.4	24.0	3.4	0.0	24/05/00	16.4	16.9	0.0
	25/05/00	0.2	3.1	26.9	3.1	0.0	25/05/00			
	26/05/00	0.0	3.2	30.1	3.2	0.0	26/05/00			
	27/05/00	4.3	2.7	28.5	2.7	0.0	27/05/00			
	28/05/00	2.7	3.1	28.9	3.1	0.0	28/05/00			
	29/05/00	1.5	2.8	30.2	2.8	0.0	29/05/00			
	30/05/00	0.0	3.2	33.3	3.2	0.0	30/05/00			
wed	31/05/00	8.1	2.2	27.4	2.1	0.0	31/05/00	12.0	21.5	0.0
	1/6/00	0.4	2.3	29.3	2.3	0.0	1/6/00			
	2/6/00	0.0	3.1	32.4	3.1	0.0	2/6/00			
	3/6/00	7.5	2.3	27.1	2.2	0.0	3/6/00			
	4/6/00	0.1	1.9	29.0	1.9	0.0	4/6/00			
	5/6/00	0.2	3.5	32.3	3.5	0.0	5/6/00			
	6/6/00	0.0	3.1	35.3	3.0	0.0	6/6/00			
wed	7/6/00	9.8	2.1	27.5	2.0	0.0	7/6/00	16.3	18.3	0.0
	8/6/00	0.5	1.8	28.8	1.8	0.0	8/6/00			
	9/6/00	0.0	2.8	31.6	2.8	0.0	9/6/00			
	10/6/00	0.1	3.0	34.4	3.0	0.0	10/6/00			
	11/6/00	0.0	2.5	36.8	2.3	0.0	11/6/00			
	12/6/00	0.0	3.0	39.5	2.7	0.0	12/6/00			
	13/06/00	4.4	3.2	37.9	2.8	0.0	13/06/00			
wed	14/06/00	0.0	2.7	40.4	2.4	0.0	14/06/00	14.8	17.4	0.0
	15/06/00	0.1	2.6	42.5	2.3	0.0	15/06/00			
	16/06/00	0.2	2.4	44.4	2.1	0.0	16/06/00			
	17/06/00	0.0	3.4	47.3	2.9	0.0	17/06/00			
	18/06/00	0.0	4.1	50.6	3.3	0.0	18/06/00			
	19/06/00	0.7	2.2	51.6	1.7	0.0	19/06/00			
	20/06/00	8.5	2.1	44.7	1.6	0.0	20/06/00			
wed	21/06/00	1.7	2.2	44.8	1.8	0.0	21/06/00	9.5	16.2	0.0
	22/06/00	0.6	2.3	46.1	1.9	0.0	22/06/00			
	23/06/00	0.9	2.3	47.1	1.9	0.0	23/06/00			
	24/06/00	0.0	2.5	49.1	2.0	0.0	24/06/00			
	25/06/00	0.0	3.5	51.9	2.8	0.0	25/06/00			
	26/06/00	0.0	2.4	53.7	1.8	0.0	26/06/00			
	27/06/00	0.0	3.7	56.4	2.7	0.0	27/06/00			
wed	28/06/00	0.0	2.3	58.0	1.6	0.0	28/06/00	3.2	14.9	0.0
	29/06/00	0.0	2.6	59.8	1.8	0.0	29/06/00			
	30/06/00	9.9	2.5	51.6	1.7	0.0	30/06/00			
	1/7/00	4.7	2.0	48.4	1.5	0.0	1/7/00			
	2/7/00	2.5	2.6	47.9	2.0	0.0	2/7/00			
	3/7/00	0.9	2.4	49.0	2.0	0.0	3/7/00			
	4/7/00	0.0	3.0	51.3	2.3	0.0	4/7/00			

Meteorological balance			DAILY DATA					Weekly Totals (mm/week)		
		meas.	calc.	calc.	calc.	mm/d		for each week ending on a Wednesday		
	DATE	RF mm/d	Eto (mm/d)	SMD (mm)	Et (mm/d)	Effective RF	DATE	RF	Et	Eff. RF
wed	5/7/00	0.0	2.5	53.3	1.9	0.0	5/7/00			
	6/7/00	0.0	2.9	55.4	2.2	0.0	6/7/00			
	7/7/00	0.0	3.4	57.9	2.5	0.0	7/7/00			
	8/7/00	4.9	2.0	54.3	1.4	0.0	8/7/00			
	9/7/00	4.6	2.2	51.4	1.6	0.0	9/7/00			
	10/7/00	0.0	3.3	53.9	2.5	0.0	10/7/00			
	11/7/00	0.7	3.3	55.6	2.5	0.0	11/7/00			
wed	12/7/00	0.0	2.6	57.5	1.8	0.0	12/7/00	10.2	14.5	0.0
	13/07/00	0.0	2.1	58.9	1.5	0.0	13/07/00			
	14/07/00	2.7	2.6	58.0	1.7	0.0	14/07/00			
	15/07/00	0.0	3.2	60.2	2.2	0.0	15/07/00			
	16/07/00	0.0	3.3	62.4	2.2	0.0	16/07/00			
	17/07/00	0.0	2.6	64.1	1.7	0.0	17/07/00			
	18/07/00	0.0	3.0	66.0	1.9	0.0	18/07/00			
wed	19/07/00	0.0	3.8	68.2	2.3	0.0	19/07/00	2.7	13.0	0.0
	20/07/00	0.0	3.8	70.5	2.2	0.0	20/07/00			
	21/07/00	0.0	4.1	72.7	2.2	0.0	21/07/00			
	22/07/00	0.0	4.5	75.0	2.4	0.0	22/07/00			
	23/07/00	0.0	3.3	76.7	1.6	0.0	23/07/00			
	24/07/00	0.0	2.8	78.0	1.3	0.0	24/07/00			
	25/07/00	0.0	2.3	79.1	1.1	0.0	25/07/00			
wed	26/07/00	0.0	2.1	80.0	1.0	0.0	26/07/00	0.0	13.1	0.0
	27/07/00	0.0	3.0	80.0	*0.0*	0.0	27/07/00			
	28/07/00	1.7	3.2	78.3	*0.0*	0.0	28/07/00			
	29/07/00	1.1	3.1	77.2	*0.0*	0.0	29/07/00			
	30/07/00	17.3	2.2	59.9	*0.0*	0.0	30/07/00			
	31/07/00	0.6	2.8	61.2	1.9	0.0	31/07/00			
	1/8/00	6.8	3.1	56.4	2.0	0.0	1/8/00			
wed	2/8/00	7.5	2.7	50.9	1.9	0.0	2/8/00	27.5	4.9	0.0
	3/8/00	0.0	2.4	52.7	1.9	0.0	3/8/00			
	4/8/00	0.3	2.0	53.9	1.5	0.0	4/8/00			
	5/8/00	0.0	2.5	55.8	1.9	0.0	5/8/00			
	6/8/00	0.4	2.8	57.3	2.0	0.0	6/8/00			
	7/8/00	1.4	2.0	57.4	1.4	0.0	7/8/00			
	8/8/00	1.8	1.9	56.9	1.4	0.0	8/8/00			
wed	9/8/00	0.1	2.2	58.4	1.6	0.0	9/8/00	11.4	11.9	0.0
	10/8/00	0.0	2.4	60.0	1.6	0.0	10/8/00			
	11/8/00	0.4	1.8	60.8	1.2	0.0	11/8/00			
	12/8/00	0.0	2.7	62.6	1.8	0.0	12/8/00			
	13/08/00	2.9	2.0	60.9	1.3	0.0	13/08/00			
	14/08/00	1.5	2.7	61.2	1.8	0.0	14/08/00			
	15/08/00	3.7	2.9	59.4	1.9	0.0	15/08/00			
wed	16/08/00	0.1	3.2	61.5	2.2	0.0	16/08/00	8.6	11.1	0.0
	17/08/00	1.9	2.5	61.2	1.7	0.0	17/08/00			
	18/08/00	11.1	2.5	51.7	1.6	0.0	18/08/00			
	19/08/00	4.2	2.6	49.5	2.0	0.0	19/08/00			
	20/08/00	0.1	2.7	51.5	2.1	0.0	20/08/00			
	21/08/00	0.8	2.6	52.6	2.0	0.0	21/08/00			
	22/08/00	0.0	2.0	54.1	1.5	0.0	22/08/00			
wed	23/08/00	0.0	3.0	56.3	2.2	0.0	23/08/00	18.2	12.9	0.0
	24/08/00	0.0	3.2	58.6	2.3	0.0	24/08/00			
	25/08/00	2.1	2.6	58.3	1.8	0.0	25/08/00			
	26/08/00	0.0	2.6	60.0	1.8	0.0	26/08/00			
	27/08/00	3.5	2.5	58.2	1.6	0.0	27/08/00			
	28/08/00	0.0	2.0	59.5	1.4	0.0	28/08/00			
	29/08/00	0.0	1.8	60.7	1.2	0.0	29/08/00			
wed	30/08/00	2.1	2.9	60.5	1.9	0.0	30/08/00	5.6	12.2	0.0
	31/08/00	2.5	2.4	59.6	1.6	0.0	31/08/00			
	1/9/00	3.8	2.3	57.3	1.5	0.0	1/9/00			
	2/9/00	0	1.8	58.6	1.3	0.0	2/9/00			
	3/9/00	0	2.0	60.0	1.3	0.0	3/9/00			
	4/9/00	3.8	1.6	57.2	1.0	0.0	4/9/00			

								Weekly Totals (mm/week)		
Meteorological balance			DAILY DATA					for each week ending on a Wednesday		
		meas.	calc.	calc.	calc.	mm/d				
	DATE	**RF mm/d**	**Eto (mm/d)**	**SMD (mm)**	**Et (mm/d)**	**Effective RF**	**DATE**	**RF**	**Et**	**Eff. RF**
	5/9/00	1.2	**1.9**	**57.3**	**1.3**	0.0	5/9/00			
wed	6/9/00	0.8	**2.1**	**58.0**	**1.5**	0.0	6/9/00	13.4	10.0	0.0
	7/9/00	0.9	**1.8**	**58.3**	**1.3**	0.0	7/9/00			
	8/9/00	0	**1.5**	**59.4**	**1.0**	0.0	8/9/00			
	9/9/00	2.2	**1.5**	**58.2**	**1.0**	0.0	9/9/00			
	10/9/00	0	**2.0**	**59.6**	**1.4**	0.0	10/9/00			
	11/9/00	0	**1.7**	**60.8**	**1.2**	0.0	11/9/00			
	12/9/00	0	**1.2**	**61.6**	**0.8**	0.0	12/9/00			
wed	13/09/00	5.5	**1.3**	**56.9**	**0.9**	0.0	13/09/00	3.9	8.1	0.0
	14/09/00	2.4	**1.3**	**55.5**	**0.9**	0.0	14/09/00			
	15/09/00	0	**2.0**	**56.9**	**1.4**	0.0	15/09/00			
	16/09/00	2.3	**1.3**	**55.5**	**0.9**	0.0	16/09/00			
	17/09/00	20.3	**1.2**	**36.1**	**0.9**	0.0	17/09/00			
	18/09/00	0	**1.6**	**37.6**	**1.5**	0.0	18/09/00			
	19/09/00	0	**1.7**	**39.1**	**1.5**	0.0	19/09/00			
wed	20/09/00	16.1	**2.1**	24.9	**1.9**	0.0	20/09/00	30.5	8.0	0.0
	21/09/00	2.7	1.6	23.8	1.6	0.0	21/09/00			
	22/09/00	1.7	1.6	23.7	1.6	0.0	22/09/00			
	23/09/00	7.7	1.1	17.1	1.1	0.0	23/09/00			
	24/09/00	0.2	1.6	18.5	1.6	0.0	24/09/00			
	25/09/00	3.7	1.5	16.4	1.5	0.0	25/09/00			
	26/09/00	8.2	1.3	9.4	1.3	0.0	26/09/00			
wed	27/09/00	9.9	1.5	1.0	1.5	0.0	27/09/00	40.3	10.6	0.0
	28/09/00	14.4	1.3	0.0	1.3	12.1	28/09/00			
	29/09/00	0.1	1.4	1.3	1.4	0.0	29/09/00			
	30/09/00	0	1.4	2.7	1.4	0.0	30/09/00			
hydrol	1/10/00	5.2	1.4	0.0	1.4	1.2	1/10/00			
	2/10/00	3.2	1.3	0.0	1.3	1.9	2/10/00			
	3/10/00	2.5	1.4	0.0	1.4	1.1	3/10/00			
wed	4/10/00	7.4	1.0	0.0	1.0	6.4	4/10/00	35.3	9.6	16.3
	5/10/00	0.1	1.2	1.1	1.2	0.0	5/10/00			
	6/10/00	0	1.2	2.3	1.2	0.0	6/10/00			
	7/10/00	0.2	1.3	3.4	1.3	0.0	7/10/00			
	8/10/00	4.8	1.4	0.0	1.4	0.1	8/10/00			
	9/10/00	3.4	1.1	0.0	1.1	2.3	9/10/00			
	10/10/00	13	0.7	0.0	0.7	12.3	10/10/00			
wed	11/10/00	0.4	1.3	0.9	1.3	0.0	11/10/00	28.9	7.9	21.0
	12/10/00	0.1	1.1	1.8	1.1	0.0	12/10/00			
	13/10/00	4.8	1.1	0.0	1.1	1.9	13/10/00			
	14/10/00	0	1.0	1.0	1.0	0.0	14/10/00			
	15/10/00	5.3	1.3	0.0	1.3	3.0	15/10/00			
	16/10/00	0.8	0.8	0.0	0.8	0.0	16/10/00			
	17/10/00	23.1	1.4	0.0	1.4	21.7	17/10/00			
wed	18/10/00	0.4	0.9	0.5	0.9	0.0	18/10/00	34.5	7.9	26.6
	19/10/00	11.6	1.1	0.0	1.1	9.9	19/10/00			
	20/10/00	0	0.7	0.7	0.7	0.0	20/10/00			
	21/10/00	0	0.8	1.5	0.8	0.0	21/10/00			
	22/10/00	12.1	1.1	0.0	1.1	9.4	22/10/00			
	23/10/00	2.2	0.7	0.0	0.7	1.5	23/10/00			
	24/10/00	2.7	0.9	0.0	0.9	1.8	24/10/00			
wed	25/10/00	0	0.7	0.7	0.7	0.0	25/10/00	29.0	6.4	22.6
	26/10/00	13.3	1.1	0.0	1.1	11.5	26/10/00			
	27/10/00	0.2	0.6	0.4	0.6	0.0	27/10/00			
	28/10/00	6.3	1.0	0.0	1.0	4.9	28/10/00			
	29/10/00	21.4	0.5	0.0	0.5	20.9	29/10/00			
	30/10/00	6	1.1	0.0	1.1	4.9	30/10/00			
	31/10/00	6.2	0.8	0.0	0.8	5.4	31/10/00			
wed	1/11/00	7.5	0.6	0.0	0.6	6.9	1/11/00	53.4	5.8	47.6
	2/11/00	5.4	0.4	0.0	0.4	5.0	2/11/00			
	3/11/00	0.5	0.6	0.1	0.6	0.0	3/11/00			
	4/11/00	6.8	0.6	0.0	0.6	6.1	4/11/00			
	5/11/00	63.9	1.2	0.0	1.2	62.7	5/11/00			

Meteorological balance			DAILY DATA					Weekly Totals (mm/week)		
		meas.	calc.	calc.	calc.	mm/d		for each week ending on a Wednesday		
	DATE	RF mm/d	Eto (mm/d)	SMD (mm)	Et (mm/d)	Effective RF	DATE			
	6/11/00	2.3	0.7	0.0	0.7	1.6	6/11/00	RF	Et	Eff. RF
	7/11/00	1.5	0.6	0.0	0.6	0.9	7/11/00			
wed	8/11/00	0	0.3	0.3	0.3	0.0	8/11/00	87.9	4.6	83.3
	9/11/00	0.6	0.4	0.1	0.4	0.0	9/11/00			
	10/11/00	2.1	1.1	0.0	1.1	1.0	10/11/00			
	11/11/00	4	0.5	0.0	0.5	3.5	11/11/00			
	12/11/00	1.7	0.7	0.0	0.7	1.0	12/11/00			
	13/11/00	1.3	0.6	0.0	0.6	0.7	13/11/00			
	14/11/00	0	0.3	0.3	0.3	0.0	14/11/00			
wed	15/11/00	5.4	0.9	0.0	0.9	4.1	15/11/00	9.7	3.8	6.3
	16/11/00	2.7	0.4	0.0	0.4	2.3	16/11/00			
	17/11/00	2.1	0.7	0.0	0.7	1.4	17/11/00			
	18/11/00	2.7	0.7	0.0	0.7	2.0	18/11/00			
	19/11/00	4.7	0.4	0.0	0.4	4.3	19/11/00			
	20/11/00	1.4	0.3	0.0	0.3	1.1	20/11/00			
	21/11/00	9.2	0.5	0.0	0.5	8.7	21/11/00			
wed	22/11/00	0.1	0.2	0.1	0.2	0.0	22/11/00	28.2	3.9	23.9
	23/11/00	1.3	0.2	0.0	0.2	1.0	23/11/00			
	24/11/00	10	1.0	0.0	1.0	9.0	24/11/00			
	25/11/00	22.4	0.9	0.0	0.9	21.5	25/11/00			
	26/11/00	1.7	0.4	0.0	0.4	1.3	26/11/00			
	27/11/00	9.5	1.0	0.0	1.0	8.5	27/11/00			
	28/11/00	12.9	0.7	0.0	0.7	12.2	28/11/00			
wed	29/11/00	6.4	0.3	0.0	0.3	6.1	29/11/00	57.9	4.3	53.6
	30/11/00	27.8	1.1	0.0	1.1	26.7	30/11/00			
	1/12/00	3.8	0.3	0.0	0.3	3.5	1/12/00			
	2/12/00	0.2	0.2	0.0	0.2	0.0	2/12/00			
	3/12/00	14.4	0.7	0.0	0.7	13.7	3/12/00			
	4/12/00	13.5	0.6	0.0	0.6	12.9	4/12/00			
	5/12/00	1	0.1	0.0	0.1	0.9	5/12/00			
wed	6/12/00	1	0.4	0.0	0.4	0.6	6/12/00	67.1	3.2	63.9
	7/12/00	8	0.3	0.0	0.3	7.7	7/12/00			
	8/12/00	0.4	0.3	0.0	0.3	0.1	8/12/00			
	9/12/00	6.6	0.3	0.0	0.3	6.3	9/12/00			
	10/12/00	9.2	0.5	0.0	0.5	8.7	10/12/00			
	11/12/00	7.3	0.6	0.0	0.6	6.7	11/12/00			
	12/12/00	8.2	0.5	0.0	0.5	7.7	12/12/00			
wed	13/12/00	0.2	0.2	0.0	0.2	0.0	13/12/00	40.7	2.9	37.8
	14/12/00	0	0.4	0.4	0.4	0.0	14/12/00			
	15/12/00	5.1	0.4	0.0	0.4	4.3	15/12/00			
	16/12/00	1	0.1	0.0	0.1	0.9	16/12/00			
	17/12/00	6.4	0.5	0.0	0.5	5.9	17/12/00			
	18/12/00	3.6	0.8	0.0	0.8	2.8	18/12/00			
	19/12/00	12.9	0.4	0.0	0.4	12.5	19/12/00			
wed	20/12/00	0.3	0.4	0.1	0.4	0.0	20/12/00	29.2	2.7	26.5
	21/12/00	0	0.4	0.6	0.4	0.0	21/12/00			
	22/12/00	0	0.2	0.8	0.2	0.0	22/12/00			
	23/12/00	14.3	0.2	0.0	0.2	13.3	23/12/00			
	24/12/00	4.5	0.2	0.0	0.2	4.3	24/12/00			
	25/12/00	0	0.4	0.4	0.4	0.0	25/12/00			
	26/12/00	0	0.2	0.6	0.2	0.0	26/12/00			
wed	27/12/00	0	0.2	0.8	0.2	0.0	27/12/00	19.1	2.0	17.7
	28/12/00	0	0.2	1.0	0.2	0.0	28/12/00			
	29/12/00	0	0.0	1.0	0.0	0.0	29/12/00			
	30/12/00	23.9	0.8	0.0	0.8	22.1	30/12/00			
	31/12/00	12.3	1.2	0.0	1.2	11.1	31/12/00			
Annual Totals 2000		1081.3			492.7	588.9	(mm)			

								Weekly Totals (mm/week)		
Meteorological balance			DAILY DATA					for each week ending on a Wednesday		
2001		meas.	calc.	calc.	calc.	mm/d				
	DATE	RF mm/d	Eto (mm/d)	SMD (mm)	Et (mm/d)	Effective RF	DATE	RF	Et	Eff. RF
	1/1/01	4.8	0.5	0.0	0.5	4.3	1/1/01			
	2/1/01	0.9	0.3	0.0	0.3	0.6	2/1/01			
wed	**3/1/01**	3.5	0.4	0.0	0.4	3.1	3/1/01	41.9	3.3	38.0
	4/1/01	8.2	0.2	0.0	0.2	8.0	4/1/01			
	5/1/01	0	0.3	0.3	0.3	0.0	5/1/01			
	6/1/01	1.4	0.6	0.0	0.6	0.5	6/1/01			
	7/1/01	0	0.3	0.3	0.3	0.0	7/1/01			
	8/1/01	0	0.3	0.7	0.3	0.0	8/1/01			
	9/1/01	0.4	0.7	0.9	0.7	0.0	9/1/01			
wed	**10/1/01**	0	0.2	1.2	0.2	0.0	10/1/01	13.5	2.9	11.5
	11/1/01	0	0.4	1.6	0.4	0.0	11/1/01			
	12/1/01	0	0.2	1.8	0.2	0.0	12/1/01			
	13/01/01	0	0.3	2.1	0.3	0.0	13/01/01			
	14/01/01	0.8	0.2	1.5	0.2	0.0	14/01/01			
	15/01/01	0	0.4	1.8	0.4	0.0	15/01/01			
	16/01/01	3.5	0.6	0.0	0.6	1.1	16/01/01			
wed	**17/01/01**	1.2	0.4	0.0	0.4	0.8	17/01/01	4.3	2.3	1.1
	18/01/01	0	0.2	0.2	0.2	0.0	18/01/01			
	19/01/01	0	0.5	0.6	0.5	0.0	19/01/01			
	20/01/01	8.6	0.9	0.0	0.9	7.0	20/01/01			
	21/01/01	18.1	0.7	0.0	0.7	17.4	21/01/01			
	22/01/01	11.1	0.5	0.0	0.5	10.6	22/01/01			
	23/01/01	2.8	0.6	0.0	0.6	2.2	23/01/01			
wed	**24/01/01**	0	0.8	0.8	0.8	0.0	24/01/01	41.8	3.8	38.0
	25/01/01	3.3	0.6	0.0	0.6	2.0	25/01/01			
	26/01/01	0	0.6	0.6	0.6	0.0	26/01/01			
	27/01/01	1.4	0.4	0.0	0.4	0.4	27/01/01			
	28/01/01	0	0.4	0.4	0.4	0.0	28/01/01			
	29/01/01	3.1	0.6	0.0	0.6	2.1	29/01/01			
	30/01/01	0	1.0	1.0	1.0	0.0	30/01/01			
wed	**31/01/01**	2.6	0.4	0.0	0.4	1.2	31/01/01	7.8	4.3	4.5
	1/2/01	1.1	0.5	0.0	0.5	0.6	1/2/01			
	2/2/01	1.7	0.8	0.0	0.8	0.9	2/2/01			
	3/2/01	9.3	0.6	0.0	0.6	8.7	3/2/01			
	4/2/01	5.6	0.5	0.0	0.5	5.1	4/2/01			
	5/2/01	11.2	0.5	0.0	0.5	10.7	5/2/01			
	6/2/01	16.9	0.6	0.0	0.6	16.3	6/2/01			
wed	**7/2/01**	2.9	0.4	0.0	0.4	2.5	7/2/01	48.4	3.8	43.6
	8/2/01	0	0.4	0.4	0.4	0.0	8/2/01			
	9/2/01	12.5	1.3	0.0	1.3	10.9	9/2/01			
	10/2/01	1.3	1.8	0.5	1.8	0.0	10/2/01			
	11/2/01	21.2	0.3	0.0	0.3	20.4	11/2/01			
	12/2/01	0	0.5	0.5	0.5	0.0	12/2/01			
	13/02/01	0	1.0	1.5	1.0	0.0	13/02/01			
wed	**14/02/01**	0.1	0.6	2.0	0.6	0.0	14/02/01	37.9	5.7	33.7
	15/02/01	2.1	0.6	0.5	0.6	0.0	15/02/01			
	16/02/01	0	0.3	0.8	0.3	0.0	16/02/01			
	17/02/01	0.4	0.6	1.0	0.6	0.0	17/02/01			
	18/02/01	0.3	0.6	1.4	0.6	0.0	18/02/01			
	19/02/01	0.2	0.8	1.9	0.8	0.0	19/02/01			
	20/02/01	0.2	1.1	2.8	1.1	0.0	20/02/01			
wed	**21/02/01**	0	1.1	3.9	1.1	0.0	21/02/01	3.3	4.6	0.0
	22/02/01	0.3	0.9	4.5	0.9	0.0	22/02/01			
	23/02/01	0	0.5	5.0	0.5	0.0	23/02/01			
	24/02/01	0	0.9	5.9	0.9	0.0	24/02/01			
	25/02/01	1.1	1.0	5.8	1.0	0.0	25/02/01			
	26/02/01	2.6	0.9	4.1	0.9	0.0	26/02/01			
	27/02/01	0	0.8	5.0	0.8	0.0	27/02/01			
wed	**28/02/01**	0	0.9	5.8	0.9	0.0	28/02/01	4.0	6.2	0.0
	1/3/01	0	0.7	6.6	0.7	0.0	1/3/01			
	2/3/01	0	0.8	7.3	0.8	0.0	2/3/01			
	3/3/01	0	0.9	8.2	0.9	0.0	3/3/01			

Meteorological balance		DAILY DATA						Weekly Totals (mm/week) for each week ending on a Wednesday		
2001		meas.	calc.	calc.	calc.	mm/d				
	DATE	RF mm/d	Eto (mm/d)	SMD (mm)	Et (mm/d)	Effective RF	DATE	RF	Et	Eff. RF
	4/3/01	0	1.3	9.6	1.3	0.0	4/3/01			
	5/3/01	2.1	1.3	8.7	1.3	0.0	5/3/01			
	6/3/01	32.6	1.2	0.0	1.2	22.7	6/3/01			
wed	7/3/01	2.7	1.2	0.0	1.2	1.5	7/3/01	34.7	7.1	22.7
	8/3/01	2.4	0.9	0.0	0.9	1.5	8/3/01			
	9/3/01	2.6	0.9	0.0	0.9	1.7	9/3/01			
	10/3/01	2	1.0	0.0	1.0	1.0	10/3/01			
	11/3/01	0	1.0	1.0	1.0	0.0	11/3/01			
	12/3/01	11.6	1.3	0.0	1.3	9.3	12/3/01			
	13/03/01	1.3	1.1	0.0	1.1	0.2	13/03/01			
wed	14/03/01	2.6	1.1	0.0	1.1	1.5	14/03/01	22.6	7.5	15.1
	15/03/01	15.3	1.1	0.0	1.1	14.2	15/03/01			
	16/03/01	1.3	1.2	0.0	1.2	0.1	16/03/01			
	17/03/01	1.9	0.7	0.0	0.7	1.2	17/03/01			
	18/03/01	0	1.2	1.2	1.2	0.0	18/03/01			
	19/03/01	0.6	1.3	1.8	1.3	0.0	19/03/01			
	20/03/01	3.5	0.7	0.0	0.7	1.0	20/03/01			
wed	21/03/01	0.5	0.9	0.4	0.9	0.0	21/03/01	25.2	7.3	17.9
	22/03/01	2.4	1.1	0.0	1.1	0.9	22/03/01			
	23/03/01	0	1.2	1.2	1.2	0.0	23/03/01			
	24/03/01	0	1.0	2.2	1.0	0.0	24/03/01			
	25/03/01	0	1.2	3.4	1.2	0.0	25/03/01			
	26/03/01	8.2	1.0	0.0	1.0	3.8	26/03/01			
	27/03/01	7.1	1.6	0.0	1.6	5.5	27/03/01			
wed	28/03/01	2.9	1.4	0.0	1.4	1.5	28/03/01	18.2	8.0	10.2
	29/03/01	0.2	1.6	1.4	1.6	0.0	29/03/01			
	30/03/01	3	1.4	0.0	1.4	0.2	30/03/01			
	31/03/01	0	2.1	2.1	2.1	0.0	31/03/01			
	1/4/01	2.1	1.3	1.3	1.3	0.0	1/4/01			
	2/4/01	0	1.5	2.8	1.5	0.0	2/4/01			
	3/4/01	3.1	1.6	1.3	1.6	0.0	3/4/01			
wed	4/4/01	8.1	2.1	0.0	2.1	4.6	4/4/01	11.3	11.0	1.6
	5/4/01	2	2.0	0.0	2.0	0.0	5/4/01			
	6/4/01	2.1	1.7	0.0	1.7	0.4	6/4/01			
	7/4/01	2.3	1.7	0.0	1.7	0.6	7/4/01			
	8/4/01	6.8	1.7	0.0	1.7	5.1	8/4/01			
	9/4/01	0.4	2.0	1.6	2.0	0.0	9/4/01			
	10/4/01	0	2.2	3.8	2.2	0.0	10/4/01			
wed	11/4/01	6.8	2.2	0.0	2.2	0.7	11/4/01	21.7	13.6	10.6
	12/4/01	2.9	1.5	0.0	1.5	1.4	12/4/01			
	13/04/01	0	1.6	1.6	1.6	0.0	13/04/01			
	14/04/01	1	1.9	2.5	1.9	0.0	14/04/01			
	15/04/01	0	1.9	4.3	1.9	0.0	15/04/01			
	16/04/01	0	2.1	6.4	2.1	0.0	16/04/01			
	17/04/01	0.6	1.8	7.7	1.8	0.0	17/04/01			
wed	18/04/01	0	1.6	9.2	1.6	0.0	18/04/01	11.3	13.0	2.1
	19/04/01	0	1.8	11.0	1.8	0.0	19/04/01			
	20/04/01	0.6	2.3	12.7	2.3	0.0	20/04/01			
	21/04/01	19.1	1.6	0.0	1.6	4.8	21/04/01			
	22/04/01	0.3	2.5	2.2	2.5	0.0	22/04/01			
	23/04/01	3	2.2	1.4	2.2	0.0	23/04/01			
	24/04/01	6.9	1.3	0.0	1.3	4.1	24/04/01			
wed	25/04/01	1.9	2.7	0.8	2.7	0.0	25/04/01	29.9	13.3	8.9
	26/04/01	0	2.9	3.8	2.9	0.0	26/04/01			
	27/04/01	1.7	1.7	3.8	1.7	0.0	27/04/01			
	28/04/01	0	2.1	5.9	2.1	0.0	28/04/01			
	29/04/01	1	2.0	6.9	2.0	0.0	29/04/01			
	30/04/01	0.3	2.7	9.3	2.7	0.0	30/04/01			
	1/5/01	0	3.2	12.5	3.2	0.0	1/5/01			
wed	2/5/01	0	2.9	15.3	2.9	0.0	2/5/01	4.9	17.4	0.0
	3/5/01	0	2.4	17.7	2.4	0.0	3/5/01			
	4/5/01	0	2.0	19.8	2.0	0.0	4/5/01			

Meteorological balance		DAILY DATA						Weekly Totals (mm/week)		
2001		meas.	calc.	calc.	calc.	mm/d		for each week ending on a Wednesday		
	DATE	RF mm/d	Eto (mm/d)	SMD (mm)	Et (mm/d)	Effective RF	DATE			
	5/5/01	0	2.8	22.5	2.8	0.0	5/5/01	RF	Et	Eff. RF
	6/5/01	0	2.5	25.1	2.5	0.0	6/5/01			
	7/5/01	0	3.2	28.3	3.2	0.0	7/5/01			
	8/5/01	0	**3.6**	**31.9**	**3.6**	0.0	8/5/01			
wed	9/5/01	0.8	**2.3**	**33.4**	**2.3**	0.0	9/5/01	0.0	19.4	0.0
	10/5/01	0	**3.1**	**36.4**	**3.0**	0.0	10/5/01			
	11/5/01	0	**3.2**	**39.3**	**3.0**	0.0	11/5/01			
	12/5/01	0	**3.5**	**42.5**	**3.1**	0.0	12/5/01			
	13/05/01	2.2	**2.8**	**42.7**	**2.4**	0.0	13/05/01			
	14/05/01	0	**3.3**	**45.5**	**2.8**	0.0	14/05/01			
	15/05/01	2.2	**3.0**	**45.8**	**2.5**	0.0	15/05/01			
wed	16/05/01	2.8	**1.4**	**44.1**	**1.2**	0.0	16/05/01	5.2	19.1	0.0
	17/05/01	0.3	**2.9**	**46.3**	**2.5**	0.0	17/05/01			
	18/05/01	0	**2.3**	**48.2**	**1.9**	0.0	18/05/01			
	19/05/01	0	**2.0**	**49.8**	**1.6**	0.0	19/05/01			
	20/05/01	0	**2.9**	**52.0**	**2.2**	0.0	20/05/01			
	21/05/01	0	**3.7**	**54.9**	**2.8**	0.0	21/05/01			
	22/05/01	0	**3.8**	**57.6**	**2.8**	0.0	22/05/01			
wed	23/05/01	0	**4.2**	**60.5**	**2.9**	0.0	23/05/01	3.1	14.9	0.0
	24/05/01	0.1	**4.0**	**63.0**	**2.6**	0.0	24/05/01			
	25/05/01	2.2	**1.8**	**62.0**	**1.2**	0.0	25/05/01			
	26/05/01	16.9	**2.0**	**46.4**	**1.3**	0.0	26/05/01			
	27/05/01	1	**2.9**	**47.8**	**2.4**	0.0	27/05/01			
	28/05/01	0	**3.7**	**50.8**	**3.0**	0.0	28/05/01			
	29/05/01	0	**4.1**	**53.9**	**3.2**	0.0	29/05/01			
wed	30/05/01	2	**3.4**	**54.5**	**2.5**	0.0	30/05/01	20.2	16.5	0.0
	31/05/01	0	**2.7**	**56.4**	**2.0**	0.0	31/05/01			
	1/6/01	0.1	**2.8**	**58.3**	**2.0**	0.0	1/6/01			
	2/6/01	0	**2.3**	**59.9**	**1.6**	0.0	2/6/01			
	3/6/01	0	**3.5**	**62.2**	**2.4**	0.0	3/6/01			
	4/6/01	0	**2.7**	**63.9**	**1.7**	0.0	4/6/01			
	5/6/01	0	**3.4**	**66.1**	**2.1**	0.0	5/6/01			
wed	6/6/01	1.5	**2.6**	**66.1**	**1.6**	0.0	6/6/01	2.1	14.3	0.0
	7/6/01	0.6	**3.3**	**67.5**	**2.0**	0.0	7/6/01			
	8/6/01	0	**3.6**	**69.6**	**2.1**	0.0	8/6/01			
	9/6/01	0	**2.6**	**71.1**	**1.5**	0.0	9/6/01			
	10/6/01	0	**3.4**	**73.0**	**1.9**	0.0	10/6/01			
	11/6/01	0	**2.0**	**74.0**	**1.0**	0.0	11/6/01			
	12/6/01	0	**2.1**	**75.1**	**1.1**	0.0	12/6/01			
wed	13/06/01	1.2	**2.2**	**75.0**	**1.1**	0.0	13/06/01	2.1	11.1	0.0
	14/06/01	16.8	**1.8**	**59.1**	**0.9**	0.0	14/06/01			
	15/06/01	1.7	**2.3**	**58.9**	**1.5**	0.0	15/06/01			
	16/06/01	0.7	**2.4**	**59.8**	**1.6**	0.0	16/06/01			
	17/06/01	0.6	**3.1**	**61.3**	**2.0**	0.0	17/06/01			
	18/06/01	5.6	**2.2**	**57.1**	**1.4**	0.0	18/06/01			
	19/06/01	0.1	**2.4**	**58.7**	**1.7**	0.0	19/06/01			
wed	20/06/01	0	**3.8**	**61.3**	**2.6**	0.0	20/06/01	26.7	10.3	0.0
	21/06/01	0	**4.2**	**64.1**	**2.8**	0.0	21/06/01			
	22/06/01	0	**2.2**	**65.4**	**1.3**	0.0	22/06/01			
	23/06/01	0	**2.5**	**66.9**	**1.5**	0.0	23/06/01			
	24/06/01	0	**3.9**	**69.2**	**2.3**	0.0	24/06/01			
	25/06/01	0	**3.4**	**71.1**	**1.9**	0.0	25/06/01			
	26/06/01	8.3	**2.4**	**64.1**	**1.3**	0.0	26/06/01			
wed	27/06/01	1.9	**3.2**	**64.2**	**2.0**	0.0	27/06/01	8.3	13.7	0.0
	28/06/01	6.9	**2.2**	**58.7**	**1.4**	0.0	28/06/01			
	29/06/01	3.4	**3.4**	**57.6**	**2.3**	0.0	29/06/01			
	30/06/01	0	**3.3**	**59.9**	**2.3**	0.0	30/06/01			
	1/7/01	0	**4.2**	**62.8**	**2.8**	0.0	1/7/01			
	2/7/01	0	**3.4**	**64.9**	**2.2**	0.0	2/7/01			
	3/7/01	1.5	**2.0**	**64.6**	**1.2**	0.0	3/7/01			
wed	4/7/01	0	**2.1**	**65.9**	**1.3**	0.0	4/7/01	13.7	14.2	0.0
	5/7/01	0	**2.6**	**67.5**	**1.5**	0.0	5/7/01			

Meteorological balance			DAILY DATA					Weekly Totals (mm/week)		
2001		meas.	calc.	calc.	calc.	mm/d		for each week ending on a		
	DATE	RF mm/d	Eto (mm/d)	SMD (mm)	Et (mm/d)	Effective RF	DATE	Wednesday		
	6/7/01	0	3.1	69.2	1.8	0.0	6/7/01	RF	Et	Eff. RF
	7/7/01	0	2.2	70.5	1.2	0.0	7/7/01			
	8/7/01	0	2.2	71.7	1.2	0.0	8/7/01			
	9/7/01	1.6	2.7	71.5	1.4	0.0	9/7/01			
	10/7/01	0.2	3.4	73.1	1.8	0.0	10/7/01			
wed	11/7/01	0.5	2.8	74.1	1.5	0.0	11/7/01	1.8	10.3	0.0
	12/7/01	0	3.2	75.7	1.6	0.0	12/7/01			
	13/07/01	7.6	3.5	69.8	1.7	0.0	13/07/01			
	14/07/01	2.7	2.8	68.7	1.6	0.0	14/07/01			
	15/07/01	0	3.0	70.4	1.7	0.0	15/07/01			
	16/07/01	19.9	3.3	52.3	1.8	0.0	16/07/01			
	17/07/01	5.5	2.2	48.5	1.7	0.0	17/07/01			
wed	18/07/01	0	2.2	50.3	1.8	0.0	18/07/01	36.2	11.6	0.0
	19/07/01	2.6	2.9	49.9	2.2	0.0	19/07/01			
	20/07/01	4.5	3.5	48.2	2.8	0.0	20/07/01			
	21/07/01	0.3	2.6	49.9	2.0	0.0	21/07/01			
	22/07/01	0	2.4	51.8	1.9	0.0	22/07/01			
	23/07/01	0.1	2.6	53.7	2.0	0.0	23/07/01			
	24/07/01	0	2.3	55.4	1.7	0.0	24/07/01			
wed	25/07/01	0	2.6	57.2	1.9	0.0	25/07/01	7.5	14.4	0.0
	26/07/01	0	3.1	59.4	2.2	0.0	26/07/01			
	27/07/01	0	3.6	61.8	2.4	0.0	27/07/01			
	28/07/01	0	3.6	64.1	2.3	0.0	28/07/01			
	29/07/01	0	3.8	66.5	2.3	0.0	29/07/01			
	30/07/01	0	3.4	68.5	2.0	0.0	30/07/01			
	31/07/01	0	3.3	70.4	1.9	0.0	31/07/01			
wed	1/8/01	0	3.1	72.1	1.7	0.0	1/8/01	0.0	15.0	0.0
	2/8/01	7.2	3.1	66.5	1.7	0.0	2/8/01			
	3/8/01	2.9	2.7	65.2	1.6	0.0	3/8/01			
	4/8/01	0	3.0	67.1	1.8	0.0	4/8/01			
	5/8/01	2.3	2.8	66.4	1.6	0.0	5/8/01			
	6/8/01	10.2	2.1	57.5	1.3	0.0	6/8/01			
	7/8/01	4.3	2.6	55.0	1.8	0.0	7/8/01			
wed	8/8/01	0.4	2.4	56.3	1.8	0.0	8/8/01	26.9	11.5	0.0
	9/8/01	0	3.1	58.5	2.2	0.0	9/8/01			
	10/8/01	1	2.7	59.4	1.8	0.0	10/8/01			
	11/8/01	0.6	2.0	60.1	1.4	0.0	11/8/01			
	12/8/01	0	1.9	61.4	1.3	0.0	12/8/01			
	13/08/01	3.1	1.7	59.4	1.1	0.0	13/08/01			
	14/08/01	36.8	1.7	23.7	1.1	0.0	14/08/01			
wed	15/08/01	1.3	2.5	24.9	2.5	0.0	15/08/01	41.9	10.6	0.0
	16/08/01	1.9	2.6	25.6	2.6	0.0	16/08/01			
	17/08/01	5.8	1.9	21.7	1.9	0.0	17/08/01			
	18/08/01	3.4	1.6	19.9	1.6	0.0	18/08/01			
	19/08/01	0.2	2.4	22.1	2.4	0.0	19/08/01			
	20/08/01	6.2	2.8	18.7	2.8	0.0	20/08/01			
	21/08/01	3.2	2.3	17.8	2.3	0.0	21/08/01			
wed	22/08/01	0	2.3	20.1	2.3	0.0	22/08/01	22.0	16.1	0.0
	23/08/01	0	2.4	22.6	2.4	0.0	23/08/01			
	24/08/01	1.8	2.2	23.0	2.2	0.0	24/08/01			
	25/08/01	0	2.7	25.7	2.7	0.0	25/08/01			
	26/08/01	0	3.0	28.7	3.0	0.0	26/08/01			
	27/08/01	0	2.8	31.5	2.8	0.0	27/08/01			
	28/08/01	0	2.7	34.2	2.7	0.0	28/08/01			
wed	29/08/01	1.3	2.2	35.0	2.1	0.0	29/08/01	1.8	18.1	0.0
	30/08/01	0.7	2.1	36.3	2.0	0.0	30/08/01			
	31/08/01	3.8	2.5	34.8	2.3	0.0	31/08/01			
	1/9/01	0.3	2.4	36.8	2.2	0.0	1/9/01			
	2/9/01	0	1.4	38.0	1.3	0.0	2/9/01			
	3/9/01	3.7	2.0	36.2	1.8	0.0	3/9/01			
	4/9/01	0.1	2.2	38.1	2.0	0.0	4/9/01			
wed	5/9/01	0.2	2.0	39.7	1.8	0.0	5/9/01	9.9	13.9	0.0

Meteorological balance			DAILY DATA					Weekly Totals (mm/week) for each week ending on a Wednesday		
2001		meas.	calc.	calc.	calc.	mm/d				
	DATE	RF mm/d	Eto (mm/d)	SMD (mm)	Et (mm/d)	Effective RF	DATE	RF	Et	Eff. RF
	6/9/01	0	**2.5**	**42.0**	**2.3**	0.0	6/9/01			
	7/9/01	0	**2.1**	**43.8**	**1.8**	0.0	7/9/01			
	8/9/01	0	**2.0**	**45.5**	**1.7**	0.0	8/9/01			
	9/9/01	0	**2.4**	**47.5**	**2.0**	0.0	9/9/01			
	10/9/01	0	**2.4**	**49.5**	**2.0**	0.0	10/9/01			
	11/9/01	0	**1.9**	**50.9**	**1.4**	0.0	11/9/01			
wed	12/9/01	2.1	**1.7**	**50.1**	**1.3**	0.0	12/9/01	0.2	13.0	0.0
	13/09/01	0.7	**1.9**	**50.9**	**1.5**	0.0	13/09/01			
	14/09/01	0.2	**1.6**	**51.9**	**1.2**	0.0	14/09/01			
	15/09/01	0	**1.8**	**53.3**	**1.3**	0.0	15/09/01			
	16/09/01	0	**1.9**	**54.7**	**1.4**	0.0	16/09/01			
	17/09/01	0	**1.8**	**56.0**	**1.3**	0.0	17/09/01			
	18/09/01	0	**2.3**	**57.6**	**1.6**	0.0	18/09/01			
wed	19/09/01	0	**2.2**	**59.1**	**1.5**	0.0	19/09/01	3.0	9.7	0.0
	20/09/01	0	**1.2**	**60.0**	**0.8**	0.0	20/09/01			
	21/09/01	0	**0.9**	**60.5**	**0.6**	0.0	21/09/01			
	22/09/01	0	**0.9**	**61.1**	**0.6**	0.0	22/09/01			
	23/09/01	0	**1.2**	**61.9**	**0.8**	0.0	23/09/01			
	24/09/01	20	**1.5**	**42.8**	**0.9**	0.0	24/09/01			
	25/09/01	6.7	**1.2**	**37.2**	**1.0**	0.0	25/09/01			
wed	26/09/01	11.4	1.6	27.2	1.5	0.0	26/09/01	26.7	6.2	0.0
	27/09/01	2.3	1.2	26.1	1.2	0.0	27/09/01			
	28/09/01	8.7	0.9	18.3	0.9	0.0	28/09/01			
	29/09/01	9.1	1.5	10.8	1.5	0.0	29/09/01			
	30/09/01	8.1	1.3	4.0	1.3	0.0	30/09/01			
hydr y	1/10/01	1.5	1.4	3.8	1.4	0.0	1/10/01			
	2/10/01	0.7	1.5	4.6	1.5	0.0	2/10/01			
wed	3/10/01	1.3	1.6	4.9	1.6	0.0	3/10/01	41.8	9.3	0.0
	4/10/01	13.4	1.1	0.0	1.1	7.4	4/10/01			
	5/10/01	9.8	1.0	0.0	1.0	8.8	5/10/01			
	6/10/01	4	1.3	0.0	1.3	2.7	6/10/01			
	7/10/01	2	0.9	0.0	0.9	1.1	7/10/01			
	8/10/01	0.4	1.6	1.2	1.6	0.0	8/10/01			
	9/10/01	0	1.2	2.5	1.2	0.0	9/10/01			
wed	10/10/01	0	1.0	3.5	1.0	0.0	10/10/01	30.9	8.8	19.9
	11/10/01	0.2	1.3	4.6	1.3	0.0	11/10/01			
	12/10/01	0	0.7	5.2	0.7	0.0	12/10/01			
	13/10/01	1.3	0.6	4.6	0.6	0.0	13/10/01			
	14/10/01	5.2	1.0	0.4	1.0	0.0	14/10/01			
	15/10/01	15.1	0.9	0.0	0.9	13.8	15/10/01			
	16/10/01	11.5	1.2	0.0	1.2	10.3	16/10/01			
wed	17/10/01	7	0.9	0.0	0.9	6.1	17/10/01	33.3	6.7	24.1
	18/10/01	0.7	1.0	0.3	1.0	0.0	18/10/01			
	19/10/01	19.6	0.7	0.0	0.7	18.6	19/10/01			
	20/10/01	0	0.5	0.5	0.5	0.0	20/10/01			
	21/10/01	0.5	0.6	0.6	0.6	0.0	21/10/01			
	22/10/01	16.1	1.0	0.0	1.0	14.5	22/10/01			
	23/10/01	2.2	1.0	0.0	1.0	1.2	23/10/01			
wed	24/10/01	2.4	0.9	0.0	0.9	1.5	24/10/01	46.1	5.6	40.5
	25/10/01	1.6	0.9	0.0	0.9	0.7	25/10/01			
	26/10/01	0.8	0.8	0.0	0.8	0.0	26/10/01			
	27/10/01	0	0.3	0.3	0.3	0.0	27/10/01			
	28/10/01	0	0.7	1.0	0.7	0.0	28/10/01			
	29/10/01	0	1.4	2.4	1.4	0.0	29/10/01			
	30/10/01	2.9	0.9	0.4	0.9	0.0	30/10/01			
wed	31/10/01	0	0.5	0.9	0.5	0.0	31/10/01	7.7	5.9	2.2
	1/11/01	0	0.8	1.7	0.8	0.0	1/11/01			
	2/11/01	0	0.6	2.3	0.6	0.0	2/11/01			
	3/11/01	0	0.6	2.9	0.6	0.0	3/11/01			
	4/11/01	0.5	0.7	3.2	0.7	0.0	4/11/01			
	5/11/01	1.8	1.0	2.3	1.0	0.0	5/11/01			
	6/11/01	3.4	0.7	0.0	0.7	0.3	6/11/01			

Meteorological balance			DAILY DATA					Weekly Totals (mm/week) for each week ending on a Wednesday		
2001		meas.	calc.	calc.	calc.	mm/d				
	DATE	RF mm/d	Eto (mm/d)	SMD (mm)	Et (mm/d)	Effective RF	DATE	RF	Et	Eff. RF
wed	7/11/01	3.9	0.4	0.0	0.4	3.5	7/11/01	5.7	4.9	0.3
	8/11/01	0	0.3	0.3	0.3	0.0	8/11/01			
	9/11/01	1.6	0.4	0.0	0.4	0.9	9/11/01			
	10/11/01	0	0.2	0.2	0.2	0.0	10/11/01			
	11/11/01	2.4	0.9	0.0	0.9	1.3	11/11/01			
	12/11/01	0	0.6	0.6	0.6	0.0	12/11/01			
	13/11/01	0	0.1	0.6	0.1	0.0	13/11/01			
wed	14/11/01	0	0.2	0.8	0.2	0.0	14/11/01	7.9	2.8	5.7
	15/11/01	0	0.4	1.3	0.4	0.0	15/11/01			
	16/11/01	0	0.5	1.8	0.5	0.0	16/11/01			
	17/11/01	0	0.3	2.1	0.3	0.0	17/11/01			
	18/11/01	0	0.3	2.4	0.3	0.0	18/11/01			
	19/11/01	0	0.1	2.5	0.1	0.0	19/11/01			
	20/11/01	0.1	0.9	3.4	0.9	0.0	20/11/01			
wed	21/11/01	0.1	0.8	4.1	0.8	0.0	21/11/01	0.1	2.9	0.0
	22/11/01	0.3	0.2	4.0	0.2	0.0	22/11/01			
	23/11/01	0	0.5	4.5	0.5	0.0	23/11/01			
	24/11/01	2.9	0.8	2.5	0.8	0.0	24/11/01			
	25/11/01	0	0.1	2.5	0.1	0.0	25/11/01			
	26/11/01	0.4	0.6	2.8	0.6	0.0	26/11/01			
	27/11/01	1.1	0.7	2.4	0.7	0.0	27/11/01			
wed	28/11/01	7.6	1.0	0.0	1.0	4.2	28/11/01	4.8	3.8	0.0
	29/11/01	3.3	1.0	0.0	1.0	2.3	29/11/01			
	30/11/01	0.1	0.5	0.4	0.5	0.0	30/11/01	26.2	20.4	8.3
	1/12/01	0.4	0.1	0.1	0.1	0.0	1/12/01			
	2/12/01	6.5	0.7	0.0	0.7	5.7	2/12/01			
	3/12/01	31.1	0.8	0.0	0.8	30.3	3/12/01			
	4/12/01	9.4	0.8	0.0	0.8	8.6	4/12/01			
wed	5/12/01	0.9	0.4	0.0	0.4	0.5	5/12/01	58.4	4.9	51.1
	6/12/01	3.5	0.9	0.0	0.9	2.6	6/12/01			
	7/12/01	1.4	0.5	0.0	0.5	0.9	7/12/01			
	8/12/01	0	0.2	0.2	0.2	0.0	8/12/01			
	9/12/01	0	0.5	0.7	0.5	0.0	9/12/01			
	10/12/01	0	0.2	1.0	0.2	0.0	10/12/01			
	11/12/01	0	0.0	0.9	0.0	0.0	11/12/01			
wed	12/12/01	0	0.2	1.2	0.2	0.0	12/12/01	5.8	2.7	4.0
	13/12/01	0	0.7	1.9	0.7	0.0	13/12/01			
	14/12/01	0	0.1	2.0	0.1	0.0	14/12/01			
	15/12/01	0	0.6	2.6	0.6	0.0	15/12/01			
	16/12/01	0	0.8	3.4	0.8	0.0	16/12/01			
	17/12/01	0	0.1	3.5	0.1	0.0	17/12/01			
	18/12/01	0	0.4	3.9	0.4	0.0	18/12/01			
wed	19/12/01	0	0.4	4.3	0.4	0.0	19/12/01	0.0	3.0	0.0
	20/12/01	0	0.1	4.4	0.1	0.0	20/12/01			
	21/12/01	3	0.8	2.2	0.8	0.0	21/12/01			
	22/12/01	0	0.0	2.2	0.0	0.0	22/12/01			
	23/12/01	0	0.5	2.7	0.5	0.0	23/12/01			
	24/12/01	0.5	1.1	3.3	1.1	0.0	24/12/01			
	25/12/01	0	0.1	3.4	0.1	0.0	25/12/01			
wed	26/12/01	1.9	0.8	2.3	0.8	0.0	26/12/01	3.5	3.0	0.0
	27/12/01	2	1.0	1.3	1.0	0.0	27/12/01			
	28/12/01	4.7	0.1	0.0	0.1	3.2	28/12/01			
	29/12/01	0	0.1	0.1	0.1	0.0	29/12/01			
	30/12/01	0	0.3	0.4	0.3	0.0	30/12/01			
	31/12/01	0	0.2	0.6	0.2	0.0	31/12/01			
Annual Totals 2001		860.4			483.1	377.9	(mm)			

Meteorological balance		DAILY DATA						Weekly Totals (mm/week)		
2002		meas.	calc.	calc.	calc.	mm/d		for each week ending on a Wednesday		
	DATE	RF mm/d	Eto (mm/d)	SMD (mm)	Et (mm/d)	Effective RF	DATE	RF	Et	Eff. RF
	1/1/02	0	0.3	0.9	0.3	0.0	1/1/02			
wed	2/1/02	15.5	0.4	0.0	0.4	14.3	2/1/02	8.6	2.8	3.2
	3/1/02	3.2	0.3	0.0	0.3	2.9	3/1/02			
	4/1/02	16.3	0.2	0.0	0.2	16.1	4/1/02			
	5/1/02	0	0.4	0.4	0.4	0.0	5/1/02			
	6/1/02	0	0.4	0.8	0.4	0.0	6/1/02			
	7/1/02	0.6	0.1	0.4	0.1	0.0	7/1/02			
	8/1/02	2.9	0.1	0.0	0.1	2.4	8/1/02			
wed	9/1/02	0	0.0	0.0	0.0	0.0	9/1/02	38.5	2.0	35.6
	10/1/02	0	0.4	0.5	0.4	0.0	10/1/02			
	11/1/02	0.2	0.8	1.1	0.8	0.0	11/1/02			
	12/1/02	7.3	0.2	0.0	0.2	6.0	12/1/02			
	13/01/02	1	0.3	0.0	0.3	0.7	13/01/02			
	14/01/02	4.2	0.5	0.0	0.5	3.7	14/01/02			
	15/01/02	0	0.5	0.5	0.5	0.0	15/01/02			
wed	16/01/02	5.5	0.8	0.0	0.8	4.3	16/01/02	12.7	2.8	10.4
	17/01/02	0.8	0.3	0.0	0.3	0.5	17/01/02			
	18/01/02	9.7	1.0	0.0	1.0	8.7	18/01/02			
	19/01/02	1.2	0.9	0.0	0.9	0.3	19/01/02			
	20/01/02	3.1	0.9	0.0	0.9	2.2	20/01/02			
	21/01/02	3.6	0.3	0.0	0.3	3.3	21/01/02			
	22/01/02	25.7	0.7	0.0	0.7	25.0	22/01/02			
wed	23/01/02	3.8	0.8	0.0	0.8	3.0	23/01/02	49.6	4.9	44.2
	24/01/02	8.1	0.3	0.0	0.3	7.8	24/01/02			
	25/01/02	16.1	1.5	0.0	1.5	14.6	25/01/02			
	26/01/02	5	0.4	0.0	0.4	4.6	26/01/02			
	27/01/02	3	1.5	0.0	1.5	1.5	27/01/02			
	28/01/02	0	0.7	0.7	0.7	0.0	28/01/02			
	29/01/02	5.7	0.5	0.0	0.5	4.5	29/01/02			
wed	30/01/02	11	0.4	0.0	0.4	10.6	30/01/02	41.7	5.8	35.9
	31/01/02	20.8	1.4	0.0	1.4	19.4	31/01/02			
	1/2/02	7.6	1.3	0.0	1.3	6.3	1/2/02			
	2/2/02	12.2	0.6	0.0	0.6	11.6	2/2/02			
	3/2/02	9.7	0.8	0.0	0.8	8.9	3/2/02			
	4/2/02	4.6	1.1	0.0	1.1	3.5	4/2/02			
	5/2/02	4.1	0.5	0.0	0.5	3.6	5/2/02			
wed	6/2/02	3.7	0.8	0.0	0.8	2.9	6/2/02	70.0	6.1	63.9
	7/2/02	2.5	1.3	0.0	1.3	1.2	7/2/02			
	8/2/02	7.7	0.9	0.0	0.9	6.8	8/2/02			
	9/2/02	2.1	0.6	0.0	0.6	1.5	9/2/02			
	10/2/02	3.2	1.2	0.0	1.2	2.0	10/2/02			
	11/2/02	0.3	0.7	0.4	0.7	0.0	11/2/02			
	12/2/02	0	0.8	1.2	0.8	0.0	12/2/02			
wed	13/02/02	0	0.7	1.9	0.7	0.0	13/02/02	19.5	6.3	14.4
	14/02/02	0	0.2	2.1	0.2	0.0	14/02/02			
	15/02/02	0	0.9	2.9	0.9	0.0	15/02/02			
	16/02/02	0	0.7	3.6	0.7	0.0	16/02/02			
	17/02/02	0.6	0.9	3.9	0.9	0.0	17/02/02			
	18/02/02	1	1.1	4.0	1.1	0.0	18/02/02			
	19/02/02	5.8	1.3	0.0	1.3	0.5	19/02/02			
wed	20/02/02	0.5	0.7	0.2	0.7	0.0	20/02/02	7.4	5.7	0.5
	21/02/02	0.3	1.5	1.4	1.5	0.0	21/02/02			
	22/02/02	1.5	0.7	0.6	0.7	0.0	22/02/02			
	23/02/02	3.5	0.7	0.0	0.7	2.1	23/02/02			
	24/02/02	3.2	1.5	0.0	1.5	1.7	24/02/02			
	25/02/02	14.9	0.9	0.0	0.9	14.0	25/02/02			
	26/02/02	5.6	0.6	0.0	0.6	5.0	26/02/02			
wed	27/02/02	3.3	0.8	0.0	0.8	2.5	27/02/02	29.5	6.6	22.9
	28/02/02	6.7	1.3	0.0	1.3	5.4	28/02/02			
	1/3/02	0	0.8	0.8	0.8	0.0	1/3/02			
	2/3/02	0	1.2	2.0	1.2	0.0	2/3/02			
	3/3/02	0	0.8	2.7	0.8	0.0	3/3/02			

Meteorological balance			DAILY DATA					Weekly Totals (mm/week) for each week ending on a Wednesday		
2002		meas.	calc.	calc.	calc.	mm/d				
	DATE	RF mm/d	Eto (mm/d)	SMD (mm)	Et (mm/d)	Effective RF	DATE	RF	Et	Eff. RF
	4/3/02	0	0.7	3.5	0.7	0.0	4/3/02			
	5/3/02	0	1.3	4.8	1.3	0.0	5/3/02			
wed	6/3/02	0	1.7	6.5	1.7	0.0	6/3/02	10.0	6.8	8.0
	7/3/02	0	0.9	7.4	0.9	0.0	7/3/02			
	8/3/02	6.2	1.0	2.2	1.0	0.0	8/3/02			
	9/3/02	15.8	1.4	0.0	1.4	12.2	9/3/02			
	10/3/02	2.6	1.2	0.0	1.2	1.4	10/3/02			
	11/3/02	0	1.5	1.5	1.5	0.0	11/3/02			
	12/3/02	0	1.4	2.9	1.4	0.0	12/3/02			
wed	13/03/02	0	1.4	4.3	1.4	0.0	13/03/02	24.6	9.0	13.7
	14/03/02	0	1.2	5.5	1.2	0.0	14/03/02			
	15/03/02	1.9	0.9	4.5	0.9	0.0	15/03/02			
	16/03/02	0.8	1.5	5.2	1.5	0.0	16/03/02			
	17/03/02	7.5	1.1	0.0	1.1	1.1	17/03/02			
	18/03/02	5.7	1.1	0.0	1.1	4.6	18/03/02			
	19/03/02	0.8	1.2	0.4	1.2	0.0	19/03/02			
wed	20/03/02	8.4	1.2	0.0	1.2	6.8	20/03/02	16.7	8.5	5.7
	21/03/02	0.8	2.2	1.4	2.2	0.0	21/03/02			
	22/03/02	0.3	1.3	2.4	1.3	0.0	22/03/02			
	23/03/02	0.5	0.9	2.7	0.9	0.0	23/03/02			
	24/03/02	0.6	1.0	3.2	1.0	0.0	24/03/02			
	25/03/02	0	1.6	4.8	1.6	0.0	25/03/02			
	26/03/02	0	1.6	6.3	1.6	0.0	26/03/02			
wed	27/03/02	0	1.3	7.7	1.3	0.0	27/03/02	10.6	9.7	6.8
	28/03/02	0	1.4	9.1	1.4	0.0	28/03/02			
	29/03/02	0	1.7	10.7	1.7	0.0	29/03/02			
	30/03/02	1.6	1.7	10.8	1.7	0.0	30/03/02			
	31/03/02	1.9	1.5	10.4	1.5	0.0	31/03/02			
	1/4/02	0.5	1.5	11.4	1.5	0.0	1/4/02			
	2/4/02	7.2	1.4	5.6	1.4	0.0	2/4/02			
wed	3/4/02	0.2	2.0	7.4	2.0	0.0	3/4/02	11.2	10.5	0.0
	4/4/02	0	2.1	9.4	2.1	0.0	4/4/02			
	5/4/02	1.7	1.6	9.3	1.6	0.0	5/4/02			
	6/4/02	0	2.3	11.6	2.3	0.0	6/4/02			
	7/4/02	0	2.9	14.5	2.9	0.0	7/4/02			
	8/4/02	0	2.2	16.6	2.2	0.0	8/4/02			
	9/4/02	0	2.1	18.8	2.1	0.0	9/4/02			
wed	10/4/02	0	1.8	20.6	1.8	0.0	10/4/02	1.9	15.1	0.0
	11/4/02	0	2.0	22.5	2.0	0.0	11/4/02			
	12/4/02	0	1.8	24.3	1.8	0.0	12/4/02			
	13/4/02	0.4	2.1	26.0	2.1	0.0	13/4/02			
	14/4/02	0	2.2	28.2	2.2	0.0	14/4/02			
	15/4/02	0	2.1	30.3	2.1	0.0	15/4/02			
	16/4/02	11.9	1.5	19.8	1.5	0.0	16/4/02			
wed	17/4/02	7.1	1.3	14.0	1.3	0.0	17/4/02	12.3	13.3	0.0
	18/4/02	0.3	2.6	16.3	2.6	0.0	18/4/02			
	19/4/02	6.5	1.8	11.6	1.8	0.0	19/4/02			
	20/4/02	7.7	1.3	5.2	1.3	0.0	20/4/02			
	21/4/02	4.3	1.2	2.2	1.2	0.0	21/4/02			
	22/4/02	0	1.9	4.0	1.9	0.0	22/4/02			
	23/4/02	0.2	2.9	6.8	2.9	0.0	23/4/02			
wed	24/4/02	1	1.6	7.4	1.6	0.0	24/4/02	26.1	13.0	0.0
	25/4/02	2.9	2.2	6.7	2.2	0.0	25/4/02			
	26/4/02	0	2.3	9.0	2.3	0.0	26/4/02			
	27/4/02	10	1.7	0.7	1.7	0.0	27/4/02			
	28/4/02	9.6	1.8	0.0	1.8	7.2	28/4/02			
	29/4/02	11.7	2.3	0.0	2.3	9.4	29/4/02			
	30/4/02	1.4	2.2	0.8	2.2	0.0	30/4/02			
wed	1/5/02	0.5	2.3	2.7	2.3	0.0	1/5/02	36.6	14.1	16.5
	2/5/02	1	2.7	4.4	2.7	0.0	2/5/02			
	3/5/02	0	2.6	6.9	2.6	0.0	3/5/02			
	4/5/02	0	3.0	10.0	3.0	0.0	4/5/02			

Meteorological balance			DAILY DATA					Weekly Totals (mm/week) for each week ending on a Wednesday		
2002		meas.	calc.	calc.	calc.	mm/d				
	DATE	RF mm/d	Eto (mm/d)	SMD (mm)	Et (mm/d)	Effective RF	DATE	RF	Et	Eff. RF
	5/5/02	0	3.3	13.3	3.3	0.0	5/5/02			
	6/5/02	0	2.5	15.8	2.5	0.0	6/5/02			
	7/5/02	1.4	2.0	16.5	2.0	0.0	7/5/02			
wed	8/5/02	0	2.6	19.1	2.6	0.0	8/5/02	2.9	18.5	0.0
	9/5/02	0	2.4	21.4	2.4	0.0	9/5/02			
	10/5/02	0	2.0	23.5	2.0	0.0	10/5/02			
	11/5/02	0	3.0	26.5	3.0	0.0	11/5/02			
	12/5/02	20.6	2.0	7.8	2.0	0.0	12/5/02			
	13/5/02	2.4	2.3	7.8	2.3	0.0	13/5/02			
	14/5/02	1.3	2.2	8.7	2.2	0.0	14/5/02			
wed	15/5/02	0	1.9	10.5	1.9	0.0	15/5/02	24.3	16.5	0.0
	16/5/02	8.4	2.2	4.4	2.2	0.0	16/5/02			
	17/5/02	0.8	2.1	5.6	2.1	0.0	17/5/02			
	18/5/02	3.3	2.9	5.2	2.9	0.0	18/5/02			
	19/5/02	17.3	2.6	0.0	2.6	9.5	19/5/02			
	20/5/02	4.3	2.7	0.0	2.7	1.6	20/5/02			
	21/5/02	14.7	2.0	0.0	2.0	12.7	21/5/02			
wed	22/5/02	3.7	2.6	0.0	2.6	1.1	22/5/02	48.8	16.3	23.8
	23/5/02	9.9	2.2	0.0	2.2	7.7	23/5/02			
	24/5/02	0.6	1.9	1.3	1.9	0.0	24/5/02			
	25/5/02	6.5	2.1	0.0	2.1	3.1	25/5/02			
	26/5/02	9.5	2.4	0.0	2.4	7.1	26/5/02			
	27/5/02	10.2	2.1	0.0	2.1	8.1	27/5/02			
	28/5/02	1.8	2.2	0.4	2.2	0.0	28/5/02			
wed	29/5/02	6.9	2.9	0.0	2.9	3.6	29/5/02	42.2	15.5	27.1
	30/5/02	0.6	3.2	2.6	3.2	0.0	30/5/02			
	31/5/02	0	2.5	5.1	2.5	0.0	31/5/02			
	1/6/02	3	2.2	4.3	2.2	0.0	1/6/02			
	2/6/02	5.3	2.9	2.0	2.9	0.0	2/6/02			
	3/6/02	0.3	3.0	4.7	3.0	0.0	3/6/02			
	4/6/02	1.3	2.4	5.7	2.4	0.0	4/6/02			
wed	5/6/02	0.5	3.5	8.7	3.5	0.0	5/6/02	17.4	19.2	3.6
	6/6/02	0	3.4	12.1	3.4	0.0	6/6/02			
	7/6/02	14.5	1.8	0.0	1.8	0.6	7/6/02			
	8/6/02	8.1	2.0	0.0	2.0	6.1	8/6/02			
	9/6/02	4.6	2.6	0.0	2.6	2.0	9/6/02			
	10/6/02	0	3.1	3.1	3.1	0.0	10/6/02			
	11/6/02	2.6	2.8	3.3	2.8	0.0	11/6/02			
wed	12/6/02	0	2.4	5.7	2.4	0.0	12/6/02	30.3	19.2	8.6
	13/6/02	7	2.4	1.1	2.4	0.0	13/6/02			
	14/6/02	1.2	3.0	2.8	3.0	0.0	14/6/02			
	15/6/02	0.7	2.1	4.2	2.1	0.0	15/6/02			
	16/6/02	16.3	2.1	0.0	2.1	10.0	16/6/02			
	17/6/02	0	3.0	3.0	3.0	0.0	17/6/02			
	18/6/02	0	2.9	5.9	2.9	0.0	18/6/02			
wed	19/6/02	0	2.9	8.7	2.9	0.0	19/6/02	25.2	17.8	10.0
	20/6/02	2.9	2.5	8.3	2.5	0.0	20/6/02			
	21/6/02	0	2.9	11.2	2.9	0.0	21/6/02			
	22/6/02	3.6	2.8	10.4	2.8	0.0	22/6/02			
	23/6/02	0	3.1	13.5	3.1	0.0	23/6/02			
	24/6/02	0	2.2	15.8	2.2	0.0	24/6/02			
	25/6/02	0	3.0	18.7	3.0	0.0	25/6/02			
wed	26/6/02	0	2.9	21.6	2.9	0.0	26/6/02	6.5	19.3	0.0
	27/6/02	0	3.3	24.9	3.3	0.0	27/6/02			
	28/6/02	0	3.1	28.0	3.1	0.0	28/6/02			
	29/6/02	1.5	2.9	29.4	2.9	0.0	29/6/02			
	30/6/02	4.1	2.6	27.9	2.6	0.0	30/6/02			
	1/7/02	2.8	3.2	28.3	3.2	0.0	1/7/02			
	2/7/02	7.9	1.9	22.4	1.9	0.0	2/7/02			
wed	3/7/02	0.3	3.4	25.5	3.4	0.0	3/7/02	16.3	19.9	0.0
	4/7/02	7.6	2.0	19.9	2.0	0.0	4/7/02			
	5/7/02	0	2.7	22.7	2.7	0.0	5/7/02			

Meteorological balance			DAILY DATA					Weekly Totals (mm/week) for each week ending on a Wednesday		
2002		meas.	calc.	calc.	calc.	mm/d				
	DATE	RF mm/d	Eto (mm/d)	SMD (mm)	Et (mm/d)	Effective RF	DATE	RF	Et	Eff. RF
	6/7/02	1.3	2.0	23.4	2.0	0.0	6/7/02			
	7/7/02	5.6	2.1	19.9	2.1	0.0	7/7/02			
	8/7/02	0	2.3	22.2	2.3	0.0	8/7/02			
	9/7/02	5.2	2.7	19.7	2.7	0.0	9/7/02			
wed	10/7/02	1.5	2.9	21.2	2.9	0.0	10/7/02	20.0	17.4	0.0
	11/7/02	4.5	2.5	19.2	2.5	0.0	11/7/02			
	12/7/02	1.3	2.8	20.7	2.8	0.0	12/7/02			
	13/7/02	0	3.5	24.2	3.5	0.0	13/7/02			
	14/7/02	0	3.0	27.3	3.0	0.0	14/7/02			
	15/7/02	0	2.7	29.9	2.7	0.0	15/7/02			
	16/7/02	0	2.9	32.8	2.9	0.0	16/7/02			
wed	17/7/02	0	3.0	35.7	2.9	0.0	17/7/02	7.3	20.4	0.0
	18/7/02	0	2.8	38.4	2.6	0.0	18/7/02			
	19/7/02	0	2.7	40.8	2.5	0.0	19/7/02			
	20/7/02	0	3.1	43.6	2.7	0.0	20/7/02			
	21/7/02	0	3.2	46.3	2.7	0.0	21/7/02			
	22/7/02	0.1	2.5	48.2	2.0	0.0	22/7/02			
	23/7/02	0	2.2	50.0	1.7	0.0	23/7/02			
wed	24/7/02	0	2.0	51.5	1.6	0.0	24/7/02	0.1	17.2	0.0
	25/7/02	0	3.1	53.9	2.3	0.0	25/7/02			
	26/7/02	2.2	2.9	53.8	2.1	0.0	26/7/02			
	27/7/02	1	2.4	54.5	1.7	0.0	27/7/02			
	28/7/02	5.3	2.2	50.8	1.6	0.0	28/7/02			
	29/7/02	1.5	2.2	51.0	1.7	0.0	29/7/02			
	30/7/02	0	2.7	53.1	2.1	0.0	30/7/02			
wed	31/7/02	0.6	2.3	54.2	1.7	0.0	31/7/02	10.0	13.1	0.0
	1/8/02	11	2.1	44.8	1.5	0.0	1/8/02			
	2/8/02	5.1	2.0	41.4	1.7	0.0	2/8/02			
	3/8/02	0	2.1	43.2	1.9	0.0	3/8/02			
	4/8/02	11.2	2.2	33.9	1.9	0.0	4/8/02			
	5/8/02	0	3.2	37.0	3.0	0.0	5/8/02			
	6/8/02	0.5	2.4	38.6	2.2	0.0	6/8/02			
wed	7/8/02	8.4	1.7	31.8	1.6	0.0	7/8/02	28.4	14.0	0.0
	8/8/02	6.8	1.9	26.9	1.9	0.0	8/8/02			
	9/8/02	0	2.5	29.5	2.5	0.0	9/8/02			
	10/8/02	3	2.8	29.3	2.8	0.0	10/8/02			
	11/8/02	0	2.1	31.4	2.1	0.0	11/8/02			
	12/8/02	3.1	2.6	30.9	2.6	0.0	12/8/02			
	13/8/02	0.9	2.1	32.1	2.1	0.0	13/8/02			
wed	14/8/02	2.9	1.6	30.8	1.6	0.0	14/8/02	22.2	15.7	0.0
	15/8/02	0	3.0	33.8	3.0	0.0	15/8/02			
	16/8/02	3.1	2.9	33.4	2.7	0.0	16/8/02			
	17/8/02	0.1	2.9	36.1	2.8	0.0	17/8/02			
	18/8/02	0	2.2	38.2	2.1	0.0	18/8/02			
	19/8/02	0	2.4	40.3	2.1	0.0	19/8/02			
	20/8/02	0	3.0	43.0	2.7	0.0	20/8/02			
wed	21/8/02	0	2.9	45.5	2.5	0.0	21/8/02	6.1	17.0	0.0
	22/8/02	0	2.2	47.3	1.8	0.0	22/8/02			
	23/8/02	0.3	3.1	49.6	2.5	0.0	23/8/02			
	24/8/02	0	2.2	51.3	1.7	0.0	24/8/02			
	25/8/02	0	2.5	53.2	1.9	0.0	25/8/02			
	26/8/02	0	3.4	55.7	2.5	0.0	26/8/02			
	27/8/02	0	2.1	57.2	1.5	0.0	27/8/02			
wed	28/8/02	0.2	2.0	58.4	1.4	0.0	28/8/02	0.3	14.5	0.0
	29/8/02	1.1	2.8	59.2	1.9	0.0	29/8/02			
	30/8/02	0	2.0	60.6	1.3	0.0	30/8/02			
	31/8/02	0	1.9	61.8	1.2	0.0	31/8/02			
	1/9/02	0	2.6	63.5	1.7	0.0	1/9/02			
	2/9/02	0	2.5	65.1	1.6	0.0	2/9/02			
	3/9/02	0	2.0	66.3	1.2	0.0	3/9/02			
wed	4/9/02	0	2.3	67.6	1.4	0.0	4/9/02	1.3	10.4	0.0
	5/9/02	0	2.2	68.9	1.3	0.0	5/9/02			

Meteorological balance			DAILY DATA					Weekly Totals (mm/week)		
2002		meas.	calc.	calc.	calc.	mm/d		for each week ending on a Wednesday		
	DATE	RF mm/d	Eto (mm/d)	SMD (mm)	Et (mm/d)	Effective RF	DATE	RF	Et	Eff. RF
	6/9/02	0	**1.8**	**70.0**	**1.0**	0.0	6/9/02			
	7/9/02	0.1	**2.3**	**71.1**	**1.3**	0.0	7/9/02			
	8/9/02	3.3	**1.8**	**68.8**	**1.0**	0.0	8/9/02			
	9/9/02	8.5	**1.9**	**61.4**	**1.1**	0.0	9/9/02			
	10/9/02	0	**2.1**	**62.8**	**1.4**	0.0	10/9/02			
wed	11/9/02	0	**2.0**	**64.1**	**1.3**	0.0	11/9/02	11.9	8.4	0.0
	12/9/02	0	**2.3**	**65.5**	**1.4**	0.0	12/9/02			
	13/9/02	0	**1.9**	**66.6**	**1.1**	0.0	13/9/02			
	14/9/02	0	**2.0**	**67.8**	**1.2**	0.0	14/9/02			
	15/9/02	0	**1.7**	**68.8**	**1.0**	0.0	15/9/02			
	16/9/02	0	**1.4**	**69.6**	**0.8**	0.0	16/9/02			
	17/9/02	0	**1.2**	**70.3**	**0.7**	0.0	17/9/02			
wed	18/9/02	0	**1.9**	**71.4**	**1.0**	0.0	18/9/02	0.0	7.5	0.0
	19/9/02	0	**1.6**	**72.2**	**0.9**	0.0	19/9/02			
	20/9/02	0	**1.6**	**73.1**	**0.9**	0.0	20/9/02			
	21/9/02	0	**1.9**	**74.1**	**1.0**	0.0	21/9/02			
	22/9/02	0	**1.3**	**74.7**	**0.7**	0.0	22/9/02			
	23/9/02	0	**1.8**	**75.6**	**0.9**	0.0	23/9/02			
	24/9/02	0	**1.8**	**76.5**	**0.9**	0.0	24/9/02			
wed	25/9/02	0	**1.7**	**77.3**	**0.8**	0.0	25/9/02	0.0	6.2	0.0
	26/9/02	0	**1.6**	**78.1**	**0.7**	0.0	26/9/02			
	27/9/02	0	**1.2**	**78.7**	**0.6**	0.0	27/9/02			
	28/9/02	0	**1.6**	**79.4**	**0.7**	0.0	28/9/02			
	29/9/02	3.6	**1.2**	**76.4**	**0.6**	0.0	29/9/02			
	30/9/02	5.7	**1.1**	**71.2**	**0.5**	0.0	30/9/02			
HYDR	1/10/02	3.6	**1.3**	**68.3**	**0.7**	0.0	1/10/02			
wed	2/10/02	3.1	**1.0**	**65.7**	**0.6**	0.0	2/10/02	12.9	4.7	0.0
	3/10/02	0	**1.5**	**66.7**	**0.9**	0.0	3/10/02			
	4/10/02	0	**1.6**	**67.6**	**0.9**	0.0	4/10/02			
	5/10/02	0	**1.4**	**68.4**	**0.8**	0.0	5/10/02			
	6/10/02	2.5	**1.3**	**66.6**	**0.7**	0.0	6/10/02			
	7/10/02	7.1	**1.0**	**60.1**	**0.6**	0.0	7/10/02			
	8/10/02	5.3	**0.7**	**55.3**	**0.5**	0.0	8/10/02			
wed	9/10/02	3.6	**0.8**	**52.3**	**0.6**	0.0	9/10/02	18.0	5.0	0.0
	10/10/02	7.8	**0.9**	**45.2**	**0.7**	0.0	10/10/02			
	11/10/02	1	**0.9**	**44.9**	**0.7**	0.0	11/10/02			
	12/10/02	0.4	**1.1**	**45.4**	**0.9**	0.0	12/10/02			
	13/10/02	4.8	**0.8**	**41.3**	**0.7**	0.0	13/10/02			
	14/10/02	0	**1.4**	**42.5**	**1.2**	0.0	14/10/02			
	15/10/02	0.2	**0.9**	**43.0**	**0.8**	0.0	15/10/02			
wed	16/10/02	0	**1.0**	**43.8**	**0.8**	0.0	16/10/02	17.8	5.5	0.0
	17/10/02	0.8	**1.3**	**44.1**	**1.1**	0.0	17/10/02			
	18/10/02	0	**1.0**	**44.9**	**0.8**	0.0	18/10/02			
	19/10/02	13.7	**1.2**	**32.2**	**1.0**	0.0	19/10/02			
	20/10/02	25.1	1.4	8.5	1.3	0.0	20/10/02			
	21/10/02	17.7	0.8	0.0	0.8	8.4	21/10/02			
	22/10/02	0.3	0.5	0.2	0.5	0.0	22/10/02			
wed	23/10/02	2.4	0.8	0.0	0.8	1.3	23/10/02	57.6	6.4	8.4
	24/10/02	22.5	1.2	0.0	1.2	21.3	24/10/02			
	25/10/02	0.9	1.3	0.4	1.3	0.0	25/10/02			
	26/10/02	17.4	1.6	0.0	1.6	15.4	26/10/02			
	27/10/02	0.6	0.6	0.0	0.6	0.0	27/10/02			
	28/10/02	20.2	0.8	0.0	0.8	19.4	28/10/02			
	29/10/02	1.8	1.1	0.0	1.1	0.7	29/10/02			
wed	30/10/02	0.2	0.5	0.3	0.5	0.0	30/10/02	65.8	7.6	58.0
	31/10/02	1.7	0.7	0.0	0.7	0.7	31/10/02			
	1/11/02	7.8	0.8	0.0	0.8	7.0	1/11/02			
	2/11/02	10.4	1.1	0.0	1.1	9.3	2/11/02			
	3/11/02	4	0.6	0.0	0.6	3.4	3/11/02			
	4/11/02	0.5	0.6	0.1	0.6	0.0	4/11/02			
	5/11/02	2.6	0.8	0.0	0.8	1.6	5/11/02			
wed	6/11/02	0.4	0.4	0.0	0.4	0.0	6/11/02	27.2	5.2	22.0

Year 2002

Meteorological balance			DAILY DATA					Weekly Totals (mm/week) for each week ending on a Wednesday		
2002		meas.	calc.	calc.	calc.	mm/d				
	DATE	RF mm/d	Eto (mm/d)	SMD (mm)	Et (mm/d)	Effective RF	DATE	RF	Et	Eff. RF
	7/11/02	3.8	1.0	0.0	1.0	2.7	7/11/02			
	8/11/02	0.7	0.9	0.2	0.9	0.0	8/11/02			
	9/11/02	5.4	0.5	0.0	0.5	4.6	9/11/02			
	10/11/02	0.7	0.6	0.0	0.6	0.1	10/11/02			
	11/11/02	6.3	0.4	0.0	0.4	5.9	11/11/02			
	12/11/02	0.2	0.7	0.5	0.7	0.0	12/11/02			
wed	13/11/02	0.6	0.4	0.3	0.4	0.0	13/11/02	17.5	4.6	13.4
	14/11/02	1.8	0.8	0.0	0.8	0.7	14/11/02			
	15/11/02	5.1	0.6	0.0	0.6	4.5	15/11/02			
	16/11/02	0	0.3	0.3	0.3	0.0	16/11/02			
	17/11/02	1.3	1.0	0.0	1.0	0.0	17/11/02			
	18/11/02	3.3	0.5	0.0	0.5	2.8	18/11/02			
	19/11/02	7.4	0.4	0.0	0.4	7.0	19/11/02			
wed	20/11/02	33	0.6	0.0	0.6	32.4	20/11/02	19.5	4.0	15.1
	21/11/02	3.7	0.5	0.0	0.5	3.2	21/11/02			
	22/11/02	2.2	0.6	0.0	0.6	1.6	22/11/02			
	23/11/02	10.1	0.6	0.0	0.6	9.5	23/11/02			
	24/11/02	10	0.3	0.0	0.3	9.7	24/11/02			
	25/11/02	9.5	0.4	0.0	0.4	9.1	25/11/02			
	26/11/02	33.6	0.4	0.0	0.4	33.2	26/11/02			
wed	27/11/02	5.1	0.3	0.0	0.3	4.8	27/11/02	102.1	3.4	98.7
	28/11/02	0.1	0.4	0.3	0.4	0.0	28/11/02			
	29/11/02	3.5	0.4	0.0	0.4	2.7	29/11/02			
	30/11/02	4.4	0.8	0.0	0.8	3.6	30/11/02			
	1/12/02	4.2	0.4	0.0	0.4	3.8	1/12/02			
	2/12/02	0.6	0.4	0.0	0.4	0.2	2/12/02			
	3/12/02	2.9	0.4	0.0	0.4	2.5	3/12/02			
wed	4/12/02	4.1	0.2	0.0	0.2	3.9	4/12/02	20.8	3.2	17.6
	5/12/02	0.0	0.1	0.1	0.1	0.0	5/12/02			
	6/12/02	0.0	0.1	0.2	0.1	0.0	6/12/02			
	7/12/02	2.0	0.7	0.0	0.7	1.1	7/12/02			
	8/12/02	0.0	0.5	0.5	0.5	0.0	8/12/02			
	9/12/02	0.0	0.2	0.6	0.2	0.0	9/12/02			
	10/12/02	0.0	0.3	1.0	0.3	0.0	10/12/02			
wed	11/12/02	0.0	0.4	1.4	0.4	0.0	11/12/02	6.1	2.1	5.0
	12/12/02	0.8	0.2	0.8	0.2	0.0	12/12/02			
	13/12/02	0.0	0.2	1.0	0.2	0.0	13/12/02			
	14/12/02	0.0	0.4	1.3	0.4	0.0	14/12/02			
	15/12/02	0.0	0.2	1.5	0.2	0.0	15/12/02			
	16/12/02	0.1	0.2	1.6	0.2	0.0	16/12/02			
	17/12/02	0.0	0.3	1.9	0.3	0.0	17/12/02			
wed	18/12/02	0.0	0.5	2.4	0.5	0.0	18/12/02	0.9	1.8	0.0
	19/12/02	2.3	0.5	0.7	0.5	0.0	19/12/02			
	20/12/02	3.7	0.5	0.0	0.5	2.6	20/12/02			
	21/12/02	6.3	0.2	0.0	0.2	6.1	21/12/02			
	22/12/02	18.9	0.4	0.0	0.4	18.5	22/12/02			
	23/12/02	20.5	0.5	0.0	0.5	20.0	23/12/02			
	24/12/02	0.9	0.2	0.0	0.2	0.7	24/12/02			
wed	25/12/02	11.1	0.3	0.0	0.3	10.8	25/12/02	52.6	2.9	47.8
	26/12/02	2.2	0.1	0.0	0.1	2.1	26/12/02			
	27/12/02	0.0	0.2	0.2	0.2	0.0	27/12/02			
	28/12/02	15.1	0.6	0.0	0.6	14.3	28/12/02			
	29/12/02	2.4	0.7	0.0	0.7	1.7	29/12/02			
	30/12/02	0.4	0.2	0.0	0.2	0.2	30/12/02			
	31/12/02	8.4	0.8	0.0	0.8	7.6	31/12/02			
Annual Totals 2002		1198.8			523.9	674.3	(mm)			

								Weekly Totals (mm/week)		
Meteorological balance			DAILY DATA					for each week ending on a Wednesday		
2003		meas.	calc.	calc.	calc.	mm/d				
	DATE	RF mm/d	Eto (mm/d)	SMD (mm)	Et (mm/d)	Effective RF	DATE	RF	Et	Eff. RF
wed	1/1/03	0.0	0.4	0.4	0.4	0.0	1/1/03	39.6	2.9	36.7
	2/1/03	0.9	0.7	0.1	0.7	0.0	2/1/03			
	3/1/03	0.0	0.1	0.3	0.1	0.0	3/1/03			
	4/1/03	0.0	0.0	0.3	0.0	0.0	4/1/03			
	5/1/03	1.0	0.1	0.0	0.1	0.7	5/1/03			
	6/1/03	0.4	0.5	0.1	0.5	0.0	6/1/03			
	7/1/03	0.0	0.2	0.3	0.2	0.0	7/1/03			
wed	8/1/03	0.0	0.1	0.4	0.1	0.0	8/1/03	2.3	1.9	0.7
	9/1/03	0.0	0.3	0.7	0.3	0.0	9/1/03			
	10/1/03	0.0	0.5	1.1	0.5	0.0	10/1/03			
	11/1/03	0.0	0.0	1.1	0.0	0.0	11/1/03			
	12/1/03	0.0	1.1	2.2	1.1	0.0	12/1/03			
	13/1/03	0.0	0.6	2.8	0.6	0.0	13/1/03			
	14/1/03	4.2	0.3	0.0	0.3	1.1	14/1/03			
wed	15/1/03	1.0	0.3	0.0	0.3	0.7	15/1/03	4.2	2.8	1.1
	16/1/03	13.9	1.2	0.0	1.2	12.7	16/1/03			
	17/1/03	0.7	0.2	0.0	0.2	0.5	17/1/03			
	18/1/03	10.3	0.5	0.0	0.5	9.8	18/1/03			
	19/1/03	12.4	0.5	0.0	0.5	11.9	19/1/03			
	20/1/03	4.8	0.3	0.0	0.3	4.5	20/1/03			
	21/1/03	0.0	0.6	0.6	0.6	0.0	21/1/03			
wed	22/1/03	0.0	0.3	0.8	0.3	0.0	22/1/03	43.1	3.6	40.1
	23/1/03	0.0	1.2	2.0	1.2	0.0	23/1/03			
	24/1/03	3.2	1.1	0.0	1.1	0.1	24/1/03			
	25/1/03	0.0	0.5	0.5	0.5	0.0	25/1/03			
	26/1/03	0.0	0.6	1.2	0.6	0.0	26/1/03			
	27/1/03	2.0	0.9	0.1	0.9	0.0	27/1/03			
Br day	28/1/03	5.5	0.5	0.0	0.5	4.9	28/1/03			
wed	29/1/03	0.1	0.5	0.4	0.5	0.0	29/1/03	10.7	5.1	5.1
	30/1/03	1.2	0.2	0.0	0.2	0.6	30/1/03			
	31/1/03	2.3	0.6	0.0	0.6	1.7	31/1/03			
	1/2/03	0.8	0.7	0.0	0.7	0.1	1/2/03			
	2/2/03	7.8	0.4	0.0	0.4	7.4	2/2/03			
	3/2/03	2.5	0.4	0.0	0.4	2.1	3/2/03			
	4/2/03	0.3	0.4	0.1	0.4	0.0	4/2/03			
wed	5/2/03	2.1	0.5	0.0	0.5	1.4	5/2/03	15.0	3.3	11.8
	6/2/03	0.4	0.6	0.2	0.6	0.0	6/2/03			
	7/2/03	0.0	0.6	0.8	0.6	0.0	7/2/03			
	8/2/03	8.3	0.5	0.0	0.5	7.0	8/2/03			
	9/2/03	3.6	0.8	0.0	0.8	2.8	9/2/03			
	10/2/03	6.6	0.7	0.0	0.7	5.9	10/2/03			
	11/2/03	0.0	1.0	1.0	1.0	0.0	11/2/03			
wed	12/2/03	0.0	0.1	1.1	0.1	0.0	12/2/03	21.0	4.6	17.2
	13/2/03	0.0	0.7	1.8	0.7	0.0	13/2/03			
	14/2/03	0.0	0.5	2.3	0.5	0.0	14/2/03			
	15/2/03	0.0	0.9	3.2	0.9	0.0	15/2/03			
	16/2/03	0.0	0.8	4.0	0.8	0.0	16/2/03			
	17/2/03	0.0	0.3	4.4	0.3	0.0	17/2/03			
	18/2/03	0.0	0.5	4.8	0.5	0.0	18/2/03			
wed	19/2/03	0.0	0.4	5.3	0.4	0.0	19/2/03	0.0	3.9	0.0
	20/2/03	1.3	0.5	4.5	0.5	0.0	20/2/03			
	21/2/03	0.0	1.0	5.4	1.0	0.0	21/2/03			
	22/2/03	5.8	0.9	0.5	0.9	0.0	22/2/03			
	23/2/03	0.0	0.8	1.4	0.8	0.0	23/2/03			
	24/2/03	1.9	1.0	0.4	1.0	0.0	24/2/03			
	25/2/03	6.7	0.6	0.0	0.6	5.6	25/2/03			
wed	26/2/03	0.4	0.6	0.2	0.6	0.0	26/2/03	15.7	5.2	5.6
	27/2/03	14	0.9	0.0	0.9	12.9	27/2/03			
	28/2/03	8.5	0.6	0.0	0.6	7.9	28/2/03			
	1/3/03	3.2	0.6	0.0	0.6	2.6	1/3/03			
	2/3/03	2.7	1.4	0.0	1.4	1.3	2/3/03			
	3/3/03	5.2	1.1	0.0	1.1	4.1	3/3/03			

								Weekly Totals (mm/week)		
Meteorological balance			DAILY DATA					for each week ending on a Wednesday		
2003		meas.	calc.	calc.	calc.	mm/d				
	DATE	RF mm/d	Eto (mm/d)	SMD (mm)	Et (mm/d)	Effective RF	DATE	RF	Et	Eff. RF
	4/3/03	1.7	1.1	0.0	1.1	0.6	4/3/03			
wed	5/3/03	0.2	1.2	1.0	1.2	0.0	5/3/03	35.7	6.4	29.3
	6/3/03	11.3	1.5	0.0	1.5	8.8	6/3/03			
	7/3/03	7.7	1.2	0.0	1.2	6.5	7/3/03			
	8/3/03	1.4	1.3	0.0	1.3	0.1	8/3/03			
	9/3/03	3.9	0.9	0.0	0.9	3.0	9/3/03			
	10/3/03	12.6	1.2	0.0	1.2	11.4	10/3/03			
	11/3/03	0	1.6	1.6	1.6	0.0	11/3/03			
wed	12/3/03	0	1.3	3.0	1.3	0.0	12/3/03	37.1	9.0	29.8
	13/3/03	0	1.0	3.9	1.0	0.0	13/3/03			
	14/3/03	0	0.9	4.9	0.9	0.0	14/3/03			
	15/3/03	0	1.4	6.2	1.4	0.0	15/3/03			
	16/3/03	0	1.4	7.7	1.4	0.0	16/3/03			
	17/3/03	0	1.7	9.3	1.7	0.0	17/3/03			
	18/3/03	0	1.5	10.8	1.5	0.0	18/3/03			
wed	19/3/03	0	1.4	12.2	1.4	0.0	19/3/03	0.0	9.2	0.0
	20/3/03	0	1.6	13.8	1.6	0.0	20/3/03			
	21/3/03	0	1.2	15.0	1.2	0.0	21/3/03			
	22/3/03	0	1.3	16.3	1.3	0.0	22/3/03			
	23/3/03	0	2.0	18.3	2.0	0.0	23/3/03			
	24/3/03	0	1.2	19.5	1.2	0.0	24/3/03			
	25/3/03	0	1.4	20.9	1.4	0.0	25/3/03			
wed	26/3/03	0	1.7	22.6	1.7	0.0	26/3/03	0.0	10.1	0.0
	27/3/03	0	1.6	24.2	1.6	0.0	27/3/03			
	28/3/03	1.2	1.0	24.0	1.0	0.0	28/3/03			
	29/3/03	5.4	1.9	20.5	1.9	0.0	29/3/03			
	30/3/03	0	1.9	22.4	1.9	0.0	30/3/03			
	31/3/03	4.7	2.3	20.0	2.3	0.0	31/3/03			
	1/4/03	0.3	1.4	21.2	1.4	0.0	1/4/03			
wed	2/4/03	0.5	1.9	22.6	1.9	0.0	2/4/03	11.6	11.9	0.0
	3/4/03	0	1.5	24.2	1.5	0.0	3/4/03			
	4/4/03	0	2.4	26.6	2.4	0.0	4/4/03			
	5/4/03	0	1.8	28.4	1.8	0.0	5/4/03			
	6/4/03	0	2.7	31.1	2.7	0.0	6/4/03			
	7/4/03	0	1.0	32.1	1.0	0.0	7/4/03			
	8/4/03	0	1.8	33.9	1.7	0.0	8/4/03			
wed	9/4/03	0	1.9	35.6	1.8	0.0	9/4/03	0.5	13.2	0.0
	10/4/03	0	1.3	36.9	1.2	0.0	10/4/03			
	11/4/03	0	1.7	38.5	1.6	0.0	11/4/03			
	12/4/03	3	1.3	36.6	1.2	0.0	12/4/03			
	13/4/03	28.4	2.1	10.2	2.0	0.0	13/4/03			
	14/4/03	0.3	1.2	11.1	1.2	0.0	14/4/03			
	15/4/03	0	1.6	12.7	1.6	0.0	15/4/03			
wed	16/4/03	0	2.1	14.9	2.1	0.0	16/4/03	31.7	10.6	0.0
	17/4/03	0	2.7	17.6	2.7	0.0	17/4/03			
	18/4/03	0	3.1	20.7	3.1	0.0	18/4/03			
	19/4/03	0	3.7	24.4	3.7	0.0	19/4/03			
	20/4/03	0	3.0	27.4	3.0	0.0	20/4/03			
	21/4/03	0	1.6	29.0	1.6	0.0	21/4/03			
	22/4/03	0	2.2	31.2	2.2	0.0	22/4/03			
wed	23/4/03	13.6	2.3	19.9	2.3	0.0	23/4/03	0.0	18.5	0.0
	24/4/03	32.6	2.4	0.0	2.4	10.3	24/4/03			
	25/4/03	2.2	2.4	0.2	2.4	0.0	25/4/03			
	26/4/03	3.6	2.4	0.0	2.4	1.0	26/4/03			
	27/4/03	8.8	2.1	0.0	2.1	6.7	27/4/03			
	28/4/03	0.5	1.6	1.1	1.6	0.0	28/4/03			
	29/4/03	2.5	2.5	1.2	2.5	0.0	29/4/03			
wed	30/4/03	4.7	2.1	0.0	2.1	1.4	30/4/03	63.8	15.8	18.0
	1/5/03	9.6	2.4	0.0	2.4	7.2	1/5/03			
	2/5/03	0.6	2.6	2.0	2.6	0.0	2/5/03			
	3/5/03	16.6	2.1	0.0	2.1	12.5	3/5/03			
	4/5/03	17.3	1.9	0.0	1.9	15.4	4/5/03			

Meteorological balance			DAILY DATA					Weekly Totals (mm/week) for each week ending on a Wednesday		
2003		meas.	calc.	calc.	calc.	mm/d				
	DATE	RF mm/d	Eto (mm/d)	SMD (mm)	Et (mm/d)	Effective RF	DATE	RF	Et	Eff. RF
	5/5/03	0.3	2.8	2.5	2.8	0.0	5/5/03			
	6/5/03	0.2	2.6	4.9	2.6	0.0	6/5/03			
wed	7/5/03	0	1.7	6.6	1.7	0.0	7/5/03	49.3	16.5	36.5
	8/5/03	0	2.6	9.3	2.6	0.0	8/5/03			
	9/5/03	1	2.9	11.2	2.9	0.0	9/5/03			
	10/5/03	0.3	2.8	13.6	2.8	0.0	10/5/03			
	11/5/03	3.1	2.7	13.2	2.7	0.0	11/5/03			
	12/5/03	7	3.0	9.2	3.0	0.0	12/5/03			
	13/5/03	0.4	3.1	12.0	3.1	0.0	13/5/03			
wed	14/5/03	2.5	3.0	12.4	3.0	0.0	14/5/03	11.8	18.9	0.0
	15/5/03	7.1	1.8	7.1	1.8	0.0	15/5/03			
	16/5/03	3.9	2.2	5.4	2.2	0.0	16/5/03			
	17/5/03	2.7	2.3	5.0	2.3	0.0	17/5/03			
	18/5/03	3.5	2.6	4.1	2.6	0.0	18/5/03			
	19/5/03	2.1	2.6	4.6	2.6	0.0	19/5/03			
	20/5/03	2.3	1.9	4.3	1.9	0.0	20/5/03			
wed	21/5/03	2.4	1.8	3.7	1.8	0.0	21/5/03	24.1	16.4	0.0
	22/5/03	0	1.8	5.4	1.8	0.0	22/5/03			
	23/5/03	2.7	3.2	5.9	3.2	0.0	23/5/03			
	24/5/03	0	2.9	8.9	2.9	0.0	24/5/03			
	25/5/03	0.9	2.0	10.0	2.0	0.0	25/5/03			
	26/5/03	3.2	1.8	8.6	1.8	0.0	26/5/03			
	27/5/03	1.6	1.7	8.8	1.7	0.0	27/5/03			
wed	28/5/03	2.6	1.8	8.0	1.8	0.0	28/5/03	10.8	15.3	0.0
	29/5/03	0	2.7	10.7	2.7	0.0	29/5/03			
	30/5/03	0	3.8	14.5	3.8	0.0	30/5/03			
	31/5/03	7.4	2.7	9.7	2.7	0.0	31/5/03			
	1/6/03	1.8	3.6	11.5	3.6	0.0	1/6/03			
	2/6/03	9.5	2.7	4.7	2.7	0.0	2/6/03			
	3/6/03	4.2	2.3	2.8	2.3	0.0	3/6/03			
wed	4/6/03	0	2.6	5.4	2.6	0.0	4/6/03	25.5	19.6	0.0
	5/6/03	6.4	2.0	1.1	2.0	0.0	5/6/03			
	6/6/03	0.7	3.5	3.8	3.5	0.0	6/6/03			
	7/6/03	0	3.1	7.0	3.1	0.0	7/6/03			
	8/6/03	1.5	3.2	8.7	3.2	0.0	8/6/03			
	9/6/03	39.7	2.0	0.0	2.0	29.1	9/6/03			
	10/6/03	3.2	2.9	0.0	2.9	0.3	10/6/03			
wed	11/6/03	1.8	2.6	0.8	2.6	0.0	11/6/03	51.5	19.2	29.4
	12/6/03	0	3.0	3.8	3.0	0.0	12/6/03			
	13/6/03	0	2.9	6.6	2.9	0.0	13/6/03			
	14/6/03	0	3.4	10.0	3.4	0.0	14/6/03			
	15/6/03	0	3.5	13.6	3.5	0.0	15/6/03			
	16/6/03	0	2.7	16.3	2.7	0.0	16/6/03			
	17/6/03	0	3.2	19.5	3.2	0.0	17/6/03			
wed	18/6/03	0	3.2	22.7	3.2	0.0	18/6/03	1.8	21.3	0.0
	19/6/03	0	2.1	24.8	2.1	0.0	19/6/03			
	20/6/03	0	3.8	28.6	3.8	0.0	20/6/03			
	21/6/03	0	3.0	**31.6**	3.0	0.0	21/6/03			
	22/6/03	0	2.1	**33.6**	2.1	0.0	22/6/03			
	23/6/03	0	2.7	**36.2**	2.6	0.0	23/6/03			
	24/6/03	0	2.8	**38.8**	2.6	0.0	24/6/03			
wed	25/6/03	0	3.3	**41.8**	3.0	0.0	25/6/03	0.0	19.3	0.0
	26/6/03	3.3	2.9	**41.1**	2.5	0.0	26/6/03			
	27/6/03	0	3.2	**43.9**	2.8	0.0	27/6/03			
	28/6/03	0	2.5	**46.0**	2.1	0.0	28/6/03			
	29/6/03	31.7	2.6	16.5	2.1	0.0	29/6/03			
	30/6/03	0.9	2.6	18.2	2.6	0.0	30/6/03			
	1/7/03	2.5	2.6	18.3	2.6	0.0	1/7/03			
wed	2/7/03	0	3.2	21.5	3.2	0.0	2/7/03			
	3/7/03	0	2.6	24.0	2.6	0	3/7/03			
	4/7/03	0	2.4	26.4	2.4	0	4/7/03			
	5/7/03	0	1.9	28.4	1.9	0	5/7/03			

								Weekly Totals (mm/week)		
Meteorological balance			DAILY DATA					for each week ending on a Wednesday		
2003		meas.	calc.	calc.	calc.	mm/d				
	DATE	RF mm/d	Eto (mm/d)	SMD (mm)	Et (mm/d)	Effective RF	DATE	RF	Et	Eff. RF
	6/7/03	0	2.0	**30.4**	2.0	0.0	6/7/03			
	7/7/03	0	2.1	**32.5**	2.1	0.0	7/7/03			
	8/7/03	0	2.8	**35.2**	2.7	0.0	8/7/03			
wed	9/7/03	0.7	2.4	**36.8**	2.2	0.0	9/7/03			
	10/7/03	0	3.7	**40.2**	3.4	0.0	10/7/03			
	11/7/03	0	3.3	**43.1**	2.9	0.0	11/7/03			
	12/7/03	0	3.3	**45.9**	2.8	0.0	12/7/03			
	13/7/03	0	2.2	**47.8**	1.8	0.0	13/7/03			
	14/7/03	0	2.6	**49.8**	2.1	0.0	14/7/03			
	15/7/03	0	2.2	**51.6**	1.7	0.0	15/7/03			
wed	16/7/03	32.5	2.3	20.8	1.7	0.0	16/7/03			
	17/7/03	0	3.6	24.4	3.6	0.0	17/7/03			
	18/7/03	11.9	2.6	15.2	2.6	0.0	18/7/03			
	19/7/03	3.3	3.2	15.0	3.2	0.0	19/7/03			
	20/7/03	3.4	2.8	14.4	2.8	0.0	20/7/03			
	21/7/03	0	2.9	17.4	2.9	0.0	21/7/03			
	22/7/03	2.5	2.1	17.0	2.1	0.0	22/7/03			
wed	23/7/03	0.9	2.5	18.6	2.5	0.0	23/7/03			
	24/7/03	4	1.9	16.6	1.9	0.0	24/7/03			
	25/7/03	0	2.6	19.2	2.6	0.0	25/7/03			
	26/7/03	0	2.7	21.9	2.7	0.0	26/7/03			
	27/7/03	5.6	3.1	19.4	3.1	0.0	27/7/03			
	28/7/03	2.2	2.3	19.5	2.3	0.0	28/7/03			
	29/7/03	3.3	2.5	18.8	2.5	0.0	29/7/03			
wed	30/7/03	13.8	2.9	7.8	2.9	0.0	30/7/03			
	31/7/03	0	3.0	10.8	3.0	0.0	31/7/03			
	1/8/03	0	2.9	13.7	2.9	0.0	1/8/03			
	2/8/03	0	3.8	17.5	3.8	0.0	2/8/03			
	3/8/03	0	2.4	19.9	2.4	0.0	3/8/03			
	4/8/03	0	3.0	22.9	3.0	0.0	4/8/03			
	5/8/03	0	3.5	26.5	3.5	0.0	5/8/03			
wed	6/8/03	0	3.5	29.9	3.5	0.0	6/8/03			
	7/8/03	0	3.9	33.8	3.9	0.0	7/8/03			
	8/8/03	0	3.8	37.4	3.6	0.0	8/8/03			
	9/8/03	0	4.2	41.3	3.9	0.0	9/8/03			
	10/8/03	0	4.0	44.8	3.5	0.0	10/8/03			
	11/8/03	0	3.7	47.9	3.1	0.0	11/8/03			
	12/8/03	0	3.0	50.4	2.4	0.0	12/8/03			
	13/8/03	0	3.4	53.0	2.6	0.0	13/8/03			
	14/8/03	0	3.8	55.8	2.8	0.0	14/8/03			
	15/8/03	0	2.6	57.7	1.9	0.0	15/8/03			
	16/8/03	0.4	3.1	59.5	2.2	0.0	16/8/03			
	17/8/03	0	2.5	61.1	1.7	0.0	17/8/03			
	18/8/03	0	2.9	63.0	1.9	0.0	18/8/03			
	19/8/03	0	2.1	64.4	1.3	0.0	19/8/03			
	20/8/03	0	2.3	65.8	1.4	0.0	20/8/03			
	21/8/03	0	3.0	67.6	1.8	0.0	21/8/03			
	22/8/03	0	2.0	68.8	1.2	0.0	22/8/03			
	23/8/03	0	2.0	69.9	1.2	0.0	23/8/03			
	24/8/03	0.2	3.6	71.7	2.0	0.0	24/8/03			
	25/8/03	0	2.1	72.8	1.2	0.0	25/8/03			
	26/8/03	1.9	1.6	71.8	0.9	0.0	26/8/03			
	27/8/03	0.1	3.5	73.6	1.9	0.0	27/8/03			
	28/8/03	0	2.5	74.9	1.3	0.0	28/8/03			
	29/8/03	0	3.4	76.6	1.7	0.0	29/8/03			
	30/8/03	0	2.6	77.8	1.3	0.0	30/8/03			
	31/8/03	0	2.2	78.9	1.0	0.0	31/8/03			
	1/9/03	2.6			70.7	0.0	1/9/03			

ACTUAL MONTHLY TOTALS _ SUMMED FROM DAILY DATA

Calendar Year

	2000			2001			2002			2003			
month	meas. RF	Et actual	Eff RF	meas. RF	Et actual	Eff RF	meas. RF	Et actual	Eff RF	meas. RF	Et actual	Eff RF	month
JAN	51.5	15.4	38.6	76.8	15.0	61.8	174.3	17.6	156.2	63.9	14.7	49.2	JAN
FEB	92.4	25.3	64.9	91.0	20.7	76.1	104.6	25.0	79.6	71.0	17.9	53.1	FEB
MAR	28.0	39.3	5.1	106.8	35.5	67.6	55.4	39.6	26.2	61.2	42.9	38.3	MAR
APR	51.2	54.2	0.0	73.0	58.5	21.7	84.6	58.5	16.5	101.0	61.6	19.4	APR
MAY	75.1	83.1	0.0	30.5	77.6	0.0	125.7	75.5	54.5	101.3	75.9	35.1	MAY
JUN	45.6	69.8	0.0	49.4	52.9	0.0	77.5	81.7	18.6	104.7	83.7	29.4	JUN
JUL	41.7	51.3	0.0	47.0	57.4	0.0	48.7	75.0	0.0				JUL
AUG	55.2	53.6	0.0	98.4	62.8	0.0	57.7	65.2	0.0				AUG
SEPT	107.9	38.8	12.1	73.6	42.8	0.0	21.2	30.6	0.0				SEPT
OCT	156.7	31.9	122.1	120.2	30.3	86.8	164.7	26.4	67.1				OCT
NOV	217.9	18.0	199.9	29.5	16.5	12.5	177.5	17.8	159.7				NOV
DEC	158.1	11.9	146.2	65.3	13.6	51.9	106.9	11.0	95.9				DEC
Totals (mm/yr)	1081.3		588.9	861.5		378.5	1198.8		674.3				

	Curtins farm monthly totals - RF, Et and Effective RF (Drainage) - deduced from weekly totals								
	2000 - 2001			2001 - 2002			2002 - 2003		
	Rainfall	Et	Effective RF	Rainfall	Et	Effective RF	Rainfall	Et	Effective RF
MONTH	(mm/mth)	(mm/mth)	(mm/mth)	(mm/mth)	(mm/mth)	(mm/mth)	(mm/mth)	(mm/mth)	(mm/mth)
OCT	181.1	37.4	134.2	159.8	36.2	86.8	172.1	29.2	66.4
NOV	183.7	16.7	167.0	18.5	14.5	6.0	166.3	17.1	149.2
DEC	198.0	14.0	184.0	76.3	16.3	58.4	120.0	12.9	107.1
JAN	67.4	13.3	55.1	142.5	15.5	126.1	60.3	13.4	46.9
FEB	93.6	20.2	77.3	126.4	24.8	101.6	51.7	17.1	34.6
MAR	112.0	40.8	67.6	73.1	44.5	34.2	84.4	46.6	59.0
APR	67.8	57.2	21.7	76.9	55.6	16.5	96.0	58.0	18.0
MAY	28.5	70.0	0.0	118.2	66.8	50.9	96.0	67.1	36.5
JUN	39.2	49.4	0.0	79.4	75.5	22.2	78.8	79.5	29.4
JULY	59.2	50.4	0.0	43.7	74.9	0.0	86.6	79.2	0.0
AUG	92.6	71.4	0.0	67.0	74.2	0.0	2.6	70.7	0.0
SEPT	39.8	42.8	0.0	13.2	32.5	0.0	40.9	30.7	0.0

Hydrological year 2000-2001						Hydrological year 2001 -2002					Hydrological year 2002-2003			
		Rainfall	Et actual	Drainage			Rainfall	Et actual	Drainage			Rainfall	Et actual	Drainage
Week	Ending	mm/week	mm/week	mm/week		Ending	mm/week	mm/week	mm/week		Ending	mm/week	mm/week	mm/week
wed	4/10/00	35.3	9.6	16.3		3/10/01	41.8	9.3	0.0		2/10/02	12.9	4.7	0.0
wed	11/10/00	28.9	7.9	21.0		10/10/01	30.9	8.8	19.9		9/10/02	18.0	5.0	0.0
wed	18/10/00	34.5	7.9	26.6		17/10/01	33.3	6.7	24.1		16/10/02	17.8	5.5	0.0
wed	25/10/00	29.0	6.4	22.6		24/10/01	46.1	5.6	40.5		23/10/02	57.6	6.4	8.4
wed	1/11/00	53.4	5.8	47.6		31/10/01	7.7	5.9	2.2		30/10/02	65.8	7.6	58.0
OCT		**181.1**	**37.4**	**134.2**		**OCT**	**159.8**	**36.2**	**86.8**		**OCT**	**172.1**	**29.2**	**66.4**
wed	8/11/00	87.9	4.6	83.3		7/11/01	5.7	4.9	0.3		6/11/02	27.2	5.2	22.0
wed	15/11/00	9.7	3.8	6.3		14/11/01	7.9	2.8	5.7		13/11/02	17.5	4.6	13.4
wed	22/11/00	28.2	3.9	23.9		21/11/01	0.1	2.9	0.0		20/11/02	19.5	4.0	15.1
wed	29/11/00	57.9	4.3	53.6		28/11/01	4.8	3.8	0.0		27/11/02	102.1	3.4	98.7
NOV		**183.7**	**16.7**	**167.0**		**NOV**	**18.5**	**14.5**	**6.0**		**NOV**	**166.3**	**17.1**	**149.2**
wed	6/12/00	67.1	3.2	63.9		5/12/01	58.4	4.9	51.1		4/12/02	20.8	3.2	17.6
wed	13/12/00	40.7	2.9	37.8		12/12/01	5.8	2.7	4.0		11/12/02	6.1	2.1	5.0
wed	20/12/00	29.2	2.7	26.5		19/12/01	0.0	3.0	0.0		18/12/02	0.9	1.8	0.0
wed	27/12/00	19.1	2.0	17.7		26/12/01	3.5	3.0	0.0		25/12/02	52.6	2.9	47.8
wed	3/1/01	41.9	3.3	38.0		2/1/02	8.6	2.8	3.2		1/1/03	39.6	2.9	36.7
DEC		**198.0**	**14.0**	**184.0**		**DEC**	**76.3**	**16.3**	**58.4**		**DEC**	**120.0**	**12.9**	**107.1**
wed	10/1/01	13.5	2.9	11.5		9/1/02	38.5	2.0	35.6		8/1/03	2.3	1.9	0.7
wed	17/01/01	4.3	2.3	1.1		16/01/02	12.7	2.8	10.4		15/1/03	4.2	2.8	1.1
wed	24/01/01	41.8	3.8	38.0		23/01/02	49.6	4.9	44.2		22/1/03	43.1	3.6	40.1
wed	31/01/01	7.8	4.3	4.5		30/01/02	41.7	5.8	35.9		29/1/03	10.7	5.1	5.1
JAN		**67.4**	**13.3**	**55.1**		**JAN**	**142.5**	**15.5**	**126.1**		**JAN**	**60.3**	**13.4**	**46.9**
wed	7/2/01	48.4	3.8	43.6		6/2/02	70.0	6.1	63.9		5/2/03	15.0	3.3	11.8
wed	14/02/01	37.9	5.7	33.7		13/02/02	19.5	6.3	14.4		12/2/03	21.0	4.6	17.2
wed	21/02/01	3.3	4.6	0.0		20/02/02	7.4	5.7	0.5		19/2/03	0.0	3.9	0.0
wed	28/02/01	4.0	6.2	0.0		27/02/02	29.5	6.6	22.9		26/2/03	15.7	5.2	5.6
FEB		**93.6**	**20.2**	**77.3**		**FEB**	**126.4**	**24.8**	**101.6**		**FEB**	**51.7**	**17.1**	**34.6**
wed	7/3/01	34.7	7.1	22.7		6/3/02	10.0	6.8	8.0		5/3/03	35.7	6.4	29.3
wed	14/03/01	22.6	7.5	15.1		13/03/02	24.6	9.0	13.7		12/3/03	37.1	9.0	29.8
wed	21/03/01	25.2	7.3	17.9		20/03/02	16.7	8.5	5.7		19/3/03	0.0	9.2	0.0
wed	28/03/01	18.2	8.0	10.2		27/03/02	10.6	9.7	6.8		26/3/03	0.0	10.1	0.0
wed	4/4/01	11.3	11.0	1.6		3/4/02	11.2	10.5	0.0		2/4/03	11.6	11.9	0.0
MAR		**112.0**	**40.8**	**67.6**		**MAR**	**73.1**	**44.5**	**34.2**		**MAR**	**84.4**	**46.6**	**59.0**
wed	11/4/01	21.7	13.6	10.6		10/4/02	1.9	15.1	0.0		9/4/03	0.5	13.2	0.0
wed	18/04/01	11.3	13.0	2.1		17/4/02	12.3	13.3	0.0		16/4/03	31.7	10.6	0.0
wed	25/04/01	29.9	13.3	8.9		24/4/02	26.1	13.0	0.0		23/4/03	0.0	18.5	0.0
wed	2/5/01	4.9	17.4	0.0		1/5/02	36.6	14.1	16.5		30/4/03	63.8	15.8	18.0
APR		**67.8**	**57.2**	**21.7**		**APR**	**76.9**	**55.6**	**16.5**		**APR**	**96.0**	**58.0**	**18.0**
wed	9/5/01	0.0	19.4	0.0		8/5/02	2.9	18.5	0.0		7/5/03	49.3	16.5	36.5
wed	16/05/01	5.2	19.1	0.0		15/5/02	24.3	16.5	0.0		14/5/03	11.8	18.9	0.0
wed	23/05/01	3.1	14.9	0.0		22/5/02	48.8	16.3	23.8		21/5/03	24.1	16.4	0.0
wed	30/05/01	20.2	16.5	0.0		29/5/02	42.2	15.5	27.1		28/5/03	10.8	15.3	0.0
MAY		**28.5**	**70.0**	**0.0**		**MAY**	**118.2**	**66.8**	**50.9**		**MAY**	**96.0**	**67.1**	**36.5**
wed	6/6/01	2.1	14.3	0.0		5/6/02	17.4	19.2	3.6		4/6/03	25.5	19.6	0.0
wed	13/06/01	2.1	11.1	0.0		12/6/02	30.3	19.2	8.6		11/6/03	51.5	19.2	29.4
wed	20/06/01	26.7	10.3	0.0		19/6/02	25.2	17.8	10.0		18/6/03	1.8	21.3	0.0
wed	27/06/01	8.3	13.7	0.0		26/6/02	6.5	19.3	0.0		25/6/03	0.0	19.3	0.0
JUN		**39.2**	**49.4**	**0.0**		**JUN**	**79.4**	**75.5**	**22.2**		**JUN**	**78.8**	**79.5**	**29.4**
wed	4/7/01	13.7	14.2	0.0		3/7/02	16.3	19.9	0.0					
wed	11/7/01	1.8	10.3	0.0		10/7/02	20.0	17.4	0.0					
wed	18/07/01	36.2	11.6	0.0		17/7/02	7.3	20.4	0.0					
wed	25/07/01	7.5	14.4	0.0		24/7/02	0.1	17.2	0.0					
JULY		**59.2**	**50.4**	**0.0**		**JULY**	**43.7**	**74.9**	**0.0**		**JULY**			
wed	1/8/01	0.0	15.0	0.0		31/7/02	10.0	13.1	0.0					
wed	8/8/01	26.9	11.5	0.0		7/8/02	28.4	14.0	0.0					
wed	15/08/01	41.9	10.6	0.0		14/8/02	22.2	15.7	0.0					
wed	22/08/01	22.0	16.1	0.0		21/8/02	6.1	17.0	0.0					
wed	29/08/01	1.8	18.1	0.0		28/8/02	0.3	14.5	0.0					
AUG		**92.6**	**71.4**	**0.0**		**AUG**	**67.0**	**74.2**	**0.0**		**AUG**			
wed	5/9/01	9.9	13.9	0.0		4/9/02	1.3	10.4	0.0					
wed	12/9/01	0.2	13.0	0.0		11/9/02	11.9	8.4	0.0					
wed	19/09/01	3.0	9.7	0.0		18/9/02	0.0	7.5	0.0					
wed	26/09/01	26.7	6.2	0.0		25/9/02	0.0	6.2	0.0					
SEPT		**39.8**	**42.8**	**0.0**		**SEPT**	**13.2**	**32.5**	**0.0**		**SEPT**			
YR TOT		1162.9	483.7	679.0		YR TOT	995.0	531.5	464.0		YR TOT			
		RF (mm)	Et actual	Drainage			RF (mm)	Et actual	Drainage			RF (mm)	Et actual	Drainage
Hydrological year 2000-2001						Hydrological year 2001 -2002					Hydrological year 2002-2003			

* There are some minor sub-total errors in the above data sheet.
* These have been caused by rounding errors, and carry over from the 'week-ending' method of calculation
* i.e. Some weeks are half in one month, half in another, but for clarity's sake, ignored to present global view

Appendix Q

Agronomic Nitrogen Loadings – Curtin's Farm

The methodologies and rationale for nitrogen loadings determinations were outlined in chapter five, section 5.5.2. In that section, data were presented grouped by spatial zone and presented for the annual time-scale (hydrological year). In this appendix, the temporal effect can be observed (weekly nitrogen loading diaries) and the total annual loadings contributed from each nitrogen source (inorganic fertiliser, dirty water, slurry, grazing animals) are also summarised for the field scale. Refer to chapter five, Figure 5.14, for plot location and agricultural management in operation at that plot. The loading diaries for each plot also indicate when a piezometer is located in that plot.

These data are presented in the following order:

	Field No. 1 (all loadings, blue, red and yellow) CUT PLOT									
Week	Fertiliser	Slurry N tot	SI *25%	Dirty H20	ANIMALS			N Deposited: Grazing Animals		Grazing
Ending	(kg/ha)	(kg N/ha)	(kg N/ha)	(kg N/ha)	Kg N	Kg N	Kg N	(kg N/week)	(kg N/Ha/week)	days
3-Oct-01				none						
10-Oct-01										
17-Oct-01										
24-Oct-01										
31-Oct-01										
7-Nov-01										
14-Nov-01										
21-Nov-01										
28-Nov-01										
5-Dec-01										
12-Dec-01										
19-Dec-01										
26-Dec-01										
2-Jan-02										
9-Jan-02										
16-Jan-02	50									
23-Jan-02										
30-Jan-02										
6-Feb-02										
13-Feb-02										
20-Feb-02										
27-Feb-02										
6-Mar-02										
13-Mar-02					14.1	14.1	14.1	42.3	16.85258964	1
20-Mar-02										
27-Mar-02		98	25							
3-Apr-02										
10-Apr-02										
17-Apr-02	100									
24-Apr-02										
1-May-02										
8-May-02					26.9	26.9	26.9	80.7	32.15139442	3
15-May-02	40									
22-May-02										
29-May-02										
5-Jun-02					26.9	26.9	26.9	80.7	32.15139442	3
12-Jun-02	50									
19-Jun-02										
26-Jun-02										
3-Jul-02										
10-Jul-02	50				9	18	9	36	14.34262948	1
17-Jul-02										
24-Jul-02										
31-Jul-02	50									
7-Aug-02										
14-Aug-02										
21-Aug-02										
28-Aug-02										
4-Sep-02										
11-Sep-02	40				18	18	27	63	25.09960159	2
18-Sep-02										
25-Sep-02										
2-Oct-02										
9-Oct-02										
16-Oct-02										
23-Oct-02					9	9		18	7.171314741	1
30-Oct-02										
6-Nov-02										
13-Nov-02										
20-Nov-02										
27-Nov-02										
4-Dec-02										
11-Dec-02										
18-Dec-02										
25-Dec-02										
1-Jan-03										
8-Jan-03										
15-Jan-03										
22-Jan-03										
29-Jan-03							5.5872			
5-Feb-03							22.3488	27	10.75697211	
12-Feb-03					23.28	19.5552		42.8352	17.06581673	3
19-Feb-03		95	22							
26-Feb-03										
5-Mar-03										
12-Mar-03										
19-Mar-03	99									
26-Mar-03										
2-Apr-03										
9-Apr-03										
16-Apr-03						10.1268	18.1584	28.2852	11.26900398	1
23-Apr-03					23.7456			23.7456	9.460398406	1
30-Apr-03										
7-May-03										
14-May-03										
21-May-03					22.698	22.698	9.0792	54.4752	21.70326693	2
28-May-03	49									
4-Jun-03										
11-Jun-03										
18-Jun-03	33				22.698	22.698	22.698	68.094	27.12908367	2.5
25-Jun-03										
2-Jul-03										
9-Jul-03										
16-Jul-03					18.1584	18.1584	13.6188	49.9356	19.89466135	2
23-Jul-03	33									
30-Jul-03										
6-Aug-03										
13-Aug-03					18.1584	18.1584	22.698	59.0148	23.51187251	2
20-Aug-03	33									
27-Aug-03										
3-Sep-03										
10-Sep-03										
17-Sep-03										
24-Sep-03					13.6188	13.6188	18.1584	45.396	18.08605578	1.5
1-Oct-03	33									
8-Oct-03										
15-Oct-03										
22-Oct-03										
29-Oct-03										
5-Nov-03										
12-Nov-03										
19-Nov-03										
26-Nov-03										
3-Dec-03										

	Field No. 2 (all loadings, blue, red and yellow) GRAZING PLOT									
Week	Fertiliser	SLURRY	SI *25%	Dirty H20	ANIMALS			N Deposited: Grazing Animals		Grazing Days
Ending	(kg/ha)	(kg/ha)	(kg N/ha)	(kg N/ha)	Kg N	Kg N	Kg N	(kg N/week)	(kg N/Ha/week)	
3-Oct-01		none		none						
10-Oct-01										
17-Oct-01										
24-Oct-01										
31-Oct-01										
7-Nov-01										
14-Nov-01										
21-Nov-01										
28-Nov-01										
5-Dec-01										
12-Dec-01										
19-Dec-01										
26-Dec-01										
2-Jan-02										
9-Jan-02										
16-Jan-02	50									
23-Jan-02										
30-Jan-02										
6-Feb-02										
13-Feb-02										
20-Feb-02										
27-Feb-02										
6-Mar-02										
13-Mar-02										
20-Mar-02					22	22	22	66	26.29482072	2.5
27-Mar-02	50									
3-Apr-02										
10-Apr-02										
17-Apr-02										
24-Apr-02										
1-May-02					0	0	27.0	27	10.75697211	1.0
8-May-02	50				27.0	27.0		54	21.51394422	1
15-May-02										
22-May-02										
29-May-02					18.0	18.0	18	54	21.51394422	3
5-Jun-02	50									
12-Jun-02										
19-Jun-02										
26-Jun-02										
3-Jul-02					27.0	27.0	18	72	28.68525896	2.7
10-Jul-02	50									
17-Jul-02										
24-Jul-02										
31-Jul-02					18.0	18.0	18	54	21.51394422	2
7-Aug-02	40									
14-Aug-02										
21-Aug-02										
28-Aug-02										
4-Sep-02	40						18.0	18	7.171314741	1.0
11-Sep-02										
18-Sep-02										
25-Sep-02										
2-Oct-02										
9-Oct-02										
16-Oct-02					18.0	18.0	18.0	54	21.51394422	2.0
23-Oct-02										
30-Oct-02										
6-Nov-02										
13-Nov-02										
20-Nov-02										
27-Nov-02										
4-Dec-02										
11-Dec-02										
18-Dec-02										
25-Dec-02										
1-Jan-03										
8-Jan-03										
15-Jan-03										
22-Jan-03										
29-Jan-03										
5-Feb-03										
12-Feb-03										
19-Feb-03						13.6188	13.6188			
26-Feb-03					15.3648			42.6024	16.97306773	1
5-Mar-03										
12-Mar-03										
19-Mar-03	49									
26-Mar-03										
2-Apr-03										
9-Apr-03										
16-Apr-03										
23-Apr-03										
30-Apr-03	49				22.698	22.698	22.698	68.094	27.12908367	2.5
7-May-03										
14-May-03										
21-May-03										
28-May-03	49				18.1584	18.1584	18.1584	54.4752	21.70326693	2
4-Jun-03										
11-Jun-03										
18-Jun-03							18.1584	18.1584	7.234422311	1
25-Jun-03	33									
2-Jul-03										
9-Jul-03										
16-Jul-03										
23-Jul-03	33									
30-Jul-03					18.1584	18.1584	27.2376	63.5544	25.32047809	2
6-Aug-03										
13-Aug-03										
20-Aug-03	33									
27-Aug-03					13.6188	13.6188	18.1584	45.396	18.08605578	2
3-Sep-03										
10-Sep-03					18.1584	18.1584	18.1584	54.4752	21.70326693	2
17-Sep-03										
24-Sep-03										
1-Oct-03										
8-Oct-03										

	Field No. 3 (all loadings, blue, red and yellow) 1 CUT - BHC.9 situated here								
Week	Fertiliser	SLURRY	Dirty H20	ANIMALS			N Deposited: Grazing Animals		Grazing
Ending	(kg/ha)	(kg/ha)	(kg N/ha)	Kg N	Kg N	Kg N	(kg N/week)	(kg N/Ha/week)	days
3-Oct-01									
10-Oct-01									
17-Oct-01									
24-Oct-01									
31-Oct-01									
7-Nov-01									
14-Nov-01									
21-Nov-01									
28-Nov-01									
5-Dec-01									
12-Dec-01									
19-Dec-01									
26-Dec-01									
2-Jan-02									
9-Jan-02									
16-Jan-02	50								
23-Jan-02									
30-Jan-02									
6-Feb-02									
13-Feb-02									
20-Feb-02									
27-Feb-02									
6-Mar-02									
13-Mar-02									
20-Mar-02				21.6	22.1	22.1	65.8	26.21513944	2.5
27-Mar-02									
3-Apr-02	100	81	20						
10-Apr-02									
17-Apr-02									
24-Apr-02									
1-May-02									
8-May-02									
15-May-02									
22-May-02									
29-May-02									
5-Jun-02									
12-Jun-02									
19-Jun-02	50								
26-Jun-02									
3-Jul-02									
10-Jul-02									
17-Jul-02									
24-Jul-02				18	18		36	14.34262948	2
31-Jul-02	50								
7-Aug-02									
14-Aug-02									
21-Aug-02	40			18	18	18	54	21.51394422	2
28-Aug-02									
4-Sep-02									
11-Sep-02									
18-Sep-02									
25-Sep-02				27	27	18	72	28.68525896	3
2-Oct-02									
9-Oct-02									
16-Oct-02									
23-Oct-02									
30-Oct-02									
6-Nov-02									
13-Nov-02				18	18	9	45	17.92828685	2
20-Nov-02									
27-Nov-02									
4-Dec-02									
11-Dec-02									
18-Dec-02									
25-Dec-02									
1-Jan-03									
8-Jan-03									
15-Jan-03									
22-Jan-03									
29-Jan-03	49								
5-Feb-03									
12-Feb-03									
19-Feb-03		87	22						
26-Feb-03									
5-Mar-03									
12-Mar-03				11.5236	11.1744	12.804	35.502	14.14422311	1
19-Mar-03									
26-Mar-03									
2-Apr-03	99								
9-Apr-03									
16-Apr-03									
23-Apr-03									
30-Apr-03									
7-May-03									
14-May-03									
21-May-03									
28-May-03									
4-Jun-03	49								
11-Jun-03									
18-Jun-03									
25-Jun-03									
2-Jul-03									
9-Jul-03	33			22.698	22.698	22.698	68.094	27.12908367	2.5
16-Jul-03									
23-Jul-03									
30-Jul-03				18.1584	18.1584	22.698	59.0148	23.51187251	
6-Aug-03	33								
13-Aug-03									
20-Aug-03									
27-Aug-03									
3-Sep-03	33			22.698	22.698	18.1584	63.5544	25.32047809	2.5
10-Sep-03									
17-Sep-03									
24-Sep-03									
1-Oct-03									
8-Oct-03									

	Field No. 4 (all loadings, blue, red and yellow) GRAZING								
Week	Fertiliser	SLURRY	Dirty H20	ANIMALS			N Deposited: Grazing Animals		Grazing
Ending	(kg/ha/week)	(kg/ha/week)	(kg/ha/week)	Kg N/week	Kg N/week	Kg N/week	(kg N/week)	(kg N/Ha/week)	days
3-Oct-01		none	none						
10-Oct-01									
17-Oct-01									
24-Oct-01									
31-Oct-01									
7-Nov-01									
14-Nov-01									
21-Nov-01									
28-Nov-01									
5-Dec-01									
12-Dec-01									
19-Dec-01									
26-Dec-01									
2-Jan-02									
9-Jan-02									
16-Jan-02	50								
23-Jan-02									
30-Jan-02									
6-Feb-02									
13-Feb-02									
20-Feb-02									
27-Feb-02									
6-Mar-02									
13-Mar-02									
20-Mar-02				22	18	25	65	25.89641434	2
27-Mar-02	50								
3-Apr-02									
10-Apr-02									
17-Apr-02									
24-Apr-02									
1-May-02									
8-May-02									
15-May-02	50			36	36	36	108	43.02788845	4
22-May-02									
29-May-02									
5-Jun-02									
12-Jun-02				27	27	27	81	32.27091633	3
19-Jun-02	60								
26-Jun-02									
3-Jul-02									
10-Jul-02	50			18	9	9	36	14.34262948	2
17-Jul-02									
24-Jul-02									
31-Jul-02									
7-Aug-02				18	18	27	63	25.09960159	2
14-Aug-02	40								
21-Aug-02									
28-Aug-02									
4-Sep-02									
11-Sep-02						18	18	7.171314741	1
18-Sep-02									
25-Sep-02	40								
2-Oct-02									
9-Oct-02									
16-Oct-02									
23-Oct-02									
30-Oct-02				18	18	18	54	21.51394422	2
6-Nov-02									
13-Nov-02									
20-Nov-02									
27-Nov-02									
4-Dec-02									
11-Dec-02									
18-Dec-02									
25-Dec-02									
1-Jan-03									
8-Jan-03									
15-Jan-03									
22-Jan-03									
29-Jan-03	49								
5-Feb-03									
12-Feb-03									
19-Feb-03									
26-Feb-03									
5-Mar-03									
12-Mar-03									
19-Mar-03	49			13.5024	14.4336	13.968	41.904	16.69482072	2
26-Mar-03									
2-Apr-03									
9-Apr-03									
16-Apr-03									
23-Apr-03									
30-Apr-03				22.698	22.698	22.698	68.094	27.12908367	2
7-May-03	49								
14-May-03									
21-May-03									
28-May-03				18.1584	18.1584	18.1584	54.4752	21.70326693	2
4-Jun-03	49								
11-Jun-03									
18-Jun-03									
25-Jun-03	33			13.6188	13.6188	13.6188	40.8564	16.2774502	1.5
2-Jul-03									
9-Jul-03									
16-Jul-03									
23-Jul-03									
30-Jul-03	33								
6-Aug-03									
13-Aug-03									
20-Aug-03									
27-Aug-03									
3-Sep-03	33			18.1584	18.1584	4.5396	40.8564	16.2774502	1.5
10-Sep-03									
17-Sep-03									
24-Sep-03									
1-Oct-03									
8-Oct-03									

	Field No. 5 (all loadings, blue, red and yellow)									
Week	Fertiliser	Slurry N tot	Sl *25%	Dirty H20	ANIMALS			N Deposited: Grazing Animals		Grazing
Ending	(kg/ha)	(kg N/ha)	(kg N/ha)	(kg/ha/week)	Kg N/week	Kg N/week	Kg N/week	(kg N/week)	(kg N/Ha/week)	days
3-Oct-01				none						
10-Oct-01										
17-Oct-01										
24-Oct-01										
31-Oct-01										
7-Nov-01										
14-Nov-01										
21-Nov-01										
28-Nov-01										
5-Dec-01										
12-Dec-01										
19-Dec-01										
26-Dec-01										
2-Jan-02										
9-Jan-02										
16-Jan-02										
23-Jan-02	50									
30-Jan-02										
6-Feb-02										
13-Feb-02										
20-Feb-02										
27-Feb-02										
6-Mar-02										
13-Mar-02										
20-Mar-02										
27-Mar-02		98	25		43.9		12.7	56.6	22.5498008	2
3-Apr-02	100									
10-Apr-02										
17-Apr-02										
24-Apr-02										
1-May-02										
8-May-02										
15-May-02										
22-May-02										
29-May-02										
5-Jun-02										
12-Jun-02										
19-Jun-02	50									
26-Jun-02										
3-Jul-02										
10-Jul-02										
17-Jul-02	40				9	9	9	27	10.75697211	1
24-Jul-02										
31-Jul-02										
7-Aug-02										
14-Aug-02	40				18	18		36	14.34262948	1
21-Aug-02										
28-Aug-02										
4-Sep-02										
11-Sep-02							27	27	10.75697211	1
18-Sep-02										
25-Sep-02					27	27		54	21.51394422	2
2-Oct-02										
9-Oct-02										
16-Oct-02										
23-Oct-02										
30-Oct-02										
6-Nov-02							9	9	3.585657371	0.3
13-Nov-02					9	9	9	27	10.75697211	1
20-Nov-02										
27-Nov-02										
4-Dec-02										
11-Dec-02										
18-Dec-02										
25-Dec-02										
1-Jan-03										
8-Jan-03										
15-Jan-03										
22-Jan-03										
29-Jan-03	49									
5-Feb-03										
12-Feb-03										
19-Feb-03										
26-Feb-03										
5-Mar-03										
12-Mar-03					15.0156	13.386	13.968	42.3696	16.88031873	2
19-Mar-03										
26-Mar-03		88	22							
2-Apr-03	99									
9-Apr-03										
16-Apr-03										
23-Apr-03										
30-Apr-03										
7-May-03										
14-May-03										
21-May-03										
28-May-03		80	20							
4-Jun-03	49									
11-Jun-03										
18-Jun-03										
25-Jun-03										
2-Jul-03					22.698	22.698	27.2376	72.6336	28.93768924	2.5
9-Jul-03	33									
16-Jul-03										
23-Jul-03										
30-Jul-03					22.698	22.698	27.2376	72.6336	28.93768924	2.5
6-Aug-03	33									
13-Aug-03										
20-Aug-03										
27-Aug-03					22.698	22.698	22.698	68.094	27.12908367	2.5
3-Sep-03	33									
10-Sep-03										
17-Sep-03										
24-Sep-03										
1-Oct-03										
8-Oct-03					18.1584	18.1584	18.1584	54.4752	21.70326693	2
15-Oct-03										

	Field No. 6 (all N, to bl, red & yellow) ONE CUT & GRAZING - BHC.10 situated here									
Week	Fertiliser N	Slurry N tot	SI *25%	Dirty H20	ANIMALS			N Deposited: Grazing Animals		Grazing
Ending	(kg N/ha)	(kg N/ha)	(kg N/ha)	(kg N/ha)	Kg N	Kg N	Kg N	(kg N/week)	(kg N/Ha/week)	days
3-Oct-01				none						
10-Oct-01										
17-Oct-01										
24-Oct-01										
31-Oct-01										
7-Nov-01										
14-Nov-01										
21-Nov-01										
28-Nov-01										
5-Dec-01										
12-Dec-01										
19-Dec-01										
26-Dec-01										
2-Jan-02										
9-Jan-02										
16-Jan-02										
23-Jan-02	50									
30-Jan-02										
6-Feb-02										
13-Feb-02										
20-Feb-02										
27-Feb-02										
6-Mar-02										
13-Mar-02										
20-Mar-02										
27-Mar-02		96	24		30	24		54	21.51394422	3
3-Apr-02										
10-Apr-02	100									
17-Apr-02										
24-Apr-02										
1-May-02										
8-May-02										
15-May-02										
22-May-02										
29-May-02										
5-Jun-02										
12-Jun-02	50									
19-Jun-02										
26-Jun-02										
3-Jul-02										
10-Jul-02										
17-Jul-02					27	27	32	86	34.26294821	3
24-Jul-02	40									
31-Jul-02										
7-Aug-02										
14-Aug-02					18	18	18	54	21.51394422	2
21-Aug-02	40									
28-Aug-02										
4-Sep-02										
11-Sep-02										
18-Sep-02										
25-Sep-02					18	18	18	54	21.51394422	2
2-Oct-02										
9-Oct-02										
16-Oct-02										
23-Oct-02										
30-Oct-02										
6-Nov-02					18	18	18	54	21.51394422	2
13-Nov-02										
20-Nov-02										
27-Nov-02										
4-Dec-02										
11-Dec-02										
18-Dec-02										
25-Dec-02										
1-Jan-03										
8-Jan-03										
15-Jan-03										
22-Jan-03										
29-Jan-03	49									
5-Feb-03										
12-Feb-03										
19-Feb-03		90	23							
26-Feb-03										
5-Mar-03										
12-Mar-03										
19-Mar-03					15.8304	13.2696	12.6876	41.7876	16.64844622	1.5
26-Mar-03										
2-Apr-03	99									
9-Apr-03										
16-Apr-03										
23-Apr-03										
30-Apr-03										
7-May-03										
14-May-03										
21-May-03										
28-May-03		60	15							
4-Jun-03	49									
11-Jun-03										
18-Jun-03										
25-Jun-03	33				18.1584	18.1584	18.1584	54.4752	21.70326693	2
2-Jul-03										
9-Jul-03										
16-Jul-03										
23-Jul-03										
30-Jul-03	33				27.2376	27.2376	27.2376	81.7128	32.5549004	3
6-Aug-03										
13-Aug-03										
20-Aug-03					18.1584	18.1584	18.1584	54.4752	21.70326693	2
27-Aug-03	33									
3-Sep-03										
10-Sep-03										
17-Sep-03										
24-Sep-03										
1-Oct-03										
8-Oct-03					22.698	22.698	22.698	68.094	27.12908367	2.5
15-Oct-03										

	Field No. 7 (all N, to bl, red & yellow) TWO CUT								
Week	Fertiliser	SLURRY	Dirty H20	ANIMALS			N Deposited: Grazing Animals		Grazing
Ending	(kg/ha)	(kg/ha)	(kg N/ha)	Kg N	Kg N	Kg N	(kg N/week)	(kg N/Ha/week)	days
3-Oct-01		none	none						
10-Oct-01									
17-Oct-01									
24-Oct-01									
31-Oct-01									
7-Nov-01									
14-Nov-01									
21-Nov-01									
28-Nov-01									
5-Dec-01									
12-Dec-01									
19-Dec-01									
26-Dec-01									
2-Jan-02									
9-Jan-02									
16-Jan-02									
23-Jan-02	50								
30-Jan-02									
6-Feb-02									
13-Feb-02									
20-Feb-02									
27-Feb-02									
6-Mar-02									
13-Mar-02									
20-Mar-02									
27-Mar-02									
3-Apr-02		98		47.1		32.2	79.3	19.38875306	3
10-Apr-02									
17-Apr-02	100								
24-Apr-02									
1-May-02									
8-May-02									
15-May-02									
22-May-02									
29-May-02									
5-Jun-02									
12-Jun-02									
19-Jun-02	100								
26-Jun-02									
3-Jul-02									
10-Jul-02									
17-Jul-02									
24-Jul-02									
31-Jul-02	50								
7-Aug-02									
14-Aug-02									
21-Aug-02									
28-Aug-02									
4-Sep-02									
11-Sep-02									
18-Sep-02				36	36	36	108	26.40586797	4
25-Sep-02	40								
2-Oct-02									
9-Oct-02									
16-Oct-02									
23-Oct-02				27	27	27	81	19.80440098	3
30-Oct-02									
6-Nov-02									
13-Nov-02									
20-Nov-02									
27-Nov-02									
4-Dec-02									
11-Dec-02									
18-Dec-02									
25-Dec-02									
1-Jan-03									
8-Jan-03									
15-Jan-03									
22-Jan-03									
29-Jan-03	49								
5-Feb-03									
12-Feb-03									
19-Feb-03		90	23						
26-Feb-03									
5-Mar-03									
12-Mar-03									
19-Mar-03									
26-Mar-03				39.6924	34.92	40.3908	115.0032	28.11814181	4.25
2-Apr-03									
9-Apr-03	99								
16-Apr-03									
23-Apr-03									
30-Apr-03									
7-May-03									
14-May-03									
21-May-03									
28-May-03		90	23						
4-Jun-03	99								
11-Jun-03									
18-Jun-03									
25-Jun-03									
2-Jul-03									
9-Jul-03									
16-Jul-03									
23-Jul-03									
30-Jul-03	33								
6-Aug-03									
13-Aug-03									
20-Aug-03									
27-Aug-03									
3-Sep-03									
10-Sep-03	33			27.2376	27.2376	36.3168	90.792	22.19853301	3
17-Sep-03									
24-Sep-03									
1-Oct-03									
8-Oct-03									

	Field No. 8 (all N, to bl, red & yellow) TWO CUT									
Week	Fertiliser	Slurry N tot	Sl *25%	Dirty H20	ANIMALS			N Deposited: Grazing Animals		Grazing
Ending	(kg/ha)	(kg N/ha)	(kg N/ha)	(kg N/ha)	Kg N	Kg N	Kg N	(kg N/week)	(kg N/Ha/week)	days
3-Oct-01				none						
10-Oct-01										
17-Oct-01										
24-Oct-01										
31-Oct-01										
7-Nov-01										
14-Nov-01										
21-Nov-01										
28-Nov-01										
5-Dec-01										
12-Dec-01										
19-Dec-01										
26-Dec-01										
2-Jan-02										
9-Jan-02										
16-Jan-02										
23-Jan-02	50									
30-Jan-02										
6-Feb-02										
13-Feb-02										
20-Feb-02										
27-Feb-02										
6-Mar-02										
13-Mar-02										
20-Mar-02										
27-Mar-02					12.4	26.6	12	51	14.01098901	2
3-Apr-02		88	22							
10-Apr-02										
17-Apr-02	100									
24-Apr-02										
1-May-02										
8-May-02										
15-May-02										
22-May-02										
29-May-02										
5-Jun-02										
12-Jun-02										
19-Jun-02	100									
26-Jun-02										
3-Jul-02										
10-Jul-02										
17-Jul-02										
24-Jul-02										
31-Jul-02	50									
7-Aug-02										
14-Aug-02										
21-Aug-02										
28-Aug-02										
4-Sep-02										
11-Sep-02										
18-Sep-02					27	27	18	72	19.78021978	2.3
25-Sep-02	40									0.7
2-Oct-02										
9-Oct-02										
16-Oct-02										
23-Oct-02										
30-Oct-02					18	18		36	9.89010989	2
6-Nov-02										
13-Nov-02										
20-Nov-02										
27-Nov-02										
4-Dec-02										
11-Dec-02										
18-Dec-02										
25-Dec-02										
1-Jan-03										
8-Jan-03										
15-Jan-03										
22-Jan-03										
29-Jan-03	49									
5-Feb-03										
12-Feb-03										
19-Feb-03		90	23							
26-Feb-03										
5-Mar-03										
12-Mar-03										
19-Mar-03					33.174	22.3488	28.8672	84.39	23.18406593	3
26-Mar-03										
2-Apr-03										
9-Apr-03	99									
16-Apr-03										
23-Apr-03										
30-Apr-03										
7-May-03										
14-May-03										
21-May-03										
28-May-03		106	27							
4-Jun-03	99									
11-Jun-03										
18-Jun-03										
25-Jun-03										
2-Jul-03										
9-Jul-03										
16-Jul-03										
23-Jul-03										
30-Jul-03	33									
6-Aug-03										
13-Aug-03										
20-Aug-03										
27-Aug-03										
3-Sep-03					36.3168	36.3168	36.3168	108.9504	29.93142857	4
10-Sep-03										
17-Sep-03	33									
24-Sep-03										
1-Oct-03										

	Field No. 9 (ALL N to all plots blue, red & yellow) GRAZING - BHC.3 situated here									
Week	Fertiliser	Slurry N tot	SI *25%	Dirty H20	ANIMALS			N Deposited: Grazing Animals		Grazing
Ending	(kg/ha)	(kg N/ha)	(kg N/ha)	(kg N/ha)	Kg N	Kg N	Kg N	(kg N/week)	(kg N/Ha/week)	days
3-Oct-01				none						
10-Oct-01										
17-Oct-01										
24-Oct-01										
31-Oct-01										
7-Nov-01										
14-Nov-01										
21-Nov-01										
28-Nov-01										
5-Dec-01										
12-Dec-01										
19-Dec-01										
26-Dec-01										
2-Jan-02										
9-Jan-02										
16-Jan-02										
23-Jan-02										
30-Jan-02										
6-Feb-02										
13-Feb-02										
20-Feb-02	50									
27-Feb-02										
6-Mar-02										
13-Mar-02										
20-Mar-02										
27-Mar-02										
3-Apr-02										
10-Apr-02										
17-Apr-02										
24-Apr-02										
1-May-02					18	18	18	54	21.95121951	2
8-May-02	50									
15-May-02										
22-May-02										
29-May-02										
5-Jun-02					27	27	27	81	32.92682927	3
12-Jun-02	60									
19-Jun-02										
26-Jun-02										
3-Jul-02					18	18	18	54	21.95121951	2
10-Jul-02	50									
17-Jul-02										
24-Jul-02										
31-Jul-02					9	9	9	27	10.97560976	1
7-Aug-02					9	9	9	27	10.97560976	1
14-Aug-02										
21-Aug-02										
28-Aug-02										
4-Sep-02					36	36	36	108	43.90243902	4
11-Sep-02	40									
18-Sep-02										
25-Sep-02										
2-Oct-02										
9-Oct-02										
16-Oct-02					18	18	18	54	21.95121951	2
23-Oct-02										
30-Oct-02										
6-Nov-02										
13-Nov-02										
20-Nov-02										
27-Nov-02	250									
4-Dec-02										15
11-Dec-02										
18-Dec-02										
25-Dec-02										
1-Jan-03										
8-Jan-03										
15-Jan-03										
22-Jan-03										
29-Jan-03	49									
5-Feb-03										
12-Feb-03										
19-Feb-03										
26-Feb-03										
5-Mar-03							10.8252	10.8252	4.400487805	
12-Mar-03										
19-Mar-03	40									
26-Mar-03										
2-Apr-03										
9-Apr-03	49				28.4016	28.4016		56.8032	23.09073171	2.5
16-Apr-03										
23-Apr-03										
30-Apr-03										
7-May-03							13.6188	13.6188	5.536097561	
14-May-03					22.698	22.698	27.2376	72.6336	29.52585366	4
21-May-03							18	18	7.317073171	
28-May-03	49									
4-Jun-03										
11-Jun-03										
18-Jun-03	49				22.698	22.698	22.698	68.094	27.6804878	2.5
25-Jun-03										
2-Jul-03										
9-Jul-03										
16-Jul-03	33				22.698	22.698	22.698	68.094	27.6804878	2.5
23-Jul-03										
30-Jul-03					13.6188	13.6188	9.0792	36.3168	14.76292683	1.5
6-Aug-03										
13-Aug-03	33									
20-Aug-03										
27-Aug-03										
3-Sep-03					13.6188	13.6188	22.698	49.9356	20.29902439	2
10-Sep-03										
17-Sep-03										
24-Sep-03										
1-Oct-03	33									

	Field No. 10 (all N loads to all plots) DIRTY WATER PLOT												
	Fertiliser	Slurry N tot	Dirty H20	TN * 85%		Plot	DW irrig	ANIMALS			N Deposited: Grazing Animals		Grazing
Week Ending	(kg/ha)	(kg N/ha)	TN Kg/ha/week	TN Kg/ha/week	TN (mg/l)		(mm/run)	Kg N	Kg N	Kg N	(kg N/week)	(kg N/Ha/week)	Days
3-Oct-01		NONE											
10-Oct-01													
17-Oct-01													
24-Oct-01													
31-Oct-01													
7-Nov-01													
14-Nov-01													
21-Nov-01													
28-Nov-01													
5-Dec-01													
12-Dec-01													
19-Dec-01			16	14	200	10 RED	19						
26-Dec-01			16	14		10 RED	19						
2-Jan-02			16	14		10 RED	19						
9-Jan-02			16	14		10 RED	19						
16-Jan-02			16	14		10 RED	19						
23-Jan-02			16	14		10 RED	19						
30-Jan-02			16	14		10 RED	19						
6-Feb-02			10.72	9.12	150	10 YELL	24						
13-Feb-02			10.72	9.12		10 YELL	24						
20-Feb-02	50		10.72	9.12		10 YELL	24						
27-Feb-02			10.72	9.12		10 YELL	24						
6-Mar-02			10.72	9.12		10 YELL	24						
13-Mar-02			10.72	9.12		10 YELL	24						
20-Mar-02			10.72	9.12		10 YELL	24						
27-Mar-02			10.72	9.12		10 YELL	24						
3-Apr-02			10.72	9.12		10 YELL	24						
10-Apr-02			10.72	9.12		10 YELL	24						
17-Apr-02													
24-Apr-02													
1-May-02	50		3.80	3.23	108	10 BLUE	4						
8-May-02			1.37	1.16	20	10 RED	7						
15-May-02			0.80	0.68	20	10 YELL	4						
22-May-02													
29-May-02	50							27	27	27	81	34.3220339	3
5-Jun-02			0.55	0.47	20	10 RED	3						
12-Jun-02			5.20	4.40	40	10 BLUE	13						
19-Jun-02			9.00	7.50	200	10 RED & 10 YELL	5						
26-Jun-02								18	18	27	63	26.69491525	2.3
3-Jul-02	50												
10-Jul-02													
17-Jul-02													
24-Jul-02													
31-Jul-02			8.00	6.80	317.5	10 BLUE	3						
7-Aug-02			8.70	7.40	300	10 RED	3						
14-Aug-02													
21-Aug-02													
28-Aug-02													
4-Sep-02													
11-Sep-02	40		10.60	9.01	220	10 BLUE	5	18	18	18	54	22.88135593	2
18-Sep-02			6.80	5.78	200	10 RED	3						
25-Sep-02													
2-Oct-02													
9-Oct-02													
16-Oct-02													
23-Oct-02								27	27	27	81	34.3220339	3
30-Oct-02													
6-Nov-02			7.30	6.21	75	10 BLUE	10						
13-Nov-02			14.00	11.90	150	10 YELL	9						
20-Nov-02													
27-Nov-02													
4-Dec-02													
11-Dec-02													
18-Dec-02													
25-Dec-02													
1-Jan-03													
8-Jan-03													
15-Jan-03													
22-Jan-03													
29-Jan-03													
5-Feb-03													
12-Feb-03													
19-Feb-03													
26-Feb-03													
5-Mar-03								11.9892	17.2272	14.0844	43.3008	18.34779661	1.5
12-Mar-03	49												
19-Mar-03													
26-Mar-03													
2-Apr-03													
9-Apr-03													
16-Apr-03													
23-Apr-03													
30-Apr-03	49							27.2376	27.2376	22.698	77.1732	32.70050847	3
7-May-03			17.16	14.59	267	10 BLUE	6						
14-May-03			9.93	8.44	200	10 RED	5						
21-May-03								18.1584	18.1584	22.698	59.0148	25.00627119	2
28-May-03	49												
4-Jun-03			99.65	84.70	823	10 BLUE	12						
11-Jun-03			34.67	29.47	600	10 RED	6						
18-Jun-03								22.698	22.698		45.396	19.23559322	2
25-Jun-03	33												
2-Jul-03			39.07	33.21	400	10 YELL	10						
9-Jul-03													
16-Jul-03													
23-Jul-03	33		12.10	10.29	300	10 YELL	4	27.2376	27.2376	22.698	77.1732	32.70050847	3
30-Jul-03			12.62	10.73	363	10 BLUE	7						
6-Aug-03			12.62	10.73	363	10 BLUE	7						
13-Aug-03			6.00	5.00	300	10 RED	2						
20-Aug-03	33							13.6188	18.1584	18.1584	49.9356	21.15915254	2
27-Aug-03													
3-Sep-03													
10-Sep-03								13.6188	13.6188	13.6188	40.8564	17.3120339	1
17-Sep-03													
24-Sep-03													
1-Oct-03													
8-Oct-03													

	Field No. 11 (All N loadings to all plots) Dirty Water Plots												
Week	Fertiliser	Slurry N tot	Dirty H20	TN * 85%		Plot	DW irrig	ANIMALS			N Deposited: Grazing Animals		Grazing
Ending	(kg/ha)	(kg N/ha)	TN Kg/ha/week	TN Kg/ha/week	TN (mg/l)	(ha =)	(mm/run)	Kg N	Kg N	Kg N	(kg N/week)	(kg N/Ha/week)	days
3-Oct-01		NONE											
10-Oct-01													
17-Oct-01													
24-Oct-01													
31-Oct-01													
7-Nov-01													
14-Nov-01			26	22	482	11BLUE	16						
21-Nov-01			26	22	482	(0.77ha)	16						
28-Nov-01			26	22	482	TN = 79kg/ha	16						
5-Dec-01													
12-Dec-01													
19-Dec-01													
26-Dec-01													
2-Jan-02													
9-Jan-02													
16-Jan-02													
23-Jan-02													
30-Jan-02													
6-Feb-02													
13-Feb-02													
20-Feb-02	50												
27-Feb-02													
6-Mar-02													
13-Mar-02													
20-Mar-02													
27-Mar-02													
3-Apr-02													
10-Apr-02								27	27	18	72	32	2.7
17-Apr-02	50		5.71	4.85	100	11 YELL	11						
24-Apr-02			5.71	4.85		11 YELL	11						
1-May-02													
8-May-02													
15-May-02								27	27	36	90	40	3.3
22-May-02	50		0.70	0.60	20	11 RED & 11BLUE	4						
29-May-02													
5-Jun-02													
12-Jun-02													
19-Jun-02	50							27	27	27	81	36	3
26-Jun-02			19.90	16.92	437	11 BLUE	5						
3-Jul-02													
10-Jul-02								18	18	18	54	24	2
17-Jul-02	40												
24-Jul-02			4.20	3.57	300	11 YELL	1						
31-Jul-02													
7-Aug-02								27	27	27	81	36	3
14-Aug-02	40		15.00	12.75	300	11 YELL	5						
21-Aug-02													
28-Aug-02													
4-Sep-02													
11-Sep-02	40							27	27		54	24	2
18-Sep-02													
25-Sep-02			5.70	4.90	150	11 YELL	11						
2-Oct-02			5.70	4.90	150	11 YELL	11						
9-Oct-02			5.70	4.90	150	11 YELL	11						
16-Oct-02													
23-Oct-02													
30-Oct-02								18	18	27	63	28	2.3
6-Nov-02													
13-Nov-02													
20-Nov-02													
27-Nov-02													
4-Dec-02													
11-Dec-02													
18-Dec-02			12.81	10.88	150	11 YELL	17						
25-Dec-02			12.81	10.88	150	11 YELL	17						
1-Jan-03			12.44	10.57	95	11 BLUE	13						
8-Jan-03			6.66	5.66	150	11 YELL	18						
15-Jan-03			6.66	5.66	150	11 YELL	18						
22-Jan-03			6.66	5.66	150	11 YELL	18						
29-Jan-03			6.66	5.66	150	11 YELL	18						
5-Feb-03													
12-Feb-03													
19-Feb-03													
26-Feb-03								13.7352	10.476	14.55	38.7612	17.2272	1.5
5-Mar-03			14.48	12.31	180	11 BLUE	24						
12-Mar-03			14.48	12.31	180	11 BLUE	24						
19-Mar-03	49		14.48	12.31	180	11 BLUE	24						
26-Mar-03			14.12	12.01	150	11 RED	19						
2-Apr-03			14.12	12.01	150	11 RED	19						
9-Apr-03													
16-Apr-03													
23-Apr-03								31.7772	31.7772	27.2376	90.792	40.352	3
30-Apr-03	49		15.25	12.97	150	11 YELL	10						
7-May-03													
14-May-03													
21-May-03													
28-May-03	49							22.698	22.698	27.2376	72.6336	32.2816	3
4-Jun-03													
11-Jun-03													
18-Jun-03													
25-Jun-03	33		36.45	30.98	500	11 YELL	7	22.698	22.698		45.396	20.176	2
2-Jul-03													
9-Jul-03													
16-Jul-03													
23-Jul-03	33							18.1584	18.1584	27.2376	63.5544	28.2464	2.5
30-Jul-03													
6-Aug-03													
13-Aug-03													
20-Aug-03	33							18.1584	18.1584	18.1584	54.4752	24.2112	2
27-Aug-03													
3-Sep-03			4.91	4.17	300	11 YELL	2						
10-Sep-03			16.87	14.34	300	11 RED	11						
17-Sep-03			16.87	14.34	300	11 RED	11						
24-Sep-03													
1-Oct-03								22.698	22.698	22.698	68.094	30.264	2.5
8-Oct-03													

	Field No. 12 (all N loads to plot 12, blue, red, yellow) DIRTY WATER - BHC.7												
Week	Fertiliser	Slurry N tot	Dirty H20	TN * 85%		Plot	DW irrig	ANIMALS			N Deposited: Grazing Animals		Grazing
Ending	(kg/ha)	(kg N/ha)	TN Kg/ha/week	TN Kg/ha/week	TN (mg/l)	(ha =)	(mm/run)	Kg N	Kg N	Kg N	(kg N/week)	(kg N/Ha/week)	days
3-Oct-01		NONE											
10-Oct-01													
17-Oct-01													
24-Oct-01													
31-Oct-01													
7-Nov-01													
14-Nov-01													
21-Nov-01													
28-Nov-01													
5-Dec-01			25	21	272	12 BLUE (0.8649ha)	18						
12-Dec-01			25	21	272	TN = 49.5 kg/ha	18						
19-Dec-01													
26-Dec-01													
2-Jan-02													
9-Jan-02													
16-Jan-02													
23-Jan-02													
30-Jan-02													
6-Feb-02													
13-Feb-02													
20-Feb-02	50												
27-Feb-02													
6-Mar-02													
13-Mar-02													
20-Mar-02													
27-Mar-02													
3-Apr-02													
10-Apr-02								27	27	27	81	32.4	3
17-Apr-02	50							18	18	18	54	21.6	2
24-Apr-02													
1-May-02													
8-May-02													
15-May-02								27	27	27	81	32.4	3
22-May-02	50												
29-May-02													
5-Jun-02													
12-Jun-02													
19-Jun-02								18	18	18	54	21.6	2
26-Jun-02	40												
3-Jul-02			4.27	3.63	300	12 YELL	4						
10-Jul-02			4.27	3.63	300	12 YELL	4	27	27	36	90	36	3
17-Jul-02	40		4.27	3.63	300	12 YELL	4						
24-Jul-02													
31-Jul-02			5.83	4.95	300	12 YELL	2						
7-Aug-02								27	27		54	21.6	2
14-Aug-02	40		21.20	18.02	367	12 BLUE	6						
21-Aug-02			13.80	11.73	300	12 RED	5						
28-Aug-02			12.79	10.87	200	12 YELL	13						
4-Sep-02			12.79	10.87	200	12 YELL	13						
11-Sep-02													
18-Sep-02								27	27		54	21.6	2
25-Sep-02	40												
2-Oct-02													
9-Oct-02													
16-Oct-02			22.00	19.00	150	12 YELL	29						
23-Oct-02			22.00	19.00	150	12 YELL	29						
30-Oct-02													
6-Nov-02													
13-Nov-02								18	18		36	14.4	2
20-Nov-02			15.40	13.09	150	12 RED	10						
27-Nov-02			10.56	8.98	135	12 BLUE	16			28	28	11.2	1
4-Dec-02			10.56	8.98	135	12 BLUE	16				64	25.6	
11-Dec-02													
18-Dec-02													
25-Dec-02													
1-Jan-03													
8-Jan-03													
15-Jan-03													
22-Jan-03													
29-Jan-03													
5-Feb-03			11.48	9.75	224	12 BLUE	20						
12-Feb-03			11.48	9.75	224	12 BLUE	20						
19-Feb-03			11.48	9.75	224	12 BLUE	20						
26-Feb-03			11.48	9.75	224	12 BLUE	20						
5-Mar-03													
12-Mar-03													
19-Mar-03													
26-Mar-03													
2-Apr-03	49							18.1584	25.1424	25.1424	68.4432	27.37728	2.5
9-Apr-03			7.06	6.00	150	12 YELL	14						
16-Apr-03			7.06	6.00	150	12 YELL	14						
23-Apr-03			7.06	6.00	150	12 YELL	14						
30-Apr-03													
7-May-03	49							22.698	22.698	22.698	68.094	27.2376	2.5
14-May-03													
21-May-03			11.03	9.37	200	12 RED	6						
28-May-03			12.18	10.36	280	12 BLUE	4						
4-Jun-03	49							22.698	22.698	22.698	68.094	27.2376	2.5
11-Jun-03													
18-Jun-03			26.00	22.00	600	ALL 3 in 12	5						
25-Jun-03													
2-Jul-03	33							22.698	22.698	22.698	68.094	27.2376	2.5
9-Jul-03			17.73	15.07	400	12 YELL	9						
16-Jul-03			17.73	15.07	400	12 YELL	9						
23-Jul-03													
30-Jul-03	33							22.698	22.698		45.396	18.1584	2
6-Aug-03													
13-Aug-03													
20-Aug-03			19.28	16.39	300	12 YELL	13						
27-Aug-03			19.28	16.39	300	12 YELL	13						
3-Sep-03	33							22.698	22.698	18.1584	63.5544	25.42176	2.5
10-Sep-03			11.75	9.98	200	12 YELL	6						
17-Sep-03													
24-Sep-03													
1-Oct-03													
8-Oct-03								18.1584	18.1584	18.1584	54.4752	21.79008	2

				Field No. 13 GRAZING					
Week	Fertiliser	Slurry N tot	Dirty H20	ANIMALS			N Deposited: Grazing Animals		Grazing
Ending	(kg/ha)	(kg N/ha)	(kg N/ha)	Kg N	Kg N	Kg N	(kg N/week)	(kg N/Ha/week)	days
3-Oct-01		NONE	NONE						
10-Oct-01									
17-Oct-01									
24-Oct-01									
31-Oct-01									
7-Nov-01									
14-Nov-01									
21-Nov-01									
28-Nov-01									
5-Dec-01									
12-Dec-01									
19-Dec-01									
26-Dec-01									
2-Jan-02									
9-Jan-02									
16-Jan-02									
23-Jan-02									
30-Jan-02	50								
6-Feb-02									
13-Feb-02									
20-Feb-02									
27-Feb-02									
6-Mar-02									
13-Mar-02									
20-Mar-02									
27-Mar-02									
3-Apr-02									
10-Apr-02									
17-Apr-02									
24-Apr-02									
1-May-02	50			18	18	18	54	41.37931034	2
8-May-02									
15-May-02									
22-May-02									
29-May-02				9	9	9	27	20.68965517	1
5-Jun-02	50								
12-Jun-02									
19-Jun-02									
26-Jun-02									
3-Jul-02				9	9	18	36	27.5862069	1.3
10-Jul-02	50								
17-Jul-02									
24-Jul-02									
31-Jul-02				9	9	9	27	20.68965517	1
7-Aug-02	40								
14-Aug-02									
21-Aug-02									
28-Aug-02				18	18	9	45	34.48275862	2.3
4-Sep-02	40								
11-Sep-02									
18-Sep-02									
25-Sep-02									
2-Oct-02									
9-Oct-02									
16-Oct-02				18	18	9	45	34.48275862	1.7
23-Oct-02									
30-Oct-02									
6-Nov-02									
13-Nov-02									
20-Nov-02									
27-Nov-02									
4-Dec-02									
11-Dec-02									
18-Dec-02									
25-Dec-02									
1-Jan-03									
8-Jan-03									
15-Jan-03									
22-Jan-03									
29-Jan-03	49								
5-Feb-03									
12-Feb-03									
19-Feb-03									
26-Feb-03									
5-Mar-03									
12-Mar-03									
19-Mar-03									
26-Mar-03									
2-Apr-03									
9-Apr-03				12.804	9.7776	8.6136	31.1952	23.90436782	1
16-Apr-03	49								
23-Apr-03									
30-Apr-03									
7-May-03									
14-May-03				9.0792	9.0792	9.0792	27.2376	20.87172414	1
21-May-03									
28-May-03	49								
4-Jun-03									
11-Jun-03				13.6188	13.6188	13.6188	40.8564	31.30758621	1.5
18-Jun-03	33								
25-Jun-03									
2-Jul-03									
9-Jul-03									
16-Jul-03	33			13.6188	13.6188	13.6188	40.8564	31.30758621	1.5
23-Jul-03									
30-Jul-03									
6-Aug-03									
13-Aug-03	33			9.0792	9.0792	13.6188	31.7772	24.35034483	1
20-Aug-03									
27-Aug-03									
3-Sep-03									
10-Sep-03									
17-Sep-03	33			9.0792	9.0792	9.0792	27.2376	20.87172414	1
24-Sep-03									
1-Oct-03									
8-Oct-03									

Field No. 14 GRAZING

Week Ending	Fertiliser (kg/ha)	Slurry N tot (kg N/ha)	SI *25% (kg N/ha)	Dirty H20 (kg N/ha)	ANIMALS Kg N	Kg N	Kg N	N Deposited: Grazing Animals (kg N/week)	(kg N/Ha/week)	Grazing Days
3-Oct-01				NONE						
10-Oct-01										
17-Oct-01										
24-Oct-01										
31-Oct-01										
7-Nov-01										
14-Nov-01										
21-Nov-01										
28-Nov-01										
5-Dec-01										
12-Dec-01										
19-Dec-01										
26-Dec-01										
2-Jan-02										
9-Jan-02										
16-Jan-02	50									
23-Jan-02										
30-Jan-02										
6-Feb-02										
13-Feb-02										
20-Feb-02										
27-Feb-02										
6-Mar-02										
13-Mar-02										
20-Mar-02										
27-Mar-02										
3-Apr-02										
10-Apr-02										
17-Apr-02										
24-Apr-02										
1-May-02	50									
8-May-02										
15-May-02										
22-May-02										
29-May-02	50				18	18	18	54	21.95121951	2
5-Jun-02										
12-Jun-02										
19-Jun-02										
26-Jun-02					18	18	18	54	21.95121951	2
3-Jul-02	50									
10-Jul-02										
17-Jul-02										
24-Jul-02										
31-Jul-02					18	18	18	54	21.95121951	2
7-Aug-02	40									
14-Aug-02										
21-Aug-02										
28-Aug-02					27	27	18	72	29.26829268	2.6
4-Sep-02	40									
11-Sep-02										
18-Sep-02										
25-Sep-02										
2-Oct-02										0.7
9-Oct-02					9	9	18	36	14.63414634	0.7
16-Oct-02										
23-Oct-02										
30-Oct-02										
6-Nov-02										
13-Nov-02					18	18	9	45	18.29268293	1.7
20-Nov-02										
27-Nov-02										
4-Dec-02										
11-Dec-02										
18-Dec-02										
25-Dec-02										
1-Jan-03										
8-Jan-03										
15-Jan-03										
22-Jan-03										
29-Jan-03	49									
5-Feb-03										
12-Feb-03										
19-Feb-03										
26-Feb-03										
5-Mar-03										
12-Mar-03										
19-Mar-03										
26-Mar-03										
2-Apr-03										
9-Apr-03					25.608	18.624	19.0896	63.3216	25.7404878	2
16-Apr-03										
23-Apr-03										
30-Apr-03	49									
7-May-03					22.698	22.698	27.2376	72.6336	29.52585366	3
14-May-03	49									
21-May-03										
28-May-03										
4-Jun-03					18.1584	18.1584	18.1584	54.4752	22.14439024	2
11-Jun-03	49									
18-Jun-03										
25-Jun-03										
2-Jul-03										
9-Jul-03	33				18.1584	18.1584	22.698	59.0148	23.9897561	2
16-Jul-03										
23-Jul-03										
30-Jul-03										
6-Aug-03										
13-Aug-03	33									
20-Aug-03										
27-Aug-03										
3-Sep-03	33				9.0792	9.0792	9.0792	27.2376	11.07219512	1
10-Sep-03										
17-Sep-03										
24-Sep-03										
1-Oct-03										
8-Oct-03										

	Field No. 15 Two Cut - BHC.1 is situated here									
Week	Fertiliser	Slurry N tot	SI *25%	Dirty H20		ANIMALS		N Deposited: Grazing Animals		Grazing
Ending	(kg/ha)	(kg N/ha)	(kg N/ha)	(kg N/ha)	Kg N	Kg N	Kg N	(kg N/week)	(kg N/Ha/week)	days
3-Oct-01				NONE						
10-Oct-01										
17-Oct-01										
24-Oct-01										
31-Oct-01										
7-Nov-01										
14-Nov-01										
21-Nov-01										
28-Nov-01										
5-Dec-01										
12-Dec-01										
19-Dec-01										
26-Dec-01										
2-Jan-02										
9-Jan-02	50									
16-Jan-02										
23-Jan-02										
30-Jan-02										
6-Feb-02										
13-Feb-02										
20-Feb-02										
27-Feb-02					10	40		50	20.32520325	1.8
6-Mar-02					30		41	71	28.86178862	2.5
13-Mar-02										
20-Mar-02										
27-Mar-02										
3-Apr-02					37		13	50	20.32520325	2
10-Apr-02										
17-Apr-02	100	99	25							
24-Apr-02										
1-May-02										
8-May-02										
15-May-02										
22-May-02										
29-May-02										
5-Jun-02										
12-Jun-02										
19-Jun-02	100									
26-Jun-02										
3-Jul-02										
10-Jul-02										
17-Jul-02										
24-Jul-02										
31-Jul-02	50									
7-Aug-02										
14-Aug-02										
21-Aug-02										
28-Aug-02	40				18	18	18	54	21.95121951	2
4-Sep-02										
11-Sep-02										
18-Sep-02										
25-Sep-02										
2-Oct-02										
9-Oct-02					18	27	18	63	25.6097561	2.3
16-Oct-02										
23-Oct-02										
30-Oct-02										
6-Nov-02										
13-Nov-02					14	14	14	42	17.07317073	1.5
20-Nov-02										
27-Nov-02										
4-Dec-02										
11-Dec-02										
18-Dec-02										
25-Dec-02										
1-Jan-03										
8-Jan-03										
15-Jan-03										
22-Jan-03										
29-Jan-03	49									
5-Feb-03										
12-Feb-03										
19-Feb-03		90	23							
26-Feb-03										
5-Mar-03										
12-Mar-03										
19-Mar-03										
26-Mar-03										
2-Apr-03					12.4548	12.4548	12.4548	37.3644	15.18878049	1.5
9-Apr-03	99									
16-Apr-03										
23-Apr-03										
30-Apr-03										
7-May-03										
14-May-03										
21-May-03										
28-May-03		98	25							
4-Jun-03										
11-Jun-03	99									
18-Jun-03										
25-Jun-03										
2-Jul-03										
9-Jul-03										
16-Jul-03										
23-Jul-03										
30-Jul-03	33									
6-Aug-03										
13-Aug-03										
20-Aug-03	33				9.0792	9.0792	13.6188	31.7772	12.91756098	1
27-Aug-03										
3-Sep-03										
10-Sep-03										
17-Sep-03										
24-Sep-03										
1-Oct-03					13.6188	13.6188	13.6188	40.8564	16.60829268	2
8-Oct-03										

	Field No. 16 (TWO CUT)								
Week	Fertiliser	Slurry N tot	Dirty H20	ANIMALS			N Deposited: Grazing Animals		Grazing
Ending	(kg/ha)	(kg N/ha)	(kg N/ha)	Kg N	Kg N	Kg N	(kg N/week)	(kg N/Ha/week)	days
3-Oct-01			NONE						
10-Oct-01									
17-Oct-01									
24-Oct-01									
31-Oct-01									
7-Nov-01									
14-Nov-01									
21-Nov-01									
28-Nov-01									
5-Dec-01									
12-Dec-01									
19-Dec-01									
26-Dec-01									
2-Jan-02									
9-Jan-02	50								
16-Jan-02									
23-Jan-02									
30-Jan-02									
6-Feb-02									
13-Feb-02									
20-Feb-02				12	7	37	56	22.76422764	4
27-Feb-02									
6-Mar-02									
13-Mar-02									
20-Mar-02									
27-Mar-02									
3-Apr-02				9	9	23	41	16.66666667	1.5
10-Apr-02									
17-Apr-02	100	99							
24-Apr-02									
1-May-02									
8-May-02									
15-May-02									
22-May-02									
29-May-02									
5-Jun-02									
12-Jun-02									
19-Jun-02	100								
26-Jun-02									
3-Jul-02									
10-Jul-02									
17-Jul-02									
24-Jul-02									
31-Jul-02	50								
7-Aug-02									
14-Aug-02									
21-Aug-02									
28-Aug-02				9	9	18	36	14.63414634	1.5
4-Sep-02	40								
11-Sep-02									
18-Sep-02									
25-Sep-02									
2-Oct-02									
9-Oct-02				18	18	18	54	21.95121951	1.3
16-Oct-02									
23-Oct-02									
30-Oct-02									
6-Nov-02									
13-Nov-02									
20-Nov-02				14	14	14	42	17.07317073	2
27-Nov-02									
4-Dec-02									
11-Dec-02									
18-Dec-02									
25-Dec-02									
1-Jan-03									
8-Jan-03									
15-Jan-03									
22-Jan-03									
29-Jan-03	49								
5-Feb-03									
12-Feb-03									
19-Feb-03		84							
26-Feb-03									
5-Mar-03									
12-Mar-03									
19-Mar-03									
26-Mar-03				12.222	19.6716	12.4548	44.3484	18.02780488	1.5
2-Apr-03									
9-Apr-03	83								
16-Apr-03									
23-Apr-03									
30-Apr-03									
7-May-03									
14-May-03									
21-May-03									
28-May-03		100							
4-Jun-03									
11-Jun-03	99								
18-Jun-03									
25-Jun-03					13.6188		13.6188	5.536097561	0.5
2-Jul-03									
9-Jul-03									
16-Jul-03									
23-Jul-03									
30-Jul-03	33								
6-Aug-03									
13-Aug-03									
20-Aug-03									
27-Aug-03	33			9.0792	13.6188	9.0792	31.7772	12.91756098	1
3-Sep-03									
10-Sep-03									
17-Sep-03									
24-Sep-03				13.6188	13.6188	13.6188	40.8564	16.60829268	1.5
1-Oct-03									
8-Oct-03									

	Field No. 17 GRAZING (BHC.2 located here)								
Week	Fertiliser	Slurry N tot	Dirty H20	ANIMALS			N Deposited: Grazing Animals		Grazing
Ending	(kg/ha)	(kg N/ha)	(kg N/ha)	Kg N	Kg N	Kg N	(kg N/week)	(kg N/Ha/week)	days
3-Oct-01			NONE						
10-Oct-01									
17-Oct-01									
24-Oct-01									
31-Oct-01									
7-Nov-01									
14-Nov-01									
21-Nov-01									
28-Nov-01									
5-Dec-01									
12-Dec-01									
19-Dec-01									
26-Dec-01									
2-Jan-02									
9-Jan-02									
16-Jan-02									
23-Jan-02									
30-Jan-02	50								
6-Feb-02									
13-Feb-02									
20-Feb-02									
27-Feb-02									
6-Mar-02									
13-Mar-02									
20-Mar-02									
27-Mar-02									
3-Apr-02									
10-Apr-02									
17-Apr-02									
24-Apr-02				45	45	45	135	50.61867267	5
1-May-02	50								
8-May-02									
15-May-02									
22-May-02				18	18	27	63	23.62204724	2.3
29-May-02	50								
5-Jun-02									
12-Jun-02									
19-Jun-02									
26-Jun-02	50			18	18	18	54	20.24746907	2
3-Jul-02									
10-Jul-02									
17-Jul-02									
24-Jul-02	40			27	27	36	90	33.74578178	3.3
31-Jul-02									
7-Aug-02									
14-Aug-02									
21-Aug-02				18	18	27	63	23.62204724	2.3
28-Aug-02	40								
4-Sep-02									
11-Sep-02									
18-Sep-02									
25-Sep-02									
2-Oct-02				27	27	18	72	26.99662542	2.7
9-Oct-02									
16-Oct-02									
23-Oct-02									
30-Oct-02									
6-Nov-02									
13-Nov-02				9	9	27	45	16.87289089	2
20-Nov-02									
27-Nov-02									
4-Dec-02									
11-Dec-02									
18-Dec-02									
25-Dec-02									
1-Jan-03			NONE						
8-Jan-03									
15-Jan-03									
22-Jan-03									
29-Jan-03	49								
5-Feb-03									
12-Feb-03									
19-Feb-03									
26-Feb-03									
5-Mar-03									
12-Mar-03									
19-Mar-03									
26-Mar-03									
2-Apr-03									
9-Apr-03									
16-Apr-03	49			33.9888	29.2164	34.92	98.1252	36.79235096	3.5
23-Apr-03									
30-Apr-03									
7-May-03									
14-May-03	49			22.698	22.698	27.2376	72.6336	27.23419573	3
21-May-03									
28-May-03									
4-Jun-03									
11-Jun-03	49			22.698	22.698	22.698	68.094	25.53205849	2.5
18-Jun-03									
25-Jun-03									
2-Jul-03									
9-Jul-03	33			22.698	22.698	27.2376	72.6336	27.23419573	3
16-Jul-03									
23-Jul-03									
30-Jul-03									
6-Aug-03									
13-Aug-03	33			22.698	22.698	22.698	68.094	25.53205849	2.5
20-Aug-03									
27-Aug-03									
3-Sep-03									
10-Sep-03									
17-Sep-03									
24-Sep-03	33			22.698	22.698	22.698	68.094	25.53205849	2.5
1-Oct-03									
8-Oct-03									

Field No. 18 GRAZING

Week Ending	Fertiliser (kg/ha)	Slurry N tot (kg N/ha)	Dirty H20 (kg N/ha)	ANIMALS Kg N	Kg N	Kg N	N Deposited: (kg N/week)	Grazing Animals (kg N/Ha/week)	Grazing days
3-Oct-01			NONE						
10-Oct-01									
17-Oct-01									
24-Oct-01									
31-Oct-01									
7-Nov-01									
14-Nov-01									
21-Nov-01									
28-Nov-01									
5-Dec-01									
12-Dec-01									
19-Dec-01									
26-Dec-01									
2-Jan-02									
9-Jan-02									
16-Jan-02									
23-Jan-02									
30-Jan-02									
6-Feb-02									
13-Feb-02									
20-Feb-02	50								
27-Feb-02									
6-Mar-02									
13-Mar-02									
20-Mar-02									
27-Mar-02									
3-Apr-02									
10-Apr-02									
17-Apr-02				36	36	45	117	40.76655052	4.3
24-Apr-02	50								
1-May-02									
8-May-02									
15-May-02				27	27		54	18.81533101	2
22-May-02									
29-May-02	50								
5-Jun-02									
12-Jun-02									
19-Jun-02				27	27		54	18.81533101	2
26-Jun-02	50								
3-Jul-02									
10-Jul-02									
17-Jul-02				27	27	9	63	21.95121951	2.3
24-Jul-02	50								
31-Jul-02									
7-Aug-02									
14-Aug-02									
21-Aug-02									
28-Aug-02									
4-Sep-02									
11-Sep-02									
18-Sep-02									
25-Sep-02									
2-Oct-02									
9-Oct-02				27	18	9	54	18.81533101	1.7
16-Oct-02									
23-Oct-02									
30-Oct-02									
6-Nov-02									
13-Nov-02									
20-Nov-02				14			14	4.87804878	0.5
27-Nov-02									
4-Dec-02									
11-Dec-02									
18-Dec-02									
25-Dec-02									
1-Jan-03									
8-Jan-03									
15-Jan-03									
22-Jan-03									
29-Jan-03	49								
5-Feb-03									
12-Feb-03									
19-Feb-03									
26-Feb-03									
5-Mar-03									
12-Mar-03									
19-Mar-03									
26-Mar-03									
2-Apr-03				28.6344	18.9732	32.1264	79.734	27.78188153	3
9-Apr-03	49								
16-Apr-03									
23-Apr-03									
30-Apr-03									
7-May-03				27.2376	27.2376	40.8564	95.3316	33.21658537	3
14-May-03	49								
21-May-03									
28-May-03									
4-Jun-03				27.2376	27.2376	27.2376	81.7128	28.47135889	3
11-Jun-03	49								
18-Jun-03									
25-Jun-03									
2-Jul-03									
9-Jul-03									
16-Jul-03									
23-Jul-03									
30-Jul-03									
6-Aug-03	33			22.698	22.698	27.2376	72.6336	25.30787456	3
13-Aug-03									
20-Aug-03									
27-Aug-03									
3-Sep-03									
10-Sep-03									
17-Sep-03	33			18.1584	18.1584	22.698	59.0148	20.56264808	2
24-Sep-03									
1-Oct-03									
8-Oct-03									

Field No. 19 GRAZING									
Week Ending	Fertiliser (kg/ha)	Slurry N tot (kg N/ha)	Dirty H20 (kg N/ha)	ANIMALS			N Deposited: Grazing Animals		Grazing days
				Kg N	Kg N	Kg N	(kg N/week)	(kg N/Ha/week)	
3-Oct-01			NONE						
10-Oct-01									
17-Oct-01									
24-Oct-01									
31-Oct-01									
7-Nov-01									
14-Nov-01									
21-Nov-01									
28-Nov-01									
5-Dec-01									
12-Dec-01									
19-Dec-01									
26-Dec-01									
2-Jan-02									
9-Jan-02									
16-Jan-02									
23-Jan-02									
30-Jan-02	50								
6-Feb-02									
13-Feb-02									
20-Feb-02									
27-Feb-02				36	36	36	108	42.12332774	4
6-Mar-02									
13-Mar-02									
20-Mar-02									
27-Mar-02									
3-Apr-02									
10-Apr-02									
17-Apr-02									
24-Apr-02									
1-May-02	50								
8-May-02									
15-May-02									
22-May-02									
29-May-02				18	18	18	54	21.06166387	2
5-Jun-02	40								
12-Jun-02									
19-Jun-02									
26-Jun-02				36	36	36	108	42.12332774	4
3-Jul-02	40								
10-Jul-02									
17-Jul-02									
24-Jul-02									
31-Jul-02				27	27		54	21.06166387	2
7-Aug-02	40								
14-Aug-02									
21-Aug-02									
28-Aug-02				27	27	9	63	24.57194118	2.3
4-Sep-02	40								
11-Sep-02									
18-Sep-02									
25-Sep-02									
2-Oct-02									
9-Oct-02									
16-Oct-02				18	18	27	63	24.57194118	2.3
23-Oct-02									
30-Oct-02									
6-Nov-02									
13-Nov-02									
20-Nov-02				14	14	14	42	16.38129412	2
27-Nov-02									
4-Dec-02									
11-Dec-02									
18-Dec-02									
25-Dec-02									
1-Jan-03									
8-Jan-03									
15-Jan-03									
22-Jan-03									
29-Jan-03	49								
5-Feb-03									
12-Feb-03									
19-Feb-03									
26-Feb-03									
5-Mar-03									
12-Mar-03									
19-Mar-03									
26-Mar-03									
2-Apr-03									
9-Apr-03									
16-Apr-03	49			23.9784	25.7244	46.2108	95.9136	37.40925933	3.5
23-Apr-03									
30-Apr-03									
7-May-03									
14-May-03	49			18.1584	18.1584	18.1584	54.4752	21.24700651	2
21-May-03									
28-May-03									
4-Jun-03									
11-Jun-03				18.1584	18.1584	18.1584	54.4752	21.24700651	2
18-Jun-03	49								
25-Jun-03									
2-Jul-03									
9-Jul-03									
16-Jul-03	33			22.698	22.698		45.396	17.70583876	1.7
23-Jul-03									
30-Jul-03									
6-Aug-03									
13-Aug-03	33			22.698	22.698	9.0792	54.4752	21.24700651	2
20-Aug-03									
27-Aug-03									
3-Sep-03									
10-Sep-03				18.1584	18.1584	18.1584	54.4752	21.24700651	2
17-Sep-03	33								
24-Sep-03									
1-Oct-03									
8-Oct-03									

Hydrological Year 2001-2002												
		Atmospheric N (wet)		Fertiliser		SLURRY		Dirty Water		Animals		
	Area	(kg N/ha)	kg N	(kg N/ha)	kg N	(kg N/ha)	kg N	(kg N/ha)	kg N	kg N/ha	(kg N)	GR. Days
Field 1	2.5104	9	23	380	954	98	247			150	377	14
Field 2	2.5104	9	23	330	828					184	463	17.2
Field 3	2.5104	9	23	290	728	81	203			145	363	13.5
Field 4	2.5104	9	23	340	854					193	484	18
Field 5	2.5104	9	23	280	703	98	247			118	296	11
Field 6	2.5117	9	23	280	703	96	241			150	377	14
Field 7	4.09	9	37	340	1391	98	402			72	296	11
Field 8	3.648	9	33	340	1240	88	320			66	242	9
Field 9	2.4663	9	22	250	617					185	457	17
Field 10	2.3608	9	21	240	567			276	653	129	304	11.3
Field 11	2.2496	9	20	320	720			136	306	239	538	20
Field 12	2.5098	9	23	310	778			129	323	225	565	21
Field 13	1.305	9	12	280	365					239	312	11.6
Field 14	2.4634	9	22	280	690					138	339	12.6
Field 15	2.4663	9	22	340	839	99	244			134	331	12.3
Field 16	2.4665	9	22	340	839	99	244			120	296	11
Field 17	2.667	9	24	280	747					191	509	18.9
Field 18	2.8707	9	26	250	718					137	393	14.6
Field 19	2.5639	9	23	260	667					192	492	18.3

TOTAL ORGANIC N

wrt NO3 Directive		
kg N/ha	kg N	
248	624	Field 1
184	463	Field 2
226	567	Field 3
193	484	Field 4
216	543	Field 5
246	618	Field 6
171	698	Field 7
154	562	Field 8
185	457	Field 9
405	957	Field 10
375	845	Field 11
354	888	Field 12
239	312	Field 13
138	339	Field 14
233	575	Field 15
219	540	Field 16
191	509	Field 17
137	393	Field 18
192	492	Field 19

Hydrologic Year 2002 - 2003												
		Atmospheric N (wet)		Fertiliser		SLURRY		Dirty Water		Animal Deposition		
	Area	(kg N/ha)	kg N	(kg N/ha)	Kg N	(kg N/ha)	Kg N	(kg N/ha)	kg N	kg N/ha	(kg N)	GR. Days
Field 1	2.5104	9	23	282	709	95	238			172	431	16
Field 2	2.5104	9	23	248	623					155	390	15
Field 3	2.5104	9	23	298	749	87	218			86	215	8
Field 4	2.5104	9	23	298	747					118	296	11
Field 5	2.5104	9	23	298	749	168	422			137	344	13
Field 6	2.5117	9	23	298	749	150	377			139	350	13
Field 7	4.09	9	37	314	1286	180	736			67	276	10
Field 8	3.648	9	33	314	1147	196	715			63	229	9
Field 9	2.4663	9	22	338	833					196	484	18
Field 10	2.3608	9	21	248	586			265	626	199	471	18
Field 11	2.2496	9	20	248	559			232	523	225	506	19
Field 12	2.5098	9	23	248	623			283	709	209	525	20
Field 13	1.305	9	12	282	368					179	234	9
Field 14	2.4634	9	22	298	733					135	334	12
Field 15	2.4663	9	22	314	775	188	464			91	223	8
Field 16	2.4665	9	22	298	734	184	454			85	210	8
Field 17	2.667	9	24	298	794					192	511	19
Field 18	2.8707	9	26	264	759					152	436	16
Field 19	2.5639	9	23	298	763					184	471	18

TOTAL ORGANIC N		
wrt NO3 Directive		
kg N/ha	kg N	
267	669	Field 1
155	390	Field 2
173	434	Field 3
118	296	Field 4
305	766	Field 5
289	727	Field 6
247	1012	Field 7
259	944	Field 8
196	484	Field 9
465	1097	Field 10
457	1029	Field 11
492	1234	Field 12
179	234	Field 13
135	334	Field 14
279	687	Field 15
269	664	Field 16
192	511	Field 17
152	436	Field 18
184	471	Field 19

	Slurry application Details										RESULTS FROM THE LAB - M. RYANS				
			1, 7,					Kg/ha			mg/kg	mg/kg	mg/kg	mg/kg	
2002	**Smp XKO**	**Plot**	**Trtmt**	**Plot Area ha**	**Date**	**Rate(gls/ac)**	**T/ha**	**SLURRY**	**Tot.N (Kg/ha)**	**N * 25% (N kg/ha)**	**Tot.N**	**Tot.Mg**	**Tot.P**	**Tot.K**	**%DM**
Appl. 1 02	1	6	1cut	0.8657	27/3/02						3381	536	643	4226	6.7
Appl. 1 02	2	6			27/3/02	2455.6	27.5				3569	586	709	4402	7.6
Appl. 1 02					Mean			27500	96	24	3475	561	676	4314	7.15
Appl. 1 02	3	5	1cut	0.8652	28/3/02						3475	589	696	4556	7.6
Appl. 1 02	4	5			28/3/02	2499	27.99				3550	568	699	4506	7.5
Appl. 1 02					Mean			27990	98	25	3512.5	578.5	697.5	4531	7.55
Appl. 1 02	5	3	1cut	0.8652	29/3/02						1763	282	392	869	8
Appl. 1 02	6	3			29/3/02	2499	27.99				3448	571	714	4282	7.6
Appl. 1 02					Mean			27990	73	18	2605.5	426.5	553	2575.5	7.8
Appl. 1 02	7	8	2cut	1.257	2/4/02				89		1013	1013	687	4187	8.4
Appl. 1 02	8	8			2/4/02	2547	28.53				5128	916	1064	5109	10.5
Appl. 1 02					Mean			28530	88	22	3070.5	964.5	875.5	4648	9.45
Appl. 1 02	10	15	2cut	0.85	5/4/02	2473	27.7				3691	711	688	5852	7.1
Appl. 1 02	11	16			6/4/02	2535.6	28.39				3542	742	662	6191	12.6
Appl. 1 02		1	**also, not m ryan cups**		29/3/02			28390	103	26	3616.5	726.5	675	6021.5	9.85
Appl. 1 02		7			29/3/02										
no 2nd slurry application in 2002															
2003															
Appl. 1 03		1			17/2/03	3012			95	22					
Appl. 1 03	89	3	1cut	0.8652	18/3/03						2491		351		
Appl. 1 03	90	3			18/3/03	3012	33.73				2641		410		
Appl. 1 03					Mean			33730	87	22	2566		380.5		5.67
Appl. 1 03	91	6	1cut	0.8657	18/3/03	3057	34.24	34240	90		2642		413		4.94
Appl. 1 03															
Appl. 1 03	92	5	1cut	0.8652	18/3/03	2959	33.14	33140	88	22	2658		411		5.39
Appl. 1 03															
Appl. 1 03	93	8	2cut	1.257	27/3/03						2618		408		
Appl. 1 03	94	8			27/3/03						2563		393		
Appl. 1 03	95	8			27/3/03	3068	34.36	34360	89	22	2580		383		
Appl. 1 03					Mean						2587		394.6667		2.07
Appl. 1 03	96	16	2cut	0.85	28/3/03						2570		393		
Appl. 1 03	97	16			28/3/03	2821	31.6	31600	84	21	2646		417		
Appl. 1 03					Mean						2608		405		2.15
Appl. 1 03	98	15	2cut	0.85	28/3/03	3181	35.63	35630	93	23	2603		413		1.93
		7			28/3/03	3127			90						
Appl. 2 03															
Appl. 2 03		7			26/5/03	3015			90	23					
Appl. 2 03		no 1 this time							90	23					
Appl. 2 03		3			26/5/03				100	25	3173		696		8.16
Appl. 2 03															
Appl. 2 03		16			26/5/03				100	25	3000		625		8.21
Appl. 2 03															
Appl. 2 03		5			26/5/03				80	20	2962		654		8.29
Appl. 2 03															
Appl. 2 03		15			26/5/03				98	25	3063		656		8.17
Appl. 2 03															
Appl. 2 03		6			26/5/03				60	15	2905		619		7.9
Appl. 2 03															
Appl. 2 03		8			26/5/03				106	27	3046		659		8.2

Appendix R

Groundwater Hydrochemistry – Curtin's Farm

This appendix contains full analyses results for each water quality parameter analysed. Groundwater monitoring and analyses methods were presented in chapter five, section 5.3. Groundwater quality was discussed in chapter six, generally in section 6.3 and more specifically in section 6.4.6.

Groundwater quality results are presented in tabular format in this appendix as follows:

Parameter	**Page**
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Ammonium-nitrogen	655
Nitrite-nitrogen	656
Potassium	657
Sodium	659
Potassium:Sodium ratios	661
Phosphorus	662
Calcium	664
Sulphate	665
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Also presented are groundwater nutrient and water level trend graphs for each piezometer location and the River Funshion, as follows:

Piezometer	**Page**
BHC.1	667
BHC.2	668
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BHC.4	670
BHC.5	671
BHC.7	672
BHC.8	673
BHC.9	674
BHC.10	675
River Funshion	676

		NO3_N	NO3_N	NO3_N	NO3_N	NO3_N	NO3_N	NO3_N	NO3_N	NO3_N	NO3_N	
		BHC.1	BHC.2	BHC.3	BHC.4	BHC.5	BHC.7	BHC.8	BHC.9	BHC.10	RIVER	AVERAGE
nov	**11/23/01**		19.8				25.2					22.5
dec	**12/5/01**		19.9				25.1					22.5
jan	**01/19/02**		16.1		11.0	10.9	21.7		8.9	15.3		13.7
feb	**02/05/2002**	7.4	9.4		19.7	12.8	23.2	25.2	8.2	5.5		15.1
feb	**02/19/02**	7.0	11.8		20.9	9.5	22.0		8.6	5.2		13.3
mar	**03/12/2002**	6.8	17.0	11.2	15.8	13.2	20.7	25.6	11.7	5.8	5.5	15.2
mar	**03/26/02**	8.0	19.6	20.1	19.2	13.4	25.6	25.1	13.9	7.3		18.1
apr	**04/09/2002**	6.3	21.6	13.3	17.7	13.9	26.9	31.0	13.1	7.1		18.0
apr	**04/23/02**	6.6	21.4	19.3		12.8	23.0	22.4	13.9	5.2	5.3	17.1
may	**05/23/02**	5.5						19.5		3.9	3.6	12.5
jun	**06/04/2002**	7.4		13.6				11.7		3.5		10.9
jun	**06/19/02**	7.4	12.2	20.3	22.0	17.3	27.0		15.4	2.9		17.4
jul	**07/04/2002**	6.27	17.99		18.44		24.10	24.1	13.93		4.54	17.5
jul	**07/16/02**	5.39	22.32	20.64	13.98	16.16	23.82	27.13	15.53		5.26	18.1
aug	**08/15/02**	4.0	17.1	8.8	23.1	7.2	18.1	8.6	23.0		3.0	13.7
sept	**09/19/02**		21.9	20.0	6.8	13.9	22.2	24.3	11.6		5.0	17.2
oct	**10/24/02**		20.2		6.5		21.1		10.8		5.9	14.6
nov	**11/21/02**	7.0	16.5	7.6	13.0	12.3	18.0		9.3			12.0
dec	**12/05/02**	9.0	12.9				8.6		9.4			10.0
dec	**12/10/02**	12.2	11.6	9.7	23.2	12.7	17.3	21.5	11.0			14.9
jan	**1/16/03**	9.7	11.9		20.3		14.0		11.3	1.1	5.7	13.5
jan	**1/29/03**	10.9	12.9	8.6	14.2	16.5	16.5	16.2	12.0	0.9	5.0	13.5
feb	**02/12/03**	8.9	13.2	9.2	14.6	13.9	16.9	14.6	11.2	1.3	4.9	12.8
feb	**02/26/03**	8.7	13.4	8.7	15.4	13.8	15.2	14.0	12.2	1.4	6.0	12.7
mar	**03/03/03**	8.3	14.0		14.8		15.6		11.9			12.9
mar	**03/05/03**	8.2	13.8	8.5	14.3	13.4	15.7	14.4	11.8	0.8	3.6	12.5
mar	**03/12/03**	7.8	12.5		14.6	13.7	16.6	13.8	11.3	1.8		12.9
apr	**04/09/03**	5.8	13.3		13.3	13.8	14.7	13.5	11.3			12.2
may	**05/07/03**	5.6	13.2		14.6	11.6	13.7		9.9			11.4
jun	**06/06/03**	4.9	15.5	10.1	13.3	13.3	13.9	13.8	10.7		3.6	11.9
jul	**07/02/03**	4.6	15.6	9.8	9.1	13.4	13.1	12.5	10.3	1.5	3.9	11.1
sep	**09/03/03**		17.6	11.1	4.0	12.0	14.0	14.1	10.9		4.8	11.9

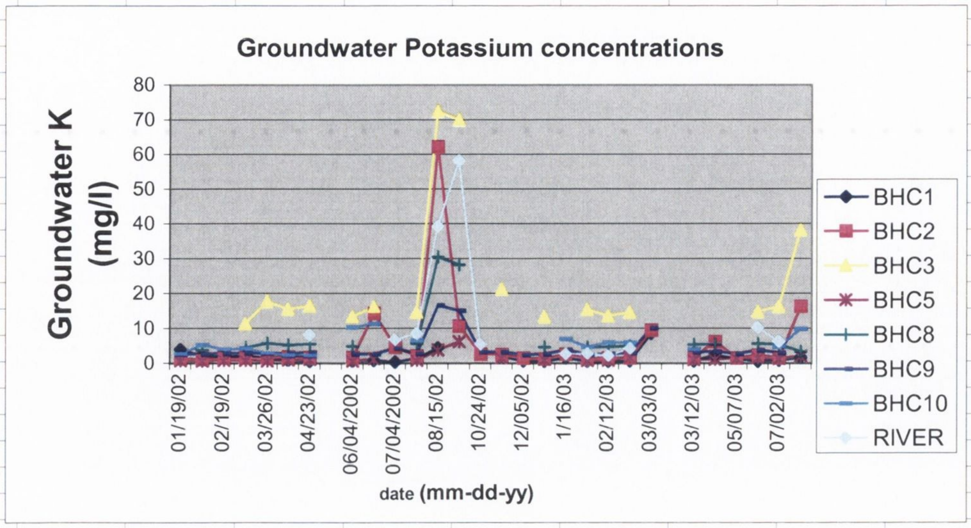
MAX	**12.2**	**22.3**	**20.6**	**23.2**	**17.3**	**27.0**	**31.0**	**23.0**	**15.3**	**6.0**
MIN	**4.0**	**9.4**	**7.6**	**4.0**	**7.2**	**8.6**	**8.6**	**8.2**	**0.8**	**3.0**
RANGE	**8.2**	**12.9**	**13.0**	**19.2**	**10.1**	**18.3**	**22.3**	**14.9**	**14.5**	**2.9**
	BHC.1	**BHC.2**	**BHC.3**	**BHC.4**	**BHC.5**	**BHC.7**	**BHC.8**	**BHC.9**	**BHC.10**	**RIVER**
AVERAGE	**7.3**	**15.9**	**12.8**	**15.1**	**13.1**	**19.1**	**18.7**	**11.9**	**4.1**	**4.7**

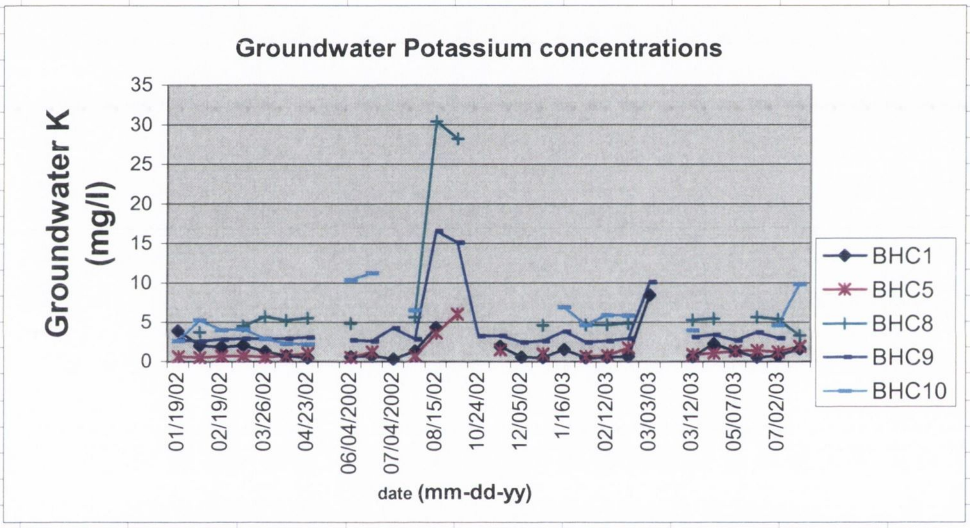
Groundwater concentrations of ammonium-N (mg/l) at Curtin's farm (River Funshion data also shown)										
	NH4_N	NH4_N	NH4_N	NH4_N	NH4_N	NH4_N	NH4_N	NH4_N	NH4_N	NH4_N
	BHC.1	BHC.2	BHC.3	BHC.4	BHC.5	BHC.7	BHC.8	BHC.9	BHC.10	River
01/19/02	0.13	0.14		1.56	0.04	0.13		0.04	0.05	
02/05/2002	0.04	0.05		0.48	0.12	0.03	0.03	0.03	0.29	
02/19/02	0.03	0.08		0.26	<0.01	<0.01		<0.01	0.15	
03/12/2002	0.08	0.18	0.04	0.69	<0.01	<0.01	<0.01	<0.01	0.14	<0.01
03/26/02	0.02	0.16	<0.01	1.74	<0.01	0.04	<0.01	<0.01	0.08	0.02
04/09/2002	0.09	0.33	0.09	1.80	0.10	0.09	0.10	0.09	0.17	
04/23/02	0.06	0.19	0.07		0.03	0.06	0.04	0.06	0.18	0.05
05/23/02	0.07	0.26	0.06	1.52	0.12	0.08	0.06	0.04	0.31	0.13
06/04/2002	0.02	0.08	0.03	0.55	0.04	0.06	0.05	0.03	0.25	
06/19/02	0.01	2.28	0.07	0.13	0.01	0.02		0.02	0.99	
07/04/2002	<0.1	0.67		0.94		<0.1		<0.1	<0.1	
07/16/02	<0.1	<0.1	<0.1	1.115	<0.1	<0.1	<0.1	<0.1	0.73	<0.1
08/15/02	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
09/19/02		0.1	<0.1	3.1	0.1	<0.1	<0.1	<0.1	<0.1	<0.1
10/24/02		<0.1		3.98		<0.1		<0.1	0.04	<0.1
11/21/02	<0.1	<0.1	<0.1	2.03	<0.1	<0.1		<0.1		
12/05/02	0.12	0.1665				0.12		<0.1		
12/10/02	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1		
1/16/03	<0.1	<0.1		1.4595		<0.1		<0.1	1.9005	<0.1
1/29/03	<0.1	<0.1	<0.1	0.987	<0.1	<0.1	<0.1	<0.1	0.2205	<0.1
02/12/03	<0.1	0.138	<0.1	1.8435	<0.1	<0.1	<0.1	0.262	0.922	<0.1
02/26/03	<0.1	<0.1	<0.1	1.19	0.17	<0.1	<0.1	<0.1	<0.1	<0.1
03/03/03	<0.1	<0.1		1.23		<0.1		<0.1		
03/05/03	<0.1	<0.1	<0.1	0.76	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1
03/12/03	<0.1	<0.1		0.225	<0.1	<0.1	<0.1	<0.1	0.070	<0.1
04/09/03	0.24	0.02		2.17	<0.1	0.1	<0.1	<0.1		
05/07/03	<0.1	<0.1		0.639	<0.1	<0.1		<0.1		
06/06/03	<0.1	<0.1	<0.1	0.7205	<0.1	<0.1	<0.1	<0.1	<0.1	
07/02/03	<0.1	<0.1	<0.1	2.1	<0.1	<0.1	<0.1	<0.1	1.0	0.1
09/03/03		<0.1	<0.1	2.7	<0.1	<0.1	<0.1	<0.1	<0.1	

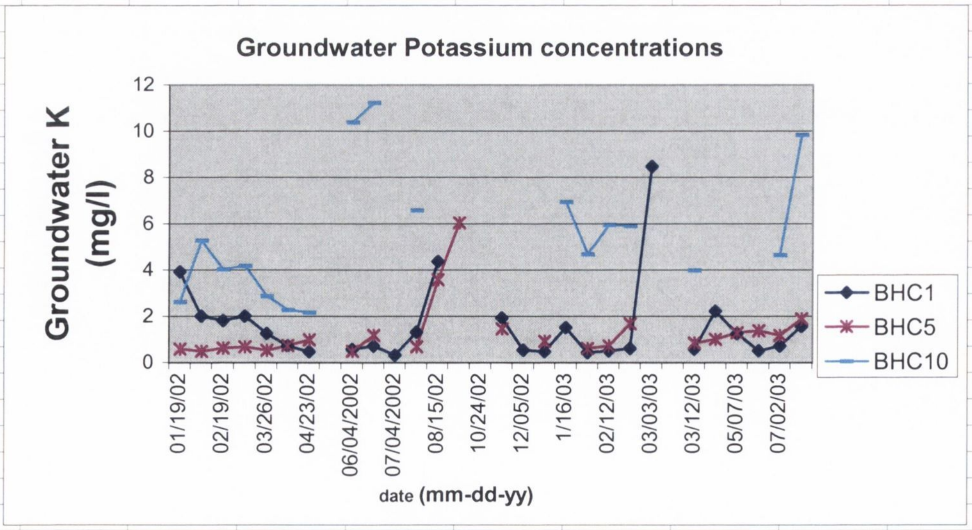
Groundwater concentrations of nitrite-N (mg/l) at Curtin's farm (River Funshion data also shown)

	NO2_N	NO2_N	NO2_N	NO2_N	NO2_N	NO2_N	NO2_N	NO2_N	NO2_N	NO2_N
	BHC1	**BHC2**	**BHC3**	**BHC4**	**BHC5**	**BHC7**	**BHC8**	**BHC9**	**BHC10**	**RIVER**
01/19/02	0.08	0.00		0.48	0.00	0.13		0.00	0.03	
02/05/2002	0.18	0.01		0.03	0.01	0.03	0.01	0.01	0.02	
02/19/02	0.04	0.03		0.01	<0.01	<0.01		<0.01	0.03	
03/12/2002	0.03	0.05	0.03	0.06	0.01	0.01	0.02	0.01	0.03	0.02
03/26/02	<0.01	0.02	<0.01	<0.01	<0.01	<0.01	0.10	<0.01	<0.01	<0.01
04/09/2002	<0.1	0.08	<0.1	0.03	<0.1	<0.1	<0.1	<0.1	<0.1	
04/23/02	<0.01	0.05	<0.01		<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
05/23/02	<0.1	0.31	<0.1	0.03	<0.1	<0.1	<0.1	<0.1	<0.1	0.01
06/04/2002	<0.001	0.08	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	
06/19/02	<0.01	4.68	<0.01	<0.01	<0.01	0.02		<0.01	<0.01	
07/04/2002	<0.001	1.39		<0.001		<0.001		<0.001		0.01
07/16/02	<0.001	0.2	<0.001	<0.001	<0.001	<0.001	<0.001	0.07	0.01	0.01
08/15/02	<0.001	1.265	<0.001	<0.001	<0.001	0.65	0.4	<0.001		0.005
09/19/02		0.095	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001		<0.001
10/24/02		<0.001		0.006		<0.001		<0.001		0.013
11/21/02	0.001	<0.001	<0.001	0.007	<0.001	<0.001		<0.001		
12/05/02	<0.001	<0.001				<0.001		<0.001		
12/10/02	<0.001	<0.001	<0.001	0.01	2	0.06	<0.001	<0.001		
1/16/03	<0.001	0.1325		0.003		0.002		0.0015	0.0255	0.0215
1/29/03	0.0015	0.0825	0.003	0.0195	0.0025	0.004	0.011	0.0035	0.017	0.0295
02/12/03	0.0015	0.014	0.007	0.012	0.007	0.007	0.0075	0.0055	0.022	0.021
02/26/03										
03/03/03										
03/05/03										
03/12/03										
04/09/03	0.059	0.008		0.02	0.004	0.008	0.009	0.008		
05/07/03	<0.001	<0.001		0.013	<0.001	<0.001		<0.001		
06/06/03	<0.001	<0.001	<0.001	0.01	<0.001	<0.001	<0.001	<0.001		0.0385
07/02/03	<0.001	<0.001	<0.001	0.113	<0.001	<0.001	0.003	<0.001	0.022	0.033
09/03/03		0.011	0.017	0.030	0.009	0.011	0.011	0.009		0.019

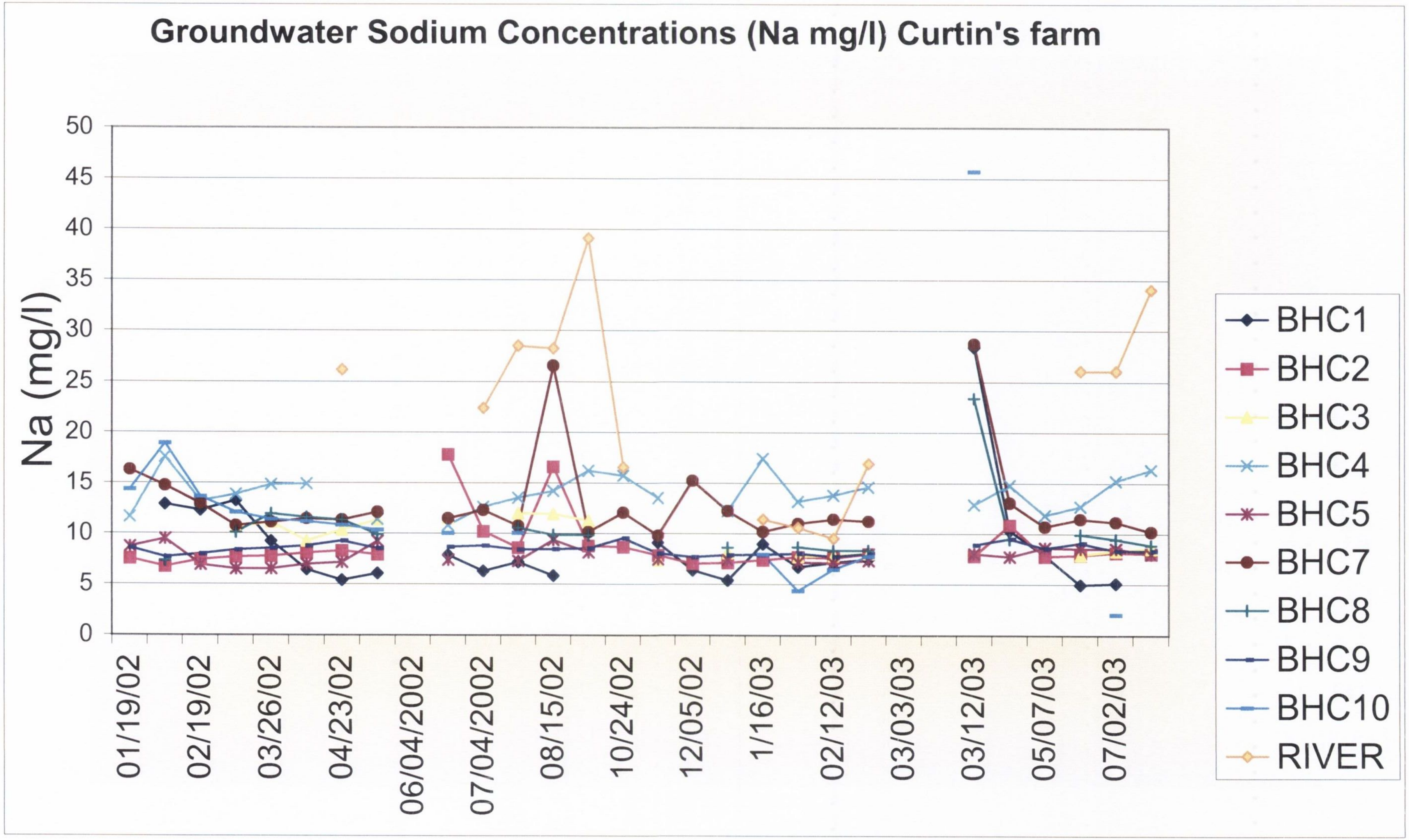
Groundwater Potassium concentrations				(K mg/l)						
	(K mg/l)	(K mg/l)	(K mg/l)	(K mg/l)	(K mg/l)	(K mg/l)	(K mg/l)	(K mg/l)	(K mg/l)	(K mg/l)
mm-dd-yy	BHC1	BHC2	BHC3	BHC4	BHC5	BHC7	BHC8	BHC9	BHC10	RIVER
01/19/02	3.9	1.2		10.4	0.6	24.5		2.7	2.6	
02/05/2002	2.0	1.0		49.9	0.5	4.4	3.8	2.6	5.3	
02/19/02	1.8	1.4		28.1	0.6	5.7		2.8	4.0	
03/12/2002	2.0	1.4	11.3	31.0	0.7	3.0	4.6	2.9	4.2	
03/26/02	1.3	1.5	17.7	35.3	0.5	4.2	5.7	2.9	2.9	
04/09/2002	0.7	1.7	15.5	31.1	0.7	4.9	5.3	2.9	2.3	
04/23/02	0.5	1.5	16.5		1.0	4.8	5.6	3.1	2.2	8.0
05/23/02										
06/04/2002	0.6	1.5	13.4	14.6	0.5	3.9	4.9	2.7	10.4	
06/19/02	0.7	14.2	16.2	8.6	1.2	4.5		2.6	11.2	
07/04/2002	0.3	4.5		19.2		6.5		4.3		6.7
07/16/02	1.3	1.9	14.6	19.9	0.7	5.2	5.7	2.8	6.6	8.5
08/15/02	4.4	62.0	72.3	129.6	3.6	215.0	30.4	16.5		39.3
09/19/02		10.5	69.9	197.3	6.0	22.8	28.2	15.1		58.2
10/24/02		2.4		45.1		5.4		3.2		5.3
11/21/02	1.9	2.3	21.2	29.5	1.4	2.7		3.3		
12/05/02	0.5	1.3				2.3		2.4		
12/10/02	0.5	1.1	13.3	25.2	0.9	2.6	4.6	2.6		
1/16/03	1.5	2.4		44.8		3.1		3.8	6.9	2.5
1/29/03	0.4	1.1	15.4	31.7	0.6	1.3	4.6	2.4	4.7	2.6
02/12/03	0.5	1.3	13.5	33.8	0.7	1.6	4.7	2.6	5.9	2.1
02/26/03	0.6	1.3	14.5	33.1	1.7	2.3	4.8	2.9	5.9	4.1
03/03/03	8.4	9.3		8.2		17.6		10.1		
03/05/03										
03/12/03	0.6	1.4		13.2	0.8	3.1	5.3	3.1	4.0	
04/09/03	2.2	6.0		39.7	1.0	4.4	5.5	3.4		
05/07/03	1.2	1.3		17.1	1.3	4.7		2.7		
06/06/03	0.5	2.2	14.7	16.2	1.3	3.1	5.7	3.7		10.2
07/02/03	0.7	1.3	16.2	31.5	1.1	2.5	5.4	2.9	4.6	6.1
09/03/03	1.6	16.1	38.2	1.0	1.9	5.0	3.3		9.8	
Average	1.4	6.7	25.0	38.0	1.5	14.7	8.5	4.6	6.5	12.8
Max	8.4	62.0	72.3	197.3	6.0	215.0	30.4	16.5	11.2	58.2
MIN	0.3	1.1	13.3	1.0	0.5	1.3	3.3	2.4	4.0	2.1
Range	8.1	60.9	59.1	196.4	5.6	213.7	27.1	14.1	7.2	56.1
MEDIAN	0.7	1.7	15.5	31.0	1.0	4.2	5.3	2.9	5.3	6.4


Groundwater Potassium concentrations
Groundwater K (mg/l)
80
70
60
50
40
30
20
10
0
01/19/02
02/19/02
03/26/02
04/23/02
06/04/2002
07/04/2002
08/15/02
10/24/02
12/05/02
1/16/03
02/12/03
03/03/03
03/12/03
05/07/03
07/02/03
date (mm-dd-yy)
BHC1
BHC2
BHC3
BHC5
BHC8
BHC9
BHC10
RIVER


Groundwater Potassium concentrations
Groundwater K (mg/l)
35
30
25
20
15
10
5
0
01/19/02
02/19/02
03/26/02
04/23/02
06/04/2002
07/04/2002
08/15/02
10/24/02
12/05/02
1/16/03
02/12/03
03/03/03
03/12/03
05/07/03
07/02/03
date (mm-dd-yy)
BHC1
BHC5
BHC8
BHC9
BHC10


Groundwater Potassium concentrations
Groundwater K (mg/l)
12
10
8
6
4
2
0
01/19/02
02/19/02
03/26/02
04/23/02
06/04/2002
07/04/2002
08/15/02
10/24/02
12/05/02
1/16/03
02/12/03
03/03/03
03/12/03
05/07/03
07/02/03
date (mm-dd-yy)
BHC1
BHC5
BHC10

Groundwater Sodium concentrations (Na mg/l)										
	Na (mg/l)	Na (mg/l)	Na (mg/l)	Na (mg/l)	Na (mg/l)	Na (mg/l)	Na (mg/l)	Na (mg/l)	Na (mg/l)	Na (mg/l)
mm-dd-yy	**BHC1**	**BHC2**	**BHC3**	**BHC4**	**BHC5**	**BHC7**	**BHC8**	**BHC9**	**BHC10**	**RIVER**
01/19/02		7.5		11.7	8.7	16.3		8.6	14.4	
02/05/2002	12.9	6.7		17.6	9.5	14.7	7.3	7.7	18.9	
02/19/02	12.3	7.4		13.2	6.9	13.0		8.0	13.6	
03/12/2002	13.3	7.7	10.6	13.9	6.5	10.8	10.1	8.4	12.1	
03/26/02	9.3	7.8	11.1	14.8	6.5	11.1	12.0	8.6	11.4	
04/09/2002	6.4	8.1	9.3	14.9	7.0	11.5	11.6	8.8	11.2	
04/23/02	5.4	8.3	10.4		7.2	11.4	11.4	9.3	10.8	26.2
05/23/02	6.1	7.9	11.4	11.4	9.3	12.1	9.9	8.6	10.4	
06/04/2002										
06/19/02	7.9	17.9	11.6	10.8	7.4	11.5		8.7	10.1	
07/04/2002	6.3	10.2		12.7		12.3		8.8		22.4
07/16/02	7.2	8.6	12.0	13.6	7.3	10.8	10.6	8.4	10.1	28.6
08/15/02	5.9	16.6	12.0	14.2	9.4	26.6	9.9	8.5		28.3
09/19/02		8.8	11.3	16.2	8.1	10.2	9.9	8.6		39.1
10/24/02		8.7		15.7		12.1		9.6		16.6
11/21/02	9.1	7.9	7.4	13.5	7.5	9.8		8.1		
12/05/02	6.4	7.0				15.2		7.7		
12/10/02	5.4	7.1	8.1	12.3	7.4	12.3	8.7	7.9		
1/16/03	9.0	7.4		17.5		10.2		8.0	8.0	11.5
1/29/03	6.7	7.7	7.8	13.2	7.2	11.0	8.7	8.1	4.4	10.6
02/12/03	7.2	7.6	7.9	13.8	7.1	11.5	8.4	7.8	6.5	9.6
02/26/03	7.5	8.0	8.1	14.6	7.4	11.3	8.4	8.1	7.8	17.0
03/03/03										
03/05/03										
03/12/03	28.5	7.8		12.9	8.1	28.7	23.4	8.9	45.8	
04/09/03	10.4	10.9		14.8	7.7	13.1	9.5	9.6		
05/07/03	7.9	7.8		11.9	8.7	10.7		8.6		
06/06/03	5.0	7.9	7.9	12.7	8.6	11.5	10.0	9.1		26.1
07/02/03	5.1	8.2	8.3	15.3	8.5	11.2	9.5	8.3	2.0	26.1
09/03/03		8.1	8.6	16.4	8.0	10.2	8.9	8.4		34.1
Average	8.1	9.1	9.5	13.9	7.9	13.0	10.5	8.5	11.6	22.8
Max	28.5	17.9	12.0	17.5	9.4	28.7	23.4	9.6	45.8	39.1
MIN	5.0	7.0	7.4	10.8	7.1	9.8	8.4	7.7	2.0	9.6
Range	23.5	10.8	4.7	6.6	2.3	18.9	15.1	1.9	43.7	29.6


Groundwater Sodium Concentrations (Na mg/l) Curtin's farm
Na (mg/l)
50
45
40
35
30
25
20
15
10
5
0
01/19/02
02/19/02
03/26/02
04/23/02
06/04/2002
07/04/2002
08/15/02
10/24/02
12/05/02
1/16/03
02/12/03
03/03/03
03/12/03
05/07/03
07/02/03
BHC1
BHC2
BHC3
BHC4
BHC5
BHC7
BHC8
BHC9
BHC10
RIVER

Groundwater Potassium:Sodium ratios

	K:Na	K:Na	K:Na	K:Na	K:Na	K:Na	K:Na	K:Na	K:Na	K:Na
mm-dd-yy	BHC1	BHC2	BHC3	BHC4	BHC5	BHC7	BHC8	BHC9	BHC10	RIVER
01/19/02		0.2		0.9	0.1	1.5		0.3	0.2	
02/05/2002	0.2	0.1		2.8	0.05	0.3	0.5	0.3	0.3	
02/19/02	0.1	0.2		2.1	0.1	0.4		0.3	0.3	
03/12/2002	0.2	0.2	1.1	2.2	0.1	0.3	0.5	0.3	0.3	
03/26/02	0.1	0.2	1.6	2.4	0.1	0.4	0.5	0.3	0.2	
04/09/2002	0.1	0.2	1.7	2.1	0.1	0.4	0.5	0.3	0.2	
04/23/02	0.1	0.2	1.6		0.1	0.4	0.5	0.3	0.2	0.3
05/23/02										
06/04/2002										
06/19/02	0.1	0.8	1.4	0.8	0.2	0.4		0.3	1.1	
07/04/2002	0.0	0.4		1.5		0.5		0.5		0.3
07/16/02	0.2	0.2	1.2	1.5	0.1	0.5	0.5	0.3	0.6	0.3
08/15/02	0.7	3.7	6.0	9.1	0.4	8.1	3.1	1.9		1.4
09/19/02		1.2	6.2	12.2	0.7	2.2	2.9	1.8		1.5
10/24/02		0.3		2.9		0.4		0.3		0.3
11/21/02	0.2	0.3	2.9	2.2	0.2	0.3		0.4		
12/05/02	0.1	0.2				0.1		0.3		
12/10/02	0.1	0.1	1.6	2.1	0.1	0.2	0.5	0.3		
1/16/03	0.2	0.3		2.6		0.3		0.5	0.9	0.2
1/29/03	0.1	0.1	2.0	2.4	0.1	0.1	0.5	0.3	1.1	0.2
02/12/03	0.1	0.2	1.7	2.4	0.1	0.1	0.6	0.3	0.9	0.2
02/26/03	0.1	0.2	1.8	2.3	0.2	0.2	0.6	0.4	0.8	0.2
03/03/03										
03/05/03										
03/12/03	0.0	0.2		1.0	0.1	0.1	0.2	0.3	0.1	
04/09/03	0.2	0.5		2.7	0.1	0.3	0.6	0.4		
05/07/03	0.2	0.2		1.4	0.1	0.4		0.3		
06/06/03	0.1	0.3	1.9	1.3	0.2	0.3	0.6	0.4		0.4
07/02/03	0.1	0.2	2.0	2.1	0.1	0.2	0.6	0.4	2.3	0.2
09/03/03		2.0	4.5	0.1	0.2	0.5	0.4			

hydrological year 2001 - 2002

Groundwater P concentrations (mg/l) mean of two samples

	BHC.1		BHC.2		BHC.3		BHC.4		BHC.5		BHC.7		BHC.8		BHC.9		BHC.10		RIVER	
	P (filtered)	P (raw GW)	P (filtered)	P (raw GW)	P (filtered)	P (raw GW)	P (filtered)	P (raw GW)	P (filtered)	P (raw GW)	P (filtered)	P (raw GW)	P (filtered)	P (raw GW)	P (filtered)	P (raw GW)	P (filtered)	P (raw GW)	P (filtered)	P (raw GW)
11/23/01																				
12/5/01																				
01/19/02	0.014	0.006	0.018	0.025			0.948	0.987	0.020	0.011	0.030	0.017			0.034	0.012	0.016	0.026		
02/05/2002																				
02/19/02	0.009	0.001	0.008	0.002			0.018	0.014	0.009	0.008	0.009	0.029			0.025	0.016	0.071	0.049		
03/12/2002	0.025		0.018	0.018	0.024	0.022	0.050	0.048	0.032	0.017	0.030	0.030	0.020	0.013	0.033	0.024	0.089	0.092	0.047	0.050
03/26/02	0.007	<0.001	0.007	0.027	0.016	0.015	0.025	0.030	0.007	0.005	0.003	0.010	<0.001	<0.001	0.008	0.012	0.053	0.048		
04/09/2002	0.003	<0.005	0.002	0.004	0.006	0.011	0.027	0.050	0.002	0.005	0.002	0.014	0.001	0.003	0.008	0.019	0.048	0.036		
04/23/02	0.004	<0.005	0.006	0.012	0.011	0.014			0.008	0.010	0.006	0.029	0.005	0.010	0.012	0.022	0.052	0.063	0.094	0.124
05/23/02	0.007	<0.005	0.009	0.012	0.018	0.016	0.099	0.064	0.023	0.014	0.013	0.017	0.020	0.009	0.019	0.019	0.085	0.073	0.057	0.079
06/04/2002																				
06/19/02	0.065	0.100	0.034	0.033	0.084	0.127	0.115	0.114	0.068	0.094	0.079	0.112			0.067	0.088	0.062	0.068		
07/04/2002	0.015	<0.005	0.008	0.020			0.059	0.077			0.009	0.023			0.021	0.046			0.055	0.078
07/16/02	0.003	<0.005	0.002	0.007	0.005	0.012	0.032	0.047	0.006	0.010	0.003	0.008	0.002	0.003	0.010	0.018	0.046	0.055	0.112	0.131
09/19/02			<0.005	<0.005	<0.005	<0.005	0.027	0.051	<0.005	0.04	<0.005	0.01	<0.005	<0.005	<0.005	<0.005			0.035	0.04

hydr. Yr	BHC.1		BHC.2		BHC.3		BHC.4		BHC.5		BHC.7		BHC.8		BHC.9		BHC.10		RIVER	
2001-2002	**P filtered**	P	**P filtered**	P	**P filtered**	P	**P filtered**	P	**P filtered**	P	**P filtered**	P	**P filtered**	P	**P filtered**	P	**P filtered**	P	**P filtered**	P
MAX	**0.065**	0.100	**0.034**	0.033	**0.084**	0.127	**0.948**	0.987	**0.068**	0.094	**0.079**	0.112	**0.020**	0.013	**0.067**	0.088	**0.089**	0.092	**0.112**	0.124
MIN	**0.003**	0.001	**0.002**	0.002	**0.005**	0.011	**0.018**	0.014	**0.002**	0.005	**0.002**	0.008	**0.001**	0.003	**0.008**	0.012	**0.016**	0.026	**0.035**	0.041
RANGE	**0.062**	0.099	**0.033**	0.031	**0.079**	0.116	**0.931**	0.973	**0.066**	0.090	**0.078**	0.104	**0.019**	0.010	**0.059**	0.077	**0.073**	0.067	**0.077**	0.084
MEDIAN	**0.008**	0.006	**0.008**	0.015	**0.016**	0.015	**0.041**	0.051	**0.009**	0.010	**0.009**	0.017	**0.005**	0.009	**0.020**	0.019	**0.053**	0.055	**0.056**	0.079

	BHC.1		BHC.2		BHC.3		BHC.4		BHC.5		BHC.7		BHC.8		BHC.9		BHC.10		RIVER	
	P filtered	P	**P filtered**	P	**P filtered**	P	**P filtered**	P	**P filtered**	P	**P filtered**	P	**P filtered**	P	**P filtered**	P	**P filtered**	P	**P filtered**	P
AVERAGE	**0.015**	0.036	**0.011**	0.016	**0.023**	0.031	**0.167**	0.148	**0.021**	0.021	**0.018**	0.027	**0.009**	0.008	**0.024**	0.027	**0.058**	0.056	**0.067**	0.084

HYDROLOGICAL YEAR 2002 - 2003: GROUNDWATER PHOSPHORUS CONCENTRATIONS FOR EACH SAMPLING EVENT

	BHC.1		BHC.2		BHC.3		BHC.4		BHC.5		BHC.7		BHC.8		BHC.9		BHC.10		RIVER	
	P (filtered)	P (raw)	P (filtered)	P (raw)	P (filtered)	P (raw)	P (filtered)	P (raw)	P (filtered)	P (raw)	P (filtered)	P (raw)	P (filtered)	P (raw)	P (filtered)	P (raw)	P (filtered)	P (raw)	P (filtered)	P (raw)
10/24/02			0.008	0.016			0.021	0.052			0.005	0.013			0.010	0.017			0.075	0.105
11/21/02	0.005	0.008	<0.005	<0.005	<0.005	<0.005	0.025	0.037	<0.005	0.008	<0.005	0.008			0.012	0.074				
12/05/02	<0.005	<0.005	<0.005	<0.005							<0.005	<0.005			<0.005	<0.005				
12/10/02	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	<0.005	0.033	<0.005	<0.005	<0.005	0.006				
1/16/03	<0.005	<0.005	<0.005	<0.005			0.010	0.018			<0.005	0.031			0.015	<0.005	0.020	<0.005	0.016	0.045
1/29/03	0.015	0.019	0.019	0.047	0.018	0.011	0.013	0.027	0.010	0.045	0.008	0.030	0.037	0.070	0.055	0.055	0.064	0.144	0.053	0.078
02/12/03	0.044	0.049	0.041	0.060	0.045	0.056	0.051	0.068	0.047	0.060	0.060	0.060	0.040	0.092	0.049	0.084	0.112	0.125	0.033	0.090
02/26/03	0.002		<0.005		0.007		<0.005		<0.005		0.020		<0.005		<0.005		0.006		<0.005	
03/03/03	<0.005		<0.005		<0.005		<0.005		<0.005		<0.005				<0.005					
03/05/03	<0.005		<0.005		<0.005		<0.005		0.018		<0.005		<0.005		<0.005		0.006		0.017	
03/12/03	<0.005	0.009	<0.005	0.010			<0.005	0.008	<0.005	0.016	<0.005	0.076	<0.005	<0.005	<0.005	0.010	0.028	0.053		
04/09/03		0.005		0.000				0.016		0.016		0.000		0.000		0.010				
05/07/03	<0.005	<0.005	<0.005	<0.005			<0.005	<0.005	<0.005	<0.005	<0.005	<0.005			<0.005	<0.005				
06/06/03	<0.005	<0.005	<0.005	0.009	<0.005	<0.005	0.008	0.021	<0.005	<0.005	<0.005	0.021	<0.005	<0.005	0.007	0.014			0.043	0.064
07/02/03	<0.005	<0.005	<0.005	<0.005	<0.005	0.010	<0.005	<0.005	<0.005	<0.005	<0.005	0.015	<0.005	<0.005	0.006	0.006	0.048	0.077	0.067	0.080
09/03/03			<0.005	0.017	0.007	0.020	<0.005	0.018	0.007	<0.005	<0.005	0.007	<0.005	<0.005	0.012	<0.005			0.035	0.039

	BHC.1		BHC.2		BHC.3		BHC.4		BHC.5		BHC.7		BHC.8		BHC.9		BHC.10		RIVER	
	P filtered	P	P filtered	P	P filtered	P	P filtered	P	P filtered	P	P filtered	P	P filtered	P	P filtered	P	P filtered	P	P filtered	P
MAX	0.044	0.049	0.041	0.060	0.045	0.056	0.051	0.068	0.047	0.060	0.060	0.076	0.040	0.092	0.055	0.084	0.112	0.144	0.075	0.105
MIN	0.002	0.005	0.008	0.000	0.007	0.010	0.008	0.008	0.007	0.008	0.005	0.000	0.037	0.000	0.006	0.006	0.006	0.053	0.016	0.039
RANGE	0.042	0.044	0.033	0.060	0.039	0.046	0.043	0.061	0.040	0.052	0.055	0.076	0.003	0.092	0.049	0.078	0.106	0.091	0.059	0.067
MEDIAN	0.010	0.009	0.019	0.016	0.013	0.015	0.017	0.021	0.014	0.016	0.014	0.021	0.039	0.070	0.012	0.014	0.028	0.101	0.039	0.078

	BHC.1		BHC.2		BHC.3		BHC.4		BHC.5		BHC.7		BHC.8		BHC.9		BHC.10		RIVER	
	P filtered	P	P filtered	P	P filtered	P	P filtered	P	P filtered	P	P filtered	P	P filtered	P	P filtered	P	P filtered	P	P filtered	P
AVERAGE	0.017	0.018	0.022	0.022	0.019	0.024	0.021	0.029	0.020	0.029	0.023	0.027	0.039	0.054	0.021	0.031	0.040	0.099	0.042	0.071

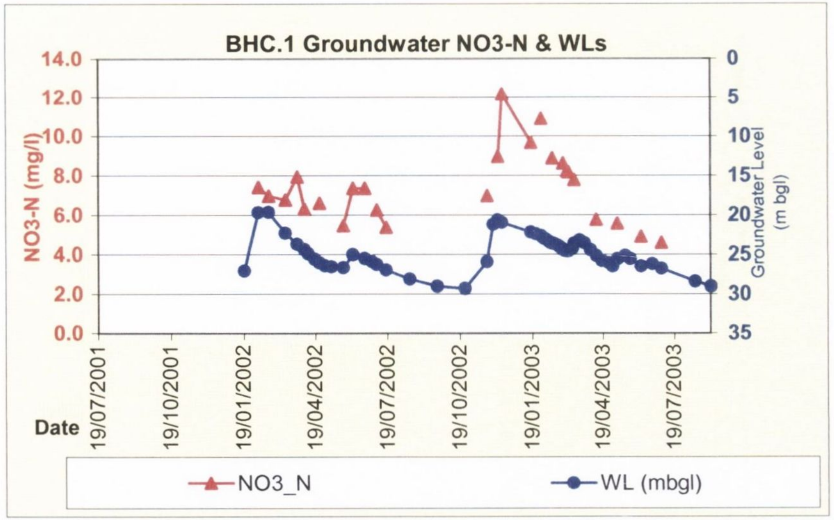
Groundwater Calcium concentrations (Ca mg/l) Curtin's farm

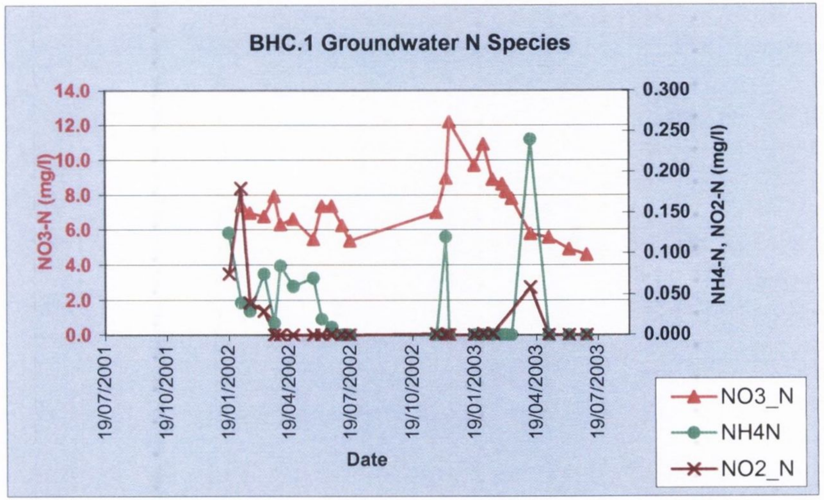
	Ca	Ca	Ca	Ca	Ca	Ca	Ca	Ca	Ca	Ca
mm-dd-yy	**BHC1**	**BHC2**	**BHC3**	**BHC4**	**BHC5**	**BHC7**	**BHC8**	**BHC9**	**BHC10**	**RIVER**
01/19/02										
02/05/2002	112.1	134.8		171.2	120.3	143.1	135.1	130.1	121.7	105.8
02/19/02	96.5	136.9		155.7	120.2	150.8	134.7	124.1	114.5	
03/12/2002	116.7	132.6	137.8	147.7	118.5	144.0	130.4	128.8	123.1	115.8
03/26/02	114.2	139.9	133.2	144.4	116.9	139.5	126.6	126.0	120.6	
04/09/2002	117.0	129.3	132.1	126.6	114.1	139.5	123.3	124.3	118.5	120.0
04/23/02	115.9	129.6	130.9		116.6	124.6	118.7	120.0	125.6	62.5
05/23/02										
06/04/2002										
06/19/02	116.8	80.5	140.5	155.9	118.4	131.6		121.9	146.0	
07/04/2002	122.4	115.9		152.5		129.8		120.9	56.8	
07/16/02	134.4	140.7	140.0	171.6	158.3	125.6	136.3	136.7	129.4	64.1
08/15/02	73.5	73.1	137.7	156.2	108.1	101.8	137.5	111.9		36.0
09/19/02		134.2	144.5	153.0	115.4	135.5	157.4	128.7		64.9
10/24/02		135.6		144.2		133.8		116.5		47.2
11/21/02	120.3	124.7	122.3	140.1	110.5	135.7		112.2		
12/05/02	123.5	124.9				131.2		128.2		
12/10/02	139.2	131.2	125.0	146.9	117.1	130.3	127.8	123.7		
1/16/03	115.9	115.2		131.7		113.4		107.5	103.4	52.1
1/29/03	117.6	121.0	119.2	126.1	112.0	119.1	116.7	114.3	96.8	51.4
02/12/03	127.0	136.4	133.0	147.5	126.0	134.5	132.5	127.4	117.4	60.4
02/26/03	119.8	127.5	124.9	132.9	116.6	130.6	117.6	118.2	112.0	77.1
03/03/03										
03/05/03										
03/12/03	122.4	130.5		139.4	121.7	125.8	120.5	121.7	120.2	
04/09/03	114.4	109.7		131.2	115.5	119.2	117.5	117.1		
05/07/03	109.8	125.8		132.3	116.3	122.7		118.3		
06/06/03	114.7	126.8	129.1	134.9	115.6	121.4	121.2	84.7		43.6
07/02/03	97.0	122.6	113.0	149.1	120.3	135.7	133.7	125.2	81.5	42.6
09/03/03		119.2	127.1	131.4	112.1	117.3	116.4	110.0		67.1
								overall BHs	**125.1**	
Average	116.7	121.3	129.8	143.2	118.8	126.0	127.2	118.3	108.9	55.7
Max	139.2	140.7	144.5	171.6	158.3	135.7	157.4	136.7	146.0	77.1
MIN	73.5	73.1	113.0	126.1	108.1	101.8	116.4	84.7	56.8	36.0
Range	65.7	67.6	31.5	45.5	50.3	34.0	41.1	52.0	89.2	41.1

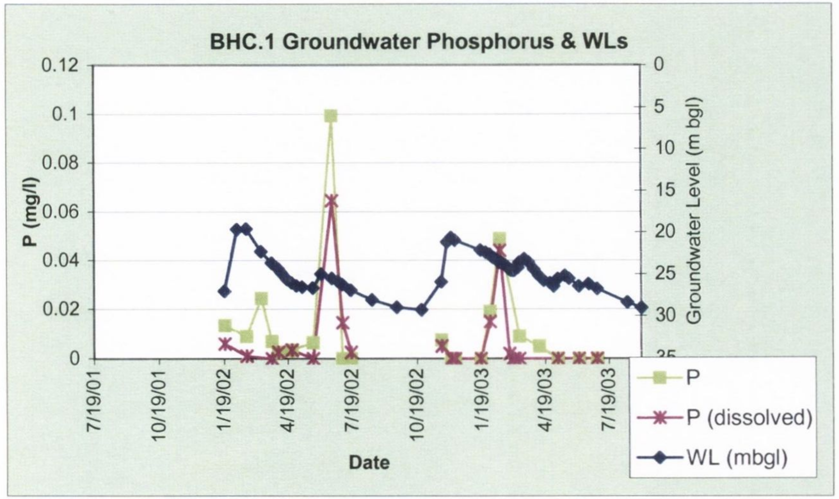
Groundwater Sulphate Concentrations (mg/l SO4) - Curtin's farm

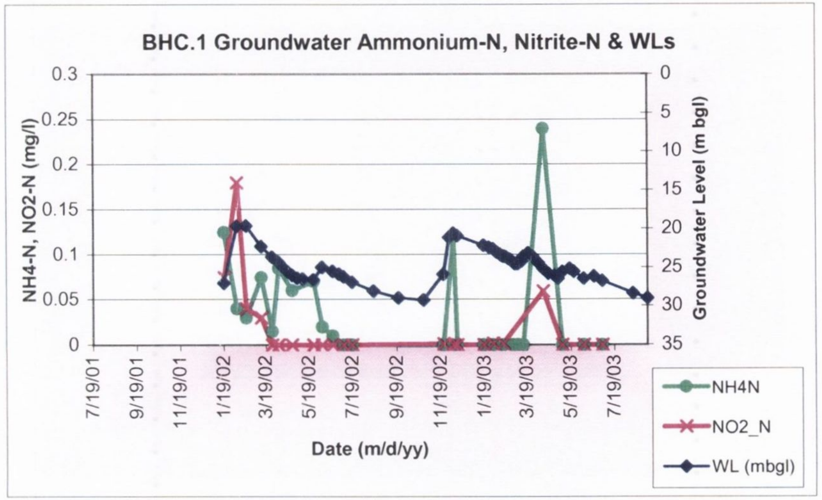
	SO4	SO4	SO4	SO4	SO4	SO4	SO4	SO4	SO4	SO4
mm-dd-yy	**BHC1**	**BHC2**	**BHC3**	**BHC4**	**BHC5**	**BHC7**	**BHC8**	**BHC9**	**BHC10**	**RIVER**
01/19/02										
02/05/2002										
02/19/02										
03/12/2002										
03/26/02										
04/09/2002										
04/23/02	7.8	9.3	9.2		11.9	9.8	8.5	18.2	13.3	8.3
05/23/02	13.1	8.6	7.9	7.5	16.7	8.7	9.7	18.5	7.1	1.7
06/04/2002	19.9	9.4	6.8	6.7	16.6	6.6	8.0	18.2	16.9	
06/19/02	19.0	8.5	7.5	19.2	12.1	8.8		18.4	17.8	
07/04/2002	18.0	7.4		6.0		7.5		17.1		6.5
07/16/02	4.3	8.2	7.1	6.4	13.4	8.1	15.9	18.8	8.2	9.4
08/15/02	15.5	17.2	19.0	30.2	15.3	15.5	18.0	17.6		4.3
09/19/02	15.7	14.6	17.3	12.1	14.7	17.1	15.7		12.1	
10/24/02		11.3		8.2		18.3		18.0		7.7
11/21/02	3.4	5.4	19.1	10.9	12.8	5.0		18.0		
12/05/02	6.4	13.4				11.3		4.0		
12/10/02	4.0	4.8	8.7	6.5	13.2	12.1		19.2		
1/16/03	12.1	8.4		12.1		10.2		11.7	13.8	8.8
1/29/03	19.1		15.9	8.4	10.5		19.3	7.8		6.7
02/12/03	8.2	10.0	7.1	9.3	13.0	9.9	8.0	17.0	13.7	9.3
02/26/03	9.8	9.9	19.1	8.8	13.0	9.1	8.4	18.3	8.5	12.6
03/03/03	18.1	14.0		33.1		24.4		20.1		
03/05/03	8.8	9.1	19.3	7.8	12.1	8.7	8.4	18.2	19.6	6.0
03/12/03	8.6	22.6		19.7	13.2		10.5	12.7		
04/09/03	8.0	9.6		9.7	13.1	10.0	8.9	18.7		
05/07/03	15.5	18.1		16.0	12.5	18.6		13.4		
06/06/03	16.1	18.2	15.2	15.2	11.6	18.6	16.4	14.1		4.2
07/02/03	14.1	7.5	12.1	18.6	13.3	6.5	17.3	15.1		2.1
09/03/03	24.3	6.8	16.3	13.3	12.9	7.0	17.3		13.5	
									12.9	
Average	12.6	11.0	13.0	13.0	13.3	11.4	12.7	16.0	13.1	6.7
Max	24.3	22.6	19.3	33.1	16.7	24.4	19.3	20.1	19.6	12.6
MIN	3.4	4.8	6.8	6.0	10.5	5.0	8.0	4.0	8.2	2.1
Range	20.9	17.9	12.5	27.2	6.2	19.4	11.3	16.1	11.4	10.5

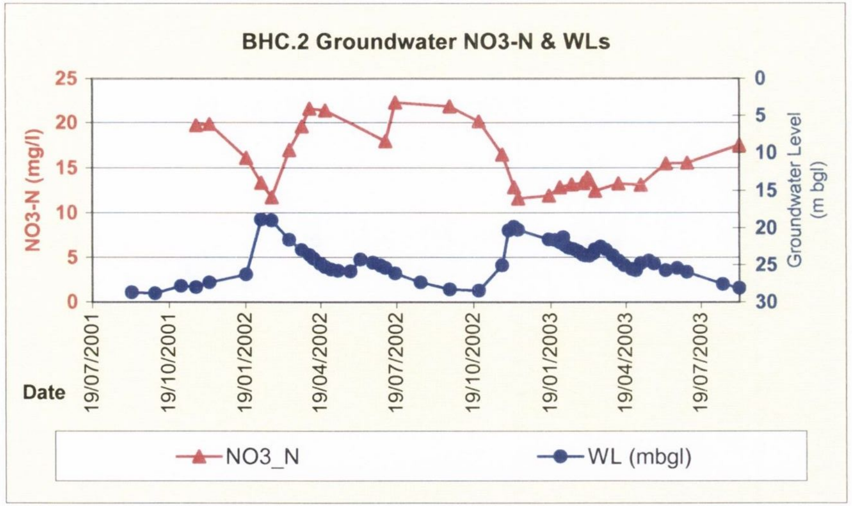
Groundwater Chloride Concentrations (mg/l Cl) at Curtin's farm										
	CL	CL	CL	CL	CL	CL	CL	CL	CL	CL
mm-dd-yy	**BHC1**	**BHC2**	**BHC3**	**BHC4**	**BHC5**	**BHC7**	**BHC8**	**BHC9**	**BHC10**	**RIVER**
01/19/02										
02/05/2002										
02/19/02										
03/12/2002	34.0	16.4	12.7	35.0	38.5	17.0	17.4	24.1	41.5	28.4
03/26/02	22.3	14.7	16.8	44.2	39.1	17.2	23.7	24.3	47.0	24.8
04/09/2002	16.3	15.1	12.8	40.7	38.9	16.2	21.5	24.2	47.4	
04/23/02	13.3	15.2	14.6		37.9	15.5	21.7	23.6	49.6	50.0
05/23/02	14.9	15.9	15.4	41.4	31.2	15.9	19.8	22.6	33.3	28.6
06/04/2002	13.7	14.8	16.3	29.4	33.1	17.5	16.9	21.5	23.4	
06/19/02	16.5	16.4	16.6	25.2	39.3	16.5		22.7	26.5	
07/04/2002	14.1	14.9		31.1		15.7		23.6		39.7
07/16/02	15.0	14.0	15.0	34.2	37.1	14.8	18.7	22.3	34.8	58.8
08/15/02	5.7	15.6	9.8	10.6	6.5	16.1	9.3	11.0		34.6
09/19/02		7.5	5.9	30.4	20.2	8.0	9.6	11.2		60.1
10/24/02		14.6		48.0		13.5		19.2		26.7
11/21/02	12.2	12.8	5.5	35.5	34.1	13.1		16.6		
12/05/02	18.5	16.6				18.3		19.9		
12/10/02	19.6	9.4	8.8	26.4	44.5	13.9	10.6	18.1		
1/16/03	16.6	11.2		54.4		12.1		19.1	20.5	18.6
1/29/03	17.4	10.6	9.5	28.4	44.0	13.8	9.5	21.9	7.4	17.6
02/12/03	21.7	15.7	13.6	38.2	51.3	21.9	13.3	25.4	19.6	22.6
02/26/03	23.2		12.6	56.6	49.0	22.3	18.4	24.6	24.3	37.5
03/03/03										
03/05/03	18.0	13.9	12.3	31.9	49.7	22.4	12.6	24.6	22.8	22.9
03/12/03		14.3		29.5	52.3			24.4		
04/09/03	23.0	16.8		40.6	49.5	18.7	13.3	24.3		
05/07/03	16.6	16.4		30.3	43.3	19.5		22.0		
06/06/03	13.6	16.9	12.0	32.1	47.0	21.0	17.2	24.7		47.1
07/02/03	11.9	16.4	11.1	45.8	47.6	20.1	14.7	22.9		49.9
09/03/03		17.7	10.5	48.3	40.8	18.2	16.3	24.0		69.9
									22.6	
Average	16.1	14.4	11.8	35.6	39.9	16.8	14.8	21.3	26.2	39.0
Max	23.2	17.7	16.6	56.6	52.3	22.4	19.8	25.4	34.8	69.9
MIN	5.7	7.5	5.5	10.6	6.5	8.0	9.3	11.0	7.4	17.6
Range	17.6	10.2	11.1	46.1	45.8	14.4	10.5	14.4	27.5	52.3

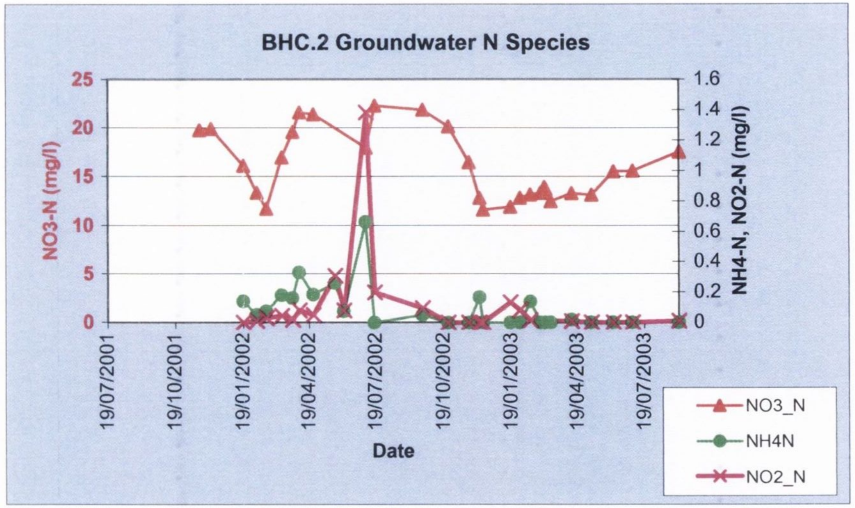

BHC.1 Groundwater NO3-N & WLs
NO3-N (mg/l)
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Groundwater Level (m bgl)
0
5
10
15
20
25
30
35
Date
19/07/2001
19/10/2001
19/01/2002
19/04/2002
19/07/2002
19/10/2002
19/01/2003
19/04/2003
19/07/2003
NO3_N
WL (mbgl)

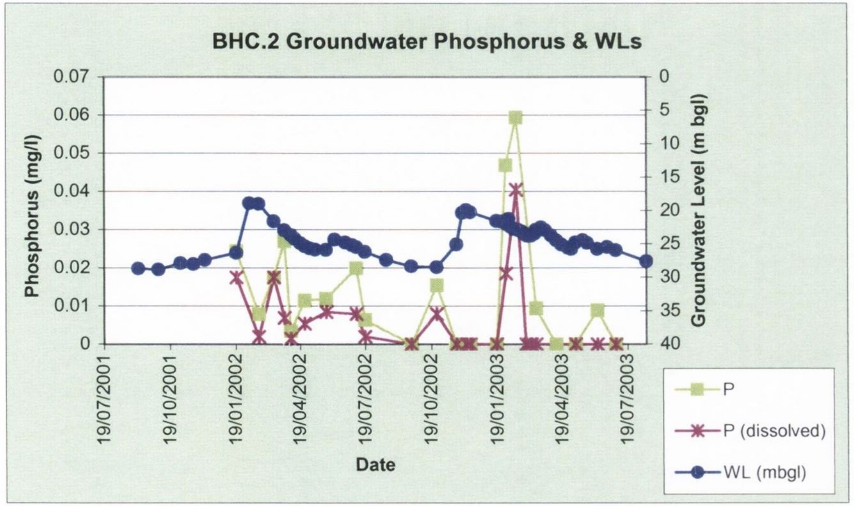

BHC.1 Groundwater N Species
NO3-N (mg/l)
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
NH4-N, NO2-N (mg/l)
0.300
0.250
0.200
0.150
0.100
0.050
0.000
Date
19/07/2001
19/10/2001
19/01/2002
19/04/2002
19/07/2002
19/10/2002
19/01/2003
19/04/2003
19/07/2003
NO3_N
NH4N
NO2_N

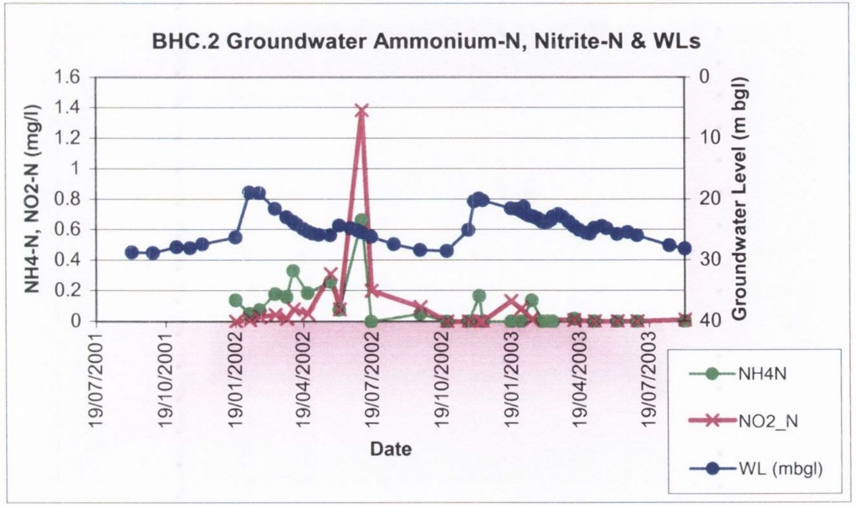

BHC.1 Groundwater Phosphorus & WLs
P (mg/l)
0.12
0.1
0.08
0.06
0.04
0.02
0
Groundwater Level (m bgl)
0
5
10
15
20
25
30
35
Date
7/19/01
10/19/01
1/19/02
4/19/02
7/19/02
10/19/02
1/19/03
4/19/03
7/19/03
P
P (dissolved)
WL (mbgl)

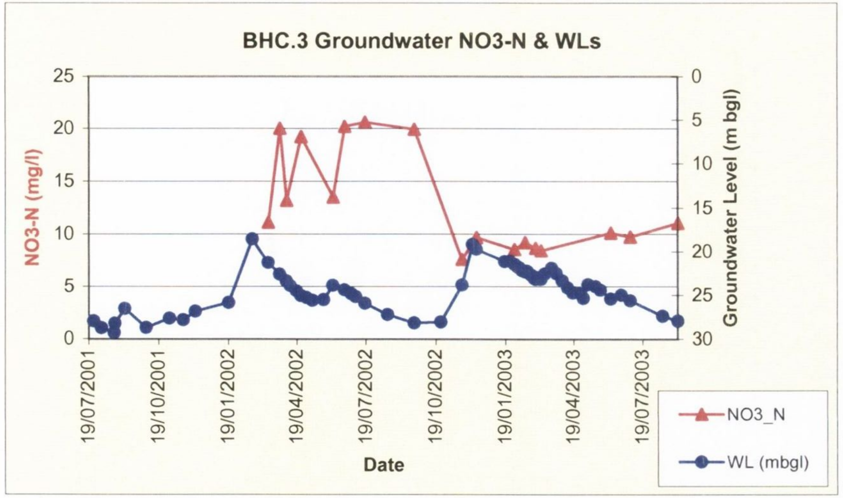

BHC.1 Groundwater Ammonium-N, Nitrite-N & WLs
NH4-N, NO2-N (mg/l)
0.3
0.25
0.2
0.15
0.1
0.05
0
Groundwater Level (m bgl)
0
5
10
15
20
25
30
35
Date (m/d/yy)
7/19/01
9/19/01
11/19/01
1/19/02
3/19/02
5/19/02
7/19/02
9/19/02
11/19/02
1/19/03
3/19/03
5/19/03
7/19/03
NH4N
NO2_N
WL (mbgl)

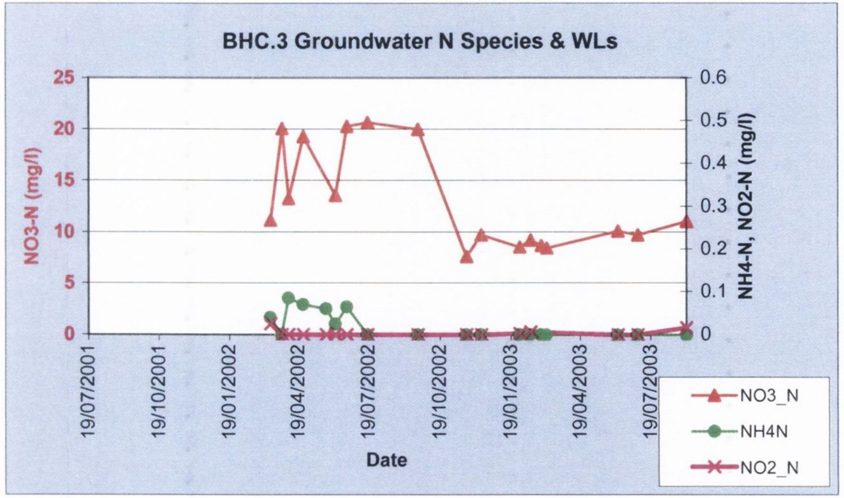

BHC.2 Groundwater NO3-N & WLs
NO3-N (mg/l)
0
5
10
15
20
25
Groundwater Level (m bgl)
0
5
10
15
20
25
30
Date
19/07/2001
19/10/2001
19/01/2002
19/04/2002
19/07/2002
19/10/2002
19/01/2003
19/04/2003
19/07/2003
NO3_N
WL (mbgl)

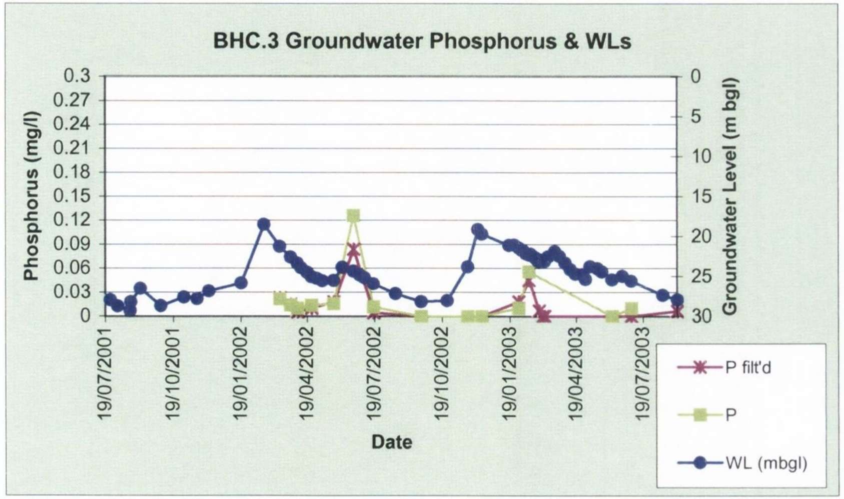

BHC.2 Groundwater N Species
NO3-N (mg/l)
0
5
10
15
20
25
NH4-N, NO2-N (mg/l)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
Date
19/07/2001
19/10/2001
19/01/2002
19/04/2002
19/07/2002
19/10/2002
19/01/2003
19/04/2003
19/07/2003
NO3_N
NH4N
NO2_N

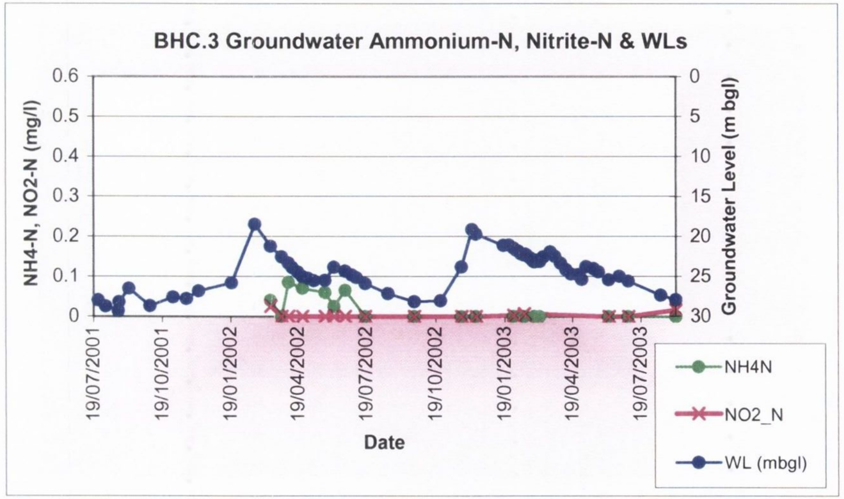

BHC.2 Groundwater Phosphorus & WLs
Phosphorus (mg/l)
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
Groundwater Level (m bgl)
0
5
10
15
20
25
30
35
40
Date
19/07/2001
19/10/2001
19/01/2002
19/04/2002
19/07/2002
19/10/2002
19/01/2003
19/04/2003
19/07/2003
P
P (dissolved)
WL (mbgl)


BHC.2 Groundwater Ammonium-N, Nitrite-N & WLs
NH4-N, NO2-N (mg/l)
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6
Groundwater Level (m bgl)
0
10
20
30
40
Date
19/07/2001
19/10/2001
19/01/2002
19/04/2002
19/07/2002
19/10/2002
19/01/2003
19/04/2003
19/07/2003
NH4N
NO2_N
WL (mbgl)

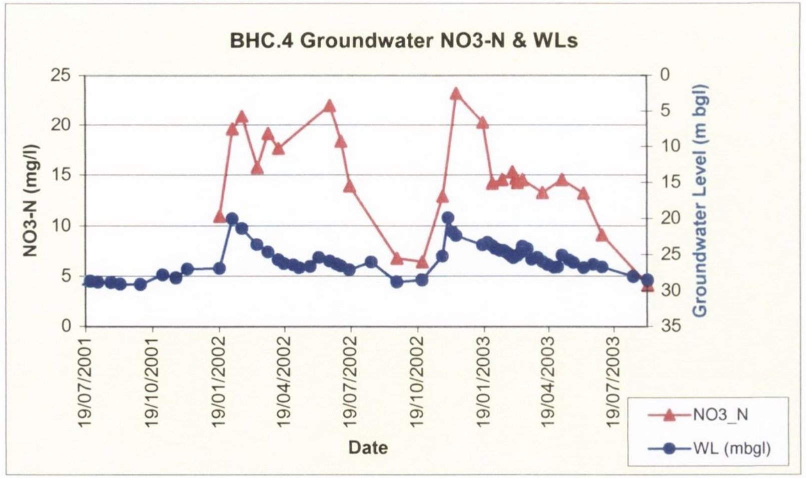


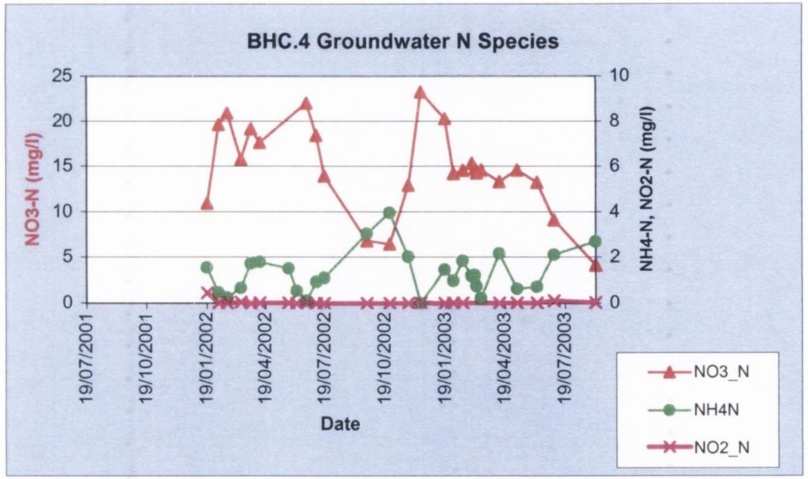


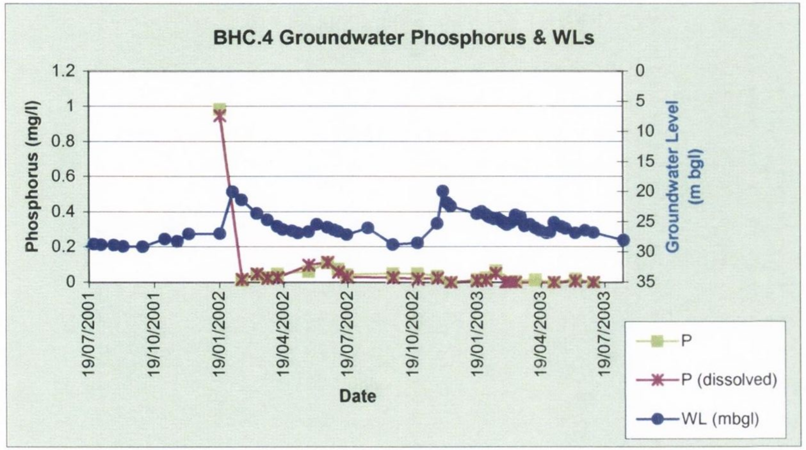


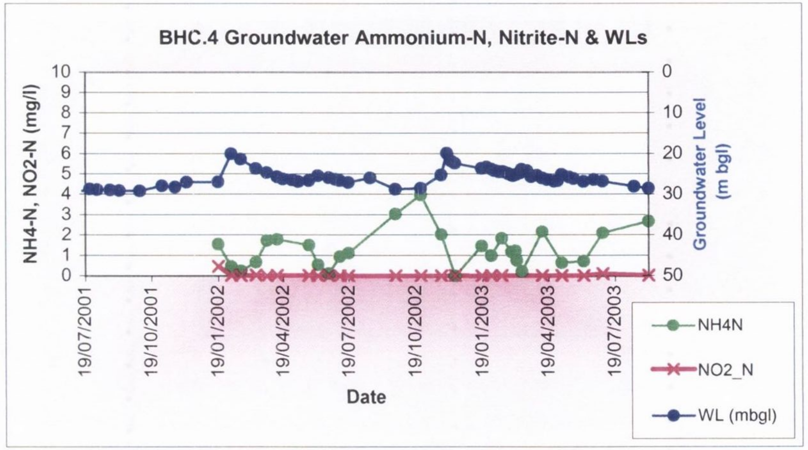


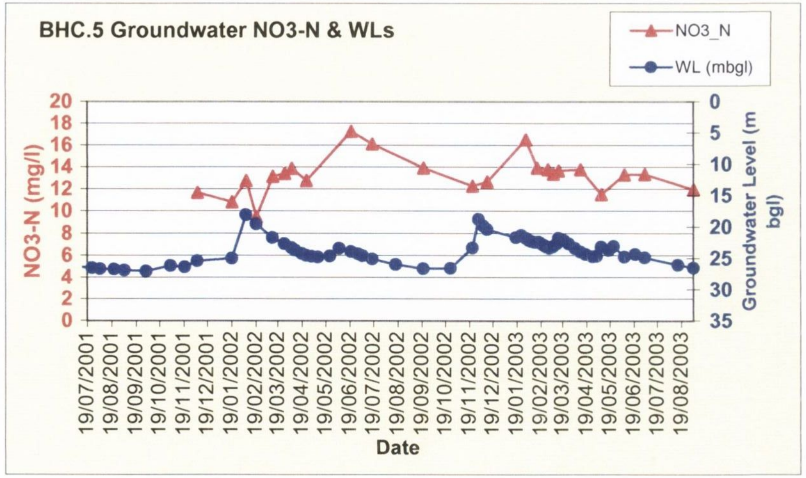
19th June 2002 P peak, matched by peak in Ammonia

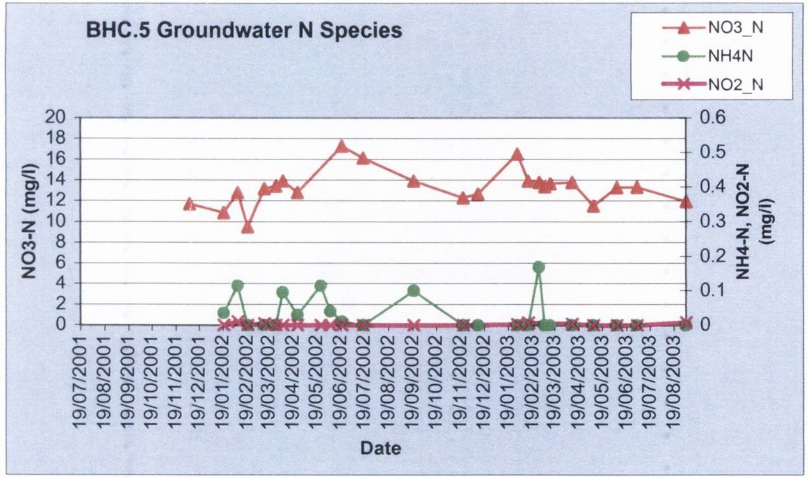

BHC.4 Groundwater NO3-N & WLs
NO3-N (mg/l)
25
20
15
10
5
0
Groundwater Level (m bgl)
0
5
10
15
20
25
30
35
19/07/2001
19/10/2001
19/01/2002
19/04/2002
19/07/2002
19/10/2002
19/01/2003
19/04/2003
19/07/2003
Date
NO3_N
WL (mbgl)

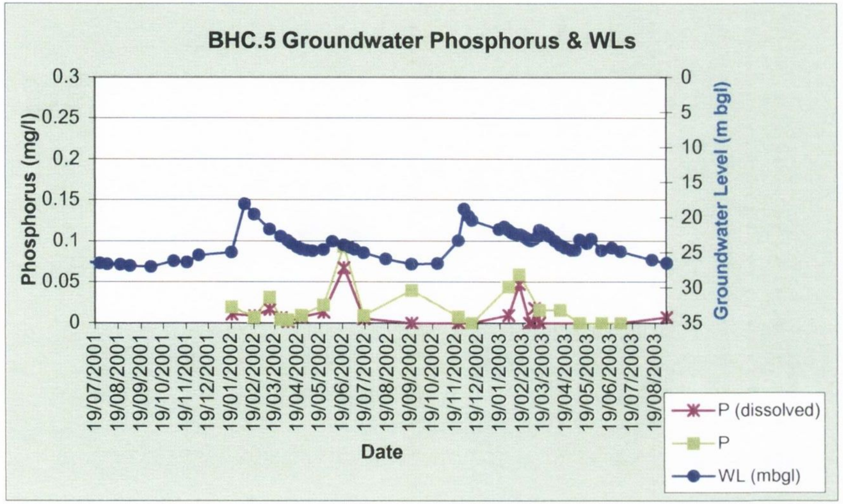

BHC.4 Groundwater N Species
NO3-N (mg/l)
25
20
15
10
5
0
NH4-N, NO2-N (mg/l)
10
8
6
4
2
0
19/07/2001
19/10/2001
19/01/2002
19/04/2002
19/07/2002
19/10/2002
19/01/2003
19/04/2003
19/07/2003
Date
NO3_N
NH4N
NO2_N

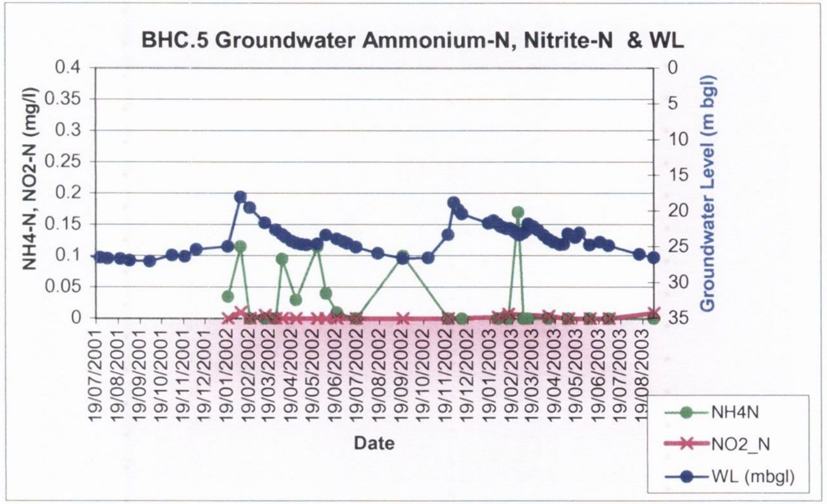

BHC.4 Groundwater Phosphorus & WLs
Phosphorus (mg/l)
1.2
1
0.8
0.6
0.4
0.2
0
Groundwater Level (m bgl)
0
5
10
15
20
25
30
35
19/07/2001
19/10/2001
19/01/2002
19/04/2002
19/07/2002
19/10/2002
19/01/2003
19/04/2003
19/07/2003
Date
P
P (dissolved)
WL (mbgl)

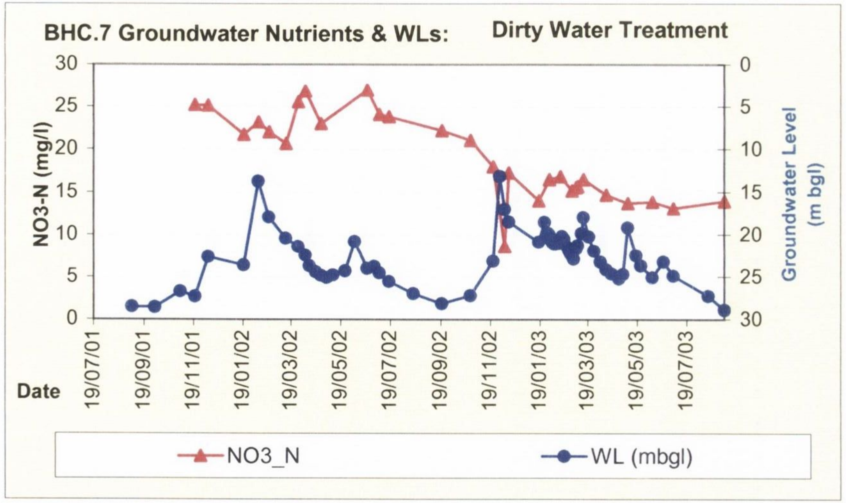

BHC.4 Groundwater Ammonium-N, Nitrite-N & WLs
NH4-N, NO2-N (mg/l)
10
9
8
7
6
5
4
3
2
1
0
Groundwater Level (m bgl)
0
10
20
30
40
50
19/07/2001
19/10/2001
19/01/2002
19/04/2002
19/07/2002
19/10/2002
19/01/2003
19/04/2003
19/07/2003
Date
NH4N
NO2_N
WL (mbgl)

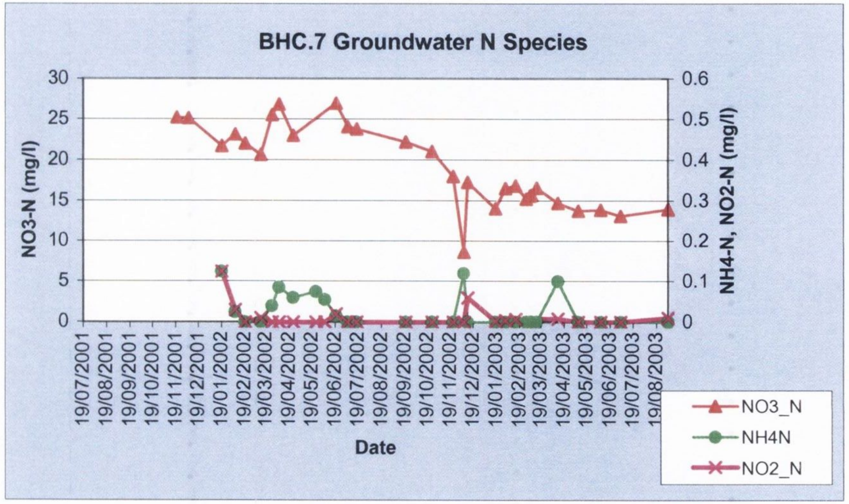

BHC.5 Groundwater NO3-N & WLs
NO3_N
WL (mbgl)
NO3-N (mg/l)
20
18
16
14
12
10
8
6
4
2
0
Groundwater Level (m bgl)
0
5
10
15
20
25
30
35
19/07/2001
19/08/2001
19/09/2001
19/10/2001
19/11/2001
19/12/2001
19/01/2002
19/02/2002
19/03/2002
19/04/2002
19/05/2002
19/06/2002
19/07/2002
19/08/2002
19/09/2002
19/10/2002
19/11/2002
19/12/2002
19/01/2003
19/02/2003
19/03/2003
19/04/2003
19/05/2003
19/06/2003
19/07/2003
19/08/2003
Date


BHC.5 Groundwater N Species
NO3_N
NH4N
NO2_N
NO3-N (mg/l)
20
18
16
14
12
10
8
6
4
2
0
NH4-N, NO2-N (mg/l)
0.6
0.5
0.4
0.3
0.2
0.1
0
19/07/2001
19/08/2001
19/09/2001
19/10/2001
19/11/2001
19/12/2001
19/01/2002
19/02/2002
19/03/2002
19/04/2002
19/05/2002
19/06/2002
19/07/2002
19/08/2002
19/09/2002
19/10/2002
19/11/2002
19/12/2002
19/01/2003
19/02/2003
19/03/2003
19/04/2003
19/05/2003
19/06/2003
19/07/2003
19/08/2003
Date

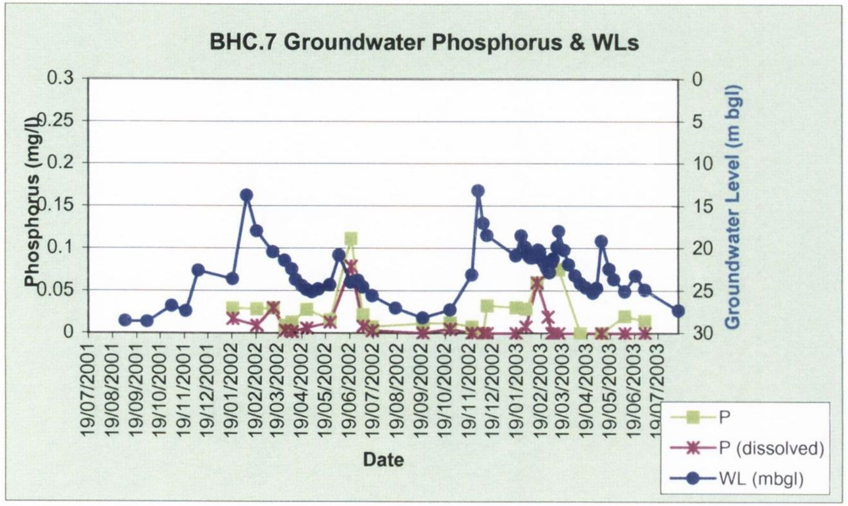

BHC.5 Groundwater Phosphorus & WLs
Phosphorus (mg/l)
0.3
0.25
0.2
0.15
0.1
0.05
0
Groundwater Level (m bgl)
0
5
10
15
20
25
30
35
19/07/2001
19/08/2001
19/09/2001
19/10/2001
19/11/2001
19/12/2001
19/01/2002
19/02/2002
19/03/2002
19/04/2002
19/05/2002
19/06/2002
19/07/2002
19/08/2002
19/09/2002
19/10/2002
19/11/2002
19/12/2002
19/01/2003
19/02/2003
19/03/2003
19/04/2003
19/05/2003
19/06/2003
19/07/2003
19/08/2003
Date
P (dissolved)
P
WL (mbgl)

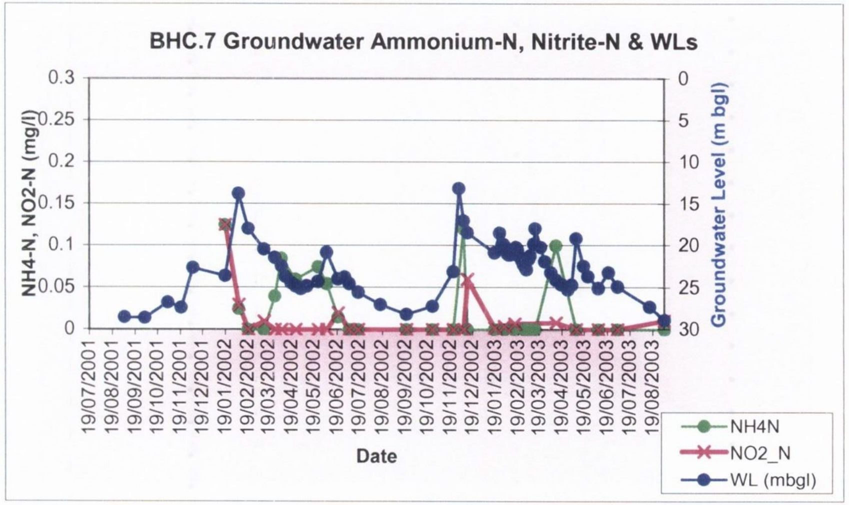

BHC.5 Groundwater Ammonium-N, Nitrite-N & WL
NH4-N, NO2-N (mg/l)
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
Groundwater Level (m bgl)
0
5
10
15
20
25
30
35
19/07/2001
19/08/2001
19/09/2001
19/10/2001
19/11/2001
19/12/2001
19/01/2002
19/02/2002
19/03/2002
19/04/2002
19/05/2002
19/06/2002
19/07/2002
19/08/2002
19/09/2002
19/10/2002
19/11/2002
19/12/2002
19/01/2003
19/02/2003
19/03/2003
19/04/2003
19/05/2003
19/06/2003
19/07/2003
19/08/2003
Date
NH4N
NO2_N
WL (mbgl)

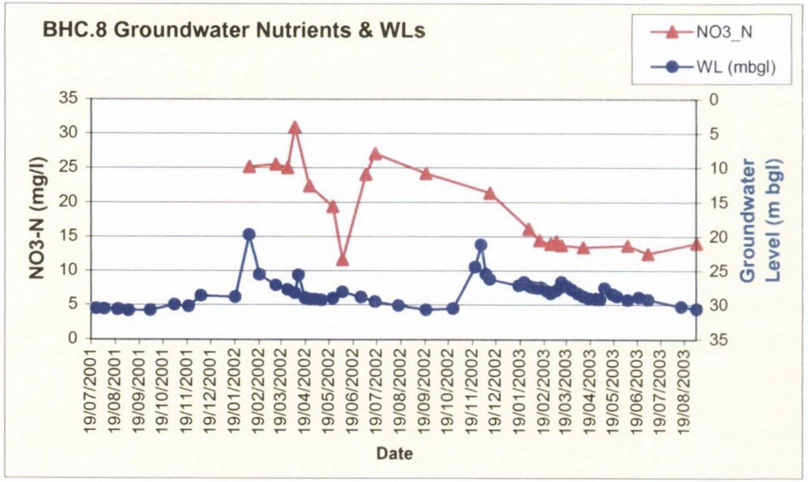


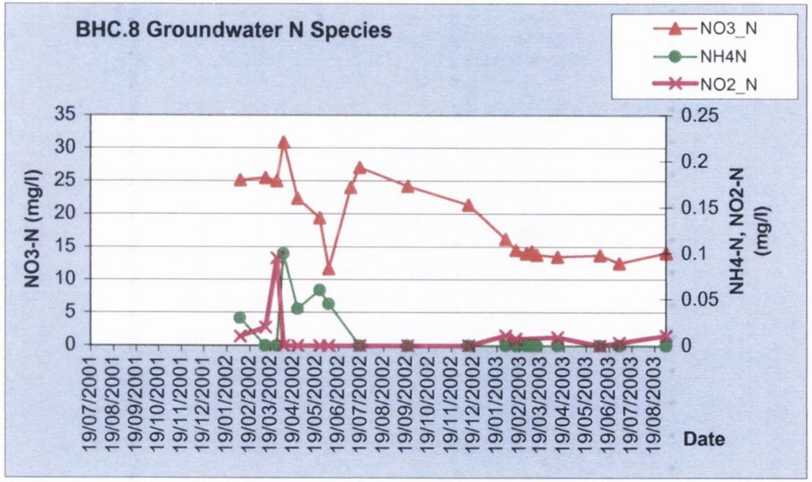


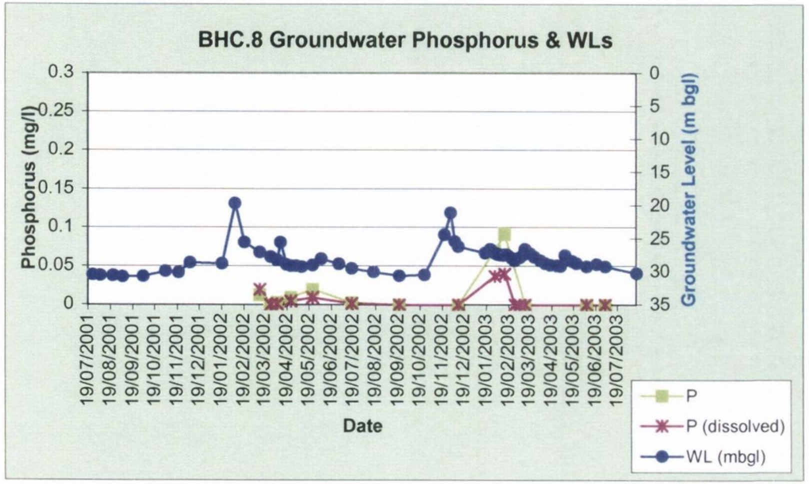
26/11/02 33mm effective rainfall, 29th peak WL and associated drop in GW NO3-N conc.

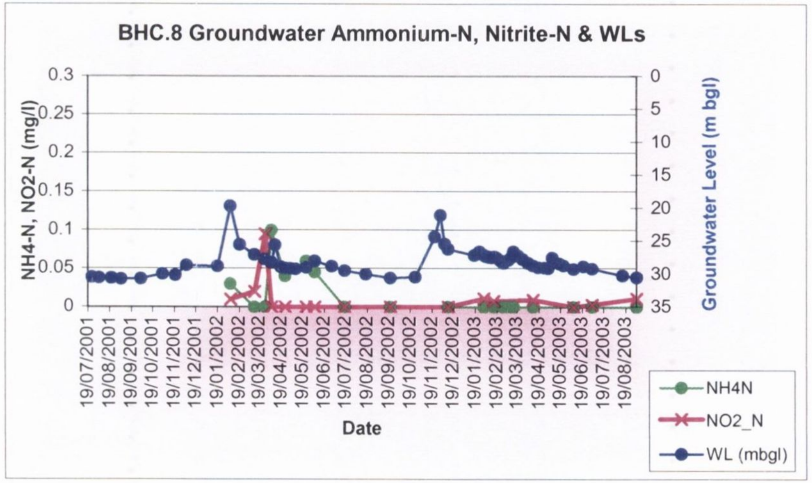


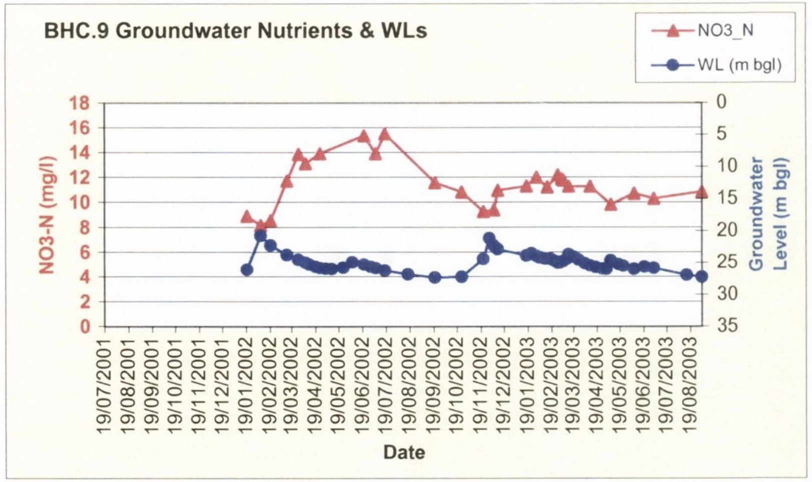


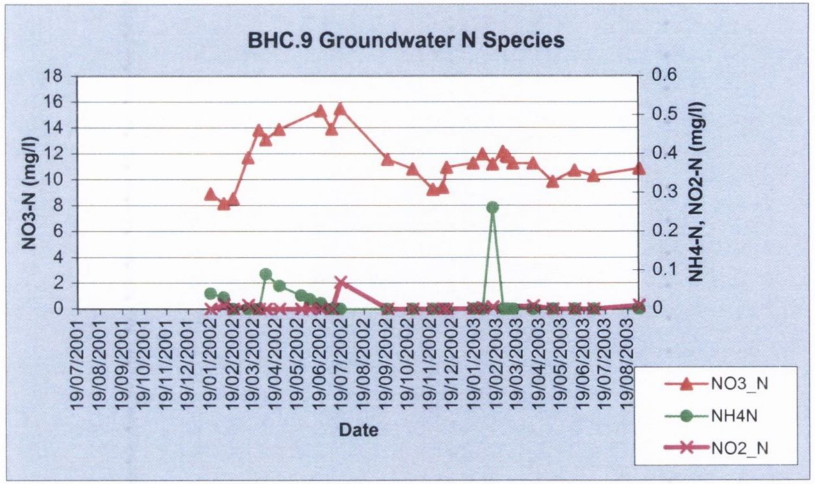

BHC.8 Groundwater Nutrients & WLs
NO3_N
WL (mbgl)
NO3-N (mg/l)
35
30
25
20
15
10
5
0
Groundwater Level (m bgl)
0
5
10
15
20
25
30
35
19/07/2001
19/08/2001
19/09/2001
19/10/2001
19/11/2001
19/12/2001
19/01/2002
19/02/2002
19/03/2002
19/04/2002
19/05/2002
19/06/2002
19/07/2002
19/08/2002
19/09/2002
19/10/2002
19/11/2002
19/12/2002
19/01/2003
19/02/2003
19/03/2003
19/04/2003
19/05/2003
19/06/2003
19/07/2003
19/08/2003
Date

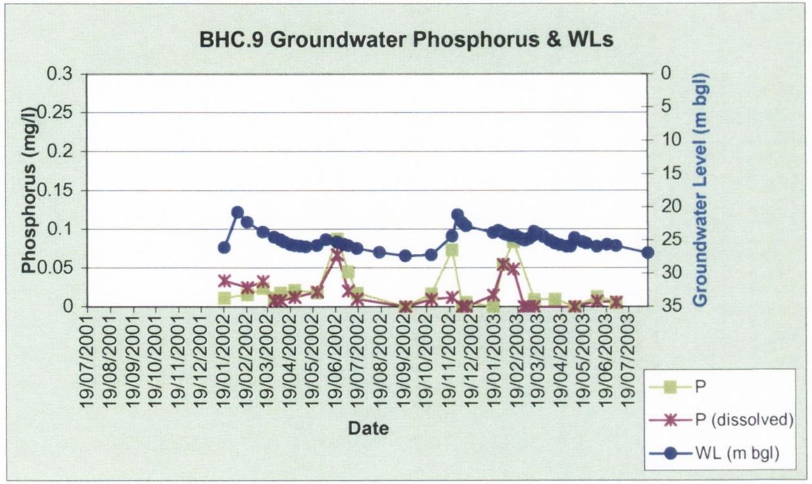

BHC.8 Groundwater N Species
NO3_N
NH4N
NO2_N
NO3-N (mg/l)
35
30
25
20
15
10
5
0
NH4-N, NO2-N (mg/l)
0.25
0.2
0.15
0.1
0.05
0
19/07/2001
19/08/2001
19/09/2001
19/10/2001
19/11/2001
19/12/2001
19/01/2002
19/02/2002
19/03/2002
19/04/2002
19/05/2002
19/06/2002
19/07/2002
19/08/2002
19/09/2002
19/10/2002
19/11/2002
19/12/2002
19/01/2003
19/02/2003
19/03/2003
19/04/2003
19/05/2003
19/06/2003
19/07/2003
19/08/2003
Date

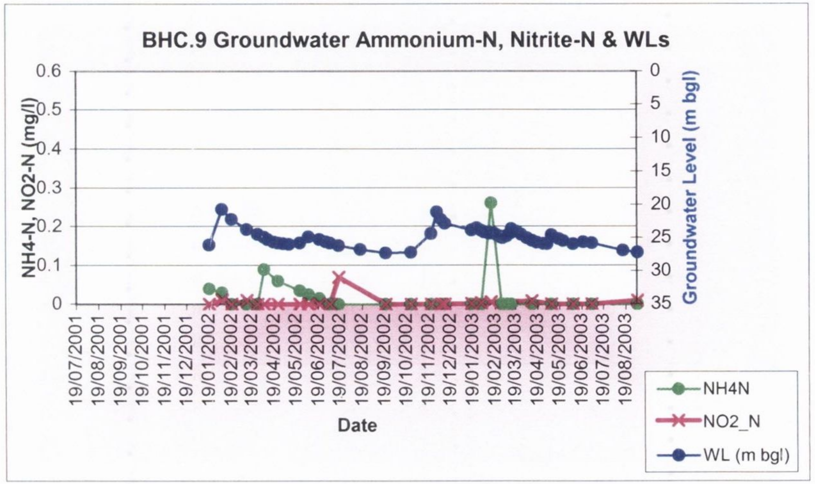

BHC.8 Groundwater Phosphorus & WLs
Phosphorus (mg/l)
0.3
0.25
0.2
0.15
0.1
0.05
0
Groundwater Level (m bgl)
0
5
10
15
20
25
30
35
19/07/2001
19/08/2001
19/09/2001
19/10/2001
19/11/2001
19/12/2001
19/01/2002
19/02/2002
19/03/2002
19/04/2002
19/05/2002
19/06/2002
19/07/2002
19/08/2002
19/09/2002
19/10/2002
19/11/2002
19/12/2002
19/01/2003
19/02/2003
19/03/2003
19/04/2003
19/05/2003
19/06/2003
19/07/2003
Date
P
P (dissolved)
WL (mbgl)

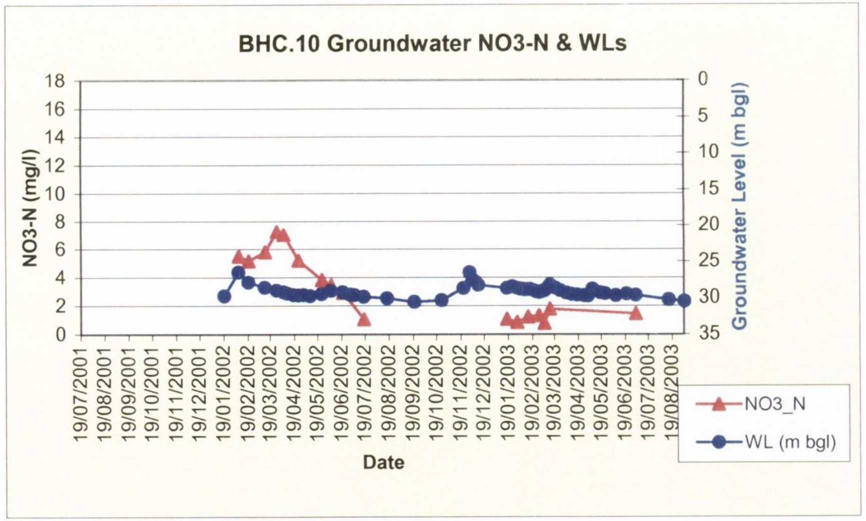

BHC.8 Groundwater Ammonium-N, Nitrite-N & WLs
NH4-N, NO2-N (mg/l)
0.3
0.25
0.2
0.15
0.1
0.05
0
Groundwater Level (m bgl)
0
5
10
15
20
25
30
35
19/07/2001
19/08/2001
19/09/2001
19/10/2001
19/11/2001
19/12/2001
19/01/2002
19/02/2002
19/03/2002
19/04/2002
19/05/2002
19/06/2002
19/07/2002
19/08/2002
19/09/2002
19/10/2002
19/11/2002
19/12/2002
19/01/2003
19/02/2003
19/03/2003
19/04/2003
19/05/2003
19/06/2003
19/07/2003
19/08/2003
Date
NH4N
NO2_N
WL (mbgl)

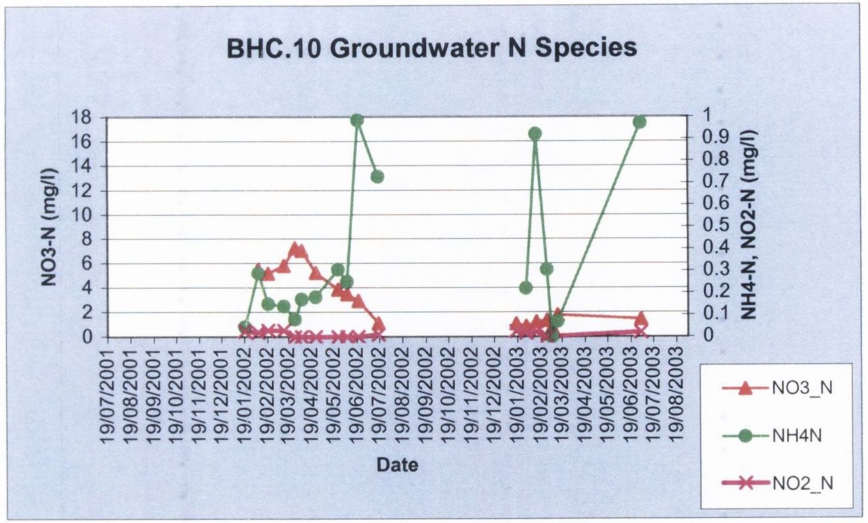

BHC.9 Groundwater Nutrients & WLs

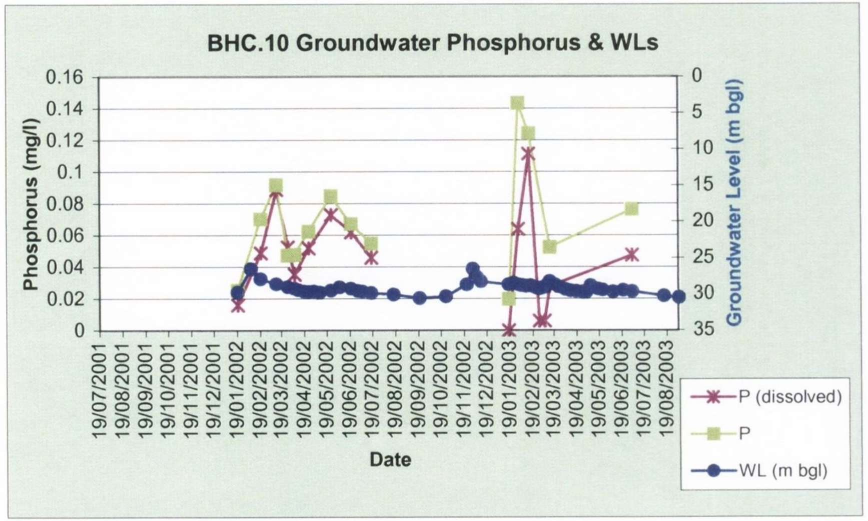

BHC.9 Groundwater N Species

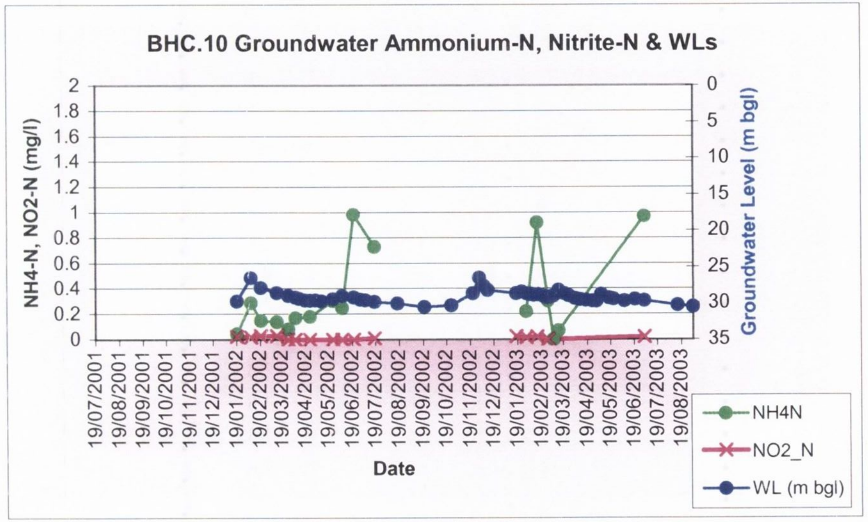

BHC.9 Groundwater Phosphorus & WLs

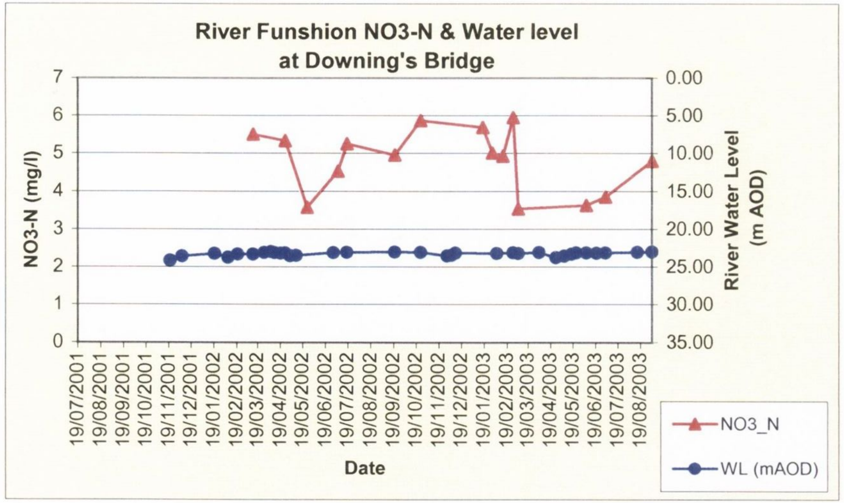

BHC.9 Groundwater Ammonium-N, Nitrite-N & WLs

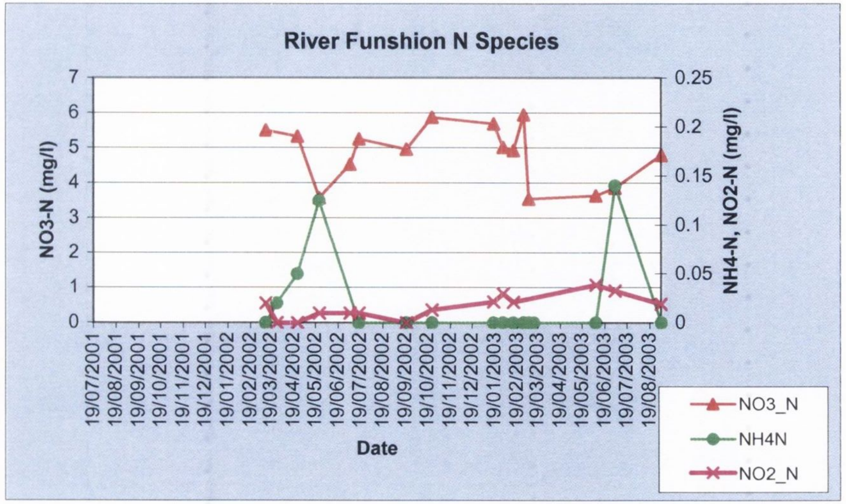

BHC.10 Groundwater NO3-N & WLs

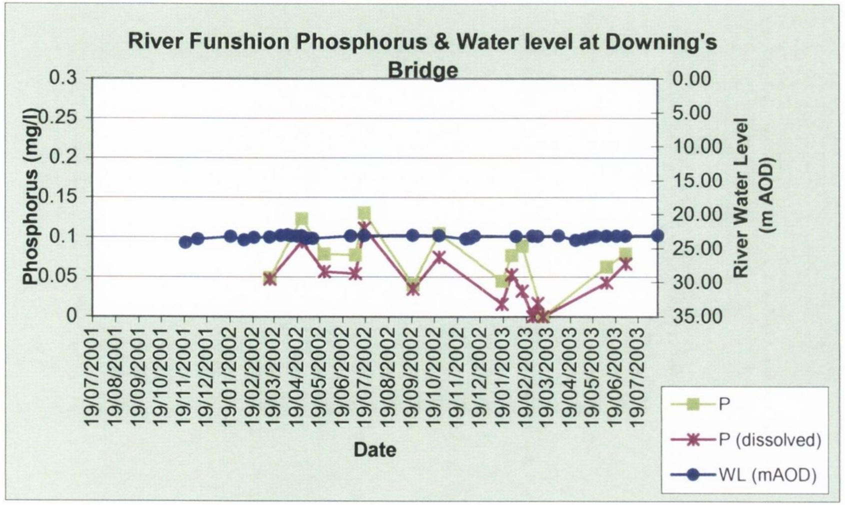

BHC.10 Groundwater N Species

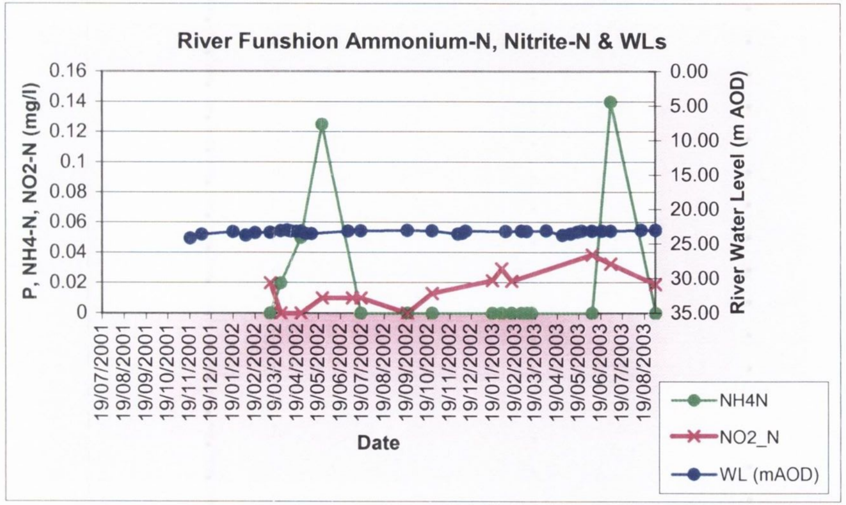

BHC.10 Groundwater Phosphorus & WLs


BHC.10 Groundwater Ammonium-N, Nitrite-N & WLs


River Funshion NO3-N & Water level at Downing's Bridge
NO3-N (mg/l)
7
6
5
4
3
2
1
0
River Water Level (m AOD)
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
19/07/2001
19/08/2001
19/09/2001
19/10/2001
19/11/2001
19/12/2001
19/01/2002
19/02/2002
19/03/2002
19/04/2002
19/05/2002
19/06/2002
19/07/2002
19/08/2002
19/09/2002
19/10/2002
19/11/2002
19/12/2002
19/01/2003
19/02/2003
19/03/2003
19/04/2003
19/05/2003
19/06/2003
19/07/2003
19/08/2003
Date
NO3_N
WL (mAOD)


River Funshion N Species
NO3-N (mg/l)
7
6
5
4
3
2
1
0
NH4-N, NO2-N (mg/l)
0.25
0.2
0.15
0.1
0.05
0
19/07/2001
19/08/2001
19/09/2001
19/10/2001
19/11/2001
19/12/2001
19/01/2002
19/02/2002
19/03/2002
19/04/2002
19/05/2002
19/06/2002
19/07/2002
19/08/2002
19/09/2002
19/10/2002
19/11/2002
19/12/2002
19/01/2003
19/02/2003
19/03/2003
19/04/2003
19/05/2003
19/06/2003
19/07/2003
19/08/2003
Date
NO3_N
NH4N
NO2_N


River Funshion Phosphorus & Water level at Downing's Bridge
Phosphorus (mg/l)
0.3
0.25
0.2
0.15
0.1
0.05
0
River Water Level (m AOD)
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
19/07/2001
19/08/2001
19/09/2001
19/10/2001
19/11/2001
19/12/2001
19/01/2002
19/02/2002
19/03/2002
19/04/2002
19/05/2002
19/06/2002
19/07/2002
19/08/2002
19/09/2002
19/10/2002
19/11/2002
19/12/2002
19/01/2003
19/02/2003
19/03/2003
19/04/2003
19/05/2003
19/06/2003
19/07/2003
Date
P
P (dissolved)
WL (mAOD)


River Funshion Ammonium-N, Nitrite-N & WLs
P, NH4-N, NO2-N (mg/l)
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
River Water Level (m AOD)
0.00
5.00
10.00
15.00
20.00
25.00
30.00
35.00
19/07/2001
19/08/2001
19/09/2001
19/10/2001
19/11/2001
19/12/2001
19/01/2002
19/02/2002
19/03/2002
19/04/2002
19/05/2002
19/06/2002
19/07/2002
19/08/2002
19/09/2002
19/10/2002
19/11/2002
19/12/2002
19/01/2003
19/02/2003
19/03/2003
19/04/2003
19/05/2003
19/06/2003
19/07/2003
19/08/2003
Date
NH4N
NO2_N
WL (mAOD)

Appendix S

Bromide Tracing Monitoring Results

A surface applied bromide tracer was applied at one location (Plot 12BLUE) on Curtin's farm. Details of experimental rationale, study site and methodologies were presented in chapter five, section 5.4. The results of the tracing experiment were fully discussed in chapter six, sections 6.5 and 6.7.

The data in this appendix are arranged as follows:

- Bromide analysis results for BHC.7, the piezometer specifically targeted for the bromide tracing experiment test site……………………………………….page 678;
- Bromide analysis results for all other piezometers…………………………page 679;
- Bromide analysis results summary table for the six subsoil ceramic cups targeted in the same plot in which BHC.7 is sited…………………………………………page 680;
- Results tables for each cup with response to all loadings (meteorological and agronomic)………………………………………………………pages 681 – 688;
- Groundwater level data for each piezometer for the duration of the bromide monitoring programme……………………………………………………………page.689.

Appendix Bromide Analysis Results

(a) BHC.7

Bromide Applied 28th January 2003			BHC 7
day no.	Date Sampled	Bromide (mg/l) - BHC.7	TWL (mAOD) - BHC.7
-49	10/12/02	0.00	35.45
2	29/01/03	0.00	33.92
4	31/01/03	0.00	33.30
6	02/02/03	0.00	33.00
8	04/02/03	0.00	32.83
12	08/02/03	0.00	32.91
14	10/02/03	0.00	32.89
16	12/02/03	0.00	33.48
18	14/02/03	0.44	33.72
20	16/02/03	1.15	33.45
22	18/02/03	0.30	32.95
30	26/02/03	1.20	31.38
32	28/02/03	0.25	31.05
35	03/03/03	0.59	32.27
37	05/03/03	0.40	32.65
42	10/03/03	0.00	34.09
44	12/03/03	5.04	35.95
51	19/03/03	0.00	33.70
64	02/04/03	0.00	30.70
71	09/04/03	0.00	29.80
78	16/04/03	0.00	29.30
87	25/04/03	0.00	28.70
92	30/04/03	0.00	29.22
98	06/05/03	0.00	34.75
108	16/05/2003	0.00	31.47
114	22/05/2003	0.00	30.25
128	05/06/2003	0.27	28.85
142	19/06/2003	0.26	30.70
155	01/07/2003	0.45	29.05

Appendix Bromide Other boreholes' bromide concentration

Day No.	Date Sampled	BHC.1	BHC.2	BHC.3	BHC 4	BHC.5	BHC.8	BHC.9	BHC 10
-49	10-Dec-02	0	0	0	0	0	0	0	0
16	12-Feb-03				0	0	0		
18	14-Feb-03				0	0	0		
20	16-Feb-03		0		0	0	0		
22	18-Feb-03	0	0	0	0	0	0	0	0
44	12-Mar-03	0	0.00	0.00	5.912	0.338	0	0	0
51	19-Mar-03	0	0	0	0	0	0	ns	0.296
87	25-Apr-03	0	0	0	0	0	0	0	0.00
97	6-May-03	0	0	0	0.34	0.35	0.00	5.71	
114	22-May-03	0			0	0			
129	5-Jun-03					0			
142	19-Jun-03	0	0.00		0	0.0	0.00	0.00	0.405
153	1-Jul-03	0	0	0	0	0.0	0.00	0.00	0.00

ns denotes no sample

Appendix Bromide concentrations in the subsoil ceramic cups

		Bromide concentrations in ceramic cups at 1m depth in the subsoil							
CUP Sampling Date	Experimental Day No.	CUP 1 Br (mg/l)	CUP 2 Br (mg/l)	CUP 3 Br (mg/l)	CUP 4 Br (mg/l)	CUP 5 Br (mg/l)	CUP 6 Br (mg/l)	CUP 7 Br (mg/l)	CUP 8 Br (mg/l)
08/01/03		0.00	0.00	0	ns	0		0	0
29/01/03	2	0.00	0.00	0	ns	0	0		ns
05/02/03	9	0.00	0.00	0	ns	0	0	0	ns
12/02/03	**16 (cup 5)**	0.00	0.00	0	0	**2.72**	0	0	0
19/02/03	**23 (cup 8)**	ns	0.00	0	ns	52.24	ns	ns	**0.3**
26/02/03	**30 (cup 1)**	**0.99**	0.00	0	0	76.5	ns	ns	ns
05/03/03	37	ns	0.00	ns	0	ns	ns	0	ns
12/03/03	**44 (cups 2 & 7)**	0.25	**0.44**	ns	ns	ns	ns	**0.45**	ns
19/03/03	50	ns	3.14	ns	ns	ns	ns	ns	ns
26/03/03	57	ns	9.90	ns	ns	ns	ns	ns	ns
02/04/03	64	0.38	19.47	ns	ns	451.89	ns	ns	ns
09/04/03	71	ns	20.15	ns	ns	443.53	ns	ns	ns
16/04/03	78	ns	30.73	ns	ns	442.22	ns	ns	ns
23/04/03	85	ns	31.52	ns	ns	449.57	ns	ns	ns
30/04/03	92	ns	35.29	ns	ns	422.74	ns	ns	ns
07/05/2003	99	ns	72.24	ns	ns	ns	ns	65.95	ns
14/05/2003	**106 (cup 6)**	**127.60**	148.10	ns	ns	ns	**16.13**	ns	ns
23/05/2003	115	ns	199.00	ns	ns	ns	ns	167.90	ns
29/05/2003	121	ns	**213.50**	ns	ns	**748.00**	61.47	197.30	ns
04/06/2003	**126 (cup 4)**	ns	202.50	ns	**146.00**	628.30	ns	211.60	ns
11/06/2003	134	ns	194.30	ns	162.80	599.90	95.60	224.30	ns
18/06/2003	141	ns	211.70	ns	196.90	272.10	**141.30**	**271.10**	ns
25/06/2003	**148 (cup 3)**	ns	204.00	**75.56**	**247.80**	197.60	ns	248.50	ns
04/07/2003	156	ns	194.40	ns	ns	228.30	ns	218.30	ns
		ns	ns	ns	ns	ns	ns	ns	ns
		ns	ns	ns	ns	ns	ns	ns	ns

ns denotes no sample obtained from the instrument

Appendix BROMIDE continued

Individual cups response to all meteorological, agronomic loadings and bromide response (ns denotes no sample)

Cup 1

Week	RF	Eff RF	Cum. RF	Cum.	Experimental	CUP 1	
Ending	(mm/week)		(mm)	Eff RF (mm)	Day No.	Br (mg/l)	Agr. Loading
1/1/03	39.6	37					
8/1/03	2.3	1			Background	0.00	
15/1/03	4.2	1					
22/1/03	43.1	40	1mm BR applied 28/1/03				
29/1/03	10.7	5	5	5	2	0.00	
5/2/03	15	12	20	17	9	0.00	
12/2/03	21	17	41	34	16 (cup 5)	0.00	Cup 1
19/2/03	0	0	41	34	23 (cup 8)	ns	24/02/2002
26/2/03	15.7	6	57	40	30 (cup 1)	0.99	16mm DW
5/3/03	35.7	29	92	69	37	ns	
12/3/03	37.1	30	130	99	44 (cups 2 & 7)	0.25	
19/3/03	0	0	130	99	50	ns	
26/3/03	0	0	130	99	57	ns	1 grazing day
2/4/03	6.9	0	136	99	64	0.38	
9/4/03	0.5	0	137	99	71	ns	
16/4/03	31.7	0	169	99	78	ns	
23/4/03	0	0	169	99	85	ns	
30/4/03	63.8	14	232	113	92	ns	
7/5/03	49.3	37	282	149	99	ns	2.5 grazing days
14/5/03	11.8	0	294	149	106 (cup 6)	127.6	
21/5/03	24.1	0	318	149	115	ns	23/5/02
28/5/03	10.8	0	328	149	121	ns	4mm DW
4/6/03	25.5	0	354	149	126 (cup 4)	ns	(SMD = 9mm)
11/6/03	51.5	29	405	179	134	ns	2.5 grazing days
18/6/03	1.8	0	407	179	141	ns	19/6/03
25/6/03	0.0	0	407	179	148 (cup 3)	ns	3mm DW
2/7/03	0.0	0	407	179	156	ns	(SMD = 10mm)
9/7/03	38.4	0	446	179		ns	2.5 grazing days
			Recharge & time taken to first arrival			56mm	30 days
			Recharge & time taken to PEAK			>165 mm	>106 days
						CUP 1	

This table represents the effects of animal urinations in a qualitative rather than quantitative format.

Appendix BROMIDE continued

Individual cups response to all meteorological, agronomic loadings and bromide response (ns denotes no sample)

Cup 2

Week Ending	RF	Eff RF	Cum. RF (mm)	Cum. Eff RF (mm)	Experimental Day No.	CUP 2	
	(mm/week)					Br (mg/l)	Agr. Loading
1/1/03	39.6	37					
8/1/03	2.3	1			Background	0.00	
15/1/03	4.2	1					
22/1/03	43.1	40	**1mm BR applied 28/1/03**				
29/1/03	10.7	5	5	5	2	0.00	
5/2/03	15	12	20	17	9	0.00	
12/2/03	21	17	41	**34**	**16 (cup 5)**	0.00	**Cup 2**
19/2/03	0	0	41	34	**23 (cup 8)**	0.00	**23/02/2002**
26/2/03	15.7	6	57	**40**	**30 (cup 1)**	0.00	**16mm DW**
5/3/03	35.7	29	92	69	37	0.00	
12/3/03	37.1	30	130	**99**	**44 (cups 2 & 7)**	**0.4**	
19/3/03	0	0	130	99	50	3.1	
26/3/03	0	0	130	99	57	9.9	**1 grazing day**
2/4/03	6.9	0	136	99	64	19.5	
9/4/03	0.5	0	137	99	71	20.2	
16/4/03	31.7	0	169	99	78	30.7	
23/4/03	0	0	169	99	85	31.5	
30/4/03	63.8	14	232	113	92	35.3	
7/5/03	49.3	37	282	149	99	72.2	**2.5 grazing days**
14/5/03	11.8	0	294	**149**	**106 (cup 6)**	148.1	
21/5/03	24.1	0	318	149	115	199.0	**23/5/02**
28/5/03	10.8	0	328	149	121	**213.5**	**4mm DW**
4/6/03	25.5	0	354	**149**	**126 (cup 4)**	202.5	**(SMD = 9mm)**
11/6/03	51.5	29	405	179	134	194.3	**2.5 grazing days**
18/6/03	1.8	0	407	179	141	211.7	**19/6/03**
25/6/03	0.0	0	407	**179**	**148 (cup 3)**	204.0	**3mm DW**
2/7/03	0.0	0	407	179	156	194.4	**(SMD = 10mm)**
9/7/03	38.4	0	446	179		ns	**2.5 grazing days**
			Recharge & time taken to first arrival			**115mm**	**44 days**
			Recharge & time taken to PEAK			**165mm**	**121 days**
						CUP 2	

This table represents the effects of animal urinations in a qualitative rather than quantitative format.

Appendix BROMIDE continued

Individual cups response to all meteorological, agronomic loadings and bromide response (ns denotes no sample)

Cup 3

Week	RF	Eff RF	Cum. RF	Cum.	Experimental	CUP 3	
Ending	(mm/week)		(mm)	Eff RF (mm)	Day No.	Br (mg/l)	Agr. Loading
1/1/03	39.6	37					
8/1/03	2.3	1			Background	0	
15/1/03	4.2	1					
22/1/03	43.1	40	1mm BR applied 28/1/03				
29/1/03	10.7	5	5	5	2	0	
5/2/03	15	12	20	17	9	0	
12/2/03	21	17	41	34	16 (cup 5)	0	Cup 3
19/2/03	0	0	41	34	23 (cup 8)	0	22/02/2002
26/2/03	15.7	6	57	40	30 (cup 1)	0	16mm DW
5/3/03	35.7	29	92	69	37	ns	
12/3/03	37.1	30	130	99	44 (cups 2 & 7)	ns	
19/3/03	0	0	130	99	50	ns	
26/3/03	0	0	130	99	57	ns	1 grazing day
2/4/03	6.9	0	136	99	64	ns	
9/4/03	0.5	0	137	99	71	ns	
16/4/03	31.7	0	169	99	78	ns	
23/4/03	0	0	169	99	85	ns	
30/4/03	63.8	14	232	113	92	ns	
7/5/03	49.3	37	282	149	99	ns	2.5 grazing days
14/5/03	11.8	0	294	149	106 (cup 6)	ns	
21/5/03	24.1	0	318	149	115	ns	23/5/02
28/5/03	10.8	0	328	149	121	ns	4mm DW
4/6/03	25.5	0	354	149	126 (cup 4)	ns	(SMD = 9mm)
11/6/03	51.5	29	405	179	134	ns	2.5 grazing days
18/6/03	1.8	0	407	179	141	ns	19/6/03
25/6/03	0.0	0	407	179	148 (cup 3)	75.6	3mm DW
2/7/03	0.0	0	407	179	156	ns	(SMD = 10mm)
9/7/03	38.4	0	446	179		ns	2.5 grazing days
			Recharge & time taken to first arrival			195mm	148 days
			Recharge & time taken to PEAK			only 1 sample returned	
						CUP 3	

This table represents the effects of animal urinations in a qualitative rather than quantitative format.

Appendix BROMIDE continued

Individual cups response to all meteorological, agronomic loadings and bromide response (ns denotes no sample)

Cup 4

Week	RF	Eff RF	Cum. RF	Cum.	Experimental	CUP 4	
Ending	(mm/week)		(mm)	Eff RF (mm)	Day No.	Br (mg/l)	Agr. Loading
1/1/03	39.6	37					
8/1/03	2.3	1			Background	ns	
15/1/03	4.2	1					
22/1/03	43.1	40	**1mm BR applied 28/1/03**				
29/1/03	10.7	5	5	5	2	ns	
5/2/03	15	12	20	17	9	ns	
12/2/03	21	17	41	**34**	**16 (cup 5)**	0	**Cup 4**
19/2/03	0	0	41	34	**23 (cup 8)**	ns	**22/02/2002**
26/2/03	15.7	6	57	**40**	**30 (cup 1)**	0	**16mm DW**
5/3/03	35.7	29	92	69	37	0	
12/3/03	37.1	30	130	**99**	**44 (cups 2 & 7)**	ns	
19/3/03	0	0	130	99	50	ns	
26/3/03	0	0	130	99	57	ns	**1 grazing day**
2/4/03	6.9	0	136	99	64	ns	
9/4/03	0.5	0	137	99	71	ns	
16/4/03	31.7	0	169	99	78	ns	
23/4/03	0	0	169	99	85	ns	
30/4/03	63.8	14	232	113	92	ns	
7/5/03	49.3	37	282	149	99	ns	**2.5 grazing days**
14/5/03	11.8	0	294	**149**	**106 (cup 6)**	ns	
21/5/03	24.1	0	318	149	115	ns	**23/5/02**
28/5/03	10.8	0	328	149	121	ns	**4mm DW**
4/6/03	25.5	0	354	**149**	**126 (cup 4)**	**146.0**	**(SMD = 9mm)**
11/6/03	51.5	29	405	179	134	162.8	**2.5 grazing days**
18/6/03	1.8	0	407	179	141	196.9	**19/6/03**
25/6/03	0.0	0	407	**179**	**148 (cup 3)**	**247.8**	**3mm DW**
2/7/03	0.0	0	407	179	156	ns	**(SMD = 10mm)**
9/7/03	38.4	0	446	179		ns	**2.5 grazing days**
			Recharge & time taken to first arrival			**165mm**	**126 days**
			Recharge & time taken to PEAK			**~195mm**	**148 days**
						CUP 4	

This table represents the effects of animal urinations in a qualitative rather than quantitative format.

Appendix BROMIDE continued

Individual cups response to all meteorological, agronomic loadings and bromide response (ns denotes no sample)

Cup 5

Week	Week	RF	Eff RF	Cum. RF	Cum.	Experimental	CUP 5	
Number	Ending	(mm/week)		(mm)	Eff RF (mm)	Day No.	Br (mg/l)	Agr. Loading
	1/1/03	39.6	37					
	8/1/03	2.3	1			Background	0	
	15/1/03	4.2	1					
	22/1/03	43.1	40	**1mm BR applied 28/1/03**				**Cup 5**
1	29/1/03	10.7	5	5	5	2	0.0	**30th Jan & 2nd Fe**
2	5/2/03	15	12	20	17	9	0.0	**32mm DW**
3	12/2/03	21	17	41	**34**	**16 (cup 5)**	**2.7**	
4	19/2/03	0	0	41	34	**23 (cup 8)**	52.2	
5	26/2/03	15.7	6	57	**40**	**30 (cup 1)**	76.5	
6	5/3/03	35.7	29	92	69	37	ns	
7	12/3/03	37.1	30	130	**99**	**44 (cups 2 & 7)**	ns	
8	19/3/03	0	0	130	99	50	ns	
9	26/3/03	0	0	130	99	57	ns	**1 grazing day**
10	2/4/03	6.9	0	136	99	64	451.9	
11	9/4/03	0.5	0	137	99	71	443.5	
12	16/4/03	31.7	0	169	99	78	442.2	
13	23/4/03	0	0	169	99	85	449.6	
14	30/4/03	63.8	14	232	113	92	422.7	
15	7/5/03	49.3	37	282	149	99	ns	**2.5 grazing days**
16	14/5/03	11.8	0	294	**149**	**106 (cup 6)**	ns	**16/5/02**
17	21/5/03	24.1	0	318	149	115	ns	**4mm DW**
18	28/5/03	10.8	0	328	149	121	**748.0**	**(SMD = 5mm)**
19	4/6/03	25.5	0	354	**149**	**126 (cup 4)**	628.3	**2.5 grazing days**
20	11/6/03	51.5	29	405	179	134	599.9	**14/6/03**
21	18/6/03	1.8	0	407	179	141	272.1	**3mm DW**
22	25/6/03	0.0	0	407	**179**	**148 (cup 3)**	197.6	**(SMD = 10mm)**
23	2/7/03	0.0	0	407	179	156	228.3	**2.5 grazing days**
24	9/7/03	38.4	0	446	179		ns	
				Recharge & time taken to first arrival			**66mm**	**16 days**
				Recharge & time taken to PEAK			**182mm**	**144 days**
							CUP 5	

This table represents the effects of animal urinations in a qualitative rather than quantitative format.

Appendix BROMIDE continued

Individual cups response to all meteorological, agronomic loadings and bromide response (ns denotes no sample)

Cup 6

Week Ending	RF (mm/week)	Eff RF (mm/week)	Cum. RF (mm)	Cum. Eff RF (mm)	Experimental Day No.	CUP 6 Br (mg/l)	CUP 6 Agr. Loading
1/1/03	39.6	37					
8/1/03	2.3	1			Background		
15/1/03	4.2	1					
22/1/03	43.1	40	1mm BR applied 28/1/03				Cup 6
29/1/03	10.7	5	5	5	2	0 ←	31/01/2002
5/2/03	15	12	20	17	9	0	16mm DW
12/2/03	21	17	41	34	16 (cup 5)	0	
19/2/03	0	0	41	34	23 (cup 8)	ns	
26/2/03	15.7	6	57	40	30 (cup 1)	ns	
5/3/03	35.7	29	92	69	37	ns	
12/3/03	37.1	30	130	99	44 (cups 2 & 7)	ns	
19/3/03	0	0	130	99	50	ns	
26/3/03	0	0	130	99	57	ns ←	1 grazing day
2/4/03	6.9	0	136	99	64	ns	
9/4/03	0.5	0	137	99	71	ns	
16/4/03	31.7	0	169	99	78	ns	
23/4/03	0	0	169	99	85	ns	
30/4/03	63.8	14	232	113	92	ns	
7/5/03	49.3	37	282	149	99	ns ←	2.5 grazing days
14/5/03	11.8	0	294	149	106 (cup 6)	16.1	16/5/02
21/5/03	24.1	0	318	149	115	ns ←	4mm DW
28/5/03	10.8	0	328	149	121	61.5	(SMD = 5mm)
4/6/03	25.5	0	354	149	126 (cup 4)	ns ←	2.5 grazing days
11/6/03	51.5	29	405	179	134	95.6	14/6/03
18/6/03	1.8	0	407	179	141	**141.3** ←	3mm DW
25/6/03	0.0	0	407	179	148 (cup 3)	ns	(SMD = 10mm)
2/7/03	0.0	0	407	179	156	ns ←	2.5 grazing days
9/7/03	38.4	0	446	179		ns	
			Recharge & time taken to first arrival			165mm	106 days
			Recharge & time taken to PEAK			>195mm	>141 days
						CUP 6	

This table represents the effects of animal urinations in a qualitative rather than quantitative format.

Appendix BROMIDE continued

Individual cups response to all meteorological, agronomic loadings and bromide response (ns denotes no sample)

Cup 7

Week	RF	Eff RF	Cum. RF	Cum.	Experimental	CUP 7	
Ending	(mm/week)		(mm)	Eff RF (mm)	Day No.	Br (mg/l)	Agr. Loading
1/1/03	39.6	37					
8/1/03	2.3	1			Background	0	
15/1/03	4.2	1					
22/1/03	43.1	40	1mm BR applied 28/1/03				Cup 7
29/1/03	10.7	5	5	5	2		01/02/2002
5/2/03	15	12	20	17	9	0	16mm DW
12/2/03	21	17	41	34	16 (cup 5)	0	
19/2/03	0	0	41	34	23 (cup 8)	ns	
26/2/03	15.7	6	57	40	30 (cup 1)	ns	
5/3/03	35.7	29	92	69	37	0	
12/3/03	37.1	30	130	99	44 (cups 2 & 7)	0.45	
19/3/03	0	0	130	99	50	ns	
26/3/03	0	0	130	99	57	ns	1 grazing day
2/4/03	6.9	0	136	99	64	ns	
9/4/03	0.5	0	137	99	71	ns	
16/4/03	31.7	0	169	99	78	ns	
23/4/03	0	0	169	99	85	ns	
30/4/03	63.8	14	232	113	92	ns	
7/5/03	49.3	37	282	149	99	66.0	2.5 grazing days
14/5/03	11.8	0	294	149	106 (cup 6)	ns	16/5/02
21/5/03	24.1	0	318	149	115	167.9	4mm DW
28/5/03	10.8	0	328	149	121	197.3	(SMD = 5mm)
4/6/03	25.5	0	354	149	126 (cup 4)	211.6	2.5 grazing days
11/6/03	51.5	29	405	179	134	224.3	14/6/03
18/6/03	1.8	0	407	179	141	**271.1**	3mm DW
25/6/03	0.0	0	407	179	148 (cup 3)	248.5	(SMD = 10mm)
2/7/03	0.0	0	407	179	156	218.3	2.5 grazing days
9/7/03	38.4	0	446	179		ns	
			Recharge & time taken to first arrival			115mm	44 days
			Recharge & time taken to PEAK			195mm	141 days
						CUP 7	

This table represents the effects of animal urinations in a qualitative rather than quantitative format.

Appendix BROMIDE continued

Individual cups response to all meteorological, agronomic loadings and bromide response (ns denotes no sample)

Cup 8

Week Ending	RF	Eff RF	Cum. RF (mm)	Cum. Eff RF (mm)	Experimental Day No.	CUP 8	
	(mm/week)					Br (mg/l)	Agr. Loading
1/1/03	39.6	37					
8/1/03	2.3	1			Background	0	
15/1/03	4.2	1					
22/1/03	43.1	40	1mm BR applied 28/1/03				Cup 8
29/1/03	10.7	5	5	5	2	ns	02/02/2002
5/2/03	15	12	20	17	9	ns	16mm DW
12/2/03	21	17	41	34	16 (cup 5)	0	
19/2/03	0	0	41	34	23 (cup 8)	0.3	
26/2/03	15.7	6	57	40	30 (cup 1)	ns	
5/3/03	35.7	29	92	69	37	ns	
12/3/03	37.1	30	130	99	44 (cups 2 & 7)	ns	
19/3/03	0	0	130	99	50	ns	
26/3/03	0	0	130	99	57	ns	1 grazing day
2/4/03	6.9	0	136	99	64	ns	
9/4/03	0.5	0	137	99	71	ns	
16/4/03	31.7	0	169	99	78	ns	
23/4/03	0	0	169	99	85	ns	
30/4/03	63.8	14	232	113	92	ns	
7/5/03	49.3	37	282	149	99	ns	2.5 grazing days
14/5/03	11.8	0	294	149	106 (cup 6)	ns	17/5/02
21/5/03	24.1	0	318	149	115	ns	4mm DW
28/5/03	10.8	0	328	149	121	ns	(SMD = 5mm)
4/6/03	25.5	0	354	149	126 (cup 4)	ns	2.5 grazing days
11/6/03	51.5	29	405	179	134	ns	14/6/03
18/6/03	1.8	0	407	179	141	ns	3mm DW
25/6/03	0.0	0	407	179	148 (cup 3)	ns	(SMD = 10mm)
2/7/03	0.0	0	407	179	156	ns	2.5 grazing days
9/7/03	38.4	0	446	179		ns	
			Recharge & time taken to first arrival			49mm	23 days
			Recharge & time taken to PEAK			only 1 sample returned	
						CUP 8	

This table represents the effects of animal urinations in a qualitative rather than quantitative format.

Appendix Groundwater Level Data for the duration of Bromide Experiment

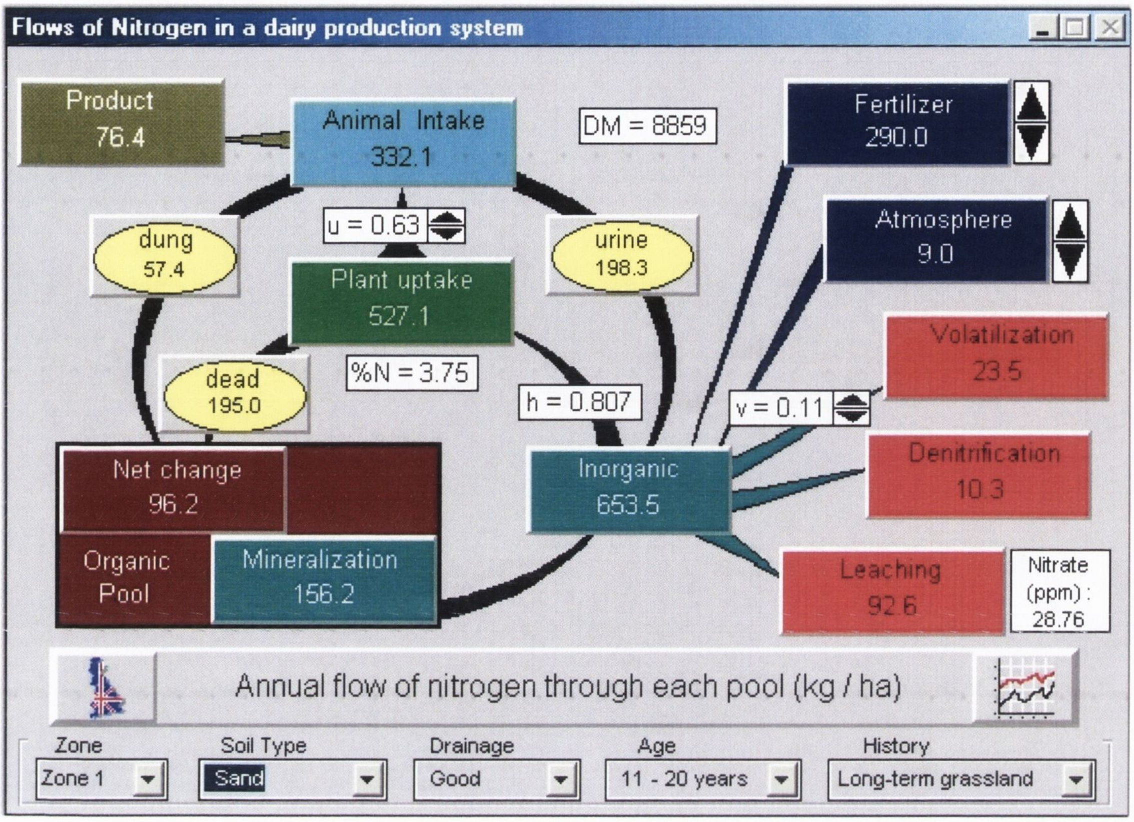
- Change in piezometer water levels for the duration of the tracing experiment,
- Changes expressed relative to previous monitoring day (e.g. difference between 10th and 8th of February),
- Cumulative effective rainfall is presented as value relative to previous monitoring day also,
- Water level increases are highlighted and are observed only to occur on response to significant effective rainfalls

	Rise (+) or fall (-) in piezometer TWL's (metres)									Cumulative
Date	**BHC.1**	**BHC.2**	**BHC.3**	**BHC.4**	**BHC.5**	**BHC.7**	**BHC.8**	**BHC.9**	**BHC.10**	**Eff RF (mm)**
28-Jan-03						Br Appl.>>				
29-Jan-03						-0.14				5.0
31-Jan-03	-0.19					-0.62	-0.15			0.6
2-Feb-03	-0.15	-0.18				-0.3	-0.1			1.8
4-Feb-03	-0.1	-0.11	-0.1	-0.07	-0.09	-0.17	0	-0.04	0.04	9.5
6-Feb-03						-0.01	-0.09			1.4
8-Feb-03	-0.27	-0.28	-0.33	-0.17	-0.16	0.09	-0.01			0.0
10-Feb-03	-0.16	-0.1	-0.04	-0.09	-0.07	-0.02	-0.05	-0.03	0.03	9.8
12-Feb-03	-0.09	-0.06	-0.13	0.05	0.01	0.59	0.07	0.03	0.01	5.9
14-Feb-03	-0.01	-0.03	-0.05	0.01	0.03	0.24	0.03	0.02	0.01	0.0
16-Feb-03	-0.08	-0.09	-0.13	-0.13	-0.11	-0.27	-0.12	-0.08	-0.07	0.0
20-Feb-03	-0.22	-0.21	-0.31	-0.27	-0.28	-0.98		-0.24	-0.14	0.0
22-Feb-03	-0.16		-0.17	-0.18	-0.14	-0.39		-0.12	-0.09	0.0
24-Feb-03	-0.17		-0.21	-0.15	-0.17	-0.4	-0.13	-0.12	-0.08	0.0
26-Feb-03	-0.17	-0.2	-0.13	-0.17	-0.14	-0.3	-0.22	-0.14	-0.05	5.6
28-Feb-03	-0.13	-0.08	0.2	-0.13	-0.11	-0.33		-0.03	0.03	12.9
3-Mar-03	-0.03	0.01	-0.17	0.25	0.2	1.22		0.21	0.14	10.4
5-Mar-03	0.01	-0.02	-0.01	0.05	0.05	0.38		0.03	0.04	6.0
10-Mar-03	0.32	0.34	0.58	0.45	0.46	1.44	0.46	0.41	0.45	29.8
12-Mar-03	0.62	0.55		0.85	0.85	1.86	0.81	0.69	0.37	11.4
19-Mar-03	0.43	0.39		-0.31	-0.34	-2.25	-0.65	-0.38	-0.47	0.0
25-Mar-03	-0.4	-0.43	-0.57	-1.51	-0.52	-1.69	-0.5	-0.45	-0.31	0.0
2-Apr-03	-0.85	-0.78	-0.86	0.27	-0.7	-1.3	-0.56	-0.53	-0.32	0.0
9-Apr-03	-0.75	-0.73	-0.78	-0.6	-0.57	-0.91	-0.4	-0.4	-0.2	0.0
16-Apr-03	-0.6	-0.62	-0.59	-0.42	-0.4	-0.48	-0.28	-0.25	-0.1	0.0
25-Apr-03	-0.3	-0.51	-0.06	-0.4	-0.36	-0.62	-0.08	-0.23	-0.07	6.4
30-Apr-04	-0.4	-0.15	-0.59	0.08	0.01	0.52	-0.08	-0.04	-0.03	9.1
6-May-03	0.9	0.95	1.58	1.64	1.5	5.53	1.63	1.35	0.9	35.1
16-May-03	0.4	0.31	-0.21	-0.69	-0.52	-3.28	-0.89	-0.59	-0.45	0.0
22-May-03	-0.35	-0.36	-0.42	-0.33	0.64	-1.22	-0.31	-0.26	-0.15	0.0
5-Jun-03	-0.95	-0.92	-1	-0.73	-1.68	-1.4	-0.51	-0.49	-0.28	0.0
19-Jun-03	0.3	0.3	0.43	0.45	0.4	1.85	0.37	0.31	0.22	29.0
1-Jul-03	-0.6	-0.52	-0.61	-0.37	-0.5	-1.65	-0.35	-0.19	-0.18	0.0

Appendix T

Selection of Model Simulation Output Sheets

The NCYCLE (Scholefield et al., 1991) and RAM network routing model (ESI, 2000) model combination was tested in this work. Simulation results were discussed in chapter six, section 6.6. Typical model outputs for simulation with each model are presented herein. NCYCLE simulation sheets are provided (pages 691 – 695) and a series of sheets from one RAM application is then presented (pages 696 – 701).

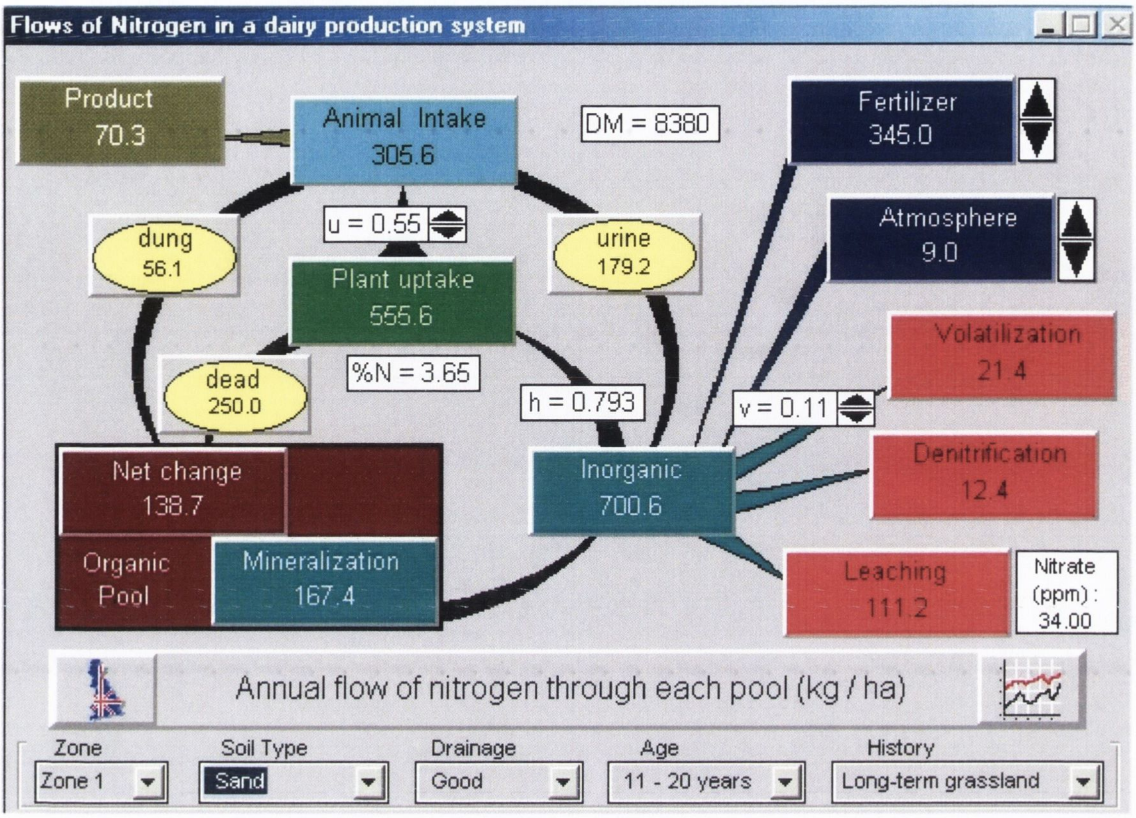


Flows of Nitrogen in a dairy production system

Annual flow of nitrogen through each pool (kg / ha)

Zone: Zone 1
Soil Type: Sand
Drainage: Good
Age: 11 - 20 years
History: Long-term grassland

NCYCLE output window for simulation of nitrogen cycle losses for Curtin's farm average fertiliser N application rate of 290 kg N/ha in the 'Grazing Treatment' 2001-2002. The simulation suggests a nitrate leaching concentration of 28.76mg/l.



Zone: Zone 1

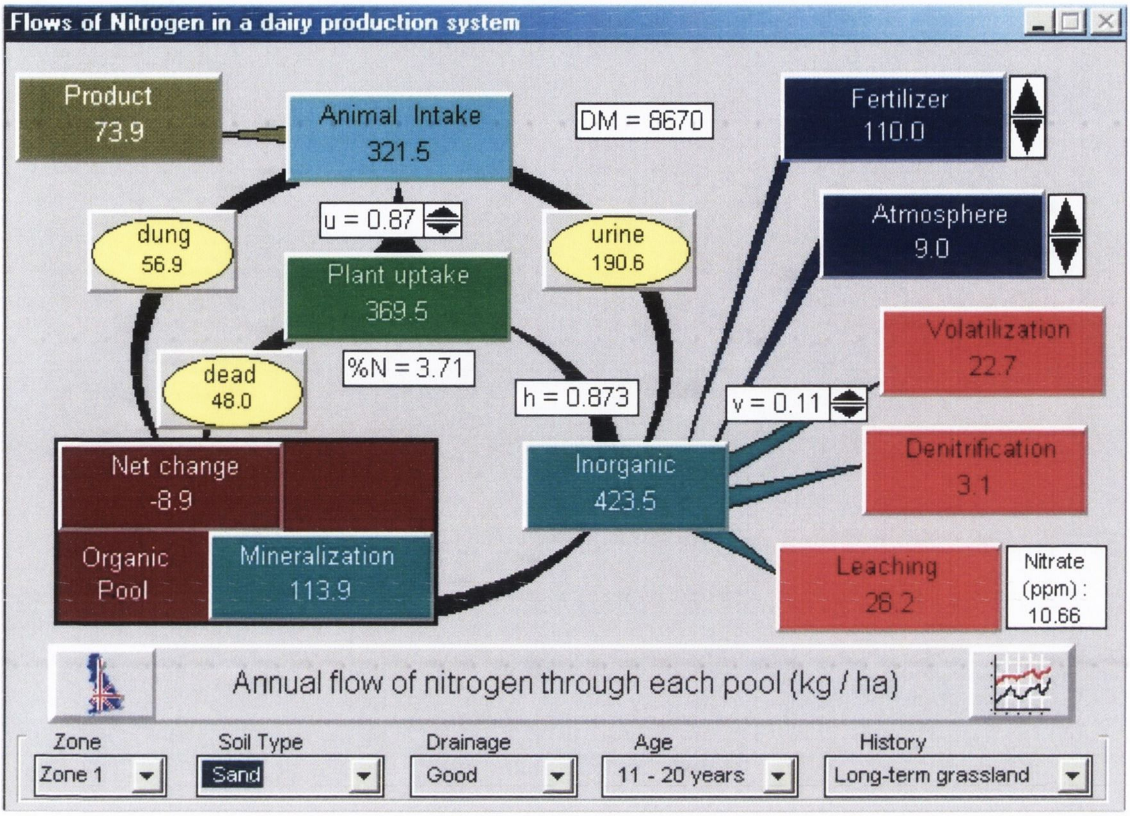
Soil Type: Sand

Drainage: Good

Age: 11 - 20 years

History: Long-term grassland

NCYCLE output simulation window of nitrogen cycle component losses for Curtin's farm 'Two cut silage and grazing treatment' fertiliser application rate of 345 kgN/ha 2001-2002.



Flows of Nitrogen in a dairy production system

Product 73.9

Animal Intake 321.5

DM = 8670

Fertilizer 110.0

Atmosphere 9.0

u = 0.87

dung 56.9

urine 190.6

Plant uptake 369.5

%N = 3.71

dead 48.0

h = 0.873

v = 0.11

Volatilization 22.7

Denitrification 3.1

Net change -8.9

Inorganic 423.5

Organic Pool

Mineralization 113.9

Leaching 26.2

Nitrate (ppm) : 10.66

Annual flow of nitrogen through each pool (kg / ha)

Zone: Zone 1

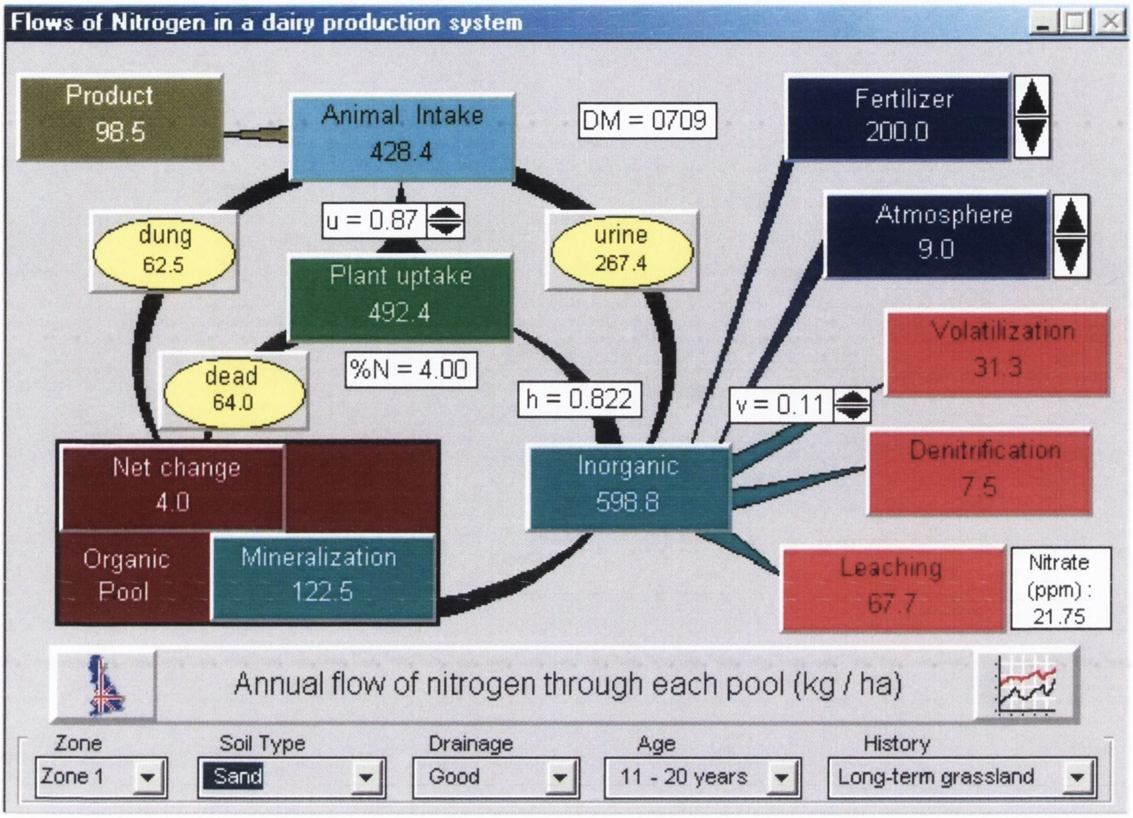
Soil Type: Sand

Drainage: Good

Age: 11 - 20 years

History: Long-term grassland

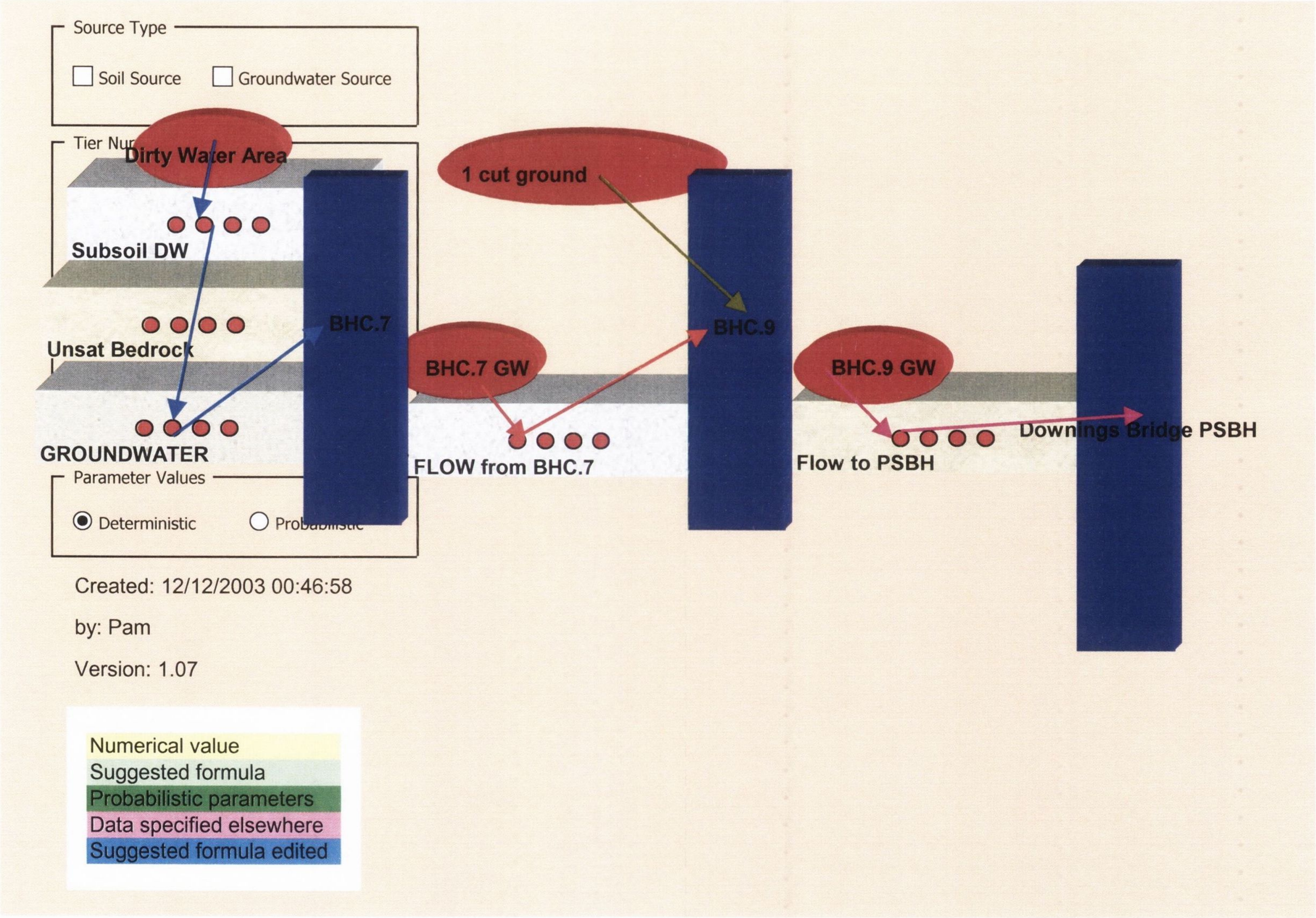
NCYCLE output simulation window of nitrogen cycle component losses for Curtin's farm scenario testing for reducing organic nitrogen load/grazing intensity, thereby reducing fertiliser application rate for example, application rate = 110 kg N/ha.



Zone: Zone 1
Soil Type: Sand
Drainage: Good
Age: 11 - 20 years
History: Long-term grassland

NCYCLE output simulation window of nitrogen cycle component losses for Curtin's farm scenario testing for reducing fertiliser application rate for example, application rate = 200 kg N/ha.

Example RAM Model built application



Source Type

☐ Soil Source ☐ Groundwater Source

Parameter Values

● Deterministic ○ Pro

Created: 12/12/2003 00:46:58

by: Pam

Version: 1.07

Numerical value
Suggested formula
Probabilistic parameters
Data specified elsewhere
Suggested formula edited

YDROGEOLOGICAL UNITS

ydrogeological Units		Subsoil DV	Unsat Bed	GROUNDV	FLOW fron
ydrogeology_Unit_Thickness	m	1.5	20	2	6
ydrogeology_Log_Hydraulic_Conductivity	log(m/s)	-5	-4.5	-4.5	-4
ydrogeology_Hydraulic_Conductivity	m/s	0.00001	3.16E-05	3.16E-05	0.0001
ydrogeology_Head	m	0.5	20	20	20
ydrogeology_Hydraulic_Gradient	[-]	0.1	0.002	0.002	0.002
ydrogeology_Porosity	[-]	0.4	0.1	0.1	0.05
ydrogeology_Velocity	m/s	2.5E-06	6.32E-07	6.32E-07	0.000004
ydrogeology_Tortuosity	[-]				

CONTAMINANT INFORMATION

			Species1
Source determinand names	▲▼	1	NO3-N

Receptor Target Concentrations

	Name	Values in mg/L
Quality Standard 1	Nitrates Directive	11.3
Quality Standard 2	IGV	5.6
Quality Standard 3		
Quality Standard 4		

Generic Contaminant Properties

Contaminants_Organic_Carbon_Water_Partition_Coefficient_Koc	**L/kg**	
Contaminants_Free_Water_Diffusion_Coefficient	**m2/s**	0.000001

PATHWAY SUMMARY

Path 1

		Section 1		Section 2		Section 3		Section 4
Path 1 Type		Source		Unit		Unit		Receptor
Path 1 Name		**Dirty Water Area**		**Subsoil DW: Node 2**		**GROUNDWATER: Node 2**		**BHC.7**
Path 1 Process		Constant source		No Processes		ADRD (1D) + Dilution		Monitoring Borehole
Path 1 Standards							Target Standard	Nitrates Directive
Path 1 Parameter1	**Q_managed [m3/s]**				**Velocity [m/s]**	6.325E-07		
Path 1 Parameter2	**Managed time [years]**				**Dispersivity [m]**	10.0		
Path 1 Parameter3	**Q_path [m3/s]**	7.110E-04			**Travel Distance [m]**	20.0		
Path 1 Parameter4	**Q_decline [m3/s]**	0.000E+00			**Mixing Depth [m]**	0.5		
Path 1 Parameter5					**Mixing Width [m]**	10.0		
Path 1 Parameter6			**Q_Dilute [m3/s]**	0	**Q_Dilute [m3/s]**	3.162E-07	**Q_dilute [m3/s]**	0.000E+00

Path 2

		Section 1		Section 2
Path 2 Type		Source		Receptor
Path 2 Name		**1 cut ground**		**BHC.9**
Path 2 Process		Constant source		Monitoring Borehole
Path 2 Standards			Target Standard	Nitrates Directive
Path 2 Parameter1	**Q_managed [m3/s]**			
Path 2 Parameter2	**Managed time [years]**			
Path 2 Parameter3	**Q_path [m3/s]**	7.110E-04		
Path 2 Parameter4	**Q_decline [m3/s]**	0.000E+00		
Path 2 Parameter5				
Path 2 Parameter6			**Q_dilute [m3/s]**	0.000E+00

Path 3

		Section 1		Section 2		Section 3
Path 3 Type		Source		Unit		Receptor
Path 3 Name		**BHC.7 GW**		**FLOW from BHC.7: Node 1**		**BHC.9**
Path 3 Process		Constant source		ADRD (1D) + Dilution		Monitoring Borehole
Path 3 Standards					Target Standard	Nitrates Directive
Path 3 Parameter1	**Q_managed [m3/s]**		**Velocity [m/s]**	4.000E-06		
Path 3 Parameter2	**Managed time [years]**		**Dispersivity [m]**	1.0		
Path 3 Parameter3	**Q_path [m3/s]**	7.110E-04	**Travel Distance [m]**	200.0		
Path 3 Parameter4	**Q_decline [m3/s]**	0.000E+00	**Mixing Depth [m]**	10.0		
Path 3 Parameter5			**Mixing Width [m]**	10.0		
Path 3 Parameter6			**Q_Dilute [m3/s]**	2.000E-05	**Q_dilute [m3/s]**	0.000E+00

Path 4

		Section 1		Section 2		Section 3
Path 4 Type		Source		Unit		Receptor
Path 4 Name		**BHC.9 GW**		**Flow to PSBH: Node 1**		**Downings Bridge PSBH**
Path 4 Process		Constant source		ADRD (1D) + Dilution		Abstraction Borehole
Path 4 Standards					Target Standard	Nitrates Directive
Path 4 Parameter1	**Q_managed [m3/s]**		**Velocity [m/s]**	1.197E-05		
Path 4 Parameter2	**Managed time [years]**		**Dispersivity [m]**	80.0		*Flux from source &*
Path 4 Parameter3	**Q_path [m3/s]**	7.110E-04	**Travel Distance [m]**	300.0		*in previous units*
Path 4 Parameter4	**Q_decline [m3/s]**	0.000E+00	**Mixing Depth [m]**	2.0		*accounted for*
Path 4 Parameter5			**Mixing Width [m]**	10.0		
Path 4 Parameter6			**Q_Dilute [m3/s]**	1.197E-05	**Q_dilute [m3/s]**	8.277E-03

ATTENUATION PARAMETERS

Hydrogeological Units		Subsoil DV	Unsat Bed	GROUNDV	FLOW fror	Flow to PSBH

General properties

Attenuation_Dry_bulk_density	**kg/m3**	1700	2000	2200	2200	2200
Attenuation_Fraction_organic_carbon	**[-]**					

Contaminant specific parameters

NO3-N

Attenuation_Partition_Coefficient_Kd_Species_1	**L/kg**	0	0.00001	0.00001	0.00001	0.00001
Attenuation_Retardation_Species_1	**[-]**	1	1.0002	1.00022	1.00044	1.00044
Attenuation_Half_Life_Species_1	**days**	No Decay	No Decay	No Decay	No Decay	No Decay
Attenuation_Decay_Coefficient_Species_1	**1/s**	0	0	0	0	0

SOURCE CONCENTRATIONS: BHC9 GW

Source Data Options

● Pore water concentrations
○ Leaching test
○ Soil contaminant concentrations
○ User defined

Source Type

● Constant source
○ Declining source

Source Geometry

BHC9_GW_Source_length	200	**m**
BHC9_GW_Source_width	1000	**m**
BHC9_GW_Source_area	200000	**m2**
BHC9_GW_Source_thickness	10	**m**
BHC9_GW_Source_volume	2000000	**m3**

Source Contaminant Information

Source determinand names		NO3-N
BHC9_GW_Pore_water_concentration	**mg/L**	16.2

SOURCE CONCENTRATIONS: A 1 cut ground

Source Data Options

● Pore water concentrations
○ Leaching test
○ Soil contaminant concentrations
○ User defined

Source Type

● Constant source
○ Declining source

Source Geometry

A_1_cut_ground_Source_length	300	m
A_1_cut_ground_Source_width	200	m
A_1_cut_ground_Source_area	60000	m2
A_1_cut_ground_Source_thickness	4	m
A_1_cut_ground_Source_volume	240000	m3

Source Contaminant Information

Source determinand names		NO3-N
A_1_cut_ground_Pore_water_concentration	**mg/L**	10

SOURCE CONCENTRATIONS: Dirty Water Are

Source Data Options

● Pore water concentrations
○ Leaching test
○ Soil contaminant concentrations
○ User defined

Source Type

● Constant source
○ Declining source

Source Geometry

Dirty_Water_Are_Source_length	200	**m**
Dirty_Water_Are_Source_width	200	**m**
Dirty_Water_Are_Source_area	40000	**m2**
Dirty_Water_Are_Source_thickness	1.5	**m**
Dirty_Water_Are_Source_volume	60000	**m3**

Source Contaminant Information

Source determinand names		NO3-N
Dirty_Water_Are_Pore_water_concentration	**mg/L**	40

Appendix U

Grazing Days relation to Average Groundwater Nitrate Concentrations

A positive correlation was found between the number of days that a plot was grazed and the average groundwater nitrate concentration in the succeeding recharge period. This Appendix shows relevant data. Readers are also referred to chapter five, Figure 5.14, where more information regarding grazing intensities can be found. This significance of this important finding is discussed in chapter six, sections 6.4.7 & 6.7.

Year 1

2001-2002 Summary Groundwater Nitrate-N Concentration Statistics (mg/l NO3-N)

	BHC.1	**BHC.2**	**BHC.3**	**BHC.4**	**BHC.5**	**BHC.7**	**BHC.8**	**BHC.9**	**BHC.10**	**RIVER**
MAX	7.95	22.32	20.64	23.05	17.295	26.975	30.955	23.03	15.335	5.505
MIN	3.99	9.41	8.76	6.82	7.15	18.08	8.625	8.17	2.94	3
RANGE	3.96	12.91	11.88	16.23	10.145	8.895	22.33	14.86	12.395	2.505
	BHC.1	**BHC.2**	**BHC.3**	**BHC.4**	**BHC.5**	**BHC.7**	**BHC.8**	**BHC.9**	**BHC.10**	**RIVER**
AVERAGE	**6.5**	**17.7**	**16.3**	**17.1**	**12.7**	**23.5**	**22.2**	**13.1**	**6.2**	**4.6**

Year 2

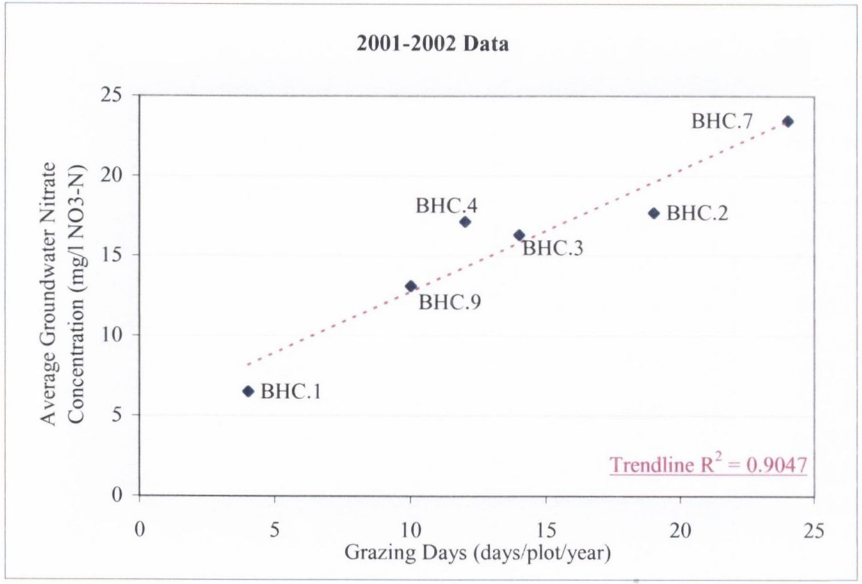
2002-2003 Summary Groundwater Nitrate-N Concentration Statistics (mg/l NO3-N)

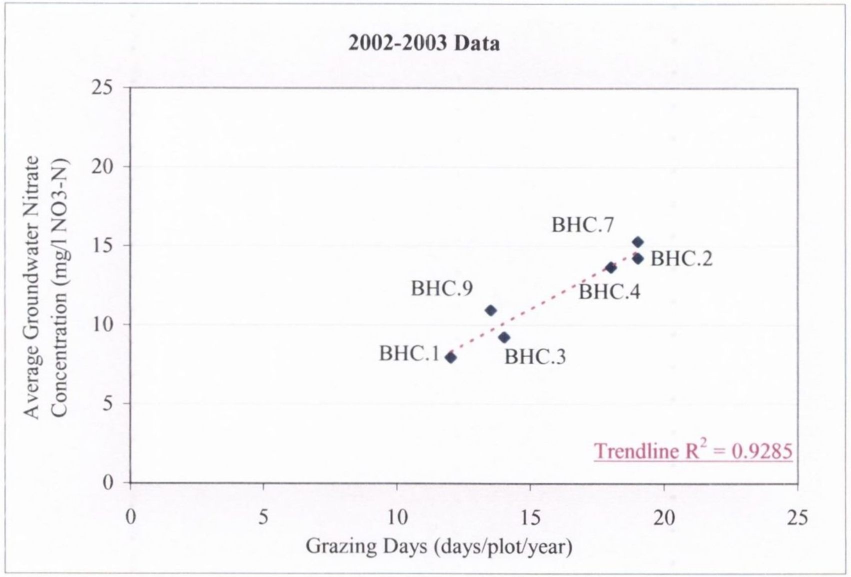
	BHC.1	**BHC.2**	**BHC.3**	**BHC.4**	**BHC.5**	**BHC.7**	**BHC.8**	**BHC.9**	**BHC.10**	**RIVER**
MAX	12.2	20.1795	11.0655	23.242	16.5455	21.078	21.459	12.2	1.8	5.95
MIN	4.6	11.6275	7.61	4.1675	11.5535	8.6305	12.539	9.283	0.8	3.55
RANGE	7.6	8.552	3.4555	19.0745	4.992	12.4475	8.92	2.917	1	2.4
	BHC.1	**BHC.2**	**BHC.3**	**BHC.4**	**BHC.5**	**BHC.7**	**BHC.8**	**BHC.9**	**BHC.10**	**RIVER**
AVERAGE	**8.0**	**14.2**	**9.2**	**13.7**	**13.4**	**15.3**	**14.8**	**11.0**	**1.2**	**4.8**

see Chapter Five, Figure 5.15 for grazing day numbers per field and piezometer locations

	2001 Grazing Days/field/year	**GW NO3-N**			**2002 Grazing Days/field/year**	**GW NO3-N**	
		MAX	**AVERAGE**			**MAX**	**AVERAGE**
BHC.1	4	**8**	6	**BHC.1**	12	**12**	8
BHC.2	19	**22**	18	**BHC.2**	19	**20**	14
BHC.3	14	**21**	16	**BHC.3**	14	**11**	9
BHC.4	12	**23**	17	**BHC.4**	18	**23**	14
BHC.7	24	**27**	23	**BHC.7**	19	**21**	15
BHC.9	10	**23**	13	**BHC.9**	13.5	**12**	11
	R2	0.8022993	0.951163025			0.91878782	0.963580383

*The relationship is stronger when average data are used


2001-2002 Data
Average Groundwater Nitrate Concentration (mg/l NO3-N)
25
20
15
10
5
0
BHC.7
BHC.4
BHC.2
BHC.3
BHC.9
BHC.1
Trendline $R^2 = 0.9047$
0
5
10
15
20
25
Grazing Days (days/plot/year)


2002-2003 Data
Average Groundwater Nitrate Concentration (mg/l NO3-N)
25
20
15
10
5
0
BHC.7
BHC.2
BHC.9
BHC.4
BHC.1
BHC.3
Trendline $R^2 = 0.9285$
0
5
10
15
20
25
Grazing Days (days/plot/year)