Water Use

Regulatory Method (WAT-RM-24)

Pumping Test Methodology

Version: v4.0

Released: Apr 2013

Copyright and Legal Information

Disclaimer
Whilst every effort has been made to ensure the accuracy of this document, SEPA cannot accept and hereby expressly excludes all or any liability and gives no warranty, covenant or undertaking (whether express or implied) in respect of the fitness for purpose of, or any error, omission or discrepancy in, this document and reliance on contents hereof is entirely at the user's own risk.

Registered Trademarks
All registered trademarks used in this document are used for reference purpose only.

Other brand and product names maybe registered trademarks or trademarks of their respective holders.

Update Summary

Version	Description
v1.0	First issue for Water Use reference using approved content from the following documents: *GWABS_5_Pumping_Test_Requirements_and_Monitoring_ Methodology_v1_8.doc*
v2.0	Test pumping requirements clarified / changes to standard groundwater level monitoring frequencies during test pumping.
v3.0	Document simplified & updated to reflect changes to *WAT-RM-11: Licensing Groundwater Abstractions including Dewatering*.
v4.0	Expired CMS links reviewed and updated.

Notes

References: Linked references to other documents have been disabled in this web version of the document. See the References section for details of all referenced documents.

Printing the Document: This document is uncontrolled if printed and is only intended to be viewed online.

If you do need to print the document, the best results are achieved using Booklet printing or else double-sided, Duplex (2-on-1) A4 printing (both four pages per A4 sheet).

Always refer to the online document for accurate and up-to-date information.

Table of Contents

1. Introduction, Purpose & Scope 4

2. Types of Pumping Tests 5

2.1 Equipment Test 5

2.2 Step Tests 5

2.3 Constant Rate Pumping Test 5

2.4 Recovery Test 6

3. When to Monitor 7

3.1 Baseline Monitoring 7

3.2 Pumping and Recovery Test Monitoring 7

3.3 Timing of Pumping Tests 7

4. Monitoring Parameters 8

4.1 Groundwater Level 8

4.2 Surface Water Monitoring 9

4.3 Existing Local Abstractions 10

4.4 Rainfall and Barometric Pressure 10

4.5 Saline Waters or Waters of Different Chemical Composition 11

4.6 Pumping Rate 11

5. Borehole Construction 12

5.1 Abstraction Borehole 12

5.2 Observation Wells 12

6. Accuracy, Duration, Frequency of Monitoring 13

6.1 Accuracy 13

6.2 Monitoring Duration and Frequency 13

7. Discharge of Water 16

8. Recording and Submission of Data 17

References 18

1. Introduction, Purpose & Scope

This document provides guidance for SEPA Hydrogeologists on the pumping test and associated monitoring that, if required, should be detailed in a time-limited drill and pumping test licence.

SEPA may issue a time limited licence to allow the drilling and test pumping of a borehole where a groundwater abstraction application has failed one or more of the screening tests detailed in *WAT-RM-11: Licensing Groundwater Abstractions including Dewatering*.

A pumping test allows an estimation of aquifer characteristics to be made. These characteristics can then be used to predict the impact of the abstraction on groundwater-dependant water features through calculation or modelling. The pumping test may also provide direct evidence of short term impact through monitoring of these water features. The level of detail required will be proportional to the volume of the abstraction and the sensitivity of the identified water features.

The information required by the time limited abstraction licence will be used to assess the acceptability of an ongoing abstraction at this location. It is important that the information is accurate and complete. It should be noted that other information, in addition to the data gathered from the pumping test, may be required to help determine the abstraction licence e.g. where groundwater dependant wetlands have been identified within the survey area an ecological baseline report may be required. Further information is provided in *WAT-RM-16: Groundwater Abstraction - Hydrogeologist Impact Assessment*.

Where applicants wish to increase their testing beyond the minimum described in Tables 1 and 2 they should submit their proposals to SEPA as early in the process as possible. SEPA will aim to accommodate any proposals where possible.

In some cases the applicant will lack the technical ability to supply the requested information. In such cases they are advised to seek the services of a competent person.

2. Types of Pumping Tests

2.1 Equipment Test

Tests to check that equipment is installed properly and in working order do not form part of the pumping test programme and should last no longer than a total of 8 hours. It is recommended that the tests include an assessment of the adequacy of the discharge arrangements and monitoring equipment, and also enable the operators to be familiar with the pumping equipment, to enable an efficient pump test to be undertaken (e.g. know how far to open a valve to achieve the desired pumping rate).

2.2 Step Tests

Step discharge pumping tests are useful in estimating the potential maximum sustainable yield of the well and setting the appropriate rate for the constant discharge test. SEPA does not require step tests to be undertaken. However, where they are undertaken, the data should be submitted with the results of the constant discharge test.

A step test will typically comprise four to six steps of 60 to 100 minutes each, where the abstraction rate increases in roughly equal amounts between the lowest attainable pumping rate and 110% to 120% of the required operational abstraction rate. The steps can be undertaken consecutively or a recovery period (usually of a similar duration to the steps) can be allowed between each step.

Following a step test, water levels must recover fully before the constant rate test starts.

It is recommended that, where step drawdown tests are undertaken, the advice given in *BS ISO 14686:2003* is followed.

2.3 Constant Rate Pumping Test

This should consist of a test at the proposed maximum abstraction rate and be at a constant discharge rate. The duration of the test will depend upon the magnitude of the abstraction and will be specified by SEPA. It will normally be for at least the length of time indicated in *Table 1*.

In certain circumstances SEPA may extend the duration of the test. For example, where the following are predicted:

- a delayed yield
- barrier effects
- deterioration in water quality, or
- where it is essential to measure the effects upon an identified water feature.

Where the test duration exceeds twice that recommended in *Table 1*, or the cost of extending the pumping test by the necessary interval is greater than the financial benefit derived from the abstraction, SEPA may request the use of long term monitoring to gain the necessary information, which will be regulated in the form of conditions included in an abstraction licence. The applicant should note that, if long term adverse effects are identified as a result of the monitoring, the abstraction licence may be varied, suspended or revoked.

2.4 Recovery Test

On completion of the pumping test, a further period of monitoring will be required, during which time groundwater levels should recover towards their original pre-test levels. Monitoring of the abstraction borehole and other features identified in the time limited pumping test licence should continue over the recovery period for the duration detailed in the time limited abstraction licence. *Table 1* and *Table 2* can be used to help set the monitoring frequency and duration.

The data from the recovery period can be analysed to determine aquifer characteristics. This data can be of better quality than that obtained during the pumping test as the pumping rate, which can vary slightly, will not affect the results. Furthermore, it provides a second data set to supplement the pumping phase data, should this be inadequate.

3. When to Monitor

Monitoring may be required for three stages in the test pumping process, pre-pumping test (or baseline), pumping test and recovery. In some cases, long-term monitoring may also be required. The monitoring regime will be specified by SEPA in the conditions attached to any time-limited abstraction licence that is issued.

3.1 Baseline Monitoring

Baseline monitoring is necessary to establish the conditions that exist prior to the pumping test so that any effects caused by the abstraction can be assessed.

A number of factors can cause fluctuations to occur in groundwater levels in addition to an abstraction and the baseline monitoring should aim to characterise these effects where possible. Such effects may be caused by changes in the hydrological, hydrogeological and climatological regimes. These fluctuations may be periodic or singular.

The pumping test should begin immediately after completion of the baseline monitoring period to provide a continuous and comparable data record. In situations where a baseline monitoring period has been chosen to ensure other impacts on the aquifer are minimised (e.g. when other abstractions are not operational), and these cannot be achieved immediately before the pumping test, baseline monitoring should continue from the preferred period to the start of the test.

3.2 Pumping and Recovery Test Monitoring

This will require monitoring of the same features as the baseline monitoring but the frequency will be increased for some parameters. It should continue for the full period of the pumping and recovery test.

3.3 Timing of Pumping Tests

Ideally, pumping tests should take place only under conditions that will maximise the quality of the data collected. For example, impacts upon river flows are often difficult to detect except at low flows. Similarly, rapidly changing conditions, such as when groundwater levels respond rapidly to significant rainfall events (e.g. in fissured or very shallow aquifers), may be an inappropriate time for testing. However, SEPA acknowledges that weather and other conditions can change rapidly and will aim to be practical in its requirements where possible.

4. Monitoring Parameters

Groundwater level (depth below a fixed datum) and pumping rate (m^3/day) will always need to be monitored

Others, such as those listed below, will only be required in specific circumstances, e.g. barometric pressure will only affect confined or partially confined aquifers.

- Flowing surface waters (m^3/ second or cumecs and/or height above/below a fixed datum)
- Standing surface waters (height above/below a fixed datum)
- Tides (for abstractions near to the coastline) (height above/below a datum)
- Pumping regime of other local abstractions (volume, times and duration)
- Rainfall (amount, usually mm/day)
- Barometric Pressure (Pascals or mbars)
- Water quality (parameter to be defined by SEPA)

The parameters to be monitored will be specified by the Groundwater Unit. It should be noted that SEPA can only ask for parameters that are of relevance to the abstraction assessment to be monitored.

4.1 Groundwater Level

Groundwater levels fluctuate as a response to natural or anthropogenic influences. It is important to identify and measure these fluctuations to be able to make compensation for them in the pumping test data. The locations for monitoring groundwater level will be specified by SEPA in the time limited abstraction licence. The depth to groundwater from a common datum, preferably Ordnance Datum, should be measured as accurately as possible but at least to the nearest centimetre.

Groundwater Level can be measured using manual or automatic measurement devices. Water level dippers are a common form of manual measuring device. These consist of a probe attached to a measuring tape. The probe is sensitive to water so that when the water table is intercepted a light (and/or buzzer) is activated.

Automatic water level devices take a number of forms. Amongst the most common are pressure transducers with data loggers. These invariably measure changes in water pressure, due to differences in the water table elevation, to measure water level. The rating of the device should ensure the greatest accuracy in water level measurement possible. Pressure transducer water level measurements should be validated with manual measurements periodically.

4.2 Surface Water Monitoring

4.2.1 Ponds, Springs or Wetlands with Outflow

Flow monitoring should be undertaken using a weir or flume, as appropriate, that allows the reliable measure of at least 10% of the test pumping rate e.g. if the pumping rate is 100 m^3/day, the equipment should be capable of measuring flows in the surface water of 10 m^3/day. If measurement is to be made manually, 10% should represent a change in water level in the weir or flume of at least 0.5cm.

4.2.2 Ponds or Wetlands with Standing Water

Water level monitoring should be undertaken using a gauge board or a stilling well / piezometer (screened over a minimum of one metre beginning approximately 50cm above the base of the water body), with a common datum, preferably Ordnance Datum. The piezometer may be installed within or close to the surface water body to be monitored, provided that the screened interval is in close hydraulic continuity with the pond or wetland.

4.2.3 Wetlands without Standing Water

Water level monitoring should be undertaken using two piezometers, screened between approximately 0.75 and 2.0 metres below ground surface. The piezometers must have a common datum, preferably Ordnance Datum.

4.2.4 Rivers, Burns or Streams

For small flows the monitoring regime described in *section 4.2.1 above* may be used. It may be difficult or impossible to measure the impacts of an abstraction upon a river or stream where the flow is large compared to the abstraction volume. In many cases the impact may not become apparent for a period much longer than the duration of the pumping test. Where this is the case the impact should be predicted from hydrological and hydrogeological information and long term monitoring may be included as an abstraction licence condition.

Flow monitoring must be undertaken when the proposed maximum abstraction volume exceeds 10% of the Q95 flow. An estimate for the Q95 flow can be obtained from SEPA.

Ideally, river flow data from continuously monitored flow gauging structures, which will usually be operated by SEPA, should be used. However, when such structures are not available, spot flow (current meter) measurements should be made using an appropriate flow meter in a relatively uniform reach with predominantly laminar flow. The cross section of the stream bed must be described and depth measurements taken. Alternatively calibrated stage measurements could be used. In very high risk situations piezometers and a stilling well could be installed. The screened interval of the piezometers must

be in close hydraulic continuity with the material underlying the channel and be at least one metre long.

4.2.5 Tidal Variations

When requested, tide tables covering the period of baseline monitoring and pumping testing may be obtained from the internet, chandleries or the harbour master of the nearest measuring station to the abstraction location. Both the height and the timing of high and low tide should be noted. Where the nearest monitoring point is distant from the site, two measurement points may need to be considered and the data extrapolated between these. Where tidal data is critical, a site specific monitoring point may need to be installed (e.g. gauge board) and water level data loggers may be needed to record the timing and heights of the tides.

4.3 Existing Local Abstractions

If there are local abstractions that are not continuously pumped at a constant rate, fluctuations in groundwater levels will occur. These may render the monitoring and pumping test measurements difficult or impossible to interpret. The abstraction regime of all local abstractions should be examined to determine those that are intermittent. It may be possible to arrange for a stable pumping regime from these during the period covered by the baseline monitoring, pumping test and recovery period. Alternatively, the baseline monitoring period or frequency should be chosen so as to eliminate these fluctuations by taking measurements when the full effect of the local regime is apparent so that the monitoring measurements include any effects of the other abstraction(s). Details of the pumping regime(s) (volume and duration) should be collected if possible and submitted with the pumping test and monitoring results. The use of data loggers may overcome difficulties in timing readings.

4.4 Rainfall and Barometric Pressure

Local and regional effects of rainfall may cause changes in groundwater levels. Changes in barometric pressure are invariably regional although localised low pressure events are not unknown (tornados). Rainfall and barometric pressure data is collected by the Meteorological Office and data from their nearest station can be used, providing climatic conditions at the weather station are similar to those at the abstraction site. It should be remembered that topography and latitude are important causes of rainfall and barometric pressure variations. These aspects should be considered when comparing the weather station and abstraction sites.

A custom weather station that will measure rainfall and barometric pressure may need to be used where local conditions vary greatly from the nearest Met Office station.

4.5 Saline Waters or Waters of Different Chemical Composition

Where the groundwater abstraction has been predicted to intercept a zone of potential saline intrusion, or the boundary of formations containing water of different chemical composition, chemical testing of waters will be requested in the monitoring regime. The chemical testing entails the measurement of conductivity or other suitable parameters (chloride, pH, Dissolved Oxygen, etc.) in specified springs, observation or abstraction wells, and groundwater supported features. Some parameters, such as pH and Dissolved Oxygen, require on-site measurement; others (e.g. chloride) may be tested on-site or in a laboratory. Where possible, continuous on-site measurement is preferred.

The applicant should ensure that any water sampled or tested is representative of the local groundwater conditions. This is particularly important when sampling observation boreholes or abstraction boreholes that are not operational during the monitoring period. Purging of between three and five borehole volumes is usually considered sufficient to remove stagnant water, although this may not always be the case. However, when considering saline intrusion, downhole logging may be more useful than taking purged samples.

4.6 Pumping Rate

The constant rate test should be pumped at a discharge equal to the maximum abstraction rate applied for. The rate that water is pumped from the abstraction borehole must be measured accurately. Ideally, two forms of independent measurement should be used to ensure the accuracy of the readings. Typical measurement devices include inline meters, weir tanks and containers of known volume.

5. Borehole Construction

5.1 Abstraction Borehole

The document *An applicants guide to water supply boreholes* provides useful information on how to site, design and construct abstraction boreholes.

Borehole construction and development should be completed before monitoring for the pumping test begins and sufficient time must be allowed for equilibrium conditions to be established. This may be 3 -7 days for boreholes without development but may require significantly longer for boreholes where there has been development to increase yield. Monitoring of level and/or quality should be used to establish when equilibrium conditions have been achieved.

5.2 Observation Wells

5.2.1 Location and Number of Observation Wells

To obtain accurate estimates of aquifer characteristics, changes in water level at other locations close to the pumping well are necessary. An existing well (or wells), may provide the information, if the construction, dimensions and location are satisfactory. In other cases construction of an observation well (or wells) may be necessary before the pumping test takes place. Monitoring of observation wells will be required for abstractions where a risk of impact upon a water feature has been identified and a suitable existing monitoring point does not exist. The number and location of observation well(s) will be specified by SEPA.

5.2.2 Depth of Observation Wells

More aquifer information can be obtained if multiple piezometers / boreholes are installed, screened to different levels. These can be of particular use in layered aquifers where the impact in a lower or higher aquifer, or on a groundwater dependant feature, is being monitored. Where a single observation well is used it should penetrate to the same depth and be screened over the same interval as the pumping well.

6. Accuracy, Duration, Frequency of Monitoring

6.1 Accuracy

6.1.1 Manual Measurement

Time measurements should be made as accurately as possible but, during the first 10 minutes of pumping an error greater than 5 seconds should be avoided.

Borehole level measurements should be accurate to at least 1 cm, stilling well measurements to 0.5mm.

Weir flow measurement should be accurate to 1% of the coefficient of discharge (see *BS ISO 14686:2003*).

6.1.2 Automatic Measurement

Where automatic water level measurements are made then the accuracy should be at least as good as for manual measurements. Ideally the recorder should be programmed to start at a small measurement interval (for example, 30 seconds) and ramp upward logarithmically to a 10-minute measurement interval. Where this is not possible recorders should be set to measure at 30 second intervals.

6.2 Monitoring Duration and Frequency

The duration and frequency of monitoring will depend upon the variability of the parameter being measured, some parameters may require a small number of measurements, others may need frequent or continuous measurement for an extended period. The data gathered during the early stages of the monitoring should be reviewed by the Applicant and carefully analysed for periodic fluctuations and the monitoring regime increased, if appropriate, so that it appropriately records changes in levels. The adjustments may require a shorter interval between measurements e.g. from twice daily to 6 hourly, or a change in the time of measurement, e.g. from morning/evening to midday/midnight.

The agreement of SEPA must be sought for any deviation from the scheduled monitoring programme.

The typical frequency and duration of monitoring is indicated in Tables 1 and 2 below. **These periods should be regarded as the minimum and may be extended**.

Test pumping should be discontinued if the impact is judged by SEPA or the operator to be causing significant environmental effects.

Table 1 Monitoring and Testing Periods

Abstraction Rate	Pre-Test Monitoring	Pump Test Duration	Recovery Period
Up to 500	2 times pumping test duration, min 3 days	1 day (24hrs)	1 day (24hrs)
500 to 1000		2 days (48hrs)	2 days (48hrs)
1000 to 3000		4 days (96hrs)	4 days (96hrs)
3000 to 5000		7 days (168hrs)	7 days (168hrs)
>5000		10 days (240hrs)	10 days (240hrs)

Table 2 Monitoring Frequency

Parameter for Measurement	Pre-Test Frequency	Pump Test & Recovery Period Frequency
Rainfall	Daily	Daily
Barometric Pressure	2 times daily	2 x Daily
Tides	Each max/min	Each max/min
Surface waters	2 times daily	2 x daily
Salinity testing	Every 4 hours suggested to see tidal variation	• Hourly for the first six hours • Two hourly from 6 to 24 hours • Four hourly from 24hours to 4 days • Six hourly thereafter • (A salinity logger is suggested)
Groundwater levels	4 times daily (including immediately before the pumping starts)	Abstraction and Observation Boreholes[1] • Every 30 seconds for the first 10 minutes • Every 2 minutes from 10 to 20 minutes • Every 5 minutes from 20 to 60 minutes • Every 10 minutes from 60 to 100 minutes • Every 20 minutes from 100 to 300 minutes • Every 50 minutes from 300 to 1000 minutes • Every 100 minutes from 1000 to 3000 minutes • Every 200 minutes thereafter until completion of the test, unless circumstances require more frequent measurements.
		Other Observation Points (Surface waters, wells, and wetlands) • 1 hour prior to startup • Every 2 hours thereafter In the event that drawdown/impact is probable or detected, the period between measurements should be decreased to: • Once every 10 minutes during the first hour and • Hourly or less thereafter, as appropriate.

[1] Time measurements should be made as accurately as possible but, during the first 10 minutes of pumping an error greater than 5 seconds should be avoided.

7. Discharge of Water

If not appropriately carried out the disposal of the discharge from the pumping test may cause pollution e.g. the discharged water may be contaminated with drilling fluids, cuttings, or the products of borehole development (e.g. acidisation). This may impact upon surface waters and groundwater and may cause pollution or affect other users of the water environment. Therefore, the means of disposal of the discharge from the pumping test should be carefully considered at the earliest opportunity as it is often an underestimated part of the test requiring considerable time and monetary expenditure. Discharge options that can be considered are listed in *Table 3*.

It is the responsibility of the applicant to ensure that any activity associated with drilling, development and testing of an abstraction well does not cause adverse environmental impacts.

It may be necessary to remove, or make provision to remove, the water initially abstracted from the borehole which could be contaminated with drilling fluids, particulates or the by-products of borehole development (such as suspended solids or drilling muds). This is often done using tankers, or by storing the water in a tank to allow the sediment to fall out of solution prior to discharging the water to another discharge point.

Table 3 Discharge Disposal Options and Considerations

Term	Definition
General	Must not impact on a monitoring point.
Surface water course	Discharge authorisation may be required and measures must be taken to ensure the watercourse does not become polluted e.g. with low oxygen content or highly turbid water or fines or cause erosion. The additional water should not cause flooding.
Foul sewer	Permission for discharge must be sought from the appropriate utility provider.
Ground	The ground must have sufficient absorption capacity to prevent water logging or flooding. The discharge point must be sufficiently distant to prevent recirculation of the water to the aquifer being tested and/or abstraction point. The water must be of suitable quality.

8. Recording and Submission of Data

Manual monitoring data should be recorded clearly in tabular form indicating the location, the date and the time for each measurement. The data can also be submitted in the form of electronic files, provided they are in a standard spreadsheet format e.g. Microsoft Excel. Where electronic data loggers are used the information may be submitted solely in the form of electronic files, provided documentation is supplied identifying the files and indicating their content.

The data from baseline and pumping test monitoring, including that from the pumped well and other observation points, should be compiled into a report and submitted to SEPA for assessment. Interpretation of the data should be provided for all complex licence applications. An interpretative report may significantly reduce the time needed for the assessment. It will also provide the applicant with an independent analysis of the sustainable yield from the borehole and the environmental impacts. Where the results of the pumping test and monitoring do not support the proposed abstraction volume e.g. the required yield has shown not to be sustainable, or there are adverse environmental effects, the Applicant may wish to apply for a reduced volume when they apply to vary their time-limited abstraction licence. If this is the case the advice of SEPA may be sought.

References

NOTE: Linked references to other documents have been disabled in this web version of the document.

See the Water >Guidance pages of the SEPA website for Guidance and other documentation (*www.sepa.org.uk/water/water_regulation/guidance.aspx*).

All references to external documents are listed on this page along with an indicative URL to help locate the document. The full path is not provided as SEPA can not guarantee its future location.

Regulatory Methods & Guidance

WAT-RM-11: Licensing Groundwater Abstractions including Dewatering

WAT-RM-16: Groundwater Abstraction - Hydrogeologist Impact Assessment

An applicants guide to water supply boreholes (www.sepa.org.uk/water)

British Standards

Available from *http://www.standardsuk.com/*

- Hydrometric determinations. Pumping tests for water wells. Considerations and guidelines for design, performance and use (BS ISO 14686:2003)
- Water well casing. Specification for steel tubes for casing (BS 879-1:1985)
- Water well casing. Specification for thermoplastics tubes for casing and slotted casing (BS 879-2:1988)

- End of Document -