METHODOLOGY FOR ESTABLISHING GROUNDWATER THRESHOLD VALUES AND THE ASSESSMENT OF CHEMICAL AND QUANTITATIVE STATUS OF GROUNDWATER, INCLUDING AN ASSESSMENT OF POLLUTION TRENDS AND TREND REVERSAL

Environmental Protection Agency
An Ghníomhaireacht um Chaomhnú Comhshaoil

Hydrometric and Groundwater Section
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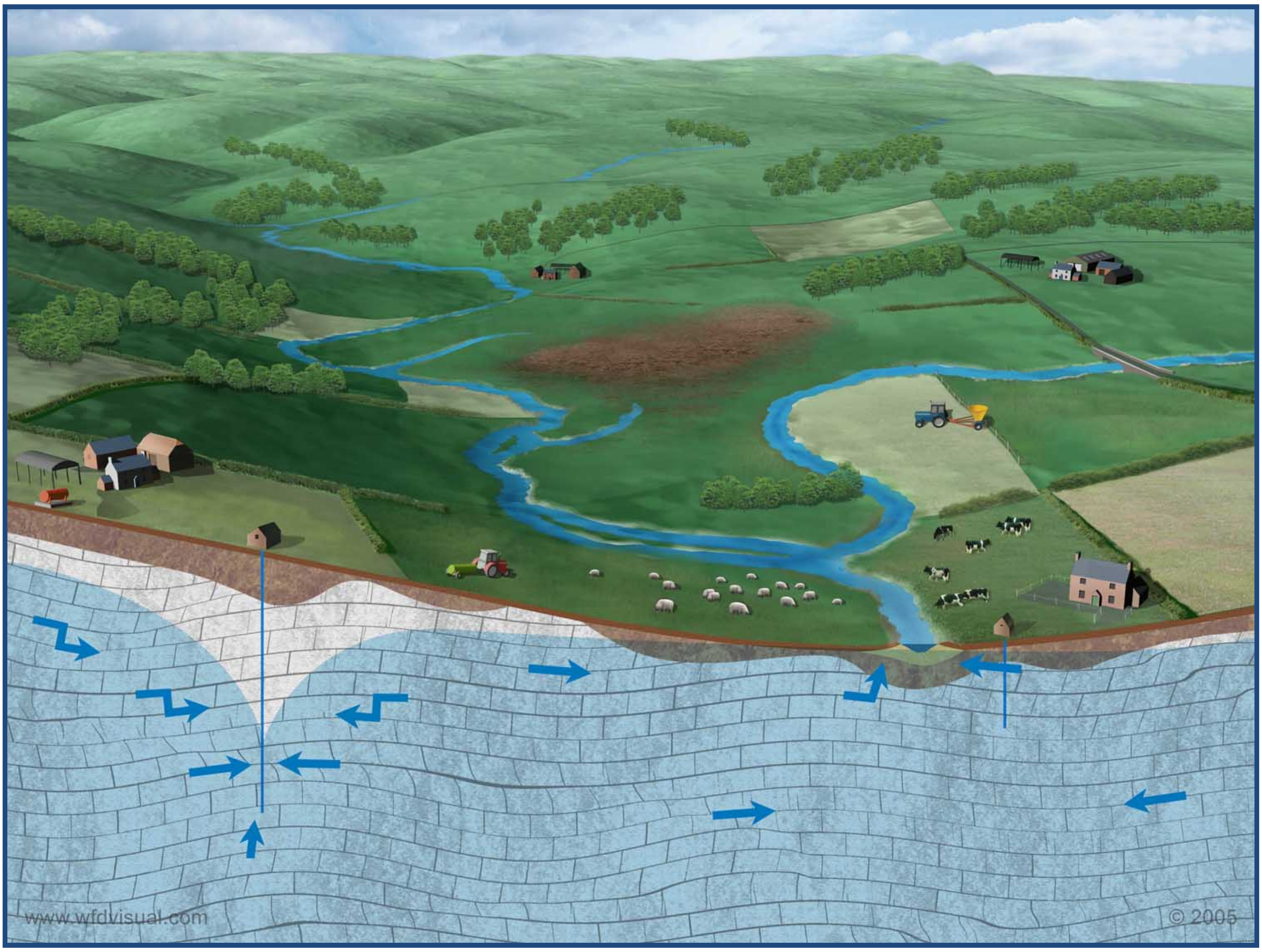

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Contents

1 Introduction

The European Communities Environmental Objectives (Groundwater) Regulations, 2010 (S.I. 9 of 2010) establish a new strengthened regime for the protection of groundwater in line with the requirements of the Water Framework Directive (2000/60/EC) and the Groundwater Directive (2006/118/EC). Parts (IV) – (VI) of the Regulations identify the Environmental Protection Agency as the responsible body for establishing and maintaining a list of Threshold Values (TVs) for pollutants in groundwater, assessing the chemical and quantitative status of groundwater bodies and undertaking pollutant trend and trend reversal assessments.

Under Regulations 48–52, the Environmental Protection Agency is required to establish, and where appropriate maintain and update, a list of TVs for pollutants in groundwater. Threshold Values only have to be derived for pollutants placing a groundwater body at risk of failing to achieve a WFD objective. The values are used as triggers to help determine whether the conditions for good chemical status are being met.

Regulations 33–44 identify the conditions for assessing groundwater body status. The achievement of good groundwater status involves meeting this series of conditions, which are designed to satisfy the criteria defined in the WFD and the Groundwater Directive. In order to assess whether these conditions are being met, a series of tests has been prescribed for each of the quality elements defining good (chemical and quantitative) groundwater status.

There are five chemical and four quantitative tests (Figure 1). Each test is applied independently and the results are combined to give an overall assessment of groundwater body chemical and quantitative status. The worst-case classification from the relevant chemical status tests is reported as the overall chemical status for the groundwater body, and the worst-case classification of the quantitative tests is reported as the overall quantitative status for the groundwater body. The worst result of the chemical and quantitative assessments is reported as the overall groundwater body status.

Part VI of the Regulations indicates that the Environmental Protection Agency shall undertake an assessment of pollution trends. This includes the identification of significant and sustained upward trends in the concentration of pollutants in groundwater bodies or groups of bodies identified as being at risk of failing to achieve the objectives of the WFD. Where necessary, the Environmental Protection Agency should undertake an assessment of trends to verify that plumes from contaminated sites do not expand to such an extent that they put a groundwater body at poor status.

The Environmental Protection Agency must also identify the starting point for trend reversal. The starting point for trend reversal is to be expressed as a percentage of the relevant groundwater quality standard or TV. The start date for trend reversal is based on the significance of the trend and the risk associated with failing an objective of the WFD.

The assessment of trends in groundwater pollutant concentrations is also required in two of the chemical status assessments. For the Drinking Water Protected Area and Saline Intrusion tests, trend assessments are required, on a case by case basis, where TVs have been exceeded for one or more pollutants.

The classification assessments have generally followed the procedures set out in EU Guidance Document No. 18: Guidance on Groundwater Status and Trends (EC, 2009), UKTAG Paper 11b(i): Groundwater Chemical Classification for the purposes of the Water Framework Directive and the Groundwater Daughter Directive (UKTAG, 2008a), UKTAG Paper 11b(ii): Groundwater Quantitative Classification for the purposes of the Water Framework Directive (UKTAG, 2008b) and UKTAG Guidance on Groundwater Trend Assessments (UKTAG, 2009).

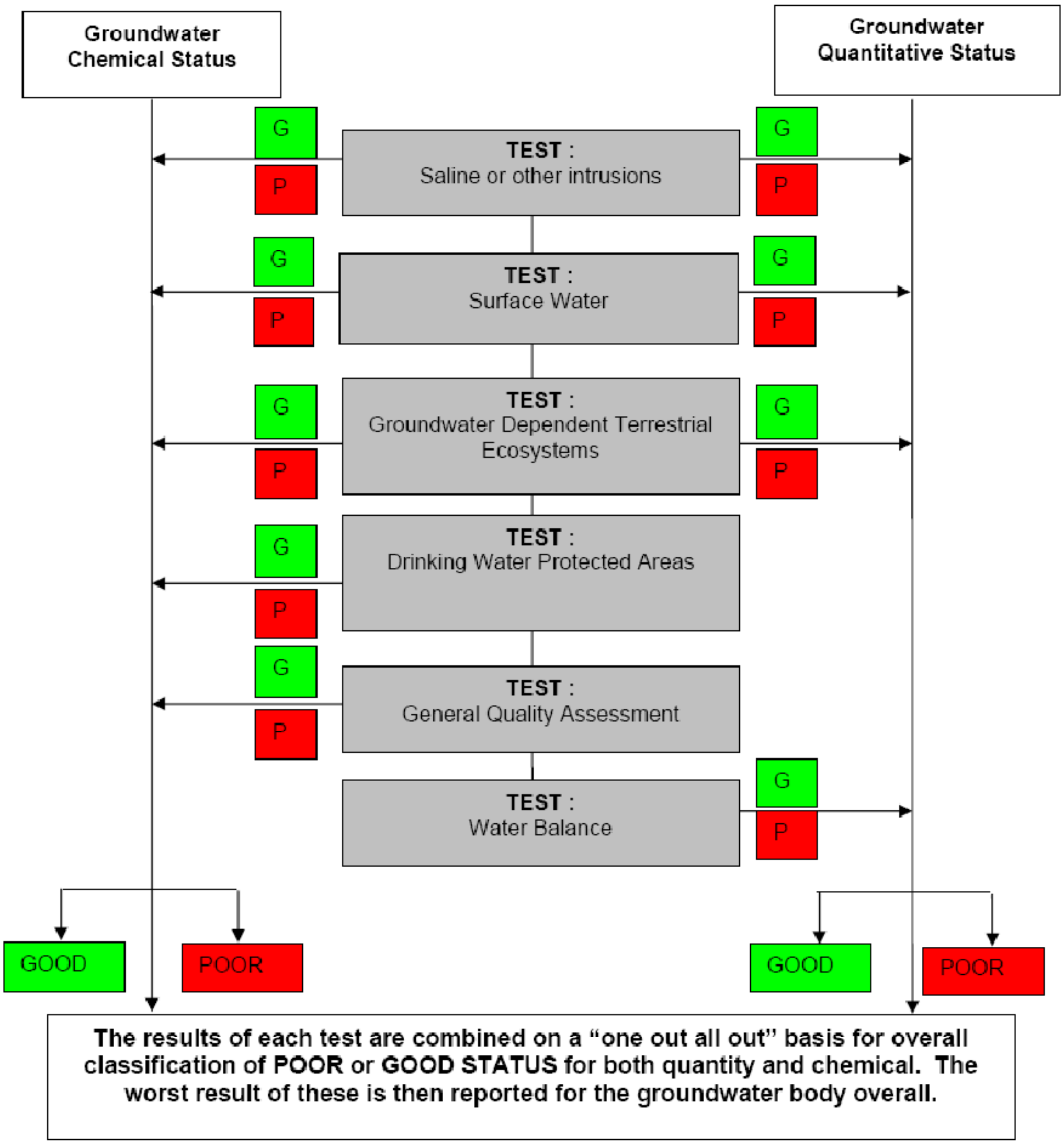

Figure 1 Overview of the status assessment (Classification) process (UKTAG, 2008a)

The results of chemical status, quantitative status, overall status and trend assessments are reported in the River Basin Management Plans for each River Basin Management District[1], and are available from the WFD Ireland "Water Matters" website (http://www.wfdireland.ie).

Regulation 58 places a duty on the Environmental Protection Agency to prepare and publish a detailed technical report containing:

a) *The methods and procedures used to assign groundwater quantitative status;*
b) *The methods and procedures used to assign groundwater chemical status;*
c) *All Threshold Values established for all bodies or groups of bodies of groundwater, together with a summary of the information regarding the relevant pollutants and their indicators;*

[1] See individual River Basin District websites for the reports, e.g. http://www.serbd.com for the South Eastern River Basin District.

d) The methods and procedures used to identify those bodies which are subject to a significant and sustained upward trend in concentration of any pollutant, or which are showing a reversal of that trend, and how trend assessment from individual monitoring points within a body or a group of bodies of groundwater has contributed to this identification;
e) The reasons for the starting points for pollution trend reversal;
f) Where undertaken by the Agency and other parties, the results of the additional monitoring and trend assessments for identified pollutants used to verify that plumes from contaminated sites do not expand, do not cause the chemical status of the body or group of bodies of groundwater to deteriorate and do not present a risk to human health and the environment.

The remainder of this report provides information on the establishment of TVs and how they are used in the chemical status assessments. The report then documents the methods and procedures used to assess the chemical and quantitative status of groundwater bodies. Finally, the document provides information on the methods and procedures used to assess pollution trends and trend reversal.

2 Threshold Values

Threshold Values are groundwater quality standards that are to be established by each Member State for the purpose of assessing the chemical status of groundwater bodies[2]. Threshold Values are also used when undertaking trend assessments. They can be set nationally or on a local groundwater body scale. They are triggers, such that their exceedance prompts further investigation to determine whether the conditions for Good Status have been met. As such, they do not represent the boundary between good and poor status.

Regulation 40 states that when assessing chemical status, the groundwater quality standards for nitrates and pesticides, prescribed in the Directive, shall be used. However, Schedule 4 of the Regulations indicates that more stringent TVs may be required for nitrates and pesticides to ensure the requirements of other Directives are met. In addition, TVs are required for other pollutants that have been identified as contributing to the characterisation of groundwater bodies being at risk of failing to achieve a WFD objective. Schedule 2 of the Regulations provides the minimum list of pollutants that need to be considered when setting TVs.

The groundwater quality standards prescribed for nitrate and pesticides are used in the assessment process in the same way. However, if all standards and TVs are met at all monitoring points in the National Groundwater Monitoring Network then, under Regulation 43(a), the groundwater body is considered to be at Good Status and no further investigation is necessary.

The TV for each status test must be appropriate to the receptor being considered for that test, e.g. an associated surface water body, a groundwater dependent terrestrial ecosystem (GWDTE) or groundwater that is used, or could be used for drinking water supply. The way in which monitoring data are compared to the TVs during classification (i.e. whether data are aggregated across the groundwater body or used in isolation) varies between the individual classification tests. This is essential to ensure a reliable assessment of status.

2.1 Rationale for Threshold Values

Threshold Values only have to be derived for pollutants placing a groundwater body at risk of failing to achieve a WFD objective. In total there are five chemical status tests, although in practice, the objectives of the Drinking Water Protected Areas and General Chemical tests are similar, in that they are both designed to assess the impact of pollutants on water that is used, or could potentially be used, for human consumption. The Surface Water Ecological/Chemical and GWDTE Chemical tests are also similar in nature, in that they are designed to assess the impact of pollutants on receptors associated with groundwater bodies.

2.2 Drinking Water Protected Areas and General Chemical tests

Drinking water standards are expressed as maximum admissible concentrations, i.e. peak concentrations. Therefore, to ensure consistency, the assessment of groundwater in relation to drinking water criteria, i.e. for the Drinking Water Protected Area and General Chemical status tests, should also be made against peak concentrations. As groundwater quality monitoring programmes are not continuous, it is likely that peak concentrations in pollutants will be missed. Consequently a statistical approach is required to take account of this. To ensure a consistent approach throughout classification, comparison of monitoring data against a standard or TV should be based upon a 95th percentile or equivalent approach (UKTAG, 2008a).

However, groundwater quality data are often not collected frequently enough to derive statistically robust 95th percentiles. If the 95th percentile cannot be used, a suitable TV is required, against which mean concentrations in the monitoring data can be compared with

[2] Whilst the standards and conditions that are applied to environmental permits should reflect the need to meet all WFD objectives, including good chemical status, these are not TVs.

adequate confidence (UKTAG, 2008a). The outcome should, as far as possible, be equivalent to using a 95th percentile.

Where there are sufficient reliable monitoring data for each individual site, then the 95th percentile value is calculated and used as the TV. Where data are insufficient to calculate 95th percentiles for individual sites, the TV must be set so that, if the mean of a dataset is not exceeded, there is a reasonable expectation that the 95th percentile would not exceed the maximum admissible concentration, if those 95th percentiles could be calculated.

On this basis, the UKTAG guidance (2008a) proposes that were insufficient data are available to determine the 95th percentile, the TV should be set at a value of 75% of the relevant drinking water standard. This percentage has been selected because it takes into account the large variability in hydrogeological settings, potential temporal variability in parameter values and because it introduces what is believed to be an adequate degree of protection such that the risk of misclassification is acceptable.

Insufficient data were available to calculate the 95th percentile for monitoring sites in the Irish National Groundwater Monitoring network during the 1st River Basin planning cycle. Therefore, 75% of the relevant drinking water standard has been used to calculate the TV. The 95th percentile will be calculated during the 2nd River Basin planning cycle, and TVs will be revised if the 95th percentile is significantly different to the current TVs.

As part of the Article 5 Risk Assessment (Working Group on Groundwater, 2005), anthropogenic pressures and historical groundwater quality data were used to determine which pollutants were causing groundwater bodies to be at risk of failing to meet the WFD objectives. However, with regard to drinking water, TVs could not be derived for parameters that did not have an existing drinking water standard. Additionally, in Ireland very little data were available to determine if "point source" pollutants were impacting on drinking water sources, as very few of these pollutants require assessment under the Drinking Water Regulations (S.I. 278 of 2007).

In general, the main pollutants (or indicators of pollution) that are putting groundwater bodies at risk of failing WFD objectives with regard to drinking water requirements are derived from the following pressures:

Agricultural Pressures: Nitrate, Electrical Conductivity, Nitrite, Ammonium, Chloride and Pesticides;

Point Source Pressures (e.g. Landfill, Contaminated Land, Urban Pressures, Discharge to Groundwater): Nitrate, Electrical Conductivity, Nitrite, Ammonium, Chloride, Sulphate, Sodium, Boron, Cyanide, Chromium, Arsenic, Lead, Nickel, Mercury, Cadmium, Copper, Aluminium and selected Organics;

Mining: Electrical Conductivity, Chloride, Sulphate, Chromium, Arsenic, Lead, Nickel, Mercury, Cadmium, Copper and Aluminium.

The TVs for metals in the Groundwater Regulations are taken to be dissolved metals, whilst the Drinking Water Standards for metals are taken to be total metals. Although the TVs are derived from the Drinking Water Standards for metals, it should be recognised that the standards relate to different assessments.

TVs have been derived for dissolved metals and not total metals because, from an environmental perspective, the dissolved fraction is a better representation of the biologically active portion of the metal when considering water going to rivers and springs. Most groundwater supplies are unfiltered because there is little sediment and in most instances the results of total and dissolved analysis in groundwater should be similar, if not the same.

Therefore, while the TVs are based on Drinking Water Standards, from an environmental perspective the dissolved fraction is more representative than what is measured at the tap (which includes metals bound to sediment in the water supply network). The dissolved metal

concentration should be similar to the total concentration in groundwater before it reaches the water supply network, and as such, it is a comparison of the dissolved metal concentration that should be made with the TV.

2.3 Surface Water Ecological/Chemical and GWDTE Chemical tests

In surface waters and wetlands, TVs are only required for those pollutants that are considered to be contributing to water quality problems in those surface waters or wetlands, and where a surface water Environmental Quality Standard (EQS) or wetland trigger action value has been established. As the associated receptor must be at less than Good Status, or have suffered ecological damage, the TV should relate to the water quality standard or trigger action value that has caused the problem in the associated receptor.

The groundwater contribution to surface water bodies and wetlands varies because of differences in rainfall distribution, soil and subsoil type, aquifer type, hydraulic connectivity with the receptor etc. To ensure consistency in the status assessments, the TV needs to be derived from the surface water EQS or wetland trigger action value. Thereafter, if the TV is exceeded at a monitoring point in the groundwater body, further investigation will consider the site-specific dilution and attenuation factors and the groundwater contribution to the associated receptor.

Surface Water EQSs have been established for rivers, lakes and transitional and coastal water bodies (see S.I. 272 of 2009 for more information). Molybdate Reactive Phosphorus and Ammonium EQSs are two of the key pollution indicators that have been established for river water bodies. Molybdate Reactive Phosphorus is regarded as the key limiting nutrient that causes eutrophication in rivers. Some of the other surface water EQSs that have been established, such as Temperature, are not applicable for status assessments in groundwater.

Additional TVs may be required in the future, e.g. for Nitrate (in relation to transitional and coastal waters), Total Phosphorus (in relation to lakes), some metals (in relation to the impact of mines on surface water) and parameters relating to the impact of point sources on surface water bodies (e.g. metals, organics etc.).

2.4 Saline (or Other) Intrusions test

Schedule 6 (Part B) of the Groundwater Regulations indicates that, as a minimum, Electrical Conductivity TVs should be established where groundwater abstractions could potentially be causing saline intrusion. Other potential indicators or saline (or other) intrusions could be Chloride or Sulphate. The latter parameter is more indicative of deeper connate water intrusions, rather than coastal intrusions. As these parameters occur naturally in groundwater, the TV should be set at the Natural Background Level for these parameters, i.e. when concentrations are above the typical natural concentration, this will trigger further investigation. The Natural Background Levels for these parameters have been established in Ireland (OCM, 2007).

Threshold Values were established for Chloride and Electrical Conductivity, as these parameters are both indicative of saline intrusion. A TV was not established for Sulphate because this parameter is not causing groundwater bodies to be at risk of failing to meet a WFD objective and monitoring data does not suggest that any abstractions are causing ingress of deeper connate water.

2.5 Application of Threshold Values

Exceedance of a TV triggers further investigation, i.e. an assessment of whether the pollution is of sufficient magnitude to prevent the groundwater body achieving its status objectives under the WFD and is therefore not just causing a localised impact. This further investigation is undertaken as part of the status assessments, for example, to determine the pollutant loading from groundwater to surface water ecosystems.
It is only if the concentration of pollutants exceeds the TV and any supporting evidence confirms the presence of an impact that compromises the achievement of WFD status objectives, that the groundwater body is classified as Poor Status.

2.6 Reporting of Threshold Values

Threshold Values are listed in Schedule 5 of the Groundwater Regulations. If the Environmental Protection Agency wishes to amend the list of TVs, it may do so by making recommendations to the Minister of the Environment.

3 Chemical Status classification

An assessment of groundwater body status is required to comply with the Water Framework Directive (2000/60/EC) and the Groundwater Directive (2006/118/EC). In 2005, the WFD Article 5 Risk Assessments (Working Group on Groundwater, 2005) were undertaken to identify groundwater bodies that were at risk of failing to meet objectives of the Water Framework Directive (WFD). Status assessments are required for all such groundwater bodies that were identified as being at risk.

Status assessments are undertaken at the end of every six year river basin management planning cycle and are used to generate a snap shot that shows the impacts of abstraction and pollution on groundwater. The risk assessments are carried out at the beginning of the six year cycles. Whilst similar in nature, the goals of status assessments and ongoing risk assessments are different in that the risk assessments help determine the requirements for future monitoring and investigation, and help identify areas where future developments could impinge on the groundwater status objectives of the WFD. Essentially, the risk assessments are assessments of whether objectives of the WFD may not be achieved in the future, whilst status assessments consider compliance with the WFD objectives in the past.

Additionally, status assessments consider widespread impact across a groundwater body. Therefore, a groundwater body can be at Good Status, but there can still be an environmental risk, e.g. where the local impacts on groundwater quality are not substantial enough to impact on the status of the whole groundwater body. However, where a groundwater body has been classified as being at Poor Status, this implies that there is also a risk of failing WFD objectives in the future.

Chemical classification of groundwater bodies is split into five tests (Figure 2). The tests are designed to assess whether the objectives of the WFD are being met. The worst case is reported for a groundwater body, so “failure” of one or more of the tests causes a groundwater body to be at Poor Status.

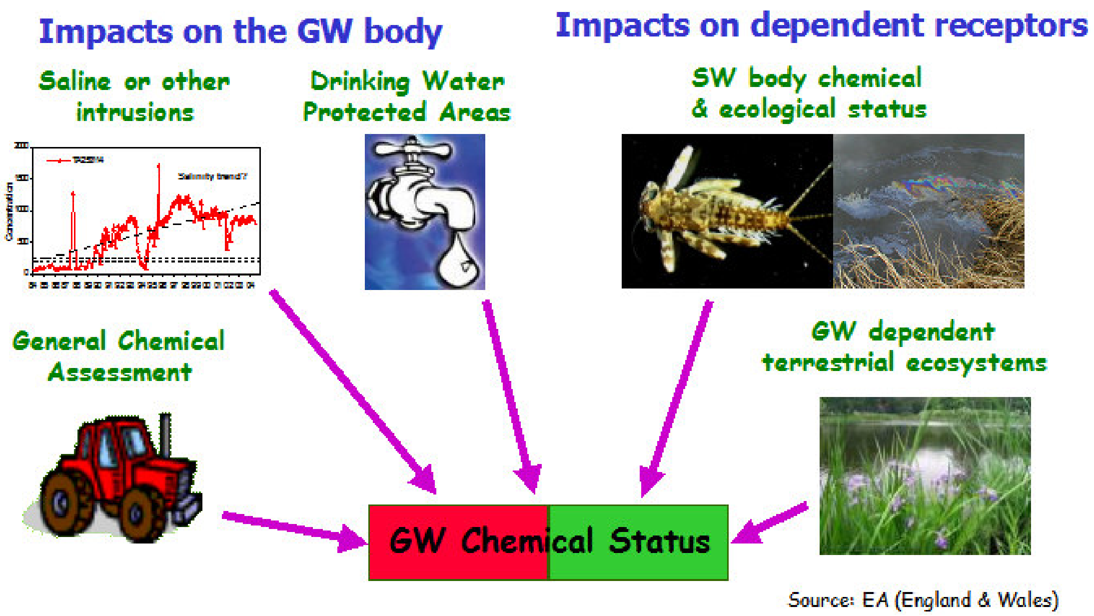

Figure 2 Chemical Status Assessment Tests

Due to the lack of information on trigger action values for GWDTEs, the GWDTE ecological/chemical assessment could not be undertaken. This assessment will be undertaken in the 2nd River Basin planning cycle.

3.1 Test 1: Saline or Other Intrusions Test

Key concept:
Status, and the presence of an intrusion of poor quality water into the groundwater body, is determined through an assessment of trends in Electrical Conductivity or other indicator substances. The test is designed to detect the presence of an intrusion that is induced by the abstraction of groundwater.

Threshold Values:
Set at the upper limit of the natural background range for key determinands. Threshold Values are only used in combination with trend assessment(s).

The conditions for good quantitative status are not met when:
Threshold Values are exceeded and there is either a significant and sustained rising trend in one or more key determinands at relevant monitoring points or there is an existing significant impact on a point of abstraction as a consequence of an intrusion.
(UKTAG, 2008a)

3.1.1 Introduction

The Saline (or Other) Intrusions Test is intended to identify groundwater bodies where there is intrusion of poor quality water as a result of groundwater abstraction and this intrusion is leading to sustained upward trends in pollutant concentrations or a significant impact on one or more groundwater abstractions (UKTAG, 2008a).

Note: the saline intrusion test mirrors the test undertaken for the Quantitative Status assessment.

3.1.2 Background

This test is undertaken to identify where groundwater quality is deteriorating, or there have already been impacts on the quality of abstracted water, as a result of the intrusion of poor quality water into the groundwater body. The EU guidance (EC, 2009) and UKTAG guidance (UKTAG, 2008a) indicates that the intrusion must be caused by groundwater abstraction and must be sustained, i.e. temporary intrusions should not be considered. Therefore, the test focuses on groundwater bodies where there is a risk that abstraction pressures may cause significant and sustained intrusions.

Groundwater intrusion can occur when the saline-freshwater interface in coastal regions is drawn inland and upwards by abstraction. Groundwater abstraction can also lead to upward movement (up coning) of poor quality deeper water, the leakage of saline surface waters to an underlying groundwater body, or drawing in of poorer quality groundwater from an adjacent aquifer. The EU and UKTAG guidance indicates that parameters in groundwater that are indicative of intrusion should be assessed, e.g. Electrical Conductivity and Chloride.

Where Electrical Conductivity and Chloride concentrations are above Natural Background Levels and there is either a significant upward trend[3] in concentration of that parameter, or there is already an impact on a point of abstraction (e.g. where a water supply has been decommissioned due to saline intrusion), then the groundwater body will be at Poor Status. Otherwise it will be at Good Status.

The WFD indicates that confidence in the status assessment needs to be reported. As per UKTAG guidance (UKTAG 2008a), a weight of evidence approach has been adopted when assigning confidence, with High Confidence (HC) or Low Confidence (LC) assigned to status assessments. For example, confidence is high where there is evidence of significant and

[3] Further information on trend assessments is provided in Section 5 of this report.

sustained upward trends and there is evidence of impact at a water supply. Confidence is low when the evidence is less comprehensive, e.g. no impact on water supplies or when monitoring is limited. Confidence does not indicate how close the groundwater body status is to the status boundary.

The linkages between Risk, Status and Confidence are summarised in Table 1.

Table 1 Risk Assessment and Status for the Saline Intrusion Test

Risk assessment					**Status & Confidence**
Abstraction in GWB	Abstraction <20km from the coast	Concentration at Monitoring Point >TV	Elevated Concentration Caused by Abstraction	Upward Trend in Concentration	
No	-	-	-	-	Good-HC
Yes	No	-	-	-	Good-HC
Yes	Yes	No	-	-	Good-HC
Yes	Yes	Yes	No	-	Good-LC
Yes	Yes	Yes	Yes	No	Good-LC
Yes	Yes	Yes	Yes	Yes	Poor-LC
Yes	Yes	Yes	Yes	Yes	Poor-HC*

* Evidence of impacts of saline intrusion on nearby receptors

3.1.3 Information Required for This Test

The Saline (or Other) Intrusions Test assesses the presence of an intrusion of poor quality water into the groundwater body as a result of groundwater abstraction and is determined through the identification of upward trends in Electrical Conductivity and Chloride.

The following information was gathered for this test.

Threshold Values[4]

Threshold Values were only derived for pollutants that are indicative of saline (or other) intrusions.

- Electrical Conductivity = 800 µS/cm
- Chloride = 24 mg/l.

Groundwater Quality Data

For each site, six years of Electrical Conductivity and Chloride monitoring data (2003-2008), from the EPA's National Groundwater Monitoring network, were assessed to identify and calculate the maximum and average parameter concentrations respectively. Ten years of monitoring data (1999–2008), were used to assess trends in the parameter concentration.

Monitoring Points Assessed

Groundwater bodies identified in the Article 5 Risk Assessment (Working Group on Groundwater, 2005) as being At Risk from saline intrusion: Monitoring locations were assessed in groundwater bodies that were at risk of failing to meet WFD objectives in relation to Saline Intrusion, as reported in the Article 5 Risk Assessment.

Coastal location: All monitoring locations, within 20 km of the coast or coastal inlets, were assessed if the average Electrical Conductivity and Chloride concentrations exceeded the TV, or where the averages were lower than the TV, but the maximum Electrical Conductivity and Chloride concentrations were significantly higher than the TV.

Groundwater bodies with abstraction pressures: Monitoring locations were assessed in groundwater bodies that were at risk of failing to meet WFD objectives because of unsustainable abstractions.

[4] TVs determined as the upper limit of the Natural Background Level (NBL) from OCM, 2007.

3.1.4 Methodology

The steps undertaken as part of the Saline (or Other) Intrusion Test are outlined below:

Trend assessments were undertaken using the MAKESENS Mann-Kendall/Sen's non-linear trend analysis model (Salmi *et al*, 2002). The model was used to identify statistically significant upward trends in Electrical Conductivity and Chloride at monitoring points. Section 5 of this report contains more detail on the trend analysis that was undertaken.

The annual average concentrations for Electrical Conductivity and Chloride were calculated at monitoring points, over a period of ten years (1999–2008), if the maximum Electrical conductivity and Chloride concentrations exceeded the TV during that period. Annual averages have been calculated because the annual monitoring frequency has varied historically and prior to 2007 the monitoring frequency was insufficient to distinguish seasonal variations in parameter concentrations.

The trend assessment was not undertaken when a monitoring point had less than six years data during the ten-year period because MAKESENS requires at least six years data to determine significant trends.

Where trends could be determined at individual monitoring points, the statistical significance of the trend was determined using MAKESENS. Trends were identified as being non-existent, upward or downward and the statistical significance of the trend was reported as being 90%, 95%, 99% or 99.9% significant, or the trend was not statistically significant.

When assessing the impact of saline intrusion on groundwater, the presence of a statistically significant upward trend in both Chloride and Electrical Conductivity at any individual monitoring point resulted in the groundwater body being classified at Poor Status. Monitoring locations with significant upward trends in Chloride, but not in Conductivity, or vice versa, remained at Good Status, but are at risk of failing WFD objectives in the future. These monitoring points will be investigated further in the 2nd River Basin Planning cycle.

Information on the reasons for water supplies being decommissioned was unavailable. Often water supplies are decommissioned when new water infrastructure projects are being undertaken and it was not clear if water quality problems are a contributory factor to supplies being decommissioned.

The overall assessment approach is summarised in Table 2.

Table 2 Summary of criteria to determine status and confidence

Status	Confidence	Example Criteria
Good	High	No exceedance of the TV levels, OR Exceedance of TV levels not caused by abstraction
	Low	Exceedance of TV levels but further investigation has determined there are no sustained rising trends OR Possible risk identified but no monitoring available
Poor	Low	Exceedance of TV levels caused by abstraction with sustained rising trends OR Exceedance of TV levels caused by abstraction AND impacted abstraction
	High	Exceedance of TV levels with sustained rising trends caused by abstraction AND The Intrusions have caused a significant impact on abstraction(s)

3.1.5 Future Developments

The National Groundwater Quality Monitoring network has undergone significant development since 2007, with many new sites added to the network. Summary statistics for groundwater

quality are therefore based, in many cases, on limited data. There are currently insufficient data at many monitoring sites to carry out robust trend assessments. Longer records of monitoring data will enable more reliable trend assessments to be carried out at all monitoring sites in the National Groundwater Quality Monitoring network in the 2nd River Basin Planning cycle.

3.2 Test 2: Impact of Groundwater on Surface Water Ecological/Chemical Status Test

Key concept:
Status is determined through a combination of surface water classification results and an assessment of chemical inputs from groundwater bodies into surface water bodies. The surface water bodies can comprise rivers, standing waters and transitional waters. The test is designed to determine whether the contribution from groundwater quality to surface water quality, or any consequent impact on surface water ecology, is sufficient to threaten the WFD objectives for these associated water bodies.

Threshold Values:
Surface water quality standards adjusted by dilution and, where appropriate, attenuation factors.

The conditions for good chemical status are not met when:
An associated surface water body does not meet its objectives, TVs are exceeded and groundwater contributes at least 50% of the relevant surface water standard.
(UKTAG, 2008a)

3.2.1 Introduction

The Impact of Groundwater on Surface Water Ecology and Chemistry Test is undertaken in those groundwater bodies that are contributing to a surface water body that is not meeting its good ecological or chemical status objectives because of diffuse pollution pressures (UKTAG, 2008a).

3.2.2 Background

Most rivers and standing waters (lakes) derive their water from both surface water runoff and groundwater discharge. The contribution from each component varies during the year and with aquifer type underlying the surface water body. In some cases a large proportion (50–100%) of the surface water can be made up of groundwater discharge and so the quality and quantity of groundwater discharging to surface water will have a big influence on surface water quality.

This test is undertaken to identify surface water bodies that receive a significant proportion of flow from groundwater, and where pollutant concentrations in groundwater are elevated and may contribute significantly to those associated surface water bodies not meeting their environmental objectives, i.e. Good Status or better. There are a number of elements that are assessed in determining overall surface water ecological status, but the key element for this test is chemistry. For surface water bodies to be at Good Status or better there must be no significant impact on the ecology or failures of the EQSs that have been established for surface water.

Where pollutant concentrations in groundwater are elevated above Natural Background Levels and this polluted groundwater is contributing significantly to a corresponding surface water body failure; then the groundwater body will be at Poor Status. When making this assessment, consideration is given to the dilution effects in the surface water by estimating the contribution of groundwater to the overall flow or volume in the surface water. Consideration is also given to the attenuation (degradation) potential within the groundwater system, where this is known.

3.2.3 Information Required for This Test

The Impact of Groundwater on Surface Water Ecology and Chemistry Test assesses the potential adverse impacts of groundwater pollutants to associated surface water bodies (rivers, lakes and transitional and coastal waters) that are at less than Good Status.

The following information was gathered for this test.

Threshold Values
This test was undertaken for parameters identified as causing a surface water body to be at less than Good Status. The TVs were based on the parameter EQS for the associated surface water receptor.

- Molybdate Reactive Phosphorus (as P) = 35 µg/l (based on River EQS)
- Ammonium (as N) = 65 µg/l (based on River EQS)

Groundwater Quality Data
For each site, six years of monitoring data (2003-2008), from the EPA's National Groundwater Monitoring network, were assessed to calculate the average parameter concentrations.

Groundwater Bodies Assessed
The assessment was undertaken for groundwater bodies associated with surface water bodies designated as being at less than Good Status due to diffuse pressures. The assessment was not undertaken where point source discharges were the cause of the less than Good Status designation. Additionally, the assessment was not undertaken where an overriding element (e.g. alien species or absence of a protected area species, such as the *Margaritifera* pearl mussel) had caused the less than Good Status designation.

Monitoring Points Assessed
Groundwater bodies identified in the Article 5 Risk Assessment (Working Group on Groundwater, 2005) as being At Risk of having an adverse impact on associated surface water bodies: Monitoring locations were assessed if they were located in groundwater bodies or groups of groundwater bodies that were At Risk of failing WFD objectives in relation to groundwater impacts on surface water ecology/chemistry in the Article 5 Risk Assessment.

Surface water bodies at less than Good Status: Monitoring locations were assessed if they were located in groundwater bodies or groups of groundwater bodies associated with surface water bodies designated as being at less than Good Status due to diffuse pressures.

3.2.4 Methodology

The steps taken to assess the impact of groundwater on the ecological and chemical status of surface water bodies are detailed below.

(i) A conceptual understanding of the groundwater contribution to surface water bodies was developed for each groundwater body.

- On behalf of the Shannon RBD, RPS Group used the MIKE NAM model (DHI, 2004) to develop a conceptual representation of the hydrogeological cycle for typical settings in Ireland (RPS, 2009).
- In simple terms, the model separates rainfall into three different stores: overland flow, intermediate flow and deep groundwater flow. RPS (2009) have defined the components of the three stores as follows:
  Overland flow: Surface runoff, including flows in subsurface land drains;
  Intermediate flow: Interflow through soils and subsoils <u>and</u> shallow (top of bedrock) groundwater;
  Deep groundwater flow: Groundwater flow beneath the water table that interacts with the surface water system.
- Modelling was undertaken on surface water catchments nationwide and flow apportioned to the three components for a total of 124 catchments (RPS, 2009).

- The WFD defines groundwater as "all water which is below the surface of the ground in the saturation zone and in direct contact with the ground or subsoil". In undertaking this test, the groundwater input consists of both the "deep" groundwater flow and the shallow "top of the rock" groundwater flow.
  - The intermediate flow component was separated using hydrogeological information on the aquifer, subsoil and soil types within each modelled catchment.
  - The calculated "shallow groundwater flow" component was added to the "deep groundwater flow" component to give a "total groundwater" component in line with the WFD definition.
- Modelling in the karst dominated groundwater bodies was not straightforward because of difficulties apportioning/splitting the intermediate flow component, as groundwater can often behave in a similar manner to surface water in karst aquifers and can be difficult to distinguish in a river hydrograph.
  - Therefore, a water balance approach was devised to calculate the groundwater contribution from the karst dominated aquifer types (Rk and Lk aquifers[5]).
  - Five karst dominated catchments were selected for a water balance assessment.
  - It was assumed that the total volume of water entering the catchment was equal to that leaving the catchment. Therefore, the karst component is the total volume of water, less the surface water component and the groundwater component from any other aquifers types in the catchment (which had already been calculated using the model). The remaining volume of water was assumed to be the Rk and Lk karst groundwater component.
- The annual average groundwater contribution to surface water bodies was calculated for each aquifer type across all the 124 modelled catchments. The results are shown in Table 3.
- An overall water balance was calculated for each aquifer type in each groundwater body. This was calculated by dividing the total groundwater component for each aquifer type by the total volume of water entering the catchment, i.e. rainfall less evapotranspiration. The groundwater components from each aquifer type were summed and divided by the total volume of water entering the catchment to give an overall groundwater contribution to surface water bodies for each groundwater body.

Table 3 Estimated groundwater contributions to surface water for different aquifer types

Aquifer type	Annual Average Groundwater contribution (%)
Pl/Pu	21
Ll	27
Rf/Lm	65
Rk/Lk	74
Rg/Lg	90

(ii) Surface water bodies at less than Good Status due to diffuse pressures were identified from the Surface Water Classification results. A Geographical Information System (GIS) shapefile of the groundwater bodies was overlaid with the shapefile of surface water bodies at less than Good Status and groundwater bodies potentially contributing to these surface water bodies were identified.

(iii) The average concentration of Molybdate Reactive Phosphorus (MRP) was calculated using six years of data for monitoring points within groundwater bodies (and associated grouped groundwater bodies) potentially contributing to surface water bodies at less than Good Status.

[5] Information on the aquifer categories in Ireland can be obtained from the GSI website (http://www.gsi.ie/Programmes/Groundwater/)

Whilst locally elevated concentrations of ammonium in groundwater could impact on the ecology and chemistry of a river, ammonium concentrations at groundwater monitoring locations were generally low and were not considered to have a regional impact on surface water. Therefore, the test was not undertaken any further for ammonium.

Note: the WFD allows grouping of groundwater bodies, and use of data from monitoring points within grouped groundwater bodies, where the hydrogeological settings and pressures are similar (EC, 2007).

(iv) The test requires an assessment of groundwater inputs (loading) to determine if groundwater contributes greater than 50% of the loading to the surface water body that would result in a breach of the surface water EQS, i.e. 35 µg/l for MRP in rivers. Therefore the surface water loading relating to the MRP EQS was calculated using the total volume of water entering the catchment x 35 µg/l.

(v) The groundwater loading of MRP to rivers was calculated using the total volume of groundwater entering the river system (total volume of water entering the catchment x average groundwater contribution across the groundwater body x average MRP concentration across the groundwater body).

(vi) Groundwater bodies that contributed greater than 50% of the loading that would result in a breach of the surface water body EQS were at Poor Status. Groundwater bodies that contributed less than 50% of the loading were at Good Status.

Confidence was high where there was extensive monitoring in the groundwater body and/or good supporting evidence of the groundwater contribution. Where monitoring and/or the evidence were more limited, confidence was low.

The overall assessment approach is summarised in Table 4.

Table 4 Summary of criteria to determine status and confidence

Status	Confidence	Example Criteria
Good	High	No surface water body at less than Good Status OR Surface water body at less than Good Status, but groundwater concentrations < 50% of EQS and therefore Groundwater unable to contribute > 50% of the load to surface water.
	Low	Surface water body at less than Good Status, but further investigation indicates groundwater loading < 50% of loading required to breach EQS OR Elevated pollution concentrations in groundwater unlikely to impact on the associated surface water body, e.g. where MRP is likely to be bound or attenuated by the overlying subsoil
Poor	Low	Surface water body at less than Good Status, and further investigation indicates groundwater loading > 50% of loading required to breach EQS
	High	Surface water body at less than Good Status, and further investigation indicates groundwater loading > 50% of loading required to breach EQS AND Detailed site specific studies (e.g. groundwater tracing) identify and quantify direct connection between groundwater and surface water.

3.2.5 Methodology Issues and Future Developments

The monitoring network has undergone significant development over the last six years with many new sites added to the network. Summary statistics for groundwater quality are therefore based, in many cases, on limited data. Longer records of monitoring data will enable more reliable trend assessments to be carried out at all monitoring sites in the National Groundwater Quality Monitoring network in the 2nd River Basin Planning cycle.

There is considerable uncertainty about the interactions between groundwater and surface water and the input from groundwater to surface water, so the assessment is based on logical, but relatively simple assumptions.

Assessments of the contribution of groundwater to lakes that are at less than Good Status will be undertaken when more data are gathered in the 2nd River Basin Planning cycle. The groundwater contribution to transitional and coastal waters will also be undertaken in the 2nd River Basin Planning cycle. The study of groundwater/surface water interactions for transitional and coastal waters are likely to be highly complex, involving the study of the interactions between groundwater, rivers and estuaries, and will require the establishment of relevant surface water EQSs, which can then allow the derivation of groundwater TVs.

Whilst the whole groundwater body is assessed in this test, it is likely that measures and pollution controls will focus on the areas surrounding the surface water body or areas of extreme groundwater vulnerability, where pollutants such as MRP can readily get into groundwater as they bypass the soil and subsoil where attenuation can occur.

Ongoing research is required in this area to improve our understanding of groundwater/surface water interactions.

3.3 Test 3: Groundwater Dependent Terrestrial Ecosystems – Chemical Assessment Test

Key concept:
Status is determined through a combination of GWDTE assessments to determine ecological damage and an assessment of chemical inputs from groundwater bodies into GWDTEs. The test is designed to determine whether the contribution from groundwater quality to GWDTEs and consequent impact on GWDTE ecology is sufficient to threaten the WFD objectives for these associated GWDTEs.

Threshold Values:
Wetland quality standards or action values adjusted by dilution and, where appropriate, attenuation factors.

The conditions for good chemical status are not met when:
The ecology of an associated GWDTE is damaged due to the chemical contribution from the groundwater body, TVs are exceeded and groundwater loading is sufficient to cause a breach of the relevant GWDTE quality standard.

3.3.1 Introduction

This section describes the method used to assess the chemical status of groundwater bodies with respect to significant damage to GWDTEs, i.e. wetlands. The test is only applied to wetlands/GWDTEs that have been formally identified as protected areas under Regulation 8 of S.I. 722 of 2003.

3.3.2 Background

GWDTEs are defined here as wetlands where habitats and species are dependent on groundwater to maintain the environmental supporting conditions that are required to sustain the habitat and/or species.

This test considers the concentrations of nutrients (primarily phosphates, nitrates and ammonium) in groundwater bodies and the potential for these to affect groundwater dependent wetlands, such that the groundwater chemistry causes significant damage to the wetland ecology.

Where significant damage as a result of chemical pressures is confirmed, the groundwater body is at Poor Status.

To assess the impact there is a need to determine whether, and if so how, chemical pressures in the groundwater body affect the quality of the water supporting the wetland and also whether the change in water quality (if any) affects the groundwater dependent ecological features (flora and fauna).

The National Parks and Wildlife Service (NPWS) produced a list of Sites of Special Scientific Interest (SSSIs) which they consider to be GWDTEs for the Article 5 Risk Assessment in 2005.

The Article 5 Risk Assessment (Working Group on Groundwater, 2005) identified GWDTEs where the ecology was potentially damaged and therefore may have been impacted by groundwater abstraction or pollution. However, generally the cause of the damage was unclear, and may have been caused by quantitative or chemical contributions from groundwater, or both.

A small number of wetland studies have been undertaken since the Article 5 Risk Assessment, but these have been site specific. More generic attempts to classify the requirements of GWTDEs, in terms of groundwater chemistry (mainly nutrients) and the quantity of groundwater (both flow and levels) have been unsuccessful, and clearly highlight the complexity of wetlands as they may be extremely sensitive to any fluctuations to the habitat's supporting conditions.

A number of projects were established to help determine the chemical (and quantitative) requirements of the wetlands, e.g. for Turloughs. The findings of these projects will be used to derive action values for generic wetland types, which in turn will enable the determination of TVs for groundwater bodies. Until these projects are complete, it will not be possible to undertake chemical status assessments of the groundwater bodies that are associated with GWDTEs.

Initial work from the GWDTE projects has resulted in improved GWDTE boundaries (within the SSSIs) and has enabled NPWS to update the GWDTE list and improve upon the initial Article 5 Risk Assessment.

3.3.3 Methodology for Future Assessments

Future assessments of GWDTEs will require confirmation that the ecology of the wetland is damaged (or at risk of being damaged) and that this damage is being caused by change in the regional groundwater contributions to the wetland. This groundwater contribution to the wetlands could be quantitative (flow or levels) or chemical (pollutants), or both.

Where pollutants are contributing to the ecological damage in the wetland, chemical standards (or action values) will need to be established for the wetland, and in turn TVs will be established for the groundwater body. The development of TVs will take account of natural background concentrations for a particular pollutant.

If pollutants exceed these TVs at monitoring points in the National Groundwater Monitoring network that are located in the associated groundwater body, then further investigation will be undertaken to determine if groundwater is contributing to ecological damage in the associated GWDTE.

Once TVs have been established for a GWDTE, the groundwater loading to the wetland will be calculated in a similar manner to the surface water ecological/chemical status test.

Groundwater inputs (loading) to the GWDTE will be calculated for the parameters of concern. If the loading from groundwater exceeds the environmental supporting condition of the GWDTE, then the groundwater body will be at Poor Status.

The overall assessment approach is summarised in Table 5.

3.3.4 Future Developments

There is considerable uncertainty with this test and there are a number of research projects that aim to address these issues. Currently there is little monitoring of water quality on GWDTE sites and therefore there are few measurable data on the nutrient environmental supporting conditions requirements of the wetland flora and fauna or of the effects of elevated nutrients on the flora and fauna.

Table 5 Summary of criteria to determine status and confidence

Status	Confidence	Example Criteria
Good	High	No ecological damage to GWDTE OR Ecology of GWDTE damaged, but groundwater concentrations < wetland trigger action value/concentration
	Low	Ecology of GWDTE damaged, but further investigation indicates groundwater loading < loading required to breach wetland trigger action value/concentration
Poor	Low	Ecology of GWDTE damaged, and further investigation indicates groundwater loading > loading required to breach wetland trigger action value/concentration
	High	Ecology of GWDTE damaged, and further investigation indicates groundwater loading > loading required to breach wetland trigger action value/concentration AND Detailed site-specific studies identify and quantify direct connection between groundwater and GWDTE.

There is also a need to research the level of attenuation of nutrients between the groundwater body and discharge on site, and information is required on the hydraulic linkages between groundwater and the wetland.

In future there is a need to extend the scientific knowledge of groundwater dependency of the wetland ecology. Critically, information is required on the chemical, flow and water level requirements of the ecology.

This test will be undertaken in the 2nd River Basin Planning cycle.

3.4 Test 4: Drinking Water Protected Area Test

Key concept:
Good chemical status requires an assessment, at the point of abstraction for water intended for human consumption, of whether there is deterioration in groundwater quality due to anthropogenic influences that could lead to an increase in purification treatment. **Note:** the stated aim of the Drinking Water Protected Area (DWPA) objective in the WFD is to provide the necessary protection to avoid deterioration in water quality in order to reduce the need for purification treatment. This has been interpreted as a minimum requirement to prevent deterioration in groundwater quality at the point of abstraction for drinking water supply.

Threshold Values:
An appropriate percentage of Drinking Water Standards or any other requirement to ensure that drinking water is free from contamination that could constitute a danger to human health (in accordance with the Drinking Water Directive).

The conditions for good chemical status are not met when:
There is a significant and sustained rising trend in one or more key determinands at the point of abstraction and TVs are exceeded.
(UKTAG, 2008a)

3.4.1 Introduction

This section describes the steps that were taken in classifying the chemical status of groundwater bodies for the "Drinking Water Protected Area Test". The test identifies groundwater bodies which are currently failing to meet the DWPA objectives defined in Article 7 of the Water Framework Directive and those that are risk of doing so in the future. In Ireland, all groundwater bodies are DWPAs and so this test applies to all groundwater bodies.

3.4.2 Background

The DWPA objectives of the WFD require that groundwater is protected to avoid deterioration in water quality that would lead to an increased level of treatment at points of abstraction. DWPAs are groundwater bodies that are used for the abstraction of more than 50 m^3/day of water intended for human consumption, or for supplying more than 50 people. Because of these low thresholds, all groundwater bodies have been designated as DWPAs in Ireland.

This test is undertaken to identify where there is likely to be a need for water purification treatment in the future, or an increase in the level of existing treatment, as a result of deteriorating water quality that has been caused by pollution. The test requires an assessment of the concentrations of pollutants in groundwater and how they are changing over time at a representative selection of drinking water abstractions. Trend assessments were used to identify current exceedances of drinking water standards and to project pollutant concentrations into the future, in order to identify exceedances of drinking water standards that were likely to occur in the next two River Basin Management cycles (i.e. by 2021). It is at these sources (and associated groundwater bodies) that there may be a need for increased treatment of raw water in the future.

Groundwater bodies were at Poor Status where there was evidence that there was an existing exceedance of a TV and where there was a significant upward trend in the concentrations of the relevant pollutant(s). Where there was evidence that concentrations were less than the TV, but there were significant and sustained upward trends in the concentrations of the relevant pollutant(s) and the concentrations were projected to exceed the TV by 2021, the groundwater body was at Good Status, but was at risk of failing to meet its WFD objectives in future.

The relatively low frequency of sampling at monitoring sites means that exceedances of drinking water standards may not be easily detected in the national monitoring programme. Therefore, the only reliable statistic that can be used effectively for assessment is the mean concentration. However, because the drinking water standards relate to maximum admissible concentrations, the TVs have to be set at a lower value than the drinking water standard, to allow comparison of mean concentrations. The use of this TV is equivalent to comparing the maximum concentration with the drinking water standard (see Section 2 on Threshold Values for more information).

Where there was evidence of exceedances and significant upward trends at a monitoring point and local authority data showed similar concentrations, confidence in the assessment was high. Where limited or no local authority data existed, or there was conflict between the datasets, then confidence was low. Confidence does not indicate how close the groundwater body status is to the Good/Poor status boundary.

3.4.3 Information Required for This Test

The Drinking Water Protected Area Test assesses trends in the concentration of pollutants at representative drinking water sources. This test is only undertaken for pollutants that have a prescribed standard relating to the human use of water, i.e. drinking water standard.

Most water supplies already have chlorination in place, so this forgoes the need for microbiological assessment, although viruses and protozoa such as cryptosporidium, are more difficult to assess. If additional treatment is required to reduce the impacts of pollution (including increased chlorination), then the monitoring point, and therefore the associated groundwater body, default to Poor Status.

The following information was gathered for this test.

Threshold Values
Threshold Values were only derived for pollutants that are placing a groundwater body at risk of failing WFD objectives and where these pollutants have a prescribed drinking water standard. Threshold Values were derived for the following pollutants:

- Nitrate (as NO_3) = 37.5 mg/l
- Ammonium (as N) = 175 µg/l
- Electrical Conductivity = 1,875 µS/cm
- Nitrite (as NO_2) = 375 µg/l
- Chloride = 187.5 mg/l
- Sulphate = 187.5 mg/l
- Sodium = 150 mg/l
- Boron = 750 µg/l
- Individual Pesticides = 0.075 µg/l
- Total Pesticides = 0.375 µg/l

Trend Assessments
Trend assessments were undertaken using the MAKESENS Mann-Kendall/Sen's non-linear trend analysis model (Salmi *et al*, 2002). Further information on the trend assessment is provided in Section 5 of this report. The MAKESENS model reports the significance for the trend assessment, i.e. trend not significant (<90% significance) or the trend is 90%, 95%, 99%, or 99.9% significant.

Groundwater Quality Data
Ten years of monitoring data (1999–2008) from the EPA's National Groundwater Monitoring network, were used to identify trends for this test. The local authorities supplied supplemental water quality data for drinking water abstractions >100 m^3/d. These data were used as part of the risk assessment and to improve confidence in the assessment, but were not used to determine status because the local authority data is sampled after treatment has taken place.

Monitoring Points Assessed
Drinking Water Abstractions. All monitoring locations in the EPA's National Groundwater Monitoring network that are also used for drinking water supply.

3.4.4 Methodology

The steps taken in carrying out the Drinking Water Protected Area test are outlined below.

(i) Groundwater monitoring data were complied for representative monitoring points in the EPA's National Groundwater Monitoring network that are also drinking water abstractions.

(ii) The maximum and annual average concentrations were calculated for a 10 year reporting period (1999–2008) at these monitoring sites.

(iii) Initially the data were screened at these monitoring sites – no further assessment was undertaken where the average concentration was less than the screening value (half the drinking water standard) or where there were no measured individual concentrations above the TV. These sites default to Good Status (with high confidence).

(iv) Where elevated concentrations for a determinand were detected at monitoring points, checks were made to determine if the natural background concentrations were elevated in the aquifers being monitored, e.g. for iron and manganese. If the natural background levels were higher than monitored concentrations, these sites default to Good Status (high confidence).

(v) Further assessment was required at the remaining sites:
    - The EU guidance (EC, 2009) defines the concentration in 2007 as the *baseline condition* for future trend assessments. At each site with elevated determinand

concentrations, the mean concentration was calculated (for the relevant pollutants) for the year 2007;

- Where the mean concentration for a pollutant was greater than the TV in 2007, further assessments were undertaken to determine if there were significant upward trends in the pollutant concentration.
- Where the mean concentration for pollutants was less than the TV in 2007, the sites default to Good Status, but trends were assessed to determine if the site was at risk of failing WFD objectives in the future.

  Note: increases in determinand concentration beyond the baseline condition are allowable, as long as they do not exceed the TV or bring about the need for an increased level of purification / treatment at the water supply.

- Trend assessments were undertaken at individual monitoring sites to determine if there are statistically significant upward trends in pollutants:
  - To undertake the statistical assessment, a minimum of 80% real data in the dataset was required, i.e. there must be no more than 20% LOD/LOQ data.
  - Statistically significant trends could not be calculated for datasets with less than six years data because the MAKESENS model cannot detect significant trends with less than six years of data.
  - The trend significance was calculated using the MAKESENS model.
- Where the baseline condition concentration was above the TV, but trends were downward or were not statistically significant, or assessments could not be undertaken because of a lack of data, then the monitoring sites default to Good Status (with low confidence).
- Where the baseline condition concentration was below the TV, but assessments could not be undertaken because of a lack of data, then the monitoring sites default to Good Status (with low confidence).
- Where the baseline condition concentration was below the TV, and trends were downward or were not statistically significant, the monitoring sites default to Good Status (with high confidence).
- Where statistically significant upward trends were detected at monitoring sites, the trend was projected forward until 2021 (using the MAKESENS model), to determine if the trend will be environmentally significant in the future, i.e. will breach a TV before 2021.
  - Where there was a significant trend and the concentration already exceeded the TV, these sites (and associated groundwater bodies) were at Poor Status (high confidence) in the 2009 reporting period. As the TV has already been exceeded, the starting point (year) for trend reversal is 2009.
  - Where there was a significant trend and the baseline condition concentration was below the TV, but was projected to exceed the TV by 2021, these sites (and associated groundwater bodies) were at Good Status (low confidence), but were at risk of failing to meet the WFD objectives in the future[6].
  - In the case of the previous point, the year when 75% of the TV concentration is breached was identified from the MAKESENS model. This is the starting point (year) that trend reversal should begin, i.e. measures should be introduced prior to this year.
- Crosschecks in the assessment were undertaken using local authority drinking water returns:
  - Where the annual average concentration for a determinand was similar to that calculated above, then there was high confidence in the status assessment.

[6] Note that this approach is slightly different to that undertaken by the UK. In the UK, when the baseline condition concentration was below the TV, but there was a significant upward trend that was projected to exceed the TV by 2012, these sites (and associated groundwater bodies) were at Poor Status.

— Where the local authority data provided conflicting evidence or did not exist, then the initial status determination remained, but with low confidence.

The overall assessment approach is summarised in Table 6.

Table 6 Summary of criteria to determine status and confidence

Statistically significant trend in data	Mean concentration currently below TV	Mean concentration currently above TV
Down	Good (also not at risk)	Good (at risk)
No trend	Good (also not at risk)	Good (at risk)
Up	Good (at risk where predicted concentration in 2021 > TV, otherwise not at risk)	Poor (at risk)

3.4.5 Future Developments

The monitoring network has undergone significant development over the last six years with many new sites added to the network. In many cases data records are not long enough to carry out robust trend assessment. Providing that monitoring is continued, better data will be available for trend assessment in the future.

Additional information is required on the current level of treatment at water supplies. Blending of water from multiple abstraction points is commonly used to maintain the quality of water supplied from drinking water schemes. Additional water supply sources and abstraction points are often introduced to maintain the status quo in water quality, but this would be perceived as additional treatment under WFD and therefore the groundwater body would be at Poor Status. Therefore, information on the actual abstractions, blending and treatment regimes are required to ensure compliance with this WFD objective in the future.

3.5 Test 5: General Chemical Assessment Test

Key concept:
Status is determined through an assessment of the areal extent of a groundwater body exceeding a TV for a pollutant. It is only conducted for determinands for which:

- an EU prescribed standard is set; or
- the risk characterisation process has indicated that pollutants may cause significant impairment of human uses of groundwater.

Threshold Values:
An appropriate percentage of the EU prescribed standards for nitrates and pesticides or a use-related standard that is appropriate for existing or planned use of the groundwater body.

The conditions for good chemical status are not met when:
Threshold Values are exceeded at individual monitoring points, and a representative aggregation of the monitoring data at the groundwater body scale indicates that there is a significant environmental risk or a significant impairment of human uses of the groundwater body.
(UKTAG, 2008a)

3.5.1 Introduction

The General Chemical Assessment Test identifies groundwater bodies where widespread deterioration in quality has, or will, compromise strategic use of groundwater.

The status of the groundwater body is Poor if there is a widespread exceedance of relevant groundwater TVs or quality standards (UKTAG, 2008a)

3.5.2 Background

The General Chemical Assessment Test is undertaken where there is deterioration in groundwater quality at a scale that may compromise strategic use of groundwater for existing or planned, human consumption and/or other potential purposes. The test is not intended to identify local pollution impacts.

This test looks at concentrations of nitrate, pesticides and other pollutants in groundwater that put groundwater bodies at risk of failing to meet WFD objectives. Where TVs are exceeded at individual monitoring points, an aggregated average pollutant concentration across the groundwater body (or group of bodies) is calculated. Where the pollution of groundwater is confirmed as being widespread, i.e. widespread exceedance of the TV, the groundwater bodies are at Poor Status for this test, otherwise they are at Good Status.

This test assesses the impact of widespread diffuse pressures on groundwater quality, and includes an assessment of pollutants from significant point sources, e.g. mining activities and contaminated land.

3.5.3 Information Required for This Test

The General Chemical Assessment Test assesses whether there is a widespread exceedance of relevant groundwater quality standards or groundwater TVs. This test is only undertaken for determinands that are applicable to human uses of groundwater.

The following information was gathered for this test.

Pressures
As part of the initial groundwater characterisation, groundwater bodies were delineated along hydrogeological boundaries. In addition, groundwater bodies were delineated when activities, such as contaminated land or mining were considered to be having a widespread impact on groundwater quality. The Article 5 Risk Assessment (Working Group on Groundwater, 2005) identified groundwater bodies that were at risk of failing to meet WFD objectives.

Threshold Values
Threshold Values were only derived for pollutants that are placing a groundwater body at risk of failing to meet WFD objectives and where these pollutants have a prescribed standard relating to the human use of water, i.e. drinking water standard. Threshold Values were derived for the following pollutants:

- Nitrate (as NO_3) = 37.5 mg/l
- Ammonium (as N) = 175 µg/l
- Electrical Conductivity = 1,875 µS/cm
- Nitrite (as NO_2) = 375 µg/l
- Chloride = 187.5 mg/l
- Sulphate = 187.5 mg/l
- Sodium = 150 mg/l
- Boron = 750 µg/l
- Individual Pesticides = 0.075 µg/l
- Total Pesticides = 0.375 µg/l
- Chromium = 37.5 µg/l
- Arsenic = 7.5 µg/l
- Lead = 18.75 µg/l
- Nickel = 15 µg/l
- Mercury = 0.75 µg/l
- Cadmium = 3.75 µg/l
- Copper = 1500 µg/l
- Aluminium = 150 µg/l
- Cyanide = 37.5 µg/l
- 1,2-Dichloroethane = 2.25 µg/l

- Vinyl Chloride = 0.375 µg/l
- Total Tetrachloroethene & Trichloroethene 7.5 µg/l
- Benzene = 0.75 µg/l
- Benzo(alpha)pyrene = 7.5 ng/l
- Total Polycyclic Aromatic Hydrocarbons = 0.075 µg/l
- Total Trihalomethanes = 75 µg/l

Groundwater Quality Data
For each site, six years of monitoring data (2003-2008), from the EPA's National Groundwater Monitoring network, were assessed to calculate the average parameter concentrations.

Point Source Data
Mines: Groundwater quality data were gathered for historic mines by the Geological Survey of Ireland/Exploration and Mining Division. Data included samples taken from wells and mine adits, as well as leach test data from mine waste areas and mine workings. The data were collectively assessed to determine the average concentrations of different metals across the worked mine area. Further information is available in the Classification of Groundwater Bodies: General Chemical Test for Closed Mines (GSI, 2009).

Contaminated Land: Groundwater quality data were gathered for IPPC and Waste sites where there has been historical contamination at the site location. The annual environmental reports for IPPC and waste sites were consulted to improve conceptual understanding of groundwater flow and identify the locations of groundwater monitoring and levels of contamination.

Urban Areas: Groundwater quality data were gathered for monitoring sites in urban areas across Ireland. This included data gathered from public water supplies, industrial supplies, private abstractions and monitoring at IPPC and waste sites. Further information is available in the Urban Pressures Further Characterisation study (CDM, 2008).

Historical Landfill: The information required to assess the impact of old dumps on groundwater quality was insufficient to undertake an assessment.

Discharge to Groundwater: The information required to assess the impact of discharges to groundwater on groundwater quality was insufficient to undertake an assessment.

3.5.4 Methodology

Data from the EPA's National Groundwater Monitoring network were used to assess whether there was a widespread impact on groundwater quality across groundwater bodies. The steps taken in carrying out the General Chemical Assessment Test for a groundwater body are detailed below:

(i) Groundwater monitoring data were compiled for individual monitoring points in the EPA's National Groundwater Monitoring network.

(ii) In accordance with EU Guidance (EC, 2007), groundwater bodies with similar hydrogeologies and pressures were grouped, and monitoring data from the group of monitoring points within these groundwater bodies were used to assess groundwater quality.

(iii) Where a TV was exceeded at an individual monitoring point, an aggregated average pollutant concentration was calculated across the groundwater body group for the relevant pollutant. This quantified the extent of the problem and whether there are any significant risks to the environment or impairment to human use.

  - The six year average concentration for the relevant pollutant was calculated at all monitoring points in the groundwater body group.
  - Data from all monitoring points in the groundwater body group were aggregated and the six year average concentration for the relevant pollutant was calculated for the groundwater body group.

- For some groundwater body groups, a weighting factor was applied to certain monitoring points in the group to ensure that the monitoring data was representative of the groundwater quality across the groundwater bodies. However, for most groundwater body groups, a weighting factor was not required and the aggregation was an un-weighted average from the monitoring points.

(iv) An assessment was undertaken to determine if the elevated concentrations were due to natural conditions. Where the natural background concentrations for the relevant pollutant were higher than the average concentration, the group of bodies defaulted to Good Status.

(v) For the remaining pollutants, where the aggregated concentration was higher than the TV, all groundwater bodies in the group were at Poor Status.

(vi) High confidence was assigned where there was good evidence of widespread impacts on human uses of groundwater, i.e. concentrations above the Drinking Water Standard.

Further assessment was undertaken to determine if pollution, from activities such as contaminated land or mining, was impacting on the status of groundwater bodies. The assessment was based on a conceptual understanding of contaminant transport from the contaminated areas of the groundwater body, taking into account variation in groundwater quality across the whole groundwater body.

(i) Groundwater monitoring data were compiled for areas contaminated by point sources activities.

(ii) Supporting evidence of impact on receptors was also gathered, i.e. any evidence of impact on drinking water abstractions, surface watercourses or wetlands.

(iii) For each of the assessed groundwater bodies, there were monitoring sites that were representative of the contaminant plume and those that were representative of the remaining areas of the groundwater body.

- The mean concentrations of hazardous contaminants in remaining areas of the groundwater body were assumed to be zero, unless there were additional contaminated land sites within the groundwater body (e.g. in urban areas);
- The mean concentration of the non-hazardous contaminants in the remainder of the groundwater body should reflect the mean concentrations in the groundwater body that surrounds the contaminated land site, i.e. the average concentrations calculated from the EPA's National Groundwater Monitoring network.

(iv) An assessment was undertaken to determine whether the extent of the pollution was significant enough to impact on status of the groundwater body.

- An area-weighted aggregation of the contaminant plume was calculated using monitoring data from the site (see below).

> **Area-Weighted Average Concentration** = ((Polluted area x Estimated average concentration in polluted area) + (Area of the remainder of the GWB x Estimated average concentration in this area)) / Total GWB area

- If the area-weighted average concentration was higher than the TV, the groundwater body was at Poor Status.
- High confidence was assigned where there is good evidence of widespread impacts of pollution, i.e. recorded impacts on drinking water abstractions, surface watercourses or wetlands.

(v) Crosschecks were made with EPA site inspectors to ascertain if remediation programmes were in place at the contaminated sites and whether the remediation would bring about

marked improvement by 2015. If remediation was completed or was ongoing, and was likely to cause a significant reduction in the contaminant plume concentrations and the extent of the plume, the groundwater body defaulted to Good Status, but with low confidence.

(vi) Crosschecks were made with the GSI/EMD to determine if the elevated metal concentrations at mines were natural or if they had been caused by the mining activities. If the concentrations were not directly caused by the mining activity, i.e. were considered to be naturally elevated, the groundwater body defaulted to Good Status, but with low confidence.

The overall assessment approach is summarised in Table 7.

Table 7 Summary of criteria to determine status and confidence

Status	Confidence	Example Criteria
Good	High	No individual site concentrations higher than TV(s)
	Low	Aggregated pollutant concentration < TV(s), but individual site concentrations higher than TV(s) OR Aggregated pollutant concentration > TV(s), but aggregated pollutant concentrations lower than Natural Background concentrations OR Evidence of remediation causing a significant reduction in pollutant concentrations
Poor	Low	Aggregated pollutant concentration > TV(s)
	High	Aggregated pollutant concentration > TV(s) and individual sample concentrations greater than Drinking Water Standard OR Aggregated pollutant concentration > TV(s) and evidence of impact on drinking water abstractions, surface watercourses or wetlands

3.5.5 Future Developments

The monitoring network has undergone significant development over the last six years with many new sites added to the network. In many cases, summary statistics for groundwater quality are therefore based on limited data. Future rounds of classification will have more robust data and better summary information.

Detailed information on the impacts of landfill and discharge to groundwater is required in the 2nd River Basin Planning cycle to determine their impact on the status of groundwater bodies. Further detailed studies of contaminated land sites and mines are required in the 2nd River Basin Planning cycle. In particular, detailed information on the extent of contaminant plumes is required.

4 Quantitative Status

An assessment of groundwater body status is required to comply with the Water Framework Directive (2000/60/EC) and the Groundwater Directive (2006/118/EC). In 2005, the WFD Article 5 Risk Assessments (Working Group on Groundwater, 2005) were undertaken to identify groundwater bodies that were at risk of failing to meet the objectives of the WFD. Status assessments are required for all groundwater bodies that were identified as being At Risk.

Status assessments are undertaken once every six years, at the end of the river basin management planning cycles, and are used to generate a snap shot that shows the impacts of groundwater abstraction and pollution on groundwater. The risk assessments are carried out at the beginning of the six year cycles. Whilst similar in nature, the goals of status assessments and ongoing risk assessments are different in that the risk assessments help determine the requirements for future monitoring and investigation, and help identify areas where future developments could impinge on the groundwater status objectives of the WFD. Essentially, the risk assessments are assessments of where objectives of the WFD may not be achieved in the future, whilst status assessments consider compliance with the WFD objectives in the past.

Additionally, status assessments consider widespread impact across a groundwater body. Therefore, a groundwater body can be at Good Status, but there can still be an environmental risk, e.g. a local reduction in water levels in close proximity to an abstraction can impact on neighbouring water supplies, but are not substantial enough to impact on the status of the whole groundwater body. However, where a groundwater body has been classified as being at Poor Status, this implies that there is also a risk of failing to meet WFD objectives in the future.

Quantitative classification of groundwater bodies is split into four tests (see Figure 3). The tests are designed to assess whether the objectives of the WFD are being met. The worst case is reported for a groundwater body, so "failure" of one or more of the tests causes a groundwater body to be at Poor Status.

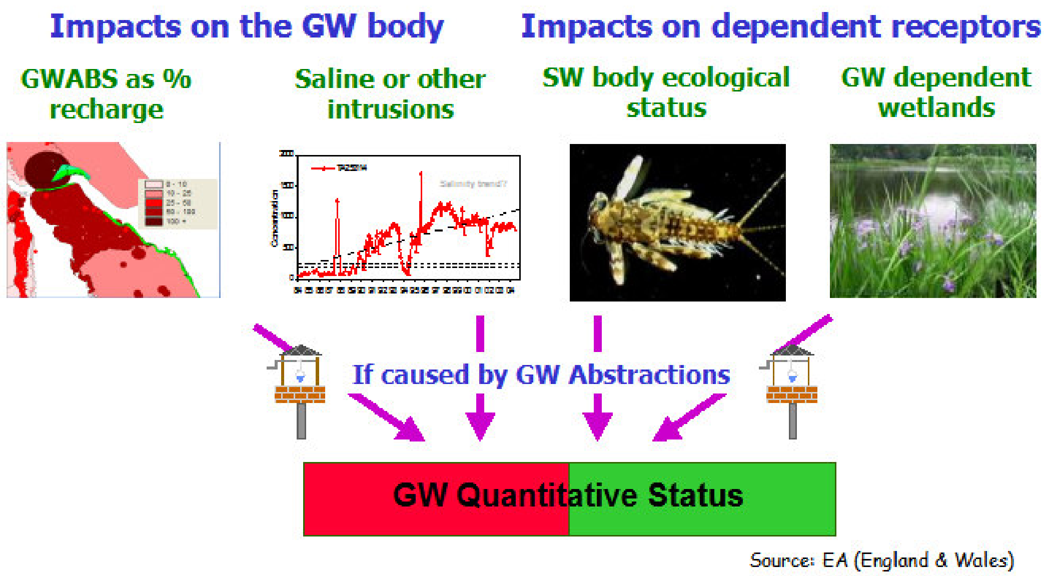

Figure 3 Quantitative Status Assessment Tests

Due to a lack of information on ecological flow standards for surface water bodies, the surface water ecological/quantitative assessment could not be undertaken. This assessment will be undertaken in the 2nd River Basin Planning cycle.

4.1 Test 1: Saline (or Other) Intrusions Test

Key concept:
Status, and the presence of an intrusion of poor quality water into the groundwater body, is determined through an assessment of trends in Electrical Conductivity or other indicator substances. The test is designed to detect the presence of an intrusion that is induced by the abstraction of groundwater.

Threshold Values:
Set at the upper limit of the natural background range for key determinands. Threshold Values are only used in combination with trend assessment(s).

The conditions for good quantitative status are not met when:
Threshold Values are exceeded and there is either a significant and sustained rising trend in one or more key determinands at relevant monitoring points, or there is an existing significant impact on a point of abstraction as a consequence of an intrusion.
(UKTAG, 2008a)

4.1.1 Introduction

The Saline (or Other) Intrusions Test is intended to identify groundwater bodies where there is intrusion of poor quality water as a result of groundwater abstraction and this intrusion is leading to sustained upward trends in pollutant concentrations or a significant impact on one or more groundwater abstractions (UKTAG, 2008a).

Note: the saline intrusion test mirrors the test undertaken for the Chemical Status assessment.

4.1.2 Background

This test is undertaken to identify where groundwater quality is deteriorating, or there have already been impacts on the quality of abstracted water, as a result of the intrusion of poor quality water into the groundwater body. The EU guidance (EC, 2009) and UKTAG guidance (UKTAG, 2008a) indicate that the intrusion must be caused by groundwater abstraction and must be sustained, i.e. temporary intrusions should not be considered. Therefore, the test focuses on groundwater bodies where there is a risk that abstraction pressures may cause significant and sustained intrusions.

Groundwater intrusion can occur when the saline-freshwater interface in coastal regions is drawn inland and upwards by abstraction. Groundwater abstraction can also lead to upward movement (up coning) of poor quality water, the leakage of saline surface waters to an underlying groundwater body or drawing in of poorer quality groundwater from an adjacent aquifer. The EU and UKTAG guidance indicates that parameters in groundwater that are indicative of intrusion should be assessed, e.g. Electrical conductivity and Chloride.

Where Electrical Conductivity and Chloride concentrations are above Natural Background Levels and there is either a significant upward trend in concentration of that parameter, or there is already an impact on a point of abstraction (e.g. where a water supply has been decommissioned due to saline intrusion), then the groundwater body will be at Poor Status. Otherwise it will be at Good Status.

The WFD indicates that confidence in the status assessment must be reported. UKTAG guidance suggests a weight of evidence approach when assigning confidence, with High Confidence (HC) or Low Confidence (LC) assigned to status assessment. For example, confidence is high where there is evidence of significant and sustained upward trends and there is evidence of impact at a water supply. Confidence is low when the evidence is less comprehensive, e.g. no impact on water supplies or when monitoring is limited. Confidence does not indicate how close the groundwater body status is to the status boundary.

The linkages between Status and Confidence are summarised in Table 8.

Table 8 Risk Assessment and Status for the Saline Intrusion Test

Risk assessment					Status & Confidence
Abstraction in GWB	Abstraction <20km from the coast	Concentration at Monitoring Point >TV	Elevated Concentration Caused by Abstraction	Upward Trend in Concentration	
No	-	-	-	-	Good-HC
Yes	No	-	-	-	Good-HC
Yes	Yes	No	-	-	Good-HC
Yes	Yes	Yes	No	-	Good-LC
Yes	Yes	Yes	Yes	No	Good-LC
Yes	Yes	Yes	Yes	Yes	Poor-LC
Yes	Yes	Yes	Yes	Yes	Poor-HC*

* Evidence of impacts of saline intrusion on nearby receptors

4.1.3 Information Required for This Test

The Saline (or Other) Intrusions Test assesses the presence of an intrusion of poor quality water into the groundwater body as a result of groundwater abstraction and is determined through the identification of upward trends in Electrical Conductivity and Chloride.

The following information was gathered for this test.

Threshold Values[7]
Threshold Values were only derived for pollutants that are indicative of saline (or other) intrusions.

- Electrical Conductivity = 800 µS/cm
- Chloride = 24 mg/l.

Groundwater Quality Data
For each site, six years of Electrical Conductivity and Chloride monitoring data (2003-2008), from the EPA's National Groundwater Monitoring network, were assessed to identify and calculate the maximum and average parameter concentrations respectively. Ten years of monitoring data (1999–2008), were used to assess trends in the parameter concentration.

Monitoring Points Assessed
Groundwater bodies identified in the Article 5 Risk Assessment (Working Group on Groundwater, 2005) as being At Risk from Saline Intrusion: Monitoring locations were assessed in groundwater bodies that were at risk of failing to meet WFD objectives in relation to Saline Intrusion, as reported in the Article 5 Risk Assessment.

Coastal Location: All monitoring locations, within 20 km of the coast or coastal inlets, were assessed if the maximum Electrical Conductivity and average Chloride concentrations exceeded the TV.

Groundwater bodies with Abstraction Pressures: Monitoring locations were assessed in groundwater bodies that were at risk of failing to meet WFD objectives because of unsustainable abstractions.

[7] TVs determined as the upper limit of the Natural Background Level (NBL) from (OCM, 2007).

4.1.4 Methodology

The steps undertaken as part of the Saline (or Other) Intrusion Test are outlined below:

Trend assessments were undertaken using the MAKESENS Mann-Kendall/Sen's non-linear trend analysis model (Salmi *et al*, 2002). The model was used to identify statistically significant upward trends in Electrical Conductivity and Chloride at monitoring points. Section 5 of this report has more detail on the trend analysis that was undertaken.

The annual average concentrations for Electrical Conductivity and Chloride were calculated at monitoring points, over a period of ten years (1999–2008), if the maximum Electrical Conductivity and Chloride concentrations exceeded the TV during that period. Annual averages have been calculated because the annual monitoring frequency has varied historically and prior to 2007 the monitoring frequency was insufficient to distinguish seasonal variations in parameter concentrations.

The trend assessment was not undertaken when a monitoring point had less than six years data during the ten-year period because MAKESENS requires at least six years data to determine significant trends.

Where trends could be determined at individual monitoring points, the statistical significance of the trend was determined using MAKESENS. Trends were identified as being non-existent, upward or downward and the statistical significance of the trend was reported as being 90%, 95%, 99% or 99.9% significant or the trend was not statistically significant.

When assessing the impact of saline intrusion on groundwater, the presence of a statistically significant upward trend in both Chloride and Electrical Conductivity at any individual monitoring point resulted in the groundwater body being classified at Poor Status.

Monitoring locations with significant upward trends in Chloride, but not in Conductivity, or vice versa, remained at Good Status, but are at risk of failing to meet WFD objectives in the future. These monitoring points will be investigated further in the 2nd River Basin planning cycle.

Information on the reasons for water supplies being decommissioned was unavailable. Often water supplies are decommissioned when new water infrastructure projects are being undertaken and it was not clear if water quality problems were a contributory factor to supplies being decommissioned.

The overall assessment approach is summarised in Table 9.

Table 9 Summary of criteria to determine status and confidence

Status	Confidence	Example Criteria
Good	High	No exceedance of the TV levels, OR Exceedance of TV levels not caused by abstraction
	Low	Exceedance of TV levels but further investigation has determined there are no sustained rising trends OR Possible risk identified but no monitoring available
Poor	Low	Exceedance of TV levels caused by abstraction with sustained rising trends OR Exceedance of TV levels caused by abstraction AND impacted abstraction
	High	Exceedance of TV levels with sustained rising trends caused by abstraction AND The Intrusions have caused a significant impact on abstraction(s)

4.1.5 Future Developments

The National Groundwater Quality Monitoring network has undergone significant development since 2007, with many new sites added to the network. Summary statistics for groundwater quality are therefore based, in many cases, on limited data. There are currently insufficient data at many monitoring sites to carry out robust trend assessments. Longer records of monitoring data will enable more reliable trend assessments to be carried out at all monitoring sites in the National Groundwater Quality Monitoring network in the 2nd River Basin Planning cycle.

4.2 Test 2: Impact of Groundwater on Surface Water Ecological/Quantitative Status Test

Key concept:
Status is determined through a combination of surface water classification results and an assessment of the potential impact of groundwater abstraction on the flow required to support surface water ecology. The surface water bodies can comprise rivers, standing waters, and transitional waters.

Standards:
Ecological flow requirements/standards for surface water bodies

The conditions for good quantitative status are not met when:
The ecology of an associated surface water body is damaged due to groundwater abstraction(s) impacting the groundwater flow from the groundwater body to the associated surface water receptor.

4.2.1 Introduction

This section describes the method used to assess the Quantitative Status of groundwater bodies with respect to deterioration of dependent surface water body ecological status that is caused by groundwater abstraction(s). The assessment is undertaken in those groundwater bodies where groundwater abstractions are causing an associated surface water body to not meet the ecological objectives of the WFD (UKTAG, 2008b).

4.2.2 Background

This test considers the impact of groundwater abstractions on the ecological status of surface water bodies. This requires an assessment of the impact of groundwater abstraction on the ecological flow requirements of surface waters, i.e. surface water flow standards.

This test is only undertaken where the surface water body is classified as less than Good Status; due to a failure of surface water body flow standards, which are caused by abstraction. Where there is a significant upstream groundwater abstraction(s), then the groundwater body, upon which both the abstractions and surface water flows depend, is also classified as being at Poor Status. Otherwise the groundwater body is at Good Status.

4.2.3 Information Required for This Test

The Surface Water Ecological/Quantitative Test assesses the potential adverse impacts of groundwater abstraction on the flow requirements of associated surface water bodies that are at less than Good Status.

The following information was gathered for this test.

Less Than Good Status Surface Water Bodies
The locations of surface water bodies that are at less than Good Status because they did not meet their ecological objectives.

Environmental Flow Indicators for Surface Water Bodies
Low flow standards that are required to maintain the ecology of rivers and lakes. Currently these do not exist for Ireland.

Abstraction Data
The location and current volume of water abstracted from groundwater abstraction points.

4.2.4 Methodology

The steps undertaken as part of the Surface Water Ecological/Quantitative Test are outlined below.

Groundwater bodies associated with surface water bodies that are at less than Good Status due to ecological damage were identified.

Flow standard(s) were required for surface water bodies that were at less than Good Status, i.e. the minimum flow required to maintain the ecology of the river. However, this information was not available. Consequently the test could not be undertaken.

4.2.5 Methodology for Future Assessments

If the low flows in the surface water body do not fall below the flow standard, then the ecology of the river is not being damaged by over abstraction, and the damage is being caused by something else, e.g. pollution. Therefore, the groundwater body would be at Good Status in relation to this test. Similarly, if there were no groundwater abstractions in the surface water body catchment, then the groundwater body would be at Good Status.

If the low flows in the surface water body fall below the flow standard, then it is likely that abstractions are contributing to the reduced flow and are causing the surface water body to be at less than Good Status. The impacts of groundwater abstractions up-gradient of the surface water body should be assessed to determine their impact on surface water flow.

Where there are groundwater abstractions up-gradient of a surface water body that has low flows that are below the flow standard, then the “allowable abstraction” in the surface water catchment should be calculated. The “allowable abstraction” is the total volume of water available to the surface water catchment, i.e. rainfall less evapotranspiration, less the volume required to maintain the flow standard in the surface water body.

Groundwater abstractions within these groundwater bodies should be identified and the total abstracted volume calculated for all groundwater bodies contributing to the surface water body that is at less than Good Status.

Note: Assessments should take into account any water locally returned and ignore non-consumptive abstractions, as these are being discharged back into the surface water catchment.

If the total volume of groundwater abstractions are >50% of the “allowable abstraction” for the surface water catchment, then groundwater abstractions are significantly contributing to the flow standard being breached and the groundwater body should be at Poor Status. Where groundwater abstractions are <50% of the “allowable abstraction”, the groundwater body is at Good Status, but at risk of failing the objectives of the WFD in the future. The groundwater bodies remain at risk because any management plan needs to take account of both surface water and groundwater, i.e. switching from a surface water abstraction to a groundwater abstraction is unlikely to resolve the problem.

4.2.6 Future Developments

Relationships between flow and ecology remain poorly understood and this test cannot be undertaken unless biologically derived ecological flow requirements for surface water bodies become available.

Detailed information on abstractions will be required to undertake this test. To improve confidence in the assessment, the actual abstracted quantities and abstraction regimes would be beneficial.

This test will be undertaken in the 2nd River Basin planning cycle.

4.3 Test 3: Groundwater Dependent Ecosystems – Quantitative Assessment Test

Key concept:
Status is determined through determination of ecological damage at the GWDTE, and then assessment of the impact of groundwater abstraction on GWDTE ecology. The test is designed to assess whether groundwater abstractions reduce the contribution from groundwater (in terms of water level or groundwater flow) to GWDTEs and if the consequent impact on GWDTE ecology is sufficient to threaten the WFD objectives for these associated GWDTEs.

Standards:
Wetland flow and/or water level standards.

The conditions for good quantitative status are not met when:
The ecology of an associated GWDTE is damaged due to groundwater abstraction reducing the contribution of flow/water level in the groundwater body, which in turn has an impact in flow/water level in the GWDTE.

4.3.1 Introduction

This section describes the method used to assess the Quantitative Status of groundwater bodies with respect to significant damage to GWDTEs, i.e. wetlands. The test is only applied to wetlands/GWDTEs that have been formally identified as protected areas under Regulation 8 of S.I. 722 of 2003.

4.3.2 Background

GWDTEs are defined here as wetlands where habitats and species are dependent on groundwater to maintain the environmental supporting conditions that are required to sustain the habitat and/or species.

The National Parks and Wildlife Service (NPWS) produced a list of Sites of Special Scientific Interest (SSSI's) which they consider to be GWDTEs for the Article 5 Risk Assessment in 2005.

The Article 5 Risk Assessment identified GWDTEs where the ecology was potentially damaged and therefore may have been impacted by groundwater abstraction or pollution. However, generally the cause of the damage was unclear, and may have been caused by quantitative or chemical contributions from groundwater, or both.

A small number of wetland studies have been undertaken since the Article 5 Risk Assessment, but these have been site specific. More generic attempts to classify the requirements of GWTDEs, in terms of groundwater chemistry (mainly nutrients) and the quantity of groundwater (both flow and levels) have been unsuccessful and clearly highlight the complexity of wetlands, as they may be extremely sensitive to any fluctuations to the habitat's supporting conditions.

A number of projects were established to help determine the quantitative (and chemical) requirements of the wetlands, e.g. for Turloughs. Where these projects have been completed, it has been possible to undertake this status test. The findings of these projects will also be used to derive action values for generic wetland types, which in turn will enable the determination of flow standards for groundwater bodies. Until these projects are complete, it will not be possible

to undertake quantitative status assessments for the remaining groundwater bodies that are associated with GWDTEs.

Initial work from the GWDTE projects has also resulted in improved GWDTE boundaries (within the SSSIs) and has enabled the NPWS to update the GWDTE list and improve upon the initial Article 5 Risk Assessment.

4.3.3 Methodology

This test considers the potential impact regional groundwater abstraction(s) have on the hydrological conditions of a wetland that support groundwater dependent ecological features.

Where a GWDTE suffers significant ecological damage as a result of groundwater abstractions, the groundwater body was placed at Poor Status.

To assess the impact, there was a need to determine whether abstractions from the groundwater body affect the flow and water levels supporting the wetland, and also whether the change in water flow or level affects the groundwater dependent ecological features (flora and fauna).

Environmental flow or water level standards (or action values) for a GWDTE are the minimum flows or water levels required to maintain the ecology of the GWDTE. The standards require good understanding of the hydraulic links between the groundwater body and the wetland, and the links between water level and ecology.

Where flow or water level standards (or action values) have been established for a GWDTE, e.g. at Pollardstown Fen in Co. Kildare, a regional water balance assessment for the supporting groundwater body has been undertaken to establish the impact abstractions may be having on the wetland.

Where the ecology of the GWDTE has been damaged and water level/flow in the GWDTE has fallen below the environmental flow standard, the impact of groundwater abstractions in the groundwater body that supports the GWDTE have been assessed.

Where there was evidence (through groundwater monitoring) that groundwater abstraction(s) were causing a regional reduction in groundwater flow or levels, or where the groundwater abstractions exceed an identified “allowable abstraction” volume, that relates to a reduction in flow and drop in groundwater levels at the GWDTE, then the groundwater body was at Poor Status.

Assessments have taken into account any water locally returned and have ignored non-consumptive abstractions, as these were being discharged back into the groundwater body.

Where the ecology of the GWDTE has not been damaged or the water level/flow in the GWDTE has not fallen below the environmental supporting condition, or where the ecological damage was being caused by other factors, such as small drains, then the groundwater body was at Good Status. Similarly, if there were no groundwater abstractions in the groundwater body that supports the GWDTE, then the groundwater body was at Good Status.

The overall assessment approach is summarised in Table 10.

4.3.4 Future Developments

There is considerable uncertainty with this test and there are a number of research projects that aim to address these issues. Currently there is little monitoring of water levels in the vicinity of GWDTEs and therefore there are few measurable data on the flow/water level environmental supporting condition requirements of wetland flora and fauna, or of the effects of falling water levels and decreased flows on the flora and fauna.

Future assessments of GWDTEs will require confirmation that the ecology of the wetland is damaged (or at risk of being damaged) and that this damage is being caused by change in the regional groundwater contributions to the wetland. This groundwater contribution to the wetlands could be quantitative (flow or levels) or chemical (pollutants), or both.

Table 10 Summary of criteria to determine status and confidence

Status	Confidence	Example Criteria
Good	High	No ecological damage to GWDTE OR Ecology of GWDTE damaged, but no associated significant groundwater abstractions in the GWB
	Low	Ecology of GWDTE damaged, but further investigation indicates groundwater abstractions not impacting on the wetland
Poor	Low	Ecology of GWDTE damaged, and further investigation indicates groundwater abstractions are impacting on the wetland
	High	Ecology of GWDTE damaged, and further investigation indicates groundwater abstractions are impacting on the wetland AND Detailed site-specific studies identify and quantify direct connection between groundwater and GWDTE.

There is also a need to research the hydraulic linkages between the groundwater body and wetlands. Critically, information is required on the chemical, flow and water level requirements of the ecology.

4.4 Test 4: Water Balance Test

Key concept:
Status is determined through an assessment of a water balance that is undertaken at the groundwater body scale. The test is designed to detect the presence of groundwater body wide-scale over-abstraction, resulting in insufficient water being left to support the ecology of surface water bodies and wetlands, or resulting in falling groundwater levels.

Standards:
Groundwater abstractions do not exceed an appropriate percentage of recharge and groundwater levels are not falling.

The conditions for good quantitative status are not met when:
The long-term annual average volume of water abstracted from the groundwater body represents more than 80% of the long-term annual average volume of recharge.
OR
The long-term annual average volume of water abstracted from the GWB represents more than the appropriate percentage of recharge required to support dependent surface water receptors **and** there is a long-term drop in groundwater levels.

4.4.1 Introduction

This section describes the method used to assess the Quantitative Status of groundwater bodies with respect to groundwater abstraction pressures on the groundwater body resource balance. This test considers the cumulative effects of groundwater abstraction across the groundwater body.

4.4.2 Background

Groundwater levels are referred to in the WFD as a monitored parameter which should provide a basis for quantitative status classification, but EU guidance (EC, 2009) and UKTAG guidance (UKTAG, 2008b) recognises that literal application of this wording is problematic because

groundwater levels vary continuously, as a reflection of the locally shifting balance between recharge and discharge. Whilst water levels may identify impact in the vicinity of the abstraction, it is possible that they may not pick up the regional effects of abstraction; in particular the impacts on unmonitored streams, rivers and wetlands.

However, groundwater levels assist conceptual understanding of the way an aquifer system works, particularly when long term falling water levels are observed, which are indicative of over abstraction. Generally, on their own, groundwater level monitoring data can rarely be considered to represent the overall groundwater body Quantitative Status.

4.4.3 Information Required for This Test

For the Water Balance Test, an assessment of annual average abstraction against “available groundwater resource” in the groundwater body is required. The available groundwater resource is an approximate value, based on recharge and the flow requirements to support the ecology in surface water bodies and terrestrial ecosystems that are dependent on the groundwater body.

As such, for a groundwater body to be at Good Status the long-term ecological flow needs of receptors dependent on groundwater must be considered. Therefore, the available groundwater resource means the long-term annual average rate of overall recharge to the body of groundwater minus the long-term annual rate of flow required to achieve the ecological quality of associated surface water receptors.

Where reliable information on groundwater levels across the groundwater body are available, these data can be used to identify the presence of a sustained long-term decline in water levels caused by long-term groundwater abstraction. Where such a decline is present it will indicate that the conditions for Good Status may not be being met and the groundwater body will be at Poor Status.

The annual average abstraction rate should include all abstractions from the groundwater body. Abstracted groundwater that has been locally returned to the aquifer or, in certain circumstances, to a river that is directly in connection with the aquifer may be discounted (for example, this may occur during irrigation or at a quarry / mine dewatering operation).

Flow (lateral or vertical) between adjacent groundwater bodies needs be taken account of when carrying out the water balance test. Alternatively groundwater bodies can be grouped to simplify the water balance assessment. Therefore, groundwater bodies that have been delineated because of the presence of point sources of pollution or for urban areas may be joined with their parent groundwater body for the purposes of this test.

Abstractions can impact on the flow and potentially the ecology of surface waters and wetlands, particularly during periods of naturally lower flows. The ecological flow requirements for surface water and GWDTEs are needed so the impacts of groundwater abstraction on flows can be assessed. The methods used to determine the impact of groundwater abstractions depends on the degree to which groundwater abstractions affect the surface water and the GWDTE. Depending on the complexity of the hydrogeological interactions, the methods may use local technical knowledge, simple tools or may require sophisticated models.

The EU guidance (EC, 2009) and UKTAG guidance (UKTAG, 2008b) recommends estimating the groundwater contribution needed to support rivers and ecosystems across the groundwater bodies as part of the calculation of the available groundwater resource; this in turn is used to decide on the status. The impact of groundwater abstractions on ecosystems has not been studied sufficiently in Ireland and therefore there is little information on which to base the ecological flow requirements of rivers. However, a proportion of recharge must be allocated to fulfil the flow requirements of rivers and wetlands.

The WFD Working Group on Groundwater Guidance Document No. 5 (2004) and the SNIFFER WFD 53 Report (2005) provide abstraction-recharge ratio figures that can be used to determine abstraction risk, and these have also been applied for the status assessment in Ireland.

4.4.4 Criteria for Poor Status

In accordance with the WFD, groundwater bodies where abstraction exceeds recharge are classified at Poor Status (with high confidence). Therefore, if the calculated abstraction: recharge ratio is greater than 100%, the groundwater body automatically defaults to Poor Status.

However, this does not leave any water resource to support rivers and wetlands across the groundwater body. Therefore a nominal percentage of the resource must be left to support the rivers and wetlands. In the absence of any clear minimum flow requirements for rivers and wetlands in Ireland, an arbitrary figure of 20% of recharge was left to support the flow in rivers and wetlands. Therefore, where the Abstraction: Recharge ratio was greater than 80%, the groundwater body was at Poor Status (with high confidence).

From the WFD Working Group on Groundwater Guidance Document No. 5 (2004), a groundwater body is at risk of failing its WFD objectives if the Abstraction: Recharge ratio is greater than:

- 5% for groundwater bodies that are supporting a GWDTE;
- 20% for bedrock groundwater bodies; and
- 30% for gravel groundwater bodies.

Where these percentages were exceeded and there was evidence of falling groundwater levels, the groundwater body was at Poor Status (with low confidence).

4.4.5 Methodology

The test is based on an analysis of recharge; ecological flow needs and groundwater abstraction volumes. It is a groundwater body-wide test.

The following information is required for this test.

Average annual recharge: This was estimated for each groundwater body using the Working Group on Groundwater Recharge Map (2008), produced by CDM and Compass Informatics. No account was taken of any potential inflows from the surrounding groundwater bodies, although some groundwater bodies were grouped together for the assessment.

Average annual abstraction: The average annual abstraction quantity was approximated as the sum of all the groundwater abstractions from each groundwater body; these included public water supplies, private group schemes, industrial supplies and dewatering of mines and quarries. Private domestic supplies were not accounted for.

Note: Many of the larger private groundwater abstractions, such as for farms, golf courses and small industries were not included in the assessment, as this information was not available. However, this was balanced to some degree at least because on-site wastewater treatment discharges were not taken into account. Spring abstractions that have intercepted flows and were not actively pumped were not included in the abstracted quantity.

Ecological flow requirements: No scientifically derived ecological flow standards are available in Ireland. Therefore, in the absence of these standards, approximate ecological flow requirements were established for average flow conditions, taking account of the recommendations provided in the WFD Working Group on Groundwater Guidance Document No. 5 (2004) and the SNIFFER Research project WFD 53 Report (2005). These recommendations have been used to assist in deciding on the status categories, as shown in Table 11.

Groundwater level monitoring data: Where a groundwater body was considered to be at risk from over-abstraction and there was evidence of sustained falling water levels in the EPA's National Groundwater Monitoring network, the groundwater body was classed as Poor Status.

The Abstraction: Recharge ratio was calculated for each groundwater body. Groundwater bodies were classified as Poor Status if the Abstraction: Recharge ratio was greater than 80%.

Groundwater bodies were also classified as Poor Status where the Abstraction: Recharge ratio was greater than 5%, 20% or 30% for groundwater bodies supporting GWDTEs, bedrock groundwater bodies, or gravel groundwater bodies respectively, and where there was evidence of sustained falling groundwater levels at monitoring points within the groundwater body.

Table 11 Status category based on proportion of recharge used by abstractions

Annual Abstraction / Recharge Ratio	Groundwater Body Type	Falling Water Levels	Status & Confidence
>80%	-	-	Poor – High Confidence
30-80%	Gravel	Yes	Poor – Low Confidence
30-80%	Gravel	No	Good – Low Confidence
<30%	Gravel	-	Good – High Confidence
20-80%	Bedrock	Yes	Poor – Low Confidence
20-80%	Bedrock	No	Good – Low Confidence
<20%	Bedrock	-	Good – High Confidence
5-80%	Supporting a GWDTE	Yes	Poor – Low Confidence
5-80%	Supporting a GWDTE	No	Good – Low Confidence
<5%	-	-	Good – High Confidence

Where the Abstraction: Recharge ratio was greater than 80%, the groundwater body was at Poor Status (with high confidence); otherwise all other Poor Status groundwater bodies had low confidence assigned. Good Status was assigned to all other groundwater bodies, with low confidence assigned to groundwater bodies where the Abstraction: Recharge ratio was greater than 5%, 20% or 30% for groundwater bodies supporting GWDTEs, bedrock groundwater bodies or gravel groundwater bodies respectively, but there was no supporting water level data. The remaining groundwater bodies were assigned Good Status (with high confidence).

4.4.6 Future Developments

This is a groundwater body wide test, which uses average annual abstraction and recharge values. Therefore estimates of the groundwater abstraction impacts used in the test are basic and the more detailed surface water and GWDTE tests should identify impacts on receptors that are dependent on groundwater.

Further consideration of the impacts of groundwater abstraction on low flows will be required in future, where it is found that groundwater abstractions are, or in the future could be, having an unsustainable impact on water resources or the flow to associated receptors.

5 Trend and Trend Reversal Assessments of Pollution

5.1 Introduction

Part VI of the Groundwater Regulations indicate that the Agency should identify significant and sustained upward trends in the concentration of pollutants in groundwater bodies or groups of bodies identified as being at risk of failing to achieve the objectives of the WFD. In groundwater bodies or groups of bodies that are not at risk of failing to achieve the objectives of the WFD, it may also be necessary to undertake trend assessments, to determine changes in natural conditions or to identify future changes due to anthropogenic activity.

Regulation 56 indicates that trend assessments must be undertaken, where necessary, to verify that plumes from contaminated sites do not expand to such an extent that they put a groundwater body at Poor Status.

Where significant and sustained upward trends are identified, Member States are required to reverse these trends through the introduction of programmes of measures (PoMs). Generally, it will take a number of years before the impact of measures is seen in groundwater systems. Therefore, upward trends need to be identified in sufficient time, so PoMs can bring about a reduction in pollution and prevent deterioration in groundwater quality, thereby reducing the chance of failing the relevant WFD objectives.

Regulation 55 indicates that the starting point for trend reversal must be expressed as a percentage of the relevant groundwater quality standard or Threshold Value (TV). The start date for trend reversal is based on the significance of the trend and the risk associated with it. By default, Schedule 8 (Part B) of the Regulations indicates that the starting point for trend reversal is the date when 75% of the standard or TV is likely to be exceeded, but an earlier or later starting date can be chosen to meet the environmental objectives in a cost effective manner.

Regulation 58 require that the trend assessment methodology and, where sufficient data are available, the first assessment of trends, be reported in, or with, the first River Basin Management Plan, and then at least every six years thereafter.

Regulation 32 indicates a black dot must be used on River Basin Management Plan maps to identify groundwater bodies with significant upward trends. A blue dot must be used where upward trends have been reversed within a groundwater body.

5.2 Background

Trend and trend reversal assessments must be based on monitoring data gathered at individual surveillance and operational monitoring points (EC, 2009), although this may be supplemented by additional representative data from other sources, where this improves confidence in the assessment. Monitoring should be sufficient (spatially and temporally) to take account of short-term variability in pollutant concentrations and natural fluctuations (e.g. in groundwater recharge).

The baseline year for the assessment of trends is 2007, which relates to the implementation of surveillance and operational monitoring programmes (EC, 2009), although data gathered from representative monitoring points prior to this year can be utilised where the data are available. Given the nature of trend assessments, it is unlikely that enough data are available at locations where monitoring began in 2007, and for these monitoring points, a reliable assessment of trends cannot be undertaken in the first planning cycle.

The length (period) of time series required for robust trend assessments depends on the hydrogeological characteristics of the groundwater body and how the system reacts to changes in land use practices and remedial measures. The minimum assessment period should relate to

the monitoring frequency and the robustness of the statistical trend method used. However, in order to avoid bias in the assessment, a consistent length of time series of data should be used for each monitoring point undergoing trend assessment.

In the context of the WFD, Regulation 3 indicates that a significant and sustained upward trend is a trend that is both statistically and environmentally significant, causing an increase in concentration of a pollutant, group of pollutants, or indicator of pollution in groundwater for which trend reversal would be required. Article 2 of the Groundwater Directive indicates that the pollutants are those that would present a significant risk of harm to the quality of aquatic or terrestrial ecosystems, to human health, or to actual or potential legitimate uses of the water.

A statistically significant trend is one that is identified using a recognised statistical trend assessment technique (EC, 2009). An environmentally significant trend is one that is statistically significant, which if not reversed would lead to the failure of one or more of the WFD's environmental objectives (EC, 2009).

5.3 Requirements for Trend and Trend Reversal Assessment

5.3.1 Initial Assessment of Trend Significance

Trend assessments should initially be undertaken at individual monitoring points to determine whether a groundwater body has significant and sustained upward or downward trends in concentrations of natural parameters or pollutants (UKTAG, 2009). Where a statistically significant upward trend is identified at an individual monitoring point, this trend must be tested for environmental significance.

Regulation 53 indicates that trend assessments must be undertaken for parameters that are placing a groundwater body at risk of failing a groundwater chemical status objective, i.e. those parameters that relate to drinking water, saline intrusion, surface water or groundwater dependent wetland assessments.

For each of these objectives, the test for environmental significance depends on the WFD objective being assessed, e.g. when assessing the use (or potential use) of groundwater as a source of drinking water, the test for environmental significance relates to TVs derived from drinking water standards.

5.3.2 Assessing Trends Across Groundwater Bodies

Where an environmentally and statistically significant upward trend is identified at an individual monitoring point, EU Guidance (EC, 2009) recommends that an additional trend assessment should be undertaken using aggregated data from all the monitoring points within the groundwater body or group of bodies. The presence of an environmentally and statistically significant upward trend at any individual monitoring point will not on its own lead to a requirement to report that the groundwater body or group of bodies have an upward trend (UKTAG, 2009). However, the presence of an environmentally and statistically significant upward trend for the aggregated data will lead to a requirement to report that the groundwater body or all bodies in the group have an upward trend.

To ensure that PoMs are introduced in sufficient time, the test for environmental significance requires a determination as to whether the environmental objectives of the WFD will not be met in the future. Given the planning cycle for PoMs and the likely timescale required before the impact of measures are seen in groundwater, the test of environmental significance should be projected forward two River Basin Management Planning cycles, i.e. for the first planning cycle, trends should be projected forward and the concentration predicted in 2021 (UKTAG, 2009).

Where an environmentally and statistically significant upward trend has been reported for a groundwater body or group of bodies, and where PoMs have been implemented, further trend assessments should be undertaken to demonstrate the reversal of trends.

5.3.3 Assessing Trends to Support Status Assessments

In addition to identifying whether significant and sustained upward trends in the concentration of pollutants exist in groundwater bodies or groups of bodies, trend assessments are also used as part of the status assessments in relation to certain WFD objectives, e.g. Drinking Water and Saline Intrusion. The status trend assessments are undertaken at individual monitoring points.

When assessing the use of groundwater as a source of drinking water or when assessing the impact of saline intrusion, the presence of an environmentally and statistically significant upward trend at any individual monitoring point results in the whole groundwater body being reported as having an upward trend (UKTAG, 2009).

5.3.4 Data Requirements and Trend Assessment Techniques

When assessing trends, data should be considered for as long a time series as is deemed necessary to demonstrate a trend. As a minimum, a time series length of six years is required, with at least one measurement in each year (UKTAG, 2009). Where data gaps exist, the length of time series should be extended. Identification of trend reversal is only required where an environmentally significant upward trend has been identified, and measures have been put in place to reverse the trend.

As groundwater data have asymmetric of non-normal distributions, non-parametric statistical methods are required for trend assessment (UKTAG, 2009). Many groundwater systems have considerable seasonal variability in parameter concentrations, which can impact on trend assessments. The non-parametric Seasonal Kendall test is a statistical method that reduces the impact of seasonality on trend assessments (Salmi *et al*, 2002). Where significant trends have been detected, the Sen's method can be used to project the trend into the future, as this method is robust when there are outliers or gaps in the time series data (Salmi *et al*, 2002).

Where parameter concentrations are reported as being below the analytical limit of quantification (LOQ), the recommended approach for statistical analysis is to replace these values with half the reported LOQ (UKTAG, 2009). However, trend assessments should not be undertaken on datasets that comprise of more than 80% of values that are below the LOQ (UKTAG, 2009).

As data availability improves, confidence in the assessment should also improve, although for a trend to be reported as being statistically significant there should be at least 90% confidence that the trend is statistically significant (UKTAG, 2009).

5.4 Methodology

5.4.1 Statistical Approach

An Excel program MAKESENS (incorporating a Mann-Kendall test for trends and a Sen's test for slope projection) has been developed by the Finnish Meteorological Institute (Salmi *et al*, 2002) for detecting and estimating trends in time series using annual values. MAKESENS performs two types of statistical analyses. First the presence of a monotonic increasing or decreasing trend is tested with the non-parametric Mann-Kendall test, and secondly, the slope of a linear trend is estimated with the non-parametric Sen's method (Gilbert, 1987).

MAKESENS reports a positive value for an upward trend and a negative value for a downward trend. In MAKESENS, a two-tailed test is used to determine the significance of trends at four different levels (Salmi *et al*, 2002). Respectively, a significance level of 0.1 means that there is a 90% probability that there is a significant trend, 0.05 means that there is a 95% probability that there is a significant trend. 0.01 means that there is a 99% probability that there is a significant trend and 0.001 means that there is a 99.9% probability that there is a significant trend. Where no value is reported, the trend is not deemed to be significant.

MAKESENS uses the Sen's non-parametric method to estimate the true slope of an existing trend (recorded as a change year on year) and projects the slope forward to a pre-defined date. MAKESENS also computes 99% and 95% confidence intervals around the predicted

concentrations. If a positive trend is detected, the trend has been projected forward until 2021 (two River Basin Planning cycles) to determine environmental significance, i.e. to determine if a TV will be breached within two planning cycles.

5.4.2 Determination of Trends at Individual Monitoring Points

Annual average concentrations were calculated at monitoring points over a period of ten years (1999–2008). Annual averages have been calculated because the annual monitoring frequency has varied historically, and prior to 2007, the monitoring frequency was insufficient to distinguish seasonal variations in parameter concentrations.

Annual average concentrations have been calculated for parameters deemed to be placing a groundwater body at risk, although parameters were not considered for trend assessment unless they had a minimum of six years data during the ten-year period. Assessments were undertaken for Conductivity, Chloride, Sulphate, Sodium, Ammonium, Nitrate, Molybdate Reactive Phosphorus (MRP), Iron and Manganese, as these are the only parameters that are placing a groundwater body at risk that are not specific to pollution from point sources, and that have data records greater than six years.

Where trends could be determined at individual monitoring points, the statistical significance of the trend was determined using MAKESENS. Trends were identified as being non-existent, upward or downward, and the confidence of the statistical significance of the trend was 90%, 95%, 99%, 99.9% or trend not statistically significant (see Annex 1 for examples of trends).

If a statistically significant upward trend was discovered at an individual monitoring point, the environmental significance of the trend was determined using MAKESENS, i.e. the concentration of the parameter with the significant trend was predicted in 2021. This predicted concentration was compared with the appropriate TV. If the predicted concentration exceeded the TV in 2021, the trend was deemed to be statistically and environmentally significant.

5.4.3 Determination of Trends for Groundwater Bodies or Groups of Bodies

Where a statistically significant trend was discovered at an individual monitoring point, data for the upward trending parameter were aggregated for all monitoring points in the groundwater body or group of bodies. Annual average concentrations were calculated for the whole group of monitoring points and trends were determined using MAKESENS. If a statistically significant upward trend was discovered for the group of monitoring points, the concentration of the parameter with the significant trend was predicted in 2021. If the concentration exceeded the TV in 2021, the groundwater body or group of bodies were deemed to have statistically and environmentally significant trends and are therefore subject to trend reversal.

5.4.4 Determination of the Starting Point for Trend Reversal

Regulation 58(e) requires the Agency to define the starting point for trend reversal as a percentage of the groundwater quality standards or TVs. As per Schedule 8 (Part B) of the Regulations, the starting point for trend reversal is when the concentration of the pollutant reaches 75% of the parametric value of the groundwater quality standards or TVs included in the Regulations. Therefore, measures should be introduced on or before the date when 75% of the TV (concentration) of the parameter with the statistically and environmentally significant trend is exceeded. MAKESENS predicts the concentration for a particular parameter in each year until 2021. This allows the year in which the trend is predicted to exceed 75% of the TV to be determined. This year becomes the starting date for trend reversal and is the year in which PoMs should be introduced, although an early start date can also be chosen.

5.5 Future Requirements

Further data is required to resolve some of the uncertainties surrounding the trend assessment, particularly in relation to saline intrusion assessments. The majority of the issues that are associated with data, e.g. LOD/LOQ data in the time series and data spikes, should become less of a factor as longer time series of data become available.

Further trend assessments will be undertaken in the 2nd River Basin Management Planning cycle, and trend assessments will be undertaken for the first time at the monitoring points where monitoring began in 2007 and historical records were not available. Trend assessments will also be undertaken to evaluate contamination plumes from point sources, as this information was not available during the first River Basin management planning cycle.

6 References

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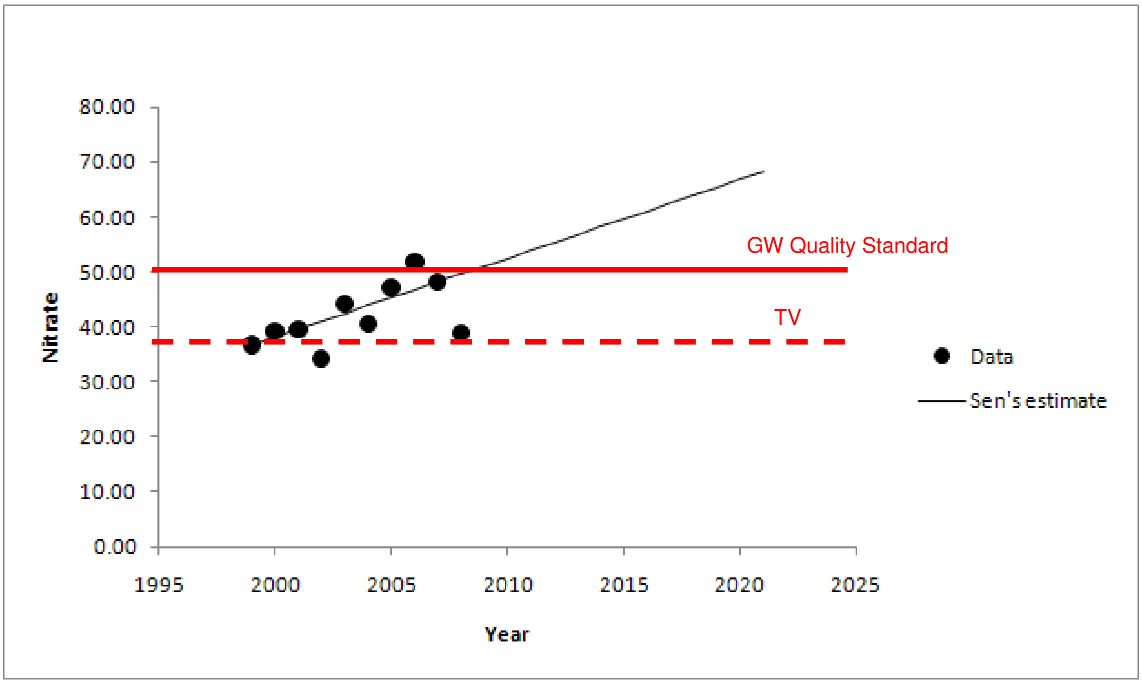
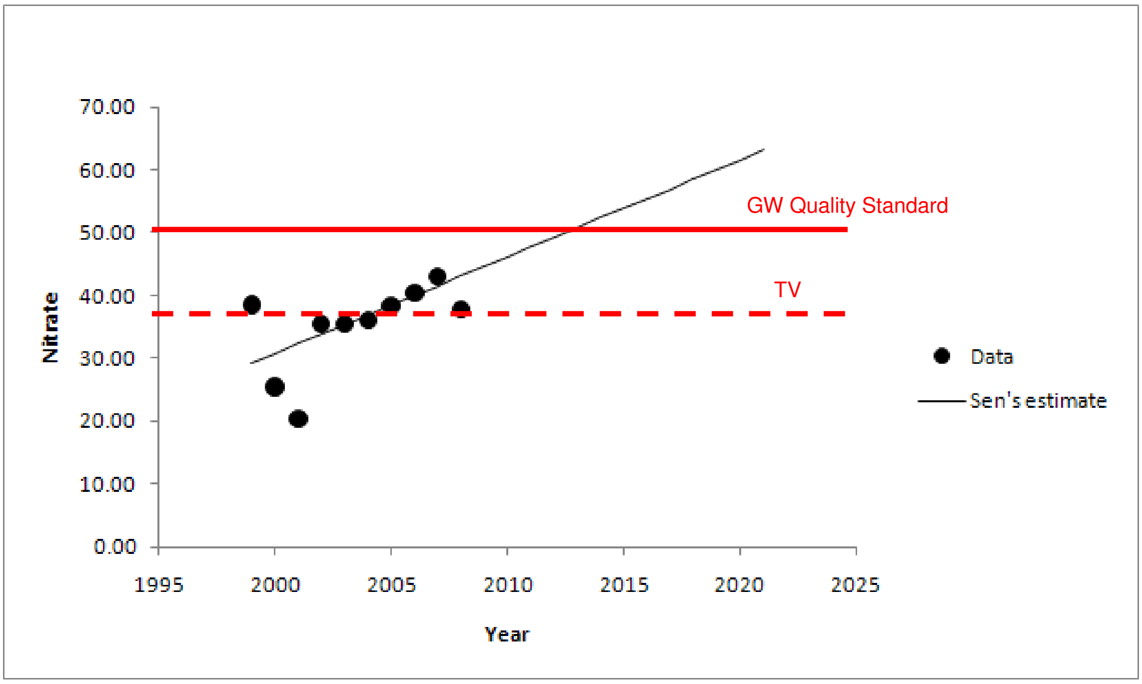
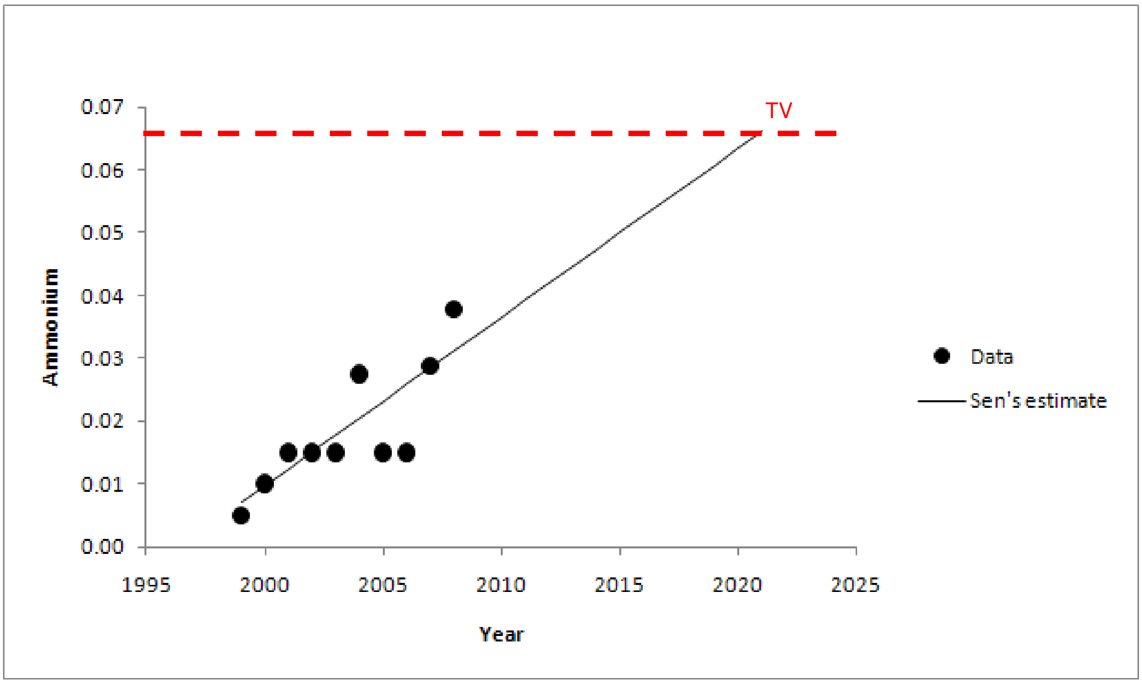
Annex 1 Trend Assessment Examples



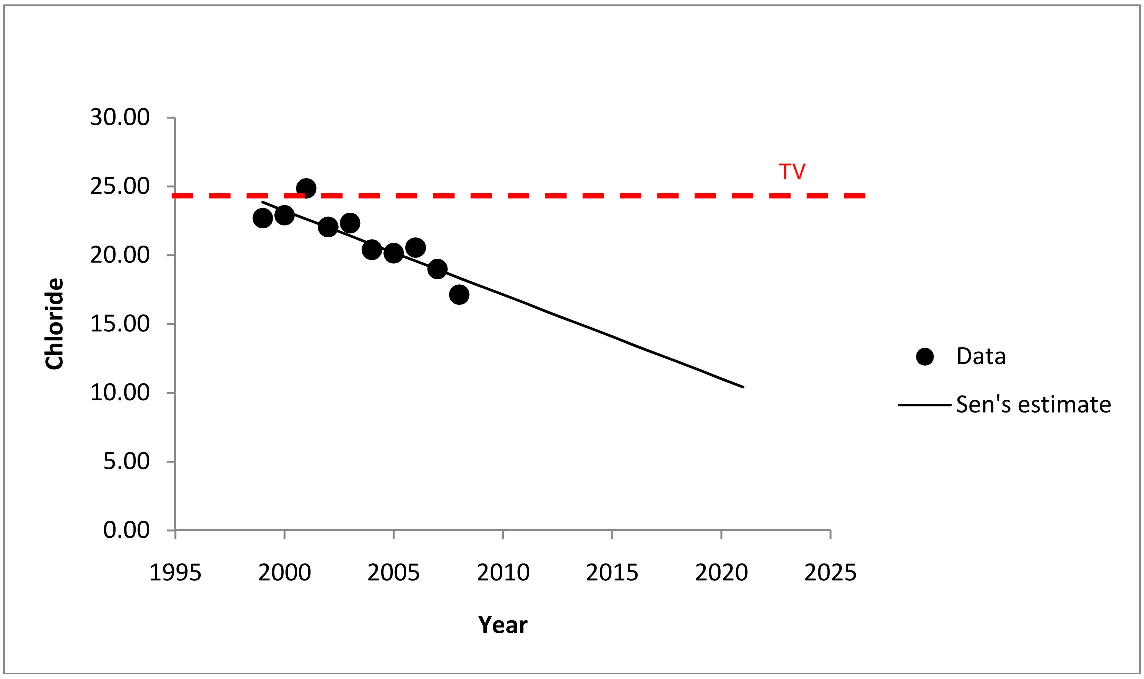
Environmentally and Statistically Significant Upward Trend for Nitrate at Durrow (11_006)



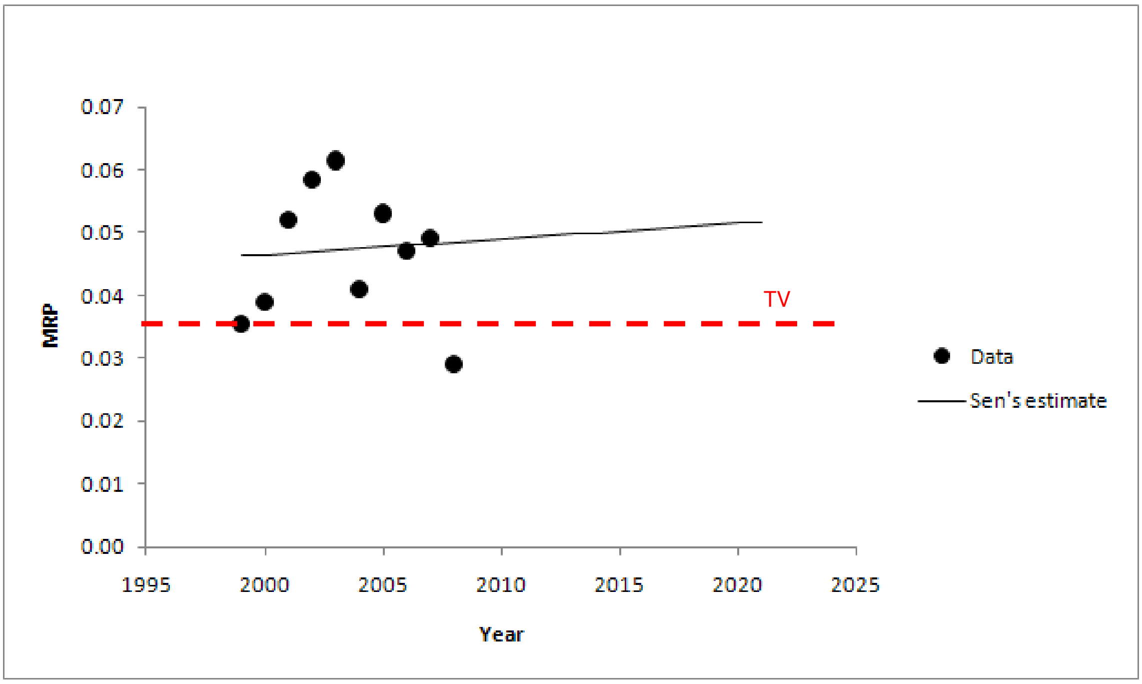
Environmentally and Statistically Significant Upward Trend for Nitrate at Ballyheigue (08_001)



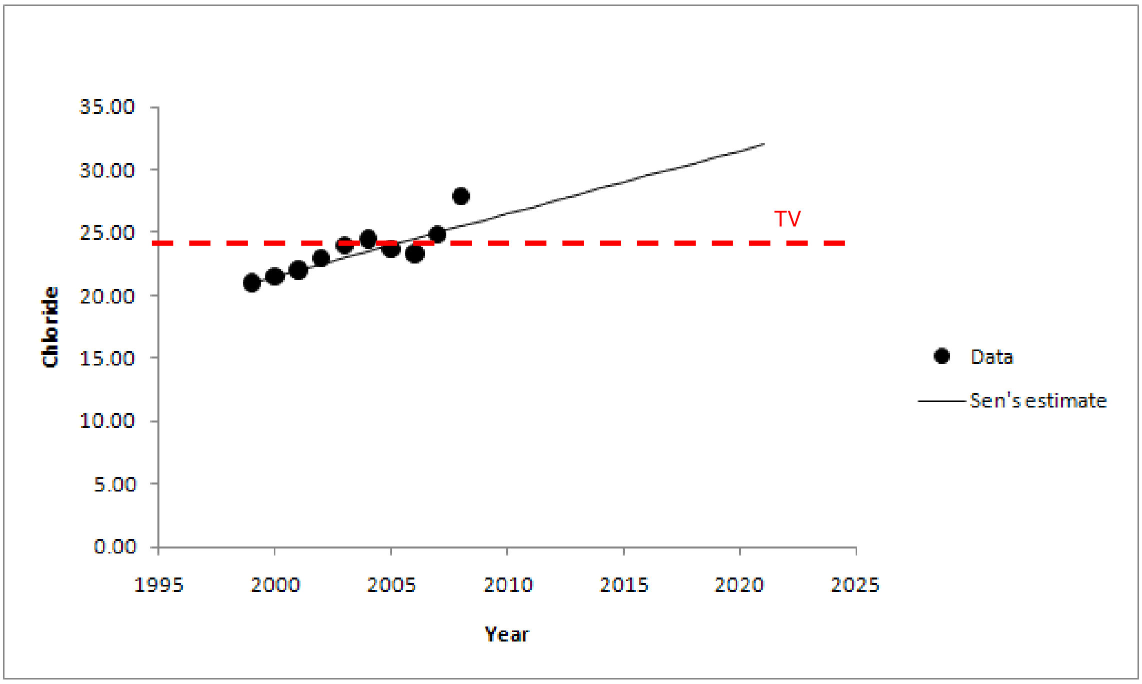
Significant Upward Trend for Ammonium at Tir na League (05_005)



Statistically Significant Downward Trend for Chloride at Doon (13_008)



No Significant Trend for Molybdate Reactive Phosphorus at Boyle-Rockingham (20_006)



Statistically Significant Upward Trend for Chloride for a group of Groundwater Bodies