GIS tool to delineate groundwater capture zones

M.W. Toews

M.A. Gusyev

GNS Science Report 2012/06
March 2013

BIBLIOGRAPHIC REFERENCE

Toews, M.W.; Gusyev, M.A. 2013. GIS tools to delineate groundwater capture zones, *GNS Science Report* 2012/06. 24p.

M.W. Toews GNS Science, PO Box 30368, Lower Hutt
M.A. Gusyev GNS Science, PO Box 30368, Lower Hutt

© Institute of Geological and Nuclear Sciences Limited, 2013

ISSN 1177-2425
ISBN 978-0-478-19885-0

CONTENTS

FIGURES

APPENDICES

ABSTRACT

GNS Science has developed a capture zone delineation toolkit (GNS Groundwater Tools) to apply either the calculated fixed radius or the uniform flow equation methods to conduct capture zone delineation using ArcGIS 9.3 and 10.0. The toolkit consists of both the capture zone delineation ArcGIS toolboxes for versions 9.3 and 10.0, as well as the core algorithms, programmed in Python, which can be implemented in other GIS applications (e.g., Quantum GIS).The capture zone is mapped as a polygon for a groundwater well or a spring and represents the surrounding aquifer area sourcing groundwater to the outlet point. This report provides of a brief theoretical background of the equations used in the calculated fixed radius and the uniform flow equation methods, describes the limiting assumptions of each method and demonstrates the use of the tools with ArcGIS software.

KEYWORDS

GIS, Python, capture zone, fixed radius, uniform flow equation

1.0 INTRODUCTION

A number of countries require delineation of protective zones around water supply wells in order to ensure that water quality is maintained (USEPA 1987, 1994; UKEA 2009). These protective zones are called capture zones and are mapped on the top of the terrain surface (Figure 1). The capture zone represents the aquifer volume in which groundwater flow is diverted into the pumping well from the surrounding aquifer. Land use activities that occur within the delineated capture zone can potentially influence drinking water quality.

Several methods have been established by USEPA (1987) to delineate capture zones for different aquifer settings (Gusyev et al., 2011). These methods vary from simple approaches using relatively arbitrary guidelines to complex methods using computer numerical modelling. The selection of the appropriate capture zone delineation method to use depends on capture zone accuracy required and the availability of site data. Semi-analytic and numerical models are currently being used by GNS Science to establish capture zones at groundwater monitoring wells used as a part of the National Groundwater Monitoring Programme (NGMP) (Gusyev et al., 2011). Typically, when modelling capture zones using numerical modelling methods, it is necessary to adopt simplifying assumptions such as steady-state conditions and a constant pumping rate. Where possible, complex aquifer hydrogeology should be incorporated (e.g., faults, multiple layers, hydraulic connectivity). However, in many cases, only limited hydrogeological information is available for capture zone delineation and it is necessary to apply simple capture zone delineation methods (USEPA 1987, 1994; Carey et al., 2009). In New Zealand, the capture zone methodologies are currently under review in order to develop national guidelines to be used in delineating capture zones for wells, springs, small lakes, and wetlands (Ministry of Business, Innovation and Employment, 2009).

The use of an analytical model is a relatively simple approach that can be used to delineate capture zones and some of these type models can be implemented with a custom-build spreadsheet. However, the combination of analytical solution methods and spatial data, such as groundwater levels, is not trivial, nor is the sensitivity analysis on the input parameters. Therefore, in order to draw first approximation capture zones using such methods, there is a need for a GIS-based user-friendly tool that will be available for regional authorities and other interested parties for sustainable groundwater management purposes.

This report introduces the "GNS Groundwater Tools" which consist of an ArcGIS Toolbox to delineate capture zones around pumping wells with analytical solutions such as the calculated fixed radius and uniform flow equation. This report provides a brief theoretical background of the equations used in the GNS Groundwater Tools and demonstrates the use of these tools in ArcGIS versions 9.3 and 10.0. It also contains the core algorithms programmed in Python (http://www.python.org), should the user want to implement these tools in other GIS software (e.g., Quantum GIS). Examples of the use of this tool can be found in Gusyev & Toews (2012) and are not discussed further in this report.

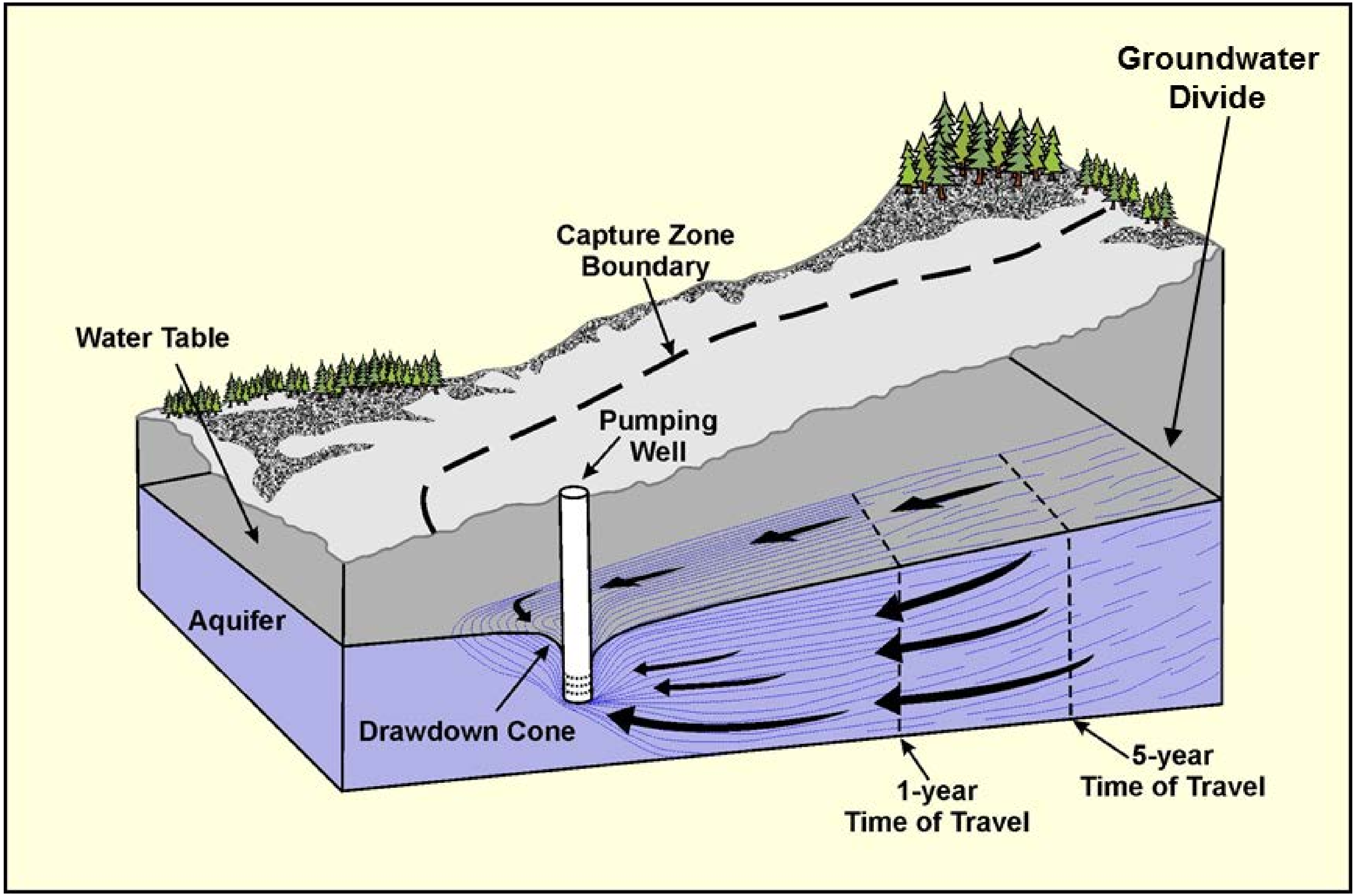

Figure 1. Idealised shape of a capture zone for a well in a homogeneous, isotropic, unconfinedaquifer. The regional groundwater flow direction is from right to left (modified from British Columbia Ministry of the Environment, 2004).

2.0 ANALYTICAL CAPTURE ZONE DELINEATION METHODS

Analytical methods such as the calculated fixed radius equation (USEPA 1987, 1994) and the uniform flow equation (Bear and Jacobs 1965; Todd 1980; Grubb 1993) are some of the simplest capture zone delineation methods. These analytical methods do not factor in many of the real world complexities of aquifer systems, but are compatible with limited available information.

2.1 Calculated Fixed Radius

2.1.1 Method

The calculated fixed radius method uses the groundwater volume of a cylinder as the water, which is available for abstraction from an aquifer. In this method, a homogeneous isotropic aquifer with constant thickness and without hydraulic gradient is assumed. As a result of these assumptions, a radius *r* [L][1] of a circular capture zone is obtained from (USEPA 1987):

$$\mathrm{r} = \sqrt{\frac{\mathrm{Qt}}{\pi \mathrm{nb}}} \qquad (1)$$

Where Q [L^3/T] is the pumping rate t [T] is the travel time, n [L^3/L^3] is the effective aquifer porosity and b [L] is the saturated thickness of the aquifer, which assuming horizontal flow can be approximated as the length of well screen. Selecting the length of well screen as the b term in the equation provides for a larger capture zone than would be the case if the actual aquifer thickness was used and therefore is more conservative.

The time variable in the equation (1) represents the time of travel of groundwater particles in the aquifer towards the well or the spring. Using this method, capture zones can be delineated using a travel time criteria. Often several travel times can be used to delineate several capture zone "rings" around a well, representing different travel times (e.g., 30-days, 1-year, etc.).These groundwater travel times can be linked to contaminants with a specific life span in an aquifer. For example the maximum pathogen persistence in an aquifer is estimated to be 50 days (UKEA, 2009) and can be used in equation (1) to delineate a capture zone for microbial protection of the drinking water production well.

2.1.2 Limitations

The calculated fixed radius method of capture zone delineation does not account for aquifer extent and type, hydraulic gradient, groundwater recharge, variations in aquifer properties and pump rates, or boundary effects of springs, streams and nearby pumping wells. In addition, other sources of water such as rainfall recharge and aquifer leakage are also ignored in equation (1). Therefore, this method is most appropriate for confined aquifers with no vertical leakage from overlying hydrostratigraphic layers and less suitable for unconfined aquifers, as it does not consider the variable height of the water table.

[1] The first letter stands for the variable of concern (r for capture zone radius in this case) while the letter in brackets indicates the units (L means units of length and T means units of time).

2.2 Uniform Flow Equation

2.2.1 Method

In this method a coordinate system is defined with the pumping well at the origin, the x-axis along the ambient flow direction through the pumping well and the y-axis, perpendicular to the x-axis, through the origin. The uniform flow equation provides a capture zone boundary of a parabolic shape for a steady-state pumping well (the origin of the coordinate system) in a homogeneous, isotropic aquifer with constant thickness and uniform hydraulic gradient (Bear and Jacobs 1965; Todd 1980):

$$x = \frac{-y}{\tan\left(\frac{y 2\pi Q_0}{Q}\right)} \tag{2}$$

Where Q [L^3/T] is the discharge from the pumping well, Q_o [L^2/T] is the ambient specific discharge flow in the aquifer along the *x*-direction per 1 m in the *y*-direction, and x [L] and y [L] are the distances from the pumping well at the origin to the bounding streamline in *x*-direction and *y*-direction, respectively. Note that solving equation (2) for y requires iterative methods. The ambient uniform flow is based on Darcy's law and, therefore, depends on whether or not the aquifer is confined as follows (Todd 1980):

- for a confined aquifer:

$$Q_0 = Kbi \tag{3}$$

  Where K [L/T] is the hydraulic conductivity, b [L] is the aquifer thickness, and i [L/L] is the hydraulic gradient in the aquifer.

- for an unconfined aquifer:

$$Q_0 = Kh_{avg}i \tag{4}$$

  Where $\mathrm{h_{avg}}$ [L] is the average water table height in the unconfined aquifer.

From equation (2), the capture zone boundary, which is shown by the green line, separates groundwater captured by the pumping well and groundwater that is not captured (Figure 2). In Figure 2, the capture zone has a parabolic shape in planar view and the orientation of the capture zone is governed by the ambient flow direction, which is uniform and is parallel to the *x*-axis. The bounding streamline of the capture zone is drawn using five calculated points for the pumping well placed in the origin. The first point, which is also known as the stagnation point, is located on the *x*-axis in the negative *x*-direction (a downgradient tip of the capture zone boundary). The other four points are symmetrical to the *x*-axis. The two points are located on the *y*-axis opposite the well and the two points are located infinitely far away from the well. The locations of these five points can be found using the following equations:

The distance x_0 [L] from the pumping well to the stagnation point, can be expressed as:

$$x_0 = \frac{-Q}{2\pi Q_o} \tag{5}$$

The distance in the *y*-direction from the pumping well to the capture zone boundary is the half-width of the capture zone above and below the well:

$$y_0 = \frac{\pm Q}{4Q_o} \tag{6}$$

Assuming the distance upgradient from the pumping well in the *x*-direction leads to the maximum half-width of the capture zone boundary from equation (2):

$$y_{max} = \frac{\pm Q}{2Q_0} \tag{7}$$

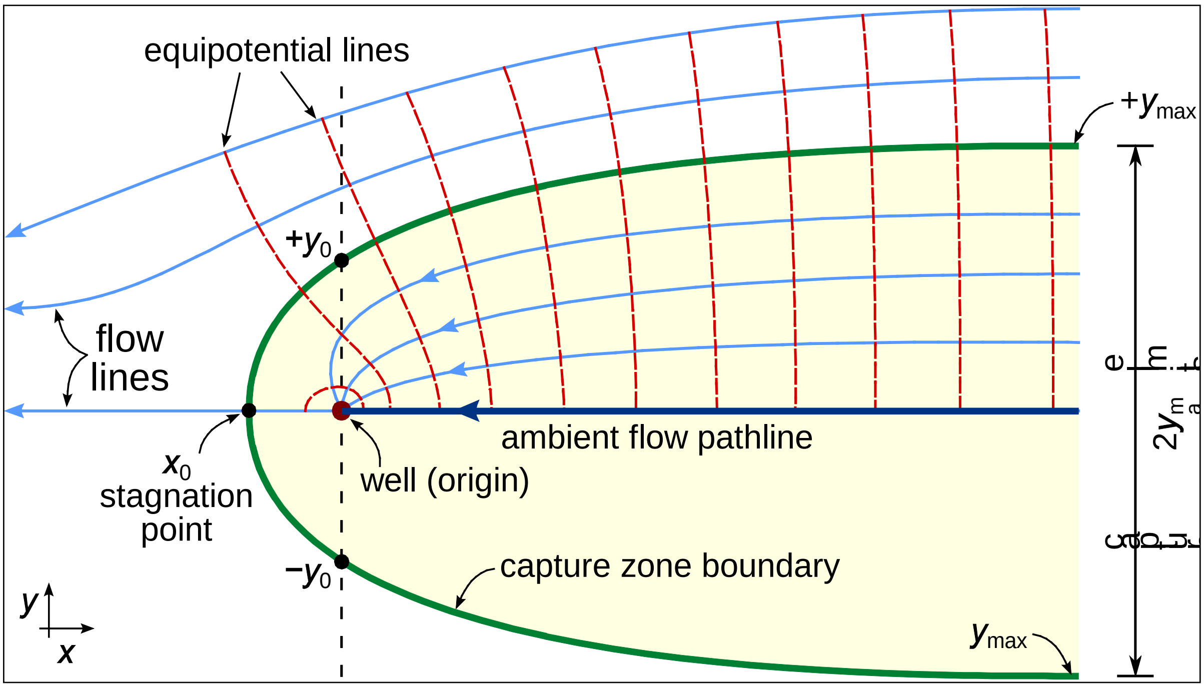

Figure 2. A plan view of the capture zone for a pumping well (modified from USEPA 1987). The origin for the coordinate system is at the pump well.

Average ambient groundwater velocity, $\bar{v}$ [L/T], can be calculated using Darcy's law:

$$\bar{v} = \frac{Ki}{n} \tag{8}$$

Where *n* [L^3/L^3] is the aquifer porosity. However the influence of the pumping well accelerates groundwater flow as water approaches the well. Thus, the travel time t_x [T] from a point r_x on the *x*-axis to the pumping well can be determined using the equation (4-7) in USEPA (1994):

$$t_x = \frac{1}{\bar{v}}\left[r_x + x_0 \ln\left(1 - \frac{r_x}{x_0}\right)\right] \tag{9}$$

The distance term $\mathrm{r_x}$ [L] is the distance over which groundwater travels along the *x*-axis and is positive if the point is upgradient and is negative if down gradient the well. Note that solving equation (9) for $\mathrm{r_x}$ requires iterative methods. Different travel time represented as t_x can be used to delineate several capture zones based on a travel time criteria, (e.g., 30-days, 1-year, etc.).

2.2.2 Limitations

The uniform flow capture zone method does not account for groundwater recharge, variations in aquifer properties and pump rates, or boundary effects of springs, streams and nearby pumping wells. This method assumes an ambient uniform flow in the aquifer with one hydraulic groundwater gradient and cannot account for spatially variable groundwater gradients.

3.0 GNS GROUNDWATER TOOLS

The GNS Groundwater Tools consist of a Python module and a Toolbox for ArcGIS. All of the algorithms are programmed in Python, and do not depend on ArcGIS. Therefore, the tools can be implemented in other GIS applications (e.g., Quantum GIS). These instructions assume use within ArcGIS versions 9.3 or 10.

3.1 Software Requirements

Shapely (version 1.2.14 or later) is required, which can be installed on the version of Python used by ArcGIS. Shapely is a Python extension to process geometries using the GEOS library, a part of the Java Topology Suite. Shapely can be downloaded from one of the following sources:

- http://pypi.python.org/pypi/Shapely
- http://www.lfd.uci.edu/~gohlke/pythonlibs/#shapely

To choose the correct version of Shapely to download and install, it is important to match the version and platform of Python used by ArcGIS. Generally, this is Python 2.5 for ArcGIS 9.3 and Python 2.6 for ArcGIS 10.

3.2 GNS Groundwater Tools File Contents

Extract the contents of the GNS Groundwater Tools into a folder of your choice. The folder should now contain the following subdirectories and files:

- GNS Groundwater Tools – *main folder*
    - ArcGIS 9.3
        - GNS Groundwater Tools.tbx
    - ArcGIS 10.0
        - GNS Groundwater Tools.tbx
    - Python – *package files*
        - ArcGIS_CZCalculatedFixedRadius.py
        - ArcGIS_CZUniformFlow.py
        - ggw – *module files with algorithms*
        - tests – *unit tests*

3.3 Adding the Toolbox to ArcGIS

The toolbox can be added to ArcGIS by browsing through files in the ArcCatalog (Figure 3) or drag-and-drop in ArcMap (Figure 4). It can also be attached by right-clicking the Toolbox iconand selecting"Add Toolbox..." (Figure 5). Then locate the correct Toolbox file for the version of ArcGIS.

Figure 3. Selecting the relevant Toolbox version.

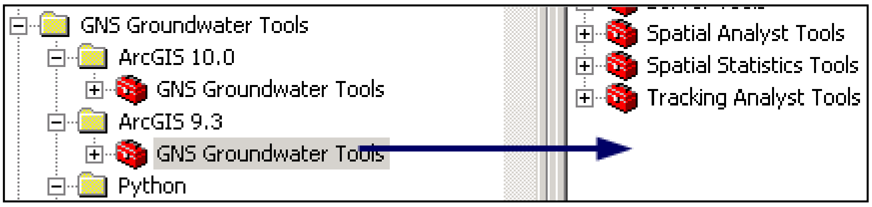

Figure 4. Adding to the ArcGIS Toolbox using a drag-and-drop.

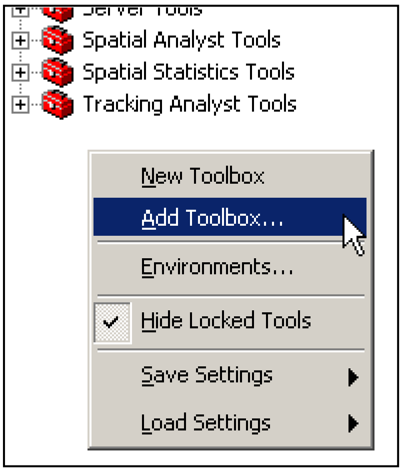

Figure 5. Adding to the ArcGIS Toolbox using “Add Toolbox” feature.

3.4 Using the GNS Groundwater Toolbox in ArcGIS

3.4.1 Calculated Fixed Radius

The calculated fixed radius method requires a point shapefile with the location of a well, as well as information about pump rate, travel time, effective porosity, and either the saturated aquifer thickness or the screen length (Figure 6). After a successful run (Figure 7), the delineated capture zone should appear in the ArcGIS window as a new polygon shapefile (Figure 8).

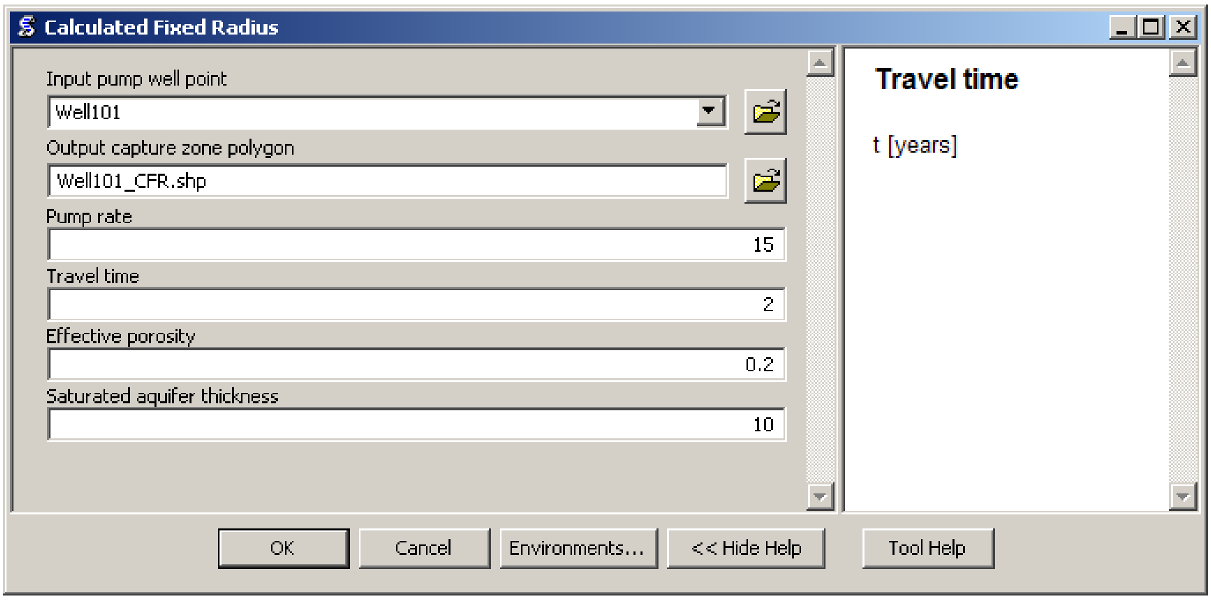

Figure 6. Using the calculated fixed radius capture zone tool.

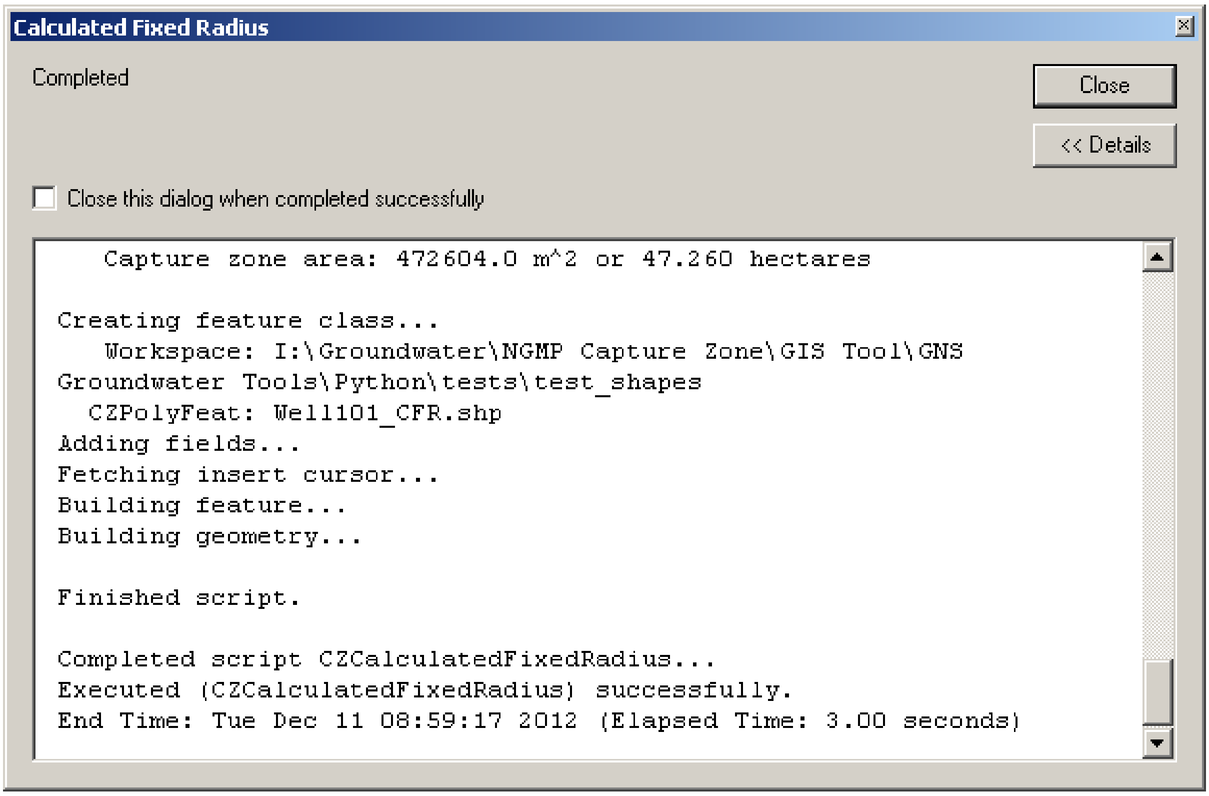

Figure 7. Results from the calculated fixed radius capture zone tool.

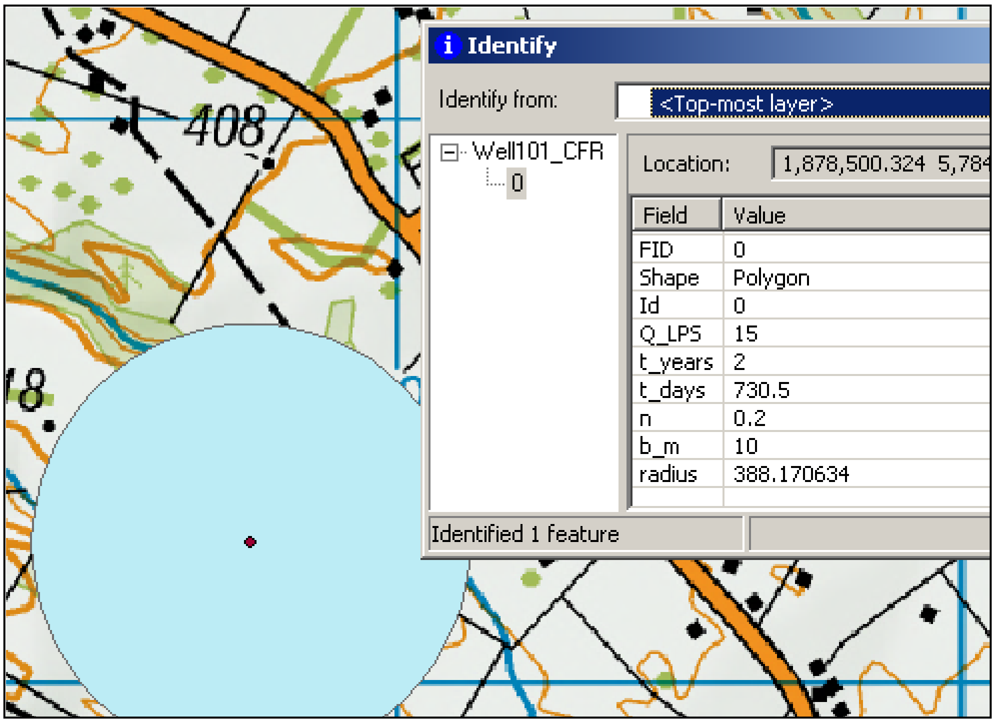

Figure 8. Map showing a well and calculated fixed radius capture zone. The feature attributesare also shown to the right.

3.4.2 Uniform Flow Equation

3.4.2.1 Digitising Ambient Flow Path Direction

A polyline shapefile representing the ambient flow path direction must be created either by digitising an existing groundwater flow path map or through interpretation of groundwater contours (Figure 9). The latter can be obtained by interpolating from discrete measurements.

The polyline should start at the well and should follow a path upstream that is perpendicular to groundwater contours and ends at the highest groundwater elevation. In the edit mode in ArcGIS, the shortcut CTRL + E can be used to draw lines perpendicular to other contour polyline layers. The edge snapping option (Edit toolbar) can be used to trace directly on contours. If a path is traced in the opposite direction (from upstream to the well), it needs to be “flipped” by selecting the object in the map view in edit mode, right clicking the map and selecting "flip" from the context menu. Make sure to save and stop editing the feature before proceeding any further.

If no groundwater contours are available topographic contours may be used as a proxy to derive both the gradient direction and value for unconfined aquifers in areas of low topographic gradients.

The flow path polyline should stop where a hydraulic boundary relevant to the aquifer is met, typically a groundwater divide or a fault.

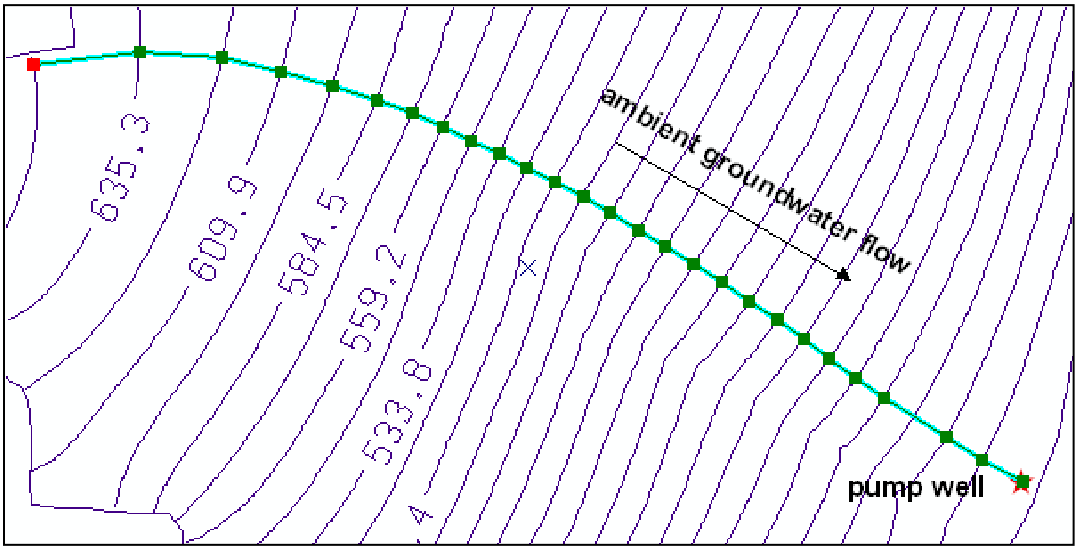

Figure 9. Digitising an ambient flow pathline using groundwater contour data. The line is digitised starting at the pump well, and is drawn upstream perpendicular to the groundwater contour lines using the CTRL + E key combination. The red square represents the end of the line, which should be the furthest upstream coordinate for the ambient flow pathline.

3.4.2.2 Capture Zone Delineation Using the Uniform Flow Equation

Double-clicking on the tool icon of the ArcGIS tool “Toolbox” > "GNS Groundwater Tools" > "Capture Zone" > "Uniform Flow" will open the tool dialog (Figure 10). The required parameters are hydraulic conductivity [m/day], saturated aquifer thickness [m], and pump rate [L/s]. For the interpretation of thickness for confined or unconfined aquifers see equations (3) and (4), respectively. For confined aquifers, use the aquifer thickness, whereas for unconfined aquifers use the average saturated thickness (e.g., from the aquifer bottom to the water table). The time input is optional enabling capture zone delineation on travel time criteria.

An example summary of a successful capture zone calculation is shown in Figure 11. After a successful run, the delineated capture zone should appear in ArcGIS window as a new polygon shapefile (Figure 12).

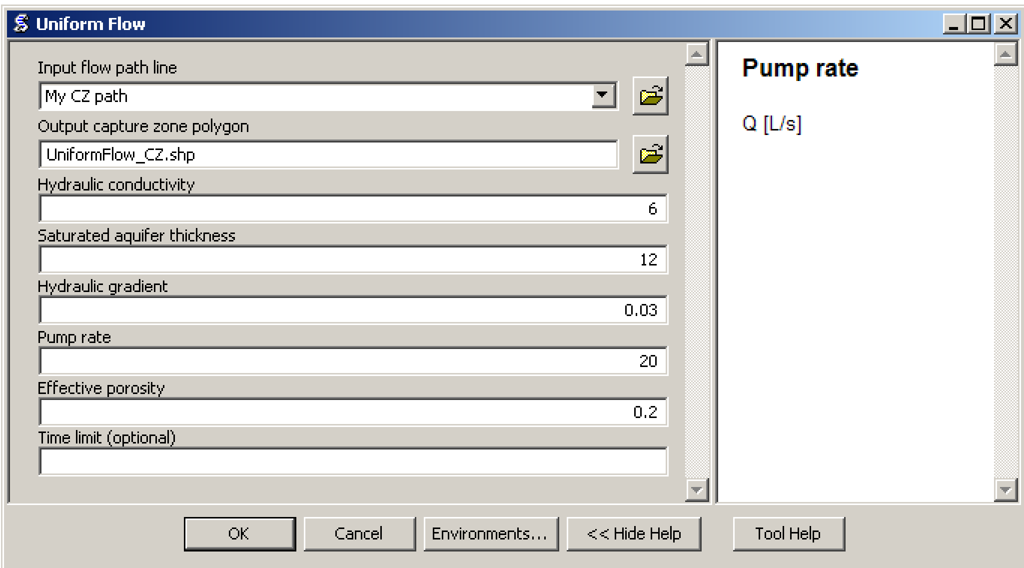

Figure 10. Using the uniform flow equation capture zone tool.

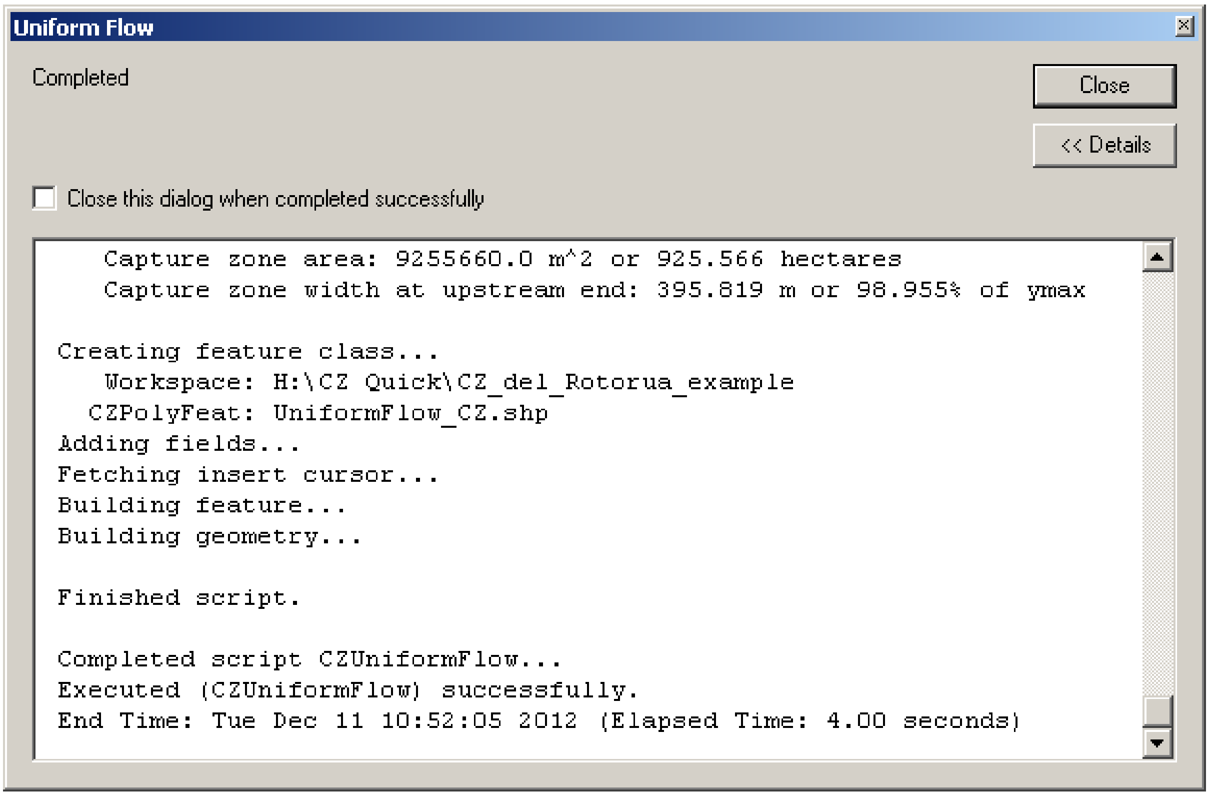

Figure 11. Results from the uniform flow capture zone tool.

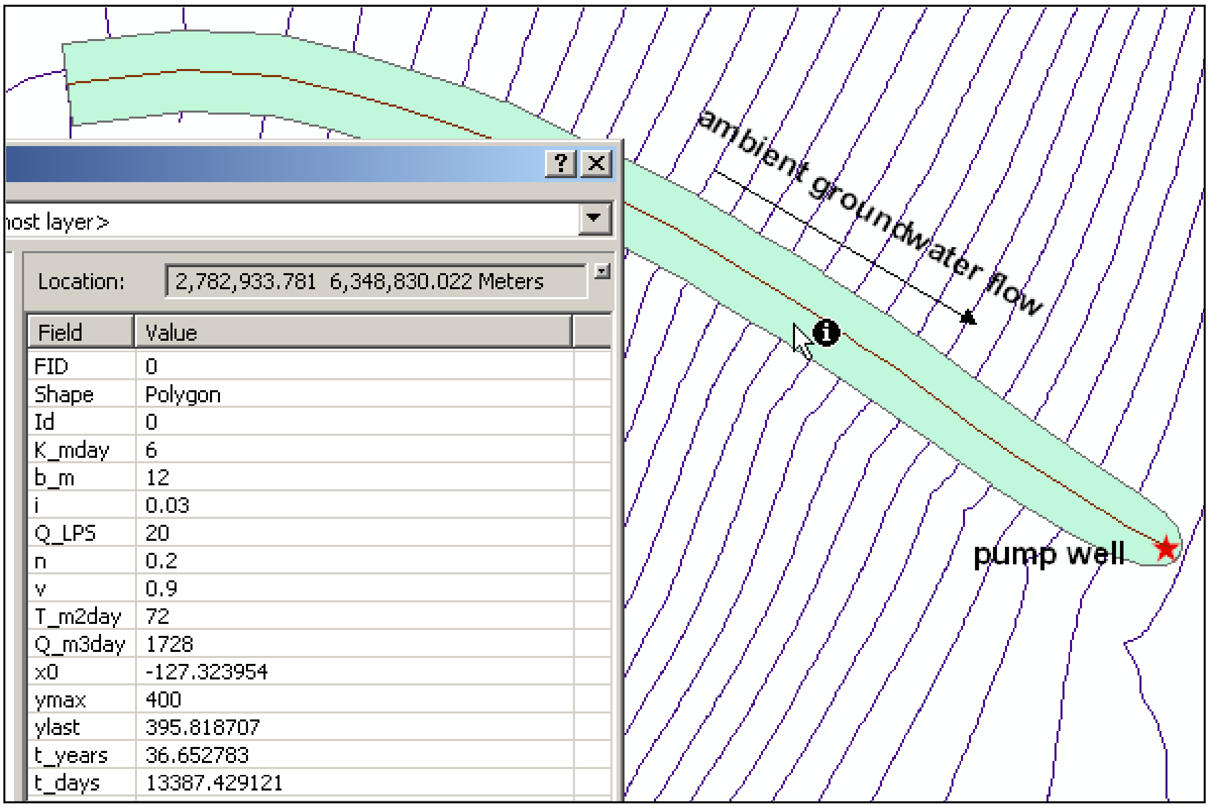

Figure 12. Map showing a well and the calculated uniform flow capture zone. The feature attributes are also shown to the left.

3.4.3 Batch Mode of the GNS Groundwater Tools

A sensitivity analysis of the resulting capture zone shape can be done by running the capture zone delineation tools in batch mode. Any ArcGIS tool can be run in batch mode by right clicking on the tool (Figure 13). The console of the batch model should appear which is shown in Figure 14. The number of capture zone runs is set to a default value of 3 and can be expanded by clicking the “+” icon. Each batch run uses the same ambient flow path and requires the same input as the single capture zone delineation. Figure 15 shows a sensitivity analysis on hydraulic conductivity, while the remaining input parameters are kept the same. Each of the batch model runs will result in the generation of a capture zone shapefile.

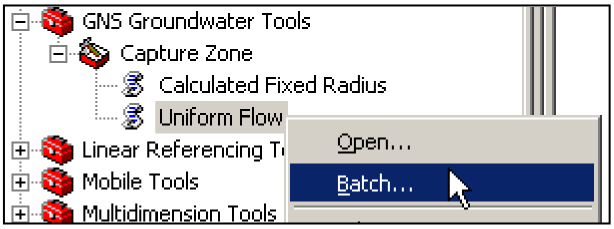

Figure 13. Selecting the batch mode

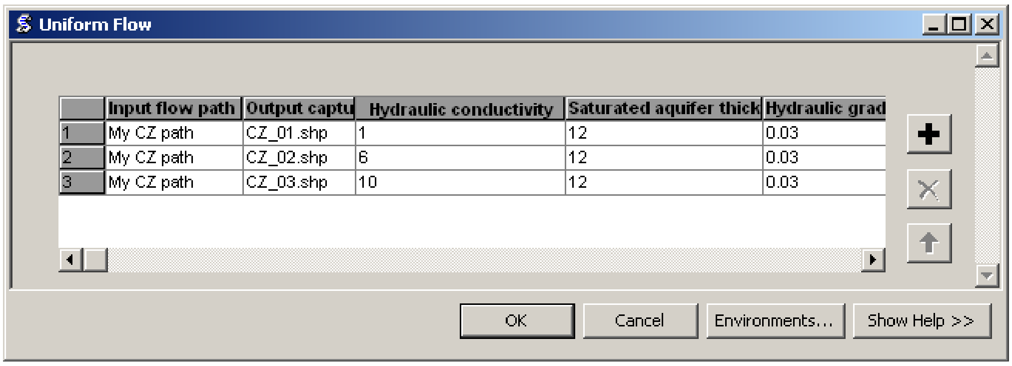

Figure 14. Input data for the the batch mode operation with varying hydraulic conductivity values.

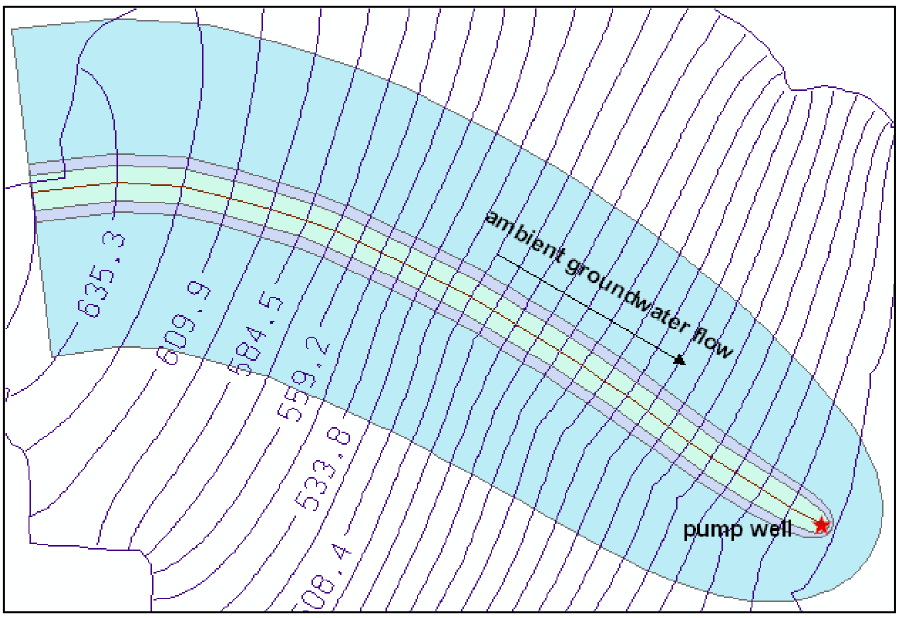

Figure 15. Mapped results of a batch process showing three different capture zones generated using different hydraulic conductivity values.

4.0 SUMMARY

GNS Science has developed a user-friendly, GIS-based capture zone delineation toolkit (GNS Groundwater Tools) to help delineate capture zones using either the calculated fixed radius or the uniform flow equation methods. The toolkit consists of the capture zone delineation ArcGIS toolbox (either version 9.3 or 10, as appropriate for the version installed on the user's computer), as well as the core algorithms, programmed in Python, which can be implemented in other GIS applications (e.g., Quantum GIS). Sensitivity and uncertainty analysis for delineated capture zones in any of the ArcGIS capture zone tools can be performed through batch processing for hydraulic parameters.

Simple capture zone delineation methods (i.e., calculated fixed radius and the uniform flow equation methods) require minimum data and can provide quick mapping of an estimated capture zone. Groundwater recharge, aquifer extent, variations in aquifer properties, and effects of streams and nearby pumping wells are not taken in account in these methods. With the calculated fixed radius method, the resulting capture zone is a circular polygon, calculated from pump rate, travel time, aquifer thickness and effective porosity. With the uniform flow equation, the resulting capture zone is a parabolic polygon that follows the ambient flow path upgradient. The width of the capture zone is calculated from hydraulic conductivity, saturated aquifer thickness, hydraulic gradient, well pumping rate, effective porosity and optional time travel limit. The GNS Groundwater Tools are suited for first approximation capture zone delineation; however, should more data become available or groundwater flow models be developed, the capture zones could be refined by using more sophisticated methods.

5.0 ACKNOWLEDGEMENTS

We thank Magali Moreau-Fournier, Conny Tschritter and Gil Zemansky for their reviews and insightful comments on the report.

6.0 REFERENCES

Bear, J and Jacobs, M. 1965 On the Movement of Water Bodies injected into Aquifers. Journal of Hydrology 3: 37-57.

British Columbia Ministry of the Environment. 2004 Well Protection Toolkit Step 2 (electronic resource). 24 p. Accessed 30 January 2013 at http://www.env. gov.bc.ca/wsd/plan_ protect_sustain/groundwater/wells/well_protection/pdfs/step2.pdf .

Carey, M.; Hayes, R.; Renner, A. 2009 Groundwater Source Protection Zones - Review of Methods. Environment Agency Science Report. SC070004/SR1, UK Environment Agency. 92 pp.

Grubb, S. 1993 Analytical model for estimation of steady-state capture zones of pumping wells in confined and unconfined aquifers. Ground Water 31, no. 1: 27-32.

Gusyev, M.A.; Tschritter, C.; Moreau-Fournier, M.; Daughney, C.J. 2011 Capture zone delineation for National Groundwater Monitoring Programme sites in the Southland region. Lower Hutt: GNS Science. GNS Science report 2011/31. 54 p.

Gusyev, M.A.; Toews, M.W. 2012 Capture zone delineation and analysis of the public water supply well #1762, Ruataniwha Plains, Hawke's Bay. GNS Science consultancy report 2012/28LR. 11 p.

Ministry of Business, Innovation and Employment, 2009 Tools Development Envirolink Grant Round 6, R6-2-capture zoneGNSX1001: Capture zone guidelines for hydrogeological features, Accessed 19 February 2013 at http://www.envirolink.govt.nz/Envirolink-tools/

Todd, D.K. 1980 Groundwater Hydrology. John Wiley and Sons, NY. 535 p.

UKEA. 2009 Groundwater Source Protection Zones – Review of Methods. Environment Agency Science Report: SC070004/SR1, UK Environment Agency. 101 p.

USEPA. 1987 Guidelines for Delineation of Wellhead Protection Areas. U.S. Environmental Protection Agency, Office of Ground-water protection. 215 p.

USEPA. 1994 Handbook of Ground Water and Wellhead Protection. U.S. Environmental Protection Agency, EPA/625/R-94/001. 288 p.

APPENDICES

APPENDIX A – UNIT TESTING

Unit tests are included with GNS Groundwater Tools to ensure that the tools behave as expected on different computer setups. ArcGIS is not required. Either Python version 2.7 or greater or the unittest2 package is required.

The unit tests are written in Python, and can be run from CMD.EXE. First CD into the "GNS Groundwater Tools\Python" folder, then run the command "python setup.py test". For example, to run the tests with Python version 2.5 installed by ArcGIS, use the command "c:\Python25\python.exe setup.py test"

```
C:\WINDOWS\system32\cmd.exe
Microsoft Windows XP [Version 5.1.2600]
(C) Copyright 1985-2001 Microsoft Corp.

C:\>cd C:\ARCGIS\GNS Groundwater Tools\Python

C:\ARCGIS\GNS Groundwater Tools\Python>c:\Python25\python.exe setup.py test
running test
test_command_line (tests.unit_tests.TestArcGISCZCalculatedFixedRadius) ... ok
test_command_line (tests.unit_tests.TestArcGISCZUniformFlow) ... ok
test_bad_input (tests.unit_tests.TestCZCalculatedFixedRadius) ... ok
test_basic_usage (tests.unit_tests.TestCZCalculatedFixedRadius) ... ok
test_Excel_spreadsheet_tool (tests.unit_tests.TestCZUniformFlow) ... ok
test_bad_input (tests.unit_tests.TestCZUniformFlow) ... ok
test_basic_usage (tests.unit_tests.TestCZUniformFlow) ... ok
test_case1 (tests.unit_tests.TestCZUniformFlow) ... ok
test_case2 (tests.unit_tests.TestCZUniformFlow) ... ok
test_dhdl (tests.unit_tests.TestCZUniformFlow) ... ok
test_shapes (tests.unit_tests.TestCZUniformFlow) ... ok

----------------------------------------------------------------------
Ran 11 tests in 8.329s

OK

C:\ARCGIS\GNS Groundwater Tools\Python>
```

APPENDIX B – DISCLAIMER

Institute of Geological and Nuclear Sciences Limited (GNS Science)

Aquifer Capture Zone Delineation Toolkit

Terms of Access and Use

By using the capture zone delineation software toolkit (the Product) you agree to the following terms and conditions.

GNS Science grants you on these terms and conditions a personal, non -exclusive, non-assignable licence to access, download and use the Product for aquifer capture zone delineation.

You may not:

- transfer or sublicence the Product;
- publish or provide copies of all or any substantial part of any of the Product to any other parties, without prior written permission from GNS Science; or
- on-sell the Product or portions of the Product to make a commercial or financial gain.

Where you publish portions of the Product or data derived from use of the Product you must:

- identify the source of the Product and the derived data, and acknowledge GNS Science by citing Toews M.W. and Gusyev M. A. (2013) GIS tools to delineate groundwater capture zones, GNS Science Report 2012/06.19 p. ;
- state that the Product is held under licence from GNS Science; and
- state that GNS Science gives no warranties and makes no representations (express or implied) as to the accuracy, completeness, currency or fitness for purpose of the Product or that use of the Product will not infringe any third party intellectual property rights.

Derivative material created from the Product must, where practicable, acknowledge GNS Science and contain a statement that they are derived from the Product, and that the Product is held under licence from GNS Science.

GNS Science retains title to all intellectual property rights in the Product, including copyright.

Although GNS Science has made all reasonable endeavours to ensure the accuracy and completeness of the Product, the Product are licenced “AS IS” and “AS AVAILABLE” and its use is at your sole risk. Accordingly, GNS Science gives no warranties and makes no representations (express or implied) as to the accuracy, completeness, currency or fitness for purpose of the Product or that any information obtained from the Product will be accurate or reliable or that use of the Product will not infringe any third party intellectual property rights.

GNS Science excludes and shall have no liability for any loss, damage or expense, however caused, whether through its negligence or otherwise resulting from you or any other person, company or organisation using or relying on the Product, or any derivatives created from the Product or on information obtained from the Product or derivatives. License holder assumes all responsibility for use of and reliance on the Product, derivatives and information obtained from them.

Any Product downloaded is done at your own risk and you are solely responsible for any loss or damage to your computer system or loss of data that results from the download.

The term of this licence is indefinite, but it may be terminated by GNS Science for breach.

This licence agreement is governed by New Zealand law. References to “you” in these terms of use include the organisation for whom you are accessing and using the Product.

www.gns.cri.nz

Principal Location

1 Fairway Drive
Avalon
PO Box 30368
Lower Hutt
New Zealand
T +64-4-570 1444
F +64-4-570 4600

Other Locations

Dunedin Research Centre
764 Cumberland Street
Private Bag 1930
Dunedin
New Zealand
T +64-3-477 4050
F +64-3-477 5232

Wairakei Research Centre
114 Karetoto Road
Wairakei
Private Bag 2000, Taupo
New Zealand
T +64-7-374 8211
F +64-7-374 8199

National Isotope Centre
30 Gracefield Road
PO Box 31312
Lower Hutt
New Zealand
T +64-4-570 1444
F +64-4-570 4657