HAWKESBURY-NEPEAN CATCHMENT GROUNDWATER VULNERABILITY MAP

Within the Hawkesbury-Nepean Catchment, the features which were deemed important in the development of the groundwater vulnerability map included: Depth to Water Table, Recharge, Aquifer Media, Soil Media, Topography, and Impact of Vadose Zone. Ranges and ratings for the DTWT, Topography, and Aquifer Media are given in Tables 1, 2, and 3 respectively.

Depth to Watertable

The depth to groundwater is one of the major parameters when dealing with vulnerability of groundwater, (ie the shorter the distance to groundwater, the less soil and underlying unsaturated material there is to act as a filter or retardant). Depth to groundwater also affects the transit time available for various abiotic and biotic processes to degrade the pollutant (National Research Council, US, 1993). Minimum Depth to Groundwater (MDGW) in groundwater vulnerability mapping, refers to the depth to the watertable in unconfined conditions and the depth to the potentiometric surface in the semi-confined and confined conditions where watertable conditions are either missing or temporal. Both of these surfaces are defined by the SWL of the bores.

The Depth to Watertable Component Map is a representation of the spatial distribution of the depth to the groundwater. Depth to groundwater information and data is obtained from historical records and bore logs, existing reports, as well as specific fieldwork. The resulting map is however quite subjective and represents a simplified model of the groundwater conditions of the catchment.

The construction of the DTWT map relied, in the first instance, on the most recent SWL information available for data points; or, in the second instance, the SWL value indicating the seasonally highest SWL value. Where semi-confining/confining aquifer conditions were present and/or watertable was absent, an assessment by the hydrogeologist using driller's information extracted from the Groundwater Data System (GDS) was used to choose the approximate depth to the watertable. Often this meant the use of the potentiometric surface where the material above the logged aquifer was thought to be impermeable (i.e where large amounts of clay or shale were acting as a confining layer). Data points were then contoured with consideration to the groundwater system operating, topography, geology, and local knowledge.

The construction of a map portraying water level conditions of a range of aquifer types, ie confined, semi-confined and unconfined, across hydrogeological units is a very complicated task. Data was insufficient to take account for seasonal variations, which particularly effect the unconfined aquifers, and aquifer details in some of the fractured rock areas.

The DTWT Component Map for the Hawkesbury Nepean Catchment is a generalisation of the depth to groundwater found within the study area, and was produced at 1:250,000 scale. The map was constructed specifically for the purposes of the groundwater vulnerability mapping, and should be used only as a guide to the expected DTWT.

Table 1 - Ranges and Ratings for Depth to Water

Depth to Water Table (m)

Range	Rating
< 5	10
5 – 10	7
10 – 15	4
>15	1
Weight 3	

Slope

The slope component map was compiled within the GIS environment from the nine second digital elevation model (DEM) data currently available from the Land Information Centre (LIC). This map was then used to help compile Recharge map as the relief of an area plays an important factor in the quantity of recharge.

Table 2 - Ranges and Ratings for Topography

Topography as Slope %

Range	Rating
< 10%	10
10 - 20%	8
20 - 30%	5
30 - 40%	3
>40%	1
Weight 1	

Aquifer Media

The aquifer media component map governs the route and path length (flow system) within the aquifer. The path length is important in determining the time available for attenuation processes such as sorption, reactivity, and dispersion. The aquifer medium also influences the amount of effective surface area of materials with which the contaminant may come in contact within the aquifer. The route that a contaminant will take can be strongly influenced by fracturing, porosity, or by an interconnected series of openings which may provide pathways for easier flow.

For the Hawkesbury Nepean Catchment, the aquifer media was defined by its geology. Geology is the major component relating to groundwater in terms of both its chemical and physical parameters. Therefore, geology is very important in segregating different hydrogeologic systems and provides a prediction of groundwater conditions. The aquifer media component map has been produced from the following published geological maps;

Goulburn, Singleton, Sydney and Wollongong 1:250 000 Geological Map Sheets,

The geology has been grouped into the following broad categories;

- Quaternary Alluvium - unconsolidated sediments associated with the major groundwater production channels.
- Tertiary Alluvium - this is a broad classification for all the lower yield alluvium not associated with the major channel alluvium. This includes alluvial deposits within the hardrock terrain.
- Hawkesbury Sandstone - these rocks are usually associated with the Great Artesian Basin intake beds. They are considered to be relatively unaffected by past tectonic events and therefore display only primary porosity.
- Limestone - these rocks represent formations of the New England Fold Belt and have been affected by past tectonic events. As a result, they have a reduced primary porosity and consequently have developed a secondary porosity in the form of fractures, faults and joints from which groundwater is available.
- Volcanic - most of the volcanic rocks within the Basin are Tertiary aged basalts. These rocks convey groundwater through cracks, fractures, and joints formed mainly during the cooling of the volcanic material.
- Plutonic - these rocks are also associated with the New England Fold Belt, however they are relatively young for plutonic rocks being typically Permian in age. As a result of the slow cooling

during the formation of plutonic bodies, they typically have a low intensity of fracturing. These rocks include, granite, granodiorite and adamellite.

- Metasediments - these rocks are generally the older rocks of the New England Fold Belt. They consist typically of low grade metamorphosed, usually fine grained sedimentary rocks. They exhibit secondary porosity in the form of fractures, faults and joints.

Table 3 - Ranges and Ratings for Aquifer Media

Aquifer Media

Range (Geology Type)	Rating
Quaternary Alluvium	10
Tertiary Alluvium	9
Hawkesbury Sandstone	8
Limestone	7
Volcanic	6
Londonderry Clay	5
Sedimentary	5
Metasediments	3
Wiannamatta Shale	2
Plutonic	1
Weight 5	

The derivation of the a) Recharge, b) Vadose Zone Impact, and c) Soil Media maps will now be discussed.

Recharge

This feature is generated as a map which is specific for the study area. It incorporates available features into an equation which are believed to be important to the recharge component of the study area. The equation used calculates the ability of an area to act as a recharge zone relative to another area. The factors used to generate the Recharge map for the Hawkesbury-Nepean catchment include: slope, soil permeability, and rainfall. DTWT and aquifer media are considered to be minor contributors, however, as they are used as other component maps, they will not be used in the recharge map. The soil permeability map was created by assigning relative permeability factors to the basic soil classification groups within the catchment.

The following equation is used to generate a **Recharge Value**. This Recharge Value is then grouped into a range of values which are given a rating for use in the final DRASTIC calculation.

Recharge Value = Slope % + Rainfall + Soil Permeability

Where:

Slope %

Range	Factor
<10%	5
10 - 20%	4
20 - 30%	3
30 - 40%	2
>40%	1

Rainfall (mm)

Range	Factor
>1250mm	4
1050 - 1250mm	3
850 - 1050mm	2
<850mm	1

Soil Permeability

Range	Factor
Deep Alluvial Loams	5
Stony Sandy Loams + Shallow Loams	4
Stony Sandy Loams	4
Deep Structured Red and Brown Clays + Massive Red and Yellow Earths	3
Deep Structured Red and Brown Clays	3
Yellow and red texture contrast soils	2
Deep friable red and brown clays	1

The maximum Recharge Value is: 14

The minimum Recharge Value is: 3

The rating table for Recharge is shown in Table 4.

Table 4 - Ranges and Ratings for Recharge

Recharge

Range	Rating
12-14	10
10-12	8
8-10	5
6-8	3
3-6	1
Weight 2	

Impact of Vadose Zone

As discussed previously this feature attempts to classify that zone of soil and regolith (saprolite) found above the water table, known as the vadose zone, with regard to its ability to allow any

potential contaminant to move through this zone towards the aquifer. The Vadose zone for the purposes of the Hawkesbury-Nepean vulnerability map incorporates the Soil Attenuation type, and DTWT. The soil attenuation map was created by assigning relative soil attenuation factors to the basic soil classification groups within the catchment.

An equation is used incorporating these factors, believed to be important to the vadose zone for the study area. The equation provides a **Vadose Zone Value** for a particular area defined by these factors and which is relative to another zone within the context of the study area. This **Vadose Zone Value** is then grouped into a range of values which are given a rating for use in the final DRASTIC calculation.

Impact of Vadose Zone = Soil Attenuation Type + DTWT

Where:

Soil attenuation type, as previously stated, has been developed from the differing soil units measured characteristics, but is factored for its contribution to the vadose zone impact.

Depth to water table has previously been calculated, but is factored for its contribution to the vadose zone impact.

Soil Attenuation

Range	Factor
Deep Alluvial Loams	5
Stony Sandy Loams + Shallow Loams	4
Stony Sandy Loams	4
Deep Structured Red and Brown Clays + Massive Red and Yellow Earths	3
Deep Structured Red and Brown Clays	3
Yellow and red texture contrast soils	2
Deep friable red and brown clays	1

Depth To Water Table (m)

Range	Factor
< 5	4
5 – 10	3
10 – 15	2
>15	1

The maximum **Vadose Zone Impact Value** is: 9

The minimum **Vadose Zone Impact Value** is 2

The ratings for **Vadose Zone Impact** are displayed in Table 5.

Table 5 - Ranges and Ratings for Vadose Zone Impact

Vadose Zone Impact

Range	Rating
8-9	10
7-8	9
6-7	7
5-6	5
4-5	3
2-4	1
Weight 5	

Soil Media

The soils feature attempts to classify the unique soil of the study area with regard to its ability to allow any potential contaminant to move through this zone towards the aquifer.

The impact of the soil media within the Hawkesbury-Nepean catchments was based solely on the soil attenuation capacity as this reflects grain size, textural, and ionic adsorption characteristics of the differing soil units.

The ranges and ratings for soils have been classified as outlined in Table 6.

Table 6 - Ranges and Ratings for Soil Media

Soil Attenuation

Range	Rating
Deep Alluvial Loams	10
Stony Sandy Loams + Shallow Loams	8
Stony Sandy Loams	8
Deep Structured Red and Brown Clays + Massive Red and Yellow Earths	6
Deep Structured Red and Brown Clays	6
Yellow and red texture contrast soils	4
Deep friable red and brown clays	2
Weight 2	

AQUIFER VULNERABILITY CLASSIFICATION IN THE HAWKESBURY-NEPEAN CATCHMENT

Five classes of vulnerability ranking have been chosen to describe the relative assessment of the probability of a groundwater resource to contamination; *low, moderately low, moderate, moderately high* and *high*. These classes are shown as distinct colours on the vulnerability map.

"High" vulnerability ranked groundwater resources are found in the unconfined, shallow, highly permeable aquifers, such as the Quaternary Alluvial Aquifers, particularly areas with minimal soil coverage and low slope such as the Nepean River between Penrith and Richmond. Depth to water table also plays a significant role in groundwater vulnerability. The alluvial system along the Capertee River also has an area of high vulnerability due to the shallow water table found in this area. Other areas of high vulnerability can be found in the south along the alluvial belts between Tarago and Goulburn along the Wollondilly River. Also upstream of the Wingecarribee Dam, and downstream of the Nepean River north of Camden are considered areas of high groundwater vulnerability. Large pockets of highly vulnerable groundwaters occur along the Hawkesbury River upstream of Broken Bay. These aquifers within this class require a high level of protection.

"*Moderately High*" vulnerability ranked groundwater resources for the Hawkesbury-Nepean Catchment, refers to a large portion of the area and includes shallow aquifers associated with moderate slopes, higher rainfall and higher recharge. The soils are often moderately to highly permeable, with a moderate to high cation exchange capacity and a depth to water of less than 10 metres. In general the large area covered by this class corresponds to the Hawkesbury Sandstone geological unit. This vulnerability ranking covers most of the sandstone terrain and the sandstone strata of the Narrabeen Group.Other areas encompassing this class can be found south of Lithgow where granitic plutons occur. Limestone aquifers around the Oberon area are also found to be moderately high in vulnerability to pollution.

"Moderate" vulnerability ranked groundwater resources refers to areas associated generally with moderate slopes, in hard rock terrain, water tables greater than 10 metres, and there is moderate recharge. No one combination of vulnerability factors is responsible for this class, but it is observed that moderately vulnerable aquifers are consistent with moderate classes in the component maps.

"*Moderately Low*" vulnerability ranked groundwater resources is the dominant classification for 'pockets' in much of the hilly or steeper terrain associated with the western areas of the map. These areas generally have moderate soil permeability with the depth to water often being greater than 15 metres. The dominant aquifers for this rating are the metasediments, basalt or sedimentary aquifers.

"*Low*" vulnerability ranked groundwater resources in the Hawkesbury-Nepean Catchment are generally associated with the strata of the Wianamatta Group and also the Tertiary Alluvial aquifers. These aquifers require less protection measures because they have good barriers to the groundwater resource below or the aquifer is considered to be poor in these areas.

Level of Assessment Required

Groundwater vulnerability maps do not directly consider the chemical nature of the pollutant in assessing vulnerability. They are concerned only with the hydrogeological setting which makes the groundwater susceptible to contamination from a surface source.

When a development application is being prepared or considered, it is important that the impact of the development, on both surface and groundwater resources is assessed. It is important to know who uses these resources (beneficial use) and what the current quality of the water is. Potentially groundwater polluting developments should not be allowed within highly vulnerable areas. Where such activities are proposed, significant engineering measures would be necessary to minimise the risks of pollution.

The following Table, modified after the Australian Water Resources Council (AWRC), Draft Guidelines for Groundwater Protection, (1992), is a guide to the amount of groundwater assessment required for a development that requires consent in either of the five aquifer vulnerability classes.

Vulnerability Classification	Groundwater Assessment Requirements
Low	Groundwater Contamination Assessment Report A desk study is required to identify the concerns and potential risk to groundwater or the environment and the need for any further action to be presented in the development application. A standard format hydrogeological report would most likely result.
Moderately Low	Site Investigation With Monitoring A potential risk is indicated by the vulnerability map requiring site investigation and groundwater monitoring. The extent of work should involve a limited amount of site investigation, soil and water sampling and testing, definition of flow systems and reporting, in addition to a desk study.
Moderate	Detailed Site Investigation and Monitoring For moderately high vulnerability areas, or where the previous levels of investigation indicate a demonstrated risk to groundwater, a detailed groundwater site investigation is required. The work should include an ongoing monitoring program, details on the protection design factors, (natural attenuation, physical barriers, etc) in addition to the previous levels of investigation.
Moderately High	Demonstrated Groundwater Protection System The risk to groundwater, as demonstrated by the vulnerability map, is an area in which contamination to groundwater cannot be tolerated. The work should include a desk study, detailed site investigation, and implementation of an on-going monitoring program, as indicated above. In addition, the protection design system incorporating natural attenuation, hydraulic barriers, physical barriers etc, needs to be demonstrated, to be effective. The proposal will need to include a feasibility plan for a clean-up, in addition to a detailed monitoring and ongoing assessment program.
High	Demonstrated Remedial Action Plan/Prohibition This classification identifies the area as having a potential risk so great as to warrant a demonstrated remedial action plan. The work should include a desk study, site investigations, ongoing monitoring, plus a demonstrated remedial action plan for clean-up, which analyses the effectiveness of the remediation approach in achieving designated water quality criteria. The financial capacity of the responsible party to enact the plan should also be evaluated. In the event that the risk to groundwater is unacceptable, an activity may be banned by the responsible authority.

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