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REVIEW OF WATER TABLE ELEVATION ON THE SWAN COASTAL PLAIN AND THE AAMGL CONCEPT

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ABSTRACT

Local Government approves plans for land development, associated with which is protection from inundation from surface water and groundwater. On the Swan Coastal Plain the shallow water table in many places presents the most likely risk of inundation. With increasing development of land mapped as wetland, Local Government Engineers require appropriate methods for determining acceptable risk.

In recent years, the concept of Average Annual Maximum Groundwater Level (AAMGL) has been developed by State Government environment agencies as the minimum level for new drainage works. The justification for use of AAMGL was to prevent excessive discharge of nutrients in groundwater to the river systems and to protect wetlands from drying out.

The paper describes the difficulty in defining AAMGL given climate variability, changing land use and the presence of a perched water table above the regional water table in some places.

The paper provides a basis for a new concept of Controlled Water Table (CWT) which may be above or below the previous AAMGL concept, but which is maintained by installed drainage at land use change.

1 **Introduction**

The Swan Coastal Plain has an unconfined aquifer, the upper surface of which is the water table. The water table intersects the ground surface at a myriad of wetlands, comprising lakes, sumplands, damp lands, etc., as shown on Figure 1. The elevation of the water table (in m AHD) varies seasonally in response to rainfall recharge, typically reaching a peak in September/October and a minimum in April/May each year. Annual rainfall variability results in the peaks and troughs varying from year to year.

One of the earliest maps of water table elevation was produced by Allen (1981). The Perth Urban Water Balance Study, (WAWA 1987) also included a map of water table contours for a specific date, April 1985 (WAWA 1987) (see Figure 2). This shows essentially two groundwater mounds, the Gnangara Mound north of the Swan River and the Jandakot Mound south of the Swan River respectively reaching elevations of 60 and 20m AHD.

Subsequently an A3 Atlas of Perth Groundwater at 1:15,000 scale was produced (WRC 1997) showing contours of "estimated maximum water table contours in metres AHD", an extract of which is shown in Figure 3. These maximum contours were hand contoured through maximum recorded water levels taking into account surface topography. Reduced versions of a water table map and seasonal variation are included in Davidson (1995).

In Perth there may well be an increased danger of flooding (inundation) associated with water table rise rather than surface water runoff in drains, creeks and rivers. This is in contrast to cities of eastern states of Australia which generally do not have a shallow water table and local authorities have only to deal with surface water flooding risk. Inundation from a rising water table is also likely to effect a greater area of land and for a longer period of time.

Hydrologists once believed that cities reduced the amount of recharge to the underlying groundwater because of the impermeablity of urban surfaces. This myth has been widely discredited since a group of hydrogeologists began to present research from various cities around the world, summarised by Lerner (2002).

Now it is widely accepted that infrastructure for water supply and drainage generates large amounts of recharge through leaks. In almost all environments worldwide, urbanisation leads to an increase in recharge (see Figure 4). Lerner (2002) suggests that worldwide the sandy aquifer underlying Perth is probably the most extensively studied urban aquifer, citing work by Appleyard (1995) and Davidson (1995). From these reports a summary statement is made that recharge to non urban parts of Perth is 15 to 25% of average annual rainfall, compared with up to 37% urban recharge, i.e. an approximate doubling attributed to clearing of native vegetation, import of water and infiltration of stormwater (see Fig. 4).

It follows that the prognosis for Perth under steady climate conditions must be for a rise in water table, even though in recent years low rainfall may have caused a short term opposite affect.

The extent to which either State or Local Authorities have made allowance for a likely rise in water table associated with planning consents for land use change in Perth is unclear.

This paper discusses the factors which affect the elevation of the water table. Consideration is given to the Average Annual Maximum Groundwater Level (AAMGL) which was introduced as a basis for the setting of drainage inverts for land development in the 1990's.

The extent to which climate variability results in changes to the elevation of the water table is considered within this paper, and the extent to which the taking of an average such as the AAMGL is a rational basis for planning of drainage design and protection from water table inundation.

2 Factors affecting water table elevation at a specific location

Spatial variation of water table elevation is mostly influenced by the location of the groundwater mounds fed by rainfall recharge. The recharge from rainfall is in dynamic equilibrium with the discharge of groundwater at the ocean, rivers and wetlands so that a groundwater mound of specific elevation has developed.

Variation of water table at a specific location with time can be affected by the following factors:

- Removal of trees and vegetation (water table rise).
- Groundwater abstraction from wells (water table falls)
- Imported scheme water (water table rises)
- Export of storm water run-off (water table falls)
- Infiltration of storm water run-off (water table rises)
- Climate variability (Water table rise or fall)

3 Climate variability

Figure 5 shows annual Perth rainfall since 1880 together with a 10 year moving average indicating a gradual reduction since about 1975 compared with earlier values. The apparent 20 to 30 year cycles evident in the moving average are probably spurious, associated with the taking of a 10 year moving average.

To respond to the effects of climate variability the Institution of Engineers Australia has recently issued a draft Position Paper with guidelines (IEA 2003). The Position Paper argues the case for a risk analysis where climate variability is largely unpredictable and calls for a comprehensive review of existing flood mitigation measures. While the Position Paper deals largely with "floods", a similar approach is appropriate for Perth where a rising water table may equally result in inundation.

Evidence for climate variability in hydrology in Australia research (Franks & Kuczera, 2002) questions the assumption that flood peaks in New South Wales Rivers are independent and follow the same probability distribution from year to year. This work has shown that their persistent climate modes that modulate regional climates over multi year time scales around the globe.

It is known that there was a significant shift in Indian Ocean and Pacific Ocean sea surface temperatures and other atmospheric variables in the mid 1940's. Using this as a cut off date, the same authors analysed flood records before and after 1945 and found that there was evidence that the probability of floods was significantly different before and after that date. This has implications for flood risk assessment from surface water in New South Wales at least. No such analysis has yet been conducted in Western Australia so far as we are aware. However, the Centre for Water Research is currently examining the effect of multi-scale hydrodynamic variability on flood frequency in WA.

Clearly if flood data are used from one part of a climate period and extrapolated without reference to a subsequent climate period, either over or under estimation will result.

Subsequent research by the same researchers (Kiem, Franks and Kuczera, 2002) show the importance of cold El Niño Southern Oscillation (ENSO) events (La Nina) as the dominant drivers of increased flood risk in New South Wales. An analysis of multi decadal modulation of flood risk was achieved using the Inter-decadal Pacific Oscillation (IPO) index. Again this analysis has not been applied to Western Australia surface water flood data, nor to water table elevations.

Tyson (1987) draws attention to such cycles and the possible influence on rainfall in Southern Africa. It has been identified in the literature that this cycle is caused by atmospheric circulation, which determines the synoptic scale variations (lows and highs) in the atmosphere. In the Southern Hemisphere, the air circulates clockwise in lows (depressions) and anticlockwise in highs (anticyclones). The air pressures resulting from the atmospheric circulations vary seasonally. This is generally linked to the (ENSO) effects. ENSO is a natural part of the global climate system. It results from large-scale interactions between the oceans and the atmosphere, which occurs mostly across its core region in the tropical-subtropical Pacific to Indian Ocean basins (Allan 2000). It has been said that ENSO is the primary cause of the inter-annual climatic variability over Australia.

The Southern Oscillation Index (SOI) is an indicator of an ENSO event and its strength. During normal conditions, the South Equatorial Current maintains a large pool of warm water in the Pacific Ocean. This warm water drives high convection which rises and travels across the equatorial Pacific. This air cools and descends over the south east trade winds making the temperature in the Western Pacific to be 3ºC to 8ºC warmer than the eastern Pacific.

During El Niño conditions, the Walker Cell (an atmospheric circulation cell over the Pacific Ocean) contracts and moves east as the south-east trades weaken. This causes the equatorial current to reverse and drive the warm pool east towards the coast of South America. The cloud producing processes tend to follow this warm pool making the ocean water in the central or eastern Pacific to be as warm as the western Pacific.

During La Niña conditions, the Walker circulation intensifies, strengthening the south-east trade winds which results in the cooling of the eastern Pacific. These changes often bring widespread rain and flooding to Australia.

The literature therefore describes several mechanisms for climate variability and yet, the following Western Australian publications on groundwater and water table elevation do not make any reference to there being cycles in groundwater levels:

- Davidson (1995) – *Hydrogeology of Perth*
- WRC (1997) – *Perth Groundwater Atlas*
- Water Authority (1987) – *Perth Urban Water Balance Study*

4. AAMGL

Over the last decade or so, the Water Authority of WA (then Water and Rivers Commission now DOE) has advocated the use of the Average Annual Maximum Groundwater Level for the setting of drainage inverts for new drainage works in Perth and the south west of WA generally.

This has become known as the AAMGL policy and was designed to minimise the export of nutrient rich groundwater as well as protecting the significant wetlands from over drainage.

However, the AAMGL has never been defined in terms of the period of data (ie. the span of years) over which the AAMGL shall be calculated, nor the method of correlation with long term data to a particular site.

This has led to significant anomalies due to different practitioners using different methods in estimating AAMGL for adjacent properties and deriving different elevations at the common boundary. This is clearly an unsatisfactory situation.

Figure 6 shows a typical water level record with AAMGL estimates over various periods superimposed, ranging by approximately 1m. Clearly the duration of record used affects the AAMGL chosen.

Clearly one of the significant risks of poor estimation of water table and drainage setting is that in wet years damage may result as the water table rises. Under these conditions roads or structures may experience foundation problems and there may be water damage or inundation also.

On the other hand during periods of relatively low rainfall, such as is occurring at present lesser damage will occur, particularly on sandy soils although in clay situation shrinkage affects may be important.

5. **WRC Position**

WRC Manual for Managing Urban Stormwater Quality in Western Australia (WRC 1997) does not specifically refer to the AAMGL concept.

Section 2.11 "Preventing groundwater inputs" argues the case for preventing groundwater inflow to constructed wetlands using membrane liners. This approach seems to be at variance with that taken by WRC in other reports where the ubiquitous nature of groundwater and its importance in the water balance of all wetlands is stressed. There is a passing reference to AAMGL in the design example for a constructed wetland but no advice on how it is to be calculated.

The WRC Interim Position Statement Urban Stormwater Management in W.A. (WRC 2003) makes no reference to the AAMGL concept at all, possibly because it is a high level document.

Recent drafts of a new manual by WRC also makes no reference to AAMGL. Presumably some description of the important shallow water table in Perth and the Coastal Plain will be added as it is of utmost importance.

The lack of clarity on this issue is a major concern to all practitioners.

6. A Way Forward

Following specific cases could be identified:

- Areas where the water table is currently controlled by existing rural or urban drainage systems.

  In these areas new drainage system associated with land development or re-development could be placed at inverts of the existing drainage system and the concept of a Controlled Groundwater Level (CGL) used.

- Areas subject to land use change distant from significant wetlands.

  These areas drainage inverts and should be based on a regional analysis of water table gradient and drainage capacity. A check on whether lowering of the water table would result in downstream water quality change should be conducted.

- Areas adjacent to significant wetlands.

  In these areas the Environmental Water Requirements (EWR) of the wetlands both form maximum and minimum levels should be identified and a drainage system appropriately designed. However clearly water table mapping needs to be carried out over sufficiently large areas and should rely on data collected. The use of a GIS to adequately incorporate a contour such data sets is to be preferred. Mapping of water table in isolation on individual properties or sub-catchment is likely to lead to inconsistencies with the regional picture.

7. **Conclusions**

The water table on the coastal plain varies spatially as well as temporarably. The latter is of particular significance as it affects the risk of inundation as well as affecting environmentally significant features such as wetlands.

It is widely accepted that urbanisation leads to a rise in water table and that in the south-west of WA the recent dry climate has generally prevented this rise from occurring.

It follows that the prognosis must be for a rising water table should the rainfall return to its earlier average.

The concept of AAMGL is ill defined and it is suggested that State Government through DoE should take responsibility for clarifying design requirements for local governments to work within.

8. **References**

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WRC (1997) – *A Manual for Managing Urban Stormwater Quality in Western Australia.*

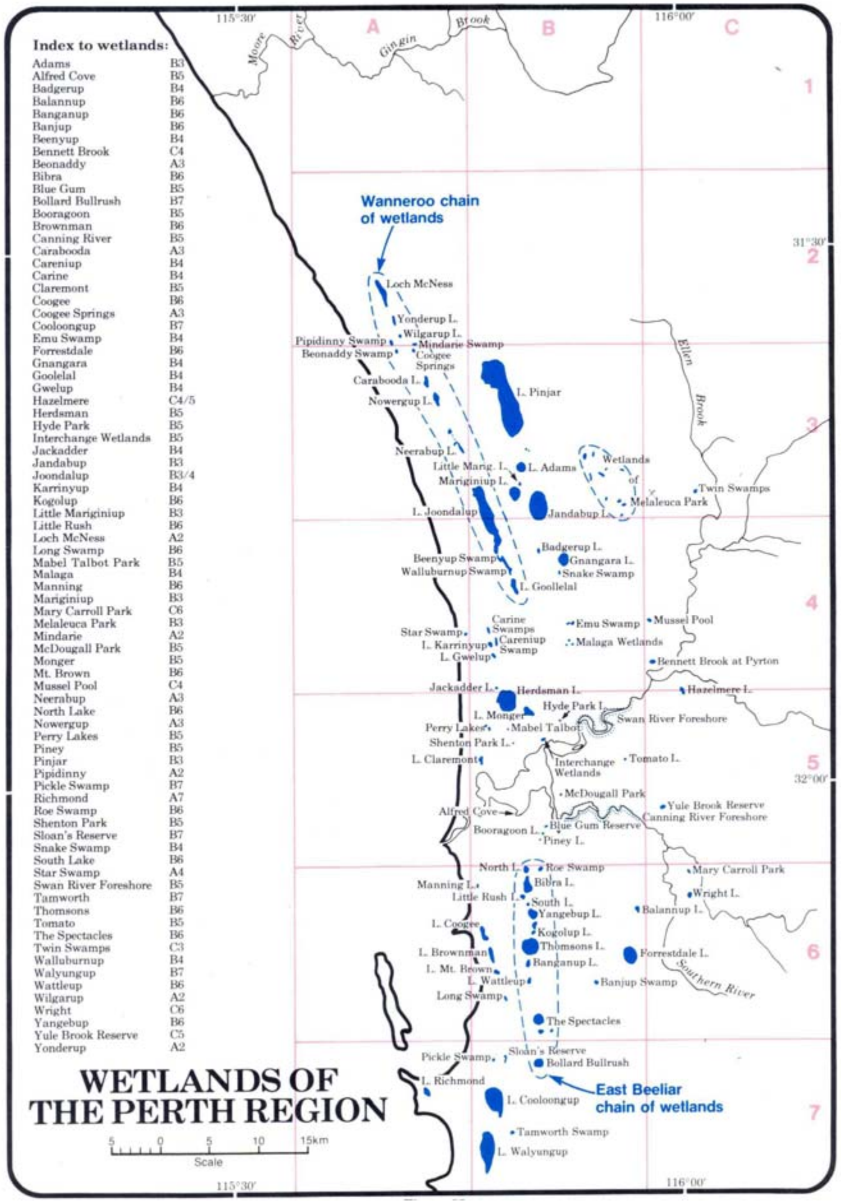

Figure 1: Perth Wetlands (reproduced WAWA, 1987)

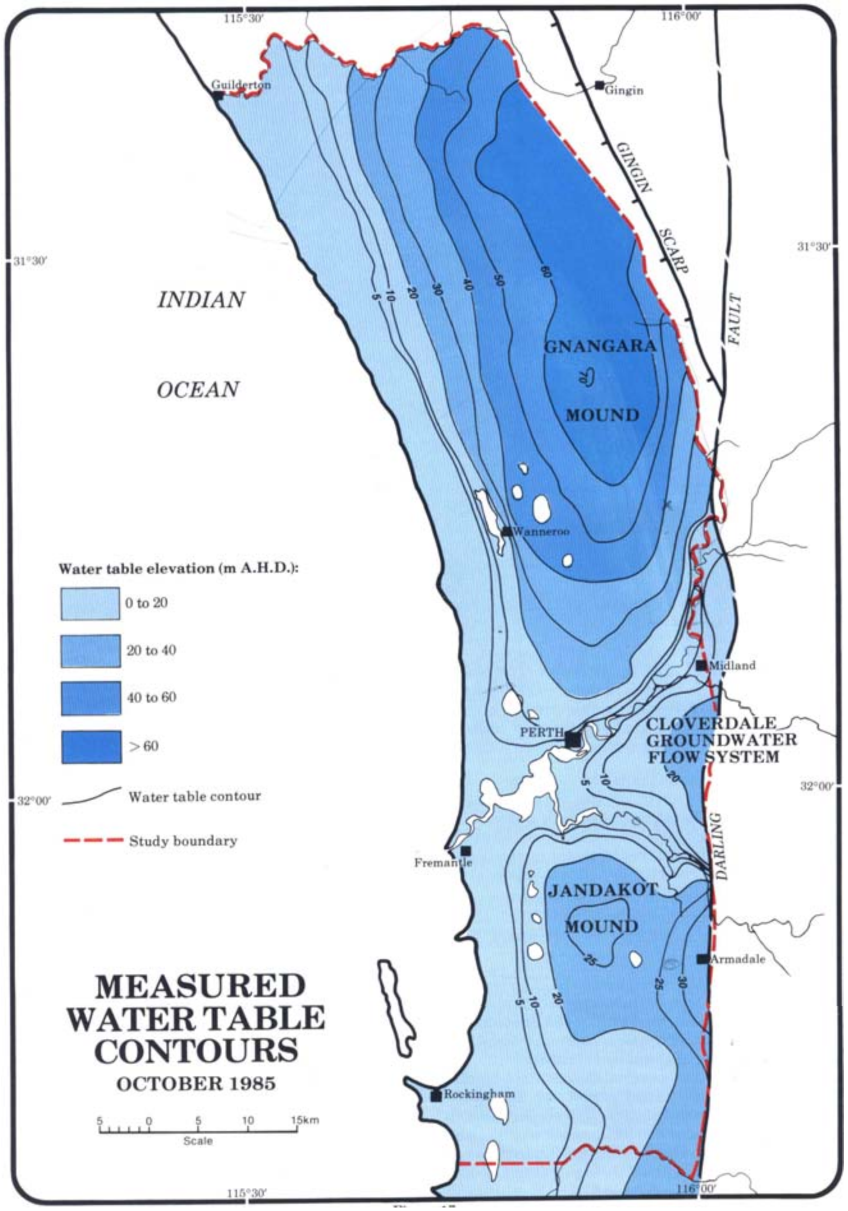

Figure 2: Water Table Contours (reproduced WAWA, 1987)

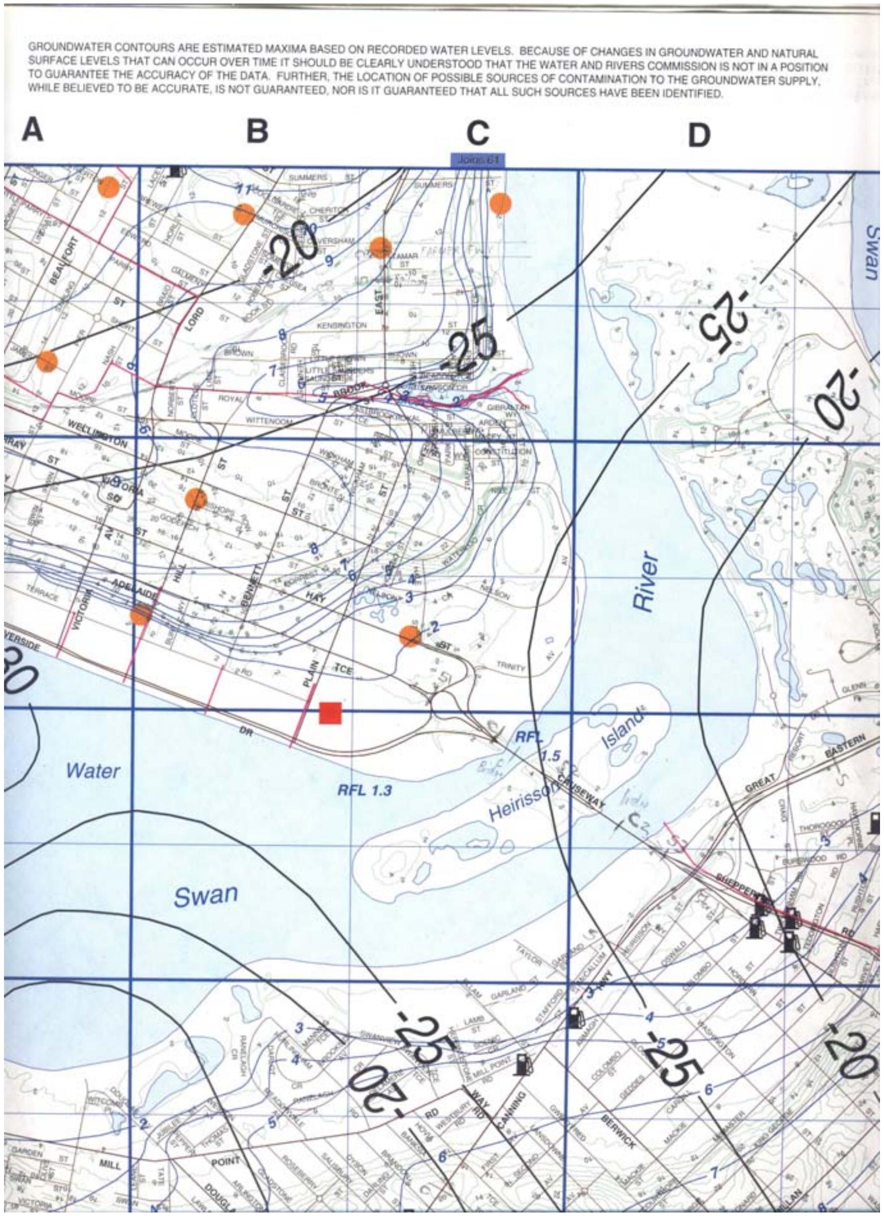

Figure 3: Extract of Perth Groundwater Atlas (WRC, 1997)

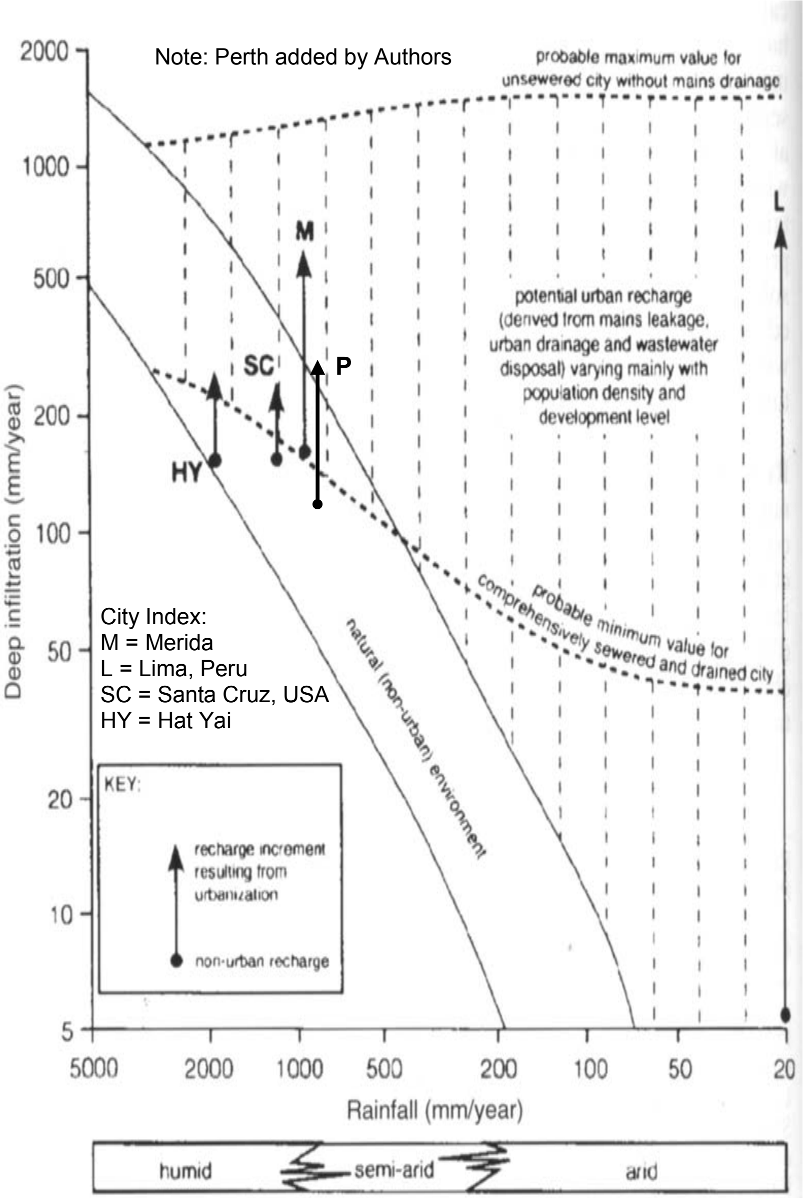

Figure 4: Recharge to Water Table (deep infiltration)
(reproduced from Hydrogeology Journal Vol 10, 2002)

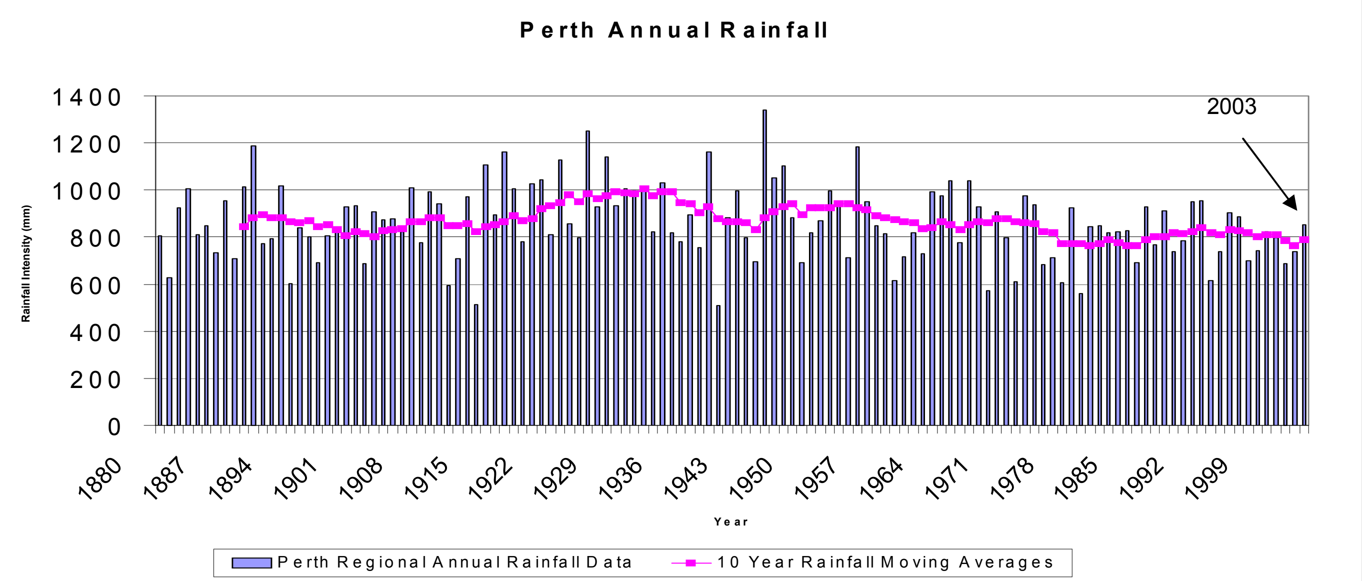

Figure 5: Perth Regional Annual Rainfall (BoM, 2004)

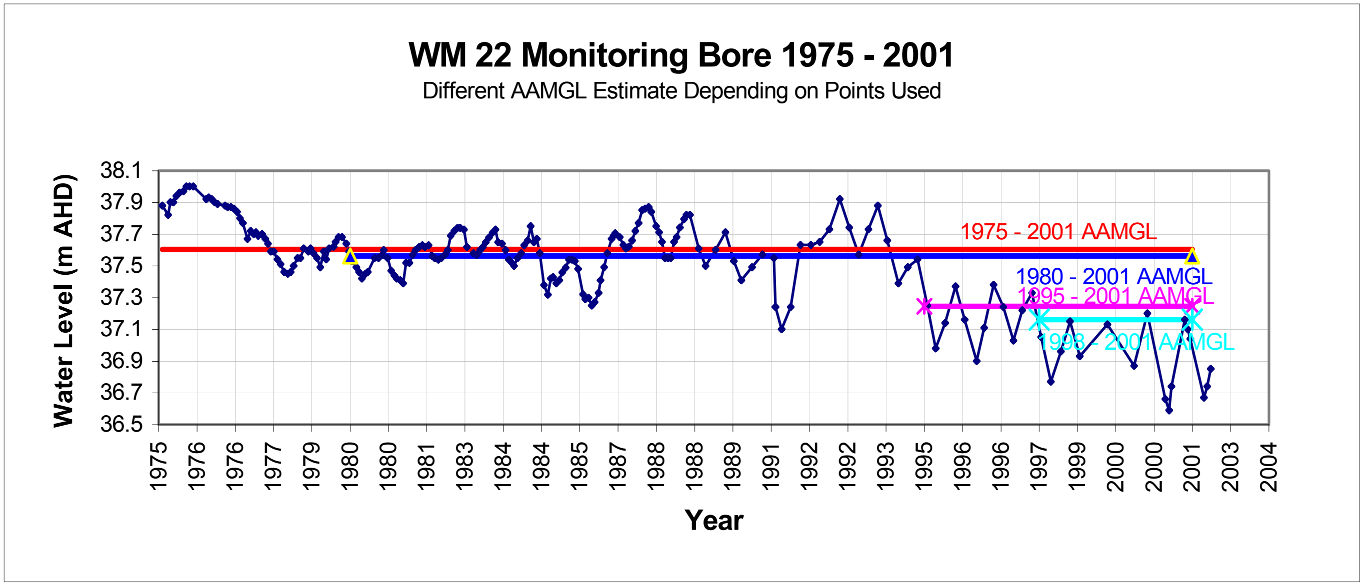

Figure 6: WM22 Monitoring Bore (DoE, 2002)