Department of **Water**
Government of **Western Australia**

Looking after all our water needs

Groundwater quality impacts associated with urbanisation in Perth, Western Australia

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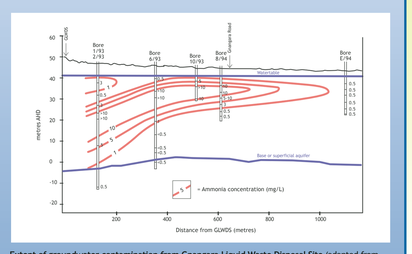
Former liquid waste disposal site, Gnangara

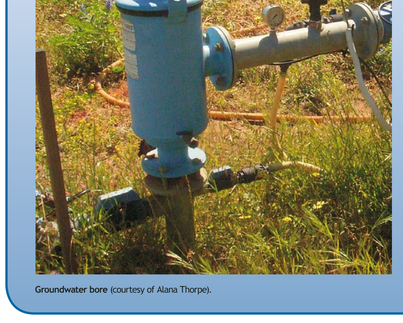
- Ammonia plume found to extend from the site, with concentrations ranging from 0.3 to 27 mg/L (average 12 mg/L).
- High concentrations of bacteria recorded, with heterotrophic plate counts at 35ºC ranging from 60 to 4000 cfu/mL.
- Investigation recommended relocation of proposed drinking water supply bore.
- This site is located in a P1 area of Gnangara PDWSA. Wastewater treatment and disposal would now be considered incompatible in P1 and P2 areas, however would be "compatible with conditions" (such as an appropriate level of wastewater treatment and lined ponds) in P3 areas.



Extent of groundwater contamination from Gnangara Liquid Waste Disposal Site (adapted from Water Authority, 1994).

Source: Water Authority (1994) Investigation of groundwater contamination from the Gnangara Liquid Waste Disposal Site, Report No WG 189, Water Authority, Perth, Western Australia.

Septic tanks, Gwelup



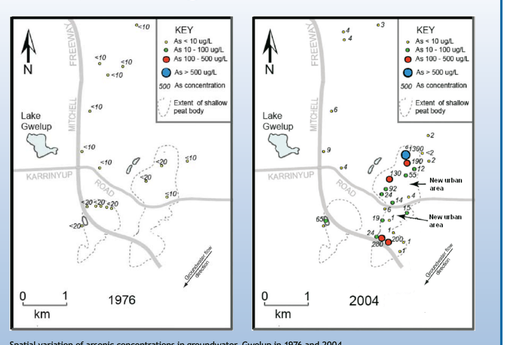
Groundwater bore (courtesy of Alana Thorpe).

- Analysis of ~40 domestic bores (some in Gwelup PDWSA) found:
  - NO_3-N concentrations ranged from <1 to 15 mg/L with high concentrations generally associated with unsewered areas
  - Pathogen presence indicative of faecal contamination in five bores where septic tanks were nearby.
- Septic tanks are "incompatible" to P3 areas. New residential development requires connection to deep sewerage, however, many older residential areas (some in P3 areas) still have septic tanks.

Source: Otto, C., Barber, C. and Bates, L. (1994) Evaluation of pathogenic and nutrient contamination of residential borewater in the Gwelup Public Water Supply Area: an overview for the Water Authority of Western Australia, Report 94/21, CSIRO Division of Water Resources, Perth, Western Australia.

Residential development, Stirling

- Dewatering, excavation and stockpiling of acid sulfate soils for urban development has led to increased acid and heavy-metal levels in groundwater.
- Domestic bore sampling found high arsenic (40% exceeding ADWG criteria of 0.007mg/L), iron (up to 1300 mg/L), aluminium (up to 290 mg/L) and sulfate (up to 4400 mg/L) concentrations.
- Drilling investigation in 2004 found low arsenic concentrations upgradient of development, but high concentrations downgradient (up to 7mg/L)
- Some deeper drinking water bores within Gwelup wellfield had arsenic concentrations of 0.005-0.015 mg/L.
- Urban subdivision is an acceptable activity within P3 areas.



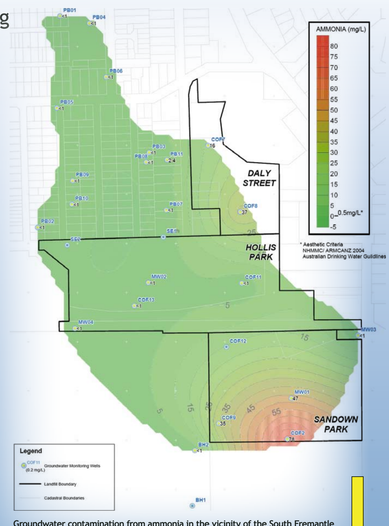
Spatial variation of arsenic concentrations in groundwater, Gwelup in 1976 and 2004 (adapted from Appleyard et al., 2006).

Sources: Appleyard, S., Wong, W., Willis-Jones, B., Angeloni, J. and Watkins, R. (2004) Groundwater acidification caused by urban development in Perth, Western Australia: source, distribution, and implications for management, Australian Journal of Soil Research 42, 579-585; and Appleyard, S.J. Angeloni, J and Watkins, R. (2006) Arsenic-rich groundwater in an urban area experiencing drought and increasing population density, Perth, Australia, Applied Geochemistry 21, 83-97.

Former landfill site, South Fremantle

- Received array of waste from surrounding urban area from 1930s to 1991.
- High ammonia, nitrate and arsenic concentrations present in groundwater with impacts extending off-site.
- 39% of on-site groundwater samples contained evidence of pathogen contamination.
- This site is not located within a PDWSA. Putrescible landfills are "incompatible" within PDWSA.

Typical landfill (courtesy James Milne, Department of Environment and Conservation)

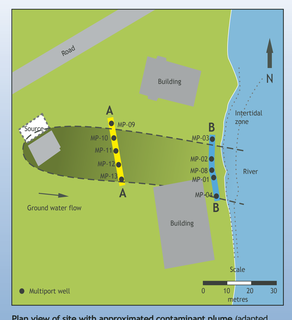


Groundwater contamination from ammonia in the vicinity of the South Fremantle landfill (from Golder Associates, 2006b).

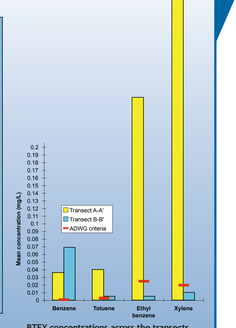
Source: Golder Associates (2006b) Report on review of the groundwater monitoring program, South Fremantle Landfill site, Golder Associates, West Perth, Western Australia.

Underground storage tank, City of Melville

- BTEX (benzene, toluene, ethyl benzene and xylene) and naphthalene plume extends from a leaking underground storage tank (UST) towards the Canning River.
- Concentrations of BTEX greatly exceed ADWG criteria.
- Chemical storage in UST is 'compatible with conditions' (e.g. double-lined tanks and leak detection systems) in P3 areas.



Plan view of site with approximated contaminant plume (adapted from Westbrook et al., 2005).



BTEX concentrations across the transects.

Source: Westbrook, S.J., Rayner, J.L., Davis, G.B., Clement, T.P., Bjerg, P.L. and Fisher, S.J. (2005) Interaction between shallow groundwater, saline surface water and contaminant discharge at a seasonally and tidally forced estuarine boundary, Journal of Hydrology 302, 255-269.

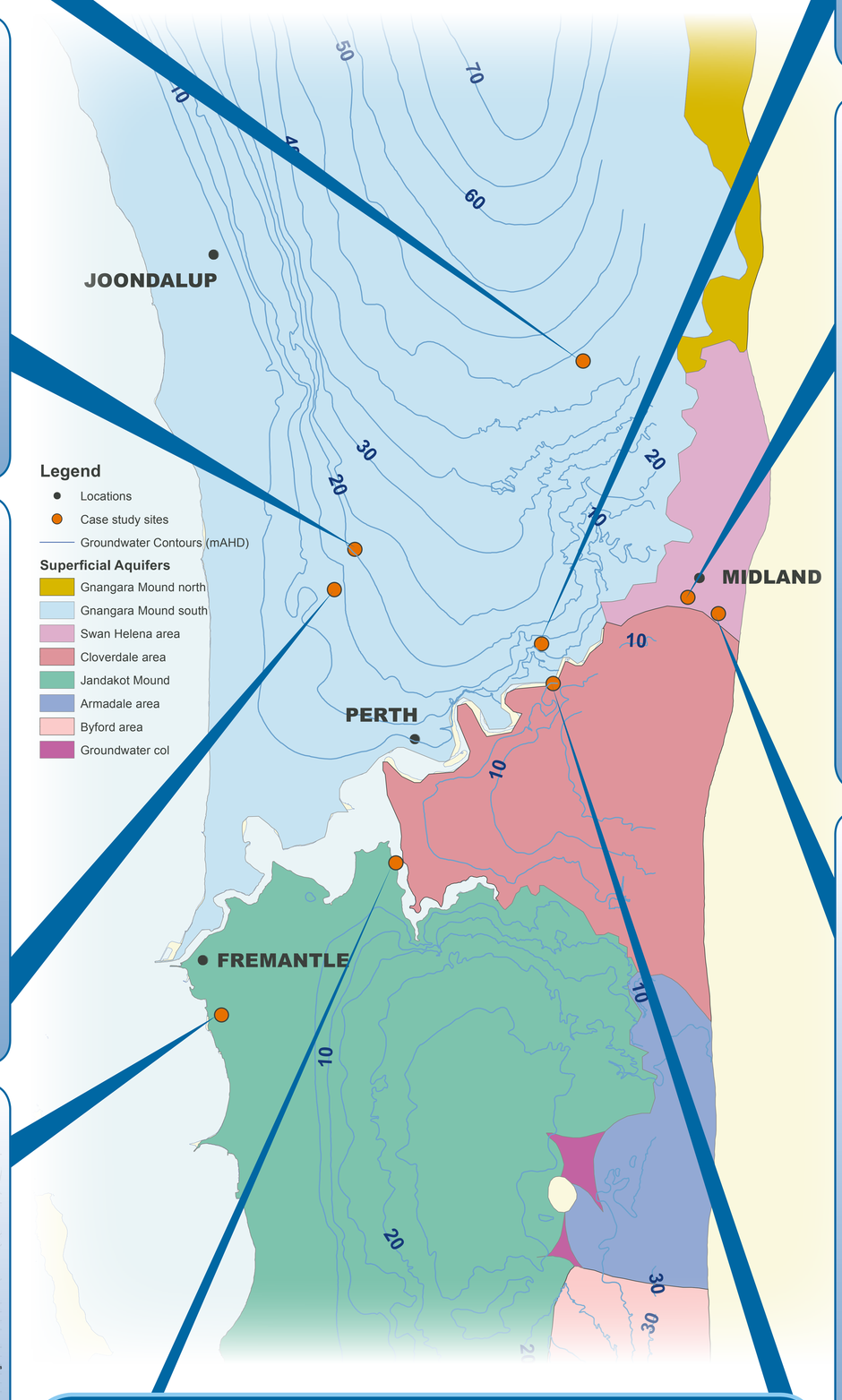
Protection of drinking water sources

The Australian Drinking Water Guidelines 2004 (ADWG) provide the framework for a preventative, risk-based, multiple-barrier approach to manage drinking water. The guidelines also give criteria for aesthetic and health-related water quality parameters that should not be exceeded to achieve safe, good quality drinking water.

The Department of Water implements the ADWG through a drinking water source protection program. This includes three different protection areas declared within Public Drinking Water Source Areas (PDWSA):

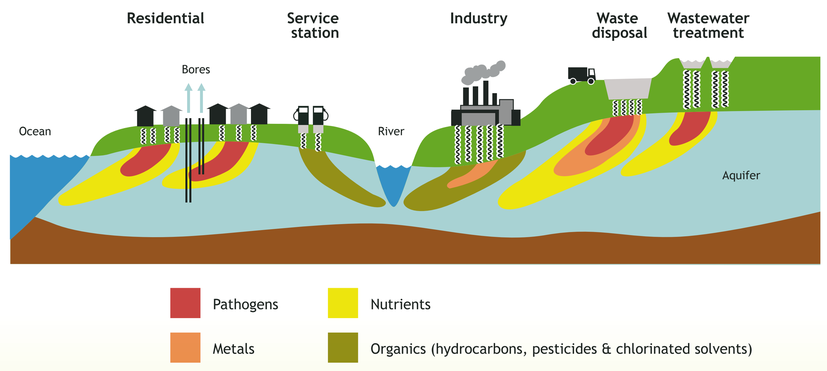
- Priority 1 (P1) areas are managed for risk avoidance.
- Priority 2 (P2) areas are operated under the principle of risk minimisation.
- Priority 3 (P3) areas are defined for risk management.

The Department's water quality protection note: *Land use compatibility in Public Drinking Water Source Areas* outlines activities and land uses that are "acceptable", "compatible with conditions" or "incompatible" within each of the priority areas.



Perth has sandy soils and shallow unconfined aquifers. Urban development overlies these aquifers, making them vulnerable to contamination. Some 60% of Perth's drinking water is sourced from groundwater, therefore it's crucial urban development is properly managed.

Groundwater quality threats from urbanisation



Former fertiliser manufacturing site, Bayswater

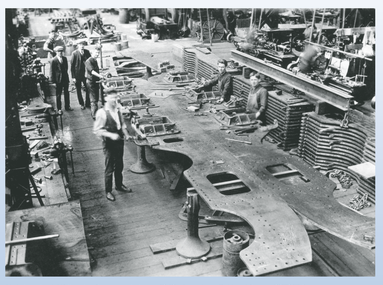
- Site used for fertiliser manufacturing and hydrochloric acid production since the 1920s.
- Continued and extensive groundwater contamination exists, including:
  - high acidity and sulphate
  - a suite of heavy metals exceeding ADWG by 10 times or more.
- Health warning was issued to surrounding private bore owners.
- This site is not located within a PDWSA, however, fertiliser manufacturing is "compatible with conditions" in P3 areas.

Aerial photograph of the premises, 1969 (courtesy Battye Library 342847PD).

Source: Parsons Brinckerhoff (2004) Final remediation works for the former Cresco site, Bayswater - Public Environmental Review. CSBP Limited, Perth.

Former railway workshops, Midland

- Site used for the manufacture and maintenance of locomotives and rolling stock from 1904 to 1994.
- Groundwater monitoring indicates:
  - elevated heavy metals, with nickel exceeding ADWG criteria (up to 10 mg/L)
  - high concentrations of hydrocarbons and chlorinated solvents (above ADWG criteria).
- This site is not located within a PDWSA. Heavy industry, such as metal production/finishing and power stations, is "incompatible" within PDWSA.

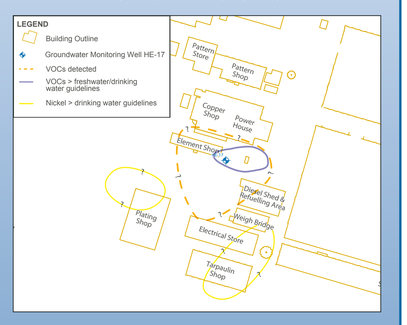


Metalwork at Midland railway workshops 1940s (courtesy Battye Library 007317d).

Groundwater monitoring results - Bore HE-17 (mg/L).

Contaminant	ADWG	Bore HE-17
Benzene	0.001	0.009
Xylenes	0.02*	1.1
Vinyl Chloride	0.0003	0.32
Carbon tetrachloride	0.003	0.59
Dichloromethane	0.004	0.098
1,2 Dichloroethane	0.003	0.085
Tetrachlorethene	0.05	31

** aesthetic guideline level*



Onsite volatile organic compound (VOC) and nickel contamination (adapted from ATA Environmental, 2006).

Source: ATA Environmental (2006) Helena East Precinct remediation and redevelopment - Public Environmental Review, Volume I, Report No 2005/142, ATA Environmental, Perth, Western Australia.

Former waste recycling and treatment facility, Bellevue

- Operated from 1987 until 2001 when a large fire destroyed the premises.
- Historical practices and the fire has resulted in two plumes, in which contaminants greatly exceed ADWG criteria:
  - a mixed plume containing chlorinated benzenes, BTEX (benzene, toluene, ethyl benzene and xylene) and chlorinated solvents
  - a chlorinated solvent plume.
- This site is not located within a PDWSA, however, above ground chemical storage is "compatible with conditions" (such as bunding) in P2 and P3 areas.

Onsite groundwater monitoring results (mg/L).

Contaminant	ADWG	Max	Mean**
1,2 Dichlorobenzene	0.001*	3.48	0.15
1,4 Dichlorobenzene	0.003*	0.138	0.02
Benzene	0.001	0.099	0.02
Ethyl benzene	0.003*	57.7	3.53
Toluene	0.025*	125	14.14
Xylene - Total	0.02*	342	15.17
Tetrachloroethene	0.05	5.74	0.31
1,1-Dichloroethene	0.03	0.41	0.04
cis-1,2-Dichloroethene	0.06	7.92	0.78

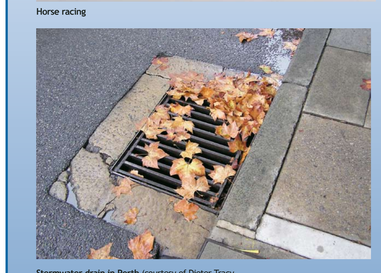
** aesthetic guideline level ** of samples with detected values*

Leaking chemicals due to poor storage (courtesy of Department of Environment).

Source: Golder Associates (2006a) Report on human health and ecological risk assessment, former waste control site, Bellevue, Golder Associates, West Perth, Western Australia

High density urban area, City of Belmont

Horse racing



Stormwater drain in Perth (courtesy of Dieter Tracy, Department of Water).

- Mix of residential, commercial, industrial and recreational uses.
- Stormwater monitoring indicates:
  - elevated nitrate levels (average 14.7 mg/L NO_3-N) as a direct result of a racecourse and horse stables
  - detections of hydrocarbons and heavy metals, with lead (average 0.034 mg/L) exceeding ADWG criteria (0.01 mg/L).
- This area is not located within a PDWSA, however, residential housing, light industry, horse stables and irrigation of recreational areas are all "compatible with conditions" in P3 areas.

Sources: Department of Water (2007b) Water Information (WIN) database - discrete sample data, Department of Water, Water Information Provision section, Perth, Western Australia; and Department of Water and South East Regional Centre for Urban Landcare (SERCUL) (2007) City of Belmont stormwater quality monitoring program Winter/Spring 2007 - Sampling and analysis plan, Department of Water and SERCUL, Perth, Western Australia.

Conclusion

When shallow groundwater resources and urbanisation co-exist, as they do in Perth, problems can arise with groundwater quality. This is particularly problematic when it is a major source of drinking water. The above case studies demonstrate the susceptibility of the superficial aquifer to contamination from urban land uses and the potential extent and long lasting effects of this contamination.

Declining water quality within PDWSA can cause increased health risks, greater water treatment costs and public expenditure, therefore protection is crucial. Current management prevents high-risk activities such as heavy industry and landfills from being established within PDWSA.

A certain degree of risk is accepted in P3 areas as pre-existing urban land uses, and social and economic pressures are recognised as needing to coexist with water resource protection.

This reflects the objective of risk management for P3 areas. Best management practices are promoted for land owners and operators within P3 areas to mitigate contamination risks. However, in P1 and P2 areas it is important to continue to prevent the establishment of urban land uses thereby preventing increased risk of contamination.

Where practical, when selecting new groundwater resources for drinking water supply, urbanised areas should be avoided as the quality of that water may have been compromised.

In conclusion, the current preventative, risk-based approach should continue to be implemented in order to ensure safe, good quality drinking water for Perth now and into the future.

A detailed explanation of all elements of drinking water source protection can be obtained via our website

drinkingwater.water.wa.gov.au