

2006 CHAST Lecture

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Sydney Groundwater – Friend or Foe?



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INTRODUCTION – SOME GROUNDWATER FACTS

Some 97% of all the freshwater that is found on the planet is stored underground.

Approximately 1500 million people depend upon groundwater to drink!

Groundwater supplies are recharged by rainwater that infiltrates the soil.

Groundwater can be extremely old – rain that fell 30,000 years ago is common.

Groundwater supplies have supported human settlements since their beginning.

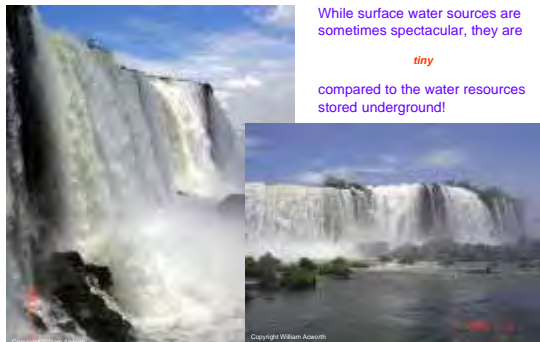
Groundwater is becoming increasingly polluted by a range of sources:

- agriculture
- foul water and sewage from cities
- chemical leaching from waste tips
- industrial processes
- mining.

There is a need to assess aquifer vulnerability and manage accordingly.



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Groundwater in Society

"Because the links between users and the resource are often not apparent, and because many benefits associated with groundwater are public goods, the overall economic value of groundwater goes unrecognised.

As a consequence, groundwater resources tend to be used with little regard for economic and other externalities.

From an economic perspective, the total value of groundwater is the sum of extractive and *in situ* values. Extractive values tend to accrue to individual users while *in situ*, or existence, values are generally public goods".

Groundwater and Society: Resources, Tensions and Opportunities
Themes in groundwater management for the twenty-first century

Jacob Burke and Marcus Moench (2000)
United Nations Department of Economic and Social Affairs



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Sydney Groundwater: Friend or Foe?

- Two aquifers – aeolian sands and fractured sandstone
- The Botany Aquifer
 - What is the aquifer?
 - How much water is there?
 - How much can we use?
 - Where is the pollution?
 - What can we do about it?
 - Can we still use the aquifer?
- Fractured Sandstone
 - What is the aquifer?
 - How much water is there?
 - How much can we use?



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The 'Botany Aquifer' – 150,000 years ago

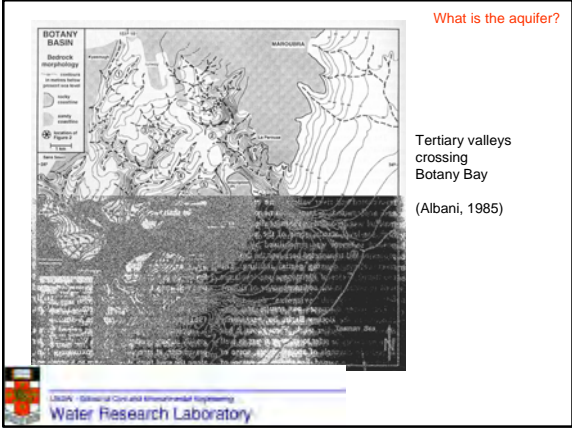
What is the aquifer?



Valleys in the Hawkesbury Sandstone surface were cut during the Tertiary Period that ended 1.5m years ago.

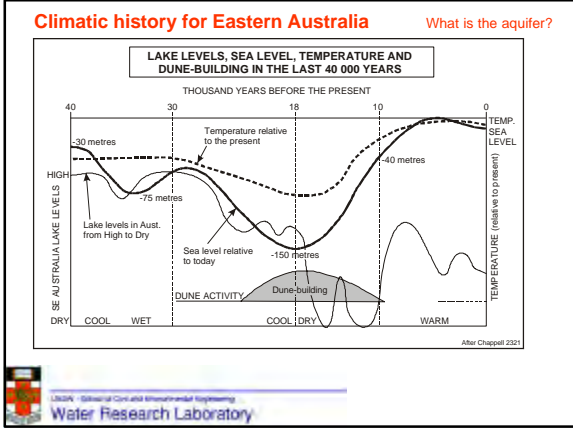


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What is the aquifer?

Tertiary valleys crossing Botany Bay (Albani, 1985)



Climatic history for Eastern Australia What is the aquifer?



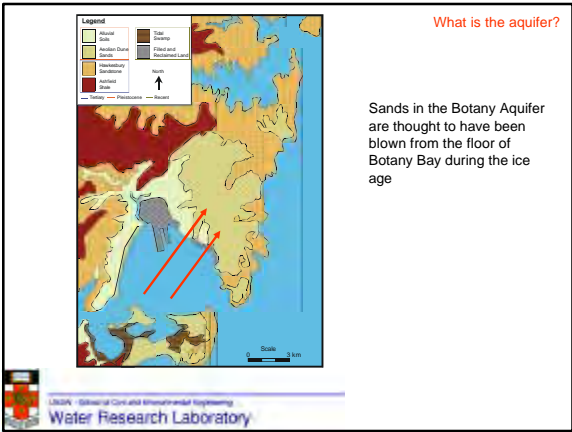
What is the aquifer?

Wind blown sand in the Namib desert – slowly moving to cover an old eroded and exposed rock surface.



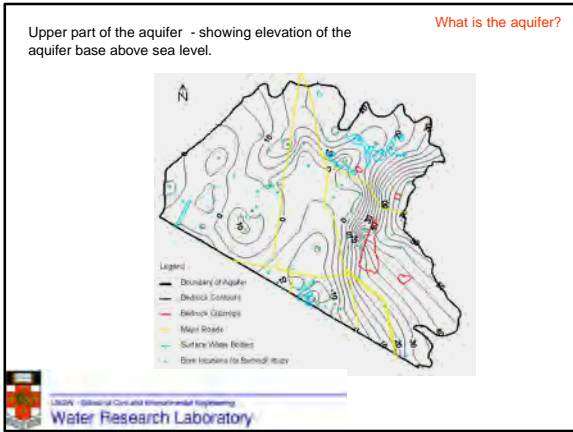
What is the aquifer?

Sand dunes encroach on a town in Peru and swallow an oasis in Yemen



What is the aquifer?

Sands in the Botany Aquifer are thought to have been blown from the floor of Botany Bay during the ice age



What is the aquifer?

Upper part of the aquifer - showing elevation of the aquifer base above sea level.

What is the aquifer?



Grassy fields (from afar)



Lush vegetation

Pictures taken in Hat Head National Park on an extensive area of sand dunes and wetlands similar to Botany Bay in 1788



Just right for grazing!

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What is the aquifer?



Getting rid of the rubbish!

Many sand dunes were first mined for their sand and then rubbish was dumped into the hole before a little sand was placed over the top and a golf course or playing field constructed



Astrolabe Park - 2006

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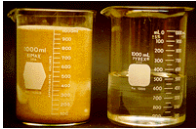
Approximate outline of the Botany Sands Aquifer



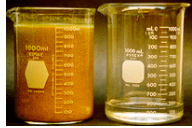
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How much water is there?

Porosity Demonstration



Beakers full of dry sand (1L) and 500mL of water



Water was slowly added to the sand until the water surface just covered the sand

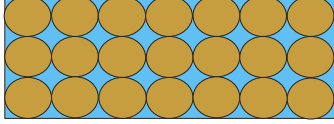
150mL of water was left in the beaker – 350mL now occupies the pore space in the sand.

The porosity is 35%

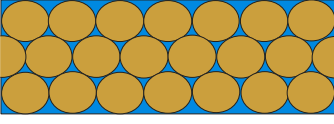
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How much water is there?

How much water do the sands contain?



Perfect cubic packing
porosity is 47.8%
478 Liters in every cubic meter of sand

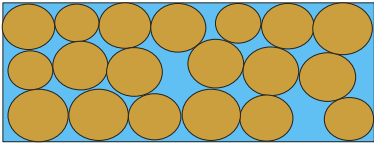


Perfect rhombohedral packing
porosity is 26%
260 Liters in every cubic meter of sand

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How much water is there?

Reality!
Botany aquifer sands have a typical porosity of 35%



350 L for every cubic meter of sand.
250 L can be drained from each cubic meter – the residual is left behind as soil moisture.

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How much can we use?

Some Botany Aquifer facts

If the volume of sands is known – then a simple calculation tells how much water is held in the aquifer. The northern part of the aquifer holds approximately 72 GL of water.

But

If we take out all of the water, then the wetlands will dry up completely, the parks will be brown – and the sand dunes that are left, will start moving again!

Groundwater moves from the recharge areas to Botany Bay at approximately 150 m/year. That is 50 years from Centennial Park to the Bay.

There is a record of more than 50 years of contamination in the southern and western parts of the aquifer.

But

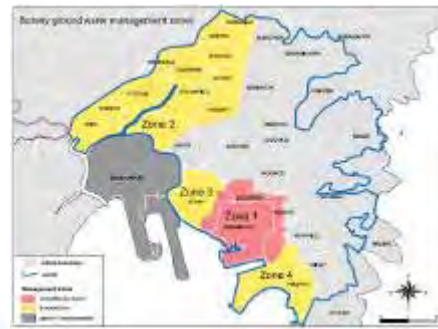
The water quality in the northern 2/3 of the aquifer remains of extremely high quality, despite receiving storm water run off for the last 130 years!



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Where is the pollution?

Contaminated groundwater zones



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Contaminated groundwater from the Botany Aquifer



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What can we do about it?

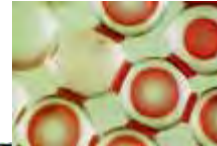
Contamination

Chemical spills of many different types...

If the chemical is soluble in water – then the contamination is relatively easily removed.

If the chemical is of another fluid that does not readily dissolve in water, then the contamination is long lasting and almost impossible to remove.

The most problematic contamination is caused by chemicals that are more dense than water and that are not miscible in water – the Dense Non Aqueous Phase Liquids or DNAPLs that are responsible for the Orca plumes.



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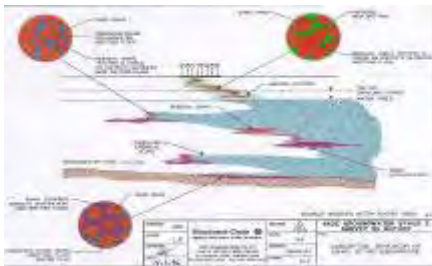
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What can we do about it?
Not a lot!

DNAPL contamination results in a plume of dissolved phase DNAPL carried away from the DNAPL fluid. The dissolved phase can be captured and treated but the free phase is recalcitrant to any known treatment so far. This means that production of the dissolved phase will continue for hundreds of years!



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Can we still use the aquifer?

Chemical quality of groundwater in Centennial Park



Parameter	Pump bore in Centennial Park	Sydney Water supply	Drinking water guidelines*
pH	5.5-6.3	8	6.5-8.5
TDS	100	110	<500
Iron	10	0.016	<0.3
Nitrate as N	0.2	0.3	11.3
E.Coli	mostly ND	ND in 99%	ND in 98%
Total P	0.05		
Zinc	0.02		
Cu, Pb, Ni, Cr	ND		
ND = not detected			

If the iron is removed then the water is fit to drink



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Can we still use the aquifer?

The chemical quality of groundwater as far south as Daceyville remains excellent and is used by UNSW, Randwick Race Course and by Councils to water many parks and gardens.



Drilling a replacement borehole at David Phillips Field, UNSW



Can we still use the aquifer?

The Botany Aquifer has been recharged with storm water for the past 130 years. Bondi Junction storm water is directed to Model Yacht Pond in Centennial Park.



Bottles and plastic collected in the trash racks at Model Yacht Pond

Flood mark from September 2006 rains


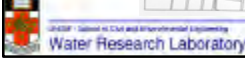


Can we still use the aquifer?

Stormwater Recharge

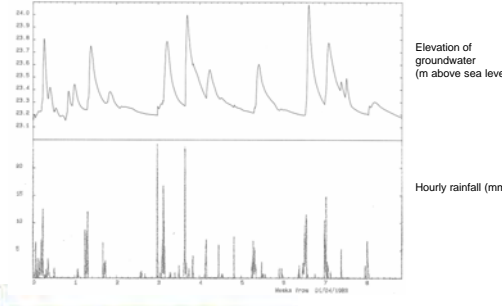
Five of the ponds in Centennial Park receive direct inflow from stormwater with major inflows to

Model Yacht, Musgrave, Randwick, Busby's and Kensington Ponds


Can we still use the aquifer?

Groundwater Level Response to Rainfall in the Botany Aquifer



Elevation of groundwater (m above sea level)

Hourly rainfall (mm)



Can we still use the aquifer?

Managed aquifer recharge is already occurring in Centennial Park and has been going on for the last 130 years.


There are no known impacts on aquifer water quality, which remains very good!

Is it possible to augment this recharge and increase the water in storage in the aquifer?

We need to check to see if it is possible to divert other storm water to the Park. If this is possible, then additional water can be easily sourced.

In many parts of the world, treated effluent is used to recharge groundwater. A continuous additional source of water would raise the groundwater levels in the Park and in the aquifer beyond the Park.

Raised groundwater levels would lead to increased baseflow, higher pond levels and would allow Councils to abstract more water for watering during droughts – keeping all the Parks green.



Can we still use the aquifer?

The fine grained sand in the Botany Aquifer is an excellent filter medium.


Effluent recharged at the top of the Park would spend approximately **10 years** slowly moving through the sand before it came to the park boundary.

This compares with a travel time of **<10 hours** used to polish sewage effluent in conventional treatment works, before it is chlorinated and returned for use.

There is a large community of naturally occurring bacteria that attach themselves to the sand grains in the aquifer and effectively treat the water as it slowly passes by!

Typical abstraction bores in the Botany Aquifer have yields of 1.5ML/day and cost approximately \$35,000. This compares very favorably with proposed bores into the fractured sandstone.

Increased recharge to the aquifer from treated wastewater could be recovered by new abstraction bores and used for supply with minimal treatment.



Summary

Yes – we can still use the upper part of the Botany Aquifer as a significant source of water.

We could easily enhance recharge to the aquifer and then increase the abstraction from the aquifer. Many of the ponds in Centennial Park are acting as recharge ponds.

The southern part of the aquifer is likely to remain contaminated for many decades - unless some new affordable technology is invented to completely remove oil adhered to sand grains. This is not considered likely from what we currently know. The oil industry leave behind 10 to 15% of oil in the ground.

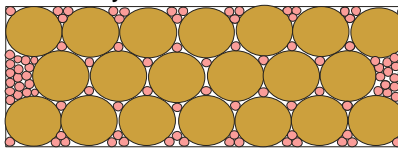
This amount of DNAPL would cause a major plume similar to that at Orica.

What about water in the fractured sandstone?



Hawkesbury Sandstone

What is the aquifer?



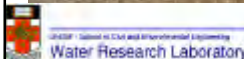
Two grain sizes mixed together greatly reduce porosity



A conglomerate is a mixture of different grain sizes and will have a much reduced porosity.

Conglomerates, sands and gravels are deposited by rivers.

The Hawkesbury Sandstone is a fluvial deposit that has later been subject to compression and cementation.



What is the aquifer?



Photomicrographs of a sandstone rock



Note how the pore space is clogged with smaller grain size particles or new crystals growing in the pore space.

The lack of primary porosity explains the low yields of the Hawkesbury Sandstones and why it is necessary to search for areas where the sandstones have been broken and fractured by later earth movements.



What is the aquifer?

Sandstone exposed at Belrose

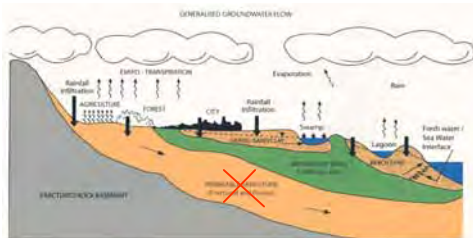


Groundwater seepage from bedding plane in sandstone

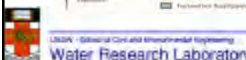


What is the aquifer?

Sydney Catchment Authority Model



Sandstone has low porosity and low permeability with little if any regional flow!



How much water is there?

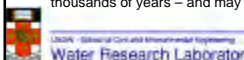
Water is found in fractures in the sandstone and along bedding planes.

Fractures form when the ground is moved by geological (plate tectonic) processes.

The quantity of water is inherently difficult to predict as we can not know the extent of fracturing. This is backed up by the SCA results that picked 7 sites for detailed investigation – based upon predicted fracture trends. Only 2 sites gave reasonable supplies of water. It is possible that these 2 sites lie on the same structure.

The only way to assess the quantity of water available in the fractured sandstone is to carry out a long term pumping test. The results from one test can not be extrapolated to another area.

These programs are expensive and may not lead to a guaranteed supply of water. It is possible to pump water from the system that has been there for thousands of years – and may take thousands of years to be replenished.



How much water is there?

Water from the fractured sandstone is generally of good quality.

As the prospective area is far away from sources of contamination – there is little risk of pollution.

There is a risk that swamps and seeps on the sandstone may be dried up by groundwater abstraction.

BUT the major reservation is one of cost!

The SCA have estimated that the bores into fractured sandstone will cost approximately \$50 million dollars. Much of this cost is made up by the cost of installing the required power supplies to the pumps. The costs do not include the power required to run the pumps.

Each bore is estimated to yield 1ML/day – although some bores are returning more promising yields up to 3ML/day. It has been estimated that 50 bores (50ML/day) are required to provide an emergency water source for Sydney.



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SUMMARY

The Botany aquifer can be further developed by making use of artificial recharge

There is a possibility that further stormwater could be diverted to the Centennial Park area, but

the simplest way to obtain significant additional water is to use treated effluent. Studies are required to establish how much additional water could be made available by this technique.

The sandstone aquifer does **NOT** extend under Sydney as a major resource.

There may be small increments of water that can be obtained from zones of fractured sandstone, but the cost of development is disproportionate to the size of the resource. It does not normally make economical sense to drill 200m to obtain 12.6L/s or 1ML/day.

Groundwater is NOT a solution to Sydney's water supply problem.



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