WELL PUMPING TESTS SHORT COURSE

21st November 2019

SCHEDULE

9:15–9:45	Introduction and course outline Objectives of pumping tests	BM
9:45–10:45	A refresher about radial flow to wells and common assumptions and misconceptions in well pumping tests Step drawdown tests, constant rate tests and recovery tests Common steady-state and non-steady state analysis methods	BM
10:45–11:15	Design, Construction and Operation of Water Supply Boreholes in Ireland. Influence of well design on abstraction, drawdown and quality.	DB
11:15-11:30	Coffee	
11:30-12:00	Yield-drawdown relationships in fractured aquifers. Assessing sustainable yields from pumping tests & using operational data	BM
12:00–12:30	Summarising transmissivity & storage of Irish aquifers; the implications for a sustainable yield.	THW
12:30-13:00	Pump selection based on test pumping results Case study – Assessments and Interpretations from operational pumping records.	HM DB
13:00–14:00	Lunch	
14:00–14:45	Practicalities of undertaking well testing: – planning, set-up and implementation. Possible constraints. Onsite data analysis and decision-making.	HM
14:45-15:15	Pump test analyses software and their uses and limitations	HM
15:15-16:00	Case Study - Quarry Dewatering	DB
	Case Study - *To Be Determined*	DB
16:00-16:30	Discussion; final questions; and close of course	

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Geological Survey
Suirbhéireacht Gheolaíochta
Ireland | Éireann

Summarising transmissivity & storage in Irish aquifers

Taly Hunter Williams
Geological Survey Ireland

Acknowledgements: Coran Kelly (TOBIN), Bruce Misstear (TCD), Eugene Daly, Donal Daly, Geoff Wright , Vincent Fitzsimons, Bob Aldwell (all formerly GSI), David Burdon, **& all practising Hydrogeologists and Drillers in Ireland**

Outline

- Conceptual models for Irish fractured aquifers
- Aquifer properties
- Influence on borehole yield of aquifer heterogeneities
- Implications for sustainable yield
- Summary and Conclusions

CONCEPTUAL MODELS

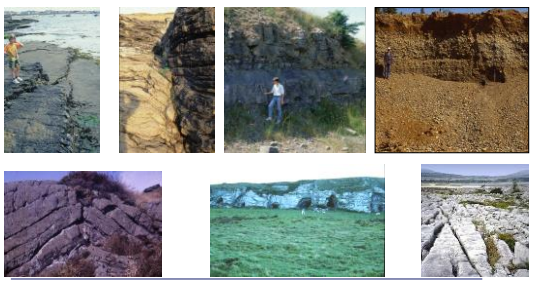
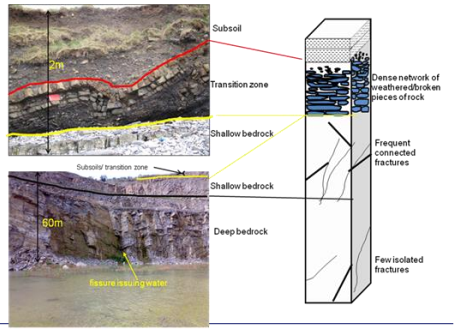


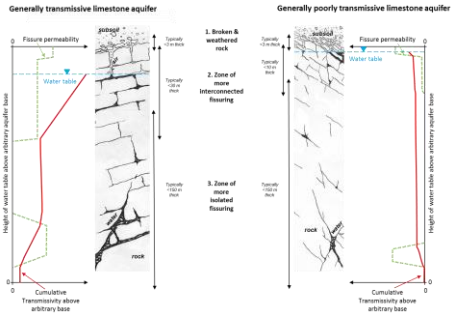
Photo credits: Donal Daly/others

Fissured bedrock aquifer conceptual model



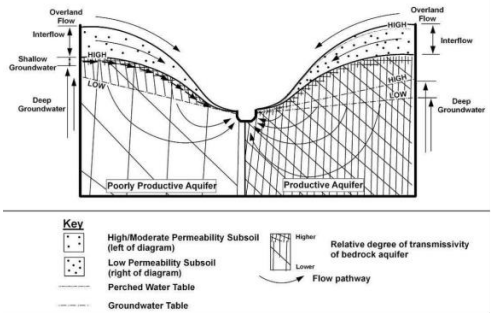
from Kelly et al. (2015)

Fissured bedrock aquifer conceptual model



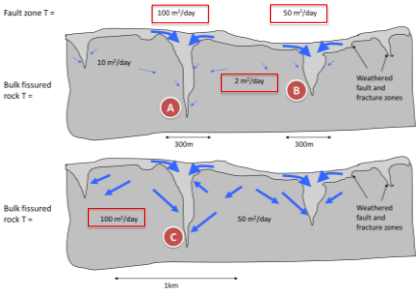
from Fitzsimons et al. (2005)

Fissured bedrock aquifer conceptual model



by Daly and Hunter Williams, in RPS 2008

Fissured bedrock aquifer conceptual model



A 3 km long fault zone. Theoretical yield 600 m^3/d

B 0.5 km long fault zone. Theoretical yield 100 m^3/d

C 3 km fault zone. Theoretical yield 2,000 m^3/d

Annual recharge of 250 mm in all cases

From GSI (in prep.) and adapted from images and calculations by Vincent Fitzsimons

AQUIFER PROPERTIES

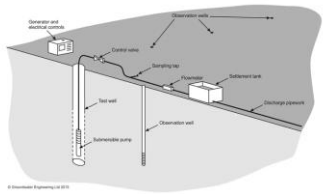
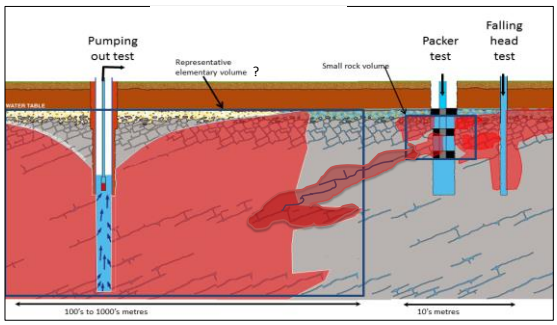
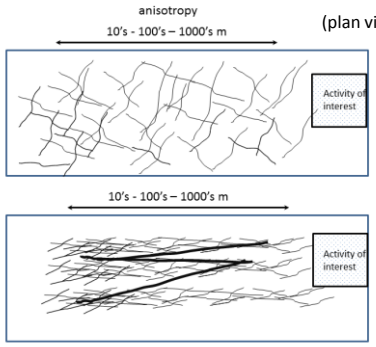


Image: https://www.groundwatereng.com/pumping-tests

Scale of measurement

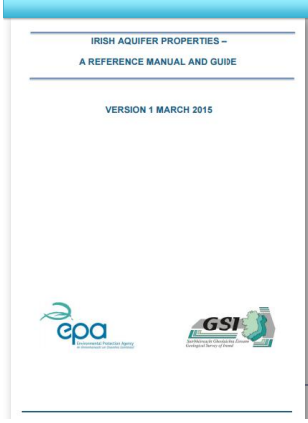


Anisotropy & scale of heterogeneity



Limitations of typical Irish pumping test data

- analytical assumptions often not met
- relatively short tests
- declining or variable pumping rates
- unknown geology/ construction details
- frequently single well
- none/inadequate observation well data
- throttling of different fractures
- bias towards one single large fracture
- often only yield and specific capacity reported



http://www.gsi.ie/programmes/groundwater/aquifer+classification

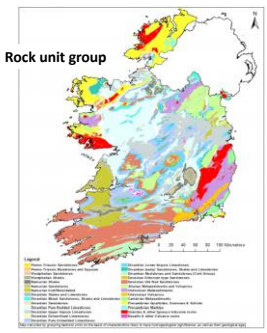
Aquifer properties database

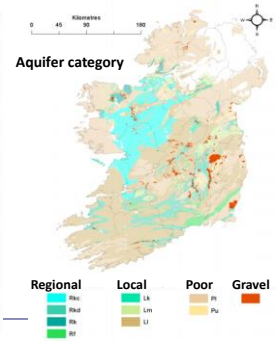
- Compiled >600 data, many 3rd party
- Screening for quality, detailed 'paper trail'
- Issues with data
  - 'pseudo T', 'bulk K', fracture K, biases
  - obtaining data – no legal framework
- Database is beginning of a useful reference for practitioners within a hydrostratigraphic framework
- Summary tables indicate typical properties and ranges
- Focus on transmissivity, more fracture K and storage parameters needed

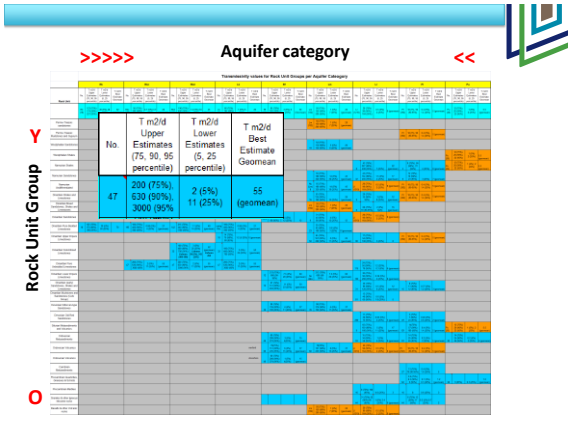
Aquifer properties database

- Biases in dataset
  - "high" quality T data tend to be from successful water supply investigations
  - "supplementary" data from smaller abstractions with less precise measurements
  - short tests can give overestimates
- Uncertainties in dataset
  - interval(s) being tested
  - influence of heterogeneities
- Number of data per aquifer type similar to area, but rock unit groups over/under-represented

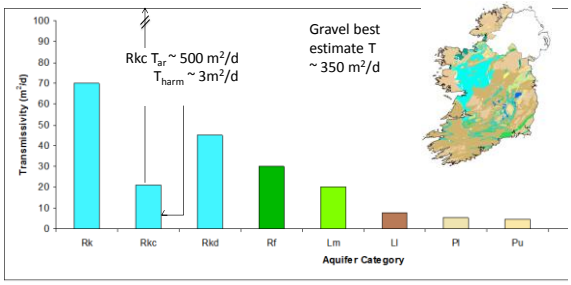
Reporting framework for aquifer properties





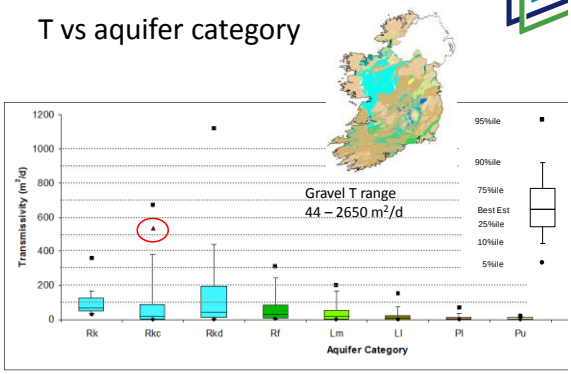


Best estimate T vs aquifer category

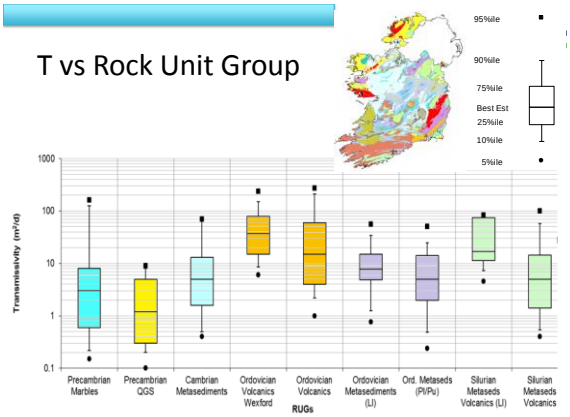


Best estimate: Geometric mean except for Rkc (arithmetic and harmonic)

T vs aquifer category



T vs Rock Unit Group



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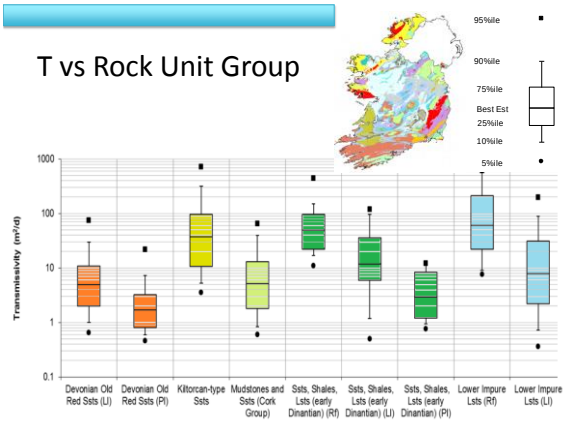
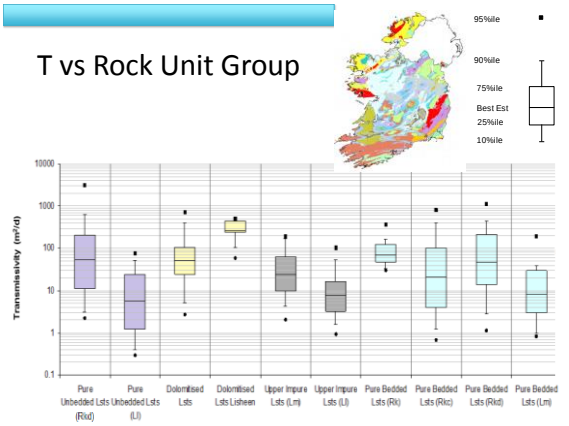
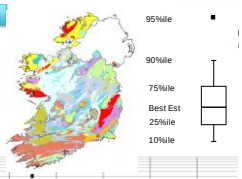
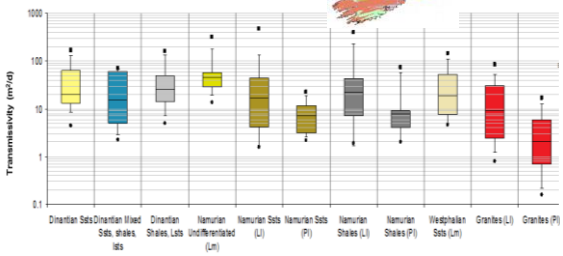


T vs Rock Unit Group

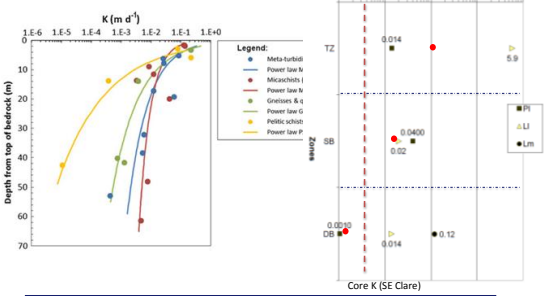


T vs Rock Unit Group





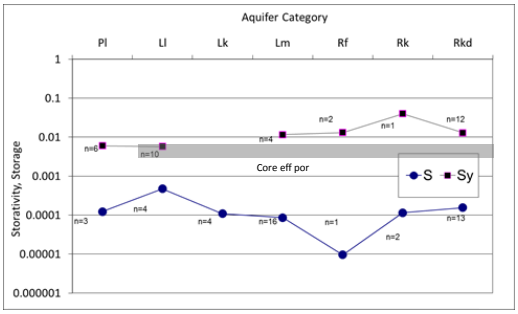
Bulk permeability vs depth



From Comte et al. (2012)

Adapted from Kelly et al. (2015)

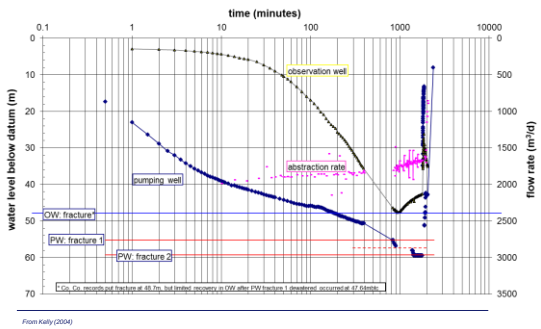
Confined and unconfined aquifer storage



from Kelly et al., 2015

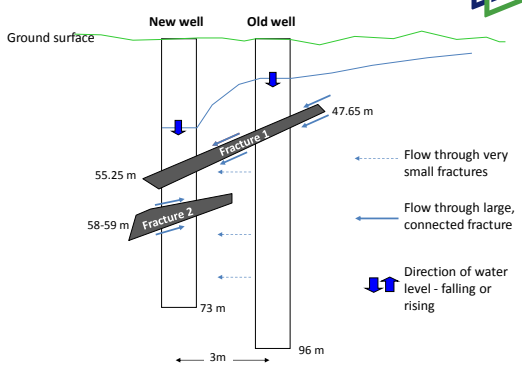
INFLUENCE OF HETEROGENEITIES ON YIELD

Photo: Robbie Meehan

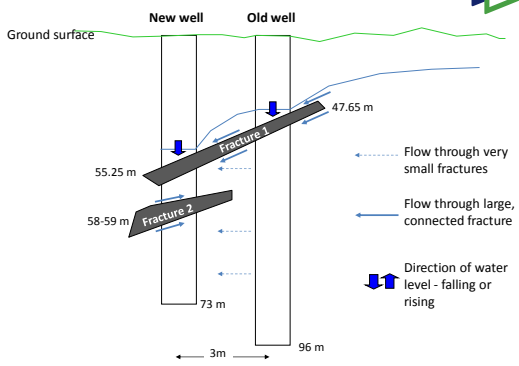


From Kelly (2004)

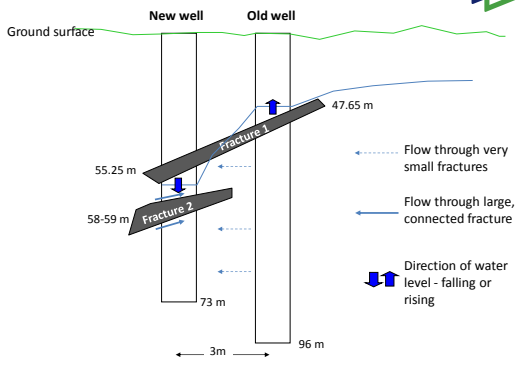
Early time during pumping test: ~100 mins



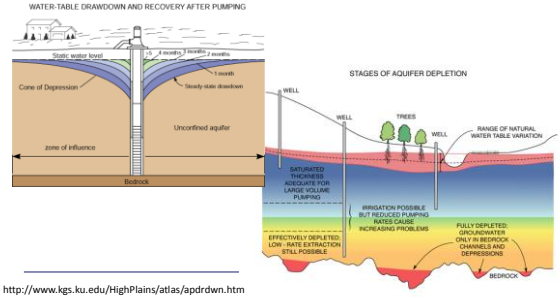
Mid-early time during pumping test: ~500 mins



Mid- time during pumping test: ~1000 mins

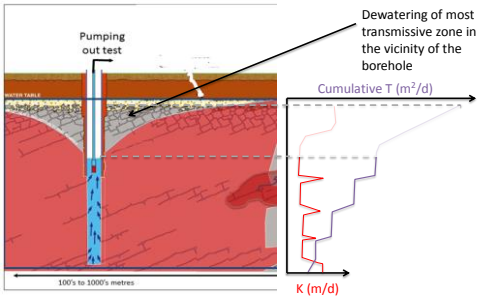


IMPLICATIONS FOR SUSTAINABLE YIELD

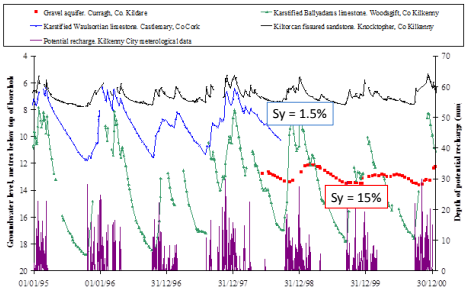


http://www.kgs.ku.edu/HighPlains/atlas/apdrdwn.htm

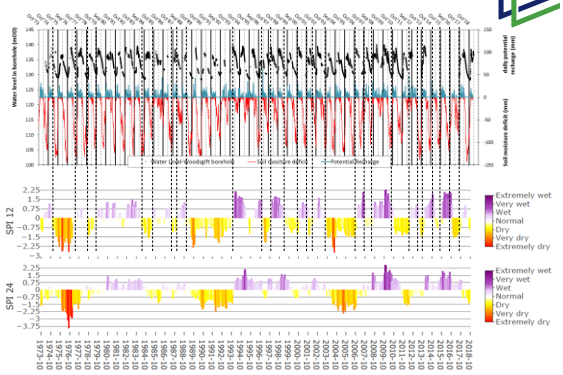
Implications for sustainable yield – hydraulics



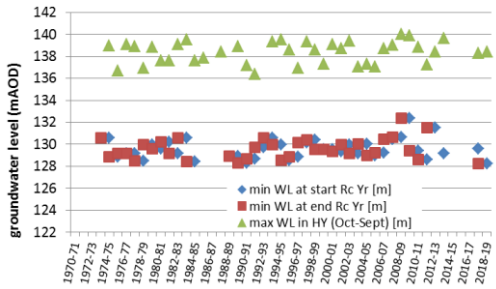
Implications for sustainable yield – storage



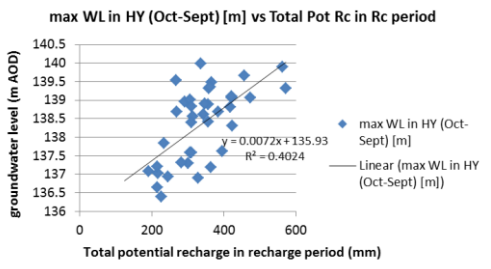
from Fitzsimons & Missteor (2005)



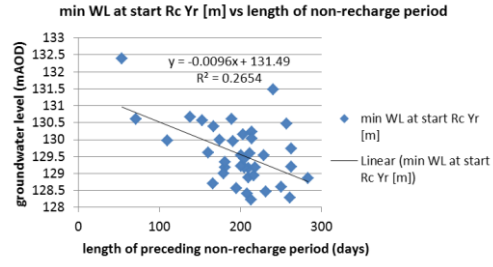
Maximum and minimum GW levels at Woodsgift/Borrismore Creek



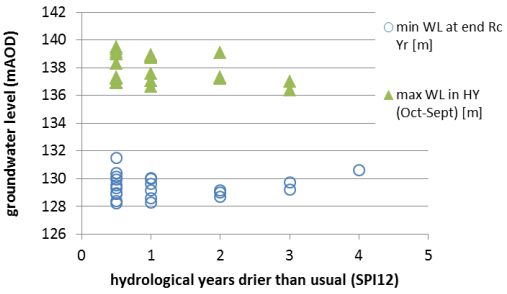
Maximum GW levels vs total potential recharge



Minimum GW levels vs duration of non-recharge period



Maximum and minimum GW levels after dryer than usual years



Summary (1)

- Detailed studies and general pumping-out tests show that permeability typically decreases with depth and can have a significant impact on sustainable yield.
- Effective porosity and unconfined groundwater storage is low across all fissured bedrock aquifer categories.
- Low storage in Irish fissured bedrock aquifers can result in water level declines and decrease in saturated thickness of most transmissive zone
  - During non-recharge periods or after prolonged dry weather, higher transmissivity zone thickness decreases and yields drop off
  - GSI recharge map represents 'deep' groundwater zone for this reason
- Poorly productive aquifers (i.e. Pu, Pl, Ll) are probably self-limiting in dry weather scenarios
  - Once higher transmissivity shallow zone dewaters, groundwater flow decreases and wide-spread overexploitation difficult

Summary (2)

- Seems to be a multi-annual groundwater level 'memory' related to dry years. However, this is a small effect at Woodsgift.
- Generally, groundwater level recovery in unconfined fractured aquifers is rapid after onset of potential recharge period
  - Fractured bedrock groundwater systems may be resilient to historical weather patterns
  - Dry winters more relevant than dry summers
  - IF wetter winters and longer, dryer summers become the norm, then poorly productive aquifers *may* generally behave as normal – the issue arises with increased water demand and the duration of the dry period

Conclusions

- Developing sustainable yields from Irish bedrock aquifers requires an understanding of the nature and distribution of the fissuring that generates permeability within the aquifer, and how this will influence groundwater supply source development and operation.
- The low storage capacity of Irish fractured bedrock aquifers in one sense is a drawback: low storage results in seasonal groundwater level declines of at least several metres, and often more. This results in a decrease in saturated thickness of the transmissive 'shallow bedrock', which then impacts on possible abstraction rates.
- However, low effective porosity and storage may also be seen as beneficial, since groundwater levels recover rapidly with the onset of the groundwater recharge period.
- Need to deal with what nature has provided us with and adapt our usage of the resource – "sip" the aquifer.