Troubled Waters: Tackling Issues With Wells

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NC Cooperative Extension

Probability of Microbial Contamination

Public Water Supply

Treated with a sanitizer

Ground Water

Surface Water

Open to Environment

Produce Safety ALLIANCE

Groundwater Vulnerability to Microbial Contamination

By Kelly A. Reynolds, MSPH, Ph.D.

The vulnerability of groundwater supplies is further exemplified by drinking water outbreak data where the majority of documented outbreaks were traced to a groundwater source.

Of the 751 drinking water waterborne outbreaks that occurred in the United States from 1971-2000, ***62 percent*** *were linked to groundwater systems*

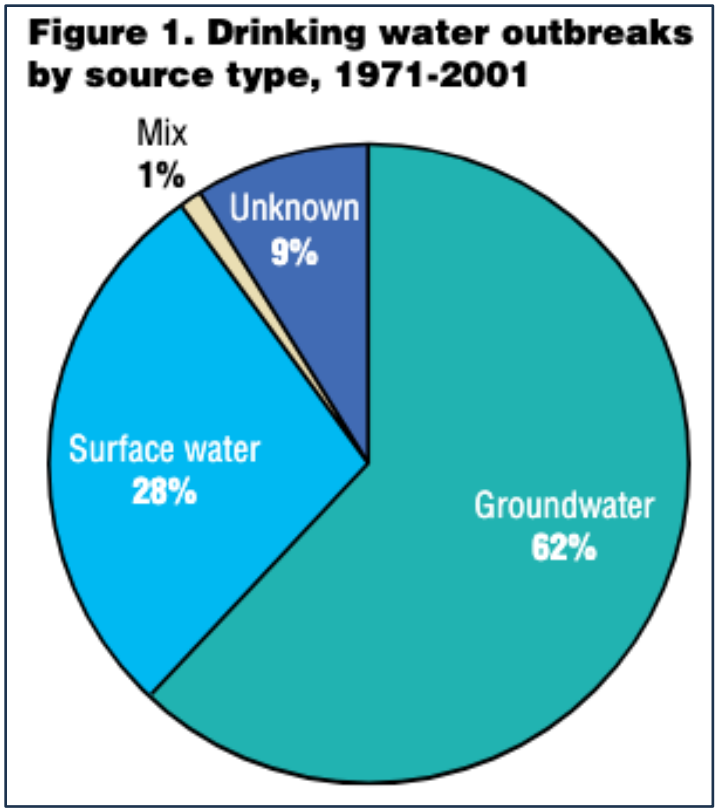


Table 1. Evidence of groundwater well contamination

Sample Description	Virus Positive	Source
448 utility wells, 35 states	32% virus positive	Abbaszadegan et al., 2003
50 homeowner wells	8% virus positive	Borchardt et al., 2003
29 utility wells	16% virus positive	Fout et al., 2003
48 midwest utility wells	42% enterovirus positive 6% norovirus group 1 positive	Borchardt et al., 2004

https://esrac.arizona.edu/sites/default/files/2004_12_on_tap.pdf

microorganisms

MDPI

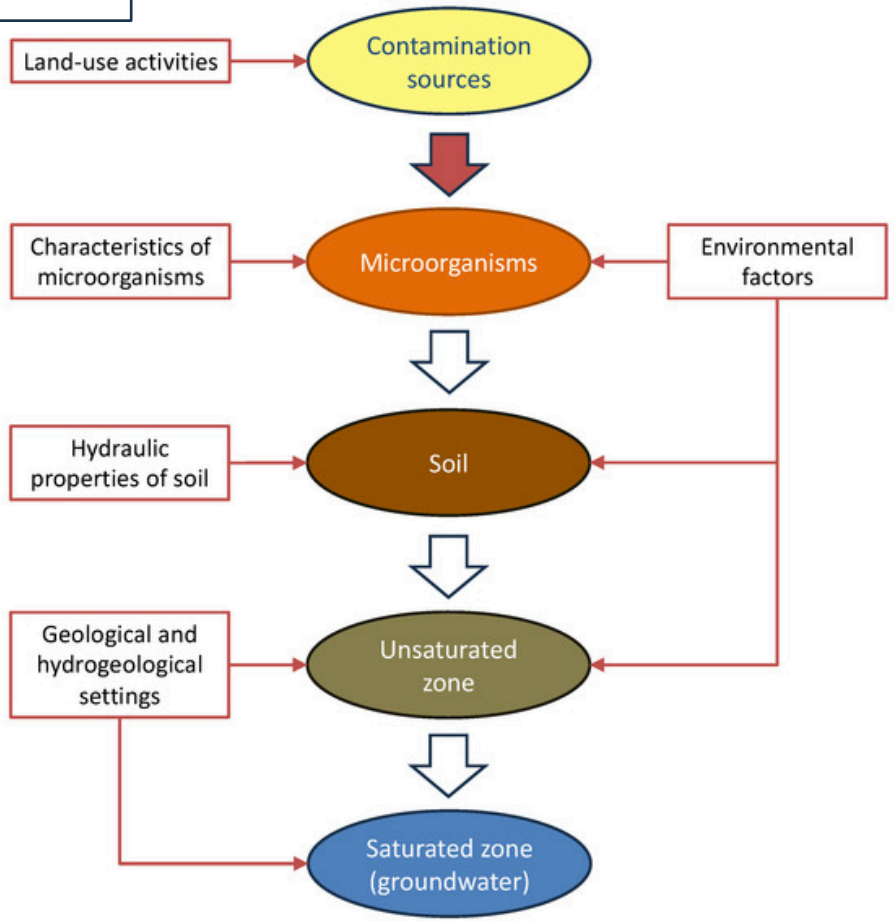
Review

Factors Influencing Microbial Contamination of Groundwater: A Systematic Review of Field-Scale Studies

Francesco Bagordo [1], Silvia Brigida [2], Tiziana Grassi [2,*], Maria Clementina Caputo [3], Francesca Apollonio [4], Lorenzo De Carlo [3], Antonella Francesca Savino [5], Francesco Triggiano [4], Antonietta Celeste Turturro [3], Antonella De Donno [2], Maria Teresa Montagna [4] and Osvalda De Giglio [4]

"Microorganisms are released onto the soil, infiltrate, and then cross the unsaturated zone of the aquifer, before eventually reaching the saturated zone and contaminating the groundwater."

"During each of these phases, microorganisms are subject to the influence of various factors, including land-use activities, environmental conditions, the hydraulic properties of the soil, and other geological and hydrogeological settings."

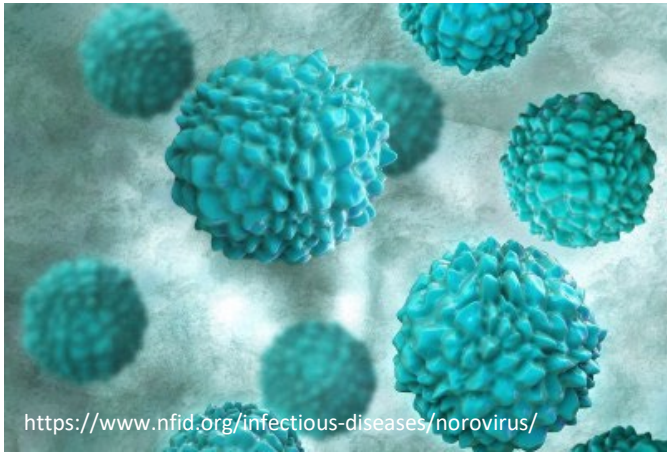


Microorganisms **2024**, *12*(5), 913; https://doi.org/10.3390/microorganisms12050913

Microbial Pathogens of Public Health Concern

- **Bacteria**
  - Pathogenic *E. coli*
  - *Salmonella*
  - *Listeria*

- **Viruses**
  - Hepatitis A
  - Noroviruses

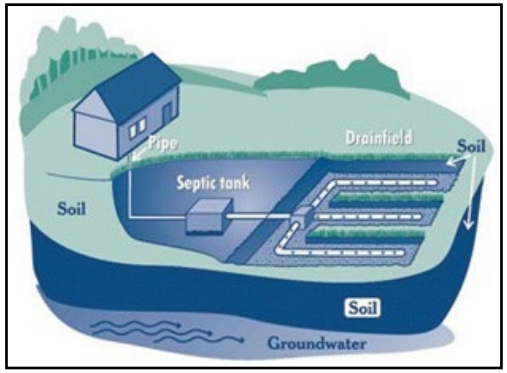


- **Parasites**
  - *Cyclospora*

Sources of Microbial Pathogens in the Environment

- Fecal pathogens (*Salmonella*, *E. coli*, Noroviruses, *Cyclospora*)
  - **"Zoonotic"** pathogens: those capable of infecting animals as well as humans
    - Livestock and animal manures
    - Wildlife
  - Seepage from on-site septic systems
  - Poorly/untreated human sewage

- Naturally occurring
  - i.e. *Listeria*

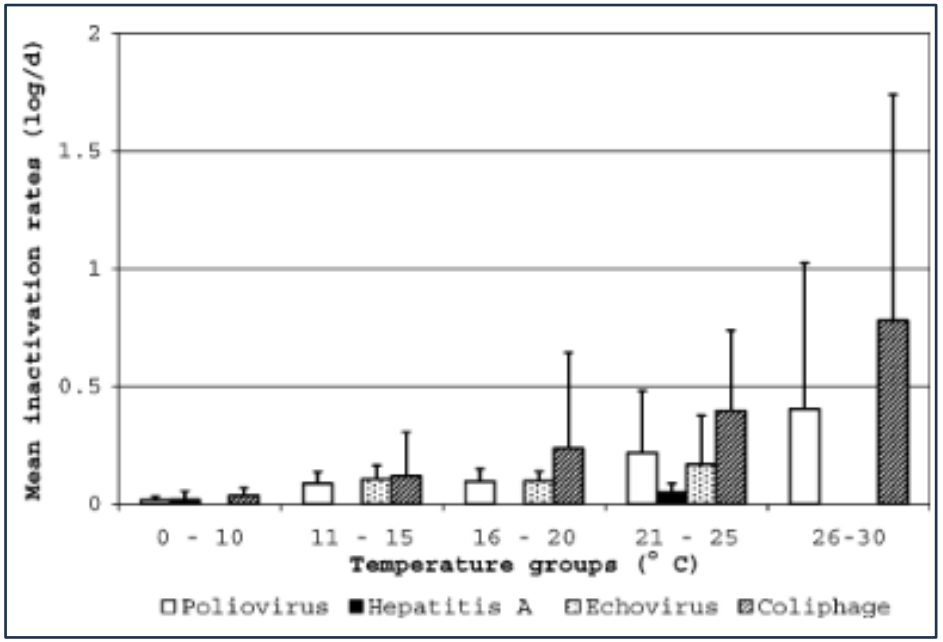


Critical Review

Review of Factors Affecting Microbial Survival in Groundwater

DAVID E. JOHN*,† AND JOAN B. ROSE*,‡

The geometric mean value for inactivation rates for coliphage, poliovirus, echovirus, coliform bacteria, enterococci, and Salmonella spp. were similar at approximately ***0.07-0.1 log_{10}/day****, while geometric mean inactivation rates for hepatitis A virus, coxsackievirus, and phage PRD-1 were somewhat less at* ***0.02-0.04 log_{10}/day****.*



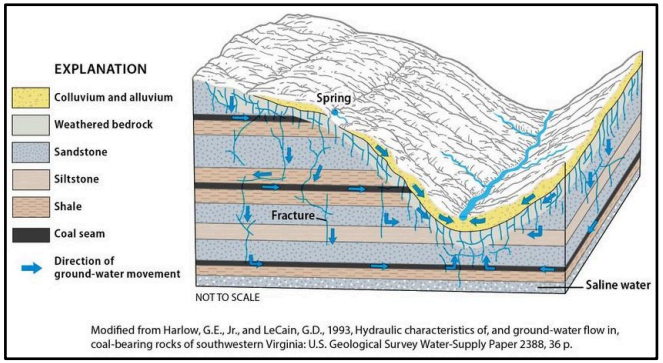
Average US groundwater temp = 5°C to 22°C
https://www3.epa.gov/ceampubl/learn2model/part-two/onsite/ex/jne_henrys_map.html

https://doi.org/10.1021/es047995w

Assessing Risks from Groundwater

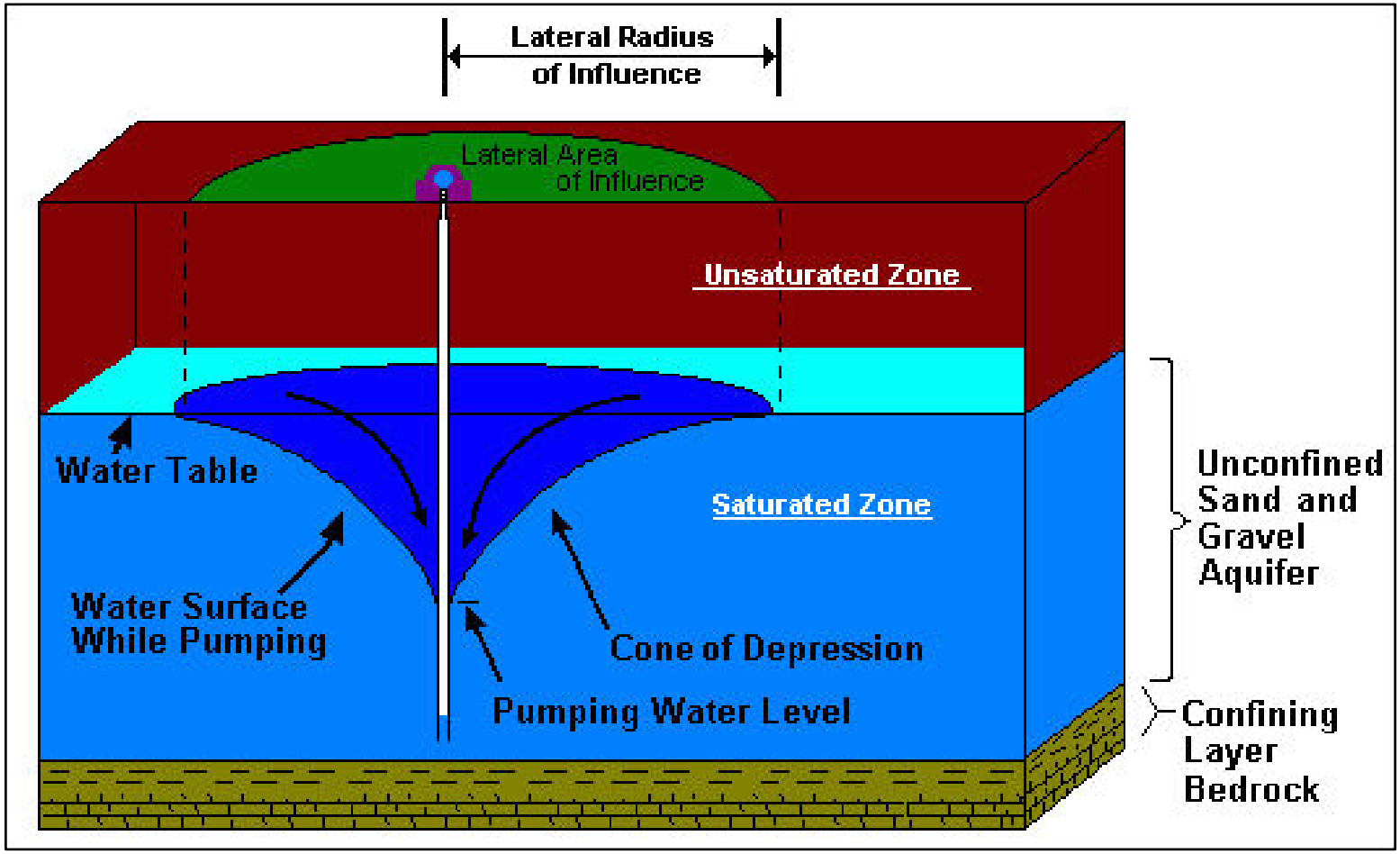
When assessing microbial risks with groundwater, it is important to consider potential issues arising from:

1. Adjacent Land Use (Environmental Sources),
2. Hydrogeologic Pathways,
3. Pathways associated with well construction, and
4. Other Special Cases.



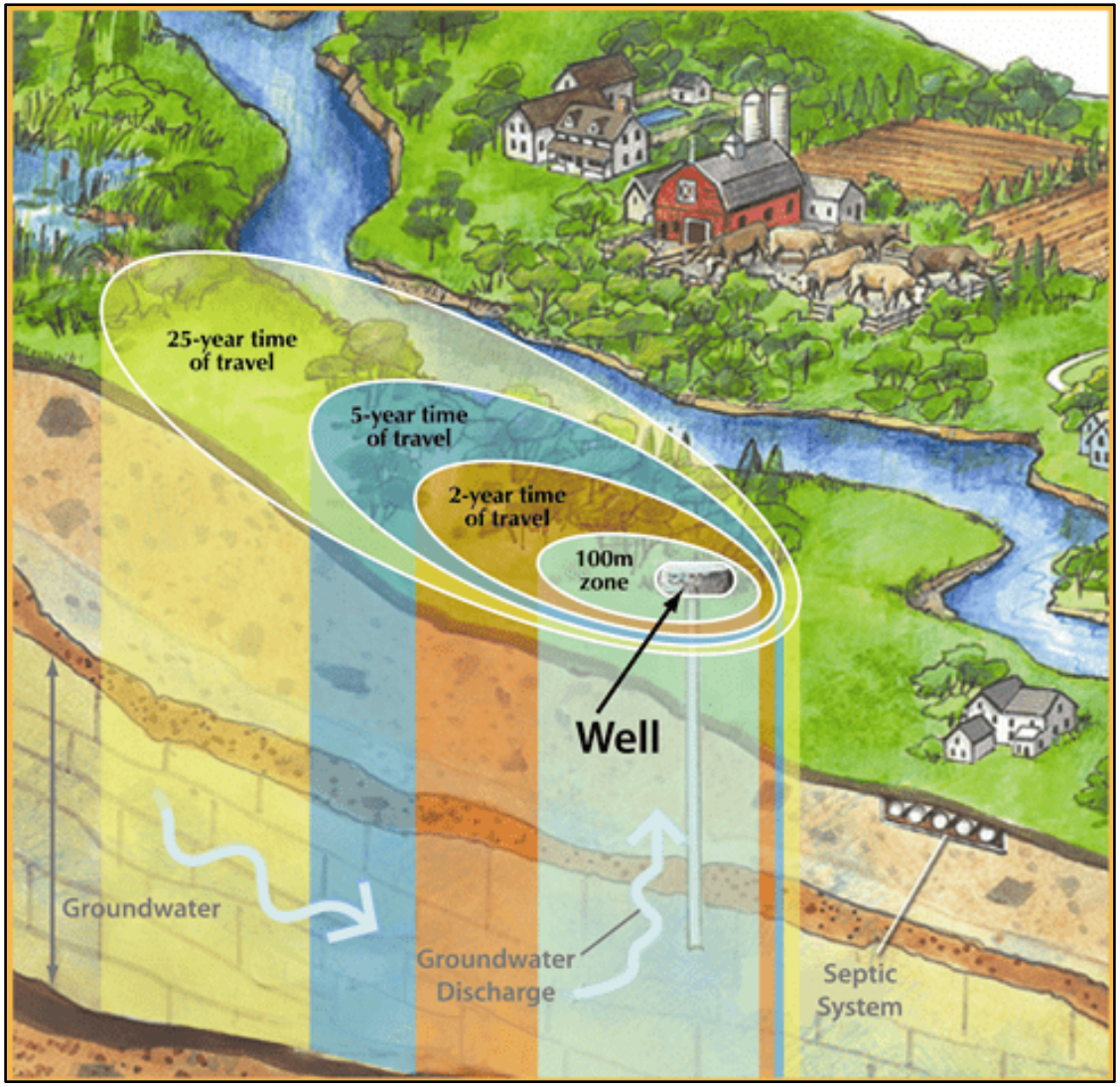
Modified from Harlow, G.E., Jr., and LeCain, G.D., 1993, Hydraulic characteristics of, and ground-water flow in, coal-bearing rocks of southwestern Virginia: U.S. Geological Survey Water-Supply Paper 2388, 36 p.

Adjacent Land Use: Lateral Zone of Influence



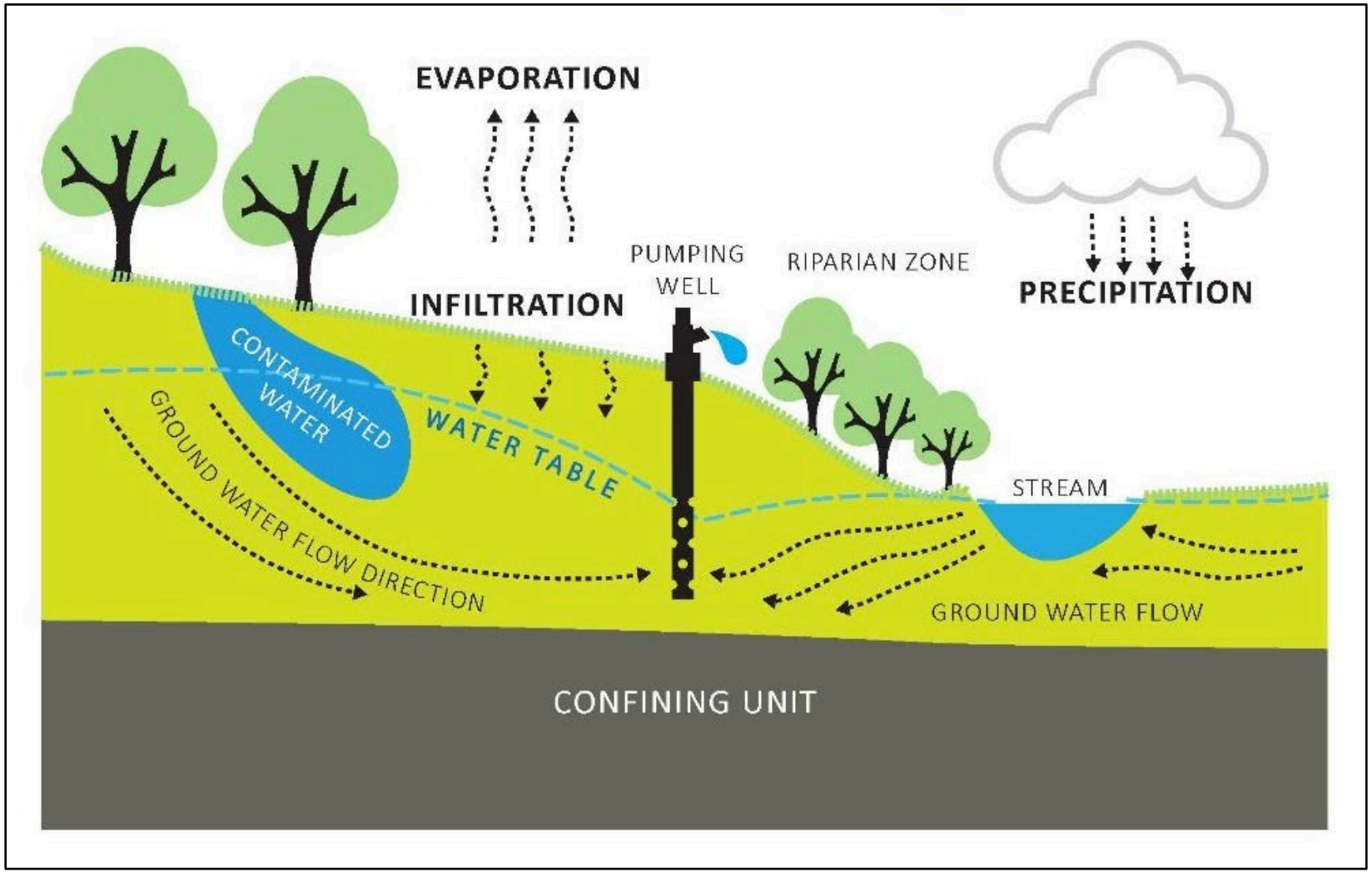
https://epa.illinois.gov/topics/water-quality/groundwater/wellhead-protection.html

Adjacent Land Use : Lateral Zone of Influence



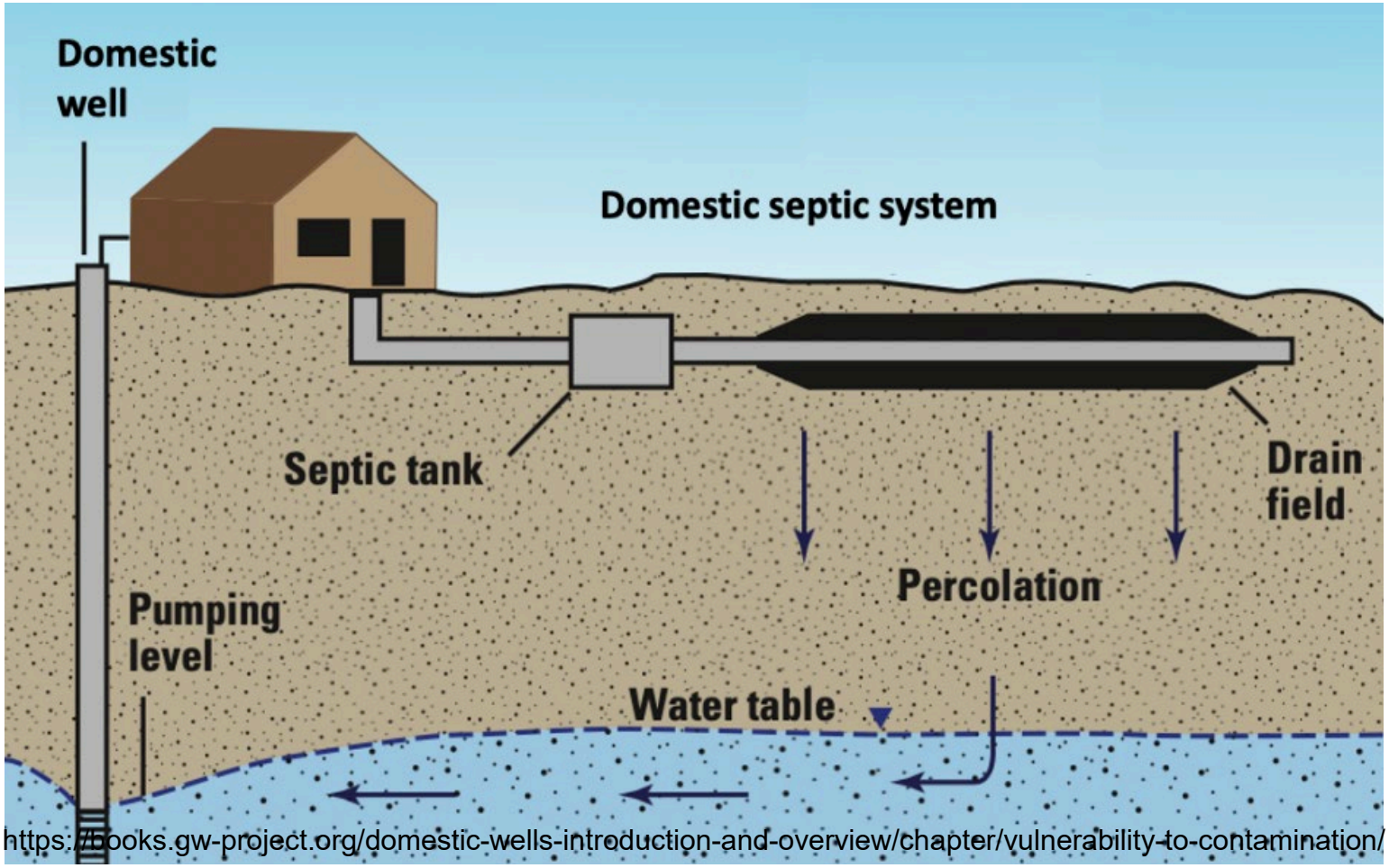
https://www.protectingwater.ca/planning-process/vulnerable-areas/wellhead-protection-areas/

Adjacent Land Use : Lateral Zone of Influence



https://www.hopkinsmn.com/995/Wellhead-Protection

Adjacent Land Use: Onsite Septic Systems



Leachates from onsite septic systems can lead to contamination through subsurface flow

Outbreak of Viral Gastroenteritis Due to a Contaminated Well

International Consequences

Michael Beller, MD, MPH; Andrea Ellis, DVM, MSc; Spencer H. Lee, PhD; Michael A. Drebot, PhD; Sue Anne Jenkerson, MSN, FNP; Elizabeth Funk, MD, MPH; Mark D. Sobsey, PhD; Otto D. Simmons III, MSPH; Stephan S. Monroe, PhD; Tamie Ando, PhD; Jacqueline Noel; Martin Petric, PhD; John P. Middaugh, MD; John S. Spika, MD

Context.—Small round-structured viruses (SRSVs) are known to cause viral gastroenteritis, but until now have not been confirmed in the implicated vehicle in outbreaks.

Objective.—Investigation of a gastroenteritis outbreak.

Design.—After applying epidemiologic methods to locate the outbreak source, we conducted environmental and laboratory investigations to elucidate the cause.

Setting.—Tourists traveling by bus through Alaska and the Yukon Territory of Canada.

Participants.—Staff of a restaurant at a business complex implicated as the outbreak source, convenience sample of persons on buses that had stopped there, and bus employees.

Main Outcome Measures.—Odds ratios (ORs) for illness associated with exposures. Water samples from the restaurant and stool specimens from tourists and restaurant staff were examined by nucleic acid amplification using reverse transcription polymerase chain reaction and sequencing of viral amplification products.

Results.—The itineraries of groups of tourists manifesting vomiting or diarrhea were traced back to a restaurant where buses had stopped 33 to 36 hours previously. Water consumption was associated with illness (OR, 5.3; 95% confidence interval [CI], 2.3-12.6). Eighteen of 26 employees of the business complex were ill; although not the index case, an employee ill shortly before the outbreak lived in a building connected to a septic pit, which was found to contaminate the well supplying the restaurant's water. Genotype 2/P2B SRSV was identified in stool specimens of 2 tourists and 1 restaurant employee. Stools and water samples yielded identical amplification product sequences.

Conclusions.—The investigation documented SRSVs in a vehicle epidemiologically linked to a gastroenteritis outbreak. The findings demonstrate the power of molecular detection and identification and underscore the importance of fundamental public health practices such as restaurant inspection, assurance of a safe water supply, and disease surveillance.

JAMA. 1997;278:563-568

SMALL ROUND-structured viruses (SRSVs), also called Norwalk-like viruses, are human enteric viruses in the family Caliciviridae.[1] These viruses have not been cultivated in vitro, do not have a practical animal model in which they can be propagated, and are shed in relatively low numbers for only a short time during human illness.[2] Nevertheless, SRSVs have been established as the major cause of viral gastroenteritis among adults worldwide.[1,3] Outbreaks due to person-to-person[4-6] or common-source transmission by foodhandlers,[5,7-12] and consumption of contaminated oysters,[13-18] ice,[19,20] and celery[21] have occurred. Waterborne outbreaks involving community water systems[22,23] and contaminated wells[24-26] have been reported. Transmission via aerosolized vomitus may be possible.[6,27-30] Although epidemiologic and laboratory investigations of SRSV outbreaks have been thorough, none has identified SRSVs in the incriminated vehicle. We investigated a gastroenteritis outbreak in tourists traveling by tour bus between the United States and Canada, which provided an opportunity to develop novel laboratory methods not previously used to study SRSVs.

METHODS

Background

The outbreak was reported to the Alaska Division of Public Health after a Fairbanks, Alaska, hotel operator recognized that ill bus passengers were staying at the hotel. Ill bus passengers were also identified in hotels in Skagway and Valdez, Alaska; the investigation subsequently implicated a restaurant in the Yukon Territory of Canada in a small community on the Alaska Highway. The restaurant, which catered largely to

From the Division of Public Health, Alaska Department of Health and Social Services, Anchorage (Drs Beller, Funk, Middaugh, and Ms Jenkerson); Bureau of Disease Surveillance and Field Epidemiology, Laboratory Centre for Disease Control, Ottawa, Ontario (Dr Ellis); National Centre for Enteroviruses, Halifax, Nova Scotia (Drs Lee and Drebot); Division of Viral and Rickettsial Diseases, National Center for Infectious Diseases, US Centers for Disease Control and Prevention, Atlanta, Ga (Drs Monroe, Ando, and Ms Noel); Department of Environmental Sciences and Engineering, School of Public Health, University of North Carolina, Chapel Hill (Dr Sobsey and Mr Simmons); Virology Laboratory, Department of Microbiology, Hospital for Sick Children, Toronto, Ontario (Dr Petric); Bureau of Infectious Disease, Laboratory Centre for Disease Control, Ottawa, Ontario (Dr Spika). Dr Ellis is now with the Bureau of Infectious Disease, Laboratory Centre for Disease Control, Ottawa, Ontario.

Reprints: Michael Beller, MD, MPH, Division of Public Health, Alaska Department of Health and Social Services, PO Box 240249, Anchorage, AK 99524 (e-mail: mikeb@healtn.state.ak.us).

1. **Epidemiologic Investigation**

   Overall, of the 654 bus passengers represented in the trips analyzed in this report, 274 persons were interviewed (there were no refusals) and 108 met the case definition. Detailed data on symptoms were collected from 54 ill passengers and 10 ill bus company A employees; most frequent symptoms were diarrhea, vomiting, and nausea (Table 2).

2. **Environmental Investigation**

   There were 2 shallow wells at the business complex. Well 1 was located under the motel and about 45 m from a lake and served the motel and restaurant. Sewage from the motel was piped to a septic pit lined with wood about 15 m from well 1, located between the well and the lake.

3. **Laboratory Investigation**

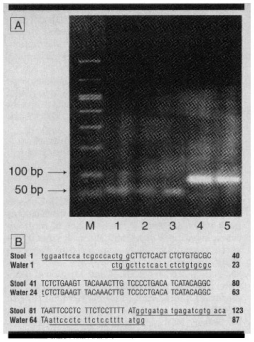
   Stool cultures for bacterial pathogens were negative for the initial 9 specimens; electron microscopy revealed SRSVs or small round viruses in 8 of the subse-

Bacterial contamination in well:
TC= 10-50 CFU; FC= 2-18 CFU

Die Test: motel > restaurant

COMMENT

This investigation confirmed that a contaminated well supplying a restaurant caused an outbreak of SRSV gastroenteritis. Prior to recognition of the outbreak among bus passengers, there was illness in persons at the business complex. Four ill persons lived in a building connected to a septic pit contaminating the well and became ill on June 13



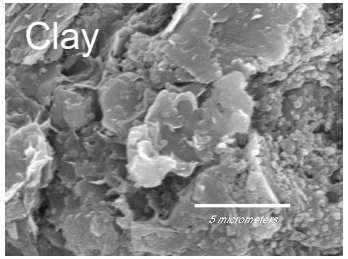
completed. Finally, the outbreak cause and vehicle were established by molecular analysis showing SRSV genetic material found in water from the restaurant matched that of virus found in stools of ill bus passengers and an ill restaurant employee.

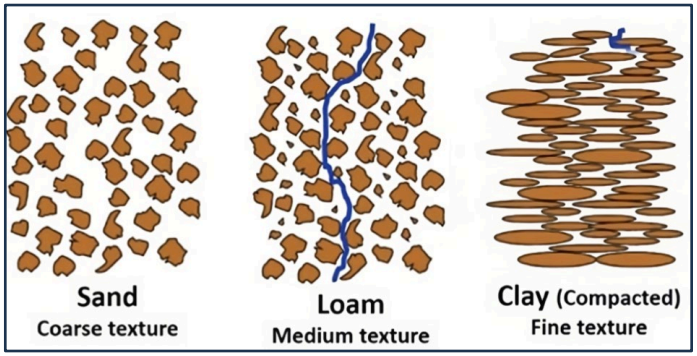
Adjacent Land Use: Point / Non-Point Sources

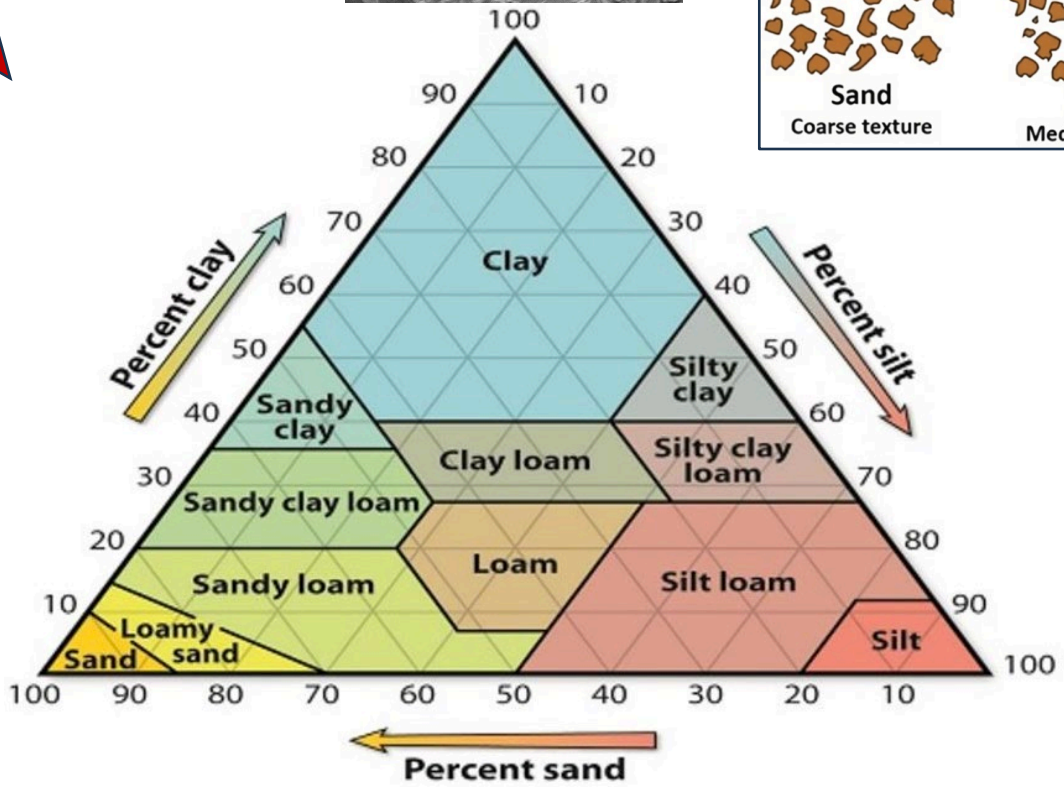
Hydrogeological Pathways: Impacts of Soil Type on Water and Pathogen Movement

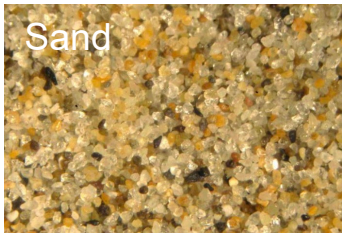
Low Porosity
(slow/little water movement)

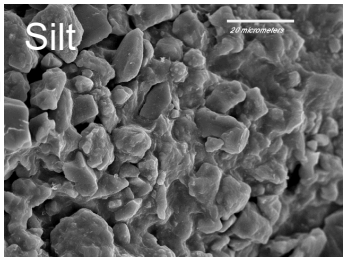
High Porosity
(fast/greater water movement)





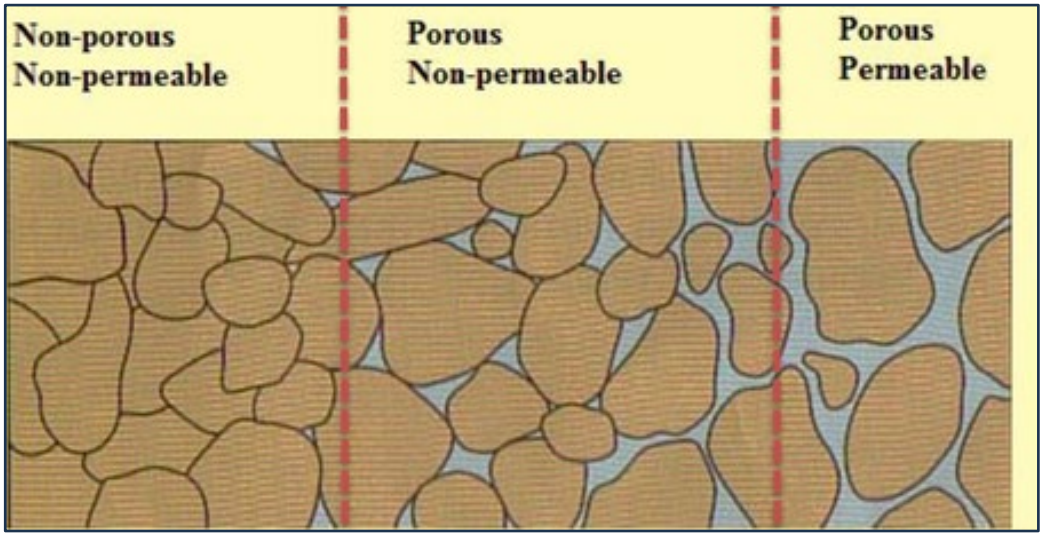


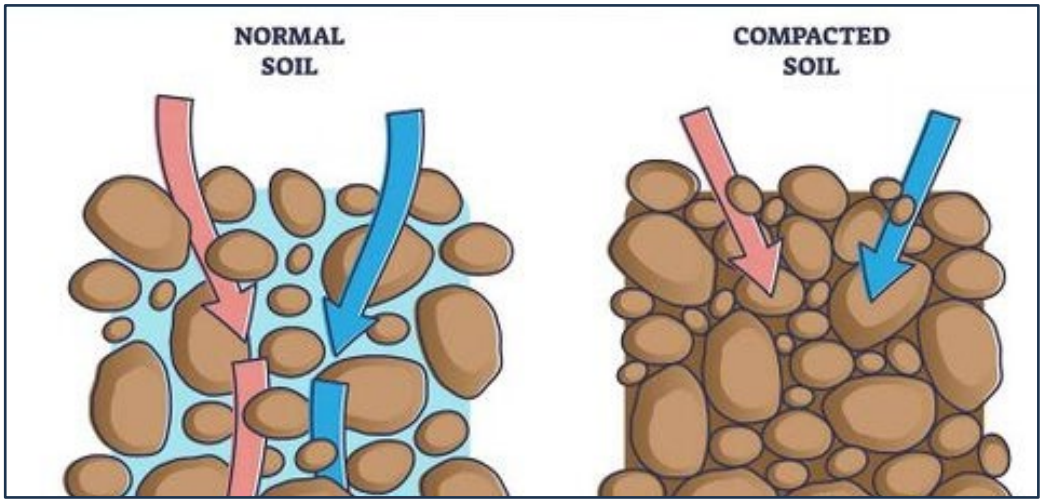




https://www.scientistcindy.com/soils-and-groundwater.html

Hydrogeological Pathways: Impacts of Soil Compaction on Water and Pathogen Movement



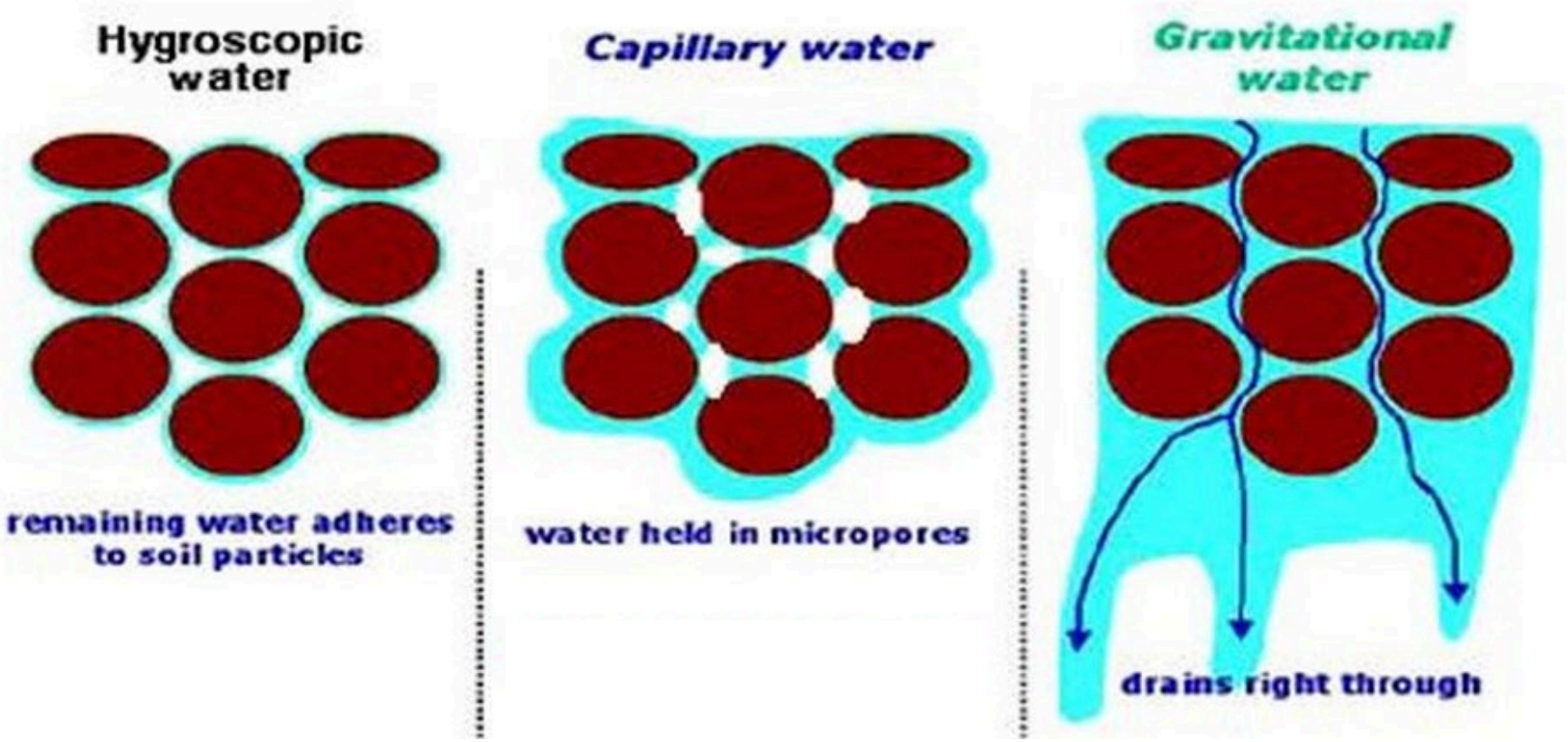


Compacted soils limit water flow

limited water flow limits pathogen movement

https://soil.evs.buffalo.edu/index.php/Porosity

Hydrogeological Pathways: Impacts of Soil Saturation on Water and Pathogen Movement



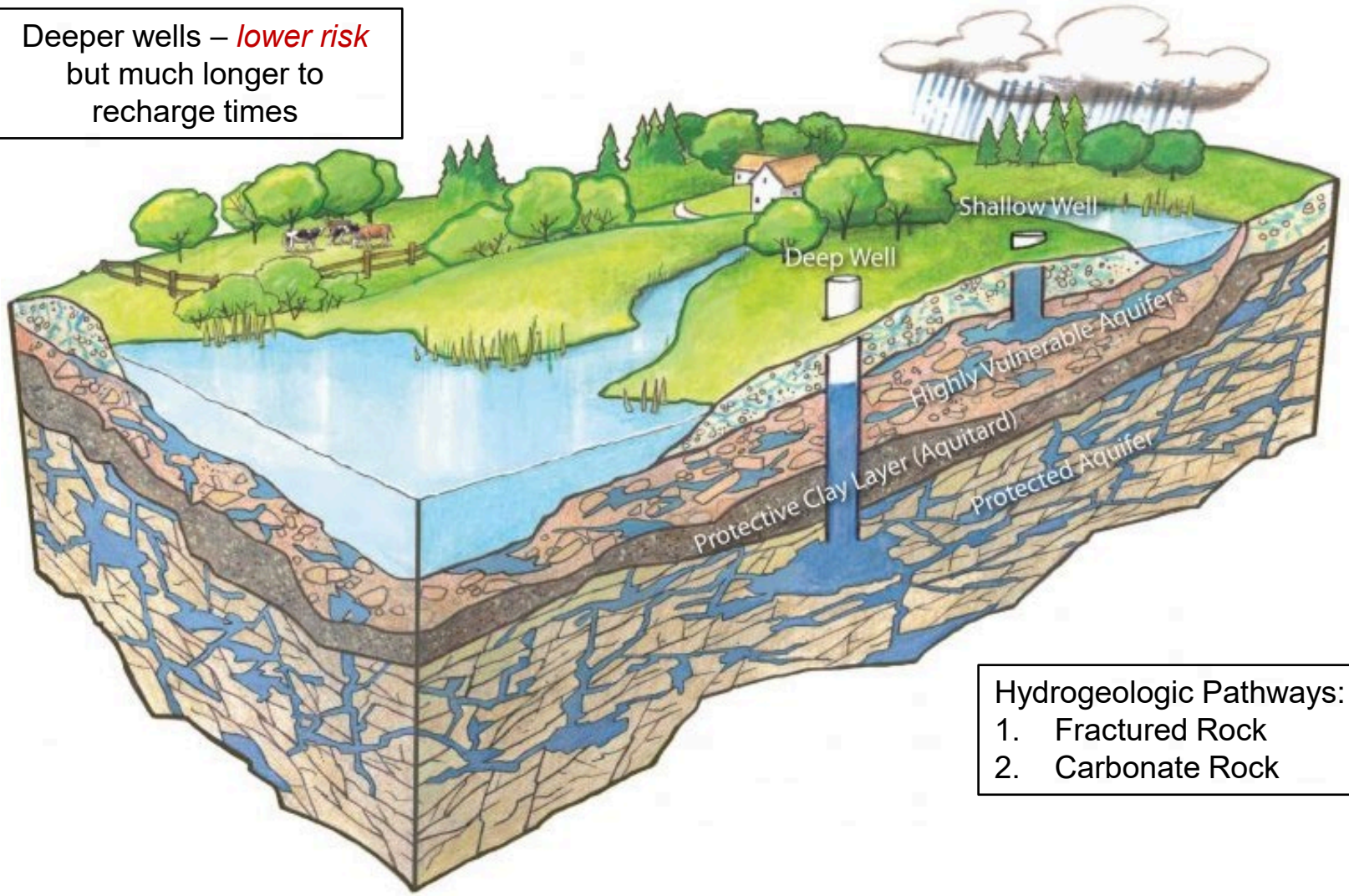
A soils ability to retain water is strongly related to particle size (i.e. soil type)

Clays retain more water than sand or silt >>
water passes quickly and easily through sand

https://www.scientistcindy.com/soils-and-groundwater.html

Hydrogeological Pathways: Highly Vulnerable Aquifers

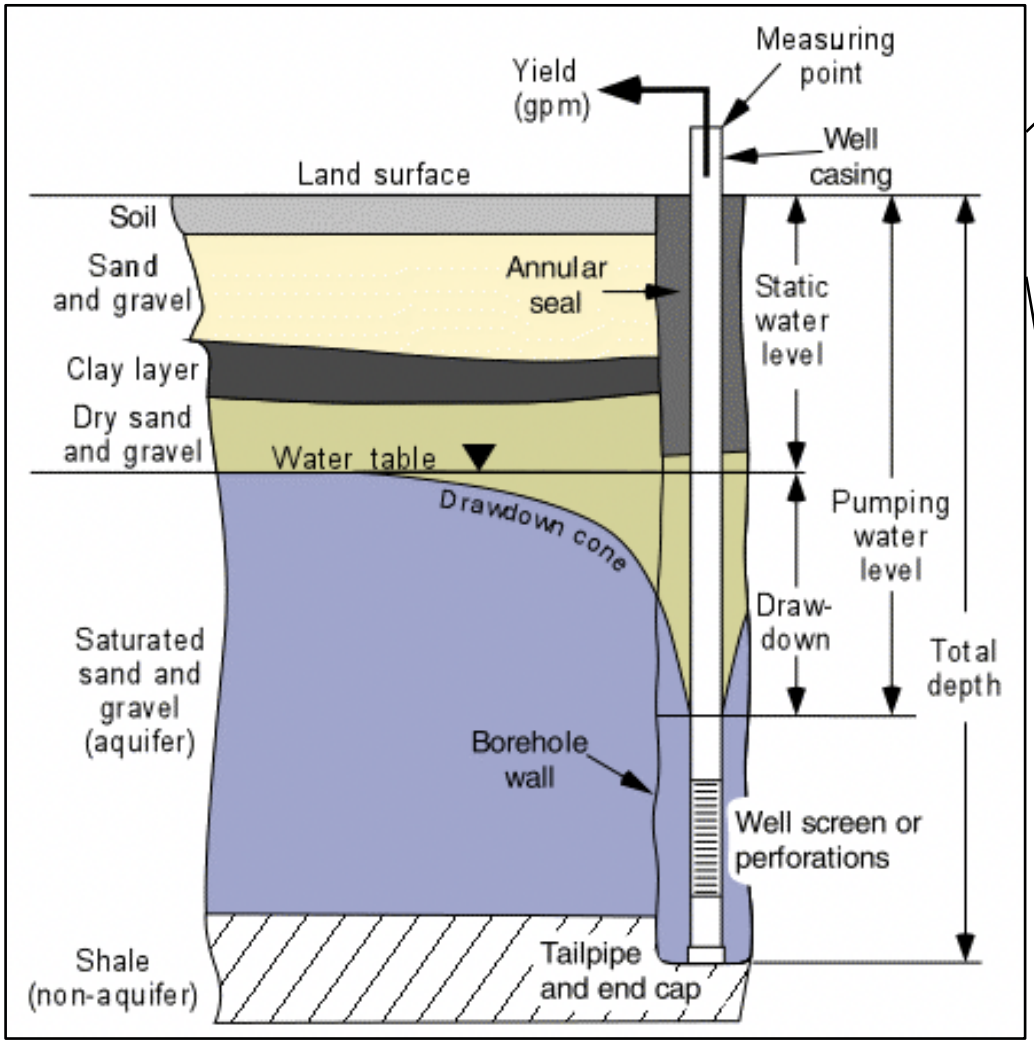
Deeper wells – *lower risk* but much longer to recharge times



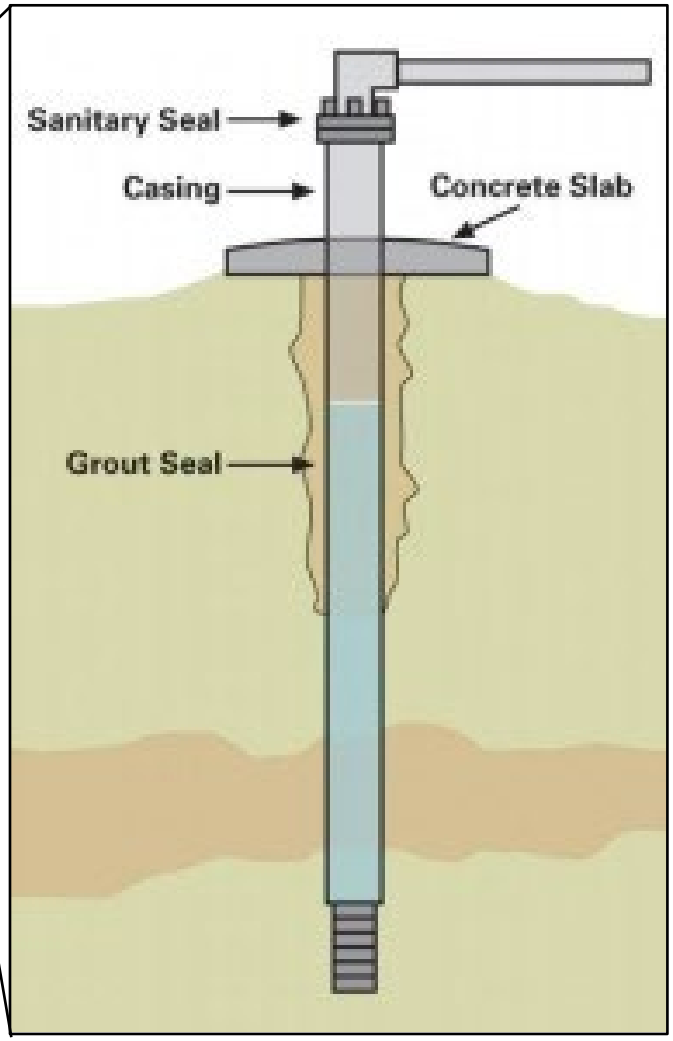
Hydrogeologic Pathways:
1. Fractured Rock
2. Carbonate Rock

https://ourwatershed.ca/drinking-water/vulnerable-areas/

Considerations with Well Construction



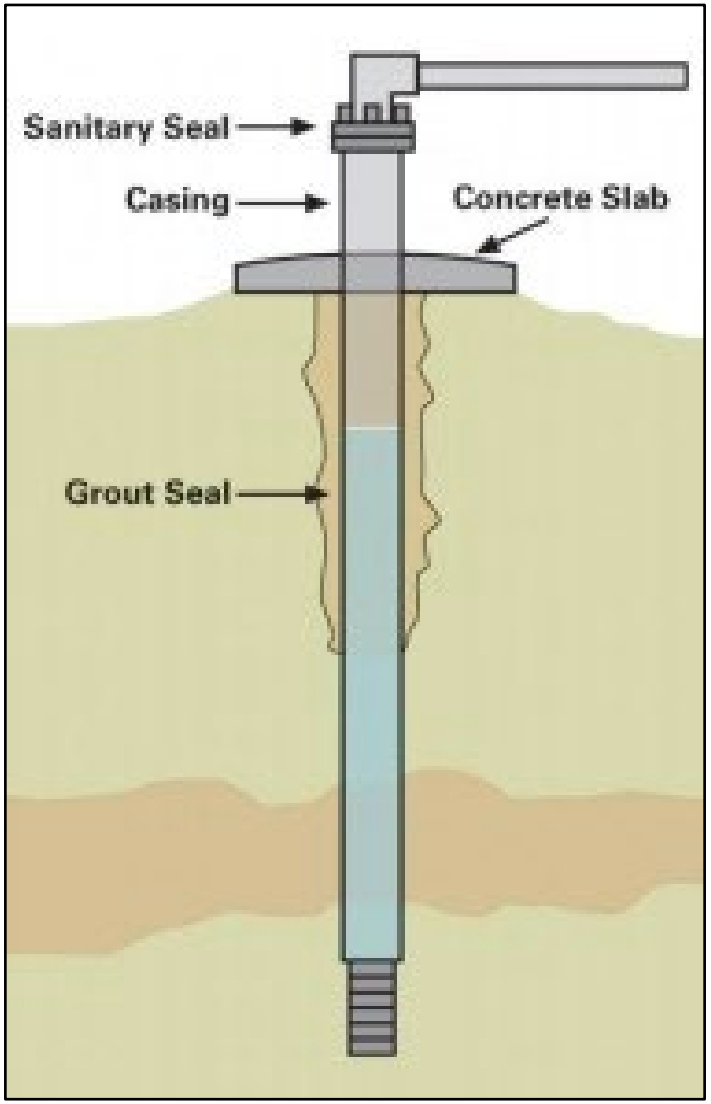
https://mbmggwic.mtech.edu/sqlserver/v11/help/welldesign.asp



https://gregknowswater.com/protect-your-wellhead/

Considerations with Well Construction

- Well siting (and degree of protection)
- Well casing
  - Casing height
  - Casing depth
  - Intact?
- Sanitary well cap/seal
- Backflow prevention



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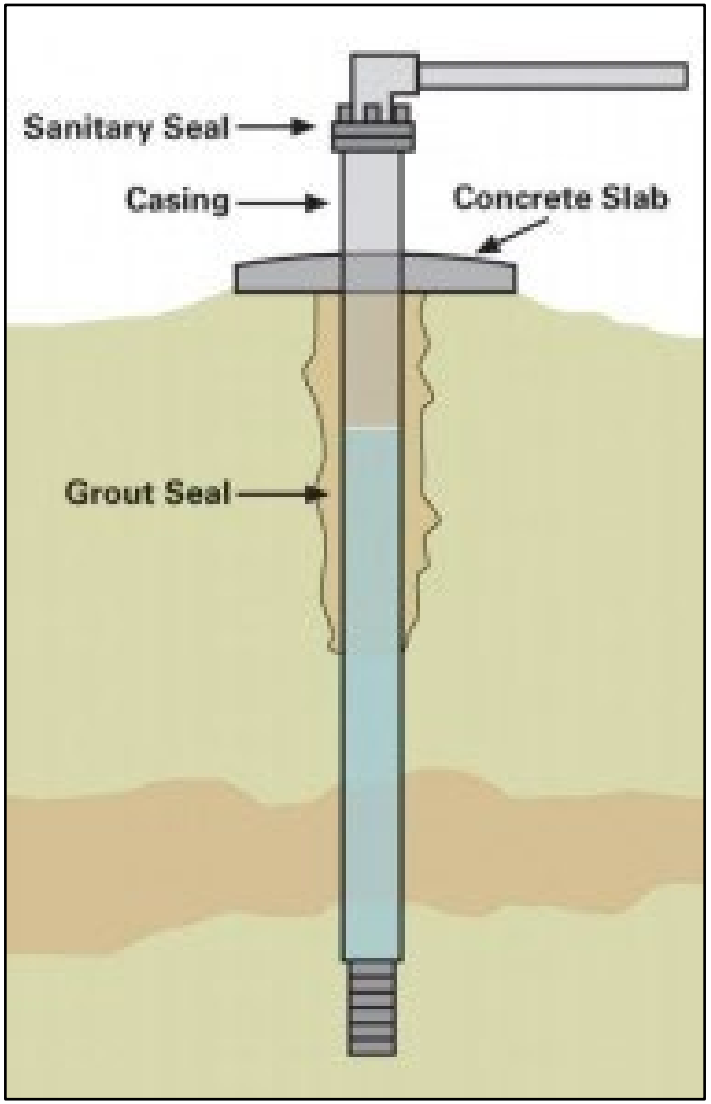
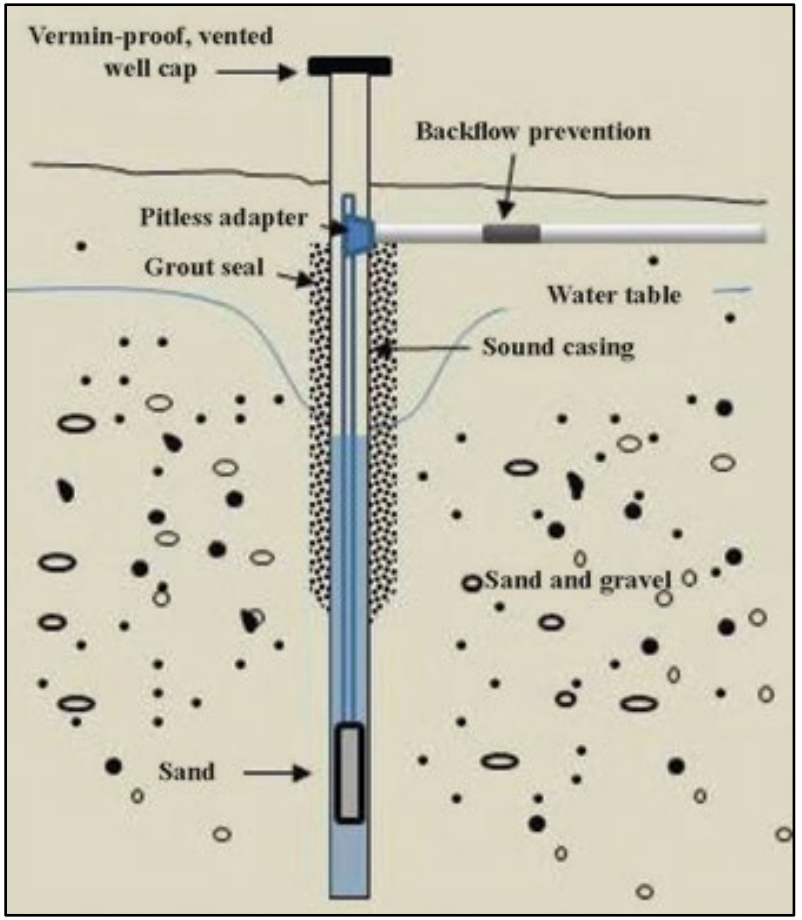


https://gregknowswater.com/protect-your-wellhead/

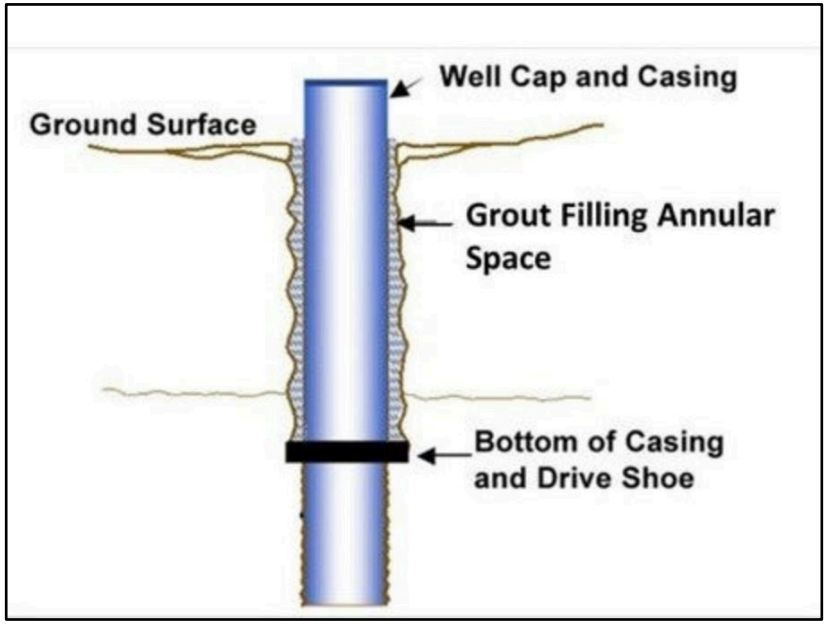
Backflow Prevention: Critical System Component

https://www.knowyourh2o.com/indoor-4/the-care-and-feeding-of-your-well



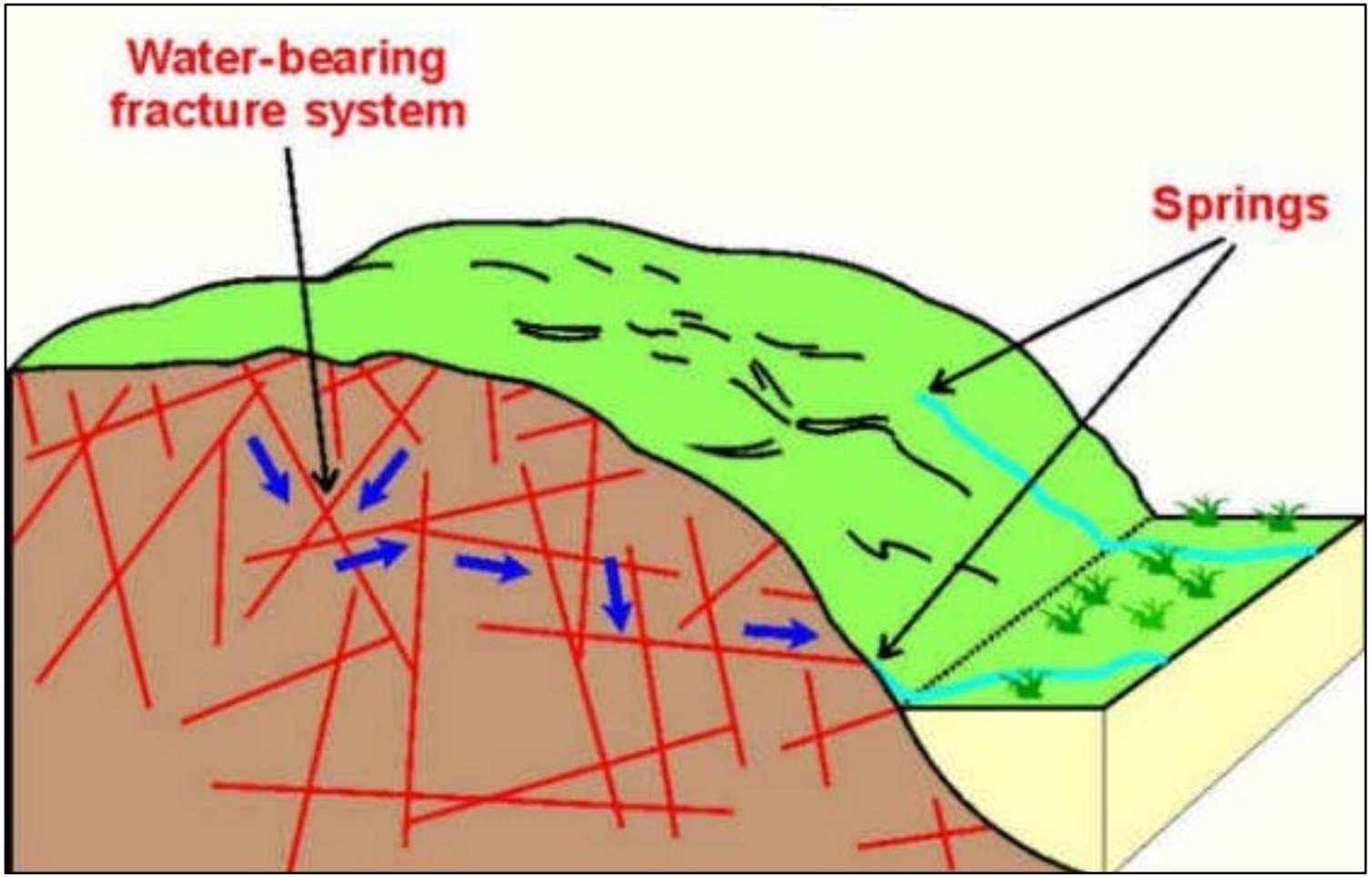
https://extensionpubs.unl.edu/publication/g2050/na/html/view

Assessing Risks from Well Construction



- Does the ground slope away from well?
- Is there grout/concrete that seals the well casing?
- Does the well cap have an adequate seal?
- Is the well vented? Does the vent allow for contamination?
- Backflow prevention?? Does it work?

Assessing Risks from Groundwater: Special Cases



https://nre.tas.gov.au/water/groundwater/aquifers/fractured-rock-aquifer

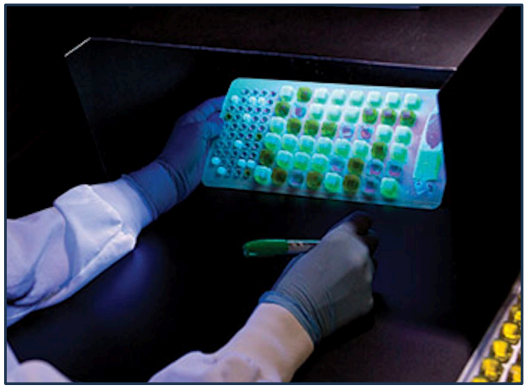
Assessing Risks from Groundwater: Special Cases

Springs occur where groundwater comes to the surface

Huge potential for aquifer contamination if not properly protected

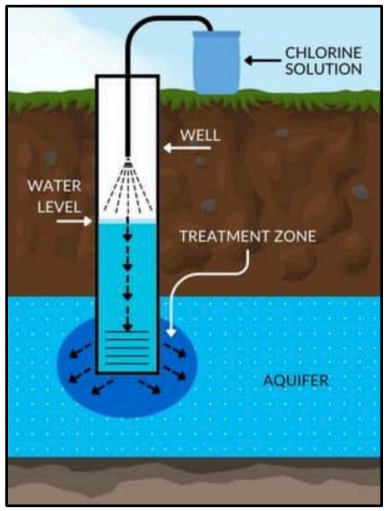
Groundwater Monitoring

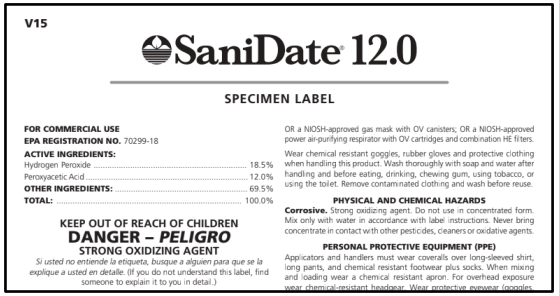
- Water can be tested to assess the sanitary quality
  - There should be no detectable generic *E. coli* per 100 mL (0 or less than the detection limit of assay)
- If there is an issue, repairs and mitigation steps should be taken then water should be tested more frequently to ensure that it is of adequate sanitary quality for use



Groundwater Mitigation

- If well is contaminated, mitigation steps should be implemented:
  - Shock Chlorination
    1. add bleach to 200 ppm
    2. Allow for 24 – 48 hours of contact time,
    3. Chlorinated water should be flushed through the entire water system
  - Continuous point-of-use (POU) disinfection (Sanidate 12.0, UV irradiation, etc.)
  - Point-of-use (POU) filtration (cartridge filters, reverse osmosis)




V15

SaniDate 12.0

SPECIMEN LABEL

FOR COMMERCIAL USE
EPA REGISTRATION NO. 70299-18
ACTIVE INGREDIENTS:
Hydrogen Peroxide 18.5%
Peroxyacetic Acid 12.0%
OTHER INGREDIENTS: 69.5%
TOTAL: 100.0%

KEEP OUT OF REACH OF CHILDREN
DANGER – *PELIGRO*
STRONG OXIDIZING AGENT
Si usted no entiende la etiqueta, busque a alguien para que se la explique a usted en detalle. (If you do not understand this label, find someone to explain it to you in detail.)

OR a NIOSH-approved gas mask with OV canisters; OR a NIOSH-approved power air-purifying respirator with OV cartridges and combination HE filters.

Wear chemical resistant goggles, rubber gloves and protective clothing when handling this product. Wash thoroughly with soap and water after handling and before eating, drinking, chewing gum, using tobacco, or using the toilet. Remove contaminated clothing and wash before reuse.

PHYSICAL AND CHEMICAL HAZARDS
Corrosive. Strong oxidizing agent. Do not use in concentrated form. Mix only with water in accordance with label instructions. Never bring concentrate in contact with other pesticides, cleaners or oxidative agents.

PERSONAL PROTECTIVE EQUIPMENT (PPE)
Applicators and handlers must wear coveralls over long-sleeved shirt, long pants, and chemical resistant footwear plus socks. When mixing and loading wear a chemical resistant apron. For overhead exposure wear chemical-resistant headgear. Wear protective eyewear (goggles,

Conclusions

- There are numerous sources of microbial contaminants in the environment
  - Once in groundwater, microbial contaminants can **persist** for long periods of time

- Groundwater contamination can be associated with:
  1. Adjacent land use,
  2. Hydrogeologic pathways,
  3. Issues with well construction, and
  4. Other special cases.

- **Water testing** can help verify the sanitary quality of groundwater used on farms.

- When groundwater is contaminated, **mitigation strategies** can be implemented to ensure the sanitary quality of the water.

Your Turn: Assessing Risks from Groundwater


AMTROL
VALUE-WELL


PUMP IDENTIFICATION
PUMP INSTALLERS NAME
REG. #
PUMP BRAND
DEPTH OF PUMP
HP
DATE


PICKLE BUCKET

Questions / Comments??

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