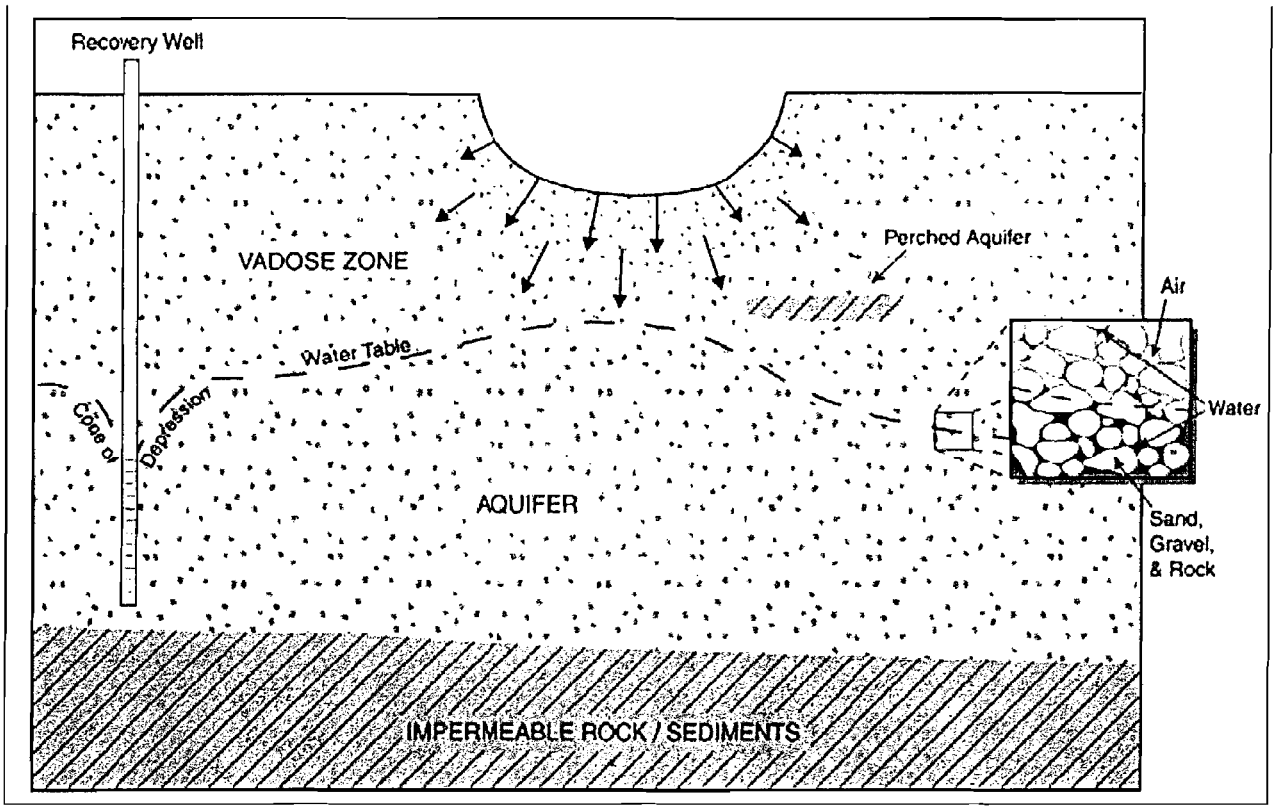
Water Quality Issues & Groundwater Hydrology in Groundwater Recharge.

(A superficial overview)

1) How do you put water into (or back into) the ground?

Percolation Ponds:



Advantages – Not energy-intensive, straightforward to monitor, plugging can be controlled through operating strategies.

Disadvantages – Algal growth in long storage times, area requirements can be high.

Injection Wells:

Advantages: No large land areas required, can be done without large storage requirements
Disadvantages: Water must be of very high quality to avoid plugging, due to small area through which lots of water must flow.

Subsurface Infiltration Galleries:

Advantages: No open water surface, no algal production, otherwise, like perc pond.
Disadvantages: Little or no opportunity for further oxygenation, does not remove land requirement.

In general, what happens when water is injected into the subsurface? If that water has organics in it, even innocuous compounds, that can be degraded, biofilm will grow on the surface of the soil particles. This will change the flow regime, hydraulic conductivity, and potentially the water quality.

2) Contaminants that can be introduced with introduction of surface water to ground water:

biological – coliforms (the regulated organisms) and pathogens (the organisms we're actually worried about). Generally, microorganisms are more an issue with reclaimed wastewater than surface water, but surface water can contain protozoa (*Giardia, Cryptosporidium*) that survive well at low temperatures for long periods. Even treated wastewater can contain viruses, and the fate and transport of these is not well understood or predictable.

chemical –

TDS/salts – generally, Montana surface water is less "salty" than groundwater, but both are low in TDS. Reclaimed wastewater can be significantly higher.

Metals – generally speaking, metals that are soluble in surface water can be attenuated when introduced to groundwater, but only until surface adsorption sites are filled up. Metals and their fate and transport are sensitive to redox potential and other factors in water chemistry.

Redox potential – in other words, how "oxidizing" or "reducing" is the environment in the surface water and in the subsurface. Usually, surface water is close to saturation with dissolved oxygen, and its ability to oxidize compounds is higher than in groundwater. In fact, groundwater that has been in contact with wastewater can be significantly more reducing than surface water. Changing this condition can mobilize or immobilize other contaminants in the water and soils. Example: Arsenic mobilization can occur through interaction of surface water with groundwater in the Madison valley. BIG example: Interaction of surface water with mine tailings generates acid mine drainage (e.g., the Berkeley Pit). Knowledge of the subsurface soil chemistry is necessary to estimate potential impacts of surface water recharge.

Nutrients – Nitrogen & phosphorus. If water is not severely impacted by wastewater discharge, these are generally low in concentration. However, there is the potential for further reduction of nutrient levels through interaction with soils. In areas receiving high fertilization rates, surface runoff can contain high concentrations of nutrients.

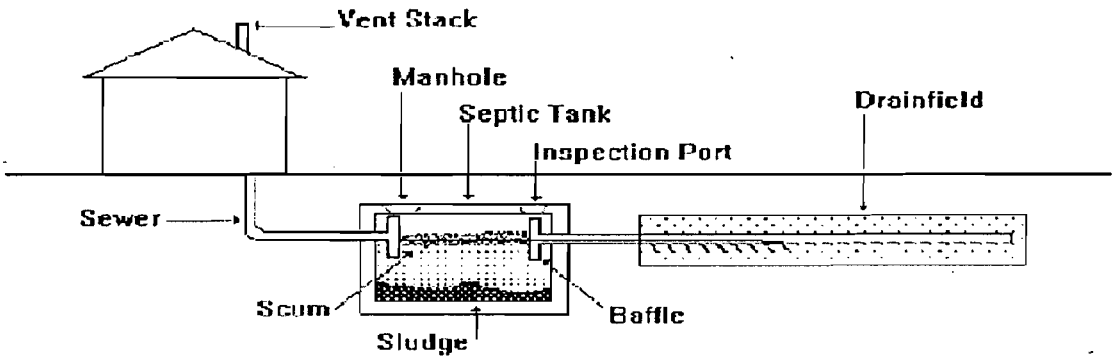
Nitrogen primarily occurs as ammonia in wastewater, but aerobic processes convert the ammonia to nitrate. Nitrate levels above 10 mg/L are unacceptable in drinking water, and this level is about 5 times lower than could be produced in a typical domestic wastewater. This means that treatment must remove the nitrogen or significant dilution is necessary.

Organics – "BOD" = Biochemical Oxygen Demand. Usually of very little concern with pristine surface and groundwaters, but can be significant in wastewater-impacted sources. The main effect in groundwater recharge will be to grow microorganisms, reduce hydraulic conductivity, and create reducing conditions that change mobility of other ions (e.g. metals). Operating plan needs to account for plugging potential and also consider biological contamination.

3) Overview of wastewater treatment.

Untreated wastewater: a million coliforms per milliliter. Nutrient levels capable of producing nitrates at 3-10 times the regulatory limit. Organic material capable of significant plugging of the soils, and of growing many more organisms.

Individual septic systems & drainfields – regulations are based on design of the system, and typically oversize. This is because there is no effective way for monitoring system operation at the individual home level. Homeowners bear sole responsibility for O&M, and often neglect their systems, which often continue to function regardless!



Good news: Large solids are removed in a septic tank, and the soils to which the rest of the wastewater is discharged have enough surface area to grow lots of helpful microorganisms that degrade practically all of the contaminants in the wastewater. Coliforms have, in some studies, been shown to be removed to below detection limits in less than a foot of percolation. In most diverse soils, phosphates are removed in a foot or two. Nitrogen removal can occur with properly operated systems. At low enough population density, septic systems and drainfields have been used for many decades with no ill effects. As indicated above, often so overdesigned that failure requires serious neglect.

Bad news: Any level of control, monitoring, or access to the system is very limited. Toxic compounds, endocrine disruptors, viruses, and some kinds of other organics can be transported long distances. Safety of the groundwater that is strongly impacted by septic system discharges (e.g., large subdivisions) relies strongly on informing and educating the users – ask Tim Roark this afternoon! Overdesign can also result in loss of performance of some processes, such as nitrogen removal.

Larger wastewater treatment systems –

Many configurations are possible – activated sludge, trickling filters, membrane bioreactors, RBC's. Most of the large systems discharge back to surface water, requiring a permit for same, but permit is required for subsurface discharge as well.

Surface water discharge: The aerobic environment (availability of oxygen) typically results in (eventually) conversion of most pollutants, with the exception of nutrients ... and EDCs!? Significant dilution is often present, should a "spike" in concentration occur.

Subsurface water discharge: Also great capacity for dilution, but not much for *mixing*. Typical mixing zone is only a few times larger than the area over which the disposal takes place. No opportunity exists for addition of more oxygen, so spikes in organic concentration can have a long lifetime.

Good news: These systems are operated with a much higher level of control than an on-site septic system. Contaminants (e.g., solvents, petroleum-associated contaminants) that get through a drainfield can be removed significantly in a larger system. Regular monitoring is required by state and federal law, but is focused on traditional contaminants like BOD.

Bad news: Actually, not much, as the permitting process and TMDL process account for much of the possible variation in operation. The primary issue with large systems is their long-term functionality in the face of changing regulations – usually as we find out more about how the ecosystems operate, the more we know we need to do.

4) Drinking Water Treatment Regulations – mostly located in the rules that come out of the Safe Drinking Water Act. ***So far***, those regulations are concerned with:

- toxic compounds on the EPA priority pollutant list (more or less) –
- Metals (usually well attenuated by soil)
- Toxic organics (highly variable – depends on degradability, charge, polarity); issues are usually that regulatory limits are very small (e.g., PCE < 5μg/L)
- Site with injection wells in Kansas was required to monitor for over 200 contaminants on a regular basis.

- Pathogens and their indicators – viruses, coliforms & protozoa
- fate & transport processes in soil are very different from a water treatment plant.
- Water treatment regulations often focus on protozoa (*Giardia, Cryptosporidium*) and on best practices for their removal, since detection is so difficult
- Viruses *usually* well neutralized by conventional disinfection, but their transport through soil likely is unimpeded.

- Following some initial sampling after development of a source, most groundwater sources require no more than disinfection.
- Groundwater under the influence of surface water is *treated like surface water* for regulatory purposes. Generally, subsurface storage of surface water won't bypass the need for treatment as though it were still surface water.

[DISCLAIMER: This information is assembled with the intention of stimulating discussion, not with the goal of comprehensive coverage of all possible ramifications. It should not be used as a reference guide.]