Part 1 Key

1. Radial, Trellis
2. A
3.
    a. Cone of Depression-The zone around a well in an unconfined aquifer that is normally saturated, but becomes unsaturated as a well is pumped, leaving an area where the water table dips down to form a cone shape. The shape of the cone is influenced by porosity and the water yield or pumping rate of the well.
4.
    a. Bored Wells-A shallow well is a hole which has been dug, bored, driven or drilled into the ground for the purpose of extracting water is a well. A well is considered to be shallow if it is less than 50 feet deep. The source of a well is an aquifer.
    b. Consolidated- A well made up of tightly bound geologic formation composed of sandstone, limestone, granite, or other rock.
    c. Unconsolidated- A well made of loosely bound geologic formation composed of sand and gravel.
5. K
    a. Containment, treatment or removal of contaminated groundwater. May also include containment, treatment or removal of contaminated soil above the water table.
    b. Air Sparging: Air sparging is literally the process of blowing air directly into the contaminated groundwater through the use of specific air blower remediation equipment. Contaminants are then removed from the groundwater by physical contact with the air as the bubbles rise to the surface, a process called stripping. This is typically used in conjunction with another form of groundwater remediation technology known as soil vapor extraction to get rid of what gets left in the soil.
    c. Dual Phase Vacuum Extraction: Dual phase vacuum extraction (DPVE) is a groundwater remediation technology that utilizes high-vacuum extraction well remediation equipment to remove contaminants. The ability of this technology to attack what's known as the capillary fringe, often times the most contaminated section of groundwater, is highly sought after in the industry.
    d. Pump and Treat: This is probably the most well-known and common of remediation equipment, because it is usually used in conjunction with other technologies. As the name implies, the groundwater is pumped out and treated by other physical, chemical, or biological means.

e. **Bioaugmentation**[edit]

f. If a treatability study shows no degradation (or an extended lab period before significant degradation is achieved) in contamination contained in the groundwater, then inoculation with strains known to be capable of degrading the contaminants may be helpful. This process increases the reactive enzyme concentration within the bioremediation system and subsequently may increase contaminant degradation rates over the nonaugmented rates, at least initially after inoculation.[2]

g. **Bioventing**[edit]

h. Bioventing is an in situ remediation technology that uses microorganisms to biodegrade organic constituents in the groundwater system. Bioventing enhances the activity of indigenous bacteria and archaea and stimulates the natural in situ biodegradation of hydrocarbons by inducing air or oxygen flow into the unsaturated zone and, if necessary, by adding nutrients.[3] During bioventing, oxygen may be supplied through direct air injection into residual contamination in soil. Bioventing primarily assists in the degradation of adsorbed fuel residuals, but also assists in the degradation of volatile organic compounds (VOCs) as vapors move slowly through biologically active soil.[4]

i. **Biosparging**[edit]

j. Biosparging is an in situ remediation technology that uses indigenous microorganisms to biodegrade organic constituents in the saturated zone. In biosparging, air (or oxygen) and nutrients (if needed) are injected into the saturated zone to increase the biological activity of the indigenous microorganisms. Biosparging can be used to reduce concentrations of petroleum constituents that are dissolved in groundwater, adsorbed to soil below the water table, and within the capillary fringe.

k. **Bioslurping**[edit]

l. Bioslurping combines elements of bioventing and vacuum-enhanced pumping of free-product that is lighter than water (light non-aqueous phase liquid or LNAPL) to recover free-product from the groundwater and soil, and to bioremediate soils. The bioslurper system uses a “slurp” tube that extends into the free-product layer. Much like a straw in a glass draws liquid, the pump draws liquid (including free-product) and soil gas up the tube in the same process stream. Pumping lifts LNAPLs, such as oil, off the top of the water table and from the capillary fringe (i.e., an area just above the saturated zone, where water is held in place by capillary forces). The LNAPL is brought to the surface, where it is separated from water and air. The biological processes in the term “bioslurping” refer to aerobic biological degradation of the hydrocarbons when air is introduced into the unsaturated zone.[5]

m. **Phytoremediation**[edit]

n. In the phytoremediation process certain plants and trees are planted, whose roots absorb contaminants from ground water over time, and are harvested and destroyed. This process can be carried out in areas where the roots can tap the ground water. Few examples of plants that are used in this process are Chinese Ladder fern Pteris vittata, also known as the brake fern, is a highly efficient accumulator of arsenic. Genetically altered cottonwood trees are good absorbers of mercury and transgenic Indian mustard plants soak up selenium well.[6]

o. **Permeable Reactive Barriers**[edit]

p. *Main article: Permeable reactive barriers*

q. Certain types of permeable reactive barriers utilize biological organisms in order to remediate groundwater.

r. **Chemical treatment technologies**[edit]

s. **Chemical precipitation**[edit]

t. Chemical precipitation is commonly used in wastewater treatment to remove hardness and heavy metals. In general, the process involves addition of agent to an aqueous waste stream in a stirred reaction vessel, either batchwise or with steady flow. Most metals can be converted to insoluble compounds by chemical reactions between the agent and the dissolved metal ions. The insoluble compounds (precipitates) are removed by settling and/or filtering.

u. **Ion exchange**[edit]

v. Ion exchange for ground water remediation is virtually always carried out by passing the water downward under pressure through a fixed bed of granular medium (either cation exchange media and anion exchange media) or spherical beads. Cations are displaced by certain cations from the solutions and ions are displaced by certain anions from the solution. Ion exchange media most often used for remediation are zeolites (both natural and synthetic) and synthetic resins.[2]

w. **Carbon absorption**[edit]

x. The most common activated carbon used for remediation is derived from bituminous coal. Activated carbon absorbs volatile organic compounds from ground water by chemically binding them to the carbon atoms.

y. **Chemical oxidation**[edit]

z. In this process, called In Situ Chemical Oxidation or ISCO, chemical oxidants are delivered in the subsurface to destroy (converted to water and carbon dioxide or to nontoxic substances) the organics molecules. The oxidants are introduced as either liquids or gasses. Oxidants include air or oxygen, ozone, and certain liquid chemicals such as hydrogen peroxide, permanganate and persulfate. Ozone and oxygen gas can be generated on site from air and electricity and directly injected into soil and groundwater contamination. The process has the potential to oxidize and/or enhance naturally occurring aerobic degradation. Chemical oxidation has proven to be an effective technique for dense non-aqueous phase liquid or DNAPL when it is present.

aa. **Surfactant enhanced recovery**[edit]

bb. Surfactant enhanced recovery increases the mobility and solubility of the contaminants absorbed to the saturated soil matrix or present as dense non-aqueous phase liquid. Surfactant-enhanced recovery injects surfactants (surface-active agents that are primary ingredient in soap and detergent) into contaminated groundwater. A typical system uses an extraction pump to remove groundwater downstream from the injection point. The extracted groundwater is treated aboveground to separate the injected surfactants from the contaminants and groundwater. Once the surfactants have separated from the groundwater they are re-used. The surfactants used are non-toxic, food-grade, and biodegradable. Surfactant enhanced recovery is used most often when the groundwater is contaminated by dense non-aqueous phase liquids (DNAPLs). These dense compounds, such as trichloroethylene (TCE), sink in groundwater because they have a higher density than water. They then act as a continuous source for contaminant plumes that can stretch for miles within an aquifer. These compounds may biodegrade very slowly. They are commonly found in the vicinity of the original spill or leak where capillary forces have trapped them.[7]

cc. **Permeable reactive barriers**[edit]

dd. *Main article: Permeable reactive barriers*

ee. Some permeable reactive barriers utilize chemical processes to achieve groundwater remediation.

ff. **Physical treatment technologies**[edit]

gg. **Pump and treat**[edit]

hh. Pump and treat is one of the most widely used ground water remediation technologies. In this process ground water is pumped to the surface and is coupled with either biological or chemical treatments to remove the impurities.

ii. **Air sparging**[edit]

jj. Air sparging is the process of blowing air directly into the ground water. As the bubbles rise, the contaminants are removed from the groundwater by physical contact with the air (i.e., stripping) and are carried up into the unsaturated zone (i.e., soil). As the contaminants move into the soil, a soil vapor extraction system is usually used to remove vapors.[8]

kk. **Dual phase vacuum extraction**[edit]

ll. Dual-phase vacuum extraction (DPVE), also known as multi-phase extraction, is a technology that uses a high-vacuum system to remove both contaminated groundwater and soil vapor. In DPVE systems, a high-vacuum extraction well is installed with its screened section in the zone of contaminated soils and groundwater. Fluid/vapor extraction systems depress the water table and water flows faster to the extraction well. DPVE removes contaminants from above and below the water table. As the water table around the well is lowered from pumping, unsaturated soil is exposed. This area, called the capillary fringe, is often highly contaminated, as it holds undissolved chemicals, chemicals that are lighter than water, and vapors that have escaped from the dissolved groundwater below. Contaminants in the newly exposed zone can be removed by vapor extraction. Once above ground, the extracted vapors and liquid-phase organics and groundwater are separated and treated. Use of dual-phase vacuum extraction with these technologies can shorten the cleanup time at a site, because the capillary fringe is often the most contaminated area.[9]

mm. **Monitoring-Well Oil Skimming**[edit]

nn. Monitoring-wells are often drilled for the purpose of collecting ground water samples for analysis. These wells, which are usually six inches or fewer in diameter, can also be used to remove hydrocarbons from the contaminant plume within a groundwater aquifer by using a belt style oil skimmer. Belt oil skimmers, which are simple in design, are commonly used to remove oil and other floating hydrocarbon contaminants from industrial water systems.

oo. A monitoring-well oil skimmer remediates various oils, ranging from light fuel oils such as petrol, light diesel or kerosene to heavy products such as No. 6 oil, creosote and coal tar. It consists of a continuously moving belt that runs on a pulley system driven by an electric motor. The belt material has a strong affinity for hydrocarbon liquids and for shedding water. The belt, which can have a vertical drop of 100+ feet, is lowered into the monitoring well past the LNAPL/water interface. As the belt moves through this interface it picks up liquid hydrocarbon contaminant, which is removed and collected at ground level as the belt passes through a wiper mechanism. To the extent that DNAPL hydrocarbons settle at the bottom of a monitoring well, and the

lower pulley of the belt skimmer reaches them, these contaminants can also be removed by a monitoring-well oil skimmer.

pp. Typically, belt skimmers remove very little water with the contaminant, so simple weir type separators can be used to collect any remaining hydrocarbon liquid, which often makes the water suitable for its return to the aquifer. Because the small electric motor uses little electricity, it can be powered from solar panels or a wind turbine, making the system self-sufficient and eliminating the cost of running electricity to a remote location.[10]

6. A Point-of-Use water treatment system is installed in an individual source line ahead of any or all of the building's taps, faucets or other dedicated outlets used to dispense water for drinking, cooking or bathing. Good POU systems are often expected to capture whatever escapes the POE system.
7. Darcy's law is a constitutive equation that describes the flow of a fluid through a porous medium. The law was formulated by Henry Darcy based on the results of experiments on the flow of water through beds of sand, forming the basis of hydrogeology, a branch of earth sciences.

$$v = K(h_1 - h_2)/d$$

8. Hydraulic head is a measurement of the total mechanical energy per weight of the groundwater flow system. In other words, it is the fluid potential for flow through porous media. It is predominantly comprised of pressure and elevation heads.
9. The vadose zone, also termed the unsaturated zone, is the part of Earth between the land surface and the top of the phreatic zone, the position at which the groundwater (the water in the soil's pores) is at atmospheric pressure ("vadose" is from the Latin for "shallow").