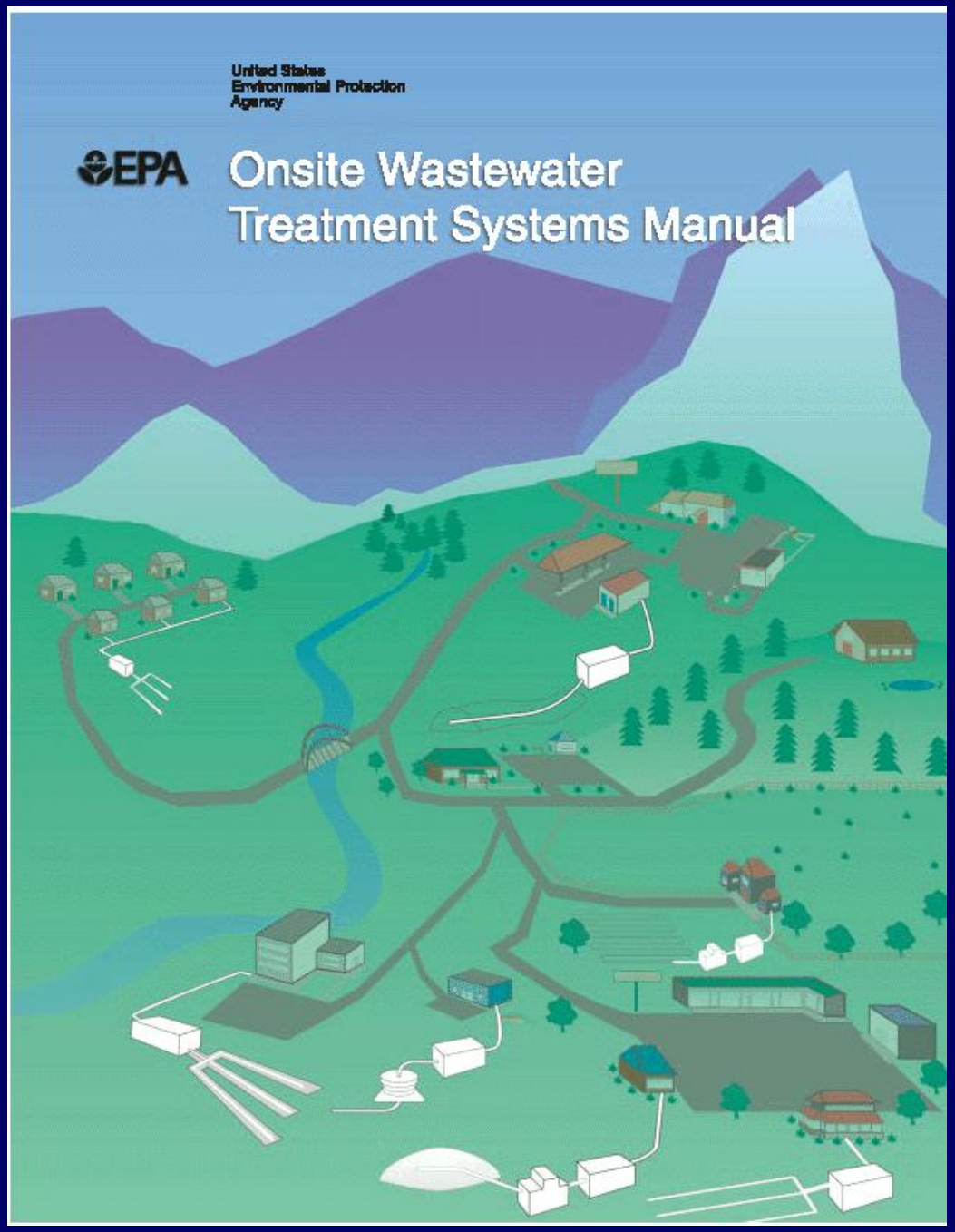
Decentralized Wastewater Treatment

Processes and Technologies

Jim Kreissl

Tetra Tech

http://www.epa.gov/nrmrl/pubs/625r00008/html/625R00008.htm

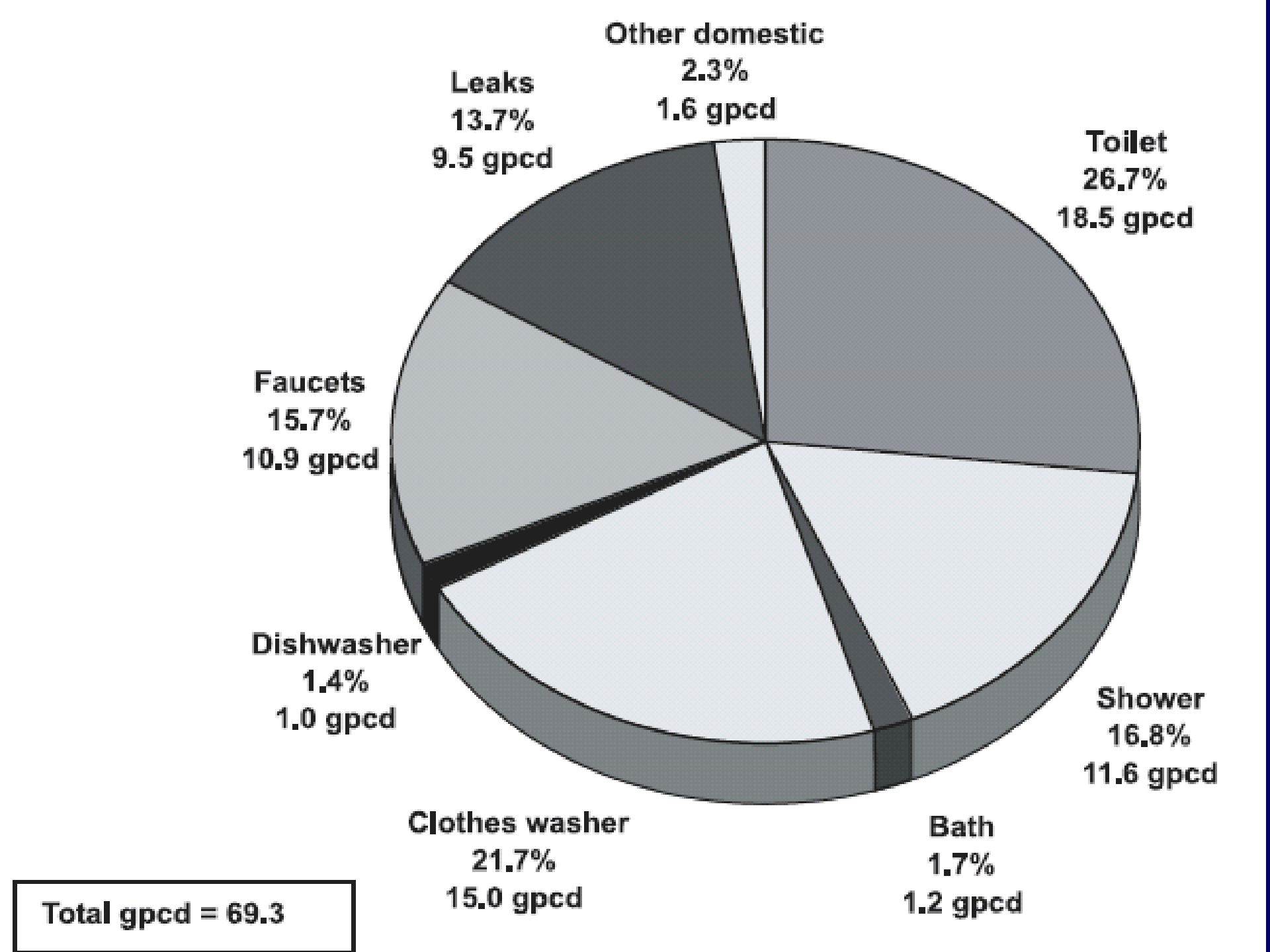


Pollutants of Concern

- Pathogens – bacteria & viruses mainly; plus protozoa, worm eggs
- Nitrogen – causes algal growth in nitrogen-limited (mostly coastal) waters; nitrate can cause “blue baby” syndrome
- Phosphorus – causes algal growth in P-limited (mostly inland fresh) waters
- Others – pharmaceuticals, personal care products, cleaners, solvents, & other toxics (most of which can affect certain treatment processes)

Pollutant loading & concentration averages in residential wastewater

Constituent	Mass loading (grams/person/day)	Concentration[b] (mg/L)
Total solids (TS)	115–200	500–880
Volatile solids	65–85	280–375
Total suspended solids (TSS)	35–75	155–330
Volatile suspended solids	25–60	110–265
5-day biochemical oxygen demand (BOD_5)	35–65	155–286
Chemical oxygen demand (COD)	115–150	500–660
Total nitrogen (TN)	6–17	26–75
Ammonia (NH_4)	1–3	4–13
Nitrites and nitrates (NO_2-N; NO_3-N)	<1	<1
Total phosphorus (TP)[c]	1–2	6–12
Fats, oils, and grease	12–18	70–105
Volatile organic compounds (VOC)	0.02–0.07	0.1–0.3
Surfactants	2–4	9–18
Total coliforms (TC)[d]	–	10^8–10^{10}
Fecal coliforms (FC)[d]	–	10^6–10^8


Other domestic
2.3%
1.6 gpcd
Leaks
13.7%
9.5 gpcd
Toilet
26.7%
18.5 gpcd
Faucets
15.7%
10.9 gpcd
Dishwasher
1.4%
1.0 gpcd
Shower
16.8%
11.6 gpcd
Clothes washer
21.7%
15.0 gpcd
Bath
1.7%
1.2 gpcd
Total gpcd = 69.3

TREATMENT ISSUES BY POLLUTANT

- Microbial pathogens
  - Sorption, natural die-off & predation in soil; some removal via pretreatment processes; big decreases via disinfection
- Phosphorus
  - Primarily by soil adsorption; little removal in most pretreatment systems
- **Nitrogen**
  - Little removal in pretreatment; quick nitrification in soil; poor denitrification of nitrate in many soils
- Suspended solids & BOD
  - Significant removal in pretreatment & essentially complete removal in soil
- Other pollutants
  - Aerobic soil environment removes & degrades organics, toxics, and metals

Pharmaceuticals and Personal Care Products

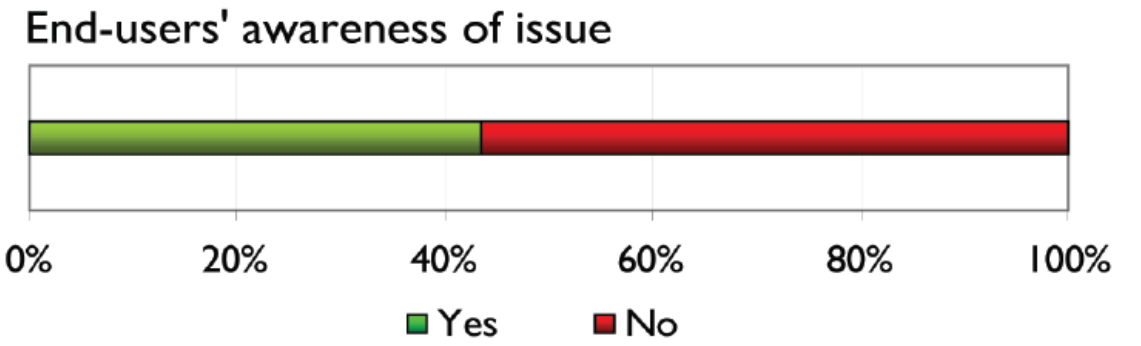
- ~ $250 billion spent in U.S. annually
- Use is rising among all age groups
- One in six Americans takes 3 or more drugs
- More than half of the pharms ingested are passed to wastewater
- 75,000 chemical compounds in use

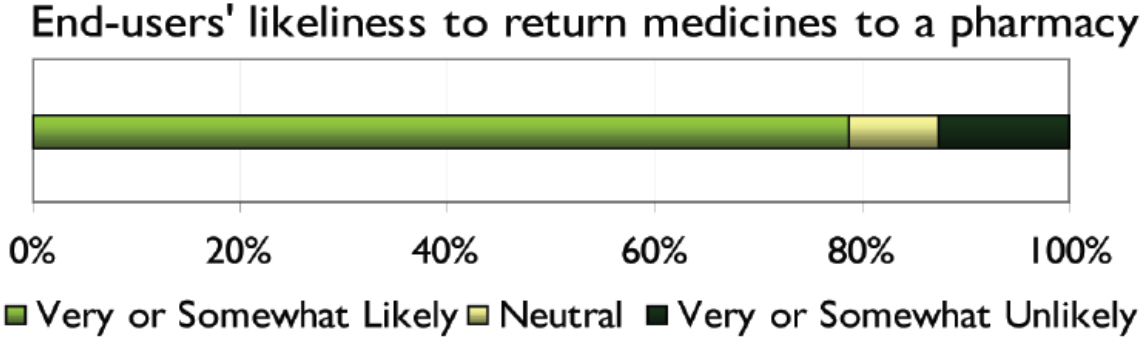
Pharmaceuticals & Personal Care Products (PPCPs)

- Residential disposal of PPCPs via toilets and trash identified as the major source of environmental proliferation
- Conventional wastewater & drinking water treatment are not very effective in removal
- Proper disposal should be reverse distribution & incineration
- Livestock feeding operations shown to be a significant source in some areas

Where do the PPCPs go?

Results from Santa Barbara CA Survey





Treatment of PPCPs

- Activated carbon & reverse osmosis are very effective
- Chlorine disinfection can remove some compounds, ozone removes most, as does high energy UV
- Advanced oxidation processes work well
- Soil treatment removes most organic compounds

PPCP SUMMARY

- PPCPs are persistent in the environment
- They are present at low levels in surface water, groundwater, and some drinking water
- Human impacts of very low concentrations uncertain
- Effects have been found on aquatic species
- No EPA-required water quality testing at this time

Treatment Sequence

Raw wastewater (sewage)

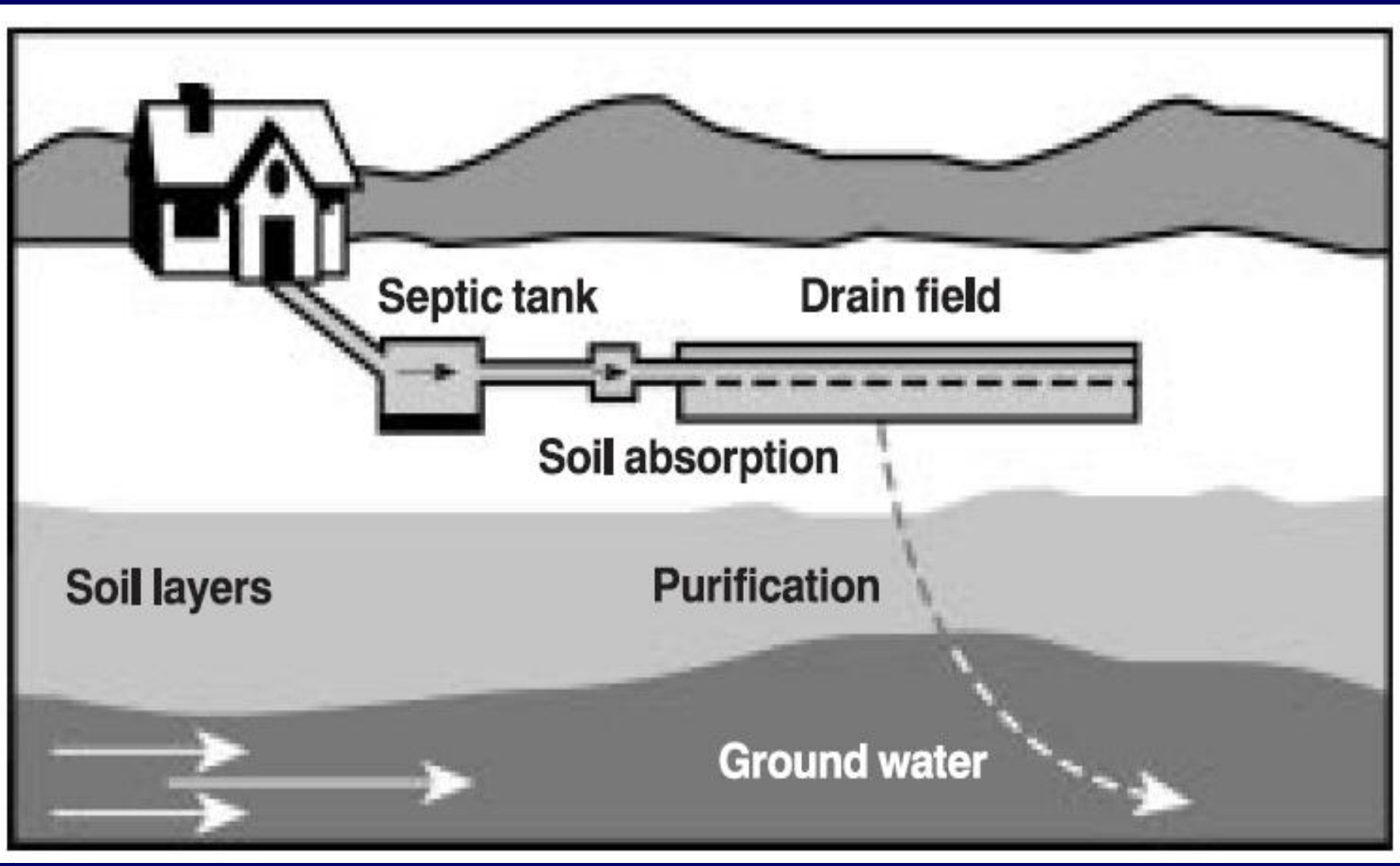
Pretreatment processes (1 or more)

Soil dispersal (how applied to infiltrative surface)

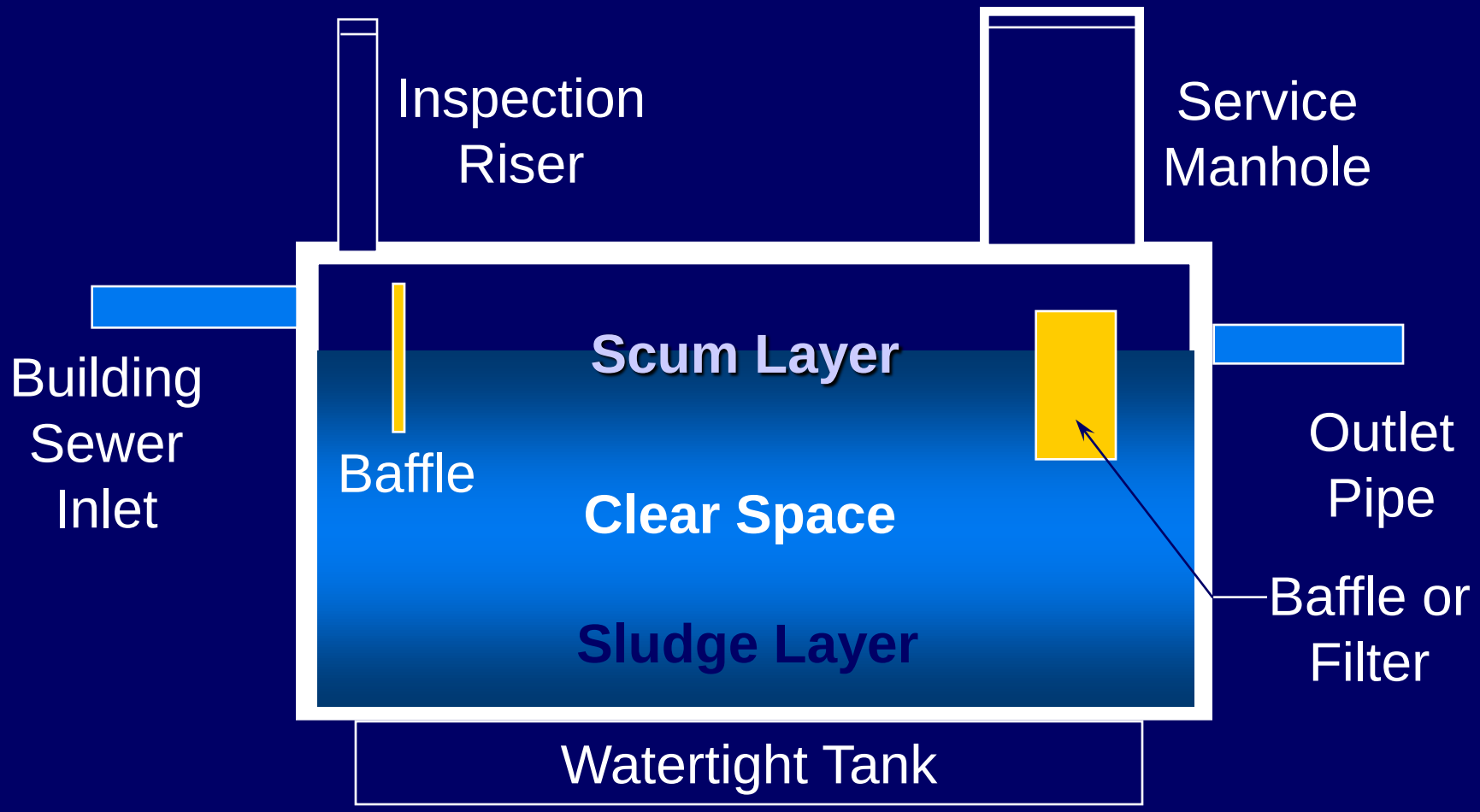
Soil treatment

Ground water incorporation

CONVENTIONAL SEPTIC SYSTEM



PRETREATMENT-SEPTIC TANK



SEPTIC TANK PERFORMANCE

- BOD ~50% still 100 to 200 mg/L
- TSS >75% still 50 to 100 mg/L
- TN ~10% still 40 to 70 mg/L
- TP ~10% still 5 to 10 mg/L
- FC <1 log still 10^6 to 10^8 per 100 ml
- VIRUS <1 log still almost the same

HOW WE THINK TECHNOLOGIES SHOULD BE CHOSEN

- Choose technologies that perform needed removals of specific pollutants in order to meet local watershed or subsequent process requirements
- Passive, low-maintenance technologies are preferred
- Complex, unstable treatment systems and surface water discharge are least desirable

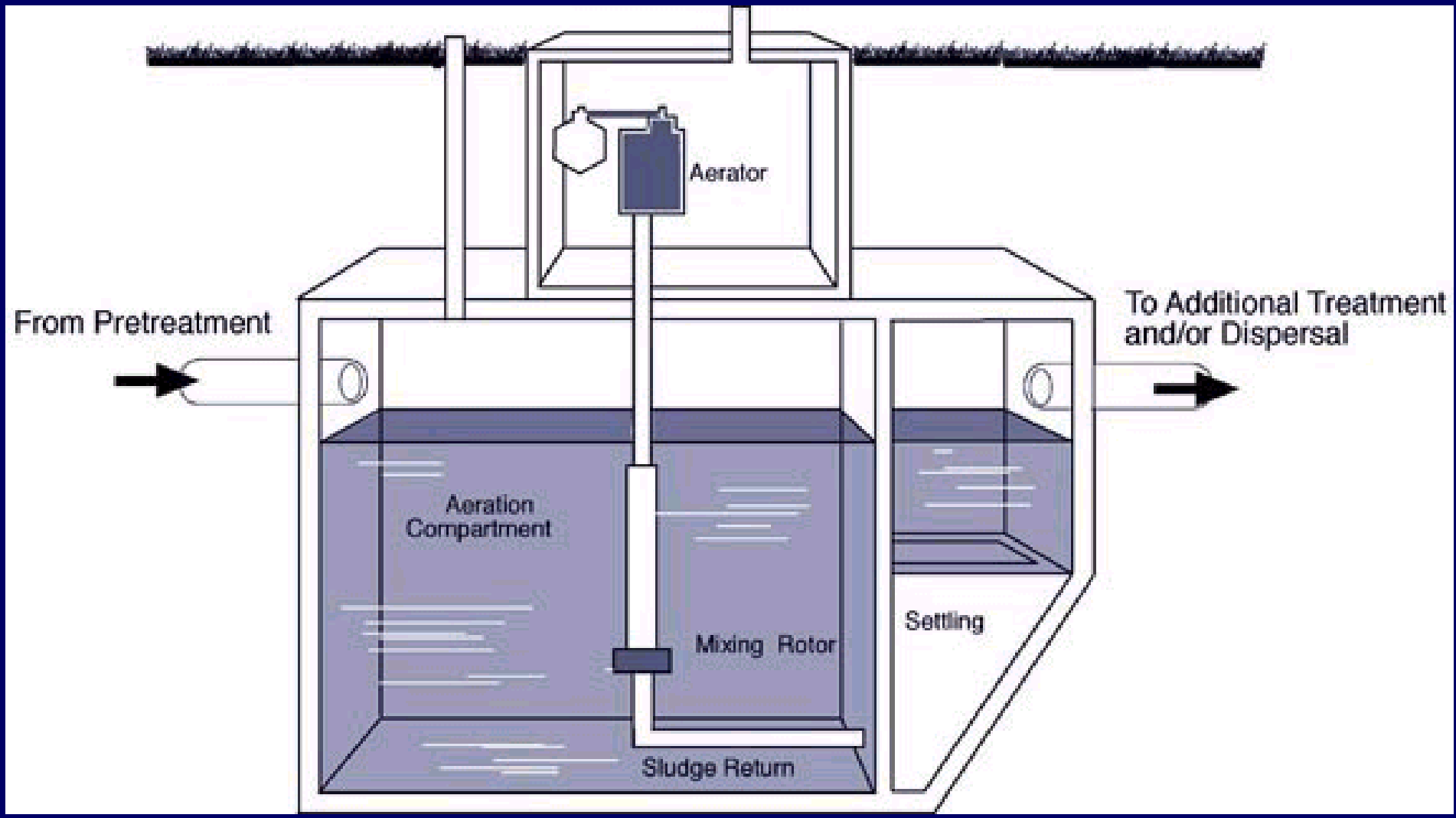
HOW ARE THEY ACTUALLY CHOSEN?

- Technology, location, and minimum acceptance rate are dictated by regulations that are enforced locally
- Any unit process must first be approved at the state level
- Special accommodations or credits for certain unit processes are also stated in regulations
- Few states permit surface discharges

EXAMPLE:
Better TSS & BOD Removal

- Recommend fixed-growth systems (trickling filter, media filter, etc) instead of suspended-growth systems (activated sludge types)
  - Lower O/M requirements
  - Better resistance to upset from influent surges and constituents
  - Less biosolids production
  - Less power demand

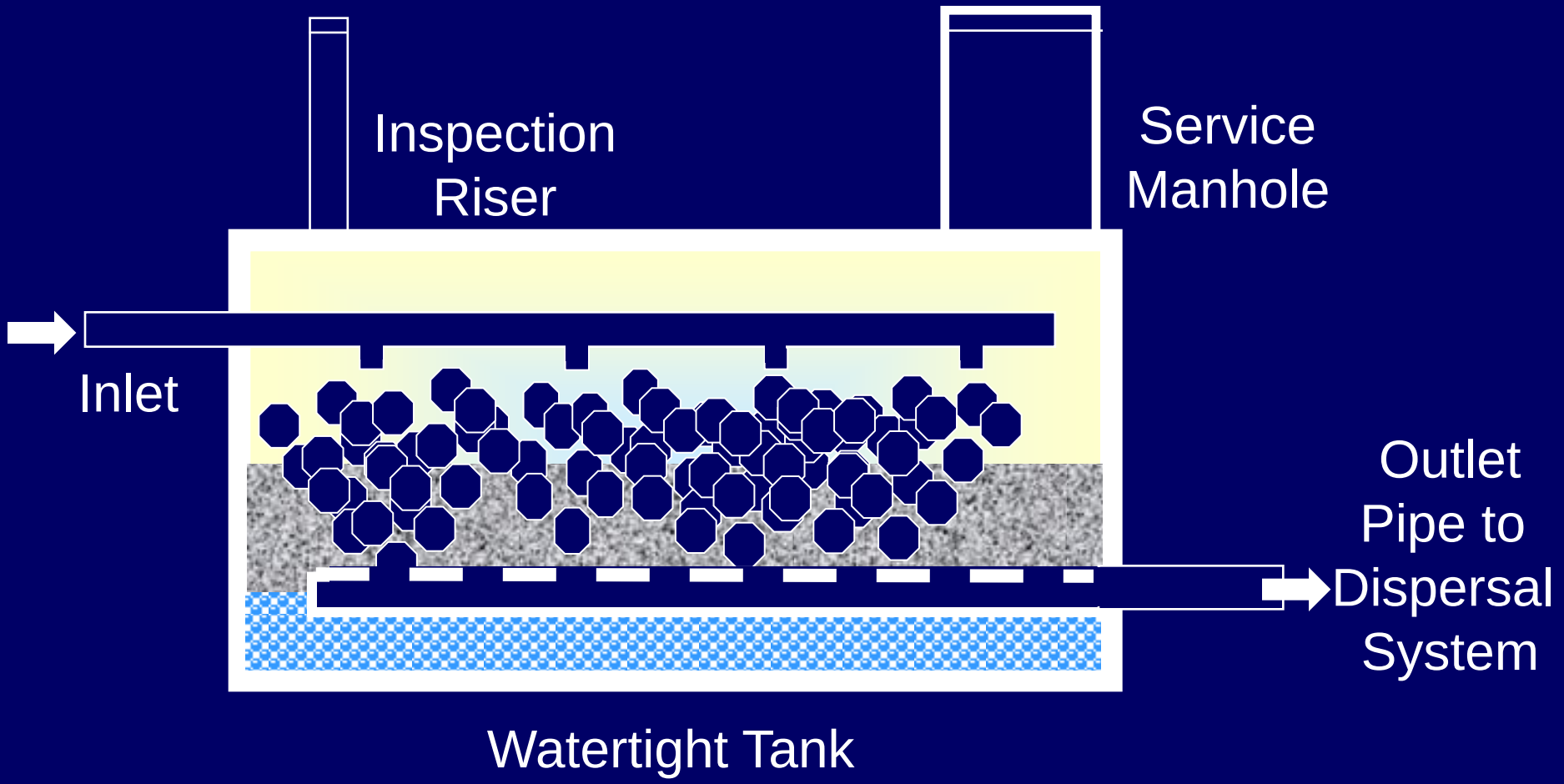
Aerobic Treatment Unit suspended growth system



Suspended growth (ATU) systems

- Most popular pretreatment system after the septic tank with the smallest footprint
- Most O/M manpower-intensive process
- Worst performance record of advanced pretreatment systems owing to lack of needed level of management
- Certain failures are difficult to identify
- Most power-demanding process

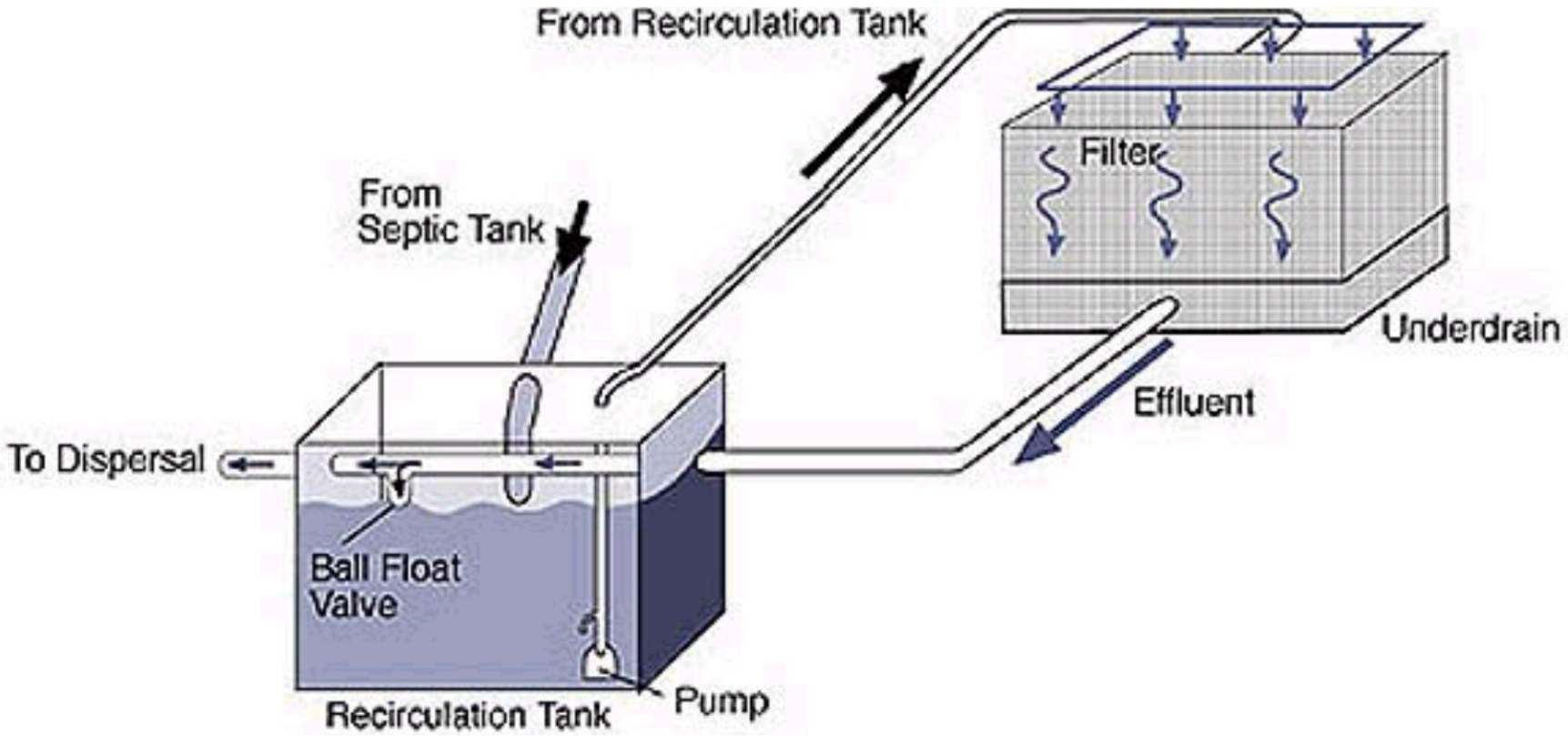
SINGLE-PASS FILTER
fixed-growth system



SINGLE-PASS MEDIA FILTERS

Photo: University of Minnesota

RECIRCULATING MEDIA FILTERS



RECIRCULATING MEDIA FILTERS

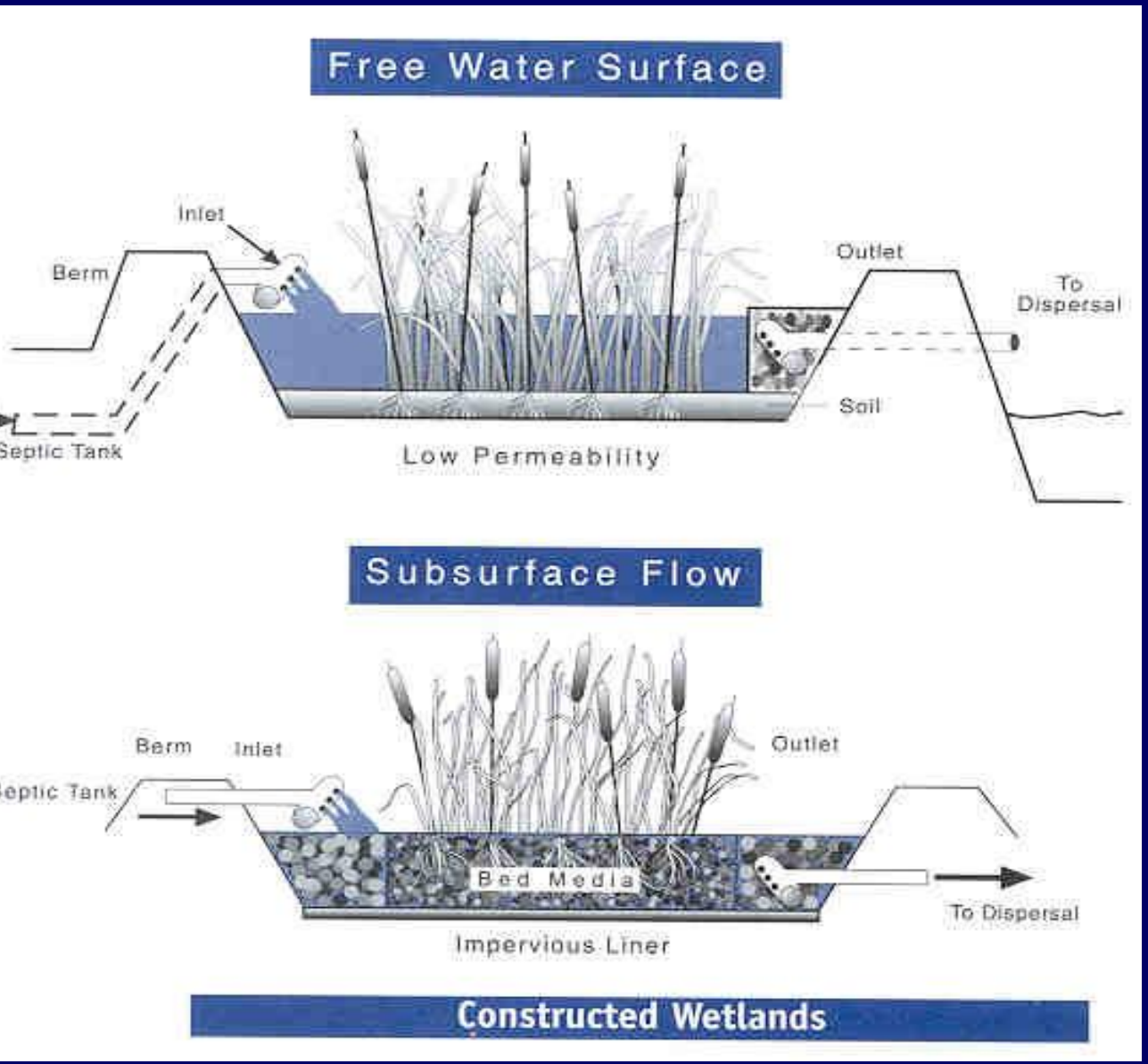
Photo: Virginia Department of Health

PRE-PACKAGED SYSTEMS

Treatment system effectiveness

Pollutant Parameter	Septic Tank Effluent (mg/L)	Aerobic Treatment Unit (FIXED OR SUSP) (mg/L)	Media Filter Treatment (ONCE-THRU) (mg/L)	Coarse Media, Foam or Textile Unit (RECIRC FILTER) (mg/L)	Removal Rate (%): ~3' of Soil
BOD/SS (mg/l)	100-150	30-50	2-15	5-15	>90%
TN (mg/l)	40-70	30-50	30-50	20-30	20-50%
TP (mg/l)	5-10	4-8	4-8	4-8	90-100%
FC Bacteria	10^6-10^8	10^4-10^6	10^1-10^2	10^2-10^3	>99.99%

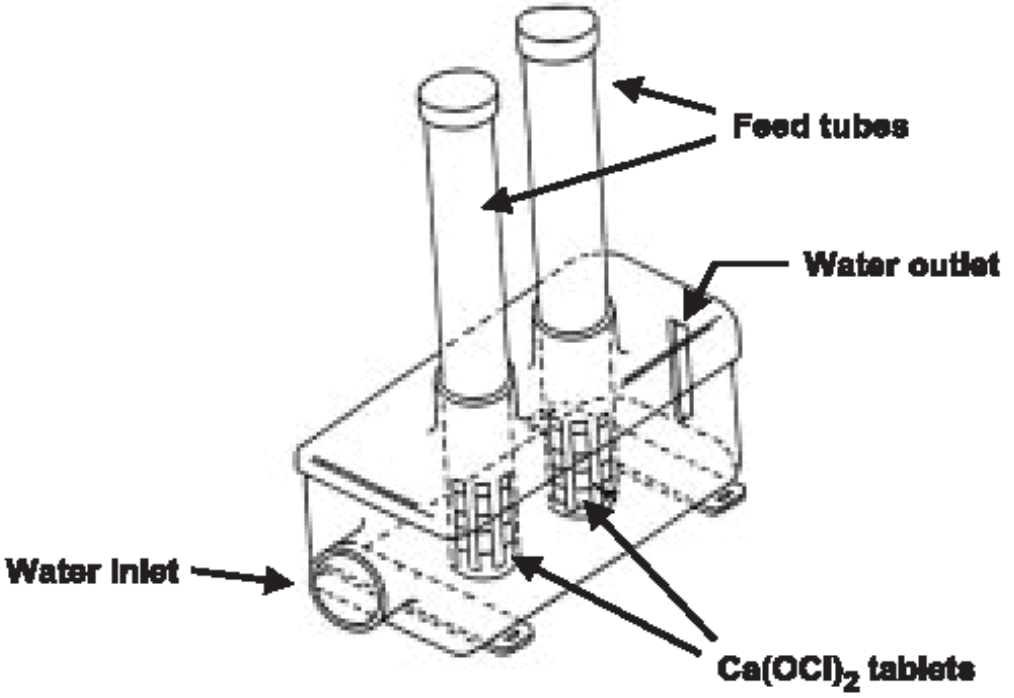
VEGETATED SUBMERGED BEDS



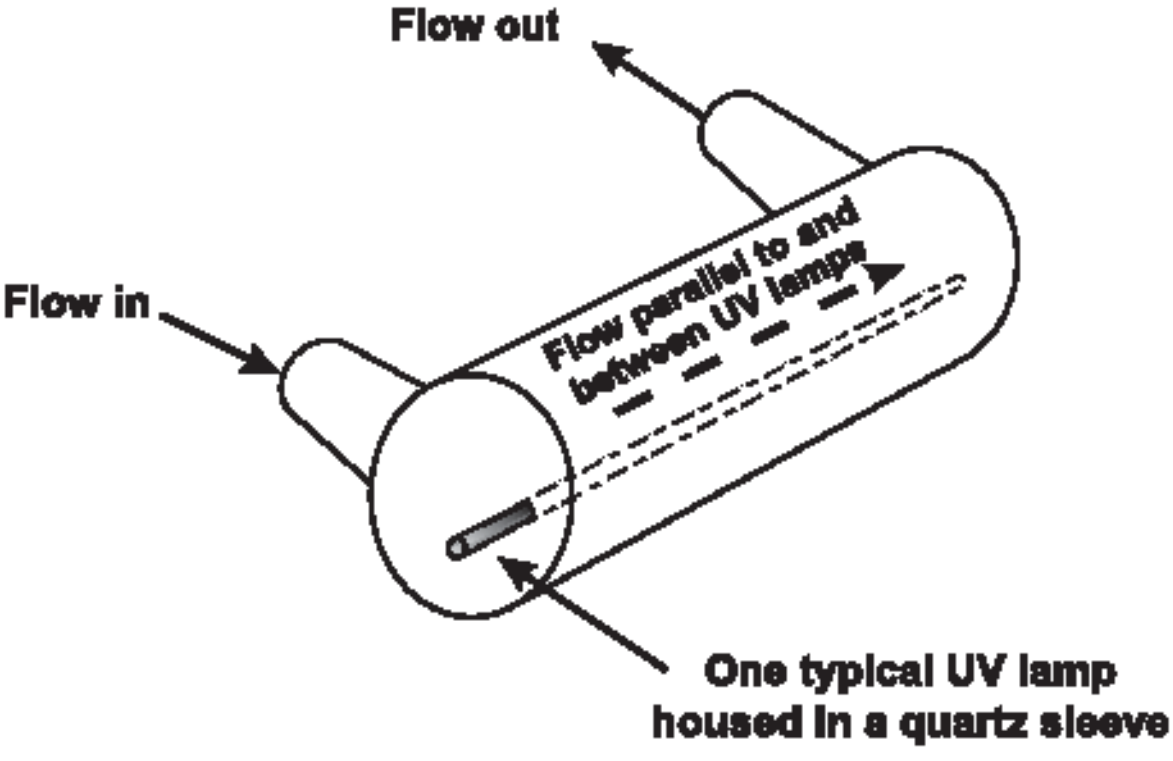
- Most commonly used for onsite and small cluster systems
- Wastewater flows horizontally below the media surface.
- Effluent quality of 30 mg/l BOD/TSS and no DO is the norm

Single home VSB

DISINFECTION OPTIONS



Tablet chlorinator



UV disinfection unit

Which disinfection method is best?

- Chlorine tablets tend to overdose or underdose owing to uneven rates of tab dissolution and flow variations, requiring frequent checks by operator-owners
- UV has performed well with less general concern for operational needs. Preventive O/M plans generally call for annual bulb replacement for < $100/yr

Questions?

Soil:

The most important treatment system component for onsite systems!

SOILS ARE THE HEART OF ONSITE SYSTEMS

- Unsaturated soils and the biomat on the infiltrative surface achieve the great majority of treatment performance of septic systems

- Slow and even passage of liquid through unsaturated soil maximizes biochemical *oxidation* of carbon and nitrogen; *adsorption* of phosphorus, virus, metals, and some toxic organics; and *filtration* of solids, parasites, and bacteria

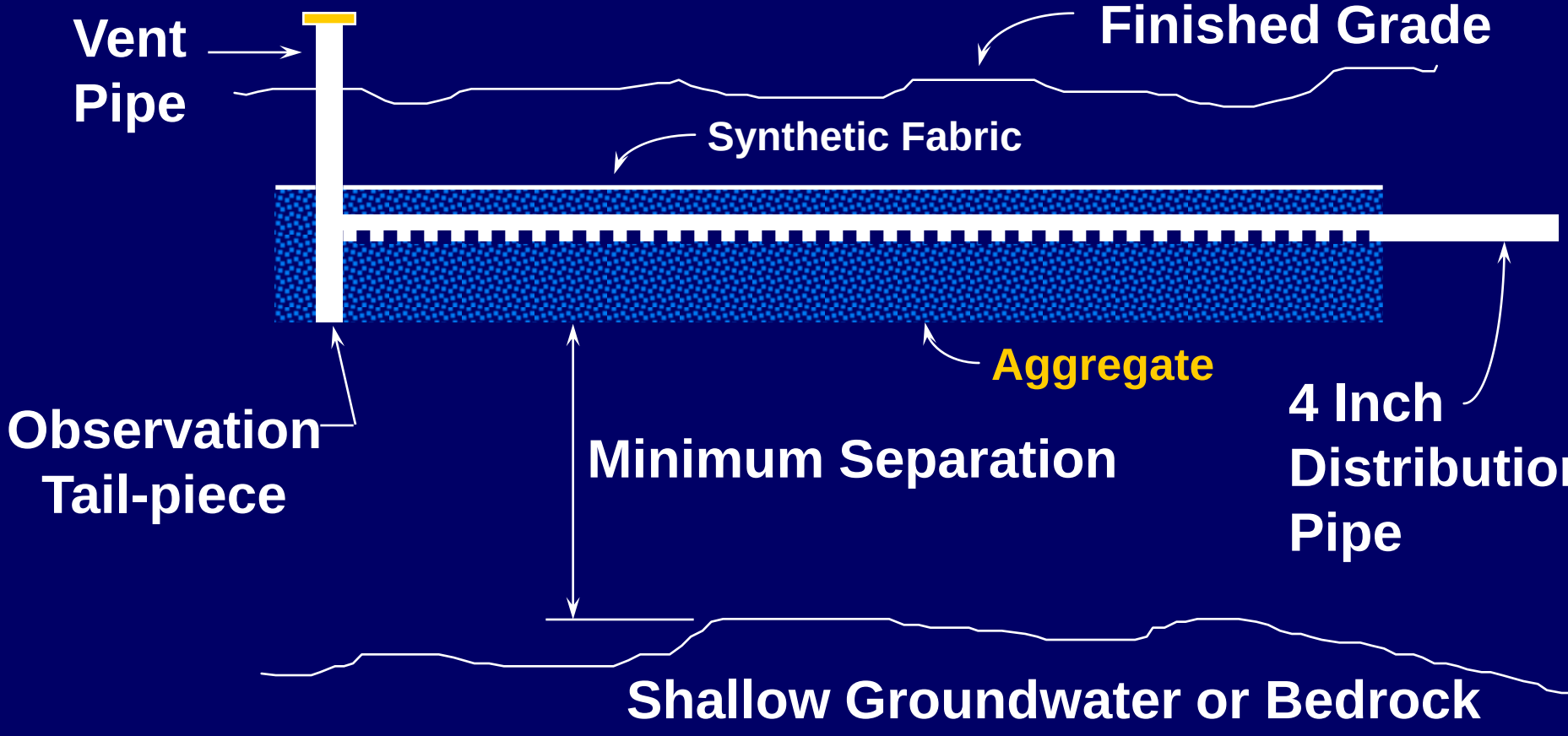
Soil treatment of septic tank effluent at varying soil depths

Pollutant Parameter	Septic Tank Effluent	Avg. after 24” soil filtration	Avg. after 48” soil filtration
BOD (mg/l)	93.5	<1	<1
TN (mg/l)	40-50	30-35	20 – 25
TP (mg/l)	8.6	0.4	0.18 – 1.8
F. Coli (log #)	4.57	Non-detect	Non-detect
F. Strep (log #)	3.6	Non-detect	Non-detect

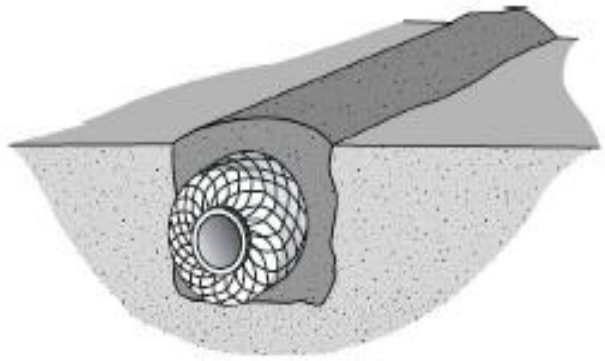
METHODS OF SOIL DISPERSAL

- Traditional Gravity Flow
- Alternating systems (long term resting)
- Siphon dosing (volume)
- Pump dosing (timed and/or volume)
- Low Pressure Pipe
- Drip Dispersal
- Spray Irrigation

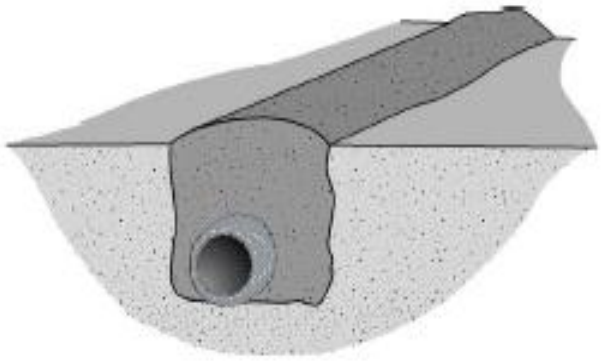
TRADITIONAL GRAVITY DISTRIBUTION



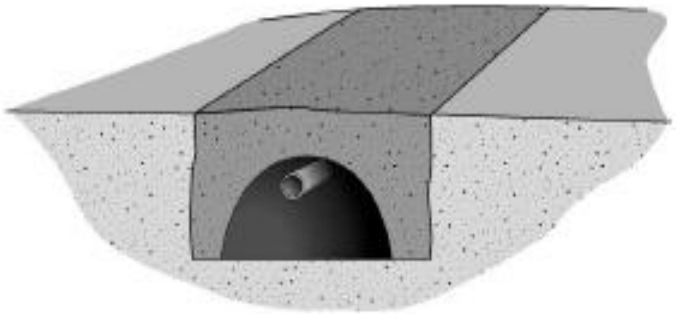
GRAVELESS DISTRIBUTION SYSTEMS



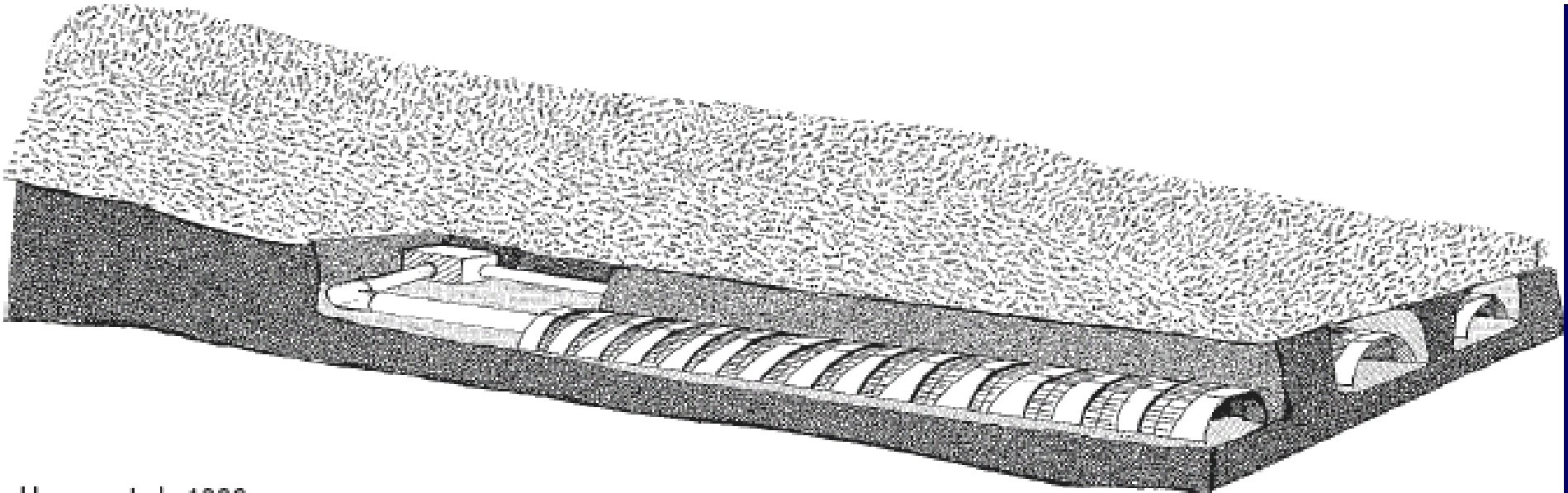
Polystyrene
Wrapped Pipe



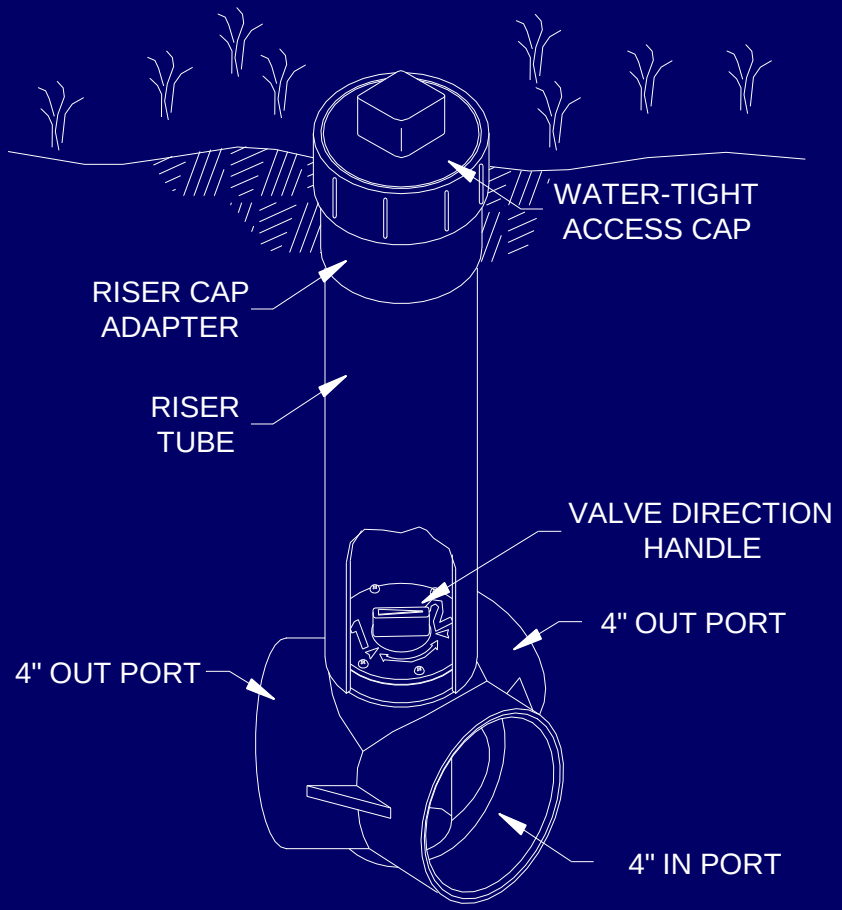
Geotextile
Wrapped Pipe



Chamber



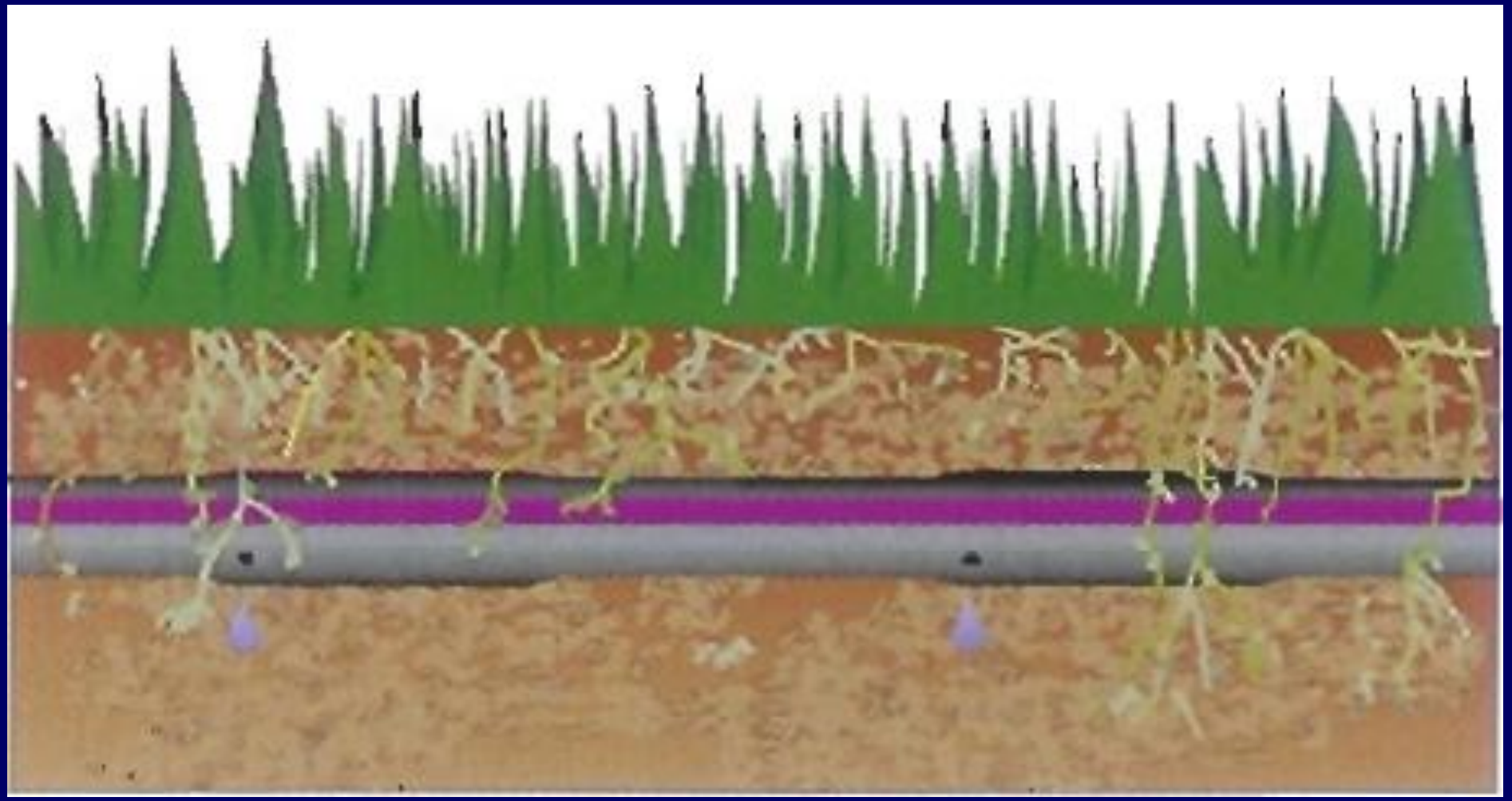
Alternating drainfield systems



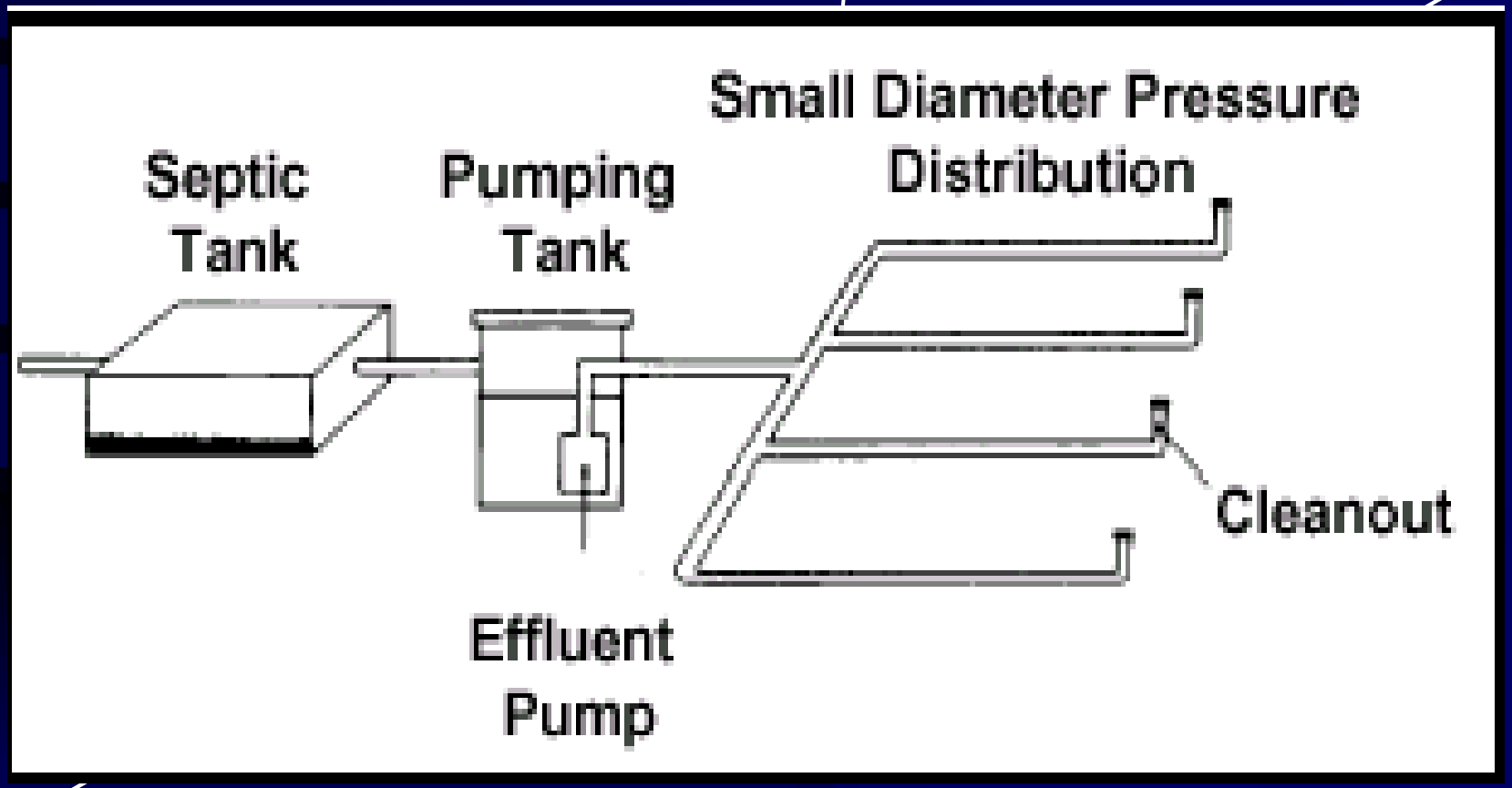
The Diversion Valve

- Rejuvenates resting trenches
- Immediate relief for hydraulic overload
- Provides long-term reliability

DISPERSING HIGH IN THE SOIL PROFILE IS BETTER



Pressure distribution of septic tank / treatment system effluent

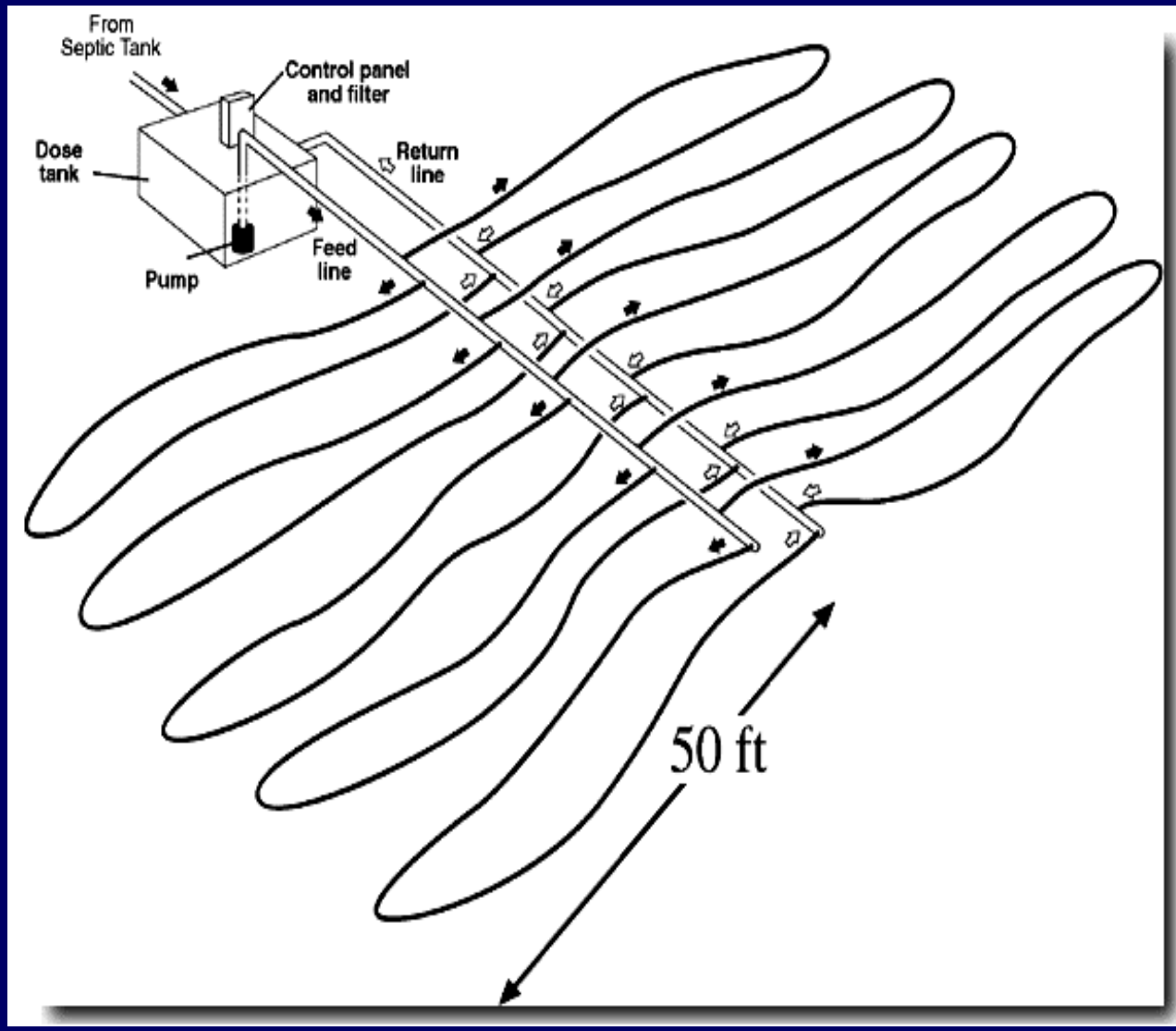


PRESSURE DOSING ADVANTAGES

- Uniformity of Dispersal Maximizes Soil Contact Time and retards clogging
- Eliminates Instantaneous Flow Variations
- Alternating Wet and Dry Conditions Facilitate Aerobic Biological Degradation
- Does Not Require Advanced Treatment

Drip dispersal systems

- Drip lines high in the soil profile enhance treatment
- Good for sites with high water tables
- Can be used on sloping sites with trees, etc.



DRIP DISPERSAL

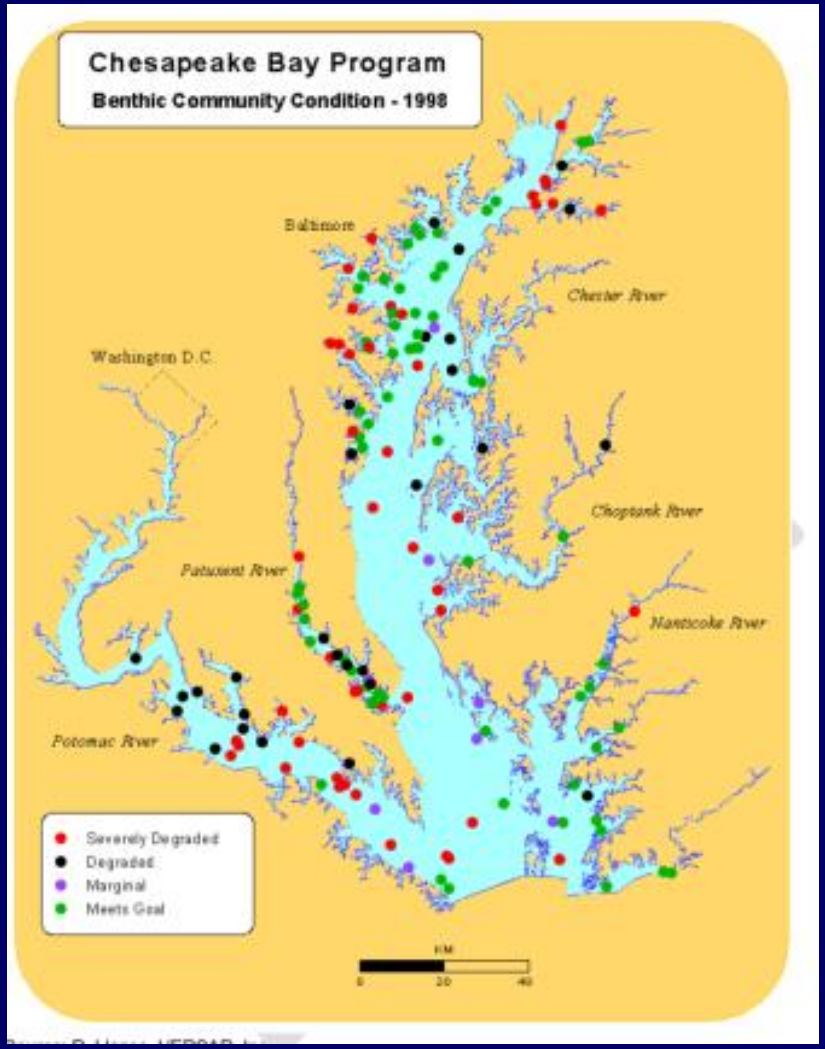
- By far the best means of spreading flow evenly over entire lateral field (uniform distribution)
- Reduced setbacks from surrounding areas compared to surface irrigation systems
- Can accommodate several times the hydraulic loadings per unit land area allowed in conventional soil systems (smaller footprint)
- Requires additional pretreatment over septic tank to minimize emitter plugging

Drip dispersal application

Questions?

COMMON SITE DESIGN CHALLENGES

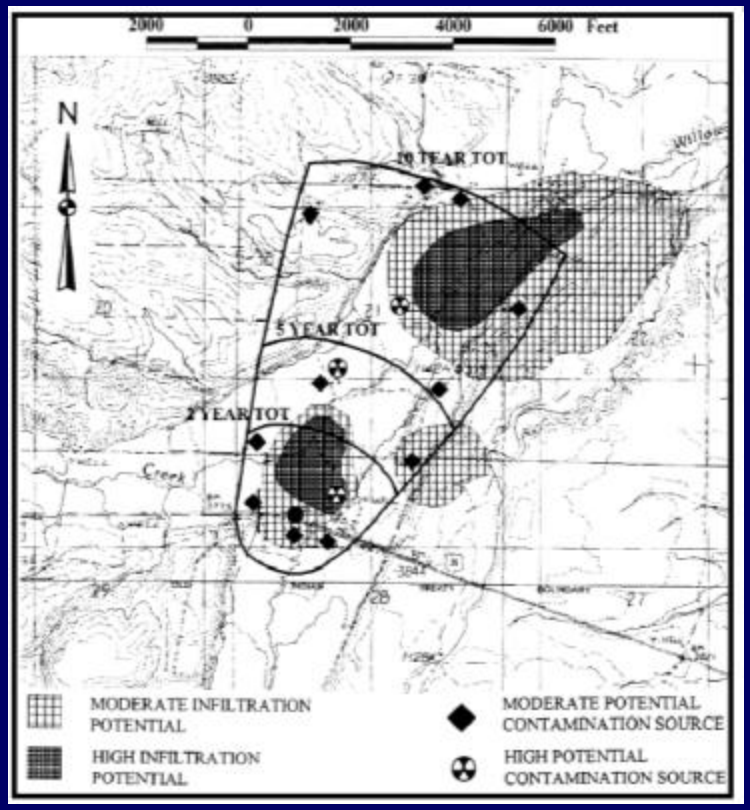
- High groundwater table
- Nitrate loading limits
- Phosphorus loading limits



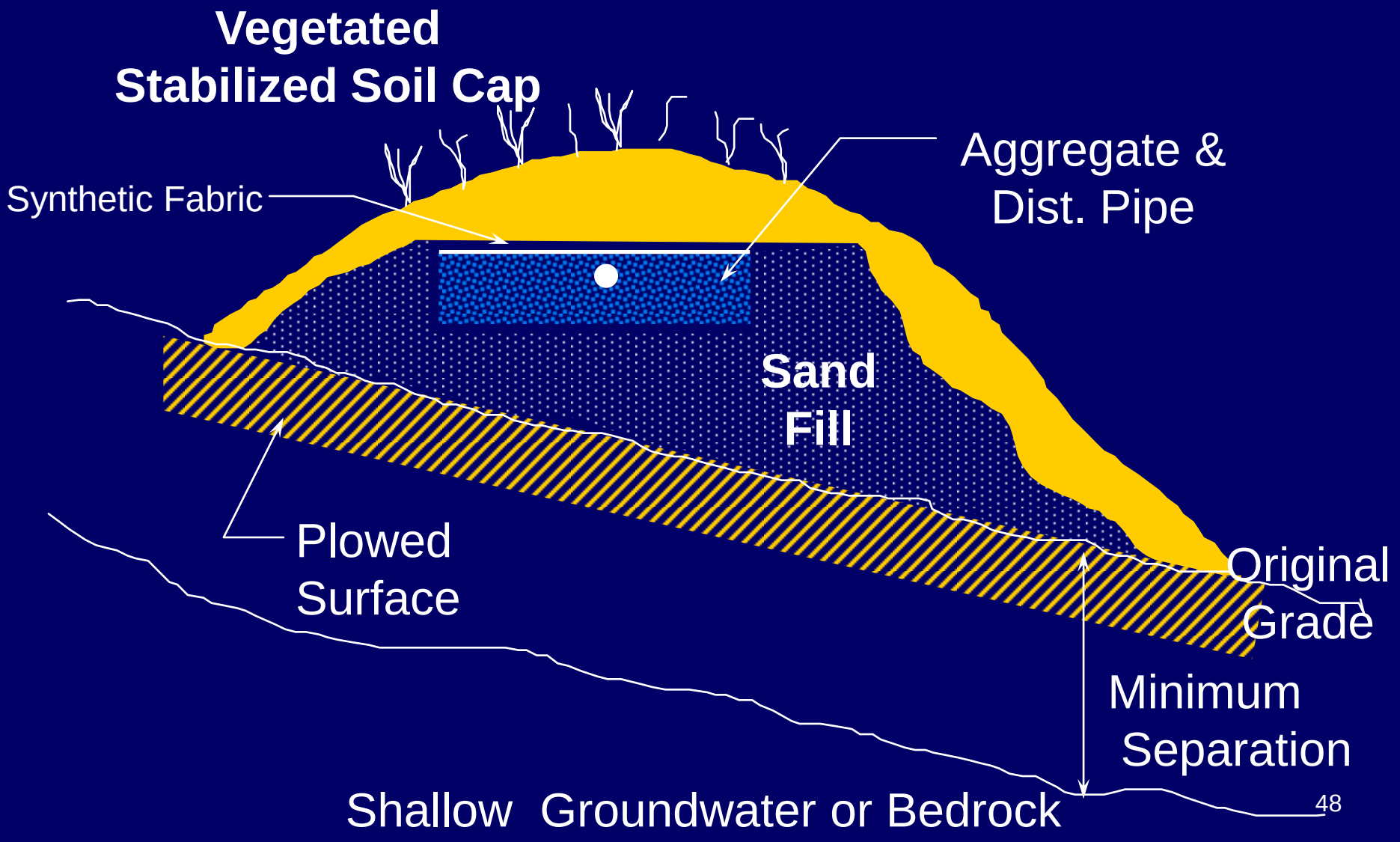
HIGH GROUND WATER TABLE

- Problem =

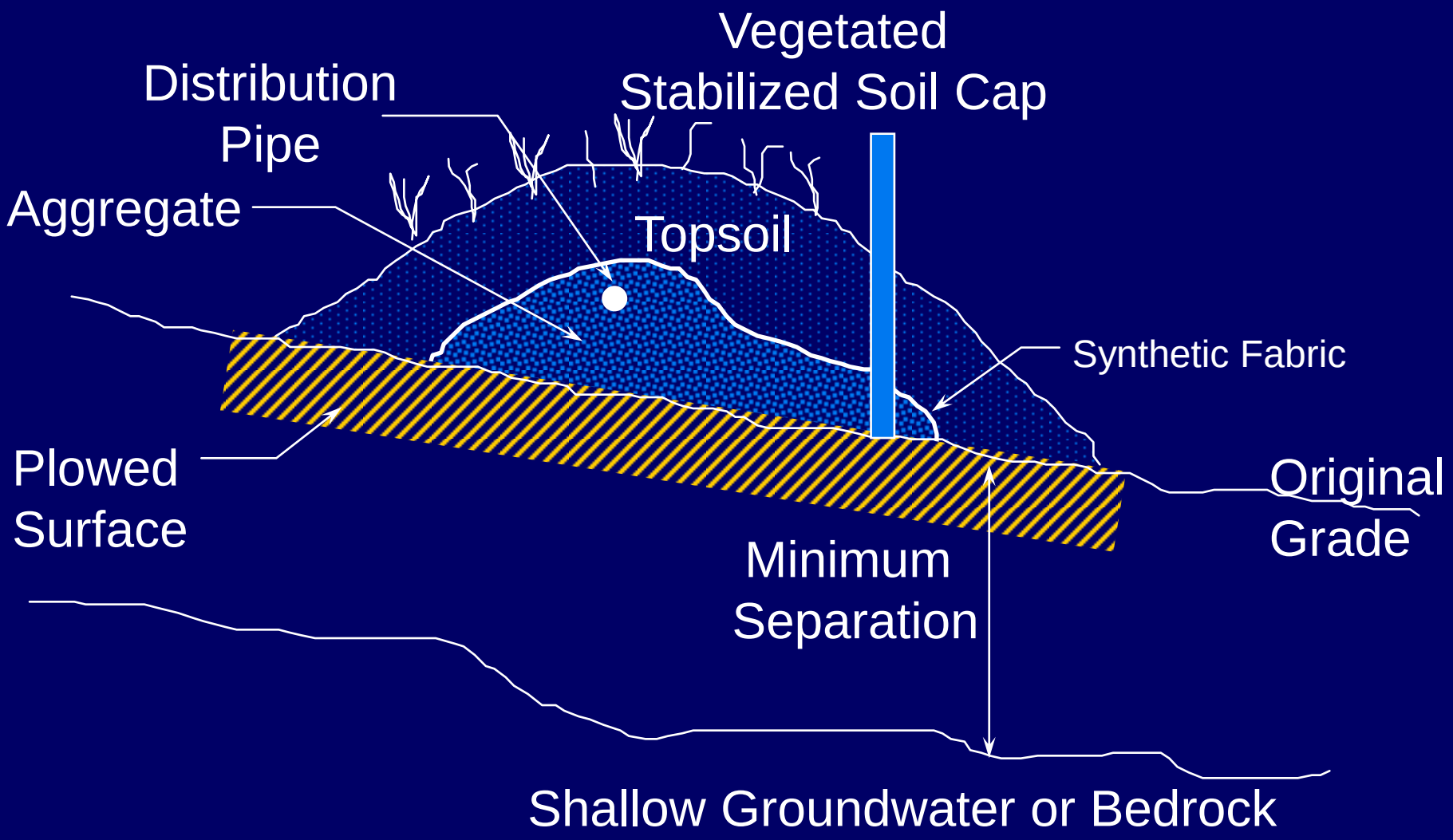
  Lack of sufficient depth of unsaturated soil for treatment
- Solutions =
  - Mounds
  - At-Grade Systems
  - Pressure/Drip Dispersal



MOUND SYSTEM



At-grade system details

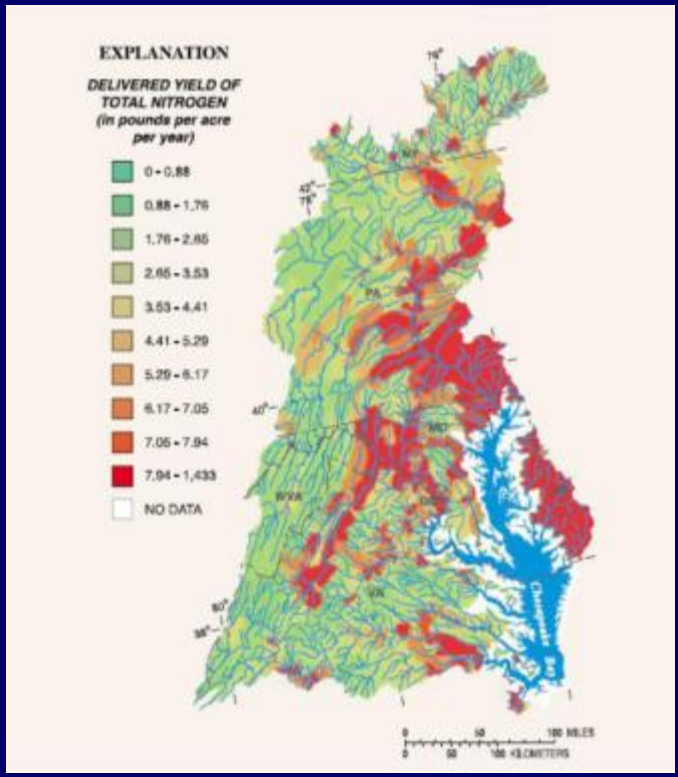


Excessive Nitrogen Loading

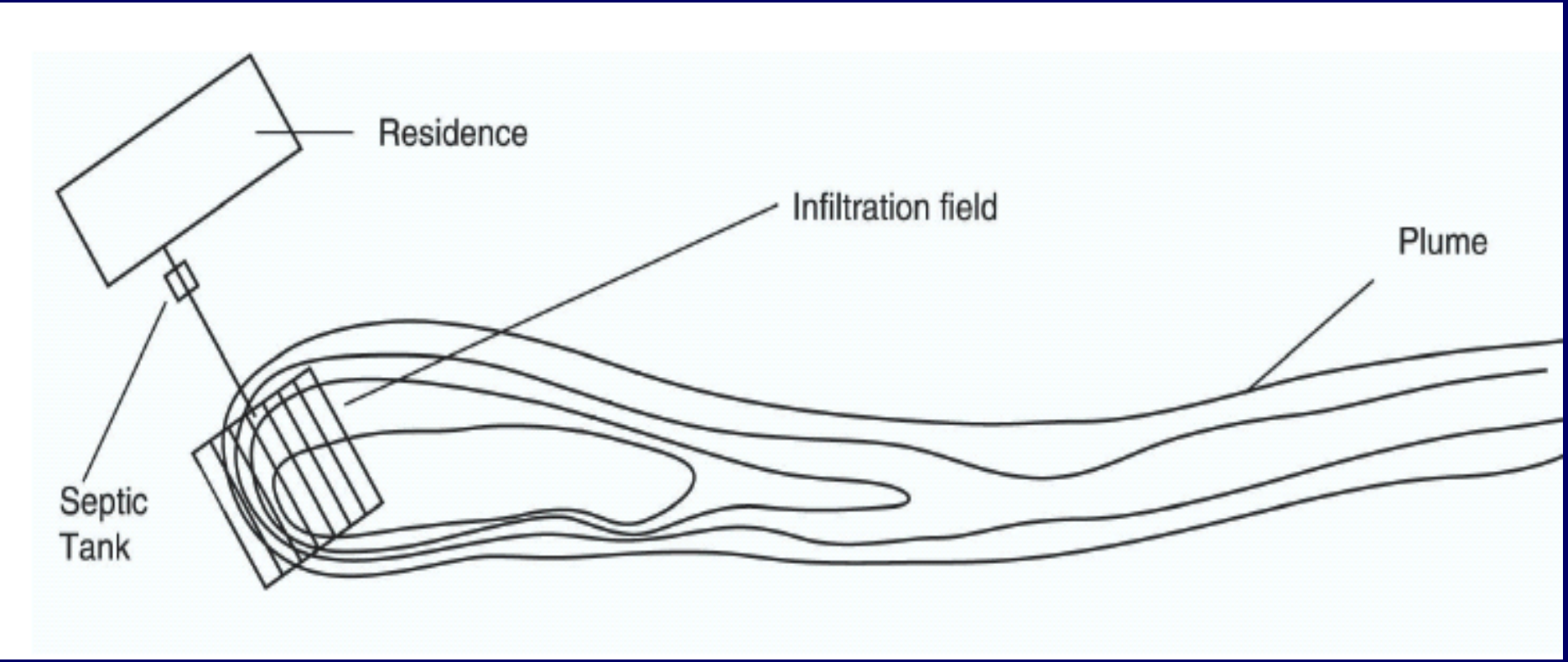
- Problem =

  Nitrogen removal limited to 20-30% in unsaturated soil with gravity distribution, and the rest generally travels with the natural ground water plume

- Solutions =
  - Add nitrogen removal to pretreatment steps
  - Intercept high-nitrate ground water plume and treat it before it enters local surface waters



GROUND WATER PLUMES



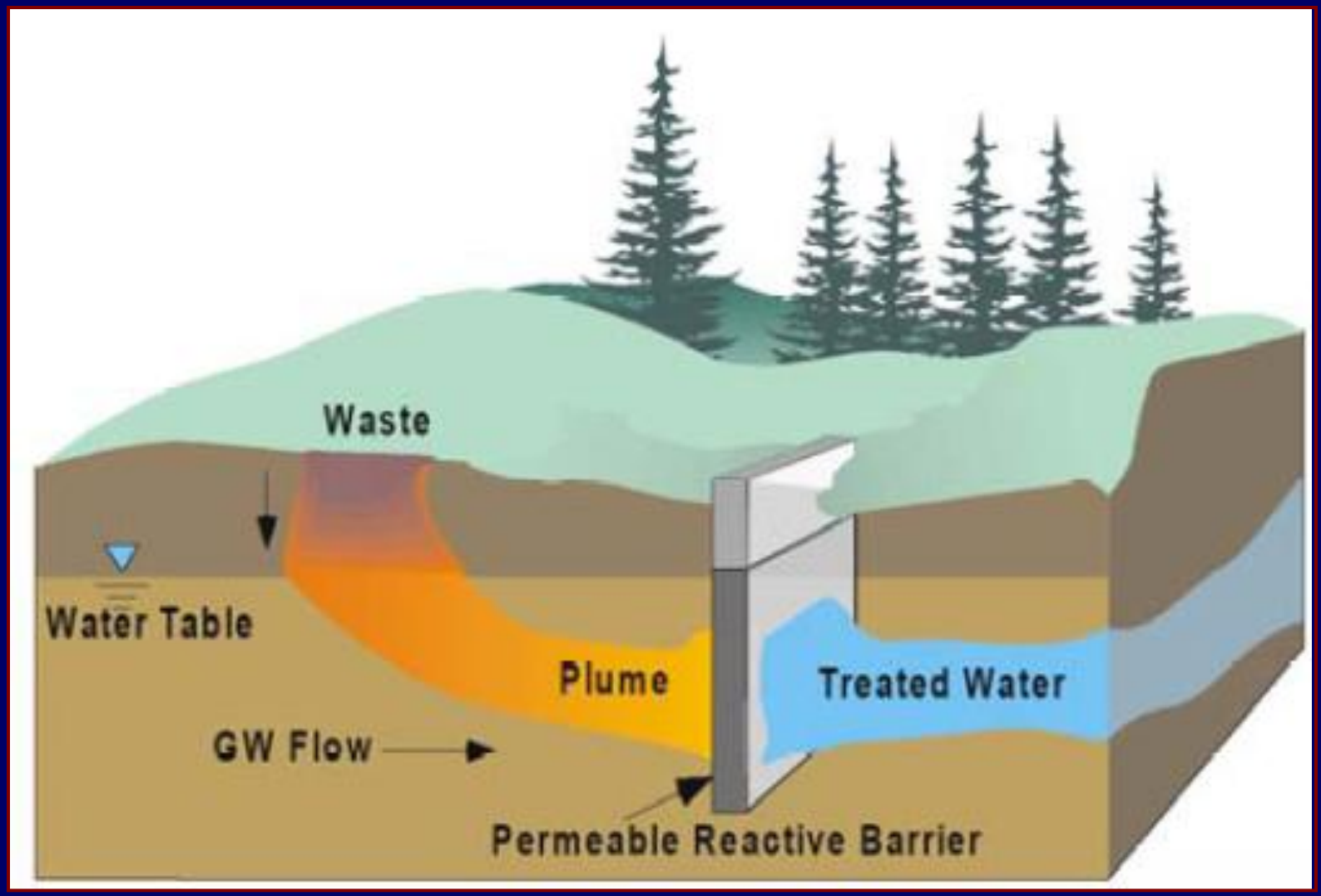
Nitrogen Pretreatment

- Septic tank effluent nitrogen is ~75% NH_4-N and 25% organic-N
- Passive, low-residual-generating systems like RMFs (attached growth) resist upset and simplify management while providing about 50% TN removal and BOD & TSS of about 10 mg/L
- Subsequent denitrification step must provide excess concentrations of labile carbon or elemental sulfur to drive the reaction

Nitrogen Removal

- Pretreated wastewater (TN mostly in ammonium form) is nitrified immediately below infiltrative surface, and the nitrate then moves readily with treated wastewater
- Gravity-dosed soil nitrogen removals vary from 10% for coarser soils to 40% for silts and clays
- If 50% TN removal is desired, it can be achieved by pressure/drip dispersal or by an RMF
- Higher removals require an additional unit process for denitrification; passive commercial units are available

Permeable Reactive Barriers (PRBs) for Nitrate Removal



EXCESSIVE PHOSPHORUS LOADING

- Problem:
  - P capture by soil is functioning poorly

  Solutions:
  - Improve contact opportunities between soil and effluent with better soil dispersal
  - Minimize P in sewage by product substitutions or by pretreatment

Phosphorus Source Reduction

- Several states require P-content of detergents to be no more than 0.5% by weight.
- Those states have seen their daily P per person loading drop 59%
- Similar restrictions on dishwashing detergents are predicted to reduce the P loading from 2.7 g/cap/day by another 23% to about 2.1 g/cap/day

Phosphorus Pretreatment

Special media filters (eg, sodium aluminate, or sands with high iron oxide content) can significantly reduce total phosphorus with relatively low O&M demands

What impacts phosphorus capture in soils?

- P fixation is related to:
  - Low or high pH (+)
  - Calcium content (+)
  - Aluminum content (+)
  - Iron content (+)
  - Organic content (-)
  - Uniform distribution/dosing (+)
  - Clay content (+)

Phosphorus Overview

- P leached to ground water depends on:
  - Soil characteristics
  - Unsaturated zone thickness
  - Applied P loading rate
  - Age of system
  - Dispersal system type

Miscellaneous issues

- Additives – None have been shown successful, and some can damage soil and cause groundwater contamination
- Grease Traps – Generally not necessary for residential wastewater; Necessary for restaurants, food processing facilities
- Tank Pumping Frequency – Monitor sludge/scum buildup every 2 to 3 years as part of normal O&M visits to determine when pumping needed

Management and Operations

- Subsequent seminars in this series will deal with these issues
- Management should be appropriate to the technologies and service area capacity/characteristics
- The decentralized approach is suited to watershed-scale water management

THANKS FOR YOUR ATTENTION

Any Questions?