Soil Aquifer Treatment and Recovery for Water Reuse

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Brown and Caldwell

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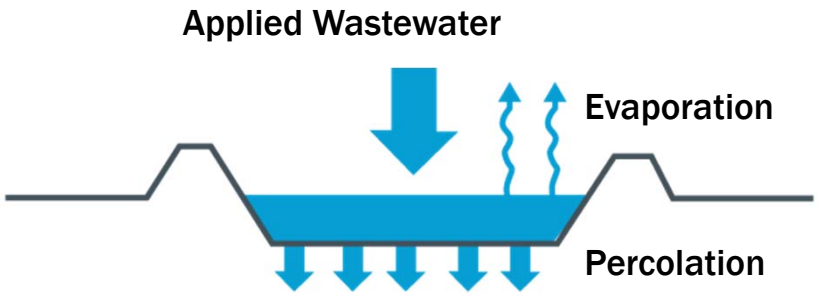
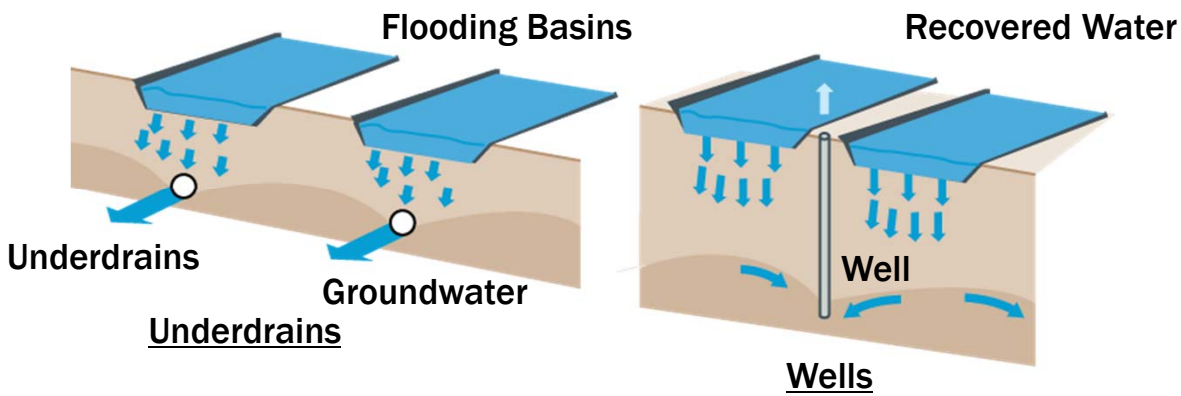
Soil Aquifer Hydraulic Pathways

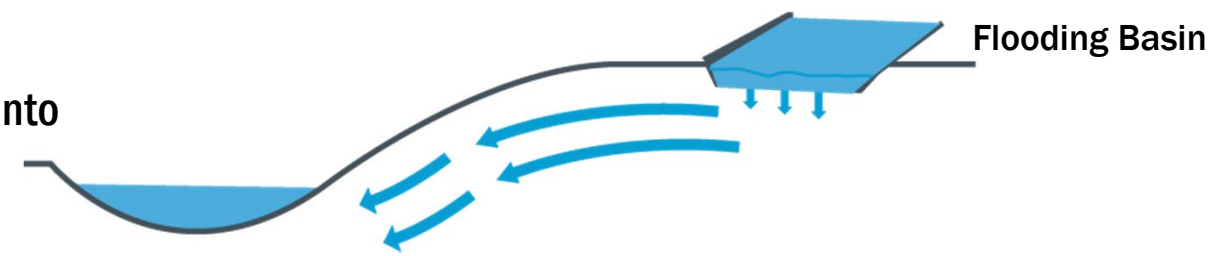
Hydraulic Pathway



Recovered Pathways



Natural Drainage into Surface Waters



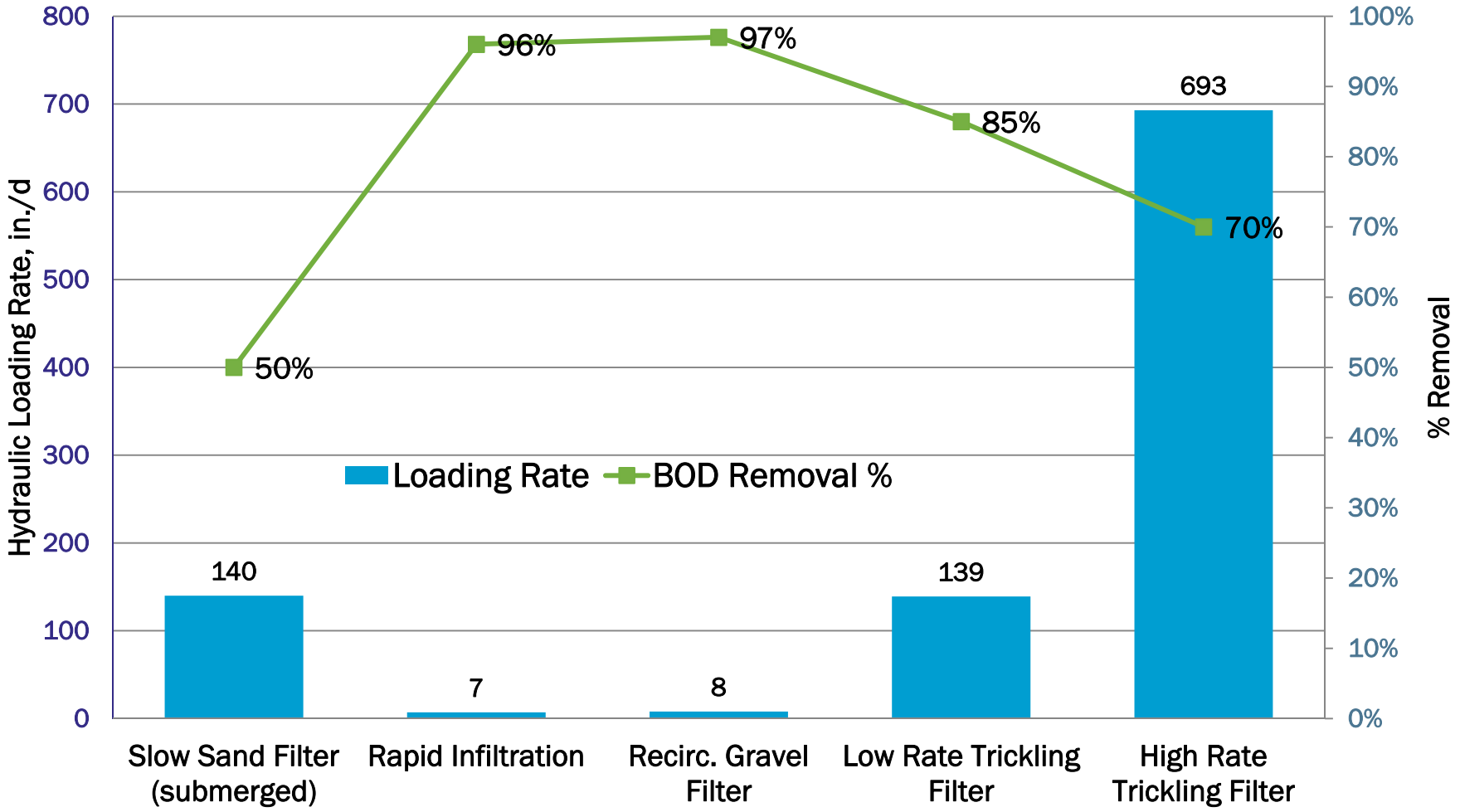
History of Soil Aquifer Treatment

- Over 100 years of practice
- Calumet, Michigan system operating since 1888
- Term coined by Herman Bouwer
- Also known as Rapid Infiltration
- Denitrification of up to 93 percent of nitrogen loaded
- Organics removal depends on loading rate and detention time

Treatment Mechanisms

- Biological filter - microbes remove organics and nitrogen
- Surface spreading allows volatilization and photodecomposition
- Physical filter - soil filters out suspended solids, bacteria and turbidity
- Chemical filter - soil adsorbs organics, viruses, metals and phosphates
- Temperature – equalization with ground and aquifer thermal mass
- Soil is a sponge, not just a sieve

Comparison of RI with Other Media Based Treatment



Phoenix SAT System

- Research and demonstration plots
- Primary and secondary pretreatment
- Loading rate of 300 ft/yr
- Groundwater wells 600 ft down-gradient
- Recovery wells

BOD Removal in SAT

Location	Hydraulic Load,ft/yr	BOD in, mg./L	BOD out mg/.L
Lake George, NY	140	38	1.2
Phoenix, AZ.	360	15	1.0
Hollister, CA	50	220	8.-0

Nitrogen Removal in Soil Aquifer Treatment

Location	Applied Wastewater, mg/L	Process Effluent, mg/L
Calumet, MI	24	7.1
Ft. Devens, MA	50	19.6
Hollister, CA	40	2.8
Phoenix, AZ	27	5.5

Phosphorus Removal in Soil Aquifer Treatment

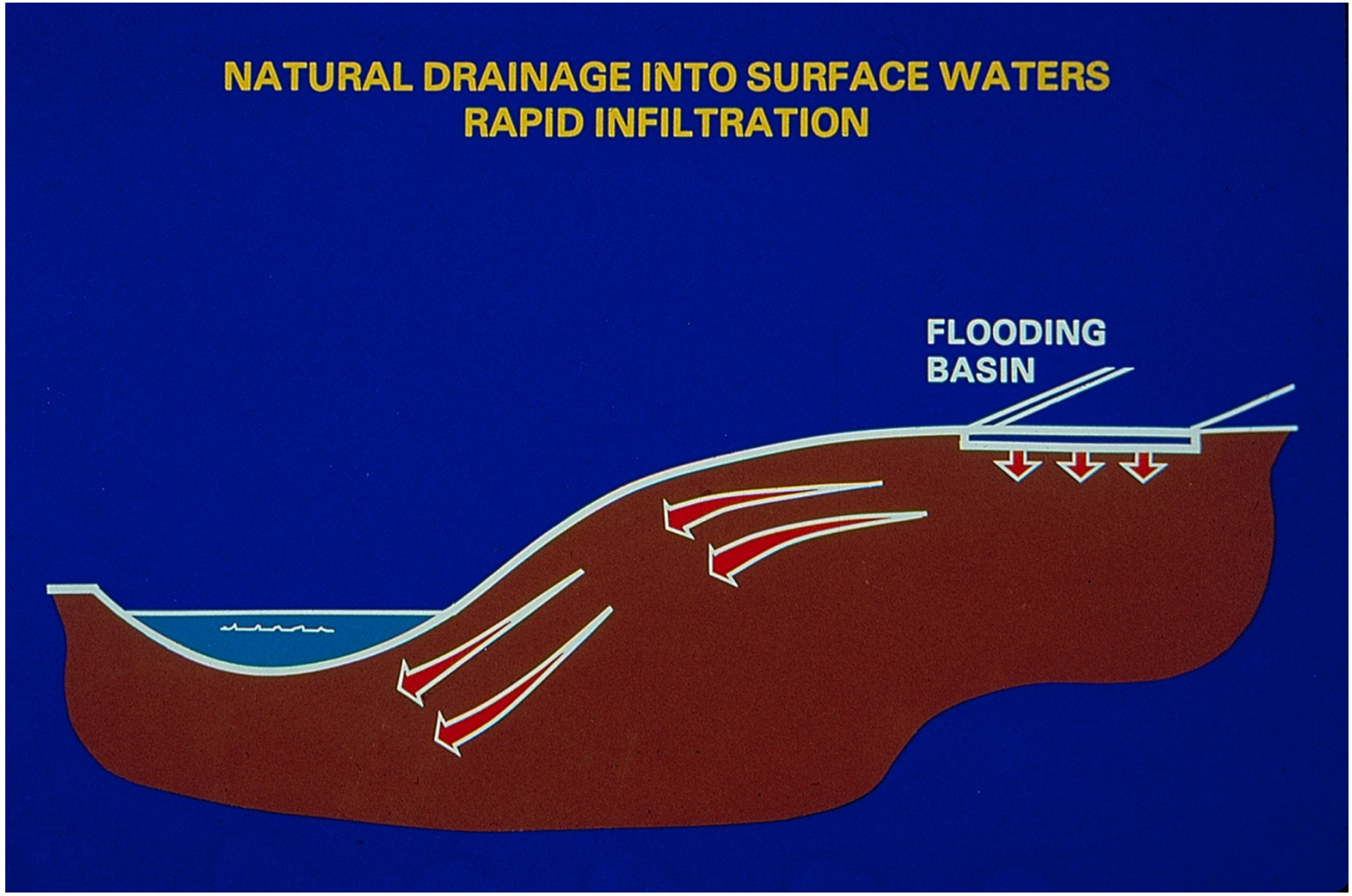
Location	Applied Wastewater, mg/L	Percolate Effluent, mg/L
Brookings, SD	3.0	0.45
Calumet, MI	3.5	0.03
Ft Devens, MA	9,0	0.1
Lake George, AZ	2.1	0.014
Phoenix, AZ	7.9	0.51

Prediction of P Removal

- $P_x = Pe^{-kt}$
- Where
  - X = travel distance
  - K = constant = 0.048/d
  - t = time

  - If P = 10 mg/L
  - and t = 110 days
  - then P_x = 0.05 mg/L

Hyporheic Discharge



Calumet, Michigan

Calumet SAT Basin Maintenance

Wetting and Drying Cycles

Intermittent application critical to long-term performance

- Adds oxygen during drying cycle
- Restores infiltration rate
- Minimizes algae growth
- Promotes nitrification and denitrification
- Allows surface solids to dry

Mesquite, Nevada Flooded Basin

Mesquite, Nevada SAT Dry Basin

Entry Ramp for Maintenance

Lake George, NY

- Flow = 1.1 mgd summer; 0,4 mgd winter
- SAT area = 5.4 acres
- HLR = 140 ft/yr
- Effluent applied = secondary
- Loading cycle 8-24 hr on

  4-5 days off summer

  5-10 days off winter

Ft Devens, MA

- Flow = 1.3 mgd
- SAT area = 16.6 acres
- HLR = 94 ft/yr
- Effluent applied = primary
- Loading cycle 2 days on
  14 days off

Hollister, CA Aerial of SAT System

Summary of Typical Wet/Dry Ratios

- Barnstable 0.14
- Boulder 0.03
- Calumet 0.14
- Ft. Devens 0.14
- Hollister 0.07
- Lake George 0.08
- Phoenix 0.75

Soil Treatment (SAT) in CDPH Regulations

- Indicators of the effectiveness of SAT must be identified and measured
- Pick at least 3 relevant indicators based upon an occurrence study approved by CDPH
- Monitor quarterly
  - prior to SAT and
  - no more than 30 days downgradient
- If a 90% reduction (excluding the effect of dilution) is not demonstrated
  - investigate
  - and report

SAT Removes Most Constituents of Emerging Concern (CECs)

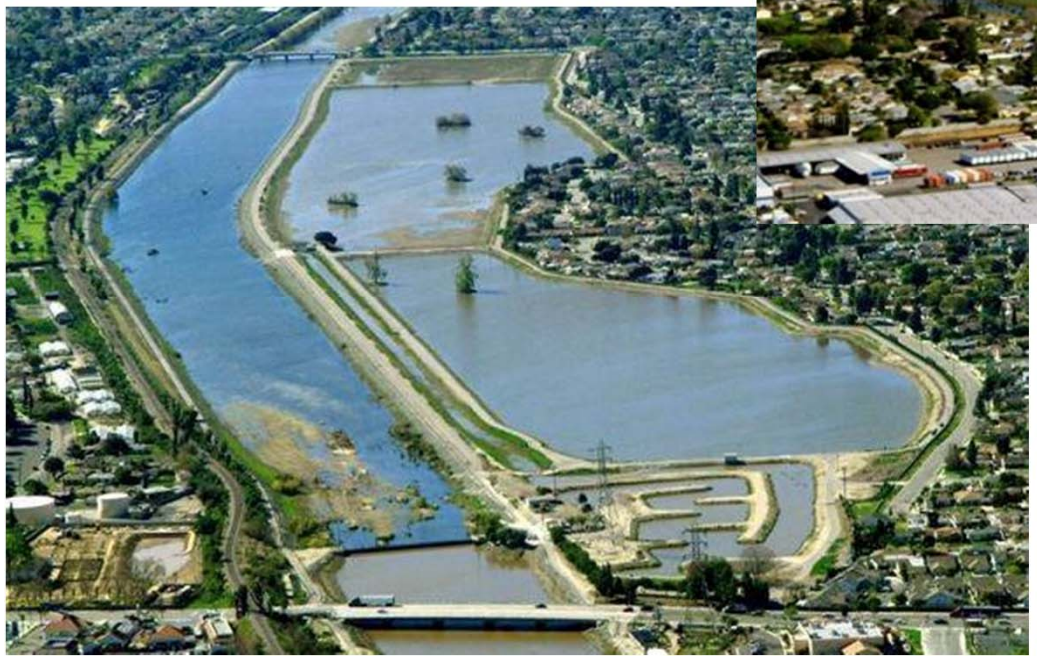
SAT removes > 90% of these:

- Acetaminophen
- Atenolol
- Atorvastatin (Lipitor)
- Bisphenol A
- Caffeine
- DEET
- Diclofenac
- Erythromycin–H_2O
- 17β-Estradiol (E2)
- Estriol (E3)
- Estrone (E1)
- Fluoxetine (Prozac)
- Gemfibrozil
- Hydrocodone (Vicodin)
- Ibuprofen
- Iopromide
- Ketoprofen
- Metoprolol (Lopressor)
- Naproxen
- Nonylphenol
- Propranolol

Estrogenic Activity Reduction

Sample location	Fraction removed
Primary effluent	0.00
Secondary effluent	0.65
Depth 2.5 ft	0.77
Depth 10 ft	0.83
Depth 60 ft	0.93
Depth 120 ft	0.99

LA County San District's Recharge



Whittier Narrows, SAT System

- Operational since 1962
- First secondary effluent, blended with stormwater and imported water
- Now disinfected tertiary, blended with stormwater and imported water
- Groundwater recharge
- Private wells downgradient

Microconstituent Removal at Rio Hondo

- 90+% removal of Acetaminophen, Caffeine, DEET, Estrone, Triclosan
- 50-90% removal of Dilantin, Nonylphenol and Primidone
- -25% removal of Atrazine and Carbamazepine

Removal of PhPCP at Tucson, AZ

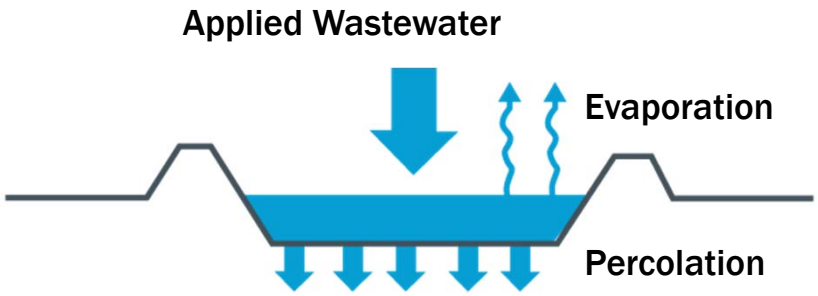
- 99.9% removal of Atenolol
- 90% removal of Caffeine
- 98% removal of Triclosan
- 96+% removal of Ibuprofen
- 90% removal of Naproxen

RI, Recharge, and Extraction

- Orange County, California
  - 5-year anniversary
  - Groundwater recharge
  - Recovery wells for potable reuse
- Rapid infiltration/recovery (RIX)
  - San Bernardino (33 mgd secondary)
  - Fresno (68 mgd secondary)
    - 6 log virus removal

Soil Aquifer Hydraulic Pathways

Hydraulic Pathway



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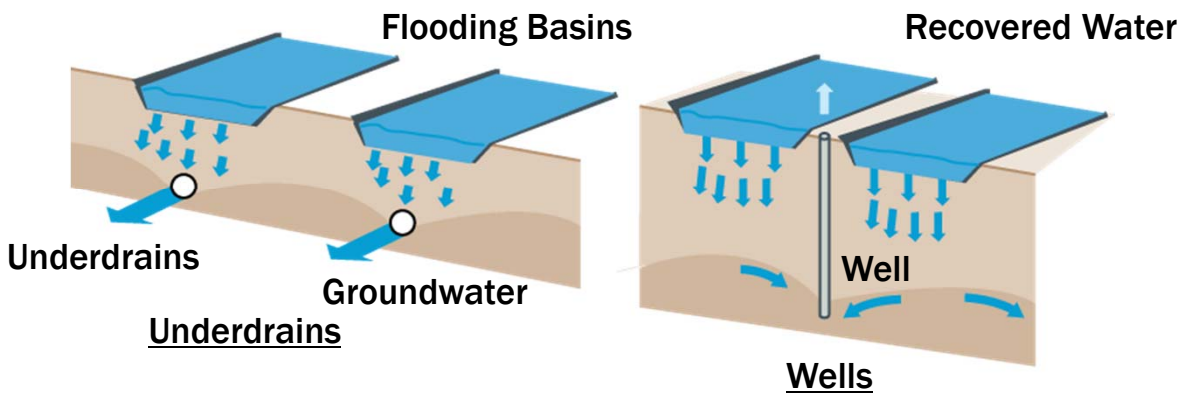

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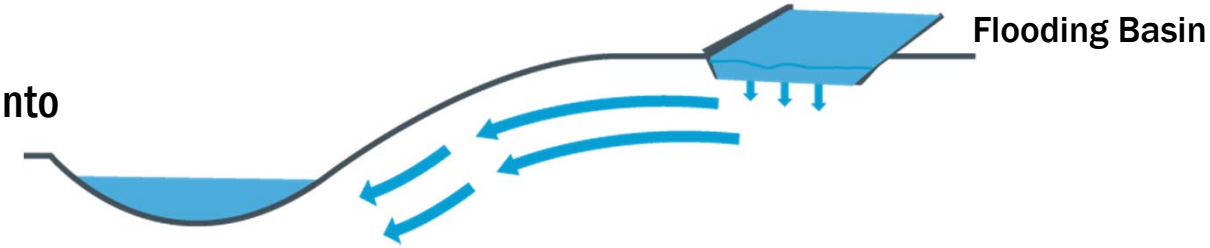

Aquifer Storage and Recovery

- Can be used with SAT for seasonal storage and recovery
- Recovery wells can be used to produce irrigation water or for stream flow augmentation
- Can be used to meet TMDL requirements for phosphorus by treating with SAT and recovering and discharging low phosphorus water at the appropriate time of the year

Questions?