# Mitigating hydrologic impacts of development: lessons learned in Dane County, Wisconsin

Steve Gaffield
Rock River Educational Forum:
*Targeting Water Quality Improvements*
May 19, 2011

www.ma-rs.org

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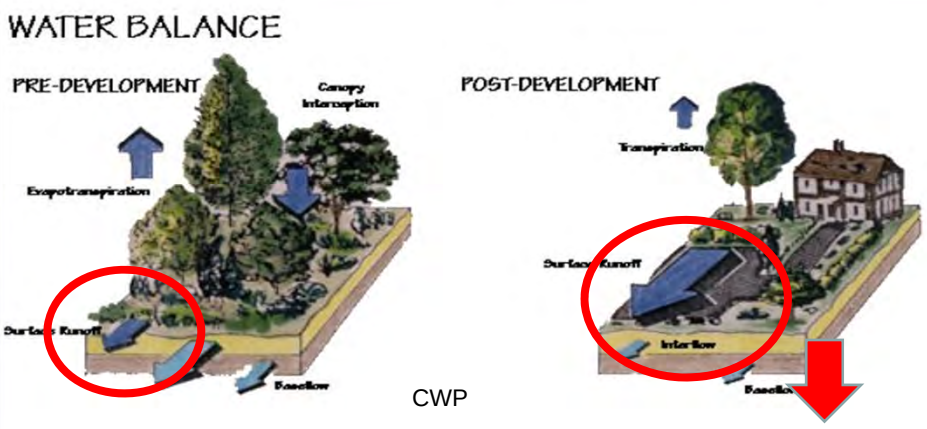
# Urban Water Cycle Impacts

- Increased runoff volume
- Water quality impacts
- EPA recognizing that quantity affects quality




CWP

# Experience in Dane County

1. Stormwater infiltration & groundwater recharge
2. Water performance standards based on local aquatic resources
3. Mitigating impacts of groundwater withdrawals
4. Need for integrated water management

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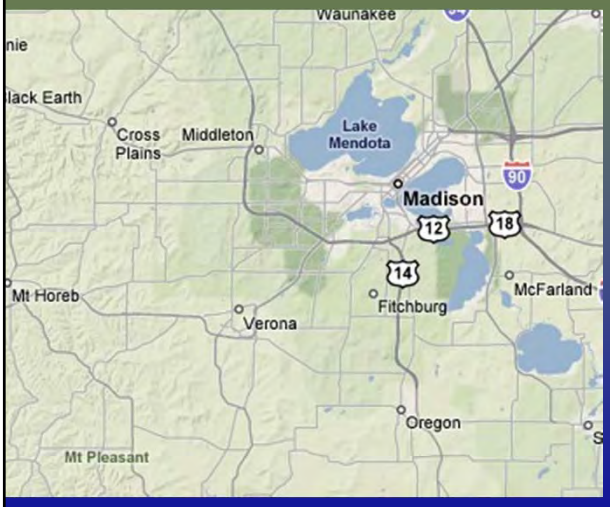
# Geographic Setting




- Agriculture surrounding urban area
- Rivers and lakes
- Strong state and local stormwater regulations
- Regional groundwater and surface water models available

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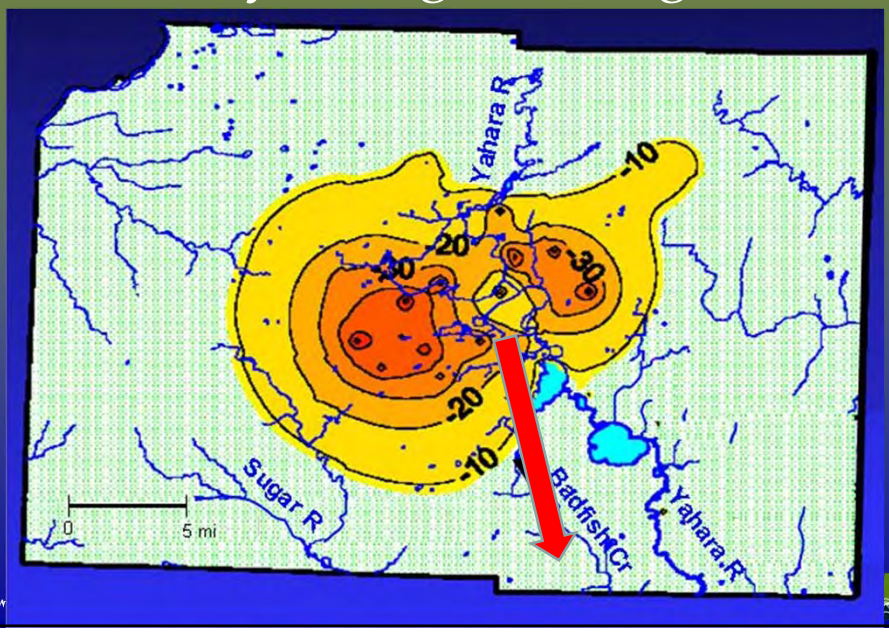
# Hydrologic Setting




# Regulatory Setting

- State: NR151
- Dane County: more stringent than NR151
- Municipal: stormwater flooding, LID emphasis
- Capitol Area Regional Planning Commission: pushing for zero increase in annual runoff volume

# (1) Infiltration and Groundwater Recharge

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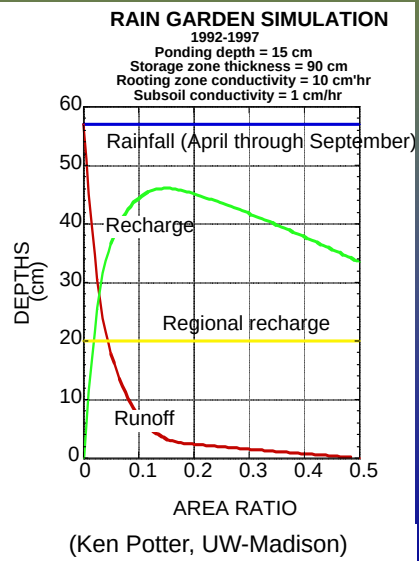
# Infiltration and Recharge




(Ken Potter, UW-Madison)

- Can produce recharge rates greater than pre-development
- Runoff declines with increasing rain garden size
- Recharge increases with rain garden size until evapotranspiration dominates

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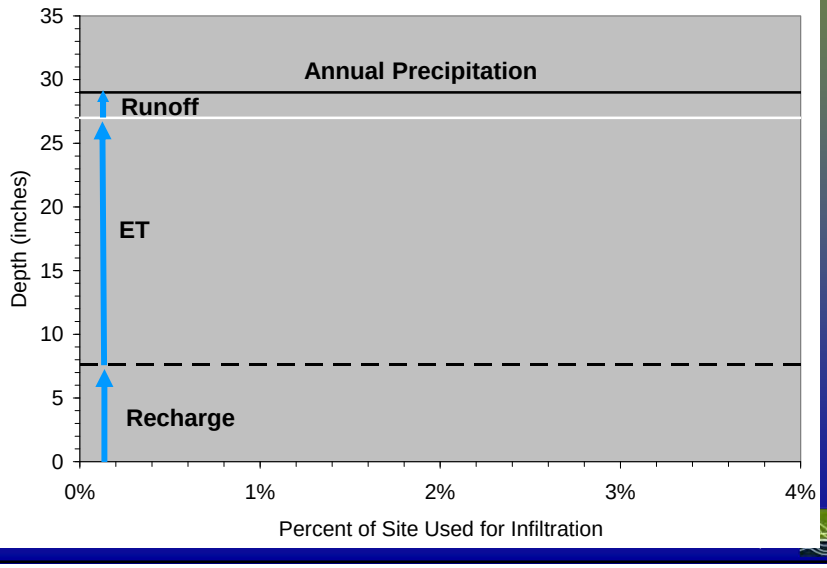
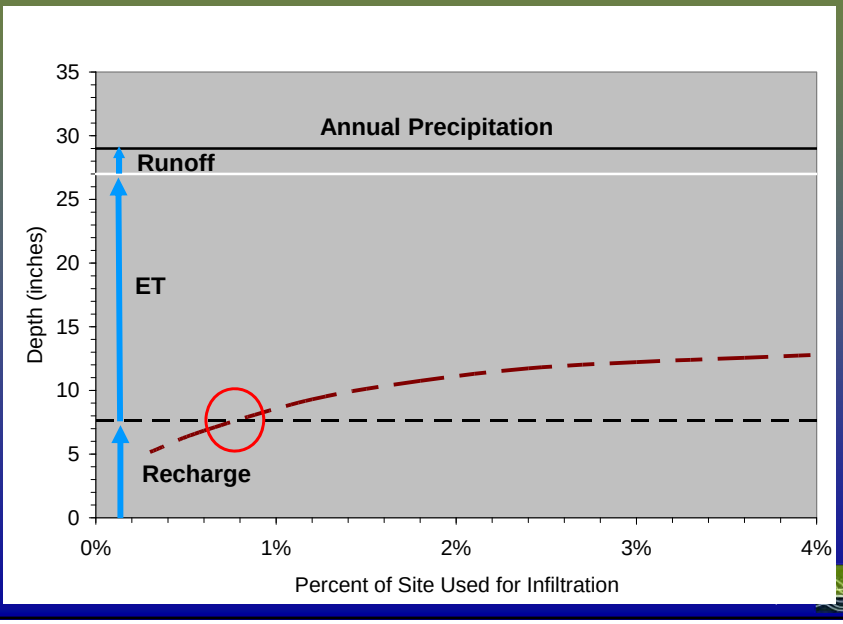
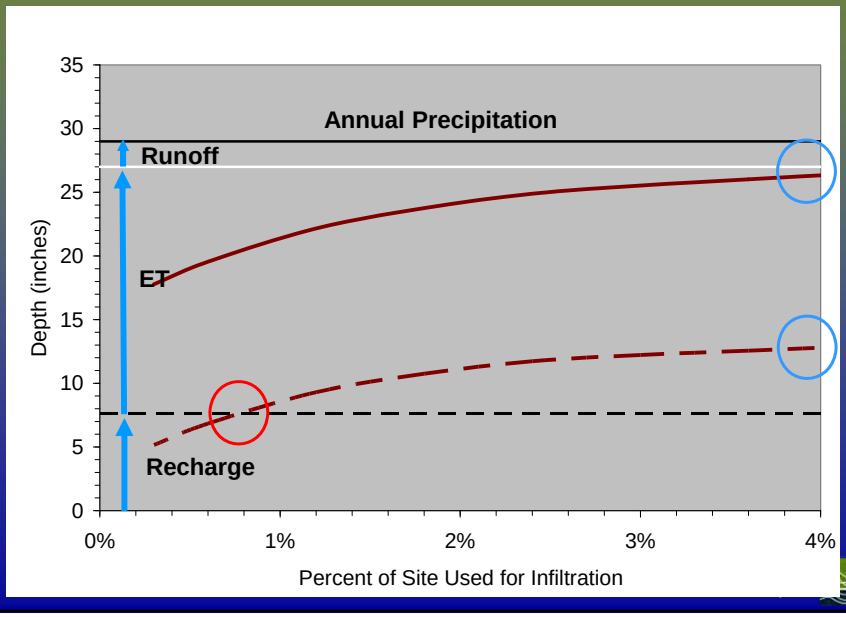
# Recharge vs. Runoff




# Recharge vs. Runoff



# Recharge vs. Runoff




# Pervious vs. Impervious Surfaces

| | Agricultural (e.g. row crops) | Impervious (e.g. parking lot) |
|---|---|---|
| Precipitation | 29 | 29 |
| Runoff | 4 | 21 |
| Recharge | 8 | 0 |
| Evapotranspiration | 17 | 8 |

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# Capabilities of Stormwater Infiltration

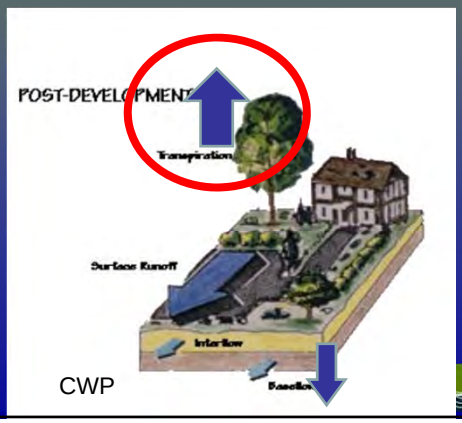
- Can maintain groundwater recharge
- Eliminating runoff volume increase requires more infiltration
  - Difficult to make up for ET loss
  - May not be feasible in some settings
  - May help compensate for groundwater withdrawals
  - May produce water table rise



# Making up for loss of plant evapotranspiration is important

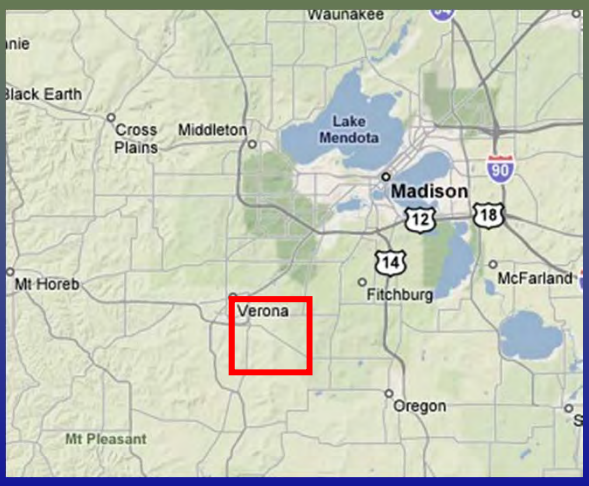
MMSD, Walnut Way Neighborhood

1. Harvest & reuse stormwater
2. Reduce impervious footprint




CWP

# (2) Resource – based hydrologic performance standards

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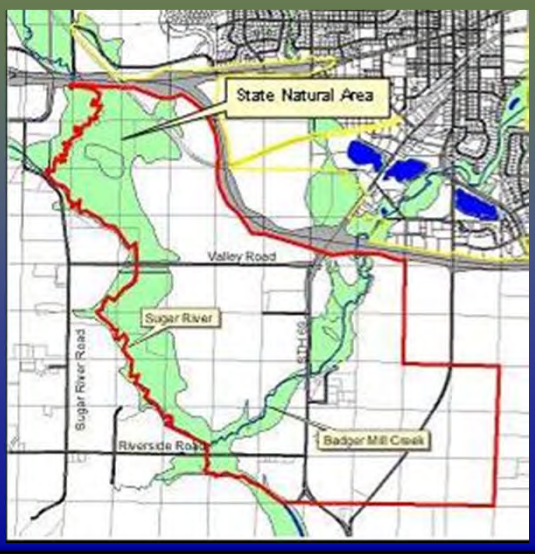
# Planning Study: Upper Sugar R. & Badger Mill Cr.




- Rolling terrain, trout streams and State Natural Area wetland
- Rapid urban growth
- Urban service area expansion required Regional Planning Commission approval

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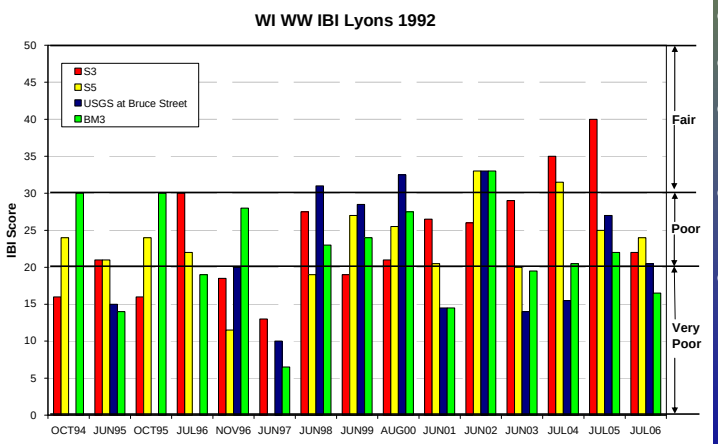
# Reviewed Lots of Existing Data




Madison Metro Sewerage District

- Trout
- Invertebrates
- Water quality
- Dissolved oxygen
- Sugar R in better condition

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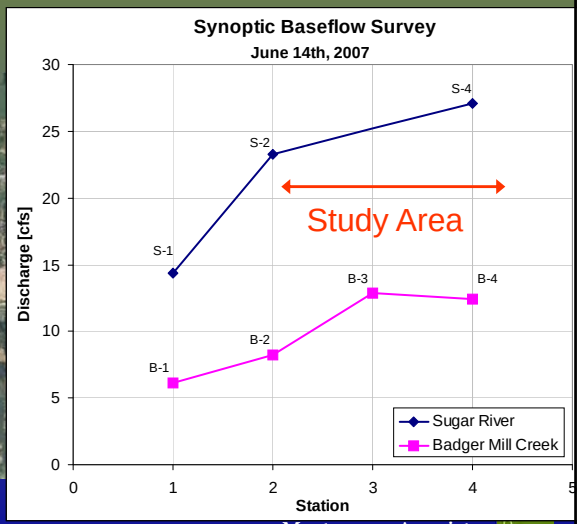
# Collected New Monitoring Data

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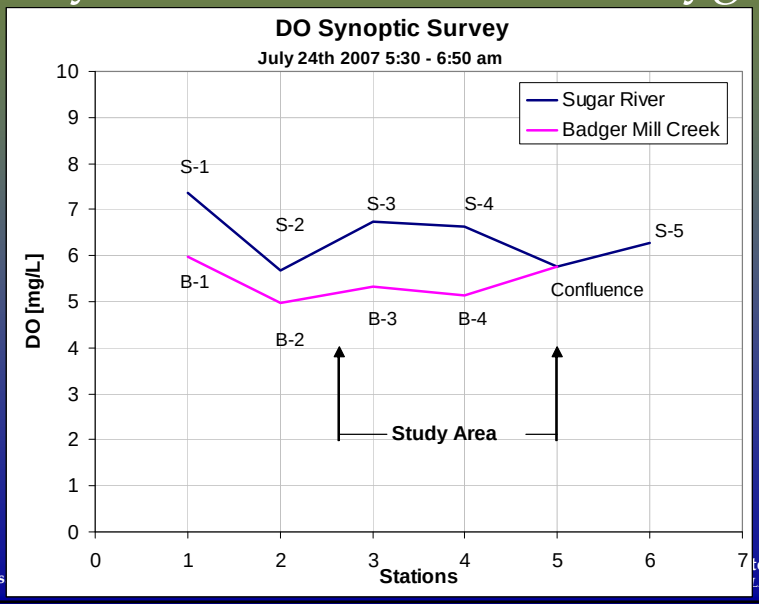
# Daily Minimum Dissolved Oxygen

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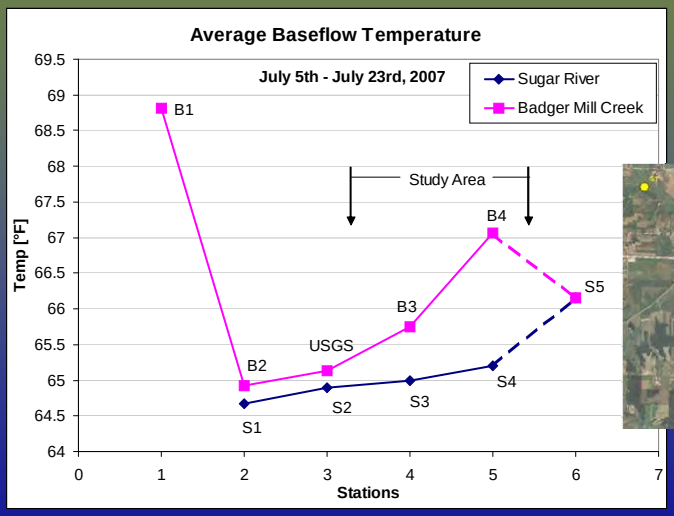
# Stream Temperature during Baseflow



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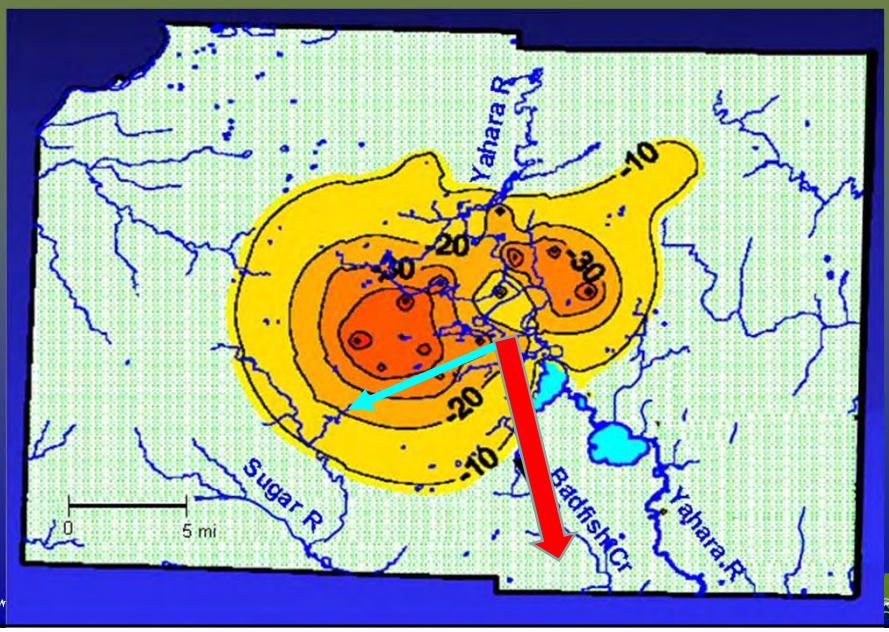
# Wastewater Effluent Return

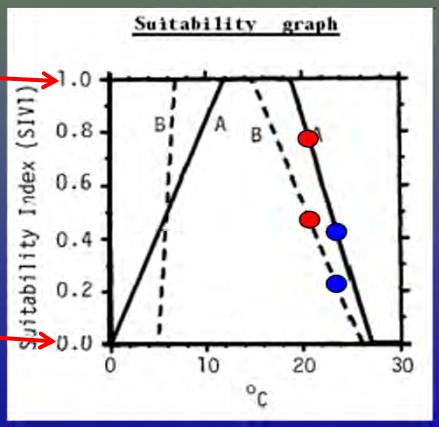



# Sensitivity: Brown Trout Habitat Suitability Index (USFWS)

Max Summer Water Temperature

Optimal

Unsuitable




A = Adults & Juveniles
B = Fry

Red = Sugar R.
Blue = Badger Mill

Summer temperature sensitivity → Maintaining recharge & baseflow important

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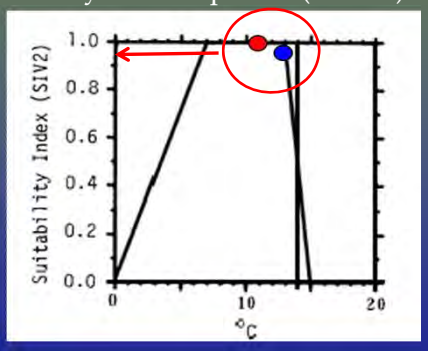
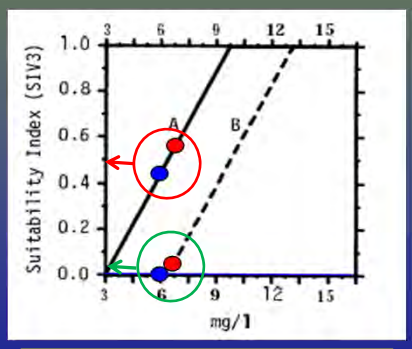
# Sensitivity: Brown Trout H.S.I.

Max temperature during embryo development (winter)




OK

Late season dissolved oxygen




Fair – poor → Baseflow & temperature issue

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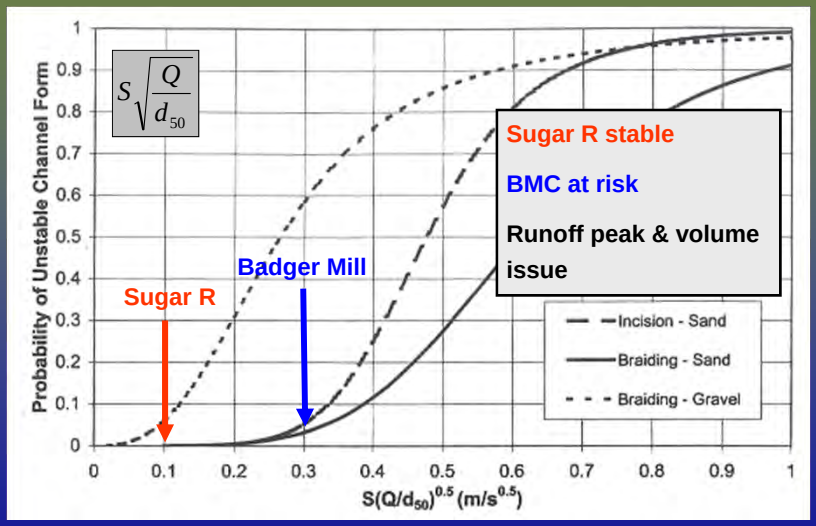
# Sensitivity: Stream Stability Index
(Bledsoe & Watson, 2001)




S = slope  Q = "channel forming discharge"  $d_{50}$ = median bed grainsize

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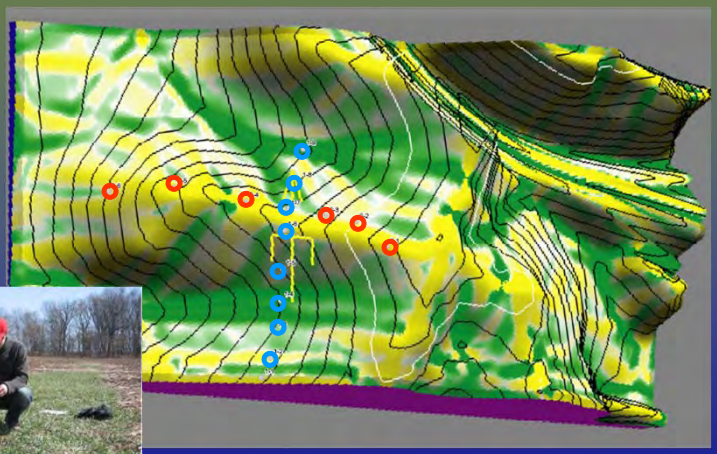
# Soil Depth vs. Landscape Position: Infiltration Potential



Natural Resources Consulting, Inc.
(now Stantec)

www.ma-rs.org

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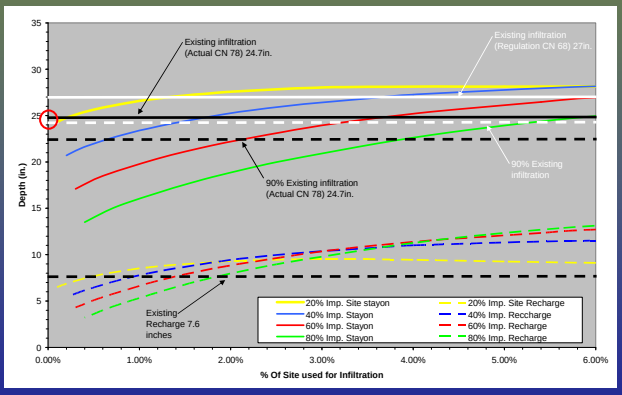
# Projected Infiltration Performance w/ RECARGA




- Feasibility of infiltration for different soil types?
- Impact of infiltration area caps?

Upland soils: 0.24 in/hr infiltration rate

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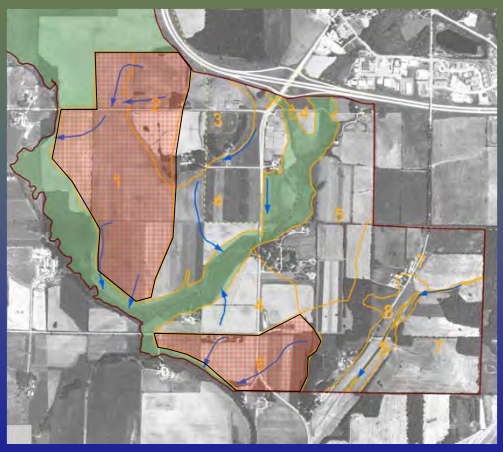
# Recommendations: Sugar River Watershed



Priorities

- Maintain groundwater recharge
- Direct runoff away from State Nat. Area

Proposed Infiltration Standard

- County ordinance +
- All sites must meet 7.6 in/yr recharge

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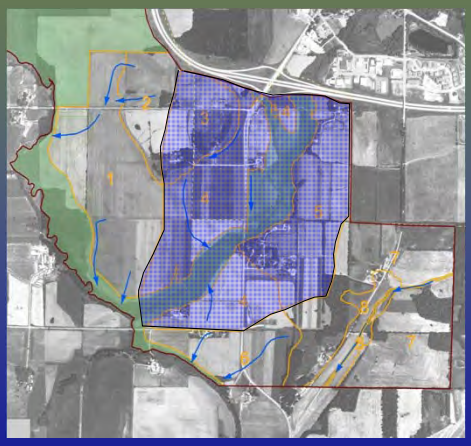
# Recommendations: Badger Mill Creek Watershed



Priorities

- Maintain recharge
- Minimize runoff volume increase

Proposed Infiltration Standard

- County ordinance +
- All sites meet 90% infiltration (w/ 2% cap)
- Provides greater runoff volume control

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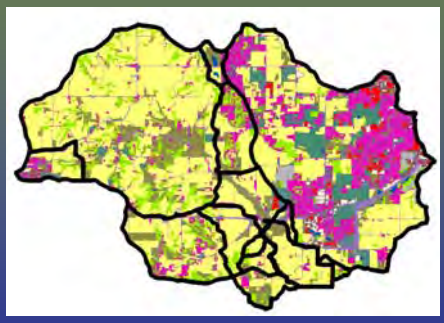
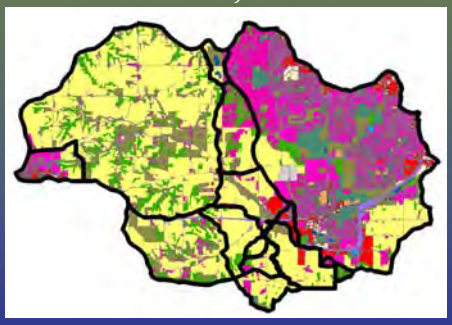
# Cumulative Impacts?

Current Land Use



2050 Projection



Sugar River: 1% runoff volume increase

Badger Mill Creek: 2% runoff volume increase

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# Results

- City viewed this as logical way to plan
- Complicated by larger land use debate
- Different standards for different watersheds not maintained by Regional Planning Commission
- Approval process continues

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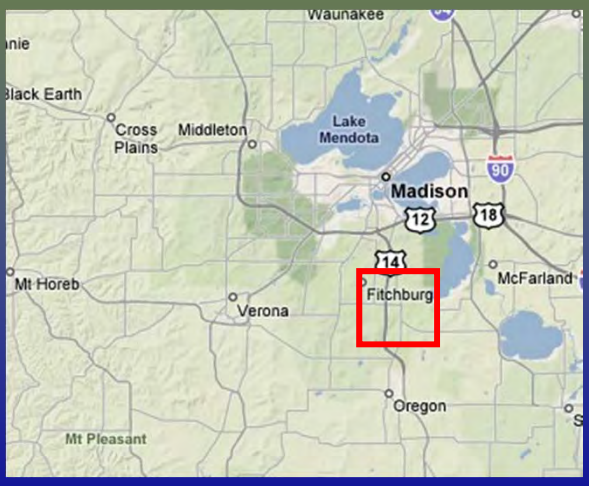
# (3) Mitigating Impacts of Groundwater Pumping

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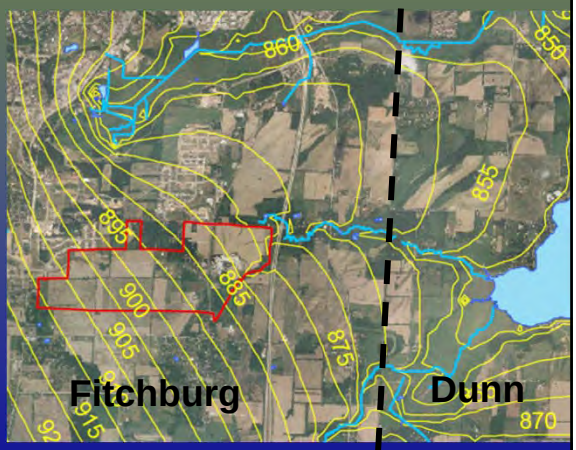
# Planning Fitchburg's McGaw Neighborhood

- Strong sustainability goals in Fitchburg
- Preservation mindset in Dunn
- Significant local streams, springs & wetlands

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# Pumping and Diversion Have Decreased Groundwater Flow to Springs, Streams and Lakes

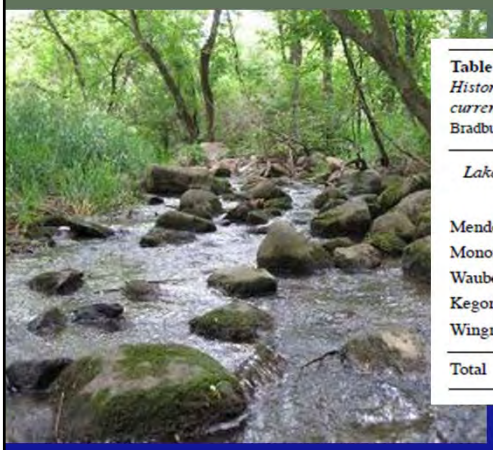

**Table 1.** Simulated groundwater inflow to the Madison Lakes. *Historic* flows represent a simulation with no groundwater pumping; *current* rates assume pumping at year 2002 pumping rates. Source: K. Bradbury, Wis. Geol. Nat. Hist. Survey.

| *Lake* | *Historic (cfs)* | *Current (cfs)* | *Change (cfs)* | *Pct Change* |
|---|---|---|---|---|
| Mendota | 23.9 | 4.4 | -19.5 | -82% |
| Monona | 8.7 | -1.5 | -10.2 | -117% |
| Waubesa | 10.3 | 6.5 | -3.8 | -37% |
| Kegonsa | 10.2 | 8.8 | -1.4 | -14% |
| Wingra | 3.3 | 1.2 | -2.1 | -64% |
| Total | 56.4 | 19.4 | -37.0 | -66% |

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# Sustainability Goals

- Smart location and linkage (30 points)
  - Transit service, wetland and waterbody conservation, floodplain avoidance
- Neighborhood pattern and design (39 points)
  - Compact, mixed-use development
- Green construction & technology (31 points)
  - Building & landscaping water efficiency, stormwater management, wastewater management
- Innovation and design process (6 points)

PILOT VERSION
LEED for Neighborhood Development Rating System

Developed through a partnership of the Congress for New Urbanism, Natural Resources Defense Council and the U.S. Green Building Council

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# Future Neighborhood Water Demand and New Wells

Projected demand = 15 -20% increase city-wide.

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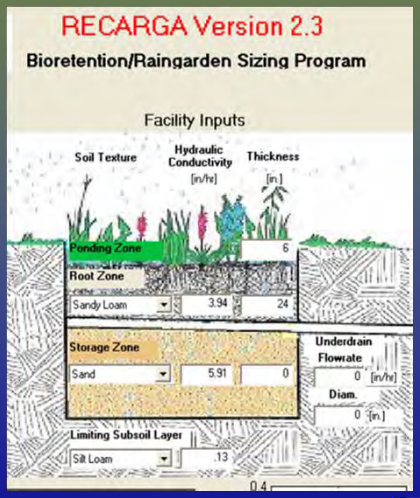
# Stormwater Infiltration to Enhance Groundwater Recharge

- Neighborhood average recharge rate increase of 2 in/yr possible
- Slight water table rise near adjacent neighborhoods (caused some concern)

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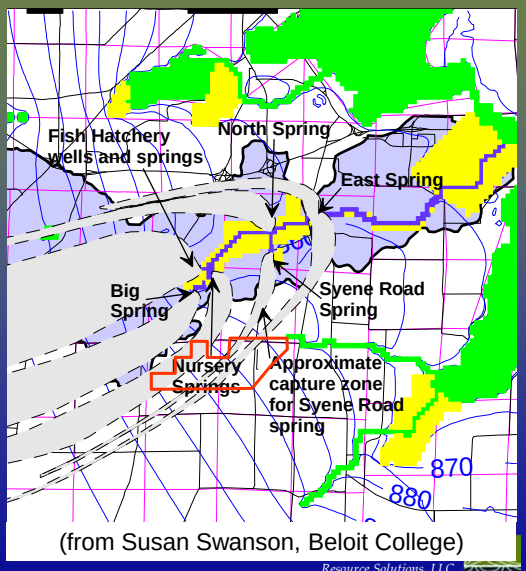
## Simulation of Pumping and Infiltration

- Existing groundwater model available
- Infiltration partially compensates for pumping impacts (1-5% flow decrease)
- Benefits smaller farther away – not putting water back into aquifer where it's being withdrawn




(from Susan Swanson, Beloit College)

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## Result: Water Resource Considerations included in Neighborhood Plan

- Water supply pumping impacts defined
- Strategies to promote recharge and reduce water use
- Even aggressive plan has trouble fully offsetting pumping impacts

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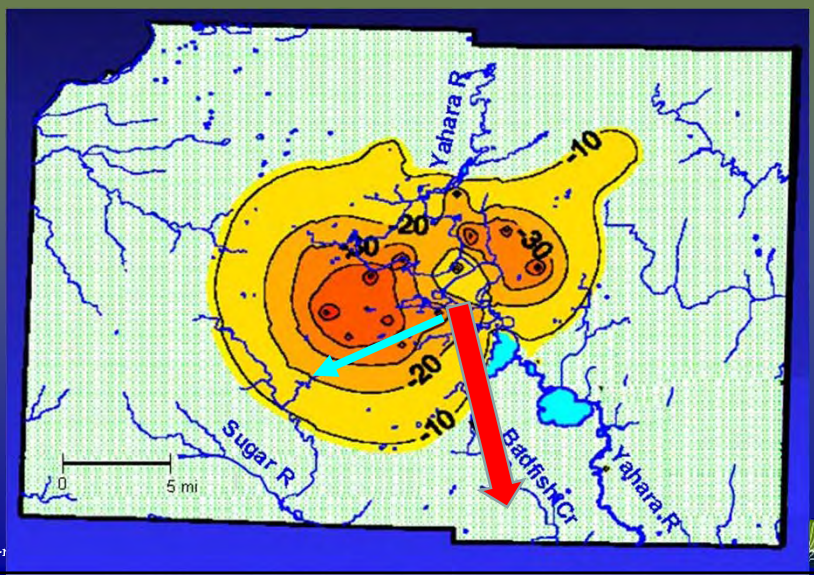
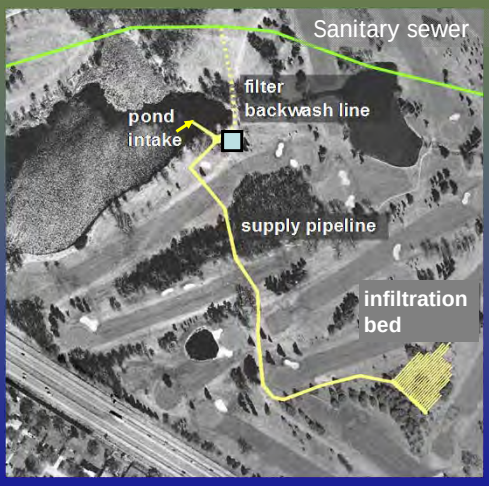
# (4) Need for Integrated Water Management




www.ma-r

# Odana Hills Recharge System

- Built by MG&E and UW-Madison
- Draws stormwater from pond
- Filters water
- Pumps to subsurface infiltration bed
- Recharges ~50 million gallons per year to groundwater

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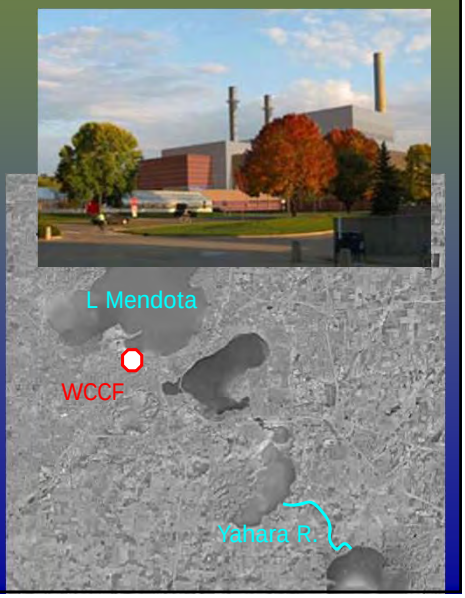
# Why was it built?

- Concern about groundwater decline & low-flow impacts in Yahara River
- Mitigation for West Campus Cogeneration Facility's consumptive use of Lake Mendota water
- Required by WDNR permit

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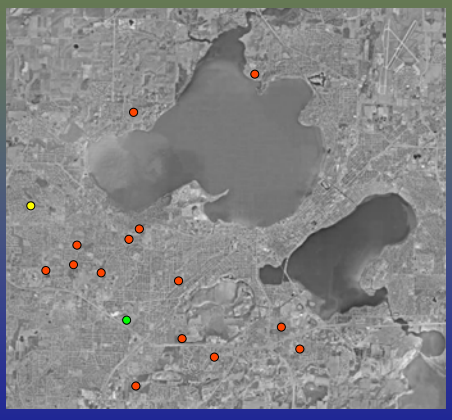
# Why at Odana Hills?



Some of the locations considered.

- Large pond to store stormwater
- Large watershed with high runoff volume
- Away from public water supply wells
- Diverts stormwater from Lake Wingra
- Available land
- Suitable geology

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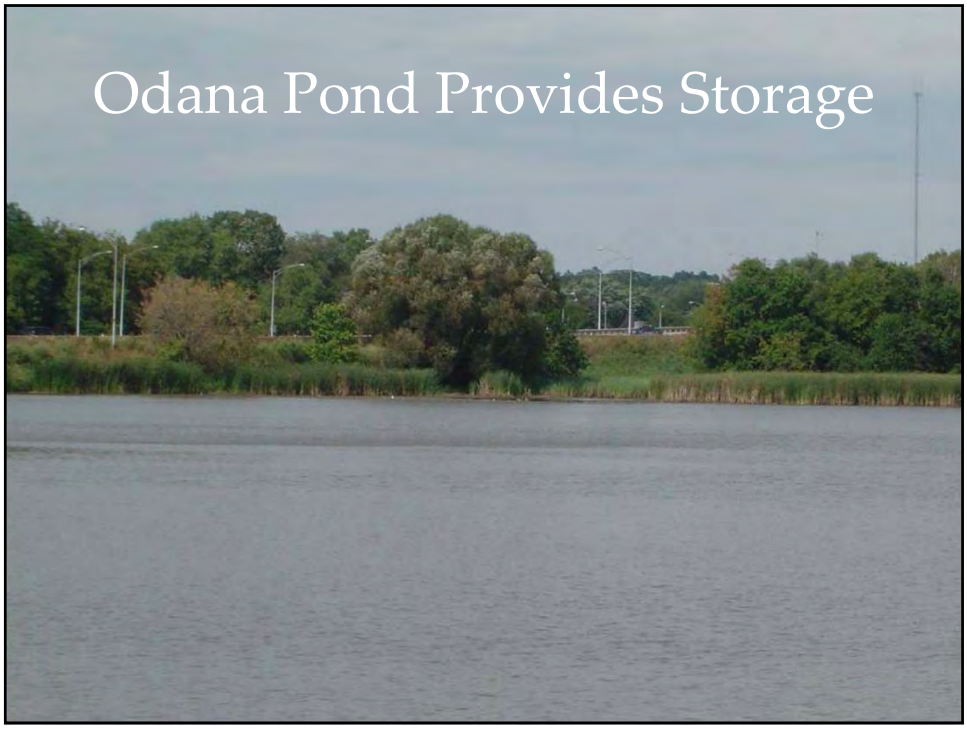
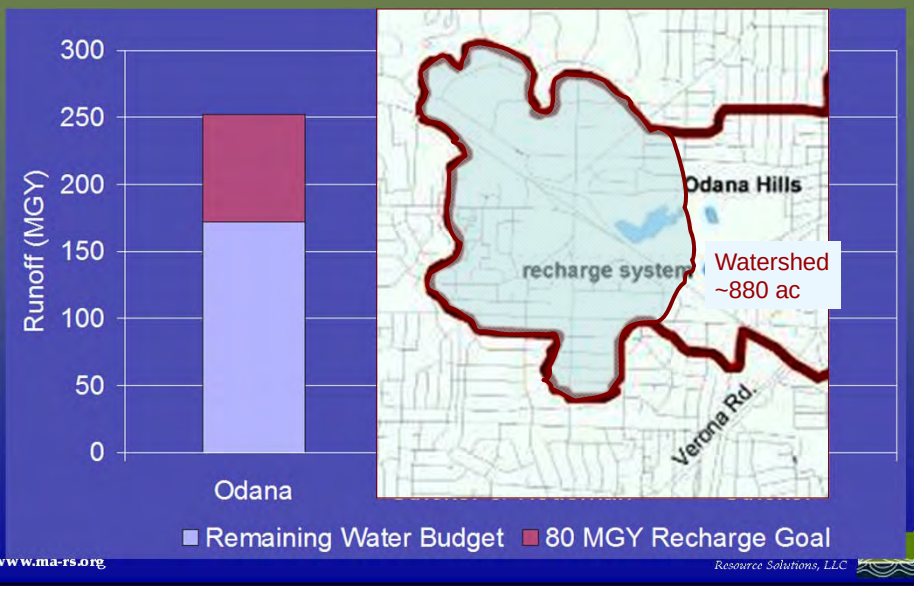
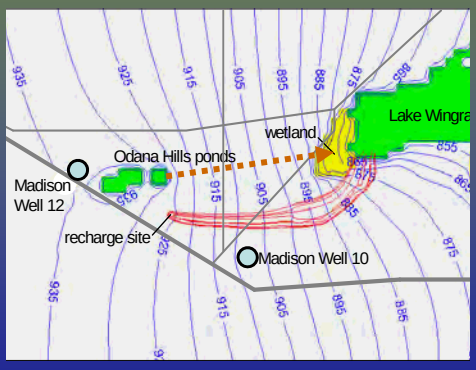
# Odana Pond Provides Storage



# Recharge Goal vs. Available Runoff



# Where does the water go?




(Model from Swanson, 2000)

- Odana pond delivers rapid pulses of stormwater to Lake Wingra via storm sewers
- Groundwater model predicts gradual flow to Lake Wingra over several decades
- Recharged water not in predicted well capture zones

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# Pond Intake

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# Filters

- Microfiltration (0.1 µm) removes sediment that could clog recharge bed & particulate pollutants.
- Backwash discharged to sanitary sewer.

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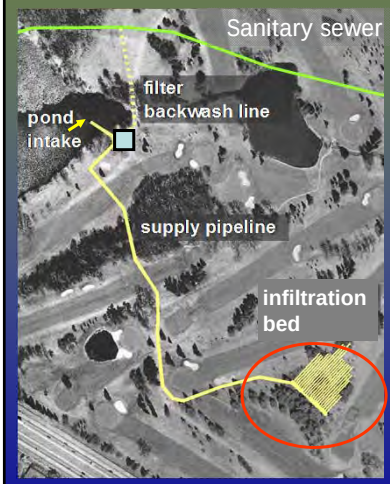
# Recharge Bed in Golf Course Rough




Excavation ~ 10 ft deep

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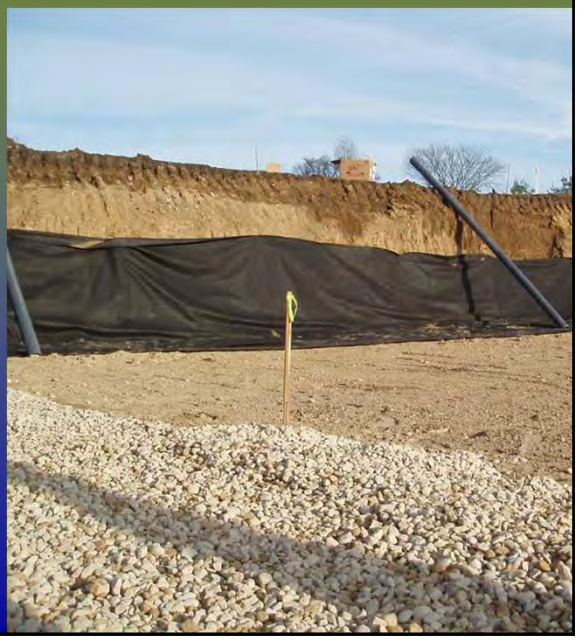
# Recharge Bed

- Clear stone
- Distribution piping
- Observation wells



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# Recharge Volumes: 2007-2009

| | Flow, million gallons / year | | |
|---|---|---|---|
| Year | Pumped from Pond | Filtrate recharged | Backwash to sewer |
| 2007 | 60 | 55 | 5 |
| 2008 | 79 | 71 | 8 |
| 2009 | 67 | 60 | 7 |
| **Average** | **69** | **62** | **7** |

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# Groundwater Quality Monitoring

- Complex effects
- Chloride from road salt in pond & was already in groundwater
- Changing redox conditions can mobilize naturally occurring metals (e.g. Mn, As) – local effect

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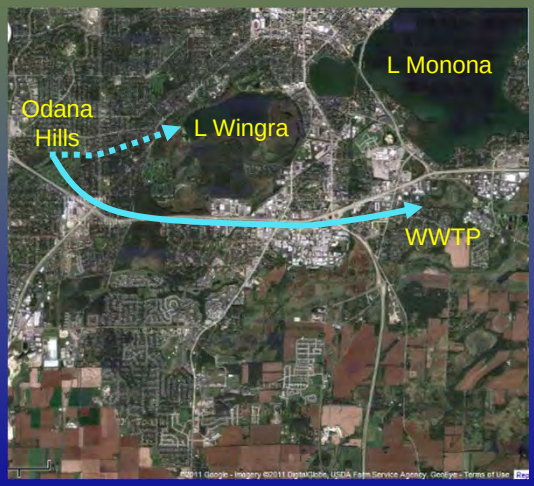
# Watershed Implications




- Recharge increase ~ 2 inches / year over Pond's watershed
- 30% or more phosphorous diverted from Lake Wingra (to WWTP)

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# Conclusions

1. Need multiple approaches for runoff volume reduction to compensate for loss of ET
2. Resource-based approach allows more logical & beneficial water management
3. Groundwater pumping impacts difficult to offset completely, but can help
4. Need to consider stormwater, drinking water and wastewater impacts

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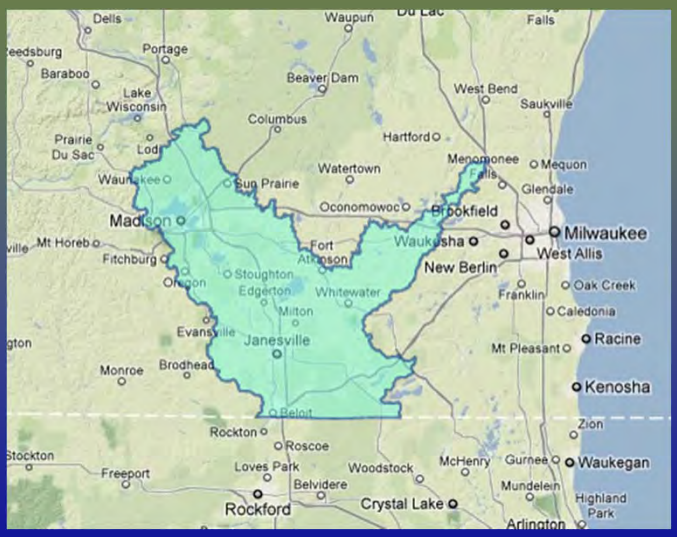
# Thank You

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