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

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

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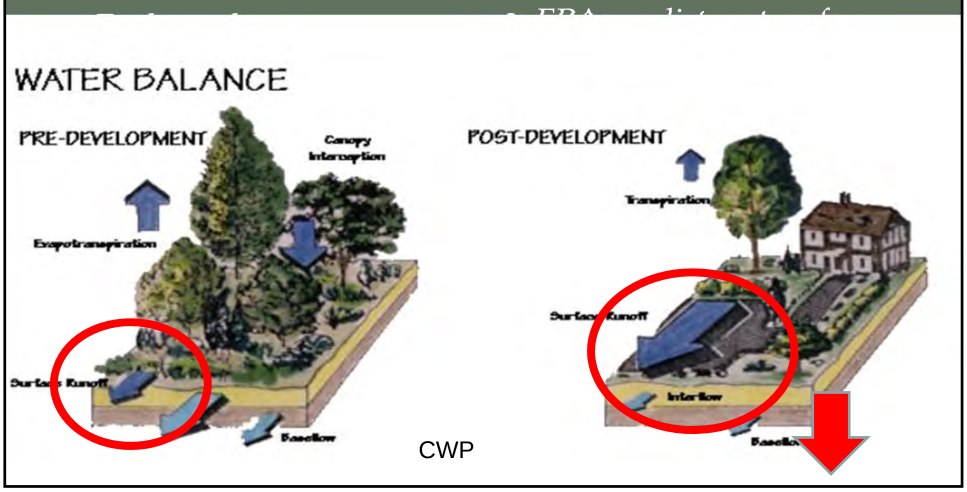
Urban Water Cycle Impacts

- Increased runoff volume
- Water quality impacts

- EPA recognizing that quantity affects quality



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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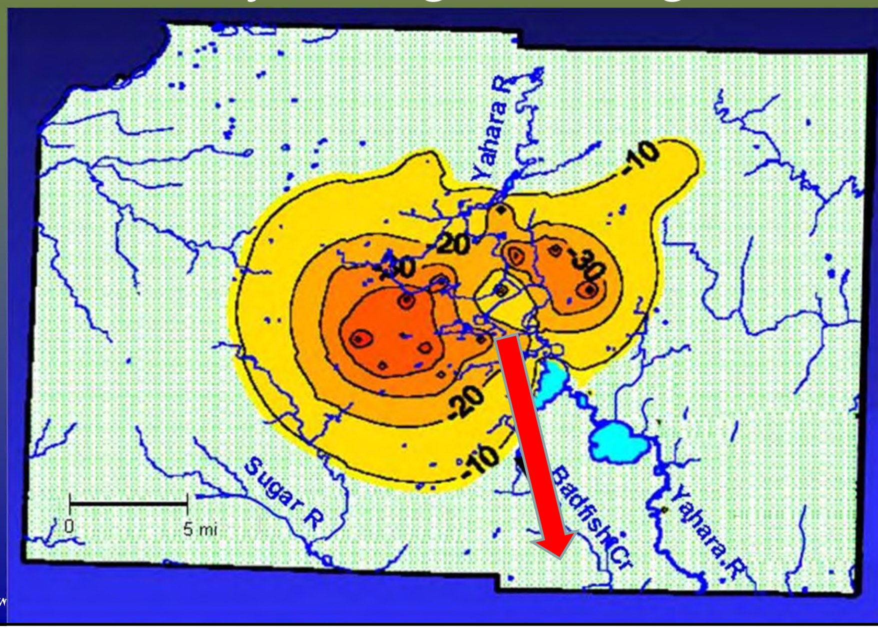
Hydrologic Setting

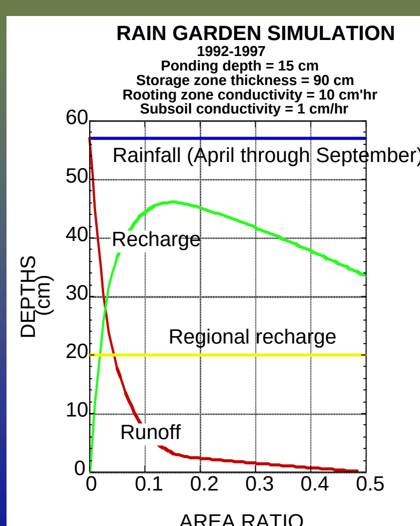


Regulatory Setting

- 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

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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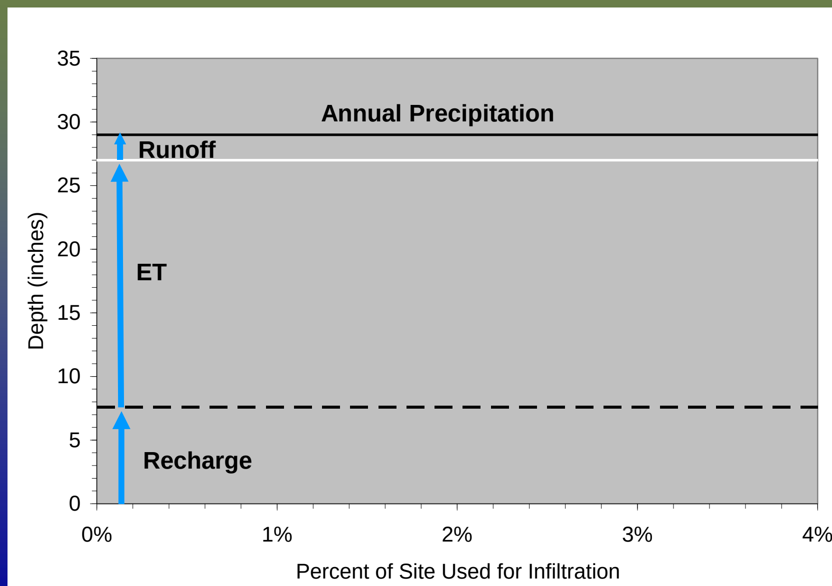
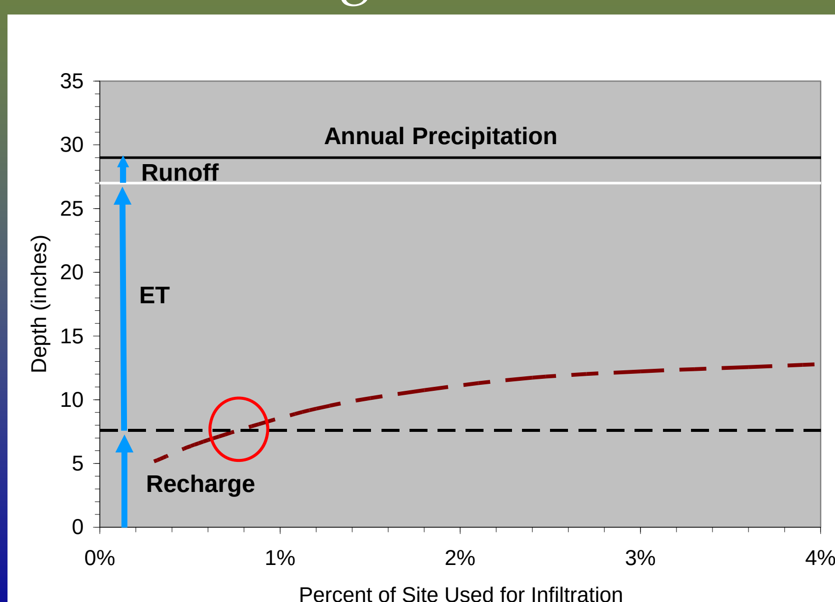
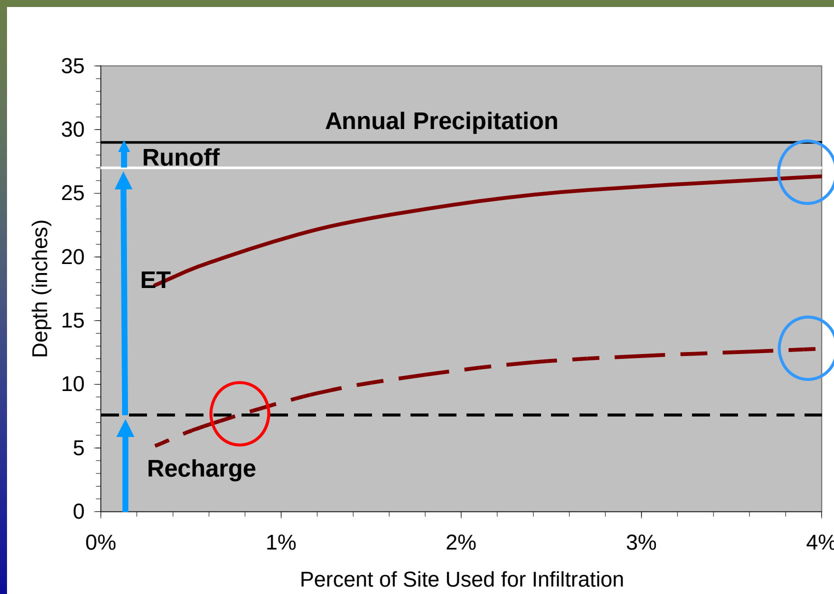
Recharge vs. Runoff



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

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

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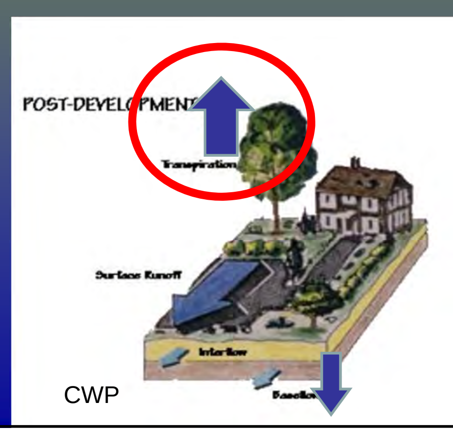
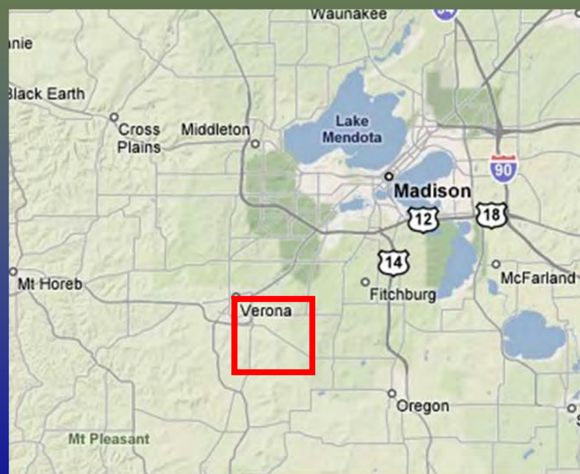
Making up for loss of plant evapotranspiration is important

1. Harvest & reuse stormwater
2. Reduce impervious footprint



(2) Resource – based hydrologic performance standards



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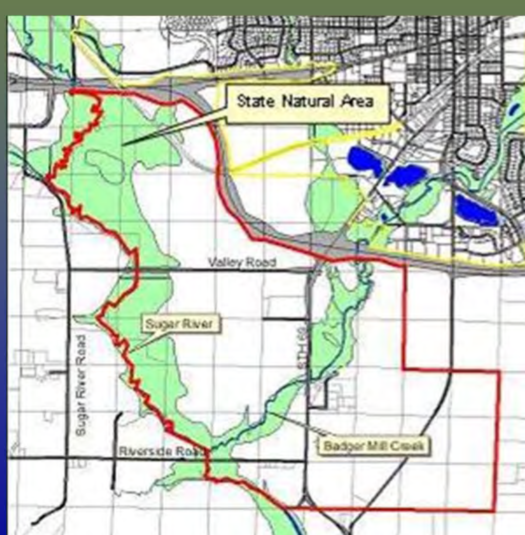
Planning Study: Upper Sugar R. & Badger Mill Cr.



- 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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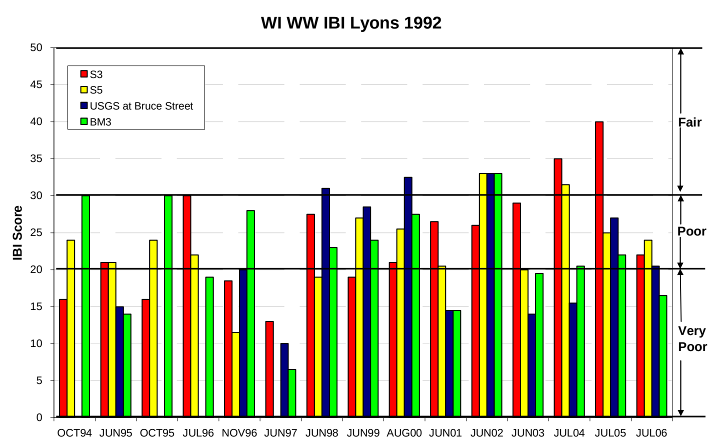
Reviewed Lots of Existing Data



Madison Metro Sewerage District

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

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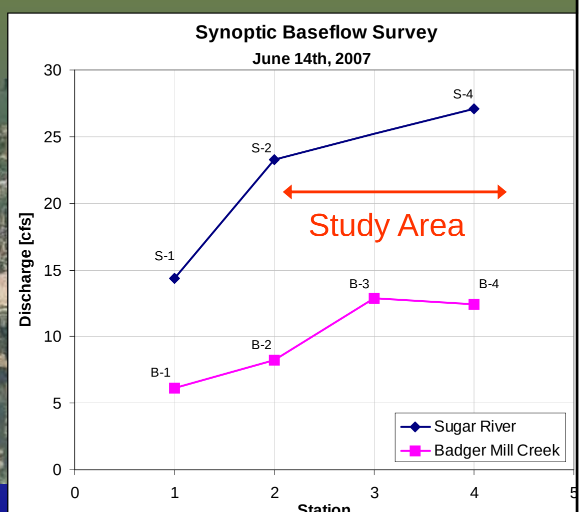
Collected New Monitoring Data



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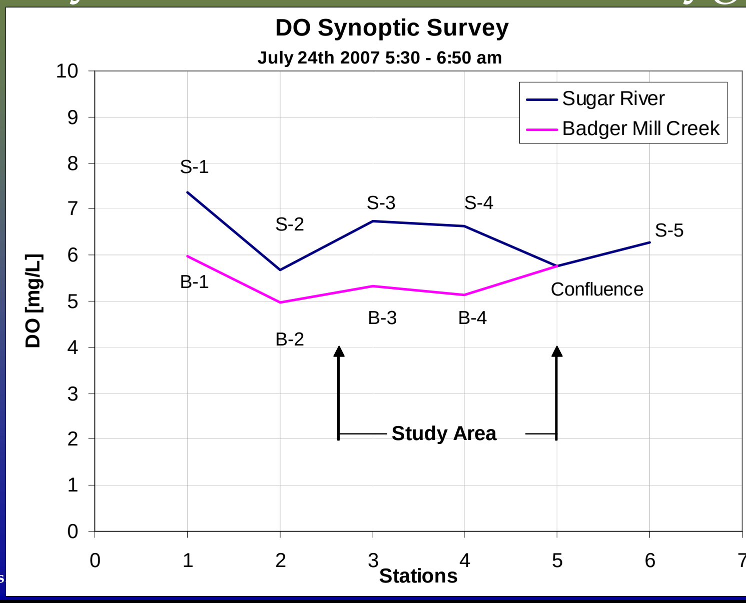
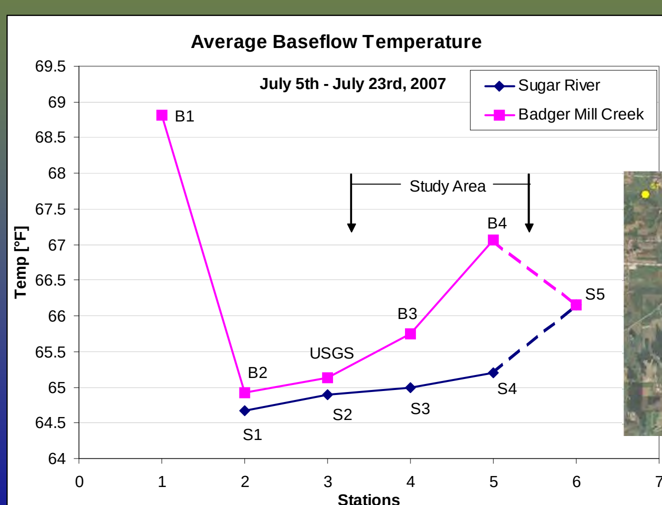
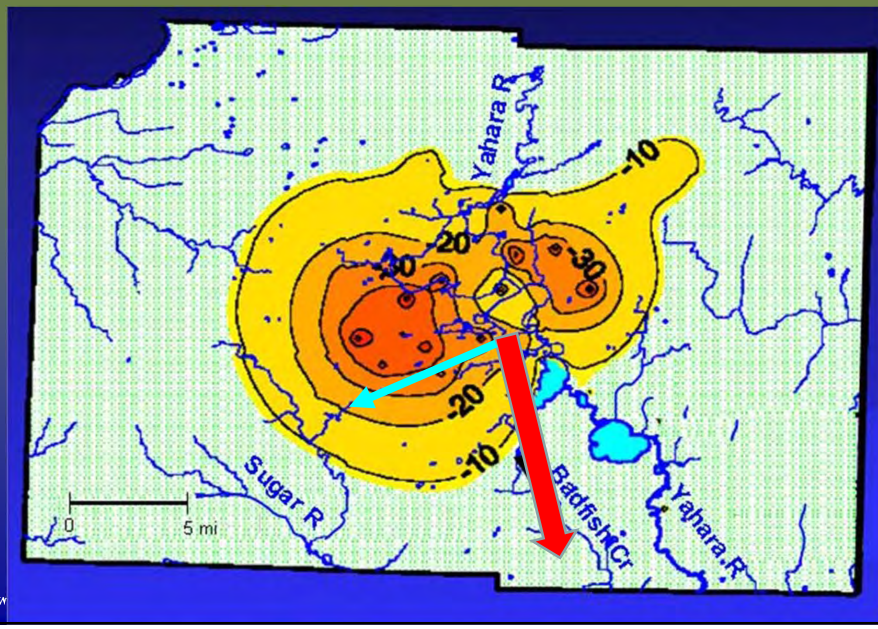
Daily Minimum Dissolved Oxygen



Stream Temperature during Baseflow



Wastewater Effluent Return

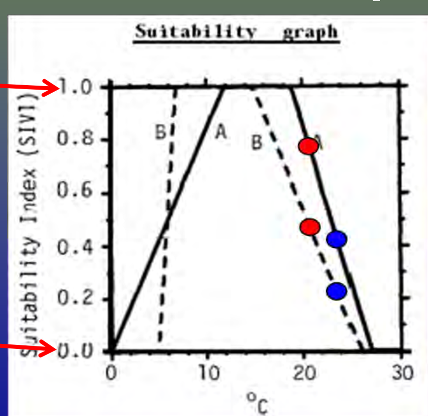


Sensitivity: Brown Trout Habitat Suitability Index (USFWS)

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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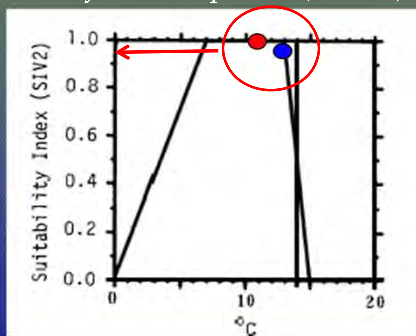
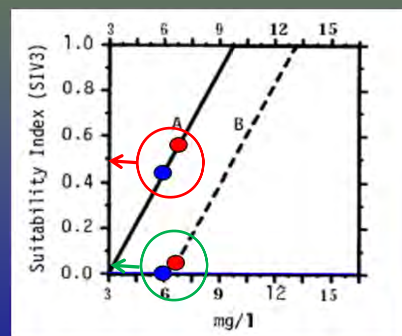
Sensitivity: Brown Trout H.S.I.

Max temperature during embryo development (winter)



Late season dissolved oxygen



OK

Fair – poor → Baseflow & temperature issue

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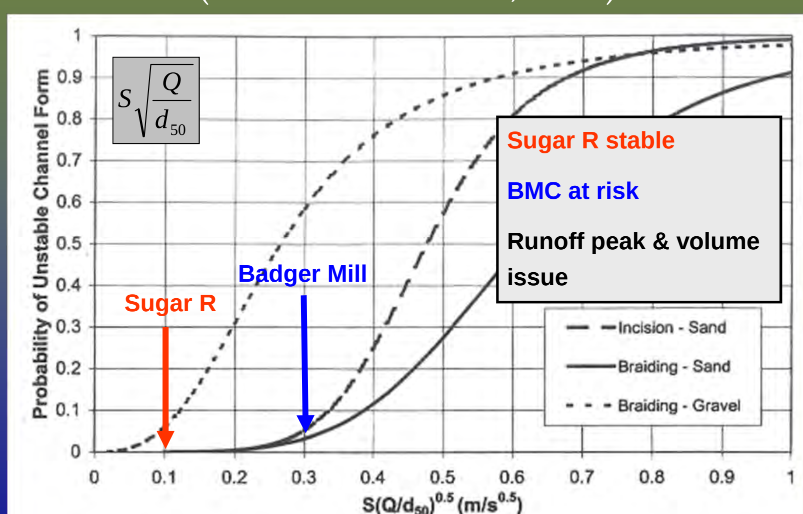
Sensitivity: Stream Stability Index

(Bledsoe & Watson, 2001)



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

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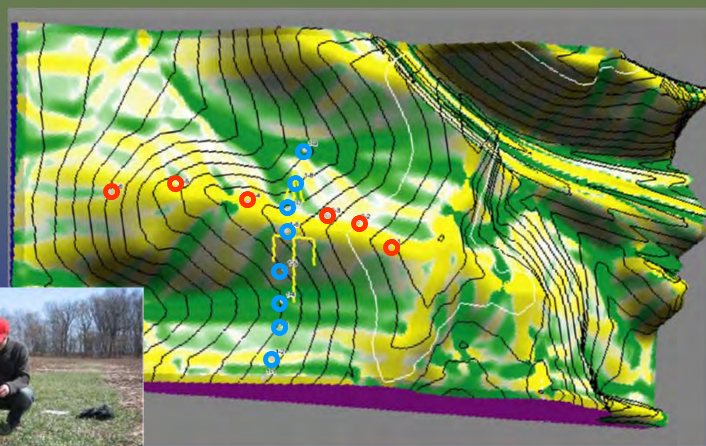
Soil Depth vs. Landscape Position: Infiltration Potential



Natural Resources Consulting, Inc.
(now Stantec)

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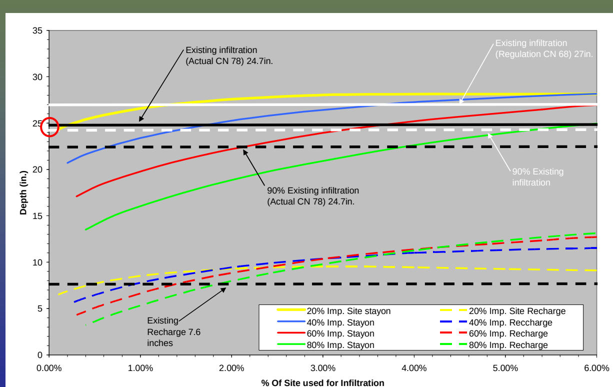
Projected Infiltration Performance w/ RECARGA



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

Upland soils: 0.24 in/hr infiltration rate

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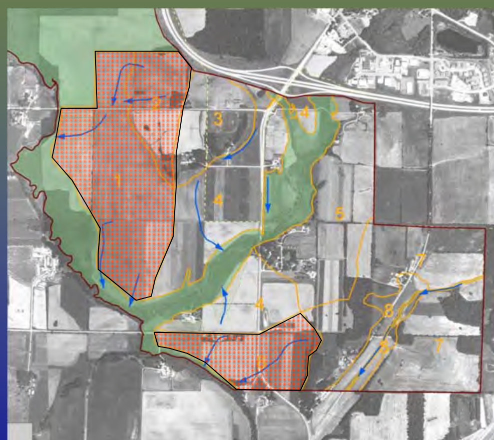
Recommendations:
Sugar River Watershed



<u>Priorities</u>

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

<u>Proposed Infiltration Standard</u>

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

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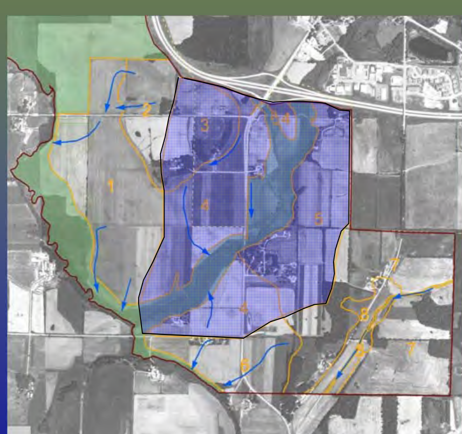
Recommendations:
Badger Mill Creek Watershed



<u>Priorities</u>

- Maintain recharge
- Minimize runoff volume increase

<u>Proposed Infiltration Standard</u>

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

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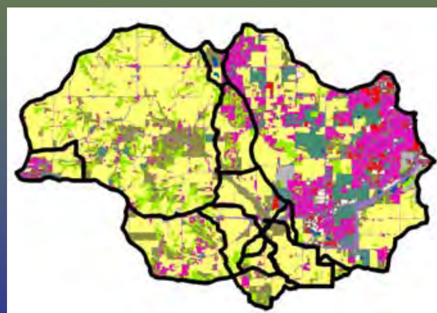
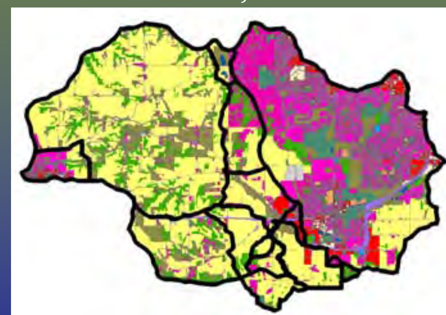
Cumulative Impacts?

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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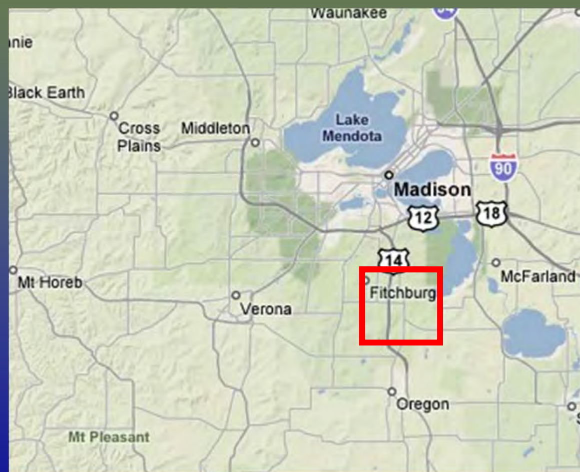
(3) Mitigating Impacts of Groundwater Pumping



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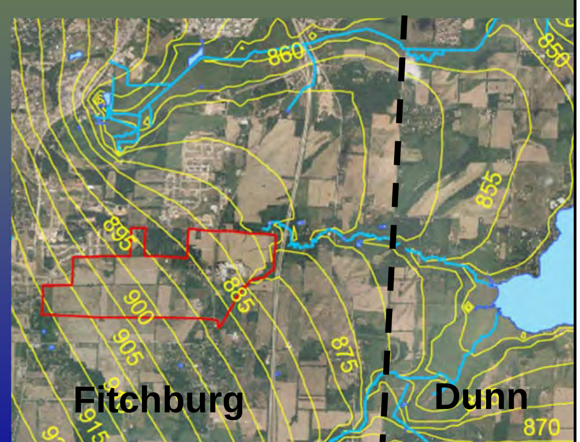
Planning Fitchburg's McGaw Neighborhood

- 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

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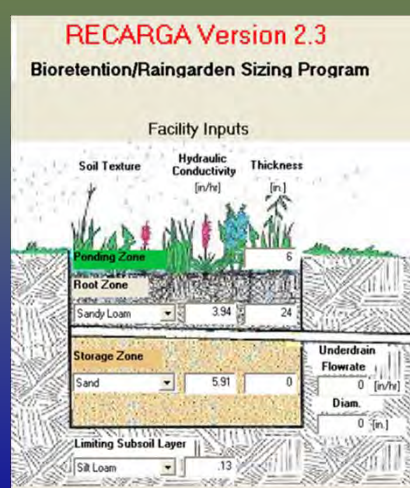
Future Neighborhood Water Demand and New Wells

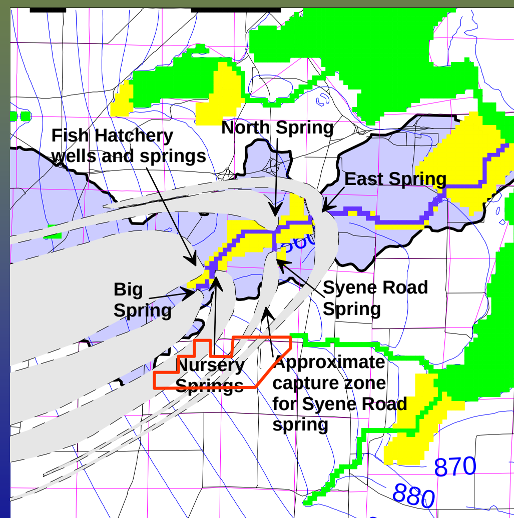
Stormwater Infiltration to Enhance Groundwater Recharge

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



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

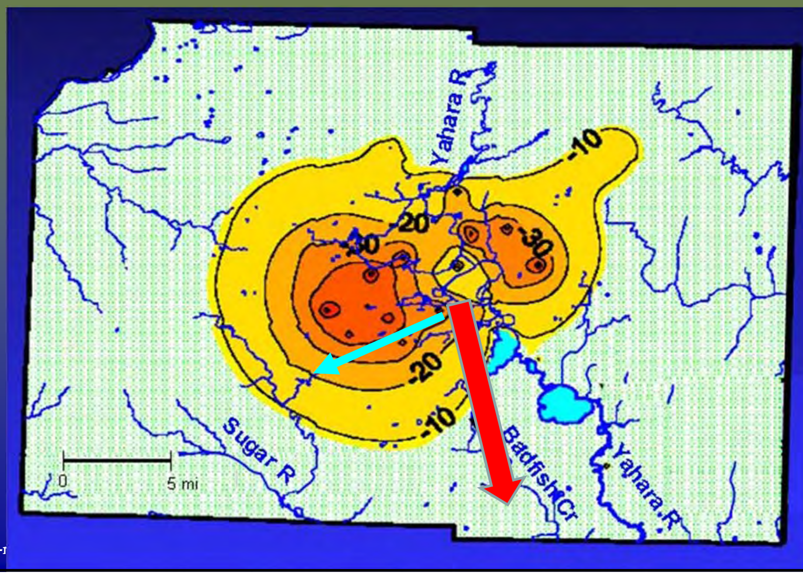


(from Susan Swanson, Beloit College)

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

(4) Need for Integrated Water Management

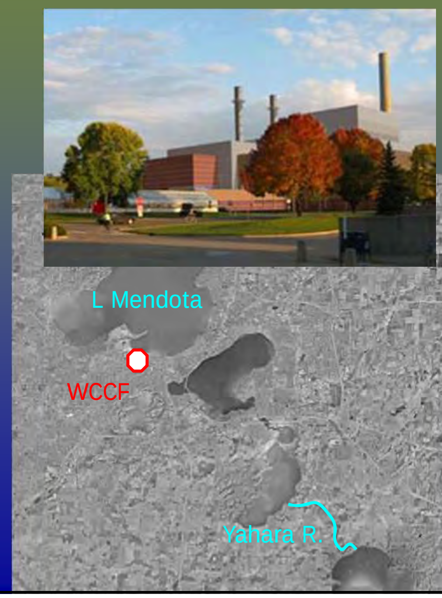


Odana Hills Recharge System

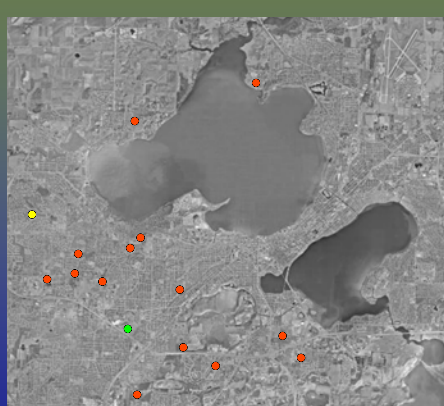
- Built by MG&E and UW-Madison
- Draws stormwater from pond
- Filters water
- Pumps to subsurface infiltration bed
- Recharges ~50 million gallons per year to groundwater

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



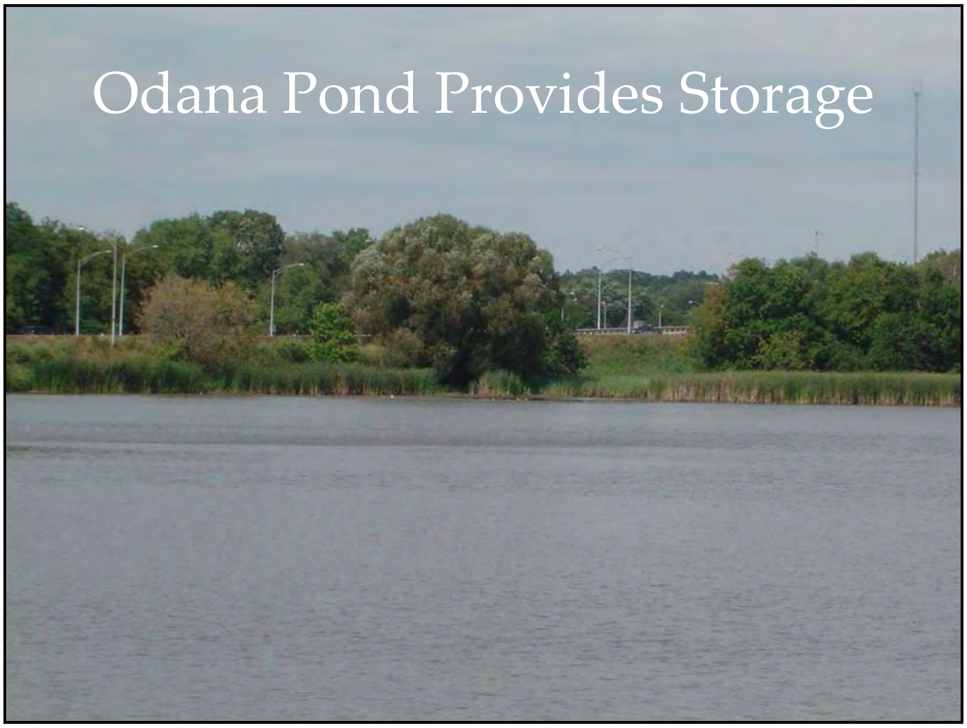
Why at Odana Hills?



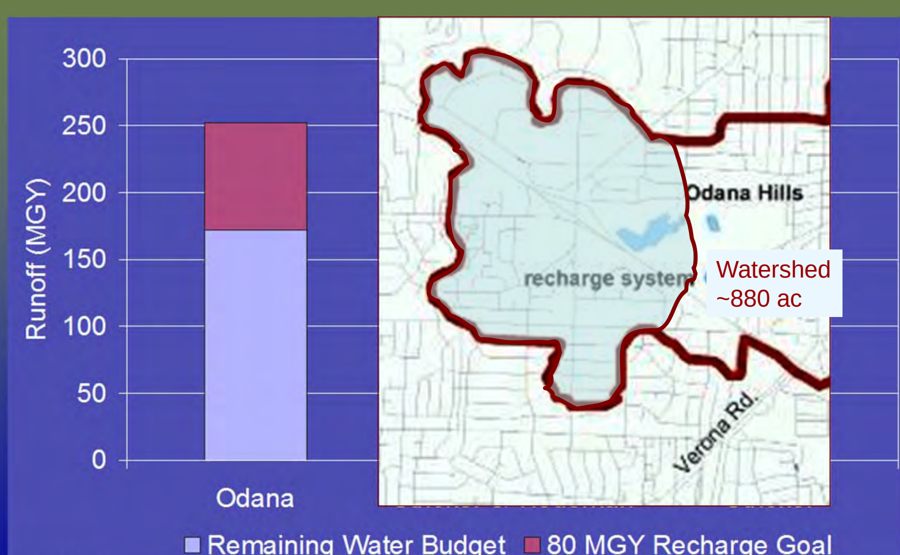
Some of the locations considered.

- 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

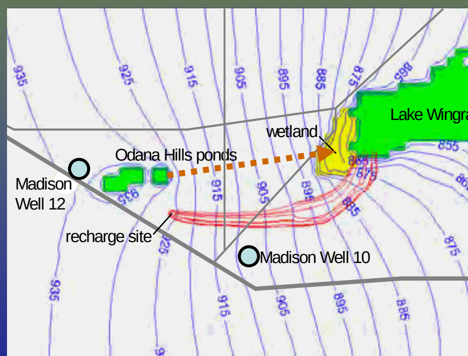
Odana Pond Provides Storage



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

Pond Intake

Filters

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

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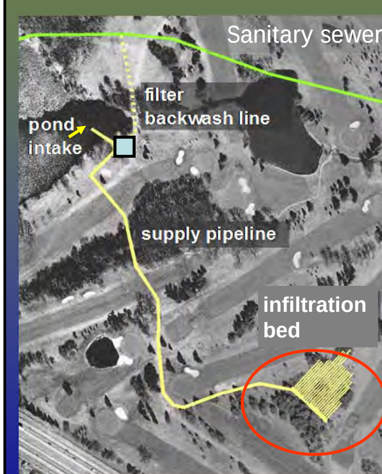
Recharge Bed in Golf Course Rough



Excavation ~ 10 ft deep

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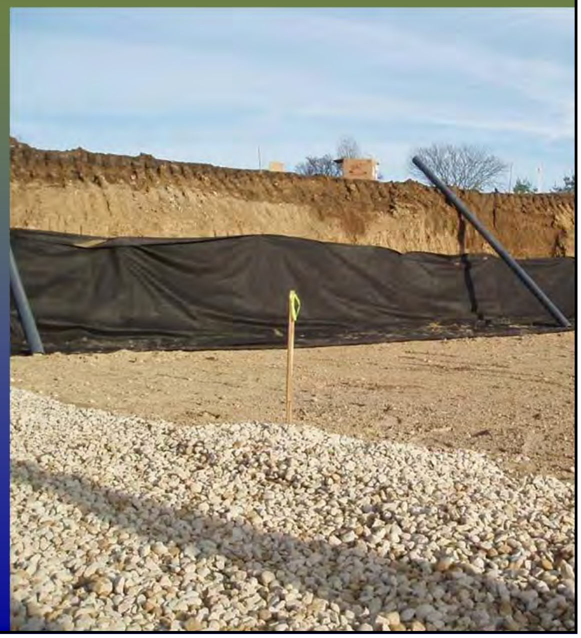
Recharge Bed

- 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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