Sustainability?
Think “Negative Entropy”

John Milne, P.E.

John.Milne@clark.wa.gov

ENTROPY-BASED RESOURCE MANAGEMENT

An Organizing Principle for developing sustainability strategies

1. Concept
2. Examples
3. The future……

ENTROPY-BASED *WATERSHED* MANAGEMENT

"Instead of engineered facilities, why don't you use holistic, watershed-based methods that *"mimic natural processes?"*

Agree…….*but what exactly does that mean???*

“MIMIC NATURAL PROCESSES”

Natural processes always act to minimize energy loss at all times and leave all resources in a *state of minimum entropy* after each process has been completed

The resource is always maintained in its highest, most ordered state, at the highest energy level possible

“Entropy-based watershed management”

A holistic, watershed-based strategy that mimics natural processes.

ENTROPY-BASED WATERSHED MANAGEMENT NATURAL EXAMPLES

SNOWPACK

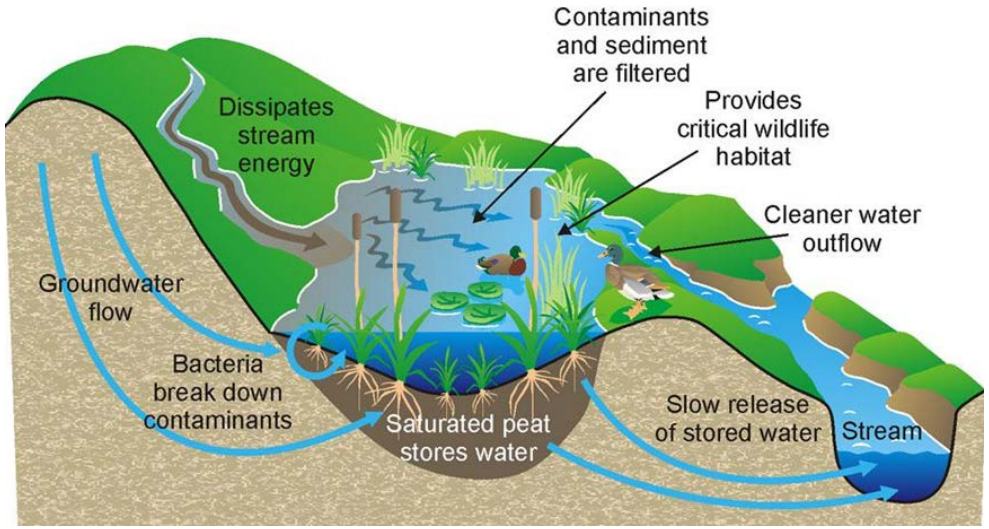
Water in solid phase at the highest potential energy possible.

….next best thing??

HIGH GROUNDWATER

Water in liquid phase at the highest potential energy possible.

"Pump up the groundwater as high as possible (then plant everything)"



Some considerations…..

"Top-down watershed management"

Why "Organizing Principle?"

How can we use this?

TOP-DOWN WATERSHED MANAGEMENT
“A TALE OF TWO WHISKIES….”

WHY "ORGANIZING PRINCIPLE?"

"Physical laws work the same today as they did yesterday"

"Physical laws work the same here as they do over there"

For these to be true:

- Physics is perfect
- Natural systems are very efficient, and perfectly reliable

A valuable piece of knowledge – let's put it to use *right away!*

HOW CAN WE USE THIS?

Using natural processes and working in a "top-down" sequence allows us to move forward quickly on sustainability initiatives :

- Accuracy is sufficient to make *reasonable policy decisions*
- Only need *"apples to apples"* comparisons
- Go quickly to a *reasonable* solution to a *known problem*

HOW CAN WE USE THIS?

Also, the organizing principle:

- Brings separate sustainability initiatives together in a holistic strategy
- Establishes “order”, not only on the molecular scale, but also in all other management, planning and regulatory operations

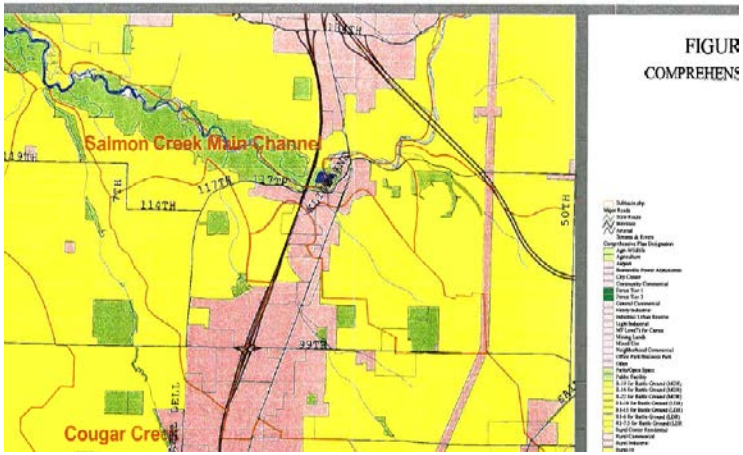
Can be thought of as a “back to basics” approach to sustainability.

ENTROPY-BASED WATERSHED MANAGEMENT EXAMPLES

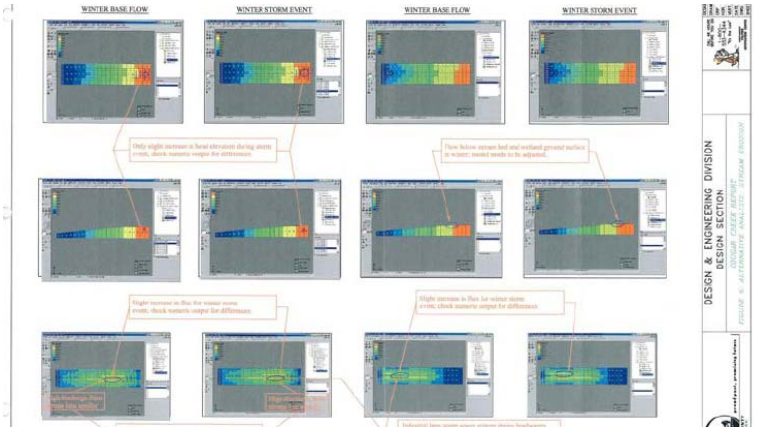
- Sustainable Land Use Plan
- LID on a watershed scale
- Hydrologic Accounting and the 2008-2011 SCIP
- Sub-basin retrofit plans
- Offsite stormwater mitigation as watershed rehabilitation
- Groundwater Recharge *and Discharge*

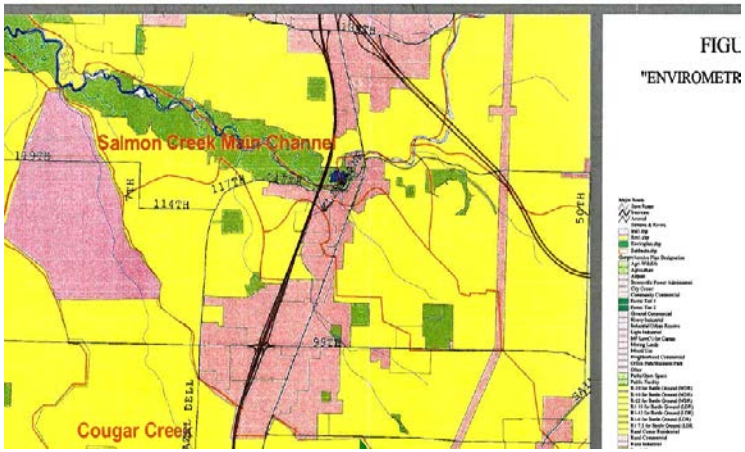
SUSTAINABLE LAND USE PLAN

1. Current Land Use Plan

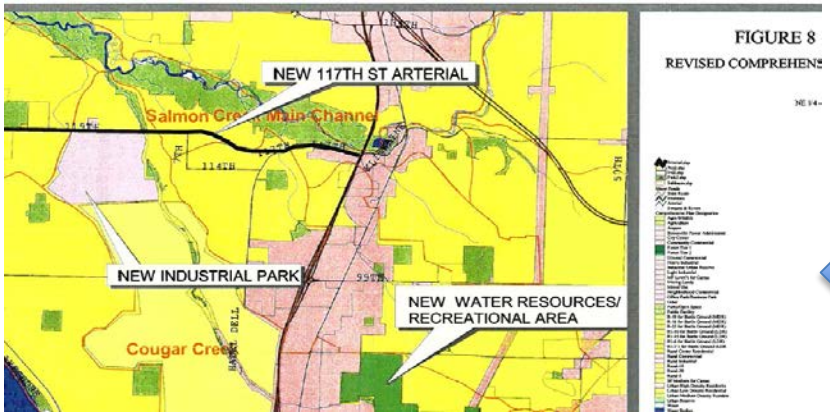


2. Use GW model to determine the optimal land use arrangement



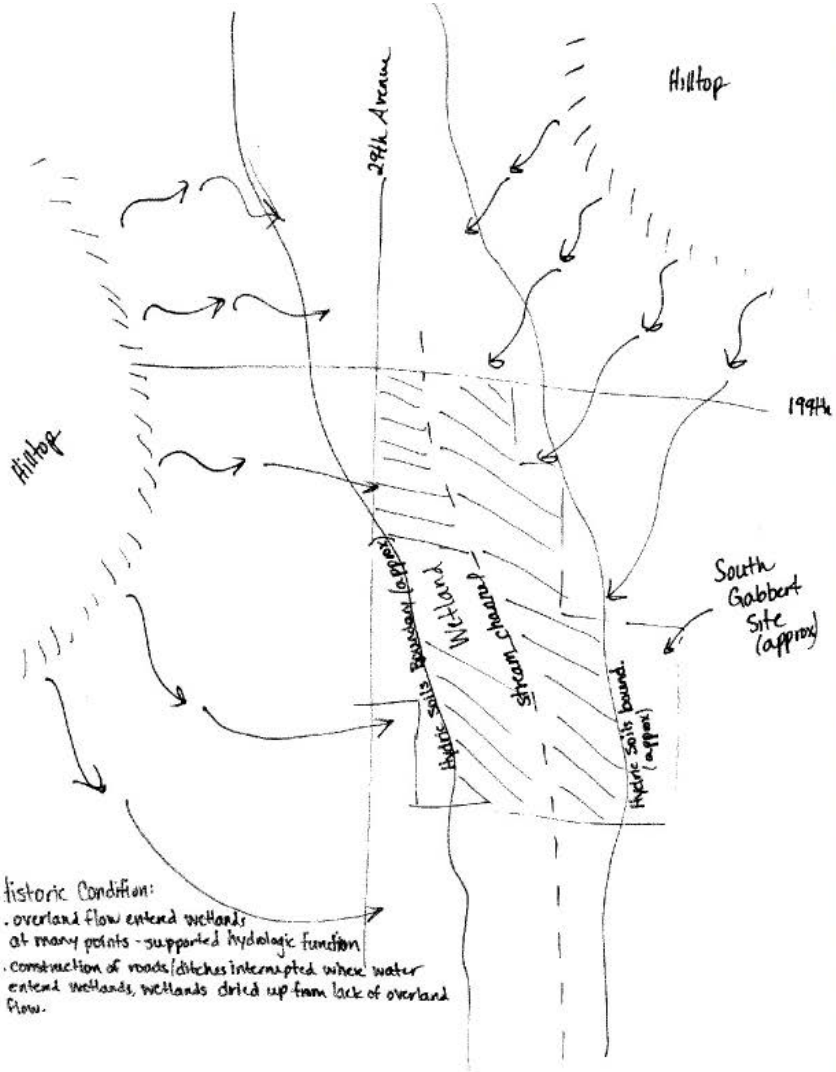


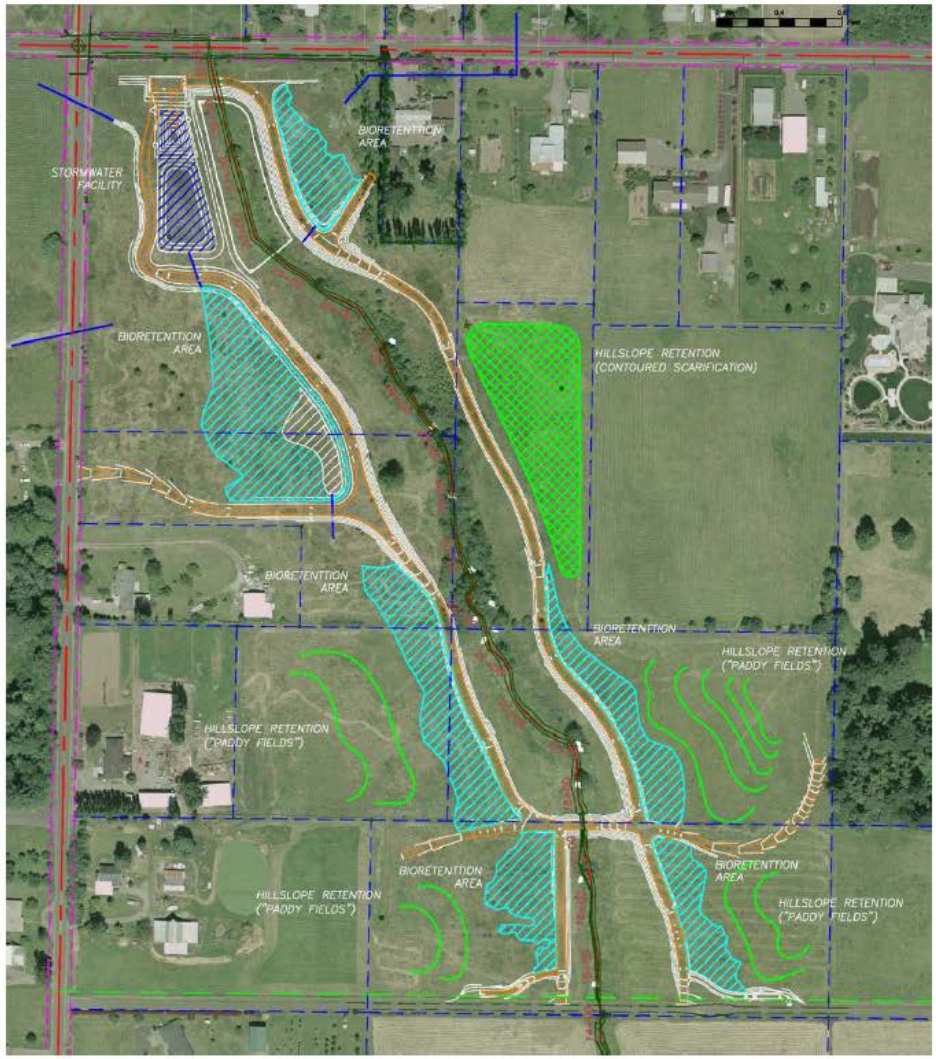
3. "Envirometric" land use plan



4. Finalized plan

"LID ON A WATERSHED SCALE"
WEST MILL CREEK HEADWATERS ENHANCEMENT PROJECT





HYDROLOGIC ACCOUNTING AND THE 2008-2011 SCIP

"Hydrologic Accounting" was used to:

- Determine the cost-effectiveness of projects
- Select and prioritize capital projects
- Evaluate alternative designs

…….and quickly move projects forward into construction.

SUB-BASIN RETROFIT PLAN

1. Use Watershed Sensitivity/Impact mapping to identify priority sub-basins

2. Use “Top-down BMP selection” to identify the most cost-effective infiltration BMP at every possible retrofit location

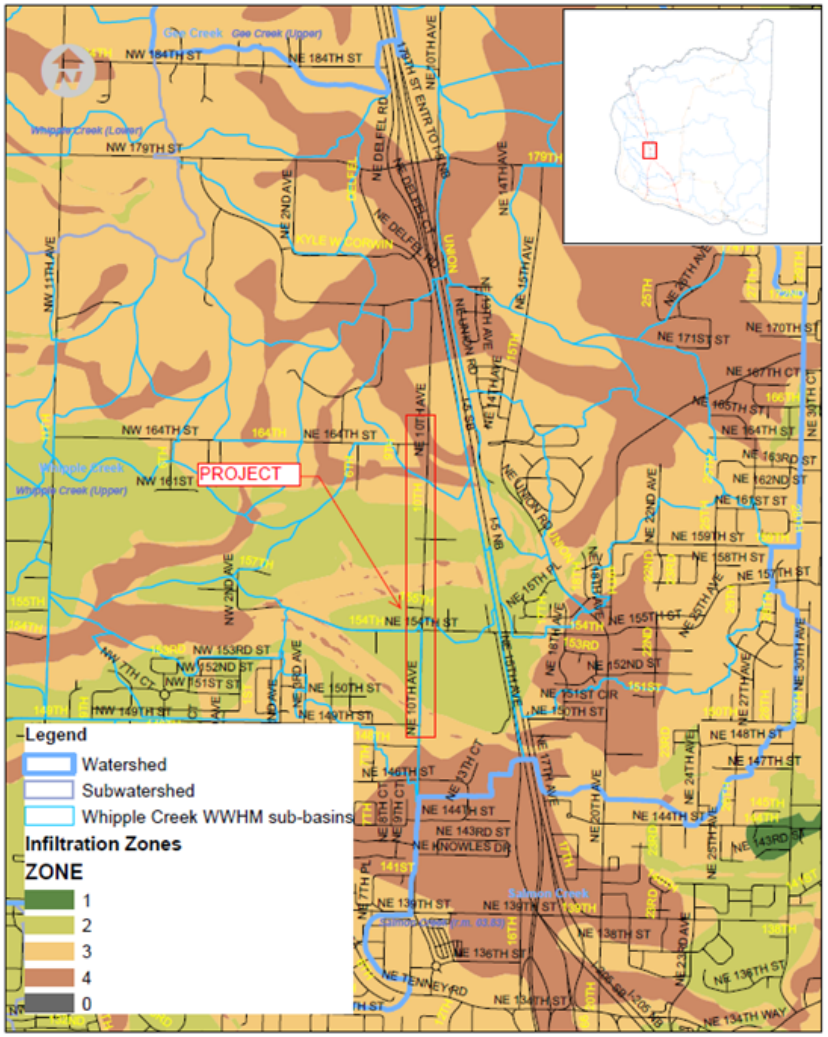
3. Use *Hydrologic Accounting* to select the most cost-effective combination of BMPs to form a “Plan Alternative”

4. Use *Hydraulic Accounting* to confirm and adjust the *selected* Plan Alternative

5. Complete the final project design using standard hydrologic and hydraulic models

STEP 2: IDENTIFY THE MOST COST-EFFECTIVE INFILTRATION BMP AT EVERY POSSIBLE RETROFIT LOCATION

NE 10th Avenue; NE 149th Street to NE 164th Street
Figure 8: Infiltration Zones



		Hydrologic Soil Groups			
		A*	B	C	D
Depth to GW	D >20 ft	ZONE 1	ZONE 2	ZONE 3	ZONE 3
	D=11 ft to 20 ft	ZONE 2	ZONE 2	ZONE 3	ZONE 3
	D=0 ft to 10 ft	ZONE 3	ZONE 3	ZONE 4	ZONE 4

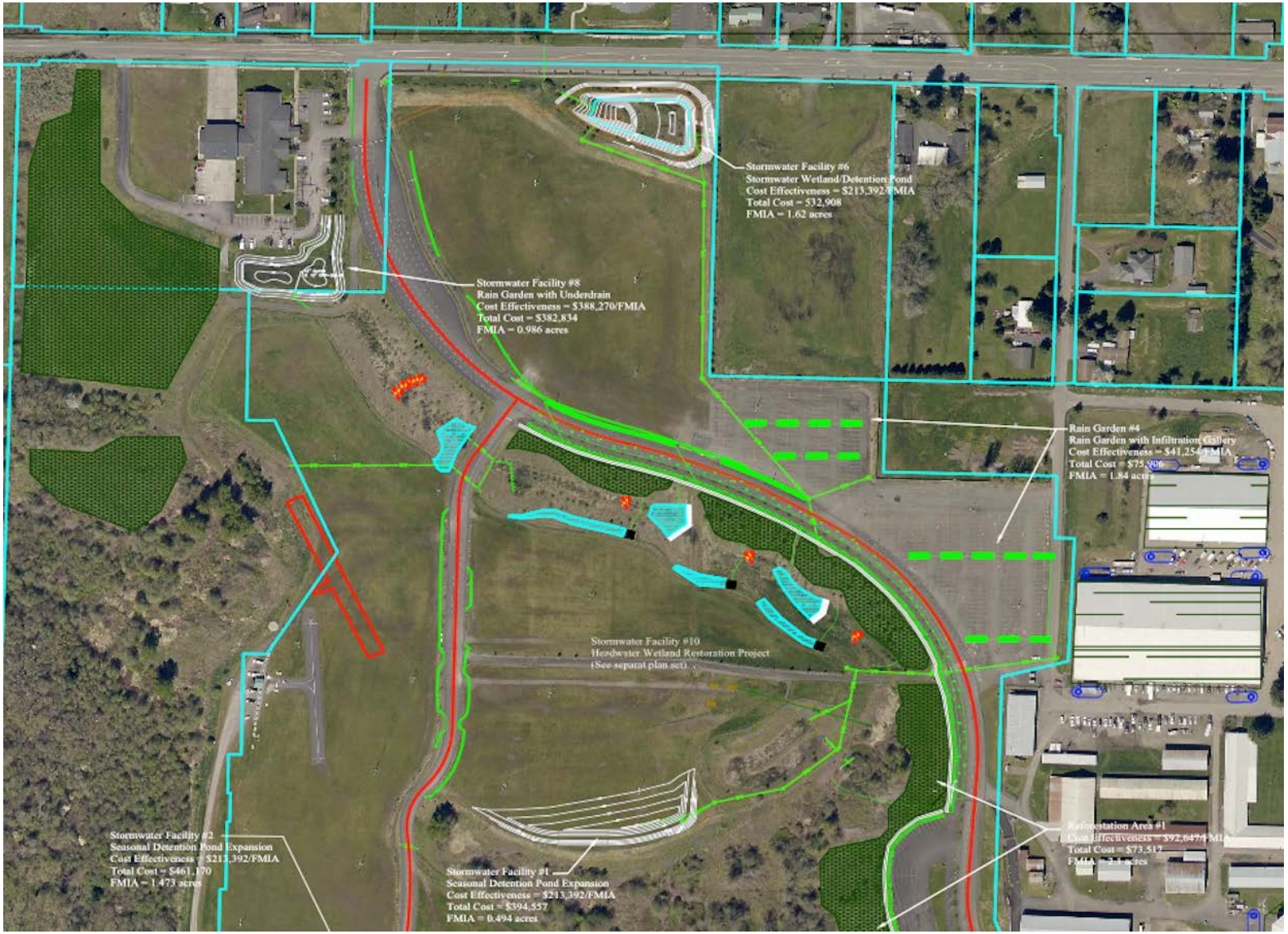
The grid maps were combined to create an "Infiltration Zone Map" with four zones.

- Zone 1 – Good Infiltration Area
- Zone 2 – Potentially Good Infiltration Area (groundwater depth and soil investigation required)
- Zone 3 – Limited Potential Infiltration Area
- Zone 4 – Poor Potential Infiltration Area

BMP COST-EFFECTIVENESS
($/Fully-Mitigated Impervious Acre)

BMP	*INFILTRATION ZONE*			
	1	*2*	*3*	*4*
Detention Pond	*Don't Use*	*Don't Use*	*$317,559*	*$317,559*
Rain Garden (w/Inf. Gallery)	*$27,166*	*$56,878*	*Don't Use*	*Don't Use*
Rain Garden (w/Underdrain)	*Don't Use*	*$535,329*	*$535,329*	*$535,329*
Green Roof	*$7,920,000*	*$7,920,000*	*$7,920,000*	*$7,920,000*
Reforestation (of pasture)	*$135,821*	*$135,625*	*$92,647*	*$92,647*
Reforestation (R. & R. asphalt)	*$1,880,000*	*$1,880,000*	*$1,286,000*	*$1,286,000*
Roadside Rain Garden (w/Inf. Gallery)	*$47,811*	*$99,929*	*Don't Use*	*Don't Use*
Roadside Rain Garden (w/Underdrain)	*Don't Use*	*Don't Use*	*$917,538*	*$917,538*
Parking Lot Rain Garden (w/Inf. Gallery)	*$86,426*	*$181,856*	*Don't Use*	*Don't Use*
Parking Lot Rain Garden (w/Underdrain)	*Don't Use*	*Don't Use*	*$1,745,818*	*$1,745,818*

STEP 3: DEVELOP PLAN ALTERNATIVE 1: "MAXIMUM IMPROVEMENT"



SUB-BASIN RETROFIT PLANS: CONCLUSIONS

- Fast, watershed-based project selection
- Identifies needed, effective and cost-effective projects
- “Top-down” procedure addresses all watershed needs
- Multi-benefits for environmental programs
- Speedy and effective watershed restoration

completed very quickly, without the need for a large-scale watershed plan.*

OFFSITE STORMWATER MITIGATION AND WATERSHED REHABILITATION: “WHAT’S UP WITH DAT?”

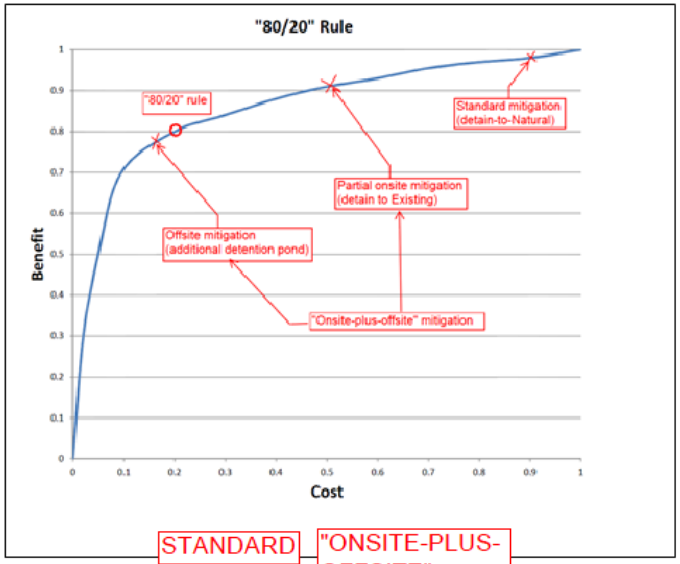
DAT = a process where obligated funds from public road projects can potentially be used to advance watershed rehabilitation:

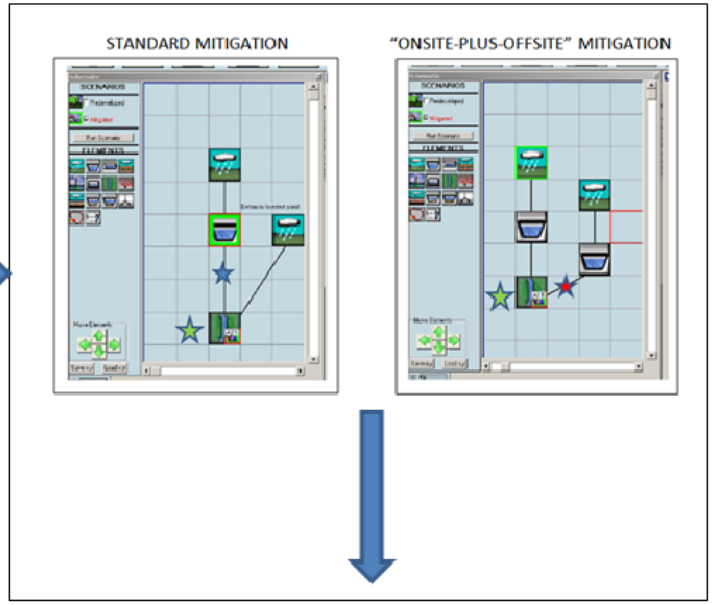
1. Determine if you have a *“qualifying project”*
2. Develop a *“watershed-based proposal”* for using offsite stormwater mitigation

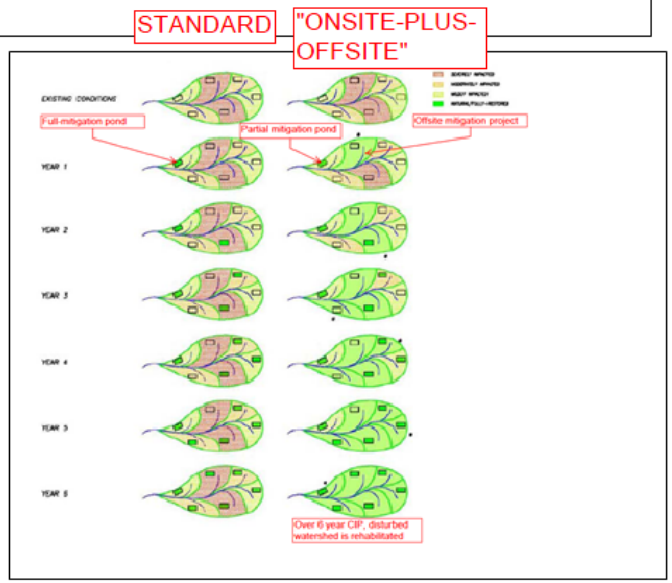
The proposal is then reviewed by the **D**emonstrative **A**pproach **T**eam

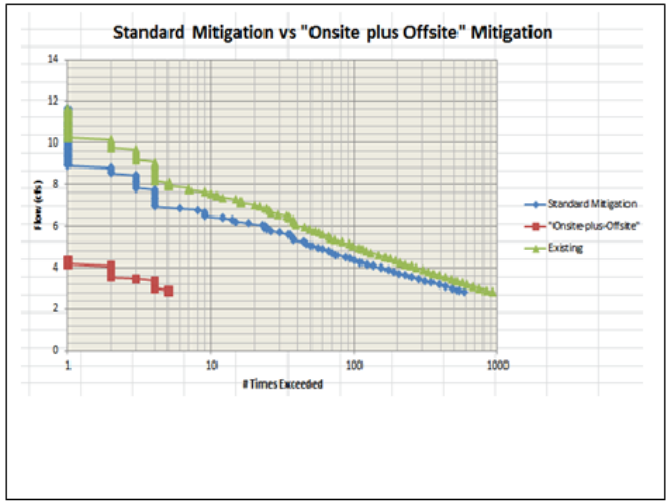
WATERSHED-BASED PROPOSAL

STANDARD MITIGATION VS. "ONSITE-PLUS-OFFSITE" MITIGATION





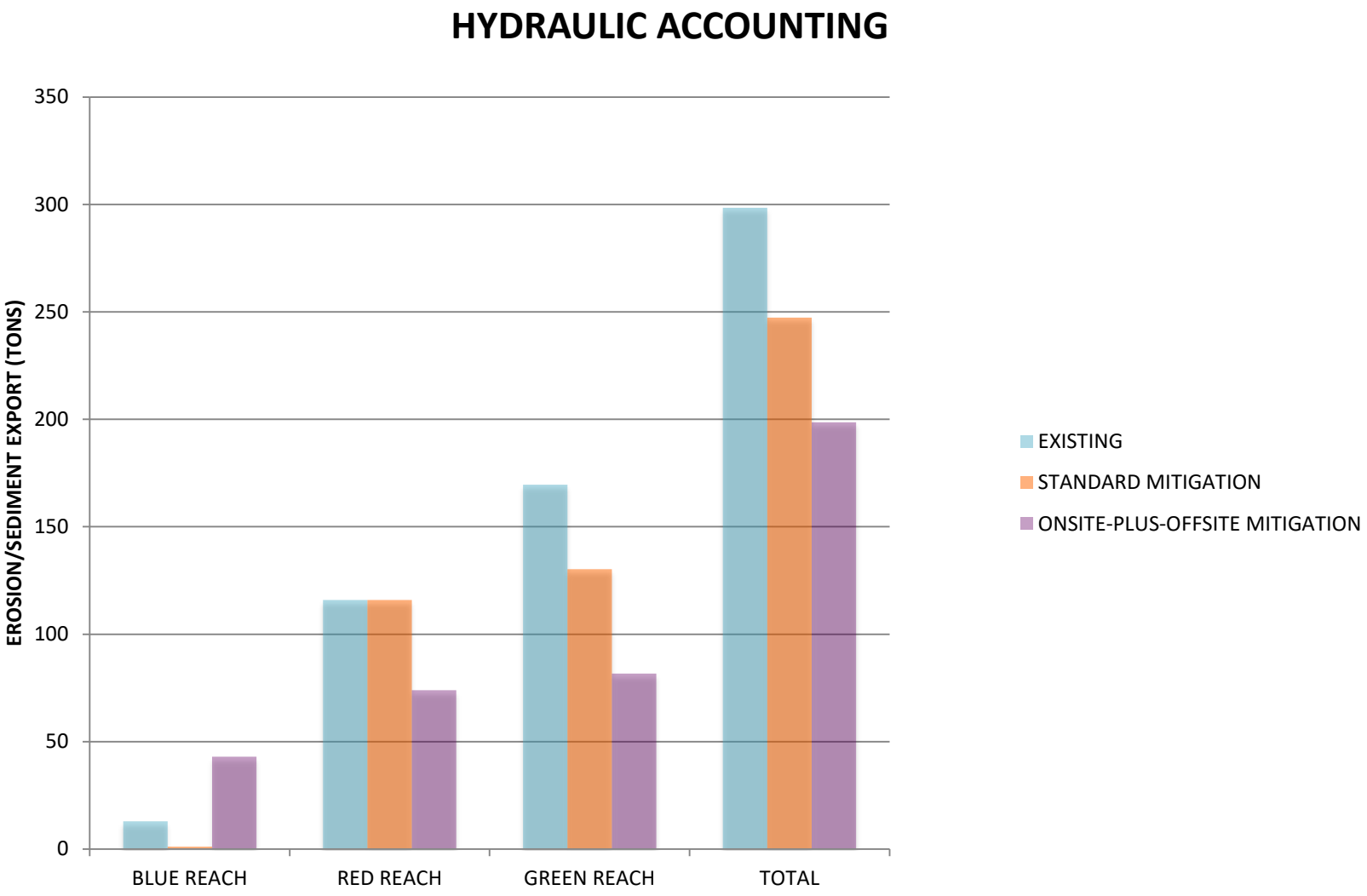




OFFSITE MITIGATION PROJECT TYPES

1. Detention pond retrofit
2. New detention pond
3. Headwater wetland restoration
4. Flood plain bench
5. Culvert replacement (for fish passage)
6. Stream stabilization project (channel-spanning log jam)

SELECTED PROJECT
HYDRAULIC ACCOUNTING RESULTS



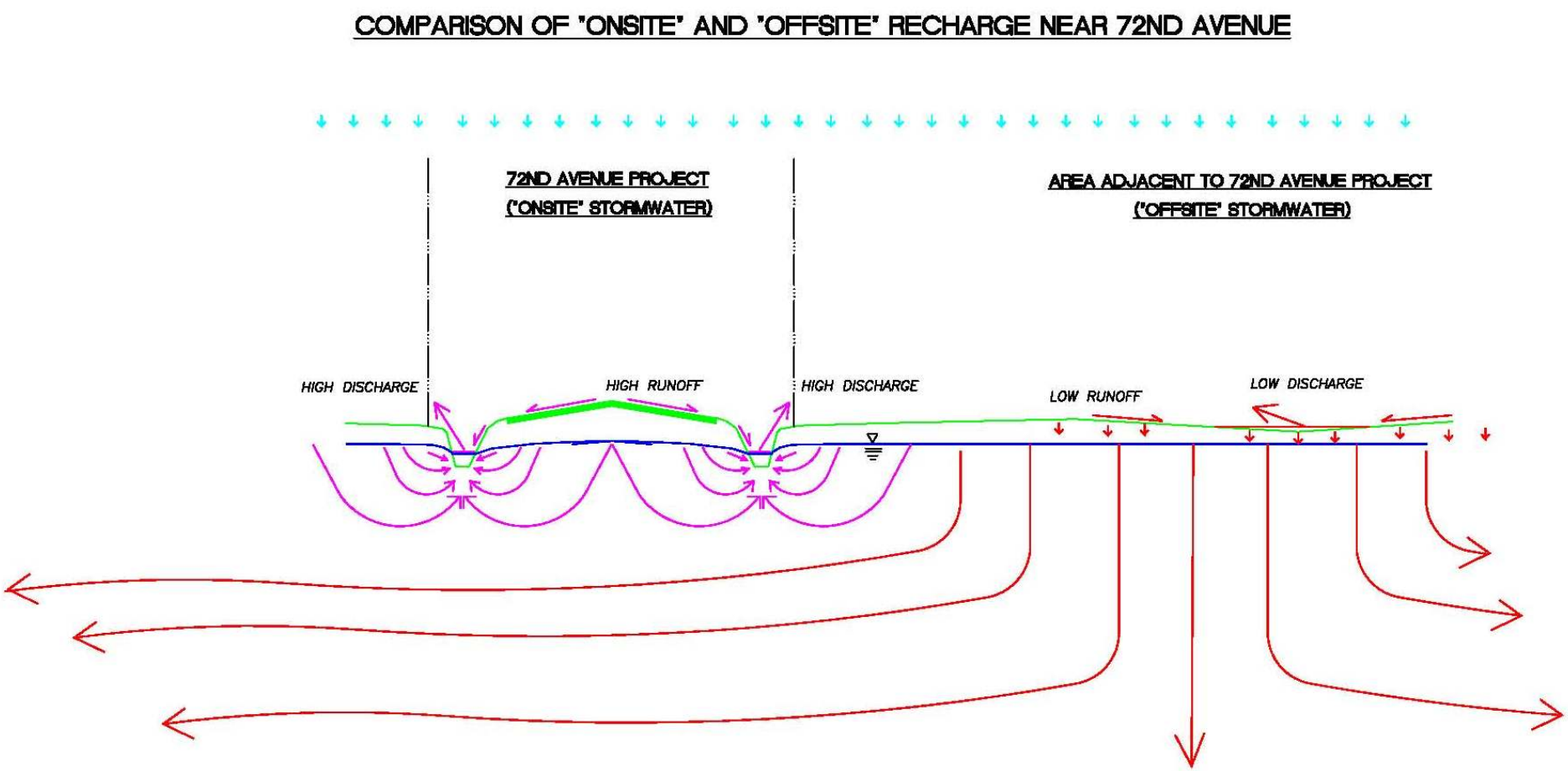
"DAT" AND OFFSITE STORMWATER MITIGATION CONCLUSIONS AND RECOMMENDATIONS

1. Good watershed-based project-selection
2. Cost-effective watershed rehabilitation
3. Project types can be quantifiably linked to flow control
4. Need watershed-based *review procedures*

Recommend:

- Expand DAT to allow a wider range of project types
- Consider linking DAT to NPDES permit

GROUNDWATER RECHARGE *AND DISCHARGE*



ENTROPY BASED *RESOURCE* MANAGEMENT

What is the most sustainable……*roadway grid?*

Use entropy-based resource management to design a roadway grid which uses the least energy for a given commute:

A. Maximize the PE of the resource (oil):
   - minimize the entropy change from liquid with high PE to gas with high KE
   - cars travel at all times that the engine is running

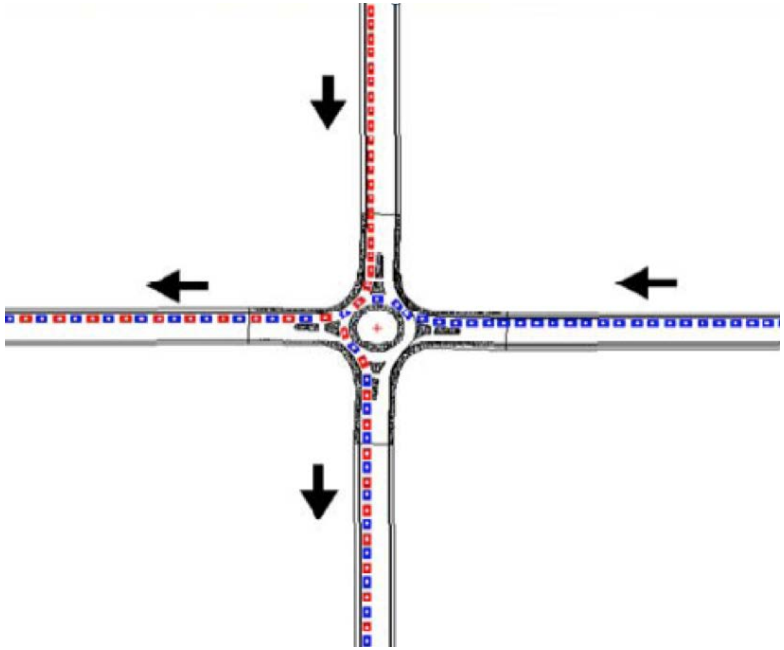
B. Mimic a natural system:
   - minimize entropy by designing intersections to achieve the most *orderly* flow

Hypothesis = use roundabout intersections

SUSTAINABLE ROADWAY GRID
B. Mimic a natural system

Roundabout

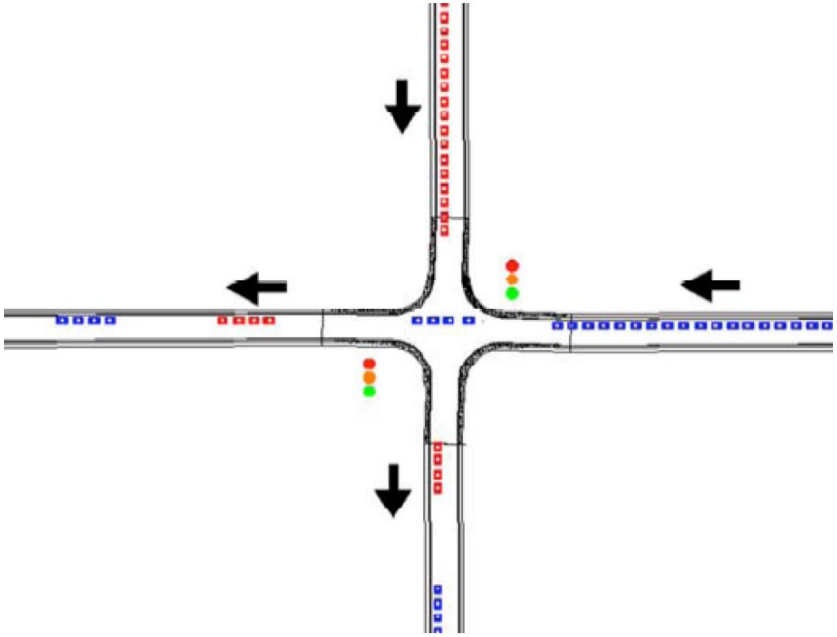
Smooth flow and no gaps



No gaps…orderly…continuous
- *like a liquid*

Regular Intersection

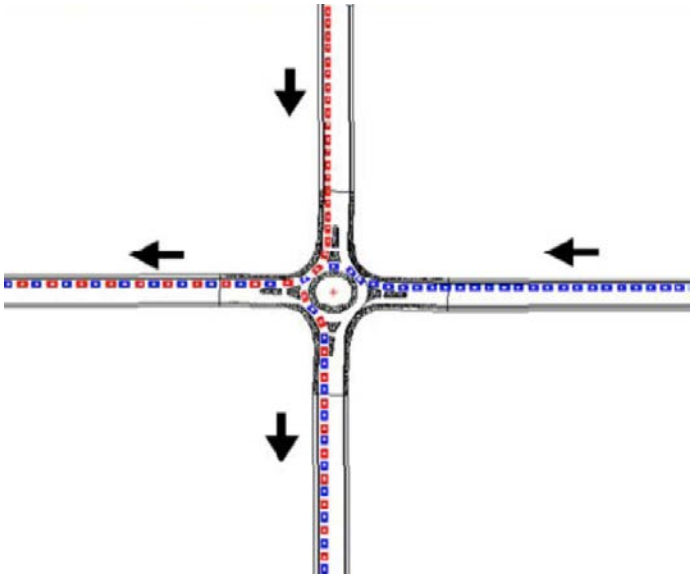
Platooning



Gaps…disorderly…random
- *like a gas*

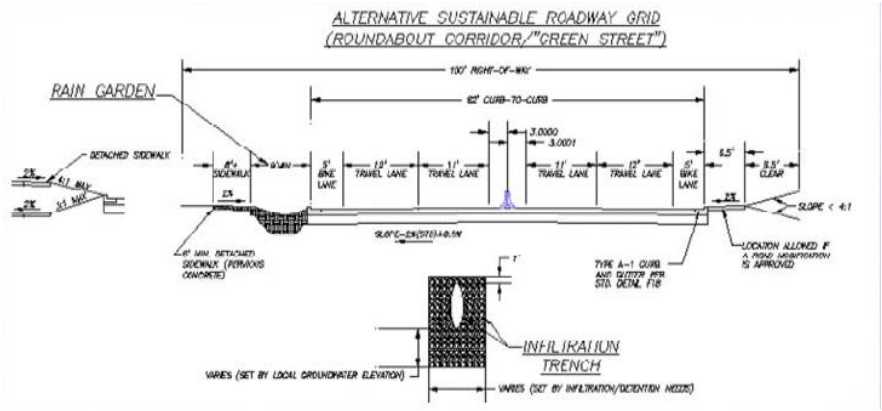
SUSTAINABLE ROADWAY GRID

Roundabout corridor



- No stoppages/less energy use
- Minimize entropy change from liquid/PE to gas/KE
- Less emissions

Green Street



- Infiltration of stormwater runoff
- Increased groundwater recharge
- High groundwater table
- Reduced stream erosion
- Narrower road section
- Less impervious area and less wetland impacts

SUSTAINABLE ROADWAY GRID

ENERGY-WATER-*AIR*

	CURRENT STANDARD	"SUSTAINABLE ROADWAY GRID"	DIFFERENCE	% REDUCTION
TRANSPORTATION AND ENERGY USE				
Capital cost*	$10.4m/mile	$8.6m/mile	$1.8m	17%
Design Schedule/Permitting*	3 years/2 years	2 years/1 year	1 year	33%
Annual Fuel Costs (travel through 1 mile corridor)	$1,168,000	$922,720	$245,280	21%
Travel Time				21%
Intersection Fatalities				89%
Intersection injuries				76%
Left turns across oncoming traffic	Yes	No		100%
Signal Maintenance/Operational costs/Failures		None		100%
STORMWATER AND WATER CONSERVATION				
Annual Runoff Volume (to stream)	22.38 ac.-ft.	0.01 ac.-ft.	22.37 ac.-ft.	100%
Stream Erosion				Reduced
Annual Groundwater Recharge Volume (from SWF)		22.37 ac.-ft.		
Value of recharge (as water supply)		$22,370	$22,370	
Stream Water Quality (Annual Pollutant Loadings)				**(See below)**
Total Suspended Solids	452.70 lbs	0 lbs	452.70 lbs	100%
Total Zinc	2.82 lbs	0 lbs	2.82 lbs	100%
Dissolved Zinc	2.01 lbs	0 lbs	2.01 lbs	100%
Total Copper	0.65 lbs	0 lbs	0.65 lbs	100%
Dissolved Copper	0.35 lbs	0 lbs	0.35 lbs	100%
Summer Stream Temperature				Reduced
ENVIRONMENTAL AND ANNUAL AIR EMISSIONS				
Project Impervious Area*	10.06 acres	9.09 acres	0.97 acres	9%
Wetland Impact*	1.89 acres	0 acres	1.89 acres	100%
Permitting*	2 years	1 year	1 year	50%
Total Hydrocarbons				26%
Carbon Monoxide				19%
Nitrous Oxide				16%
Carbon Dioxide	2102 tons	1660 tons	442 tons	21%
Methane, Nitrous Oxide, HFC	105 tons	83 tons	22 tons	21%
Wetland hydrology				Improved
* Capital Project consideration				

ENTROPY-BASED RESOURCE MANAGEMENT

THE FUTURE…….

What I'd like to see….
…….Sustainable Land Use Plan

Purpose = minimize the entropy in an urban watershed

Need = sustainable economy and environment

- Addresses Water, Energy *(& Air Quality)*
- Serviced by a sustainable roadway grid
- Continued improvements in LID BMPs and regulations
- *Increased protection and restoration of headwater wetlands*
- *Raise and stabilize incised stream channels*
- *Close off ditches and field drains*
- *Expand use of trench dams on pipe trenches*
- *De-emphasize watershed plans; expand use of sub-basin retrofit plans*
- More holistic environmental regulations and reviews (compatible, flexibly-applied, more ordered)
- Expanded use of offsite stormwater mitigation to promote watershed rehabilitation (DAT linked to NPDES permit terms)

…….developed and implemented by a Public-Public Partnership

- Multi-discipline team
- Headed up by an Applied Physicist
- Planner-Transportation Engineer-Water Resources Engineer-Architect-Biologist
- Each discipline charged with:
  - developing an entropy-based strategy
  - reconciling it with other disciplines
  - responsible for getting their own agency's permit approvals

Causes for optimism……..

- *Increasing LID*
- *WSDOE Stormwater Control Transfer Program*
- *WSDOE Stormwater Financial Assistance Program (SFAP).*
- Turbines inside gravity water supply lines
- Increasing solar energy
- Wind energy linked to pumped storage or underground injection of compressed air
- Artificial photosynthesis for fuel
- “Maximum Entropy Method” (Systems analysis)

Sustainability: "Life, liberty and the pursuit of negative entropy"

Thanks to:

Eileen Ellison, Bill Wenk, Dr. James Guo, Bob Rodgers, Dr. Phil Gaddis, Rod Swanson, Ross Milne, The Brown sisters (Peg and Anne)

And

Emmy Noether

Jock Stein and the Lisbon Lions

The mighty Pacific Salmon

LINKS

John Milne APWA articles (Linked-in address)

- https://www.linkedin.com/pulse/20140905200504-301288726-sustainability-life-liberty-and-the-pursuit-of-negative-entropy?trk=prof-post

Other articles of interest:

- http://seit.unsw.adfa.edu.au/research/details2.php?page_id=573
- http://www.cms.bgu.tum.de/publications/2012_Christodoulou_ICCCBE.pdf
- http://www.siwi.org/prizes/stockholmwaterprize/laureates/2015-2/http://bangalorenotes.com/negative_entropy.htm
- http://www.cnki.com.cn/Article/CJFDTOTAL-JAXG200110012.htm
- http://www.columbian.com/news/2013/feb/24/a-new-hope-in-energy-storage-bonneville-ross-wind/
- http://www.scotsman.com/news/transport/glasgow-uni-discovery-set-to-solve-energy-crisis-1-3664735
- http://www.opb.org/news/article/portland-now-generating-hydropower-in-its-water-pipes/