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FIFTH PARADIGM OF INTEGRATED URBAN WATERSHED MANAGEMENT AND METRICS OF ASSESSMENT

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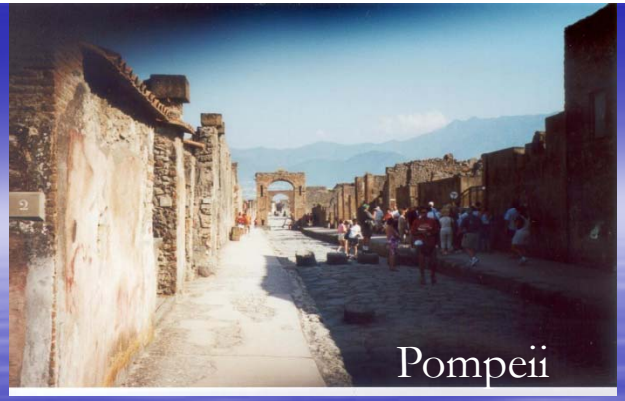
Paradigms of urban drainage have changed over millennia


Pompeii


Pont du Gard

I. **Wells for water supply , streets for drainage, night soil disposal**

II. **Long distance water transfers and storm water with some sewage drained by sewers**

Rainwater harvesting and storage were added thousands years ago


Cloaca Maxima


6th century water cistern in Istanbul

Stony Brook entry into 12 km culvert

Deep tunnel in Milwaukee (similar to Chicago's Tunnel and Reservoir Project -TARP)

Paradigm III

- After flushing toilets were introduced stream smell became obnoxious, epidemics were deadly , some stream were buried.

- Combined sewers with some treatment (primary) were built at the end of the 3rd paradigm period. Beginning of point source (sewage) treatment around 1910 (CSSC)

Paradigm IV

- As a result of Clean Water Act, point source clean up became mandatory after 1972 (NPDES)

- CSO control and Stormwater permitting were added resulting in large storage/treatment requirements.

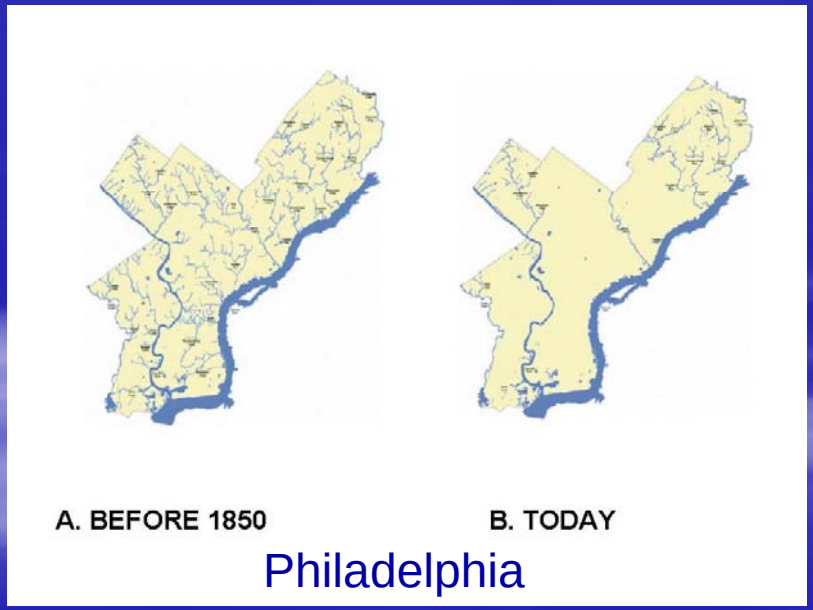
- Some best management practices (BMPs for control of other diffuse pollution (construction sites) were added.

PROBLEMS WITH THE 4th PARADIGM

- **Natural hydrologic status of urban water bodies and watersheds has been modified by imperviousness, building sewers and stream modifications with the impacts on**
  - Streams
    - Increased high flows (more flooding).
    - Peak flows increase by a factor of 4 to 10
    - Less base flow - not enough base flow to sustain viable fish population
    - Pollution persists
    - Increased variability (flow, temperature, DO)
    - Increased stream bank erosion
  - Groundwater
    - Groundwater recharge is diminished, leading to dropping the groundwater table.
      - Effect on foundations (Boston, Venice, Mexico City)
      - Diminishing groundwater supply
      - Diminished base flow

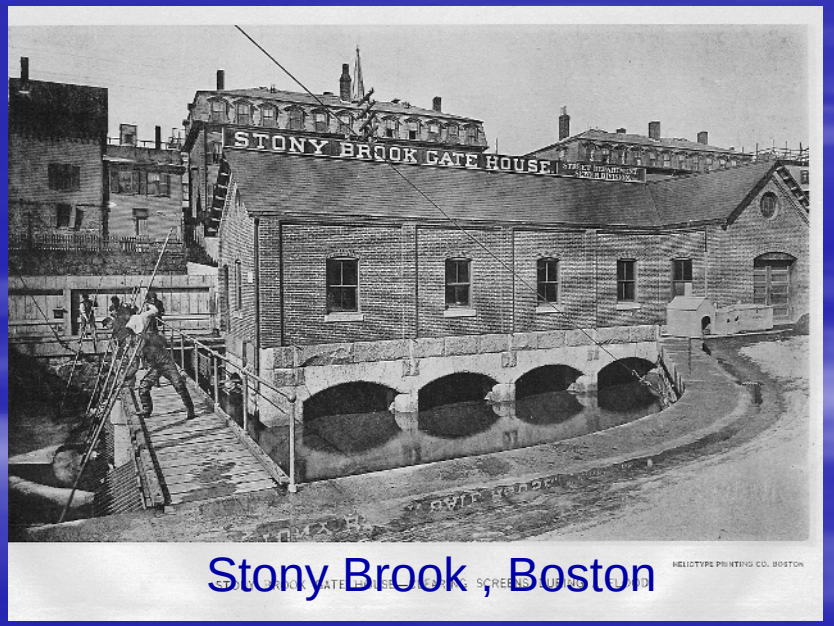
Under the 4th Paradigm

- Surface streams disappeared from surface



Philadelphia

Credit Howard Neukrug



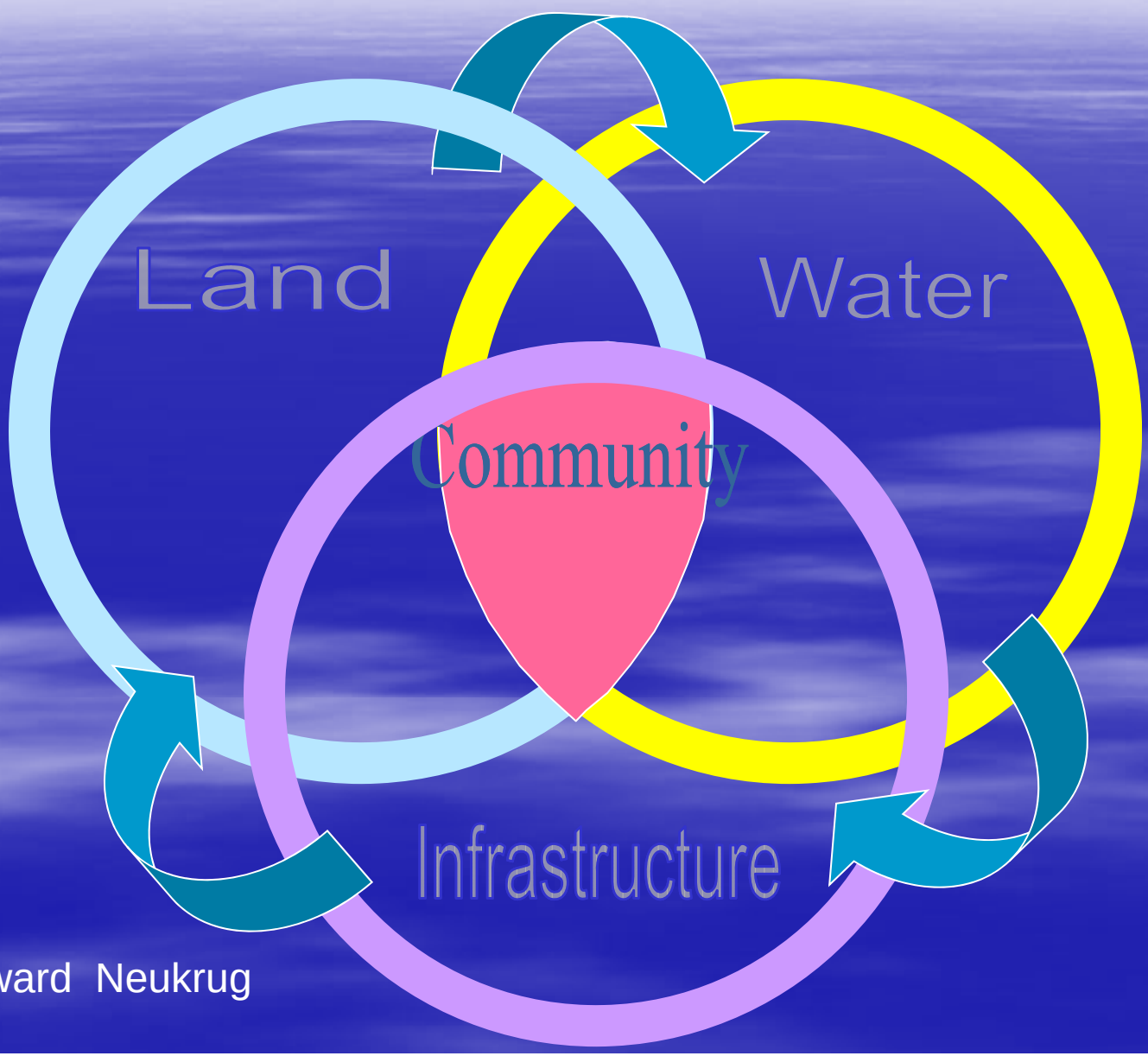
Stony Brook , Boston

New (5th) Urban Water Sustainability Paradigm is Needed

VISION: Achieve sustainable integrated urban water, energy reclamation, drainage and transportation infrastructures connected to receiving waters that will be resilient to natural and anthropogenic stresses, including extreme events, implement water conservation, provide good quality of reclaimed water for diverse uses and would be either carbon neutral or reduce carbon emissions when compared to the current situation.

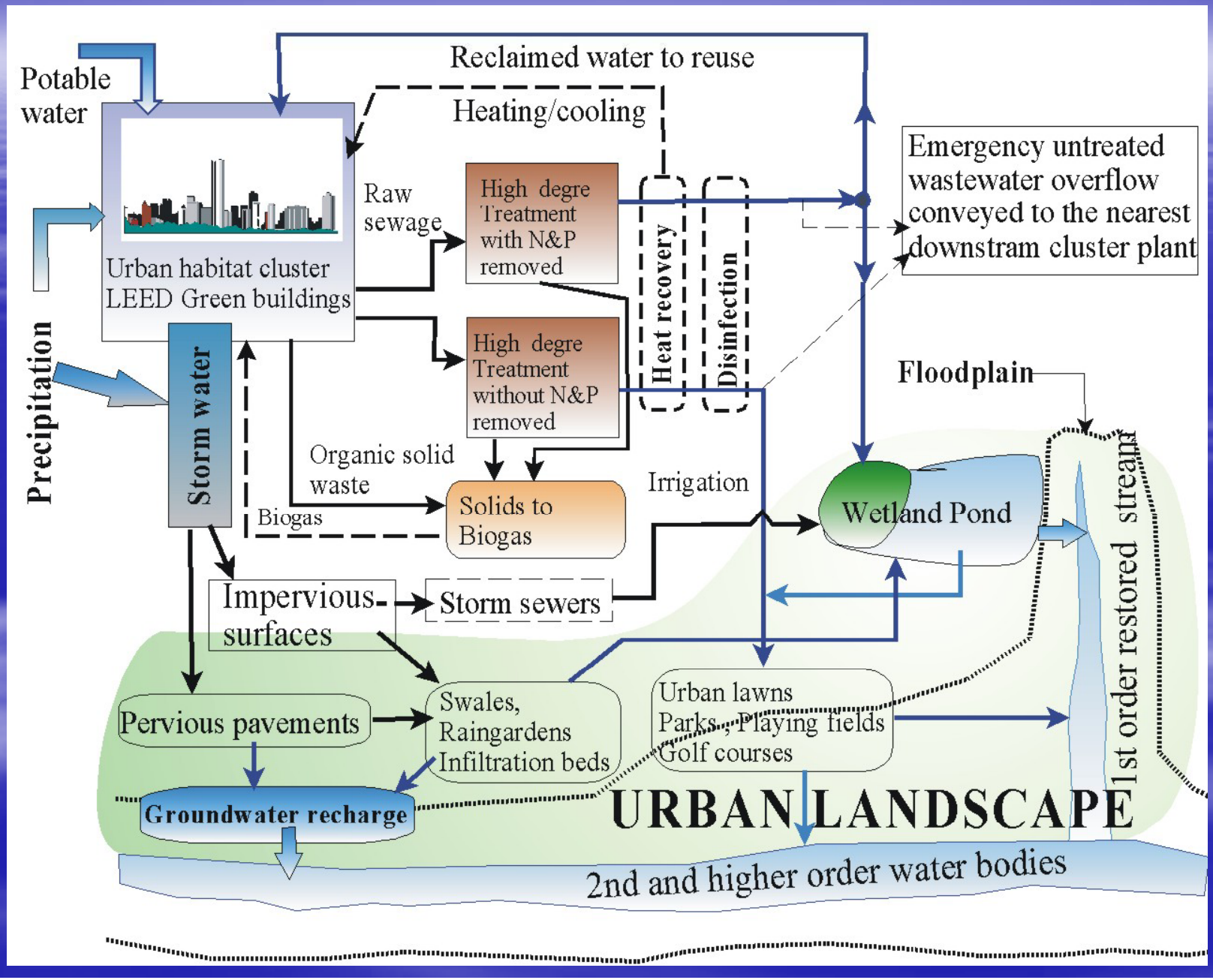
Urban (green) infrastructure, resilient and hydrologically and ecologically functioning landscape and water resources will constitute one system

Linking Land and Water



Credit Howard Neukrug

DECENTRALIZED CLUSTER WATER MANAGEMENT



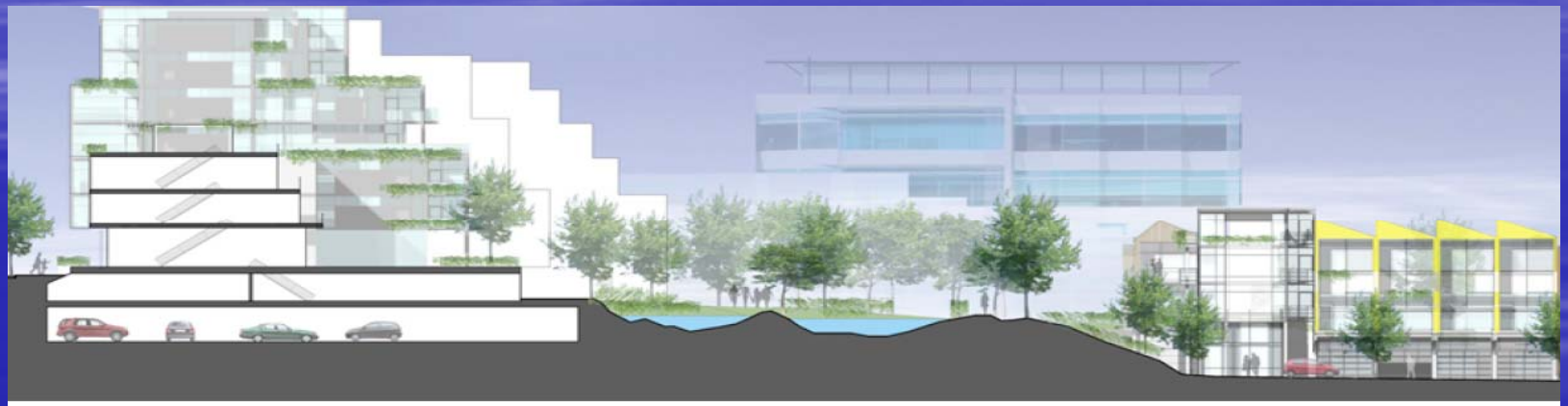
Microscale Assessment

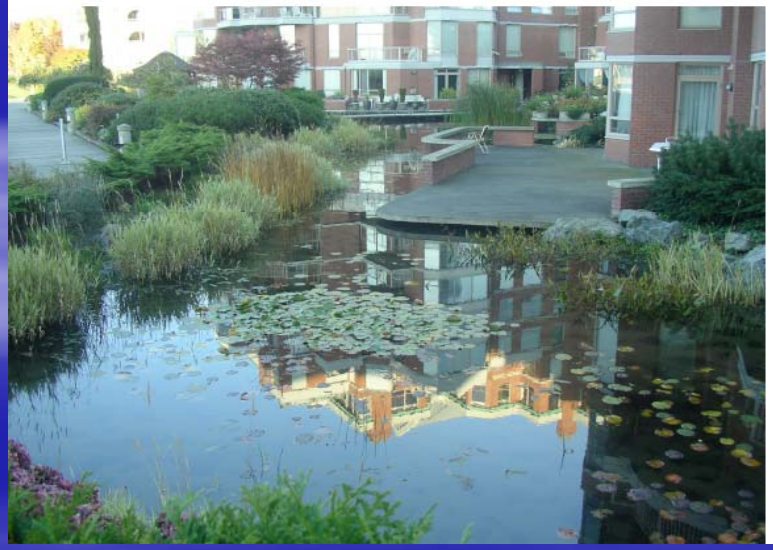
- Microscale (buildings, neighborhoods, subdivision
  - Leadership in Energy and Environmental Design-LEED
    - Sustainability of the site – smart location
    - Green design
    - Energy efficiency
    - Indoor environmental quality
    - Innovation and design
    - Neighborhood patterns, etc.

  - Low Impact Development (LID)
    - Capture, storage and infiltration of precipitation, mimicking predevelopment hydrology
  - Best management practices (BMP)
    - Prevention
    - Source Controls
      - Construction erosion control
      - Home lawn pesticide and fertilizer management
    - Hydrologic modifications
      - Porous pavements
    - Reduction of delivery
      - Swales and biofiters
    - Storage and treatment
      - Ponds and wetlands

CITY OF THE FUTURE

BUILDINGS AND "NEIGHBORHOODS" CONFORMING TO LEED CRITERIA CONNECTED TO SUSTAINABLE SURFACE DRAINAGE





Courtesy AquaTex

CITY OF THE FUTURE

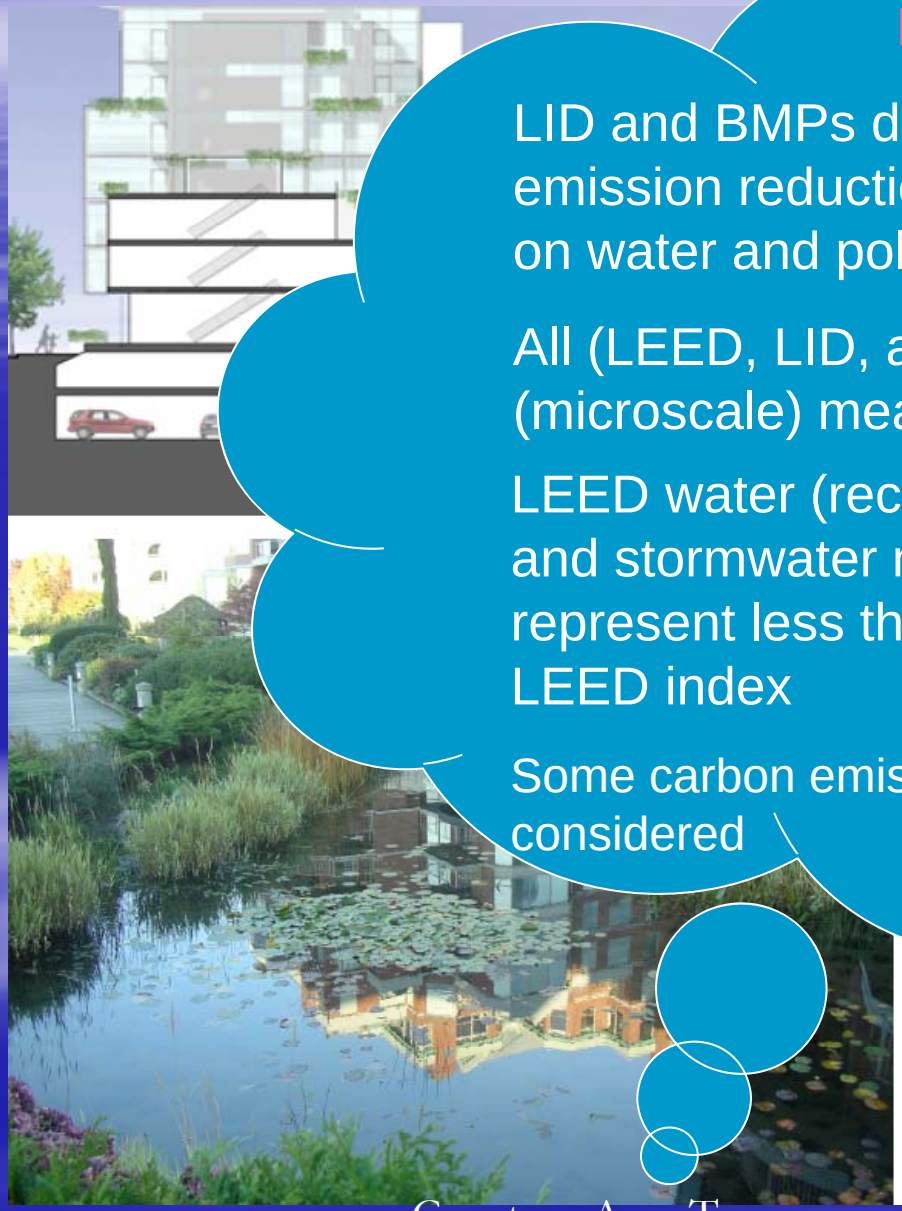
POTENTIAL PROBLEM

LID and BMPs do not consider carbon emission reduction they are strictly focused on water and pollution

All (LEED, LID, and BMPs) are small (microscale) measures.

LEED water (reclamation, conservation and stormwater management) criteria represent less than 10 % of the Total LEED index

Some carbon emission controls are implicitly considered



Courtesy AquaTex

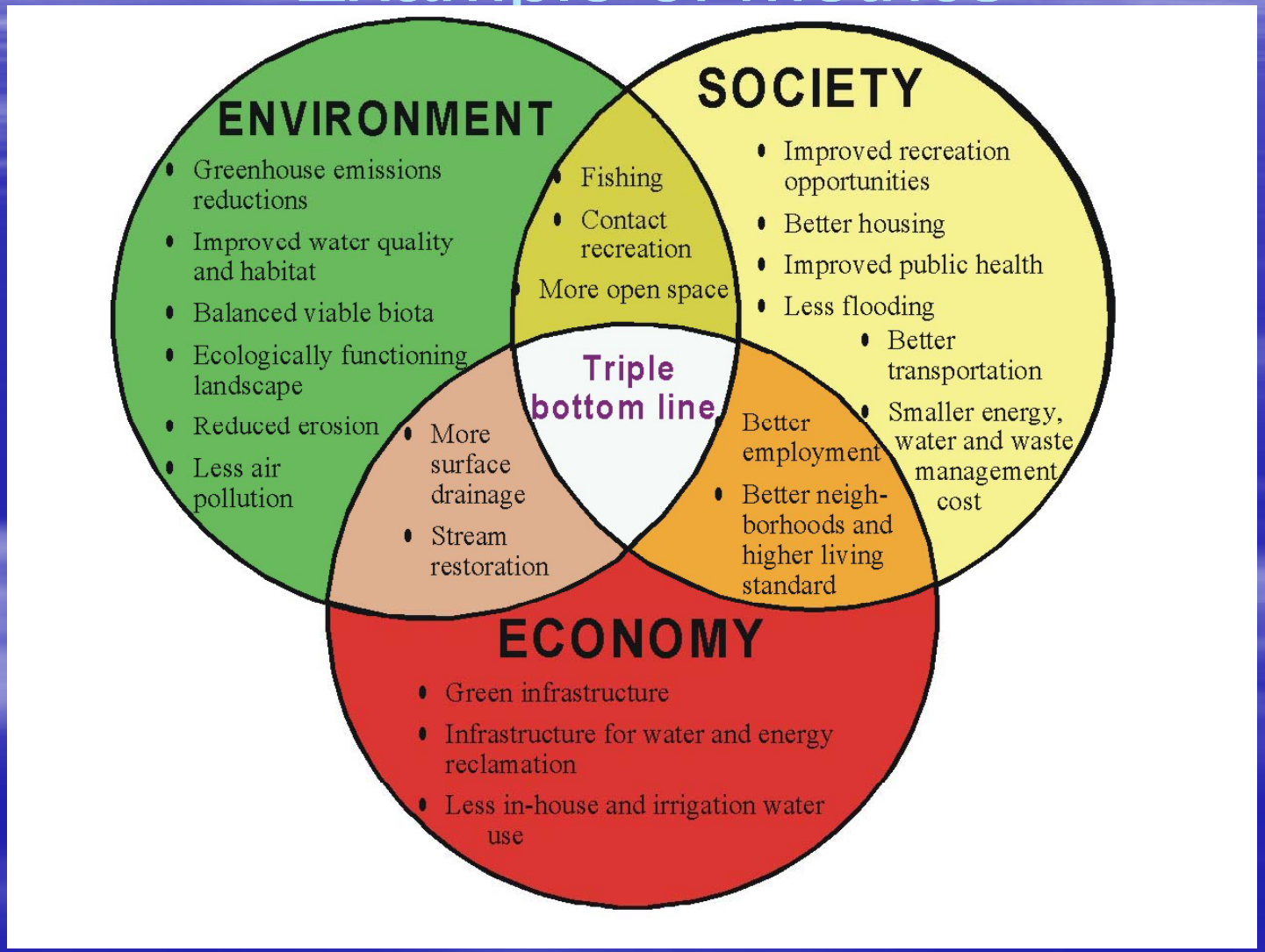
Missing link in the assessment

- Fuzzy impact of LEED and similar criteria on
  - Sustainability of water resources, their water quality and integrity
  - Improving resilience against the impact of extreme events
  - Protection and enhancement of urban natural resources (nature preserves or parks)
  - Access of people to recreation
- Conversion to or building ecocities, requires a comprehensive and hierarchical macroscale approach to the microscale and often fragmented piecemeal transformation

Macroscale assessment is needed for water centric sustainable future cities

- Sustainable horizontally decentralized (macroscale) but vertically integrated (cluster) water distribution, stormwater capture and wastewater treatment for reuse
- Goals:
  - Providing good water quality water for multiple uses
    - Ecologic flow for existing restored and daylighted streams for aquatic life and recreation
    - Irrigation, toilet flushing, cooling, street washing, etc.
  - Reduce carbon emissions
  - Resilience to the effects of extreme events
  - Provide recreation

Sustainability = Triple Bottom Line Life Cycle Assessment Example of metrics



Premise of the TBL LCA

- Water (both delivered and reclaimed) is an economic resource
- Protect and save the environment and make a profit doing it by
  - Creating a new environmentally friendly urban environment and retrofitting older urban sections
  - Capturing rainwater (stormwater), treating it and blending it with highly treated wastewater so they can be reused
  - Daylighting buried streams and restoring damaged streams on the surface to increase resiliency against flooding and aesthetics
  - Restoring green ecotones (riparian zones and floodplains) surrounding the surface waters to recreate urban ecosystems
  - Increasing resilience against flooding and storing reclaimed water for the times of shortages
  - Reclaiming brownfields by removing and/r containing contaminants and use the reclaimed are for green ecotones and commercial development

Integrated Resource Management

- Discussed at the Hague World Water Forum in 2000
  - Adopted by developed countries but resisted by undeveloped and developing countries

CONTRASTING VIEWS

Water is a resource that has a commercial value and should be used and reused

Water is public good and should be provided free or at minimal cost

Economic Developed countries

Social Undeveloped countries

Trinity of sustainability

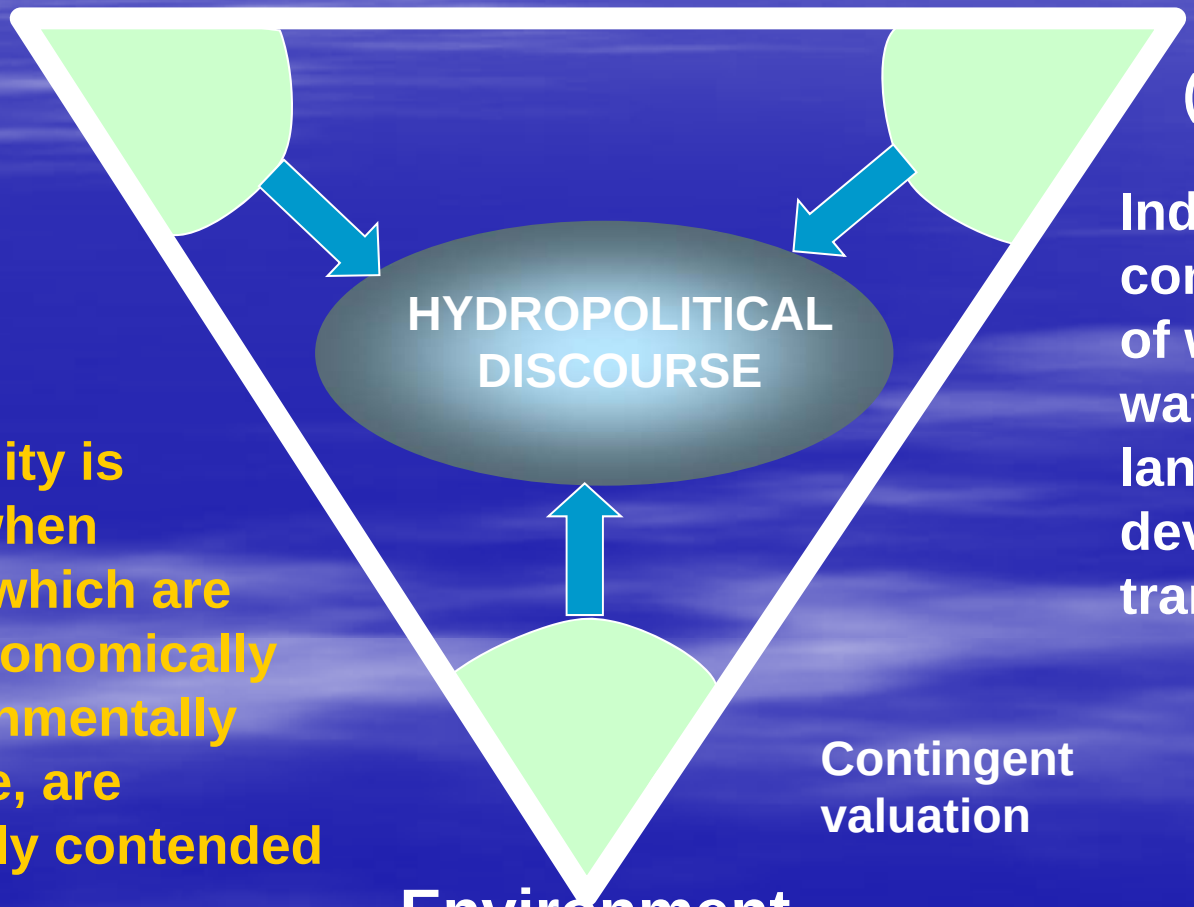
Society

Domestic use, basic food production

Economy

(Infrastructure)

Industrial and commercial use of water and water resources, land development, transportation



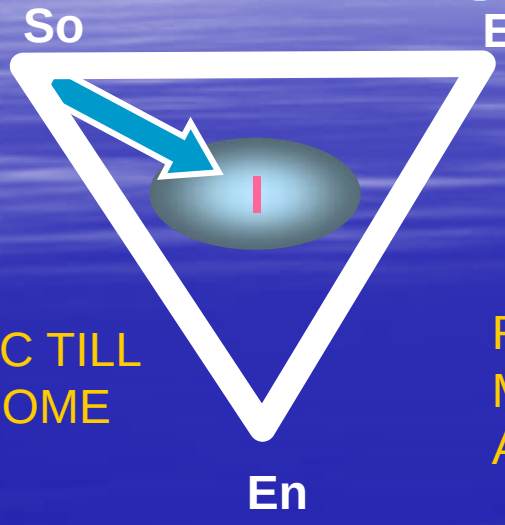
Sustainability is achieved when outcomes which are socially, economically and environmentally sustainable, are successfully contended

(J.A. Allan)

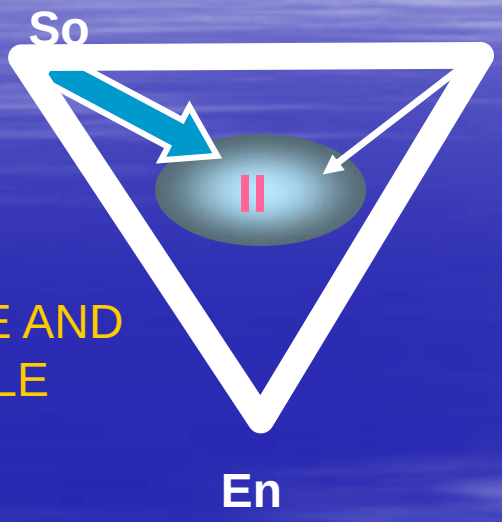
Contingent valuation

Environment water and air

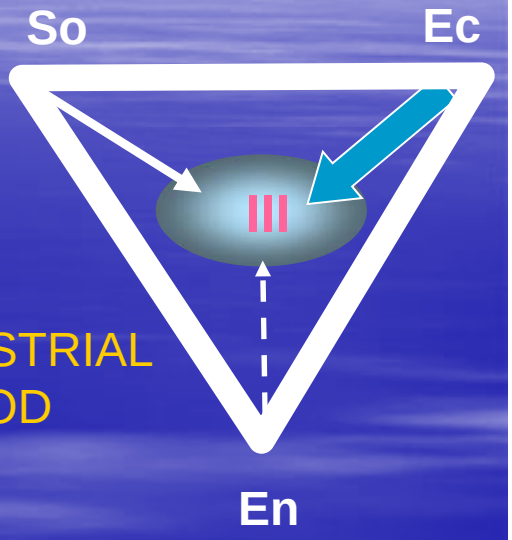
Towards the paradigm of urban water sustainability



BC TILL ROME

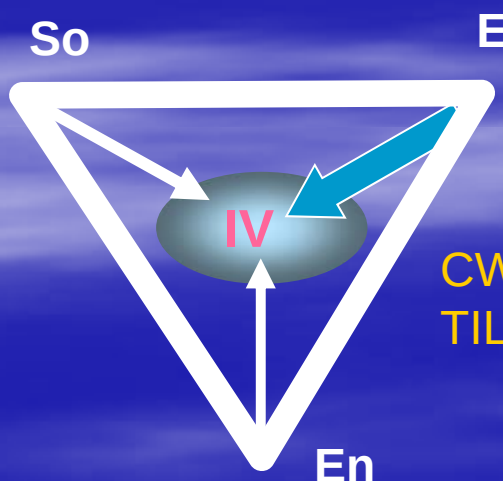


ROME AND MIDDLE AGES

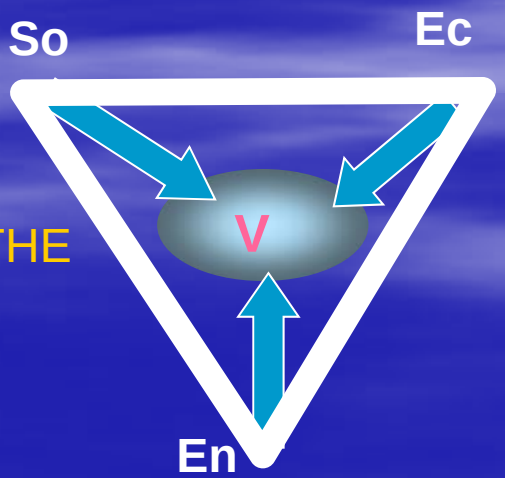


INDUSTRIAL PERIOD

PARADIGMS OF URBAN WATER MANAGEMENT



CWA PASSAGE TILL TODAY



CITIES OF THE FUTURE

LEED Microscale Water Related Criteria

- Proximity to water and wastewater infrastructure
- Wetland and water body conservation
- Floodplain avoidance
- Brownfield development and contaminants reduction
- Steep slope protection
- Green buildings
- Reduced water use
- Stormwater management
- Wastewater and waste management
- Construction erosion reduction
- Alternate energy sources (solar, renewable)

OUT OF THE TOTAL 106 POINTS LESS THAN 15 ARE RELATED TO WATER AND ECOLOGY. CERTIFICATION CAN BE RECEIVED WITHOUT CONSIDERING WATER, POLLUTION REDUCTION AND ENERGY.

Macroscale societal metrics

- Reduction of greenhouse emissions (self preservation)
- Providing water of good quality for
  - water supply (life support and public health)
  - aquatic life, including habitat (salient cognition of protecting nature)
  - recreation, etc. (well being)
- Protecting and renaturalizing stream corridors (protecting nature, aesthetics, recreation and public health))
- Increase resilience of watershed against extreme events (self preservation)
- Revitalizing neighborhoods (salient cognition for community well being)

Need to develop measures (e.g., contingent valuation)

Macroscale economic metrics of urban water systems sustainability

TRIPLE BOTOM LINE-LIFE CYCLE ASSESSMENT OUTPERFORMS THE TRADITIONAL APPROACHES

- Water supply
  - Improvement of quality and quantity of the source water
  - Ecologic benefits of protection zones
  - Distance of water transmission and energy use (pumping)
  - Impact of the reduced water withdrawal on the downstream uses including more flow, better aquatic biota and providing conditions for fish migration
  - Water treatment (chemicals use, energy, waste byproducts and their disposal)

- On-site water and energy use recovery and management
  - Watershed wide water use and water conservation
  - Watershed wide reduction of energy use (energy saving appliances, house insulation, alternate and renewable energy sources) and ensuing reduction of green house gasses emissions
  - Irrigation water demand reduction or elimination, rainwater harvesting
  - Green roofs to reduce runoff and energy losses of the buildings (a practice known in Scandinavia for centuries)

- Watershed wide stormwater management
  - Reduction and control of pollution loads from impervious surface (streets, parking lots and highways)
  - Use of best management practices – LID
  - Reduction of imperviousness
  - Reduction of clean water inputs into underground conduits and storages and cost of pumping
  - Storage and treatment of stormwater in surface ponds and wetlands for further reuse
  - Stormwater infiltration (rain gardens, infiltration ponds) and groundwater recharge
  - Stormwater treatment units (swirl concentrators, stormwater separators)
  - In many cases, no need for storm sewers

- Wastewater management and water, fertilizer and energy reclamation
  - High efficiency cluster treatment plants
  - Heat and cooling energy recovery by heat pumps and other energy recovery units
  - Possible energy supplement from geothermal sources to provide most of the heat/cooling energy needs of the cluster
  - Biogass recovery and use
  - Fertilizer recovery

- Stream restoration and daylighting – creation of ecotones – nature preservation and water quality
  - Receiving water quality – taking out of the 303d listing of impaired water body
  - Hydrologically functioning landscape, recreational use, wild life habitat
  - Urban stream and lake restoration/rehabilitation, restoring the stream continuum and removing fragmentation (culverts impassable by biota, large drops and dams)
  - Daylighting previously buried streams (often converted to storm or combined sewers)
  - Riparian buffer/flood zone restoration and preservation – urban water ecotones

Need for Research

- Can we develop an unbiased index with proper weights of the parameters?
  - Problem with cross-correlation – not all parameters are needed
  - How to estimate proper weights?
  - How to link LEED microscale criteria to macroscale assessment?
  - How to estimate the optimum size of the ecoblock/cluster ? Research the cluster/ecoblock components.
  - Develop a virtual model of the watershed and its sustainability components

Conclusions

- There is a tremendous need for fixing crumbing infrastructure and new urban developments. Why not to do it right and implement the fifth paradigm?
- The concepts of ecocity and sustainable Cities of the Future is work in progress but most of technology is known.
- LEED criteria certification may not lead to a better integrated urban water management but it is implicitly implied that it might
- Macroscale criteria and (side specific) performance index need to be developed by science and modeling
- If we do not do it someone else will (China, Singapore, British Columbia, EC) and will economically benefit

Thank you

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