

## **Use of Nature-Based Principles as a Design and Evaluation Tool for a Stormwater Mitigation Project in Nederland, Colorado**

*“I want to live in a place where you can’t tell where the city ends and Nature starts.”*

Matt, engineering student, CU Boulder.

This is an ambitious vision, but not an impossible one. Repurposing existing infrastructure is a place to start realizing this vision and the Town of Nederland, Colorado has begun the process, one project at a time. They started by deciding to design with Nature a stormwater mitigation project in their downtown area by consulting life’s genius using the science of biomimicry.

Biomimicry is learning from, and then emulating natural forms, processes and ecosystems to create more sustainable designs. By asking the question “*What would Nature do here?*” designers can discover a truly sustainable solution, or at least find a path to move towards sustainability.

The Town of Nederland contacted the Environmental Protection Agency’s Certified Biomimicry Professional with a request for assistance to solve a problem with flooding due to their poorly designed storm water system. Nature has developed many strategies to collect, store and distribute water with low energy process and these sustainable design ideas are available for use with the added benefit of 3.8 billion years of research and development. An initial scoping meeting was held with Town of Nederland (the Town) administrators and interested Town residents on May 31, 2012 to discuss the problem and identify a nature-based approach that could be implemented. As a result of this meeting, EPA’s Pollution Prevention and Toxics Unit, in partnership with EPA’s Stormwater Program, offered to provide the requested services for this project:

- A workshop on biomimicry designed for the Town’s selected consultants.
- A workshop designed for the public that will address sustainability topics relating to this challenge. This will provide the public with an overview of the mitigation and design options that will be addressed in greater detail during presentations of plans by the consultants.
- A stormwater/drainage specialist from the EPA who would be willing to serve on their Technical Review Committee, a group of individuals who would provide technical review and assistance to the consultants in focused meetings.

The Town released a Request for Proposal (RFP) to assist them in identifying the parameters for the final design solution. The RFP required that the selected contractor participate in an EPA sponsored two-part biomimicry education session and to hire a biologist who would assist in identifying opportunities to incorporate biomimicry’s Life’s Principles into the project design. Life on earth is made up of an ever-changing and complex network of interconnected and interdependent organisms. Scientist, working to discover how nature works, have found a pattern of common principles that all surviving organism use to fit in on this planet. These common principles are called Life’s Principles and they represent nature’s strategies for sustainability. Using Life’s Principles to guide a design provides a basis for the mind shift that must occur in order to move human designs towards sustainability.

The Town's goal for this project is a design that mimics the natural processes as much as possible, resulting in a low energy system that will adapt and evolve over time. The Town agreed to procure existing maps and resources that identify the original drainage in the watershed before human development (identify what the water wants to do) and to identify local individuals who have the specific technical expertise and the willingness to assist with this project.

The two biomimicry educational sessions were held with the Design Team (Team) that included the following individuals:

Marie Zanowick, Certified Biomimicry Professional, EPA

Greg Davis, Stormwater Program, EPA

Conor Merrigan, Principal, C2 Sustainability

Darrin Masters, Certified Wildlife Biologist, Smith Environmental & Engineering

David Kim, P.E., Huitt-Zollars

Kim A. Martin, P.E., Huitt-Zollars

During the biomimicry sessions the Team developed an understanding of the current stormwater system, identified the functions that were necessary for a sustainable system and learned how to apply Life's Principles to the design solution. Functions that have been lost due to past development include:

- Conveying of water for flood control, recharge of groundwater and improved water quality
- Providing natural habitat for aquatic and wildlife life and restore riparian areas
- Providing transportation for excess water, humans (walking, car and bike) and for other organisms (fish and wildlife)

The Team visited the site, met with the Technical Review Committee and EPA's Stormwater expert identified options for sustainable solutions to the stormwater issues (Attachment 1). The Team considered each sustainable solution recommended by EPA's stormwater expert and identified the Life Principles that was satisfied by this action (Attachment 2). Designs that meet Life's Principles will likely emerge as well adapted to the conditions in Nederland. This type of evaluation is essentially ensuring that the solution has been designed with nature in mind. Evaluating using biomimicry is a way for humans to critique the appropriateness of a design as well as check for missed opportunities. This approach provides a higher standard than conventional measurement tools such as those for quality, safety and compliance. A nature-based evaluation will improve the evaluation stage by bringing the local conditions into the conversation.

In this evaluation, the proposed solutions were matched to corresponding Life's Principle in a matrix in order to determine if all of the functions were being addressed (Attachment 2). The Team biologist from Smith Environmental & Engineering provided detailed information on appropriate structures, pathways, vegetation and culvert design that would promote a return of the necessary system functions. The Team engineers from Huitt-Zollars identified physical, cost, and/or regulatory barriers that must be considered for each design idea. Permeable pavement and

bioswales could be used to restore basic infiltration functions, although these options have limits. The most significant barriers were not enough room for bioswales in the existing easement and restrictions placed on the design by Colorado water laws and environmental regulations. For example, the use of permeable pavement in the design would decrease the amount of excess water that needs to be managed, but the amount of water that is infiltrated cannot be adequately measured and cannot be considered as a mitigating factor in calculating the final design solution.

The matrix also highlights which functions are not being addressed, such as restoring the migration pathways for animals living in the Nederland ecosystem. The biomimicry Life Principle matrix indicates how each of the design options identified by the Team contributes to restoring the functions identified as important for a sustainable solution and which Life Principles are met by these options. The overall goal of a sustainable system is to meet all of Life's Principles and to restore all necessary function to the system. Adoption of a design that meets all of Life's Principles is not economically or physically possible for the Town due to the pre-existing site conditions, existing easements and placement of buildings, and other regulatory barriers.

#### Next Steps:

- The next step in this process is to present the work of the Team to the Town. As additional design ideas are generated, they should be added to the matrix in order to generate a clear vision of which of Life's Principles are met in the final project design.
- The Town should identify which functions and Life Principles are significant in meeting their sustainability goals. The Town has a sustainability goal and how this project fits into their overall sustainability goals should be considered.
- The Town needs an overall sustainability plan for development. This project is an attempt to "green" one project, and there is no process to tie all of the individual Town projects, underway or planned, together. Addressing each one separately may not produce a sustainable outcome. For example, the Town could consider broad-based solutions such as a parking garage at one end of Town and promoting walking and biking instead of more car parking spaces throughout the street and could look at a sub-station delivery area for businesses instead of widening the roads to allow this kind of delivery to each store. A whole systems approach to Town planning to address these type of problems will result in a more sustainable solution.
- The Town has a responsibility to maintain the functions of the new system. Education on the system needs, functions, benefits and stewardship responsibilities for the finished project should be provided to Town residents, especially those who live along the affected street. The library should be considered as a possible site for interpretive and conservation education. The site would potentially include a kiosk and a meeting place for educators to discuss the scope of the Towns sustainability master plan and how it is being implemented.
- The Town should consider placing restrictions on redevelopment based on the ability to retain the system's functions.
- As the Town considers other projects, biomimicry's Life Principles should be used to evaluate the long-term sustainability of the considered solutions, as this evaluation will

highlight opportunity for sustainable, low energy options as well as identify areas where the design may fail in the future, areas where Life's Principles are not met.

## Attachment 1

### Ned Ped Write-Up of Sustainability & Utility

Biomimetic Functions Performed by the Ned Ped path:

1. Conveyance of water (flood control/water quality)
2. Habitat (aquatic/riparian/wildlife habitat)
3. Transportation and connectivity\* (fish/wildlife migration, pedestrian/bike movement)

Biomimetic Form/Process/Ecosystem:

1. Form – Mixed compacted alluvium and rock benches adjacent to perennial stream with
2. Process – Infiltration nearby streambed through large pore space alluvium/ conveyance of water through alluvial transport to downstream / small stream pooling for pollutant deposition / riparian plant pollutant uptake / habitat creation through / compacted alluvium and rocks allow transportation adjacent to stream and to water source when absent perennial flow
3. Ecosystem – Montane Forest

Related biomimicry notes:

1. Resilience is created through variation, redundancy, decentralization
2. Function is performed through use of sunlight, water, gravity

Measures of Success for the Project:

1. Maintenance of biomimetic functions
2. Cost-effectiveness
3. Experience (placemaking/aesthetics)
4. Measured Sustainability (Resolution 2011-21/LEED)
5. Maintainable

Notes from the November 16, 2012 Meeting in Relation to Measures of Success:

Maintenance of biomimetic functions (1):

1. Flood control could be greatly enhanced by managing upstream flow the community center and parking lot through onsite retention and infiltration systems
2. Some level of flooding at periodic intervals is to be expected
3. Infiltration could be enhanced:
  - a. The path could contain a pattern/strip of looser material for increased infiltration
  - b. Infiltration in the road itself could be enhanced to promote infiltration
  - c. Use of substrates with varying porosity and porous pipes could be used to guide and infiltrate flows
4. Habitat could be enhanced by selective pooling areas

- a. Alternating small pools/infiltration strips adjacent to 2<sup>nd</sup> downstream of the roundabout are proposed
- b. Opportunity areas for pooling should be considered utilizing stream enhancement and/or culvert design (e.g., library/roundabout/existing culverts)

#### Cost-Effective (2)

1. Not paving the street and incorporating curb/gutter more cost-effective
2. A porous pavement system is not likely cost-effective due to high product/install costs
3. Porous pavement systems/porous concrete/porous asphalt all come with a cost associated with the uncertainty in terms of maintenance and reliability

#### Experience (3)

1. Traffic speed reduction/ traffic calming should be considered
2. People don't want sidewalks (but don't seem to mind the downtown gridded cement walks)
3. A maintained path with connectivity allows for more reliable multi-modal transportation
4. The path needs to be distinct – Distinction draws people to use the path, enhancing connectivity, safety from traffic through distinct color/elevation/texture
5. Library area habitat enhancements would provide habitat/function with a unique option for education/

#### Measured Sustainability (4)

1. Use of concrete rubble by the lake would meet significant LEED criteria for local materials
2. Connectivity of public services (post office/library/transit) meets LEED ND

#### Maintenance (5):

1. Whatever is used, if it can become a standard for Nederland, that will make it much more maintainable. If equipment is needed like a vac-truck, then it could be used at multiple areas
2. Materials need to be:
  - a. Permeable
  - b. Plowable
  - c. Safe (textured/delineated)
3. Creekside owners need education on planting, preventing deterioration to function and design, and to enable habitat/function enhancement through planting and land use
4. Restrictions on re-development could be considered based on function

Presentation – Need to identify opportunities that meet multiple metrics for success are met and slides for those (e.g., library – aesthetics/habitat/function)

\* Connectivity is a measure of how the landscape facilitates animal movement between resources patches and promotes continuous movement of wildlife over long distances.



## Attachment 2: NedPed Project – Applying Biomimicry’s Life Principles to the Project Design

		<b>BIOMIMICRY’S LIFE PRINCIPLES</b>							
<b>FUNCTION</b>	<b>SYSTEM GOAL</b>	<b>EVOLVE TO SURVIVE:</b> <i>Continually incorporate &amp; embody information to ensure enduring performance.</i>	<b>BE RESOURCE EFFICIENT:</b> <i>Skillfully &amp; conservatively take advantage of local resources &amp; opportunities.</i>	<b>ADAPT TO CHANGING CONDITIONS:</b> <i>Appropriately respond to dynamic contexts.</i>	<b>INTEGRATE DEVELOPMENT AND GROWTH:</b> <i>Invest optimally in strategies that promote both development and growth.</i>	<b>BE LOCALLY ATTUNED AND RESPONSIVE:</b> <i>Fit into and integrate with the surrounding environment.</i>	<b>USE LIFE FRIENDLY CHEMISTRY:</b> <i>Use chemistry that supports life processes.</i>	<b>BARRIERS</b>	<b>NOTES</b>
<b>Applicable to All Functions</b>	<b>Meet Nederland’s Sustainability Vision</b>	*Educate Ned population on system needs, functions, benefits & stewardship responsibilities. Use library for signs. * Place restrictions on redevelopment based on retaining system functions.	* No paving for road or pathways. *Connectivity of public services (post office, library, transit) would meet LEED requirements.		* Place restrictions on redevelopment based on retaining system functions. *The Town needs to develop a sustainability master plan, and process for implementation.	*Material selected for project should become a Nederland standard. *Educate Ned population on system needs, functions, benefits & stewardship responsibilities. Use library for signs. *Connectivity of public services (post office, library, transit) would meet LEED requirements.		* There are 7 master plans for the Town without enough correlation between plans.	
<b>Conveyance of Water</b>	<b>Flood Control</b>	* Some level of flooding is to be expected.	* Use of concrete rubble by the lake would make use of local material. *Materials selected should be permeable.	* Enhance infiltration in the road. * Some level of flooding is to be expected. * Use substrates with varying porosity and porous pipes to guide infiltration flows.	* Upstream flow managed by onsite retention and infiltration system.	* Incorporate bio swales into the design. * Alternate small pools & infiltration strips adjacent to 2 <sup>nd</sup> St. below the roundabout.		* Colorado water laws places 48 hour hold restriction on rainwater. * Not enough room for bio swales in easement. * Quantifiable metrics required by design do not include those achieved by permeable pavement.	* Where would you place retention pond? * If road is paved add features to increase infiltration. * Must consider maintenance cost and reliability of porous pavement * Utilize stream enhancement and culvert design to increase pooling.
	<b>Recharge Groundwater</b>		* Materials selected should be permeable.	* Enhance infiltration in the road.					
	<b>Water Quality</b>			* Some level of flooding is to be expected. * Use substrates with varying porosity and porous pipes to guide infiltration flows. * Incorporate bio swales into the design.	* Upstream flow managed by onsite retention and infiltration system. * Incorporate bio swales into the design.			* Not enough room for bio swales in easement. * Quantifiable metrics required by design do not include those achieved by permeable pavement.	
<b>Provide Natural Habitat</b>	<b>Protect Aquatic Life</b>								* Enhance habitat by selective pooling.



## Attachment 2: NedPed Project – Applying Biomimicry’s Life Principles to the Project Design

	<b>Provide Riparian Habitat</b>		*Alternate small pools & infiltration strips adjacent to 2 <sup>nd</sup> St. below roundabout.	* Some level of flooding is to be expected.					
	<b>Provide Wildlife Habitat</b>								
<b>Provide Transportation</b>	<b>Transport Excess Water</b>	* Enhance infiltration thru path pattern or strip of loose fill material.		* Use substrates with varying porosity and porous pipes to guide infiltration flows. * Some level of flooding at periodic intervals is to be expected. * Materials selected should be plowable.				* Quantifiable metrics required by design do not include those achieved by permeable pavement.	
	<b>Fish Movement</b>			* Culvert replacement will allow for more room for migration.					* Is this a goal of the Town? * All culverts need to be replaced and they will be larger, providing more access to fish and wildlife.
	<b>Wildlife Migration</b>			* Culvert replacement will allow for more room for migration.					
	<b>Pedestrian Movement</b>		* No street paving, incorporate curb and gutter. * Residents do not want sidewalks.			* Residents do not want sidewalks. * Materials selected should be plowable. * Maintained pathway with connectivity promotes multi-modal transportation. * Distinct pathway to draw people’ use (color, texture, elevation).		*Cannot have curb and gutter without paving. * Must be ADA compliant.	* Consider traffic speed reduction and traffic calming. * Residents want a pathway, not a paved sidewalk.
	<b>Bike Movement</b>		* No street paving, incorporate curb and gutter. *Residents do not want sidewalks.			* Materials selected should be plowable.		*Cannot have curb and gutter without paving. * Is there enough room for bikes and people?	* How will a road meander affect bikes? * Consider traffic speed reduction and traffic calming.
	<b>Auto Movement</b>		* No street paving, incorporate curb and gutter.			* Materials selected should be plowable. *Residents do not want sidewalks. * Parking spaces designated for snow storage in winter		* Delivery trucks block road.	* Consider traffic speed reduction and traffic calming.