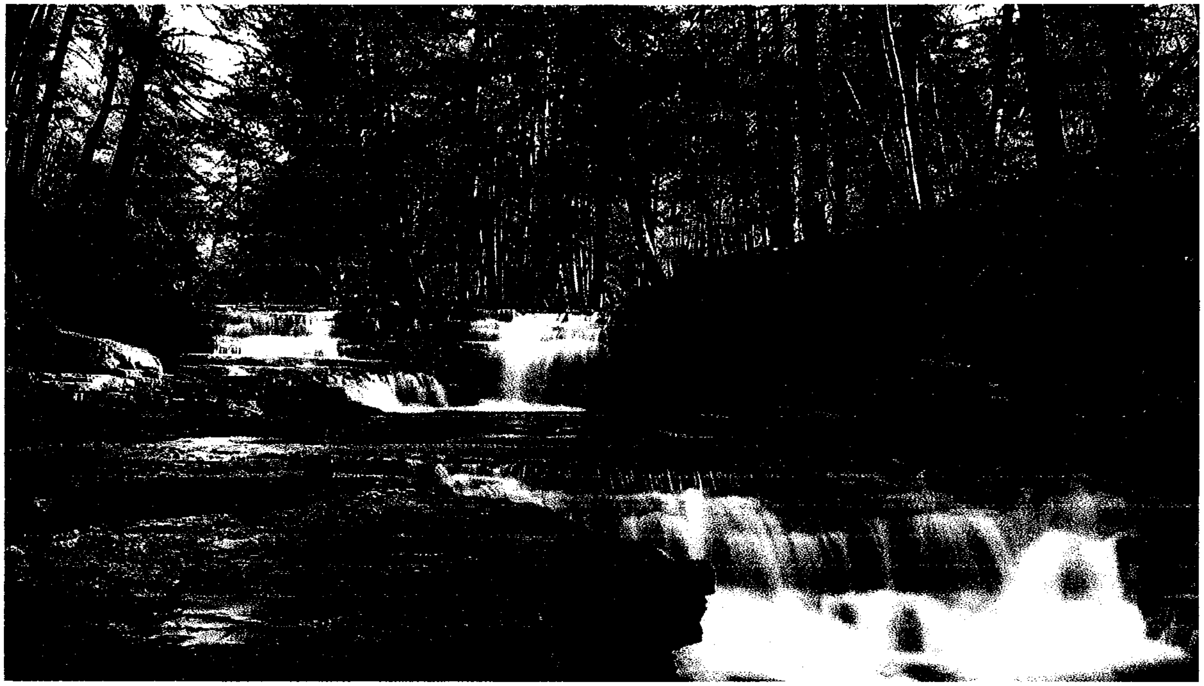
Daylighting Streams:

Breathing Life into Urban Streams and Communities

American Rivers



Forested, headwater stream, Fall Brook, Salt Spring State Park, Franklin, PA | Nicholas A. Tonelli

About American Rivers

American Rivers is the leading organization working to protect and restore the nation's rivers and streams. Rivers connect us to each other, nature, and future generations. Since 1973, American Rivers has fought to preserve these connections, helping protect and restore more than 150,000 miles of rivers through advocacy efforts, on-the-ground projects, and the annual release of America's Most Endangered Rivers®.

Download the report at: AmericanRivers.org/DaylightingReport

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Written by Amy Trice

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

Preserving and protecting small streams is the best approach to ensure environmental and community benefits such as clean water and flood reduction. In highly urbanized areas, however, where small, headwater streams are often buried, hidden, and forgotten, protecting headwater streams is not possible. Stream daylighting is a relatively new approach that brings these buried waterways back to life by physically uncovering and restoring them. Daylighting is an applicable technique to assist communities in reducing polluted runoff, addressing flash flooding concerns, and improving the livability of the built environment.

This report describes the importance of small streams and provides the context for why many of today's urban streams are buried. It also identifies and analyzes the benefits of stream daylighting, including water quality improvements, flood mitigation, and community and economic revitalization. Case studies below illustrate the benefits provided to communities by daylighting. While there are many examples of daylighting, we found daylighting projects in both Kalamazoo, Michigan and Yonkers, New York illustrated the most developed benefits to flood mitigation and community revitalization, respectively.

Daylighting is an applicable technique to assist communities in reducing polluted runoff, addressing flash flooding concerns, and improving the livability of the built environment.

Daylighting, furthermore, provides economic benefits to communities through cost effective alternatives to ongoing culvert maintenance and by keeping stormwater out of combined sewer systems, thereby reducing water treatment costs. Municipalities also gain ecological and water quality benefits, such as improved habitat and nutrient retention, by revitalizing a previously buried stream. In fact, daylighting streams can also mitigate floods by restoring floodplains which increases hydraulic storage, reducing channelization which slows water thereby decreasing flooding potential, and removing choke points such as culverts where water backs up and causes localized flooding.

Finally, to identify ways to better facilitate daylighting projects in the future, this report examines barriers to daylighting, including major water policies. This report also highlights numerous case studies where communities have implemented daylighting, and provides potential funding mechanisms for communities considering daylighting. Recommendations for enhancing the use of stream daylighting as a tool to improve clean water and communities, improve habitat, and reduce localized flooding include:

1. **Increasing scientific research and comprehensive monitoring**
   Additional research and monitoring efforts will improve scientific data on daylighting allowing for more comprehensive guidance.

2. **Utilizing a standardized daylighting database**
   A comprehensive database with a set of standardized measureable values would vastly assist stream daylighting implementation.

3. **Removing policy barriers to aid the implementation of stream daylighting where appropriate**
   Policies and funding which make daylighting projects easier to implement are imperative in order to make these more common practices.

4. **Raising awareness of buried streams to galvanize community involvement and reconnect people to rivers**
   Raising awareness of buried streams within urbanized environments can engage community residents and create interest in clean water, community health, and revitalization.

Implementing these recommendations can vastly improve daylighting, while also making it easier for communities addressing stormwater controls and water quality issues to adopt this relatively new approach. Currently, there are a suite of innovative practices used to control stormwater runoff including bioretention, rain gardens, and green roofs; however, daylighting could add to this repertoire and in some instances be a more economical and environmentally effective option, if certain policy barriers are removed and scientific data improved. As communities find ways to improve their built environment, daylighting should be considered as a viable option within the suite of techniques used to improve urban environments.

INTRODUCTION

Small streams, which scientists refer to as headwater streams, provide a wide array of benefits to communities, such as nutrient and pollution removal, groundwater recharge, and flood mitigation. Headwater streams are essentially where every river is born,[1] often as a small seep, spring, or brook that eventually gains water and size as it moves through the terrestrial environment. Collectively, these small streams that make up the majority of stream miles in the U.S. provide numerous ecosystem services that are important not only to downstream, larger rivers but to cities and communities as well.[2] Largely unnamed and mostly absent from maps, these critical small streams suffer from a lack of visibility. Being unnamed, however, doesn't lessen their importance. In fact, due to their small size and dominance within the stream network, headwater streams offer the greatest opportunity for groundwater exchange between the water and land, serving as critical connections with the terrestrial environment. Scientific research has consistently demonstrated that healthy headwater systems provide crucial downstream community benefits including clean water, flood control, and water supply, yet we routinely destroy these streams as part of the land development process.[3]

Poorly planned land development, from suburban subdivisions to urban city centers, threatens or destroys small, headwater streams and their associated ecosystems. Suburban development often channelizes or buries small streams. In fact, typical urban development during the nation's industrialization period buried most small streams.[4] Because the importance of small streams was not fully understood during much of the 20th century, cities often buried headwater streams and used them as sewer *pipes* to transport waste out of cities.[5] The legacy of these decisions remains as streams are largely absent from urban areas. As a result of stream burial, urban and suburban areas lose the benefit of a highly important service provided by streams – nutrient pollution reduction – which is highly sensitive to alterations in land use, yet vital to keep our water clean.[6]

Destruction of small headwater streams has already impacted many communities resulting in less reliable sources of clean water and potential for increased flooding. Cities and their residents are now reviving these once buried ecosystems and restoring them to vital community assets. This relatively new approach of *daylighting* streams promises not only to improve stream health but improve community livability as well.

This paper aims to explain the importance of small streams and better define their role in our communities. It aims, furthermore, to analyze the effectiveness and value of daylighting streams as a way to restore small, buried streams in urbanized areas. To encourage and empower local communities to implement daylighting where appropriate, this paper will also provide case studies and financing strategies. It ultimately concludes with policy recommendations for including daylighting in stormwater retrofits, flood mitigation, and infrastructure funding.

Fish and wildlife depend on small streams

Small streams, which scientists refer to as headwater streams, exist in a range of geographic settings thereby differences in temperature, light, water chemistry, and substrate type provide diverse habitats for animals.[7] Some headwater streams are characterized as *intermittent*, in which they flow continuously for only portions of the year or *ephemeral* which flow during rainfall or snowmelt but then shrink to become individual pools filled with water. Despite this discontinuous flow, these streams provide habitat for distinct species well adapted to these conditions. Research shows that intermittent streams—even those with periods of no streamflow at all—provide habitat for numerous fish species, including juvenile coho salmon.[8] Those headwater streams with continuous flow, referred to as *perennial*, also provide unique habitat diversity that create niches for diverse organisms, including species of invertebrates, amphibians, and fish who are headwater specialists.[9] Headwater streams also provide refuge during specific animal life history stages specifically in fish and amphibians. Coho and chum salmon as well as steelhead, rainbow, and cutthroat trout migrate into these small tributaries to spawn.[10] Without small streams, these important recreational fish populations, which also bring millions of dollars to economies, would diminish.

DEFINITIONS

Combined Sewer System — Combined sewer systems collect and transport stormwater runoff, domestic sewage, and industrial wastewater in the same pipe for treatment at a sewage treatment plant, before being discharged to a water body.[11] As cities have grown, however, the increase in stormwater runoff during high precipitation events has exceeded the capacity of stormwater conveyance systems resulting in frequent combined sewer overflows in many older cities.

Green infrastructure — Green infrastructure uses natural or engineered systems that enhance overall environmental quality and provides services by protecting, restoring, or replicating natural function. As a general principal, green infrastructure techniques use soils and vegetation to infiltrate, evapotranspire, and/or recycle stormwater runoff.[12]

Grey infrastructure — In the context of stormwater management, grey infrastructure can be thought of as the hard, engineered systems to capture and convey runoff, such as gutters, storm sewers, tunnels, culverts, detention basins, and related systems.

Headwater Streams - The smallest streams in a watershed network which are a source of water for larger rivers. Scientists often use the term headwater to refer to zero-, first-, and second-order streams. Zero-order streams are hollows that lack distinct stream banks. First-order streams are the smallest distinct channels that generally flow from a spring. Second-order streams are formed when two first-order channels combine, whereas third-order streams are formed by the combination of two second-order streams, and so on. Headwater streams can take on numerous forms - from small, clear, heavily-shaded springs, to those that flow intermittently following snow melt or rain, and even desert streams that arise from a spring and run above ground.

Impervious Cover (or, impervious area, imperviousness) — Any surface that cannot be effectively (easily) penetrated by water, thereby resulting in runoff. Examples include pavement (asphalt, concrete), buildings, rooftops, driveways/roadways, parking lots, and sidewalks.

Sanitary Sewer System — A sanitary sewer specifically transports sewage and industrial wastewater from houses, commercial buildings, and industrial areas to wastewater treatment plants. Sanitary sewers are operated separately and independently of storm sewers.

Stream Burial - A process in which streams are directed into culverts, pipes, concrete-lined ditches, or simply paved over.[13] Burial can range in length from a few meters to 100s of meters and is one of the most extreme impacts of urbanization on streams.

Stream Daylighting - Stream daylighting revitalizes streams by uncovering some or all of a previously covered river, stream, or stormwater drainage. Although most stream daylighting involves restoring a stream to a more natural state, other forms include architectural and cultural restoration. Architectural restoration involves restoring a stream to the open air while confining the channel within concrete walls, whereas cultural restoration celebrates a buried stream through markers or public art used to inform the public of the historic path, although the stream remains buried.[14] This report largely focuses on natural restoration daylighting because it provides the most benefits.

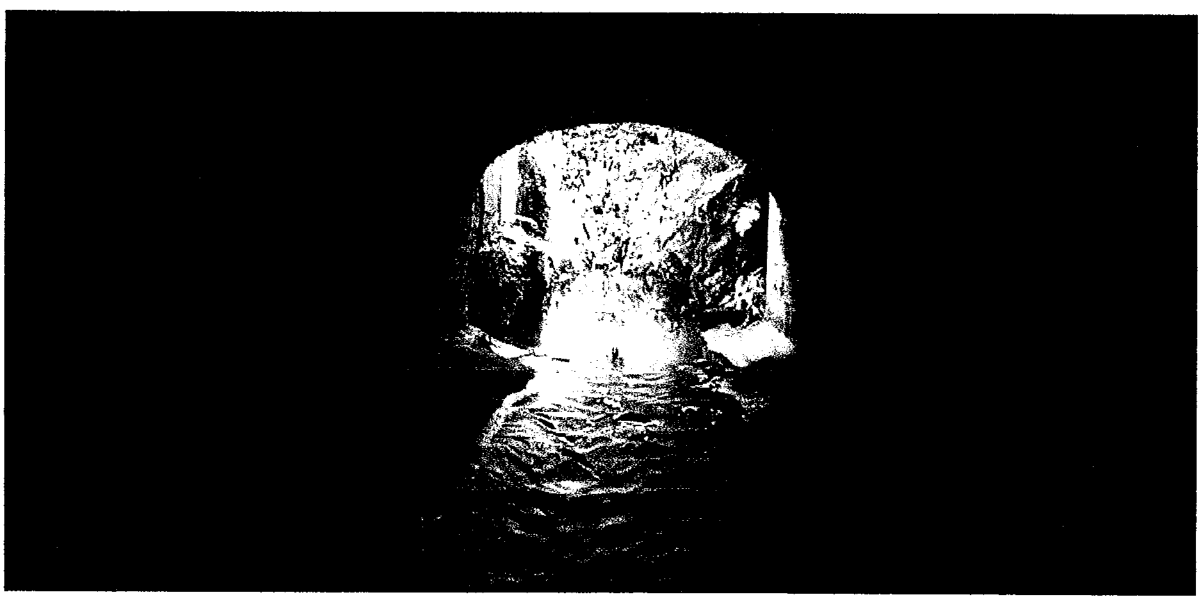
Stormwater (or, runoff) — Precipitation that becomes polluted as it flows over driveways, streets, parking lots, construction sites, agricultural fields, lawns, and industrial areas. Pollutants associated with stormwater include oils, grease, sediment, fertilizers, pesticides, herbicides, bacteria, debris, and litter. Stormwater washes these pollutants through the storm sewer system and into local streams. In addition, because impervious surfaces prevent precipitation from soaking into the ground, more precipitation becomes runoff, and the greater volumes and velocities of stormwater can scour stream and river channels, creating erosion and sediment problems.

DEVELOPMENT EFFECTS ON HEADWATER STREAMS

Channelizing, diverting, and burying headwater streams—all part of a typical development process—unavoidably impact small streams by altering runoff patterns, changing water availability to downstream reaches, and eliminating habitats.[15] In forested, grassland, or other more natural areas, for example, rainfall and snowmelt are stored in vegetation, soil, or surface depressions and naturally infiltrate over time, recharging groundwater supplies, and sustaining streamflow. Urbanization, in stark contrast, often substantially alters the transport of groundwater and surface water within a watershed. In urbanized areas, trees and vegetation are removed, replacing natural filters with impervious hard surfaces including roads, rooftops, and parking lots. In some cases, the natural drainage system of a landscape is replaced with a network of sewer and storm systems all of which have less capacity to store water.[16] Although urbanization effects on urban surface streams are well understood, the detrimental effects of paving over or burying streams in culverts, pipes, or ditches on aquatic systems are only theoretical in knowledge with only a few studies addressing buried streams specifically.[17] For instance, in the Baltimore area, where research has been conducted, findings indicate headwater streams were essentially eliminated from most small watersheds with nearly 73% of headwater streams being buried.[18] This burial likely causes a suite of stressors on communities and ecosystems. Land development impacts the function of small streams through altered hydrology and increased flooding, changes in water supply availability, increased water pollution, and decreased habitat.

Mapping buried streams

Researchers, Andrew Elmore and Sujay Kaushal, at the University of Maryland mapped headwater streams and buried streams in the Gunpowder-Patapsco watershed in Baltimore, Maryland. Their findings are eye opening, revealing that 73% of streams in Baltimore have been buried.[19] The majority of headwater streams remaining are in state parks or other land protection areas. The burial of streams in stormwater pipes greatly increases the connectivity between streams and impervious surfaces, which amplifies the transport of nutrients, road salts, metals, and organic contaminants from urbanized landscapes into larger streams and rivers, deprived of the filtration capacity once provided by small streams. Documenting the extent of stream burial in urban basins through mapping is a first step toward raising awareness of the issues caused by stream burial. These maps can then be used to develop policies for stream protection, restoration, and daylighting.



Buried stream, Molendinar Burn, Glasgow, Scotland | Ben Cooper

Documenting the extent of stream burial in urban basins through mapping is a first step toward raising awareness of the issues caused by stream burial.

Unfortunately, land development consistently degrades streams often causing what is referred to as the ***urban stream syndrome***, with symptoms ranging from a flashier hydrograph (more frequent, larger flow events with faster ascending and descending hydrograph), altered channel stability, reduced biotic richness, and elevated concentrations of nutrients and contaminants.[20] Urban streams tend to be more *flashy*[21] primarily driven by impervious surfaces and piped stormwater drainage systems.[22] Flashier streams lead to increased channel and stream bank erosion, which increases sediment. This sediment then not only degrades water quality and aquatic habitat but also excessively burdens downstream communities by increasing flooding and drinking water treatment costs. Large deposits of sediment can overfill streams and floodplains, greatly increasing flood potential.[23] High impervious surface cover of roads, rooftops, and parking lots (and conversely a lack of natural cover) and a flashier hydrograph also mean streams cannot store and retain nutrients and other pollutants effectively. From a strictly ecological perspective, extreme high and low flows caused by urbanization exert pressure on stream fish and wildlife populations, threatening their potential success to thrive and reproduce.[24] Research has found that groundwater recharge decreases with urbanization, due to fast runoff volumes and impervious surfaces, where water is unable to recharge baseflow,[25] leading to less drinking water availability.

Small stream hydrology and flooding impacts

Burying and destroying small streams throughout the landscape changes the hydrology, resulting in increased flooding. Channeling stormwater away from certain areas via traditional stormwater management techniques (grey infrastructure), such as paved channels or pipes, rather than providing infiltration or retention on-site, transfers hydrologic impacts downstream causing increased flooding.[26] These adverse hydrologic effects caused by urban development, moreover, are often greatest among small streams in a watershed.[27] The result of urbanization and lack of well-planned stormwater management is typically flash flooding – resulting in floods that peak more rapidly than those in less impacted watersheds.[28]

Flooding often results from land development, including the burial of small streams, and is a direct result of a loss of water absorption capacity within the landscape. The shape or morphology of the channel also impacts downstream flooding rates. Whereas water velocity is slowed in natural headwater streams with rough streambeds, woody debris, and irregularly shaped channels,[29] conversely with development, straightening, deepening, or piping small streams alter ecological function by making the hydrology smoother, essentially transmitting the flood downstream faster.[30]

Urbanization markedly increased flood magnitudes in the U.S. during much of the 20th century.[31] Weather services report an average of 110 deaths per year in flood related accidents.[32] During the same time period, flood costs in the U.S. are estimated at an annual average of two billion dollars.[33] In Salt Creek, Illinois, for example, during the last half of the 20th century large floods have increased by about 100% (from 1,000 cubic feet per second (cfs) to 2,000 cfs) while small floods have increased 200% (from 400 cfs to 1200 cfs).[34] One study estimated that an increase in impervious surface from 0% to 25% in a watershed increased the likelihood of a flood event of a specific size occurring every 100 years to one likely occurring every five years, and could become an annual event when impervious cover reaches 65%.[35] Both studies highlight the direct relationship between urban land use and increased flood impacts on communities and rivers. To put imperviousness in perspective, within the Potomac River watershed in the Washington, DC area, over 25% is impervious, reaching as much as 45% in some urban areas.[36] The Bronx River watershed (New York) ranges from 44% imperviousness in urbanized areas to less than 2% in smaller, less developed tributaries.[37] As development continues with increased imperviousness, we are likely to see enhanced flooding in communities.

Water quality

Headwater streams and the presence of riparian buffer zones in their natural state filter pollutants, including nutrients, providing high quality water for communities. These small streams and their riparian corridors absorb pollutants via uptake by in-stream and surrounding riparian vegetation, algal uptake, and microbial uptake resulting in less water pollution released into stream flows. Streams do not have to flow year-round to make significant contributions to water quality by processing and retaining nutrients.[38] Fertilizers and other pollutants enter stream systems during storms and other times of high runoff, the same time that ephemeral and intermittent streams are most likely to have water and the capacity to process nutrients.[39] When human actions, such as encasing streams in pipes, sever within stream and riparian buffer connections, poorer water quality, degraded fish habitat downstream, and loss of capacity to process nutrients result.[40] Protecting or restoring these small streams, therefore, translates into less water pollution and cleaner water for communities.

Suburban and urban development impacting small streams places a burden on communities, particularly with regards to clean water and flooding, by increasing management costs and potential health risks. Because development creates impervious surfaces that prevent infiltration, stormwater runs rapidly into streams carrying heavy metals, bacteria, oil, gas, and an array of pollutants that foul our waters and put our health at risk. Not only are these pollutants detrimental to public and stream health, but the rapid movement of stormwater overwhelms a streams natural capacity to absorb water resulting in erosion of stream banks and flash flooding. Controlling stormwater, building and planning effectively in cities and suburbs, as well as revitalizing buried streams can all improve water quality for communities while saving these communities money.

DAYLIGHTING AS A POTENTIAL TOOL TO RESTORE SMALL STREAMS AND COMMUNITY BENEFITS IN URBANIZED AREAS

What is daylighting?

Daylighting projects expose some or all of a previously covered river, stream, or stormwater drainage.[41] Daylighting exists in several forms including:

1. Natural restoration – restoring a stream to natural stream conditions;*

2. Architectural restoration – restoring a stream to open air, flowing water but within a constructed channel; or

3. Cultural restoration – celebration of a buried stream through markers or public art used to inform the public of the historic stream path, although the stream remains buried.[42]

*It is important to note that often natural restoration will have a constructed channel but the channel recreates a natural system with a porous, natural streambed rather than a concrete lined channel as with architectural restoration.

Research being conducted on a buried stream | Michael Pennino

Although all of these types of daylighting have potential benefits, natural restoration will be most effective overall for flood mitigation, water quality, and stormwater control. While architectural and cultural restoration have important benefits, including reconnecting people to their rivers, this paper focuses on natural restoration unless otherwise stated. It also provides myriad examples of daylighting projects throughout the text with additional examples provided in **Appendix 1.**

The plan for natural restoration daylighting will depend primarily on the original alterations which occurred to the stream – depending on whether the stream is completely buried, whether construction of permanent infrastructure on floodplains and banks are present, or introduction of nonnative species that cannot be removed are present.[43] Stream restoration should enhance the stream to the least degraded and most ecologically dynamic state possible given the context.[44] Essentially, restoration is a regionally and context dependent activity but physical, chemical, and biological stream improvements should be an overall goal: "Successful restoration projects should not be viewed as an all or nothing single endpoint, but rather as an adaptive process where iterative accomplishments along a predefined trajectory provide mileposts towards reaching broader ecological and societal objectives."[45]

Benefits of daylighting

Daylighting results in numerous benefits, including increased hydraulic capacity for flood control, slowing water velocity to reduce downstream erosion, removal of water from combined sewer systems resulting in fewer sewer overflows, community and ecological revitalization, as well as water quality improvements.[46] These multiple ecosystem benefits, coupled with numerous community amenities, make daylighting an attractive choice to address stormwater or ecological concerns resulting from stream burial. Not only does daylighting provide numerous benefits to the community, daylighting streams provide enhanced recreation opportunities as well. For example, projects might include enhancing recreational space, reconnecting adults with and introducing children to nature, developing an outdoor laboratory for schools, increasing property value, benefiting nearby businesses by creating a space that attracts people, and creating an urban greenway with bike trails and walking paths. Daylighting may also be quite cost effective when compared to repairing a failing culvert. In a combined sewer system where both stormwater and untreated waste water are recombined, the technique can also provide an alternative to conventional sewer separation by diverting stormwater out of the sewage system, while also providing additional water quality and flood mitigation benefits. The design can also provide more aesthetic amenities compared to a strictly grey or traditional infrastructure approach.[47]

Daylighting may also be quite cost effective when compared to repairing a failing culvert.

Nutrient retention benefits

The ecological and water quality benefits gained by revitalizing a previously buried stream are best illustrated by nutrient pollution removal. Because of a small stream's significant capacity to store and transform nutrients – thereby allowing their slow and steady release rather than the short-term pulse that results in pollution and algal blooms – functioning small streams in undeveloped areas provide an essential service for communities and ecosystems.[48] Compared to large streams, small headwater streams have more water in contact with the stream channel, allowing nutrient particles to be removed from the water column quickly. Headwater stream communities of fungi, bacteria, algae, and aquatic insects consume nutrients (inorganic nitrogen and phosphorus) converting them into less harmful, more biologically useful materials.[49] Without this valuable service of nutrient uptake, downstream reaches receive high amounts of nitrogen and phosphorus, causing eutrophication in reservoirs and coastal areas, which trigger green algal blooms coupled with the less visible dead zones, areas of low dissolved oxygen.[50] These dead zones have detrimental effects on fisheries in well-known areas such as the Gulf of Mexico and the Chesapeake Bay. While nutrient retention will be highest in undeveloped headwater streams, daylighting buried streams will likely enhance nutrient retention, and even more so if coupled with both floodplain restoration and channel habitat improvements.[51] In fact, studies currently underway are showing promising trends of stream daylighting significantly improving nutrient uptake and stream metabolism compared to buried stream channels.[52]

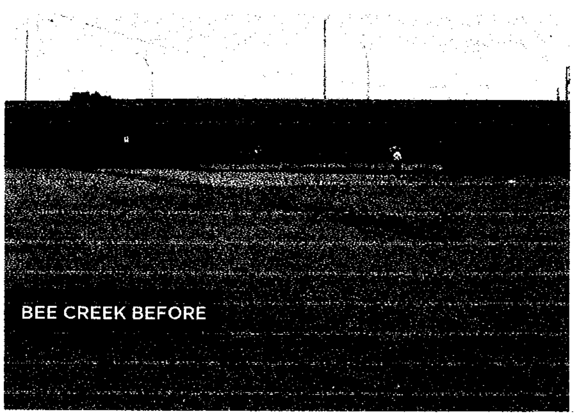
Daylighting streams for flood mitigation, Bee Branch Creek, Iowa

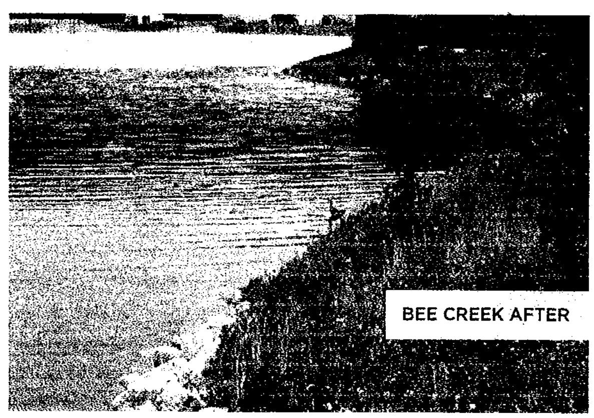
Citizens of Dubuque, Iowa, experienced a tornado in May of 1999 and while waiting out the storm, their basements also began to flood. Hundreds of basements flooded, pressuring the city to take action. The city invested $275,000 on an engineering study which determined that 1,150 homes and businesses were at risk of flood damage during heavy rains.

Three projects were then recommended to eliminate the high flood risk: 1) Carter Road detention basin; 2) West 32nd detention basin; and 3) the Bee Creek restoration project. The Bee Creek restoration project includes the daylighting of one mile of buried stream making it eligible for Clean Water State Revolving Funds (SRF). As defined by EPA's Green Project Reserve guidance, "daylighting is established as a categorical green infrastructure project."[53] The Upper Bee Branch Creek project will restore the stream that was once buried and channeled through storm water pipes to its natural hydrology. The restored creek will be 15-25 feet in width with a 150-180 foot floodplain buffer.

The project addresses stormwater flooding at a site that has been declared a presidential disaster six times in the past dozen years as a result of the public and private property damage following heavy rains. Construction of two upstream detention basins further addresses the flooding issue. The project obtained funding through the Environmental Protection Agency's Green Project Reserve by daylighting 4,500 feet of buried creek, including restoration of the floodplain, constructing rain gardens and bioswales to promote stormwater infiltration, planting over 1,000 trees along the stream's edge, and installing pervious pavement. Other project highlights include a 4,500 foot hike/bike trail which connects 26 miles of Heritage trail between Dubuque and Dyersville, Iowa to the Mississippi River and Mines of Spain trail system as well as an outdoor amphitheater and interpretative signs outlining the history of the creek.

Construction of the Lower Bee Branch began in fall of 2010 and was completed in fall of 2011. Upper Bee Branch is expected to be completed by summer 2014. The overall project costs total $59 million funded using a combination of general obligation bonds, Iowa Disaster Relief funds, SRF, City of Dubuque stormwater utility fees, Federal Highway Administration funds as well as contributions from local businesses, organizations, and citizens. Additionally, a State $2.25 million River Enhancement Community Attraction and Tourism (RECAT) grant was awarded for amenities associated with the Bee Branch Creek restoration project and a state $3.9 million I-JOBS II grant was awarded for the Lower Bee Branch Creek restoration project based on the disaster prevention measures associated with the project. Up to a $4.4 million forgivable loan was approved for the Upper Bee Branch Creek restoration project through the SRF/EPA Green Project program based on the environmental benefits of daylighting the Bee Branch Creek.

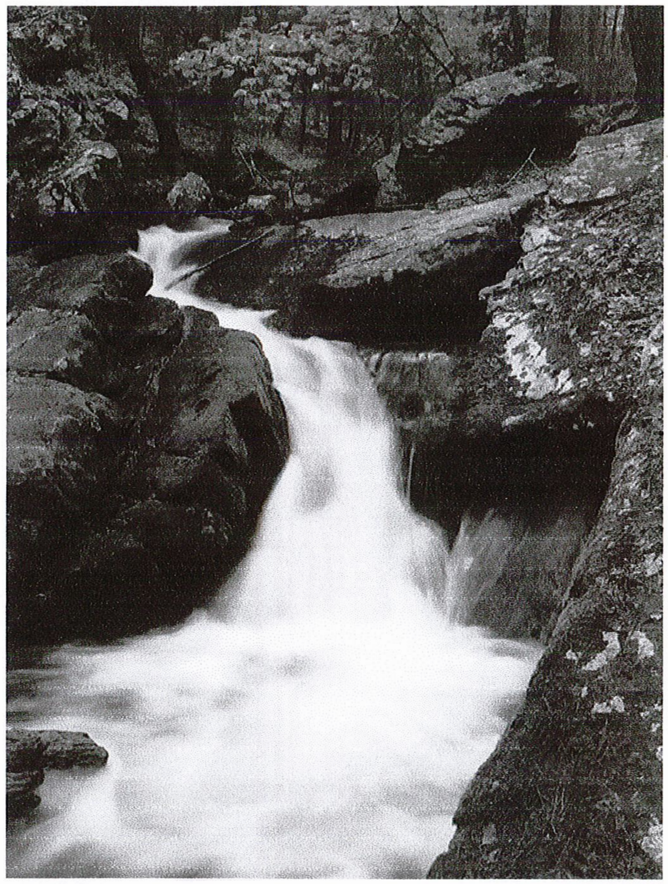




Bee Branch Creek before and after daylighting, Dubuque, IA | City of Dubuque, IA

Flood mitigation benefits

Using daylighting as a flood mitigation strategy offers another community benefit. Heavy urbanization along urban centers is the principal reason warm season thunderstorms result in flash flooding in watersheds.[54] This is especially prevalent in cities in the eastern United States. As discussed previously, altered stream hydrology is tied to expanding storm drainage networks and increased impervious surfaces, both causing less capacity for water storage and sensitivity to short duration rainfall rates, likely leading to flash flooding.[55] Moreover, urban river basins, because of their concentrated population and economic assets, have the potential for high flood damage.[56] Daylighting streams can mitigate flooding in several ways. First, if floodplains are properly restored, stream daylighting will increase hydraulic storage capacity. Second, by reducing channelization water is slowed, decreasing downstream flooding potential. Lastly, choke points such as culverts, where water often backs up causing localized flooding, are removed. Flood problems can be further addressed by diverting urban runoff from storm systems by capturing, treating, and reusing water on-site.[57] Flood mitigation will be most effective by daylighting small streams, revitalizing previously buried floodplains, and integrating green infrastructure practices to control stormwater where it falls.



Flowing headwater stream, Swift Run, Bald Eagle State Park, Howard, PA | Nicholas A. Tonelli

Economic benefits of daylighting

Daylighting projects also offer economic benefits for the community. Not only has daylighting proven to be cost effective compared to repairing failing culverts and designing new pipes,[58] but many dollars can be saved keeping stormwater out of combined sewer systems and reducing the corresponding combined sewer overflow treatment or upgrade costs. These unique projects can also revitalize neighborhoods, increase property value, and benefit nearby businesses by creating an amenity that attracts people to the area on evenings and weekends.[59] In contrast, buried streams result in a range of problems, such as abandonment of buildings as observed in Boston and Philadelphia.[60] For instance, buried streams can trigger a series of events including drainage problems, flooded basements, rising insurance costs linked with owners eventually moving out, and a lack of reinvestment that eventually results in neighborhood declines.[61] Planners are beginning to notice these trends associated with proximity to buried streams, which although have yet to be observed everywhere, are worth considering by communities.

Although the best solution would be to protect the stream from burial, planners and city managers can address flooding and drainage problems by daylighting streams and controlling stormwater. Daylighting also has the potential to reduce municipal budgets as open streams require minimal maintenance compared to deteriorating culverts. Cost-reduction may also be achieved because stream daylighting represents a one-time cost, versus ongoing investments needed to maintain culverts.[62] Mitigating costs can additionally be achieved when buried streams are removed from combined sewer systems. With this modification, stream water does not mix with sewer discharges and is prevented from flowing to the wastewater treatment plant. By reducing the amount of water requiring treatment, including sediment removal, maintenance and treatment costs are reduced.

There are also potential job creation opportunities associated with building and maintaining a stream or park, further stimulating the local economy.[63] Of course, the creation and maintenance of these jobs will depend on the market for daylighting and stormwater maintenance. As more communities recognize the value of daylighting and adopt sustainable practices, the demand for green jobs will increase. Non-profit groups such as Sustainable South Bronx in New York provide training for green collar jobs in infrastructure implementation and maintenance. The organization reports that prior to training, nearly all students were on public assistance; however, after the training, 80% of graduates hold well-paying, steady jobs while 15% are attending college. Daylighting streams coupled with stormwater maintenance can enhance the value of cities, breathing new life into revitalized areas while also creating jobs and workforce development opportunities for its citizens.

Daylighting streams for community revitalization, Arcadia Creek, Michigan

Arcadia Creek, Kalamazoo, Michigan | Downtown Kalamazoo, Inc

Arcadia Creek in Kalamazoo, Michigan, was buried underground for almost 100 years before portions were daylighted as part of a major downtown redevelopment. This project highlights one of the most highly urbanized locations to be daylighted. While the stream was buried, flooding was frequent as the culvert containing Arcadia Creek was not large enough to handle increased runoff. City engineers researched replacing the culvert but found daylighting the creek to be cheaper.[64] Construction of the project was between 1982 and 1992 with the project being completed in 1995. The total length daylighted was 1,550 feet with total project cost at $18 million, $7.5 million specifically for daylighting. Post daylighting, downtown businesses no longer have to pay for flood insurance.[65] This downtown amenity now hosts over five major summer festivals which generates $12 million in revenues

To fund the revitalization, the downtown development authority issued bonds based on tax-increment financing. Those bonds are now being paid back by property tax revenues which have increased from $60,000 to $400,000.[66]

Post daylighting, downtown businesses no longer have to pay for flood insurance.

Future progress

While there are a number of strong examples of daylighting to demonstrate its community and economic benefits, as with many restoration projects, daylighting lacks robust, comprehensive data and modeling of its environmental improvements. Currently, limited scientific research has been conducted on daylighting projects (but see Myer et al. 2005, Elmore and Kaushal 2008, ongoing research at the Environmental Protection Agency's National Risk Management Research Laboratory).[67] However, because the effects of urbanization on streams are well known, we can make inferences based on known urbanization effects, healthy stream function, and restoration research about the benefits of stream daylighting. While studies, for instance, have suggested nutrient retention in daylighted streams is better than in piped steams,[68] further investigation is needed to improve the understanding and application of stream daylighting projects.

As more daylighting projects are conducted, monitoring efforts should be used to measure actual benefits. We know removing culverts can enable movement of fish upstream and are important in improving connectivity of river systems but additional data would be useful to improve, modify, and target projects.[69] Monitoring is essential to improve guidance on daylighting. A proper database, as well as careful attention to how data are recorded, shared, and published (see Bernhardt et al. 2005 for details on a comprehensive restoration database and Wild et al. 2011 for a daylighting website)[70] would greatly improve daylighting data thereby improving implementation. These monitoring efforts could further assist in targeting project implementation while also identifying areas where daylighting may not be a viable strategy.

Challenges to daylighting

Although daylighting offers many community, ecological, and economic benefits, there are certain challenges associated with these projects. Streams in urbanized areas are generally buried beneath concrete and thus daylighting requires major excavation. Not only does daylighting require excavation of unwanted material, but restoration of some floodplain would provide the greatest benefit and is sometimes not physically possible in highly developed areas due to constraints imposed by adjacent infrastructure. If stream daylighting is possible, displacement of existing use areas such as parking lots are also problematic as well as obtaining necessary funding. Issues often result from multiple agencies and permitting coordination with a question of concern with who is responsible for maintaining the site. These issues may become more pressing with higher degrees of urbanization.[71] These challenges, like any met with implementing new projects, can be solved with careful design, planning, and outreach.

Saw Mill River after completion of daylighting, Yonkers, NY | Groundwork Hudson Valley

Daylighting Saw Mill River, Yonkers, New York

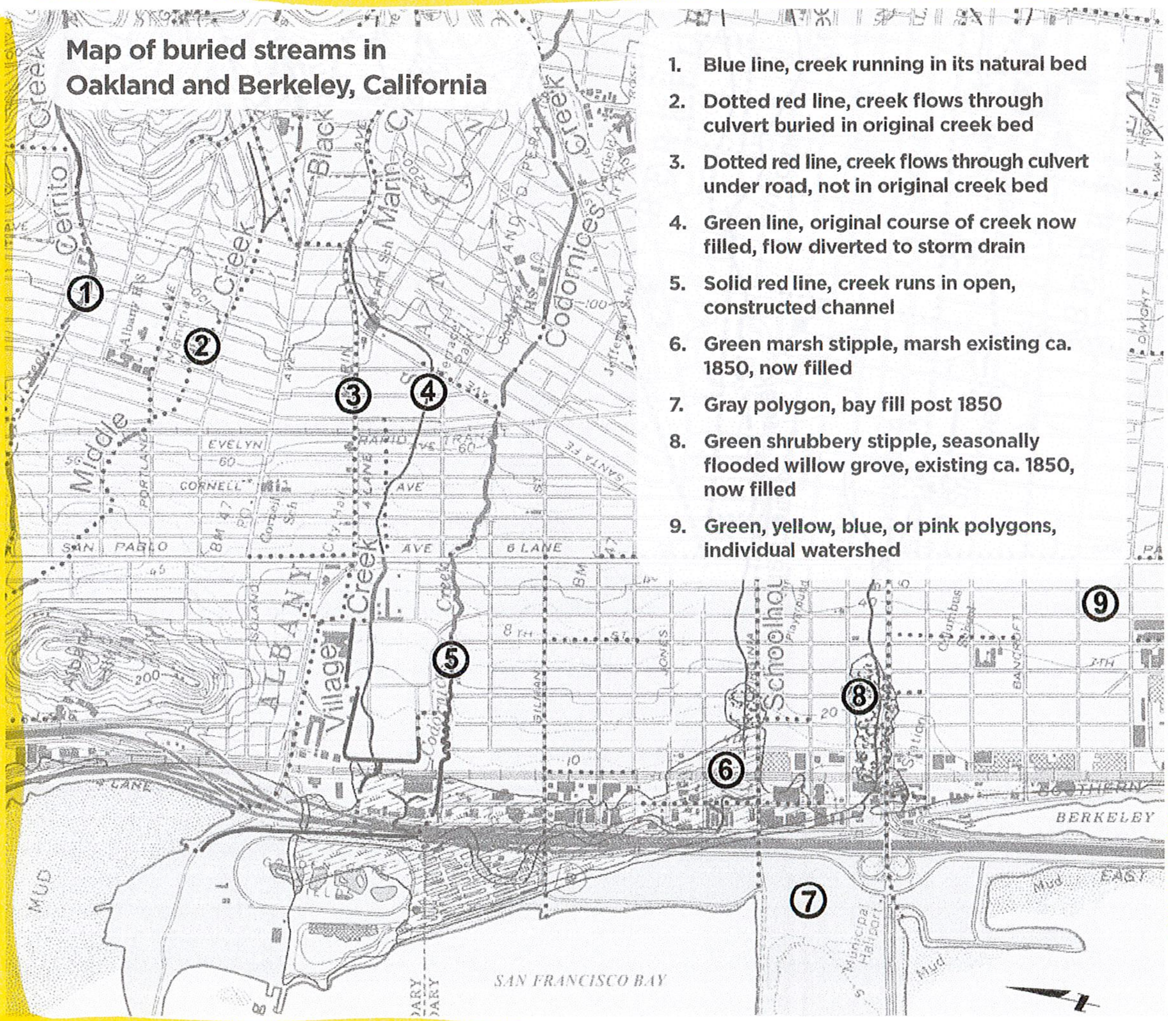
The Saw Mill River, which flows through Westchester County before emptying into the Hudson River in Yonkers, was buried in the 1920's in response to Yonkers' development and rapidly expanding population. Through the 1990's, pollution levels in the Saw Mill River were high due in part to its industrial past, rampant illegal dumping, and sewage overflows during flooding events. Research conducted by U.S. Geological Survey found the stream contained the highest concentration of metals from all sites measured in the National Water Quality Assessment Program. Yonkers received $250,000 from the U.S. EPA Brownfield Program to daylight the river and redevelop an associated downtown brownfield site.

Groundwork Hudson Valley, an environmental justice non-profit that works with communities to improve their physical and social environment, used the funds to establish the Saw Mill River Coalition in 2001 and began initial research and public discussion. An architect for preliminary daylighting design was also commissioned. Eight grants totaling $278,776 were awarded to Groundwork Hudson Valley through the New York State Department of Environmental Conservation Hudson River Estuary Program (HREP) from 2002-2007, supporting numerous Saw Mill River Coalition projects. Essentially, HREP grants acted as seed money allowing the Coalition to move forward with daylighting while striving for a plan that focuses on habitat and water quality. The grants also provided opportunity to leverage other funding sources. Numerous other grants also assisted with daylighting Saw Mill River.[72]

The Saw Mill River daylighting project was initiated in December 2010 in Yonkers, New York. The project created 13,775 square feet of aquatic habitat. Plantings were also made along the floodplain and within the stream to attract insects beneficial to the American eel and various Hudson River fish. The daylighting of Saw Mill River was the centerpiece of revitalizing the space for hosting outdoor ecological workshops and musical performances as well as a providing a reading area and wireless internet, all of which incentivize residents to come downtown. The daylighting project has also sparked a downtown revitalization project with plans for a new minor league ballpark and new housing and retail development. The daylighting was completed in December 2011 with a cost of $19 million. A natural river now parallels an old underground Army Corps of Engineers flume; the existing flume serves as an overflow channel to protect downtown from flooding.

Before proceeding with a daylighting project, however, cities should think about how best to engage the community. Many citizens likely have no knowledge that buried streams even exist in the area. Proper communication and education will ensure more meaningful results. Public interest can be enhanced by creating disappearing stream maps, which indicate paths of buried streams, as well as locations of remaining open space.[73] Cities such as Oakland, California; Baltimore, Maryland; and Portland, Oregon, have prepared buried stream maps used for restoration, protection, and education efforts.[74] These maps, such as the image from Oakland, California, below, give citizens a sense of where streams exist within the community while emphasizing the sense of place within a watershed. Interest and approval are also peaked when citizens are involved from the beginning rather than as an afterthought.

Daylighting projects require active community outreach and engagement, but many case studies prove daylighting benefits to cities. Yonkers, New York, for instance, centered its city revitalization effort on daylighting Saw Mill River. The project revitalized aquatic habitat while also creating a space for outdoor ecological workshops, musical performances, as well as a reading area, all of which are incentives to encourage residents to spend time downtown. Dubuque, Iowa, daylighted Bee Branch Creek to address stormwater flooding at a site that had been declared a presidential disaster six times in the past dozen years, resulting in high levels of public and private property damage. These projects can create excitement within the community as work is done to revitalize and bring back something which was originally lost.



Creek and Watershed Map of Oakland and Berkeley, California | Janet M. Sowers and Christopher M. Richard

Daylighting using funding from the American Rivers - EPA Potomac Highlands Grant Program

The city of Staunton, Virginia, and city partners' aim to improve the water quality of Peyton Creek, strengthen Staunton's green infrastructure, encourage desirable redevelopment, provide permanent open spaces, conserve natural resources and prevent the spread of urban sprawl. With these goals in mind, Staunton is currently daylighting Peyton Creek, which eventually drains to the South Fork of the Shenandoah River. The Virginia Department of Environmental Quality listed Lewis Creek, immediately downstream of Peyton Creek, on Virginia's 1996 Section 303(d) list for Clean Water Act violations based on benthic invertebrate assessments. Restoring Peyton Creek will greatly improve the water quality in both Peyton and Lewis Creeks. Riparian buffers will provide increased filtration of polluted runoff, stream bank stabilization, and reduced sedimentation. The project will remove a total of 900 linear feet of stream from culverts and restore the stream to free flowing conditions, as well as plant 2.8 acres of riparian vegetation. A rain garden to reduce stormwater runoff will also be built. The Peyton Creek daylighting project will address the environmental water quality concerns while also improving socio-economics of the city. The city and partners will rehabilitate a blighted property, improve and revitalize the North Central Avenue Business District, increase pedestrian traffic, and highlight the importance of Peyton Creek, all while encouraging additional daylighting projects in the city. The project cost is $209,244 with funding provided by American Rivers-EPA Potomac Highlands Grant Program.

Daylighting projects, although quite expensive, can be a cost effective investment when evaluating the full range of multiple benefits provided. Depending on the scope of the project and length of stream being daylighted, costs will vary. A general rule of thumb is $1,000 per linear foot of stream daylighted; however, case studies have ranged in values from $15 to $5,000 per linear foot.[75] These costs will inherently increase or decrease depending on a number of factors including: the extent of urbanization and adjacent infrastructure, whether volunteers or in kind donations are used, whether the stream is on public or private land, if property must be purchased, or additional community amenities are added such as parks and greenways. Potential funding sources for daylighting projects are listed below in **Appendix 2**.

POLICY ANALYSIS

While stream daylighting is an important tool to integrate into water management, a number of existing policies fail to facilitate this approach. The following analysis evaluates several of the primary federal policy drivers in urban areas to determine how they encourage or present barriers to stream daylighting.[76] Numerous local policies, however, such as zoning and building codes, could affect daylighting projects that are not addressed here.

Stormwater policy

While stream daylighting can play a role in reducing polluted stormwater runoff, it is not commonly used, in part because there are no specific retrofit requirements to reduce existing pollution. Stormwater in municipal areas is regulated under the Clean Water Act (CWA) by the Environmental Protection Agency (EPA). Current stormwater regulations and permits attempt to reduce impacts from new construction by requiring developers to mitigate stormwater discharges both during development and after completion of the project. Stormwater permits are required for cities with populations over 50,000, densely urbanized areas (which could have populations less than 50,000), industrial facilities, and construction activities disturbing one acre or greater. Although these address stormwater for certain categories, little has been done to reduce pollution from existing impervious areas and there are no specific retrofit requirements to reduce stormwater pollution under the CWA. Retrofitting existing impervious areas, using techniques including daylighting, could substantially improve water quality as these areas are significant sources of stormwater runoff, and ultimately will be necessary to meet water quality standards given the pollution contribution from existing developed areas.

The EPA currently has an opportunity to integrate retrofit requirements into the municipal stormwater program through phased planning and implementation as it updates regulations governing the stormwater program.[77] In addition to the benefits to water quality, a regulatory requirement for retrofits to reduce existing impervious area may spur development of new practices and help to establish a comprehensive body of information about the performance of various stormwater mitigation techniques including daylighting, further increasing their adoption. Retrofit requirements could be directed at both publically owned properties (e.g., right of way) and private property through permits or other mechanisms to reduce imperviousness. In turn, this would facilitate the use of daylighting as one retrofit tool in highly urbanized areas with benefits for clean water and flood reduction.

Daylighting streams during retrofits, Blackberry Creek, California

Blackberry Creek was historically a tributary of Middle Creek until the late 1940s – 1960s when the City of Berkeley buried portions during urban development. Portions of Blackberry Creek were buried underneath Thousand Oaks Elementary School in Berkeley, California. After the stream burial, the area became prone to frequent flooding. During the Loma Prieta Earthquake in 1989, however, structural damage occurred to the school. In 1992, when funds became available for upgrades, the Parent Teacher Association proposed daylighting as a means to mitigate localized flooding while also integrating the creek into the school's science curriculum.[78] The creek was daylighted as part of an earthquake retrofit with $144,000 in funding provided by the California Department of Water Resources Urban Stream Restoration Program. Native dogwoods were also planted along the banks. Blackberry Creek has now become a treasured feature of the school while also addressing flooding issues. The school has now become a magnet school focusing on ecology with the creek used as an outdoor laboratory. According to ten year post-daylighting observations, the creek has not overflowed its banks despite the occurrence of a 10 year flood event and no localized flooding has occurred.[79]

Stormwater runoff, Washington, DC | Lynette Batt, American Rivers

Flood Policy

Despite the role of functioning small streams in mitigating flood losses, currently, stream daylighting and protection of small streams is not considered under federal flood policy. Flood policy in the U.S. is largely driven by the National Flood Insurance Program (NFIP) administered by the Federal Emergency Management Agency (FEMA). Through the NFIP, communities that meet basic floodplain management requirements are eligible to purchase flood insurance through the federal government. FEMA also helps communities to undertake flood mitigation activities that reduce future flood damages through several grant programs. Stream daylighting, furthermore, could be better integrated into both these grant programs. First, FEMA's grant programs all include "minor localized flood reduction projects" as eligible activities.[80] To qualify for funding, projects should "lessen the frequency or severity of flooding and decrease predicted flood damages, such as the installation or modification of culverts and stormwater management activities such as creating retention and detention basins."[81] The overall objective of these grant programs is to reduce federal flood insurance claims by engaging in flood mitigation prior to a flood. Protection of headwater streams or restoration efforts such as daylighting, along with watershed scale planning, can lessen the frequency or severity of localized flooding and thus, should all be considered by FEMA as eligible strategies for funding under FEMA's hazard mitigation programs. Likewise, disaster relief funding should incentivize communities to implement flood mitigation with non-structural solutions (i.e., green infrastructure and stream daylighting) that also reduce their flood risk and long-term recovery costs. With increasing climate change, these non-structural solutions will be even more important as many regions will experience frequent and more severe flooding.

Second, there are opportunities to integrate protection and restoration of small streams as part of FEMA's floodplain management approach. The NFIP only requires participating communities to undertake minimum floodplain management requirements. To encourage communities to go beyond the minimum in order to protect their citizens and property, FEMA created the Community Rating System (CRS). Under this voluntary program, property owners' flood insurance premiums are discounted to reflect the mitigation actions taken by the community.[82] These actions can include efforts to: reduce flood damage to existing buildings; manage development in areas not mapped by NFIP; protect new buildings beyond the minimum NFIP protection level; help insurance agents obtain flood data; and help people obtain flood insurance.[83] In 2013, the CRS is expected to be updated to increase the credits offered to communities that preserve open space, protect natural floodplain function, and manage stormwater. As part of this update, the CRS should encourage innovation with techniques such as stream daylighting that can reduce a community's flood risk.

Citywide policies promote daylighting

The City of Zurich, Switzerland provides an excellent model for effective city policies that promote stream daylighting. Based on field investigations with old maps as reference, the existence of buried streams and potential for daylighting was evaluated in Zurich. After assessing the need for space, as well as the legal and technical aspects of daylighting specific stream sections, the study found over 40 km of streams could be daylighted or revitalized (streams which were not buried but needed habitat improvements) in the city. Since the project was initiated in 1988, more than 40 projects and over 20,000 meters of stream have been daylighted or revitalized. These daylighting projects have diverted 300 liters per second or 10.6 cubic feet per second (cfs) of stormwater runoff from the combined sewer system. This diverted volume equates to nearly 37% of stormwater runoff not entering into Zurich's wastewater treatment plant, thereby contributing to a significant reduction not only in wastewater treatment costs but also to loading within the combined sewer system.[84]

Federal Water Infrastructure Funding - State Revolving Funds

Clean Water and Drinking Water State Revolving Funds (SRF) are two programs in which monies are appropriated by Congress each year and then distributed to states. The funds provide low-interest loans to communities to undertake wastewater, stormwater and drinking water infrastructure projects to improve public health and the environment.[85] While billions of dollars have improved public health and water quality, the great majority of funding has been used for large, centralized infrastructure such as drinking water treatment plants and distribution systems as well as wastewater treatment plants and collection systems. However, a much broader array of projects are eligible for this funding, including nonpoint source pollution control, green infrastructure, water efficiency, and stream restoration. Since 2009, some of this funding has been dedicated to more innovative purposes, including green infrastructure and water and energy efficiency, and the demand from the states has well outstripped availability.[86] While stream restoration is still a minor use of funds, there are examples.[87] Iowa, for instance, used $4.4 million from the SRF as part of the Bee Creek daylighting project mentioned above.

Daylighting should continue to be funded and additionally encouraged through the State Revolving Funds.

Daylighting should continue to be funded and additionally encouraged through the SRF because of proven water quality benefits. Daylighting can also reduce demands placed on existing wastewater infrastructure as illustrated in the case study on Zurich, Switzerland. Dedicated funding for innovative projects should be continued and increased to support state demand for green infrastructure projects to address water quality problems and help reduce the burden on existing infrastructure. More importantly, removing state barriers to funding innovative green techniques such as daylighting is key. States should revise their funding criteria to take environmental restoration into account to ensure that such projects can compete fairly for funds against bigger projects. Additionally, states can choose to provide grants instead of loans to facilitate projects that are more innovative thereby allowing accessibility to non-traditional recipients, who can take an active role in achieving ecological and water quality benefits.

Additional funding sources for communities are referenced in Appendix 2.

Removing barriers to implementation

Stream daylighting is a relatively new tool for urban water management. As with any new approach, there are questions about how daylighting fits into the existing regulatory framework and about potential project costs. However, mechanisms which can reduce barriers to daylighting can greatly improve integration as a viable option for mainstream water management as part of achieving clean water regulatory compliance. Enhancing scientific research and awareness of innovative practices, like daylighting, can help overcome local skepticism to aid in implementation.

Legal and regulatory barriers can also be changed to further facilitate daylighting in stormwater requirements, flood management, and infrastructure funding. Other avenues for daylighting integration could be through reviewing state policies and providing incentives for using sustainable practices. Preventing stream burial in the first place, furthermore, is the ideal scenario, and communities can develop stream protection ordinances that discourage this practice.

RECOMMENDATIONS

1. **Additional scientific research and comprehensive monitoring needed to maximize results.** Numerous community benefits of stream daylighting have been outlined within this paper and demonstrated in case studies; however, the need for further and more comprehensive research and monitoring is of high importance. Monitoring efforts will improve scientific data on daylighting allowing for more comprehensive guidance for future projects. The ability to establish which streams within an urbanized setting should be restored in order to achieve maximum water quality (nutrient retention) and water quantity (flood mitigation) benefits is of significant importance. Researchers who can provide applied information on headwater streams, nutrient retention, and hydrology to communities who are implementing daylighting would vastly improve the mechanisms for how daylighting sites are chosen. Models incorporating data on hydrology, historical stream boundaries, precipitation, pollution levels, political boundaries, urban development, and other green infrastructure projects could aid in determining potential daylighting sites. These sites could then serve as pilot projects within the community. Planning should be done in a way to daylight streams in the most effective areas while also considering other green infrastructure projects where both could complement one another. Moving from single demonstration projects and toward more ecosystem or city wide approaches that maximize water quality, water quantity, and community revitalization benefits should be a priority.

2. **A standardized daylighting database should be utilized.** Case studies highlight the benefits within a given community but a more comprehensive database with a set of standardized, measurable values would vastly improve not only stream daylighting but our understanding of urbanization effects on ecosystems. Data gathered from these monitoring studies could also provide values for the influence of daylighting on the resilience of urban stream ecosystems. A standardized database, utilized by researchers, would improve daylighting implementation, making it easier for interested communities to access the successes and failures of daylighting, thereby improving future projects. (It should be noted that a daylighting site has been established by Wild et al. 2011. This site or a universal restoration database as in Bernhardt et al. 2005 should be utilized and funded to ensure success.)

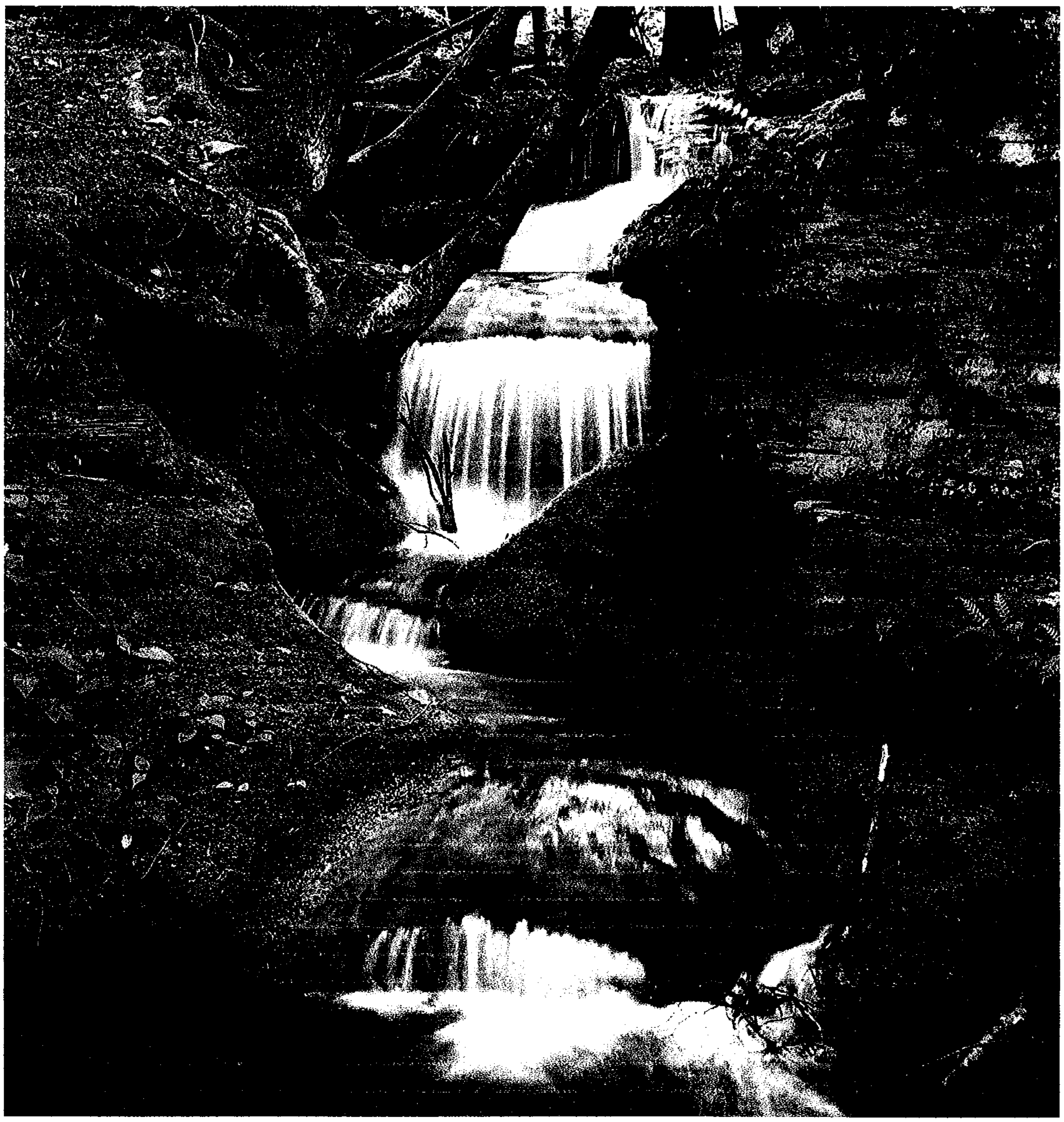
3. **Barriers should be removed to encourage implementation of stream daylighting where appropriate.** Policies which make daylighting projects easier to implement are imperative for projects to become a more common practice. As described above, many water policies fail to recognize the full benefits of restoring small streams, discouraging communities who may want to use innovative techniques but feel confined by existing regulations.

4. **Raise awareness of buried streams to galvanize community involvement and reconnect people to rivers.** Raising awareness of buried streams within the urban environment can engage people and galvanize interest in clean water, community health, and revitalization. Considering stream daylighting and its potential to help solve a city's stormwater and flooding problems could help spur widespread acceptance. Engaging communities in the discussion and design of new and more sustainable and cost effective practices like daylighting will improve our built environment and urban waterways.

Recommendations

CONCLUSION

Robust scientific research consistently shows the importance of small streams to downstream communities. Preserving and protecting small streams, therefore, is the best approach to conserve ecosystem function, but in highly urbanized areas where headwater streams are often buried, hidden, and forgotten, this approach is not an option. With the understanding that most urbanized streams are buried and therefore unable to be preserved, stream daylighting becomes a valuable option to improve water quality and habitat, reduce flooding, and revitalize communities. While a relatively new approach, daylighting is a promising technique assisting communities in reducing polluted runoff, addressing flash flooding concerns, and improving the livability of the built environment.



Forested headwater stream, Beach Bottom Run. Susquehannaock State Forest, York, PA | Nicholas A. Tonelli

Download this report at AmericanRivers.org/DaylightingReport

APPENDIX 1
Additional Stream Daylighting Case Studies

Bloody Run Creek, Detroit, Michigan

Bloody Run Creek is a planned daylighting project in Detroit, Michigan. Funded by a grant $450,00 from the Kresge Foundation to the University of Detroit's Collaborative Design Center, the project initiative is aimed at revitalizing sections of Detroit whose population has declined while also encouraging sustainable development and addressing sewer issues. Bloody Run Creek, named by the British after a gruesome battle with Chief Pontiac in the mid-18th century, has been buried for over a century as part of the city's sewer system. The proposed project would become the central theme for over 3,000 acres of sustainable development projects within Detroit. Exposing the buried stream would reduce strain on Detroit's sewer system by removing an estimated three million gallons of water a year from the sewer treatment plant.[88]

Cheonggyecheon, Seoul, South Korea

The Cheonggyecheon runs through the heart of Seoul and has a history of flooding, dredging, straightening and degradation due to intense development in the city. Cheonggyecheon, rich with history, was the main reason Seoul was selected as the capital city during the Choson Dynasty nearly 600 years ago. The stream has been deepened and widened with dykes, bridges and embankments built as far back as the 15th century. As the city continued to grow through the centuries, a continued cycle of dredging and higher embankments were built. Seoul decided in the 1950's to address their sanitation issues by paving over the stream, turning Cheonggyecheon stream into Cheonggyecheon road. In the 1970's, the Cheonggyecheon freeway was built above the road which buried the stream. Needless to say, the highly urbanized area left little remnants of a stream. The city then decided to bring the Cheonggyecheon back to life. The project had broad public support with 79% of Seoul's residents in favor of daylighting the stream. From 2002-2005 at a cost of $380 million (all provided by the South Korean government) the freeway was demolished, road ripped out, and 4 miles of stream daylighted. The site now includes art installations as well as stone step bridges. The city also reused about 75% of the demolished concrete to build walkways, fountains, and bridges. Citizens now frequent the area. Through monitoring efforts the city has found increases in fish, birds, and insects as well as an increase in surrounding property value. Average temperatures in the area have decreased by as much as 3.6°C compared to other areas in Seoul. Removing the highway decreased the small particle pollution in the air from 74 micrograms per cubic meter to 48 micrograms per cubic meter. The project is not without some criticism as the water is currently pumped from the Han River, which is not an encouraged practice; however, the current environment is preferred over that of a freeway.[89]

Dunnes Creek, Indiana Dunes State Park, Indiana

Dunnes Creek at the Indiana Dunes State Park was once diverted through a pipe that ran under a parking lot at the state park. The enclosed stream, a tributary to Lake Michigan, was found to contribute to the presence of *E. coli* bacteria in the lake. Beaches were often closed because of *E. coli* and the stream enclosure was found to be an incubator of the bacteria, and exposing the creek resolved the issue. The project was funded by NOAA through 1.4 million in federal stimulus funds from the American Recovery and Reinvestment Act of 2009 as well as $140,000 from Federal Emergency Management Agency funds. Both the Dunnes Creek channel and wetland were restored to their original location thereby improving water quality, providing habitat for diverse species, flood protection and enhancing a public park's recreational appeal.[90]

Kid's Creek, Traverse City, Michigan

In a partnership between Munson Medical Center, the Watershed Center Grand Traverse Bay, and the Grand Traverse Conservation District the goal of the stream daylighting was to improve the environmental health of Kid's Creek while also making it accessible to the community. The daylighted section is part of a 2-mile stretch of creek on Michigan's Impaired Waters List for sediment, flow regime alteration, and other stormwater related issues. Stream restoration experts, including hired consultants and the Michigan Department of Natural Resources and Michigan Department of Environmental Quality, were consulted to help design the new section of creek in order to restore its natural sinuosity and provide a natural riparian buffer design. Over the years this tributary has become constrained in culverts, channelized ditches, and underground pipes. As a result, flooding during rainstorms is a serious concern for Munson Medical Center and the neighborhood directly adjacent to the hospital. Stream habitat has been negatively impacted due to excessive sand, silt and impaired water flow. The culverts create unsuitable aquatic habitat and prevent young trout from moving upstream. The daylighting project will ultimately restore fish passage to 4,500 feet of stream. The project is expected to be complete by October 2013. Cost of the project is estimated at $2.5 million with $250,000 coming from an Environmental Protection Agency Great Lakes Restoration Initiative grant and the remaining funds from Munson Medical Center.[91]

Madrona Creek, Seattle, Washington

This daylighting project initiated by the community removed a quarter mile of the spring-fed Madrona Creek from pipes thereby providing habitat, environmental education and aesthetic value to Madrona Park. The stream is now reconnected to Lake Washington with increased habitat benefits for wildlife including the endangered Chinook salmon and other salmon species. The project, totaling $890,000, took around three years and was completed through a combination of contract services and volunteer time and labor. Funding for the project was found through in-kind services, cash donations and grants. Over 300 volunteers helped with the watershed restoration suggesting not only were habitats reconnected but citizens were reconnected to their stream.[92]

Strawberry Creek, Berkeley, California

Strawberry Creek is one of the earliest documented daylighting projects. Located in Berkeley, California, the project removed a 200 foot section of culvert beneath an empty lot and transformed the stream into the centerpiece of a park in 1985 at a cost of about $50,000. Four acres of abandoned rail yard were transformed into a park for an additional cost of $530,000. The daylighting project funded by the City of Berkeley has had quite a community impact with property values near Strawberry Creek increasing, crime decreasing, and a nearby empty warehouse has now been converted into offices and a bakery. The park also draws dozens to hundreds of people daily.[93]

List of other daylighting projects

Codornices Creek, Berkeley, CA
Cow Creek, Hutchinson, KS
Darbee Brook, Roscoe, NY
Embarrass Creek, Urbana, IL
Jenkins Creek, Maple Valley, WA
Jolly Giant Creek, Arcata, CA
Little Sugar, Charlotte, NC
Nine Mile Run, Pittsburgh, PA
Petty's Run, Trenton, NJ
Phalen Creek, St. Paul, MN
Rocky Branch, Raleigh, NC
San Luis Obispo Creek, San Luis Obispo, CA
Shoal Creek Tributary, Dekalb, GA
Upper Baxter Creek, El Cerrito, NY
Valley Creek, Port Angeles, WA
Village Creek, Albany, NY
West Ox Pasture Brook, Rowley, MA

For additional information on daylighting case studies see:
Pinkham, R. 2000. Daylighting: new life for buried streams. Rocky Mountain Institute. Old Snowmass, Colorado.

APPENDIX 2
Potential Funding Sources for Stream Daylighting

There are numerous funding mechanisms communities can use to implement daylighting projects. Depending on the scope of the project and length of stream being daylighted, costs will vary. A general rule of thumb noted by Pinkham (2000) is $1,000 per linear foot of stream daylighted. These costs will inherently increase or decrease depending on the extensiveness of urbanization, whether volunteers or in kind donations are pursued, presences of stream on public or private land, or additional community amenities are added such as parks and greenways. Funding sources where daylighting projects could be categorized are listed below.

California Department of Water Resources Urban Stream Restoration Program

The Urban Stream Restoration Program, through the California Department of Water Resources, provides funds to local communities to reduce flooding and erosion and associated property damages; restore, enhance, or protect the natural ecological values of streams; and promote community involvement, education, and stewardship. Projects include stream daylighting, bank stabilization projects, improving stream channels for floodplain function and floodplain property easements.[94]

Chesapeake Bay Small Watershed Grant Program

The Chesapeake Bay Small Watershed Grants program is funded by EPA's Chesapeake Bay Program Office, as well as the US Forest Service, the National Oceanic and Atmospheric Administration and the DC Department of the Environment. The program provides grants to organizations and local governments working on projects to improve local small watersheds in the Chesapeake Bay basin.[95]

Clean Water Act 319 Funding

Funding through the Clean Water Act Section 319(h) provides states and tribal agencies with monies to implement nonpoint source management programs. Programs include technical assistance, financial assistance, education, training, technology transfer, demonstration projects and regulatory programs. Decisions of project funding are state specific; however, daylighting projects which assist in addressing nonpoint source pollution are applicable.[96]

Environmental Protection Agency Brownfields and Land Revitalization Program

Brownfields are properties which may contain or have the potential to contain hazardous substances, pollutants, or contaminants which make expansion, redevelopment or reuse difficult. The Brownfield Program provides direct funding for brownfield assessment cleanup, revolving loans and environmental job training. The program also collaborates with other EPA programs, federal partners and state agencies to enhance resources for brownfield sites. EPA also provides technical information on financing.[97]

Environmental Protection Agency Urban Waters Small Grants

Through the Environmental Protection Agency's Urban Waters Small Grants program, EPA is supporting communities in improving their urban waters. The program specifically looks to fund several goals that also support community revitalization including: fostering collaborations and partnerships among stakeholders; developing educational programs to provide training on how to implement practices that reduce water pollution and stormwater as well as promote green infrastructure; map trails and walkways along water bodies to identify gaps or areas where connectivity is needed; or provide education and training related to preparing community members for anticipated jobs in green infrastructure, water quality restoration or other water quality improvements. Although direct funds cannot be used to implement a daylighting revitalization, funds can be used for education, feasibility or creating stream maps to highlight current buried or impacted streams.[98]

Federal Emergency Management Agency Flood Relief and Flood Prevention

The Federal Emergency Management Agency Hazard Mitigation Assistance program provides funds to reduce risk of loss of life and property due to natural hazards. Funding allows for projects that remove choke points and undersized culverts as well as flood reduction projects.[99]

Five Star Restoration Program Funding

The Five Star Restoration Program is a partnership of funds with the National Association of Counties, the National Fish and Wildlife Foundation and the Wildlife Habitat Council. Other partners include US Environmental Protection Agency, Southern Company and FedEx. The program funds local partners for wetland, riparian and coastal habitat restoration which demonstrate measurable ecological, educational and community benefits.[100]

Long Island Sound Futures Fund

The Long Island Sound Futures Fund is a partnership with US Environmental Protection Agency, National Fish and Wildlife Foundation, The US Fish and Wildlife Service and the National Resources Conservation Service in an effort to restore and protect Long Island Sound. Under the clean water and healthy watershed category of the program, funding will focus on greening urban and suburban communities, water quality monitoring, watershed plan implementation projects, riparian restoration or development of watershed planning.[101]

State Revolving Funds

Clean Water and Drinking Water State Revolving Funds provide states with low cost loans as well as other assistance to public water systems to finance cost of infrastructure to achieve clean and safe drinking water. Green infrastructure projects such as daylighting can be funded through these allocations. States are also authorized to use a portion of funds for activities such as source water protection, capacity development and operator certification. [102]

Sustain Our Great Lakes Community Grants Program

Sustain Our Great Lakes is a partnership among ArcelorMittal, U.S. Environmental Protection Agency, U.S. Fish and Wildlife Service, U.S.D.A. Forest Service, National Fish and Wildlife Foundation, National Oceanic and Atmospheric Administration, and Natural Resources Conservation Service. The partnership awards grants for on-the-ground habitat restoration and enhancement aimed at sustaining, restoring and protecting fish, wildlife and habitat in the Great Lakes basin.[103]

Additional funding sources can be found at:

Buchholz, T. and T. Younos. 2007. Urban stream daylighting case study evaluations. Virginia Water Research Center. Virginia Tech. Blacksburg, VA.

ENDNOTES

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4 Elmore, A.J. and S.S. Kaushal. 2008. Disappearing headwaters: patterns of stream burial due to urbanization. *Frontiers in Ecology and the Environment.* 6: 308-312.

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Elmore, A.J. and S.S Kaushal. 2008. Disappearing headwaters: patterns of stream burial due to urbanization. *Frontiers in Ecology and the Environment.* 6: 308-312.

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