A Preliminary Assessment of Implementing Stream Daylighting Strategies on Little Black Creek in Muskegon County, MI

Logan Knoper[1], Tara Kneeshaw[1], John Koches[2]

[1]Geology Department, Grand Valley State University, Allendale, MI 49401, [2]Robert B. Annis Water Resources Institute, Grand Valley State University, Muskegon, MI 4944

Abstract

Daylighting is a relatively new stream restoration technique being used in urban environments where natural streams have been redirected through underground culverts and combined with storm sewer systems. The technique involves removing culverts and unburying streams. Daylighting is done not only to restore natural stream habitats, but to address urban issues such as minimizing runoff of polluted water, reducing flash floods, and improving the livable environment. The city of Muskegon Heights, Michigan has proposed daylighting Little Black Creek as a component of their urban revitalization plan.

Spatial understanding of the length of culverted portions of streams as well as the proximity to the downtown area are key factors in constructing an assessment. As such, this study sought to identify and measure portions of Little Black Creek that are culverted. In addition, water level data were collected at three specific study areas along the creek in order to establish baseline water levels and evaluate the changes in water level during rain events. In some instances, additional physical (i.e. stream profiles) and hydrochemical (i.e. temperature, conductivity) data were collected to further understand the current health of the stream. The results were combined with those from previous research on Little Black Creek and compared to other daylighting projects of similar scale. While further investigation is necessary to determine the feasibility of daylighting opportunities, the results from this preliminary assessment highlight the pros and cons of implementing daylighting strategies on portions of Little Black Creek.

Introduction

What is *daylighting*?

- The term daylighting refers to returning "daylight" to the stream through opening up the stream channel
- **How?** removing culverts (where streams have been diverted into pipes)
- **Goal:** return a stream to a natural, self-sustaining condition with an above ground channel

Why are *culverts* detrimental to stream health?

- Inhibit groudwater recharge
- Higher flow velocities during rainfall events and flooding downstream
- Ususally part of a storm water management system and storm drain input significantly contributes to heavy metal and nutrient contamination in streams
- Decrease biodiversity by creating discontinuous stream habitats or completely destroying stream habitats

Fig. 1. Recent daylighted stream in Auckland, New Zealand (Neale 2016).

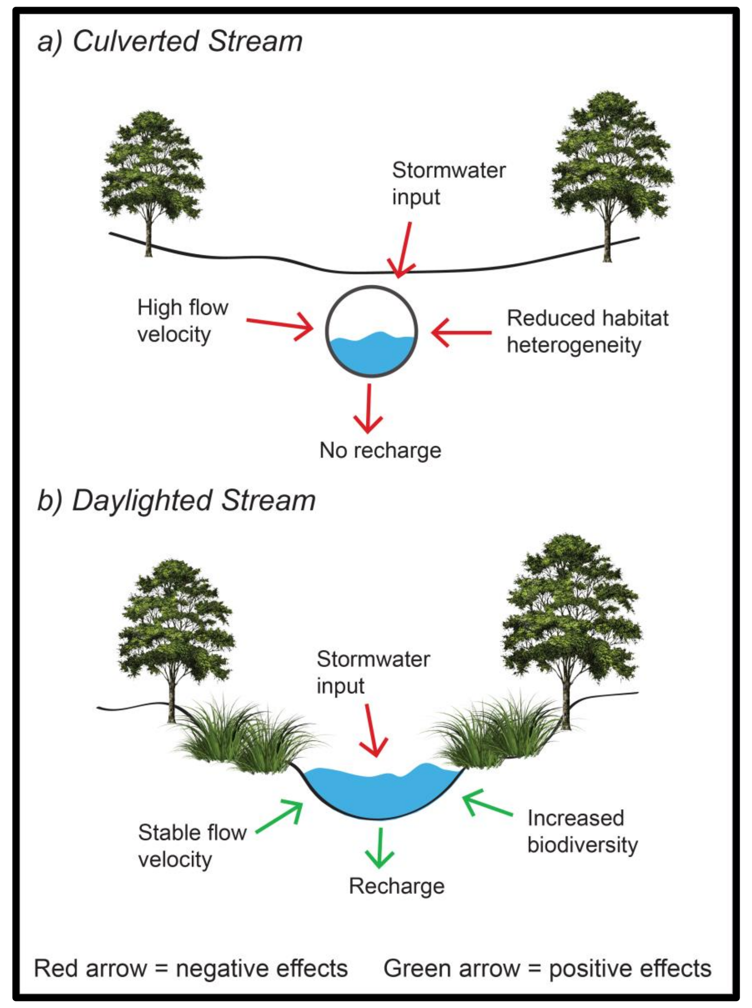


Fig. 2. Negative and positive environmental effects associated with culverts and daylighted streams

Location of Research

- Little Black Creek (LBC) in Muskegon Heights, Muskegon County, MI (~4km east of Lake Michigan)
- Daylighting was considered for LBC which is listed on the EPA's Section 303(d), because the stream doesn't support cold water fish or macroinvertebrates
- 3 hydrologic monitoring sites where selected to evaluate for effects of urbanization on the watershed

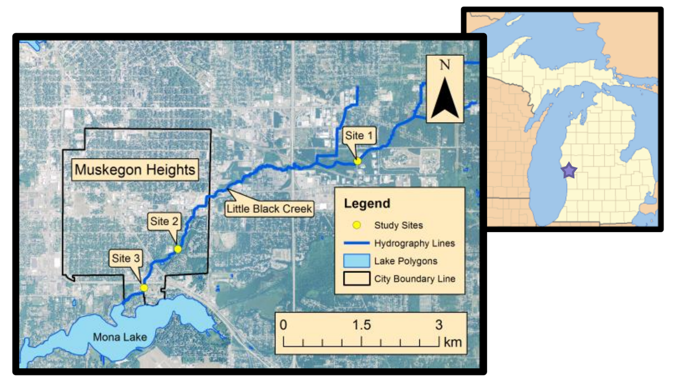


Fig. 3. Site location map showing the Muskegon Heights city boundary, hydrologic monitoring sites, and lakes and rivers in Muskegon County

Methods

Spatial Analysis

- Culverts were identified visually using a 2014 aerial raster image of Muskegon County, MI in GIS software (ESRI **ArcMap 10.1**).
- A culvert was defined as an engineered, closed channel of the stream, and culvert diameter was not taken into account for this study
- Local zoning ordinances were superimposed on the culvert location map, because location of projects related to community development was a key consideration in daylighting case studies.
- Historical aerial images were used from Google Earth to cross reference ArcMap results

Field Data Collection

- At each monitoring site, conductivity and water level measurements were recorded between July 2015 and September 2015.
- A **YSI Model 30 Conductivity Probe** was used to record conductivity measurements.
- Water pressure and barometric pressure was recorded hourly using **HOBO U20 Water Level Loggers** from which water level was calculated using Hoboware Pro software.
- Daily total rainfall data at the Muskegon County Airport weather station were obtained from the NOAA National Climatic Data Center.

Results

Spatial Analysis

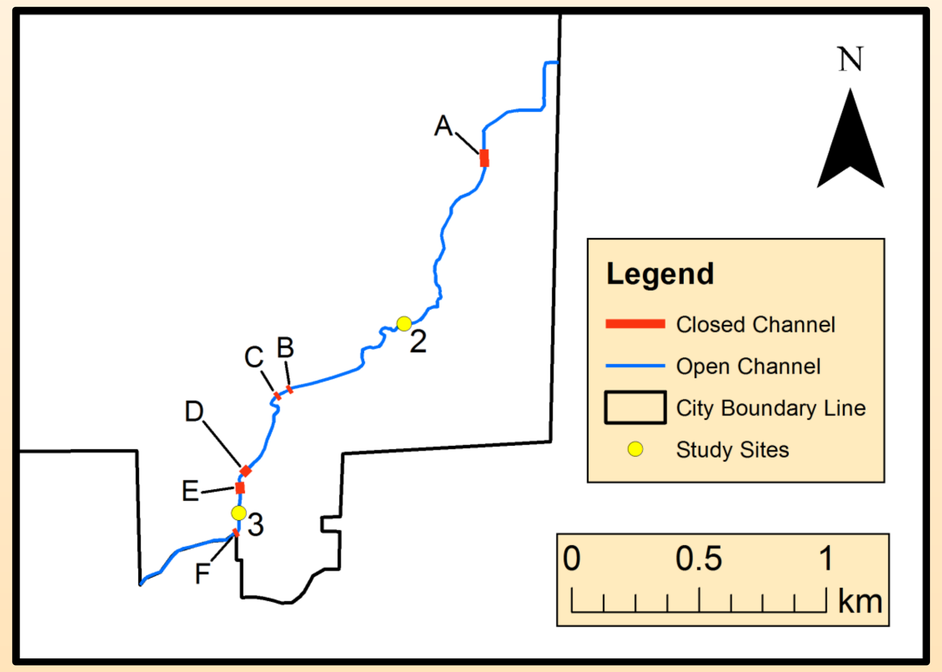
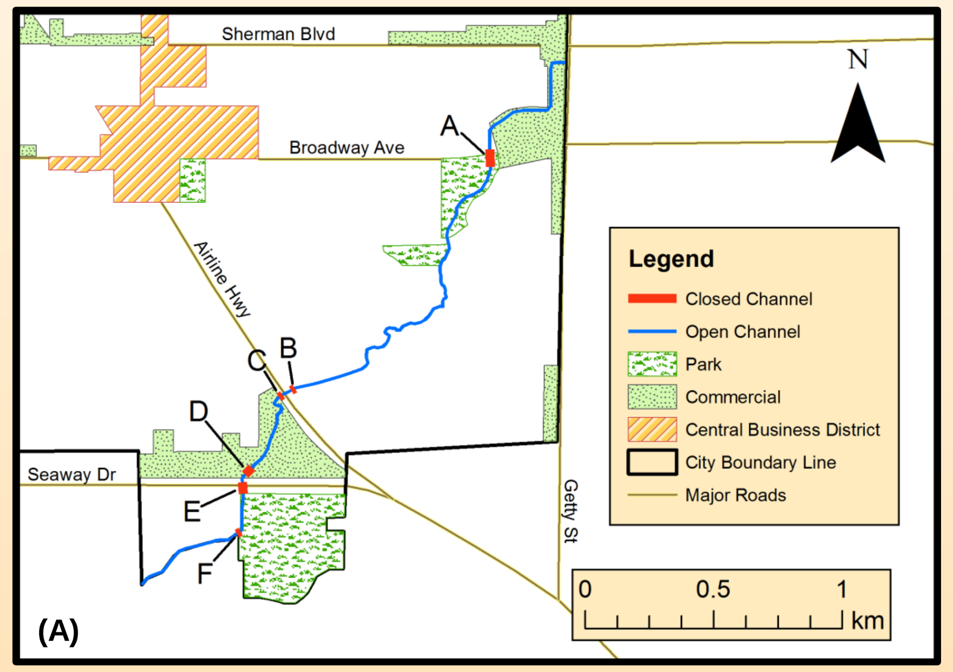


Fig. 4. Map showing culverts and hydrologic monitoring sites on Little Black Creek



Google Earth (2011)

Google Earth (2011)

Fig. 5. (A) Local zoning ordinances superimposed with culvert locations. (B) Aerial photo of segment A culvert. (C) Aerial photo of segment D culvert.

Table 1. Segment names and length (meters) of culverts on Little Black Creek

Segment	A	B	C	D	E	F
Length (m)	70.9	15.6	17.7	38.3	44.3	16.6

Culvert identification

- Six culverts (A, B, C, D, E, and F) were identified in Muskegon Heights
- Culvert length ranged from 15.6m–70.9m
- In Muskegon Heights, 6.4% of LBC was culverted. This figure was lower than expected for an urbanized watershed

Zoning comparison

- Segments C, B, E, and F only spanned the width of roads and thus no daylighting opportunities were viable
- Segments A and D were located near parks or commercial zones and lengths were significant for a daylighting project

Field Data Collection

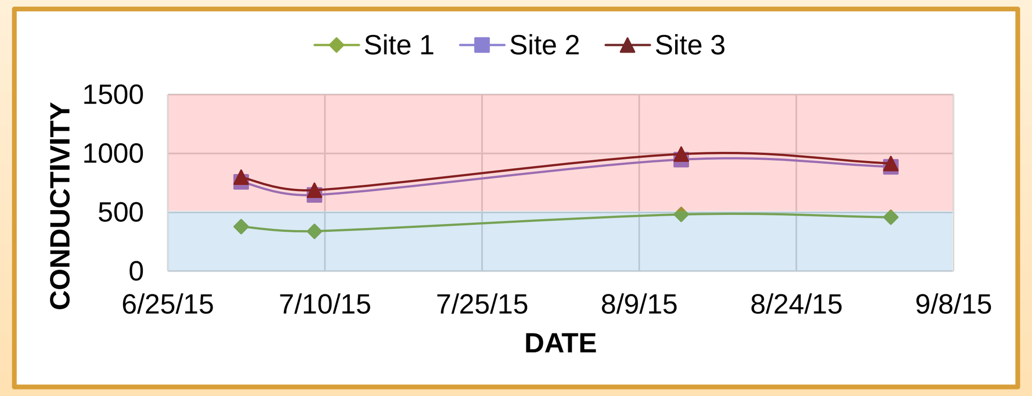


Fig. 6. Four conductivity measurements were taken between at each of the three monitoring sites between 7/2/15 and 9/2/15. The shaded red region represents stream conductivity above healthy levels (500 uS/cm).

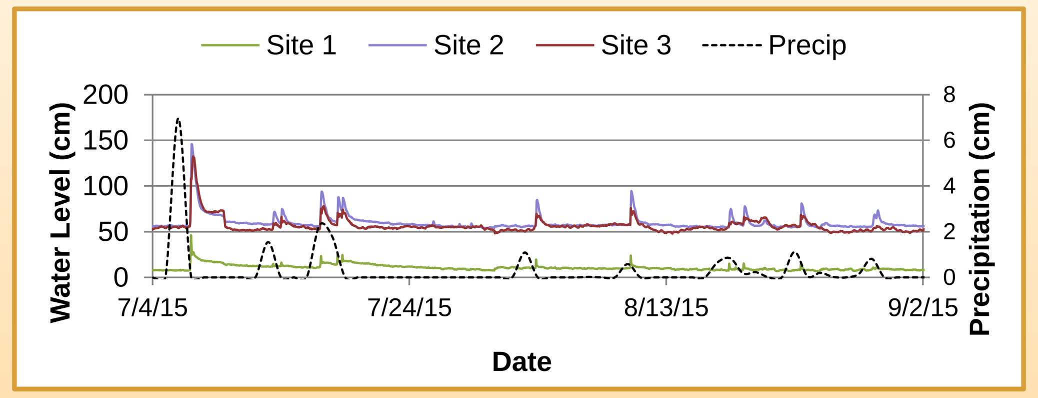


Fig. 7. Water level readings against precipitation show a hydrograph that is indicator of a watershed with a high percentage of impervious cover (Walsh, 2005). Precipitation: NOAA National Climatic Data Center.

Conductivity

- Sites 2 and 3 were found to have conductivity readings higher than a typical healthy freshwater stream (Behar, 1997)

Water Level

- Sharp increase in water level immediately following rainfall events
- Site 1, located at the headwaters, had a much lower average water level than Sites 2 and 3, located in Muskegon Heights

Discussion

Possible daylighting opportunities

- Important criteria: ***Segment length*** and ***zoning ordinances***
- Segments B, C, E, and F only spanned the distance of roads and did not present a practical daylighting opportunity
- Viable daylighting opportunities: Segment A and D meet both criteria

Daylighting as a stream restoration method

- Objectives were generally based on environmental and economic goals (i.e. improving water quality)
- Evidence for the positive effect of daylighting was sparse and very few studies have attempted to quantify environmental effects of daylighting
- *Watershed-scale restoration is necessary in most cases in order to improve water quality*
  - In a recent study in Aukland, New Zealand, daylighting improved biodiversity, but the standard hydrologic metrics showed no water quality improvement
- Cost can be a significant barrier for daylighting projects (Table 2)

Table 2. Summary of daylighting projects and their objectives, outcomes, and costs

Location	Objectives	Outcomes	Cost	References
Arcadia Creek, Kalamazoo, MI, USA	Flood relief / downtown amenity	Protection from 500 year flood / economic investment downtown / community space	**$7.5 mil.**	Pinkham, 2000
Cheonggycheon, Seoul, Korea	Urban regeneration / politically based	Hard engineered channel / tourist attraction and community space	**$351 mil.**	Cho, 2010
Baxter Creek, El Cerrito, CA, USA	Improve water quality / facilitate education	Improved biodiversity and habitat / stormwater storage	**$992,000**	Pinkham, 2000 Goodman, 2006
Kilgoblin Wetland, Barrington, IL, USA	Improve downstream water quality	Macroinvertebrate Biotic Index improved	**$55,000**	Pinkham, 2000
Blackberry Creek, Berkeley, CA, USA	Educational site / park improvements / flood relief	Integrated ecology curriculum at local school / social impact	**$144,000**	Pinkham, 2000
Waitahurangi & Paruhiku, Auckland, New Zealand	Create a sustainable stormwater management system / daylighting cost less than replacing culvert	Increased biodiversity, but no water quality improvements / stormwater storage was successful	Unknown	Neale, 2016

Recommendations

- **Daylighting has not been shown to improve water quality, therefore other stream restoration methods should be explored for LBC if environmental concerns are the motivating factor for restoration**
- If daylighting was still desired, culvert segments A and D pose the most viable daylighting opportunities
- Daylighting projects costs varied greatly. A proper estimate of cost for a daylighting project in Muskegon Heights would require a cost analysis specific to the area
- Future daylighting studies would benefit from studying the effect immediately before a culvert and immediately after a culvert to constrain data to the effects of culverts

Acknowledgements

This research was supported in part by a grant from the *Norman and Helen Gibson Geology Field Study Scholarship*. I would also like to thank the *Annis Water Resources Institute* for lending field equipment, and *Gabrielle Thelen* for her assistance in the field and laboratory.

References Cited

Behar, S., 1997, Definition of water quality parameters: http://fosc.org/WQData/WQParameters.htm (accessed March 2016).

AWRI, 2006, Population Density 2000 Census Mona Lake Watershed: U.S. Census Bureau, 2000, scale 1:70000.

Cho, M.-R., 2010, The politics of urban nature restoration: The case of Cheonggyecheon restoration in Seoul, Korea: International Development Planning Review, v. 32, p. 145–165.

Cooper, M.J., Rediske, R.R., Uzarski, D.G., Burton, T.M., Sediment contamination and faunal communities in two subwatersheds of Mona Lake, Michigan, 2009, J. Environ. Quality., v. 36, p. 1255-1265.

Lee, J., and Anderson, C., 2013, The Restored Cheonggyecheon and the Quality of Life in Seoul: Journal of Urban Technology, v. 20, p. 3–22.

Lee, M., and Jung, I., 2015, Assessment of an urban stream restoration project by cost-benefit analysis: The case of Cheonggyecheon stream in Seoul, South Korea: KSCE Journal of Civil Engineering

National Weather Service Forecast Office, 2015, Observed Weather Reports (July - August 2015): http://w2.weather.gov/climate/index.php?wfo=grr (August 2015).

Neale, M.W. and Moffett, E.R., 2016, Re-engineering buried urban streams: Daylighting results in rapid changes in stream invertebrate communities: Ecological Engineering, v. 87, p. 175-184.

Pinkham, R. (2000). Daylighting: new life for buried streams. In Rocky Mountain Institute. Retrieved from http://www.rmi.org/Knowledge-Center/Library/W00-32_DaylightingNewLifeBuriedStreams

Polkowska, Z., Grynkiewicz, M., Zabiegala, B., Namieśnik, J., 2001, Levels of pollutants in runoff water from roads with high traffic intensity in the city of Gdańsk, Poland, Polish Journal of Environmental Studies

Rediske, R., Uzarski, D., Chu, M., Cooper, M., Burton, T., 2008, Preliminary investigation of the extent of sediment contamination in Mona Lake Watershed, MI: U.S. Environmental Protection Agency Project Report

Steinman, A., Rediske, R., Denning, R., Nemeth, L., Chu, X., Uzarski, D., Biddanda, B., Luttenton, M., 2006, An environmental assessment of an impacted, urbanized watershed: the Mona Lake Watershed, Michigan, Arch. Hydrobiol., v. 166, p. 117-144

Steinman, A.D., Ogdahl, M.E., Rediske, R., Ruetz III, C.R., 2011, A study of surface run-off from U.S. 31 and Seaway Drive on Little Black Creek, Muskegon County, MI: Grand Valley State University, Annis Water Resources Institute Final Report for the Michigan Department of Transportation

Trice, A. (n.d.). Daylighting streams: breathing life into urban streams and communities. In American Rivers. Retrieved from http://www.americanrivers.org/wp-content/uploads/2014/04/daylighting-streams-2.pdf

Violin, C.R., Cada, P., Suddeth, B.E., Hassett, B.A., Penrose, D.L., and Bernhardt, E.S., 2011, Effects of urbanization and urban stream restoration on the physical and biological structure of stream ecosystems, Ecological Applications, v. 21, p. 193-1949.

Walsh, C.J., Roy, A.H., Feminella, J.W., Cottingham, P.D., Groffman, P.M., and Morgan II, R.P., 2005, The urban stream syndrome: current knowledge and the search for a cure: Journal of the North American Benthological Society, v. 24, p. 706-723.

Wild, T.C., Bernet, J.F., Westling, E.L., Lerner, D.N., 2011, deculverting: Reviewing the evidence on the 'daylighting' and restoration of culverted rivers, Water and Environment Journal, v. 25, p. 412-421

Goodman, J., Lunde, K.B., Zaro, T., 2006, Baxter Creek Gateway Park: assessment of an urban stream restoration project: Water Resources Collections and Archives University of California