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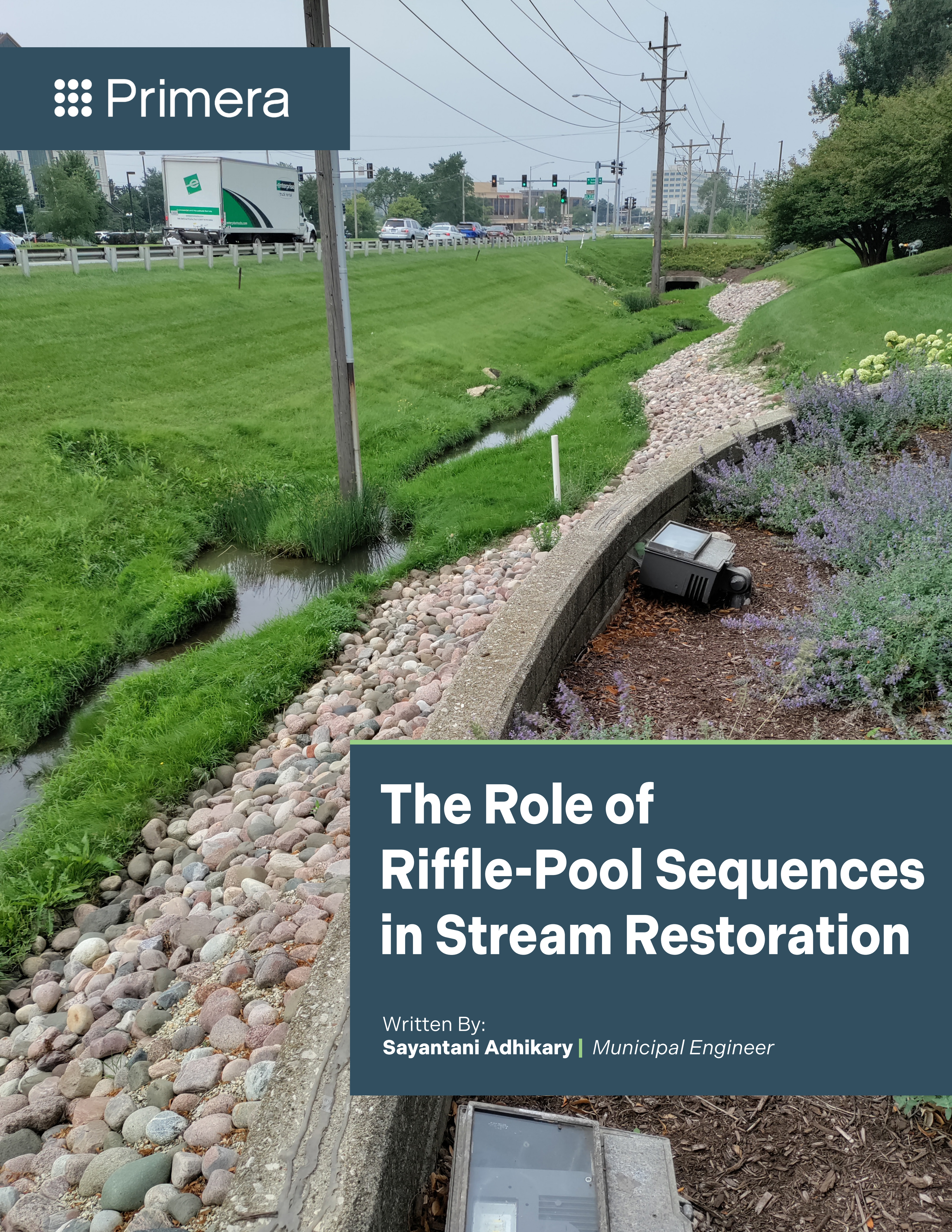

The Role of Riffle-Pool Sequences in Stream Restoration

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Introduction

Integrating natural systems into engineered solutions is a powerful way to promote sustainable infrastructure and environmental resilience. Among these systems are riffle-pool sequences, which are fascinating features found in natural streams, characterized by alternating shallow and deep sections within a channel. These features play a crucial role in the dynamics and ecology of stream environments by restoring ecological balance and promoting long-term stream stability.

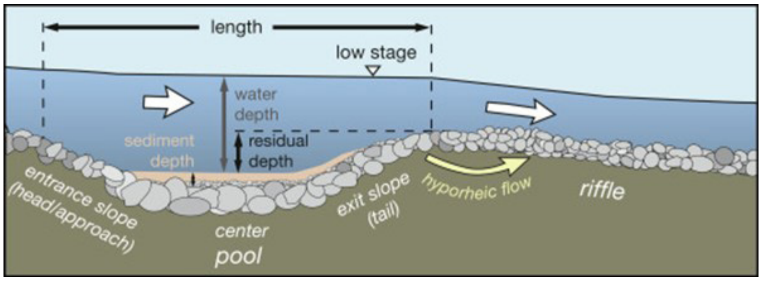


Image courtesy of www.sciencedirect.com. Depiction of a naturally occuring riffle-pool sequences.

Riffle-pool sequences can form in various types of streams, including alluvial, bedrock, meandering, and straight channels. Pools, the deeper sections, typically have a triangular profile shape with an entrance slope (head) and an exit slope (tail), resembling bowls and having a low flow velocity. In contrast, riffles are shallower, have faster flow velocities, and are more rectangular in shape. The ypacing between riffles and pools is about 5-7 bankfull widths, mimicking natural stream behavior.

Formation of Riffle-Pool Sequences

Riffle-pool sequences occur naturally in channels because of the efficient transport of sediment. This process follows the path of least resistance, where the minimal time rate of potential energy expenditure per unit mass of water is achieved. In other words, the stream expends as little energy as possible while transporting sediment. Meandering channels and flow convergence also contributes to the formation of these sequences. How a stream functions is a result of flowrate: at low flow rate, the entire stream may behave like a pool due to low velocities encouraging a depositional environment. At high flow rates the stream may behave like a riffle, discouraging deposition. Research continues into how riffle-pool sequences are maintained, focusing on factors like velocity reversal, shear stress reversal, and turbulent flow that move and settle particles. Despite extensive studies, there is still no general consensus on how these sequences are naturally maintained nor is there established guidance to construct riffle-pool sequences.

Benefits of Riffle-Pool Sequences

Riffle-pool sequences are essential for supporting healthy habitat conditions in streams, with biodiversity levels often varying greatly between segments. They provide critical spawning areas for fish, with pools offering ideal environments for fish to lay their eggs. Pools have poorer water quality due to less dissolved oxygen and reduced rate of sediment transfer. Midges, mollusks, and worms may flourish in these areas. Riffles provide an environment for aquatic insects such as mayflies or small algae to flourish that may be eaten by fish or birds.

Additionally, riffle-pool sequences are commonly used in restoration projects for channelized streams. These sequences contribute to the long-term stability of stream channels by influencing hydrodynamic behavior. Riffle-pool sequences help dissipate energy, reducing erosion and promoting channel stability. During low discharge, velocities are higher in riffles due to their shallower nature, while high discharge results in more uniform flow and water surface levels across the length of the channel. A condition, known as the velocity reversal mechanism, where pool velocity exceeds riffle velocity at or above bankfull flow, is thought to aid in the self-maintenance of these sequences.

Riffle-pool sequences offer several important benefits to stream environments. They provide diversity for various aquatic life and fish, encourage the self-stabilization of the stream channel, and contribute to long-term bank stabilization while reducing erosion. Some of the key advantages include:

1. Providing habitats that support a range of aquatic organisms and fish species
2. Promoting the self-stabilization of stream channels
3. Enhancing long-term bank stabilization and reducing erosion

Design Requirements for Riffle-Pool Sequences

Designing effective riffle-pool sequences requires careful planning and an understanding of the stream dynamics. Because each site presents unique conditions, a case-by-case approach is essential. Currently, there is little established guidance proven to work reliably, and this remains an active area of research. However, here are some factors to consider:

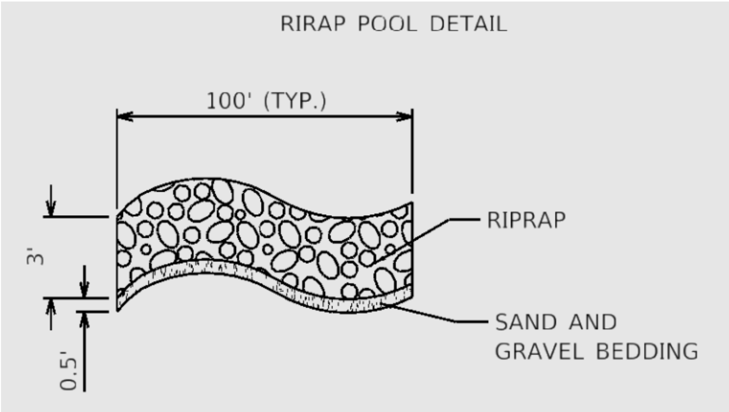
Illinois Department of Transportation (IDOT) Butterfield Phase I project planned for restoration.

1. Spacing: The spacing between riffles and pools should be 5-7 channel widths to mimic natural conditions.
2. Riffle Construction: Riffles should be built using natural stream gravel to ensure stability and functionality.
3. Pool Depth: Pools must have a minimum depth of at least one foot, although this can vary depending on specific stream characteristics .
4. Reinforcement: Utilize riprap to strengthen the banks and mitigate erosion.

These design elements mimic natural stream behavior and are essential for creating sustainable and effective riffle-pool sequences in restoration projects.

Maintenance

Ongoing maintenance is essential to ensure that riffle-pool sequences continue to function effectively and support stream health over time. There are studies that have explored human maintenance or rehabilitation of streams by incorporating riffle pool sequences. Some general considerations are to record stage data or survey the stream to assess any changes in the riffle-pool structure. Furthermore, monitoring biodiversity is important to make sure the incorporation of riffle-pool sequences has not affected the ecosystem adversely. This may include quantitative analysis of fish and aquatic insects as these are markers for water quality.



This detail has been developed for the Butterfield Road project to show how the riffle-pool sequences should be constructed. The detail shows a crest-to-crest length of 100' with pool bottoms of 1-1.5 feet in depth. The riprap bedding should be 3 feet in thickness with a sand and gravel bedding of 6 inches.

Project Application

A portion of the Illinois Department of Transportation (IDOT) Butterfield Phase I project area has been designated as Waters of the United States (WOUS) and is federally protected under the Clean Water Act. The existing channel exhibited varying degrees of bank erosion along its 2,000 linear feet. To support the protection and long-term sustainability of these federally protected waters, the proposed design incorporates a series of enhancements, including riffle-pool sequences spaced 100 feet crest-to-crest, pools with a depth of one foot, riprap armoring, and vegetative fill.

This design is expected to mitigate several areas of bank erosion along the Lombard Tributary on the north side of Butterfield Road. The incorporation of riffle-pool sequences improves the longevity of the channel, decreases maintenance, and sustains aquatic life

Conclusion

Riffle-pool sequences offer numerous benefits to stream environments, including habitat support, long-term stability, and energy dissipation. Despite the challenges in characterizing these sequences in the field and the ongoing debates about their natural formation, they remain a vital component of healthy stream ecosystems. Understanding and applying riffle-pool sequences in stream restoration can greatly enhance both the ecological and hydrodynamic functions of a waterway, contributing to its overall health and long-term sustainability. These systems not only serve a vital engineering purpose but also reflect the natural beauty and balance found in untouched streams—just how Mother Nature intended.

REFERENCES

- https://www.collectionscanada.gc.ca/obj/s4/f2/dsk2/ftp03/MQ40414.pdf
- https://www.sciencedirect.com/topics/earth-and-planetary-sciences/pool-riffle-sequence
- https://www.sciencedirect.com/science/article/abs/pii/S092585741400247X
- https://www.researchgate.net/profile/Douglas-Thompson-4/publication/325189897_Pool-Riffle_Sequences links/5b084c52aca2725783e5d573/Pool-Riffle-Sequences.pdf
- https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2011WR011789
- https://www.lakesuperiorstreams.org/understanding/riffle_run_pool.htm
- https://www.fondriest.com/news/no-stone-unturned-little-worlds-inside-stream-riffles-and-pools.htm

ABOUT THE AUTHOR

Sayantani (Tani) Adhikary is an experienced engineer in training in Primera's drainage and Phase I engineering group. Her experience includes design for streetscape, airport, roadway, sidewalk, and structural projects. Prior to joining Primera, she served as a stormwater watershed lead/associate engineer for the Metropolitan St. Louis Sewer District and as an environmental, health, and safety specialist for a major online retailer.