STREAM SYSTEMS TECHNOLOGY CENTER

STREAM NOTES

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A Geomorphic Perspective on Things to Think About Before Starting a Gravel Augmentation Project

by Kristin Bunte, John P. Potyondy, and Daniel A. Cenderelli

Gravel augmentation for the purpose of spawning habitat improvement has been carried out episodically by various government agencies since the 1960's, and renewed interest in gravel augmentation was generated during the relicensing of numerous hydroelectric projects in the 1990's. From a scientific and engineering perspective, not much was known about gravel augmentation and consequently, a trial and error approach was often used with varied success.

The report, ***State of the Science Review, Gravel Mitigation and Augmentation Below Hydrolelectric Dams: A Geomorphological Assessment*** (Bunte, 2004) provides a comprehensive review of the different approaches to gravel augmentation, the tools used in gravel augmentation projects, and the analyses needed to arrive at a final gravel augmentation plan. Written from a geomorphological perspective, the review places much of its focus on gravel augmentation projects that emphasize the link between the geomorphic and biological functioning of the stream. Many of the technologies and concepts presently used in gravel augmentation are still in the process of vigorous development. Most will be modified over time as more is learned about the geomorphic and biological responses of streams to augmentation. The full report is available from the U.S. Department of Agriculture, Forest Service, Stream Systems Technology Center, Fort Collins, Colorado.

Here we summarize the major approaches to gravel augmentation discussed in Bunte (2004), the strengths and limitations of those approaches, and the data that need to be analyzed to successfully implement a gravel augmentation project.

Approaches to Gravel Augmentation

Many different approaches to spawning habitat augmentation have been applied that vary widely in temporal and spatial scales. Successful approaches tend to emphasize "working with the stream." Gravel augmentation is a complex and geomorphologically and biologically challenging

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John Potyondy, Program Manager.

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CORRESPONDENCE:
E-Mail: rmrs_stream@fs.fed.us
Phone: (970) 295-5983
FAX: (970) 295-5988

Web Site:
www.stream.fs.fed.us

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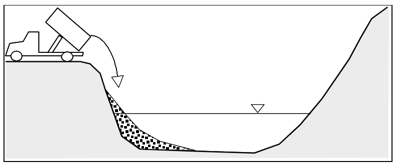
undertaking, with a high degree of uncertainty regarding the volume of gravel needed and whether the created spawning habitat will have any long-lasting beneficial effect. Tackling gravel augmentation in an interdisciplinary way is essential for the best chance of achieving the desired outcome.



Gravel augmentation approaches, from the simple to the more complex, can be categorized as:

1) Local, indirect, or passive gravel additions,
2) Direct placement of gravel based on hydraulic and sediment modeling, and
3) Comprehensive restoration of geomorphic and biological function.

Approach 1: Local, indirect, or passive gravel additions

Indirect or passive gravel augmentation supplies spawning gravel to a logistically convenient stream location at which the gravel is likely to be entrained and transported downstream by relatively frequent high flow events. Natural downstream deposits of the introduced gravel can provide spawning habitat if the deposits are large enough and contain the preferred sized gravel for the fish species of interest. The volume must be sufficient to deposit the necessary patch sizes used by the target species. However, spawning habitat created this way may be subject to destruction or deterioration if moderate or large floods scour the gravel or if the gravel is stable during smaller floods and not moved sufficiently to wash out potential infiltration of fines.

This method is the cheapest approach to gravel augmentation, because the amount of pre-project computation is typically small and implementation is easy (e.g., dumping gravel from a truck, close to a gravel source, whenever gravel becomes available). To have a long-term beneficial effect, the stream must have gravel conveyance such that the passively supplied gravel can be transported downstream over time and provide spawning habitat along the way. Flows with a competence to entrain these gravels from the augmentation site and to transport them further downstream must also occur frequently enough to be geomorphically and biologically effective.

Approach 2: Direct placement of gravel based on hydraulic and sediment modeling

These designs rely heavily on hydraulic and sediment transport modeling. Design outcomes are still faced with relatively high uncertainty because knowledge of actual pre- and post-restoration bedload transport rates is limited. The approach requires expertise in stream restoration and hydraulic/sediment transport modeling.

The first step in hydraulic and sediment modeling is identifying the major objectives for the site. The objective may be to create large amounts of high quality spawning habitat, provide for beneficial intra-gravel conditions, provide for geomorphic sustainability, or to efficiently use the amount of gravel within economic constraints.

A hydraulic model calibrated to the site is used to predict hydraulic conditions for the entire reach. Design scenarios are evaluated for factors such as the amount of spawning habitat of different quality created within the reach, whether critical flow for entrainment will be reached or exceeded at various flows, habitat variability downstream of hydraulic controls, or the amount of gravel needed to implement the design.

This highly computational approach to gravel augmentation is based on detailed field measurements (topographic surveys, flow hydraulics, bed material size, intra-gravel flow conditions, and redd counts) and expertise in salmon spawning habitat requirements. It also requires expertise in hydraulic modeling, involves significant survey and modeling efforts, and is limited to those channel types that can be adequately modeled. Successfully applied, it optimizes the chances of creating suitable and long-lasting spawning habitat.

Approach 3: Comprehensive restoration of geomorphic and biological function

The foremost goal of a comprehensive approach to gravel augmentation is restoration of the

Table 1. Overview of parameters for which information may be required in gravel augmentation projects.

	Unknown parameter or interaction	What to measure and compute	Methods used
Streambed Topography	Current cross-sectional shape for pre-project condition and its change over time	x-y coordinates of cross-section at geomorphologically active locations, repeated over time	Topographical Survey
	Stream gradient	x-y coordinates of longitudinal profile	
Sediment supply	Status of sediment supply: is the stream aggrading or degrading?	Areal extent of stream-bed covered by different geomorphological units and facies units	Topographical survey; Mapping geomorphological units and facies units, digitization, and spatial analysis
Bedload transport	Bed mobility, critical flow for gravel entrainment, pre-and post-project	Bed surface particle-size distribution	Pebble count
		Post-flood displacement distance of seeded D_{84}, D_{50} and D_{31} particles at different flows	Tracer study
	Depth of scour and re-deposition	Pre- and post flood x-y coordinates of top and bottom of scour core	Topographical survey of scour cores
	Current bedload transport rates, annual load, amount of gravel to be supplied	Bedload transport rates during flood events, annual load	Bedload sampling, annual load computation
	Amount of gravel to be supplied	Stream-bed elevation before and after flood events, prior to which gravel was applied; scour depth	Topographic survey, topographic differencing; scour cores
Spawning gravel	Current quantity of spawning gravel	Area suitable for spawning based on appropriate flow depth, velocity, and bed material size; redd counts	Stream mapping, digitization and spatial analysis
	Quality of spawning gravel	Particle-size distribution; intra-gravel flow, temp., turbitidy, dissolved oxygen	Unstratified bulk samples; Piezometer water samples, egg/alevin counts
	Sources and sinks for fines	Amount of fines in pools and other deposits, veneer thickness, bulk density, total amount of fines per stream segment; tributary supply of fines	Visual assessment, stream mapping, digitization, spatial analysis; geomorphic analysis at confluence; bedload sampling
Modeling complex interactions	Stream-bed topography	x-y coordinates of stream bed within project reach	Topographic modeling, DEM
	Interaction of water depth, velocity, total flow volume, and surface gradient in pre- and post-project channel shape	Current flow hydraulics for model validation; Flow dynamics for specified flow and channel shape	Hydraulic modeling, 1-D or 2-D
	Critical flow for incipient motion	Ratio of actual flow to an assumed critical flow	Based on output of hydraulic model and critical flow equation
	Sediment transport and channel change for specified flows in pre- and post-project channel	Current bedload transport rates for model validation; Transport rates for specified flow & channel shape	Bedload transport modeling, based on output of 1-D hydraulic model and bedload equation

geomorphic functionality of an entire stream or multiple stream reaches, based on the understanding that if the pool-riffle or alternate bar morphology is restored within the context of the existing altered flow regime, fish habitat will develop as a natural process, fulfilling various biological functions at different stream locations. Measures to restore geomorphic functionality may include: (1) shaping the channel by adding or removing gravel to ensure that the post-dam 1.5-

year recurrence interval flow fills the channel to its morphological bankfull stage, (2) adding bed material that can be partially mobilized at bankfull flow, and (3) continuing gravel additions that match post-restoration transport capacity as a long-term measure. As these projects incorporate the concept of mobile gravel, unimpeded downstream gravel conveyance, and overall stream and habitat restoration, the spatial project scale may extend over stream segments several tens of miles long or multiple reaches, while the temporal scale typically covers multi-year and decade long periods.

This approach provides for a long-term solution that, once a geomorphologically and biologically functioning stream is established, requires little maintenance apart from episodic or regular passive gravel additions for replenishing insufficient upstream gravel supply. Complete river restoration requires expertise in fluvial geomorphology and bedload transport processes, as well as in conducting field measurements and habitat assessments. All of the tools and skills necessary for detailed hydraulic and sediment transport modeling and evaluation are typically employed. In spite of the extensive expertise required in the biological and engineering sciences, project outcomes are still highly uncertain because no such project has been fully implemented, monitored, and evaluated to date. These efforts, however, provide great opportunities to expand our knowledge of morphological processes in gravel-bed rivers and how these processes create aquatic habitat.

Data Needed for Analysis

The outcome of gravel augmentation projects is difficult to predict with a high degree of certainty. In order to go forward with gravel augmentation projects, while still lacking complete scientific understanding, adaptive management is generally recommended as a project strategy. Under this strategy, a project is treated as a scientific experiment with potentially unknown outcome and the project is modified over time based on data from monitoring and evaluation.

Table 1 provides an overview of the information that may be required for a specific project. The table is intended to illustrate the complexity of the issues likely to be encountered in a typical project and reinforce the need for an interdisciplinary and adaptive management approach.

Conclusions

In summary, gravel augmentation is a difficult and complex endeavor challenging the biological, geomorphic, and engineering sciences. Successful projects require extensive geomorphic and biological understanding and experience and are hampered by our current poor understanding of gravel transport processes coupled with a high degree of uncertainty associated with existing computational models.

Because gravel augmentation can exert a large influence on stream processes and channel response, engaging in this undertaking requires a deep understanding of geomorphic and biological processes as well as experience in gravel augmentation projects. The larger the spatial and temporal scale of the project, the wider the range of factors that influence the project outcome and are influenced by it. This implies that large-scale projects have a particularly pressing need for an interdisciplinary approach including fluvial geomorphology, fisheries biology, watershed sciences, and riparian ecology.

References

Bunte, K. 2004. State of the Science Review, Gravel Mitigation and Augmentation Below Hydroelectric Dams: A Geomorphological Perspective. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. Report submitted to the Stream Systems Technology Center, Fort Collins, CO. 234 p. Available: http://www.stream.fs.fed.us/publications/PDFs/Gravel Augmentation Report.pdf.

Kristin Bunte is a Research Scientist, Department of Civil Engineering, Engineering Research Center, Colorado State University, Fort Collins CO, 970-491-3980, kbunte@engr.colostate.edu.
John P. Potyondy is Program Manager, USDA Forest Service, Stream Systems Technology Center, 2150A Centre Ave. Suite 368, Fort Collins, CO 80526, 970-295-5986, jpotyondy@fs.fed.us.
Daniel A. Cenderelli is a Fluvial Geomorphologist, USDA Forest Service, Stream Systems Technology Center, 2150A Centre Ave. Suite 368, Fort Collins, CO 80526, 970-295-5984, dcenderelli@fs.fed.us.