STREAM SYSTEMS TECHNOLOGY CENTER

STREAM NOTES

To Aid in Securing Favorable Conditions of Water Flows

Rocky Mountain Research Station

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Comparison of Three Pebble Count Protocols (EMAP, PIBO, and SFT) in Two Mountain Gravel-bed Streams

by Kristin Bunte, Steven R. Abt, John P. Potyondy, and Kurt W. Swingle

Pebble counts are one of the most frequently used field methods to assess the size distribution of bed surface sediment in gravel-bed and cobble-bed streams. Although the term ''pebble count'' is in widespread use, there is no standardized methodology used for the field application of this procedure. Each pebble count analysis is the product of several methodological choices, any of which are capable of influencing the final result. Pebble counts have nine individual components:

1. Length of the sampling reach.
2. Sampling scheme (spatially integrated over the reach or segregated into different units).
3. Sampling pattern (transects, small-scale grids, or random).
4. Sampled portion of stream width.
5. Spacing and number of particles collected per transect.
6. Sample size per reach.
7. Identifying the particles to be extracted.
8. Measuring particle size.
9. Particle-size analyses.

For each component, there are several methodological options illustrated in figure 1. For example, the component "particle-size determination" includes the options of measuring the particle b-axis with a ruler, visually estimating the particle b-axis size class, or passing a particle through a gravelometer template. Because there are virtually countless variations on pebble count protocols, the question of how results differ when applied to the same study reach is important. The overarching aim of this study is to raise awareness of the fact that selection of different methodological options can have notable consequences on the results. To demonstrate some of these cause-and -effect connections, we examined the procedures and results of three pebble count protocols on two mountain, gravel-bed streams.

Methods

This study compares two well-known pebble count protocols and one rigorous pebble count protocol in two mountain gravel-bed streams in Colorado; Willow Creek and North St. Vrain Creek.

One of the well-known pebble count protocols is the one used by the

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The PRIMARY AIM *is to exchange technical ideas and transfer technology among scientists working with wildland stream systems.*

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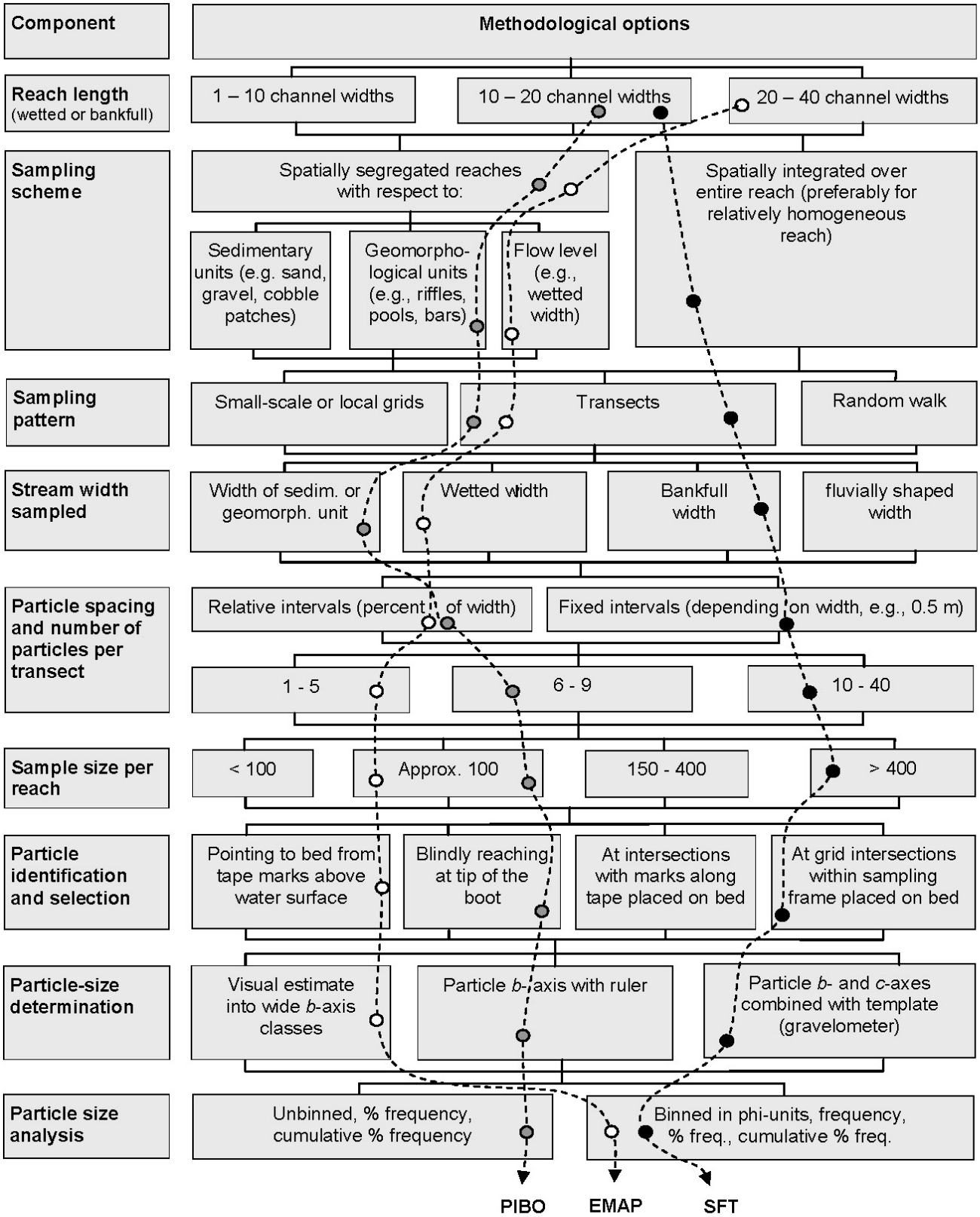

Figure 1. Components of pebble counts, their methodological options, and pathways followed by three example pebble count protocols: EMAP, PIBO, and SFT. The majority of methodological options refer to differences in sampling location.

Environmental Monitoring and Assessment Program (EMAP) developed by the Environmental Protection Agency for physical habitat characterization (Peck and others 2006). The procedure includes a surface pebble count to monitor changes in the conditions of aquatic habitat and in the amount of silt and sand (particle less than 2 mm in diameter) supplied to a stream. The EMAP protocol was developed for rapid reach characterization and samples the wetted width of the channel. The protocol is applied in large national stream studies and uses many operators.

The second pebble count protocol selected is from the Pacific Anadromous and Inland Fish Strategy Biological Opinion (PIBO) Effectiveness Monitoring Program initiated in 1998 for long-term monitoring of aquatic and riparian resources in streams on Forest Service and Bureau of Land Management lands within the Upper Columbia River Basin (Henderson and others 2005). Pebble counts as part of the PIBO program are used to monitor the median (D_{50}) surface sediment size and the percent fines less than 6 mm of the surface sediment on riffles.

The EMAP and PIBO pebble count protocols were selected for study because they are among the most widely used, with applications that involve hundreds of streams. These protocols were also selected because they differ widely in their methodological details (fig. 1) and they represent major differences in sampling approaches; EMAP uses a reach-averaged approach and PIBO uses a habitat-specific (riffle only) approach. Although the PIBO pebble count protocol has since been recently modified to correspond more closely to the EMAP protocol, the procedure and results discussed here refer to the original PIBO protocol that exclusively sampled riffles.

The EMAP and PIBO pebble count protocols were developed to measure long-term change for a large number of streams within a region rather than for use at individual sites. However, the simplicity, speed, widespread use and reference in the literature make these protocols appealing for application to individual sites. The intent of this study is not to make an evaluation of whether the EMAP and PIBO protocols achieve their stated aims for long-term regional studies, but rather to compare the results of different sediment sampling approaches and illustrate some of the consequences of methodological choices associated with simple and rapid assessments.

The third protocol used is referred to as the Sampling Frame and Template (SFT) method. The SFT method is a rigorous, data-intensive approach developed to minimize operator error and sampling bias in field studies (Bunte and Abt 2001a, 2001b). The key features of the SFT procedure are: 1) identifying particles under intersections of thin elastic bands within a sampling frame placed directly on the bed, 2) measuring particle sizes with a 0.5-phi template to eliminate operator error and achieve compatibility with sieve data, and 3) covering the entire reach in a systematic grid pattern the dimensions of which are determined by study objectives. This time and data intensive approach provides an accurate account of the reach -averaged particle-size distribution and a detailed spatial record of particle-size location to facilitate comprehensive post-sampling data analysis. The SFT method for measuring coarse sediments is intended to represent "best technical practice.''

Results and Discussion

The study found significant differences in sampling results due to methodological options employed by the EMAP and PIBO protocols (fig. 2). Some methodological options caused underrepresentation of fines less than 5.6 mm, others overrepresented the amount of silt and sand (particle less than 2 mm in diameter), some resulted in overly high percentages of cobbles, and others resulted in overly low percentages of cobbles. In PIBO's case, the selected methodological options generally caused a coarsening of the results. In EMAP's case, one methodological option (sampling 40 percent of all particles at the waterline) caused oversampling fines (if the water line runs along cut banks). These effects were fortuitously offset by another methodological option (not sampling on exposed bars where fines are stored) that caused under sampling of fines. These findings illustrate that sampling results are highly protocol-dependent and that results from different protocols cannot be used interchangeably and must be carefully interpreted.

Particle-size distributions varied among the three pebble count protocols because of differences in

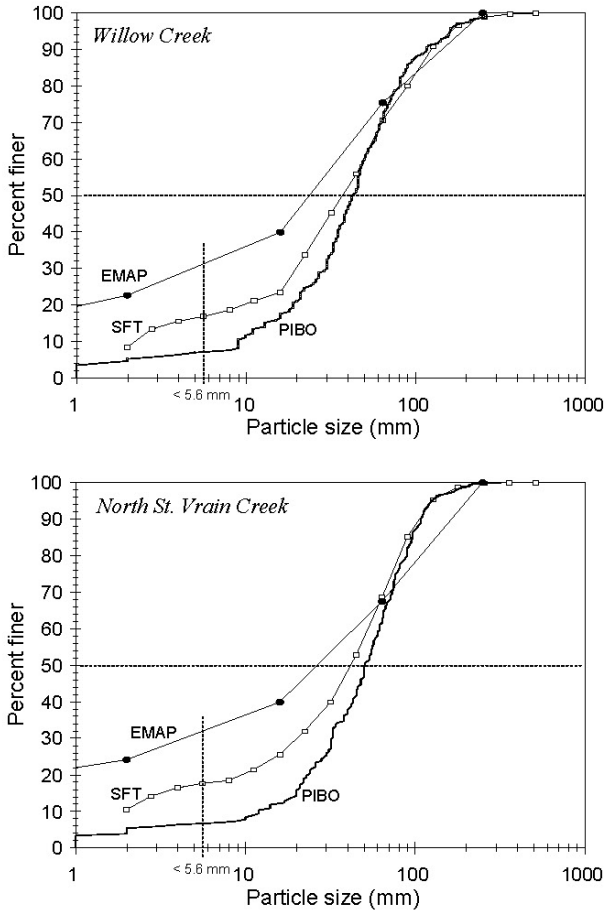

Figure 2. Particle-size distributions obtained from the three pebble count procedures at two gravel-bed streams. The cut-off point for fines less than 5.6 mm is indicated by the dashed line.

sample locations within a stream reach and along a transect, in particle selection, and particle-size determination. Approximately half of the difference was due to sampling at different areas within the study reach (i.e., wetted width, riffles, and bankfull width) and at different locations within a transect. The other half was attributed to using different methods for particle selection from the bed, particle-size determination, and the use of wide, non-standard size classes. Most of the differences in sampling outcomes can be eliminated by using simple field tools (sampling frame and template), by collecting a larger sample size (greater than 400 particles), and by systematically sampling the entire bankfull channel and all geomorphic units within the reach.

Additional Information

For a more in-depth discussion on this topic along with a comprehensive list of references, please refer to the following publication: Bunte, K.; Steven R. Abt, S.R.; Potyondy, J.P.; Swingle, K.W. 2009. Comparison of three pebble count protocols (EMAP, PIBO, and SFT) in two mountain gravel-bed streams. Journal of the American Water Resources Association 45(5):1209-1227. Copies of this article are available online at http://www.stream.fs.fed.us/publications/documentsStream.html.

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The International Instream Flow Program Initiative

The International Instream Flow Program Initiative project was initiated in 2006 to:

- Identify trends and opportunities to help state and provincial fish and wildlife management agencies develop, maintain, and improve their ability to participate in water management decisions.
- Identify trends in fish and wildlife agencies' flow management activities.
- Develop potential strategies that agencies and others can use to better manage water resources for the benefit of fish and wildlife.

To address these objectives, the International Instream Flow Program Initiative conducted a week-long workshop that followed up on two extensive web-based surveys assessing the status and effectiveness of state and provincial fish and wildlife agencies' instream flow efforts over the past decade. Additionally, the International Instream Flow Program Initiative project identified potential strategies to improve agency effectiveness for addressing instream flow and water management issues.

The publication, ***International Instream Flow Program Initiative Report*** (fig. 1), provides a comprehensive summary of state and provincial fish and wildlife agency instream flow and water management activities. Authored by seven members of the Instream Flow Council, this report provides a detailed look at the technical, institutional, legal, and public involvement functions and capacities of 50 state and six provincial fish and wildlife agencies. The report identifies many of the most pressing challenges facing state and provincial agencies, details recent trends in agency function, and discusses opportunities that agencies can embrace. It also presents a wide range of strategies that agencies can consider to improve their effectiveness for managing water and the fish and wildlife communities that are supported by streams, rivers, lakes, and reservoirs.

Although intended to help agencies better fulfill their public trust stewardship responsibilities, this report can easily be used by non-governmental organizations and other instream flow supporters to assist fish and wildlife management agencies in this effort. Other governmental entities that are involved in the complex business of managing water for fish and wildlife may also find benefit in the information contained in this report.

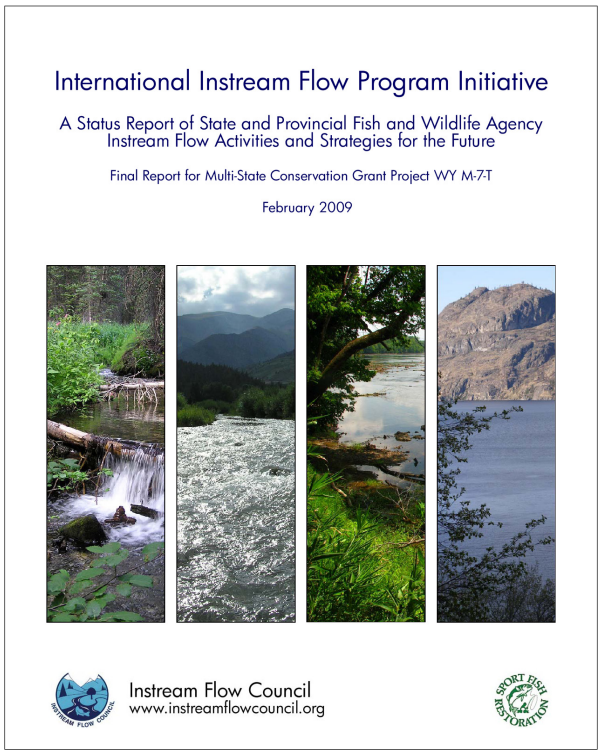

Figure 1. Cover page of the publication, ***International Instream Flow Program Initiative Report***.

The publication, ***International Instream Flow Program Initiative Report,*** can be downloaded at http://www.instreamflowcouncil.org/iifpireport.htm. The citation for the report is: Annear, T., D. Lobb, C. Coomer, M. Woythal, C. Hendry, C. Estes, and K. Williams. 2009. International Instream Flow Program Initiative: A Status Report of State and Provincial Fish and Wildlife Agency Instream Flow Activities and Strategies for the Future. Final Report for Multi-State Conservation Grant Project WY M-7-T. Instream Flow Council, Cheyenne, WY.

Global Climate Change Impacts in the United States

The report, ***Global Climate Change Impacts in the United States***, synthesizes a wide variety of scientific assessments and published research into a comprehensive summary of what is known about the observed and projected consequences of climate change on the United States (fig. 1). The report includes analyses of climate-change impacts on various societal and environmental sectors such as water resources, energy supply and use, transportation, agriculture, ecosystems, human health, and society at the national level and for specific regions of the United States.

The report was produced by a diverse group of experts from 13 United States government agencies and from several major universities and research institutes. As a result, the report provides an up-to-date comprehensive synthesis of climate change in the United States and the potential impact of climate change on various aspects of society with or without mitigation efforts to reduce the rate and amount of global warming.

The report, ***Global Climate Change Impacts in the United States***, can be organized into four sections:

- Global and National Climate Change;
- Climate Change Impacts by Sector;
- Regional Climate Change Impacts; and
- Recommendations for Future Climate Change Assessments.

The first section consists of two chapters that focus on climate change occurring globally and in the United States. Although the focus of the report is on climate change in the United States, global climate change is discussed to provide the necessary background for understanding present and future climate change in the United States. Each of these chapters provides a succinct, but complete summary of more comprehensive reports discussing the various lines of evidence of human-induced global warming over the past 50 years.

The second section consists of seven chapters that examine the potential impacts of climate change on

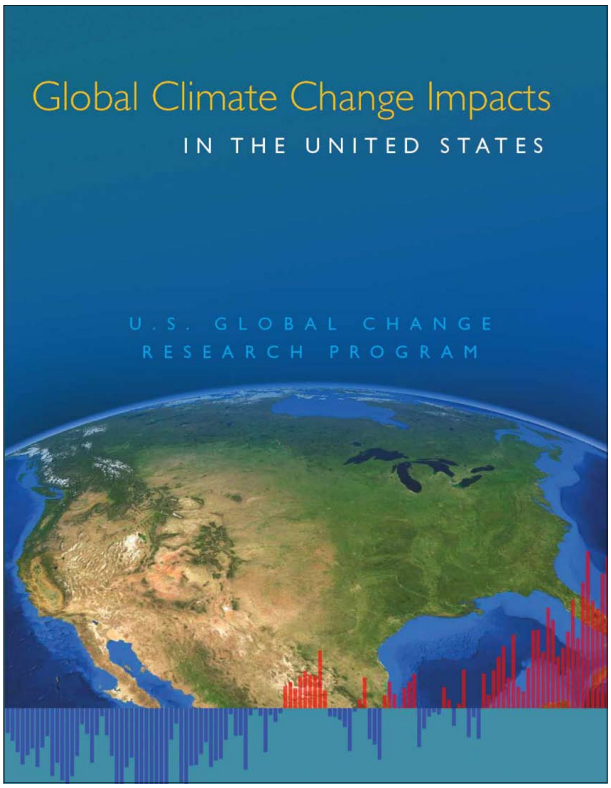

Figure 1. Cover page of the publication, ***Global Climate Change Impacts in the United States.*** The bars at the bottom of the cover show global annual average temperature from 1900-2008.

various societal and environmental sectors such as water resources, energy supply and use, transportation, agriculture, ecosystems, human health, and society in the United States. The seven sectors considered in this report provide an integrated national perspective of how future climate change will affect existing infrastructure, natural resources, and human health in the United States (table 1).

The third section consists of nine chapters that evaluate the similarities and differences in the climate-related issues and consequences that confront various regions of the United States. For example, water is a key issue in all regions of the United States, but specific changes and impacts to water resources from climate change vary regionally (table 2). Thus, regional perspectives are

Table 2. Observed water-related changes in different regions of the United States during the last century. Modified from the publication, ***Global Climate Change Impacts in the United States.***

Observed Change	Direction of Change	Region Affected
Timing of peak streamflows from snowmelt	Earlier	West and Northeast
Proportion of precipitation falling as snow	Decreasing	West and Northeast
Duration and extent of snow cover	Decreasing	Most of the United States
Mountain snow water equivalent	Decreasing	Southwest
Annual precipitation	Increasing	Most of the United States
Annual precipitation	Decreasing	Southwest
Frequency of heavy precipitation events	Increasing	Most of the United States
Runoff and streamflow	Decreasing	Colorado and Columbia River Basins
Streamflow	Increasing	Most of the East
Amount of ice in mountain glaciers	Decreasing	West and Alaska
Water temperature of lakes and streams	Increasing	Most of the United States
Ice cover on lakes and rivers	Decreasing	Great Lakes and Northeast
Periods of drought	Increasing	Parts of West and East
Salinization of surface waters	Increasing	Florida, Louisiana
Widespread thawing of permafrost	Increasing	Alaska

critical for understanding the various responses that will occur because of climate change.

While the primary focus of the first three sections of the report is on observed and projected climate change and its impacts on the United States, it also includes discussions on some of the mitigation and adaptation actions our society can take to respond to the challenges of climate change. Mitigation refers to options for reducing emissions of heat-trapping gases and particles into the atmosphere to reduce the extent of climate change. Adaptation refers to local measures taken to reduce the damage from future climatic and environmental conditions.

Table 1. Highlights of how water-related impacts from climate change affects other sectors. Modified from the publication, ***Global Climate Change Impacts in the United States.***

Sector	Examples of Impacts
Human Health	Heavy downpours increase incidence of waterborne diseases and floods, resulting in potential hazards to human life and health.
Energy Supply and Use	Hydropower reduction is reduced due to low flows in some regions. Power generation is reduced in fossil fuel and nuclear plants due to increased water temperatures and reduced cooling water availability.
Transportation	Floods and droughts disrupt transportation. Heavy downpours affect harbor infrastructure and inland waterways. Declining Great Lakes levels reduce freight capacity.
Agriculture and Forests	Intense precipitation can delay spring planting and damage crops. Earlier spring snowmelt leads to increased number of forest fires.
Ecosystems	Coldwater fish threatened by rising water temperatures. Some warmwater fish will expand ranges.

The last section consists of a brief chapter that provides several recommendations on studies needed to improve our: 1) understanding of the impacts of climate change on ecosystems, social and economic systems, human health, and infrastructure, 2) ability to predict climate change at smaller, local scales where critical resource and infrastructure decisions are made, 3) ability to deliver relevant information on climate change and its impacts to decision makers and the public, 4) understanding of thresholds that may trigger abrupt changes in climate and ecosystems, and 5) understanding of mitigation and adaptation actions that can be taken to reduce climate-change impacts.

The report, ***Global Climate Change Impacts in the United States,*** can be downloaded at http://www.globalchange.gov/usimpacts. Alternatively, hard copies of the report can be ordered from Cambridge University Press (http://www.cambridge.org).

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Literature Synthesis On Effectiveness Of Forest Road BMPs

The USDA Forest Service San Dimas Technology and Development Center and Northern Research Station and the Environmental Protection Agency are working on a synthesis of the literature on the effectiveness of forest road Best Management Practices (BMPs). The synthesis will focus on how well the effectiveness of individual forest road-related BMPs has been scientifically validated. The synthesis will also review BMPs or techniques used in other road types and activities that have application to forest roads.

We have performed an initial search of the literature and have compiled a list of road-related BMP citations, which is available at http://www.fs.fed.us/t-d/programs/wsa/pdfPubs/road_bmp.pdf. But we think there are other publications out there in journals, graduate student theses, gray literature, etc. that you may know about. If you have applicable literature that is not on the citation list, please let us know about it. Although we prefer to receive hard copies or electronic copies of any relevant documents, we will also accept citations. We would like to receive documents no later than 28 February 2010, but submissions after that date will still be welcomed and appreciated. Please mail or email your documents to Pam Edwards; Research Hydrologist; P.O. Box 404; Parsons, WV 26287; pjedwards@fs.fed.us.

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