Brookfield

Brookfield Smoky Mountain Hydropower LLC
314 Growdon Blvd
Tallassee, Tennessee 37878

July 31, 2013

Kimberly D. Bose, Secretary
Federal Energy Regulatory Commission
888 First Street NE
Washington, D.C. 20426

RE: Brookfield Smoky Mountain Hydro Project (FERC No. 2169-036)
License Article 406 – Gravel Enhancement Plan

Dear Secretary Bose:

I am writing on behalf of Brookfield Smoky Mountain Hydropower LLC (BSMH), licensee of the Brookfield Smoky Mountain Hydro Project (FERC No. 2169) (Project), in response to the Federal Energy Regulatory Commission's (Commission) letter dated July 2, 2013, regarding BSMH's (1) implementation of effectiveness monitoring for 2010 and 2012 under the Commission-approved Project Gravel Enhancement Plan (Plan); (2) reporting on effectiveness monitoring for 2010 under the Plan; and (3) allocation of funding for continued effectiveness monitoring. The purpose of this letter is to provide relevant information to the Commission regarding BSMH's Plan-related efforts, and to request a meeting and/or conference call among BSMH, Commission Staff, and the resource agencies that have been involved in this effort (the U.S. Fish & Wildlife Service, U.S. Forest Service, North Carolina Wildlife Resources Commission, and North Carolina Department of Environment and Natural Resources) (Resource Agencies) to clarify BSMH's implementation responsibilities going forward.

Background

Article 406 of the Project license required the development of a Gravel Enhancement Plan for the bypassed reach of the Cheoah River. Article 406 specified that the Plan had to include, at a minimum (1) methods to monitor the success or failure of the gravel introductions; (2) an introduction of 100 cubic yards (cy) of gravel at two sites within the bypassed reach during the first year of the new license; (3) the introduction of an additional 100 cy of gravel every other year after the initial introduction depending on the results of follow-up hydrologic and biological monitoring; (4) the type and frequency of techniques used to conduct hydrologic and biological monitoring; (5) the types of aquatic species to be monitored in the bypassed reach; (6) the source, type, size, and composition of the gravels to be used; and (7) a schedule for implementing the monitoring Plan within one full construction season after the Plan has been approved by the Commission.

The Plan was filed with the Commission for approval on August 31, 2005. Section 3.2 of the Plan discusses effectiveness monitoring of the required gravel introductions as follows:

> The Resource Agencies will conduct monitoring to determine the effectiveness of the gravel introductions. In 2002 and 2003, the Resource Agencies used the Wolman pebble count method (Wolman 1954) to collect baseline (pre-supplementation) data along eight pre-existing instream

> flow transects to assess the availability of gravel sized substrates in the streambed of the river. Wolman pebble counts will be conducted along the same river transects as before, post-supplementation. A comparison between the two data sets will allow the Resource Agencies to evaluate the changes that have occurred in the substrate characteristics as a result of periodic gravel introductions.
>
> Additionally, the Resource Agencies plan to measure the total volume of gravel placed along the river bank, which will serve as a benchmark for subsequent measurements. After one or more high flow events, the Resource Agencies will measure the volume of the gravel that remains on the bank. The difference between the two measurements will represent the volume of gravel that has been transported downstream.
>
> Monitoring will be conducted within a year of the first gravel introduction and *will be conducted periodically (annually or possibly based on the occurrence of flood flows)* thereafter. The results of the monitoring will be used by the Resource Agencies to determine the specifics of subsequent gravel introductions, including timing, location, and quantity.

(Emphasis added.) Section 4 of the Plan, which discusses implementation and schedule, sets forth the timing of effectiveness monitoring and additional gravel introductions as follows:

> The effectiveness monitoring described in section 3.2 will be implemented within one year of the first gravel introduction. Monitoring results will be provided to [the licensee] and submitted to FERC.
>
> Additional gravel will be introduced every other year after the initial introduction or more or less frequently as determined by the effectiveness monitoring.

By order dated August 11, 2006, the Commission approved the Plan with no modifications.

Plan Implementation

Effectiveness Monitoring

In its letter, the Commission asserts that BSMH did not comply with the Plan's effectiveness monitoring requirements because, beyond the Resource Agencies' undocumented observations, aquatic biota response was not measured for the gravel augmentation effort in 2010 and 2012. BSMH respectfully disagrees for the following reasons.

Since implementing the Plan in 2008, the Project's licensees, previously Alcoa Power Generating Inc. (APGI) and now BSMH, have cooperated extensively with the Resource Agencies not only to facilitate gravel introductions (e.g., conducting environmental assessments, securing various required permissions from State and federal agencies, locating a source of gravel), but also to monitor the effectiveness of those introductions. Based on the excerpted language above and discussions with the Resource Agencies, BSMH has understood that, beyond the specific monitoring required within one year of the first introduction, the effectiveness monitoring required by the Plan would be <u>periodic</u> and ongoing, as determined collectively by the licensee and the Resource Agencies and depending on the physical and biological responses observed in the river system.

Since gravel was first introduced in 2008, the Resource Agencies have focused heavily on the biotic responses in the Cheoah River arising from multiple operational and management changes, which typically occur over a longer period of time. BSMH and the Resource Agencies have been monitoring at a frequency that allows us to make decisions about subsequent gravel introductions, as well as the scheduling and implementation of the aquatic base flow and high flow event regime (required by Appendix A to the Project license); introduction of species such as the Appalachian elktoe, wavy-rayed lamp mussel, spotfin chubs, and wounded darters; and the management of vegetation within and along the river corridor. Since 2008, monitoring and publishing of research on the river have been extensive, and BSMH will work with the Resource Agencies to make as much of these data available to the Commission as it would like. BSMH intended its report dated March 1, 2013, merely to summarize the large amount of monitoring data that has been collected and can be made available. Some of our monitoring efforts specific to measuring aquatic biota response to the gravel introductions are discussed briefly below.

The Commission's July 2, 2013 letter acknowledges that gravel introductions occurred in 2008, 2010, and 2012 in accordance with the Plan. The letter also acknowledges that the effectiveness monitoring required within a year after the first gravel introduction occurred in 2008 and that a monitoring report thereon was filed on February 27, 2009. After gravel was introduced in 2010, the Project licensee and the Resource Agencies retained Pennington and Associates in 2011 to monitor the Appalachian elktoe to determine the effectiveness of several enhancement measures being implemented at the Cheoah River, including the gravel introductions. More specifically, that monitoring assessed the gravel introductions explicitly in 2011 by identifying the eight locations where gravel had been introduced in 2008 and 2010 and carefully checking the river substrate for colonization by Appalachian elktoe mussels. During the 2011 survey, Appalachian elktoes were found in the vicinity where most had been collected in past surveys. Since no immature mussels were found in the 2011 survey, and numbers of individuals were reduced when compared to those found previously, gravel enhancement measures to date appear not to have been measurably effective in increasing the Appalachian elktoe population in the Cheoah River. These data were documented in a report filed with the Commission on April 27, 2012, which was in turn incorporated by reference into BSMH's March 1, 2013 report.

In addition to that Appalachian elktoe monitoring in 2011, the North Carolina Wildlife Resources Commission (NCWRC) conducted ongoing assessment surveys of reintroduced fish and mussels in the Cheoah River in 2010, 2012, and 2013, to assess recovery efforts of fish and mussels. NCWRC has been reintroducing spotfin chubs to the Cheoah River since 2009. These assessment surveys are funded by the North Carolina Resource Management and Enhancement Fund (NC Fund) Board, and the survey results are discussed at the Board's annual meetings. The NC Fund also funded Conservation Fisheries Inc. to conduct ongoing monitoring of reintroduced fish species, including the spotfin chub and wounded darter, in the Cheoah River. Further, under the direction of the Resource Agencies, Virginia Polytechnic Institute has monitored macroinvertebrate response to the gravel augmentation since 2008. All of these monitoring efforts focused on trying to better understand the impact and effectiveness of the gravel introductions on fish, mussels, and macroinvertebrates. The Resource Agencies have discussed the results of these monitoring efforts at the annual NC Fund Board meetings. Data documenting the use of the new gravel by river chubs and other fish in their nests are available.

As mentioned above, biotic responses happen over a longer period of time and trends are not easily monitored and documented during frequent, short-term monitoring events. BSMH and the

Resource Agencies understand that the Cheoah River will be restored gradually, over time, and that the collective body of monitoring data (quantitative and qualitative) will need to be used to determine whether restoration and enhancement measures (e.g., gravel introductions) succeed.

Reporting
In its letter, the Commission also asserts that BSMH did not timely meet the Plan's reporting requirements for 2010. BSMH respectfully disagrees, for the following reasons.

The Commission-approved Plan does not specifically require reporting on any given time interval except after monitoring, which, as previously stated, BSMH understands to be periodic. Nonetheless, during the term of the license, APGI and BSMH have frequently reported on the implementation and effects of the Plan. In-depth reports were filed with the Commission on February 27, 2009, and March 1, 2013. In addition, APGI filed with the Commission an Appalachian elktoe report on April 27, 2012, as well as annual reports regarding the implementation of the Endangered Species Management Plan (since 2008) and the work of the NC Fund Board (since 2005), both of which discuss the required gravel introductions and associated effectiveness monitoring.

Perhaps there is a better way to present all of this information in summary form to the Commission in the future, so as to avoid or minimize any misunderstanding of the significant level of work and monitoring ongoing in the Cheoah River corridor. BSMH would welcome an opportunity to discuss possible reporting approaches during a meeting and/or conference call with Commission Staff and the Resource Agencies.

Subsequent Gravel Introductions
In its letter, the Commission indicates that it anticipates that gravel will be introduced in 2014. Again, section 4 of the Plan provides that "Additional gravel will be introduced every other year ... or more or less frequently as determined by the effectiveness monitoring", and that, per section 3.2, monitoring shall be conducted "periodically." Consistent with that, BSMH plans to meet with the Resource Agencies in October 2013 to discuss whether gravel introductions are needed in 2014. Previously, the Licensee and Resource Agencies agreed to double the amount of gravel installed in 2012 (from 100 cy to 200 cy) in order to forego installing 100 cy of gravel in 2014. The Resource Agencies have recommended adding a larger volume of gravel to the river less frequently, which BSMH and the Resource Agencies understand would comply with the Plan as approved by the Commission.

Plan Implementation Funding
In its letter, the Commission expresses some confusion as to why, as BSMH reported in its March 1, 2013 Plan report, the Resource Agencies "'may be able to allocate funds' toward continued monitoring, when apparently none has been conducted other than informal monitoring/observation of the gravel augmentation sites...." To clarify, BSMH and the Resource Agencies agreed that the gravel introductions and effectiveness monitoring required by the Plan would be funded through the NC Fund. BSMH annually provides to the NC Fund $25,000, escalated in accordance with the Relicensing Settlement Agreement and Project license. The NC Fund Board and BSMH meet annually in October to prioritize projects and funding for the next calendar year. Each June, BSMH reports to the Commission regarding the activities of the NC Fund Board, including how funding is being used. The annual reports also typically

include NC Fund Board meeting summaries, which not only discuss what projects have been funded, but also present relevant monitoring data. BSMH will continue to make the required financial contributions to the NC Fund and will continue to use best efforts to ensure that necessary gravel introductions and associated monitoring are fully funded.

Concluding Remarks & Request for Meeting/Conference Call

In conclusion, BSMH believes that it is in compliance with the Plan because appropriate and adequate monitoring and reporting have been conducted and available data are being used to make informed decisions about the implementation of enhancement measures, including future gravel introductions, within the river corridor.

Since the Commission issued its letter, BSMH has consulted with the Resource Agencies, and they agree that the Plan was written with an adaptive management approach in mind, which provides the flexibility needed to continue refining the details of subsequent introductions based on documented physical and biological responses. The Resource Agencies also agree that BSMH is in compliance with the Plan's requirements. Copies of letters from the Resource Agencies are attached. At this time, BSMH does not believe that the Plan needs to be amended.

It is clear, however, that BSMH, the Resource Agencies, and the Commission may not share a common understanding of the Plan's requirements. Consequently, BSMH, on behalf of itself and the Resource Agencies, requests to meet and/or participate in a conference call with interested and involved Commission Staff to discuss how best to move forward. Specifically, BSMH and the Resource Agencies would like to better understand what type of data and reporting the Commission expects to see and with what frequency. BSMH believes that opportunities exist to collect additional physical data, such as the pebble count data previously collected, and to provide these additional data to the Commission. If you agree that a meeting and/or conference call would be beneficial, please contact me.

Thank you for considering all the information provided to the Commission. I can be reached at (865) 255-4240 or marshall.olson@brookfieldrenewable.com.

Sincerely,

Marshall L Olson

Marshall L. Olson
Compliance Manager

cc: Thomas J. LoVullo – FERC DHAC
Robert Ballantine – FERC DHAC
Myra Hair – BSMH

Attachments

MARCH 3, 1849

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Asheville Field Office
160 Zillicoa Street
Asheville, North Carolina 28801

July 18, 2013

Mr. Marshall Olson
Compliance Specialist
Brookfield Smoky Mountain Hydropower, LLC.
314 Growdon Boulevard
Tallassee, Tennessee 37878

Subject: COMMENTS and RECOMMENDATIONS on a letter of compliance to Brookfield Smoky Mountain Hydro Project, North Carolina (P-2169-036).

Dear Mr. Olson:

We have reviewed the July 2, 2013, Federal Energy Regulatory Commission's (FERC) letter of "Compliance with the gravel enhancement plan pursuant to license article 406" for the Brookfield Smoky Mountain Hydro Project, FERC Project No. 2169-036. On March 1, 2013, Brookfield Smoky Mountain Hydropower, LLC filed a gravel enhancement report for the Cheoah River in Graham County, North Carolina. In its report, the Licensee described the times and amounts of gravel augmentation efforts, as well as the results of effectiveness monitoring. In the July 2, 2013 letter, the FERC raised issues with the adequacy and timeliness of the report.

We do not agree that the Licensee is out of compliance with the approved gravel augmentation plan, license article 406, or the Commission's Order approving the gravel enhancement plan.

COMMENTS AND RECOMMENDATIONS

Cheoah River is important to the U.S. Fish and Wildlife Service. The USFWS is quite sensitive to the condition of the Cheoah River because it provides habitat for the endangered mussel Appalachian elktoe, the threatened plant Virginia spiraea, and a diversity of fishes and other aquatic community members, including those resulting from intensive restoration efforts by the resource agencies in coordination with the Licensee and the Cheoah Fund. This reach of the Cheoah River is also designated as critical habitat for the endangered Appalachian elktoe.

1. In making recommendations that led to the FERC inclusion of License article 406, we were interested in making measured, controlled additions of gravel substrate to the Cheoah River, since gravel transport was expected to change with the new flow regimes.

2. The USFWS is satisfied that the level of monitoring and reporting has been appropriate for the careful restoration of gravel to the Cheoah River, in a manner that has improved habitat conditions, while not disrupting natural bedload movement.

3. The recommendations of the resource agencies, and the addition of gravel to the Cheoah River has been guided by the information gained from monitoring. We feel that the information has been adequate to make these important decisions and recommendations.

The Cheoah River is dynamic and gravel addition is not the sole restoration effort in place. Since these gravel augmentation efforts are part of the restoration of a new seasonally variable baseflow release regime, periodic scheduled higher flow events, as well as unscheduled high flow events from spill and tributary inflows, we recommended careful application of gravel in order to achieve a beneficial balance at the Cheoah River. We realized that we could not restore a healthy, active bedload to the dynamic Cheoah River with a single restoration action, even under regulated conditions, so our agreement, and the License article requiring initial careful gravel additions followed by physical and biotic monitoring. We have also found that the biotic responses to the gravel restoration efforts are rapid is some ways, while colonization rates of some animals is slower. We have been careful to balance the gravel augmentation with the extant biota, to avoid harm to existing endangered Appalachian elktoe, other rare mussels, the current distribution of Virginia spiraea, and the benthic habitat of other focal species, including the threatened fish, spotfin chub, subject of recent reintroduction efforts.

The gravel additions have been refined. Even with 3 separate gravel additions, the size, source, and type of materials, as well as placement techniques have been refined and improved. The first gravel additions (2008) were placed on the stream bank, above the normal water line, so that entrainment and transport would occur only during higher flows - though this worked well, we became aware of other equipment to spread gravel across the stream channel, and used this technique in subsequent additions (2010, 2012). This is an improved means of gravel augmentation. Locations of gravel augmentation have been changed as we understand transport rates relative to flows and channel slope, identify other gravel inputs, and prioritize treatment areas.

The Cheoah River Bypassed Reach Gravel Enhancement Plan is specific about monitoring the *initial* gravel augmentation, but adaptive thereafter. We reviewed the Cheoah River Bypassed Reach Gravel Enhancement Plan during its development, and do not agree that the requirement of Section 3.2 *Effectiveness Monitoring* establishes a requirement for intensive monitoring of each gravel addition, but rather includes possibility of other factors and timeframes.

> *Monitoring will be conducted within a year of the first gravel introduction and will be conducted periodically (annually or possibly based on the occurrence of flood flows) thereafter. The results of the monitoring will be used by the Resource Agencies to determine the specifics of subsequent gravel introductions, Including timing, location, and quantity.*

Section 3.2 of the Plan requires that effectiveness monitoring be conducted within a year of the *first* gravel introduction. These monitoring results were submitted to the FERC timely.

The Gravel Plan included a footnote "*Per the Resource Agencies' recommendations, the introduction of gravel into the Cheoah River will be cautious and additional amounts of gravel may be added based on the results of effectiveness monitoring*".

Because of the presence of listed species and critical habitat, we have not been hasty in gravel additions, or to base changes solely on fine-scale pebble counts. Besides the gravel additions to date, particle size in the Cheoah River has been influenced by tributary contributions, and re-mobilization of gravel previously sequestered under alder and other vegetation that has now retreated due to the new baseflow and high flow event regime. Our gravel augmentation plans includes consideration of the contributions of gravel from tributaries, and re-mobilization of in-channel gravel previously sequestered under vegetation that is now responding to changed flow conditions. The Resource agencies considered all of these sources of uncertainty in development of the gravel plan, and now in our response evaluations. The USFWS is satisfied with the progress and the level of information available for guiding future gravel additions pursuant to Article 406, and to make beneficial improvements to designated critical habitat and the habitat of a diverse aquatic community. We do not believe that funding has limited our ongoing implementation of the gravel plan.

Summary. We look forward to working with Brookfield Smoky Mountain Hydropower, LLC, and others to ensure impacts to fish and wildlife resources are minimized during the remainder of the license period for the Project. We recommend inclusion of Commission staff in more detailed discussions of the gravel augmentation, monitoring, and reporting expectations. If you have any questions about these comments, please contact me at 828/258-3939, Ext. 227.

Sincerely,

- - original signed - -

Mark A. Cantrell
Fish & Wildlife Biologist

cc:
USFWS – Atlanta (Ziewitz)
USDOI - SOL (Knoxville - Thornton)

Attachments.

McManamay, R.A., D.J. Orth, C.A. Dolloff, and M.A. Cantrell. 2010. Gravel addition as a habitat restoration technique for tailwaters. *North American Journal of Fisheries Management* 30:1238-1257.

North American Journal of Fisheries Management 30:1238–1257, 2010

DOI: 10.1577/M10-007.1

[Management Brief]

Gravel Addition as a Habitat Restoration Technique for Tailwaters

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Abstract.—We assessed the efficacy of passive gravel addition at forming catostomid spawning habitat under various flow regimes in the Cheoah River, a high-gradient tailwater river in North Carolina. The purpose was to provide a case study that included recommendations for future applications. A total of 76.3 m^3 (162 tons) of washed gravel (10–50 mm) was passively dumped down the streambank and into the channel in four locations. Gravel sites differed in terms of average reach slope, bank slope, and the initial volume of gravel added, which could have influenced gravel entrainment. Maps of gravel movement under various flows suggested that large-magnitude discharges (≥ 113 m^3/s) caused extensive migration; however, less obvious, smaller discharges (~ 28 m^3/s) still caused substantial shifting, which may influence the stability of catostomid spawning substrates. Following gravel addition, the proportion of gravel in the streambed was significantly higher at all gravel sites. However, comparisons of sites to reference stream reaches suggested that sand, gravel, and cobble were still extremely deficient. Additionally, the volume of gravel was inadequate to create gravel depths that provided suitable habitat for catostomid spawning. Although periodic, passive gravel additions may take years to provide suitable spawning habitat for some fish species, we found that river chub *Nocomis micropogon* utilized the newly added gravel for spawning.

Anthropogenic disturbances have altered freshwater rivers more than any other ecosystem, leading to widespread declines in species diversity (Vitousek et al. 1997; Sondergaard and Jeppesen 2007). River regulation due to impoundments is certainly no exception. Dams not only homogenize the natural flow regime responsible for transporting sediment (Poff et al. 2007) but also trap and store sediments, leaving the downstream river channel gravel starved (Kondolf 1997; Renwick et al. 2005). The lack of sediment inputs causes channel degradation and armoring (Kondolf 1997), which only intensifies the separation of a river channel and its floodplain (Trush et al. 2000; Nislow et al. 2002; Gordon and Meentemeyer 2006). Ultimately, macroinvertebrate and fish spawning habitats are lost, and species are either lost or replaced. With more than 82,000 dams in the United States (USACE 2009), river managers are faced with a growing need for techniques that restore the physical processes that govern habitat formation.

Restoring the natural flow regime of regulated river systems is critical to improving below-impoundment conditions (Poff et al. 1997); however, the restoration of impaired habitat by the reregulation of flows will be limited if gravel substrata are greatly diminished. Gravel additions have been used to restore the morphological and ecological integrity of gravel bed salmonid rivers in the western United States (Kondolf et al. 1996; Merz and Setka 2004; Merz and Chan 2005; Sarriquet et al. 2007) and Europe (Pedersen et al. 2009), and have been shown to enhance salmon spawning and macroinvertebrate habitat (Kondolf et al. 1996; Merz and Setka 2004).

Despite the extensive literature on salmonid spawning enhancement, less information exists for gravel additions for other fish species that utilize gravel habitat for foraging, cover, and spawning. We did, however, find evidence that gravel addition, via artificial riffle construction, successfully provided habitat for Neosho madtom *Noturus placidus* in the Midwest (Fuselier and Edds 1995) and enhanced degraded streambed conditions for macroinvertebrates in Tennessee (Gore et al. 1998). We also found two documented projects in Georgia where gravel additions have been conducted to improve spawning habitats for robust redhorse *Moxostoma robustum*, a state-listed

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endangered species and a candidate for federal listing (SARP 2009a, 2009b).

Monitoring the effects of habitat restoration is essential for adaptive management (Downs and Kondolf 2002; Bernhardt et al. 2005; Palmer et al. 2005). In the case of substrate restoration, developing sediment budgets and predicting bed load transport is a critical step for river managers in determining the amount, location, and persistence of gravel additions (Merz et al. 2006) as well as the flows needed to mobilize gravel sediments and maintain gravel habitats (Nelson et al. 1987; Wilcock et al. 1996a, 1996b; Singer and Dunne 2006). However, the relationship between flow magnitude and the formation of specific habitat types following indirect gravel placement has received less attention and is especially important considering the expense of gravel additions and the need to maximize the benefit-cost of habitat restoration for particular species.

The Cheoah River provided a unique opportunity to observe gravel migration in a regulated, high-gradient, boulder-dominated system in western North Carolina. The construction of Santeetlah Dam in 1927 substantially altered the sediment supply and hydrology of the Cheoah River. Because the dam is a surface release operation, Santeetlah Reservoir traps all bed load and most sediment from entering the lower 14.6 km of the river, which resulted in bed coarsening and loss of gravel-sized substrates (Normandeau Associates 2002; Dilts et al. 2003; R2 2003). To remediate the effects of habitat degradation, a settlement agreement with natural resource agencies along with corresponding Federal Energy Regulatory Commission (FERC) orders in 2005 and 2006 required Alcoa Power Generating, Inc. to (1) provide a seasonally variable streamflow regime punctuated by higher flow events, and (2) develop an adaptive management plan to add and monitor gravel on a biannual basis (FERC 2005, 2006).

Historically, the Cheoah River may have had over 40 fish species (R. Jenkins and D. A. Etnier, personal communication). Due to regulations, the Cheoah currently is a coolwater water system with 18 species of fish. Also, because of substantial reductions in their habitat and population, the Appalachian elktoe *Alasmidonta raveneliana*, a mussel species, was listed as federally endangered in 1994 (USFWS 1994). Gravel enhancement was conducted to improve habitat conditions for macroinvertebrates, mussels, and fish that utilize gravel for spawning, foraging, cover, or a combination thereof (FERC 2006). Based on recommendations by consultants, the FERC-approved Gravel Enhancement Plan required initial monitoring to determine the effectiveness of passive gravel additions at enhancing the streambed by evaluating changes in (1) surface particles and (2) gravel volume in relation to flow (FERC 2006). Because the gravel was obtained from a foreign source and could clearly be differentiated from native substrate in the Cheoah River, we were able to observe gravel migration, deposit formation, and stability under various flow regimes within a nonuniform, rough channel where gravel movement studies are deficient (Kondolf et al. 1991). The Gravel Enhancement Plan also required that "monitoring" be conducted to determine the biological effectiveness of gravel in providing habitat for "aquatic species," which was fairly open-ended. Although gravel additions in the Cheoah River have been proposed for multiple groups of aquatic biota, we chose three fish species—a mound-building chub (river chub *Nocomis micropogon*) and two catostomid redd nesters (northern hog sucker *Hypentelium nigricans* and black redhorse *Moxostoma duquesnei*)—as target biota to determine the effectiveness of passive gravel addition techniques at creating spawning habitat. We chose to monitor spawning habitat for these species based on the site location and the size range of gravel augmented (10–50 mm). We attempted to observe spawning activity and measured habitat characteristics (water depth, velocity, and gravel depth) at gravel addition sites to determine if suitable spawning habitat had been created.

The overall purpose of this paper is to provide observations of the effectiveness of passive gravel at enhancing the streambed and providing spawning habitat while making recommendations for managers. Specifically, our goals were to (1) determine the cost-benefit of gravel addition in terms of the volume added and the amount of streambed enhanced in relation to flow, and (2) evaluate the effectiveness of passive gravel addition at creating spawning habitat for three fish species.

Study Site

The Cheoah River is a regulated system located in western North Carolina within the Blue Ridge physiographical province (Figure 1). The Cheoah River drains Santeetlah Lake, a 456-km^2 reservoir, and runs 14.6 km before emptying into the Little Tennessee River System downstream of Cheoah Reservoir. The 143-km^2, predominately forested watershed is primarily located within Nantahala National Forest. The area generally receives 150–230 cm of precipitation annually. The Cheoah River is a high-gradient system, falling from 533 m at the dam to less than 335 m over its length (~1.3%). Valley relief is relatively steep, approximately 30% grade. Geology is dominated by gneiss, sandstone, and granite (Normandeau Associates 2002). In general,

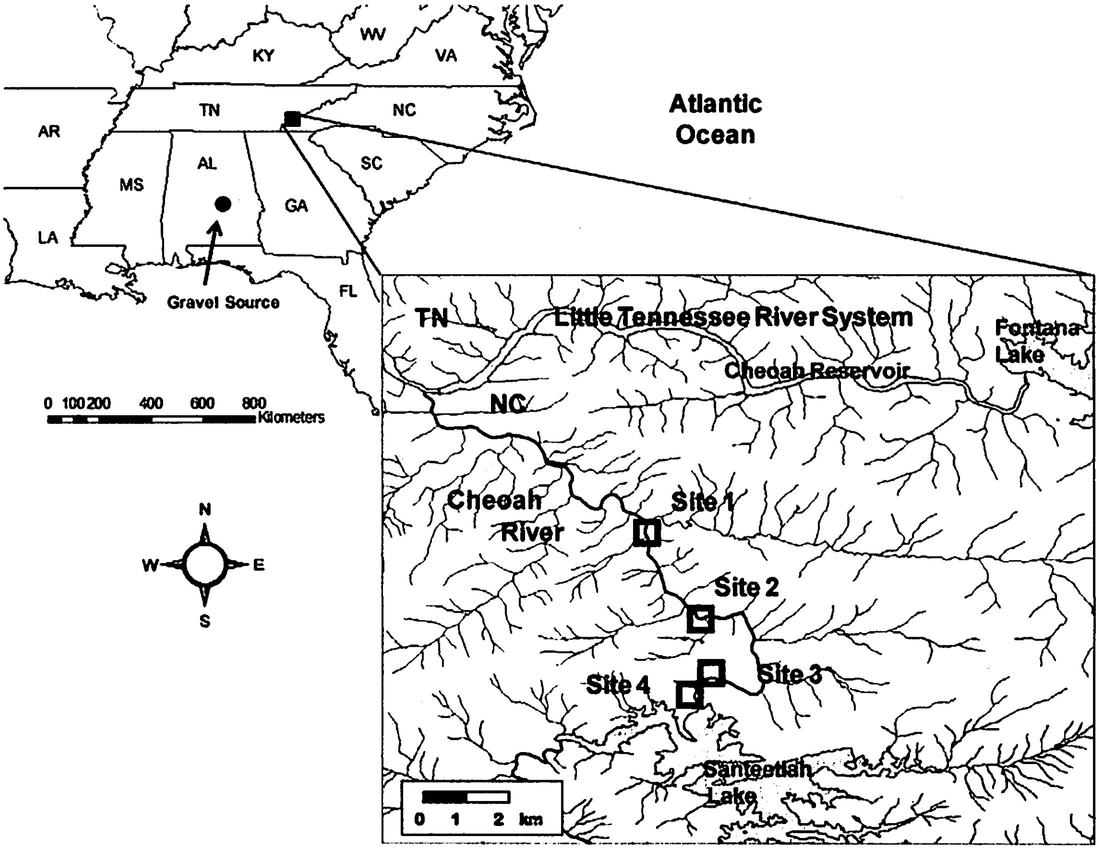

FIGURE 1.—Map of the Cheoah River from Santeetlah Lake to the Little Tennessee River (14.8 km). Gravel (10–50 mm) was transported from a mining operation in abandoned floodplains of the Alabama River near Montgomery, Alabama, to the Cheoah River and dumped down the bank at four sites in February 2008. A total of 30.7 m^3 was added at the most downstream site (site 1), 8.2 m^3 at site 2, and approximately 19 m^3 each at sites 3 and 4.

the Cheoah River is constrained by the valley and bedrock along with the high road embankment, leading to very little lateral migration (Normandeau Associates 2002). The upper 2 mi of the river are dominated by bedrock and large boulders (median particle size [D_{50}] = 370 mm), and have a relatively low gradient (0.3–0.6%). The lower 7 mi generally has a steeper gradient (1–2%) and, although gravel and cobble substrates tend to increase with distance from the dam, the streambed is still very coarse (D_{50} = 230 mm) and sediment starved (R2 2003).

Background

Because of surface release operations, sediment supply has been cut off from entering the Cheoah River and is limited to tributary input and episodic landslides below Santeetlah Dam (Normandeau Associates 2002; Dilts et al. 2003). Prior to 2005, flow from Santeetlah Dam into the lowermost 14.6 km of the Cheoah River was limited to leakage from the dam (<0.002 m^3/s), inputs from tributaries, and occasional large pulses (>24 m^3/s) from the reservoir. Following impoundment, river channel migration and the magnitude of episodic flows generally decrease, both of which lead to the encroachment of riparian vegetation (Gordon and Meentemeyer 2006). Because of low-flow conditions, riparian vegetation has encroached much of the upper Cheoah River, which has locked up finer substrate (Normandeau Associates 2002). The high-gradient nature of the Cheoah River only intensified sediment-starved conditions below the dam. Sediment supply, streambed particles, discharge, and channel slope are all intricately balanced in a river system (Gordon et al. 2004). Thus, rivers respond to reduced sediment supply by channel degradation (lower slope) and streambed armoring (coarser substrate) below dams (Gordon et al. 2004). Altered hydrology and sediment supply led to degraded habitat for many aquatic biota, including the federally listed Virginia spiraea *Spiraea virginiana* and the federally endangered mussel Appalachian elktoe *Alasmidonta raveneliana* (USFWS 1994).

The relicensing process was a collaborative effort between Alcoa Power, U.S. Department of Agriculture (USDA) Forest Service, U.S. Fish and Wildlife Service, North Carolina (NC) Wildlife Resources Commission, NC Division of Water Resources–Department of Environment and Natural Resources (DENR), and many other interested parties. Consultant groups were contracted to assess existing conditions in the river and make recommendations for future management actions, including environmental flow prescriptions and substrate augmentation (Normandeau Associates 2002; R2 2003; Dilts et al. 2003). R2 consultants were contracted by the U.S. Forest Service to provide technical plans for substrate supplementation in the Cheoah River, especially considering the deficiency of historical data prior to the construction of the Santeetlah Dam in 1927. Based on simulated "without-dam" hydrologic data and bed load rating curves developed from U.S. Geological Survey (USGS)-derived sediment transport rates (from neighboring reference gauge), R2 consultants estimated the percentage of mobile particles historically found in the Cheoah River (mobile refers to particles sizes transported at bank-full flow, 1.5 years recurrence interval; R2 2003). R2 estimated that there was an average of 50% less mobile particles in the upper half of the river compared with historical conditions. Under the current flow regime and existing particle sizes, R2 estimated that 383 m^3/year (>670 tons) of bed load should be augmented to multiple reaches to attain historical conditions; however, they recommended to conservatively add (76.5 cubic meters) to two locations on a biannual basis and to monitor the distribution of sediments under a range of flows (R2 2003). Secondly, based on deficient size-classes and large differences in gradient, R2 proposed augmenting a median particle size of 15 mm in the low-gradient, upstream areas near the dam and 40 mm in downstream reaches where gradient increases.

The FERC issued the new 40-year license in effect March 1, 2005 (FERC 2005). The license includes requirements for seasonally variable base flows between 1.13 and 2.83 m^3/s along with periodic high-flow events (28.3 m^3/s) to enhance aquatic diversity (FERC 2005). Agencies decided to be even more conservative than recommendations made by R2; thus, they determined that a total of 76.5 m^3 should be supplemented across multiple sites rather than at each of two sites. The license specifically requires that (1) 76.5 m^3 of gravel must be supplemented on a biannual basis to the lower river reaches and (2) monitoring of the effects of flow and substrate enhancement should be initiated. Because of permitting issues on federal land, the inability to augment in areas directly upstream or adjacent to Appalachian elktoe mussel beds and Virginia spiraea, and the rapidly approaching FERC deadline to augment gravel, sites were limited to Alcoa Power property and chosen only a month prior to addition.

Methods

Gravel augmentation.—During February 21–23, 2008, washed gravel (mined from drained floodplains of the Alabama River in a quarry near Montgomery, Alabama) was transported to the Cheoah River and dumped down the streambank and into the channel in four locations (Figure 1). The gravel was initially filtered to the desired size (10–50 mm) and washed by the mining operation and then transported in dump trucks to the field sites by subcontractors. Generally, the dump truck was backed until it was close as possible to the edge of the embankment and then dumped down the bank. A track hoe was then used to push gravel closer to the stream channel. However, at site 4, access to the embankment was limited because of vegetation; thus, gravel was placed nearby and then transported by a front-end loader. Embankments were fairly steep to promote gravel migration into the channel.

The gravel addition sites differed in terms of gradient, embankment slope, and in-channel–bank vegetation. Site 1 was a high-gradient (1.3%) riffle–run reach, followed by a series of high-gradient riffles and deeper runs with a pool at the downstream end. Site 2 was also high-gradient (1.18%) step pool reach characterized by deep runs. Site 3 was characterized by a slow run with low gradient (0.35%). Site 4 had slightly higher gradient (0.58%) and was characterized by a consistent riffle–run. Site 4 had considerable amounts of within-channel vegetation (mostly alder *Alnus glutinosa*) upstream and downstream of the gravel site. The channel at site 3 also had instream vegetation outcrops immediately across from and downstream of the site; however, vegetation was not as extensive as that at site 4. Sites 1 and 2 had no vegetated outcrops in the channel. Bank slope, calculated as the change in elevation from the crest of the bank to the water level at base flow (2.83 m^3/s) divided by the lateral distance × 100 (see Table 1), was highest at downstream sites 1 and 2 (58.3% and 60.7%, respectively) and lowest at upstream sites 3 and 4 (38.1% and 48.6%, respectively; Table 1).

Approximately 19 m^3 (40 tons) of 10-mm gravel (mean) were dumped down the bank at the upstream

TABLE 1.—Gravel area, volume, and volume change in relation to time period, maximum discharge, and slope at each gravel site (GS). Volume change is calculated as the change in volume between two measurements divided by the total days between the measurements. Maximum discharge is the peak flow during each time period. Bank slope was measured by subtracting the elevation of the bank at the water surface during base flow (28.3 m^3/s) from the elevation of the crest of the bank and dividing that value by the lateral distance × 100.

Site	Amount dumped (m^3)	Days since dump	Enhanced area (m^2)	Within-channel volume (m^3)	Outside-channel volume (m^3)	Percent mobilized	Volume change (m^3/d)	Maximum discharge (m^3/s)	Reach slope (%)	Bank slope (%)
GS 1	30.7	0.29	461			~100		28.8	1.30	58.3
		51	1,664	23.6	~7	~100	0.46	133		
GS 3	19.1	51	230	7.36	0	39	0.14	133	0.35	38.1
		237	184	13.3	0	70	0.03	31		
		335	387	18.9	0	99	0.06	232		
GS 4	19.3	51	129	2.64	0	14	0.05	133	0.58	48.6
		237	156	6.08	0	32	0.02	31		
		335	452	16.6	0	86	0.11	232		

locations near the dam (gravel sites 3 and 4). Further downstream, 8.2 m^3 (17 tons) of 40-mm gravel (mean) were dumped at gravel site 2 and 30.7 m^3 (64 tons) of 40-mm gravel were dumped at the furthest downstream site, gravel site 1. Based on recommendations made by R2 consultants, smaller-size gravels were dumped at the upstream locations due to lower gradient. Because such a small volume of gravel was dumped at site 2 and entrainment was high, gravel movement was difficult to track and it was not included in our analysis.

Streamflow.—Streamflow, stage, and temperature was measured by the USGS at gauge station 0351706800, located at river kilometer (rkm) 4.3. (Alcoa Power Generating, Inc., also publishes its releases from the dam [rkm 14.6] at http://www.alcoa.com/tapoco/en/info_page/santeetlah.asp.) We used a calibrated staff gauge at rkm 11.3 to supplement these records while in the field.

Gravel migration.—Because the extent of gravel migration was so large at site 1, it passed through several different mesohabitats. We used delineated mesohabitats obtained from Entrix Consultants (see Acknowledgments) to qualitatively describe how channel characteristics influence gravel migration. Gravel migration at sites 3 and 4 was not as extensive and remained within the same mesohabitat. Thus, we do not discuss implications of mesohabitats on gravel migration at these sites.

Because the augmented stone was obtained from a foreign source, it could easily be differentiated from native substrates in the river and its migration could be tracked. Prior to the gravel additions, one longitudinal transect was established along the bank from each of the three gravel addition locations to 60 m downstream. Transects were used to measure gravel migration and also to establish monuments from which pebble counts before and after augmentation could be conducted. As gravel migrated from the pile at the bank into the channel, transects were extended downstream. Gravel migration, changes in depth, and total volume were observed after periodic visits, each pertaining to a different flow regime (Figure 2). Gravel migration was assessed by measuring the longitudinal distance along each transect and the width of gravel "enhancement" in the streambed. The width of enhancement was measured as the distance (perpendicular to the flow) from the longitudinal transect to the furthest extent that particles had dispersed in the channel, regardless of the depth of deposits. The total area enhanced by gravel could then be calculated. Because gravel coverage and depth within the channel was not uniform, it obviously could influence our estimate of total volume. Therefore, we assessed percent coverage of gravel by taking digital pictures of a submerged 60-cm^2 metal grid with 10-cm^2 subgrids overlain on newly added gravel. The total "enhanced" area was divided into 3-m^2 subsections, and the grid was placed in every subsection. At each grid placement, an overhead digital picture and two depth measurements of newly added gravel deposits were taken. Because the new gravel was very loosely deposited and not compacted, the depth of augmented gravel deposits were measured by inserting a metal meter stick into the substrate until it reached the armored streambed. The intersections of each subgrid were used to assess percent coverage (total 47 intersections). Each digital photograph was analyzed, and the total number of intersections that fell over the new gravel was divided by 47. The percent area calculated for each grid was extrapolated to the area of the subsection it represented to give a corrected area value. The corrected area value was then multiplied by the average depth so that an accurate volume could be estimated. Because different flows of various magnitudes can scour and deposit gravel, we wanted to produce a figure to show not only migration but also changes in depth. However, gravel depths are not

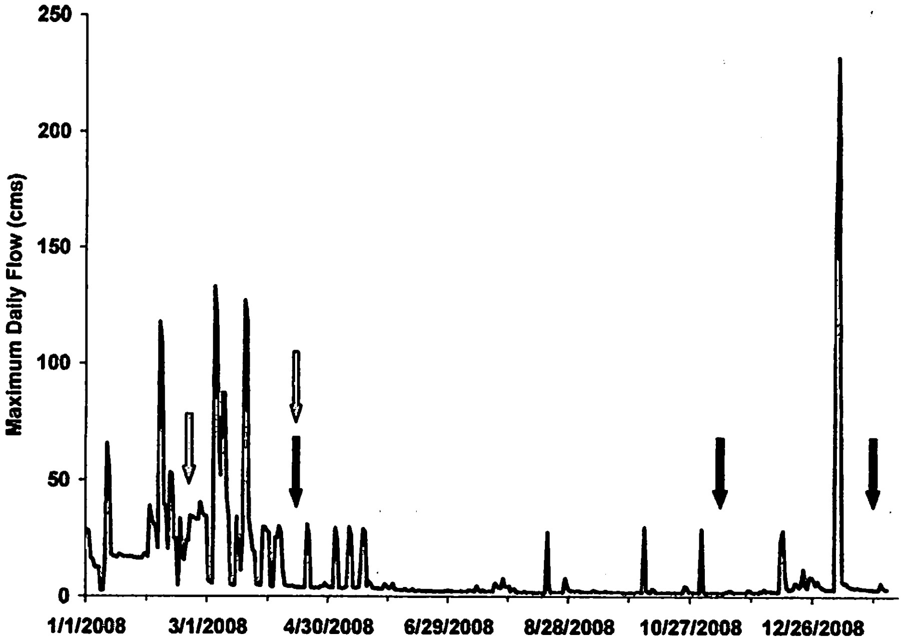

FIGURE 2.—Maximum daily flow (m^3/s) in the study reach during the study period. Gravel was initially augmented during February 21–23, 2008 (first gray arrow). Gravel migration was observed immediately following augmentation and on April 12, 2008, at site 1 (second gray arrow). Gravel migration was observed on April 12, 2008; November 6, 2008; and January 24, 2009 at both sites 3 and 4 (black arrows).

uniform across the channel; thus, our raw depth values would be an overestimate. Thus, we divided the volume in each subsection by the subsection's area to calculate a corrected depth value. This value integrates percent area and volume into the same measurement. The corrected depth values were plotted in ESRI ARC GIS 9.3, and we conducted an interpolation function that estimated depths between each corrected depth value (Figures 3–5).

Gravel migration at site 1 occurred immediately after it was dumped and could be visualized from the bank. However, high-flow conditions (34.3 m^3/s) at that time made it impossible to wade in the channel. Thus, a visual estimate was made from the streambank of the migration of gravel in the channel by recording the longitudinal distance of the gravel slug and then estimating its width in the channel using a stadia rod for scale. We were unable to accurately assess depth and, consequently, volume at site 1 immediately after gravel addition; however, for visual purposes, we estimated the depth from photos to use in Figure 5. In April, gravel migration and depth measurements at site 1 were conducted similarly to those at sites 3 and 4 in the shallower mesohabitats. However, due to cold temperatures and safety precautions we were unable to assess gravel deposits in deeper areas (≥ 2 m) until later in the summer. In July, when flows were lower and temperatures warmer, we snorkeled the entire reach and measured the dimensions of each deposit and their depth. The percent coverage and depth was calculated to provide a corrected depth value.

Particle size distribution.—Along each 60-m transect, 50 pebble counts were conducted at 10-m monuments before and after gravel addition at each gravel site. At gravel site 1, pre- and postpebble counts were conducted in reach A (Figure 5). However, because gravel migration was extremely rapid and deposits were formed over 120 m downstream, additional transects were established in reach B, where only post–gravel addition pebble counts were conducted (Figure 5). We used Mann–Whitney tests to test for differences in particle size distributions before and after gravel additions. We used a paired *t*-test to test for differences in the proportion of particles within particular size-classes (depending on gravel site) before and after gravel addition, using transects as replicates. Also, pebble counts were compared with particle size distributions within riffle–run habitats in five reference streams (data from another study). Three of the streams—Santeetlah Creek, Snowbird Creek, and Little Cheoah River—are the major tributaries that flow into Santeetlah Lake and have been used as reference

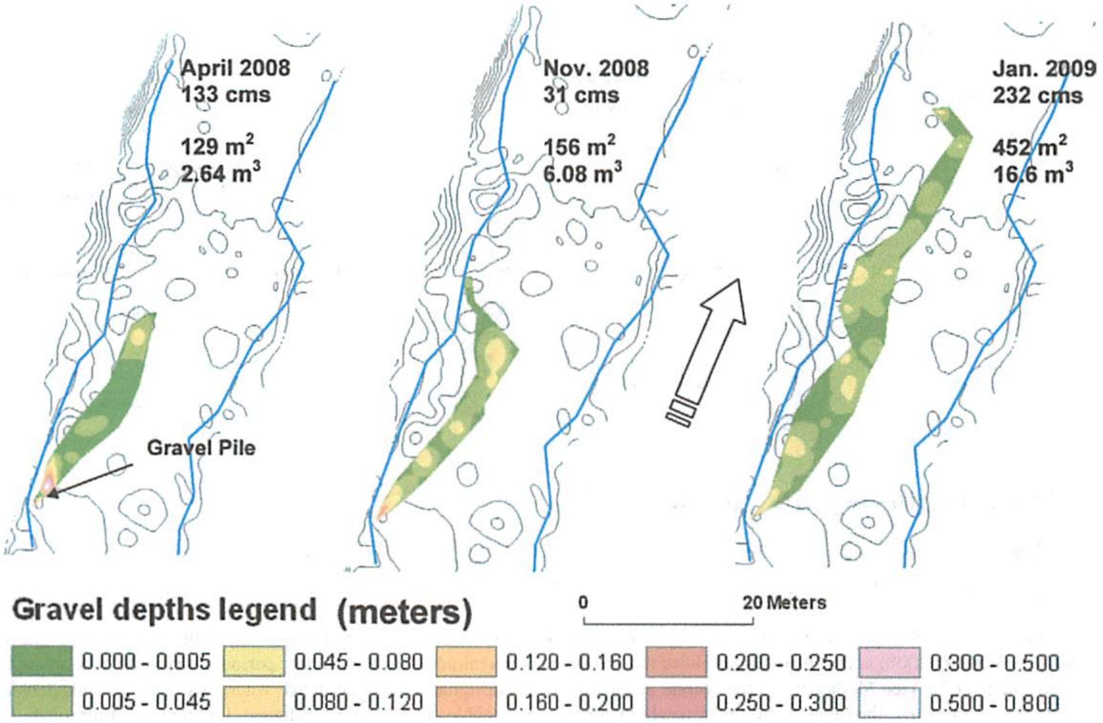

FIGURE 3.—Gravel migration, volume, and depth of augmented gravel in the channel downstream of the gravel pile at site 4 in April and November 2008 and January 2009. Contour lines indicate 0.3-m elevation changes. Flows refer to the peak magnitude during each time period; the arrow indicates flow direction. The m^2 value refers to the aerial coverage of the gravel in the channel, whereas the m^3 value refers to the total volume of gravel in the channel.

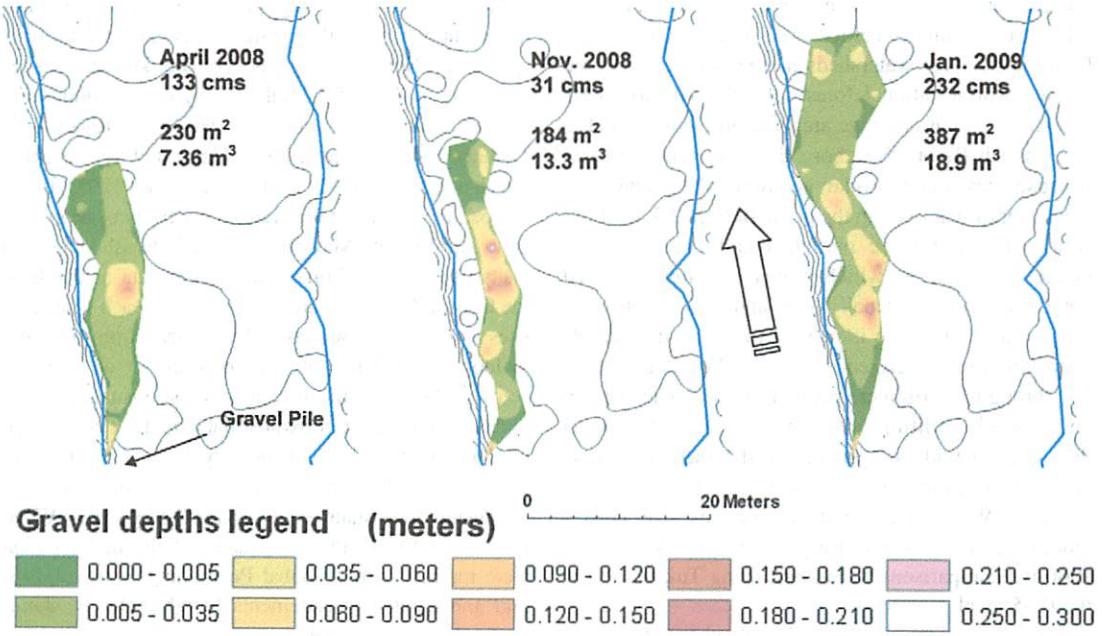

FIGURE 4.—Gravel migration, volume, and depth of augmented gravel in the channel downstream of the gravel pile at site 3 in April and November 2008 and January 2009. See Figure 3 for additional details.

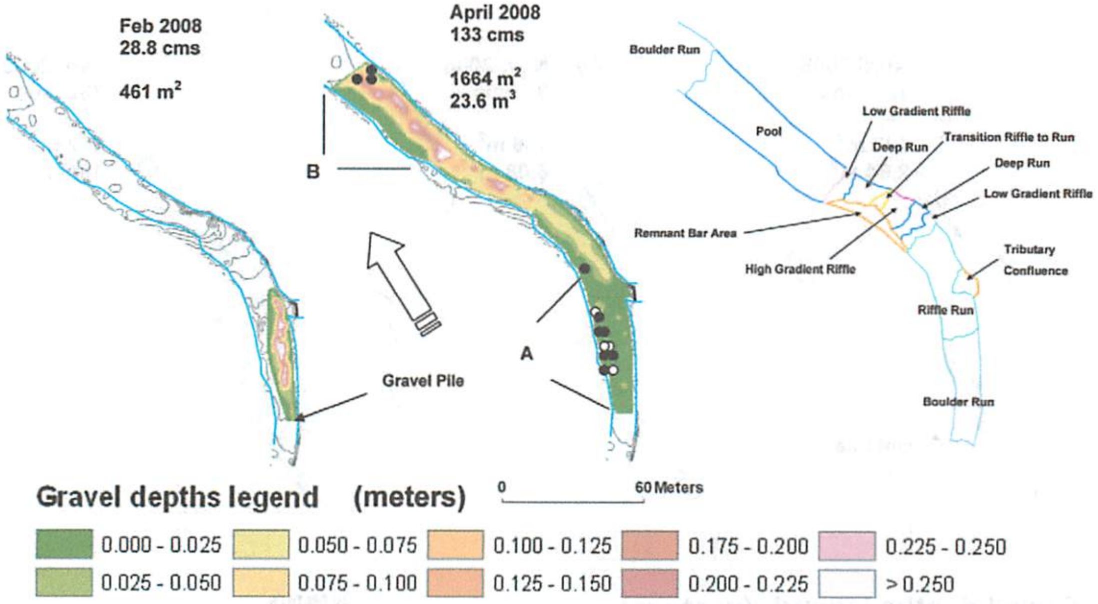

FIGURE 5.—Gravel migration, volume, and depth of augmented gravel in the channel downstream of the gravel pile at site 1 after 7 h (February 2008) and in April 2008. Flows refer to the peak magnitude during each time period (no volume measurement was available at 7 h [see Methods]). In the second panel the letter A designates the upper reach where both pre- and postpebble counts were conducted, the letter B the lower reach where only postpebble counts were conducted. Differences in mesohabitat along the stream reach can influence the distribution and deposition of gravel. By April, newly added gravel particles were only sparsely deposited in the riffle–run areas but created larger deposits in the deeper runs and pools. The white dots in the second panel indicate river chub nests built with added gravels that were found in May 2008; the black dots indicate nests that were found in May 2009.

comparisons by consultant groups. The other two reference streams—Tellico and Citico Creek—are found in adjacent watersheds that are unregulated, are located within national forest land (heavily forested), and share similar drainage area size and valley relief to the Cheoah River. We chose these reference streams because they share similar geomorphology and have reach slopes that overlap the gradient (0.5–2.3%) of our study sites. Reference particle counts were used to gauge the extent to which gravel addition improved conditions in the Cheoah River and how much more volume and what size is needed to match the particle distribution in the reference streams. We calculated the D_{10} through D_{50} (in increments of five) for each stream and gravel addition site. We assume that most difference would be seen below the median particle size (D_{50}); thus, D_{55}–D_{90} were excluded in this analysis. We tested for differences in size classes among stream reaches using a Kruskal–Wallis test. Post hoc comparisons were made using Tukey's test at the 0.05 level.

Fish spawning activity.—Gravel-enhanced reaches were surveyed twice in April and twice in May in 2008 and 2009 to determine whether redd nesters (black redhorses or northern hog suckers) or mound builders (river chub) were utilizing the newly added gravel for spawning. Northern hog suckers are known to start spawning around 15°C, followed by black redhorses at 16–18°C, and river chub at 16–19°C (Raney and Lachner 1946; Bowman 1970; Curry and Spacie 1984; Kwak and Skelly 1992; Etnier and Starnes 1993). In the Cheoah River, these temperatures generally overlap with early April to late May. We were able to schedule field visits using the real-time temperature data available at the Cheoah USGS stream gauge. During each visitation, sites 3 and 4 were waded and visualized from the bank to look for evidence of fish spawning or any general activity. At site 1, the stream was also visualized from the bank and waded in shallow habitats. However, in the pool and deep-run habitats in early April at site 1, water was deep and slightly turbid; thus, snorkeling was conducted to visualize any spawning activity. When nests were found, the coordinates of the nest location were marked with a Global Positioning System (GPS) unit and habitat measurements (depth, velocity, dominant substrate) were taken.

We conducted habitat measurements during early April and late May at base flows (5.3 and 4.9 m^3/s, respectively). Flows during April ranged from 5.2 to 18.6 m^3/s and 4.9–43.0 m^3/s during May. At sites 3 and 4, habitat measurements were conducted at two locations along transects placed every 5 m along the path of gravel migration. At site 1, we conducted habitat measurements on top of gravel deposits in the pool and deep run where wading was feasible. In shallower habitats at site 1, we established one transect in the riffle run and one in the high gradient riffle mesohabitats (Figure 5), and conducted five habitat measurements along each. Water depth, velocity (0.6 × depth), dominant substrate, and GPS coordinate measurements were recorded at each location. Global Positioning System coordinates were overlaid on gravel depth maps in ARCMap to obtain gravel depth information for each location.

We wanted to compare habitat characteristics of areas augmented with gravel with characteristics of catostomid spawning habitat recorded in the literature to determine whether suitable habitat was created. We did not include river chub in this part of the analysis because (1) river chub nests were found all throughout the Cheoah River prior to this study and do not seem to be limited by gravel sources or gravel deposits, and (2) river chub build nests in a greater range of habitats than that of catostomids, which would make comparisons difficult. We collected information on the spawning habitat characteristics (such as water depth, velocity, and dominant substrate) of four catostomid species (black redhorse, golden redhorse *M. erythrurum*, northern hog sucker, and white sucker *Catostomus commersonii*) by reviewing published literature and one unpublished master's thesis specialized on catostomid habitat (Raney and Lachner 1946; Bowman 1970; Curry and Spacie 1984; Kwak and Skelly 1992; Grabowski and Isely 2007; Favrot 2009). Although golden redhorses and white suckers are not found in the Cheoah River, they are found in the Little Tennessee River below the confluence of the Cheoah River (Figure 1) and are considered potential recolonizers. We compared values of spawning habitat measurements found in the literature with areas augmented with gravel (water depth, velocity, and dominant substrate) using a Kruskal–Wallis test followed by Tukey's test for post hoc comparisons. If only ranges of values were presented in the literature, we assumed a normal distribution and used the mean value, along with the minimum and maximum values for each study. If only the mean and some form of deviation were presented, we assumed that the range was three times the SD and used values similarly as mentioned above.

Habitat is influenced by many factors simultaneously; thus, we wanted to compare values from the literature with values found in our study to determine whether any overlap occurred in multidimensional space. We also assume that depth of gravel deposits, rather than dominant substrate alone, is also an important component of catostomid spawning habitat (Jennings et al. 2010). However, information on gravel depths needed for suitable catostomid spawning habitat was very limited. Robust redhorses *M. robustum* had reported egg burial depths of 6–15 cm (Freeman 1998; Jennings et al. 2010). However, Hackney et al. (1968) reported river redhorses *M. carinatum* forming redds 22–30 cm deep. Many other studies report disturbances and depressions of the streambed during catostomid spawning but do not report depths (Raney and Lachner 1946; Bowman 1970; Burr and Morris 1977; Kwak and Skelly 1992). According to a review conducted by DeVries (1997) on egg depth threshold criteria for salmonids, 75% of the species reviewed required gravel depths greater than 10 cm (to top of egg pocket; threshold indicates minimal depth needed in relation to scour). Most depths required for the bottom of the egg pocket were 15–35 cm. In our study, we assumed that gravel depths of at least 10 cm were suitable habitat for most catostomids to adequately deposit eggs and because this depth allows for at least two layers of gravel over the armored stream bottom. Because sufficient data were not available on required gravel depths for catostomids, we were unable to compare required ranges with values from our study. In studies where both water depth and velocity measurements were taken, we used mean depth and velocity values along with 10-cm gravel depth values as coordinates in the three-dimensional plot. If gravel depths from our study exceeded 10 cm, we assigned them 10 cm so that gravel depths would be comparable to literature values. For gravel depths from 0 to 5 cm, we automatically assigned these values a maximum of 5 cm. We then plotted water depth, velocity, and gravel depth values (in meters) from our study with values taken from the literature to determine if any overlap occurred.

Results

Site Location, Stream Morphology, and Effectiveness

The area of gravel migration at site 1 after 7 h was already larger than the total area enhanced by site 3 or 4 at the end of the study. After 51 d since the initial addition, 23.6 m^3 of the original 30.7-m^3 added gravel had migrated in the channel at site 1, the majority of which had moved immediately following addition. This suggested that 7.1 m^3 was left on the gravel pile; however, we observed that less than 1 m^3 was left on the bank. Gravel deposits were found outside the wetted channel during base flow, which most likely composed the remainder of the gravel. Thus, we concluded that approximately 100% of the gravel added at site 1 had been mobilized (Table 1). Very little gravel was deposited outside the base flow channel at sites 3 and 4. After 335 d, 99% of the original added gravel had migrated in the channel at site 3, and 86% of the original added gravel had migrated at site 4 (Table 1). Although site 4 had a higher reach average slope than site 3, its transport rate (m^3/d) was less than that of site 3 for the first two periods (Table 1). However, its transport rate was higher following the 232 m^3/s peak flow event (Table 1).

Gravel Migration

We observed gravel migration after periodic visits following flow events of various magnitudes. We measured the area of enhancement as the total area that had any deposits of gravel, regardless of whether they were consistent layers of gravel or sparse accumulations. Because the streambed was extremely armored and natural gravel deposits were virtually absent prior to addition, maps of gravel migration and depths pertain to newly added gravels only and do not include existing gravels prior to addition (Figures 3–5). Thus, maps of gravel enhancement include areas of contiguous layers of gravel interspersed with sparse and patchy deposits.

Gravel migration patterns were similar between sites 3 and 4 during the entire study. For example, migration was initially rapid during the 133-m^3/s peak flow but showed little change between April and November where flows peaked at 31 m^3/s (Figures 3, 4). A peak flow of 232 m^3/s caused significant migration again at both sites in the time period between November and January. Although migration was not substantial under lower magnitude flows, shifts in gravel depths showed substantial changes across the entire study period (Figures 3, 4). For example, the 31 m^3/s peak flow did not seem to increase the size of the enhanced area, but it did increase volume at both sites and gravel was deposited in new areas. At site 3, the size of the enhanced area decreased from 230 to 184 m^2 (Figure 4). However, the size of the gravel-enhanced area at site 4 increased during all periods (Figure 3). At both sites, newly added gravel did not enhance the entire streambed during the study. By January, depths of gravel at site 4 generally ranged from 0 to 0.12 m, and at site 3, from 0 to 0.30.

Gravel migration at site 1 was different from that at sites 3 and 4 primarily because entrainment occurred immediately after the gravel was added, and by April gravel particles were found across the entire channel (Figure 5). Gravel dispersal was high through the boulder run and riffle run environments, which evenly dispersed particles throughout the channel instead of creating large deposits (Figure 5). The deposition of particles in the boulder run and riffle run environments were sparsely located behind boulders and did not form a consistent layer of gravel over the armored streambed. Gravel depths across the boulder and riffle run habitats were very shallow, ranging from 0 to 0.075 m. Although some deep habitats also had sparse gravel coverage, most of the larger gravel deposits (0.10 to >0.25 m) occurred in the deep-run habitats that were below riffle habitats and in the pool at the bottom of the reach. Deposits observed in July were similar in size and location as those in April; thus, we assumed that little migration had occurred between the two time periods.

Particle Size Distribution

Particle size distributions were significantly different following gravel addition at sites 1 and 3 ($\chi^2 = 25.29$, df = 1, $P < 0.001$; and $\chi^2 = 14.67$, df = 1, $P < 0.001$, respectively), indicating that there was a higher amount of finer material following gravel addition (Figure 6). Particle size distribution was not significantly different following gravel addition at site 4 ($\chi^2 = 1.530$, df = 1, $P = 0.216$). At site 4, the distribution shifted towards the right except for the 10-mm size-class (Figure 6), which suggests a coarsening instead of a fining of the streambed. Changes in the particle size distribution were strongly indicative of the size of particles added. For example, only the D_{25} and D_{10} decreased at sites 1 and 3, respectively. The percent of particles less than 64 mm was significantly higher at site 1 following gravel addition (paired *t*-test: $P = 0.047$). Similarly, the percent of particles less than 16 mm was significantly higher at site 3 post gravel addition (paired *t*-test: $P = 0.011$). Even though the percent of particles less than 16 mm were significantly higher at site 4 (paired *t*-test: $P = 0.004$), the D_{50} actually increased from 128 to 256, suggesting a coarsening of the bed material.

Particle size-classes D_{10}–D_{50} were significantly different among stream reaches ($\chi^2 = 29.05$, df = 7, $P < 0.001$; Figure 7). Sites 1 and 3 were significantly different than the reference reaches (Tukey's test: $P < 0.05$; Figure 7). Site 4 was not significantly different from the reference reaches or site 1 but was significantly different from site 3 (Tukey's test: $P < 0.05$). Cumulative particle size distributions of sites 3 and 4 overlapped with reference stream particle size distributions for particle sizes less than 16 mm but departed from reference particle sizes greater than 16 mm (Figure 7). Size distribution for site 1 did not overlap with reference stream particle size distributions.

Fish Spawning Activity

Northern hog suckers and black redhorses were not observed spawning in any of the gravel sites in 2008 or

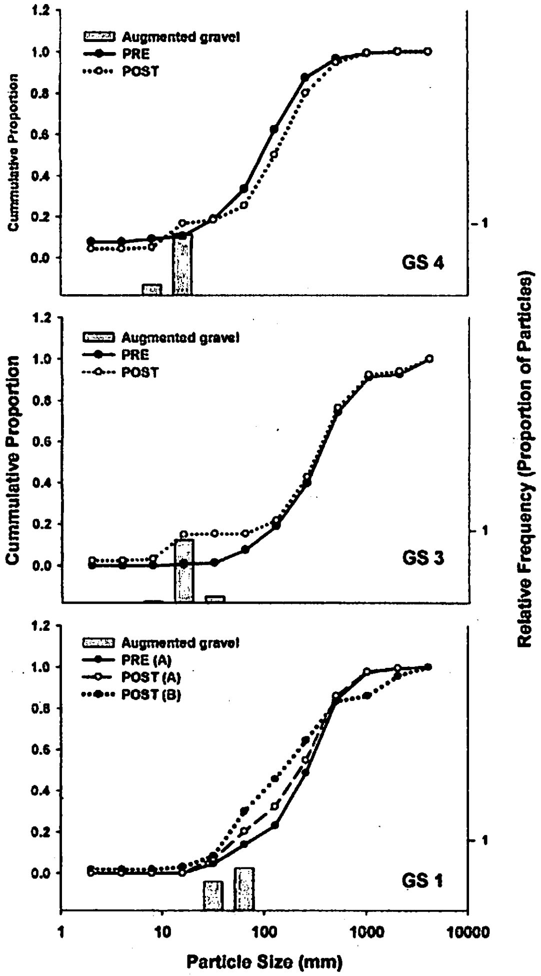

FIGURE 6.—Particle size distributions before and after gravel addition and the relative frequency of the particle sizes of the added gravel at sites (GS) 1, 3, and 4. The graph for GS1 shows particle size distributions before and after at reach A and after only at reach B (see Figure 5).

2009. Because the gravel differed in coloration, we could observe whether river chubs had incorporated the augmented gravel in their nest. At site 1 in May 2008, we found four river chub mounds that had mixtures of native gravels and the newly augmented gravel (shown in white dots in Figures 5, 8). The following year, May 2009, we found 10 river chub mounds that had also incorporated the newly added gravel (shown in black dots in Figure 5). We did not observe any river chub spawning activity at sites 3 and 4. Because chub mounds were found at site 1, we compared particle size distribution of augmented particles with the size of particles found on chub nests (unpublished study) to determine the degree of overlap. We found that the size of augmented particles at site 1 overlapped with the size range utilized by river chub (Figure 9).

We found that depth, velocity, and dominant substrate were significantly different among gravel sites and the values reported in the literature for catostomid spawning ($\chi^2 = 30.4$, df = 6, $P < 0.0001$; $\chi^2 = 22.5$, df = 6, $P = 0.001$; and $\chi^2 = 23.9$, df = 6, $P = 0.005$, respectively; Figure 10). Golden redhorses and black redhorses spawning water depths were significantly lower than that of other fish and those found in gravel sites, which were not significantly different from one another (Tukey's test: $P < 0.05$). Site 3 had velocities significantly lower than those required by black redhorses, whereas the remainder of the other sites and values for species were not significantly different (Tukey's test: $P < 0.05$). Dominant substrate at site 1 was significantly coarser than that required by golden redhorses and northern hog suckers; however, the remainder of the values were not significantly different (Tukey's test: $P < 0.05$). White suckers spawned in lower water depths and in finer substrate than values at gravel sites and other species; however, it was not significantly different.

We compared water depth, velocity, and gravel depth values for catostomid species found in the literature with those of habitat where gravel was augmented in a three-dimensional plot to determine whether any overlap occurred (Figure 11). There was little overlap in multidimensional space between values from the literature and measurements made at gravel sites. Northern hog suckers had values that overlapped with measurements from gravel sites in deeper water habitats. Site 4 had a few values that overlapped with the range required by catostomids. Although site 1 had water depth and velocity measurements that overlapped with catostomid spawning values, gravel depth was not deep enough in these areas to allow overlap in multidimensional space.

Discussion

We found that passive gravel addition successfully deposited new gravel particles in the streambed following high-flow events. However, the volume of gravel added was insufficient to accumulate multiple layers of gravel and provide adequate catostomid spawning habitat. Because suitable habitat may have been created with deeper gravel deposits, we recommend that periodic passive gravel additions be used to enhance streambed habitat for target biota, if augmented in reaches that facilitate habitat formation.

Maximizing the benefit-cost of habitat restoration is a realistic aspect of management. Losses of gravel due to transport, mechanical compaction, and settling are inevitable and lead to inefficiency at enhancing stream-

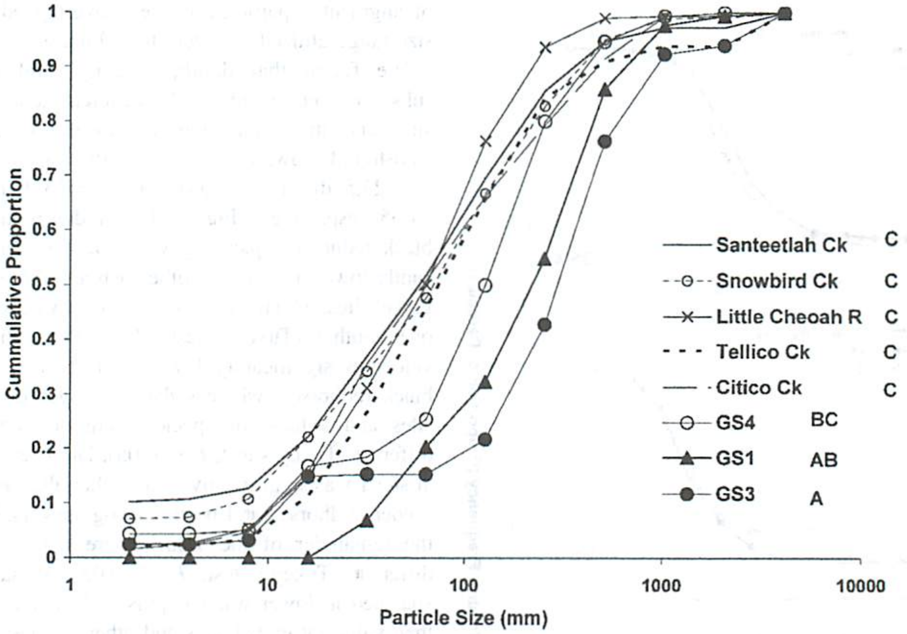

FIGURE 7.—Comparison of particle size distributions at the three gravel sites (post gravel addition) and five reference stream reaches from rivers with morphology similar to that of the Cheoah River. Different letters indicate significant differences at the 0.05 level in post hoc comparisons (Tukey's test) using the D_{10} through D_{50} size-classes (increments of five).

beds (Merz et al. 2006). Because the gravel additions were expensive, in terms of transport costs relative to volume purchased, our goal was to mobilize the highest percentage of gravel from the bank into the channel. We found that gravel successfully migrated into the streambed and that losses due to settling on the streambank were small. For example, after 51 d, we estimate that 100% of the gravel had been mobilized at site 1 (Table 1). After almost a year, 99% of the gravel had been mobilized at site 3 compared with 86% at site 1.

If gravel is added passively (i.e., by dump truck), the site location should provide as close an access as possible to the stream channel while maximizing the influence of gravity on gravel migration toward the channel (highest bank slope). We attribute differences in gravel migration among sites to differences in reach characteristics. For example, reach slope, bank slope, and vegetation (bank and instream) were substantially different among the three gravel sites. We also expected that the volume of gravel initially added and its interaction with reach characteristics would influence the area enhanced by gravel. For example, at site 1, 30.7 m^3 was augmented compared with approximately 19 m^3 at the other sites, and the area of enhancement at site 1 was over 3.5 times that of sites 3 and 4 (Table 1). Site 1 also had a steeper reach slope and steeper bank slope compared with the other sites and entrainment was observed instantaneously, despite having larger-sized gravel (40 mm) than the other sites (10 mm; Table 1). Site 4 also had a steeper reach slope, a steeper bank slope, and smoother channel (lower D_{50}) than site 3 and was located on the outside of a meander, all of which should facilitate faster transport. Although we expected higher entrainment at site 4 compared with site 3, gravel migration was lower at site 4 during the first two periods (Table 1). We believe that the

FIGURE 8.—Photograph of a river chub mound built with newly augmented gravel (golden particles) and native geologic material (darker particles).

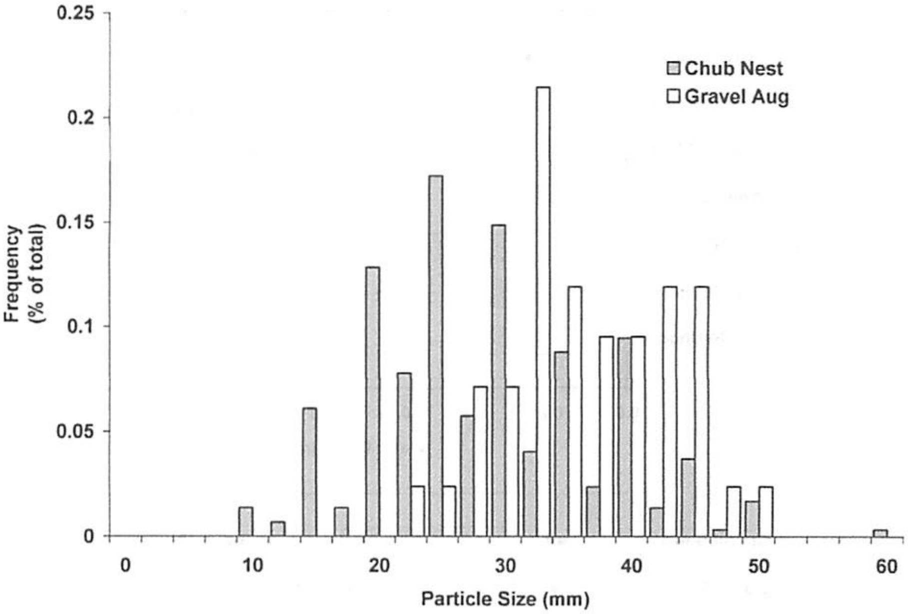

FIGURE 9.—Frequency histograms of particle size in 30 river chub nests and augmented gravel at site 1.

higher amount of instream vegetation upstream and directly adjacent to site 4 (see study site description), along with higher bank vegetation, possibly reduced bank and streambed shear stress and led to lower transport rates than expected. Ultimately, this led to lower effectiveness at enhancing the streambed and resulted in some losses due to settling on the streambank (14%; Table 1). Bank irregularities can influence boundary shear stress and thus influence the particle size distribution in rivers (Buffington and Montgomery 1999). Alder outcrops along the bank and directly upstream from site 4 was extensive and spanned almost the entire channel, leaving only smaller braided channels to allow flow. However, the 232-m^3/s flow event led to higher transport rates at site 4 than at site 3 during the last time period. This suggests that a threshold was surpassed during this flow event, which eliminated any reductions in transport due to vegetation.

Because we were limited in the number of gravel addition sites and the number of visits following each flow event, we were limited to observations and not a formal statistical analysis. Thus, we cannot conclude with certainty how and the extent to which different site variables (i.e., reach slope, bank slope, instream vegetation) influenced gravel migration. Also, large differences among sites and the low number of replicates also made it difficult to form definite conclusions regarding the influence of particle size on movement as well. However, we believe that our results are valuable in that inherent differences in site location can influence gravel migration and should be considered prior to augmentation.

Gravel Migration

Understanding the relationship between the flow magnitude, entrainment of gravel, and stability of gravel sediments is important information for river managers. For instance, gravel displacement influences fry survival and emergence (Kondolf et al. 1991), while streambed stability may influence fish abundance (Edwards and Cunjak 2007). Because impoundments reduce daily and peak flow magnitudes (as in the case of the Trinity River, California), fine sediment accumulates within the interstitial pores between gravel particles and can reduce salmonid fry survival (Nelson et al. 1987; Wilcock et al. 1996b). Therefore, dam operations may require maintenance flows of a specific magnitude to flush finer sediment from the streambed while still attempting to maintain stability of larger gravel particles (Nelson et al. 1987; Wilcock et al. 1996b). Within this study, two aspects of the flow regime emerged that apparently influenced gravel entrainment and deposition in different ways at sites 3 and 4. First, large-magnitude flow events (>113 m^3/s) led to extensive gravel migration and enhancement of the streambed (Figures 3, 4). Secondly, smaller-magnitude flow events (~28.3 m^3/s) did not lead to extensive migration but did cause substantial shifting of gravel sediments. Flow events that far surpass

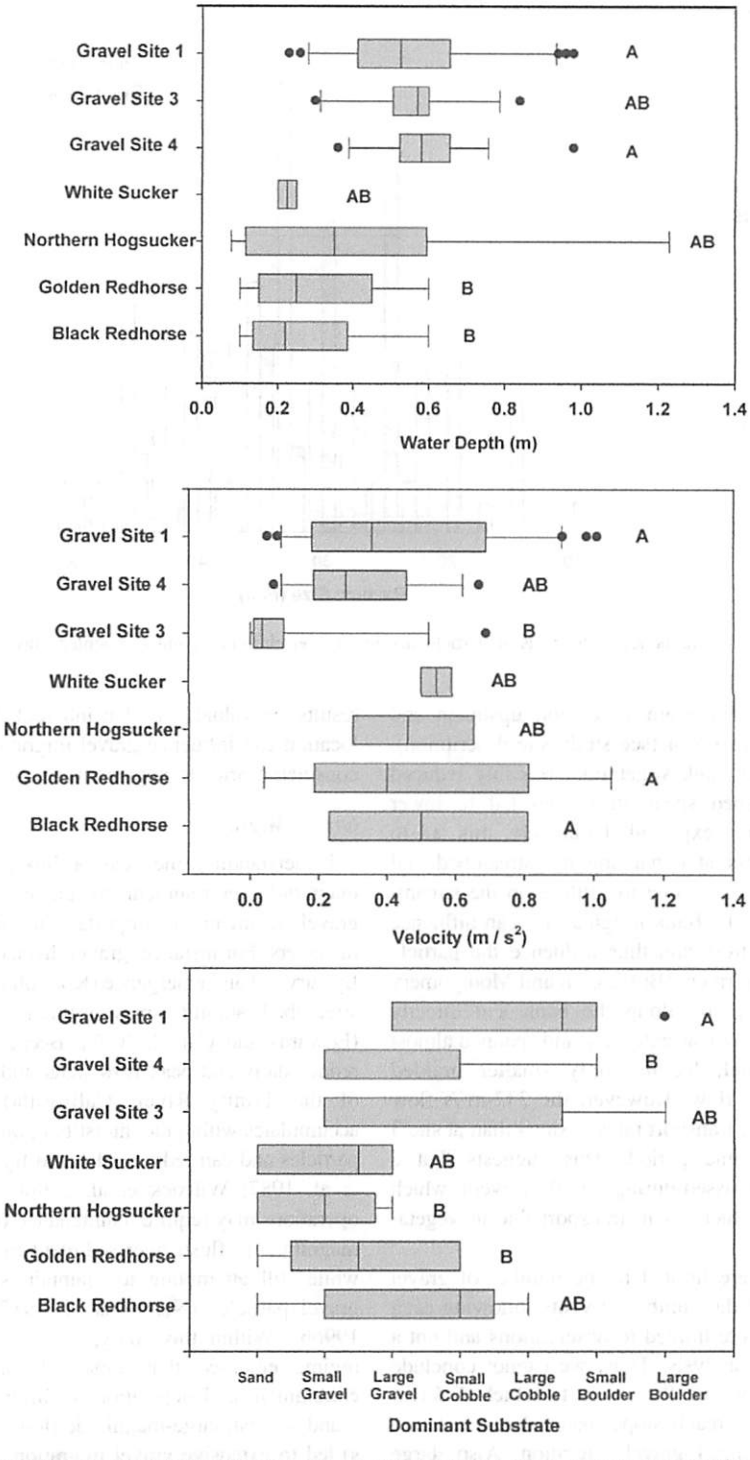

FIGURE 10.—Comparison of water depth, velocity, and dominant substrate among gravel augmentation sites and with the values found in the literature for the spawning habitat of four catostomid sucker species. Different letters indicate significant differences at the 0.05 level in post hoc comparisons (Tukey's test).

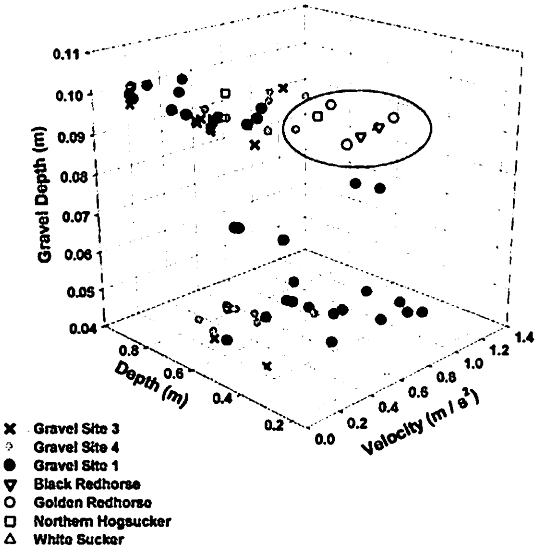

FIGURE 11.—Three-dimensional graph of habitat measurements (water depth, velocity, and gravel depth) at three gravel addition sites and measurements found in the literature for four catostomid species. Gravel depths greater than 0.1 m were assigned a depth of 0.1 m. All catostomids were assumed to need 0.1 m of gravel depth as spawning habitat. The oval circle indicates the multidimensional space designated as suitable catostomid spawning habitat.

critical shear stress thresholds led to high bed load transport rates and enhancement of the streambed. Smaller flows may still surpass critical shear stress but are not characterized by high streambed mobilization. Instead, these flows simply shift sediments at areas that already have deposits. From our observations, the initial flow magnitude of 133 m^3/s caused extensive gravel migration, which filled in the interstitial areas between larger substrate. Even though the smaller-magnitude flow (31 m^3/s) did not cause a substantial increase in the enhanced area, it did increase the volume of gravel in the channel, suggesting that more gravel was moving from the pile (Figures 3, 4). This also suggests that once a base layer of finer material has been deposited, it may generate a smoother streambed condition that facilitates future gravel movement despite lower-magnitude flows.

Interestingly, at sites 3 and 4 the width (i.e., distance perpendicular to the flow) of the enhanced gravel in the stream channel decreased from April to November (Figures 3, 4). There are two explanations that we can give concerning this phenomenon: (1) during the low-flow period, gravel may have fallen through the interstitial areas between large boulders and become less obvious when we mapped out the migration; or (2) the different flow magnitudes may have shifted gravel sediments differently. For example, after the 31-m^3/s flow, there were deeper deposits and a higher volume of gravel in the channel, suggesting that gravel had migrated from the pile. However, different magnitude flows can vary in their turbulence near the streambed. Thus, particles may have been entrained from the edge and deposited further downstream.

Because gravel migration at site 1 was extensive, we were able to observe transport and deposition in various mesohabitats. Gravel transport was rapid through riffle and shallow-run habitats, and then deposited in deep-run and pool habitats (Figure 5). We also found that gravel at site 1 formed deposits in small pockets behind large boulders. Similarly, Kondolf et al. (1991) found that gravel deposits in natural high-gradient boulder streams occurred in areas of lower shear stress and in areas protected by flow divergence. Although we predicted that deposits would be nonuniform, we did not expect the migration to be immediate nor did we expect that the majority of the gravel would be swept downstream to deeper areas, only leaving scattered particles behind. We believe that gravel was extremely unstable in the Cheoah River because sand and fine gravels were not incorporated into the augmentation, both of which should lock up larger particles and prevent mobilization. The majority of particles added at site 1 were between 32 and 46 mm (Figure 6). Without finer material within interstitial areas, lift forces can dislodge particles more easily, leading to higher mobility. Future gravel additions should include plans to incorporate finer material into the augmentation regime.

Particle Size Distribution

All gravel sites showed shifts in their particle size distribution following gravel addition. Sites 1 and 3 displayed obvious shifts towards finer material (Figure 6), whereas site 4 showed only a slight shift exactly at the mean particle size that was added. Prior to addition, site 4 had a considerable amount of sand and finer gravel in the channel. Thus, the addition of 10-mm particles at site 4 migrated over sand and fine gravel, which led to a coarsening of the streambed surface following gravel addition.

We compared pebble counts at gravel sites with those of reference streams to gauge to what extent gravel addition improved substrate conditions. We chose reference streams with very similar morphology and gradient to the Cheoah River. The reference streams had very similar substrate compositions to one another, suggesting that high-gradient, unregulated, heavily forested watersheds in the Blue Ridge Physiographic Province should have significant quantities of sand and gravel. The comparison revealed that even after gravel addition, sand, coarse gravel particles (32 to 64 mm), and cobble material (64 to 128 mm) are size-classes that are still extremely deficient in the Cheoah River (Figure 7). This is especially evident considering that reference streams had over 40% particles less than 64 mm compared with 25% or less at the gravel addition sites. The deficiency of gravel substrates following gravel addition in the Cheoah River relative to reference streams suggests that the volume of gravel was not sufficient to restore the streambed to reference conditions.

Fish Spawning

One of the limitations of our study was the inability to survey sites during the spawning season prior to gravel addition to assess how gravel augmentation enhanced spawning habitat. Although we are limited in the scope of our conclusions, we could at least assess whether fish utilized the gravel deposits that had formed. We found that river chub had utilized the newly added gravel to build their nests in 2008 and 2009 (Figures 5, 8). Male chubs *Nocomis* spp. carry gravel particles in their mouth to build mounds, upon which they spawn females (Vives 1990; Maurakis et al. 1991; Sabaj et al. 2000). We compared the size of gravel added at site 1 with the size of gravel measured in river chub mounds and found that the augmented gravel was well within the particle size distribution used by river chub (Figure 9). We observed that river chub build mounds very close to the bank in lower-to-moderate velocities, most likely in order provide shelter from high velocities while providing sufficient oxygenation for eggs. Similarly, Lobb and Orth (1988) found that bigmouth chub *N. platyrhynchus* constructed mounds close to the bank, away from high-flow velocities in the New River, Virginia. Despite large influences of landscape modification, mound builders are considered the least imperiled of all the North American minnows (Johnston 1999), possibly because they can build their own suitable spawning habitat. Thus, it seems likely they would be among the first species to utilize new and available substrate. Nests constructed by chubs *Nocomis* spp. are highly conspicuous and can last for weeks after spawning has ceased (Lobb and Orth 1988). We may have not been able to witness any spawning activity by redd nesters because we were unable to visit sites weekly and redd nests were not conspicuous due to deep and turbid water at site 1 during April (turbidity caused by immediate upstream confluence of the tributary Yellow Creek). Although we snorkeled in the pool at site 1, we did not observe any catostomid spawning activity. We did observe one northern hog sucker at site 1 that appeared to be spent; however, we are uncertain if and where spawning took place. We assumed that site 1 would possibly be a suitable location for black redhorse spawning, especially since large schools of 10–20 individuals have been observed feeding in the pool at the bottom of the reach during snorkel surveys in June and July 2008 and 2009, and many catostomids are found congregating in pool areas near spawning grounds (Bowman 1970; Kwak and Skelly 1992).

We found water depth was generally greater at gravel sites than was required by all species except the northern hog sucker. Although white suckers spawn in depths much less than those found at gravel sites, their values were not significantly different due to sample size. However, ranges in water depth at gravel sites overlapped with requirements of all four species. Mean water velocity was extremely low at site 3 compared with the requirements of most catostomids, whereas sites 1 and 4 had values overlapping with those from the literature. However, northern hog suckers have been reported spawning in pool habitats, but no depth or velocity measurements were reported (Raney and Lachner 1946). Although dominant substrate at gravel sites overlapped with values reported for catostomid spawning, comparisons of dominant substrate suggested, once again, that sand is deficient in the Cheoah River. Sand and fine gravel is generally reported as being abundant substrate in the surface and subsurface (Bowman 1970; Kwak and Skelly 1992; Freeman 1998; Jennings et al. 2010). We conjecture that clean, silt-free sand (0.5–2 mm) and fine gravels (2–8 mm) are not only needed to stabilize spawning substrate but also may aid in egg burial. Deeper habitats at site 1 had an abundance of gravel that could have been utilized; however, riffle–run habitats were dominated by small boulders and some cobble as a result of extremely sparse and patchy gravel deposition following augmentation. Dominant substrate at site 1 was coarser than values reported for northern hog suckers, golden redhorses, and white suckers but was not significantly different from values reported for black redhorses, which tend to spawn in coarser gravel and cobble habitats (Bowman 1970; Kwak and Skelly 1992).

Although differences in habitat variables emerged between our study sites and the requirements for catostomid spawning, we did observe some overlap and wanted to compare habitat use in multidimensional space. Also, dominant substrate may be misleading, especially if it does not occur in sufficient accumulations to enable egg burial. Thus, we postulated that the depth of gravel deposits at sites is especially important in providing stable spawning habitats and should be included in the analysis. We assumed that at least 10 cm was sufficient to provide gravel stability, sufficient egg depths, and flow through interstitial pores between particles. In our study, augmented gravel depths designated 5 cm or less were generally characterized by sparse, highly unstable gravel deposits that did not form a consistent layer of finer substrate over the armored (boulder–bedrock) stream bottom, which we assume is required for sufficient for egg deposition. Furthermore, even though egg burial depths for some catostomids may be less than 10 cm, gravel bed depths may extend substantially deeper than this to stabilize gravel but also to allow sufficient exchange of surface and hyporheic water, as in the case for salmonid redd site selection (Geist and Dauble 1998; Geist et al. 2002). Egg burial depths are generally related to fish size (DeVries 1997); thus, we believe that 10 cm is a conservative estimate since many of the northern hog suckers and black redhorses in the Cheoah River reach lengths in excess of 380 and 483 mm, respectively, which overlap in size with some larger salmonid species.

Although depth and velocity overlapped with the spawning requirements of catostomids, gravel depth was insufficient. Generally, catostomids spawn in shallow, high-velocity riffle–shoal habitats that are characterized by gravel beds (Bowman 1970; Curry and Spacie 1984; Kwak and Skelly 1992; Grabowski and Isely 2007). Large changes in the composition of the streambed are needed to provide adequate spawning habitat for these species. Thus, gravel should be added in sufficient volumes and in habitats that facilitate the formation of gravel deposits and bars.

When passively adding gravel, it may take multiple additions of various sizes and multiple years of high-flow events to develop suitable spawning habitat for these species (Bunte 2004). Although more costly and invasive, direct placement of gravel into riffle areas may be a more effective approach at enhancing spawning substrates and immediately providing habitat (Bunte 2004). A "hybrid" approach exists where reach segments are selected that promote suitable spawning habitat formation and gravel is passively augmented upstream (Bunte 2004). This approach would require some prior research and possibly bed load transport modeling to ensure gravel accumulation and retention; however, it may be more feasible than direct placement. Locating shallower, high-velocity habitats in lower-gradient reaches may facilitate the formation of gravel bars. If creating spawning habitat is a priority, we believe that gravel placement directly into appropriate spawning habitats is preferred rather than choosing future sites solely on the basis of high transport capacity.

Although the method of gravel placement is extremely important, we found that sufficient volume is needed to adequately enhance substrates. Augmented volumes of gravel were more than an order of magnitude less than recommended gravel volumes. For example, R2 consultants originally recommended augmenting 383 m^3/year of gravel at each site. Pasternack (2008) developed a rule of thumb for placement volume for salmonid spawning enhancement based on experience and research using the equation

$$\text{placement volume} = \alpha \times A \times D,$$

where A is the plan view area (m^2), D is the average depth (m) at spawning flows, and α is a scaling factor that equals 0.5 for reaches composed of riffles, runs, and pools (more conservative than the factor of 0.8 for individual riffles). Using Pasternack's rule of thumb, we found that gravel sites 1, 3, and 4 needed approximately 860, 530, and 425 m^3, respectively, to effectively enhance the entire reach, whereas only 30.7, 19.1, and 19.3 m^3, respectively, were augmented at each respective site. By evaluating the shift in the particle size distribution following gravel addition under the current bed load transport regime, we suggest that almost 95 yd^3/year of gravel substrates alone (2–64 mm) are needed at site 1 on an annual basis and over 50 yd^3 of gravel substrates alone are needed at site 3 on a multi-year basis to adequately match substrate conditions in the reference streams. Future augmentations should include large amounts of sand and cobble, which we also found to be deficient and would increase the total volume required. Ultimately, our results suggest that volumes should be added in high amounts to sufficiently enhance the streambed and provide spawning habitat. We found that gravel were added in such low amounts that the entire streambed of the reach was not enhanced (Figures 3–5). Thus, for adaptive management to occur, gravel should be added in sufficient amounts to create an adequate "treatment effect" so that areas of streambed enhancement can be easily demarcated as experimental units and appropriate measurements can be made.

Conclusions and Implications for Management

Our results suggest that gravel was rapidly entrained from the streambank and incorporated into the streambed and that it provided spawning habitat for at least one species in a sediment-starved stream. Gravel sites differed in the volume of gravel added, the bank slope, and reach slope, which could have contributed to different rates of gravel migration and stability among the three sites. Monitoring flow versus habitat relationships is also essential to providing flow regime guidelines for regulators. Obviously, larger-magnitude flows lead to higher mobility and potential increases in the enhanced area of the streambed.

However, careful consideration should be taken in determining how higher-frequency, smaller-magnitude flows may cause less-obvious shifts in gravel sediments, which may influence the stability of spawning habitats.

Comparisons of the particle size distributions in the Cheoah River and reference streams indicated that gravel-augmented reaches in the river are still far coarser than in reference streams, that is, sand, coarse gravel, and cobble material are still deficient. We recommend that a mixture of particle sizes, especially significant quantities of sand, be incorporated into the augmentation regime to match conditions in reference streams and promote gravel accumulation in shallower water depths. Secondly, because bed load transport was high at site 1 and substantial shifting occurred at all sites, finer materials would stabilize gravel substrates.

We found that gravel sites, gravel volume, and variability in the size of the material added did not facilitate the formation of suitable spawning habitat, at least for catostomids. However, because river chub construct their own nests, they were able to utilize the material. When passively adding gravel substrates to create habitat, special consideration of site location is extremely important. Complete substrate restoration of an alluvial channel would require augmenting gravel according to the transport capacity of a river, given its flow regime. However, realistically, funds and other resources may be limiting and, thus, maximizing fish habitat may be a priority. Our results suggest that when considering maximizing fish habitat, passive placement of gravel may not be the most appropriate method.

If local gravel sources are unavailable or intermittent, transport costs can be substantial. However, we believe that gravel shape, size, and composition should not be compromised. Dumping bulk quantities at a staging area and then adding gravel when suitable may be a more cost-effective way to create gravel habitats. Also, if gravel quantity is limiting, we suggest that dumping large amounts at fewer sites is preferred to dumping insignificant quantities at multiple sites. The advantages of passive gravel placement include low costs, easy logistics, less permitting, and no need for heavy equipment near the streambed, whereas disadvantages include intermittent entrainment (only during high-flow events) and unpredictable habitat creation, which may delay suitable spawning habitat creation for many years (Bunte 2004). Alternatively, placing gravel directly in the stream channel or forming bars suitable for spawning may be more effective at creating fish habitat, especially considering situations where gravel sources are expensive or limited (Bunte 2004). Also, placing gravel in the stream in various configurations and monitoring the migration can still aid in determining the longevity of the project and the transport capacity of a river (Bunte 2004), both of which may be crucial for refining restoration goals. Ultimately, we believe that for gravel restoration to be effective, extensive prior research of site location, appropriate volumes, and variability in the size of material needed should be conducted to maximize the biological benefits.

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USDA **United States Department of Agriculture** **Forest Service** **National Forests in North Carolina**
Nantahala National Forest
Cheoah Ranger District

1070 Massey Branch Rd
Robbinsville, NC 28771-7899
828-479-6431

File Code:
Date: July 22, 2013

Mr. Marshall Olson
Brookfield Smoky Mountain Hydropower, LLC
314 Growdon Boulevard
Tallahassee, Tennessee 37878

Dear Mr. Olson:

This letter is in regard to our review of the July 2, 2013, Federal Energy Regulatory Commission's (FERC) letter of "Compliance with the gravel enhancement plan pursuant to license article 406" for the Brookfield Smoky Mountain Hydro Project, FERC Project No. 2169-036.

As a significant landowner within the Cheoah River watershed, the U.S. Forest Service (USFS) is concerned with the ecological health of the Cheoah River system; including the federally endangered and threatened species located within the river corridor. We do not agree that the Licensee is out of compliance with the approved gravel augmentation plan, license article 406.

The USFS was involved in the recommendations that led to the FERC inclusion of License article 406. Alcoa Power Generating Inc. (APGI) and Brookfield Smoky Mountain Hydropower, (BSMH) have cooperated with the USFS to facilitate gravel introductions and to monitor the effectiveness of the introductions. The USFS is satisfied that the level of monitoring and reporting has been appropriate for the careful restoration of gravel to the Cheoah River, in a manner that has improved habitat conditions, while not disrupting natural bedload movement.

The Project's licensee, previously Alcoa Power Generating Inc. (APGI) and now BSMH, has cooperated with the Resource Agencies extensively since initiating the implementation of the Gravel Enhancement Plan in 2008 to not only facilitate the gravel introductions, which required environmental assessments, securing various required permissions from State and federal agencies, locating a source of gravel, etc., but to also monitor the effectiveness of the introductions.

The Cheoah River Bypassed Reach Gravel Enhancement Plan is specific about monitoring the initial gravel augmentation, but adaptive thereafter. We reviewed the Cheoah River Bypassed Reach Gravel Enhancement Plan and do not agree that the requirement of Section 3.2 *Effectiveness Monitoring* establishes a requirement for intensive monitoring of each gravel addition, but rather includes the possibility of additional monitoring depending upon other factors and timeframes.

> *Monitoring will be conducted within a year of the first gravel introduction and will be conducted periodically (annually or possibly based on the occurrence of flood flows)*

> *thereafter. The results of the monitoring will be used by the Resource Agencies to determine the specifics of subsequent gravel introductions, Including timing, location, and quantity.*

The Gravel Plan also included a footnote "*Per the Resource Agencies' recommendations, the introduction of gravel into the Cheoah River will be cautious and additional amounts of gravel may be added based on the results of effectiveness monitoring*".

The USFS and other resource agencies have utilized an adaptive management approach which has proven effective in implementing on-the-ground resource improvements that would have been otherwise precluded. The USFS is satisfied with the progress and the level of information available for guiding future gravel additions pursuant to Article 406, and to make beneficial improvements to designated critical habitat and the habitat of a diverse aquatic community. The recommendations of the resource agencies, including the USFS, and the addition of gravel to the Cheoah River have been guided by the information gained from monitoring. We feel that the information has been adequate to make these important decisions and recommendations. The gravel augmentation has been balanced with the existing conditions that we have encountered on the ground to avoid adverse effects to federally listed species.

If you have any questions about these comments, please contact Jason Farmer at (828) 479-6431.

Sincerely,

/s/ Lauren Stull

LAUREN STULL
DISTRICT RANGER

North Carolina Wildlife Resources Commission
Gordon S. Myers, Executive Director

July 23, 2013

Mr. Marshall Olson
Compliance Specialist
Brookfield Smoky Mountain Hydropower, LLC
314 Growdon Boulevard
Tallassee, TN 37878

RE: Brookfield Smoky Mountain Hydro Project (FERC No. 2169)
License Article 406 – Gravel Enhancement Plan

Dear Mr. Olson:

This correspondence is in reference to the July 2, 2013 Federal Energy Regulatory Commission (FERC) compliance letter regarding the gravel enhancement plan for the Cheoah River.

As you know, the North Carolina Wildlife Resources Commission has been very involved throughout the development and implementation phases of the gravel enhancement plan. We have reviewed your reply letter to the FERC and concur with your characterization of the situation and your responses to the issues. We look forward to working with Brookfield Smoky Mountain Hydropower, the other resource agencies, and the FERC to better understand the requirements of the license and gravel plan, and to find mutually acceptable ways to meet those conditions.

If you have any questions concerning these comments, please call me at 828-652-4360 ext. 223.

Sincerely,

Chris Goudreau

Chris Goudreau
Special Projects Coordinator

Mailing Address: Division of Inland Fisheries • 645 Fish Hatchery Road • Marion, NC 28752
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NCDENR
North Carolina Department of Environment and Natural Resources
Division of Water Resources

Pat McCrory
Governor

Thomas A. Reeder
Director

John E. Skvarla, III
Secretary

July 25, 2013

Mr. Marshall Olson
Compliance Specialist
Brookfield Smoky Mountain Hydropower, LLC
314 Growdon Boulevard
Tallassee, TN 37878

RE: Brookfield Smoky Mountain Hydro Project (FERC No. 2169)
License Article 406 – Gravel Enhancement Plan

Dear Mr. Olson:

This correspondence is in reference to the July 2, 2013 Federal Energy Regulatory Commission (FERC) compliance letter regarding the gravel enhancement plan for the Cheoah River below the Santeetlah Reservoir Dam.

The Division of Water Resources (DWR) has been designated by the N.C. Funding Board with the fiduciary responsibility for the Resource Management and Enhancement Fund ("Fund"). The Fund allocated a total of amount of $97,837.32 to Virginia Polytechnic Institute and State University ("Tech") between December, 2008 and November, 2011 for a range of studies, including hydrology, gravel transport, and macroinvertebrate and fish responses to gravel augmentation in the Cheoah River. The Tech project was concluded on September 30, 2011. Nine deliverables were listed in the N.C. Fund Board Annual Report for 2011. The FERC issuance cites an amount of $25,000.00 as the annual contribution to the Fund by the licensee, Brookfield Smoky Mountain Hydro LLC ("Brookfield"). In fact, Brookfield deposited an amount of $30,111.00 on January 28, 2013.

DWR looks forward to a continued partnership with Brookfield and the other resources agencies on adaptive management strategies in the Cheoah River. DWR is also available to sit down with FERC to discuss the issues raised. Thank you for the opportunity to comment. If you have any questions concerning these comments, please call me at 919-707-9029, or by email at Fred.Tarver@ncdenr.gov.

Sincerely,

Fred R. Tarver III
Aquatic Monitoring Unit

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