Sediment Issues for the Bryson Project

Based on information in the First Stage Consultation Report (FSCR), the Technical Leadership Team (TLT), identified sediment accumulation in the main-stem reservoirs as a major area of concern. The TLT also recommended the development of a sediment management plan for the Bryson Project. The present plan contains information about sediment accumulation in the reservoir, particle size analysis in different areas of the reservoir, cleaning trash racks, downstream bank stability and a review of bathymetric mapping results for 1999 and 2001.

The Bryson Project only generates electricity when there is sufficient flow in the river; any flows in excess of 412 cfs, the flow sufficient for two-unit operation, are spilled. There is negligible useable storage for electric generation and, consequently, there is no need nor are there plans for dredging sediments from the reservoir. The only maintenance activity in the reservoir is trash and debris removal from the trash racks.

<u>Bathymetric Surveys</u>

Bathymetric surveys were conducted in August 2001. Measurements were taken along transects used to produce the1999 maps (Nantahala Power and Light 2000). An aluminum boat equipped with an outboard motor and an electric trolling motor was used to obtain depth readings using a depth finder with an accuracy of +/- 0.5 ft. The shoreline points used in the 1999 survey were used to establish transects used in the 2001 survey. To locate each transect, a Trimble model AgGPS 132, with sub-meter differential accuracy (correction factors from Omnistar Satellite service) was used to establish GPS points established as close to the right-hand bank left-hand bank (facing downstream) as possible. At some locations the GPS points were established a considerable distance from the shore due to a lack of signal availability because of overhanging trees. Here, the GPS points were located on the map (e.g. transect 10 in Figure 5.3.7-1) and depths recorded along regular intervals to the shore. A field estimate was made as to the distance to the bank; a more accurate distance measure was made using the Arc-View (version 3.2a) measuring tool on the aerial imagery. The image was geo-referenced and has a 3-ft resolution. The bathymetric map was produced by transferring the GPS points, transects, and depth data to the aerial image.

Sediment samples were collected from transects established at points 1/5th, 2/5th, 3/5th, and 4/5th along the midline of the impoundment from the dam to the headwater area. At each transect, PONAR grab samples were taken at 4 equidistant points across the impoundment. Particle sizing was done according to ASTM D422 method using standard sieve sizes (number in parenthesis is sieve opening in mm) of: # 4 (4.750 mm), #10 (2.000 mm), #20 (0.850 mm), #40 (0.425 mm), #60 (0.250 mm), #80 (0.180 mm), #100 (0.150 mm), #120 (0.125 mm), #200 (0.075 mm), #270 (0.053 mm). Sediment particle size analysis was done by Standard Laboratories, Inc. of Jacksboro, Tennessee.

Results and Discussion

The results of the June 2001 bathymetry survey compared to the 1999 depth profiles reveal no major changes. Comparisons of the maps yield little information regarding changes in the storage volume of the reservoir and give no useable information about the rate of sediment accumulation.

There are several reasons why detailed comparisons can not be made. The accuracy of the 2001 and 1999 depth measurements is roughly comparable (+/- 0.5 ft). Though the 1999 transects were re-run in 2001, the intervals where depth measurements were taken are not the same. The 1999 survey relied on taking depth readings at timed intervals along a transect(the accuracy of the distance measured for this was not available) or, where the reservoir was narrow enough, a calibrated chain was used (the original data were not available). In 2001, depth readings were taken at given distances based on distances measured using a hip chain (a distance measuring device where a thin thread-line runs across a calibrated wheel; accurate to +/- 0.5 ft per 100 ft). Due to the difference in the measuring methods, the distances from shore where the depth measurements were taken were not the same. The 1999 depth and distance results were plotted on an enlargement of a topographic map and the depth contours drawn by hand. The resulting maps had no horizontal scale so distances could not be measured on the 1999 bathymetric maps. The 2001 depth and distance data were plotted on a geo-registered digital photo with GPS points used to locate the contour lines. Cross sections of the reservoir could be measured to +/- 3 ft using the ArcView (version 3.2a) GIS software. Placement of the contour lines is an important variable in determining volumes of the reservoir. Selection of the 1999 contour intervals, the distance from shore and the actual depth interval, determined the accuracy of the comparisons for evaluating any loss of reservoir volume. The depth intervals were also too great for the amount of sedimentation that might have actually occurred between the two measurement periods. Furthermore, as discussed below, it appears that filling of the reservoir has reached a balance in which either deposition or scouring is predominant depending on river flows.

Sediment carried by the Oconaluftee River is highly mobile and composed of suspended sands and silts which are deposited on the falling limb of the hydrograph in backwater areas, but easily re-suspended and moved during high flow events. Based on the bathymetric maps, the general form of the channel bed upstream of the dam remained unchanged. Material deposited behind the dam is very fine grained (generally less than 1 mm) and is of such a composition that it is easily re-suspended during high flows. There is no decrease in particle size from upstream to downstream near the dam, which would have indicated coarse particles aggrading due to backwater effects of the dam. Particle sizes along the length of the reservoir indicate that deeper areas have 1 mm particles, and shallower areas have essentially very fine, suspendable particles less than 0.1 mm (see A through D Figure 5.3.7-1 and Table 5.3.7-1). During high flows, observations upstream and downstream of the dam indicated the presence of large amounts of suspended materials; as flows dropped, this material was not stored in the main channel except for in backwaters and deep pools.

The bathymetry and particle size data show that the reservoir is similar to a river with a sandy-silt bed (Figure 5.3.7-1). Sediment translocation within and transport through the reservoir are dependent on the river flows. During periods of lower flows (roughly less than half bankfull) there is sediment deposition, and during high flows (roughly bankfull or greater) there is sediment mobilization and transport through and out of the reservoir. The river channel width is confined by rock, which limits lateral migration; thus, only the channel bed can change in response to flow changes. Scouring occurs at set points in the reservoir, such as in bends and in constricted areas. The extent of scouring changes in relation to flow and the incoming sediment loads. Since the flow is unregulated and, considering the present sediment accumulation within the reservoir, there will be little net increase of sediment storage.

Sediment in the system consists of suspended silts and sands that deposit only when stopped by downstream controls. Trash blocking the trash rack and preventing these suspended sediments from moving through the system enhances deposition. The routine maintenance removal of trash and debris from the trash rack assures that the trash rack opening does not become obstructed. The funneling effect of water entering the unit intakes causes an increase in the water velocity in the forebay area. The increased flow velocity causes erosion of the toe of the foreset slope and the sediments are transported downstream.

Sediment accumulation is not occurring at the dam face due to the shear stress at the tainter gates. The elevation of the bottom of the tainter gate opening determines the depth of sediment accumulation at the dam, and acts as the "base level". The funneling effect of water where flow enters the gate causes an increase in the water velocity in the forebay area. The increased flow velocity and shear stress causes erosion of any deposited sediment and the sediments are transported downstream. Headward (upstream) migration of the deposited sediments continues, creating a channel within the sediments. This channel is evident from the bathymetric data, and the depth of the channel approximately equals the depth of the tainter gates.

There is no delta formation (i.e., indicating excessive sediment availability) downstream of Bryson dam. There appears to be a balance between sediment delivered to this area and the ability of the river to move this material (US Army Corps of Engineers 1997).

Trash Rack Maintenance

Based on a review of hydro operations at Bryson, it was determined that the main operational problems were related to debris accumulation on the trash racks. Sediment accumulation in the reservoirs had little direct effect on unit operation. The trash racks are designed to keep large debris from blocking or entering the hydro unit and causing damage. The racks also accumulate small debris, such as leaves. This small debris is continuously removed using a leaf rake to keep the rack open so that the debris does not accumulate to such an extent that the flow into the penstock would be reduced or stopped. The small amount of sediment associated with routine debris removal is carried downstream and widely dispersed by the water used in generation. However, the leaf rakes do not keep the racks completely clean and small debris and leaves accumulate in front of the racks and become buried under silt and sediment. Once this layer forms the leaf rake cannot remove this material and a new layer starts to form. This process is repeated until the debris and sediment mixture has accumulated to such an extent that it interferes with unit operation and it must be cleaned to provide sufficient water flow to the unit. Compounding the problem of routine cleaning is the presence of large objects, such as trees, which have lodged against the rack and interfere with the rake cleaning. Eventually the debris and sediment obstruction must be removed in order to provide sufficient water depth and flow for the unit.

Historical Review of Maintenance Activities

The review of operational maintenance activities indicates that, in general, major cleaning of the trash racks is done about every 7 to 8 years at Bryson. This cleaning of the racks is done with large equipment, such as track hoes and clam-shells, that is capable of removing the accumulated debris. Bryson Reservoir was drained on two occasions. The reservoir was drained from October 19, 1988 to December 13, 1988 for head gate maintenance. The reservoir was drained again from October 4, 1993 to February 25, 1994 to replace the J-seal on the tainter gates, install seal guides and to remove debris from the trash racks.

Proposed debris/sediment management plan

Routine trash rack cleaning is done using leaf rakes on a day-to-day basis. Major cleaning using heavy equipment will be done when operations become affected by debris build-up. The major debris removal can be done at any time of year and under different flow regimes since no flow will pass through the turbines during this time (see 5.3.7.2.3 below for details). As noted above, historically, major debris removal from trash racks occurs approximately every 7 to 8 years. It is difficult to provide a more precise estimate for scheduling cleaning of the racks, since the rate of debris accumulation is dependent on the amount of debris transported from the area upstream of the project. There are no permit requirements for trash rack maintenance and Duke Power plans to continue the routine maintenance program.

Major debris removal process

Present plans call for cleaning the racks under a wide range of flow conditions. Prior to cleaning, the generating units will be shut off and the water will be allowed to spill over the dam so that currents in the debris removal area are minimized. The impoundment will be kept at full pond during the entire debris removal operation. The debris will be removed using large equipment (clam shell or track hoes) and disposed of properly. Once debris removal ceases, the sediments that became suspended will either settle out or will be carried over the dam and dispersed by the downstream currents. Once the debris removal is completed and the heavy equipment removed, the generating unit will be ready for operation. The reservoir will be maintained at full pond during the entire operation so there is never a time when the pond is drained or lowered. The debris removal operation may take two to three days to complete.

Required Drawdowns for Planned or Emergency Work

The Licensee shall notify the North Carolina Department of Environment and Natural Resources (NCDENR), the North Carolina Wildlife Resources Commission (NCWRC), and the United States Fish and Wildlife Service (USF&WS) at least 15 days prior to planned major debris removal activities or planned drawdowns for maintenance or inspection purposes that will require a temporary modification of the reservoir elevation limits. The licensee shall notify the NCDENR, the NCWRC, and the USF&WS as soon as practical, but no later than ten days after any temporary modification of the reservoir elevation limits required by an operating emergency beyond the control of the Licensee.

Drawdown Procedure

The tainter gates will be used to release water during normal or emergency drawdowns at the Bryson Project. Using the tainter gates to release water will provide for the best dispersion of debris and sediment downstream of the project. If the automatic tainter gates fail to operate, water will be released by opening the motor operated sluice gate located on the right side of the dam, facing downstream. The sluice gate will not completely drain the reservoir. The turbines will not be used during drawdowns, due to the potential for major debris build-up in front of the intake racks.

Timing of Drawdown

Considering local weather patterns and inflow levels, summer and fall are the preferred times of year for planned drawdowns. The NCWRC and Duke fisheries biologists will be consulted as to the spawning periods for the species that inhabit the project reservoir. Drawdowns during the spawning period will be avoided whenever possible to ensure that spawning beds will not be de-watered. Whenever possible drawdowns will be scheduled during high flow periods of the year to ensure that adequate flow will be available to move the sediment through the system.

Rate of Drawdown

Historically, drawdown of the Bryson Reservoir was accomplished in 2-3 hours. The current drawdown procedure for scheduled maintenance is to gradually drain the reservoir over a 24-hour period. This slower drawdown rate should minimize any flow or sediment related downstream impacts. To address the drawdown rate, a cooperative field study with representatives from North Carolina resource agencies and the USFWS will be conducted to develop project-specific guidelines for the Bryson Project.

Rate of Refilling

Typically, to facilitate maintenance and repair activities, drawdowns will be conducted in the summer or fall during the natural low-flow period of the year. Refilling the reservoir during the low-flow period may be difficult, depending upon the magnitude of downstream minimum flow requirements and the sporadic nature of rain events at this time of the year. To address the refill rate and minimum flow issues, a cooperative field study with representatives from North Carolina resource agencies and the USFWS will be conducted to develop project-specific guidelines for the Bryson Project.

Agency Notification

The Licensee shall notify the NCDENR, the NCWRC, and the USFWS at least 15 days prior to commencing planned drawdowns for maintenance or inspection purposes that will require a temporary modification of the reservoir elevation limits or planned major debris removal activities. The licensee shall notify the NCDENR and the NCWRC of any temporary modification of the reservoir elevation limits required by an operating emergency beyond the control of the Licensee as soon as practical, either before, during, or immediately following such emergency, but no later than ten days after each such incident.

Downstream Bank Erosion

Based on information in the FSCR, the TLT identified excessive bank erosion as a potential problem below Bryson Dam. The concern about downstream bank erosion in excess of the natural rate is based, in part, on the erosive power of water released from storage reservoirs.

"Initially, after reservoir construction, the hydraulics of flow (velocity, slope, depth, and width) remain unchanged from pre-project conditions. However, the reservoir acts as a sink and traps sediment, especially the bed material load. This reduction in sediment delivery to the downstream channel causes the energy in the flow to be out of balance with the boundary material for the downstream channel. Because of the available energy, the water attempts to re-establish the former balance with sediment load from material in the streambed, and this results in a degradation trend. Initially, degradation may persist only a short distance downstream from the dam because the equilibrium sediment load is soon re-established by removing material from the stream bed." (US Army Corps of Engineers 1997).

At the Bryson Project, the sediment rich waters and the lack of sediment trapping ability of the reservoir mean that any waters released from the project are essentially "in balance", and removal of sediment from the streambed is minimal. In order to approximate the rate of streambed and, consequently, bank erosion, the TLT agreed that a comparison of the river channel downstream of the dam over a long time interval should indicate if extensive bank erosion has occurred over time. To that end, historical (circa 1970) USDA aerial photographs were examined to determine if excessive bank erosion was occurring downstream of the project. Additionally, an aerial photograph from a March 8, 1967 TVA over-flight (Figure 5.3.7.4-) was obtained and compared to the digital photograph taken in February 2001 (Figure 5.3.7.4-). A visual comparison of these figures revealed no major changes in the downstream bank configuration nor any signs of excessive bank erosion had occurred over the 34-yr time period. Additionally, visual searches for a distance of 200 meters downstream of the dam for obvious signs of bank erosion were made as part of macrobenthic sampling or bathymetric mapping. Those searches also support the lack of excessive bank erosion downstream of the Bryson Project.

Literature Cited:

Nantahala Power and Light. 2000. FERC relicensing first stage consultation package. Bryson (Ela) Hydroelectric Project. Nantahala Power and Light, Division of Duke Energy Corporation, Franklin, NC.

US Army Corps of Engineers. 1997. Hydroelectric engineering requirements for reservoirs. EM 1110-2-1420.

Table 5.3.7-1. Bryson Project. Percentage of sediments passed through nested standard
correspond to locations in Figure 5.3.7-1. Results are represented with RIGHT a

Location A **Location C**

Sieve size (mm)	RIGHT 1P1	1P2	1P3	LEFT 1P4
4,75	100	100	100	100
2	100	99,86	99,9	99,91
0,85	99,45	98,97	98,81	99,64
0,425	97,55	97,1	95,81	98,55
0,25	92,87	94,27	90,45	96,8
0,18	89,11	88,36	81,69	94,52
0,15	85,56	82,24	75,19	90,31
0,125	74,12	67,67	65,62	82,09
0,075	65,09	56,16	59,33	73,16
0,053	59,92	50,61	52,94	64,95

Location B **Location D**

Sieve size (mm)	2P1	2P2	2P3	2P4
4,75	100	100	99,98	100
2	100	99,78	97,64	99,96
0,85	99,89	98,63	81,45	99,86
0,425	97,03	95,75	35,73	99,52
0,25	75,69	86,54	28,09	99,12
0,18	52,72	75,96	25,59	98,78
0,15	44,97	66,18	23,82	98,63
0,125	38,94	57,85	21,41	97,38
0,075	35,71	53,35	19,95	96,02
0,053	33,27	51,9	18,58	94,39

sieves. Locations designated by capital letters
as the right-hand side facing the dam.

Sieve size (mm)	RIGHT 3P1	3P2	3P3	LEFT 3P4
4,75	99,59	99,76	100	90,65
2	97,43	98,21	99,79	78,97
0,85	71,36	87,6	94,78	49,17
0,425	37,93	45,83	56,58	27,77
0,25	32,69	33,18	37,69	22,83
0,18	30,99	29,77	28,72	20,22
0,15	29,66	27,67	24,2	18,03
0,125	27,51	24,49	20,28	15,11
0,075	26,38	21,82	16,82	12,75
0,053	25,16	19,45	14,26	11,19

Sieve size (mm)	4P1	4P2	4P3	4P4
4,75	76,93	93,58	100	100
2	72,49	92,19	99,67	100
0,85	53,62	85,87	97,82	98,21
0,425	23,59	53,45	95,67	96,88
0,25	14,9	26,22	91,78	95,64
0,18	12,35	19,76	83,2	93,86
0,15	10,79	16,98	71,42	86,44
0,125	8,41	14,11	58,14	77,33
0,075	6,66	11,73	51,73	68,97
0,053	5,32	9,7	48,95	63,75


Bryson Tailrace from
Digital Photography
February 2001
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