SOUTH CAROLINA ELECTRIC & GAS COMPANY

COLUMBIA, SOUTH CAROLINA

SALUDA HYDROELECTRIC PROJECT

(FERC NO. 516)

EVALUATION OF THE POTENTIAL FOR A SELF-SUSTAINING BROWN AND RAINBOW TROUT POPULATION IN THE LOWER SALUDA RIVER

NOVEMBER 2007

Prepared by:

Saluda Hydroelectric Project
Instream Flow/Aquatic Habitat Technical Working Committee

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DRAFT

1.0 INTRODUCTION

During the Saluda Hydroelectric Project relicensing consultation, interest was expressed by stakeholder groups in the potential for a "self-sustaining" trout fishery in the Lower Saluda River (LSR). According to the stakeholders, the primary benefits of establishing a self-sustaining trout fishery would be the reduction or elimination of annual stockings that are currently required to maintain a sport fishery and the establishment of a balanced trout population with cohorts of various age classes represented. The Relicensing Technical Working Committee agreed to discuss the potential to establish self-sustaining trout populations.

The purpose of this document is to:

1. discuss how macrohabitat characteristics of the LSR could affect the potential for a self-sustaining trout population[1],
2. summarize the management options for trout in the LSR, and
3. identify management goals that can be reasonably addressed in the relicensing of the Saluda Project.

The LSR is a Fall-Line river with a relatively cool annual water temperature regime, bedrock-dominated riffles with limited gravel and cobble, and a high percentage of pool habitat. The LSR currently supports a tailrace fishery for brown trout (*Salmo trutta*) and rainbow trout

[1] Macrohabitat considerations are watershed-scale factors such as water quality, water temperature, geology and ecology that may influence the biological resource independently of any management actions taken by man, such as flow modification, stocking, etc.

(*Oncorhynchus mykiss*) that is managed by the South Carolina Department of Natural Resources (SCDNR) as a Put, Grow and Take fishery.[2] This management approach is generally recommended where trout habitat is marginal but can at least provide sufficient growth and survival of enough sub-adult trout to support a recreational fishery (D. Christie, SCDNR, Pers. Comm.). Trout are not native to the LSR, and the fishery is maintained through annual stocking of sub-adult rainbow and brown trout. Presently, the SCDNR stocking program runs from early December until mid-April, with the total number of trout stocked annually averaging around 35,000. Approximately two-thirds of the trout stocked annually are rainbow trout (typically 9-10 inches in length), with the remainder being 7-8 inch brown trout (H. Beard, SCDNR, unpublished data). Angler creel surveys conducted in 1995-97 indicated a pronounced seasonal fishery that coincides with the stocking season (H. Beard, SCDNR, pers. Comm.).

[2] Trout Put, Grow and Take Waters, are defined by the South Carolina Department of Health and Environmental Control (SCDHEC) – Bureau of Water as freshwaters suitable for supporting the growth of stocked trout and a balanced, indigenous aquatic community of fauna and flora (SCDHEC 2004).

2.0 REQUIREMENTS FOR A SELF-SUSTAINING TROUT POPULATION

A self-sustaining population requires that recruitment from natural reproduction must exceed mortality from both natural and manmade sources (Everhart and Youngs, 1981; Moyle and Cech, 2004). Therefore, establishment of any self-sustaining population requires several basic components including spawning adults; spawning habitat (including macrohabitat considerations such as water temperature, water depth and flow, dissolved oxygen); fry/nursery habitat; and acceptable levels of intra- and inter- species-specific competition.

2.1 Spawning Adults

A self-sustaining population requires spawning adults. To obtain spawning age, trout must survive in the Lower Saluda for more than one year. Both rainbow and brown trout will spawn at age II, but fecundity is low (Raleigh et al, 1984; 1886); Age III and IV fish may be required to sustain a population because they produce much higher numbers of eggs.

The habitat requirements needed to provide recruitment into older age classes are well understood for brown trout (*Salmo trutta*) and rainbow trout (*Oncorhynchus mykiss*). The preferred temperature range of brown trout is 12.4 – 17.6 C. Upper lethal limits are 25-29 C and above (Jenkins and Burkhead, 1993). At water temperatures greater than 10^{o}C, brown trout generally avoid water with dissolved oxygen levels of less than 5 mg/L. Rainbow trout prefer water temperatures of 12-19 C, and 15 C is considered most favorable for growth. The upper lethal temperature threshold is 25 C (Jenkins and Burkhead, 1993). Optimal dissolved oxygen conditions for adult rainbow trout (and embryos) are > 7.0 mg/L at water temperatures < 15^{o}C and > 9.0 mg/L at water temperatures > 15^{o}C. Rainbow trout can tolerate dissolved oxygen below those thresholds; however, growth and metabolic function may be inhibited. A level of 3.0 mg/L is considered to be the incipient lethal level for dissolved oxygen and can prevent spawning (Raleigh et al., 1984).

2.2 Spawning and Spawning Habitat

Brown trout spawning typically occurs in the fall, although spawning has been reported as late as February (Raleigh et al., 1986). Spawning behavior is triggered by decreasing day length, increased late fall flows, and by decreases in water temperature to between 6^{o}C and 12^{o}C (depending on latitude). Actual spawning typically takes place at water temperatures around 7^{o}C to 9^{o}C, with females digging an egg pit (*redd*) in clean, well-washed gravel deposits (Scott and Crossman, 1973). Optimal gravel size for brown trout redds is approximately 0.50 inches (1 cm) to 2.75 inches (7 cm), but they will spawn in gravel that ranges in size from 0.12 inches (0.30 cm) to 4 inches (10 cm). Gravels with high embeddedness can restrict oxygen exchange, and cause entombment, resulting in mortality (Raleigh et al., 1986). According to Raleigh et al. (1986), at least 5% of a given stream must meet these criteria in order to provide habitat required for good reproduction.

Brown trout spawning sites typically consist of areas influenced by upwelling of cold water and/or fast flow through spawning sized gravels, or by water currents that flow down into the gravel to allow for proper aeration of embryos (Raleigh et al, 1986). Following fertilization, the female covers the redd with gravel that allows flow to freely aerate and cleanse the egg during incubation.

Optimal water velocity for spawning brown trout is reported as 1.3 to 2.3 feet per second (fps), with a full range of velocities ranging from 0.5 to 3 fps. Optimal water depth during spawning and for redd construction is reported as 0.8 to 1.5 feet, with a range of 0.4 to 3 feet. Optimal incubation temperatures for brown trout embryos are reported as ranging from 7^{o}C to 13^{o}C, although water temperatures as low as 0^{o}C and as high as 15^{o}C are reported as tolerable, though temperatures exceeding 13.3^{o}C may result in hatching failure. Egg incubation may last from 34 to 148 days, depending on ambient temperature, and climatic conditions (Raleigh et al, 1986).

Rainbow trout typically spawn in the spring as water temperatures approach or exceed 6^{o}C to 7^{o}C (Behnke, 2002). However, spawning is theoretically possible with temperatures ranging up to 16^{o}C (Raleigh et al., 1984). Spawning can begin as early as

January in temperate western United States watersheds or as late as July in colder climates. Hatchery strains may spawn at other times of the year (Behnke, 2002). Eggs are deposited by females in redds as with other salmonids. Redds are located in fast flowing, well-washed gravel-cobble bars that promote good aeration of the eggs during development. Suitable substrate for redd construction and embryo development consists of clean gravels and cobbles ranging in size from 0.6 inches (1.5 cm) to 4 inches (10 cm), depending on the size of the adult fish. Substrates of larger sizes will be used if optimal gravel is not present (Raleigh et al. 1984). After fertilization, the female buries the redd with additional gravels that protect the redd from predation or dislocation during the incubation period (Scott and Crossman, 1973).

Optimum temperature for rainbow trout embryo incubation ranges from 7^{o}C to 12^{o}C. Highest egg survivability rates are reported at temperatures ranging from 7.5^{o}C to 10^{o}C. Suitable temperature for the growth of fry during the spring and early summer months (during the four month period after hatching) ranges from 10^{o}C to 21^{o}C (Raleigh et al., 1984). Egg incubation may last from four to seven weeks, depending on ambient temperature, and climatic conditions (Scott and Crossman, 1973).

Rainbow trout spawning can occur in depths from 0.6 to 8.2 feet; suitable water depth for incubating eggs is generally assumed to be identical to that reported for spawning fish. Optimum water velocity for rainbow trout spawning and egg incubation is between 1.5 and 3.0 fps. Water velocity less than 1.0 or greater than 3.0 fps is considered unsuitable for spawning and incubating rainbow trout (Raleigh et al., 1984).

Due to the extended egg incubation time, flow regime or water quality changes occurring between egg deposition and fry emergence may affect the productivity of a redd. For example if water temperature increases precipitously after egg deposition, eggs may be subject to mortality (Raleigh et al., 1986). Typically, a 1:1 ratio of pool and riffle habitat is considered optimal to support both spawning and rearing life stages of rainbow trout (Raleigh et al., 1984).

2.3 Fry/Juvenile Nursery Habitat Requirements

Upon hatching, each brown and rainbow trout fry remains buried in the substrate until the yolk sac is absorbed. Transition to the swim-up fry (alevin) stage requires approximately three to seven days, depending on ambient water temperature (Scott and Crossman, 1973). Alevin emerge from the substrate and can swim weakly.

Brown trout fry are most often found in object cover at the edge of riffles or in river margins where water depth is 0.6 to 1.0 feet, where velocity, competition, and predation from larger fish is minimized and summer water temperature is moderate (Raleigh et al, 1986). Fry are rarely found in backwater or in areas with a small gravel substrate. Fry morph into young-of-year (YOY) juveniles during late spring to early summer in northern climates (Scott and Crossman, 1973).

During the winter months, brown trout juveniles seek refuge in the gravelly stream substrate, often at depths of 0.3 to 1.3 feet. Riverine habitat composition in productive brown trout streams is typically characterized by clear cool to cold water; relatively silt-free rocky substrate in riffle areas; a 50% to 70% pool to 30% to 50% riffle-run habitat combination with areas of slow, deep water; well vegetated, stable stream banks; abundant instream cover; and relatively stable annual water flow and temperature regimes (Raleigh et al., 1986).

Rainbow trout fry generally inhabit run or stream margin habitat with slower water velocity. Competition with 1+ and older fish for pool habitat often limits young-of-year distribution to other habitats. As fry shift to the YOY juvenile phase they gravitate to somewhat deeper water with more complex cover (Raleigh et al, 1984). Over-wintering habitat for juveniles is comprised of gravels in runs; during the growing season juveniles typically inhabit runs, pools and riffles with gravel/cobble/boulder substrates. The accumulation of fines in riffle habitat can limit invertebrate production, as well as spawning, if gravels are too embedded with silts and sands (Raleigh et al, 1984).

2.4 Intra and Inter – Species Specific Competition

Self-sustaining trout populations typically occur in relatively oligotrophic cold-water ecosystems where population and ecosystem dynamics differ from those found in mesotrophic/eutrophic warmwater streams. Interactions between co-occurring warmwater competitors and predators often result in reduced abundance and viability of coldwater populations. For example, a smallmouth bass introduction to a coldwater salmonid river ecosystem in Maine has impaired the abundance, growth and catch per unit effort of the natural trout population, because the adult bass are both insectivores and piscivores and therefore compete with, and prey on juvenile trout. Juvenile bass also compete for both microhabitat niches and food sources with adults and juvenile trout (Boucher and Bonney, 2004).

3.0 FEASIBILITY OF SUCCESSFUL SELF-SUSTAINING TROUT POPULATIONS IN THE LOWER SALUDA RIVER

3.1 Spawning Adults

A self-sustaining population of either rainbow or brown trout will require the presence of adequate numbers of spawning adults. The specific number of adult spawners required to sustain an exploitable population would depend on specific management objectives that would need to be established by SCDNR. The potential number of redds would be limited by the area of available spawning habitat. When spawning habitat is scarce, there may be insufficient space for enough redds to produce adequate catchable sized trout to measurably contribute to a fishery (Everhart and Youngs, 1981).

Available information suggests that adult spawning escapement may be variable or limited. Evidence from electrofishing and angling records indicate some trout do survive for longer than one-year in the river (Kleinschmidt et al., 2003; H. Beard, SCDNR, Pers. Comm.), and thus could be available as spawning stock. A 2003 growth study found a minimum of two distinct age classes of trout present during the study period (Kleinschmidt et al., 2003). Further, the study found that, of 441 brown and rainbow trout collected, 74 were greater than 16 inches in length. Data from an ongoing study begun by SCDNR to evaluate annual mortality of stocked trout in the LSR suggests that carryover of trout through the spring and summer may vary annually (H. Beard, SCDNR, Pers. Comm.).

Creel data and annual electrofishing by SCDNR generally indicates a significant decline in LSR adult trout abundance beginning in early summer (H. Beard, SCDNR, unpublished data). The reasons for the observed decline in trout abundance during late summer and the variability in yearly adult survival are not fully understood, but it is probable that the cumulative effects of heavy fishing effort and liberal creel limits, as well as predation and physical habitat degradation may limit the number of fish available to recruit to age II and older. As previously noted, creel surveys conducted in 1995-97 indicated a pronounced seasonal fishery that coincides with the stocking season (H. Beard, SCDNR, unpublished data). Although environmental conditions in the late summer and early fall (particularly water temperature and dissolved oxygen (DO)) are factors with potential to limit survival, water temperatures in the LSR near the most downstream and presumably warmest extent of trout habitat in the river do not exceed the lethal limit for trout of 25°C (maximum of 23.9°C during the 2002 – 2006 period; USGS Gage # 02169000). Recent modifications made to the Saluda Project turbines have also resulted in improved DO levels (Table 1); the DO in the LSR provides suitable growing conditions during the growing season for sub-adult and adult trout, (average growth of 0.67 inches per month (Kleinschmidt et al, 2003)). In the past, low DO, combined with high water temperature, has been attributed to minimal survival of trout (D. Christie, SCDNR, Pers. Comm.).

Table 1: Average Maximum, Minimum, and Average Mean Dissolved Oxygen Levels in the Lower Saluda River from 2000 to 2006, as measured at USGS Gage # 02168504

MONTH	AVERAGE MAX	AVERAGE MIN	AVERAGE MEAN
September	8.0	4.3	6.2
October	8.0	5.6	6.5
November	9.3	7.2	8.3
December	10.8	9.8	10.2
January	11.5	10.4	10.8
February	11.7	10.5	11.0
March	10.6	9.4	10.0
April	9.7	7.9	8.7
May	9.5	6.8	8.1
June	8.9	6.0	7.6
July	8.6	5.6	7.3
August	8.0	5.0	6.7
Absolute Min Value	0.2	(9/25/2000)	-
Absolute Max Value	14.4	(2/25/2005)	-
Lowest Daily Mean	1.2	(9/29/2004)	-
Highest Daily Mean	13	(3/13/2005)	-

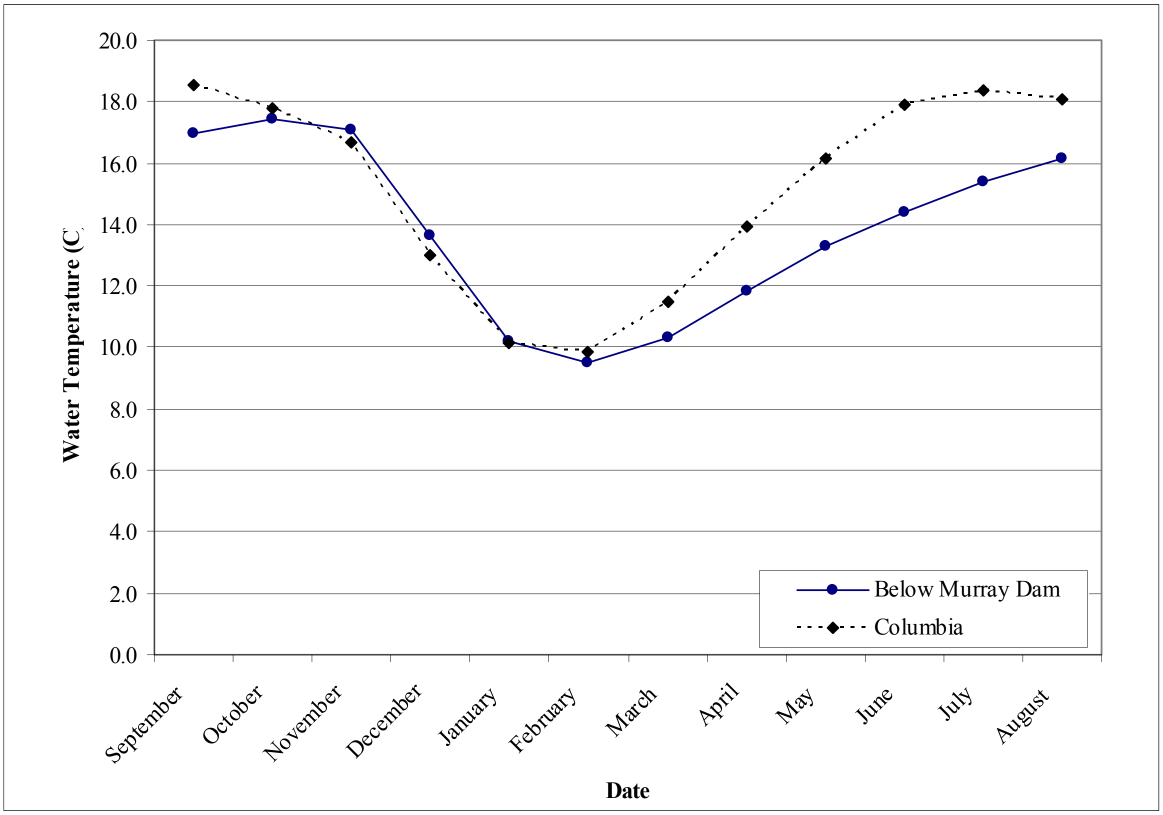

Figure 1: Average Water Temperature in the Lower Saluda River from the Period 08.01.2000 through 08.01.2006 as Measured at USGS Gages 2168504 (below Murray Lake) and 2169000 (Columbia)

3.2 Spawning Habitat

3.2.1 Macrohabitat Considerations

Average water temperature in the lower Saluda River ranges from approximately 17 to 10^{o}C during the brown trout spawning and incubations season (Figure 1). Thus, the ambient temperatures are marginal for supporting brown trout spawning, and would most likely not provide suitable incubation conditions for eggs. In contrast, water temperatures in releases from the Philpott Dam on the Smith River in Virginia, where a self-sustaining population of brown trout exists, range from 4 to 14°C annually (Orth et al., 2003).

Average water temperature throughout the late winter, spring, and early summer months (February – July) in the lower Saluda River ranges from 9.5^{o}C to 15.4^{o}C and is within the tolerances for adult rainbow trout (Figure 1). Assuming that rainbow trout spawning occurred February or March, ambient water temperature in the lower Saluda River would likely support egg development. Similarly, suitable water temperatures in the spring and early summer months (March – June) would likely exist for embryo development and rearing of post-emerged larval rainbow trout, as average water temperature typically remains between 10°C and 14°C. Suitable temperature conditions would likely be present for developing rainbow trout fry in the spring and early summer months (Figure 1).

3.2.2 Mesohabitat Considerations

Trout species are habitat specialists that require a series of spatially-linked mesohabitat types (*i.e*. riffles, runs, pools) that have specific parameters unique to each lifestage (Scott and Crossman, 1973, Raleigh, et al., 1986) including a pool/riffle ratio for optimal production. Barthelow et al. (2003) demonstrated that contiguous and sequential downstream linkage of spawning/rearing/nursery habitat was highly correlated to production of an abundance of sub-adult salmonids; conversely, discontinuous or isolated spawning habitats resulted in bioenergetic and predation mortality penalties to cohorts of fry emerging from isolated spawning sites and reduced recruitment success. Similarly, Shirvell and Dungey (1983) concluded that brown trout population size might be limited by the amount of the least abundant activity-specific habitat.

The LSR lacks the pool/riffle ratio and sequencing characteristic of most productive trout streams. Although some mesohabitat components can be found, Instream Flow Incremental Methodology studies performed on the LSR in the early 1990's (Isley et al.1995) and in 2007 (Kleinschmidt Associates, 2007), as well as aerial videography (DTA, 2005) all consistently document that most of the LSR below Lake Murray Dam consists of low-gradient, slow-moving, runs and pools intermittently separated by bedrock dominated shoal. Substrates are dominated by fines interspersed with boulder and gravel. Bedrock is the dominant substrate in the shallow shoal areas that separate pool and run/glide habitat.

According to Isley et al. (1995), there is approximately 0.8 river miles (8.5 percent) of riffle habitat in the lower Saluda River. Both rainbow and brown trout require riffle habitat featuring unimbedded clean gravel substrate (Photo 1) that ranges in size from 1/8 of an inch to 4 inches. The majority of riffle habitat in the LSR consists of bedrock-controlled shoals that have little value as spawning habitat. Ocean Boulevard/Oh Brother Rapids potentially provides the greatest concentration of suitable spawning substrate in an extensive gravel-cobble dominated riffle area. However, these substrates are marginal for spawning due to embedded fines and the lack of uniform gravels (Photo 2).

In addition to embeddedness, suitable LSR spawning substrates are scattered and occupy a relatively small area compared to the length of the LSR. For example, in the nine miles of river reach, the spawning gravels in the Oh Brother Rapids area only occupy an area of approximately 200 feet long by 300 feet wide. As noted above, the gravels in this area are not optimal due to particle size and embeddness. Thus only a relatively small portion of this area would likely provide suitable redd production potential. For the reasons discussed above, these redds would not necessarily generate viable juveniles. This one isolated area would not likely promote juvenile recruitment extensive enough to provide a fishery along a nine-mile segment of river. This would not likely support redd formation on a scale sufficient to support a self-sustaining trout population. Studies conducted in other Southeastern tailwaters have identified that the lack of suitable sized substrate was one of the limiting factors to trout reproduction (Banks and Bettoli, 2000). Furthermore, there is no contiguous connection between this spawning site and downstream fry-rearing habitat. Any fry produced in this area would drift downstream into deep slow moving pools and runs which are unsuitable for fry nursery habitat, and thus survivorship to older lifestages would be limited.

In some large river systems, significant trout spawning may occur in smaller tributaries. There are several tributaries that enter the LSR (*e.g.,* Rawls

Creek and 12-mile Creek); however, these tributaries differ significantly from the lower Saluda River in that they are low-gradient, warmwater reaches unsuitable for coldwater trout.

Isley et al. (1995), Kleinschmidt Associates (present IFIM study) and aerial videography all consistently document that the pool to riffle ratio in the lower Saluda River far exceeds that which is required for optimum productivity of fry and juveniles. Isley et al. (1995) classified the reach as containing approximately 58 percent pool habitat with 8.5 percent riffle habitat, a ratio of 6.8 to 1.

3.3 Intra and Inter – Species Specific Competition

Self-sustaining trout populations generally occur in cold-water habitats. In South Carolina, these cold-water habitats would be classified as trout natural streams. Here, fish species diversity is generally low and the highest-level predator is typically the trout, or at least other top predators are unlikely to prey on trout. Such self-sustaining (or "wild") trout streams are limited to the extreme northwest portion of South Carolina and include the Chattooga River and other headwater streams of the Blue Ridge Escarpment (EBTJV, 2007). The fifty-seven or so species of fish documented in the LSR are warmwater species with the exception of the two trout species (SCE&G and SCDNR, unpublished data, as summarized in Kleinschmidt Associates, 2005). It is well documented that striped bass prey on the stocked trout, and that anglers fishing for striped bass often use trout as bait (H. Beard, SCDNR, Pers. Comm.). This is consistent with observations from other river systems in which brown trout have been stocked in waters containing striped bass populations that would normally not occupy the same ecosystem. For example, in the lower Kennebec River, adult striped bass have been documented consuming introduced adult brown trout (Photo 3).

Other species such as largemouth bass and chain pickerel prey on trout as well. Largemouth bass, smallmouth bass and chain pickerel are reported as predators on salmonids in other ecosystems (Keith and Barkley, 1971; Warner and Havey, 1985;

Boucher and Bonney, 2004). Besides predation on the stocked trout, it is suspected that if trout successfully reproduce, these other fish species would prey on the eggs, fry and juveniles as well.

Photo 1: Example of Unimbedded Gravel Spawning Bar Substrates Used by Salmonids, Kennebec River, Maine

Photo 2: Example of Embedded Substrate in Oh Brother Rapids Area, Saluda River, SC

Photo 3: Remains of a 10-Inch Adult Brown Trout Expelled from Stomach of Adult Striped Bass, Lower Kennebec River, Maine, August 2002 (from Yoder and Kulik, 2003)

4.0 CONCLUSIONS AND RECOMMENDATIONS

The existing habitat and water quality in the Saluda River generally provides suitable growing conditions for much of the year for adult brown and rainbow trout. However, self-sustaining populations require specific spawning and nursery habitat conditions to allow for sufficient amounts of recruitment to compensate for mortality. These conditions are limited or marginal in the LSR.

Spawning Recruitment. Adult survivorship is likely limited during some years, potentially due to a variety of biotic and abiotic factors including predation, competition, angling exploitation, hydro operations, as well as water quality and other environmental conditions. As a result, few fish survive to reach age II and older. It should be noted that conditions for trout will improve with adherence to the new DO standard and with modified hydro-units operation that will lower temperatures during the late summer/early fall season. Notwithstanding these improvements, it will still be unlikely that spawning recruitment will be sufficient to support self-sustaining populations of trout for other reasons stated.

Limited Spawning and nursery potential. Spawning potential is insufficient to support self-sustaining populations of either species. Factors identified that support this conclusion include marginal spawning and incubation water temperature (brown trout), limited amount and quality of gravel spawning beds for both species, and discontinuous and limited fry and juvenile nursery habitat. It should be noted that conditions for trout will improve with adherence to the new DO standard and with modified hydro-units operation that will lower temperatures during the late summer/early fall season. Not withstanding these improvements, it will still be unlikely that spawning will be sufficient to support self-sustaining populations of trout for other reasons stated.

Mortality in the present fishery is compensated for by annually stocking 35,000 sub-adult trout. Although it is theoretically possible that incidental natural reproduction may presently occur, at least for rainbow trout, the magnitude and frequency of production would not likely support the present level of the recreational fishery given the natural vagaries of reproduction in trout populations, and suboptimal conditions discussed above. This conclusion is consistent with results of recent studies downstream of the Bridgewater Project on the Catawba River in the upper piedmont in North Carolina. Although natural reproduction of brown and rainbow trout has been documented in the Bridgewater tailwater, the study found that wild fish contribute only approximately 10 to 25 % of Age-0 fish, necessitating continued stocking efforts to maintain the fishery (Besler, 2003; Besler, 2002).

The proximity to an urban area and the popularity of angling (where it is reasonable to expect pressure on this fishery to remain the same if not increase) was not assessed in this report but is also a mortality factor. Few if any urban trout fisheries located in native or at least more favorable cold water ecosystems are maintained by natural reproduction. Given the public expectations for this fishery, and the marginal potential for self-sustaining coldwater salmonid populations, it is not clear what material benefit would be derived by altering LSR trout fishery management to rely on natural reproduction rather than the existing stocking strategy.

Focus should be placed on maximizing the potential for this river to maintain a Put-Grow and Take trout fishery in a manner that will ensure increased survival and growth of the river's trout population. If successful, this should lead to additional year to year survivorship and result in additional years classes contributing to the fishery. This can be accomplished, in part, by determining ways to modify project operations to provide more favorable water temperatures in July through September; to ensure that dissolved oxygen standards are being met and to implement instream flows that enhance habitat for adult trout. However, pursuing a goal of establishing a self-sustaining trout population in the LSR is not considered an appropriate management strategy because of the limited potential for its success due to poor recruitment potential

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