APPALACHIAN POWER COMPANY
CLAYTOR HYDROELECTRIC PROJECT NO. 793-018
INSTREAM FLOW NEEDS STUDY

Claytor IFN Study –Final Report

Addendum: Water Willow and Riparian Analysis

Prepared for:

American Electric Power/Appalachian Power Company

Prepared by:

Thomas R. Payne & Associates
Fisheries Consultants
890 L Street
Arcata, California 95521

January 2009

TABLE OF CONTENTS

LIST OF TABLES

INTRODUCTION

The Claytor Project instream flow needs (IFN) study plan identified water willow as an aquatic species of concern. In addition, riparian vegetation was suggested as a candidate for analysis within the framework of the IFN study. No specific assessment approach was identified in the study plan for evaluating flow effects on these two vegetative groups. However, it was implicit that cross sections established for the instream aquatic habitat PHABSIM study would be incorporated. Because no specific criteria were documented from literature or other sources, it was proposed to use stage-discharge relationships developed for the PHABSIM transects to illustrate changes in depths and velocities occurring at differing flow levels over water willow beds. Similarly, the location of riparian vegetation relative to water surface levels would be examined.

Water willow

This aquatic macrophyte forms dense beds along stream margins and provides nursery habitat for many fish species and cover for juvenile fish during spring and summer. Water willow beds have been found to increase streambed stability, act as catchments for stream sediment and provide habitat for many aquatic invertebrates such as insects, snails and mussels (Fritz et al. 2004b). Water willow beds persist through the growing season, May to September. The relationship between water willow and instream flows is little known, though the plant appears to be persistent even after drought or flood events. This is likely due to extensive rhizome and root systems in established beds, which prevent scouring at high flows and allow plants to access groundwater in dryer conditions. A recent study on the effects of fluctuating reservoir levels on water willow found mortality was very low for plants exposed to extended periods of drying (Stakosh et al. 2005). The same study found mortality increased with increasing periods of inundation, assumed to be a result of inadequate sunlight. Similarly, shading from riparian vegetation may affect the growth and density of water willow (Fritz et al. 2004a).

During the transect selection process for the IFN study, water willow beds were incorporated in a select number of cross sections, both main channel and side channel. The boundaries of these beds were identified during the 2007 low flow period during transect substrate and cover coding. A total of eight cross sections containing water willow beds were assessed. All beds were established on substrate with various mixtures of cobble and gravel. Beds were also associated with depositional areas either near shore or around island complexes.

Total inundation of all but one bed occurred at flows less than 3,500 cfs, with 4 beds fully inundated at less than 2,000 cfs (Table 1). Average depth based on all transects when beds were fully inundated was 0.58 feet (range 0.19 to 1.05 ft). Average velocity when beds were fully inundated was 0.46 fps (range 0.16 to 0.74 fps). Depth and velocity measurements over the beds took place in March, when no plants were visible above the substrate. During the growing season, velocity would be much lower within the beds, even during relatively high flow events.

Table 1. Study sites and cross sections used for evaluating water willow beds in relation to flow level, depth and velocity for the Claytor Hydroelectric Project on the New River, Virginia. (RC = right channel; LC = left channel)

	Radford – Slow Riffle 43 *Water Willow Bed Width 41.3 ft*			**Radford – Run 44** *Water Willow Bed Width 26 ft*			**Berton – Glide 185 LC** *Water Willow Bed Width 24+80 ft*[1]			**Whitethorne – Pool 144 RC** *Water Willow Bed Width 20 ft*		
Main Channel Flow (cfs)	**Percent In-Water (%)**	**Average Depth (ft)**	**Average Velocity (fps)**	**Percent In-Water (%)**	**Average Depth (ft)**	**Average Velocity (fps)**	**Percent In-Water (%)**	**Average Depth (ft)**	**Average Velocity (fps)**	**Percent In-Water (%)**	**Average Depth (ft)**	**Average Velocity (fps)**
500	0			0			0			55	0.42	0.05
700	0			0			0			55	0.68	0.09
900	0			7	0.07	0.02	35	0.12	0.02	73	0.71	0.11
1,100	0			14	0.20	0.05	81	0.32	0.11	73	0.90	0.15
1,300	0			36	0.23	0.11	83	0.48	0.19	91	0.87	0.15
1,500	0			71	0.23	0.13	85	0.60	0.27	91	1.01	0.19
1,700	5	0.04	0.08	79	0.35	0.19	85	0.70	0.35	100	1.05	0.20
1,900	24	0.09	0.11	100	0.41	0.22	87	0.77	0.43		1.18	0.24
2,100	48	0.14	0.22		0.54	0.28	91	0.82	0.49		1.30	0.27
2,300	57	0.21	0.28		0.66	0.33	94	0.86	0.56		1.41	0.30
2,500	71	0.25	0.30		0.77	0.38	96	0.90	0.65		1.51	0.34
2,750	95	0.30	0.40		0.90	0.44	100	0.93	0.74		1.63	0.38
3,000	95	0.40	0.52		1.03	0.49		1.00	0.86		1.75	0.41
3,250	100	0.48	0.59		1.14	0.55		1.06	0.97		1.86	0.45
3,500		0.58	0.69		1.26	0.59		1.12	1.08		1.97	0.49
3,750		0.68	0.77		1.36	0.64		1.17	1.19		2.07	0.53
4,000		0.77	0.84		1.46	0.69		1.22	1.30		2.16	0.56
4,250		0.86	0.92		1.56	0.74		1.27	1.40		2.25	0.60
4,500		0.94	0.98		1.65	0.78		1.32	1.51		2.34	0.63
4,750		1.02	1.05		1.74	0.82		1.36	1.61		2.43	0.67
5,000		1.11	1.11		1.83	0.86		1.40	1.71		2.51	0.70
6,000		1.41	1.28		2.16	1.02		1.55	2.12		2.81	0.84
7,000		1.69	1.47		2.45	1.17		1.69	2.52		3.09	0.97
8,000		1.95	1.64		2.72	1.31		1.80	2.91		3.33	1.09
9,000		2.20	1.80		2.97	1.44		1.91	3.30		3.56	1.21
10,000		2.43	1.95		3.20	1.57		2.01	3.68		3.78	1.33

[1] Two water willow beds: one 24 feet wide on RB, one 80 feet wide on mid-channel bar

Table 1 (cont). Study sites and cross sections used for evaluating water willow beds in relation to flow level, depth and velocity for the Claytor Hydroelectric Project on the New River, Virginia.

	Eggleston – Glide 211 *Water Willow Bed Width 21 ft*			**Rich Creek – Slow Riffle 381 RC** *Water Willow Bed Width 30 ft*			**Rich Creek – Slow Riffle 381 LC** *Water Willow Bed Width 18 ft*			**Rich Creek – Slow Riffle 382 LC** *Water Willow Bed Width 22 ft*		
Main Channel Flow (cfs)	**Percent In-Water (%)**	**Average Depth (ft)**	**Average Velocity (fps)**	**Percent In-Water (%)**	**Average Depth (ft)**	**Average Velocity (fps)**	**Percent In-Water (%)**	**Average Depth (ft)**	**Average Velocity (fps)**	**Percent In-Water (%)**	**Average Depth (ft)**	**Average Velocity (fps)**
500	0			0			0			0		
700	0			19	0.05	0.21	0			0		
900	0			50	0.11	0.26	0			8	0.21	0.10
1,100	0			50	0.21	0.41	0			17	0.32	0.11
1,300	88	0.07	0.07	56	0.28	0.48	0			17	0.52	0.15
1,500	100	0.19	0.16	56	0.36	0.48	0			25	0.50	0.13
1,700		0.31	0.24	69	0.37	0.58	0			25	0.67	0.18
1,900		0.42	0.31	88	0.37	0.54	10	0.05	0.32	42	0.52	0.18
2,100		0.52	0.38	100	0.38	0.56	20	0.11	0.46	50	0.56	0.25
2,300		0.61	0.44		0.44	0.64	20	0.20	0.66	58	0.60	0.29
2,500		0.70	0.50		0.50	0.70	20	0.28	0.84	67	0.64	0.33
2,750		0.80	0.58		0.58	0.79	20	0.36	1.00	75	0.70	0.39
3,000		0.89	0.65		0.66	0.86	20	0.44	1.14	75	0.83	0.47
3,250		0.98	0.72		0.74	0.92	20	0.52	1.28	92	0.78	0.49
3,500		1.06	0.79		0.80	0.99	30	0.39	0.97	100	0.82	0.54
3,750		1.14	0.85		0.88	1.05	30	0.46	1.14		0.93	0.63
4,000		1.21	0.92		0.88	1.05	40	0.41	1.01		1.03	0.72
4,250		1.28	0.98		0.94	1.10	60	0.33	0.78		1.12	0.80
4,500		1.35	1.05		1.01	1.15	70	0.35	0.76		1.22	0.88
4,750		1.41	1.11		1.07	1.20	90	0.31	0.63		1.26	0.92
5,000		1.47	1.17		1.13	1.24	100	0.36	0.65		1.40	1.03
6,000		1.71	1.41		1.19	1.29		0.53	0.80		1.65	1.23
7,000		1.91	1.64		1.35	1.41		0.59	0.85		1.73	1.30
8,000		2.09	1.86		1.41	1.45		0.81	1.01		2.01	1.54
9,000		2.25	2.08		1.61	1.59		1.01	1.16		2.29	1.78
10,000		2.40	2.29		1.79	1.72		1.20	1.29		2.54	2.00

Average depth and velocity over water willow beds based on all transects for simulated flows between 500 and 10,000 cfs are shown in Table 2. Using an average plant height of 2.0 feet, portions of the foliage would still be above water at flows up to 8,000 cfs. However, at this flow, velocities averaging just over 1.0 fps could effectively submerge the plants. A photographic record of water willow beds at low and middle calibration flows measured during the IFN study is attached (Photos 1-16). No photos were taken at higher flow levels.

Table 2. Average of combined depth and velocity for eight transects used to evaluate water willow beds in relation to flow levels for the Claytor Hydroelectric Project on the New River, Virginia.

Main Channel Flow (cfs)	Average of All Transects	
	Average Depth (ft)	Average Velocity (fps)
500	0.05	0.01
700	0.09	0.04
900	0.15	0.06
1,100	0.24	0.10
1,300	0.31	0.14
1,500	0.36	0.17
1,700	0.44	0.23
1,900	0.48	0.29
2,100	0.55	0.36
2,300	0.62	0.44
2,500	0.69	0.50
2,750	0.77	0.59
3,000	0.87	0.68
3,250	0.94	0.75
3,500	1.00	0.77
3,750	1.09	0.85
4,000	1.14	0.89
4,250	1.20	0.91
4,500	1.27	0.97
4,750	1.32	1.00
5,000	1.40	1.06
6,000	1.63	1.25
7,000	1.81	1.42
8,000	2.02	1.60
9,000	2.22	1.79
10,000	2.42	1.98

Riparian

Riparian vegetation acts to settle out sediment and dissipate velocity at high flows, provides shade and cover for aquatic species and is a source for woody debris recruitment into the channel (Roghair et al. 2002) and terrestrial insects as food for surface feeding fish. In addition, roots of trees and herbaceous plants associated with riparian vegetation help stabilize banks and prevent erosion. The majority of literature concerning the relationship of riparian vegetation to flow pertains to either mountainous or arid regions (Stromberg and Patten 1991, Auble et al. 1994, Polzin and Rood 2000). Riparian vegetation can also add to the scenic quality of river corridors (Brown and Daniel 1991).

Presence/absence of riparian vegetation in relation to stream cross sections can be sporadic. Riparian areas are longitudinally distributed, and can be absent or negligible in some locations perpendicular to a transect. Another potential problem lies with identifying the boundary of a riparian zone. The extent of the riparian zone may apply to overhanging vegetation (Riparian Photo 1), the base of large rooted trees (Riparian Photos 2 and 3) or the margin of seasonal grasses and herbs that extend the zone during the growing season (Riparian Photo 4). Additionally, discriminating the edge of the riparian zone along steep banks can be problematic (Riparian Photo 5).

Based on flow levels and vegetation edges identified during cover and substrate coding of transects used in IFN study, the edge of the riparian zone occurs at an average flow of 6,500 cfs (Table 3). This does not include outliers identified as flows of 10,000+ cfs. The extent and proximity of the riparian zone to the water's edge in the New River appears to be primarily a function of mean daily flows and not high or low flow events. Spring average daily flows fall within a range of 4,000 to 6,000 cfs (Table 4); slightly lower than the flow level identified from the IFN study transect data. Whether the periphery of the riparian zone is a function of project peaking flows is not known. In many locations the boundary is dictated by channel stabilization adjacent to dwellings, roads or railroads.

However, additional observations suggest that portions of the riparian zone are often subject to inundation, particularly shallow areas associated with islands and bars (Riparian Photos 6-8) at flows between 4,000 and 6,000 cfs. Though higher flows, above 5,000 cfs may inundate riparian areas, the magnitude is relatively small with the average change in WSE from 5,000 and 8,000 cfs of roughly 0.8 feet, and an increase of 1.3 feet at 10,000 cfs (Table 5).

Table 3. Average flow level at which water surface comes in contact with riparian vegetation based on instream flow study transect for the Claytor Hydroelectric Project on the New River, Virginia.

Study Site	Habitat Type - Unit #	Main Channel Flow Level	Side Channel Flow Level	Note
Radford	Slow Riffle – 43	7,500	------	
	Run – 44	6,500	------	
	Deep Pool – 46	6,000	------	
	Pool – 53	7,500	------	
	Glide – 54	4,750	------	
Whitethorne	Glide – 143 LC	5,000	2,250	
	Glide – 143 RC	4,250	2,338	
	Pool – 144 LC	5,000	2,250	
	Pool – 144 RC	4,875	2,680	
	Pool – 146	8,000	------	LB open
	Glide – 147	5,500	------	
Berton	Pool – 184	6,000	------	RB only
	Glide – 185 LC	7,000	2,289	RB only
	Glide – 185 RC	6,000	4,707	LB only
	Run – 186 LC	7,000	2,289	RB only
	Run – 186 RC	------	------	No data
	Slow Riffle – 188	8,000	------	RB only
	Pool – 193	7,000	------	
Eggleston	Glide – 211	8,000	------	
	Slow Riffle – 212	10,000+	------	
	Run – 215	6,000	------	
	Pool – 216	5,000	------	
	Deep Pool – 219	4,750	------	Steep RB
Ripplemead	Slow Riffle – 269	5,500	------	
	Run – 270	7,000	------	
	Pool – 271	4,750	------	LB only
	Glide – 272	4,750	------	
	Pool – 273	7,000	------	RB only
Rich Creek	Pool – 376	6,500	------	
	Glide – 377	5,000	------	Grassy slope LB
	Pool – 378	8,000	------	
	Slow Riffle – 381 LC	5,375	1,785	
	Slow Riffle – 381 RC	9,000	4,420	
	Run – 382 LC	9,000	3,040	
	Run – 382 RC	10,000+	5,000+	
Shanklin's Ferry	Glide – 138	7,000	------	
	Riffle – 139	8,000	------	
	Run – 140	8,000	------	
	Pool – 142	10,000+	------	RB only

Table 4. Average daily flows (cfs) at Radford for the period 1939-2006 (From USGS Radford Gage 03171000).

Day	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	3,870	4,420	5,650	5,930	4,660	4,040	2,610	2,630	2,460	3,400	2,680	3,630
2	4,330	4,760	5,700	5,810	4,390	4,070	2,700	2,510	2,370	2,970	2,970	3,360
3	4,350	5,210	5,280	5,810	4,750	3,800	2,930	2,450	2,210	2,660	3,110	3,180
4	4,500	5,060	5,480	5,750	4,620	3,670	2,590	2,590	2,180	2,530	3,210	3,610
5	4,110	4,730	5,510	6,840	4,670	4,180	3,270	2,570	2,270	2,390	3,270	3,870
6	3,800	5,090	5,800	6,040	4,430	3,730	3,360	2,460	2,370	2,310	3,060	3,640
7	3,850	5,300	5,720	5,510	4,360	3,480	3,070	2,390	2,610	2,250	3,910	3,430
8	4,460	4,960	5,520	5,490	4,730	3,610	2,930	2,430	2,610	2,600	3,230	3,780
9	4,150	4,650	5,440	5,620	4,610	3,540	2,960	2,560	2,580	2,790	3,040	3,340
10	4,000	4,660	5,270	5,930	4,320	3,670	2,740	2,680	2,390	2,600	3,030	3,170
11	3,780	5,010	5,160	5,450	4,110	3,600	2,890	2,480	2,210	2,430	2,910	3,760
12	3,690	5,000	5,210	5,380	4,570	3,570	2,890	2,530	2,120	2,240	2,930	3,990
13	3,710	5,440	5,740	5,540	4,440	3,550	2,880	2,900	2,070	2,400	2,950	3,680
14	3,830	5,670	5,710	5,850	4,350	3,450	2,820	3,950	2,270	2,470	2,790	3,360
15	4,920	5,220	5,660	5,720	4,290	3,460	2,810	3,330	2,300	2,400	2,540	3,480
16	4,590	4,990	5,440	5,590	4,570	3,460	2,820	2,950	2,320	2,350	2,810	3,470
17	3,950	5,120	6,060	5,380	4,280	3,790	2,920	3,070	2,610	2,500	2,890	3,290
18	3,840	5,500	6,100	5,040	4,430	3,750	2,820	3,240	3,490	2,910	2,680	3,290
19	4,500	5,410	6,260	5,000	4,010	3,590	2,660	2,730	3,080	2,960	3,030	3,260
20	4,430	4,870	6,210	5,250	4,050	3,470	2,590	2,440	2,640	2,890	3,510	3,180
21	4,330	5,190	6,340	5,000	4,190	4,120	2,510	2,270	2,280	2,770	3,050	3,420
22	4,510	5,710	6,200	4,980	4,470	3,790	2,480	2,360	2,750	2,510	2,790	3,580
23	4,360	5,970	5,930	4,650	4,080	3,370	2,610	2,290	3,090	2,590	2,770	3,400
24	4,510	5,750	6,630	4,850	3,910	3,240	2,480	2,330	2,330	2,670	2,890	3,190
25	4,560	6,080	6,330	5,010	3,910	3,070	2,440	2,280	2,060	2,820	3,110	2,840
26	4,920	5,950	5,840	4,750	3,790	3,130	2,430	2,180	2,140	2,960	3,380	3,530
27	4,710	5,500	5,950	5,020	3,710	3,380	2,600	2,220	2,270	2,800	3,220	3,850
28	4,640	4,930	6,190	5,200	4,950	3,400	2,560	2,440	2,840	2,560	3,360	3,860
29	4,340	4,290	6,140	4,930	4,880	3,120	2,600	2,550	3,040	2,530	3,640	4,270
30	4,190		6,310	4,760	4,160	2,890	2,800	2,470	3,060	2,550	3,560	4,050
31	4,160		6,530		4,080		2,750	2,730		2,540		4,140

Table 5. Water surface elevation (WSE) change between two sets of flows based on stage-discharge relationships developed transects used in the Claytor Hydroelectric Project instream flow study on the New River, Virginia.

		WSE Change (ft) 5,000 to 8,000 cfs			WSE Change (ft) 5,000 to 10,000 cfs		
Study Site	**Habitat Type - Unit #**	**All Channel Types**	**Main Channel Only**	**Side Channel Only**	**All Channel Types**	**Main Channel Only**	**Side Channel Only**
Radford	Slow Riffle – 43	0.84	0.84		1.32	1.32	
	Run – 44	0.89	0.89		1.37	1.37	
	Deep Pool – 46	0.87	0.87		1.35	1.35	
	Pool – 53	1.27	1.27		1.99	1.99	
	Glide – 54	1.29	1.29		2.00	2.00	
Whitethorne	Glide – 143 LC	0.79		0.79	1.22		1.22
	Glide – 143 RC	0.85		0.85	1.31		1.31
	Pool – 144 LC	0.76		0.76	1.18		1.18
	Pool – 144 RC	0.82		0.82	1.27		1.27
	Pool – 146	0.85	0.85		1.30	1.30	
	Glide – 147	0.79	0.79		1.21	1.21	
Berton	Pool – 184	0.63	0.63		0.96	0.96	
	Glide – 185 LC	0.40		0.40	0.61		0.61
	Glide – 185 RC	0.64		0.64	0.98		0.98
	Run – 186 LC	0.54		0.54	0.83		0.83
	Run – 186 RC	0.62		0.62	0.96		0.96
	Slow Riffle – 188	0.60	0.60		0.92	0.92	
	Pool – 193	0.69	0.69		1.06	1.06	
Eggleston	Glide – 211	0.62	0.62		0.93	0.93	
	Slow Riffle – 212	0.59	0.59		0.90	0.90	
	Run – 215	0.89	0.89		1.38	1.38	
	Pool – 216	1.01	1.01		1.56	1.56	
	Deep Pool – 219	0.86	0.86		1.32	1.32	
Ripplemead	Slow Riffle – 269	1.04	1.04		1.59	1.59	
	Run – 270	1.12	1.12		1.72	1.72	
	Pool – 271	1.27	1.27		1.96	1.96	
	Glide – 272	1.25	1.25		1.94	1.94	
	Pool – 273	1.25	1.25		1.94	1.94	
Rich Creek	Pool – 376	0.81	0.81		1.24	1.24	
	Glide – 377	0.75	0.75		1.15	1.15	
	Pool – 378	0.63	0.63		0.96	0.96	
	Slow Riffle – 381 LC	0.45		0.45	0.84		0.84
	Slow Riffle – 381 RC	0.28		0.28	0.66		0.66
	Run – 382 LC	0.62		0.62	1.14		1.14
	Run – 382 RC	0.34		0.34	0.78		0.78
Shanklin's Ferry	Glide – 138	1.04	1.04	1.04	1.65	1.65	1.65
	Riffle – 139	1.13	1.13	1.13	1.73	1.73	1.73
	Run – 140	1.13	1.13	1.13	1.73	1.73	1.73
	Pool – 142	1.15	1.15	1.15	1.75	1.75	1.75
	Average	**0.83**	**0.94**	**0.59**	**1.30**	**1.44**	**0.98**

CONCLUSION

Establishment and maintenance riparian areas on the New River appears to be linked more to daily average and annual flows, rather than intermittent and short duration peaking. But, major changes in sustained minimum or maximum flows could alter the boundaries and plant community assemblage of the riparian zone through drying or flooding. Water willow seems to be more associated with channel morphology and hydraulics that create depositional areas. These stream features are created by high flow events outside the capacity of the project, and would still persist with changes in project operations.

References:

Auble, G.T., J.M. Friedman, and M.L. Scott. 1994. Relating riparian vegetation to present and future streamflows. Ecological Applications 4(3): 544-554.

Brown, T.C., and T.C. Daniel. 1991. Landscape aesthetics of riparian environments: relationship of flow quantity to scenic quality along a wild and scenic river. Water Resources Research 27:1787-1795.

Fritz, K.M, M.A. Evans and J.W. Femminella. 2004a. Factors affecting biomass allocation in the riverine macrophyte *Justicia americana*. (Abstract only). Aquatic Botany 78:279-288.

Fritz, K.M, M.M. Gangloff and J.W. Femminella. 2004b. Habitat modification by the stream macrophyte Justicia americana and its effects on biota. Oecologia 140:388-

Polzin, M.L., and S.B. Rood. 2000. Effects of damming and flow stabilization on riparian processes and black cottonwoods along the Kootenay River. Rivers 7(3): 221-232.

Roghair, C.N., C.A. Dolloff, and M.K. Underwood. 2002. Response of a brook trout population and instream habitat to a catastrophic flood and debris flow. Transactions of the American Fisheries Society 131:718-730.

Strakosh, T.R., J.L. Eitzmann, K.B. Gido and C.S. Guy. 2005. The response of water willow *Justicia americana* to different water inundation and desiccation regimes. North American Journal of Fisheries Management 25:1476-1485.

Stromberg, J.C., and D.T. Patten. 1991. Instream flow requirements for cottonwoods at Bishop Creek, Inyo County, California. Rivers 2(1): 1-11.