Sustainable Rivers Program

Ohio River Systems Analysis - Appendices

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Above: R. C. Byrd Locks and Dam in Huntington District (USACE photo)

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Appendix 1: Physical Features of the Locks and Dams

Lock and Dam Name	Miles below Pittsburgh	Travel time from upstream L/D (hours)	Conversion to 1929 NGVD	Conversion to NAVD 1988	Upper Pool Elevation	Ordinary High Water (OHW) (downstream)	Ordinary High Water (OHW) (upstream)	Locks			
								DIMENSIONS (feet)		Lift (feet)	Downstream Lock Sill Elevation
								Main Chamber	Auxiliary Chamber		
	0						718.5				
Emsworth	6.2	2.4		0.49	710.0	708.2	710.0	110 X 600	56 X 360	18.0	
Emsworth Back Channel	6.1			0.49	710.0			none	none	none	
Dashields	13.3	4.8		0.47	692.0	698.0	703.3	110 X 600	56 X 360	10.0	
Montgomery	31.7	9.6		0.40	682.0	681.4	686.1	110 X 600	56 X 360	17.5	
New Cumberland	54.4	12		0.55	664.5	660.2	664.8	110 X 1200	110 X 600	20.5	622.9 (estimated)
Pike Island	84.2	14.4		0.69	644.0	638.2	644.8	110 X 1200	110 X 600	21.0	
Hannibal	126.4	21.6			623.0	614.0	623.6	110 X 1200	110 X 600	21.0	
Willow Island	161.7	19.2	0.425	0.529	602.0	594.7	602.5	110 X 1200	110 X 600	20.0	567.0
Belleville	203.9	19.2	0.487	0.610	582.0	573.0	583.1	110 X 1200	110 X 600	22.0	545.0
Racine	237.5	12	0.046	0.605	560.0	551.5	560.2	110 X 1200	110 X 600	22.0	523.0
R.C Byrd	279.2	14.4	0.366	0.649	538.0	529.3	539.3	110 X 1200	110 X 600	23.0	497.0
Greenup	341	16.8	0.562	0.620	515.0	504.3	515.3	110 X 1200	110 X 600	30.0	470.0
C.A. Meldahl	436.2	21.6	0.73	0.74	485.0	476.5	485.4	110 X 1200	110 X 600	30.0	
Markland	531.5	26.4	0.74	0.62	455.0	442.3	455.0	110 X 1200	110 X 600	35.0	405.0
McAlpine	604.4 (Dam) 606.8 (Locks)	19.2	0.82	0.49	420.0	409.5	420.0	110 X 1200	110 X 1200	37.0	371.0
Cannelton	720.7	26.4	0.67	0.35	383.0	377.2	383.0	110 X 1200	110 X 600	25.0	343.0
Newburgh	776.1	16.8	0.54	0.30	358.0	362.5	363.5	110 X 1200	110 X 600	16.0	326.0
John T. Meyers	846.0	24.0	0.35	0.34	342.0	342.7	343.9	110 X 1200	110 X 600	18.0	308.0
Smithland	918.5	21.6	0.71	0.20	324.0	315.1	324.0	110 X 1200	110 X 1200	22.0	287.0
Olmsted	964.4	12	0.56	-0.18	295-300	306.2	306.2	110 X 1200	110 X 1200	22.0	261.0

LRH L&D OHW from Nav charts
Elevations in RED reference NGVD 1929

Appendix 1: Physical Features of the Locks and Dams

	Locks		Weirs				Gates					Hydropower	
Lock and Dam Name	Upstream Lock Sill Elevation	Top of Lock Walls	Navigable Pass (feet)	Fixed Length (feet)	Top Elevation	Dam (feet)	Number of Gates	Gate Type	Gate Width	Sill Elevation	Top of Gate (Closed)	Existing?	Capacity (CFS)
Emsworth	690.0				709.1	898	13 (8 on main)	Vertical Lift	100	698	707	N	-
Emsworth Back Channel	none	none	none	none		556	5	Vertical Lift			707		
Dashields	677.6		-	1585	692.0	1585	-	-	-	-	-	N	-
Montgomery	665.0					1110	10	Vertical Lift	100	667	681	N	-
New Cumberland	639.0					1315	11	Tainter	110	645	666.5	N	-
Pike Island	616.0				646.0	1110	9	Tainter	110	617	646	N	-
Hannibal	596.0				625.0	982	8	Tainter	110	596	625	Y	
Willow Island	567.0				604.0	1001	8	Tainter	110	576	604	Y	36,000
Belleville	545.0				584.0	1001	8	Tainter	110		584	Y	40,000
Racine	523.0				562.0	1309	8	Tainter	110	528	562	Y	31,300
R.C Byrd	497.0				540.0	1116	8	Roller	126.5	508.5	538	N	-
Greenup	470.0				517.0	1026	9	Tainter	100	480	517	Y	36,600
C.A. Meldahl	440.0				487.0	1369	12	Tainter	100	450	487	Y	65,000
Markland	405.0		-	-	-	1395	12	Tainter	100	415	457	Y	38,190
McAlpine	371.0		-	7590	423.0	1065	9	Tainter	100	401	423	Y	44000 (theoretical)
Cannelton	343.0	402.0	-	195	388.0	1395	12	Tainter	100	346	388	Y	51,000
Newburgh	326.0	380.0	1300	1300	362.0	1140	9	Tainter	110	330	362	N*	-
John T. Meyers	308.0	362.0	2239	2239	344.0	1265	10	Tainter	110	312	344	N*	-
Smithland	287.0		1375	1375	326.0	2140	11	Tainter	110	290	326	Y	59,000
Olmsted	261.0	310	1400	426	303.5	-	5	Tainter	110	270	302	N	-

* Has FERC License, but no current plans to construct

Appendix 1: Physical Features of the Locks and Dams

	Hydropower	Notes		
Lock and Dam Name	**Max Design Head (feet)**	**Constraints**	**Challenges**	**Considerations**
Emsworth	-		Significant operational complexities related to maintenance of stages at Point of Pittsburgh related to confluence of Monongahela and Allegheny Rivers	Upper Ohio Navigation Project construction to replace lock
Emsworth Back Channel				Constant flow over fixed weir
Dashields	-	No gates to control pool - fixed weir only		Upper Ohio Navigation Project construction to replace lock
Montgomery	-	Top of gates and fixed weir both currently below Normal Pool, difficulty retaining pool		Upper Ohio Navigation Project construction to replace lock (near-term)
New Cumberland	-			
Pike Island	-	Water intakes may be at high elevations		
Hannibal				
Willow Island	20			Non-federal hydropower
Belleville	22			Non-federal hydropower
Racine	22			Non-federal hydropower
R.C Byrd	-	High elevation of wate rintakes on Kanawha River below Winfield L&D No freeboard when roller gates completely closed Hard bottom below Winfield L&D on the Kanawha if pool drops below 12.5 ft at low flow.	Known existence of threatened and endangered mussels below the dam	
Greenup	21			Non-Federal Hydropower; Hydropower already has design head lower than max lift, so would not impact
C.A. Meldahl	30			Non-federal hydropower
Markland	34			Non-Federal Hydropower; Hydropower already has design head lower than max lift, so would not impact
McAlpine	37	Maintains 12.3 upper pool due to Louisville Waterfront Development		Non-federal hydropower
Cannelton	25			Non-Federal Hydropower; Gates/weir higher than normal pool
Newburgh	-		Known dredging challenges in pool	Gates/weir higher than normal pool
John T. Meyers	-			
Smithland	23		Known dredging challenges in pool	Non-Federal Hydropower; Operations to support Olmsted Hinged Pool operations
Olmsted	-	RM 925 Natural gas pipeline hardpoint	Highly complex operation of hinged pool and wicket dam in close proximity to two major tributaries + significant influence of Mississippi River on TW	Tries to maintain Smithland TW >=12.2 to prevent hydropower cavitation. Kentucky Lake TW and Lake Barkley TW elevations

Appendix 2: Ecological Characteristics of Navigation Pools within the Ohio River

District	Navigation Pool	States	Authorized Project Purposes	Dam Type	DSAC	Pool Level	Pool Length (mi)	Hydroelectric Facility	Channel Maintenance Cost ($)	Water Intakes/Outfalls
Pittsburgh	Emsworth	PA	1. Navigation	Gated (2)	4 (2017)	710	23.9 mi Allegheny= 6.5 mi Monongahela = 11 mi Ohio = 6.5 mi	No FERC license, new construction initiated	$172,255	12
	Dashields	PA	1. Navigation	Fixed crest	5 (2016)	692	7.1 mi	No FERC license	$172,255	7
	Montgomery	PA	1. Navigation	Gated	4 (2019)	682	18.5 mi	No FERC license, new construction initiated	$172,255	19
	New Cumberland	OH, WV	1. Navigation 2. Recreation	Gated	4 (2018)	644.5	22.6 mi	No FERC license	$172,255	14
	Pike Island	OH, WV	1. Navigation 2. Recreation	Gated	4 (2018)	644	30 mi	No FERC license	$172,255	27
	Hannibal	OH, WV	1. Navigation 2. Recreation	Gated	4 (2017)	623	42.2 mi	Yes	$172,255	23

Appendix 2: Ecological Characteristics of Navigation Pools within the Ohio River

District	Navigation Pool	Docks/Marinas/ Ramps	National Wild & Scenic River	Major Tributaries	Islands	Wildlife Refuge(s)	Backwater/Slackwater
Pittsburgh	Emsworth	5	No	Chartiers Creek	Brunot (industrial) Davis (deciduous forest) Neville (partial, industrial)	None	Analysis not completed
	Dashields	6	No	Montour Run	Neville (partial, industrial)	None	Shallow water shoal downstream of Emsworth L/D considered Resource Cat. 1 habitat (USFWS) with benefits to migratory birds, walleye and sauger (feeding/spawning), and prey species of fish and bird
	Montgomery	4	No	Raccoon Creek, Beaver River, Big Sewickley Creek, Little Sewickley Creek, Four Mile Run	None	None	Shallow water habitat from confluence of Beaver Run (RM 25.5) to RM 28.0 Montgomery Slough - 100-acre embayment considered Resoruce Cat. 1 habitat (USFWS) with benefits to forage fish (nursey) and as feeding and cover habitat for birds and fish, intact riparian corridor
	New Cumberland	10	No	Yellow Creek, Little Yellow Creek, Little Beaver Creek, Congo Run, Tomlinson Run, Squirrel Run	Phillis (forested) Georgetown Babbs (largest) Cluster Islands (eroding)	USFWS ORINWR - Phillis & Georgetown Islands	101.2 acres of backchannel habitat associated with islands 7 embayments with 4.4 mi of slackwater habitat 4 priority wetland and embayment areas - near Phillis and Georgetown Islands, Congo Run, & Tomlinson Run = total of 120.7 acres of immature bottomland habitat, riverine open water, and palustrine forested habitat
	Pike Island	18	No	Short Creek, Buffalo Creek, Cross Creek, Harman Creek, Kings Creek	Griffen Browns	USFWS ORINWR - Buffalo Creek	Analysis not completed
	Hannibal	15	No	Procter Creek, Opossum Creek, Sunfish Creek, Fish Creek, Captina Creek, Big Grave Creek, Little Grave Creek, Wheeling Creek	Fish Creek Captina Boggs Wheeling Upper Sister (submerged) Lower Sister	USFWS ORINWR - Fish Creek, Captina, and Wheeling (partial) Islands	Analysis not completed

Appendix 2: Ecological Characteristics of Navigation Pools within the Ohio River

District	Navigation Pool	Mussels	Fish Community	Threatened & Endangered Species	Invasive Species	ORSANCO ORFIN
Pittsburgh	Emsworth	7 species Fat Mucket, Pink Heelsplitter, Fragile Papershell, Threehorn Wartyback, Mapleleaf, Fawnsfoot	41 (ORSANCO 2018)	2 species Indiana bat, Northern Long-eared Bat	Known: Asiatic clams, zebra mussels, hydrilla Possible: Eurasian watermillfoil, tree-of-heaven, Japanese knotweed, etc.	2007 - 34.20 (Good) 2012 - 26.63 (Fair) 2018 - 27.83 (Fair)
	Dashields	10 species Fluted Shell, Fragile Papershell, Threehorn Wartyback, Pink Heelsplitter, Mapleleaf, Fawnsfoot, Threeridge, White Heelsplitter, Pistolgrip, Rainbow	43 (ORSANCO 2013)	2 species Indiana bat, Northern Long-eared Bat	Known: Asiatic clams, zebra mussels, hydrilla Possible: Eurasian watermillfoil, tree-of-heaven, Japanese knotweed, etc.	2008 - Fair 2013 - 30.8 (Good)
	Montgomery	9 species Fragile Papershell, Threehorn Wartyback, Pink Heelsplitter, Mapleleaf, Threeridge, White Heelsplitter, Flat Floater, Rainbow, Deertoe	42 (ORSANCO 2015)	2 species Indiana bat, Northern Long-eared Bat	Known: Asiatic clams, zebra mussels, hydrilla, marine scuds Possible: Eurasian watermillfoil, tree-of-heaven, Japanese knotweed, etc.	2006 - 24 (Fair) 2010 - 33 (Good) 2015 - 32 (Good)
	New Cumberland	12 species Mucket, Spike, Mapleleaf, Fragile Papershell, Pink Heelsplitter, Paper Pondshell, Fawnsfoot, Threehorn Wartyback, Giant Floater, Fat Mucket, Fluted Shell, Deertoe	40 (ORSANCO 2017)	2 species Indiana bat, Northern Long-eared Bat	Known: Asiatic clams, zebra mussels, hydrilla, marine scuds Possible: Eurasian watermillfoil, tree-of-heaven, Japanese knotweed, etc.	2005 - 36.3 (Good) 2011 - 24 (Fair) 2017 - 27.8 (Fair)
	Pike Island	Data not available	43 (ORSANCO 2018)	3 species Indiana bat, Northern Long-eared Bat, Running Buffalo Clover	Known: Asiatic clams, zebra mussels, hydrilla Possible: Eurasian watermillfoil, tree-of-heaven, Japanese knotweed, etc.	2007 - 43.0 (Very Good) 2012 - 32.9 (Good) 2018 - 24.2 (Fair)
	Hannibal	5+ species Clubshell, Fanshell, Pink Mucket, Sheepnose Mussel, Snuffbox Mussel	50 (ORSANCO 2013)	8 species Indiana bat, Northern Long-eared Bat, Clubshell, Fanshell, Pink Mucket, Sheepnose Mussel, Snuffbox Mussel, Running Buffalo Clover	Known: Hydrilla Possible: Asian clam, Eurasian watermillfoil, tree-of-heaven, Japanese knotweed, zebra mussels, etc.	2008 - Good 2013 - 34.4 (Good)

Appendix 2: Ecological Characteristics of Navigation Pools within the Ohio River

District	Navigation Pool	ORSANCO Macroinvertebrates	Floodplain considerations	Substrate	Oxygen (Strat.)	Temperature (Strat.)
Pittsburgh	Emsworth	Good (2018)	Roads and railroads adjacent to river along most of pool Heavy industrial and residential development Limited riparian corridor	Boulder (9.8%), cobble (16.9%), gravel (22.3%), sand (28.6%), fines (16.4%), hardpan (2.0%), other (4.2%) (ORSANCO 2018)	Weak, minimum DO 6.5 mg/L	Weak (< 5“F)
	Dashields	Data not available	Heavily developed adjacent to river, with fragmented habitat beyond Roads present along river	Boulder (4.3%), cobble (16.7%), gravel (30.7%), sand (28.6%), fines (14.2%), hardpan (3.5%), other (2.0%) (ORSANCO 2013)	Weak, minimum DO 6.5 mg/L	Weak (< 5“F)
	Montgomery	Fair (2015)	Roads present along river Primarily industrial/developed land use No riparian buffer in upper half of pool Habitat fragmented	Boulder (5.0%), cobble (12.0%), gravel (19.4%), sand (32.9%), fines (29.8%), hardpan (0.3%), other (0.6%) (ORSANCO 2015)	Weak, minimum DO 7.0 mg/L	Weak (< 5“F)
	New Cumberland	Fair (2017)	Less developed than upstream with clusters of residential and industrial development Large tracts of undeveloped land adjacent to river with intact riparian vegetation along left descending bank	Boulder (7.2%), cobble (14.6%), gravel (23.4%), sand (23.0%), fines (26.9%), hardpan (3.3%), other (1.5%) (ORSANCO 2017)	Weak, minimum DO 6.5 mg/L	Moderate (5-10“F)
	Pike Island	Data not available	Heavily influenced by industry with large amount of barge activity Shoreline supports a moderate degree of vegetaton	Boulder (4.7%), cobble (15.8%), gravel (26.4%), sand (28.0%), fines (21.4%), hardpan (1.4%), other (2.3%) (ORSANCO 2018)	Moderate, minimum DO 6.5 mg/L (drought minimum 5.1 mg/L) Increasing trend	Weak (< 5“F)
	Hannibal	Data not available	Large amount of aquatic vegetation on the shorelines Heavily influenced by industry and barge activitiy	Boulder (4.4%), cobble (11.7%), gravel (20.6%), sand (28.8%), fines (32.6%), hardpan (0.8%), other (1.1%) (ORSANCO 2013)	Moderate, minimum DO 6.4 mg/L (drought minimum 5.2 mg/L) Increasing trend	Weak (< 5“F)

Appendix 2: Ecological Characteristics of Navigation Pools within the Ohio River

District	Navigation Pool	Metals (Strat.)	Water Quality Issues	Notes
Pittsburgh	Emsworth	Strong, decreasing trend	Listed for CSOs, Dioxin, PCBs, Chlordane, & fish consumption. Decreasing metals, SO4, & acidity. Increasing water temperature, turbidity, alkalinity, pH, algae, chlorophyll, salts, conductivity, hardness, & nutrients.	Peregrine falcon present (PNDI)
	Dashields	Moderate, decreasing trend	Listed for CSOs, dioxin, PCBs, chlordane, & fish consumption. Decreasing metals, SO4, & acidity. Increasing water temperature, turbidity, alkalinity, pH, algae, chlorophyll, salts, conductivity, hardness, & nutrients.	Peregrine falcon present (PNDI)
	Montgomery	Moderate, decreasing trend	Listed for CSOs, dioxin, PCBs, chlordane, & fish consumption. Decreasing metals, SO4, & acidity. Increasing water temperature, turbidity, alkalinity, pH, algae, chlorophyll, salts, conductivity, hardness, & nutrients.	Peregrine falcon, prothonotary warbler, rock skullcap, ghost shiner, warmouth, and bigmouth buffalo present (PNDI)
	New Cumberland	Moderate, decreasing trend	Listed for CSOs, dioxin, PCBs, bacteria,& metals. Decreasing metals, SO4, & acidity. Increasing water temperature, turbidity, alkalinity, pH, algae, chlorophyll, salts, conductivity, hardness, & nutrients.	Prothonotary warbler, bigmouth buffalo, warmouth, longear sunfish present (PNDI)
	Pike Island	Moderate, decreasing trend	Listed for CSOs, dioxin, PCBs, bacteria, & metals. Decreasing metals, SO4, & acidity. Increasing water temperature, turbidity, alkalinity, pH, algae, chlorophyll, salts, conductivity, hardness, & nutrients.	ORSANCO 2018: Macroinvertebrate data could not be scored due to presence of high flows affecting recovery of Hester-Dendy samplers
	Hannibal	Moderate, decreasing trend	Listed for CSOs, Dioxin, PCBs, bacteria, and metals. Decreasing metals, SO4, & acidity. Increasing water temperature, turbidity, alkalinity, pH, algae, chlorophyll, salts, conductivity, hardness, & nutrients.	

Appendix 2: Ecological Characteristics of Navigation Pools within the Ohio River

Huntington	Willow Island	OH, WV	1. Navigation 2. Recreation 3. Fish/Wildlife	Tainter gates	3	602 ft m.s.l	35.3 mi	Yes	$16,000	18
	Belleville	OH, WV	1. Navigation 2. Recreation 3. Fish/Wildlife	Tainter gates	4	582 ft m.s.l	42.2 mi	Yes	$32,000	19
	Racine	OH, WV	1. Navigation 2. Recreation 3. Fish/Wildlife	Tainter gates	4	560 ft m.s.l	33.6 mi	Yes	$42,000	7
	R.C. Byrd	OH, WV	1. Navigation 2. Recreation 3. Fish/Wildlife	Roller gates	4	538 ft m.s.l	41.7 mi	No	$250,000	21

Appendix 2: Ecological Characteristics of Navigation Pools within the Ohio River

Huntington	Willow Island	5	No	Middle Island Creek, Fishing Creek	Lower Brothers Island Middle Brothers Island Middle Island Grape Island 2 Unnamed Island, Wells Island Witten Towhead Williamson Island Paden Island	USFWS ORINWR Wayne National Forest	Analysis not completed
	Belleville	15	No	Hocking River, Little Hocking River, Muskingum River, Little Muskingum River, Duck Creek, Lee Creek, Little Kanawha River, Big Run	Mustapha Island Newbery Island Blennerhassett Island Neal Island Halfway Island Mukingum Island Marietta Island	USFWS ORINWR	Analysis not completed
	Racine	4	No	Shade River, Mill Creek, Sandy Creek, Little Sandy Creek, Pond Creek	Letart Island Buffington Island	USFWS ORINWR	Analysis not completed
	R.C. Byrd	13	No	Kanawha River, Racoon Creek	Eight Mile Island Gallipolis Island	None	Analysis not completed

Appendix 2: Ecological Characteristics of Navigation Pools within the Ohio River

Huntington	Willow Island	Data not available	49 (ORSANCO 2016)	7 species Indiana Bat, Northern Long-eared Bat, Clubshell, Fanshell, Pink Mucket (pearlymussel), Sheepnose Mussel, Snuffbox Mussel	9 species: Goldfish, Common Carp, Asian Clam, Zebra Mussel, Monoecious Hydrilla, Purple Loosestrife, Morone chrysops × saxatilis (wiper), Eurasian watermilfoil, Brittle waternymph	35.8 (Good)
	Belleville	29 species Mucket, Threeridge, Flat Floater, Butterfly Mussel, Elephant Ear, Spike, Wabash Pigtoe, Plain Pocketbook, Pocketbook, Fatmucket, White Healsplitter, Flutedshell, Fragile Papershell, Black Sandshell, Washboard, Threehorn Wartyback, Round Hickorynut, Sheepnose, Ohio Pigtoe, Round Pigtoe, Pink Healsplitter, Ohio Healsplitter, Monkeyface, Pimpleback, Mapleleaf, Pistolgrip, Fawnsfoot, Deertoe, Paper Pondshell	52 (ORSANCO 2014)	9 species Indiana Bat, Northern Long-eared Bat, Clubshell, Fanshell, Northern Riffleshell, Pink Mucket (pearlymussel), Purple Cat's Paw, Sheepnose Mussel, Snuffbox Mussel	7 species: Goldfish, Grass Carp, Asian Clam, Zebra Mussel, Craspedacusta sowerbyi (freshwater jellyfish), Apocorphium lacustre (scud), Monoecious Hydrilla	24.5 (Fair)
	Racine	Mucket, Threeridge, Flat Floater, Butterfly Mussel, Elephant Ear, Spike, Wabash Pigtoe, Plain Pocketbook, Pocketbook, Fatmucket, White Healsplitter, Flutedshell, Fragile Papershell, Black Sandshell, Washboard, Threehorn Wartyback, Round Hickorynut, Sheepnose, Ohio Pigtoe, Round Pigtoe, Pink Healsplitter, Ohio Healsplitter, Monkeyface, Pimpleback, Mapleleaf, Pistolgrip, Fawnsfoot, Deertoe, Paper Pondshell	40 (ORSANCO 2015)	10 species Indiana Bat, Northern Long-eared Bat, Clubshell, Fanshell, Northern Riffleshell, Pink Mucket (pearlymussel), Purple Cat's Paw, Sheepnose Mussel, Snuffbox Mussel, Running Buffalo Clover	7 species: Goldfish, Common Carp, Asian Clam, Zebra Mussel, Apocorphium lacustre (scud), Monoecious Hydrilla, Possum Shrimp	31 (Good)
	R.C. Byrd	20 species Mucket, Threeridge, Butterfly Mussel, Wabash Pigtoe, Plain Pocketbook, Fatmucket, Yellow Sandshell, White Healsplitter, Flutedshell, Fragile Papershell, Black Sandshell, Washboard, Threehorn Wartyback, Ohio Pigtoe, Pink Healsplitter, Kidney Shell, Monkeyface, Pimpleback, Mapleleaf, Deertoe	41 (ORSANCO 2013)	10 species Indiana Bat, Northern Long-eared Bat, Clubshell, Fanshell, Northern Riffleshell, Pink Mucket (pearlymussel), Purple Cat's Paw, Sheepnose Mussel, Snuffbox Mussel, Running Buffalo Clover	9 species: Grass Carp, Bighead Carp, Asian Clam, Zebra Mussel, Craspedacusta sowerbyi (freshwater jellyfish), Apocorphium lacustre (scud), Monoecious Hydrilla, Possum Shrimp, Calanoid Copepod	30.8 (Good)

Appendix 2: Ecological Characteristics of Navigation Pools within the Ohio River

Huntington	Willow Island	Very good	Land primarily consists of forests and cropland with some cattle land as well as mineral extraction sites Most of the shoreline is federally protected national forest, only a few smaller downs border the shoreline	Boulder (9%), cobble (4.6%), gravel (13%), sand (30%), fines (40.3%), hardpan (1.5%), other (1.5%) (ORSANCO 2016)	None/minimal	None/minimal
	Belleville	Data not available	Moderately influenced by industry and barge activity Largest cities on the pool are Marietta, OH and Parkersburg, W	Boulder (1.5%), cobble (6.6%), gravel (23.0%), sand (29.6%), fines (34.6%), hardpan (2.1%), other (2.6%) (ORSANCO 2014)	None/minimal	None/minimal
	Racine	Fair	Mostly undeveloped land with little impact from industry Majority of the shorlines are shallow with mixes of fines and sands	Boulder (13%), cobble (8.3%), gravel (17.6%), sand (29.6%), fines (31.4%), hardpan (11.3%), other (0.5%) (ORSANCO 2015)	None/minimal	None/minimal
	R.C. Byrd	Data not available	Heavily influenced by industry with large amount of barge activity Majority of watershed is forested with some pasture lands and row crops	Boulder (2.3%), cobble (7.3%), gravel (17.6%), sand (29.6%), fines (31.4%), hardpan (11.3%), other (0.5%) (ORSANCO 2013)	None/minimal	None/minimal

Appendix 2: Ecological Characteristics of Navigation Pools within the Ohio River

Huntington	Willow Island	None/minimal	Listed for dioxin, iron	WVDEP 2016 303d listing
	Belleville	None/minimal	Listed for bacteria, dioxin, iron. Recent harmful algal blooms (HABs)	WVDEP 2016 303d listing
	Racine	None/minimal	Listed for bacteria, dioxin, iron	WVDEP 2016 303d listing
	R.C. Byrd	None/minimal	Listed for bacteria, iron. Recent HABs	WVDEP 2016 303d listing

Appendix 2: Ecological Characteristics of Navigation Pools within the Ohio River

Huntington	Greenup	OH, KY	1. Navigation 2. Recreation 3. Fish/Wildlife	Tainter gates	5	515 ft m.s.l	61.8 mi	Yes	$1,900,000	51
	Meldahl	OH, KY	1. Navigation 2. Recreation 3. Fish/Wildlife	Tainter gates	5	485 ft m.s.l	95.2 mi	Yes	$500,000	22
Louisville	Markland	OH, KY	1. Navigation	Gated	4	455	95.3 mi	Yes	$8,529	78

Appendix 2: Ecological Characteristics of Navigation Pools within the Ohio River

Huntington	Greenup	23	No	Little Sandy River, Big Sandy River, Twelvepole Creek, Fourpole Creek, Guyandotte River	None	None	Analysis not completed
	Meldahl	37	No	Scioto River, Little Scioto River	Brush Creek Island Manchester Islands (2)	USFWS ORINWR	Analysis not completed
Louisville	Markland	619	Yes Little Miami Wild and Scenic River	Little Miami River, Licking River, Mill Creek, Great Miami River, Tanners Creek, Hogan Creek, Laughery Creek, Big South Fork	Laughery Island	None	Analysis not completed

Appendix 2: Ecological Characteristics of Navigation Pools within the Ohio River

Huntington	Greenup	31 species Mucket, Threeridge, Pimpleback, Butterfly Mussel, Elephant Ear, Spike, Ebony Shell, Wabash Pigtoe, Longsolid, Plain Pocketbook, Pocketbook, Fatmucket, Yellow Sandshell, White Healsplitter, Flutedshell, Fragile Papershell, Black Sandshell, Washboard, Wartyback, Sheepnose, Ohio Pigtoe, Round Pigtoe, Pink Healsplitter, Giant Floater, Monkeyface, Wartyback, Pimpleback, Mapleleaf, Pistolgrip , Fawnsfoot, Deertoe	45 (ORSANCO 2016)	17 species Gray Bat, Indiana Bat, Northern Long-eared Bat, Clubshell, Fanshell, Northern Riffleshell, Orangefoot Pimpleback, Pink Mucket (pearlymussel), Rabbitsfoot, Ring Pink, Rough Pigtoe, Sheepnose Mussel, Snuffbox Mussel , Spectaclecase, Running Buffalo Clover, Small Whorled Poginia, Virginia Spiraea Indiana Bat Critical Habitat located within pool	14 species: Goldfish, Grass Carp, Common Carp, Bighead Carp, Asian Clam, Zebra Mussel, Craspedacusta sowerbyi (freshwater jellyfish), Apocorphium lacustre (scud), Monoecious Hydrilla, Purple Loosestrife, Possum Shrimp, Calanoid Copepod, Morone chrysops × saxatilis (wiper), red-bellied pacu	44.5 (Very good)
	Meldahl	27 species Mucket, Threeridge, Purple Wartyback, Butterfly Mussel, Elephant Ear, Ebony Shell, Wabash Pigtoe, Longsolid, Plain Pocketbook, Pocketbook, Yellow Sandshell, White Healsplitter, Fragile Papershell, Black Sandshell, Washboard, Threehoarn Wartyback, Sheepnose, Ohio Pigtoe, Pink Healsplitter, Pink Papershell, Monkeyface, Wartyback, Pimpleback, Mapleleaf, Pistolgrip, Fawnsfoot, Deertoe	45 (Orsanco 2017)	17 species Gray Bat, Indiana Bat, Northern Long-eared Bat, Clubshell, Fanshell, Northern Riffleshell, Orangefoot Pimpleback, Pink Mucket (pearltmussel), Rabbitsfoot, Ring Pink, Rough Pigtoe, Sheepnose Mussel, Snuffbox Mussel , Spectaclecase, Running Buffalo Clover, Small Whorled Poginia, Virginia Spiraea Indiana Bat Critical Habitat located within pool	15 species: Goldfish, Grass Carp, Common Carp, Bighead Carp, Silver Carp, Asian Clam, Zebra Mussel, Craspedacusta sowerbyi (freshwater jellyfish), Apocorphium lacustre (scud), Echinogammarus ischnus (scud), Monoecious Hydrilla, Purple Loosestrife, Nile Tilapia, Possum Shrimp, Atlantic sharpnose shark	36.15 (Good)
Louisville	Markland	57 species Mucket, Slippershell Mussel, Threeridge, Flat Floater, Cylindrical Papershell, Spectaclecase, Purple Wartyback, Fanshell, Butterfly, Elephantear, Spike, Catspaw, Northern Riffleshell, Snuffbox, Wabash Pigtoe, Longsolid, Pink Mucket, Plain Pocketbook, Wavyrayed Lampmussel, Pocketbook, Fatmucket, Yellow Sandshell, White Heelsplitter, Creek Heelsplitter, Flutedshell, Fragile Papershell, Black Sandshell, Washboard, Threehorn Wartyback, Hickorynut, Ring Pink, Round Hickorynut, Orangefoot Pimpleback, Sheepnose, Clubshell, Ohio Pigtoe, Rough Pigtoe, Pyramid Pigtoe, Round Pigtoe, Pink Heelsplitter, Pink Papershell, Kidneyshell, Giant Floater, Rabbitsfoot, Monkeyface, Wartyback, Pimpleback, Mapleleaf, Pistolgrip, Ebonyshell, Salamander Mussel, Creeper, Lilliput, Fawnsfoot, Deertoe, Pondhorn, Rainbow	80	17 species Gray Bat, Indiana Bat, Northern Long-eared Bat, Clubshell, Fanshell, Northern Riffleshell, Orangefoot Pimpleback, Pink Mucket, Purple Cat's Paw, Rabbitsfoot, Rayed Bean, Ring Pink, Rough Pigtoe, Sheepnose Mussel, Snuffbox Mussel, Spectaclecase, Running Buffalo Clover	12 species Goldfish, Grass Carp, Common Carp, Bighead Carp, Silver Carp, Asian Clam, Zebra Mussel, Quagga Mussel, *Craspedacusta sowerbyi* (freshwater jellyfish), *Echinogammarus ischnus* (scud), Monoecious Hydrilla, Purple Loosestrife	2005 - 43.4 (Very Good) 2009 - 43.4 (Very Good) 2014 - 37.7 (Good)

Appendix 2: Ecological Characteristics of Navigation Pools within the Ohio River

Huntington	Greenup	Good	Heavily influenced by by industry with a large amount of barge activity Cities of Huntington, WV and Ashland, KY also reside in this pool.	Boulder (11.3%), cobble (7.4%), gravel (16.9%), sand (32.2%), fines (26.6%), hardpan (4.5%), other (1.4%) (ORSANCO 2016)	None/minimal	None/minimal
	Meldahl	Fair	Forested sandy shoreline are prevalent as well as instream woody cover Most of the land is covered in deciduous forest and small amounts of agricultural and pastoral land. Cities of Portmouth, OH and Maysville, KY reside in this pool.	Boulder (10.2%), cobble (12.4%), gravel (22.3%), sand (28.8%), fines (18.2%), hardpan (7%), other (1.2%) (ORSANCO 2017)	None/minimal	None/minimal
Louisville	Markland	Data not available	Heavily influenced by industry with large amounts of barge activity Primarily forested, but with considerable row crop and pasture land use in watershed Riprap shorelines are common throughout pool Roads present along river Narrow to no riparian buffer along much of the pool	Dominant habitat class: D - shallow sand/fines. Notable measures: some degree of woody cover was observed at each site (ORSANCO 2014)	Primarily weak (95% of profiles <= 2 mg/L of difference)	Weak (< 5“F)

Appendix 2:		Ecological Characteristics of Navigation Pools within the Ohio River		
Huntington	Greenup	None/minimal	Data not available	
	Meldahl	None/minimal	Data not available	
Louisville	Markland	Magnesium: strong significant increase. Aluminum, Iron, Manganese, and Zinc are either decreasing or no significant trend	Listed for E. coli, Dioxin, and PCBs (KDOW Water Health Portal);	

Appendix 2: Ecological Characteristics of Navigation Pools within the Ohio River

Louisville	McAlpine	KY, IN	1. Navigation	Gated	4	420	75 mi	Yes	$238,784	6
	Cannelton	KY, IN	1. Navigation	Gated	4	383	114 mi	Yes	$394,188	4
	Newburgh	KY, IN	1. Navigation	Gated	4	358	55 mi	No	$267,284	15

Appendix 2: Ecological Characteristics of Navigation Pools within the Ohio River

Louisville	McAlpine	387	No	Beargrass Creek, Harrods Creek, Indian Kentuck Creek, Kentucky River	Shippingport Island Towhead Island Six Mile Island Twelve Mile Island Eighteen Mile Island	IDNR Charlestown State Park/Nature Preserve KNP Six Mile Island State Nature Preserve	Analysis not completed
	Cannelton	278	No	Sinking Creek, Blue River, Little Blue River, Indian Creek, Salt River	Flint Island Sand Island	Falls of Ohio National Wildlife Conservation Area Hoosier National Forest Mouth of Blue River Nature Preserve/Harrison Crawford State Forest Otter Creek Recreation Area	Analysis not completed
	Newburgh	325	No	Anderson River, Blackford Creek, Little Pigeon Creek	Scuffletown Island French Islands (2) Ellis Island Little Hurricane Island Yellowbank Island	None	Analysis not completed

Appendix 2: Ecological Characteristics of Navigation Pools within the Ohio River

Louisville	McAlpine	44 species Mucket, Threeridge, Purple Wartyback, Fanshell, Butterfly, Elephantear, Spike, Northern Riffleshell, Wabash Pigtoe, Longsolid, Pink Mucket, Plain Pocketbook, Pocketbook, Yellow Sandshell, White Heelsplitter, Fragile Papershell, Black Sandshell, Washboard, Threehorn Wartyback, Hickorynut, Ring Pink, Round Hickorynut, Orangefoot Pimpleback, Sheepnose, Clubshell, Ohio Pigtoe, Rough Pigtoe, Pyramid Pigtoe, Round Pigtoe, Pink Heelsplitter, Pink Papershell, Giant Floater, Rabbitsfoot, Monkeyface, Wartyback, Pimpleback, Mapleleaf, Pistolgrip, Ebonyshell, Lilliput, Fawnsfoot, Deertoe, Pondhorn, Little Spectaclecase	66	15 species Gray Bat, Indiana Bat, Northern Long-eared Bat, Clubshell, Fanshell, Northern Riffleshell, Orangefoot Pimpleback, Pink Mucket, Purple Cat's Paw, Rabbitsfoot, Ring Pink, Rough Pigtoe, Sheepnose Mussel, Spectaclecase, Running Buffalo Clover	11 species Grass Carp, Common Carp, Bighead Carp, Silver Carp, Asian Clam, Zebra Mussel, *Craspedacusta sowerbyi* (freshwater jellyfish), *Lophopodella carteri* (freshwater bryozoan), *Echinogammarus ischnus* (scud), *Daphnia lumholtzi* (waterflea), Monoecious Hydrilla	2009 - 35.2 (Good) 2014 - 43.9 (Very Good)
	Cannelton	49 species Mucket, Elktoe, Threeridge, Cylindrical Papershell, Spectaclecase, Purple Wartyback, Fanshell, Butterfly, Elephantear, Spike, Snuffbox, Wabash Pigtoe, Longsolid, Pink Mucket, Plain Pocketbook, Wavyrayed Lampmussel, Fatmucket, Yellow Sandshell, Fragile Papershell, Black Sandshell, Washboard, Threehorn Wartyback, Hickorynut, Ring Pink, Round Hickorynut, Orangefoot Pimpleback, Sheepnose, Clubshell, Ohio Pigtoe, Rough Pigtoe, Pyramid Pigtoe, Round Pigtoe, Pink Heelsplitter, Fat Pocketbook, Pink Papershell, Giant Floater, Rabbitsfoot, Monkeyface, Wartyback, Pimpleback, Mapleleaf, Pistolgrip, Ebonyshell, Salamander Mussel, Lilliput, Fawnsfoot, Deertoe, Pondhorn, Little Spectaclecase	64	15 species Gray Bat, Indiana Bat (critical habitat), Northern Long-eared Bat, Clubshell, Fanshell, Northern Riffleshell, Orangefoot Pimpleback, Pink Mucket, Rabbitsfoot, Ring Pink, Rough Pigtoe, Sheepnose Mussel, Spectaclecase, Running Buffalo Clover, Short's Goldenrod	14 species Goldfish, Grass Carp, Common Carp, Bighead Carp, Silver Carp, Black Carp, Asian Clam, Zebra Mussel, Quagga Mussel, *Craspedacusta sowerbyi* (freshwater jellyfish), *Echinogammarus ischnus* (scud), Monoecious Hydrilla, Purple Loosestrife, Narrow-leaved Cattail	2006/2007 - 39.6 (Good) 2011 - 43.6 (Very Good) 2016 - 41.8 (Very Good)
	Newburgh	30 species Threeridge, Rock Pocketbook, Purple Wartyback, Fanshell, Butterfly, Elephantear, Spike, Wabash Pigtoe, Plain Pocketbook, Pocketbook, Yellow Sandshell, Fragile Papershell, Black Sandshell, Washboard, Threehorn Wartyback, Hickorynut, Ring Pink, Orangefoot Pimpleback, Sheepnose, Ohio Pigtoe, Pink Heelsplitter, Rabbitsfoot, Monkeyface, Wartyback, Pimpleback, Mapleleaf, Pistolgrip, Ebonyshell, Fawnsfoot, Deertoe	57	15 species Gray Bat, Indiana Bat, Northern Long-eared Bat, Clubshell, Fanshell, Fat Pocketbook, Northern Riffleshell, Orangefoot Pimpleback, Pink Mucket, Purple Cat's Paw, Rabbitsfoot, Ring Pink, Rough Pigtoe, Sheepnose Mussel, Spectaclecase	7 species Bighead Carp, Silver Carp, Asian Clam, Zebra Mussel, *Craspedacusta sowerbyi* (freshwater jellyfish), *Echinogammarus ischnus* (scud), Curly-leaf Pondweed	2007 - 42.0 (Very Good) 2012 - 46.2 (Very Good) 2017 - 33.6 (Good)

Appendix 2: Ecological Characteristics of Navigation Pools within the Ohio River

Louisville	McAlpine	Data not available	Moderately developed floodplain Pool is heavily influenced by industry and associated barge activity Portions of rocky forested shoreline are intact Roads adjacent to river along most of the pool Limited riparian buffer along much of the pool	Dominant habitat class: C/D - mixed substrates/shallow sand flat. Notable measure: rocky shores (B habitats) were still common (ORSANCO 2014)	Weak	Weak (< 5“F)
	Cannelton	Data not available	Roads/railroad tracks present along some of the pool Forest and row crop/pasture are prevalent in areas adjacent to pool The pool also runs through heavy industrial/residential area Where agriculture/heavily developed areas are present, little to no riparian area is present	Boulder (6.2%), cobble (3.4%), gravel (19.3%), sand (34.0%), fines (29.6%), hardpan (7.3%), other (0.1%) (ORSANCO 2016)	Primarily weak (91% of profiles <= 2 mg/L of difference)	Weak (< 5“F)
	Newburgh	Data not available	Roads present along some of the pool Forest and row crop/pasture are prevalent in areas adjacent to pool Where agriculture/heavily developed areas are present, little to no riparian area is present	Boulder (5.5%), cobble (10.6%), gravel (23.9%), sand (31.4%), fines (16.4%), hardpan (11.8%), other (0.4%) (ORSANCO 2017)	Primarily weak (13/17 profiles <= 2 mg/L of difference)	Weak (< 5“F)

Appendix 2:		Ecological Characteristics of Navigation Pools within the Ohio River		
Louisville	McAlpine	Magnesium: strong significant increase. Aluminum, Iron, Manganese, and Zinc are either decreasing or no significant trend	Listed for E. coli, Dioxin, and PCBs (KDOW Water Health Portal);	
	Cannelton	Magnesium: strong significant increase. Aluminum, Iron, Manganese, and Zinc are either decreasing or no significant trend	Listed for E. coli, Dioxin, and PCBs (KDOW Water Health Portal);	
	Newburgh	Magnesium: strong significant increase. Aluminum, Iron, Manganese, and Zinc are either decreasing or no significant trend	Listed for E. coli, Iron, Dioxin, and PCBs (KDOW Water Health Portal);	

Appendix 2: Ecological Characteristics of Navigation Pools within the Ohio River

Louisville	John T. Myers	KY, IN	1. Navigation	Gated	4	342	70 mi	No	$541,876	9
	Smithland	KY, IL	1. Navigation	Gated	4	324	72.6 mi	Yes	$1,315,974	3
	Olmsted	KY, IL	1. Navigation	Wickets	4	300	45.9 mi	No	$1,408,146	9

Appendix 2: Ecological Characteristics of Navigation Pools within the Ohio River

Louisville	John T. Myers	363	No	Highland Creek, Pigeon Creek,Little Pigeon Creek, Green River	Slim Island Towhead Island Mt. Vernon Towhead Diamond Island Deadman's Island Henderson Island Dutch Island	Green River National Wildlife Refuge and Conservation Partnership Sloughs Wildlife Management Area (KY WMA) Ashumbala State Nature Preserve (IDNR) Hovey Lake Fish and Wildlife Area (IDNR)	Analysis not completed
	Smithland	134	No	Bay Creek, Tradewater River, Wabash River, Saline River	Stewarts Island Sisters Islands Pryor Island Ron Deau Island Hurricane Island Cave In Rock Island Sturgeon Island Cincinnati Island Wabash Island	Shawnee National Forest/Garden of the Gods Recreation Area/Cretaceous Hills Nature Preserve Big Rivers WMA and State Forest (KY) Ohio River Islands WMA (KY)	Analysis not completed
	Olmsted	336	No	Tennessee River, Cumberland River	Hamletsburg Island Cumberland Island Towhead Island Owens Island	Massac Forest Nature Preserve (Illinois DNR) Ballard WMA (KY) Chestnut Hills Nature Preserve (Illinois DNR)	Analysis not completed

Appendix 2: Ecological Characteristics of Navigation Pools within the Ohio River

Louisville	John T. Myers	41 species Mucket, Threeridge, Rock Pocketbook, Purple Wartyback, Fanshell, Butterfly, Elephantear, Spike, Catspaw, Snuffbox, Wabash Pigtoe, Longsolid, Pink Mucket, Plain Pocketbook, Pocketbook, Yellow Sandshell, Flutedshell, Fragile Papershell, Black Sandshell, Washboard, Threehorn Wartyback, Hickorynut, Ring Pink, Round Hickorynut, Sheepnose, Ohio Pigtoe, Pyramid Pigtoe, Round Pigtoe, Pink Heelsplitter, Fat Pocketbook, Giant Floater, Rabbitsfoot, Monkeyface, Wartyback, Pimpleback, Mapleleaf, Pistolgrip, Ebonyshell, Fawnsfoot, Deertoe, Pondhorn	65	16 species Gray Bat, Indiana Bat, Northern Long-eared Bat, Clubshell, Fanshell, Fat Pocketbook, Northern Riffleshell, Orangefoot Pimpleback, Pink Mucket, Purple Cat's Paw, Rabbitsfoot, Ring Pink, Rough Pigtoe, Sheepnose Mussel, Spectaclecase, Short's Bladderpod	9 species Bighead Carp, Silver Carp, Black Carp, Asian Clam, Zebra Mussel, *Craspedacusta sowerbyi* (freshwater jellyfish), *Echinogammarus ischnus* (scud), Purple Loosestrife, Common Water-Hyacinth	2005 - 45 (Very Good) 2010 - 36 (Good) 2015 - 38 (Good)
	Smithland	39 species Mucket, Threeridge, Flat Floater, Rock Pocketbook, Purple Wartyback, Butterfly, Elephantear, Spike, Wabash Pigtoe, Plain Pocketbook, Pocketbook, Yellow Sandshell, White Heelsplitter, Flutedshell, Fragile Papershell, Black Sandshell, Washboard, Threehorn Wartyback, Hickorynut, Ring Pink, Sheepnose, Clubshell, Ohio Pigtoe, Rough Pigtoe, Pyramid Pigtoe, Pink Heelsplitter, Fat Pocketbook, Pink Papershell, Giant Floater, Rabbitsfoot, Monkeyface, Wartyback, Pimpleback, Mapleleaf, Pistolgrip, Ebonyshell, Salamander Mussel, Fawnsfoot, Deertoe	81	16 species Gray Bat, Indiana Bat, Northern Long-eared Bat, Clubshell, Fanshell, Fat Pocketbook, Northern Riffleshell, Orangefoot Pimpleback, Pink Mucket, Rabbitsfoot, Ring Pink, Rough Pigtoe, Sheepnose Mussel, Spectaclecase, Monarch Butterfly (candidate species), Prices Potato-bean	15 species Grass Carp, Common Carp, Bighead Carp, Silver Carp, Black Carp, Asian Clam, Zebra Mussel, Quagga Mussel, *Craspedacusta sowerbyi* (freshwater jellyfish), *Echinogammarus ischnus* (scud), Brazilian Waterweed, Purple Loosestrife, Water Mint, Brittle Waternymph, Keek (*Rorippa sylvestris*)	2008 - (Good) 2013 - 31.2 (Good)
	Olmsted	45 species Mucket, Threeridge, Flat Floater, Rock Pocketbook, Spectaclecase, Purple Wartyback, Fanshell, Butterfly, Elephantear, Spike, Snuffbox, Wabash Pigtoe, Longsolid, Pink Mucket, Plain Pocketbook, Pocketbook, Yellow Sandshell, White Heelsplitter, Fragile Papershell, Black Sandshell, Washboard, Threehorn Wartyback, Hickorynut, Ring Pink, Bankclimber, Orangefoot Pimpleback, Sheepnose, Clubshell, Ohio Pigtoe, Pyramid Pigtoe, Pink Heelsplitter, Fat Pocketbook, Pink Papershell, Bleufer, Giant Floater, Rabbitsfoot, Monkeyface, Wartyback, Pimpleback, Mapleleaf, Pistolgrip, Ebonyshell, Lilliput, Fawnsfoot, Deertoe	60	17 species Gray Bat, Indiana Bat, Northern Long-eared Bat, Clubshell, Fanshell, Fat Pocketbook, Northern Riffleshell, Orangefoot Pimpleback, Pink Mucket, Purple Cat's Paw, Rabbitsfoot (critical habitat), Ring Pink, Rough Pigtoe, Sheepnose Mussel, Spectaclecase, Monarch Butterfly (candidate species), Prices Potato-bean	8 species Grass Carp, Common Carp, Bighead Carp, Silver Carp, Black Carp, Asian Clam, Zebra Mussel, Purple Loosestrife	2009 - 30.2 (Good) 2014 - 37.1 (Good)

Appendix 2: Ecological Characteristics of Navigation Pools within the Ohio River

Louisville	John T. Myers	Data not available	Moderately developed portion of the river Heavily infludenced by agricultural practices and related industry/barge activity Few roads adjacent to road Limited riparian corridors along most of the pool, especially in agriculturally-dominated areas	Boulder (8.7%), cobble (1.4%), gravel (11.2%), sand (38.5%), fines (31.5%), hardpan (4.9%), other (3.8%) (ORSANCO 2015)	Weak	Weak (< 5“F)
	Smithland	Data not available	Primarily forested watershed, but with considerable row crop and pasture land use in watershed Few roads adjacent to pool Limited riparian corridors along most of the pool, especially in agriculturally-dominated areas	Dominant habitat class: D - shallow sand/fines. Notable measures: vast areas of submerged trees and stumps are common along the shorelines (ORSANCO 2013)	Primarily weak (90% of profiles <= 2 mg/L of difference)	Weak (< 5“F)
	Olmsted	Data not available	Primarily forested watershed, but with considerable row crop and pasture land use in watershed Large amounts of barge activity	Dominant habitat class: D - shallow sand/fines. Notable measures: instream habitats and conditions are more fluid and less predictable below Locks 52 and 53 (ORSANCO 2014)	Data not available	Weak (< 5“F)

Appendix 2:		Ecological Characteristics of Navigation Pools within the Ohio River		
Louisville	John T. Myers	Magnesium: strong significant increase. Aluminum, Iron, Manganese, and Zinc are either decreasing or no significant trend	Listed for E. coli, Iron, Dioxin, and PCBs (KDOW Water Health Portal);	
	Smithland	Magnesium: strong significant increase. Aluminum, Iron, Manganese, and Zinc are either decreasing or no significant trend	Listed for E. coli, Iron, Dioxin, and PCBs (KDOW Water Health Portal);	
	Olmsted	Magnesium: strong significant increase. Aluminum, Iron, Manganese, and Zinc are either decreasing or no significant trend	Listed for E. coli, Iron, Dioxin, and PCBs (KDOW Water Health Portal);	

Appendix 3: Riparian Land Use Analysis of Navigation Pools within the Ohio River

		District	Pittsburgh						Huntington			
		Navigation Pool	Emsworth	Dashields	Montgomery	New Cumberland	Pike Island	Hannibal	Willow Island	Belleville	Racine	R.C. Byrd
Land Use Classification	Bare Rock/Sand/Clay	Area (sqft)	48,433.50	29,060.11	1,210,851.67	377,784.21	2,324,822.08	1,947,204.72	281,775.44	213,761.53	273,285.00	710,410.39
		Relative Area (%)	0.41%	0.28%	4.11%	1.53%	5.92%	2.56%	0.50%	0.31%	0.60%	1.35%
	Cultivated Crops	Area (sqft)	0.00	0.00	0.00	0.00	38,747.56	0.00	766,248.45	3,317,441.20	4,145,409.61	5,134,327.54
		Relative Area (%)	0.00%	0.00%	0.00%	0.00%	0.10%	0.00%	1.37%	4.87%	9.03%	9.73%
	Deciduous Forest	Area (sqft)	716,814.90	435,902.22	2,431,391.36	7,420,071.91	5,841,109.70	14,744,501.07	10,295,626.47	11,266,023.11	5,986,740.11	6,980,619.75
		Relative Area (%)	6.01%	4.21%	8.26%	30.02%	14.86%	19.41%	18.38%	16.55%	13.05%	13.23%
	Developed High Intensity	Area (sqft)	5,821,707.32	2,547,603.92	7,022,941.24	3,555,046.95	7,090,700.98	5,880,351.13	634,237.23	1,650,811.76	354,036.22	2,946,169.21
		Relative Area (%)	48.78%	24.58%	23.85%	14.38%	18.04%	7.74%	1.13%	2.42%	0.77%	5.59%
	Developed, Low Intensity	Area (sqft)	900,863.21	2,537,918.11	5,046,831.88	3,438,805.90	5,269,594.43	13,146,130.62	6,741,654.55	9,415,669.74	3,501,062.87	10,109,136.14
		Relative Area (%)	7.55%	24.49%	17.14%	13.91%	13.41%	17.30%	12.03%	13.83%	7.63%	19.16%
	Developed, Medium Intensity	Area (sqft)	4,019,979.53	3,816,564.06	9,367,145.30	5,327,727.04	9,638,330.26	15,316,071.61	3,008,313.23	6,659,768.04	1,649,949.62	6,798,963.00
		Relative Area (%)	33.69%	36.82%	31.81%	21.55%	24.53%	20.16%	5.37%	9.78%	3.60%	12.89%
	Developed, Open Space	Area (sqft)	309,974.41	755,563.21	3,070,719.83	1,191,473.79	3,787,530.54	8,738,159.82	9,347,656.99	6,748,792.69	3,126,830.13	4,953,080.42
		Relative Area (%)	2.60%	7.29%	10.43%	4.82%	9.64%	11.50%	16.68%	9.91%	6.81%	9.39%
	Emergent Herbaceous Wetlands	Area (sqft)	0.00	9,686.71	0.00	184,049.01	619,951.96	484,379.32	95,862.29	243,130.14	80,922.22	112,341.96
		Relative Area (%)	0.00%	0.09%	0.00%	0.74%	1.58%	0.64%	0.17%	0.36%	0.18%	0.21%
	Evergreen Forest	Area (sqft)	0.00	0.00	309,979.41	116,241.61	38,746.80	67,813.53	287,960.56	275,962.16	59,395.57	9,437.17
		Relative Area (%)	0.00%	0.00%	1.05%	0.47%	0.10%	0.09%	0.51%	0.41%	0.13%	0.02%
	Grasslands/Herbaceous	Area (sqft)	67,806.90	145,300.61	445,593.55	1,617,691.70	2,140,773.91	3,632,867.84	1,943,264.07	1,508,634.62	1,265,737.21	1,553,007.75
		Relative Area (%)	0.57%	1.40%	1.51%	6.54%	5.45%	4.78%	3.47%	2.22%	2.76%	2.94%
	Mixed Forest	Area (sqft)	48,433.50	67,807.00	368,098.97	910,555.48	2,034,230.21	8,031,165.01	13,796,233.38	12,975,729.54	9,017,524.77	2,301,523.92
		Relative Area (%)	0.41%	0.65%	1.25%	3.68%	5.18%	10.57%	24.63%	19.06%	19.65%	4.36%
	Pasture/Hay	Area (sqft)	0.00	9,686.71	106,555.51	581,205.44	222,796.89	3,458,574.79	8,260,023.86	12,993,371.79	15,740,797.60	11,010,852.64
		Relative Area (%)	0.00%	0.09%	0.36%	2.35%	0.57%	4.55%	14.74%	19.09%	34.31%	20.87%
	Shrub/Scrub	Area (sqft)	0.00	0.00	67,807.95	0.00	67,806.90	96,876.81	73,951.01	96,804.64	128,516.07	0.00
		Relative Area (%)	0.00%	0.00%	0.23%	0.00%	0.17%	0.13%	0.13%	0.14%	0.28%	0.00%
	Woody Wetlands	Area (sqft)	0.00	9,686.71	0.00	0.00	184,050.27	435,925.10	492,403.06	714,694.96	553,119.64	131,532.60
		Relative Area (%)	0.00%	0.09%	0.00%	0.00%	0.47%	0.57%	0.88%	1.05%	1.21%	0.25%

Appendix 3: Riparian Land Use Analysis of Navigation Pools within the Ohio River

		District			Louisville							
		Navigation Pool	Greenup	Meldahl	Markland	McAlpine	Cannelton	Newburgh	John T Myers	Smithland	Olmsted	TOTAL
Land Use Classification	Bare Rock/Sand/Clay	Area (sqft)	1,139,293.85	2,088,809.00	3,113,437.10	3,602,710.70	5,312,817.28	1,833,814.69	2,635,116.19	1,293,396.14	2,893,318.12	**31,330,101.71**
		Relative Area (%)	1.55%	1.74%	2.25%	2.71%	3.77%	2.13%	2.12%	0.94%	2.76%	**2.13%**
	Cultivated Crops	Area (sqft)	3,236,995.42	5,616,398.04	11,421,753.58	6,728,687.43	26,335,349.07	24,958,936.53	27,529,179.90	24,708,326.52	9,173,054.97	**153,110,855.83**
		Relative Area (%)	4.39%	4.69%	8.27%	5.05%	18.69%	29.02%	22.18%	18.05%	8.74%	**10.40%**
	Deciduous Forest	Area (sqft)	13,987,507.83	41,481,970.39	40,248,228.39	47,349,739.71	69,570,411.83	20,066,275.46	24,789,646.86	28,105,418.45	13,835,999.45	**365,553,998.98**
		Relative Area (%)	18.99%	34.64%	29.15%	35.56%	49.38%	23.33%	19.98%	20.53%	13.18%	**24.83%**
	Developed High Intensity	Area (sqft)	3,086,084.13	742,012.06	7,058,638.24	7,590,106.73	2,002,141.70	3,579,089.28	3,625,906.36	1,088,866.15	2,198,065.64	**68,474,516.27**
		Relative Area (%)	4.19%	0.62%	5.11%	5.70%	1.42%	4.16%	2.92%	0.80%	2.09%	**4.65%**
	Developed, Low Intensity	Area (sqft)	15,939,473.80	7,881,938.78	12,399,651.41	8,754,409.64	2,608,068.47	4,816,593.94	6,187,276.77	2,420,982.55	2,470,174.34	**123,586,237.17**
		Relative Area (%)	21.64%	6.58%	8.98%	6.58%	1.85%	5.60%	4.99%	1.77%	2.35%	**8.40%**
	Developed, Medium Intensity	Area (sqft)	9,224,440.01	5,052,638.31	11,997,129.87	9,297,568.06	3,535,679.40	6,570,631.52	6,996,773.09	2,646,199.93	4,248,003.73	**125,171,875.59**
		Relative Area (%)	12.52%	4.22%	8.69%	6.98%	2.51%	7.64%	5.64%	1.93%	4.05%	**8.50%**
	Developed, Open Space	Area (sqft)	7,105,197.07	5,934,119.49	11,494,567.29	7,373,930.62	5,294,161.13	3,110,128.24	4,009,082.79	2,574,035.25	1,834,918.79	**90,759,922.52**
		Relative Area (%)	9.64%	4.96%	8.32%	5.54%	3.76%	3.62%	3.23%	1.88%	1.75%	**6.17%**
	Emergent Herbaceous Wetlands	Area (sqft)	470,526.44	1,500,841.17	862,018.09	1,232,118.09	3,648,670.18	2,504,197.67	6,279,624.96	9,590,925.67	8,627,951.24	**36,547,197.12**
		Relative Area (%)	0.64%	1.25%	0.62%	0.93%	2.59%	2.91%	5.06%	7.01%	8.22%	**2.48%**
	Evergreen Forest	Area (sqft)	75,452.49	510,028.66	91,565.09	89,255.73	306,610.01	2,386,778.82	1,588,234.64	189,604.38	156,475.72	**6,559,542.35**
		Relative Area (%)	0.10%	0.43%	0.07%	0.07%	0.22%	2.78%	1.28%	0.14%	0.15%	**0.45%**
	Grasslands/Herbaceous	Area (sqft)	2,902,879.95	4,151,454.34	3,757,860.66	6,181,608.87	2,715,820.68	930,509.36	3,657,929.55	2,129,350.89	3,156,981.29	**43,905,073.75**
		Relative Area (%)	3.94%	3.47%	2.72%	4.64%	1.93%	1.08%	2.95%	1.56%	3.01%	**2.98%**
	Mixed Forest	Area (sqft)	2,392,695.67	14,978,903.64	15,622,913.89	17,211,887.20	3,031,379.54	2,239,745.69	6,844,164.62	2,629,274.36	1,764,333.48	**116,266,599.85**
		Relative Area (%)	3.25%	12.51%	11.31%	12.93%	2.15%	2.60%	5.51%	1.92%	1.68%	**7.90%**
	Pasture/Hay	Area (sqft)	13,189,625.14	26,924,807.07	15,069,568.46	14,526,039.63	12,005,481.60	1,953,973.38	1,623,721.43	3,492,674.79	1,378,994.63	**142,548,751.37**
		Relative Area (%)	17.90%	22.49%	10.91%	10.91%	8.52%	2.27%	1.31%	2.55%	1.31%	**9.68%**
	Shrub/Scrub	Area (sqft)	209,164.25	416,702.14	171,602.77	44,781.73	24,823.42	62,029.47	48,447.04	92,929.17	17,310.69	**1,619,554.06**
		Relative Area (%)	0.28%	0.35%	0.12%	0.03%	0.02%	0.07%	0.04%	0.07%	0.02%	**0.11%**
	Woody Wetlands	Area (sqft)	712,577.09	2,454,560.46	4,770,810.07	3,154,297.02	4,490,858.27	10,984,724.94	28,287,879.11	55,921,480.88	53,235,987.39	**166,534,587.58**
		Relative Area (%)	0.97%	2.05%	3.46%	2.37%	3.19%	12.77%	22.79%	40.85%	50.71%	**11.31%**

Appendix 4: Target Species List

Taxa	Species	Scientific Name	Status	Habitat Preference	Range in Ohio River (Region)	Suggested Action/Operational Change	Notes
Birds	Interior least tern	*Sternula antillarum*	Endangered	Sand-bars (for nesting)	Lower	Lower water surface elevation in the lower reach from April 15-June 15 to increase nesting habitat	Would benefit from exposed shores during the nesting season (April 15 - June 15)
	King rail	*Rallus elegans*	N/A	Densely vegetated marshes and shores	Lower	Lower water surface elevation	Would benefit from an increase in emergent aquatic vegetation in the shallows of the Ohio River
	American black duck	*Anas rubripes*	N/A	Shallow vegetated wetlands (dabbling habitat)	Lower, Middle, Upper	Lower water surface elevation	Would benefit from an increase in emergent aquatic vegetation in the shallows of the Ohio River
	Lesser scaup	*Aythya affinis*	N/A	Shallow vegetated wetlands (diving habitat)	Lower, Middle, Upper	Lower water surface elevation	Would benefit from an increase in emergent aquatic vegetation and macroinvertebrates (such as crayfish) in the shallows of the Ohio River
	Pied-billed grebe	*Podilymbus podiceps*	N/A	Shallow vegetated wetlands (diving habitat)	Lower, Middle, Upper	Lower water surface elevation	Would benefit from an increase in emergent aquatic vegetation in the shallows of the Ohio River
	American bittern	*Botaurus lentiginosus*	N/A	Densely vegetated marshes and shores	Lower, Middle, Upper	Lower water surface elevation	Would benefit from an increase in emergent aquatic vegetation and macroinvertebrates (such as crayfish) in the shallows of the Ohio River
	Least bittern	*Ixobrychus exilis*	N/A	Densely vegetated marshes and shores	Lower, Middle, Upper	Lower water surface elevation	Would benefit from an increase in emergent aquatic vegetation and macroinvertebrates (such as crayfish) in the shallows of the Ohio River
	Yellow-crowned night heron	*Nyctanassa violacea*	N/A	Densely vegetated marshes and shores	Lower, Middle, Upper	Lower water surface elevation	Would benefit from an increase in emergent aquatic vegetation and macroinvertebrates (such as crayfish) in the shallows of the Ohio River
Fish	Paddlefish	*Polyodon spathula*	Extirpated (PA) Threatened (OH) Protected (WV)	Inhabits large, deep, slow-moving rivers, lakes, and reservoirs. It is a filter feeder, straining zooplankton.	Lower	Restore connection for fish migration to improve food access/reproduction/winter survival	Status of paddlefish in the Ohio River is categorized by border-states as extirpated in the upper river (Pennsylvania), threatened (Ohio) and protected (West Virginia) in mid-river reaches, and commercially harvested in mid-river and lower river reaches (Kentucky, Indiana, and Illinois). Highly migratory nature. Loss of spawning and rearing habitat due to environmental alteration. Dam construction has eliminated spawning sites, interrupted natural spawning migrations, altered water flow, and eliminated backwaters that were important as nursery and feeding areas.
	Lake sturgeon	*Acipenser fulvescens*	Extirpated (Eastern basin)	Typically on the bottom of a riverbed or lake. Acipenser fulvescens prefer a river or lake bottom that has clear sand or gravel.	Lower	Restore connection for fish migration to improve food access/reproduction/winter survival Maximize flow during low/normal pool conditions to encourage scouring of fine sediments.	Most abundant in the western portion of the mainstem of the Ohio River and the lower reaches of major tributaries in this area and are virtually extirpated in the eastern portion of the basin
	Shovelnose sturgeon	*Scaphirhynchus platorynchus*	N/A	Live in the open channels of large rivers. Stay on the bottom, often in areas with a swift current and sandy or gravelly bottom, and are tolerant of high turbidity.	Lower	Restore connection for fish migration to improve food access/reproduction/winter survival Maximize flow during low/normal pool conditions to encourage scouring of fine sediments.	Important host for many species of mussels. One of these species is the hickory-nut mussel, whose only known host is the shovelnose sturgeon. Most abundant in the western portion of the mainstem of the Ohio River and the lower reaches of major tributaries in this area and are virtually extirpated in the eastern portion of the basin

Appendix 4: Target Species List

Taxa	Species	Scientific Name	Status	Habitat Preference	Range in Ohio River (Region)	Suggested Action/Operational Change	Notes
Fish	Sauger	*Sander canadensis*	N/A	Sauger occur in lakes, reservoirs, and large rivers, and prefer turbid waters. They generally prefer waters where temperatures in the entire water column are within their temperature preference.	Lower, Middle, Upper	Restore connection for fish migration to improve food access/reproduction/winter survival	Found throughout much of the mainstem and are the most highly sought after game fish
	Blue sucker	*Cycleptus elongatus*	N/A	Deep, swift water in channels of large rivers with sand, gravel, or rubble bottoms. Tolerant of high turbidities, if currents are swift enough to prevent siltation. Found over cobble and/or bedrock substrates; adults occupy deep riffles (typically 1-2 m depth) in areas of very swift flow, with current speeds from 100-260 cm/s; juveniles occupy shallower, less swift water	Lower, Middle	Restore connection for fish migration to improve food access/reproduction/winter survival Maximize flow during low/normal pool conditions to encourage scouring of fine sediments.	Distribution is relatively unknown but abundance is thought to generally follow that of the sturgeons.
	Invasive carp spp. (Bighead, black, silver, and grass carp)	*Hypopthalmichthys nobilis, Hypopthalmichthys molitrix, Mylopharyngodon piceus,* and *Ctenopharyngodon idella*	Invasive	Reproduction: Asian carps release their eggs into the water column, which develop as they float down stream. Seasonal changes in river conditions, such as an increase in depth, turbulence, flow, and water temperature stimulate spawning, because these conditions are needed for early egg development.	Lower, Middle	Limit carp movement among pools	
Mussels	Pink mucket	*Lampsilis abrupta*	Endangered	Inhabits shallow riffles and shoals of major rivers and tributaries and is found in rubble, gravel or sand substrates that have been swept free of silt by the current.	Lower, Middle	Improve flow conditions / maximize flow during low/normal pool conditions	
	Orangefoot pimpleback	*Plethobasus cooperianus*	Endangered	Clean, fast-flowing water in silt-free rubble, gravel or sand of medium to large rivers.	Lower, Middle	Improve flow conditions / maximize flow during low/normal pool conditions	
	Fat pocketbook	*Potamilus capax*	Endangered	sand, mud, and fine gravel bottoms of large rivers.	Lower	Improve flow conditions / maximize flow during low/normal pool conditions	
	Clubshell	*Pleurobema clava*	Endangered	clean, loose sand and gravel in medium to small rivers and streams.	Lower, Middle	Improve flow conditions / maximize flow during low/normal pool conditions	

Appendix 4: Target Species List

Taxa	Species	Scientific Name	Status	Habitat Preference	Range in Ohio River (Region)	Suggested Action/Operational Change	Notes
Mussels	Fanshell	*Cyprogenia stegaria*	Endangered	medium to large rivers. It buries itself in sand or gravel in deep water of moderate current	Lower, Middle	Improve flow conditions / maximize flow during low/normal pool conditions	
	Northern riffleshell	*Epioblasma torulosa rangiana*	Endangered	wide variety of streams from large to small. It buries itself in bottoms of firmly packed sand or gravel	Lower, Middle	Improve flow conditions / maximize flow during low/normal pool conditions	
	Rabbitsfoot	*Quadrula cylindrica cylindrica*	Threatened	shallow water areas along the bank and adjacent runs and shoals with reduced water velocity. May occupy deep water runs, having been reported in 9 to 12 feet of water. Bottom substrates generally include gravel and sand	Lower, Middle	Improve flow conditions / maximize flow during low/normal pool conditions	
	Sheepnose	*Plethobasus cyphyus*	Endangered	larger rivers and streams where they are usually found in shallow areas with moderate to swift currents that flow over coarse sand and gravel. However, they have also been found in areas of mud, cobble and boulders, and in large rivers they may be found in deep runs.	Lower, Middle	Improve flow conditions / maximize flow during low/normal pool conditions	
	Ring pink	*Obovaria retusa*	Endangered	shallow water over silt-free sand and gravel bottoms of large rivers	Lower, Middle	Improve flow conditions / maximize flow during low/normal pool conditions	
	Rough pigtoe	*Pleurobema plenum*	Endangered	stable substrates composed of a mixture of relatively firm and clean gravel, sand, and silt.	Lower, Middle	Improve flow conditions / maximize flow during low/normal pool conditions	
	Spectaclecase	*Cumberlandia monodonta*	Endangered	prefer areas sheltered from the main force of the river current. This species often clusters in firm mud and in sheltered areas, such as beneath rock slabs, between boulders and even under tree roots.	Lower, Middle	Improve flow conditions / maximize flow during low/normal pool conditions	
	Snuffbox	*Epioblasma triquetra*	Endangered	inhabits areas with a swift current. Adults often burrow deep in sand, gravel or cobble substrates	Middle	Improve flow conditions / maximize flow during low/normal pool conditions	

Appendix 4: Target Species List

Taxa	Species	Scientific Name	Status	Habitat Preference	Range in Ohio River (Region)	Suggested Action/Operational Change	Notes
Mussels	Asian clam	*Corbicula fluminea*	Invasive	found at the sediment surface or slightly buried. Haas ability to reproduce rapidly, but has low tolerance of cold temperatures	Lower, Middle, Upper		
	Zebra mussel	*Dreissena polymorpha*	Invasive	Can be transported by current, hitch-hiking on boats, boat trailers, and other aquatic equipment. Adults feed by filtering plankton and detritus.	Lower, Middle, Upper		
Mammals	Gray Bat	*Myotis grisescens*	Endangered	live in caves year-round. In the summer, they roost in caves which are scattered along rivers. Feeds along rivers or lakes.	Lower, Middle	Improve flow conditions / maximize flow during low/normal pool conditions	
	Northern long-eared bat	*Myotis septentrionalis*	Threatened	Feeds and roosts along rivers or lakes.	Lower, Middle, Upper	Improve flow conditions / maximize flow during low/normal pool conditions	
	Indiana bat	*Myotis sodalis*	Endangered	Feeds and roosts along rivers or lakes.	Lower, Middle, Upper	Improve flow conditions / maximize flow during low/normal pool conditions	
Plants	Hydrilla	*Hydrilla* spp.	Invasive	submersed perennial herb. Crowds out native species; impedes irrigation and boating	Lower, Middle, Upper		
	Japanese knotweed	*Fallopia japonica*	Invasive	commonly found along streams and rivers. thrives in disturbed areas and once established can spread rapidly, creating monoculture stands	Lower, Middle, Upper		
	Tree of heaven	*Ailanthus altissima*	Invasive	rapidly growing deciduous tree native to China; crowds out native species and secretes a chemical into the soil that is toxic to surrounding plants	Lower, Middle, Upper		

Appendix 5: Area of Change Analysis of Navigation Pools within the Ohio River

District	Pool	Normal Pool Elevation (FT, ORD)	Lower Pool 1 Ft			Raise Pool 1 Ft		
			New Pool Elevation (FT, ORD)	Area Exposed (sq ft)	Area Exposed (acres)	New Pool Elevation (FT, ORD)	Area Submerged (sq ft)	Area Submerged (acres)
Pittsburgh	Emsworth	Not analyzed	Not analyzed	Not analyzed	Not analyzed	Not analyzed	Not analyzed	Not analyzed
	Dashields	Not analyzed	Not analyzed	Not analyzed	Not analyzed	Not analyzed	Not analyzed	Not analyzed
	Montgomery	682	681	1,497,177.00	34.37	683	1,341,606.00	30.80
	New Cumberland	665	654	5,644,827.00	129.59	666	1,575,934.00	36.18
	Pike Island	644	643	1,862,202.00	42.75	645	2,052,936.00	47.13
	Hannibal	623	622	2,691,194.00	61.78	624	2,721,746.00	62.48
Huntington	Willow Island	570	569	10,261,489.67	235.57	571	10,104,325.50	231.96
	Belleville	548	547	1,445,320.80	33.18	549	1,920,996.00	44.10
	Racine	526	525	1,315,468.44	30.20	527	1,577,046.24	36.20
	R.C. Byrd	Not analyzed	Not analyzed	Not analyzed	Not analyzed	Not analyzed	Not analyzed	Not analyzed
	Greenup	473	472	6,407,170.16	147.09	474	7,654,703.41	175.73
	Meldahl	442	441	966,944.88	22.20	443	1,816,364.88	41.70
Louisville	Markland	455	454	11,924,238.45	273.74	456	6,299,046.34	144.61
	McAlpine	Not analyzed	Not analyzed	Not analyzed	Not analyzed	Not analyzed	Not analyzed	Not analyzed
	Cannelton	383	382	9,132,606.60	209.66	384	4,658,364.23	106.94
	Newburgh	358	357	7,047,289.08	161.78	359	11,725,603.39	269.18
	John T Myers	342	341	13,768,217.32	316.07	343	10,186,348.77	233.85
	Smithland	324	323	17,194,958.23	394.74	325	16,285,254.75	373.86
	Olmsted	Not analyzed	Not analyzed	Not analyzed	Not analyzed	Not analyzed	Not analyzed	Not analyzed

Appendix 6

Hydraulic Analysis – Conceptual Evaluation of Impacts from Lower Pool Levels on Navigation

Introduction:

One measure considered as part of the Sustainable Rivers Program (SRP) Ohio River Systems Analysis was temporarily lowering the pool elevation maintained by the navigation dams. To evaluate the feasibility of such a measure, hydraulic modeling was performed to determine at what flow levels it is possible to lower navigation pool elevations immediately upstream of a navigation dam on the Ohio River system while still maintaining minimum depths and widths required to provide the authorized 9-foot draft navigation channel. The USACE SRP Environmental Team selected Pike Island L/D (LRP), Greenup L/D (LRH), and Smithland L/D (LRL) as test candidates that may benefit from lowering pool elevations to expose additional land for aquatic habitat. The study was performed using the best available modeling and supporting information at the time of the analysis, primarily being the River Analysis System model developed by the USACE Hydrologic Engineering Center (HEC-RAS) that is used for river forecasting by the Great Lakes and Ohio River Division (LRD) Water Management team. Version 6.0 of HEC-RAS was used for this analysis.

Model Background:

The Ohio River forecast model geometry is based upon the "Community" Model, an unsteady flow HEC-RAS model developed in cooperation between the USACE, National Weather Service (NWS), and the US Geological Survey (USGS). The process of developing the Community HEC-RAS model geometry began in 2006 utilizing freely available sources of input, combining previously existing channel cross-section data, bathymetric data, LIDAR, and digital elevation model (DEM) data (Adams, *et. al.*, 2010). The model began use for forecasting in approximately 2011 (USACE LRD). The sources of this geometry data for specific locations or reaches in the model are not readily documented, but it is understood that the channel was generally defined based upon previously surveyed cross section data and LIDAR mapping provided by the USACE and the USGS available at that time. This data was adjusted from its various original source datum to reference the North American Vertical Datum of 1988 (NAVD 88). The model bathymetry has been updated in limited areas, with the most recent updates occurring in 2018. This HEC-RAS model is just one of the main components of the larger LRD Corps Water Management System (CWMS) Model, along with other HEC software Meteorological Visualization Utility Engine (HEC-MetVue) and Hydrologic Modeling System (HEC-HMS). The CWMS model is used for flood event elevation predictions for the purposes of flood warning, preparedness, and decision making for flood risk management during high flow events. The model can also be used for daily forecasting purposes; however, it should be noted that calibration of this model has been focused on high flows conditions rather than the lower flow regime that this conceptual feasibility evaluation focuses on.

Analysis Development:

The lock and dam (L/D) structures maintain navigable depths for commercial navigation traffic, even during absolute minimum low flow situations. For extreme low flow situations where inflows approach zero, the dams and their upper pool elevation were designed to maintain a "flat" pool to facilitate navigation by vessels drafting up to nine feet from the downstream sill of the next dam upstream and neglecting leakage that occurs under and through the dams. The Ohio River watershed carries sediment laden runoff (e.g., gravels, sands, silts, etc.) to the river channel. The river bottom regularly transports this fine-grained material from one location to another with the natural ebb and flow caused by precipitation events. Where buildup ("shoaling") of sediment occurs, dredging may be required to ensure that this nine-foot depth is maintained should extreme low flow conditions occur. To provide adequate area for water displacement around the moving vessel, and to prevent the need for continuous dredging due to the constant movement of sediment, the channel is maintained to a depth of 12-feet below the normal pool elevation.

As discussed, when inflows approach zero, the pool becomes nearly flat between the downstream dam and its counterpart upstream. The dams operate under a "run-of-river" principle, such that the dam maintains a relatively constant elevation ("normal pool") immediately upstream of the structure, and regulates this elevation by opening gates to pass any flows in excess of that necessary to maintain the normal pool elevation. The result is, as flow naturally increases due to runoff from the watershed caused by precipitation and groundwater flows, the additional flow in the river increases depths downstream of the dam, thereby increasing the slope of the water surface within the pool.

The natural erosion processes and transport of sediment means that the geometry of the river is not constant, thus there are locations where the river becomes shallower and shoaling can be problematic. The first task is to identify the shallowest areas and examine the depths for a range of low flows to determine what minimum flows may be required to maintain minimum depths for navigation. The depths can be determined by using the HEC-RAS model to compute water surface elevations (WSEL) based on the lowered pool elevation at the controlling dam.

Flows Analyzed:

To examine the change of WSEL under different flows, a range of 10 low flow discharges were entered into the HEC-RAS model. The lower limit of the range of low flows considered was established as the 7Q10 flow; the USGS defines this as:

> *One of the most common low-flow statistics is the annual minimum 7-day average streamflow with a 10-year recurrence interval (7Q10). In terms of probability of occurrence, there is a 1/10 or 10-percent probability that the annual minimum 7-day average flow in any 1 year will be less than the estimated 7Q10 value.* (https://www.usgs.gov/centers/sawsc/science/low-flow-frequency-and-flow-duration-statistics-continuous-record-gages-south)

The 7Q10 flows used for this analysis were from a 1994 memorandum establishing these values at selected gauges along the Ohio River mainstem, included as Plate 1. The age of this document and the data that it was developed from is noteworthy, and an update of these low flow estimates is recommended for future analysis. Because the Pike Island L/D is considerably removed from the adjacent points of reference in the document, that being Sewickley, PA near Dashields L/D upstream and St. Marys, WV downstream, drainage area proportioning was used to estimate the 7Q10 flow from the published values

for these adjacent stations. Flows greater than the 7Q10 discharge that were analyzed were established at regular intervals; 5,000 cfs increments were chosen for the Pike Island pool since it is much higher in the watershed where the drainage area is less, and 10,000 cfs increments were used for the Greenup and Smithland pools. These flows are listed in Table 1. Because no significant tributaries join the Pike Island and Smithland pools, a single flow value was used for the full pool length; flows for the Greenup pool were ratioed at the Guyandotte, Big Sandy, and Little Sandy Rivers based upon contributing drainage area. For the purposes of comparison to inform the Environmental Team, the analysis was run for both a 1-foot reduction and a 3-foot reduction in upper pool elevation at the dam.

Table 1 Model discharges

Pool / Profile		Pike Island L/D	Greenup L/D				Smithland L/D
	Ohio River Mile		279.19	305.50	317.00	336.30	
	Tributary		Guyandotte River	Big Sandy River	Little Sandy River	Greenup L&D	
1 (7Q10)		5,400	9,120	9,290	9,920	10,500	17,000
2		10,000	17,520	19,430	19,830	20,000	20,000
3		15,000	26,280	29,150	29,750	30,000	30,000
4		20,000	35,040	38,860	39,660	40,000	40,000
5		25,000	43,810	48,580	49,580	50,000	50,000
6		30,000	52,560	58,290	59,490	60,000	60,000
7		35,000	61,330	68,010	69,410	70,000	70,000
8		40,000	70,080	77,720	79,320	80,000	80,000
9		45,000	78,850	87,440	89,240	90,000	90,000
10		50,000	87,600	97,150	99,150	100,000	100,000

Model Geometry:

The base model geometry from the LRD CWMS model was used as the best readily available data, with the understanding that river changes were likely to have occurred since the model was developed or updated in 2018. Within HEC-RAS, the tool readily available to view river water surface profiles represents the river bottom profile by plotting the lowest point on each cross section ("thalweg"). Since it is representing only these deepest points, this profile may not represent the depth of the river in the channel where vessels travel ("sailing line") nor represent the available width. An understanding of the actual ground profile along the sailing line and the available widths was needed. Bathymetric data for most recent surveys as of May 2021 for the pools of interest was downloaded from the USACE eHydro repository (https://navigation.usace.army.mil/Survey/Hydro). The raw point data is normally processed as depth below a fixed minimum pool elevation for the subject pool. This data was reconfigured in ArcGIS through use of raster math functions to become elevations relative to the appropriate datum, that being the Ohio River Datum for the Smithland L/D and Greenup L/D pools, and the National Geodetic Vertical Datum of 1929 (NGVD 29) for the Pike Island pool. This revised raster data was imported as a terrain for each pool utilizing tools within the HEC-RAS Mapper toolset. This data was compared first to the HEC-RAS thalweg profile and used as a better representation of the subsurface elevations to identify shallow points within the pool. The existing HEC-RAS cross section closest to the shallow point

was compared with a cross section cut from the eHydro bathymetry at the same locations – it is noted that, due to spacing of HEC-RAS sections, they may not exactly correspond to the highest points shown in the profile. Datum adjustments were made to convert the extracted profile and cross section data from the eHydro bathymetry to NAVD 88 manually [1]. These profile and cross section comparisons are shown in Plates 2 through 12. For the purposes of this screening study, the model geometry was not updated based upon the eHydro bathymetry. While differences in model cross section geometry do affect the model's computed WSEL, it was expected that the differences would not be substantial enough to affect the conclusions of this proof-of-concept analysis.

Observations:

Profile plates 2, 6 and 10, generally show both the model thalweg profile and the sailing line profile extracted from the eHydro bathymetry from recent survey data for the respective pools evaluated for the scenario of lowering the pools 1 foot. Plates 3, 7, and 11 show corresponding information for the scenario of lowering the pool 3 feet. On each plate, water surface profiles are also shown for the 7Q10 flow. The profile plates also show a line designating the 7Q10 elevation minus 12 feet for comparison to the river bottom. Select computed WSEL profiles for higher flows are also shown, as well as lines showing 12-foot of depth at these flows. The remaining cross section plates show the computed water surface for the 7Q10 for both the 1-foot and 3-foot reductions, and show the required space necessary for navigation, defined by the 12-foot navigable depth by 300-foot wide. This navigation channel boundary is generally centered on the current navigation channel, although it is assumed than in most cases the channel can be adjusted laterally to a degree where depth is inadequate for the full 300-foot width. On some plates, the channel representation may be adjusted laterally for visual representation purposes only of some alternatives. The following are some of the observations made:

1. Pike Island L/D Pool: Based upon the profile view (Plates 2 and 3), the shallowest points were identified near River Mile (RM) 56.25 and RM 60.75 (Plates 3 and 4 respectively). It is noted for the 7Q10 flow with a 1-foot reduction in pool, the 12-foot navigation depth is maintained at all locations except RM 60.75; a flow of approximately 10,000 cfs to is needed to ensure a 12-foot depth at the location. For a reduction of 3 -foot, a minimum of 30,000 cfs would be required to maintain 12 feet of depth. It should be noted that this assumes the eHydro bathymetry is more representative of current conditions, given the noted difference in river bathymetry at RM 56.25 (shown in Plate 4). Based upon drainage area proportioning, 10,000 cfs and 30,000 cfs flows in the Pike Island pool corresponds to approximately 8,000 cfs and 24,000 cfs flows at the Sewickley gauge respectively. Based upon a preliminary analysis of daily flow data at the Sewickley gauge dating back to 1933, 8,000 cfs or more occurs approximately 84.5% of the year on average, and flows greater than or equal to 24,000 cfs occurs approximately 49.6% of the year.

[1] The adjustment to convert between datum along the long path of the Ohio River can be complex due to the spatial variability of the datum referenced. To simplify this analysis, it is assumed that average adjustments for the entire length of the pool of interest can be applied without introducing significant impact on the results. Average values of -0.8 feet and -1.1 feet were used to convert from Ohio River Datum to NAVD 88 for the Smithland and Greenup pools respectively. An average value of -0.62 feet was used to convert from NGVD 29 to NAVD88 for the Pike Island pool.

2. Greenup L/D Pool: Plate 6 shows that for all cross sections a 1-foot reduction in pool appears to still provide the 12-foot navigation depth even at the 7Q10 flow. A 3-foot reduction will barely provide this necessary 12-foot depth at RM 284.5 for a 7Q10 discharge (Plates 7 and 8).
3. Smithland L/D Pool: Per Plate 10, the Smithland pool overall appears shallower than the other pools reviewed, and differences between the model geometry and the eHydro bathymetry were more pronounced; some of these changes were qualitatively validated by the LRL Dredge Team Lead as reflective of changes observed in the river. Shallow points at RM 854.44, 865.91, 870.77, and 872.06 were examined in more detail (see Plates 12-15 respectively). RM 854.44 is generally in the vicinity of Raliegh Bar, an area that is regularly monitored for shoaling, and is generally the controlling point for navigation through this area for this analysis. For a 1-foot reduction in pool, flows of 60,000 cfs or greater would be required to maintain adequate depth, and for a 3-foot reduction, 70,000 cfs would be needed specifically at this cross section. Based upon approximately 14 years of data available from recorded USGS flows at Smithland, 60,000 cfs is exceeded approximately 93.6% of a year on average. However, inspection of the sailing line profile indicated higher points may exist between the model cross sections and are not reflected by the eHydro sections cut at those locations. These higher points may require flows on the order of 120,000 cfs to ensure the 12-foot depth channel is maintained for a 3-foot reduction in pool, which is equaled or exceeded approximately 81.8% of the time annually.

It is noted that of the three pools used for this preliminary study, the model bathymetry for the Greenup pool was more closely representative of the eHydro bathymetry than the others. The Smithland pool appeared to have the most difference between the model and eHydro updated bathymetry.

Known Limitations:

Interpretation of the observations above should consider several limitations to the models used and potential forecasting applications that would be necessary to implement lowering the upper pool at a locks and dam. For pools where maintaining the required navigable depth is dependent on the available flow entering the pool, implementing a lower pool alternative will rely on forecasts of flows from models such as the LRD CWMS model; therefore, the following limitations should be known and improvements made where feasible:

LRD Community CWMS Model:

The limitations with regards to the MetVue and HEC-HMS models are twofold. MetVue is dependent on gridded rainfall, and NWS Stage 3 radar is normally used. Stage 3 radar is ground-truthed, but there are uncertainties with regards to the measurements of the radar beams as well as the volume or precipitation measured in the ground stations. HEC-HMS produces estimated flows out of the ungauged sub-basins based on this radar and assumed hydrologic conditions. Given the large area that the model covers, choosing parameters that reflect the hydrological conditions accurately is always a challenge. At present, the HEC-HMS model does not estimate flows for corresponding gauged sub-basins, which would allow direct calibration of the hydrologic parameters for that sub-basin and could be used to inform parameter selection for the nearby ungauged sub-basin.

HEC-RAS model

1. There are very few locations on the Ohio River where flow is measured in real-time: Sardis, WV; Ironton, OH; Greenup, KY; Markland, KY; Louisville, KY; Cannelton, IN, Shawneetown, IL, and Smithland, KY. Even at these locations, flow stage relationships are based off a rating (function of head differential at the dam, river slope, gate opening, etc. developed from multiple measurements) which do not necessarily produce accurate values for all ranges of flow.
2. Outflows at each lock and dam are available but most are computed based on hydropower releases and gate rating tables of varying age and level of detail. It is expected that the hydropower releases are relatively accurate, but the gate ratings do not necessarily produce accurate values for all ranges of flow.
3. The inputs into the model generally do not reflect the relative local flows at each L/D which, in addition to optimum operation of the structure, result in computed flows, water surface elevations, and trends diverging from actual observed values rather quickly after the start of simulation.
4. Optimum operations of the L/D predicted by the model based upon rule sets do not reflect the local operational parameters or local restrictions for each L/D. Gates used to control flow are controlled discretely with respect to actual opening (i.e., established protocols for incremental gate opening) and time due to electrical, mechanical or workload limitations.
5. As mentioned above, cross sections in the forecast model do not accurately reflect reaches of the river where the river bottom is regularly changing due to high sediment movement, bank erosion and/or lateral migration. Impacts of commercial dredging and navigation maintenance dredging are assumed to be minimal but have not been measured. The significance of this overall limitation has not been investigated and may vary throughout the length of the river, as significant portions of the Ohio River Channel are very stable.

Conclusions:

This preliminary steady-state analysis of select pools has shown that lowering the pool by small increments is potentially feasible while still supporting adequate navigable depths but flows greater than the 7Q10 to sustain river slopes are necessary in certain cases in order to achieve these depths, depending upon the level that the pool is lowered. Implementation of such a measure will require substantial improvements in data and understanding of low flow performance of the navigation dams on the Ohio River and other parameters like groundwater interchange which have a greater influence on the low flow regime, in order to improve forecasting capabilities. This analysis does not consider operational constraints or the impacts that lowering the pools for periods of time might have on sediment patterns or other geomorphology mechanisms that could impact the navigable depth, particularly in the shallowest areas. Further, detailed analysis will be required as part of any further feasibility analysis to implement this measure.

Literature Cited:

Adams, T., S. Chen, R. Davis, T. Schade, and D. Lee. 2010. The Ohio River Community HEC-RAS model. *World Environmental and Water Resources Congress 2010: Challenges of Change***.** American Society of Civil Engineers.

U.S. Army Corps of Engineers, Great Lakes and Ohio River Division (USACE LRD). Unpublished. CWMS Manual For The Ohio River: Daily Forecasting Model. USACE LRD, Cincinnati, Ohio.

Plate 1:
Ohio River Division Memorandum on 7Q10 Discharges

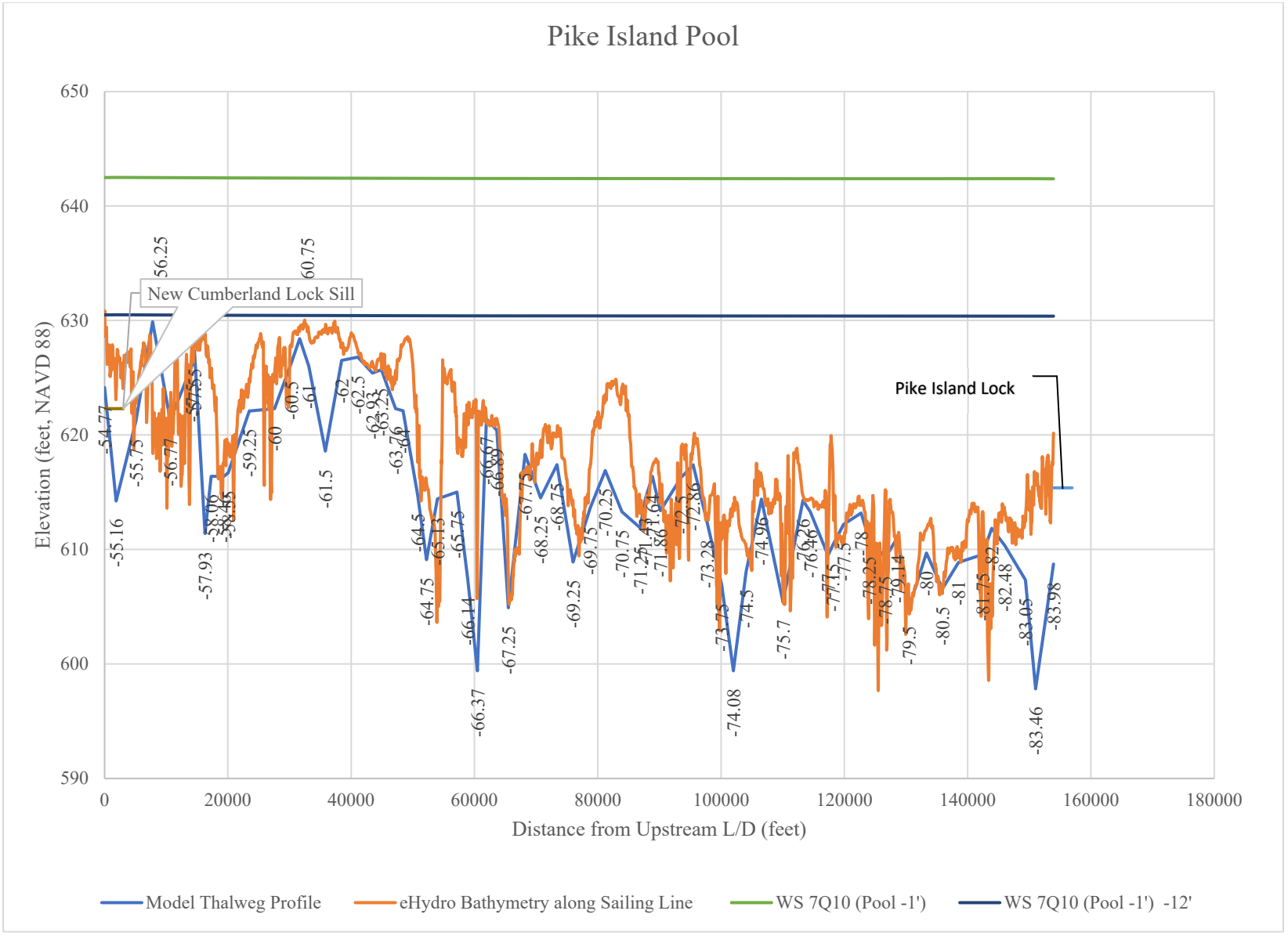

Plate 2: Profile data, Pike Island L/D Pool (Pool -1 foot)

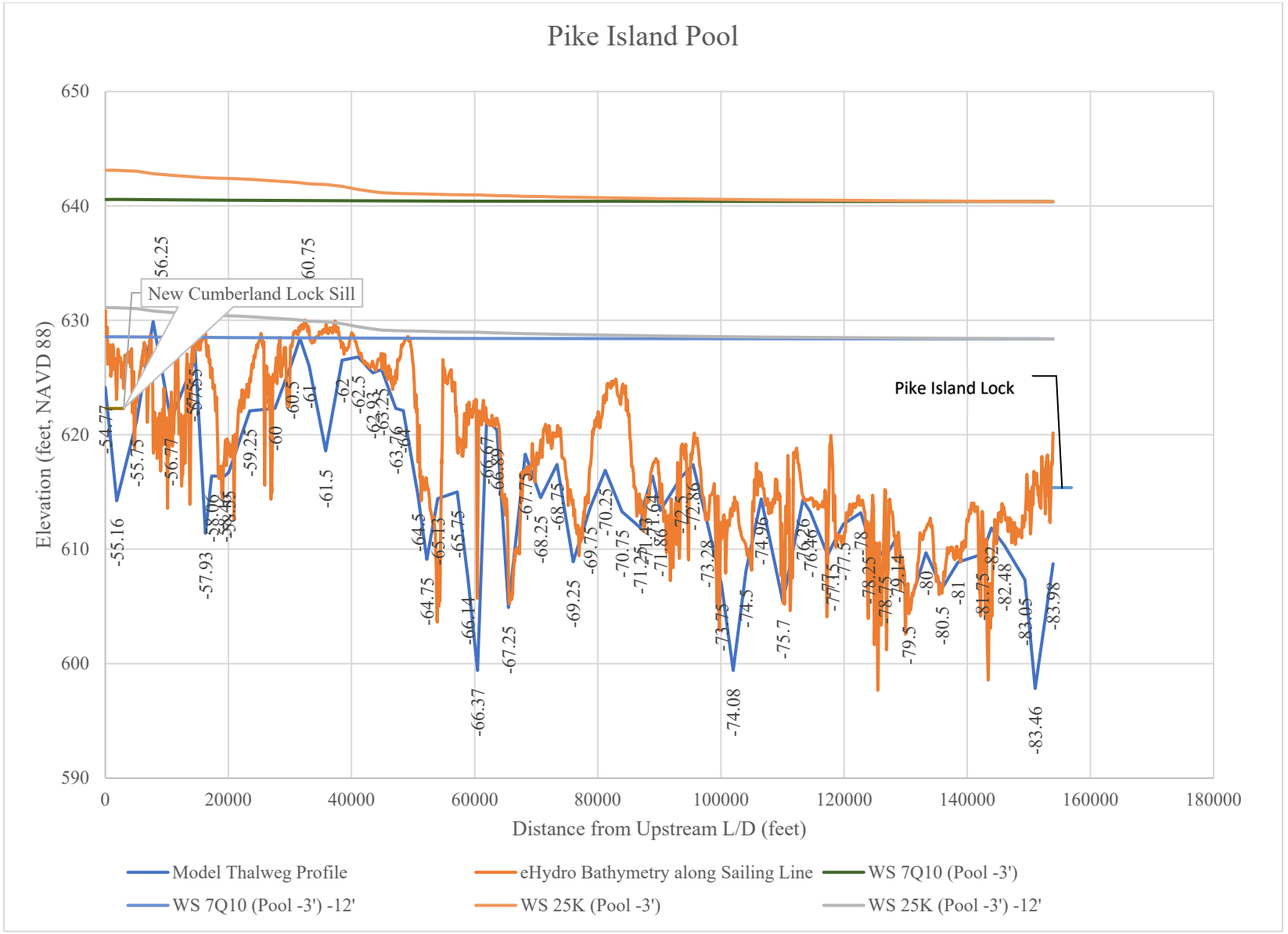

Plate 3: Profile data, Pike Island L/D Pool (Pool -3 feet)

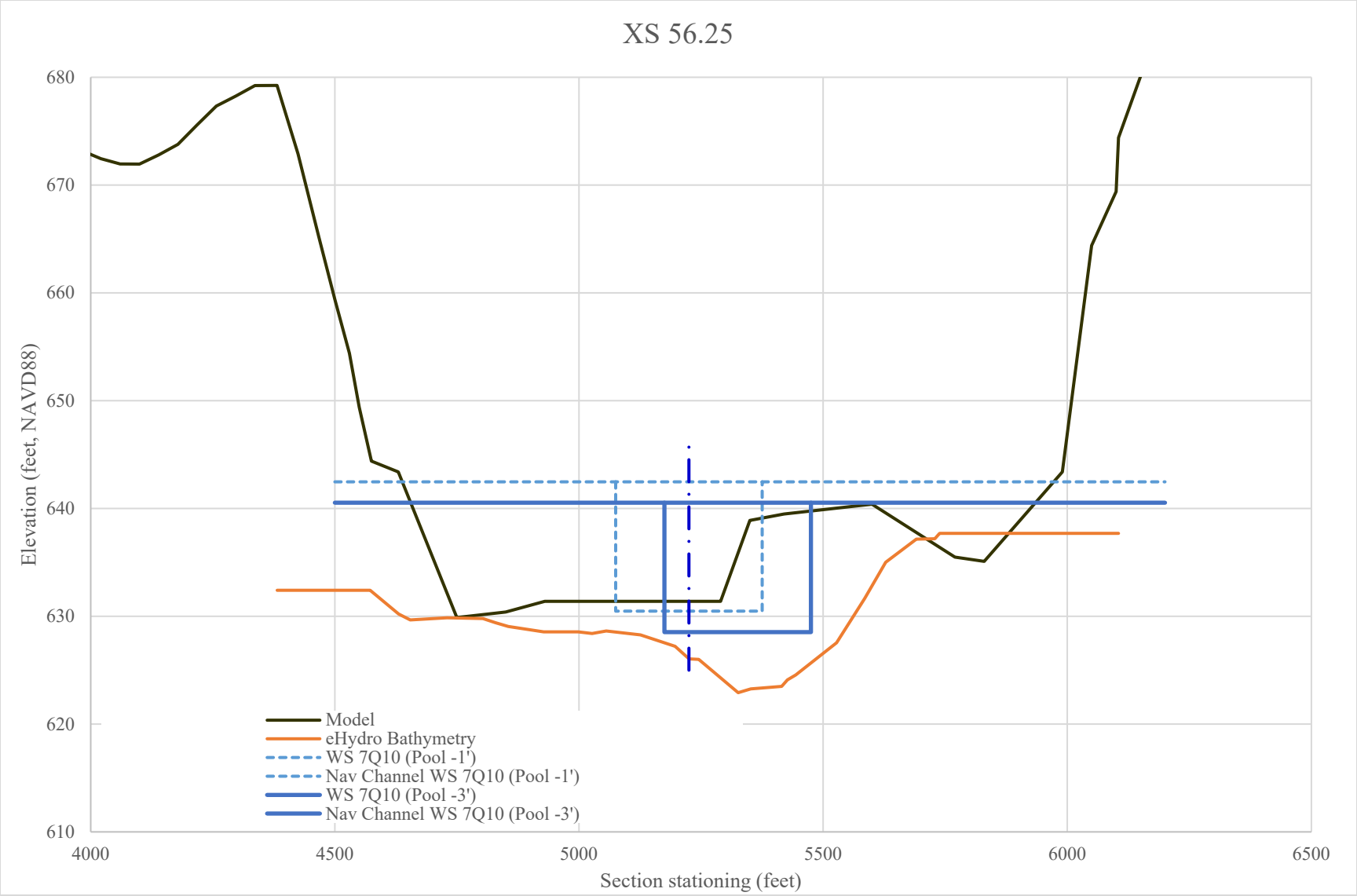

Plate 4: River Section at River Mile 56.25 (Pike Island L/D Pool)

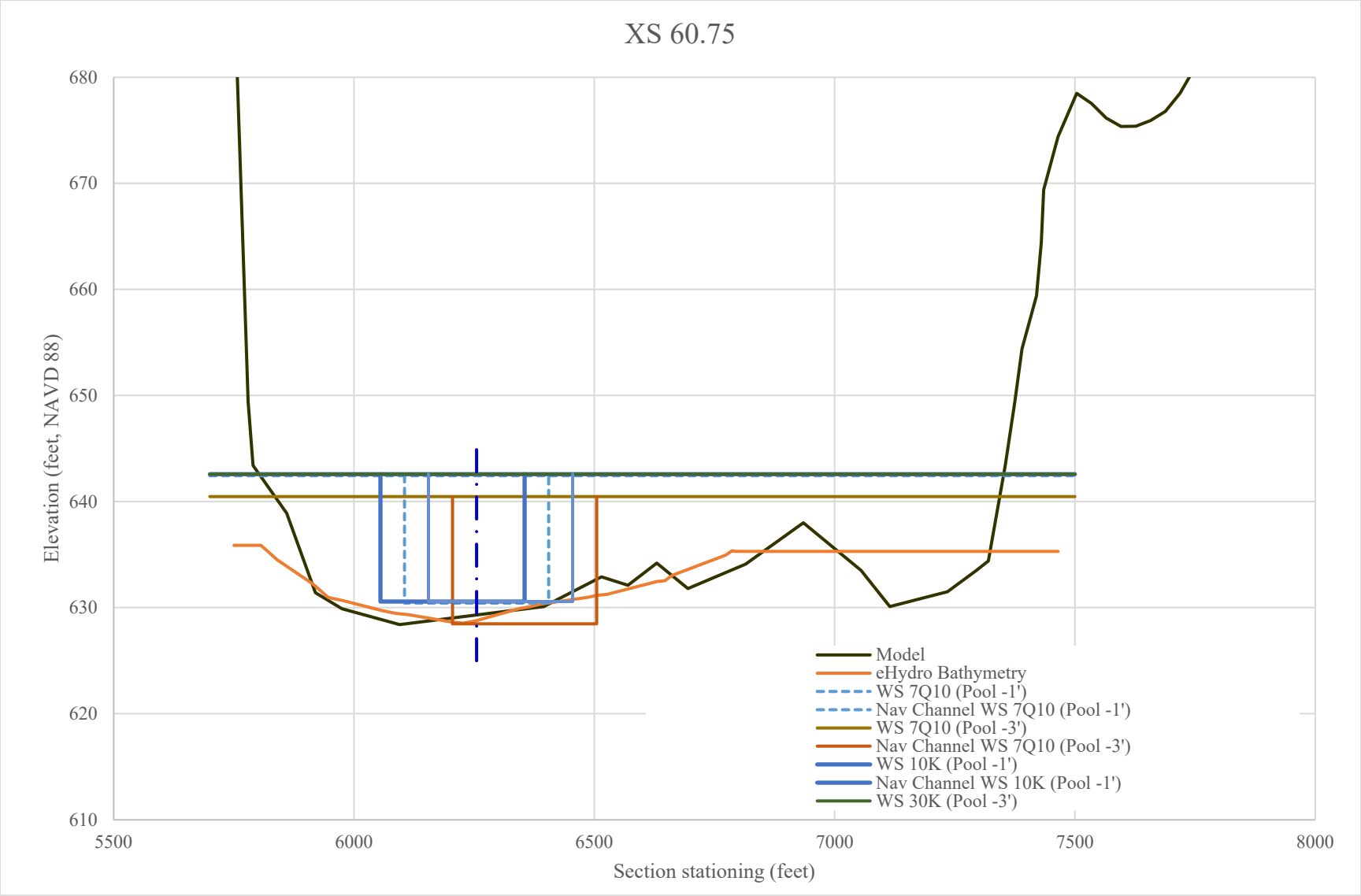

Plate 5: River Section at River Mile 60.75 (Pike Island L/D Pool)

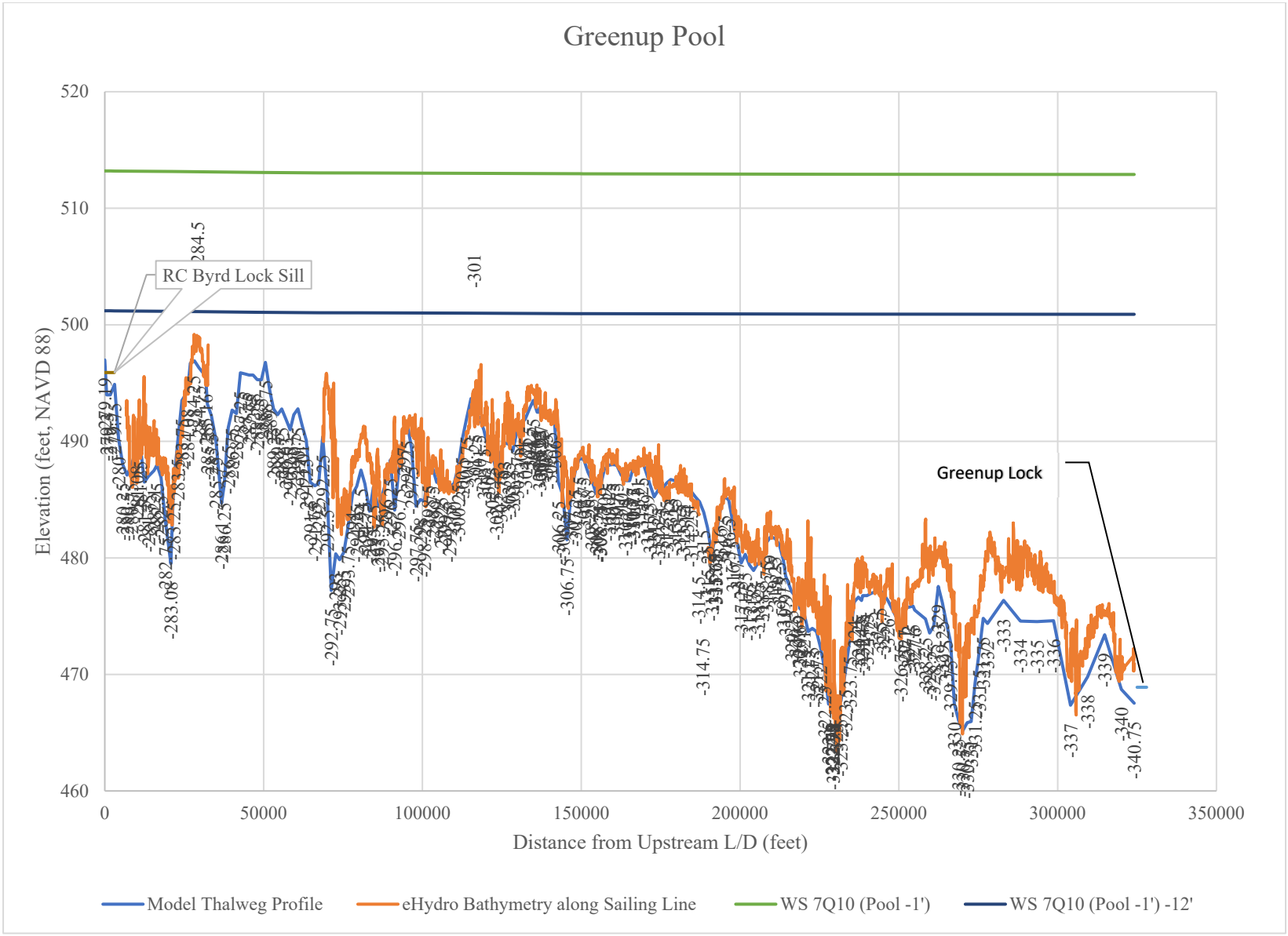

Plate 6: Profile Data, Greenup L/D Pool (Pool -1 foot)

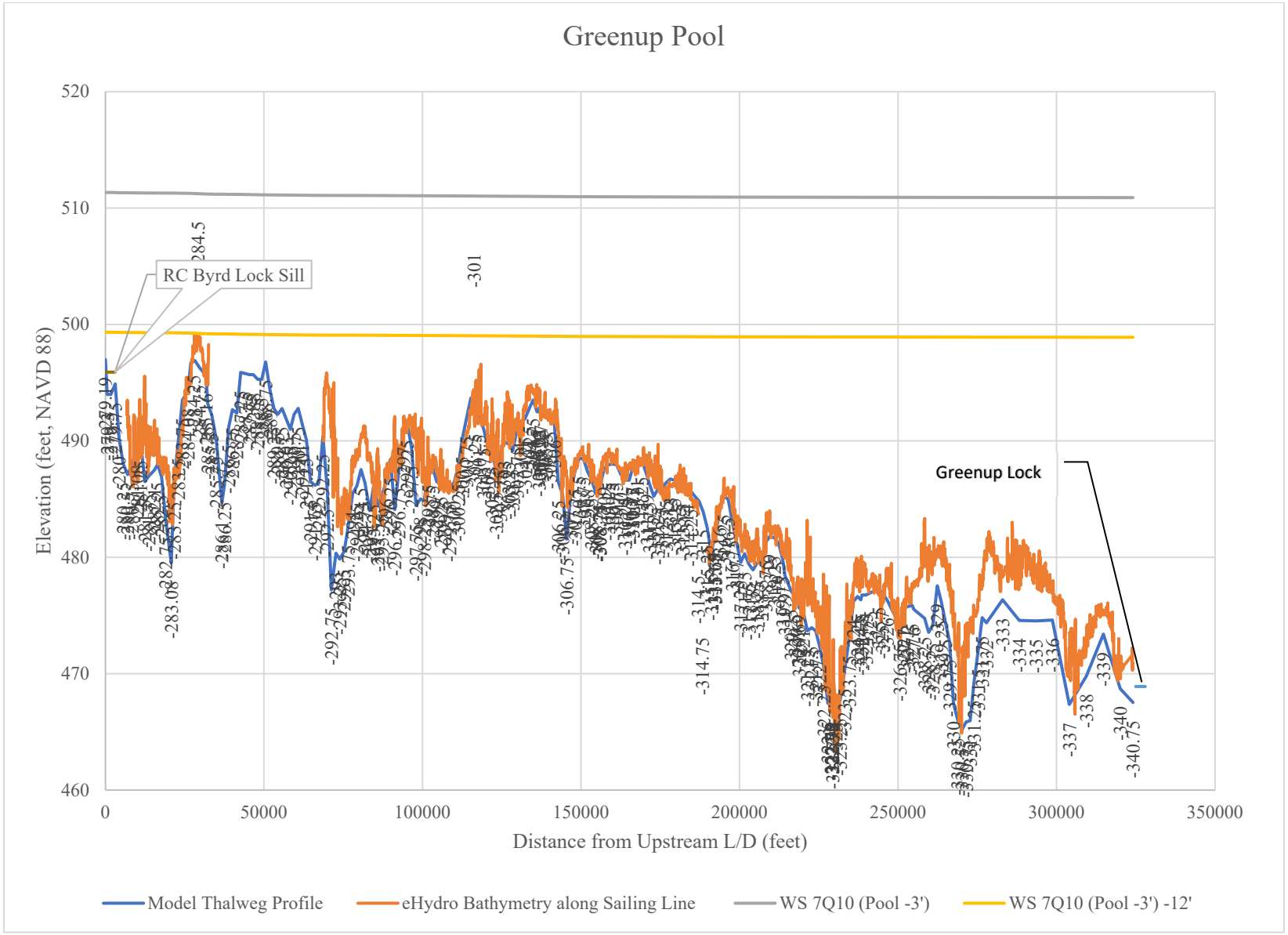

Plate 7: Profile Data, Greenup L/D Pool (Pool -3 feet)

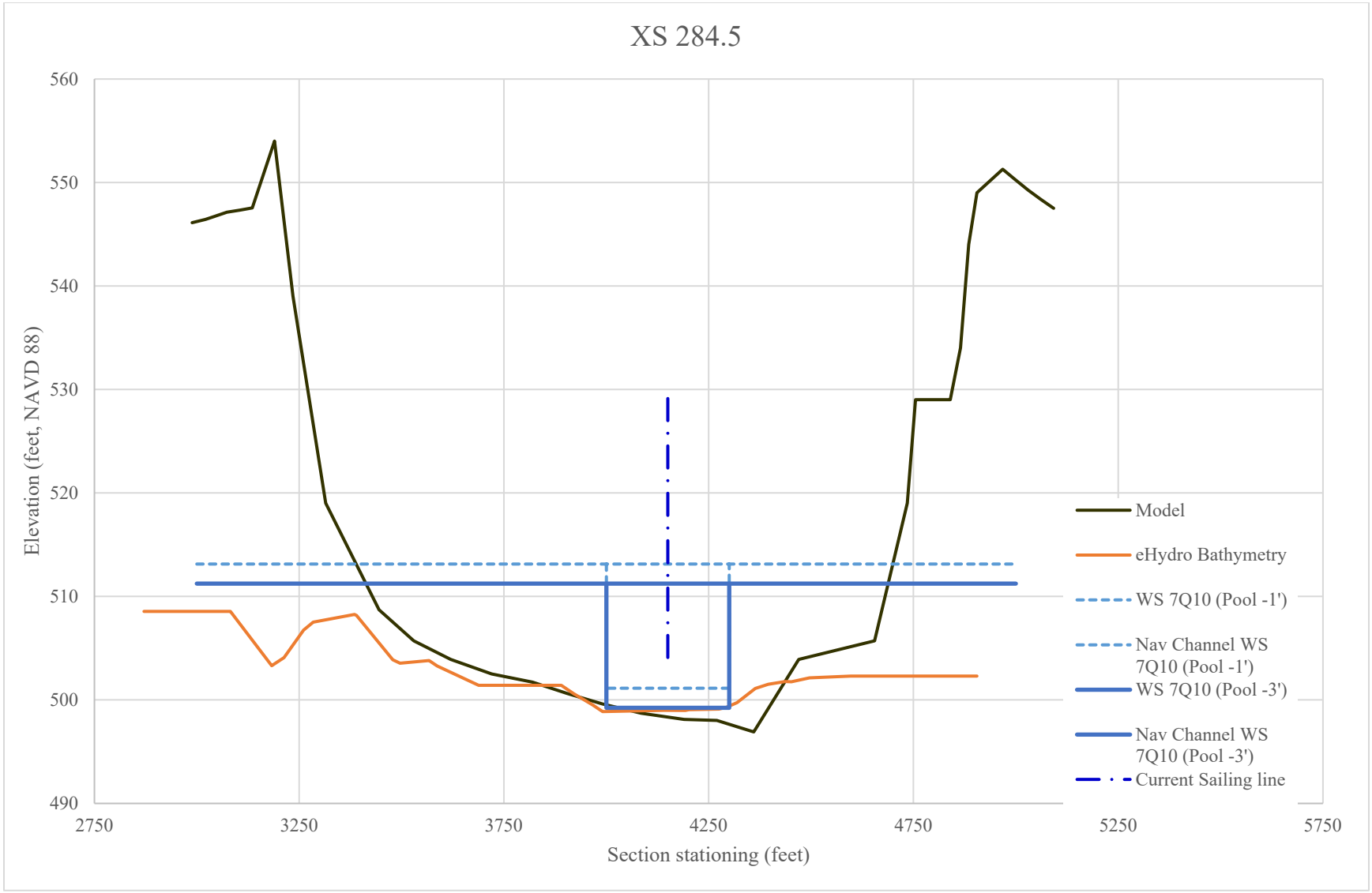

Plate 8: River Section at River Mile 284.5 (Greenup L/D Pool)

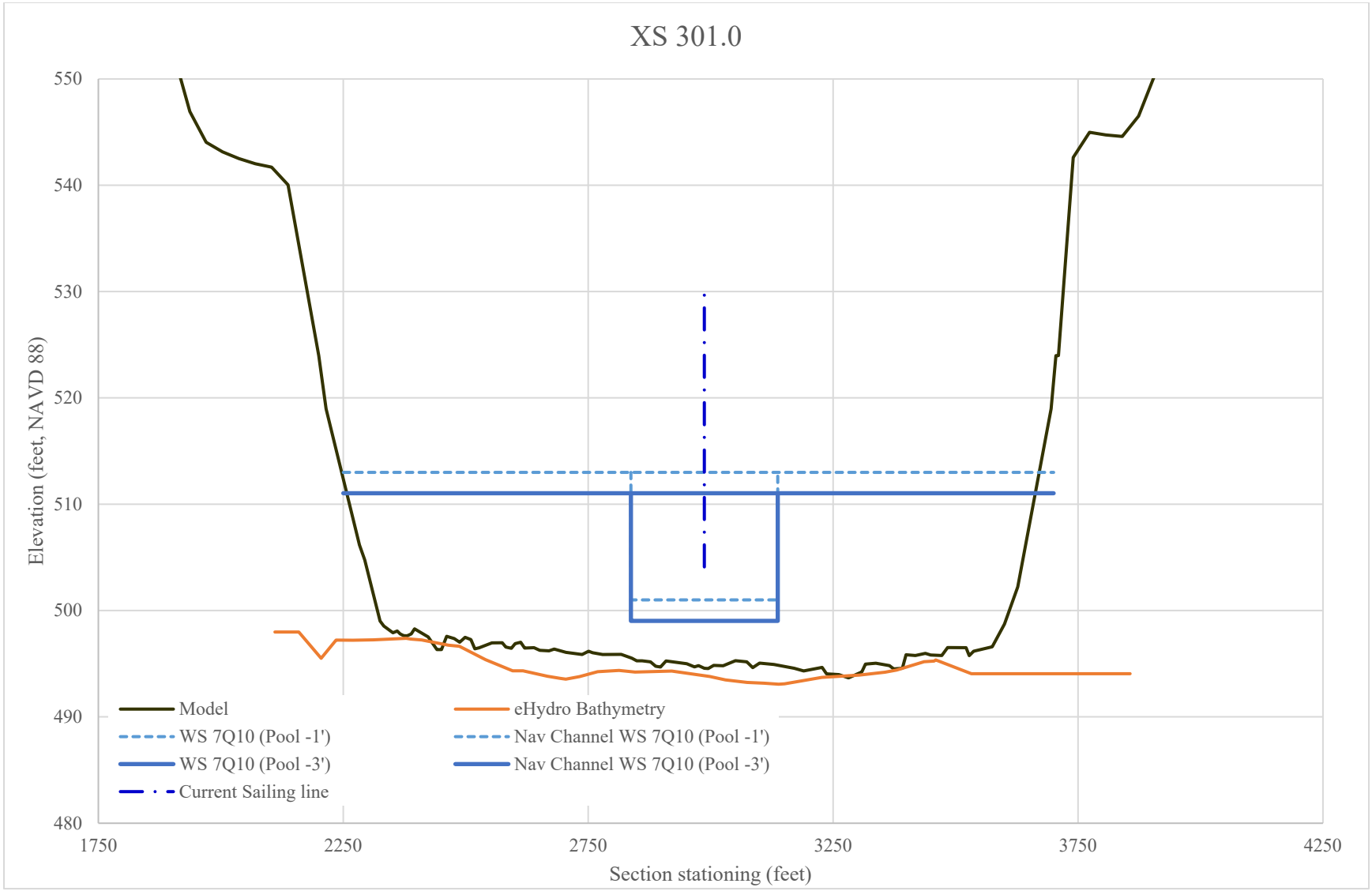

Plate 9: River Section at River Mile 301.0 (Greenup L/D Pool)

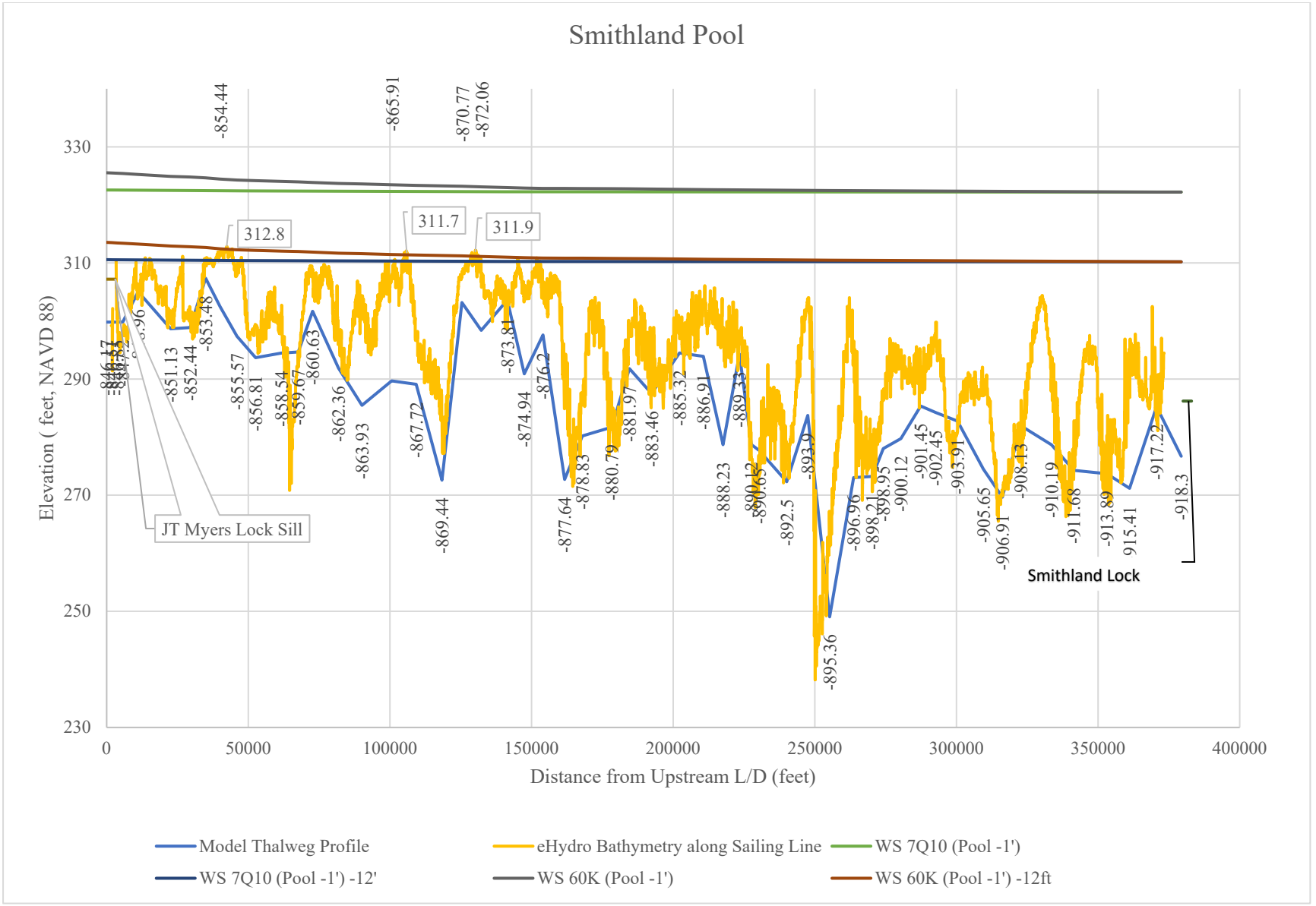

Plate 10: Profile Data, Smithland L/D Pool (Pool -1 foot)

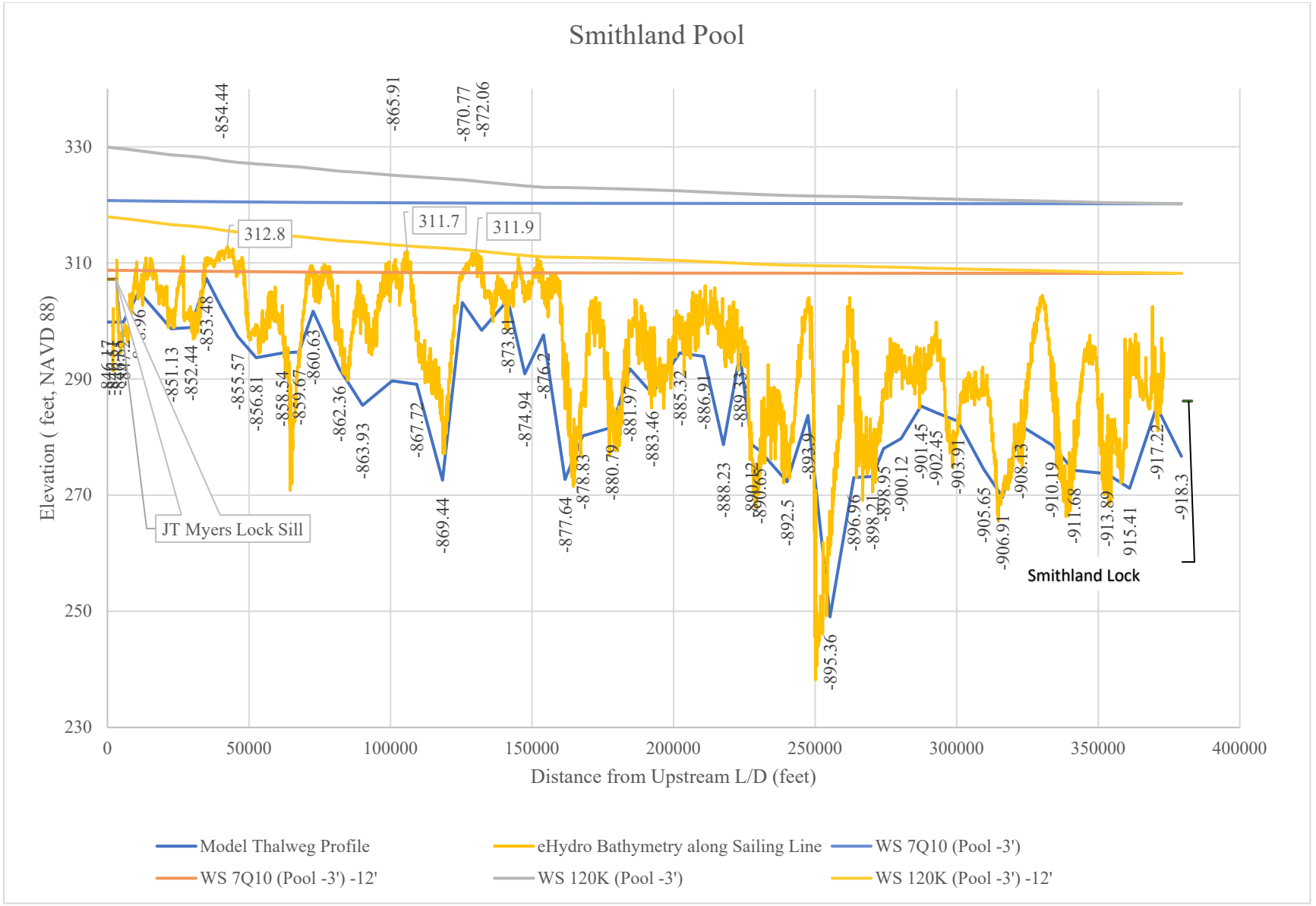

Plate 11: Profile Data, Smithland L/D Pool (Pool -3 feet)

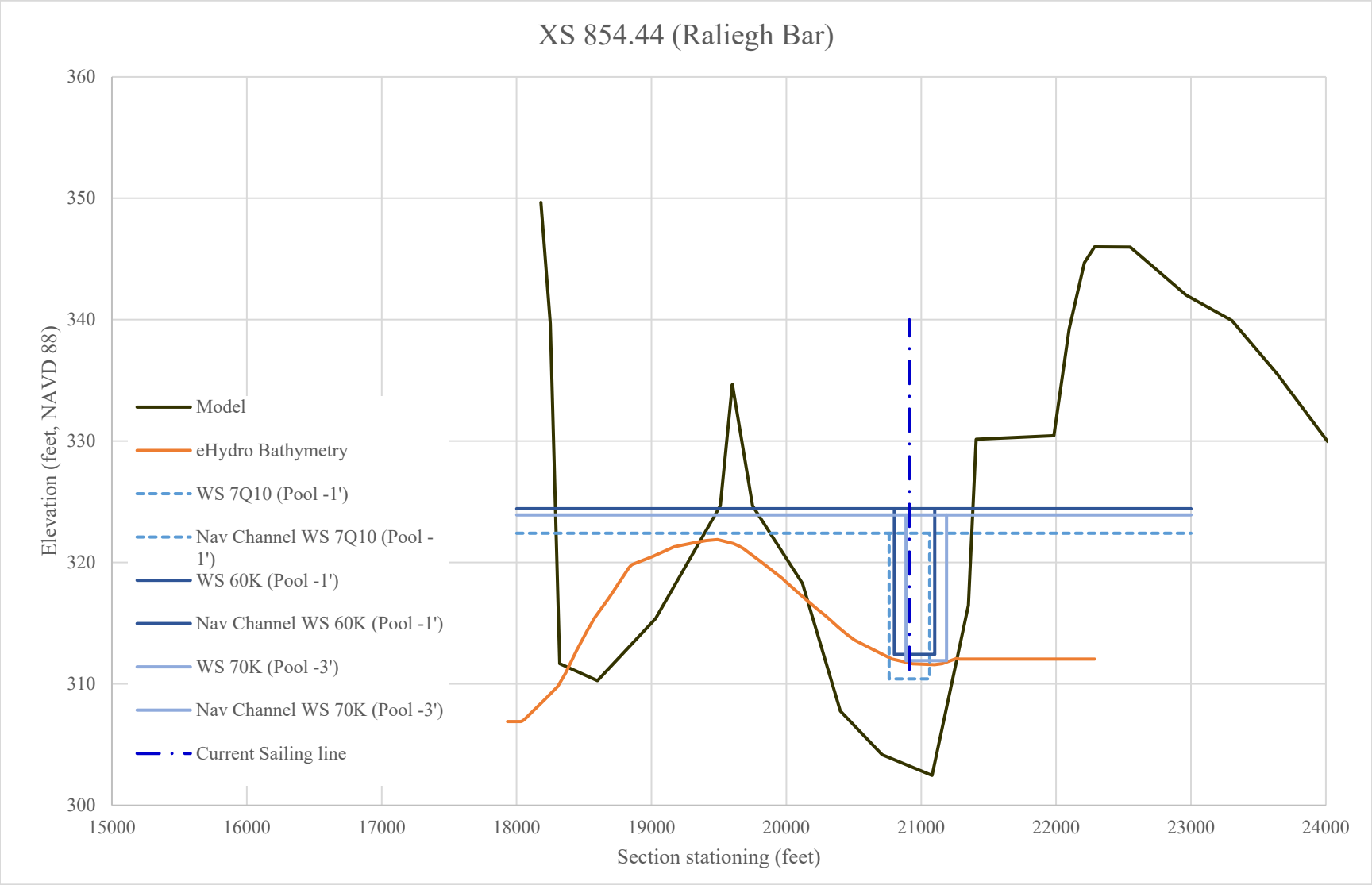

Plate 12: River Section at River Mile 854.4 (Smithland L/D Pool)

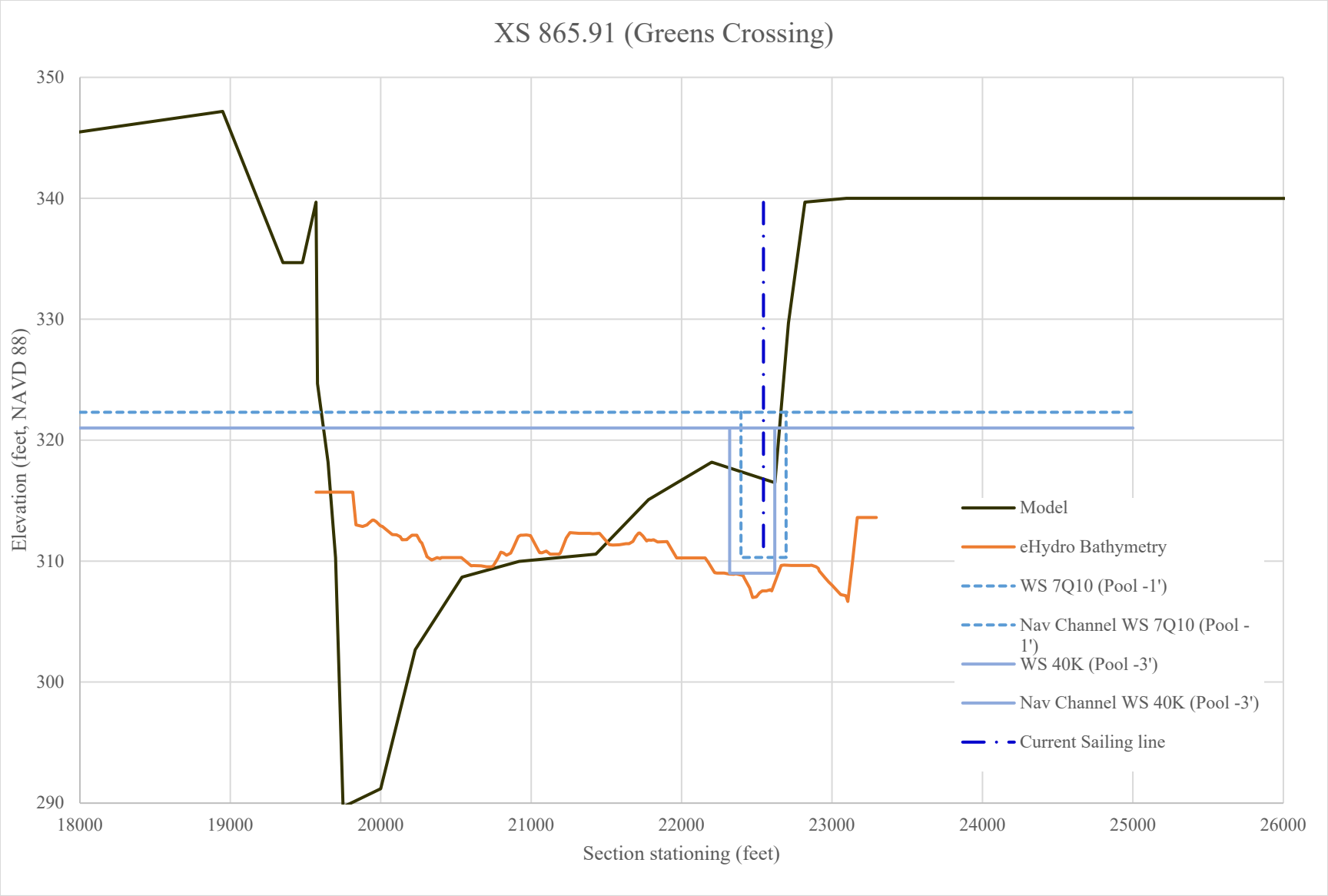

Plate 13: River Section at River Mile 865.91 (Smithland L/D Pool)

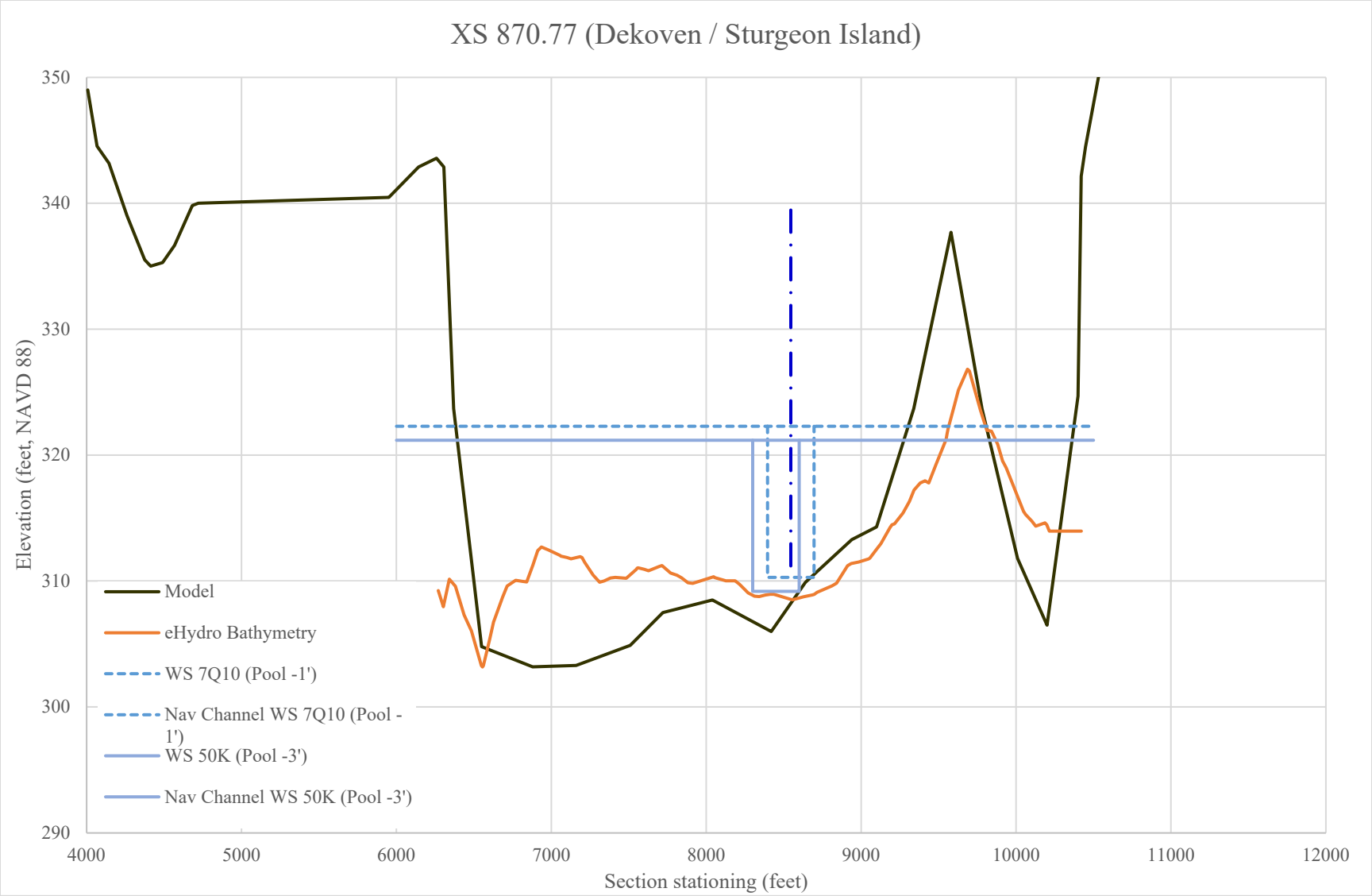

Plate 14: River Mile at River Mile 870.77 (Smithland L/D Pool)

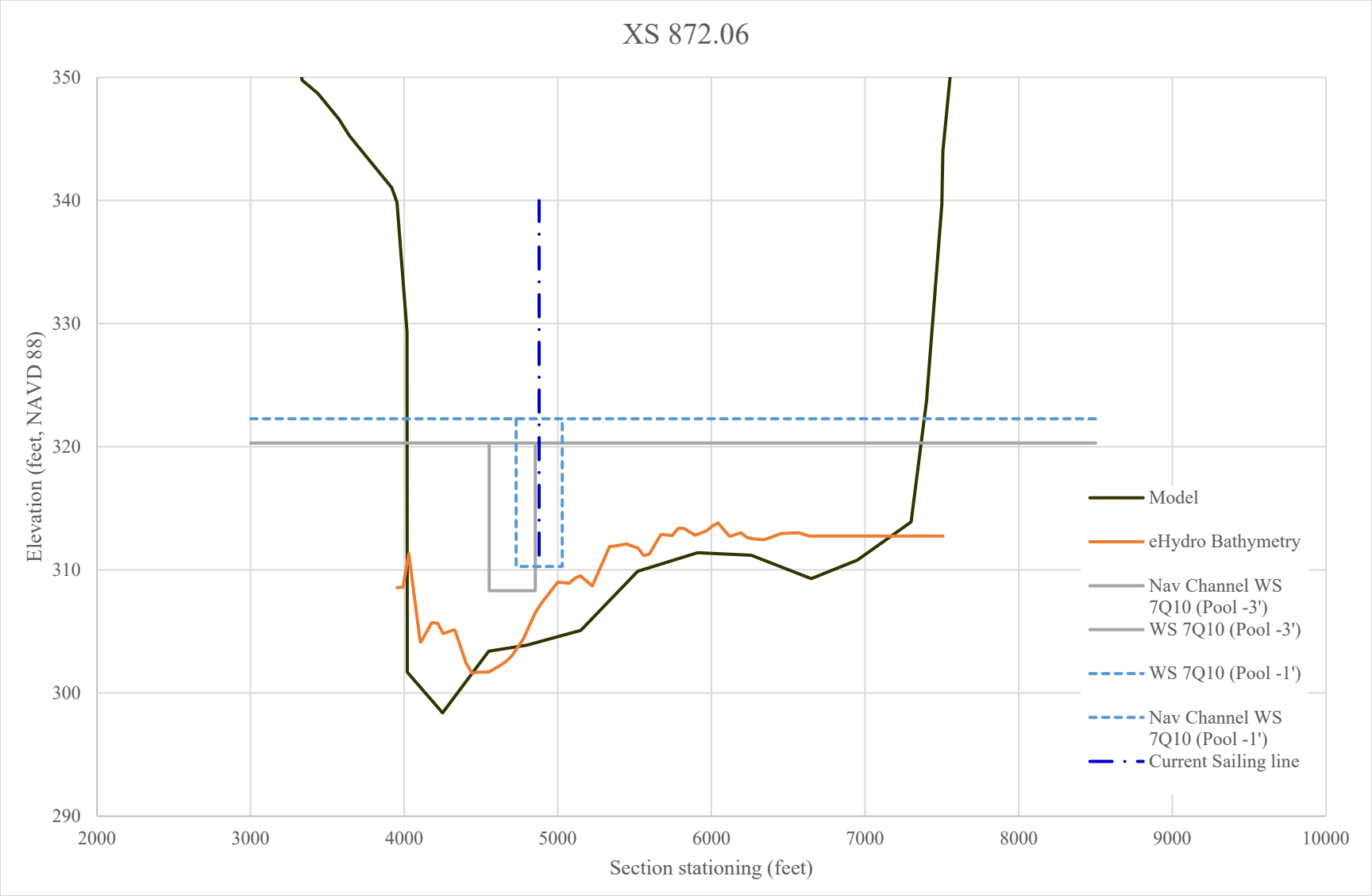

Plate 15: River Section at River Mile 872.06 (Smithland L/D Pool)