

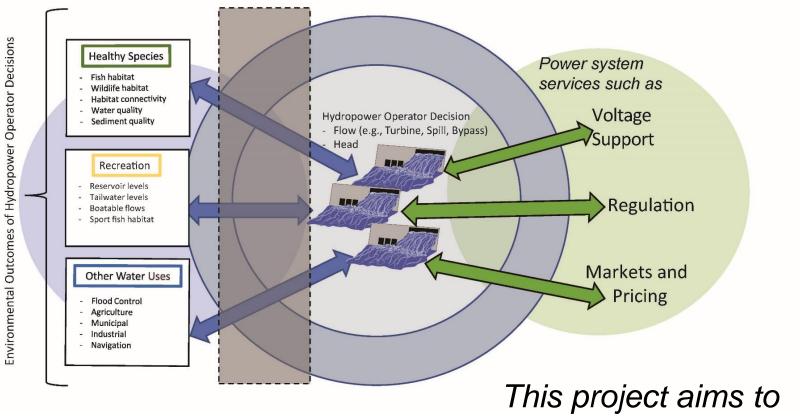
Improving Hydropower Benefits by Linking Environmental and Power System Tradeoffs Through Flow Release Decisions

Brenda Pracheil 10 February 2020

ORNL is managed by UT-Battelle, LLC for the US Department of Energy



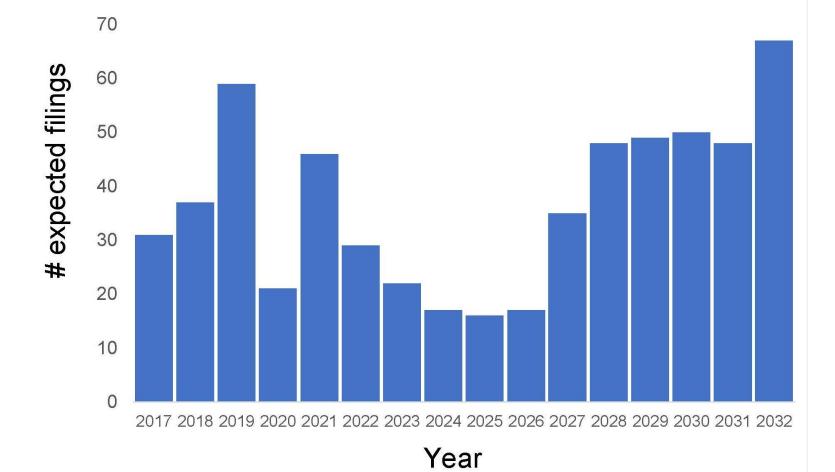




This project aims to quantify hydropower operational flexibility given non- flow requirements



# Large numbers of hydropower projects are expected to be relicensed in the coming years





3

Open slide master to edit

## U.S. Hydropower Regulatory Process

- Regulatory process stakeholder-driven
  - Environmental
  - Recreational
  - Developers
  - Investors
  - Tribal
  - State
  - Federal
- Stakeholders help determine Protection, Mitigation, and Enhancement measures like environmental flow

requirements

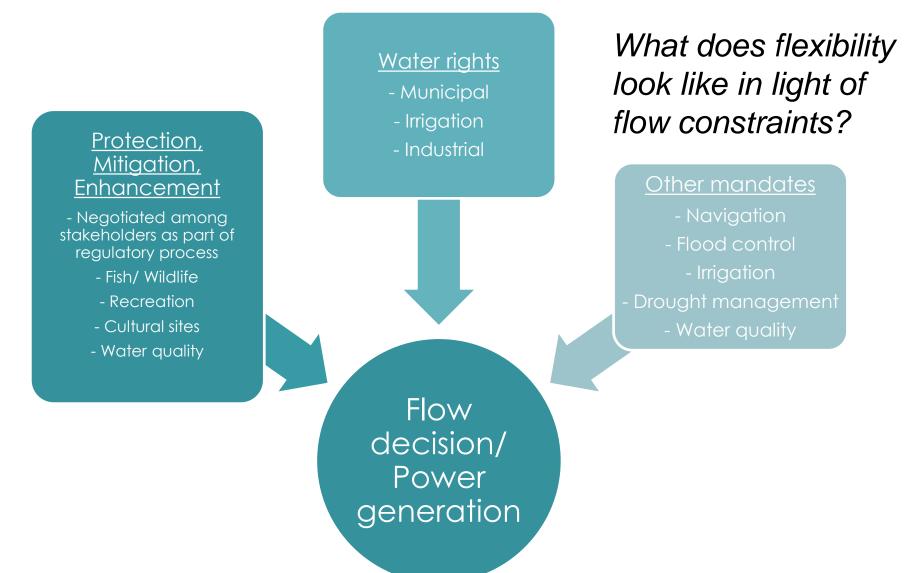






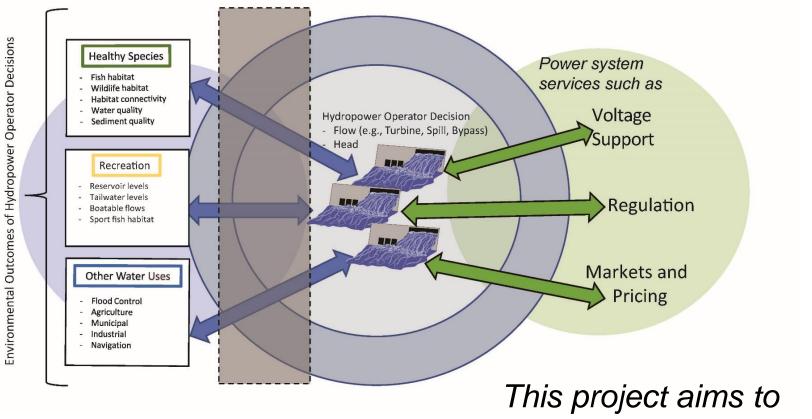


## Non-power constraints on flexibility





5

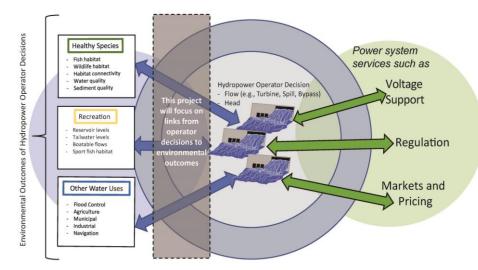


This project aims to quantify hydropower operational flexibility given non- flow requirements



## Project approach

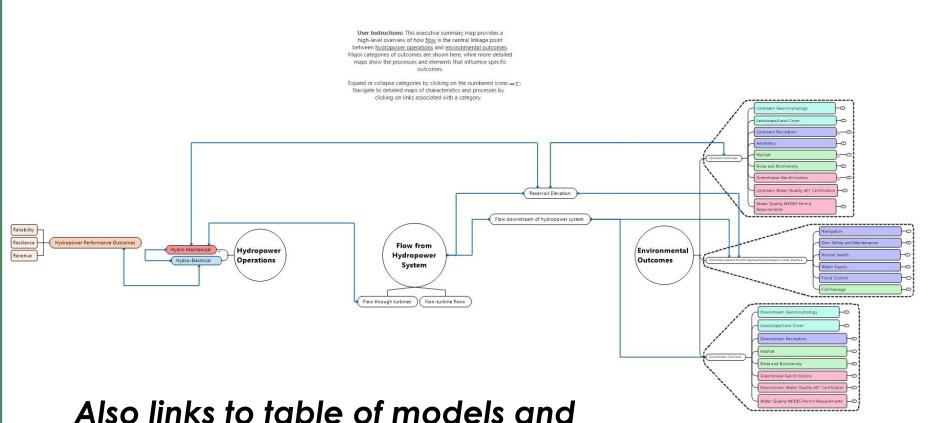
- Quantify hydropower operational flexibility given nonpower flow requirements by linking power system and environmental outcomes through the common hub of flow decisions
  - Task 1: Linking flow decisions to environmental outcomes
  - Task 2: Linking power system needs to flow decisions
  - Task 3: Case studies demonstrating co-optimization of power system and environmental outcomes





## Power system to environment linkage map

#### file://ornIdata.ornI.gov/Home/HydroWIRES/Case%20studies/ExecutiveSummaryMap%20(2).html



tools needed to create linkages



## Dataset of environmental flow requirements

File     Home     Inset     Draw     Page Layout     Formulas     Data     Review     View     Help     Acrobit     C Seach     Image: Constraints     I	-	C - E	ß -	Ŧ						FY20 Q1	Deliverab	le Flow I	Env Miti	igations.xls	x - Excel			Prach	eil, Brenda M.	Ō				×	
Image: From Web       Existing Connections       Image: From Table/Range       Image: From Table/Range <t< td=""><td>w</td><td>Draw</td><td>Pa</td><td>ige Lay</td><td>yout</td><td>Fo</td><td>ormulas</td><td>Dat</td><td>а</td><td>Review</td><td>View</td><td>Hel</td><td>lp 4</td><td>Acrobat</td><td>,</td><td>:h</td><td></td><td></td><td></td><td></td><td>🖻 Share</td><td>PC</td><td>omme</td><td>ents</td></t<>	w	Draw	Pa	ige Lay	yout	Fo	ormulas	Dat	а	Review	View	Hel	lp 4	Acrobat	,	:h					🖻 Share	PC	omme	ents	
1911       1 <th1< th=""> <th1< th=""></th1<></th1<>	ent ting	Recent So Existing (	ource Conne	ections	s F	Refresh	h E Pro	perties	onnect				1.		$\bigcirc \Box$		What-I	f Forecast	<b>⊉</b> ∃Ungrou	р – -:					
A         B         C         D         E         F         G         H         J         K         L           1         roject_number         Datetorught         State2_Fer_folly_name         Aug_time_pd_and         Add1 sug_time_pd         Aug_att         Aug_att         Flow_preg         Aug_att         Aug_at		ata					Queries &	& Connect	ions			Sort &	Filter		Data	Tools	Fo	recast	Outline	2	Fa				
IP reject, number         Date, issued         State         State         State         Flow, reg         Provided           3         Borel         Dypess reach         1-feb         24-feb         instream flow requirement         Minimum flow         200           3         State         2006537 CA         Borel         Borel         Dypess reach         1-feb         24-feb         instream flow requirement         Minimum flow         200           3         State         2006537 CA         Borel         Borel         Dypess reach         1-Mar         31-Mar         instream flow requirement         Minimum flow         20           3         State         2006537 CA         Borel         Borel         Dypess reach         1-Mar         31-Mar         instream flow requirement         Minimum flow         20           3         32005537 CA         Borel         Borel         Dypess reach         1-Mar         31-Mar         instream flow requirement         Minimum flow         30           0         382         2005537 CA         Borel         Borel         Dypess reach         1-Mar         31-Mar         instream flow requirement         Minimum flow         20         20         20         20         20         20         20	f	f <sub>x</sub>	F	Fishing	g/Hal	bitat																			
IProject.under Basel         Statel         Statel         Statel         Statel         Statel         Statel         Plow_req         Plow_req           Image: Statel         Borel         bypass rech         1-feb         2.8         2.0005517 CA         Borel         bypass rech         1-feb         3.8         2.000				F				F			G			н			1		1		к			м	
S82         20060517 CA         Borel bypass reach         1-dam         31-dam         31-dam         Instram flow requirement         Minimum flow         20           S82         20060517 CA         Borel bypass reach         1-Mar         31-Mar         Instram flow requirement         Minimum flow         20           S82         20060517 CA         Borel bypass reach         1-Mar         31-Mar         Instram flow requirement         Minimum flow         20           S82         20060517 CA         Borel bypass reach         1-Mar         31-Mar         Instram flow requirement         Minimum flow         25           S82         20060517 CA         Borel bypass reach         1-Mar         31-Mar         Instram flow requirement         Minimum flow         25           S82         20060517 CA         Borel bypass reach         1-Mar         31-Mar         Instram flow requirement         Minimum flow         35           S82         20060517 CA         Borel bypass reach         1-Mar         30-Mar         Instram flow requirement         Minimum flow         36           S82         20060517 CA         Borel bypass reach         1-Mar         30-Mar         Instram flow requirement         Minimum flow         36           S82         20060517 CA         <	litv	Facility nar	ame	-			Aug time r	nd start	Δ			Addtl au	g time nd			Aug cat		- Διισ		F					
382         2006517 CA         Borel byses reach         1-bei         28-res         Instem flow requirement         Minimum flow         20           382         2006517 CA         Borel byses reach         1-bar         30-bar         Instem flow requirement         Minimum flow         20           382         2005517 CA         Borel byses reach         1-bar         30-bar         Instem flow requirement         Minimum flow         25           382         2005517 CA         Borel byses reach         1-bun         30-bar         Instem flow requirement         Minimum flow         50           382         2005517 CA         Borel byses reach         1-bun         30-bar         Instem flow requirement         Minimum flow         50           382         2005517 CA         Borel byses reach         1-bar         30-bar         Instem flow requirement         Minimum flow         50           382         2005517 CA         Borel byses reach         1-bar         30-bar         Instem flow requirement         Minimum flow         20           382         2005517 CA         Borel byses reach         1-bar         30-bar         Instem flow requirement         Minimum flow         20           382         2005517 CA         Borel byses reach         1-bar				-h			Aug_child_j	Ju_start		ag_unic_pa_			g_cninc_pu								low_req	20			
382       2005372 CA       Borel bysas resch.       1.Mar       31.Mar       Instram flow requirement       Minimum flow       20         382       2005372 CA       Borel bysas resch.       1.May       31.Mar       Instram flow requirement       Minimum flow       20         382       2005372 CA       Borel bysas resch.       1.May       31.Mar       Instram flow requirement       Minimum flow       25         382       2005372 CA       Borel bysas resch.       1.May       31.Mar       Instram flow requirement       Minimum flow       50         382       2005372 CA       Borel bysas resch.       1.4.Mar       31.Mar       Instram flow requirement       Minimum flow       50         382       2005517 CA       Borel bysas resch.       1.5.ep       30.6ct       Instram flow requirement       Minimum flow       50         382       2005517 CA       Borel bysas resch.       1.4.ev       30.4dt       Instram flow requirement       Minimum flow       20         382       2005517 CA       Borel bysas resch.       1.4.ev       30.4dt       Instram flow requirement       Minimum flow       20         382       2005517 CA       Borel bysas resch.       1.4.ev       Borel bysas resch.       1.0.ev       20 <td< td=""><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></td<>																									
382         2000517 (A         Borel bysas reach         1-Apr         SD-p         Instream flow requirement         Minimum flow         20           382         2000517 (A         Borel bysas reach         1-Jun         30-Jun         Instream flow requirement         Minimum flow         55           382         2000517 (A         Borel bysas reach         1-Jun         30-Jun         Instream flow requirement         Minimum flow         55           382         2000517 (A         Borel bysas reach         1-Aug         31-Jug         Instream flow requirement         Minimum flow         50           382         2000517 (A         Borel bysas reach         1-Aug         31-Jug         Instream flow requirement         Minimum flow         50           382         2000517 (A         Borel bysas reach         1-Oct         31-Oct         Instream flow requirement         Minimum flow         20           382         2000517 (A         Borel bysas reach         1-Oct         31-Oct         Instream flow requirement         Minimum flow         20           382         2000517 (A         Borel bysas reach         1-Oct         31-Oct         Instream flow requirement         Minimum flow         20           382         20005017 (A         Borel bysas reach																									
382         2000517 (A         Bort bypass reach         1-May         3-May         Instream flow requirement         Minimum flow         25           382         2000517 (A         Bort bypass reach         1-Jul         3-Jul         Instream flow requirement         Minimum flow         50           382         2000517 (A         Bort bypass reach         1-Jul         31-Jul         Instream flow requirement         Minimum flow         50           382         2000517 (A         Bort bypass reach         1-Sep         30-Sep         Instream flow requirement         Minimum flow         50           382         2000517 (A         Bort bypass reach         1-Sep         30-Sep         Instream flow requirement         Minimum flow         25           382         2000517 (A         Bort bypass reach         1-No         30-O         100         30																									
382         2006517 (A         Borl bypass reach         1-Jul         30-Jun         Instream flow requirement         Minimum flow         50           382         2006517 (A         Borl bypass reach         1-Jul         31-Jul         Instream flow requirement         Minimum flow         50           382         2006517 (A         Borl bypass reach         1-Jul         31-Jul         Instream flow requirement         Minimum flow         50           382         2006517 (A         Borl bypass reach         1-Joc         30-Ct         Instream flow requirement         Minimum flow         50           382         2006517 (A         Borl bypass reach         1-Joc         30-Ct         Instream flow requirement         Minimum flow         20           382         2006517 (CA         Borl bypass reach         1-Joc         30-Ct         Instream flow requirement         Minimum flow         20           382         2006517 (CA         Borl bypass reach         1-Joc         30-Ct         Instream flow requirement         Minimum flow         800           382         2006517 (CA         Borl bypass reach         1-Joc         30-Ct         Instream flow requirement         Minimum flow         800           382         2006517 (CA         Borl bypass reach																									
S82         20050517 CA         Borel bypass reach         1-Jul         31-Jul         Instram flow requirement         Minimum flow         50           S82         20050517 CA         Borel bypass reach         13-Sep         30-Sep         Instram flow requirement         Minimum flow         50           S82         20050517 CA         Borel bypass reach         13-Sep         30-Sep         Instram flow requirement         Minimum flow         50           S82         20050517 CA         Borel bypass reach         1-Not         30-Ot         Instram flow requirement         Minimum flow         20           S82         20050517 CA         Borel bypass reach         1-Not         30-Not         Instram flow requirement         Minimum flow         20           S82         20050517 CA         Borel bypass reach         Minimu flow         200         Minimum flow         200           S82         20050517 CA         Borel bypass reach         Minimu flow         200         4000 TO           S82         20050517 CA         Borel bypass reach         Minimu flow         200         400 TO           S82         20050517 CA         Borel bypass reach         Minimu flow         200         Minimu flow         200           S82         2005070 FPA																									
382         200537 CA         Borel bypass reach         1-Aug         3-Aug         Instream flow requirement         Minimum flow         50           382         200557 CA         Borel bypass reach         1-0-ct         3-0-ct         Instream flow requirement         Minimum flow         25           382         200557 CA         Borel bypass reach         1-0-ct         31-0-ct         Instream flow requirement         Minimum flow         25           382         200557 CA         Borel bypass reach         1-0-bc         5-0-bc         Instream flow requirement         Minimum flow         30           382         200557 CA         Borel bypass reach         1-0-bc         5-0-9C         Instream flow requirement         Minimum flow         30           382         200557 CA         Borel bypass reach         1-0-bc         5-0-9C         Instream flow requirement         Minimum flow         30           382         200557 CA         Borel bypass reach         1-0-bc         1-0-bc         Instream flow requirement         Minimum flow         30           467         2050708 PA         Borel bypass reach         1-0-bc         isk consecutive Fridays for a 5 hour period (10-am         Recreation/Boating         Minimum flow         0         3000           467																									
382         20060517 CA         Borel kpass reach         1-9cp         30-5cp         Instram flow requiremedt         Minimum flow         50           382         20060517 CA         Borel kpass reach         1-9cp         30-400         Instram flow requiremedt         Minimum flow         30           382         20060517 CA         Borel kpass reach         1-9cp         30-400         Instram flow requiremedt         Minimum flow         30           382         20060517 CA         Borel kpass reach         Memorial day         Labor day weekends and holidays         Recreation/Boating         Minimum flow         30           382         20060517 CA         Borel kpass reach         Memorial day         Labor day weekends         Recreation/Boating         Minimum flow         300           382         20060517 CA         Borel kpass reach         1-90         1-90         S0         300																									
382         20060317 (A         Borel bypass reach         1-Oct         31-Oct         instream flow requirement         Minimum flow         25           382         20060517 (A         Borel bypass reach         1-bor         30-0         instream flow requirement         Minimum flow         20           382         20060517 (CA         Borel bypass reach         1-bor         31-0ct         instream flow requirement         Minimum flow         20           382         20060517 (CA         Borel bypass reach         1-bor         31-0ct         instream flow requirement         Minimum flow         20           382         20060517 (CA         Borel bypass reach         1-bor         31-0         Minimum flow         400-50           382         20060517 (CA         Borel bypass reach         1-bor dwivelends and holidays         Recreation/Boating         Minimum flow         400-50           485         20141222 (CA         AL         Bartlet's Fry dam         Storoscutive fridays for a Shour period (10m-         Recreation/Boating         Minimum flow         200           487         20050708 PA         powerhouse         first Saturday after Jun 1         first Saturday after Jun 1         trow season, weeknds 6 am- 9 pm         Fishing/Habitat         Minimum flow         600 orinflow																									
382       20060517 CA       Borel bypass reach       1-hov       300/000       Instream flow requirement       Minimum flow       20         382       20060517 CA       Borel bypass reach       1-boz       3109C       Instream flow requirement       Minimum flow       800         382       20060517 CA       Borel bypass reach       1-boz       1-boz       800																									
382       20060517 CA       Borel bypass reach       1.Dac       31-DE       Instream flow requirement       Minimum flow       20         382       20060517 CA       Borel bypass reach       Menorial day       Labor day       weekends       Recreation/Boating       Minimum flow       800         485       20141222       GA       A       Bartlett's Ferry dam       400-500       Maximum discharge capacity       530000         487       20050708       PA       Wilsonville dam       5ix consecutive Fridays for a 5 hour period (10m - for y p																									
382       20060517       CA       Borel bypass reach       Memorial day       Labor day       weekends and holidays       Recreation/Boating       Minimum flow       800         382       20060517       CA       A       Borel bypass reach       1-Jul       Labor day       weekends       Recreation/Boating       Minimum flow       400-500         487       20050708       PA       Wilsonille dam       First Friday on or after Jul 1       Six consecutive Fridays for a 5 hour period (10mr)       Recreation/Boating       Minimum flow       1200         487       20050708       PA       powerhouse       first Friday on or after Jul 1       Six consecutive Fridays for a 5 hour period (10mr)       Recreation/Boating       Minimum flow       1200         487       20050708       PA       powerhouse       first Saturday after Jul 1       first Saturday after Jul 1       trou season, weekends 6 an- 9 pm       Fishig/Habitat       Minimum flow       no generation         486       20050708       PA       Warick dam       15-May       trou season, weekends 6 an- 9 pm       Fishig/Habitat       Minimum flow       no generation         486       20081128       GA       Warick dam       15-May       trou season, weekends 6 an- 9 pm       Fishig/Habitat       Minimum flow       200       600 or inflow																									
382       20060517 CA       Borl bypass reach       1-Jul       Labor day       weekends       Recreation/Boating       Minimum flow       400-500         485       20141222 GA       A       Bartlett's Ferry dam       Maximum discharge capacity       50000         487       20050708 PA       Wilsonville dam       Minimum flow       6 pm       Maximum discharge capacity       50000         487       20050708 PA       powerhouse       first Friday on after Jul       six consecutive Fridays for a 5 hour period (10am of pm)       Recreation/Boating       Minimum flow       1200         487       20050708 PA       powerhouse       first Staurday after Apr 11       first Staurday after Jul 11       trous weekends each year during Sep or Oct       Recreation/Boating       Minimum flow       0000       1200         487       20050708 PA       powerhouse       first Staurday after Jul 1       first S																									
485       2014122 GA       AL       Bartlett's Ferry dam       Second Secon								Memor						lays											
487       20050708       PA       Wilsonville dam       Maximum discharge capacity       56700         487       20050708       PA       powerhouse       first Friday on or after Juli 1       6 pm)       six consecutive Fridays for a 5 hour period (100m)       Recreation/Boating       Minimum flow       1200         487       20050708       PA       powerhouse       first Saturday after Juli 1       for wowekends each year during Sep or Oct       Recreation/Boating       Minimum flow       000         487       20050708       PA       powerhouse       first Saturday after Juli 1       for useanon, weekends each year during Sep or Oct       Recreation/Boating       Minimum flow       000       1200         487       20050708       PA       Warick dam       first Saturday after Juli 1       for useanon, weekends 6 am- 9 pm       Fishing/Habitat       Minimum flow       000									1-Jul		Labor da	ay weekends	5			Recreation/B	oating						_		
487       20050708       PA       powerhouse       first Friday on or after Jul 1       six consecutive Fridays for a 5 hour period (10am 6 pm)       Recreation/Boating       Minimum flow       1200         487       20050708       PA       powerhouse       first Saturday after Apr 11				m																_					
487       20050708       PA       powerhouse       first Friday on or after Jul 1       for pm       Mccreation/Jobiting       Minimum flow       1200         487       20050708       PA       powerhouse       first Studray after Jul 1       two weeknds each year during Sep or OCt       Recreation/Jobiting       Minimum flow       1200         487       20050708       PA       powerhouse       first Studray after Jul 1       frost Studray after Jul 1       trout season; weeknds 6 am 9 pm       Fishing/Hobitat       Minimum flow       600 or inflow         659       20081128       GA       Warick dam       GT       Studray after Jul 1       frost Studray after Jul 1<	onv	Wilsonville	.e dam															Maximum dis	charge capacity			56700			
487     20050708 PA     powerhouse     first friday on or after Jul 1     6 pm     A minimum flow     1200       487     20050708 PA     powerhouse     first Staturday after Apr 11     first Staturday after Jul 1     two weekends each year during Sep or Oct     Recreation/Boating     Minimum flow     000       487     20050708 PA     powerhouse     first Staturday after Apr 11     first Staturday after Jul 11     trout season; weekends 6 am-9 pm     Fishing/Habitat     Minimum flow     0600 or inflow       659     20081128 GA     Warick dam     15-Mar     15-Mar     Fishing/Habitat     Minimum flow     000       719     20040527 WA     dam     11-Aug     15-Oct     Instream flow requirement     Minimum flow, rate_cfs     1.8       719     20040527 WA     dam     13-Aug     15-Oct     Instream flow requirement     Minimum flow, rate_cfs     3.5       719     20040527 WA     dam     13-Oct     30-Apr     Instream flow requirement     Moring Matrix flow_rate_cfs     3.5       719     20040527 WA     dam     15-Oct     30-Apr     Instream flow requirement     Moring Matrix flow_rate_cfs     3.5       719     20040527 WA     dam     11-Aug     31-Jul     Instream flow requirement     Moring Matrix flow_rate_cfs     3.5       719 <t< td=""><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td>cutive Frida</td><td>lays for a 5 hou</td><td>ır period (10am -</td><td>Recreation/R</td><td>oating</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></t<>													cutive Frida	lays for a 5 hou	ır period (10am -	Recreation/R	oating								
487       20050708 PA       powerhouse       first Saturday after Apr 11       first Saturday after Apr 11       first Saturday after Jun 11       trout season; weekends 6 am 9 pm       Fishing/Habitat       Minimum flow       no generation         659       20081128 GA       Warick dam       Maximum flow       600 or inflow							first Frid	day on or afte	er Jul 1								-		•						
659       20081128 GA       Warkk dam       610       Instream flow requirement       Minimum flow       6600 or inflow         659       20081128 GA       Warkk dam       15-May       Fishing/Habitat       Minimum flow       run of river         659       20081128 GA       Warkk dam       15-May       Fishing/Habitat       Minimum flow       000         659       20081128 GA       Warkk dam       0       Maximum discharge capacity       8000         719       20040527 WA       dam       1-Aug       15-Oct       Instream flow requirement       Minimum flow       0.25         719       20040527 WA       dam       1-Aug       15-Oct       Instream flow requirement       Maximum flow_rate_rfs       1.8         719       20040527 WA       dam       15-Oct       S0-Apr       Instream flow requirement       Mormal_Wate_ryear_min_flow_rate_rfs       3.55         719       20040527 WA       dam       15-Oct       30-Apr       Instream flow requirement       MVert_Year_min_flow_rate_rfs       3.55         719       20040527 WA       dam       15-Oct       30-Apr       Instream flow requirement       MVert_Year_min_flow_rate_rfs       3.55         719       20040527 WA       dam       15-Oct       30-Apr																									
659       20081128 GA       Warkk dam       15-Mar       15-May       Fishing/Habitat       Minimum flow       run of river         659       20081128 GA       Warkk dam         Maximum discharge cape city       8000         659       20081128 GA       Warkk dam         Maximum discharge cape city       8000         719       20040527 WA       dam        15-Oct       ow flow season       Instream flow requirement       Minimum flow       0.25         719       20040527 WA       dam       15-Oct       30-Apr       Instream flow requirement       Minimum flow_rate_cfs       3.8         719       20040527 WA       dam       15-Oct       30-Apr       Instream flow requirement       Normal_Water_Year_min_flow_rate_cfs       3.8         719       20040527 WA       dam       15-Oct       30-Apr       Instream flow requirement       Normal_Water_Year_min_flow_rate_cfs       3.8         719       20040527 WA       dam       15-Oct       30-Apr       Instream flow requirement       Normal_Water_Year_min_flow_rate_cfs       3.8         719       20040527 WA       dam       15-Oct       30-Apr       Instream flow requirement       Normal_Water_Year_min_flow_rate_cfs       3.8         71							first Sa	turday after	Apr 11	first Satu	day after Jun 1	1 trout sea	son; weeker	nds 6 am- 9 pm											
669     20081128 GA     Wark dam     Maximum discharge capacity     8000       719     20040527 WA     dam     Instream flow requirement     Maximum flow     0.25       719     20040527 WA     dam     1-Aug     15-Oct     Instream flow requirement     Maximum flow     0.25       719     20040527 WA     dam     1-Aug     15-Oct     Instream flow requirement     Maximum flow     0.25       719     20040527 WA     dam     15-Oct     30-Apr     Instream flow requirement     Normal Water Year min flow rate, cfs     3.8       719     20040527 WA     dam     15-Oct     30-Apr     Instream flow requirement     Normal Water Year min flow, rate, cfs     3.3       719     20040527 WA     dam     15-Oct     30-Apr     Instream flow requirement     Normal Water Year min flow, rate, cfs     3.3       719     20040527 WA     dam     15-Oct     30-Apr     Instream flow requirement     Normal Water Year min flow, rate, cfs     3.3       712     20040527 WA     dam     1-Aug     31-Jul     Instream flow requirement     Normal Water Year min flow, rate, cfs     3.3       719     20040527 WA     dam     11-Aug     31-Jul     Instream flow requirement     Nininum flow     run of canal       7125     20170522 NF																									
1       20040527       WA       dam       Instream flow       Instream flow requirement       Minimum flow       0.25         719       20040527       WA       dam       1-Aug       15-Oct       Instream flow requirement       Maximum flow       0.25         719       20040527       WA       dam       1-Aug       15-Oct       Instream flow requirement       Mormal_Water_Year_min_flow_rate_fs       1.8         719       20040527       WA       dam       15-Oct       30-Apr       Instream flow requirement       Normal_Water_Year_min_flow_rate_fs       3.55         719       20040527       WA       dam       15-Oct       30-Apr       Instream flow requirement       Normal_Water_Year_min_flow_rate_fs       3.55         719       20040527       WA       dam       15-Oct       30-Apr       Instream flow requirement       Normal_Water_Year_min_flow_rate_fs       3.55         719       20040527       WA       dam       15-Oct       30-Apr       Instream flow requirement       Normal_Water_Year_min_flow_rate_fs       3.55         719       20040527       WA       dam       1-May       31-Jul       Instream flow requirement       Normal_Water_Year_min_flow_rate_fs       3.55         712552       VE       Monore p								1	5-Mar		15-Ma	ay				Fishing/Habi	tat				run o				
Process			m																						
1     20040527     WA     dam     1-Aug     15-Oct     Instream flow requirement     Normal_Water_Year_min_flow_rate_cfs     1.8       719     20040527     WA     dam     15-Oct     30-Apr     Instream flow requirement     DRY_Water_Year_min_flow_rate_cfs     3.55       719     20040527     WA     dam     15-Oct     30-Apr     Instream flow requirement     DRY_Water_Year_min_flow_rate_cfs     3.55       719     20040527     WA     dam     15-Oct     30-Apr     Instream flow requirement     DRY_Water_Year_min_flow_rate_cfs     2.3       719     20040527     WA     dam     1-May     31-Jul     Instream flow requirement     DRY_Water_Year_min_flow_rate_cfs     5       710522     NE     Monroe powerhouse     Monroe powerhouse     run of canal       1256     20170522     NE     Monroe powerhouse     Mainum discharge capacity     3000       1256     20170522     NE     Columbus powerhouse     Instream flow requirement     Minimum flow     1000-4800																									
1     20040527     WA     dam     15-Oct     30-Apr     Instream flow requirement     DRY_Water_vear_min_flow_rate_cfs     3.55       719     20040527     WA     dam     15-Oct     30-Apr     Instream flow requirement     Normal_Water_vear_min_flow_rate_cfs     2.3       719     20040527     WA     dam     15-Oct     30-Apr     Instream flow requirement     Normal_Water_vear_min_flow_rate_cfs     2.3       719     20040527     WA     dam     1-May     31-Jul     Instream flow requirement     Normal_Water_vear_min_flow_rate_cfs     5       20170522     NE     Monroe powerhouse     Instream flow requirement     Minimum flow     run of canal       1256     20170522     NE     Monroe powerhouse     Maximum discharge capacity     3000       1256     20170522     NE     Columbus powerhouse     Instream flow requirement     Minimum flow     100-0400													season												
Year																									
Yes     Yes <th t<="" td="" yes<=""><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></th>	<td></td>																								
1256         20170522 NE         Monroe powerhouse         Instream flow requirement         Minimum flow         run of canal           1256         20170522 NE         Monroe powerhouse         monroe powerhouse         monroe powerhouse         monroe powerhouse         3000           1256         20170522 NE         Columbus powerhouse         Columbus powerhouse         Minimum flow         0004000																Instream flo	v requirement								
1256         20170522         NE         Monroe powerhouse         Maximum discharge capacity         3000           1256         20170522         NE         Columbus powerhouse         Columbus powerhouse         Minimum flow         3000									1-May		31-J	ul								fs					
1256 20170522 NE Columbus powerhouse Instream flow requirement Minimum flow 1000-4800																Instream flo	v requirement				run of				
1256 20170522 NE Columbus powerhouse 6180	mbu	Columbus p	powerhc	ouse												Instream flo	v requirement	Minimum flov	v		1000	-4800			
	mbu	Columbus p	powerhc	ouse														Maximum dis	charge capacity			6180			
data dictionary     long form data     dropdown lists               •             •	ng	long fo	form	data	dr	opdo	wn lists	+							÷ •									►	



## Examples of environmental flow requirements

- Walleye spawning flows\*
  - 800 cfs minimum flow beginning when water temp is <u>></u> 4°C for 4 consecutive days after Mar 15 to 30 days after water temp is <u>></u> 10°C for 4 consecutive days
- Whitewater flows\*
  - Up to 70 hr of 525 cfs releases/ year to support whitewater races
- Maximum flows\*
  - When inflow is 200-399 cfs, releases < 1.5 times inflow from July 1-15

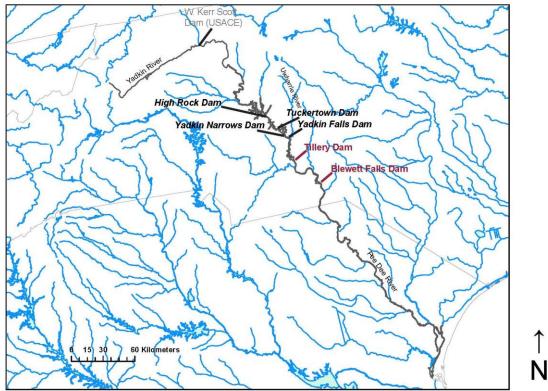
### \*Above requirements all from FERC hydropower licenses



## Case studies

Yadkin-Pee Dee River Basin

- Energy- environment trade-offs
- Two producers



Also focused case studies on:

- 1. economic valuation of hydro flexibility (Poe Project, California)
- 2. new modeling techniques to assess environment tradeoffs with hydro flexibility (Glen Canyon Dam, Arizona) AK RIDGE

CAK RIDGE



