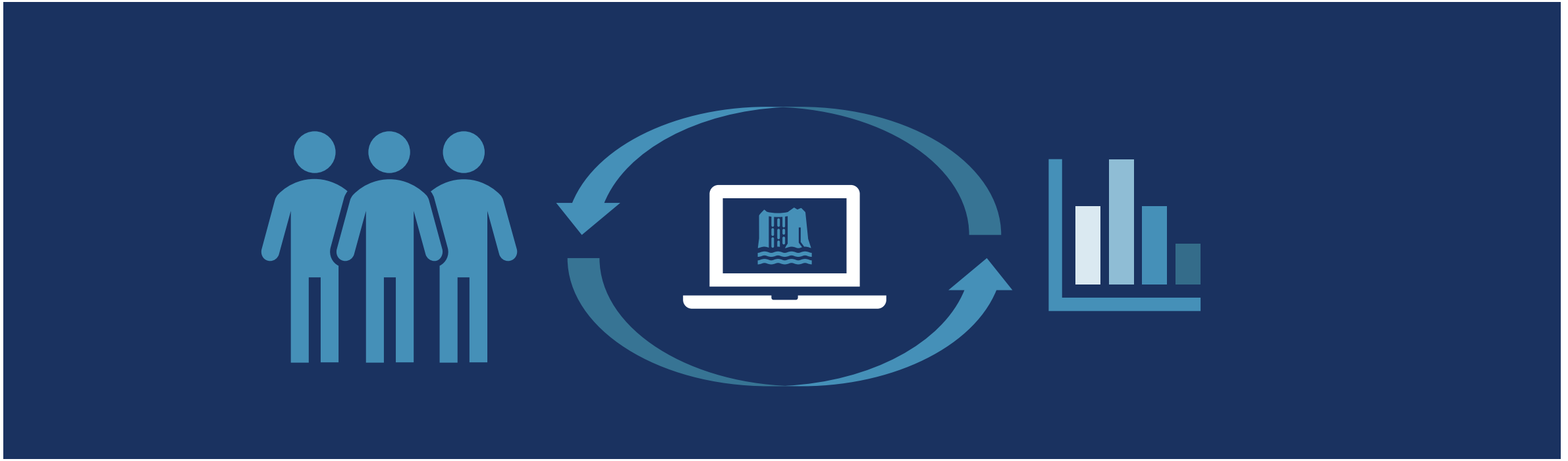
LINKING MODELS AND THEIR USERS

Enhancing accessibility of the fbwR dam passage model through an R Shiny app

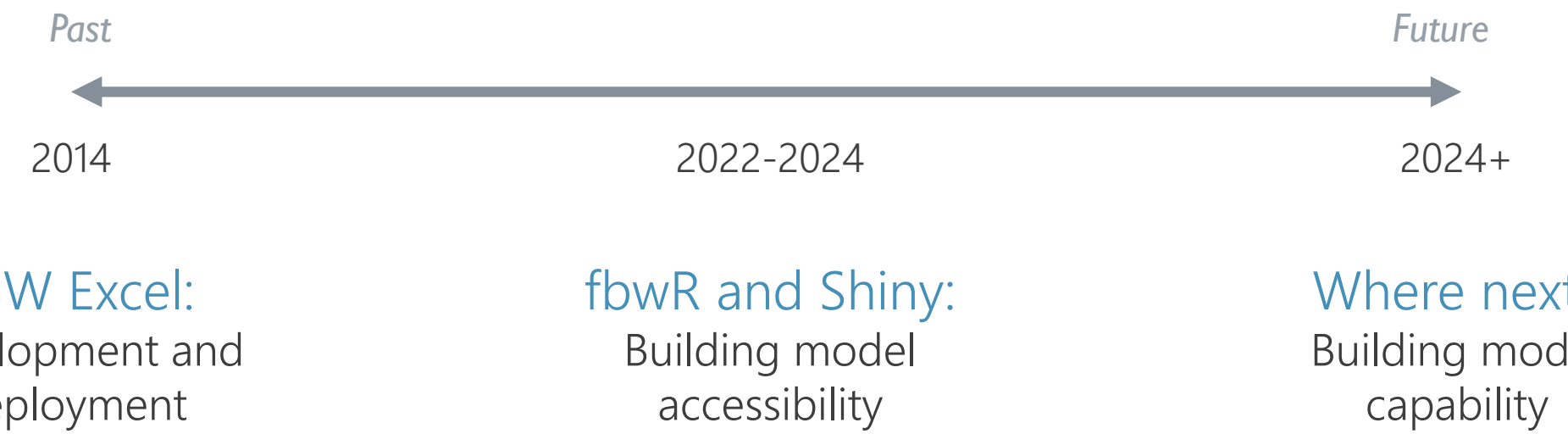


Integrated Fish Passage Project

Mairin Deith, Aaron Greenberg, Roberto Licandeo, Eric Parkinson, Tom Porteus, Murdoch McAllister

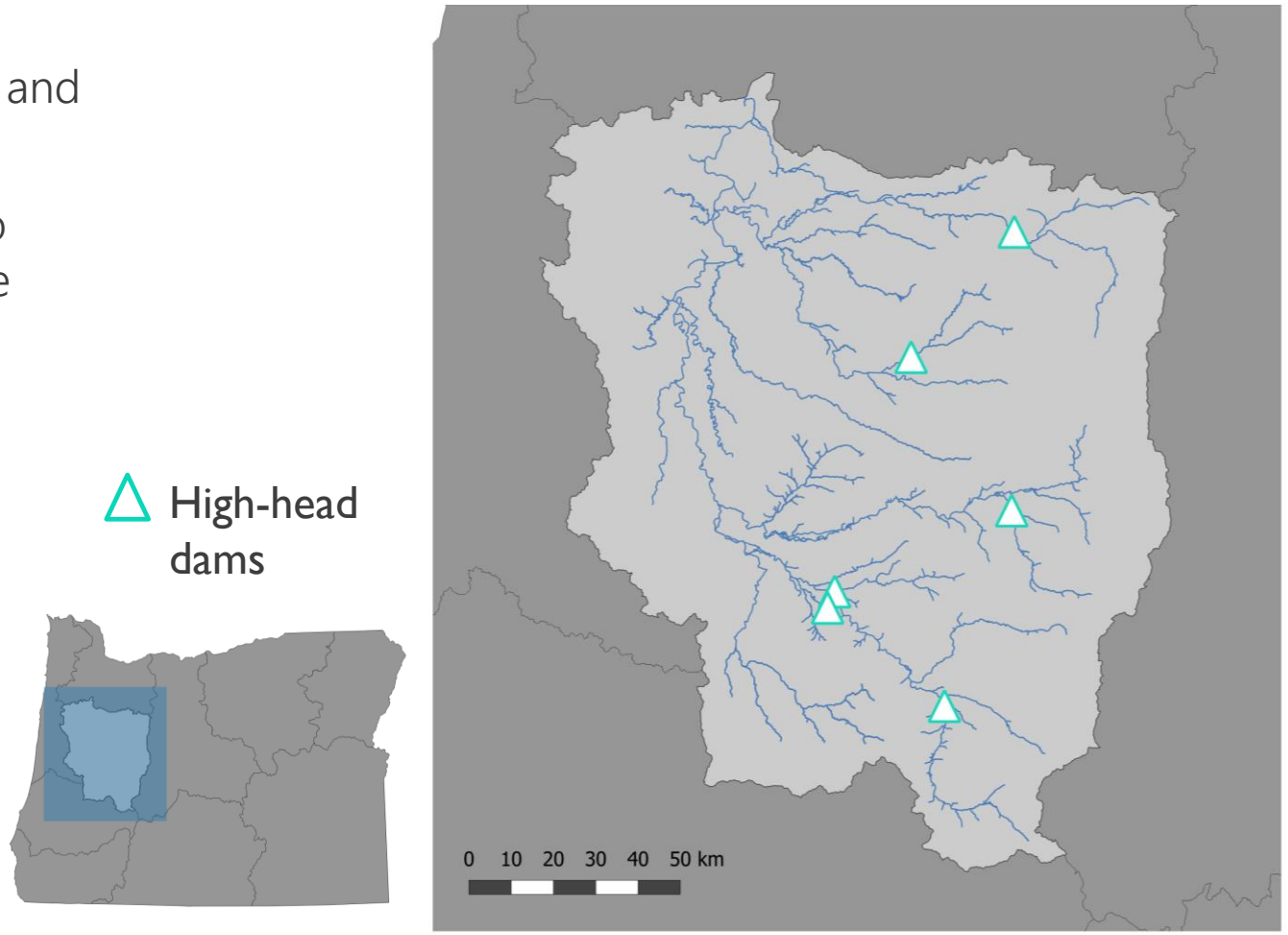
April 4, 2024 - Willamette Fisheries Science Review

Overview of the talk: Past, present, and future of FBW



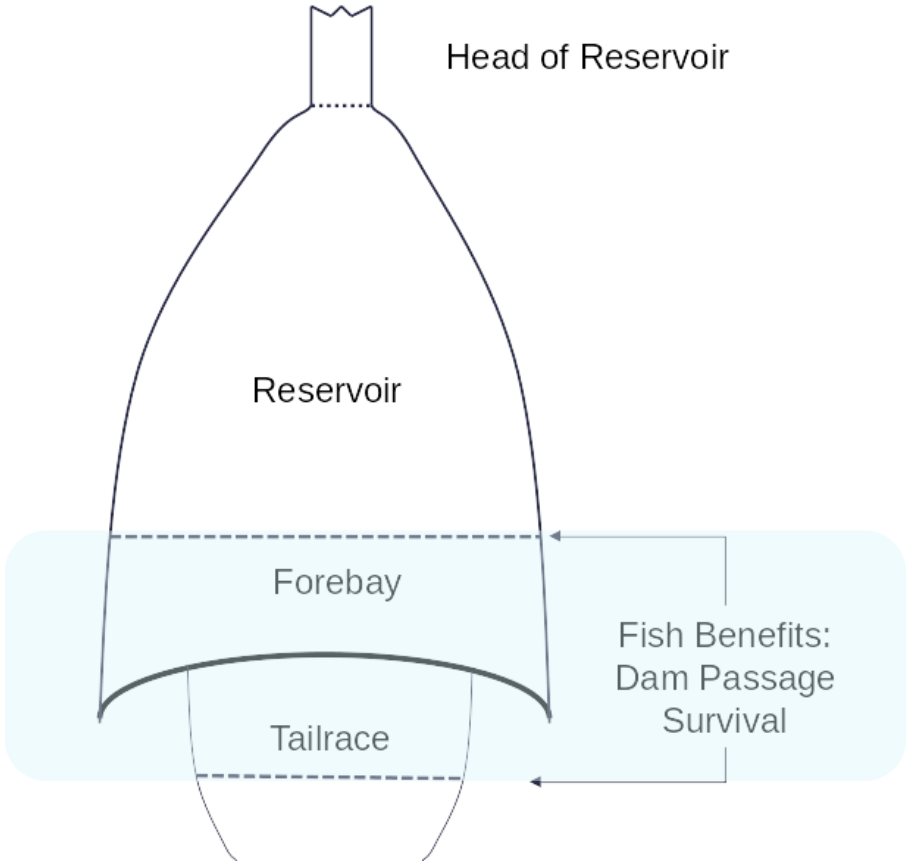
Origins of FBW

- 1999: ESA-listing of spring Chinook salmon and winter steelhead in the Willamette Basin
- 2008 NOAA Fisheries Biological Opinion: to reduce Willamette Projects' impact on these species, improve juvenile dam passage *and other measures*



Origins of FBW

- 2014: Fish Benefits Workbook (FBW) designed by the Army Corps with inputs from NOAA, ODFW, others
  - *Purpose:* Simulate downstream dam passage of juvenile salmonids from forebay → tailrace to rank alternative dam passage measures
  - Excel and VBA-based model



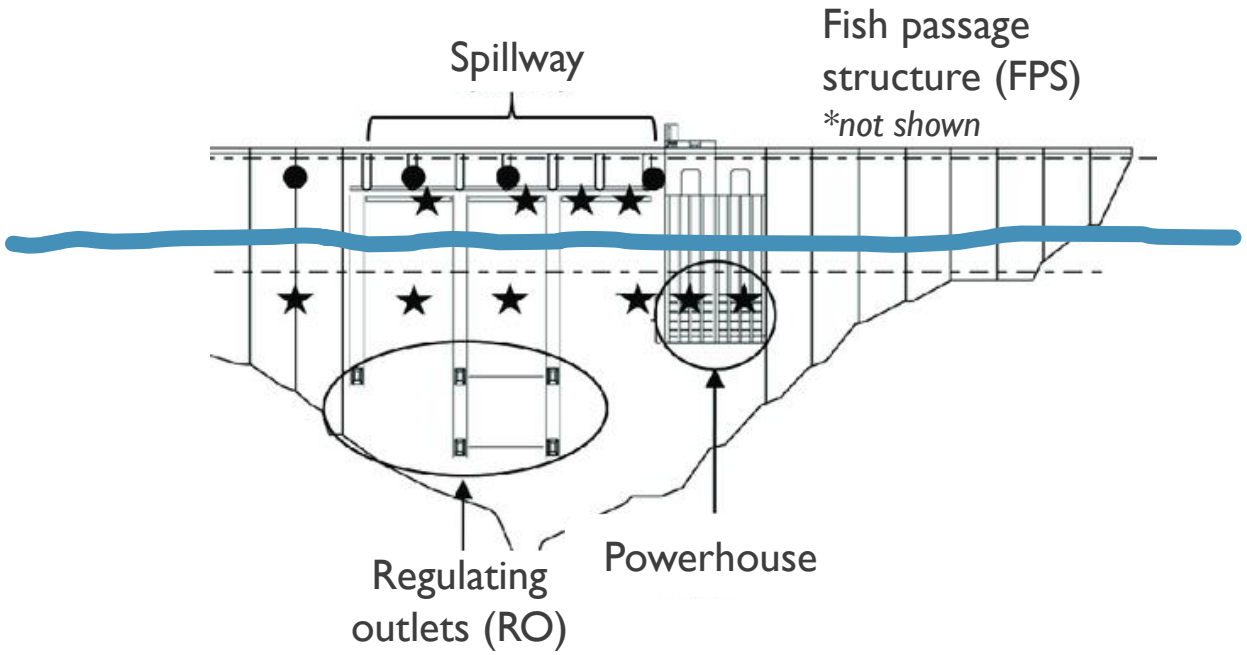
USACE Portland (2012)

Overview of FBW

- Step 1: Input results from a ResSim model (simulates dam hydrology under some assumed dam operation)

  For each day in a 70-year+ period of record:

  - Pool elevation



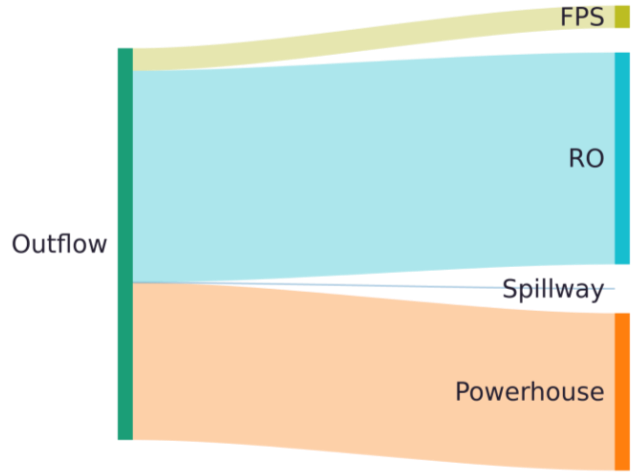
Kock et al. (2015; USGS Report 2015-1220)

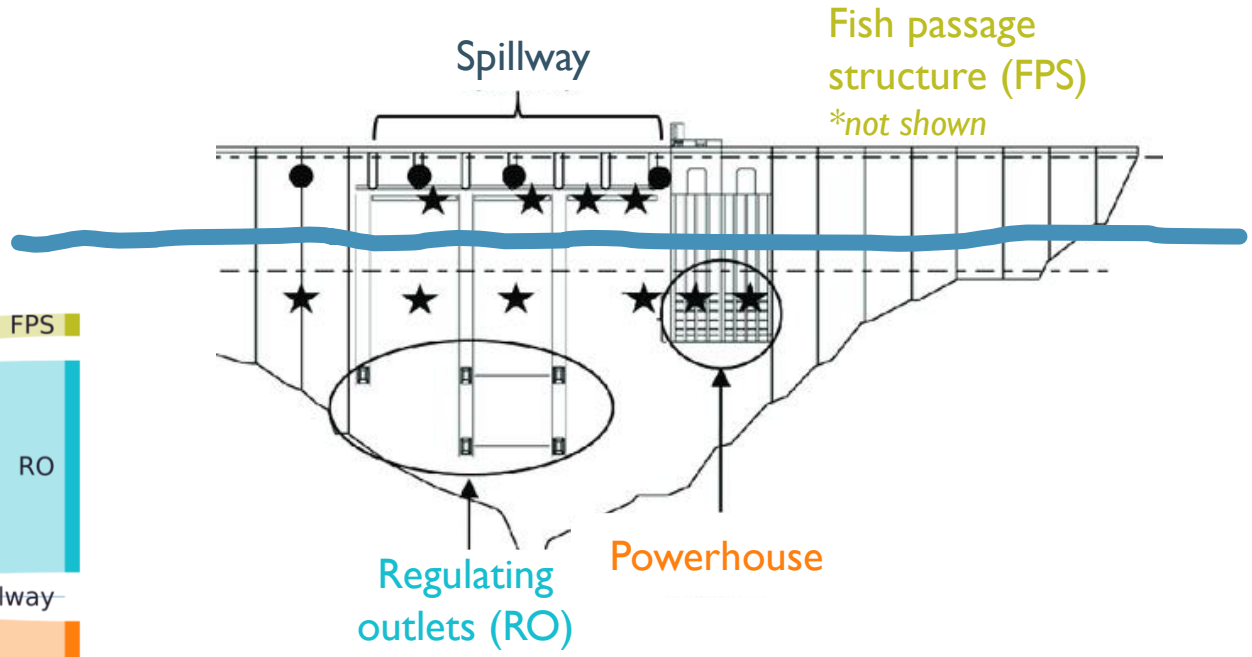
Overview of FBW

- Step 1: Input results from a ResSim model (simulates dam hydrology under some assumed dam operation)

  For each day in a 70-year+ period of record:

  - Pool elevation
  - Total outflow
  - Distribution of flow between **available outlets**

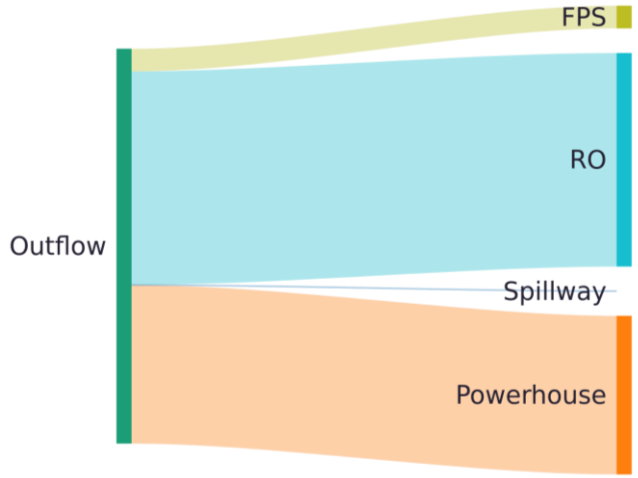




Kock et al. (2015; USGS Report 2015-1220)

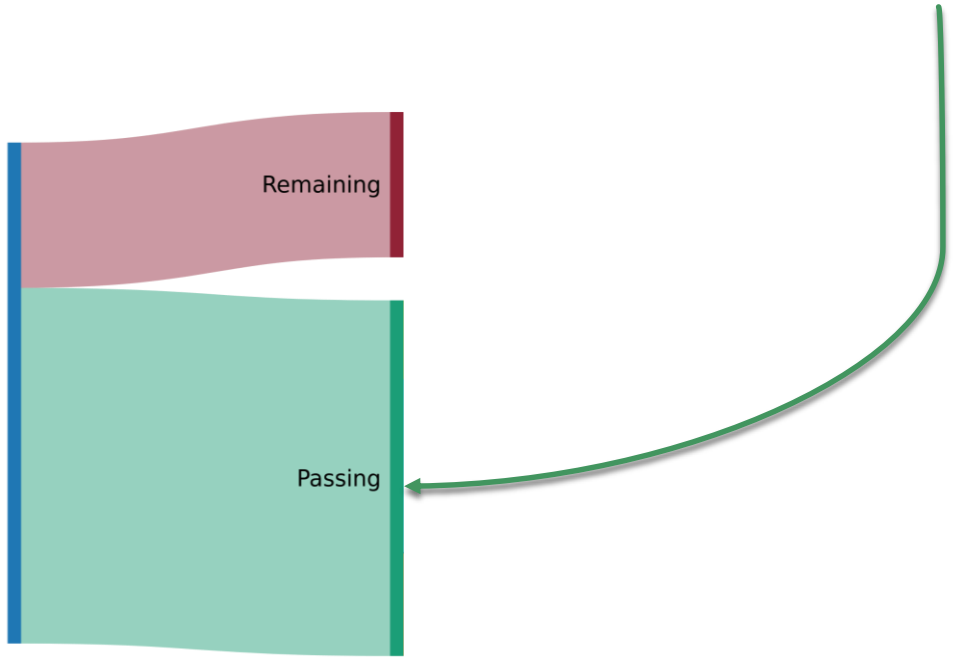
Overview of FBW

- Step 1: Input results from a ResSim model



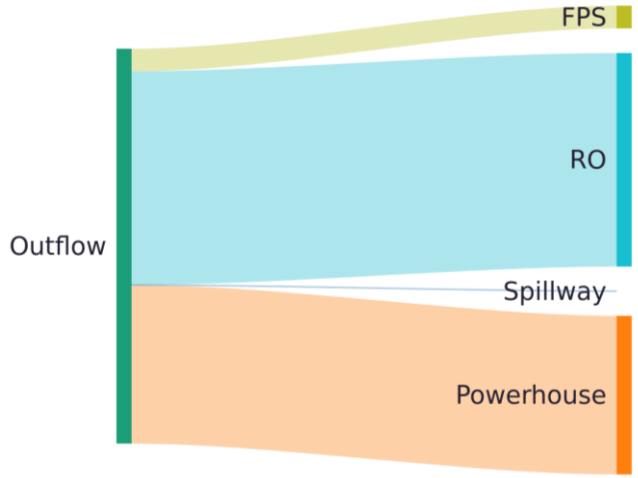
- Step 2: Input biological parameters that describe how fish interact with dam hydrology

  How pool elevation informs dam passage efficiency



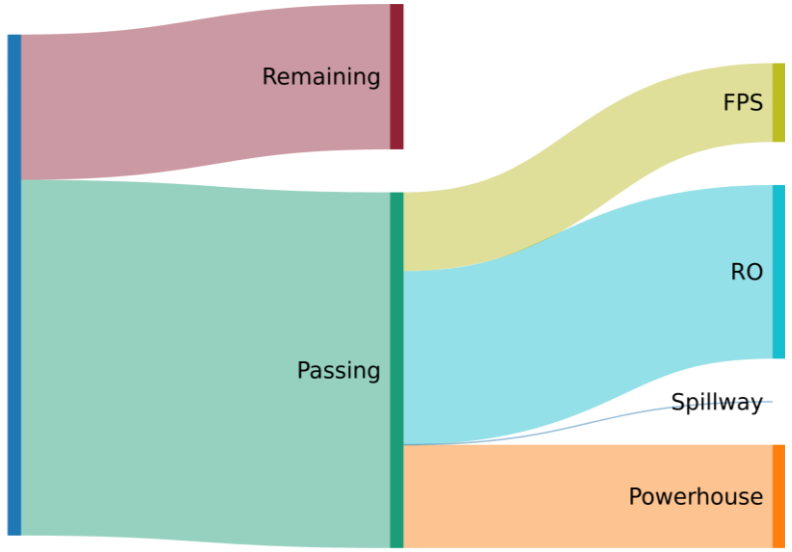
Overview of FBW

- Step 1: Input results from a ResSim model



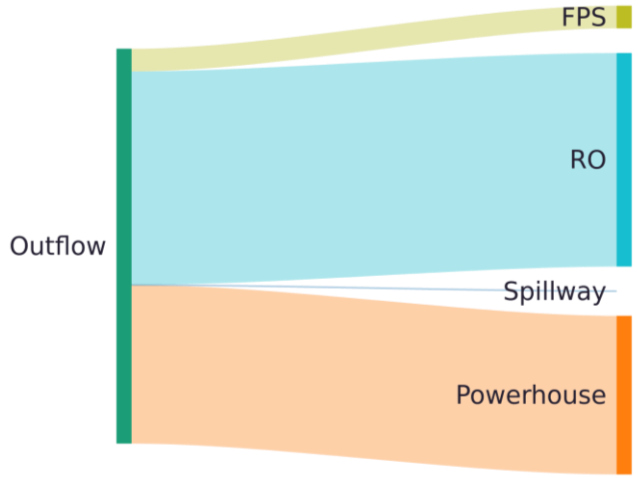
- Step 2: Input biological parameters that describe how fish interact with dam hydrology

  How pool elevation informs dam passage efficiency,
  How fish distribute according to flow



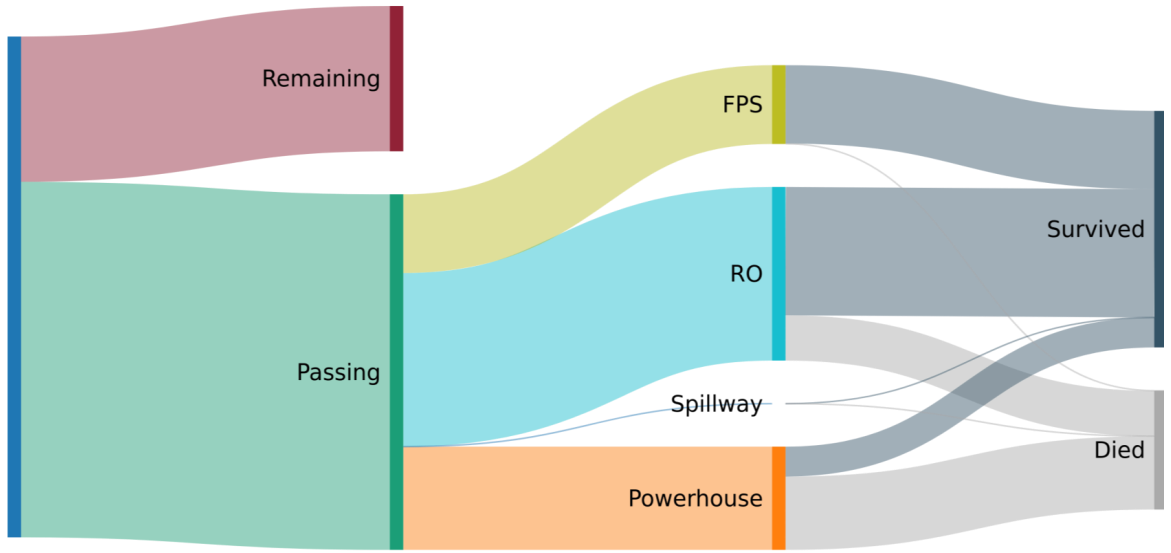
Overview of FBW

- Step 1: Input results from a ResSim model



- Step 2: Input biological parameters that describe how fish interact with dam hydrology

How pool elevation informs dam passage efficiency,
How fish distribute according to flow, and
How flow through each outlet influences survival



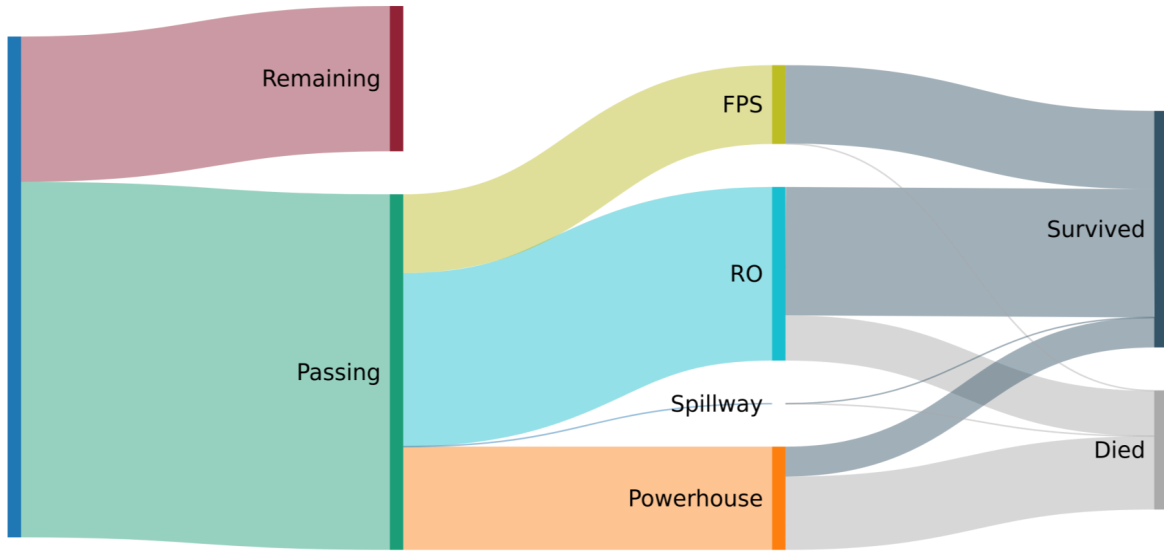
Overview of FBW

- Step 1: Input results from a ResSim model

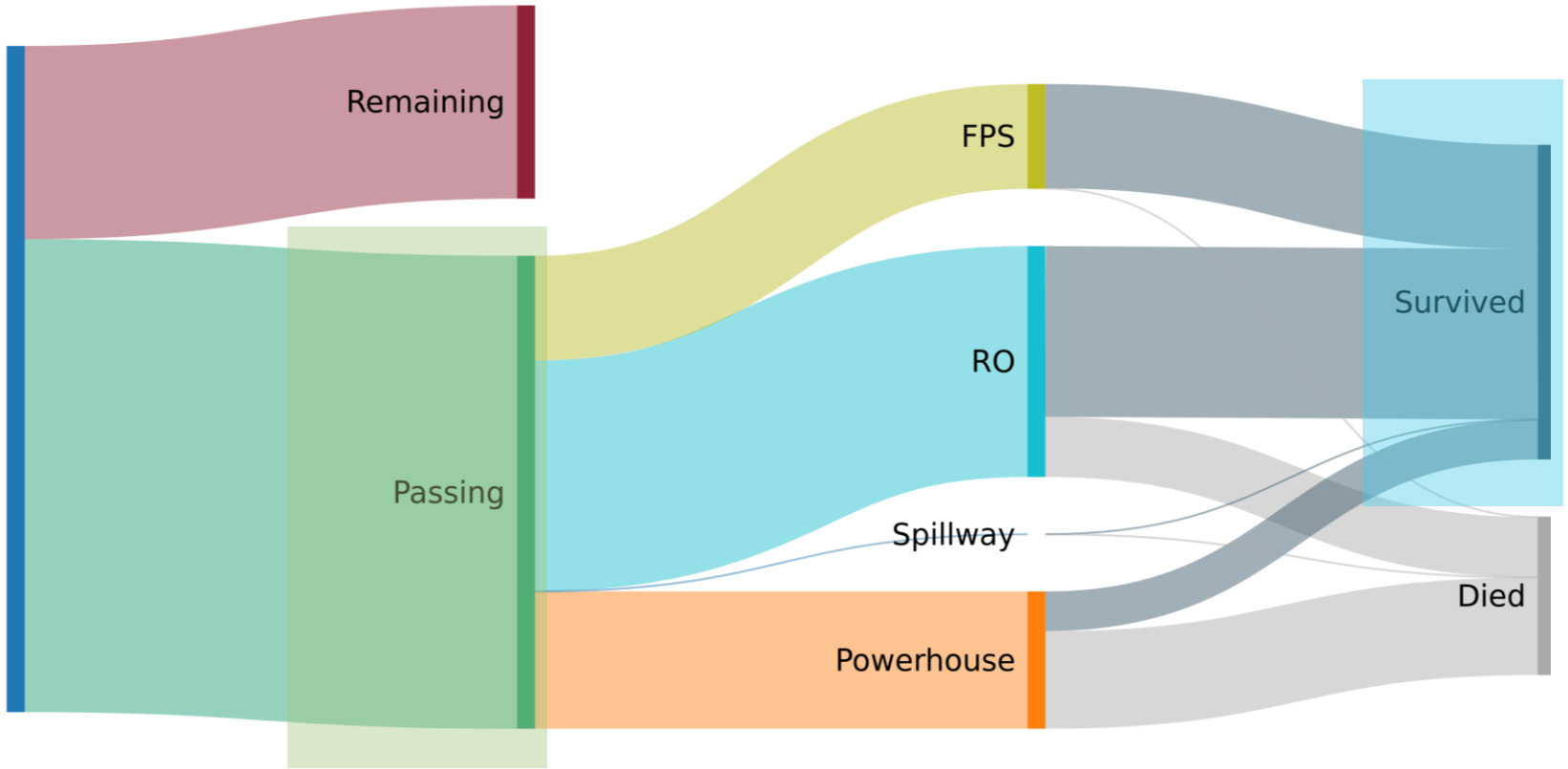
Many parameters are inter-dependent and
influenced by outflow,
dam operating rules,
and other inputs

- Step 2: Input biological parameters that describe how fish interact with dam hydrology

How pool elevation informs dam passage efficiency,
How fish distribute according to flow, and
How flow through each outlet influences survival



FBW's Key Outputs

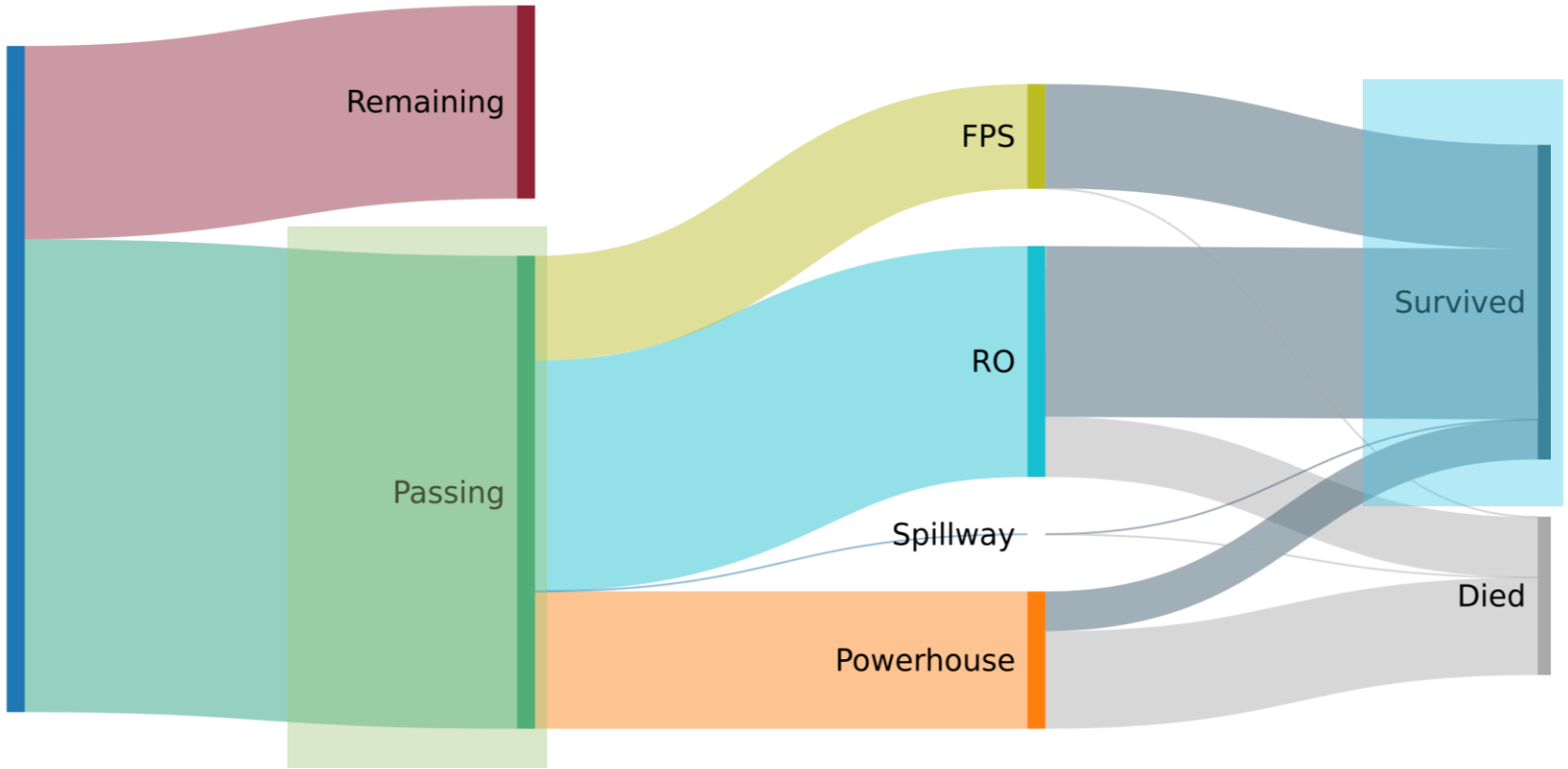


Step 3: Run FBW model

For each day in the period of record, calculate

- Dam passage efficiency (DPE)
- Dam passage survival (DPS)

FBW's Key Outputs



Step 3: Run FBW model

For each day in the period of record, calculate

- Dam passage efficiency (DPE)
- Dam passage survival (DPS)

then summarize average DPE and DPS by year, month, water year type for use in life cycle models

State of the model

- 2014: FBW parameterized and reviewed by Alden Research Laboratory, then reviewed by Independent Scientific Advisory Board

Issues identified:

- Limited data available to inform inputs
- Excel not suited to incorporate uncertainty (point estimates only)
- Limited model flexibility

State of the model

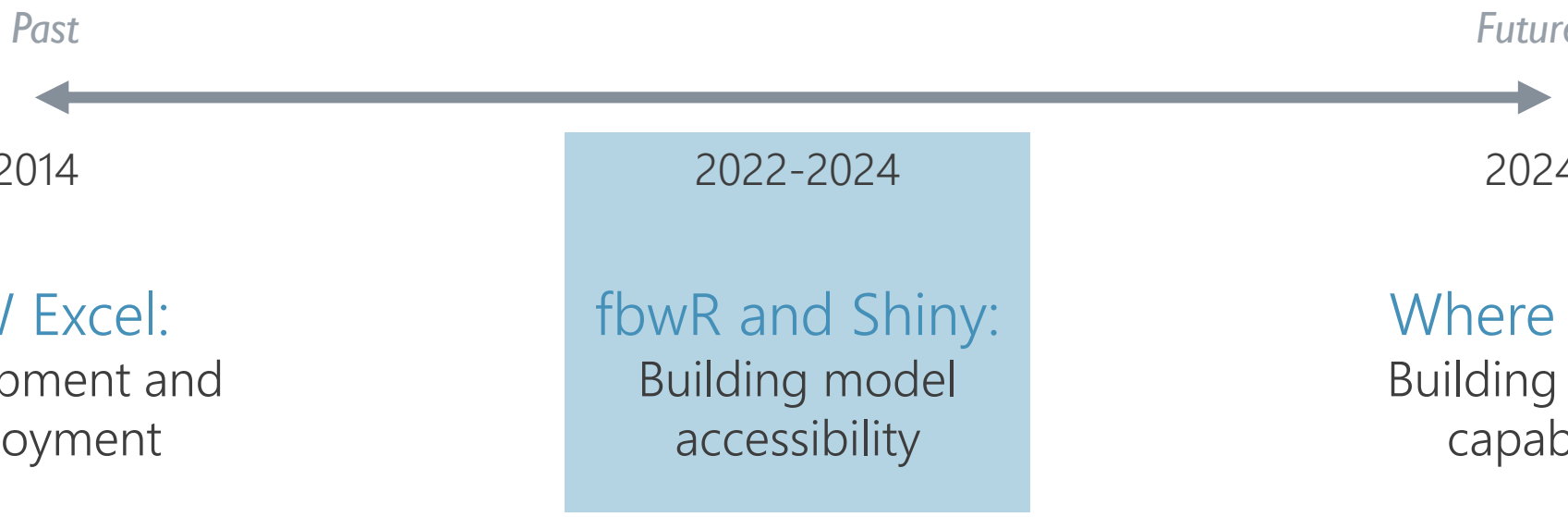
- 2014: FBW parameterized and reviewed by Alden Research Laboratory, then reviewed by Independent Scientific Advisory Board

Issues identified:

- Limited data available to inform inputs
- Excel not suited to incorporate uncertainty (point estimates only)
- Limited model flexibility

From recent experience:

- VBA and Excel pose a barrier to development and dissemination of the model


Past
Future
2014
2022-2024
2024+
FBW Excel:
Development and deployment
fbwR and Shiny:
Building model accessibility
Where next?
Building model capability

Why translate FBW Excel into R?

Compared to Excel, more flexible programming languages can be used to build models that are

1. More transparent and reproducible,
2. more reusable and adaptable, and
3. capable of quantifying uncertainty.

R is commonly used by scientists in many fields, well-developed, free and open source

Incerti *et al.* (2022) doi:10.1016/j.jval.2019.01.003

Why translate FBW Excel into R?

Compared to Excel, more flexible programming languages can be used to build models that are

1. More transparent and reproducible,
2. more reusable and adaptable, and
3. capable of quantifying uncertainty.

R is commonly used by scientists in many fields, well-developed, free and open source

Re-built FBW in R and Shiny with goal of improving:

1. User-friendliness,
2. Data validation and real-time feedback, and
3. Customizability.

Incerti *et al.* (2022) doi:10.1016/j.jval.2019.01.003

A user-friendly interface

FBW Excel

- VBA-based workbooks with macros: issues with distribution, security, and development

A user-friendly interface

FBW Excel

- VBA-based workbooks with macros: issues with distribution, security, and development

fbwR in Shiny

- Use the model as an R script,

```
> library(fbwR)
> fbwR::runFBW()
```

Chang *et al.* (2021). shiny: Web Application Framework for R.

A user-friendly interface

FBW Excel

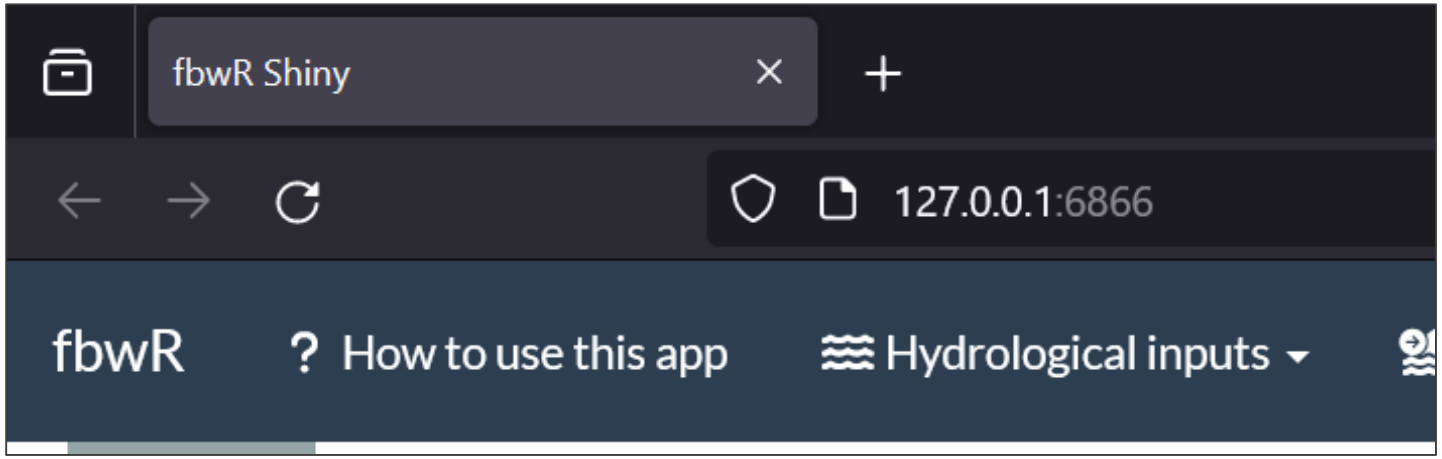
- VBA-based workbooks with macros: issues with distribution, security, and development

fbwR in Shiny

- Use the model as an R script,

```
> library(fbwR)
> fbwR::runFBW()
```

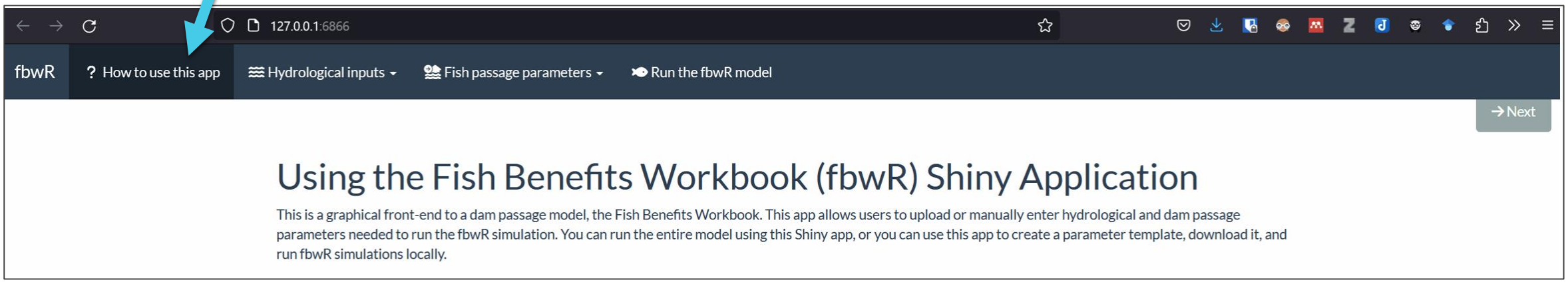
...or access a Shiny graphical interface in any browser



Chang *et al.* (2021). shiny: Web Application Framework for R.

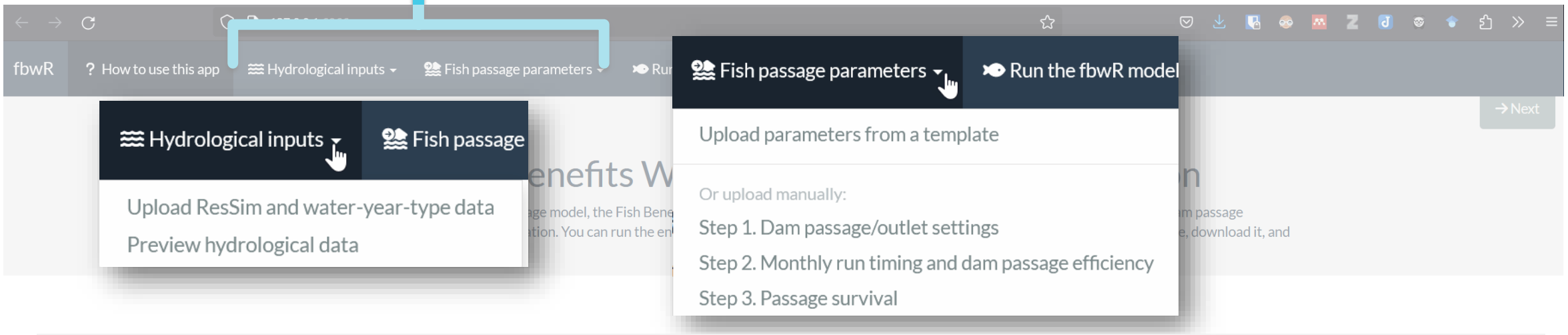
A user-friendly interface: Navigating the Shiny app

Information, drop-down menus, and Next/Back buttons guide the user through data entry



A user-friendly interface: Navigating the Shiny app

Information, **drop-down menus**, and Next/Back buttons guide the user through data entry



Animated gif demonstrating drop-down menus that walk through several steps to inputting parameters into the fbwR Shiny app. Clicking on each of the top-level menu items shows a drop-down set of options.

Immediate data validation and interactive graphics

There is always some risk of incorrectly inputting data;

fbwR and Shiny app designed to help spot these issues when they happen

e.g.,

- Preview compiled data
- Preview the results of calculations

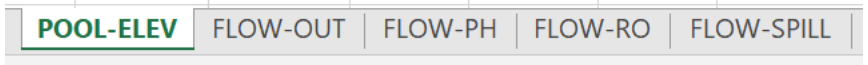
e.g., Tables/graphics

- Immediate data validation and pre-run error check

Immediate data validation: ResSim

FBW Excel

- ResSim results are **manually copy-pasted** into **several sheets** in the FBW Excel workbook
  → easy to make mistakes



- **No data checking/date alignment**, does not check if the years in the period of record match

Pool Elevation: Period of record begins in 1946

7		1946	1947	1948	1949	1950
8	1-Jan	1619.64	1541.18	1534.16	1532.10	1532.10
9	2-Jan	1614.84	1539.97	1541.97	1532.10	1532.10
10	3-Jan	1609.95	1538.52	1545.25	1532.10	1532.10
11	4-Jan	1608.14	1536.98	1546.21	1532.10	1532.10
12	5-Jan	1609.72	1535.47	1546.39	1532.10	1532.10
13	6-Jan	1604.77	1533.77	1564.11	1532.10	1532.10

POOL-ELEV | FLOW-OUT | FLOW-PH | FLOW-RO | FLO

RO Outflow: Period of record begins in 1945

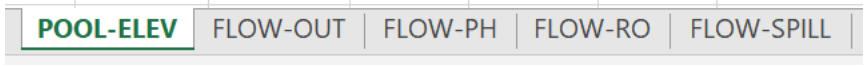
	1945	1946	1947	1948	1949
1-Jan	0.00	4059.50	380.65	355.28	0.00
2-Jan	0.00	4113.65	376.90	383.12	0.00
3-Jan	0.00	4197.98	371.51	393.27	0.00
4-Jan	0.00	3428.64	365.77	434.03	0.00
5-Jan	0.00	2709.53	360.15	420.19	0.00

POOL-ELEV | FLOW-OUT | FLOW-PH | FLOW-RO

Immediate data validation: ResSim

FBW Excel

- ResSim results are **manually copy-pasted** into **several sheets** in the FBW Excel workbook
  → easy to make mistakes



- **No data checking/date alignment**, does not check if the years in the period of record match

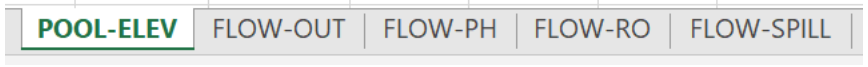
fbwR

- Users upload ResSim as a single workbook, with the data processing handled by software
- Hydrological data merged by date

Immediate data validation: ResSim

FBW Excel

- ResSim results are **manually copy-pasted** into **several sheets** in the FBW Excel workbook
  → easy to make mistakes



- **No data checking/date alignment**, does not check if the years in the period of record match

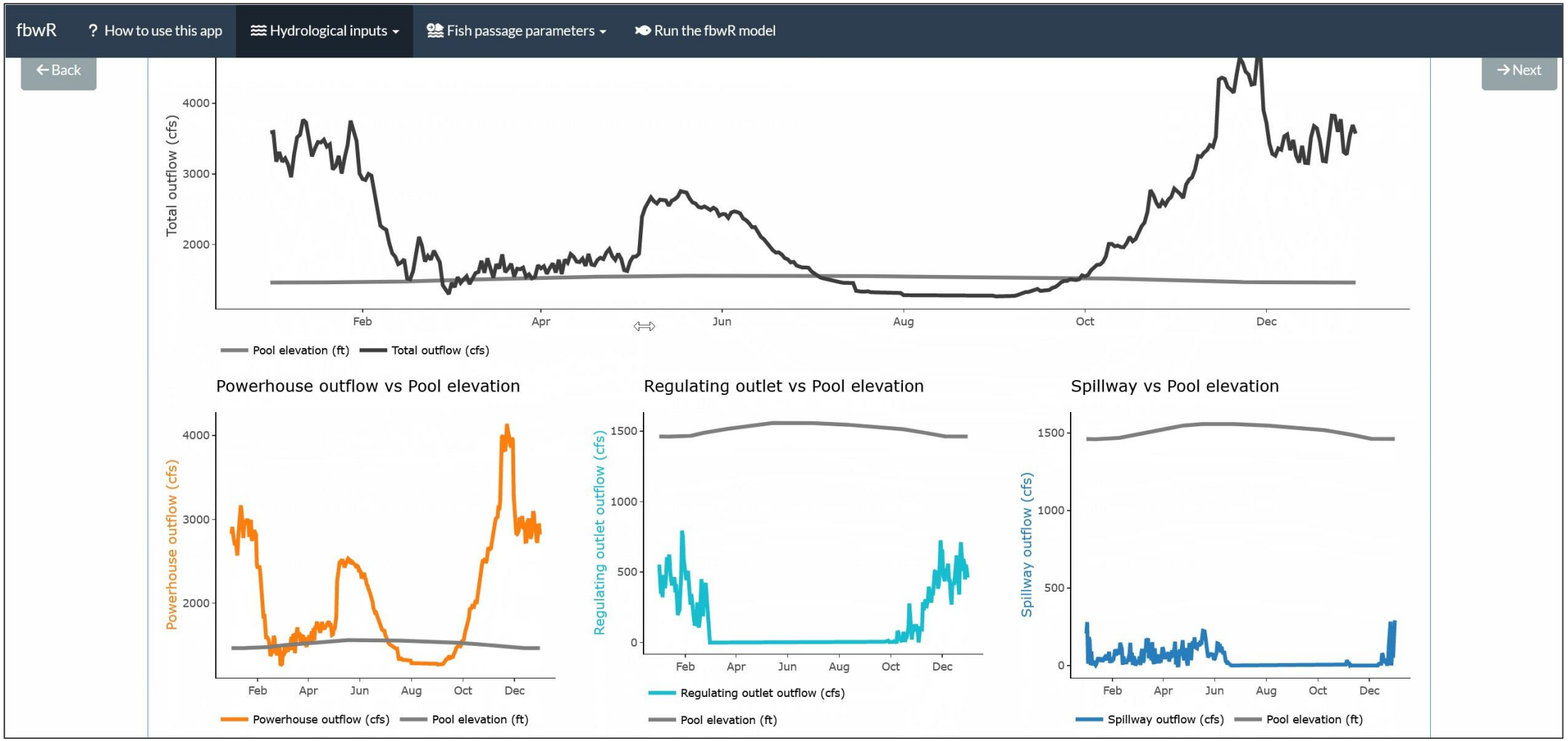
fbwR

- Users upload ResSim as a single workbook, with the data processing handled by software
- Hydrological data merged by date

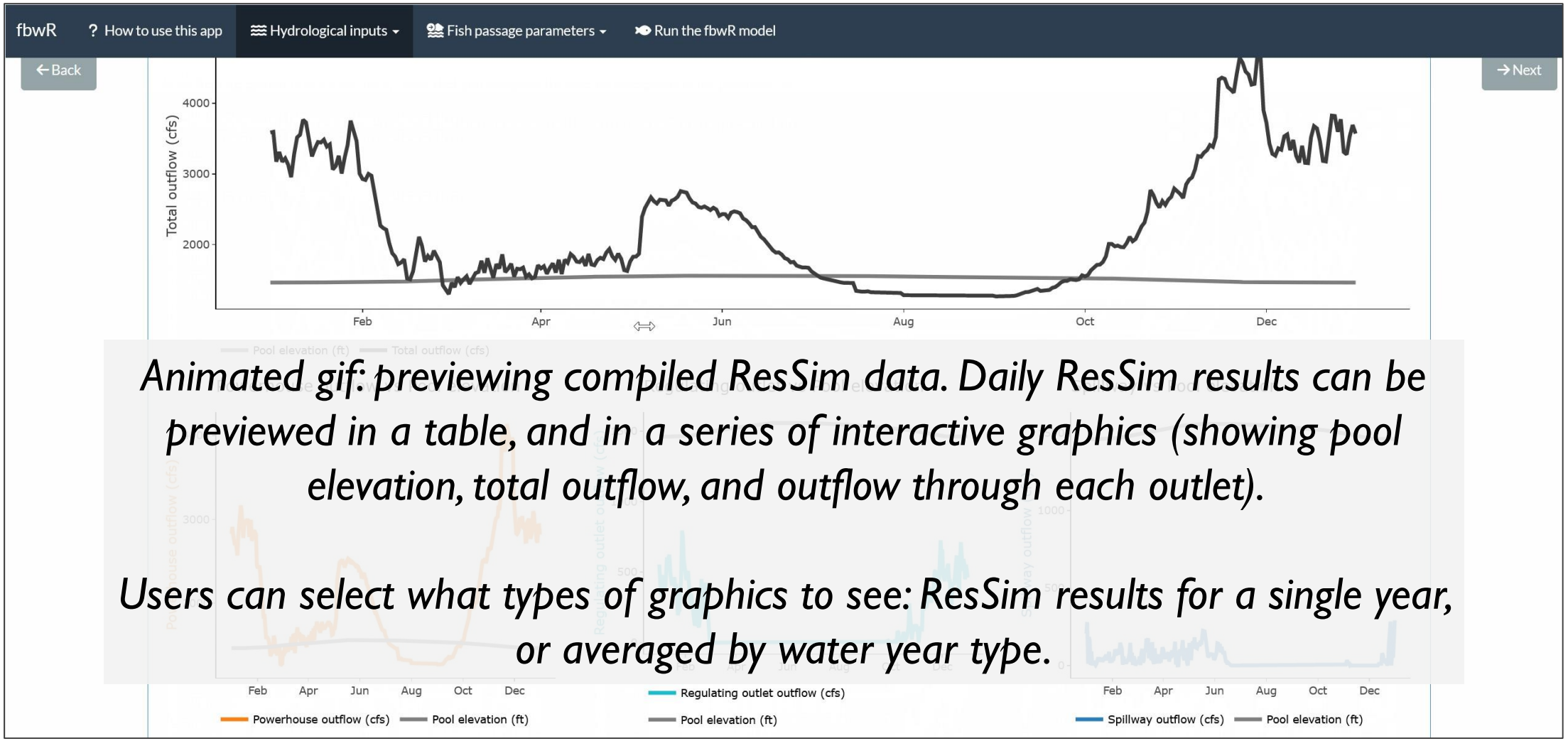
fbwR in Shiny

- In Shiny, after uploading ResSim, preview date-merged hydrological data and graphics

Immediate data validation: ResSim



Immediate data validation: ResSim



Animated gif: previewing compiled ResSim data. Daily ResSim results can be previewed in a table, and in a series of interactive graphics (showing pool elevation, total outflow, and outflow through each outlet).

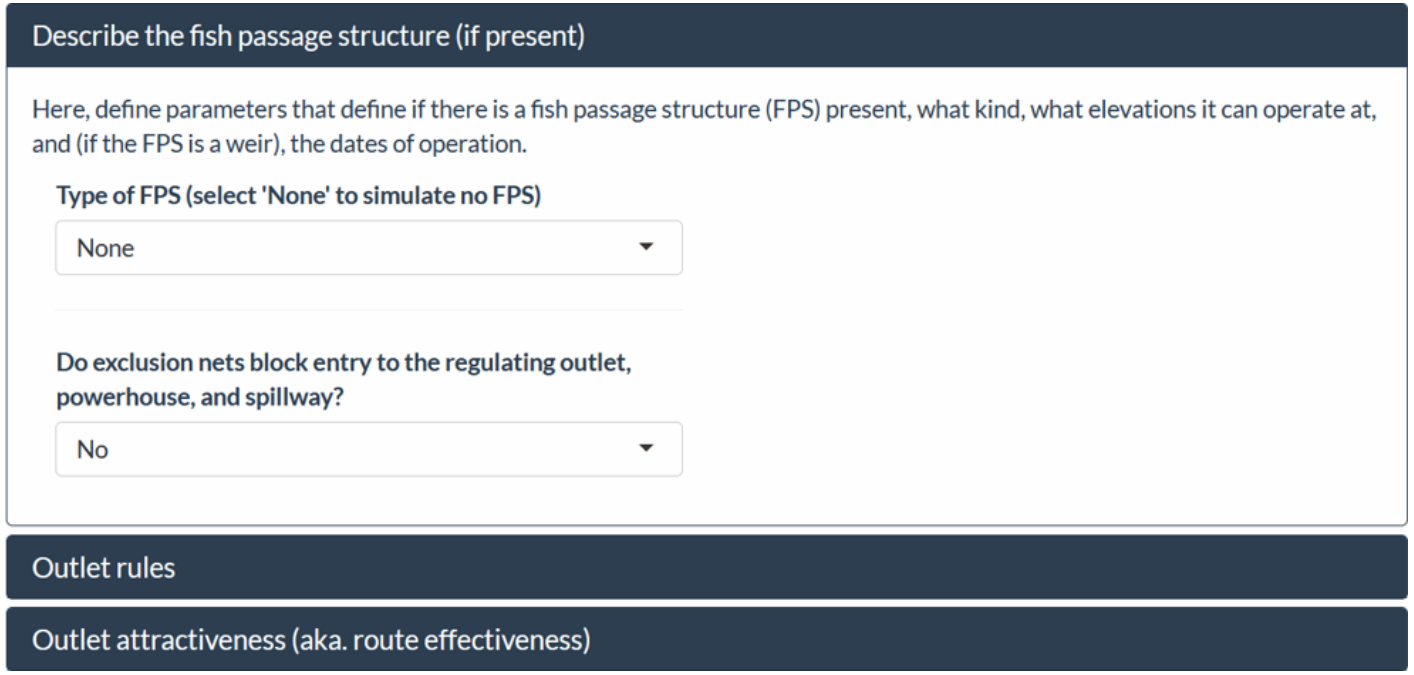
Users can select what types of graphics to see: ResSim results for a single year, or averaged by water year type.

Interactivity and real-time feedback: Biological parameters

- Interactive elements help users to know which parameters are required for what kinds of model runs

e.g., Reactive inputs based on which fish passage structure type is chosen, like

Only weir-type fish passage structures may have date-specific use

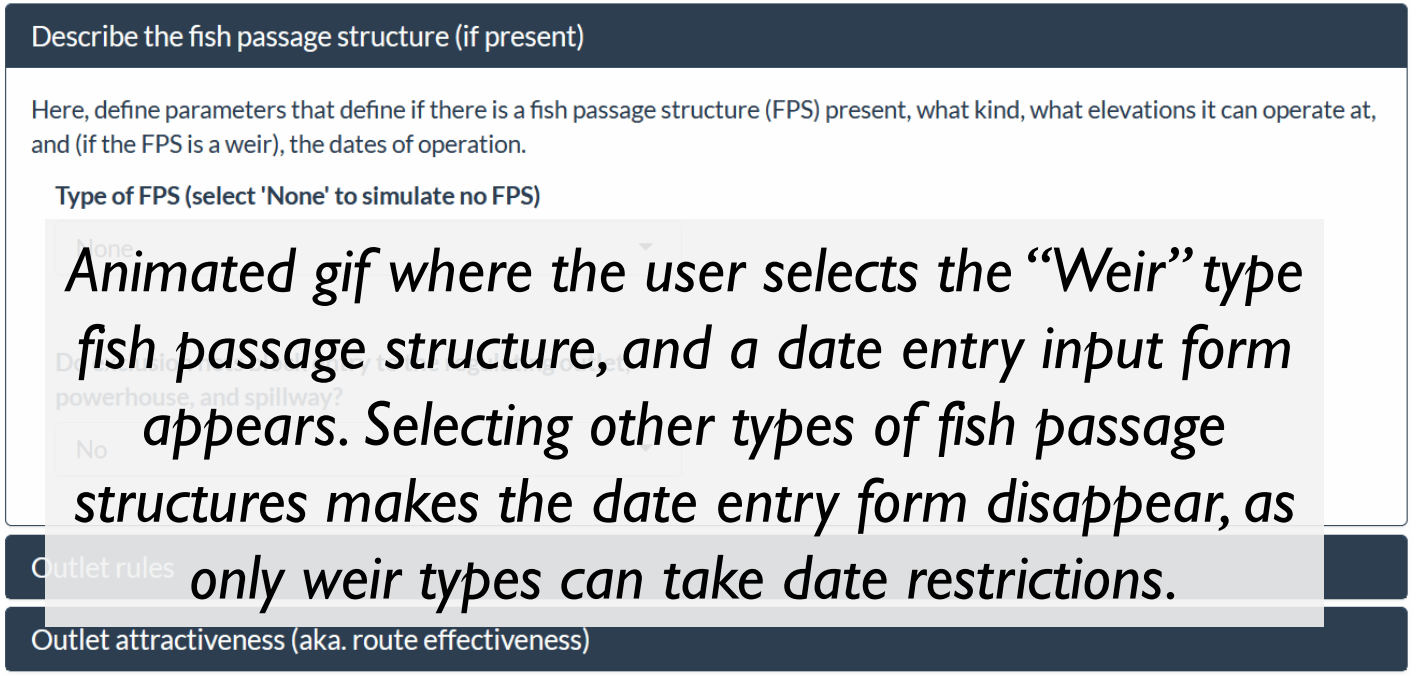


Interactivity and real-time feedback: Biological parameters

- Interactive elements help users to know which parameters are required for what kinds of model runs

e.g., Reactive inputs based on which fish passage structure type is chosen, like

Only weir-type fish passage structures may have date-specific use



Interactivity and real-time feedback: Biological parameters

- Interactive elements help users to know which parameters are required for what kinds of model runs

- Some interactive tables are immediately formatted to help users identify the range of values and improve the ease and speed of debugging

	Regulating outlet R.E.	Turbine R.E.	Spillway R.E.	FPS R.E.
Q Ratio: 0	0.00	0.00	0.00	0.00
Q Ratio: 0.1	0.09	0.50	2.00	4.43
Q Ratio: 0.2	0.09	0.25	2.25	4.43
Q Ratio: 0.3	0.09	0.17	2.69	2.69
Q Ratio: 0.4	0.04	0.13	2.38	2.38
Q Ratio: 0.5	0.06	0.10	1.90	1.90
Q Ratio: 0.6	0.06	0.08	1.58	1.58
Q Ratio: 0.7	0.08	0.27	1.36	1.36
Q Ratio: 0.8	0.12	0.69	1.19	1.19
Q Ratio: 0.9	0.20	0.89	1.06	1.06
Q Ratio: 1	1.00	1.00	1.00	1.00

e.g., Use of a colour gradient to show ranges of values

Interactivity and real-time feedback: Biological parameters

Interactivity is especially useful for parameters that depend on multiple other inputs
e.g, structure-specific Dam Passage Efficiency

What fish passage structure should be used to calculate DPE?

Use baseline DPE

Minimum pool elevation (feet) where fish passage structure is accessible

Maximum pool elevation (feet) where fish passage structure is accessible

Fish can only access the FPS when the reservoir pool is between the minimum and maximum elevation.

Pool elevation (feet)	Elevation description	Baseline DPE	FSS DPE	FSC DPE	Weir DPE
1340	Upper RO	0.77			
1375	25' over top of RO	0.77			
1415	40' over top of RO	0.30			
1425	Min power	0.77			
1450	Min cons.	0.27			

+ Add row

− Remove row

Table defines DPE for each structure as a function of pool elevation

Interactivity and real-time feedback: Biological parameters

Interactivity is especially useful for parameters that depend on multiple other inputs
e.g, structure-specific Dam Passage Efficiency

What fish passage structure should be used to calculate DPE?

Use baseline DPE

Minimum pool elevation (feet) where fish passage structure is accessible

Maximum pool elevation (feet) where fish passage structure is accessible

Fish can only access the FPS when the reservoir pool is between the minimum and maximum elevation.

Pool elevation (feet)	Elevation description	Baseline DPE	FSS DPE	FSC DPE	Weir DPE
1340	Upper RO	0.77			
1375	25' over top of RO	0.77			
1415	40' over top of RO	0.30			
1425	Min power	0.77			
1450	Min cons.	0.27			

+ Add row

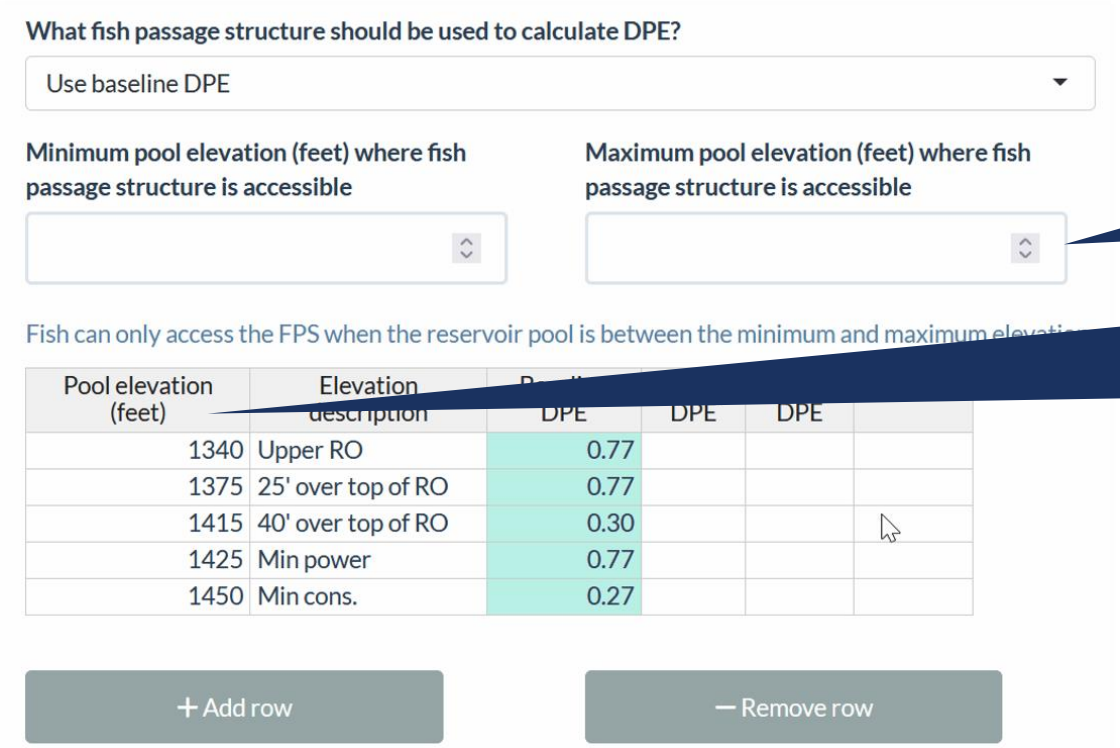
− Remove row

Function of:

1. Which column in the table to use?

Interactivity and real-time feedback: Biological parameters

Interactivity is especially useful for parameters that depend on multiple other inputs
e.g, structure-specific Dam Passage Efficiency



Function of:

1. Which column in the table to use?
2. Elevation restrictions

Interactivity and real-time feedback: Biological parameters

Animated gif showing how user inputs on the left (via the DPE table and inputs above the table) influence actually calculated DPE. The graphic on the right and the blue highlighting in the DPE table both update depending on user inputs.

What fish passage structure should be used to calculate DPE?

Use baseline DPE

Minimum pool elevation (feet) where fish passage structure is accessible

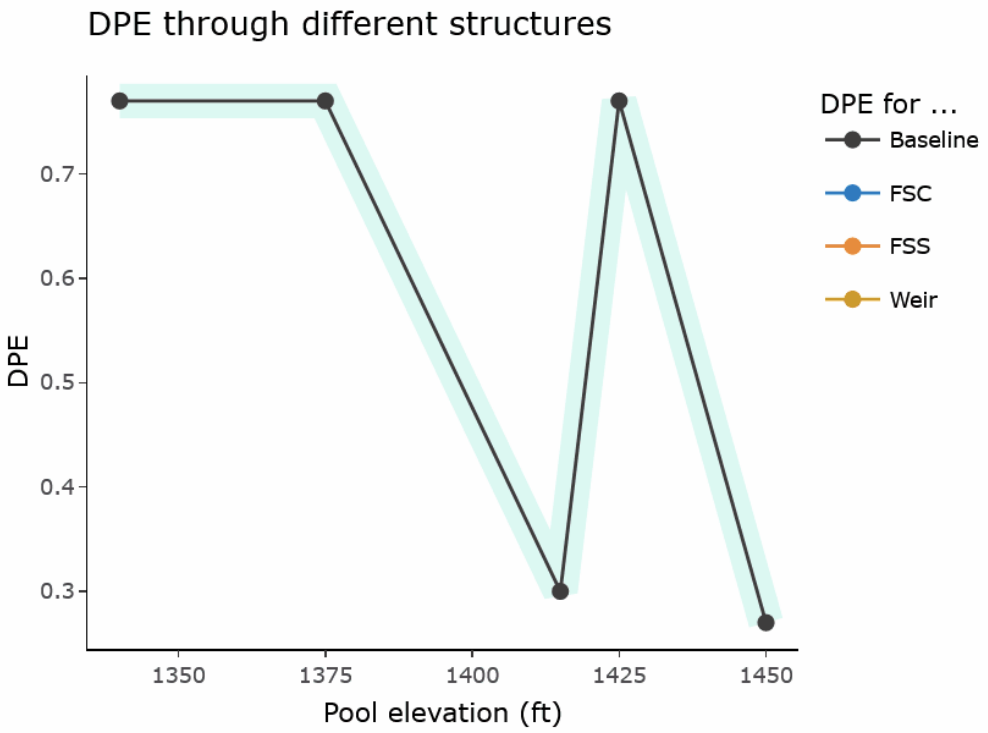
Maximum pool elevation (feet) where fish passage structure is accessible

Fish can only access the FPS when the reservoir pool is between the minimum and maximum elevation.

Pool elevation (feet)	Elevation description	Baseline DPE	FSS DPE	FSC DPE	Weir DPE
1340	Upper RO	0.77			
1375	25' over top of RO	0.77			
1415	40' over top of RO	0.30			
1425	Min power	0.77			
1450	Min cons.	0.27			

+ Add row

− Remove row



Interactivity and real-time feedback: Biological parameters

Animated gif showing how user inputs on the left (via the DPE table and inputs above the table) influence actually calculated DPE. The graphic on the right and the blue highlighting in the DPE table both update depending on user inputs.

What fish passage structure should be used to calculate DPE?

Fish surface collector (FSC)

Minimum pool elevation (feet) where fish passage structure is accessible

1400

Maximum pool elevation (feet) where fish passage structure is accessible

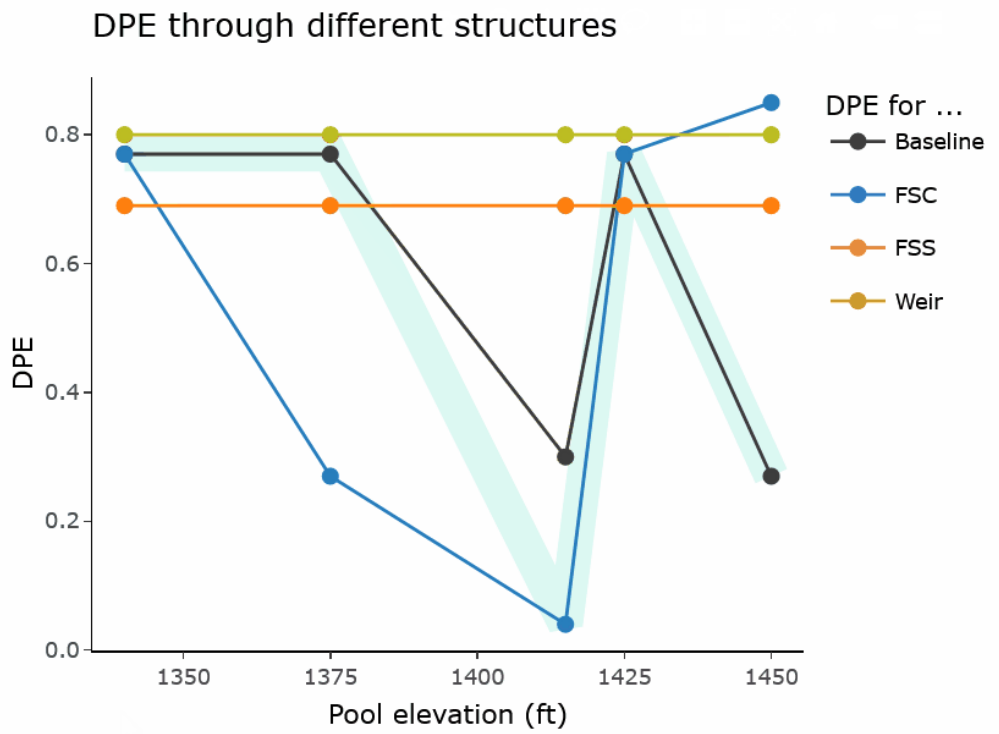
1420

Fish can only access the FPS when the reservoir pool is between the minimum and maximum elevation.

Pool elevation (feet)	Elevation description	Baseline DPE	FSS DPE	FSC DPE	Weir DPE
1340	Upper RO	0.77	0.69	0.77	0.80
1375	25' over top of RO	0.77	0.69	0.27	0.80
1415	40' over top of RO	0.30	0.69	0.04	0.80
1425	Min power	0.77	0.69	0.77	0.80
1450	Min cons.	0.27	0.69	0.85	0.80

+ Add row

− Remove row



Interactivity and real-time feedback: Results

Before running the model, the app performs a final data check.

If no errors: Run the model and provide results in

summarized

- Results summarized by month/outlet
- Results summarized by water year type
- Unsummarized FBW results (daily for each day in the period of record)

and daily formats

Interactivity and real-time feedback: Results

Summarized results presented in

color-coded tables and linked graphics

Average monthly fish distribution and survival

Month	% Approaching (calculated)	Population: Forebay	Population: FPS	Population: Turbines	Population: RO	Population: Spillway	Route Survival: FPS	Route Survival: Turbines	Route Survival: RO	Route Survival: Spillway
Jan	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Feb	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Mar	0.060%	0.009%	0.050%	0.000%	0.000%	0.001%	0.049%	0.000%	0.000%	0.001%
Apr	0.100%	0.015%	0.079%	0.000%	0.000%	0.002%	0.079%	0.001%	0.000%	0.002%
May	0.160%	0.024%	0.127%	0.001%	0.000%	0.005%	0.125%	0.002%	0.000%	0.003%
Jun	0.610%	0.092%	0.509%	0.001%	0.000%	0.008%	0.499%	0.001%	0.000%	0.006%
Jul	0.050%	0.008%	0.042%	0.000%	0.000%	0.000%	0.041%	0.000%	0.000%	0.000%
Aug	0.020%	0.003%	0.016%	0.001%	0.000%	0.000%	0.016%	0.001%	0.000%	0.000%

Fish distribution between months and outlets

Fish distribution * survival

Interactivity and real-time feedback: Results

Summarized results presented in
color-coded tables and linked graphics

Proportion in fish passage structure

Proportion in fish passage structure * survival

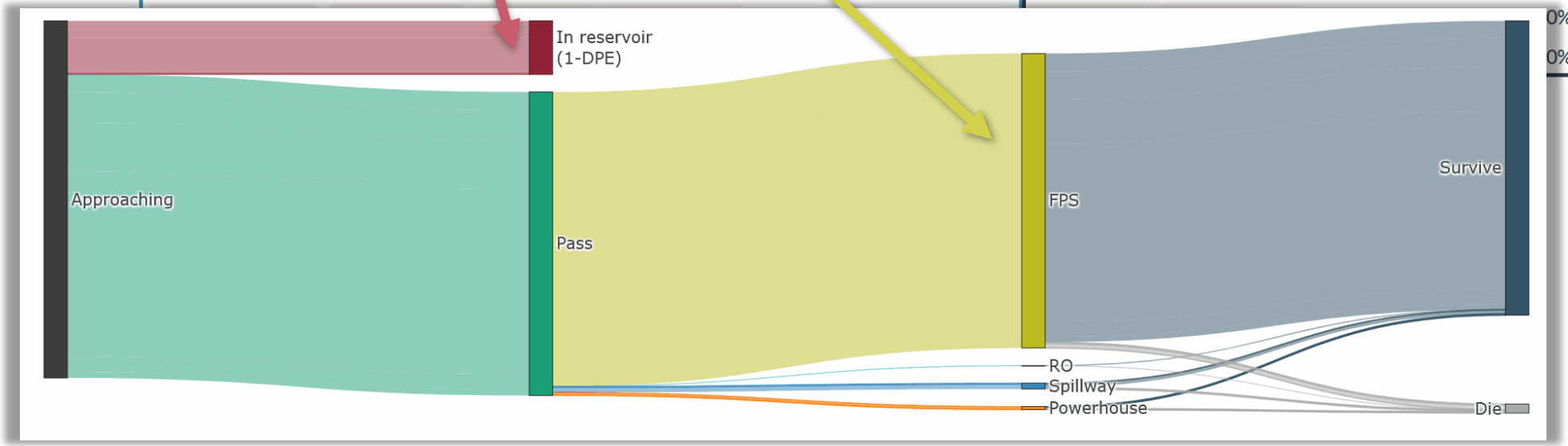
Average monthly fish distribution and survival

Month	% Approaching (calculated)	Population: Forebay	Population: FPS	Population: Turbines	Population: RO	Population: Spillway	Route Survival: FPS	Route Survival: Turbines	Route Survival: RO	Route Survival: Spillway
Jan	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Feb	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Mar	0.060%	0.009%	0.050%	0.000%	0.000%	0.001%	0.049%	0.000%	0.000%	0.001%
Apr	0.100%	0.015%	0.081%	0.002%	0.000%	0.002%	0.079%	0.001%	0.000%	0.002%
May	0.160%	0.024%	0.127%	0.004%	0.000%	0.005%	0.125%	0.002%	0.000%	0.003%
Jun	0.610%	0.092%	0.509%	0.001%	0.000%	0.008%	0.499%	0.001%	0.000%	0.006%
Jul	0.050%	0.008%	0.042%	0.000%	0.000%	0.000%	0.041%	0.000%	0.000%	0.000%
Aug	0.020%	0.003%	0.016%	0.001%	0.000%	0.000%	0.016%	0.001%	0.000%	0.000%

Interactivity and real-time feedback: Results

Average monthly fish distribution and survival

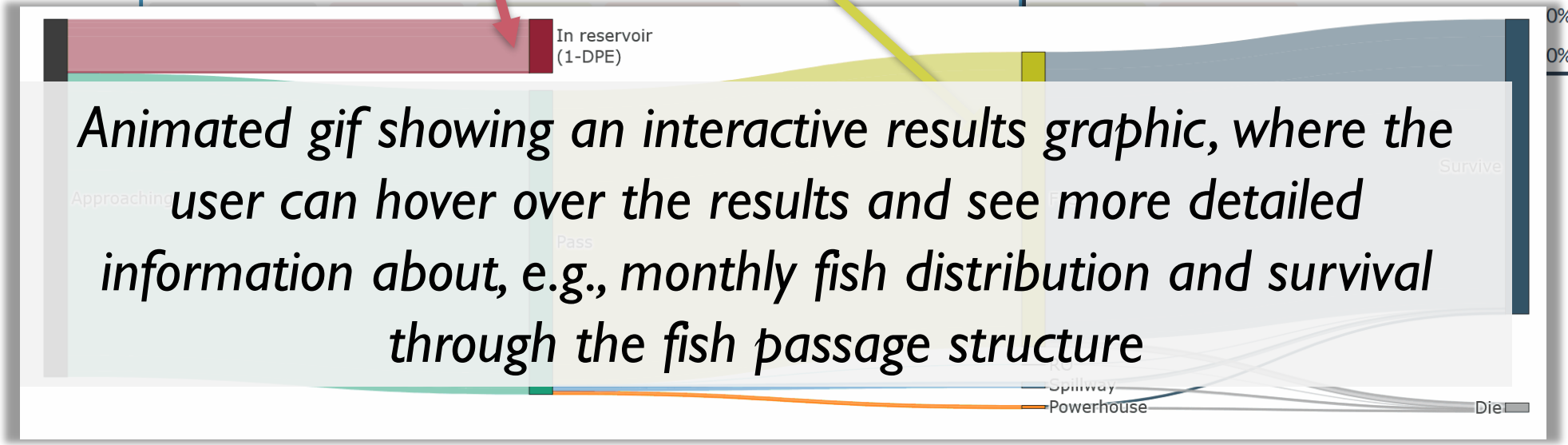
Month	% Approaching (calculated)	Population: Forebay	Population: FPS	Population: Turbines	Population: RO	Population: Spillway	Route Survival: FPS	Route Survival: Turbines	Route Survival: RO	Route Survival: Spillway
Jan	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Feb	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Mar	0.060%	0.009%	0.050%	0.000%	0.000%	0.001%	0.049%	0.000%	0.000%	0.001%
Apr	0.100%	0.015%	0.081%	0.002%	0.000%	0.002%	0.079%	0.001%	0.000%	0.002%
May	0.160%	0.024%	0.127%	0.004%	0.000%	0.005%	0.125%	0.002%	0.000%	0.003%
Jun	0.610%	0.092%	0.509%	0.001%	0.000%	0.008%	0.499%	0.001%	0.000%	0.006%



Interactivity and real-time feedback: Results

Average monthly fish distribution and survival

Month	% Approaching (calculated)	Population: Forebay	Population: FPS	Population: Turbines	Population: RO	Population: Spillway	Route Survival: FPS	Route Survival: Turbines	Route Survival: RO	Route Survival: Spillway
Jan	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Feb	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%	0.000%
Mar	0.060%	0.009%	0.050%	0.000%	0.000%	0.001%	0.049%	0.000%	0.000%	0.001%
Apr	0.100%	0.015%	0.081%	0.002%	0.000%	0.002%	0.079%	0.001%	0.000%	0.002%
May	0.160%	0.024%	0.127%	0.004%	0.000%	0.005%	0.125%	0.002%	0.000%	0.003%
Jun	0.610%	0.092%	0.509%	0.001%	0.000%	0.008%	0.499%	0.001%	0.000%	0.006%



Animated gif showing an interactive results graphic, where the user can hover over the results and see more detailed information about, e.g., monthly fish distribution and survival through the fish passage structure

Overview of the talk: Past, present, and future of FBW

2014

FBW Excel:
Development and deployment

2022-2024

fbwR and Shiny:
Building model accessibility

2024+

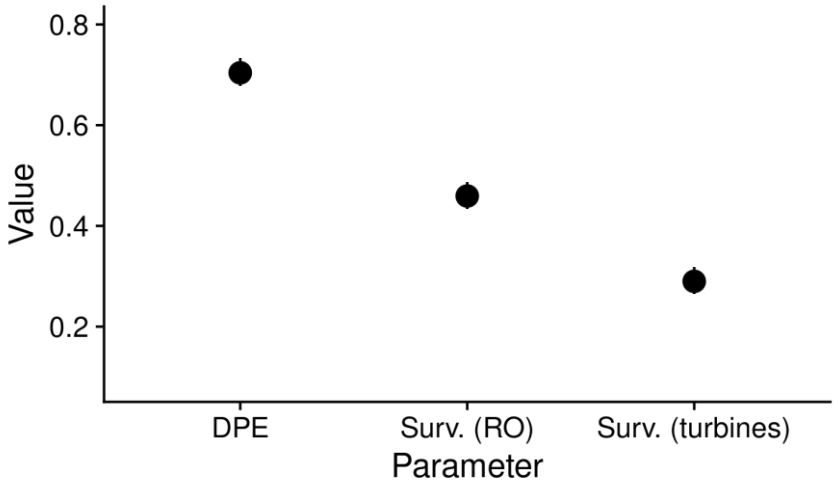
Where next?
Building model capability

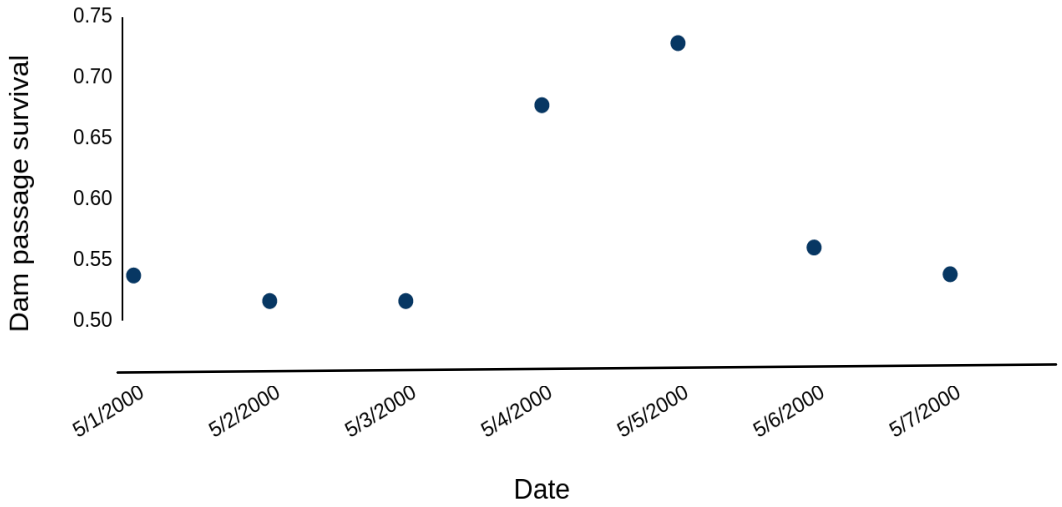
What is next for fbwR Shiny?

- **Current version**: replicates FBW Excel model structure and input types, has been validated against Excel
  - **Over the next year:** Revise the fbwR model and Shiny app to include propagation of uncertainty, new model features

What is next for fbwR Shiny?

- **Current version**: replicates FBW Excel model structure and input types, has been validated against Excel
  - **Over the next year:** Revise the fbwR model and Shiny app to include propagation of uncertainty, new model features

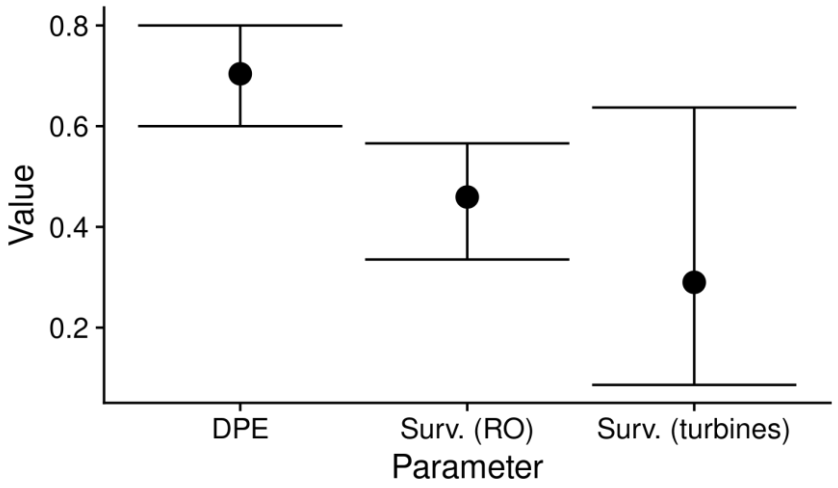


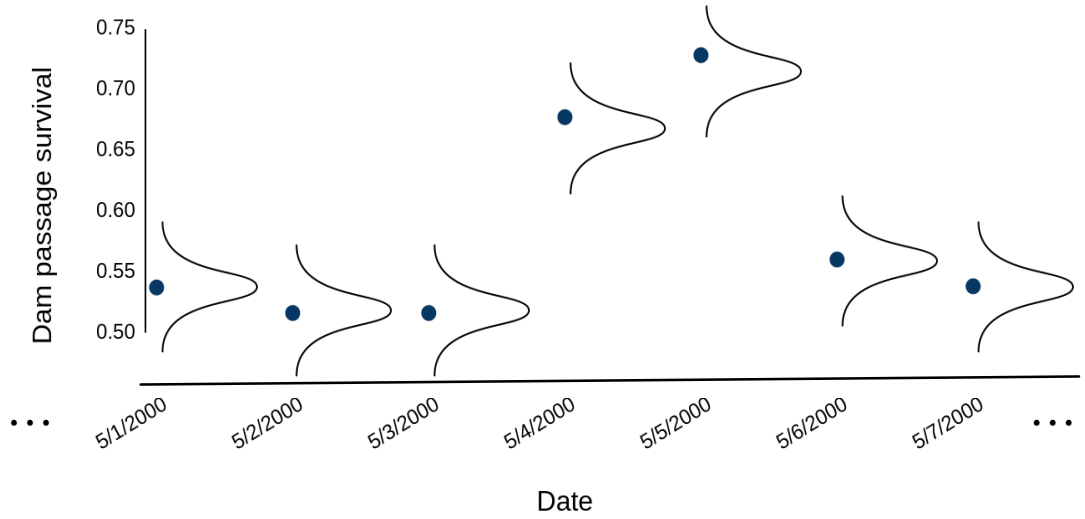


Range of DPE and route survival estimates at Cougar Dam, Beeman *et al.* (2012, 2014)

What is next for fbwR Shiny?

- **Current version**: replicates FBW Excel model structure and input types, has been validated against Excel
  - **Over the next year:** Revise the fbwR model and Shiny app to include propagation of uncertainty, new model features

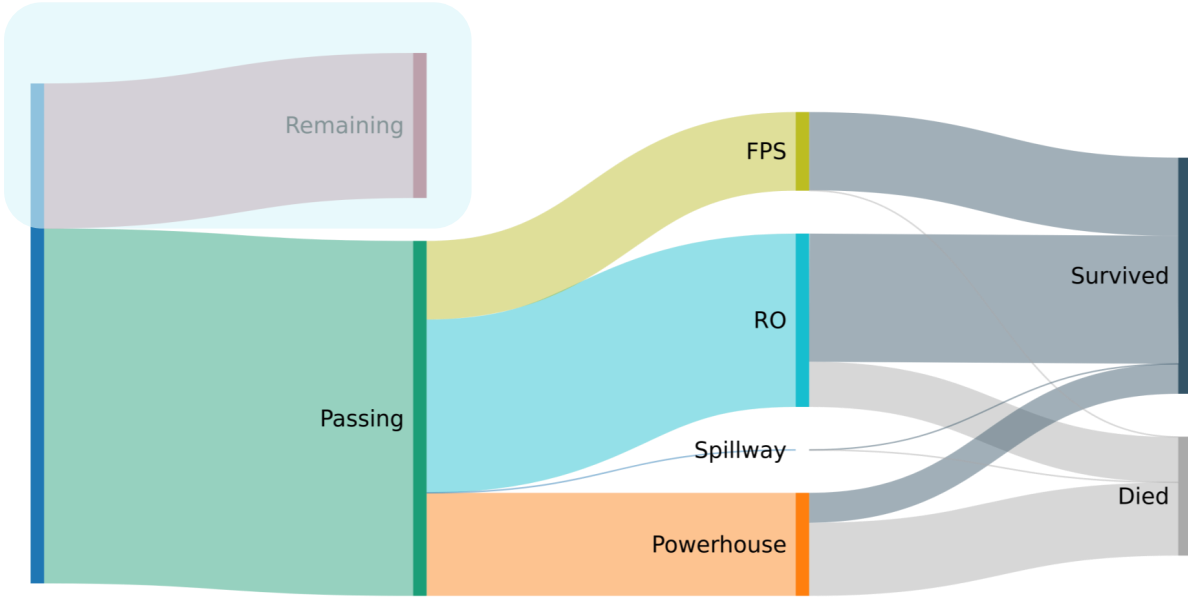




Range of DPE and route survival estimates at Cougar Dam, Beeman *et al.* (2012, 2014)

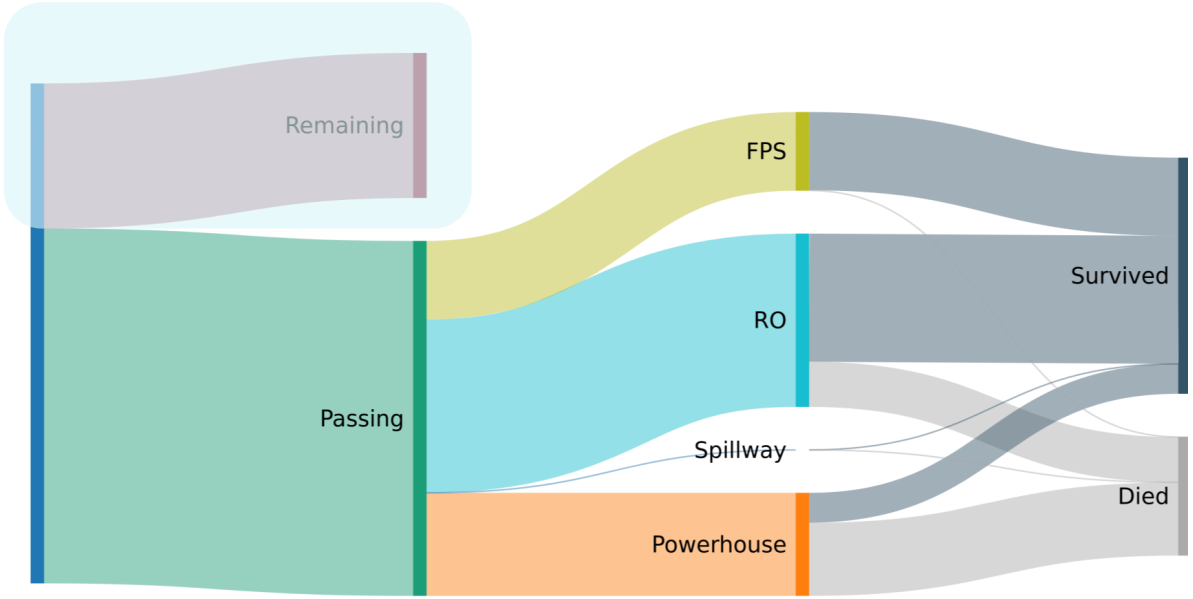
What is next for fbwR Shiny?

- **Current version**: replicates FBW Excel model structure and input types, has been validated against Excel
  - **Over the next year:** Revise the fbwR model and Shiny app to include propagation of uncertainty, new model features



What is next for fbwR Shiny?

- **Current version**: replicates FBW Excel model structure and input types, has been validated against Excel
  - **Over the next year:** Revise the fbwR model and Shiny app to include propagation of uncertainty, new model features

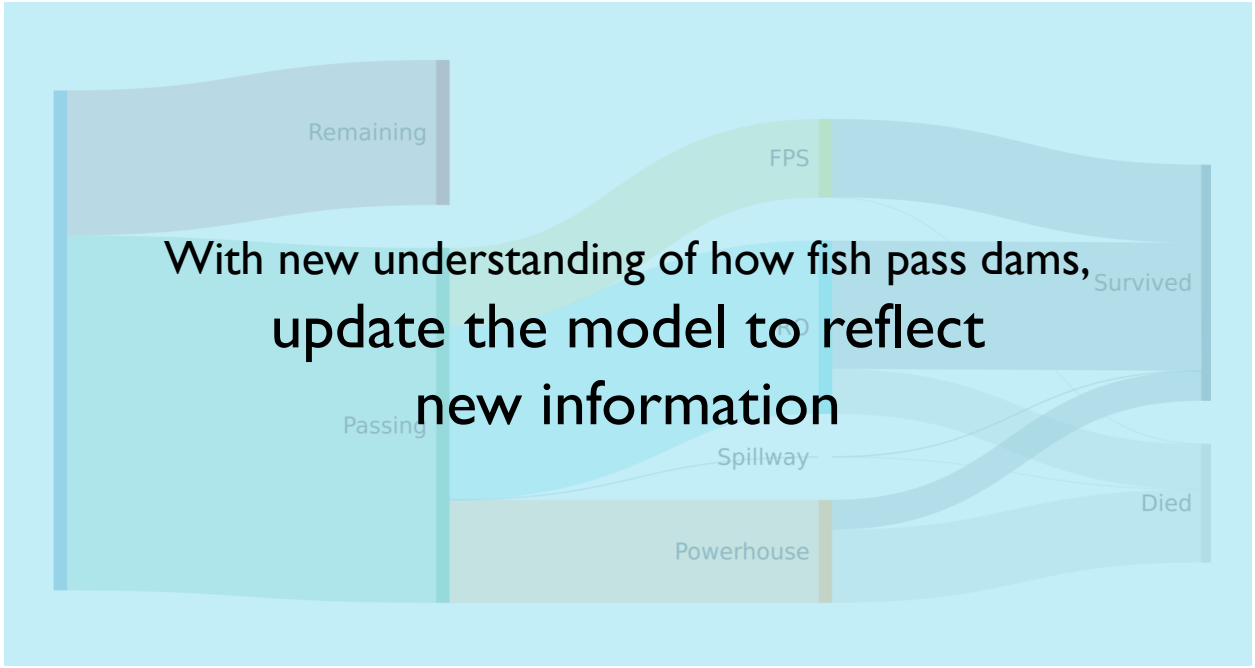


e.g., Model those fish which do not pass the dam

What if they try to pass again the next day?

What is next for fbwR Shiny?

- **Current version**: replicates FBW Excel model structure and input types, has been validated against Excel
  - **Over the next year:** Revise the fbwR model and Shiny app to include propagation of uncertainty, new model features



e.g., Model those fish which do not pass the dam

What if they try to pass
again the next day?

Acknowledgements

- Ryan Woolbright
- Rachel Laird
- Richard Piaskowski
- Michael Koohafkan for software suggestions
- Joshua Roach and Norm Buccola for debugging support
- Biotech and Alden Research Laboratory for documentation, parameterization
- Independent Scientific Advisory Board for comments and review in 2014

and the human guinea-pigs who participated in fbwR testing sessions in summer 2023.

Integrated Fish Passage Project

Interested in participating in an fbwR Shiny demo session?

- Scanning this QR code will take you to a Google Form asking for your **name and an email address** where I will contact you when the Shiny app ready for demonstration

https://forms.gle/DeGTBAJzbPn148kH9

m.deith@oceans.ubc.ca

Integrated Fish Passage Project