U.S. Department of the Interior
U.S. Geological Survey

Background Information for “Proposal to Amend the High-Flow Experiment (HFE) Protocol”

Glen Canyon Dam Adaptive Management Program
Adaptive Management Work Group Meeting
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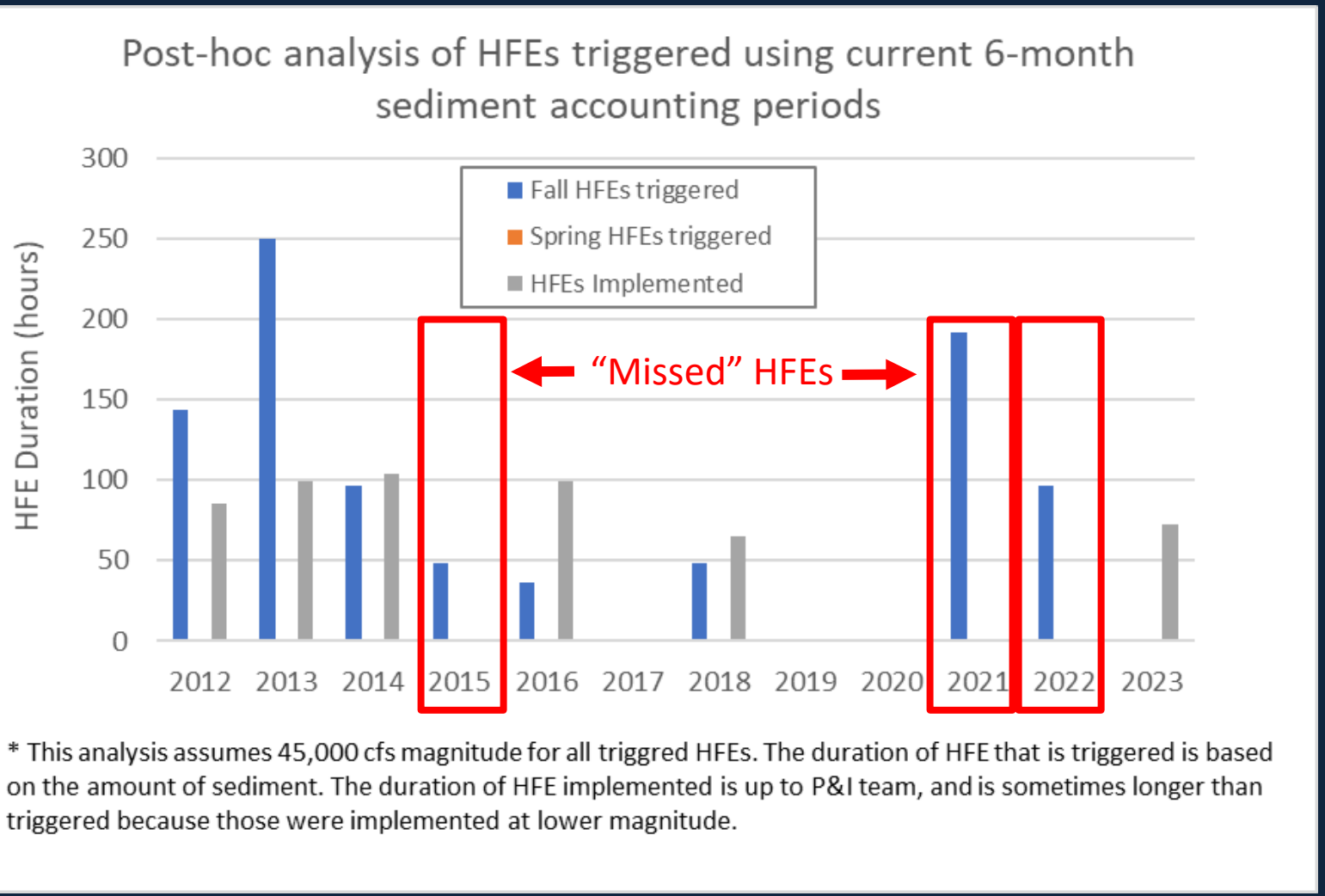
HFE Protocol: 2012 - 2022



* This analysis assumes 45,000 cfs magnitude for all triggred HFEs. The duration of HFE that is triggered is based on the amount of sediment. The duration of HFE implemented is up to P&I team, and is sometimes longer than triggered because those were implemented at lower magnitude.

- For 11-year period of HFE Protocol (including LTEMP)
  - 8 Fall HFEs triggered
  - 5 Fall HFEs implemented
  - 0 Spring HFEs triggered
  - 1 HFE implemented in spring 2023 (as "one-off", not following Long-Term Experimental Management Plan (LTEMP) Protocol)

Motivation for proposed changes to HFE Protocol:
3 HFE opportunities "missed" because of concerns with fall timing and risks related to non-native fish and low reservoir levels

Preliminary results, subject to review, do not cite

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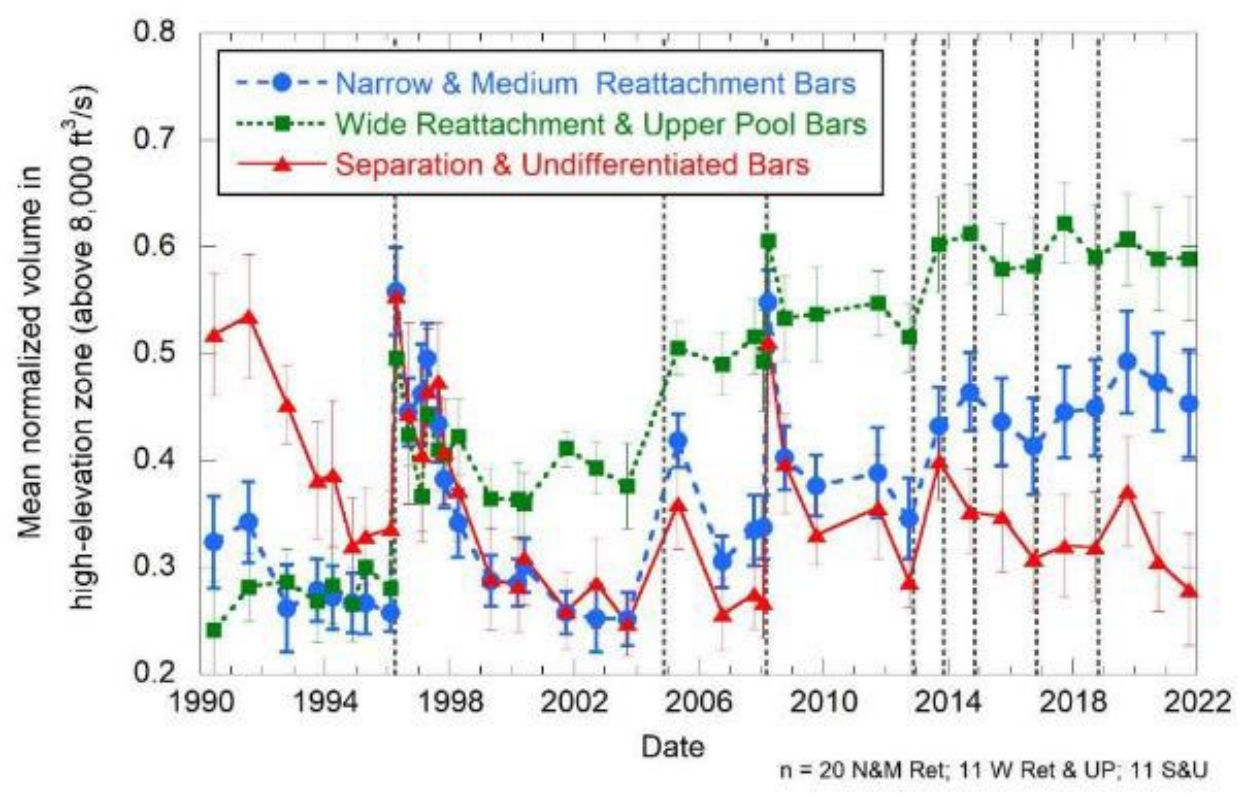
Sandbar monitoring results by bar type: 1990 to 2021

Sand above 8,000 ft^3/s stage



Wide Reattachment & Upper Pool Bars
- Less common campsites and least responsive to HFEs.
- No change 2020 to 2021.

Narrow & Medium Reattachment Bars
- Common campsites and most responsive to HFEs.
- Net decrease 2020 to 2021

Separation & Undifferentiated Bars
- Common campsites and variable response to HFEs.
- Net decrease 2020 to 2021.

All Bar Types
- 2012 to 2019 net increase during period with frequent HFEs
- 2020 to 2021 decrease or no change during period without HFEs

Three Key Ingredients for Successful HFEs:

1. There is sufficient sand in the system to build sandbars without causing net erosion.
   - *Addressed in HFE Protocol by using sediment model to design HFE.*
2. Sand grain size is sufficiently fine to create conditions of high sand concentration in eddies.
   - *Addressed in HFE Protocol by using sediment model to design HFE.*
3. HFE magnitude is high enough to deposit sand at the high-elevation parts of sandbars and campsites.
   - *Addressed in HFE Protocol by step-down approach to find the largest HFE that can be implemented for the available sand supply (consistent with 1 and 2, above).*

These guidelines are embedded in the LTEMP ROD and are based on observations from first three HFEs (1996, 2004, and 2008) and verified by observations from recent HFEs (2012, 2013, 2014, 2016, and 2018)

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HFE magnitude, duration, and frequency all affect response and are not interchangeable

- **HFE Magnitude** controls potential deposit size.
- **HFE Duration** is needed to maximize the period of elevated sand concentrations.

  → Magnitude and duration are optimized using model in HFE planning.

- **Frequency** is needed to rebuild the deposits that erode between HFEs.

  → Frequency is optimized by use of sediment accounting periods to identify conditions of sand enrichment.

Hazel and others (2022), Wiele and others (1999)

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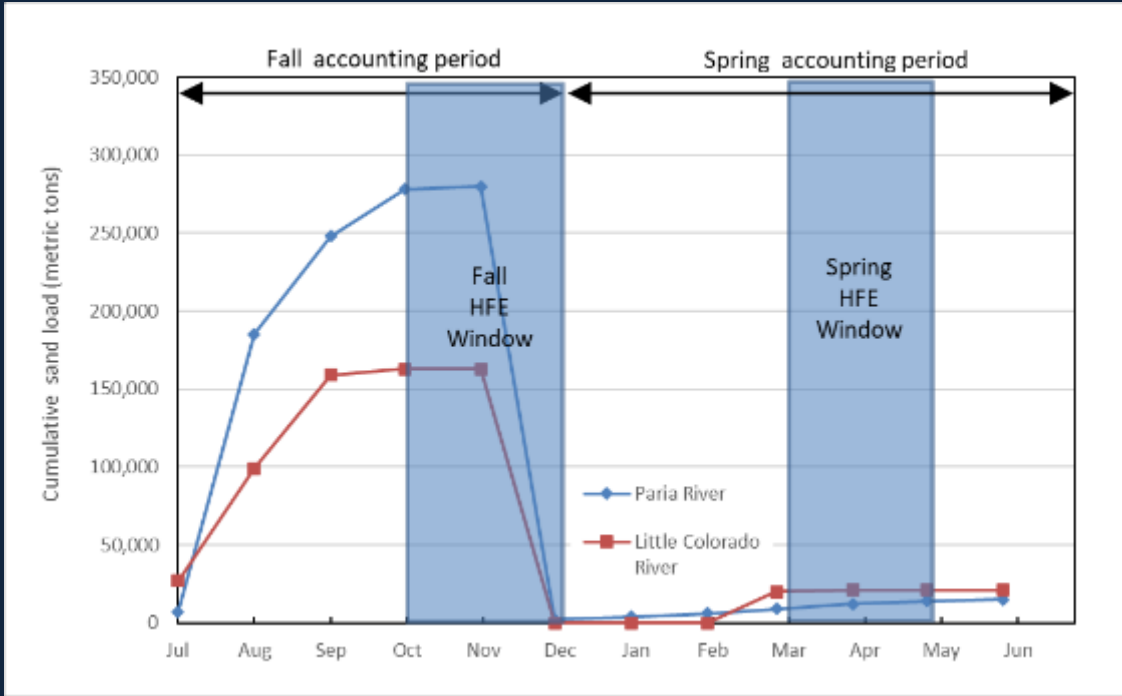
Revised sediment accounting periods

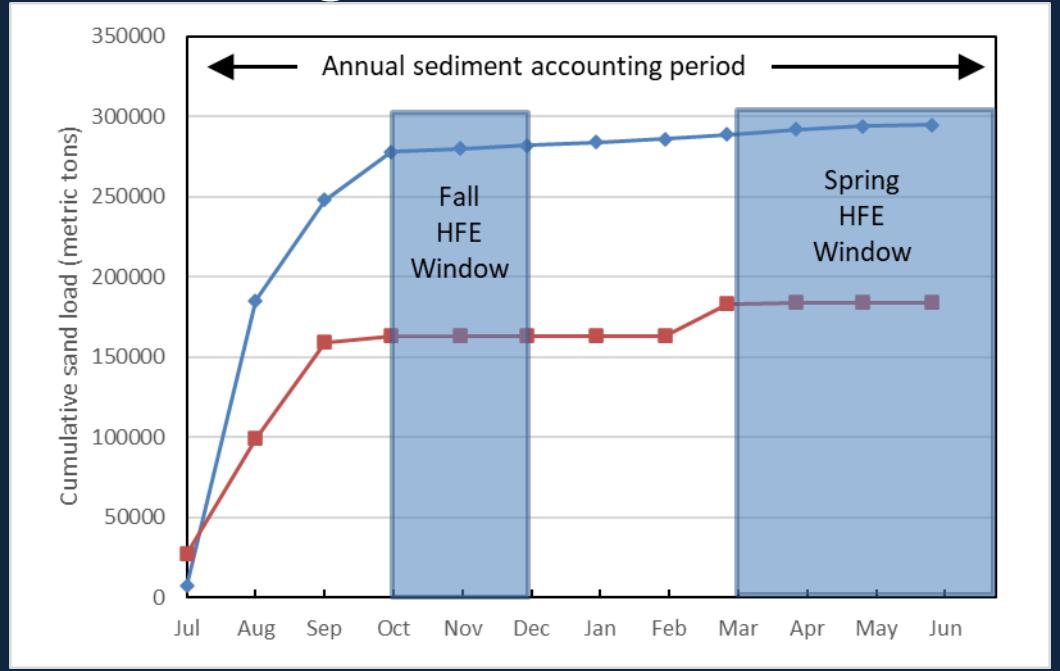
LTEMP sediment accounting



Optimizes to implement HFE as soon after Paria sediment inputs as possible.

- **Important when winter releases are high.**

Proposed one-year sediment accounting



Optimizes to implement HFE following accumulation of both Paria and LCR inputs.

- **Works best when winter releases are low.**

Data from www.gcmrc.gov/discharge_qw_sediment

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The sediment accounting method for HFE planning

Sand inputs from Paria River (plus estimate for ungaged tributaries)

Sand transport at RM 61

Marble Canyon Sand Mass Balance

The sediment "accounting period" is the time period over which the mass balance is calculated to estimate the amount of new Paria-supplied sand available for building sandbars with an HFE

- The sand mass balance can be computed over any time period based on observations (*www.gcmrc.gov/discharge_qw_sediment*)
- The mass balance can also be predicted using the sand routing model
  - For HFE planning, the model is run using observed Paria sand inputs
  - The model then predicts how much of those inputs remain using planned dam operations (including potential HFE) for the rest of the accounting period

The "optimal" HFE is the one that results in a mass balance just greater than zero for the accounting period

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Post-hoc modeling for HFE implementation using 1-year accounting window

	HFEs triggered and implemented under HFE Protocol and LTEMP EIS			Duration triggered (Oct 15 model run)			Duration triggered (LTEMP accounting)	Duration triggered (Mar 15 model run)	Duration triggered (May 15 model run)		
Year*	Magnitude triggered (cfs)	Magnitude implemented (cfs)	Duration implemented (hours)	Nov HFE (hours)	Apr HFE (hours)	Jun HFE (hours)	Apr HFE (hours)	Apr HFE (hours)	Jun HFE (hours)	"Best" Implementation month***	Choice following proposed decision approach****
2012	45000	44,500	85	144	96	96	0	144	96	Nov & Apr	Nov or Apr
2013	45000	37,000	99	250	250**	250**	0	250	250	Any	Any month**
2014	45000	38,000	104	96	72	72	0	72	72	Nov	Nov
2015	45000		-	48	12	1	0	48	36	Nov and Apr	Nov
2016	45000	36,500	99	36	1	0	0	12	12	Nov	Nov
2017			-	0	0	0	0	0	0		-
2018	45000	39,500	65	48	12	1	0	72	60	Apr	Nov
2019			-	0	0	0	0	0	0		-
2020			-	0	0	0	0	0	0		-
2021	45000		-	192	144**	144**	0	144	144	Nov	Any month**
2022	45000		-	96	96	72	0	96	72	Any	Nov or Apr

Red box = information for October decision Orange box = updated information for Spring implementation

* Year of beginning of sediment accounting window. Fall HFEs are in same year; Spring HFEs are in following calendar year.

**** Extended duration with advance warning:**

There are opportunities (Yellow boxes) where it would be possible to test the desired extended duration HFEs with long advance notice. Testing those was part of LTEMP, but they have not been implemented, in part because it's difficult to initiate a major experiment with short notice.

*** Evaluation for best implementation month assumes that all HFEs > 96 hour duration are equal. That may not be correct and needs to be tested with extended duration HFE.

**** Possible decision approach:**

- If 96 hr or longer is possible in Fall or Spring (based on Oct. prediction), choose implementation month based on other resource considerations.
- If 96 hr or longer is possible in Fall, but less than 96 hr in Spring (based on Oct. prediction), choose Fall unless resource impacts force Spring choice.
- If less than 96 hr is possible in Fall (based on Oct. prediction), choose implementation month based on other resource considerations.

Assumptions:

All HFEs are 45,000 cfs magnitude

4000 cfs/hr ramp up, 2500 cfs/hr ramp down

mass balance evaluated from July 1 to conclusion of HFE

used lower bound Paria sand load prediction (10% uncertainty), no inputs after prediction date

Preliminary results, subject to review, do not cite

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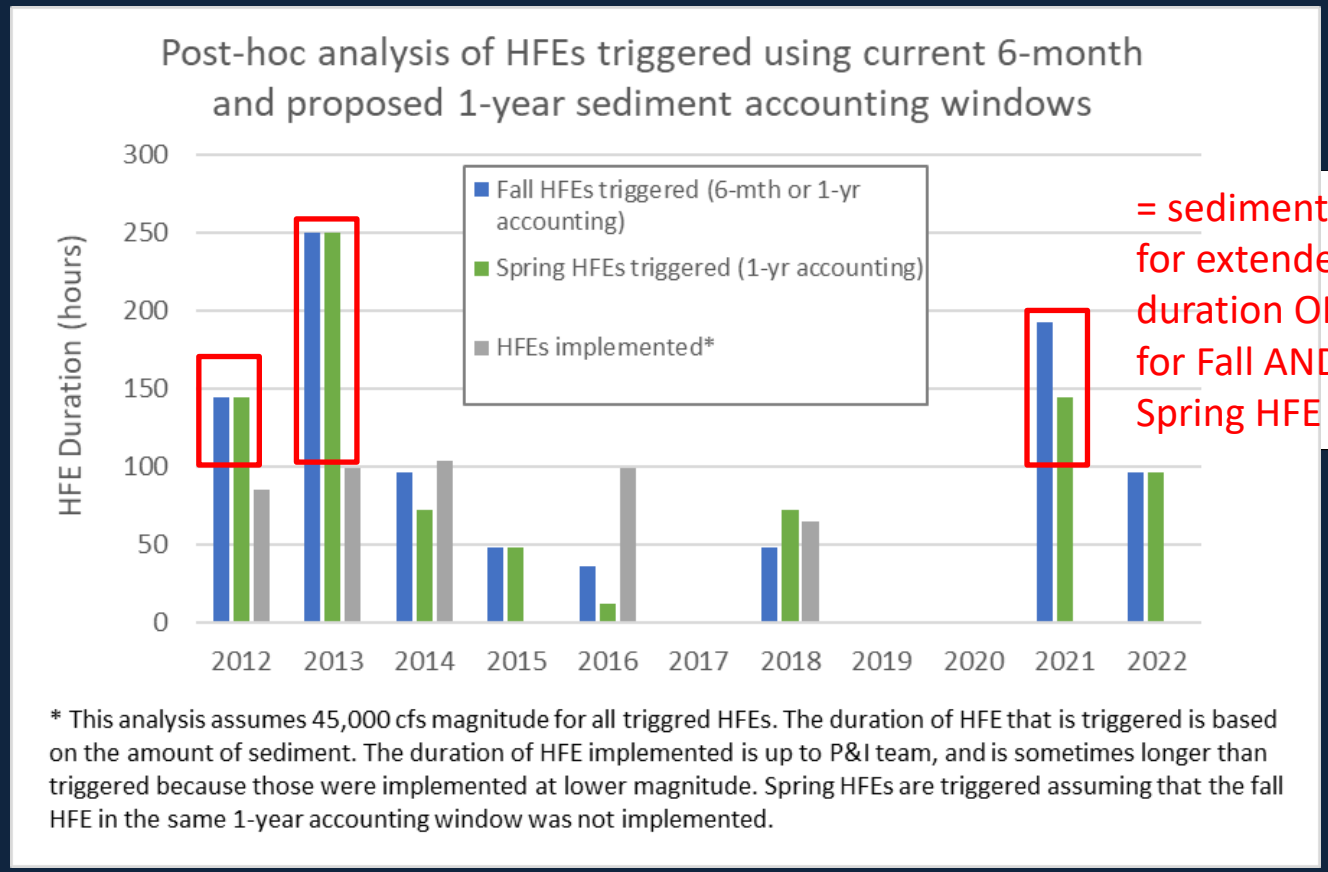
Expected HFE frequency: LTEMP vs proposed 1-year sediment accounting

- LTEMP Fall HFEs:
  - LTEMP Analysis: 15 out of 20 years (77%)
  - Triggered (2012-2022): 8 out of 11 years (73%)
  - Implemented (2012-2022): 5 out of 11 years (45%)
- LTEMP Spring HFEs:
  - LTEMP Analysis: 5 out of 20 years (26%)
  - Triggered (2012-2022): 0 out of 11 years (0%)

- Proposed 1-year sediment accounting:
  - LTEMP Analysis: TBD
  - Post-hoc of actual (2012-2022): 8 out of 11 years (73%) could do either Fall or Spring
    - 3 out of 11 years may have the opportunity to do both fall and spring



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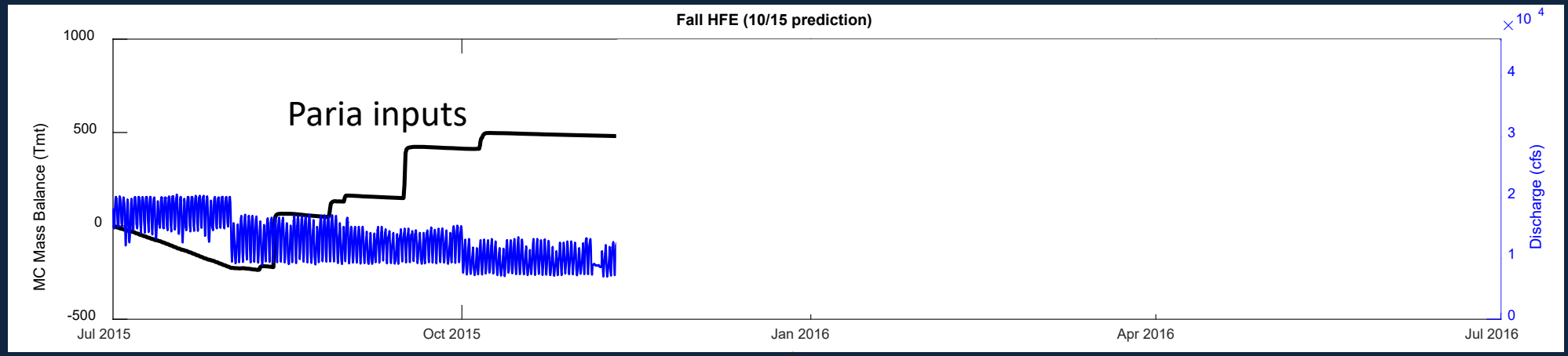
Example: 2015 sediment year



Planning process

- Step 1 (Aug-Oct): Monitor Paria inputs in late summer and fall.

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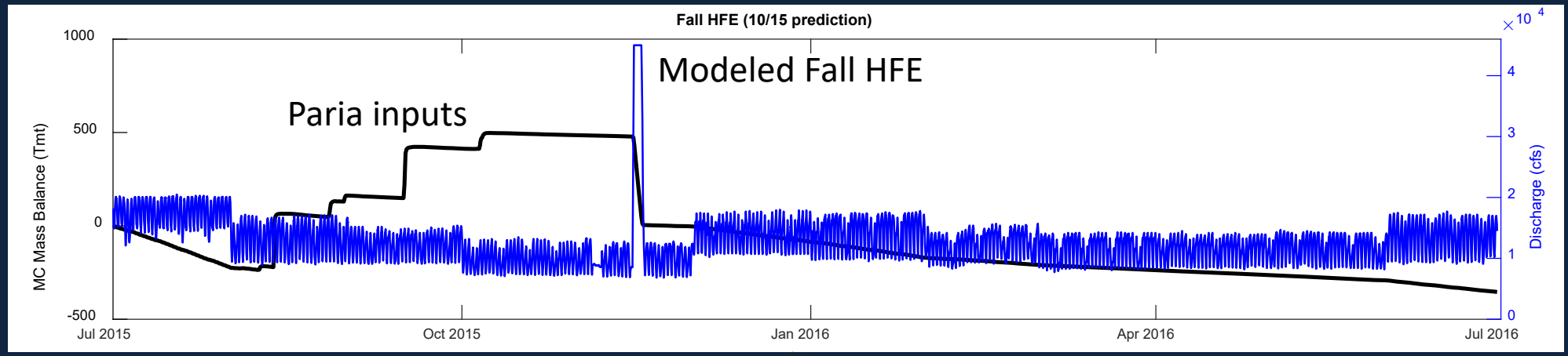
Example: 2015 sediment year

Oct. projection: 48 hr Fall HFE



Planning process

- Step 1 (Aug-Oct): Monitor Paria inputs in late summer and fall.
- Step 2a (Sep-Oct): Model potential fall HFE for P&I Team consideration.

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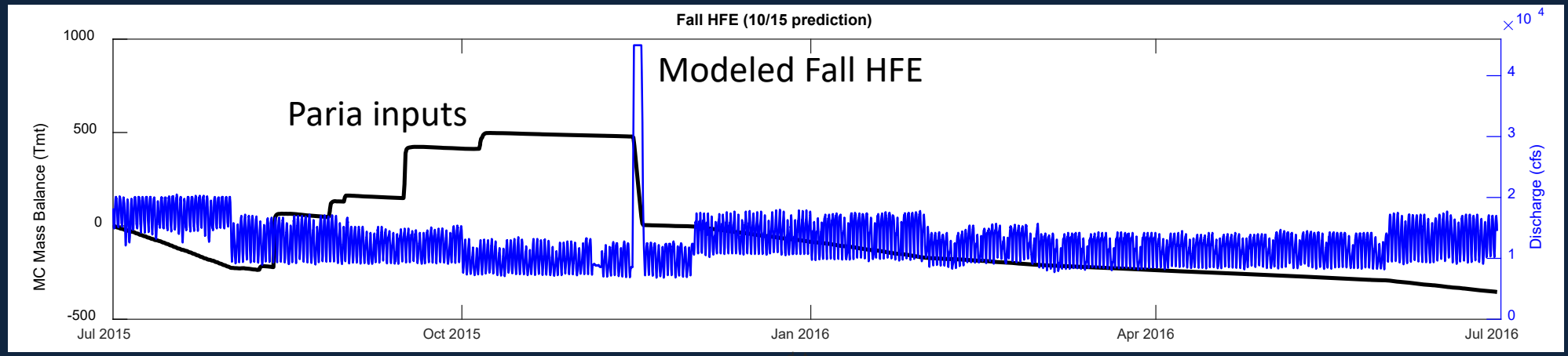
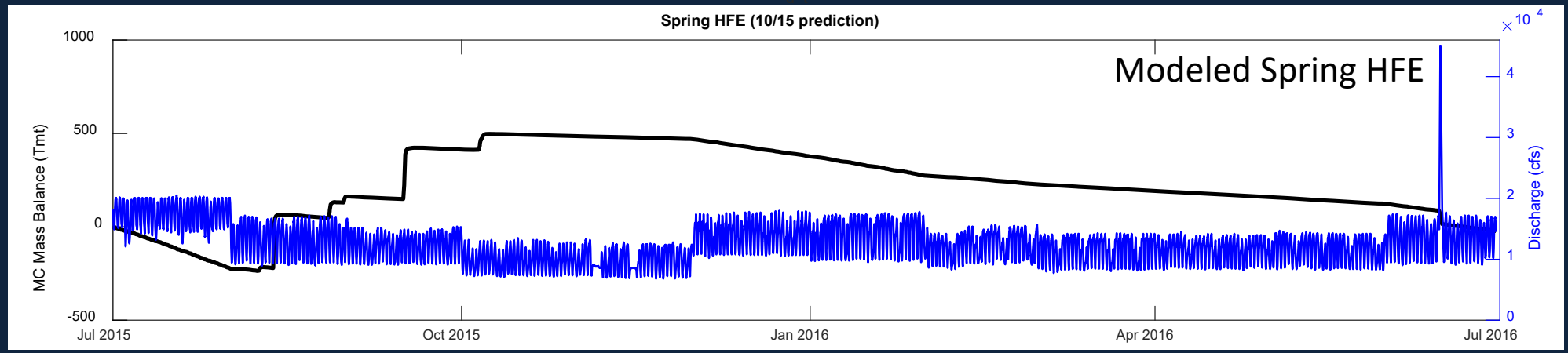
Example: 2015 sediment year

Oct. projection: 48 hr Fall HFE

OR

Oct. projection: 1 hr Spring HFE





Planning process

- Step 1 (Aug-Oct): Monitor Paria inputs in late summer and fall.
- Step 2a (Sep-Oct): Model potential fall HFE for P&I Team consideration.
- Step 2b (Sep-Oct): Model potential spring HFE for P&I Team consideration.

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Example: 2015 sediment year

Oct. projection: 48 hr Fall HFE

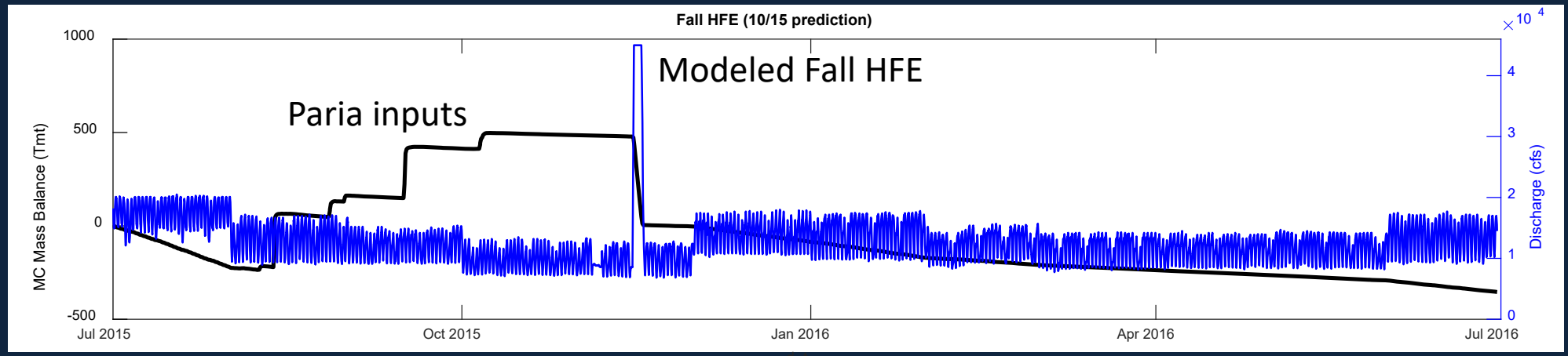
OR

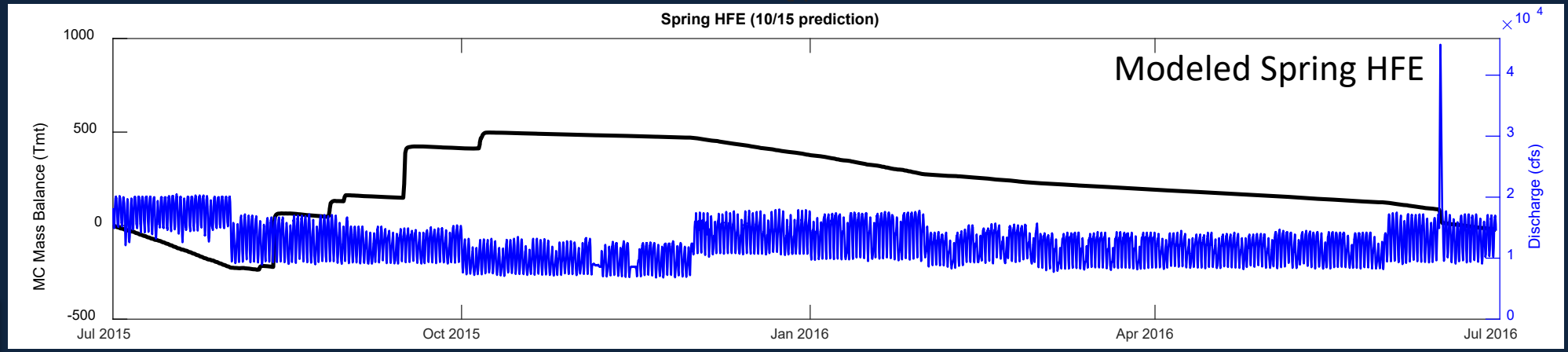
Oct. projection: 1 hr Spring HFE

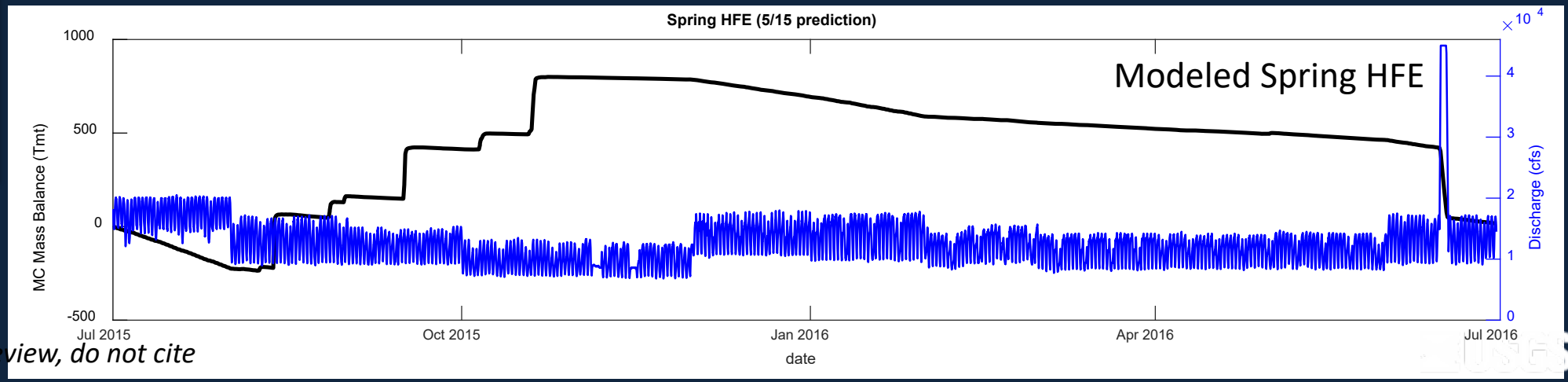
Planning process

- Step 3 (Feb-Mar): Re-model potential spring HFE for P&I Team consideration.

Apr. projection: 36 hr Spring HFE







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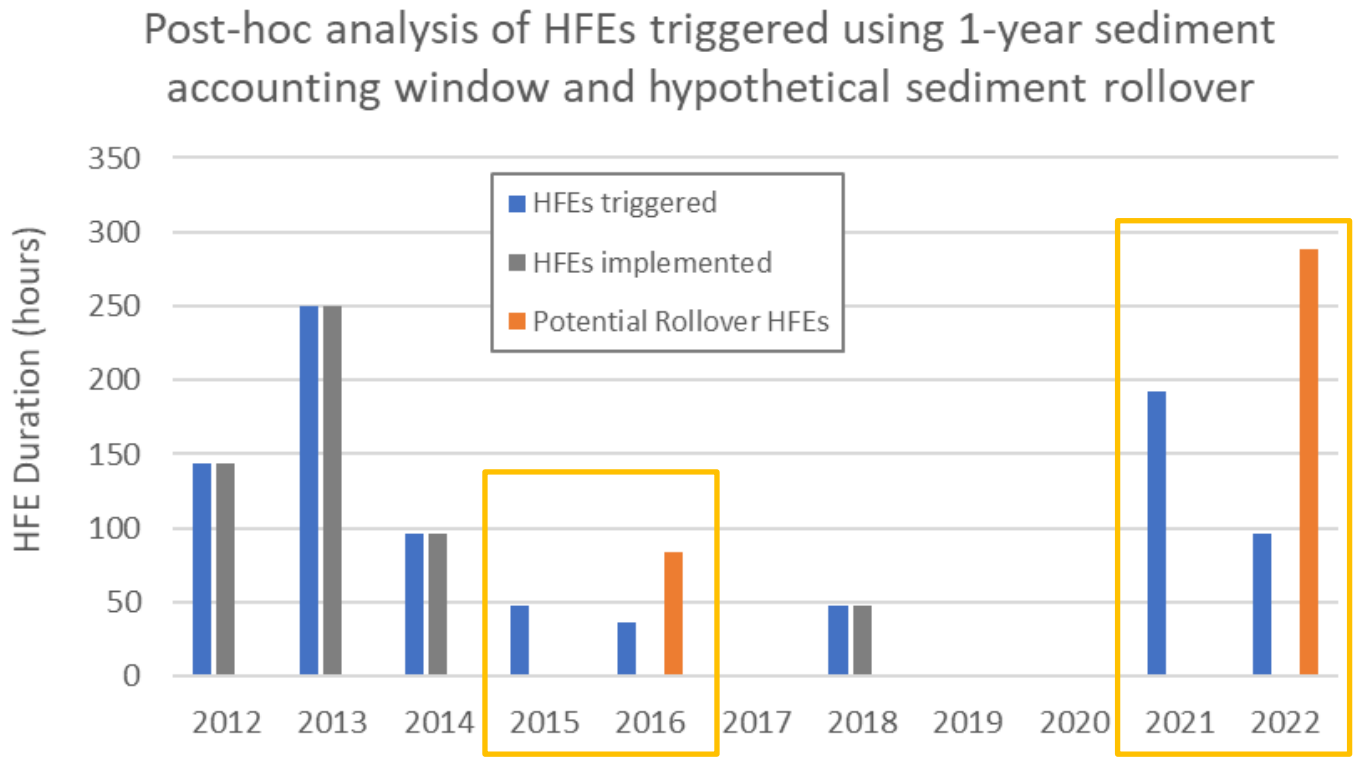
How would sediment “rollover” affect HFE frequency?



* This analysis assumes 45,000 cfs magnitude for all triggred HFEs. In the "rollover" scenario, HFEs were not implemented in 2015 and 2021 and that sediment was carried forward. The result is fewer HFEs implemented, but the HFEs in 2016 and 2022 could be longer duration, subject to recommendation by P&I team.

- “Rollover” only occurs when HFEs are **not** implemented → can’t increase HFE frequency.
- In this example, HFEs were not implemented in 2015 and 2021 and that sediment was carried forward.
- In rollover scenarios, one HFE is implemented for two “triggers”.
- The rollover HFEs *could* be longer duration, subject to recommendation by P&I team.

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