A Predictive Model of Irrigation System Management on the Henry's Fork

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Wood River Water Collaborative, December 19, 2018

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Outline

1. Watershed description and background
2. Model structure and components
3. Model implementation and performance
4. Transferability to other watersheds

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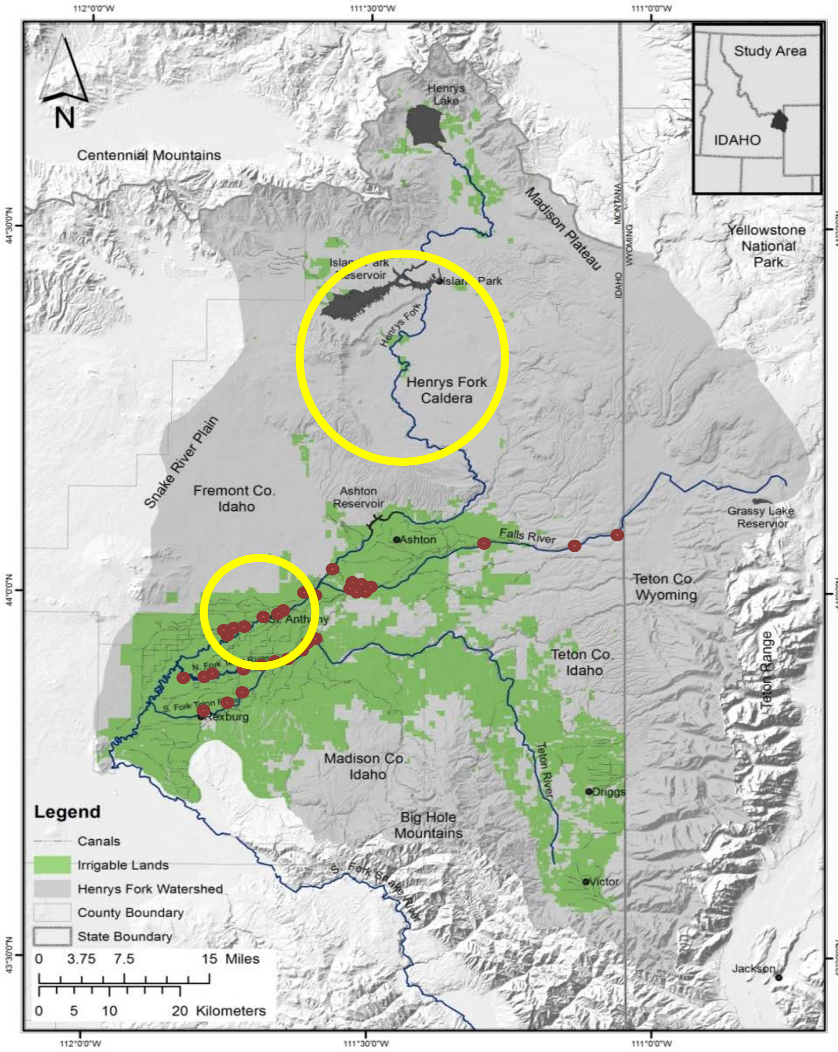

Henry's Fork: The Working River

Three Storage Reservoirs

- Henrys Lake: 90,000 a-f
- Island Park Reservoir: 135,000 a-f
- Grassy Lake: 15,000 a-f

- 450,000 acres with irrigation water rights (22% of total area)
- 250,000 acres in Fremont-Madison Irrigation District (FMID)
- 35 major canal systems
- 450 miles of canal
- Over 150 points of diversion
- 1504 water rights for irrigation from surface water

Seven hydroelectric plants

- Island Park
- Ashton
- Chester
- St. Anthony
- Buffalo River
- Marysville
- Felt

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Background

- 1984: HFF founded to "conserve, restore, and protect the unique fishery, wildlife and aesthetic qualities of the Henry's Fork", focused on 15 miles of river immediately downstream of Island Park Reservoir (Caldera Reach)
- 1980s-1990s: Research identified flow-dependent winter survival of juvenile trout as single factor limiting trout recruitment in this reach
- 1993: Henry's Fork Watershed Council formed
- 2003: Reclamation facilities transferred to FMID; Congressional act required collaborative drought management planning (DMP)
- 2005-2016: Core of HFF's work still focused on Caldera reach:
    1. Fish passage into Buffalo River (tributary downstream of dam)
    2. Work through DMP to store more water in reservoir Sept-Nov to allow higher flow Dec-Mar when trout need it most
- 2016: 4th year of severe drought

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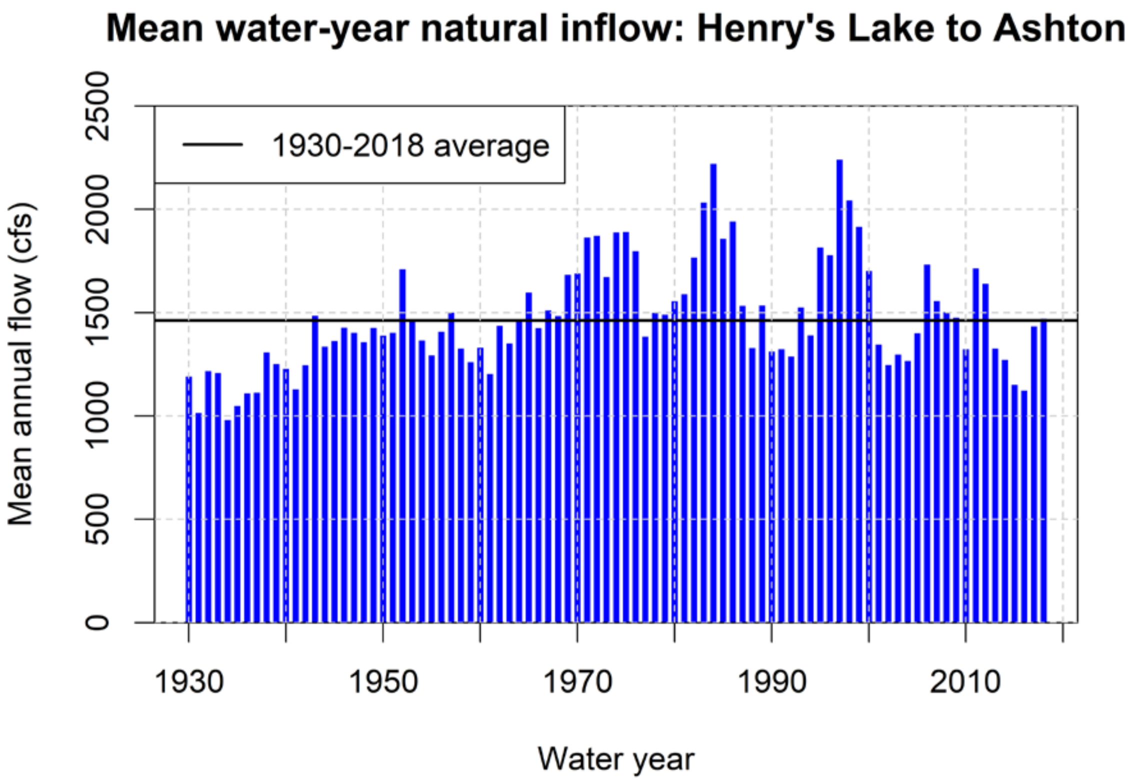
Drought of 2016



- Driest 4-year sequence since late 1930s
- Warm spring caused snowmelt 3 weeks early
- Delivery of storage water began 3 weeks early
- Reservoir was drained to 15% capacity
- Water quality was poor
- Anglers were angry with irrigators and HFF

After 2016: Preparing for the new normal

<u>Comprehensive scientific assessment</u>

- Climate
- Water quality
- Aquatic invertebrates
- Angler satisfaction
- Hydrology and water management
- Effectiveness of previous programs

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Increased reliance on reservoir storage delivery to meet demand

INCREASES
- Algae and cyanobacteria in reservoir
- Mid-summer flow below reservoir
- Suspended sediment delivery
- Turbidity
- Water temperature downstream

DECREASES
- Quality of angling experience in river
- Winter flow when refilling
- Trout recruitment (dependent on winter flow)
- Quality of stream habitat and invertebrate community structure
- Certainty of refill of storage rights the following year

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12 years of fish passage and winter flow management =

- $100,000s - $1,000,000s
- 9% increase in trout population (year-to-year variability is 25%)

<u>New strategies</u>

1. Audience-specific communication, education and outreach
2. Incentive-based on-farm programs to reduce mid-summer diversion
3. Managed aquifer recharge
4. Precise water management in real time

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Predictive System Management Model

At daily time scale, model tracks:

- Natural streamflow
- Irrigation diversion
- River gains from/losses to groundwater
- Reservoir storage/delivery
- Resulting regulated streamflow

Features

- Written from scratch in R
- Predicts April-September hydrology based only on April-1 conditions
- Stochastic (most inputs come from probability distributions)
- Outputs include probability intervals
- Operational criteria and constraints can be varied to test scenarios

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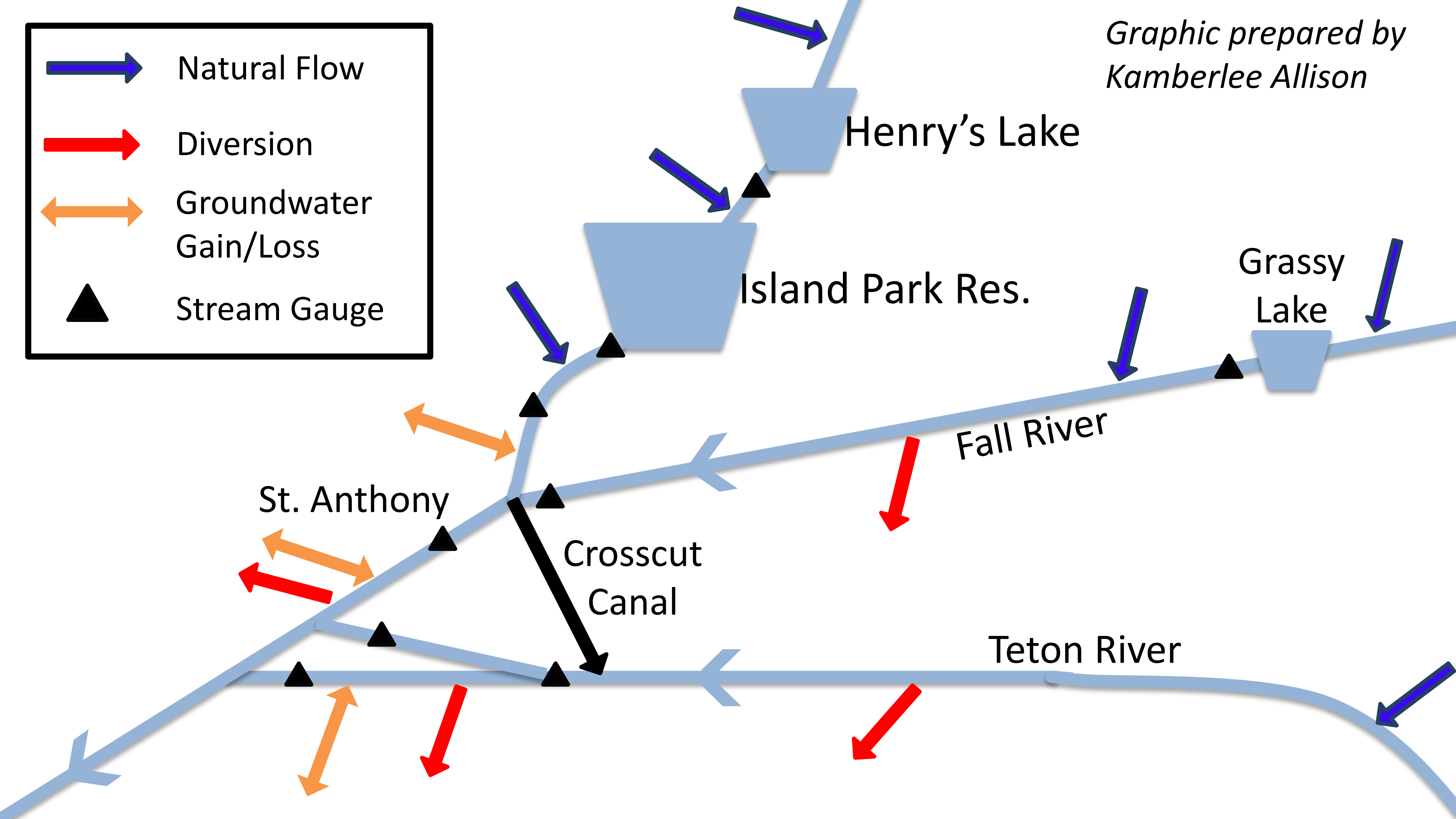


Natural Flow
Diversion
Groundwater Gain/Loss
Stream Gauge
Graphic prepared by Kamberlee Allison
Henry's Lake
Island Park Res.
Grassy Lake
Fall River
St. Anthony
Crosscut Canal
Teton River

Predictors and statistical models for inputs

<u>Natural streamflow volume: multiple regression</u>

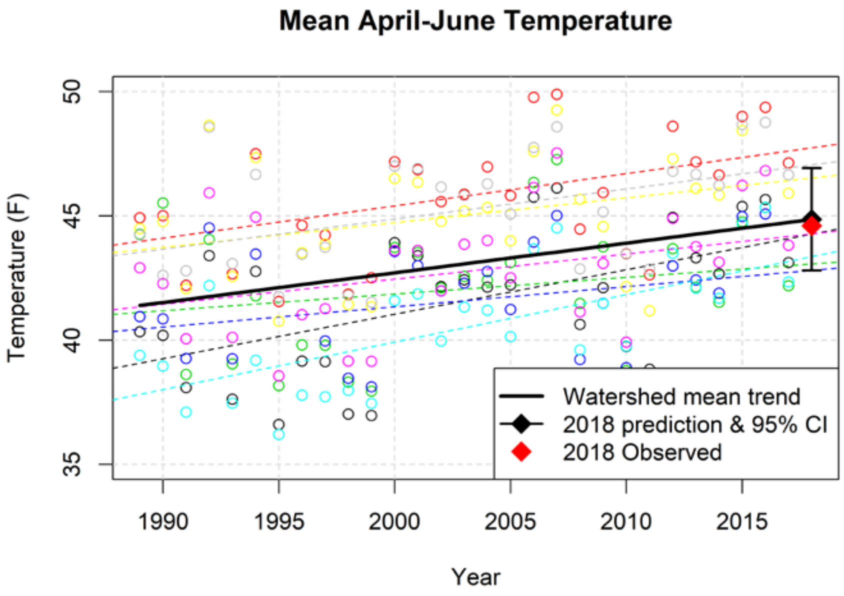
- April 1 snow water equivalent
- October-March baseflow

<u>Timing of runoff: multiple regression</u>

- April 1 snow water equivalent
- April-June temperature, from trend

<u>Irrigation diversion: time series model</u>

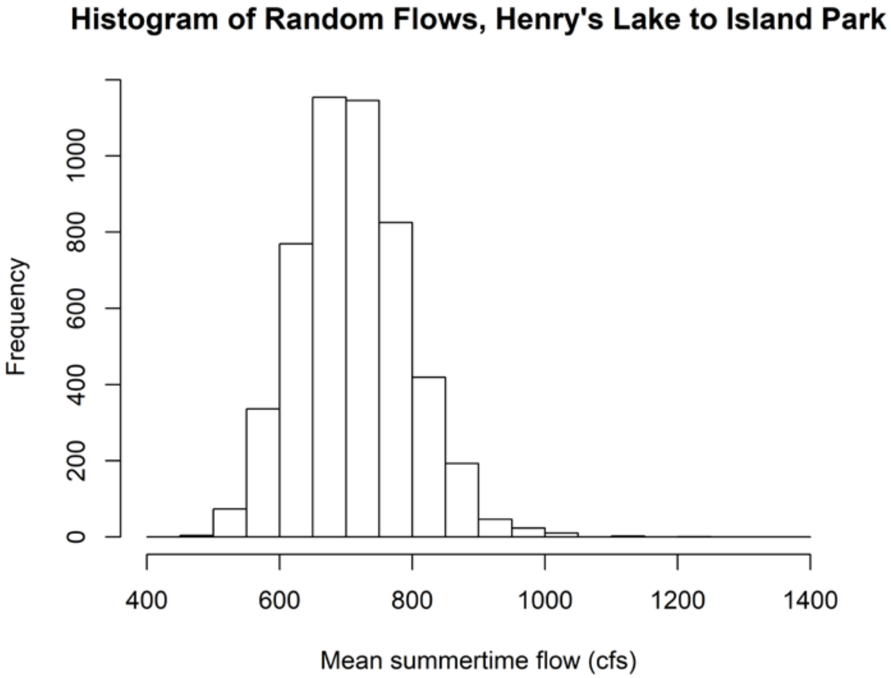
- Based on 40-year trend

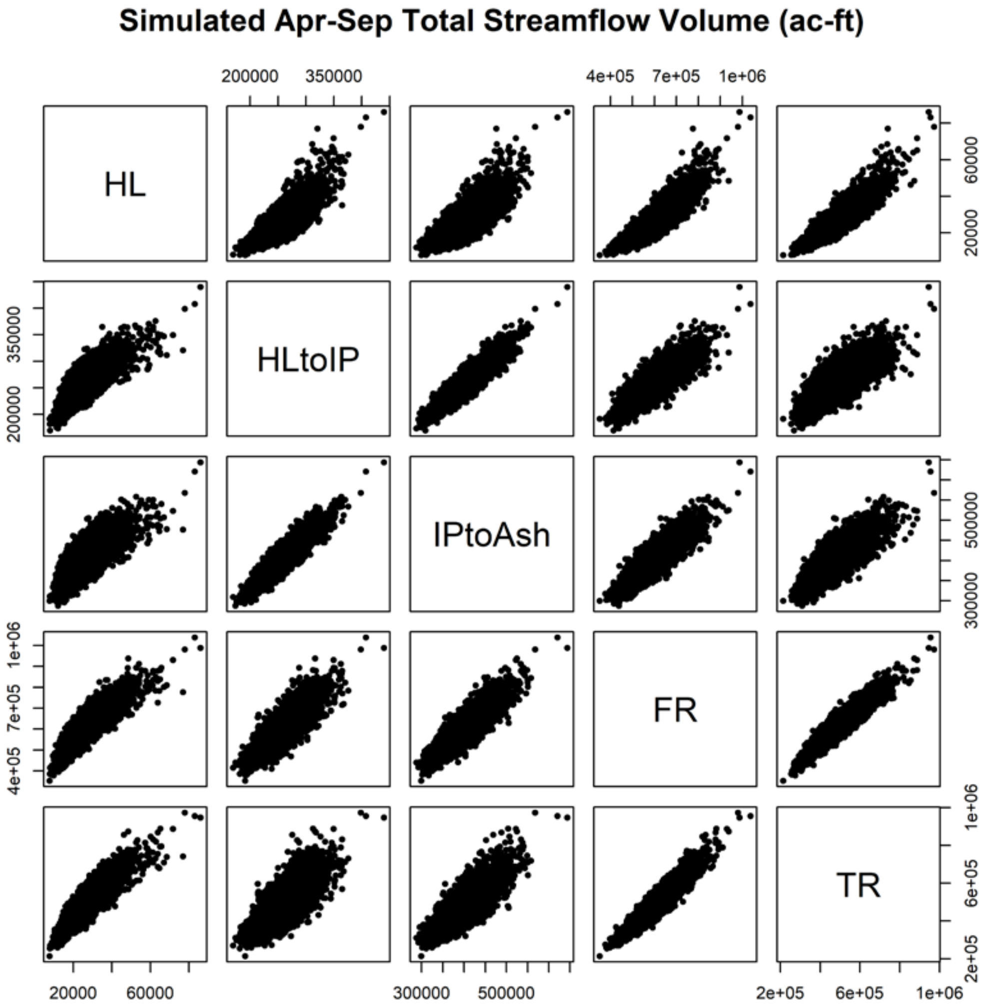


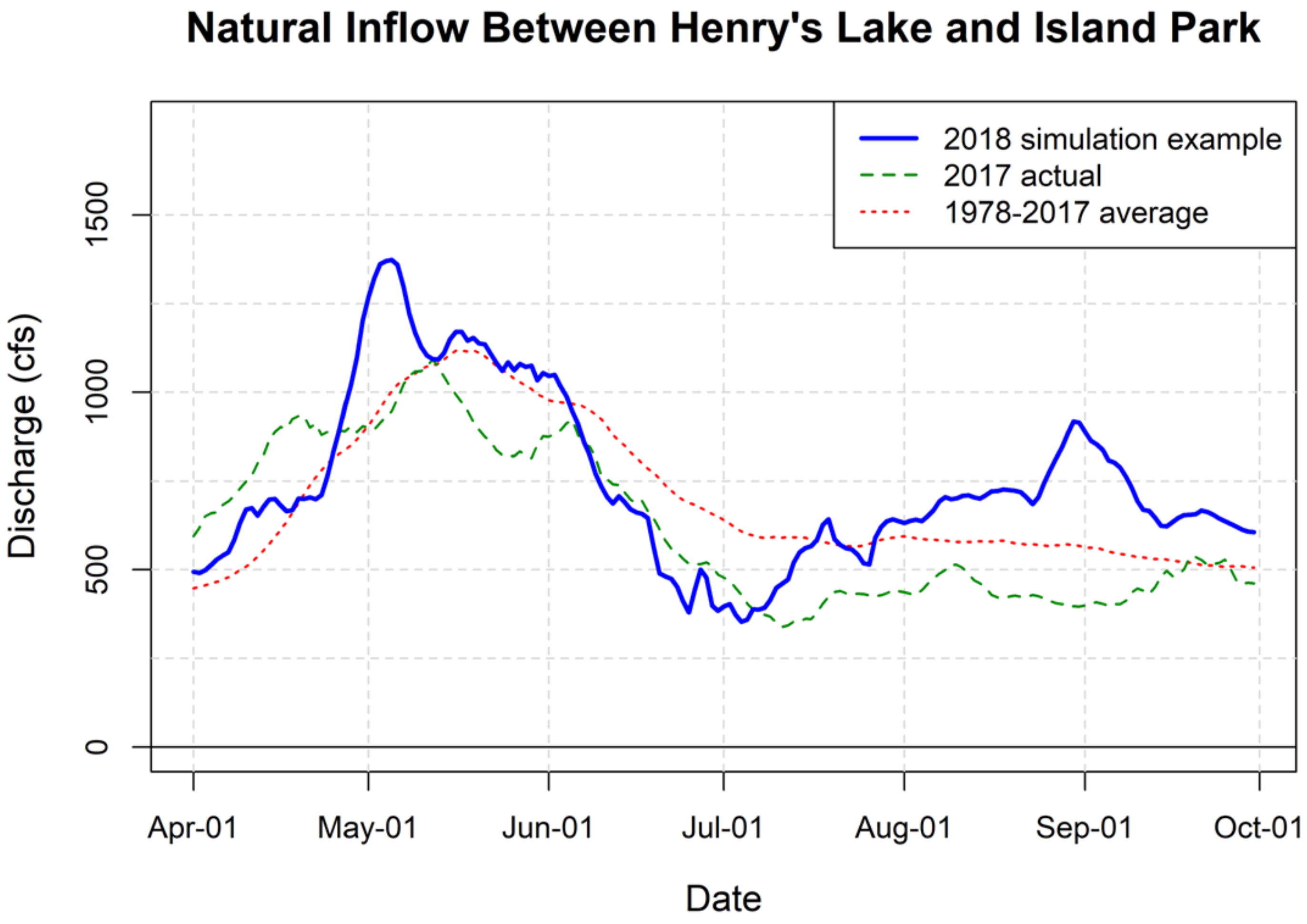
<u>Groundwater gains/losses</u>

- Currently static, using averages
- Next year will be predicted
- In 2-3 years will be dynamic, with managed recharge options

Distributions of streamflow volume used in simulations







Example of simulated natural flow:

Volume ≈ 110% of average

Timing = water-year 2002

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System Operation

- Fill reservoirs as soon as possible
- After fill but before delivery, reservoir outflow = inflow
- After runoff, set Henry's Lake outflow to 70 cfs
- Set minimum flow target in HF at St. Anthony
- Set Crosscut Canal delivery to meet demand on Teton River once natural flow does not
- On first day storage is needed (or July 15, whichever is later), set Grassy Lake outflow to 50 cfs
- Deliver 3,000 ac-ft from Grassy Lake (30 days at 50 cfs)
- Set IP Reservoir outflow to keep flow at St. Anthony no lower than target

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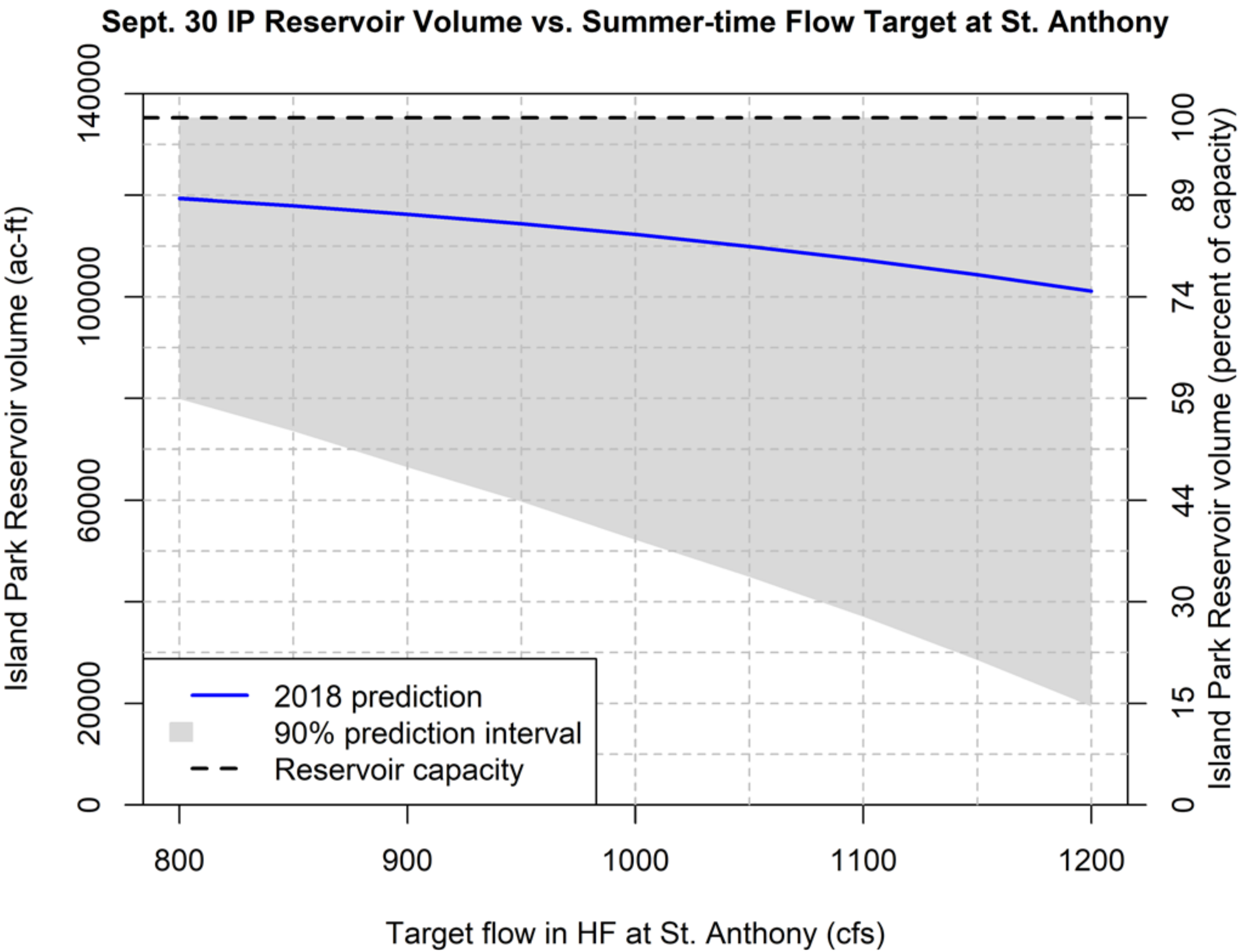

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Implementation

- DMP Committee sets St. Anthony flow target in May (1,000 cfs in 2018)
- HFF issues water-supply report every workday morning (and weekends during summer as needed)
- USBR keeps IP reservoir 100% full until first day delivery is needed
- As model-predicted date of first delivery approaches, refine prediction with real-time data
- Determine initial release of storage two days ahead
- HFF, USBR and FMID communicate 3-4 times per week and daily when conditions change rapidly
- FMID manages Crosscut Canal and Teton River and communicates changes
- HFF maintains model and predictions
- USBR orders flow changes at IP Dam based on FMID needs

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Advertisement for Daily Water Report

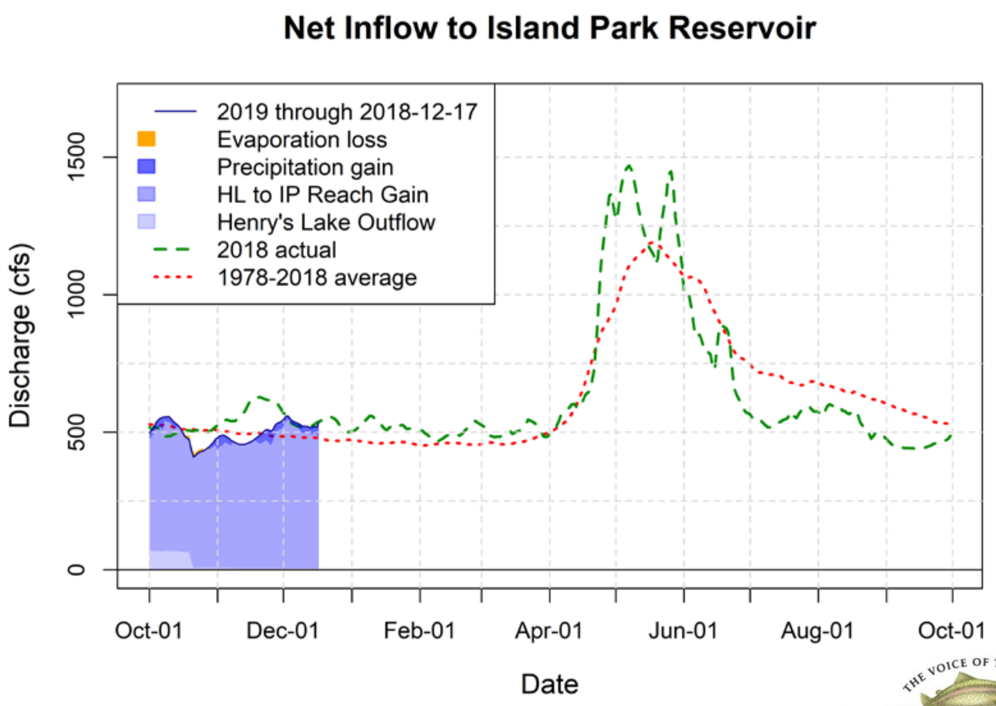
Parameters

- Climate
- Natural flow
- Reservoir management
- Diversion
- Water quality

Data sources

- NRCS SnoTel
- USBR AgriMet/HydroMet
- USGS Streamflow
- Water District 01/IDWR
- HFF instrument network

Information is packaged in relevant and understandable format for 170 email subscribers.



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2018 Results

<u>Precision in meeting St. Anthony flow target of 1,000 cfs</u>

- St. Anthony flow was constraining for 90 days: July 3 – Sept 30
- Mean flow over that period: 1,081 cfs
- Flow dropped below 1,000 cfs on 10 days
- Mean over those 10 days was 980 cfs

<u>Sample of predicted vs. observed hydrographs</u>

- Teton River above Crosscut Canal
- Crosscut Canal delivery to Teton River
- HF at St. Anthony
- Outflow from Island Park Reservoir
- Island Park Reservoir volume
- Island Park Reservoir volume vs. St. Anthony flow target

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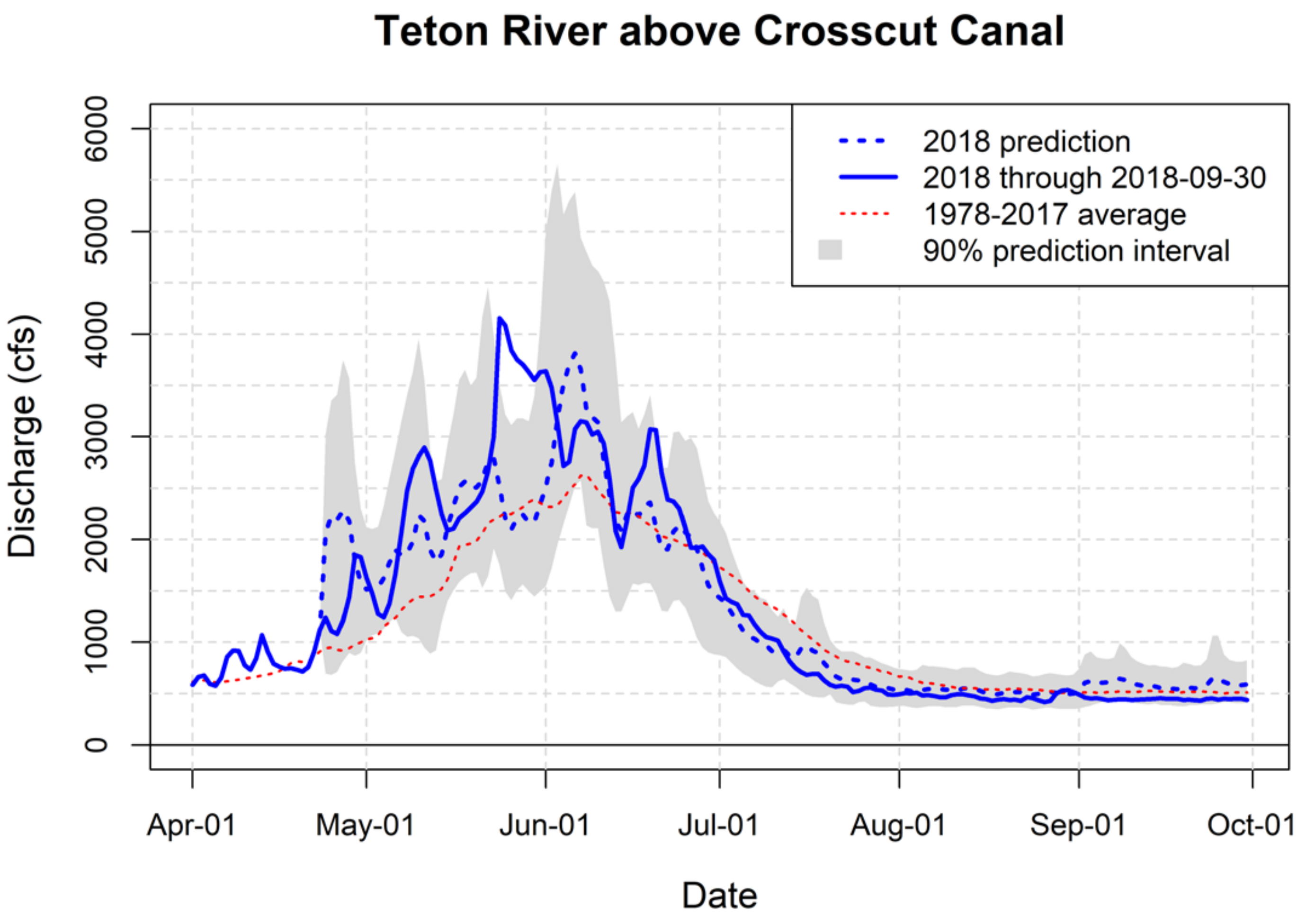

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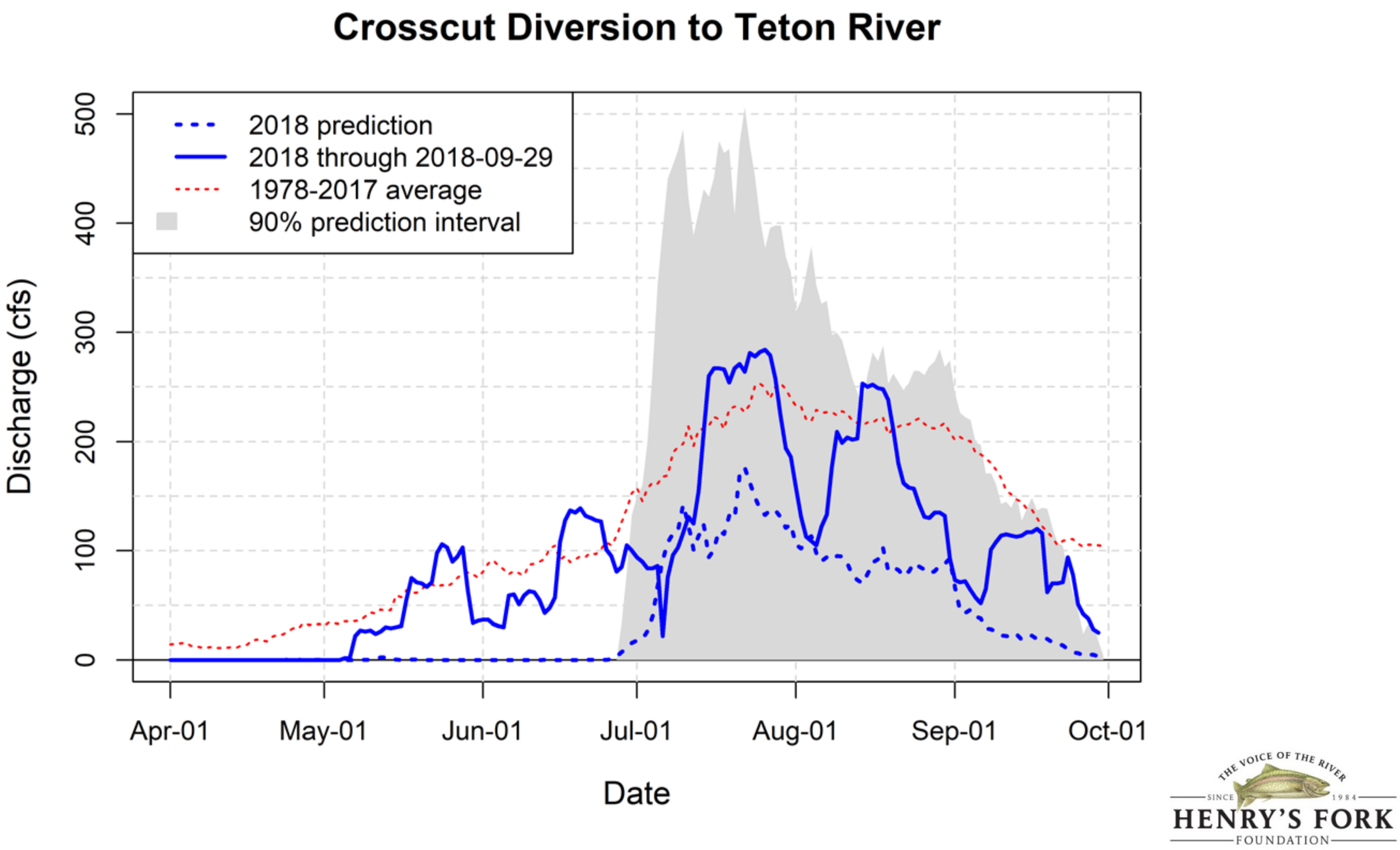
Crosscut Diversion to Teton River
2018 prediction
2018 through 2018-09-29
1978-2017 average
90% prediction interval
Discharge (cfs)
0
100
200
300
400
500
Apr-01
May-01
Jun-01
Jul-01
Aug-01
Sep-01
Oct-01
Date
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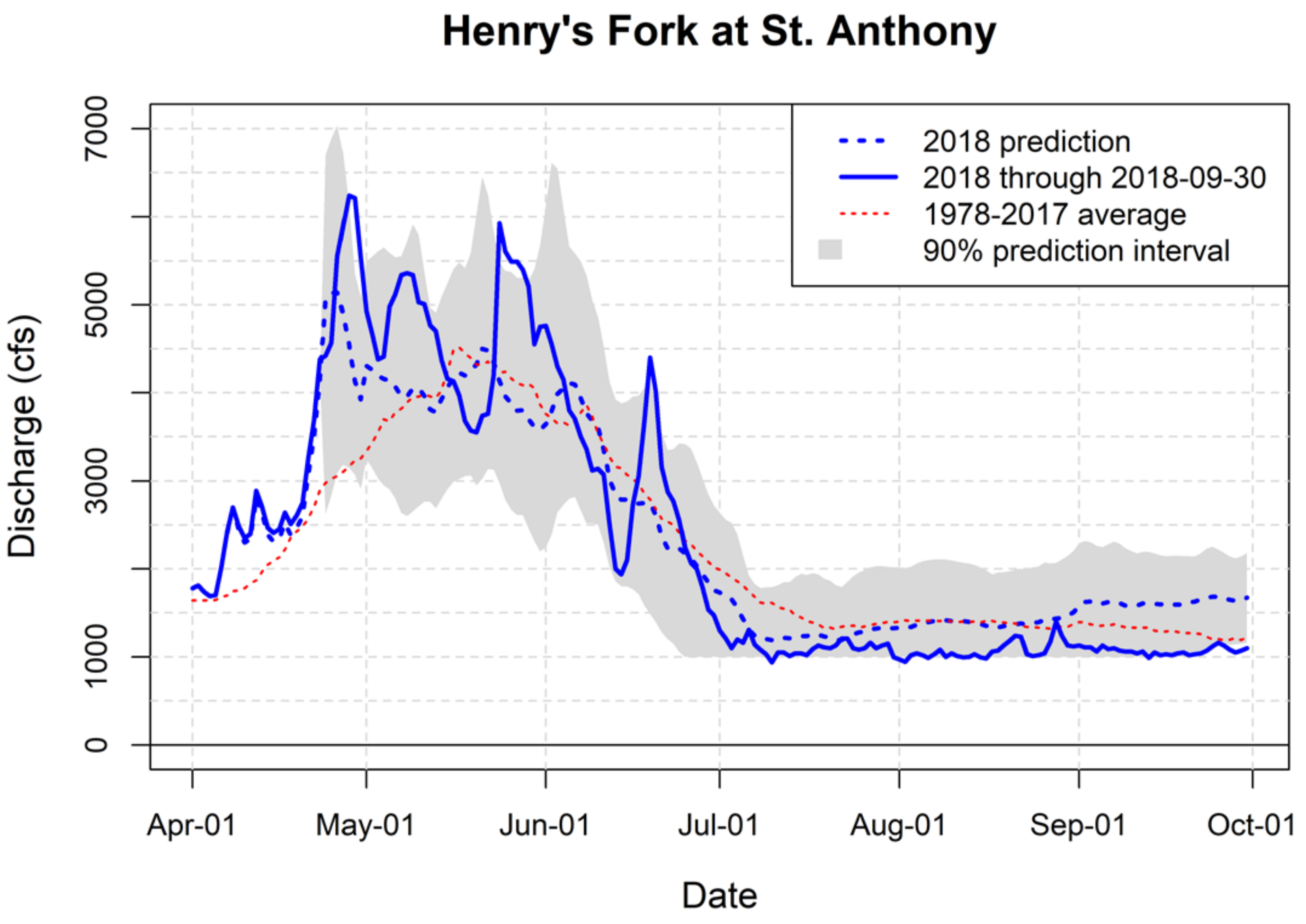

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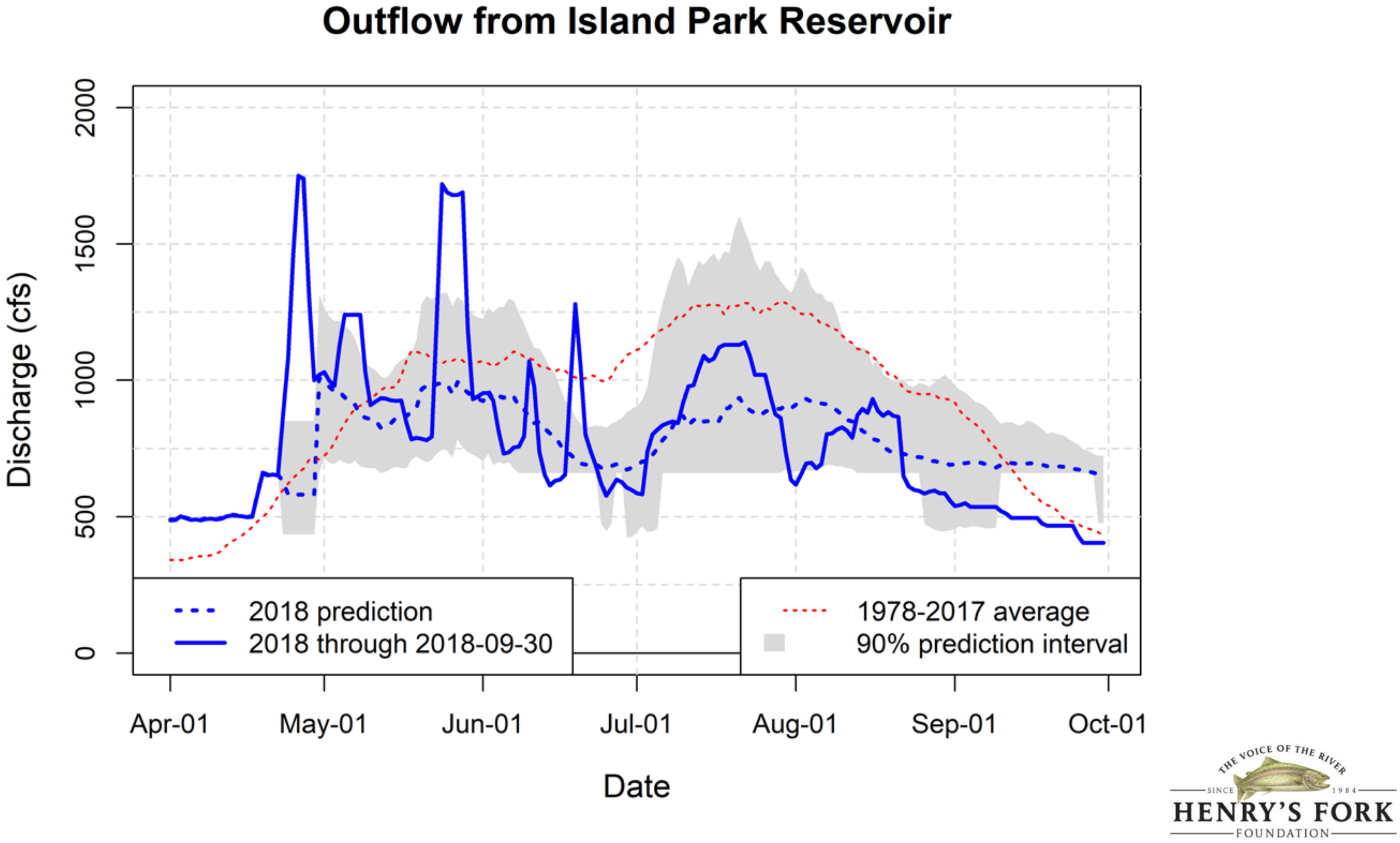
Outflow from Island Park Reservoir
Discharge (cfs)
0
500
1000
1500
2000
Apr-01
May-01
Jun-01
Jul-01
Aug-01
Sep-01
Oct-01
Date
2018 prediction
2018 through 2018-09-30
1978-2017 average
90% prediction interval
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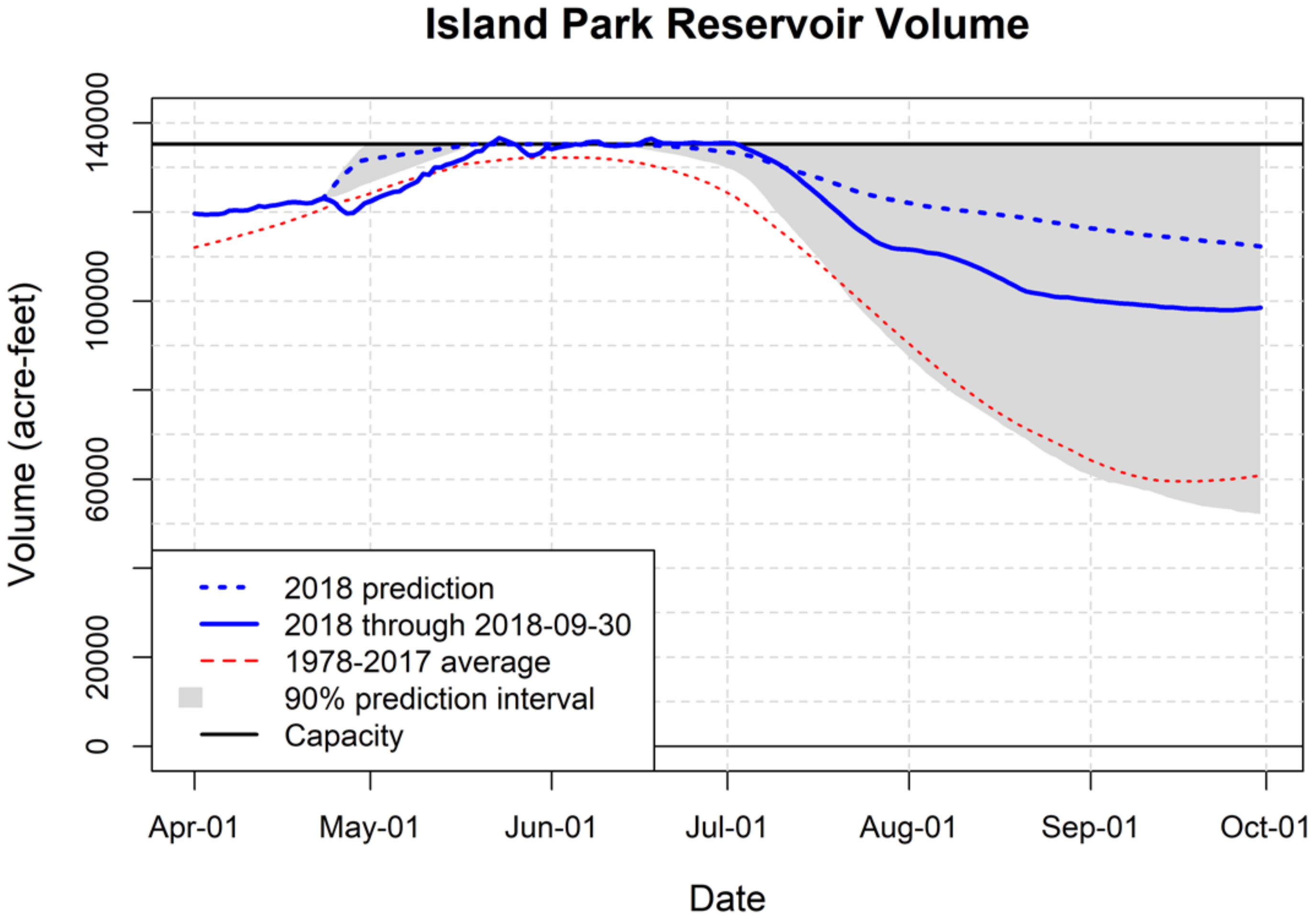

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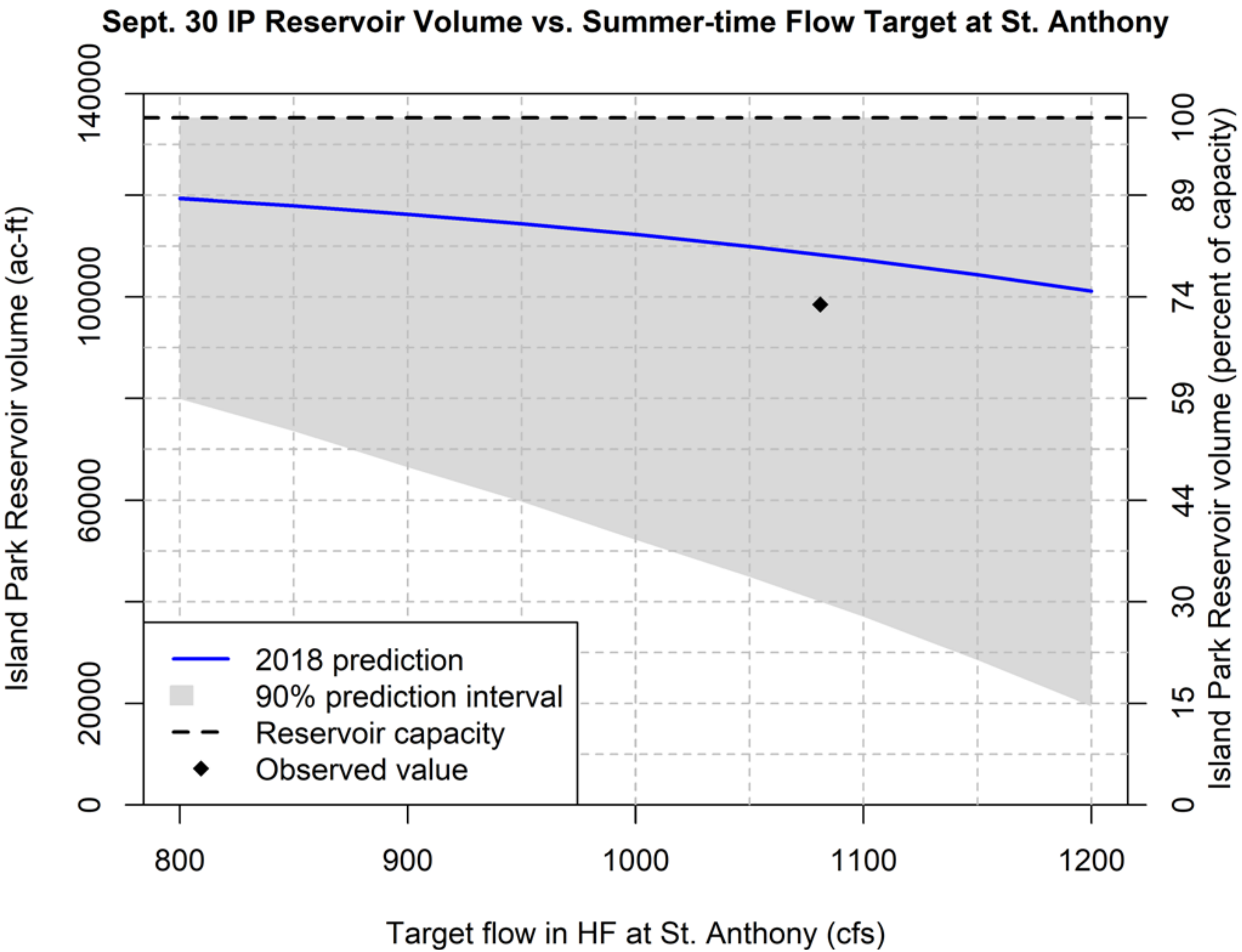

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Success of combined strategies in 2018

- Water-year 2018 was pretty average
  - 102% of average precipitation
  - 105% of average streamflow
  - Very dry summer
  - Summer flow 85% of average, BUT

- Reservoir carryover way above average
  - Mean Sept. 30 content: 43% full
  - Sept. 30 content: 74% full
  - Saved storage equivalent to 60% increase in winter outflow (480 cfs vs. 300 cfs)

Transferability to other watersheds: Required Ingredients

- 30+ years of data: streamflow, SWE, temperature, diversion
- Basic data on stream reach gains/losses and groundwater interactions
- “Local knowledge” of irrigation practices and management
- Technical capabilities: statistical modeling, stochastic simulation, coding
- Clearly defined goals and objectives for model development and application
- Trust in the science and modeling process
- Communication among water users, water managers and stakeholders
- 30+ years of collaboration?

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Questions?

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