EAST BAY MUNICIPAL UTILITY DISTRICT

Summary of Sur-Rebuttal Testimony

Benjamin S. Bray, Ph.D., P.E.

(EBMUD Exhibit 103)

EBMUD-103

Dr. Nader-Tehrani's rebuttal

Dr. Nader-Tehrani testified on rebuttal that:

- **He is not aware of any systematic model bias at Freeport.**
  [5/5/2017 Transcript Vol. 40, p.206:19-22]

- **He did not know the model version I used for bias correction.**
  [5/11/2017 Transcript Vol. 43, pp.138:15-140:8]

- **He believes my bias correction methodology improperly introduced new systematic under- and over-prediction.**
  [5/5/2017 Transcript Vol. 40, pp.207:7-208:5]

Summary of responses

- The DSM2 model version used by Petitioners for this hearing (V8.0.6) systematically over-predicted minimum velocity at Freeport.
- This problem caused Petitioners' modeling to significantly underestimate Significant Reverse Flow Events (SRFEs) at Freeport.
- Therefore, it was necessary and appropriate to develop bias correction of Petitioners' modeling to remove the underestimation of SRFEs.

Summary of responses

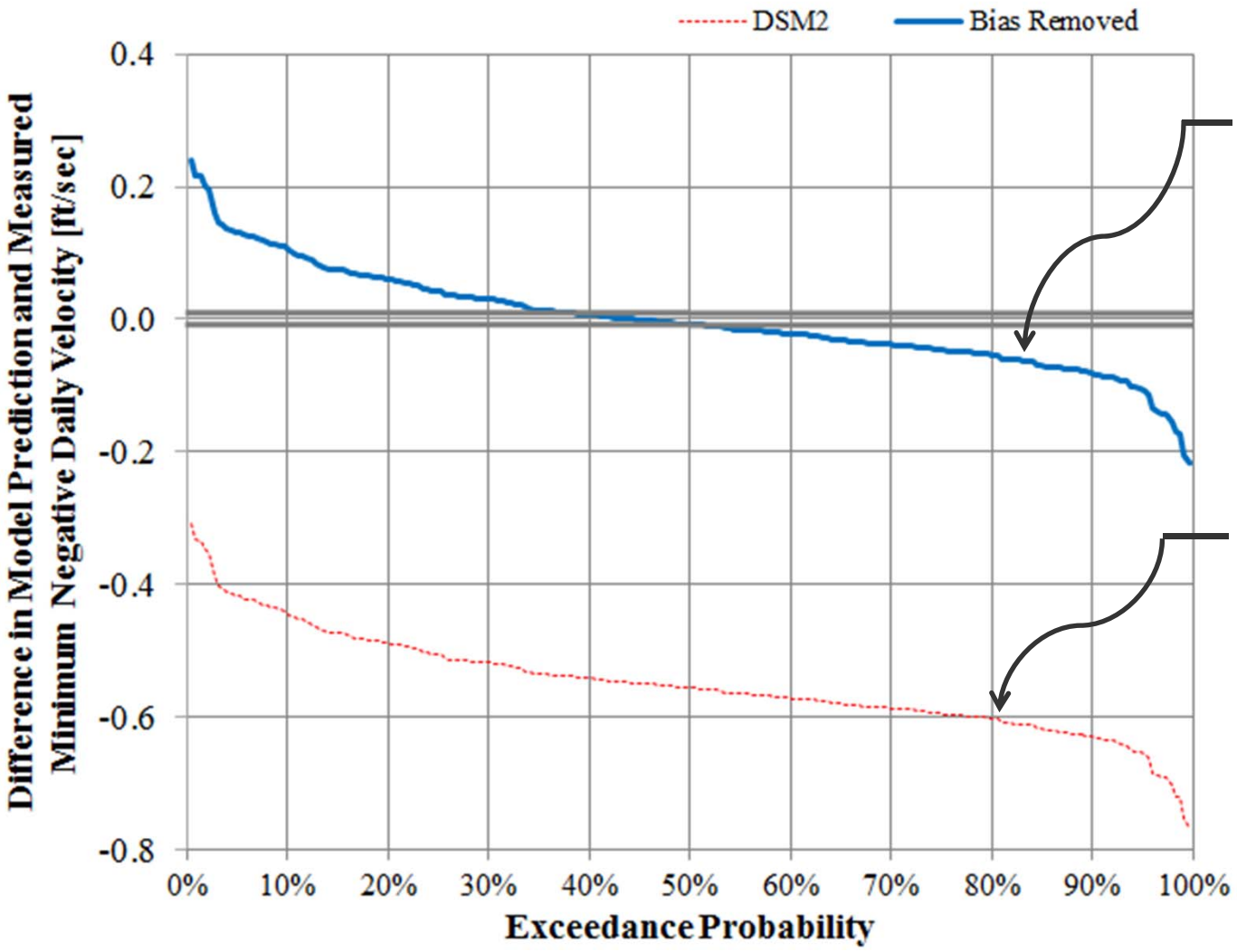
- The DSM2 version I used to calculate the bias correction offset (V8.1.2) was the best available choice. It included the benefit of a longer and more recent historical simulation.
- My use of V8.1.2 to develop the offset did not introduce any additional new bias – to the contrary, it removed bias.
- Liberty Island flooding appears to have no significant effect on tidal hydrodynamics at Freeport during low-flow periods when SRFEs typically occur.

Systematic model bias at Freeport

DSM2 systematically over-predicts minimum velocity at Freeport.

- DSM2's upstream boundary condition is located in close proximity to Freeport.
- The model assumes *positive downstream flows at all times* at the boundary.
- This constant flow boundary causes DSM2 to *systematically under-predict reverse flows* during low flows when tidal influence extends upstream of Freeport.

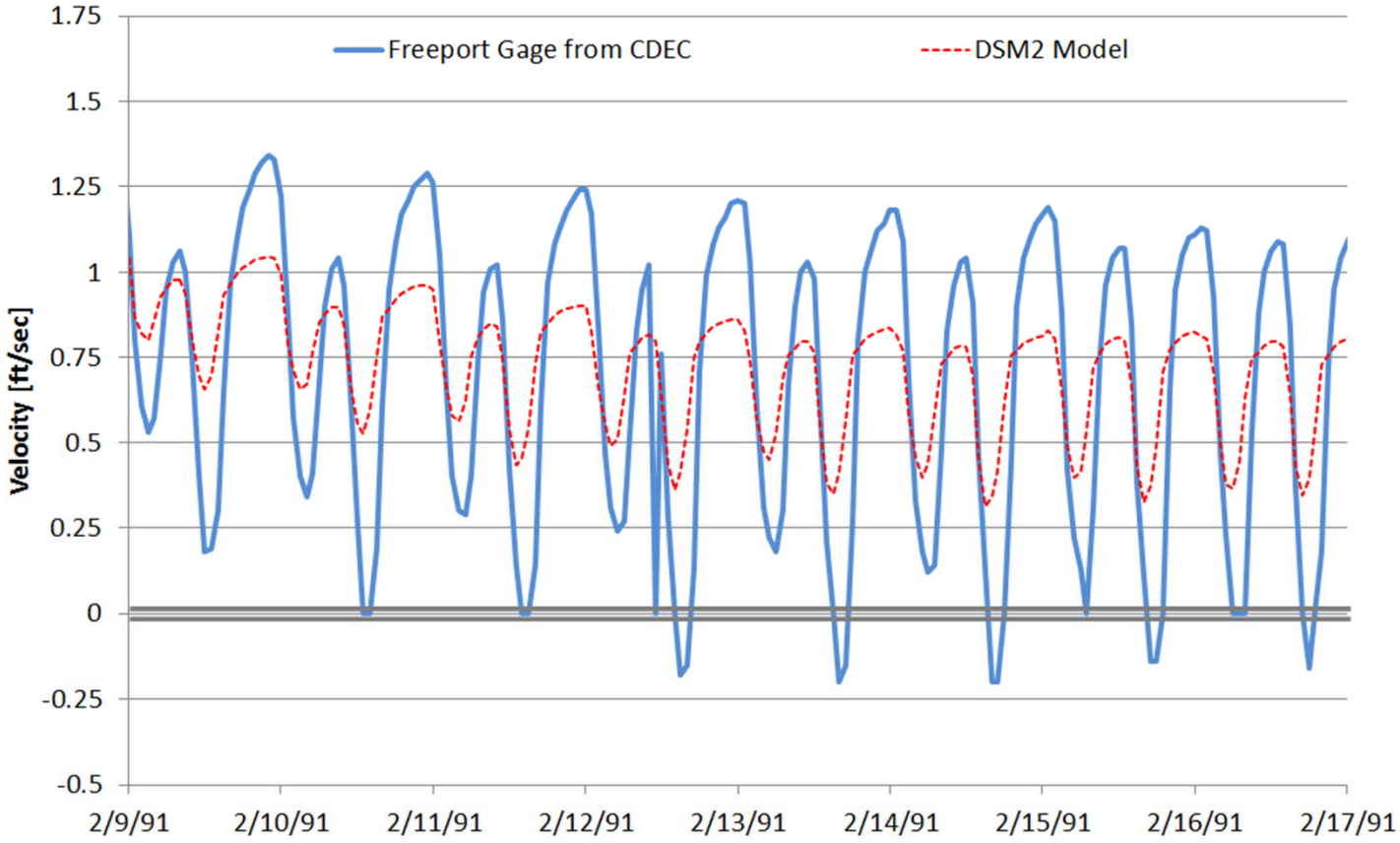
Systematic model bias at Freeport



Systematic model bias removed. Roughly the same amount of over- and under-prediction.

Depicts DSM2's systematic bias: minimum velocity is *consistently over-predicted*, i.e., more positive than gage data. (Data is from DSM2 V8.0.6, the version Petitioners used for this hearing.)

Systematic model bias at Freeport



This is a representative example of DSM2 V8.0.6 *consistent and systematic overestimation* of minimum velocity at Freeport as compared to the historical gage. Note the model's failure to simulate reverse flows that actually occurred during this period.

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Systematic model bias at Freeport

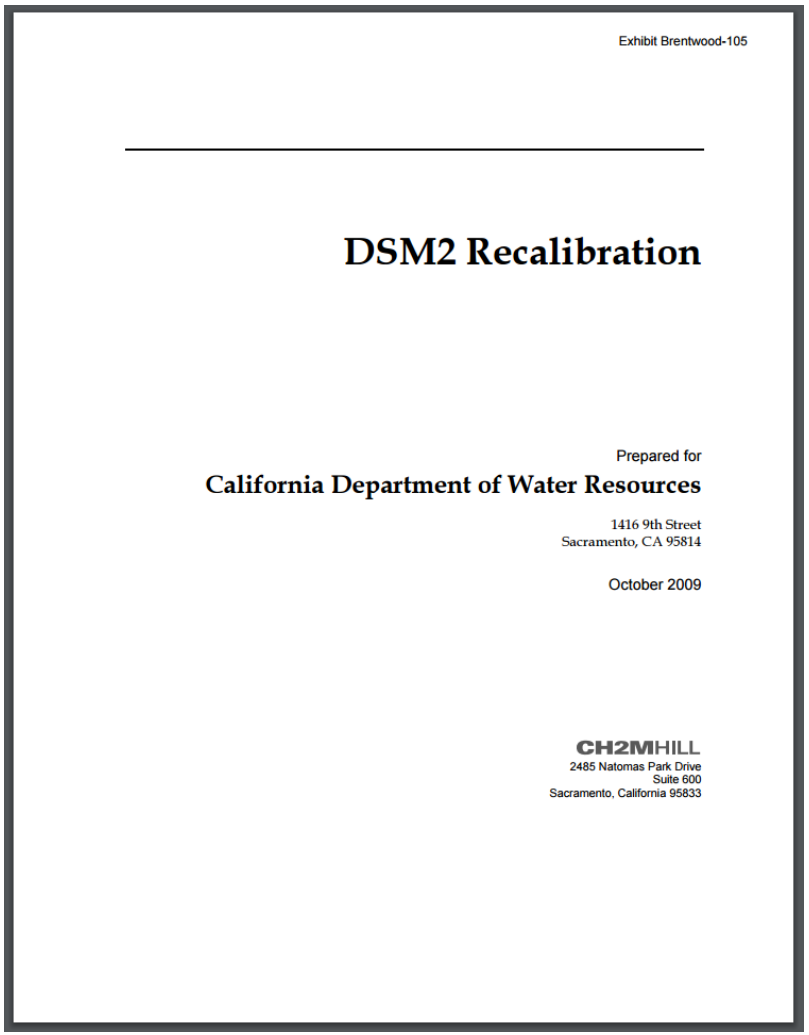


Exhibit Brentwood-105

DSM2 Recalibration

Prepared for

California Department of Water Resources

1416 9th Street
Sacramento, CA 95814

October 2009

CH2MHILL
2485 Natomas Park Drive
Suite 600
Sacramento, California 95833

- DWR is well aware of this model deficiency.
- DWR's 2009 DSM2 recalibration attempted to address it with limited success.

Systematic model bias at Freeport

Sacramento River at Rio Vista. Comparisons were also performed between simulated and observed tidal flows on Cache Slough.

2.2.2 Extension of Model Boundaries on Sacramento River

Peak ebb tidal flows simulated in DSM2 near to the upstream boundary on the Sacramento River were attenuated as compared to the observed data. It was hypothesized, that one of the reasons for the ebb attenuation may be the proximity of the rigid upstream boundary on the Sacramento River, which is located at the City of Sacramento in the DSM2. The daily averaged flow measured at the Freeport gage south of the city is used as the inflow boundary for Sacramento River. At times of low inflow, tidal variation in stage and flow extend upstream beyond Sacramento. Therefore, the inflow boundary condition that is constant over a 24-hour period does not account for the effects of the miles of channels above the upstream boundary that are under tidal influence. In addition, since DSM2 does not allow propagation of tidal waves at the boundary, an incoming tidal wave would be reflected at the boundary rather than to continue propagating upstream and be dissipated. The reflected wave could lead to errors in simulated stage and flow near the upstream end of the Sacramento River (Shum, 2006).

In an effort to reduce the reflective wave issue, the rigid boundary on Sacramento River was extended upstream while keeping the location of the boundary inflow unchanged in DSM2

Exhibit Brentwood-105 (2009 DSM2 Recalibration Report)

Systematic model bias at Freeport

DWR's 2009 recalibration *did not* successfully correct the model's systematic under-prediction of reverse flows at Freeport.

1. The recalibration extended DSM2's upstream boundary northward to partially address the boundary condition issue at Freeport.

   [See Exhibit Brentwood-105, § 2.2.2]

2. However, recalibration only *slightly* improved the model's tidal representation at Freeport, despite significantly improving tidal representation at Rio Vista. *[See Exhibit Brentwood-105, Figs. 4-4 and 4-6]*

Systematic model bias at Freeport

DWR's 2009 recalibration *did not* successfully correct the model's systematic under-prediction of reverse flows at Freeport.

3. The recalibrated model did an even *worse* job simulating flows at Freeport in October 2001, which is the lowest-flow month during the calibration period.
   [See Exhibit Brentwood-105, Fig. 4-6]

4. The under-prediction problem is most severe during low flows – yet, DWR's recalibration did not consider extreme low-flow periods when tidal influence at Freeport is most extreme. *[See Exhibit Brentwood-105, §§ 4.1, 5.1]*

Model versions

- Dr. Nader-Tehrani testified on rebuttal that he did not know the model version I used to develop my bias correction offset.
- I used V8.1.2, which was appropriate for this purpose:
    - **More up-to-date.** V8.1.2 includes more recent data than V8.0.6, especially for extreme low-flow conditions in which SRFEs typically occur.
    - **More conservative.** V8.1.2 is relatively less-biased than V8.0.6, and therefore it yielded a more conservative offset than V8.0.6 would have.

Model versions: data available

DSM2 homepage shows available model versions:

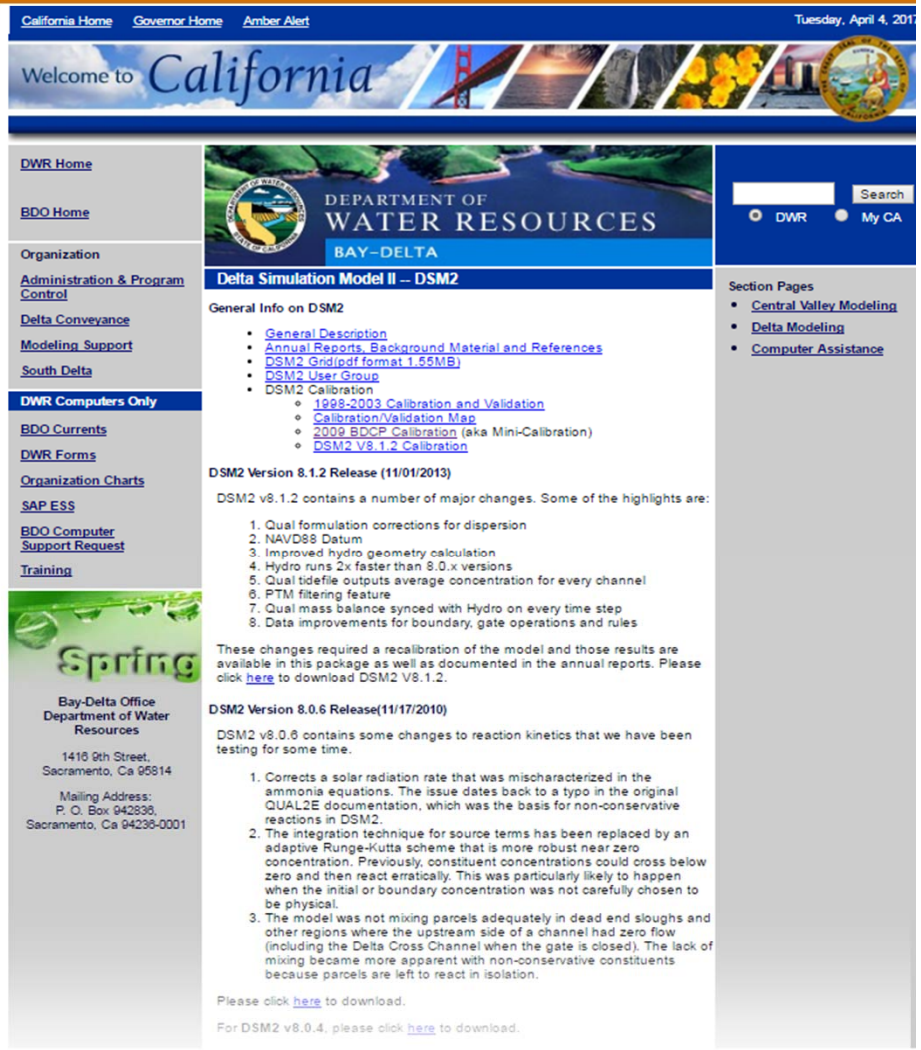
V8.0.6 (11/17/2010)

- 1990-2006 historical simulation.
- No extreme low flows after 1994.

V8.1.2 (11/1/2013)

- 1990-2012 historical simulation.
- Extreme low flows in early 1990s and in 2008-2009.

Petitioners used V8.0.4 for all BDCP modeling, and V8.0.6 for all CWF modeling efforts but also used V8.1.2 for BA temperature modeling.

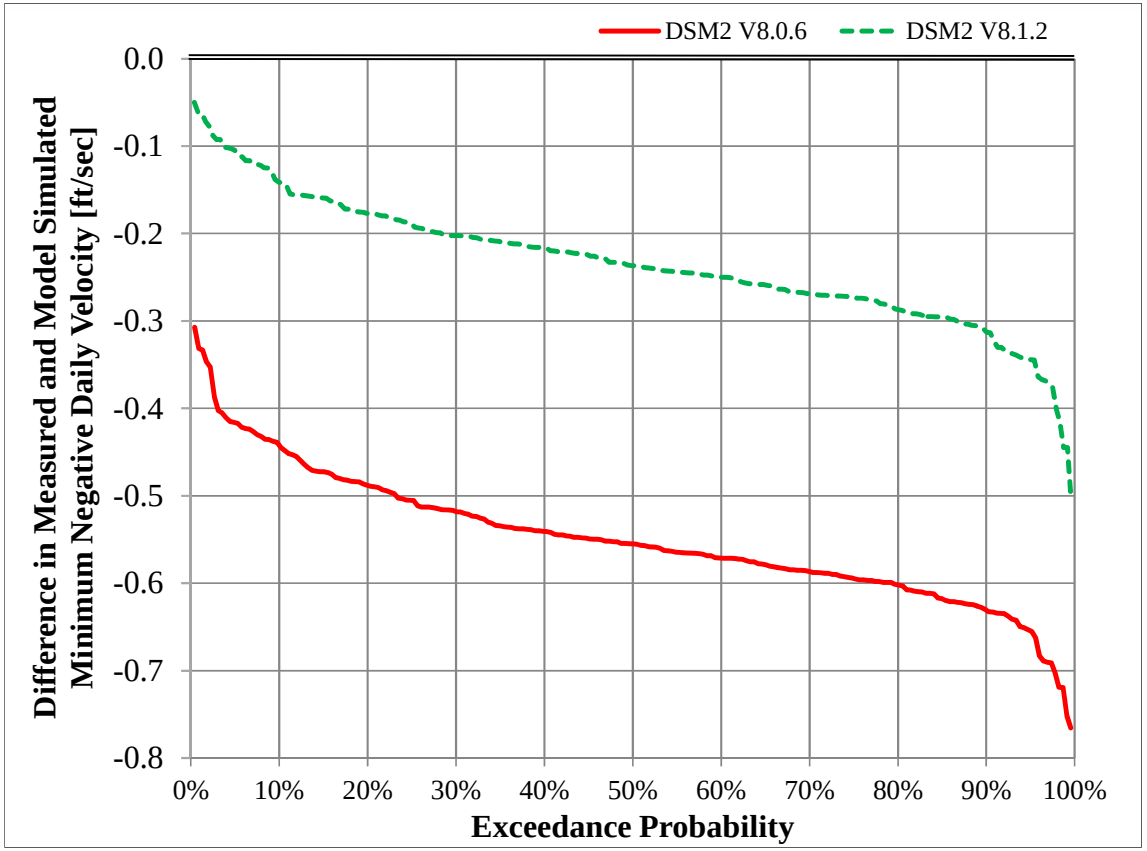


Source: http://baydeltaoffice.water.ca.gov/modeling/deltamodeling/models/dsm2/dsm2.cfm

Model versions: degree of bias

V8.0.6 has a *larger bias* in simulating minimum velocities than V8.1.2.

Applying bias correction to DSM V8.1.2 corrected some, *but not all*, of the bias inherent in V8.0.6.



Therefore, my use of V8.1.2 *did not* systematically "overcorrect" the model output, nor introduce any new bias.

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Model versions: time period

My original testimony documented the set of months I used to estimate the bias correction offset.

Reverse flows occurred at Freeport in each of these months.

23 To correct that under-prediction bias, I calculated an appropriate velocity offset to apply
24 to Petitioners' DSM2 velocity output to match minimum reverse flow velocities. I calculated the
25 optimal offset by minimizing the sum-of-square error between model simulation and historical
26 Freeport gage data over 15 months of historical low-flow periods in which reverse flow events
27 //
28 //

1 occurred.[7] I applied the optimal offset to the simulated output to align as closely as possible with

26
27 [7] These were the months of October and November 1990, February 1991, May 1991, May
28 through August 1992, October and November 1992, April through June 1994, December 2008, and November 2009.

Exhibit EBMUD-152, pp.9:24–10:1, p.10 fn.7

Model versions: Liberty Island

Dr. Nader-Tehrani speculated that Liberty Island flooding could have affected Delta hydrodynamics so as to reduce tidal influence at Freeport and thereby affect the frequency of SRFEs.

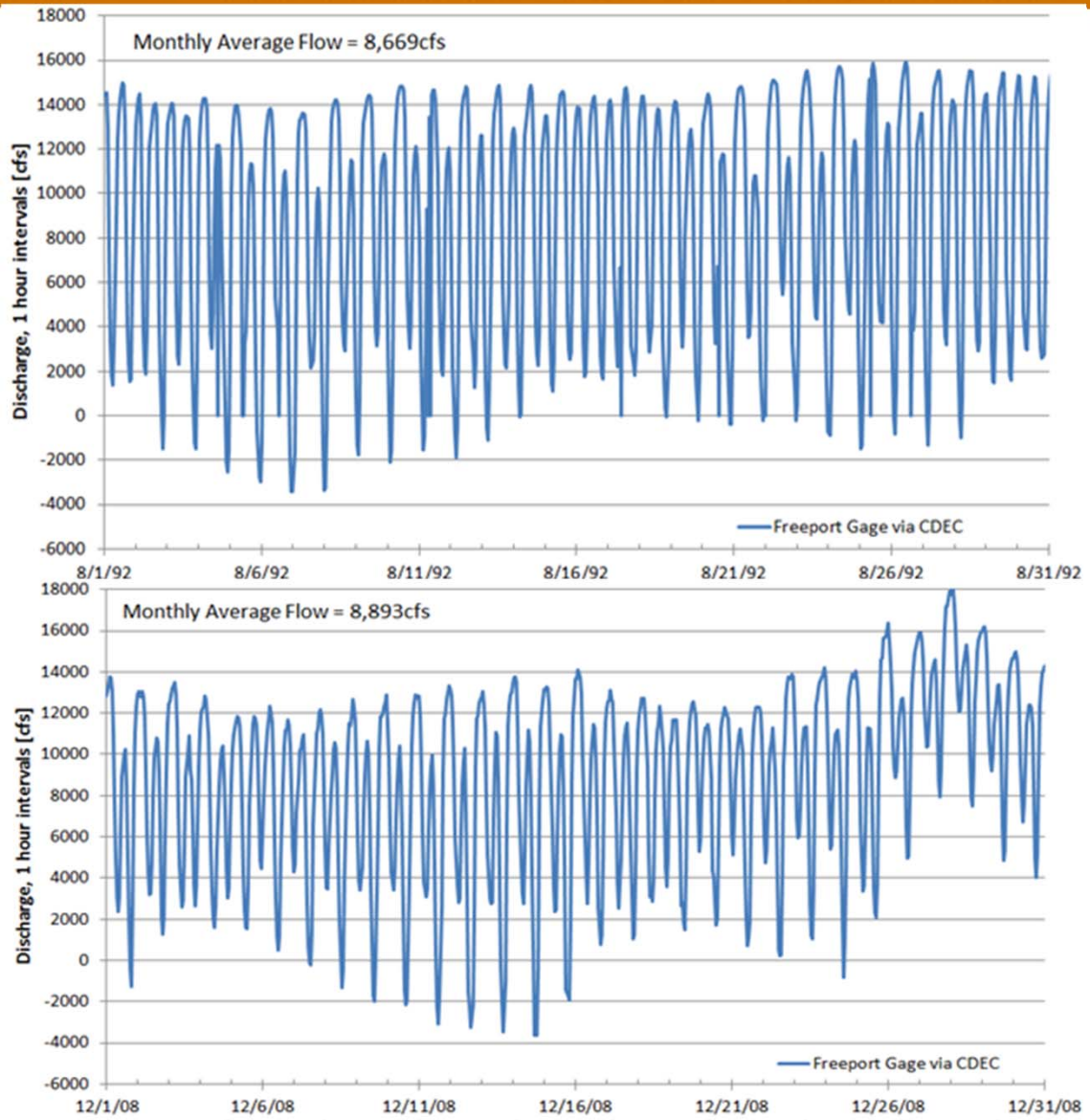
He did not present evidence for this.

I found no effect during low-flow months.

Model versions: Liberty Island

I compared two low-flow months with a similar monthly average at the Freeport Gage: one *before* Liberty Island flooding, and one *after* it.

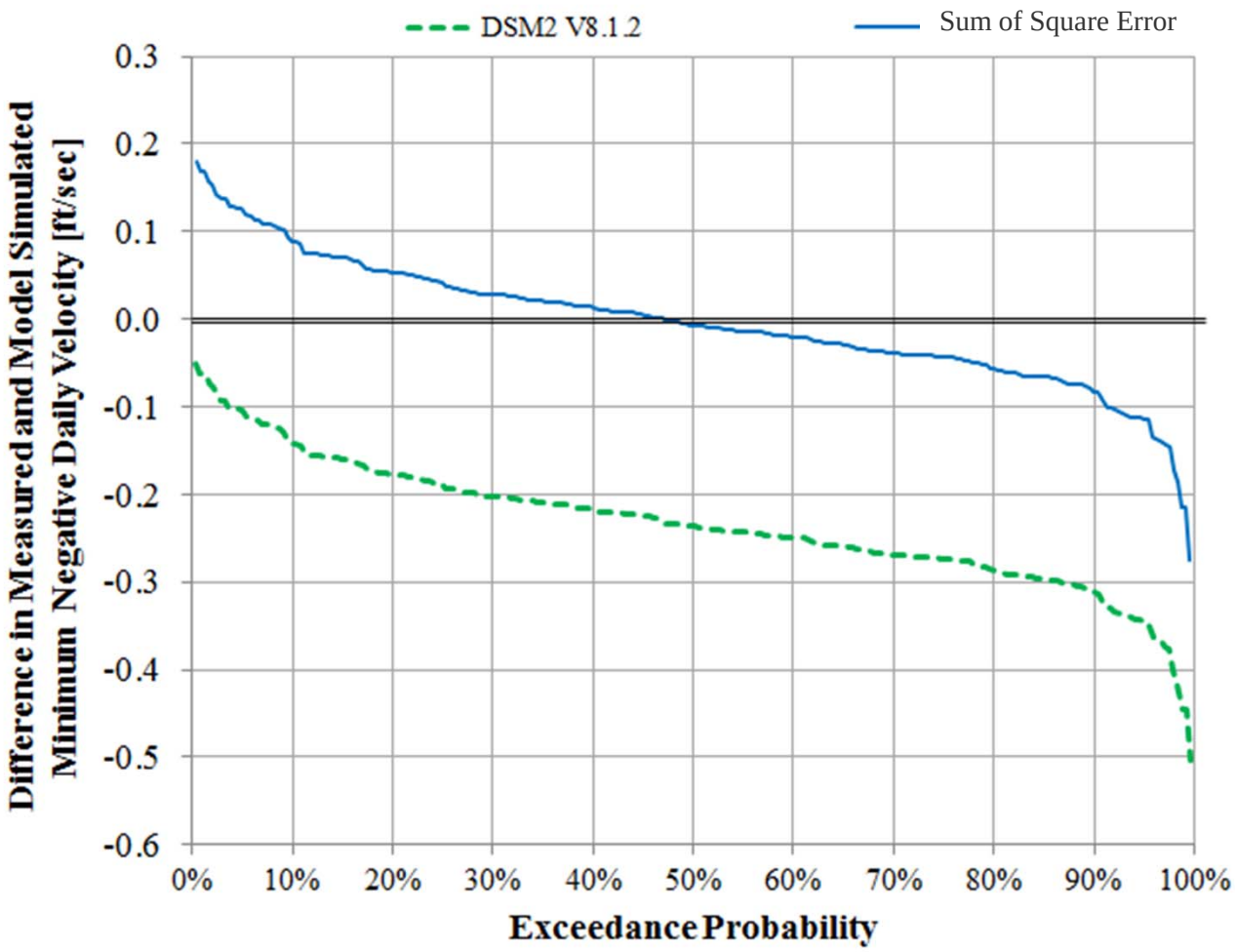
Tidal range is consistent and minimums are similar: daily minimum flows between -2,000 cfs and -4,000 cfs.



Bias correction method

Least-squares minimization *removes* the bias, resulting in small near-zero mean error.

Another accepted method (minimizing sum of absolute error) yields the same offset metric.



Conclusions

- Petitioners' modeling included a significant systematic bias: DSM2 consistently over-predicted minimum velocities at Freeport – *and therefore under-predicted SRFEs* – due to a boundary condition deficiency known to Petitioners.

- Using DSM2 V8.1.2 to calculate a conservative bias-correction offset using the least-squares minimization method is appropriate. This offset improved (without entirely eliminating) the bias inherent in Petitioners' modeling, improving DSM2's representation of SRFEs.