USGS
science for a changing world

Using Multi-criteria Decision Analysis to Explore Management Options in the Grand Canyon

Michael C. Runge, *USGS Patuxent Wildlife Research Center*
Kirk E. LaGory, *Argonne National Laboratory*
Kendra Russell, *Bureau of Reclamation*
Janet R. Balsom, *National Park Service*
Robert P. Billerbeck, *National Park Service*
Glen W. Knowles, *Bureau of Reclamation*

NCER 2016, Coral Springs, FL
20 April 2016, Session 20
Decision Analysis in Support of Ecosystem Restoration Projects

Photo credit: M.C. Runge, © 2012.
Used with permission

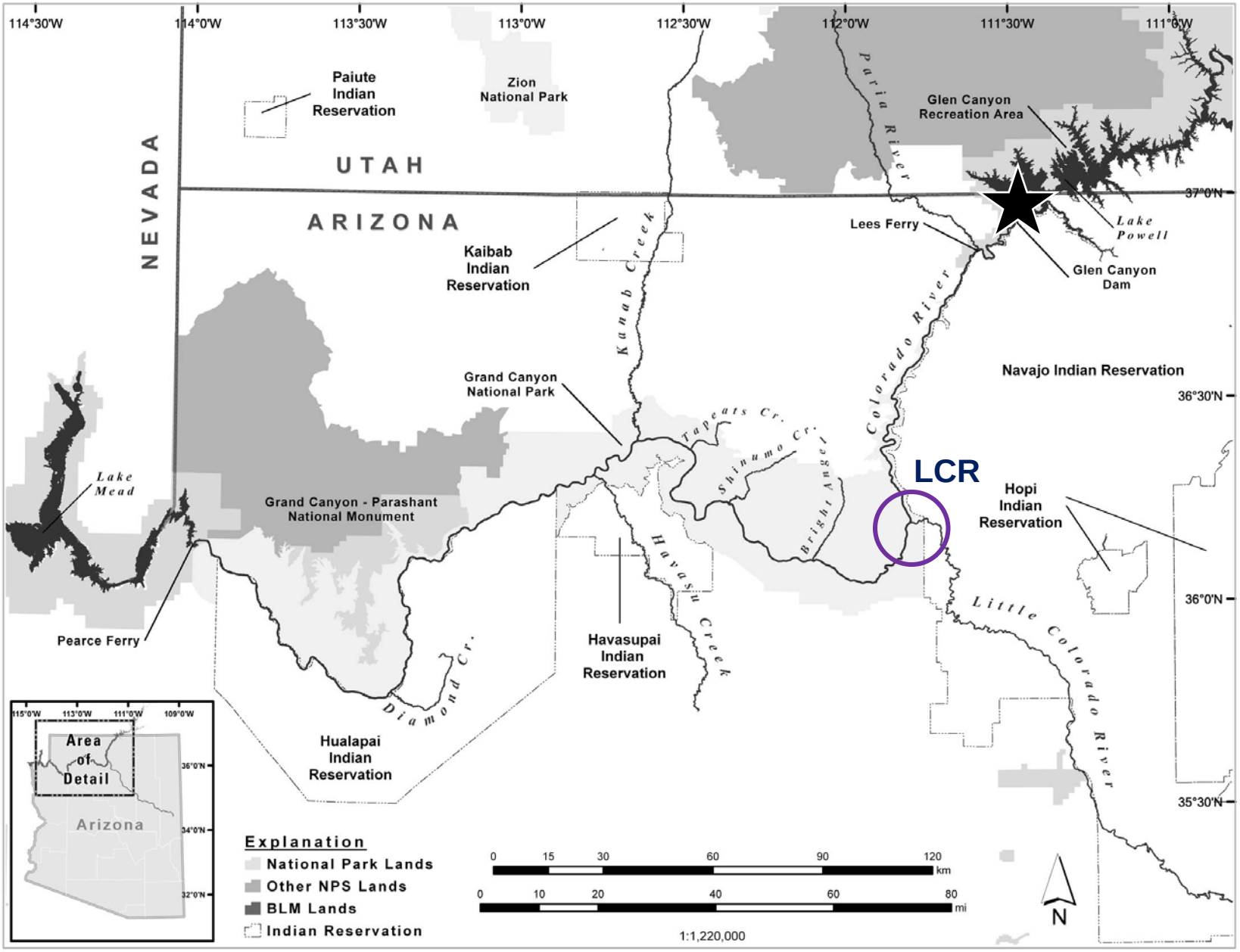
Glen Canyon Dam

USGS

Dam Operations

- Long-term Experimental & Management Plan (LTEMP)
  - A 20-year plan for operations of Glen Canyon Dam, and related activities
  - Will replace the 1996 Environmental Impact Statement and Record of Decision
  - Draft EIS published in January 2016
- Developed jointly by Bureau of Reclamation and National Park Service
  - With input from a large number of Cooperating Agencies, Tribes, and other stakeholders

USGS



Map credit: Thomas Gushue, U.S. Geological Survey. Public domain.

Humpback Chub

USGS

Photo credit: © Amy S. Martin Photography.
Used with permission.

Permissions: “Humpback chub”, George Andrejko, public domain; “Glen Canyon Dam”, Bureau of Reclamation, public domain; “Fly fishing rods”, troutster.com, CC BY 3.0; “Dark Sky”, Bob Wick, BLM, CC BY 2.0; “Grand Canyon Rafting”, M.J. Thomas, CC0; “Grand Canyon 10”, Antoine Taveneaux, CC BY-SA 3.0.

MCDA Process

- Multi-Criteria Decision Analysis steps to frame and analyze a decision
  - Elicit objectives from decision-makers and stakeholders
  - Develop a set of creative alternatives
  - Evaluate the alternatives (on ecological, economic, social, and spiritual scales)
  - Elicit values-based tradeoffs among the objectives
  - Evaluate uncertainty, using expected value of information
- Central to this approach is recognition that the decision has to discern and integrate social values and scientific understanding

USGS

Objectives

- Humpback chub
- Native fish
- Trout fishery
- Archaeological properties
- Hydropower generation and capacity
- Recreation
- Native vegetation
- Sediment deposition
- Water delivery
- Tribal goals
  - Health of the ecosystem
  - Respect for life
  - Sacred integrity

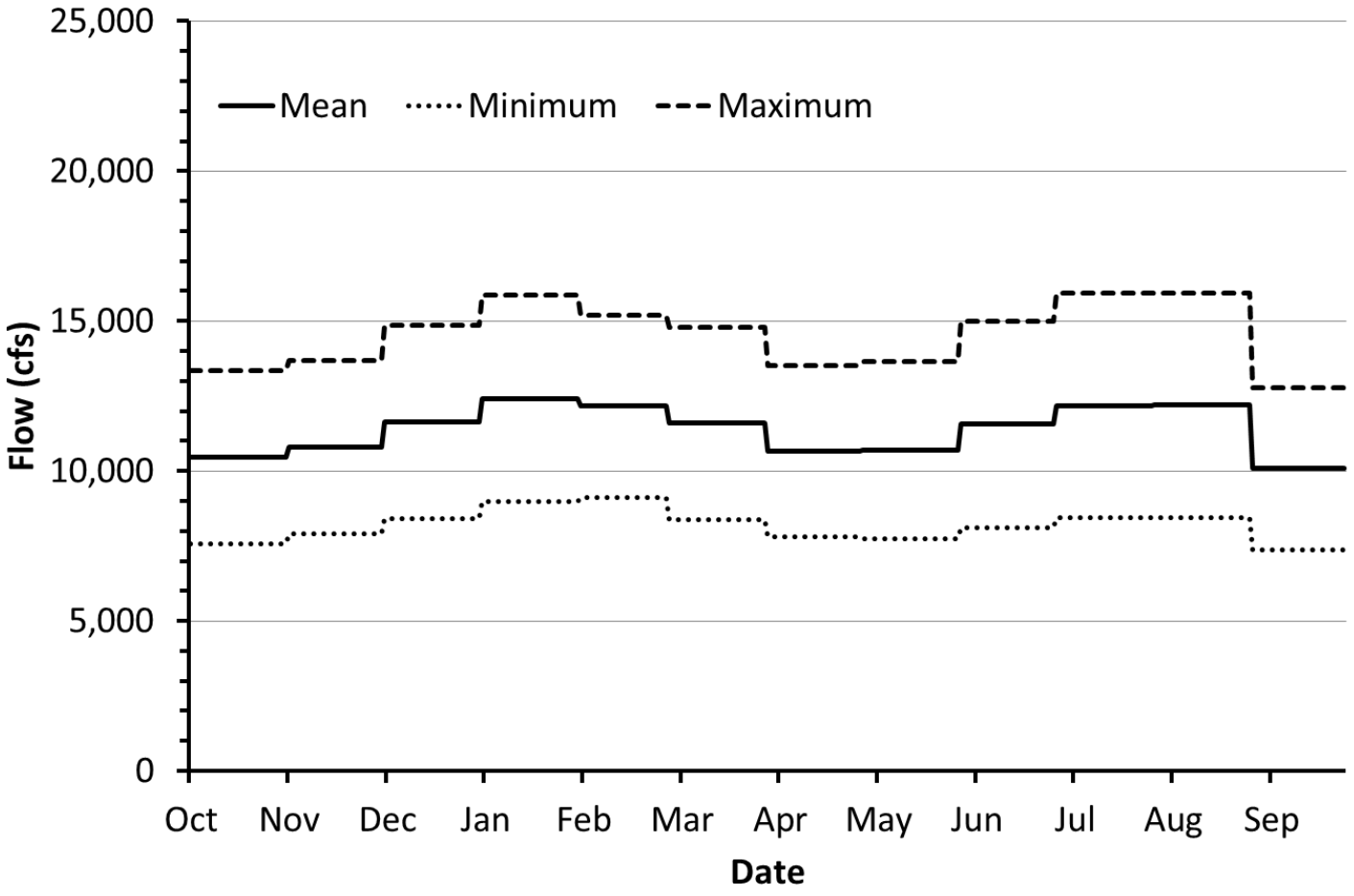
USGS

Alternatives

- Seven alternatives developed for analysis
  - Status quo (“No Action”)
  - Two from stakeholder agencies
  - One from the joint-lead agencies
  - Two from concepts discussed in the past
  - One (a “hybrid”) developed after analysis of the first six
- Each alternative is a complex portfolio
  - Monthly, daily, hourly flow volumes
  - Various special flow operations
  - Non-flow actions (trout removal, vegetation management)
  - Experimental procedures for untested operations

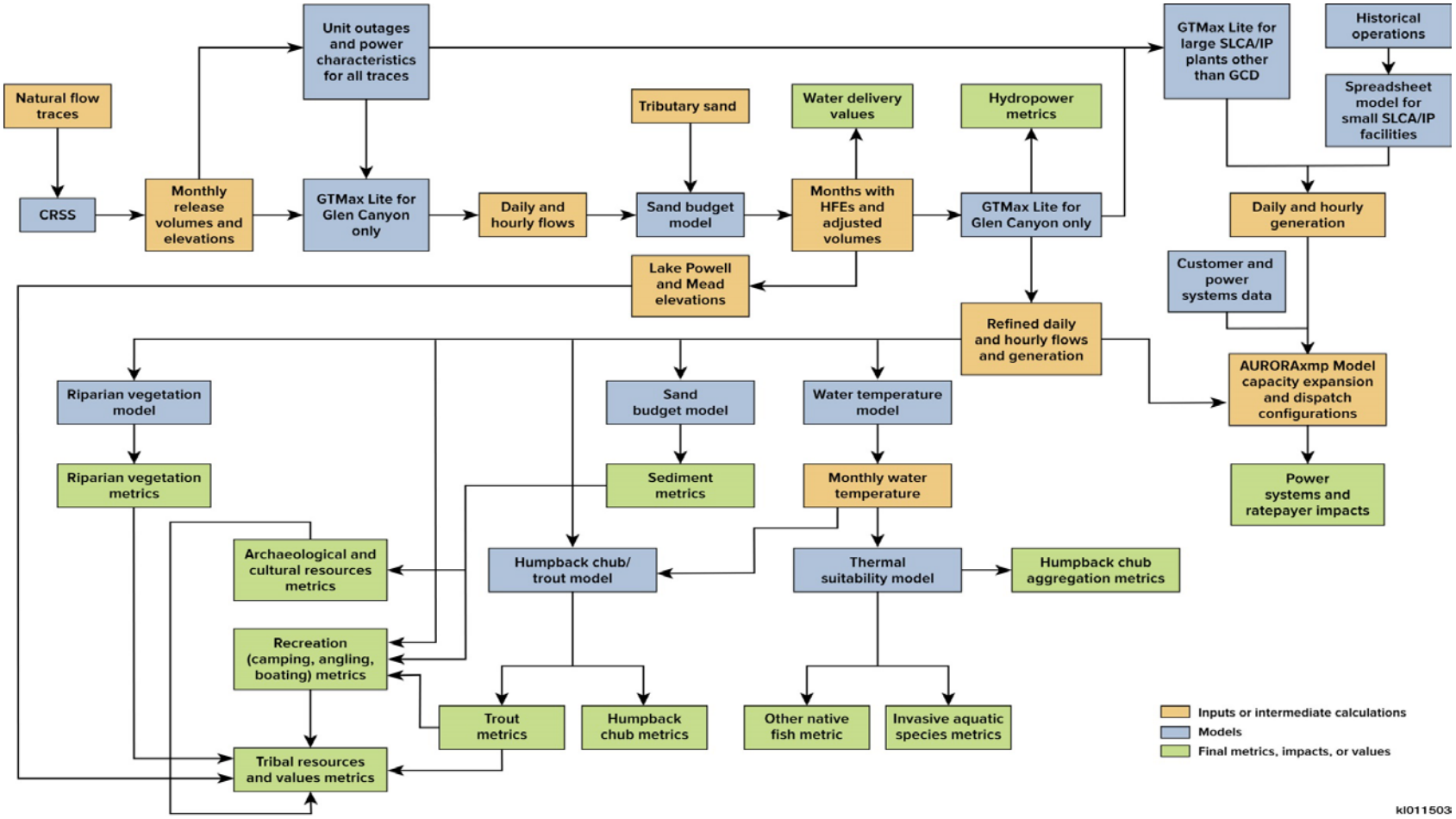
USGS

Sample Hydrograph



USGS

Modeling Framework



USGS

Consequence Table

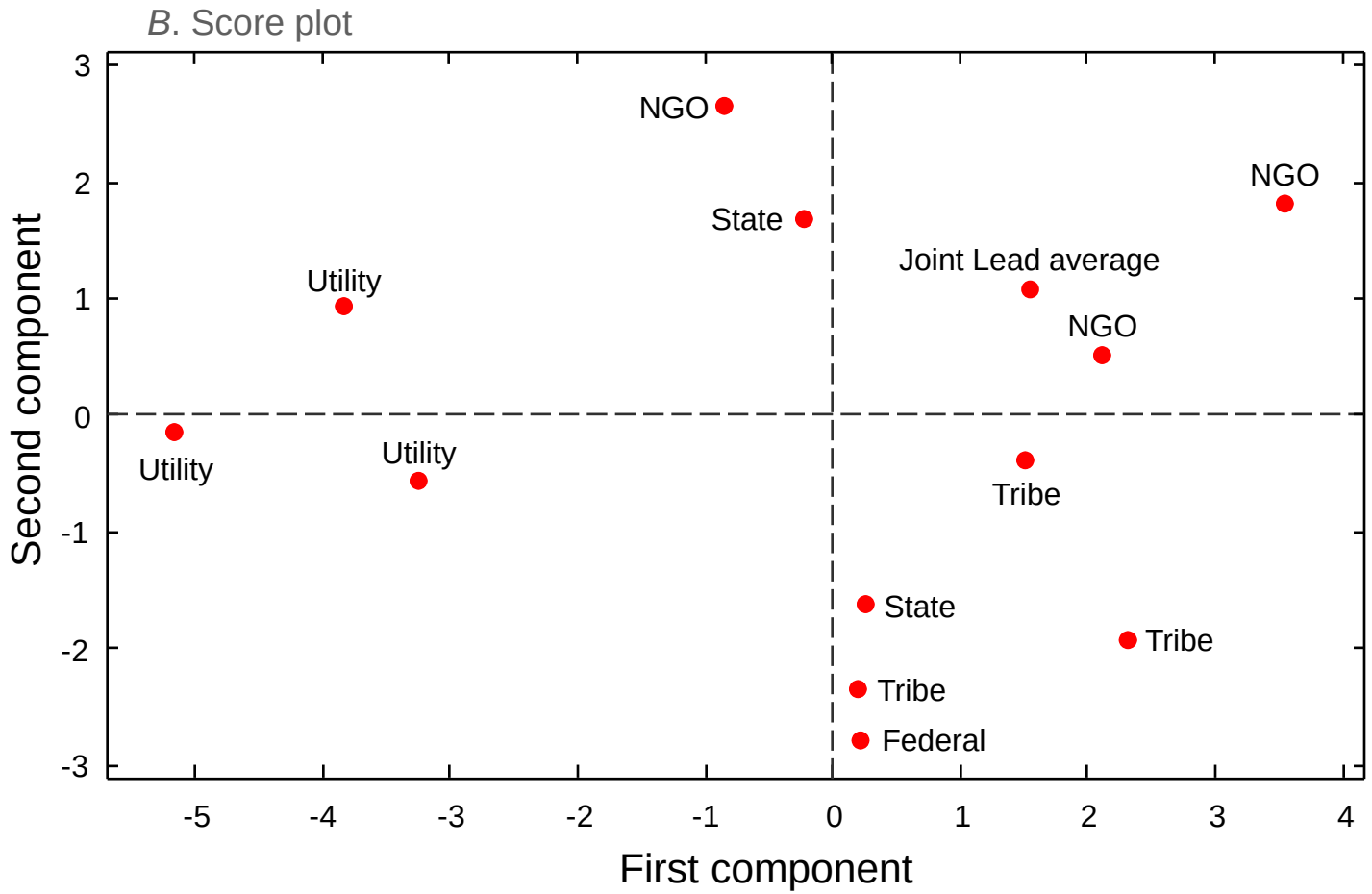
Best performing alternative for this metric
Alternative performs better than No Action
Alternative performs worse than No Action
Worst performing alternative for this metric

Performance Metric

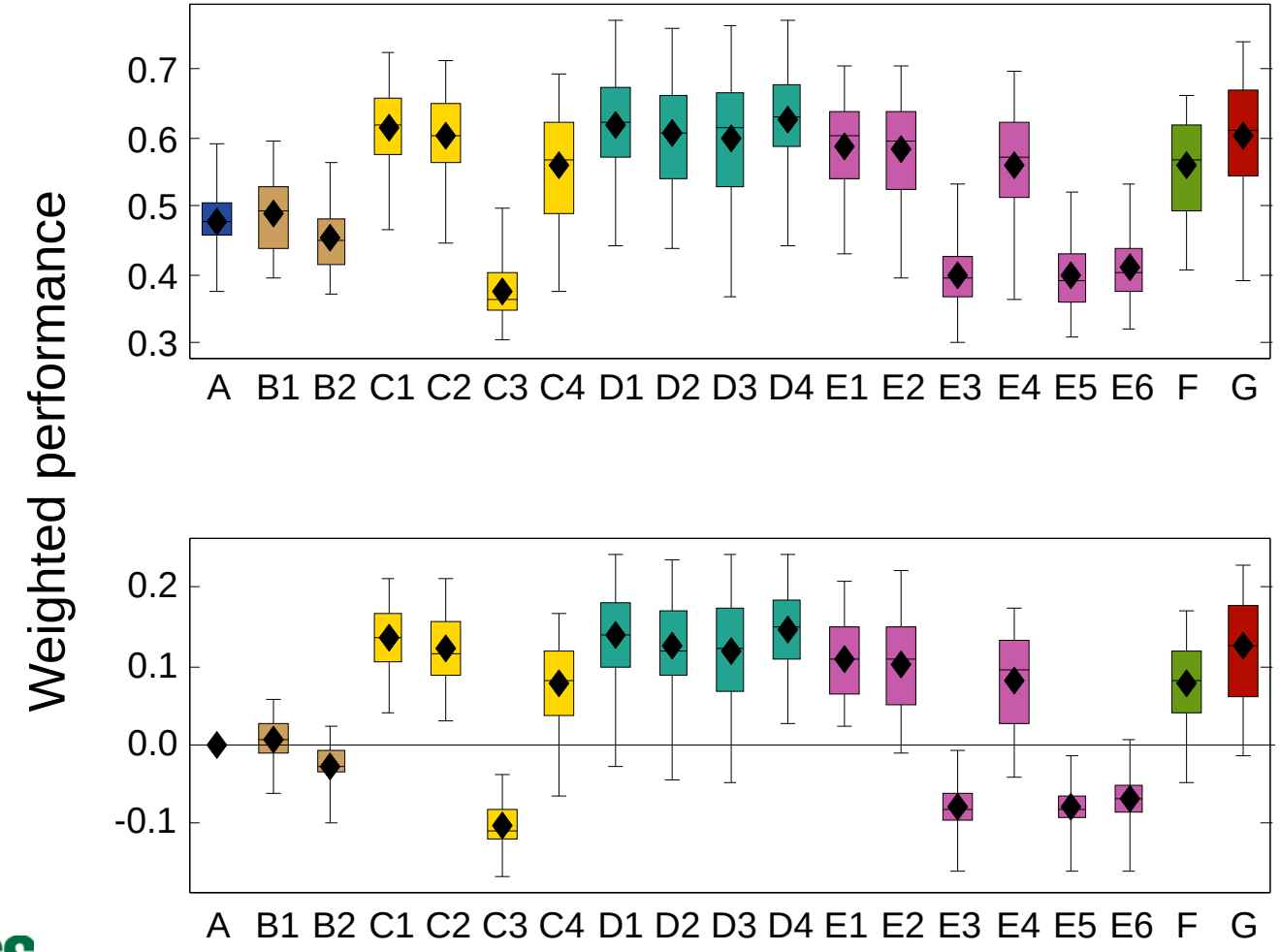
Alternative	1 HBC	2 Temp Suit	3 CPE	4 Trout Emig.	5 Qual. Trout	6 WTSI	7 GC flow	8 TOR	9 Power	10 Cap.	11 CAI	12 FI	13 GC raft	14 Veg	15 SLI	16 Wet-land	17 MR	18 TMF
	High	High	High	Low	High	High	Low	High	High	High	High	High	Low	High	High	High	Low	Low
A	4991	0.097	2.11	36,699	769	0.159	22.7	0.823	148.5	28.5	0.139	0.786	49	3.66	0.211	0.72	0.07	0.0
B1	5392	0.097	1.67	29,586	867	0.171	23.1	0.823	149.4	30.4	0.146	0.420	71	3.87	0.234	0.80	0.44	3.0
B2	5541	0.097	1.46	24,172	920	0.144	23.1	0.823	150.4	32.4	0.122	0.256	72	3.12	0.222	0.17	0.30	3.1
C1	5016	0.082	2.23	43,683	748	0.377	21.8	0.824	147.3	20.8	0.376	0.935	315	3.18	0.536	0.25	0.00	6.5
C2	4527	0.079	3.18	66,890	640	0.365	21.8	0.823	147.2	19.5	0.371	0.929	307	3.18	0.534	0.25	0.00	0.0
C3	5335	0.079	1.90	33,559	830	0.043	18.5	0.821	148.9	20.8	0.043	0.924	0	2.83	0.065	0.25	0.74	0.0
C4	4874	0.079	2.72	55,076	707	0.334	21.0	0.823	147.6	20.8	0.335	0.928	83	2.98	0.483	0.25	2.80	0.0
D1	5247	0.094	2.02	40,784	811	0.379	23.5	0.835	146.6	23.8	0.359	0.741	348	3.67	0.531	0.75	1.67	3.9
D2	5181	0.095	2.15	43,981	796	0.378	23.6	0.835	146.1	19.6	0.360	0.784	351	3.69	0.535	0.76	2.02	6.9
D3	4876	0.095	2.63	55,811	711	0.378	23.5	0.836	146.8	23.8	0.359	0.724	348	3.70	0.533	0.78	2.95	0.0
D4	5241	0.097	2.03	40,936	810	0.380	23.5	0.836	146.7	25.1	0.358	0.741	348	3.95	0.529	0.84	1.69	3.8
E1	5269	0.090	1.93	37,614	826	0.311	21.3	0.839	148.0	22.8	0.303	0.568	177	3.54	0.456	0.62	0.00	2.6
E2	5015	0.086	2.33	47,450	761	0.297	21.3	0.837	147.9	21.8	0.292	0.534	174	3.84	0.443	0.85	0.00	0.0
E3	5477	0.087	1.68	28,499	891	0.030	18.4	0.836	149.3	22.8	0.028	0.517	0	3.93	0.046	1.10	0.47	0.0
E4	5103	0.087	2.19	42,806	781	0.281	20.9	0.838	148.1	22.8	0.272	0.529	79	3.93	0.415	0.91	1.73	0.0
E5	5470	0.083	1.68	28,561	890	0.029	18.5	0.835	147.2	21.8	0.028	0.517	0	3.87	0.046	1.05	0.00	0.0
E6	5708	0.087	1.42	22,415	956	0.032	18.8	0.837	149.3	22.8	0.030	0.518	0	3.93	0.049	1.10	0.00	2.4
F	4450	0.030	3.37	71,869	592	0.299	36.8	0.749	141.0	11.2	0.406	0.997	919	3.14	0.558	0.14	0.00	0.0
G	4741	0.102	2.81	58,533	702	0.465	24.7	0.840	142.9	18.0	0.451	0.981	512	3.40	0.576	0.42	3.05	11.0

USGS

Swing Weighting PCA



Joint Lead Weighted MCDA



USGS

MCDA by Agency

Stakeholder Agency

Alternative	Joint Lead	Federal	State	State	Utility	Utility	Utility	Tribe	Tribe	Tribe	NGO	NGO	NGO
A	0.479	0.508	0.483	0.448	0.472	0.448	0.459	0.515	0.530	0.477	0.508	0.450	0.429
B1	0.488	0.504	0.511	0.450	0.493	0.485	0.474	0.512	0.538	0.495	0.511	0.474	0.443
B2	0.454	0.434	0.447	0.402	0.491	0.495	0.484	0.457	0.477	0.446	0.504	0.416	0.384
C1	0.615	0.539	0.484	0.508	0.458	0.410	0.410	0.574	0.599	0.521	0.544	0.604	0.637
C2	0.602	0.515	0.465	0.518	0.426	0.376	0.391	0.570	0.591	0.511	0.549	0.589	0.631
C3	0.376	0.433	0.378	0.369	0.418	0.400	0.412	0.411	0.410	0.374	0.445	0.315	0.280
C4	0.559	0.507	0.452	0.497	0.441	0.392	0.405	0.532	0.544	0.488	0.529	0.555	0.573
D1	0.619	0.573	0.542	0.540	0.489	0.450	0.436	0.596	0.630	0.559	0.553	0.634	0.648
D2	0.607	0.574	0.526	0.535	0.470	0.424	0.414	0.581	0.615	0.547	0.534	0.630	0.642
D3	0.599	0.557	0.526	0.540	0.472	0.425	0.428	0.584	0.614	0.550	0.544	0.621	0.637
D4	0.628	0.590	0.560	0.553	0.500	0.460	0.445	0.610	0.646	0.574	0.559	0.647	0.662
E1	0.589	0.535	0.522	0.506	0.475	0.447	0.430	0.572	0.607	0.535	0.550	0.587	0.592
E2	0.583	0.539	0.533	0.515	0.459	0.428	0.418	0.579	0.616	0.542	0.547	0.588	0.594
E3	0.400	0.488	0.482	0.411	0.450	0.445	0.434	0.463	0.483	0.445	0.461	0.373	0.319
E4	0.560	0.543	0.532	0.509	0.468	0.436	0.427	0.563	0.597	0.536	0.534	0.575	0.569
E5	0.400	0.481	0.474	0.406	0.438	0.434	0.422	0.459	0.482	0.437	0.459	0.369	0.318
E6	0.412	0.498	0.492	0.415	0.460	0.462	0.440	0.469	0.491	0.451	0.467	0.382	0.326
F	0.559	0.465	0.396	0.484	0.311	0.269	0.293	0.509	0.536	0.431	0.475	0.535	0.622
G	0.605	0.559	0.478	0.532	0.456	0.385	0.397	0.563	0.588	0.524	0.514	0.634	0.669

USGS

Best performing alternative for this metric
Alternative performs better than No Action
Alternative performs worse than No Action
Worst performing alternative for this metric

Sensitivity Analysis

- Used Expected Value of Information to evaluate the effect of uncertainty on the ranking of alternatives
  - Effect of hydrology, sediment input (1.5%)
  - Effects of various hypotheses regarding the response of trout and chub to actions (0.0%)

USGS

Outcomes

- Formal methods of decision analysis helped to structure the analysis, articulate objectives, and develop alternatives
- The ranking of alternatives
  - Was affected by the values placed on objectives by stakeholders
  - But was not strongly affected by any of the uncertainties articulated
- Comprehensive decision analysis (incl., MCDA, EVPI) included in the Environmental Impact Statement

USGS