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Hazen

Reservoir Forecasting for Triggering Drought Measures in Gwinnett County

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Gwinnett County Department of Water Resources

watersmart INNOVATIONS '15

Agenda

A Perfect Storm:

- Threatened Supply + Decreased Revenue

Preparing for the Storm

- What to do?

Analyzing and responding to risk

- Lake level forecasting
- When to pull trigger and act

Applications

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A Perfect Storm:

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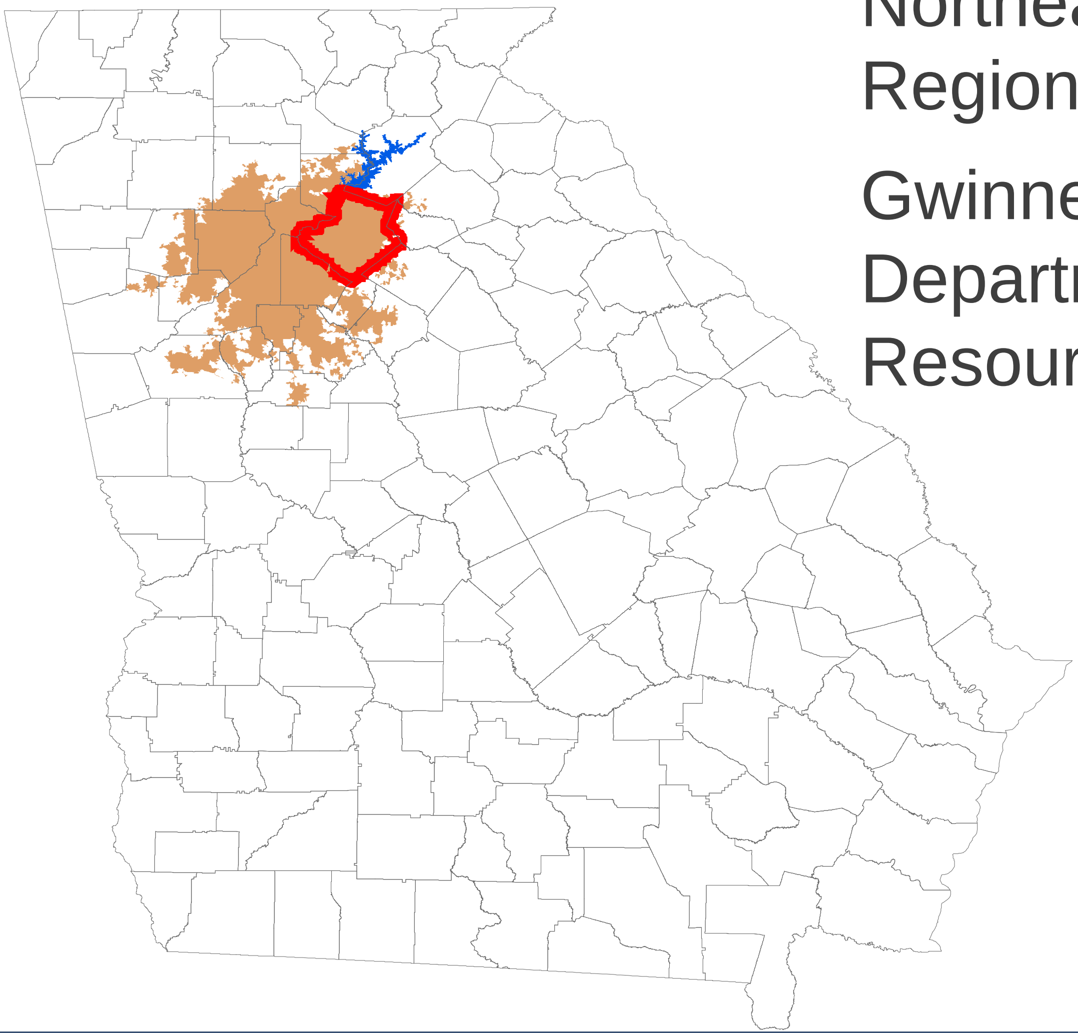
Applications

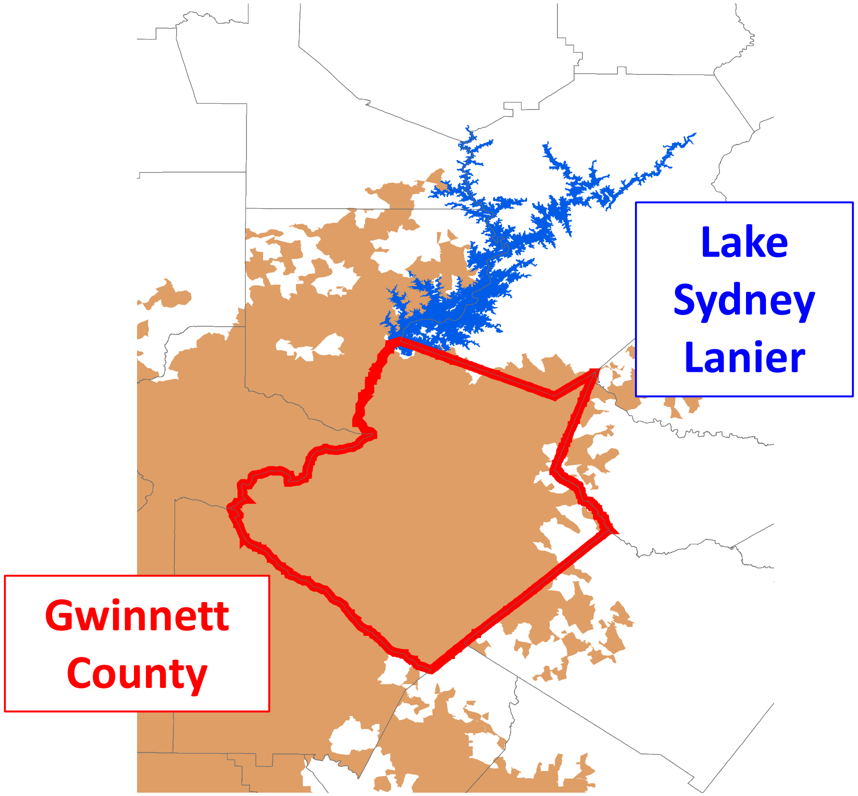
Gwinnett County, GA



Northeast Metro Atlanta Region

Gwinnett County Department of Water Resources (GCDWR)

Gwinnett County, GA



Single source of water supply: Lake Sydney Lanier

- 90 MGD annual average permit

ACF Watershed

Lake Lanier

West Point Lake

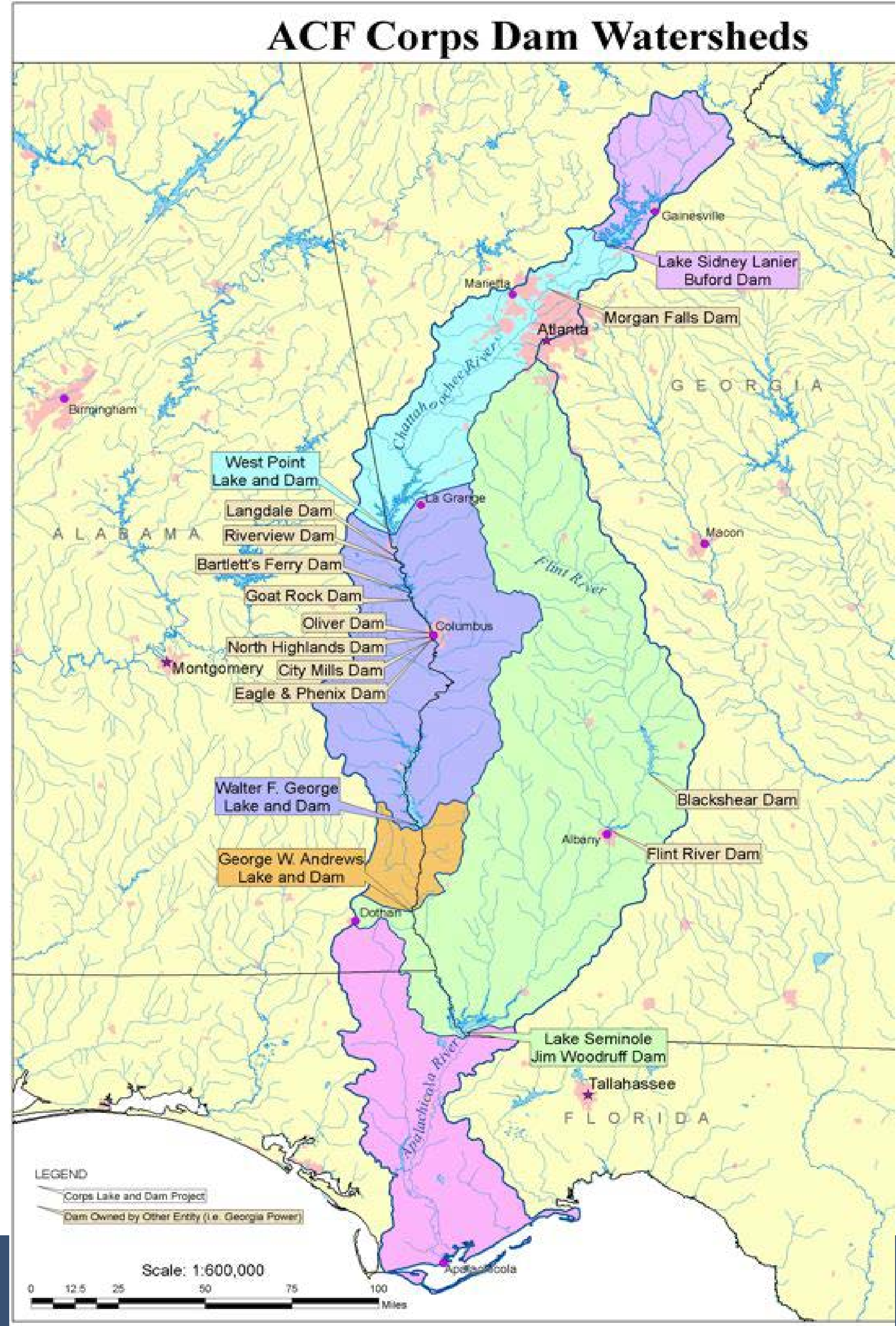
Lake George

Lake Andrews

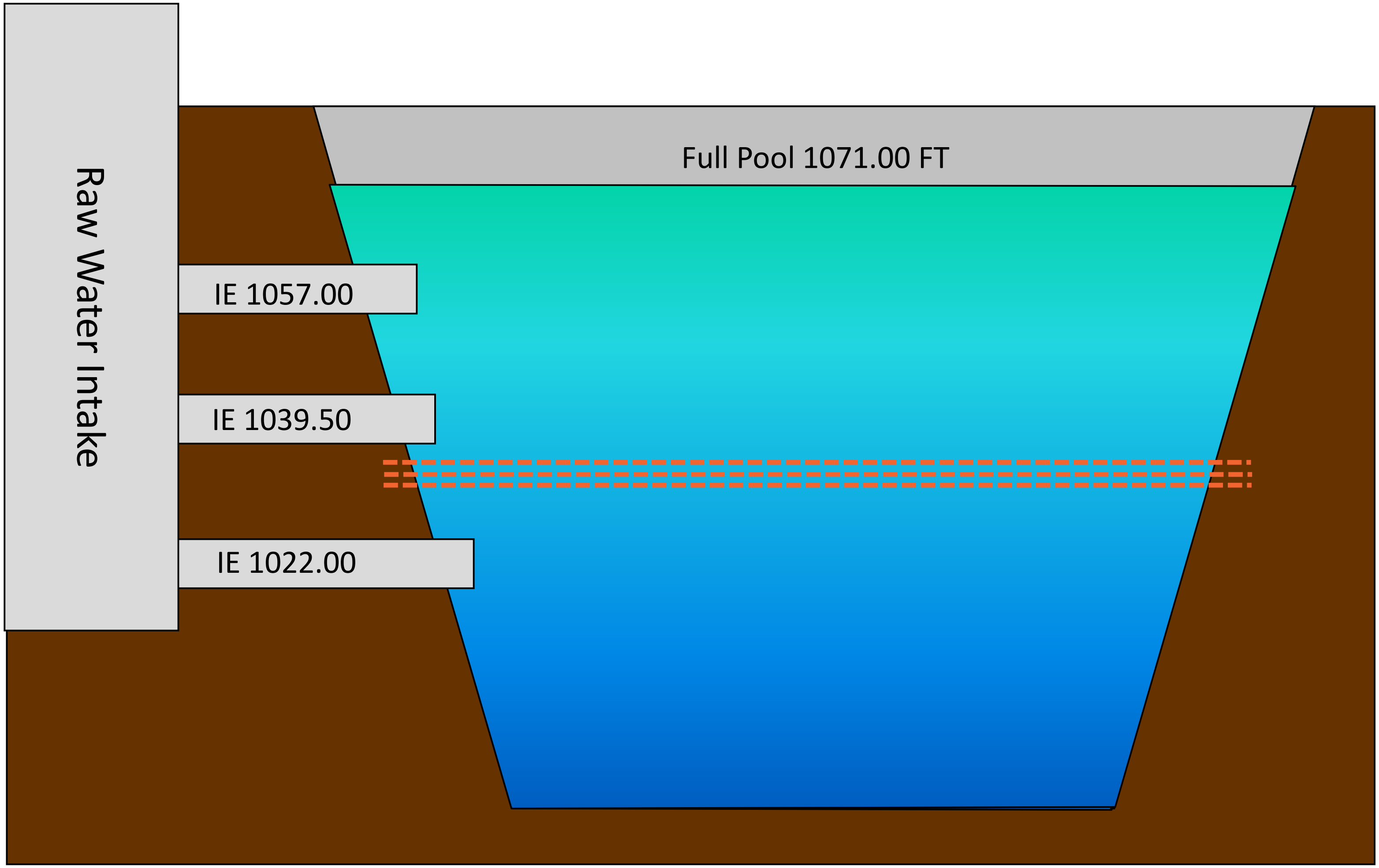
Lake Seminole

Flint River

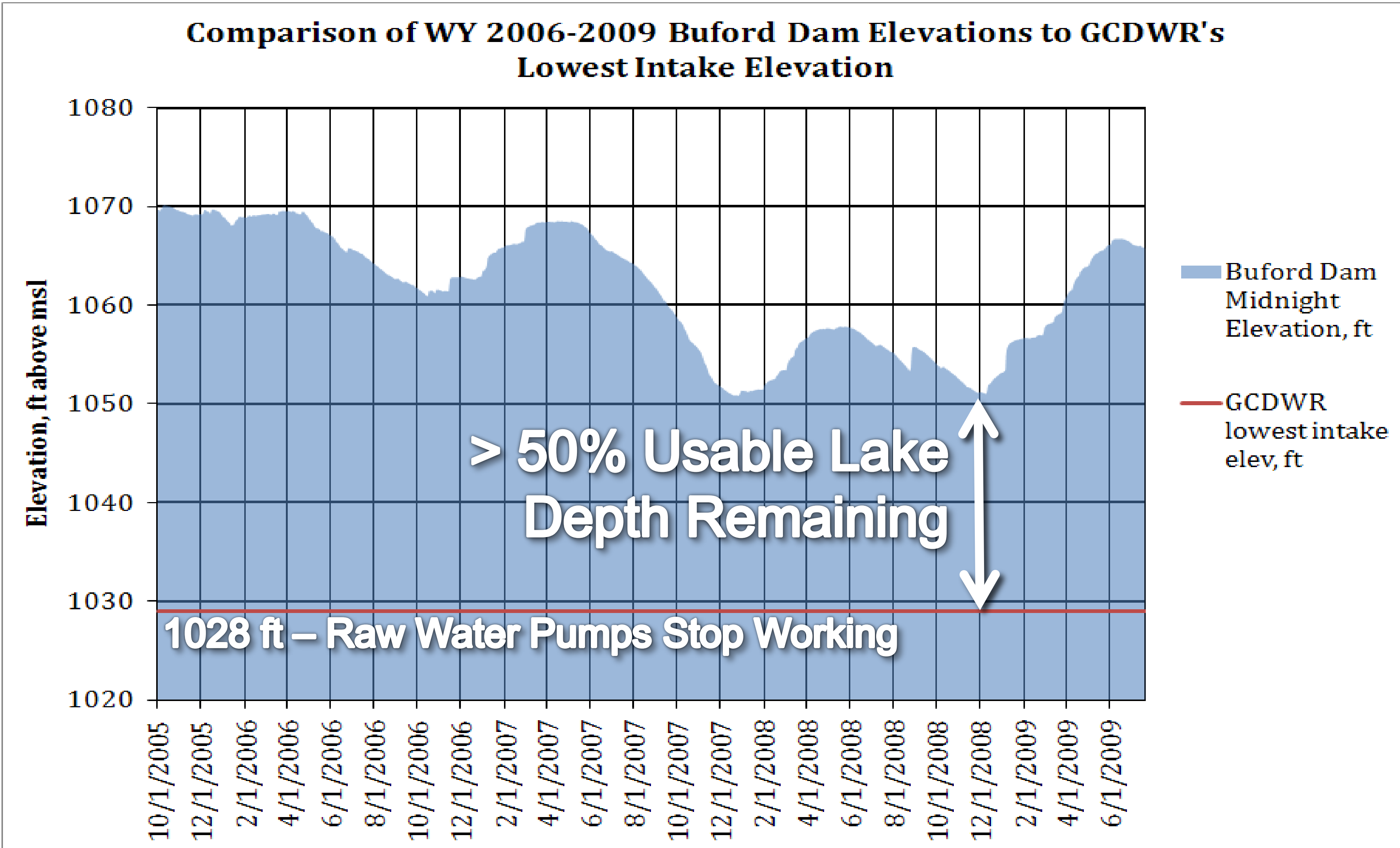
Apalachicola River



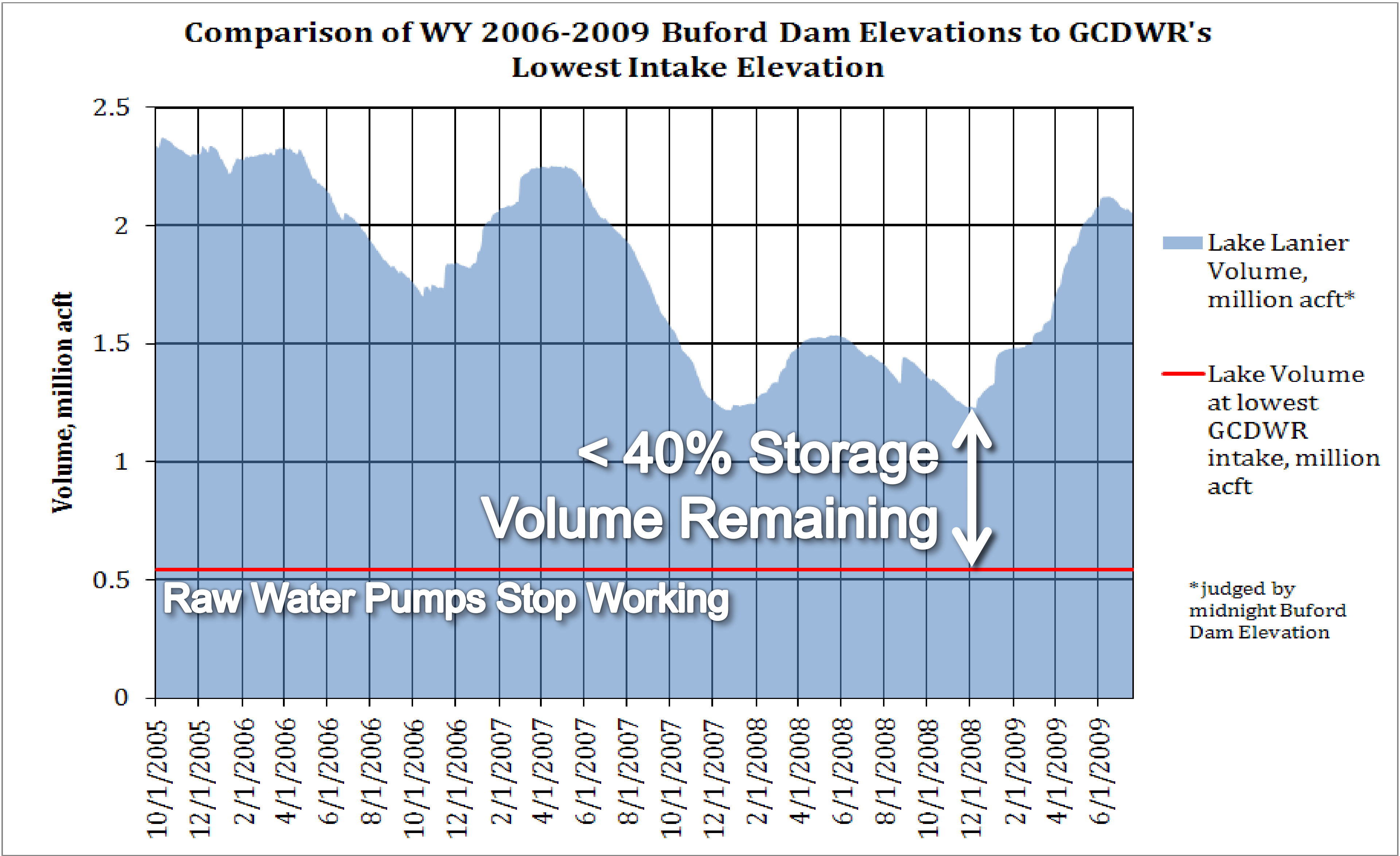
Critical Lake Elevations for DWR Supply



2007-2008 Drought: Historic Low Levels

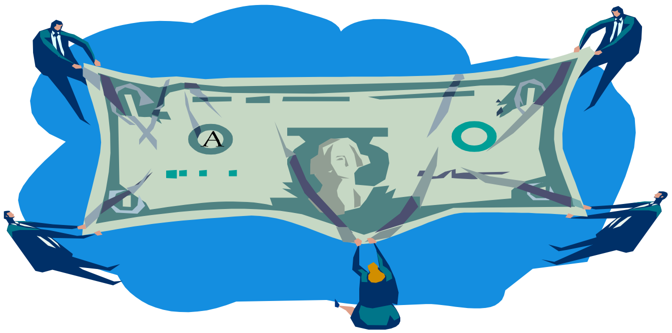


2007-2008 Drought: Historic Low Levels



2007-2008 Drought: Less Revenue

- Water use restrictions + additional statewide water conservation mandate from Governor
  - 17% annual average decrease in water demand
  - 10% to 40% drop in monthly average demand
  - Approximately 5% reduction in revenue
- Continued lower demand and revenue since 2008
  - Economic effects, rate increases, wet weather (except 2011)



Agenda

A Perfect Storm:

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Preparing for the Storm

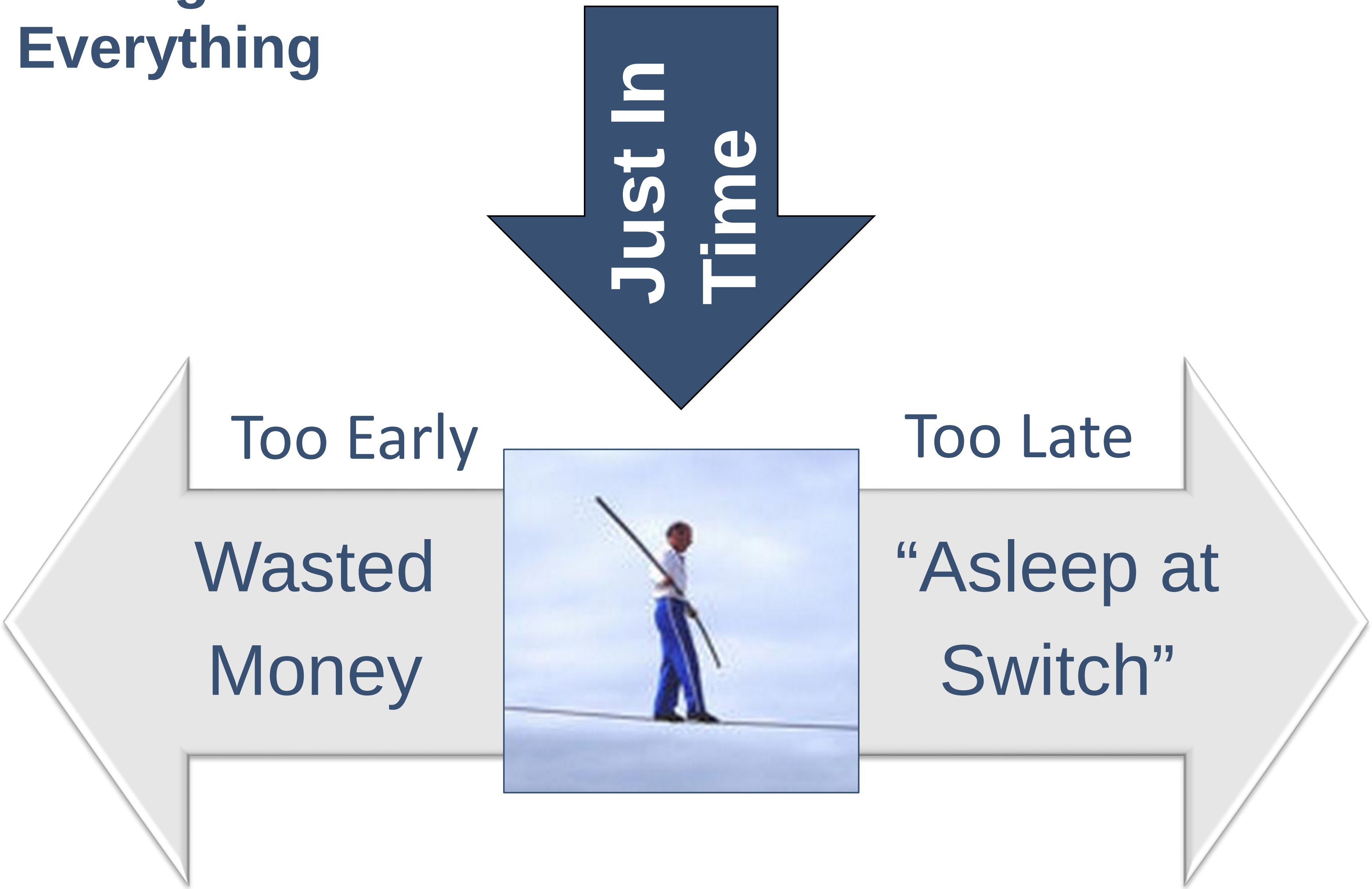
- **What to do?**

Analyzing and responding to risk

- Lake level forecasting
- When to pull trigger and act

Applications

Timing is Everything



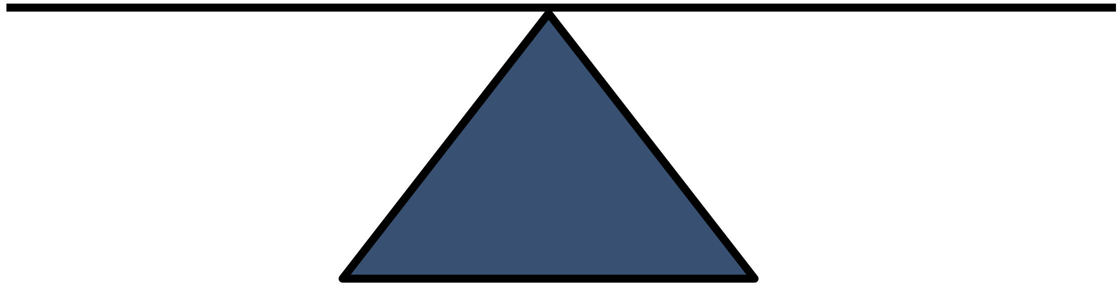
Efficient, Safe Plan For Emergency Supply

Timing is Everything

- Specify Technology and Implementation
- Balance risks of over-reaction, under-reaction

Potential Money Waste

Potential Supply Loss



Plan Strategies

Best value

Seek solution that is cost effective at full implementation

Pay-as-you-go

schedule phased implementation to commit costs only as needed

Respond to risk

Trigger phases by quantifying risk (likelihood) of near-term lake depletion – lake forecast tools

Temporary Intake Concepts

Floating Owned
Pump Station

Floating Rental
Pump Station

Land Based
Rental Pump Station

Selected Option – Land Based Pump Rental

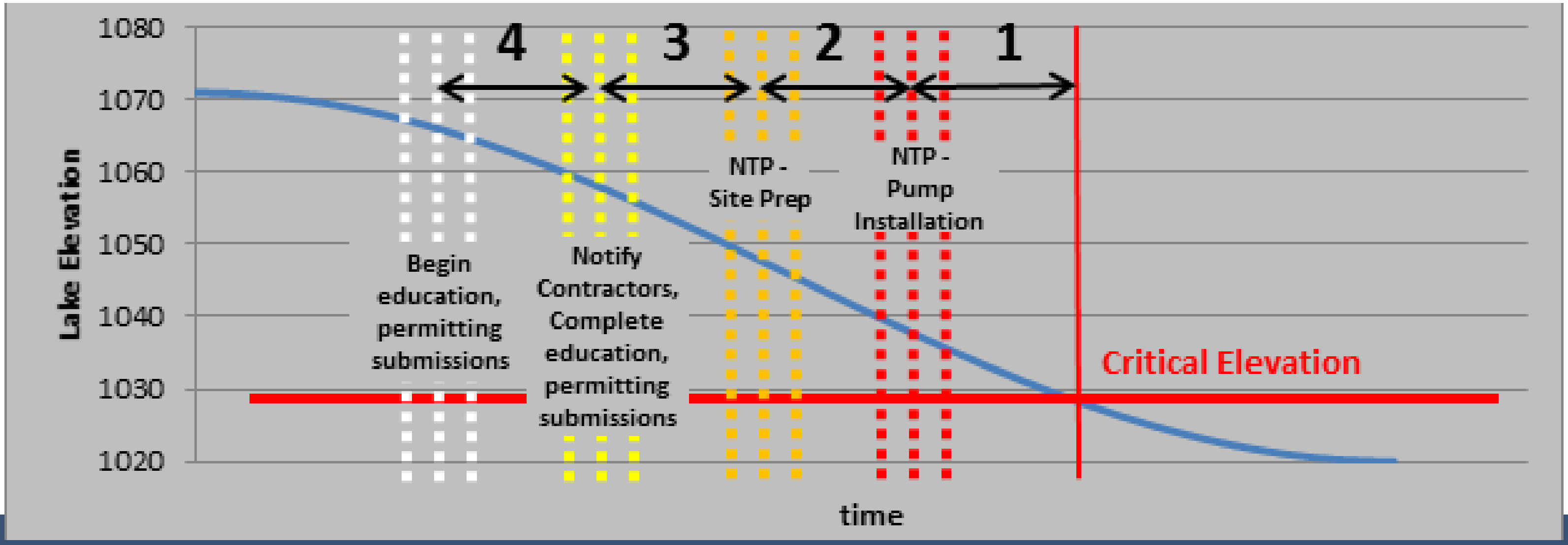
- Lowest Life Cycle Cost
- Least Up Front Cost
- Shortest Installation Time
- Proven in Application
- USACE has Permitted Similar Facility on Lanier
- Rent to Own Option
- Flexible and Reliable
- Just-In-Time Implementation
- Minimize Lost Opportunity Costs
- Maximize Safety – Public & GCDWR Personnel

Contract Implementation

General Contractor On-Call for Multiple Years

Three Work Packages (Triggers)

- Work Package No. 1 - Project Plan & Submittals
- Work Package No. 2 - Site and Electrical Work
- Work Package No. 3 - Pump and Piping Installation



When Should Implementation Begin?

- Implement pump station phases only when high risk (likelihood) of supply loss detected
  - Detect risk before loss actually occurs
  - Differentiate between high risk and low risk
  - Differentiate between near-term, longer-term risk
- Progressive implementation as risk increases and becomes more short term

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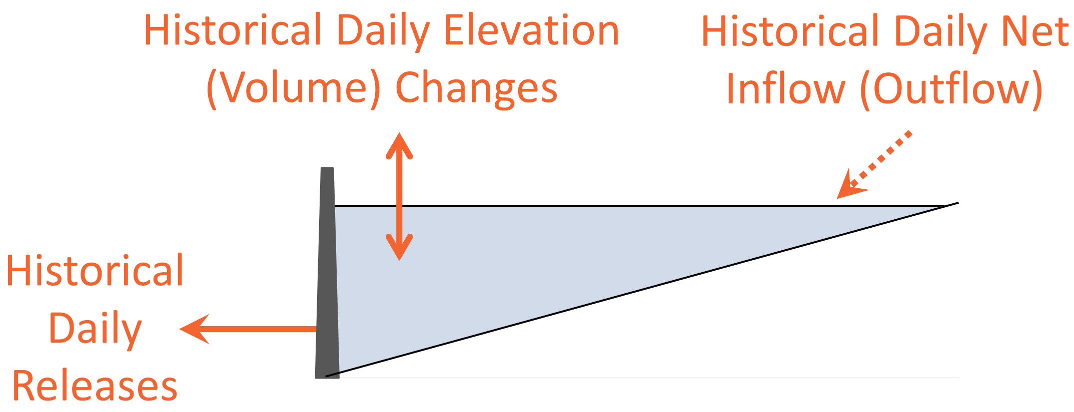
- **Lake level forecasting**
- **When to pull trigger and act**

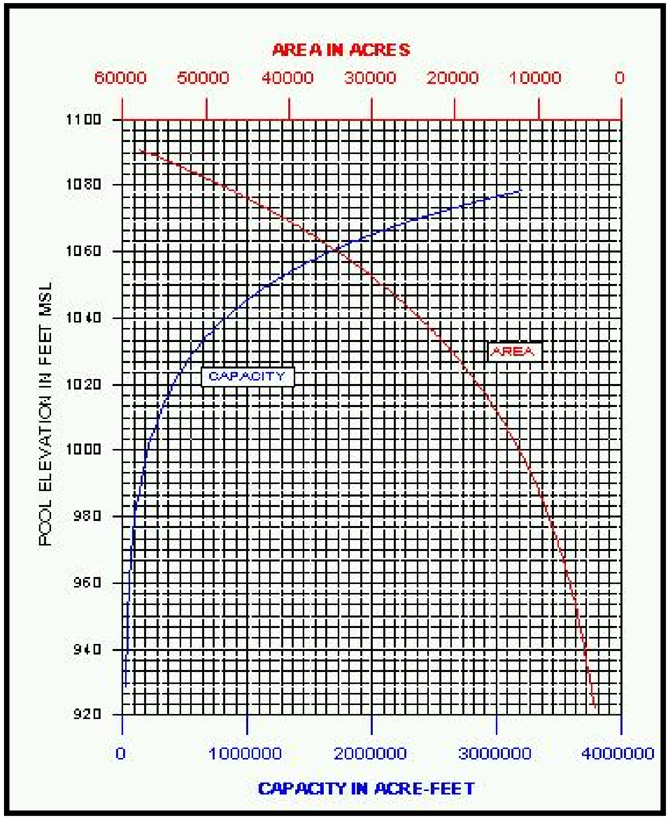
Applications

Detecting Risk:
A Simple Lake Volume Model

Elevation\volume curve

Historical seasonal inflows (back-calculate from historical elevation and discharge data)





Vol2 = Vol1 + Net Inflows - Daily Buford Dam Releases

Detecting Risk: Lake Forecast Procedure

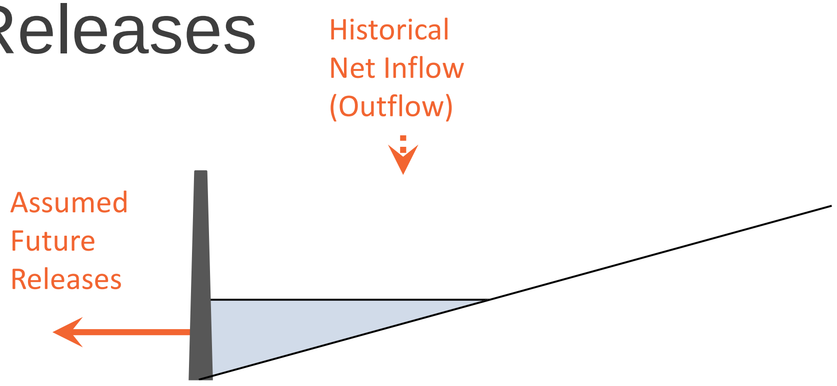
Current Observed Elevation

Assumed Future Buford Releases

Historical 365-day inflow scenarios

beginning @ same day of year as the current observed elevation

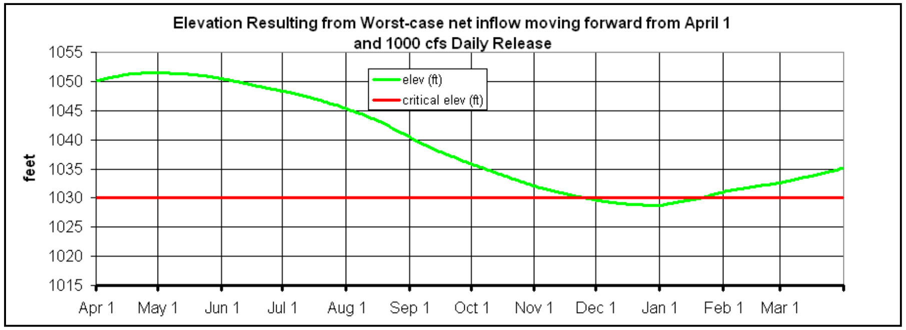
See where elevation would go under historical inflows + future releases



Two Risk Forecast Methods

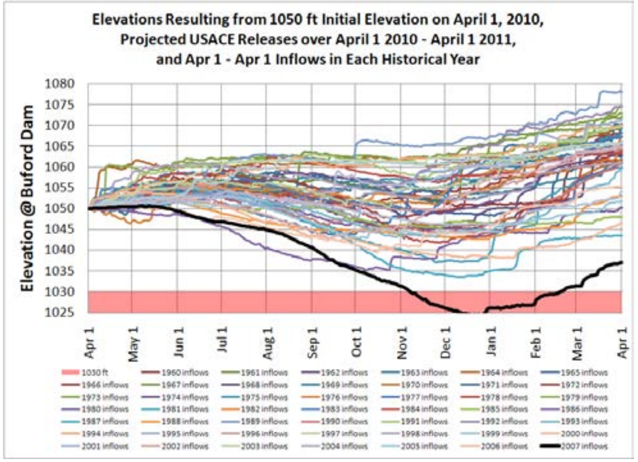
Worst Case Inflow Scenario

Would supply loss occur under worst case inflows?



Reservoir Reliability

How likely would supply loss be under the range of inflows?



Worst Case Scenario Example

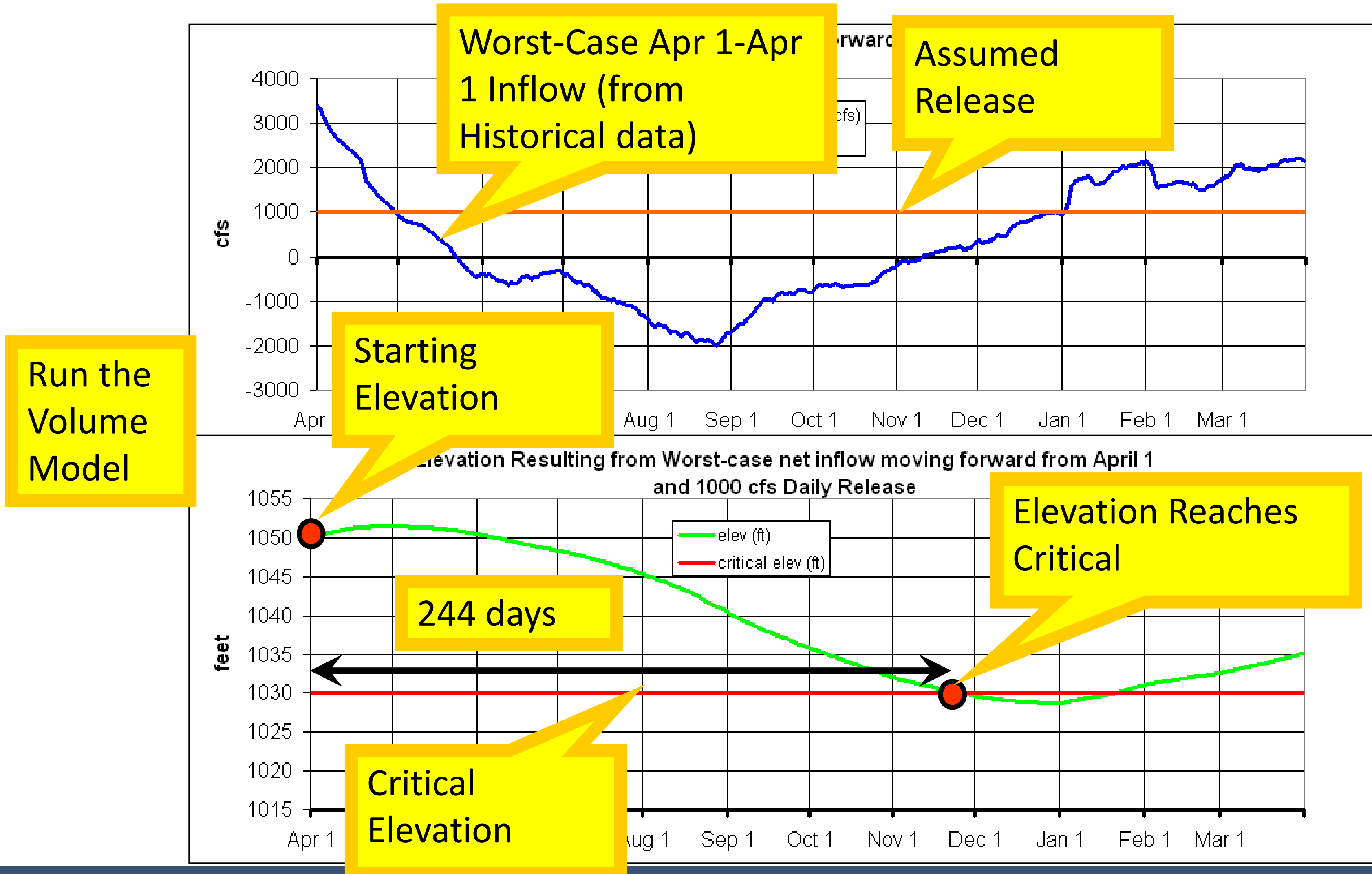
Initial conditions

- Lake level = 1050 ft on April 1, 2010

Assumed USACE release rates

- average 1000 cfs over April 1 – April 1 (365 days)

Worst Case Scenario Example



Worst Case Scenario Tabular Results

Repeat for multiple starting elevations, release rates

Determine and chart worst-case estimates of days-to-critical

Start Date:Apr 01			Critical Elevation: 1030.0 ft (24.75 Bcf)				
	Assumed USACE Buford Dam Release Rate, cfs						
Assumed Lake Lanier Starting Elevation, ft	800 cfs	1000 cfs	1200 cfs	1400 cfs	1600 cfs	1800 cfs	2000 cfs
1030	80	70	63	56	49	43	37
1030.5	86	73	66	60	53	46	41
1031	92	77	69	63	56	50	44
1031.5	97	81	71	65	59	53	48
1032	101	86	75	68	62	56	51
1032.5	104	91	78	70	65	59	54
1033	107	96	82	73	67	62	56
1033.5	111	100	86	76	69	64	59
1034	114	103	92	80	72	67	62
1034.5	117	107	96	84	75	69	64
1035	121	110	100	88	78	72	67
1035.5	124	112	103	92	82	74	69
1036	127	115	106	96	85	77	71
1036.5	130	118	109	99	89	80	73
1037	133	122	111	102	93	83	76
1037.5	135	125	114	105	96	87	79
1038	137	128	117	108	99	90	82
1038.5	139	130	119	110	102	93	85
1039	141	133	122	113	105	96	88
1039.5	144	135	125	115	107	99	91
1040	146	137	128	118	109	102	94
1040.5	149	139	131	121	112	104	97
1041	152	141	133	124	115	107	100
1041.5	155	144	135	127	117	110	102
1042	159	146	138	130	120	112	105
1042.5	162	149	140	132	123	115	108
1043	166	152	142	134	126	117	110
1043.5	172	156	145	137	129	121	113
1044	180	160	148	140	132	124	116
1044.5	187	164	152	142	135	127	119
1045	192	169	155	145	137	130	122
1046	206	182	163	151	143	136	129
1047	225	193	172	158	148	140	134
1048	> 365	204	183	165	154	145	138
1049	> 365	219	193	174	161	151	143
1050	> 365	244	203	185	168	157	148
1051	> 365	> 365	218	195	178	164	154
1052	> 365	> 365	241	206	188	172	161
1053	> 365	> 365	> 365	220	197	182	168
1054	> 365	> 365	> 365	239	209	191	177
1055	> 365	> 365	> 365	260	221	200	186
1056	> 365	> 365	> 365	> 365	237	210	194
1057	> 365	> 365	> 365	> 365	254	222	202
1058	> 365	> 365	> 365	> 365	> 365	236	212
1059	> 365	> 365	> 365	> 365	> 365	250	222
1060	> 365	> 365	> 365	> 365	> 365	275	235
1061	> 365	> 365	> 365	> 365	> 365	> 365	256
1062	> 365	> 365	> 365	> 365	> 365	> 365	> 365
1063	> 365	> 365	> 365	> 365	> 365	> 365	> 365
1064	> 365	> 365	> 365	> 365	> 365	> 365	> 365
1065	> 365	> 365	> 365	> 365	> 365	> 365	> 365
1066	> 365	> 365	> 365	> 365	> 365	> 365	> 365
1067	> 365	> 365	> 365	> 365	> 365	> 365	> 365
1068	> 365	> 365	> 365	> 365	> 365	> 365	> 365
1069	> 365	> 365	> 365	> 365	> 365	> 365	> 365
1070	> 365	> 365	> 365	> 365	> 365	> 365	> 365
1071	> 365	> 365	> 365	> 365	> 365	> 365	> 365

Start Date:Apr 01 | Critical Elevation: 1030.0 ft (24.75 Bcf)

Assumed Lal	Assumed USACE Buford Dam Release Rate, cfs						
	800 cfs	1000 cfs	1200 cfs	1400 cfs	1600 cfs	1800 cfs	2000 cfs
1030	80	[illegible]	63	56	49	43	[illegible]
1030.5	86	[illegible]	66	60	53	46	[illegible]
1031	92	[illegible]	69	63	56	50	[illegible]
1031.5	[illegible]	[illegible]	[illegible]	65	[illegible]	[illegible]	[illegible]
1032	[illegible]	[illegible]	[illegible]	68	[illegible]	[illegible]	[illegible]
1032.5	[illegible]	[illegible]	[illegible]	70	[illegible]	[illegible]	[illegible]
1033	[illegible]	[illegible]	[illegible]	73	[illegible]	[illegible]	[illegible]
1033.5	[illegible]	[illegible]	[illegible]	76	[illegible]	[illegible]	[illegible]
1047	225	[illegible]	[illegible]	158	148	140	[illegible]
1048	> 365	[illegible]	183	165	154	145	[illegible]
1049	[illegible]	219	193	174	161	151	143
1050	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	148
1051	[illegible]	> 365	218	195	178	164	154
1052	> 365	> 365	241	206	188	172	161
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1059	> 365	> 365	> 365	> 365	> 365	250	222
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1062	> 365	> 365	> 365	> 365	> 365	> 365	> 365
1063	> 365	> 365	> 365	> 365	> 365	> 365	> 365
1064	> 365	> 365	> 365	> 365	> 365	> 365	> 365
1065	> 365	> 365	> 365	> 365	> 365	> 365	> 365
1066	> 365	> 365	> 365	> 365	> 365	> 365	> 365
1067	> 365	> 365	> 365	> 365	> 365	> 365	> 365
1068	> 365	> 365	> 365	> 365	> 365	> 365	> 365
1069	> 365	> 365	> 365	> 365	> 365	> 365	> 365
1070	> 365	> 365	> 365	> 365	> 365	> 365	> 365
1071	> 365	> 365	> 365	> 365	> 365	> 365	> 365

Reach 1030 ft in 244Days

Reach 1030 ft in 148 Days

Using the Worst-Case Scenario Results

- Monitor worst-case days-to-critical at the beginning of each month
- Trigger implementation phases when certain thresho days-to-critical are reached
- Increase in Buford Dam Releases would trigger revised analysis

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1043.5	172	156	145	137	129	121	113
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1044.5	187	164	152	142	135	127	119
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1070	> 365	> 365	> 365	> 365	> 365	> 365	> 365
1071	> 365	> 365	> 365	> 365	> 365	> 365	> 365

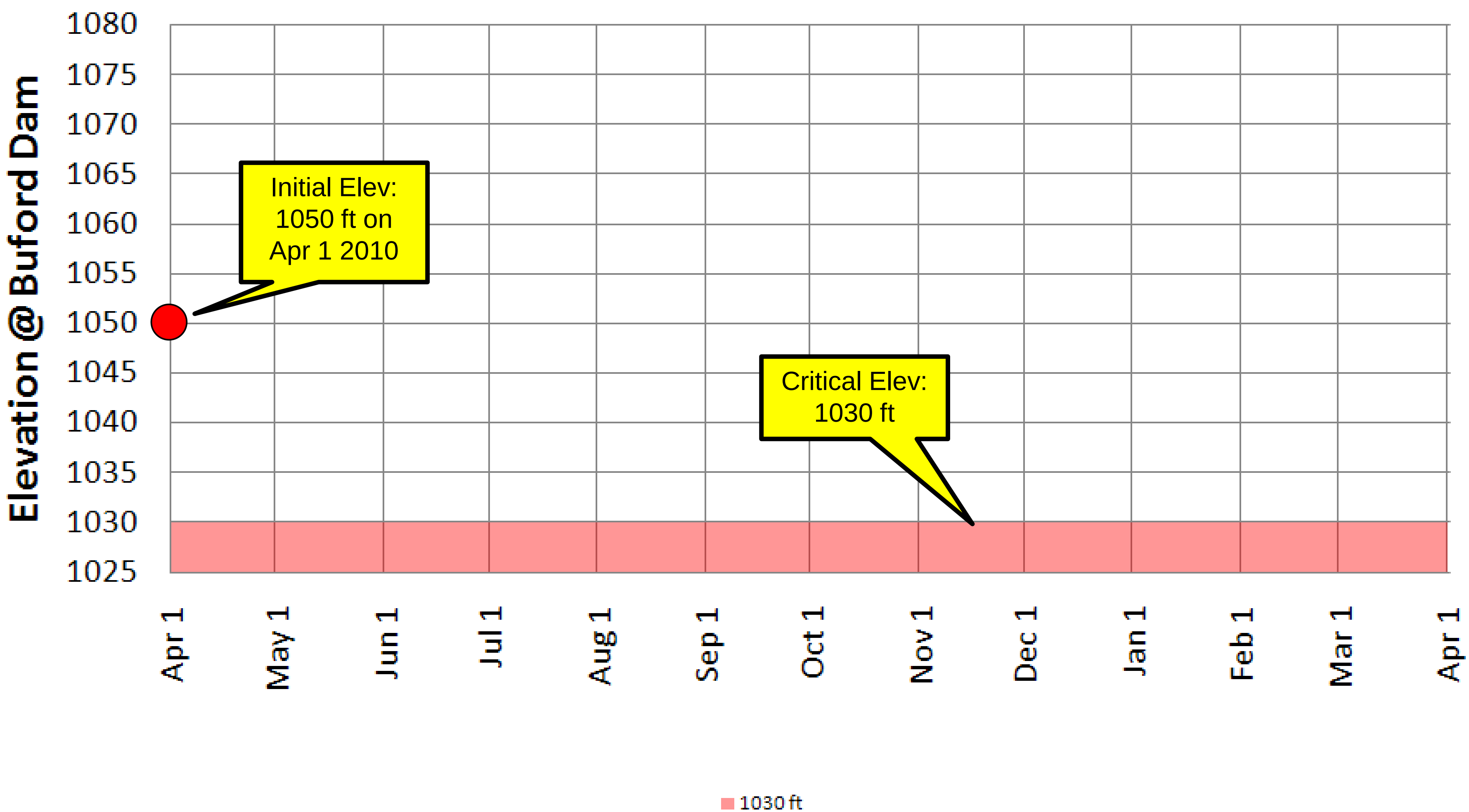
Reservoir Reliability Example

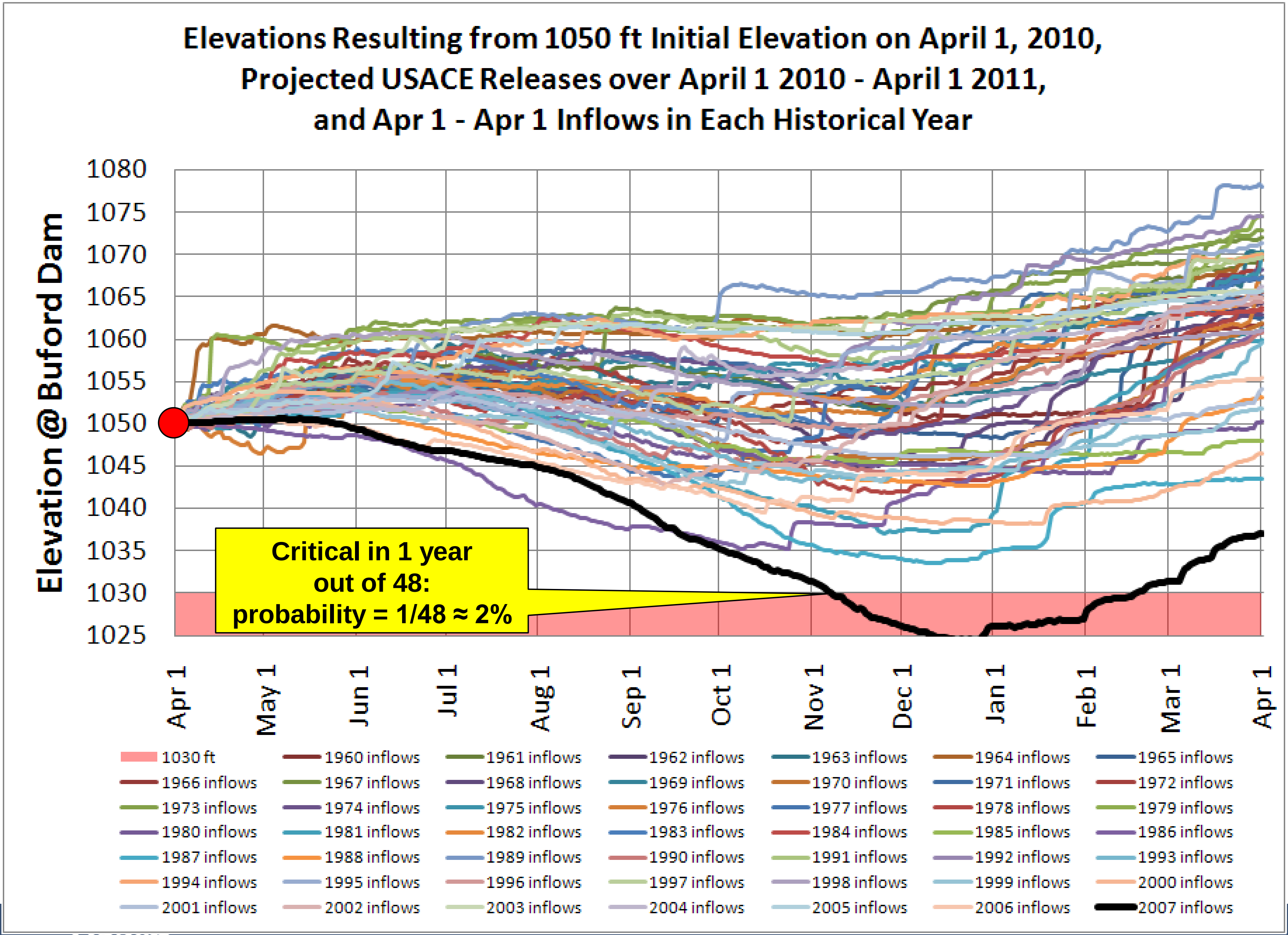
Same initial conditions (1050 ft on Apr 1 2010)

Same assumed releases (1000 cfs avg)

Now, look at *multiple* historical Apr 1 – Apr 1 scenarios

Elevations Resulting from 1050 ft Initial Elevation on April 1, 2010, Projected USACE Releases over April 1 2010 - April 1 2011, and Apr 1 - Apr 1 Inflows in Each Historical Year





Elevations Resulting from 1050 ft Initial Elevation on April 1, 2010,
Projected USACE Releases over April 1 2010 - April 1 2011,
and Apr 1 - Apr 1 Inflows in Each Historical Year
Elevation @ Buford Dam
1080
1075
1070
1065
1060
1055
1050
1045
1040
1035
1030
1025
Critical in 1 year out of 48: probability = 1/48 ≈ 2%
Apr 1
May 1
Jun 1
Jul 1
Aug 1
Sep 1
Oct 1
Nov 1
Dec 1
Jan 1
Feb 1
Mar 1
Apr 1
1030 ft
1960 inflows
1961 inflows
1962 inflows
1963 inflows
1964 inflows
1965 inflows
1966 inflows
1967 inflows
1968 inflows
1969 inflows
1970 inflows
1971 inflows
1972 inflows
1973 inflows
1974 inflows
1975 inflows
1976 inflows
1977 inflows
1978 inflows
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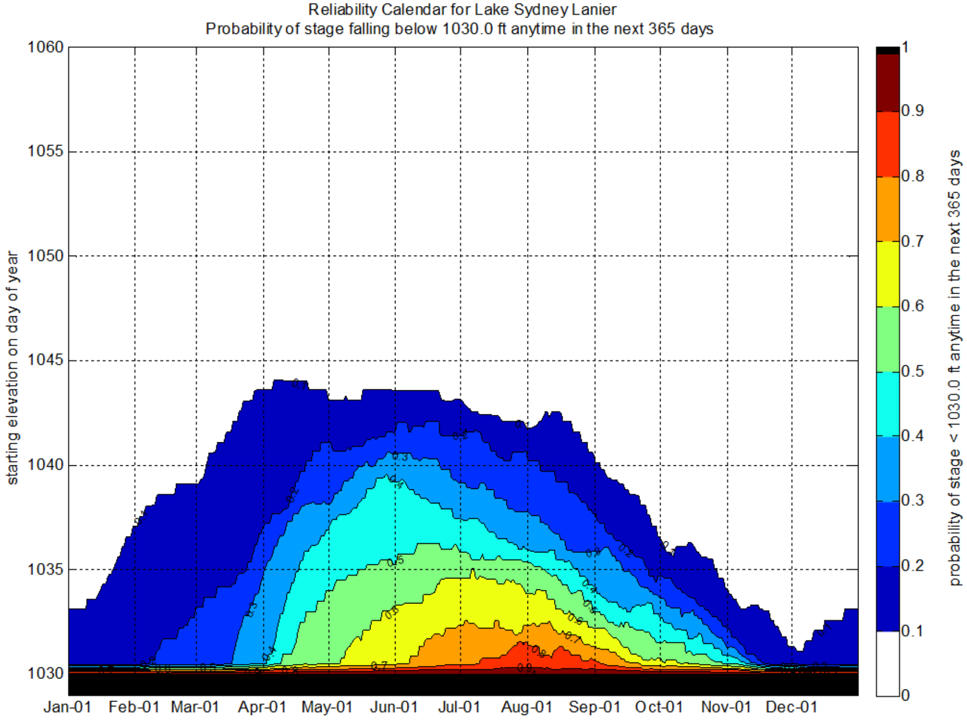
1991 inflows
1992 inflows
1993 inflows
1994 inflows
1995 inflows
1996 inflows
1997 inflows
1998 inflows
1999 inflows
2000 inflows
2001 inflows
2002 inflows
2003 inflows
2004 inflows
2005 inflows
2006 inflows
2007 inflows

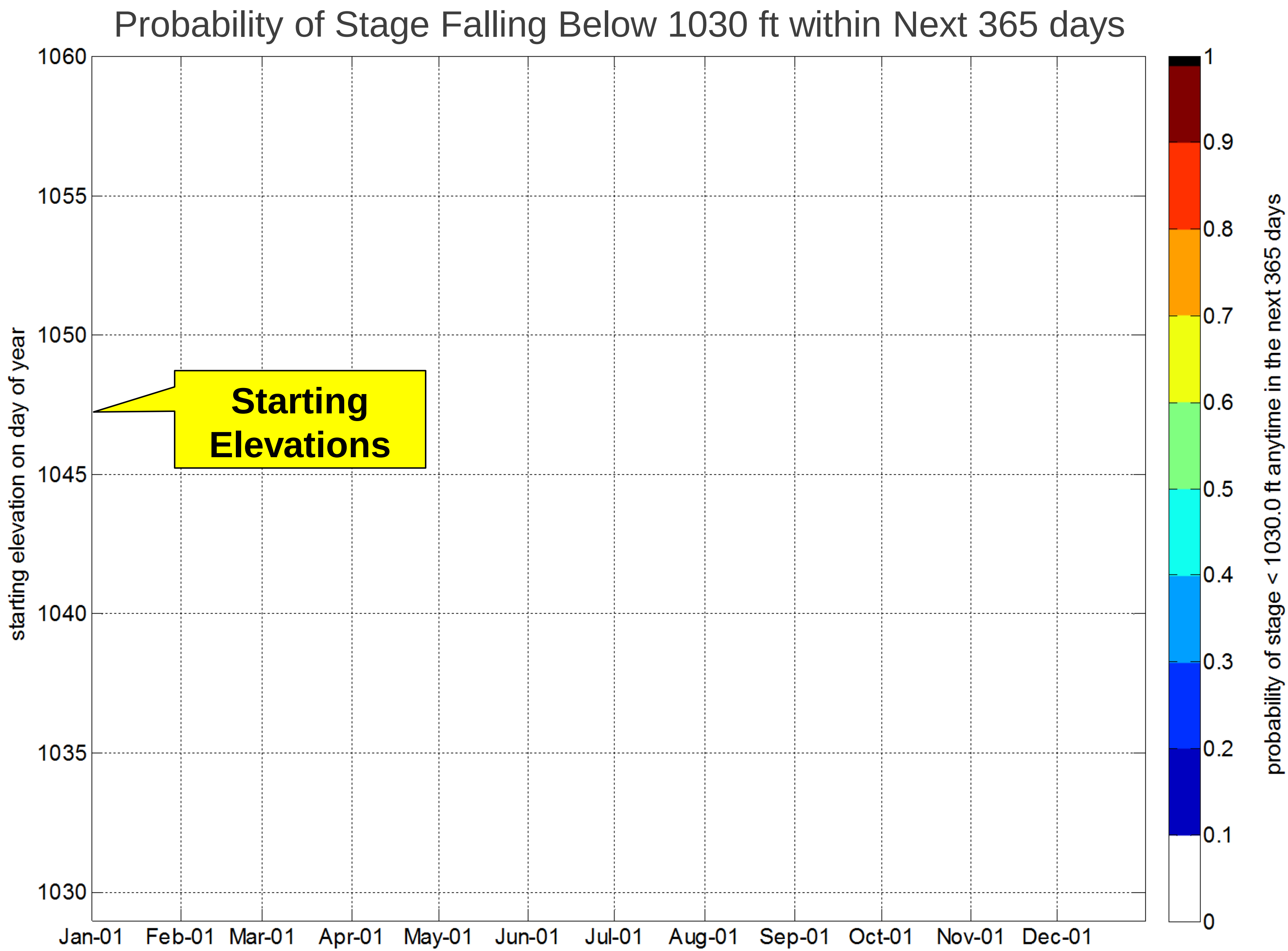
Reliability Calendar

Repeat the calculation for multiple starting dates and initial conditions

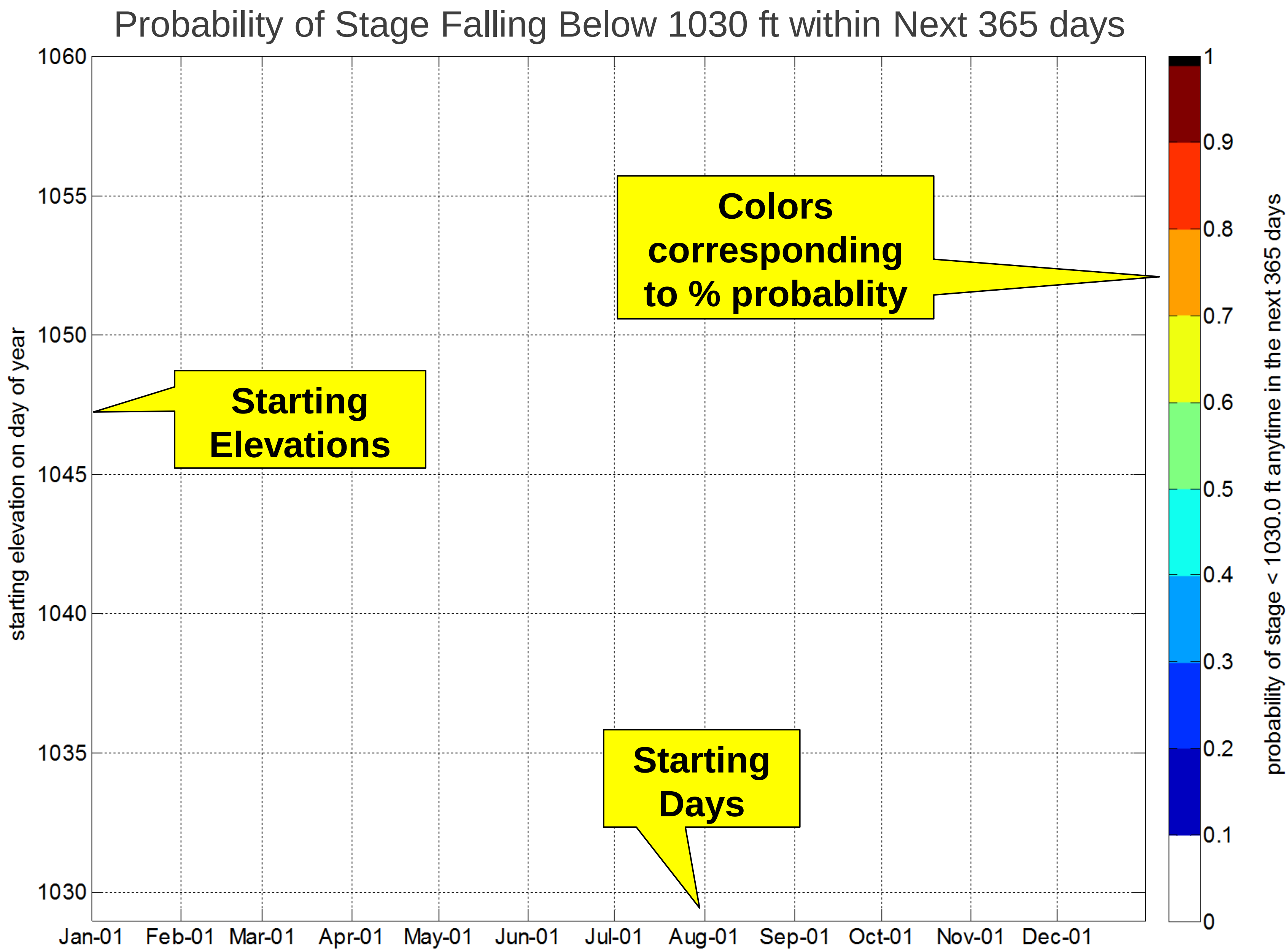
Plot contours of probability versus

- starting date (x-axis)
- starting stage (y-axis)

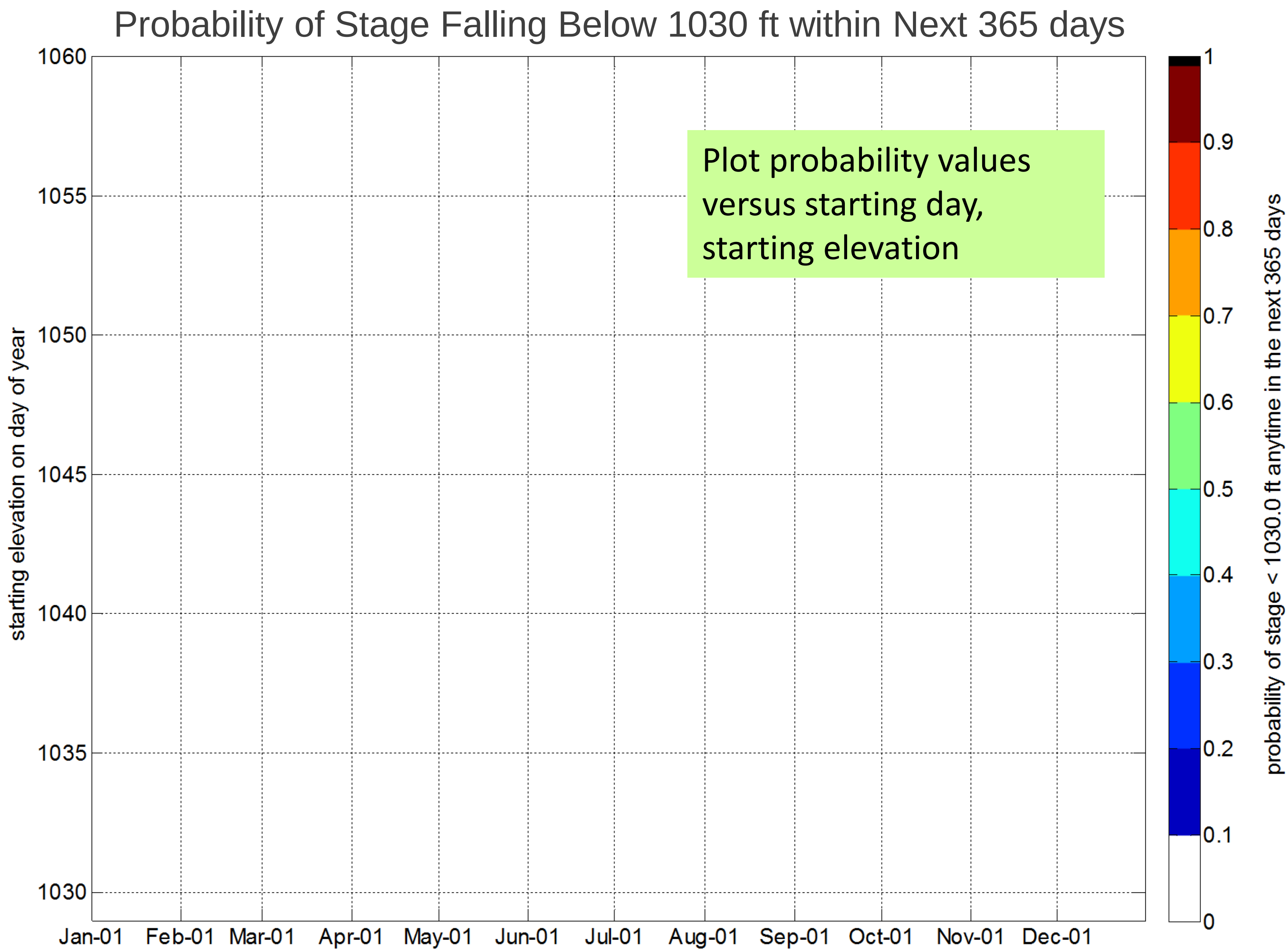


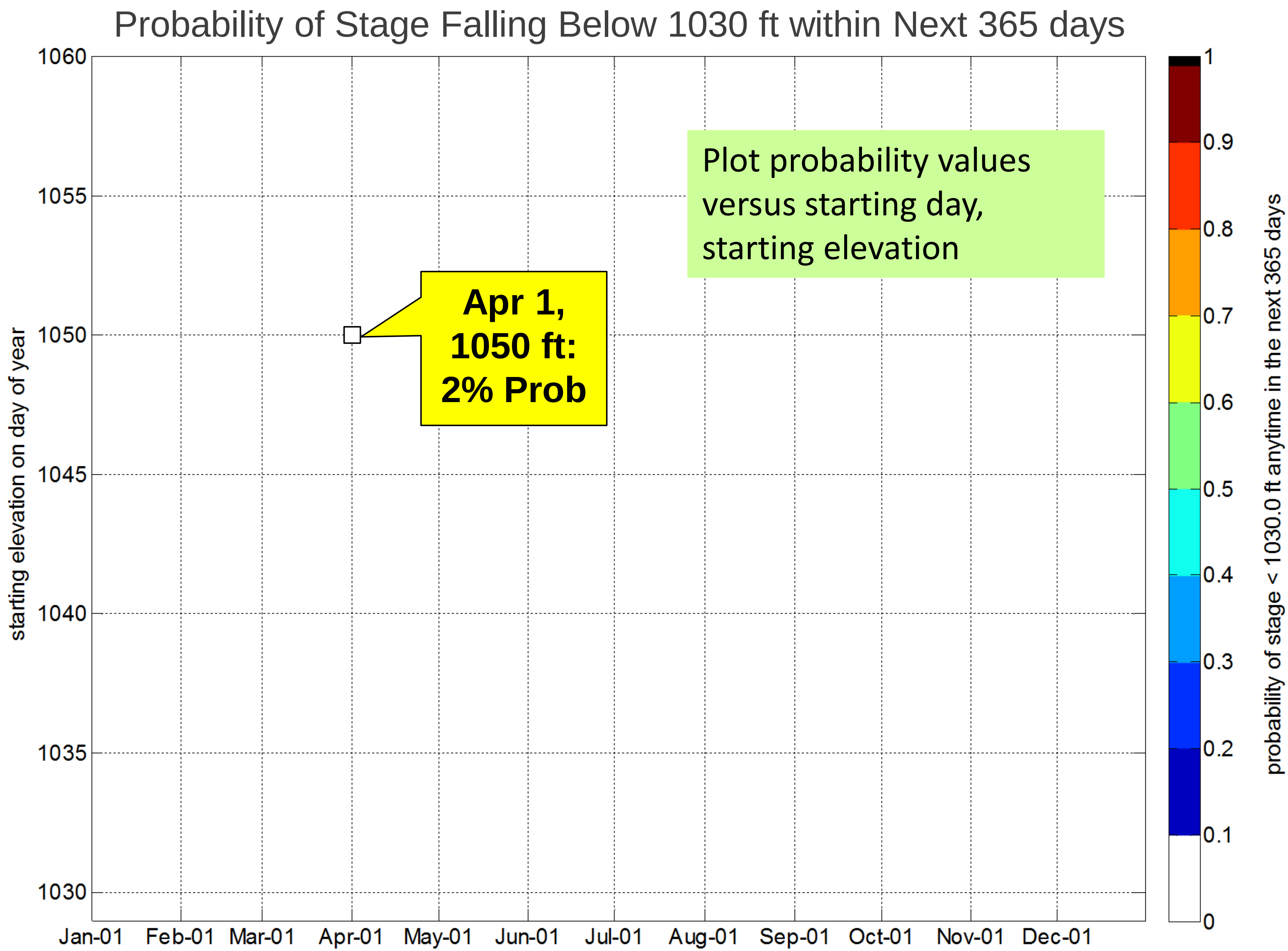


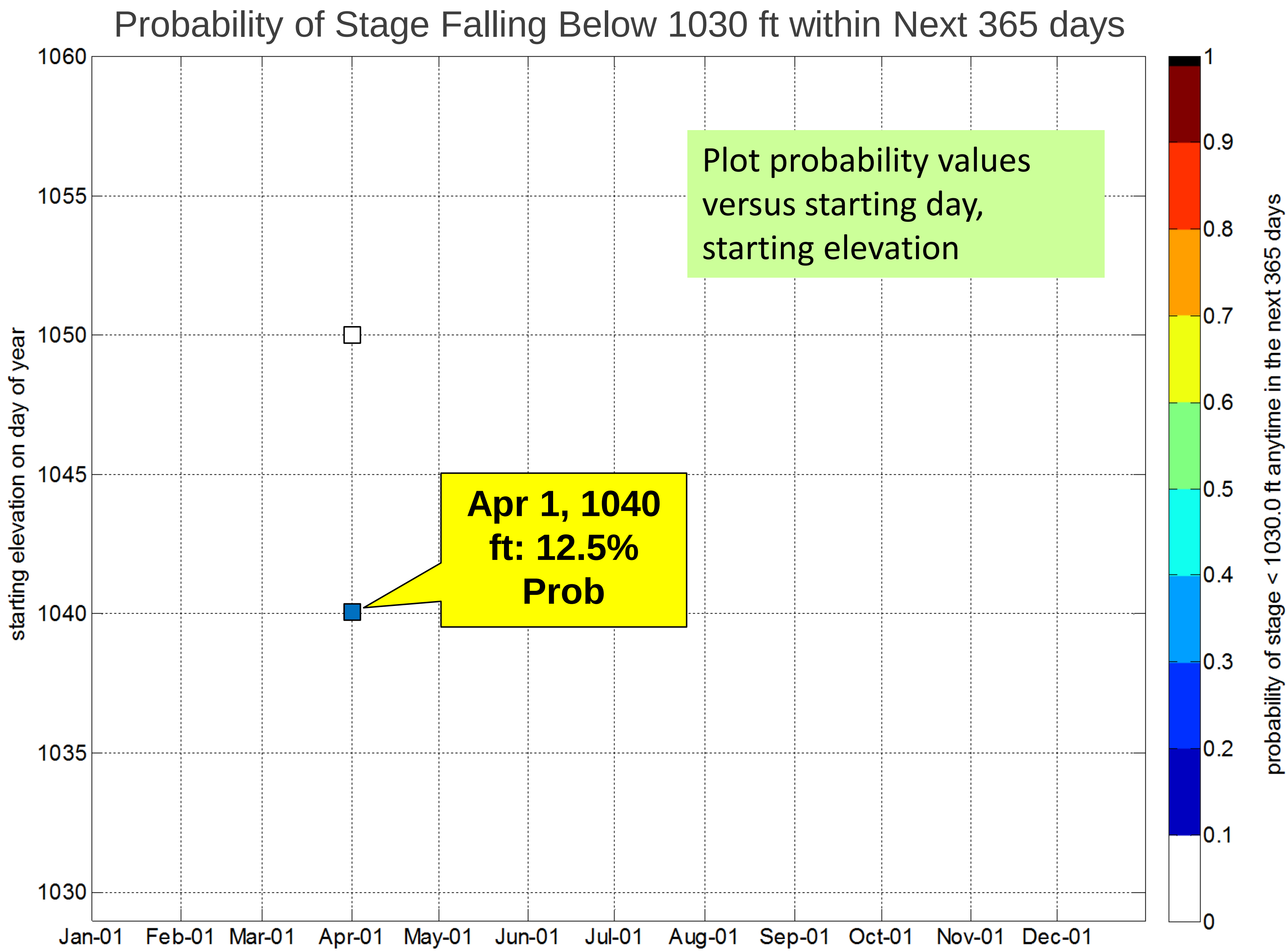
Probability of Stage Falling Below 1030 ft within Next 365 days
1060
1055
1050
1045
1040
1035
1030
starting elevation on day of year
Starting Elevations
Jan-01
Feb-01
Mar-01
Apr-01
May-01
Jun-01
Jul-01
Aug-01
Sep-01
Oct-01
Nov-01
Dec-01
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
probability of stage < 1030.0 ft anytime in the next 365 days

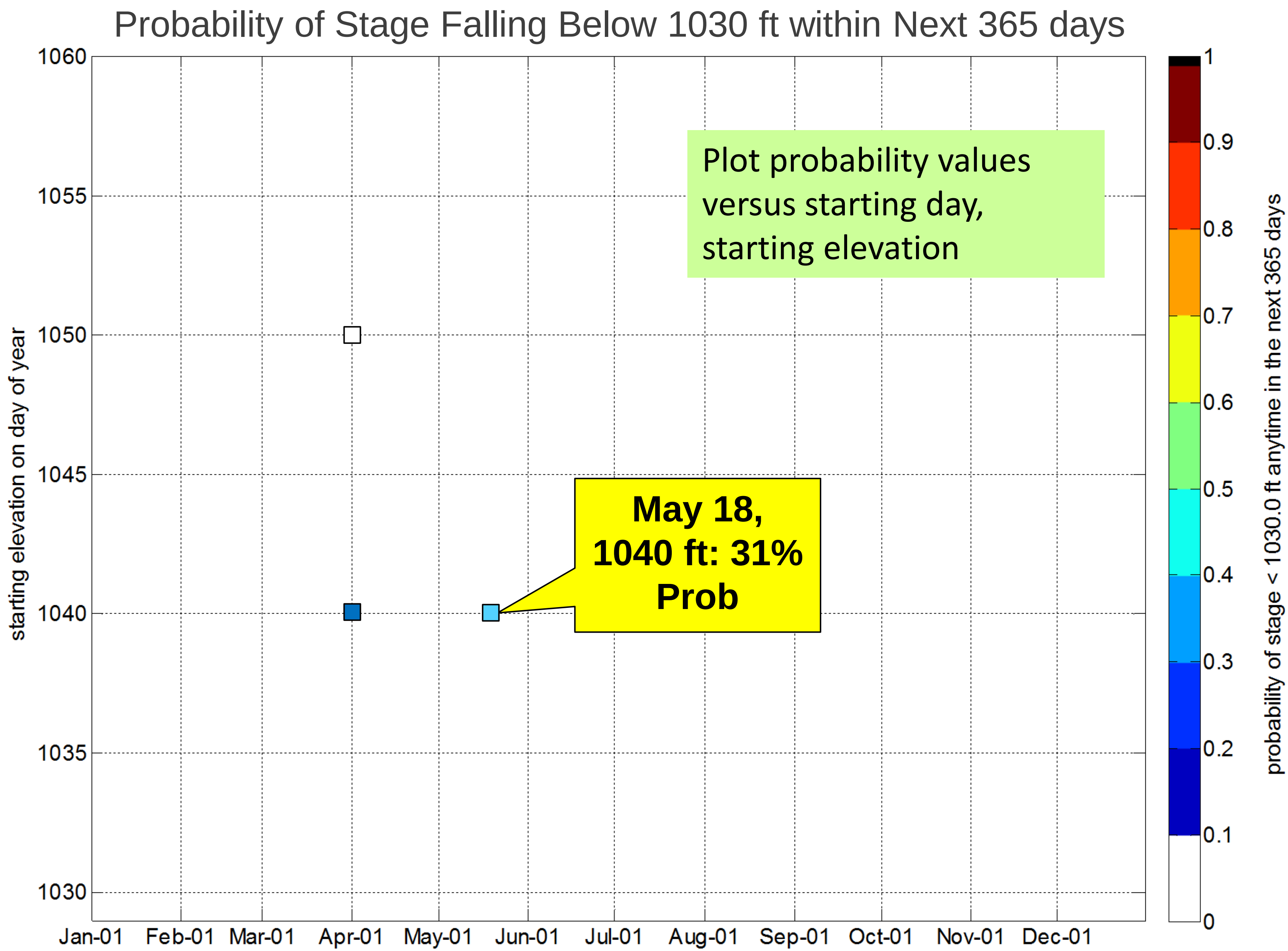


Probability of Stage Falling Below 1030 ft within Next 365 days
starting elevation on day of year
1060
1055
1050
1045
1040
1035
1030
Jan-01
Feb-01
Mar-01
Apr-01
May-01
Jun-01
Jul-01
Aug-01
Sep-01
Oct-01
Nov-01
Dec-01
Colors corresponding to % probablity
Starting Elevations
Starting Days
probability of stage < 1030.0 ft anytime in the next 365 days
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

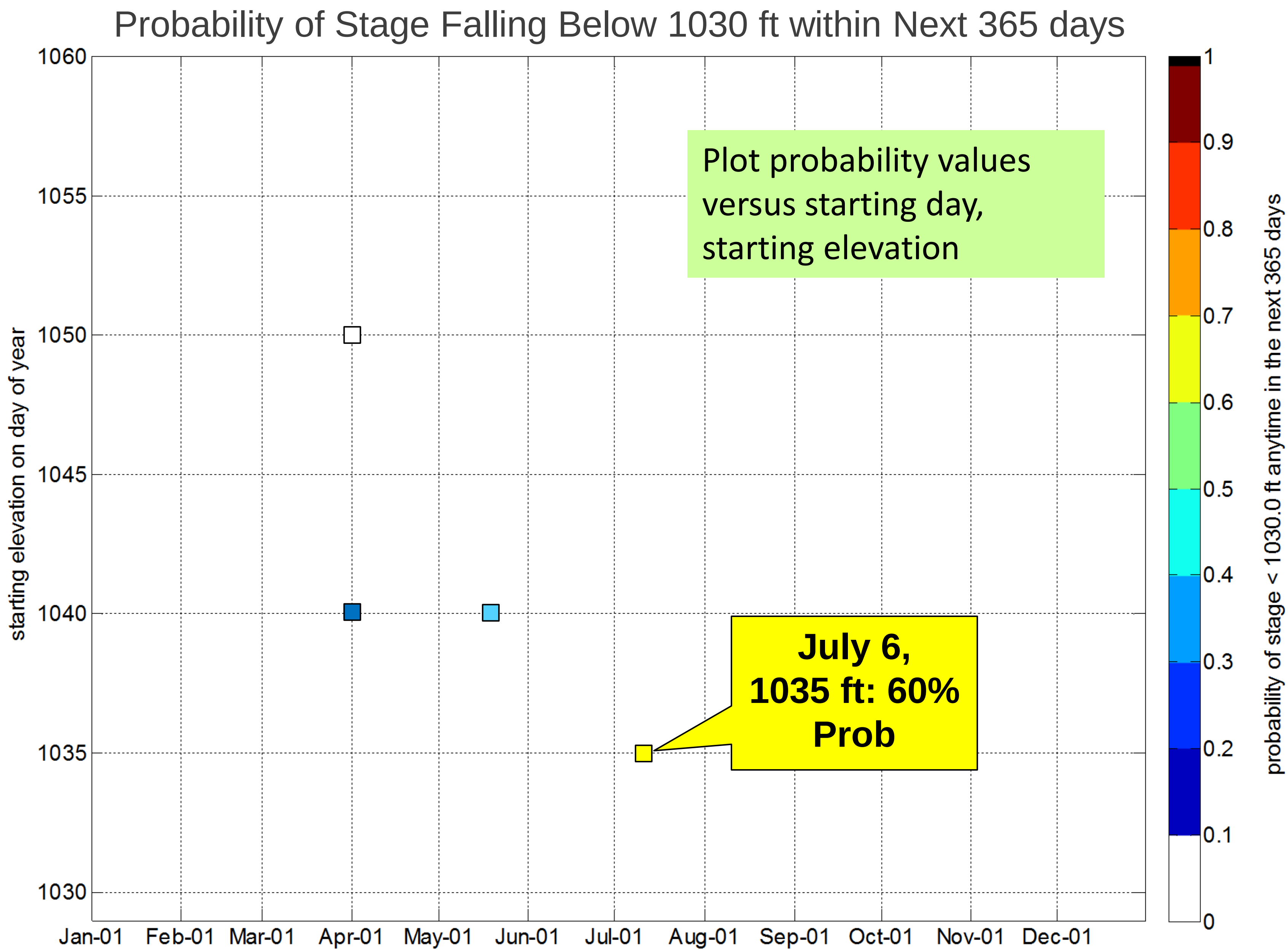

Probability of Stage Falling Below 1030 ft within Next 365 days
Plot probability values versus starting day, starting elevation
starting elevation on day of year
1060
1055
1050
1045
1040
1035
1030
Jan-01
Feb-01
Mar-01
Apr-01
May-01
Jun-01
Jul-01
Aug-01
Sep-01
Oct-01
Nov-01
Dec-01
probability of stage < 1030.0 ft anytime in the next 365 days
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0

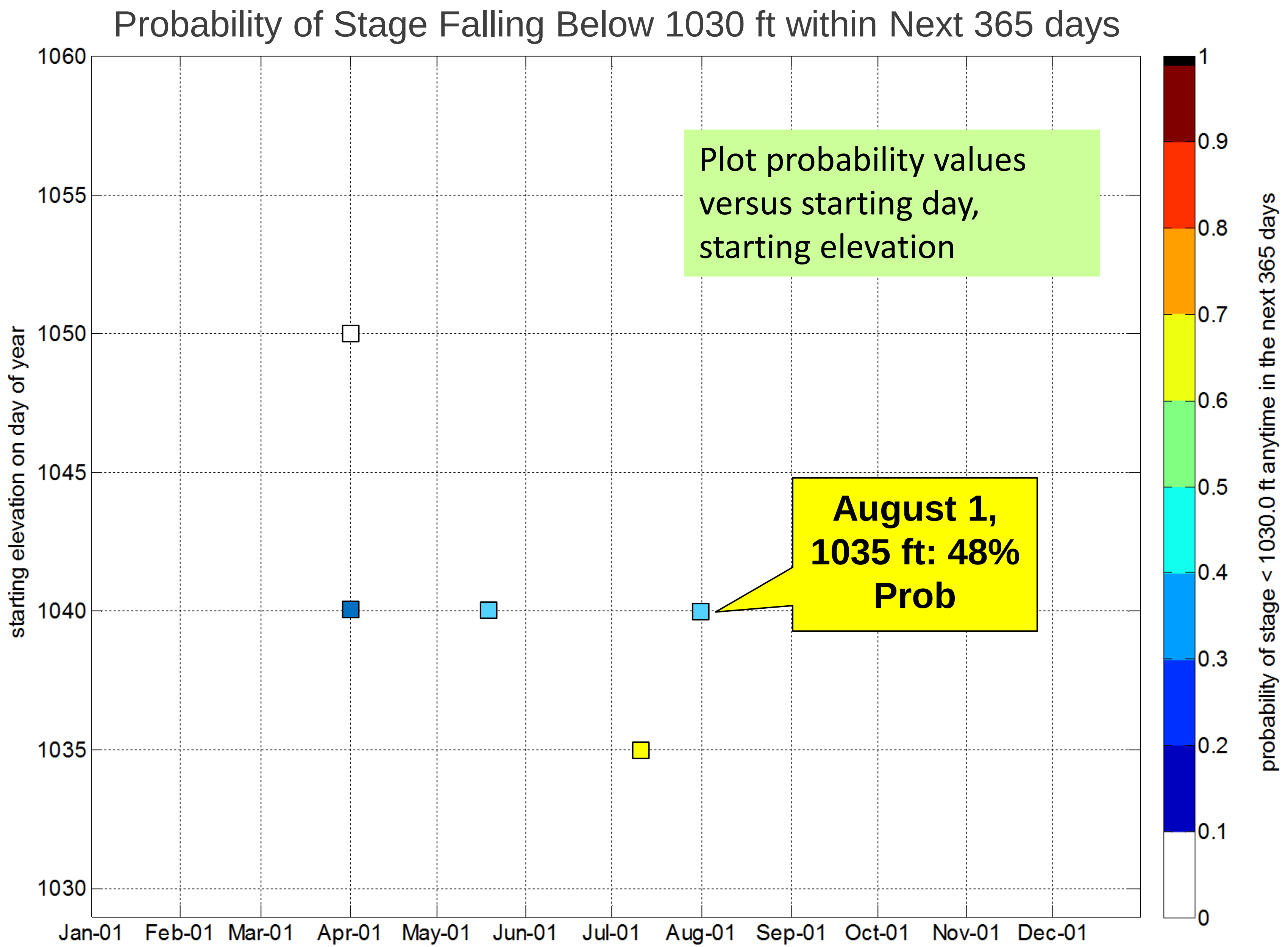

Probability of Stage Falling Below 1030 ft within Next 365 days
starting elevation on day of year
1060
1055
1050
1045
1040
1035
1030
Jan-01
Feb-01
Mar-01
Apr-01
May-01
Jun-01
Jul-01
Aug-01
Sep-01
Oct-01
Nov-01
Dec-01
Plot probability values versus starting day, starting elevation
Apr 1, 1050 ft: 2% Prob
probability of stage < 1030.0 ft anytime in the next 365 days
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

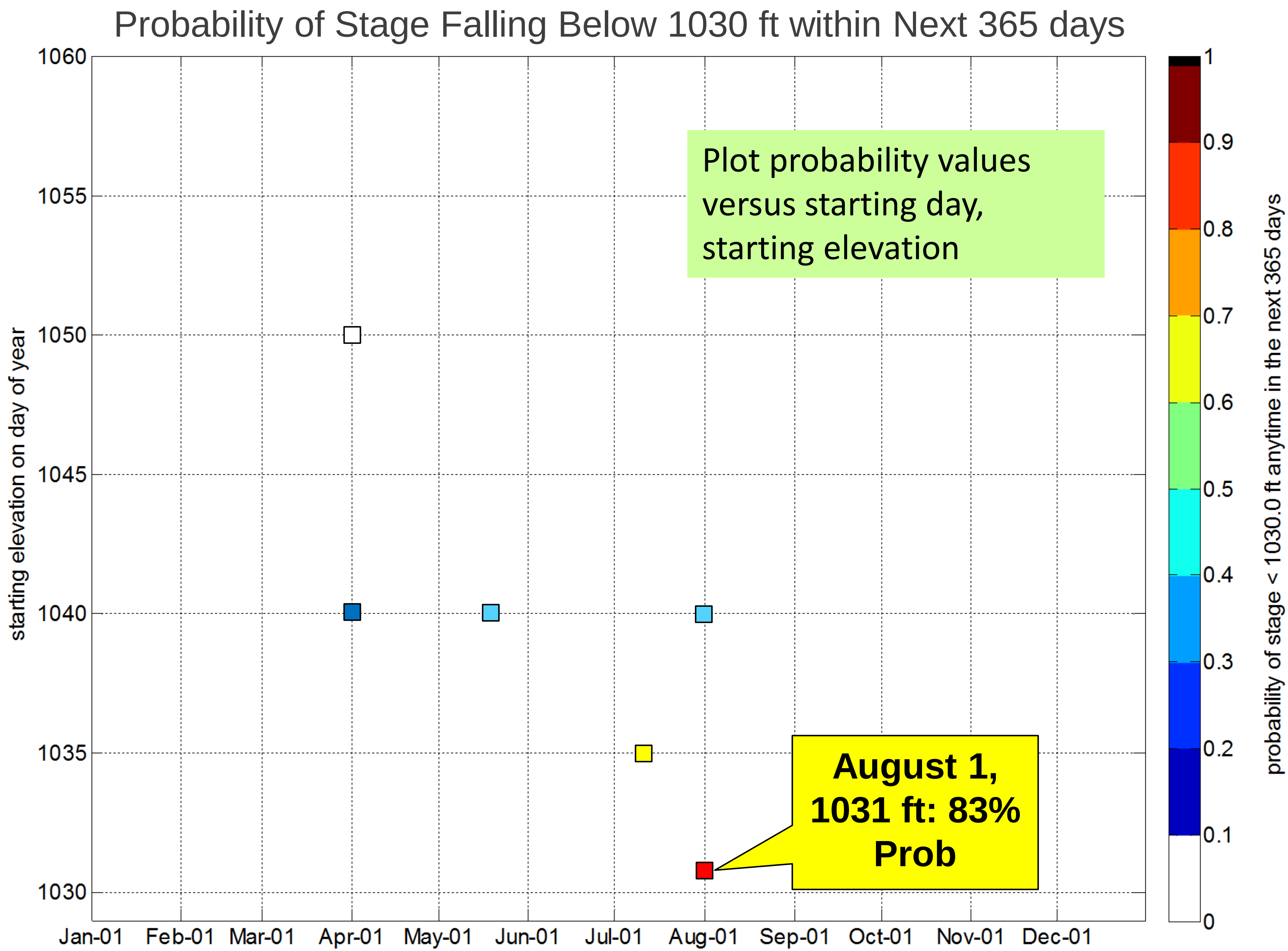

Probability of Stage Falling Below 1030 ft within Next 365 days
starting elevation on day of year
1060
1055
1050
1045
1040
1035
1030
Jan-01
Feb-01
Mar-01
Apr-01
May-01
Jun-01
Jul-01
Aug-01
Sep-01
Oct-01
Nov-01
Dec-01
Plot probability values versus starting day, starting elevation
Apr 1, 1040 ft: 12.5% Prob
probability of stage < 1030.0 ft anytime in the next 365 days
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

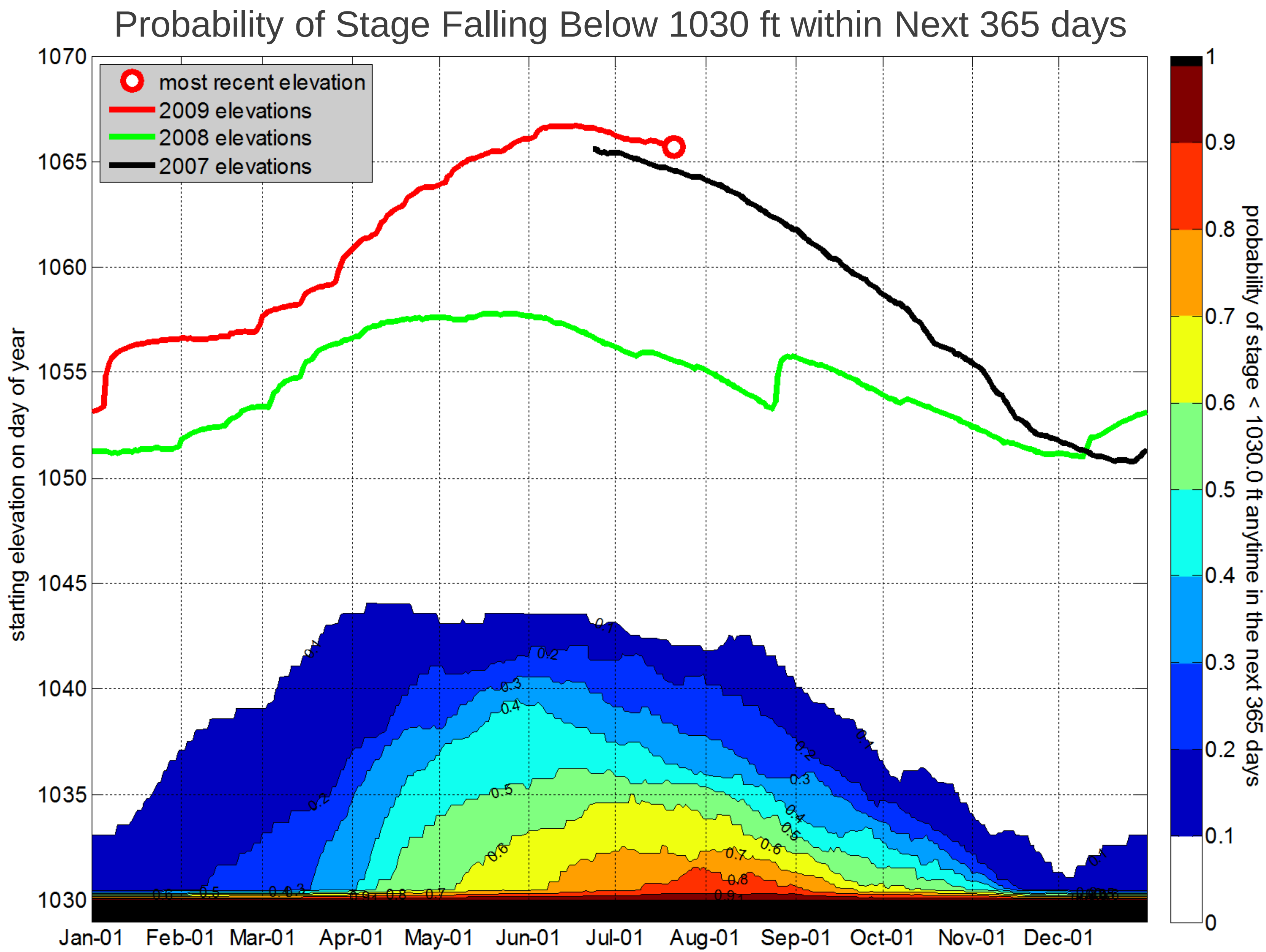


Probability of Stage Falling Below 1030 ft within Next 365 days
Plot probability values versus starting day, starting elevation
May 18, 1040 ft: 31% Prob
starting elevation on day of year
1060
1055
1050
1045
1040
1035
1030
Jan-01
Feb-01
Mar-01
Apr-01
May-01
Jun-01
Jul-01
Aug-01
Sep-01
Oct-01
Nov-01
Dec-01
probability of stage < 1030.0 ft anytime in the next 365 days
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0


Probability of Stage Falling Below 1030 ft within Next 365 days
starting elevation on day of year
1060
1055
1050
1045
1040
1035
1030
Jan-01
Feb-01
Mar-01
Apr-01
May-01
Jun-01
Jul-01
Aug-01
Sep-01
Oct-01
Nov-01
Dec-01
Plot probability values versus starting day, starting elevation
July 6, 1035 ft: 60% Prob
probability of stage < 1030.0 ft anytime in the next 365 days
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

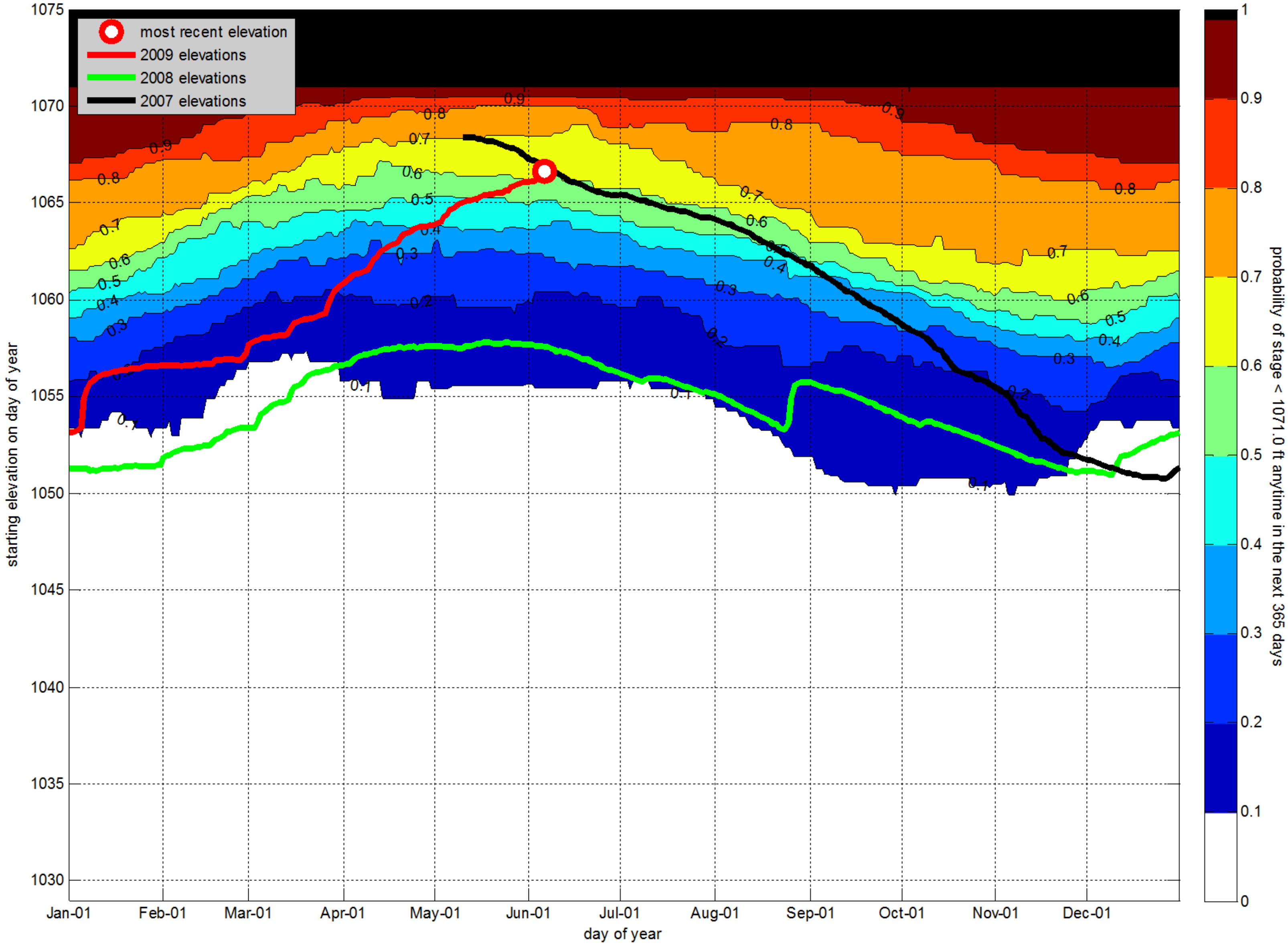

Probability of Stage Falling Below 1030 ft within Next 365 days
starting elevation on day of year
1060
1055
1050
1045
1040
1035
1030
Jan-01
Feb-01
Mar-01
Apr-01
May-01
Jun-01
Jul-01
Aug-01
Sep-01
Oct-01
Nov-01
Dec-01
Plot probability values versus starting day, starting elevation
August 1, 1035 ft: 48% Prob
probability of stage < 1030.0 ft anytime in the next 365 days
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1


Probability of Stage Falling Below 1030 ft within Next 365 days
1060
1055
1050
1045
1040
1035
1030
starting elevation on day of year
Jan-01
Feb-01
Mar-01
Apr-01
May-01
Jun-01
Jul-01
Aug-01
Sep-01
Oct-01
Nov-01
Dec-01
Plot probability values versus starting day, starting elevation
August 1, 1031 ft: 83% Prob
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
probability of stage < 1030.0 ft anytime in the next 365 days



Probability of Stage Falling Below 1030 ft within Next 365 days
most recent elevation
2009 elevations
2008 elevations
2007 elevations
starting elevation on day of year
1070
1065
1060
1055
1050
1045
1040
1035
1030
Jan-01
Feb-01
Mar-01
Apr-01
May-01
Jun-01
Jul-01
Aug-01
Sep-01
Oct-01
Nov-01
Dec-01
probability of stage < 1030.0 ft anytime in the next 365 days
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0

Probability of Stage Returning to 1071 ft (Full Pool) within Next 365 days



Agenda

A Perfect Storm:

- Threatened Supply + Decreased Revenue

Preparing for the Storm

- What to do?

Analyzing and responding to risk

- Lake level forecasting
- When to pull trigger and act

Applications

Monthly Lake Update During Drought

Action Box

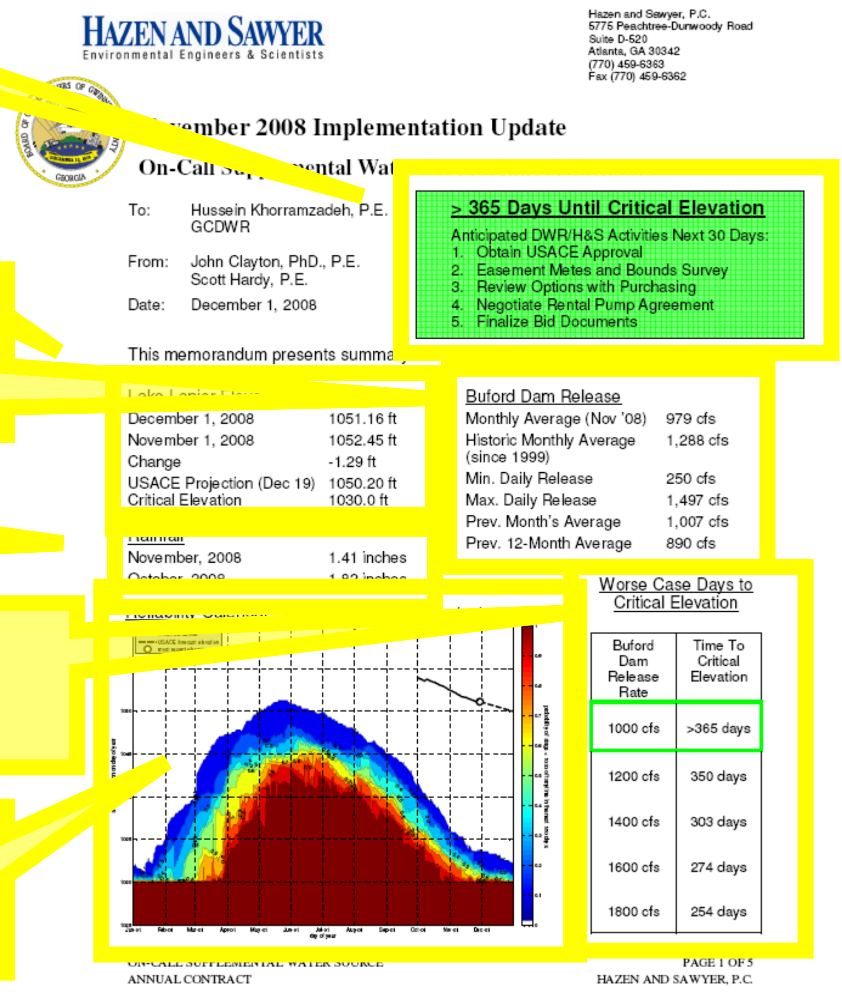
Lake Level

Buford Dam Release

Rainfall

Worse-Case Days Remaining

Reliability Calendar



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Atlanta, GA 30342
(770) 459-6363
Fax (770) 459-6362

...ember 2008 Implementation Update

On-Call ... ental Wat...

To: Hussein Khorramzadeh, P.E.
GCDWR

From: John Clayton, PhD., P.E.
Scott Hardy, P.E.

Date: December 1, 2008

> 365 Days Until Critical Elevation

Anticipated DWR/H&S Activities Next 30 Days:
1. Obtain USACE Approval
2. Easement Metes and Bounds Survey
3. Review Options with Purchasing
4. Negotiate Rental Pump Agreement
5. Finalize Bid Documents

This memorandum presents summa...

December 1, 2008	1051.16 ft
November 1, 2008	1052.45 ft
Change	-1.29 ft
USACE Projection (Dec 19)	1050.20 ft
Critical Elevation	1030.0 ft

Buford Dam Release

Monthly Average (Nov '08)	979 cfs
Historic Monthly Average (since 1999)	1,288 cfs
Min. Daily Release	250 cfs
Max. Daily Release	1,497 cfs
Prev. Month's Average	1,007 cfs
Prev. 12-Month Average	890 cfs

Rainfall

November, 2008	1.41 inches

Worse Case Days to Critical Elevation

Buford Dam Release Rate	Time To Critical Elevation
1000 cfs	>365 days
1200 cfs	350 days
1400 cfs	303 days
1600 cfs	274 days
1800 cfs	254 days

ON-CALL SUPPLEMENTAL WATER SOURCE
ANNUAL CONTRACT

PAGE 1 OF 5
HAZEN AND SAWYER, P.C.

Monthly Lake Update During Drought

- Used Internally to assess budgets and aid decision-making for phased pump implementation
  - Don’t commit costs until risk-justified
- Educate Board, customers, stakeholders about true risks to supply
  - Prevent panic
  - Develop confidence in implementation decisions

Walking the Tightrope…

Before study and design

- 2007-2009: historic low lake levels: true risks not fully understood
- GCDWR was ready to commit to permanent new infrastructure immediately

After study and design

- Realized that even the historic low levels did not pose a short-term supply risk
- Drought ended and levels rose before short-term risk ever emerged

Committing the costs would have been a big mistake, but GCDWR avoided it!

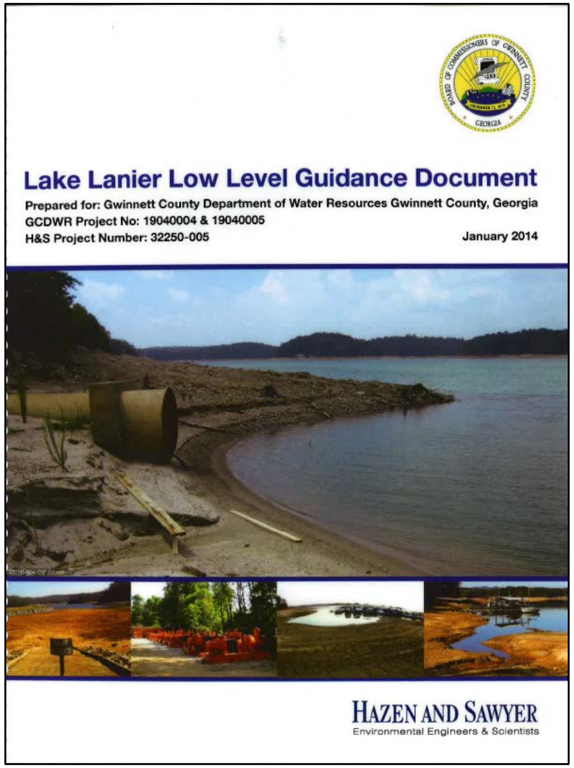
It Worked Again!

Another drought came in 2011… another success!

- Near-historic low levels
- GCDWR remembered the 2007-2009 events (despite some staff turnover), restarted updates
- Again, no short-term supply risk
- Drought ended and levels rose before short-term risk ever emerged

Moved to institutionalize this knowledge in 2012

- *Lake Lanier Low Level Guidance Document*


Lake Lanier Low Level Guidance Document

Prepared for: Gwinnett County Department of Water Resources Gwinnett County, Georgia
GCDWR Project No: 19040004 & 19040005
H&S Project Number: 32250-005
January 2014

HAZEN AND SAWYER
Environmental Engineers & Scientists

General Application of Forecast-Based Water Shortage Management

Automatically adaptive

- Decisions informed by initial conditions and seasonal weather/hydrology

Risk-oriented

- Decisions based on probability and consequences of shortage

Flexible

- Used to inform decisions, not dictate them (no fixed decision thresholds)

Can be extended to include demand management

- Justify management actions through hydrologic risk

Contact

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