Sustainable Water Management Initiative
Public Information Session

Presentation Title: Safe Yield: Step by Step

Date of Presentation: 17 February 2012

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SWMI Technical Q&A

February 17, 2012

Safe Yield
Step by Step

Massachusetts G.L. c. 21G, § 2. Safe Yield Definition

"the maximum dependable withdrawals that can be made continuously from a water source including ground or surface water during a period of years in which the probable driest period or period of greatest water deficiency is likely to occur; provided, however, that such dependability is relative and is a function of storage and drought probability."

Statement of Clarification of Safe Yield November 3, 2009

Safe Yield interpretation includes environmental protection factors, including ecological health of river systems, as well as hydrologic factors.

Safe Yield and Environmental Protection

Major Basin Scale

Allocatable Water

WMA Safe Yield =

55% of Drought Basin Yield + Reservoir Storage

Safe Yield Environmental Protection Factor (EPF) =

Remaining 45% of Drought Basin Yield

+

Subbasin Scale

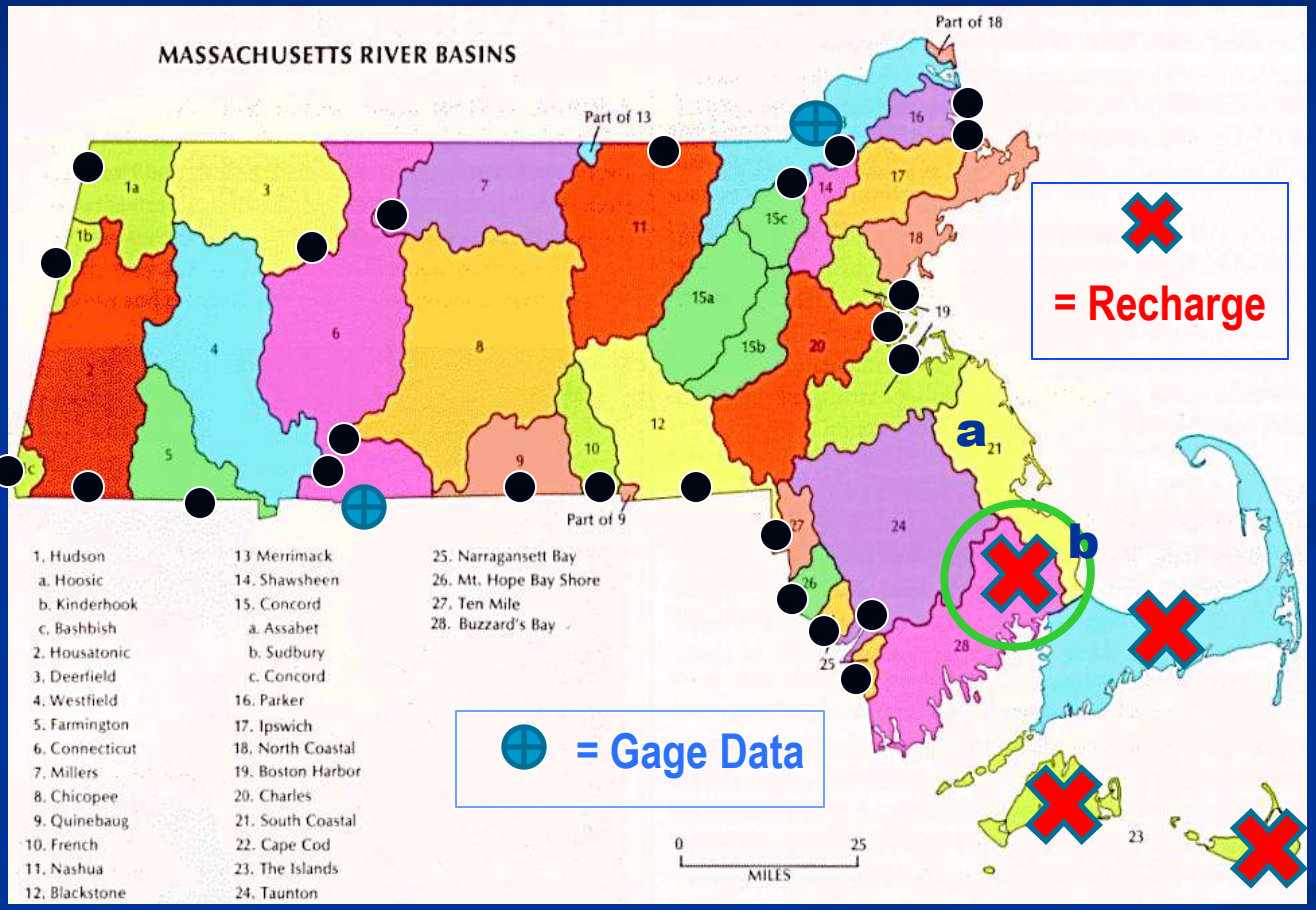
Seasonal Flow

Streamflow Criteria

Basin Yield or Drought Year Flows

- Each major basin analyzed using SYE (Sustainable Yield Estimator) unimpacted flows
- SYE generated daily flows WY 1961-2004
- Daily flows separated into monthly values (1961-2004)
- Percentiles of low flows calc'd for each month (1961-2004)
- An artificial Drought Year was developed using the 90th percentile flows from each month
- The Drought Year flows were then compared to lowest drought year in record (generally 1965 or 1981)

SYE Run for Each Major Basin



SYE Unimpacted Flows WY 1961-2004

Millers					Flow	Flow
					cfs	cfsm
		10	1	1960	861.41	2.21
		10	2	1960	624.33	1.60
		10	3	1960	559.78	1.44
		10	4	1960	497.09	1.28
		10	5	1960	469.79	1.21
		10	6	1960	434.68	1.12
		10	7	1960	397.98	1.02
		10	8	1960	351.82	0.90
		10	9	1960	351.75	0.90

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		9	21	2004	1236.52	3.18
		9	22	2004	813.47	2.09
		9	23	2004	592.57	1.52
		9	24	2004	527.35	1.36
		9	25	2004	447.09	1.15
		9	26	2004	398.06	1.02
		9	27	2004	331.07	0.85
		9	28	2004	434.75	1.12
		9	29	2004	1027.73	2.64
		9	30	2004	1378.29	3.54

Daily Flows → Monthly

All April daily flows

4	24	1962	651.19	1.67
4	25	1962	558.51	1.44
4	26	1962	526.40	1.35
4	27	1962	526.32	1.35
4	28	1962	468.00	1.20
4	29	1962	467.93	1.20
4	30	1962	651.09	1.67
4	1	1963	2980.12	7.66
4	2	1963	4350.39	11.18
4	3	1963	12560.05	32.28
4	4	1963	7938.76	20.40
4	5	1963	3319.55	8.53
4	6	1963	2362.60	6.07

All April daily flows Ranked by Flow

	Flow	Monthly
Order	Sorted	percentile, %
1	46.59	0.08
2	46.12	0.15
3	44.27	0.23
4	43.38	0.30
5	42.51	0.38
6	42.07	0.45
7	41.65	0.53
8	41.22	0.61
9	39.98	0.68
10	38.78	0.76
11	38.39	0.83
12	38.00	0.91

Basin Yield

Annualized Drought Volume Calculated from SYE Statistics using Monthly 90th percentile low flows

Millers													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Q98	0.24	0.34	0.56	0.92	0.44	0.21	0.14	0.09	0.08	0.16	0.22	0.27	0.31
Q95	0.34	0.43	0.74	1.05	0.54	0.25	0.16	0.14	0.12	0.20	0.26	0.40	0.38
Q90	0.44	0.57	0.91	1.28	0.70	0.30	0.20	0.15	0.15	0.23	0.34	0.48	0.48
Q80	0.62	0.72	1.16	1.72	0.98	0.40	0.25	0.20	0.21	0.31	0.51	0.63	0.64
Q75	0.70	0.80	1.32	1.93	1.11	0.46	0.26	0.22	0.22	0.34	0.58	0.73	0.72
Q50 (Medians of Daily Means)	1.11	1.23	2.24	2.95	1.63	0.84	0.39	0.33	0.33	0.53	1.11	1.29	1.16
Median of Monthly Means, cfsm	1.54	1.49	2.94	4.11	2.06	1.02	0.56	0.40	0.46	0.66	1.31	1.54	1.50

Monthly values are time-weighted and "rolled up" into an average annual value *

* =((Jan x 31 days) + (Feb x 28 days) + (Mar x 31 days) + (Apr x 30 days) + (May x 31 days) + (Jun x 30 days) + (Jul x 31 days) + (Aug x 31 days) + (Sep x 30 days) + (Oct x 31 days) + (Nov x 30 days) + (Dec x 31 days))/365 days

Monthly Q90 Rollup:

A synthesized low-flow year.
How does it compare to real years?
What is the recurrence interval?

We compared all the SYE Simulated Years

	Monthly Median of Daily Mean Flows, cfsm												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
1961	0.88	0.88	3.52	6.13	2.52	1.04	0.53	0.31	0.41	0.45	0.89	0.95	1.54
1962	1.76	0.95	2.02	4.56	1.86	0.65	0.24	0.28	0.17	0.99	2.73	2.11	1.53
1963	1.70	1.16	2.59	2.24	1.60	0.79	0.20	0.10	0.06	0.06	1.33	1.52	1.11
1964	1.29	1.72	2.96	2.66	1.60	0.52	0.46	0.06	0.04	0.12	0.15	0.39	1.00
1965	0.44	1.12	1.52	1.72	0.93	0.45	0.12	0.14	0.15	0.21	0.28	0.27	0.61
1966	0.33	1.17	2.72	1.23	1.00	0.46	0.12	0.10	0.17	0.26	0.73	0.61	0.74
1967	0.81	0.68	1.83	3.90	2.97	1.38	0.61	0.30	0.21	0.25	0.66	1.15	1.23
1968	1.34	1.25	2.97	1.66	1.07	1.80	0.67	0.20	0.12	0.35	1.44	1.63	1.21
1969	1.31	1.56	2.22	3.89	1.52	0.57	0.22	0.24	0.21	0.28	2.33	2.71	1.42
1970	1.58	2.39	1.60	2.70	1.70	0.93	0.57	0.14	0.15	0.30	1.29	1.02	1.19
1971	0.78	1.82	3.54	3.29	2.57	0.99	0.33	0.10	0.14	0.24	0.41	1.66	1.32
1972	1.25	1.53	4.20	3.70	2.57	3.31	1.96	0.33	0.55	0.62	2.38	2.58	2.08
1973	2.44	2.15	3.28	4.78	3.17	1.09	0.84	0.26	0.13	0.14	0.65	1.96	1.74

1965 Min Year

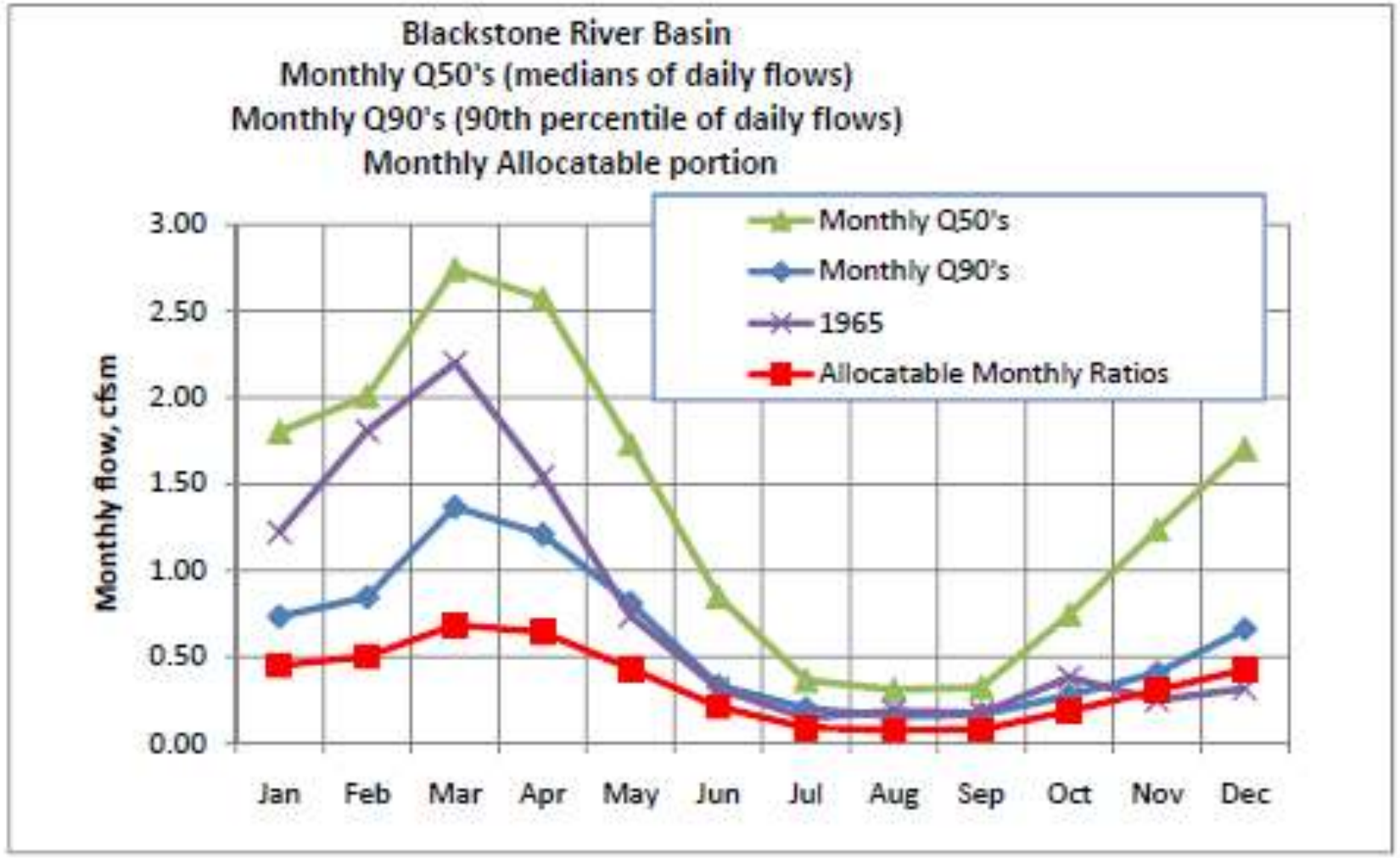
1972 High Year

90th Percentile Simulated Year is lower than or near 1965

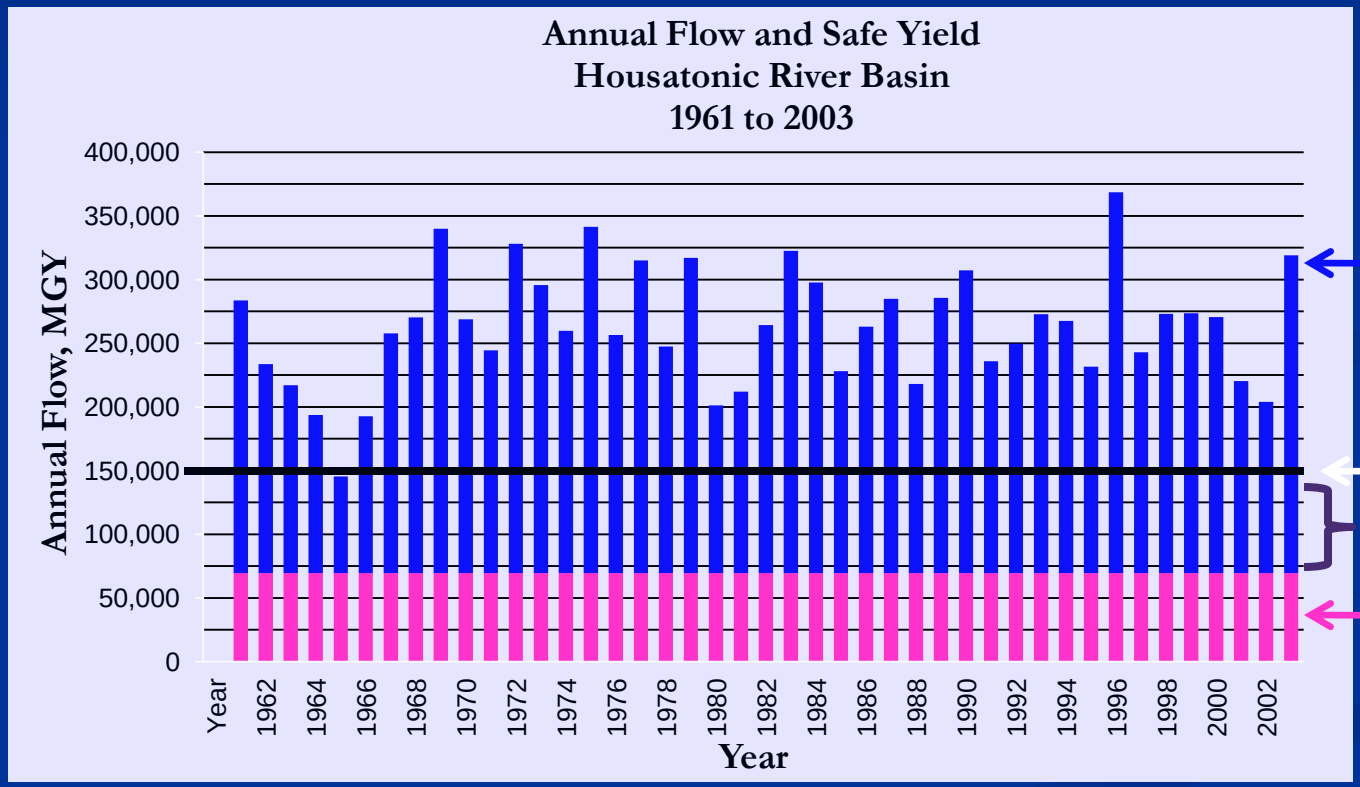
Safe Yield = 55% of Q90 Simulated Year

Annualized Q90 Rollup:

A synthesized low-flow year.
How does it compare to real years?



Most years there will be MUCH MORE water in the rivers



(@ EPF = 45% of Q90)

Safe Yield
Reservoir Storage Volumes

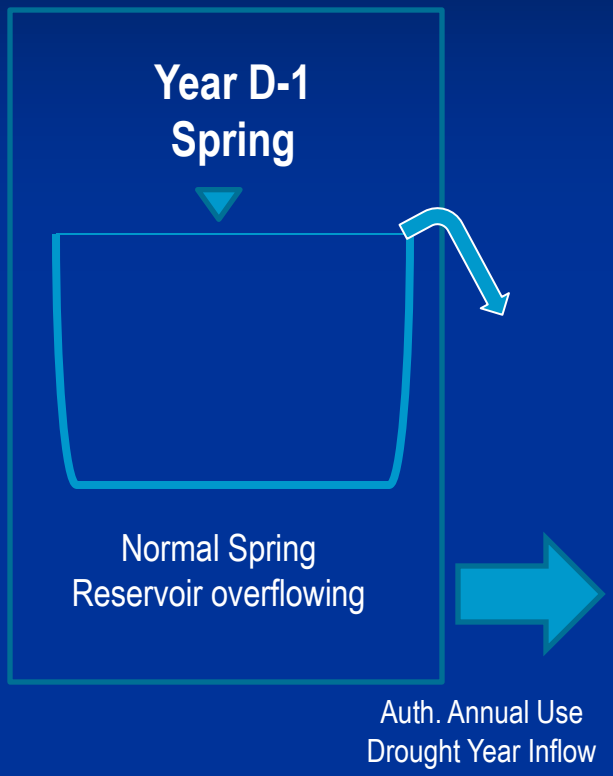
Safe Yield Storage Volume

- When storage is greater than Drought Year Inflow, Annual System Use, and Average Annual Inflow, maximum safe yield storage volume = average annual inflow rate to the reservoir

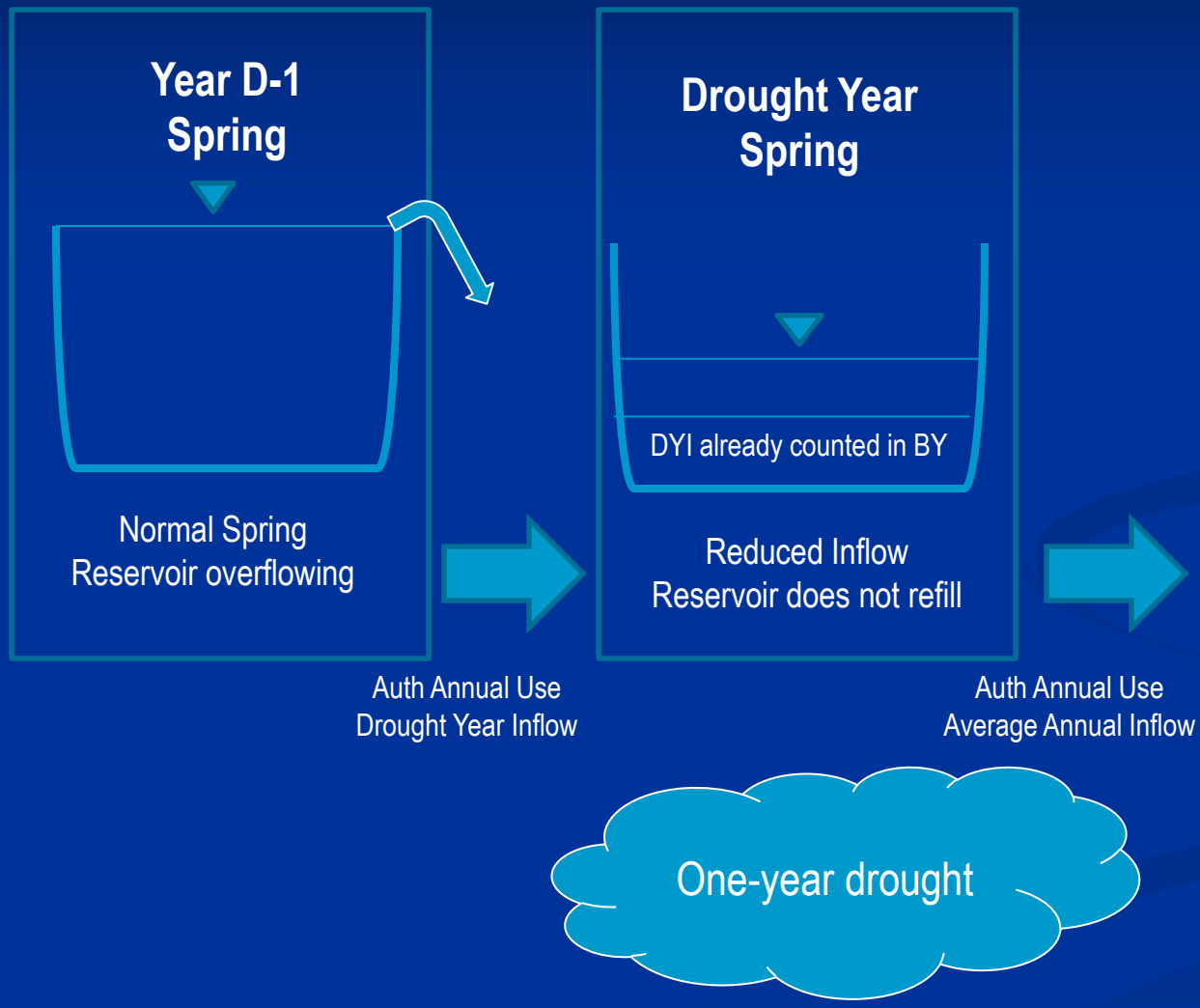
- A lesser amount of “excess storage” for amounts of storage above Annual System Use plus Drought Year Inflow, but less than the Average annual inflow volume

- For multiple reservoir systems within a single major basin that pump between reservoirs, the total volumes, inflows, and withdrawals can be analyzed together

Safe Yield Reservoir Storage Volumes



Safe Yield Reservoir Storage Volumes



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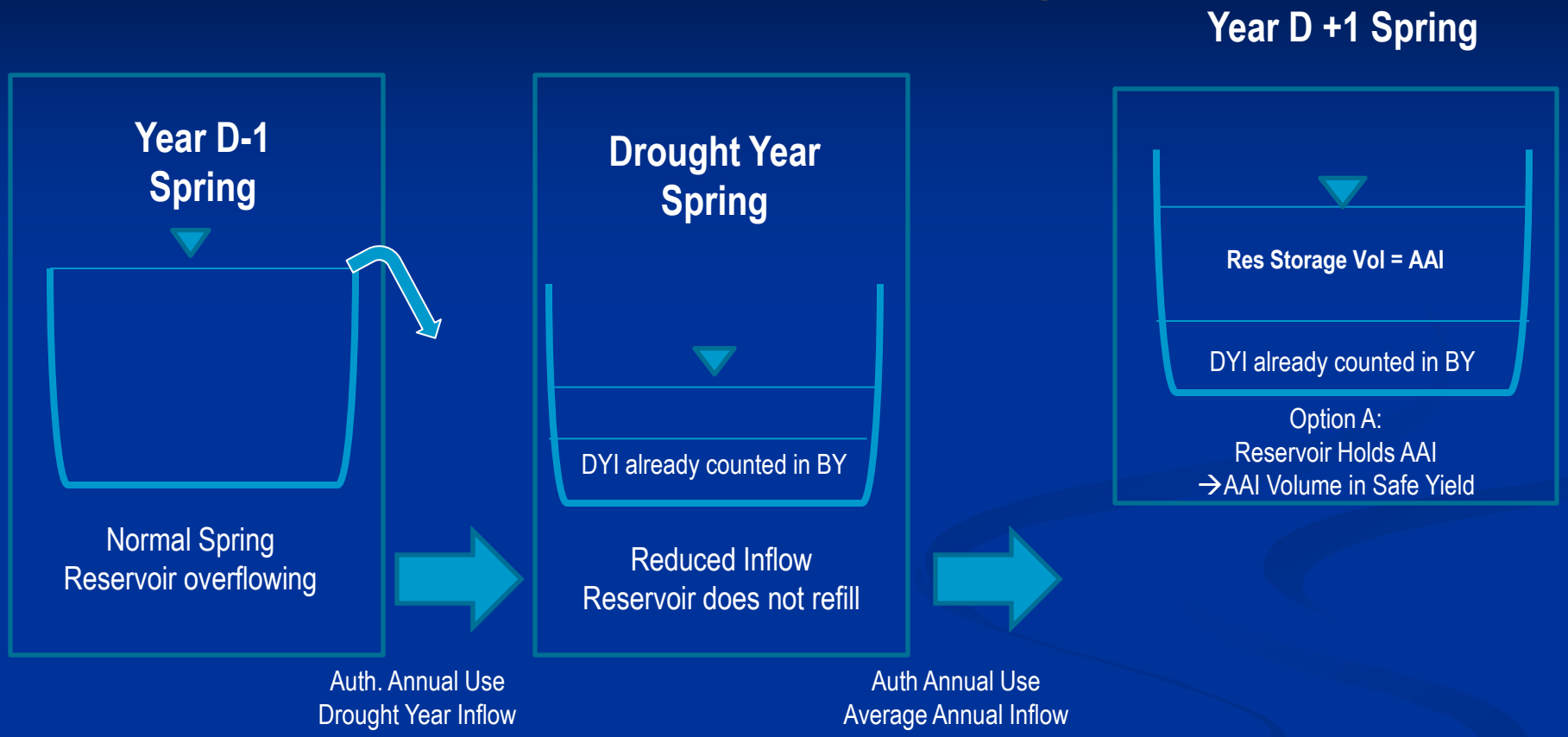

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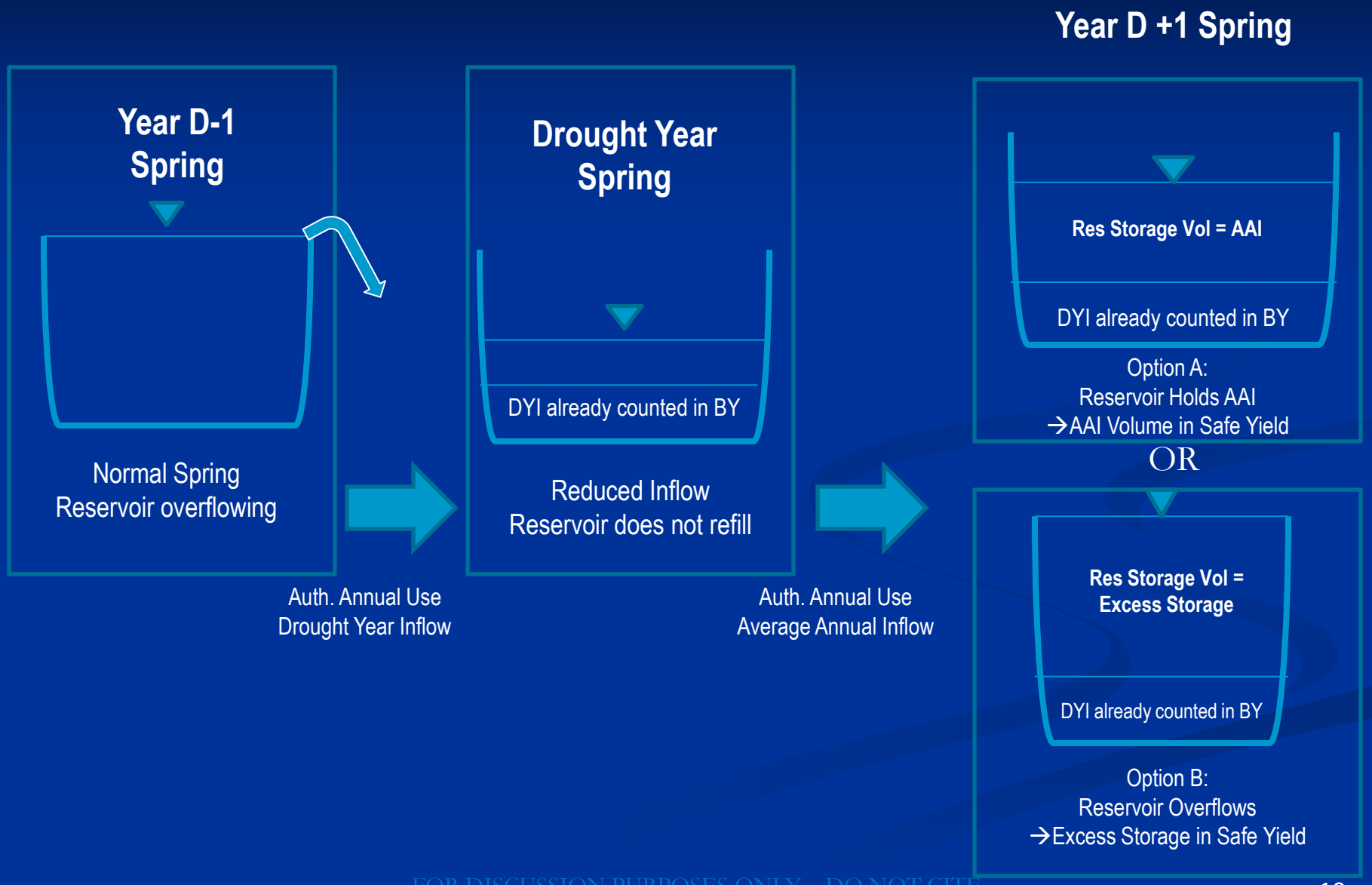


Reservoir Storage Volume Methodology
Appendix A

Data Needs

Screening
Steps 1 and 2

Analysis
Steps 3 to 5

Reservoir Storage Volume Methodology

Reservoir and Basin Data Needs for Analysis

Determine Reservoir Storage Volume in millions of gallons (volume between intake and spillway)

Determine Which Reservoirs are Connected in Series or if Separate Analyses Needed

Determine Drought Year Inflow
Use Basin Yield for Major Basin and scale reservoir inflow to reservoir drainage area
Major Basin Yield (MGD)/Basin Area (Sq Mi) X Drainage Area to Reservoir = Basin Yield Reservoir Inflow, MGD
Multiply Reservoir Inflow X 365 days/year = Reservoir Inflow in Millions of Gallons (MG)

Calculate Annual System Use
WMA allocation of reservoir or reservoir system (registered plus permitted volumes) (MG)
+ release requirement (if applicable) (MG)
= Maximum Annual System Use Volume (MG)

Calculate Average Annual Inflow:
Use SYE to calculate Average Annual Inflow at a point coincident with the reservoir dam or outlet
Convert resultant flow in cfs to MGD (cfs/1.55 = MGD)

Screening Steps 1 and 2:

Step 1: Compare Reservoir Storage Volume to Drought Year Inflow

If Reservoir Storage < Drought Year Inflow — Then no Safe Yield Storage Volume
If Reservoir Storage > Drought Year Inflow — Then continue to Step 2

Step 2: Compare Reservoir Storage to Annual System Use

If Reservoir Storage < Annual System Use — Then no Safe Yield Storage Volume
If Reservoir Storage > Annual System Use — Then continue to Step 3

Analysis Steps 3 to 5:

Step 3: Compare Reservoir Storage to Drought Year Inflow + Annual System Use

If Reservoir Storage < Drought Year Inflow + Annual System Use — Then no Safe Yield Storage Volume
If Reservoir Storage > Drought Year Inflow + Annual System Use — Then continue to Step 4

Step 4: Compare Reservoir Storage to Drought Year Inflow + Annual System Use + Average Annual Inflow

If Reservoir Storage < Drought Year Inflow + Annual System Use + Average Annual Inflow
Then Calculate Excess Safe Yield Storage Volume — Continue to Step 5A

If Reservoir Storage > Drought Year Inflow + Annual System Use
Then Maximum Safe Yield Storage Volume — Continue to Step 5B

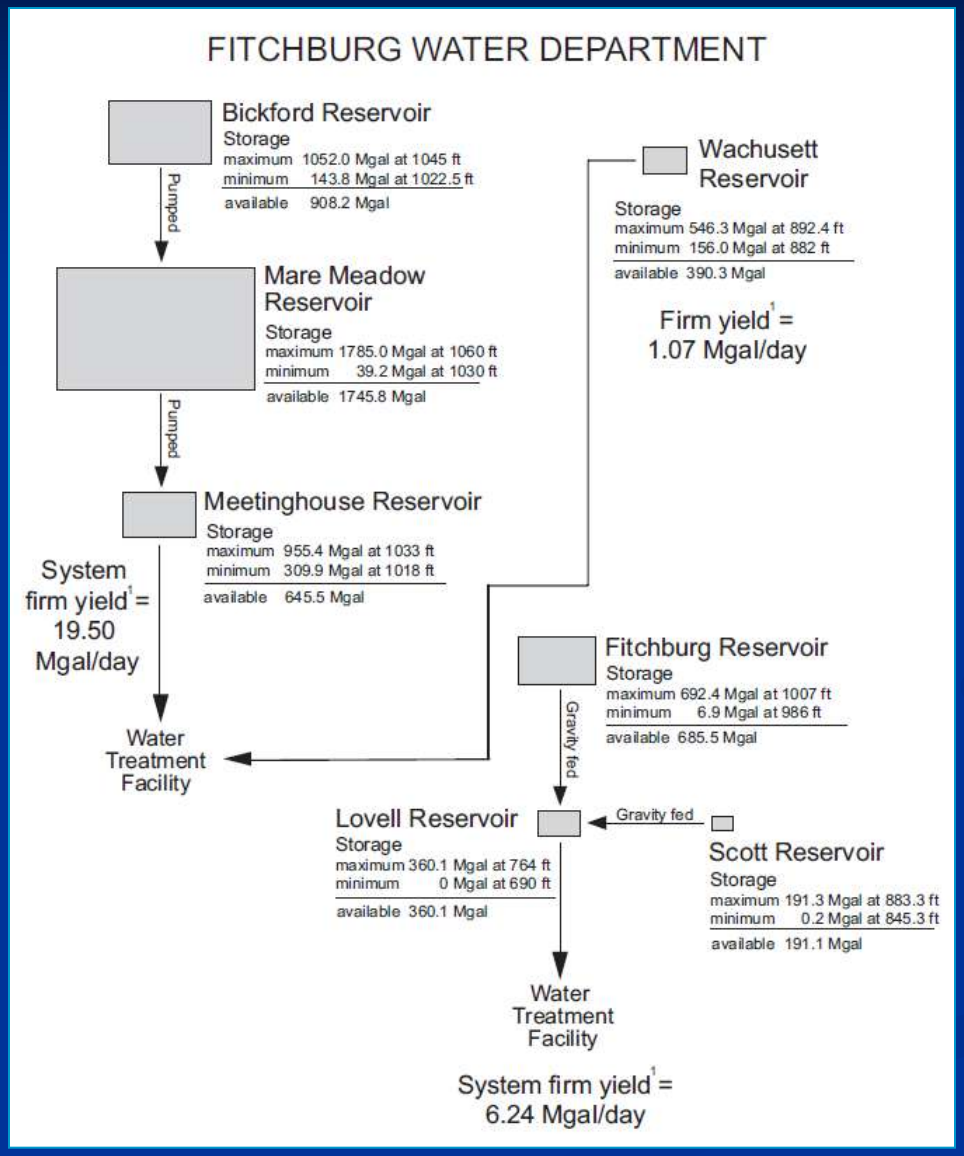
Step 5: Calculate Safe Yield Storage Volume

Step 5A: Excess Storage Safe Yield Credit = Storage above Annual Use + Drought Year Inflow
= Reservoir Storage – (Drought Year Inflow + Annual System Use)

Step 5B: Maximum Safe Yield Volume = Average Annual Inflow
Unless exceeds Reservoir Firm Yield Cap. If so, Reservoir Firm Yield is Safe Yield Storage Volume

Reservoir Storage Volume Data Needs

USGS SIR 2006-5044 (Firm Yield)

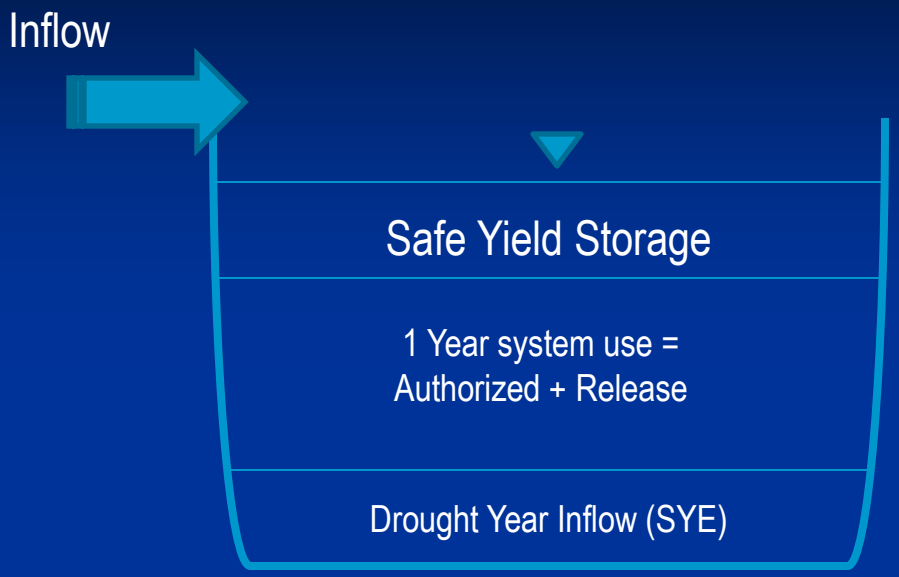


Check Reservoir System Routing

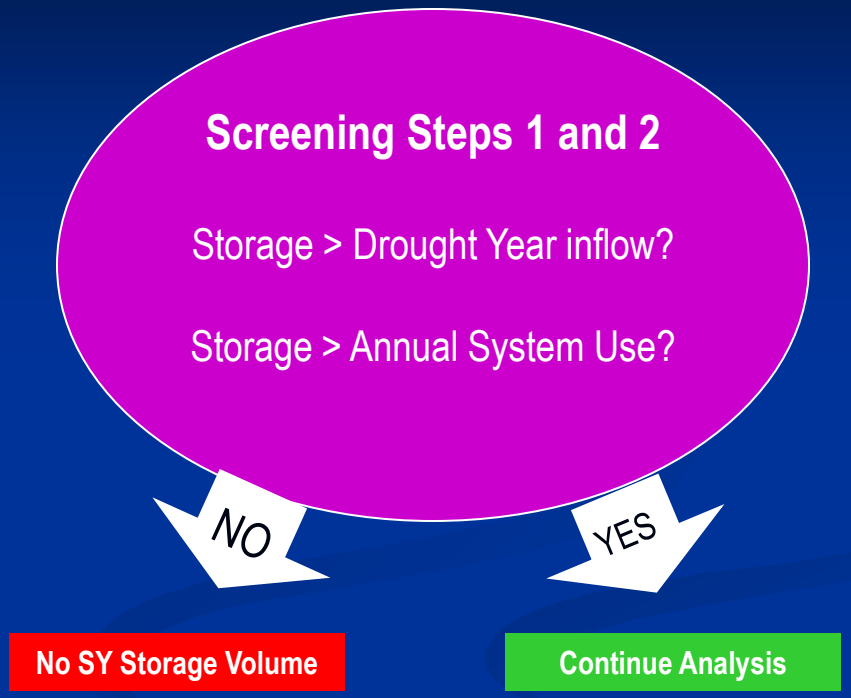
Analyze most downstream point(s)

Consider potential for reservoirs to pump to/from each other

Safe Yield Reservoir Storage Volumes

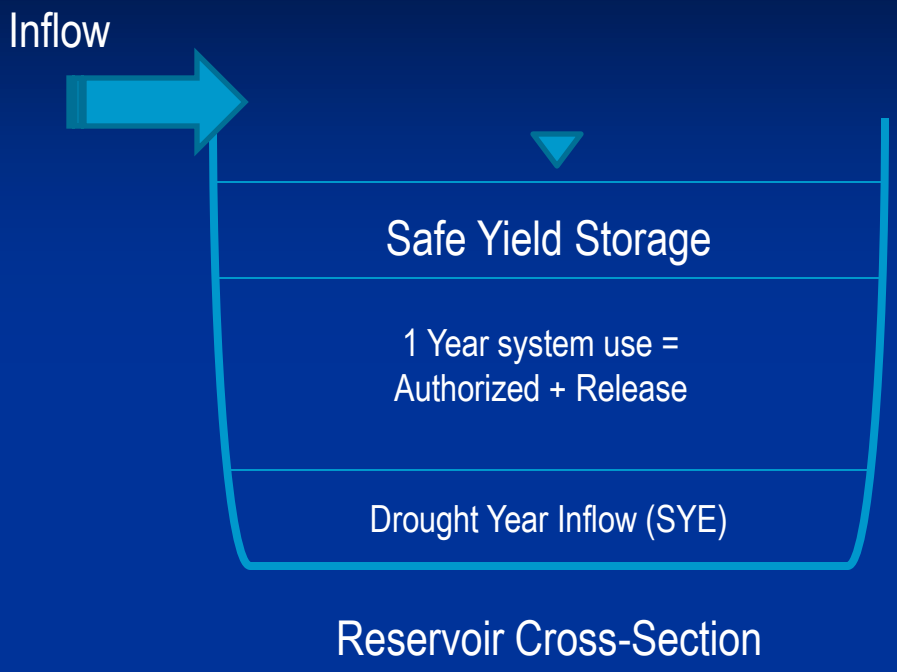


Reservoir Cross-Section



- Add storage volumes to basins with large amounts of storage:
  - Storage exceeds one year of drought year inflow
  - storage also exceeds one year of authorized water use.
- The first year of inflow cannot be added to the Safe Yield, since it is already included in the SYE flow estimate for the basins.

Safe Yield Reservoir Storage Volumes



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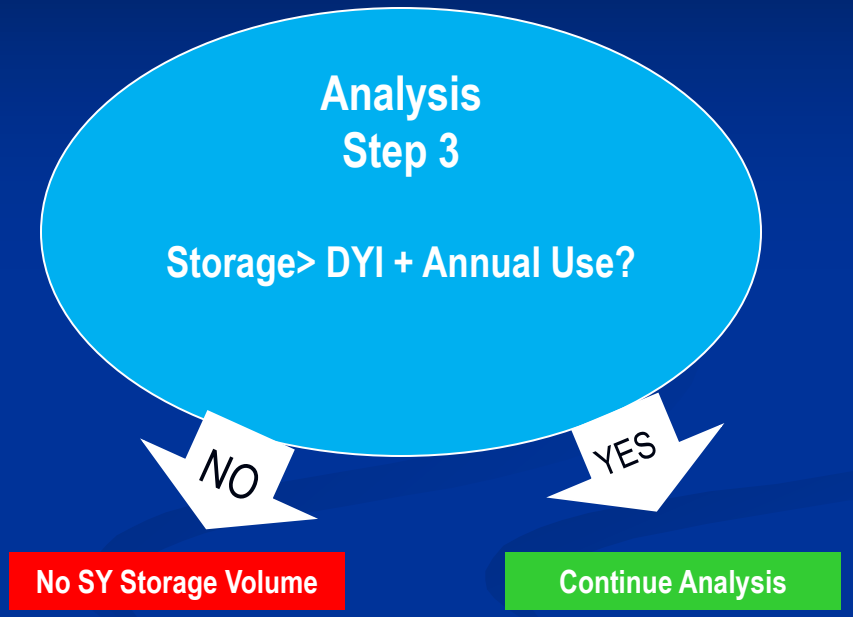

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Safe Yield Reservoir Storage Volumes

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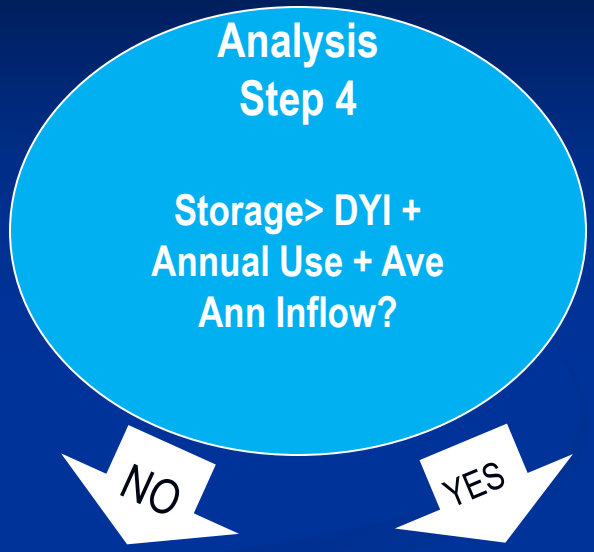
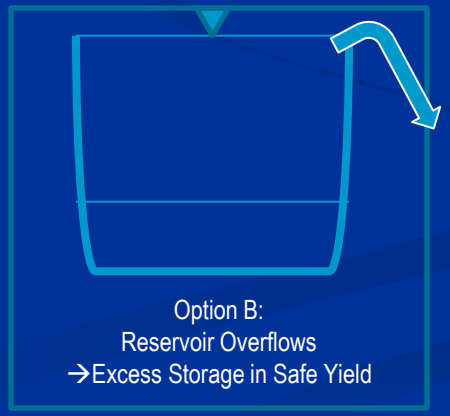


Excess SY Storage Volume



AAI SY Storage Volume