



US Army Corps of Engineers
Portland District



ESP Scenario Analysis Processor (ESAP)

It is time to put some more tools
in the toolbox!

Randal T. Wortman

Portland District

Columbia River Forecasting Group

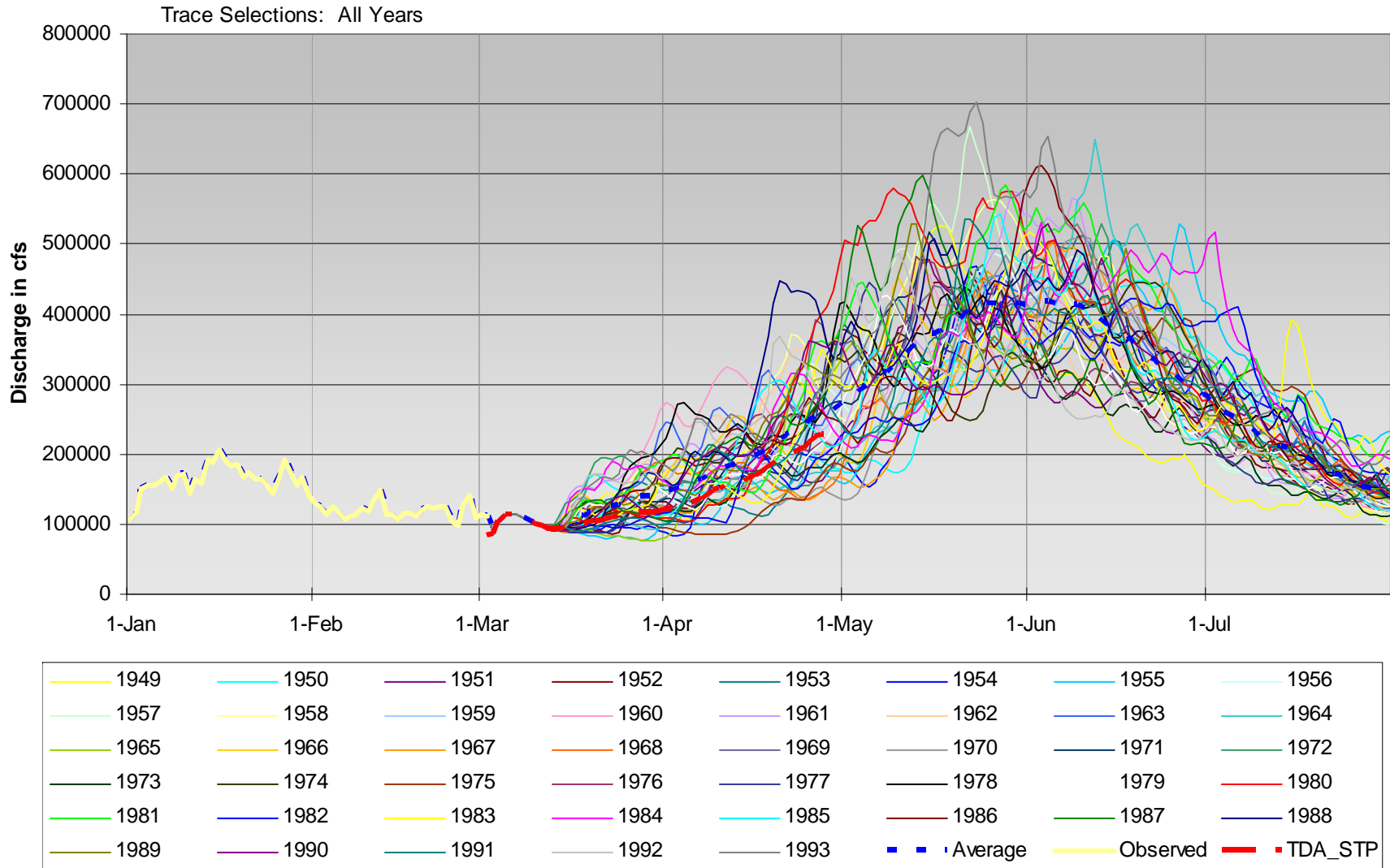
Portland, Oregon

March 12, 2009

BUILDING STRONG_{SM}

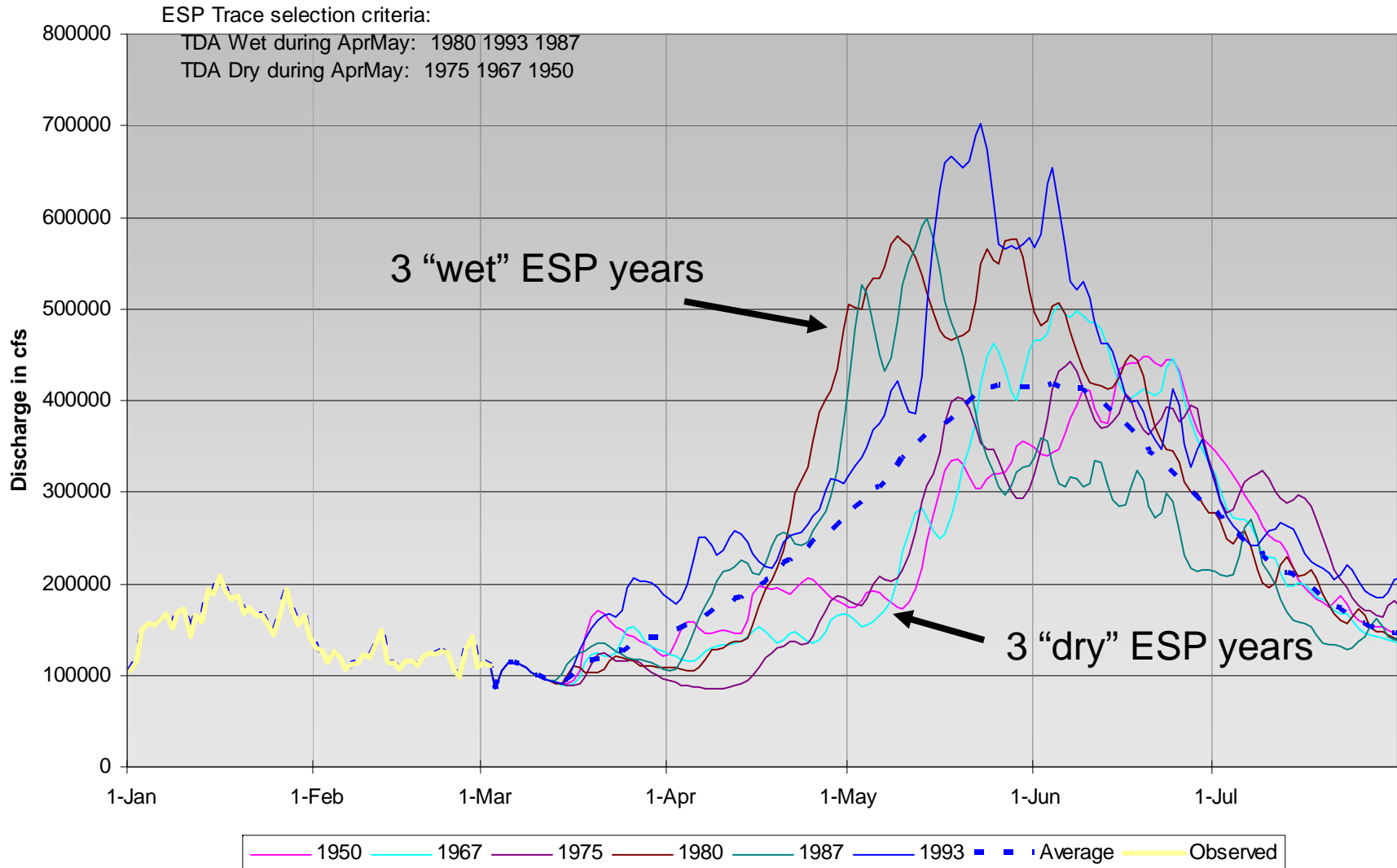


ESP hydrographs at The Dalles (unfiltered)





Filtered ESP hydrographs (3 wet, 3 dry)





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ESP Scenario Analysis prepared for Six Locations

Libby

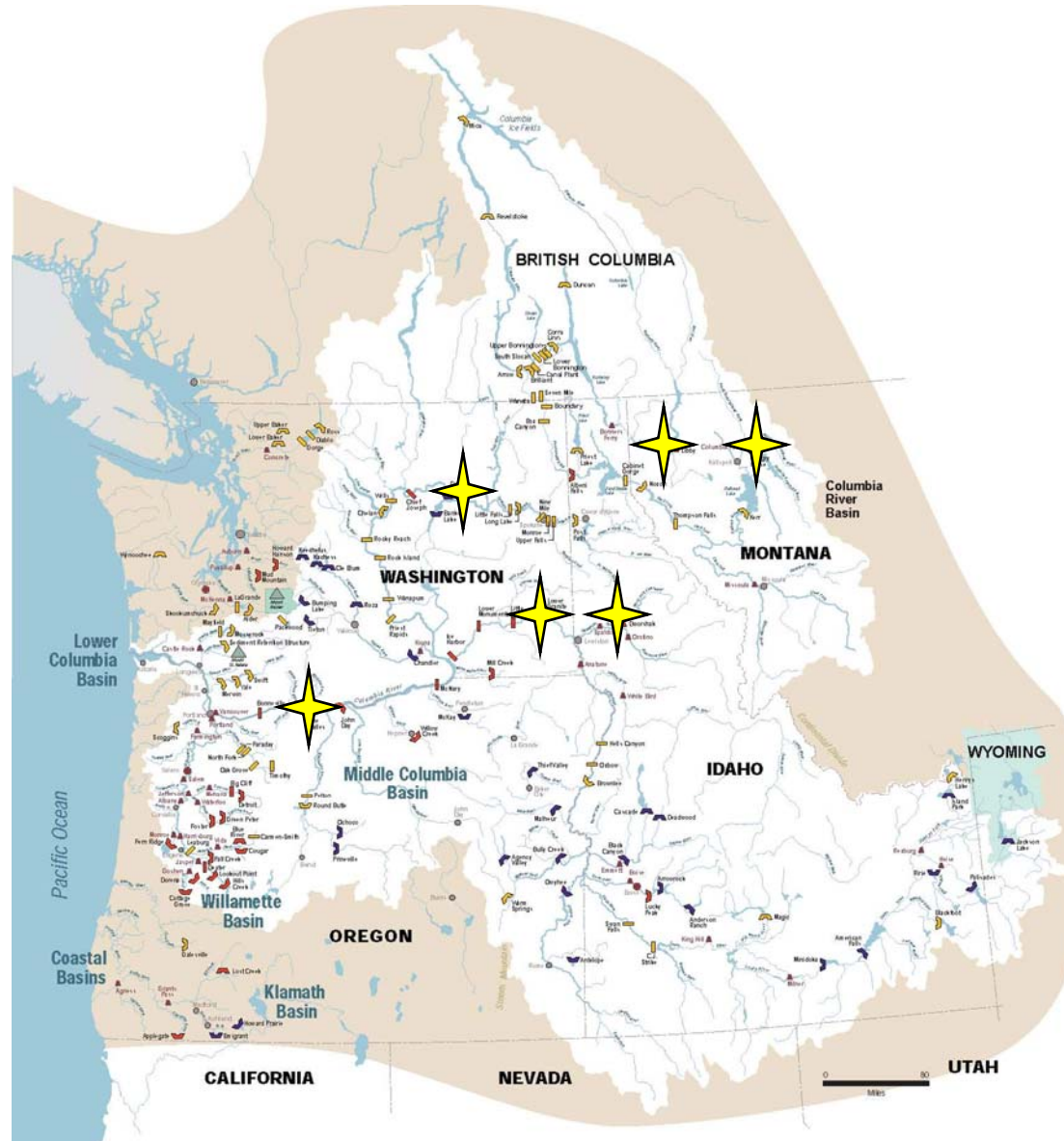
Hungry Horse

Grand Coulee

Dworshak

Lower Granite

The Dalles





ESP Scenario Analysis Processor (ESAP)

- Select ESP Years based on:
 - **VOLUME:** Comparison of Seasonal Volume to Water Supply Forecast (no consideration of runoff shape/timing)
 - **SHAPE:** Comparison of ESP daily flow hydrographs to ESP Daily Mean flow hydrograph



ESP Scenario Analysis Processor

- Select ESP Years based on:
 - **VOLUME: Comparison of Seasonal Volume to Water Supply Forecast (no consideration of runoff shape/timing)**
 - Choose ESP Years that are closest to local basin WSF volume
 - Choose ESP Years where TDA is closest to TDA WSF volume
 - Choose ESP Years based on “all basins” closest to local basin WSF volume
 - Comparison of ESP daily flow hydrographs to ESP Daily Mean flow hydrograph



- Water Supply Forecast Volume Selection Tool –
 - Local Basin
 - The Dalles
 - Columbia Basinwide

Select Years

Select All Clear All Year-Depth 4 Continue

Water Supply Forecast Volume Filters | ESP Shape and Timing Filters

Select ESP traces for years with:

- Local basin: ESP volume near WSF volume**
- The Dalles: TDA ESP volume near TDA WSF volume
- Basinwide: All local volumes near local WSF

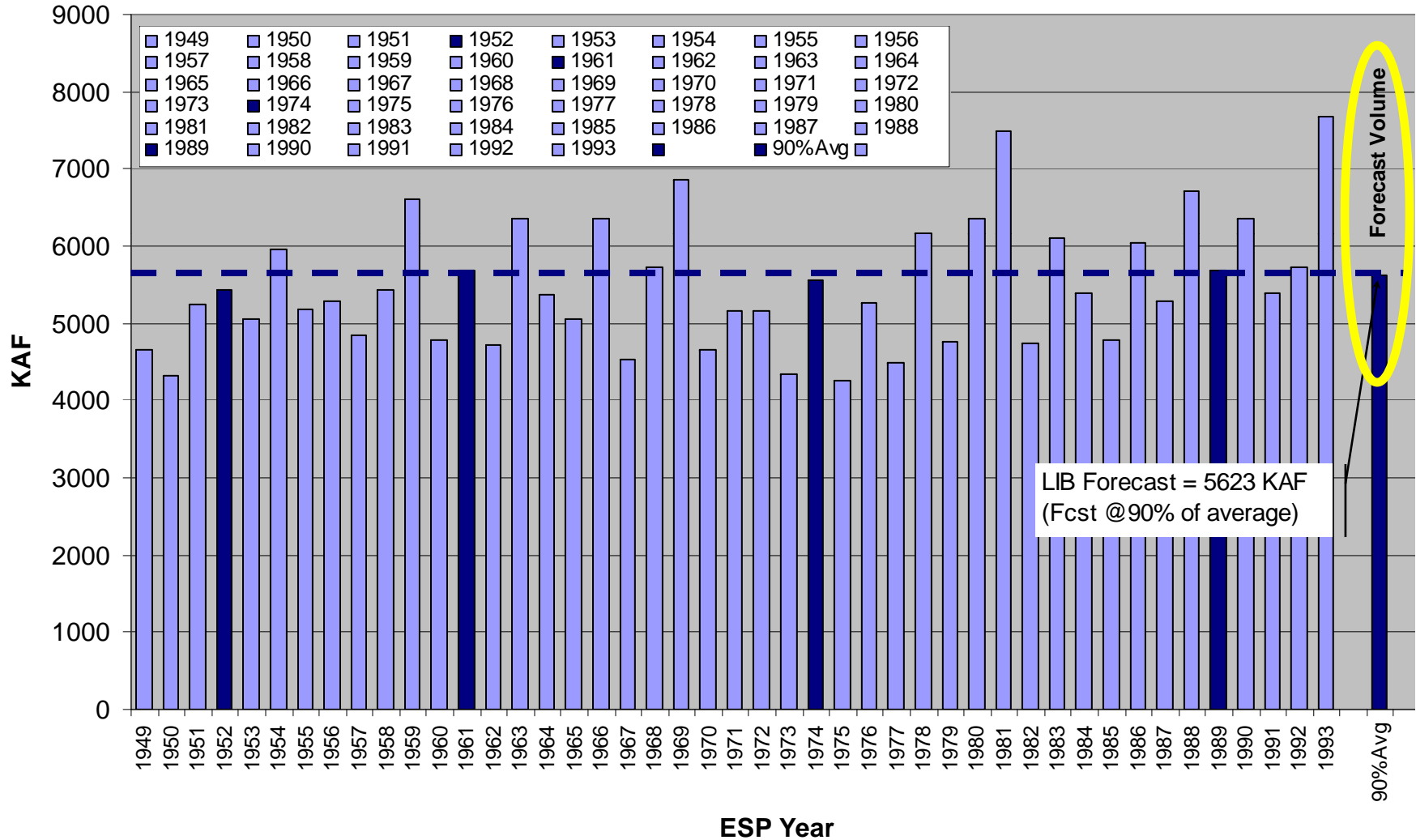
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<input type="checkbox"/> 1950	<input type="checkbox"/> 1960	<input type="checkbox"/> 1970	<input type="checkbox"/> 1980	<input type="checkbox"/> 1990
<input type="checkbox"/> 1951	<input type="checkbox"/> 1961	<input type="checkbox"/> 1971	<input type="checkbox"/> 1981	<input checked="" type="checkbox"/> 1991
<input checked="" type="checkbox"/> 1952	<input type="checkbox"/> 1962	<input type="checkbox"/> 1972	<input type="checkbox"/> 1982	<input type="checkbox"/> 1992
<input type="checkbox"/> 1953	<input type="checkbox"/> 1963	<input type="checkbox"/> 1973	<input type="checkbox"/> 1983	<input type="checkbox"/> 1993
<input type="checkbox"/> 1954	<input type="checkbox"/> 1964	<input type="checkbox"/> 1974	<input checked="" type="checkbox"/> 1984	
<input type="checkbox"/> 1955	<input type="checkbox"/> 1965	<input type="checkbox"/> 1975	<input type="checkbox"/> 1985	
<input type="checkbox"/> 1956	<input type="checkbox"/> 1966	<input type="checkbox"/> 1976	<input type="checkbox"/> 1986	
<input type="checkbox"/> 1957	<input type="checkbox"/> 1967	<input type="checkbox"/> 1977	<input type="checkbox"/> 1987	
<input checked="" type="checkbox"/> 1958	<input type="checkbox"/> 1968	<input type="checkbox"/> 1978	<input type="checkbox"/> 1988	



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Selecting Four ESP Volumes Closest to Forecast Volume - Libby



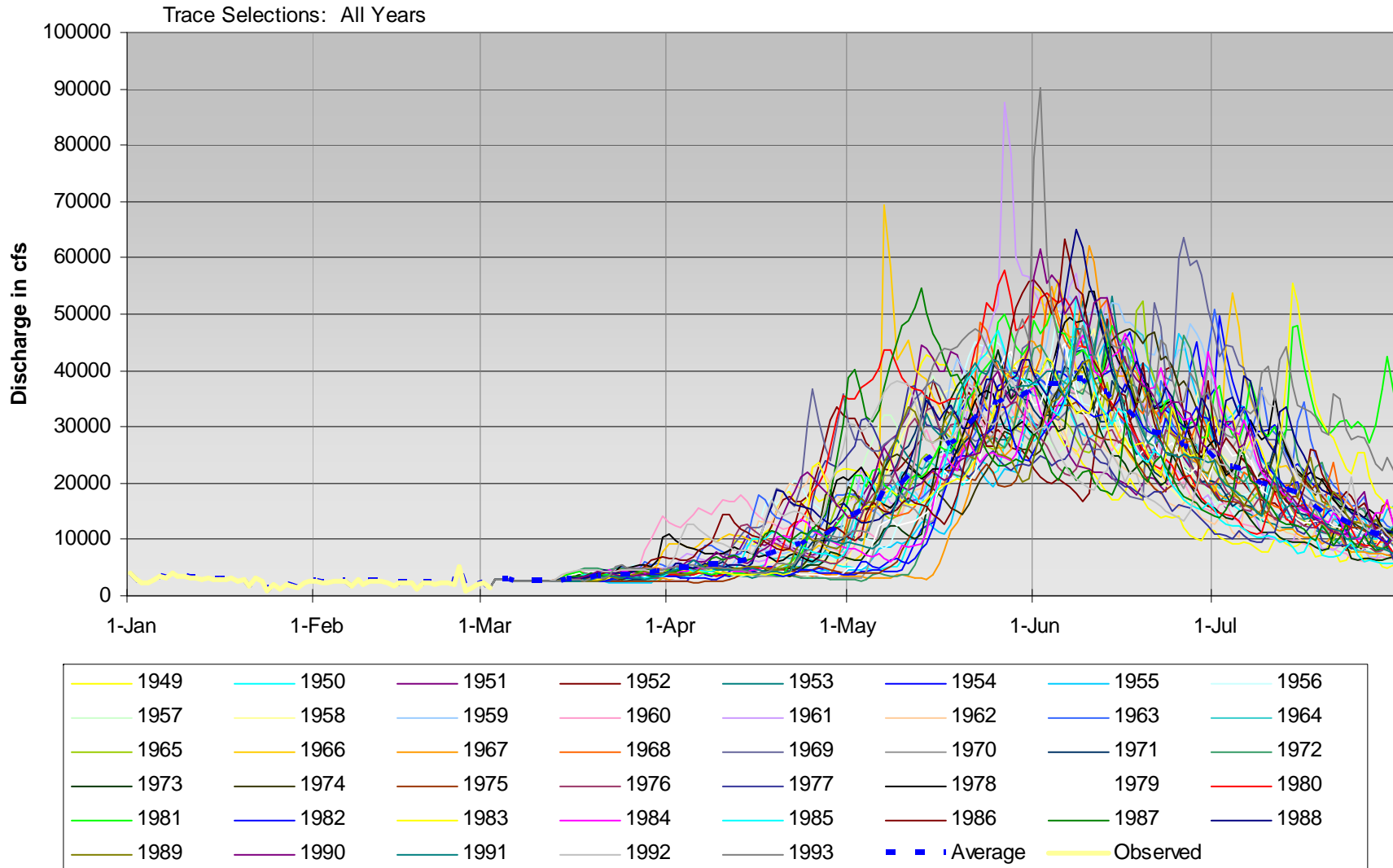


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Libby ESP Unregulated Flow Hydrographs

3/5/2009





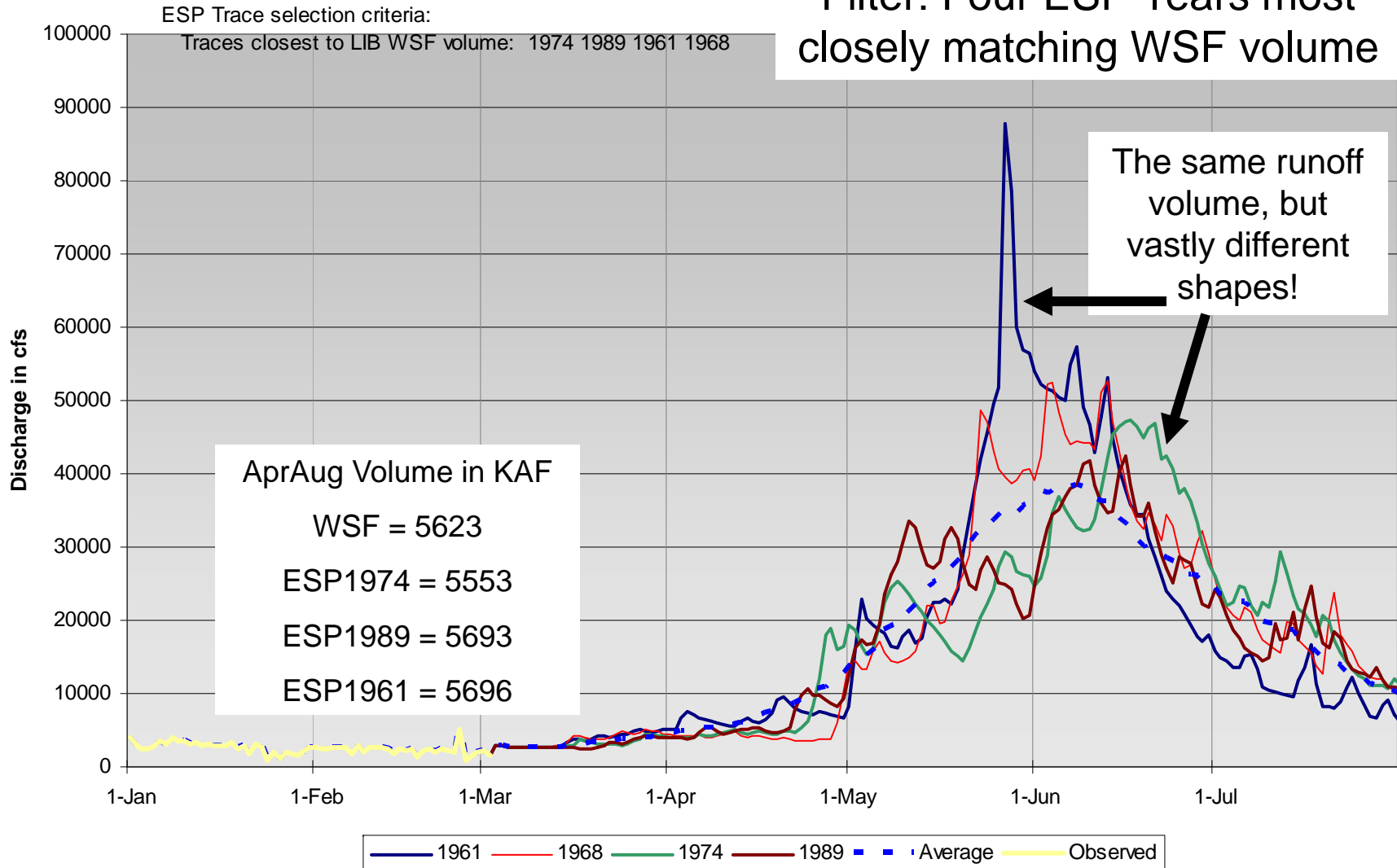
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Libby ESP Unregulated Flow Hydrographs

3/6/2009

Filter: Four ESP Years most closely matching WSF volume





Multi-Basin WSF Filter

Select ESP years where multiple basins match their water supply forecasts, e.g.

- Libby flows match Libby WSF volume

and

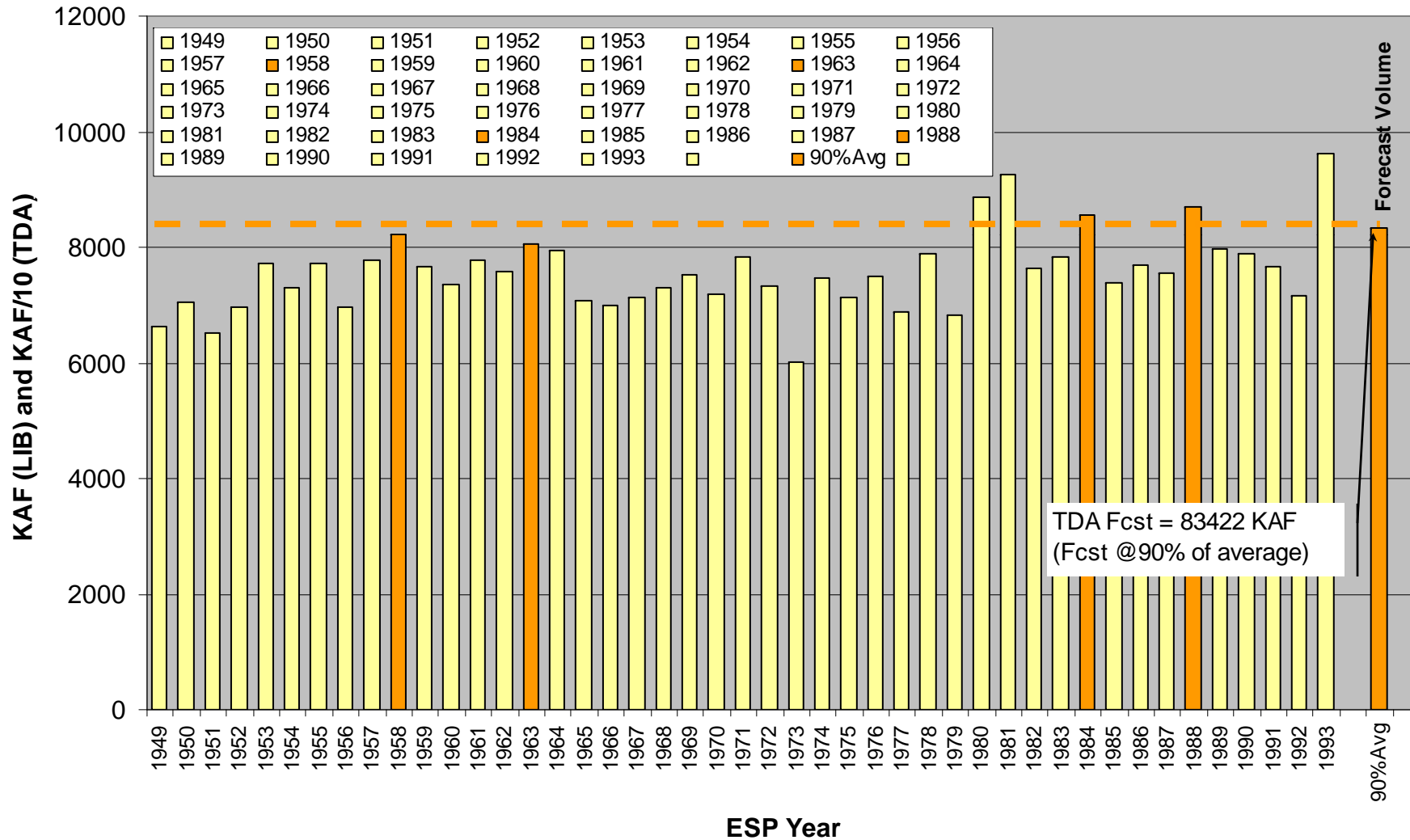
- The Dalles flows match The Dalles WSF volume.

Example: Assume WSF=90% of historical average at both LIB and TDA.

Caution: There is often little similarity between basins when selecting ESP years based on “volumes similar to WSF”



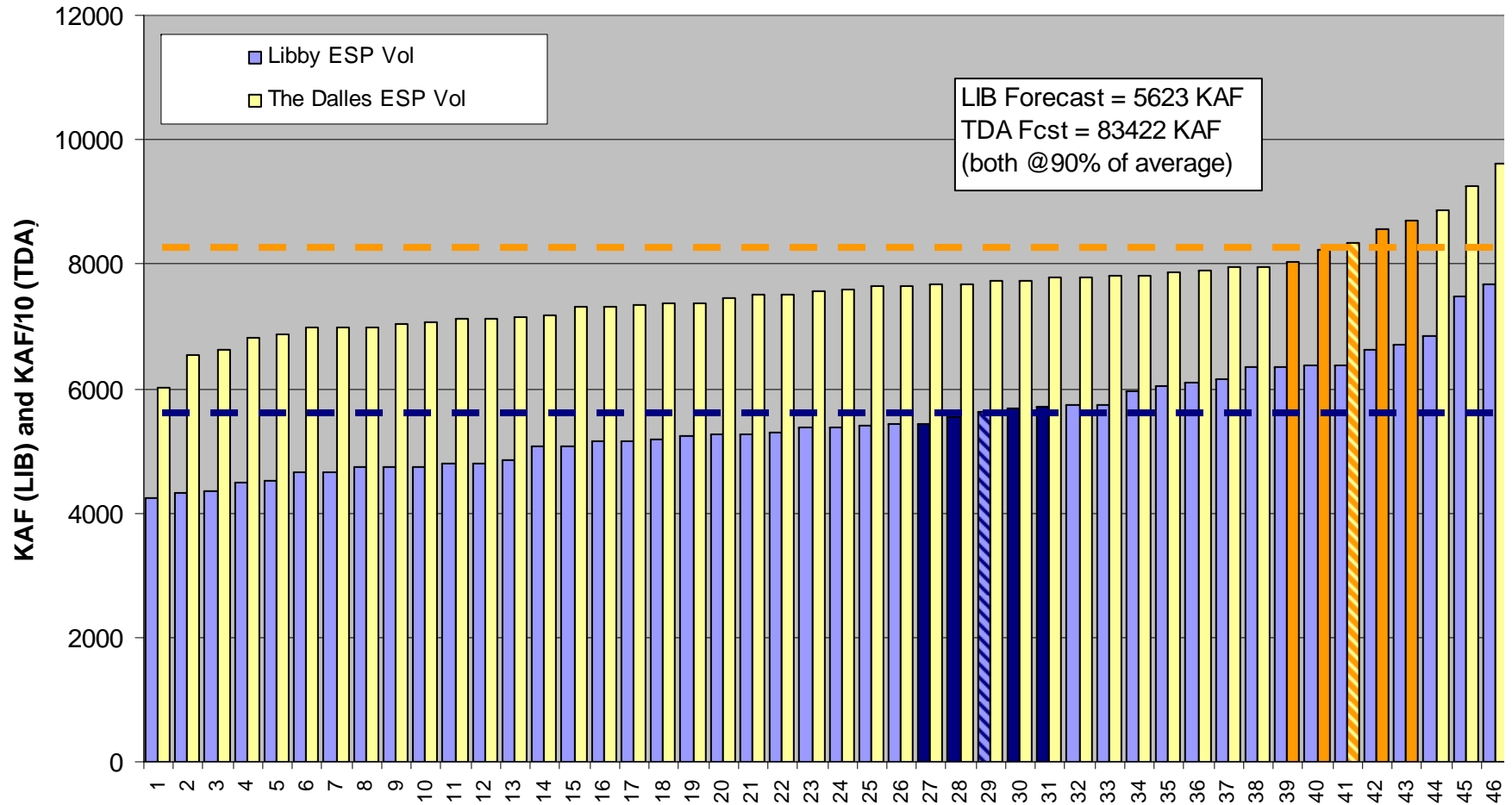
Selecting Four ESP Volumes Closest to Forecast Volume - The Dalles



TDA Fcst = 83422 KAF
(Fcst @90% of average)



Selecting Four ESP Volumes Closest to Forecast Volume

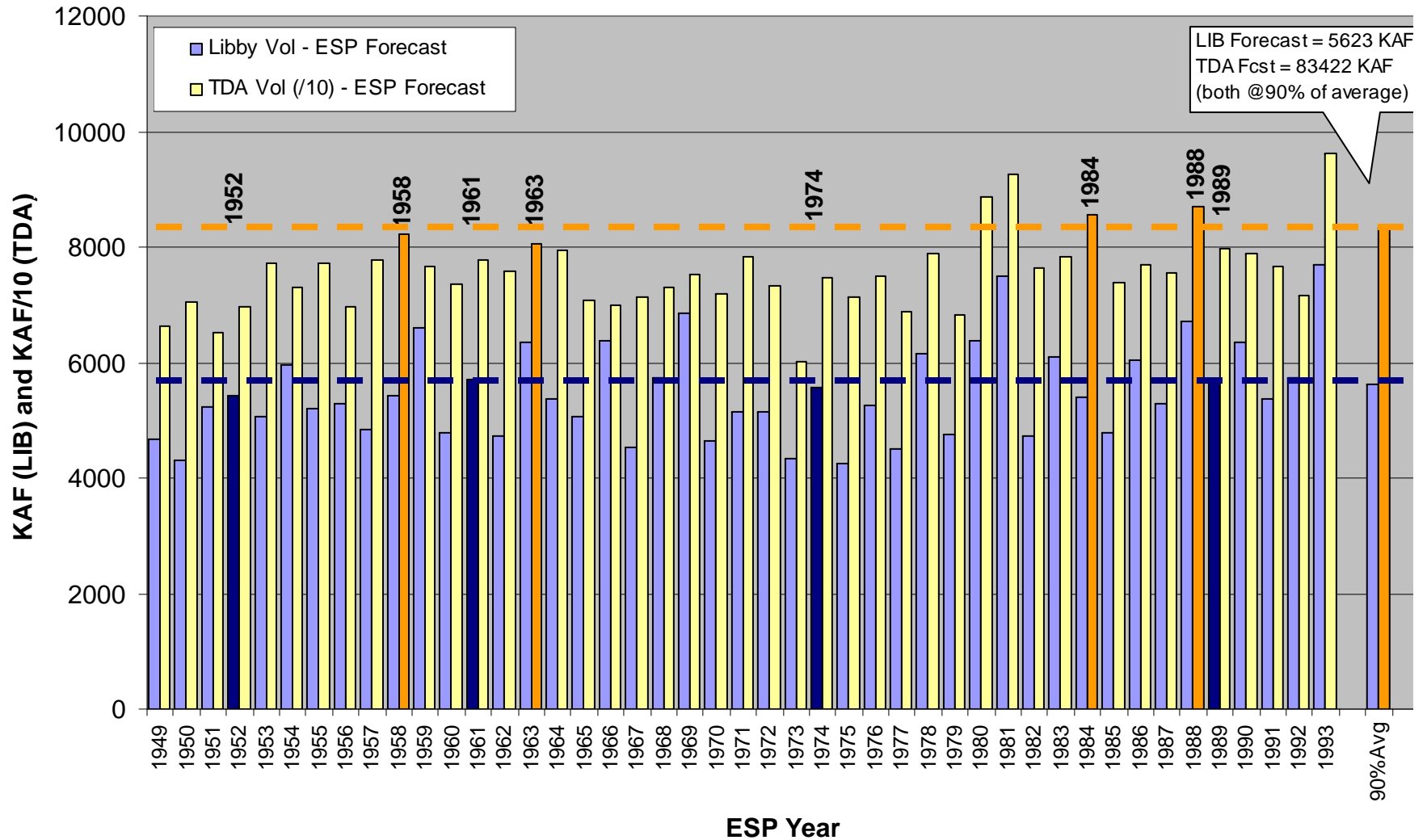




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Selecting Four ESP Volumes Closest to Forecast Volume





Selecting ESP Years: ESP Volumes Compared to WSF

Water Supply Forecast Volume

	83422	5623	1940	2776	54600	19100
	100%	100%	100%	100%	100%	100%
ESP Years closest to local WSF Volume * Factor						
TDA	LIB	HGH	DWR	GCL	LWG	
1958	1974	1970	1959	1984	1988	
1984	1989	1988	1981	1989	1991	
1963	1961	1961	1984	1986	1955	
1988	1968	1987	1953	1969	1982	
1989	1992	1982	1970	1990	1990	
1964	1952	1962	1960	1987	1978	
1990	1958	1974	1957	1978	1989	
1978	1984	1975	1980	1961	1975	
1971	1991	1984	1961	1964	1971	
1983	1964	1950	1955	1983	1960	
1980	1954	1991	1954	1959	1970	
1961	1956	1954	1964	1963	1950	
1957	1987	1966	1990	1958	1983	
1953	1976	1958	1958	1971	1963	
1955	1951	1959	1950	1976	1961	
1986	1986	1965	1952	1982	1965	
1959	1955	1951	1971	1955	1964	

ESP Years at TDA-
Years at top are
closest to TDA
WSF volume

ESP Years at LIB,
Years at top are
closest to LIB
WSF volume

Shadings display
where three "best"
TDA years fit in
ranked listing for
local basins, i.e.
"The ESP volume for
1984 was very close to
the WSF volume at TDA,
DWR and GCL, and also
fairly close at LIB and
HGH"



Basin-Wide Water Supply Selection Tool

ESP year with TDA volume closest to WSF = **1958**

ESP years with runoff volume for all basins closest to WSF = **1961**

Basin-Wide Comparison: ESP Pct Deviation							Average	Sorted Avg	Smallest
ESP Years closest to local WSF Volume * Fac							%DevWSF	%DevWSF	%DevWSF
ESP Year	TDA	LIB	HGH	DWR	GCL	LWG	AllBasins	AllBasins	ESP Year
1949	21%	17%	14%	19%	19%	18%	18%	4%	1961
1950	15%	23%	4%	8%	17%	6%	12%	5%	1984
1951	22%	7%	7%	28%	19%	24%	18%	5%	1989
1952	16%	3%	21%	9%	16%	9%	12%	6%	1991
1953	7%	10%	11%	2%	10%	9%	8%	7%	1955
1954	12%	6%	5%	6%	10%	9%	8%	7%	1990
1955	7%	8%	12%	5%	7%	1%	7%	7%	1958
1956	16%	6%	16%	19%	14%	16%	14%	7%	1988
1957	7%	14%	17%	5%	14%	18%	12%	8%	1954
1958	1%	4%	7%	7%	6%	17%	7%	8%	1959
1959	8%	18%	7%	0%	4%	11%	8%	8%	1982
1960	12%	15%	16%	5%	12%	5%	11%	8%	1978
1961	7%	1%	1%	5%	4%	7%	4%	8%	1971
1962	9%	16%	2%	11%	7%	8%	9%	8%	1974
1963	4%	13%	10%	13%	5%	7%	9%	8%	1953
1964	5%	4%	29%	6%	4%	8%	9%	9%	1963

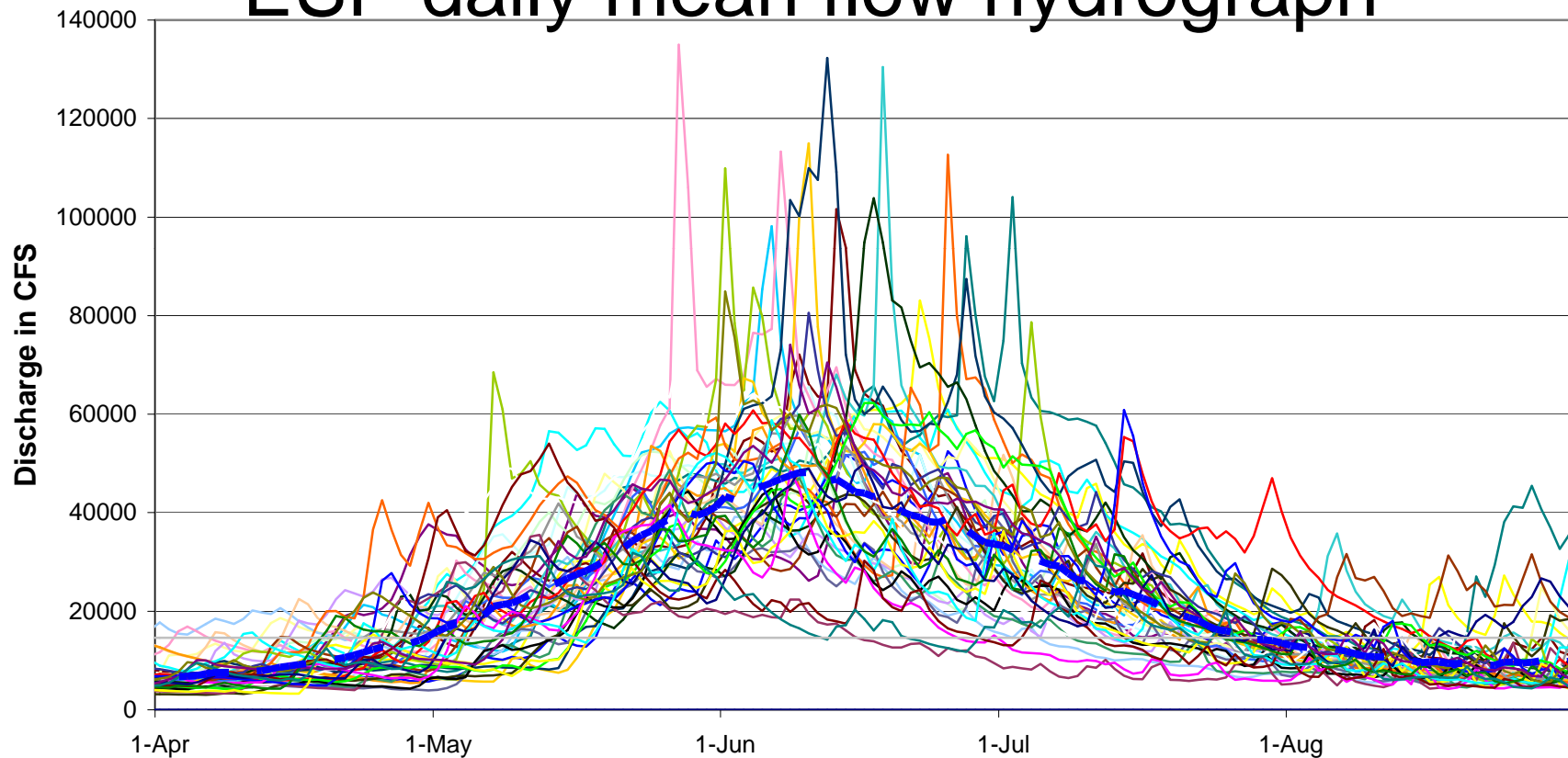


ESP Scenario Analysis Processor

- Select ESP Years based on:
 - VOLUME: Comparison of Seasonal Volume to Water Supply Forecast (no consideration of runoff shape/timing)
 - **SHAPE: Comparison of ESP daily flow hydrographs to ESP Daily Mean flow hydrograph**



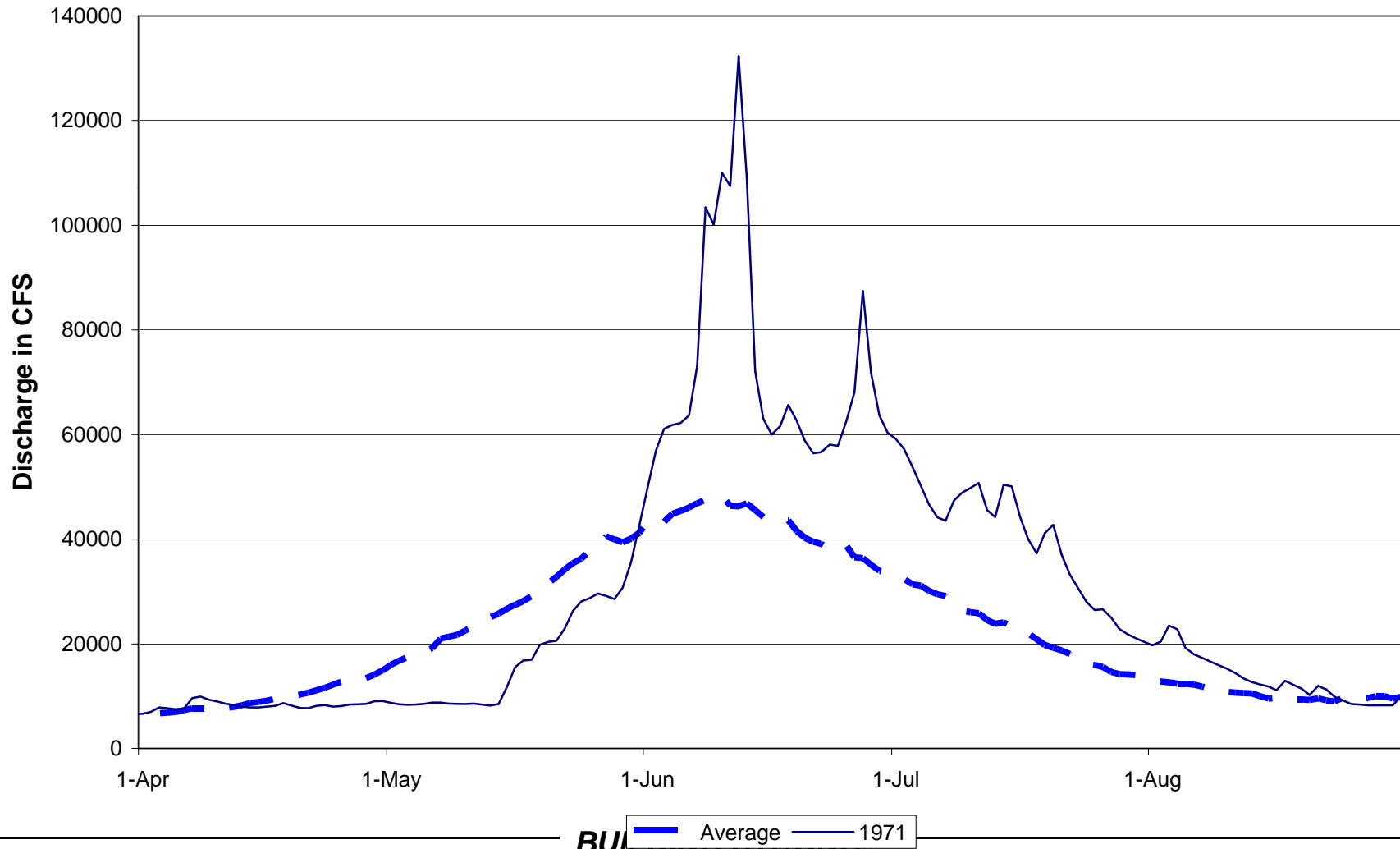
ESP hydrographs are compared to the ESP daily mean flow hydrograph



1949	1950	1951	1952	1953	1954	1955	1956
1957	1958	1959	1960	1961	1962	1963	1964
1965	1966	1967	1968	1969	1970	1971	1972
1973	1974	1975	1976	1977	1978	1979	1980
1981	1982	1983	1984	1985	1986	1987	1988
1989	1990	1991	1992	Observed	Average		



Libby 1971 ESP Hydrograph and ESP daily average hydrograph

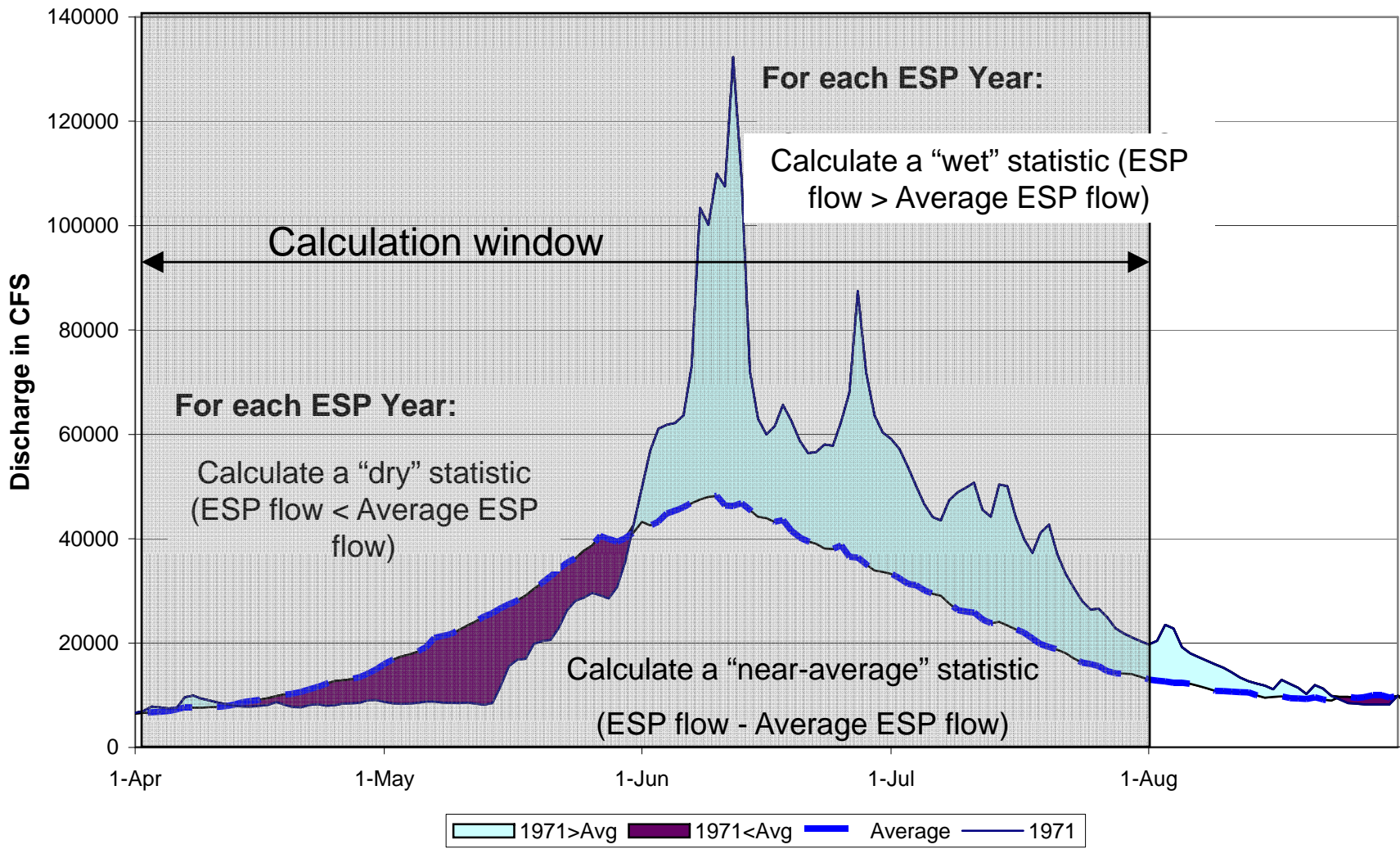




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Libby 1971 ESP Hydrograph Compared to daily average ESP values





Scenario Selection using “wet” and “dry” statistics

- Define a “season” (first and last dates for calculation window)
- Within date window, compute wet & dry statistics for each ESP hydrograph
- Rank ESP hydrographs based on:
 - ESP Years Near ESP average
 - Wet ESP years
 - Dry ESP years



ESAP Controls to define “seasons”

LIB

Season	Starting Month	Ending Month
Main	Apr	Aug
Early	Apr	May
Late	Jun	Jul
<i>Custom</i>	<i>May</i>	<i>Jun</i>

Click on the cell for any Starting or Ending Month to change it's value

ESP Flows updated	Obs Flows updated	Date of latest observed flow
03-Mar at 11:43:23 AM	03-Mar at 11:42:27 AM	2-Mar



ESP Shape and Timing Filter

- Select Season
- Select GeoFocus
- Select Hydrologic Criteria
- Select Depth
(number of ESP years with best match to criteria)
- Optional manual selection

The screenshot shows a software window titled "Select Years" with a close button (X) in the top right corner. At the top left are "Select All" and "Clear All" buttons. To the right is a "Year-Depth" field set to "3" with up and down arrows, and a "Continue" button. Below this is a tabbed interface with two tabs: "Water Supply Forecast Volume Filters" and "ESP Shape and Timing Filters", with the latter being active. The "ESP Shape and Timing Filters" tab contains three sections: "Season" with radio buttons for "Main Season: AprAug", "Early Season: AprMay", "Late Season: JunJul", and "Custom Season: MayJun"; "GeoFocus" with radio buttons for "Local Basin", "The Dalles", and "Basinwide"; and "Criteria" with radio buttons for "Near ESP average", "Wet traces", and "Dry traces". Below these sections is a "Select ESP Years" button and a "Reset" button. At the bottom of the window is a grid of years from 1949 to 1988, each with a checkbox. The years 1949, 1977, and 1987 are checked.

<input checked="" type="checkbox"/> 1949	<input type="checkbox"/> 1959	<input type="checkbox"/> 1969	<input type="checkbox"/> 1979	<input type="checkbox"/> 1989
<input type="checkbox"/> 1950	<input type="checkbox"/> 1960	<input type="checkbox"/> 1970	<input type="checkbox"/> 1980	<input type="checkbox"/> 1990
<input type="checkbox"/> 1951	<input type="checkbox"/> 1961	<input type="checkbox"/> 1971	<input type="checkbox"/> 1981	<input type="checkbox"/> 1991
<input type="checkbox"/> 1952	<input type="checkbox"/> 1962	<input type="checkbox"/> 1972	<input type="checkbox"/> 1982	<input type="checkbox"/> 1992
<input type="checkbox"/> 1953	<input type="checkbox"/> 1963	<input type="checkbox"/> 1973	<input type="checkbox"/> 1983	<input type="checkbox"/> 1993
<input type="checkbox"/> 1954	<input type="checkbox"/> 1964	<input type="checkbox"/> 1974	<input type="checkbox"/> 1984	
<input type="checkbox"/> 1955	<input type="checkbox"/> 1965	<input type="checkbox"/> 1975	<input type="checkbox"/> 1985	
<input type="checkbox"/> 1956	<input type="checkbox"/> 1966	<input type="checkbox"/> 1976	<input type="checkbox"/> 1986	
<input type="checkbox"/> 1957	<input type="checkbox"/> 1967	<input checked="" type="checkbox"/> 1977	<input checked="" type="checkbox"/> 1987	
<input type="checkbox"/> 1958	<input type="checkbox"/> 1968	<input type="checkbox"/> 1978	<input type="checkbox"/> 1988	

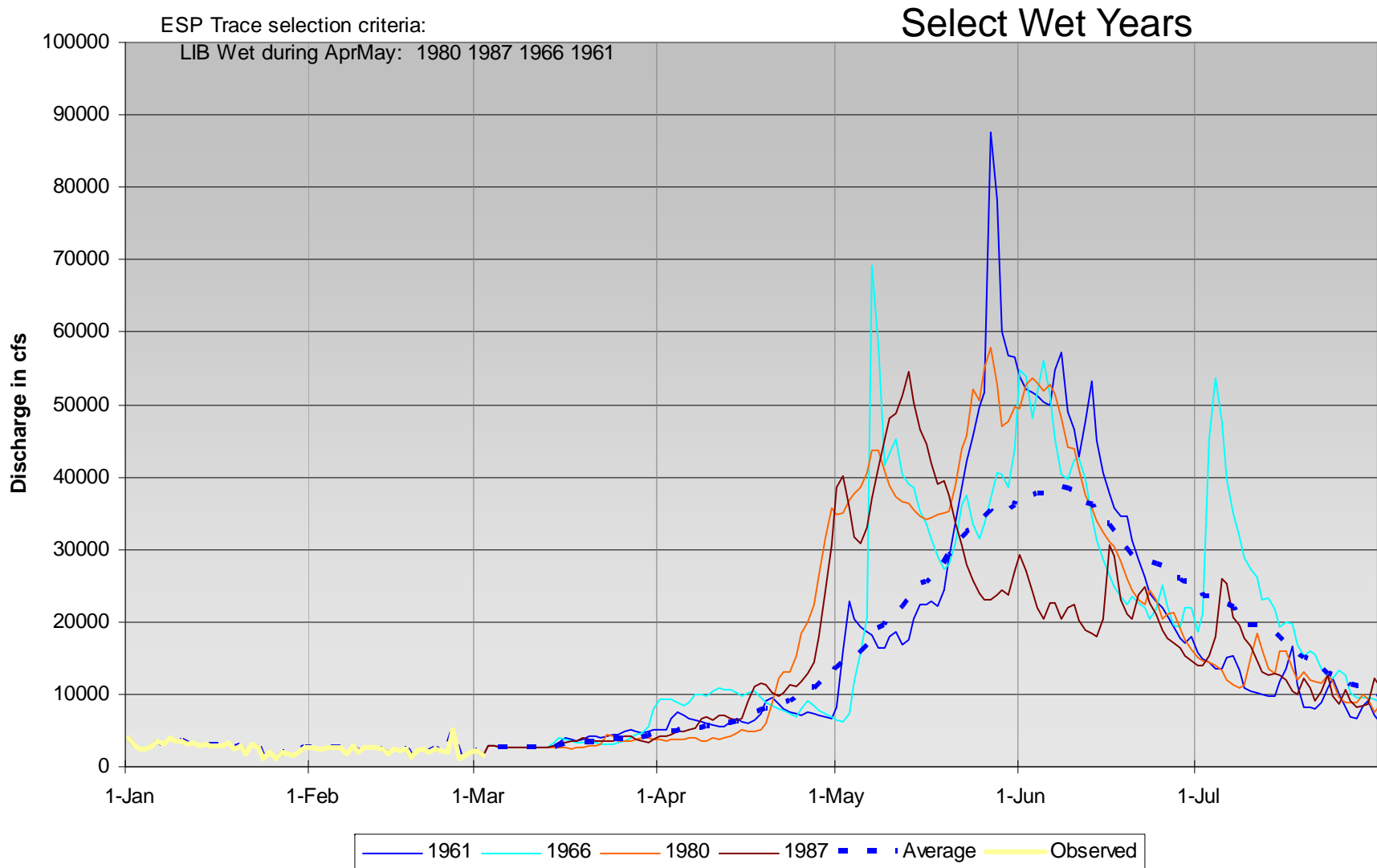


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Libby ESP Unregulated Flow Hydrographs

3/5/2009



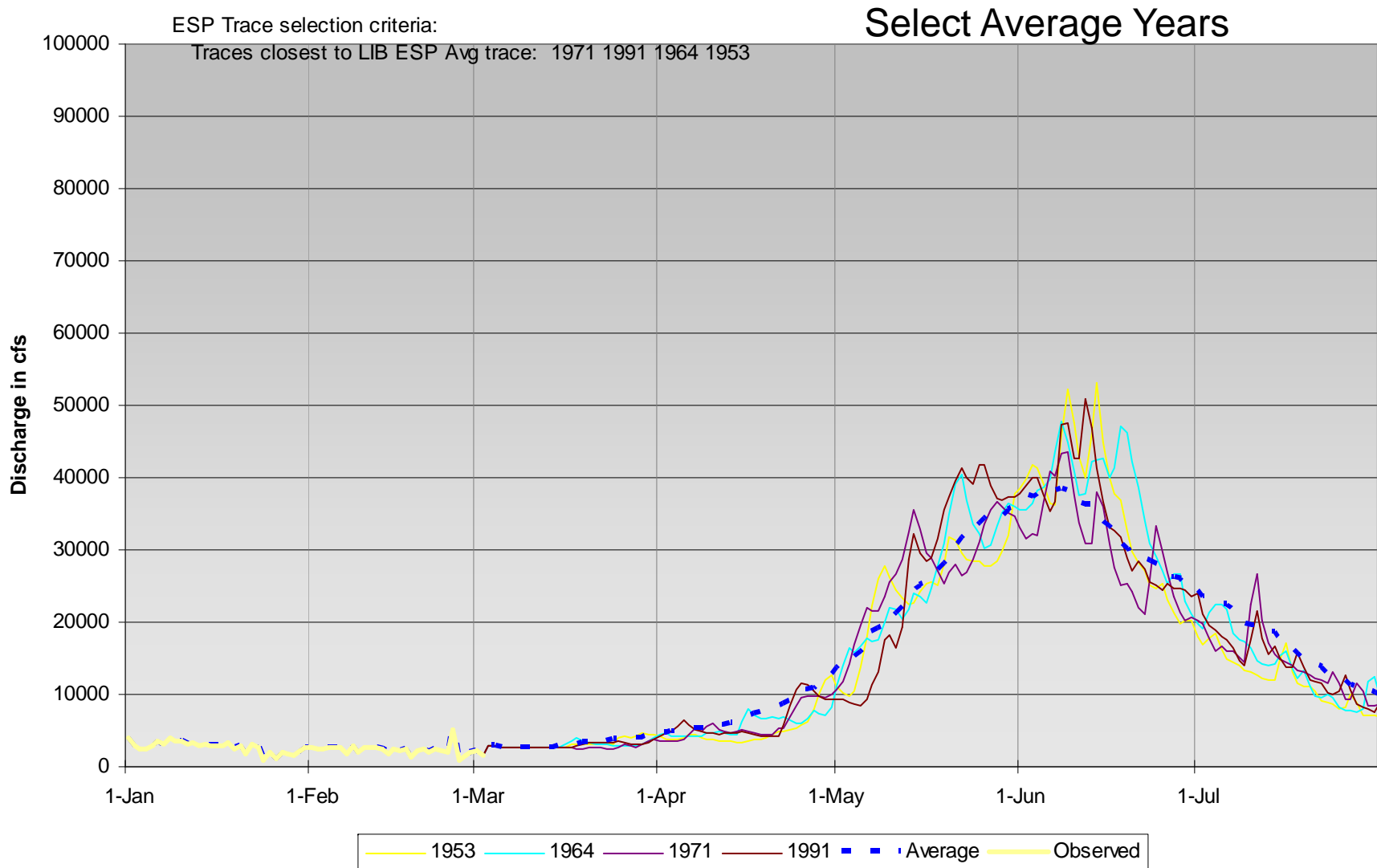


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Libby ESP Unregulated Flow Hydrographs

3/6/2009



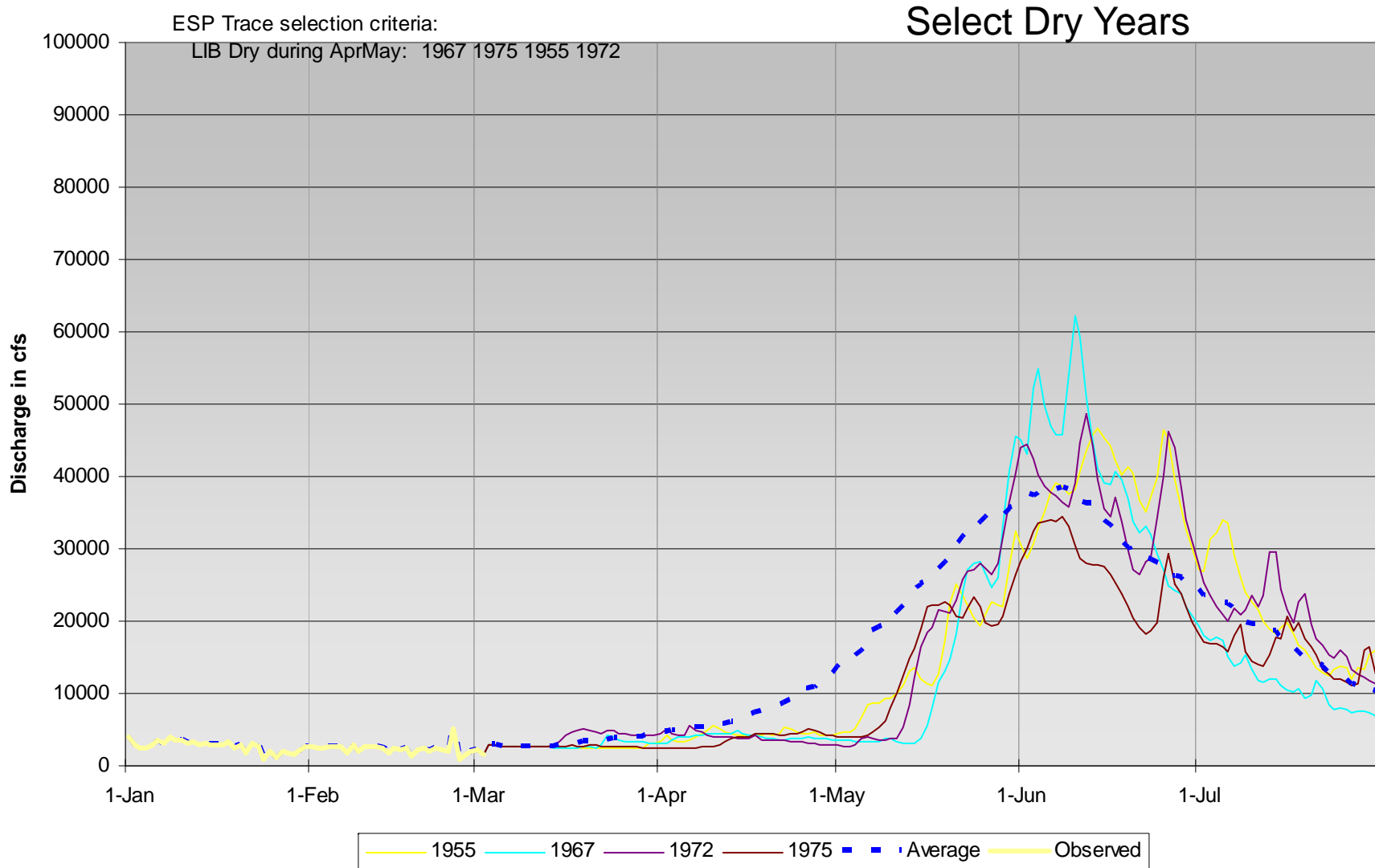


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Libby ESP Unregulated Flow Hydrographs

3/6/2009





Ranking Libby ESP Hydrographs by Wet & Dry statistics

ESP Years corresponding to sorted data vectors											
Main Season					Early Season			Late Season			
	LIB	LIB	LIB	LIB	LIB	LIB	LIB	LIB	LIB	LIB	LIB
	AprAug	AprAug	AprAug	AprAug	AprAug	AprMay	AprMay	AprMay	JunJul	JunJul	JunJul
Rank	ESP Year	Vol	Wet SSQ	Dry SSQ	Total SSQ	WetSSQ	DrySSQ	TotalSSQ	WetSSQ	DrySSQ	TotalSSQ
1	1975	4253	1950	1988	1971	1982	1951	1964	1962	1993	1979
2	1950	4316	1979	1981	1991	1955	1992	1965	1949	1981	1989
3	1973	4337	1975	1993	1964	1970	1980	1971	1977	1954	1991
4	1977	4496	1973	1959	1953	1975	1988	1953	1976	1988	1971
5	1967	4523	1971	1963	1979	1950	1969	1978	1973	1972	1970
6	1970	4653	1970	1990	1965	1972	1949	1976	1960	1959	1982
7	1949	4661	1982	1978	1958	1984	1981	1963	1951	1990	1950
8	1962	4730	1991	1964	1970	1965	1993	1991	1987	1968	1964
9	1982	4734	1953	1991	1968	1967	1959	1959	1950	1963	1958
10	1979	4752	1985	1968	1978	1954	1964	1988	1975	1978	1975
11	1960	4788	1965	1966	1989	1953	1971	1981	1957	1986	1956
12	1985	4792	1962	1971	1950	1979	1962	1985	1979	1984	1968
13	1957	4851	1964	1983	1956	1964	1963	1990	1971	1955	1953
36	1978	6163	1988	1955	1967	1951	1979	1955	1954	1960	1987
37	1963	6350	1983	1952	1977	1993	1970	1975	1963	1985	1988
38	1990	6351	1959	1950	1961	1949	1984	1952	1966	1973	1992
39	1966	6365	1961	1973	1949	1952	1954	1992	1990	1951	1977
40	1980	6367	1987	1992	1966	1992	1950	1969	1988	1952	1959
41	1959	6610	1966	1975	1980	1969	1982	1967	1983	1962	1983
42	1988	6711	1980	1987	1981	1961	1972	1961	1959	1992	1949
43	1969	6856	1981	1967	1987	1966	1955	1966	1969	1987	1981
44	1981	7485	1969	1977	1969	1987	1975	1980	1981	1977	1969
45	1993	7679	1993	1949	1993	1980	1967	1987	1993	1949	1993

Years with largest statistics (e.g. "wettest" and "driest" years) are at bottom of column; Nearest Avg ESP years are at top of Total column.



ESP Hydrograph Selection: Season=AprAug, Criteria=Avg, Wet, Dry

Main Season						AprAug											
Closest to Avg ESP (smallest deviation)						Overall Wet (largest deviation)						Overall Dry (largest deviation)					
TDA	LIB	HGH	DWR	GCL	LWG	TDA	LIB	HGH	DWR	GCL	LWG	TDA	LIB	HGH	DWR	GCL	LWG
1959	1971	1968	1989	1991	1961	1993	1993	1964	1964	1980	1957	1949	1949	1977	1993	1949	1992
1991	1991	1971	1963	1959	1972	1980	1969	1980	1957	1993	1984	1973	1977	1992	1992	1973	1966
1963	1964	1978	1976	1978	1976	1981	1981	1981	1958	1981	1993	1992	1967	1987	1975	1975	1973
1971	1953	1979	1974	1971	1962	1984	1980	1987	1971	1987	1964	1975	1987	1949	1987	1951	1949
1969	1979	1959	1956	1963	1989	1957	1966	1975	1953	1988	1958	1951	1975	1969	1973	1967	1987
1965	1965	1963	1954	1965	1954	1987	1987	1953	1955	1955	1981	1950	1992	1967	1949	1950	1951
1968	1958	1957	1961	1979	1977	1988	1961	1970	1970	1961	1953	1967	1973	1972	1951	1977	1969
1978	1970	1990	1988	1953	1985	1955	1959	1989	1960	1983	1980	1955	1950	1952	1966	1954	1975
1979	1968	1966	1968	1968	1959	1964	1983	1950	1959	1984	1955	1977	1952	1975	1955	1955	1974
1985	1978	1991	1986	1985	1960	1958	1988	1993	1992	1964	1982	1970	1955	1950	1964	1957	1950
1962	1989	1965	1969	1962	1963	1992	1954	1961	1979	1986	1975	1987	1962	1973	1950	1970	1967
1956	1950	1984	1965	1966	1965	1982	1990	1988	1987	1992	1992	1966	1972	1956	1983	1952	1970
1990	1956	1982	1977	1969	1952	1986	1992	1986	1980	1982	1988	1974	1982	1976	1967	1992	1968
1972	1976	1960	1983	1990	1983	1961	1986	1962	1981	1989	1971	1982	1951	1986	1986	1982	1956
1953	1985	1958	1952	1970	1968	1983	1963	1992	1984	1957	1990	1954	1960	1951	1982	1972	1986
1952	1982	1951	1985	1958	1956	1989	1952	1949	1975	1969	1991	1952	1985	1955	1991	1956	1982
1989	1973	1983	1951	1972	1971	1960	1949	1974	1990	1976	1950	1964	1957	1983	1970	1979	1955
1976	1984	1973	1967	1952	1978	1953	1978	1977	1950	1958	1963	1979	1954	1954	1978	1976	1964
1966	1957	1985	1982	1956	1986	1949	1974	1982	1972	1949	1978	1956	1970	1970	1984	1965	1979



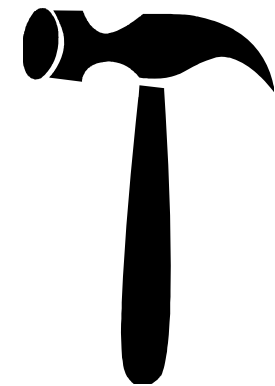
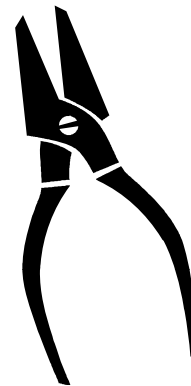
ESP Scenario Analysis Processor (ESAP) Trace Selection Tools:

- Select ESP Trace(s):
 - For years with local volume near Local WSF
 - For years with TDA volume near TDA WSF
 - For years with all basins near their local WSF

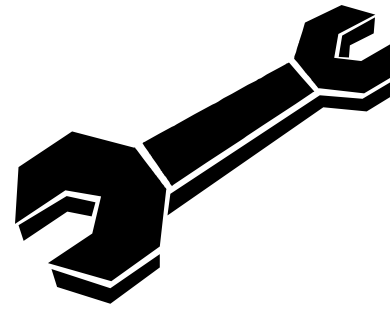
 - For “wet” years within date window (local)
 - For “dry” years within date window (local)
 - For years near ESP daily average within date window (local)
 - For “wet” years within date window (TDA)
 - For “dry” years within date window (TDA)
 - For years near ESP daily average within date window (TDA)



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Questions?





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Multi-Basin WSF Filter

Filter for ESP years where Libby flows match Libby WSF volume and The Dalles flows match The Dalles WSF volume.

Example: Assume WSF=90% of historical average at both LIB and TDA.

Caution: There is often little similarity between basins when selecting ESP years based on "volumes similar to WSF"

	AprAug ESP Year	AprAug Vol		AprAug ESP Year	AprAug Vol	
1	1975	4253		1	1973	60028.3
2	1950	4316		2	1951	65293.6
3	1973	4337		3	1949	66226.8
4	1977	4496		4	1979	68257.7
5	1967	4523		5	1977	68736.2
6	1970	4653		6	1952	69752.4
7	1949	4661		7	1956	69757.1
8	1962	4730		8	1966	69865.0
9	1982	4734		9	1950	70508.3
10	1979	4752		10	1965	70652.3
11	1960	4788		11	1967	71256.6
12	1985	4792		12	1975	71272.7
13	1957	4851		13	1992	71527.9
14	1965	5059		14	1970	71884.7
15	1953	5065		15	1968	73034.5
16	1971	5151		16	1954	73084.3
17	1972	5161		17	1972	73347.2
18	1955	5189		18	1960	73664.1
19	1951	5240		19	1985	73759.5
20	1976	5265		20	1974	74657.6
21	1987	5279		21	1976	75080.8
22	1956	5287		22	1969	75147.8
23	1964	5381		23	1987	75599.8
24	1991	5384		24	1962	75838.1
25	1984	5396		25	1982	76464.8
26	1958	5424		26	1991	76613.6
27	1952	5430		27	1959	76678.6
28	1974	5553		28	1986	76877.9
	Fcst=90%Avg	5623		29	1955	77287.5
29	1989	5693		30	1953	77341.7
30	1961	5696		31	1957	77757.0
31	1968	5730		32	1961	77771.9
32	1992	5735		33	1983	78183.2
33	1954	5950		34	1971	78283.2
34	1986	6051		35	1978	78754.1
35	1983	6102		36	1990	78931.5
36	1978	6163		37	1964	79503.4
37	1963	6350		38	1989	79590.3
38	1990	6351		39	1963	80470.9
39	1966	6365		40	1958	82269.6
40	1980	6367			Fcst=90%Avg	83422
41	1959	6610		41	1984	85657.3
42	1988	6711		42	1988	87012.9
43	1969	6856		43	1980	88765.3
44	1981	7485		44	1981	92476.0
45	1993	7679		45	1993	96136.6