APPENDIX I

Flood Hydrograph Modifications and Floodplain Activation Flood Update

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TECHNICAL MEMORANDUM

Date:	October 18, 2012 (Revised March 7, 2013)
To:	AECOM
From:	Sridhar Ponangi, P.E., Chris Campbell, M.S.
Project:	11-1009 – Lower Feather River Corridor Management Plan
Subject:	Flood Hydrograph Modifications and Floodplain Activation Flood Update

1 INTRODUCTION

This Technical Memorandum (TM) describes the modification to the Shanghai Bend – Yuba River Centering 2- and 10-year flood hydrographs and an update to the estimated Floodplain Activation Flood (FAF) flow, all of which will serve as boundary conditions in the hydrodynamic and sediment transport model (see Figure 1) that is being developed for the Lower Feather River (LFR) Corridor Management Plan (CMP). The flood hydrographs at the model boundaries were previously provided by MBK Engineers (MBK, 2012) and were originally developed by the US Army Corps of Engineers (USACE) for the Yuba River Basin Project General Reevaluation (USACE, 2008). Based on information from the California Department of Water Resources (DWR) hydrologists, the synthetic flood hydrology likely overestimates the flood peaks and volumes for the more frequent flood events (e.g., FAF, 2-year, and 10-year) and could result in over prediction of floodplain inundation, duration, and associated ecological benefits. Therefore, the flood hydrographs at the model boundaries were modified using a combination of updated flood frequency analyses, published flood flows, and hydrologic routing.

The prior FAF flow analyses for the LFR, as performed by PWA as part of the Bear River (PWA, 2005) and Feather River (PWA, 2008) levee setback projects, largely relied on USGS flow data on the Feather River at Nicolaus with a short, 14-year period of record (i.e., water years 1969 to 1983). Longer periods of record exist (i.e., water years 1969 to 2012) for flow gages on the Feather River and Yuba River upstream of their confluence. The FAF flows for the LFR CMP were updated using these longer periods of record.

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2 MODIFICATION TO THE 2- AND 10-YEAR FLOOD HYDROLOGY

2.1 FLOOD FREQUENCY ANALYSIS

The hydrodynamic model for the LMR CMP project extends 1.6 miles upstream of the 10th Street bridge on the Feather River (RM 29.25), 1.4 miles upstream of Simpson Lane Bridge on the Yuba River (RM 2.83), 16.75 miles upstream of the Feather River confluence on the Bear River (RM 12.5), 1.6 miles north in the Sutter Bypass (RM 68.13) above the Feather River confluence, and 4.4 miles downstream of the Feather River (RM 61.82). The extents of the hydrodynamic model are shown in Figure 1.

The flows in the Feather River, Yuba River, and Bear River reaches within the model area (see Figure 1) are regulated by upstream reservoirs. Previous flood frequency analyses (USACE, 1999; DWR, 2004) of regulated peak flows were performed for the Feather River at Gridley[1] (GRL), the Yuba River near Marysville (MRY), and the Feather River below Shanghai Bend in 1999 and for the Bear River near Wheatland (BRW) in 2004. The flood frequencies were determined based on the USGS (1981) guidelines using Bulletin 17B. These previous analyses were performed using peak flow data through the water year 1997 for the Feather River and Yuba River and through water year 2001 for the Bear River (see Appendix A). Using the USACE's Statistical Software Package (HEC-SSP), the previous flood frequencies at these locations were verified per Bulletin 17B guidelines using published data (see Table 1).

As a part of the current analysis, flood flow frequencies were updated for the stream gages closest to the model boundaries (see Figure 1 and Table 1). Due to limited flow records at the Butte Slough near Meridian (BSL, DWR A02972) along the Sutter Bypass and the lack of flow records at locations along the tributaries to the Feather River (i.e., Honcut Creek and Jack Slough) and the Bear River (i.e., Dry Creek, Union Pacific Interceptor Canal (UPIC) and Yankee Slough), no flood frequency analyses were performed along these channels. Previous flood frequencies for GRL, MRY, and BRW were updated to include annual peak flows through water year 2011. Regulated peak flows were obtained from USGS and DWR published data as well as minimal unpublished data (see notes in Table 1). Table 1 provides a summary of the historical data periods used for the updated flood frequency analyses. Table 2 presents a summary of the updated flood frequency discharges based on expected probability, as shown by Figure 2 through Figure 4, compared to the previous analyses, as shown in Appendix A. Table 2 also presents the peak flows from the Shanghai Bend – Yuba River Centering flood hydrographs at the gage locations for comparison.

As shown in Table 2, there was typically a relatively small decrease in the 2- and 10-year updated peak discharges from the previously calculated flood frequency values. The additional years of record included in the current analyses, i.e., water years 1998 through 2011 for the Feather and Yuba Rivers and 2002 through 2011 for the Bear River, without the addition of historical maxima during the period, contributed to the decrease in the statistical flows. Table 2 also shows the large discrepancy between the flood peaks from the synthetic hydrology and the flood peaks for the current flood frequency analysis. For a 2-year recurrence interval, the updated peak flows at GRL, MRY, and BRW are 32%, 68%,

[1] This is also described as Feather River at Oroville Lake and Dam by USACE (1999)

and 124% of the synthetic peaks, respectively. For the 10-year recurrence interval, the peak flows at GRL, MRY, and BRW are 85%, 71%, and 129% of the synthetic peaks.

Table 1. Stream gages and historical data periods for updated flood frequency analyses

Stream Gage Location (CDEC ID)	Systematic Record[1,2]	Historical Maximum[3]	Historical Period[1,2]
Feather River at Gridley (GRL) USGS 11407150 (through 1998) DWR A05165 (post 1998)	1969 – 2011	1997	1902-2011
Yuba River near Marysville (MRY)[4] USGS 11421000	1969 – 2011	1956, 1965, 1986, 1997	1904-2011
Feather River below Shanghai Bend USGS 11421700	1970 - 1980	1965, 1986, 1997	1904 - 1997
Bear River near Wheatland (BRW)[4] USGS 11424000	1964 – 2011	---	1905-2011

Notes:
[1] The beginning of the systematic record is identical to previous flood flow frequency analyses
[2] The end of the systematic and historical period was extended from the previous flood flow frequency analyses to include water year 2011
[3] The historical maximums are identical to the previous flood flow frequency analyses
[4] The peak flow for water year 2011 was not yet published by the USGS, so an unpublished value was obtained from CDEC website

Table 2. Comparison of regulated flood frequency discharges

Stream Gage Location (CDEC ID)	2-year Recurrence Interval			10-year Recurrence Interval		
	Current[1]	Previous[2]	Synthetic[3]	Current[1]	Previous[2]	Synthetic[3]
Feather River at Gridley at RM 50.7 (GRL)	15,000	17,000	47,400	85,000	90,000	100,000
Yuba River near Marysville at RM 6.09 (MRY)	19,000	19,000	27,780	60,000	66,000	92,890
Feather River below Shanghai Bend at RM 22.9	---	25,000	---	---	125,000	---
Bear River near Wheatland at RM 12.0 (BRW)	7,500	9,000	6,030	22,000	25,000	17,050

Notes:
[1] This study
[2] Previous studies include USACE (1999) and DWR (2004)
[3] Based on the Shanghai Bend – Yuba River Centering flood hydrographs at the gage locations

2.2 FLOOD HYDROGRAPH DEVELOPMENT

The flood hydrographs at the model boundaries, as provided by MBK, were based on Shanghai Bend – Yuba River Centering (USACE, 2008) as developed for the Comprehensive Study methodologies (USACE, 2002). The Shanghai Bend – Yuba River Centering, with a specific centering on the Yuba River and slightly more frequent concurrent events on the Feather River above Oroville, produces the maximum inundation areas along the lower reaches of the Feather River and Yuba River. To be consistent with this centering, the current study modified the Shanghai Bend – Yuba River centered flood hydrographs along the Feather River, the Yuba River, the Bear River and the Sutter Bypass at the model boundaries to incorporate the following criteria:

- Peak flows for the 2- and 10-year flood events at MRY, based on the current (updated) flood frequency analyses, were used to identify real flood hydrographs in recent history with similar peak flows as those shown in Table 2.
- Real hydrographs in recent history were obtained from 15-minute flow records. However, it was not always possible to use flood hydrographs with peak flows that more closely matched the recurrence interval flows in Table 2 (e.g., no 15-minute data existed at MRY for water year 1981, which corresponded to a 10-year recurrence interval).
- For these specific flood hydrographs at MRY, concurrent peak flows at GRL were verified to be more frequent.
- Selected flood hydrographs at MRY were scaled to match the current peak flow estimates for the 2- and 10-year flood events as shown in Table 2, and as described below. For consistency, this scaling factor was then applied to the flood hydrographs at GRL, BRW and BSL.
- Real (and scaled) flood hydrographs at GRL, BRW and BSL were translated and combined with local tributaries to the model boundaries. As there were no additional flows from local tributaries to the Yuba River between the gage location and the model boundary, the real (and scaled) flood hydrographs at MRY were simply translated to reflect the delay in peak flows at the model boundary.

Using the screening criteria described above, the 2-year flood hydrographs were based on the May 2009 flood event and the 10-year flood hydrographs were based on the New Years Eve 2005 flood event. Figure 5 and Figure 6 show the flood hydrographs, as recorded at GRL, MRY, ,BRW and SBL, for the May 2009 and New Years Eve 2005 flood events, respectively. For the May 2009 flood event, the peak flow at MRY was 20,000 cfs, which corresponded to a 2-year recurrence interval and required a scaling factor of 0.95. The concurrent flows at GRL and BRW were 4,900 cfs and 2,500 cfs, respectively, which have an approximate 1-year recurrence interval based on current flood frequency analyses. The concurrent peak flow at BSL was 940 cfs. For the New Years Eve 2005 flood event, the peak flow at GRL was 83,700 cfs which corresponded to an approximate 10-year recurrence interval. However, the peak flows at MRY and BRW were 113,200 cfs and 34,800 cfs, respectively, which corresponded to an approximate 20-year recurrence interval and required a scaling factor of 0.53. The concurrent peak flow at BSL was 111,000 cfs. The scaling factor was applied to GRL and BSL as well.

The real (measured) hydrographs for the three gages were scaled equally per flood event such that the 2- and 10-year peak flows at MRY matched the peak flows derived from the current flood frequency analysis. The scaled 2- and 10-year real flood hydrographs (modified hydrographs) for the four gages are also shown by Figure 5 and Figure 6, respectively.

Due to the absence of flow gages along tributaries to the Feather River (i.e., Honcut Creek and Jack Slough) and the Bear River (i.e., Dry Creek, UPIC and Yankee Slough), no frequency analyses of flood flows were performed. Hence, the 2- and 10-year flood hydrographs provided by MBK were retained to represent the flows from the local tributaries. The flow data for the Tisdale bypass, a tributary to Sutter Bypass, was obtained from the Tisdale Weir Spill to Sutter Bypass near Grimes (DWR A02960) gage. This data along with flow and stage data for the Sacramento River below Wilkins Slough near Grimes (USGS 11390500) was used for evaluating the Tisdale flows to the Sutter Bypass.

The modified hydrographs for the Feather River (i.e., GRL), Yuba River (i.e. MRY), and Bear River (i.e., BRW) at the gage locations and synthetic hydrographs for the local tributaries were translated to the model boundaries using spreadsheet analysis methods assuming a flow velocity of 3 fps for the Feather River and its tributaries, 3.5 fps for the Yuba River, and 2.5 fps for the Bear River and its tributaries. This approach was first validated by routing only synthetic hydrographs for the main rivers at the gage locations and their local tributaries (as provided by MBK) to the model boundaries and comparing them with the synthetic hydrographs at the model boundaries (as previously provided by MBK). Figure 7 through Figure 10 validate that the routing approach for the 2- and 10-year flows was reasonable for approximating the flood hydrographs at the model boundaries without the need for numerical routing. However, on Figure 8, the Bear River 2-year routed hydrograph differs from the synthetic hydrograph at the model boundary due partially to the reverse flow from the Feather River followed by a surge due to the release of stored volume (see third flood peak). This hydraulic phenomenon could not be simulated using the spreadsheet tool.

Having validated the routing tool, the timeframe of the 2-year modified hydrograph for MRY was shifted such that the timing of the peak flow aligns with the timing of peak flow for the synthetic hydrograph. This time shift was applied to the modified hydrographs at GRL, BRW and BSL to preserve the relative timing between the hydrographs. Similar adjustments to the timeframe were performed for the 10-year modified MRY hydrograph and consistently applied to the GRL, BRW and BSL hydrographs. The modified hydrographs for the Feather River (i.e., GRL) and Bear River (i.e., BRW) at the gage locations and synthetic hydrographs for the local tributaries were then translated to the model boundaries using the routing tool. As there were no additional flows from local tributaries to the Yuba River between the gage location and the model boundary, the modified flood hydrographs at MRY were translated to reflect the delay in peak flows at the model boundary. Figure 11 through Figure 16 show the modified flood hydrographs compared to the synthetic flood hydrographs at the model boundaries. These figures, along with Table 3, generally show that the 2- and 10-year peaks of the modified flood hydrographs at the model boundaries are approximately 21% and 50% of the synthetic peaks for the Feather River, 69% and 65% for the Yuba River and 55% and 103% for the Bear River. The ratios for the 2-year peaks on the Feather River and Yuba River at the model boundaries (per Table 3) are consistent with the ratios at the gage locations (per Table 2). The ratios for the 10-year peaks on the Yuba River and Bear River at the model boundaries (per Table 3) are consistent with the ratios at the gage locations (per Table 2).

The modified 2- and 10-year real flood hydrographs for the Sutter Bypass (i.e. BSL) were translated to the model boundary using spreadsheet analysis methods similar to those used for GRL, MRY and BRW assuming a flow velocity of 2 fps. However, the routing validation could not be performed as the synthetic flow hydrographs near the BSL gage were not readily available. Instead, the flow velocity was validated by reviewing past flood hydrographs at BSL and Sutter Bypass at Long Bridge (LNB).

Analysis of flows for the Sacramento River below Wilkins Slough near Grimes (USGS 11390500) revealed that the scaled 2- and 10-year real flows in the Sacramento River would not over top the Tisdale Weir and spill into the Sutter Bypass. Figures 17 and 18 shows the scaled 2- and 10-year real flood hydrographs in the Sacramento River and the stage derived from the flow and stage relationship at the gage. The figures indicates that the peak stage in the Sacramento River under modified 2- and 10-year recurrence interval is below the Tisdale weir crest (44.12 ft-NAVD88). Therefore, the hydrographs at BSL were routed to the model boundary along the Sutter Bypass assuming no flow from the Tisdale Bypass.

Figure 19 and 20 show the modified 2- and 10-year flood hydrographs compared to the synthetic flood hydrographs at the model boundary along the Sutter Bypass. These figures as well as the peak flows summarized in Table 3, show that the 2- and 10-year peaks of the modified flood hydrographs at the model boundary along the Sutter Bypass are approximately 2% and 59% of the synthetic peak, respectively.
For the modified 2-year flood (i.e., May 2009) relative to the synthetic flood hydrology:

- The Feather River baseflow is significantly reduced and the flood peak is largely absent.
- The Yuba River baseflow is significantly reduced along with the volume of the flood wave.
- The Bear River baseflow is significantly reduced and the duration of the primary flood wave (i.e., middle peak) is slightly longer.
- The Sutter Bypass baseflow, peak flow along with the volume of the flood wave are significantly reduced.

For the modified 10-year flood (i.e., New Years Eve 2005) relative to the synthetic flood hydrology:

- The Feather River baseflow is significantly reduced and the primary flood wave volume is significantly reduced.
- The Yuba River baseflow is reduced along with the volume of the primary flood wave.
- The Bear River baseflow is significantly reduced and the primary flood wave, though similar in magnitude, is significantly flashier on the rising and falling limbs.
- The Sutter Bypass baseflow is reduced along with the peak flow and volume of the flood wave.

Table 3. Comparison of modified and synthetic flood peaks at model boundaries

Model Boundary	2-year Recurrence Interval		10-year Recurrence Interval	
	Modified	Synthetic[1]	Modified	Synthetic[1]
Feather River at RM 29.25	10,654	50,260	55,845	112,660
Yuba River at RM 2.83	19,000	27,540	60,000	92,180
Bear River at RM 2.76	4,447	8,150	19,902	19,340
Sutter Bypass at RM 68.13	893	55,331	58,300	99,194

Notes:
[1] Based on the Shanghai Bend – Yuba River Centering flood hydrographs at the model boundaries as provided by MBK

2.3 STAGE HYDROGRAPH DEVELOPMENT

The stage hydrograph for the downstream model boundary (RM 61.82) was initially developed using the Feather Sutter discharge rating curves provided by MBK Engineers (MBK, 2012). However, the downstream stage resulted in significant backwater effects at lower flows that are ecologically significant. Therefore, a new stage hydrograph was developed for the downstream model boundary (RM 61.82) using the flow and stage data for the May 2009 and NYE 2005 flood events. To be consistent with the scaling and timing of the flood hydrographs, the following procedure was used:

- The flows at the model boundary were estimated as follows:
  Flow at the model boundary = flow at the Fremont Weir gage + flow at the Sacramento River gage near Verona – flow at the Sacramento River gage below Wilkins Slough near Grimes routed to the Sacramento River gage at Verona
- The stage at the model boundary was estimated by interpolating the stage at the Feather River gage near Nicolaus and the Sacramento River gage near Verona
- Using the estimated flow and interpolated stage, a new flow-stage relationship was developed
- The estimated flows at the model boundary were scaled using scaling factors of 0.95 and 0.53 to approximate flows for 2-year and 10-year recurrence interval. This approach is consistent with the scaling applied at MRY gage as discussed in section 2.2.
- The stage at the model boundary was then determined for the scaled flow using the new flow-stage relationship
- The timestamp was modified using the adjustment similar to that applied at the MRY gage. Figure 21 shows the 2- and 10-year stage hydrographs for the downstream model boundary.

Figure 22 compares the flow-stage relationship developed for the May 2009 and NYE 2005 floods with the Feather Sutter discharge rating curves provided by MBK Engineers. The figure shows that at lower flows, which are ecologically significant, the Feather Sutter rating curve will create significant backwater effects. Therefore, the modified stage hydrograph described above and as shown in Figure 21 was used.

3 UPDATE TO THE FLOODPLAIN ACTIVATION FLOOD

The Floodplain Activation Flood (FAF) is a representative flow at which ecological flood benefits are expected to accrue during small magnitude, spring time floods (PWA, 2006). The FAF criteria were originally defined to meet the needs of native fish species (i.e., splittail and Chinook salmon), the production of biologically available carbon, and seed dispersal for cottonwood. The FAF criteria in terms of timing, duration, and frequency were defined as follows:

1. Timing – period of March 15 to May 15
2. Duration – active flooding persists for at least 7 days
3. Frequency – occurs at least every 2 out of 3 years or 67% exceedence

The above criteria were used to reassess the FAF flow for LFR CMP purposes given its importance as it relates to flow activation of proposed enhancement features (e.g., the diversion to Old Feather River channel at Eliza Bend). The four (4) gages shown by Figure 1 and Table 4 were analyzed using the USACE's Ecosystem Functions Model (HEC-EFM) and the FAF criteria defined above. Daily flow records were processed by HEC-EFM to identify the FAF flow for the 44-year period of record (i.e., water years 1969 to 2012). The Feather River at Yuba City flows (YUB) were analyzed relative to the GRL flows to determine if a scaling factor (increase) was needed to account for the tributary contributions from Honcut Creek and Jack Slough as measured by the YUB gage. The YUB gage has a shorter period of record, so a 16-year comparative analysis between GRL and YUB was used to identify a potential scaling factor (increase). Based on the results shown in Table 4, a scaling factor was not needed.

For the purposes of this analysis, the daily flows were added together before performing the FAF analyses. For the Feather River upstream of the Bear River, the GRL and MRY flows were summed on a daily time step since the travel times are less than half a day for each gage to the Feather-Yuba confluence. For the Feather River downstream of the Bear River, the GRL, MRY, and BRW flows were summed on a daily time step since the travel times are less than a day for each gage to the Feather-Bear confluence. This approach differs (and represents a significant improvement in methodology and therefore accuracy) from the prior FAF analyses (PWA, 2005; PWA, 2008), which used individual gage analyses and simple subtraction / addition to define the FAF flows upstream and downstream of the Bear River.

Table 4 shows the results of the FAF analysis. The FAF flows on the Feather River upstream and downstream of the Bear River are 5,170 cfs and 5,522 cfs, respectively. Based on prior FAF analyses (PWA, 2005; PWA, 2008), Feather River flows upstream of the Bear River ranged between 7,373 cfs to 8,414 cfs upstream of the Bear River based on multiple gage analyses and was 9,030 cfs downstream of the Bear River. Per the updated FAF analyses, Feather River flows are 30% to 39% lower upstream of the Bear River and 39% lower downstream of the Bear River. This is an important update to the FAF analysis for the LFR CMP. Flow diversions and floodplain inundation from proposed enhancement features as part of the CMP may occur less often and for shorter durations. Higher flows at higher stages will likely be needed to activate the proposed enhancement features. This may be a more critical concern given

the recent breaching of the Modesto Formation at Shanghai Rapids, and the potential loss of hydraulic head or backwater previously created by the presence of the intact formation underlying the rapids.

To better understand how flows vary from year to year, Figure 23 shows the results of the FAF analysis for flows meeting criteria #1 and #2 by water year relative to the updated FAF flows. The updated FAF flows for the Feather River upstream and downstream of the Bear River are largely defined by a threshold flow between below normal (BN) and above normal (AN) water years as defined by the Sacramento Valley Index. In dry (D) and critically dry (C) water years, it is highly probable that FAF flows will not occur. Flows well in excess of the FAF flows are typically associated with wet (W) water years.

Table 4. Floodplain Activation Flood flow summary

Gage	Period	Flow (cfs)	Flow Upstream Bear River (cfs)	Flow Downstream Bear River (cfs)
GRL	1969 – 1984	3,700	---	---
YUB[1]	1969 – 1984	3,700	---	---
GRL+MRY[2]	1969 - 2012	5,170	5,170	---
GRL+MRY+BRW[2]	1969 - 2012	5,522	---	5,522
Prior Analysis[3]	---	---	7,373 – 8,414	9,030

Notes:
[1] Perform paired FAF analysis on GRL and find concurrent YUB flow
[2] Add daily flows before performing FAF analysis
[3] PWA (2005, 2008): 1969 - 1983 upstream of the Bear River; 1963 - 2003 for the Bear River, 1969 - 1983 downstream of the Bear River

4 REFERENCES

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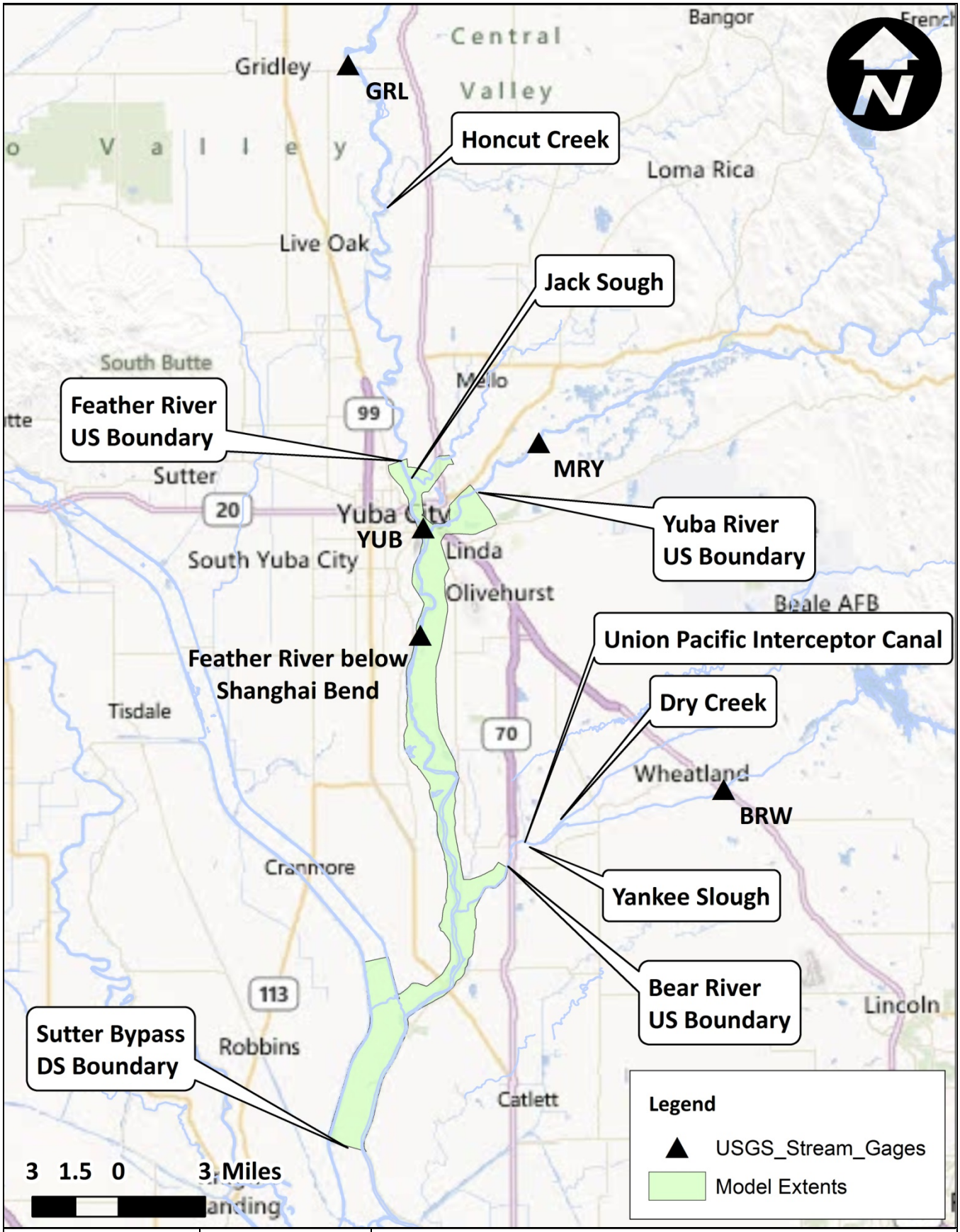

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Lower Feather River Corridor Management Plan

Model extents and Stream gage locations

Project No. 11-1009	Created By: SP	**Figure 1**

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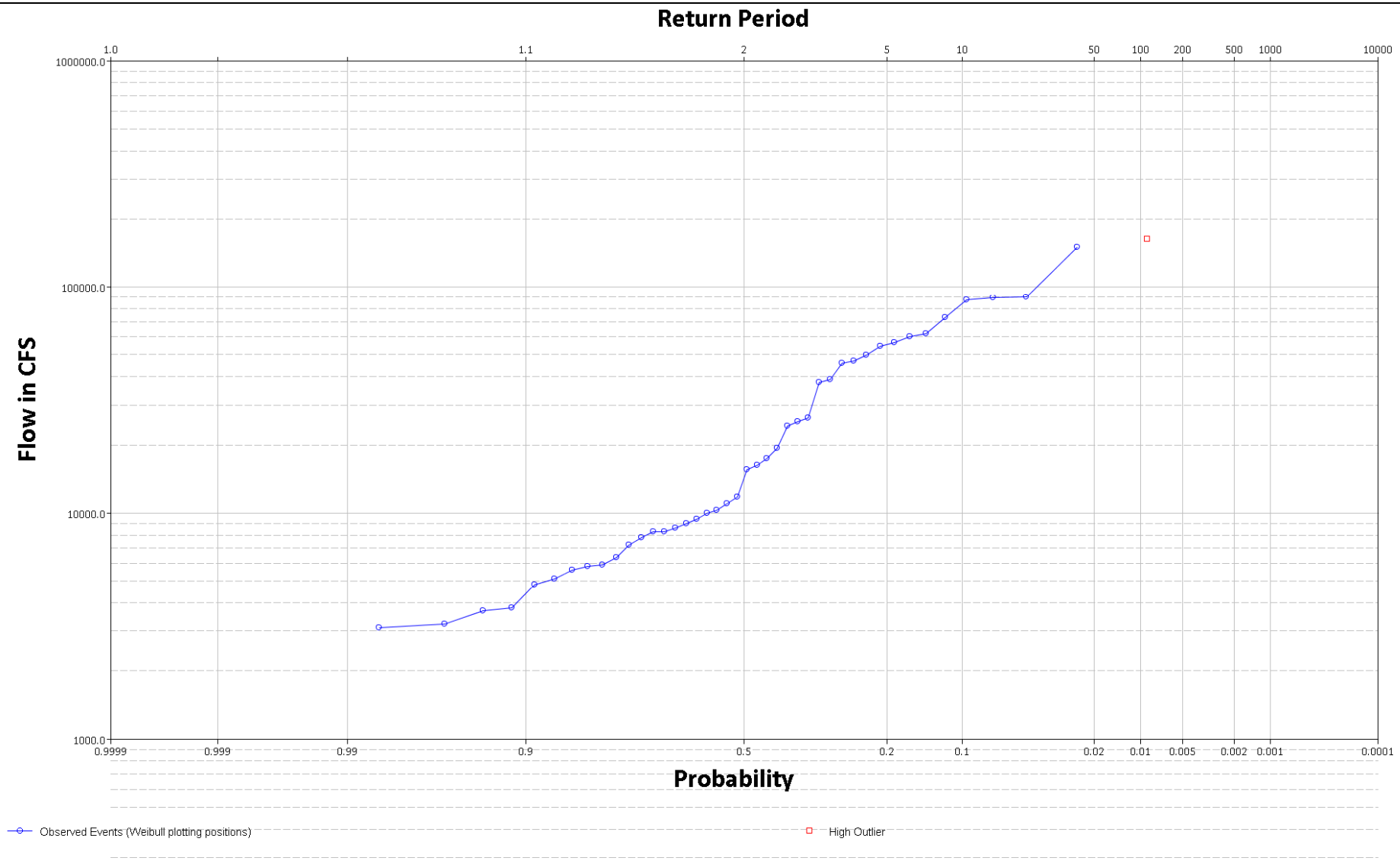

Notes:
High Outlier flows represent the historical maximum floods that are given a weight of 1.0 for determining the plotting positions.

Lower Feather River Corridor Management Plan

Feather River near Gridley flood frequency

Project No. 11-1009	Created By: SP	**Figure 2**

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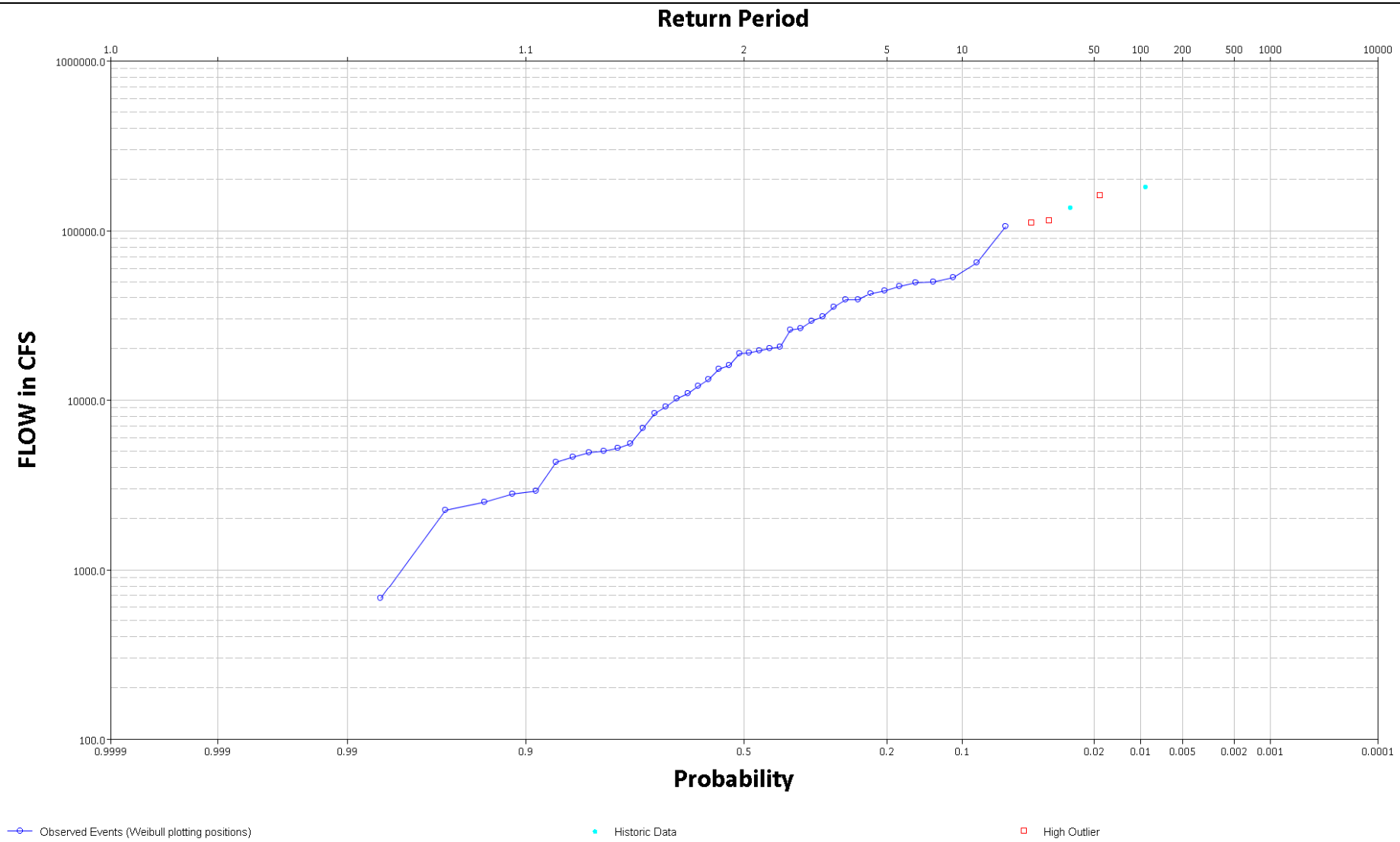

Notes:
High Outlier flows represent the historical maximum floods that are given a weight of 1.0 for determining the plotting positions.

Lower Feather River Corridor Management Plan

Yuba River near Marysville flood frequency

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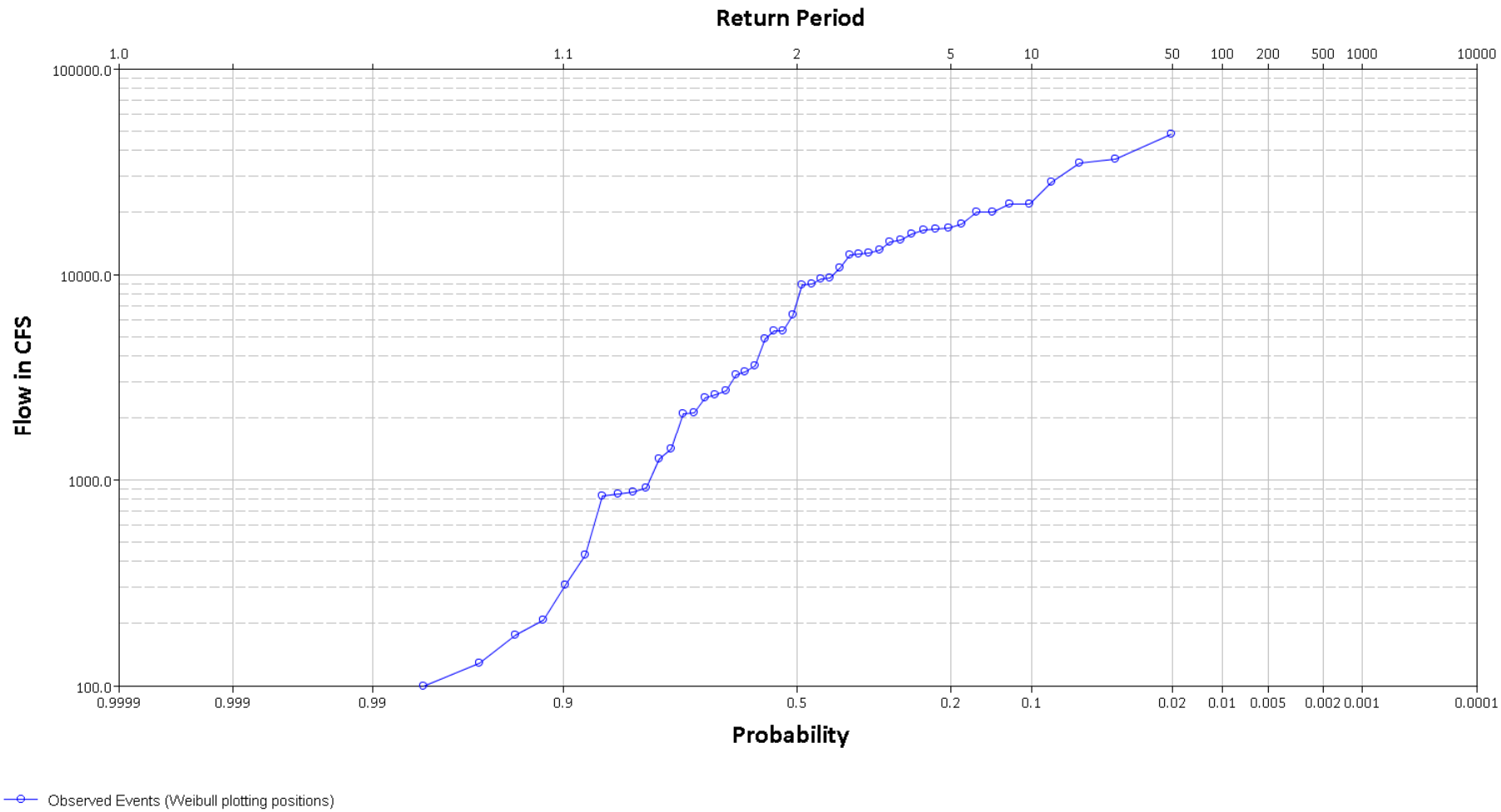

Notes:
High Outlier flows represent the historical maximum floods that are given a weight of 1.0 for determining the plotting positions.

Lower Feather River Corridor Management Plan

Bear River near Wheatland flood frequency

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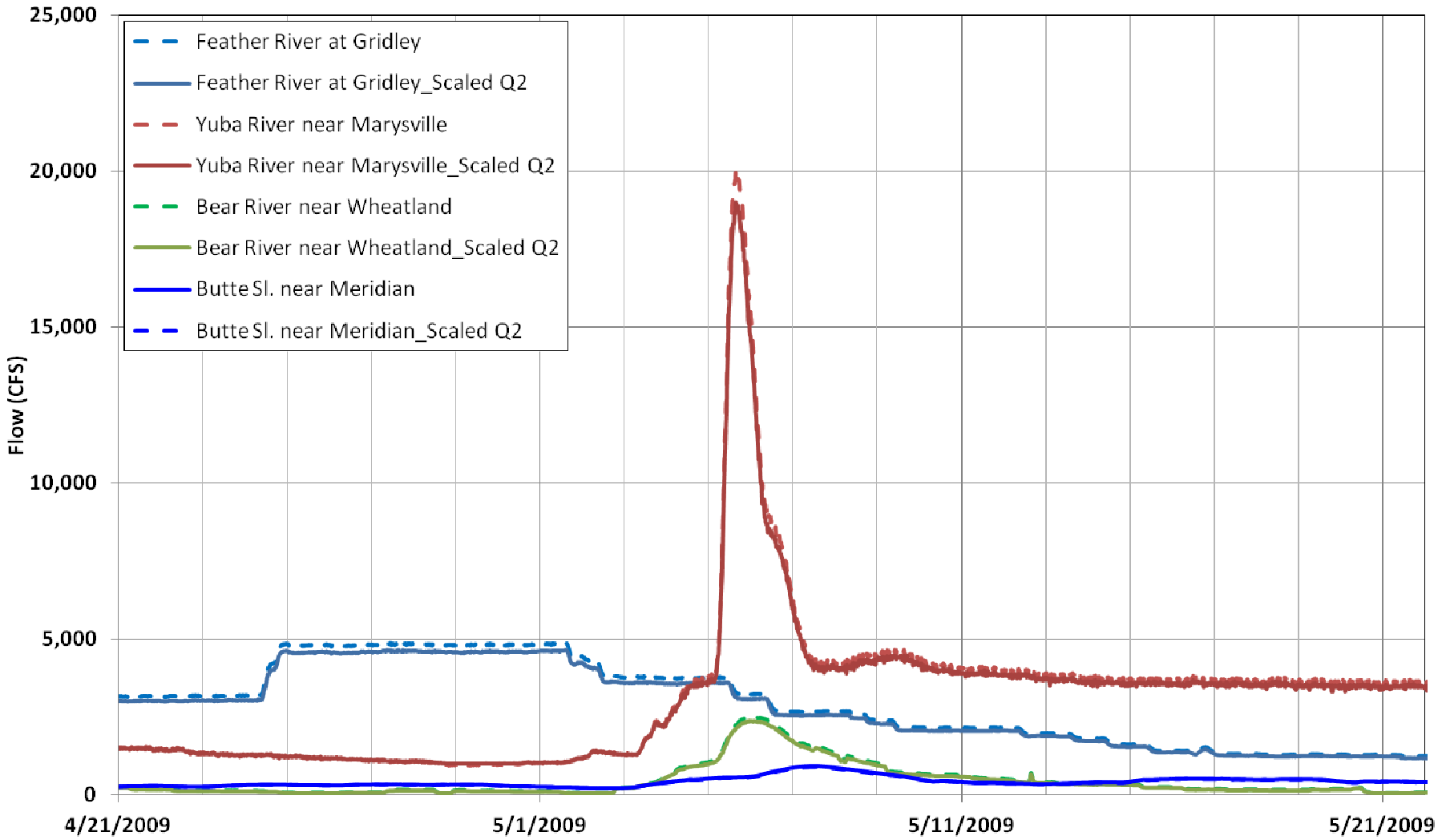

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Lower Feather River Corridor Management Plan

May 2009 and scaled 2-yr flood hydrographs

Project No. 11-1009	Created By: SP	**Figure 5**

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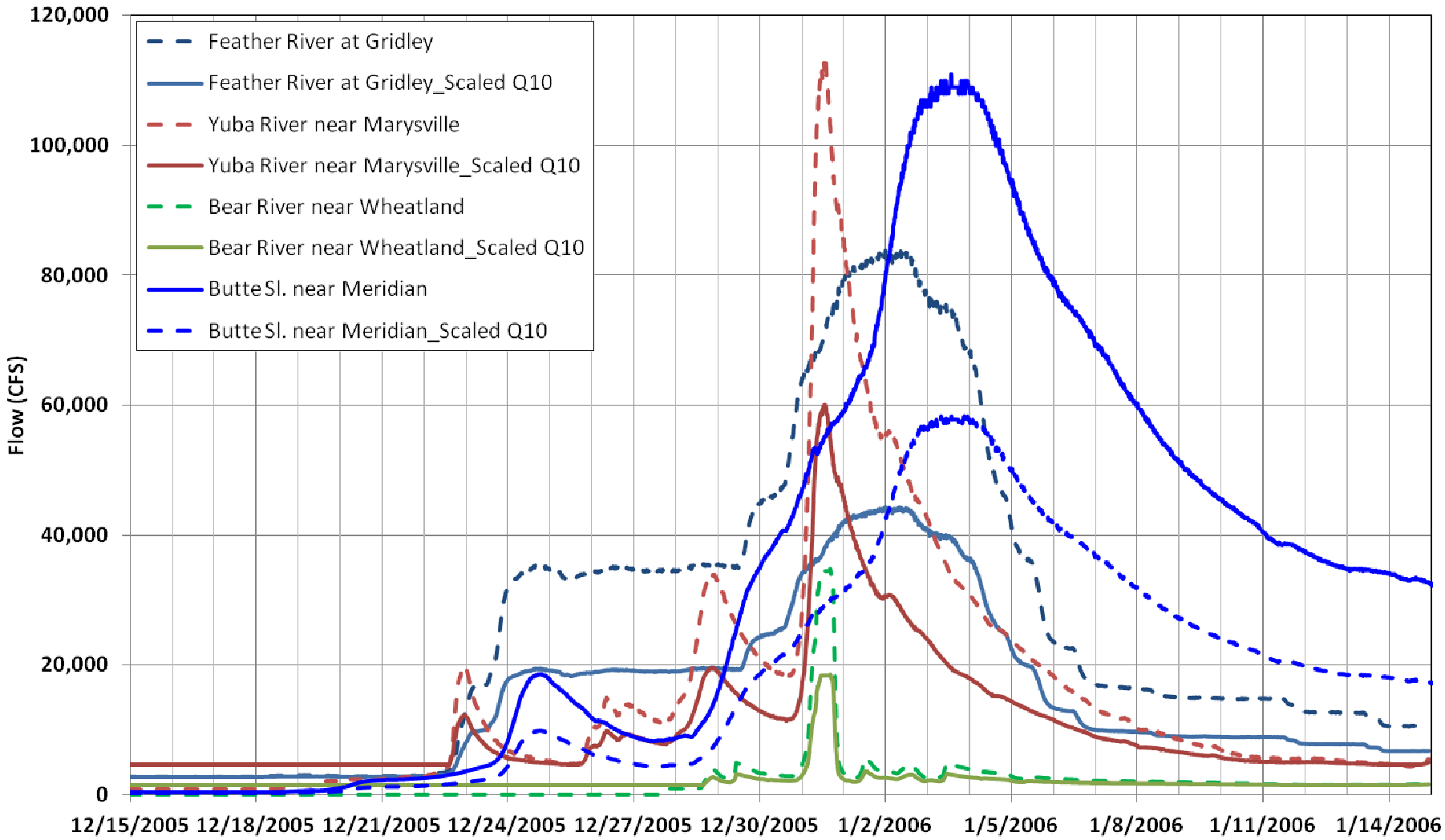

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Lower Feather River Corridor Management Plan

New Years Eve and scaled 10-yr flood hydrographs

Project No. 11-1009	Created By: SP	**Figure 5**

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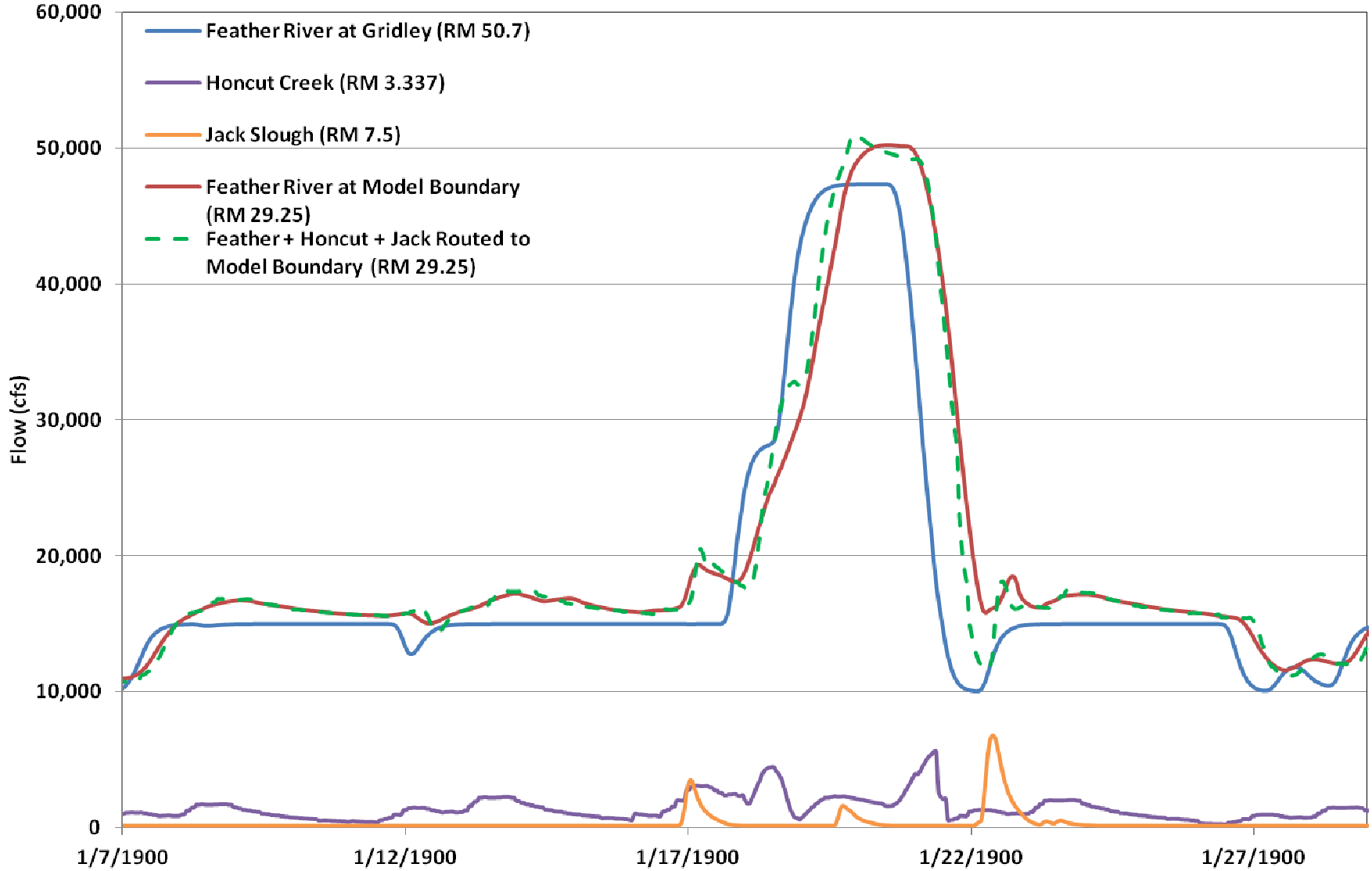

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Lower Feather River Corridor Management Plan

Synthetic routing validation - Feather River 2-yr

Project No. 11-1009	Created By: SP	**Figure 7**

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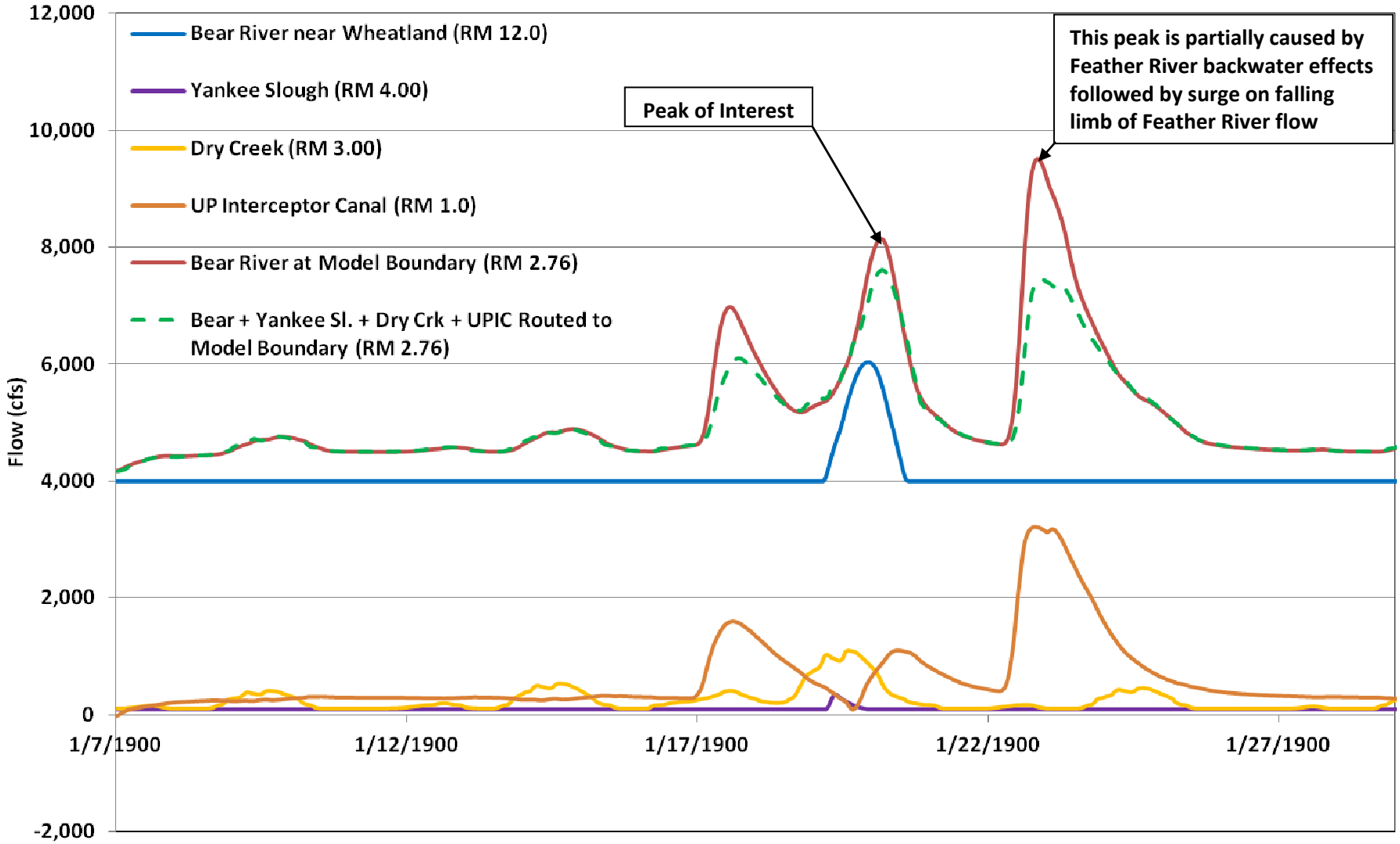


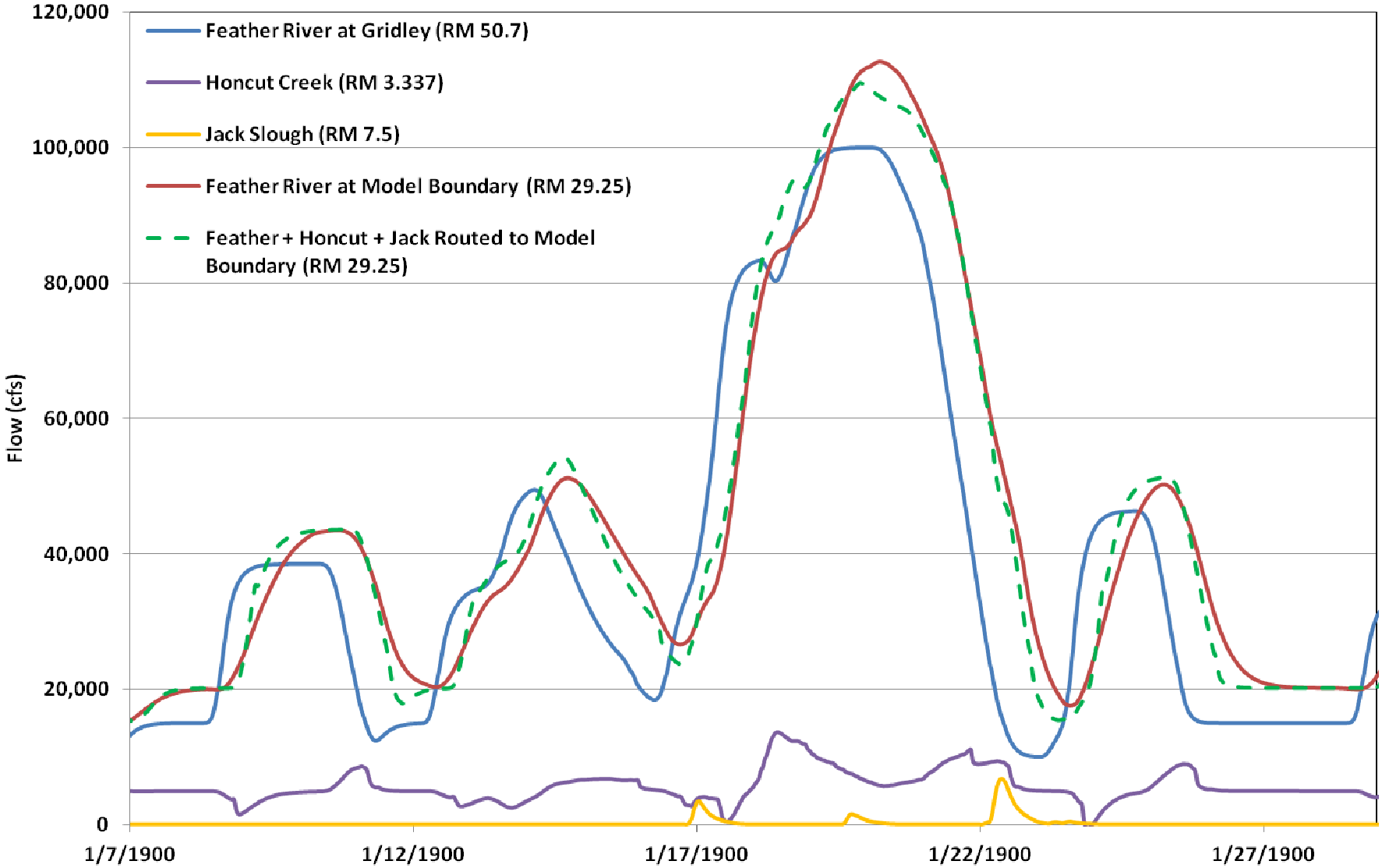
Notes:

Lower Feather River Corridor Management Plan

Synthetic routing validation - Bear River 2-yr

Project No. 11-1009	Created By: SP	**Figure 8**

R:\Projects\11-1009_Feather_R_CMP\Reporting\Flows\Figures\Fig_8.docx
10/16/2012



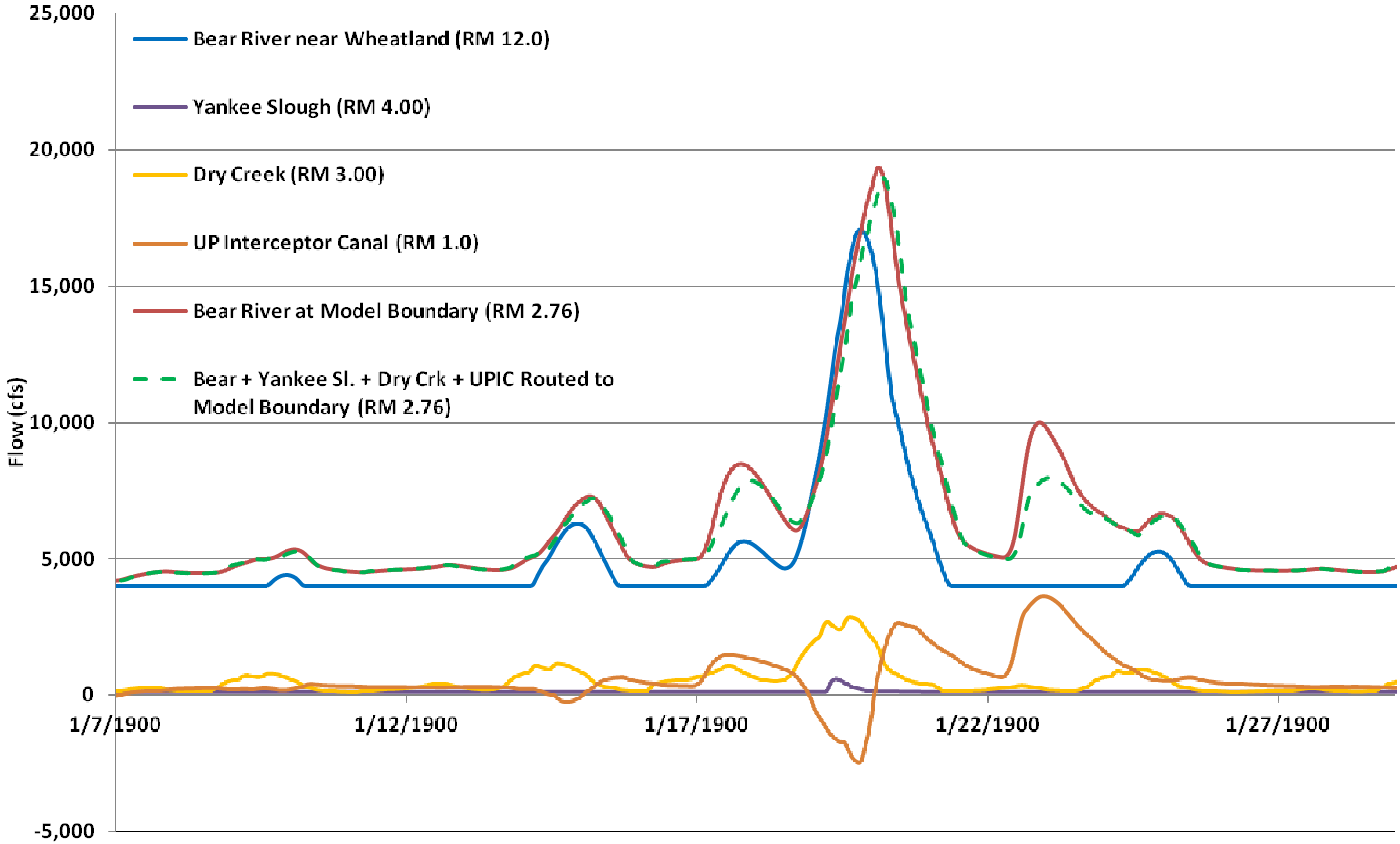
Notes:

Lower Feather River Corridor Management Plan

Synthetic routing validation - Feather River 10-yr

Project No. 11-1009	Created By: SP	**Figure 9**

R:\Projects\11-1009_Feather_R_CMP\Reporting\Flows\Figures\Fig_9.docx
10/16/2012



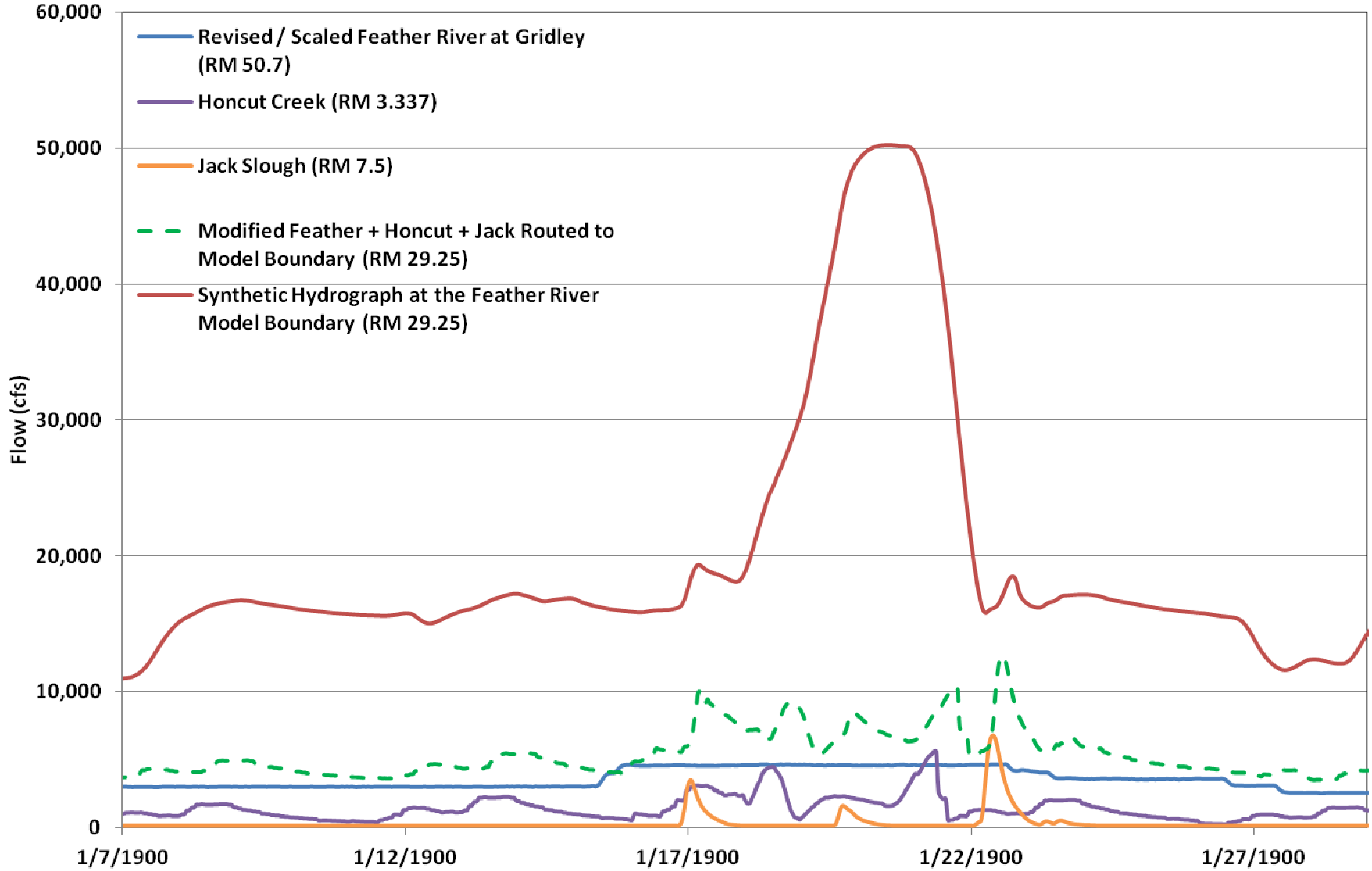
Notes:

Lower Feather River Corridor Management Plan

Synthetic routing validation – Bear River 10-yr

Project No. 11-1009	Created By: SP	**Figure 10**

R:\Projects\11-1009_Feather_R_CMP\Reporting\Flows\Figures\Fig_10.docx
10/16/2012



Notes:

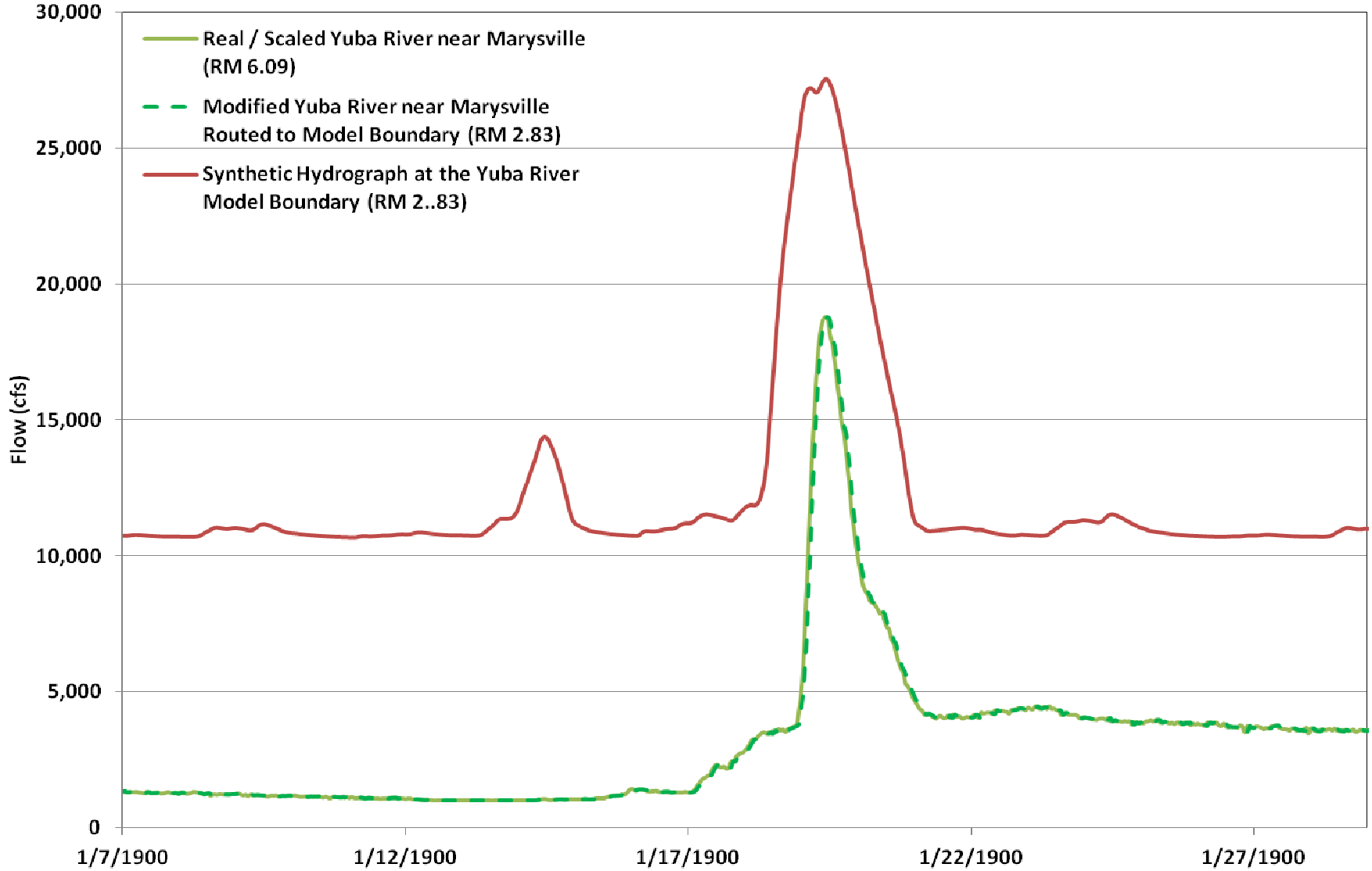
cbec eco engineering

Lower Feather River Corridor Management Plan

Modified boundary condition - Feather River 2-yr

Project No. 11-1009	Created By: SP	**Figure 11**

R:\Projects\11-1009_Feather_R_CMP\Reporting\Flows\Figures\Fig_11.docx
10/16/2012



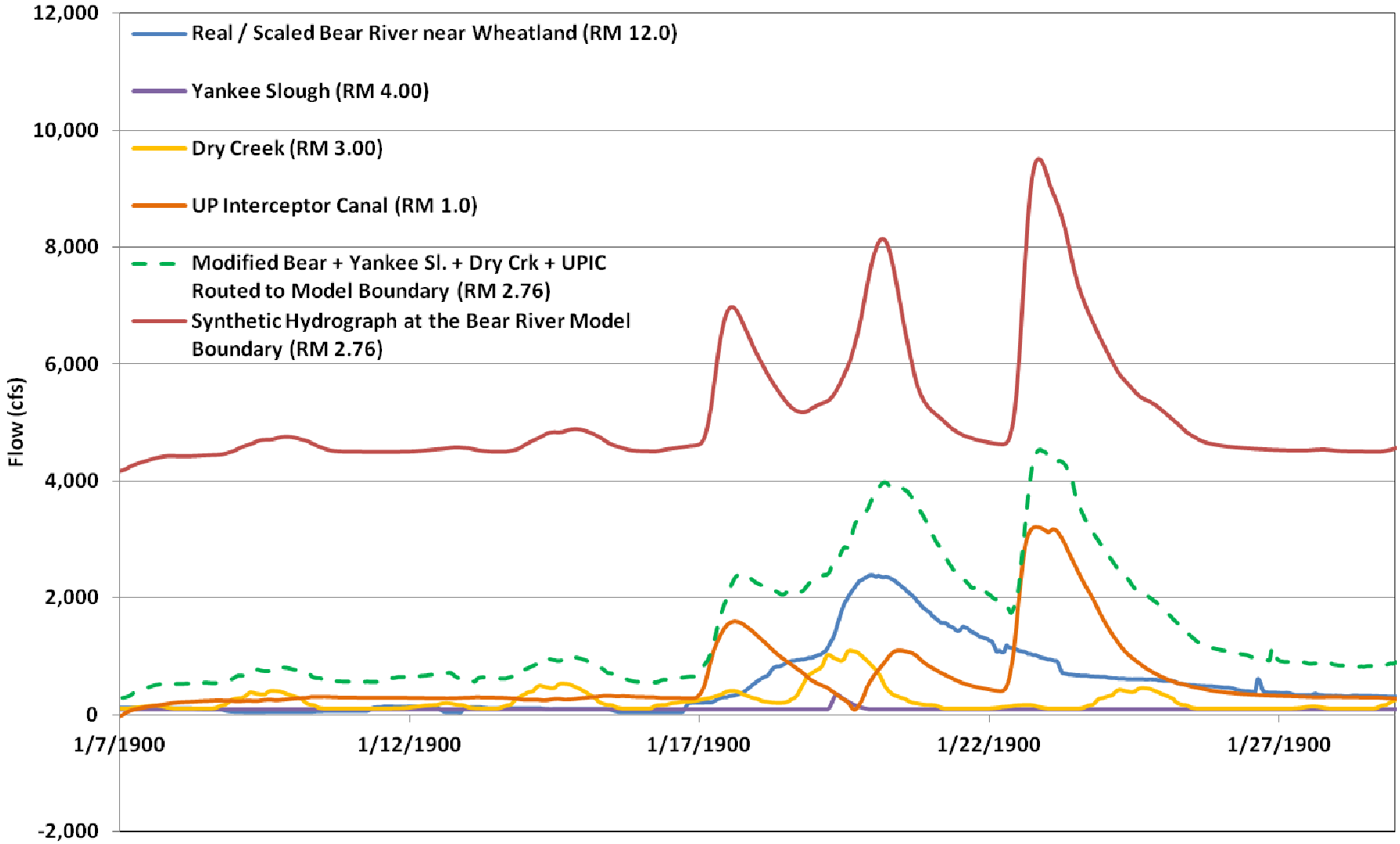
Notes:

Lower Feather River Corridor Management Plan

Modified boundary condition - Yuba River 2-yr

Project No. 11-1009	Created By: SP	**Figure 12**

R:\Projects\11-1009_Feather_R_CMP\Reporting\Flows\Figures\Fig_12.docx
10/16/2012



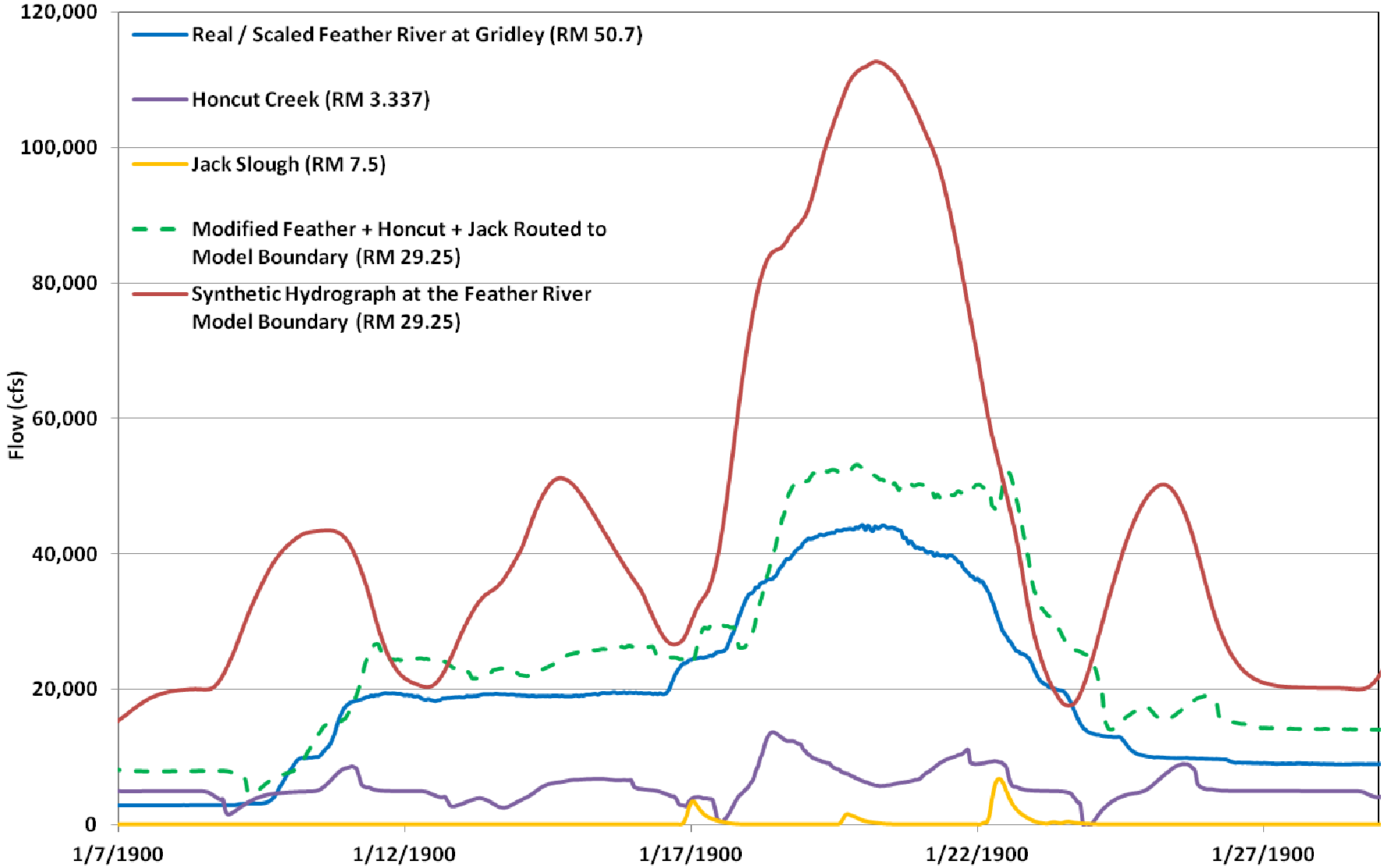
Notes:

Lower Feather River Corridor Management Plan

Modified boundary condition - Bear River 2-yr

Project No. 11-1009	Created By: SP	**Figure 13**

R:\Projects\11-1009_Feather_R_CMP\Reporting\Flows\Figures\Fig_13.docx
10/16/2012



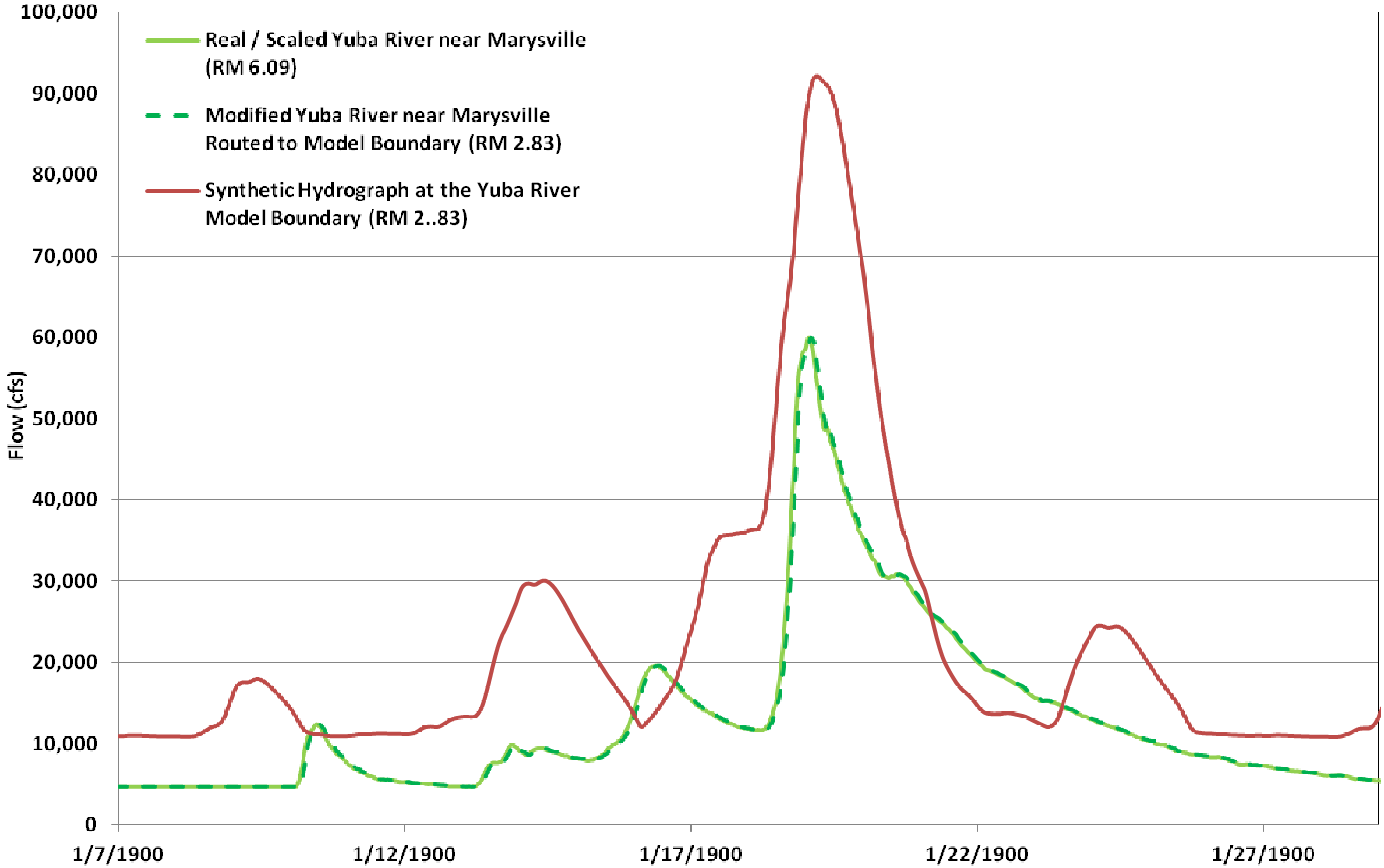
Notes:

Lower Feather River Corridor Management Plan

Modified boundary condition - Feather River 10-yr

Project No. 11-1009	Created By: SP	**Figure 14**

R:\Projects\11-1009_Feather_R_CMP\Reporting\Flows\Figures\Fig_14.docx
10/16/2012



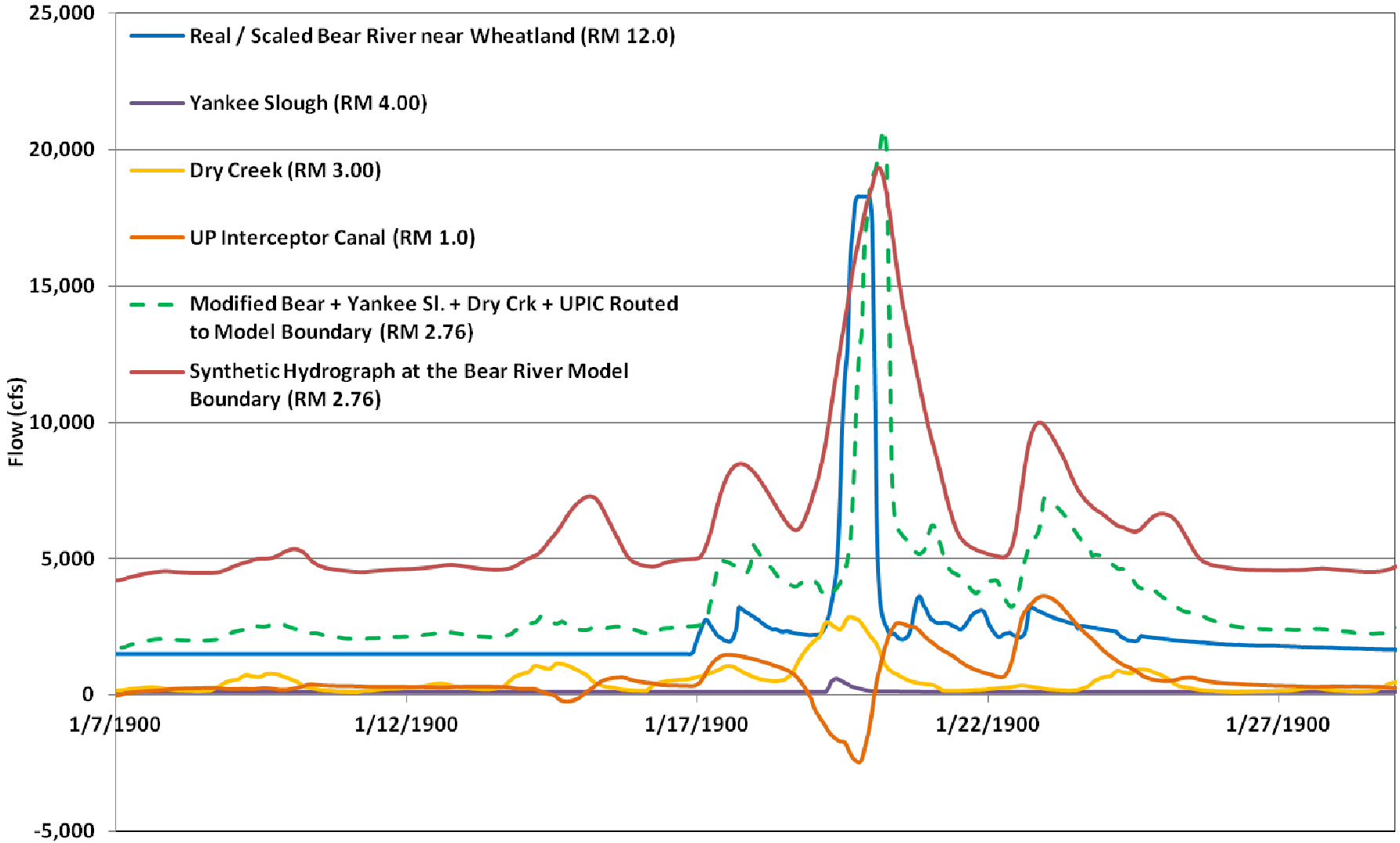
Notes:

Lower Feather River Corridor Management Plan

Modified boundary condition - Yuba River 10-yr

Project No. 11-1009	Created By: SP	**Figure 15**

R:\Projects\11-1009_Feather_R_CMP\Reporting\Flows\Figures\Fig_15.docx
10/16/2012



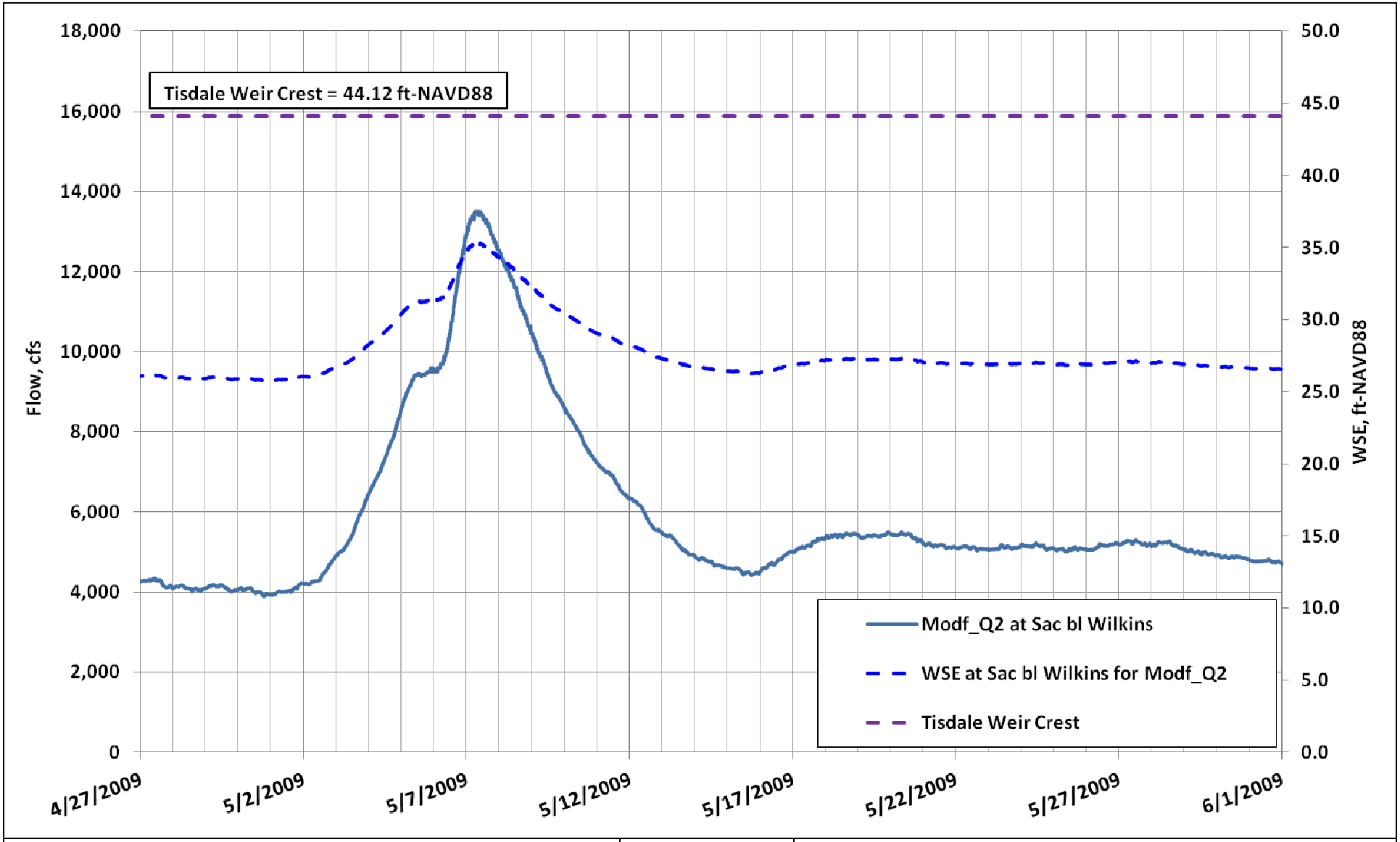
Notes:

Lower Feather River Corridor Management Plan

Modified boundary condition - Bear River 10-yr

Project No. 11-1009	Created By: SP	**Figure 16**

R:\Projects\11-1009_Feather_R_CMP\Reporting\Flows\Figures\Fig_16.docx
10/16/2012



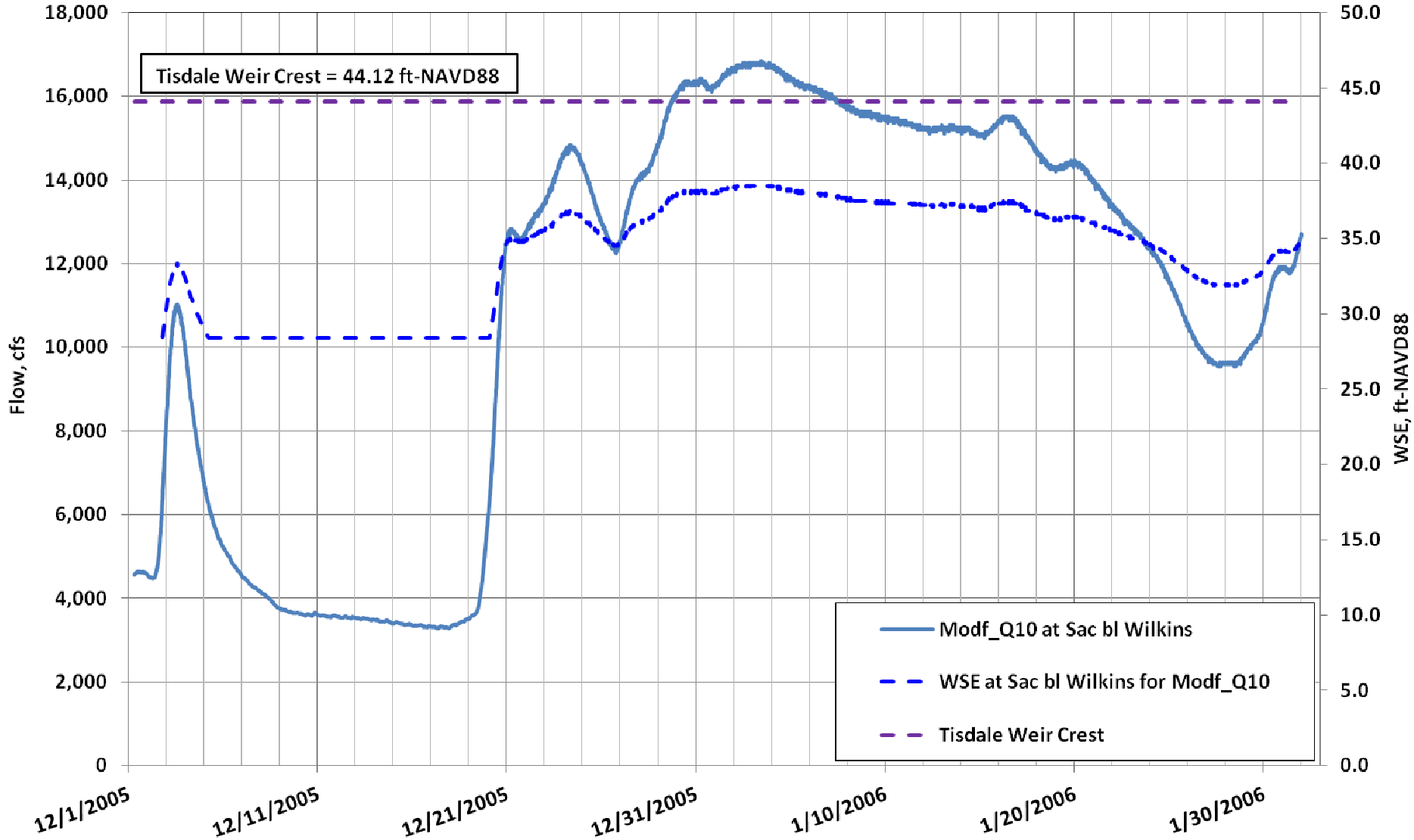
Notes:
May 2009 hydrograph was scaled using a factor of 0.95 consistent with the Yuba River near Marysville (MRY).

Lower Feather River Corridor Management Plan

Real/scaled flow & stage in Sacramento River 2-yr

Project No. 11-1009	Created By: SP	**Figure 17**

R:\Projects\11-1009_Feather_R_CMP\Reporting\Flows\Hydro_TM_Mar2013\Figures\Fig_17.docx
8/30/2013



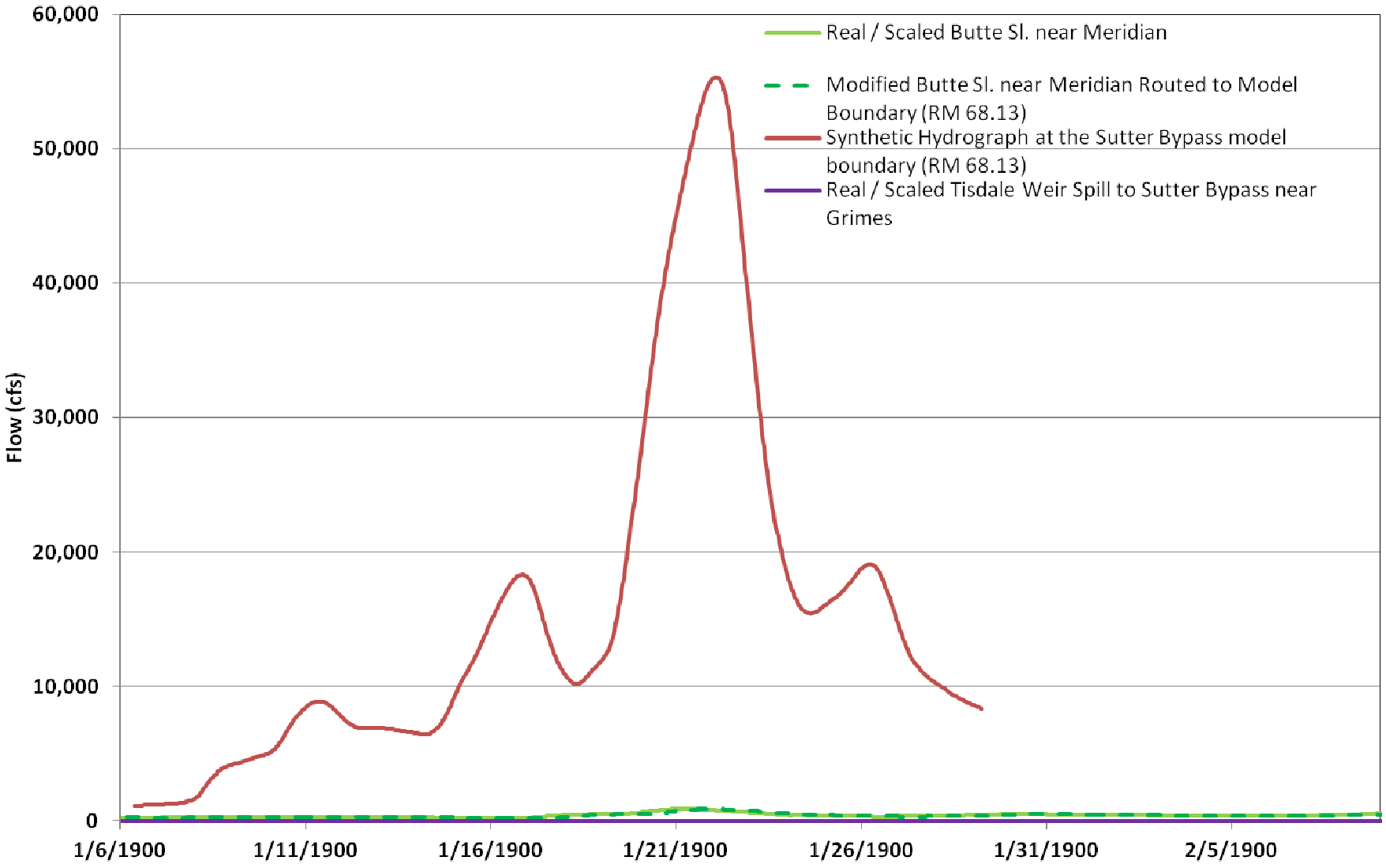
Notes:
NYE 2005 hydrograph was scaled using a factor of 0.53 consistent with the Yuba River near Marysville (MRY).

Lower Feather River Corridor Management Plan

Real/scaled flow & stage in Sacramento River 10-yr

Project No. 11-1009	Created By: SP	**Figure 18**

R:\Projects\11-1009_Feather_R_CMP\Reporting\Flows\Hydro_TM_Mar2013\Figures\Fig_18.docx
8/30/2013



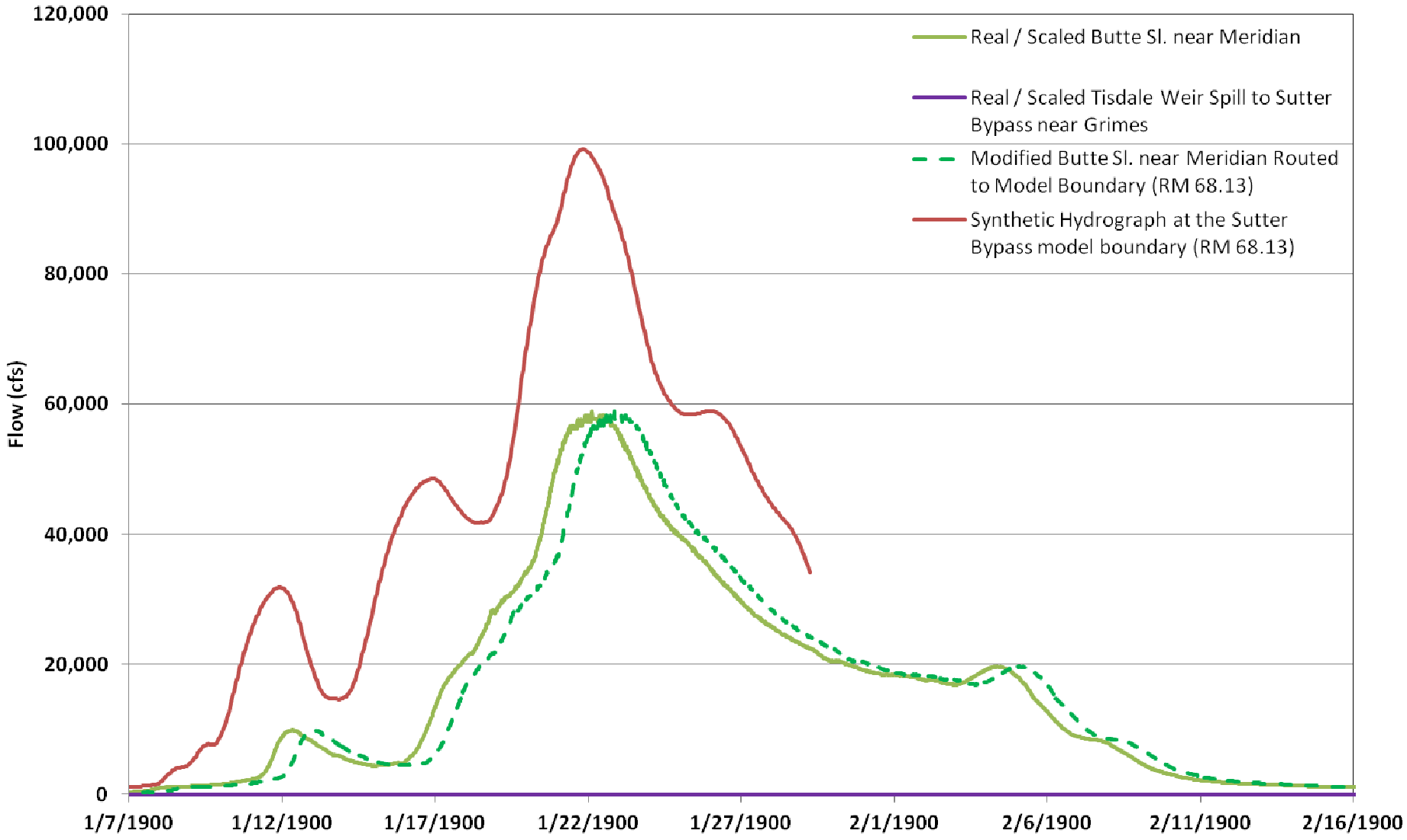
Notes:

Lower Feather River Corridor Management Plan

Modified boundary condition - Sutter Bypass 2-yr

Project No. 11-1009	Created By: SP	**Figure 19**

R:\Projects\11-1009_Feather_R_CMP\Reporting\Flows\Hydro_TM_Mar2013\Figures\Fig_19.docx
8/30/2013



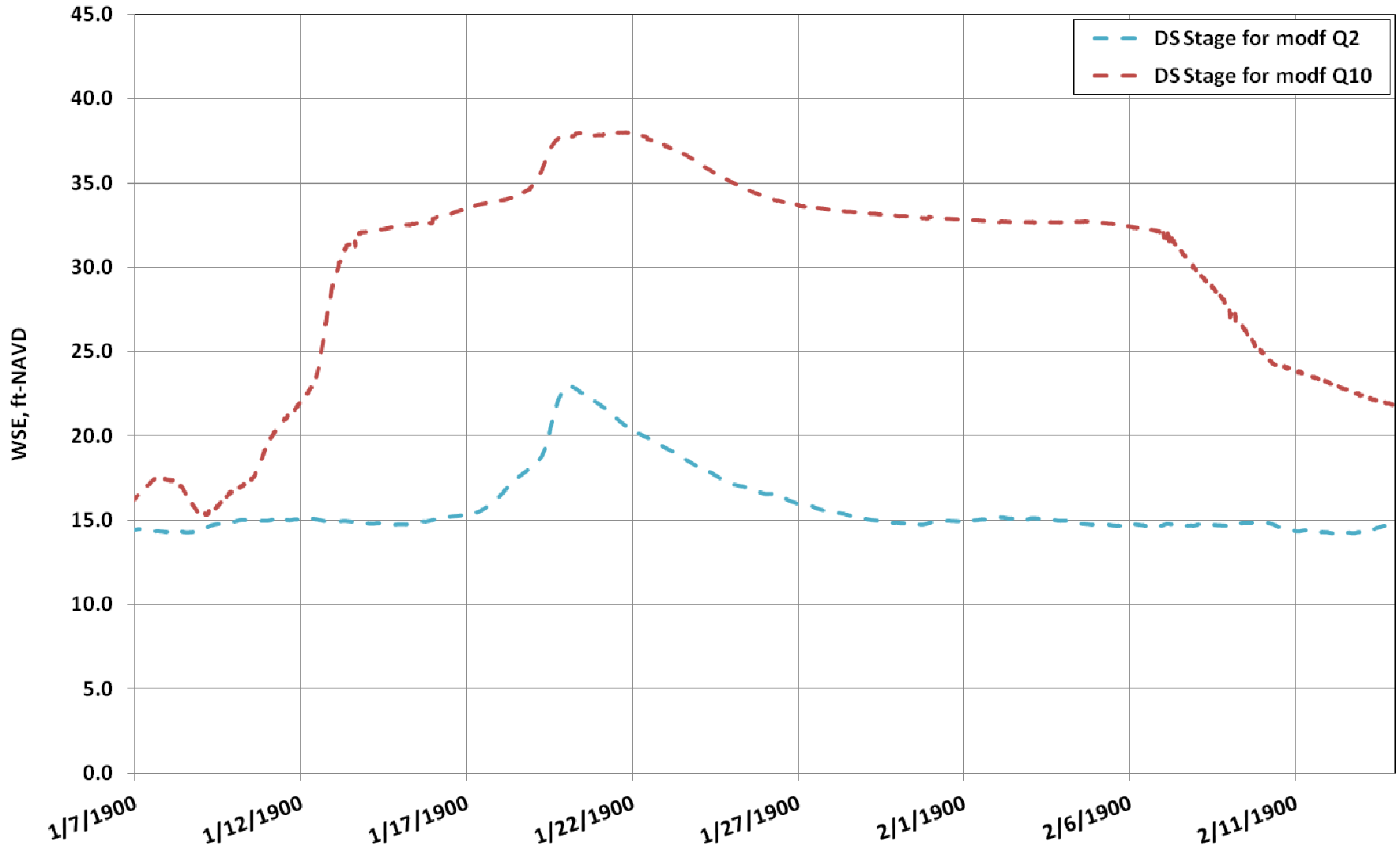
Notes:

Lower Feather River Corridor Management Plan

Modified boundary condition - Sutter Bypass 10-yr

Project No. 11-1009	Created By: SP	**Figure 20**

R:\Projects\11-1009_Feather_R_CMP\Reporting\Flows\Hydro_TM_Mar2013\Figures\Fig_20.docx
8/30/2013



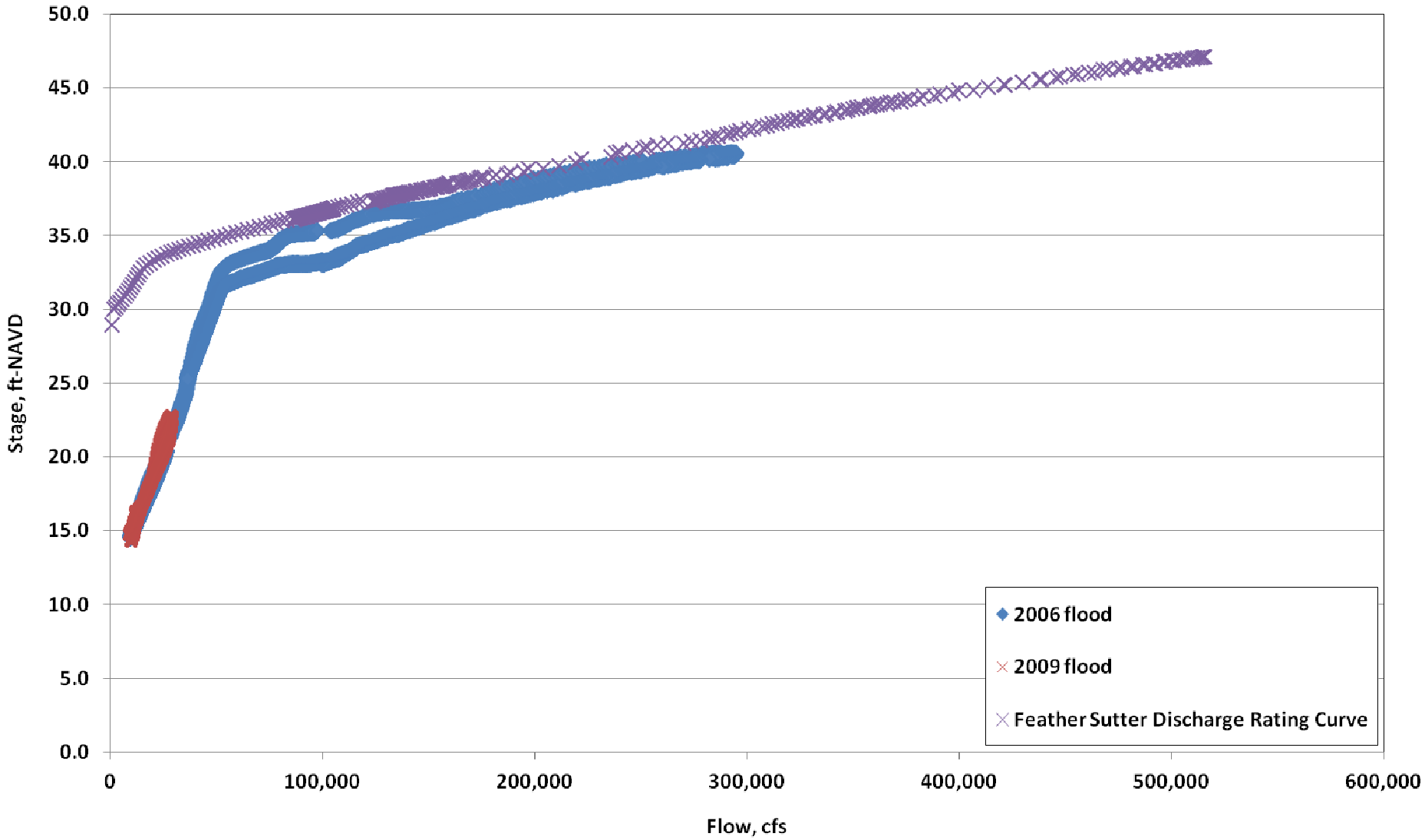
Notes:

Lower Feather River Corridor Management Plan

Modified downstream stage – 2- and 10-year

Project No. 11-1009	Created By: SP	**Figure 21**

R:\Projects\11-1009_Feather_R_CMP\Reporting\Flows\Hydro_TM_Mar2013\Figures\Fig_21.docx
8/30/2013



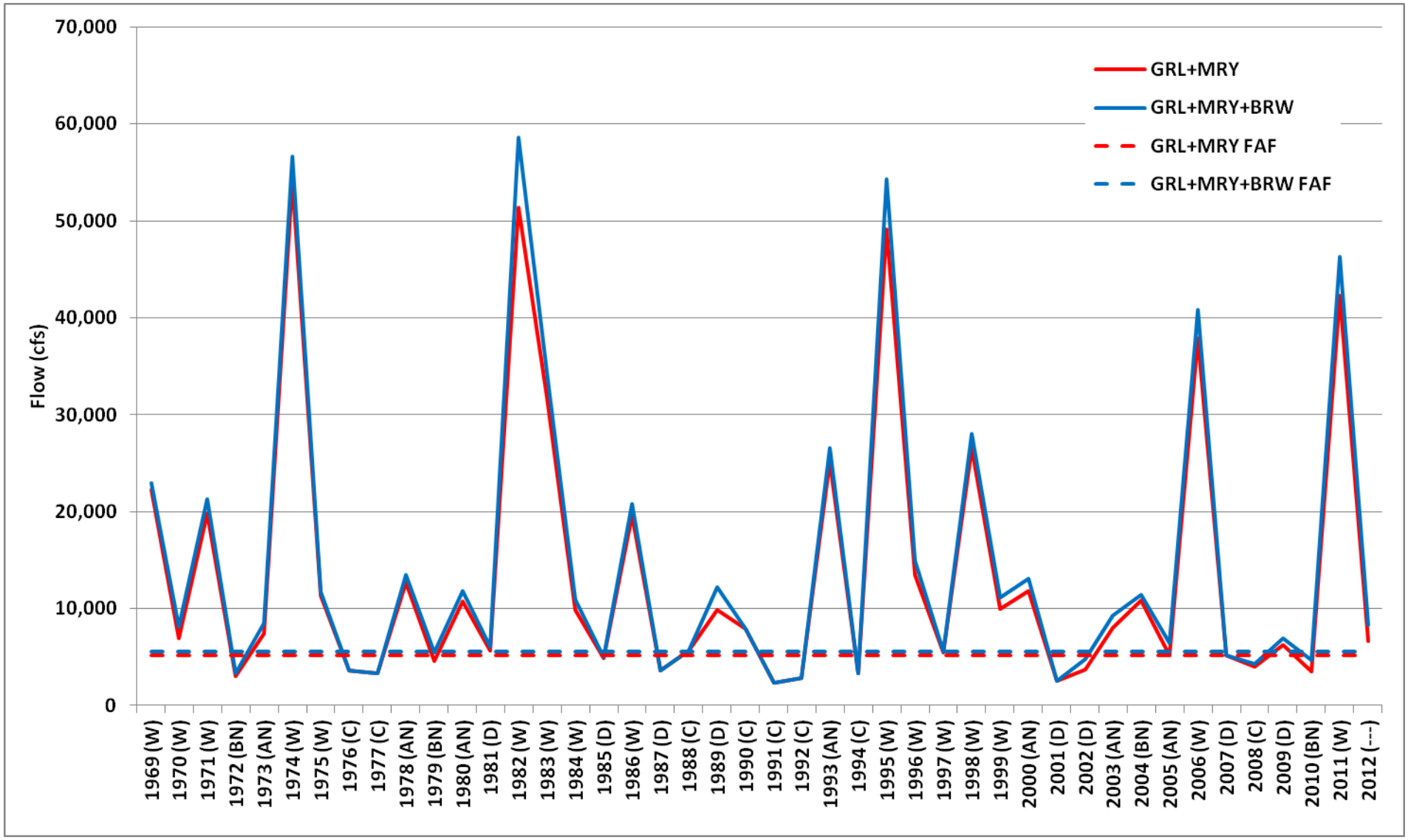
Notes:

Lower Feather River Corridor Management Plan

Comparison of discharge rating curves

Project No. 11-1009	Created By: SP	**Figure 22**

R:\Projects\11-1009_Feather_R_CMP\Reporting\Flows\Hydro_TM_Mar2013\Figures\Fig_22.docx
8/30/2013



Notes:

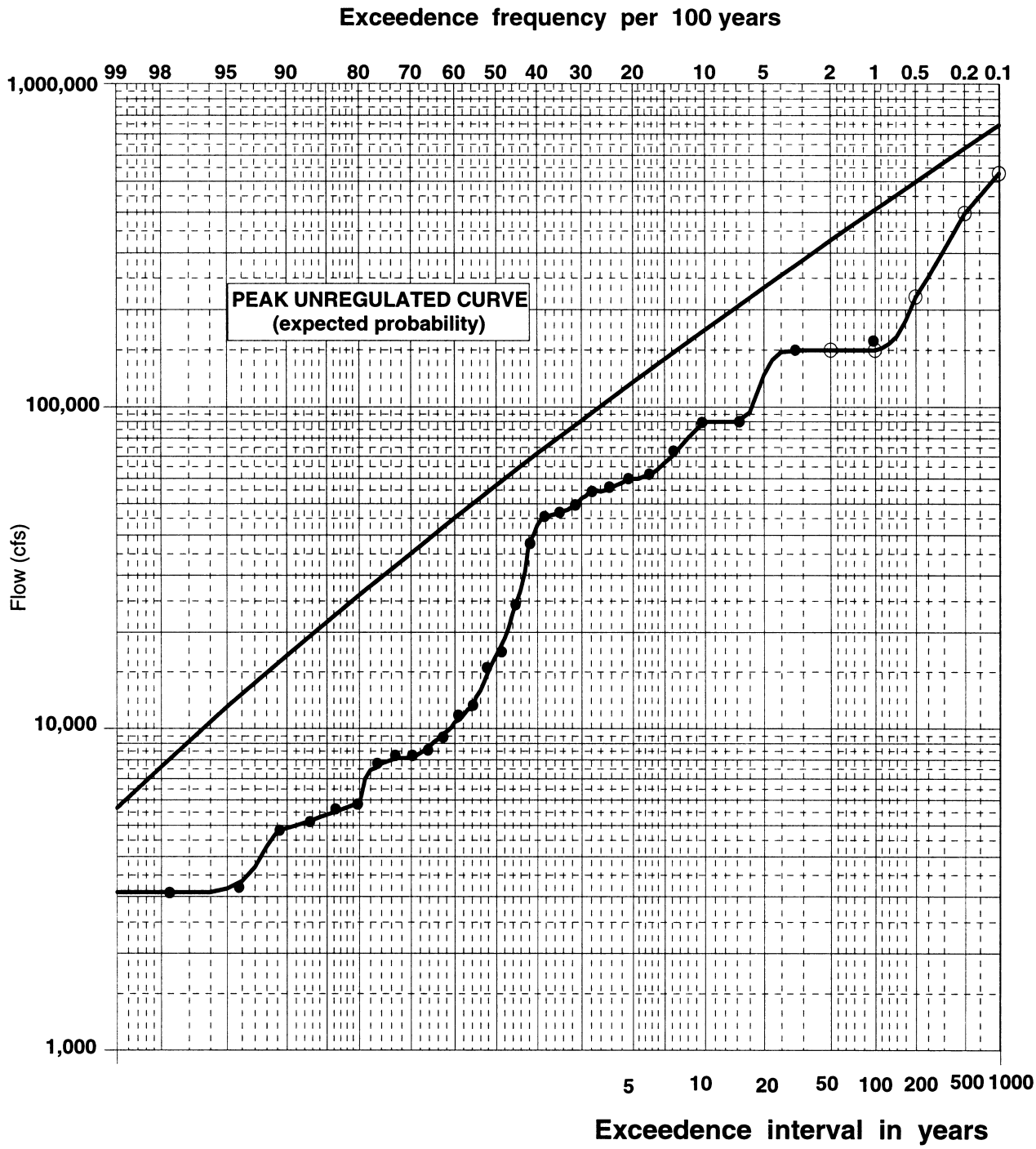
Lower Feather River Corridor Management Plan

Floodplain Activation Flood flows by water year

Project No. 11-1009	Created By: CRC	**Figure 23**

R:\Projects\11-1009_Feather_R_CMP\Reporting\Flows\Hydro_TM_Mar2013\Figures\Fig_23.docx
8/30/2013

APPENDIX A
PREVIOUS FLOOD FREQUENCY PLATES



NOTES:

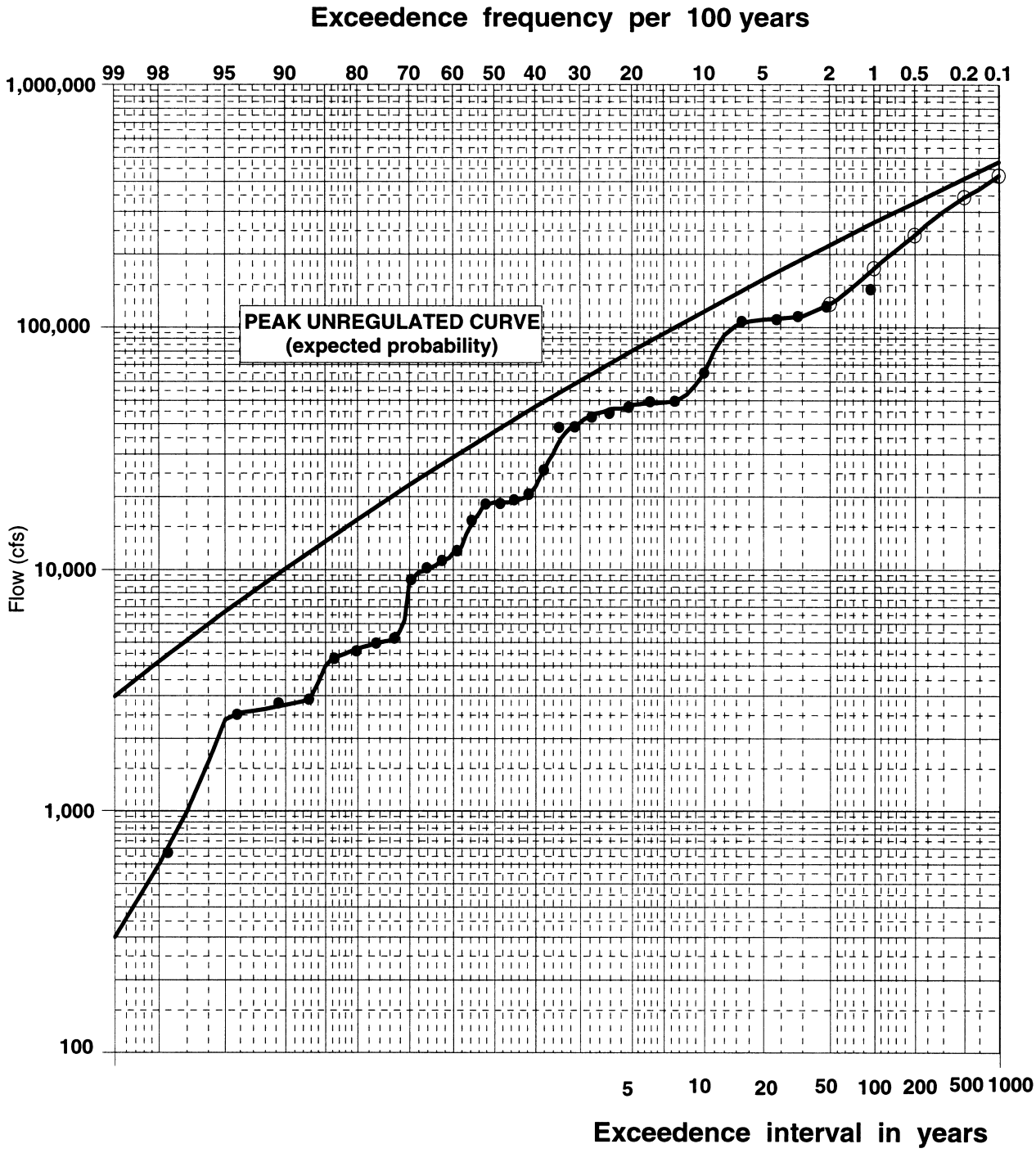
1. Weibull Plotting Positions
2. Drainage Area: 3624 sq. mi.
3. 29-year systematic record (1969 to 1997); 96-year historical period (1902-1997).
4. Historical maximum (1997).
5. Open circles represent hypothetical, and Solid circles represent historical events.

OROVILLE DAM AND LAKE
FEATHER RIVER, CALIFORNIA

PEAK RAIN FLOOD FREQUENCY CURVE
(REGULATED CONDITIONS)
EXPECTED PROBABILITY
FEATHER RIVER AT OROVILLE

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

DEVELOPED BY RM OCT 98



NOTES:

1. Weibull Plotting Positions
2. Drainage Area: 1339 sq. mi.
3. 29-year systematic record (1969 to 1997); 94-year historical period (1904-1997).
4. Estimates of historical events (1956,1965); historical maximums (1956, 1965, 1986, 1997).
5. Open circles represent hypothetical and Solid circles represent historical events.

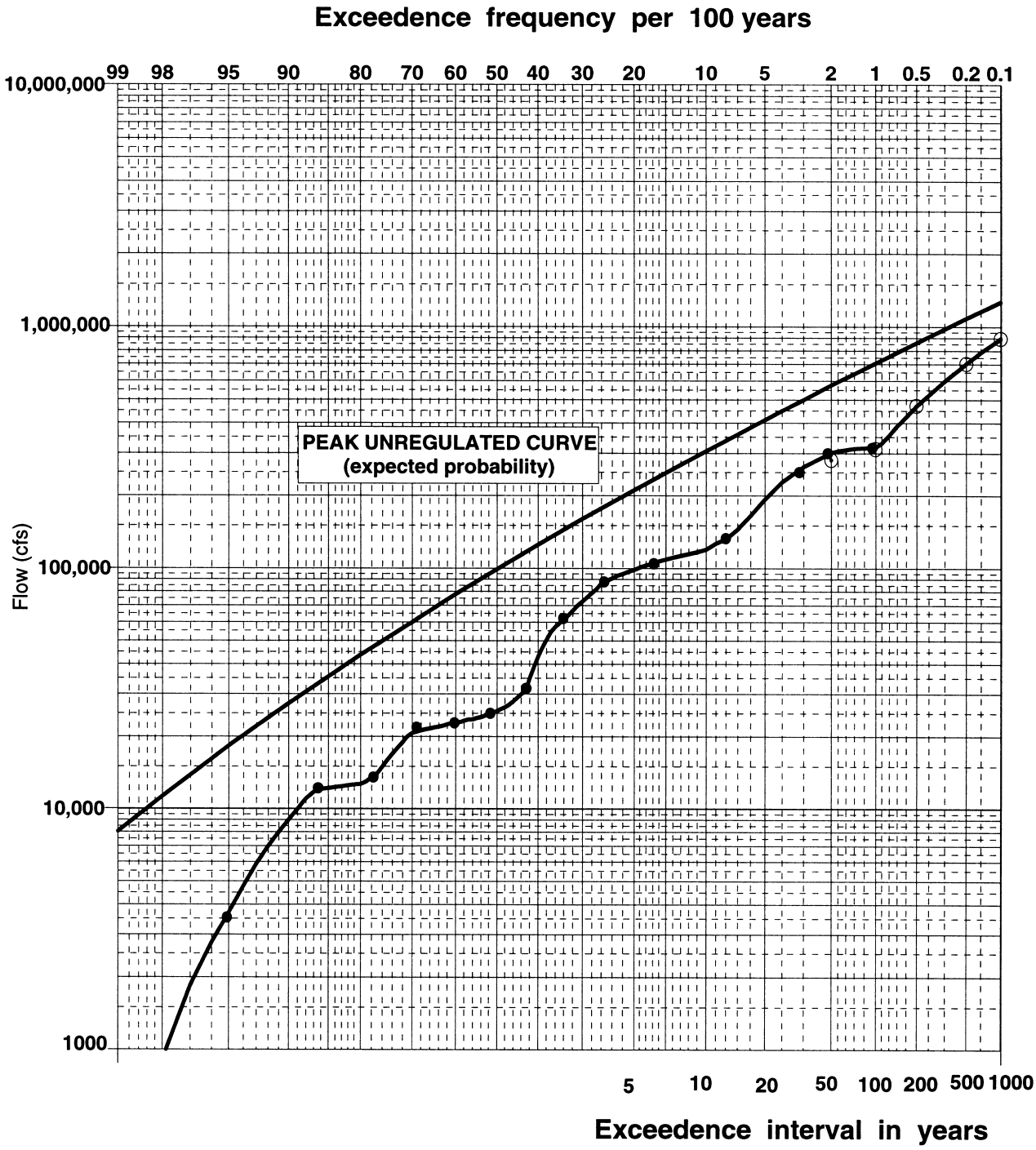
NEAR MARYSVILLE
YUBA RIVER, CALIFORNIA

PEAK RAIN FLOOD FREQUENCY CURVE (REGULATED CONDITIONS) EXPECTED PROBABILITY

YUBA RIVER NEAR MARYSVILLE

U.S. ARMY CORPS OF ENGINEERS
SACRAMENTO DISTRICT

DEVELOPED BY RM OCT 98



NOTES:

1. Weibull Plotting Positions
2. Drainage Area: 5313 sq. mi.
3. 11-year systematic record (1970 to 1980);
   94-year historical period (1904-1997).
4. Estimates of historical maximums (1965, 1986, 1997).
5. Open circles represent hypothetical and
   Solid circles represent historical events.

SHANGHAI BEND

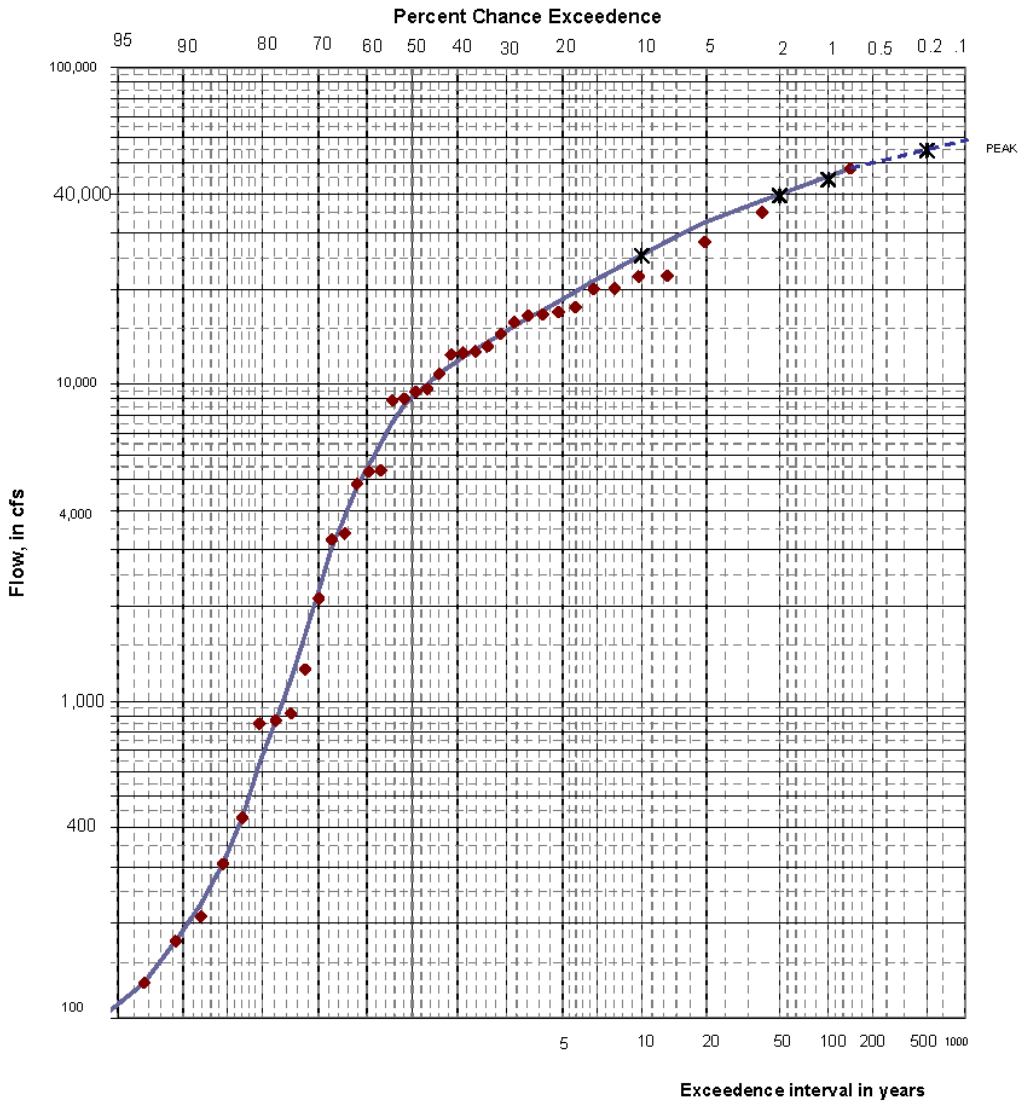
FEATHER RIVER, CALIFORNIA

PEAK RAIN FLOOD FREQUENCY CURVE
(REGULATED CONDITIONS)
EXPECTED PROBABILITY
FEATHER RIVER AT SHANGHAI BEND

U.S. ARMY CORPS OF ENGINEERS

SACRAMENTO DISTRICT

DEVELOPED BY RM **OCT 98**



X - Hypothetical values

NOTES:

1. Drainage Area: 292 sq mi
2. Period of record: WY 1964-2001
3. Plotting positions based on historical record of 97 years
   1986 flood is largest in 97 years based on 1-day values

Prepared by: BJA
Aug 2003

LOWER FEATHER RIVER FLOODPLAIN STUDY SACRAMENTO RIVER BASIN, CALIFORNIA
REGULATED CONDITIONS RAIN FLOOD FREQUENCY CURVE BEAR RIVER NR WHEATLAND
U.S ARMY CORPS OF ENGINEERS SACRAMENTO DISTRICT

Figure 8