Attachment A

Initial Lower San Joaquin River Flow Compliance Measures

Overview

On December 12, 2018, the State Water Resources Control Board (State Water Board) adopted flow objectives for the Lower San Joaquin River (LSJR) and its three salmon bearing tributaries for the reasonable protection of fish and wildlife beneficial uses in amendments to the Water Quality Control Plan for the San Francisco Bay/Sacramento-San Joaquin Delta Estuary (Bay-Delta Plan). The Bay-Delta Plan requires development of compliance measures for the unimpaired flow requirements within 180 days from the date of approval by the Office of Administrative Law (OAL). OAL approved the amendments on February 25, 2019. This document describes initial measures to monitor and evaluate compliance with the LSJR flow objectives, which may be refined over time.

The State Water Board has not yet assigned responsibility for implementing the LSJR flow objectives. The initial compliance methods described in this document serve as a starting point for identifying the compliance methods that may be required in a future water quality or water right proceeding to implement the Bay-Delta Plan. The initial compliance methods discussed in this document (that are not already included in the Bay-Delta Plan) are not in effect. Any proceeding to require additional compliance methods will provide an opportunity for public review and comment.

The compliance methods discussed in this document focus on the unimpaired flow requirement and do not address compliance methods or issues associated with allowable adaptive implementation methods identified in the Bay-Delta Plan that will be developed at a later time (due 12 months after OAL's approval). This document also does not address compliance methods or issues associated with potential voluntary agreements (VAs). As part of a VA, parties may propose specific compliance methods for consideration by the State Water Board. Efforts are currently underway to develop a VA including a package of proposed flow and non-flow restoration actions. At this time, the VA is still under development and the State Water Board has not made any decisions relative to the VA.

In addition to a narrative objective, the Bay-Delta Plan requires 40 percent of the unimpaired flow to be maintained from February through June in the Stanislaus, Tuolumne, and Merced Rivers, within an adaptive range of 30 to 50 percent of the unimpaired flow. During this same time period, the flows at Vernalis on the San Joaquin River, as provided by the unimpaired flow objective, are required to be no

lower than a base flow of 1,000 cubic feet per second (cfs), with an adaptive range between 800 and 1,200 cfs, inclusive.

As stated in the *Unimpaired Flow Compliance* Section of the Bay-Delta Plan, the State Water Board recognizes that information and specific measures are needed to achieve the LSJR flow objectives and to monitor and evaluate compliance:

> Implementation of the unimpaired flow requirement for February through June will require the development of information and specific measures to achieve the flow objectives and to monitor and evaluate compliance. The STM [Stanislaus, Tuolumne, and Merced] Working Group, or State Water Board staff as necessary, will, in consultation with the Delta Science Program, develop and recommend such proposed measures. The State Water Board or Executive Director will consider approving the measures within 180 days from the date of OAL's approval of this amendment to the Bay-Delta Plan. The approved measures will inform State Water Board water right proceedings, FERC licensing proceedings, or other implementation actions to achieve the February through June flows. As information and methods improve, specific measures to achieve the flow objectives and to monitor and evaluate compliance may be modified and submitted for approval.

The State Water Board has already developed, and included in the Bay-Delta Plan, the principal unimpaired flow compliance measure of how and where to determine compliance. The Bay-Delta Plan includes methods to estimate unimpaired flows and identifies locations where flows are measured. As part of the Bay-Delta Plan adoption process, in September 2016, the State Water Board released proposed plan amendment language and a Recirculated Draft Substitute Environmental Document (Draft SED), which analyzed the environmental and other effects of the proposed amendments and alternatives. The 2016 proposed amendments did not include an equation for calculating unimpaired flow or compliance locations and gages in the flow objectives. During the comment period on the proposed amendments and Draft SED, commenters requested that an equation for calculating unimpaired flow be added to the objective. In response, the State Water Board amended Footnote 14 of Table 3, *Water Quality Objectives for Fish and Wildlife Beneficial Uses,* in the proposed amendments to include a method for calculating compliance, including gaging stations where flows would be measured to evaluate compliance and a method for estimating unimpaired flows. The State Water Board then provided another comment period for commenters to address any revisions to the amendments and responded to those comments in writing.

Although Footnote 14 provides the methodology to estimate unimpaired flow and identify where and how flows are measured to evaluate compliance, there are several issues that will need to be further addressed for implementation purposes. This document discusses approaches that may be used to address these issues as the compliance methods are refined for implementation purposes.

Unimpaired Flow

The LSJR flow objectives are expressed as a percent of unimpaired flow. As defined in the Bay-Delta Plan, unimpaired flow is the natural water production of a river basin, unaltered by upstream diversions, storage, or by export or import of water to or from other watersheds. Unimpaired flow is therefore a direct way to establish a variable quantity of water that is allocated to fish and wildlife protection, because it represents a portion of the variable total water production in a river. This is a different way to express flow requirements than was previously used in the 2006 Bay-Delta Plan.

The unimpaired flow approach is used in the Bay-Delta Plan because it reflects the frequency, timing, magnitude, and duration of the natural flows to which fish and wildlife have adapted and have become dependent upon. A flow objective based on unimpaired flows is intended to provide for a portion of the flow to a watershed to remain in the stream for the fish and wildlife. Because this approach differs from prior approaches, new compliance approaches are needed.

Implementation of the LSJR flow objectives requires two primary types of data: 1) daily unimpaired flow at the dams of the three major reservoirs on each of the three tributaries (rim dams); and 2) daily stream flow at the three tributary compliance locations and at Vernalis (Figure 1).

Unimpaired flow is the runoff that would have occurred had water remained in rivers and streams instead of being stored in reservoirs, imported, exported, or diverted. Unimpaired flows are calculated assuming that the river channels of the valley are in their present configuration, and that extant alterations such as channel improvements, levees, flood bypasses, and channels disconnected from the floodplains are in place. Unimpaired flows do not actually represent the flows that would have occurred in a pre-historical or un-modified state.

The percent of unimpaired flow requirement is based on the daily unimpaired flow, also referred to as full natural flow (FNF), that is estimated at the rim dams associated with each reservoir on each of the three LSJR tributaries, as shown in Figure 1. Following are the names and associated three-letter California Department of Water Resources (DWR) gage codes for these three locations, which are collectively referred to as the three FNF stations:

- Stanislaus at Goodwin (DWR Gage GDW)
- Tuolumne at Don Pedro (DWR Gage TLG)
- Merced at McClure (DWR Gage MRC)

DWR currently posts calculated daily unimpaired flows for these and several other major rivers on its California Data Exchange Center website (CDEC). Per the

DWR website, the FNF estimate posted on CDEC is the same thing as unimpaired flow:

> "Full Natural Flow" or "Unimpaired Runoff" represents the natural water production of a river basin, unaltered by upstream diversions, storage, or by export or import of water to or from other watersheds. Gauged flows at the given measurement points are increased or decreased to account for these upstream operations. The flows reported here are based on calculations done by project operators on the respective rivers, the US Army Corps of Engineers and/or Snow Surveys.
>
> Daily Full Natural Flow (FNF) calculations are based on less data than is available at the completion of each month. The sum of daily FNF reported here will not exactly match the calculated monthly FNF reported on the seasonal and water year reports. Due to the lag between the effect of upstream operations and downstream flow measurements, calculated daily FNF will fluctuate from day to day.

Compliance Locations

Compliance with the LSJR flow objective is determined at the following three gages near the confluence of each of the LSJR tributaries (as shown in Figure 1):

- Stanislaus River at Koetitz (DWR Gage KOT)
- Tuolumne River at Modesto (U.S. Geological Survey [USGS] Gage 11290000, also referred to as DWR Gage MOD)
- Merced River near Stevenson (DWR Gage MST)

The mainstem minimum flow requirement for the LSJR is determined at Vernalis (DWR Gage VNS).

Real time daily stream flow data for the above three gages on the three tributaries is available on CDEC. These stations are currently the farthest downstream gage on each of the three tributaries. The Bay-Delta Plan allows the Executive Director to approve changes to the compliance locations (and associated gage station numbers) set forth in Table 3 of the Bay-Delta Plan if information shows that another location more accurately represent the flows of the LSJR tributary at its confluence with the LSJR.

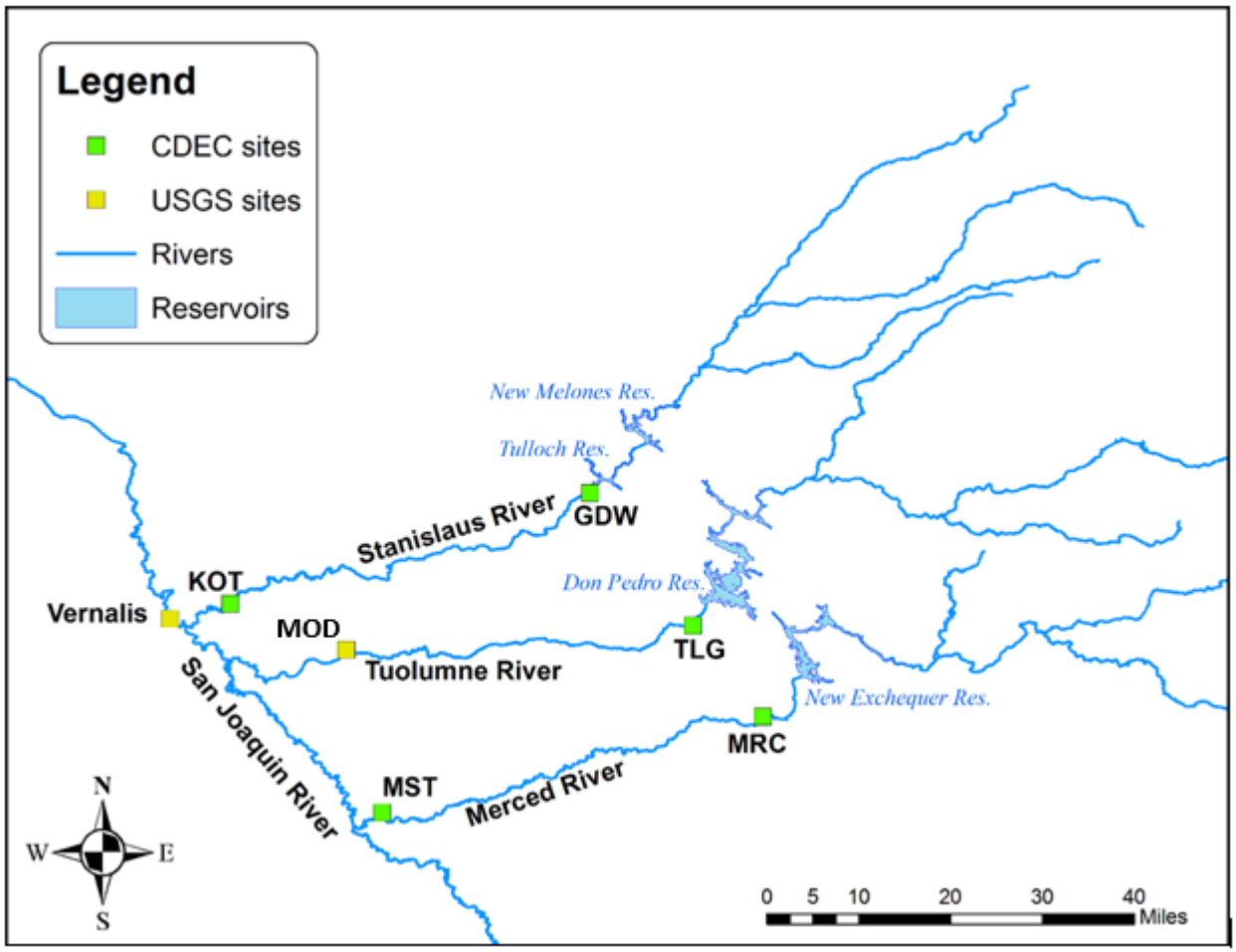

Figure 1. Full Natural Flow Gages and Unimpaired Flow Compliance Locations

Compliance Methods

Compliance with the default percent of unimpaired flow requirement[1] is considered in the context of providing flows that protect fish and wildlife and operational rules that maximize operational clarity and flexibility. The 7-day averaging period strikes a balance between the fish benefits of a shorter averaging period and the operational benefits of a longer averaging period. In general, the shorter the averaging period, the more that flows provided will mimic biologically beneficial characteristics of unimpaired flow- matching the frequency, timing, magnitude, and duration. Shorter averaging periods, however, make compliance with the flow objectives more difficult. This document identifies challenges with successfully monitoring compliance with the 7-day averaging period and describes general methods that will be further evaluated to address those issues.

[1] The Bay-Delta Plan also allows for adaptive implementation of the of the LSJR flows. Compliance methods for adaptive implementation are forthcoming.

Very simply, compliance with the unimpaired flow requirement is determined by dividing the 7-day running average of the observed flow at a compliance location by the 7-day running average of the corresponding full natural flow at the three FNF stations, described above, as shown in Equation 1:

$$\% \text{ of UIF} = \frac{Q_{7-day\ ave,\ Compliance\ Location}}{Q_{7-day\ ave,\ FNF\ Station}} \qquad \text{(Equation 1)}$$

Following are steps to evaluate compliance:

1. Download flow data for the three compliance locations from CDEC
2. Download FNF data for the three FNF stations from CDEC
3. Calculate the 7-day running averages of daily flow from the above gages
4. Divide the 7-day running average for the compliance location by the 7-day running average for the corresponding FNF station (Equation 1)
5. Compare the result obtained in Step 4 with the required percentage of unimpaired flow

Compliance with the flow requirement at Vernalis is determined by calculating the 7-day running average of the daily flow recorded at VNS to make sure that the minimum flow requirement is also achieved. Modeling has shown that the 40 percent flow requirement will result in flows at Vernalis far higher than the Vernalis minimum flow requirement most of the time, however, when the percentage of unimpaired flow requirement is insufficient to meet the minimum base flow requirement, the three tributaries must provide the flows in proportion to their average unimpaired contribution to the LSJR, as specified in the Bay-Delta Plan:

- Stanislaus River – 29 percent
- Tuolumne River – 47 percent
- Merced River – 24 percent

Issues for Further Consideration

As discussed above, there are several aspects of compliance that require further consideration prior to implementation of the objectives. Conceptual methods for addressing these issues are discussed below, including methods for addressing the following issues:

- Data reporting lag times
- Missing data and gage outages
- Erroneous estimates of unimpaired flow, including zero or negative values

- Accretions/depletions downstream of FNF stations used to determine unimpaired flow
- Lagged determination of compliance

Data Reporting Lag Times

Unimpaired flows are currently estimated on daily and monthly time steps; however, the daily unimpaired flows are not generally available for real-time decision making. Daily flow records at the compliance locations typically lag by one day because the daily flow value is the mean value of river discharge measured at 15-minute intervals during the day. This means the mean value for the entire day can only be determined by midnight of the same day, or shortly after, in the morning of the next day. The FNF estimates then frequently lag by 2 to 3 days due to computational and data processing time. To address this issue, State Water Board staff will evaluate the operational feasibility of allowing for a lag time to be incorporated to determine compliance with the 7-day running average unimpaired flow or relying on forecasts when flow conditions are relatively stable and predictable.

Missing Data and Gage Outages

Occasionally, gaged flow values at the compliance locations or the FNF values are reported as “missing” on CDEC. This occurs when there are measuring or transmission equipment failures or technical problems with the gages. For missing flow data, flow may be calculated using data from a nearby reference gage. An initial regression analysis has been performed for each of the seven gages shown in Figure 1. The regression equations provided in Table 1 show that there is a good correlation between the target gage and reference gage. These correlations are based upon historical data. The suitability of using these regressions to correlate flows, and fill in missing data, under changed future flow regimes will be evaluated.

Table 1. Regression Equations developed to Estimate missing Flows at Target Gages

Target Gage	Reference Gage	Correlation Coefficients	Regression Equation
KOT	RIP	0.98	KOT = 0.87 × RIP + 56
MOD	LGN	0.99	MOD = 0.99 × LGN + 66
MST	CRS	0.97	MST = 0.92 × CRS + 33
VNS	MRB	0.98	VNS = 1.1 × MRB + 341
GDW	NML	0.95	GDW = 1.1 × NML - 174
TLG	MRC	0.94	TLG = 1.8 × MRC + 264
MRC	MBB	0.92	MRC = 0.94 × MBB + 38

RIP = Stanislaus River at Ripon.
LGN = Tuolumne River below La Grange Dam near La Grange.
CRS = Merced River at Cressy.
MRB = San Joaquin River at Maze Rd Bridge.
NML = New Melones Reservoir.
MRC = Merced River near Merced Falls.
MBB = Merced River near Briceburg.

In addition, missing data may result in either more or less water being provided than will later be determined was required on a 7-day average. The amount of water provided that is in addition to what is required would be an excess flow, and any shortage that does not meet the required flow would be a flow deficit. These flow excesses and deficits may occasionally not be known until many days after flows have been provided. It may therefore be desirable to allow for, and keep track of, any excess and deficit flows, and to allow some operational flexibility, as long as the required percent of unimpaired flow is eventually provided, and fish and wildlife protection goals are achieved. Potential methods for doing this will be evaluated.

Erroneous Estimates of Unimpaired Flow, Including Zero or Negative Values

Some calculated FNF values reported are zero or negative, which is physically impossible. This occurs when some input parameters used in DWR's method for calculating the FNF are overestimated or underestimated. For example, changes in reservoir storage are used, in part, in the calculations. Reservoir storage is, in some instances, determined by reservoir water elevations, which can be affected by environmental factors such as wind, which has the effect of pushing water higher or lower at the location of a stage gage. This means that reservoir elevation and storage could be overestimated or underestimated. It would not make sense to base required flows on negative or zero flows.

Generally, missing and zero or negative data pose a potential problem mostly during times when hydrologic conditions are changing rapidly, such as rainfall or large snowmelt events. At other times, when flow conditions are relatively constant, or are

following a simple and predictable trend, such erroneous data pose no serious challenge because flow trends can be used to easily replace the erroneous data. Whereas rapidly changing hydrologic conditions would make estimates of those values more uncertain, and a more sophisticated method might be needed for their estimation.

Missing, negative and zero values tend to occur outside the February to June period. Table 2 shows the number of days and percentage that the flow values were reported as missing, negative or zero for the FNF stations and compliance gages. A more comprehensive review of FNF data calculations will be conducted to identify the issues that cause missing, negative, and zero flow values.

Table 2. Number of Days and Percentage of Missing, Negative and Zero Flow Values during February and June in the Past Ten Years*

River	Stanislaus		Tuolumne		Merced		LSJR
Gage	KOT	GDW	MOD	TLG	MST	MRC	VNS
Total Number of Days Recorded	601	601	1,532	1,532	1,532	1,532	1,532
Number of Reported Missing Values	20	0	201	2	38	1	6
Number of Reported Zero values	0	0	0	0	1	0	0
Number of Negative Values	0	0	0	0	0	0	0
% of Missing Values	3.3%	0.0%	13.1%	0.1%	2.5%	0.1%	0.4%
% of Zero and Negative Values	0.0%	0.0%	0.0%	0.0%	0.1%	0.0%	0.0%

* The recorded period for Gages KOT and GDW was from February 1, 2016 to June 30, 2019, because flow data for KOT was only available from July 2015.

At times when conditions are not changing rapidly, it appears reasonable to replace zero or negative values that occur for one or two consecutive days with a value, or the continuing trend of the values, reported for the days prior, for which there are no zero or negative values (data interpolation). If the zero or negative values occur for more than two days, this interpolated data can be augmented by use of correlated data, using the regression method discussed above. This method will be further evaluated. The State Water Board is also in the process of developing the ability to independently calculate FNF. This method may also allow the State Water Board to eliminate or minimize the frequency of zero, negative values, or otherwise erroneous data.

Accretions and Depletions Downstream of FNF Stations

Accretions and depletions of stream flow occur in the catchment area between a compliance location and its corresponding FNF station, and are not accounted for in the above method. Unimpaired flows would generally be higher at downstream locations than at upstream locations because with the increased size of the watershed there is more rainfall (or snowmelt) runoff. This means that the

calculated FNF at the rim dams will, in general, be lower than FNF calculated at the downstream compliance locations. The difference in unimpaired flow between the rim dams and the confluence of each river is relatively small except during large rainfall runoff events on the valley floor, which could lead to significantly higher unimpaired flows of short duration downstream of the rim dams than at the rim dams themselves. This means that accretions from rainfall runoff downstream of the rim dams helps to meet the unimpaired flow requirement because compliance with the flow requirements is based on attaining a percent of unimpaired flow for FNF calculated at the rim dams. These differences would have only a small effect on the determination of unimpaired flows because the biggest differences would be of short duration during high valley floor rainfall runoff flow periods.

Flows downstream of the rim dams are also affected by other factors, including groundwater losses and gains, agricultural return flows, and surface water diversions. Accretions from groundwater and return flows increase flows, while depletions from diversions and groundwater losses reduce flows. Water right holders subject to the unimpaired flow requirement would get the benefit of flow accretions, including the unimpaired flow accretions, but must also make up for the losses attributable to depletions.

The State Water Board will evaluate the effects of depletions on compliance with the unimpaired flow requirement when assessing how to assign responsibility to meeting the flow objectives. Characterization and quantification of accretions and depletions between the rim dams and the compliance locations could help to inform implementation actions. The State Water Board will work with the STM Working Group and the other relevant stakeholders to assess the seasonal accretions and depletions in the subject river reaches.

Lagged Determination of Compliance

It may not be possible to always determine compliance with the 7-day average flow requirement in real time. With imperfect data, and the general nature of water operations, flows higher or lower than the flow requirement may occur. Attempts to make up for the resulting excess or deficit flows could result in oscillating flows (going from high to low and vice versa) that are not reflective of daily unimpaired flows and are much higher or lower flows than the percent of unimpaired flow requirement. The State Water Board will seek to eliminate the potential for flow patterns that would result in undesirable negative effects on fish and wildlife. For example, limits may need to be determined on the allowable rates of changes in flows, that are based on observed rates of changes in unimpaired flows.

The State Water Board will also consider how excess flows above the percent of unimpaired flow requirement and deficit flows that may occur below the requirement

could best be tracked and accounted for in a way that both the goals of fish and wildlife protection and operational feasibility are considered.

Public Process

This document identifies initial measures and approaches to inform future compliance with the unimpaired flow objectives, as well as issues for future consideration. More detailed methods and specific recommendations will be developed in future processes. The State Water Board will reach out to stakeholders, including likely participants in the STM Working Group, and request their input and recommendations. As stakeholders join the STM Working Group, they will engage in developing the detailed compliance methods and specific recommendations. The State Water Board acknowledges that this will be an iterative process and welcomes the engagement of interested persons.