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BEFORE THE STATE WATER RESOURCES CONTROL BOARD

ENFORCEMENT ACTION ENFO1949 DRAFT CEASE AND DESIST ORDER REGARDING UNAUTHORIZED DIVERSIONS RO THREATENED UNAUTHORIZED DIVERSIONS OF WATER FROM OLD RIVER IN SAN JOAQUIN COUNTY	WRITTEN REBUTTAL TESTIMONY OF NICHOLAS F. BONSIGNORE, P.E. Hearing Date: March 21, 2016 Hearing Officer: Frances Spivy-Weber

1. I, Nicholas F. Bonsignore, submit this written testimony at the request of The West Side Irrigation District (**WSID**) in the above referenced enforcement action. I have personal knowledge of the facts stated herein and could testify competently thereto if called as a witness, except as to matters stated on my information and belief, and as to such matters, I am informed the same to be true.

2. I previously prepared written testimony in this matter on behalf of WSID and also on behalf of Byron Bethany Irrigation District (**BBID**) in connection with the State Water Resources Control Board, Division of Water Rights' (**Division**) Enforcement Action ENF01951 against BBID. My written testimony and my accompanying expert report have been previously entered into evidence as Exhibits **WSID-0121** and **WSID-0122**, respectively. **WSID-0121** includes a summary of my experience and qualifications, and attaches a copy of my professional resume.

3. In support of WSID's rebuttal to the Division's direct testimony, I was retained by WSID to provide a professional opinion on the facilities and methods used by WSID to measure flows in the Bethany Drain in 2015. My activities in this regard included a site visit to WSID on

November 17, 2015; discussion with Mr. Rick Martinez, WSID's Supervising General Foreman; and independent research and calculations.

4. During my site visit of November 17, 2015, I observed and made dimensional measurements of the weir that WSID has installed in the Bethany Drain for the purpose of measuring drainage flows therein. This weir is described by Mr. Martinez in his direct testimony (**WSID-0060** at paragraph 13). Mr. Martinez provides additional information regarding this weir in his rebuttal testimony (**WSID-0174**). In my opinion the subject weir provides a reasonable means of measuring flows within the Bethany Drain during non-storm periods during the irrigation season. Because the weir is located near the terminal end of the Bethany Drain, the flows measurements made at the weir characterize flows discharged from the Bethany Drain to the WSID intake channel under "free-flow" conditions.

5. For reference I have attached a generic cross-section sketch of a weir taken from the publication *"Measuring Irrigation Water, Circular 473"*, by the University of California Division of Agricultural Sciences, January 1959 (**WSID-0176**). As shown on the sketch, the dimension "**H**" refers to the depth of water over the weir crest in the pool upstream of the weir and is called the "head" on the weir. The location where the flow passes over the weir is called the "nappe"; I have circled the nappe in red on WSID-0176.

6. For standard weir shapes there is a mathematical relationship between the head on the weir and the flow passing over the weir crest under "free-flow" conditions. A weir is in a free-flow condition when the water surface on the downstream side of the weir is sufficiently below the weir crest so that air moves freely beneath the nappe (aeration). The head-flow relationship for a particular weir shape is based on laboratory experimentation by researchers. For rectangular-shaped weirs, such as the Bethany Drain weir, the head-flow relationship is characterized by the following general formula:

$$Q = C \, x \, L \, x \, H^{3/2}$$

Where:

Q = flow passing over the rectangular weir crest in units of cubic feet per second (cfs)
C = a coefficient based on laboratory experimentation
L = the length of the weir crest in units of feet

H = head on the weir in units of feet

For a particular weir crest length L, and using an appropriate coefficient C, the formula can be used to generate a discharge table that lists flow rates for various measurements of heads. A discharge table provides a ready reference in the field for determining flow from head measurements.

7. Following my site visit, Ms. Jeanne Zolezzi, counsel for WSID, provided the discharge table that Mr. Martinez uses to convert head measurements to flow rates. This discharge table (**WSID-0163**) provides flow rates for rectangular weirs having a crest length of 6 feet (72 inches) for heads ranging from 2 inches to 18 inches in quarter-inch increments, and from 18 inches to 21 inches in half-inch increments.

8. Because, per Ms. Zolezzi, the origin of **WSID-0163** is unknown to Mr. Martinez, I compared the flow rates in **WSID-0163** with flow rates computed for a 6-foot rectangular weir based on a standard formula for rectangular weirs. Specific formulas for preparing discharge tables for weirs are based on laboratory experimentation by researchers, and different researchers have developed different formulas for the same types of weirs. For this evaluation, I selected a commonly used formula for fully contracted rectangular weirs known as the Francis formula (although there are other formulas that could be used). The Francis formula takes the form: $Q = 3.33 \times (L - (0.2 \times H)) \times H^{3/2}$

9. For the 71 entries in **WSID-0163** corresponding to the quarter-inch and half-inch increments of head, the flows in Mr. Martinez's discharge table on average underestimate flow relative to the Francis formula by 0.3 percent, with individual differences ranging from 6.0 percent underestimated to 3.2 percent overestimated. Based on these results I conclude that the discharge table used by Mr. Martinez is not based on the Francis formula, but is in reasonable agreement with the Francis formula.

10. During my November 2015 site visit I measured the weir crest length to be 70 inches. This is 2 inches less than the 6-foot (72-inch) crest length upon which **WSID-0163** is based. Based on the Francis formula, computed flows based on a crest length of 72 inches are about 3 percent greater than computed flows based on a crest length of 70 inches. Because

WSID-0163 is for a 72-inch crest length instead of a 70-inch crest length, I would expect it to similarly overestimate flows by about 3 percent for the Bethany Drain weir.

11. During my November 2015 site visit, Mr. Martinez showed me that he measures the head at the nappe (see WSID-0176), i.e. he measures the depth of flow at the weir crest. All standard weir formulas, including the Francis formula, are based on laboratory experiments that measure the head in the pool well upstream of the weir crest, as depicted in WSID-0176. In order for a flow measurement to be accurate the location where head is measured should be similar to the location that was used to experimentally generate the weir formula. Various publications that I have reviewed state that the location of the head measurement should be at a distance 3 to 4 times the head upstream of the weir plate. At this distance the head measurement is not affected by the drawdown of the water surface as it passes over the weir crest at the nappe. Because the water surface draws down as the flow passes over the nappe, Mr. Martinez's measurement of head at the nappe underestimates the actual head on the weir. Therefore, his use of the nappe measurement to determine flows from **WSID-0163** *underestimates* the actual flow that would result from using the proper head measurement in **WSID-0163**.

12. In my opinion, Mr. Martinez's *underestimation* of flow based on using the wrong head likely offsets his *overestimation* of flow based on the use of the wrong weir crest length, and may underestimate flow even more so. For example, using the Francis formula for a 6-foot weir crest, the flow computed for a head of 0.5 feet (6 inches) is about 3 percent less than the flow computed for a head of 0.51 feet (about 6-1/8").

13. There are other factors that affect the applicability of a particular weir formula to a particular weir installation in the field. For example, most weir formulas are based on laboratory experiments using "sharp-crested" weir plates. In **WSID-0176** it can be seen that the weir crest has a sharp edge. In the field a sharp edge can be obtained by using a steel plate, perhaps 1/8-inch to 1/4-inch thick, with a 45-degree bevel on the downstream side. For the Bethany Drain weir, the weir crest is a "2-by" surfaced wood board and thus has a breadth of about 1.5 inches; hence it is more of a "broad-crested" weir. In discussing broad-crested weirs Brater and King states *"When the head reaches one to two times the breadth, the nappe becomes*

detached and the weir becomes essentially sharp-crested." (*Handbook of Hydraulics for the Solution of Hydraulic Engineering Problems*, by Ernest F. Brater and Horace William King, Sixth Edition). Thus for the Bethany Drain weir, the weir board may operate as a sharp-crested weir at heads as low as 1.5 inches. Exhibit **WSID-0162** is a photo of flow passing over the Bethany Drain weir, which I am informed was taken by Mr. Martinez. **WSID-0162** shows the drawdown of the nappe and its detachment from the weir board. With reference to paragraph 12 herein, it appears that the drawdown of the nappe visible in **WSID-0162** is much greater than 0.01 feet.

14. The accuracy of a particular weir measurement also depends upon certain approach channel (pool) conditions. The cross-sectional area of the approach channel should be sufficiently large relative to the cross-sectional area of the weir overflow to avoid high flow velocities approaching the weir, otherwise the measurement of head may be too low resulting in an underestimate of flow. Exhibit WSID-0162 shows quiescent conditions on the upstream side of the weir. While I did not measure the upstream channel conditions precisely, the weir is constructed in a long straight run of ditch having a width of about 19 feet (measured at the top of the 4-foot high concrete weir wall), which is over 3 times the weir crest length, and the crest of the weir board is set 14 inches above the channel bottom, which exceeds the minimum recommended height of 12 inches. To the extent that these dimensions might result in an approach channel cross-sectional area that is less than that recommended for all measured flow conditions, the error would be an underestimation of flow, in which case WSID's measured values are conservative. It is further noted that most weirs using wooden boards leak to some degree. Such leakage is unmeasured flow; therefore, to the extent that leakage occurs WSID's measured flow underestimates actual flow.

15. In her testimony in this matter, the Division's Kathy Bare expressed concern as to *"whether the weir is calibrated accurately"* (WR-13 at page 6). A weir is a flow measuring device.. It should not require calibration if it is properly installed and operated. Being a field device, "calibration" of the Bethany Drain weir would require using some other type of flow measuring device or method suitable for use in the field (unlike flow meters used to measure

pipe flow, the Bethany Drain weir cannot be shipped off to a lab for calibration). A current meter could be used to make corroborating flow measurements in the Bethany Drain, but even current meter measurements have some degree of error depending upon channel conditions and the expertise of the technician making the measurement. Based on paragraphs 12 and 14 herein, to the extent that there are deficiencies in WSID flow measurements, the accumulation of contributing factors weigh on the side of *underestimating* flows. "Calibration" or some other type of field flow measurement should not be necessary unless one is interested in exploring by how much WSID undercounted flow in its 2015 measurements.

I declare under penalty of perjury under the laws of the State of California that the foregoing is true and correct.

Executed this 19th day of February, 2016, in Sacramento, California.

NICHOLAS F. BONSIGNORE, P.E.