Hearing on the Matter of California Department of Water Resources and United States Bureau of Reclamation Request for a Change in Point of Diversion for California WaterFix - Part 2

Testimony of Kit H. Custis

On Behalf of AquAlliance

I Kit H. Custis, do hereby declare:

Introduction

I have a Bachelor's and a Master's Degree in Geology from California State University at Northridge. I have additional graduate studies as a PhD student in Hydrological Sciences at the University of California at Davis. I have worked for 38 years as a professional engineering geologist and hydrogeologist. I hold licenses in California as a Professional Geologist, PG 3942; Certified Engineering Geologist, EG 1219; and Certified Hydrogeologist, HG 254. I have worked in consulting and as an employee of the State of California. As the latter, I've worked for the State Water Resources Control Board, the Central Valley Regional Water Quality Control Board, the California Geological Survey, and the Department of Fish and Wildlife. A copy of my curriculum vitae is attached as AquAlliance Exhibit 200

Purpose of Testimony

The purpose of my testimony is to provide information on the groundwater in the Sacramento Valley and Delta that supplements my previous WaterFix Part 1 testimony by providing additional information and exhibits on the potential impacts of to the environment from the WaterFix Project. Comments and exhibits provided in my WaterFix Part 1 testimony, AquAlliance Exhibits 5 through 33, are applicable to this WaterFix Part 2 testimony because the losses to surface water and groundwater resources as a result of groundwater substitution or crop idling transfers affect both water rights and environmental resources. My WaterFix Part 2 testimony will present information on the condition of groundwater in the Delta and areas upstream of the Delta that hasn't been adequately provided in the November 2013 U.S. Bureau of Reclamation's (BOR) Draft EIR/EIS for the Bay Delta Conservation Plan (DEIS/EIR), the 2015 BOR Recirculated Draft Environmental Impact Report/Supplemental Draft Environmental Impact Statement (RDEIR/SDEIS), or the 2016 California Department of Water Resources (DWR)/BOR Bay Delta Conservation Plan/WaterFix Final Environmental Impact Report/Environmental Impact Statement (Final EIR/EIS). AquAlliance Exhibit 201 is a pdf file of my testimony presentation.

General Statements about the Final EIR/EIS Preferred Alternative

My WaterFix Part 1 testimony focused on impacts resulting from Alternative 4. The WaterFix Final EIR/EIS has selected Alternative 4A as the preferred alternative for both California Department of Water Resources (DWR) under California Environmental Quality Act (CEQA) and U.S. Bureau of Reclamation (BOR) under National Environmental Protection Act (NEPA) (page ES-4). Alternative 4A is a modification of the Bay Delta Conservation Plan (BDCP) Alternative 4, which includes construction of three intake facilities on the east bank of the Sacramento River between Clarksburg and Courtland for dual conveyance tunnels with a maximum north Delta diversion rate of 9,000 cubic feet per second (cfs). Alternative 4A water conveyance facilities will be constructed and maintained identical to those proposed under Alternative 4 (page ES-30). AquAlliance Exhibit 203 shows the general location of Alternative 4A water conveyance facilities. Alternative 4A will utilize Intakes 2, 3 and 5 (Table ES-7). See Tables ES-5 and ES-7 (pages ES-31 and ES-35) for a comparison of Alternatives 4 and 4A. Alternative 4A is now known as "The California WaterFix."

In addition to Alternative 4A, the WaterFix Final EIR/EIS includes Alternatives 2D and 5A as modifications of Alternative 4. The construction and maintenance of Alternatives 2D and 5A water conveyance facilities will be similar to those proposed under Alternatives 4 and 4A (page ES-33). Alternative 2D will use five intakes (Intakes 1 through 5) and increases north Delta diversion capacity to 15,000 cfs (Table ES-7), while Alternative 5A will use one intake, (Intake 2) and reduces the diversion capacity to 3,000 cfs.

Although my past and current testimony for WaterFix Parts 1 and 2 assumed that the north Delta diversion rate would be 9,000 cfs, the increase or decrease in diversion rate under Alternatives 2D or 5A shouldn't affect the conclusions of my testimony because the impacts to the Sacramento Valley from north-of-the-Delta transfers are similar and proportional to the amount of water transferred. Impacts to groundwater flows in the Delta are also similar because the size and location of main tunnel conveyance facilities are nearly identical with all three alternatives.

Overview of Testimony for the WaterFix Part 2

In my WaterFix Part 1 testimony (AquAlliance Exhibit 5), I reviewed: (1) the condition of the groundwater system in the Sacramento Valley; (2) the impacts to well owners in the Sacramento Valley from groundwater substitution and crop idling water transfers; (3) the impact to surface water resources and groundwater recharge from groundwater substitution and crop idling water transfers; and (4) the potential impact to the Delta groundwater system from groundwater and crop idling water transfers. My testimony in WaterFix Part 1 is applicable to Part 2 because the issues and the resulting impacts that affect water users and water rights also affect environmental conditions, plants, wildlife habitat and wildlife. In this WaterFix Part

2 testimony, I will refer to comments in my WaterFix Part 1 testimony that provide a more detailed background, discussion or foundation for my Part 2 comments.

This WaterFix Part 2 testimony covers three areas: (1) the potential impacts to the environment of the Delta and adjacent lands from the disruption of groundwater flows resulting from construction of the WaterFix tunnels; (2) potential impacts to plants, aquatic and terrestrial habitat, and wildlife in the Sacramento Valley because of increased opportunity to convey water transfers from the Sacramento Valley across the Delta using the WaterFix tunnels; and (3) potential for environmental impacts to the Delta from construction of the WaterFix tunnels through operating natural gas fields.

1. <u>Potential Impacts to Delta Groundwater System from Construction of Alternatives 4, 4A, 2D, or 5A.</u>

   In the 2016 Final EIR/EIS Bay Delta Conservation Plan/California WaterFix, DWR and BOR have identified Alternative 4A as the preferred alternative (page ES-4). The water conveyance facilities constructed and maintained under Alternative 4A are identical to those of Alternative 4 (page ES-30). In addition, two other Alternatives 2D and 5A have similar conveyance facilities with variations on the number of intakes. Alternative 2D has five intakes, while Alternative 5A has one intake. The location of conveyance facilities and alignment alternatives are shown in AquAlliance Exhibit 203 (Figure ES-3).

   The environmental analysis of potential WaterFix project impacts to groundwater resources is given in Chapter 7 for the WaterFix Final EIR/EIS. The analysis found that with the exception of the No Action Alternative and Alternative 9, all alternatives would reduce local groundwater supplies during construction of the water conveyance facilities as a result of dewatering. The WaterFix Final EIR/EIS concludes that groundwater levels would return to pre-project conditions within months of the cessation of dewatering (Section 7.0). In the discussion of Impact GW-2 - During Operations, Deplete Groundwater Supplies or Interfere with Groundwater Recharge, Alter Local Groundwater Levels or Reduce the Production Capacity of Preexisting Nearby Wells, a statement is given that the *operation of the tunnel would have no effect on existing wells or yields given the facilities would be located more than 100 feet underground and would not substantially alter groundwater levels in the vicinity.* The WaterFix Final EIR/EIS doesn't provide any other analysis or reasoning as to why the tunnel structure can't impact groundwater flows during operations other than saying that groundwater levels will eventual rise once dewatering stops. Addition analysis of the impacts to aquifer flow is warranted because the 40-foot inside diameter tunnels will be constructed for approximately linear 39 miles across the Delta creating a continuous impermeable structure. See Section 3.3.1.1 on page 3-33 of WaterFix Final EIR/EIS for general description of tunnel dimensions under the different alternatives.

The construction of 39-mile long, 40-foot inside diameter tunnels across the Delta at a depth of approximately 100 to 165 feet below the ground (see Figure 9-4c to 9-4g in Chapter 9 of the WaterFix Final EIR/EIS) will likely interrupt the horizontal flow of groundwater in interbedded sands and fine-grained sediments of the Delta. The present day general direction of ground flow in the Delta is from west to east, AquAlliance Exhibit 204. This is due in part to groundwater pumping in Sacramento and San Joaquin counties that has created a sustained north-south oriented groundwater depression. The north-south oriented WaterFix tunnel structure will cut almost perpendicular to the general eastward direction of regional groundwater flow. Groundwater flow may or may not be able to divert around this impermeable barrier depending on the continuity of shallow aquifer interconnections. The WaterFix Final EIR/EIS doesn't provide any hydrogeologic data on the subsurface or aquifer characteristics in the Delta other than 25 widely spaced boring logs along the tunnel alignment (see Figures 9-4a to 9-4g in Chapter 9). No information is provided on how the aquifer system in the Delta interconnects with the aquifers to the east that are being pumped in the depression area of Sacramento and San Joaquin counties. There is however other published technical information that can help describe the hydrogeologic conditions in Sacramento and San Joaquin counties, their relationship to the Delta, and the potential impacts of the WaterFix tunnels to the shallow groundwater flow system.

<u>Mokelumne River Area</u>

Shlemon (1971) described the Quaternary Deltaic and channel systems in the the Mokelumne River area. Three and possibly four Mokelumne River Fan deposits and gravel-filled channels were identified that interfinger with deltaic sediments. Shlemon describes the alluvium of the Delta:

> *The ancestral Sacramento and San Joaquin rivers, major drainages of the Great Valley, intermixed in the California Delta before passing through the Carquinez Strait and northern San Francisco Bay on the way to the sea. The Delta, although some fifty miles (80 km) from the Pacific Ocean, also responded to Pleistocene climatic change by expanding and contracting areally with each glacioeustatic oscillation. In the California Delta, channels of the lower Sacramento-San Joaquin river system and local tributaries apparently were repeatedly incised and backfilled with each major climatic fluctuation.*

AquAlliance Exhibit 205 is a map of the Mokelumne River Fan deposits and the Delta that shows the general known extent, as of 1971, of coarse-grained Pleistocene channels deposits. These channel deposits increase in depth to the west and become the shallow aquifers of the Delta. AquAlliance Exhibit 206 is a cross-section of the Mokelumne Fan and Delta shows the four sequences of channel deposits interfingering with the Delta sediments. Both Exhibits have the approximate location of Alternative 4A WaterFix tunnels shown.

AquAlliance Exhibit 207 is a map of four approximate high-tide shorelines near San Francisco during the past 15,000 years (Atwater, 1977, Figure 6). These depict the lowering of sea level during most recent glacial period that caused a significant change in the geology of the Delta because the channels incise to follow the lowering of sea level and then backfill with the rise. This typically produces a fining-upward sequence of channel sediment deposits with coarser grained materials at the base and fine material on top. These coarse-grained base sediments provide more conductive zones for groundwater movement. The incised channels cut across finer-grained Delta sediment deposits creating the potential for interconnecting the buried channel and fan deposits of the Delta's shallow aquifer system with these high conductivity pathways.

Shlemon estimates that the oldest channel deposits, Laguna age, may occur approximately 310 feet below sea level beneath Sherman Island. AquAlliance Exhibit 206 shows that younger channel deposits intercept Delta deposits at a depth similar to the WaterFix tunnels, approximately 100 to 165 feet below sea level (30 to 50 meters). Shlemon also notes that there are two buried channels of Riverbank age, 80,000 to 105,000 years old, on the American River about 30 miles north of the Mokelumne area. The American River Riverbank-age channel may be equivalent to those in the Mokelumne Fan.

<u>Sacramento County Area</u>

A more detailed description of the hydrogeology of the Sacramento area is provided by DWR in Bulletin 118-3 (1974). Pleistocene age sediments in Sacramento County are described as being derived from glacial runoff from the Sierra Nevada that deposited boulders, gravels and glacial debris onto the American River flood plain, burying deposits of Laguna and Fair Oaks age. These glacial rivers were much larger than the American River today with the riverbed in some places as much as 8,000 feet wide. AquAlliance Exhibits 208A and 208B show the locations of shallow coarse-grained channel deposits, called the superjacent series, across Sacramento County. The superjacent series consists of deposits of Laguna, Fair Oaks, and Victor formations as well as all Holocene deposits.

These coarse-grained deposits would have interbedded with the finer-grained Delta deposits somewhere in the southwestern portion of Sacramento County. DWR arbitrarily set the maximum extent of the Delta at the zero-elevation contour, which roughly coincides with the contact between organic and non-organic soils. AquAlliance Exhibit 209A shows the location of geologic cross-sections for Sacramento County (Bulletin 118-3). AquAlliance Exhibits 209B and 209C show northeast-southwest oriented cross-sections E-E' and F-F'. AquAlliance Exhibits 209D and 209E show northwest-southeast oriented cross-sections G-G', H-H' and I-I'. The location of WaterFix Alternative 4A tunnels is shown in cross-sections E-E', F-F' and I-I'. These cross-sections clearly show that coarse-grained sediments extend to a depth of several hundred feet in the Delta. DWR estimates that the older channel deposits that crop out near Folsom meanders southwest and combines with the Sacramento River near Clarksburg at a depth of approximately 100 feet below sea level

<u>San Joaquin County Area</u>

A description of the hydrogeologic setting of San Joaquin County is given in DWR Bulletin 146 (1967). DWR found that there is a southwest-northeast directional trend to sediment deposits in San Joaquin County (page 6 of Bulletin 146). Younger sediments in the county are similar to those of Sacramento County. AquAlliance Exhibit 210 is an isopach map (a contour map showing equal thicknesses) of the thickness of sands between the depth intervals of 50 to 100 feet near Stockton. The northern portion of AquAlliance Exhibit 210 overlaps with the Mokelumne River study area of Shlemon (see AquAlliance Exhibit 205). AquAlliance Exhibit 210 shows that the thickness of sand deposits varies significantly across the area, but the general southwest-northeast orientation is visible in the Stockton area. In the Mokelumne River area, the orientation of the sand deposits shifts slightly towards east to west as described by Shlemon (1971). Although DWR didn't produce isopach maps of sand deposits deeper than 100 feet, they state that the continental environmental relationship of the formations suggests a similar condition at depth (page 6 of Bulletin 146).

AquAlliance Exhibits 211A shows the location of two northeast-southwest oriented cross-sections of the shallow geologic units. AquAlliance Exhibits 211B, section A-A', and Exhibit 211C, section B-B', provide subsurface information on the locations of sand and gravel deposits that are fresh-water bearing. The scattered occurrence of coarse-grained material, sands and gravels that make up the shallow aquifer system is similar to those found in Sacramento County (see AquAlliance Exhibits 209A to 209E). DWR found that in the Mokelumne River area the Laguna Formation is approximately 400 feet thick and thickens to approximately 1,000 feet in the Stockton area. The depth of the Laguna Formation in the area of the Delta is greater than the 310 feet below sea level estimated by Shlemon (1971). The interbedded sands and gravels with finer-grained materials is consistent with the sediment sequence encountered along the conveyance facility alignment for WaterFix Alternative 4A, see Figures 9-4a to 9-4g in Chapter 9 of the WaterFix Final EIR/EIS.

<u>Conclusions of Potential Impacts to Delta Groundwater Flow from the WaterFix Tunnels</u>

The published hydrogeology data for the Delta and the shallow water bearing aquifers to the east show that there is a series of buried river channels that have variable thicknesses of coarse-grained deposits that were deposited from east to west in Sacramento County and the Moklumne River area, and southwest to northeast in the area of Stockton. These coarse-grained deposits interfinger with the fine-grained deposits of the Delta creating a complex system of fresh water aquifers. There is no obvious fixed location where the fine-grained Delta deposits stop, in part due to the fluctuations in sea level and changes in sedimentation rates. The coarse-grained deposits are known to extend down to and below the proposed depth of the WaterFix tunnels. The coarse-grained deposits encountered by the geologic borings along the conveyance alignment are likely laterally connected to these aquifers that originate to the east of the Delta.

The construction of the WaterFix tunnels will create a 39-mile long, 40-foot-thick impermeable barrier across the shallow aquifer systems in the Delta, which can cause a number of environmental impacts. The tunnels will likely cause some disruption of horizontal and vertical flows within the shallow aquifers. The results of the disruption will vary from disconnecting the aquifer system to re-orienting the flow directions. For example, west of the tunnel barrier, groundwater may be forced to flow vertically upward or downward depending on the relative vertical permeability. Increased vertically upward flow may cause added impacts to agriculture or near surface structures. New flows oriented along the north-south edge of the tunnel barrier may redirect groundwater into adjacent aquifers or into river channels, possibly impacting levees with increased seepage. East of the tunnel barrier, the disconnection with the source of the groundwater could reduce water levels or piezometric heads in the aquifers. A reduction in head could cause increases in vertical groundwater flow between aquifers that aren't disrupted by the tunnel barrier. This may cause an increase in downward vertical flow from shallow aquifers or surface water bodies. There could also be an upward increase in vertical groundwater flow if the piezometric head in the aquifers blocked by the tunnel drops below the piezometric head in lower unblocked aquifers. This would change a condition from one of shallow groundwater recharging deeper groundwater, to the reverse. The condition of deeper groundwater flowing upward into shallower aquifers carries a potential risk of decreased water quality as more saline deep groundwater mixes with better quality shallow water. See Isbicki and others (2006) for a more detailed discussion of this issue in the Eastern San Joaquin County groundwater subbasin area. In addition to potential impacts from changes in vertical groundwater gradient, reduction in the amount of groundwater available for horizontal flow in aquifers east of the tunnel barrier may cause an increase in the depth of the north-south groundwater depression east of the Delta because of a lack of groundwater to supply the pumping wells.

Therefore, the potential impacts to groundwater flow caused by the construction of the tunnels that will act as a regional impermeable barrier should be analyzed. The assertion in the WaterFix Final EIR/EIS that the 100-foot depth of the tunnels prevents any significant groundwater impacts isn't supported by existing regional geologic data or analysis in the WaterFix Final EIR/EIS. Changes in either vertical or horizontal flows can cause local and regionally significant changes in the environment that aren't easily remedied. The depth and extent of the tunnel barrier will make correcting any environmental impacts that develop during operations difficult and costly to study and mitigate.

2. Sacramento Valley Environmental Impacts from WaterFix Project Alternatives 4, 4A, 2D, or 5A

The WaterFix Final EIR/EIS discusses water transfers in Section 5.1.2.7 – Delta Water Transfers, and notes that there is no maximum on the amount of water that can be conveyed through or delivered from the Delta as long as it is consistent with the operational criteria and the transfer is not limited by other factors including hydrological, regulatory and contracts conditions. The WaterFix Final EIS/EIR states that because no specific agreements have been identified for water transfers, any project level analysis of impacts upstream of the Delta would be speculative and therefore the WaterFix will not cover the requirements of any specific transfer. The WaterFix Final EIR/EIS leaves analysis of any potential upstream impacts as a future study once a specific transfer has been proposed (page 5-29 of Chapter 5).

The statement that no specific water transfer agreements are identified appears to ignore the recent completion in March 2015 of the Bureau of Reclamation and the San Luis and Delta-Mendota Water Authority (BOR/SLDMWA) 10-Year Long-Term Water Transfer Final EIS/EIR. The BOR/SLDMWA 10-Year Transfer Project identifies specific Sacramento Valley water agencies that wish to sell water and proposes to transfer up to 290,496 acre-feet per year (AFY) using groundwater substitution and up to 177,362 AFY using crop idling. These annual volumes of cross-Delta transfers are less than the 600,000 to 1,000,000 AFY of cross-Delta transfers assumed in the WaterFix Final EIR/EIS (page 5-52), and less than the 400,000 AFY of groundwater substitution and 507,000 crop idling transfers identified as upstream of the Delta water available for potential transfer in Section 5C.11 of Appendix 5C WaterFix Final EIR/EIS (pages 5C-22 and 5C-23). Many of the agencies identified in the WaterFix Final EIR/EIS on page 5C-18 as engaging in groundwater substitution transfers are the same agencies that are named in the BOR/SLDMWA 10-Year Transfer Project (see AquAlliance Exhibit 212). Thus, the areas of impact from the 10-Year Transfer Project will likely be the same of those facilitated by the WaterFix Project tunnels. Although the transfers conducted under the 2015 BOR/SLDMWA 10-Year Transfer Project will only occur between 2015 and 2024, the impacts to the Sacramento Valley from those transfers as well as earlier transfers will continue for decades following each transfer. Impacts from groundwater substitution or crop idling transfers will generally be the same regardless of the date of transfer, as discussed below. The environmental impacts to the Sacramento Valley identified for the 2015 BOR/SLDMWA 10-Year Transfer Project will likely be similar to those resulting from any future transfers that utilize the WaterFix project conveyance facilities because the same water agencies are participating and the quantity of water transferred is similar, although slightly less, than the amounts proposed for the WaterFix project. Therefore, the WaterFix Final EIS/EIR should include analysis of potential impacts from water transfers from upstream of the Delta using the assumed WaterFix Final EIR/EIS maximum annual volume of transfer as a worse-case scenario.

Analysis of the potential environmental impacts to the Sacramento Valley from past and future groundwater substitution and crop idling transfers can be done with the information already available on the past transfers, for example the 2009 transfers (see WaterFix Part 1 AquAlliance Exhibit 5 comments 3B and 3D), and the 2015 BOR/SLDMWA 10-Year Transfer Project analyses using the maximum 600,000 to 100,000,000 AFY available transfer water assumed in the WaterFix Final EIR/EIS. This is possible because the general physical and hydrologic changes that occur from groundwater substitution and crop idling transfer are not unique to a specific project. Changes in groundwater levels, groundwater storage, and surface water flows are proportional to the volume of water transferred. While the amount of impact at a specific location depends on the distance between the impacted surface waters to the area of groundwater extraction or crop idling along with the hydrogeologic setting, there have been and will continue to be impacts from these transfers. The science to estimate those impacts is well established. I have taken this approach in preparing my WaterFix Part 1 testimony and continue this approach for my Part 2 testimony.

Impacts to the environment of Sacramento Valley resulting from the construction and operation of the WaterFix tunnels include: (1) reductions in river flows and surface waters, decreases in groundwater storage, and lowering of groundwater levels; (2) reductions in available surface water and/or groundwater needed to maintain river habitat, fisheries and various aquatic species, plants and terrestrial wildlife that depends on that habitat; (3) reduction in groundwater availability to groundwater dependent ecosystems (GDE) not in direct contact with a surface water body, that results in loss of plants and habitats, such as wetlands, that plants and wildlife depend on. These impacts are the result of the potential increase in groundwater substitution or crop idling cross-Delta transfers due to the operating of the WaterFix tunnels.

A. In my WaterFix Part 1 testimony, I discussed the long-term changes in the Sacramento Valley groundwater system from the early 1920s to 2010 based on results of DWR's C2VSIM groundwater model (see testimony in 1F starting on page 10 of AquAlliance Exhibit 5 in WaterFix Part 1). The graph in AquAlliance Exhibit 18 of WaterFix Part 1 shows that the long-term loss in accretion (groundwater discharging to surface waters) is equal to approximately 80% of the historical increase in groundwater extraction. This loss of accretion is one part of the stream depletion process known as "capture."

   The concept of "capture" of surface waters resulting from groundwater extraction is broader than what is commonly considered streamflow depletion (Konikow and Leake, 2014). Capture can include: (1) increases in stream or surface water seepage when groundwater levels decline; (2) decrease in groundwater discharge to springs, streams or surface waters with interception of groundwater by pumping that would otherwise have discharged to the surface; (3) increased recharge from a decline in groundwater level in areas that previously would reject deep percolation because of a shallow water-table; and (4) decrease in evapotranspiration with a lowering of the water table. The capture of surface waters will have a direct impact on the environment by impacting aquatic life from reduced flows, GDEs with lowering of the groundwater table, and the wildlife that depends on these habitats.

In a study of 31 aquifers or areas within, and two outside, the United States, Konikow and Leake (2014) re-examined the sources of water derived from a pumping well. Their study evaluated long-term cumulative impact of groundwater extraction volume by dividing the sources of water to the well into two parts, (1) the change in aquifer storage, named depletion fraction, and (2) capture of surface water, named capture fraction. The aquifer system of the Central Valley of California was included their study. Konikow and Leake (2014) used the existing U.S. Geological Survey's (USGS) Central Valley groundwater model (Faunt and others, 2009) to calculate the depletion and capture fractions that supply extracting wells. AquAlliance Exhibit 213 is taken from Konikow and Leake (2014) and gives a graph (Figure 14) of the change in the capture fraction and the aquifer depletion fraction for the Central Valley as calculated by the USGS Central Valley model for years 1961 to 2003. The capture-depletion graph shows dashed lines for annual fraction values and a solid line for cumulative fraction. By the end of the model in year 2003, the cumulative capture fraction is approximately 85%. AquAlliance Exhibit 214 is taken from Table S1 in Konikow and Leake (2014) and lists more precise cumulative values of capture depletion fraction and aquifer depletion fractions with the Central Valley values listed on their page 2. In several model years, the annual capture depletion is approximately 1, or 100%, with the corresponding aquifer depletion fraction going to zero. Note that the sum of the two fractions equals 1, or 100%.

The finding of Konikow and Leake (2014) that the cumulative percentage of capture for the Central Valley is approximately 85% is consistent with my estimate of 80% loss of accretion from the results of DWR's Sacramento Valley C2VSIM model. This is because the accretion term used in the DWR model is included in the capture term of Konikow and Leake (2014). A reduction in accretion occurs when a pumping well intercepts groundwater that would otherwise have discharged to the surface (positive accretion), or causes an increase in surface water seepage into an underlying aquifer when groundwater levels decline (negative accretion). The similar values of the long-term cumulative capture fractions from the two Central Valley groundwater models, USGS and DWR, suggest that: (1) these values are representative of the long-term impacts to surface water and groundwater from groundwater extractions; (2) there is a need to reassess how the environmental impacts from transfers on surface waters are taken into account during a groundwater substitution transfer. These model results show that impacts to surface water from groundwater substitution transfers occur after the year-of-transfer and at a volume much greater than what is assumed by BOR and DWR. The cumulative long-term impacts of capture by a pumping well can extend for decades after the year of the transfer, and sum to 80% to 85% of the groundwater extracted for the transfer.

The WaterFix Final EIR/EIS states that for groundwater substitution transfers, a minimum allowance of 12% for impacts on stream flows (page 23 in WaterFix Appendix 5C), or a stream depletion factor (SDF) of 13% as required in DWR's 2016 groundwater substitution transfer checklist[1]. This minimal value is required unless it can be shown that the well(s) used in the transfer doesn't have a significant hydraulic connection to surface water system tributary to the Delta. Because the actual cumulative impact from groundwater substitution transfers to the surface water bodies in the area of groundwater extraction is closer to 80% or 85% of the volume of water transferred, based on the results of the USGS and DWR Central Valley groundwater models, the year-of-transfer allowance of 12% or 13% is inadequate to mitigate the long-term losses in surface water caused by a groundwater substitution transfer and inadequate to mitigate the environmental impacts caused by the transfer.

The possibility that a pumping well in the Sacramento Valley or Delta can be hydraulically disconnected from surface waters is likely very small. As the WaterFix Final EIR/EIR notes, the Sacramento Valley has been divided into subbasins, but these subbasins are not *hydraulically distinct, have a high degree of interconnection, and tend to behave as single extensive alluvial aquifer systems* (page 3 in Chapter 7). The WaterFix Final EIR/EIS also describes the tributary streams to the Sacramento River as almost *all losing streams (water from the streams enters and recharges the groundwater system) in their upper reaches, but some transition to gaining streams (water from the groundwater enters the streams) farther downstream closer to their confluences with the Sacramento River* (page 43 in Chapter 7). The WaterFix Final EIR/EIS goes on to state that *groundwater modeling studies of the Sacramento Valley suggest that, on average, the flux of groundwater discharging to the rivers is approximately equal to the quantity of water that leaks from streams to recharge the aquifer system*. The fact that the groundwater subbasins of the Sacramento Valley *have a high degree of interconnection,* and that stream flow losses in upper tributaries eventually become groundwater discharging to rivers or streams at lower reaches, shows that even a well that is hydraulically disconnected from the adjacent stream can cause down gradient impacts to surface flows by "capturing" water that would have eventually discharged to a down gradient

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http://www.water.ca.gov/watertransfers/docs/Water_Transfers_Groundwater_Substitution%20Checklist.pdf accessed 11_21_2017 river. Thus, the 80% to 85% capture of surface waters by Central Valley groundwater pumping should be applied even to hydraulically disconnected wells.

The accumulation of 80-85% capture from a pumping well associated with a groundwater substitution transfer occurs for many years beyond the year-of-the-transfer loss assumed in the WaterFix Final EIR/EIS and DWR's transfer procedures (also see comments 3A to 3F in AquAlliance Exhibit 5 in WaterFix Part 1). In addition, surface water losses from groundwater substitution transfers may occur on streams, rivers or other water bodies that the 12% or 13% transfer allowance can't reach, such as tributaries to the river where the transfer allowance is discharged. See my comment 3F, and AquAlliance Exhibits 24 and 25 in WaterFix Part 1 for discussion of impacts to multiple surface waters, and to counties from 2015 Glenn-Colusa Irrigation District's proposed supplemental water supply project (GCID, 2015). At any given well, the percentage of capture that occurs each year following the pumping for the transfer is approximately the same regardless of the volume pumped, thus the duration of capture is approximately the same. A shorter duration of capture could occur if the pumping well is closer to a stream or surface water body. In that case the rate of capture each year would be higher, but in the end the amount of capture should be equal to or greater than the 80% to 85% estimated by the USGS and DWR groundwater models.

Therefore, the long-term capture of surface water from groundwater substitution transfer pumping will likely approach 80% to 85% regardless of the amount or location of pumping. The areas of pumping impacts by the BOR/SLDMWA 10-Year Long-Term Transfer Project are likely to be much of the same areas affected by future WaterFix transfers up-stream of the Delta because many of the same sellers will participate in both projects. The immediate area of impact will vary with the location, duration and volume pumped, but the amount of capture and the duration of loss to surface waters will closely resemble those identified by the USGS and DWR groundwater models, the 2009 groundwater substitution transfers (CH2M Hill, 2010), and 2015 Long-Term 10-Year Transfer Project (BOR/SLDMWA, 2015).

B. Through the process of capture a groundwater substitution transfer in the Sacramento Valley eventually removes from surface waters 80-85% of the groundwater pumped, while the remained water is taken from aquifer storage (Konikow and Leake, 2014). Although crop idling transfers don't extract groundwater, this method of transfer does take surface water out of basin of origin, in this case the Sacramento Valley, while at the same time reducing the amount of deep percolation or recharge from irrigation. The WaterFix Final EIR/EIS assumes that crop idling won't exceed 20 percent of the irrigated lands and with that limit the maximum water available for transfer will be 507,000 AFY (page 22 in Appendix 5C). The reduction in irrigation water deep percolation caused by crop idling transfers will depend on the type of irrigation, crop type, duration of irrigation, irrigation efficiency, and underlying soils. A crop idling transfer will cause a loss to groundwater storage by the amount that would have occurred without the transfer because of the loss of deep percolation. AquAlliance Exhibit 14 in my Waterfix Part 1 testimony provides a table of the DWR's C2VSim groundwater model estimates for water years' 2000-2009 annual agricultural water deliveries, groundwater pumping, M&I surface water deliveries, and M&I groundwater pumping (sum = 6,740,222 AFY), and an estimate of annual groundwater recharge (1,173,639 AFY). Using the values listed in AquAlliance Exhibit 14, the estimate of annual recharge from applied water from all sources is approximately 17%. If the M&I surface water deliveries and groundwater pumping are excluded, the sum of agricultural applied water is now 6,140,362 AFY. The percentage of groundwater recharge to agricultural applied water is approximately 19%. These values are within the range of the 15% to 20% loss in aquifer storage, depletion fraction, resulting from groundwater substitution transfers. A maximum crop idling transfer of 507,000 AFY might decrease groundwater recharge by approximately 86,200 AFY to 96,300 AFY, while a maximum groundwater substitution transfer will eventually reduce aquifer storage by 60,000 AFY to 80,000 AFY. Therefore, implementing crop idling transfers could remove a source of groundwater recharge needed to backfill the aquifer storage lost through the groundwater substitution transfers.

C. Conveyance of water generated by Sacramento Valley cross-Delta transfers using the WaterFix tunnels may cause an increase in impacts to the Delta by reducing the amount of surface water in the Delta at various times, which lowers the surface water elevation in the Delta, which in turn reduces the amount of seepage into the Delta groundwater system and/or change the quality of the seepage water. The groundwater substitution or crop idling transfers to buyers south of the Delta can cause impacts to the Sacramento Valley environment because the impacts are the result of upstream actions that occur regardless of the method of conveyance through the Delta. In my comment 4 of AquAlliance Exhibit 5 in WaterFix Part 1, I also discuss the potential impacts to the Delta from increases in groundwater substitution transfers as a result of increases in pumping and/or reduction in groundwater recharge from crop idling transfers that may cause an expansion of the north-south oriented groundwater depression east of the Delta (see AquAlliance Exhibit 204). Groundwater levels at the center of this depression are below sea level with the depth in some areas ranging from 30 feet to 70 feet below sea level. In addition to potential changes in river seepage and groundwater elevation from reduction in Delta flows with operating the WaterFix tunnels, there are additional potential environmental impacts to the Delta and adjacent lands from the WaterFix tunnels as a result of the construction of a 39-mile long, 40-foot inside diameter impermeable groundwater barrier across the Delta. This impermeable barrier could alter the quantity and quality of groundwater flow, flow directions, and rates of flow in Delta's shallow groundwater (see my comment 1 in this WaterFix Part 2 testimony). Changes in the shallow groundwater could impact Delta aquatic habitat and GDE such as riparian vegetation, plants, and wetlands, and thereby impact the wildlife that depends on these habitats. Changes in groundwater flow direction and quantity could impact areas by increasing groundwater levels, and seepage pressure, or decrease groundwater levels by redirecting upgradient sources of water. All of these impacts may occur at the same time just at different locations.

Because the WaterFix Final EIR/EIS fails to analyze the potential impacts from cross-Delta transfers from up-stream water sources, which include groundwater substitution and crop idling transfers, the environmental analysis of the impacts to Sacramento Valley and Delta groundwaters, surface waters, and the habitats and wildlife that depend on these waters is inadequate. Therefore it lacks adequate monitoring to identify and mitigation measures to remedy future operations' impacts, many of which will likely occur and be similar to past transfer impacts.

D. The Sacramento Valley has a number of streams, rivers and areas that are considered critical habitat, and areas that are managed as wildlife refuges or have conservation easements. These critical habitats and wildlife areas can be affected when surface water is reduced, and/or groundwater levels are lowered by groundwater substitution or crop idling transfers. The BOR/SLDMWA 10-Year Long Term Transfer Project simulated the areas of potential impact in Sacramento Valley using several climate scenarios. AquAlliance Exhibits 215A, 215B and 215C show the drawdown results for three aquifer intervals based on the September 1990 simulated hydrologic conditions. The 1990 simulation period represents *the fourth year of a multi-year drought with transfers occurring in each year of the drought* (see Section 3.3.2.4.2 in BOR/SLDMWA Draft EIS/EIR). This simulation of a multi-year drought may represent a worse-case scenario, but the simulation does give a frame of reference for understanding the potential impact areas from transfers in the Sacramento Valley. Water resources in California should be managed to address issues in times of drought.[2]

The following is a list of eight wildlife map sets, attached as exhibits, that show the areas of critical habitat or wildlife management in the Sacramento Valley overlain with outlines of the 1-foot drawdown areas for the BOR/SLDMWA 10-yr transfer 1990 simulations. There are three 1990 simulation drawdown outlines, shallow (aquifer depth approximately 35 feet), intermediate (aquifer depth approximately 200-300 feet), and deep (aquifer depth approximately 700-900 feet). This set of maps shows how diverse the plants and wildlife, and environment are in the Sacramento Valley, and how many of these areas may be affected by cross-Delta transfers. In addition to the map sets, AquAlliance Exhibit 224 provides a list without detailed geographic references of Special-

[2] https://ca.water.usgs.gov/data/drought/

Status animals and plants that have the potential to occur in both the seller and buyer areas of the BOR/SLDMWA 10-Year Long Term Transfer Project (from Appendix I in BOR/SLDMWA, 2015). Note that AquAlliance Exhibits 223A, B and C use a base map developed on the August 1997 version of California Department of Fish and Wildlife's Natural Diversity Database. Species per section maps using a more recent version of the database weren't publicly available. The following is a brief description of the attached wildlife exhibits.

- AquAlliance Exhibits 216A, B and C – Critical habitat for Chinook Salmon in the Sacramento Valley with simulated 1990 shallow (A), intermediate (B), and deep (C) drawdown from groundwater substitution transfers. Source is CDFW GIS Clearinghouse.

- AquAlliance Exhibits 217A, B and C – Critical habitat for Steelhead in the Sacramento Valley with simulated 1990 shallow (A), intermediate (B), and deep (C) drawdown from groundwater substitution transfers. Source is CDFW GIS Clearinghouse.

- AquAlliance Exhibits 218A, B and C – Critical habitat for Sacramento Valley all layers except Chinook and Steelhead with simulated 1990 shallow (A), intermediate (B), and deep (C) drawdown from groundwater substitution transfers. Source is CDFW GIS Clearinghouse.

- AquAlliance Exhibits 219A, B and C – Critical habitat for U.S. Fish and Wildlife vernal pools in Sacramento Valley with simulated 1990 shallow (A), intermediate (B), and deep (C) drawdown from groundwater substitution transfers. Source is CDFW GIS Clearinghouse.

- AquAlliance Exhibits 220A, B and C – California Department of Fish and Game owned and operated lands and conservation easements in the Sacramento Valley with simulated 1990 shallow (A), intermediate (B), and deep (C) drawdown from groundwater substitution transfers. Source is CDFW GIS Clearinghouse.

- AquAlliance Exhibits 221A, B and C – Wetland areas and rice fields in the Sacramento Valley of California with simulated 1990 shallow (A), intermediate (B), and deep (C) drawdown from groundwater substitution transfers. Source is Ducks Unlimited from Northern California Water Association web site.

- AquAlliance Exhibits 222A, and B – (A) Groundwater dependent wetlands in northern California, (B) Groundwater dependence index in northern California. Source is Howard and Merrifield, 2010.

- AquAlliance Exhibits 223A, B, C and D – Map of Federally listed species in California, number of species per section per CDFW Natural Diversity

Database, data date August 1997. Exhibit 223A is full California map with legend. Maps 223B, C and D show Sacramento Valley with with simulated 1990 shallow (A), intermediate (B), and deep (C) drawdown from groundwater substitution transfers. Source is California Department of Pesticide Regulation web site.

- AquAlliance Exhibits 224 – Special-Status animals and plants with potential to occur in the area of analysis, from Appendix I – BOR/SLDMWA 10-Year Long Term Water Transfer Final EIS/EIR, March 2015, pp. 74.

3. <u>Potential Environmental Impacts from Construction of WaterFix Project Alternatives 4, 4A, 2D, or 5A Through the California Delta Gas Fields</u>

The WaterFix tunnels of Alternatives 4, 4A, 2D, or 5A will have intake structures on the Sacramento River near Clarksburg and Courtland and dual 40-foot inside diameter tunnels that run south across the central portion of the Delta to the Clifford Court Forebay (see AquAlliance Exhibit 203). In Chapter 26 – Mineral Resources, the WaterFix Final EIS/EIR discusses the potential impact of the tunnels on the availability to extract natural gas from the Delta and states that Alternatives 4, 4A, 2D, and 5A would result in a 352 acres in the Delta being lost for access to the natural gas fields (page 26-1 and Figure 26-0). Section 26.1.2.2 discusses the oil and gas resources of the project area and lists in Table 26-2 the type and number of oil and gas wells by county with a total of 3,439 known wells. Figure 24-5 in Chapter 24 of the WaterFix Final EIR/EIS give a map of the wells in the WaterFix project area. The earliest natural gas extraction is said to have been in 1854 in San Joaquin County with greatest production occurring in the vicinity of the Delta (page 26-7 in Chapter 26 of the WaterFix Final EIR/EIS). Today there are 21 natural gas fields in San Joaquin county (see Figure 26-2). The Rio Vista gas field in Solano County is the largest field producing non-associated gas (gas not found with oil) in California, and has been producing since 1936 (page 26-5). In addition, there are at least 9 other natural gas fields in Solano County. AquAlliance Exhibits 225A, B, C and D are maps of the oil and gas fields and wells along the approximate location of the Alternative 4, 4A, 2D and 5A tunnel alignment. These maps are taken from the California Department of Conservation's Division of Oil, Gas and Geothermal Resources (DOGGR) Well Finder web site.[3]

Information on the potential hazards from constructing and operating the WaterFix project are given in WaterFix Final EIR/EIS Chapter 24 – Hazards and Hazardous Material. Chapter 24 notes that active oil and gas wells occur within the Waterfix project area. Most of these wells are used for natural gas extraction (Section 24.1.2.3 on page 24-5). Section 24.1.2.3 states that approximately 3,400 oil and gas

[3] DOGGR Well Finder web site: https://maps.conservation.ca.gov/doggr/welfinder/#close (accessed on 10_15_2017)

wells have been drilled in the WaterFix project area since 1936 and *many of these wells are present along the proposed water conveyance facilities alignments under consideration for the action alternatives.* The section also states that locations of active wells are relatively easy to determine, but *older oil and gas wells may have been abandoned or shut-in without highly detailed location data*. In addition, Chapter 24 warns that:

> *Additionally, active, abandoned, and shut-in oil and gas wells may be present in areas where excavation is planned. Improperly sealed natural gas wells have the potential to act as natural gas conduits from deep reservoirs to shallow strata where flammable gases may pose hazards to excavation or tunneling activities. The locations of many abandoned or shut-in wells may be unknown due to inadequate or missing data or poor record-keeping* (page 24-6).

The potential hazards from construction of the WaterFix tunnels and facilities under Alternative 4 (presumably applicable to Alternatives 4A,, 2D, and 5A) are given in Section 24.3.3.9 - Impact Haz-1 on page 24-144 of Chapter 24. The hazards from natural gas accumulation in the water conveyance tunnels are discussed on page 24-148, where it states that during construction there is a potential for gas to accumulate at flammable or explosive concentrations in the tunnel bores or other excavations. The gases that might accumulate include methane generated from peat or organic soils, or natural gas from deep reservoirs by way of improperly sealed well boreholes, or natural conduits such as faults or fractures (page 24-148). The section states that there are no active wells, but there are 15 known inactive oil or gas wells along the proposed Alternative 4 (4A, 2D, and 5A) project alignment. Also that Alternative 4 (4A, 2D, and 5A) tunnels may require safety measures under Cal-OSHA, or the Federal Mine Safety and Health Administration (MSHA) because of the presence of natural gas wells along the alignment. The WaterFix Final EIR/EIS leave to a future study an evaluation of how the gas fields along Alternative 4 (4A, 2D, and 5A) could be affect the construction of the tunnels.

Other potential environmental impacts associated with constructing the WaterFix tunnels through natural gas fields that don't appear to be discussed in the WaterFix Final EIR/EIS include: (1) tunnel construction disturbance of the surrounding soils or boring vibrations that damage or rupture the seals in nearby abandoned, inactive or active oil or gas wells; (2) encountering an abandoned gas or oil well whose location is unknown or is improperly located; (3) procedures that will be used to identify the presence of an oil, gas, or water well in the path of the tunnel during construction; (4) how the 15 known inactive wells be modified to allow for the tunnel construction while maintaining the well seal; and (5) procedures that will be used should the tunnel boring machine encounter and/or be damaged by a known or unknown well casing. All of these issues have a potential to cause significant impacts to the environment if proper monitoring and mitigation measures aren't implemented. The potential for impacts from construction and operating the WaterFix tunnels in a natural gas resource area should be analyzed, and monitoring and mitigation measure provided as part of the WaterFix project environmental review and permit documents, not left to a future study. Environmental impacts and questions that should be addressed include:

- Is there a potential for natural gas or saline water to migrate into shallow groundwater aquifers and contaminate the water supply or possibly create a flammable or explosive buildup of natural gas from disturbance of soils or excessive boring vibrations that damage the well seal or well plug of a gas well? What is the minimum setback distance from the tunnel boring needed to maintain well seals and plugs?

- What procedures will be implemented to identify and prevent the tunnel-boring machine from unexpectedly encountering a well? These procedures are needed because documentation of actual well locations and well abandonment in the past may not be up to current standards. Thus, there is a potential that more than 15 inactive wells will be encountered along the WaterFix tunnel alignment. What environmental impacts might be caused in the process of finding unknown wells, such as subsurface excavations in areas where a well is thought to be located?

- How will the known 15 inactive wells be modified for the tunnel construction? Will there be surface excavation of these wells down to 160+ feet depth to cut off and remove the well casing? How will the remaining well plug and borehole seal be tested to ensure the well continues to be properly abandoned? What happens if the well is found to be improperly plugged, sealed and/or abandoned? What are the procedures and associated environmental impacts that will be used to re-seal and re-abandon a well, if it is necessary?

- What are the potential environmental impacts from the tunneling machine unexpectedly encountering a well? What happens if the tunneling machine needs to be repaired? A recent tunneling machine encounter with a well casing in Seattle required that the cutting head be brought to the surface for repair.[4] This required that a shaft be constructed down to the tunneling machine so that a crane could lift the cutting head to the surface. Excavating this type of shaft down 160 feet and the road construction needed to allow heavy equipment to cross the Delta have the potential to cause at least locally significant environmental impacts and follow-up mitigation measures to restore the disturbed lands. What are the procedures and mitigation measures that would be implemented should it be necessary to bring the boring machine to the surface somewhere along the tunnel alignment at other than a planned locations?

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[4] See reports of incident at: https://www.bloomberg.com/graphics/2015-bertha/ and https://www.seattletimes.com/seattle-news/bertharsquos-nemesis-119-foot-steel-pipe/

Conclusions for the WaterFix Part 2 testimony

Based on my testimony given above I have the following conclusions:

1. The construction of the WaterFix tunnels will create a 39-mile long, 40-foot high impermeable barrier across the shallow aquifer systems in the Delta, which can cause a number of environmental impacts. The tunnels will likely cause some disruption of horizontal and vertical flows within the shallow aquifers. The results of the disruption will vary from disconnecting the aquifer system to re-orienting the flow directions. Groundwater may be forced to flow upward or downward possibly resulting in impacts to agriculture or near surface structures. The north-south oriented edge of the tunnel barrier may redirect groundwater into adjacent aquifers or into river channels, possibly increasing seepage in levees. East of the tunnel barrier, the disconnection with the source of the groundwater could reduce water levels or piezometric heads in the aquifers, causing an increase in vertical groundwater flow between aquifers that aren't disrupted by the tunnel barrier. A downward increase in vertical flow east of the tunnel barrier may cause increased seepage from shallow aquifers or surface water bodies. An upward increase in vertical flow could result in poorer quality deeper groundwater flowing upward into shallower aquifers causing a decrease in shallow aquifer water quality. The tunnel barrier may cause a further deepening in the depth of the north-south groundwater depression east of the Delta because of a lack of groundwater to supply the pumping wells.

2. Long-term capture of surface water from groundwater substitution transfer pumping in the Sacramento Valley will likely approach 80% to 85% regardless of the amount or location of pumping. The capture of surface waters will have a direct impact on the environment by affecting aquatic life from reduced flows, GDEs with lowering of the groundwater table, and the wildlife that depends on these habitats. The areas of pumping impacts by the BOR/SLDMWA 10-Year Long-Term Transfer Project are likely be the same areas affected by future WaterFix transfers up-stream of the Delta because many of the same sellers will participate in both projects. The immediate area of impact will vary with the location, duration and volume pumped, but the amount of capture and the duration of loss to surface waters will closely resemble those identified by the USGS and DWR groundwater models, the 2009 groundwater substitution transfers (CH2MHill, 2010), and 2015 Long-Term 10-Year Transfer Project (BOR/SLDMWA, 2015). The current requirement that a groundwater substitution transfer hold back 12% or 13% of the volume transferred is inadequate to compensate for the long-term loss in stream flow.

3. Although crop idling transfers don't extract groundwater, this method of transfer does take surface water out of basin of origin, in this case the Sacramento Valley, while at the same time reducing the amount of deep percolation or recharge caused by irrigation. An estimate of the percentage of deep percolation from

applied irrigation water ranges from 17% to 19% based on results on the DWR C2VSim groundwater model. The WaterFix Final EIR/EIS assumed maximum crop idling transfer of 507,000 AFY. Assuming the percentage of deep percolation calculated from the C2VSim model, the maximum crop idling transfers may decrease groundwater recharge by approximately 86,200 AFY to 96,300 AFY, while the maximum groundwater substitution transfer of 400,000 AFY will eventually reduce aquifer storage by 60,000 AFY to 80,000 AFY. Therefore, implementing crop idling transfers could remove a source of groundwater recharge needed to backfill the aquifer storage lost through the groundwater substitution transfers.

4. Conveyance of water generated by Sacramento Valley cross-Delta transfers using the WaterFix tunnels may increase impacts to the Delta by reducing the amount of surface water in the Delta at various times, which lowers the surface water elevation in the Delta, which in turn reduces the amount of seepage into the Delta groundwater system and/or changes the quality of the seepage water. The groundwater substitution or crop idling transfers to buyers south of the Delta can cause impacts to the Sacramento Valley environment because the impacts are the result of upstream actions that occur regardless of the method of conveyance through the Delta. Potential changes in river seepage and groundwater elevation from reduction in Delta flows with operating the WaterFix tunnels may cause expansion of the north-south oriented groundwater depression east of the Delta. Additional potential environmental impacts to the Delta and adjacent lands can be expected from the WaterFix tunnels as a result of the construction of a 39-mile long, 40-foot inside diameter impermeable groundwater barrier across the Delta. This impermeable barrier could alter the quantity and quality of groundwater flow, flow directions, and rates of flow in Delta's shallow groundwater. Changes in the shallow groundwater could impact aquatic habitat and GDE such as riparian vegetation, plants, wetlands, and thereby impact the wildlife that depends on these habitats. Changes in groundwater flow direction and quantity could impact areas by raising groundwater levels, and seepage pressure, or by lowering groundwater levels by redirecting upgradient sources of water. All of these impacts may occur at the same time just at different locations.

5. The Sacramento Valley has a number of streams, rivers and areas that are considered critical habitat, and areas that are managed as wildlife refuges or have conservation easements. These critical habitats and wildlife areas can be negatively affected when surface water is reduced, and/or groundwater levels are lowered with groundwater substitution or crop idling transfers. A set of eight wildlife map are attached as exhibits that show the areas critical habitat or wildlife management in the Sacramento Valley overlain with outlines of the 1-foot drawdown areas for the BOR/SLDMWA 10-yr Long-Term Transfer Project 1990 transfer drawdown simulations. There are three 1990 simulation drawdown outlines, shallow (aquifer depth approximately 35 feet), intermediate (aquifer depth approximately 200-300 feet), and deep (aquifer depth approximately 700-900 feet drawdown). This set of maps shows how diverse

the plants and wildlife, and environment, is in the Sacramento Valley, and how many of these areas may be affected by cross-Delta transfers.

6. The WaterFix tunnels of Alternatives 4, 4A, 2D, or 5A will have dual 40-foot inside diameter, 39-mile long tunnels that run south across the central portion of the Delta through a natural gas development area. The WaterFix Final EIR/EIS doesn't appear to discuss potential environmental impacts that might be caused by: (1) disturbance of the surrounding soils or tunnel boring vibrations that damage or rupture the seals in nearby abandoned or active oil or gas wells; (2) encountering an abandoned gas or oil well whose location is unknown or is improperly located; (3) the lack of procedures that will identify during construction the presence of an oil, gas, or water well in the path of the tunnel; (4) re-abandonment of the 15 known inactive wells, and possibly other unknown wells, that need to be modified to allow for the tunnel construction while maintaining the well seal; or (5) the lack of procedures should the tunnel boring machine encounter and/or be damaged by an unknown well casing. All of these issues have a potential to cause significant impacts to the environment and should be analyzed with monitoring and mitigation measure provided as part of the WaterFix project EIR/EIS and permit documents, not left to future study.

Executed on 26 of November, 2017 in Fair Oaks, California

Kit H. Custis

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List of AquAlliance Exhibits for WaterFix Part 2

AquAlliance Exhibit 200. Curriculum vitae of Kit H. Custis

AquAlliance Exhibit 201. Powerpoint presentation of Kit H. Custis Testimony for WaterFix Part 2 in pdf file format.

AquAlliance Exhibit 202. Written Testimony of Kit H. Custis for WaterFix Part 2.

AquAlliance Exhibit 203. Location of Conveyance Facilities Alignment for Alternatives 4, 4A, 2D, and 5A, taken from Figure ES-3 *in* 2016 WaterFix Final EIR/EIS.

AquAlliance Exhibit 204. 2017 Spring Groundwater Elevations in the Area of the Delta, from DWR Groundwater Information Interactive Map Application web site, accessed 11_14_2017.

AquAlliance Exhibit 205. The California Delta and the Mokelumne Alluvial Fan with approximately alignment of WaterFix Alternative 4, 4A, 2D and 5A added; from Figure 1 in Shlemon, 1971.

AquAlliance Exhibit 206. Geologic Cross-Section of California Delta and Mokelumne Fan sediments with approximately alignment of WaterFix Alternative 4, 4A, 2D and 5A added; from Figure 3 in Shlemon, 1971.

AquAlliance Exhibit 207. Map of Approximate High-Tide Shorelines Near San Francisco During the Past 15,000 Years with 5,000, 10,000 and 15,000 shorelines retraced; from Figure 6 in Atwater, 1977.

AquAlliance Exhibit 208A, and B. Superjacent Stream Channel Deposits in Sacramento County, California with approximately alignment of WaterFix Alternative 4, 4A, 2D and 5A added to sheet 2 of 2; from Figure 3 in DWR Bulletin 118-3, 1974.

AquAlliance Exhibit 209A, B, C, and D. Geologic Cross-Sections in Sacramento County, California with approximately alignment of WaterFix Alternative 4, 4A, 2D and 5A added to cross-sections E-E', F-F' and I-I'; from Figure 4 in in DWR Bulletin 118-3, 1974.

AquAlliance Exhibit 210. Isopach Map of 50-100 Foot Depth Interval, San Joaquin County, California with approximately alignment of WaterFix Alternative 4, 4A, 2D and 5A added; from Plate 7A in DWR Bulletin 146, 1967.

AquAlliance Exhibit 211A, B, and C. Areal Geology and Geologic Cross-Section for San Joaquin County Near Stockton, California approximately alignment of

WaterFix Alternative 4, 4A, 2D and 5A added; from Plates 2A, 3 and 4 in DWR Bulletin 146, 1967.

AquAlliance Exhibit 212. Table of Potential Sacramento Valley Sellers for 10-Year Long-Term Transfers; from Table ES-2 in BOR/ SLDMWA 10-Year Long-Term Water Transfer Final EIS/EIR, March 2015.

AquAlliance Exhibit 213. Figure of the Results of Water Budget Calculations of the Central Valley, California from USGS Central Valley groundwater model; from Figure 14 in Konikow and Leake, 2014.

AquAlliance Exhibit 214. Table of Supporting Data and References for Estimates of Groundwater Depletion including Central Valley, California; from Table S1 in Konikow and Leake, 2014.

AquAlliance Exhibit 215A, B, and C. Maps of Simulated Changes in Water Table (approximately 35 feet),and Groundwater Heads, (approximately 200-300 feet and 700-900 feet) Based on September 1990 Hydrologic Conditions; from Figures 3.3-29, 3.3-30, and 3.3-31 in BOR/SLDMWA 10-Year Long-Term Water Transfer Final EIS/EIR, March 2015.

AquAlliance Exhibits 216A, B and C. Critical habitat for Chinook Salmon in the Sacramento Valley with simulated 1990 shallow (A), intermediate (B), and deep (C) drawdown from groundwater substitution transfers. Source is CDFW GIS Clearinghouse.

AquAlliance Exhibits 217A, B and C. Critical habitat for Steelhead in the Sacramento Valley with simulated 1990 shallow (A), intermediate (B), and deep (C) drawdown from groundwater substitution transfers. Source is CDFW GIS Clearinghouse.

AquAlliance Exhibits 218A, B and C. Critical habitat for Sacramento Valley all layers except Chinook and Steelhead with simulated 1990 shallow (A), intermediate (B), and deep (C) drawdown from groundwater substitution transfers. Source is CDFW GIS Clearinghouse.

AquAlliance Exhibits 219A, B and C. Critical habitat for U.S. Fish and Wildlife vernal pools in Sacramento Valley with simulated 1990 shallow (A), intermediate (B), and deep (C) drawdown from groundwater substitution transfers. Source is CDFW GIS Clearinghouse.

AquAlliance Exhibits 220A, B and C. California Department of Fish and Game owned and operated lands and conservation easements with simulated 1990 shallow (A), intermediate (B), and deep (C) drawdown from groundwater substitution transfers. Source is CDFW GIS Clearinghouse.

AquAlliance Exhibits 221A, B and C. Wetland areas and rice fields in the Sacramento Valley of California with simulated 1990 shallow (A), intermediate (B), and deep (C) drawdown from groundwater substitution transfers. Source is Ducks Unlimited from Northern California Water Association web site.

AquAlliance Exhibits 222A, and B. (A) Groundwater dependent wetlands in northern California, (B) Groundwater dependence index in northern California. Source is Howard and Merrifield, 2010.

AquAlliance Exhibits 223A, B, C and D. Map of Federally listed species in California, number of species per section per CDFW Natural Diversity Database, data date August 1997. Exhibit 223A is full California map with legend. Maps 223B, C and D show Sacramento Valley with with simulated 1990 shallow (A), intermediate (B), and deep (C) drawdown from groundwater substitution transfers. Source is California Department of Pesticide Regulation web site.

AquAlliance Exhibits 224. Special-Status animals and plants with potential to occur in the area of analysis, from Appendix I – BOR/SLDMWA 10-Year Long Term Water Transfer Final EIS/EIR, March 2015, pp. 74.

AquAlliance Exhibits 225A, B, C, D. Maps of Oil and Gas Wells Along the WaterFix Alternatives 4, 4A, 2D, 5A tunnel alignment; from California Division of Oil, Gas and Geothermal Resources (DOGGR) Well Finder GIS web site, accessed 11_19_2017.