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Subject: Review of Technical Reports in Support of Water Rights Application No.30166, El Sur Ranch, Monterey County, California, May 2005

Water Right Application No. 30166 seeks to extract ground water from underflow at the mouth of the Big Sur River. The point of diversion is two existing agricultural irrigation wells located in the flood plain northwest of the river within the Andrew Molera State Park. The El Sur Ranch (ESR) has submitted three technical documents in support of their Water Rights Application. These documents provide data and technical analyses assessing the environmental impacts from the ground water pumping on the lower reach of the Big Sur River. The two ESR agriculture wells are called the Old Well and the New Well. A third, smaller well, called the Navy Well, is operated by State Parks and Recreation Department, and pumps groundwater from the same aquifer. At the request of the Department of Fish and Game, Agreement No. P0530003, I have reviewed the three technical reports listed below. This letter presents my findings and opinions on the hydrologic, hydrogeologic and biologic data and environmental assessment presented in these reports.

Hydrologeologic Investigation and Conceptual Site Model Within the Lower Big Sur River, by The Source Group, Inc. (SGI), dated May 20, 2005

Assessment of Habitat Quality & Availability Within the Lower Big Sur River: April-October 2004, by Hanson Environmental, Inc. (HER), dated March 11, 2005

Reasonable Beneficial Use-Land Use Study for El Sur Ranch Irrigated Pastures, Water Rights Application #30166, by Natural Resources Consulting Engineers, Inc. (NRCE), dated May 18, 2005

Based on my review and analysis of these reports, I have the following conclusions and recommend that the Department of Fish and Game consider these issues in their evaluation of the Water Right Permit No.30166:

- Results and conclusions from the 2004 study period may not represent the potential impacts from the maximum permit extraction rate or total volume.

- The pumping of the ESR wells results in a reduction in the flows of the Big Sur River as extracted ground water is recharged from surface waters.

- The depletion of surface water flows due to ESR well pumping is spread along several hundreds of feet of river reach. While the loss at any one location may be small, the cumulative loss can exceed 90% of the well yield for prolonged periods of pumping.

- Losses from the river due to pumping extend beyond the period of pumping as the aquifer is recharged. For the highly conductive water table aquifer in the study area, this extended depletion period may extend for several days after cessation of pumping.

- Additional hydraulic data and analysis are needed to document the upwelling of ground water in the area of water quality stations 7, 8, and 9 to demonstrate its presence, rate of inflow and response to ESR pumping.

- Documentation of the methodology for collecting water quality data is needed to evaluate the impact of short-term variations on the report's conclusions.

- Additional documentation and discussion of the saltwater model setup is needed to evaluate the applicability of the model results in assessing potential pumping impacts from the ESR well field on the rate and extent of saline water intrusion.

<u>Hydrogeologic Setting</u>

The mouth of the Big Sur River flows through an alluvial filled valley within Andrew Molera State Park that is approximately 1,500 feet wide (SGI Figure 3-3). The alluvial fill consists mostly of permeable, recent-age sand and gravels (see SGI Section 3.3.2 and well logs in SGI Appendix B). Elevation and thickness of the alluvial aquifer varies (SGI Figures 3-8, 3-11 and 3-12). Thickness of the alluvium at the New Well is approximately 33 feet (Appendix B). The saturated thickness of the unconfined aquifer at the New Well during the pumped well test was approximately 24 feet (Appendix N). Thickness of the aquifer increases to the south towards the ocean (SGI Figure 3-8) within the ancestral canyon of Big Sur River (SGI Section 3.3.2). The contours of SGI Figure 3-8 show the base of the alluvial aquifer filling a canyon cut into Franciscan bedrock. At the present shoreline, the elevation of the base of the alluvial aquifer is approximately 100 feet below sea level. Contours of the base of the alluvial aquifer suggest that the ancient river canyon extended inland with a northern branch trending towards the Old Well, and the main channel trending eastward beneath the central portion of the Creamery Meadow.

SGI Table 2-1 provides a summary of the well construction, and SGI Appendix B provides the well logs for recently constructed wells. Information on the design of the Old Well is minimal. The total depth of the Old Well is not available, although SGI Figure 3-8 shows the elevation of bedrock at approximately –27 feet mean sea level (msl), apparently based on geophysical data (SGI Figure 3-8). The well log of the New Well indicates a total alluvial depth of approximately 33 feet, with a screened interval between 14 and 32 feet below the ground surface (bgs). The well log for the Navy Well shows that total alluvial depth of approximately 38 feet, with a screened interval from 20 to 38 ft bgs.

Pumping well tests on the New Well conducted by Jones and Stokes in 1998 and re-evaluated by SGI for their 2005 report found that the transmissivity (T) of the unconfined aquifer ranges from approximately 53 to 71 square feet-per-minute, or 570,000 gpd/ft (gallons-per-day-per-foot) to 765,000 gpd/ft (SGI Appendix N). Hydraulic conductivity (K) for the alluvial aquifer was found to range from approximately 3,048 to 4,086 feet-per-day (ft/day), with an average value of 3623 ft/day (SGI Section 3.3.2). Alluvial materials filling the ancient river canyon below an elevation of negative 20 feet are identified as having large boulders and cobbles (SGI Section 3.3.2). The hydraulic conductivity of this lower boulder zone is estimated at 15,000 ft/day (SGI Sections 3.3.2 and 3.5.3). The alluvial aquifer is bounded by low permeability Franciscan bedrock and older terrace deposits (SGI Figure 3-3). Ground water flow in the Franciscan bedrock is interpreted to be an insignificant source of base flow (SGI Section 3.4.4). Contributions to base flow from ground water in the Older Terrace deposits are also minor, estimated at 463 acre-feet-per-year (ac-ft/yr) (SGI Section 3.44 and SGI Table 3-3). Hydraulic conductivity of the Older Terrace material is estimated at 100 ft/day (SGI Table 3-3), approximately 30 times lower than the alluvial aquifer.

The unconfined aquifer of the lower Big Sur River is in good hydraulic connection with the river channel (SGI Section 3.4.8). The 27-hour, 1150 gpm pumped well test of New Well by Jones and Stokes in 1998 found that the aquifer northwest of the river responded rapidly to pumping stresses. However, Jones and Stokes saw no effects from pumping in monitoring well JSA-05 located across the river from the well. The hydraulic gradient of the water table aquifer is approximately 0.002 during the times prior to and after pumping (SGI Section 3.3.3; Figures 3-14 ad 3-18). The estimated average ground water inflow to the Creamery Meadow area near cross-section A-A’ (SGI Figure 3-10) is approximately 3.45 cubic-feet-per-second (cfs) (SGI Section 3.3.2). The estimated underflow in the study area ranges from 3.16 to 3.81 cfs (SGI Section 3.3.2).

The quality of ground water at the mouth of the Big Sur River is influenced by the presence of the ocean. The discharge from fresh-water aquifers to the ocean typically creates a salt-water interface where denser saline ocean water forms a landward thinning wedge below the fresh water (Fetter, 2001). Seawater intrusion into coastal fresh-water aquifers due to over-pumping of wells has been extensively studied (Fetter, 2001; Freeze and Cherry, 1979; Cooper, H.H., Jr., and others, 1964). Tidal fluctuation can enlarge the width of the zone where fresh-water and saline-water mix (Fetter, 2001; Cooper, H.H., 1959).

The SGI report suggests that water quality and quantity in the Big Sur River adjacent to the study area is influenced by "upwelling" of ground water caused by a constriction of Franciscan bedrock near the mouth of the river (SGI Section 3.4.6.1). The width of the alluvial flood plain is approximately 800 feet (SGI Figure 3-8; Figure 3-12, cross-section D-D').

Ground Water Pumping Rates

The El Sur Ranch has extracted ground water from the lower Big Sur River since the 1950s (SGI Section1.0). The water is used to irrigate approximately 290 acres of pasture located on the terrace lands northwest of the wells (NRCE Figure 2-1 and SGI Figure 3-1). The Old Well has been pumping since 1950 and the New Well since 1975 (SCI Section 2.6.1). These two wells typically operate during the dry months, operating from late-April to mid-October during the 2004 study period of these three reports (Section 3.4.5). The volume of water pumped by each well is an estimate because neither well has a meter to measure total flow (SGI Section 3.4.5). Water Rights Application No. 30166 is requesting a water right for maximum annual diversion of 1,800 acre-feet (ac-ft) at a maximum rate of 5.84 cfs or 2,621 gallons-per-minute (gpm) (5.84 cfs * 7.48 gal/cu.ft. * 60 sec./min = 2,620.99 gpm).

During the 2004 DEIR study period, the Old Well pumped an average of 1.36 cfs (SGI Section 3.4.5) or approximately 610 gpm. The maximum pumping rate of the Old Well during the 2004 study period was 2.59 cfs (SGI Table 2-2) or 1,164 gpm. Pumping of the Old Well is controlled to prevent pump cavitation (SGI Section 3.4.3). The average pumping rate of the New Well during the 2004 study period was 1.86 cfs, or approximately 835 gpm, with a maximum rate of 3.57 cfs or approximately 1,600 gpm. During the 2004 study period, an estimated 1,136 ac-ft of ground water were pumped, approximately 63% of the 1,800 ac-ft requested in the permit. SGI reported that the average (mean) daily total extraction rate was 3.3 cfs (SGI Section 3.4.5). The daily pumping variation of these two wells during the 2004 study period is graphed in SGI Figure 3-30 and tabulated in SGI Table 2-2.

Based on the daily average pumping rates given in SGI Table 2-2, the combined pumping of the two wells equaled or exceeded the maximum (Application No. 30166) rate of 5.84 cfs, 2,620 gpm, on only three days during the 2004 DEIR study period, approximately 1.7% of the time (see SGI Figure 3-30). These three days all occurred within the first 10 days of pumping. Combined pumping rates exceeded 5 cfs, 2,240 gpm, only 13 % of the time, a total of 24 days, and only 30% of the daily pumping exceeded 4 cfs, or 52 days. A review of the statistics of these pumping data found that the pumping rates are skewed. The best estimate of data that are skewed is often the median value rather than the average. For the combined daily pumping of the ESR wells during the 2004 study period, the median rate was approximately 2.68 cfs, approximately 275 gpm less than the average rate of 3.3 cfs reported by SGI. Although the pumping during the 2004 study period is said to be within the 90 percentile of pumping for years 1975 to 2004 (see abstract page iii), the 2004 median pumping rate of 2.68 cfs is only about 45 percent of the 5.84 cfs rate requested in the Application No. 30166. As will be discussed below, estimates of the impact of ground water pumping at variable rates on a stream can be made by assuming the "average" of the pumping rates occurs throughout the period of extraction. Although there were periods where the rate of pumping was near the maximum Application rate, 22 of the 24 total days greater than 5 cfs, approximately 92%, were before July 12, 2004 when the first pumping-period water quality data were collected.

Therefore, the impacts observed during the 2004 study period may not represent the impacts from the maximum extraction rate of 5.84 cfs requested in Application No. 30166. In addition, the total ground water extracted is only a portion of the 1,800 ac-ft maximum applied for in the permit application.

Impacts of Pumping on Steam Flow

Central to the assessment of impacts from the proposed water diversion is the question of whether pumping the two El Sur Ranch irrigation wells has an effect on the flow of the lower Big Sur River. The SGI report addresses this issue and summarizes their finding in Section 3.4.8.2. Evaluation of the effects of pumping on river flows was done primarily at Transect #2 which is approximately 300 feet from the ESR 10A/B/C cluster of monitoring wells.

An assessment of the effects of increasing the pumping from one well to two wells is shown in SGI Figure 3-35 which plots the water levels from mid-September to early October in 2004 at Velocity Transect #2 and ESR 10-B monitoring well. Figure 3-35 shows that the changes in water levels at each location differ substantially. The conclusion SGI draws from this data is that the increase in pumping has only a half-inch change in the surface water elevation of the stream (Section 3.4.8.2) a minor amount. A follow up comparison was made in mid-October 2004 when both wells were turned off (SGI Figure 3-36). Following cessation of pumping on October 16, 2004 there was no immediate rise in surface water elevation. The surface water elevation began to rise the following day approximately 5 inches higher by October 18th. A rain event on October 17th and 18th may have contributed to the increased flow. SGI apparently reached the conclusion that the change in surface water level after October 16th is due to runoff as they state that no noticeable effect on the surface water elevation was noted (SGI Section 3.4.8.2). I offer the following observations and analysis on the potential impacts of the ESR well pumping on flows in Big Sur River.

The impacts of a well pumping and unconfined aquifer adjacent to a hydraulically connected stream are well studied (Butler, and other, 2001; Chen and Shu, 2002; Chen Yin, 2004; Glover, 1959; Hantush, 1965; Hunt, 1999; Hunt and others, 2001; Jenkins, 1968, 1969; Nyholm and others, 2002; Sophocleous and others, 1995; and Zlotnik and others, 1999). The effects of ground water extraction on the stream are controlled by a number of factors including the hydraulic characteristics of the aquifer and the stream bed, the distance between the stream and well(s), the width and depth of the stream and aquifer, distance from the well(s) to impermeable or recharge boundaries, and the orientation of the stream channel. Although these factors influence the well-stream interaction, several simplified analytical models have been successfully used in evaluating stream losses from pumping wells, particularly with longer periods of pumping as is the case with the ESR well field (Miller and Durnford, 2005; Pattle Delamore Partners Ltd., and Environment Canterbury, 2000). Even though the site conditions are not ideally matched, the SDF model can be applied to the ESR well field to provide insight into the interactions between the aquifer pumping and stream flow.

The simplified analytical model often used is known as the “SDF” or Jenkins’ model (Miller and Durnford, 2005; Jenkins, 1968, 1969) based on a method originally proposed by Glover (1959). This analytical model uses a “stream depletion factor” or SDF which is a constant factor based on the hydraulic characteristics of the pumped aquifer and the distance to the well. In practice, a set of response curves is developed from which the percentage of the pumped well water depleted from the stream can be calculated for any given time after pumping starts (Miller and Durnford, 2005, Figure 1). In addition to stream depletion losses during pumping, the method can also calculate stream losses after cessation of pumping using the principle of superposition.

The results of applying the SDF method to the ESR well field finds that the stream should rapidly respond to the well pumping. After a day of pumping the New Well, the stream depletion rate is approximately 80% of the pumping rate. For the Old Well, the percentage is approximately 60% after a day. After 15 days the rate of stream loss is at or above 90% for both wells. After pumping stops, stream depletion continues creating a residual loss. For the New Well, stream losses occur for approximately one and a half days before the loss is reduced to below 10% of the pumping rate. For the Old Well, the residual depletion continues for 3 days before losses are below 10%. Jenkins (1968, 1969) showed that stream losses from variable pumping rates can be reasonably estimated by using the average rate of pumping. Miller and Durnford (2005) noted that when the rate of stream depletion approaches the rate of pumping, then approximately half of the accretion occurs within a length of stream centered on the well that is twice the closest stream-to-well distance. In the ESR well field, the average distance from the wells to the Big Sur River along the southeastern side of the flood plain is approximately 750 feet ([450 ft + 1000 ft]/2 = 725 ft). Twice this distance is approximately 1,500 feet. Transect#2 as well as water quality monitoring stations 7, 8, and 9 are within this distance. Along a reach length of 10 times the nearest distance approximately 87% of the stream depletion occurs.

The analysis of impacts of increasing pumping from one to two wells (SGI Section 3.4.8.2) noted that surface water levels decreased only a half-inch with increased pumping. This analysis does not fully evaluate the impacts of increased pumping. As the SDF model notes, loss of flow from a stream extends for some distance both upstream and downstream of the well. Unlike a direct surface water diversion where all flows are taken out at one location, stream depletion from pumping wells is cumulative. The measurement of surface water levels changes at one station only reflects a very small portion of the total loss. Applying the SDF model in the case of the September 2004 change in ESR well pumping rates, the losses at Velocity Transect#2 would be less than one half gallon-per-minute, but over the 1,500 feet of stream nearest the wells the cumulative loss would be approximately 1.2 cfs. The evidence of this increase in stream loss can be found by comparing the hydraulic gradient between Transect #2 and ESR-10B before and after the increase in pumping. Before September 19th, the Old Well was pumping at 2.55 cfs (SGI Table 2-2). After the New Well began, the total rate of pumping was 4.81 or an increase of approximately 88%. Because the flow of ground water follows Darcy's law (Q = KiA) an increase in flow (Q) should result in a proportional increase in hydraulic gradient (i) assuming that the aquifer hydraulic conductivity (K) and saturated cross-sectional area (A) remain nearly constant. With increased pumping the hydraulic gradient increases approximately 50 percent (SGI Figure 3-36), which agrees with the SDF model that half of the stream loss occurs within 2 times the nearest distance.

The purpose of this discussion is to demonstrate that the data from the 2004 study period shows a reasonable match to theoretical SDF curves even though the hydrogeologic setting is not the ideal assumed for the theory. Therefore, these theoretical curves might be used to evaluate the potential impacts of pumping the El Sur Ranch wells on flows in the Big Sur River. This is especially true for the impacts of extracting for a prolonged period at the maximum permit diversion of 5.84 cfs. Based on the SDF curves, pumping of the two El Sur Ranch wells at the maximum proposed permit rate for longer than 5 days results in losses to the river of approximately 80% of the pumping rate or approximately 4.7 cfs, with approximately 50% (2.34 cfs) of that loss occurring along an approximate 1,500-foot section of the river between the wells and Creamery Meadow. Although the average stream loss rate would be approximately 1.56×10^{-3} cfs per linear-foot, or less than one gallon per minute, the cumulative loss may be significant during low flow periods. This amount of loss at a single point is so small that it is within accepted standard of error for stream flow measurement.

Impacts of Upwelling on Water Quality of Stream

Surface water quality measurements were made along the Big Sur River at 21 stations located along the river from the mouth to the State Park parking lot on the eastern side of Creamery Meadow (SGI Sections 3.4.6, Figure 2-2). Water quality monitoring for temperature, electrical conductivity (EC), and dissolved oxygen (DO) began in April 2004 and ended in October 2004. Results of the water quality monitoring are shown in SGI Figure 3-31 for temperature and HER Figures 25 to 64. An initial pre-pumping set of measurements for temperature and EC was done on April 18, 2004. The first measurements taken during pumping were done on July 12, 2004, 82 days after the pumping began (see SGI Figure 3-31, SGI Appendix M and HER Figures 25 to 64 for graphic results of measurements). As a result of the surface water quality monitoring, a portion of the river nearby the New Well was identified as having anomalously low temperature, EC, and DO values (SGI Section 3.4.6.1 and Figure 3-31). These lower values occurred mostly at water quality stations 7 and 8 and occasionally at station 9.

Water quality measurements were taken for ground water in the monitoring wells and the production wells beginning in July or August 2004 (see SGI Appendix M and values labeled on graphic SGI Figure 3-31 and HER Figures 35 to 44). SGI states that the cause of this anomalous water quality is the inflow of ground water to the river due to a narrowing of the width of the alluvial aquifer at the mouth of the river (SGI Section 3.4.6.1 and Figure 3-3). This "upwelling" or inflow of ground water to the river is thought to occur throughout the summer irrigation season regardless of the pumping conducted (SGI Section 4.0). I offer the following observations and analysis on the potential impacts of the ground water upwelling on the surface water quality in the lower Big Sur River.

The basis for the groundwater upwelling condition is two fold. First, the anomalous quality of the surface waters at stations 7, 8, and 9 have values nearer those of ground water than surface water suggesting a ground water source. Second, the narrowing of the alluvial aquifer width would reduce the ability of ground water to flow, and the principle of continuity would require the ground water level to rise, resulting in a discharge to the river. A review of the data in the SGI and HER reports suggests that additional evidence is needed to document the hydrogeologic condition for ground water upwelling and demonstrate that pumping has no effect on the condition.

ESR indicates that the water quality data show ground water upwelling in the area of stations 7, 8, and 9 appears to have occurred throughout the 2004 study period regardless of pumping (SGI Section 4.0). To support this conclusion they cite the water quality data taken in April 2004, prior to turning on the pumps, and on October 28, when both pumps were off. A review of the water quality graphs (HER Figures 25 to 64) does not seem to clearly support the discharge of ground water during the April 18 and October 28, 2004 sampling event. During periods of pumping, the ground water upwelling hypotheses is supported at stations 7, 8, and 9 by a marked drop in the values of temperature, EC, and DO. However, for the two pre- and post-pumping days, the measured water quality parameters at stations 7, 8, and 9 are not anomalous from the trend of the stations above and below; suggesting the upwelling is not occurring or the river flows overwhelm the rate of ground water inflow masking the effect. During the irrigation season, some level of pumping was occurring on all but two days (SGI Figure 3-30 and Table 2-2). Water quality data were collected on only one of the non-pumping days, September 30, 2004. However, ESR has indicated in an October 10, 2005 response to DFG's comments that pumping was occurring on this day and the report will be modified (see response 9-2). Thus, there is no water quality data to conclude support of the hypothesis that the upwelling occurs outside of the pumping period.

In regards to the water quality data, the issue of the short term variability of the data may be of greater significance than the lack of non-pumping data. HER Figure 70 shows the hourly water temperature measurement taken at the bottom of the river channel at sampling station CT-3 and similar graphs are presented in SGI Appendix H. HER Figures 35 to 44 show the temperature data for different sampling periods and are an enlargement of data shown of SGI Figure 3-31. Since HER sampling station CT-3 is near water quality station 7 (HER Figure 9), it can be assumed that the variability in the hourly temperature similarly occurred to the station 7 data. HER Figure 79 shows that the CT-3 temperature typically fluctuates over a range of approximately 9° F between April and August 2004. For example, the pre-pumping April 18th temperature is reported at 55.40°F (HER Figure 35) which is near the lower limits of the hourly fluctuations on HER Figure 70. But during the same period, the upper limits of the hourly temperatures were approximately 64°F. Thus, the timing of when a sample is taken can have a significant impact on the interpretation. A review of the temperature data for the other sampling periods suggests that the reported data are not consistently taken at the same place in the fluctuations. For example, on September 2 the temperature at station 7 is reported as 57.87 °F (HER Figure 40) which is near the upper end of the hourly fluctuations data on HER Figure 70. On September 15th the reported value is nearer the middle of the fluctuations, while on September 30th the reported value is again near the upper end. On October 15th the reported temperature of 56.57 °F is nearer to the middle of the temperature fluctuations, HER Figure 70. The SGI discussion of river water quality data (Section 3.4.6.1) does not indicate whether the data presented in Figure 3-31 is taken from a particular time interval or statistically derived, i.e., average daily value. With the high degree of at station variability and the lack of documentation on how data were collected and selected for presentation, the water quality data at this time cannot be considered definitive evidence of the ground water inflow or upwelling in the area of water quality stations 7, 8, and 9.

The second line of evidence for ground water upwelling is the narrowing of the alluvial valley at the mouth of the Big Sur River. Although the surface width of the alluvium narrows, the surface width is not the only factor to consider in evaluating the impact of this bedrock constriction. SGI Figure 3-8 shows that the base of the alluvial aquifer increases from an elevation of approximately -30 feet msl near stations 7 and 8 (cross-section B-B' on SGI Figure 3-11) to approximately -80 feet msl at cross-section D-D' (SGI Figure 3-12) and eventually to an elevation approximately –100 feet msl at the ocean. Thus, the thickness of the alluvium continues to increase as the ancient river channel deepens from the area of upwelling to the present day shoreline.

Although there is no site-specific data on the hydraulic conditions in the area of ground water upwelling, i.e., monitoring wells and river stage data, there is regional hydrogeologic data that suggest that upwelling may not occur during periods of non-pumping. The flow of ground water is governed by Darcy's law, $Q = K^* I^* A$, and all three variables have an impact of the rate and volume of ground water flow.

The narrowing of the width of the alluvial aquifer occurs at an area where the thickness of the aquifer is increasing. The area of the alluvial aquifer at cross-section D-D is approximately 34,000 square feet (sq-ft) close to the 31,000 sq-ft aquifer cross-sectional area estimated at eastern end of the study area at cross-section A-A' (SGI Table 3-2). The hydrogeologic model for the mouth of the Big Sur River has very coarse-grained alluvial aquifer material deposited below an elevation of –20 feet msl (SGI Sections 3.3.2 and 4.0). This basal coarse alluvium is thought to have a hydraulic conductivity of approximately 15,000 ft/day, as used in the salt water intrusion modeling, a value approximately 4 times that of the overlying aquifer, average value of 3,626 ft/day found at the New Well (SGI Section 3.3.2). The ability of the alluvial aquifer to transmit water will be influenced by the higher hydraulic conductivity layer. Thus, even with a slight decrease in cross-sectional area, the rate of ground water flow in the aquifer at the mouth of the river may not be significantly lower if the hydraulic gradient is similar.

The hydraulic gradient during non-pumping conditions at the eastern edge of the study area, cross-section A-A' and in the area of ESR well field is approximately the same, 0.0026 versus 0.002, respectively (SGI Section 3.3.3 and Table 2-3). Influx of ground water at the eastern edge of the study area is estimated to average 3.45 cfs during the 2004 study period (SGI Section 3.3.2 and Table 2-3). No estimate was made of only the ground water outflow to the ocean is given (SGI Section 3.4.7.4). SGI Table 3-6B provides a combined runoff and underflow to the ocean of 16.7 cfs, but this was solved as part of the water balance. Ground water underflow in the alluvial aquifer is estimated to range from 3.16 to 3.81 cfs (SGI Section 3.3.2), but the non-pumping amount that reaches the ocean is not provided.

In order to document the nature of the ground water upwelling, additional water level data are needed on the river stage and ground water potentiometric head of both the southern and northern banks. In addition, an estimate of the actual seepage volume would be beneficial as this inflow volume is critical to evaluating the impacts of pumping.

Saltwater Intrusion Model

A density dependent flow and transport model was developed to evaluate the impacts of saline intrusion on the water quality of the El Sur Ranch wells (SGI Section 3.5.3). The model was a multilayer model, but used only two hydraulic conductivity values, 1,500 ft/day for the shallow alluvial and 15,000 ft/day for the deeper coarse-grained, boulder zone layer. Documentation for the model did not show the model extent of these two aquifer materials. The model did not simulate recharge or discharge to the river, but did simulate the upwelling ground water by increasing the pumping rate of the ESR wells by 50%. The model simulation period utilized the historic tidal fluctuations from June 15 to July 10, 2004. SGI concluded from the modeling that,

> *"… the high hydraulic conductivities associated with a boulder zone at depth in the alluvium, the high summer spring tides combined with pumping stresses and the density driven flow of a saltwater wedge are completely consistent with the interpretation that salinity impacts to the Navy and Old Wells are the result of subsurface saltwater intrusion and the movement of it accompanying diffusion front."* (SGI Section 3.5.4).

I offer the following observations and analysis on the saltwater model of the lower Big Sur River.

The discussion of alluvial aquifer characteristics (SGI Section 3.3.2) states that the coarse-grained, boulder zone alluvium fills the ancient river channel at the mouth of the river below a depth of –20 feet msl. The saltwater intrusion model assumed that this boulder zone extended along the “north valley wall” (SGI Section 3.3.2). The actual extent of this layer is not provided, but presumably it extends partially up the tributary drainage towards the Old Well. However, the –20 foot msl contour as shown on SGI Figure 3-8 extends much further inland, extending almost to the New Well and eastward well beneath the Creamery Meadow. In fact, it extends beneath the area of ground water upwelling near water quality stations 7 and 8. Because higher hydraulic conductivity layers can more easily transmit ground water, the results of modeling simulations are often dependant on placement. Additional information is needed on the extent of the high hydraulic conductivity to document the applicability of the simulation to the site conditions.

The setup of the saltwater model also reduced the hydraulic conductivity of the shallow alluvial aquifer to approximately half the value measured by the pumping well test of the New Well, 1,500 ft/day versus 3626 ft/day, respectively (SGI Sections 3.3.2 and 3.5.3). No reasoning was given for this reduction from the known value. As noted above, high hydraulic conductivity layers allow greater flow of ground water. A reduction in hydraulic conductivity would result in greater flows in the higher conductivity layers. Because the ESR wells are thought to be screened in the upper 30 feet of alluvial aquifer, a high percentage of the ground water extracted should come from the shallow zone. A reduction in the shallow zone hydraulic conductivity accompanied with an underlying zone of much higher hydraulic conductivity would likely result in higher rates of flow in the deeper zone. Additional information and discussion of the model setup is needed to justify the use of reduced hydraulic conductivity for the shallow alluvial aquifer.

The saltwater intrusion model did not simulate losses from the river due to recharge of the ground water. The loss of ground water due to upwelling was simulated by increasing the pumping rate of the ESR wells by 50% (SGI Section 3.5.3). The report doesn’t provide any data to justify this upwelling rate, which is 2.65 cfs or approximately 1,200 gpm. Modeling of the upwelling ground water loss at the ESR wells instead of the eastern edge of the model would likely reduce the extent that the saltwater migrates towards Creamery Meadow. The model could simulate the upwelling losses at water quality station 7 and 8 using one or more shallow wells along the trace of the river at those locations. The proper placement and quantity of the upwelling losses is important to evaluate the potential for pumping of the New Well to draw in saline waters. As noted above, pumping rates in the Old Well are restricted to prevent the pump from cavitating, the actual restricted rate was not provided in the SGI report. However, if Application No. 30166’s maximum rate of 5.84 cfs and 1,800 ac-ft/yr of diversion is granted, pumping of the New Well may allow for rates and durations not tested in the 2004 study period or yet simulated by the modeling effort.

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