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HYDRAULIC MODELING REPORT

BHE Renewable Salton Sea - Infrastructure

Imperial County, CA

02/05/2024

Prepared by:

Kiewit Engineering Group Inc

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ISSUANCE APPROVAL		
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CONTENTS

Table of Figures

1.0 INTRODUCTION

1.1 PROJECT DESCRIPTION

BHE Renewables, LLC (BHER) is an independent power producer that oversees unregulated solar, wind, hydro, and geothermal projects. Through its subsidiaries, Black Rock Geothermal LLC, Elmore North Geothermal LLC, and Morton Bay Geothermal LLC, BHER is planning to design, permit, and construct three new geothermal power plants in the Salton Sea Known Geothermal Resource Area (KGRA), adding to their ten geothermal plants currently in operation.

1.2 PURPOSE

The hydrotechnical model shows the overland flow during a large event on the Alamo River. This information can be used to develop mitigation measure to reduce the risk of flooding at the project locations. The purpose of the site planning is to obtain a floodplain permit from Imperial County pending coordination with the Imperial Irrigation District (IID) on finalizing the flood control mitigation measures. The model will also be used to make sure no private property, other than property owned by BHE Renewables, is negatively impacted during high flow conditions on the Alamo River.

2.0 WATERSHED

2.1 ALAMO RIVER PHYSICAL DESCRIPTION

The Alamo River starts near the US-Mexico border and drains into the Salton Sea. The discharge in the Alamo River is mostly comprised of agricultural return flows. However, high discharges recorded by the USGS river gauge on the Alamo River near Niland (10254730) indicate that runoff from large storm events will contribute significant discharge. The current Alamo River cross section was shaped by the 1904 flood that created the Salton Sea. This flood resulted in an incised channel, capable of conveying larger flows without spilling into the overbanks. In addition, it appears that dredge material from maintenance activities was placed along the riverbanks, resulting in an additional 2' to 3' banks along most of the river.

2.2 FEMA FLOOD HAZARD AREA

The Alamo River near the Salton Sea is formed in highly erodible alluvial material. Considering the potential of realignment of the Alamo River within the alluvial fan, the area surrounding the Alamo River near the Salton Sea is considered an approximate flood hazard zone by FEMA (Zone A). An approximate flood hazard zone means that no flood elevations have been established for the mapped inundation extent. It should be noted that the incised nature of the river will limit the risk of realignment considerably, with the placed dredge material on top of the embankments being at the greatest risk of failure.

2.3 HYDROMETRIC DATA

The flow conditions on the Alamo River show a torrential flood regime. Average flows in the river are low, but peak flows can be large. USGS gauge 10254730 reports peak daily average flows[1] of 4,500 cfs in 1977, and 4,000 cfs in 1983. The reported peak daily average flow in 1992 approach 2,500 cfs, while for the other years of record, the peak flow was near or below 2,000 cfs. During large events, the Alamo River will overtop its banks, as well as back flow into drainage ditches that could result in alternative flow paths to the Salton Sea. It is unclear how accurate the peak flow observations are for the extreme events, as well as the impact of sediment depositions on the flow measurements.

2.4 SINCLAIR ROAD BRIDGE

The Sinclair bridge over the Alamo River spans the entire waterway, with the deck elevation above the 100-year flood elevation. The bridge piers form a minor obstruction for the floodwater in the river. The roadway embankment of Sinclair Road creates a backwater in the overbanks of the Alamo River. While some flood waters might flow to the Salton Sea through an alternative flow path, most flow will continue through the bridge opening.

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[1] While the USGS typically reports Instantaneous Peak Flows, the provided qualification code on these data indicate the reported values are Maximum Daily Average Flows. See section 3.2 for a conversion factor.

2.5 GARST ROAD BRIDGE

Downstream of Sinclair Road, large floods are expected to flood the surrounding lands, creating alternate flow paths to the Salton Sea. While Garst Road south of the Alamo River is not expected to be inundated during a large flood, the area north of the Alamo River is lower and flooding should be expected. While the existing Garst Road bridge is not expected to be overtopped during a 100-year event, it is likely that pressure flow would occur during a large event due to the lack of clearance between the bottom girders and the flood water levels in the Alamo River.

2.6 CHANNEL MIGRATION AND STREAM WIDENING

As rivers flow, they gain or release energy, resulting in erosion or deposition of sediment. The river will adjust its width to accommodate the sediment load and channel slope. The erosion of one bank and deposition of sediment along the other bank results in a river laterally migrating. Both the stream width and channel migration are natural processes. However, they could result in damage to nearby structures like bridges.

While the banks of the Alamo River are made up out of highly erodible materials, vegetation on the banks provides protection against lateral migration of the river. Historical aerial photography does not indicate any active meandering of the Alamo River near the Salton Sea. Furthermore, the channel has a very confined flow path, and the bridge locations are visually outside the channel migration zone.

3.0 HYDROLOGY

3.1 HYDROMETRIC GAUGING NETWORK

The USGS operates the Alamo River gauge near Niland (10254730) at the mouth of the Alamo River. The drainage area of the station has not been determined. The discharge at the site is largely agricultural irrigation return flows. Mean Daily Flow (MDF) data is available since 1960 and 15-minute data is available since 1990. No adjustments were made for the slightly smaller drainage areas at the bridge location than the gauge location. It is expected that most runoff is generated in the basin headwaters.

3.2 FLOW DATA

The reported daily flows at the Alamo River gauge are the mean daily flow (MDF). The use of MDF data for structure design typically results in the design flow being underestimated. Bridge waterway designs should be based on the instantaneous peak flow (IPF), which could be considerably larger than the MDF values. The annual peak 15-minute flow was considered the Annual Instantaneous Peak Flow (IPF). Due to some missing values in the record, this yielded a 22-year record for annual IPFs. This was deemed too short to evaluate the 100-year flow, and the record was extended using the adjusted MDF record for the years without IPF data.

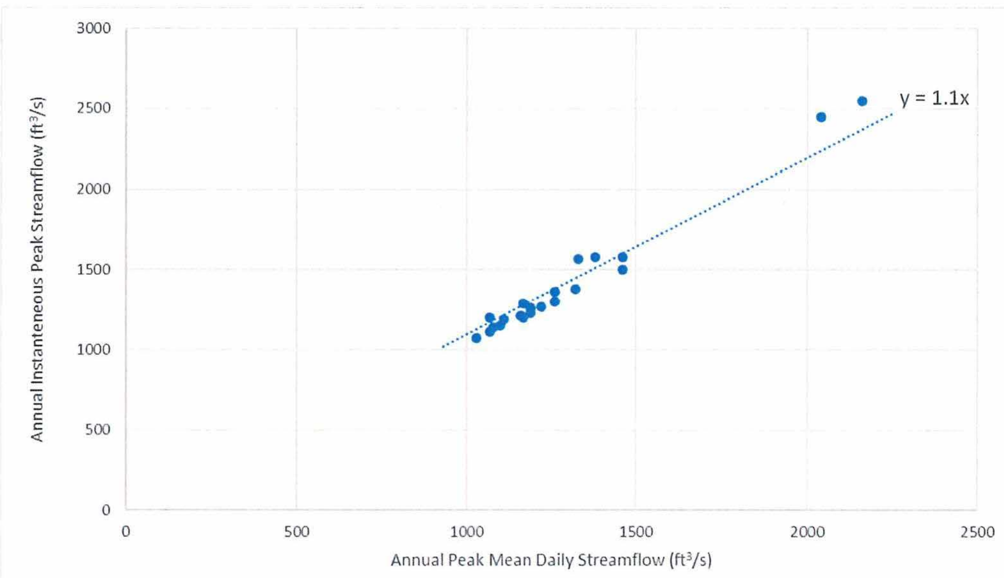

Figure 1. Correlation between Annual Instantaneous Peak and Mean Daily Peak Flows for the Alamo River

The adjustment was based on the overlapping record of the MDF and IPF. The 22-year overlapping record indicates the IPF is 10% larger than the MDF. For the years without IPF data, the MDF was scaled to provide a peak streamflow record of 62 years.

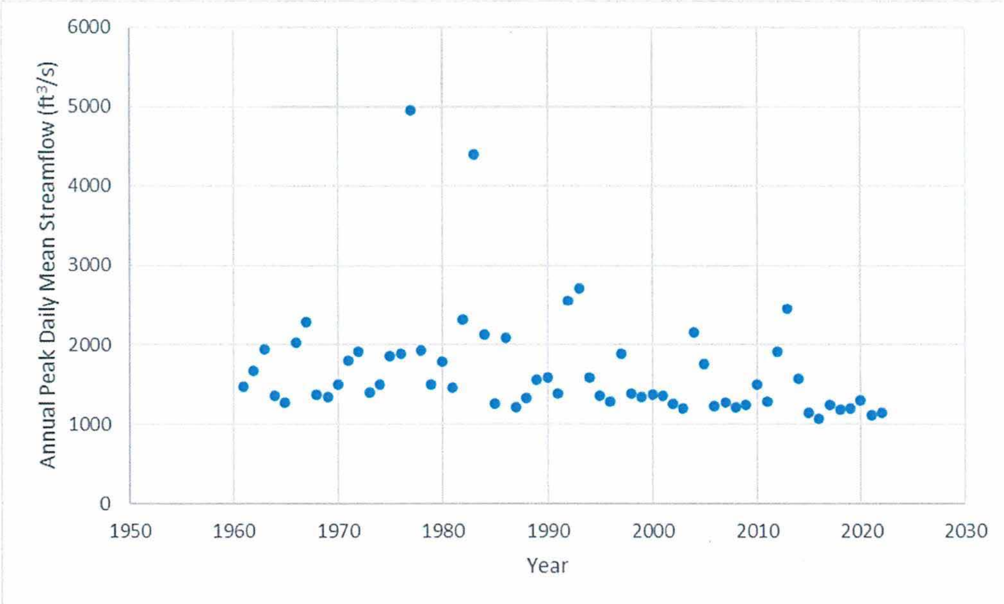

Figure 2. Annual Instantaneous Peak Streamflow at the Alamo River gauge near Niland

3.3 LOG PEARSON TYPE III (LP3)

Figure 3 shows that the resulting LP3 distribution closely matches the higher frequency observations but misses the extreme IPF from 1977 (4,950 cfs) and 1983 (4,400 cfs).

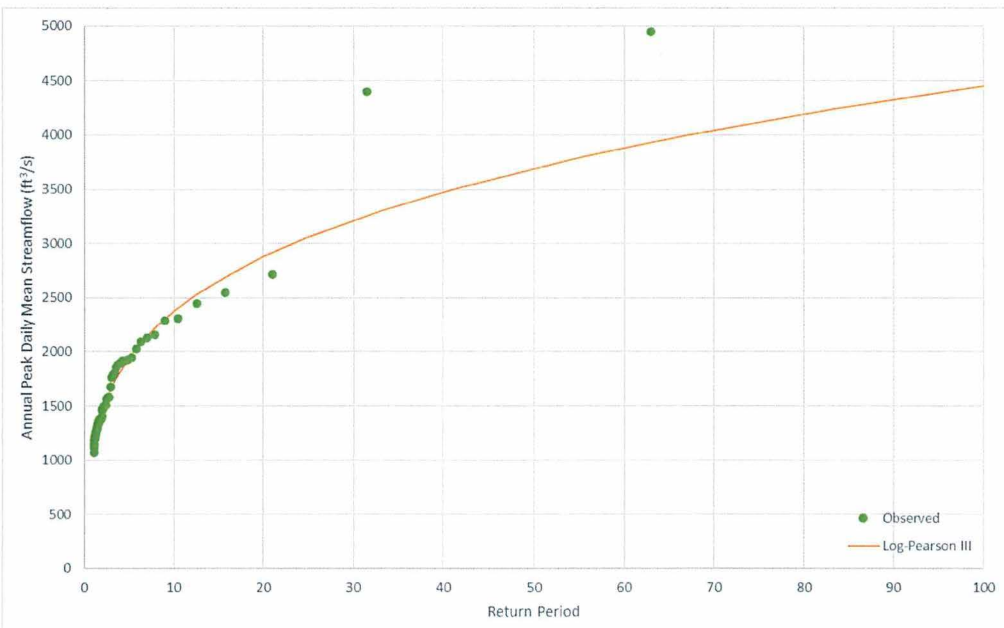

Figure 3. Extreme Value Analysis using LP3 for the Annual Instantaneous Peak Flow at the Alamo River

The results of the fitted distributions are listed in **Table 1**.

Table 1 *Instantaneous Flow Frequency at the mouth of the Alamo River*

Return Interval	Instantaneous Peak Flow (ft^3/s)
100-YEAR	4,450
50-YEAR	3,690
25-YEAR	3,060
10-YEAR	2,375
2-YEAR	1,460

4.0 HYDRAULIC MODELING

4.1 MODEL DEVELOPMENT

HEC-RAS 6.3 was used to model the Alamo River reach to obtain the velocities and water levels associated with the design flow. Due to the large floods early in the last century, the Alamo River is very incised. While the area should still be considered an active alluvial fan, the incised channels are expected to be relatively stable.

4.2 TERRAIN DATA DEVELOPMENT

Jacobs Engineering Group, Inc, (Jacobs) on behalf of BHER, provided the terrain data based on LiDAR. Care was taken to identify the embankment elevations correctly as vegetation on the embankments of the Alamo River obscured much of the embankments. Jacobs developed an automated algorithm that identified the bare ground through the vegetation canopy, while verifying for reasonable ground slopes. The terrain model was evaluated using multiple HEC-RAS simulations; for low flows, no water spilled out of the river, and as the flows were increased, water started to overflow in low lying areas. This indicated the automated algorithm correctly identified embankment elevations. Downstream of the Garst Road bridge, a section of dense vegetation obscured some of the LiDAR survey, resulting in a section of approximately 200 feet of the left bank not being identified in the terrain model. The embankment dimensions for this section were estimated based on available photography and the surrounding area and added to the terrain data.

The LiDAR data did not capture the bathymetry. A channel was burned into the terrain model and iterated until a baseflow of 600 ft^3/s resulted in water levels approximately lining up with the water surface indicated by the LiDAR. 600 ft^3/s is a typical low discharge for the Alamo River, and this approach will yield a slightly undersized channel, thus providing conservative water level elevations.

The Pumice drain runs along the south side of Sinclair Rd from near the Alamo River to the Salton Sea. The outfall culvert of the Pumice drain was included as a large box culvert in the terrain model.

4.3 GEOREFERENCING AND PROJECTION

The projection was in California State Plane, Zone 6.

4.4 TERRAIN ROUGHNESS

The terrain roughness was based on Chow (1959). The overbanks were considered agricultural lands with field crops and assigned a roughness of 0.040. The channel was assigned a roughness of 0.035, considering the relatively straight reaches and the vegetation encroaching into the channel. Approximately north of Hoober Road, the vegetation on the banks becomes dense. To reflect this, the vegetation was delineated and assigned a roughness value of 0.1, to reflect the density of the observed vegetation. Open water along the Alamo River was assigned a low roughness value of 0.02.

Table 2. Roughness coefficient.

Land Cover	Value
Overbanks	0.040
Channel	0.035
Vegetated Banks	0.100
Open Water	0.020

4.5 FLOW CONDITIONS

Based on the hydrological analysis presented in chapter 3, the selected design event in the HEC-RAS model was 4,450 ft^3/s.

4.6 DOWNSTREAM BOUNDARY CONDITIONS

The downstream boundary of the model is the Salton Sea. The water elevation of the Salton Sea was set at -237', as a single event on the Alamo River is not expected to impact the water level in the Salton Sea.

4.7 GEOMETRY

A perimeter was created along the Alamo River from just upstream of Peterson Road to the Salton Sea. Preliminary modeling showed that the 100-year flood will be largely contained in the Alamo River at this upstream location. Ample space was given within the perimeter to the left and right of the river, allowing for overland flow directly to the Salton Sea. Break lines were used to align the cells with the direction of flow, as well as to capture localized high ground and major farm ditches.

4.8 EXISTING BRIDGES

The piers of the existing bridges were added as ground modifications to reflect the pier dimensions and locations. The grid was refined around the piers to capture the piers.

4.9 MODEL SETUP

The HEC-RAS model setup, including calculation mesh, break lines, and the location of model boundaries is shown in Figure 4. Initial wetting of the model resulted in unrealistic water levels at the start of the model, and a restart file was created by slowly ramping up the flow to 600 ft^3/s, at which time a restart file was written. Based on the USGS gauge record, 600 ft^3/s was considered a low flow condition in the channel at which rate no flooding outside the channel and ponds should be expected.

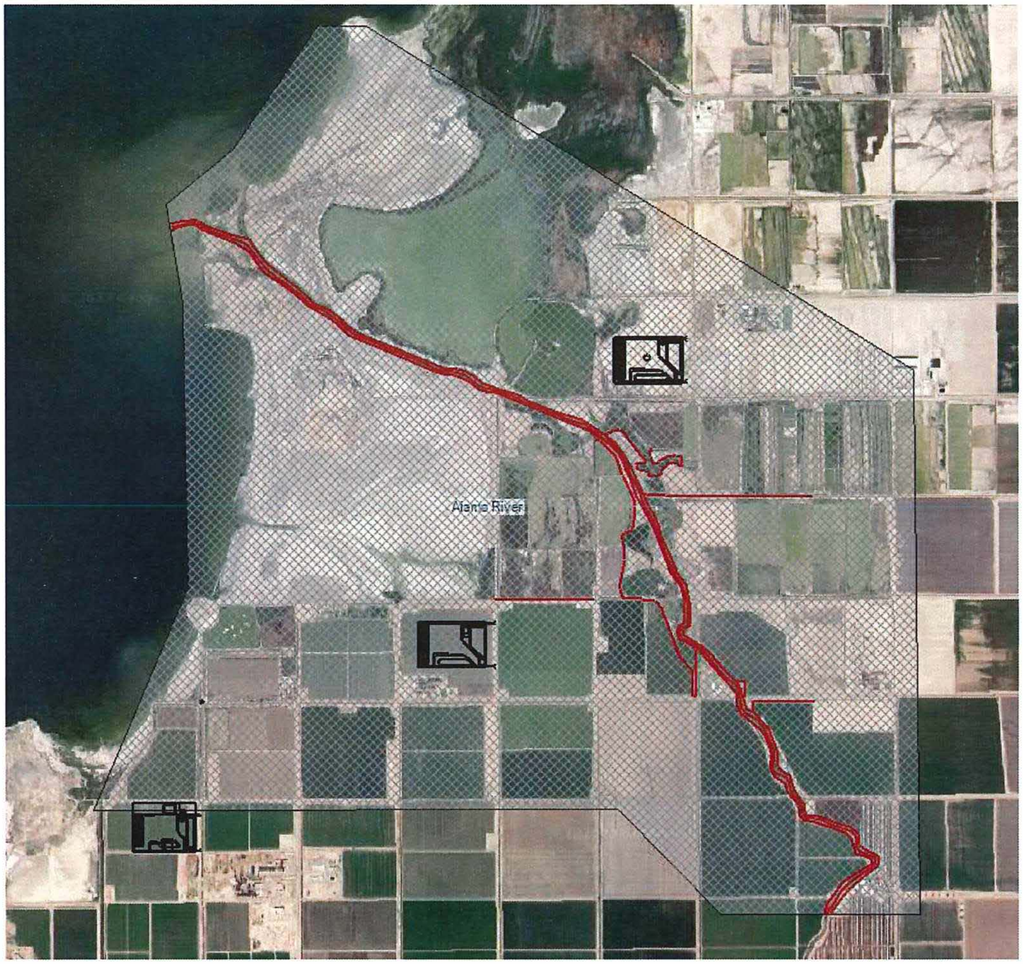

Figure 4. Alamo River Model Setup (break lines in red)

The 100-year model run started with the 600 ft^3/s base flow, then ramped up to 4,450 ft^3/s in 12 hours. The peak flow was maintained for 24 hours, after which it was brought back to 600 ft^3/s for the remainder of the run. This is considered a conservative synthetic hydrograph, but matched the observation record that shows that large flows can persists for a day or more. The longer run time allowed the model to identify areas subject to flooding from slow moving overland flow.

4.10 MODELING RESULTS (EXISTING CONDITION)

Figure 5 shows the floodplain during a 100-year event in the Alamo River. It shows that significant flooding outside the Alamo River starts just upstream of Sinclair Road bridge. The figure also shows that the Garst Road embankment acts as a barrier for surface drainage to the Salton Sea. The revetment on the west side of Garst road indicates the original purpose of the embankment was to keep the Salton Sea from encroaching east. As the Garst Road embankment blocks the drainage to the Salton Sea, the water fills up the low-lying lands and spills south over an access trail in the extension of Merkly Road. Once this parcel filled, the water spills west over Garst Road. The area to the west of Garst Road is protected on the North by a Salton Sea levee that currently no longer functions to protect the area from Salton Sea flooding but does obstruct the drainage of the Alamo River overflow to the Salton Sea. As a result, these parcels collect all water overtopping Garst Road, with evaporation or infiltration being the only natural means to evacuate the water from these areas.

Figure 5. Alamo River Q100 floodplain showing the Morton Bay, Elmore North, and Black Rock locations.

Additional details of the existing conditions for each of the project locations are included in the proposed conditions to allow for a direct comparison with the proposed conditions.

5.0 PROPOSED CONDITIONS

5.1 POWER PLANT DEVELOPMENT

Based on the HEC-RAS modeling of the existing conditions, Elmore North will be almost fully inundated, Morton Bay will have minor ponding water, and Black Rock is outside the flooded area during the 100-year event. The proposed terrain modifications are intended to keep the proposed sites out of the floodplain, while still providing a berm with a minimum height of two feet around the property in line with the requirements in Division 16 of the County of Imperial Codified Ordinances § 91605.00-C.2. See Chapter 6 for additional details.

5.1.1 Morton Bay

The flood waters of the Alamo River are kept out of the Morton Bay location by the W Schrimpf road embankment and a berm along the west site of the property. Neither the berm north nor the roadway embankment are certified levees, and some leakage through the embankments should be expected. The leakage could happen through seepage, a localized depression in the embankment, or an unmapped penetration. A nuisance berm around the project location at two feet in height should be installed to provide a protection against this leakage, as well as against flooding sources other than the Alamo River. Figure 6 shows the floodplain of the 100-year Alamo River flood all around the Morton Bay property, but no flooding inside the property.

Figure 6. Morton Bay 100YR Flooded Area (identical under existing and proposed conditions)

5.1.2 Black Rock

During a 100-year event in the Alamo River, the river water will overflow the banks downstream of the Sinclair Road bridge and, without any improvements, eventually flood the parcels to the north and northeast of the Black Rock site. The McKendry Road embankment protects the Black Rock site from flooding from the Alamo River. Like Morton Bay, a nuisance berm around the project location at two feet in height should be installed to provide a protection against flooding sources other than the Alamo River. Other than the nuisance berm, no additional flood protection is proposed for the Black Rock location. However, the improvement proposed for the Elmore North site will increase the distance between the Black Rock site and the Alamo 100-year floodplain.

Figure 7. Black Rock 100YR Alamo River Flood under proposed conditions (no flooding))

5.1.3 Elmore North

Figure 5 show the Elmore North site being inundated during the 100-year storm under existing conditions. The flow path for the overflow from the Alamo River to the Salton Sea is blocked by the Salton Sea levees. While simply removing these manmade levees would result the overflow to reach the Salton Sea without flooding any private property, a solution that keeps the levees intact is preferred.

Raising the current access trail at the extension of Merkly Road, west of the Alamo River would require only a minor improvement and force the water over the Garst Road embankment to the Salton Sea. To allow for Garst Road to be operational during a 100-year event, a spillway structure will be added to the road to avoid overtopping the road. The design of the spillway will be such that the existing 100-year flood conditions upstream of Garst Road will not be impacted. Figure 8 shows the tentative design of the Merkly Road berm. The final location of the berm will be impacted by property boundaries and available right of way. Due to the general slope of the terrain, some floodwater will enter the property to the east of Elmore North by overtopping Sinclair Road. The Imperial Irrigation Districti (IID) operates a pumping plant in the corner of Garst Road and Merkly Road to pump this into the ditch along Garst Road, north of Merkly Road. This pumping plant was not included in the HEC-RAS model, but operating this pumping plant during and immediately following a large flood event will reduce the floodplain east of Garst Road between Sinclair and Merkly Roads. The discharge of this pumping is not expected to have a significant impact on the nature preserve north of Merkly Road.

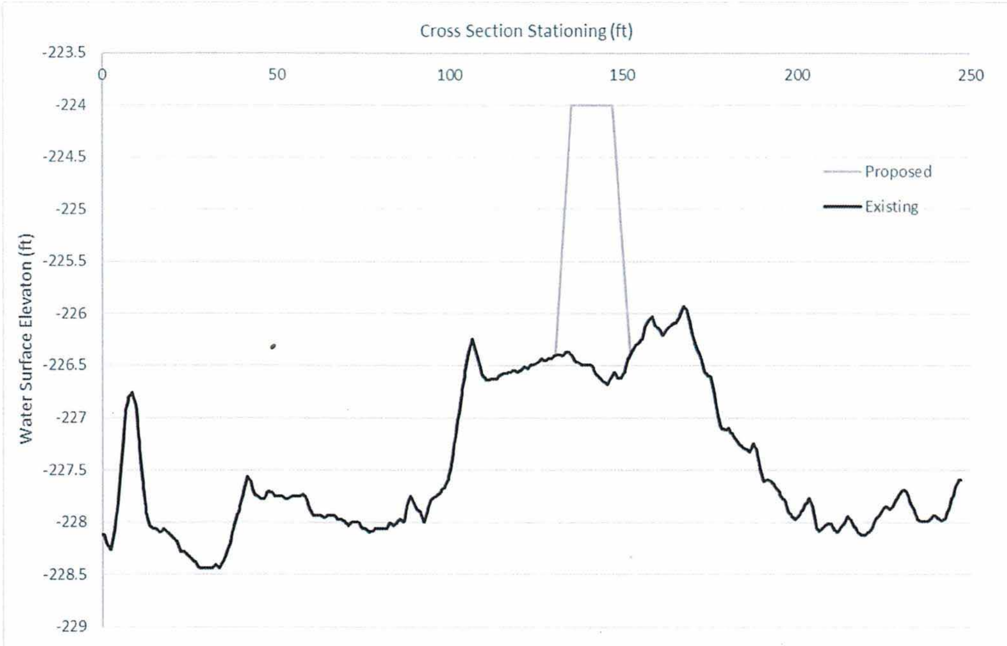

Figure 8. Proposed Merkly Berm

Figure 9. Elmore North under proposed conditions

Raising the Merkly Road berm without a Garst Road spillway would increase the water level east of Garst by approximately 0.6 feet. While the spatial impact of this increase is minimal, the Garst spillway will be designed to offset this increase. The low point in the current Merkly access trail is slightly below --226 feet. To minimize impacting the existing conditions during more frequent flood events, the spillway crest will be set at -226.5 feet. Initial modeling shows that the weir should pass a peak flow of approximately 750 cubic feet per second to maintain a pre-berm peak water level of -225.1 feet east of Garst Road.

6.0 FLOOD DAMAGE PREVENTION COMPLIANCE

6.1 REGULATORY FRAMEWORK

The flood damage prevention regulations for Imperial County are included in Division 16 of Title 9 of the Land Use Ordinance for the County of Imperial. The flood damage prevention regulations of Imperial County are the implementation of FEMA's National Flood Insurance Program (NFIP). The NFIP regulations are part of the Code of Federal Regulations (CFR), chapter 44, parts 59, 60, 65, and 70.

6.2 BASE FLOOD ELEVATION

The project location is in a FEMA A zone and pursuant to § 91604.02-B.3 and B.4, the base flood elevation was obtained by the detailed method using the USACE HEC-RAS model. Due to the size of the basin and the nearby USGS stream gage, the 100-year discharge was obtained using a gauge analysis as described in chapter 3 of this report.

The development of the power plants do not result in a change to the external flood hazard area boundaries. The nuisance berms are not designed to remove the project locations from the FEMA designated flood hazard areas. No base flood elevation has been determined by FEMA. Thus, per § 91604.02-B.5, it is not required to make a submission to FEMA.

§ 91604.02-A.4 requires that in areas where a floodway has not been designated, the cumulative effect of the development activities will not increase the base flood elevation more than one foot anywhere in the community. The HEC-RAS modeling indicates only marginal variations in water levels throughout the county.

7.0 REFERENCES

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ATTACHMENT A

HEC-RAS Modeling Results

Kiewit

Figure 10. Alamo River Q100 floodplain under existing conditions

Figure 11. Alamo River Q100 under existing conditions – Start of overtopping Merkly Road

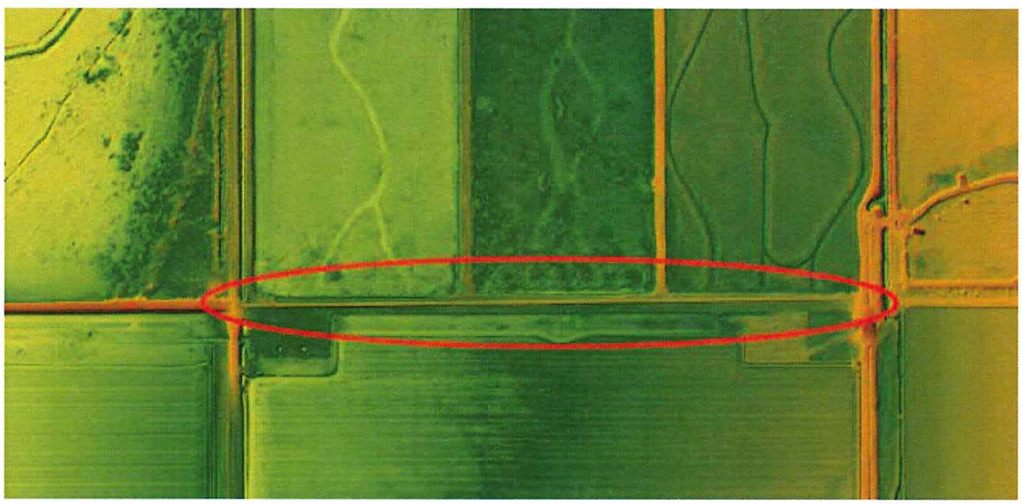

Figure 12. Proposed Merkly Road Berm (circled in red)

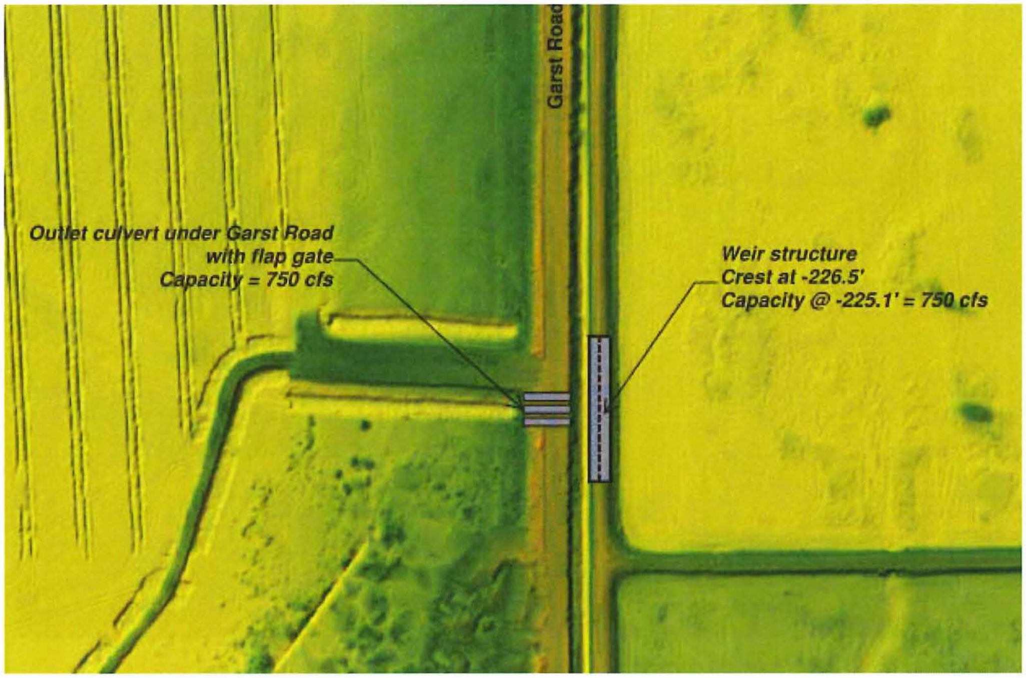

Figure 13. Indicative Garst Spillway structure to maintain existing Q100 water levels east of Garst Road

Figure 14. Alamo River Q100 floodplain under proposed conditions