FEMA Public Assistance Determination Memo

Date:	03-12-2019				
Applicant Name:	California Department of Water Resources - DWR			Applicant Type:	☒State Agency ☐Local Government ☐Tribe ☐Private Nonprofit
Disaster Number:	4308				
PW #(s):	1425	Category	D	PW Facility/Title:	Oroville Dam Spillways Repairs (LOPs 14 and 15)
Amount Requested:	$306,449,619			Amount Approved:	$0.00

Project Description:

Between February 1, 2017, and February 23, 2017, severe winter storms, flooding and mudslides caused extensive damage throughout much of the State of California. The widespread damage resulted in a major disaster declaration (FEMA-4308-DR-CA), which authorized Public Assistance (PA) in multiple counties, including Butte County. The Oroville Dam and related facilities are located in Butte County. The California Department of Water Resources (DWR) owns and operates these facilities.

During the incident period, heavy rains within the Feather River Watershed filled Lake Oroville necessitating high-volume releases over 10,000 cubic feet per second (cfs) through the Oroville Dam Gated Spillway. During these releases, which increased to over 50,000 cfs, a failure of approximately 750 square feet (SF) of the Gated Spillway occurred immediately below Station 33+00 on February 7, 2017. Due to this failure, DWR closed the Gated Spillway gates to inspect damages and determine if repairs could be made to the concrete chute. However, knowing that the continued use of the Gated Spillway would be necessary to maintain a safe reservoir level, DWR reopened the gates to ensure safe operation of the dam. Nevertheless, on February 11, 2017, water flowed over the Emergency Spillway weirs (or crest structure) for the first time since the Oroville Dam's construction in 1968. The Emergency Spillway discharge caused extensive erosion to the natural hillside immediately below the crest structure. Because the erosion threatened a failure of the Emergency Spillway crest structure, which would have caused catastrophic flooding, DWR increased the Gated Spillway discharge to cease the flow of water over the Emergency Spillway. The high volume redirected flows to the Gated Spillway severely eroded the lower concrete chute.[1]

As a result of the damage to the Gated Spillway (List of Projects (LOP) #14) and Emergency Spillway (LOP #15) that occurred during the incident period, DWR is requesting PA funding for the costs it incurred to replace the entire Gated Spillway concrete chute and to reinforce the Emergency Spillway, which included a new overflow section, stepped roller compacted concrete (RCC) apron, and secant wall.

[1] The Project Description is based on information contained in the Independent Forensic Team Report, Oroville Dam Spillway Incident (Jan. 5, 2018) (IFT Report) and February 2017 Oroville Spillway Incident, Emergency Recovery Efforts for the Gated Spillway and Emergency Spillway prepared by the California Department of Water Resources (Aug. 17, 2018) (DWR Report).

Issues:

1) Is the upper Gated Spillway concrete chute (Station 13+00 to Station 28+25, which is approximately 1,525 linear feet) (Upper Chute) eligible for permanent repairs under the PA program?

2) Is the Emergency Spillway, below the weirs/crest structures, an improved and maintained natural feature eligible for permanent repairs under the PA program?

Applicable Law, Regulations, and FEMA Policy:

Robert T. Stafford Disaster Relief and Emergency Assistance Act, as Amended
Section 406 (codified as amended at 42 U.S.C. § 5172)

Title 44 of the Code of Federal Regulations
§ 206.223 (a) "*General.* To be eligible for financial assistance, an item of work must: (1) be required as the result of the emergency or major disaster event;"[2]

§ 206.201(c) "*Facility* means any publicly or privately-owned building, works, system, or equipment, built or manufactured, or an improved and maintained natural feature."[3]

FEMA Policy
FP-104-009-02 *Public Assistance Program and Policy Guide* (PAPPG), at 15-16, 20-21, 50, 117, 134 (Apr. 2017)

Analysis:

I. The Upper Chute of the Gated Spillway Is Not Eligible under the PA Program Because It Was Not Damaged as a Direct Result of the Disaster.

Based on Section 406(a) of the Stafford Act and 44 C.F.R. § 206.223(a), FEMA determined that the Upper Chute of the Gated Spillway is not eligible for Public Assistance funding because it was not damaged as a direct result of the disaster. Damage to the Upper Chute was due to the result of long-term, pre-existing conditions. Section 406(a) of the Stafford Act authorizes FEMA to provide financial assistance to State and local governments and certain private nonprofit organizations for the repair, restoration, and replacement of facilities damaged or destroyed as a result of a major disaster. FEMA administratively categorizes this work as "permanent work."[4]

To be eligible for financial assistance, FEMA implementing regulation, 44 C.F.R. § 206.223(a), states that an item of work must be required as a result of a disaster.[5] Therefore, for permanent work to be eligible, an applicant must demonstrate that the damage was caused directly by the

[2] LOP #14.
[3] LOP #15.
[4] FP-104-009-02, *Public Assistance Program and Policy Guide*, at 20 (Apr. 2017) (PAPPG).
[5] 44 C.F.R. § 206.223(a)(1).

effects of the event, such as hurricane-force winds or flooding, which took place during the incident period.[6] If the work in question addresses damage resulting from a cause other than the designated incident, such as deterioration, deferred maintenance, or negligence,[7] the work is not eligible for PA funding.[8] It is an applicant's responsibility to substantiate its claim as eligible.[9] If an applicant does not provide sufficient documentation to support its claim as eligible for PA, FEMA cannot provide PA funding for the work.[10]

Pre-existing Condition of Gated Spillway

After the failure of the Gated Spillway, the Federal Energy Regulatory Commission (FERC), which is the Federal entity that licenses the Oroville Dam, required DWR to engage an Independent Forensics Team (IFT) to develop findings and opinions on the causes of the incident.[11] The IFT Report identified two categories of physical factors that contributed to the failure of the Gated Spillway: (1) inherent vulnerabilities in the spillway designs and as-constructed conditions, and subsequent chute slab deterioration; and (2) poor spillway foundation conditions in some locations.[12]

The IFT Report details that:

> "The inherent vulnerability of the service spillway design and as-constructed conditions reflect lack of proper modification of the design to fit the site conditions. Almost immediately after construction, the concrete chute slab cracked above and along underdrain pipes, and high underdrain flows were observed. The slab cracking and underdrain flows, although originally thought of as unusual, were quickly deemed to be 'normal,' and as simply requiring on-going repairs. However, repeated repairs were ineffective and possibly detrimental."[13]

> "The seriousness of the weak as-constructed conditions and lack of repair durability was not recognized during numerous inspections and review processes over the almost 50-year history of the project. Over time, chute flows and temperature variations led to progressive deterioration of the concrete and corrosion of steel reinforcing bars and anchors, with likely loss of slab strength and anchor capacity. There was likely also some shallow underslab erosion and some loss of underdrain system effectiveness, which contributed to increased slab uplift forces. The particularly poor foundation conditions at

[6] PAPPG, at 20; 44 C.F.R. § 206.32(f).
[7] 44 C.F.R. § 206.223(e) *stating that* "no assistance will be provided to an applicant for damages caused by its own negligence".
[8] PAPPG at 20-21.
[9] *Id.* at 134.
[10] *Id.*
[11] IFT Report at 1.
[12] *Id.*at S-1.
[13] *Id.*

> the initial service spillway chute failure location contributed to likely low anchor capacity and shallow underslab erosion."[14]
>
> "Due to the unrecognized inherent vulnerability of the design and as-constructed conditions and the chute slab deterioration, the spillway chute slab failure, *although inevitable*, was unexpected" (emphasis added).[15]
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> "Although the poor foundation conditions at both spillways were well documented in geology reports, these conditions were not properly addressed in the original design and construction, and all subsequent reviews mischaracterized the foundation as good quality rock. As a result, the significant erosion of the service spillway foundation was also not anticipated."[16]

DWR's Claimed Damage to the Lower Chute

The claimed damage to the Lower Chute of the Gated Spillway occurred on February 7, 2017, when the chute flow was approximately 52,500 cubic feet per second (cfs).[17] The claimed damage consisted of missing sections of the chute slab, which created a hole over an area of approximately 750 SF just below Station 33+00. A large erosion hole was also observed in the area where the slab sections were missing, with additional erosion along the east side of the concrete chute. Although the Gated Spillway gates were closed to inspect the damage, the gates were reopened on February 8, 2017, due to the multiple rain events and anticipated inflows into the reservoir. The gates remained open until May 19, 2017. Between February 8 and May 19, 2017, additional sections of the chute slabs were displaced and the erosion area enlarged significantly. Specifically, the resulting damage to the Lower Chute of the Gated Spillway is described as:[18]

> Complete destruction (or loss) of the concrete chute apron over an area of approximately 136,816 SF, including 1,653 linear feet (LF) of the concrete chute wall. This includes the destruction of the underdrain system and loss of concrete slab anchors. These damages and repairs are addressed in PW 1410.
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> Erosion of the spillway foundation (integral ground) over an area of approximately 169,727 SF, with an average depth of 40 feet for a total loss of approximately 251,447 cubic yards (CY) of materials. These damages and repairs are addressed in PW 1410.
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> Due to stress from turbulent flow and debris impacts, the entirety of the concrete chute and walls below Station 29+50 to the end of the spillway at Station 43+00 (1,350 LF) was severely damaged and/or undermined. These damages and repairs are addressed in

[14] *Id.* at S-1, S-2.
[15] *Id.* at S-2.
[16] *Id.*
[17] By comparison, the original design capacity for the Gated Spillway was 296,000 cfs, and the highest flow ever recorded at the Gated Spillway was about 160,000 cfs on January 1, 1997. IFT Report at 9 and 18.
[18] Descriptions from Project Worksheets 1410 (Category D – Lower Chute of the Gated Spillway) and 37 (Category A – Debris removal).

PW 1410.

Damage occurred to all four of the concrete monolithic energy dissipaters (also referred to as the "dragon's teeth") at the end of the spillway which reduce the force of the water entering the Feather River below the spillway. Large chunks of concrete were broken off the structures due to debris impacts. The concrete support pad (55 LF x 183 FT) had surface damage, but was structurally intact. These damages and repairs are addressed in PW 1410.

The deposit of approximately 2,000,000 CY of debris into the Thermalito Diversion Pool (Feather River), which is a maintained engineered channel in this area. Debris removal and repairs to this channel are addressed in PW 37.

It should be noted that the IFT Report acknowledges DWR performed regular repairs and maintenance on the dam and passed numerous FERC inspections over the past 50 years.[19] Based on the IFT Report and a review of DWR maintenance records, FEMA determined in PW 1410 that damages to the Lower Chute of the Gated Spillway were a result of the declared disaster and not caused by deferred maintenance. As noted in the IFT Report, issues with the design of the Gated Spillway, underlying soil conditions, and long-term deterioration, which were unknown to DWR at the time of the incident, contributed to the failure of the Lower Chute of the Gated Spillway.[20] However, the February 1-23, 2017 severe storm and flooding was the triggering event which ultimately caused the failure of the Lower Chute beginning on February 7, 2017. As detailed by the IFT Report, the initial damage to the Lower Chute is attributed to an approximate time (10:10 am) and location (Station 33+50) of a concrete slab failure on February 7, 2017.[21] From that initial failure, the force of water down the Gated Spillway rapidly led to additional slab failures and erosion of foundation materials on the Lower Chute.[22]

DWR's Claimed Damage to the Upper Chute

In addition to the identified damage to the Lower Chute of the Gated Spillway, DWR submitted a claim for repairs and reconstruction performed for the Upper Chute of the Gated Spillway during reconstruction of the Lower Chute. Unlike the Lower Chute, there was no observable damage to the concrete portions of the Upper Chute of the Gated Spillway from the February 2017 incident. During post-event inspections in April and July 2017, DWR discovered potential damage beneath the concrete chute.[23] DWR claims that this damage was a direct result of the declared major disaster, and the permanent repair/replacement of the Upper Chute should be eligible for PA funding. Since the IFT Report identifies significant pre-disaster deterioration underneath the Gated Spillway, which, unlike the Lower Chute, is the only damage observed related to the Upper Chute, FEMA requested that DWR substantiate its claim that this damage was a direct result of the disaster from February 1-23, 2017. It should be noted that FEMA considers the entire Gated Spillway as a

[19] IFT Report at F2-7 – F2-10.
[20] *Id.* at S-1 – S-2.
[21] *Id.* at 29-30.
[22] *Id.*
[23] DWR Report at 8-9.

single facility for the purposes of PA eligibility. However, FEMA considers the sections of the Gated Spillway between stations to be individual components of a larger system[24] and, thus, has separated the Lower and Upper Chutes into separate PWs as part of the PA eligibility review.

In order to substantiate its claim for the visibly intact Upper Chute of the Gated Spillway, DWR provided FEMA with a report that it prepared entitled "The February 2017 Oroville Spillway Incident, *Emergency Recovery Efforts for the Gated Spillway and Emergency Spillway*" dated August 17, 2018 (DWR Report). DWR summarizes the basis for its decision to replace the Upper Chute in the DWR Report as follows:

> Over the course of 2017, investigations carried out on the Gated Spillway chute by DWR resulted in the conclusion by DWR, the Independent Board of Consultants (IBOC), Federal Energy Regulatory Commission (FERC), and California Division of Safety of Dams (DSOD) that the surviving chute section had sustained damage beneath the concrete slabs that were remaining and that the structure was no longer structurally sound to perform the function required of it, thus no longer capable of fulfilling its design function. For example, the Independent Board of Consultants concludes:
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> - *"The upper chute section and its training walls will also need to be completely replaced or restored to a condition acceptable for long term service;"*
> - *"There are significant doubts about the type and condition of materials that underlie the concrete chute floor;" and*
> - *"This reaffirms the position of the Independent Board of Consultants that if at all possible, the removal and replacement option of the chute should be pursued."*

As a result of these concerns, these parties collectively concluded that the only reasonable and reliable engineering solution to repair the observed damage to the Gated Spillway chute was the complete replacement of the structure. In fact, the Independent Board of Consultants (IBOC) appointed by FERC was concerned about the possibility of hidden damage beneath the Upper Chute of the Gated Spillway and was adamant that for public safety purposes, as much of the upper chute as possible should be replaced during the 2017 construction season.[25]

FEMA does not dispute that replacing the entire Gated Spillway was a prudent decision, but the record indicates that the need to replace the Upper Chute was not related to damage occurring as a direct result of the disaster. Specifically, the IBOC conclusions quoted by DWR in their report recommending the replacement of the Upper Chute are

[24] PAPPG at 103.
[25] DWR Report at 10-11.

from two Memoranda dated March 10, 2017 and March 17, 2017,[26] which is a month prior to when DWR claims to have discovered any damage associated with the Upper Chute.[27] While the IBOC was rightfully concerned about the conditions underneath the concrete chute floor, further investigation in the IFT Report indicates these conditions pre-dated the disaster.

FEMA's Request for Information and DWR Responses

Following FEMA's review and analysis of the DWR Report, FEMA sent a Request for Information to the California Governor's Office of Emergency Services (Cal OES) dated September 19, 2018 (RFI) to ensure that FEMA had all the information it considered necessary to determine the eligibility of the work for which DWR was requesting PA funding. Specifically, FEMA requested information and documentation supporting DWR's claim that the Upper Chute was damaged as a direct result of the disaster and if shown to be damaged, it was not as a result of the progressive deterioration of the concrete chute and underlying substructure.[28]

On October 12, 2018, DWR submitted a response to the RFI to Cal OES. Cal OES transmitted DWR's response to FEMA by letter dated October 16, 2018 (RFI Response). In the RFI Response, DWR claims that the nature of the hidden damage to the Upper Chute and "facts and inferences" show that this damage was caused by the disaster. The facts and inferences cited by DWR in the RFI Response are discussed below with FEMA's response to each point:

DWR: DWR asserted that an increase in underdrain flows between January 13 and January 27, 2017, is evidence of the sudden (in other words, disaster-related) deterioration of the Gated Spillway.

> FEMA: Although the IFT agrees that the amount of water discharged from the drains was unprecedented, the IFT points out that high underdrain flows were observed almost immediately after Oroville Dam's construction[29] and that regardless of the amount of water discharged, high drain flows consistently occurred.[30] The IFT cites a report prepared in 1969 by the California Division of Safety of Dams (DSOD) that states "that the high flows from the spillway drains are mystifying but *probably* not dangerous as the chute is anchored" (emphasis added).[31] The IFT then expresses its agreement with DSOD's conclusion that the high drain flows are principally attributable to leakage through cracks and joints in the Gated Spillway chute.[32] The fact that high drain outfall flows have been observed for approximately 50 years contradicts DWR's assertion that high underdrain flows over a 2-week period is evidence of sudden deterioration or

[26] Independent Board of Consultants (IBOC) for Oroville Emergency Recovery, Memorandum No. 1 (Mar. 10, 2017) and BOC for Oroville Emergency Recovery, Memorandum No. 2 (Mar. 17, 2017).
[27] DWR Report at 8-9.
[28] RFI at 2.
[29] IFT Report at S-1.
[30] *Id.* at 22.
[31] *Id.*
[32] *Id.*

damage to the chute.[33] DWR has provided no evidence that the underdrain flows over this 2-week period were any higher than those previously observed over the 50 years of operation, and the IFT Report indicates that drain flows were sporadic over the 50 year life of the dam.[34] Conversely, if high outfall flows evidence sudden deterioration, then the Gated Spillway has been rapidly deteriorating for almost 50 years. Furthermore, the incident period for the declared major disaster (DR-4308) was February 1-23, 2017. If the increased underdrain flows from January 13-27, 2017 were a proximate cause of deterioration under the Upper Chute, then the damage to the Upper Chute occurred prior to the declared incident.

DWR: In the RFI Response, DWR claims that the majority of the post-disaster work it performed on the Upper Chute was because there was "new damage" to the Upper Chute in the form of cracking and spalling. In support of this claim, DWR states that these conditions had not been observed or present during the 2009 and 2013 repairs.[35] DWR attributes this damage to the unprecedented volume of discharge flows over the Gated Spillway for an extended period of time.

FEMA: As noted in the IFT Report, DWR has historically viewed work that addressed spalling, delamination, and cracking as "routine maintenance" not repairs.[36] Therefore, the claimed conditions were historically viewed by DWR as the equivalent of "wear and tear." Routine or "normal" maintenance work is not eligible for PA funding.[37]

As discussed in the IFT Report, DWR undertook "five major repair efforts" in the Gated Spillway chute between 1977 and 2013.[38] The IFT identifies three recurring problems necessitating these major repair efforts: (1) cracking over the herringbone drains, which are located within the chute slab; (2) the opening of formed construction joints and removal of the filler during spillway flows; and (3) delamination and spalling at joints and cracks.[39] The last two major repair efforts took place in 2009 and 2013 – an interval of only four years. Therefore, it is reasonable to conclude that the same conditions that required DWR to undertake major repair efforts in 2009 and 2013 existed in the Upper Chute in February 2017, particularly since "no concerted effort was made to investigate the underlying factors causing failures involving cracking, delamination, and spalling and the subsequent need for repeated repairs including recurrences at the same locations."[40] In fact, it is likely that the conditions were more exaggerated due to the accelerating rate of deterioration. Furthermore, DWR did not provide any documentation or explain what information it is relying upon in support of its assertion that new, post-disaster damage to the Upper Chute was observed.

[33] *Id.*
[34] *Id.* at F1-23 – F1-26.
[35] RFI Response at 13.
[36] IFT Report at 52-53.
[37] PAPPG at 20, 50, and 117.
[38] IFT Report at G-2.
[39] *Id.* at G-1, G-2.
[40] *Id.* at G-2.

DWR: DWR points to the failure of the Lower Chute and subsequent damage in February 2017 as evidence that the Upper Chute was damaged as a result of the disaster. DWR claims that it is reasonable to expect that the Upper Chute suffered similar but lesser damage than the Lower Chute, which failed on February 7, 2017.

> FEMA: As detailed in the IFT Report, the failure of the Lower Chute was inevitable as a result of a combination of pre-disaster factors with the design and construction of the Gated Spillway.[41] Although the events that occurred during the incident period may have triggered the failure of the Lower Chute, the failure of the Lower Chute does not in and of itself support concluding that the Upper Chute suffered hidden damage as a direct result of the disaster.

DWR: DWR states that the IFT identifies the 5-year drought immediately preceding the 2017 California winter storms as a contributing factor to the failure of the Lower Chute in February 2017. DWR asserts that the physical effects or impact of the drought factor into the susceptibility of the Upper Chute failures.

> FEMA: DWR did not provide any information in support of its assertion that the drought was a contributing factor. Regardless, the drought was not the result of events occurring during the incident period. Moreover, the IFT describes the drought as "a potential but low probability factor" in the failure of the Lower Chute.[42]

DWR: DWR claims that the intermittent and large spillway discharges and the rapid opening and closing of the spillway gates "may have contributed to cyclic flows within the underdrain system and surrounding rock that could facilitate internal erosion and the sedimentation of eroded materials..."[43] In the RFI Response, DWR also points to the presence of fine-grained sediment in one herringbone underdrain within the Upper Chute (at Station 22+50) as evidence of disaster-related hidden damage in the form of internal erosion/piping beneath the concrete slabs. In the DWR Report, DWR states that this sediment "was most likely deposited near the cessation of the Gated Spillway flows of 2017 and was not accumulation from previous years."[44] In the RFI Response, DWR points to "facts and reasoning" as the source for this statement.

> FEMA: DWR erroneously appears to be claiming that the hidden erosion/piping damage in the Upper Chute is attributable to the disaster. First, any damage that occurred subsequent to the close of the incident period (February 23, 2017) is only eligible if DWR can demonstrate that the damage is the direct result of events that occurred during the incident period. Second, the post-disaster presence of sedimentation in one herringbone drain in the Upper Chute is not evidence of hidden disaster damage. It is simply evidence of erosion. As illuminated in the IFT Report, cracking occurred predominantly over the

[41] *Id.* at S-1.
[42] *Id.* at D-16.
[43] RFI Response at 7.
[44] DWR Report at 9.

herringbone drains.[45] These cracks provided pathways for sediment leakage and would have caused piping (internal erosion that creates an alternate channel through which water can flow) of foundation material. This material would be discharged through the underdrain system.[46] Therefore, sediment in the herringbone underdrain was likely deposited over a longer period of time through the pre-existing cracks, and DWR has provided no evidence to the contrary. Thus, DWR has failed to establish that the sedimentation and erosion occurred as a direct result of disaster-related events taking place during the incident period.

For the reasons summarized above, FEMA has determined that DWR has not provided sufficient documentation to demonstrate that the Upper Chute was damaged as a direct result of the disaster. FEMA does not dispute that DWR's decision to replace the Upper Chute was reasonable and prudent. It is FEMA's position, however, that the reasons for doing so are unrelated to the disaster. The documentation provided to FEMA substantiates that the inherent vulnerabilities in the design and as-constructed conditions, regular high drain flow, recurring unaddressed damage (such as cracks, spalling, and delamination of the concrete slabs), and inadequate repairs led to the *inevitable* failure of the lower portion of the Gated Spillway,[47] that led to the replacement of the Upper Chute as well. In fact, the first paragraph of the IFT Report states the following: "[t]he Oroville Dam spillway incident was caused by a long-term systemic failure of the California Department of Water Resources (DWR), regulatory, and general industry practices to recognize and address inherent spillway design and construction weaknesses, poor bedrock quality, and deteriorated service spillway chute conditions."[48]

United States Army Corps of Engineers' Concurrence

FEMA requested that the United States Army Corps of Engineers (USACE) provide technical input on FEMA's analysis of the eligibility of the replacement of the Upper Chute. To do so, the USACE reviewed the DWR Report, IFT Report, Kiewit Contract Change Orders, Plans and Specifications from the Kiewit Contract, and DWR's response to FEMA's RFI (Spillway Documents). FEMA asked the USACE to perform a technical review and analysis of DWR's repair course of action on the Gated Spillway and applicability of Stafford Act assistance and PA Program and Policy Guide, differentiating between the Lower and Upper Chutes as appropriate.

USACE submitted its response in the form of "Enclosure 1" dated November 7, 2018, to FEMA on December 21, 2018 (USACE Assessment). Based on its technical review and analysis of the FEMA-Provided Documents, USACE opined that the Upper Chute "did not experience any documented event related damage resulting from the 2017 event."[49] USACE further opined that "damage to the upper chute foundation and drainage system was the result of many years of

[45] IFT Report at 19 ("By the time of the 2017 incident, cracks were present over almost all the herringbone drains, and most cracks had likely been present since 1969. The cracks provided pathways for leakage through the slab at times when there was water in the chute.").
[46] *Id.* at 32 and 35.
[47] IFT Report at S-2.
[48] IFT Report at S-1.
[49] USACE Assessment at 2.

spillway gate leakage entering cracks in the chute, resulting from insufficient cover over the drain pipes, and flow rates through the foundation and drainage system."[50] In short, the USACE agreed with both FEMA's determination that the Upper Chute was not damaged as a direct result of the disaster, but nevertheless warranted replacement because the Upper Chute suffered the same deficiencies and level of degradation/deterioration.

Conclusion

The Upper Chute of the Gated Spillway is not eligible for permanent work under the PA program because it was not damaged as a direct result of the disaster. The IFT Report supports the conclusion that, although unknown to DWR at the time of the incident, the foundation underneath the entire concrete chute was deteriorated from pre-disaster inherent vulnerabilities in the design and as-constructed conditions, regular high drain flow, and recurring unaddressed damage through ineffective repairs. DWR has not provided sufficient documentation to the contrary. This pre-disaster damage to the foundation is the only damage identified by DWR related to the Upper Chute. While these pre-disaster conditions made the entire Gated Spillway more susceptible to failure, unlike the Lower Chute, the applicant did not prove that the Upper Chute suffered damage due to the February 2017 severe storm and flooding incident.

II. The Emergency Spillway Is Not An Improved and Maintained Natural Feature and Therefore Is Ineligible for PA Funds.

As defined in 44 C.F.R. § 206.201(c), a "facility" means any publicly or privately owned building, works, system, or equipment, built or manufactured, *or an improved and maintained natural feature*.[51] For an "improved and maintained natural feature" to be eligible for PA, the natural feature must have a designed and constructed improvement to its natural characteristics, such as a terraced slope or drainage system, which enhances the function of the unimproved natural feature.[52] Additionally, an applicant must show that it maintained that improvement on a regular schedule to ensure that it performs as designed.[53] Furthermore, only the section of a natural feature that meets these criteria is eligible. For example, if only 150 linear feet (LF) of a natural channel bank is armored with rip rap[54] and maintained, the eligible facility is limited to only that 150 LF.[55]

In describing the Emergency Spillway, the IFT Report refers to the area immediately below the emergency spillway crest structure as a natural feature with no reference to any improvements:

> "The emergency spillway is also located on the right abutment, to the right of the service spillway. The emergency spillway consists of two /sections: a 930-foot long, gravity ogee weir on the left side, and an 800-foot long broad crested weir on the right side. The ogee

[50] *Id.*
[51] *See also* PAPPG at 15.
[52] *Id.* at 15-16.
[53] *Id.*
[54] E.g., loose stone used to protect a slope from erosion.
[55] PAPPG at 16.

> weir section of the spillway is shown in Figure 3-3.... *Water flowing over the emergency spillway crest structure then passes over natural terrain to the Feather River*" (emphasis added).[56]
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> "During the incident response, in preparation for using the emergency spillway, *trees had been cleared from the natural hillside downstream of the spillway crest structure* before flow over the crest structure occurred. As the emergency spillway discharge flowed over the natural ground downstream of the crest structure, erosion began to occur" (emphasis added).[57]
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> "The area downstream of the emergency spillway crest structure is for the most part a natural hillside with variations in topography. The hillside also contained some infrastructure features, such as access roads and transmission towers."[58]

Due to the damage to the Gated Spillway and the failure of the Emergency Spillway, DWR performed emergency protective measures on an unimproved slope below the Emergency Spillway weirs. These emergency protective measures were implemented in case the Gated Spillway could no longer be used and DWR was required to re-engage the Emergency Spillway. Thus, erosional damage to the unimproved slope immediately below the weirs was repaired using grouted rip-rap. The emergency work performed on the Gated and Emergency Spillways is described in PW 36.

DWR claims that the hillside below the weirs (crest structure) of the Emergency Spillway is a facility, and, the post-disaster improvements made to the Emergency Spillway below the crest structure are eligible for PA funding for permanent work. As defined in 44 C.F.R. § 206.201(c), a "facility" means any publicly or privately owned building, works, system, or equipment, built or manufactured, *or an improved and maintained natural feature*.[59] That facility must be built or manufactured to be eligible is reinforced by Section 406(e) of the Stafford Act and implementing regulation, 44 C.F.R. § 206.226, which base the amount of assistance for permanent work on the "design of the facility as it existed immediately before the disaster event" and applicable standards.[60]

The IFT indicates that the emergency spillway was designed with "the intention that the crest structure would be founded on "good" rock, *and that the downstream hillside would be left in its natural condition*" (emphasis added).[61] In 2005, as part of the Oroville Dam re-licensing process, Friends of the River, along with the Sierra Club and the South Yuba Citizens League, questioned the safety of the emergency spillway regarding the potential for extensive erosion of the hillside

[56] IFT Report at 9.
[57] *Id.* at 38.
[58] *Id.* at 40.
[59] *See also* PAPPG at 15.
[60] FEMA Second Appeal Analysis, *Office of Coastal Protection and Restoration*, FEMA-4080-DR-LA, at 4 (Jul. 27, 2017).
[61] IFT Report at 54.

below. FERC requested that DWR investigate this issue. In a November 29, 2005 Memorandum, DWR stated:

> "The Emergency Spillway does not empty onto a bare dirt hillside. Instead, it empties onto a hillside composed of solid amphibolite bedrock extending from the spillway crest down to the Feather River."[62]

FEMA notes that DWR does not dispute that the Emergency Spillway empties onto a hillside and disagrees only with characterization or nature of the slope beneath the crest structures, yet nothing in the above description or any other documentation provided by DWR demonstrates that the natural hillside below the Emergency Spillway crest structure was improved and maintained aside from other infrastructure, such as the access road, that FEMA is funding under separate PWs.

DWR has not provided FEMA with any documentation, such as engineering specifications, design criteria, or as-built drawings showing that the hillside below the crest structures was a "designed and constructed improvement." In fact, the absence of any measures taken to improve and maintain the hillside to provide erosion control/protection downstream of the crest structures was noted in the IFT Report.[63] DWR has also failed to provide FEMA with any documentation establishing that it had a written regular maintenance plan or activity log demonstrating that it performed maintenance on a regular schedule. The IFT describes clearing and grubbing of the area downstream from the crest structures on February 8, 2017, to prepare for using the Emergency Spillway for the first time, which indicates that these activities were not routinely performed to clear the Emergency Spillway.[64]

Because DWR has not sufficiently demonstrated that the hillside below the crest structures was an improved and maintained structure, the hillside is not an eligible facility for PA.

PA Determination: ☐Approved ☐Partial ☒Denied

1. The Upper Chute was not damaged as a direct result of the disaster and, therefore, is not eligible for permanent repairs under the PA program.

2. The Emergency Spillway, below the weirs/crest structures, was not an improved and maintained feature and, therefore, is not an eligible facility for permanent repairs under the PA program.

Approved-PA Senior Leadership: Michael Gayrard, Infrastructure Branch Chief

Signature: _____ Date: 3/12/19

[62] *Id.* at C-30.
[63] *Id.* at 40.
[64] *Id.* at 38, L-4, L-6, and L-14.

DEPARTMENT OF THE ARMY
U.S. ARMY CORPS OF ENGINEERS
441 G STREET, NW
WASHINGTON, DC 20314-1000

Mr. Mark Wingate
Acting Recovery Director
FEMA Region 9
Federal Emergency Management Agency
U.S. Department of Homeland Security
1111 Broadway Suite 1200
Oakland, California 94607-4052

Dear Mr. Wingate,

Enclosed is our response to your email on 28 August 2018 requesting the U.S. Army Corps of Engineers technical input in their decisions on federal participation in the ongoing Oroville Dam repairs. FEMA requested input on four questions and provided documents to the Corps for review at their Sacramento office. The questions and the responses are included in Enclosure 1.

The technical point of contact for this review is Mr. David Serafini, Geotechnical NTS, SPD-DSPC, who can be reached at 916-557-7585, or at david.c.serafini@usace.army.mil.

MCCALLISTER.LARRY.DWAYNE.1144889661

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DN: c=US, o=U.S. Government, ou=DoD, ou=PKI, ou=USA, cn=MCCALLISTER.LARRY.DWAYNE.1144889661
Date: 2018.12.21 12:12:05 -05'00'

LARRY D. McCALLISTER, PhD, PE, PMP, SES
Chief, Engineering and Construction
U.S. Army Corps of Engineers

Enclosure

ENCLOSURE 1:

U.S. Army Corps of Engineers Responses to FEMA Questions on the Repairs to the Oroville Spillways

A. Documents Provided or Made Available for Review by FEMA at their Sacramento Office:
   a. 17 August 2018 DWR Emergency Recovery Efforts for the Gated Spillway and Emergency Spillway Report
   b. Independent Forensic Team (IFT) Report (2018)
   c. DWR Contract Files on Change Orders for the Kiewit Contract (reviewed at the Sacramento FEMA office)
   d. Review of the Plans and Specifications from the Kiewit Contract (reviewed at the DWR Office)
   e. 16 October 2018 Letter from Cal OES to FEMA Subject: Response to Request for Information – PW 1410 (was provided to the Corps during the review process).

B. FEMA Oroville Questions for Technical Input

1. **Provide review of the 17 August 2018 DWR *Emergency Recovery Efforts for the Gated Spillway and Emergency Spillway and* provide a brief assessment of state repair course of action on the main (gated) spillway and applicability of Stafford Act assistance, differentiating between lower and upper sections as appropriate, in conjunction with 2017 FEMA Public Assistance (PA) Program and Policy Guide (PAPPG).**

   Response:
   The California Department of Water Resources (DWR) responded as responsible dam owners following the 2017 Oroville Incident. Following the event DWR quickly engaged and collocated a high caliber design team utilizing resources from DWR, Federal Agencies, and multiple engineering consulting firms. DWR also engaged an expert level Board of Consultants (BOC) to review the expedited design for the 2017 and 2018 construction seasons. The 17 August 2018 *DWR* Report provided a summary of the 2017 event, key lessons learned, input from the BOC and the Independent Forensic Team (IFT) Report, and a summary of the designs for the Gated and Emergency Spillways. However, the report did not contain a detailed description of the emergency repairs made to both spillways during the 2017 event. FEMA already determined these emergency repairs are eligible for FEMA Public Assistance, prior to engaging the Corps on this review.

   FEMA has segmented the gated spillway into two sections for the purpose of determining Public Assistance eligibility. The Corps understands that FEMA has already determined the lower section of the gated spillway, from Station 29+50 to 43+00, is eligible for reimbursement. As documented in the IFT Report, the spillway incident started near station 30+50 and propagated upstream to approximately station 29+00 and downstream to station 43+00. Upon closure of the gated spillway for the season in April 2017, the spillway chute near Station 29+00 had been significantly damaged and was unstable due to head cutting immediately beneath the chute slabs. This section was temporarily supported with rock anchors (during shutdown periods) to adequately allow for safe spillway operation when lowering the reservoir level.

   During the 2017 construction year, the DWR plan for the gated spillway outlet chute was to stabilize the remaining slope and concrete chute up to the upstream limit of the eroded and damaged area. The unstable slope required stabilization to allow for the safe construction of

roller compacted concrete (RCC) within the eroded section of the chute between Stations 29+00 to 38+25. This was a critical first step in repairing the spillway prior to the 2018 flood season. Furthermore, the damaged upper chute section was removed upstream to Station 28+25 to facilitate slope stabilization. Accordingly, the Corps recommends that the lower chute section repairs be defined from Station 28+25 to 43+00.

The 17 August 2018 DWR Report also provided supporting information to assist FEMA in the determination of eligibility for demolition and reconstruction of the remaining gated spillway chute section upstream of station 28+25. Unlike the lower section, the upper section of the chute did not experience any documented event related damage resulting from the 2017 event. Nonetheless, DWR maintains that the 2017 event caused damage within the upper chute to include:

- erosion of the bedrock under the chute;
- fouled drains; and
- delamination of concrete in the chute.

The report indicated that the July 2017 video inspection of the underdrain system "confirmed some areas of internal erosion of the bedrock and partial sediment blockages". The report also stated that "Material subsequently recovered from the underdrains consisted mostly of eroded bedrock material as well as some degraded concrete components. Based on the quantity of underdrain flows in 2017, and the mechanics and process of erosion and deposition in the underdrains, this material was most likely deposited near the cessation of Gated Spillway flows in 2017 and was not an accumulation from flows in previous years." The 16 October 2018 Cal OES letter mentioned potential effects on the lower and upper chute from the sustained drought prior to the 2017 event. The letter also indicated that damage to the upper chute foundation may have been the result of sustained cyclic releases and flows in the underdrain system based on the abrupt openings and closings of the gates during and after the 2017 event.

A sustained duration of high flows occurred during the 2017 event within the gated spillway chute. However, no direct conclusion can be made based on the information provided to support the severity of damage that may have occurred to the underdrain system and foundation solely from the 2017 event; particularly since the gated spillway outlet chute has historically experienced higher flows (up to 132,900 cfs). It is likely that damage to the upper chute foundation and drainage system was the result of many years of spillway gate leakage entering cracks in the chute, resulting from insufficient cover over the drain pipes, and flow rates through the foundation and drainage system. The direct extent of damage resulting to the subdrain system and foundation from the preceding drought and/or 2017 cyclic operations of the gated spillway are largely unknown. However, the rapid cyclic increases and decreases in gated spillway operational flows and the resulting flow changes within the subdrain system have never been experienced over the life of the project from previous operations.

It should be noted that 16 OCT 2018 Cal OES letter included a statement that Ground Penetrating Radar (GPR) "is not a method that is used as a part of normal or routine maintenance or inspections by DWR or any dam owner". The Corps has utilized this technology to assist in the inspection of conduits and spillways.

There is no question that the expedited demolition and reconstruction of the upper chute and training walls were required to provide a condition acceptable for long term service, given that

the original design for the upper chute contained the same deficiencies as noted in the IFT report which led to the lower chute incident in 2017. Over time, portions of the upper chute might be expected to perform similarly to the lower chute.

2. **Provide assessment/basis for major cost over-runs/contract change orders associated w/Kiewit contract.**

Response:

The accelerated approach and contracts utilized to provide a timely recovery from the 2017 event were unprecedented. However, these accelerated approaches were required to quickly restore life and public safety to the downstream populace. Recovery designs were fast-tracked and in progress while the 2017 event was still eroding portions of the lower chute. This approach would maximize the available construction window in 2017. As a result, the original invitation for bid package included designs at approximately a 30% level in which major contract change orders and modifications should be anticipated given the design level reached and the number of unknowns that existed. Many items in the solicitation, such as the stabilization of the lower chute and the foundation conditions of the lower chute for RCC placement could not be well defined until spillway flows ceased, which occurred after solicitation of the contract. These items can be directly tied to several of the contract modifications processed to date. In addition, the design continued throughout the 2017 construction year to ensure that the lower chute would be functional at a reduced capacity in time for the 2017/2018 flood season. Per the original contract the bidders were to assume normal work days and hours with no weekend, no Holiday work and no overtime. This requirement was most likely unreasonable given the extent of the severity of the damage/destruction and the limited timeline available to reconstruct the lower chute.

Numerous change orders/modifications were required to achieve rebuilding in advance of the 2017/2018 flood season. This including design revisions during construction to add details for the RCC chute section tie in and the temporary RCC walls needed to convey flood flows. Other significant change orders were required to accelerate the contract to meet the 1 November 2017 milestone for the 2017/2018 season. However, based on the information provided for this review, it remains uncertain if the lower chute, upper chute, and/or emergency spillway was accelerated by these changes. Hence, it is strongly recommend that FEMA request the following items from DWR to clarify how these change orders impacted each work feature:

1) The original award project Contract Completion date (possibly multiple dates for phasing of the project),
2) Changes to the Contract Completion Date based on the addendums during solicitation and Change Orders during construction; including, detailed schedule submissions that support the time extension and acceleration requests,
3) Contractor submitted and DWR (Engineer reviewed) approved baseline schedule, and adjustments to the baseline schedule, and
4) Backup information for each change order to include the Engineers Estimate (DWR) and efforts taken to negotiate each change order.

3. **Provide assessment of main (gated) spillway repair designs/costs/construction with regard to current design standards and/or site-specific functionality/requirements.**

Response:
The recovery design and construction of the gated spillway chute appears to follow current design standards for a structure of this size and its potential risk to the downstream public. DWR started design of the gated spillway chute following the destruction of the lower section. DWR promptly assembled, organized, and utilized a high caliber design team of DWR Engineers and A/E Consultants and subsequently integrated a seamless review process with highly qualified technical/construction reviewers from A/E consultants, the State of California Division of Safety of Dams (DSOD), other Federal Agencies and recognized world class experts. The design included two phases of construction to restore the gated spillway chute to the original design capacity of 296,000 cfs.

For the first phase, the "2017 Oroville Emergency Recovery - Spillways Task Force Objectives" were to 1) Temporarily restore the capacity of the upper section of the Gated Spillway chute to pass a peak discharge flow of 270,000 cfs without sustaining significant damage (need to last through a single flood season), and 2) Restore the capacity of the lower section of the Gated Spillway chute to pass a peak discharge of 100,000 cfs without developing significant damage, but up to 270,000 cfs with potential damage. The first phase was to replace the destroyed lower section of chute before the 1 November 2017 milestone and included RCC placement in the primary eroded area to create a temporary RCC chute with a RCC formed wall for the 2017/2018 season. The first phase also included replacement of the lower reinforced concrete chute slab/walls, anchors, and subdrains downstream of the major erosional area.

The second phase of construction is currently in progress and includes removal of the interim RCC walls and reconstruction of the remainder of the reinforced concrete chute slab/walls, anchors, and subdrains from the gated spillway control structure to the lower section replaced in the 2017 construction season.

While this phased approach led to a greater level of effort in construction and cost, it did provide sufficient functionality for the 2017/2018 season. At the conclusion of the 2018 construction season, the gated spillway chute is to be returned to its original design capacity of 296,000 cfs.

The recovery design and details appear to incorporate the loading conditions, the site specific foundation conditions, and the functionality requirements. The recovery design includes a thicker chute slab, an additional layer of reinforcement in the chute slab (two layers), slightly wider and taller chute walls, an increased number of slab anchors (with longer embedment), and a modern designed chute subdrain system accounting for filter compatibility. Each of these design components are required to provide a fully functional gated spillway chute to the original hydraulic design capacity requirements and to address the variable foundation conditions. Based on the change orders, contract modifications, and construction photos it also appears that several of the design details were adjusted during construction to address actual site conditions.

4. **Provide assessment of emergency spillway repair designs/costs/construction with regard to current design standards and/or site-specific functionality/requirements.**

Response:

The Emergency Spillway repair design includes two primary components: 1) a Secant Pile Wall located approximately 750 feet downstream of the Emergency Spillway ogee weirs, and 2) a stepped RCC apron to be placed between the existing ogee spillway weir and the Secant Pile cutoff wall. The Secant Pile Wall was constructed in 2017 with DWR's intent to have an initial emergency discharge capacity of at least 30,000 cfs (approximately 10% of its original design capacity of 371,000 cfs) available (in time) for the 2017/2018 season. However, the Corps has concluded that the constructed secant pile wall, by itself, did not provide for the limited use of Emergency Spillway. The Corps believes that the significantly reduced emergency spillway discharge capacity from original design was likely a result of the potential for scour erosion to initiate upstream of the secant pile wall. Scour within this area could potentially occur as a result of the removal of the armoring (grouted rip rap), as positioned during the 2017 emergency response, for the RCC apron placement in 2018. Acceleration of Emergency Spillway work features (construction contract) ahead of the 2017/2018 season may not have been necessary since the Emergency Spillway repairs made during 2017already allowed for the limited use of the emergency spillway. The stepped RCC apron (between the ogee spillway weir and the Secant Pile cutoff wall) is currently under construction and is planned to be complete before the 2018/2019 flood season.

In general, the design and planned repair work appears to provide additional stability and improvement to the energy dissipation from overflow discharge in the area downstream of the emergency spillway ogee weir. This repair and stabilization work will aid in returning this feature to a serviceable condition, since emergency grouted rip rap (placed in 2017) has been removed. However, as noted in the 17 August 2018 DWR Emergency Recovery Efforts for the Gated Spillway and Emergency Spillway Report, the design intent of these features has not been fully developed and additional analyses will be needed to determine what measures will be necessary to restore the Emergency Spillway to its original design capacity of 371,000 cfs. The report also stated "The scope of repairs undertaken to date is not considered adequate to safely pass large flood flows such as the Probably Maximum Flood (PMF) as required by DSOD and FERC". It is unknown what flow capacity will be allowable by Regulators (FERC and DSOD) with the current as designed repairs constructed. However, it is worth noting that in the 16 October 2018 Letter, DWR indicated that the RCC armoring and secant pile wall are designed to withstand a peak flow of 100,000 cfs.

The Emergency Spillway is a critical feature to the Oroville Project as it functions to prevent an overtopping failure of Oroville Dam during extreme flood flow conditions (flood volume exceeds the capacity of the Gated Spillway). The Corps believes that the Emergency Spillway will perform adequately for a peak flow of 100,000 cfs, especially with the addition of the stepped RCC chute and secant pile wall. However, the emergency spillway design flood conveyance system should address the current understanding of the hydrologic conditions of the watershed commensurate with the downstream public and life safety risk.

End of Document

PA-09-CA-4308-PW-01425(0) P	
Applicant Name:	Application Title:
CALIFORNIA DEPARTMENT OF WATER RESOURCES - DWR	ODGSWD2 - Oroville Dam Spillways Repairs
Period of Performance Start:	Period of Performance End:
04-01-2017	10-01-2018

Bundle Reference # (Amendment #)	Date Awarded

Subgrant Application - FEMA Form 90-91

Note: The Effective Cost Share for this application is 75%

FEDERAL EMERGENCY MANAGEMENT AGENCY

PROJECT WORKSHEET

DISASTER	PROJECT NO.	PA ID NO.	DATE	CATEGORY
FEMA 4308 - DR -CA	ODGSWD2	000-U0FD2-00	02-07-2019	D

APPLICANT: CALIFORNIA DEPARTMENT OF WATER RESOURCES - DWR	WORK COMPLETE AS OF: 02-07-2019 : 95 %
Site 1 of 2	
DAMAGED FACILITY: Upper Gated Spillway (Sta 13+00 to 28+25)	COUNTY: Butte

LOCATION:	LATITUDE:	LONGITUDE:
Current Version: Oroville Dam is located on the Feather River, approximately 75 miles north of Sacramento, California and 5 miles northeast of the City of Oroville. The Gated Spillway is located near the northwest abutment of the dam in a natural saddle. Geodetic coordinates taken at the midpoint of the spillway. Lat. 39.539833, Long. -121.496155	39.539833	-121.49615

DAMAGE DESCRIPTION AND DIMENSIONS:

Current Version:
This site addresses LOP Item No. 14 for the California State Department of Water Resources (DWR). Oroville Dam is owned, operated, and maintained by DWR.

BACKGROUND

During the incident period of February 1st 2017 through February 23rd 2017, precipitation from severe winter storms within the Feather River Watershed filled Oroville Lake necessitating high-volume water releases through the primary flood control outlet (the Gated Spillway) and via the Emergency Spillway. From February 6, 2017 through February 10, 2017, a reported 12.8 inches of rain fell across the Feather River watershed. Over a five day period from 2/7 to 2/11, inflow into Oroville Lake averaged 115,260 cfs with a corresponding lake level rise of 40 ft to a record elevation of 902.57 feet above mean sea level (ft-msl).

Prior to this rain event, no significant releases of water via the Gated Spillway had occurred since 2011. Minor releases of less than 10,000 cfs occurred at various times between 2011 and February 2017. Significant releases of water did not occur until February 6, 2017 when between 42,000 cfs and 45,000 cfs was discharged. On February 7, 2017, failure of the Gated Spillway chute was first noted around 10:00am while discharges were at approximately 52,000 cfs. Although sustained releases greater than 52,000 cfs have occurred in the past, they are relatively infrequent and typically occur during years of significantly higher than normal precipitation. The last time discharge rates exceeded 50,000 cfs was in the winter of 2005/2006.

Initial damage to the Gated Spillway was inspected after gate closure at 11:25am on February 7th and consisted of broken (and missing) portions of the concrete apron over an approximate area of 750 sq-ft just below Station 33+00. A significant erosion hole had developed

below the missing apron with additional erosion along the outside of the east chute wall. Knowing that use of the gated spillway would be required to maintain a safe lake level, the Gated Spillway was re-engaged on February 8th with an initial discharge of 20,000 cfs, which was incrementally increased to 65,000 cfs. Due to continued deterioration of the concrete chute and back-cut erosion threatening high-voltage transmission towers, discharges were reduced and kept around 55,000 cfs.

Because of DWRs decision to limit damage and discharge via the Gated Spillway, the resulting flow rates were not sufficient to prevent engagement of the Emergency Spillway which occurred on February 11th and marked the first time in the history of the facility that the Emergency Spillway was used. A maximum lake level of 902.57 ft-msl was recorded, which is 1.57 ft higher than the elevation of the Emergency Spillway concrete weir. This resulted in flow over the Emergency Spillway for a 36 hour duration that began February 11th and peaked at 12,500 cfs on February 12th.

Erosion of the unimproved natural earthen slope below the Emergency spillway was immediate and with a severity that was unexpected by DWR officials. This erosion, with continued use, threatened the integrity of the concrete weir's foundation, which resulted in the order to evacuate the City of Oroville. As soon as this erosion was noted, discharges through the Gated Spillway were ramped up to 100,000 cfs to minimize flow over the Emergency Spillway. Flow over the Emergency Spillway stopped within 24 hrs, while high discharges were maintained via the Gated Spillway until a target lake elevation of 850 ft-msl was reached. These high volume discharges caused severe damage to the lower portion of the Gated Spillway chute.

For a detailed analysis of the cause of failure, refer to the attached "Independent Forensic Team Report - Oroville Dam Incident, dated January 5, 2018."

DESCRIPTION AND DIMENSIONS OF GATED SPILLWAY

Oroville Dam and its associated spillways were built in the 1960s with final construction completed in 1968. The main flood control outlet for Oroville Lake is referred to as the Gated Spillway or Service Spillway. For consistency with DWR reports, the term "Gated Spillway" is used in this PW. The following is a general description of the Gated Spillway prior to the incident period. Please refer to the design drawings for further details.

The Gated Spillway is located on the right abutment of the main dam. It consists of an unlined approach channel, a gated headworks structure with an effective crest length of 140.7 feet wide, and a concrete-lined chute extending to just above the Feather River which flows from the base of the dam. The main elements consist of the following:

-- A headworks structure consisting of eight outlet bays controlled by eight top-seal radial gates with a sill elevation of 813.6 ft-msl. The individual gates are 17 feet, 8 inches wide and 33 feet, 6 inches high with the top of the gates at elevation of 847 ft-msl.

-- The concrete lined chute downstream of the headworks structure is 178 ft 8 inches between the chute walls and 3,000 ft long. The upper 1,000 feet of the chute slopes at about 5.6 percent, after which the chute transitions to a much steeper slope of about 24.5 percent for the last 1,455 feet.

-- The terminus of the chute consists of four large, 45-foot long reinforced concrete dentates (energy dissipaters) sitting on a thick concrete pad that is 55 LF with side walls that flare out from the chute width of 178 ft 8 inches.

-- The concrete apron of the chute is constructed of reinforced structural concrete a minimum of 15 inches thick, which varied in thickness due to terrain. Concrete reinforcement consisted of a single layer No. 5 bars spaced 12 inches apart in each direction.

-- The concrete apron was anchored using No. 11 anchor bars placed in a grid with 10-ft spacing and set at various depths in to the foundation.

-- The chute walls were constructed of reinforced concrete with a height that varies between 20 ft and 27 ft high. The chute walls along the top section of the chute were 27 ft high with a 2 ft 4 inch thickness at its base that tapers to 1 foot at the top. Along the middle section, the chutes walls are between 27 ft and 20 ft high with a thickness that tapers from 1.5 ft at the base to 1 ft at the top. The bottom section has chute walls 20 ft high and thickness of 1.5 ft at the base and 1 ft at the top.

-- A drain system underlined the concrete apron with lateral drains spaced every 25 ft on the upper portion of the spillway and 20 ft apart on the lower, steeper portion of the spillway. The drains consisted of 6-inch vitrified clay pipe and were set into the concrete apron. The drain system was designed to control potential groundwater seepage beneath the chute slab.

-- No foundation material is specified in the original construction. The structural concrete apron was placed over graded natural material, which varied between competent bedrock and fine grained soil-like material.

-- According to the 1970 Report on Reservoir Regulation for Flood Control, the service spillway maximum discharge capacity is 296,000 cfs, with the reservoir at Elevation 917 and all gates fully open. Historically, the maximum recorded daily discharge occurred in 1987 at 132,916 cfs.

SPECIFIC DAMAGES TO GATED SPILLWAY

Damage to the Gated Spillway was initiated when lake water releases were increased to 52,000 cfs due to the storm event that occurred during the incident period. Failure of the concrete chute occurred on 2/7/17 with initial damage consisting of a hole in the concrete apron over an area of approximately 750 sq-ft just below Station 33+00 (See Gated Spillway Damage Photos). A significant erosion hole into the foundation was also observed at this time, with additional erosion along the east side of the concrete chute. Due to the magnitude of the storm event and erosion of the Emergency Spillway, additional releases through the Gated Spillway were required prior to any repair efforts. The resulting damage caused from the continued release of water is as follows:

-- Complete destruction (loss) of the concrete chute apron over an area of 136,816 sq-ft, including 1,653 LF of concrete chute wall. This

includes destruction of the underdrain system and loss of concrete anchors.

-- Erosion of the spillway foundation (integral ground) over an area of 169,727 sq-ft with an average depth of 40 ft for a total of approximately 251,447 CY.

-- Due to stress from turbulent flow and debris impacts, the entirety of the concrete chute and walls below Station 29+50 to the end of the spillway at Station 43+00 (1,350 LF) was severely damaged and/or undermined.

-- Damage occurred to all four of the concrete monolithic energy dissipaters at the end of the spillway. Large chucks of concrete were broken off the structures due to debris impacts. The concrete support pad (55 LF x 183 ft) had some surface damage, but is structurally intact.

-- Deposition of approximately 2,000,000 CY of debris into the Thermalito Diversion Pool (Feather River), which is a maintained engineered channel in this area. Debris removal and repairs to this channel are addressed in PW-00037-DR4308.

OROVILLE DAM INSPECTIONS AND MAINTENANCE

The Oroville Dam (including spillways) has been inspected on a regular basis since its construction in 1968. California Division of Safety of Dams (DSOD) has formally inspected the dam annually at a minimum, and twice a year during some years. The purpose of the DSOD inspections was to verify that the dam is performing as intended by inspecting the water impounding structures including the Gated and Emergency Spillways.

Federal Energy Regulatory Commission (FERC) also conducts a formal annual inspection of the facility. During some years, the DSOD and FERC inspections are conducted jointly, while other years they were not. This can result in one to three formal inspections per year. Every five years, FERC defers inspections to an Independent Consultant that conducts a much more rigorous inspection of all elements associated with the dam. Based on the findings of the annual inspections, FERC issues follow-up letters with action items and requests a plan and schedule from DRW for completion of these items. Action items could range from performing studies to conducting repairs.

In addition to the formal inspections, DWR staff routinely observe the dam and appurtenant structures on a daily basis as part of the normal job duties. The staff also performs other observations for weekly and monthly data collection during which they view the structures more closely to detect any unusual behavior or conditions. For further information on the inspection process, refer to the attached DWR Inspection Process Memo (Attachment 1).

At the request of FEMA, DWR provided copies of inspection reports and maintenance records dating back to 1978 that pertained to the Gated and Emergency Spillways. There is no evidence of DWR not addressing any action items cited in any inspection reports.

*****NOTE: SEE PW 1410 FOR ALL ATTACHMENTS*****

SCOPE OF WORK:

Current Version:
The DWR scope of work for the Gated Spillway, in general, includes: removal and replacement of the entire spillway chute and walls to current design standards; repair of energy dissipaters; construction of site access roads with associated drainage and erosion control measures; and necessary engineering, environmental, inspection and project management.

WORK COMPLETED:

General scope of work from Engineer's Estimate/Construction Pay Estimate within main repair contract (Gated & Emergency Spillways). Items below may/may not apply to Gated Spillway repair. See accompanying explanation below:
Temporary Crossing
Work site security
Temporary traffic control
Project information sign
Access restriction signs
Barricades
Temporary type K railing
Mobilization and demobilization
Foundation preparation
Foundation preparation - dental excavation
Foundation preparation - dental concrete
Selective demolition (upper flood control outlet chute)
Selective demolition (lower flood control outlet chute)
Selective demolition (emergency spillway)
Clearing and grubbing
Select tree removal
Dewatering
Excavation
Rock excavation
Select fill
Pervious backfill
Rock slope protection
Geotextile fabric
Hydrauger - type 1

Hydrauger - type 2
Hydrauger - type 3
Rock anchor - type 1 (class 2)
Rock anchor - type 2 (class 2)
Rock anchor - type 3 (class 2)
Rock anchor - type 4 (class 1)
Relief wells (monolith)
Relief wells (secant wall)
Relief wells (collection pipes)
Relief drain (monolith)
Underdrain type 1 (flood control outlet chute perforated drain)
Underdrain type 2 (flood control outlet chute wall solid drain)
Underdrain type 3 (wall backfill perforated drain)
Corrugated metal pipe (CMP) 24"
Corrugated metal pipe (CMP) 36"
Aggregate base
Chain link fence
Walk gate
20 foot double drive gate
Construction access gate
Seeding
Fiber rolls
Silt fence
Straw bale barrier
Reinforcing steel
Reinforcing steel (epoxy coated)
Reinforcing steel (galvanized)
Reinforcing steel (stainless steel)
Structural concrete
Erosion resistant concrete
Test panels
Mass concrete
Leveling concrete
Slush grout
Bedding mortar
Emergency spillway cut off wall
Emergency spillway secant pile cutoff wall
Shotcrete
Drilling and grouting chute dowel anchors
Roller compacted concrete (flood control outlet chute)
Roller compacted concrete (emergency spillway)
Concrete coatings
Fixed time-lapse camera

Construction costs, in general, have been apportioned to three locations as follows: Upper Gated Spillway (Station 13+00 to Station 28+25), Lower Gated Spillway (Station 28+25 to 43+00) and Emergency Spillway. As work to repair the three cited areas are currently underway and actual quantities and final expenditures for each are not known at this time, general percentages for each have been assigned and incurred costs allocated accordingly. Final costs will be adjusted through subsequent versions once work is complete and ultimate quantities and costs are known. See backup for assessed percentages and cost allocations. Costs for the Oroville Spillways Project are to date expenditures provided by DWR. DWR, FEMA and CalOES are in full agreement with this method of partial payment for costs incurred.

While it is understood that the entire spillway will be reconstructed as recommended by FERC/DSOD to address long term operational safety concerns, eligibility/funding for the Upper Gated Spillway, which was not damaged, has been separated out and determined not eligible.

Submitted costs to date include three separate awarded contracts to: KIEWIT, SYBLON REID & TEICHERT

Costs for all other contract work, force account or other expenditures have not been submitted at this time for reimbursement. Eligibility of these costs will be determined after submission in subsequent versions.

UPPER GATED SPILLWAY (Station 13+00 to Station 28+25)

***Competitive Bid Main Repair Contract #C51544 – KIEWIT
Estimated costs up to and including Progress Payment #26, August 2018
Bid line items for upper Gated Spillway work = $70,594,393 (see attached spreadsheet for costs and allocations)

Contract Change Orders # 1 through #81 = $14,757,992 (excluding CCO #68) (see attached spreadsheet for costs and allocations)

Total KIEWIT = $85,352,385

Note: Eligibility of CCO #68 has not been determined at this time, therefore costs for this CCO line item has not been included. Eligibility will be determined in a subsequent version.

*** Emergency Time & Material Contract #C51539 – SYBLON REID
Construction Orders under this contract considered permanent work have been removed from the Category B PW (4308 Project Worksheet #36) and included in this PW.

Includes Contract Orders: #33, 35, 39, 52, 53, 55-57, 60, 63, 65
Total for above COs = $1,747,023 (see attached spreadsheet for costs and allocations)

Note: Eligibility of CO #41, 43, 61 has not been determined at this time, therefore costs for these CO line items have not been included. Eligibility will be determined in a subsequent version.

*** Contract #C51543 – TEICHERT
Teichert Contract for access roads to project sites and emergency recovery
Contract Work = $1,354,647 (see attached spreadsheet for costs and allocations)
Total Change Orders = $521,302 (see attached spreadsheet for costs and allocations)
Total TEICHERT = $1,875,949

Total contract work for Upper Gated Spillway only for above 3 contracts (KIEWIT, SYBLON REID & TEICHERT) = $85,352,385 + $1,747,023 + $1,875,949 = $88,975,357

Engineering/Design for the upper Gated Spillway - costs for upper chute portion is not known, therefore costs to be estimated utilizing Cost Estimating Format (CEF). For design details, including pertinent Standards for replacement of chute, see backup.

Cost Estimating Format (CEF) upper Gated Spillway = $113,210,465 (see attached)

See Determination Memo (DM) for Upper Gated Spillway

LOWER GATED SPILLWAY (Station 28+25 to Station 43+00) see PW 1410

WORK TO BE COMPLETED:
Not included. Costs for all other contract work, force account or other expenditures have not been submitted at this time for reimbursement. Eligibility of these costs will be determined after submission in subsequent versions.

Notes:
Detailed plans for construction of the Gated Spillway chute can be requested from DWR for review. Plans have not been included in this PW since this is critical infrastructure with restrictions on dissemination of information.

FEMA requested that DWR provide information supporting the division of the upper undamaged spillway section from the lower damaged spillway section. Per letter dated November 16, 2018 from DWR to OES (see attached), DWR has provided sufficient information to justify the uppermost station of 28 + 25, as work to stabilize the over-steepened "Arena Cut" area would require flattening of the spillway chute slope above the scour hole to enable repair work to be performed safely.

****NOTE: SEE PW 1410 FOR ALL ATTACHMENTS****

Site 2 of 2

DAMAGED FACILITY:	COUNTY: Butte	
Emergency Spillway		
LOCATION:	LATITUDE: 39.544598	LONGITUDE: -121.49363
Current Version: Oroville Dam is located on the Feather River, approximately 75 miles north of Sacramento, California and 5 miles northeast of the City of Oroville. The Emergency Spillway is located northwest and adjacent to the Gated Spillway. Geodetic coordinates taken at the midpoint of the Emergency Spillway concrete ogee weir. Lat. 39.544598, Long. -121.493633		

DAMAGE DESCRIPTION AND DIMENSIONS:

Current Version:
This site addresses LOP No. 15 for the California Department of Water Resources (DWR).

GENERAL DESCRIPTION OF THE EMERGENCY SPILLWAY

The Emergency Spillway is located on the right (northwest) abutment, to the right of the Gated Spillway and consists of two sections: a 930-foot long, gravity ogee weir and an 800-foot long broad crested weir that ends at a natural hillside. The crests of both sections are at 901 ft-msl, which is 1 foot above the maximum normal operating reservoir level of 900 ft-msl. The ogee weir is a large concrete structure with a maximum height of 50 ft on its southeast end that tapers down towards the northwest. There is a concrete apron at the base which is approximately 11.67 feet wide. Along the south end of the ogee weir, a channel with dimensions of approximately 250 ft long at the base of the weir x 300 ft long downhill was cut into the natural slope to direct flow. The first approximately 40 feet of this channel is lined with grouted rock. The remaining portion of the channel is unimproved.

The broad crested weir section of the Emergency Spillway has a control crest consisting of a 4-ft wide by 800 LF concrete weir with gentle slopes on either side. Upstream of this weir is the location of a paved parking lot and downstream is unlined natural slope. The downstream slope was shaped for approximately the first 250 ft at a very low gradient, then transitions into natural terrain.

DAMAGES TO EMERGENCY SPILLWAY

The concrete ogee gravity weir was not damaged during its use and is structurally intact. None of the grouted riprap section of the channel below this weir was damaged. Similarly, the concrete section of the broad crested weir structure was not damaged.

Due to the emergency situation regarding both of Oroville Dam's spillways, emergency repairs to the Emergency Spillway unimproved slope were conducted immediately after flow over this spillway stopped on February 12th. This was done in case the Gated Spillway could not be used and re-engagement of the Emergency Spillway was required. Erosional damage to the unimproved slope adjacent to the Emergency Spillway was repaired using grouted rip-rap. Refer to Category PW-00036-DR4308 for details of the temporary emergency repairs.

Additional damage caused by the erosion of the Emergency Spillways drainage slope was the deposition of approximately 200,000 CY of debris into the Thermalito Diversion Pool (Feather River), which is a maintained engineered channel in this area. Debris removal and repairs to this channel are addressed in PW-00037-DR4308. Also, a significant section of Oroville Dam Road was washed away which runs through the path of the Emergency Spillway (refer to PW ODB&RC1).

****NOTE: SEE PW 1410 FOR ALL ATTACHMENTS****

SCOPE OF WORK:

Current Version:
Following is the scope of work, in general, for the newly engineered Emergency Spillway. Modifications will include upgrades to the existing undamaged concrete weirs and improvements to the natural unimproved slope:

Removal of grouted rock armoring of the spillway slope placed as an emergency protective measure

Clearing and grubbing of vegetation over approximately 23 acres and removal of approximately 1,500 trees

Construction of aggregate surfaced access roads including drainage and erosion control measures

Construction of 1,450 long X 35 ft to 65 ft deep concrete secant pile wall (cut-off wall) with 36 relief wells to an average depth of 50 ft

Removal and replacement and of the 800 ft long broad-crested control weir to new design. Relief wells will be added to both the ogee weir and broad crested weir. Forty wells are proposed along the weirs with an average depth of 50 ft

Installation of 10 ft thick roller compacted concrete splash pad. Dimensions are 1,730 ft along the top at weirs by 700 ft downslope and 1,450 ft at the terminus along the secant pile wall. Foundation preparation work includes removal of loose material (soil and weathered rock) and contour grading to direct flows to the main drainage channel where additional armoring in the channel is planned to further reduce erosion

Installation of roller compacted buttress to the concrete weirs to further support these structures. Preparation for placement of the concrete buttress will include removal of material down to competent bedrock with slush grout to fill voids. The buttress base will reach down to competent bedrock and extend the length of both weirs for 1,730 LF x 30 ft wide

WORK COMPLETED:

General scope of work from Engineer's Estimate/Construction Pay Estimate within main repair contract (Gated & Emergency Spillways). Items below may/may not apply to Gated Spillway repair. See accompanying explanation below:
Temporary Crossing
Work site security
Temporary traffic control
Project information sign
Access restriction signs
Barricades
Temporary type K railing
Mobilization and demobilization
Foundation preparation
Foundation preparation - dental excavation
Foundation preparation - dental concrete
Selective demolition (upper flood control outlet chute)
Selective demolition (lower flood control outlet chute)
Selective demolition (emergency spillway)
Clearing and grubbing
Select tree removal
Dewatering
Excavation
Rock excavation
Select fill
Pervious backfill

Rock slope protection
Geotextile fabric
Hydrauger - type 1
Hydrauger - type 2
Hydrauger - type 3
Rock anchor - type 1 (class 2)
Rock anchor - type 2 (class 2)
Rock anchor - type 3 (class 2)
Rock anchor - type 4 (class 1)
Relief wells (monolith)
Relief wells (secant wall)
Relief wells (collection pipes)
Relief drain (monolith)
Underdrain type 1 (flood control outlet chute perforated drain)
Underdrain type 2 (flood control outlet chute wall solid drain)
Underdrain type 3 (wall backfill perforated drain)
Corrugated metal pipe (CMP) 24"
Corrugated metal pipe (CMP) 36"
Aggregate base
Chain link fence
Walk gate
20 foot double drive gate
Construction access gate
Seeding
Fiber rolls
Silt fence
Straw bale barrier
Reinforcing steel
Reinforcing steel (epoxy coated)
Reinforcing steel (galvanized)
Reinforcing steel (stainless steel)
Structural concrete
Erosion resistant concrete
Test panels
Mass concrete
Leveling concrete
Slush grout
Bedding mortar
Emergency spillway cut off wall
Emergency spillway secant pile cutoff wall
Shotcrete
Drilling and grouting chute dowel anchors
Roller compacted concrete (flood control outlet chute)
Roller compacted concrete (emergency spillway)
Concrete coatings
Fixed time-lapse camera

Construction costs, in general, have been apportioned to three locations as follows: Upper Gated Spillway (Station 13+00 to Station 28+25), Lower Gated Spillway (Station 28+25 to 43+00) and Emergency Spillway. As work to repair the three areas above are currently underway and actual quantities and final expenditures for each are not known at this time, general percentages for each have been assigned and incurred costs allocated accordingly. Final costs will be adjusted through subsequent versions once work is complete and ultimate quantities and costs are known. See backup for assessed percentages and cost allocations. Costs for the Oroville Spillways Project are to date expenditures provided by DWR. DWR, FEMA and CalOES are in full agreement with this method of partial payment for costs incurred.

Submitted costs to date include three separate awarded contracts to: KIEWIT, SYBLON REID & TEICHERT

Costs for all other contract work, force account or other expenditures have not been submitted at this time for reimbursement. Eligibility of these costs will be determined after submission in subsequent versions.

EMERGENCY SPILLWAY
***Competitive Bid Main Repair Contract #C51544 – KIEWIT
Estimated costs up to and including Progress Payment #26, August 2018
Bid line items for Emergency Spillway work = $81,155,027 (see attached spreadsheet for costs and allocations)

Contract Change Orders # 1 through #81 = $67,133,587 (excluding CCO #68) (see attached spreadsheet for costs and allocations)
Total KIEWIT = $148,288,614

Note: Eligibility of CCO #68 has not been determined at this time, therefore costs for this CCO line item has not been included. Eligibility will be determined in a subsequent version.

*** Emergency Time & Material Contract #C51539 – SYBLON REID

Construction Orders under this contract considered permanent work have been removed from the Category B PW (4308 Project

Worksheet #36) and included in this PW.

Includes Contract Orders: #33, 35, 39, 52, 53, 55-57, 60, 63, 65
Total for above COs = $1,707,640 (see attached spreadsheet for costs and allocations)

Note: Eligibility of CO #41, 43, 61 has not been determined at this time, therefore costs for these CO line items have not been included. Eligibility will be determined in a subsequent version.

*** Contract #C51543 – TEICHERT
Teichert Contract for access roads to project sites and emergency recovery
Contract work = $1,354,647(see attached spreadsheet for costs and allocations)
Total Change Orders = $6,521,302 (see attached spreadsheet for costs and allocations)

Total TEICHERT = $1,875,949

Total contract work for Emergency Spillway only for above 3 contracts (KIEWIT, SYBLON REID & TEICHERT) = $148,288,614 + $1,707,640 + $1,875,949 = $151,872,203

Engineering/Design for the Emergency Spillway - costs for emergency spillway is not known, therefore costs to be estimated utilizing Cost Estimating Format (CEF). For design details, including pertinent Standards for replacement of spillway, see backup.

Cost Estimating Format (CEF) Emergency Spillway = $193,239,154 (see attached)

WORK TO BE COMPLETED

Not included. Costs for all other contract work, force account or other expenditures have not been submitted at this time for reimbursement. Eligibility of these costs will be determined after submission in subsequent versions.

See Determination Memo (DM) for Emergency Spillway

Notes:
Detailed plans for construction of the Emergency Spillway can be requested from DWR for review. Plans have not been included in this PW since this is critical infrastructure with restrictions on dissemination of information.

****NOTE: SEE PW 1410 FOR ALL ATTACHMENTS****

Does the Scope of Work change the pre-disaster conditions at the site? ☑ Yes ☐ No	Special Considerations included? ☑ Yes ☐ No
Hazard Mitigation proposal included? ☐ Yes ☑ No	Is there insurance coverage on this facility? ☐ Yes ☑ No

PROJECT COST

ITEM	CODE	NARRATIVE	QUANTITY/UNIT	UNIT PRICE	COST
		*** Version 0 ***			
		CEF			
1	9000	Site 1 Upper Gated Spillway (Sta 13+00 to 28+25) CEF	1/LS	$ 113,210,465.00	$ 113,210,465.00
2	9000	Site 2 Emergency Spillway CEF	1/LS	$ 193,239,154.00	$ 193,239,154.00
		Other			
3	9999	***Ineligible Project - See DM for Upper Gated and Emergency Spillways***	1/LS	$ -306,449,619.00	$ -306,449,619.00
				TOTAL COST	$ 0.00

PREPARED BY KAREN SCHIEBERL	TITLE Project Specialist	SIGNATURE
APPLICANT REP. Christy Jones	TITLE	SIGNATURE