Appendix HY-3

Climate Change/Hydrology Memo

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TECHNICAL MEMORANDUM

To:	Todd Smith – Sacramento County Planning Department
From:	Ken Giberson
Cc:	Michael Johnson – Sacramento County DWR
Date:	November 14, 2018
Subject:	Climate Change Impact Analysis For Mather South Specific Plan Development

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1. INTRODUCTION

Mather South Specific Plan (Mather South) is a large planning area that is in the watershed of the 180± square mile Morrison Creek Stream Group. Recently, Sacramento County has expressed concern regarding the potential long-term effect climate change may have on the proposed drainage and flood control improvements within Mather South.

Traditional methods for estimating the flow rate for the 10-year and 100-year design events assume that flow rate will not change over time. The drainage and flood control facilities included in the Mather South Drainage Master Plan where predicated on the assumption that these flow rates are stationary, and they will not change over time.

However, the uncertainty associated with climate change indicates that the potential for flows rates to vary over time needs to be addressed. Current understanding, supported by research and broad consensus of the scientific community, is that our climate is changing over time. This means that flood hazard, which is driven partially by climate, will also change over time.

Additionally, some stakeholders have expressed concern that the Mather South development has not addressed the 200-year design event. The threat of flooding from the 200-year event as a design standard is applicable to some, but not all, developing areas within Sacramento County. The applicability of the 200-year design standard for Mather South needs some discussion.

2. PROBLEM STATEMENT

The Mather South development is currently undergoing environmental review by Sacramento County in conjunction with land use entitlement applications that have been filed by the applicant. Notwithstanding the existence of an approved drainage master plan for the Mather South development, the extent of additional flooding that may occur within and downstream of Mather South during the 10-year and 100-year events assuming the affects of climate change needs to be determined. Additionally, the applicability of the County's 200-year design standard need to be addressed.

3. METHODOLOGY

Currently, Sacramento County doesn't require proposed drainage and flood control improvements to be designed to withstand the effects of climate change. Additionally, the long-term effects of climate change have not been quantified with a reasonable degree of precision at this time. Accordingly, today it is beyond the ability of the engineering community to predict the probable magnitude of climate change on local hydrology.

In the absence of adopted hydrologic design standards for climate change, a reasonable approach to evaluating the effects on climate change on the flood control improvements proposed for the Mather South project needs to be developed. In essence, these proposed Mather South improvements need to be evaluated for their resiliency to withstand the additional flows that may be generated from the effects of climate change.

The precipitation and runoff characteristics of the Mather South project area under existing and development conditions was extensively modeled during the preparation of the Drainage Master Plan for the project. The SacCalc precipitation modeling for the project yielded the total volume of runoff and peak flow for both the pre and post development scenarios.

The resulting hydrographs were analyzed from the pre-project to the post-project conditions and input into the HEC-RAS models for Morrison Creek and Todd Creek for evaluation of the proposed flood control improvements. The SacCalc and HEC-RAS models were used to determine the adequacy of the facilities tributary to each creek to accommodate the resultant flows during the 10-year and 100-year design events during climate change conditions. The results of the Master Plan analysis indicated that the facilities provide the required level of protection from the 10-year/24-hour, the 100-year/24-hour, and the 100-year/10-day design events.

The methodology to be used to check the resiliency of the Mather South drainage and flood control facilities to endure the effects of climate change will incorporate climate change influences on the existing-climate discharge frequency curves from the Central Valley Flood Protection Project (CVFPP) derived by the California Department of Water Resources (DWR) for the CVFPP in 2017. [1]

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[1] California Department of Water Resources, *2017 CVFPP Update – Climate Change Analysis Technical Memorandum* (March 2017)

California DWR estimated the impacts that climate change may have on the runoff from various creek systems in the Central Valley.

The California DWR analysis can be used to derive hydrologic scaling factors from the climate change analysis. Scaling factors were derived from this analysis for three design events (10-year, 100-year and 200-year events) and five (5) different durations (1, 3, 7, 15 and 30-days).

These scale factors will be used to adjust the existing hydrographs from the Mather South Drainage Master Plan to estimate the resultant climate-changed flow conditions that are projected to occur over time as a result of climate change. That is, the scale factors will be used to increase the predicted hydrographs previously derived from the SacCalc precipitation modeling mentioned above.

Sacramento County DWR requested a bookend approach to evaluating the resiliency of the projected Mather South flood control improvements. Sacramento County suggested using the scaling factors for Arcade Creek and Pleasant Gove Creek Canal (PGCC) during the preparation of this Technical Memorandum. Sacramento County DWR suggested that the differences in scaling factors between these two creeks should provide an adequate range of impacts for analysis for this level of study.

The scaling factors for the two creeks is shown below in Tables 1 and 2. Note that the 10-Day volume scaling factors were straight line interpolation from the 7-Day and 15-Day Volumes.

Table 1
Scaling Factors for Arcade Creek

Annual Exceedence Probability	Return Period (Yr.)	Arcade Creek Scaling Factors					
		Derived from California DWR Analysis					**10-Day Volume (Calc.)**
		1-Day Volume	3-Day Volume	7-Day Volume	15-Day Volume	30-Day Volume	
0.005	200	0.99	1.06	1.13	1.26	1.32	**1.18**
0.01	100	1.08	1.14	1.21	1.31	1.36	**1.25**
0.1	10	1.46	1.44	1.48	1.50	1.50	**1.49**

Note: 10-Day Volume Scaling Factors were derived by straight line interpolation between the 7-Day and 15-Day Volumes .

The scaling factors for the 10-year and 100-year events will be used to estimate the climate-changed hydrographs for the watersheds within the Mather South project. These adjusted hydrographs will then be input into the approved HEC-RAS models for the project to determine a range of the effects that climate change might have on the proposed improvements.

Table 2
Scaling Factors for Pleasant Grove Creek Canal

Annual Exceedence Probability	Return Period (Yr.)	Pleasant Grove Creek Canal Scaling Factors Derived from California DWR Analysis					
		1-Day Volume	3-Day Volume	7-Day Volume	15-Day Volume	30-Day Volume	**10-Day Volume (Calc.)**
0.005	200	1.60	1.53	1.38	1.28	1.25	**1.34**
0.01	100	1.54	1.48	1.36	1.27	1.24	**1.33**
0.1	10	1.35	1.32	1.25	1.22	1.20	**1.24**

Note: 10-Day Volume Scaling Factors were derived by straight line interpolation between the 7-Day and 15-Day Volumes .

The threshold of significance for evaluating these effects on the resiliency of the proposed improvements to withstand climate change are listed below:

1. Detention Basins:
   a. Freeboard encroachment is permissible so long as top of berm elevations are not exceeded.
   b. Use of spillways is permissible so long as the capacity of the spillway is not exceeded (assuming no freeboard).
2. Creeks:
   a. Freeboard encroachment is permissible so long at the top of channel elevations are not exceeded (assuming no freeboard).
   b. Flooding of proposed building pads will not be allowed (1' minimum freeboard from water surface elevation to pad elevation will be maintained.)
3. Compliance Points
   a. Peak flows and stages at downstream compliance points does not exceed the flow rate and stage of pre-development levels assuming the effects of climate change on existing conditions.

Of special importance, two upstream watersheds contribute significant pass-through flows at the eastern edge of the Mather South project area. The Folsom South Canal parallels the eastern boundary of the Mather South Project area. Two branches of Morrison Creek cross the canal in concrete flumes which discharge into two branches of the creek as it traverses across the project area in an east to west direction. These two branches of the creek reach a point of confluence midway across the project area and the main creek continues westerly to a point of discharge under Eagles Nest Road, a gravel road, before discharging into the Mather wetland preserve.

Upstream of these flumes are large detention facilities that detain significant volumes of creek flows thereby attenuating the peak discharge of the upper reaches of the Morrison Creek watershed. In essence, these two flumes act as flow restrictors that limit the amount of flow that crosses the flume and enters the project area. During preparation of the Mather South Drainage Master Plan, Sacramento County DWR provided hydrographs of the attenuated discharge from the flumes. These hydrographs were included in the flood modeling for the project and the on-site project drainage improvements were designed to accommodate these flows.

During the preparation of this climate change analysis, Sacramento County advised that they didn't have updated flume hydrographs reflecting the effects of climate change and couldn't prepare them in a timely basis for this analysis. Staff directed that this climate change analysis be prepared by simply scaling up the earlier provided hydrographs.

Staff acknowledged that the results of scaling up the previously provided hydrographs would exaggerate the peak flow that crosses the flumes into the project site. Clearly, using this approach will result in very conservative estimates of flow entering the project area across the flumes since the beneficial affects of peak flow attenuation within the upstream detention basins will be ignored.

Notwithstanding the conservative nature of approach, this analysis was prepared using the simplified methodology suggested by Staff. The results thereof will, by definition, be conservative. This is particularly important due to the timing effect of the overstated rates and durations of flow entering the project area across the flume. The extended nature of the peak flows discharging from the flumes will conflict from a timing perspective with the peak discharges from the on-site watersheds resulting in higher stage elevations in the creek as it crosses the Mather South project area.

4. CLIMATE CHANGE ANALYSIS

The approved existing conditions and developed conditions HEC-RAS models for Mather South were modified to include the climate changed scaling described above. Two models were prepared for the Master Plan (one model for Todd Creek and one model for Morrison Creek). For Todd Creek twelve (12) model scenarios were made for the purposes of scaling the storms to account for climate change and for Morrison Creek sixteen (16) additional scenarios were created.

The additional scenarios (model plans) are as follows:

a. Todd Creek Model
    i. Arcade Creek Scaling Factor

1. Existing Climate Changed 10-Year/24-Hour Model.
2. Existing Climate Changed 100-Year/24-Hour Model
3. Existing Climate Changed 100-Year/10-Day Model
4. Proposed Climate Changed 10-Year/24-Hour Model.
5. Proposed Climate Changed 100-Year/24-Hour Model
6. Proposed Climate Changed 100-Year/10-Day Model

ii. PGCC Scaling Factor

1. Existing Climate Changed 10-Year/24-Hour Model.
2. Existing Climate Changed 100-Year/24-Hour Model
3. Existing Climate Changed 100-Year/10-Day Model
4. Proposed Climate Changed 10-Year/24-Hour Model.
5. Proposed Climate Changed 100-Year/24-Hour Model
6. Proposed Climate Changed 100-Year/10-Day Model

b. Morrison Creek Model

i. Arcade Creek Scaling Factor

1. Existing w/ Ex Offsite Climate Changed (CC) 10-Year/24-Hour Model.
2. Existing w/ Ex Offsite CC 100-Year/24-Hour Model
3. Existing w/ Ex Offsite CC 100-Year/10-Day Model
4. Proposed w/ Ex Offsite CC 10-Year/24-Hour Model.
5. Proposed w/ Ex Offsite CC 100-Year/24-Hour Model
6. Proposed w/ Ex Offsite CC 100-Year/10-Day Model
7. Proposed w/ Dev Offsite CC 100-Year/24-Hour Model
8. Proposed w/ Dev Offsite CC 100-Year/10-Day Model

ii. PGCC Scaling Factor

1. Existing w/ Ex Offsite Climate Changed (CC) 10-Year/24-Hour Model.
2. Existing w/ Ex Offsite CC 100-Year/24-Hour Model
3. Existing w/ Ex Offsite CC 100-Year/10-Day Model
4. Proposed w/ Ex Offsite CC 10-Year/24-Hour Model.
5. Proposed w/ Ex Offsite CC 100-Year/24-Hour Model
6. Proposed w/ Ex Offsite CC 100-Year/10-Day Model

7. Proposed w/ Dev Offsite CC 100-Year/24-Hour Model
8. Proposed w/ Dev Offsite CC 100-Year/10-Day Model

Several compliance points were established in the approved Master Plan for purposes of comparison of pre and post development flows leaving the project area. See Figure 1. These same compliance points were used in this analysis to compare pre and post development climate change flows. The compliance point results of this modeling exercise are shown in Tables 3 and 4 below. Table 5 shows the basin information and model results.

Table 3
Compliance Point Table Arcade Scaling Factors

Arcade Scaled Flows	Existing Conditions			Developed Conditions		
	10-yr/ 24-hr	100-yr/ 24-hr	100-yr/ 10-day	10-yr/ 24-hr	100-yr/ 24-hr	100-yr/ 10-day
CP1	50	59	41	30	43	35
CP2	34	42	19	0	0	0
CP3	498	529	624	465	504	600
CP4	46	56	29	37	45	21
CP5	78	93	59	57	90	59
CP6	139	164	127	92	117	117
CP7	87	106	62	0	0	0

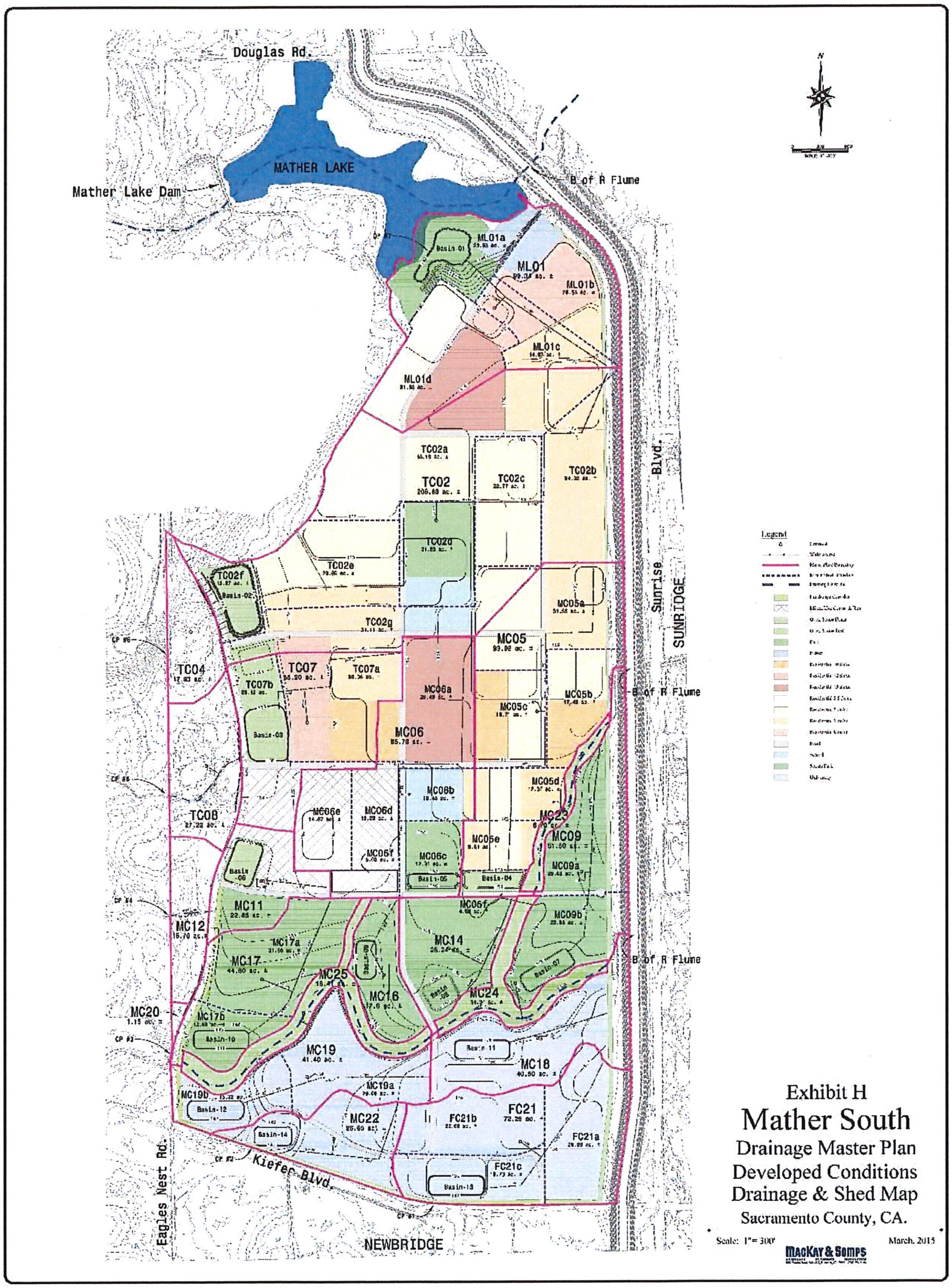
Note: Bold & Yellow Highlighted Results Exceed Existing Conditions Flows.

Table 4
Compliance Point Table PGCC Scaling Factors

PGCC Scaled Flows	Existing Conditions			Developed Conditions		
	10-yr/ 24-hr	100-yr/ 24-hr	100-yr/ 10-day	10-yr/ 24-hr	100-yr/ 24-hr	100-yr/ 10-day
CP1	45	87	44	26	**92**	38
CP2	31	60	21	0	0	0
CP3	458	785	673	428	723	641
CP4	42	81	31	34	65	23
CP5	71	135	63	53	**152**	**66**
CP6	126	245	136	79	245	133
CP7	80	154	67	0	0	0

Note: Bold & Yellow Highlighted Results Exceed Existing Conditions Flows.

Figure 1
Compliance Point Exhibit



Source: Mather South Drainage Master Plan Storm, November 2017 (MacKay & Somps Civil Engineers).

Table 5
Basin Information & Model Results

Basin Information (Master Plan)											100-Year/24-Hr		10-Year/24-Hr		100-Year/10-Day	
Basin Number	Modeling Number	Basin Bottom Elevation	Hydromod Bot. Flow Orifice Size	Hydromod Low Flow Orifice Size	Hydromod Mid Flow Orifice Size	Hydromod High Flow Orifice Size	Top of Hydromod Riser Elev.	Top of Berm Elevation	Basin Volume w/ Freeboard (Ac. Ft.)	Basin Volume No Freeboard (Ac. Ft.)	100-year Storage (Arcade Creek SF)	100-year Storage (PGCC SF)	10-year Storage (Arcade Creek SF)	10-year Storage (PGCC SF)	10-Day Storage (Arcade Creek SF)	10-Day Storage (PGCC SF)
1	RAS	137	0.8' x 0.8' @ 137'	N/A	4' x 2' @ 140.5'	N/A	144.5	147	45.8	51.7	**45.0**	**52.0**	**41.1**	**39.1**	**45.5**	**46.9**
2	B2	147	0.3' x 0.2' @ 147	1' x 1' @ 152.5	N/A	N/A	153.5	156	34.5	39.4	**35.0**	**38.0**	**17.0**	**16.0**	**34.0**	**35.0**
3	B3	146.5	0.4' x 0.25' @ 146.5	1' x 1' @ 152	N/A	N/A	154.5	156.5	41.7	47.2	**42.0**	**47.0**	**20.0**	**18.0**	**39.0**	**41.0**
4	B4	153	0.3' x 0.5' @ 153'	0.5' x 1' @ 154.5'	2' x 1' @ 155'	N/A	156	158	7.4	9.5	**6.5**	**7.0**	**5.9**	**5.7**	**6.2**	**6.3**
5	B5	153	0.2' x 0.5' @ 153'	0.5' x 0.5' @ 154'	2' x 1' @ 154.5'	2' x 1' @ 154.5'	155.5	158	8.6	11	**6.1**	**6.7**	**5.5**	**5.3**	**5.9**	**6.0**
6	B6	151	0.5' x 0.5' @ 151'	0.5' x 0.5' @ 152.5'	N/A	N/A	153	155	5.2	7.2	**4.6**	**5.1**	**3.9**	**3.7**	**4.2**	**4.3**
7	B7	146	0.2' x 0.2' @ 146'	0.5' x 0.5' @ 148.5'	0.7' x 0.7' @ 149'	1' x 1' @ 150'	151	154	11.8	13.8	**10.0**	**12.0**	**8.2**	**7.6**	**9.9**	**10.0**
8	B8	142	0.5' x 0.5' @ 142'	1.5' x 1.5' @ 144'	1.5' x 1.5' @ 144'	N/A	146.5	150	19.2	22.4	**12.0**	**14.0**	**10.0**	**9.8**	**11.0**	**12.0**
10	B10	140	0.25' x 0.5' @ 140'	0.5' x 1' @ 142.5'	1' x 1' @ 144'	N/A	146	148	29.3	34	**28.0**	**32.0**	**17.0**	**16.0**	**28.0**	**29.0**
11	B11	149	0.3' x 0.5' @ 149'	0.5' x 0.5' @ 150'	1' x 1' @ 151'	2' x 1' @ 152'	153	155	4.8	5.9	**3.7**	**4.2**	**3.1**	**3.0**	**3.4**	**3.5**

Notes: 1. Values in Bold and Green Highlight represent Storage Volumes that have greater than or equal to Master Plan freeboard requirements.
2. Values in Bold and Yellow Highlight represent Storage Volumes that encroach into but don't exceed the Master Plan freeboard.
3. Values in Bold and Red Highlight represent Storage Volumes that exceed top of berm elevations (i.e., Volume overtops basin top of berm).

Based on this analysis, several observations can be made regarding the resiliency of the proposed flood protection improvements within the Mather South project to withstand the additional flows resulting from climate change. The observations are as follows:

a. Under the Arcade scaling scenario most basins continue to have 1-foot of freeboard.
b. Under the PGCC scaling scenario water surface elevations in the basins will encroach into the freeboard but not overtop (Except Basin No. 1 (RAS Basin)).
c. The project remains in compliance with peak discharge requirements in the Arcade scaling scenarios.
d. Peak flow compliance at the project boundary is not met for all storms when using the PGCC scaling factors. If PGCC scaling is adopted, two basins will need to be adjusted.
e. The main branch of Morrison Creek remains in compliance under all conditions.
f. The area of greatest effect due to climate change is in the north portion of the project area. This is where sheds were shifted away from Mather Lake.
g. Shed shifts cause the greatest impact on flood control facilities when subject to increased scaling of storms.

Whether climate change manifests itself in flows within the Mather South project area being closer in magnitude to those estimated using the Arcade Creek or those using Pleasant Grove Creek Canal scaling factors, it appears that the proposed flood control facilities can handle the projected climate change flows without overtopping the top of berm elevations of the basins. The one exception is during the 100-year/24-hour event in the Todd Creek model. Here there is an exceedance of about two tenths of a foot over the top of berm in the worst-case climate change scenario (PGCC).

If the PGCC scaling factors are adopted, then the proposed design of this basin would require a minor revision to prevent overtopping during the 100-year PGCC-scaled event. Prior to tentative map approvals, and once the County has adopted specific climate change design standards, the preliminary design of all facilities shown in the master plan should be studied for resiliency against the effect of climate change.

The overall design of Mather South shows resiliency in mitigating peak flow discharged from the site during climate change. The flood control facilities will have water surface elevations encroach into the freeboard. The one basin of particular concern is Basin No. 1 which does not adequately store the 100-year/24-hour PGCC scaled flows. Once a climate change standard has been adopted, the design of this basin should be modified as needed to, at a minimum, not overtop the basin bank elevation.

5. 200-YEAR LEVEL OF FLOOD PROTECTION

In compliance with the requirements of SB 5, and the requirements of the California Central Valley Flood Protection Board (CVFPB) for Urban Level of Flood Protection (ULOP), Sacramento County amended the Safety Element of the Sacramento County General Plan to address the need to protect urbanizing lands from the threat of flooding during the 200-year event.

During that adoption process, the County created a 200-Year ULOP Applicability Area exhibit (see Figure 2). Figure 2 shows the areas within the unincorporated areas of the County where the ULOP criteria for 200-year level of protection are applicable.

Inspection of Figure 2 clearly reveals that the Mather South project area is not within the ULOP Applicability Area. Accordingly, the Mather South project area is not required to provide ULOP mandated levels of flood protection.

6. CONCLUSION

Flows increase under all climate change scenarios presented in this analysis. The result of this increase is an increased peak flow baseline in the existing conditions models.

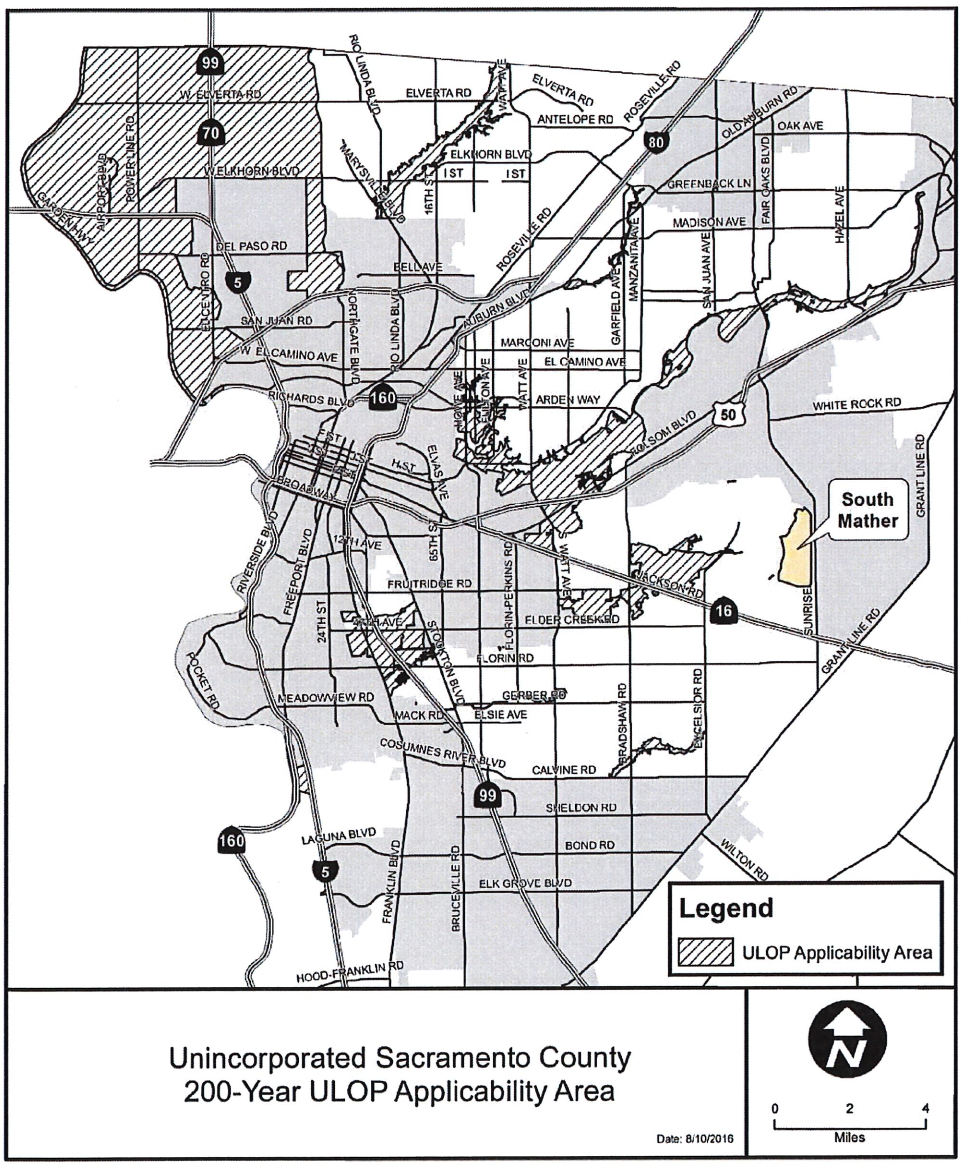
Generally, the project continues to provide adequate mitigation to pre-project flows. The only exceptions to this are found in the PGCC scaling factors at two compliance points (CP1 and CP5). The design of the basins discharging to these two compliance points will require minor modification, including potential expansion, to address this increase in flow if scaling factors similar to the PGCC scaling factors are adopted as the climate change standard for Sacramento County.

If scaling factors similar to the Arcade Creek scaling factors become the design standard of the County, then it is likely that no design changes will be required as the use of the Arcade Creek scaling factors did not indicate that changes in the project design would be necessary for peak flow mitigation under climate change conditions.

Figure 2
200-Year ULOP Applicability Area

Attachment 1
Agenda Date: December 13, 2016

APPENDIX D
200-Year ULOP Applicability Area



In addition to the compliance point peak flows, flow in downstream channels of Todd Creek and Morrison Creek were analyzed in the HEC-RAS models to determine if the resulting higher stages in the creeks would exceed the design capacity of the facility. While the stages were found to have significantly increased when subject to climate change analysis, the increased stages didn't encroach into the one-foot freeboard requirement.

In Morrison Creek the area of greatest concern is directly upstream of Zinfandel Road where the existing culvert crossing of the road will impede flow. In Todd Creek the area of greatest concern is upstream of the proposed road crossing. Freeboard at both locations is still adequate to adjacent grades. Nonetheless, if necessary, the design of the crossings can be modified to pass the increased flow from climate change.

The volume changes resulting from the climate change scaling factors has a greater effect on the detention basins then on the peak flow. All detention basins continue to provide peak flow mitigation, but many basins no longer have one foot of freeboard. In one instance the basin overtops the banks during the PGCC scaling climate change model. The design of this basin will need to be modified to include additional freeboard at the tentative map level design stage assuming a climate change scaling factor has been established as the County standard.

Based on the analysis presented in this Technical Memorandum it is apparent that the approved drainage and flood control improvements for the Mather South project have resiliency against the potential effects of climate change. Most of the facilities proposed in the Master Plan do not require modification to be effective even under the most conservative scaling factors for climate change. The design of those facilities which are not adequately sized for climate change can be modified with minor changes once a standard has been established. The preliminary climate change models established in this document do not present a scenario which is without solution.

This analysis demonstrates that the effects of climate change are not significant. Further, this analysis demonstrates that minor changes in the proposed design of proposed Mather South drainage facilities are feasible if required. Any modifications to the proposed drainage and flood control facilities needed to accommodate the effects of climate change should be analyzed at the tentative map stage for the project.

7. REFERENCES

The following documents were used as reference materials in the preparation of this Technical Memorandum:

a. 200-Year ULOP Applicability Area Exhibit for Unincorporated Sacramento County (Appendix D), December 13, 2016 (Sacramento County).

b. Flood Plain Management Ordinance, September 26, 2014 (Sacramento County).

c. 2030 General Plan of Sacramento County, November 9, 2011 (Sacramento County).

d. 2030 General Plan of Sacramento County – Safety Element, September 26, 2017 (Sacramento County).

e. Storm Drainage Master Plan for Mather South, November 2017 (MacKay & Somps Civil Engineers).

f. Urban Level of Flood Protection Criteria, November 2013 (California Department of Water Resources).