HIGH LINE CANAL

STORMWATER TRANSITION AND MANANGEMENT PLAN

PREPARED FOR:

MHFD

MILE HIGH FLOOD DISTRICT

12575 W Bayaud Ave
Lakewood, CO 80228

PREPARED BY:

ICON ENGINEERING

10825 E Geddes Ave, Suite 420 | Centennial, CO 80112
(303) 221-0802 | www.iconeng.com
Project no.: 24-033

January 14th, 2025

TABLE OF CONTENTS

Tables

Figures

Appendices

1.0 PURPOSE AND INTENT

1.1 High Line Canal Roadmap

In December of 2024 the High Line Canal Stormwater Transition and Management Plan (HLC STAMP) Team and stakeholders gathered at the Mile High Flood District (MHFD) headquarters to discuss and align the goals of many projects along the High Line Canal. The roadmap was developed to define what will and will not be addressed in the STAMP effort. Also, it outlined several other HLC related deliverables. The project chartering roadmap (**Figure 1**) is shown on the next page. This report, its appendices, and the accompanying web based deliverables will aim at addressing the topics identified on the roadmap.

1.2 Stormwater Transition and Repurpose

It is important to note that the roadmap mentioned in **Section 1.1** was created under the condition that the HLC would no longer be used to deliver irrigation flows. The last time the Canal was used to deliver water to rights holders along the corridor was 2021. This method of water delivery is costly and inefficient. Along the High Line Canal there are many hydraulic connection points to ponds and natural waterways. At these connections there are hydraulic structures, known as waste'

gates, that allow stormwater to flow out of the Canal into other bodies of water. These wastegates are locked open when the Canal is not being used to deliver water. This means that when a water rights holder on the Canal would like to utilize their rights and have water delivered via the Canal, the canal owner needs to deploy laborers to close the wastegates along the canal, this is timely and expensive. Additionally, the water conveyed through the canal is estimated to lose about 50 to 70 percent of the divereted water due to evaporation and infiltration, making it a very inefficient water delivery method.

The STAMP does not consider the Canal's use as a water delivery method, instead it focuses solely on stormwater conveyance in the Canal. In the Canal's 142 year history, this is the first time that planning for the Canal has only considered stormwater conveyance. This is an exciting and momentous time for the Canal that will create the opportunity for multi-benefit use projects along the Canal corridor. This report will identify and rank stormwater risks associated with the Canal and provide guidance as to how best to mitigate these risks.

1.3 Opportunities

With this fundamental change in the day to day operation and usage of HLC comes many new opportunities. Perhaps the most obvious opportunity is the repurpose of historic infrastructure, initially built for water distribution purposes, to be used to safely convey stormwater along the HLC and provide water quality improvement opportunities. As stormwater moves through the Canal it is the first priority to ensure that this happens in a safe manner, and to provide guidance and recommend projects that aim at mitigating flooding risk from stormwater spilling out of the Canal banks. With this primary goal, there is an ancillary goal and significant opportunity to provide water quality and to treat the stormwater as it moves through the Canal or at strategically placed release points along the Canal. The multitude of stormwater related opportunities that exist along the transitioned Canal corridor will be discussed in detail in **Chapters 7, 8, and 9**.

HIGH LINE CANAL ROAD MAP

THEME	DESCRIPTION & KEY QUESTIONS TO ANSWER	POTENTIAL SOLUTIONS / MILESTONES	RESPONSIBLE PARTY	TARGET COMPLETION DATE	DELIVERY SOURCE
Define Roles, Responsibilities, & Regulation	1. How might we establish a permanent funding and govenernance structure to bring clarity and consistency? 2. Identify who is responsible for what 3. Delineate and align O&M along the entire length and width of the HLC. 4. What are the liabilities and who do they lie with? 5. What is the uniform minimum level of care for maintenance? 6. What notifications need to be made? 7. Need to communicate that stormwater is already in the canal. 8. How can we prove it is a good thing?	High Line Canal Org Chart for transition period and post transition	Arapahoe County, HLCC, DW	February 14, 2025	Transition Commuity Plan
		Intergovernmental Communications Plan	Arapahoe County, HLCC, MHFD	April 1, 2025	Management & Operation Plan
		Section in the STAMP to discuss stormwater in the canal (pros (veg, water quality) vs. cons (extreme cost to remove))	MHFD	January 1, 2026	STAMP
		Explore the legal liabilities of being the canal owner and/or maintainer	MHFD, Arapahoe County	April 1, 2025	Legal Meeting/Consultation
		Setup decision trees/flow charts for common items with responsibility identified	Arapahoe County		Management & Operation Plan
		Answer the easy to answer How-might-we questions and distribute	MHFD	March 1, 2025	Email Q&A
		Establish emergency management protocol/plan	Arapahoe County	January 1, 2026	Management & Operation Plan
		Centralized maintenance agreement	MHFD	NOW	Centralized Agreement
		Create an AGO map with ownership and maintenance responsibility clearly shown that all entities have access to	MHFD, Arapahoe County	March 1, 2025	Management & Operation Plan
		Define a consistent LOS goal for maintenance and stormwater overtopping. Assess existing conditions and identify gaps	MHFD	January 1, 2026	STAMP
		Identify estimated management costs for each community and potential funding sources			
		Setup consistent, flexible, and clear recreational and stormwater use agreements with success/failure criteria	Arapahoe County	June 1, 2025	Use Agreements
Define Denver Water's Water Works Purposes	1. What is the likelihood that an irrigation run will occur? 2. Can we exclude irrigation from Waterton Canyon as a consideration? There are other more efficient ways of water delivery. 3. Can we count on an alternative delivery method to satisfy contractual obligations? 4. What is the likelihood that a capital improvement would be removed for waterworks purposes? Who pays for the removal?"	Memo from Denver Water addressing the issues identified. Needs to be communicated in a centralized and concise format. Include risk factor for improvements - how likely is it that DW will remove improvements? Who will pay for the removal?	Denver Water	May 1, 2025	STAMP
Historic Preservation	1. How can we honor the history of the canal with projects?	Develop guidance on historical preservation	High Line Canal Conservancy	May 1, 2025	Management & Operation Plan
Water Quality	1. What does it look like? 2. What is the classification of the canal? (water of the state vs. __) 3. How do MS4's get credit for enhancing water quality?	Engage legal consultant to better define the classification of the canal and how/if MS4 water quality credit can be claimed	MHFD	May 1, 2025	STAMP
		Survey canal Partners to determine the importance of MS4 water quality credit from the state	High Line Canal Conservancy	March 1, 2025	
		Provide recommendations to improve water quality	MHFD	January 1, 2025	
Multi-Benefit Approach	1. How might we understand and address risks? 2. How might we confirm or deny that putting stormwater into the canal is a net benefit? 3. How do we make sure we are not missing opportunities? 4. Coordinate capital improvement projects 5. How might we take the opportunity to restore and improve natural drainageways in this process? 6. Is groundwater seepage a problem?	Identify risks with likelihood and impact to prioritize and rank risks. Include do nothing scenario	MHFD	January 1, 2025	STAMP
		Consistent definitions and use of, many people are on different pages			
		Setup project checklists for items to evaluate given a range of situations for various project types			
Centralized Approach	1. How might we work toegther to manage data + standards for the canal between jurisdictions/ agencies/partners?	Centralized maintenance contract	MHFD	NOW	STAMP
		Data sharing - setup standardized data scema for CMMS or AGO to show what maintenance is being performed and the status of it	MHFD	September 1, 2025	STAMP
		Create partnership outlines	Arapahoe County, MHFD		Management & Operation Plan
		Data sharing agreements and/or data management plan			
		Identify lead agency for data standards	MHFD	January 1, 2025	STAMP
		Canal wide design standards	Arapahoe County, MHFD	January 1, 2026	
		Create a prioritized capital improvement plan for the canal as a whole	MHFD		

2.0 HISTORY

2.1 Origins and original use

After pioneers settled in the Denver area in search of gold in 1859, farms developed in the surrounding area to sustain the growing population. The High Line Canal was conceptualized in 1881 as a water delivery method for these food production sites, taking water from the South Platte River and delivering it across the plains to the south and east of the Denver metro area for the express purpose of agricultural demand. The construction of the High Line Canal was completed in 1883, and it began delivering water to irrigate about 20,000 acres of land through 165 headgates. As the Denver metro area expanded in the mid-20th century these farms began to disappear as the Denver Metro area developed. The last time the HLC was used to convey irrigation flow was in 2021 and since then the wastegates have been locked open rendering it as a stormwater conveyance element only.

2.2 Denver Water Policy

As the areas surrounding the HLC became urbanized and developed into residential neighborhoods, some of these developments discharged stormwater runoff from the newly developed land to the Canal. In 1999, Denver Water wrote a policy disallowing any unpermitted stormwater discharges into the Canal.

Once this policy was in effect, only governmental or quasi-governmental entities could request a License Agreement for a Stormwater Use Permit allowing a new discharge into the Canal. The entity would then have to ensure that the new discharge meets the same quality, quantity or manner of flow of existing stormwater in the Canal. Once the permit is approved then the entity is responsible for maintenance of the discharge and receiving area of the Canal.

In June of 2024, Denver Water transferred ownership of 45 miles of the HLC to Arapahoe County. Accompanying this ownership transfer, Denver Water is working with their remaining irrigation water customers along the HLC to find solutions for decommissioning HLC for irrigation. Since the ownership transfer the HLC corridor is now being prioritized as a natural asset and recreational amenity. Currently the County is working through storm water use agreements with government agencies along the Canal which will determine future stormwater discharge policies for HLC.

2.3 Previous Planning Studies

2014 High Line Canal Feasibility Study

This study was completed by RESPEC for the Urban Drainage and Flood Control District in August of 2014. Its purpose was to assess the feasibility of utilizing the HLC as a stormwater conveyance element to alleviate stress on downstream storm drains while providing water quality. Considering the Canal was still being utilized for water delivery at the time of this study the finding within the study could not be put into practice. This study was important in that it began the conversation of transitioning the use of the HLC and developed several conceptual designs with respect to the Canal as a stormwater amenity.

2018 High Line Canal Stormwater and Operations Master Plan

This 2018 study was also completed by RESPEC for the Urban Drainage and Flood Control District in October of 2018. While the 2014 study focused on conceptual design of stormwater elements within the Canal, the 2018 Stormwater and Operations Master Plan aimed at understanding how stormwater interfaces with the canal in existing conditions and then made recommendations on implementing water quality berms along the Canal to mitigate the flood risk associated with existing conditions. It is important to note that when the 2018 HLC Plan was created it was still being utilized as an irrigation Canal, and RESPEC assessed the Canal's impact on stormwater under two conditions, one with wastegates open (a non-irrigation case) and one with wastegates closed simulating irrigation flow conditions. To analyze the hydrologic and hydraulic impact the Canal has on surface runoff through the basins it intersects RESPEC developed a 1D hydrologic-hydraulic Storm Water Management Model (SWMM) for both irrigation and non-irrigation scenarios. The 1D SWMM was updated with more recent land use and impervious value, and the non-irrigation flow scenario (wastegates open) was used as a baseline for the 2026 STAMP.

2.4 2026 STAMP

There have been significant advancements in hydraulic modeling software since the 2018 HLC Plan was completed. This coupled with the decommissioning of the HLC as an irrigation Canal sparked the 2026 HLC STAMP effort. This planning study leverages the advancements made in modeling software to provide a better understanding of the existing conditions urban flood risk caused by stormwater spill flows out of the HLC. Through 2D hydraulic modeling, higher resolution on location and flow conditions of spills along the Canal have been determined and shown in this plan. From the increased resolution on this spill data more informed decisions can be made on how to best mitigate these spills and protect the people and property affected by this risk.

This plan assumes that the Canal is no longer utilized for water works purposes and is considered solely as a stormwater conveyance element. As such, all wastegates are assumed to be open in both existing and proposed conditions modeling. While the primary focus of proposed conditions modeling is to mitigate downstream risk, other considerations have been made in alternatives including water quality benefits, multi-use purpose (aligning trails, maintenance, and flood protection), and ecological alignment.

In addition to analyzing existing conditions and making flood risk mitigation recommendations, the 2026 STAMP plan also integrates and evaluates other aspects of transitioning the usage of the HLC from irrigation canal to stormwater amenities including water quality, operations and maintenance and their associated costs.

3.0 SUMMARY

3.1 Vicinity Map

The headwaters for the High Line Canal are along the South Platte River at the mouth of Waterton Canyon in the southwest corner of the Denver Metro area. The Canal runs for about 65 miles heading east northeast through the south Denver Metro area until it finally discharges into the First Creek in Aurora. The Canal intersects 106 roadways, 31 historic drainage basins, 27 waterways, 11 municipalities, and four counties from Waterton Canyon to First Creek. **Figure 2** on the next page shows the general location and alignment of the High Line Canal.

3.2 Hydrology

The hydrology for the STAMP study comes from 2018 High Line Canal Stormwater and Operations Master Plan by RESPEC engineering. In partnership with RESPEC the 2018 hydrologic model was updated with more discrete and recent land use data and updated impervious values that were not available at the time the 2018 study was completed. The land cover data was updated with 2020 DRCOG land use data and the impervious values were updated to reflect the 2024 MHFD Urban Storm Drainage Criteria Manual updates. This revised hydrology will be referred to as the 2025 updated SWMM model throughout this report. For more information on the hydrology used in the STAMP effort see **Chapter 4**.

3.3 Hydraulics

The STAMP hydraulic modeling utilized two-dimensional hydraulic modeling using the Hydrologic Engineering Center-River Analysis System (HEC-RAS) version 6.4.1 engine. This methodology provides much more detail than either 1D SWMM or 1D HEC-RAS modeling, showing more detail on spill locations and magnitude, allowing for more accuracy in identifying and mitigating spill flows and recommendations on alternatives. For more information on the hydraulic modeling utilized in the STAMP effort see **Chapter 5**.

3.4 Risk Identification

The risk associated with each existing spill flow was developed in partnership with Michael Baker International. The risk from flooding was assessed utilizing a Values at Risk (VAR) methodology that approximates the presence of humans who might be in harm's way during a flood event. This VAR is determined by the number of structures, roadways, and trail networks within the flooding area due to each spill. Flood risk scores are then developed from the VAR along the length of the HLC. For more information on the risk identification of existing spill flows in the STAMP effort see **Chapter 6**.

3.5 Alternative Evaluation

There were two major funding parters for the High Line Canal STAMP effort, the City and County of Denver and Arapahoe County. 13 spill flow flooding mitigation alternatives were developed and considered for each of these partners. While some of these alternatives were deemed infeasible, the remaining alternatives were modeled and their impact on flood risk mitigation assessed. Alternatives are evaluated through several lenses including total risk mitigated, cost, and community benefit. The modeled alternatives fall into four categories: conveyance, bank manipulation, treatment drains, and increasing capacity. Each of these mitigation types are explained in more detail below.

A. Conveyance

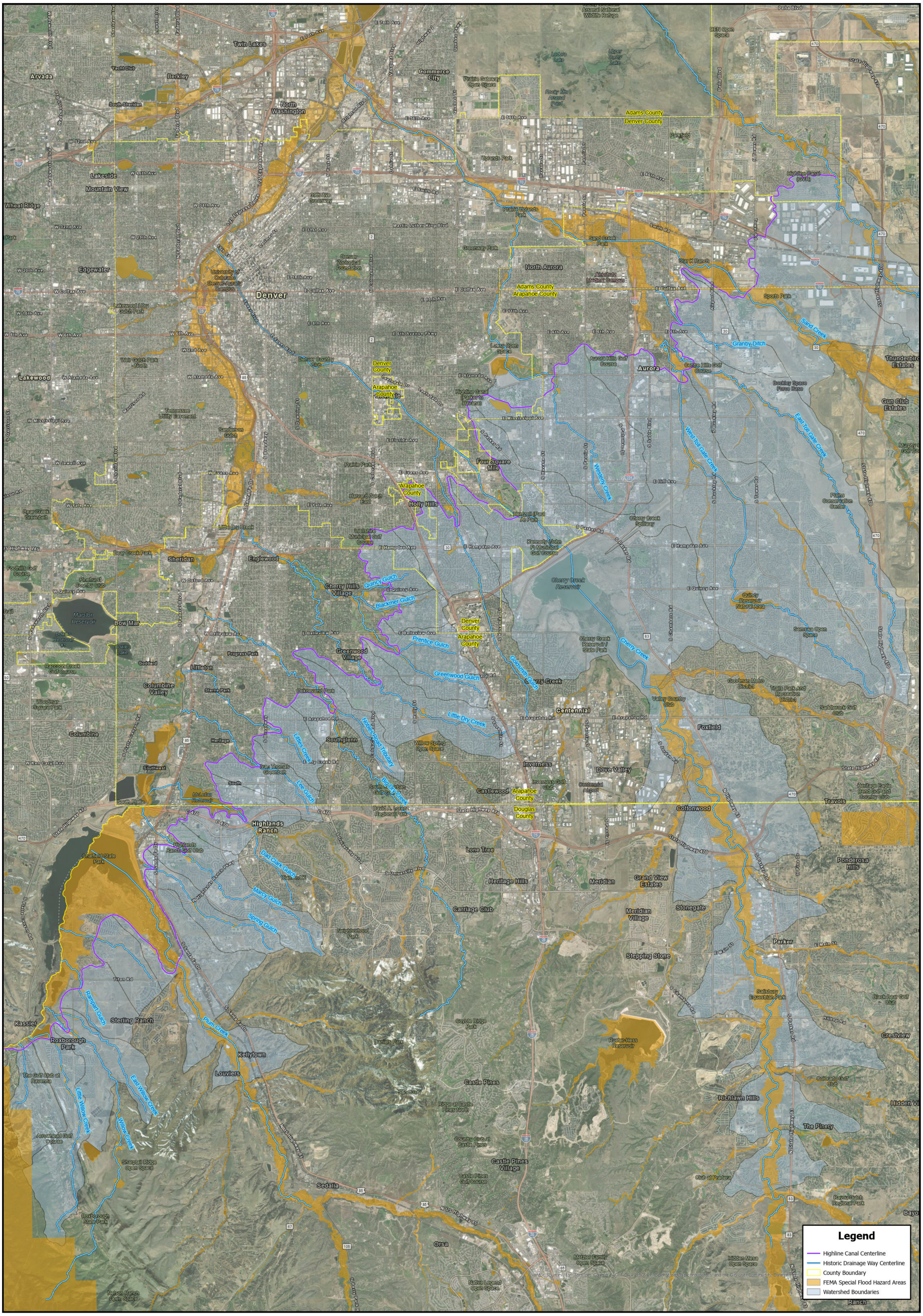
The conveyance mitigation alternative consists of formalizing the conveyance of stormwater from the Canal channel to natural waterways that intersect the Canal. The conveyance alternatives model the Canal channel as being directly connected to the natural waterway from both the up Canal and down Canal side of the Canal, allowing stormwater to exit the canal freely into the existing channel. Not only does this type of alternative mitigate Canal flooding risk by putting more stormwater into channelized waterways where a regulatory floodplain exists, but it also provides an ecological uplift to the surrounding area by directing and returning storm flows to existing channels and the associated riparian areas along those channels.

B. Bank Manipulation

The bank manipulation mitigation alternatives consist of both lowering and raising the downstream Canal embankment (bank) at certain locations. Locations where the bank has been lowered were selected to safely allow stormwater flow from the Canal to discharge into greenspace or natural waterways which would mitigate adjacent spill flows into areas with a higher risk. The purpose of raising the bank is to prevent water from spilling out at those locations. These locations were also strategically chosen so as not to be at risk of being considered a non-jurisdictional dam. Where bank raising is proposed, the existing bank is lower than the adjacent bank, and the proposed grade change is only to match the elevation of the adjacent bank elevations.

C. Treatment Drains

The treatment drain mitigation alternative connects the Canal to an existing or proposed storm drain system that passes under the Canal. This alternative is a combination of two existing outlet structures, a type C outlet set below the 100-year water surface elevation (WSEL) in the Canal with separate water quality outlets on the upstream and downstream side of the structure providing water quality treatment in lower return intervals. The stormwater is then conveyed into the storm drain system until. By redirecting stormwater in the Canal into a storm drain this mitigation alternative reduces the WSEL in the Canal which ultimately reduces or eliminates spill flows over the downstream bank of the Canal.



ICON ENGINEERING

HIGHLINE CANAL STORMWATER TRANSITION AND MANAGMENT PLAN - VICINITY MAP

MHFD MILE HIGH FLOOD DISTRICT

N

Miles

0 1 2

D. Increase Capacity

The increase capacity mitigation alternative looked at increasing the conveyance capacity of the Canal at roadway crossings as in some locations the capacity is greatly reduced at a roadway crossing. By increasing the opening of the roadway crossing of the canal this would increase capacity in hopes of eliminating or reducing adjacent spill flows.

For more information on alternatives evaluation of existing spill flows in the STAMP effort see **Chapter 7**.

3.6 Water Quality

The very mild slope of the HLC conveys stormwater at low velocities and in larger events this stormwater begins to pond in the Canal resulting in a large volume of water. As such, with modifications there is an opportunity for a large amount of stormwater quality treatment within the Canal. The conveyance, bank manipulation, and treatment drain alternatives all provide an opportunity for water quality. For the conveyance and bank manipulation this water quality could simply be infiltration, or the stormwater could be redirected into a rain garden or regional detention facility once it safely exits the Canal. For the treatment drain alternative water quality is inherent in the water quality outlet design allowing water to slowly percolate through the orifice plate allowing suspended solids to filter out before discharging into the storm drain. With this large water quality benefit municipalities have the opportunity to gain water quality credits through the Municipal Separate Storm Drain System (MS4) permit requirements which could act as a driving force to construct some of these alternatives. For more information on water quality opportunities within the Canal see **Chapter 8**.

3.7 Operation and Maintenance

The Canal as an aging irrigation and stormwater conveyance element has, does, and will always require maintenance along its entire corridor. Routine trash and debris removal and trail maintenance are an ongoing need, in addition to mosquito abatement and the removal of aging and dying trees along with the planting of new vegetation are all considerations and necessary work for the municipal crews that serve the HLC. As flood mitigation alternatives or other Canal improvements are constructed, these too will have routine maintenance for upkeep and to maintain the performance of the structure. Additionally, there may be new stormwater outlet connections to the Canal as development occurs upstream, each of these new connections will also need their own maintenance. Other considerations for operations and maintenance along the Canal are frequency, access points, and costs. The operations and maintenance components of the HLC are discussed in more detail in **Chapter 9**.

4.0 HYDROLOGY

4.1 Hydrologic Coordination with Other Studies

The hydrology for the HLC STAMP originates from the hydrology developed for RESPEC's 2018 High Line Canal Stormwater and Operations Master Plan. There were two rainfall methodologies used in the 2018 RESPEC Master Plan. These rainfall inputs created two different types of hydrologic models, flood control and operational. For the HLC STAMP 2D model only the flood control model from the 2018 Master Plan was considered since this 2D HEC-RAS modeling effort looks specifically at the transition of the High Line Canal as a stormwater utility with wastegates open (wastegates include different types of weirs that when open allow water to flow out of the canal into adjacent streams or ponds) and no irrigation flow in the canal.

4.2 STAMP Hydrologic Approach

It's important to note that the STAMP modeling uses an updated version of RESPEC's 2018 hydrology. Since the 2018 Master Plan the land cover dataset, Colorado Urban Hydrograph Procedure (CUHP) versioning, and percent impervious values from the Urban Storm Drainage Criteria Manual (USDCM) Volume 1 Chapter 6 have been updated. The 2018 1D SWMM model used impervious values that were based on 2011 NLCD land cover information and CUHP version 2.0.0. The 2025 updated SWMM model impervious values come from 2020 DRCOG LiDAR land cover information and the 1D SWMM model is now informed by results from CUHP version 2.0.1 and updated impervious values from the USDCM. A comparison of peak discharge values and total inflow volumes at canal inflow points, within the Belleview to Quebec 2D model, between 2018 existing conditions (CUHP v. 2.0.0) and the 2025 updated land cover (CUHP v. 2.0.1) 1D SWMM models are shown below.

Note that the inflow comparisons in the table below are for the Broadway to Belleview hydraulic model, which is only one of the seven models for the entire length of the Canal. All of the 2026 inflows into the Canal are available to view on the AGO map.

Bellview to Quebec Inflow Locations		2011 NLCD / CUHP 2.0.0		2020 DRCOG Land Cover / CUHP 2.0.1		100-Year Peak Inflow Comparison		100-Year Total Inflow Volume Comparison	
Station	SWMM Link Name	100-Year Peak Inflow (cfs)	100-Year Total Inflow Volume (ac-ft)	100-Year Peak Inflow (cfs)	100-Year Total Inflow Volume (ac-ft)	2020 DRCOG - 2011 NLCD (cfs)	2020 DRCOG - 2011 NLCD (%)	2020 DRCOG - 2011 NLCD (ac. ft)	2020 DRCOG - 2011 NLCD (%)
1289+66	hlc_FS_WQ342_dum	51.3	5.2	55.4	5.4	4.1	8	0.2	4
1311+65	hlc_FS_WQ341_dum2_ssa	58.9	4.0	68.3	4.3	9.4	16	0.3	7
1324+21	hlc_FS_WQ340_dum2_ssa	16.2	1.2	21.0	1.4	4.8	29	0.1	12
1354+20	hlc_FS_WQ337_dum2_ssa	11.0	0.5	50.0	0.3	39.0	357	-0.2	-35
1370+98	hlc_FS_WQ336_dum2_ssa	22.7	2.3	26.2	2.5	3.5	15	0.2	7
1381+84	hlc_FS_WQ335_dum	12.7	1.4	14.7	1.5	2.0	16	0.1	9
1386+40	hlc_FS_WQ334_dum2_ssa	13.6	1.3	17.0	1.5	3.4	25	0.1	9
1390+59	hlc_FS_WQ333_dum	16.7	2.4	25.0	2.7	8.3	50	0.3	14
1402+23	hlc_FS_WQ332_dum	29.9	3.7	40.3	4.2	10.4	35	0.4	11
1414+42	hlc_FS_WQ331_dum	18.6	2.9	23.7	3.1	5.1	28	0.3	9
1426+61	hlc_FS_WQ330_dum	14.3	2.0	18.2	2.1	3.8	27	0.2	9
1442+94	hlc_FS_WQ329_dum	14.3	1.2	19.4	1.4	5.1	36	0.2	14
1451+06	hlc_FS_WQ328_dum	39.9	3.5	48.8	3.8	9.0	22	0.3	8
1475+78	hlc_FS_WQ327_dum	84.4	5.8	102.5	6.3	18.1	21	0.5	9
1479+97	hlc_FS_WQ326_dum	125.8	13.0	164.0	14.3	38.2	30	1.3	10
1491+54	hlc_FS_WQ325_dum2_ssa	2.6	0.3	3.2	0.3	0.6	24	0.0	10
1501+68	hlc_FS_WQ320_dum	343.6	28.6	415.9	31.1	72.2	21	2.5	9
1508+94	hlc_FS_WQ318_dum	184.5	17.9	248.6	20.1	64.0	35	2.2	12
1517+79	hlc_FS_WQ317_dum	91.7	8.2	119.1	9.1	27.4	30	0.9	10
1530+91	hlc_FS_WQ316_dum	113.3	7.2	146.4	8.0	33.1	29	0.9	12
1540+88	hlc_FS_WQ315_dum2_ssa	106.2	6.7	151.6	7.8	45.3	43	1.1	17
1566+80	hlc_FS_WQ314_dum	59.5	4.6	77.5	5.1	18.0	30	0.5	11
1579+58	hlc_FS_WQ313_dum2_ssa	101.3	10.4	152.6	11.8	51.3	51	1.5	14
1598+03	hlc_FS_WQ312_dum2_ssa	154.7	9.3	198.6	10.4	43.9	28	1.2	13
1629+49	hlc_FS_WQ310_dum	201.7	18.5	294.3	21.4	92.6	46	2.9	16
1658+98	hlc_FS_WQ263_dum	144.3	7.8	198.3	9.1	54.0	37	1.3	17
1678+93	hlc_FS_WQ260_dum	340.9	32.0	510.2	36.8	169.2	50	4.8	15
1702+75	hlc_FS_WQ259_dum	171.1	13.1	229.4	14.9	58.3	34	1.8	14
1738+36	Blackmer_Gulch_dum	313.4	35.9	463.1	40.5	149.7	48	4.6	13
1749+51	Blackmer_Gulch_Trib_dum	343.0	38.5	506.9	43.5	163.8	48	4.9	13
1774+57	hlc_FS_WQ258_dum	183.3	11.9	237.4	13.8	54.1	30	1.9	16
1802+67	HLC_178771_oc	461.0	214.8	274.5	77.1	-186.5	-40	-137.6	-64

Table 1: High Line Canal 100 - Year Inflow Comparison Table (NLCD 2011 / CUHP 2.0.0 vs DRCOG 2020 / CUHP 2.0.0) from S Quebec St to E Belleview Ave

The differences in peak inflow and total inflow volume values between the 2011 NLCD land use (CUHP v. 2.0.0) and 2020 DRCOG land use (CUHP 2.0.1) are significant. Most differences are about 10 to 50 percent above the original 2018 Master Plan values for both peak inflow and total inflow volume. These differences are attributed to increased resolution in the land cover dataset, as well as development that has taken place since the 2018 HLC Master Plan was complete. The 2011 NLCD land cover has a raster cell size of 30 feet whereas the 2020 DRCOG land cover data set has a raster cell size of 1 foot, increasing the resolution of the land cover data 900 times. This comparison was conducted to show the magnitude of changes in runoff volume between the updated land cover and 2018 land cover 1D SWMM models. The updated land cover 1D SWMM model inflow hydrographs, for all return intervals, were used as inflow boundary conditions at corresponding locations in the HLC STAMP 2D HEC-RAS model. For more information on the 2D HEC-RAS modeling approach for the HLC STAMP see **Chapter 5** below.

Given the completion of the HLC was nearly 100-years before the creation of the Federal Emergency Management Agency (FEMA), and FEMA's regulatory hydrology ignores canal geometry when calculating floodplain flow, there is a disconnect between the hydrology developed for HLC studies and regulatory hydrology for the basins that the Canal intersects. When it rains within any given basin, runoff is produced. All the rainfall that falls upstream of the Canal either flows into the Canal or into a regulatory floodplain. The canal hydrology reflects real-world conditions in that there are direct inflows into both the Canal and the Regulatory Floodplain in any Canal basin. Whereas regulatory hydrology assumes all the runoff flows unimpeded by the Canal to the regulatory floodplain. This difference in hydrology causes Redirected Flow within Canal Basins but does not duplicate or double count flow.

This redirected flow has a couple of differences between Canal and regulatory hydrology worth noting:

1) The Canal hydrology consists not only direct inflows into the canal but also, when the Canal exceeds its capacity, spill flows out of the downstream side of the Canal. These spill flows are unique to Canal hydrology given that the regulatory hydrology for canal basins ignores the Canal geometry impacts to runoff.

2) The Canal hydrology conveys stormwater flow down Canal. The stormwater flow within the Canal can have three outcomes: 1) Spill out of the Canal, 2) Spill into the regulatory floodplain the Canal intersects, 3) Continue down Canal potentially becoming trans basin flow. Again, this Canal flow is unique to canal hydrology given that the regulatory floodplain hydrology for Canal basins ignores Canal geometry.

These differences in Canal vs regulatory hydrology cause adverse impacts on some regulatory drainageways and their associated drainage basins. However, in general these negative impacts do not cause consistent risk to downstream property due to the infrequency of storms equal to or greater than the 1%-Annual-Chance frequency. Additionally, a large majority of the canal has 1-foot or more of freeboard and the STAMP modeling shows 58 spill locations outside of regulatory floodplains along its entire 65-mile corridor. These spills and trans basin flows are a baseline condition of the High Line Canal, and the STAMP proposes alternatives to help mitigate the risk posed by this baseline condition. For more details on Canal versus regulatory hydrology see the Regulatory Hydrologic Assessment Memorandum in **Appendix A**.

5.0 HYDRAULICS

5.1 Hydraulic Coordination with Other Studies

As mentioned above, the inflows into the HLC STAMP 2D modeling come from the updated 2018 RESPEC SWMM model. It's important to note that the 2025 updated hydrology reflects 2020 existing conditions land use and existing storm infrastructure in basins upstream of the Canal. Aside from the difference in inflows, the major difference in hydraulic modeling between RESPEC's 2018 study and the HLC STAMP is the modeling of flows both within the banks of the Canal and spilling out of the Banks of the Canal. In the 2018 1D SWMM hydraulic / hydrologic model, the Canal's geometry was assumed to be consistent for long lengths of the Canal not accounting for variable bank elevation changes along these lengths, whereas the HLC STAMP 2D hydraulic model uses 2020 DRCOG LiDAR surfaces that can capture these discrete elevation changes along the entire length of the Canal. Despite the differences in model resolution, some spill flow locations seemed to match between the 2018 and the HLC STAMP hydraulic models, an example of this is shown below.

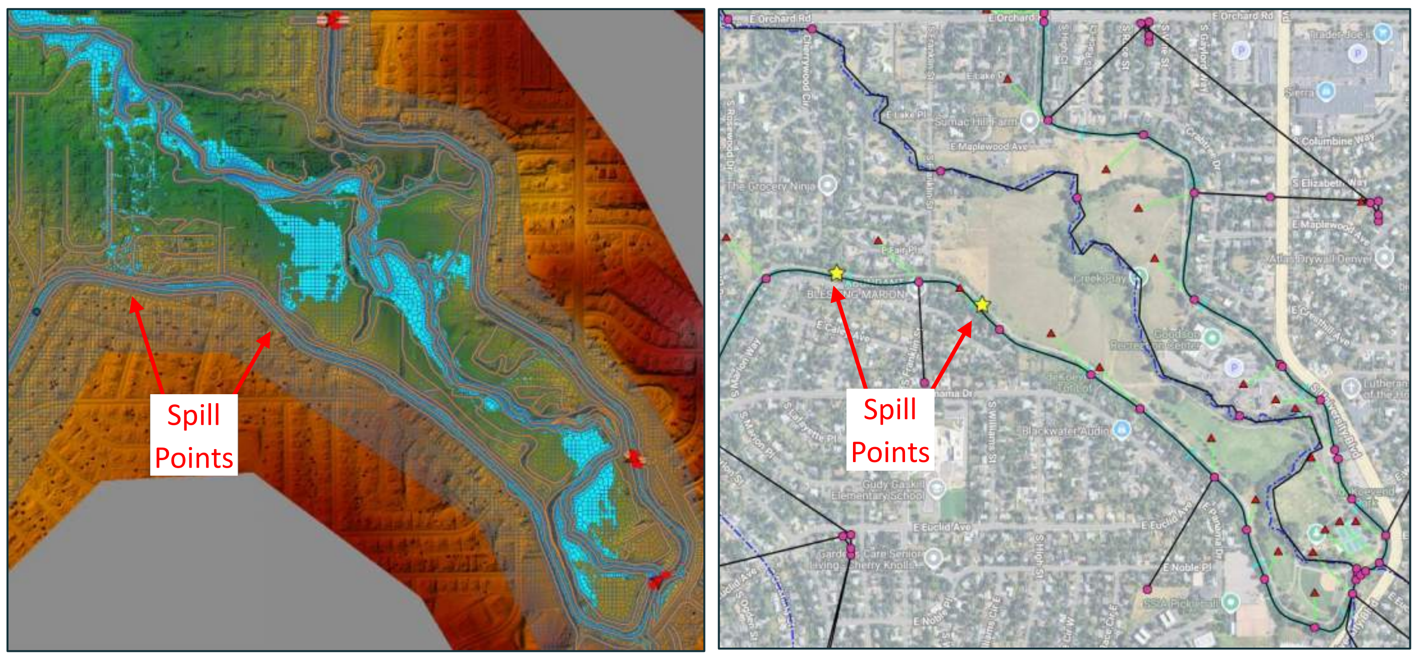


Figure 3: HLC STAMP 2D HEC-RAS (left) compared to RESPEC 2018 1D SWMM (right) Spill Flow Locations

While the 2D HEC-RAS modeling spills differ from the 1D SWMM spills in that they also include spills at major drainageway crossings and in general there are more of them and the locations don't always correspond to the locations of spills in the 1D SWMM modeling, these two spill locations up Canal of Big Dry Creek matching between the modeling sources is a good check that the existing conditions of the Canal has been modeled consistently and points to the general accuracy of both modeling sources. Given the higher resolution of the HLC STAMP modeling as well as the updates made to the hydrology used to inform this model, the 2025 HLC STAMP 2D hydraulic modeling now supersedes the 2018 1D SWMM hydraulic modeling and is considered more accurate than the previous modeling and is the best available information for stormwater flows in the canal.

5.2 Unique Canal Hydraulics

The Canal, on average, drops two feet in elevation for every mile of channel length giving it a slope of about 0.04%, this is an extremely flat slope and is closer to that of a pond than a conveyance element. Flow velocities in the Canal, even in large storm events, remain low due to the flat slope of the Canal's alignment. This is abnormal compared to typical stormwater conveyance such as streams and storm drains and thus does not require the same amount of reinforcement to prevent erosion. Additionally, since it is so flat, when point flow enters the canal, it doesn't travel directionally but rather spreads out from the point source and starts flowing both up and down Canal from the inflow location. This creates a backwater effect along the Canal, causing water to back up since the down Canal flow is moving so slowly.

5.3 STAMP Hydraulic Approach

ICON created seven 2D models using HEC-RAS version 6.4.1 to cover the entire 65 mile length of the Canal. Making smaller models allowed for a reduction in file sizes and much shorter run times per model which increased the efficiency of troubleshooting and calibration. This section will speak about the approach taken in all seven models and will reference the Belleview to Quebec 2D model as an example reach and data from this example reach model is used in tables throughout this section.

A. Boundary Conditions

Most of the inflow boundary conditions ICON utilized in the 2D HEC-RAS models come from the 2025 updated SWMM model. These boundary conditions include all the in-canal inflow hydrographs for each contributing sub watershed. See the 1D SWMM Inflow Locations layer on the AGO map for exact locations and 100-year peak inflow values for all 2D HEC-RAS model inflows. These values are based on 2020 DRCOG land use and updated impervious values.

The upstream inflow hydrograph for each 2D model comes from the upstream 2D HEC-RAS models. This is the case for all models barring the headwater model as the headgates to the canal are closed, thus there is no inflow modeled here. Similarly, the downstream boundary condition for each model is a rating curve of depth and flow information from the downstream 2D HEC-RAS model. This is the case for all models barring the most downstream model as the canal ultimately discharges into First Creek. The other outflow boundary conditions in the 2D HEC-RAS models are normal depth boundary conditions. The normal depth boundary conditions are based on the slope of the terrain at the border of the model.

Note that all the inflow hydrograph boundary conditions are unsteady flow boundary conditions. This includes both the hydrographs that come from the 1D SWMM model and the upstream inflow boundary conditions that are from the upstream 2D HEC-RAS models.

B. Surface

A HEC-RAS terrain was created using 2020 DRCOG LiDAR digital elevation map data. Due to the dense tree canopy over the canal, there were many locations along the canal with poor LiDAR information causing inconsistent cross section geometry and discontinuity in the conveyance of water through the Canal. To address this issue with the LiDAR data, the canal geometry was manipulated throughout the Canal. Invert elevations were found at locations that had a typical canal cross section, likely where there wasn't tree cover or any other obstruction over the canal, up-canal of the poor LiDAR information. This cross section was then applied through the length of the canal with poor LiDAR information at a constant slope to a down-canal location with good LiDAR information. Similarly, in places where the canal goes under a roadway, the geometry of the terrain was stamped to allow for continuous conveyance through the example reach. The deck and abutments, or culvert geometry of the crossing roadway were then added to the 2D HEC-RAS geometry to accurately represent the crossing. See the Crossing Structures table within this subsection for specific crossing structure elevations through the example reach, a crossing structure table for the entire Canal can be found in **Appendix C**. The bank geometry was also modified at one location in the example reach (at approximately station 1418+88 to station 1438+19), due to excessive spilling caused by poor LiDAR information. The bank was raised up to approximately a half foot based on typical canal geometry adjacent to this area. Throughout the entire HLC 2D HEC-RAS modeling, terrain has been similarly modified based on engineering judgment and adjacent geometry where the LiDAR surface appears to be reliable. See the images below for a comparison of the original 2020 DRCOG LiDAR terrain versus the modified terrain at the problem area identified above.

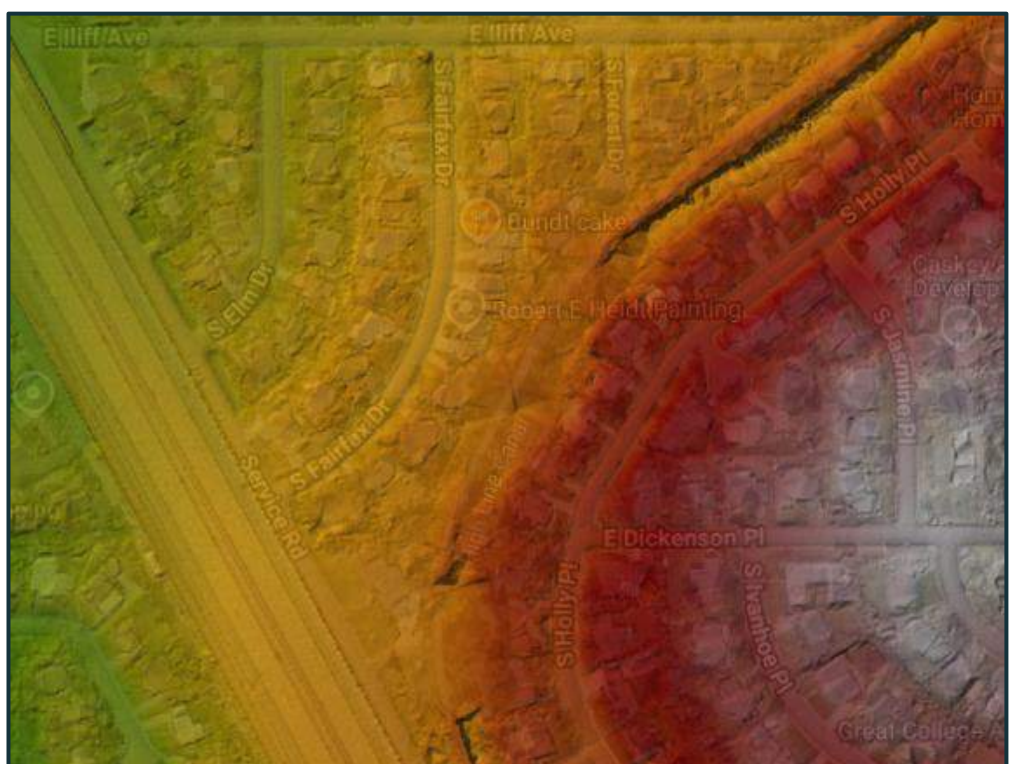


Figure 4: Original 2020 DRCOG LiDAR Terrain

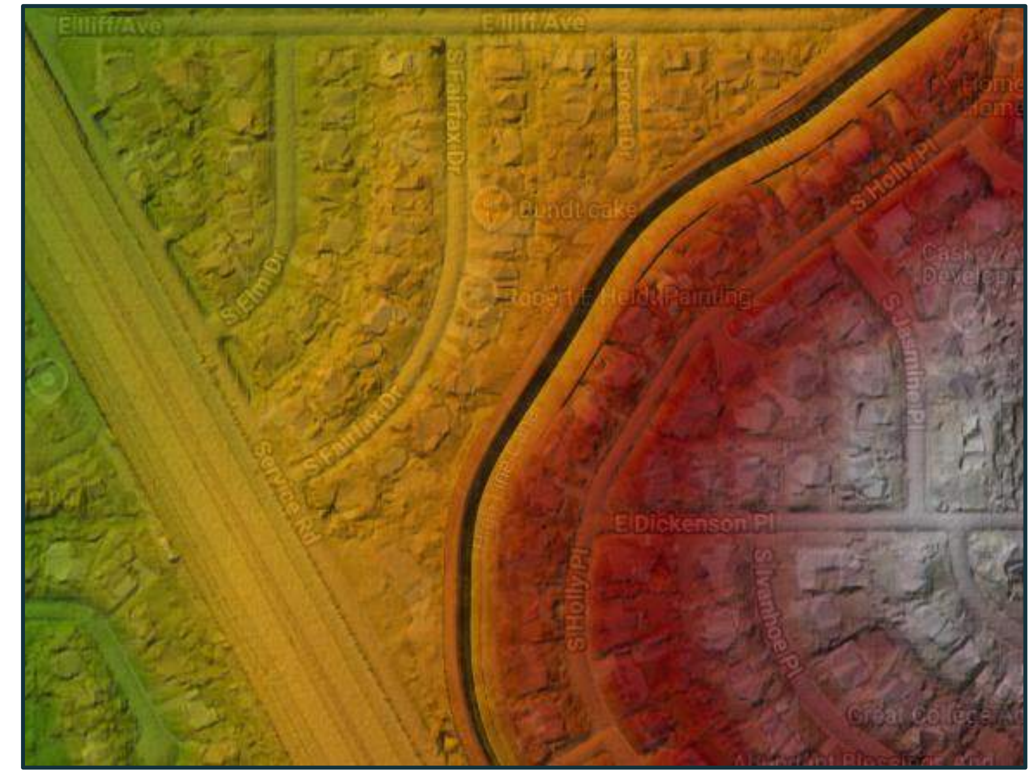


Figure 5: Modified 2020 DRCOG LiDAR Terrain Used in 2D HEC-RAS Model

Lengths of the canal that were identified to have poor LiDAR information were confirmed by Google Street View, aerial imagery or in some cases a site visit.

C. Crossing Structures

Crossing structures were modeled using data from the 1D HEC-RAS model from WRC Engineering Inc.'s 2004 Denver High Line canal (Dad Clark Gulch to Mississippi Avenue) Major Drainageway Planning (MDP) Phase B Preliminary Design where available. Outside of this 1D HEC-RAS model, crossing structures were modeled using additional data collected as part of RESPECs 2018 HLC master plan. The same approach was used for both bridges and culverts. Crossing structures that were not included in either the WRC MDP or RESPEC's data collection were estimated using LiDAR and Google Street View. There are 33 crossing structures in the example reach, and 185 crossing structures over the entire length of the Canal. See the table below for a list of all the crossing structures through the example reach, and the table in **Appendix C** for those along the entire Canal. Although WRC Engineering, Inc.'s 1D HEC-RAS model included pedestrian bridges, some have been added or removed since the 2004 master plan and only the roadway crossings were modeled in the 2018 SWMM model, thus no pedestrian bridges are included in the 2D HEC-RAS model.

Station	Location (Bellview to Quebec Crossing Structures)	Type	Bridge Data: Upstream Low Chord Elevation (ft)	Bridge Data: Upstream High Chord elevation (ft)	Bridge Data: Deck Thickness (ft)	Bridge Data: Upstream Invert Elevation (ft)	Structure Modeled (Y/N)
1267+43	E Iliff Ave Ped Bridge	Bridge	5476.98	5475.8	0.9	5468.2	N
1296+18	East Yale Ave Road Crossing	Bridge	5477.48	5481.98	4.5	5469.6	Y
1304+22	East Amherst Ave Ped Bridge	Bridge	5479.82	5479.3	0.5	5469.7	N
1325+94	Goldsmith Gulch Trail Ped Bridge	Bridge	5479.44	5479.5	0.7	5469.9	N
1348+52	S Newport St and E Bucknell Pl Ped Bridge	Bridge	5478.85	5478.8	0.5	5470.2	N
1358+69	East Bates Ave Ped Bridge	Bridge	5480.32	5480.8	0.6	5470.7	N
1368+61	East Yale Ave Road Crossing	Bridge	5480.24	5484.74	4.5	5471.1	Y
1375+25	South Monaco Pkwy Road Crossing	Bridge	5479.46	5484.29	4.8	5471.5	Y
1411+83	South Holly St Road Crossing	Bridge	5478.17	5482.67	4.5	5473.4	Y
1468+81	East Yale Ave Road Crossing	Bridge	5479.87	5483.87	4.0	5474.4	Y
1488+73	Interstate 25 Light Rail and Road Crossing	Bridge	5480.05	5485.55	5.5	5475.2	Y
1491+73	South Holly St Ped Bridge	Bridge	5484.22	5484.4	1.0	5475.5	N
1504+20	South Forest St Ped Bridge	Bridge	5482.51	5484.4	0.5	5475.5	N
1526+88	South Dalia St Road Crossing	Bridge	5481.6	5486.6	5.0	5476.2	Y
1542+00	South Bellaire St Ped Bridge	Bridge	5483.55	5484.8	1.2	5476.6	N
1550+28	High Line Canal Ped Bridge Downstream of S Colorado Blvd	Bridge	5485.54	5484.3	1.0	5476.8	N
1551+10	South Colorado Blvd Road Crossing	Bridge	5483.04	5488.04	5.0	5476.9	Y
1552+58	Wellshire Golf Course Ped Bridge #1	Bridge	5483.48	5482.4	1.0	5476.9	N
1555+99	Wellshire Golf Course Ped Bridge #2	Bridge	5484.36	5483.1	1.1	5476.9	N
1558+06	Wellshire Golf Course Ped Bridge #3	Bridge	5486.53	5486.2	0.9	5476.9	N
1561+89	Wellshire Golf Course Ped Bridge #4	Bridge	5483.28	5486.2	2.0	5476.9	N
1586+50	Wellshire Golf Course Ped Bridge #5	Bridge	5485.98	5487	1.6	5477.7	N
1588+49	Wellshire Golf Course Ped Bridge #6	Bridge	5485.68	5486.4	1.7	5477.8	N
1592+18	Wellshire Golf Course Ped Bridge #7	Bridge	5486.5	5486	1.0	5477.9	N
1593+92	East Hampden Ave Road Crossing	Bridge	5485.55	5489.55	4.0	5478	Y
1595+15	High Line Canal Ped Bridge Upstream of E Hampden Ave	Bridge	5486.3	5487.3	1.0	5478	N
1600+82	Covington Dr Ped Bridge	Bridge	5489.08	5487.9	0.8	5478.1	N
1648+39	South Colorado Blvd Road Crossing	Bridge	5488.41	5493.41	5.0	5479.5	Y
1662+14	East Oxford Pl Ped Bridge	Bridge	5487.6	5488.2	1.9	5480	N
1674+28	South Dahlia St Ped Bridge	Bridge	5489.71	5490.5	2.0	5480.4	N
1692+24	East Quincy Ave Road Crossing	Bridge	5488.61	5493.11	4.5	5481	Y
1721+86	South Dahlia St High Line Canal Parking Lot Ped Bridge	Bridge	5488.24	5489.9	2.8	5482	N
1742+48	West of East Union Ave Ped Bridge	Bridge	5490	5490.7	0.7	5483.4	N
1780+63	Northwest of South Birch St Ped Bridge	Bridge	5492.3	5494	1.7	5483.5	N

Table 2: High Line Canal Crossing Structures and Their Key Elevations from S Quebec St to E Belleview Ave

Like the 2018 SWMM model, only road crossing bridges were modeled in the 2D HEC-RAS example reach model. Additionally, the pedestrian bridges generally appear to be higher above the channel invert than the roadway crossings and much less of an impediment to flow or are designed to be break away structures. Below are screen shots of the Google street view of a road crossing at South Holly Place and East Yale Avenue and a pedestrian bridge crossing at South Bellaire Street and East Yale Avenue illustrating the differences noted above. Note that 106 roadway crossings were modeled for the entire length of the HLC, there are 79 pedestrian crossings that were not included in the HLC STAMP 2D modeling.

Figure 6: High Line Canal Road Crossing at S Holly Pl and E Yale Ave (Looking Downstream)

Figure 7: High Line Canal Pedestrian Crossing at S Bellaire St and E Yale Ave (Looking Upstream)

D. Roughness Values

To create a Manning's roughness layer in the 2D model, 2020 DRCOG land cover vector data was used. DRCOG assigns a land use value to each polygon in the vector layer, and this land use value was correlated to a land use type and associated manning's n-value. See the table below for a summary of the land use values and corresponding roughness value.

DRCOG Land Use Number	Land Use Type	Manning's n-value
1	Buildings	0.2
2	Paved surfaces	0.02
3	Open Water	0.04
4	Grass Buffers	0.04
5	Tree Cover	0.06
6	Landscaped Grass	0.04
7/9	Barren Earth	0.025

Table 3: DRCOG Land Use Manning's n-values

E. Cell Size

The typical cell size in the 2D HEC-RAS model is 30 feet, however this cell size is used only outside of the canal area. Around the canal and at some spill locations there are break lines that force the face of the 2D mesh to pick up the high and low points where the break lines are drawn. Where possible, the cell size on the break line along the centerline of the canal is 3 feet, however in some cases, due to errors in the mesh because of canal geometry, the cell size is 5 feet. The cell size for break lines on the canal banks is 5 feet. For break lines downstream of the canal spills, the crowns and flow lines of roads, and other significant high and low points the cell ranges from 10 to 20 feet.

F. Storm Drains

No storm drains are modeled in the 2D model for several reasons. Storm drains upstream of the 2D model are handled by the SWMM model and are considered in the inflows into the canal, thus modeling these storm drains in the 2D HEC-RAS would be redundant. There is storm drain infrastructure downstream of the canal in some of the spill areas, but direct connection to storm drains has not been determined. To stay conservative in the flooding risk from spills out of the canal, no storm drain systems have been modeled in areas downstream of canal spill locations. Additionally, to accurately model downstream storm drains additional hydrologic analysis would be needed on the basins downstream of the canal which is outside of the scope of this planning study.

G. Canal Structures

Other considerations in the 2D model are wastegates, siphons, and flumes. Although there are no canal structures through the example reach, all canal structures are modeled in the HLC STAMP 2D HEC-RAS modeling. Wastegates and flumes are both structures that when open allow water conveyed through the canal to discharge into adjacent streams or pond. Wastegates are different types of weirs, and flumes are elevated structures connecting the canal above historic drainageways, flumes also have sluice gate weirs on the downstream side. All weirs and flume sluice gates are currently open (locked in the open position with chains and a pad lock) to allow water to flow out of the canal into adjacent bodies of water. Thus, all these structures have been modeled true to their geometry, and open, allowing water to escape from the canal into adjacent bodies of water. Siphons are structures that carry water through a closed conduit under a historic drainage connecting the HLC on either side. Due to 2D HEC-RAS modeling limitations siphons have been modeled as closed culverts with no depression.

H. Modeled Storms

Storm recurrence intervals of 2-, 5-, 10-, 25-, 50-, and 100-year were analyzed through the example reach. The level of service for any spill location can be analyzed on the AGO map by turning on and off the different recurrence interval layers under the Existing Conditions 2D HEC-RAS group.

For subsequent models storm recurrence intervals of 2-, 5-, 10-, 25-, 50-, 100-, and 500-year were analyzed. The freeboard for each return interval was also determined and is displayed on the ArcGIS Online (AGO) map for convenience. Throughout this report there is a hyperlink on the words "AGO map" that, when clicked, will take you to the HLC STAMP ArcGIS Online Experience Builder Map for this project.

I. Results

All existing and proposed conditions results for the entire length of the canal are hosted on the AGO map.

6.0 RISK IDENTIFICATION

6.1 Level of Service

Mitigating urban flood risk caused by stormwater spill flows out of the Canal for the 100-year storm recurrence interval is the primary level of service desired for the entire length of Canal. While the owner of the Canal has yet to specify their level of service requirements for the Canal, the HLC STAMP project team set a goal of providing 1-foot of freeboard during the 100-year event as a secondary level of service for stormwater usage in the HLC. Note that this 1-foot freeboard level of service would be applicable to normal Canal cross sections and not to areas where there is a controlled spill flow release (e.g. conveyance and bank manipulation alternatives). While the 1-foot of freeboard in the 100-year event level of service was set as a goal, the alternatives analysis performed as part of this plan does not accomplish this level of service. For 1-foot of freeboard to be achieved along the entire Canal corridor, it would take changes to the Canal beyond the scope of this study. However, this plan does offer solutions to mitigating urban flood risk in key locations within the major funding partners service area. It is recommended that these communities begin with these improvements on the Canal and focus first on mitigating urban flood risk in the 100-year event.

Keeping with the primary level of service being the mitigation of urban flood risk related to Canal spills, ICON shared depth, velocities, and hazard data from the hydraulic models for all storm return intervals with Michael Baker International who developed risk assessment data. This effort arose out of MHFD's goal of developing risk data based on impacts to people versus the cost of infrastructure at risk of damage. Michael Baker International used four metrics in determining the risk associated with any spill, these include structures at risk (SAR), roads at risk (RAR), trails at risk (TAR), and critical facilities. These metrics were then aggregated per spill area to determine a Values and Risk (VAR) score for each spill area. Using the sum of the SAR, RAR, and TAR values ICON shows the ranked risks on the AGO map. See **Appendix E** for more information on how these risk scores were developed. See **Section 10.4** for a discussion on the risk ranking for each alternative.

6.2 2D Modeled Spill Flows

The HLC 2D modeling identifies 80 discrete 100-year existing conditions spill flow locations along the 65 mile length of the Canal. The total volume spilled and peak flow rate of the spill locations are reported under the Existing Conditions 2D HEC-RAS group on the AGO map at all these spill locations for the 2-, 5-, 10-, 25-, 50-, 100-year, and 500-year storm frequencies. Note that since the spill points correspond to the 100-year storm event that lower return intervals will have values of zero for some of these spill locations while not all of the 500-year spill points will be captured in the spill point geometry.

6.3 2D Modeled Freeboard

Given the higher resolution of the 2D HEC-RAS model Canal freeboard was calculated for the 100-year (1%-Annual-Chance) storm event every one foot along the downstream bank of the Canal for the entire length of the Canal. This assessment was conducted for both existing conditions and each of the 23 recommended alternatives. This high resolution on freeboard enables stakeholders along the Canal to assess the current freeboard at any given location and compare that to the proposed conditions freeboard for any of the relevant alternatives through their area of interest. In some places along the Canal corridor there is negative freeboard in the 100-year event (i.e. spills). These are considered gaps in level of service, and places where proposed projects could result in increased freeboard. Sometimes these gaps in level of service occur adjacent to open space or riparian areas and are seen as less of a priority to mitigate than gaps where there is developed land downstream. It is recommended that each municipality along the Canal utilize the AGO map to better understand where these gaps are through their service area.

6.4 Additional Risks

The primary risk of stormwater in the Canal is the damage associated with spill flows out of the Canal. As mentioned above the risk assessment data compiled by Michael Baker International categorizes and ranks the existing conditions risk accordingly. Other risks to consider associated with stormwater in the Canal will be discussed in the following subcategories below: nuisance flooding and ponding risk, debris flow risk and geotechnical risk.

A. Nuisance Flooding and Ponding Risk

There are areas where stormwater reaches the top of Canal bank and releases a small amount (1 cubic foot per second [cfs] or less) of stormwater in the 100-year (1%-Annual-Chance) storm event. These areas can be identified on the AGO map as flooding depth that is displayed outside of indicated spill areas. While this type of flooding will not cause any appreciable damage downstream it does pose a risk of damage in future events and can be used to identify areas where the Canal's capacity could be increased.

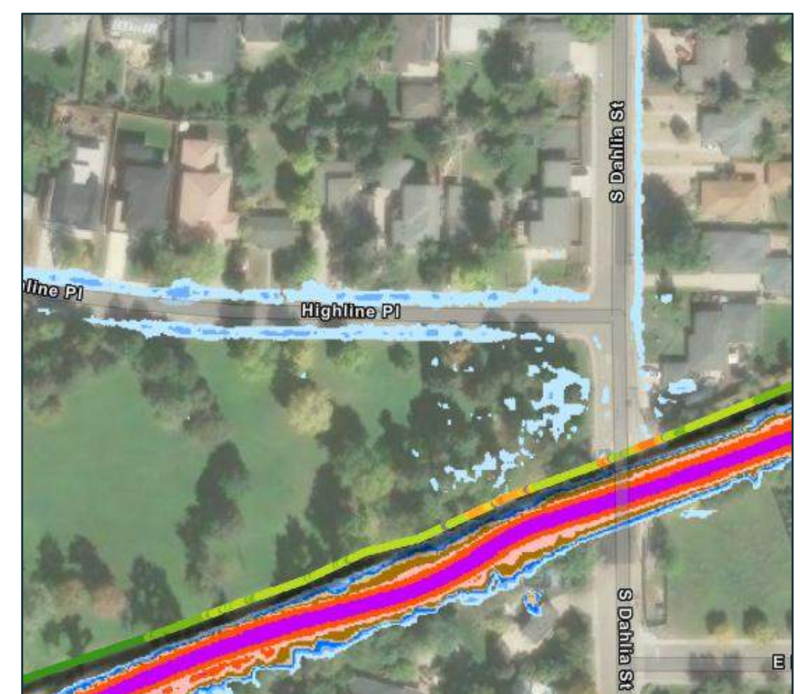


Figure 8: Nuisance Flooding at S Dahlia St as Shown on the High Line Canal AGO Map

There are some cases in which water overtops the upstream bank of the canal and ponds behind the upstream Canal embankment. This is a result of the relatively flat slope of the canal and the effect of water ponding in the canal and exceeding the elevation of the upstream bank. In cases where this water ponds, it tends to leave the Canal on the upstream side and settle in a natural depression. While this type of flooding is a concern it generally happens slowly, at very low velocities and is contained in a small area. It also is important to note that most of these flooding locations occur adjacent to an inflow location where there is an inflow hydrograph putting water into the 2D model at that precise location. Real world conditions are best approximated by these inflow locations; however, they may not be truly representative of the manner in which stormwater makes it into the Canal. The screenshot below shows an area where there is ponding at an inflow location the 277 cfs and 990 cfs are point inflows in the 2D model.

Figure 9: Ponding on Upstream Canal Embankment at S E Costilla Ave as Shown on the High Line Canal AGO Map

B. Debris Flow Risk

As the Canal fills and conveys stormwater there is a risk of debris being mixed into this stormwater flow. This debris could be leaf litter, trash, or branches and logs that fall into the Canal. This debris increases the surface roughness of the Canal affecting the hydraulic conditions and has the potential to cause debris blockage at crossing structures. Both of these conditions have the potential to increase the urban flood risk associated with spill flows out of the Canal. A roughness sensitivity analysis was conducted to assess the impact of the added roughness in the Canal and can be found in **Appendix B**. The increased flood that is a result of debris blockages at crossing structures can be mitigated through routine maintenance, this is discussed in more detail in **Chapter 9**.

C. Geotechnical Risk

There has been concern from project stakeholders regarding the risk of Canal embankment failure due to stormwater in the Canal. These concerns are not unique to the HLC STAMP effort and have been addressed in RESPEC's 2018. The Canal embankment has failed in a few known places but not because of stormwater in the Canal. It failed during large storm events either due to an excess of water on the upstream side of the embankment causing a failure or due to burrowing animals weakening the structure of the embankment. Given that stormwater within the Canal has not solely been the cause of a Canal embankment failure, the geotechnical risk posed by the Canal embankment is seen as insignificant. However, municipal operations should take note to relocate burrowing animal populations that seek shelter on the Canal embankment and it should be a priority to get stormwater into the Canal, as long as it matches historic quantity, quality, or manner of flow, instead of letting it pond up against the upstream side of the embankment.

7.0 ALTERNATIVE EVALUATION

Once existing conditions modeling was completed and the urban flood risk associated with spills out of the Canal assessed, the project team began to develop alternatives to mitigate these risks. Based on coordination with project stakeholders ICON developed 27 alternatives, however only 23 were hydraulically analyzed and their results are included in the alternatives analysis of this study. The four alternatives that do not have hydraulic results included in this study are Arapahoe County Mitigation Alternative 10, and City and County of Denver Mitigation Alternatives 7, 9, and 13. The reason these results are not included are described in more detail within the subsections of this chapter. Note that each of these alternatives was analyzed for the 100-year (1%-Annual-Chance) storm event only. These alternatives can be broken down into four types: conveyance, bank manipulation, treatment drains, and increased capacity. Note that the National Flood Hazard Layer discussed in **Section 7.1** has both conveyance and bank manipulation alternative types incorporated within its analysis. Each will be discussed in more detail in the subsections below. The design standards for each of these alternative types follow recommendations given within the MHFD Urban Flood Drainage Criteria Manuals (USDCM). As any of these alternatives are further considered and move into design phase the USDCM standards should be referenced and used for design guidance.

Most of the mitigation alternatives that were assessed were within the jurisdictional area of the HLC of the major funding partners, Arapahoe County and the City and County of Denver. In general, the jurisdiction specific alternatives follow linear order along the HLC from upstream to downstream, except for City and County of Denver alternatives 12 and 13. These alternatives were added after the original 11 were assessed for feasibility and came out of conversations with Denver staff and project stakeholders. Thus, they do not fit the pattern of linear order along the Canal alignment.

7.1 National Flood Hazard Layer Alternative

One alternative was developed Canal wide and took the approach of formalizing conveyance or adding spillways to allow water to flow from the Canal to every drainageway with a regulatory floodplain that intersects the Canal. Unlike the four alternative types discussed below, this alternative was not developed within any one jurisdictional boundary and assesses the impacts of many controlled release points along the Canal. These controlled release locations either incorporate the conveyance or bank manipulation alternatives to convey stormwater flow from the Canal to drainageways with a regulatory floodplain. This alternative is called the National Flood Hazard Layer (NFHL) diversion mitigation alternative in the AGO map. More discussion on the direct impact this mitigation alternative has on mitigating urban flood risk can be found in **Appendix A**.

7.2 Conveyance

The conveyance mitigation alternative consists of formalizing the conveyance of stormwater from the Canal channel to natural waterways that intersect the Canal. These alternatives model the Canal channel as being directly connected, via a naturalized channel, to the natural waterway from both the up Canal and down Canal side of the Canal, allowing stormwater to exit the canal freely into the existing channel. Not only does this type of alternative mitigate risk by putting more stormwater into channelized waterways where a floodplain exists, but it also provides an ecological uplift to the surrounding area. The cost of the conveyance type alternatives is estimated to be about $500,000 each, note this does not include the addition of water quality features, historic preservation, or repurpose of existing infrastructure.

There are five conveyance alternatives that were assessed for feasibility, four for Arapahoe County and one for County of Denver. All of which were deemed feasible and results are included in the AGO map. These alternatives are described in more detail below.

- **Arapahoe County Mitigation Alternative 2 – Conveyance to Lee Gulch**
  This alternative consists of constructing conveyance channels on the up and down Canal sides of the Lee Gulch flume and potentially removing or relocating the flume. See the **Historic Preservation** header within this subsection for more details.

- **Arapahoe County Mitigation Alternative 6 – Conveyance to Big Dry Creek**
  This alternative consists of constructing conveyance channels on the up and down Canal sides of the Big Dry Creek siphon, blocking the siphon from stormwater usage, and potentially removing the wastegate structure on the upstream side.

- **Arapahoe County Mitigation Alternative 7 – Conveyance to Little Dry Creek**
  This alternative consists of constructing conveyance channels on the up and down Canal sides of the Little Dry Creek siphon, blocking the siphon from stormwater usage, and potentially removing the wastegate structure on the upstream side.

- **Arapahoe County Mitigation Alternative 11 – Conveyance to West toll Gate Creek**
  This alternative consists of constructing conveyance channels on the up Canal sides of West Toll Gate Creek siphon, blocking the siphon from stormwater usage, and potentially removing the wastegate structure on the upstream side.

- **City and County of Denver Mitigation Alternative 10 – Conveyance to Cherry Creek**
  This alternative consists of constructing conveyance channels on the up and down Canal sides of the Cherry Creek siphon, blocking the siphon from stormwater usage, and potentially removing the wastegate structure on the upstream side.

A. Historic Preservation

The wooden flume structure over Lee Gulch is original and historically significant. While this structure is known to attract vandalism and potentially pose a safety risk, it is also an important piece of HLC history. There are several ways in which the structure can be historically preserved while minimizing risk to public safety or property defacement. By constructing conveyance channels on either side of the flume this provides an opportunity for the flume to be hydraulically disconnected to the HLC channel. This would prevent easy access to the flume from the HLC channel which is likely how the public is accessing the flume today. With proper lighting and strategic fencing, it is possible that the preservation of the Lee Gulch flume can be in line with the goals of Arapahoe County Mitigation Alternative 2. Many other configurations of how this alternative and the flume preservation fit together are possible and can be optimized as this design progresses.

B. Additional Opportunities

Aside from the opportunity of historic preservation of the Lee Gulch flume structure, constructing natural conveyance channels offers ecologic uplift, an opportunity for the construction of water quality elements, and an opportunity for repurposing existing stormwater infrastructure.

The current wastegates at siphons and flumes along the HLC discharge water directly from the Canal to receiving waterways, either flowing over concrete wastegates or out of vertical weir wastegates. Both discharge paths cause the water to enter the receiving waters at higher velocities which leads to erosion at the confluence. By constructing a naturalized channel conveyance between the Canal and the receiving waterways, the rougher surface slows down the water, dissipating energy and provides additional area for native vegetation and local organisms to inhabit.

The construction of naturalized conveyance elements provides an opportunity for the addition of water quality features (extended detention basins, or rain gardens) between these elements and the receiving waters. While these water quality features add cost to the conveyance alternative, they also provide benefits to the municipality who constructs them in the form of water quality credits. The City and County of Denver Mitigation Alternative 10 – Conveyance to Cherry Creek is a great location for such a water quality opportunity, as multiple regional trails intersect here, and there is an additional value add in the form of public education and such a feature could be coupled with a recreational amenity for a full multi benefit project.

The conveyance alternatives include blocking siphons under waterways from stormwater use; this allows for them to be used for other purposes. One such purpose would be to utilize these siphons for running dry utilities under existing streams. The benefit of this is two-fold; municipalities could lease the siphon space to utility companies and in turn the utility companies would not have to bore new connections under urban streams.

7.3 Bank Manipulation

The bank manipulation mitigation alternatives consist of both lowering and raising the trail at certain locations. Locations where the bank has been lowered were selected to safely allow stormwater flow to discharge into greenspace or natural waterways which would mitigate adjacent spill flows by consolidating the spills and directing them into areas with lower flood damage risk. The purpose of raising the bank is to prevent water from spilling out at those locations. These locations were also strategically chosen so as not to be at risk of being considered a non-jurisdictional dam. Where bank raising is proposed, the existing bank is lower than the adjacent bank, and the proposed grade change is only to match the elevation of the adjacent bank elevations. The bank manipulation alternatives range from about $50,000 for raising the trail in sections along the Canal to $250,000 for constructing a spillway with a riprap run down. This alternative option does offer the possibility of outside funding through Great Outdoors Colorado, as they offer grants for trail projects throughout the state.

There are seven bank manipulation alternatives that were assessed for feasibility, four for Arapahoe County and three for County of Denver. Six of which were deemed feasible and results are included in the AGO map. Denver Alternative 7 was considered unfeasible as discussed below; the remainder of the alternatives are described in more detail below.

- **Arapahoe County Mitigation Alternative 1 – Spillway into Jackass Gulch**
  This alternative consists of lowering the HLC trail by about two feet where it abuts the Jackass Gulch natural drainageway. Providing a stormwater release point at this natural drainageway increases the freeboard adjacent to this alternative location.

- **Arapahoe County Mitigation Alternative 3 – Spillway into Littles Creek**
  This alternative consists of significant (>2 feet) lowering of the grade of the HLC trail where it abuts the Littles Creek natural drainageway. This spillway proposes large changes in grade to alleviate the major urban flood risk posed by overtopping the Canal banks adjacent to the location. The exact configuration of the trail, connection to the upstream neighborhood, and interface with the E Highline Cir roadway are yet to be determined. However, a release point for stormwater at this location is highly recommended and has the potential to eliminate significant flooding risk in the adjacent areas.

- **Arapahoe County Mitigation Alternative 5 – Spillway into Big Dry Creek Open Space**
  This alternative consists of lowering the HLC trail by about two feet to formalize a spill flow path into the Dekoevend Park open space area just northwest of Tot Lot Park. There are two locations up Canal of the proposed spillway location in which the trail was raised one to two feet to prevent undesired spilling. The chosen spillway location is adjacent to a natural depression / drainage within the parks open space area making it an ideal location for a spillway.

- **Arapahoe County Mitigation Alternative 8 – Spillway into Greenwood Gulch**
  This alternative consists of significant (>2 feet) lowering of the grade on the downstream Canal embankment where it abuts the Greenwood Gulch natural drainageway. This alternative provides a stormwater release point into the Greenwood Gulch drainage way and eliminates much of the urban flood risk that exists adjacent to this spill point in existing conditions.

- **City and County of Denver Mitigation Alternative 1 – Spillway into Skeel Reservoir**
  This alternative consists of significant (>2 feet) lowering of the grade on the downstream Canal embankment to provide a release point for stormwater in the Canal to flow into Skeel Reservoir adjacent to Wellshire Golf Course in South Denver. While there are currently plans to decommission Skeel Reservoir as a jurisdictional dam, reducing its size and capacity to attenuate water, providing stormwater storage in its current condition does eliminate several spill flows that contribute to urban flood risk adjacent to this alternative location.

- **City and County of Denver Mitigation Alternative 7 – Spillway into Bible Park Open Space**
  This alternative consists of lowering the HLC trail adjacent to the Bible Park Open Space area just northeast of the intersection of E Brown Pl and S Newport St. While this location is ideal for a spillway in that there is a safe stormwater release point on the downstream side of the Canal, the existing conditions 100-year water surface elevation (WSEL) is several feet below the Canal banks making a spillway at this location infeasible. Also, due to the undersized crossing structure at the HLC and S Monaco St Parkway, there are not any adjacent spills that pose significant urban flood risk threats in the Bible Park area. This further reinforces the lack of benefit of this alternative and therefore, it is not recommended to construct this spillway. Thus, hydraulic results of this alternative are not included in the AGO map.

- **City and County of Denver Mitigation Alternative 12 – Trail Raising East of I-25**
  This alternative consists of raising the HLC trail just east of the HLC crossing with I-25. In existing conditions there is a depression in the trail at this location causing a natural release point for stormwater in the Canal. While raising the trail here does eliminate the spill at this location it increases the spill just up Canal of the I-25 crossing and at several locations down Canal of this mitigation alternative location. If this alternative is to be implemented, additional analysis will be necessary during the design phase to address potential adverse impacts adjacent to the trail adjustments.

A. Location Selection Criteria

As mentioned in the alternative descriptions, locations of bank manipulation alternatives were chosen strategically. Trails were raised in locations to prevent spill flows that pose significant urban flood risk threats to downstream infrastructure and people, and banks were lowered in locations that allow for stormwater flows into natural drainages or open space adjacent to said drainages.

B. Spillways and Bank Raising

The bank manipulation alternatives consist of both spillways and bank raising to provide safe stormwater release points and protect property and lives in areas that are vulnerable to urban flood risk. The Canal banks remain under 10 feet even after the proposed trail raising that some of these alternatives suggest, this eliminates any potential complications with the State Engineers office of considering the banks of the Canal a non-jurisdictional dam.

7.4 Treatment Drains

The treatment drain mitigation alternative connects the Canal to an existing or proposed storm drain system that passes under the Canal. This alternative is a combination of two existing outlet structures, a type C outlet set below the 100-year water surface elevation (WSEL) in the Canal with water quality outlets on the upstream and downstream side of the type C outlet structure providing water quality treatment for stormwater in the Canal. For more details on the configuration of the treatment drain concept see the conceptual design drawing and figure in **Appendix G**. The stormwater is then conveyed downstream into the storm drain system until it ultimately discharges to a water way. By redirecting stormwater into a storm drain this mitigation alternative reduces the WSEL in the Canal which ultimately reduces or eliminates spill flows over the downstream bank of the Canal. Note that most of the Denver Country treatment drains connect to future storm drain systems as proposed in the 2025 Denver Storm Drainage Master Plan (SDMP). The cost of constructing a treatment drain is estimated to be about $300,000, this does not include the construction of any future storm drain systems needed to make the connection.

There are 12 treatment drain alternatives that were assessed for feasibility, five for Arapahoe County and seven for City and County of Denver. Ten of which were deemed feasible and results are included in the AGO map. Arapahoe County Alternative 10 and City and County of Denver Alternative 9 were considered unfeasible due to the reasons listed below; the remainder of the alternatives are described in more detail below.

- **Arapahoe County Mitigation Alternative 4 – Treatment Drain to S Clarkson St Storm Drain**
  This alternative consists of constructing a treatment drain from the HLC channel to the S Clarkson St Storm Drain. This drain passes under the Canal and a connection made to this storm drain helps mitigate the spill flow that currently flows out of the Canal into Milliken Park. While this alternative does mitigate in part some of the spill flow into Milliken Park it does not eliminate. An additional alternative at this location was considered, which would redirect flow from the Canal into a detention pond in the Milliken Park open space area. However, details regarding the location and size of the pond remain undetermined, thus its analysis is not included as part of the STAMP.

- **Arapahoe County Mitigation Alternative 9 – Treatment Drain to E Harvard Ave Storm Drain**
  This alternative consists of constructing a treatment drain from the HLC channel to the E Harvard Ave Storm Drain. This drain passes under the Canal and a connection made to this storm drain reduces the amount of Canal flow that makes it to the Cherry Creek wastegate. While this alternative doesn't mitigate any high risk of urban flooding, it does provide a water quality opportunity within the Canal.

- **Arapahoe County Mitigation Alternative 10 – Treatment Drain to E Iliff Ave Storm Drain**
  This alternative consists of constructing a treatment drain from the HLC channel to the E Iliff Ave Storm Drain. This drain passes under the Canal and there is the potential for a connection made to this storm drain. While there aren't any adjacent spills that would be mitigated by this alternative, it is still recommended due to its water quality benefit and convenient connection to an existing storm drain. However, the model results were unable to converge on a reasonable numerical solution for this alternative despite troubleshooting efforts. Therefore, this alternative's results are not included in the AGO map for this study. Additional analysis is required at the time of preliminary design.

- **Arapahoe County Mitigation Alternative 11 – Treatment Drain to E Alameda Ave Storm Drain**
  This alternative consists of constructing a treatment drain from the HLC channel to the E Alameda Ave Storm Drain. This drain passes under the Canal and a connection made to this storm drain has little effect on the Canal's WSEL and associated spill flows. Thus, results for this alternative are not included in the AGO map. Additional modeling will be necessary at the time of design to address any potential adverse impacts from the project.

- **Arapahoe County Mitigation Alternative 12 – Treatment Drain to Potomac St Storm Drain**
  This alternative consists of constructing a treatment drain from the HLC channel to the Potomac St Storm Drain. This drain passes under the Canal and a connection made to this storm drain reduces the amount of spill flow from 161 cfs to 111 cfs at the HLC and Potomac St.

- **City and County of Denver Mitigation Alternative 2 – Treatment Drain to Dartmouth Tributary Storm Drain**
  This alternative consists of constructing a treatment drain from the HLC channel to the Dartmouth Tributary Storm Drain. This treatment drain connects to a storm drain that is proposed in Denver's 2025 SDMP and does not currently exist. This alternative eliminates two spill flows out of the Canal and reduces the flow of several others adjacent to the alternative location.

- **City and County of Denver Mitigation Alternative 3 – Treatment Drain to Clermont Outfall Storm Drain**
  This alternative consists of constructing a treatment drain from the HLC channel to the Clermont Outfall Storm Drain. This treatment drain connects to a storm drain that is proposed in Denver's 2025 SDMP and does not currently exist. This alternative eliminates one spill flow out of the Canal and reduces the flow of several others adjacent to the alternative location.

- **City and County of Denver Mitigation Alternative 4 – Treatment Drain to Eudora Outfall Storm Drain**
  This alternative consists of constructing a treatment drain from the HLC channel to the Eudora Outfall Storm Drain. This treatment drain connects to a storm drain that is proposed in Denver's 2025 SDMP and does not currently exist. This is the highest performing single alternative, eliminating four spill flows out of the Canal and reducing the flow of several others adjacent to the alternative location. Once this SDMP improvement is constructed it is recommended that a treatment drain connection from the Canal be made the storm drain.

- **City and County of Denver Mitigation Alternative 6 – Treatment Drain to E Iliff Ave Storm Drain**
  This alternative consists of constructing a treatment drain from the HLC channel to the E Iliff Ave Storm Drain. This treatment drain connects to a storm drain that is proposed in Denver's 2025 SDMP and does not currently exist. While this alternative does not mitigate any downstream urban flood risk associated with spill flows out of the Canal it does eliminate nuisance flooding on the uphill side of the Canal down canal of the alternative location.

- **City and County of Denver Mitigation Alternative 8 – Treatment Drain to Goldsmith Gulch Culvert**
  This alternative consists of constructing a treatment drain from the HLC channel to the Goldsmith culvert that passes under the HLC. While a treatment drain connection here does not eliminate any adjacent spills out of the Canal it does provide a significant water quality benefit that connects directly to a natural drainageway.

- **City and County of Denver Mitigation Alternative 9 – Treatment Drain to Bible Park Open Space**
  This alternative consists of extending the E Amherst Ave storm drain west, under the Canal, into Bible Park, then constructing a treatment drain connecting to the extended storm drain. While this treatment drain would have a water quality benefit, it is not recommended due to the additional cost of extending the storm drain and the lack of potential benefit in mitigating spill flow risk.

- **City and County of Denver Mitigation Alternative 11 – Treatment Drain to S Havana St Outfall**
  This alternative consists of constructing a treatment drain from the HLC channel to the S Havana St Outfall Storm Drain. This treatment drain connects to a storm drain that is proposed in Denver's 2025 SDMP and does not currently exist. A connection made to this proposed storm drain eliminates the spill flow that currently flows

out of the Canal west along E Exposition Ave. There is a current stormwater project being considered at Expo Park northeast of this alternative location. The construction of this Expo Park project will likely have an impact on the Havana St storm drain hydrology, potentially reducing the surface flow that makes it into this storm drain. Upon the completion of the Expo Park project, this treatment drain alternative should be reanalyzed as the Havana St Outfall may have increased capacity to accept stormwater from the Canal.

A. Configuration

The treatment drain conceptual configuration is a Type C inlet set at the 100-year WSEL, with two water quality outlets connected on the up and down Canal sides of the inlet. The water quality outlet structures provide stormwater treatment in all storm events for the volume of water at or below the 100-year WSEL, while the Type C inlet provides an efficient drain for storm events that exceed the 100-year return interval. All stormwater that makes it into the treatment drain flows into downstream storm drain system, reduces the effects of urban flood risk due to spill flows out of the Canal. For a conceptual design drawing and general configuration of the treatment drain concept see **Appendix G**.

B. Water Quality Benefit

Given the flat slope of the Canal, associated low velocities and significant amount of attenuation of stormwater in the Canal, treatment drains provide an opportunity to significantly improve the water quality of the stormwater that is in the Canal and ultimately passes through these drains. While stormwater in the Canal currently meets the definition of Waters of the State and according to the permitting language, water quality credit can be given either upstream or downstream of Waters of the State, this definition of where water quality credits can be gained is being petitioned to change by Arapahoe County and the HLC STAMP stakeholders. It is the goal of the HLC STAMP project team to change the definition of Waters of the State in the MS4 permit language such that in Canal water quality treatment counts toward MS4 water quality credits. More discussion on the water quality is found in **Chapter 9**.

7.5 Increase Capacity

The increased capacity mitigation alternative looked at increasing the conveyance capacity of the Canal at roadway crossings as in some locations the capacity was greatly reduced at a roadway crossing the Canal. By increasing the opening of the roadway crossing of the canal this would alleviate the reduced capacity to eliminate or improve adjacent spill flows. The cost of increasing the capacity of roadway crossing structures over the Canal is upwards of $1M, making this type of alternative by far the most expensive.

There are 2 capacity increase alternatives that were assessed for feasibility, both of which are for City and County of Denver. One of which was deemed feasible and results are included in the AGO map. City and County of Denver Alternative 13 was considered unfeasible due to the reasons listed below; the other alternative is described in more detail below.

- **City and County of Denver Mitigation Alternative 5 – Increase Capacity of I-25 Culvert Crossing**
  This alternative consists of increasing the culvert capacity that conveys HLC flows under I-25 and the light rail line. This alternative does reduce spill flows up Canal of the road crossing but does increase spill flows on the down Canal side of the culvert. Without additional mitigation efforts down Canal of the I-25 crossing this alternative is not recommended due to its cost and increased risk of Canal spill flows downstream of the alternative location.

- **City and County of Denver Mitigation Alternative 13 – Increase Capacity of S Monaco Pkwy Road Crossing**
  This alternative consists of increasing the roadway crossing capacity in the HLC under S Monaco Pkwy. This alternative was analyzed after noticing a significant reduction in Canal depth through this roadway crossing. It was anticipated that by increasing the conveyance area of this crossing structure, more water could make it through the S Monaco Pkwy structure, and this would alleviate some of the backwater conditions that spill into the neighborhood west of the I-25 crossing. However, while increasing the capacity of the S Monaco Pkwy crossing did normalize the depth through the structure, it did not have any effect on the spills out of the Canal near I-25. This, coupled with the high cost of increasing the size of this crossing, deemed this alternative as not recommended. Therefore, its results are not included in the AGO map.

A. Canal Channel

The width of the Canal channel cross section in many places is limited by development on either side of the channel. In places where there is capacity to increase the capacity of the Canal Channel, the cost typically outweighs the benefit.

B. Crossing Structures

Many of the roadways crossing the HLC have a reduced capacity when compared to the capacity of the adjacent Canal cross section. This causes backwater effects at the upstream face of these structures and can lead to significant spill flows at locations such as the I-25 and Potomac St road crossings. While increasing the size of these road crossings is an option, it is not the recommended approach due to the high cost of this type of alternative.

8.0 WATER QUALITY

8.1 Existing Water Quality

Due to the amount of storage within the HLC, there is significant stormwater that is treated through infiltration in the Canal's channel bottom and banks. Additionally, RESPEC's 2018 study proposed several water quality berms along the length of the Canal and few of them were constructed within the Denver service area of the Canal. While given the current determination of the Canal as Waters of the State and the definition of this determination in the MS4 permit language, both types of water quality treatment cannot grant any water quality credit since this treatment happens within the Canal's banks. However, there are also detention ponds upstream of the HLC at several locations along the Canal's alignment. If these ponds meet MS4 requirements – including the presence of a water quality outlet and appropriate drain time – they are eligible for water quality credits given the Canal's current determination and MS4 definitions.

8.2 Treatment Drains

As mentioned in **Section 7.3**, treatment drains offer the potential for significant stormwater quality treatment. Because the Canal is so flat, when stormwater enters the Canal, it spreads out in all directions, thus a treatment drain can treat stormwater from both up and down canal, this greatly increases the water quality capture volume in minor storms.

However, for the municipalities in which these facilities are constructed to receive water quality credits the definition of water quality in Waters of the State needs to be amended in the MS4 permit language. Currently water quality credits are only available for treatment that happens outside of a body of water that is considered Waters of the State. The owners of the Canal and the HLC STAMP project team are looking at changing the water quality definition for Waters of the State to include water quality credits that happen within a body of water that is considered Waters of the State.

8.3 Additional Water Quality Opportunities

Aside from the treatment drain alternatives, there are water quality opportunities for both the conveyance and bank manipulation alternatives. While the treatment drain alternative provides an opportunity for water quality treatment within the Canal banks, water quality associated with the conveyance and bank manipulation alternatives would provide this treatment outside of the Canal banks.

For the conveyance alternative, water quality opportunities take the form of extended detention basins or rain gardens between the Canal conveyance channel and the receiving water way. A great opportunity for this type of water quality is at the location of the City and County of Denver Mitigation Alternative 10 - Cherry Creek conveyance alternative. The area in which the Cherry Creek conveyance channels discharge into is owned by the High Line Canal Conservancy and is at the intersection of the Cherry Creek and HLC trail systems. This would be an ideal location for a water quality rain garden with a community education component and is a great example of the types of multi-benefit projects that are possible along the Canal corridor.

Similarly, for the bank manipulation alternatives, spillways could discharge into either a full spectrum detention pond or rain garden in an open space area. This would provide an opportunity for municipalities to obtain water quality credits and provide additional attenuation before stormwater enters receiving waters reducing the peak flow and potential for downstream erosion.

9.0 OPERATION AND MAINTENANCE

While the HLC STAMP's primary purpose is to provide analysis and recommendations on mitigating spill flows that pose urban flood risk along the Canal's corridor, a large part of stormwater within the Canal is day-to-day operations and maintenance. There is still need to plan for large storm events that have the potential to cause injury and damage; however, it is necessary to focus on everyday Canal operations for the long term success of the Canal as a stormwater amenity. As maintenance activities are performed along the Canal it would be useful to have a centralized database to track the maintenance through each of the service areas along the Canal. It is recommended that a data schema is developed for the collection of all maintenance data and that this data be publicly available through an online GIS database. Considering that the High Line Canal Conservancy manages the maintenance activities along the Canal, it is recommended that they act as the centralized entity to manage this database.

The Canal has both active and passive stormwater reaches and the associate operations and maintenance within the Canal vary greatly depending on this distinction. In an active stormwater reach, there are typically grandfathered stormwater point inflows and there is the presence or stormwater in the Canal in both minor and major storm events. In passive stormwater reaches there usually are not any point inflows into the Canal and there is usually an absence of stormwater in the channel except in major storm events. There is a centralized maintenance contract for municipalities along the Canal. This contract is a vehicle through which maintenance in both active and passive stormwater reaches can be completed.

Additionally, there are both resource maintenance costs and facilities maintenance costs associated with the overall maintenance costs along the Canal. Both costs are accommodated for in the cost estimate tables in **Section 9.5**, however it's important to note that as mitigation alternatives are constructed the costs for maintaining these facilities will increase.

9.1 Access

Most of the maintenance activities along the Canal can utilize the HLC regional trail for access. This includes tree assessment, mosquito abatement, noxious weed control, and minor debris removal (including a vacuum truck for removing debris from future treatment drain locations). However, for large debris removal and encampment cleanup maintenance activities access to the channel may be necessary.

As flood mitigation alternatives are constructed along the Canal, maintenance access should be considered and maintenance access paths to the Canal's main channel should be designed and constructed as part of the alternative.

9.2 Debris Collection

While debris removal remains a key part to routine maintenance along the Canal, this plan provides an opportunity to refine the major debris removal locations along the Canal. In large storm events debris is carried in the Canal to roadway crossing locations that cause a constriction of the Canal's cross section. Choosing these locations for major debris removal and limiting the frequency to once or twice a year could save municipalities along the Canal money.

9.3 Equipment Choice

Regular maintenance vehicles are appropriate for most maintenance activities along the Canal. Once treatment drains are constructed a vacuum truck will be needed to clear debris from the water quality outlets. For large debris removal and encampment cleanup a skid steer may be necessary to remove large debris from the Canal. Access points to the Canal should be strategically planned and constructed as alternatives are further considered.

9.4 Costs

The costs listed below are grouped by municipality and costs for both active and passive stormwater reaches are given where applicable. Note that these costs are in line with those listed in the HLC Natural Resource Management Plan (NRMP). The NRMP has additional information regarding noxious weed treatment and vegetation management.

A. City of Aurora

Active Stormwater Reaches

	Per Mile Per Year	Basis
Tree Risk Assessment	$150-$250	Assessment every 3-5 years
Tree Canopy Care	$7,700	Estimate based on removing/pruning all medium/low-priority trees over 5 years
Debris Removal	$7,400-$14,800	2-4 passes per year
Mosquito Abatement	$1,800	4 dunk applications
Noxious Weed Control	$4,400	2 applications/year
Encampment Cleanup	$1,350	Average cost to clean up one encampment
Other O&M	?	Other activities as needed
Total	**$22,800-$30,300**	

Table 4: City of Aurora Active Stormwater Reaches Maintenance Costs

Passive Stormwater Reaches

	Per Mile Per Year	Basis
Tree Risk Assessment	$150-$250	Assessment every 3-5 years
Tree Canopy Care	$7,700	Estimate based on removing/pruning all medium/low-priority trees over 5 years
Debris Removal	$0-$3,700	0-1 pass(es) per year
Mosquito Abatement	$0	0 dunk applications
Noxious Weed Control	$4,400	2 applications/year
Encampment Cleanup	$1,350	Average cost to clean up one encampment
Other O&M	?	Other activities as needed
Total	**$13,600-$17,400**	

Table 5: City of Aurora Passive Stormwater Reaches Maintenance Costs

B. City of Centennial

	Per Mile Per Year	Basis
Tree Risk Assessment	$500-$850	Assessment every 3-5 years
Tree Canopy Care	$9,000	Estimate based on removing/pruning all medium/low-priority trees over 5 years
Debris Removal	$7,400-$14,800	2-4 pass(es) per year
Mosquito Abatement	$1,800	4 dunk applications
Noxious Weed Control	$4,400	2 applications/year
Encampment Cleanup	$1,350	Average cost to clean up one encampment
Other O&M	?	Other activities as needed
Total	**$24,450-$32,200**	

Table 6: City of Centennial Maintenance Costs

C. City of Cherry Hills Village

	Per Mile Per Year	Basis
Tree Risk Assessment	$750-$1,300	Assessment every 3-5 years
Tree Canopy Care	$18,300	Estimate based on removing/pruning all medium/low-priority trees over 5 years
Debris Removal	$7,400-$14,800	0-1 pass(es) per year
Mosquito Abatement	$1,800	0 dunk applications
Noxious Weed Control	$4,400	2 applications/year
Encampment Cleanup	$1,350	Average cost to clean up one encampment
Other O&M	?	Other activities as needed
Total	**$34,000-$41,950**	

Table 7: City of Cherry Hills Village Maintenance Costs

D. City of Greenwood Village

	Per Mile Per Year	Basis
Tree Risk Assessment	$600-$1000	Assessment every 3-5 years
Tree Canopy Care	$15,200	Estimate based on removing/pruning all medium/low-priority trees over 5 years
Debris Removal	$7,400-$14,800	2-4 passes per year
Mosquito Abatement	$1,800	4 dunk applications
Noxious Weed Control	$4,400	2 applications/year
Encampment Cleanup	$1,350	Average cost to clean up one encampment
Other O&M	?	Other activities as needed
Total	**$30,750-$38,550**	

Table 8: City of Greenwood Village Maintenance Costs

E. City of Littleton

	Per Mile Per Year	Basis
Tree Risk Assessment	$700-$1200	Assessment every 3-5 years
Tree Canopy Care	$18,800	Estimate based on removing/pruning all medium/low-priority trees over 5 years
Debris Removal	$7,400-$14,800	2-4 passes per year
Mosquito Abatement	$1,800	4 dunk applications
Noxious Weed Control	$4,400	2 applications/year
Encampment Cleanup	$1,350	Average cost to clean up one encampment
Other O&M	?	Other activities as needed
Total	**$34,450-$42,350**	

Table 9: City of Littleton Maintenance Costs

F. Denver and Unincorporated Arapahoe Counties

Active Stormwater Reaches

	Per Mile Per Year	Basis
Tree Risk Assessment	$400-$700	Assessment every 3-5 years
Tree Canopy Care	$10,700	Estimate based on removing/pruning all medium/low-priority trees over 5 years
Debris Removal	$7,400-$14,800	2-4 passes per year
Mosquito Abatement	$1,800	4 dunk applications
Noxious Weed Control	$4,400	2 applications/year
Encampment Cleanup	$1,350	Average cost to clean up one encampment
Other O&M	?	Other activities as needed
Total	**$26,050-$33,750**	

Table 10: Denver and Unincorporated Arapahoe Counties Active Stormwater Reaches Maintenance Costs

Passive Stormwater Reaches

	Per Mile Per Year	Basis
Tree Risk Assessment	$400-$700	Assessment every 3-5 years
Tree Canopy Care	$10,700	Estimate based on removing/pruning all medium/low-priority trees over 5 years
Debris Removal	$0-$3,700	0-1 pass(es) per year
Mosquito Abatement	$0	0 dunk applications
Noxious Weed Control	$4,400	2 applications/year
Encampment Cleanup	$1,350	Average cost to clean up one encampment
Other O&M	?	Other activities as needed
Total	**$16,850-$20,850**	

Table 11: Denver and Unincorporated Arapahoe Counties Passive Stormwater Reaches Maintenance Costs

G. Douglas County

Active Stormwater Reaches

	Per Mile Per Year	Basis
Tree Risk Assessment	$450-$750	Assessment every 3-5 years
Tree Canopy Care	$7,900	Estimate based on removing/pruning all medium/low-priority trees over 5 years
Debris Removal	$7,400-$14,800	2-4 passes per year
Mosquito Abatement	$1,800	4 dunk applications
Noxious Weed Control	$4,400	2 applications/year
Encampment Cleanup	$1,350	Average cost to clean up one encampment
Other O&M	?	Other activities as needed
Total	**$23,300-$31,000**	

Table 12: Douglas County Active Stormwater Reaches Maintenance Costs

Passive Stormwater Reaches

	Per Mile Per Year	Basis
Tree Risk Assessment	$450-$750	Assessment every 3-5 years
Tree Canopy Care	$7,900	Estimate based on removing/pruning all medium/low-priority trees over 5 years
Debris Removal	$0-$3,700	0-1 pass(es) per year
Mosquito Abatement	$0	0 dunk applications
Noxious Weed Control	$4,400	2 applications/year
Encampment Cleanup	$1,350	Average cost to clean up one encampment
Other O&M	?	Other activities as needed
Total	**$14,100-$18,100**	

Table 13: Douglas County Passive Stormwater Reaches Maintenance Costs

10.0 CONCLUSION

10.1 Recommended Alternatives

All 23 alternatives are recommended, in order of their associated flood risk score. **Table 14** and **Table 15** found on the next two pages are organized by highest to lowest flood risk score, from top down, associated with each of these alternatives. **Table 14** focuses on the NFHL alternative and ranks each of the individual controlled release points along the Canal by their associated flood risk score. Similarly, **Table 15** provides the same information for the jurisdiction specific alternatives. Note that City and County of Denver Mitigation Alternative 5, is not recommended as a stand-alone alternative due to its high cost and poor performance. Municipalities may want to prioritize which alternatives to first consider using different metrics than their associated flood risk. As such, both tables provide data for each alternative including type, planning level cost, existing conditions comparison, total peak flow mitigated, total spill volume mitigated, total number of spills eliminated, and total flood risk score value. The NFHL alternative table also includes the project location (intersecting stream) in which the controlled release points are proposed. These tables, in conjunction with the AGO map, are intended to be tools for agencies along the Canal to use to make more informed decisions on if and what to construct along the Canal to enhance its benefit as a stormwater amenity.

Aside from utilizing the tables below to determine alternative priority there are several alternatives that are recommended to consider and construct first. While wastegates along the Canal are chained and locked in the open position, it is recommended that these wastegates are removed or welded in the open position. Permanently opening these gates will formalize the HLC usage for stormwater flow only. This effort is expected to cost about $50,000 for the entire length of the Canal.

The next alternative recommended to consider early on is independent of the HLC STAMP effort. This is a spillway that conveys flow from the HLC channel to the Blackmer Gulch Tributary in the Cherry Hills Village segment of the HLC trail. This project will serve as a pilot project to stormwater mitigation alternatives for the HLC STAMP effort. This spillway is expected to cost about $250,000. The conceptual design of this spillway can be found in **Appendix G**.

Finally, City and County of Denver Mitigation Alternative 8 – Goldsmith Gulch Treatment Drain is recommended to construct first. While this alternative does not eliminate any urban flood risk it does provide significant water quality benefit within the Canal, and it is not dependent on the construction of any proposed Denver SDMP storm drains. The Goldsmith Gulch treatment drain is recommended because it is a good test case in which lessons learned can be carried forward to construct the more impactful City and County of Denver Alternative 4 – Eudora Outfall Treatment Drain in the future. The Goldsmith Gulch treatment drain is expected to cost about $300,000.

Capacity increase alternatives are not recommended to construct first due to their high cost and increase in urban flood risk in adjacent locations. However, these alternatives may have less adverse impact following the implementation of other mitigation alternatives and should be considered as crossing structure improvements are proposed.

10.2 Infrastructure Adaptation

Welding open the wastegates along the Canal is the prime example of infrastructure adaptation, transitioning the use of the HLC from irrigation flows to stormwater conveyance. Considering the regional trail that travels along the HLC, this was originally used by ditch riders to open and close service gates and maintain the HLC along the corridor. Although maintenance crews still utilize the trail, most regional trail users are now recreational users. Taking advantage of the unique geometry of the Canal and using downstream open space is one of the ways we can reuse the geography of the Canal to build resilient communities. As mentioned earlier in this report, the siphons that cross major drainageways along the Canal can be reused to run dry utility lines through them, providing a benefit to both leasing utility companies and the municipalities they pass through as the owner.

10.3 Stormwater Benefit

Since its construction the Canal has inadvertently been used to convey stormwater. As irrigation water users along the Canal become obsolete this ancillary use case of the HLC becomes its primary usage. By mitigating the existing flood risk adjacent to the Canal, municipalities and project partners along the Canal can begin to realize the multi-use benefit that comes with utilizing the HLC as a stormwater amenity. As the definition of Waters of the State becomes clarified in the MS4 permit language, municipalities can begin to receive water quality credit for in-Canal stormwater treatment. With this clarification, ecologists can continue to look at the HLC corridor as an ecological system and make informed decisions about planting and maintenance along the Canal. Regional parks can be coupled with water quality amenities, and historical preservation with community education can be implemented. By transitioning the lens in which the Canal operates, from irrigation to a stormwater amenity, local communities and the individuals that live therewithin will benefit.

Table 14: NFHL Alternative Risk Score Prioritization

NFHL Alternative Project Location	Project Type	Approx. Cost	Existing Conditions Total Peak Spill Flow (cfs)	Proposed Conditions Total Peak Spill Flow (cfs)	Total Peak Spill Flow Mitigated (cfs)	Existing Conditions Total Volume Spilled (ac-ft)	Proposed Conditions Total Volume Spilled (ac-ft)	Total Spill Volume Mitigated (ac-ft)	Number of Spills Eliminated	Total Flood Risk Score
Littles Creek	Bank Manipulation	$250,000	1297	257	1040	132.2	10.3	121.9	5	206
Marcy Gulch[1]	Bank Manipulation	$250,000	--	--	--	--	--	--	--	98
Big Dry Creek	Conveyance	$500,000	281	203	78	22	8.3	13.7	2	73
Quincy Gulch	Bank Manipulation	$250,000	699	0	699	95.7	0	95.7	10	36
Cherry Creek[1]	Conveyance	$500,000	--	--	--	--	--	--	--	32
East Toll Gate Creek, Granby Ditch, Sand Creek[1,2]	Conveyance/Bank Manipulation	$1,250,000	--	--	--	--	--	--	--	29
Little Dry Creek	Bank Manipulation	$500,000	177	152	25	120	62.2	57.8	0	28
Greenwood Gulch	Bank Manipulation	$250,000	500	0	500	29.2	0	29.2	7	21
West Toll Gate Creek	Conveyance	$500,000	163	118	45	4.3	3.4	0.9	0	20
Lee Gulch[1]	Conveyance	$500,000	--	--	--	--	--	--	--	10
East Willow Creek	Conveyance	$500,000	1217	558	659	297	48	249	6	9.2
Dad Clark Gulch	Conveyance	$500,000	75	35	40	2.6	1.1	1.5	1	8.7
Little Willow Creek	Bank Manipulation	$250,000	704	429	275	193.8	119.2	74.6	0	6.2
Goldsmith Gulch[1]	Conveyance	$500,000	--	--	--	--	--	--	--	6.0
Westerly Creek[1]	Bank Manipulation	$250,000	--	--	--	--	--	--	--	5.1
Blackmer Gulch	Conveyance	$500,000	589	0	589	45	0	45	4	3.3
Plum Creek	Conveyance	$500,000	28	18	10	5.8	1.5	4.3	1	2.7
Willow Creek	Bank Manipulation	$250,000	3140	0	3140	360.9	0	360.9	3	2.3
Frist Creek	Conveyance	$500,000	2	0	2	0.5	0	0.5	1	1.0

[1] While these alternatives provide controlled release points to NFHL drainages and water quality opportunity, they do not mitigate any adjacent spills that pose an urban flood risk

[2] The conveyance / bank manipulation alternatives proposed at East Toll Gate Creek, Granby Ditch, and Sand Creek all fall within the same Michael Baker Risk Score project polygon, thus are grouped together in this table

Table 15: Jurisdiction Specific Alternative Risk Score Prioritization

Jurisdiction Specific Mitigation Alternative Name	Project Type	Approx. Cost	Existing Conditions Total Peak Spill Flow (cfs)	Proposed Conditions Total Peak Spill Flow (cfs)	Total Peak Spill Flow Mitigated (cfs)	Existing Conditions Total Volume Spilled (ac-ft)	Proposed Conditions Total Volume Spilled (ac-ft)	Total Spill Volume Mitigated (ac-ft)	Number of Spills Eliminated	Total Flood Risk Score
Arapahoe County Mitigation Alternative 3	Bank Manipulation	$400,000	1297	8	1289	132	0.2	131.8	7	206
City and County of Denver Mitigation Alternative 5[2]	Increase Capacity	$2,500,000	930	946	-16	89.2	94.2	-5	0	193
City and County of Denver Mitigation Alternative 4	Treatment Drain	$300,000	1038	105	933	94.1	4	5	5	190
City and County of Denver Mitigation Alternative 1	Bank Manipulation	$250,000	1038	728	310	94.1	42.7	51.4	3	190
City and County of Denver Mitigation Alternative 2	Treatment Drain	$300,000	858	431	427	78.1	28.7	49.4	2	190
City and County of Denver Mitigation Alternative 3	Treatment Drain	$300,000	858	659	199	78.1	41.1	37	1	190
City and County of Denver Mitigation Alternative 12	Bank Manipulation	$100,000	528	459	69	65.1	57.7	7.4	1	154
Arapahoe County Mitigation Alternative 5	Bank Manipulation	$350,000	158	23	135	13.1	4.3	8.8	2	73
Arapahoe County Mitigation Alternative 6	Conveyance	$500,000	281	186	95	22	6.8	15.2	2	73
Arapahoe County Mitigation Alternative 4	Treatment Drain	$300,000	58	47	11	2.2	1.6	0.6	0	47
Arapahoe County Mitigation Alternative 13[1]	Conveyance	$500,000	--	--	--	--	--	--	--	42
Arapahoe County Mitigation Alternative 12	Treatment drain	$300,000	968	338	630	49.1	23.2	25.9	0	33
Arapahoe County Mitigation Alternative 9[1]	Treatment drain	$300,000	--	--	--	--	--	--	--	32
City and County of Denver Mitigation Alternative 10[1]	Conveyance	$500,000	--	--	--	--	--	--	--	32
Arapahoe County Mitigation Alternative 8	Bank Manipulation	$250,000	489	0	489	28.8	0	28.8	6	21
Arapahoe County Mitigation Alternative 7[1]	Conveyance	$500,000	--	--	--	--	--	--	--	17
Arapahoe County Mitigation Alternative 1[1]	Conveyance	$500,000	--	--	--	--	--	--	--	10
Arapahoe County Mitigation Alternative 2[1]	Conveyance	$500,000	--	--	--	--	--	--	--	10
City and County of Denver Mitigation Alternative 6[1]	Treatment Drain	$300,000	--	--	--	--	--	--	--	6.0
City and County of Denver Mitigation Alternative 8[1]	Treatment Drain	$300,000	--	--	--	--	--	--	--	6.0
Arapahoe County Mitigation Alternative 11[1]	Treatment drain	$300,000	--	--	--	--	--	--	--	5.1
City and County of Denver Mitigation Alternative 11	Treatment Drain	$300,000	50	0	50	14.5	0	14.5	1	4.9

[1] While these alternatives provide controlled release points and water quality opportunity, they do not mitigate any adjacent spills that pose an urban flood risk

[2] The capacity increase of the I-25 culvert has been analyzed hydraulically; however, is not recommended as a stand alone solution due to its high cost and lack of flood mitigation

REFERENCES

- *Cover Photo, High Line Canal Trail - Holly Hills,* High Line Canal Conservancy, May 2023
- *Denver High Line Canal (Dad Clark Gulch to Mississippi Avenue) Major Drainageway Planning Phase B Preliminary Design*, WRC Engineering, Inc., June 2004.
- *Highline Canal Feasibility Study,* RESPEC Consulting and Services, August 2014.
- *High Line Canal Stormwater and Operations Master Plan,* RESPEC Consulting and Services, October 2018
- *Policy Regarding Drainage of Storm Water into Denver Water's Ditches,* Denver Water, May 1999
- *High Line Canal Natural Resource Management Plan,* High Line Canal Conservancy; Biohabitats; Dig Studio, DRAFT June 2018
- *HLC STAMP Technical modeling Memorandum,* ICON Engineering Inc., April 2025
- HLC STAMP ArcGIS Online Experience Builder URL (referenced as AGO map throughout the report): https://experience.arcgis.com/experience/7e3a250b634546e28de9a75a73221202, ICON Engineering, Inc., January 2026

P:\P\24-033_HLC_STAMP\10_Reports\07_HLC STAMP\2026-01-xx_HLC_STAMP_DRAFT.docx

APPENDIX A: REGULATORY HYDROLOGY ASSESSMENT

REGULATORY HYDROLOGIC ASSESSMENT MEMORANDUM

TO: HLC STAMP Project Team
FROM: ICON Engineering, Inc
RE: Regulatory Hydrologic Assessment Memorandum
DATE: November 26th, 2025

Background and Purpose

The High Line Canal (HLC) was constructed nearly 100-years before the creation of the Federal Emergency Management Agency (FEMA). Thus, when Northern Colorado Irrigation Company began construction on the Canal, the watershed boundaries that the Canal crosses were not considered. The Canal geometry affects the hydrology of each of the drainage basins that the canal intersects. To better understand the intricacies of this hydrology, see the definitions below that will be referenced throughout this memorandum. It's important to note that this memorandum will only consider the 1%-Annual-Chance storm, but the general hydrologic concepts presented here apply to other storm events as well.

Definitions (Listed in Order of Appearance)

Canal Basins – A natural drainage basin that is intersected by the High Line Canal

Canal Hydrology – Hydrology developed for use in the HLC Stormwater Transition and Management Plan (STAMP)

Regulatory Hydrology – Hydrology developed for FEMA's national hydrology dataset and regulatory floodplains

Regulatory Floodplain – The flooding extents of the 1%-Annual-Chance storm flows (FEMA Zone AE)

Redirected Flow – Flow that is accounted for in both and treated differently between the Canal Hydrology and Regulatory Hydrology

Trans Basin Flow – Flow that travels, via the HLC, from one Canal Basin to the adjacent Canal Basin. This includes both **Inflow –** Flow from previous Canal Basin to Canal Basin of interest and **Outflow –** Flow from Canal Basin of interest to next Canal Basin

Regulatory Floodplain Flow at Canal – 1%-Annual-Chance storm flows in drainageways at their intersection with the HLC obtained from FEMA FIS reports, Flood Hazard Area Delineation Studies or Outfall Systems Plans.

When it rains within any given Canal Basin, runoff is produced. All the rainfall that falls upstream of the Canal either flows into the Canal or into a Regulatory Floodplain. The Canal Hydrology reflects real-world conditions in that there are direct inflows into both the Canal and the Regulatory Floodplain in any Canal Basin. Whereas Regulatory Hydrology assumes all the runoff flows unimpeded by the Canal to the Regulatory Floodplain. This difference in hydrology causes Redirected Flow within Canal Basins but does not duplicate or double count flow.

This Redirected Flow has a couple of differences between Canal and Regulatory Hydrology worth noting:

1) The Canal Hydrology consists not only direct inflows into the canal but also, when the Canal exceeds its capacity, spill flows out of the downstream side of the Canal. These spill flows are unique to Canal Hydrology given that the Regulatory Hydrology for Canal Basins ignores the Canal geometry impacts to runoff.

2) The Canal Hydrology conveys stormwater flow down Canal. The stormwater flow within the Canal can have three outcomes: 1) Spill out of the Canal, 2) Spill into the Regulatory Floodplain the Canal intersects, 3) Continue down Canal potentially becoming Trans Basin Flow. Again, this Canal flow is unique to Canal Hydrology given that the Regulatory Hydrology for Canal Basins ignores Canal geometry.

See **Figure 1** attached for a visual representation of the hydrologic impacts of the HLC in the example Canal Basin of Dad Clark Gulch.

The purpose of this memorandum is to assess the effects of the Redirected Flow between Canal and Regulatory Hydrology both in existing and the National Flood Hazard Layer (NFHL) alternative proposed conditions.

Hydrologic Assessment

There are 31 Canal Basins from the Canal's headwaters in Waterton Canyon to its final discharge into First Creek approximately 65 miles downstream of the Canal's origin. To better understand the hydrologic impact the canal has on the Canal Basins, two comparison tables have been developed and are attached to this report. These tables show and compare Regulatory Floodplain Flow at Canal, Total Direct Runoff to Canal, Spills out of Canal, Trans Basin Inflow, and Trans Basin Outflow. In most cases the Regulatory Floodplain Flow at Canal comes from FEMA Flood Insurance Study reports. However, for Spring Gulch, Marcy Gulch and Dad Clark Gulch the effective floodplain information comes from Flood Hazard Area Delineation (FHAD) studies, and for Irondale Gulch from an Outfall Systems Plan (OSP). Note that 7 of the 31 Canal Basins do not have a Regulatory Floodplain. A more detail description of each table and their comparison is below.

Table 1 shows a comparison of the total direct inflow into the canal versus the total spill flows out of the Canal for each Canal Basin. This table illustrates that the Canal receives a significant amount of runoff directly into the Canal channel. In some Canal Basins the total direct inflow into the canal exceeds the Regulatory Floodplain Flow at the Canal intersection. This is because the regulatory floodplain typically intersects the Canal in the middle of the Canal Basin and there are significant direct inflows into the Canal both up and down Canal of the regulatory floodplain crossing that for regulatory flow determination are considered contributory to the floodplain well downstream of the Canal intersection. Additionally, in this table you will find the number of spills out of the Canal for each Canal Basin and the associated flow spilling out of the canal. It's important to note that both the Total Direct Runoff to Canal and Spills out of Canal flow values are summations of the peak flows for all inflows and spill flows respectively within that Canal Basin. Given the typically low slope, low flow velocities, and high attenuation characteristics of the Canal channel these values do not accurately represent the complexity of the flow in and out of the canal. However, they do give a sense of magnitude, showing that a significant amount of water moves in and out of the canal within the Canal Basins.

Table 2 compares Trans Basin Inflow to Trans Basin Outflow, the difference between those values is then compared to Regulatory Floodplain Flow at Canal. For those Canal Basins without a Regulatory Floodplain no comparison could be made. While some basins have very little discrepancy between Trans Basin Inflow and Outflow, no Canal Basin shows the same amount of flow entering and leaving. Thus, there are two possible flow scenarios to consider for any basin:

1) The Trans Basin Outflow (➡) exceeds the Trans Basin Inflow (➡) for the basin; the additional flow continues to the next basin down Canal. (negative basin flow difference value)

2) The Trans Basin Inflow (➡) exceeds the Trans Basin Outflow (➡) for the basin; the additional flow is added to the Regulatory Floodplain flow within the basin. (positive basin flow difference value)

If the Trans Basin Inflow or Outflow difference is 10% or less of the Regulatory Floodplain flow, it is considered a non-issue in that it does not significantly change the regulatory flow in that basin. Cases where the basin flow difference exceeds 10% of the Regulatory Floodplain flow need to be assessed individually. Cases where the difference exceeds 10% but the additional flow is carried down Canal (flow scenario 1), do not adversely impact the Regulatory Floodplain within that basin. However, cases where the difference exceeds 10% and additional flow discharges into the Regulatory Floodplain (flow scenario 2) do have a negative impact on the Regulatory Hydrology within that basin.

Findings

Existing Conditions (1%-Annual-Chance)

As noted in the **Hydrologic Assessment** section of this memorandum, the summation of peak Canal inflows and spill flows shown in **Table 1** do not fully capture the flow conditions within each Canal Basin. However, it is important to note that in existing conditions there are four Canal Basins (Marcy Gulch, Little Dry Creek, Irondale Gulch, and First Creek) in which the summation of spills out of Canal exceeds total direct runoff to Canal. This implies that within these Canal Basins the total direct runoff to Canal does not increase the Trans Basin Outflow into the next down Canal basin.

In existing conditions, there are five Canal Basins in which the difference in Canal flow exceeds 10% of the Regulatory Floodplain flow for the respective basins. See **Table A** below for a comparison of these five Canal Basins. Of these, only two basins (Quincy and Irondale Gulch) meet flow scenario 2 outlined above and negatively impact the Regulatory Floodplain flow within the Canal Basin. Full existing conditions values for all 31 drainage basins include in **Table 2**.

Basin Names	Regulatory Floodplain Flow at Canal (cfs)	Trans Basin Inflow (cfs)	Trans Basin Outflow (cfs)	Basin Flow Difference (Inflow - Outflow) (cfs)	Basin Flow Difference Versus Regulatory Flow (%)
Little Willow Creek	1881	162	669	-507	27
Dad Clark Gulch	190	103	318	-215	113
Slaughterhouse Gulch	1450	161	318	-157	11
Quincy Gulch	445	236	152	84	19
Irondale Gulch	260	55	20	35	13

Table A: *Regulatory Flow vs Existing Conditions Canal Flow (> 10% Difference) Comparison*

NFHL Alternative Proposed Conditions (1%-Annual-Chance)

In the conceptual NFHL alternative proposed conditions STAMP modeling, flow was conveyed from the canal to all NFHL (National Flood Hazard Layer) drainageways along the canal. There are three Canal Basins (Little Willow Creek, Willow Creek, and Blackmer Gulch) in addition to the four Canal Basins listed in **Existing Conditions** above in which the summation of spills out of Canal exceeds total direct runoff to Canal. This implies that in this alternative, there are seven Canal Basins that the total direct runoff to Canal does not increase the Trans Basin Outflow into the next down Canal basin. Also, the number of spill flows for each Canal Basin is either maintained or reduced from existing to NFHL Alternative proposed conditions for 28 of the 31 Canal Basins. The three Canal Basins that see increases in number of spill flows between existing and proposed conditions are Plum Creek, Toll Gate Creek, and Westerly Creek. For Plum Creek and Toll Gate Creek this is because stormwater conveyance from the Canal occurs on both sides of the Regulatory Floodplain, adding a spill point on the down Canal side of the Regulatory Floodplain. For Westerly Creek there is an extra spill point at the intersection of Westerly Creek and the HLC where in existing conditions, there is no such connection.

In this alternative modeling, there are three Canal Basins in which the difference in Canal flow exceeds 10% of the Regulatory Floodplain flow for the respective basins. See **Table B** below for a comparison of these three Canal Basins. Of these, only one basin (Irondale Gulch) meets flow scenario 2 outlined above and negatively impacts the Regulatory Floodplain flow within the basin. Full NFHL alternative proposed conditions values for all 31 drainage basins are included in **Table 2**.

Basin Names	Regulatory Floodplain Flow at Canal (cfs)	Trans Basin Inflow (cfs)	Trans Basin Outflow (cfs)	Basin Flow Difference (Inflow - Outflow) (cfs)	Basin Flow Difference Versus Regulatory Flow (%)
Dad Clark Gulch	190	99	291	-192	101
Slaughterhouse Gulch	1450	5	320	-315	22
Irondale Gulch	260	52	15	37	14

Table B: *Regulatory Flow vs. NFHL Alternative Proposed Conditions Canal Flow (> 10% Difference) Comparison*

Conclusion

The hydrologic assessment presented within this memorandum demonstrates that there are existing adverse impacts caused by the unique hydrologic conditions of the HLC. Not only are there 80 existing conditions spill points, 58 of which happen outside of Regulatory Floodplain, there are also adverse impacts to the Regulatory Floodplain caused by Trans Basin Flow at 2 of the 24 Regulatory Floodplains crossed by the Canal. It is important to understand that these impacts are an existing condition and have been present since the construction of the HLC in 1883. However, in general these negative impacts do not cause consistent risk to downstream property due to the infrequency of storms equal to or greater than the 1%-Annual-Chance frequency. Additionally, a large majority of the canal has 1-foot or more of freeboard and although the STAMP modeling shows 58 spills outside of the Regulatory Floodplain along the banks of the canal, this is an anomaly of behavior in the 100-year storm flows through the Canal. These spills and Trans Basin Flows are a baseline condition of the High Line Canal, and the STAMP proposes alternatives to help mitigate the risk posed by this baseline condition.

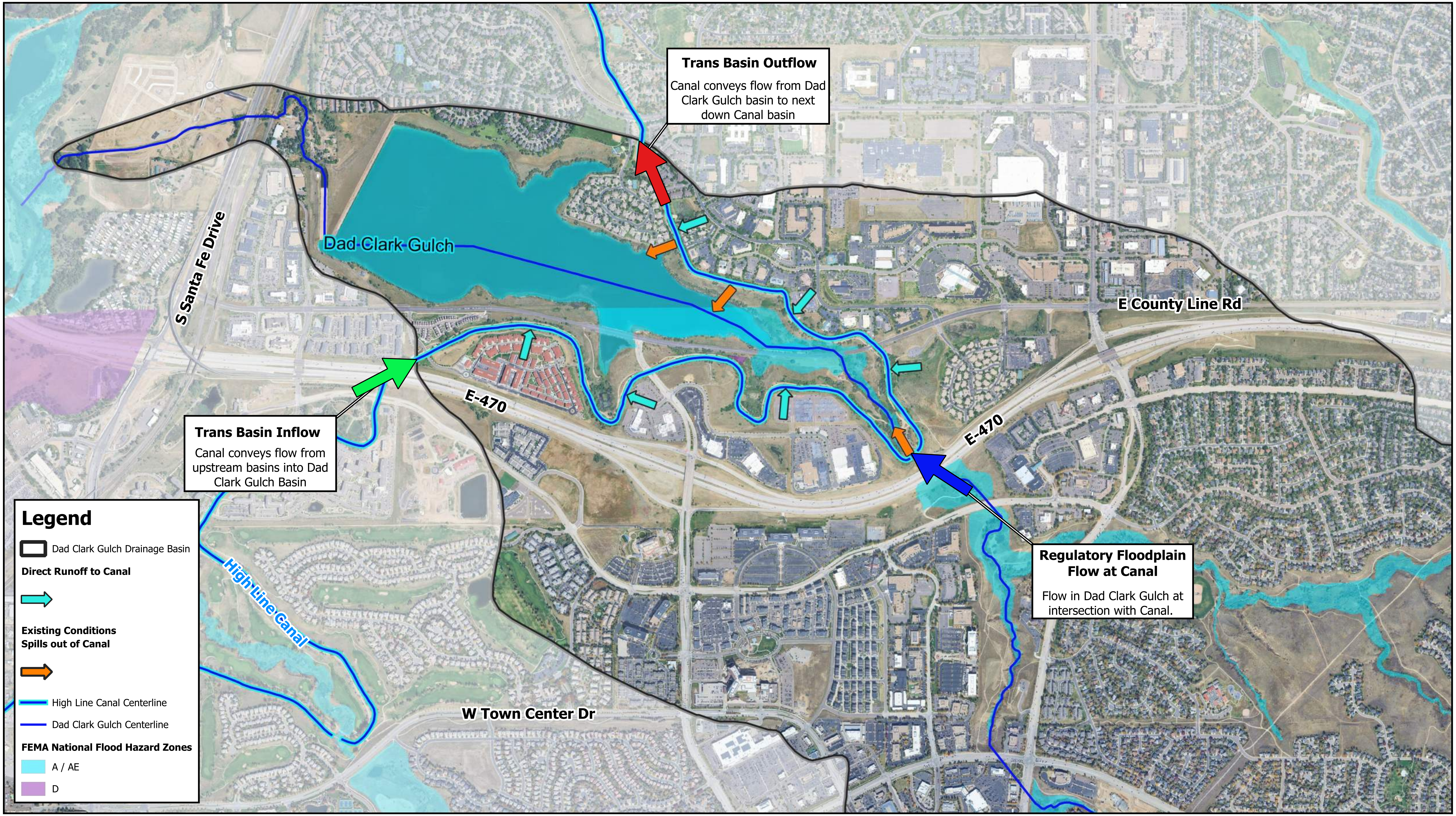
The NFHL alternative, providing conveyance to Regulatory Floodplains, not only reduces the number of spill flows that happen outside of the Regulatory Floodplain, from 58 to 23, but can also help reduce the amount of adverse impact caused by trans basin flow. Trans Basin Flow that exceeds 10% of the total regulatory flow value, is added to only one of the 24 Regulatory Floodplains in the NFHL alternative proposed condition. It is important to note that while there is a negative impact to Irondale Gulch regulatory floodplain caused by trans basin canal flow, this floodplain is from a 2011 OSP and not included in FEMA NFHL data. This memorandum focuses only on the comparison between existing conditions and the NFHL alternative proposed conditions, the STAMP proposes more than 20 alternatives that will help mitigate negative impacts from spills and Trans Basin Flow. As future studies are done in Canal Basins, Canal hydrology should be considered. As alternatives proposed in the STAMP are further considered, their individual impact on Regulatory Floodplain flows should be assessed. Also, if any of these alternatives cause notable changes to the Canal flow, the existing HLC conditions and the impacts to Regulatory Hydrology should be updated.

Note that to prevent Trans Basin Flow the Canal could be dammed at basin divides. For flow to be retained in each basin it would be best practice to regrade the portion of the Canal down Canal of the Regulatory Floodplain such that the stormwater flows in the Canal can make it back up Canal to the stream. Based on canal depth and length from Regulatory Floodplain, the regrading of the down Canal portion of the Canal may prove infeasible. The extensive amount of earthwork required and associated high cost of this type of construction along the Canal limits the feasibility of this approach. Another option would be to pipe the Canal flow at Canal Basin boundaries into downstream storm drain systems. By virtue of basin divides being along the high points of topography, there is a general lack of storm drain infrastructure at these locations which would make this option difficult and costly. It is recommended that the priority in utilizing the Canal as a stormwater amenity is to mitigate urban flood risk. As these mitigation projects are advanced the design team should ensure that any given project does not significantly increase the Regulatory Hydrology in any Canal Basin.

Attachments

- **Figure 1:** Existing Conditions Hydrologic Impacts of the High Line Canal Example Basin - Dad Clark Gulch
- **Table 1:** 1%-Annual-Chance Total Direct Runoff to Canal vs Spills out of Canal
- **Table 2:** Regulatory Floodplain Flow vs. Canal Flow for Basins Intersected by the High Line Canal

END OF MEMORANDUM



ICON ENGINEERING

High Line Canal Stormwater Transistion and Management Plan - Hydrologic Assessment

Figure 1: Existing Conditions Hydrologic Impacts of the High Line Canal Example Basin - Dad Clark Gulch

MHFD MILE HIGH FLOOD DISTRICT

Table 1: 1%-Annual-Chance Total Direct Runoff to Canal vs Spills out of Canal

Drainage Basins (in order of Canal intersection)	Total Direct Runoff to Canal	Existing Conditions			NFHL Alternative Proposed Conditions		
		Spills out of Canal		Total Direct Runoff to Less Spills out of Canal	Spills out of Canal		Total Direct Runoff to Less Spills out of Canal
	(cfs)	#	(cfs)	(cfs)	#	(cfs)	(cfs)
Arrowhead Gulch[1]	0	0	0	0	0	0	0
Little Willow Creek	1399	2	704	695	2	1442	-43
Willow Creek	4666	5	4339	327	2	4711	-45
DFA 0069[1]	1970	9	974	996	2	306	1664
Plum Creek	892	2	354	538	3	455	437
Spring Gulch[2]	210	0	0	210	0	0	210
DFA 0068[1]	83	0	0	83	0	0	83
Marcy Gulch[2]	179	1	277	-98	1	230	-51
DFA 0068[1]	346	0	0	346	0	0	346
Dad Clark Gulch[2]	2073	3	699	1374	2	770	1303
DFA 0068[1]	458	1	45	413	1	27	431
Lee Gulch	376	1	171	205	1	325	51
Little's Creek	1841	7	1287	554	2	250	1591
Slaughterhouse Gulch[3]	829	1	10	819	1	7	822
Big Dry Creek	3965	7	2029	1936	5	2107	1858
Little Dry Creek	1282	3	1375	-93	3	1634	-352
Greenwood Gulch	3040	8	2394	646	1	1276	1764
Blackmer Gulch	907	5	774	133	2	1004	-97
Quincy Gulch	937	7	674	263	1	589	348
Harvard Gulch[3]	2144	10	1067	1077	7	1028	1116
Interstate 25 Drainage[1]	18	0	0	18	0	0	18
Goldsmith Gulch	341	0	0	341	1	45	296
Cherry Creek	741	1	272	469	1	139	602
Park Hill Drainage[1]	54	0	0	54	0	0	54
Westerly Creek	1014	1	50	964	2	250	764
Toll Gate Creek	1110	2	968	142	3	326	784
Granby Ditch	85	0	0	85	1	52	33
Sable Ditch[3]	96	0	0	96	0	0	96
Sand Creek	349	1	147	202	1	68	281
Irondale Gulch[4]	13	1	17	-4	1	16	-3
First Creek	8	2	19	-11	1	15	-7
Total:		80	spills		47	spills	
Total Outside of Regulatory Floodplain:		58	spills		23	spills	

[1] No regulatory floodplain for basin

[2] No FIS flows found at Canal intersection due to Zone A floodplain, regulatory floodplain flows taken from FHAD

[3] NFHL floodplain does not intersect canal, most upstream flow from FIS used as flow at Canal intersection

[4] No FIS flows found at Canal intersection, regulatory floodplain flows come from OSP

Table 2: Regulatory (1%-Annual-Chance) Floodplain Flow vs. Canal Flow for Basins Intersected by the High Line Canal

Drainage Basins (in order of Canal intersection)	Regulatory Floodplain Flow at Canal (cfs)	Existing Conditions: Trans Basin Inflow (cfs)	Existing Conditions: Trans Basin Outflow (cfs)	Existing Conditions: Basin Flow Difference (Inflow - Outflow) (cfs)	Existing Conditions: Basin Flow Difference Versus Regulatory Flow (%)	NFHL Alternative Proposed Conditions: Trans Basin Inflow (cfs)	NFHL Alternative Proposed Conditions: Trans Basin Outflow (cfs)	NFHL Alternative Proposed Conditions: Basin Flow Difference (Inflow - Outflow) (cfs)	NFHL Alternative Proposed Conditions: Basin Flow Difference Versus Regulatory Flow (%)
Arrowhead Gulch[1]	--	150	162	-12	--	192	191	1	--
Little Willow Creek	1881	162	669	-507	-27	191	3	188	10
Willow Creek	5071	669	705	-36	-1	3	6	-3	0
DFA 0069[1]	--	705	397	308	--	6	394	-388	--
Plum Creek	38710	397	64	333	1	394	61	333	1
Spring Gulch[2]	2465	64	226	-162	-7	61	214	-153	-6
DFA 0068[1]	--	226	228	-2	--	214	218	-4	--
Marcy Gulch[2]	2822	228	326	-98	-3	218	243	-25	-1
DFA 0068[1]	--	326	103	223	--	243	99	144	--
Dad Clark Gulch[2]	190	103	318	-215	-113	99	291	-192	-101
DFA 0068[1]	--	318	323	-5	--	291	318	-27	--
Lee Gulch	2900	323	94	229	8	318	58	260	9
Little's Creek	838	94	161	-67	-8	58	5	53	6
Slaughterhouse Gulch[3]	1450	161	318	-157	-11	5	320	-315	-22
Big Dry Creek	4247	318	226	92	2	320	223	97	2
Little Dry Creek	2673	226	109	117	4	223	74	149	6
Greenwood Gulch	2450	109	240	-131	-5	74	44	30	1
Blackmer Gulch	540	240	236	4	1	44	18	26	5
Quincy Gulch	445	236	152	84	19	18	2	16	4
Harvard Gulch[3]	3250	152	53	99	3	2	47	-45	-1
Interstate 25 Drainage[1]	--	53	41	12	--	47	40	7	--
Goldsmith Gulch	1760	41	47	-6	0	40	33	7	0
Cherry Creek	7000	47	24	23	0	33	24	9	0
Park Hill Drainage[1]	--	24	30	-6	--	24	30	-6	--
Westerly Creek	1650	30	110	-80	-5	30	62	-32	-2
Toll Gate Creek	21198	110	29	81	0	62	29	33	0
Granby Ditch	411	29	46	-17	-4	29	25	4	1
Sable Ditch[3]	638	46	48	-2	0	25	32	-7	-1
Sand Creek	19312	48	55	-7	0	32	52	-20	0
Irondale Gulch[4]	260	55	20	35	13	52	15	37	14
First Creek	4000	20	0	20	1	15	0	15	0

[1] No regulatory floodplain for basin

[2] No FIS flows found at Canal intersection due to Zone A floodplain, regulatory floodplain flows taken from FHAD

[3] NFHL floodplain does not intersect canal, most upstream flow from FIS used as flow at Canal intersection

[4] No FIS flows found at Canal intersection, regulatory floodplain flows come from OSP

APPENDIX B: VEGETATION AND DEBRIS MANAGEMENT

VEGETATION AND DEBRIS MANAGEMENT MEMORANDUM

TO: HLC STAMP Project Team
FROM: ICON Engineering, Inc.
RE: Vegetation and Debris Management Memorandum
DATE: November 21st, 2025

Background and Purpose

The vegetation in and around along the High Line Canal (HLC) is essential to ecological health and provides shade and enhances the Canal's aesthetic. As trees age and die along the Canal corridor, they need to be replaced with new, healthy trees that will provide these benefits for years to come. Additionally, there are portions of the Canal that lack sufficient vegetation and provide opportunity for this benefit. Aside from planting new vegetation, a large part of vegetation management is maintenance. This maintenance includes debris removal from the Canal's channel and banks. This debris includes small and large woody debris, leaf litter, and trash. Two questions arose during the HLC Stormwater Transition and Management Plan's (STAMP) coordination meetings that this memorandum will address. The first is related to the effect of adding additional vegetation along the High Line Canal, and the second related to the effect that unremoved debris may have on stormwater conveyance through the canal. The purpose of this memorandum is to assess these effects via two dimensional (2D) hydraulic modeling.

Hydraulics

To assess the hydraulic impact of increased vegetation and unremoved debris within the HLC, the manning's n-value or roughness coefficient of the channel would need to be increased. To run the analysis, and determine typical Canal behavior, ICON chose to increase the roughness coefficient for one of the seven 2D hydraulic models created for the STAMP effort. The model chosen covers the canal from the upstream limits of the Canal's crossing with S Broadway up-canal of Littles Creek to the downstream limits of the Canal's crossing with E Belleview Ave down-canal of Greenwood Gulch. This sensitivity analysis took a conservative approach increasing the channel roughness values along the entire Canal and under each of the roadway crossings through the model. The existing conditions roughness coefficient was between 0.05 and 0.06, two iterations of the increased roughness model were run, one with a value of 0.08 and the other with a value of 0.10 for the roughness coefficient. In short, the higher the roughness coefficient used in the model, the more vegetation growth and debris blockage is being simulated in the Canal. The ~0.02 and ~0.04 increases in manning's n-value are respectively ~33% and ~66% increases in channel friction and are considered more than significant to account for minor and major vegetation increases and debris blockages within the Canal and at crossing structures.

Findings

After the roughness coefficient for the Broadway to Belleview hydraulic model was increased, the resulting peak spill flow and total spill volume at each spill location were compared to the existing conditions values. See **Figure 1** attached for the location of each of the spills through the model reach. The attached **Table 1** and **Table 2** show comparisons between peak spill flow and total spill volume for each spill location.

In general, the spills occur in roughly the same location between the increased roughness and existing conditions models. However, the magnitude of spill varies between the three models. In some cases, there are reductions and other cases increases in peak spill flow and total spill volumes between the models. There are some increases with over 1000% difference between the increased roughness and existing conditions models, this is due to the existing conditions spills being quite small at these locations, so any increase is proportionally significant. The general trend in the data is that if there was a reduction or increase in peak spill flow or total spill volume between the 0.08 manning's n-value and the existing conditions model, that difference would be increased between the 0.10 manning's n-value model and existing conditions. When looking holistically at the spills along the entire Belleview to Broadway reach, the total volume of spills in the 0.08 roughness scenario was reduced by 7.1 acre-feet or 0.4% overall. The reduction indicates that the higher roughness in certain locations can improve the effectiveness of stormwater management in the canal.

Considerations and Conclusion

It's important to note that the analysis conducted to assess the impact of increased vegetation and debris remaining within the Canal banks is very conservative. The roughness coefficient used within the existing conditions Canal model reflects the typical values for medium tree coverage, so planting trees and vegetation that our rainfall can sustain or replacing dying plants does not require additional analysis as it is an existing condition. The level of vegetation to reach the roughness coefficient value of 0.08 would require irrigation to sustain the additional vegetation growth in the front range's semi-arid climate. While this level of vegetation may be desired in some isolated locations along the Canal, it is unlikely that it would have a significant hydraulic impact. To reach the upper limit (n=0.10) of the sensitivity modeling, there would need to be an abundance of additional plantings in the Canal and an extensive irrigation system.

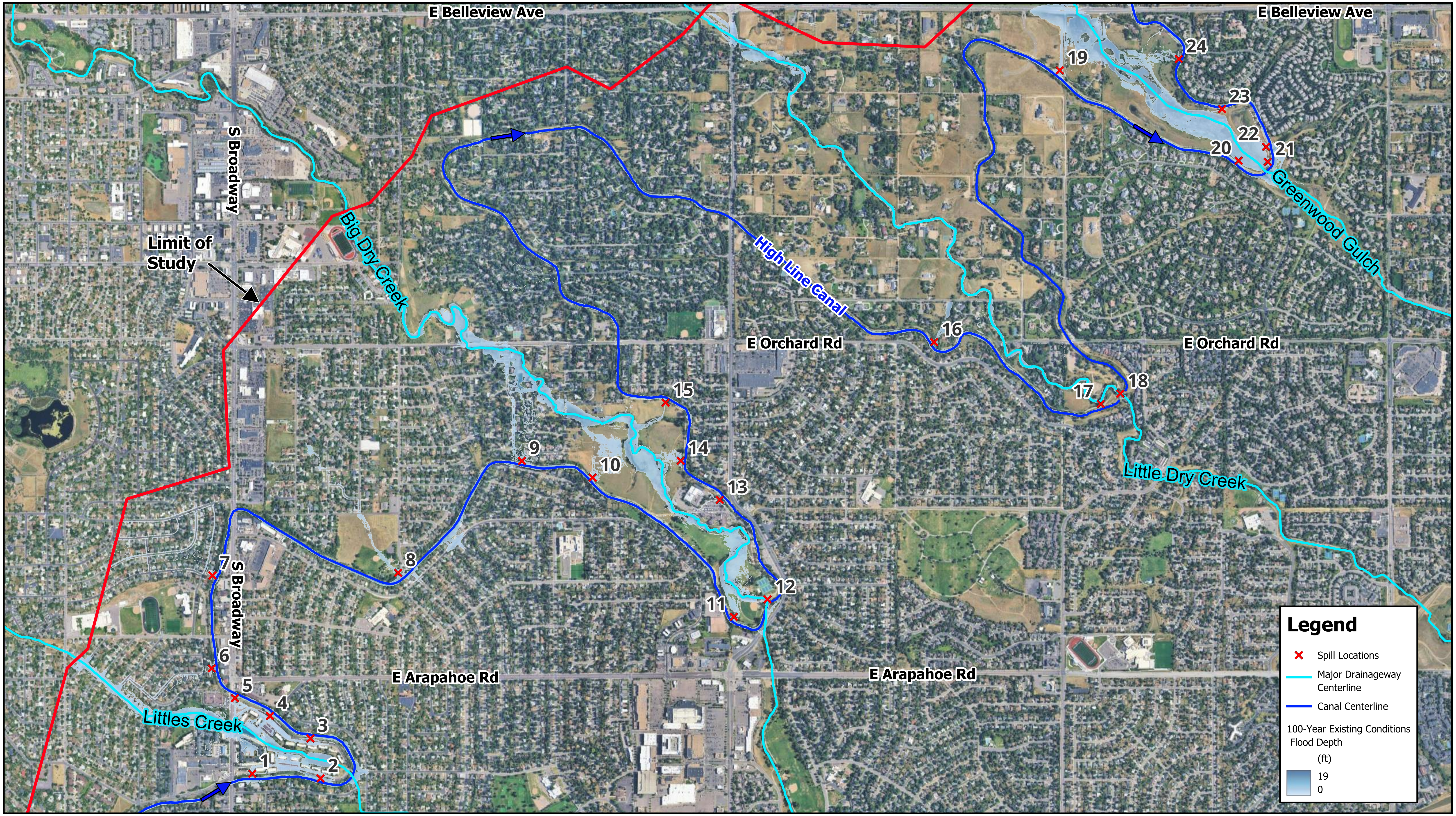
For debris management, the only type of debris that would warrant roughness coefficient values of 0.08 – 0.10 is large woody debris, which is not as common as other types of debris in most Canal reaches. The n-value was adjusted for the entire length of canal through the example reach, this would imply there was some (manning's n-value of 0.08) or a significant amount (manning's n-value of 0.10) of woody debris along the entire length of the canal through the example reach. It is highly unlikely that increased vegetation or woody debris would be present along a multi-mile stretch of Canal, but this situation was chosen for analysis to determine an upper limit of hydraulic sensitivity.

Small woody debris, leaf litter, and trash have negligible effect on hydraulics in the Canal, and some will float to outlets or water quality treatment points and can be collected during routine maintenance schedules. As the operations of the Canal transition to stormwater management it is recommended that Canal owners and partners formalize maintenance access and debris clearance locations along the Canal. Large woody debris should be removed to prevent clogging of outlets or water quality treatment locations. But the maintenance schedule that targets such debris removal can likely be less frequent than routine maintenance as this type of removal is more costly and, as shown here, nominally affects Canal hydraulics. Only in large storm events would this type of debris mobilize and have the potential to block crossing structures, outlets, and treatment points.

Attachments

- **Figure 1:** S Broadway to E Belleview Ave 2D Model Existing Conditions Spill Locations
- **Table 1:** Maximum Peak Spill Flow Comparison of Existing Conditions vs Roughness Sensitivity Analysis Modeling
- **Table 2:** Total Spill Volume Comparison of Existing Conditions vs Roughness Sensitivity Analysis Modeling

END OF MEMORANDUM



ICON ENGINEERING

High Line Canal Stormwater Transistion and Management Plan - Hydraulic Analysis

Figure 1: S Broadway to E Belleview Ave 2D Model Existing Conditions Spill Locations

MHFD MILE HIGH FLOOD DISTRICT

Table 1: Maximum Peak Spill Flow Comparison of Existing Conditions vs Roughness Sensitivity Analysis Modeling

Spill Flow Receiving Basin	Spill Location	Spill Number	Maximum Peak Spill Flow (cfs): Existing Conditions (~0.06 Manning's n-value in Channel)	Proposed Conditions (0.08 Manning's n-value in Channel)	Proposed Conditions (0.10 Manning's n-value in Channel)	Difference (0.08-EC) (cfs)		Difference (0.10-EC) (cfs)	
Littles Creek	East of W Ridge Rd and S Broadway	1	22	20	20	-2	-9%	-2	-9%
	West of SE corner of E Highline Cir	2	734	781	760	47	6%	26	4%
	South of S Sherman St and E Briarwood Dr	3	167	254	328	87	52%	161	96%
	SW of E Sterne Blvd and E Briarwood Dr	4	250	246	229	-4	-2%	-21	-8%
	South of E Arapahoe Rd and S Broadway	5	89	67	45	-22	-25%	-44	-49%
	NE of S Acoma St and S Apache Dr	6	12	3	3	-9	-75%	-9	-75%
	East of W Peakview Ave and S Acoma St	7	13	6	6	-7	-54%	-7	-54%
Slaughterhouse Gulch	SW of S Clarkson St Crossing	8	10	59	97	49	490%	87	870%
Big Dry Creek	SW of E Fair Pl cul-de-sac	9	48	68	72	20	42%	24	50%
	North of S Marion Wy cul-de-sac	10	81	98	95	17	21%	14	17%
	SW of DeKoevend Park baseball field	11	26	168	214	142	546%	188	723%
	Wastegate at Big Dry Creek and High Line Canal	12	1748	1626	1617	-122	-7%	-131	-7%
	East of Goodson Recreation Center	13	3	37	58	34	1133%	55	1833%
	SW of E Orchard Ln and E Crabtree Dr	14	116	1	102	-115	-99%	-14	-12%
	SW of Crabtree Dr and S Vine St	15	7	25	24	18	257%	17	243%
Little Dry Creek	NW of E Orchard Rd and S Cook St	16	30	73	109	43	143%	79	263%
	Wastegate upstream of Little Dry Creek siphon	17	147	195	194	48	33%	47	32%
	Spillway from High Line Canal to Little Dry Creek	18	1198	606	160	-592	-49%	-1038	-87%
Greenwood Gulch	NW of S Colorado Blvd and High Line Canal	19	283	213	173	-70	-25%	-110	-39%
	NW of Greenwood Gulch Trail and High Line Canal Trail	20	141	239	268	98	70%	127	90%
	Greenwood Gulch and High Line Canal	21	1894	1863	1849	-31	-2%	-45	-2%
	Prentice Gulch and High Line Canal	22	11	88	146	77	700%	135	1227%
	South of E Perry Pkwy	23	4	10	11	6	150%	7	175%
	SW of E Prentice Pl and E Perry Pkwy	24	45	26	24	-19	-42%	-21	-47%
		Total:	**7079**	**6772**	**6604**	**-307**	-4%	**-475**	-7%

Table 2: Total Spill Volume Comparison of Existing Conditions vs Roughness Sensitivity Analysis Modeling

			Total Volume Spilled (ac.ft)				
Spill Flow Receiving Basin	**Spill Location**	**Spill Number**	Existing Conditions (~0.06 Manning's n-value in Channel)	Proposed Conditions (0.08 Manning's n-value in Channel)	Proposed Conditions (0.10 Manning's n-value in Channel)	Difference (0.08-EC) (ac-ft)	Difference (0.10-EC) (ac-ft)
Littles Creek	East of W Ridge Rd and S Broadway	1	1.4	1.3	1.4	-0.1 -7%	0 0%
	West of SE corner of E Highline Cir	2	94	94.1	96	0.1 0%	2 2%
	South of S Sherman St and E Briarwood Dr	3	5.6	8.8	11.5	3.2 57%	5.9 105%
	SW of E Sterne Blvd and E Briarwood Dr	4	19.6	18.7	17.9	-0.9 -5%	-1.7 -9%
	South of E Arapahoe Rd and S Broadway	5	3	2.5	1.6	-0.5 -17%	-1.4 -47%
	NE of S Acoma St and S Apache Dr	6	3	1.5	1.3	-1.5 -50%	-1.7 -57%
	East of W Peakview Ave and S Acoma St	7	5.3	3.6	3.5	-1.7 -32%	-1.8 -34%
Slaughterhouse Gulch	SW of S Clarkson St Crossing	8	0.3	1.9	3.6	1.6 533%	3.3 1100%
Big Dry Creek	SW of E Fair Pl cul-de-sac	9	1.9	3.3	4	1.4 74%	2.1 111%
	North of S Marion Wy cul-de-sac	10	5.2	16.1	21.5	10.9 210%	16.3 313%
	SW of DeKoevend Park baseball field	11	5.9	58.4	86	52.5 890%	80.1 1358%
	Wastegate at Big Dry Creek and High Line Canal	12	1397.4	1353.5	1329.8	-43.9 -3%	-67.6 -5%
	East of Goodson Recreation Center	13	0.1	1.2	2.2	1.1 1100%	2.1 2100%
	SW of E Orchard Ln and E Crabtree Dr	14	8.6	0	10.8	-8.6 -100%	2.2 26%
	SW of Crabtree Dr and S Vine St	15	0.3	1.2	1.3	0.9 300%	1 333%
Little Dry Creek	NW of E Orchard Rd and S Cook St	16	1.4	3.3	5.2	1.9 136%	3.8 271%
	Wastegate upstream of Little Dry Creek siphon	17	118.6	129.7	123.3	11.1 9%	4.7 4%
	Spillway from High Line Canal to Little Dry Creek	18	90.6	47.1	38	-43.5 -48%	-52.6 -58%
Greenwood Gulch	NW of S Colorado Blvd and High Line Canal	19	19.8	17.9	15.7	-1.9 -10%	-4.1 -21%
	NW of Greenwood Gulch Trail and High Line Canal Trail	20	5.5	11.8	15	6.3 115%	9.5 173%
	Greenwood Gulch and High Line Canal	21	187.4	190.3	191.1	2.9 2%	3.7 2%
	Prentice Gulch and High Line Canal	22	0.2	2.8	5.9	2.6 1300%	5.7 2850%
	South of E Perry Pkwy	23	0.1	0.4	0.4	0.3 300%	0.3 300%
	SW of E Prentice Pl and E Perry Pkwy	24	3	1.7	1.8	-1.3 -43%	-1.2 -40%
		Total:	**1978.2**	**1971.1**	**1988.8**	**-7.1** -0.4%	**10.6** 1%

APPENDIX C: ROAD CROSSINGS

High Line Canal Road and Trail Crossings - ICON Engineering, Inc.

High Line Canal Crossing Structures			Bridge Data									Culvert Data									
			Upstream			Downstream															
Station	Location	Type	Low Chord Elevation (ft)	High Chord elevation (ft)	Invert Elevation (ft)	Low Chord Elevation (ft)	High Chord elevation (ft)	Invert Elevation (ft)	Deck Thickness (ft)	Span (ft)	Width Parallel to Flow (ft)	Shape	# of Barrels	Height (ft)	Width (ft)	Upstream Invert Elevation (ft)	Downstream Invert Elevation (ft)	Terrain Centerline Elevation (ft)	Width Parallel to Flow (ft)	Structure Modeled in 2D HEC-RAS (Y/N)	Elevation Data Souce
0+35	Culvert at Social Trail SW of First Creek HLC Trail Crossing	Culvert	--	--	--	--	--	--	--	--	--	Ellipse	1	1.5	2.5	5418.5	5417.4	5423.3	69.0	Y	SWMM
17+80	Malaya St Road Crossing	Culvert	--	--	--	--	--	--	--	--	--	Arch	1	7.0	10.7	5420.2	5420.3	5432.0	73.3	Y	SWMM
28+82	North of E 44th Ave Ped Bridge	Culvert	--	--	--	--	--	--	--	--	--	Circular	1	2.0	2.0	5420.1	5420.1	5423.0	10.0	N	Field Data
30+80	Lisbon St Road Crossing	Culvert	--	--	--	--	--	--	--	--	--	Arch	1	7.0	10.7	5420.7	5420.6	5430.1	51.6	Y	SWMM
51+86	North of Iran St Ped Crossing	Culvert	--	--	--	--	--	--	--	--	--	Circular	1	3.0	3.0	5421.7	5421.7	5424.6	6.0	N	Field Data
59+20	Himalaya Rd Road Crossing	Culvert	--	--	--	--	--	--	--	--	--	Arch	1	7.0	10.7	5422.1	5422.0	5433.5	126.3	Y	SWMM
71+83	E Mitchell Pl Road Crossing	Culvert	--	--	--	--	--	--	--	--	--	Arch	1	7.0	10.7	5422.4	5422.3	5431.7	55.4	Y	SWMM
75+90	East of Genoa St Ped Crossing	Culvert	--	--	--	--	--	--	--	--	--	Circular	1	2.0	2.0	5422.7	5422.7	5427.0	6.0	N	Field Data
82+27	North of E 41st St Pl Ped Crossing	Culvert	--	--	--	--	--	--	--	--	--	Circular	1	2.0	2.0	5422.9	5422.9	5427.1	41.5	N	Field Data
92+65	Ensenada St Road Crossing	Culvert	--	--	--	--	--	--	--	--	--	Arch	1	7.0	10.7	5423.6	5423.4	5432.1	77.5	Y	SWMM
110+99	N Argonne St Road Crossing	Culvert	--	--	--	--	--	--	--	--	--	Arch	1	7.0	10.7	5423.7	5423.7	5433.1	72.1	Y	SWMM
119+32	HLC Trail Crossing S of N Argonne St	Culvert	--	--	--	--	--	--	--	--	--	Box	1	2.0	4.0	5423.7	5423.7	5428.1	76.0	N	Field Data
123+28	HLC Trail Crossing N of E 38th Ave	Culvert	--	--	--	--	--	--	--	--	--	Box	1	2.0	4.0	5423.8	5423.8	5428.8	39.6	N	Field Data
127+01	E 38th Ave Road Crossing	Bridge	5432.25	5436.6	5423.7	5431.1	5436.4	5423.0	5.3	18.5	142.0	--	--	--	--	--	--	--	--	Y	SWMM
162+94	E 32nd Pkwy Road Crossing	Culvert	--	--	--	--	--	--	--	--	--	Ellipse	1	5.7	8.0	5427.3	5427.1	5436.2	151.4	Y	SWMM
177+09	Himalaya Rd Road Crossing	Bridge	5432.99	5436.1	5427.4	5433.1	5436.2	5427.5	3.1	33.8	33.3	--	--	--	--	--	--	--	--	Y	SWMM
178+35	I-70 Westbound Road Crossing	Bridge	5432.9	5434.2	5428.4	5432.3	5433.8	5427.9	1.4	34.8	44.3	--	--	--	--	--	--	--	--	Y	SWMM
179+24	I-70 Eastbound Road Crossing	Bridge	5432.42	5434.2	5427.2	5432.9	5434.5	5427.7	1.8	35.6	45.8	--	--	--	--	--	--	--	--	Y	SWMM
195+57	Tower Rd Road Crossing	Culvert	--	--	--	--	--	--	--	--	--	Ellipse	1	2.3	6.3	5427.9	5427.8	5435.1	124.2	Y	SWMM
206+34	E 28th Ave Road Crossing	Culvert	--	--	--	--	--	--	--	--	--	Circular	1	5.0	5.0	5428.5	5427.8	5435.7	164.3	Y	SWMM
212+37	Railroad Crossing	Culvert	--	--	--	--	--	--	--	--	--	Ellipse	1	6.3	5.5	5430.3	5429.4	5437.6	73.4	Y	SWMM
214+87	Smith Rd Road Crossing	Culvert	--	--	--	--	--	--	--	--	--	Circular	1	6.0	6.0	5429.9	5430.0	5440.3	110.0	Y	SWMM
221+91	Tower Rd Ped Bridge	Bridge	5432.5	5434.0	5428.8	5432.5	5434.0	5428.8	1.5	43.0	14.0	--	--	--	--	--	--	--	--	N	Field Data
240+92	E 22nd Ave Road Crossing	Culvert	--	--	--	--	--	--	--	--	--	Ellipse	1	5.2	7.7	5430.5	5430.3	5437.1	64.9	Y	SWMM
259+18	E 19th Ave - Tower Rd Road Crossing	Culvert	--	--	--	--	--	--	--	--	--	Ellipse	1	5.7	7.4	5430.7	5430.6	5438.0	254.3	Y	SWMM
280+12	E Colfax Ave - Tower Rd Road Crossing	Culvert	--	--	--	--	--	--	--	--	--	Ellipse	1	5.3	7.7	5429.5	5431.5	5437.1	773.5	Y	SWMM
294+56	Sand Creek Siphon	Culvert	--	--	--	--	--	--	--	--	--	Circular	1	5.5	5.5	5431.5	5437.1	5445.0	684.4	Y	SWMM
313+24	E 14th Dr Ped Bridge	Bridge	5437.3	5438.8	5434.1	5437.3	5438.8	5434.1	1.5	43.0	12.0	--	--	--	--	--	--	--	--	N	Field Data
337+23	E Colfax Ave Road Crossing	Culvert		--	--	--	--	--	--	--	--	Box	1	5.5	10.0	5434.5	5434.5	5448.3	314.5	Y	SWMM
339+15	E Colfax Ave Ped Bridge	Bridge	5440	5441.0	5434.4	5440.0	5441.0	5434.4	1.0	40.0	9.0	--	--	--	--	--	--	--	--	N	Field Data
344+88	N Airport Blvd Road Crossing	Culvert	--	--	--	--	--	--	--	--	--	Ellipse	1	8.0	14.3	5434.6	5434.9	5445.8	211.7	Y	SWMM
387+52	E 18th Pl Ped Bridge	Bridge	5439.1	5440.1	5435.8	5439.1	5440.1	5435.8	1.0	40.0	8.0	--	--	--	--	--	--	--	--	N	Field Data
410+23	Laredo St Road Crossing	Bridge	5443.33	5446.3	5435.9	5441.5	5444.5	5435.8	3.0	21.3	53.1	--	--	--	--	--	--	--	--	Y	SWMM
421+65	E Colfax Ave Ped Bridge	Bridge	5442	5443.0	5436.6	5442.0	5443.0	5436.6	1.0	40.0	8.0	--	--	--	--	--	--	--	--	N	Field Data
422+24	E Colfax Ave Westbound Road Crossing	Bridge	5440.9	5443.9	5436.6	5441.8	5444.8	5436.3	3.0	17.0	38.1	--	--	--	--	--	--	--	--	Y	SWMM
422+95	E Colfax Ave Eastbound Road Crossing	Bridge	5442.96	5446.0	5436.6	5443.2	5446.2	5436.7	3.0	17.0	40.8	--	--	--	--	--	--	--	--	Y	SWMM
437+91	Memphis St Ped Bridge	Bridge	5442	5443.0	5437.3	5442.0	5443.0	5437.3	1.0	20.0	6.0	--	--	--	--	--	--	--	--	N	Field Data
445+81	Laredo St Road Crossing	Bridge	5442.22	5445.2	5437.2	5441.8	5444.8	5437.3	3.0	16.2	62.0	--	--	--	--	--	--	--	--	Y	SWMM
468+90	E 12th Ave Road Crossing	Bridge	5445.42	5448.4	5439.7	5445.5	5448.6	5440.2	3.1	14.0	53.7	--	--	--	--	--	--	--	--	Y	SWMM
474+25	Hinkley High School Ped Bridge	Bridge	5444.3	5445.8	5440.1	5444.3	5445.8	5440.1	1.5	25.0	10.0	--	--	--	--	--	--	--	--	N	Field Data
514+33	E 7th Pl Road Crossing	Bridge	5448.47	5451.6	5440.7	5448.3	5451.3	5441.0	3.1	30.0	51.5	--	--	--	--	--	--	--	--	Y	SWMM
525+13	E 6th Ave Road Crossing	Bridge	5447.16	5450.2	5441.0	5447.5	5450.7	5441.3	3.2	16.0	105.6	--	--	--	--	--	--	--	--	Y	SWMM
527+93	E 5th Pl Road Crossing	Bridge	5448.41	5451.5	5440.9	5448.7	5451.7	5441.1	3.1	18.0	42.9	--	--	--	--	--	--	--	--	Y	SWMM
545+44	N Helena Ct Ped Bridge	Bridge	5444.5	5445.5	5442.2	5444.5	5445.5	5442.2	1.0	30.0	9.0	--	--	--	--	--	--	--	--	N	Field Data
557+58	E 1st Ave Road Crossing	Culvert	--	--	--	--	--	--	--	--	--	Arch	1	7.0	20.5	5442.3	5442.2	5453.2	69.6	Y	SWMM
563+18	Community College of Aurora Ped Bridge	Bridge	5450.3	5451.3	5442.7	5450.3	5451.3	5442.7	1.0	34.0	8.0	--	--	--	--	--	--	--	--	N	Field Data
584+72	E Toll Gate Creek Siphon	Culvert	--	--	--	--	--	--	--	--	--	Circular	1	5.5	5.5	5444.7	5439.9	5452.0	415.1	Y	SWMM
605+46	S Jasper Cir Ped Bridge	Bridge	5450.1	5451.1	5444.2	5450.1	5451.1	5444.2	1.0	44.0	7.0	--	--	--	--	--	--	--	--	N	Field Data
621+53	E Alemeda Pkwy Ped Bridge	Bridge	5449.7	5450.7	5443.9	5449.7	5450.7	5443.9	1.0	40.0	7.0	--	--	--	--	--	--	--	--	N	Field Data
623+38	W Toll Gate Creek Siphon	Culvert	--	--	--	--	--	--	--	--	--	Circular	1	8.3	8.3	5444.1	5448.9	5454.0	227.9	Y	SWMM
641+00	S Chambers Rd Road Crossing	Culvert	--	--	--	--	--	--	--	--	--	Arch	1	8.7	25.0	5444.9	5445.0	5456.2	156.8	Y	SWMM

High Line Canal Road and Trail Crossings - ICON Engineering, Inc.

High Line Canal Crossing Structures			Bridge Data									Culvert Data								Structure Modeled in 2D HEC-RAS (Y/N)	Elevation Data Souce
			Upstream			Downstream															
Station	Location	Type	Low Chord Elevation (ft)	High Chord elevation (ft)	Invert Elevation (ft)	Low Chord Elevation (ft)	High Chord elevation (ft)	Invert Elevation (ft)	Deck Thickness (ft)	Span (ft)	Width Parallel to Flow (ft)	Shape	# of Barrels	Height (ft)	Width (ft)	Upstream Invert Elevation (ft)	Downstream Invert Elevation (ft)	Terrain Centerline Elevation (ft)	Width Parallel to Flow (ft)		
661+32	E Elkhart St Ped Bridge	Bridge	5452.7	5453.7	5445.9	5452.7	5453.7	5445.9	1.0	44.0	10.0	--	--	--	--	--	--	--	--	N	Field Data
685+10	Sable Blvd Road Crossing	Culvert	--	--	--	--	--	--	--	--	--	Arch	1	7.0	20.0	5447.9	5447.8	5458.0	157.2	N	SWMM
706+05	N Blackhawk St Ped Bridge	Bridge	5459	5460.0	5451.4	5459.0	5460.0	5451.4	1.0	57.0	13.0	--	--	--	--	--	--	--	--	N	Field Data
710+73	I-225 - Abilene St Road Crossing	Bridge	5457.89	5464.1	5451.2	5457.6	5459.0	5451.0	6.2	12.0	335.0	--	--	--	--	--	--	--	--	Y	SWMM
715+93	N Potomac St Road Crossing	Bridge	5456.55	5459.5	5451.3	5456.3	5459.4	5451.4	3.1	17.0	81.5	--	--	--	--	--	--	--	--	Y	SWMM
736+75	S Ursula St Ped Bridge	Bridge	5459.4	5460.9	5452.5	5459.4	5460.9	5452.5	1.5	60.0	5.0	--	--	--	--	--	--	--	--	N	Field Data
758+51	E 2nd Ave Road Crossing	Bridge	5461.21	5463.8	5453.2	5461.2	5463.8	5453.2	2.5	18.0	63.8	--	--	--	--	--	--	--	--	Y	SWMM
777+25	Peoria St Road Crossing	Bridge	5462.45	5464.5	5455.7	5462.1	5464.3	5455.7	2.2	28.6	62.1	--	--	--	--	--	--	--	--	Y	SWMM
815+30	S Moline St Road Crossing	Culvert	--	--	--	--	--	--	--	--	--	Arch	1	7.3	22.0	5455.6	5455.4	5466.7	91.7	Y	SWMM
842+57	E Alameda Ave Road Crossing	Bridge	5461.8	5463.1	5455.8	5461.3	5463.1	5455.2	1.8	24.8	100.8	--	--	--	--	--	--	--	--	Y	SWMM
864+30	E Virginia Ave Ped Bridge	Bridge	5465.6	5466.6	5456.6	5465.6	5466.6	5456.6	1.0	90.0	8.0	--	--	--	--	--	--	--	--	N	Field Data
877+28	S Havana St Road Crossing	Bridge	5463.99	5466.0	5457.5	5464.0	5466.2	5457.5	2.1	25.0	114.3	--	--	--	--	--	--	--	--	Y	SWMM
910+03	S Dayton St Raod Crossing	Bridge	5464.41	5466.4	5458.1	5464.3	5466.6	5458.0	2.3	30.0	57.6	--	--	--	--	--	--	--	--	Y	SWMM
956+89	S Valentia St Road Crossing	Culvert	--	--	--	--	--	--	--	--	--	Arch	1	8.0	20.0	5458.6	5458.5	5470.3	73.1	Y	SWMM
963+42	Fairmount Cemetary Rd Road Crossing #1	Bridge	5468.15	5470.2	5459.2	5467.8	5469.2	5459.3	2.0	20.0	30.0	--	--	--	--	--	--	--	--	Y	SWMM
986+91	Fairmount Cemetary Rd Road Crossing #2	Bridge	5467.3	5467.4	5459.6	5467.2	5468.9	5459.6	1.7	30.5	42.1	--	--	--	--	--	--	--	--	Y	SWMM
1006+14	S Parker Rd Road Crossing	Bridge	5468.21	5473.0	5460.6	5468.4	5473.3	5460.3	4.9	20.0	103.1	--	--	--	--	--	--	--	--	Y	1D HEC-RAS
1008+46	S Parker Rd Ped Bridge	Bridge	5469.3	5471.3	5461.2	5469.3	5471.3	5461.2	2.0	42.0	9.0	--	--	--	--	--	--	--	--	N	1D HEC-RAS
1018+18	Parking Lot off S Parker Rd Ped Bridge	Bridge	5468.5	5469.5	5461.1	5468.5	5469.5	5461.1	1.0	40.0	10.0	--	--	--	--	--	--	--	--	N	Field Data
1034+08	E Florida Ave Road Crossing	Bridge	5468.6	5472.6	5461.2	5468.6	5472.9	5461.2	4.3	39.7	30.8	--	--	--	--	--	--	--	--	Y	1D HEC-RAS
1038+83	Long's Pine Grove Parking Lot Ped Crossing	Bridge	5465.3	5466.3	5461.4	5465.3	5466.3	5461.4	1.0	47.0	8.0	--	--	--	--	--	--	--	--	N	Field Data
1102+16	E Iliff Ave Road Crossing	Bridge	5470.8	5472.4	5462.2	5469.5	5474.0	5462.5	4.5	20.0	197.0	--	--	--	--	--	--	--	--	Y	1D HEC-RAS
1106+24	E Iliff Ped Bridge	Bridge	5470.7	5471.0	5462.1	5470.7	5471.0	5462.1	0.3	42.9	5.0	--	--	--	--	--	--	--	--	N	1D HEC-RAS
1120+87	S Dayton Way Ped Bridge	Bridge	5472.21	5472.5	5462.1	5472.2	5472.5	5462.1	0.3	54.0	4.5	--	--	--	--	--	--	--	--	N	1D HEC-RAS
1134+09	Beaumont Way Ped Bridge	Bridge	5469.2	5469.5	5462.1	5469.2	5469.5	5462.1	0.3	48.0	4.5	--	--	--	--	--	--	--	--	N	1D HEC-RAS
1142+62	The Greens Ped Bridge	Bridge	5471.18	5473.5	5462.5	5471.2	5473.5	5462.4	2.4	46.9	8.0	--	--	--	--	--	--	--	--	N	1D HEC-RAS
1151+99	Cherry Creek Siphon	Culvert	--	--	--	--	--	--	--	--	--	Circular	1	9.0	9.0	5458.4	5458.4	5474.8	607.7	Y	1D HEC-RAS
1158+64	S Boston St Ped Bridge	Bridge	5473.39	5477.6	5463.9	5473.4	5477.6	5463.8	4.3	26.0	31.0	--	--	--	--	--	--	--	--	Y	1D HEC-RAS
1174+72	S Yosemite St Road Crossing	Bridge	5474.16	5478.4	5465.4	5474.2	5479.2	5465.4	5.0	28.5	105.6	--	--	--	--	--	--	--	--	Y	1D HEC-RAS
1182+79	S Wabash Cir and S Willow Ct Ped Bridge	Bridge	5475.6	5476.4	5467.1	5475.6	5476.4	5466.9	0.8	38.0	8.0	--	--	--	--	--	--	--	--	N	1D HEC-RAS
1201+91	E Yale Ave Road Crossing	Bridge	5475.81	5480.6	5466.6	5475.5	5480.3	5466.5	4.8	30.0	72.7	--	--	--	--	--	--	--	--	Y	1D HEC-RAS
1220+53	E Harvard Ave Road Crossing	Bridge	5476.4	5482.0	5467.3	5475.9	5481.4	5467.3	5.7	31.0	61.6	--	--	--	--	--	--	--	--	Y	1D HEC-RAS
1242+62	S Quebec St Road Crossing	Bridge	5473.2	5476.4	5467.7	5473.9	5477.1	5467.7	3.3	18.0	88.2	--	--	--	--	--	--	--	--	Y	1D HEC-RAS
1267+43	E Iliff Ave Ped Bridge	Bridge	5477.0	5475.8	5468.2	5477.0	5477.9	5468.2	0.9	35.5	8.0	--	--	--	--	--	--	--	--	N	1D HEC-RAS
1296+18	East Yale Ave Road Crossing	Bridge	5477.5	5482.0	5469.6	5478.0	5482.5	5469.6	4.5	41.0	57.3	--	--	--	--	--	--	--	--	Y	1D HEC-RAS
1304+22	East Amherst Ave Ped Bridge	Bridge	5479.8	5479.3	5469.7	5479.8	5480.4	5469.7	0.5	79.5	5.5	--	--	--	--	--	--	--	--	N	1D HEC-RAS
1325+94	Goldsmith Gulch Trail Ped Bridge	Bridge	5479.4	5479.5	5469.9	5480.1	5480.8	5469.9	0.7	69.5	5.5	--	--	--	--	--	--	--	--	N	1D HEC-RAS
1348+52	S Newport St and E Bucknell Pl Ped Bridge	Bridge	5478.9	5478.8	5470.2	5478.9	5479.4	5470.2	0.5	60.7	5.0	--	--	--	--	--	--	--	--	N	1D HEC-RAS
1358+69	East Bates Ave Ped Bridge	Bridge	5480.3	5480.8	5470.7	5480.3	5480.9	5470.7	0.6	60.0	4.7	--	--	--	--	--	--	--	--	N	1D HEC-RAS
1368+61	East Yale Ave Road Crossing	Bridge	5480.2	5484.7	5471.1	5480.0	5484.5	5471.1	4.5	41.5	63.5	--	--	--	--	--	--	--	--	Y	1D HEC-RAS
1375+25	South Monaco Pkwy Road Crossing	Bridge	5479.5	5484.3	5471.5	5480.2	5485.0	5471.4	4.8	38.5	128.0	--	--	--	--	--	--	--	--	Y	1D HEC-RAS
1411+83	South Holly St Road Crossing	Bridge	5478.2	5482.7	5473.4	5478.7	5483.2	5473.4	4.5	33.5	74.0	--	--	--	--	--	--	--	--	Y	1D HEC-RAS
1468+81	East Yale Ave Road Crossing	Bridge	5479.9	5483.9	5474.4	5479.6	5483.6	5474.3	4.0	26.0	99.7	--	--	--	--	--	--	--	--	Y	1D HEC-RAS
1488+73	Interstate 25 Light Rail and Road Crossing	Bridge	5480.1	5485.6	5475.2	5480.3	5485.8	5475.1	5.5	36.0	135.0	--	--	--	--	--	--	--	--	Y	1D HEC-RAS
1491+73	South Holly St Ped Bridge	Bridge	5484.2	5484.4	5475.5	5484.2	5485.2	5475.5	1.0	55.0	9.0	--	--	--	--	--	--	--	--	N	1D HEC-RAS
1504+20	South Forest St Ped Bridge	Bridge	5482.5	5484.4	5475.5	5482.5	5483.0	5475.8	1.9	36.5	5.5	--	--	--	--	--	--	--	--	N	1D HEC-RAS
1526+88	South Dalia St Road Crossing	Bridge	5481.6	5486.6	5476.2	5481.6	5486.6	5476.1	5.0	30.5	59.0	--	--	--	--	--	--	--	--	Y	1D HEC-RAS
1542+00	South Bellaire St Ped Bridge	Bridge	5483.6	5484.8	5476.6	5483.6	5484.8	5476.6	1.3	42.0	10.0	--	--	--	--	--	--	--	--	N	1D HEC-RAS
1550+28	High Line Canal Ped Bridge Downstream of S Colorado Blvd	Bridge	5485.5	5484.3	5476.8	5485.5	5486.6	5476.8	1.0	50.0	10.8	--	--	--	--	--	--	--	--	N	1D HEC-RAS
1551+10	South Colorado Blvd Road Crossing	Bridge	5483.0	5488.0	5476.9	5482.8	5487.8	5476.8	5.0	26.5	101.0	--	--	--	--	--	--	--	--	Y	1D HEC-RAS
1552+58	Wellshire Golf Course Ped Bridge #1	Bridge	5483.5	5482.4	5476.9	5483.5	5484.5	5476.9	1.0	46.5	5.5	--	--	--	--	--	--	--	--	N	1D HEC-RAS

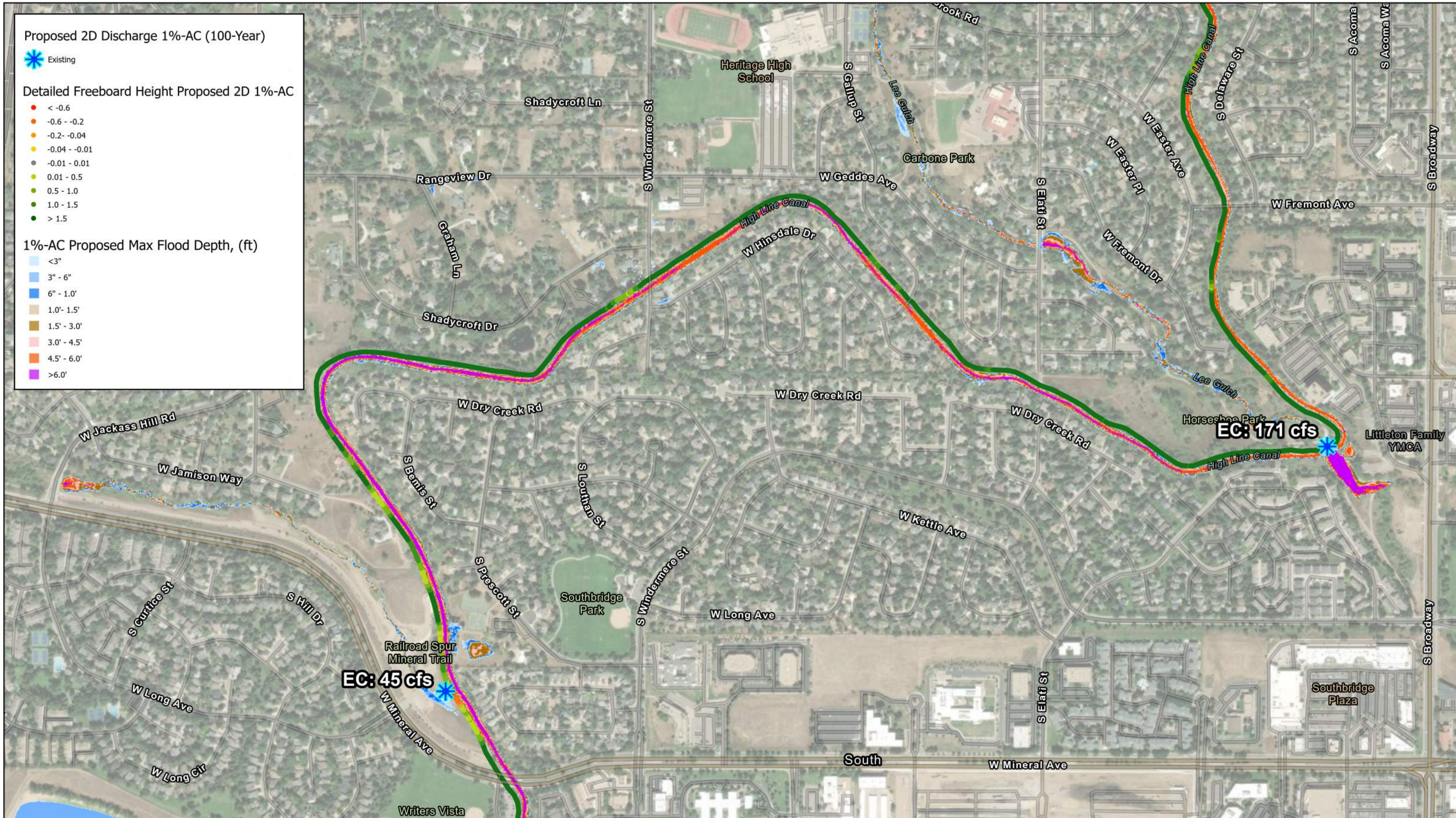
High Line Canal Road and Trail Crossings - ICON Engineering, Inc.

High Line Canal Crossing Structures			Bridge Data									Culvert Data								Structure Modeled in 2D HEC-RAS (Y/N)	Elevation Data Souce
			Upstream			Downstream															
Station	Location	Type	Low Chord Elevation (ft)	High Chord elevation (ft)	Invert Elevation (ft)	Low Chord Elevation (ft)	High Chord elevation (ft)	Invert Elevation (ft)	Deck Thickness (ft)	Span (ft)	Width Parallel to Flow (ft)	Shape	# of Barrels	Height (ft)	Width (ft)	Upstream Invert Elevation (ft)	Downstream Invert Elevation (ft)	Terrain Centerline Elevation (ft)	Width Parallel to Flow (ft)		
1555+99	Wellshire Golf Course Ped Bridge #2	Bridge	5484.4	5483.1	5476.9	5484.4	5485.4	5476.9	1.1	46.3	12.0	--	--	--	--	--	--	--	--	N	1D HEC-RAS
1558+06	Wellshire Golf Course Ped Bridge #3	Bridge	5486.5	5486.2	5476.9	5486.5	5487.4	5476.9	0.9	52.0	5.0	--	--	--	--	--	--	--	--	N	1D HEC-RAS
1561+89	Wellshire Golf Course Ped Bridge #4	Bridge	5483.3	5486.2	5476.9	5483.3	5485.3	5476.9	2.9	38.6	9.0	--	--	--	--	--	--	--	--	N	1D HEC-RAS
1586+50	Wellshire Golf Course Ped Bridge #5	Bridge	5486.0	5487.0	5477.7	5486.0	5487.6	5477.7	1.6	45.4	9.0	--	--	--	--	--	--	--	--	N	1D HEC-RAS
1588+49	Wellshire Golf Course Ped Bridge #6	Bridge	5485.7	5486.4	5477.8	5485.7	5487.4	5477.8	1.7	36.3	7.0	--	--	--	--	--	--	--	--	N	1D HEC-RAS
1592+18	Wellshire Golf Course Ped Bridge #7	Bridge	5486.5	5486.0	5477.9	5486.5	5487.5	5477.9	1.0	45.7	11.0	--	--	--	--	--	--	--	--	N	1D HEC-RAS
1593+92	East Hampden Ave Road Crossing	Bridge	5485.6	5489.6	5478.0	5487.1	5491.1	5477.9	4.0	45.0	130.0	--	--	--	--	--	--	--	--	Y	1D HEC-RAS
1595+15	High Line Canal Ped Bridge Upstream of E Hampden Ave	Bridge	5486.3	5487.3	5478.0	5486.3	5487.3	5478.0	1.0	70.0	9.5	--	--	--	--	--	--	--	--	N	Field Data
1600+82	Covington Dr Ped Bridge	Bridge	5489.1	5487.9	5478.1	5489.1	5489.8	5478.1	0.8	49.0	11.0	--	--	--	--	--	--	--	--	N	1D HEC-RAS
1648+39	South Colorado Blvd Road Crossing	Bridge	5488.4	5493.4	5479.5	5488.3	5493.3	5479.4	5.0	23.0	59.5	--	--	--	--	--	--	--	--	Y	1D HEC-RAS
1662+14	East Oxford Pl Ped Bridge	Bridge	5487.6	5488.2	5480.0	5487.6	5489.5	5480.0	1.9	59.0	8.0	--	--	--	--	--	--	--	--	N	1D HEC-RAS
1674+28	South Dahlia St Ped Bridge	Bridge	5489.7	5490.5	5480.4	5489.7	5491.7	5480.4	2.0	54.0	10.0	--	--	--	--	--	--	--	--	N	1D HEC-RAS
1692+24	East Quincy Ave Road Crossing	Bridge	5488.6	5493.1	5481.0	5488.5	5493.0	5480.9	4.5	52.0	54.0	--	--	--	--	--	--	--	--	Y	1D HEC-RAS
1721+86	South Dahlia St High Line Canal Parking Lot Ped Bridge	Bridge	5488.2	5489.9	5482.0	5488.2	5491.1	5482.0	2.8	36.0	7.0	--	--	--	--	--	--	--	--	N	1D HEC-RAS
1742+48	West of East Union Ave Ped Bridge	Bridge	5490.0	5490.7	5483.4	5490.0	5490.7	5483.4	0.7	50.0	7.0	--	--	--	--	--	--	--	--	N	1D HEC-RAS
1780+63	Northwest of South Birch St Ped Bridge	Bridge	5492.3	5494.0	5483.5	5492.3	5494.0	5483.5	1.7	82.5	6.5	--	--	--	--	--	--	--	--	N	1D HEC-RAS
1797+37	East Belleview Ave Road Crossing	Bridge	5493.2	5496.9	5484.6	5493.0	5496.7	5484.5	3.8	25.5	116.0	--	--	--	--	--	--	--	--	Y	1D HEC-RAS
1827+57	Blue Heron Dr Ped Bridge	Bridge	5494.5	5495.2	5486.8	5494.5	5495.2	5486.8	0.8	45.0	6.5	--	--	--	--	--	--	--	--	N	1D HEC-RAS
1843+61	Greenwood Gulch Trail Ped Bridge	Bridge	5497.6	5498.7	5486.5	5497.6	5498.7	5486.5	1.1	52.0	9.0	--	--	--	--	--	--	--	--	N	1D HEC-RAS
1868+61	Ped Bridge NE of S Highline Cir Cul-de-sac	Bridge	5497.1	5498.4	5486.0	5497.1	5498.4	5486.0	1.3	48.0	10.0	--	--	--	--	--	--	--	--	N	1D HEC-RAS
1882+65	S Jackson Pl Road crossing	Bridge	5496.3	5499.3	5486.5	5496.3	5499.3	5486.3	3.0	60.0	20.5	--	--	--	--	--	--	--	--	Y	Field Data
1898+08	Private Drive N of Willamette Ln	Bridge	5495.5	5496.5	5486.4	5495.5	5496.5	5486.4	1.0	47.0	9.5	--	--	--	--	--	--	--	--	N	Field Data
1902+74	Willamette Ln Road Crossing	Bridge	5496.2	5499.2	5486.9	5496.2	5499.2	5486.9	3.0	28.0	12.0	--	--	--	--	--	--	--	--	Y	1D HEC-RAS
1950+55	E Orchard Rd Road Crossing	Bridge	5495.6	5499.6	5498.7	5495.6	5499.6	5489.2	4.0	42.5	42.5	--	--	--	--	--	--	--	--	Y	1D HEC-RAS
1964+14	LDC Siphon	Culvert	--	--	--	--	--	--	--	--	--	Circular	1	10.5	10.5	5474.7	5477.2	5501.7	200.0	Y	1D HEC-RAS
1971+99	Ped Bridge N of S Ash Cir E	Bridge	5497.6	5498.6	5490.8	5497.6	5498.6	5490.8	0.9	23.0	3.0	--	--	--	--	--	--	--	--	N	1D HEC-RAS
1995+05	Ped Bridge S of S Dry Creek Ct	Bridge	5501.1	5502.6	5492.4	5501.1	5502.6	5492.4	1.5	45.0	8.0	--	--	--	--	--	--	--	--	N	1D HEC-RAS
2022+35	E Long Rd Road Crossing	Bridge	5500.8	5504.3	5493.3	5500.5	5504.0	5493.1	3.5	27.0	57.5	--	--	--	--	--	--	--	--	Y	1D HEC-RAS
2042+60	S Univerity Blvd Road Crossing	Bridge	5504.4	5507.9	5493.9	5504.4	5507.9	5493.8	3.5	24.0	113.0	--	--	--	--	--	--	--	--	Y	1D HEC-RAS
2074+70	S Franklin St Road Crossing	Bridge	5505.1	5508.6	5495.2	5505.0	5508.5	5495.1	3.5	28.0	40.0	--	--	--	--	--	--	--	--	Y	1D HEC-RAS
2122+65	Green Oaks Dr Road Crossing	Bridge	5505.8	5509.3	5496.5	5505.8	5509.3	5496.5	3.5	30.0	38.0	--	--	--	--	--	--	--	--	Y	1D HEC-RAS
2139+40	E Orchard Rd (W) Road Crossing	Bridge	5507.2	5510.7	5497.1	5506.4	5509.9	5497.0	3.5	34.0	59.5	--	--	--	--	--	--	--	--	Y	1D HEC-RAS
2177+49	S University Blvd Ped Bridge	Bridge	5509.5	5510.5	5499.4	5509.6	5510.6	5499.2	1.0	31.0	23.0	--	--	--	--	--	--	--	--	N	1D HEC-RAS
2185+80	Goodson Rec Center Dr Road Crossing	Bridge	5510.3	5516.3	5500.0	5508.2	5514.2	5499.6	6.0	46.0	56.0	--	--	--	--	--	--	--	--	Y	1D HEC-RAS
2189+76	E Weaver Ave Ped Bridge	Bridge	5508.4	5509.4	5499.8	5508.4	5509.4	5499.8	1.0	46.0	5.5	--	--	--	--	--	--	--	--	N	1D HEC-RAS
2198+28	Big Dry Creek Trail Ped Bridge	Bridge	5506.2	5507.2	5499.8	5506.2	5507.2	5499.8	1.0	43.0	8.5	--	--	--	--	--	--	--	--	N	Field Data
2207+49	S Vine St Ped Bridge	Bridge	5509.3	5501.6	5501.6	5509.7	5510.7	5501.6	1.0	68.7	7.0	--	--	--	--	--	--	--	--	N	1D HEC-RAS
2228+76	S Race Ct Ped Bridge	Bridge	5508.8	5509.8	5501.2	5508.8	5509.8	5501.2	1.0	53.0	7.0	--	--	--	--	--	--	--	--	N	Field Data
2244+47	S Franklin St Ped Bridge	Bridge	5509.4	5510.4	5501.3	5509.4	5510.4	5501.3	1.0	46.0	7.0	--	--	--	--	--	--	--	--	N	Field Data
2277+74	S Clarkson St Road Crossing	Bridge	5509.7	5515.7	5501.8	5509.7	5515.7	5502.2	6.0	26.0	48.0	--	--	--	--	--	--	--	--	Y	1D HEC-RAS
2309+70	S Broadway (N) Road Crossing	Bridge	5513.4	5516.9	5503.3	5511.4	5514.9	5503.1	3.5	38.0	179.0	--	--	--	--	--	--	--	--	Y	1D HEC-RAS
2330+49	W Euclid Ave Road Crossing	Bridge	5512.5	5517.5	5503.8	5512.4	5517.4	5503.8	5.0	20.0	50.0	--	--	--	--	--	--	--	--	Y	1D HEC-RAS
2340+44	S Broadway (C) Road Crossing	Bridge	5510.4	5514.9	5504.1	5511.9	5516.4	5504.0	4.5	33.0	100.0	--	--	--	--	--	--	--	--	Y	1D HEC-RAS
2365+18	E Costilla Ave Ped Bridge	Bridge	5514.0	5520.5	5504.5	5514.0	5520.5	5504.5	6.5	48.0	10.5	--	--	--	--	--	--	--	--	N	1D HEC-RAS
2385+94	S Broadway (S) Road Crossing	Bridge	5514.5	5522.0	5505.8	5513.9	5521.4	5505.3	7.5	30.0	100.0	--	--	--	--	--	--	--	--	Y	1D HEC-RAS
2398+31	S Bannock St Ped Bridge	Bridge	5514.5	5523.0	5505.6	5514.5	5523.0	5505.7	8.5	40.0	8.0	--	--	--	--	--	--	--	--	N	1D HEC-RAS
2424+39	W Fremont Ave Road Crossing	Bridge	5514.22	5516.2	5506.3	5514.3	5516.3	5506.7	2.0	28.5	48.7	--	--	--	--	--	--	--	--	Y	1D HEC-RAS
2443+02	W Dry Creek Ct Ped Bridge	Bridge	5518.17	5518.8	5506.3	5518.2	5518.8	5506.3	0.6	57.0	5.0	--	--	--	--	--	--	--	--	N	1D HEC-RAS
2466+67	S Elati St Ped Bridge	Bridge	5514.96	5517.3	5507.3	5515.0	5517.3	5507.3	2.3	47.5	6.0	--	--	--	--	--	--	--	--	N	1D HEC-RAS
2477+93	S Gallup St Road Crossing	Bridge	5517.42	5519.8	5507.7	5517.4	5519.4	5508.2	2.4	61.0	34.8	--	--	--	--	--	--	--	--	Y	1D HEC-RAS
2488+44	W Hinsdale Dr Ped Bridge	Bridge	5517.13	5519.1	5508.0	5517.2	5519.2	5508.0	2.0	54.5	5.5	--	--	--	--	--	--	--	--	N	1D HEC-RAS

High Line Canal Road and Trail Crossings - ICON Engineering, Inc.

High Line Canal Crossing Structures			Bridge Data									Culvert Data								Structure Modeled in 2D HEC-RAS (Y/N)	Elevation Data Souce
			Upstream			Downstream															
Station	Location	Type	Low Chord Elevation (ft)	High Chord elevation (ft)	Invert Elevation (ft)	Low Chord Elevation (ft)	High Chord elevation (ft)	Invert Elevation (ft)	Deck Thickness (ft)	Span (ft)	Width Parallel to Flow (ft)	Shape	# of Barrels	Height (ft)	Width (ft)	Upstream Invert Elevation (ft)	Downstream Invert Elevation (ft)	Terrain Centerline Elevation (ft)	Width Parallel to Flow (ft)		
2499+85	S Windemere St Road Crossing	Bridge	5517.71	5519.8	5508.5	5517.6	5519.8	5508.6	2.2	86.0	47.2	--	--	--	--	--	--	--	--	Y	1D HEC-RAS
2510+39	S Crocker Ct Ped Bridge #1	Bridge	5517.76	5520.1	5508.7	5517.8	5520.1	5508.7	2.3	31.5	6.0	--	--	--	--	--	--	--	--	N	1D HEC-RAS
2543+59	S Crocker Ct Ped Bridge #2	Bridge	5518.09	5520.4	5509.3	5518.1	5520.4	5509.3	2.3	32.0	6.0	--	--	--	--	--	--	--	--	N	1D HEC-RAS
2555+17	W Mineral Ave Road Crossing	Culvert	--	--	--	--	--	--	--	--	--	CON/SPAN Arch	1	10.5	34.0	5510.0	5509.9	5528.4	144.8	Y	1D HEC-RAS
2570+64	W Cape Cod Way Ped Crossing	Bridge	5526.05	5529.2	5510.0	5526.1	5529.2	5510.0	3.2	73.0	7.0	--	--	--	--	--	--	--	--	N	1D HEC-RAS
2592+55	West of Southpark Ln Ped Bridge	Bridge	5518.2	5519.2	5510.8	5518.2	5519.2	5510.8	1.0	36.0	9.0	--	--	--	--	--	--	--	--	N	Field Data
2606+88	W County Line Rd Road Crossing	Bridge	5523.74	5526.8	5511.5	5522.0	5525.7	5511.5	3.7	73.5	36.6	--	--	--	--	--	--	--	--	Y	1D HEC-RAS
2611+08	HLC County Line Trailhead Ped Bridge	Bridge	5518.4	5519.9	5511.8	5518.4	5519.9	5511.8	1.5	23.0	10.0	--	--	--	--	--	--	--	--	N	Field Data
2618+99	North of C-470 Centennial Trail Ped Bridge	Bridge	5524.69	5525.5	5511.8	5524.7	5525.5	5511.9	0.8	57.0	12.2	--	--	--	--	--	--	--	--	N	1D HEC-RAS
2674+02	Kendrick Castillo Way Road Crossing	Culvert	--	--	--	--	--	--	--	--	--	Box	1	8.0	20.0	5514.3	5514.1	5523.1	140.2	Y	SWMM
2692+81	Lavanto Ln Ped Bridge	Bridge	5521.2	5522.7	5514.9	5521.2	5522.7	5514.9	1.5	70.0	15.0	--	--	--	--	--	--	--	--	N	Field Data
2716+98	Primo Rd Road Crossing	Culvert	--	--	--	--	--	--	--	--	--	Box	1	7.5	20.0	5514.8	5515.0	5527.1	48.0	Y	SWMM
2722+83	C-470 Road Crossing	Culvert	--	--	--	--	--	--	--	--	--	Box	1	8.0	20.0	5515.7	5515.0	5542.0	354.3	Y	SWMM
2726+34	Plaza Dr Road Crossing	Culvert	--	--	--	--	--	--	--	--	--	Box	1	8.0	20.0	5515.7	5515.6	5529.4	131.2	Y	SWMM
2761+24	Summer Wind Ln Road Crossing	Culvert	--	--	--	--	--	--	--	--	--	Box	1	8.0	32.0	5516.6	5516.6	5529.3	39.1	Y	SWMM
2764+39	University of Denver Golf Club Maintenance Road Crossing	Culvert	--	--	--	--	--	--	--	--	--	Box	1	8.0	22.0	5516.7	5516.5	5528.3	52.8	Y	SWMM
2770+98	University of Denver Golf Club Ped Bridge #1	Bridge	5522.6	5523.6	5516.1	5522.6	5523.6	5516.1	1.0	48.0	9.0	--	--	--	--	--	--	--	--	N	Field Data
2803+51	University of Denver Golf Club Ped Bridge #2	Bridge	5526.3	5527.3	5517.9	5526.3	5527.3	5517.9	1.0	55.0	15.0	--	--	--	--	--	--	--	--	N	Field Data
2828+21	University of Denver Golf Club Ped Bridge #3	Bridge	5523.4	5524.4	5518.1	5523.4	5524.4	5518.1	1.0	45.0	8.0	--	--	--	--	--	--	--	--	N	Field Data
2843+31	US 85 Road Crossing	Culvert	--	--	--	--	--	--	--	--	--	Box	1	8.0	20.0	5519.4	5519.3	5530.4	128.2	Y	SWMM
2860+54	Carder Ct Road Crossing	Culvert	--	--	--	--	--	--	--	--	--	Box	1	8.0	20.0	5520.4	5520.4	5528.7	67.0	Y	SWMM
2901+18	W Brandon Dr Road Crossing	Bridge	5528	5529.2	5521.4	5528.0	5529.9	5521.4	1.9	25.0	33.0	--	--	--	--	--	--	--	--	Y	SWMM
2920+26	Railroad Crossing #1	Bridge	5529.7	5533.1	5521.6	5529.7	5532.7	5521.7	3.4	56.8	15.0	--	--	--	--	--	--	--	--	Y	SWMM
3016+75	Railroad Crossing #2	Bridge	5538	5542.1	5525.2	5538.0	5542.0	5525.2	4.1	55.0	13.3	--	--	--	--	--	--	--	--	Y	SWMM
3033+70	Plum Creek Siphon	Culvert	--	--	--	--	--	--	--	--	--	Circular	1	9.0	9.0	5527.5	5525.0	5540.0	1092.0	Y	SWMM
3153+36	Roxborough Park Rd Road Crossing	Culvert	--	--	--	--	--	--	--	--	--	Box	1	10.0	22.5	5530.7	5530.6	5544.0	50.1	Y	SWMM
3162+50	Lake Breeze Dr Road Crossing	Bridge	5539.5	5542.3	5531.9	5539.5	5542.4	5531.8	2.9	75.0	46.7	--	--	--	--	--	--	--	--	Y	Field Data
3178+73	Bright Sky Ln Road Crossing	Bridge	5540	5542.4	5532.2	5540.0	5542.4	5532.2	2.4	75.0	46.7	--	--	--	--	--	--	--	--	Y	Field Data
3231+55	Private Road Crossing	Bridge	5543.55	5544.5	5535.2	5542.4	5543.7	5535.2	1.3	27.0	14.6	--	--	--	--	--	--	--	--	Y	SWMM
3275+96	W Titan Rd Road Crossing	Culvert	--	--	--	--	--	--	--	--	--	Box	1	8.0	20.0	5535.1	5534.7	5546.1	49.8	Y	SWMM
3297+41	N Rampart Range Rd Road Crossing	Culvert	--	--	--	--	--	--	--	--	--	Box	1	8.0	20.0	5536.8	5536.7	5546.9	37.5	Y	SWMM
3413+86	Campfire St Ped Bridge	Bridge	5554.1	5555.1	5540.1	5554.1	5555.1	5540.1	1.0	83.0	8.0	--	--	--	--	--	--	--	--	N	Field Data
3432+21	Waterton Rd Road Crossing	Culvert	--	--	--	--	--	--	--	--	--	Box	1	8.0	20.0	5540.7	5540.7	5552.5	174.0	Y	SWMM
3437+32	Dante Dr Road Crossing	Culvert	--	--	--	--	--	--	--	--	--	Box	1	8.5	18.0	5540.9	5540.9	5556.7	123.0	Y	SWMM
3446+42	Dante Dr Ped Bridge	Bridge	5555.4	5556.4	5541.7	5555.4	5556.4	5541.7	1.0	80.0	12.0	--	--	--	--	--	--	--	--	N	Field Data

APPENDIX D: MITIGATION ALTERNATIVE FIGURES



ICON ENGINEERING

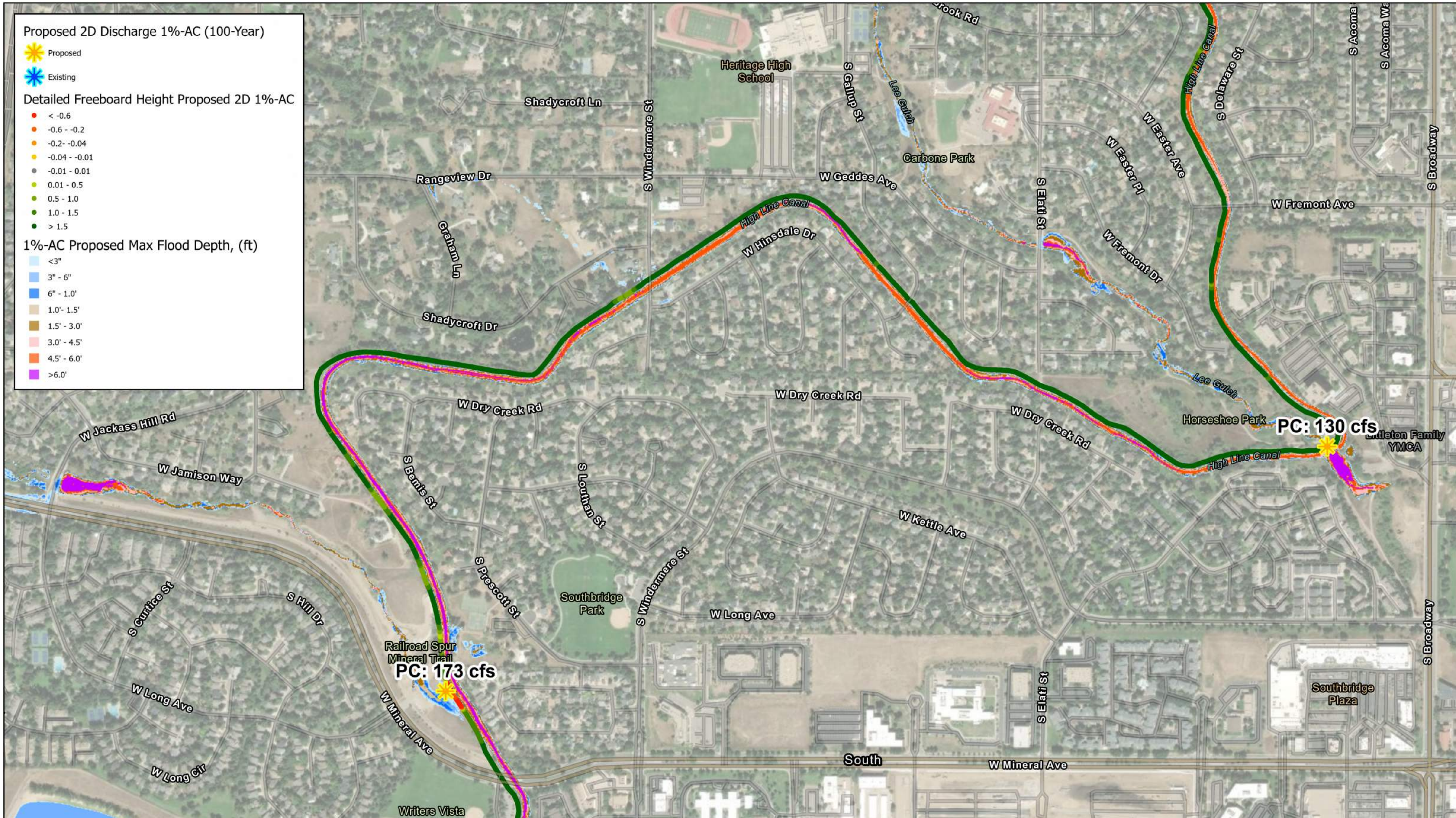
MHFD MILE HIGH FLOOD DISTRICT

ARAPAHOE COUNTY

HLC STAMP

Arapahoe County Existing Conditions

Alternative 1
Construct Spillway into Jackass Gulch

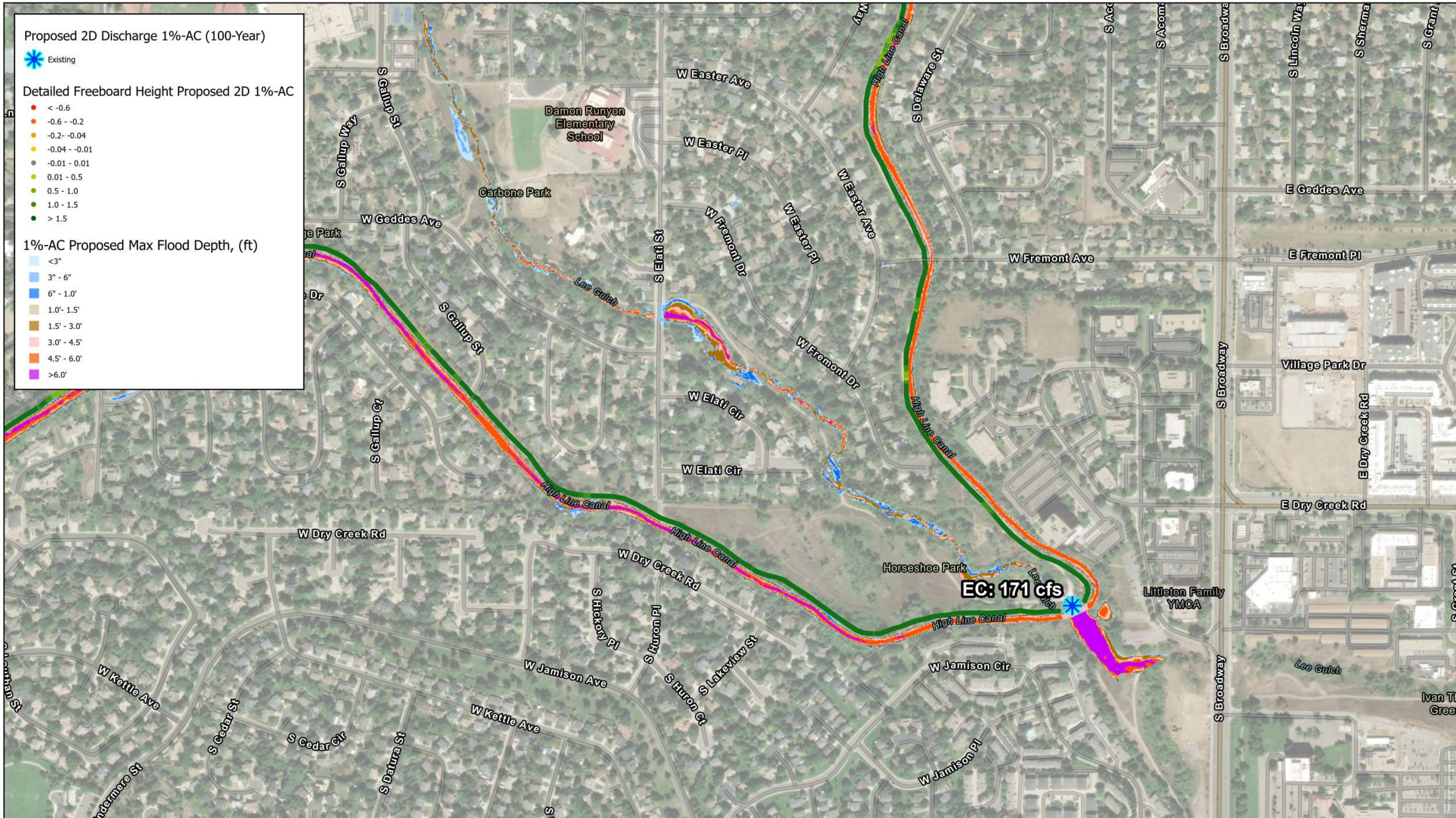


ICON ENGINEERING | MHFD MILE HIGH FLOOD DISTRICT | ARAPAHOE COUNTY

HLC STAMP

Arapahoe County Proposed Conditions

Alternative 1
Construct Spillway into Jackass Gulch



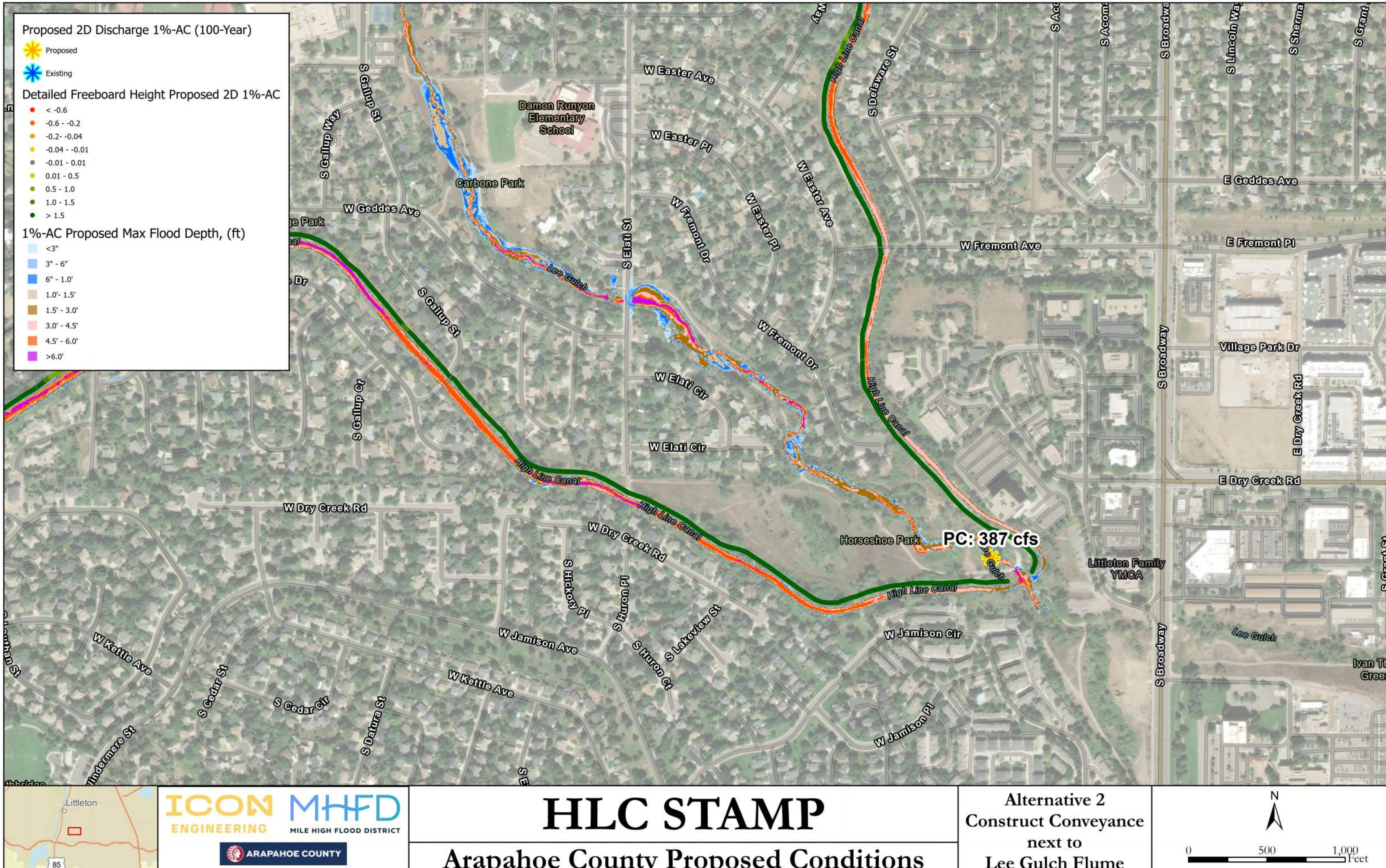
ICON ENGINEERING | MHFD MILE HIGH FLOOD DISTRICT | ARAPAHOE COUNTY

HLC STAMP

Arapahoe County Existing Conditions

Alternative 2
Construct Conveyance next to Lee Gulch Flume

N
0 500 1,000 Feet



ICON ENGINEERING

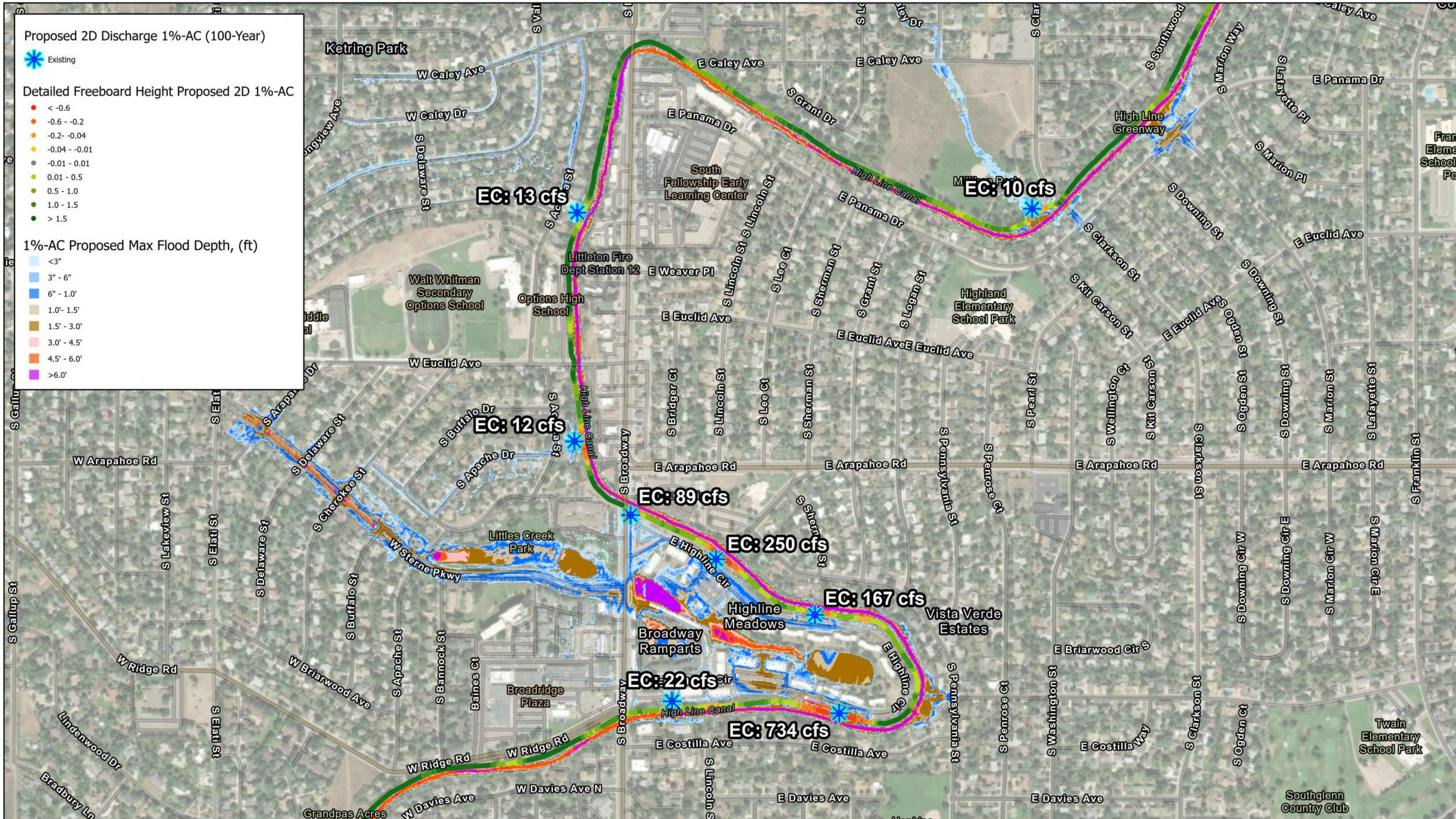
MHFD MILE HIGH FLOOD DISTRICT

ARAPAHOE COUNTY

HLC STAMP

Arapahoe County Proposed Conditions

Alternative 2
Construct Conveyance
next to
Lee Gulch Flume

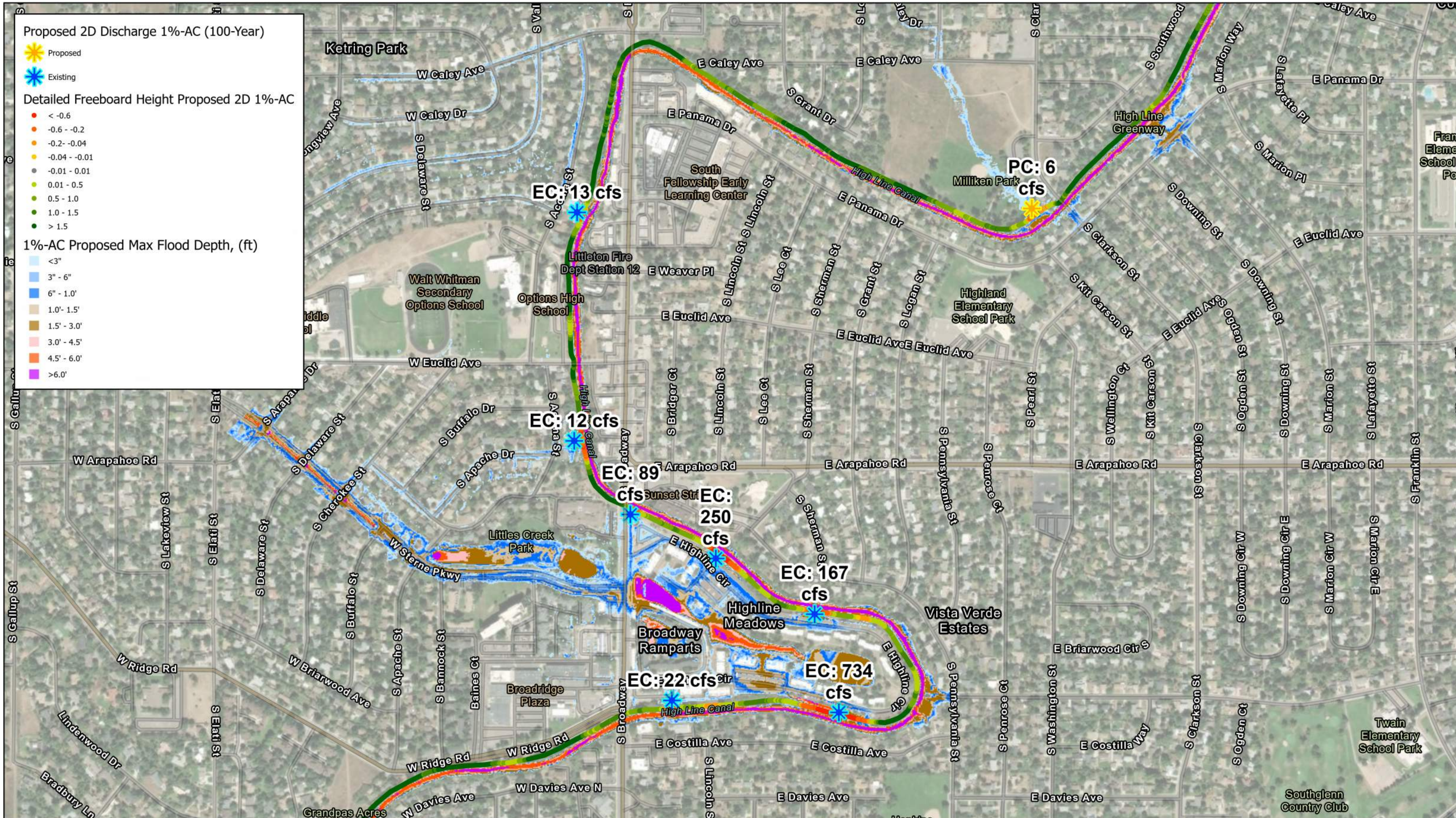


ICON ENGINEERING | MHFD MILE HIGH FLOOD DISTRICT | ARAPAHOE COUNTY

HLC STAMP

Arapahoe County Existing Conditions

Alternative 3
Treatment Drain at Littles Creek



ICON ENGINEERING

MHFD MILE HIGH FLOOD DISTRICT

ARAPAHOE COUNTY

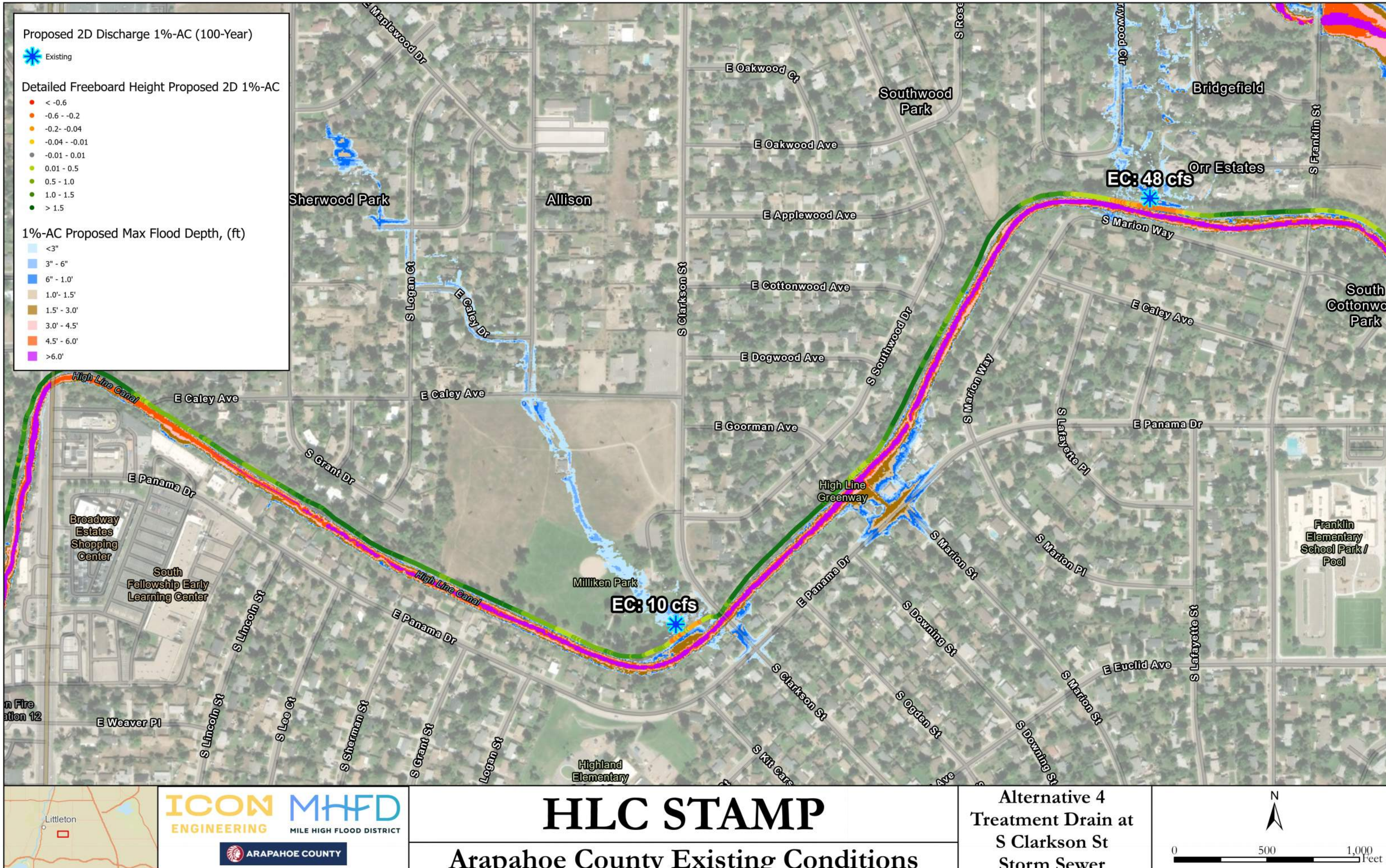
HLC STAMP

Arapahoe County Proposed Conditions

Alternative 3 Treatment Drain at Littles Creek

N

0 500 1,000 Feet

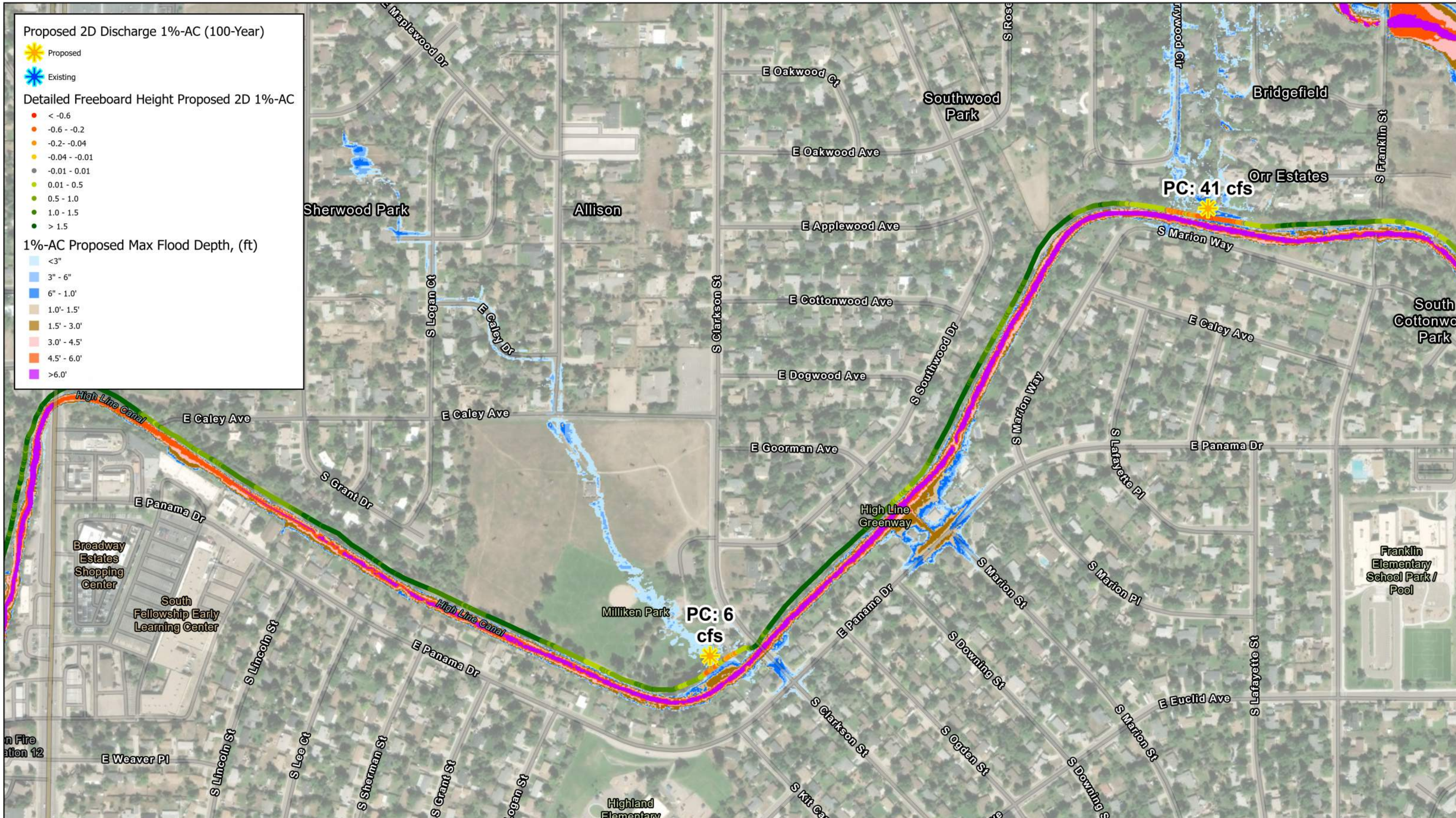


ICON ENGINEERING | MHFD MILE HIGH FLOOD DISTRICT | ARAPAHOE COUNTY

HLC STAMP

Arapahoe County Existing Conditions

Alternative 4 Treatment Drain at S Clarkson St Storm Sewer



ICON ENGINEERING
MHFD MILE HIGH FLOOD DISTRICT
ARAPAHOE COUNTY

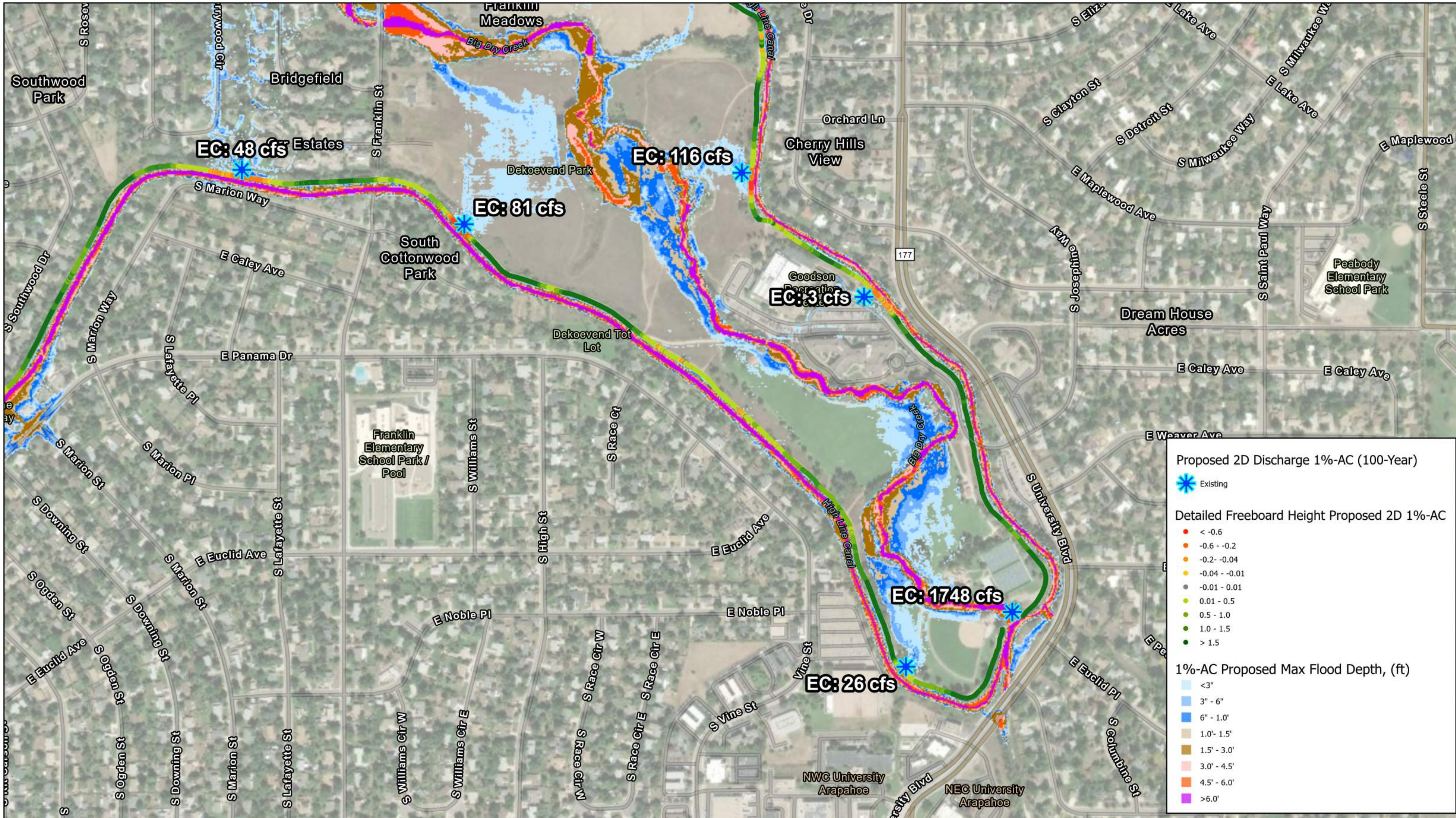
HLC STAMP

Arapahoe County Proposed Conditions

Alternative 4 Treatment Drain at S Clarkson St Storm Sewer

N

0 500 1,000 Feet



Littleton

ICON ENGINEERING

MHFD MILE HIGH FLOOD DISTRICT

ARAPAHOE COUNTY

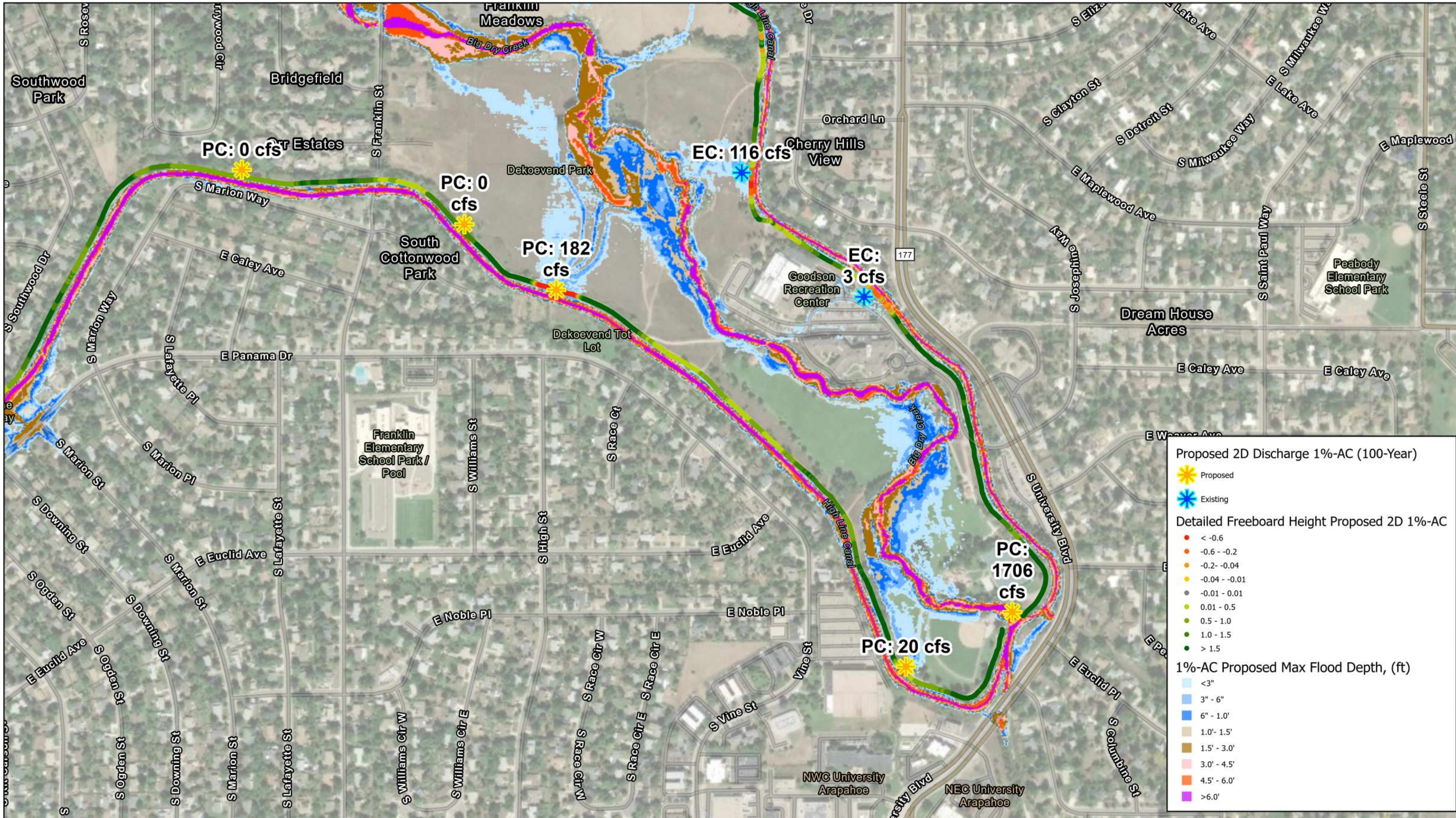
HLC STAMP

Arapahoe County Existing Conditions

Alternative 5
Construct Spillway into Big Dry Creek Open Space

N

0 500 1,000 Feet



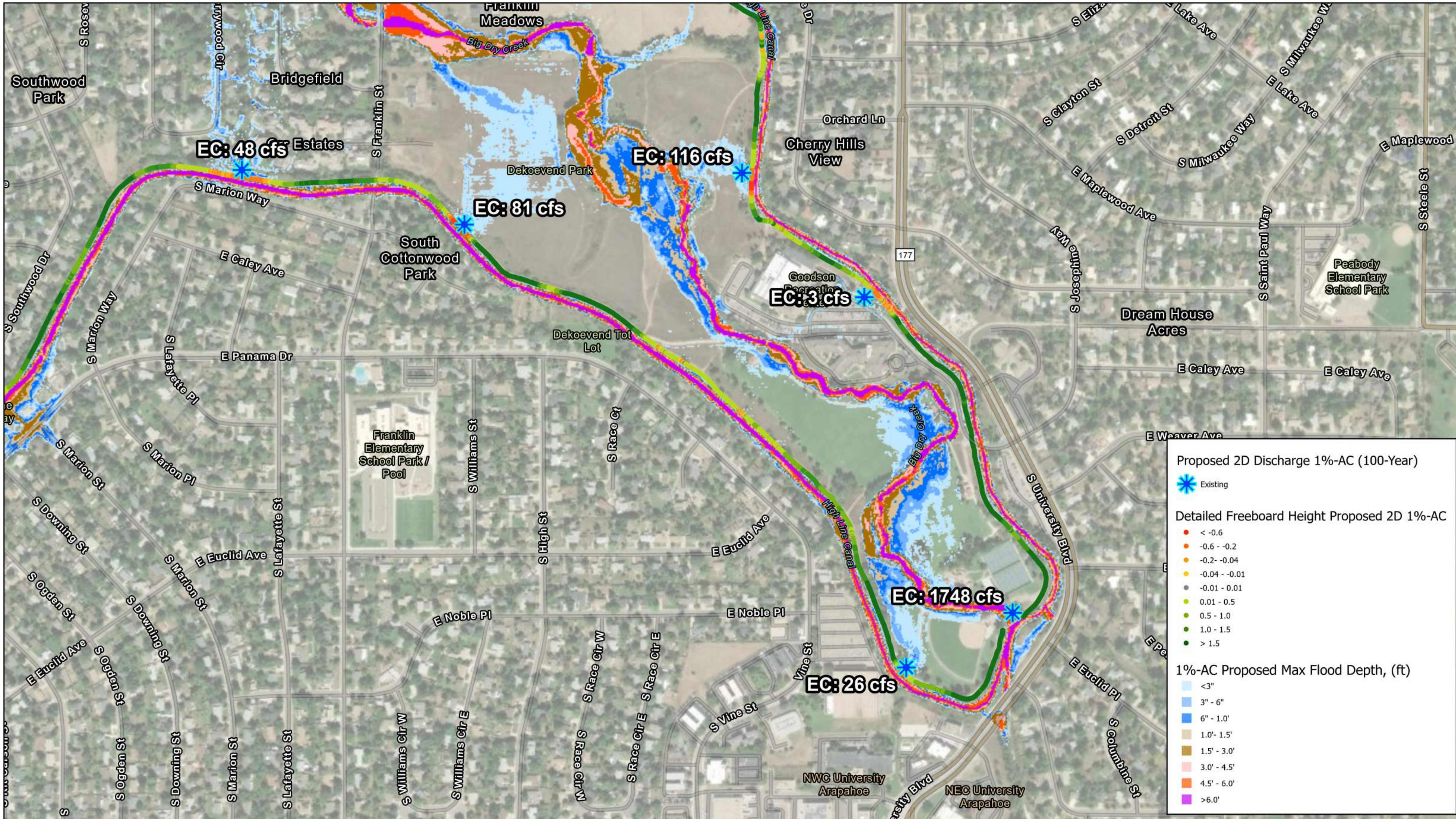
ICON ENGINEERING | MHFD MILE HIGH FLOOD DISTRICT | ARAPAHOE COUNTY

HLC STAMP

Arapahoe County Proposed Conditions

Alternative 5
Construct Spillway into Big Dry Creek Open Space

N
0 500 1,000 Feet



ICON ENGINEERING

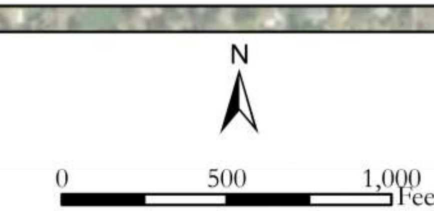
MHFD MILE HIGH FLOOD DISTRICT

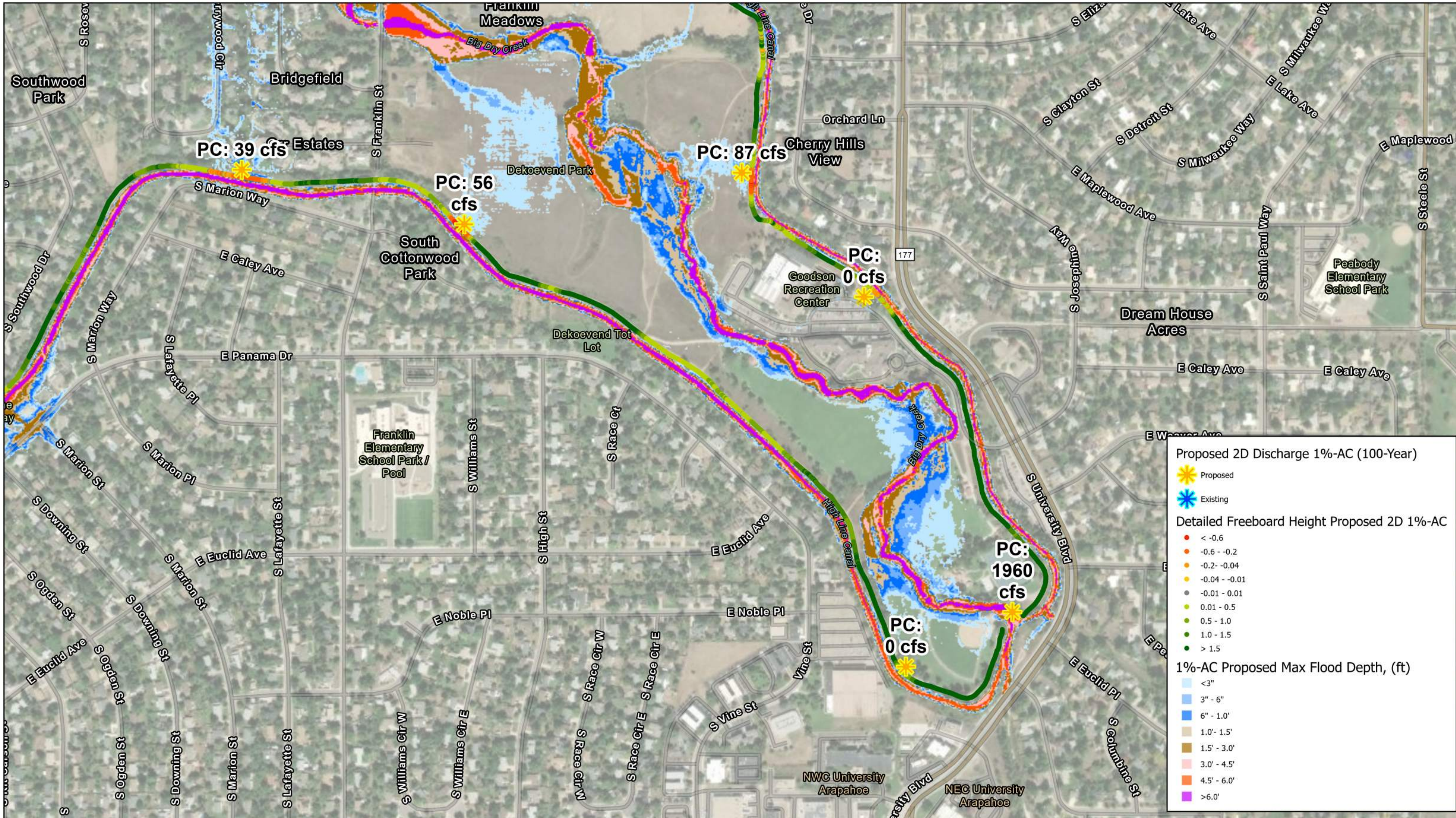
ARAPAHOE COUNTY

HLC STAMP

Arapahoe County Existing Conditions

Alternative 6
Construct Conveyance into Big Dry Creek





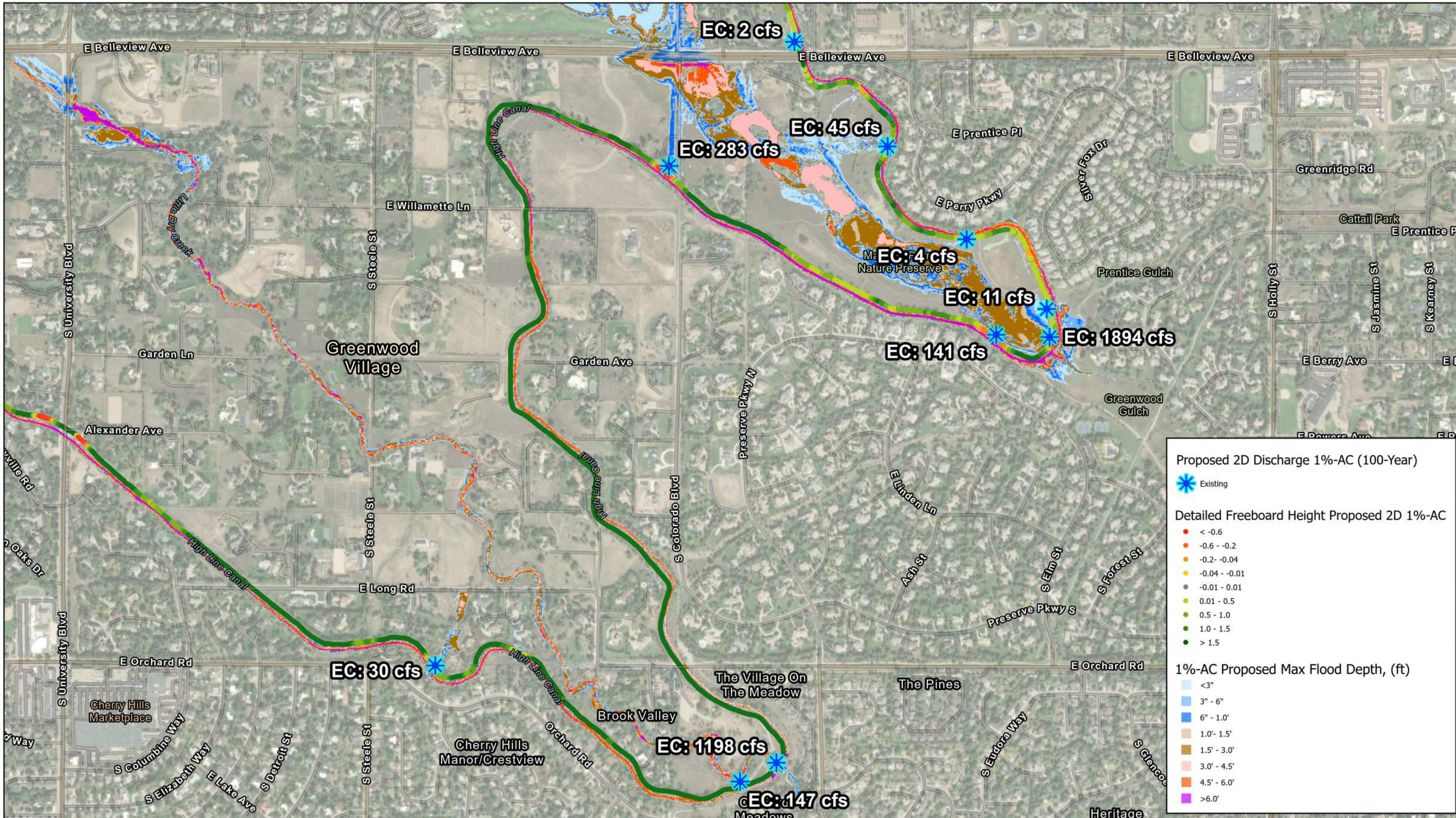
ICON ENGINEERING | MHFD MILE HIGH FLOOD DISTRICT | ARAPAHOE COUNTY

HLC STAMP

Arapahoe County Proposed Conditions

Alternative 6
Construct Conveyance into Big Dry Creek

N
0 500 1,000 Feet

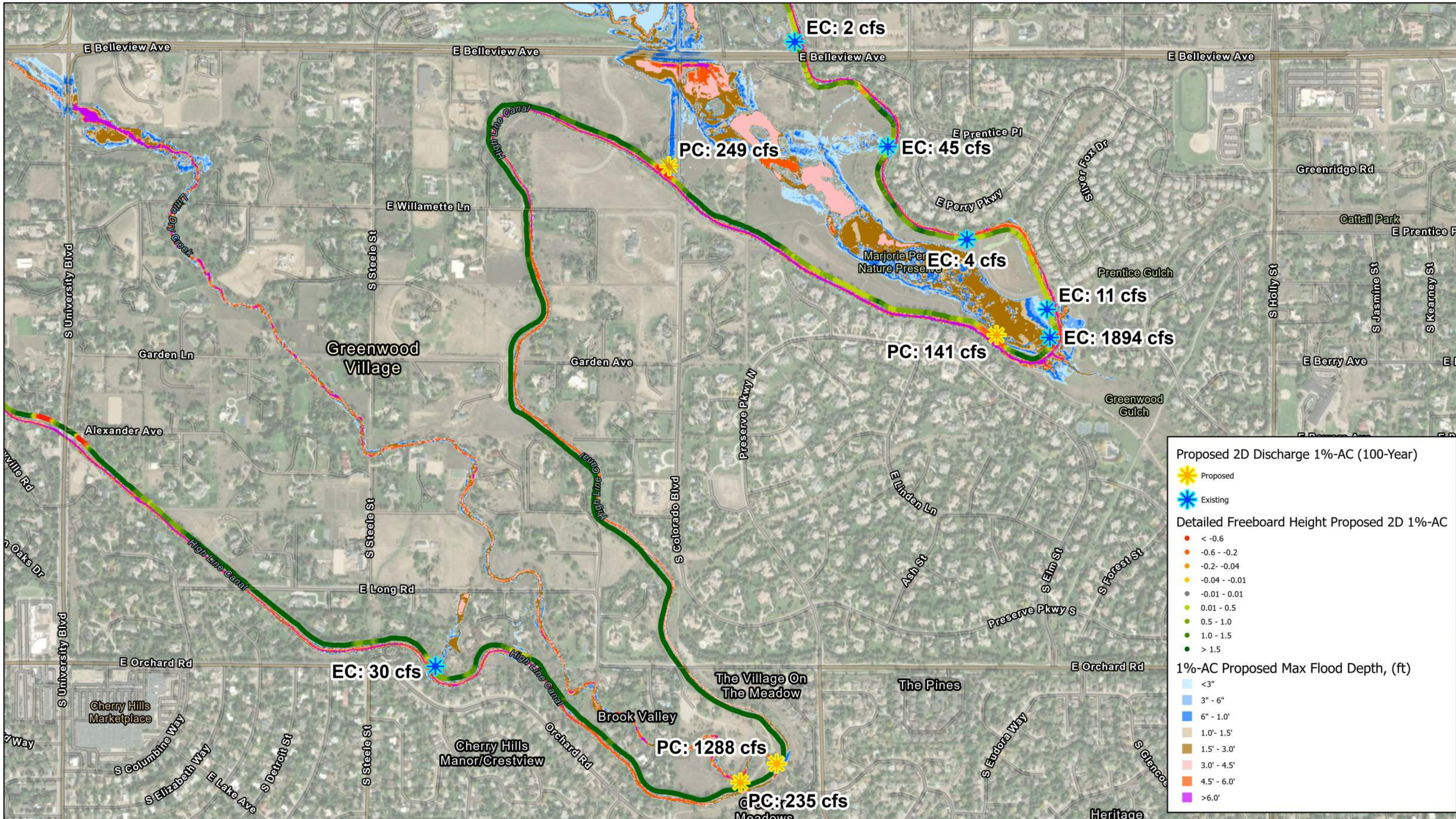


HLC STAMP

Arapahoe County Existing Conditions

Alternative 7
Construct Conveyance into Little Dry Creek

N
0 1,000 2,000 Feet

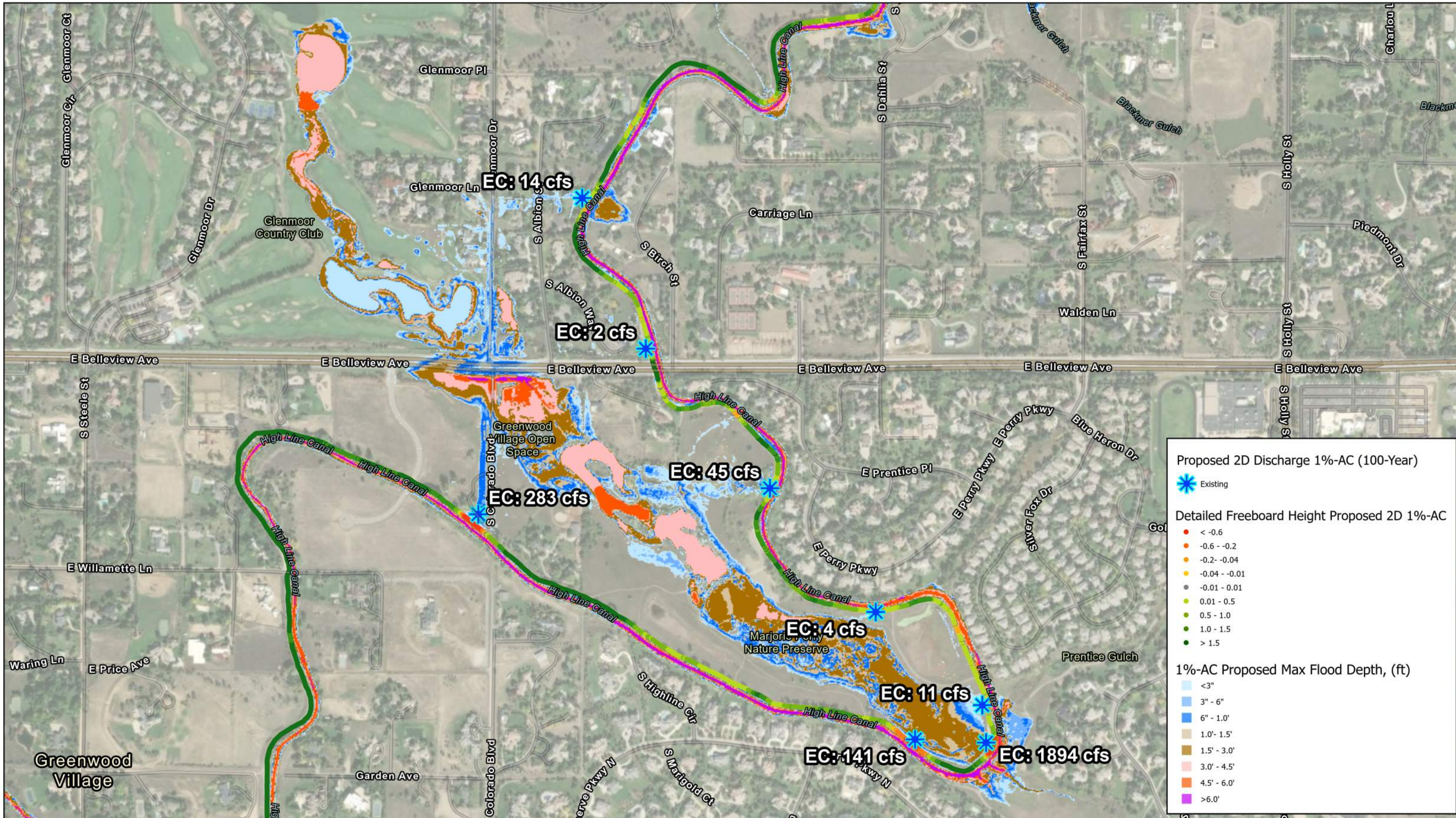


ICON ENGINEERING | MHFD MILE HIGH FLOOD DISTRICT | ARAPAHOE COUNTY

HLC STAMP

Arapahoe County Proposed Conditions

Alternative 7
Construct Conveyance into Little Dry Creek



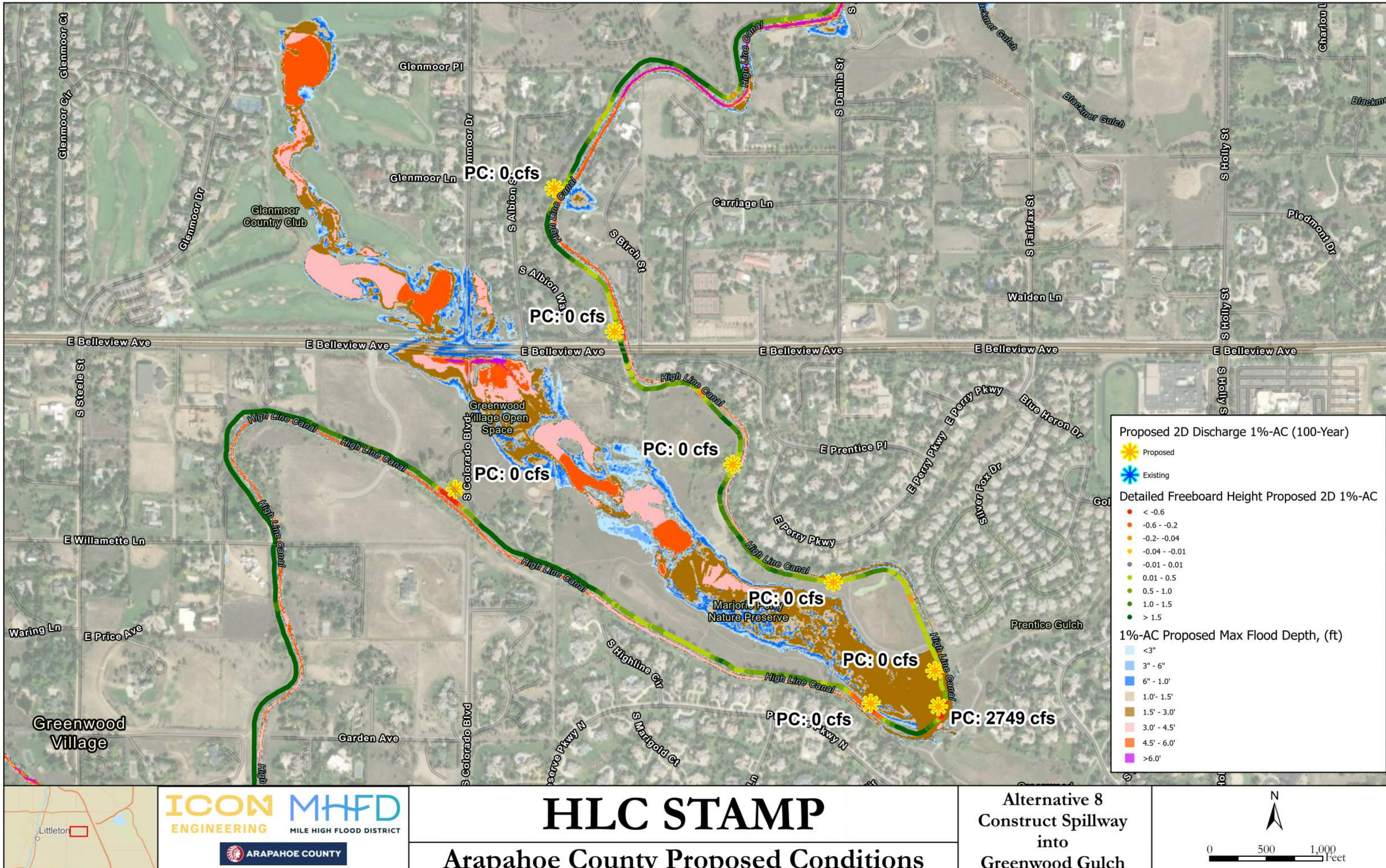
ICON ENGINEERING
MHFD MILE HIGH FLOOD DISTRICT
ARAPAHOE COUNTY

HLC STAMP

Arapahoe County Existing Conditions

Alternative 8
Construct Spillway into Greenwood Gulch

N
0 500 1,000 Feet

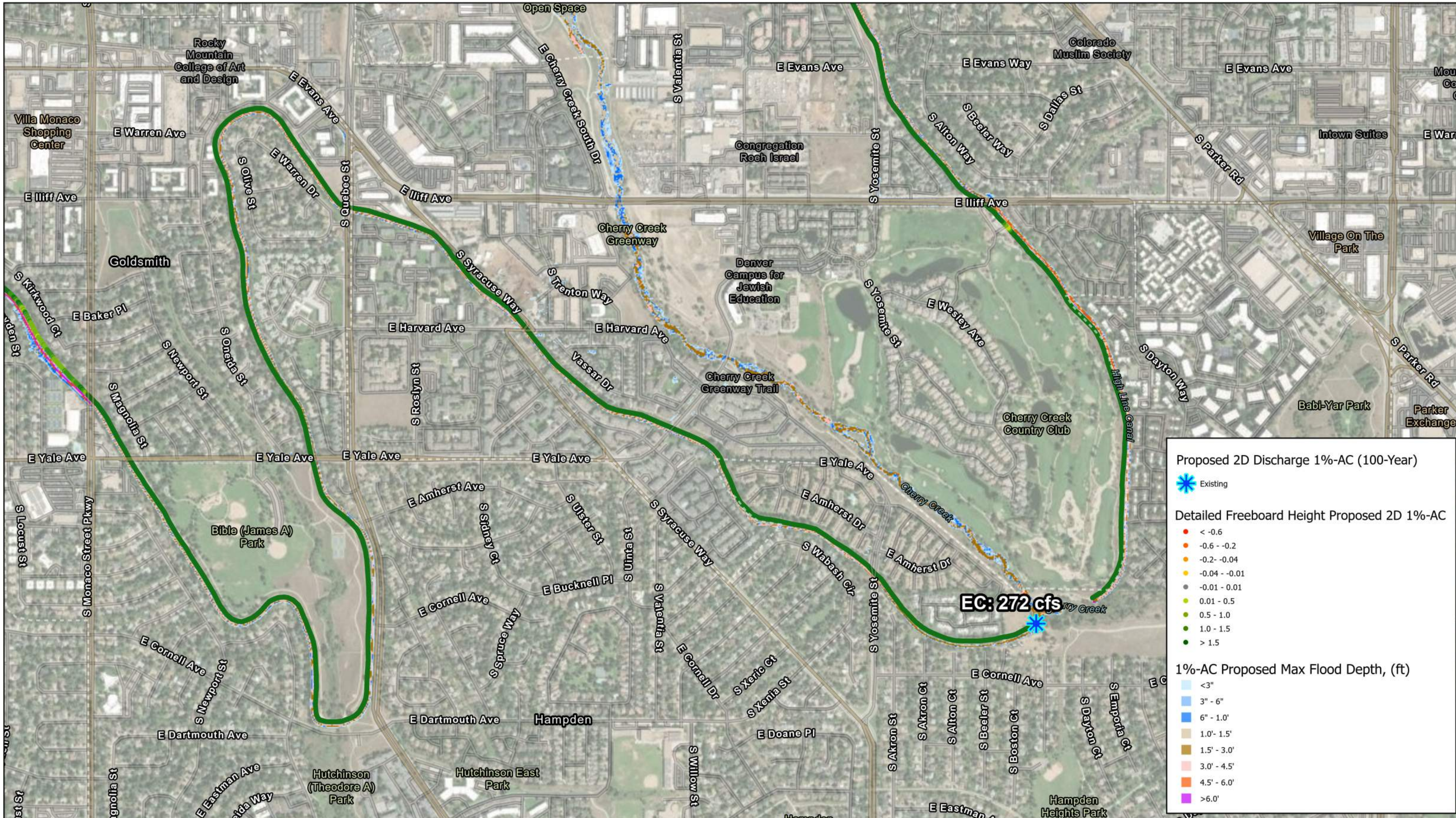


ICON ENGINEERING | MHFD MILE HIGH FLOOD DISTRICT | ARAPAHOE COUNTY

HLC STAMP

Arapahoe County Proposed Conditions

Alternative 8
Construct Spillway into Greenwood Gulch



ICON ENGINEERING | MHFD MILE HIGH FLOOD DISTRICT | ARAPAHOE COUNTY

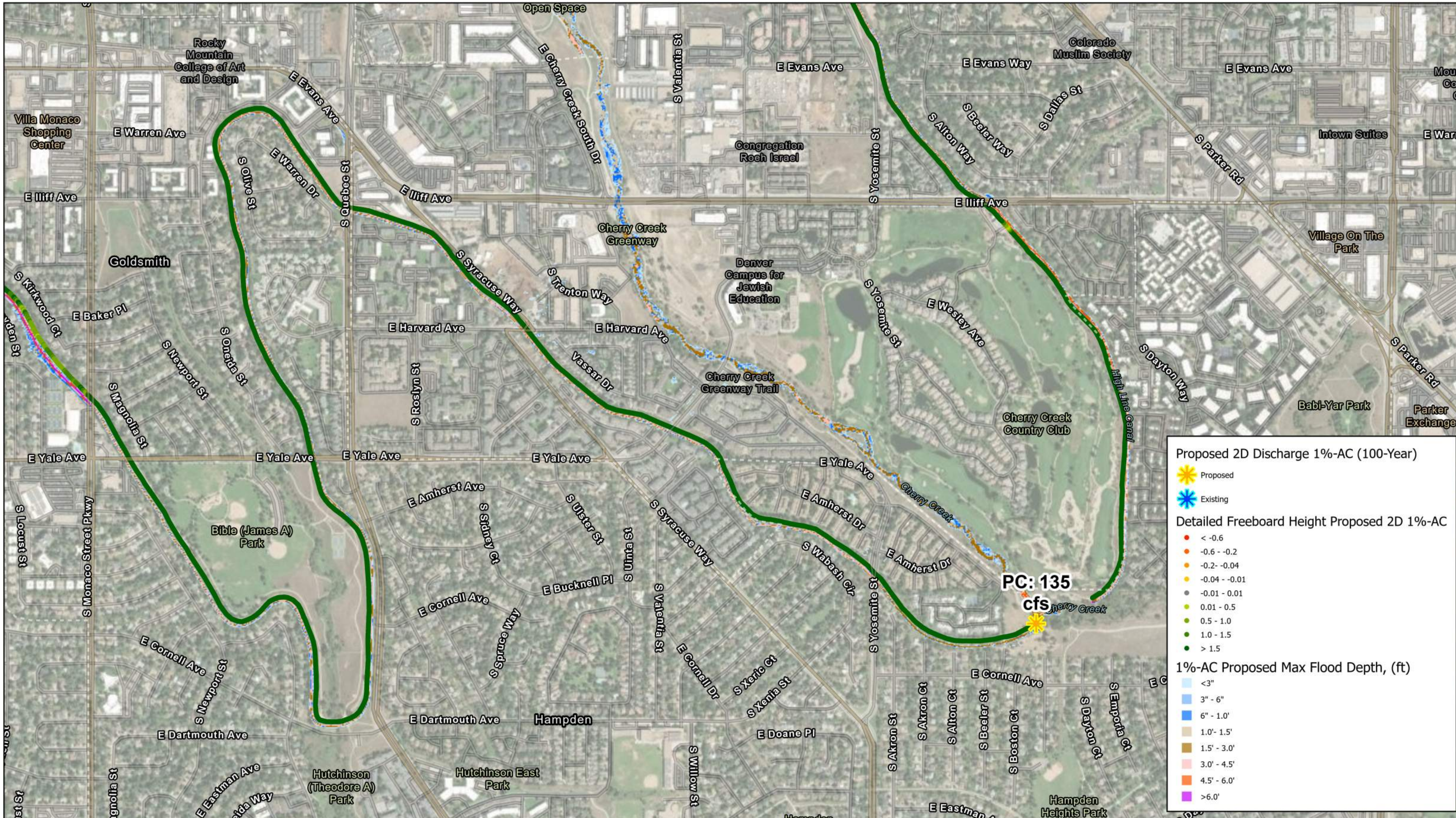
HLC STAMP

Arapahoe County Existing Conditions

Alternative 9
Treatment Drain at
E Harvard Ave
Storm Sewer

N

0 1,000 2,000 Feet



ICON ENGINEERING

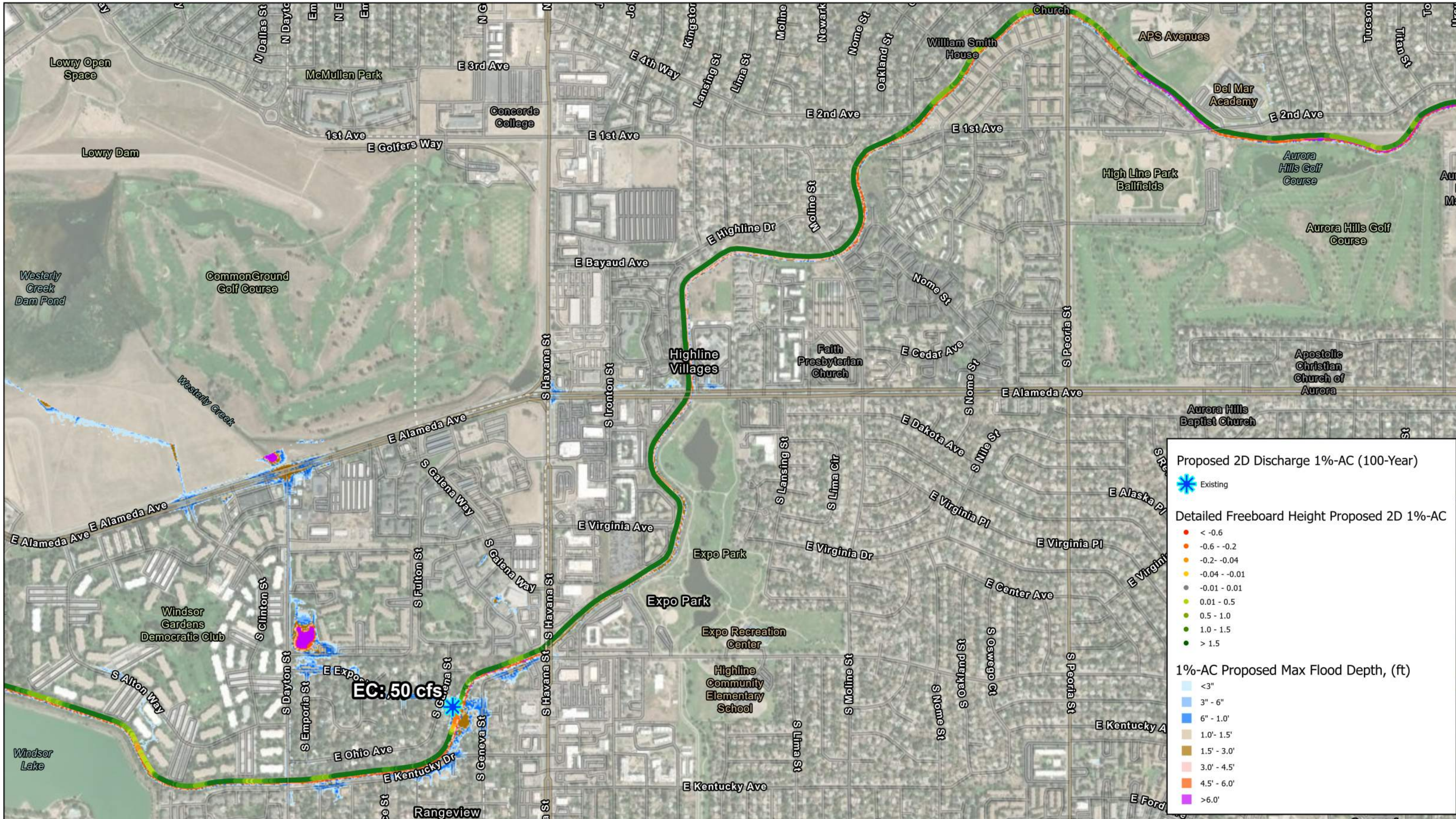
MHFD MILE HIGH FLOOD DISTRICT

ARAPAHOE COUNTY

HLC STAMP

Arapahoe County Proposed Conditions

Alternative 9
Treatment Drain at
E Harvard Ave
Storm Sewer



ICON ENGINEERING

MHFD MILE HIGH FLOOD DISTRICT

ARAPAHOE COUNTY

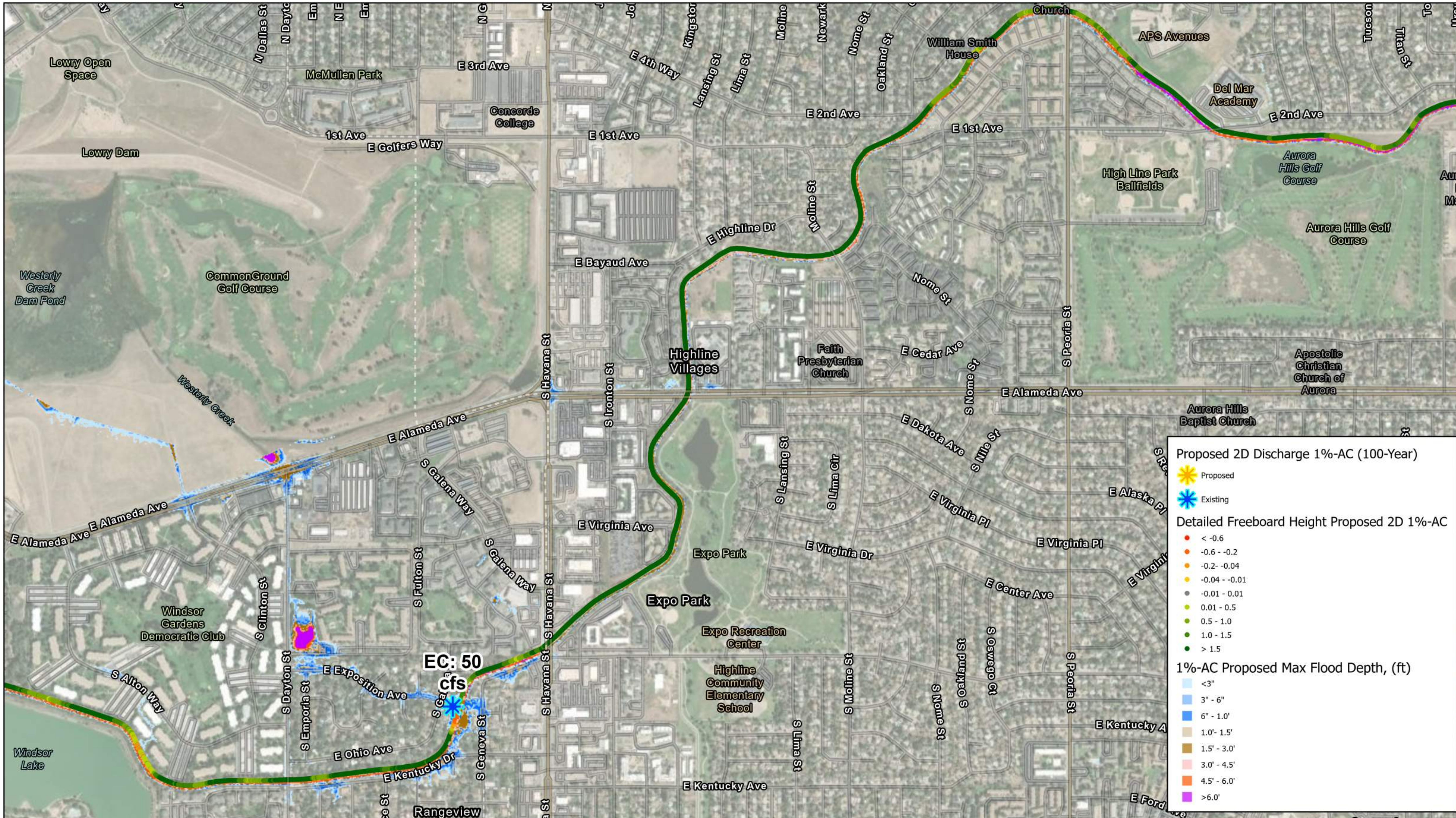
HLC STAMP

Arapahoe County Existing Conditions

Alternative 11
Treatment Drain at
E Alameda Ave
Storm Sewer

N

0 1,000 2,000 Feet



ICON ENGINEERING

MHFD MILE HIGH FLOOD DISTRICT

ARAPAHOE COUNTY

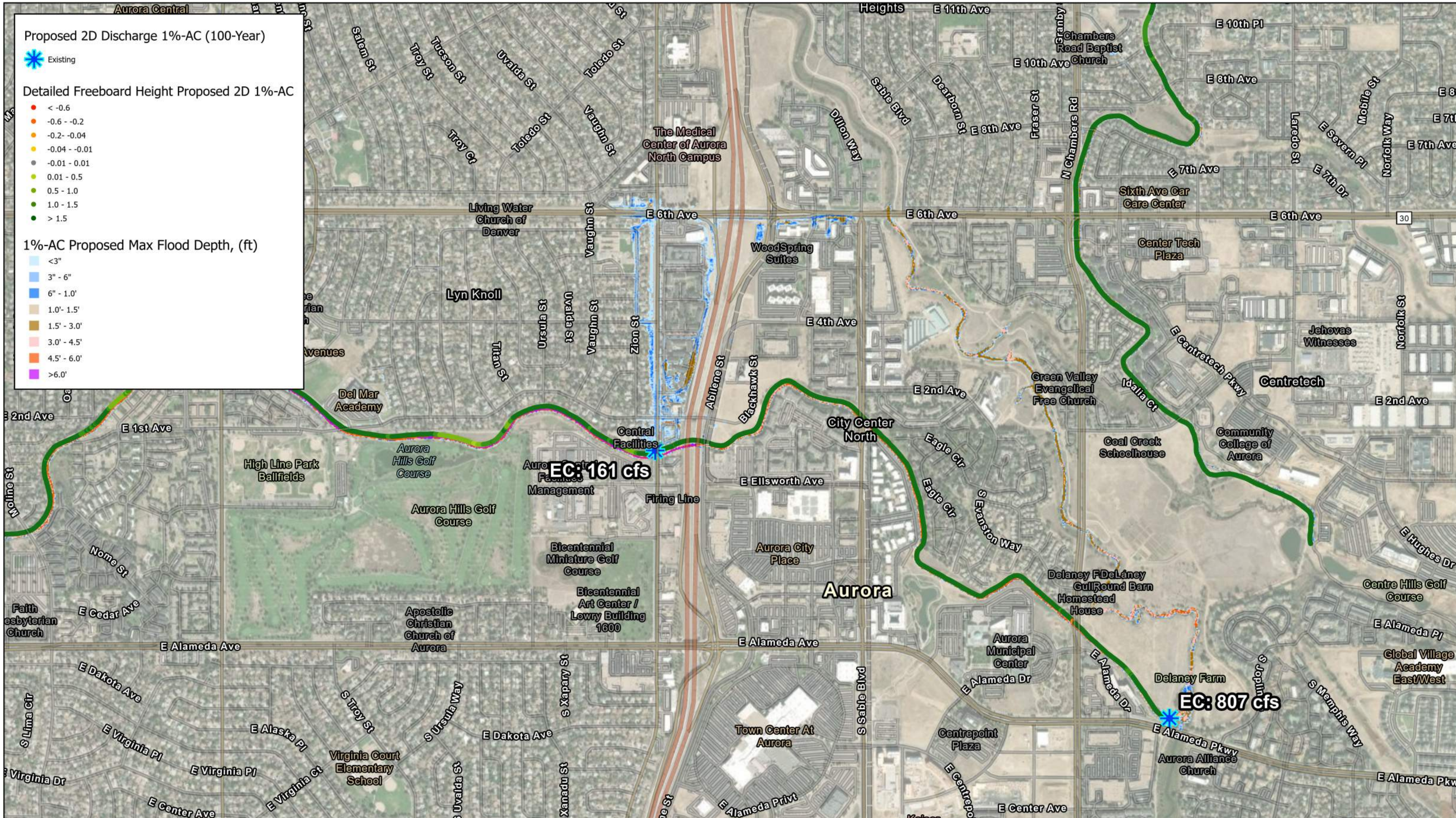
HLC STAMP

Arapahoe County Proposed Conditions

Alternative 11
Treatment Drain at
E Alameda Ave
Storm Sewer

N

0 1,000 2,000 Feet



ICON ENGINEERING

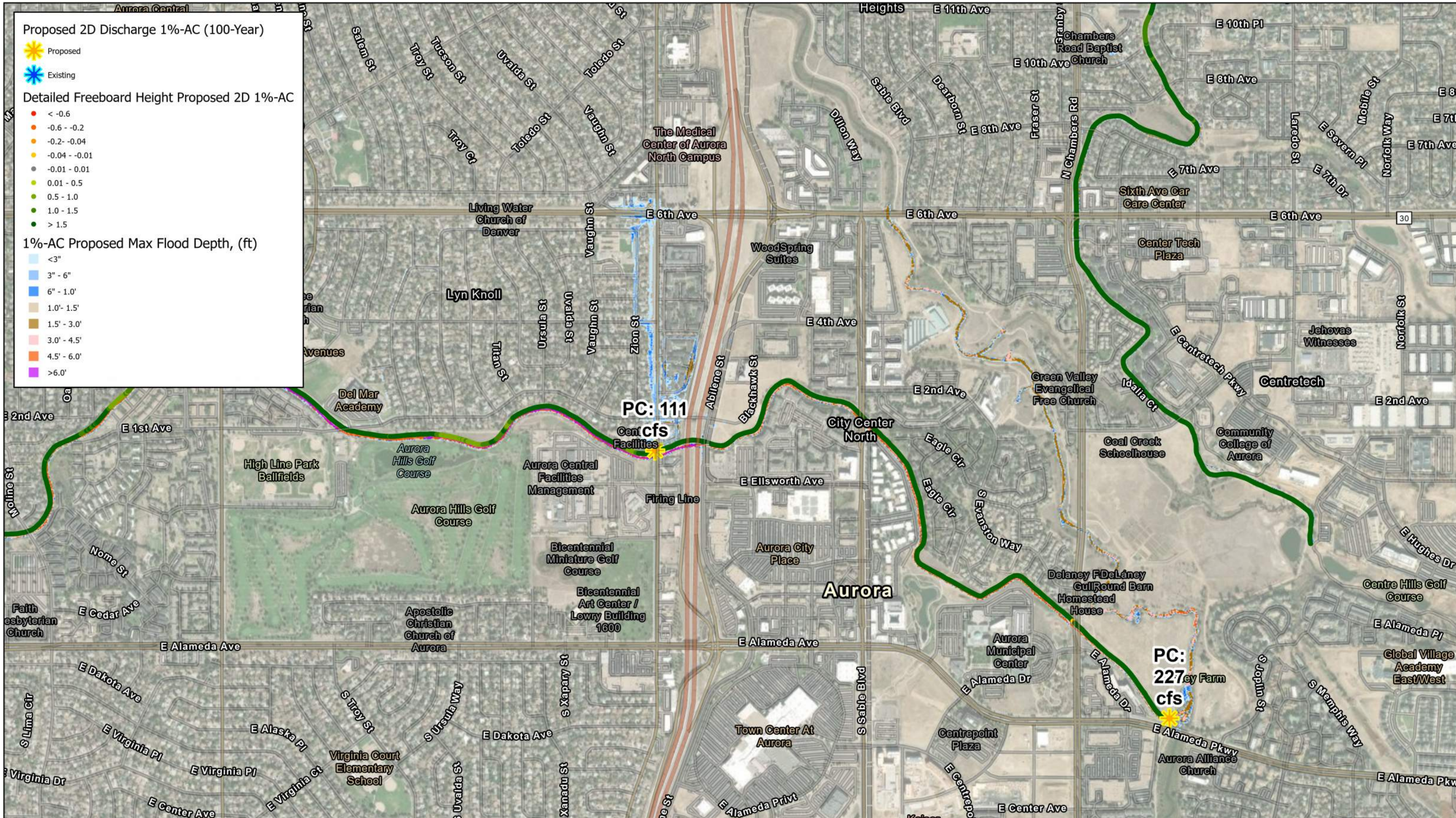
MHFD MILE HIGH FLOOD DISTRICT

ARAPAHOE COUNTY

HLC STAMP

Arapahoe County Existing Conditions

Alternative 12
Treatment Drain at
Potomac St



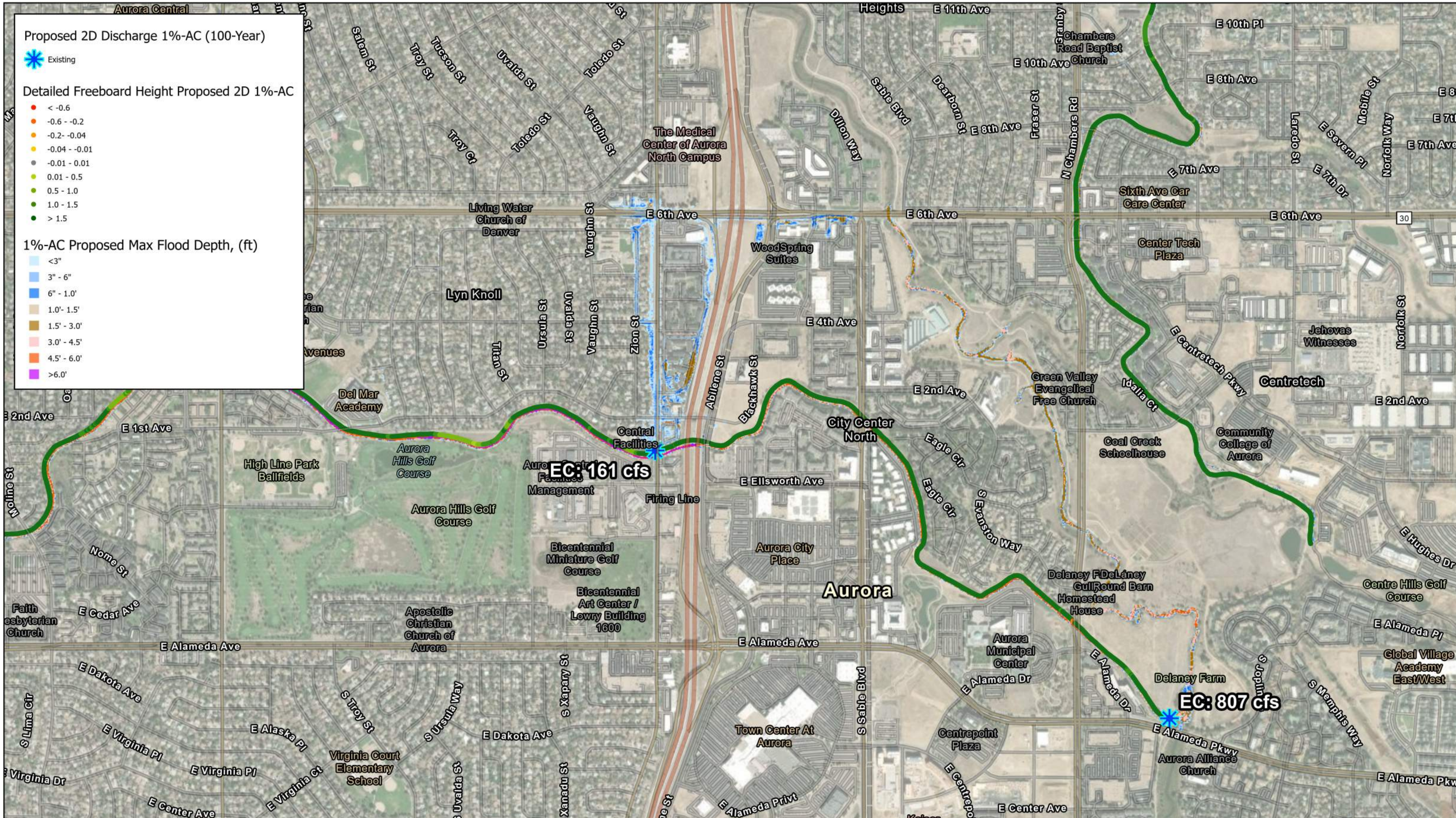
ICON ENGINEERING
MHFD MILE HIGH FLOOD DISTRICT
ARAPAHOE COUNTY

HLC STAMP

Arapahoe County Proposed Conditions

Alternative 12
Treatment Drain at
Potomac St

N
0 1,000 2,000 Feet



ICON ENGINEERING | MHFD MILE HIGH FLOOD DISTRICT | ARAPAHOE COUNTY

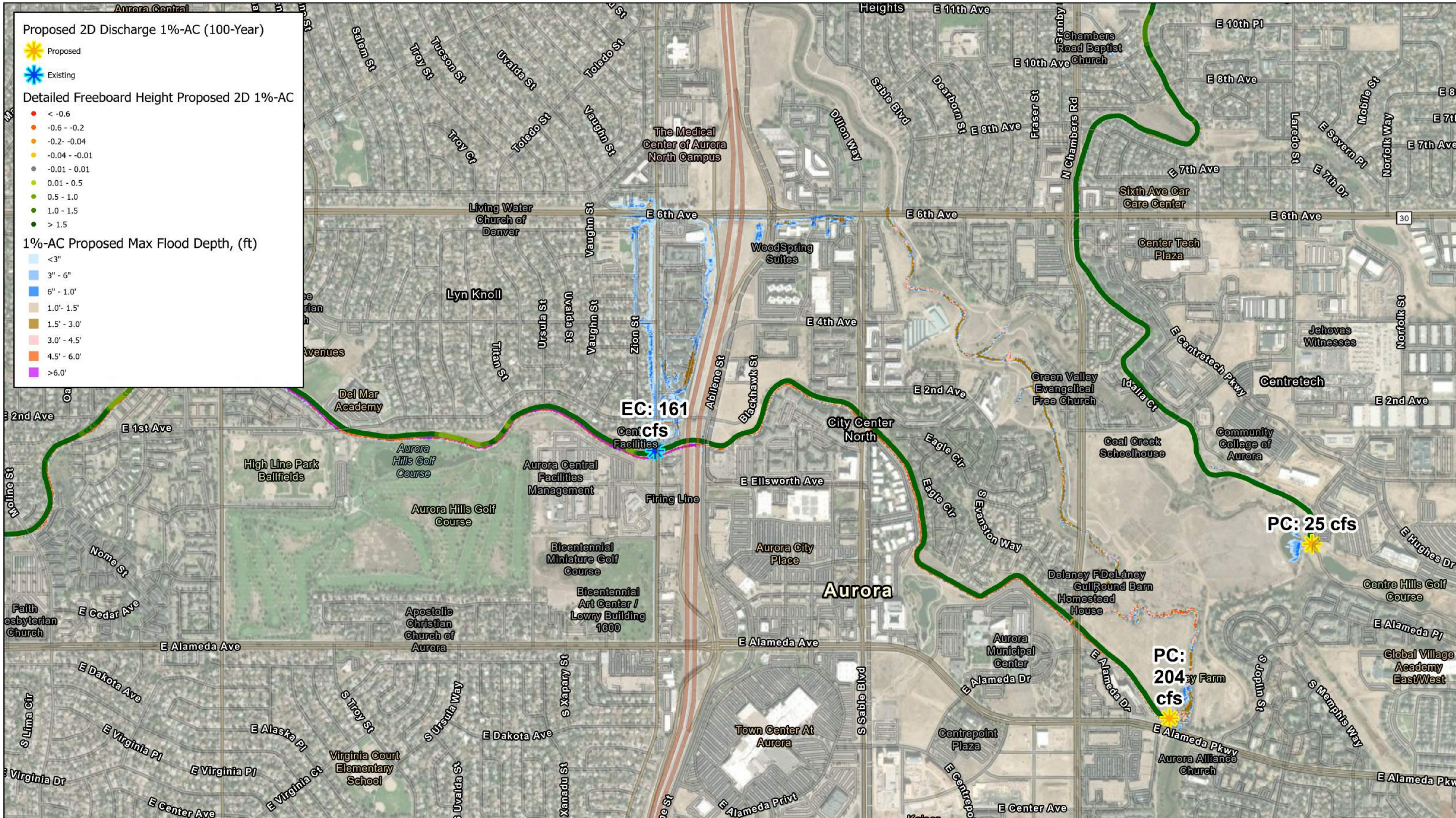
HLC STAMP

Arapahoe County Existing Conditions

Alternative 13
Construct Conveyance at West Toll Gate Creek

N

0 1,000 2,000 Feet



ICON ENGINEERING

MHFD MILE HIGH FLOOD DISTRICT

ARAPAHOE COUNTY

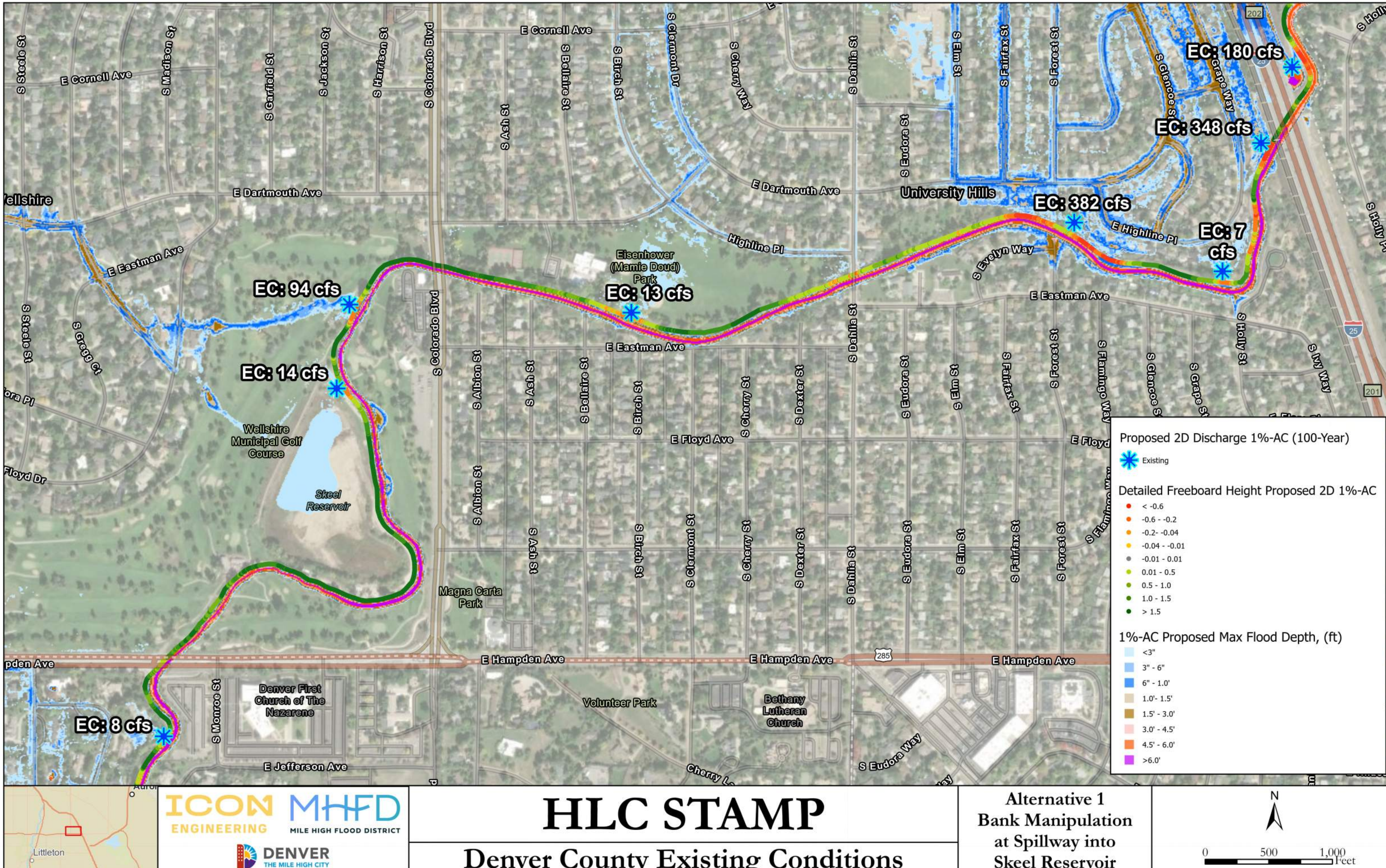
HLC STAMP

Arapahoe County Proposed Conditions

Alternative 13 Construct Conveyance at West Toll Gate Creek

N

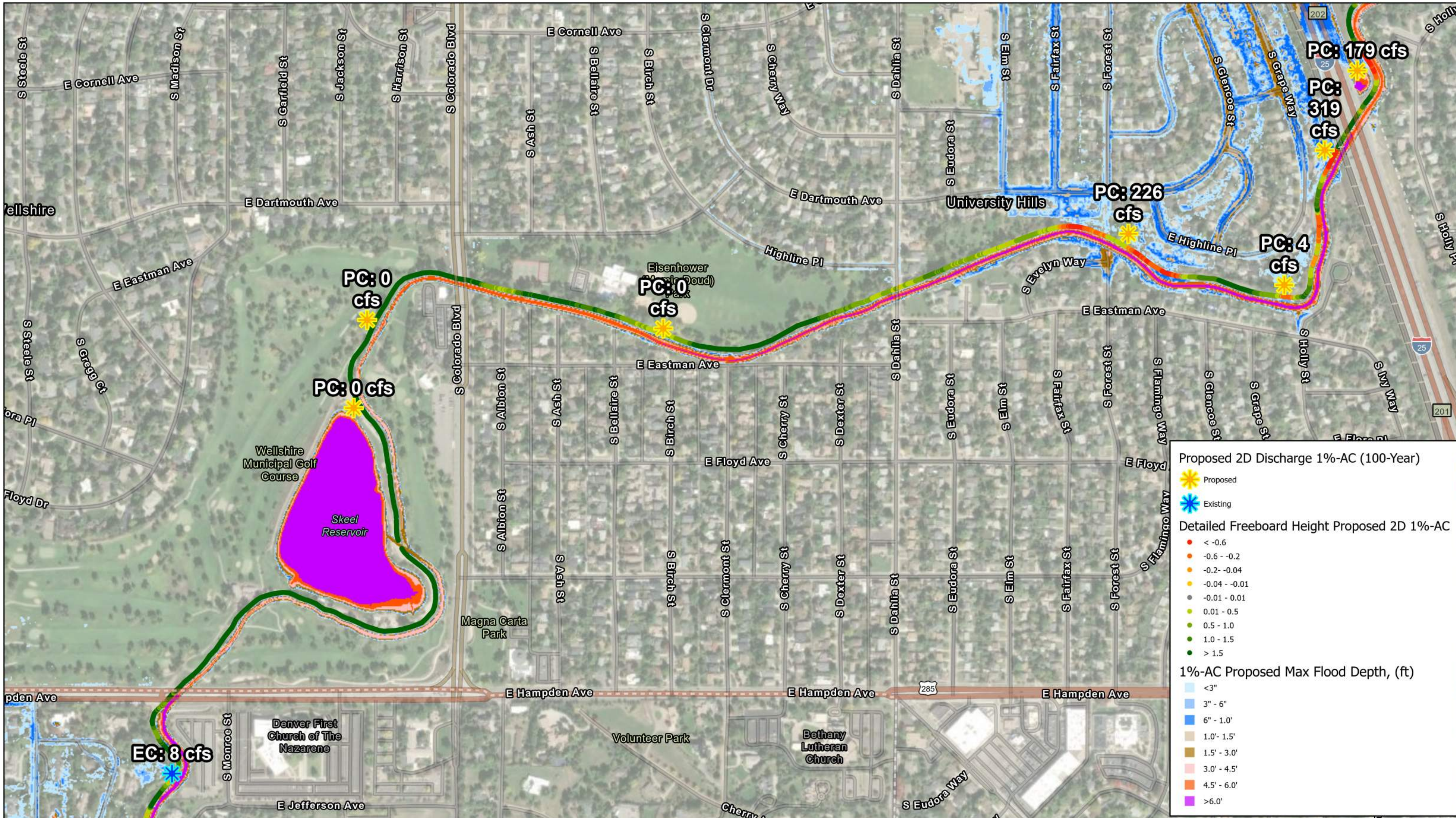
0 1,000 2,000 Feet



HLC STAMP

Denver County Existing Conditions

Alternative 1
Bank Manipulation
at Spillway into
Skeel Reservoir



Littleton

ICON ENGINEERING | MHFD MILE HIGH FLOOD DISTRICT | DENVER THE MILE HIGH CITY

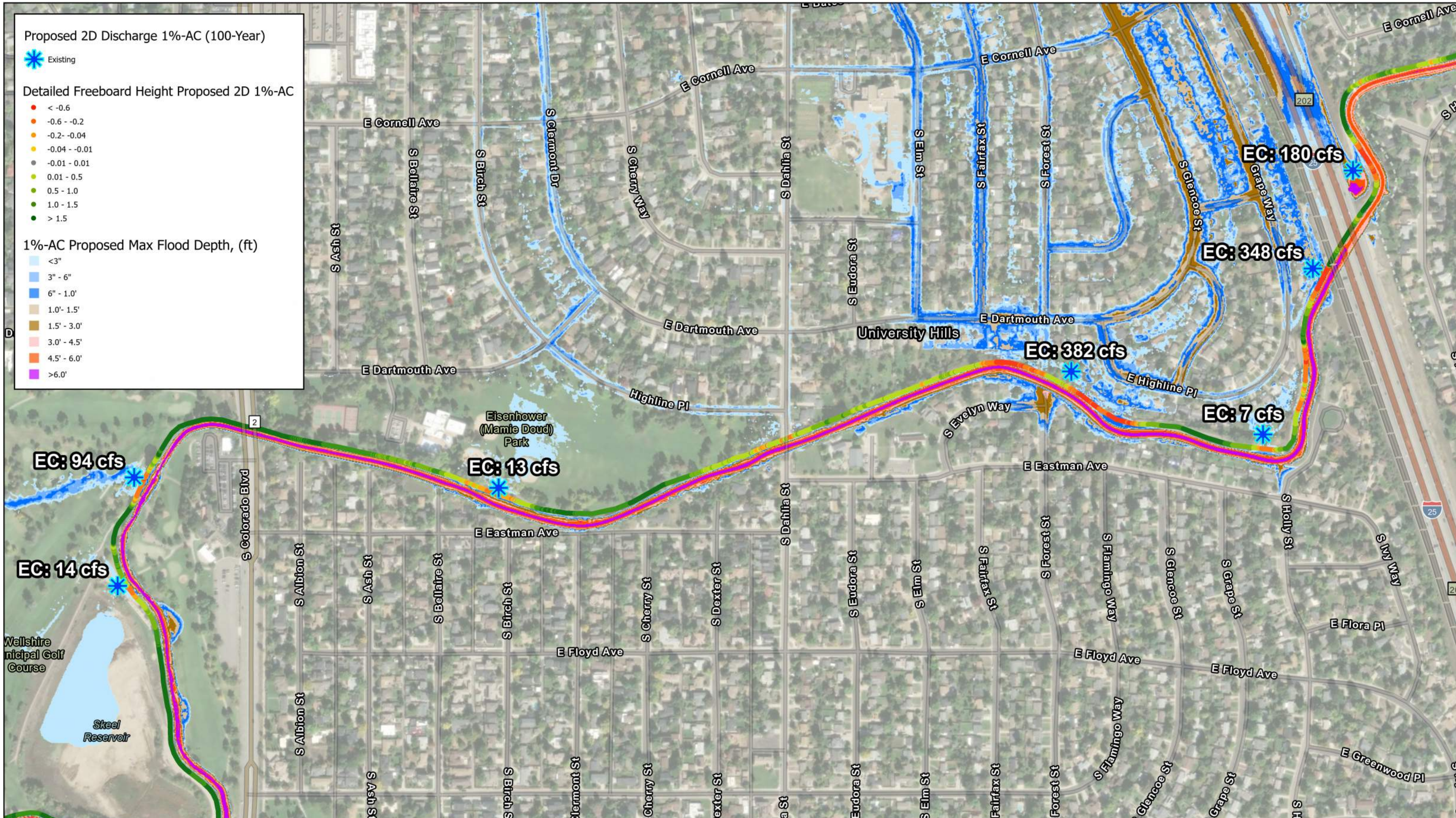
HLC STAMP

Denver County Proposed Conditions

Alternative 1
Bank Manipulation at Spillway into Skeel Reservoir

N

0 500 1,000 Feet



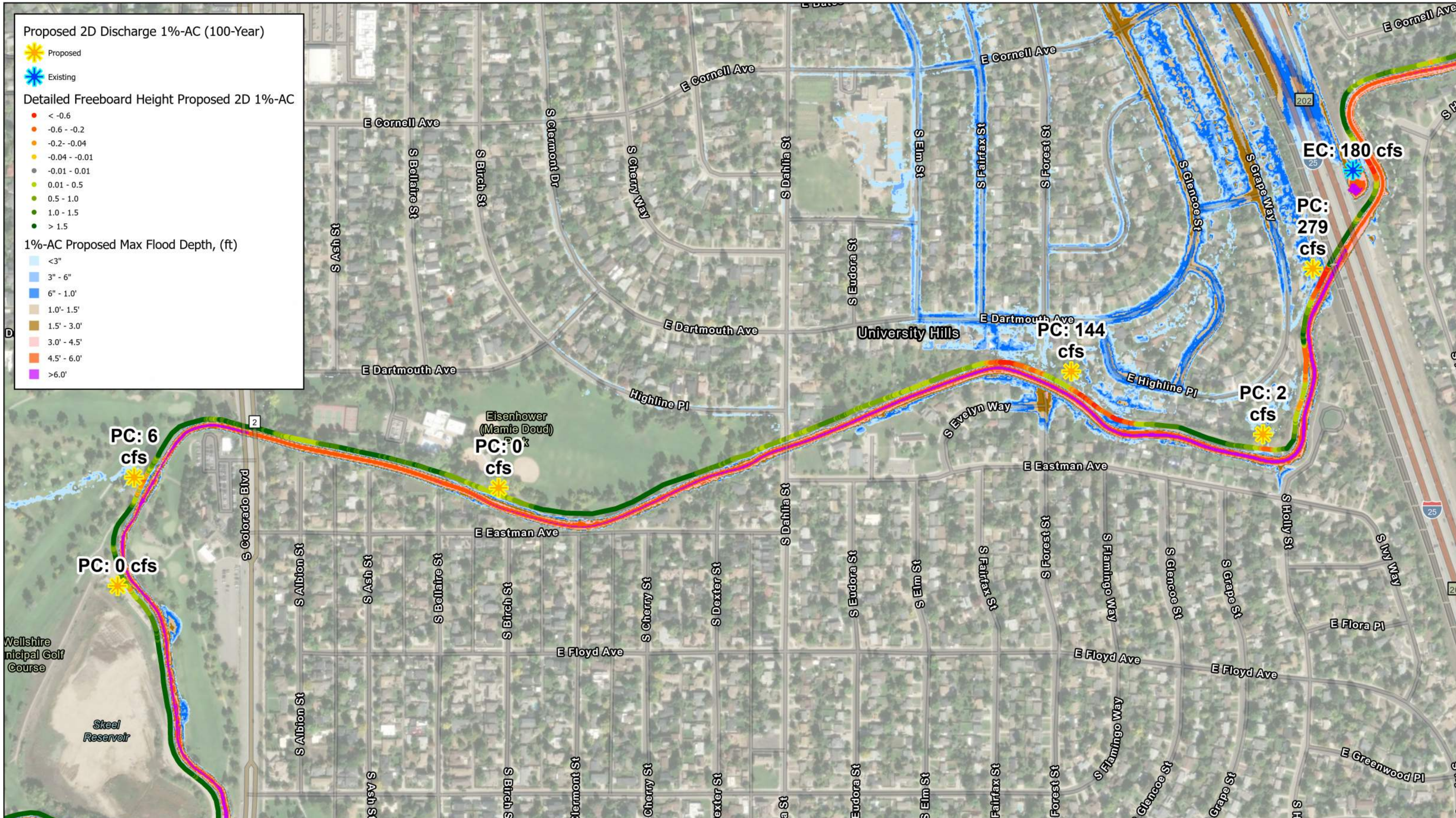
HLC STAMP

Denver County Existing Conditions

Alternative 2 Treatment Drain at Dartmouth Tributary Storm Sewer

N

0 500 1,000 Feet



ICON ENGINEERING

MHFD MILE HIGH FLOOD DISTRICT

DENVER THE MILE HIGH CITY

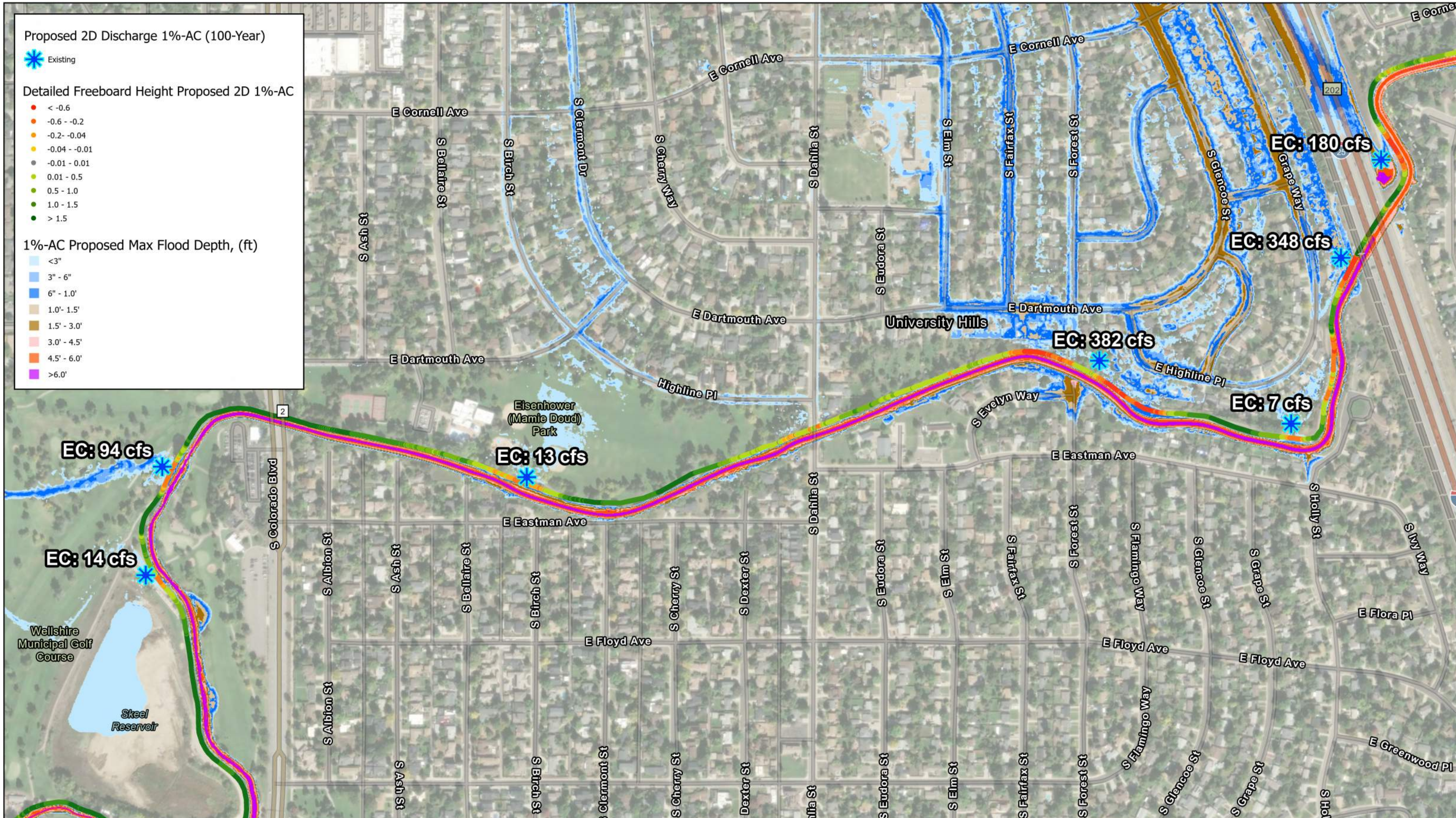
HLC STAMP

Denver County Proposed Conditions

Alternative 2
Treatment Drain at
Dartmouth Tributary
Storm Sewer

N

0 500 1,000 Feet



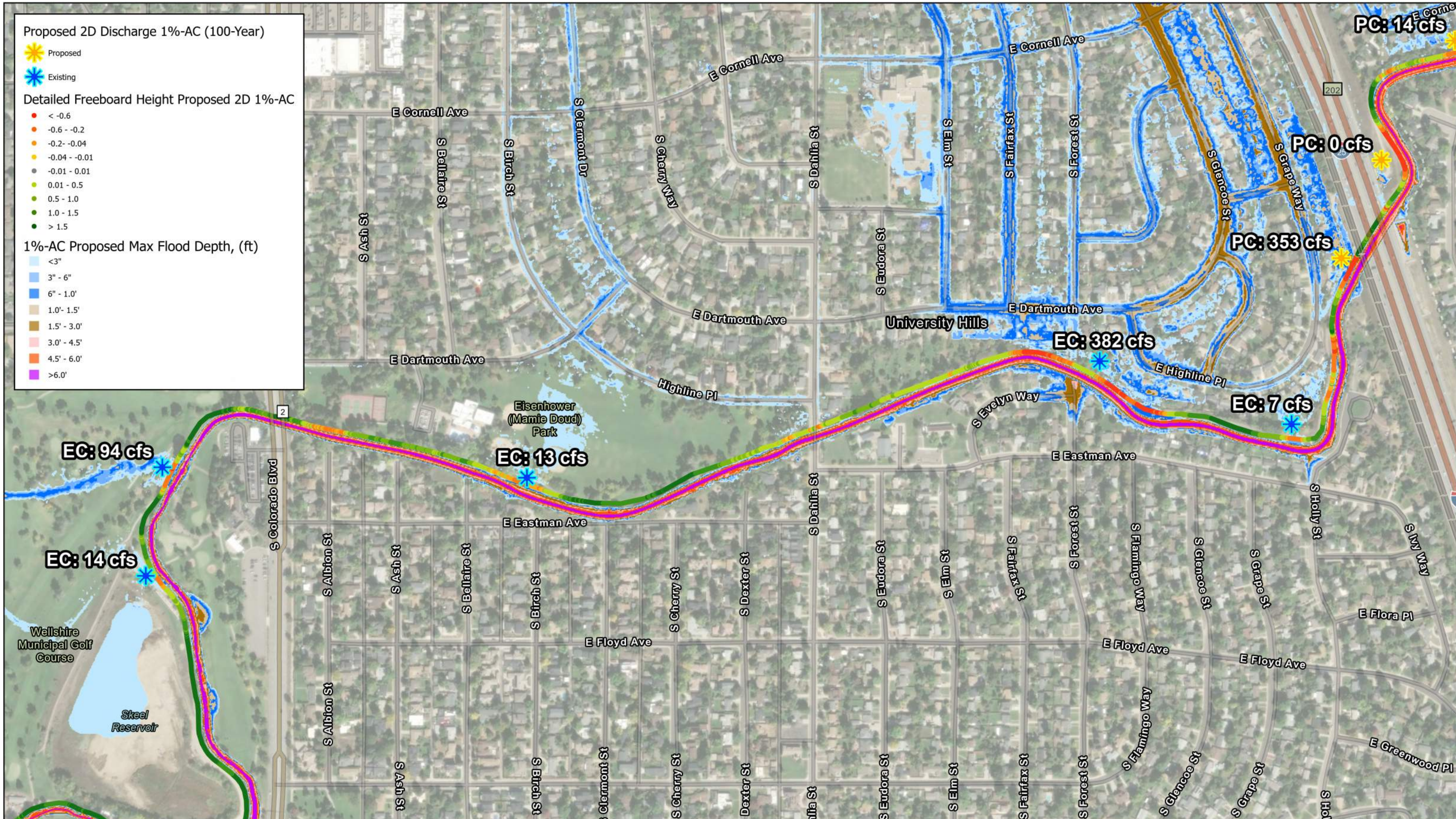
ICON ENGINEERING
MHFD MILE HIGH FLOOD DISTRICT
DENVER THE MILE HIGH CITY

HLC STAMP

Denver County Existing Conditions

Alternative 3
Treatment Drain at
Clermont Outfall
Storm Sewer

N
0 500 1,000 Feet



ICON ENGINEERING | MHFD MILE HIGH FLOOD DISTRICT | DENVER THE MILE HIGH CITY

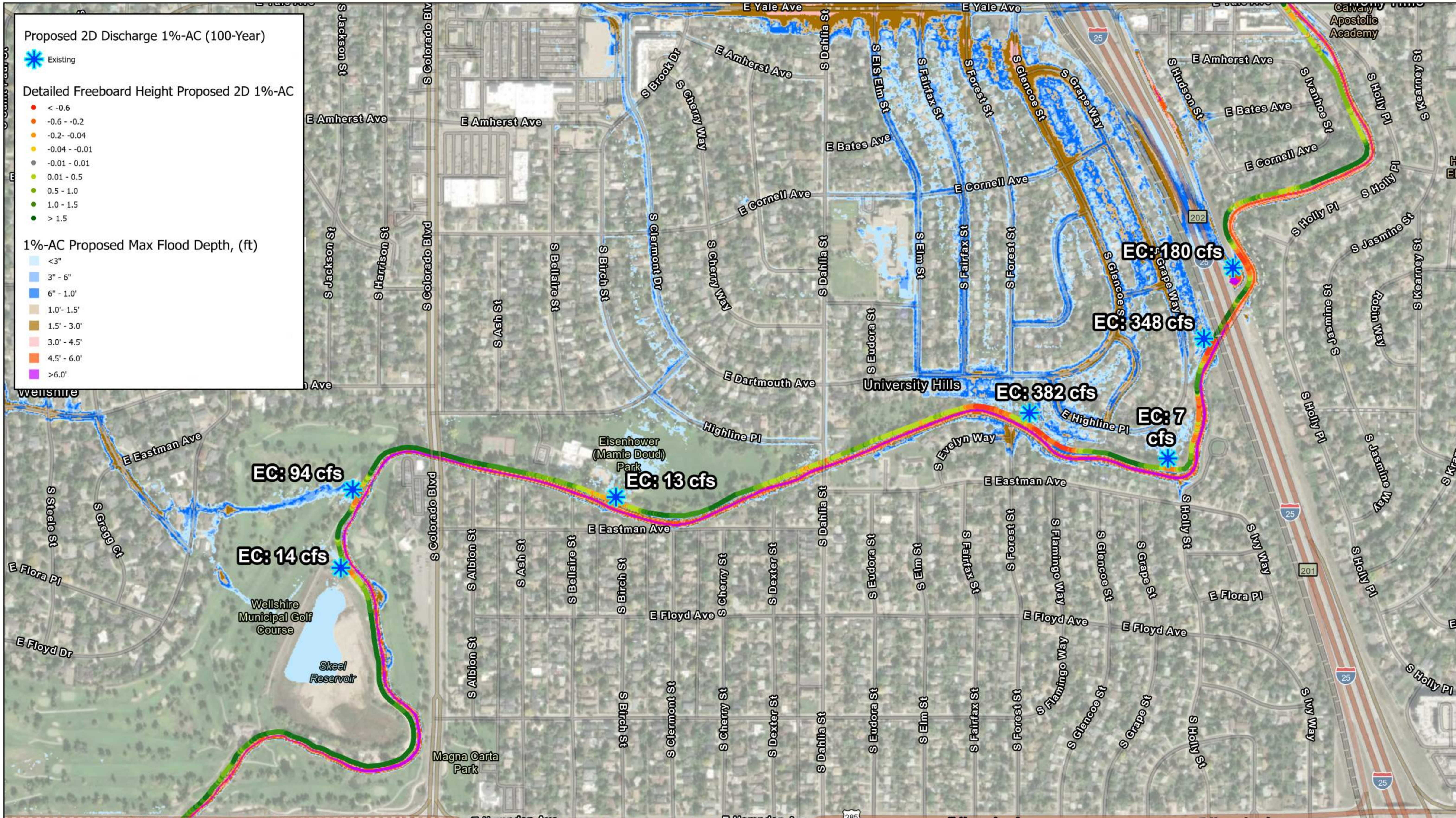
HLC STAMP

Denver County Proposed Conditions

Alternative 3
Treatment Drain at
Clermont Outfall
Storm Sewer

N

0 500 1,000 Feet



HLC STAMP

Denver County Existing Conditions

Alternative 4 Treatment Drain at Eudora Outfall Storm Sewer

ICON ENGINEERING

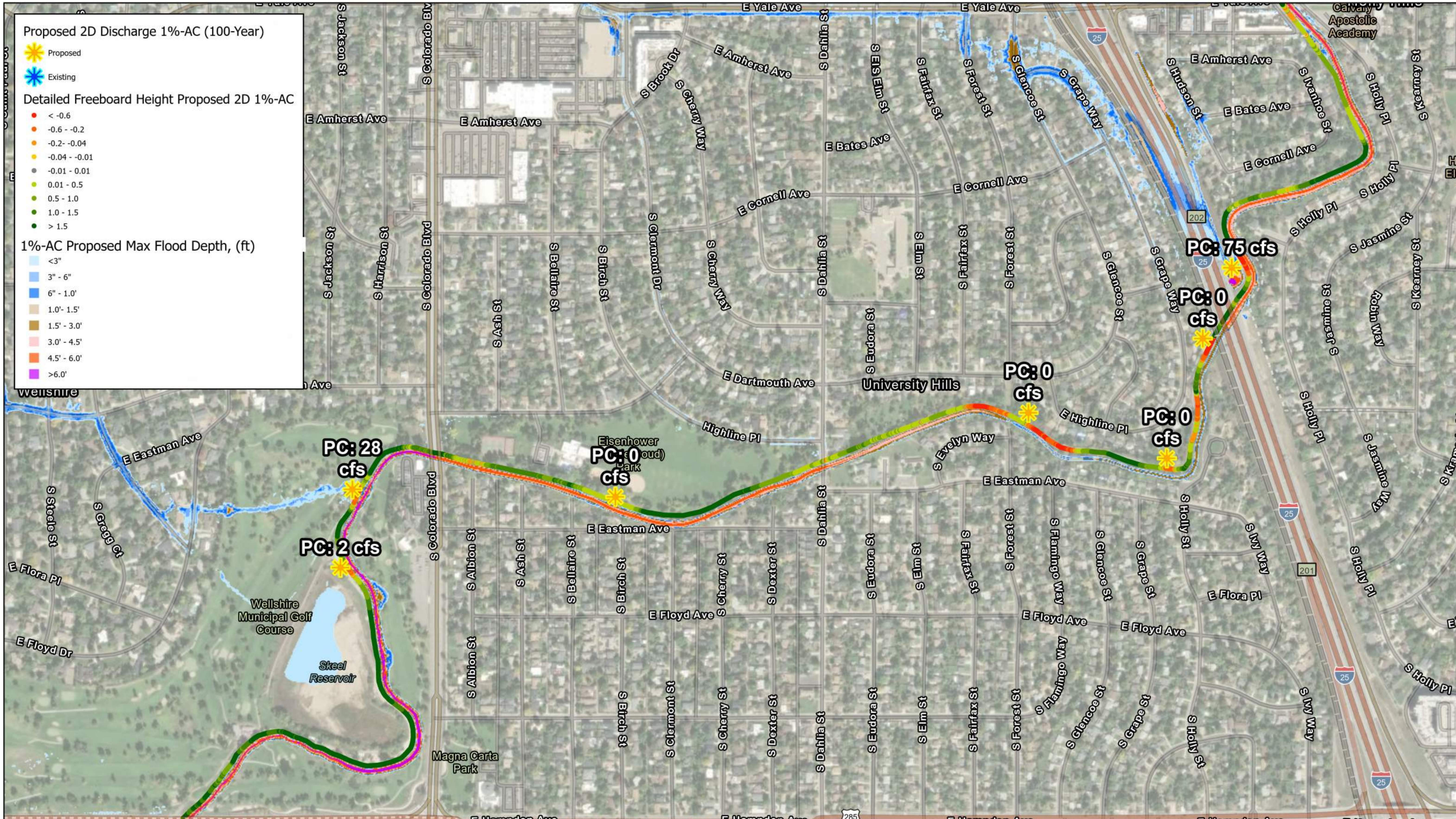
MHFD MILE HIGH FLOOD DISTRICT

DENVER THE MILE HIGH CITY

N

0 500 1,000 Feet

Littleton

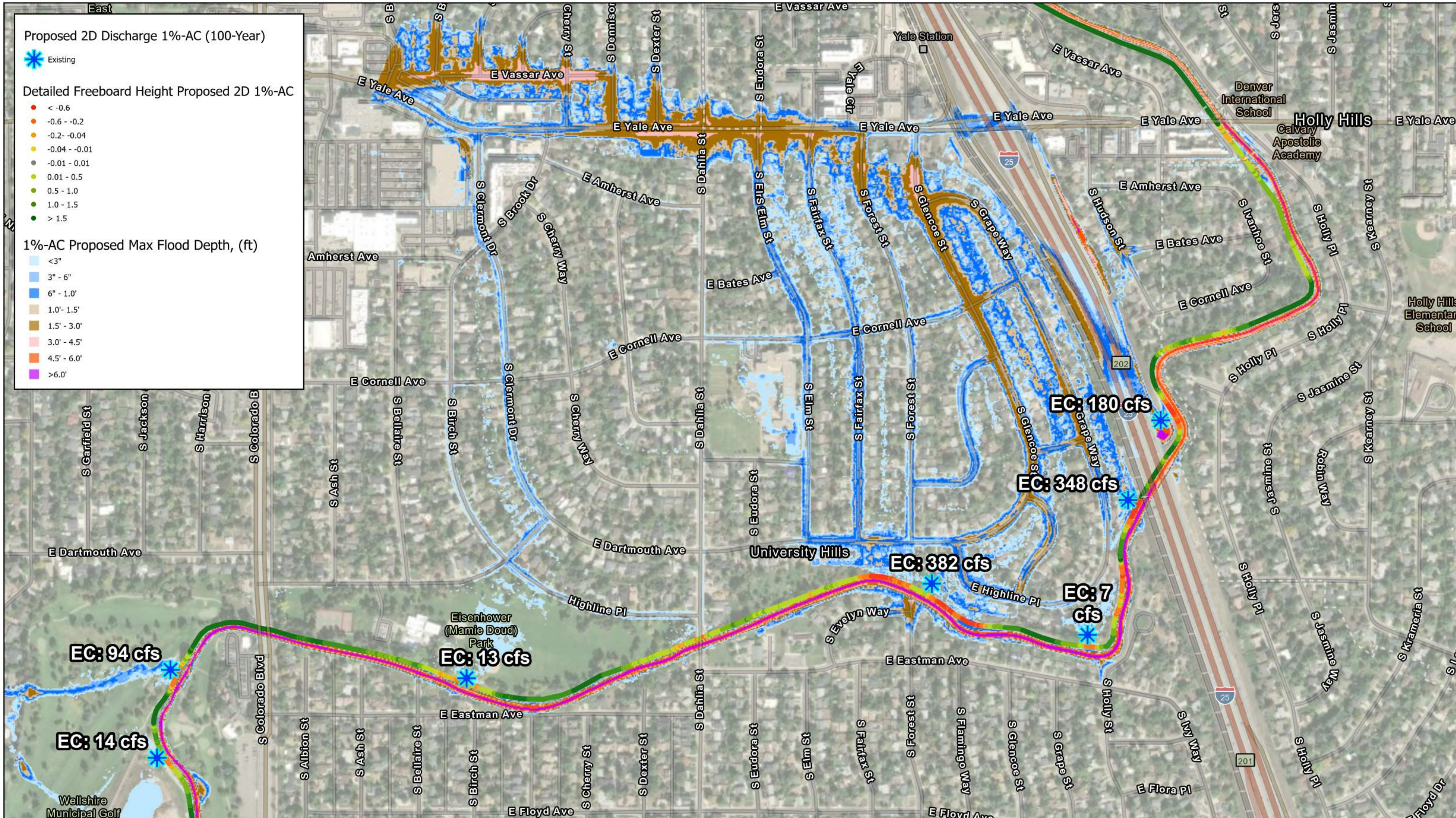


HLC STAMP

Denver County Proposed Conditions

Alternative 4
Treatment Drain at
Eudora Outfall
Storm Sewer

ICON ENGINEERING
MHFD MILE HIGH FLOOD DISTRICT
DENVER THE MILE HIGH CITY



ICON ENGINEERING

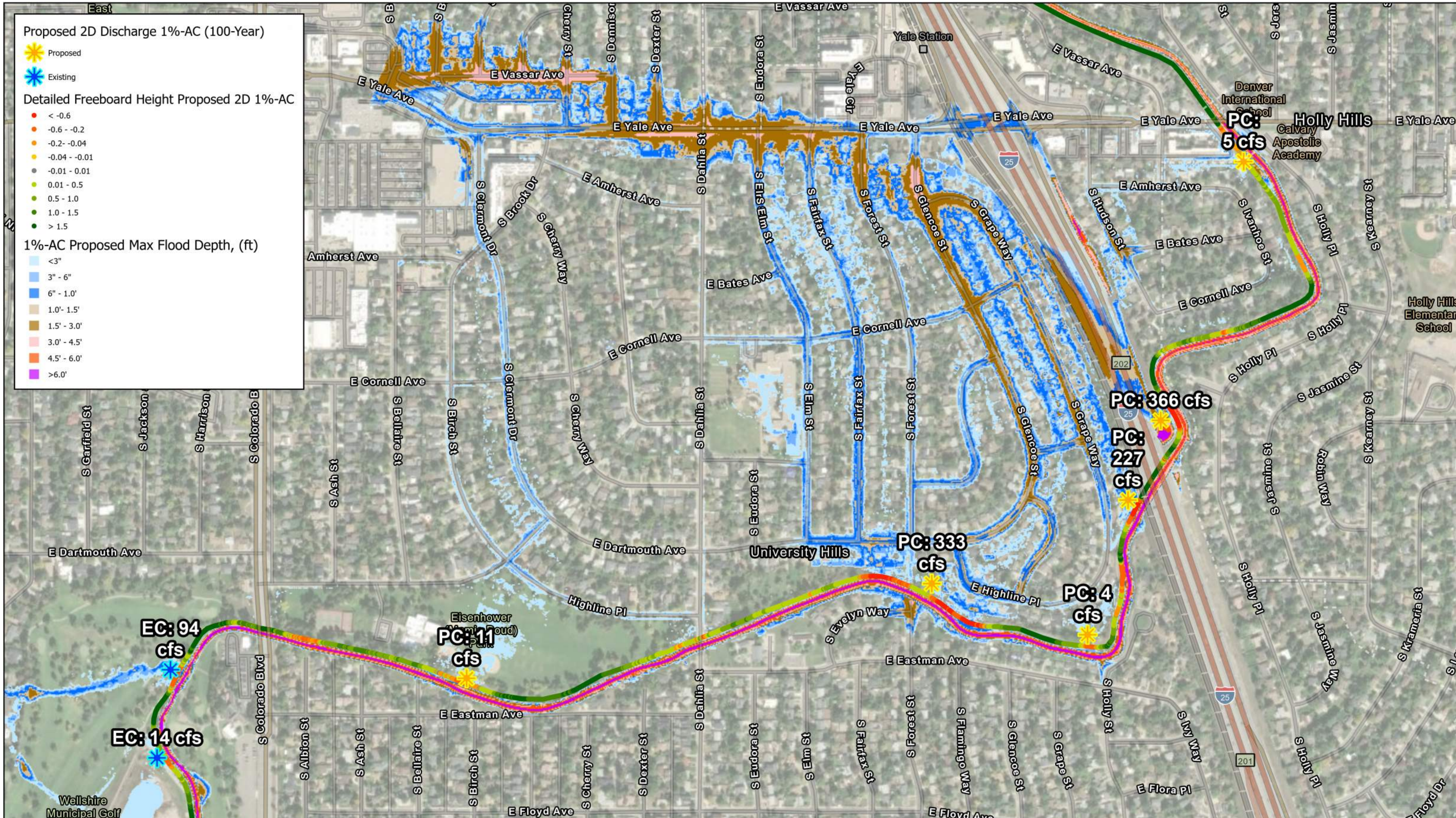
MHFD MILE HIGH FLOOD DISTRICT

DENVER THE MILE HIGH CITY

HLC STAMP

Denver County Existing Conditions

Alternative 5
Increase Culvert
Capacity Crossing I-25



ICON ENGINEERING

MHFD MILE HIGH FLOOD DISTRICT

DENVER THE MILE HIGH CITY

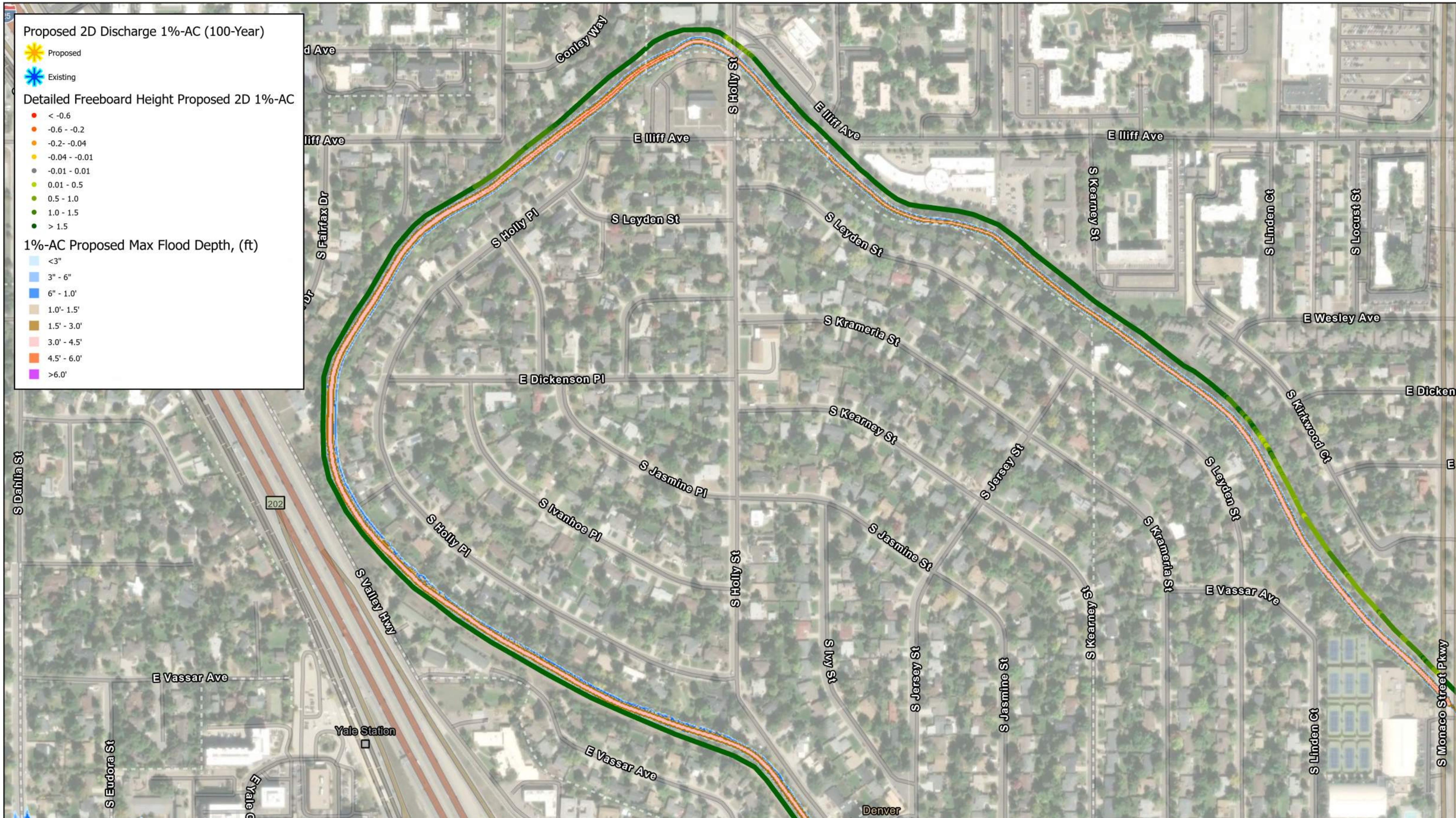
HLC STAMP

Denver County Proposed Conditions

Alternative 5
Increase Culvert Capacity Crossing I-25

N

0 500 1,000 Feet



ICON ENGINEERING | MHFD MILE HIGH FLOOD DISTRICT | DENVER THE MILE HIGH CITY

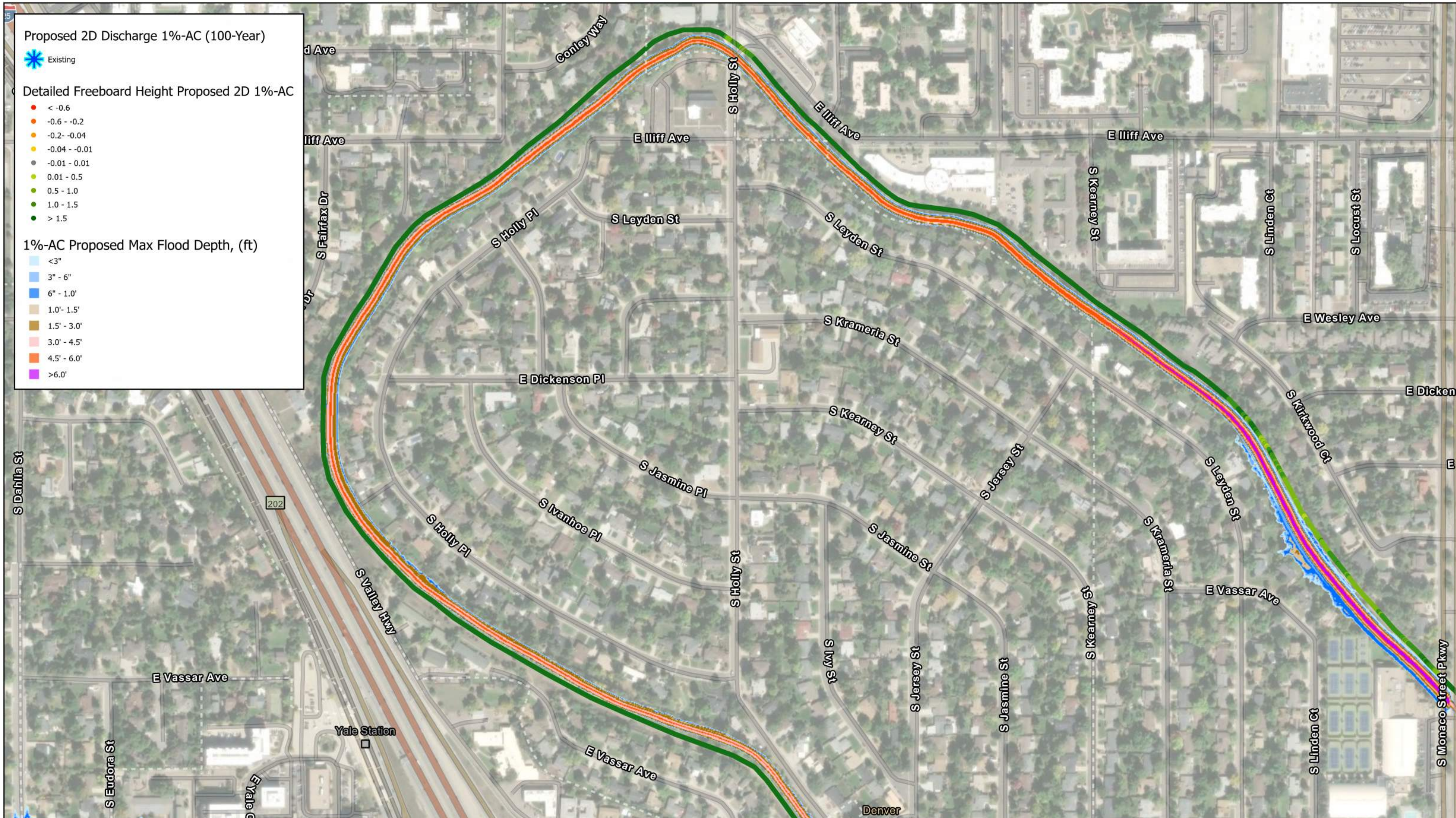
HLC STAMP

Denver County Proposed Conditions

Alternative 6 Treatment Drain at E Iliff to Storm Sewer

N

0 400 800 Feet



ICON ENGINEERING

MHFD MILE HIGH FLOOD DISTRICT

DENVER THE MILE HIGH CITY

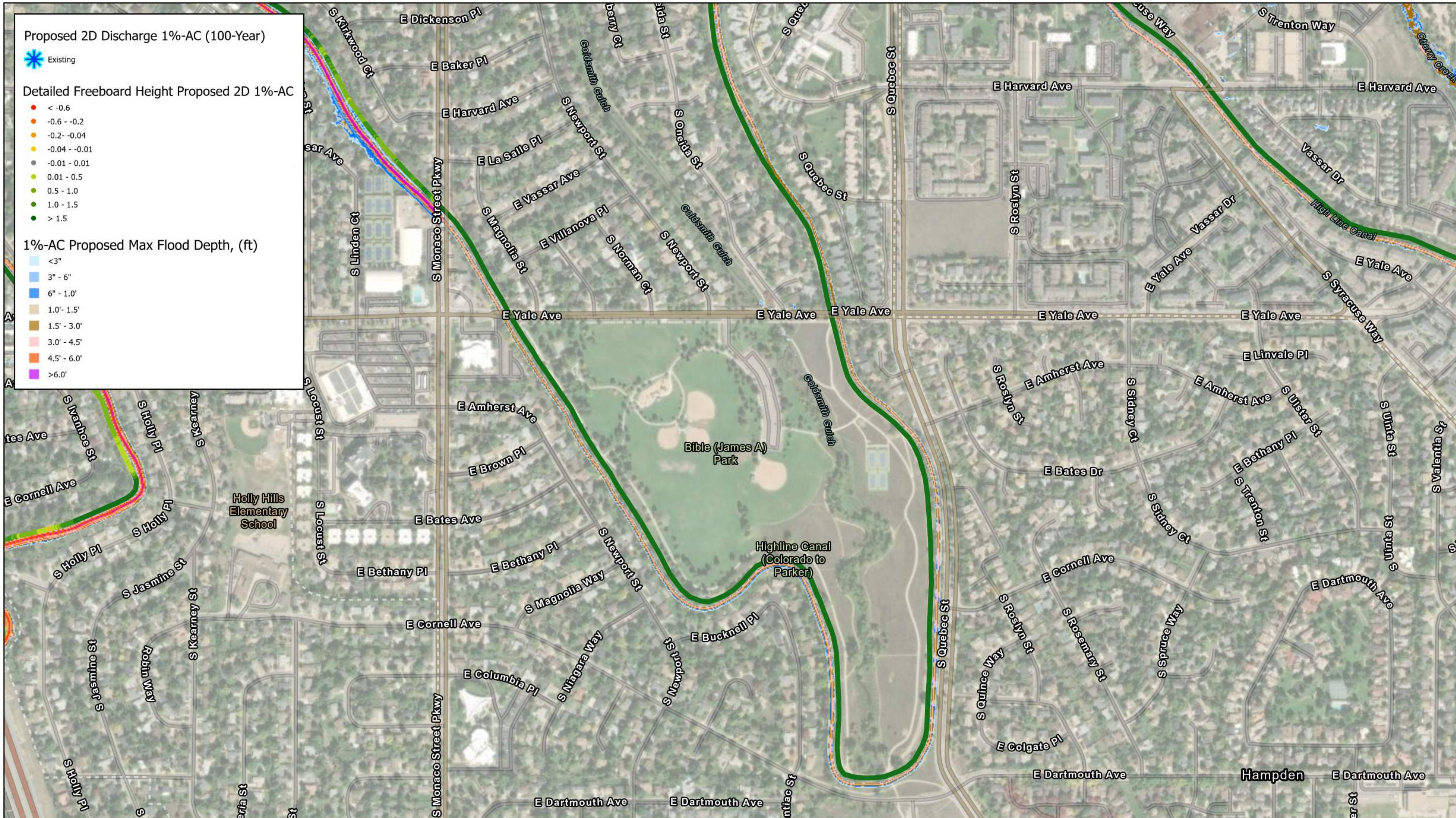
HLC STAMP

Denver County Existing Conditions

Alternative 6 Treatment Drain at E Iliff to Storm Sewer

N

0 400 800 Feet



ICON ENGINEERING | MHFD MILE HIGH FLOOD DISTRICT | DENVER THE MILE HIGH CITY

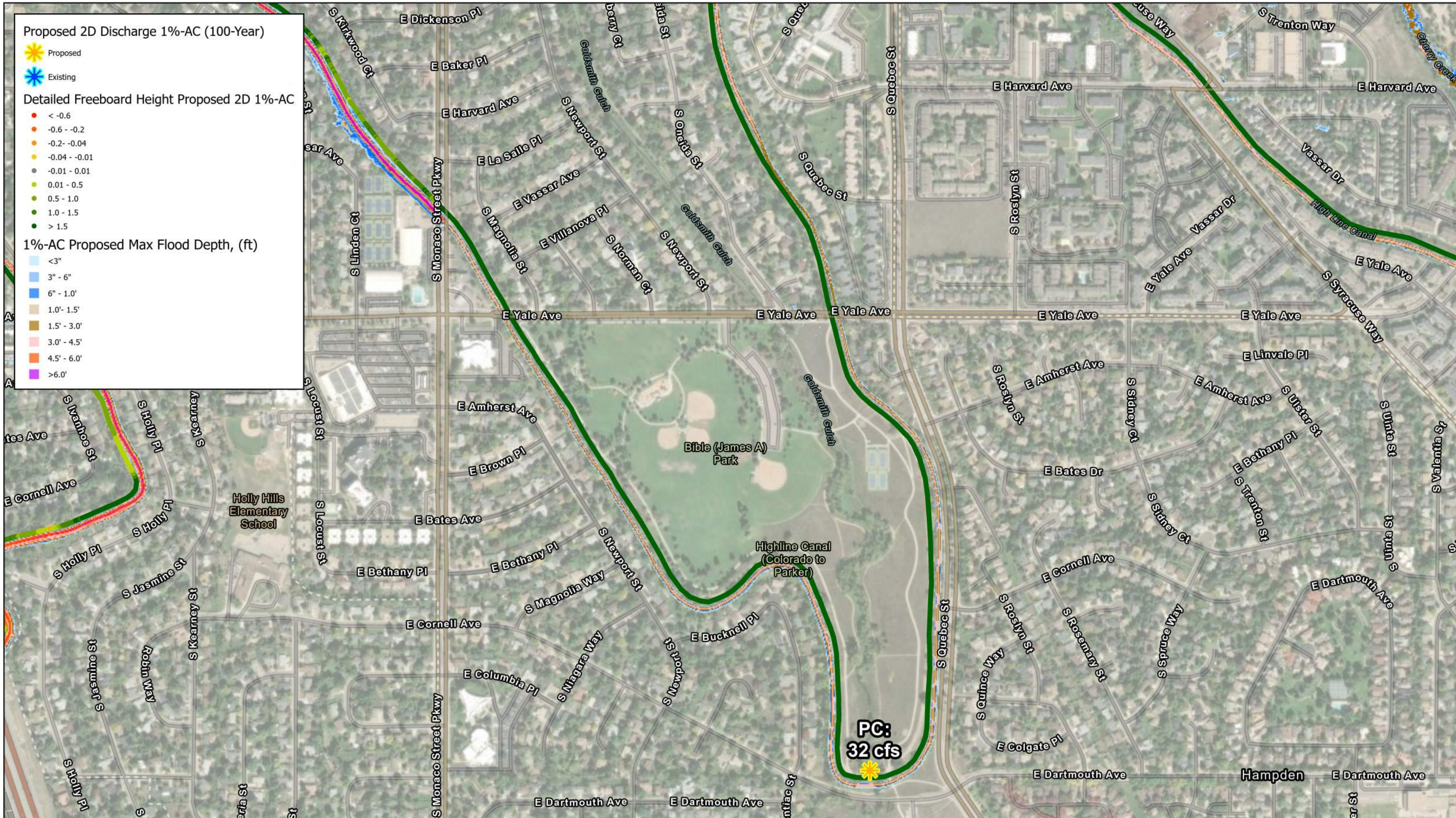
HLC STAMP

Denver County Existing Conditions

Alternative 8 Treatment Drain at Goldsmith Gulch Culvert

N

0 500 1,000 Feet



HLC STAMP

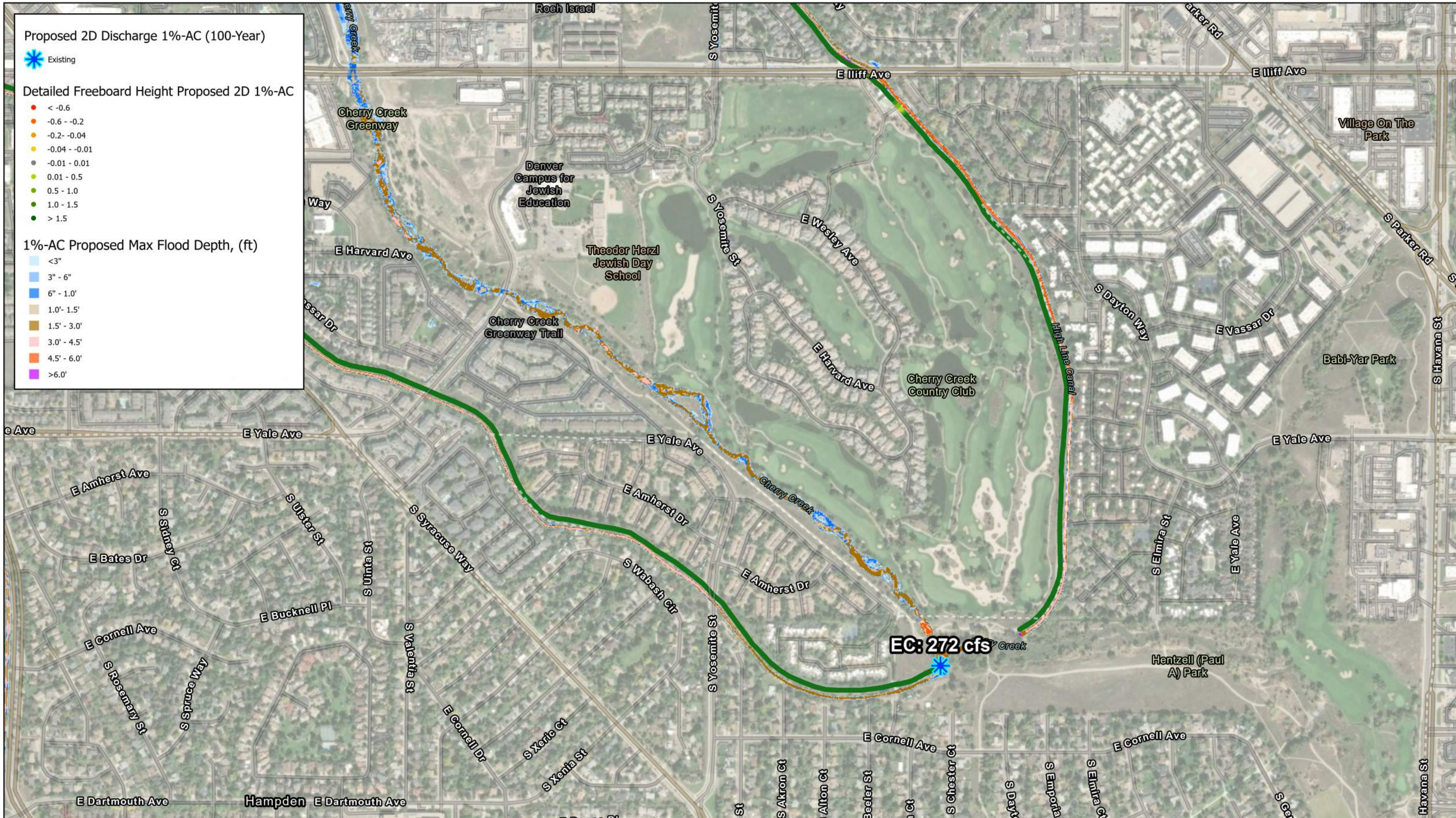
Denver County Proposed Conditions

Alternative 8 Treatment Drain at Goldsmith Gulch Culvert

ICON ENGINEERING

MHFD MILE HIGH FLOOD DISTRICT

DENVER THE MILE HIGH CITY



ICON ENGINEERING

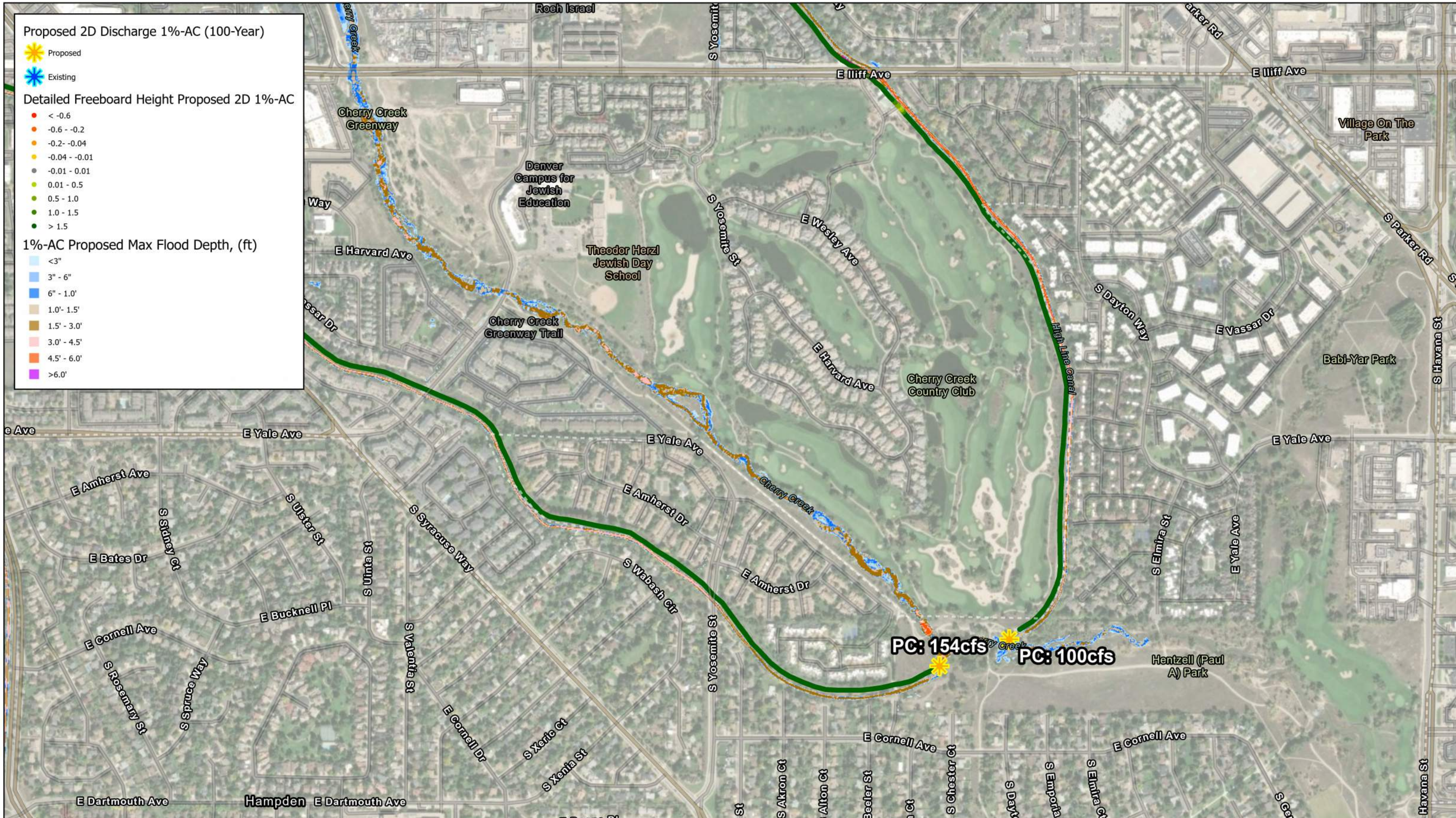
MHFD MILE HIGH FLOOD DISTRICT

DENVER THE MILE HIGH CITY

HLC STAMP

Denver County Existing Conditions

Alternative 10
Improve Conveyance of Wastegate into Cherry Creek

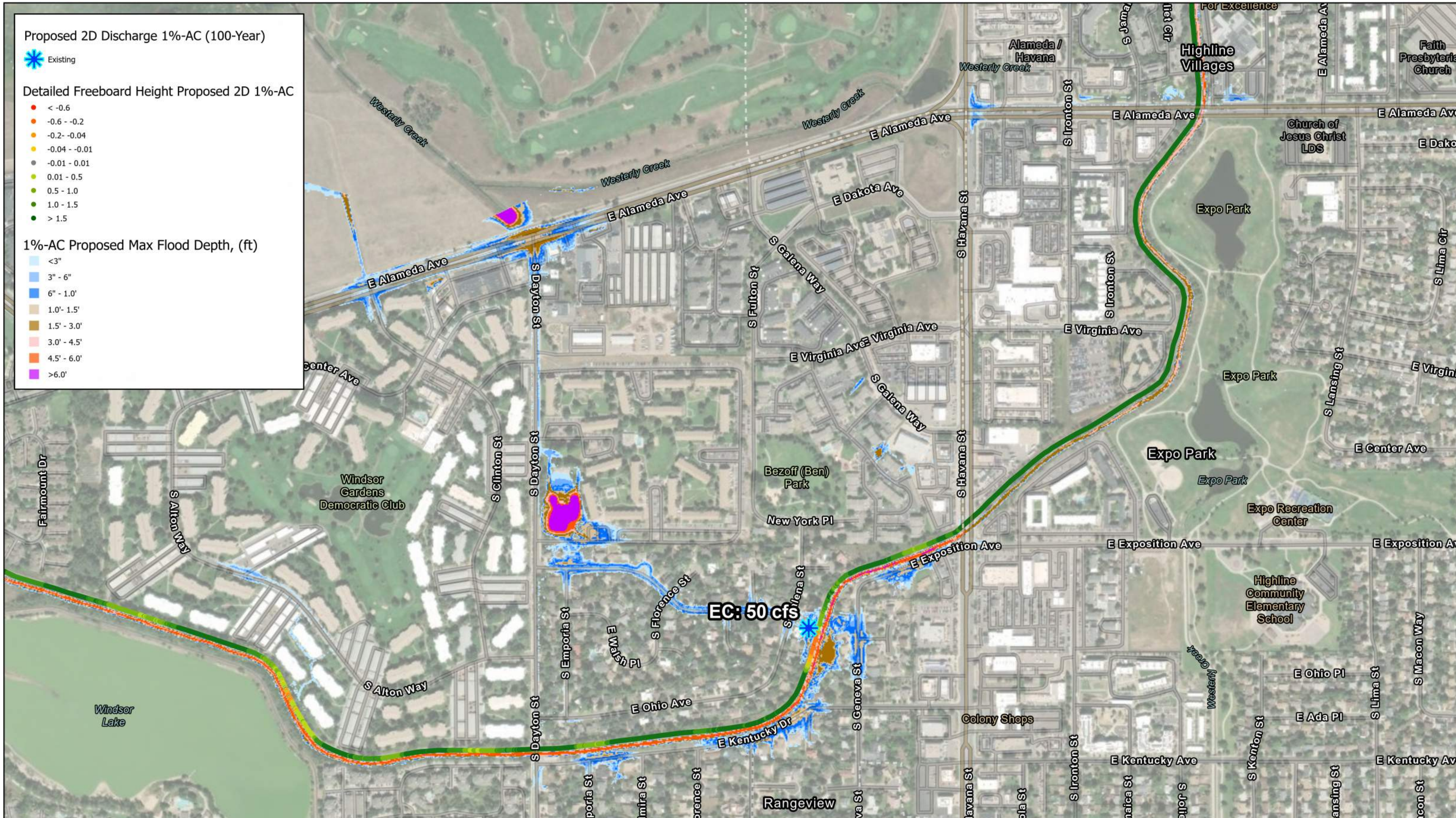


HLC STAMP

Denver County Proposed Conditions

Alternative 10
Improve Conveyance of Wastegate into Cherry Creek

ICON ENGINEERING
MHFD MILE HIGH FLOOD DISTRICT
DENVER THE MILE HIGH CITY



ICON ENGINEERING

MHFD MILE HIGH FLOOD DISTRICT

DENVER THE MILE HIGH CITY

HLC STAMP

Denver County Existing Conditions

Alternative 11
Treatment Drain at
S Havana St Outfall
Storm Sewer

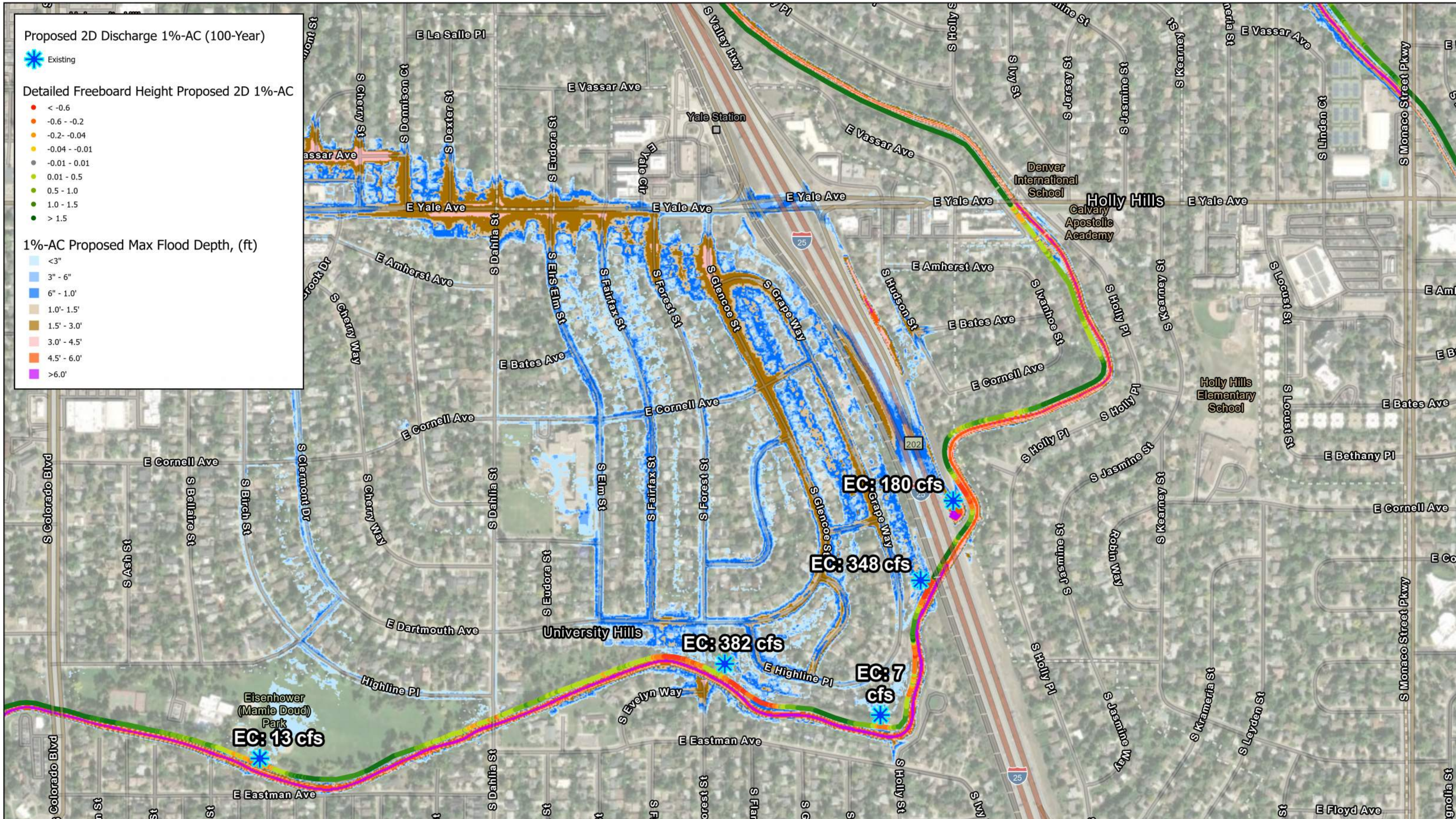
ICON ENGINEERING
MHFD MILE HIGH FLOOD DISTRICT
DENVER THE MILE HIGH CITY

HLC STAMP

Denver County Proposed Conditions

Alternative 11
Treatment Drain at S Havana St Outfall Storm Sewer

N
0 500 1,000 Feet



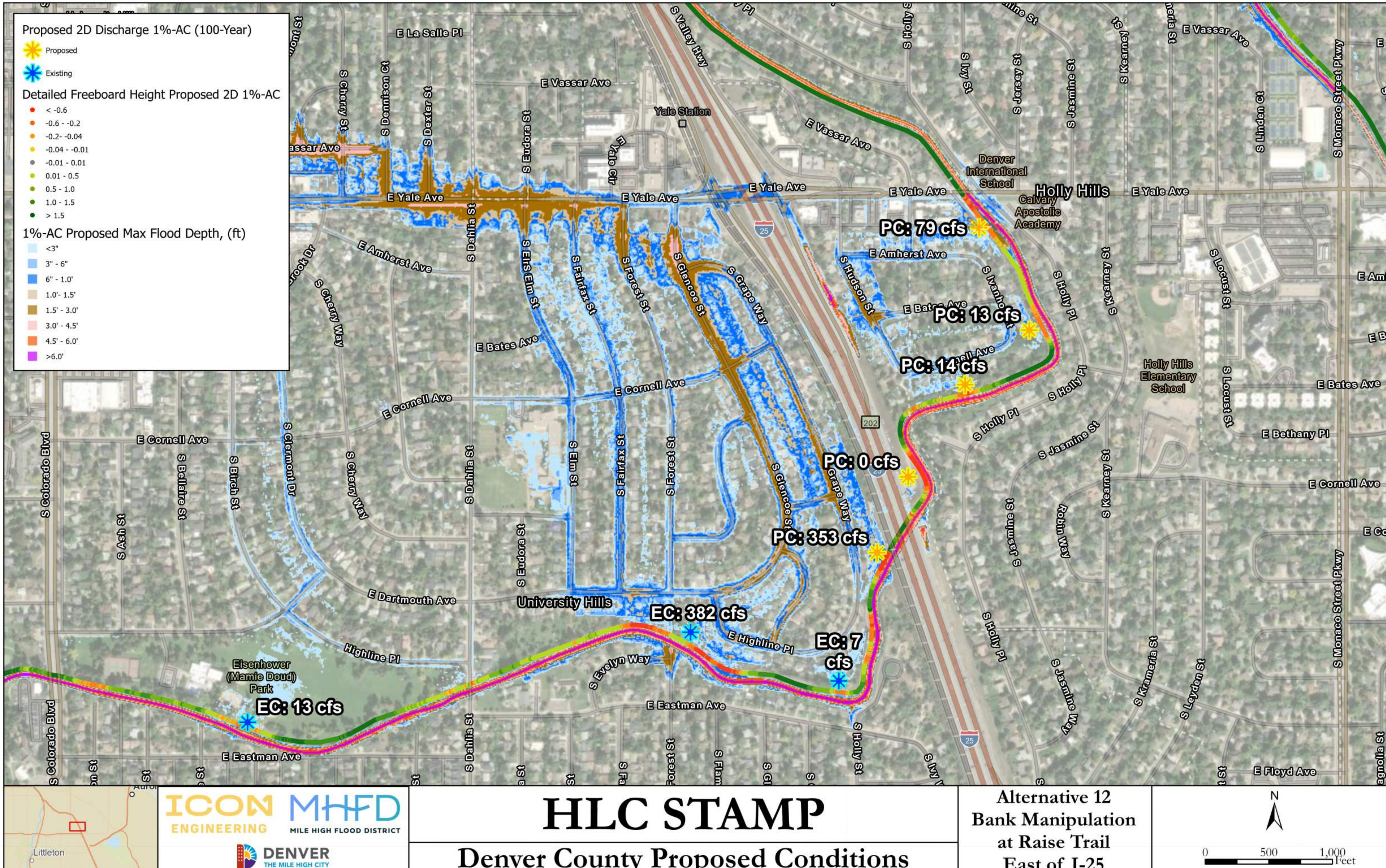
HLC STAMP

Denver County Existing Conditions

Alternative 12
Bank Manipulation
at Raise Trail
East of I-25

N

0 500 1,000 Feet



HLC STAMP

Denver County Proposed Conditions

Alternative 12
Bank Manipulation at Raise Trail East of I-25

ICON ENGINEERING | MHFD MILE HIGH FLOOD DISTRICT | DENVER THE MILE HIGH CITY

APPENDIX E: RISK ASSESSMENT MEMORANDUM

Michael Baker INTERNATIONAL

We Make a Difference

December 5, 2025

To: Brian LeDoux and David Crooks, ICON Engineering
Cc: David Anderson, MHFD
From: Daniel Aragon and Geoff Uhlemann, Michael Baker International
RE: High Line Canal Flood Risk Ratings Memorandum

We are pleased to complete the flood risk assessment component of the High Line Canal Stormwater Transition and Management Plan (STAMP). This abbreviated memo accompanies the data delivery and summarizes the content and processes used to arrive at flood risk results.

Deliverable contents:

- **data_dictionary**: Lookup tables for structures, roads, trails, and critical facilities at risk. Lookup tables for the flood risk fields.
- **results\flood_risk**: Detailed flood risk tables for individual receptors at risk (structures – SAR, roads – RAR, trails – TAR, critical facilities – cf).
- **results\flood_risk_aggregated**: Flood risk results aggregated to the project areas (spill area polygons provided by the ICON team). A detailed spatial layer and summary CSV are provided.
- **results*mask.gpkg**: Geopackage files containing polygon mask for structure locations. These were used to "zero-out" flood risk where receptors intersect hazards in 2D, but unlikely in 3D (typically bridge and culvert locations).
- **High Line Canal Flood Risk Assessment.pptx**: PowerPoint presented on 11/24/25 to the project team (updated based on several requests from David Anderson with MHFD).
- **MHFD_Risk_Receptors-AbbreviatedSummary_250912.pdf**: Summary of the receptor dataset development task.

*Note that most spatial files are provided in *.parquet* format (viewable in ArcPro 3.5 or QGIS).

Sincerely,

Daniel Aragon
Systems Developer
Daniel.Aragon@mbakerintl.com

Geoff Uhlemann
Dpt. Manager & Innovation Lead
Geoff.Uhlemann@mbakerintl.com

High Line Canal Flood Risk Assessment

Flood risk depends on accurately modeling flood hazard and correctly accounting for receptor location and vulnerability. The Mile High Flood District (MHFD) has the express goal of developing a risk ranking strategy that prioritizes the intrinsic value of impacts to people rather than financial impacts to physical assets. Therefore, "Values at Risk" (VAR) were developed to approximate the presence of humans who might be in harm's way during a flood event. These include structures, roadways, and trail networks. By evaluating the VAR datasets' exposure to flood hazard data (developed by ICON Engineering), a set of flood risk scores were developed for the High Line Canal study area.

Receptors Datasets

Structures at Risk (SAR)

The SAR dataset is a composite of National Structure Inventory data (USACE), USA Structures (FEMA), and Building Roofprints (DRCOG). DRCOG polygons were prioritized over USA structures where available. NSI point data was joined to the building polygons. Where a NSI points could not be joined to structure polygons using a reasonable search distance, a buffer was applied based on the NSI's "sqft" field to arrive at a polygon representation of the structure. A field, "geom_source", is included to document which approach was selected for each location. Users may find duplicated structure polygons which are expected where NSI points represent multiple tenants in the same structure (multi-family, commercial, etc).

The impact factor scores for structures are derived from the NSI's population estimates and are scored on a 1-6 scale.

Roads at Risk (RAR)

The RAR dataset is a composite of the open street map dataset (OSM) and a derivative of annual average daily traffic (AADT) estimates obtained through Replica (a traffic analytics platform). The OSM data provide a linear transportation network which can also be used for network routing queries. The OSM "lanes" field is used to apply a standard buffer (15 feet/lane) to arrive at a polygon representation of the transportation network. For example, a two lane road would receive a total buffer width of 30 feet. Roadway segments in the OSM data generally stretch from intersection to intersection, but also break at locations where the lane count changes. Therefore, no further segmentation of the OSM data was deemed necessary.

Replica's AADT data was obtained providing ~60% coverage of the study area's roadway network. A machine learning model was developed to expand AADT estimates to 100% of the road network. Estimated AADT is used to apply an impact factor score from 1-5.

320 South Teller Street, Suite 200 | Lakewood, CO 80226
Office: 720-514-1100 | mbakerintl.com

Trails at Risk (TAR)
The COTREX dataset is used off-the-shelf as a linear representation of trails within the study area. Due to the variability of individual feature lengths in the dataset (dozens of feet to dozens of miles), the trails were segmented into 500-foot max length segments. All trail segments are given an impact factor score of 1 for this study.

Critical Facilities
The critical facilities dataset is a composite of Mile High Flood District's Critical Facilities point dataset and the SAR data. The MHFD point data are joined to the previously developed SAR polygons. Duplications from this spatial join process are removed to ensure a 1:1 relationship between the MHFD source data and the final layer used for risk assessment.
All critical facility locations have been assigned an impact factor of 5 in the High Line Canal study.

Hazard Data
Flood hazard data were obtained from ICON for the study area. The delivered rasters included depth, velocity, and depth*velocity for the 2, 5, 10, 25, 50, 100, and 500 year recurrence-interval events. No post-processing of the hazard data was applied before flood risk assessment.

Where the High Line canal and other concentrated flow paths cross roadways, Michael Baker staff developed a mask layer which represents bridge and culvert locations. The mask layer was used to "zero-out" flood risk for roadway segments that intersect a mask location. In certain cases, the maximum extent of the flood hazard data indicated overtopping of a roadway. In those cases, no mask was applied to ensure overtopping was represented in the flood risk scores.

An edge case was discovered in the SAR and critical facilities data where a "skyway" (overhead walkway) crossed the High Line Canal. This location was treated similarly to the bridge and culvert locations where a mask was created and used to remove unrealistic flood risk from the results.

Calculating Exposure
The mean, median, and maximum values were calculated for each receptor-hazard raster pair as follows:

- RAR: from the raster pixels overlapping the road segment polygons.
- SAR and Critical Facilities: from within a 2-foot buffer applied to each structure's perimeter (but not within the structure footprint).
- TAR: from pixels intersecting each trail segment (linear features, not polygons).

As the MHFD Flood Risk Assessment methodology is under active development, this study used the max-statistic for all receptor locations as a conservative approach.

Calculating Flood Risk

Flood risk was calculated using the following formula at each receptor location:

$$Flood\ Risk = \sum_{i=1}^{n}(P_i * I * H_i)$$

Where:

- $Flood\ Risk$ – Aggregated risk score at a single receptor
- i – index for recurrence interval events (from 1 to n)
- P - Probability Factor (Annual Exceedance Probability [AEP] bin weight) for event i
- I - Impact Factor (importance of asset, categorized by class)
- H - Hazard Score (e.g., classified depth, depth*velocity, etc. per asset) for event i. The maximum hazard score from depth, velocity, or d*v is selected as H

Aggregating Flood Risk

Once flood risk scores were developed for each structure location, the project area polygons were used to aggregate risk scores. Within each project area (or spill area), the total flood risk score for each receptor class (SAR, RAR, TAR, Critical Facilities) was summed individually. Each project area was then ranked based on the individual receptor class risk scores to arrive at a receptor-based rank (see "AVG_VAR_flood_risk_rank" field in aggregated_flood_risk_High Line_Canal.parquet).

Two methods were attempted to arrive at a final ranking: "average of ranks", and "sum of flood risk scores". The average of ranks approach summed the SAR, RAR, TAR, and critical facility ranks for individual project areas, then ranked those sums against each other. This approach attempts to normalize the VAR categories (assume equal importance, regardless of total flood risk score).
The second approach is more straightforward: sum the risk scores for each receptor class within each project area, then rank those totals. The second approach aims to preserve the relative contribution of each receptor class to the project area's total risk (see "SUM_VAR_flood_risk_rank" field in aggregated_flood_risk_High Line_Canal.parquet).

Pros and cons of each approach are provided in the table below. However, the risk ranking results specific to each VAR class (ex: "sar_flood_risk_rank") provides an apples-to-apples comparison of flood risk within each project area. Given the flood risk assessment methodology is under active development, caution is recommended when attempting to use a single metric for project prioritization.

	AVG_VAR_flood_risk_rank	SUM_VAR_flood_risk_rank
Pro's	• Normalized scoring approach across VAR classes acknowledges difficulty of calibrating flood risk scores to the scale of true impacts of flooding • Top ranking project areas are likely areas of concern	• Maintains the relative contribution of each VAR class to flood risk • Top ranking project areas are likely areas of concern
Con's	• Likely to obscure the most prominent sources of flood risk and over-emphasize smaller contributors to flood risk	• Assumes that receptor scoring across classes has been equally calibrated to true impacts of flooding, which has not been validated. • Receptors with less relative exposure are likely overshadowed in the ranking (ex: impacts at Critical Facilities)

Results Summary

Zone ID	SUM VAR flood risk rank	AVG VAR flood risk rank	Flood Risk Sum	SAR Total Flood Risk	Critical Facilities Total Flood Risk	RAR Total Flood Risk	TAR Total Flood Risk	SAR Flood Risk Rank	Critical Facilities Flood Risk Rank	RAR Flood Risk Rank	TAR Flood Risk Rank
16	1	5	191.73	161.21	0.15	27.84	2.53	1	4	3	18
35	2	1	149.69	109.14	0.68	33.64	6.23	2	2	2	9
11	3	2	97.81	19.08	0.00	74.94	3.79	5	6	1	12
18	4	7	43.53	27.97	0.00	12.66	2.90	4	6	4	17
34	5	9	39.25	32.04	0.00	4.16	3.05	3	6	12	15
38	6	2	31.71	5.26	0.00	8.76	17.68	10	6	7	1
19	7	4	29.85	4.03	0.04	12.08	13.70	12	5	5	3
44	8	10	28.53	12.44	0.00	0.58	15.51	6	6	23	2
21	9	6	24.58	5.09	0.00	9.71	9.78	11	6	6	6
42	10	8	19.56	6.82	0.00	2.60	10.14	7	6	17	5
22	11	12	16.96	1.19	0.00	8.45	7.33	26	6	8	8
43	12	24	13.02	0.00	0.00	0.17	12.85	40	6	30	4
32	13	11	12.72	6.35	0.00	3.30	3.06	8	6	15	14
15	14	15	10.91	5.86	0.00	5.02	0.03	9	6	11	38
14	15	15	10.10	1.28	0.00	0.28	8.53	25	6	26	7
31	16	13	9.86	3.48	0.00	5.17	1.21	14	6	10	23
12	17	17	8.58	0.00	0.00	4.05	4.53	40	6	13	11
26	18	14	7.85	2.45	0.00	5.25	0.15	16	6	9	30
37	19	20	5.97	2.96	0.00	0.00	3.01	15	6	39	16
45	20	30	5.65	0.08	0.00	0.00	5.56	38	6	39	10
41	21	21	5.06	0.00	0.00	1.76	3.30	40	6	19	13
40	22	19	4.86	2.21	0.00	2.59	0.07	18	6	18	33
2	23	40	4.86	1.49	3.37	0.00	0.00	22	1	39	45
23	24	24	4.50	0.92	0.00	3.47	0.12	29	6	14	31
36	25	27	4.12	3.88	0.00	0.23	0.02	13	6	27	42
30	26	17	3.57	1.63	0.00	1.09	0.85	20	6	20	24
20	27	28	3.46	0.39	0.00	3.04	0.04	33	6	16	36
17	28	23	3.02	2.06	0.22	0.70	0.04	19	3	22	35
8	29	21	2.76	1.43	0.00	0.94	0.39	23	6	21	28
10	30	26	2.66	0.66	0.00	0.22	1.79	30	6	28	21
25	31	32	2.37	2.32	0.00	0.03	0.03	17	6	35	40
4	32	35	2.34	0.00	0.00	0.00	2.34	40	6	39	19
3	33	37	2.29	0.00	0.00	0.00	2.29	40	6	39	20
27	34	30	2.08	0.33	0.00	0.11	1.64	34	6	31	22

320 South Teller Street, Suite 200 | Lakewood, CO 80226
Office: 720-514-1100 | mbakerintl.com

Zone ID	SUM VAR flood risk rank	AVG VAR flood risk rank	Flood Risk Sum	SAR Total Flood Risk	Critical Facilities Total Flood Risk	RAR Total Flood Risk	TAR Total Flood Risk	SAR Flood Risk Rank	Critical Facilities Flood Risk Rank	RAR Flood Risk Rank	TAR Flood Risk Rank
7	35	28	2.00	1.59	0.00	0.39	0.03	21	6	25	39
1	36	42	1.35	1.35	0.00	0.00	0.00	24	6	39	45
6	37	32	1.13	0.94	0.00	0.10	0.09	28	6	32	32
39	38	41	1.10	1.07	0.00	0.01	0.02	27	6	38	41
46	39	32	1.02	0.44	0.00	0.08	0.50	32	6	33	27
24	40	38	0.98	0.26	0.00	0.00	0.72	36	6	39	25
9	41	35	0.97	0.30	0.00	0.01	0.66	35	6	37	26
33	42	38	0.91	0.47	0.00	0.44	0.00	31	6	24	45
47	43	42	0.35	0.00	0.00	0.00	0.35	40	6	39	29
29	44	45	0.33	0.15	0.00	0.17	0.01	37	6	29	43
28	45	46	0.08	0.03	0.00	0.02	0.03	39	6	36	37
13	46	42	0.08	0.00	0.00	0.04	0.04	40	6	34	34
5	47	47	0.00	0.00	0.00	0.00	0.00	40	6	39	44

320 South Teller Street, Suite 200 | Lakewood, CO 80226
Office: 720-514-1100 | mbakerintl.com

Appendices – Flood Risk PowerPoint, MHFD Risk Receptors Abbreviated Summary

320 South Teller Street, Suite 200 | Lakewood, CO 80226
Office: 720-514-1100 | mbakerintl.com

High Line Canal Flood Risk Assessment

Review of Results

11/24/2025

(results updated 12/3/25)

Objective

- Using 2D Riverine Flood Hazard Results, apply the Flood Risk Assessment Methodology* to calculate risk scores at Receptor Locations
- Support risk identification and project prioritization tasks

*Methodology is under active development

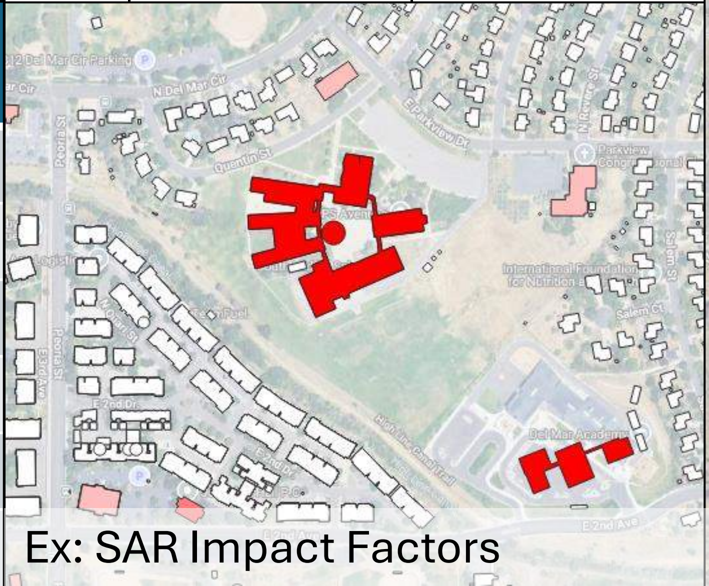
Hazard Data

- Depth, Velocity, D*V
- Recurrence intervals: 2, 5, 10, 25, 50, 100, 500 year.
- Project area polygons define limit of analysis
- [Source Terrain]

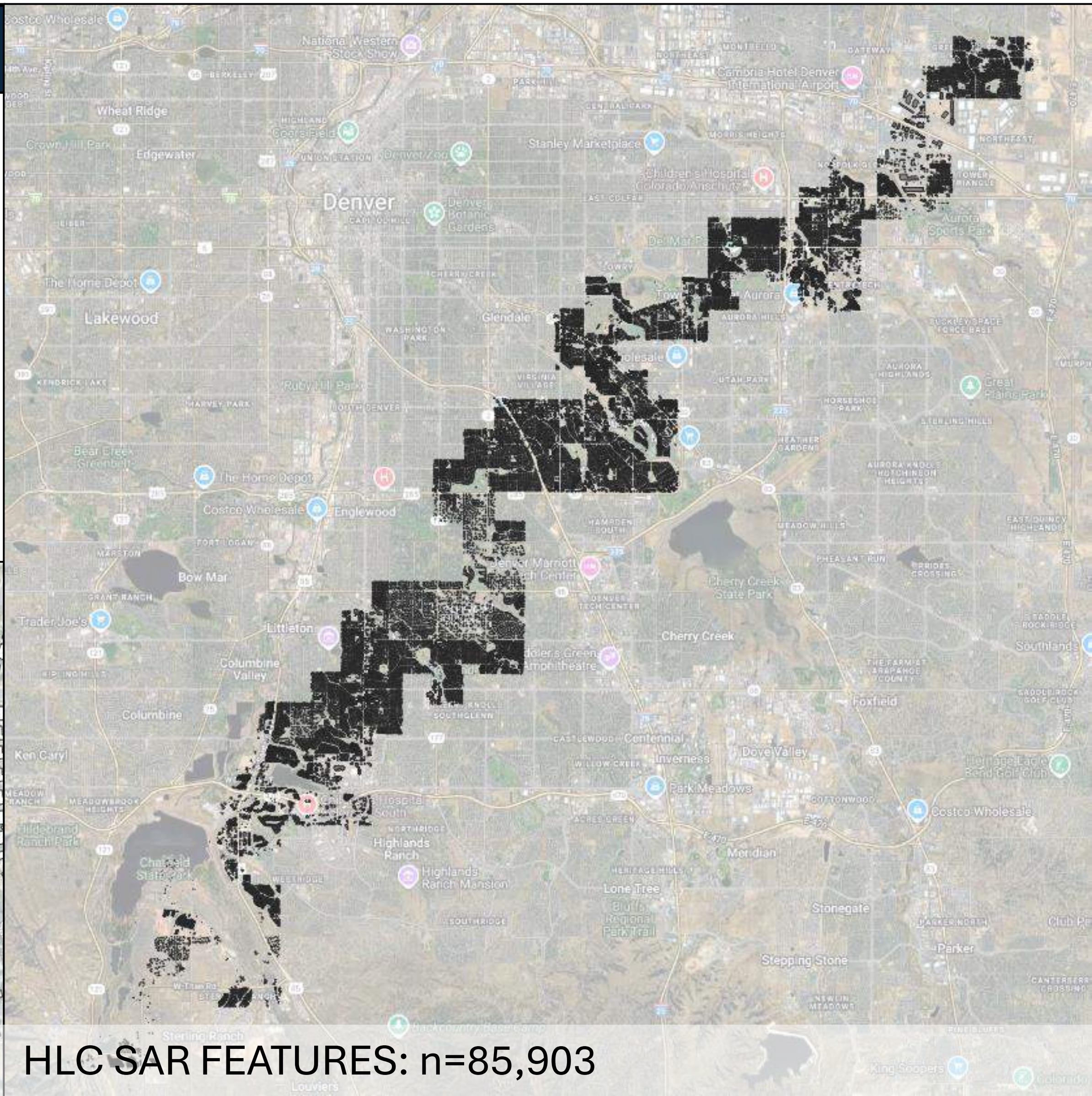
Receptor Data – Structures at Risk (SAR)

VAR	Strategic Value	Recommended Data Sources	Contribution to Program	Impact Factor Development
Structures at Risk (SAR)	Location of physical structures of various occupancy types. Construction and material types, year built, and other attributes used in depth-damage analyses, basement flood risk assessment, etc.	USACE National Structure Inventory (NSI)	Population Estimates (at structure), Attributes for Depth-Damage Assessment, Plus-Codes	Statistical evaluation of occupancy types to occupancy count estimates, partitioned by quintiles, scored 1-5.
		FEMA USA Structures	Addresses, Mobile Home ID	
		DRCOG Building Roof Prints	Newer Development, Auxiliary Building ID	

95th Percentile Occupant Count (see hidden slide)	Impact Factor
0	1
<= 6	2
7-24	3
25-35	4
36-56	5
56-897	6



Ex: SAR Impact Factors



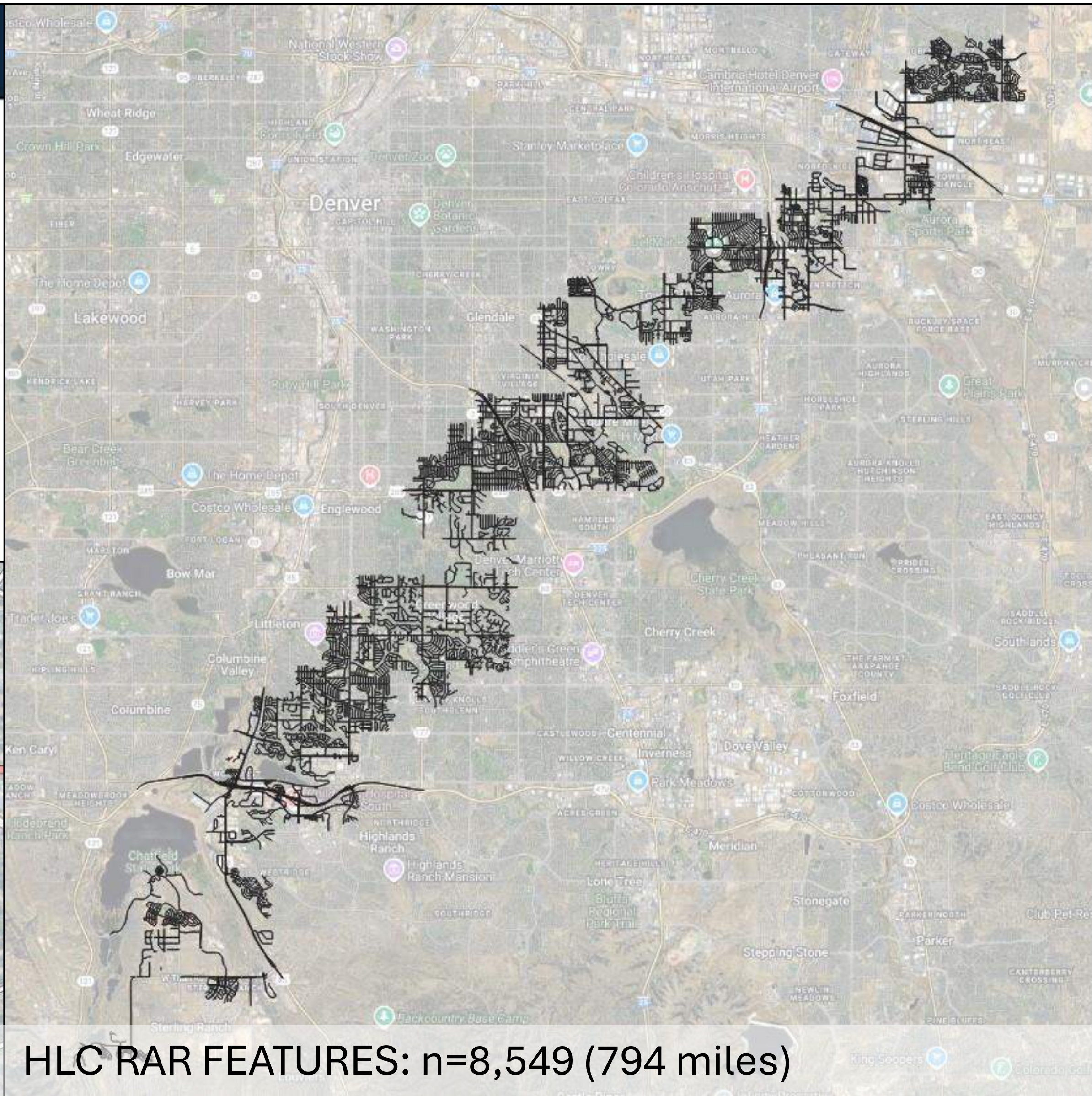
HLC SAR FEATURES: n=85,903

Receptor Data – Roads at Risk (RAR)

VAR	Strategic Value	Recommended Data Sources	Contribution to Program	Impact Factor Development
Roads at Risk (RAR)	Identification of the traveling public (vehicular traffic), transportation networks and travel patterns, roadway configurations, traffic volume, and evacuation route analysis.	Open Street Map (OSM)	Complete Coverage, Roadway Attributes, Network Analysis	Machine learning model used to predict AADT based on roadway characteristics, partitioned by quintiles, scored 1-5.
		DRCOG Edge of Pavement Planimetrics	Roadway Polygons	
		Replica	AADT from Cell Phone Data	

Estimated Annual Average Daily Traffic (AADT)	Impact Factor
0 – 1,042	1
1,043 – 2,859	2
2,860 – 7,032	3
7,033 – 14,500	4
14,501 – 86,755+	5

Ex: RAR Impact Factors



HLC RAR FEATURES: n=8,549 (794 miles)

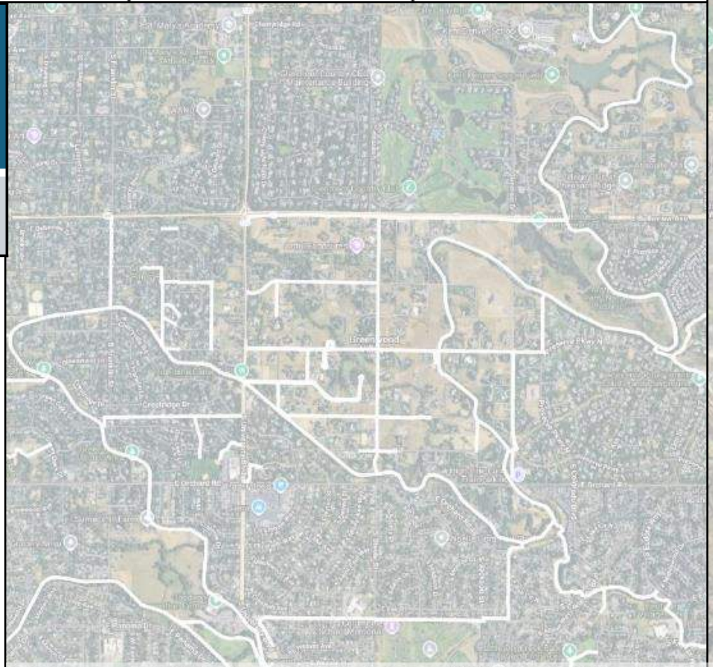
Michael Baker INTERNATIONAL

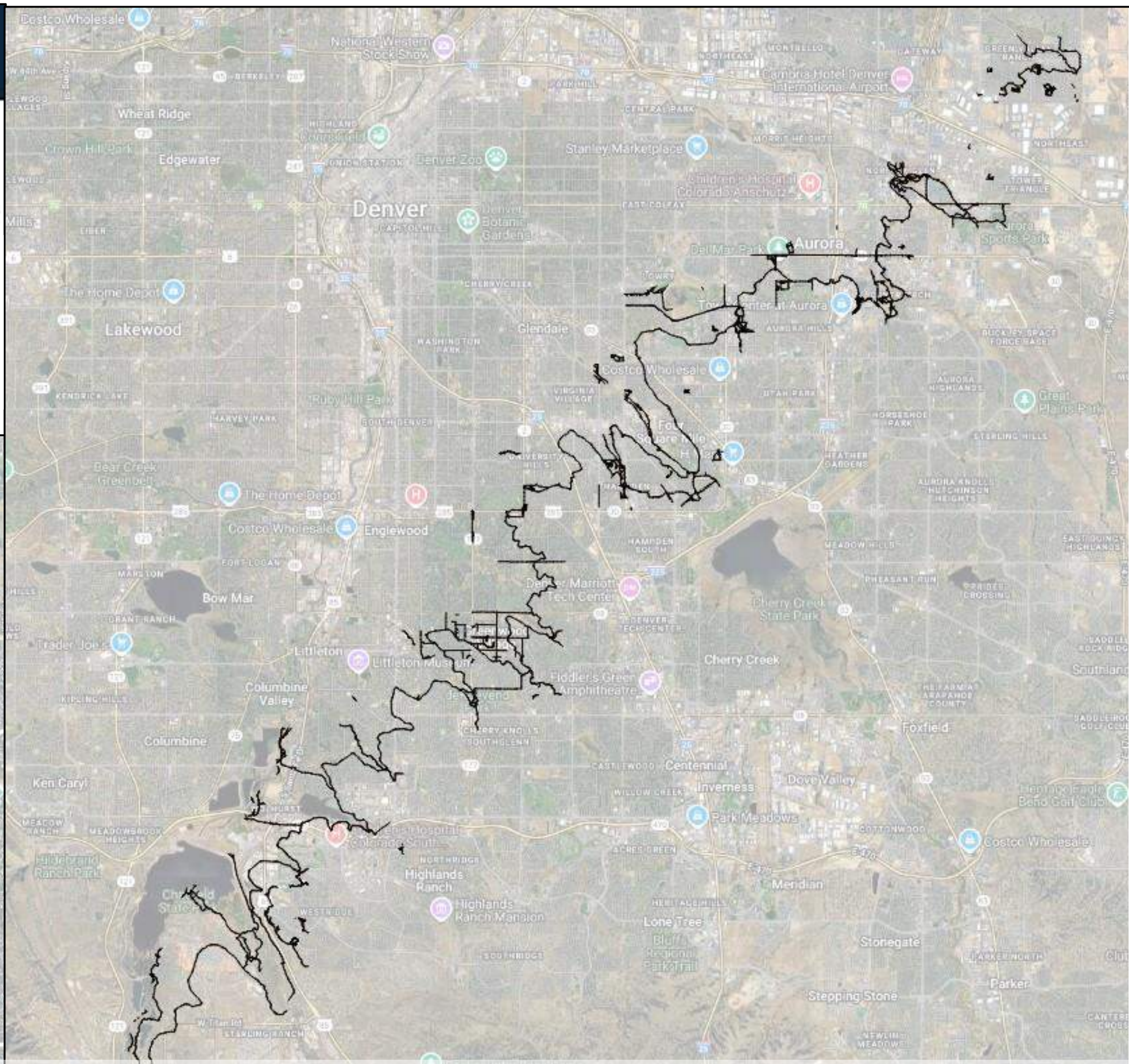
Michael Baker INTERNATIONAL

Receptor Data – Trails at Risk (TAR)

VAR	Strategic Value	Recommended Data Sources	Contribution to Program	Impact Factor Development
Trails At Risk (TAR)	Estimation of pedestrian locations and non-vehicular transportation networks.	COTREX	Pedestrian Locations	No differentiable characteristics are available related to presence of receptors.
		RTD Transit Stops	Pedestrian (Commuter) Locations	

All TAR Segments (500ft max length)	Impact Factor
ALL	1


Ex: TAR Impact Factors



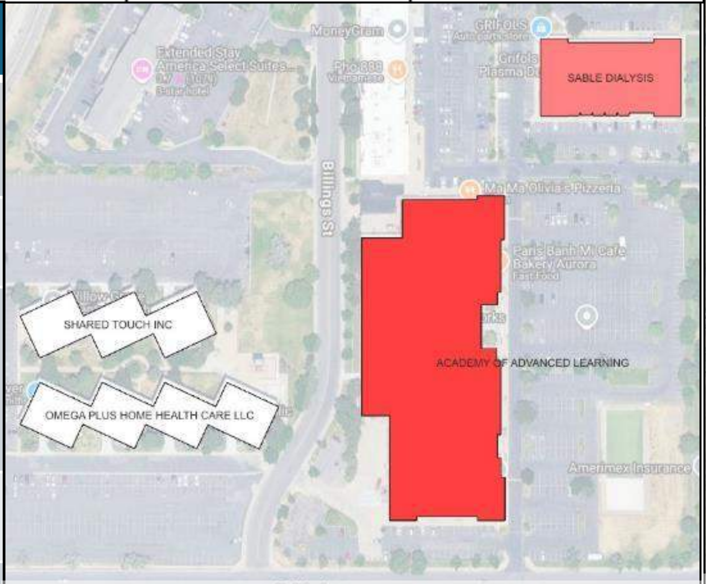
HLC TAR FEATURES: n=8,817 (176 miles)

Michael Baker INTERNATIONAL

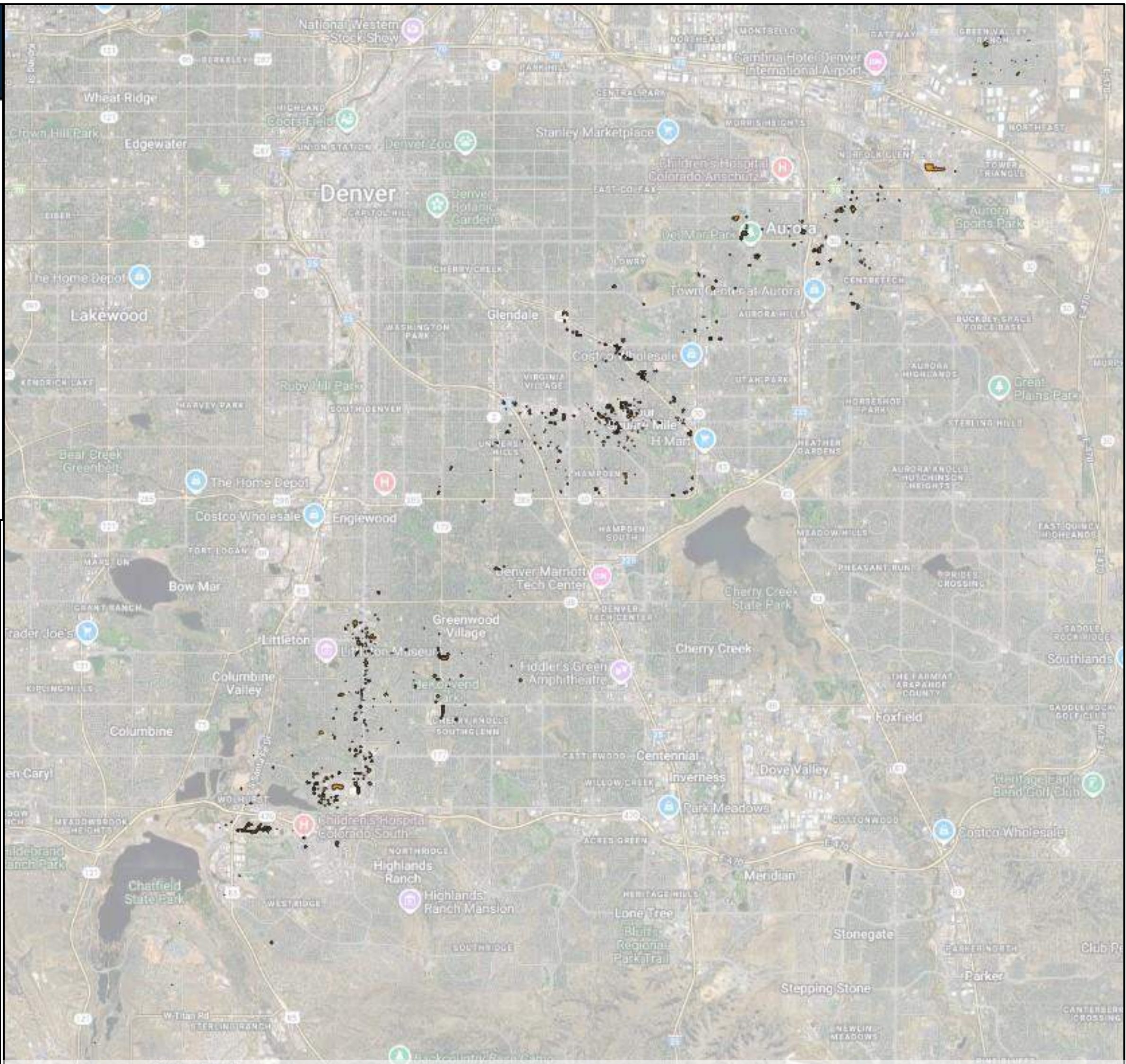
Receptor Data – Critical Facilities

VAR	Strategic Value	Recommended Data Sources	Contribution to Program	Impact Factor Development
Critical Facilities	Location of facilities housing vulnerable populations (schools, nursing homes), location of first responders, strategic medical facilities, and critical utilities.	MHFD Critical Facilities	MHFD maintained, developed from local partners, with capability to be updated based on project needs and user feedback	No quantitative methodology identified to calibrate impact factor scores. Use best judgment for MHFD's 9 asset classes. Differentiate extensive "Medical" class by subclass criticality. Score on 1-5 scale. SCORE ALL AS 5

Facility Type	Impact Factor
Airports, Haz.Mat, Business providing services to off-site patients	5
Medical providers giving appointment-based care	5
Fire/Police, In-patient, residential, overnight surgical center where patients might spend overnight or multiple days	5
Schools, Freestanding Emergency Department	5
Emergency Ops, Power & Water Utilities, Hospitals	5



Ex: Critical Facility Impact Factors



HLC CRITICAL FACILITY FEATURES: n=502

Flood Risk Scoring - Workflow

- Intersect Hazard and Receptors
- Use established thresholds (for D, V, D*V) to assign hazard score
- For each receptor, integrate across the spectrum of frequencies
- Sum results for each project area

$$Flood\ Risk = \sum_{i=1}^{n} (P_i * I * H_i)$$

Where:

- $Flood\ Risk$ – Aggregated risk score at a single receptor
- i – index for recurrence interval events (from 1 to n)
- P - Probability Factor (Annual Exceedance Probability [AEP] bin weight) for event i
- I - Impact Factor (importance of asset, categorized by class)
- H - Hazard Score (e.g., classified depth, depth*velocity, etc. per asset) for event i

Flood Risk Scoring – Hazard Thresholds

Hazard Score Assignment Ruleset				
	Units (ft, ft/s, ft^2/s)	1	2	3
SAR*	D	0.1 - 0.75	0.75 – 1.5	> 1.5
	V	0.1 – 0.75	0.75 – 6	> 6
	DV	0.1- 2.5	2.5 - 6	> 6
RAR**	D	1 – 1.65	1.65 – 3.95	> 3.95
	V	1 - 3.8	3.8 – 6.56	> 6.56
	DV	1 – 3.8	3.8 - 6.56	> 6.56
TAR**	See RAR			
Critical* Facilities	See SAR			

* MHFD Thresholds
** Literature Based Thresholds (see PPT Notes)

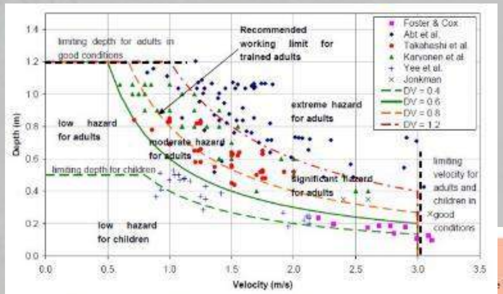
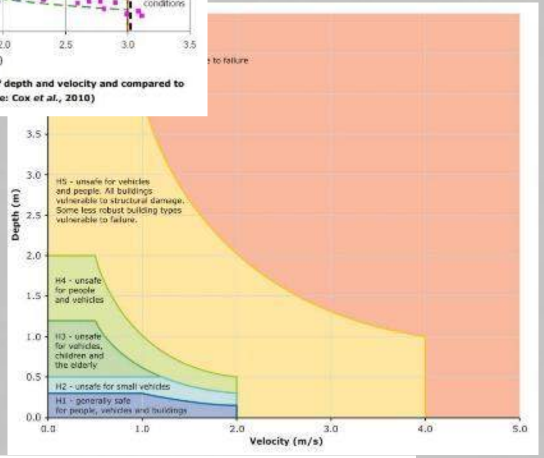


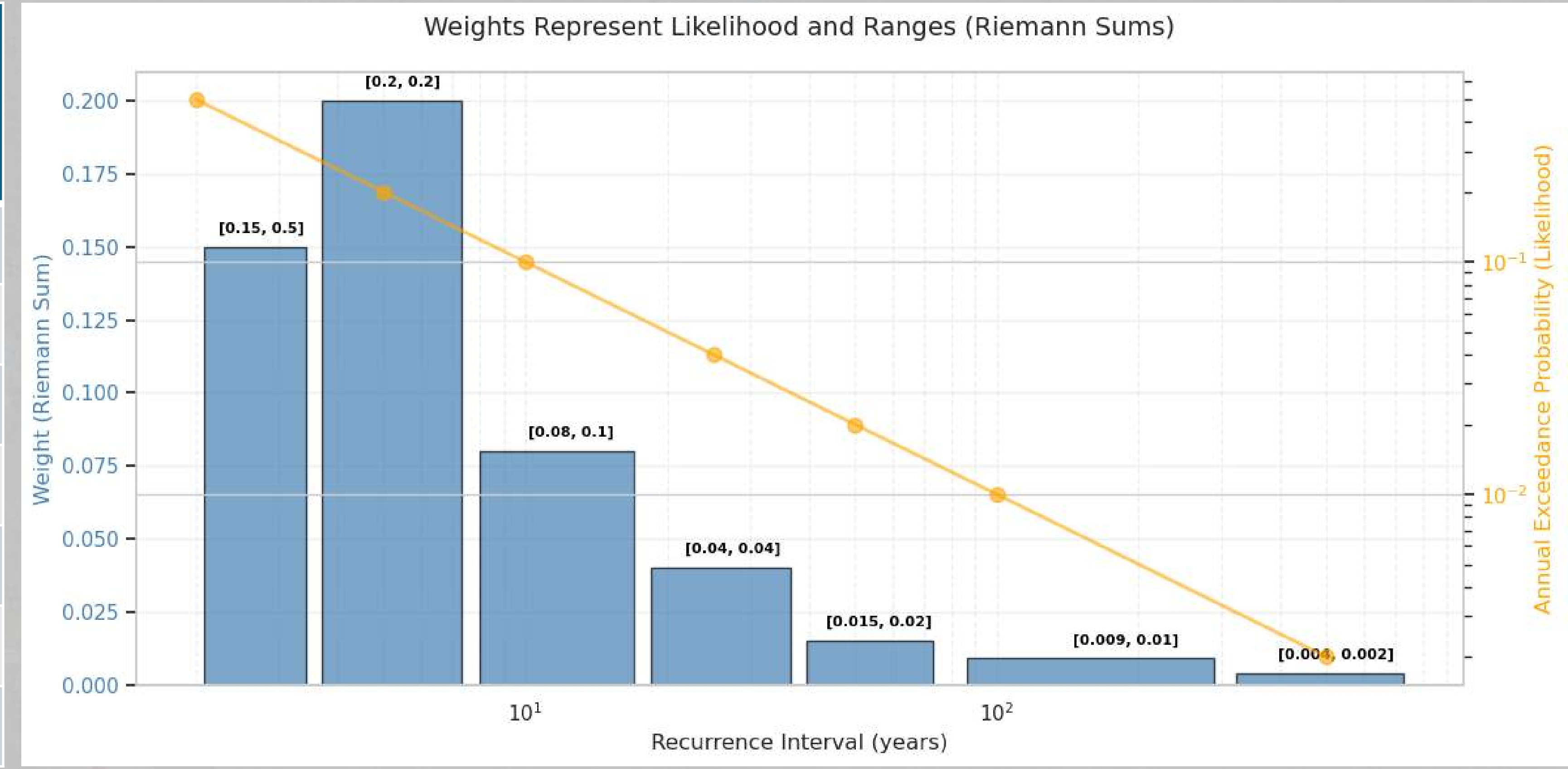
Figure 4-1: Proposed hazard regimes as a function of depth and velocity and compared to available experimental data (Source: Cox *et al.*, 2010)



MBI Hazard Class	Definition	Defined Limits
H1	Generally safe for people, vehicles, and buildings.	Depth < 0.98 ft (0.3 m) Velocity < 0.98 ft/s (0.3 m/s) D*V < 3.23 ft^2/s (0.3 m^2/s)
H2	Unsafe for small vehicles.	Depth < 1.64 ft (0.5 m) Velocity < 6.56 ft/s (2 m/s) D*V < 6.46 ft^2/s (0.6 m^2/s)
H3	Unsafe for vehicles, children, and the elderly.	Depth < 3.94 ft (1.2m) Velocity < 6.56 ft/s (2 m/s) (Same threshold as H2) D*V < 6.46 ft^2/s (0.6 m^2/s) (Same threshold as H2)
H4	Unsafe for vehicles and people.	Depth < 6.56 ft (2m) Velocity < 6.56 ft/s (2 m/s) (Same threshold as H2) D*V < 10.76 ft^2/s (1 m^2/s)
H5	Unsafe for vehicles and people. All buildings vulnerable to structural damage. Some less robust structure types vulnerable to failure.	Depth < 13.12 ft (4m) Velocity < 13.12 ft/s (4m/s) D*V < 43.05 ft^2/s (4 m^2/s)
H6	Unconditionally dangerous.	Depth > 13.12 ft (4m) Velocity > 13.12 ft/s (4m/s) D*V > 43.05 ft^2/s (4 m^2/s)

Flood Risk Scoring – Probability Factors

RI	AEP	Weight
2	0.5	0.15
5	0.2	0.2
10	0.1	0.08
25	0.04	0.04
50	0.02	0.015
100	0.01	0.009
500	0.002	0.004

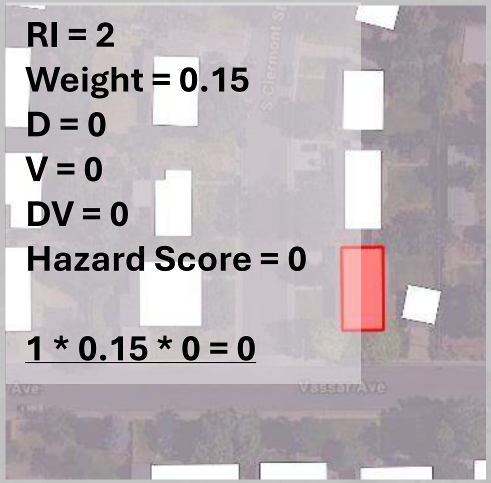


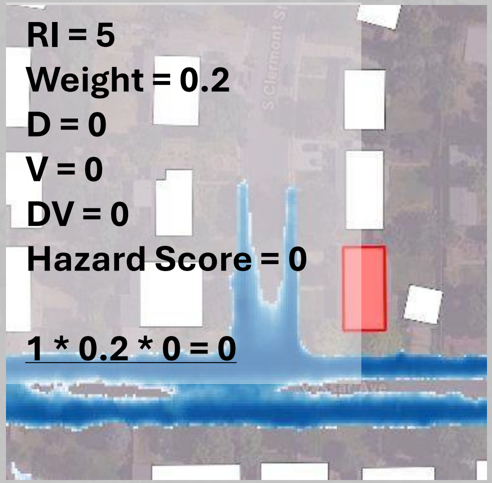
Flood Risk Scoring – Example (SAR)

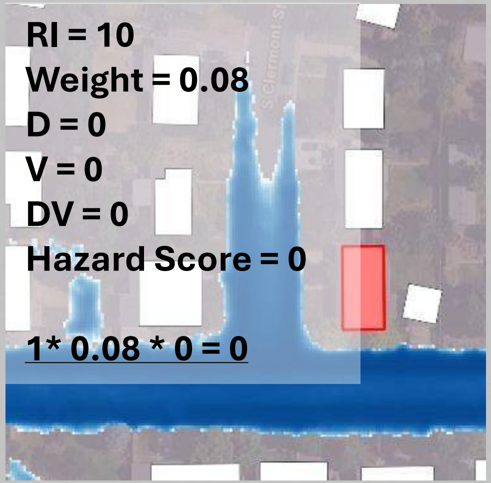
Structure "A"

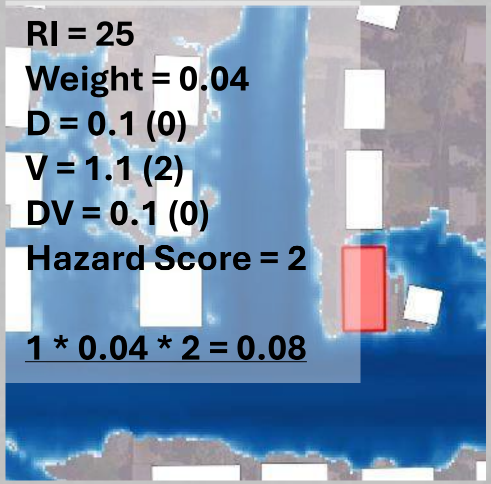
Occupancy = RES1
Est.Pop. = 4
Impact Factor = 1

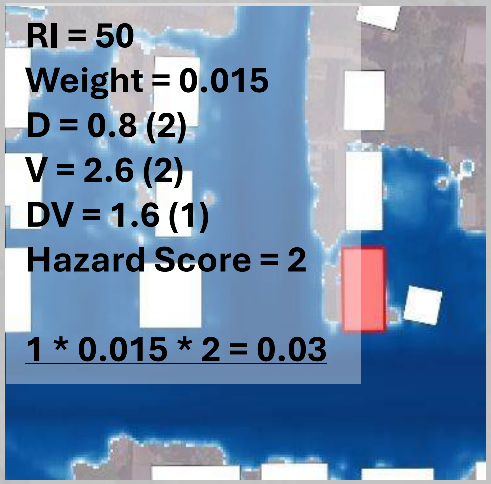
Flood Risk @ "A" =
0+0+0+0.08+0.03+
0.018+0.012
= 0.14

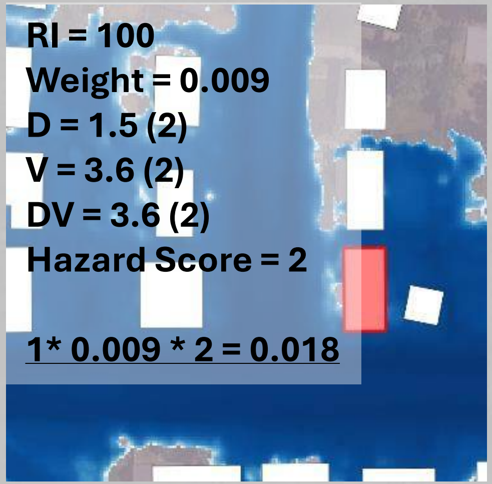


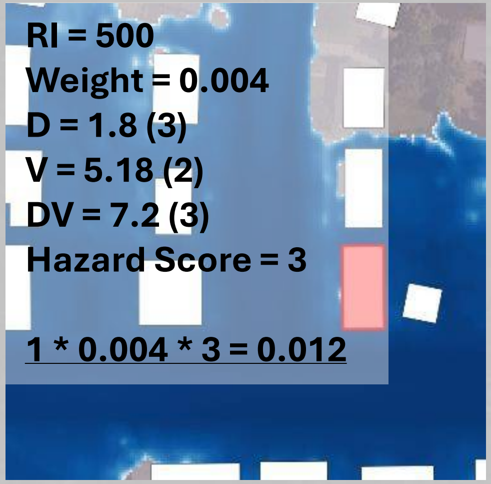












Michael Baker INTERNATIONAL

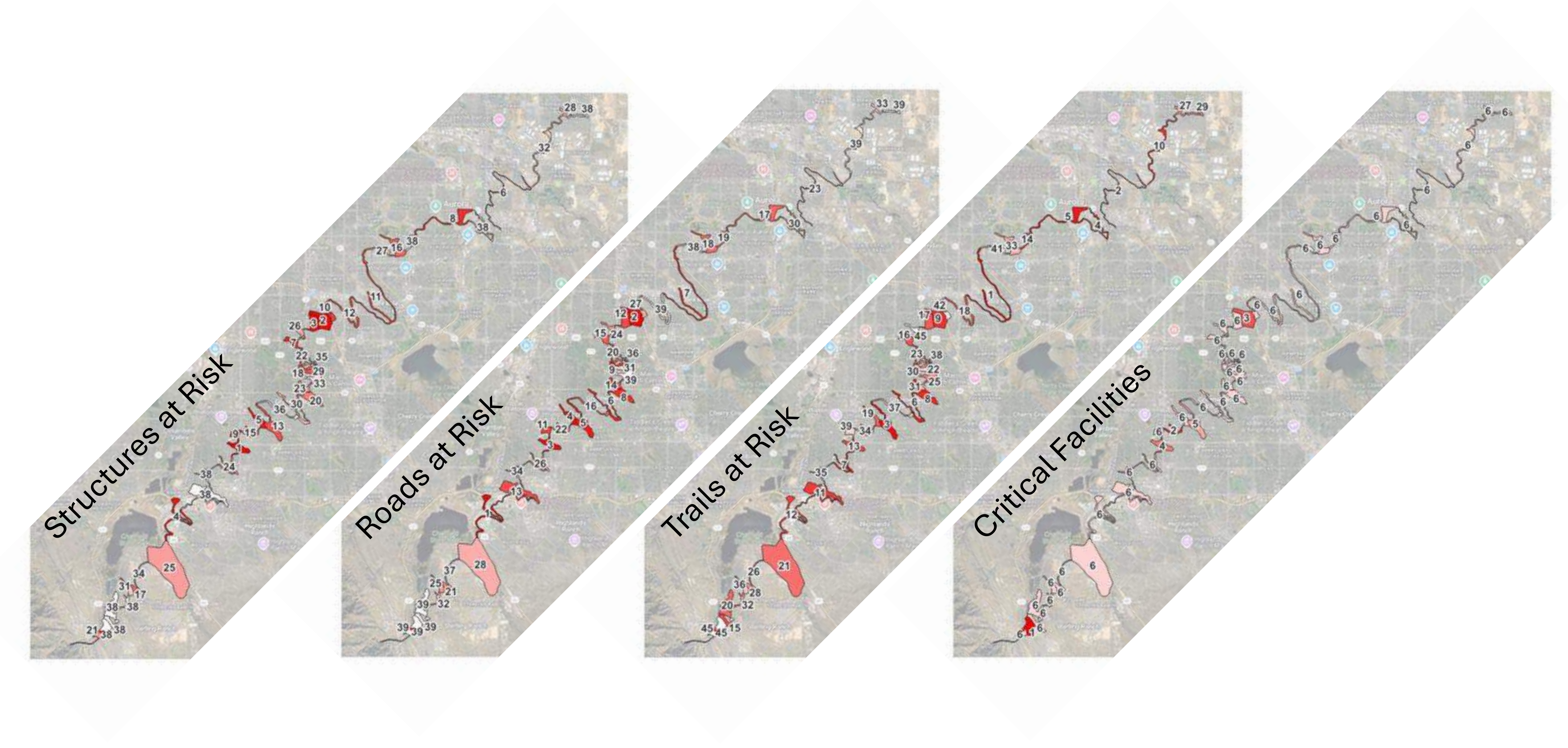
Flood Risk Scoring – Example

For zone_id “35”:

- Sum all SAR flood risk scores to arrive at Total SAR Flood Risk
- Rank Total SAR Flood Risk against all other zones
- Repeat for other values at risk (RAR, TAR, Critical Facilities)

Michael Baker INTERNATIONAL

Results – Ranked Project Areas



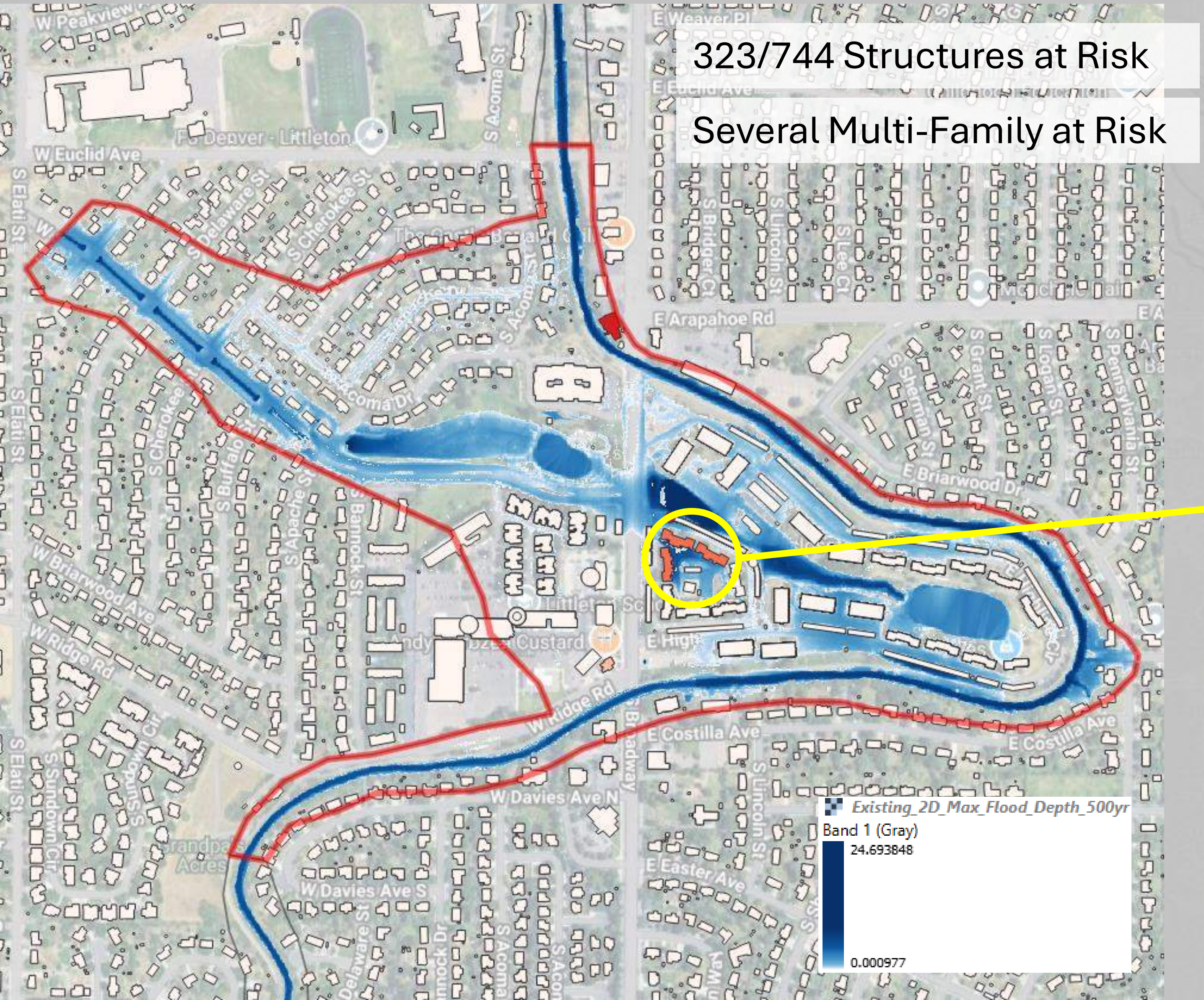
Results – Ranked Project Areas

Top 10 by Structures At Risk

Zone ID	SAR Rank	SAR Risk Total	SAR Flooded/Total	SAR % Impacted	RAR Rank	TAR Rank	Crit. Fac. Rank
16	1	161	323 / 744	43%	3	18	4
35	2	109	444 / 813	54%	2	9	2
34	3	32	97 / 445	22%	12	15	6
18	4	28	53 / 149	36%	4	17	6
11	5	19	12 / 75	16%	1	12	6
44	6	12	4 / 43	9%	23	2	6
42	7	7	111 / 619	18%	17	5	6
32	8	6	15 / 49	31%	15	14	6
15	9	6	25 / 276	9%	11	38	6
38	10	5	8 / 410	2%	7	1	6

Michael Baker
INTERNATIONAL

Results – Ranked Project Areas (Zone ID #16)



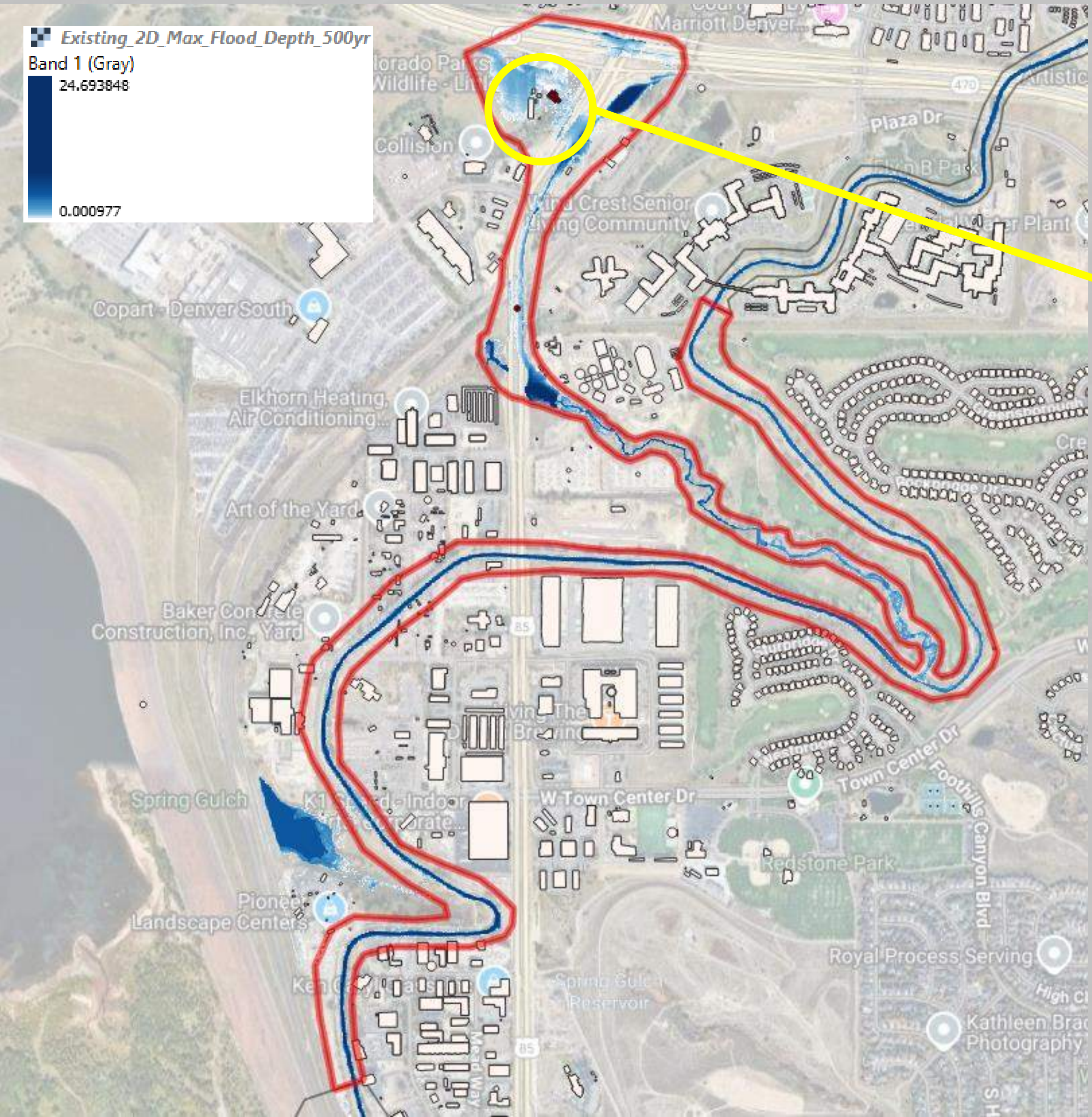
Hazard	Val	Haz. Score
depth_2_median	0.1237	1
depth_2_mean	0.1496	1
depth_2_max	0.3035	1
depth_5_median	2.4116	3
depth_5_mean	2.1450	3
depth_5_max	2.7226	3
depth_10_median	2.5146	3
depth_10_mean	2.1989	3
depth_10_max	2.8583	3
depth_25_median	2.8383	3
depth_25_mean	2.5532	3
depth_25_max	3.1503	3
depth_50_median	3.0771	3
depth_50_mean	2.7814	3
depth_50_max	3.3891	3
depth_100_median	3.3325	3
depth_100_mean	2.9618	3
depth_100_max	3.5517	3
depth_500_median	3.5766	3
depth_500_mean	2.8678	3
depth_500_max	3.9199	3
velocity_2_median	0.0446	1
velocity_2_mean	0.0446	1
velocity_2_max	0.0446	1
velocity_5_median	0.0895	1
velocity_5_mean	0.0981	1
velocity_5_max	0.3931	1
velocity_10_median	0.0913	1
velocity_10_mean	0.1005	1
velocity_10_max	0.4085	1
velocity_25_median	0.4458	1
velocity_25_mean	0.5148	1
velocity_25_max	1.9862	2
velocity_50_median	0.6373	1
velocity_50_mean	0.7268	1
velocity_50_max	2.6788	2
velocity_100_median	0.8822	2
velocity_100_mean	0.9614	2
velocity_100_max	3.4285	2
velocity_500_median	1.2219	2
velocity_500_mean	1.2380	2
velocity_500_max	4.6127	2
DV_2_median	0.0104	1

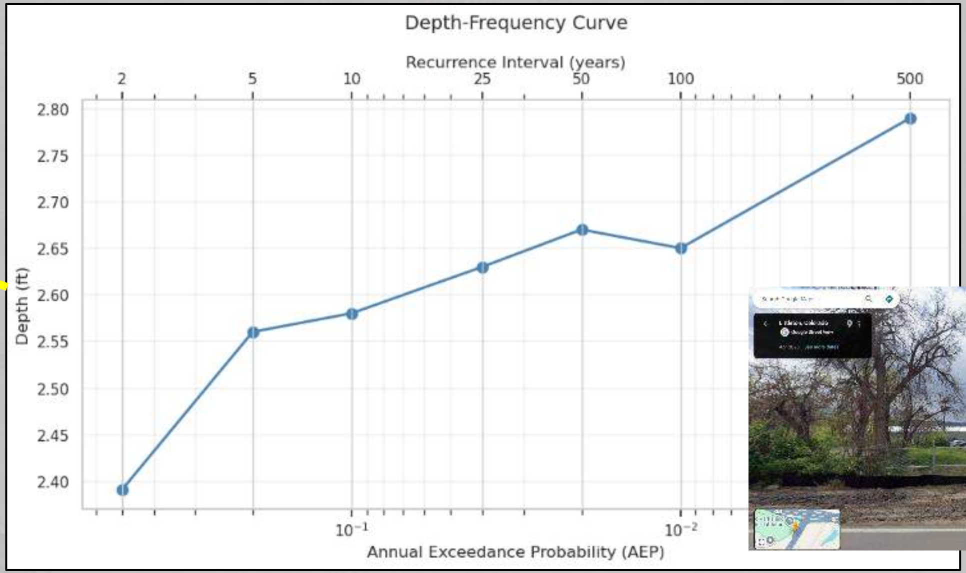
Results – Ranked Project Areas

Top 10 by Structures At Risk

Zone ID	SAR Rank	SAR Risk Total	SAR Flooded/Total	SAR % Impacted	RAR Rank	TAR Rank	Crit. Fac. Rank
16	1	161	323 / 744	43%	3	18	4
35	2	109	444 / 813	54%	2	9	2
34	3	32	97 / 445	22%	12	15	6
18	4	28	53 / 149	36%	4	17	6
11	5	19	12 / 75	16%	1	12	6
44	6	12	4 / 43	9%	23	2	6
42	7	7	111 / 619	18%	17	5	6
32	8	6	15 / 49	31%	15	14	6
15	9	6	25 / 276	9%	11	38	6
38	10	5	8 / 410	2%	7	1	6

Results – Ranked Project Areas (Zone ID #11)





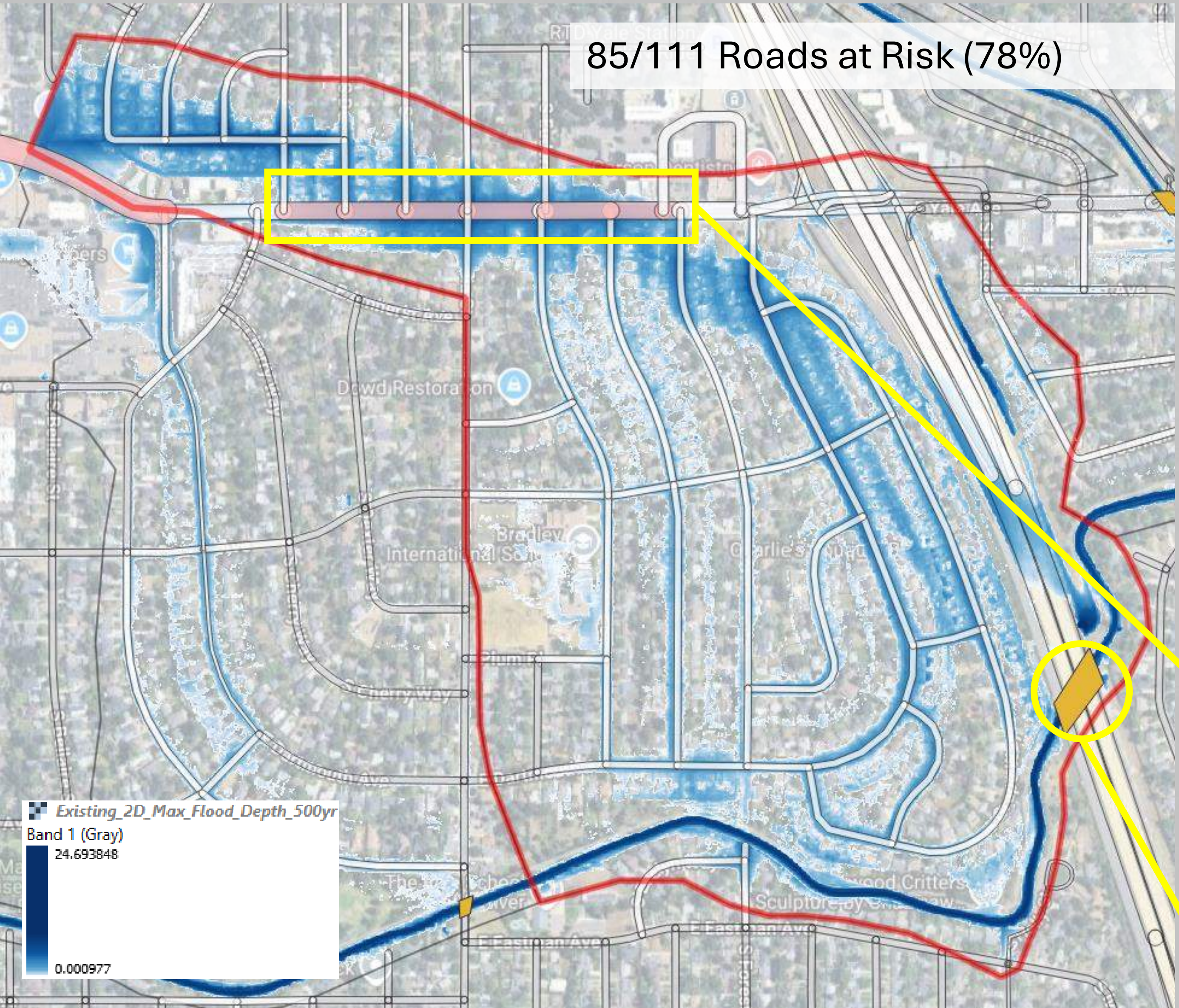
IND6 (3), COM8 (4)

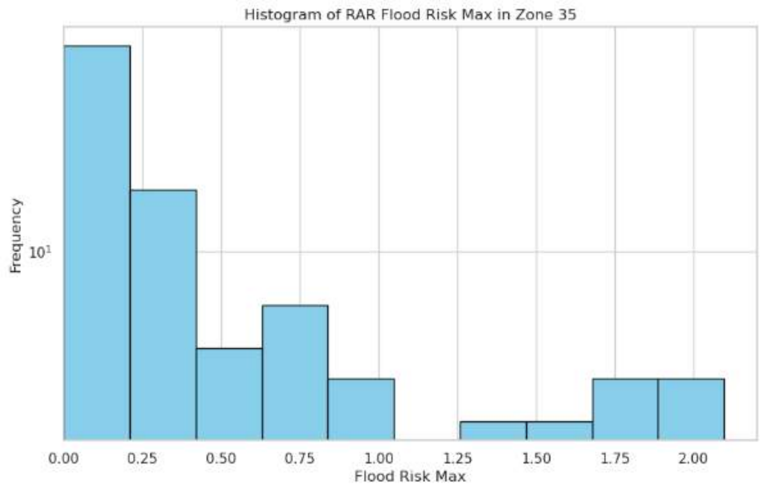
Results – Ranked Project Areas

Top 10 by Structures At Risk

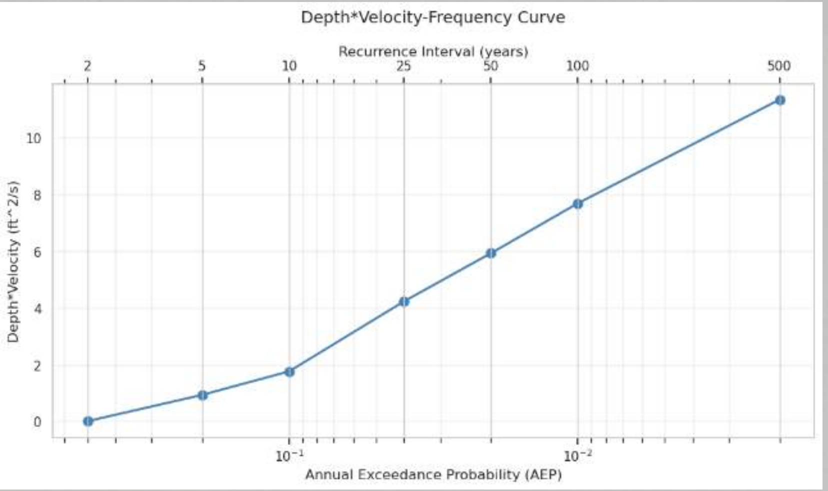
Zone ID	SAR Rank	SAR Risk Total	SAR Flooded/Total	SAR % Impacted	RAR Rank	TAR Rank	Crit. Fac. Rank
16	1	161	323 / 744	43%	3	18	4
35	2	109	444 / 813	54%	2	9	2
34	3	32	97 / 445	22%	12	15	6
18	4	28	53 / 149	36%	4	17	6
11	5	19	12 / 75	16%	1	12	6
44	6	12	4 / 43	9%	23	2	6
42	7	7	111 / 619	18%	17	5	6
32	8	6	15 / 49	31%	15	14	6
15	9	6	25 / 276	9%	11	38	6
38	10	5	8 / 410	2%	7	1	6

Results – Ranked Project Areas (Zone ID #35)



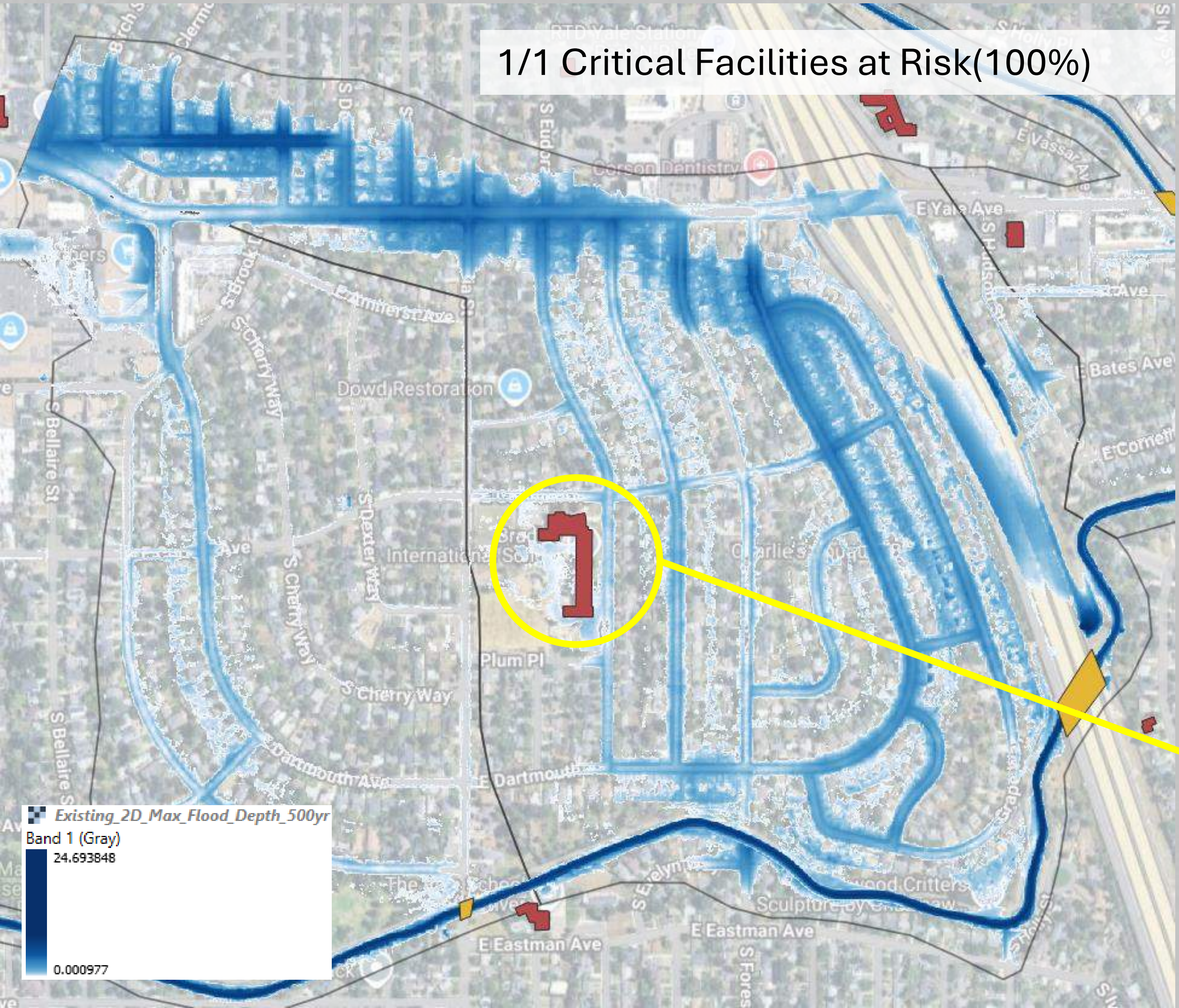


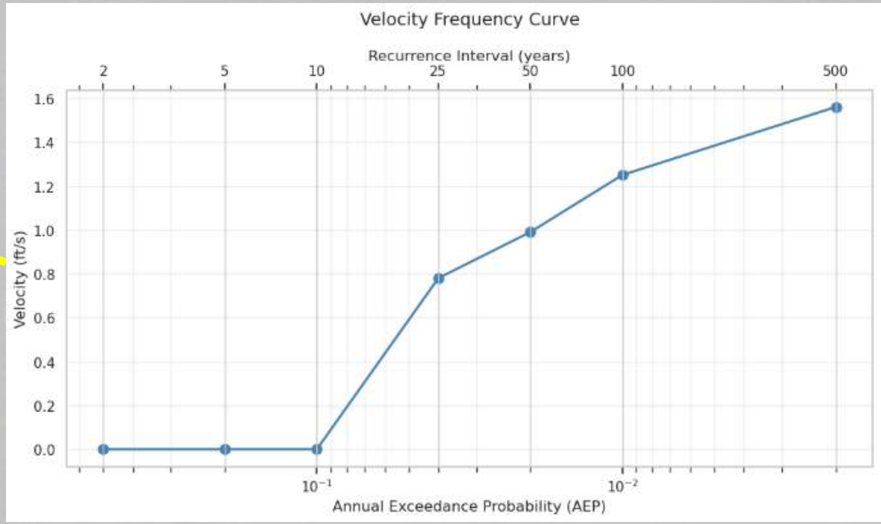
Yale Ave (Impact Factor = 4)



RAR Mask (where crossing information not available)

Results – Ranked Project Areas (Zone ID #35)





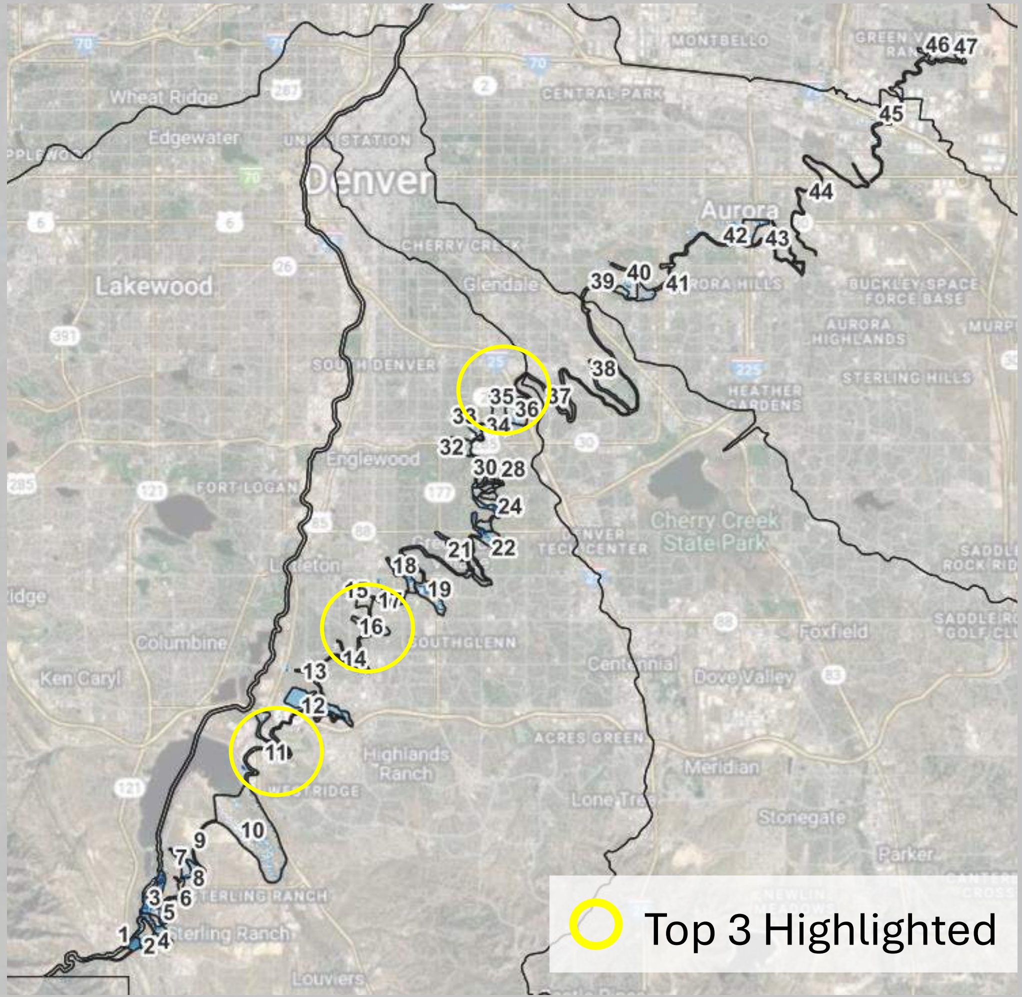
Michael Baker INTERNATIONAL

Results – Ranked Project Areas

Top 10 by normalized risk scores (SAR, RAR, TAR, Critical Facilities)

Zone ID	Total Risk Sum	SUM Var Rank**	AVG Var Rank*	SAR Rank	RAR Rank	TAR Rank	Crit. Fac. Rank
16	192	1	5	1	3	18	4
35	150	2	1	2	2	9	2
11	98	3	2	5	1	12	6^
18	44	4	7	4	4	17	6^
34	39	5	9	3	12	15	6^
38	32	6	2	10	7	1	6^
19	30	7	4	12	5	3	6^
44	29	8	10	6	23	2	6^
21	25	9	6	11	6	6	6^
42	20	10	8	7	17	5	6^

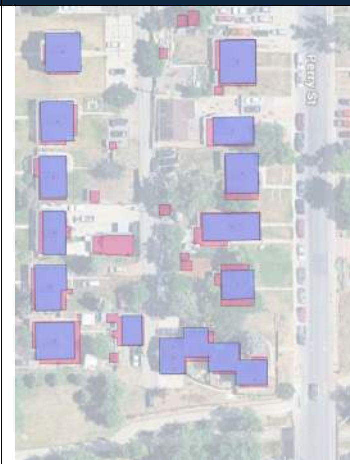
*Rank computed as a rank-of-ranks where individual VAR ranks are summed, then re-ranked
** Rank computed based on sum of flood risk scores across all VAR categories
^ Zero score = tie for last

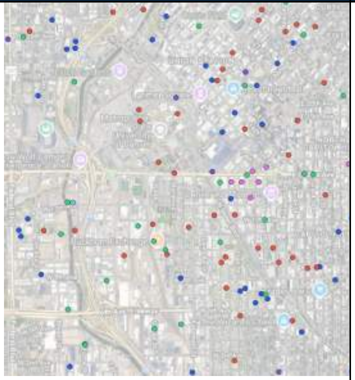
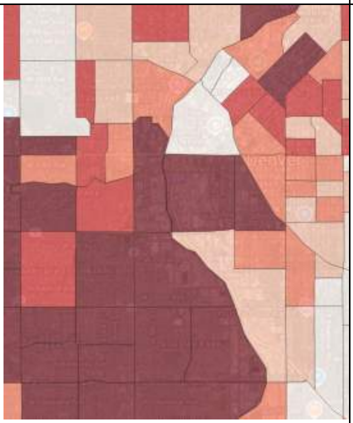


Flood Risk Assessment Deliverables

- Flood risk results for each VAR category: SAR, RAR, TAR, C.F.
- Aggregated and ranked flood risk results by project area
- Data dictionary
- Mask locations for SAR/C.F., RAR
- 2-Pager overviewing receptor data creation
- STAMP Report Contributions
  - Summary tables of ranking and stats
  - This PowerPoint as an appendix
  - Short write up on methodology

Summary – Values at Risk (VAR) Evaluation

VAR	Strategic Value	Recommended Data Sources	Contribution to Program	Impact Factor Development	Figure	Datasets Evaluated, Not Recommended
Structures at Risk (SAR)	Location of physical structures of various occupancy types. Construction and material types, year built, and other attributes used in depth-damage analyses, basement flood risk assessment, etc.	USACE National Structure Inventory (NSI)	Population Estimates (at structure), Attributes for Depth-Damage Assessment, Plus-Codes	Statistical evaluation of occupancy types to occupancy count estimates, partitioned by quintiles, scored 1-5.		▪ Lightbox ▪ CoreLogic ▪ Ecopia ▪ Local Assessor’s Data
		FEMA USA Structures	Addresses, Mobile Home ID			
		DRCOG Building Roof Prints	Newer Development, Auxiliary Building ID			
Roads at Risk (RAR)	Identification of the traveling public (vehicular traffic), transportation networks and travel patterns, roadway configurations, traffic volume, and evacuation route analysis.	Open Street Map (OSM)	Complete Coverage, Roadway Attributes, Network Analysis	Machine learning model used to predict AADT based on roadway characteristics, partitioned by quintiles, scored 1-5. Heightened scores for parts of the network critical for egress or first responders. No handling of varying exposure (segment length).		▪ CDOT Data ▪ DRCOG AADT
		DRCOG Edge of Pavement Planimetrics	Roadway Polygons			
		Replica	AADT from Cell Phone Data			
Trails At Risk (TAR)	Estimation of pedestrian locations and non-vehicular transportation networks.	All Trails (OSM Derivative)	Pedestrian Locations	No differentiable characteristics are available related to presence of receptors. Handle varying exposure by partitioning length with quintiles, scored 1-5.		▪ COTREX ▪ DRCOG Sidewalk Polygons ▪ Strava Metro Data
		RTD Transit Stops	Pedestrian (Commuter) Locations			

VAR	Strategic Value	Recommended Data Sources	Contribution to Program	Impact Factor Development	Figure	Datasets Evaluated, Not Recommended
Critical Facilities	Location of facilities housing vulnerable populations (schools, nursing homes), location of first responders, strategic medical facilities, and critical utilities.	MHFD Critical Facilities	MHFD maintained, developed from local partners, with capability to be updated based on project needs and user feedback	No quantitative methodology identified to calibrate impact factor scores. Use best judgment for MHFD's 9 asset classes. Differentiate extensive "Medical" class by subclass criticality. Score on 1-5 scale.		▪ HAZUS Inventory National Database ▪ Homeland Infrastructure Foundation-Level Data (HIFLD) ▪ NSI Attributes
Population at Risk (PAR)	Estimation of the geographic location of people during a theoretical flood event. Additional attributes for demographics.	CDC Sociovulnerability Index (SVI)	Aggregation of US Census data at the tract level for 16 demographic categories, 4 primary themes, and a single overall sociovulnerability percentile. Represents a descriptor of receptor vulnerability uncorrelated with other VAR datasets.	Use the overall sociovulnerability percentile score (RPL_THEMES). Set low and low-medium vulnerability percentiles (0-0.5) to 0, score the medium-high and high vulnerability percentiles (0.5-1) on a 1-5 scale.		▪ US Census Bureau (Decennial and American Community Survey) ▪ NSI Population Estimates

APPENDIX F: ENCAMPMENT DISCOURAGEMENT STRATEGIES

ENCAMPMENT DISCOURAGEMENT STRATEGIES MEMORANDUM

TO: HLC STAMP Project Team
FROM: ICON Engineering, Inc.
RE: Encampment Discouragement Strategies Memorandum
DATE: October 29, 2025

Background and Purpose

As the High Line Canal (HLC) project team met monthly to talk about the Stormwater Transition and Management Plan's (STAMP) progress, a question arose whether ICON could assess the hydraulic impacts of placing boulders or other material under bridge crossings over the Canal to discourage unhoused persons from seeking shelter under these crossing structures. The question asked specifically about the three HLC crossings at S Broadway. The purpose of this memorandum is to assess the impacts of using this type of discouragement strategy at these three crossings though this could apply to adding boulders or other material to any bridge underpass.

Hydraulics

To assess the hydraulic impact of adding boulders to the channel under bridges, the manning's n-value or roughness coefficient of the channel would need to be increased in these areas. To run the analysis, ICON increased the channel roughness values only under the three S Broadway crossing structures. The existing conditions roughness coefficient was between 0.04 and 0.05, for the increased roughness model, a value of 0.08 was used. This value is slightly conservative as the typical roughness coefficient for large boulders is 0.07. The value was adjusted in the channel for the along the canal length of each crossing structure, additionally n-values were increased for 10 feet upstream and downstream for each of the three bridges.

Findings

After the roughness coefficient for the three crossing structures at S Broadway were increased, the resulting peak spill flow values and total spill volume at each spill location were compared to the existing conditions values. While the spill locations remained the same, the magnitude of peak flow and total volume spilled differed between existing conditions and the roughness sensitivity model. At some spill locations the peak flow and total volume spilled was greater with an increased roughness under the S Broadway crossings and in other cases vice versa. However, the total peak flow is 5 cfs greater and the total volume spilled is ~5 ac.ft lower in existing conditions compared to the increased roughness model. For a comparison of peak flow and total volume for each spill location see **Table 1** and **Figure 1** attached. The increase in roughness under the three S Broadway crossing structures in general increases the volume of water spilled upstream of these crossings. This is particularly evident up Canal of the second crossing at S Broadway (south of E Arapahoe Rd) where the largest increases in both peak spill flow and total volume spilled from existing to proposed conditions are realized. However, the total volume spilled is only 4% higher with roughness increased at the

S Broadway crossings compared to the total volume spilled in existing conditions which indicates that such a change does not result in significant changes in total spill flow hydraulics.

Conclusion and Considerations

The increase in roughness values to simulate the addition of boulders under the three S Broadway overpasses at the HLC have some adverse effects. Of the seven spill locations that occur between the most up Canal and most down Canal S Broadway crossings there are peak spill flow increases at three of the seven locations, and total spill volume increases at all seven locations. However, the magnitude of these increases is not significant in that the total values for total peak flow and total spill volume at the seven spill locations are less than 5% different between existing and proposed conditions. It is necessary to weigh the benefit of deterring the unhoused population from seeking shelter under these overpasses with the consequence of increasing the magnitude of the spill flow, albeit minor. Additional analysis may be necessary to assess the effects of increases in roughness at one or two crossings instead of all three crossings depending on what design decisions are advanced. Furthermore, there are concurrent discussions, with the HOA downstream of the intersection of Littles Creek with the HLC, that may result in an alternative that has the potential to mitigate the spills at spill locations 1 – 5 (see **Figure 1** attached for the specific location of these spills). This would likely change the hydraulic effect of adding boulders under the S Broadway crossings and should be considered in future conversations. Note that if a similar encampment discouragement strategy were to be explored at any other location along the Canal, it is assumed that the hydraulic effects would be similar. However, additional analysis may be warranted.

While it has been shown that there are no major implications from increasing Canal's roughness under the three S Broadway overpasses, and that this type of strategy is potentially feasible from a hydraulic perspective, there have been reports of this strategy not being totally successful as a discouragement strategy for the unhoused population. Several documented examples of cities using boulders to discourage encampments have found that unhoused persons will move the boulders or just lay or rest among them. [1, 2, 3] Additionally, the Clark County Regional Flood Control District has anecdotally shared that using riprap to discourage unhoused activities has been unsuccessful and led to maintenance complications. In order to prevent this from happening consider using large boulders that are unable to be moved easily or grouting the boulders in place.

Attachments

- **Table 1:** Comparison Table for Existing vs Proposed Conditions for Encampment Discouragement Strategy
- **Figure 1:** Existing vs Proposed Conditions Spill Values for the Addition of Boulders Under S Broadway Overpasses at the High Line Canal

Sources

[1] https://www.wowt.com/2025/09/17/homeless-encampment-under-omaha-bridge-causes-concerns/

[2] https://okcfox.com/news/local/okcs-52k-boulder-effort-fails-to-deter-homeless-as-bridge-remains-a-refuge

[3] https://www.publicsource.org/downtown-pittsburgh-homeless-encampments-replaced-boulders/

END OF MEMORANDUM

Table 1: Comparison Table for Existing vs Proposed Conditions for Encampment Discouragement Strategy

Spill Location	Spill Number	Maximum Peak Spill Flow (cfs)				Total Volume Spilled (ac.ft)			
		Existing Conditions (~0.05 Manning's n-value in Channel)	Proposed Conditions (0.08 Manning's n-value in Channel)	Difference Proposed-Existing (cfs)	Difference (%)	Existing Conditions (~0.05 Manning's n-value in Channel)	Proposed Conditions (0.08 Manning's n-value in Channel)	Difference Proposed-Existing (ac.ft)	Difference (%)
East of W Ridge Rd and S Broadway	1	22	21	-1	-5	1.4	1.4	0	0
West of SE corner of E Highline Cir	2	734	699	-35	-5	94	96.3	2.3	2
South of S Sherman St and E Briarwood Dr	3	167	171	4	2	5.6	5.9	0.3	5
SW of E Sterne Blvd and E Briarwood Dr	4	250	264	14	6	19.6	21.2	1.6	8
South of E Arapahoe Rd and S Broadway	5	89	109	20	22	3	3.8	0.8	27
NE of S Acoma St and S Apache Dr	6	12	9	-3	-25	3	3.2	0.2	7
East of W Peakview Ave and S Acoma St	7	13	10	-3	-23	5.3	5.6	0.3	6
SW of S Clarkson St Crossing	8	10	9	-1	-10	0.3	0.2	-0.1	-33
SW of E Fair Pl cul-de-sac	9	48	48	0	0	1.9	1.9	0	0
	Total:	**1345**	**1340**	**-5**	**-0.4%**	**134.1**	**139.5**	**5.4**	**4.0%**

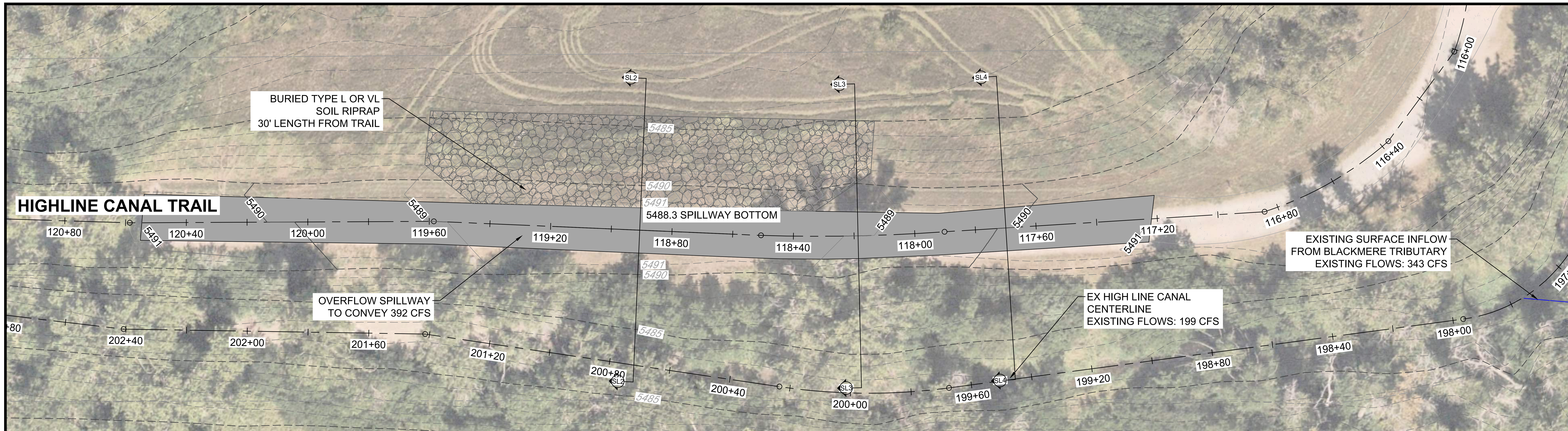
ICON ENGINEERING

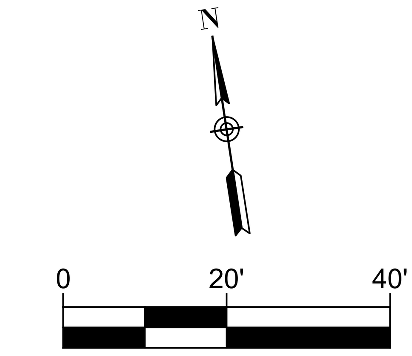
High Line Canal Stormwater Transistion and Management Plan - Hydraulic Analysis

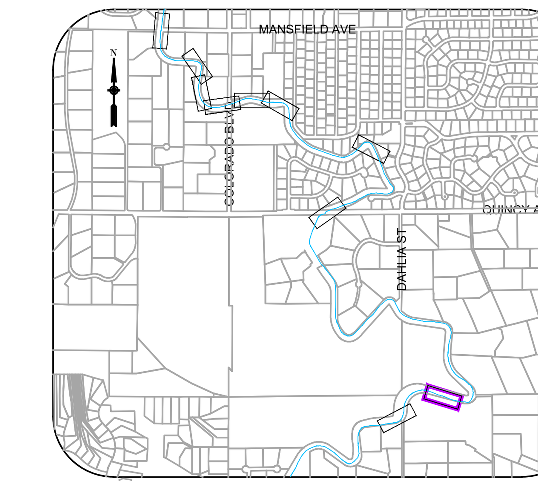
Figure 1: Existing vs Proposed Conditions Spill Values for the Addition of Boulders Under S Broadway Overpasses at the High Line Canal

MHFD MILE HIGH FLOOD DISTRICT

APPENDIX G: SPILLWAY AND TREATEMENT DRAIN CONCEPT DESIGN







LEGEND

- Soil Riprap
- Concrete
- Proposed Trail

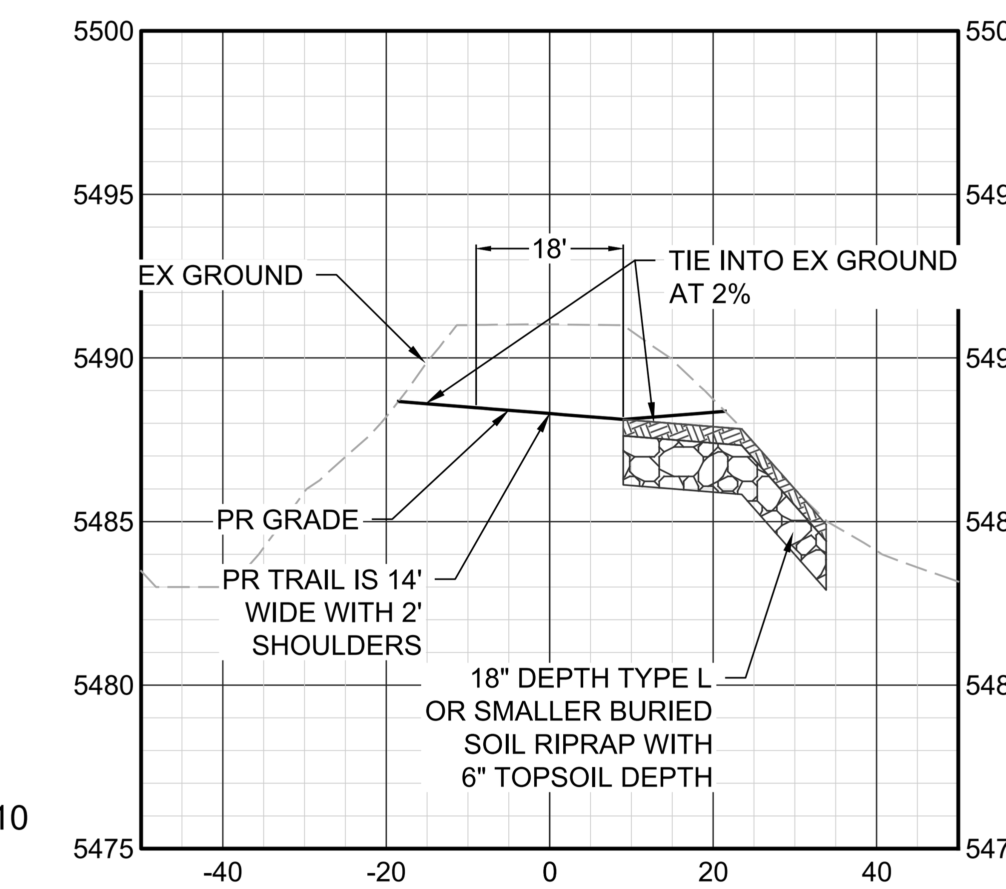
NOTES

1. SPILLWAY ALLOWS FOR 1'+ OF FREEBOARD WHILE FLOWING 392 CFS OVER THE SPILLWAY AND KEEPING 150 CFS IN THE EXISTING CHANNEL.

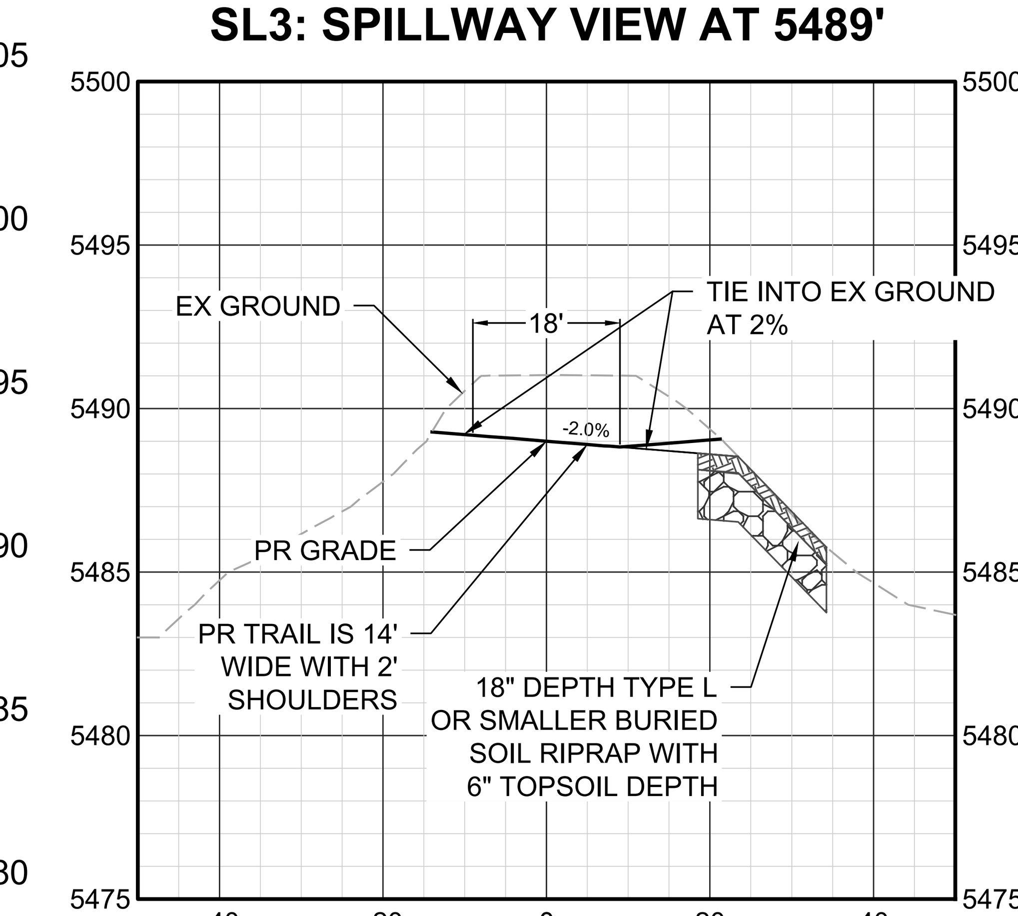
Spillway Configuration Design Options

Configuration	Trail Slope	Spillway Length (ft)	Velocity (ft/s)	Water Depth (ft)	Freeboard (ft)	Spillway Protection
Current	2%	60.6	8.7	0.52	2.18	Type L or VL Riprap
Alternative 1	1%	60.6	7.5	0.48	2.22	Type VL Riprap or Less
Alternative 2	5%	60.6	9.7	0.56	2.14	Type L or VL Riprap
Alternative 3	2%	100	7.9	0.41	2.29	Type VL Riprap or Less
Alternative 4	5%	100	8.6	0.42	2.3	Type L Riprap

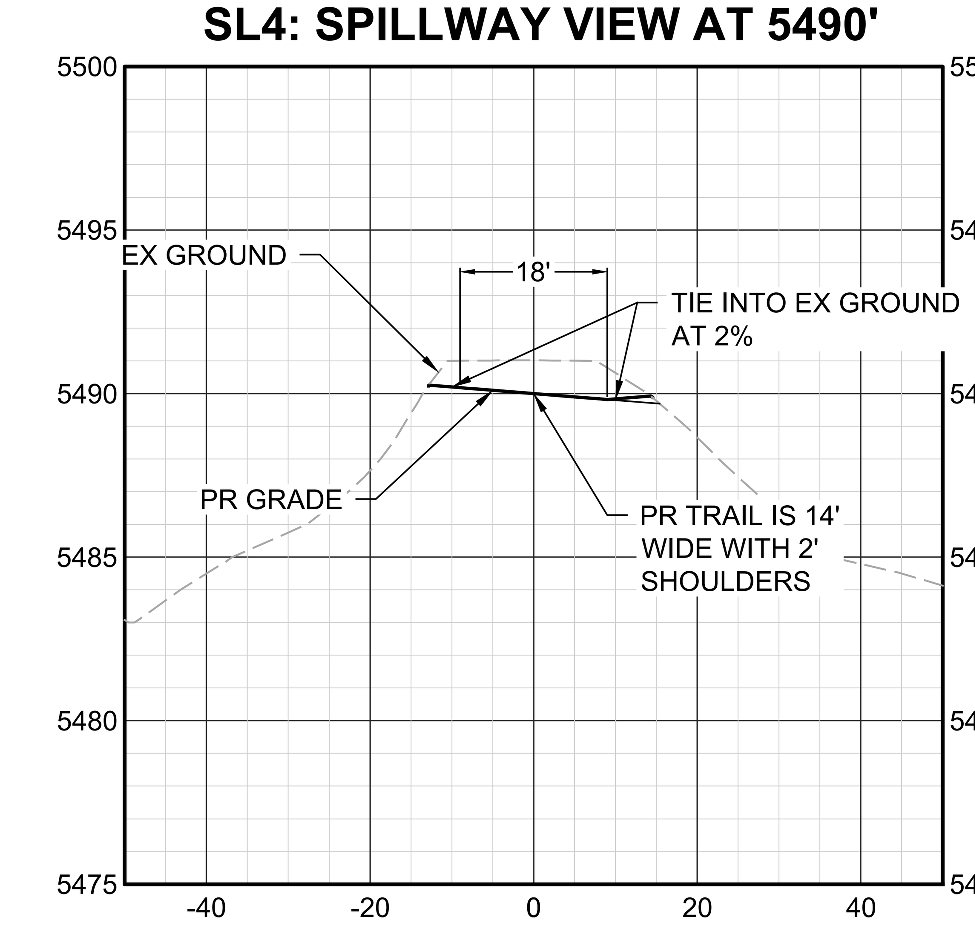
SL2: BOTTOM OF SPILLWAY VIEW



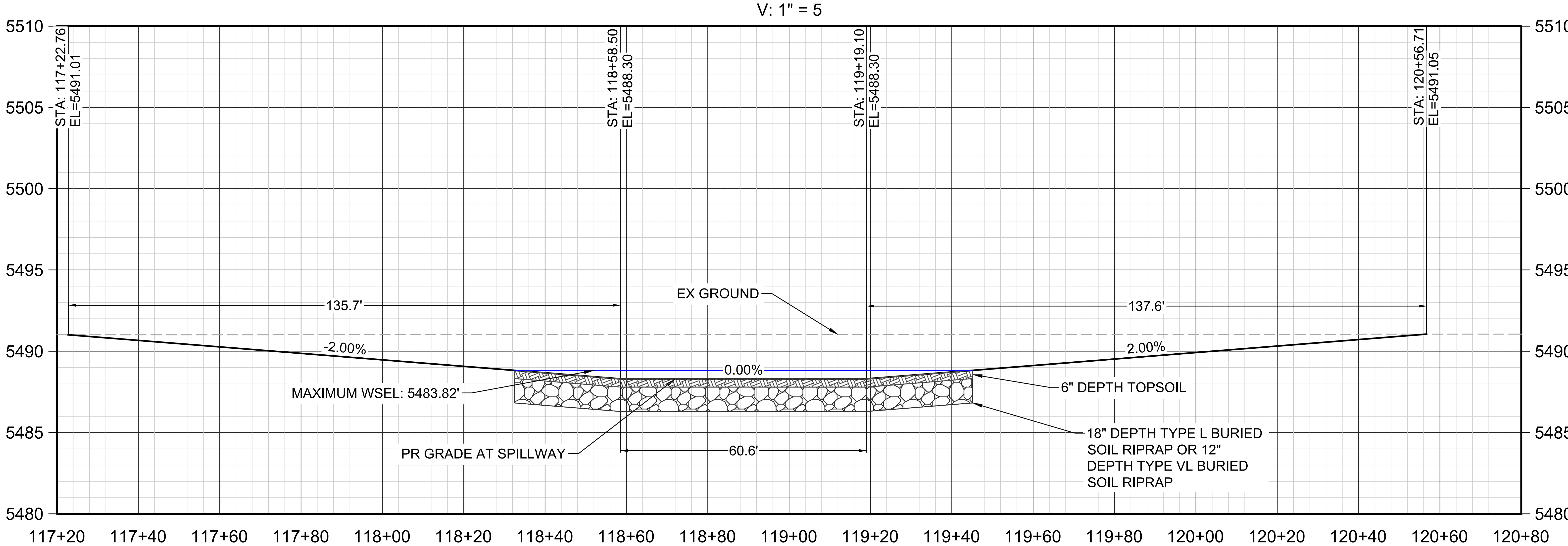
SL3: SPILLWAY VIEW AT 5489'



SL4: SPILLWAY VIEW AT 5490'



PROFILE OF CE-TRAIL
H: 1" = 20
V: 1" = 5



P:\P24-054_Blackmere_Canal_Restoration\06_DWG\03_EXHIBITS\BLACKMERE TRIBUTARY SPILLWAY.dwg; Zpurfurst; Page Setup:----; ICON.stb; 1/6/2026 9:58 AM

No.	DATE	REVISIONS	APPR.

DRAWN BY: ZJP
DESIGNED BY: ZJP
APPROVED BY: TWC

811 Know what's below. Call before you dig.

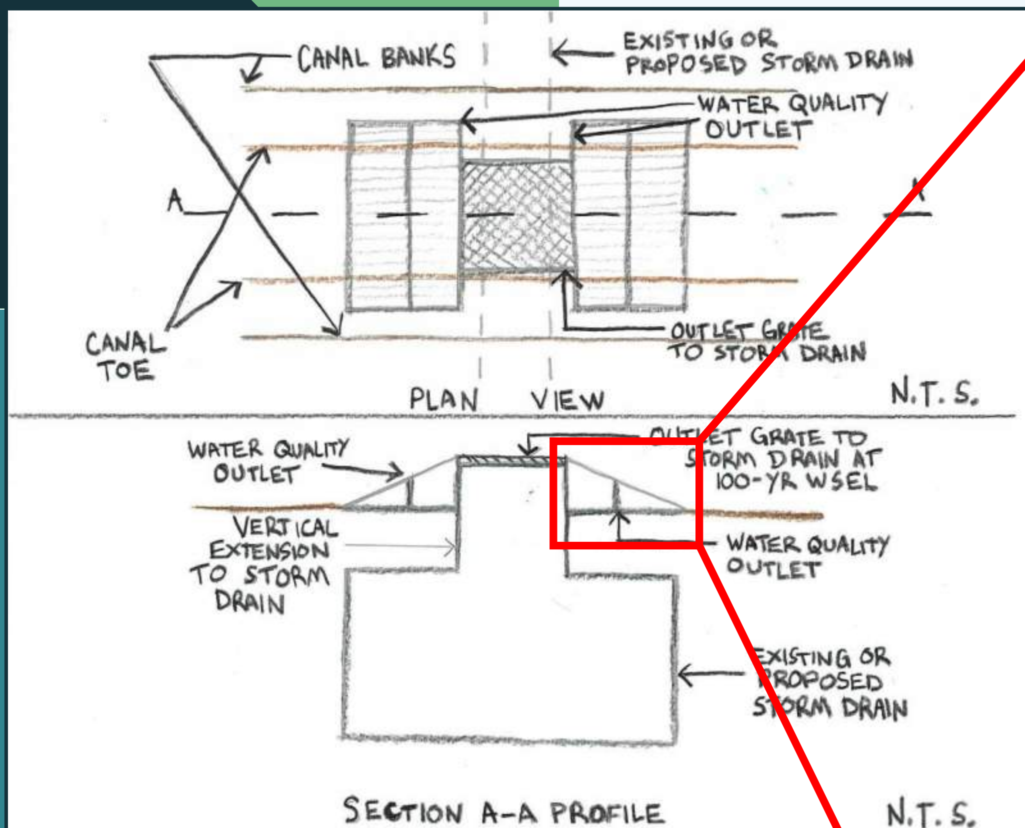
PREPARED FOR:

PREPARED BY:
ICON ENGINEERING
7000 S. Yosemite Street, Suite 120
Centennial, CO 80112
Phone (303) 221-0802

BLACKMERE TRIBUTARY
EXHIBIT
24-054
SPILLWAY ALTERNATIVE

DATE: OCT 2024
SHEET: 1 OF 1

TREATMENT DRAIN CONCEPT



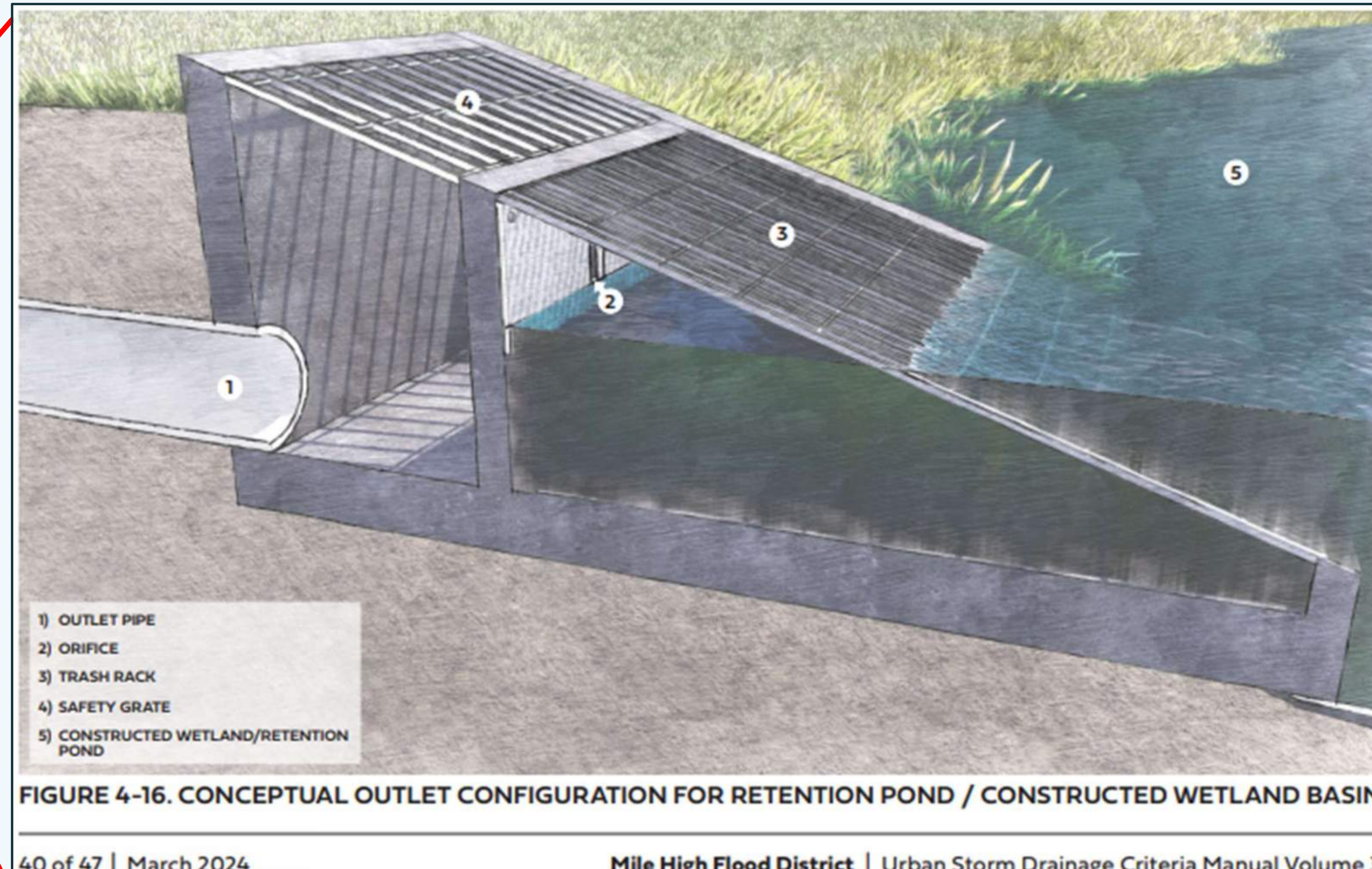


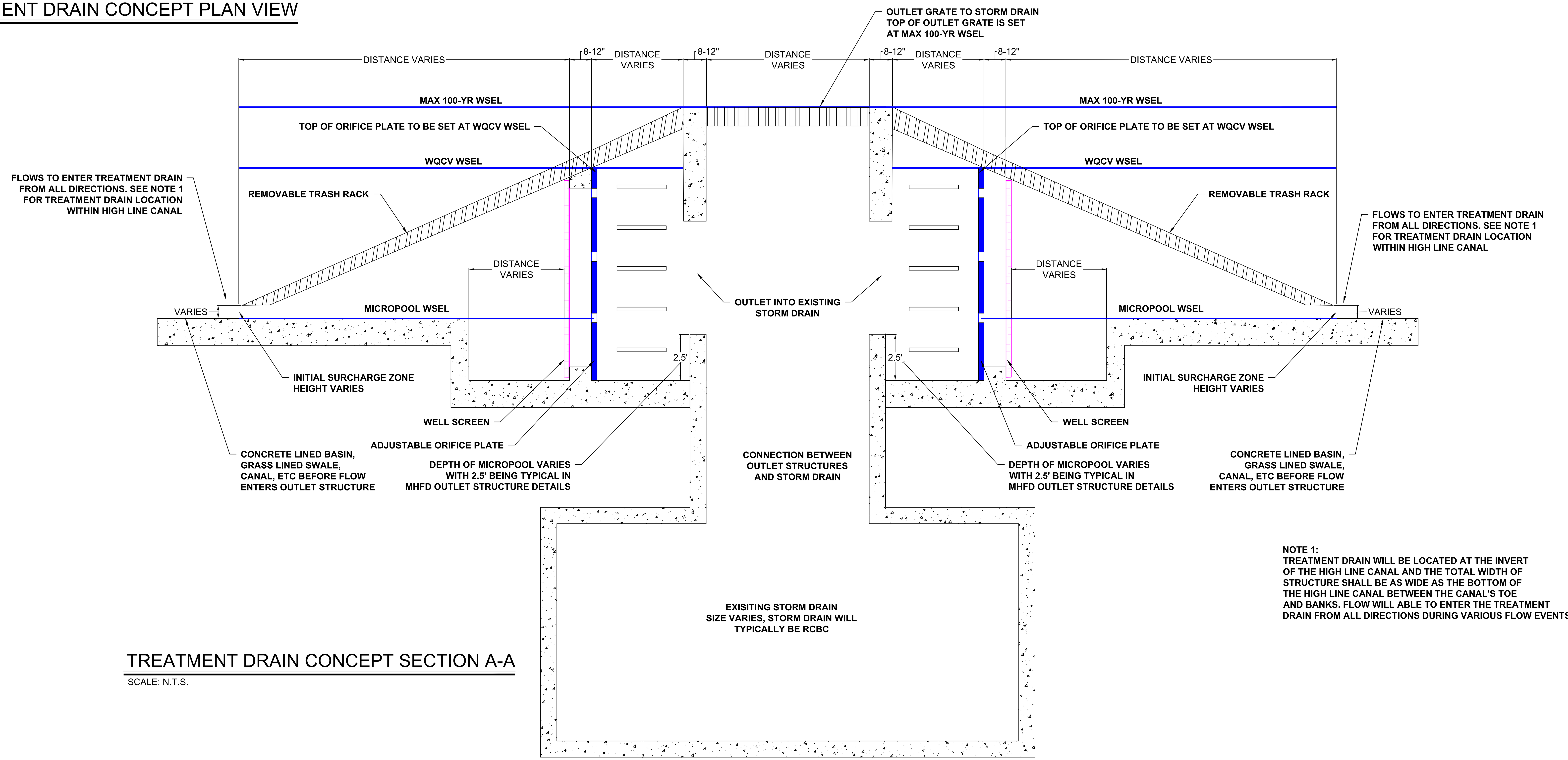
FIGURE 4-16. CONCEPTUAL OUTLET CONFIGURATION FOR RETENTION POND / CONSTRUCTED WETLAND BASIN

NOTE: Treatment Drains shall be designed to provide at least 1-foot of Canal freeboard during the 100-year event.

ICON

TREATMENT DRAIN CONCEPT PLAN VIEW

SCALE: N.T.S.



TREATMENT DRAIN CONCEPT SECTION A-A

SCALE: N.T.S.

NOTE 1:
TREATMENT DRAIN WILL BE LOCATED AT THE INVERT OF THE HIGH LINE CANAL AND THE TOTAL WIDTH OF STRUCTURE SHALL BE AS WIDE AS THE BOTTOM OF THE HIGH LINE CANAL BETWEEN THE CANAL'S TOE AND BANKS. FLOW WILL ABLE TO ENTER THE TREATMENT DRAIN FROM ALL DIRECTIONS DURING VARIOUS FLOW EVENTS

P:\P24-033_HLC STAMP\06_DWG\03_EXHIBITS\Treatment Drain Concept Detail.dwg; Zpurfurst; Page Setup:---; ICON.stb; 12/31/2025 11:25 AM

No.	DATE	REVISIONS	APPR.

DRAWN BY: ZJP
DESIGNED BY: ZJP
APPROVED BY: DC

811 Know what's below. Call before you dig.

PREPARED FOR:

PREPARED BY: ICON ENGINEERING

PRELIMINARY NOT FOR CONSTRUCTION

HIGH LINE CANAL STAMP

TREATMENT DRAIN CONCEPT P+P

24-033

DETAIL AND SECTION VIEW

DATE: DEC 2025

SHEET: 1 OF 1

APPENDIX H: DIGITAL DATA