

Engineer's Opinion Report

Meadows Taft House – Site Drainage

The Meadows, Castle Rock, Colorado

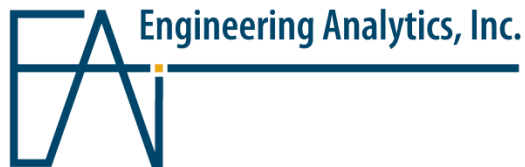
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1.0 INTRODUCTION

This report was prepared by Engineering Analytics, Inc. (EA) under the direct supervision of L. Clint Brown and presents the results of EA's analysis of the drainage issues at the Meadows Taft House which will also be called the "Project" in this report. The pool is located at 3570 Celestial Ave, Castle Rock, CO 80104, see Figure 1-1. The purpose of this Opinion Report is to present Engineering Analytics' investigation into the grading and drainage issues around the pool area. The issues were noticed and raised due to concerns about water not properly draining off site. Examples of these drainage issues are the influx of sediment and runoff water entering the pool on multiple occasions including, June 26, 2020, June 17th 2019 and July 17th 2018.

The Developer for the Meadows Taft House is Castle Rock Development Company, the site drainage engineer is 210 Engineering, the geotechnical engineer is A.G. Wassenaar, the architect is Ohlson Lavoie Collaborative and the general contractor is MW Golden Constructors. All of the mentioned parties are collectively referred to as the "Builder" in this report. EA has evaluated the standard of care for the Builder for the Project. It is EA's opinion that the standard of care for a builder is to meet applicable local, regional and universal building codes, industry standards, and manufacturers installation guidelines. As it relates to the site drainage issues for the Project, the standard of care is primarily governed by the codes and manuals of the Town of Castle Rock, the Manufacturer's (Nyloplast) recommendations and requirement for their drain system, and standard engineering practice regarding grading and drainage control.

The analysis of the drainage issues included the following tasks:

- 1.1 A site visit by EA personnel and survey of the as-built drain elevations by Farnsworth Group on September 1, 2022,
- 1.2 A site visit by EA personnel on November 3, 2022 to record relative elevations from the drains to the rim of the pool,
- 1.3 Document review of construction documents, drainage reports, and technical memorandums prepared by other consultants regarding the drainage issue, and
- 1.4 Hydrologic and hydraulic analyses to analyze as-designed conditions of the drain system and as-built conditions.

This report is a summary of voluminous writings, recordings, photographs, and other documents, which cannot be produced conveniently by way of attachment. This report is a summary of those writings, recordings, photographs and other documents, of which the originals are available for examination in the EA job file. and are incorporated into this Report by reference. EA was also provided numerous project documents including original design plans and specifications, geotechnical reports, communications, and other original project-specific documents from Burg Simpson. Those project documents are part of our file and are incorporated into this Report by reference.

2.0 DOCUMENTS REVIEWED

Engineering Analytics personnel reviewed construction plans, city guidance documents, precipitation gage data, precipitation model data, and consultant reports when preparing this opinion report and planning. A list of these documents is included in Sections 7.0 and 8.0 of this report. The following is a list of the project documents that were reviewed as well as a brief summary of the facts relevant to our analysis. No attempt has been made to summarize the documents in their entirety. Other references that were relied upon to prepare this report are also listed in Section 8.0 of this report. These materials and our visits to the site, along with my education, training and experience form the basis of my opinions.

- 2.1 April 30, 2015 – A.G. Wassenaar Inc. released a Geotechnical Study for the proposed Meadows Pool Amenity. This report provided results of testing and recommendations for site grading in addition to recommendations for many other aspects of the project.
- 2.2 July 29, 2015 – OLC Architecture finalized 100% Construction Drawings for the MNC Amenity II (Meadows Taft House and Pool). This along with RFI information from MW Golden Construction and other markups became the As-built drawing set for the Meadows Taft House. Sheet A400 shows finished surface elevations for the pool deck and trench drains.
- 2.3 October 13, 2015: An executed contract between Wember, Inc., and MNC (under declarant control of CRDC) was issued that indicated that Wember would serve as the Association's Owners Representative for the construction of the Taft House site. The contract stated that Wember would:
 - (a) *communicate with Board, gain an understanding of expectations and priorities for the Facility, provide advice regarding the construction process;*
 - (b) *establish relationships and ongoing communication with other contractors (for example, the architect and general contractor) and participate as a member of the team responsible for the Facility's construction;*
 - (c) *during construction, facilitate the process by providing response to contractor questions, and participating in problem resolution;*
 - (d) *review and advise the MNC on change orders and other requests from the Developer;*
 - (e) *assist the MNC with final acceptance of the project, including verification of completion and preparation and follow through on punch list;*
 - (f) *provide monitoring services to inform the MNC about ongoing construction activities to monitor the construction progress to determine if work is being performed consistent with the approved plans and specifications, budgets and schedules, and is meeting the requirements set forth in the construction contract and other controlling documents;*

(g) provide monthly written construction status updates to the Board to include status of time spent on project to date, by month.

- 2.4 October 23, 2015 – The Town of Castle Rock approved the Public Improvement Construction Plans prepared by 210 Engineering for the Meadows Filing 20. Sheet C4 includes the finished elevation of the pool rim and Sheet C6 shows the drain system around the Meadows Taft House and Pool.
- 2.5 October 23, 2015 – The Town of Castle Rock approved a Drainage Compliance letter prepared by 210 Engineering on October 14, 2015. This letter includes all relevant hydrologic and hydraulic calculations performed to design the drainage system for The Meadows Taft House development.
- 2.6 July 1, 2021 – Wright Water Engineers, Inc. (WWE) prepared a technical memorandum providing recommendations to improve the existing drainage conditions at The Meadows Taft Building. WWE recommended installing a compacted earthen berm, riprap rundowns, and sidewalk chase on the undeveloped site to the west for erosion control and drainage.
- 2.7 September 15, 2021 - Hayes Consulting Company produced a presentation that included pictures from the Meadows Neighborhood Company (MNC) of the pool during a storm that included hail and heavy precipitation. The pictures in the presentation also included photos that showed sediment in the pool.

Selected Photographs provided by the Meadows Neighborhood Company and photographs taken by EA personnel are provided in Appendix A.

3.0 HYDROLOGIC ANALYSIS

In order to assess the ability of the drain system to handle the design rainfall, EA performed a hydrologic analysis. The hydrologic calculations and the supporting reference information are included in Appendix B.

3.1 Hydrologic Basin

EA did a historical photo review and site review of the intersection of Low Meadows Boulevard and Meadows Boulevard and determined that the drainage inlets on Low Meadows Boulevard south of the Meadows Boulevard do not show signs of contributing to the sediment flows discussed in this report. For our analysis, EA assumed that flows from Low Meadows Boulevard are intercepted by the drainage inlets and as such the drainage inlets are adequate to prevent runoff from Low Meadows Boulevard from entering the Taft House property or pool.

The hydrologic basin of the pool area (Basin EA-1+2) consists of two subbasins (Subbasin EA-1 and Subbasin EA-2) as shown on Figure 3-1. Based on the topography of the site, Subbasin EA-1 consists of the contributing area from the adjacent lot onto the pool area and Subbasin EA-2 consists of the contributing area from the pool and building.

The total area for the entire hydrologic basin (combined Subbasins EA-1 and EA-2 or Basin EA-1+2) is 2.99 acres (ac) and the impervious area is 0.37 ac. This corresponds to a percent imperviousness of 12%. The area of Subbasin EA-1 is 1.56 ac with no impervious area.

3.2 Hydrologic Analysis Method

The Rational Method was used to determine the peak runoff flow for a given rainfall intensity. This method was selected because it is recommended in the Castle Rock Storm Drainage Design and Technical Criteria Manual (Castle Rock Water Department, 2019) for a drainage of this size.

3.3 Basin Parameters

EA determined the basin parameters of Time of concentration (T_c), Runoff Coefficient (C) and Rainfall Intensity (I) for Subbasin EA-1 and Basin EA-1+2. The methodologies used to determine T_c , C , and I are included in Appendix B. The time of concentration was calculated to be 21.20 minutes for Subbasin EA-1 and 21.29 minutes for the Basin EA-1+2.

The runoff coefficient was determined using the methods presented in the Urban Storm Drainage Criteria Manual: Volume 1 (UDFCD, 2016) as recommended by the Castle Rock Drainage Manual. According to UDFCD (2016), the runoff coefficient is determined using the Natural Resource Conservation Service (NRCS) hydrologic soil type, storm return period, and percent imperviousness. The hydrologic soil type for the basin was determined to be D according to the NRCS soil survey (NRCS, 2022). The imperviousness as stated above was 0% for the Subbasin EA-1 and 12% for Basin EA-1+2. Based on UDFCD (2016), EA calculated a runoff coefficient of 0.052 for Subbasin EA-1 and 0.160 for Basin EA-1+2 during the 5-year recurrence storm. Based on UDFCD (2016), EA calculated the runoff coefficient of 0.508 for both Subbasin EA-1 and Basin EA-1+2 for the 100-year recurrence event.

Rainfall intensity for any given storm average recurrence interval was determined using the Rainfall Intensity-Duration Curve for the Town of Castle Rock (Castle Rock Water Department, 2019). This rainfall intensity was also compared to the NOAA published point precipitation frequency estimates (NOAA, 2022). The rainfall intensities and their corresponded recurrence storm are as follows: 2.95 in/hr for the 5-year storm and 5.35 in/hr for the 100-year storm.

3.4 Precipitation Events and Recurrences

Both minor (5-year recurrence interval) and major (100-year recurrence interval) storm events were analyzed to determine peak runoff into the drain system in accordance with the Town of Castle Rock's guidance for sizing storm sewers (Castle Rock Water Department, 2019). Because the storm drain connection is designed for the major storm event (100-year recurrence interval), the standard of care would be to design the entire drain system for the major storm event. Average recurrence intervals of 5 and 100 years were both analyzed to determine the peak runoff into the drain system. All rainfall intensities are based on the Rainfall Intensity-Duration Curve for the Town of Castle Rock (Castle Rock Water Department, 2019).

One of the storm events that flooded the pool occurred on 6/26/2020. Based on the precipitation data from the CASTLE ROCK, CO NOAA gauge (Station ID 051401), the cumulative precipitation read at 9:00 am on 6/27/2020 was 0.98 inches. The duration of this storm can be approximated from the timestamps of photos and videos taken by the Meadows Neighborhood Company. Based on the time between MNC_000961 and MNC_000965, the duration of the storm on 6/26/2022 was at least 15-minutes so the recurrence interval of that storm can be estimated to be between 1-year and 25-years based on the NOAA cumulative precipitation estimate for that area. Because the start time of the storm and a definite end time are not known, this is an approximation.

Table 3-1 summarizes the peak flow for the Subbasin EA-1 and Table 3-2 summarizes the peak flow for Basin EA-1+2.

3.5 210 Engineering Drainage Analysis

210 Engineering performed a hydrologic analysis in 2015 to address a change of land use from townhomes and multi-family homes to the community center, pool, and vacant and landscaped areas (210 Engineering, 2015). 210 Engineering divided the hydrologic basin for the Meadows Taft House site into two subbasins, A-1 and A-2. These subbasins are compared to the EA subbasins on Figure 3-2. Subbasin A-1 was primarily the undeveloped lot to the west of the Taft House and the parking lot. Subbasin A-2 was the Taft House Property itself. 210 Engineering indicated that runoff from vacant lot in subbasin A-1 would flow onto the parking lot north of the Taft House and into the storm inlet at the northeast corner of the parking lot.

Peak flows from our analysis and 210 Engineering's analysis cannot be compared due to the differing subbasins and design points. The hydrologic basins and results from the 210 Engineering drainage compliance letter (210 Engineering, 2015) are summarized in Table 3-3 and Table 3-4 and relevant pages from the compliance letter are included in Appendix C.

4.0 HYDRAULIC ANALYSIS

A hydraulic analysis was performed for the entire drain system for both the as-designed and as-constructed conditions. Both the drainpipe sections between inlet grates and the inlet grates themselves were analyzed to ensure that both have sufficient hydraulic capacity to effectively drain the storm flows determined in the hydrologic analysis.

The channel drains around the pool deck were not analyzed for their capacity for three reasons. Primarily, the design intent of these drains seems to be to drain splash water from the pool and rainfall on the pool deck as opposed to acting as primary storm water control measures. The second reason being, all of these drains are very close to the elevation of the pool rim, so the drains would not be able to develop adequate hydraulic head to convey significant flow. Additionally, Photos MNC_000944 and MNC_000971 show significant standing water at these trench drains which indicates that they are not effective in draining water. The hydraulic calculations are included in Appendix D.

4.1 Drain Pipe Hydraulic Analysis

The hydraulic capacity of the drain system around the Taft House property and pool was calculated to determine if the drain inlet grates and drain piping can handle minor and major storm flows. The drain system was divided into segments typically separated by an inlet grate, manhole, or other junction with another drain or inlet. The segments and the corresponding numbers are shown on the attached mark up of Sheet C6 (Figure 4-1) (210 Engineering, 2015a). Many of the smaller drain sections, especially those directly connected to the trench drains surrounding the pool, were grouped together for simplicity and are assumed to have a constant size and slope as shown in the Construction Drawings (Sheet C6). The grouped drain segments are shown with clouds on the mark up. Manning's Equation was used to determine the capacity of each segment, assuming that each segment is flowing full. Inlet grates and the corresponding labels are shown on Figure 4-2.

4.1.1 *As-Designed Conditions*

Using the design documents, EA determined the areas of the drain system where upstream drains have greater capacity than downstream segments. In cases where the upstream capacity exceeds the downstream capacity, flow is backed up as the overall capacity is governed by the downstream section. Typically, when designing a drain system such as this, downstream pipe sections would have more capacity than upstream pipe sections to prevent bottlenecks and overflows at intersections. According to EA's analysis there are fourteen pipe sections (Sections 1, 2, 4, 7, 8, 9, 10, 11, 14, 21, 28, 30, 31, and 37) that have less capacity than the section immediately upstream. Section 7 was the only pipe section that had less capacity than the contributing of the upstream inlet grates. Segments with capacity less than upstream drain segments are shown on Figure 4-3.

4.1.2 *As-Built Conditions*

The as-built hydraulic operation of the drain system was also analyzed to compare the as-built capacity to the designed capacity of the drain pipes. EA subcontracted Farnsworth Group to perform an elevation survey of the drain inlets. Farnsworth Group utilized GPS and Real Time Kinematic (RTK) methods in performing their survey. The survey performed by Farnsworth Group was used to measure the pipe inverts at the accessible junctions and the distance between them.

The focus of the survey was the ten hydraulic sections along the south and west sides of the pool. Some of the hydraulic sections were combined for analysis purposes because the inverts of buried junctions were not measured (Hydraulic sections 8+9 were combined as well as 10+11). Of the eight analyzed hydraulic sections, three (sections 7, 8+9 and 28) were found to have less capacity than the section immediately upstream. These same three pipe sections also had less hydraulic capacity than the combined capacity of the inlet grates upstream. The drain sections where the upstream inlet drain capacity exceeds the pipe capacity are highlighted on Figure 4-4. Additionally, Section 7 had a reverse slope meaning that water would have to travel uphill to drain. Subsequently, this section would need to act under pressurized flow in order to drain, thereby backing up drain water into the junction immediately upstream.

4.2 Inlet Grate Hydraulic Analysis

In addition to determining the hydraulic capacity of each length of drain pipe, the capacity of the Nyloplast inlets was evaluated to determine how much runoff water each inlet can effectively collect. The flow capacity of each inlet is based on the allowable ponding above the inlet which develops hydraulic head. The allowable ponding for each inlet was determined based on the elevation difference between the grate inlet and the finished elevation of the pool rim. The as-designed conditions and as-built conditions were both analyzed for the drain capacity.

4.2.1 As-Designed Conditions

The as-designed conditions were developed based on the construction drawings and the finished elevation of the pool rim at 6194.00 feet. As designed, the inlet grate elevations vary from 6192.02 feet to 6193.90 feet. This results in allowable ponding head varying from 0.1 feet to 1.98 feet. No hydraulic analysis was discovered for the initial design, apart from hydraulic analysis of the main 24-inch Reinforced Concrete Pipe (RCP) Storm Drain that connects to the mainline in the road.

These allowable ponding hydraulic heads were then used with the Nyloplast inlet capacity charts for the grates used to determine allowable flow capacity. For certain inlets east of the pool, the allowable ponding exceeded the head on the Nyloplast capacity charts. In these situations, the highest capacity from the chart was used and the capacity chart was not extrapolated for a higher head than shown. No inlet grate, where the allowable head exceeded that shown on the Nyloplast chart, was found to be significant when analyzing the performance of the drain system.

The primary inlet of concern is Inlet 1, the farthest southwest inlet, just downstream of the two roof downspout connections (See Figure 4-2). Inlet 1 has a capacity of 1.288 cfs with an allowable ponding of 0.6 feet before water flows into the pool. The drain segment directly downstream of this inlet (Segment #12) has a maximum capacity of 3.87 cfs. The as-designed inlet capacity of all of the grate inlets is shown on Figure 4-5 and Table 4-1.

4.2.2 As-Built Conditions

The As-Built elevations of the drain inlets were surveyed by Farnsworth Group out of Greenwood Village Colorado. According the survey by Farnsworth Group and additional relative elevations obtained by EA staff, the pool rim varied from 6193.92 to 6194.06 on the west side where most of the inflow seemed to have occurred. The As-Built inlet grate elevations vary from 6192.30 to

6193.92 feet. This results in an allowable ponding head when compared to the closest rim elevation of the pool varying from 0.13 feet to 1.62 feet.

The primary as-built inlet of concern is still Inlet 1. This inlet has a capacity of 1.16 cfs with an allowable ponding of 0.48 feet before water flows into the pool. All of the inlets west of the pool (Inlet ID's 1-5) have a combined as-built capacity of 4.29 cfs. All of the major drains around the pool have a total inlet capacity of 32.89 cfs. The as-built inlet capacity of all of the grate inlets is shown on Figure 4-6 and Table 4-1. Table 4-2 compares the design inflow for Subbasin EA-1 and Basin EA-1+2 and compares this inflow to the drain inlet capacities for the respective basins. The survey performed by Farnsworth Group and the relative elevations obtained by EA personnel are included in Appendix E.

5.0 CONCLUSIONS, OPINIONS, AND RECOMMENDATIONS

The following conclusions, opinions, and recommendations are put forth based on a review of the documents provided, the investigation performed by Engineering Analytics, Inc. (EA), our site visits, our calculations and analyses, together with my education, training, and experience. For purposes of this report, the term Builder refers collectively to the developer, general contractor, subcontractors, vendors, or other agents that were party to the design or construction of the item discussed. The allocation or division of responsibility for each defect was not part of the scope of work for this project.

5.1 Opinions and Conclusions

- It is our opinion that the Builder did not address the grading for the undeveloped site west of the Meadows Taft House in a way that reflected the design drainage basins prepared by 210 Engineering. The Phase 1 of the Grading, Erosion and Sediment Control (GESC) Plan (210 Engineering 2015c) indicated a sediment trap to be installed on the undeveloped eastern lot with an overflow that runs east towards the Taft House site. This overflow is shown as existing on the construction drawings for the Project on Sheet C4 (210 Engineer 2015a). This overflow was either not constructed or no longer exists. The grading for the undeveloped site is built as shown on the GESC Plans which directs flow towards the Meadows Taft House. The as-constructed grading does not agree with the basins shown in 210 Engineering's hydrology analysis. The standard of care to prevent runoff water from crossing lots, as mentioned in the Castle Rock Drainage Documentation (Castle Rock Water Department. 2019). To achieve the standard of care a berm and rundown should have been constructed to prevent runoff from the vacant lot entering the Taft House as shown in the Approved Drainage Compliance Letter (210 Engineer 2015b).
- It is our opinion that the Builder did not provide sufficient hydraulic capacity to handle the major storm runoff. Drain Inlet 1, which is the only inlet for the drainage west of the Taft House (Subbasin EA-1), is inadequate to drain the 100-year recurrence rainfall event. The drain pipe which runs along the south retaining wall downstream of the first inlet, only has a capacity of 3.39 cfs which cannot handle the peak inflow to the drains west of the pool (Hydraulic Segments 10 and 12 on Figure 4-1). The standard of care would have been to design and construct the main drain inlet to be capable of draining the 100-year recurrence rainfall event.
- It is our opinion that drainage and sediment issues are occurring in storms smaller and more frequent than the 100-year recurrence event. While our analysis shows that the drain system is insufficient for the 100-year flood, sediment has been washed into the pool frequently according to the pictures provided by the Meadows Neighborhood Company. It can be inferred that when sediment is deposited in the pool, sediment is also being deposited in the drain system. As such sediment was visible in the drain junction manholes when EA personnel visited the site on November 3, 2022. The volume of sediment accumulated against the silt fence installed east of the bluff is further evidence of runoff water depositing sediment from the elevated undeveloped area west of the building. Inflows of debris and sediment into the drain system will decrease capacity. Standard of care would be to design and build the drain system to flush sediment and debris as such all of the drains should have positive slope conducting water to the public storm drain system.

- It is our opinion that the drainage control on site at the Meadows Taft House is insufficient to properly drain a major storm event. Standard of care would be to design grading to provide adequate hydraulic head for the drain inlets to drain inflow water and include a minimum freeboard of 1 foot. It is our opinion that the inlet grates have insufficient freeboard nor provide sufficient hydraulic head to pass the runoff flow. Freeboard adds a factor of safety to the design and accounts for predictable and unpredictable circumstances that can affect the design capacity. Such factors include but are not limited to; the exact final grade of the inlet grate, debris washed in with runoff water, and encroachment of landscaping materials (gravel, vegetation etc.) into the grate.

Water currently takes the path of least resistance, in this case the flat pool deck instead of the rougher landscaped areas on the south side of the pool where the primary drain inlets are located. This is proven by the flow of water from the south side of the pool circumventing the pool and flowing into the low point on the north side of the pool. This is shown in the video MNC_000963 (Included in Appendix A and shown on Figure 5-1) and the low point on the pool rim as shown on Figure 4-6. Standard of care would be to overcome this with grading to force runoff water away from the pool deck and towards the landscaped drain areas. It is our opinion that the Builder did not follow the recommendations of the Geotechnical Report (A.G. Wassenaar Inc., 2015) to provide adequate drainage away from the pool and to not allow water to pond around the slab perimeter. Evidence of this is shown in the photographs MNC_000942 and MNC_000955 included in Appendix A which show the ponding of water at both the south and north edge of the pool slab respectively.

- It is our understanding that Wember was retained as owner's representative with the duties as outlined in Section 2.0 of our report. If additional documentation indicates that Wember failed to properly monitor the construction such that work was performed in violation of the approved plans, specifications, construction contracts and/or other controlling documents, it would then be EA's opinion that Wember fell below the standard of care.

5.2 Recommendations for Remediation

EA recommends regrading the undeveloped site to the west of the Meadows Taft House to direct flow north, towards the parking lot. A berm should also be installed on the east edge of the undeveloped lot to provide additional security against flow flowing east into the Meadows Taft House site. Additionally, EA recommends that runoff west of the pool area be channelized to Inlet 1 to prevent runoff water entering the pool area. Construction of a shallow swale could properly direct flow to the landscaped primary drain area as opposed to the flatter pool deck area. This same effect can be achieved by construction of a curb around the south and west edges of the concrete pool deck. This curb would achieve more freeboard for hydraulic head above the inlet grates similar to channelization. Additional freeboard would also limit the sensitivity of the drain system to settling of the pool rim.

Additionally, the diameter of the drain pipe at the southwestern end (Hydraulic Segments 10 and 12) should be upsized to handle the off-site flow being focused at the one inlet. The slope of Drain Segment 7 should be corrected to match the construction plans. The size of the drain inlet should

also be increased for Inlet 1 to account for the channelized runoff flow. This should be paired with a retrofit of Atrium Grates (Dome shaped grates) to allow for better handling of inflow of landscaping materials and other offsite debris and sediment. Flat grates would still be appropriate for drain inlets in the pool deck area, but landscaped areas should use atrium grates, especially ones intended to capture runoff from basins with a high likelihood for debris and sediment transport.

A preliminary conceptual layout of these repair recommendations is shown on Figure 4-7.

6.0 QUALIFICATIONS

I, L. Clinton Brown, am a geotechnical engineer. Geotechnical engineering is a branch of civil engineering that deals with engineering earth materials. I obtained a Bachelor of Science degree in Civil Engineering from Colorado State University in 2001, and a Master of Science degree in Civil Engineering with an emphasis in Geotechnical Engineering from Colorado State University in 2004. At present I am a Senior Engineer and Vice President in Engineering Analytics, Inc., a consulting engineering company in Fort Collins, Colorado.

From 2001 to 2003, I worked part time as a lab instructor and graduate research assistant at Colorado State University as listed in my resume. In that capacity I instructed non-engineers on how to perform and evaluate geotechnical properties of soil. I also investigated the hydraulic properties of geosynthetic clay liners, geotechnical investigations and pavement design. In addition to the work I did at Colorado State University I was also worked part time at Telesto Solutions, Inc in Fort Collins, Colorado during 2002-2003 and full time from 2003-2005. As a staff engineer, I worked with hydrologic analysis and hydraulic design for stormwater systems, geotechnical analysis of earthen embankments, and unsaturated flow modeling.

From 2005 to 2013, I worked as a Project Manager for Smith Geotechnical, Inc. in Fort Collins, Colorado. My work at Smith Geotechnical consisted of geotechnical, structural, hydrologic, and hydraulic engineering related to the design, construction, and operation of dams and irrigation system. Specific issues at Smith Geotechnical involved design, permitting and construction of dams and hydraulic systems that move storm water through dams and irrigation systems in a safe and practical manner. Since January 2013, I have been a Principal Geotechnical Engineer with Engineering Analytics, Inc. and am a shareholder in the firm

I have 22 years of experience as a consulting engineer and have experience in forensic studies, hydraulic design, hydrologic analysis, geotechnical design and evaluation, structural design, storm water design, dam design and evaluation, for commercial projects, residential developments, public works projects, and mine facilities.

I am a licensed Professional Engineer in five States. I am the past President of the Northern Colorado Geotechnical Group. I am also a member of the American Society of Dam Safety Officials (ASDSO) Committee on Education Outreach and technical advisor for the ASDSO Dam Failure and Incidence Committee.

I have extensive experience in the evaluation of hydrologic analysis and hydraulic design of water conveyance systems. I have conducted hydrologic and hydraulic engineering analysis on dams, storm water basins, storm water channels, and sedimentation control structures in Colorado, Idaho, Nevada and Internationally.

I have extensive experience as a consulting engineer and have experience in forensic studies, pavement design and rehabilitation, concrete design and testing, residential and master planned communities, commercial and industrial facilities, development of grading plans, hydrologic analyses, chemical and explosives manufacturing plants, and mining and mine reclamation.

I have also performed forensic investigations at 3 sites for issues related hydraulic and hydrologic engineering problems. I have been qualified in United States Federal Court as an expert in hydraulic and hydrologic engineering. A copy of my curriculum vitae is included in Appendix F.

7.0 LIMITATIONS

The opinions and recommendations in this report are based on a reasonable degree of certainty. This report has been prepared based upon review of the reference documents, field investigation, laboratory testing, geotechnical analyses, site visits, and my experience. No warranty is made, express or implied. The conclusions presented represent my best judgment based on the information available. Should additional information become available we should be allowed to review that information and modify my conclusions accordingly.

8.0 DOCUMENTS REVIEWED

210 Engineering, LLC. 2015a. Public Improvement Construction Plans for The Meadows Filing 20, Phase I, Amendment No. 5, Lot 1A CD15-0030. August 11, 2015

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9.0 REFERENCES

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TABLES

Table 3-1: Results of Hydrologic Analysis EA-1

Recurrence Interval [years]	Rainfall Intensity [in/hr]	Peak Runoff Q [cfs]
5	2.95	0.24
100	5.35	4.24

Table 3-2: Results of Hydrologic Analysis EA-1+2

Recurrence Interval [years]	Rainfall Intensity [in/hr]	Peak Runoff Q [cfs]
5	2.95	1.41
100	5.35	8.13

Table 3-3: 210 Engineering Results of Hydrologic Analysis A-1

Recurrence Interval [years]	Rainfall Intensity [in/hr]	Peak Runoff Q [cfs]
5	3.32	4.48
100	6.08	12.0

Table 3-4: 210 Engineering Results of Hydrologic Analysis A-2

Recurrence Interval [years]	Rainfall Intensity [in/hr]	Peak Runoff Q [cfs]
5	3.50	1.75
100	6.15	7.50

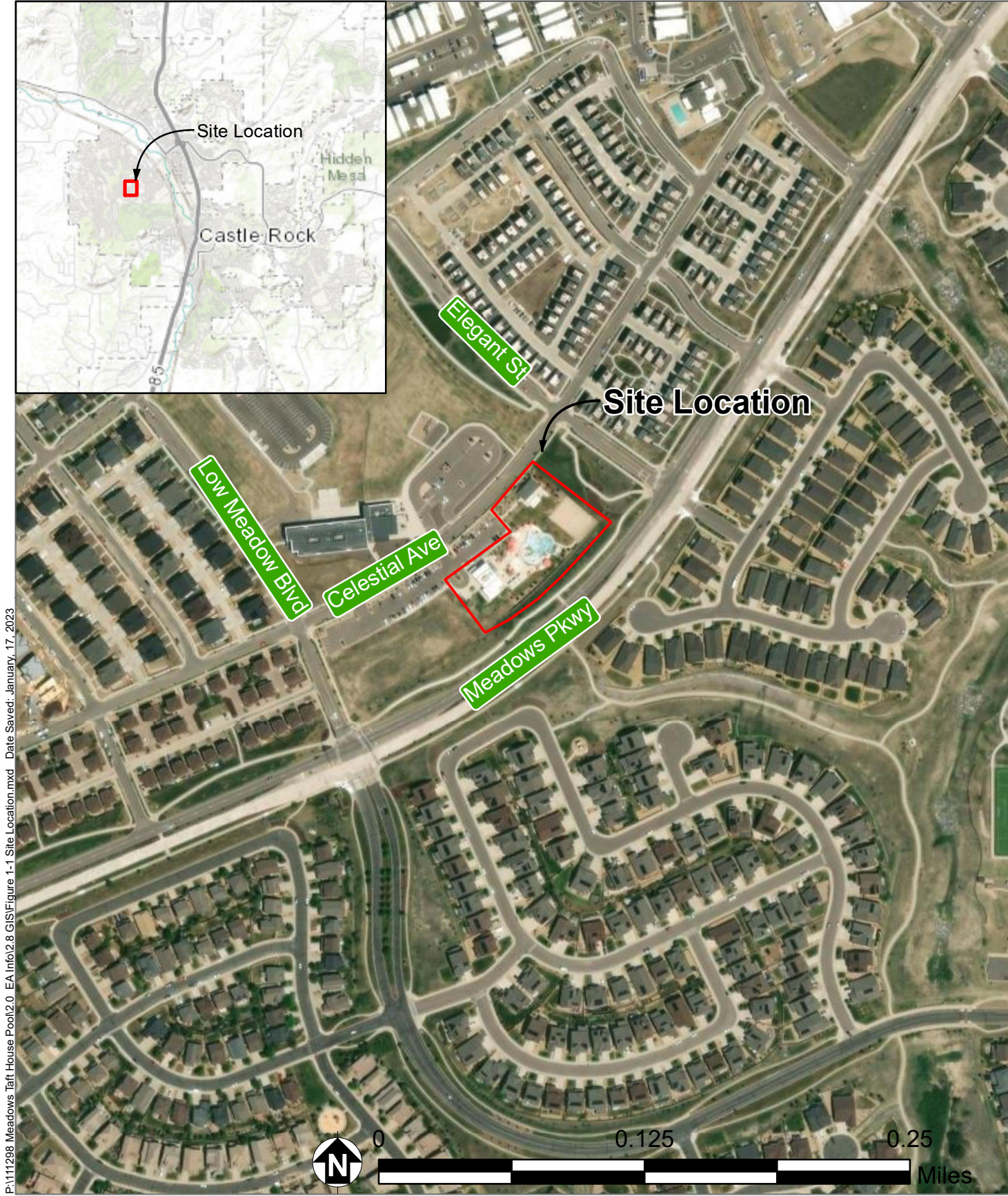
Table 4-1: Drain Inlet Capacities

Drain Inlet ID	As-Designed Available Hydraulic Head [ft]	As-Designed Hydraulic Capacity [cfs]	As-Built Available Hydraulic Head [ft]	As-Built Hydraulic Capacity [cfs]
1	0.6	1.288	0.48	1.16
2	0.6	1.288	0.49	1.17
3	0.1	0.368	0.19	0.72
4	0.1	0.368	0.13	0.56
5	0.1	0.368	0.17	0.68
6	0.6	1.288	0.16	0.66
7	0.6	1.288	0.56	1.24
8	0.98	1.704	0.87	4.90
9	1.43	1.76	1.34	5.50
10	1.43	1.76	1.01	5.30
11	1.98	1.76	1.35	5.50
12	1.98	1.76	1.62	5.50
13	1.98	5.50	-	-

Table 4-2: Design Flow and Capacity Summary

	EA-1 Inflow (100-year) [cfs]	EA-1 Drain Inlet Capacity [cfs]	EA-1+2 Inflow (100- year) [cfs]	EA-1+2 Drain Inlet Capacity [cfs]
As-Designed	4.24	1.288	8.13	16.76
As-Built	4.24	1.16	8.13	32.89

FIGURES

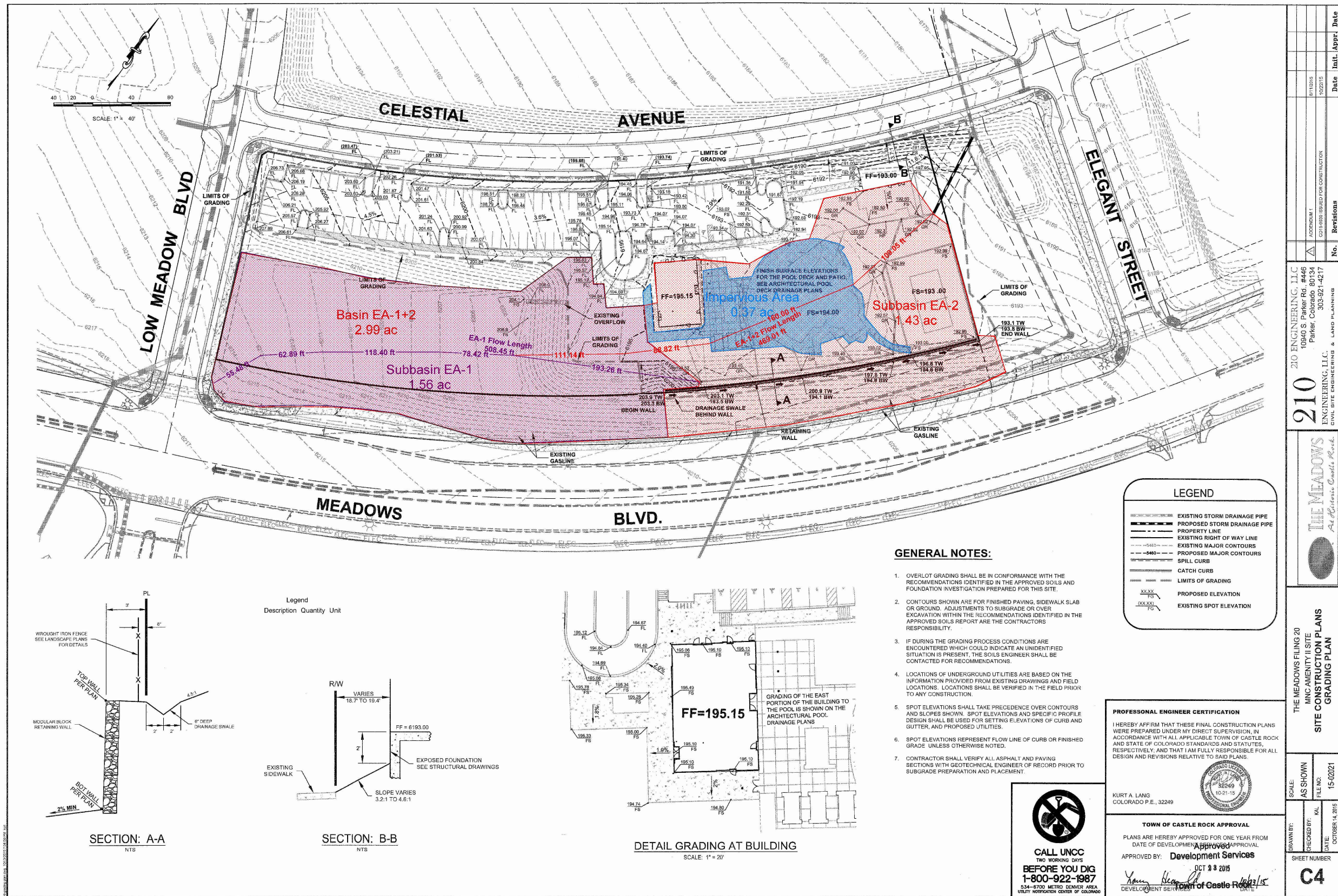


P:\111298 Meadows Taft House Pool\2.0 EA Info\2.8 GIS\Figure 1-1 Site Location.mxd Date Saved: January, 17, 2023

Project No. 111298

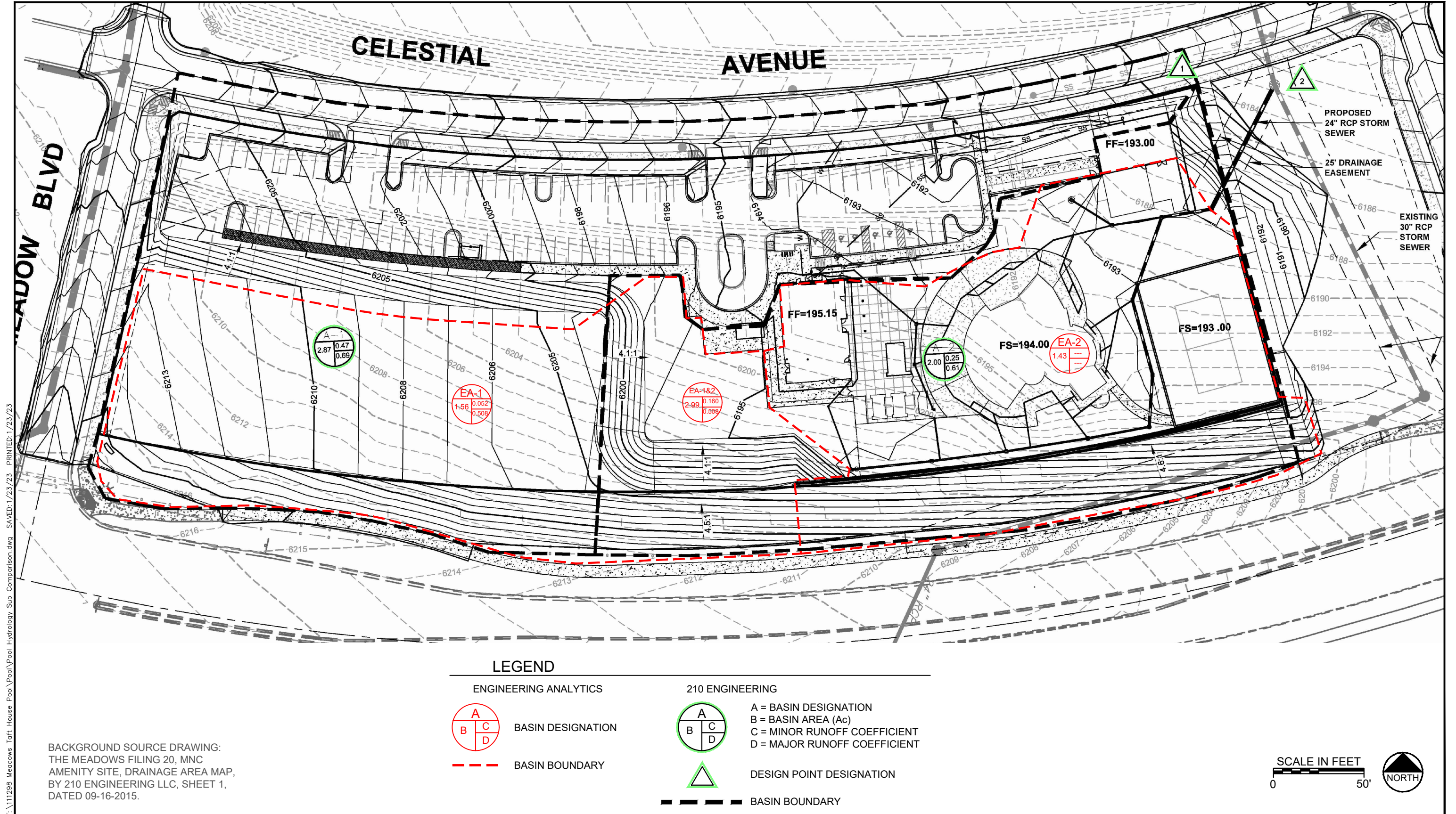
FIGURE 1-1
SITE LOCATION MAP
MEADOWS TAFT HOUSE POOL
CASTLE ROCK, COLORADO

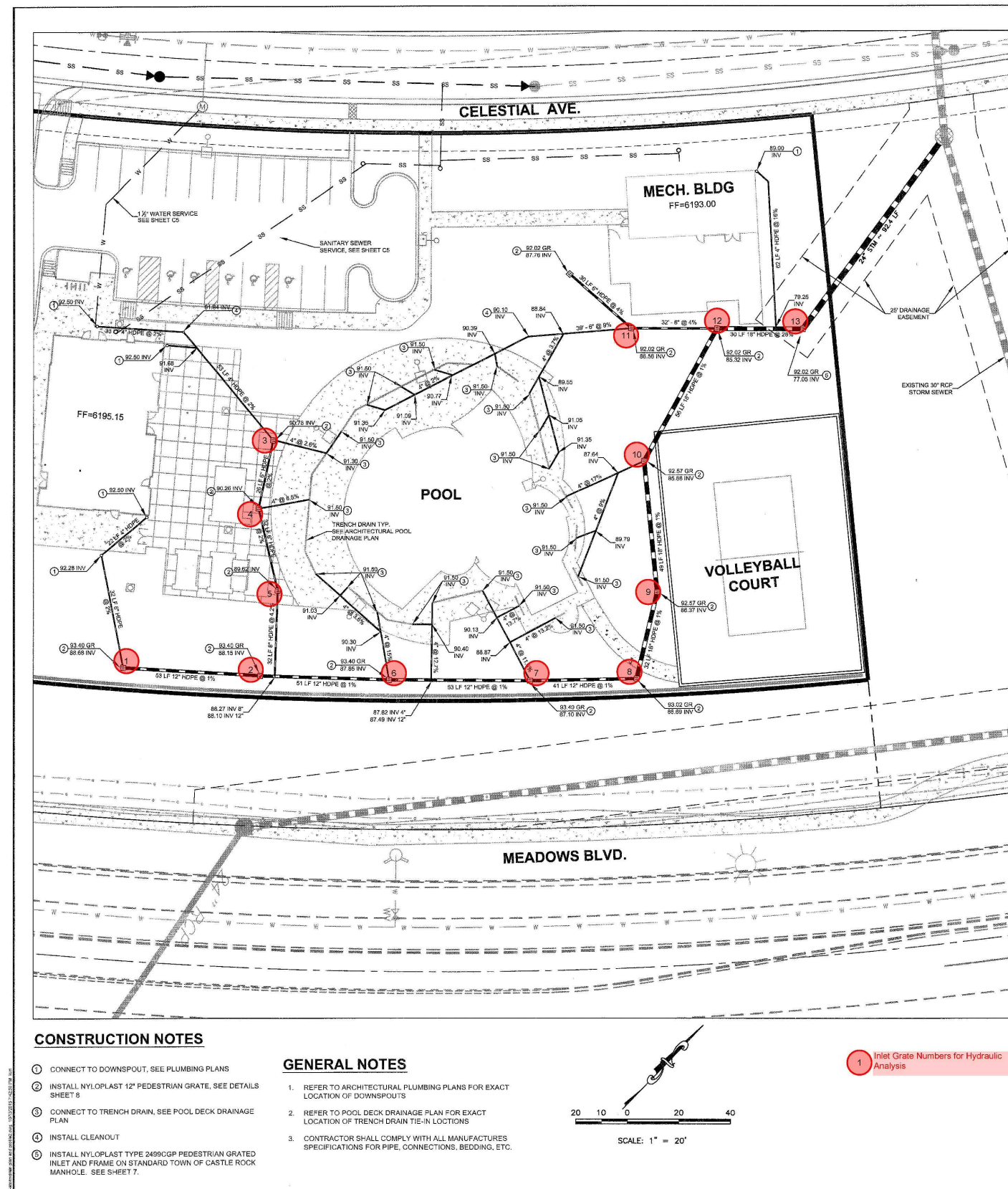
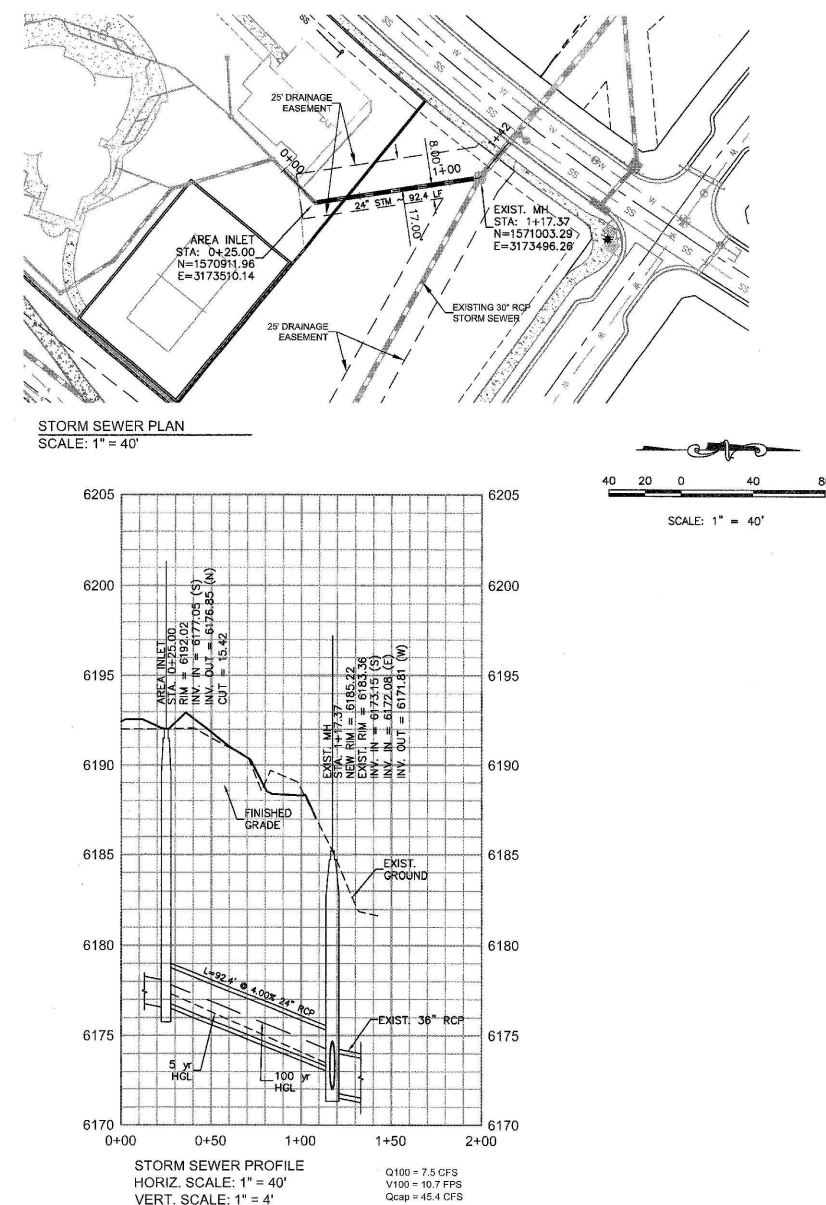
T:\111298 Meadows Taft House Pool\Pool Hydrology.dwg SAVER:1/12/23 PRINTED:1/13/23



Project No. 111298

January 2023





PROFESSIONAL ENGINEER CERTIFICATION

I HEREBY AFFIRM THAT THESE FINAL CONSTRUCTION PLANS WERE PREPARED UNDER MY DIRECT SUPERVISION, IN ACCORDANCE WITH ALL APPLICABLE TOWN OF CASTLE ROCK AND STATE OF COLORADO STANDARDS AND STATUTES, RESPECTIVELY; AND THAT I AM FULLY RESPONSIBLE FOR ALL DESIGN AND REVISIONS RELATIVE TO SAID PLANS.



KURT A. LANG
COLORADO P.E., 32241

TOWN OF CASTLE ROCK APPROVAL
PLANS ARE HEREBY APPROVED FOR ONE YEAR
DATE OF DEVELOPMENT SERVICES APPROVAL

APPROVED BY:

Larry Beards
DEVELOPMENT SERVICES

THE MEADOWS FILING 20
MNC AMENITY II SITE
SITE CONSTRUCTION PLAN
STORMDRAIN PLAN AND PRO

RAWN BY:	SCALE:	AS SHOWN	FILE NO:	45-00004
CHECKED BY:	KAL			
DATE:				

SHEET NUMBER
C6

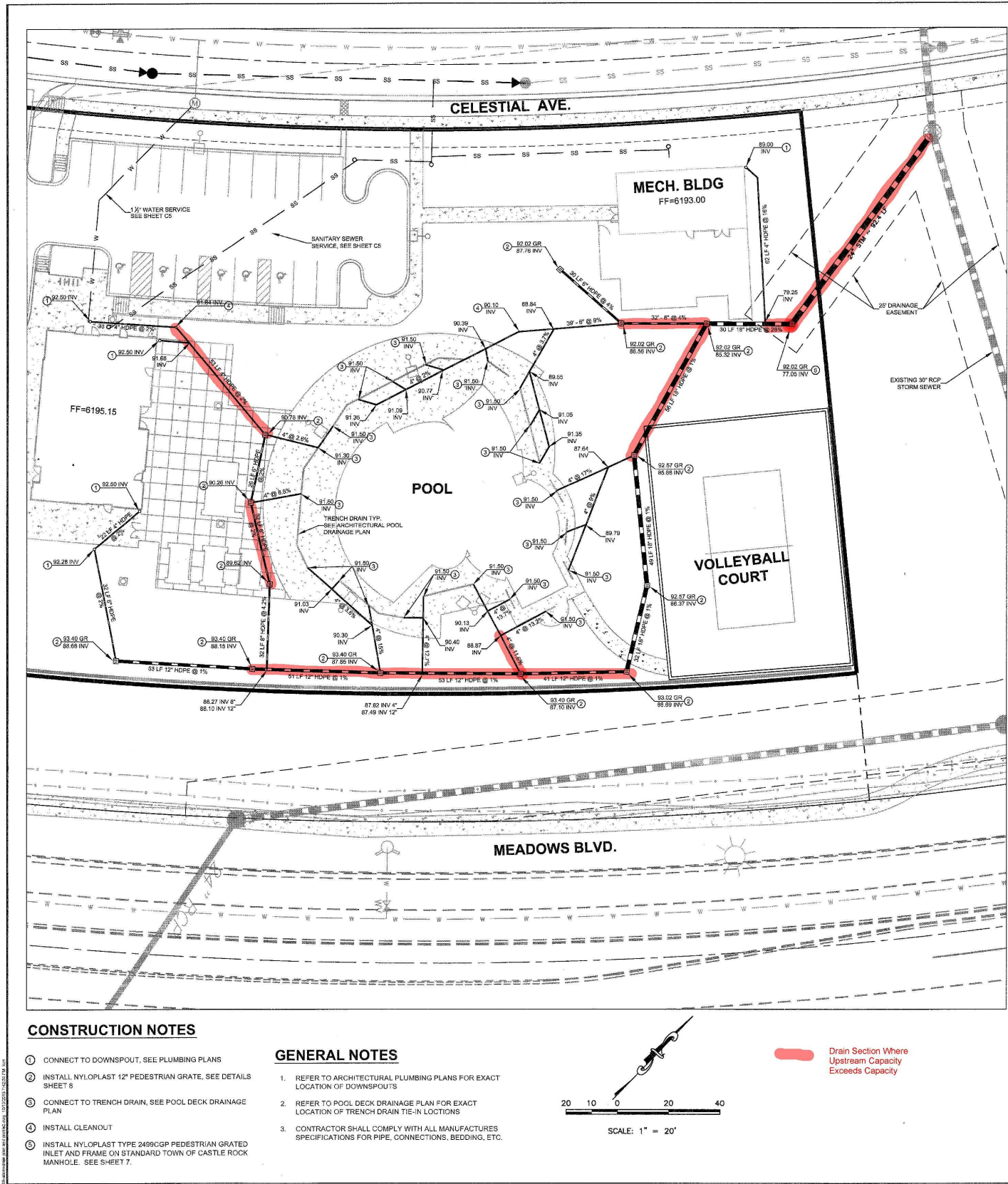
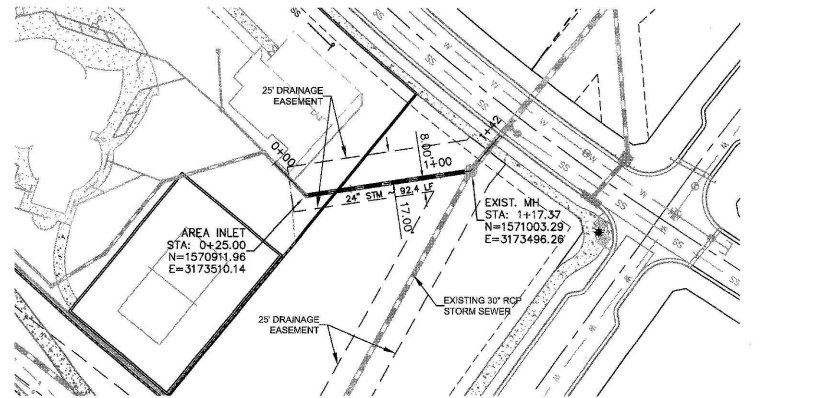
210

THE MEADOWS

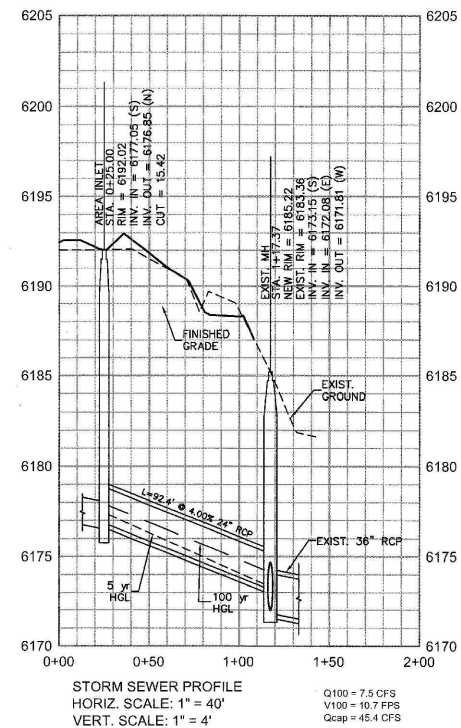
210 ENGINEERING, I.L.C.
210 ENGINEERING, I.L.C.
10940 S. Parker Rd., #446
Parker, Colorado 80134
303-921-4217

[illegible]

**FIGURE 4-2
HYDRAULIC DRAIN INLET ID'S
MEADOWS TAFT HOUSE POOL
CASTLE ROCK, COLORADO**



STORM SEWER PLAN
SCALE: 1" = 40'



PROFESSIONAL ENGINEER CERTIFICATION

I HEREBY AFFIRM THAT THESE FINAL CONSTRUCTION PLANS WERE PREPARED UNDER MY DIRECT SUPERVISION, IN ACCORDANCE WITH ALL APPLICABLE TOWN OF CASTLE ROCK AND STATE OF COLORADO STANDARDS AND STATUTES, RESPECTIVELY; AND THAT I AM FULLY RESPONSIBLE FOR ALL DESIGN AND REVISIONS RELATIVE TO SAID PLANS.

KURT A. LANG
COLORADO P.E., 32249

TOWN OF CASTLE ROCK APPROVAL

PLANS ARE HEREBY APPROVED FOR ONE YEAR FROM DATE OF DEVELOPMENT SERVICES APPROVAL

APPROVED BY: *[Signature]* 10/23/18
DEVELOPMENT SERVICES DATE

No.	Revisions	Date	Appr.	Date
1	ADDITIONAL	9/11/2013		
2	CD 15-0000 ISSUED FOR CONSTRUCTION	10/22/15		

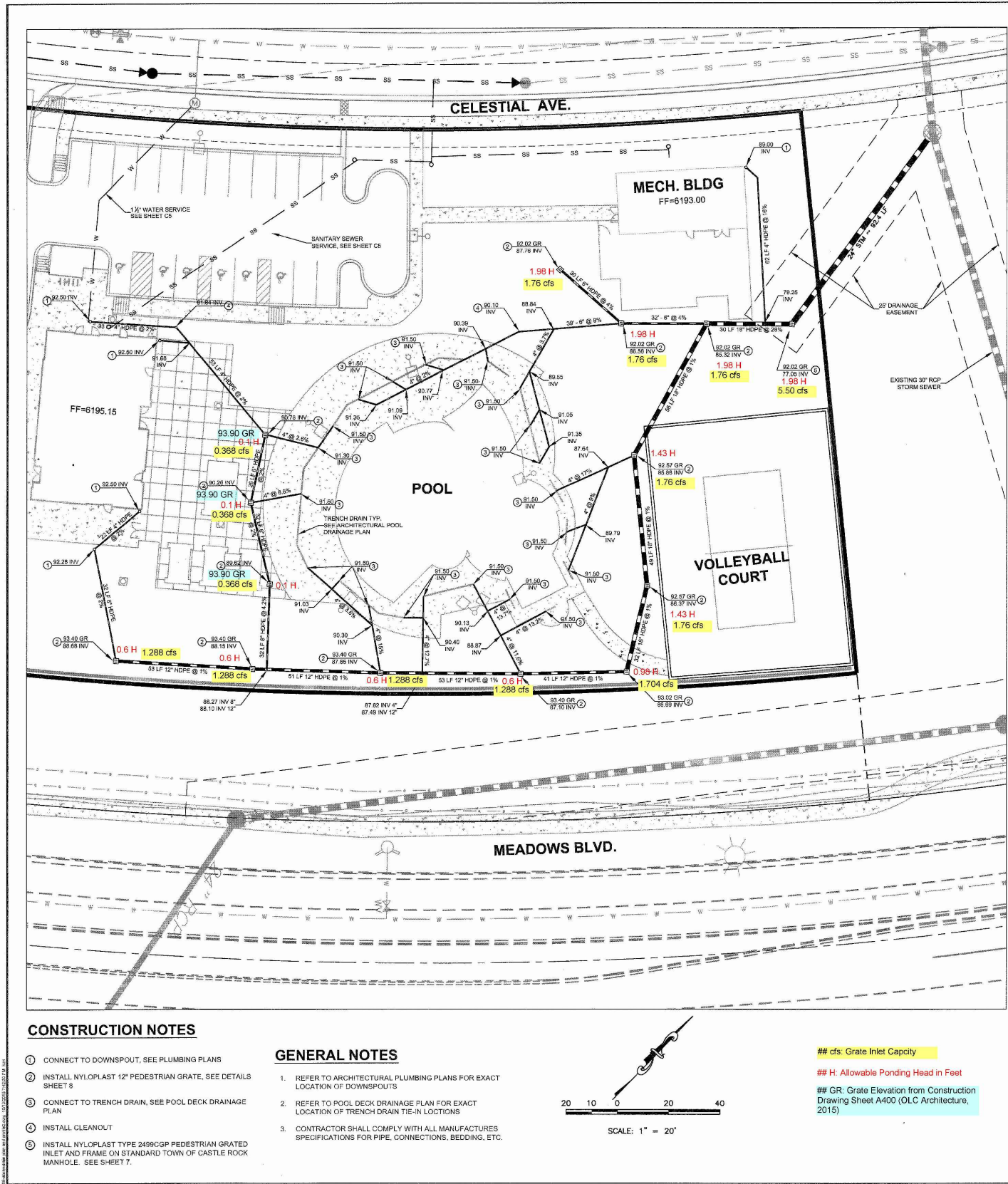
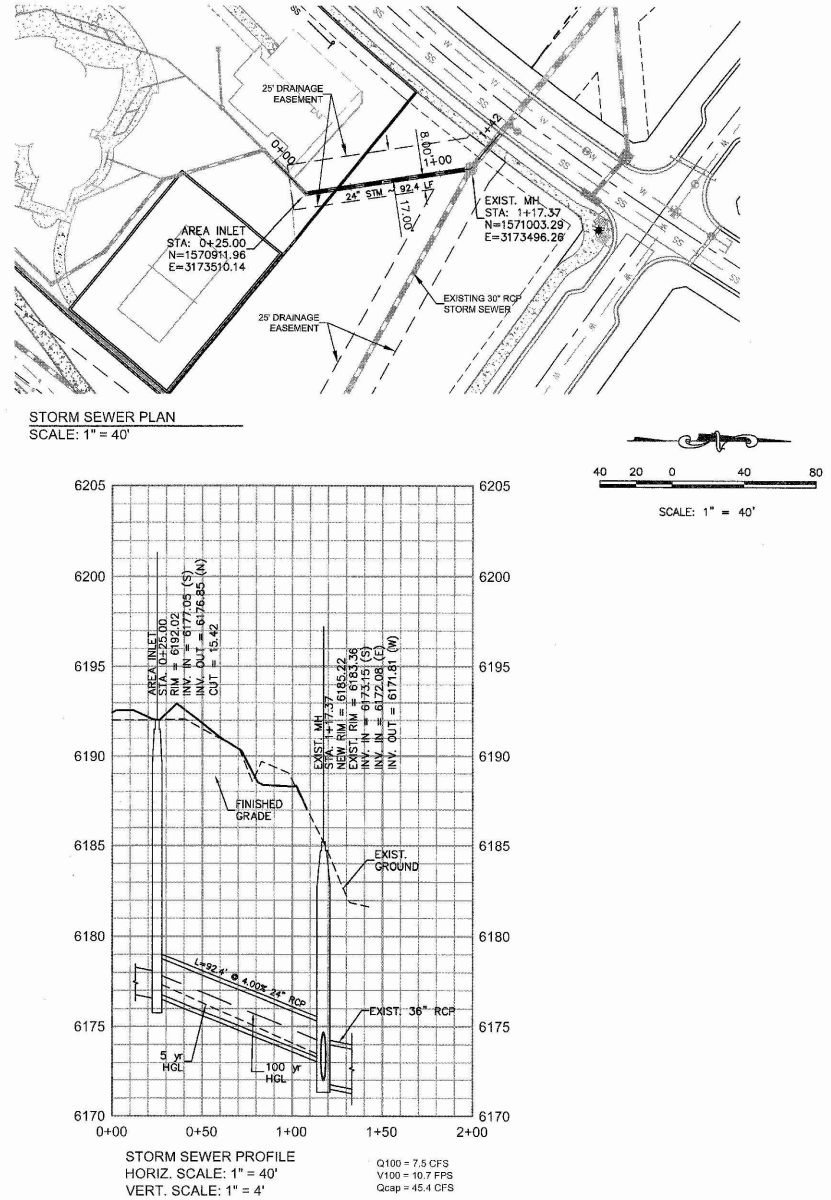
210 ENGINEERING, LLC
10940 S. Parker Rd. #448
Parker, Colorado 80134
303-921-4217

210 ENGINEERING, LLC
CIVIL SITE ENGINEERING & LAND PLANNING

THE MEADOWS
At Meadows Castle Rock

THE MEADOWS FILING 20
MNC AMENITY II SITE
SITE CONSTRUCTION PLANS
STORM DRAIN PLAN AND PROFILE

SCALE: AS SHOWN
FILE NO: 15-02021
DRAWN BY: KAL
CHECKED BY: KAL
DATE: OCTOBER 14, 2015
SHEET NUMBER
C6



PROFESSIONAL ENGINEER CERTIFICATION

I HEREBY AFFIRM THAT THESE FINAL CONSTRUCTION PLANS WERE PREPARED UNDER MY DIRECT SUPERVISION, IN ACCORDANCE WITH ALL APPLICABLE TOWN OF CASTLE ROCK AND STATE OF COLORADO STANDARDS AND STATUTES, RESPECTIVELY; AND THAT I AM FULLY RESPONSIBLE FOR ALL DESIGN AND REVISIONS RELATIVE TO SAID PLANS.

KURT A. LANG
COLORADO P.E., 32249

TOWN OF CASTLE ROCK APPROVAL

PLANS ARE HEREBY APPROVED FOR ONE YEAR FROM DATE OF DEVELOPMENT SERVICES APPROVAL

APPROVED BY: *[Signature]*
DEVELOPMENT SERVICES
DATE: 10/23/15

No.	Revisions	Date	Init.	Appr.	Date
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2	CD 15-6000 ISSUED FOR CONSTRUCTION	10/22/15			

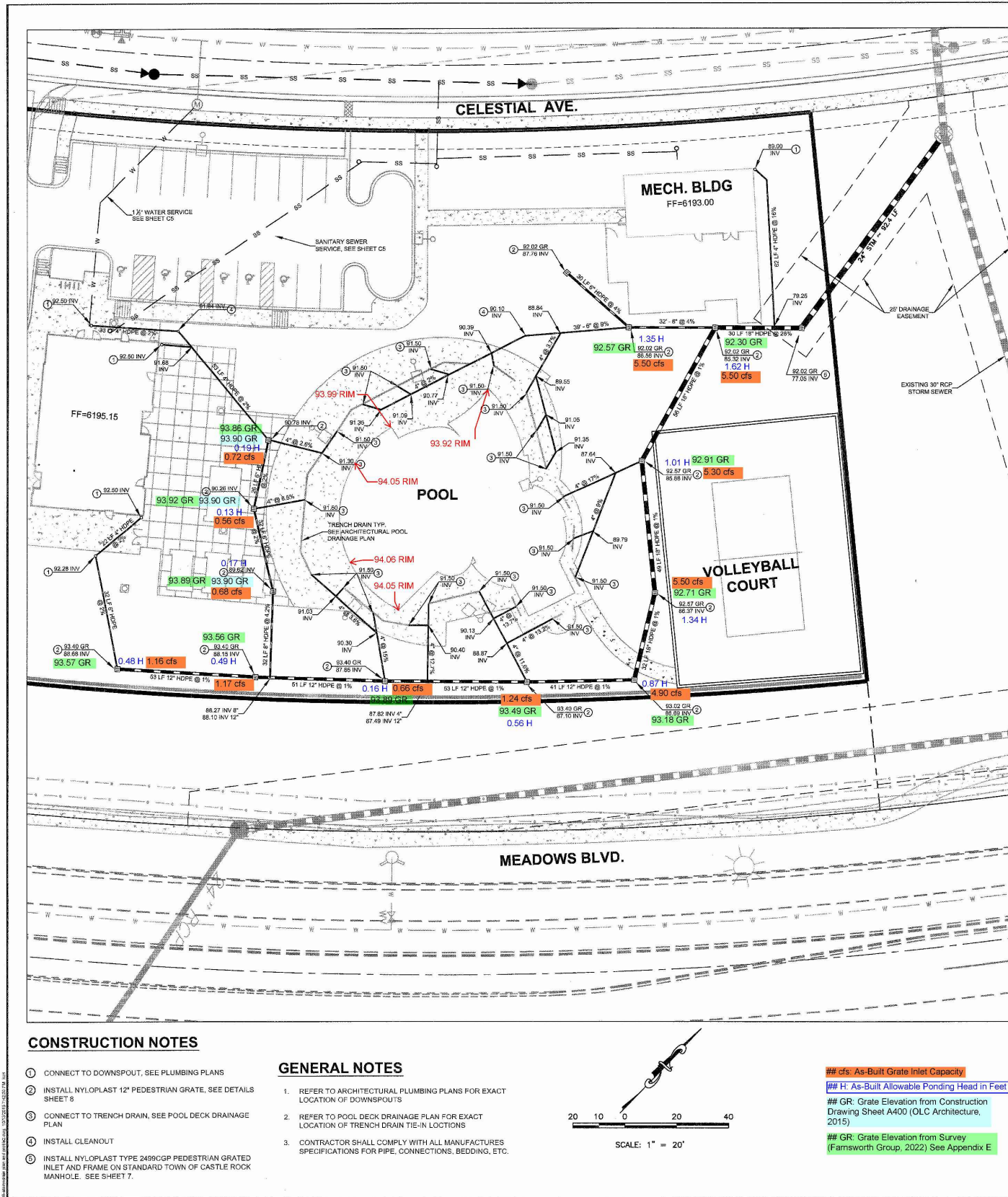
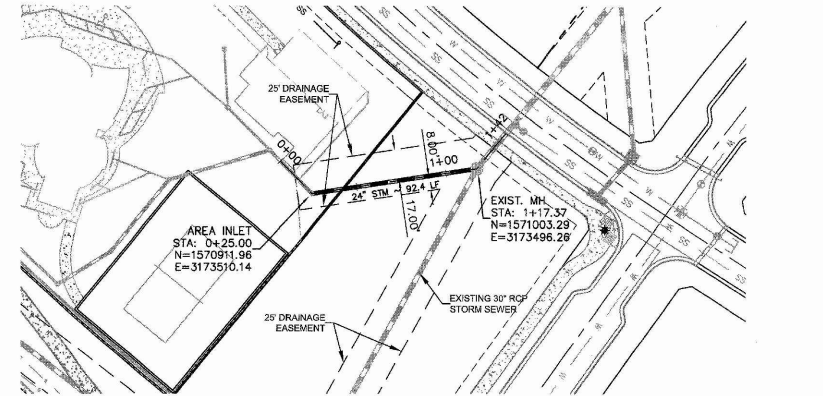
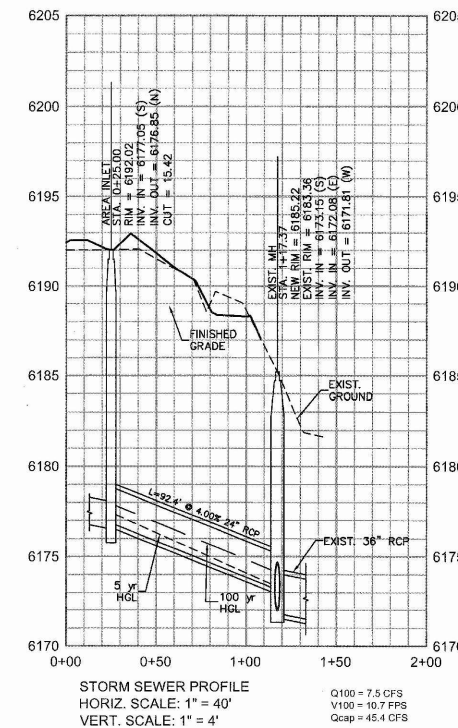
210 ENGINEERING, LLC
10940 S. Parker Rd. #448
Parker, Colorado 80134
303-921-4217

210 ENGINEERING, LLC
CIVIL SITE ENGINEERING & LAND PLANNING

THE MEADOWS
At Meadows Castle Rock

THE MEADOWS FILING 20
MNC AMENITY II SITE
SITE CONSTRUCTION PLANS
STORM DRAIN PLAN AND PROFILE

SCALE: AS SHOWN
FILE NO: 15-02021
DRAWN BY: KAL
CHECKED BY: KAL
DATE: OCTOBER 14, 2015
SHEET NUMBER
C6



PROFESSIONAL ENGINEER CERTIFICATION

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KURT A. LANG
COLORADO P.E., 32249

TOWN OF CASTLE ROCK APPROVAL

PLANS ARE HEREBY APPROVED FOR ONE YEAR FROM DATE OF DEVELOPMENT SERVICES APPROVAL

APPROVED BY: *[Signature]* 10/23/22
DEVELOPMENT SERVICES DATE

CALL UNCC
TWO WORKING DAYS
BEFORE YOU DIG
1-800-922-1987
534-6700 METRO DENVER AREA
UTILITY NOTIFICATION CENTER OF COLORADO

No.	Revisions	Date	Init.	Appr.	Date
1	ADD MANHOLE 1	9/11/2013			
2	CD 15-6000 ISSUED FOR CONSTRUCTION	10/22/15			

210 ENGINEERING, LLC
10940 S. Parker Rd. #448
Parker, Colorado 80134
303-921-4217

ENGINEERING, LLC
CIVIL SITE ENGINEERING & LAND PLANNING

THE MEADOWS
At Meadows Castle Rock

THE MEADOWS FILING 20
MNC AMENITY II SITE
SITE CONSTRUCTION PLANS
STORM DRAIN PLAN AND PROFILE

SCALE: AS SHOWN
FILE NO: 15-02021
DRAWN BY: KAL
CHECKED BY: KAL
DATE: OCTOBER 14, 2015
SHEET NUMBER
C6



Project No. 111298

January 2023

APPENDIX A
PHOTOGRAPH LOG

A.1
EA PHOTOGRAPHS

**Engineering Analytics
Photographic Record**



Client: Burg Simpson

Project Number: 111298

Site Name: Meadows Taft House Pool

Site Location: Meadows Taft House

IMG_1145

Date: 6/30/2022 8:42 AM

Direction: S

**Comments: Evidence of
bare soil and rilling
erosion on undeveloped
slope west of Taft House.**



IMG_1146

Date: 6/30/2022 8:45 AM

Direction: S

**Comments: Farthest west
(First inlet grate drain).**



**Engineering Analytics
Photographic Record**



Client: Burg Simpson

Project Number: 111298

Site Name: Meadows Taft House Pool

Site Location: Meadows Taft House

IMG_1158

Date: 6/30/2022 9:51 AM

Direction: NW

**Comments: Location of
silt fence and straw
wattles installed for
erosion control.**



IMG_1159

Date: 6/30/2022 9:51 AM

Direction: NE

**Comments: Connection
between west slope and
taft house property.**



**Engineering Analytics
Photographic Record**



Client: Burg Simpson

Project Number: 111298

Site Name: Meadows Taft House Pool

Site Location: Meadows Taft House

IMG_1161

Date: 6/30/2022 9:52 AM

Direction: SW

Comments: Silt fence and erosion on the slope west of the Taft House.



IMG_1162

Date: 6/30/2022 9:52 AM

Direction:

Comments: Buildup of sediment behind silt fence.



**Engineering Analytics
Photographic Record**



Client: Burg Simpson

Project Number: 111298

Site Name: Meadows Taft House Pool

Site Location: Meadows Taft House

IMG_1165

Date: 6/30/2022 9:53 AM

Direction: SW

**Comments: Connection
between west slope and
taft house property.**



IMG_1167

Date: 6/30/2022 10:20 AM

Direction: NE

**Comments: Buildup of
debris at inlet grate east
of the pool adjacent to the
volleyball courts.**



Engineering Analytics Photographic Record



Client: Burg Simpson

Project Number: 111298

Site Name: Meadows Taft House Pool

Site Location: Meadows Taft House

IMG_1168

Date: 6/30/2022 10:20 AM

Direction:

Comments: Buildup of debris at inlet grate east of the pool.



IMG_1169

Date: 6/30/2022 10:21 AM

Direction: SE

Comments: Landscaping rock partially blocking inlet grate south of pool adjacent to retaining wall.



Engineering Analytics Photographic Record



Client: Burg Simpson

Project Number: 111298

Site Name: Meadows Taft House Pool

Site Location: Meadows Taft House

IMG_1171

Date: 6/30/2022 10:21 AM

Direction:

Comments: Landscaping rock partially blocking inlet grate south of pool adjacent to retaining wall.



[Photograph ID/Number]

Date:

Direction:

Comments:

A.2

MEADOWS COMPANY PHOTOGRAPHS

**Engineering Analytics
Photographic Record**



Client: Burg Simpson

Project Number: 111298

Site Name: Meadows Taft House Pool

Site Location: Meadows Taft House

MNC_000941

Date: 17 July 2018

Direction: SW

**Comments: Ponding of
water around the first
drain inlet.**



MNC_000942

Date: 17 July 2018

Direction: SW

**Comments: Ponding of
water around the first
drain inlet.**



**Engineering Analytics
Photographic Record**



Client: Burg Simpson

Project Number: 111298

Site Name: Meadows Taft House Pool

Site Location: Meadows Taft House

MNC_000943

Date: 17 July 2018

Direction: E

**Comments: Ponding of
water around the first
drain inlet.**

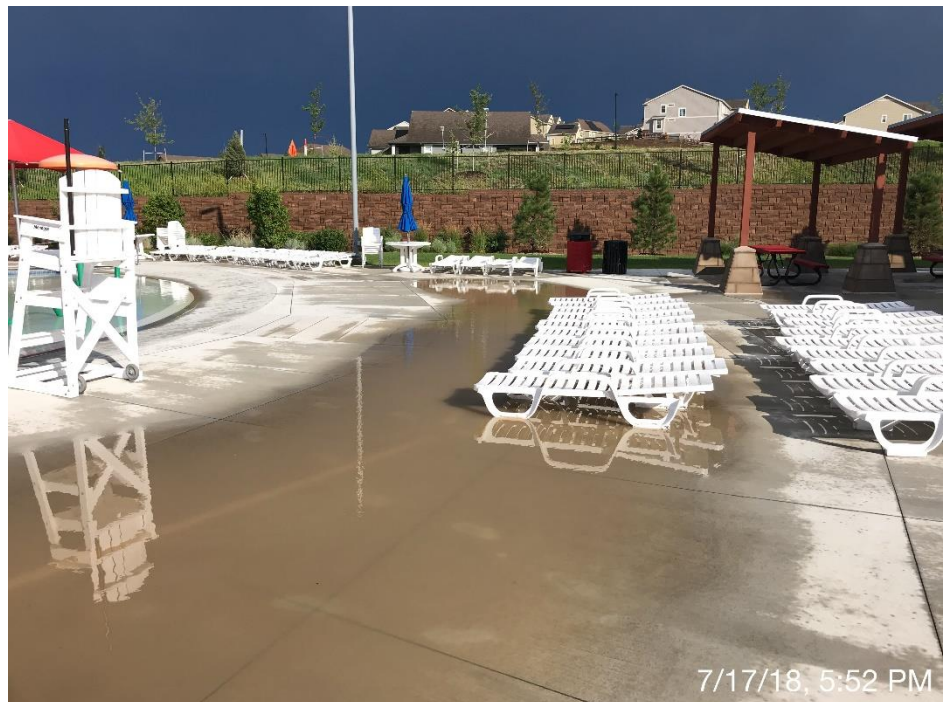


MNC_000944

Date: 17 July 2018

Direction: SE

**Comments: Ponding of
water over trench drains
on pool deck.**



**Engineering Analytics
Photographic Record**



Client: Burg Simpson

Project Number: 111298

Site Name: Meadows Taft House Pool

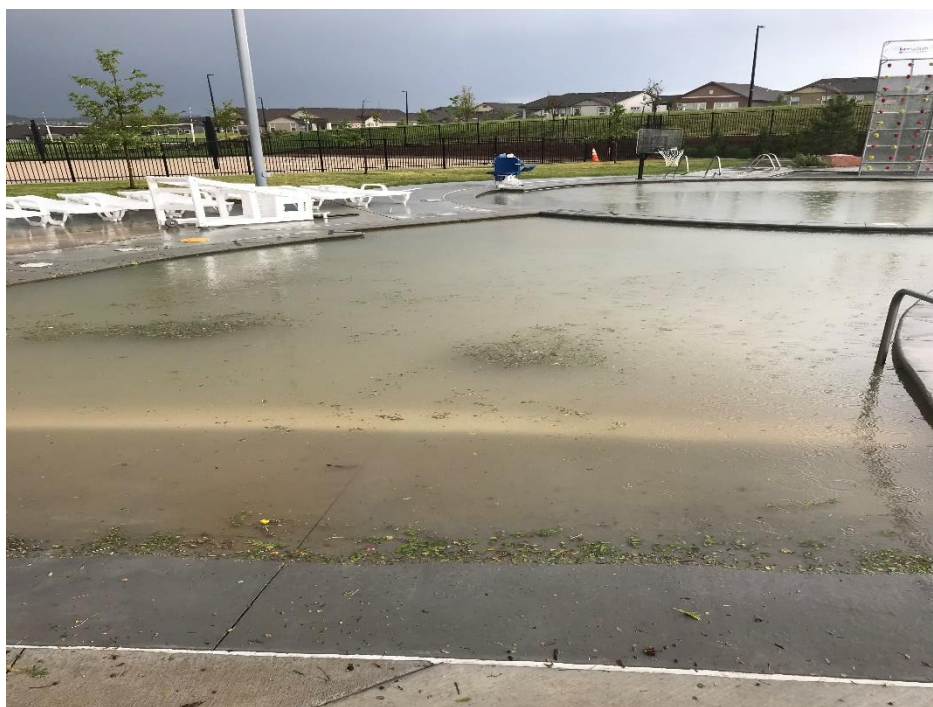
Site Location: Meadows Taft House

MNC_000955

Date: 6/17/2019 4:16 PM

Direction: E

**Comments: Grass and
sediment deposited in
north side of pool.**

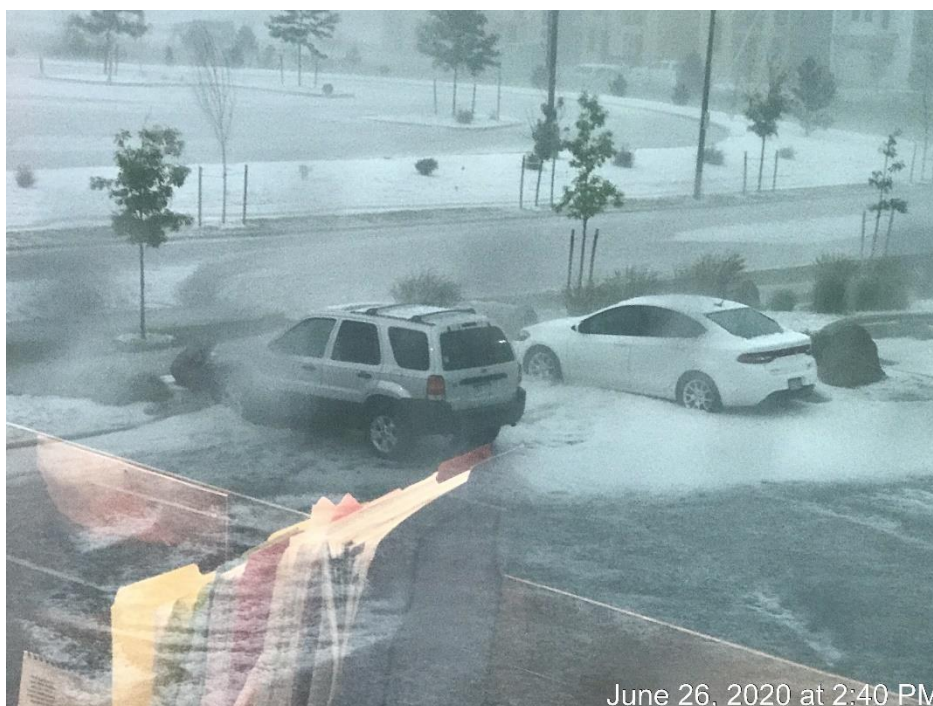


MNC_000960

Date: 6/26/2020 2:40 PM

Direction: N

**Comments:
Accumulation of hail at
storm drain inlet in
parking lot.**



**Engineering Analytics
Photographic Record**



Client: Burg Simpson

Project Number: 111298

Site Name: Meadows Taft House Pool

Site Location: Meadows Taft House

**MNC_000963 - frame at
0m3s**

Date:

Direction: NE

Comments: Frame from
video MNC_000963
showing flow of water
from right to left and
deposition of hail in north
end of pool.



MNC_000964

Date: 6/26/2020 2:45 PM

Direction: NE

Comments:
Accumulation of hail on
pool deck showing water
flow paths.



**Engineering Analytics
Photographic Record**



Client: Burg Simpson

Project Number: 111298

Site Name: Meadows Taft House Pool

Site Location: Meadows Taft House

MNC_000965

Date: 6/26/2020 3:19 PM

Direction: NE

**Comments: Post-storm
on 6/26/2020.**



MNC_000971

Date: 6/26/2020 3:33 PM

Direction: NE

**Comments: Sediment in
pool area after a storm.**



APPENDIX B
HYDROLOGY CALCULATIONS AND SUPPORTING
INFORMATION



Project: Meadows Taft House Pool Drainage
 Client: Burg Simpson
 Date: 7/18/2022
 Job Number: 111298

EA-1 Basin Characteristics				
Total Catchment Area	A	1.56	Acres	Measured from grading plan (Sheet C4 (210 Engineering, 2015a))
Impervious Area	A _i	0.00	Acres	Measured from grading plan (Sheet C4 (210 Engineering, 2015a))
Percent Impervious	%	0%		Calculated from total and impervious
Length of Overland Flow	L	313.50	Feet	
Average Slope Along Overland Flow Path	S _o	0.032	ft/ft	
Overland flow time	t _i	22.82	min	
Waterway Length	L	193.26	feet	Short Pasture / Lawn
Conveyance Factor	K	7		Short Pasture / Lawn
Average Slope Along Waterway	S _o	0.065	ft/ft	
Channelized flow time	t _t	1.81	min	USDCM Eq. 6-4
Time of Concentration	t _c	24.63	min	USDCM Eq. 6-2
Design Point Time of Concentration	t _c	21.20	min	USDCM Eq. 6-5
Minimum Time of Concentration	t _c	21.20	min	Min of USDCM Eq. 6-2 and Eq. 6-5

5 year				
Rainfall intensity	i	2.95	in/hr	per SDDTC Figure 6-1
Runoff Coefficient	C	0.052		Per USDCM Vol 1 2016 Table 6-4
Total Flow @ outlet	Q	0.24	cfs	Rational Method
Time of Concentration	t _c	21.20	mins	Per castle rock technical manual

100 year				
Rainfall intensity	i	5.35	in/hr	Per SDDTC Figure 6-1
Runoff Coefficient	C	0.508		Per USDCM Vol 1 2016 Table 6-4
Total Flow @ outlet	Q	4.24	cfs	Rational Method
Time of Concentration	t _c	5	mins	Per castle rock technical manual

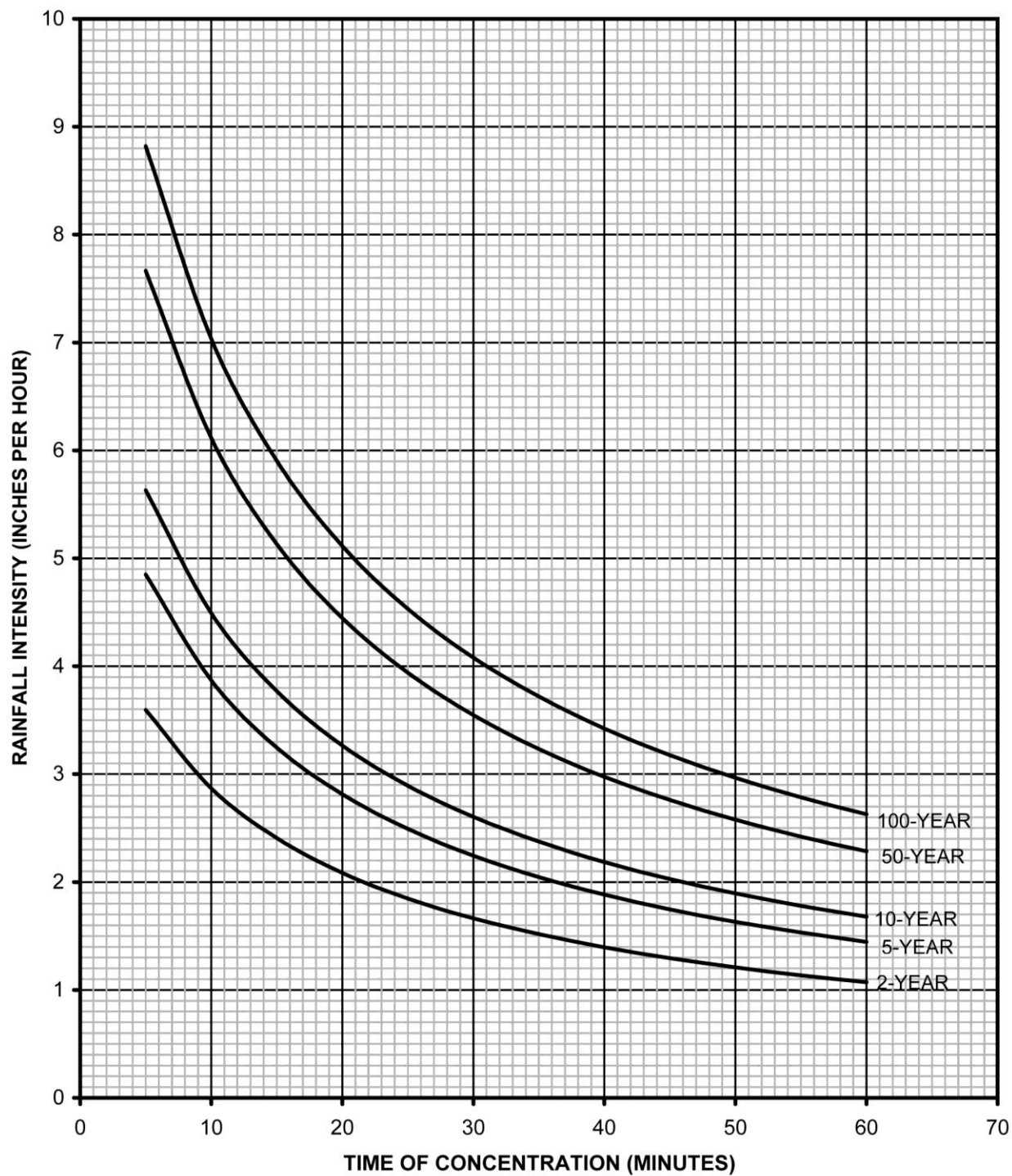
EA-1+2 Basin Characteristics				
Total Catchment Area	A	2.99	Acres	Measured from grading plan (Sheet C4 (210 Engineering, 2015a))
Impervious Area	A _i	0.37	Acres	Measured from grading plan (Sheet C4 (210 Engineering, 2015a))
Percent Impervious	%	12%		Calculated from total and impervious
Length of Overland Flow	L	313.50	Feet	
Average Slope Along Overland Flow Path	S _o	0.031	ft/ft	
Overland flow time	t _i	20.77	min	
Waterway Length	L	469.00	feet	Short Pasture / Lawn
Conveyance Factor	K	7		Short Pasture / Lawn
Average Slope Along Waterway	S _o	0.027	ft/ft	
Channelized flow time	t _t	6.85	min	USDCM Eq. 6-4
Time of Concentration	t _c	27.61	min	USDCM Eq. 6-2
Design Point Time of Concentration	t _c	21.29	min	USDCM Eq. 6-5
Minimum Time of Concentration	t _c	21.29	min	Min of USDCM Eq. 6-2 and Eq. 6-5

5 year				
Rainfall intensity	i	2.95	in/hr	Per SDDTC Figure 6-1
Runoff Coefficient	C	0.160		Per USDCM Vol 1 2016 Table 6-4
Total Flow @ outlet	Q	1.41	cfs	Rational Method
Time of Concentration	t _c	21.29	mins	Per castle rock technical manual

100 year				
Rainfall intensity	i	5.35	in/hr	Per SDDTC Figure 6-1
Runoff Coefficient	C	0.508		Per USDCM Vol 1 2016 Table 6-4
Total Flow @ outlet	Q	8.13	cfs	Rational Method
Time of Concentration	t _c	5	mins	Per castle rock technical manual

B.1
CASTLE ROCK IDF CURVE AND UDFCD REFERENCE
INFORMATION

FIGURE 6-1
RAINFALL INTENSITY-DURATION CURVE
TOWN OF CASTLE ROCK



URBAN STORM DRAINAGE

VOLUME

1

**CRITERIA
MANUAL**



MANAGEMENT, HYDROLOGY, AND HYDRAULICS

Urban Storm Drainage Criteria Manual: Volume 1 Management, Hydrology, and Hydraulics

Updated January 2016

Originally Published September 1969



Urban Drainage and Flood Control District

2480 West 26th Avenue, Suite 156B

Denver, Colorado 80211

www.udfcd.org

2.3 Limitations

The Rational Method is the simplistic approach for estimating the peak flow rate and total runoff volume from a design rainstorm in a given catchment. Under the assumption of uniform hydrologic losses, the method is limited to catchments smaller than 90 acres. Under the condition of composite soils and land uses, the area-weighted method is recommended to derive the catchment's hydrologic parameters.

The greatest drawback to the Rational Method is that it normally provides only one point (the peak flow rate) on the runoff hydrograph. When the areas become complex and where subcatchments come together, the Rational Method will tend to overestimate the actual flow, which results in oversizing of drainage facilities. The Rational Method provides no means or methodology to generate and route hydrographs through drainage facilities. One reason the Rational Method is limited to small areas is that good design practice requires the routing of hydrographs for larger catchments to achieve an economically sound design.

Another disadvantage of the Rational Method is that with typical design procedures, one normally assumes that all of the design flow is collected at the design point and that there is no water running overland to the next design point. This is not a fault of the Rational Method but of the design procedure. The Rational Method must be modified, or another type of analysis must be used, when analyzing an existing system that is under-designed or when analyzing the effects of a major storm on a system designed for the minor storm.

2.4 Time of Concentration

One of the basic assumptions underlying the Rational Method is that runoff is linearly proportional to the average rainfall intensity during the time required for water to flow from the most remote part of the drainage area to the design point. In practice, the time of concentration is empirically estimated along the selected waterway through the catchment.

The waterway is first divided into overland flow length and channelized flow lengths, according to the channel characteristics. For urban areas, the time of concentration, t_c , consists of an initial time or overland flow time, t_i , plus the channelized flow travel time, t_t , through the storm drain, paved gutter, roadside ditch, or channel. For non-urban areas, the time of concentration consists of an overland flow time, t_i , plus the time of travel in a defined drainage path, such as a swale, channel, or stream. The channelized flow travel time portion, t_t , of the time of concentration can be estimated from the hydraulic properties of the conveyance element. Initial or overland flow time, on the other hand, will vary with surface slope, depression storage, surface cover, antecedent rainfall, and infiltration capacity of the soil, as well as distance of surface flow. The time of concentration is computed by Equation 6-2 for both urban and non-urban areas:

$$t_c = t_i + t_t \quad \text{Equation 6-2}$$

Where:

t_c = computed time of concentration (minutes)

t_i = overland (initial) flow time (minutes)

t_t = channelized flow time (minutes).

2.4.1 Initial or Overland Flow Time

The initial or overland flow time, t_i , may be calculated using Equation 6-3:

$$t_i = \frac{0.395(1.1 - C_5)\sqrt{L}}{S_o^{0.33}} \quad \text{Equation 6-3}$$

Where:

- t_i = overland (initial) flow time (minutes)
- C_5 = runoff coefficient for 5-year frequency (from Table 6-4)
- L = length of overland flow (ft)
- S_o = average slope along the overland flow path (ft/ft).

Equation 6-3 is adequate for distances up to 300 feet in urban areas and 500 feet in rural areas. Note that in a highly urbanized catchment, the overland flow length is typically shorter than 300 feet due to effective man-made drainage systems that collect and convey runoff.

2.4.2 Channelized Flow Time

The channelized flow time (travel time) is calculated using the hydraulic properties of the conveyance element. The channelized flow time, t_t , is estimated by dividing the length of conveyance by the velocity. The following equation, Equation 6-4 (Guo 2013), can be used to determine the flow velocity in conjunction with Table 6-2 for the conveyance factor.

$$t_t = \frac{L_t}{60K\sqrt{S_o}} = \frac{L_t}{60V_t} \quad \text{Equation 6-4}$$

Where:

- t_t = channelized flow time (travel time, min)
- L_t = waterway length (ft)
- S_o = waterway slope (ft/ft)
- V_t = travel time velocity (ft/sec) = $K\sqrt{S_o}$
- K = NRCS conveyance factor (see Table 6-2).

Table 6-2. NRCS Conveyance factors, K

Type of Land Surface	Conveyance Factor, K
Heavy meadow	2.5
Tillage/field	5
Short pasture and lawns	7
Nearly bare ground	10
Grassed waterway	15
Paved areas and shallow paved swales	20

The time of concentration, t_c , is the sum of the initial (overland) flow time, t_i , and the channelized flow time, t_b , as per Equation 6-2.

2.4.3 First Design Point Time of Concentration in Urban Catchments

Equation 6-4 was solely determined by the waterway characteristics and using a set of empirical formulas. A calibration study between the Rational Method and the Colorado Urban Hydrograph Procedure (CUHP) suggests that the time of concentration shall be the lesser of the values calculated by Equation 6-2 and Equation 6-5 (Guo and Urbonas 2013).

$$t_c = (18 - 15i) + \frac{L_t}{60(24i + 12)\sqrt{S_o}} \quad \text{Equation 6-5}$$

Where:

- t_c = minimum time of concentration for first design point when less than t_c from Equation 6-1.
- L_t = length of flow path (ft)
- i = imperviousness (expressed as a decimal)
- S_o = slope of flow path (ft/ft).

Equation 6-5 is the regional time of concentration that warrants the best agreement on peak flow predictions between the Rational Method and CUHP. It was developed using the UDFCD database that includes 295 sample urban catchments under 2-, 5-, 10-, 50, and 100-yr storm events (MacKenzie 2010). It suggests that both initial flow time and channelized flow velocity are directly related to the catchment's imperviousness (Guo and MacKenzie 2013).

The first design point is defined as a node where surface runoff enters the storm drain system. For example, all inlets are “first design points” because inlets are designed to accept flow into the storm drain.

Typically, but not always, Equation 6-5 will result in a lesser time of concentration at the first design point and will govern in an urbanized watershed. For subsequent design points, add the travel time for each relevant segment downstream.

2.4.4 Minimum Time of Concentration

Use a minimum t_c value of 5 minutes for urbanized areas and a minimum t_c value of 10 minutes for areas that are not considered urban. Use minimum values even when calculations result in a lesser time of concentration.

2.4.5 Common Errors in Calculating Time of Concentration

A common mistake in urbanized areas is to assume travel velocities that are too slow. Another common error is to not check the runoff peak resulting from only part of the catchment. Sometimes a lower portion of the catchment or a highly impervious area produces a larger peak than that computed for the whole catchment. This error is most often encountered when the catchment is long or the upper portion contains grassy open land and the lower portion is more developed.

2.5 Rainfall Intensity

The calculated rainfall intensity, I , is the average rainfall rate in inches per hour for the period of maximum rainfall having a duration equal to the time of concentration.

After the design storm recurrence frequency has been selected, a graph should be made showing rainfall intensity versus time. The procedure for obtaining the local data and plotting such a graph is explained and illustrated in the *Rainfall* chapter of the USDCM. The UD-Rain Excel workbook can also be used for calculating the intensity. This workbook is available for download at www.udfcd.org.



Photograph 6-2. Urbanization (impervious area) increases runoff volumes, peak discharges, frequency of runoff, and receiving stream degradation.

2.5.1 Runoff Coefficient

Each part of a watershed can be considered as either pervious or impervious. The pervious part is the area where water can readily infiltrate into the ground. The impervious part is the area that does not readily allow water to infiltrate into the ground, such as areas that are paved or covered with buildings and sidewalks or compacted unvegetated soils. In urban hydrology, the percentage of pervious and impervious land is important. Urbanization increases impervious area causing rainfall-runoff relationships to change significantly. In the absence of stormwater management methods such as low impact development and green infrastructure, the total runoff volume increases, the time to the runoff peak rate decreases, and the peak runoff rate increases.

When analyzing a watershed for planning or design purposes, the probable future percent of impervious area must be estimated. A complete tabulation of recommended values of the total percent of imperviousness is provided in Table 6-3.

The runoff coefficient, C , represents the integrated effects of infiltration, evaporation, retention, and interception, all of which affect the volume of runoff. The determination of C requires judgment based on experience and understanding on the part of the engineer.

Volume-based runoff coefficients were derived to establish the optimal consistency between CUHP and the Rational Method for peak flow predictions (Guo, 2013). Using the percentage imperviousness, the equations in Table 6-4 can be used to calculate the runoff coefficients for hydrologic soil groups A, B, and C/D for various storm return periods.

Table 6-3. Recommended percentage imperviousness values

Land Use or Surface Characteristics	Percentage Imperviousness (%)
Business:	
Downtown Areas	95
Suburban Areas	75
Residential:	
Single-family	
2.5 acres or larger	12
0.75 – 2.5 acres	20
0.25 – 0.75 acres	30
0.25 acres or less	45
Apartments	75
Industrial:	
Light areas	80
Heavy areas	90
Parks, cemeteries	10
Playgrounds	25
Schools	55
Railroad yard areas	50
Undeveloped Areas:	
Historic flow analysis	2
Greenbelts, agricultural	2
Off-site flow analysis (when land use not defined)	45
Streets:	
Paved	100
Gravel (packed)	40
Drive and walks	90
Roofs	90
Lawns, sandy soil	2
Lawns, clayey soil	2

Table 6-4. Runoff coefficient equations based on NRCS soil group and storm return period

NRCS Soil Group	Storm Return Period					
	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year
A	$C_A = 0.89i$	$C_A = 0.93i$	$C_A = 0.94i$	$C_A = 0.944i$	$C_A = 0.95i$	$C_A = 0.81i + 0.154$
B	$C_B = 0.89i$	$C_B = 0.93i$	$C_B = 0.81i + 0.125$	$C_B = 0.70i + 0.23$	$C_B = 0.59i + 0.364$	$C_B = 0.49i + 0.454$
C/D	$C_{C/D} = 0.89i$	$C_{C/D} = 0.87i + 0.052$	$C_{C/D} = 0.74i + 0.2$	$C_{C/D} = 0.64i + 0.31$	$C_{C/D} = 0.54i + 0.418$	$C_{C/D} = 0.45i + 0.508$

Where:

i = % imperviousness (expressed as a decimal)

C_A = Runoff coefficient for Natural Resources Conservation Service (NRCS) HSG A soils

C_B = Runoff coefficient for NRCS HSG B soils

$C_{C/D}$ = Runoff coefficient for NRCS HSG C and D soils.

The values for various catchment imperviousness and storm return periods are presented graphically in Figures 6-1 through 6-3, and are tabulated in Table 6-5. These coefficients were developed for the Denver region to work in conjunction with the time of concentration recommendations in Section 2.4. Use of these coefficients and this procedure outside of the semi-arid climate found in the Denver region may not be valid. The UD-Rational Excel workbook performs all the needed calculations to find the runoff coefficient given the soil type and imperviousness and the reader may want to take advantage of this macro-enabled Excel workbook that is available for download from the UDFCD's website www.udfcd.org.

See Examples 7.1 and 7.2 that illustrate the Rational Method.

B.2

**HISTORIC CLIMATE DATA AND LOCATION BASED
PRECIPITATION MODEL DATA**

Climatological Data for CASTLE ROCK, CO - June 2020									
Date	Temperature				HDD	CDD	Precipitation	New Snow	Snow Depth
	Maximum	Minimum	Average	Departure					
2020-06-01	90	59	74.5	13.7	0	10	0.00	0.0	0
2020-06-02	92	62	77.0	15.9	0	12	0.00	0.0	0
2020-06-03	90	52	71.0	9.5	0	6	0.00	0.0	0
2020-06-04	91	59	75.0	13.2	0	10	0.00	0.0	0
2020-06-05	90	58	74.0	11.8	0	9	0.02	0.0	0
2020-06-06	95	69	82.0	19.5	0	17	0.00	0.0	0
2020-06-07	85	57	71.0	8.2	0	6	0.05	0.0	0
2020-06-08	91	56	73.5	10.4	0	9	0.00	0.0	0
2020-06-09	77	39	58.0	-5.5	7	0	0.00	0.0	0
2020-06-10	82	40	61.0	-2.8	4	0	0.70	0.0	0
2020-06-11	78	47	62.5	-1.6	2	0	0.00	0.0	0
2020-06-12	84	52	68.0	3.6	0	3	0.00	0.0	0
2020-06-13	91	62	76.5	11.8	0	12	0.00	0.0	0
2020-06-14	92	64	78.0	13.0	0	13	0.02	0.0	0
2020-06-15	93	58	75.5	10.2	0	11	0.00	0.0	0
2020-06-16	94	62	78.0	12.4	0	13	0.00	0.0	0
2020-06-17	96	59	77.5	11.6	0	13	0.00	0.0	0
2020-06-18	97	53	75.0	8.8	0	10	0.00	0.0	0
2020-06-19	74	52	63.0	-3.5	2	0	0.02	0.0	0
2020-06-20	71	43	57.0	-9.8	8	0	0.00	0.0	0
2020-06-21	87	55	71.0	3.9	0	6	0.00	0.0	0
2020-06-22	86	56	71.0	3.6	0	6	0.00	0.0	0
2020-06-23	86	58	72.0	4.4	0	7	0.00	0.0	0
2020-06-24	89	55	72.0	4.1	0	7	0.04	0.0	0
2020-06-25	93	58	75.5	7.3	0	11	0.00	0.0	0
2020-06-26	94	54	74.0	5.6	0	9	0.00	0.0	0
2020-06-27	89	48	68.5	-0.2	0	4	0.98	0.0	0
2020-06-28	89	60	74.5	5.6	0	10	0.00	0.0	0
2020-06-29	90	59	74.5	5.4	0	10	0.05	0.0	0
2020-06-30	93	59	76.0	6.7	0	11	0.00	0.0	0
Sum	2649	1665	-	-	23	235	1.88	0.0	-
Average	88.3	55.5	71.9	6.6	-	-	-	-	0.0
Normal	80.2	50.5	65.3	-	79	89	2.20	0.0	-

Observations for each day cover the 24 hours ending at the time given below (Local Standard Time).
Max Temperature : 9am
Min Temperature : 9am
Precipitation : 9am
Snowfall : unknown
Snow Depth : unknown



NOAA Atlas 14, Volume 8, Version 2
Location name: Castle Rock, Colorado, USA*
Latitude: 39.3973°, Longitude: -104.8903°
Elevation: 6196.4 ft**

* source: ESRI Maps
 ** source: USGS



POINT PRECIPITATION FREQUENCY ESTIMATES

Sanja Perica, Deborah Martin, Sandra Pavlovic, Ishani Roy, Michael St. Laurent, Carl Trypaluk, Dale Unruh, Michael Yekta, Geoffrey Bonnin

NOAA, National Weather Service, Silver Spring, Maryland

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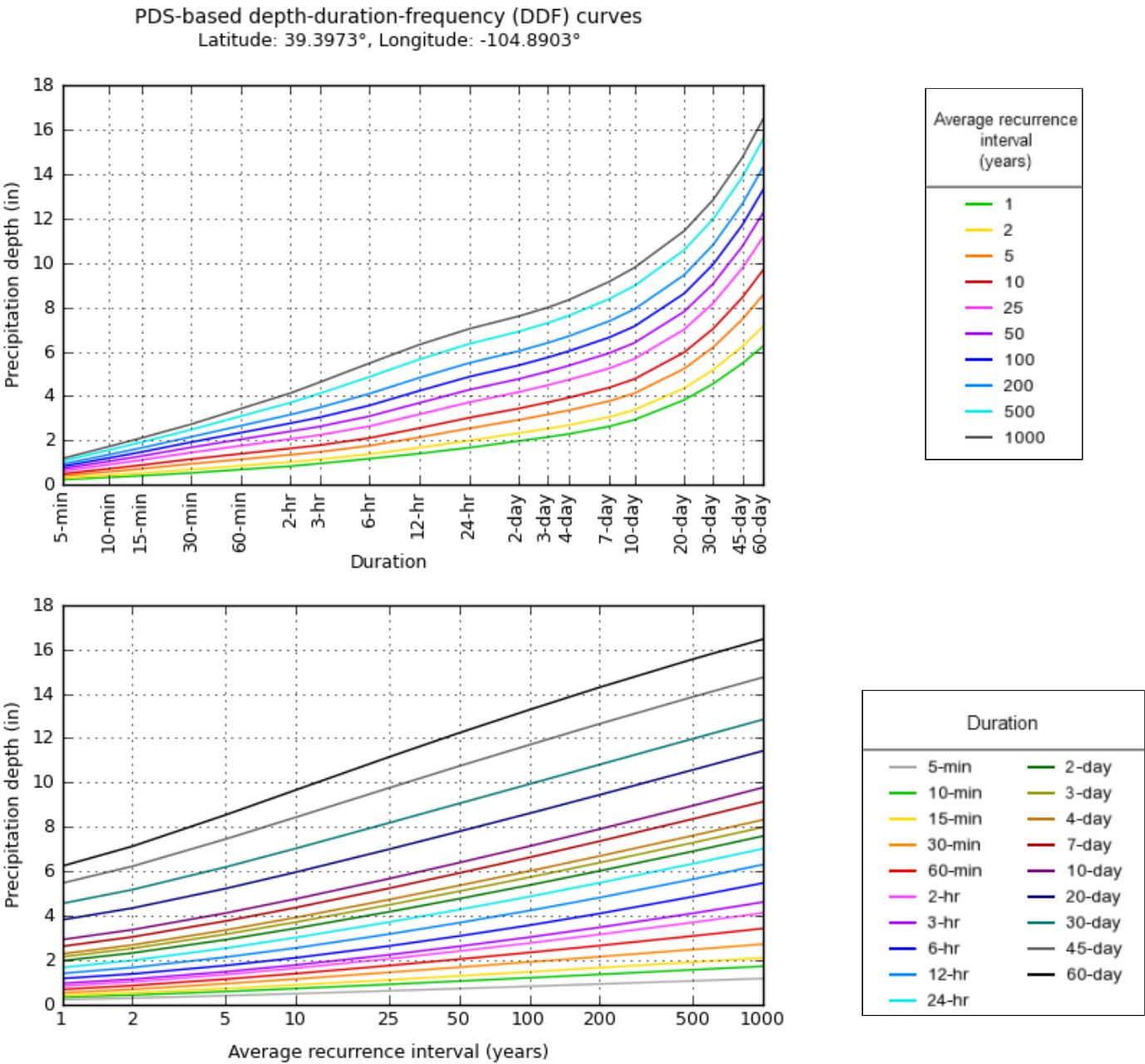
PF tabular

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches)¹										
Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	0.232 (0.196-0.280)	0.298 (0.251-0.359)	0.406 (0.341-0.491)	0.498 (0.415-0.605)	0.626 (0.500-0.790)	0.726 (0.565-0.930)	0.828 (0.618-1.09)	0.932 (0.663-1.26)	1.07 (0.729-1.50)	1.18 (0.779-1.68)
10-min	0.340 (0.287-0.410)	0.436 (0.367-0.526)	0.595 (0.499-0.719)	0.729 (0.607-0.885)	0.916 (0.732-1.16)	1.06 (0.827-1.36)	1.21 (0.905-1.59)	1.37 (0.971-1.85)	1.57 (1.07-2.19)	1.73 (1.14-2.45)
15-min	0.415 (0.350-0.500)	0.532 (0.448-0.641)	0.725 (0.609-0.877)	0.889 (0.741-1.08)	1.12 (0.893-1.41)	1.30 (1.01-1.66)	1.48 (1.10-1.94)	1.67 (1.18-2.26)	1.92 (1.30-2.68)	2.11 (1.39-2.99)
30-min	0.538 (0.454-0.648)	0.692 (0.583-0.834)	0.946 (0.794-1.14)	1.16 (0.966-1.41)	1.46 (1.16-1.84)	1.69 (1.31-2.16)	1.92 (1.44-2.53)	2.16 (1.54-2.93)	2.48 (1.69-3.47)	2.73 (1.80-3.87)
60-min	0.691 (0.583-0.832)	0.861 (0.726-1.04)	1.15 (0.966-1.39)	1.40 (1.17-1.70)	1.76 (1.41-2.23)	2.05 (1.60-2.64)	2.35 (1.76-3.10)	2.66 (1.90-3.62)	3.09 (2.11-4.33)	3.43 (2.26-4.87)
2-hr	0.843 (0.715-1.01)	1.03 (0.873-1.23)	1.36 (1.14-1.63)	1.64 (1.38-1.98)	2.07 (1.67-2.61)	2.41 (1.90-3.09)	2.78 (2.09-3.65)	3.16 (2.27-4.28)	3.70 (2.54-5.16)	4.13 (2.74-5.82)
3-hr	0.962 (0.818-1.15)	1.15 (0.976-1.37)	1.48 (1.25-1.78)	1.79 (1.50-2.15)	2.25 (1.83-2.84)	2.63 (2.08-3.37)	3.04 (2.31-3.99)	3.48 (2.52-4.71)	4.11 (2.84-5.72)	4.62 (3.08-6.49)
6-hr	1.18 (1.01-1.40)	1.39 (1.18-1.64)	1.76 (1.50-2.10)	2.11 (1.78-2.52)	2.64 (2.17-3.33)	3.09 (2.46-3.94)	3.58 (2.73-4.67)	4.11 (2.99-5.52)	4.86 (3.38-6.72)	5.48 (3.68-7.63)
12-hr	1.41 (1.21-1.66)	1.67 (1.44-1.97)	2.14 (1.83-2.52)	2.56 (2.17-3.03)	3.18 (2.61-3.95)	3.69 (2.95-4.65)	4.24 (3.25-5.48)	4.82 (3.52-6.42)	5.65 (3.95-7.74)	6.31 (4.26-8.74)
24-hr	1.67 (1.45-1.96)	1.99 (1.72-2.33)	2.54 (2.19-2.98)	3.02 (2.58-3.56)	3.72 (3.06-4.57)	4.28 (3.43-5.33)	4.87 (3.75-6.23)	5.49 (4.03-7.23)	6.35 (4.46-8.61)	7.02 (4.78-9.65)
2-day	1.98 (1.72-2.29)	2.33 (2.02-2.70)	2.93 (2.53-3.41)	3.44 (2.95-4.02)	4.18 (3.46-5.09)	4.77 (3.84-5.89)	5.38 (4.17-6.83)	6.02 (4.45-7.87)	6.90 (4.88-9.29)	7.59 (5.20-10.4)
3-day	2.15 (1.88-2.49)	2.53 (2.20-2.93)	3.17 (2.75-3.68)	3.72 (3.20-4.33)	4.49 (3.73-5.44)	5.11 (4.12-6.27)	5.74 (4.46-7.24)	6.40 (4.74-8.31)	7.29 (5.17-9.76)	7.99 (5.50-10.9)
4-day	2.29 (2.00-2.64)	2.69 (2.34-3.10)	3.36 (2.91-3.88)	3.93 (3.39-4.56)	4.73 (3.93-5.70)	5.37 (4.34-6.57)	6.02 (4.68-7.56)	6.69 (4.97-8.67)	7.61 (5.41-10.2)	8.32 (5.74-11.3)
7-day	2.63 (2.30-3.01)	3.05 (2.67-3.50)	3.76 (3.28-4.33)	4.37 (3.79-5.05)	5.24 (4.38-6.28)	5.92 (4.82-7.21)	6.63 (5.19-8.29)	7.36 (5.50-9.48)	8.36 (5.98-11.1)	9.14 (6.34-12.3)
10-day	2.93 (2.58-3.34)	3.38 (2.96-3.86)	4.12 (3.60-4.72)	4.76 (4.14-5.48)	5.67 (4.75-6.77)	6.39 (5.22-7.75)	7.13 (5.60-8.89)	7.91 (5.93-10.1)	8.96 (6.43-11.8)	9.78 (6.81-13.1)
20-day	3.82 (3.37-4.33)	4.35 (3.84-4.93)	5.23 (4.60-5.95)	5.97 (5.21-6.82)	6.99 (5.89-8.27)	7.80 (6.40-9.36)	8.61 (6.80-10.6)	9.45 (7.12-12.0)	10.6 (7.63-13.8)	11.4 (8.02-15.2)
30-day	4.56 (4.04-5.14)	5.18 (4.58-5.85)	6.20 (5.46-7.02)	7.03 (6.16-8.01)	8.18 (6.89-9.60)	9.06 (7.45-10.8)	9.93 (7.86-12.2)	10.8 (8.17-13.7)	12.0 (8.67-15.6)	12.8 (9.04-17.0)
45-day	5.47 (4.86-6.15)	6.23 (5.53-7.01)	7.45 (6.59-8.40)	8.44 (7.42-9.56)	9.75 (8.23-11.4)	10.7 (8.85-12.7)	11.7 (9.28-14.2)	12.6 (9.58-15.9)	13.9 (10.1-17.9)	14.7 (10.4-19.5)
60-day	6.24 (5.56-6.99)	7.13 (6.35-8.00)	8.54 (7.57-9.61)	9.66 (8.51-10.9)	11.1 (9.41-12.9)	12.2 (10.1-14.4)	13.3 (10.6-16.1)	14.3 (10.8-17.8)	15.6 (11.3-20.0)	16.5 (11.7-21.7)

¹ Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS). Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values. Please refer to NOAA Atlas 14 document for more information.

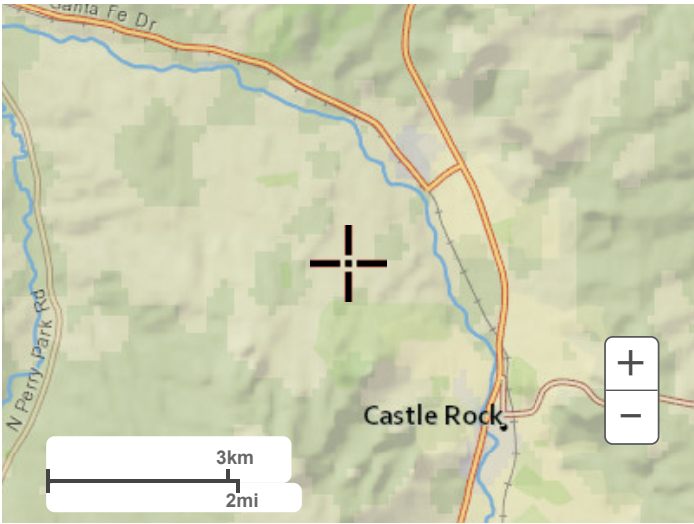
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PF graphical



Maps & aerials

Small scale terrain



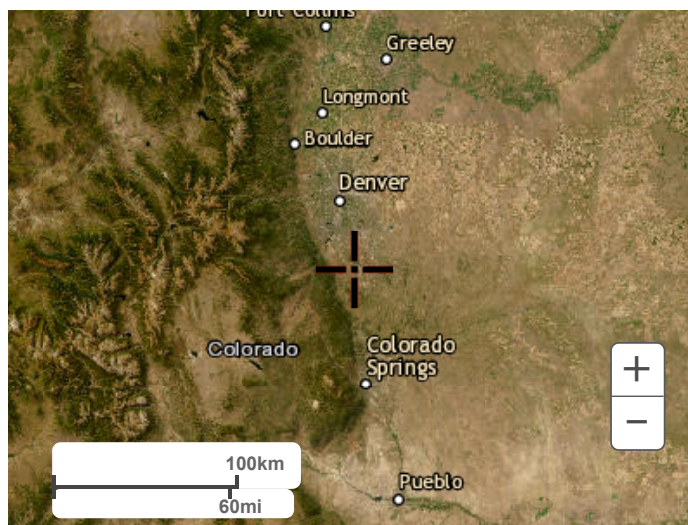
Large scale terrain



Large scale map



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NOAA Atlas 14, Volume 8, Version 2
Location name: Castle Rock, Colorado, USA*
Latitude: 39.3975°, Longitude: -104.8901°
Elevation: 6190.36 ft**
 * source: ESRI Maps
 ** source: USGS



POINT PRECIPITATION FREQUENCY ESTIMATES

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NOAA, National Weather Service, Silver Spring, Maryland

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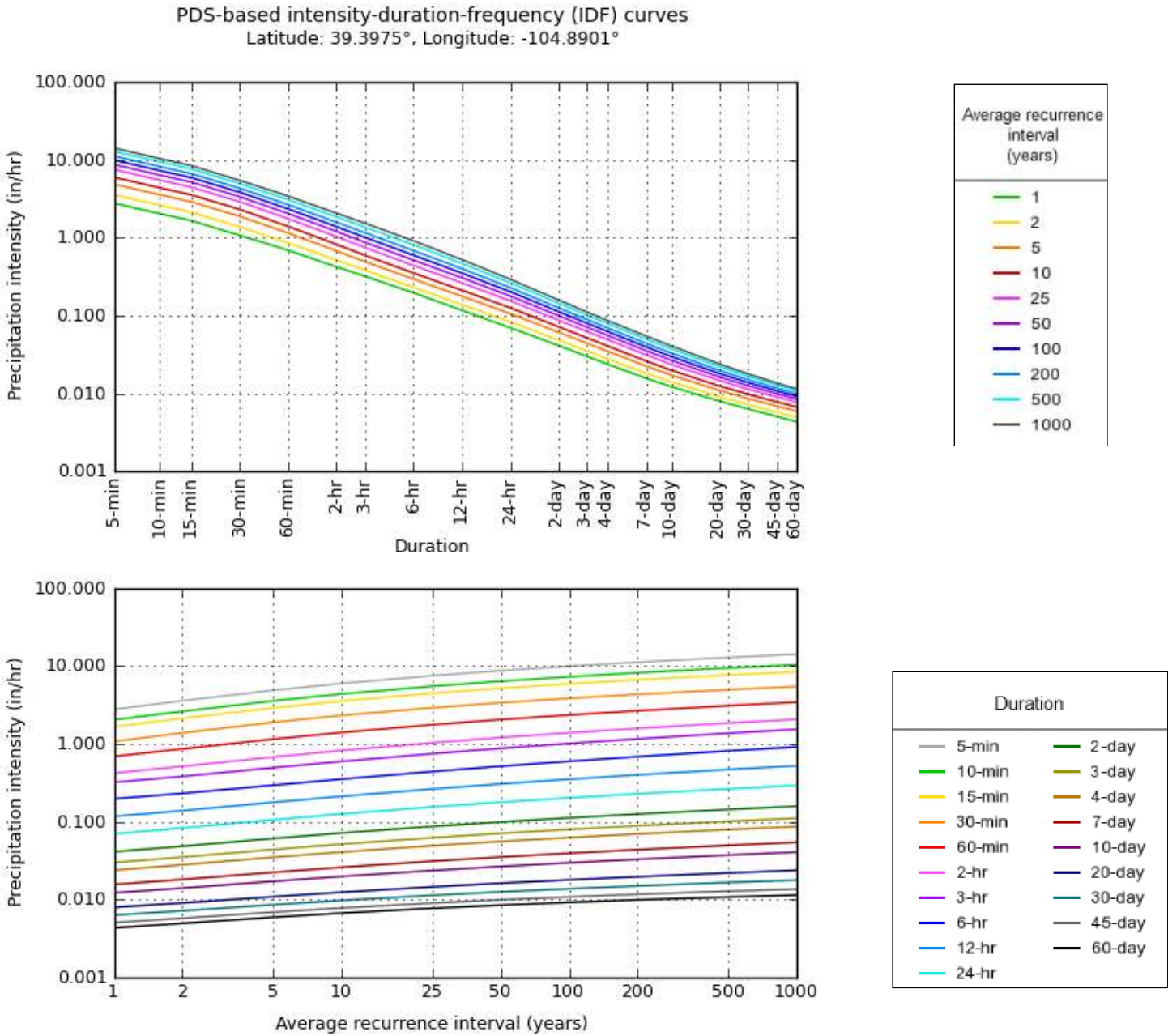
PF tabular

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches/hour) ¹										
Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	2.78 (2.35-3.36)	3.58 (3.01-4.31)	4.87 (4.09-5.89)	5.98 (4.98-7.26)	7.51 (6.00-9.48)	8.71 (6.78-11.2)	9.94 (7.42-13.1)	11.2 (7.96-15.2)	12.9 (8.75-18.0)	14.2 (9.35-20.1)
10-min	2.04 (1.72-2.46)	2.62 (2.20-3.16)	3.57 (2.99-4.31)	4.37 (3.64-5.31)	5.50 (4.39-6.94)	6.38 (4.96-8.17)	7.27 (5.43-9.56)	8.19 (5.83-11.1)	9.43 (6.41-13.2)	10.4 (6.85-14.7)
15-min	1.66 (1.40-2.00)	2.13 (1.79-2.56)	2.90 (2.44-3.51)	3.56 (2.96-4.32)	4.47 (3.57-5.64)	5.18 (4.03-6.64)	5.91 (4.42-7.78)	6.66 (4.74-9.02)	7.67 (5.21-10.7)	8.44 (5.57-12.0)
30-min	1.08 (0.908-1.30)	1.38 (1.17-1.67)	1.89 (1.59-2.29)	2.32 (1.93-2.82)	2.91 (2.33-3.67)	3.38 (2.62-4.32)	3.84 (2.87-5.05)	4.32 (3.07-5.85)	4.97 (3.37-6.93)	5.46 (3.60-7.74)
60-min	0.691 (0.583-0.832)	0.861 (0.726-1.04)	1.15 (0.966-1.39)	1.40 (1.17-1.70)	1.76 (1.41-2.23)	2.05 (1.60-2.64)	2.35 (1.76-3.10)	2.66 (1.90-3.62)	3.09 (2.11-4.33)	3.43 (2.26-4.87)
2-hr	0.422 (0.358-0.504)	0.516 (0.436-0.617)	0.678 (0.572-0.814)	0.822 (0.688-0.992)	1.03 (0.836-1.31)	1.21 (0.948-1.54)	1.39 (1.05-1.82)	1.58 (1.14-2.14)	1.85 (1.27-2.58)	2.07 (1.37-2.91)
3-hr	0.320 (0.272-0.382)	0.383 (0.325-0.457)	0.494 (0.418-0.591)	0.595 (0.500-0.716)	0.748 (0.609-0.946)	0.875 (0.692-1.12)	1.01 (0.768-1.33)	1.16 (0.837-1.57)	1.37 (0.945-1.91)	1.54 (1.03-2.16)
6-hr	0.197 (0.168-0.233)	0.231 (0.198-0.274)	0.294 (0.250-0.350)	0.353 (0.298-0.421)	0.441 (0.362-0.555)	0.516 (0.411-0.657)	0.597 (0.456-0.780)	0.686 (0.499-0.922)	0.812 (0.564-1.12)	0.915 (0.614-1.27)
12-hr	0.117 (0.101-0.138)	0.139 (0.119-0.164)	0.178 (0.152-0.209)	0.212 (0.180-0.251)	0.264 (0.217-0.328)	0.306 (0.245-0.386)	0.352 (0.270-0.455)	0.400 (0.292-0.533)	0.469 (0.328-0.642)	0.524 (0.354-0.725)
24-hr	0.070 (0.060-0.081)	0.083 (0.072-0.097)	0.106 (0.091-0.124)	0.126 (0.108-0.148)	0.155 (0.128-0.190)	0.178 (0.143-0.222)	0.203 (0.156-0.259)	0.229 (0.168-0.301)	0.264 (0.186-0.359)	0.293 (0.199-0.402)
2-day	0.041 (0.036-0.048)	0.049 (0.042-0.056)	0.061 (0.053-0.071)	0.072 (0.061-0.084)	0.087 (0.072-0.106)	0.099 (0.080-0.123)	0.112 (0.087-0.142)	0.125 (0.093-0.164)	0.144 (0.102-0.194)	0.158 (0.108-0.216)
3-day	0.030 (0.026-0.035)	0.035 (0.031-0.041)	0.044 (0.038-0.051)	0.052 (0.044-0.060)	0.062 (0.052-0.075)	0.071 (0.057-0.087)	0.080 (0.062-0.101)	0.089 (0.066-0.115)	0.101 (0.072-0.136)	0.111 (0.076-0.151)
4-day	0.024 (0.021-0.027)	0.028 (0.024-0.032)	0.035 (0.030-0.040)	0.041 (0.035-0.047)	0.049 (0.041-0.059)	0.056 (0.045-0.068)	0.063 (0.049-0.079)	0.070 (0.052-0.090)	0.079 (0.056-0.106)	0.087 (0.060-0.118)
7-day	0.016 (0.014-0.018)	0.018 (0.016-0.021)	0.022 (0.020-0.026)	0.026 (0.023-0.030)	0.031 (0.026-0.037)	0.035 (0.029-0.043)	0.039 (0.031-0.049)	0.044 (0.033-0.056)	0.050 (0.036-0.066)	0.054 (0.038-0.073)
10-day	0.012 (0.011-0.014)	0.014 (0.012-0.016)	0.017 (0.015-0.020)	0.020 (0.017-0.023)	0.024 (0.020-0.028)	0.027 (0.022-0.032)	0.030 (0.023-0.037)	0.033 (0.025-0.042)	0.037 (0.027-0.049)	0.041 (0.028-0.055)
20-day	0.008 (0.007-0.009)	0.009 (0.008-0.010)	0.011 (0.010-0.012)	0.012 (0.011-0.014)	0.015 (0.012-0.017)	0.016 (0.013-0.020)	0.018 (0.014-0.022)	0.020 (0.015-0.025)	0.022 (0.016-0.029)	0.024 (0.017-0.032)
30-day	0.006 (0.006-0.007)	0.007 (0.006-0.008)	0.009 (0.008-0.010)	0.010 (0.009-0.011)	0.011 (0.010-0.013)	0.013 (0.010-0.015)	0.014 (0.011-0.017)	0.015 (0.011-0.019)	0.017 (0.012-0.022)	0.018 (0.013-0.024)
45-day	0.005 (0.005-0.006)	0.006 (0.005-0.006)	0.007 (0.006-0.008)	0.008 (0.007-0.009)	0.009 (0.008-0.011)	0.010 (0.008-0.012)	0.011 (0.009-0.013)	0.012 (0.009-0.015)	0.013 (0.009-0.017)	0.014 (0.010-0.018)
60-day	0.004 (0.004-0.005)	0.005 (0.004-0.006)	0.006 (0.005-0.007)	0.007 (0.006-0.008)	0.008 (0.007-0.009)	0.008 (0.007-0.010)	0.009 (0.007-0.011)	0.010 (0.008-0.012)	0.011 (0.008-0.014)	0.011 (0.008-0.015)

¹ Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS). Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values. Please refer to NOAA Atlas 14 document for more information.

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PF graphical



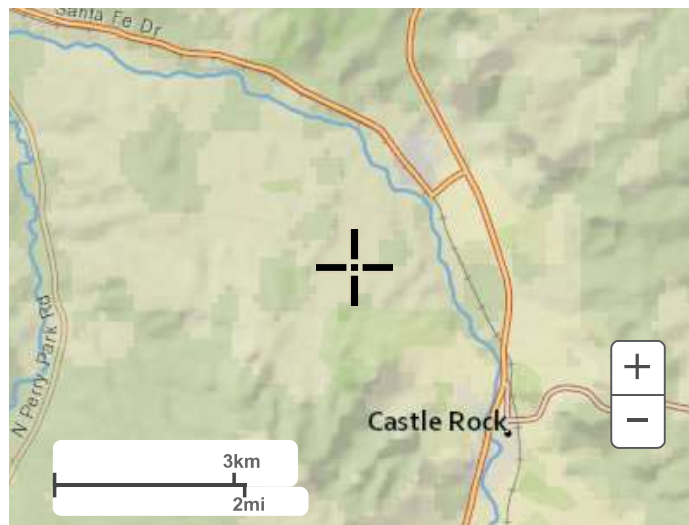
NOAA Atlas 14, Volume 8, Version 2

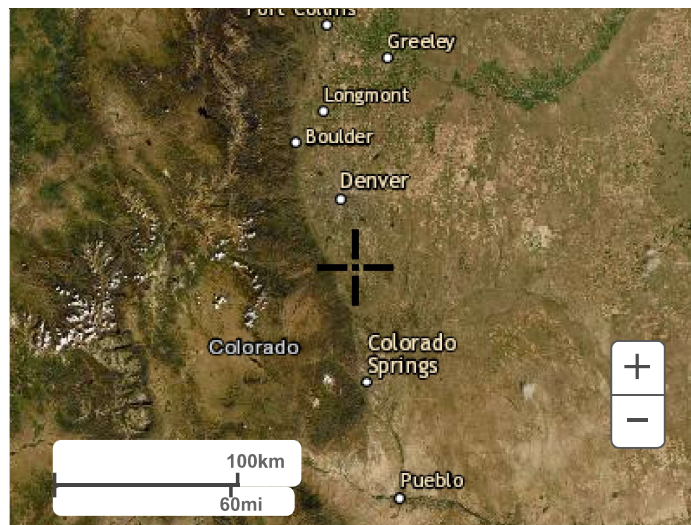
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Maps & aerials

Small scale terrain

**Large scale terrain****Large scale map****Large scale aerial**



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B.3
NRCS SOIL RESOURCE REPORT



United States
Department of
Agriculture

NRCS

Natural
Resources
Conservation
Service

A product of the National
Cooperative Soil Survey,
a joint effort of the United
States Department of
Agriculture and other
Federal agencies, State
agencies including the
Agricultural Experiment
Stations, and local
participants

Custom Soil Resource Report for **Castle Rock Area, Colorado**



July 14, 2022

Preface

Soil surveys contain information that affects land use planning in survey areas. They highlight soil limitations that affect various land uses and provide information about the properties of the soils in the survey areas. Soil surveys are designed for many different users, including farmers, ranchers, foresters, agronomists, urban planners, community officials, engineers, developers, builders, and home buyers. Also, conservationists, teachers, students, and specialists in recreation, waste disposal, and pollution control can use the surveys to help them understand, protect, or enhance the environment.

Various land use regulations of Federal, State, and local governments may impose special restrictions on land use or land treatment. Soil surveys identify soil properties that are used in making various land use or land treatment decisions. The information is intended to help the land users identify and reduce the effects of soil limitations on various land uses. The landowner or user is responsible for identifying and complying with existing laws and regulations.

Although soil survey information can be used for general farm, local, and wider area planning, onsite investigation is needed to supplement this information in some cases. Examples include soil quality assessments (<http://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/>) and certain conservation and engineering applications. For more detailed information, contact your local USDA Service Center (<https://offices.sc.egov.usda.gov/locator/app?agency=nrcs>) or your NRCS State Soil Scientist (http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/contactus/?cid=nrcs142p2_053951).

Great differences in soil properties can occur within short distances. Some soils are seasonally wet or subject to flooding. Some are too unstable to be used as a foundation for buildings or roads. Clayey or wet soils are poorly suited to use as septic tank absorption fields. A high water table makes a soil poorly suited to basements or underground installations.

The National Cooperative Soil Survey is a joint effort of the United States Department of Agriculture and other Federal agencies, State agencies including the Agricultural Experiment Stations, and local agencies. The Natural Resources Conservation Service (NRCS) has leadership for the Federal part of the National Cooperative Soil Survey.

Information about soils is updated periodically. Updated information is available through the NRCS Web Soil Survey, the site for official soil survey information.

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How Soil Surveys Are Made

Soil surveys are made to provide information about the soils and miscellaneous areas in a specific area. They include a description of the soils and miscellaneous areas and their location on the landscape and tables that show soil properties and limitations affecting various uses. Soil scientists observed the steepness, length, and shape of the slopes; the general pattern of drainage; the kinds of crops and native plants; and the kinds of bedrock. They observed and described many soil profiles. A soil profile is the sequence of natural layers, or horizons, in a soil. The profile extends from the surface down into the unconsolidated material in which the soil formed or from the surface down to bedrock. The unconsolidated material is devoid of roots and other living organisms and has not been changed by other biological activity.

Currently, soils are mapped according to the boundaries of major land resource areas (MLRAs). MLRAs are geographically associated land resource units that share common characteristics related to physiography, geology, climate, water resources, soils, biological resources, and land uses (USDA, 2006). Soil survey areas typically consist of parts of one or more MLRA.

The soils and miscellaneous areas in a survey area occur in an orderly pattern that is related to the geology, landforms, relief, climate, and natural vegetation of the area. Each kind of soil and miscellaneous area is associated with a particular kind of landform or with a segment of the landform. By observing the soils and miscellaneous areas in the survey area and relating their position to specific segments of the landform, a soil scientist develops a concept, or model, of how they were formed. Thus, during mapping, this model enables the soil scientist to predict with a considerable degree of accuracy the kind of soil or miscellaneous area at a specific location on the landscape.

Commonly, individual soils on the landscape merge into one another as their characteristics gradually change. To construct an accurate soil map, however, soil scientists must determine the boundaries between the soils. They can observe only a limited number of soil profiles. Nevertheless, these observations, supplemented by an understanding of the soil-vegetation-landscape relationship, are sufficient to verify predictions of the kinds of soil in an area and to determine the boundaries.

Soil scientists recorded the characteristics of the soil profiles that they studied. They noted soil color, texture, size and shape of soil aggregates, kind and amount of rock fragments, distribution of plant roots, reaction, and other features that enable them to identify soils. After describing the soils in the survey area and determining their properties, the soil scientists assigned the soils to taxonomic classes (units). Taxonomic classes are concepts. Each taxonomic class has a set of soil characteristics with precisely defined limits. The classes are used as a basis for comparison to classify soils systematically. Soil taxonomy, the system of taxonomic classification used in the United States, is based mainly on the kind and character of soil properties and the arrangement of horizons within the profile. After the soil

scientists classified and named the soils in the survey area, they compared the individual soils with similar soils in the same taxonomic class in other areas so that they could confirm data and assemble additional data based on experience and research.

The objective of soil mapping is not to delineate pure map unit components; the objective is to separate the landscape into landforms or landform segments that have similar use and management requirements. Each map unit is defined by a unique combination of soil components and/or miscellaneous areas in predictable proportions. Some components may be highly contrasting to the other components of the map unit. The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The delineation of such landforms and landform segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, onsite investigation is needed to define and locate the soils and miscellaneous areas.

Soil scientists make many field observations in the process of producing a soil map. The frequency of observation is dependent upon several factors, including scale of mapping, intensity of mapping, design of map units, complexity of the landscape, and experience of the soil scientist. Observations are made to test and refine the soil-landscape model and predictions and to verify the classification of the soils at specific locations. Once the soil-landscape model is refined, a significantly smaller number of measurements of individual soil properties are made and recorded. These measurements may include field measurements, such as those for color, depth to bedrock, and texture, and laboratory measurements, such as those for content of sand, silt, clay, salt, and other components. Properties of each soil typically vary from one point to another across the landscape.

Observations for map unit components are aggregated to develop ranges of characteristics for the components. The aggregated values are presented. Direct measurements do not exist for every property presented for every map unit component. Values for some properties are estimated from combinations of other properties.

While a soil survey is in progress, samples of some of the soils in the area generally are collected for laboratory analyses and for engineering tests. Soil scientists interpret the data from these analyses and tests as well as the field-observed characteristics and the soil properties to determine the expected behavior of the soils under different uses. Interpretations for all of the soils are field tested through observation of the soils in different uses and under different levels of management. Some interpretations are modified to fit local conditions, and some new interpretations are developed to meet local needs. Data are assembled from other sources, such as research information, production records, and field experience of specialists. For example, data on crop yields under defined levels of management are assembled from farm records and from field or plot experiments on the same kinds of soil.

Predictions about soil behavior are based not only on soil properties but also on such variables as climate and biological activity. Soil conditions are predictable over long periods of time, but they are not predictable from year to year. For example, soil scientists can predict with a fairly high degree of accuracy that a given soil will have a high water table within certain depths in most years, but they cannot predict that a high water table will always be at a specific level in the soil on a specific date.

After soil scientists located and identified the significant natural bodies of soil in the survey area, they drew the boundaries of these bodies on aerial photographs and

Custom Soil Resource Report

identified each as a specific map unit. Aerial photographs show trees, buildings, fields, roads, and rivers, all of which help in locating boundaries accurately.

Soil Map

The soil map section includes the soil map for the defined area of interest, a list of soil map units on the map and extent of each map unit, and cartographic symbols displayed on the map. Also presented are various metadata about data used to produce the map, and a description of each soil map unit.

Custom Soil Resource Report Soil Map



Custom Soil Resource Report

MAP LEGEND

Area of Interest (AOI)

 Area of Interest (AOI)

Soils

 Soil Map Unit Polygons

 Soil Map Unit Lines

 Soil Map Unit Points

Special Point Features

 Blowout

 Borrow Pit

 Clay Spot

 Closed Depression

 Gravel Pit

 Gravelly Spot

 Landfill

 Lava Flow

 Marsh or swamp

 Mine or Quarry

 Miscellaneous Water

 Perennial Water

 Rock Outcrop

 Saline Spot

 Sandy Spot

 Severely Eroded Spot

 Sinkhole

 Slide or Slip

 Sodic Spot

 Spoil Area

 Stony Spot

 Very Stony Spot

 Wet Spot

 Other

 Special Line Features

Water Features

 Streams and Canals

Transportation

 Rails

 Interstate Highways

 US Routes

 Major Roads

 Local Roads

Background

 Aerial Photography

MAP INFORMATION

The soil surveys that comprise your AOI were mapped at 1:20,000.

Warning: Soil Map may not be valid at this scale.

Enlargement of maps beyond the scale of mapping can cause misunderstanding of the detail of mapping and accuracy of soil line placement. The maps do not show the small areas of contrasting soils that could have been shown at a more detailed scale.

Please rely on the bar scale on each map sheet for map measurements.

Source of Map: Natural Resources Conservation Service

Web Soil Survey URL:

Coordinate System: Web Mercator (EPSG:3857)

Maps from the Web Soil Survey are based on the Web Mercator projection, which preserves direction and shape but distorts distance and area. A projection that preserves area, such as the Albers equal-area conic projection, should be used if more accurate calculations of distance or area are required.

This product is generated from the USDA-NRCS certified data as of the version date(s) listed below.

Soil Survey Area: Castle Rock Area, Colorado

Survey Area Data: Version 14, Aug 31, 2021

Soil map units are labeled (as space allows) for map scales 1:50,000 or larger.

Date(s) aerial images were photographed: Jun 9, 2021—Jun 12, 2021

The orthophoto or other base map on which the soil lines were compiled and digitized probably differs from the background imagery displayed on these maps. As a result, some minor shifting of map unit boundaries may be evident.

Map Unit Legend

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
En	Englewood clay loam	0.2	4.0%
KuE	Kutch clay loam, 8 to 20 percent slopes	5.4	96.0%
Totals for Area of Interest		5.6	100.0%

Map Unit Descriptions

The map units delineated on the detailed soil maps in a soil survey represent the soils or miscellaneous areas in the survey area. The map unit descriptions, along with the maps, can be used to determine the composition and properties of a unit.

A map unit delineation on a soil map represents an area dominated by one or more major kinds of soil or miscellaneous areas. A map unit is identified and named according to the taxonomic classification of the dominant soils. Within a taxonomic class there are precisely defined limits for the properties of the soils. On the landscape, however, the soils are natural phenomena, and they have the characteristic variability of all natural phenomena. Thus, the range of some observed properties may extend beyond the limits defined for a taxonomic class. Areas of soils of a single taxonomic class rarely, if ever, can be mapped without including areas of other taxonomic classes. Consequently, every map unit is made up of the soils or miscellaneous areas for which it is named and some minor components that belong to taxonomic classes other than those of the major soils.

Most minor soils have properties similar to those of the dominant soil or soils in the map unit, and thus they do not affect use and management. These are called noncontrasting, or similar, components. They may or may not be mentioned in a particular map unit description. Other minor components, however, have properties and behavioral characteristics divergent enough to affect use or to require different management. These are called contrasting, or dissimilar, components. They generally are in small areas and could not be mapped separately because of the scale used. Some small areas of strongly contrasting soils or miscellaneous areas are identified by a special symbol on the maps. If included in the database for a given area, the contrasting minor components are identified in the map unit descriptions along with some characteristics of each. A few areas of minor components may not have been observed, and consequently they are not mentioned in the descriptions, especially where the pattern was so complex that it was impractical to make enough observations to identify all the soils and miscellaneous areas on the landscape.

The presence of minor components in a map unit in no way diminishes the usefulness or accuracy of the data. The objective of mapping is not to delineate pure taxonomic classes but rather to separate the landscape into landforms or landform segments that have similar use and management requirements. The delineation of such segments on the map provides sufficient information for the development of resource plans. If intensive use of small areas is planned, however,

onsite investigation is needed to define and locate the soils and miscellaneous areas.

An identifying symbol precedes the map unit name in the map unit descriptions. Each description includes general facts about the unit and gives important soil properties and qualities.

Soils that have profiles that are almost alike make up a *soil series*. Except for differences in texture of the surface layer, all the soils of a series have major horizons that are similar in composition, thickness, and arrangement.

Soils of one series can differ in texture of the surface layer, slope, stoniness, salinity, degree of erosion, and other characteristics that affect their use. On the basis of such differences, a soil series is divided into *soil phases*. Most of the areas shown on the detailed soil maps are phases of soil series. The name of a soil phase commonly indicates a feature that affects use or management. For example, Alpha silt loam, 0 to 2 percent slopes, is a phase of the Alpha series.

Some map units are made up of two or more major soils or miscellaneous areas. These map units are complexes, associations, or undifferentiated groups.

A *complex* consists of two or more soils or miscellaneous areas in such an intricate pattern or in such small areas that they cannot be shown separately on the maps. The pattern and proportion of the soils or miscellaneous areas are somewhat similar in all areas. Alpha-Beta complex, 0 to 6 percent slopes, is an example.

An *association* is made up of two or more geographically associated soils or miscellaneous areas that are shown as one unit on the maps. Because of present or anticipated uses of the map units in the survey area, it was not considered practical or necessary to map the soils or miscellaneous areas separately. The pattern and relative proportion of the soils or miscellaneous areas are somewhat similar. Alpha-Beta association, 0 to 2 percent slopes, is an example.

An *undifferentiated group* is made up of two or more soils or miscellaneous areas that could be mapped individually but are mapped as one unit because similar interpretations can be made for use and management. The pattern and proportion of the soils or miscellaneous areas in a mapped area are not uniform. An area can be made up of only one of the major soils or miscellaneous areas, or it can be made up of all of them. Alpha and Beta soils, 0 to 2 percent slopes, is an example.

Some surveys include *miscellaneous areas*. Such areas have little or no soil material and support little or no vegetation. Rock outcrop is an example.

Castle Rock Area, Colorado

En—Englewood clay loam

Map Unit Setting

National map unit symbol: jqym
Elevation: 5,500 to 6,600 feet
Mean annual precipitation: 15 to 19 inches
Mean annual air temperature: 47 to 52 degrees F
Frost-free period: 120 to 135 days
Farmland classification: Prime farmland if irrigated

Map Unit Composition

Englewood and similar soils: 80 percent
Minor components: 20 percent
Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Englewood

Setting

Landform: Terraces, swales
Down-slope shape: Linear
Across-slope shape: Linear
Parent material: Weathered from alluvium derived from sedimentary rock

Typical profile

H1 - 0 to 10 inches: clay loam
H2 - 10 to 29 inches: clay
H3 - 29 to 60 inches: clay

Properties and qualities

Slope: 1 to 4 percent
Depth to restrictive feature: More than 80 inches
Drainage class: Well drained
Runoff class: Medium
Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr)
Depth to water table: More than 80 inches
Frequency of flooding: None
Frequency of ponding: None
Calcium carbonate, maximum content: 15 percent
Maximum salinity: Nonsaline to very slightly saline (0.0 to 2.0 mmhos/cm)
Available water supply, 0 to 60 inches: High (about 9.7 inches)

Interpretive groups

Land capability classification (irrigated): 2e
Land capability classification (nonirrigated): 3e
Hydrologic Soil Group: C
Ecological site: R049XB208CO - Clayey Foothill
Hydric soil rating: No

Minor Components

Sampson

Percent of map unit: 10 percent
Hydric soil rating: No

Satanta

Percent of map unit: 9 percent

Hydric soil rating: No

Fluvaquentic haplustolls

Percent of map unit: 1 percent

Landform: Terraces

Hydric soil rating: Yes

KuE—Kutch clay loam, 8 to 20 percent slopes

Map Unit Setting

National map unit symbol: jqz7

Elevation: 5,500 to 6,800 feet

Mean annual precipitation: 15 to 19 inches

Mean annual air temperature: 47 to 50 degrees F

Frost-free period: 120 to 135 days

Farmland classification: Not prime farmland

Map Unit Composition

Kutch and similar soils: 90 percent

Minor components: 10 percent

Estimates are based on observations, descriptions, and transects of the mapunit.

Description of Kutch

Setting

Landform: Valley sides

Down-slope shape: Linear

Across-slope shape: Linear

Parent material: Calcareous fine-silty clayey shale

Typical profile

H1 - 0 to 6 inches: clay loam

H2 - 6 to 32 inches: clay

H3 - 32 to 36 inches: weathered bedrock

Properties and qualities

Slope: 8 to 20 percent

Depth to restrictive feature: 20 to 40 inches to paralithic bedrock

Drainage class: Well drained

Runoff class: High

Capacity of the most limiting layer to transmit water (Ksat): Moderately low to moderately high (0.06 to 0.20 in/hr)

Depth to water table: More than 80 inches

Frequency of flooding: None

Frequency of ponding: None

Calcium carbonate, maximum content: 15 percent

Gypsum, maximum content: 2 percent

Maximum salinity: Nonsaline to slightly saline (0.0 to 4.0 mmhos/cm)

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Available water supply, 0 to 60 inches: Moderate (about 6.1 inches)

Interpretive groups

Land capability classification (irrigated): None specified

Land capability classification (nonirrigated): 6e

Hydrologic Soil Group: D

Ecological site: R049XB208CO - Clayey Foothill

Hydric soil rating: No

Minor Components

Newlin

Percent of map unit: 5 percent

Hydric soil rating: No

Fondis

Percent of map unit: 5 percent

Hydric soil rating: No

Soil Information for All Uses

Soil Reports

The Soil Reports section includes various formatted tabular and narrative reports (tables) containing data for each selected soil map unit and each component of each unit. No aggregation of data has occurred as is done in reports in the Soil Properties and Qualities and Suitabilities and Limitations sections.

The reports contain soil interpretive information as well as basic soil properties and qualities. A description of each report (table) is included.

Water Features

This folder contains tabular reports that present soil hydrology information. The reports (tables) include all selected map units and components for each map unit. Water Features include ponding frequency, flooding frequency, and depth to water table.

Hydrologic Soil Group and Surface Runoff

This table gives estimates of various soil water features. The estimates are used in land use planning that involves engineering considerations.

Hydrologic soil groups are based on estimates of runoff potential. Soils are assigned to one of four groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms.

The four hydrologic soil groups are:

Group A. Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission.

Group B. Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.

Group C. Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or

Custom Soil Resource Report

soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.

Group D. Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

If a soil is assigned to a dual hydrologic group (A/D, B/D, or C/D), the first letter is for drained areas and the second is for undrained areas.

Surface runoff refers to the loss of water from an area by flow over the land surface. Surface runoff classes are based on slope, climate, and vegetative cover. The concept indicates relative runoff for very specific conditions. It is assumed that the surface of the soil is bare and that the retention of surface water resulting from irregularities in the ground surface is minimal. The classes are negligible, very low, low, medium, high, and very high.

Report—Hydrologic Soil Group and Surface Runoff

Absence of an entry indicates that the data were not estimated. The dash indicates no documented presence.

Hydrologic Soil Group and Surface Runoff—Castle Rock Area, Colorado			
Map symbol and soil name	Pct. of map unit	Surface Runoff	Hydrologic Soil Group
En—Englewood clay loam			
Englewood	80	Medium	C
KuE—Kutch clay loam, 8 to 20 percent slopes			
Kutch	90	High	D

References

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- United States Department of Agriculture, Natural Resources Conservation Service. National range and pasture handbook. <http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/landuse/rangepasture/?cid=stelpdb1043084>

Custom Soil Resource Report

United States Department of Agriculture, Natural Resources Conservation Service. National soil survey handbook, title 430-VI. http://www.nrcs.usda.gov/wps/portal/nrcs/detail/soils/scientists/?cid=nrcs142p2_054242

United States Department of Agriculture, Natural Resources Conservation Service. 2006. Land resource regions and major land resource areas of the United States, the Caribbean, and the Pacific Basin. U.S. Department of Agriculture Handbook 296. http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/soils/?cid=nrcs142p2_053624

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APPENDIX C
210 ENGINEERING HYDROLOGY CALCULATIONS

COMPOSITE BASIN COEFFICIENTS

Project Name: The Meadows MNC

Project No. 15-02023

Calculated By: KAL

Date: 5/6/2015

A-1 **2.87** **acres**

Land Use	Imp.	C ₂	C ₅	C ₁₀	C ₁₀₀	Area	% Imp.	% C ₂	% C ₅	% C ₁₀	% C ₁₀₀
Parks (Lawns)	5	0.08	0.18	0.28	0.52	1.62	3	0.05	0.10	0.16	0.29
Commercial	95	0.80	0.82	0.84	0.89	0.86	28	0.24	0.25	0.25	0.27
Streets	100	0.89	0.90	0.92	0.96	0.39	14	0.12	0.12	0.13	0.13
TOTAL						2.87	45	0.41	0.47	0.53	0.69

A-2 **2.00** **acres**

Land Use	Imp.	C ₂	C ₅	C ₁₀	C ₁₀₀	Area	% Imp.	% C ₂	% C ₅	% C ₁₀	% C ₁₀₀
Parks (Lawns)	5	0.08	0.18	0.28	0.52	1.54	4	0.06	0.14	0.22	0.40
Commercial	95	0.80	0.82	0.84	0.89	0.46	22	0.18	0.19	0.19	0.20
Streets	100	0.89	0.90	0.92	0.96	0.00	0	0.00	0.00	0.00	0.00
TOTAL						2.00	26	0.25	0.33	0.41	0.61

STANDARD FORM SF-2 TIME OF CONCENTRATION- 5 yr

Project: The Meadows MNC

Project Name: The Meadows MNC

Project No. 15-02023

Calculated By: KAL

Date: 5/6/2015

SUB-BASIN			INITIAL/OVERLAND			TRAVEL TIME				Tc CHECK			FINAL
DATA			(Ti)			(Tt)				(URBANIZED BASINS)			
BASIN ID	D.A. (AC)	C5	L (FT)	S (%)	Ti (MIN)	L (FT)	S (%)	VEL. (FPS)	Tt (MIN)	COMP. Tc (MIN)	TOTAL LENGTH(FT)	MIN. Tc (MIN)	Tc (MIN)
A-1	2.87	0.47	360	3.5	14.4	400	3.5	3.7	1.78	16.2	760.0	14.2	14.2
A-2	2.00	0.27	200	1.3	19.7	470	1.0	2.0	3.92	23.6	670.0	13.7	13.7

NOTES:

$$T_i = (0.395 * (1.1 - C_5) * (L)^{0.5}) / (S^{0.33})$$

$$T_t = L / 60V \text{ (Velocity From Fig. 3-2)}$$

$$T_c \text{ Check} = 10 + L / 180$$

STANDARD FORM SF-3

STORM DRAINAGE SYSTEM DESIGN

(RATIONAL METHOD PROCEDURE)

Project Name: The Meadows MNC

Project No. 15-02023

Calculated By: KAL

Date: 5/6/2015

Design Storm: Minor - 5 yr.

[illegible]

STANDARD FORM SF-3

STORM DRAINAGE SYSTEM DESIGN

(RATIONAL METHOD PROCEDURE)

Project Name: The Meadows MNC

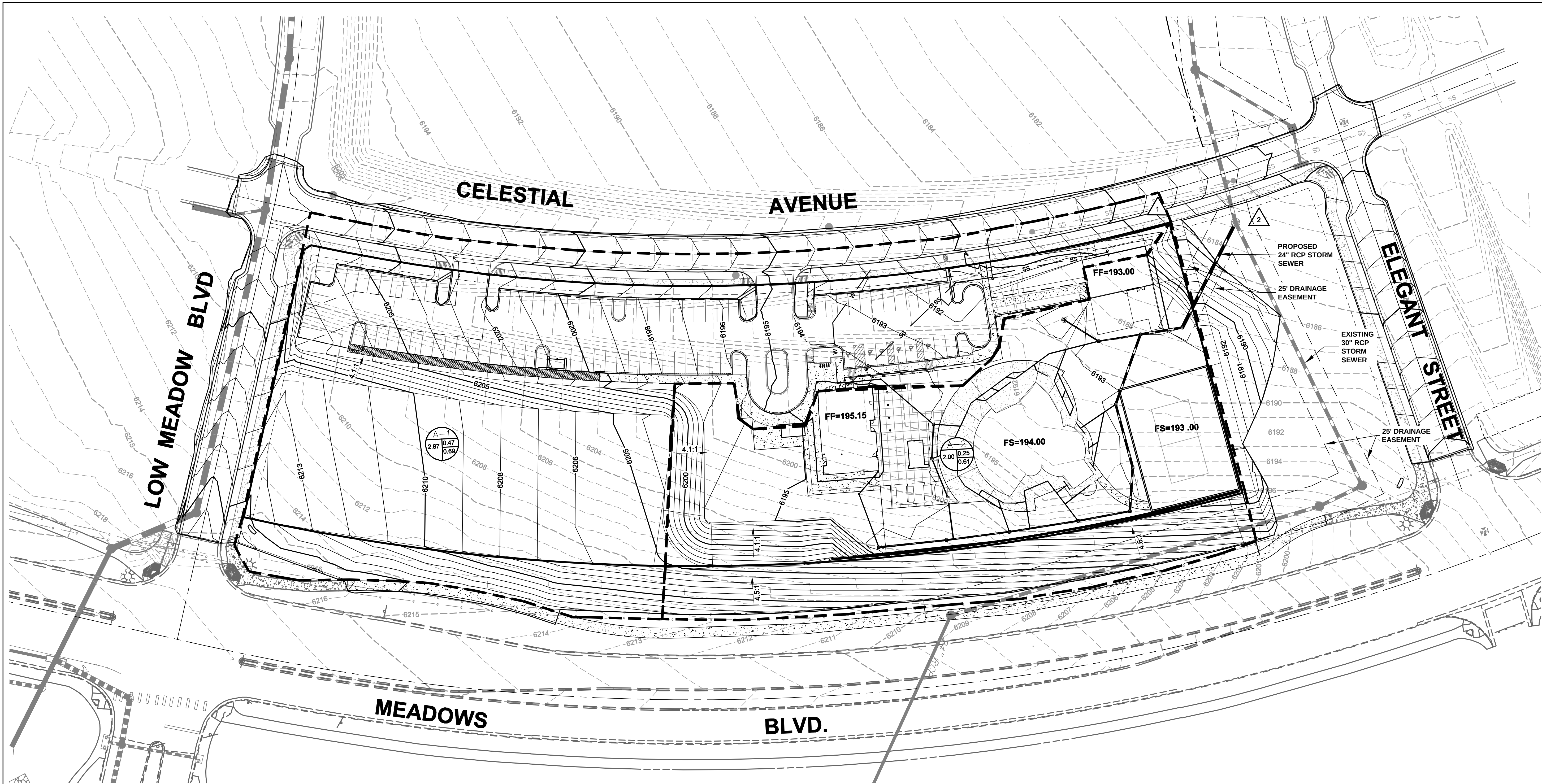
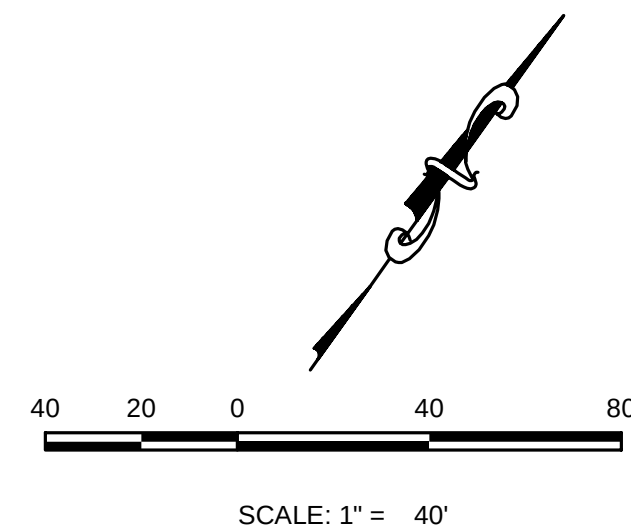
Project No. 15-02023

Calculated By: KAL

Date: 5/6/2015

Design Storm: Major - 100 yr.

[illegible]



RUNOFF SUMMARY				
DP	BASIN	AREA	Q5	Q100
1	A-1	2.87	4.48	12.00
2	A-2	2.00	1.75	7.5

LEGEND

A

B

C

D

EXISTING MAJOR CONTOUR

EXISTING MINOR CONTOUR

PROPOSED MAJOR CONTOUR

PROPOSED MINOR CONTOUR

FLOW ARROW

BASIN BOUNDARY

PROPOSED STORM PIPE

EXISTING STORM PIPE

PROPOSED TYPE-R INLET

EXISTING TYPE-R INLET

PROPERTY LINE

DESIGN POINT DESIGNATION

EXISTING MAJOR CONTOUR

EXISTING MINOR CONTOUR

PROPOSED MAJOR CONTOUR

PROPOSED MINOR CONTOUR

FLOW ARROW

BASIN BOUNDARY

PROPOSED STORM PIPE

EXISTING STORM PIPE

PROPOSED TYPE-R INLET

EXISTING TYPE-R INLET

PROPERTY LINE

210

ENGINEERING, LLC.
CIVIL SITE ENGINEERING & LAND PLANNING

210 ENGINEERING, LLC
10940 S. Parker Rd., #446
Parker, Colorado 80134
303-921-4217

ENGINEERING, LLC.
CIVIL SITE ENGINEERING & LAND PLANNING

THE MEADOWS
FILING NO. 20
DRAINAGE AREA MAP
MNC AMENITY II

SCALE:
AS SHOWN

FILE NO:
15-02023

DRAWN BY:
KAL

CHECKED BY:
KAL

DATE:
SEPTEMBER 16, 2016

NO. REVISIONS

DATE

INIT.

APPR.

DATE

1

APPENDIX D

HYDRAULIC CALCULATIONS



Project: Meadows Taft House Pool Drainage
Client: Burg Simpson
Date: 7/18/2022
Job Number: 111298

<- Chokepoint in Drain System
<- Upstream Capacity > Segment Capacity
<- Intermediate Calculation
<- Input / Result

AS-DESIGNED HYDRAULIC ANALYSIS

Section	Diameter [in]	Upstream INV	Downstream INV	Section Length [ft.]	n	Diameter [ft.]	Slope [%]	R [ft.]	A [ft ²]	Segment Capacity (Q) [cfs]	Upstream Capacity [cfs]	Upstream Segments	Drain Inlet Capacity [cfs]	Cumulative Drain Inlet Capacity [cfs]
1	24	176.85	173.15	92.4	0.015	2.00	4.00%	0.500	3.142	39.34	60.37	2	5.50	21.16
2	18	79.25	77.05	7.86	0.012	1.50	27.99%	0.375	1.767	60.37	60.57	13+3		
3	18	85.32	79.25	22.14	0.012	1.50	27.42%	0.375	1.767	59.75	12.61	14+4	1.76	15.656
4	18	-	-	26.29	0.012	1.50	1.00%	0.375	1.767	11.41	12.29	37+38	1.76	10.376
5	18	86.37	85.88	49	0.012	1.50	1.00%	0.375	1.767	11.41	11.41	6	1.76	8.616
6	18	86.69	86.37	32	0.012	1.50	1.00%	0.375	1.767	11.41	3.87	7	1.704	6.856
7	12	87.1	86.69	41	0.012	1.00	1.00%	0.250	0.785	3.87	4.57	8+21	1.288	5.152
8	12	87.49	87.1	39	0.012	1.00	1.00%	0.250	0.785	3.87	4.87	9+24		
9	12	87.65	87.49	14	0.012	1.00	1.14%	0.250	0.785	4.14	4.67	10+25	1.288	3.864
10	12	88.1	87.65	45	0.012	1.00	1.00%	0.250	0.785	3.87	6.23	11+27		
11	12	88.15	88.1	6	0.012	1.00	0.83%	0.250	0.785	3.53	3.87	12	1.288	2.576
12	12	88.68	88.15	53	0.012	1.00	1.00%	0.250	0.785	3.87	0.86	35	1.288	
13	4	89	79.25	62	0.012	0.33	15.73%	0.083	0.087	0.82	-	-		
14	6	86.56	85.32	32	0.012	0.50	3.88%	0.125	0.196	1.20	2.69	15+16	1.76	3.52
15	6	87.76	86.56	30	0.012	0.50	4.00%	0.125	0.196	1.22	-	-	1.76	
16	6	88.84	86.56	39	0.012	0.50	5.85%	0.125	0.196	1.47	0.69	17+18		
17	4	-	-	-	0.012	0.33	3.70%	0.083	0.087	0.40	-	-		
18	4	-	-	-	0.012	0.33	2.00%	0.083	0.087	0.29	-	-		
19	4	-	-	-	0.012	0.33	17.00%	0.083	0.087	0.85	-	-		
20	4	-	-	-	0.012	0.33	9.00%	0.083	0.087	0.62	-	-		
21	4	-	-	-	0.012	0.33	11.60%	0.083	0.087	0.70	1.52	22+23		
22	4	-	-	-	0.012	0.33	13.20%	0.083	0.087	0.75	-	-		
23	4	-	-	-	0.012	0.33	13.70%	0.083	0.087	0.77	-	-		
24	4	-	-	-	0.012	0.33	12.70%	0.083	0.087	0.74	-	-		
25	4	-	-	-	0.012	0.33	15.00%	0.083	0.087	0.80	0.39	26		
26	4	-	-	-	0.012	0.33	3.60%	0.083	0.087	0.39	-	-		
27	8	89.62	88.27	32	0.012	0.67	4.22%	0.167	0.349	2.70	0.86	28	0.368	1.104
28	6	90.26	89.62	32	0.012	0.50	2.00%	0.125	0.196	0.86	1.39	29+33	0.368	0.736
29	6	90.78	90.26	26	0.012	0.50	2.00%	0.125	0.196	0.86	0.63	30+34	0.368	
30	4	91.68	90.78	45	0.012	0.33	2.00%	0.083	0.087	0.29	0.85	31+40		
31	4	91.84	91.68	8	0.012	0.33	2.00%	0.083	0.087	0.29	0.29	32		
32	4	92.5	91.84	33	0.012	0.33	2.00%	0.083	0.087	0.29	-	-		
33	4	-	-	-	0.012	0.33	6.50%	0.083	0.087	0.53	-	-		
34	4	-	-	-	0.012	0.33	2.60%	0.083	0.087	0.33	-	-		
35	6	92.28	88.68	32	0.012	0.50	2.00%	0.125	0.196	0.86	0.21	36		
36	4	92.5	92.28	22	0.012	0.33	1.00%	0.083	0.087	0.21	-	-		



Project: Meadows Taft House Pool Drainage

Client: Burg Simpson

Date: 7/18/2022

Job Number: 111298

#

<- Chokepoint in Drain System

#

<- Upstream Capacity > Segment Capacity

#

<- Intermediate Calculation

#

<- Input / Result

AS-DESIGNED HYDRAULIC ANALYSIS

Section	Diameter [in]	Upstream INV	Downstream INV	Section Length [ft.]	n	Diameter [ft.]	Slope [%]	R [ft.]	A [ft ²]	Segment Capacity (Q) [cfs]	Upstream Capacity [cfs]	Upstream Segments	Drain Inlet Capacity [cfs]	Cumulative Drain Inlet Capacity [cfs]
37	18	-	-	29.71	0.012	1.50	1.00%	0.375	1.767	11.41	12.26	5+19	1.76	10.376
38	4	90.52	85.96	25	0.012	0.33	18.24%	0.083	0.087	0.88	0.16	39		
39	4	91.00	90.52	85	0.012	0.33	0.56%	0.083	0.087	0.16	-	-		
40	4	92.5	91.68	11.43	0.012	0.33	7.17%	0.083	0.087	0.55	-	-		



Project: Meadows Taft House Pool Drainage
Client: Burg Simpson
Date: 7/18/2022
Job Number: 111298

- # <- Chokepoint in Drain System
- # <- Upstream Capacity > Segment Capacity
- # <- Intermediate Calculation
- # <- Input / Result

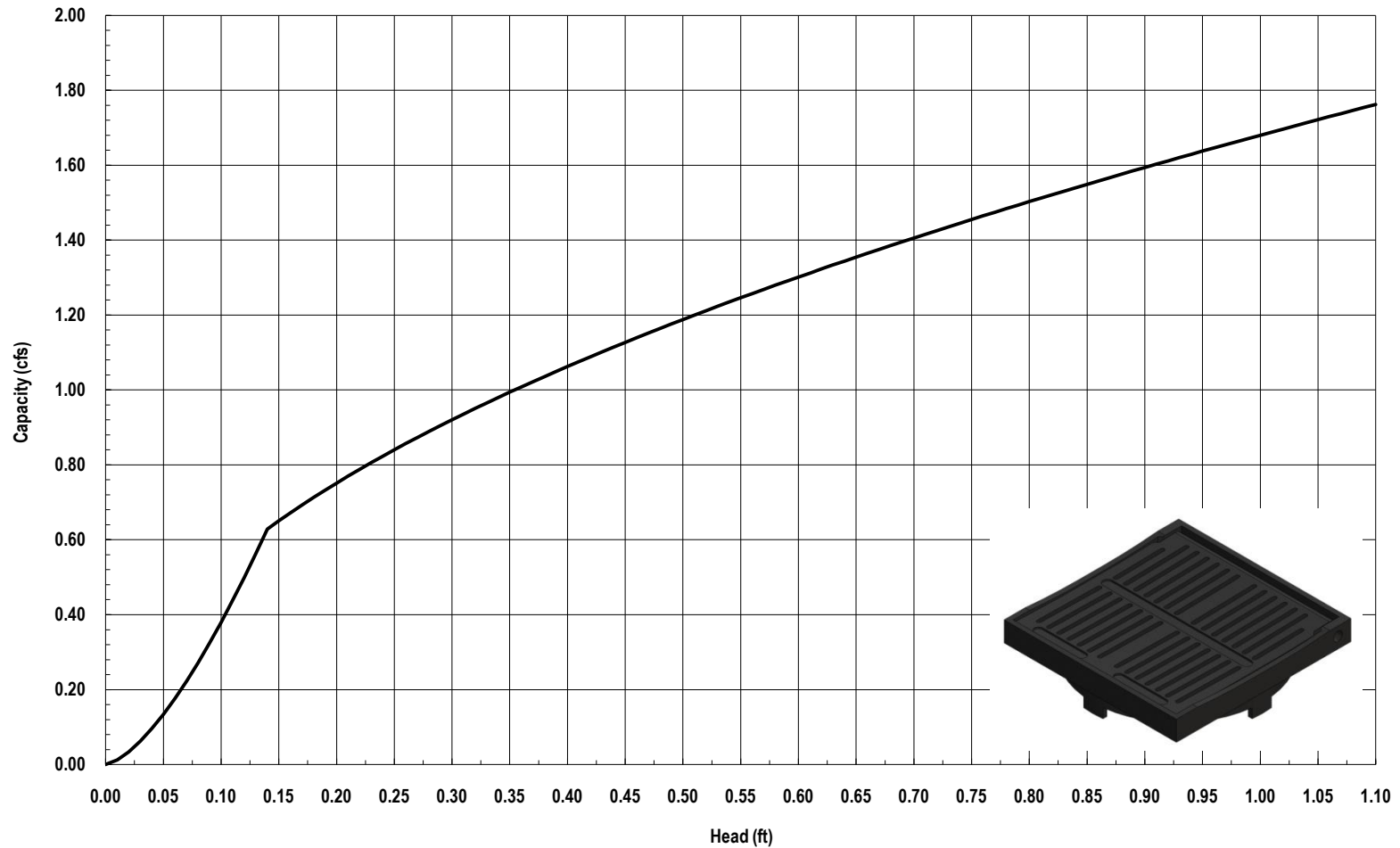
AS-BUILT HYDRAULIC ANALYSIS

Section	Diameter [in]	As-Built Upstream INV	As-Built Downstream INV	As-Built Section Length [ft.]	n	Diameter [ft.]	Slope [%]	R [ft.]	A [ft²]	As-Built Segment Capacity (Q) [cfs]	As-Built Upstream Capacity [cfs]	Upstream Segments	As-Built Drain Inlet Capacity	Cumulative Drain Inlet Capacity
6	18	6187.53	6187.21	33.93	0.012	1.50	0.94%	0.375	1.767	11.08	0.00	7	4.9	6.8
7	12	6187.44	6187.53	41.97	0.012	1.00	-0.21%	0.250	0.785	0.00	1.75	8+21	1.24	1.9
8 + 9	12	6187.60	6187.49	53.77	0.012	1.00	0.20%	0.250	0.785	1.75	-	24	0.66	3.13
10+11	12	6188.46	6187.65	49.99	0.012	1.00	1.62%	0.250	0.785	4.93	2.52	27	1.17	2.33
12	12	6188.92	6188.51	53.57	0.012	1.00	0.77%	0.250	0.785	3.39	-	35	1.16	-
27	8	6189.69	6187.62	56.09	0.012	0.67	3.69%	0.167	0.349	2.52	0.82	28	0.68	1.96
28	6	6190.35	6189.74	33.63	0.012	0.50	1.81%	0.125	0.196	0.82	0.82	29	0.56	1.28
29	6	6190.86	6190.37	26.76	0.012	0.50	1.83%	0.125	0.196	0.82	-	30+34	0.72	-

D.1

NYLOPLAST INLET GRATE CAPACITY CHARTS

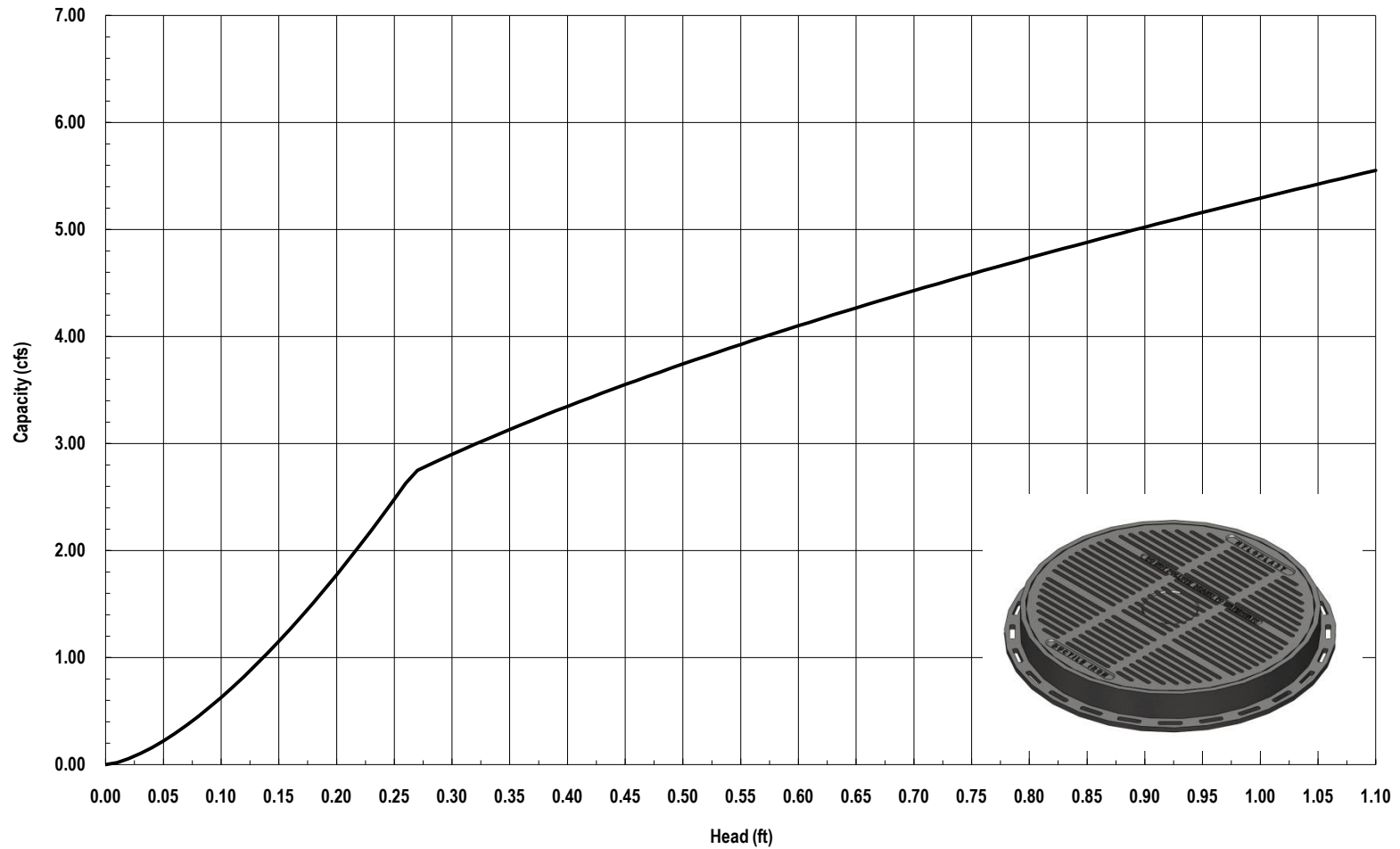
Nyloplast 12" Pedestrian Grate Inlet Capacity Chart



Nyloplast[®]

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(866) 888-8479 / (770) 932-2443 • Fax: (770) 932-2490
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Nyloplast 24" Pedestrian Grate Inlet Capacity Chart



Nyloplast[®]

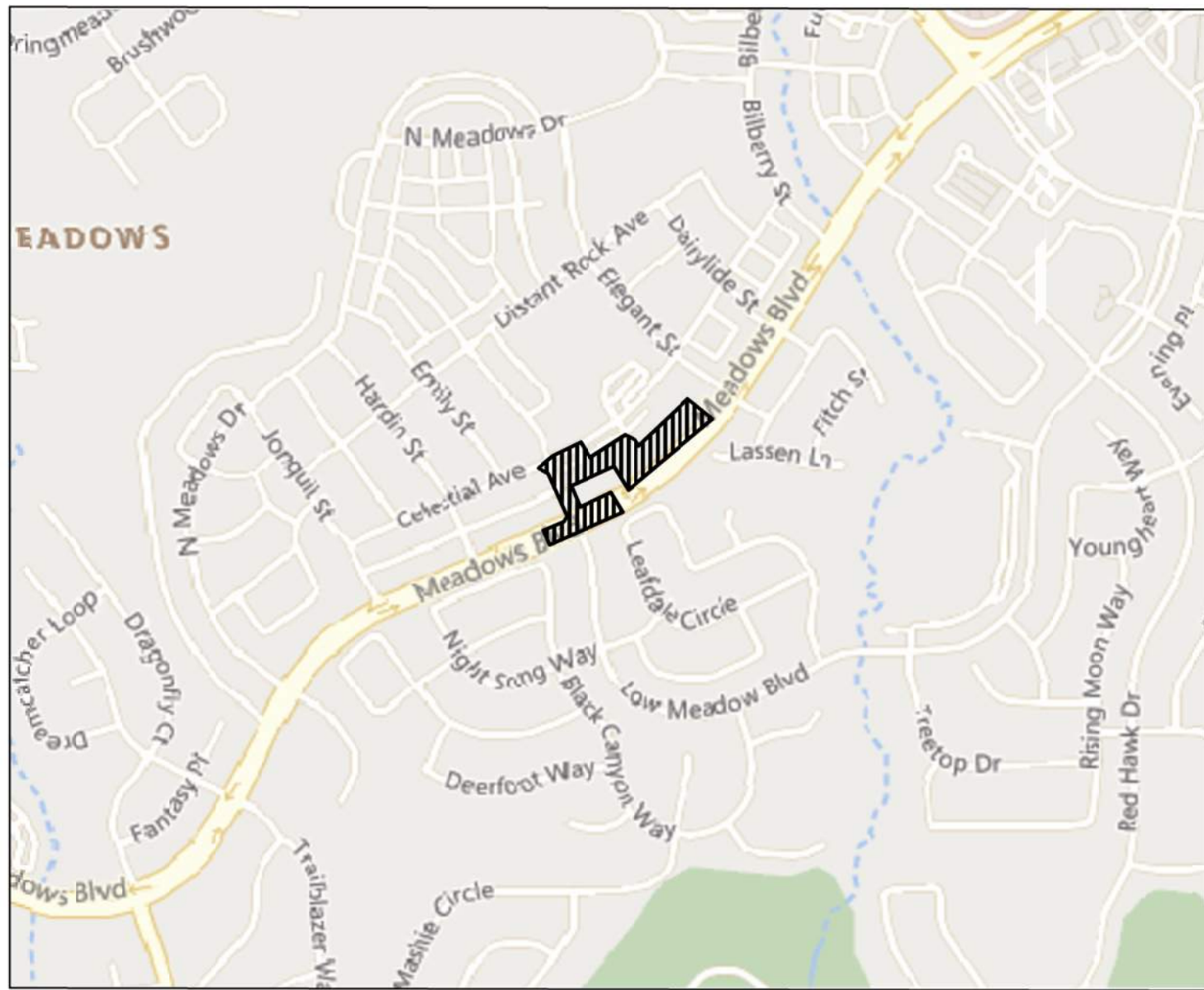
3130 Verona Avenue • Buford, GA 30518
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APPENDIX E

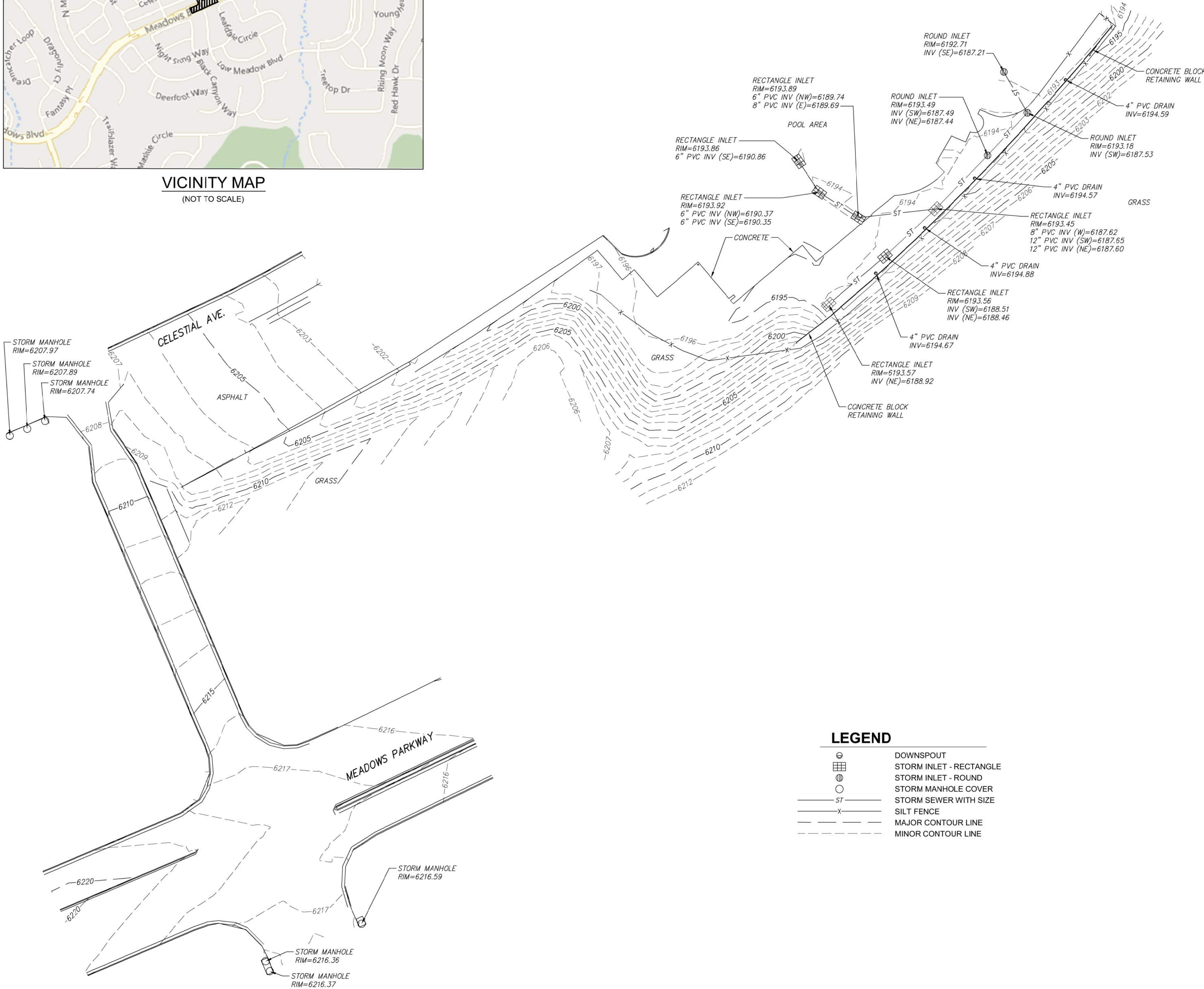
SURVEY INFORMATION

ELEVATION SURVEY - TAFT HOUSE

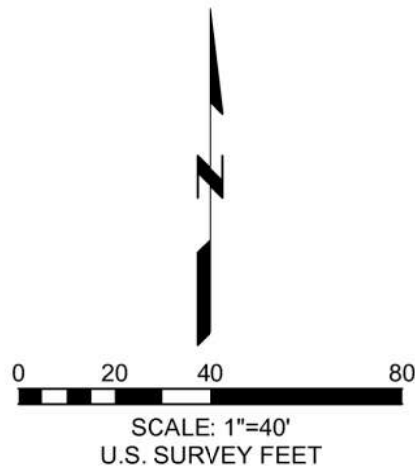
TOWN OF CASTLE ROCK, STATE OF COLORADO
LOCATED IN THE SOUTHEAST QUARTER OF SECTION 33,
TOWNSHIP 7 SOUTH RANGE 67 WEST OF THE 6TH PRINCIPAL MERIDIAN
COUNTY OF DOUGLAS, STATE OF COLORADO



VICINITY MAP
(NOT TO SCALE)



LEGEND	
	DOWNSPOUT
	STORM INLET - RECTANGLE
	STORM INLET - ROUND
	STORM MANHOLE COVER
	STORM SEWER WITH SIZE
	SILT FENCE
	MAJOR CONTOUR LINE
	MINOR CONTOUR LINE



NOTES:

- THIS ELEVATION SURVEY WAS CONDUCTED AT THE DIRECTION OF CLINT BROWN, P.E. OF ENGINEERING ANALYTICS, INC. ALL ITEMS SHOWN HEREON WERE LOCATED AT THE DIRECTION OF CLINT BROWN DURING A SITE MEETING ON 6/30/2022.
- THE FIELD SURVEY WAS PERFORMED USING GPS/RTK METHODS AND WAS COMPLETED ON 6/30/2022.
- THE HORIZONTAL COORDINATE SYSTEM FOR THIS SURVEY IS ASSUMED.
- BENCHMARK: THE BENMARK FOR THIS SURVEY IS NGS POINT K23 HAVING AN ELEVATION OF 5984.92 NAVD 88.
- SITE ADDRESS: 3570 CELESTIAL AVENUE, CASTLE ROCK, CO 80104
- NOTICE: ACCORDING TO COLORADO LAW YOU MUST COMMENCE ANY LEGAL ACTION BASED UPON ANY DEFECT IN THIS SURVEY WITHIN THREE YEARS AFTER YOU FIRST DISCOVER SUCH DEFECT. IN NO EVENT MAY ANY ACTION BASED UPON ANY DEFECT IN THIS SURVEY BE COMMENCED MORE THAN TEN YEARS FROM THE DATE OF THE CERTIFICATION SHOWN HEREON.
- ACCORDING TO THE COLORADO STATE BOARD OF LICENSURE FOR ARCHITECTS, PROFESSIONAL ENGINEERS AND PROFESSIONAL LAND SURVEYORS RULE 1.6(B)(2) THE SURVEYOR'S CERTIFICATION IS DEFINED AS A STATEMENT THAT INCLUDES THE FOLLOWING:
 - IS SIGNED AND/OR SEALED BY A PROFESSIONAL LAND SURVEYOR REPRESENTING THAT THE SURVEYING SERVICES ADDRESSED THEREIN HAVE BEEN PERFORMED BY THE PROFESSIONAL LAND SURVEYOR OR UNDER THE PROFESSIONAL LAND SURVEYOR IN RESPONSIBLE CHARGE.
 - IS BASED UPON THE PROFESSIONAL LAND SURVEYOR'S KNOWLEDGE, INFORMATION AND BELIEF,
 - IS IN ACCORDANCE WITH APPLICABLE STANDARDS OF PRACTICE, AND
 - IS NOT A GUARANTY OR WARRANTY, EITHER EXPRESSED OR IMPLIED.

SURVEYOR'S STATEMENT

I, CHRISTOPHER A. BROOKS, A LICENSED SURVEYOR IN THE STATE OF COLORADO DO HEREBY CERTIFY THAT THIS ELEVATION SURVEY WAS MADE UNDER MY DIRECT SUPERVISION AND THAT IT IS TRUE AND ACCURATE TO THE BEST OF MY KNOWLEDGE, INFORMATION, AND BELIEF.

BY: CHRISTOPHER A. BROOKS
COLORADO LICENSED PROFESSIONAL LAND SURVEYOR NUMBER 38063
FOR AND ON BEHALF OF
FARNSWORTH GROUP, INC.
5613 DTC PARKWAY, SUITE 1100
GREENWOOD VILLAGE, COLORADO 80111
(303) 692-8838



Farnsworth
GROUP

5613 DTC PARKWAY, SUITE 1100
GREENWOOD VILLAGE, COLORADO 80111
(303) 692-8838 / info@f-w.com

www.f-w.com
Engineers | Architects | Surveyors | Scientists

ISSUE:
DATE: DESCRIPTION:

ELEVATION SURVEY FOR A PORTION OF THE TAFT HOUSE

CASTLE ROCK, COLORADO

DATE: 09/01/2022

DESIGNED:

DRAWN: MBB / SWS

REVIEWED: CAB

FIELD BOOK NO.: 256850

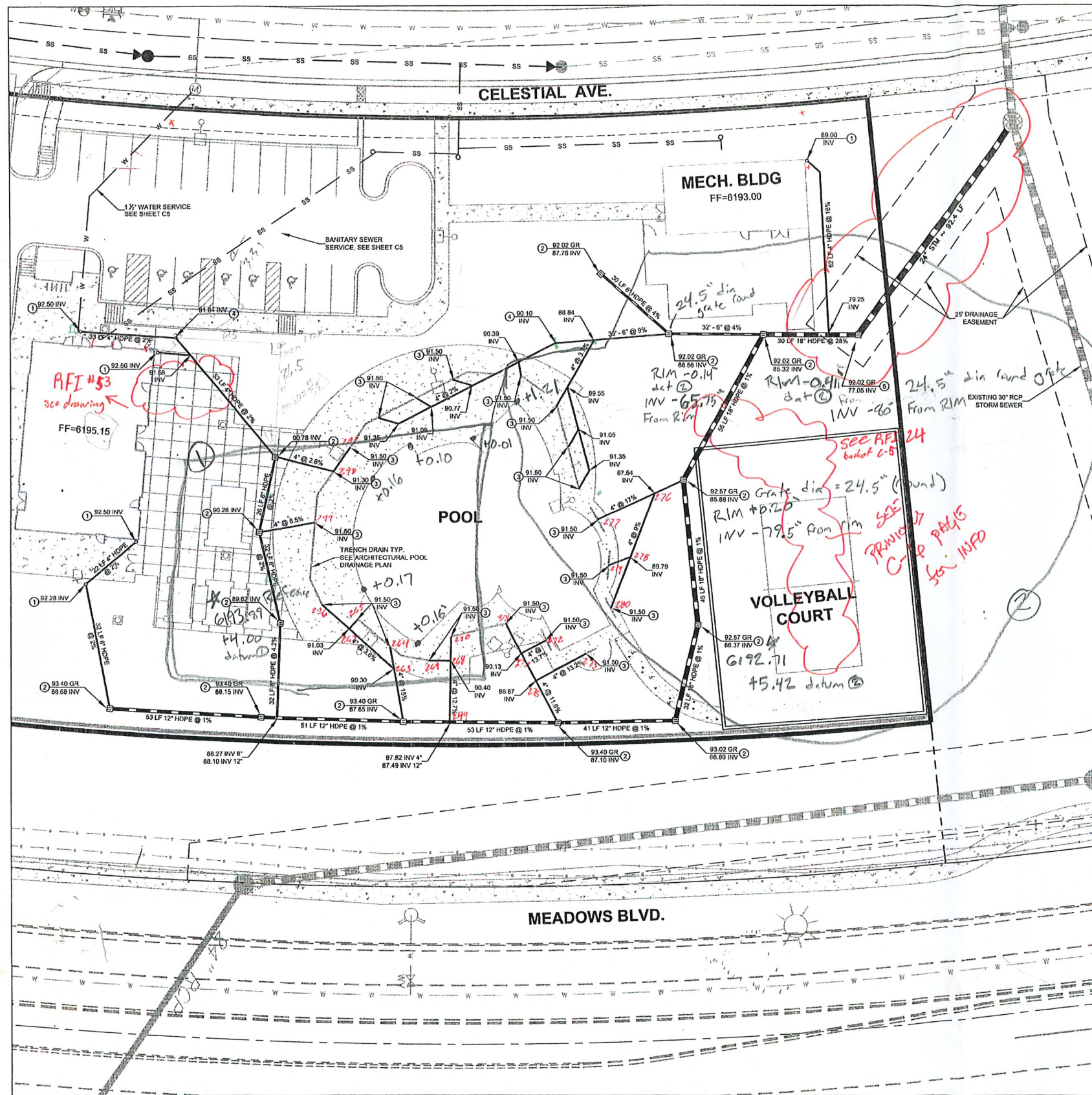
SHEET TITLE:

ELEVATION SURVEY

SHEET NUMBER:

1
OF 1

PROJECT NO.: 0221146.00

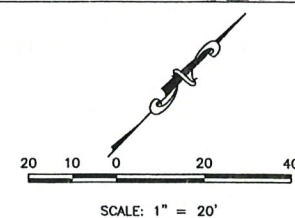
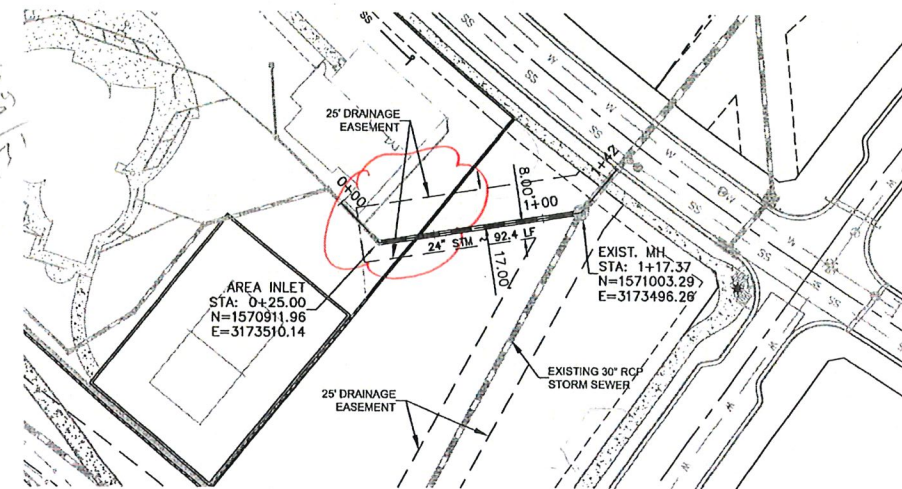


CONSTRUCTION NOTES

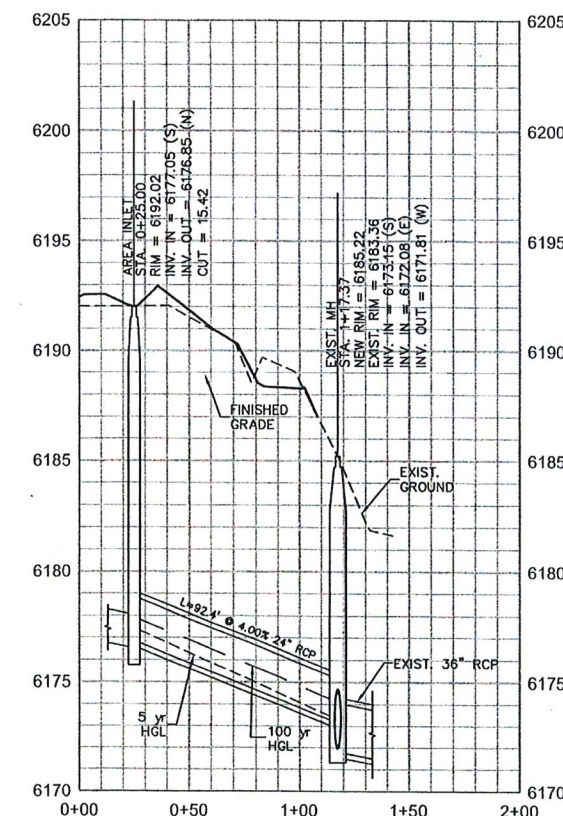
- CONNECT TO DOWNSPOUT. SEE PLUMBING PLANS
- INSTALL NYLOPLAST 12" PEDESTRIAN GRATE, SEE DETAILS SHEET 8
- CONNECT TO TRENCH DRAIN, SEE POOL DECK DRAINAGE PLAN
- INSTALL CLEANOUT
- INSTALL NYLOPLAST TYPE 2499CGP PEDESTRIAN GRATED INLET AND FRAME ON STANDARD TOWN OF CASTLE ROCK MANHOLE. SEE SHEET 7.

GENERAL NOTES

- REFER TO ARCHITECTURAL PLUMBING PLANS FOR EXACT LOCATION OF DOWNSPOUTS
- REFER TO POOL DECK DRAINAGE PLAN FOR EXACT LOCATION OF TRENCH DRAIN TIE-IN LOCATIONS
- CONTRACTOR SHALL COMPLY WITH ALL MANUFACTURERS SPECIFICATIONS FOR PIPE, CONNECTIONS, BEDDING, ETC.



STORM SEWER PLAN
SCALE: 1" = 40'



Laser = +4.0 Ft



534-6700 METRO DENVER AREA
UTILITY NOTIFICATION CENTER OF COLORADO

PROFESSIONAL ENGINEER CERTIFICATION

I HEREBY AFFIRM THAT THESE FINAL CONSTRUCTION PLANS WERE PREPARED UNDER MY DIRECT SUPERVISION, IN ACCORDANCE WITH ALL APPLICABLE TOWN OF CASTLE ROCK AND STATE OF COLORADO STANDARDS AND STATUTES, RESPECTIVELY; AND THAT I AM FULLY RESPONSIBLE FOR ALL DESIGN AND REVISIONS RELATIVE TO SAID PLANS.

KURT A. LANG
COLORADO P.E., 32249



TOWN OF CASTLE ROCK APPROVAL

PLANS ARE HEREBY APPROVED FOR ONE YEAR FROM DATE OF DEVELOPMENT SERVICES APPROVAL

APPROVED BY:

Kurt A. Lang
DEVELOPMENT SERVICES

10/23/15
DATE

No.	Revisions	Date	Init.	Appr.	Date
1	ADDENDUM 1	8/11/2015			
2	CD15-009 ISSUED FOR CONSTRUCTION	10/22/15			

THE MEADOWS FILING 20
MNC AMENITY II SITE
SITE CONSTRUCTION PLANS
STORM DRAIN PLAN AND PROFILE

210 ENGINEERING, LLC
10940 S. Parker Rd., #446
Parker, Colorado 80134
303-921-4217
CIVIL SITE ENGINEERING & LAND PLANNING

12:15-2:25 on-site from driveway drinking

11/3/22

Grate #5

Datum ① Grate Elev = 6193.89' (Farnsworth)
+ 4.00' (laser height)

Pool rim rel elev (cw)

+ 0.16'

+ 0.17'

+ 0.16'

+ 0.10'

+ 0.01'

All rel to Datum ① Grate El

Datum ② Grate #9 Elev = 6192.71' (Farnsworth)
+ 5.42' (laser height)

All following are rel to ② Grate El

Grate #10 Dia = 24.5" round

↳ Rim + 0.20' INV - 79.5" from rim

Grate #11 Dia = 24.5" round

↳ Rim - 0.14' INV - 65.75" from rim

Grate #12 Dia = 24.5" round

↳ Rim - 0.41' INV - 80" from rim

N corner pool rim = + 1.21'

APPENDIX F
CURRICULUM VITAE AND TESTIMONY LIST
OF L. CLINT BROWN

EXPERTISE

Mr. Brown has 21 years of experience in the design, project management and construction oversight involving the successful construction and rehabilitation of 25+ jurisdictional dams in Colorado, Wyoming and New Mexico. Mr. Brown's responsibilities for these projects includes: aiding the client in the procurement of funds, lead design engineer, engineering analysis (including seepage, hydraulic, hydrologic, structural, pipe design, and geotechnical analyses), construction permitting, development of construction drawings and specifications, and construction oversight. Mr. Brown also has experience in geotechnical analysis, storm water management, and water balance studies for mine sites in the Western United States, Australia, Indonesia, and Kazakhstan.

REGISTRATIONS AND CERTIFICATIONS

Professional Engineer – Colorado, Wyoming, New Mexico, California

MSHA 24-Hour New Surface Miner Safety Training

EDUCATION

M.S., Geotechnical Engineering, Colorado State University, Fort Collins, Colorado, 2004.

B.S., Civil Engineering, Colorado State University, Fort Collins, Colorado, 2001.

PROJECT EXPERIENCE

DAM ENGINEERING

- **Western Mobile Lake 4 Dam and Reservoir, Boulder County Parks and Open Space, Boulder County, Colorado:** During the flooding events of the September 2013 Western Mobile Lake 4 was overtopped and breached. Mr. Brown managed the design for the repair and rehabilitation of Western Mobile Lake 4 Dam and Reservoir. Mr. Brown oversaw site investigations and outlet inspections that were used in the development of repair options. Mr. Brown oversaw and developed multiple alternatives for the repair alternatives for review by the advisory committee, where the preferred alternative was selected. Mr. Brown will manage the final design and oversee construction compliance.
- **Swede Lake Dam and Reservoir, Boulder County Parks and Open Space, Boulder County, Colorado:** Mr. Brown managed the design for the repair and rehabilitation of Swede Dam and Reservoir. Mr. Brown oversaw site investigations

were used in the development of repair options. Mr. Brown will manage the final design and oversee construction compliance.

- **Birdseye Gulch Reservoir, Lake County, Lake County, Colorado:** Mr. Brown managed the design of the new Birdseye Gulch Reservoir. Mr. Brown oversaw site investigations were used in the development of design options. Mr. Brown will manage the final design and oversee construction compliance.
- **Georgetown Lake Dam, Town of Georgetown, Clear Creek County, Colorado:** Mr. Brown managed the design for the enlargement of the Georgetown Lake Dam Outlet. Mr. Brown conducted the site investigations and reviews that were used in the development of outlet enlargement options. Mr. Brown oversaw and developed multiple alternatives for enlargement and presented the alternatives for review by the advisory committee, where the preferred alternative was selected. Mr. Brown oversaw and developed a design that met the requirements of the advisory committee and the downstream objectors. The selected alternative was designed to increase the discharge capacity from 160cfs to over 500cfs. This design specified over 140tons of concrete to be cut from the existing spillway so an 8ft x 11ft cable drum operated crest gate could be installed. This new gate can handle extreme ice loads up to 18in thick and has a variety of safety features to ensure that the dam outlet works has a minimized risk of failure.
- **Lake Isabelle, Boulder County, Colorado:** Lake Isabelle is a high mountain reservoir located in the Indian Peaks Wilderness Area. The Lake Isabelle project involved a structural investigation of access tower and rehabilitation design for the outlet gate and gate shaft. Previously, the gate was accessed down a dangerous shaft that is 50-ft deep. The rehabilitation design incorporated a new gate shaft that can be accessed more safely and easily. Mr. Brown oversaw and conducted all structural investigations, all construction drawings, specifications, and contract documents for the project, and provided all resident inspection, quality assurance testing, and contract administration during construction.
- **Little Robber Retention Dam; Bureau of Land Management, Carbon County, Wyoming:** The Little Robber Retention dam was damaged due to flooding, that resulted in erosion of the embankment and collapse of the Outlet pipe and service spillway. Mr. Brown served as the Project Manager of the forensic analysis and rehabilitation design of outlet works and spillway. Developed and managed the geologic investigation plan. He also conducted the project management to coordinate between field personnel and subcontractors. Mr. Brown analyzed the feasibility of various rehabilitation designs and worked with Government on the selection of the preferred alternative. He also conducted geotechnical, hydraulic, and hydrologic analysis of the dam and potential repairs. Developed the construction drawings and construction specifications for the rehabilitation design.
- **Prospect Reservoir, Henrylyn Irrigation District; Hudson, Colorado:** Prospect Reservoir has an earthfill dam, 45-ft in height, and impounds approximately 6,500 ac-ft of water. During an inspection of the dam, the Colorado State Engineer determined that the outlet conduit was deteriorated and required repair. Mr. Brown

conducted the feasibility study required to obtain funding for the rehabilitation through the Colorado Water Conservation Board; inspected the outlet conduit and control gate; provided all structural and geotechnical investigations; conducted all hydrologic and hydraulic analysis required for the repair design of the outlet conduit; provided all bid and construction drawings, specifications, and contract documents for the project; bid the project for the owner; and provided all resident project inspection, QC testing, and contract administration during construction.

- **Horse Creek Reservoir; Henrylyn Irrigation District; Hudson, Colorado:** Project Manager for the rehabilitation design for the 70 foot tall 18,000 acre-ft reservoir dam. Rehabilitation consisted of the design of a new seepage collection system, evaluation of the embankment stability, reconstruction of the erosion protection system, and the rehabilitation of the reservoir outlet. During Construction Review of the previous monitoring data and reports and site investigation for the existing earthen dam and the outlet structure. Acted as the liaison between the client and the Office of the Colorado State Engineer.
- **Cornish Plains Reservoir; New Cache La Poudre Irrigating Company; Weld County, Colorado:** Mr. Brown designed and oversaw the construction of new 2,700 acre-foot irrigation storage reservoir. Mr. Brown conducted the hydrologic study and spillway design for passing the design storm and maintaining the integrity of the embankment. Mr. Brown also conducted the hydraulic design and analysis of the emergency spillway, outlet works, and toe drain system. Mr. Brown also conducted the geotechnical design and analysis of the embankment and clay core system and hydrogeological analysis of the embankment, clay core, and drainage system. Mr. Brown also oversaw the development of the construction drawings and specifications for approval by the Colorado State Engineer's Office. This project was completed on-time and under budget.

HYDRAULIC STRUCTURAL ENGINEERING

- **St. Vrain Creek Rehabilitation, Boulder County Parks and Open Space, Boulder County, Colorado:** Managed the design for the flood repair of the St. Vrain Creek. Mr. Brown was the project manager and contributed to the design and communicating with the owner.
- **Georgetown Lake Dam, Town of Georgetown, Clear Creek County, Colorado:** Managed the design for the enlargement of the Georgetown Lake Dam Outlet. Mr. Brown conducted the hydraulic layout and structural design and analysis of the gate, walls, and channels.
- **Rehabilitation of Angel Lake Dam, Weld County, Colorado:** Principal designer of a new outlet tower, spillway structure, outlet pipeline, and gate operator. Duties included structural design, hydraulic analysis, and hydrologic analysis.
- **Rehabilitation of Hiawatha Lake Dam, Larimer County, Colorado:** Principal designer of a new outlet tower, spillway structure, outlet pipeline, and gate

operator. Duties included structural design, geotechnical investigations, hydraulic analysis, and hydrologic analysis.

- **Rehabilitation of Eagle Lake Dam, Larimer County, Colorado:** Principal designer of a new outlet structure, spillway structure, outlet pipeline, and gate operator. Duties included structural design, hydraulic analysis, and hydrologic analysis.
- **Rehabilitation of Davis Dam #3, Jefferson County, Colorado:** Principal designer of a new outlet, embankment rehabilitation, spillway structure, outlet pipeline, and gate operator. Duties included structural design, hydraulic analysis, and hydrologic analysis.
- **Rehabilitation of Davis Dam #2, Jefferson County, Colorado:** Principal designer of a new outlet, embankment rehabilitation, spillway structure, outlet pipeline, and gate operator. Duties included structural design, hydraulic analysis, and hydrologic analysis.
- **Platte Valley Reservoir #1, Weld County, Colorado:** Principal designer of a reservoir including outlet, embankment, spillway structure, outlet pipeline, and gate operator. Duties included structural design, hydraulic analysis, and hydrologic analysis.
- **Prospect Reservoir Rehabilitation, Weld County, Colorado:** Principal designer of outlet, embankment, spillway structure, outlet pipeline, underground storage vault, toe drain system, lift station, and gate operator. Duties included structural design, hydraulic analysis, and hydrologic analysis.
- **Horse Creek Reservoir Rehabilitation, Weld County, Colorado:** Principal designer of outlet, embankment, spillway structure, outlet pipeline, underground storage vault, toe drain system, lift station, and gate operator. Duties included structural design, hydraulic analysis, and hydrologic analysis.
- **Independent Reservoir Rehabilitation, Boulder County, Colorado:** Principal designer of outlet tower, embankment, spillway structure, outlet pipeline, underground storage vault, toe drain system, and gate operator. Duties included structural design, hydraulic analysis, and hydrologic analysis.

GEOTECHNICAL ENGINEERING

- **Geotechnical Stability Analysis** Conducted geotechnical stability analysis on waste rock material, pit highwall material, pond embankments, and heap material.
- **Geotechnical Investigations.** Designed, prepared and reviewed geotechnical investigations and reports for various mining and water works projects.

- **Structural Design.** Structural design of retaining walls, residential foundations, and hydraulic structures.
- **Geotechnical Modeling.** Use of geotechnical modeling programs including RetainPRO 2009, Seep/W, and Slope/W.
- **Geo-Synthetic Clay Liner Evaluation.** Conducted a research program for the evaluation of using Geo-Synthetic Clay Liners (GCLs) as liners for animal waste lagoons.

HYDROLOGIC AND HYDRAULIC ENGINEERING

- **Dam Breach Inundation Mapping.** Conducted and oversaw the development of 8 inundation mapping projects, including Data Review, Dam Breach Analysis, and Flood Routing.
- **Reservoir Flow and Routing, Colorado, Idaho, Nevada, Australia, Indonesia, Uzbekistan.** Conducted flow and routing calculations for storm water basins located at reservoirs located in Northern Colorado and mine sites in Australia, Indonesia, Uzbekistan, Idaho, and Nevada.
- **Hazard Studies, Northern Colorado.** Conducted hazard studies to determine the potential hazard of proposed reservoirs in Northern Colorado.
- **Channel Design.** Designed channels and channel systems to divert flow from important and potentially hazardous structures.
- **Precipitation Calculations, Idaho, Australia, Indonesia.** Calculated precipitation return periods for remote locations in Idaho, Australia, and Indonesia from precipitation records.
- **Sediment Control Design.** Designed sediment control structures to limit the effects of sediment caused by construction activities.
- **Hydrologic and Hydraulic Programs.** Use of hydrologic and hydraulic programs including HEC-HMS, HEC-RAS, WaterCAD, and StormCAD.

OTHER ENGINEERING

- **Reservoir Design and Construction Management, Northern Colorado.** Construction/Project Manager on the design and construction of multiple reservoir projects in Northern Colorado.
- **Dam Feasibility and Design Reports, Colorado and Wyoming.** Prepared feasibility studies, loan applications, construction drawings, design reports, and construction specifications for more than 8 dams in Colorado and Wyoming.

- **Water Balance Studies.** Programmed dynamic system models (DSMs) to aid in the closure and operations modeling of process solutions for various mine sites in Nevada.

PROFESSIONAL EMPLOYMENT HISTORY

- Project Dam/Reservoir Engineer, Engineering Analytics, Inc., Fort Collins, Colorado (2013-present)
- Project Manager, Smith Geotechnical Engineering Consultants, Fort Collins, Colorado (2005-2013)
- Staff Engineer, Telesto Solutions, Inc., Fort Collins, Colorado (2002-2005)
- Graduate Research Assistant, Colorado State University, Fort Collins, Colorado (2001-2003)
- Lab Instructor, Soil Mechanics for Non-Engineers, Colorado State University, Fort Collins, Colorado (2001)
- Intern, D&M Engineering, Tempe, Arizona (2000)

PROFESSIONAL AFFILIATIONS

Tau Beta Pi

Chi Epsilon

Colorado Association of Geotechnical Engineers (CAGE)

LITIGATION SUPPORT

- Orr v. United States, No. 18-1894L, re: Olympus Dam releases during Big Thompson River flood of September 2013 (for Plaintiff), Prepared Opinion Report, Prepared Rebuttals, Expert Testimony and Deposition
- Flood Impacts on Hines property. Prepared Opinion Report

PUBLICATIONS

Brown, L. C. and Shackelford, C. D. 2007. "Hydraulic Conductivity of a Geosynthetic Clay Liner to a Simulated Animal Waste." Transactions of the American Society of Agricultural and Biological Engineers (ASABE), Vol. 50, No. 3: 831-841.

Tocher, R. J. and Brown, L. C. 2014. "Left Hand Creek Shows Its Power During the Great Front Range Flood of 2013." The Association of State Dam Safety Officials (ASDSO), Proceedings Dam Safety 2014.

Tocher, R. J. and Brown, L. C. 2014. "Dam Performance During the Great Front Range Flood of 2013" American Society of Civil Engineers (ASCE), Proceedings ASCE Geo-Conference 2014.

PRESENTATIONS

Hoeh, D, L. C. Brown, M. Baker, A. Pearson, *Social and Industry Impacts of the Lawn Lake Dam Failure of 1982*. Presentation. ASDSO Dam Safety 2022 Baltimore, Maryland Conference, Decade Dam Failure Series. September 19

Brown, L. C., D. Hoehn. 2021. *Every Tree, House, and Object in its Path: The Schaeffer Dam Failure*. Presentation. ASDSO Dam Safety 2021 Nashville, Tennessee Conference. Decade Dam Failure Series. September 14.

Hoehn, D., L C. Brown. 2021. *Assessing Risk: Techniques and tools for dam owners to evaluate risk*. Presentation. New Mexico Watershed and Dam Owners Coalition, Raton, New Mexico 2021 Conference. October 1.

Hoehn, D., L C. Brown. 2020. *St. Vrain Creek Reach 3 Restoration Project*. Presentation. ASCE Northern Colorado Branch Meeting. October 8.

Hoehn, D., L C. Brown. 2020. *The Prospect Dam Failure*. Presentation. ASDSO Dam Safety 2020 Virtual Conference. Decade Dam Failure Series. September.

Brown, L.C. New Mexico Watershed and Dam Owners Coalition. "*Lake Dorothy Spillway*"

Brown, L. C., D. Hoehn. 2019. "*The Dam is Becoming Dangerous and May Possibly Go!*": *The South Fork Dam Failure*. Presentation. ASDSO Dam Safety 2019 Orlando, Florida Conference. Decade Dam Failure Series. September.

The cases in which I have given testimony by deposition or trial are as follows:

Date Updated: January 23, 2023

LIST OF TRIAL/DEPOSITION TESTIMONY

**L. Clinton Brown
Senior Engineer
Engineering Analytics, Inc.**

Deposition Date	Project No.	Case Name	Type of Testimony / Case No.	Trial Location	Attorney	Representing
6/3/2021	111119	Elizabeth Orr, Howard Carman and Lena Carman vs. The United States of America	Deposition 18-1894L	Video Conference, Fort Collins, Colorado	Nelson P. Boyle, ESQ Burg Simpson Eldredge Hersh & Jardine, P.C.	Plaintiff
7/19,2021, 7/21/2021	111119	Elizabeth Orr, Howard Carman and Lena Carman vs. The United States of America	Trial Testimony 18-1894L	Video Conference, Denver, Colorado	Brian K. Matisse, Burg Simpson Eldredge Hersh & Jardine, P.C.	Plaintiff