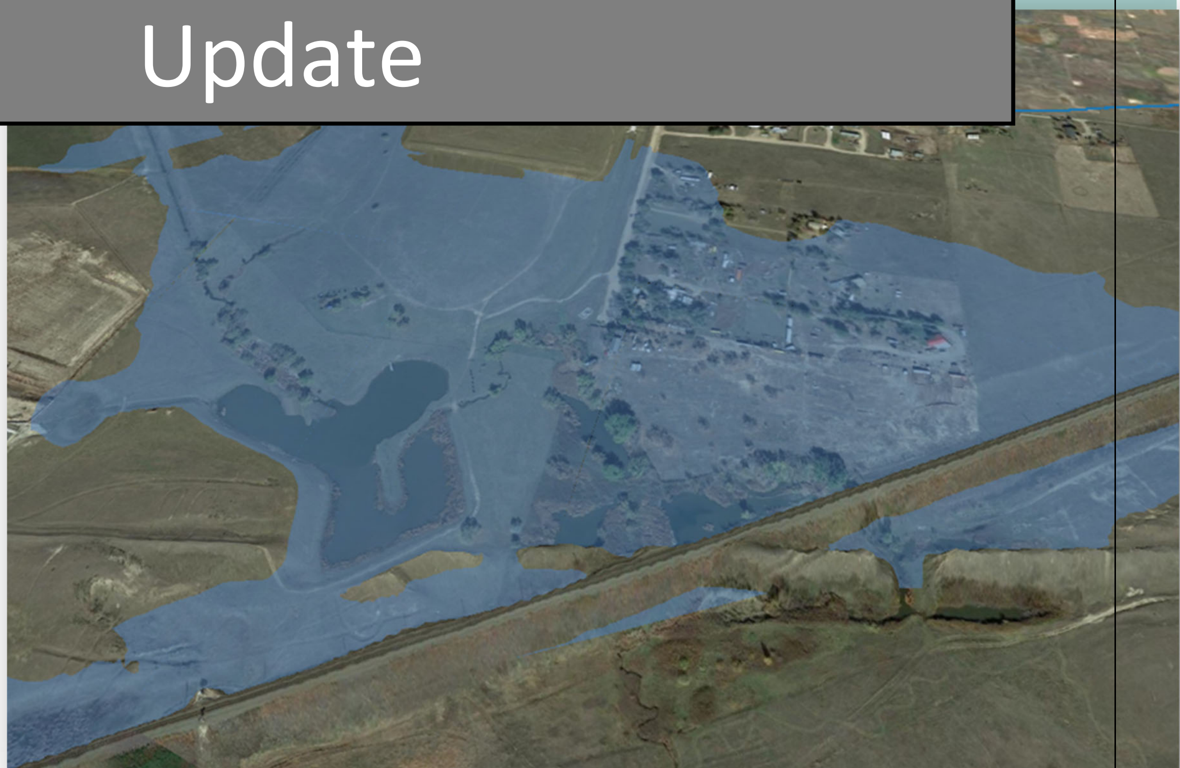
Dry Creek Drainage Master Plan Update



August 2023

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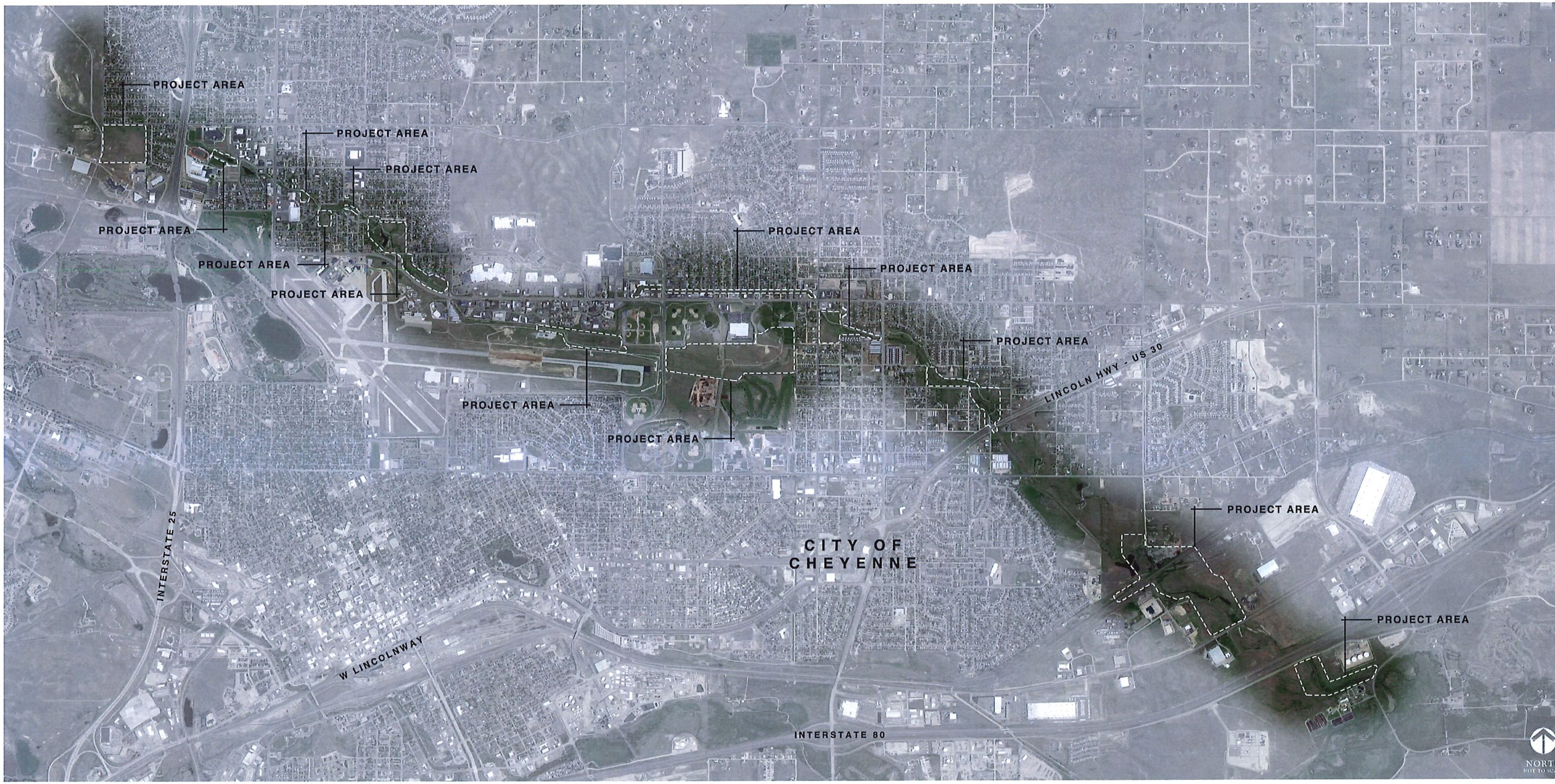
OVERALL MAP



CITY OF CHEYENNE

GLM Design Group

DHM DESIGN

I. EXECUTIVE SUMMARY

This report presents the update of the 1988 Dry Creek Drainage Master Plan for the Dry Creek drainage basin located in the north and east sides of Cheyenne as shown in **Figure 1**. The study area is approximately 16.0 square miles in size with a nearly fully urbanized land-use. The north side of Cheyenne began to develop for rural residential use prior to the 1950s with corresponding urbanization of the creek and commercial development along Dell Range Blvd. beginning in the late 1970s. Dry Creek is a tributary of Crow Creek and has its headwaters located on Francis E. Warren Air Force Base (FEW) where runoff is collected in the north and south forks of Dry Creek in the adjacent Western Hills subdivision. From their confluence, the main stem flows southeasterly for 9.3 miles to its confluence with Crow Creek.

Figure 1. Overall View of Dry Creek Basin

Much of the riparian area and floodplain of Dry Creek has been developed and the creek channelized in the north portion of the city. Some of the riparian area and floodplain remain in the eastern portion. Many of the road crossings still have insufficient capacity and need repair. This report presents an updated flood-control plan and creek restoration plan for the Dry Creek Basin. It accounts for flood control improvements and drainage management changes that have been implemented since the original 1988 Drainage Master Plan.

Current drainage issues can be tied to historically poor drainage planning for the basin in conjunction with an outstanding capital improvements list still waiting to be funded and implemented. Exacerbating this condition is an inefficient annual maintenance budget. The result is reaches of channel that are overgrown with vegetation and filled with sediment, further constraining conveyance of flow in the channel. As a part of this updated study, an assessment of channel infrastructure was conducted incorporating the *2020 Culvert and Storm Drain System Inspection Guide* by the Association of State Highway and Transportation Officials (AASHTO). Generally, many crossings were found to be in poor condition with noted piping occurring for at least four culvert crossings and a corresponding sink hole identified at the Prairie Avenue crossing. Instances of bank erosion and head cutting were also noted in the assessment.

Since 1950, much of the Dry Creek Basin has been platted and subdivided with correspondingly significant changes to the historic meandering pattern of Dry Creek. Since the turn of the last century when the Union Pacific Railroad (UPRR) was reconstructed on the east side of the city, the upstream basin has dramatically changed from a predominantly rural basin to a nearly entirely urbanized one. The existing UPRR mainline tracks were constructed shortly after 1901 with the construction of a 6' x 8' masonry box arch culvert being completed in 1903. Currently the project area serves as an unintentional detention storage area for stormwater runoff in Lower Dry Creek and has been modeled as such since at least the 1970's. Significant impoundment of floodwaters against the Union Pacific embankment has been noted by the U.S. Geological Survey (USGS) and others for flood events having occurred in the 1920's, 1950's, 1970's and for the record-setting 1985 flood event. The project area is modeled as a sump in the 1988 Dry Creek Master Drainage Plan USACE HEC-1 hydrologic model. The UP sump is a significant constriction for the upstream basin and the resulting inundated area is shown below in **Figure 2** for a 100-year flood event.

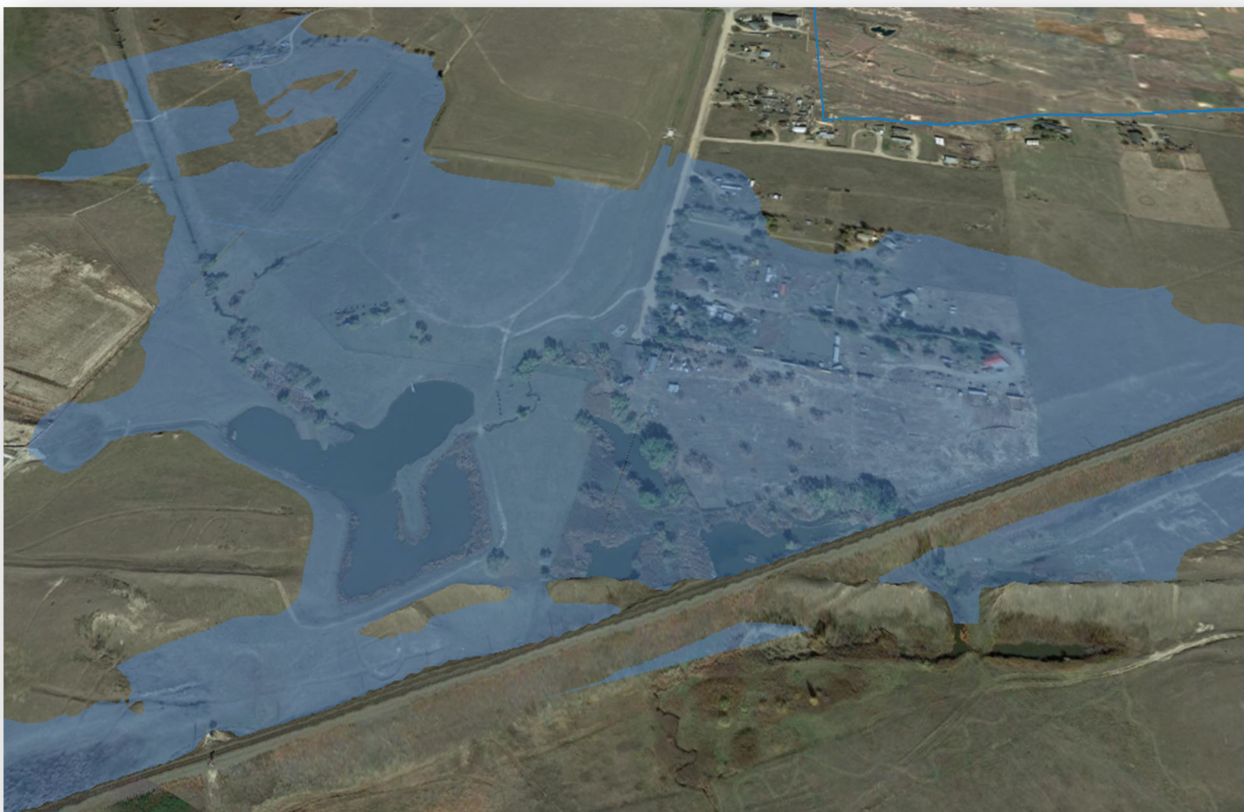


Figure 2. Detention Storage at UPRR Crossing for 100-Year Event

Cheyenne has experienced many floods. Floods with the highest peak discharges generally occurring in the Cheyenne area are the result of intensive convective rainstorms over the high plains. These storm events occur mainly during the summer months and are common in the Cheyenne area. The earliest significant flood on record was in 1883, and the most recent major flood event was in 1985. These floods and flood-producing storms are summarized in **Table 1** below.

Date	Event
1883	Significant flood along Crow Creek.
July 15, 1896	Precipitation of 4.7 inches in 3 hours and 4.86 inches in 24 hours, produced significant flood along Crow Creek.
May 20, 1904	Precipitation of 0.63 inches was recorded during the night of May 19th. During the afternoon of May 20th, 1.10 inches of rain and hail fell in 1 hour. Precipitation probably was more intense along the upstream reach of Crow Creek. Maximum discharge was estimated to be 8,500 cubic feet per second.
1918	Large flood occurred along downstream reaches of Dry Creek, approximately the same magnitude as the August 1, 1985, flood event.
June 14, 1926	Severe hailstorm lasting from 10:20 p.m. to 11:05 p.m. concentrated in a 1- by 6-mile area and produced 2.51 inches of precipitation.
April 23, 1929	Storm produced 3.20 inches of precipitation in a 24-hour period.
1929	Large flood event along Dry Creek.
June, 1929	Flood in Crow Creek (8,200 cubic feet per second on June 2nd) was caused by precipitation near the headwaters west of town, where the ground was already saturated, and tributaries were full from melting snow.
June 1935	Large flood event along downstream reaches of Dry Creek, approximately the same magnitude as the August 1, 1985, event. Precipitation during the storm was greatest in the Roundtop area at the headwaters of Dry Creek. Flooding also occurred along Crow Creek.
August 1946	Severe storm producing 1 inch of precipitation in 10 minutes caused flooding along Dry Creek.
June 1955	Intense rains occurred the afternoon of June 14th and continued into the next day producing 2.68 inches of precipitation. This produced a large flood along the downstream reaches of Dry Creek at approximately the same magnitude as the August 1, 1985, flood.
1972	A flood occurred along the downstream reaches of Dry Creek. Water surface elevations were slightly lower than those for the 1955 flood event.
August 1985	On August 1st, an intense thunderstorm produced 7 inches of precipitation in the downtown area between 6:20 p.m. and 9:45 p.m. The storm was accompanied by hail, up to 3 feet in areas. A new 24-hour Wyoming rainfall record was set. Flooding occurred along Dry Creek, Crow Creek, their tributaries, and throughout the city.
May 17, 1987	A thunderstorm developed over the west section of Laramie County during the morning. This thunderstorm marched through Laramie County with locally heavy rain and hail. Rains of over an inch were reported west and north of Cheyenne with 0.82 inches of rain reported at the Cheyenne airport. Water got as deep as 3 to 4 feet in areas of Cheyenne. This flooded some parked cars and made a few roads temporarily impassable. Numerous

Date	Event
	reports of 0.25-to-0.75-inch diameter hail were noted around Cheyenne. Drifts of hail 6 to 8 inches deep were observed about 1.5 miles north of the airport.
July 12, 1991	Heavy rains with thunderstorms brought 1.70 inches of rain 4 miles west of Cheyenne and 1.95 inches of rain 3 miles north of the airport. Street and some basement flooding was reported in Cheyenne.
August 13, 1994	A thunderstorm moved north out of Colorado into southwest Laramie County. This storm produced flash flooding in a few small streams in extreme southwest Laramie County, washing out a couple of roads. Rainfall totaled 3.26 inches in an hour and 0.65 inches in 10 minutes.
April 29, 1999	Minor flooding occurred in parts of the Laramie range into the Cheyenne foothills because of snowmelt and around 2 inches of rainfall. Flooding was reported along parts of Crow Creek in south Cheyenne with other minor flooding reported along Lodgepole Creek northwest of Cheyenne.
August 15, 2000	Heavy rains fell over parts of Laramie County west of Cheyenne, with estimates of 4 to 6 inches over an area southwest of Federal, WY. Some flooding was reported on Happy Jack Road, with parts of County Road 109 washed out.
June 30, 2004	Heavy rain fell over Orchard Valley resulting in flooding of low-lying areas. U.S. Highway 85 was closed for a time just south of Cheyenne, WY due to flooding.
August 6, 2008	Heavy rain fell over Cheyenne resulting in flooding City-wide. Carlson Road was closed for a time just west of Yellowstone Road. The Cheyenne Civic Center was flooded resulting in extensive damage totaling millions of dollars.
July 14, 2010	Heavy rain and hail fell over large areas of Cheyenne resulting in flooding and significant property damage due to hail.
September 13, 2013	Severe storms affecting Front Range of Colorado and Laramie County including Cheyenne.
September 29, 2014	0.79 inches of rain over large area of Cheyenne.
May 18, 2017	1.65 inches of rain over large area of Cheyenne.
May 27, 2019	1.65 inches of rain over large area of Cheyenne.
June 8, 2021	2.37 inches of rain over large area of Cheyenne.

Table 1. Cheyenne Flood Data

The Cheyenne flood of August 1, 1985, was one of the most devastating flash floods to occur in Wyoming. Destructive flooding occurred along Dry Creek, Crow Creek, their tributaries, and throughout the city from overland (sheet) flow. Emergency access was impeded by floodwaters overtopping the roadways. Recovery and relief efforts were impaired by roadway damage after the floodwaters subsided. This event, in large measure, prompted the commission of the 1988 Drainage Master Plans for eight of the nine City drainages to minimize flood hazards to the city and adjacent county areas. Cheyenne's 1985 flood is documented by Druse, et. al. (1986), the U.S. Geological Survey and the Wyoming Department of Transportation (WYDOT), with assistance from the City in **Figure 3**.

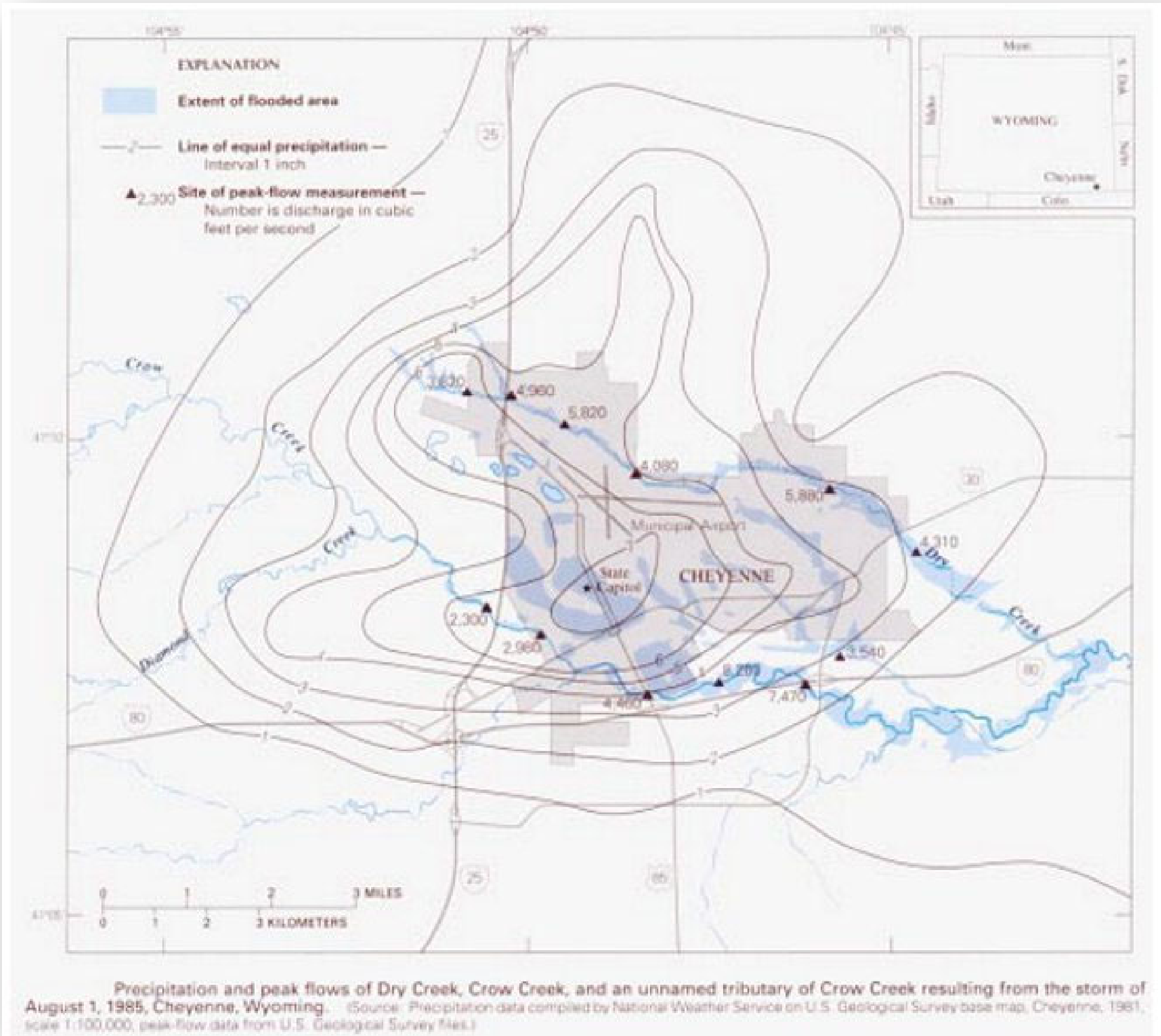


Figure 3. Perhaps the most famous Cheyenne, Wyoming Flood (1 August 1985, evening, 12 killed, 70 injured, $65 million in property damage)

The historical data show that, although the 1985 storm event produced records for precipitation and peak discharges, large flood events are not uncommon for the area. Conditions such as wet soil from preceding storms, or hardpan developed in drought conditions, intense precipitation, and storm paths moving downstream along drainages are possible. Such conditions combined with continued urban development will produce floods of similar magnitude or greater than the event that occurred on August 1, 1985.

According to the Laramie County Hazard Mitigation Plan, SHELDUS data shows that 22 damaging floods occurred in Cheyenne between 1960 and 2010. **This yields a 44% chance that a damaging flood will occur in any given year, which corresponds to a likely occurrence rating**. Additionally, the Plan estimates the potential magnitude for a flood event in Laramie County to be catastrophic. An event of limited magnitude could result in multiple severe injuries, multiple deaths, a complete shutdown of critical facilities for 30 days or more, and damage to more than 50% of the planned area. This is consistent with the flood history in the county.

The Federal Emergency Management Agency's (FEMA) National Risk Index tool indicates that Laramie County has a relatively moderate risk of riverine flooding with a corresponding score of 79.5 and a relatively high risk of hail with a corresponding score of 97.9. The annual expected loss for riverine flooding is estimated at $1.8 Million by FEMA with an estimated 2 events per year and a corresponding exposure of $17 Billion. The annual expected loss for hail is estimated at $4.4 Million by FEMA with an estimated 5.2 events per year and a corresponding exposure of $1.2 Trillion. Hail events also have the potential to block storm sewer inlets, as was the case during the 1985 storm event, causing property damage due to flooding by overland stormwater runoff. **The 1985 event is estimated to have caused $63 Million in property damage (1985 dollars).**

The 1988 Dry Creek Plan was never fully implemented due to funding limitations. The viability of the drainage system has been questionable throughout the years due to lack of maintenance and implementation of capital improvement projects. The 1988 Plan has been revisited twice since originally published. States West provided an update of five of the Drainage Master Plans including the Dry Creek basin in 1996 due to a lack of progress in implementing plan recommendations. The Surface Water Drainage Committee issued *Implementing the Drainage Master Plan for the Greater Cheyenne Area* including Dry Creek in March 2000 in support of a storm water utility ballot proposition that year. Storm drainage basins within the corporate limits of Cheyenne are shown in **Figure 4**. As of the 2023 plan update, Cheyenne was experiencing one of its wetter springs. The city received approximately 25% of its yearly average rainfall in the month of June, tied for 3rd most on record. The month of July also set records for the Cheyenne area. The year-to-date precipitation of 10.51-inches was 2.29-inches above average.

The Dry Creek Basin experienced six major flood events between 1918 and 1985 with significant impoundment of flood waters at the Union Pacific embankment for each event. It has been almost 40 years since the last major event and, in that time, urbanization of the basin has continued, increasing the overall imperviousness by 50%. Even accounting for appropriate detention storage for development of the basin, lag times for runoff have decreased and storm drainage infrastructure has generally accelerated peak discharges into Dry Creek. This is most notable in the hydrologic model supporting this report for the lower basin where new development has been replacing the historic rural open spaces. Our hydraulic model indicates an approximate 1000cfs increase in peak discharge at the Union Pacific railroad crossing of Dry Creek.

Storm drainage basins located within the corporate limits of the city are shown in **Figure 4**. The Dry Creek Drainage Basin is one of eight basins having their confluences with Crow Creek. While the Clear Creek and Allison Draw Basins are larger, the Dry Creek Basin is almost entirely contained within the city. The Dry Creek Basin has experienced the most significant changes in land use of the city's drainage basins over the last 100 years.

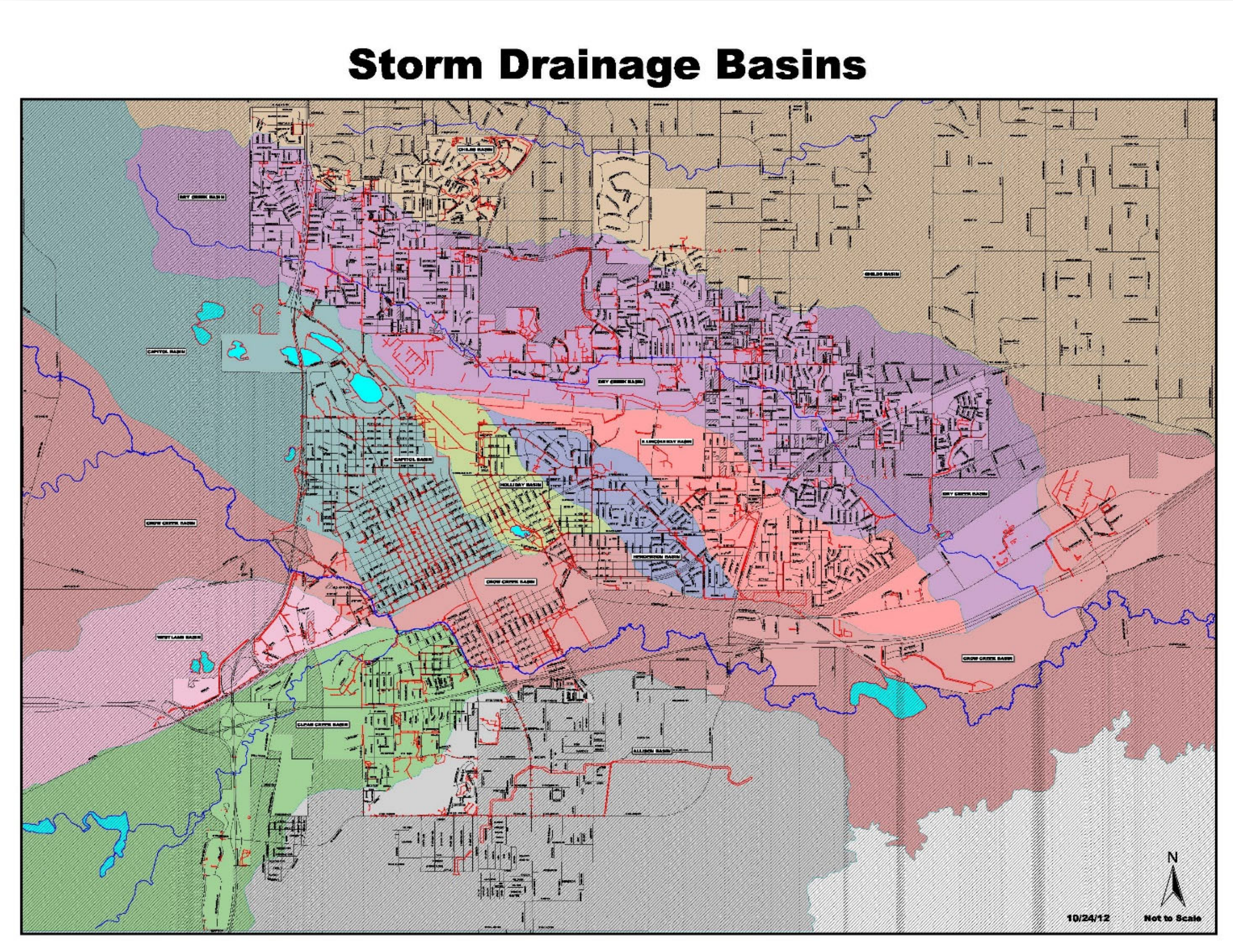


Figure 4. Cheyenne Storm Drainage Basins (Dry Creek shown in purple).

For the 1988 study, flood problems on Dry Creek were classified as life-safety hazards and/or property damage hazards. High life-safety hazard locations were defined as those areas on roadways or near structures that met one or both of the following criteria:

- 100-year flood depths exceeded 2-feet.
- The product of the 100-year flood depth (in feet) and velocity (in feet per second) is **6 or greater**.

There were 35 life-safety hazard areas identified in the 1988 study. The Plan was primarily focused on reducing life-safety hazards with a secondary focus on reducing property damage as it related to riverine flooding of Dry Creek. This singular focus was driven, in large measure, by the unfortunate fatalities of citizens attempting to drive over flooded crossings along the Sheridan Reach (driving around barricades) only to be washed into the floodwaters of Dry Creek. Although the Plan had six stated objectives, life-safety, and property damage due to flooding took precedence. So, by default, the Plan emphasized conveyance and structural drainage facilities within the drainageway to reduce flood hazards. The Selected Plan relied on three storage facilities, none of which were ever constructed.

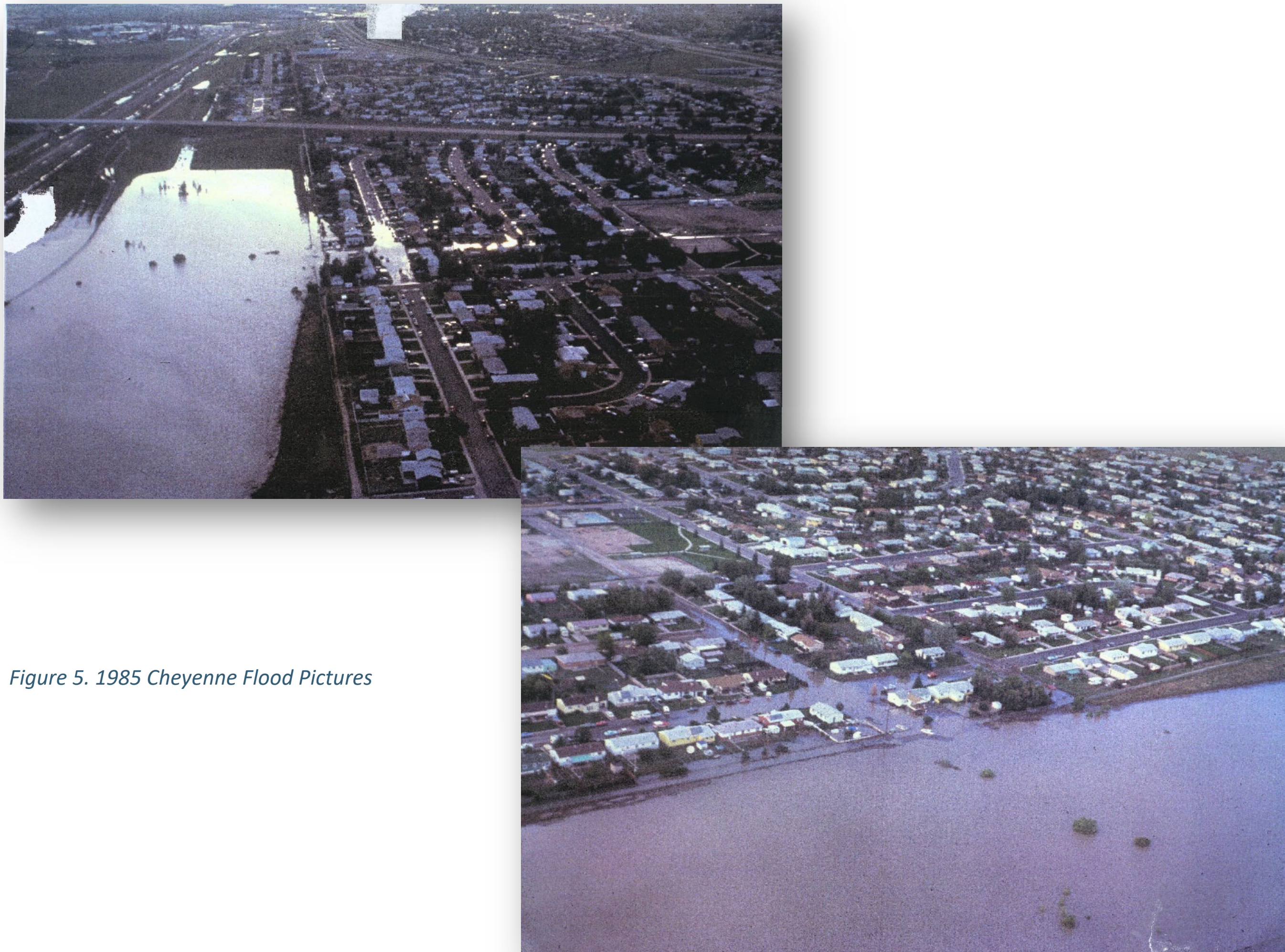


Figure 5. 1985 Cheyenne Flood Pictures

The 1996 update focused on the Yellowstone Rd., Converse Ave., Charles Street, and East Pershing Blvd. crossing improvements which were ultimately constructed. The 2000 implementation report, recognizing the shortcomings of the original 1988 Plan, focused on storage opportunities that have yet to be constructed. In fact, the most significant capital improvement project constructed in the Dry Creek basin since 1988 has been the Dry Creek Sheridan Reach Flood Control Project which was never envisioned by the 1988 or 2000 reports. It received FEMA Pre-Disaster Mitigation and EPA-319 funding, making it one of the more cost-effective projects that the city has undertaken in recent years. ***Of the 1988 report's 31 recommended projects in the selected plan of improvements for priority implementation, only 8 were constructed***. Those projects combined do not provide the level of cost-effectiveness and flood control of the Sheridan Reach Flood Control Project. The Sheridan Reach Flood Control Project addressed the six highest ranked improvements by implementation priority from the 1988 Selected Plan. Moreover, the Sheridan Reach project provided multiple benefits with Cheyenne Greenway amenities and a pedestrian crossing of Windmill Road as well as additional flood control for the Holliday and Henderson drainage basins with a trans-basin diversion. The Sheridan Reach Flood Control project included four significantly sized storage facilities and a constructed wetland to address water quality concerns in the basin.

The 2000 implementation report recommendations for headwaters storage of the South Fork and increased UPRR storage were never implemented, again, due to a lack of funding and/or impractical approach. The city's recent Evers Blvd. storm sewer interceptor project has decreased the need for additional headwaters storage for the North Fork of Dry Creek but there remains potential benefit for increased headwaters storage for the South Fork. The 2000 Union Pacific sump recommendation really wasn't feasible from a property acquisition perspective, but this study does recommend improvements to the sump location as well as emergency spillway improvement for the North Fork FEW detention storage.

This study evaluates both existing and future development conditions to estimate peak runoff volumes and discharges for a range of storm events at key design points along the Dry Creek channel. ***There is more emphasis in this study on the restoration of riverine functions and inclusion of multiple amenities within the planning approach that will provide additional value and longevity to this plan update***. Creek restoration recommendations provide both an improved quality of experience for the community and a reduced long-term maintenance cost by improving the low flow conveyance channel and reducing instances of excess vegetation and deposition of sediment which impact capacity.

The 1988 report did not place significant weight on restoration of riverine function for Dry Creek nor the added value to the community that this would bring. The 1988 Plan also did not focus on water quality features, park, and greenway amenities to any significant extent; or how these projects could facilitate economic development within the basin and incentivize private-sector investment. As an example, the 2010 Lower Dry Creek Constructed Wetland Project (another capital improvement project never envisioned in the 1988 or 2000 reports) was based on a public/private partnership between the County and a local landowner. This project was developed to facilitate residential development adjacent to the newly constructed wetland/pond and provide much needed water quality for the Dry Creek basin. This project would not have ranked very high in the original 1988 report but is now the centerpiece of Cheyenne's newly created East Park adjacent to the recently developed Chukker Ridge subdivision and was funded, in large part, with EPA-319 funding.

The major features of the 1988 selected plan included improved roadway crossings along the entire study reach, storm sewer along Evers Blvd., and detention storage ponds for the South Fork headwaters on FEW, upstream of Powderhouse Rd., and between the UPRR and Campstool Rd. Our updated plan focuses on those crossings that remain life-safety hazards and/or property damage hazards, detention storage for the South Fork headwaters including emergency spillway provisions for the existing North Branch headwaters detention storage on FEW, significant storage expansion in Mylar Park with additional storage and water quality enhancements for the Powderhouse reach, dam-safety improvements for the UPRR Sump, additional storage for the U.S. 30 to E. Pershing Blvd. reach, and significant consideration and emphasis on restoration of riverine functions, maintenance, inclusion of multiple greenway and park amenities. Moreover, the updated project recommendations are prioritized for potential for outside state and federal funding opportunities.

In general, the known drainage issues involve one or more of the following conditions:

- Flow constrictions
- Structures being located within drainage pathways
- Shallow overland flooding
- Insufficient culvert capacities and/or roadway overtopping

- An increase in basin imperviousness
- Limited storm drain systems with minimal capacity
- Impacted functionality of the creek due to urbanization, excess sediment, and/or excess vegetation
- Lack of consistent maintenance

Our mitigation measures include both structural and nonstructural recommendations to address the above referenced shortcomings in the study area. **Table 2** documents the selected plan summary of improvements. Our structural measures include the following:

1. enhanced/expanded storage in key locations to attenuate and reduce peak discharge at design points along the study reach, reducing the size of required conveyance elements.
2. improve and enhance the existing conveyance in the study area and provide new conveyance elements where appropriate.
3. and creek restoration projects to reduce annual maintenance costs and complement greenway and park amenities.

Both the hydrologic and hydraulic models incorporated in the master drainage plan update are several generations improved over the United States Army Corps of Engineers (USACE) HEC-1 and HEC-2 models used for the 1988 study. HEC-1 (Hydrologic Engineering Center's Hydrologic Modeling System) is a comprehensive hydrologic modeling system developed by the U.S. Army Corps of Engineers. It is more general-purpose and widely applicable to a range of hydrologic studies beyond urban areas. HEC-1 is used for river basin analysis, flood forecasting, dam and reservoir operations, and watershed studies. HEC-HMS is the successor modeling system to the original HEC-1 model.

EPA SWMM primarily focuses on urban stormwater management. It is designed to simulate the quantity and quality of stormwater runoff in urban areas, including runoff generation, conveyance, and pollutant transport. It is commonly used for analyzing stormwater infrastructure, flood control, and water quality management in urban settings. HEC-1 employs a lumped-parameter approach, dividing the watershed into sub-basins and analyzing the hydrologic processes within each sub-basin. HEC-1 models precipitation, evaporation, infiltration, and routing of excess rainfall using various hydrologic methods. EPA SWMM is a dynamic rainfall-runoff model that combines hydrologic and hydraulic components. It integrates rainfall, runoff generation, conveyance, and water quality processes within an urban drainage system. It uses a network-based approach to simulate stormwater flow through the interconnected system of pipes, channels, street conveyance, overland flow, and storage units.

The 1988 HEC-1 model had 14 contributing subbasins. The EPA SWMM model developed for this plan update has well over one thousand subbasins providing a much-refined hydrologic model. The SWMM model incorporates subbasin width, rainfall intensity, rainfall distribution, antecedent moisture conditions, and hydraulic properties of the drainage system in determining the peak discharge. The model utilizes a combination of these parameters and calculations to simulate stormwater runoff for a rainfall event.

Table 2. Selected Plan Summary of Improvements by Implementation Priority			
Project Location	Description	Matrix Score	Rank
Union Pacific Railroad Crossing	Reconfiguration of Storage	11.75	1
Mylar Park Improvements	Increase storage/Wetlands	10.75	2
FEW South Fork Improvements	New Storage/Wetlands for South Fork	9.75	3
Carey Reservoir Modifications	Inlet Modifications	9.75	4
Hilltop Ave. Crossing	Reduce Overtopping	9.75	5
Prairie Ave. Crossing	Eliminate Crossing	8.75	6
Education Dr. Crossing	Reduce Overtopping & Redirect into Westgate Pond	8.75	7
Gateway Dr. Crossing	Eliminate Piping & Overtopping of Gateway Dr.	8.75	8
Seminoe Crossing	Eliminate Overtopping	8.75	9
Westgate Pond	Repair Outlet Works & Expand Storage/Wetlands	8.25	10
Debris Blockage Policy Revisions	Recommendations for Mitigative Measures	7.75	11
Powderhouse Corridor	Water Quality, Greenway Improvements, & Minor Storage	7.75	12
Realigned Sheridan Reach Flow	Realign Main Channel Flow	7.25	13
Sheridan Street Capacity Improvements	Increase Low Flow Capacities	7.25	14
U.S. 30 Levee Reach	Acquisition of Properties & Elimination of Levee	7.25	15
Cheyenne Street/Polk Ave.	Increase Upstream Storage to Reduce Overtopping of Polk Avenue	7.25	16
Powderhouse to Carey Reservoir	Lower Gradient & Improve capacities into Carey Reservoir	7.25	17
Reach Upstream of N. College Dr.	Reduce Excess Vegetation & Dredge Sediment Deposition	7.25	18
Mountain Rd. Crossing	Reconstruct Hydraulic Structure	7.25	19

McCormick/Central Campus Channel Improvements	Regrade, Dredge, & Remove Excess Vegetation for Positive Conveyance of Flow	5.75	**20**
Yellowstone Downstream Reach	Regrade, Dredge, & Remove Excess Vegetation for Positive Conveyance of Flow	5.75	**21**
Dry Creek Disc Golf Course	Minor Drainage and Recreational Improvements for this Reach of Dry Creek	5.75	**22**
Drainage Requirements	Revision of Current Drainage Regulations	6.25	**23**
Property Acquisitions	Property Acquisitions along the East Side of Pierce Ave. & the North End of Parsons Pl.	6.25	**24**
Property Acquisitions	Property Acquisitions along Rock Springs Street & Cleveland Ave.	6.25	**25**

Table 2. Selected Plan Summary of Improvements by Implementation Priority

The improvements in **Table 2** are listed in priority order of recommended implementation. The criteria used to develop the priority order is as follows:

- Life-Safety Hazards due to Flooding
- Property Damage Hazards due to Flooding
- Potential for Outside State and/or Federal Funding
- Protection of Critical Facilities (I-80, I-25, Union Pacific Railroad Crossing, BOPU Treatment Plant)
- Social and Economic Impacts
- Drainage Improvements
- Feasibility of Implementation
- Improvement/Protection of Environmental Resources including Aquatic Species

Our nonstructural measures include the review of the existing Unified Development Code and Municipal Code. An evaluation of the 2014 Cheyenne Unified Development Code (UDC), Article 3, Section 3.2 – Drainage Impact Studies for relevance and effectiveness will be included as a future appendix to this report. With this project, the city has requested that we provide an update to the Storm Drainage Criteria and specifically the 2014 UDC Article 3, Section 3.2 – Drainage Impact Studies which was updated in 2015 by the city.

We are proposing a review of the Urban Storm Drainage Criteria Manual (Mile High Flood District) and adoption of those criteria appropriate for Cheyenne's elevation and precipitation patterns. We would then enhance the Mile High District Drainage Manual with additional criteria specific to Cheyenne including additional water quality standards. Much of the Mile High District criteria has become the industry standard for many communities along the Front Range. The city is currently transitioning from a reliance on WyDEQ inspectors to enforce construction site Clean Water Act violations to taking over the enforcement role as a function of the City's updated Storm Water Management Plan required under their WyPDES permit (MS4 compliance) with the state. This new enforcement role is authorized under a new ordinance and consideration will be given to tying this to new stormwater quality criteria for land-use development activities.

Included in Chapter X of the updated report is a recommended strategy of implementation with a priority ranking of structural solutions based on life-safety hazards, property damage due to flooding, and potential for outside funding for specific projects. Our recommended mitigation measures account for future developed conditions in the study area and adjacent corporate areas and include a phased approach. Our structural solutions incorporate a cost-effective approach and the most likely projects to be eligible for outside funding based on preliminary benefit-cost analyses. Next steps based on the plan conclusions, should be the development of a multi-year Capital Improvements Plan/Budget for implementation of the proposed structural/nonstructural solutions. Potential outside funding opportunities should be identified along with project grant application requirements and application deadlines for specific projects. Consideration should be given by the city to adopt a Storm Water Utility to provide the financial resources required for both annual maintenance and development of a Capital Improvements Projects list for the Dry Creek Basin.

II. INTRODUCTION

A. History/Characteristics of the Basin

The Dry Creek Drainage Basin drains approximately one third of the city of Cheyenne. It is generally formed by bluffs and rolling hills, characterized by steeper channels through the Western Hills subdivision upstream of I-25 and gradually decreasing channel slopes downstream of the interstate. The basin encompasses approximately 16 square miles (the 1988 study listed the size as 14.6 square miles). The headwaters of the basin are located west of the corporate limits on Francis E. Warren Air Force Base (FEW) where the basin has steep terrain with surface gradients of up to 360 feet per mile. The lower basin surface gradients decrease to approximately 250 feet per mile. The Dry Creek Drainage Basin extends 11 miles northwest of its confluence with Crow Creek.

Basin characteristics can strongly influence runoff patterns along with the susceptibility to flash floods. The 1985 flood event along Dry Creek has been described as a flash flood. One of the two storm cells from the 1985 event was centered over the headwaters of the Dry Creek basin. The intensity of rainfall combined with the time-to-peak produced significant peak discharges throughout much of the basin, particularly through the Sheridan Reach where twelve people perished during the 1985 flood. The long narrow basin shape, increased urbanization, and short time-of-concentration for runoff to enter the main channel combine to exacerbate flash flood risk. Factors that increase the speed and efficiency of stormwater runoff conveyance can make a basin more prone to flash flood conditions. The basin has continued to develop in the north and east areas of the city since 1988 somewhat as predicted by the future conditions land use predictions in the 1988 study. The increased urbanization of the upper basin since 1988 has increased the percentage of impermeable surfaces and compacted soils. The basin in 2023 now has a greater volume of runoff to contend with along with added roadways and storm sewers accelerating stormwater runoff to the main stem of Dry Creek.

Soils

A soils survey of the Dry Creek Basin is included in the National Cooperative Soil Survey, a joint effort of the United States Department of Agriculture, Natural Resources Conservation Service, and the Wyoming Agricultural Experiment Station "**Soil Survey of Laramie County, Wyoming, Western Part**" (1993). Soils series in the basin include the 104 Ascalon Loam, 131 Evanston Loam, 145 Merden Silty Clay Loam, 162 Pooshia Trimad Complex, 188 Urban Land Poposhia Complex, and 189 Urban Land Poposhia Trimad Complex. For the most part, soils in the basin are deep and well-drained, and have moderate permeabilities. Runoff is classified as generally slow to moderate. Along the drainageways and floodplains, soils are poorly drained and have low permeabilities.

The NRCS classifies soils into hydrologic soil groups (HSG) based on the minimum infiltration rate obtained for bare soil after prolonged wetting. Within the Dry Creek Basin, HSG B is prominent, covering 3/4 of the basin. HSG D covers the remaining 1/4 of the basin. Minimum infiltration rates for HSGs B and D are 0.15 to 0.30 inches/hour and 0.0 (no infiltration) to 0.05 inches/hour respectively (SCS, 1986).

In conjunction with the potential flash flood risk for the basin, there remains a hazardous constriction of flow at the Union Pacific Railroad (UPRR) crossing. Currently drainage flows through the UPRR embankment via a historic 6' wide x 8' tall box arch masonry structure. This structure is in red in **Figure 7**. The structure was built by the UP in 1903. The Dry Creek drainage basin contributing flow upstream of the UP culvert is approximately 12 sq. mi. in size. The lower portion of the basin, just upstream of the UP is quickly developing. Existing conditions are such that during a large storm event, stormwater is impounded against the UP Embankment until it can flow through the masonry structure. The existing embankment is approximately 25' tall in the vicinity of this arch structure. The image below indicates the FEMA 100-Year Floodplain and Floodway in the vicinity of this arch structure (the red line in the image.)

Figure 6.

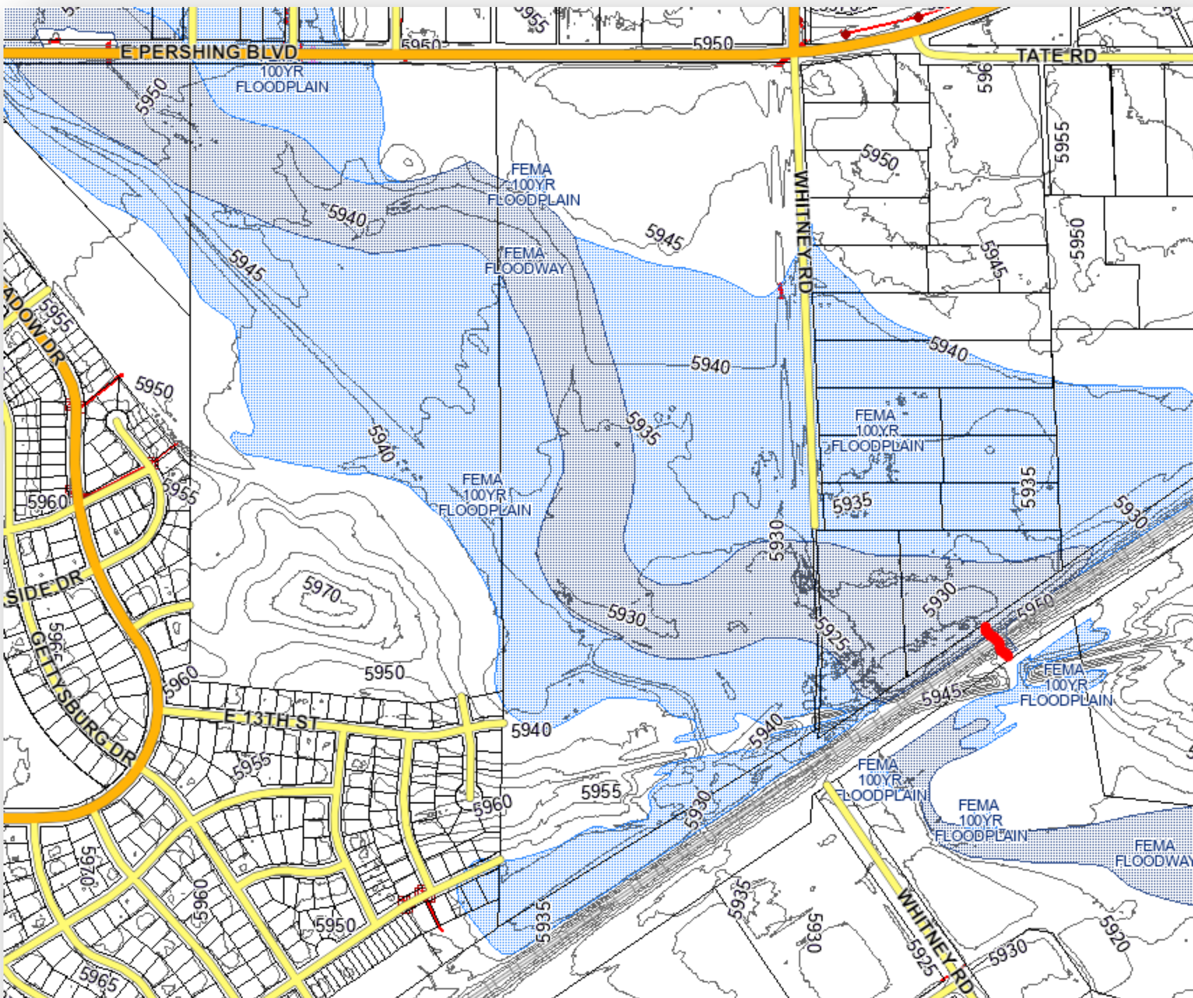


Figure 7. Historic UPRR Culvert Location

B. Land Use and Urbanization

The Dry Creek Basin was mostly urbanized in the upper and middle portions of the basin at the time of the 1988 Master Plan development. In the preceding 35 years, the upper and middle portions of the basin are approaching full urbanization while the lower portion is now quickly following with new developments and subdivisions being built. The LEADS Business Park located in the southeastern corner of the city is filling up with light and heavy industrial use. The imperviousness of the basin has increased since 1988 resulting in higher peak stormwater runoff and increased potential for risk of flooding. The ongoing urbanization of the basin has led to altered drainage patterns resulting in diversion of stormwater runoff, concentration of runoff to specific areas, and exacerbation of existing off-channel drainage issues.

C. Authorization

In April 2022, the City of Cheyenne Purchasing Office issued a request for proposals (RFP) for the Dry Creek Master Plan Update and Drainage Code Review for the Dry Creek Drainage Basin. GLM Design Group in partnership with DHM Design, ICON Engineering, and Steil Surveying Services teamed up for this study and were awarded the contract in May 2022.

D. Purpose

This master plan update is intended as a planning tool providing an evaluation of existing conditions, a comparison with 1988 results, and proposals for capital improvements and mitigation efforts to address remaining high-life safety hazards and property damage hazards due to flooding. This plan is based upon a technically driven hydrologic and hydraulic analysis to achieve the goals listed in the plan. The plan includes a priority ranking of stormwater infrastructure and mitigation measures along with an implementation schedule based on life safety hazards, property damage hazards, and potential for outside state and/or federal funding. Also recommended in the updated plan are creek restoration projects to restore and enhance the natural ecosystem of Dry Creek, including its water quality, habitat diversity, and overall ecological function. By improving the physical and biological components of the creek, restoration projects can support the recovery of native plants and animals, enhance biodiversity, and promote the overall health of the ecosystem.

Moreover, these projects can increase conveyance capacity and reduce maintenance requirements. Creek restoration projects include measures to manage and reduce flooding risks. Naturalizing stream channels, creating floodplains, and implementing bank stabilization techniques will help reduce the intensity and frequency of floods for select reaches of the creek. These projects will also help prevent erosion, protect adjacent lands from degradation, and stabilize stream banks, reducing sedimentation and the potential for property damage.

The restoration efforts will improve water quality in the creek and downstream water bodies, helping the city with its federal Clean Water Act MS4 compliance efforts. Restoring natural stream channels and reducing erosion helps decrease sedimentation and nutrient runoff, leading to improved clarity and reduced pollution levels. This, in turn, benefits aquatic organisms and downstream ecosystems. There is also a recreational and aesthetic value for our recommended creek restoration projects. Restored creeks often provide improved recreational opportunities for local communities. These projects will enhance the overall Greater Cheyenne Greenway experience. The proposed projects will improve overall aesthetics of the Dry Creek corridor, enhancing the visual appeal of the landscape and creating a sense of natural beauty within the urban area, as well as increasing adjacent property values.

E. Acknowledgements

GLM Design Group and our partners, DHM Design, ICON Engineering, and Steil Surveying would like to thank the City Engineer's Office staff and project stakeholders for their assistance and guidance during this project. We would like to also thank Mr. Kelly Hafner for his expert guidance and review comments of the supporting EPA SWMM hydrologic model.

Input from the City Engineer, Tom Cobb and the Deputy City Engineer, Wesley Bay has been instrumental in the development of the Decision/Design Log and the corresponding implementation ranking for the recommended projects and mitigation measures of this report.

III. PROJECT AREA

A. Mapping and Data Sources

Data sources utilized for this project include 2019 aerial LiDAR topography datasets and Geographic Information System (GIS) assessor datasets provided by the Cheyenne/Laramie County GIS Cooperative Information Technology. Aerial imagery included 2019 and 2020 high-definition imagery available from the Cheyenne/Laramie County Cooperative. The 2-foot contour data from the LiDAR UTM coordinate system was re-projected onto the Wyoming State Plane. The assessment in this report is largely GIS based and/or ground observations. Datasets generated with the assessments are GIS 'grid' based. A survey was also gathered to supplement GIS information specifically for channel crossings of the Dry Creek channel.

The Area of Study is approximately 16 square miles and includes areas with higher density development, rural residential, commercial development, and undeveloped areas as shown in **Figures 8, 9, and 10**. The existing land-use is largely urban residential (low and medium density) with a significant area of commercial development (community business) along Dell Range Blvd. and along N. College Dr. in the mid- and east portions of the drainage basin. Urban residential is predominately located in the upper and mid-portions of the basin and along the southeastern perimeter. Light and heavy industrial land use is predominant in the lower basin. There are also PUD zoned and Public zoned areas scattered throughout the basin.

The historically rural residential areas in the lower basin are now being developed into higher density urban residential areas to accommodate the community's growing population with townhouses and apartments. This growth is placing additional pressure on the city's stormwater management as the City Engineer's Office manages the design and construction of new stormwater infrastructure including a major storm sewer system to convey runoff from the E. Dell Range Blvd. corridor to an outfall in Dry Creek upstream of the U.S. 30 crossing.

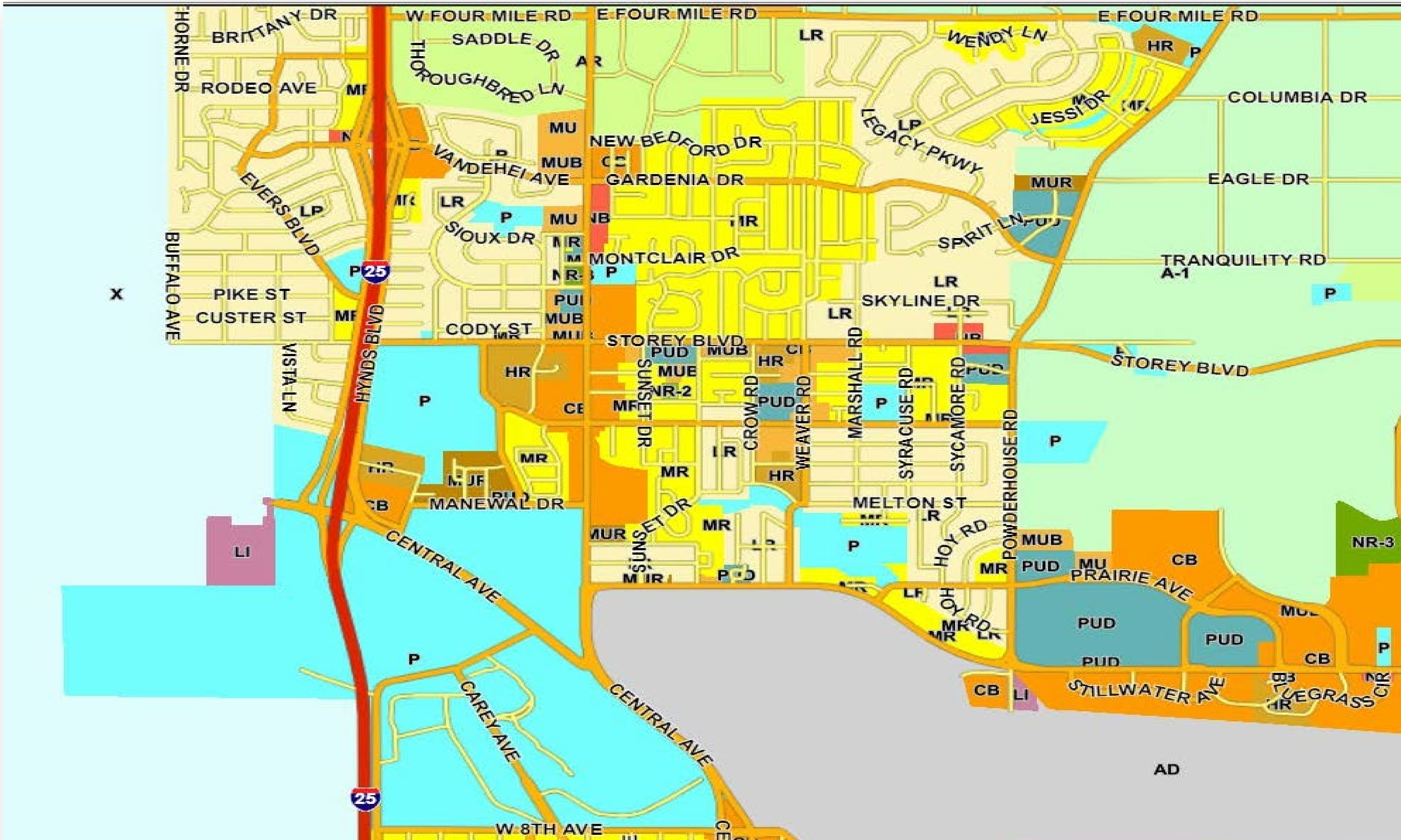


Figure 8   Upper Basin Existing Land Use

Figure 9 Mid Basin Existing Land Use

Figure 10 Lower Basin Existing Land Use

B. Project Area and Existing Land Use

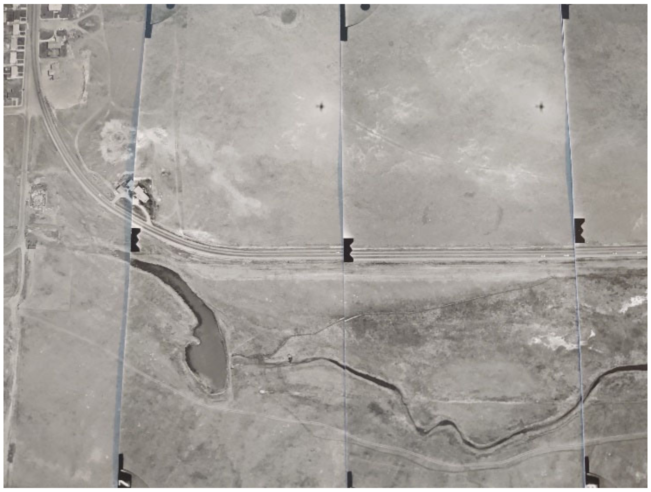
The 15.9 square mile study area is predominantly urban residential and has been mostly platted and subdivided over the last seven decades. Denser urban residential land use is quickly developing in the northeastern and southeastern areas changing the historical rural and agricultural land uses. Future urban residential development will likely fill in areas along the eastern perimeter of the study area, further exacerbating existing drainage issues with increased peak stormwater volumes and discharges. This will particularly impact on the Union Pacific sump area (sump 130 in the original 1988 study).

The Dry Creek Basin is generally formed by bluffs and rolling hills with its headwaters located on Francis E. Warren Air Force Base (FEW) property where runoff enters the city in either the North Fork or South Fork of Dry Creek within the Western Hills subdivision. Refer to **Figures 11 and 12**. At the time of the March 2000 Surface Water Drainage Committee Final Report, the consensus of committee members from the city, County, WyDOT, and F.E. Warren AFB was to divert floodwaters from the north headwaters' detention pond to the south fork headwaters. This remains a recommendation of this study update as it would reduce the cost for improvements to the emergency spillway for the north fork detention pond.

The Dry Creek Drainage Basin shape is generally linear, with stormwater runoff contributing along the entire course of the Dry Creek channel. The response time of the basin to rainfall-runoff events is relatively rapid, leading to a quick rise in water surface elevations in the creek. Intense rainfall events in the basin can overwhelm the creek capacity with rapid runoff, resulting in an increased flood risk. The 1988 study presented a flood-control plan to protect properties from projected damages ($6,540,000 1988 damage estimate) and reduce the major life-safety hazards due to flooding in the basin.

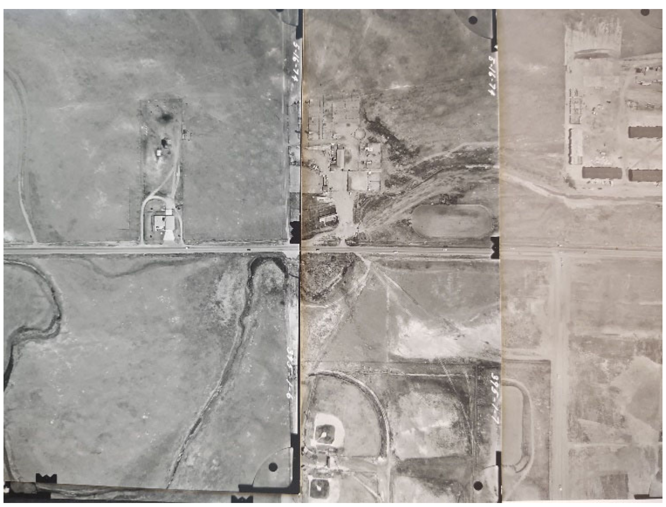
Approximately 9% of the Basin is located west of I-25. Slightly more than half of this is located on FEW property and remains undeveloped. The remaining area west of I-25 is within the city's Western Hills subdivision, a primarily single-family development. As was the case for the 1988 study, land use downstream of I-25 is in various stages of development with the upper and middle portions of the basin now nearly entirely urbanized. The change in impervious area since the 1988 study is easily 50% greater.

Prior to development of the Basin, Dry Creek meandered across a generally broad, shallow floodplain covered with native prairie grasses. Wyoming Department of Transportation (WyDOT) aerial photographs beginning in the 1950s show an un-encroached channel through the 1970s when development began to severely encroach into the natural floodplain. Significant reaches of the creek have been altered and channelized. The only remaining floodplain that is relatively undisturbed is in the lower basin due to a lack of development, but that is rapidly changing with new subdivisions and planned unit developments coming online. The aerial to the right is located at the present-day Powderhouse and Dell Range Blvd. intersection prior to the extension of Dell Range Blvd. to the west. Note the dam and pond area.



This area is on the south side of present-day Dell Range Blvd. in what is now the Meadowbrooke Park subdivision. Note the extent of the floodplain.

Contractors have told stories of how challenging it was to build infrastructure and buildings on what was bottom land for Dry Creek.



Note the City of Cheyenne Cole Fire Station 01 on the north side of Dell Range Blvd. in the Cole Fire Station Addition.

Figure 11. North Fork of Dry Creek in Western Hills

Figure 12. South Fork of Dry Creek in Western Hills

The basin below I-25 has experienced an increase in development since 1988 with an overall increase in impervious areas from residential and commercial developments and roadways. Additionally, there are new storm sewer systems concentrating and contributing stormwater runoff much quicker to the main channel of Dry Creek.

The Dry Creek channel ranges from a narrow, confined channel to a broad, shallow flood plain. The main channel through the upper and middle portion of the basin is characterized by depths ranging from 3- to 8-feet with bottom widths ranging from 10- to 50-feet. A lack of maintenance for much of the main channel has resulted in reaches with overgrown vegetation and sedimentation issues, compromising the conveyance capacity and increasing the flood risk. The main channel downstream of Ridge Road is generally characterized by a low flow channel less than 5-feet wide and less than 2-feet deep with a broad, shallow floodplain. This portion of the basin is quickly developing with new residential subdivisions.

In the upper and middle portion of the basin, urbanization has encroached into the floodplain and, in certain reaches, has eliminated the floodplain altogether. The main channel is experiencing stability problems where it has been impacted by urbanization. The floodplain has been relatively undisturbed in the lower portion of the basin but, this is now changing as this part of the basin is being developed.

At the time of the 88 study, two flood control detention storage facilities were in the basin. The uppermost pond was located on the north tributary of Dry Creek at the eastern boundary of FEW and the Western Hills subdivision. This facility is still in operation in 2023. The North Fork storage facility has a capacity of 5.5 Ac-ft for the 100-year event. A second detention storage facility (Carey Reservoir) is located south of Dell Range Blvd. between the pedestrian bridge crossing and Converse Rd. adjacent to Cheyenne Regional Airport property. Carey Reservoir has a capacity of 103 Ac-ft for the 100-year event and currently functions as an off-line storage facility. This facility is now a part of the Sheridan Reach Flood Control Project and is in series with four additional downstream detention storage facilities between Converse Rd. and Cahill Park.

Significant ponding areas also present for the 88 study and modeled in the hydrologic HEC-1 model were the Powderhouse sump (Sump 70 in the HEC-1 model), the U.S. 30 sump (Sump 110 in the HEC-1 model), and the Union Pacific Railroad sump (Sump 130 in the HEC-1 model). These sumps continue to exist but are modeled differently by the 2023 EPA SWMM model.

C. Flood History & Known Issues

In the 1988 Dry Creek Drainage Master Plan Report, flood problems were classified as life-safety hazards and/or as property damage hazards. High life-safety hazard locations were defined as those areas on roadways or near structures that met one or both of the following criteria:

- 100-year flood depth exceeded 2-feet.
- The product of the 100-year flood depth (in feet) and velocity (in feet per second) equaled 6 or greater.

There were 35 high life-safety hazard areas identified in the 1988 report including the entire Sheridan Reach - Mountain Road, Windmill Road, and Hilltop Avenue crossings where multiple fatalities occurred during the 1985 flood event. There remain areas of concern and life-safety issues along the drainage in 2023. There are 11 roadway crossing instances of overtopping in the updated model, five of which can be considered life-safety hazards, Gateway Dr., Seminoe Rd., Prairie Ave., Hilltop Ave., and Rawlins Street crossings. The update of this report corresponds with the 38th year anniversary of the 1985 storm event. The 1985 storm sat motionless over Cheyenne for over three hours unleashing as much as seven inches of rainfall and a considerable amount of hail causing the most devastating flood in Wyoming history. The 1988 Master Drainage Report that followed in the aftermath was a successor report to the ***1972 Dry Creek Drainage Basin Study by Hudspeth, Noblitt & Ball*** and the follow up ***1979 Dry Creek Drainageway***

Planning Report by BRW/Noblitt and Wright-McLaughlin Engineers. The following are known issues remaining to be addressed in 2023.

Headwaters to Yellowstone Rd. Reach (SubBasins 10, 20, 30, 40, 50, and 60 from 1988 study)

- Lingering capacity issues for south fork Discharge conveyed between the backs of houses within the Western Hills subdivision between the corporate limits and I-25 (potential property damage concern and roadway flooding of Bishop Blvd.).
- During a 100-yr event there is over ***330cfs from the F.E. Warren Air Force base (FEW) to the west that overtops an alley into the South Fork of Dry Creek***. (Potential property damage concern).
- Emergency spillway concerns remain for the North Fork FEW reservoir (Potential property damage concern in the case of a breach).
- Channel conveyance/excess vegetation & sediment for McCormick/Central campus resulting in high tailwater conditions for North Fork, South Fork, and Hynds Blvd. storm sewer outlets and flooding of Greater Cheyenne Greenway path on campus.
- Overtopping concerns at Education Dr. crossing (property damage hazard and infrastructure concerns). During a 100-year event ***approximately 550 cfs overtops Education Dr. and flows onto Carlson St.*** The water ponds on at a low point on Carlson St. at Gateway Dr. before it overtops to the south and back into Dry Creek.
- Significant overland flow between Western Hills Blvd. and Dry Creek (Property damage concern).
- Overtopping concerns at Gateway Dr. crossing (potential Life-safety hazard). There is more than ***260cfs overtopping during a 100-year event.***
- Dam-safety issue/Gateway Dr. crossing piping issue (Property/infrastrusture damage concern).
- Cody and Pawnee St. will experience 126 cfs during a 100-yr event. A 42 in culvert drains the intersection. The culvert has capacity of 70cfs. The remaining ***flow overtops Pawnee Ave to Western Hills Blvd*** *(impact on the travelling public).*

Yellowstone Rd. to Powderhouse Reach (SubBasin 70 from 1988 study)

- Overland flood risk from surface conveyance between Storey Blvd. and Dry Creek through Indian Hills subdivision. Storm drain outfalls also contribute excess sediment into the creek (***MS4 compliance issue***).
- There is an existing storm drain system that originates near Storey Blvd and Sycamore Road. The systems discharges into Dry Creek at Mylar Park Dr and Wahoo Pl. The system ranges in size from a 24in to a 48in circular pipe. By the time the system discharges into Dry Creek it has collected over 168cfs. However, there is approximately ***130cfs remaining on the street (Property damage concern).***
- Flooding/overtopping of Sunset Dr. crossing (property damage concern). Approximately ***90cfs will overtop the banks of Dry Creek and flow to the north and onto Marjon Ct before overtopping the road and back into the creek***. This issue is currently being addressed by a local developer in partnership with the city.
- Approximately 70 acres drains to the intersection of Crow Rd. and Melton St., contributing 312cfs during a 100yr event. A portion of the flow is captured in a 48-in circular storm drain, the remaining ***90cfs is conveyed as overland flow to Dry Creek***. This area has known sediment issues in the storm drainage system as well as the storm overflow location to Dry Creek (Property damage hazard and potential MS4 concern).

- Flooding/overtopping of Seminoe Rd. (life-safety hazard). This crossing consists of dual 7ft culverts. Due to the lack of head on the culverts, the ***road overtops by over 730 cfs*** (Serious life-safety hazard and infrastructure concern).
- Flooding/overtopping of Prairie Ave. crossing (Critical life-safety hazard and infrastructure concern). This crossing will experience approximately 1950cfs during a 100-year event. The three 48-in circular culverts at this location are severely undersized resulting in over ***1400cfs overtopping the road.***
- Flood inundation of property along Hoy Rd. (Property damage hazard) caused by the backing up of flows at Powderhouse Rd.
- Overtopping of Powderhouse Rd. with corresponding flood inundation of commercial properties along Dell Range Blvd. (D***ebris blockage and modeling consideration***).

Powderhouse Rd. to Carey Reservoir Reach (SubBasin 80 from 1988 study)

- A drainage channel runs along the center of the median on Prairie Ave from Powderhouse Rd. to Frontier Mall Dr. The drainage channel does not have capacity to convey the storm flows and therefore overtops, finding its way to the roundabout at Prairie Ave. and Frontier Mall Dr. There is an existing 48-in culvert at the intersection. Unfortunately, approximately ***145cfs does not reach the culvert, thus remaining on the street and flowing south along Frontier Mall Dr****. (Roadway flooding hazard)*.
- Continued development of former Cole property may place an additional burden on Prairie Ave. storm drain system. This area will ultimately drain to the drainage swale along Dell Range Blvd. The swale crosses under Dell Range Blvd through dual 54" circular culverts. These culverts are at capacity, any additional flow to the system will overtop the drainage swale and head east along Dell Range Blvd. (Roadway flooding hazard and infrastructure concern).
- Significant capacity constraint immediately upstream of Carey Reservoir (Potential property damage concern due to negligible freeboard).

Sheridan Reach (SubBasins 90 and 100 from 1988 study)

- Overtopping of Mountain Rd. by approximately ***50cfs during the 100-yr flood*** with no debris blockage (impact on the travelling public). Mountain Rd. crossing is also in poor condition (Infrastructure issue).
- There are two detention ponds located on the south end of the Walmart/Sam's Club parking lot. These ponds overtop during a 100-year event, discharging over ***100cfs onto Dell Range Blvd***. (Roadway flooding and property damage issue).
- Capacity constraint for Sheridan Reach (Property damage hazard).
- Hilltop Rd. crossing needs repair. ***Overtopping of Hilltop Rd. by approx. 90cfs*** (Life-safety hazard and infrastructure concern).
- Continued development of middle and eastern portions of former Cole property will add additional peak discharge and volume to the Sheridan Reach (Life-safety and property damage hazard).
- Plain View Rd./Chapel Hill Dr. intersection has a drainage basin of over 48 acres, contributing 170cfs. This area is drained by an under capacity 24in storm system, leaving 145cfs on Plain View Rd. The overland flow, not collected in the 24-in storm drain, continues south to Pattison Ave. A storm drainage system ranging in size from a 18-in to 42-in circular pipe, travels along Pattison

and Pineridge and ultimately discharges into Dry Creek. The system collects 75cfs, the remaining ***191cfs sheets flows across Sheridan St. and into the Dry Creek Channel*** (Life safety concern and property damage hazard).

Ridge Road to U.S. 30 Reach (SubBasin 110 from 1988 study)

- Basins along Everton, between Ridge Rd. and Harmon Ave. sheet flow through the back of homes as it makes its way to Gregg Way. The lack of drainage swales and curb & gutter in the area does not give the drainage in the area a clear drainage path (Property damage hazard).
- Approximately 44 acres contribute to the intersection of Messenger and McCann where over ***120cfs overland flows through the area and to Rock Springs St. Rock Springs St. conveys over 130cfs to Dry Creek*** (Roadway flooding concern).
- Significant increase in peak flow through this reach with future development along E. Dell Range Blvd. (Whitney Ranch). There is potential for overland, urban flood risk and capacity issues for the receiving city storm sewer systems. Discharge from this subbasin impacts low flow pedestrian crossings located between Ridge Rd. and US 30 as well as the downstream US 30 crossing. Overtopping of E. Dell Range Blvd. runoff will impact residential properties located in the County (Potential property damage hazard).
- The minimal storm drainage system along N. College Dr., south of Dry Creek, causes flooding concerns as the area continues to develop (Roadway flooding and property damage concern).
- New storm sewer system from Whitney Ranch and E. Dell Range Blvd. to Dry Creek outfall will accelerate peak discharges into main channel of Dry Creek upstream of U.S. 30.
- There is over 2050cfs in Dry Creek at Rawlings St. The four 36-in circular culverts at this location can only convey 220cfs, the remaining ***1830cfs overtop the road*** and back into Dry Creek (Life safety concern).
- Over ***100cfs sheet flows during a 100-year event to the intersection of Eastview St and Rangeview Dr.*** where it overtops and flows between homes to Dry Creek (Property damage hazard).

U.S. 30 to E. Pershing Blvd. Reach (SubBasin 120 from 1988 study)

- Levied system between U.S. 30 and E. Pershing Blvd. was never certified (Potential modeling issues with FEMA).
- Overtopping of E. Pershing Blvd. (impact on the travelling public).
- Split flow at E. Pershing Blvd with potential overtopping at both flow locations (Modeling considerations).
- Hazardous overtopping condition for the Cheyenne Street/Polk Ave. intersection (impact to the travelling public and the adjacent neighborhood).

E. Pershing Blvd. to UPRR Crossing Reach (SubBasin 130 from 1988 study)

- Minimal storm drainage system along Meadow Dr. resulting ***in flow in the street of over 100cfs at some locations***. The system was designed to overtop and flow between homes to Dry Creek. Fences block the way in some of the drainage pathways (Property damage hazard).
- Added peak discharges from new developments at Dakota Crossings, Saddle Ridge, and Chukker Ridge (Additional impact to UPRR – sump 130 in original study).

- Overland surface flooding issues in Sun Valley subdivision. Lack of downstream drainage easements for conveyance of runoff to Dry Creek across private property (Drainage easements required at some locations).
- Dam-Safety issue at UP embankment (Life-safety and property damage hazard due to potential breach hazard/infrastructure concern).
- Sump 130/UP embankment required to meet Wyoming Safety of Dams requirements.
- Existing capacity constraint at UP Sump impacting future development of the lower basin.

UPRR Crossing to Upper Campstool Rd. Reach (SubBasin 140 from 1988 study)

- Overtopping of Campstool Rd. (potential property damage hazard).
- Coordination with Laramie County Conservation District (LCCD) required for changes to discharges from Union Pacific sump.

Upper Campstool Rd. to Confluence with Crow Creek (SubBasin 140 from 1988 study)

- Some roadway flooding of Downstream Campstool Road.
- ***Overtopping of I-80 of over 130cfs during a 100-yr event*** (Potential life-safety hazard and impact to travelling public). This is an effective model condition. This Study's HEC-RAS model does not indicate overtopping of I-80 for the existing conditions.

The Evers Blvd. storm sewer was recently completed. The FEW South Fork detention storage is still being recommended with this update. The previously recommended Powderhouse Rd. detention is now recommended for upstream Mylar Park with added water quality and minor storage improvements recommended for the Powderhouse Rd. reach in coordination with the Rotary Club of Cheyenne. A revised debris blockage policy update is discussed later in this report. Additionally, there are multiple culverts in need of repair or replacement and many of the reaches have excess vegetation and sedimentation due to lack of regular maintenance resulting in a decrease of conveyance capacity. The 1988 conditions have changed considerably with added urbanization of 1988 subbasins 80, 90, 100, 110, 120, and 130. The headcut erosion damage to the downstream end of the upper Campstool culverts in subbasin 140 has been recently corrected with a rirpap scour basin at the culvert outlet. The construction of the Sheridan Reach Flood Control Project in 2008 addressed the six highest ranked projects from the 1988 Report and has served the community well since then in reducing the peak discharges through the Sheridan Street reach. On-going development of the former Cole property along with property north of the Buffalo Ridge subdivision continues to add pressure to this reach. Interestingly, Buffalo Ridge and the Sheridan Street reach were mentioned in the earlier 1972 Dry Creek Study as an issue.

D. Existing Floodplains and Special Flood Hazard Areas

This report is not re-analyzing the North Fork (Evers Blvd.) as a part of this study update because this reach has just been completed including a Letter of Map Revision (LOMR) reviewed by staff and submitted to FEMA. This report's hydraulic analysis begins at the South Fork boundary with the Base. The corresponding EPA SWMM hydrologic model does consider the full basin including the North Fork subbasins that were used for the recent LOMR. This peak discharge is combined with the South Fork flow at the confluence of North and South Forks at the western end of the McCormick – Central campus.

Vista Ln. to Education Dr. - The existing floodplain through the Vista Rd. to I-25 reach remains a property damage hazard due to flooding with respect to potential inundation of residential structures. There are twelve properties inundated through this reach for the regulatory event (100-yr. event) and both Vista Rd. and Bishop Blvd. are overtopped in this event. The most recent Cheyenne MPO Average Daily Traffic (ADT) counts for Bishop Blvd. indicate daily traffic of 3,683 vehicles. With both Vista Ln. and Bishop Blvd. inundated by floodwaters for the 100-year event, southern access into the Western Hills subdivision is effectively cut off until the floodwaters recede, hampering emergency response. Flooding through the McCormick – Central campus is relatively contained but with inundation of the pedestrian bridge connecting the two schools.

Education Dr. to Yellowstone Rd. - The existing floodplain through Education Dr. to Yellowstone Rd. reach remains both a property hazard and life safety hazard due to flooding. Education Dr. is overtopped at a low spot just north of the Education Dr. culverts contributing to flooding of Carlson Street and dangerous ponding at the Carlson – Gateway Dr. intersection. The most recent ADT counts for Education Dr. indicate daily traffic of 3,338 vehicles. For Carlson Street, east of Education Dr., the ADT count is 3,400 vehicles. Gateway Dr. is also overtopped through this reach creating a roadway flooding hazard for Westgate residents and a potential infrastructure failure of the roadway. There are three commercial properties and two townhomes inundated through this reach for the regulatory event.

Yellowstone Rd. to Sunset Dr. - The existing floodplain along Yellowstone Rd. to Sunset Dr. reach is well contained. There are three properties that are inundated for the regulatory event, but no structures. This study's HEC-RAS hydraulic model indicates overtopping of Sunset Dr. at a low spot to the north of the creek crossing. The ADT count for Sunset Rd. is 994 vehicles per day. The hydraulic model shows slightly more inundation along the south side of the Marjon Court development which may be an issue for the ongoing development of that property.

Sunset Dr. to Seminoe Rd. - The existing floodplain through Sunset Dr. to Seminoe Rd. reach expands well beyond the banks of the low flow channel. Most of the overbank area through this reach is city park or open space, however, there is one home and 1 apartment complex inundated for the regulatory event. Downstream Seminoe Rd. is overtopped resulting in a hazardous life-safety condition. The ADT count for Seminoe Rd. is 1,494 vehicles per day. Melton Rd. west of Seminoe Rd. experiences significant roadway flooding for the 100-year event.

Seminoe Rd. to Prairie Ave. - The Seminoe Rd. to Prairie Ave. reach encompasses the city's Mylar Park. The greenway pedestrian bridge is overtopped along with the Mylar Park Pond spillway and greenway path. These represent hazardous conditions for pedestrians and bicyclists, but the area is well signed. The downstream Prairie Ave. crossing is severely overtopped resulting in a very hazardous life-safety condition. Prairie Ave. has an ADT count of 3,353 vehicles per day.

Prairie Ave. to Powderhouse Rd. - The existing floodplain through Prairie Ave. to Powderhouse Rd. reach is situated in an open area. There is one home inundated for the regulatory event. The hydraulic model indicates no overtopping of the Powderhouse Rd. crossing for the existing conditions. There are no debris blockage factors applied to this structure (refer to debris blockage section of the report). There would be no overtopping of this structure even with debris blockage factors applied in the model.

Powderhouse Rd. to Lower Dell Range Blvd. - The Powderhouse Rd. to Carey Reservoir reach is a confined, urbanized reach. There are ten commercial properties, four apartment complexes, and one home inundated in this reach for the regulatory event. Through the Sheridan reach, the upstream crossing, Mountain Rd., is overtopped with approximately 6-inches of flow. Downstream Hilltop Ave. is overtopped by 1-foot of flow, making it a potential life-safety hazard. The ADT count for Hilltop is 1,601 vehicles per day. There is ongoing abutment scour of the left abutment of the pedestrian bridge due to the placement of a BOPU manhole immediately downstream of the abutment. This will be a safety concern for larger flow events through the Sheridan reach channel. There are three homes and an apartment complex inundated for the regulatory event. There is roadway flooding of Dell Range Blvd. due to overtopping of the Hilltop Ave. crossing. There is additional overtopping of Dell Range Blvd. at the creek crossing with over a foot of flow. The ADT for Dell Range Blvd. west of Ridge Rd. is 19,134 vehicles per day. Downstream Ridge Rd. is not overtopped, but the adjacent greenway tunnel is flowing full as an emergency conduit.

Ridge Rd. to U.S. 30 - The existing floodplain through Ridge Rd. to College Dr. reach is fairly contained. There is open space for the first 40% of this reach for flood waters to spread out if necessary. Downstream, 60 % of the reach has been channelized. There is one home and one commercial property just upstream of the College Dr. crossing that will be potentially damaged by flooding in the regulatory event. The College Dr. crossing is not overtopped, but the greenway tunnel is flowing full as an emergency conduit.

Downstream of College Dr. to Rock Springs Street, there are seven properties that are inundated for the regulatory event, but no structures. Cleveland Ave. is flooded for a regulatory event. ***The open space owned by the City of Cheyenne between College Dr. and Rock Springs Street should remain open space and not developed***. Consideration should be given to the acquisition of private property by the city along Rock Springs Street to provide additional open space and minor floodplain storage. This would prevent future development within the floodplain fringe. There is one commercial structure that may be damaged by flooding during the regulatory event located just upstream of Rawlins Street. There is severe overtopping of Rawlins Street for the 100-yr. event with 3-feet of flow overtopping the roadway at a low spot located immediately west of the culverts. There is considerable flooding of Pierce Ave., Laramie Street, and Parsons Pl. downstream of the Rawlins Street crossing. There are four homes inundated between Rawlins Street and U.S. 30 during the regulatory event. Consideration should be given by the city for property acquisitions along the east side of Pierce Ave. and the northern end of Parsons Pl. Rawlins Street isn't a heavily trafficked route and is considered safe with appropriate signage.

U.S. 30 to E. Pershing Blvd. - The existing floodplain through the U.S 30 to E. Pershing Blvd. reach is defined by a levied system constructed by Laramie County in the early 1990s. There are five homes and one commercial property inundated by flooding in this reach for the regulatory event. The E. Pershing Blvd. crossing is not overtopped, but E. Pershing Blvd. roadway is overtopped east of the crossing by both levied left overbank flooding and from runoff from Dakota Crossings conveyed on Wenandy Ave. The ADT for E. Pershing Blvd. west of Hayes Ave. is 5,339 vehicles per day. The city should consider acquisition of two properties to allow for elimination of the levied system and expansion of the overbank floodplain which would address one of the roadway overtopping locations. Consideration should be given by the city to acquire two properties such that the levee could be removed and the floodplain overbank area expanded considerably.

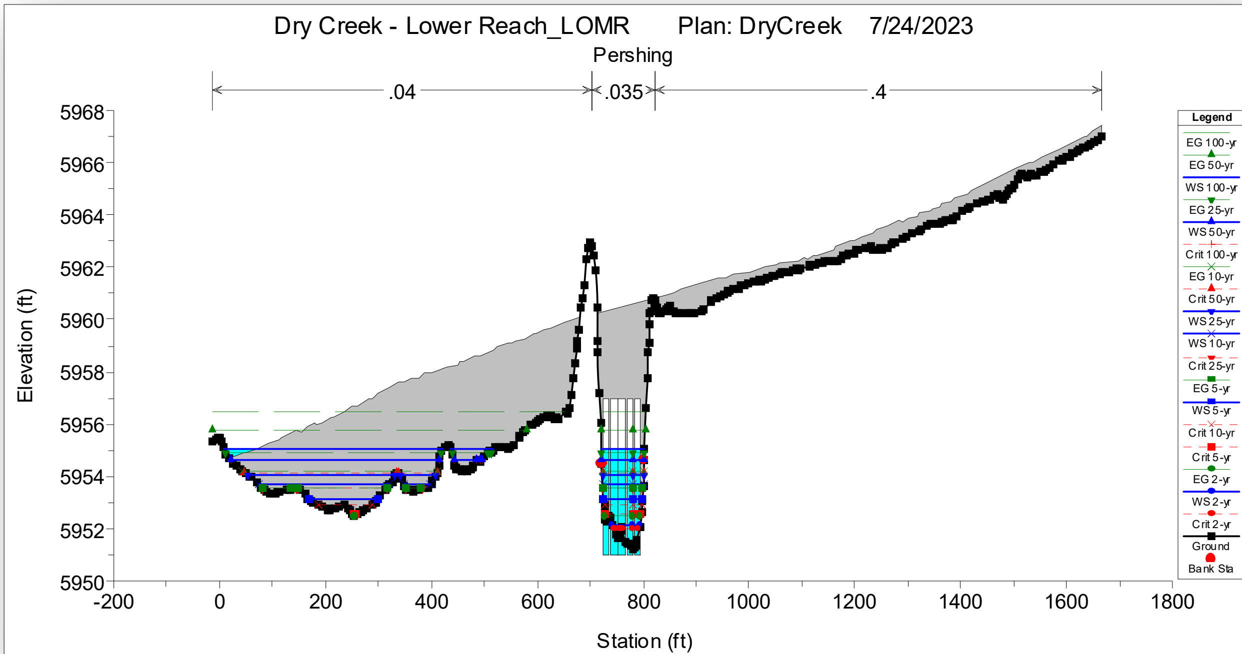


Figure 12. E. Pershing Crossing

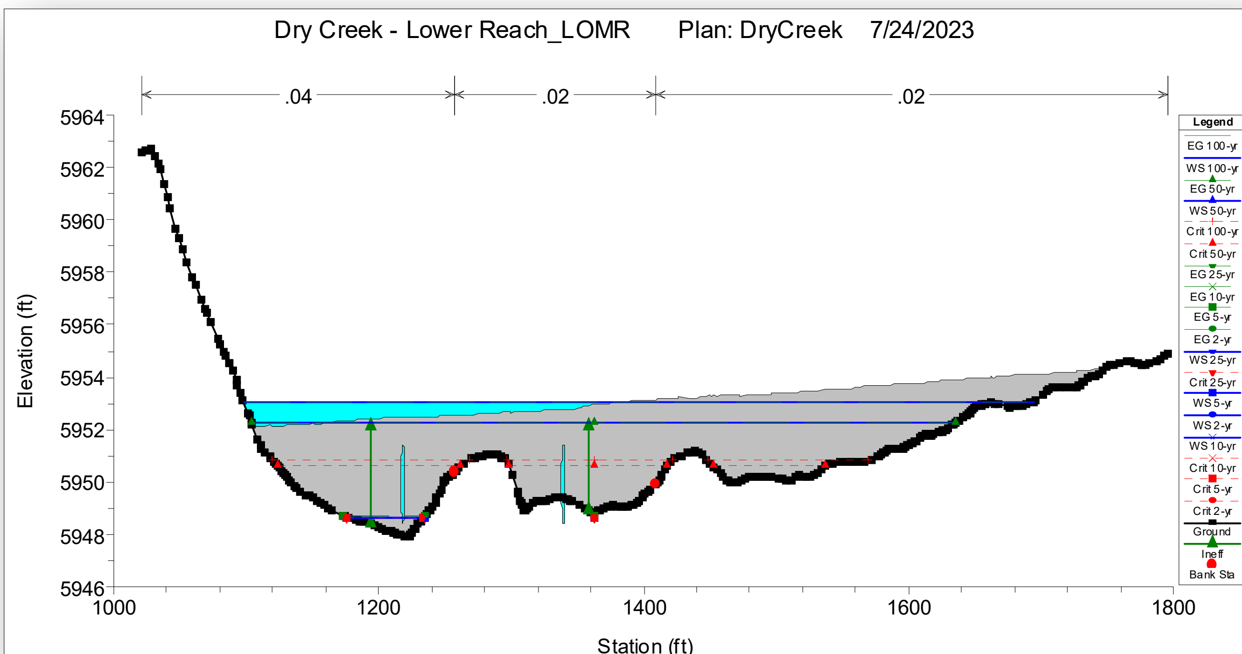


Figure 11. E. Pershing Roadway Overtopping

Pershing Blvd. to UPRR - The existing floodplain through the E. Pershing Blvd. to Union Pacific railroad embankment (UPRR) reach contains the original sump 130 area evaluated in the 1988 study. There is one commercial property and eight homes inundated by flood waters through this reach for the regulatory event. The downstream UPRR embankment is not overtopped, but the time-to-discharge stormwater impounded up against the embankment is 27-hours, resulting in a potential dam breach hazard. The city is currently in the process of acquiring the Winkler property located immediately upstream of the UPRR embankment. Consideration should be given to additional property acquisitions east of Whitney Rd. to eliminate property damage due to floodwaters and create additional floodplain storage. The ADT count for Whitney Rd. south of E. Pershing Blvd. is 98 vehicles per day.

UPRR to Confluence with Crow Creek - The existing floodplain through the UPRR to Upper Campstool Rd. crossing flows through the LEADS Business Park Open Area managed by the Laramie County Conservation District (LCCD). The downstream Upper Campstool Rd. crossing is overtopped at a low spot in the roadway west of the creek crossing. The ADT count for this location of Campstool Rd. is 3,694 vehicles per day.

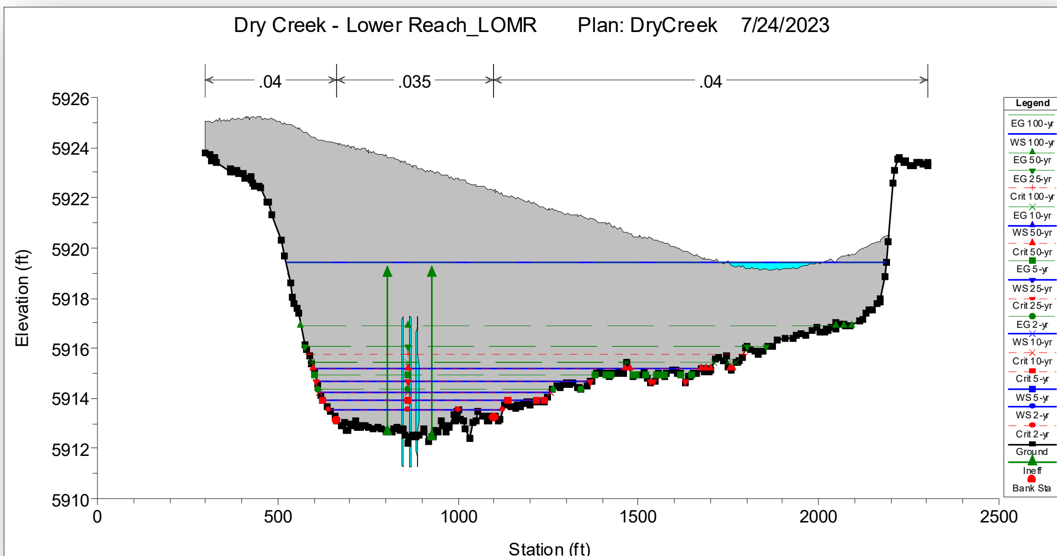


Figure 13. Campstool Rd. Overtopping

The Lower Campstool Rd. to I-80 reach is controlled by the LCCD. There are no outstanding issues with this reach. A head cut that had progressed through this reach and impacted on the Campstool Rd. culverts has recently been addressed with the construction of a scour basin at the outlets for the Campstool Rd. culverts. The I-80 crossing is not overtopped for the regulatory event in the updated HEC-RAS model. There are no outstanding issues downstream of the I-80 crossing. The Lower Campstool Rd. crossing is overtopped, but signage should be an appropriate mitigation measure for this crossing. The corresponding ADT for this location of Campstool Rd. is 2,175 vehicles per day. The BOPU has told the GLM Design Group Team and City Staff that floodwaters in Dry Creek do not affect their Dry Creek wastewater treatment plant.

The following areas can be considered Special Flood Hazard Areas (SFHAs) due to the excessive ponding/flooding of roadways for the less frequent flood events occurring in the Basin. These areas include:

- There is significant overland flow between Western Hills Blvd. and Dry Creek creating nuisance issues for frequent storm events and major ponding in large flood events. Stormwater runoff overtops Pawnee Ave to Western Hills Blvd causing impacts to the traveling public and property damage concerns. The ADT count for this location of Western Hills Blvd. is 3,320 vehicles per day.
- Approximately 550 cfs overtops Education Dr. and flows onto Carlson Street. This water combines with runoff from the neighborhood to the north and ponds at a low point at Carlson St. and Gateway Dr. creating a nuisance issue for frequent storm events and significant ponding for large storm events.
- Gateway Dr. is overtopped for less frequent events causing hazardous flooding conditions for residents attempting to access or leave the Westgate subdivision.
- The Indian Hills subdivision has street conveyance issues for less frequent storm events. The Storey Blvd./Sycamore Rd. storm sewer is undersized – leaving 130cfs for street conveyance for the 100-year event. This results in significant flooding of Wahoo Pl. with potential flooding of Melton Street.
- There is considerable overland flow/flooding conveyed to the Crow Rd/Melton Street intersection where it is conveyed via a drainage pan to a vault to trap excess sediment.
- The drainage channel in the median in Prairie Ave from Powderhouse Rd. to Frontier Mall Dr. does not have capacity to convey the storm flows and therefore overtops, finding its way to the roundabout at Prairie Ave. and Frontier Mall Dr. There is an existing 48-in culvert at the intersection. Unfortunately, approximately 145cfs does not reach the culvert, thus remaining on the street and flowing south along Frontier Mall Dr.
- There are two detention ponds located on the south end of the Walmart/Sam's Club parking lot. These ponds overtop during a 100-year event, discharging over 100cfs onto Dell Range Blvd.
- There is excessive overland flow on Plain View Rd for less frequent storm events. The overland flow, not collected in undersized storm sewers, travels along Pattison and Pineridge and ultimately discharges into Dry Creek. 191cfs sheet flows across Sheridan St. and into the Dry Creek Channel.
- Considerable overland flooding at the intersection of Messenger and McCann where over 120cfs overland flows through the area to Rock Springs St. Rock Springs St. conveys over 130cfs to Dry Creek.
- Over 100cfs overland flow is conveyed to the intersection of Eastview St and Rangeview Dr. where it overtops and flows between homes to Dry Creek in a 100-year storm event.
- There is hazardous overtopping of the Cheyenne Street/Polk Ave. intersection for less frequent storm events.
- Overland flooding on Wenandy Ave. north of E. Pershing Blvd. resulting in overtopping of E. Pershing Blvd.
- Flooding along Meadow Dr. and in particular, Atlantic Dr. in Sun Valley.
- Considerable flow from the Saddle Ridge subdivision is conveyed in the open channel adjacent to Whitney Rd.

IV. HYDROLOGIC ANALYSIS

A. Previous Studies

This study is an update of the 1988 Dry Creek Drainage Master Plan developed by CH2M Hill with support from States West Water Resources, Eagle Consultants, and Intermountain Professional Services in conjunction with a Drainage Task Force headed up by the City of Cheyenne Engineer's Office with representation from the Wyoming Department of Transportation Hydraulic Staff, the State Engineer's Office, the Laramie County Engineer, F. E. Warren Air Force Base Engineering, and the Wyoming Water Development Commission.

The hydrologic and hydraulic models used for the 1988 study were the USACE HEC-1 hydrologic model and the USACE HEC-2 hydraulic model. The HEC-1 model had 14 contributing subbasins. Peak discharges were developed at key design points and then input into the HEC-2 model. The HEC-2 model served as the basis for the updated 1994 FEMA Effective model completed by Love & Associates. This hydraulic model was updated again in 2009 with a Physical Map Revision by Ayres Associates documenting the changes to the floodplain and the Sheridan Reach by the Sheridan Reach Flood Control project. The 2007 FIS was primarily a paper to digital change with no modeling changes to the Dry Creek floodplain.

A more detailed city staff EPA SWMM model of the Dry Creek Basin was completed in 2018-19 with 130 contributing subbasins. While more focused than the 1988 model, both the HEC-1 and staff SWMM models can be viewed as higher level planning models. The staff SWMM model only evaluated existing conditions. Moreover, peak discharges from the staff SWMM model are significantly higher than those of the 1988 HEC-1 model for design points lower in the basin. The results were somewhat comparable for design points in the upper and mid-basin. These models have been reviewed along with Mr. Kelly Hafner's Evers Blvd. SWMM model, Mr. Hafner's Bluffs and Ridgeview SWMM models, associated construction plans and recent LOMRs in support of this master plan update. The Evers Blvd. model, Bluffs, and Linden Way models have been incorporated into this master plan update SWMM model.

B. Precipitation Data

The basis for development of design storms for the 1988 HEC-1 modeling was an advance copy of the 1988 U.S. Geological Survey, Water Resources Investigations Report 87-4225, Precipitation Records and Flood-Producing Storms in Cheyenne, Wyoming by J. B. Lindner-Lunsford prepared in cooperation with the City of Cheyenne. This study developed intensity-duration-frequency curves using over 100-years of precipitation data for the Cheyenne area. In the study, three data distributions were used by Lindner-Lunsford to assess the best distribution fit for the Cheyenne data. The return period values derived from the Log-Pearson Type III distribution were found to provide the best results and were used for design storm development for the 1988 master plan study.

This data is being used for this master plan update as it still represents the latest and best precipitation data for the Cheyenne area. More specifically, the incremental 2-hour design storms, shown in **Table 3** were used for this plan update. The use of the 2-hour storm events is typical for assessment of drainage tributaries that are less than 10 square miles. These design rainfall events are used for most, if not all, the detailed floodplain studies in the greater Cheyenne area. The definition for a 100-Year event is a storm event with a 1% chance (1/return period in years) of occurring any year and is based on past rainfall observations. Subsequently a 2-Year storm has a 50% chance (1/2) of occurring any year and a 50-Year storm a 2% (1/50). Again, the USGS rainfall data is specific to the greater Cheyenne area and represents the best available data for use in this report.

The Lindner-Lunsford study did not develop specific storm rainfall distributions. Instead, the study's analysis of nine flood-producing storms in Cheyenne showed a mean pattern index of 0.63. Interestingly, ***the 1985 storm of record had a pattern index of only 0.40, three standard deviations below the mean and considered an outlier in the Lindner-Lunsford study***. As documented in the 1988 master plan study, storm pattern refers to the temporal distribution precipitation within a storm and may be described by a pattern index. A pattern index of greater than 0.5 indicates an advanced hyetograph with most precipitation occurring before the midpoint of a storm.

In addition to meeting the pattern index, the 1988 Lindner-Lunsford study used an additional criterion in generating the temporal distribution of precipitation. This criterion was to meet the precipitation volumes for shorter periods within a 2-hour storm as defined by the return-period precipitation. So, within the 100-year design storm, the greatest 5-minute volume was set to the 100-year 5-minute volume described by Lindner-Lunsford. The greatest 10-minute volume in the design storm was likewise set to the 100-year 10-minute volume. This procedure was conducted with the 15-, 30-, and 60-minute interval precipitation values. This criterion was met while maintaining the storm pattern index of 0.63.

As pointed out in the 1988 Master Plan, for basins up to about 10 square miles, point precipitation data, such as developed by Lindner-Lunsford, can generally be used directly to represent precipitation over an area. This is the case for most of the drainage basins within the corporate limits of Cheyenne. For drainage areas greater than 10 square miles, a storm that blends characteristics of a thunderstorm and a general storm is probably more representative of the type of storm yielding maximum runoff. The 1988 study calculated the Dry Creek Basin at 14.6 square miles.

For our 2023 Master Plan Update, we have estimated the size of the basin at 15.9 square miles. As in the 1988 study, we have elected to distribute point precipitation over 2-hours to provide more conservative peak runoff rates and volumes for existing and future conditions within the Basin. Moreover, like the 1988 conditions, the upper and middle basins are still more urbanized than the lower basin making this a more conservative modeling approach for this study update.

Table3. Rainfall Data (Incremental Inches)							
Duration (Minutes)	Return Period/Frequency						
	(2 Year)	(5 Year)	(10 Year)	(25 Year)	(50 Year)	(100 Year)	(500 Year)
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	0.01	0.01	0.01	0.02	0.04	0.09	0.16
10	0.01	0.01	0.02	0.03	0.06	0.10	0.21
15	0.01	0.01	0.02	0.04	0.08	0.12	0.28
20	0.01	0.01	0.03	0.06	0.14	0.18	0.28
25	0.01	0.02	0.04	0.14	0.18	0.22	0.29
30	0.01	0.07	0.10	0.15	0.18	0.23	0.29
35	0.04	0.08	0.11	0.19	0.22	0.24	0.30
40	0.11	0.40	0.17	0.58	0.67	0.76	1.00
45	0.29	0.21	0.48	0.32	0.35	0.39	0.40
50	0.15	0.15	0.25	0.15	0.18	0.22	0.29
55	0.04	0.07	0.10	0.07	0.10	0.12	0.28
60	0.03	0.02	0.04	0.06	0.06	0.08	0.19
65	0.01	0.03	0.04	0.06	0.05	0.09	0.19
70	0.01	0.02	0.04	0.05	0.06	0.08	0.18
75	0.01	0.03	0.03	0.05	0.05	0.09	0.18
80	0.01	0.02	0.03	0.04	0.06	0.07	0.18
85	0.01	0.01	0.02	0.05	0.05	0.08	0.17
90	0.01	0.02	0.03	0.04	0.06	0.09	0.17
95	0.01	0.01	0.02	0.04	0.05	0.08	0.17
100	0.01	0.02	0.02	0.04	0.06	0.09	0.17
105	0.01	0.01	0.01	0.04	0.06	0.07	0.16
110	0.01	0.01	0.02	0.03	0.05	0.07	0.16
115	0.01	0.01	0.01	0.04	0.06	0.06	0.15
120	0.01	0.01	0.01	0.03	0.05	0.06	0.15
TOTALS	0.82	1.26	1.65	2.32	2.92	3.68	6.01

Table 3. Two-hour Design Storms Developed for Cheyenne

C. Rainfall Abstractions

Soils infiltration is assessed using Green-Ampt parameters based on general soils conditions. Depression storage is based on Mile High Flood Control District recommendations for urban and rural conditions. Pervious area depression storage is set at 0.1" and 0.3" for impervious and pervious conditions respectively. The Green-Ampt infiltration method considers soil properties, initial moisture conditions, and hydraulic conductivity to estimate infiltration rates. EPA SWMM applies the Green-Ampt method to calculate infiltration rates based on the input soil properties, rainfall intensity, and duration.

D. Hydrologic Model Setup and EPA SWMM Model Parameters

The existing and proposed conditions were assessed using the US EPA Stormwater Management Model (SWMM, Version 5.1.015) software. The performance of the local drainage culverts, detention systems, and overland conveyance routes were estimated in the SWMM model for the following storm events; 5-, 10-, 25-, 50-, 100-, and 500-year events. Runoff hydrographs were developed using EPA SWMM sub-catchment rainfall-to-runoff algorithms. Dynamic wave routing within the SWMM model was used to address interconnections and interactions between all collection, conveyance, storage, and regulatory elements. SWMM sub-catchment width parameters have been calibrated to staff-accepted cfs/acre values, loosely following the theory of cascading planes (see Guo reference). The subbasin width affects the peak discharge by influencing the travel time of runoff through the subbasin. The SWMM Hydrology Reference Manual proposes the width calculation of a subbasin be based on the longest flow path or travel distance from the farthest point within the subbasin to the outlet.

Professor James Guo's theory of cascading planes is a concept to analyze the movement and interactions of water flow across multiple surfaces. It suggests that water flow behaves like cascades with each plane influencing the behavior of the one below it. The width parameter used for cascading planes does not follow the guidance put forth in the SWMM Reference Manual. In Guo's theory of cascading planes, the concept of sub-catchment width refers to the width of a specific plane or surface within the overall cascading system. It focuses on the individual width of each plane and how water flow interacts with that specific width.

On the other hand, the EPA Storm Water Management Model takes a different approach in determining sub-catchment width. In SWMM, the sub-catchment width represents the longest flow path or travel distance from the farthest point within the sub-catchment to the outlet. It considers the overall width of the sub-catchment area and how water travels across that width to reach the outlet. The two approaches have different perspectives and applications in analyzing water flow and modeling hydraulic systems. Generally, Professor Guo's approach produces higher peak discharges in the model which may or may not be representative of the subbasin's underlying characteristics. Both methods are documented in the SWMM Hydrology Reference Manual published by the EPA.

Overland flow Manning's roughness coefficient 'n' was calibrated to average overland flow transitions to shallow concentrated flow and channel flow within the sub-catchment sub-areas. Detention storage volumes are based on hydrograph routing and stage-area curves from drainage plans or estimates based off City/County lidar topography. Additionally, we've introduced slight dynamic friction with mild k values on several of the reach elements within the core of the basin as suggested by city staff to provide a better convergence in the flow pattern.

For both existing and future land use conditions, hydraulic data has been developed at appropriate locations using a combination of EPA-SWMM, HEC-RAS, or HY8 hydraulic modeling programs. ***In addition, within the basin, we have utilized 2D HEC-RAS modeling to review flood risk and potential impact on existing structures and infrastructure***. We have incorporated 2D flood mapping for the reach upstream of Carey Reservoir for use in refining our riverine evaluation and analysis of flow conveyance from the Powderhouse crossing into Carey Reservoir.

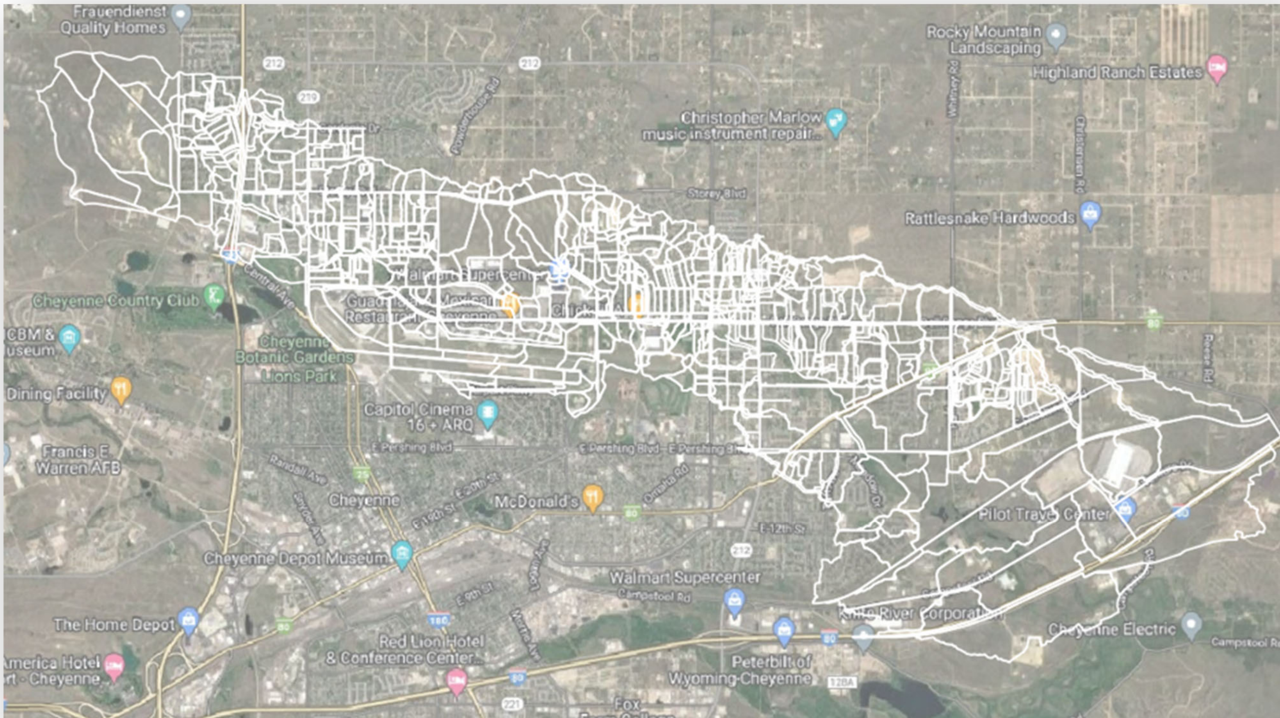


Figure 14. EPA SWMM Model Subbasins

The SWMM model developed in support of this master plan update covers the entire 16 square mile drainage basin. Unlike the original HEC-1 model or recent staff EPA SWMM model, this model is a very detailed model with over a thousand subbasins, giving it a much higher resolution than the earlier models. **Figure 11** shows the delineation of subbasins comprising the SWMM model for this master plan update. The SWMM model was set up by inputting basin data into the software. Defining the study area boundaries, specifying sub-areas, establishing drainage network elements (e.g., pipes, channels, junctions), and assigning properties to these elements (e.g., dimensions, roughness coefficients). Initial values for SWMM parameters were assigned based on engineering judgment, prior knowledge of the study area, and typical values from similar projects or published literature. These initial estimates provided a starting point for the subsequent calibration process with previous basin models and with staff guidance.

E. Comparison to 1988 HEC-1 Model Results

In general, the EPA SWMM model discharges are slightly lower than the HEC-1 model discharges to the Powderhouse crossing. The SWMM model shows no overtopping of the Powderhouse crossing and no split flow occurring downstream. As a result, the peak discharges are higher in the SWMM model between the Powderhouse crossing and Carey Reservoir**.** **Table 4** shows the peak discharge comparisons.

Table 4. Comparison of Peak Q with 1988 HEC-1 Model			
Location	1988 HEC-1	EPA SWMM	Flow Change
	cfs	cfs	cfs
Upstream End	**546**	**502**	**-44**
US Bishop	617	516	**-101**
DS Bishop	1079	1002	**-77**
DS Yellowstone	1635	1370	**-265**
US Powderhouse (+/- 1244ft)	2709	2278	**-431**
US Powderhouse	2093	2281	**188**
US Carey(+/- 543)	2442	2651	**209**
DS Carey diversion	264	398	**134**
US Dell Range	644	441	**-203**
DS Windmill	1086	818	**-268**
DS Hilltop	1528	1276	**-252**
at Channel Discharge	1969	1516	**-453**
US N College	2411	1582	**-829**
US Rawlins St	2919	2177	**-742**
DS Pershing Dr	2989	2889	**-100**
UPRR	2764	3755	**991**
DS UPRR	753	607	**-146**
US Campstool	1009	879	**-130**
at Crow Creek	1469	1171	**-298**

Table 4. Comparison of Peak Discharge Between HEC-1 and EPA SWMM for Select Design Points

The SWMM model shows slightly lower discharges through the Sheridan Reach and at the confluence with the Sheridan Reach Flood Control project outfall into the main channel immediately downstream of the Ridge Rd. crossing. The SWMM model peak discharges are significantly lower at the N. College and Rawlins Street crossings, but very close to the HEC-1 total at the E. Pershing Blvd. crossing. This was the case for the 2009 Sheridan Reach Flood Control Project HEC-RAS peak discharges as well. The effects of the 2009 flood control project are dampened out by the U.S. 30 crossing. The SWMM model peak discharge is significantly higher at the original sump 130 location (Union Pacific crossing) due to the additional runoff from Saddle Ridge, Dakota Crossings, Chukker Ridge, and Sunrise Estates. The SWMM peak discharges are slightly lower downstream of the UPRR due to more accurate modeling of the hydraulic structure.

The SWMM model has been calibrated and reviewed by staff for expected cfs/acre peak discharges for corresponding subdivisions within the Basin. The model accounts for subdivisions, planned unit developments, and commercial developments that have occurred since the 1988 study.

F. Existing and Proposed Conditions Models

The proposed conditions model includes detention storage for the headwaters of the South Fork Dry Creek, expanded detention storage for the Westgate subdivision pond, expanded detention storage for Mylar Park, minor storage increase for the Powderhouse reach, re-alignment of the main channel Dry Creek through the Sheridan Flood Control reach – bypassing the Sheridan Street reach of Dry Creek, and improvements to the Union Pacific sump area to address the potential dam breach hazard from the impoundment of floodwater against the UPRR embankment.

The proposed FEW Base Pond has a 16-acre footprint including ponded and constructed wetlands areas. The proposed improvement for the Westgate subdivision includes acquisition by the city and expansion of the wetlands around the pond. Overtopping flow from Education Dr. would be directed into this expanded facility and away from the Carlson Street/Gateway Dr. intersection. This improvement would include an improved outlet structure to eliminate overtopping of Gateway Dr. The improvements to Mylar Park Pond involve the lowering of the pond bottom to introduce an additional 20 ac-ft of available storage. The Powderhouse reach includes a minor increase in storage along with expanded wetlands.

The Carey Reservoir inlet is proposed to be reconstructed to realign the main channel flow through this reach and away from the Sheridan Street reach. Included in this improvement is a lowering of the grade between Powderhouse and Carey Reservoir to provide additional creek capacity and eliminate a "bottle neck" in the reach immediately upstream of the Carey Reservoir inlet. The existing Bureau of Reclamation energy dissipation design would be modified to accept emergency spills at a higher water surface elevation.

Figure 15. Carey Reservoir Inlet Structure

The Union Pacific floodwater impoundment area is proposed to be reconfigured such that floodwaters are kept away from the UPRR embankment and the existing 6’ x 8’ masonry box arch culvert is hydraulically isolated for use as a pedestrian connection for the Greater Cheyenne Greenway system. A repurposing of the historic transcontinental rail berm is proposed to keep floodwaters away from the UPRR embankment located immediately downstream.

Figure 16. Transcontinental Rail Berm

The proposed conditions model indicates that the additional storage elements will result in a considerable reduction of flow through the Vista Ln. reach, eliminating existing property damage upstream of Bishop Blvd. along with roadway flooding of both Vista Ln. and Bishop Blvd. flow at Education Dr. will be reduced by 100cfs assisting the proposed Westgate improvements in addressing the existing flooding of the Carlson Street/Gateway Dr. intersection as well as reducing the overtopping of Gateway Dr. in the Westgate subdivision. The Mylar Park improvements will decrease flow at the Powderhouse crossing by almost 400cfs and reduce flow into the Carey Reservoir alignment by nearly 400cfs as well. The realignment of flow through the Sheridan Flood Control route will reduce peak discharge in the former main channel upstream of the Converse Ave. crossing by 240 cfs.

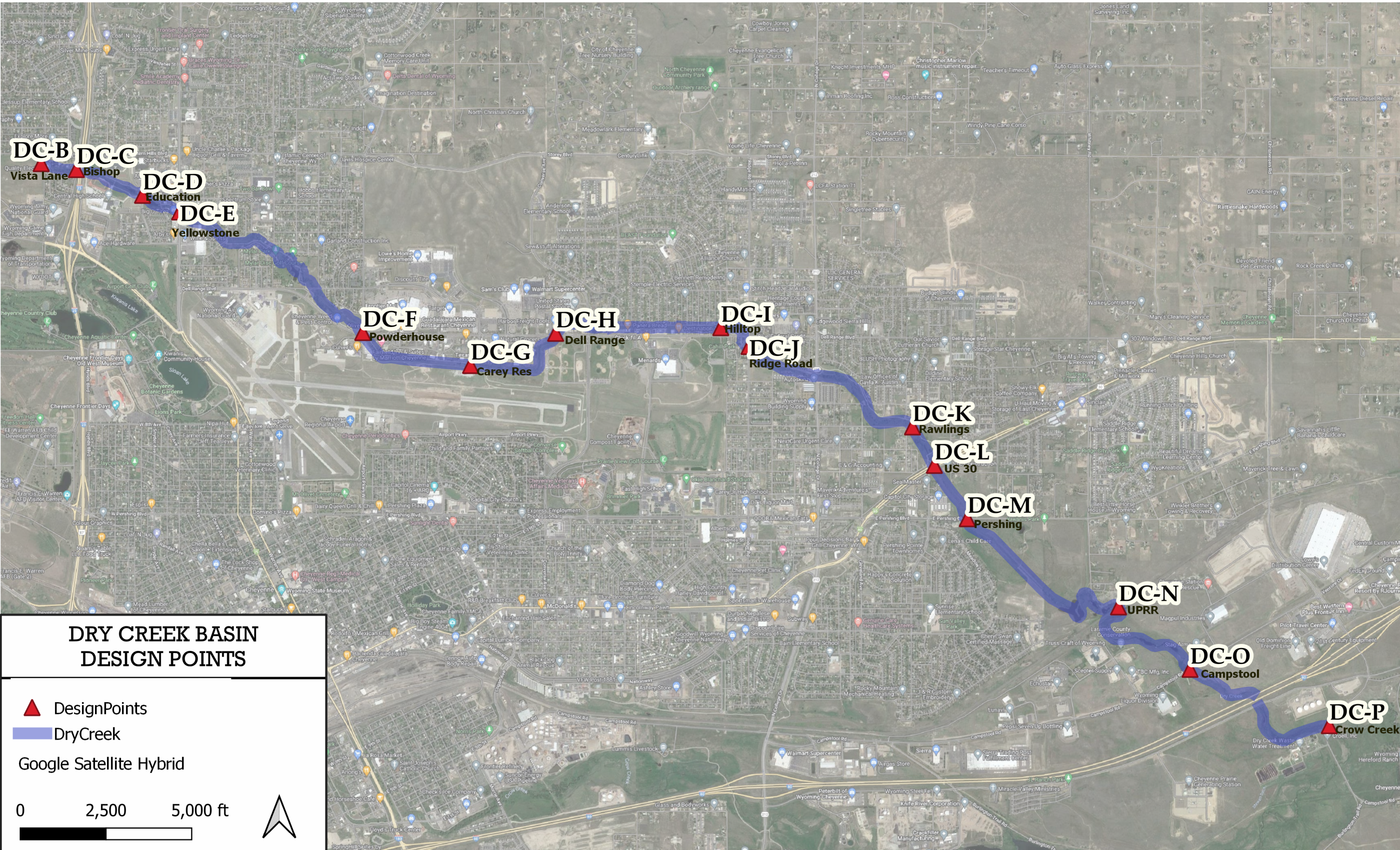
The Sheridan Street reach of Dry Creek will see minor decreases in peak discharge from the upstream improvements. Runoff from the Buffalo Ridge subdivision and the ongoing development of the former Cole Family properties to the north and east of Converse Ave. will continue to stress the allowable capacity. Upstream improvements are dampened out downstream of Ridge Rd. Proposed improvements to the existing sump 130 impoundment area will require an increase in hydraulic capacity for the new outlet pipes resulting in minor increases in peak discharge downstream of the Union Pacific railroad crossing of Dry Creek. This will have a minor impact to the upper Campstool Rd. crossing located immediately downstream.

Table 5. Comparison of Peak Q Between Existing and Proposed Models			
Location	EPA SWMM Existing Conditions	EPA SWMM Proposed Conditions	Flow Change
	cfs	cfs	cfs
Upstream End	**502**	**24**	**-478**
US Bishop	516	237	**-279**
DS Bishop	1002	901	**-101**
DS Yellowstone	1370	1255	**-115**
US Powderhouse (+/- 1244ft)	2278	1858	**-420**
US Powderhouse	2281	1918	**-363**
US Carey(+/- 543)	2651	2280	**-371**
DS Carey diversion	398	8	**-390**
US Dell Range	441	201	**-240**
DS Windmill	818	751	**-67**
DS Hilltop	1276	1227	**-49**
at Channel Discharge	1516	1478	**-38**
US N College	1582	1555	**-27**
US Rawlins St	2177	2174	**-3**
DS Pershing Dr	2889	2886	**-3**
UPRR	3755	3750	**-5**
DS UPRR	607	590	**-17**
US Campstool	879	963	**84**
at Crow Creek	1171	1187	**16**

Table 5. Comparison of Peak Discharge for EPA SWMM Existing and Proposed Conditions Models for Select Design Points

Table 6. Ponding Area Data			
Ponding Location	**General Description**	**Outlet**	**Storage Volume (Ac-ft)**
Original 1988 Study Sump 10	FEW North Fork Detention Pond upstream of Western Hills Subdivision	42-inch with a 54-inch Riser	5.5 Ac-ft for the 100-year event
Original 1988 Study Sump 70	Sump formed behind embankment at Powderhouse Rd.	Four Arch Culverts 13’ x 9’	Dynamically Routed in EPA SWMM Model
Original 1988 Study Sump 80	Carey Reservoir	48-inch Outlet to Main Channel (2) 9-foot Culverts	103 Ac-ft for the 100-year event
Original 1988 Study Sump 110	Sump formed behind U.S. 30	(5) 7’ high box culverts with total span of 42-feet	Dynamically Routed in EPA SWMM Model
Oringinal 1988 Study Sump 130	Sump formed behind Union Pacific Railroad embankment	6’ x 8’ masonry box arch culvert	463 Ac-ft for the 100-year event

Table 6. Ponding Area Data Table


DRY CREEK BASIN
DESIGN POINTS
DesignPoints
DryCreek
Google Satellite Hybrid
0
2,500
5,000 ft
DC-B
Vista Lane
DC-C
Bishop
DC-D
Education
DC-E
Yellowstone
DC-F
Powderhouse
DC-G
Carey Res
DC-H
Dell Range
DC-I
Hilltop
DC-J
Ridge Road
DC-K
Rawlings
DC-L
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Campstool
DC-P
Crow Creek

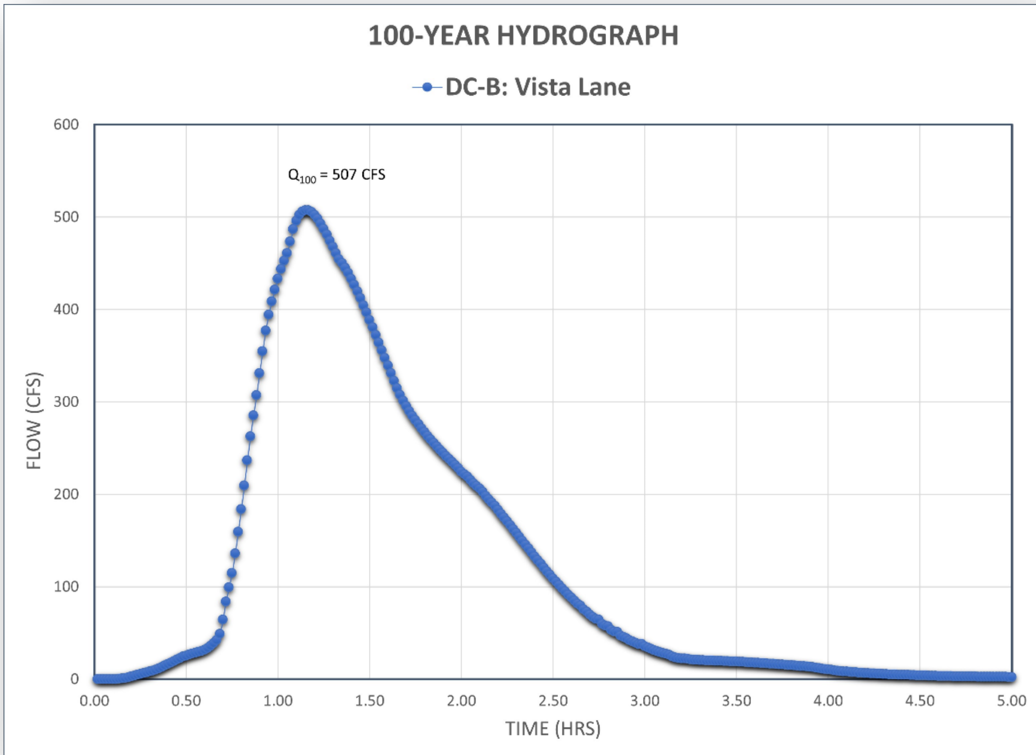


Figure 18. Hydrograph Exhibits at Select Design Points

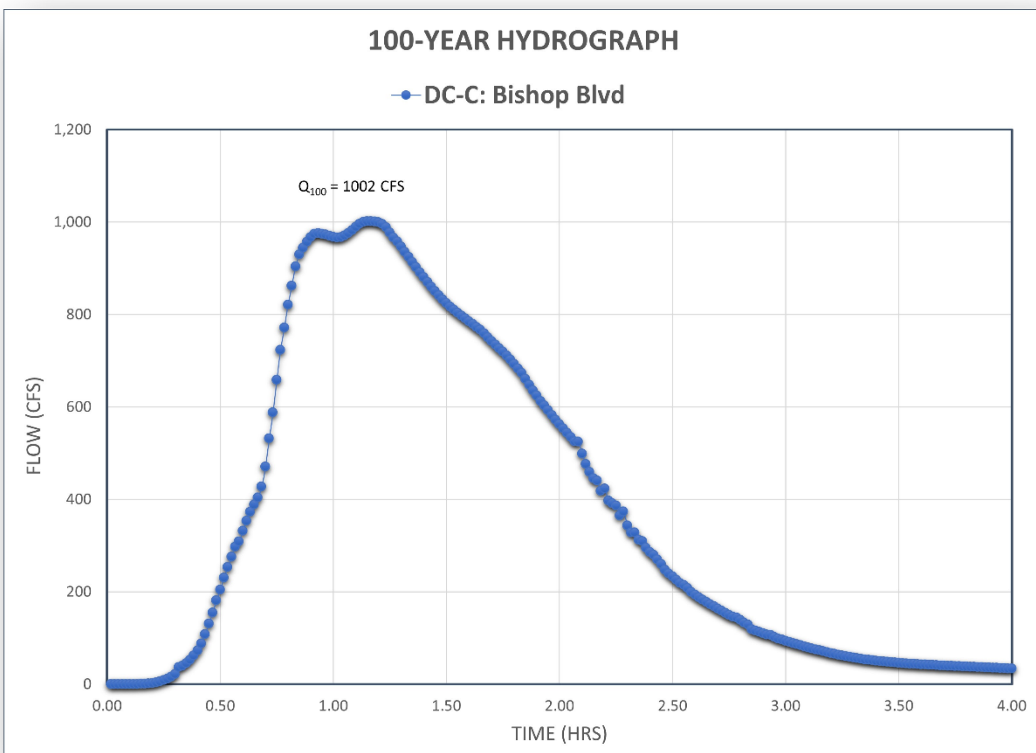


Figure 19. Hydrograph Exhibits at Select Design Points

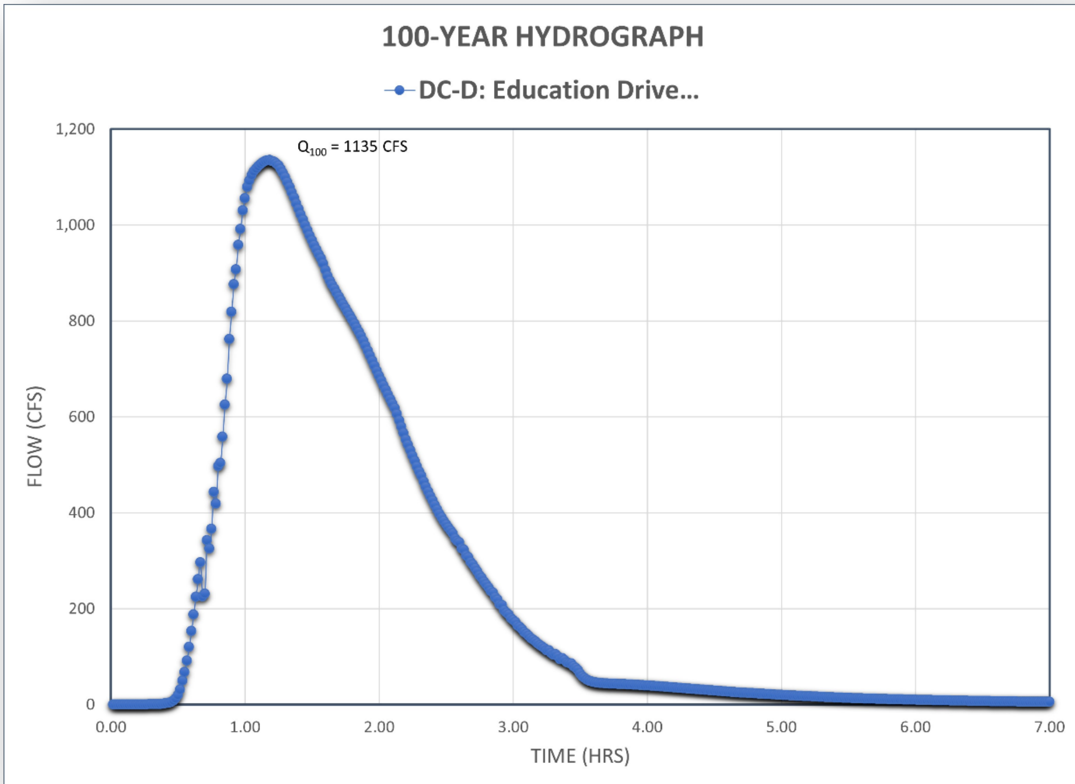


Figure 21. Hydrograph Exhibits at Select Design Points

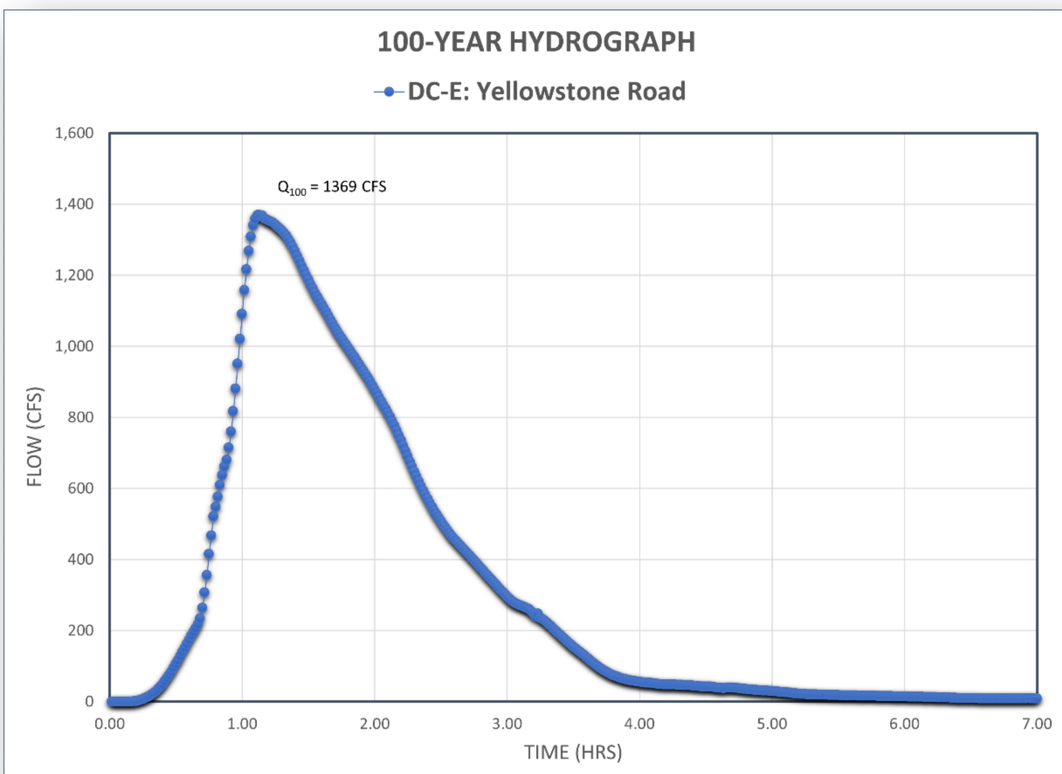


Figure 20. Hydrograph Exhibits at Select Design Points

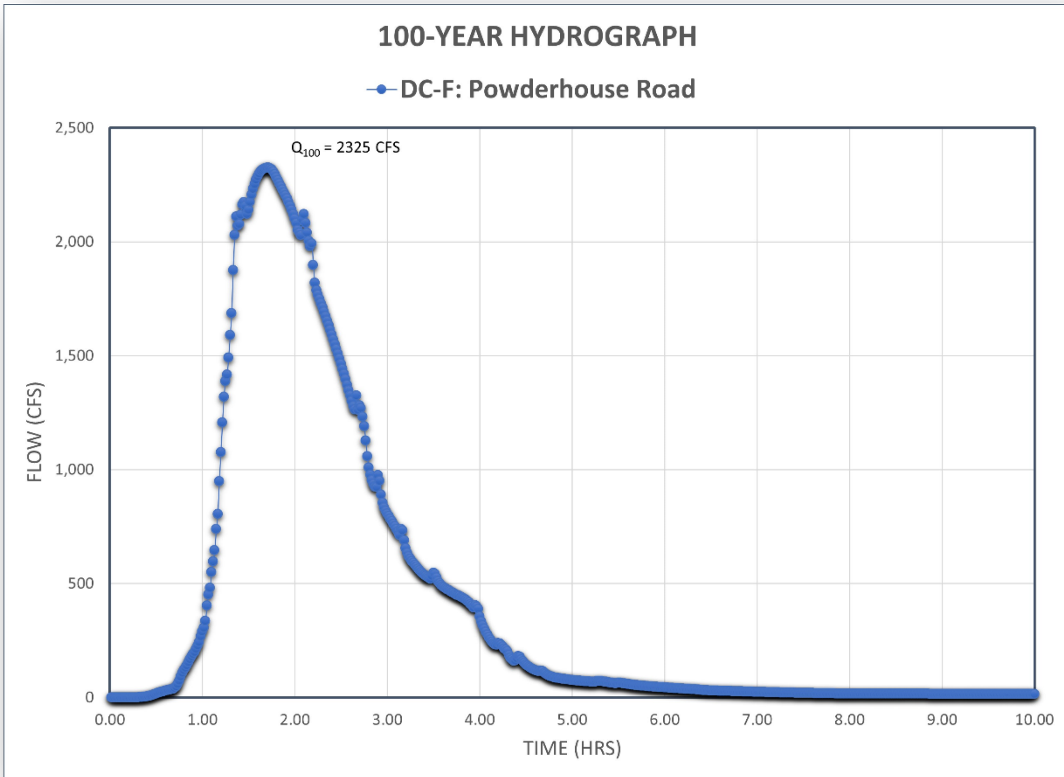


Figure 22. Hydrograph Exhibits at Select Design Points

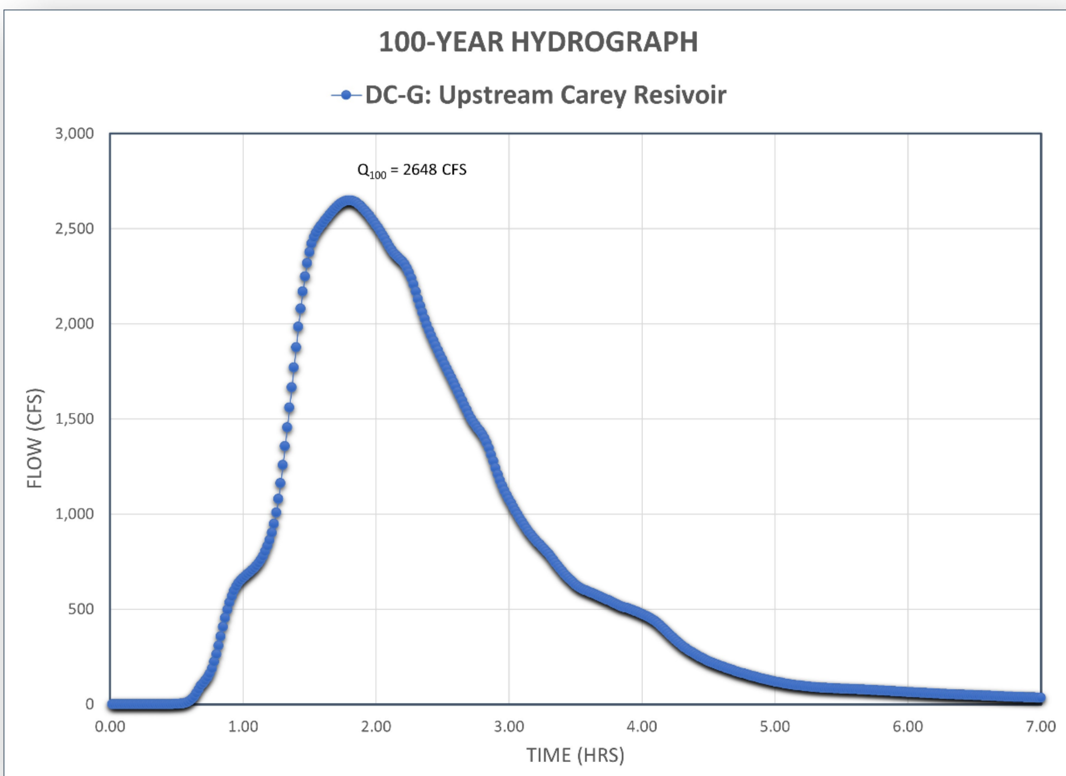


Figure 23. Hydrograph Exhibits at Select Design Points

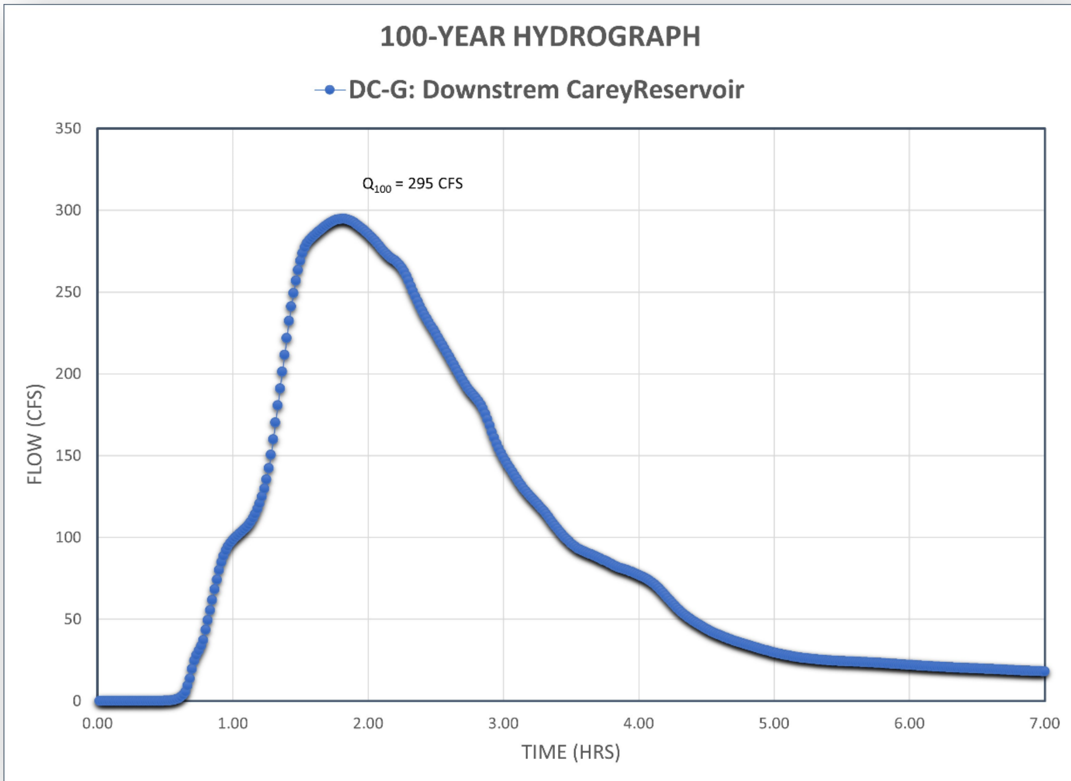


Figure 24. Hydrograph Exhibits at Select Design Points

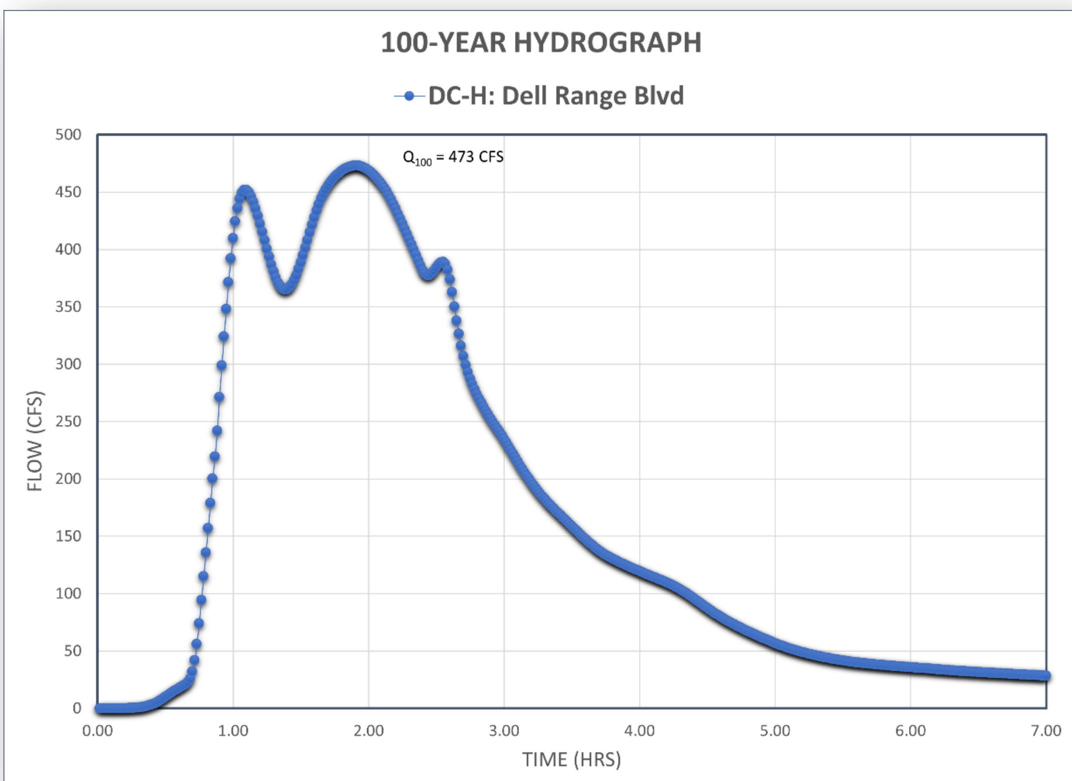


Figure 25. Hydrograph Exhibits at Select Design Points

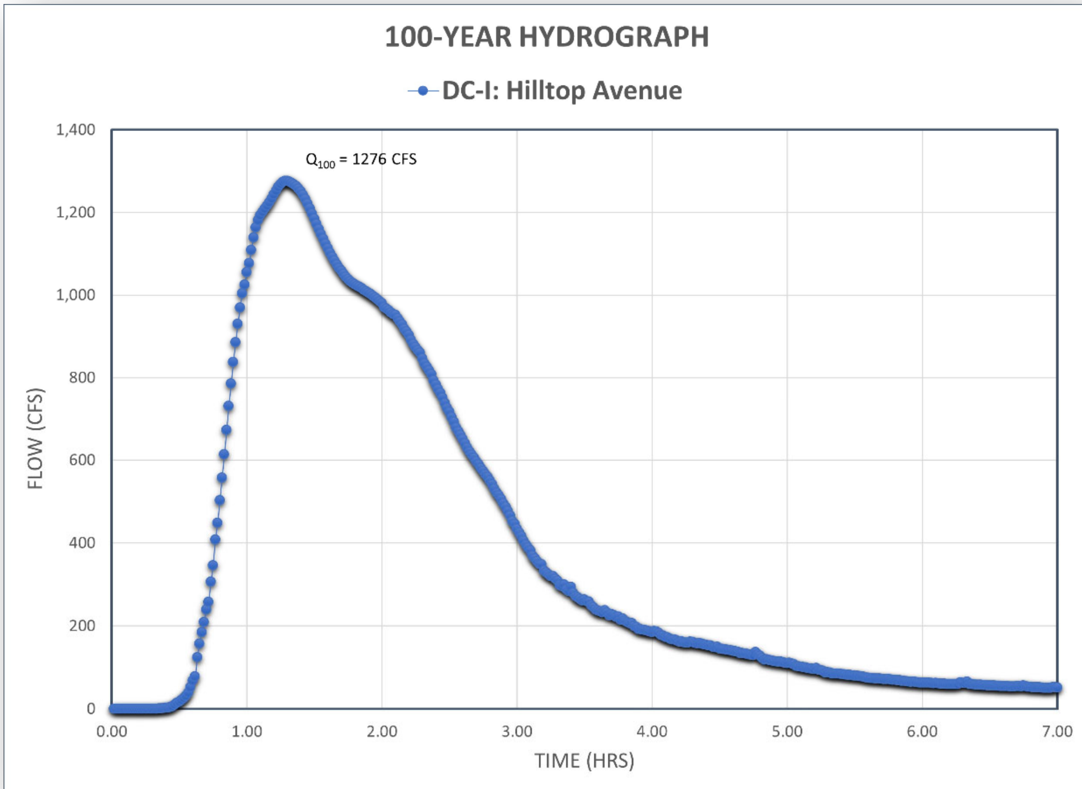


Figure 26. Hydrograph Exhibits at Select Design Points

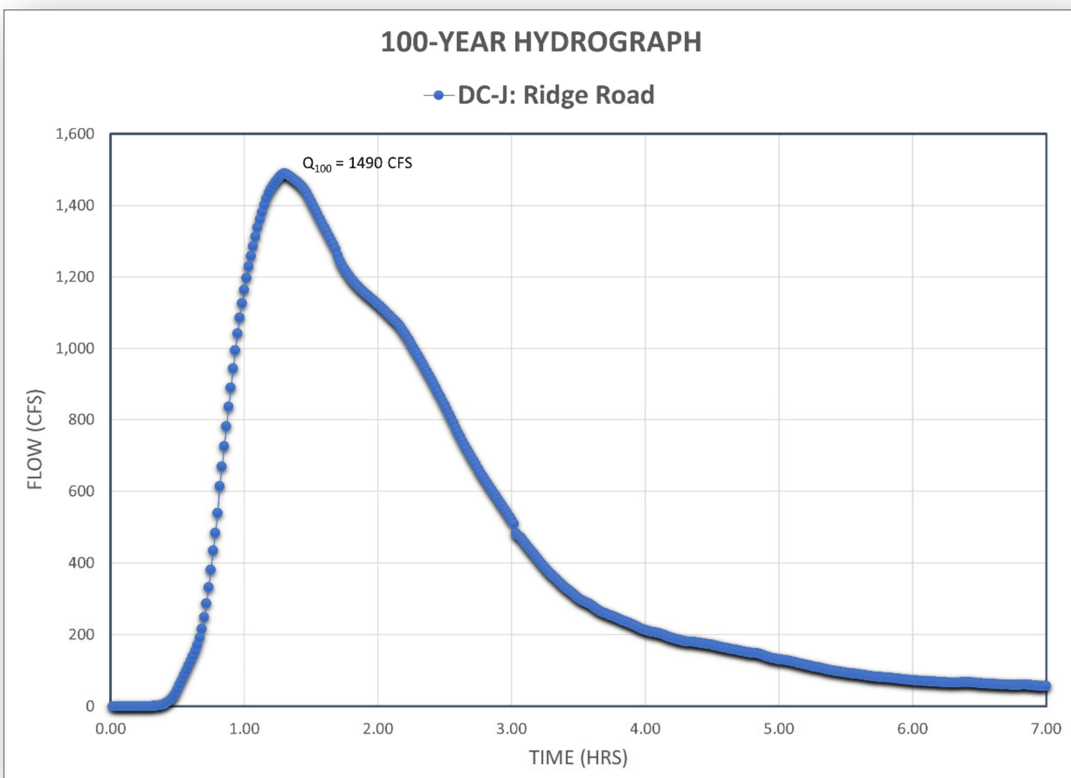


Figure 27. Hydrograph Exhibits at Select Design Points

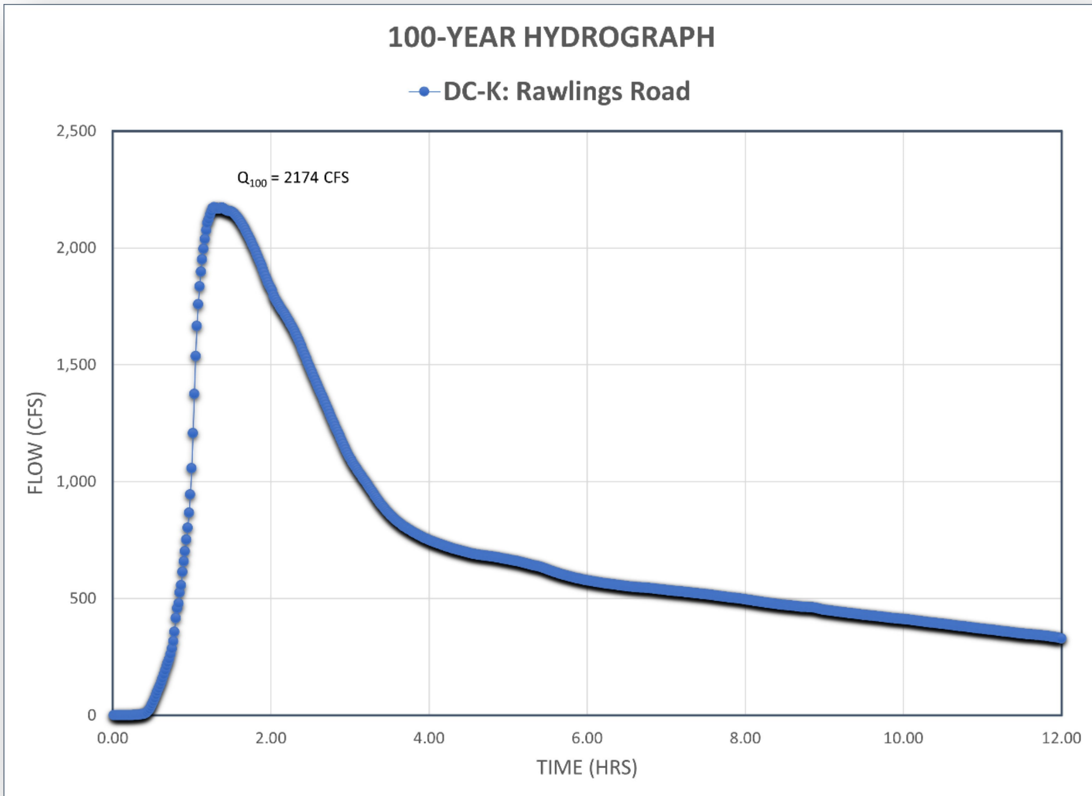


Figure 28. Hydrograph Exhibits at Select Design Points

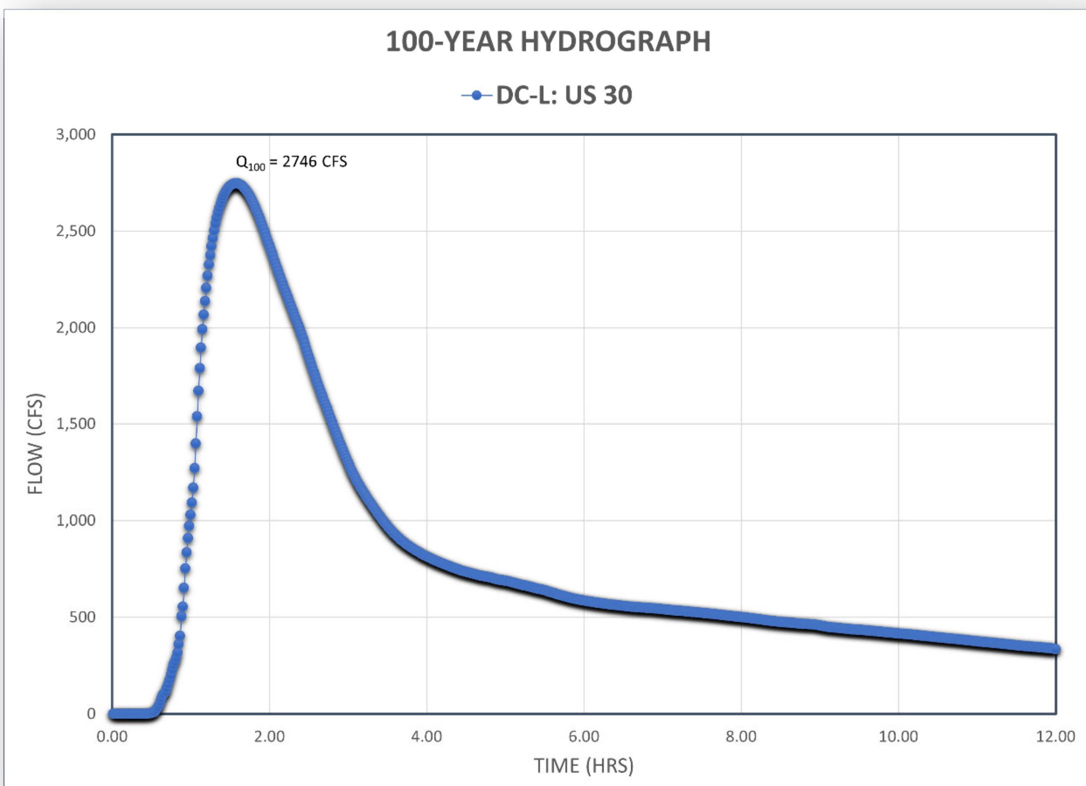


Figure 29. Hydrograph Exhibits at Select Design Points

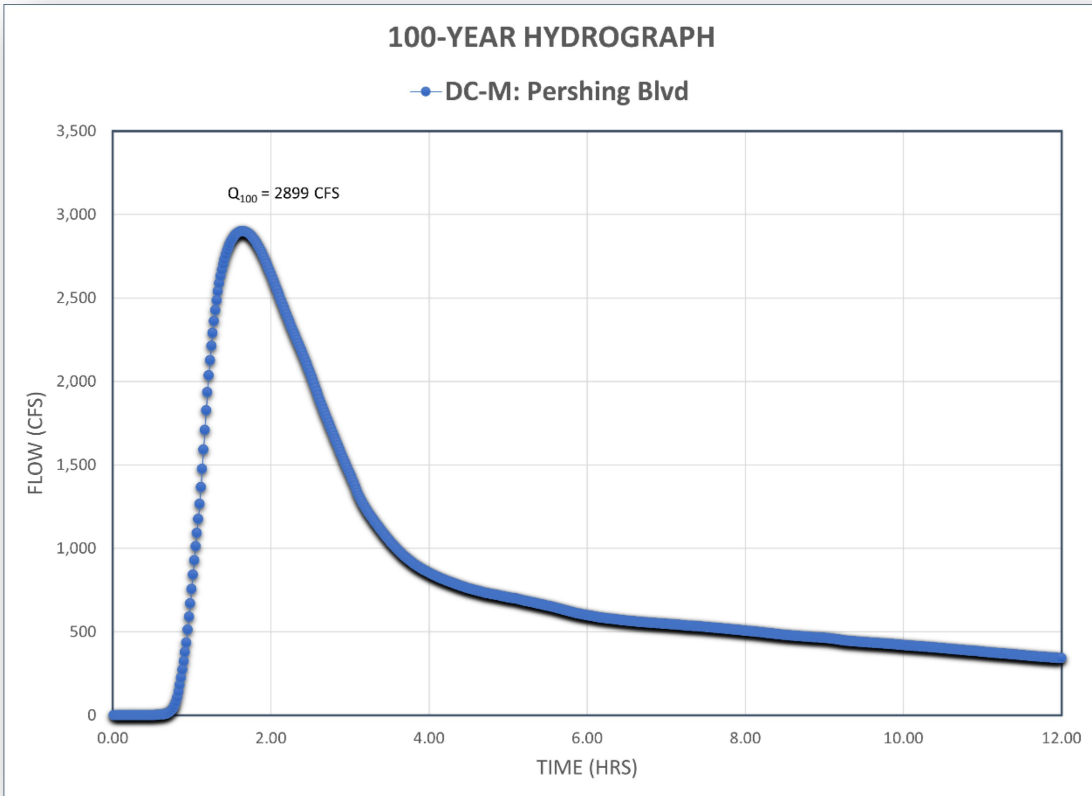


Figure 30. Hydrograph Exhibits at Select Design Points

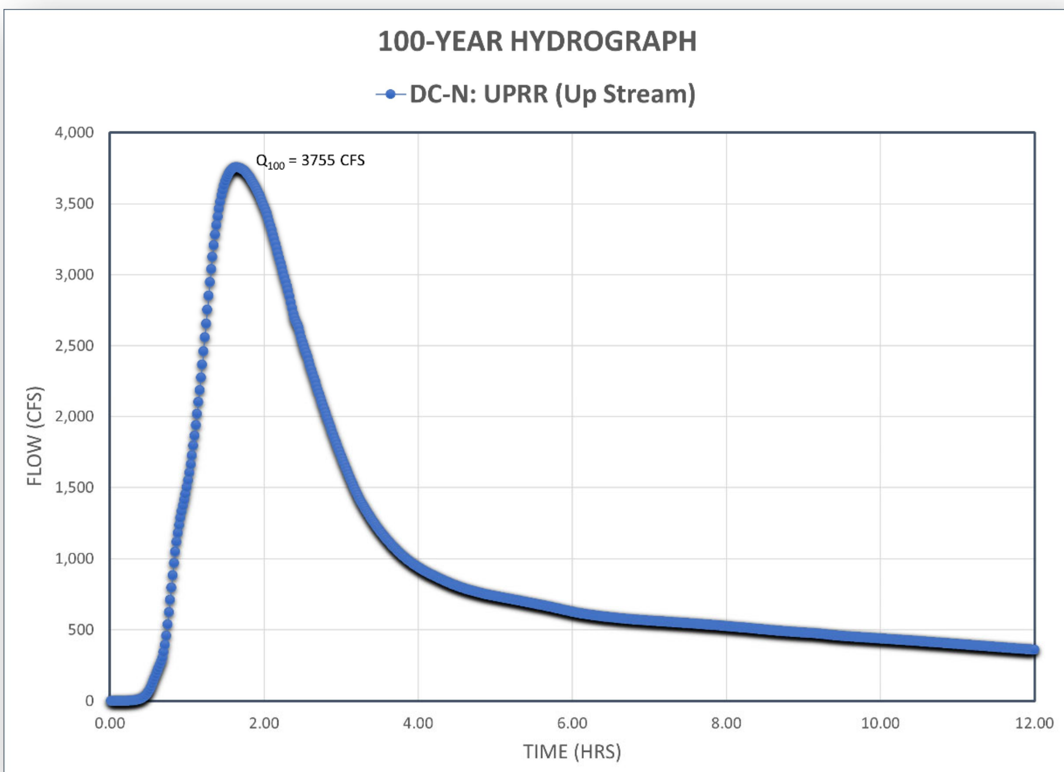


Figure 31. Hydrograph Exhibits at Select Design Points

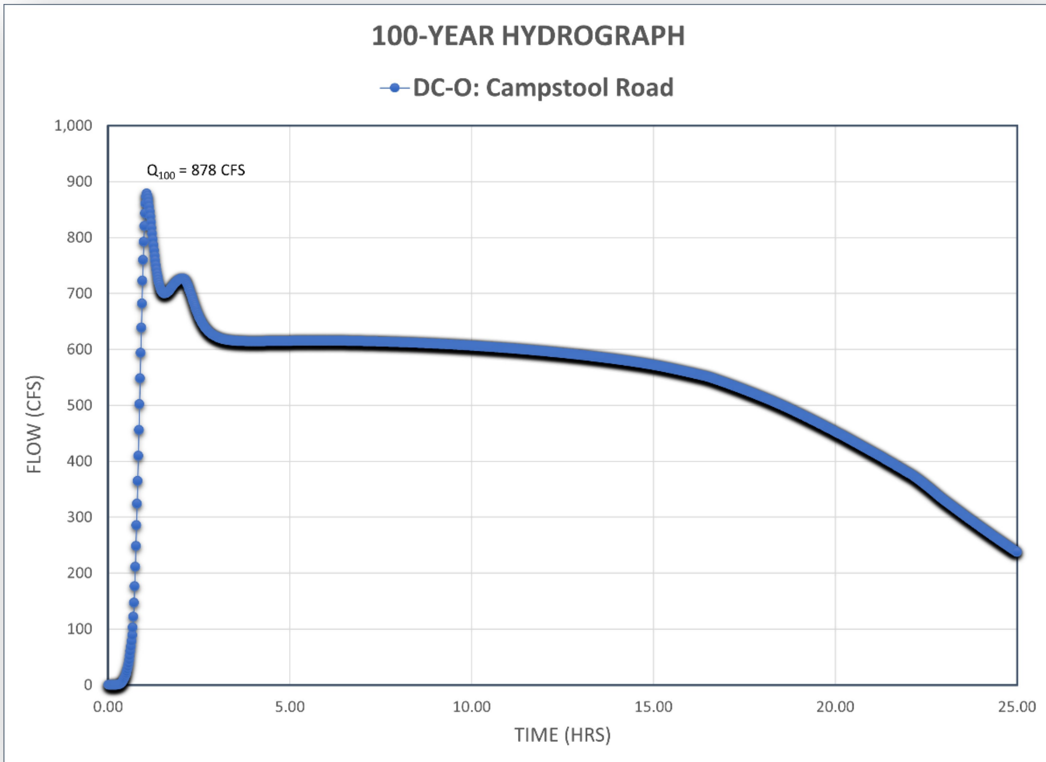


Figure 32. Hydrograph Exhibits at Select Design Points

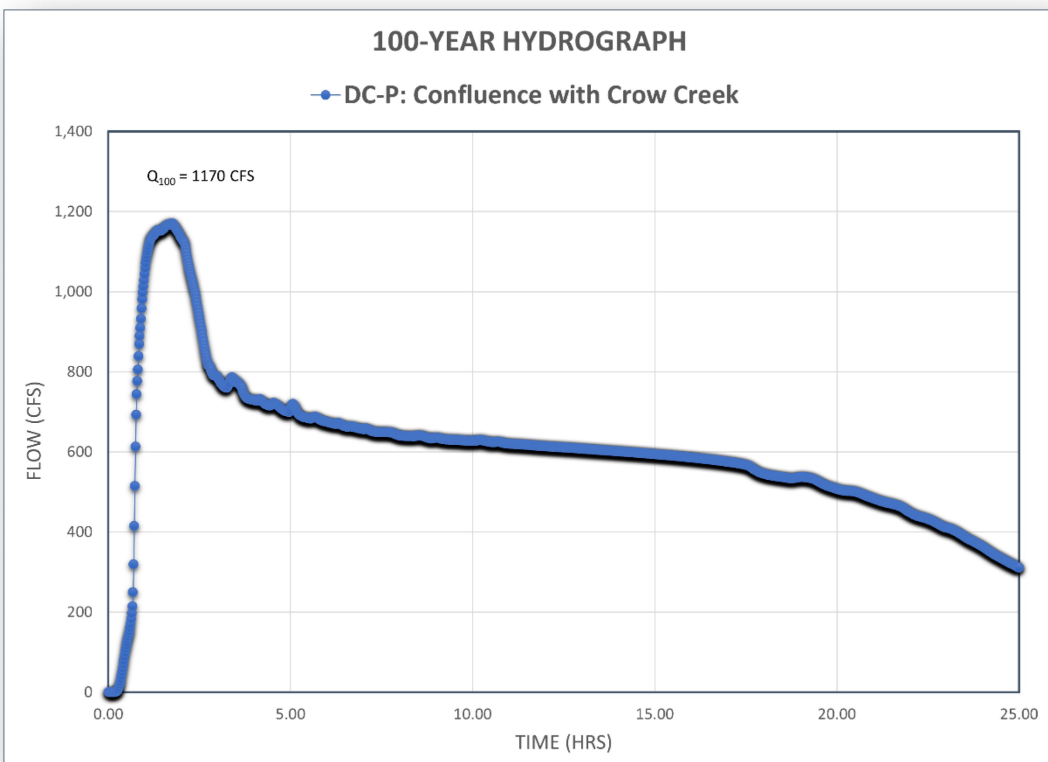


Figure 33. Hydrograph Exhibits at Select Design Points

V. HYDRAULIC ANALYSIS

A. Previous Studies

For the 1988 study, the USACE HEC-2 water surface profile program was used to delineate stream profiles along each reach of Dry Creek. Peak discharges were input at select design points from the baseline hydrologic model. The HEC-2 program uses the standard step method for determining water surface profiles from backwater calculations. Love & Associates based their Effective HEC-2 Model on the 1988 hydraulic model. For the 1988 model, channel and overland flow cross sections were plotted from topographic maps provided by the city. The maps provided had a scale of 1-inch equal to 200-feet and 2-foot contour intervals. The locations of cross sections used in the hydraulic analysis are on file at the City GIS Office in maps 47, 61 to 65, 76 to 80, 93 to 96, 109, and 110. Channel roughness characteristics for each reach were determined from field observations. Manning's "n" values were determined from descriptions given in Chow (1959) and the USGS publication authored by Barnes (1967).

Ayres Associates developed a HEC-RAS model in support of the Dry Creek Sheridan Reach Flood Control project and corresponding Physical Map Revision approved by FEMA in 2009. The HEC-RAS model was based on peak discharges generated from a revised HEC-1 model with an upstream boundary condition set at the Carey Reservoir inlet and a downstream boundary condition set downstream of the U.S. 30 crossing. The HEC-RAS model tied back into the effective HEC-2 model both upstream and downstream and showed that the effects of the flood control project were effectively dampened out by the U.S. 30 crossing. The flood control project included a minor trans basin diversion of flow into the Dry Creek Basin from the Henderson – E. Lincolnway Basins with additional flow from the Cheyenne Regional Airport being conveyed into the flood control alignment between Converse Ave. and Windmill Rd.

GLM Design Group submitted a LOMR for Lower Dry Creek at the Union Pacific crossing encompassing approximately 1000-feet of Dry Creek in 2019. The HEC-RAS model developed in support of the Lower Dry Creek LOMR was effectively a continuation of the earlier Ayres Associates model and submitted on behalf of Laramie County on behalf of a private property owner. The LOMR effort was the conclusion of the 2010 Lower Dry Creek Constructed Wetlands project completed on behalf of the County and a private property owner. The Wetlands project became the stimulus for the city's East Park where the 5-acre forebay pond and wetland chase are the focal points of a new community park and a driver for further development in this area of the Basin.

A recent EPA SWMM model was completed by the GLM Design Group in support of East Park to model improvements to the original sump 130 and hydraulically isolate the historic UPRR 6' x 8' box arch masonry culvert for use as a pedestrian connector for the Greater Cheyenne Greenway.

For the 1988 model, culvert descriptions and dimensions were determined from field measurements. Structures were modeled using the FHWA Culvert Analysis program, HY-8. The HY-8 rating curves were used in the HEC-2 hydraulic model.

B. Hydraulic Model Setup

The proposed floodplain and inundation mapping was prepared using the US Army Corps of Engineers, Hydrologic Engineering Center - River Analysis System or (HEC-RAS) software version 6.1. This software is the industry standard for floodplain modeling and several generations removed from its predecessor HEC-2 modeling software. The inundation mapping is based on the 2019 LiDAR aerial topography provided by the Cheyenne Laramie County GIS Cooperative. The hydraulic model was set up as follows:

1. Define River Geometry:
    - Cross-sections were established at regular intervals along the river reach from either Cheyenne/Laramie County LiDAR data or from surveyed information at crossings.
    - Channel width, water depth, and bank heights were evaluated at each cross-section.
    - River Stationing (distance) along the river for each cross-section was reflected in the HEC-RAS modeling.
2. Assign Manning's Roughness Coefficient:
    - Appropriate Manning's roughness coefficients (n-value) were determined for each cross-section.
    - Factors such as channel materials, vegetation, and flow conditions were also evaluated in determining appropriate roughness factors.
    - Corresponding Manning's n-values and Expansion/Contraction coefficients were then determined for each cross-section in the model.
3. Input Flow Data:
    - Streamflow data for select design points were input from the EPA SWMM hydrologic model of the basin.
    - Flow data was input into HEC-RAS, either as steady flow rates or as time-varying hydrographs.
4. Define Boundary Conditions:
    - The upstream and downstream boundary conditions for the river reach were input into the model.
    - A flow rate was input at the upstream boundary.
    - A water surface elevation or tailwater condition was then input at the downstream boundary.
5. Define Structures and Roughness Elements:
    - Structures at crossings within the river reach, such as bridges or culverts, were identified and modeled using both LiDAR and surveyed data.
    - Dimensions, openings, and flow characteristics were specified in HEC-RAS.
    - The impact of vegetation and other roughness elements on flow patterns were also considered and appropriate roughness coefficients were assigned.
6. Review and Calibrate the Model:
    - The HEC-RAS model results were validated against previously modeled data.
    - The Manning's n-values, boundary conditions, and other parameters were adjusted to achieve better agreement between model predictions and previously modeled data.
    - The model calibration process was iterated until satisfactory results were obtained.

C. Field Survey/Structure Inventory

Project base mapping for the current update is from the current regional aerial LiDAR for the City of Cheyenne. More recent GIS data from the city was incorporated for stormwater and other utilities in the model. This information was supplemented with field elevations using survey grade GPS to verify ground and pipe invert elevations for conveyance structures located within the main channel of Dry Creek. We have updated the city's GIS data where appropriate with more accurate data for storm drain outlet locations along the creek for the city's MS4 compliance efforts.

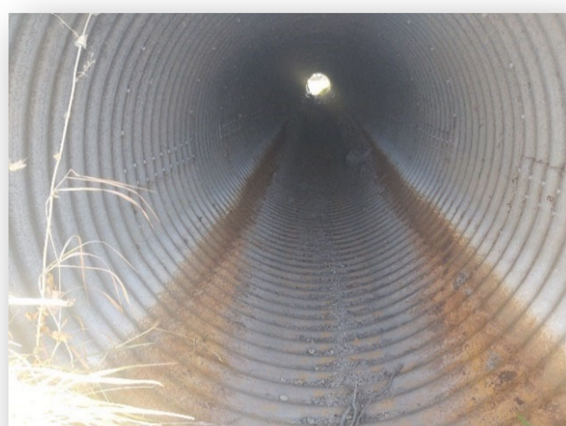
Steil Surveying Services collected field data of each of the crossings of the main channel of Dry Creek in support of this plan update. The field data covered the entire 11-mile length of the main channel, beginning at Vista Lane in Western Hills and ending at the downstream Campstool Road crossing immediately upstream of the confluence with Crow Creek. Each surveyed crossing included a detailed topographic survey extending approximately 100-feet upstream and downstream of each crossing to supplement the hydraulic model. This information was merged into the LiDAR data where appropriate to improve model quality and detail. The Northing and Easting of primary structures including elevation data for invert(s) and/or flared end sections, top of chord, top of pipe, top of structure, size of structure, and top of roadway.

At each crossing, Steil Surveying personnel collected elevation data for inverts and/or flared end sections, top of chord, top of pipe, top of structure, size of structure, top of roadway, and wingwall data. The data was collected using GPS equipment, Robotic Total Station, and laser scanner. Steil personnel surveyed 31 structures that cross the main channel of Dry Creek. Data was collected using NAD83-2011, Wyoming State Plane Coordinates, East Zone, US Survey Feet, and NAVD88 elevations. Field survey exhibits along with location maps showing the surveyed crossing locations are attached in the appendices to this report. Data from the structure survey was incorporated into the HEC-RAS hydraulic model.

D. AASHTO Infrastructure Conditions Assessment

GLM Design Group personnel conducted an infrastructure conditions assessment incorporating the 2020 Culvert and Storm Drain System Inspection Guide by the Association of State Highway and Transportation Officials (AASHTO). Culverts and storm drain outfalls were documented and photographed using the AASHTO guidelines. The AASHTO infrastructure conditions assessment forms are attached to this report.

Culvert and storm drain inspection forms were developed from AASHTO literature guidance. Structure Inspections were documented with pictures and field notes. The Condition Assessment Rating System was based on visual inspection of each structure including general integrity, accumulation of sediment and debris and other pertinent information. A summary of some of the observed conditions follows. The complete assessment forms are attached in the appendix.



Vista Lane Crossing of South Fork 5-barrel CMP with projecting inlets. Minor sedimentation upstream and overgrown vegetation in downstream channel. Minor surface damage on the inlet side. Noticeable sag in the bottom of No. 3 culvert. Generally, the structure is in good condition.

Bishop Blvd. South Fork RCB with headwall. Deposition of sediment and excess vegetation on upstream side of structure. Noticeable sag with ponding towards middle of box. Cracking at ends of headwall with some spalling/deterioration near inlet opening. Generally, the structure is in good condition.

Hynds Blvd. South Fork RCB outlet is in good condition but with a tailwater condition due to excess vegetation and deposition of sediment. The downstream channel is one of the recommended mitigation measures from this report and includes recommendations for re-grading the low-flow channel, dredging, and removal of excess vegetation.

Hynds Blvd. North Fork outlet Elliptical pipe with some joint separation of the last pipe segment. Severe sediment deposition and excess vegetation at the outlet. Refer to above recommended mitigation measure.

Hynds Blvd. Western Hills storm sewer outlet Elliptical pipe with severe sediment deposition and excess vegetation at the outlet. Refer to above mitigation measure.

Hynds Blvd. north storm sewer outlet Round pipe with a bend in the pipe at the outlet end. The pipe is in good condition. Outflow is into same downstream channel described above with sediment deposition and excess vegetation issues.

Hynds Blvd. south storm sewer outlets There are two storm sewer outlets – an 18" and a 24" that convey stormwater to the channel from the south. Both outlets are in good condition. Both convey flow to a reach of channel in need of dredging and removal of excess vegetation.

Multiple minor storm sewer outfalls for the McCormick – Central Campus There are seven minor storm sewer outfalls between I-25 and the pedestrian crossing on the McCormick – Central campus. Three that drain the Central side and four that drain the McCormick side. The four on the north or left bank looking downstream, convey flow under the greenway path. All are 18" diameter pipe or smaller and are in good condition. There are three additional minor storm sewers that drain the Central side between the pedestrian bridge and Education Dr. The McCormick drainage channel outlets from the north side in this reach. This reach contains a detention pond which this report recommends to be reconfigured and expanded.

East Side McCormick Campus drainage channel There is deposition of material at the upstream end of the pipe. There is also deposition of material along with excess vegetation at the outlet of the pipe. The pipe conveys stormwater under the greenway path. The recommended mitigation measure for this structure is to replace the drainage channel with a storm sewer with a direct outfall into Dry Creek.

Education Dr. The Education Dr. crossing consists of four (4) 4' diameter CMP. These pipes are in good condition, but do not have adequate capacity to convey the 100-year flood. Overtopping of Education Dr. results at a low point in the road north of the culverts.

Gateway Dr./Westgate Pond outlet The Westgate Pond is completely silted in with a failing railroad tie dam as shown in the accompanying picture. The "Cowlick Springs Reservoir", Permit 2396R with the state may be the reservoir permit for the Westgate community pond. This report's proposed mitigation measures are to acquire the pond from the Westgate HOA and rebuild the dam with an improved outlet structure and piping underneath Gateway Dr. The Laramie County Conservation District may be willing to partner with the city with a $35,000 grant from the small water program through the state.

The existing concrete apron on the downstream slope of the dam needs repair. The dam currently discharges flow via overtopping of the failed railroad tie dam. The receiving CMP pipe inlets are embedded in the failing concrete apron where cracking of the concrete is now facilitating piping of stormwater under Gateway Dr. If left unaddressed, this will lead to a sink hole under the roadway with potential collapse of the road. Sediment from under the road can clearly be seen deposited at the downstream outlet of the pipes. In addition, there is a tailwater condition on the pipes due to sediment and excess vegetation. It is recommended that dredging and removal of excess vegetation be done in the downstream channel.

Multiple minor storm sewer outfalls between Gateway Dr. and Yellowstone Rd. There are five minor storm drain outlets on the left side of the creek, looking downstream. These pipes convey storm drainage from W. Carlson Street and from Subway and the Wyoming State Bank. They all cross the Greater Cheyenne Greenway and are in good condition.

Yellowstone Rd. Crossing. The Yellowstone crossing is a 9' x 20' reinforced concrete box (RCB). Half of the RCB is obstructed by the greenway including having an elevated invert, reducing the height of this half of the structure by 1-foot. The channel cross section both into and out of the structure is also taken up by the greenway, reducing low-flow capacities by 50%. Both the headwall and wingwalls are in good shape. There is some minor spalling of the concrete bottom on the channel side and some damage of the RCB ceiling from bird nests. There is a severe downstream tailwater condition due to a flat longitudinal slope downstream of the Yellowstone crossing which contributes to deposition of sediment. The mitigation measure proposed by this report is to reconstruct the low flow channel to Sunset Dr. to increase slope and improve conveyance for low flow conditions.

Yellowstone Rd. north storm sewer outlet. The north storm sewer outfall discharges along the left bank, looking downstream approximately 200-feet from the Yellowstone crossing. This storm sewer is a major collector for a considerable amount of stormwater runoff from original subbasins 60 and 70 adjacent to the Yellowstone corridor. The main trunkline for this system terminates just south of Vandehei Ave. the 72-in elliptical outlet pipe is in good condition. There is a severe downstream tailwater condition due to a flat longitudinal slope downstream of the Yellowstone crossing which contributes to deposition of sediment from this outfall. If not addressed in a timely manner, this contributes to flooding of the greenway tunnel under Yellowstone Rd. The mitigation measure for this condition is listed above.

Yellowstone Rd. south storm sewer outlet. This is a smaller storm system that drains the Yellowstone Rd. corridor to the south. This system terminates just south of Dell Range Blvd. The 27-in outlet discharges from the right wingwall of the Yellowstone Rd. RCB. It appears in good condition.

Multiple minor storm sewer outfalls between Yellowstone Rd. and Sunset Dr. There are six minor storm sewer outfalls between Yellowstone Rd. and Sunset Dr. These convey minor drainages and are all in good condition.

Sunset Dr. storm sewer outlet. This is a major storm sewer outfall which comes in at a perpendicular angle to the creek. The 54-in diameter pipe discharges into a concrete energy dissipation vault and then through smaller plastic round pipes to convey low flow under the greenway path. The bank slope is riprapped beyond the greenway path and there is a concrete check dam for a utility crossing immediately downstream. A greenway fence should be considered on the bank side slope for pedestrian safety. The vault is in good shape. Some minor dredging and removal of excess vegetation is required in the creek.

Multiple minor storm sewer outfalls between Sunset Dr and Sunset Dr. There are five minor storm sewer outfalls between the Sunset Dr. energy dissipation vault and the Sunset Dr./Townsend Pl. crossing. These convey minor drainages and are all in good condition.

Sunset Dr. crossing. The Sunset crossing consists of three (3) 7’ diameter CMP. There are trees and excess vegetation located immediately upstream of the pipe openings. The culverts lack capacity to convey the 100-year flood resulting in overtopping of the crossing at a low spot located north of the culverts. A local developer is partnering with the city to improve these culverts and provide minor off-line storage immediately upstream to reduce the amount of overtopping conveyed to downstream Marjon Court. The culverts are in good condition but are not functioning well due to the excess vegetation and trees in the upstream channel.

Crow Rd. storm sewer outlet The outlet structure with grate incorporates an energy dissipator wall. The concrete wing walls are in good shape. The riprap outlet channel is in fair condition and in need of repair.

Seminoe Rd. crossing. The Seminoe Rd. crossing consists of two (2) 7’ diameter CMP. The pipes show some abrasion and rust, but are in good functional condition. There is minimum head at this crossing resulting in hazardous overtopping for less frequent flood events.

Seminoe Rd./Melton St. storm sewer outlet. There are two minor storm sewer systems that drain Seminoe Rd. and Melton Street and have a joint outfall into the creek through two minor culverts just downstream of the Seminoe crossing. These outfalls are silted in and in need of maintenance.

Multiple minor storm sewer outfalls between Seminoe Rd. and Mylar Park pedestrian bridge. There are four minor storm sewer outfalls between Seminoe Rd. and the pedestrian crossing in Mylar Park. These convey minor drainages north of the park. The culverts convey flow under the greenway path and are all in good condition.

Prairie Ave. crossing. The Prairie Ave. crossing consists of three (3) 48-inch diameter CMP. There is significant vegetation in the upstream culvert creating a piping condition under the roadway resulting in a sizeable sink hole that the city has recently repaired. These culverts have inadequate capacity to convey the 100-year flood event resulting in hazardous overtopping of the roadway.

Multiple storm sewer outlets between Prairie Ave. and Powderhouse Rd. As a rule, the outlets need to be cleaned and better maintained. These outlets are significantly silted in.

Powderhouse Rd. Crossing Overall, in good condition. There is significant vegetation in the downstream "wet" side of the structure (working culverts, not the pedestrian side).

Meadowbrooke Park Subdivision (Fairfield Inn) Detention Pond outlet. Minor storm outlet for the Fairfield Inn detention pond. There is some deformation of the outlet CMP. The detention pond is completely overgrown with trees and grass and needs to be cleaned up to function properly.

Multiple minor storm sewer outlets immediately downstream of the Powderhouse crossing. There are four minor storm sewer system outfalls immediately downstream of the Powderhouse crossing. The largest of the four drains a detention pond for the Frontier Mall. These all appear to be in good shape.

Cheyenne Regional Airport storm sewer outlet No.1 Outlet No. 1 drains to a minor drainage channel which conveys runoff from the airport into Dry Creek. The contributing storm drainage system drains a considerable amount of runway stormwater runoff. Both the storm sewer outlet and drainage channel are located on airport property and could not be closely inspected. They appear to be in good functional condition. The concern with this outfall is MS4 compliance regarding potential clean water violations related to the use of de-icing and other operations at the airport.

Multiple minor storm sewer outlets from Meadowbrooke Park Subdivision. There are four minor storm drain outfalls between the Fairfield Inn and the pedestrian bridge. These outfalls all have minor vegetation issues but appear to be in good functional condition.

Cheyenne Regional Airport storm sewer outlet No.2 Outlet No. 2 drains to a minor drainage channel which conveys runoff from the airport into Dry Creek just upstream of the pedestrian crossing. The contributing storm drainage system drains runway stormwater runoff. Both the storm sewer outlet and drainage channel are located on airport property and could not be closely inspected. They appear to be in good functional condition. The concern with this outfall is MS4 compliance regarding potential clean water violations related to the use of de-icing and other operations at the airport.

Pedestrian Crossing/riprap energy dissipator. There is some cracking of the riprap apron with exposure of cracked pvc pipe in several locations. Additionally, there is evidence of piping through the riprap which will continue to degrade the structure if not addressed. This report recommends a mitigation measure that would include the removal of this structure. The cost may be prohibitive so an interim measure would be to repair the existing riprap apron.

Drainage channel from Meadowland Dr. This channel conveys runoff from Dell Range Blvd., the Frontier Mall, and Meadowland Dr. This is a major channel conveyance structure and appears to be in good functional condition.

Cheyenne Regional Airport storm sewer outlets No.3 and 4 These are minor storm drain outfalls into Carey Reservoir. Both outlets appear in good functional condition. There is some erosion of the Carey Reservoir embankment from outlet No. 4. This report recommends that the slope be repaired with a geofabric installed to prevent future erosion from storm drain discharge.

Carey Reservoir outlet The north (original) outlet is in good condition. There is a 48-inch USBR Type VI Baffle Dissipator for this structure – also in good condition.

East Carey Reservoir Outlet Appears in good condition.

Dell Range Blvd. crossing The structure is in good condition but with heavy vegetation in the upstream channel.

Mason Way Outfall 48-inch outlet with headwall and wingwalls are in good shape.

Converse Ave. storm sewer outlet Overall, in good functional condition.

Converse Ave. crossing Generally, in good condition but with heavy vegetation in both upstream and downstream channels.

Mountain Rd. crossing The structure is in need of repair. The south bank of the creek is encroaching on two of the culverts. There is cracking of the concrete embankment. There is significant sediment deposition impacting conveyance as well as excessive vegetation in the channel.

Windmill Rd. crossing In good condition but with some bank erosion downstream of structure. Upstream bank is encroaching on the concrete box opening impacting conveyance into the box.

Lindenway storm sewer outlet Grated energy dissipator at the outlet. ***There appears to be a piping issue occurring beneath the outfall structure and potentially migrating under the roadway section***.

PineRidge Ave. storm sewer outlet The outlet is in good condition. Energy dissipation block immediately downstream of elliptical outlet.

Cahill Park Addition storm sewer outlet The 78-inch outlet is in good functional shape.

Hilltop Ave. crossing This structure is in of repair or replacement. Flared end sections are failing on two of the culverts. There is significant deposition of sediment on the upstream side of the structure with ***apparent piping occurring through the embankment***.

Sheridan Street storm sewer outlet The outlet is in good condition. There is some sedimentation at the outlet.

Dell Range Blvd. crossing The structure is in good condition. Consideration should be given to placing guard rails on the upstream side for pedestrian safety.

Multiple Dell Range Blvd. storm sewer outlets Outlets are covered with vegetation and in need of maintenance.

Darnell Pl. storm sewer outlet This outlet is in good condition. There is excessive vegetation at the outlet.

Ridge Rd. crossing Box culvert is in good condition. There are small cracks in the upstream wingwall. There is one large crack in the box wall/pier but does not appear to be structural. Consideration should be given to providing guard rail for the downstream side. Vegetation in the channel is quickly growing back from the recent dredging project.

Ridge Rd. storm sewer outlet The outlet is damaged. The flared end section is pulling away from the pipe.

Dry Creek Sheridan Reach Flood Control Alignment Outfall This outfall is in good condition along with the riprapped scour apron.

N. College Dr. crossing The structure is in good shape but there is scour occurring at the downstream face of the box. There is thick vegetation including trees in the downstream channel.

Multiple N. College Dr. storm sewer outlets The storm sewer from the north has sediment deposition at the outlet.
Curb & gutter around the east inlet on N. College Dr. is in need of reconstruction.

Fillmore Ave. storm sewer outlet Overall in good and functional condition.

Pierce Ave. storm sewer outlet There is significant vegetation at the outlet. The structure is in good condition. There is standing water in the outlet channel.

Rawlins St. storm sewer outlet The outlet is 50% filled in with sediment and leaves.

Rawlins St. Crossing Structure is good shape but there is significant scour occurring downstream which could impact the crossing if not addressed.

U.S. 30 Crossing The structure is in good functional condition with two of the boxes used for the Greater Cheyenne Greenway system.

Cheyenne Street. storm sewer outlet This outlet is in good operational condition. It is a flap gate into the levee.

East Pershing Blvd. storm sewer outlet This appears to be in good condition – also a flap gate into the levee.

East Pershing Blvd. crossing Overall, in good condition. No evidence of sedimentation.

Saddle Ridge drainage channel Built in 2010 and in good condition. Conveys Saddle Ridge drainage to the Dry Creek channel south of E. Pershing Blvd.

Union Pacific Railroad crossing This structure was inspected as a part of the East Park (Kiwanis Park) Cheyenne MPO Study in 2022 and is generally in good condition. There is some minor masonry repair required along with repair of the culvert floor in spots.

Upper Campstool Rd. crossing Appears to be good condition but with a skewed upstream channel alignment into the culverts. Downstream, a recently constructed riprap scour basin has addressed the headcutting condition.

A map of structure/outfall locations is attached in the thumb drive to this report.

E. Off-Channel Conditions Assessment

Cody and Pawnee St. overland flooding – There is significant overland flow between Western Hills and Dry Creek creating nuisance issues for frequent storm events and major ponding in large flood events. Cody and Pawnee St. will experience 126 cfs during a 100-yr event. A 42 in culvert drains the intersection. The culvert has a capacity of 70cfs. The remaining ***flow overtops Pawnee Ave to Western Hills Blvd causing impacts to the traveling public and property damage concerns.***

Westgate/Carlson flooding – There are overtopping concerns at the Education Dr. crossing (life-safety, property damage hazard, and infrastructure concerns) during a 100-year event. A***pproximately 550 cfs overtops Education Dr. and flows onto Carlson Street.*** This water ponds at a low spot on Carlson St. at Gateway Dr. before it overtops to the south and back into Dry Creek. Exacerbating this issue is significant overland flow between Western Hills Blvd. and Carlson Street that combines at this low point creating a nuisance issue for frequent storm events and significant ponding for large storm events.

Indian Hills Subdivision – There are street conveyance ponding issues for the Indian Hills subdivision. There are overland flood risks between Storey Blvd. and the Dry Creek channel. The Storey Blvd./Sycamore Rd. storm sewer is undersized – ***leaving 130cfs for street conveyance for 100-year event.*** Significant overland flow/flooding is conveyed to the Crow Rd/Melton St. intersection with potential sediment issues affecting the city MS4 compliance. There is a nuisance conveyance issue for the Hoy Rd. outfall into Dry Creek

Dell Range Blvd./ Prairie Ave. Commercial District – The drainage channel within the median of Prairie Ave from Powderhouse Rd. to Frontier Mall Dr. is undersized resulting in overtopping of the roadway. ***Approximately 145cfs is conveyed on the street and directed south along Frontier Mall Dr***. The Dell Range Blvd crossing of dual 54” circular culverts are at capacity, any additional flow to the system will overtop the drainage swale and head east along Dell Range Blvd. resulting in a flooding hazard. There are two detention ponds located on the south end of the Walmart/Sam’s Club parking lot. These ponds overtop during a 100-year event, ***discharging over 100cfs onto Dell Range Blvd***.

Buffalo Ridge Subdivision – The Plain View Rd./Chapel Hill Dr. intersection has a drainage basin of over 48 acres, contributing 170cfs. This area is drained by an under capacity 24in storm system, ***leaving 145cfs on Plain View Rd***. The overland flow, not collected in the 24-in storm drain, continues south to Pattison Ave. A storm drainage system ranging in size from an 18-in to 42-in circular pipe travels along Pattison and Pineridge and ultimately discharges into Dry Creek. The system collects 75cfs, ***the remaining 191cfs sheets flows across Sheridan St. and into the Dry Creek Channel resulting in a life safety hazard***.

East Dell Range Blvd. – The East Dell Range drainage adjacent to the Whitney Ranch subdivision has potential to overtop the roadway and flow south into county pockets having inadequate drainage infrastructure to handle the stormwater runoff. The city has entered a public/private partnership with the developer to construct a storm sewer to convey this discharge directly to the Dry Creek channel.

Dell Range Market Place North – The Basins along Everton, between Ridge Rd. and Harmon Ave., north of the Dell Range Market Place subdivision, sheet flow through the back of homes to Greg Way. The lack of drainage swales and curb & gutter in the area does not provide a clear drainage path resulting in potential property damage. The city did install a minor storm sewer system in Greg Way twenty years ago to help with nuisance flows, but drainage issues remain for larger storm events.

Rock Springs Street - Approximately 44 acres contribute to the intersection of Messenger and McCann where over ***120cfs overland flows through the area and to Rock Spring St. Rock Spring St. conveys over 130cfs to Dry Creek*** resulting in a roadway flooding concern.

N. College Dr. - The minimal storm drainage system along N. College Dr., south of Dry Creek, causes flooding concerns as the area continues to develop creating a property damage concern.

Imperial Valley Subdivision - ***Over 100cfs sheet flows during a 100-year event*** to the intersection of Eastview St and Rangeview Dr. where it overtops and flows between homes to Dry Creek resulting in a property damage hazard.

Sunnyside Subdivision - There is hazardous overtopping of the Sunnyside/Polk Ave. intersection for less frequent storm events. The city has installed signage to warn pedestrians and motorists.

Dakota Crossings Subdivision - Overland flooding on Wenandy Ave. north of E. Pershing Blvd. resulting in overtopping of E. Pershing Blvd.

Sun Valley Subdivision - Sun Valley drainage issues include having a minimal storm drainage system along Meadow Dr. ***resulting in flow in the street of over 100cfs at some locations***. The system was designed to overtop and flow between homes to Dry Creek. Fences block the way in some of the drainage pathways resulting in property damage concerns. Overland flow on Atlantic Dr. is hazardous for less frequent storm events and creates nuisance flow for frequent events.

F. Drainageway Description

As referenced in the 1988 study, the Dry Creek channel extends 9.3-miles from its confluence with Crow Creek northwesterly to I-25 as shown in **Figure 1**. The south fork extends another 0.5-mile from I-25 to FEW and the Cheyenne corporate limits. The north fork extends 1.1-miles from its confluence with the south fork at I-25. The north fork is street and storm sewer conveyance. The south fork is a narrow-confined channel between the backs of houses from Vista Lane to I-25.

Headwaters to Yellowstone Reach (SubBasins 10, 20, 30, 40, 50, and 60 from 88 study)

The north tributary has its headwaters on FEW property where north fork drainage is attenuated in a 51 Ac-ft detention pond located at the boundary of the city. Stormwater runoff is conveyed from the Base detention facility into the city by a natural channel which flows between two residences. Flow is then routed onto Rodeo Drive and through a drastically undersized detention pond. From there stormwater flows through a concrete channel to Silver Sage Avenue, then down to Juniper Drive and then to Dogwood Avenue. Flood waters flow down Dogwood Avenue to a concrete channel that drains onto Evers Blvd. where it is then intercepted by a newly constructed storm sewer that conveys flow to an 800-foot culvert beneath I-25 to a confluence with the south fork of Dry Creek.

The south fork is conveyed into the city via an open channel and a series of culverts beginning at Vista Lane. The open channel has a bottom width of 5-feet and is 8-feet deep with a longitudinal slope of 0.8 percent. This channel experienced severe flooding during the 1985 flood event. Flow from the south fork is conveyed under I-25 in a culvert. The north fork confluence with the south fork is on the east side of I-25 on the McCormick-Central campus.

The drainageway through the McCormick-Central campus is overgrown with vegetation and excess deposition of sediment between I-25 and the pedestrian bridge crossing. There is an existing pond on the east end upstream of the Education Dr. crossing. The culverts under Education Dr. are submerged. The West Gate development between Education Dr. and Yellowstone Rd. has fencing across the drainageway effectively damming overtopping of Education. The fence was knocked over by significant hydraulic forces during the 1985 event. For most events, the fence serves to direct any overtopping towards Carlson Street where it adds to severe ponding at the access drive into West Gate. The downstream dam appurtenances are in serious need of repair. There is ongoing piping occurring through the riprapped downstream slope and around the downstream culverts carrying flow under West Gate Dr. Material is being moved with excess sediment observed in the channel immediately downstream of the West Gate Dr. culverts. The Effective hydraulic model indicates overtopping occurring at Yellowstone Rd. This hydraulic structure was upgraded after the 1996 States West report. This report's HEC-RAS hydraulic model shows no overtopping of Yellowstone Rd. at the crossing. There is shallow overland flooding of Yellowstone Rd. from Carlson St.

Yellowstone Rd. to Powderhouse Reach (SubBasin 70 from 88 study)

The channel immediately downstream of the Yellowstone crossing is beset with sedimentation issues and excess vegetation due to a rather flat longitudinal slope between Yellowstone Rd. and Sunset Dr. Downstream of Townsend Pl. the channel has been straightened adjacent to the greenway resulting in abandoned meander loops south of the greenway path and an inadequate conveyance capacity through this reach. The channel through this reach is entrenched with a top width of 8-feet and a depth of 4-feet. Downstream of Seminoe Rd., the channel begins to meander with broader floodplains into a ponded area in Mylar Park. The outlet from the Mylar Park Pond conveys flow into an entrenched reach leading to the Prairie Ave. crossing. This reach has a top width of 10- to 12-feet and a depth of 10-feet before it flattens out immediately upstream of the Prairie Ave. culverts. These culverts need repair with ongoing piping due to vegetation blocking the inlets and the creation of a sink hole under Prairie Ave. (since repaired by the city). Between Prairie Ave. and Powderhouse Rd. the low flow channel has room to meander with a broader floodplain. The Effective model indicates that overtopping occurs at the Powderhouse crossing for less frequent flood events. Our modeling efforts indicate that the overtopping is due to the blockage factors applied to the culverts in the Effective hydraulic model.

Powderhouse Rd. to Carey Reservoir Reach (SubBasin 80 from 88 study)

The reach between Powderhouse Rd. and Carey Reservoir has been channelized for reclamation of flood-prone land for commercial and residential development between Dell Range Blvd. and Dry Creek. The channel conveys flow to a diversion structure at Carey Reservoir (originally a 151 Ac-ft off-line storage facility). There is a grouted riprap drop structure immediately upstream of the pedestrian bridge crossing (approximately 0.1 mile upstream of the Carey Reservoir diversion structure) that needs repair. The reach between the pedestrian bridge and the diversion structure has negligible freeboard and represents a significant capacity constraint for any additional flow in Dry Creek. The channel through this reach has an approximate 30-foot top width and is about 6-feet deep.

Sheridan Reach (SubBasins 90 and 100 from 88 study)

The 1985 flood caused severe flooding through this reach resulting in 11 fatalities as people attempted to cross overtopped structures only to be swept into the flood waters. The reach has an approximate top width of 30-feet with a 6-foot depth. The longitudinal slope is 0.5 percent. It is encroached by Sheridan Street to the north and commercial and residential development to the south. The Dry Creek Sheridan Reach Flood Control project was designed to alleviate flooding through this reach. More recent development north and west of Buffalo Ridge has begun to overwhelm available capacity in the reach. The Mountain Road and Hilltop Road crossings need repair and/or reconstruction. The Hilltop Road crossing is overtopped in less frequent flood events creating property damages for residences on the north side of Sheridan Street and potential safety hazards for the traveling public. A BOPU sanitary sewer manhole immediately downstream of the pedestrian bridge crossing upstream of Hill Top Road is causing bank erosion and potential compromise of the pedestrian bridge abutment. The channel banks are in fair condition with the north banks (left side looking downstream) seeing active erosion from stormwater runoff sheet flowing into the channel.

Ridge Road to U.S. 30 Reach (SubBasin 110 from 88 study)

Downstream of Ridge Road, the floodplain broadens slightly before narrowing upstream of the College Dr. crossing. Immediately downstream of Ridge Rd. is the outfall for the Sheridan Reach Flood Control project. There are flooding issues upstream of the College crossing due to the narrow flood channel. Downstream of College, the floodplain broadens with a small, meandering low flow channel. The reach between College and U.S. 30 is characterized by grassed overbank areas and a longitudinal slope of 0.6 percent. The Greater Cheyenne Greenway runs adjacent to the creek with several low-flow crossings. A Parks Department frisbee golf course is located within this reach as well. The U.S. 30 crossing creates a sump condition which we have modeled in the updated modeling for this report. This area of the basin has not been developed and urbanized to the point that the upper and middle portions of the basin have been. The community is now experiencing development in the eastern (lower) portions of the basin in areas that have been historically agricultural residential or rural residential.

U.S. 30 to E. Pershing Blvd. Reach (SubBasin 120 from 88 study)

This reach of Dry Creek is a confined, levied channel constructed thirty years ago by the County as a response to flooding that occurred during the 1985 flood event. Up until recently, a low flow crossing created a back water condition for frequent events which impacted the U.S. 30 culverts and caused ongoing flooding of the greenway path. This low flow channel has been relocated further down the channel alleviating this condition at U.S. 30. The city is in the process of relocating the pedestrian pathway from the western culvert to a new culvert to be constructed outside of the regulatory floodplain. Both the Effective and current HEC-RAS models indicate split flow occurring with overtopping of E. Pershing Blvd. at two different locations. Prior to the levied system being constructed, this reach had a broader, grassed floodplain with a meandering low-flow channel. The overtopping east of the crossing follows the historic Dry Creek channel alignment.

E. Pershing Blvd. to UPRR Crossing Reach (SubBasin 130 from 88 study)

This reach has a broad, grassed floodplain. The upper reach located on Ken Hess' property has been straightened. The lower reach located on city property flows into a constructed wetland chase (constructed in 2010) with a 2.5 Ac forebay pond in what is now a city park. The constructed wetland was designed to provide additional water quality to flow in Dry Creek prior to its confluence with Crow Creek, a TDML listed water of the U.S. The Union Pacific Railroad embankment forms a dam of Dry Creek at the downstream end of this reach and has been modeled as Sump 130 in the 1988 HEC-1 hydrologic model. There is a historic 6' x 8' box arch masonry culvert constructed in 1903 that conveys flow downstream of the UP crossing. The railroad embankment is approximately 25' high at this location. The box arch culvert has about a 10-yr. conveyance capacity before flood waters begin to be impounded against the UP embankment.

The Dry Creek drainage basin contributing flow upstream of the UP culvert is approximately 11 sq. mi. in size. The lower portion of the basin, just upstream of the UP is quickly developing. Existing conditions are such that during a large storm event, stormwater is impounded against the UP Embankment until it can flow through the masonry structure. The UP sump is a significant constriction for the basin and the resulting inundated area is shown below in **Figure 12** for a 100-year flood event. The State of Wyoming Dam Safety Division is requesting that this embankment be classified and regulated under Safety of Dams criteria.

The 1988 study included a maximum flood envelope curve (MFEC) derived from historical events in another region having similar hydrologic conditions. Data collected by Hugh Lowham (USGS, 1988) allowed an envelope curve flood peak discharge to be estimated for several locations in the Dry Creek Basin. The MFEC peak discharge estimated for the Union Pacific Railroad crossing was 16,900 cfs. The state Safety of Dams Office may require that the probable maximum flood be calculated for the Union Pacific embankment and that a breach analysis be conducted to develop a downstream inundation map. Such an event would have dire consequences for the LEADS business park, the upper and lower Campstool Rd. crossings and for I-80.

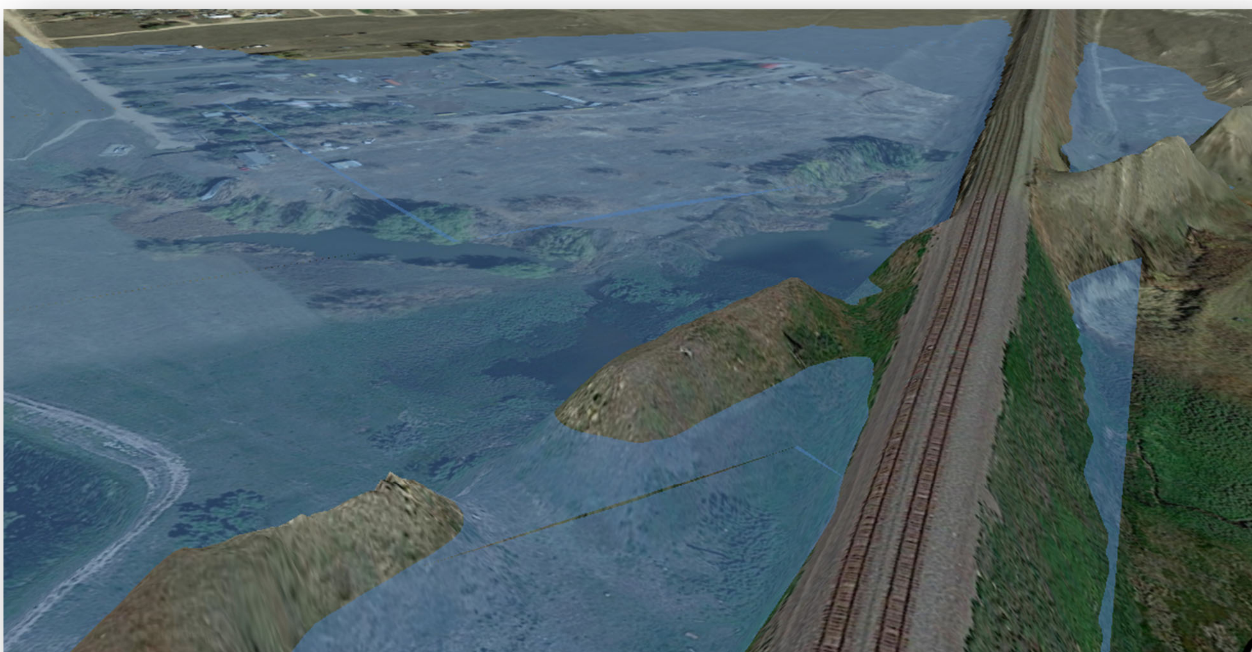


Figure 34. Detention Storage at UPRR Crossing for 100-year event

In "Risk Assessment Methodology for Dams" (FEMA P-951), FEMA provides a framework for assessing the risks associated with dams. While the document does not explicitly outline dam classification criteria, it offers guidance on characterizing dam hazards and assessing the potential consequences of failure. Here is a summary of the key aspects related to dam classification found in FEMA P-951:

- Hazard Potential Classification: FEMA P-951 emphasizes the importance of classifying dams based on their hazard potential. Hazard potential classification refers to categorizing dams according to the potential consequences of failure. It considers factors such as downstream population, infrastructure, and environmental impacts. Dams are typically classified into three categories: high hazard potential, significant hazard potential, and low hazard potential.

- Consequence Assessment: The document provides guidance on assessing the potential consequences of dam failure. It suggests considering factors such as loss of life, property damage, economic impacts, environmental impacts, and social disruption. Consequence assessment helps in determining the severity and potential impacts associated with a dam failure.
- Risk Assessment: FEMA P-951 emphasizes the need for a comprehensive risk assessment to evaluate the risks posed by dams. Risk assessment involves considering both the likelihood of dam failure and the potential consequences. It includes assessing various hazards, such as hydraulic, seismic, structural, and operational risks. The risk assessment process helps prioritize mitigation measures and inform decision-making.
- Risk Reduction Measures: The document highlights the importance of implementing risk reduction measures based on the identified risks. These measures may include structural improvements, maintenance and inspection programs, emergency action planning, and public awareness efforts. Risk reduction measures aim to mitigate the identified hazards and reduce the potential consequences of dam failure.

It is important to note that FEMA P-951 provides a general framework and guidance for assessing dam risks but does not provide specific numerical criteria for dam classification.

The Bureau of Reclamation (BOR), an agency within the U.S. Department of the Interior, has established criteria for dam classification. The specific criteria used by the BOR may vary based on the dam's purpose, size, hazard potential, and other factors. However, the BOR generally follows a dam classification system that includes the following categories:

- **High Hazard Potential:** Dams classified as having high hazard potential are those whose failure or mis operation would likely result in the loss of human life. These dams are typically located in densely populated areas or areas with critical infrastructure downstream. Examples include dams near residential areas, major highways, or essential facilities.
- **Significant Hazard Potential:** Dams classified as having significant hazard potential are those where failure or mis operation could cause significant damage to properties, economic losses, or environmental impacts. Although the potential for loss of human life is lower compared to high hazard potential dams, these dams still pose significant risks to downstream areas.
- **Low Hazard Potential:** Dams classified as having low hazard potential are those where failure or mis operation is unlikely to cause significant damage or loss of life. These dams are typically located in remote areas with limited population, infrastructure, or environmental sensitivity downstream.

Wyoming Safety of Dams regulation is administered by the Wyoming State Engineer's Office. The regulation applies to dams that meet specific criteria related to dam height and impoundment volume. The criteria for dams regulated under the Wyoming Safety of Dams regulation are as follows:

1. Dam Height: Dams that are 15 feet or higher from the natural streambed, base of the dam's embankment, or lowest point of the excavation below the natural surface fall under the regulation.

2. Impoundment Volume: Dams that have an impoundment volume of 50 acre-feet or more, regardless of the dam height, are also regulated under the Wyoming Safety of Dams regulation.

Dams that meet these criteria are required to comply with the safety standards and guidelines outlined in the regulation. This includes design, construction, inspection, maintenance, and emergency action planning to ensure the safety and integrity of the dam and its impoundment. Dam safety laws for Wyoming are contained in the Wyoming Statutes Title 41 – Water, Chapter 3 – Water Rights; Administration and Control, Article 3 – Reservoirs (W.S. 41-3-307 – 41-3-318). The Wyoming dam safety rules are in the Wyoming Administrative Rules., Agency 037 – State Engineer's Office, Program 0006 – Surface Water, Chapter 5: Reservoirs, promulgated May 28, 1980 (037.0006.5.05281980 Wyo. Admin. R. § 1 et seq.). Wyoming's dam safety program is administered by the Safety of Dams Program, a program of the Wyoming State Engineer's Office. The submission of plans for a dam, must include the following (037.0006.5.05281980 Wyo. Admin. R. § 1.b):

1. A profile drawing of the dam along the centerline, and a maximum cross-section of the proposed dam;
2. The outlet works and spillway in detail, including a computation of capacity and all necessary data;
3. Maps and drawings of sufficiently large scale;
4. For earth dams, plans that meet the design specifications of 037.0006.5.05281980 Wyo. Admin. R. § 1.b.4;
5. **For reservoirs with a dam height greater than 20 feet, or with storage capacity greater than 50 acre feet, or which are located in an area where extensive property damage or loss of life may result from overtopping, plans that demonstrate spillway capacity to pass the flood flow of a projected 100-year storm**;
6. Detailed construction plans and specifications, including underlying computations, as required by the State Engineer; and
7. A capacity table showing the capacity of the proposed reservoir shown on the reservoir filling map.

This report recommends a proposed reconfiguration of the sump 130 area such that there is no impounded floodwaters up against the Union Pacific embankment, and that there is provision for discharging the 100-year peak flow downstream. Moreover, the proposed pond must be completely empty in less than 24 hours with a spillway designed to convey the 500-year event to meet SEO requirements. The sump 130 pond empties in 27-hours for the existing condition.

For final design purposes, a breach analysis for one half of the Maximum Probable Flood (MPF) will be required by the SEO along with a downstream inundation map.

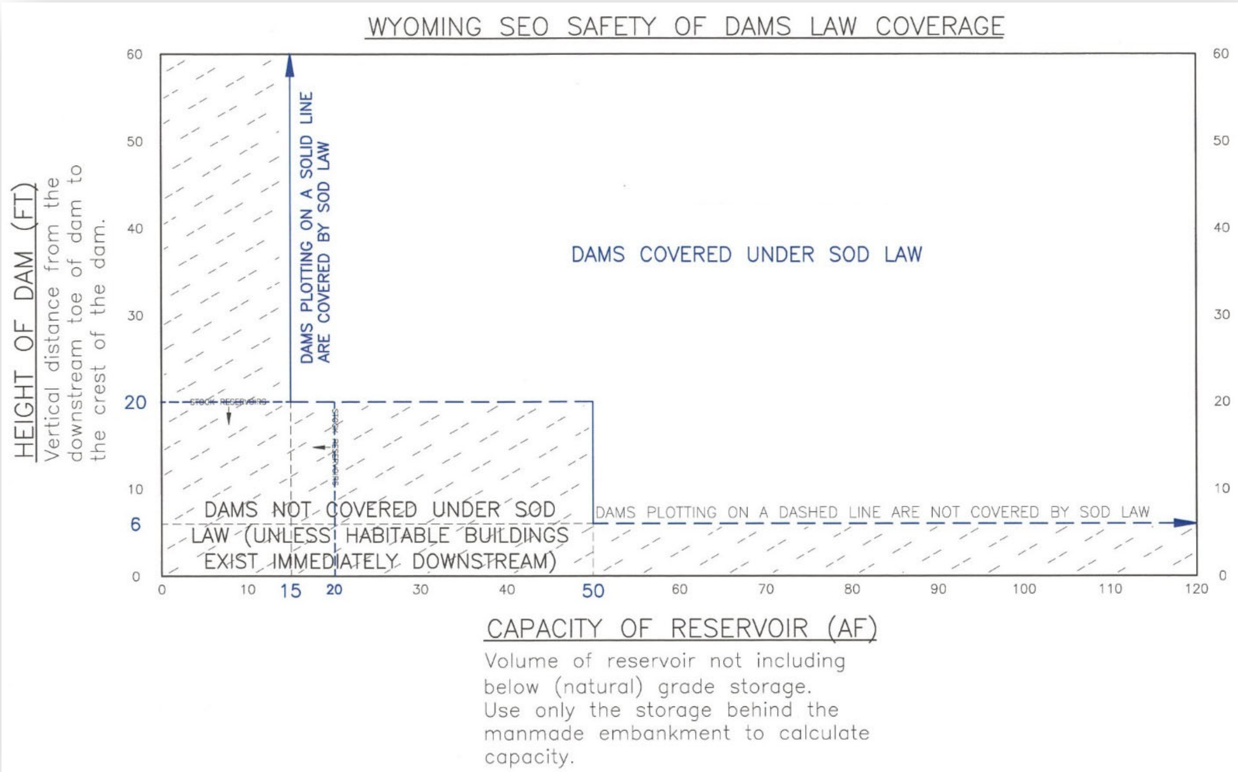


Figure 35. Wyoming SEO Safety of Dams Criteria

UPRR Crossing to Upper Campstool Rd. Reach (SubBasin 140 from 88 study)

The reach immediately downstream of the UP crossing has a broad floodplain between the UP and upper Campstool Rd. with a meandering low flow channel. There are two ponded areas, one that is currently being expanded. Managed by the Laramie County Conservation District (LCCD). The LCCD headquarters is located adjacent to this open area. The district manages the area on behalf of LEADS. The downstream Campstool Rd. crossing has recently been repaired by the city to address a head-cutting condition downstream. Campstool Rd. is overtopped in less frequent flood events at a low point located west of the crossing.

Upper Campstool Rd. to Confluence with Crow Creek (SubBasin 140 from 88 study)

The reach between upper Campstool Rd. and I-25 is entrenched with a recent active head-cut impacting the downstream face of the Campstool culverts. This has been recently improved with the construction of a riprap scour basin to protect the culvert outlet. The 1988 HEC-1 model had indicated overtopping of I-80 for the 100-yr. flood event. The current HEC-RAS model does not.

The channel downstream of I-80 is shallow with a moderate floodplain. Lower Campstool Rd. is overtopped for less frequent flood events. The confluence with Crow Creek is immediately downstream of the lower Campstool Rd. crossing. The Lower Campstool Rd. crossing is signed as a flood hazard.

G. Primary Design Point Locations

The primary design points incorporated in the 1988 HEC-1 model were as follows:

Main Channel of Dry Creek

- DC-A Buffalo Avenue, South Fork (city boundary with FEW)
- DC-B Vista Drive, South Fork
- DC-C Confluence with North Fork
- DC-D Education Drive
- DC-E Yellowstone Road
- DC-F Powderhouse Road
- DC-G Carey Reservoir
- DC-H Dell Range Blvd. (flowing north)
- DC-I Hilltop Avenue
- DC-J Ridge Road
- DC-K Rawlins Street
- DC-L U.S. 30
- DC-M E. Pershing Blvd.
- DC-N Union Pacific Railroad
- DC-O Upper Campstool Road
- DC-P Confluence with Crow Creek

H. HEC-RAS Developed Inundation Mapping

Figures 39 to 45 show the HEC-RAS model inundation for the Dry Creek channel. For the initial Headwaters of South Fork to Yellowstone Rd., there is significant overbank flooding through the Vista Ln. reach and between Education Dr. and Yellowstone Rd. For Yellowstone to Prairie Ave., there is overtopping of Sunset Dr., Seminoe Rd., and Prairie Ave. The overtopping of Seminoe Rd. and Prairie Ave. is significant for the regulatory event. For Prairie to Powderhouse Rd., the flow is generally confined to its floodplain with no overtopping of the downstream Powderhouse Rd. crossing.

Dell Range Blvd. to Carey Reservoir shows significant overbank flooding in the Meadowbrooke subdivision. Carey Reservoir to Mountain Rd. is generally confined with minor overtopping of the Mountain Rd. crossing. Mountain to Ridge Rd. is generally confined to the Sheridan reach until just upstream of the Hilltop Ave. crossing where significant overbank flooding along with overtopping of the Hilltop Ave. crossing occurs. For Ridge Rd. to Rock Springs Streets, the flow is generally confined to the channel upstream of N. College Dr. and to the floodplain downstream of N. College Dr. There is roadway flooding of Cleveland Ave. at the downstream end of this reach.

For Rock Springs Street to US. 30, there is significant overtopping of the Rawlins Street crossing along with floodwaters spreading out in the overbank areas between Rawlins Street and U.S. 30. Between U.S. 30 and E. Pershing Blvd., there is significant overbank flooding shown in the model resulting in overtopping of E. Pershing Blvd. at two locations east of the channel. Between E. Pershing Blvd. and the UPRR, there is a significant inundation of floodwaters impounded against the Union Pacific embankment. For the UPRR to Upper Campstool Rd., floodwaters spread out into available overbank floodplain on the LCCD Headquarters property. There is minor overtopping of Campstool Rd. at a low point west of the crossing.

Culvert	100-year Flow	Structure	Assumed Blockage	Overtopping Depth	Overtopping Flow
Vista Lane	504	(5) 42" dia culverts	---	0.8	138
Bishop Blvd	516	(1) 4.5ft high x 9ft wide RCBC	---	0.1	5
Education Drive	1002	(4) 48" Culverts	33%	1.2	641
Yellowstone Road	1370	(2) 9ft high x 10ft wide RCBC	---	---	---
Sunset Drive	1790	(3) 84" dia culverts	---	1.0	388
Seminoe Road	1891	(2) 84" dia culverts	50%	1.7	1572
Prairie Avenue	2278	(3) 48" dia culverts	---	2.8	1933
Powderhouse Road	2651	(4) 12.8ft x 8.3ft Elliptical Culverts	---	---	---
Dell Range Blvd	473	(2) 6ft high x 9.43ft wide RCBC	---	---	---
Converse Avenue	730	(5) 7.5ft high x 9.4ft wide RCBC	---	---	---
Mountain Road	786	(6) 48" dia culverts	---	0.6	128
Windmill Road	786	(3) 6ft high x 10ft wide RCBC	---	---	---
Hilltop Avenue	1376	(6) 48" dia culverts	---	1.3	601
Dell Range Blvd	1428	(3) 6ft high x 8ft wide RCBC	---	1.2	497
Ridge Road	1516	(3) 6ft high x 6.93ft wide, (1) 7.5ft high x 10.39ft wide	---	---	---
College Drive	1581	(4) 5ft high x 10ft wide, (1) 7.5ft high x 12ft wide	33%	---	---
Rawling Street	2228	(4) 2.4ft x 3.75 Elliptical culverts	---	3.3	2026
HWY 30	2614	(1) 7ft high x 10ft wide RCBC, (1) 7.5ft high x 10ft wide RCBC, (3) 7ft high x 7ft wide RCBC	---	---	---
Pershing Blvd	2743	(4) 6ft high x 10ft wide RCBC	---	1.7	786
UPRR	3755	(1) 8ft high x 6ft wide Arch culvert	---	---	---
Campstool	879	(3) 72" dia culverts	---	0.34	72.76
I-80	879	(5) 4ft x 6.3ft Elliptical Culverts	---	---	---

Table 7. 100-year Floodplain Information at Select Design Point Crossings of Dry Creek


DRY CREEK BASIN
100-YR FLOODPLAIN
HEADWATERS TO YELLOWSTONE
Channel Flowline
100-yr Floodplain
0
2,500
5,000 ft
Western Hills Blvd
Hynds Blvd
Education Dr
Cody St
Manor Ln
Walker Rd
Hacker Ct
Cascade Ave
Ferguson Ave
Quincy Rd
Brookfield Ct
McCormick Junior High School
FOOTBALL FIELD
TENNIS COURTS
Central High School

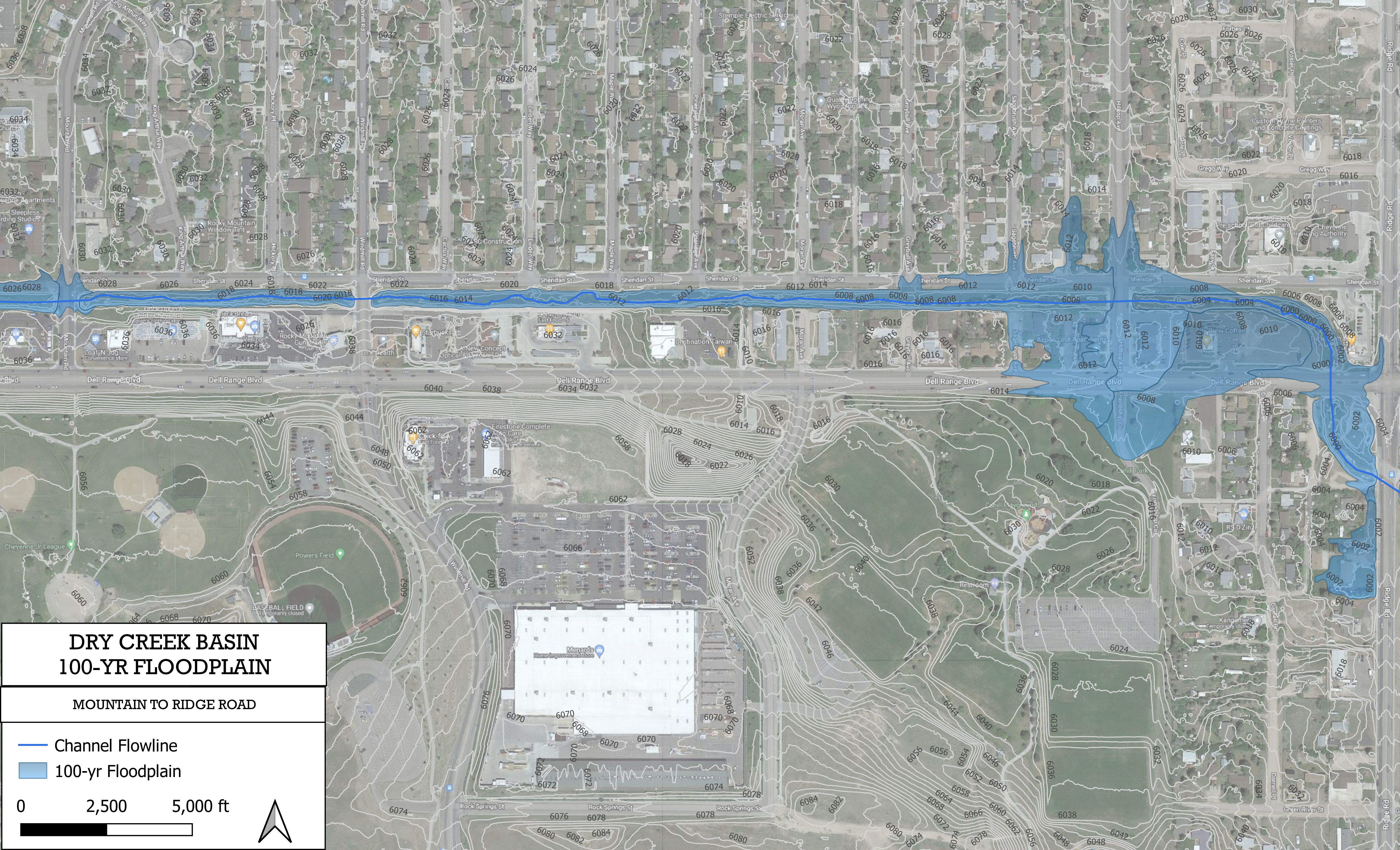
DRY CREEK BASIN
100-YR FLOODPLAIN
YELLOWSTONE TO PRAIRIE
Channel Flowline
100-yr Floodplain
0
2,500
5,000 ft

DRY CREEK BASIN
100-YR FLOODPLAIN

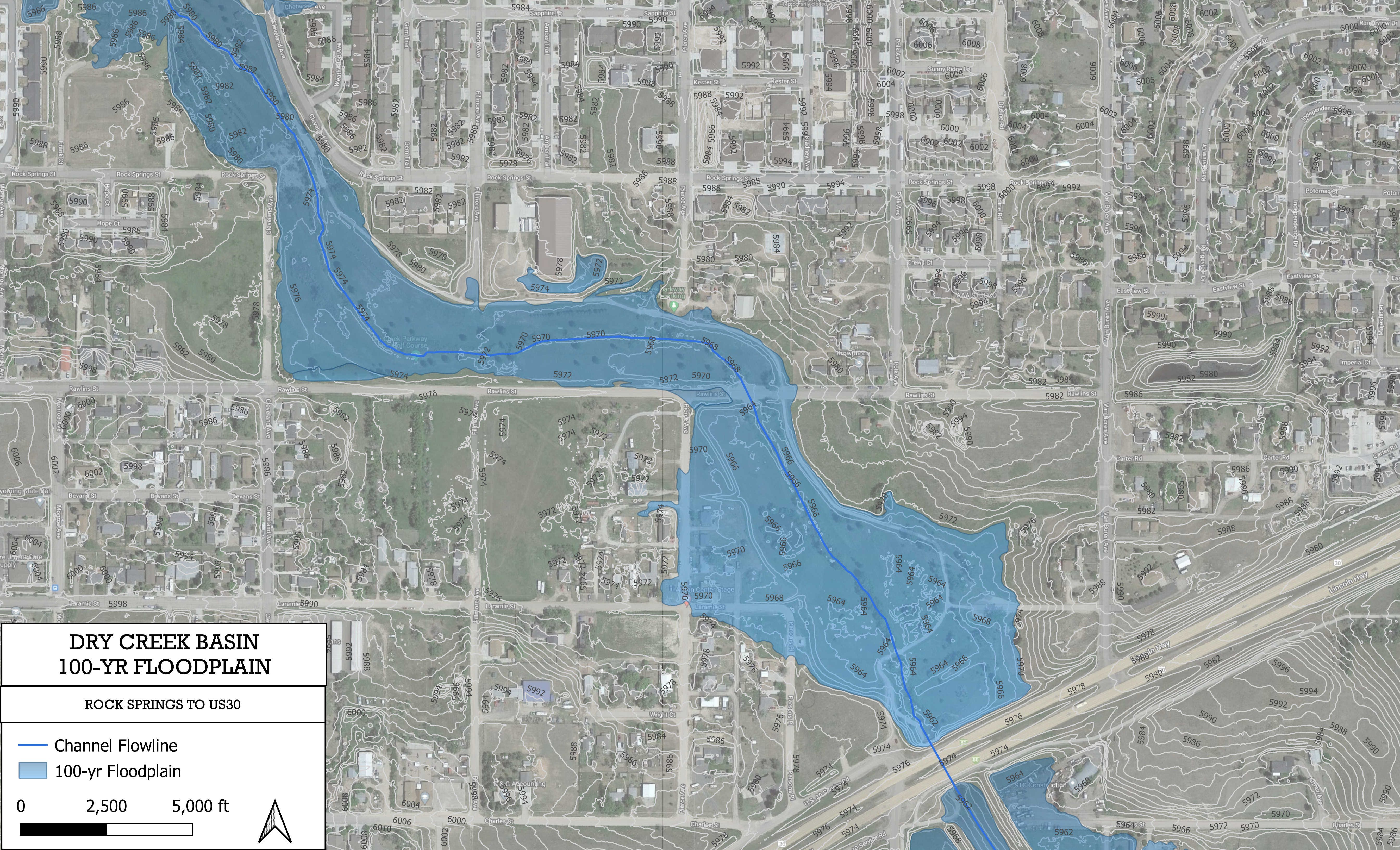
PRAIRIE TO DELL RANGE

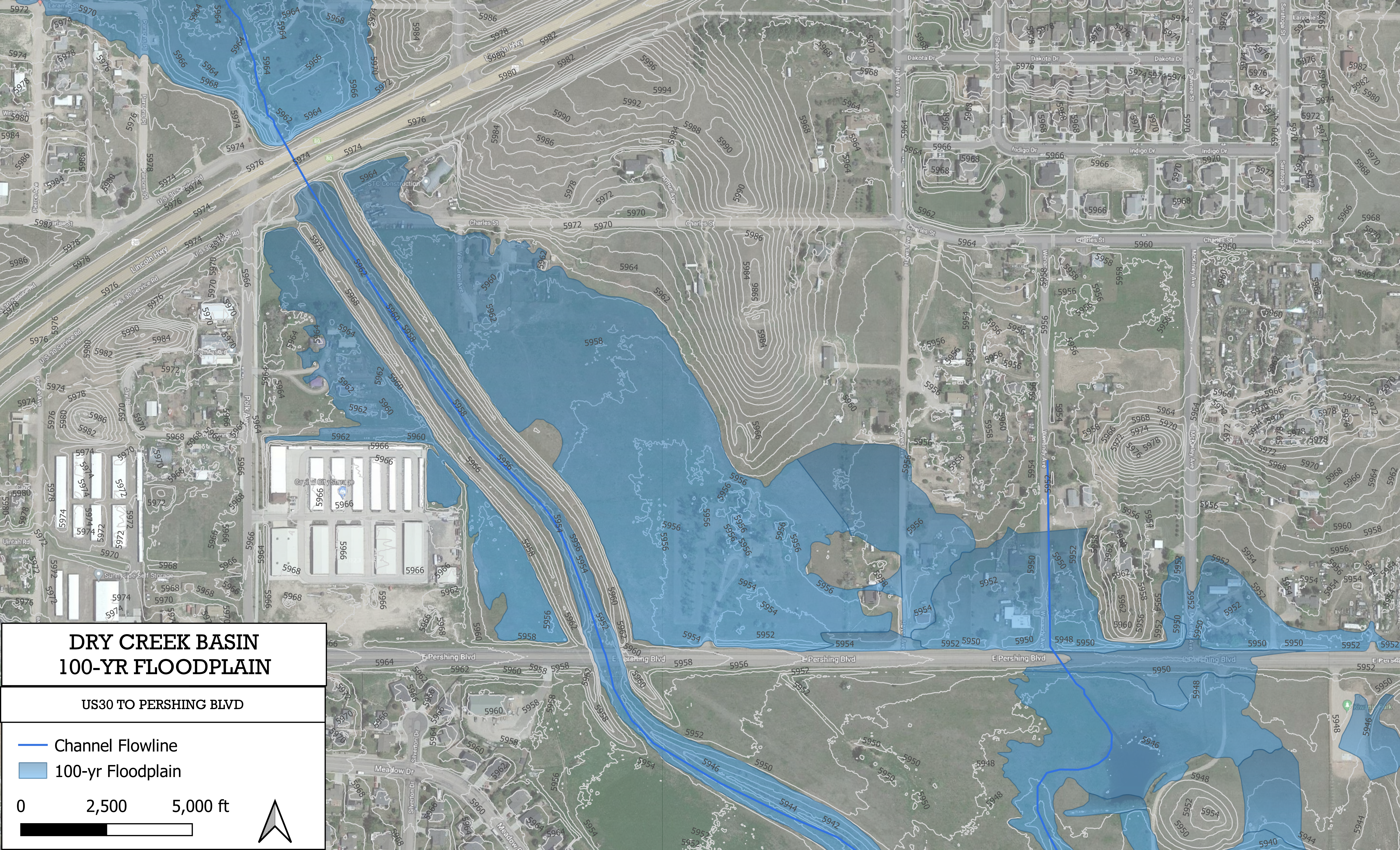

DRY CREEK BASIN
100-YR FLOODPLAIN
DELL RANGE TO CAREY RESERVOIR
Channel Flowline
100-yr Floodplain
0
2,500
5,000 ft
Dell Range Blvd
Stillwater Ave
Meadowland Dr
Edgewater Ave

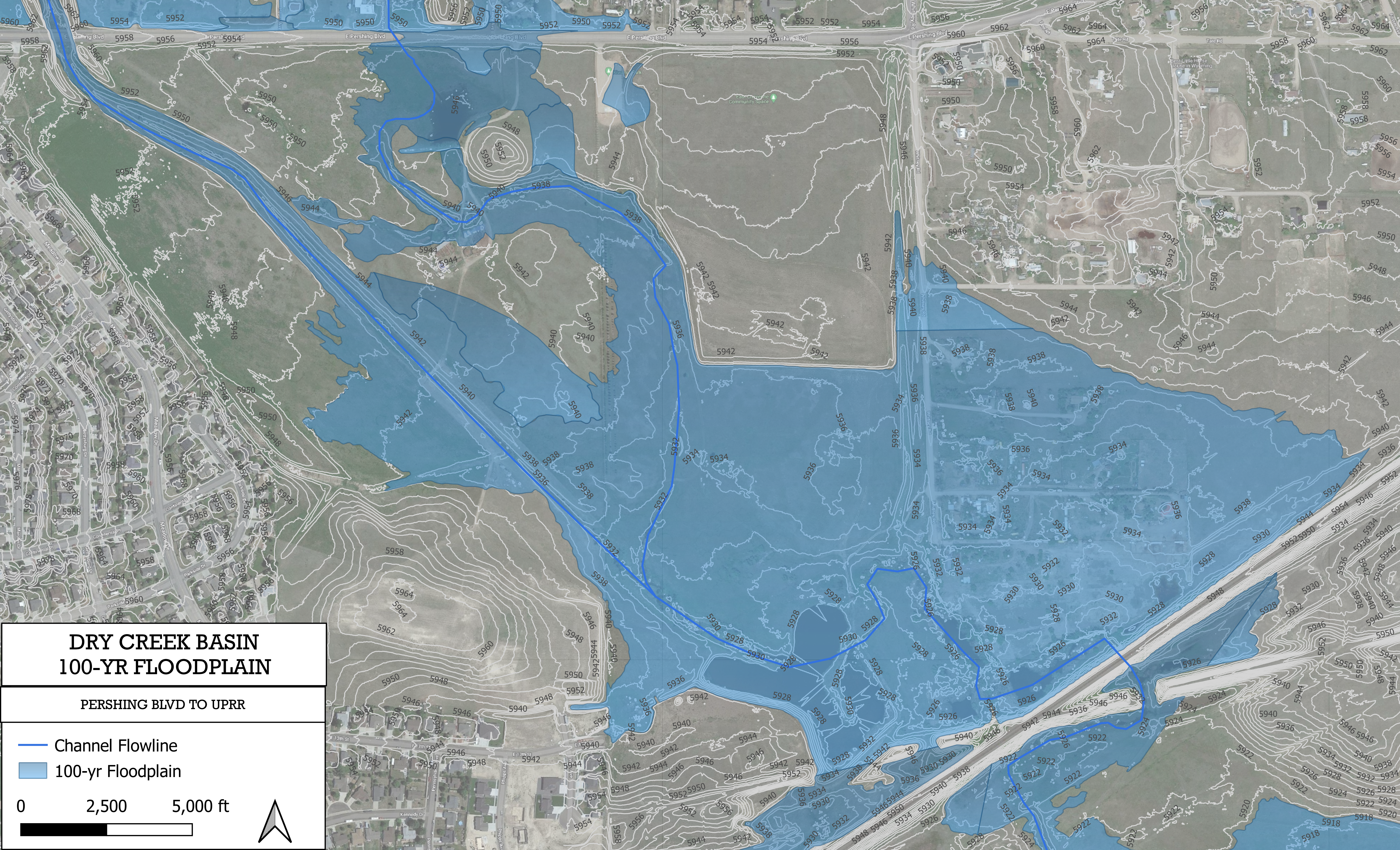

DRY CREEK BASIN
100-YR FLOODPLAIN
CAREY RESERVOIR TO MOUNTAIN
Channel Flowline
100-yr Floodplain
0
2,500
5,000 ft
Dell Range Blvd
Converse Ave

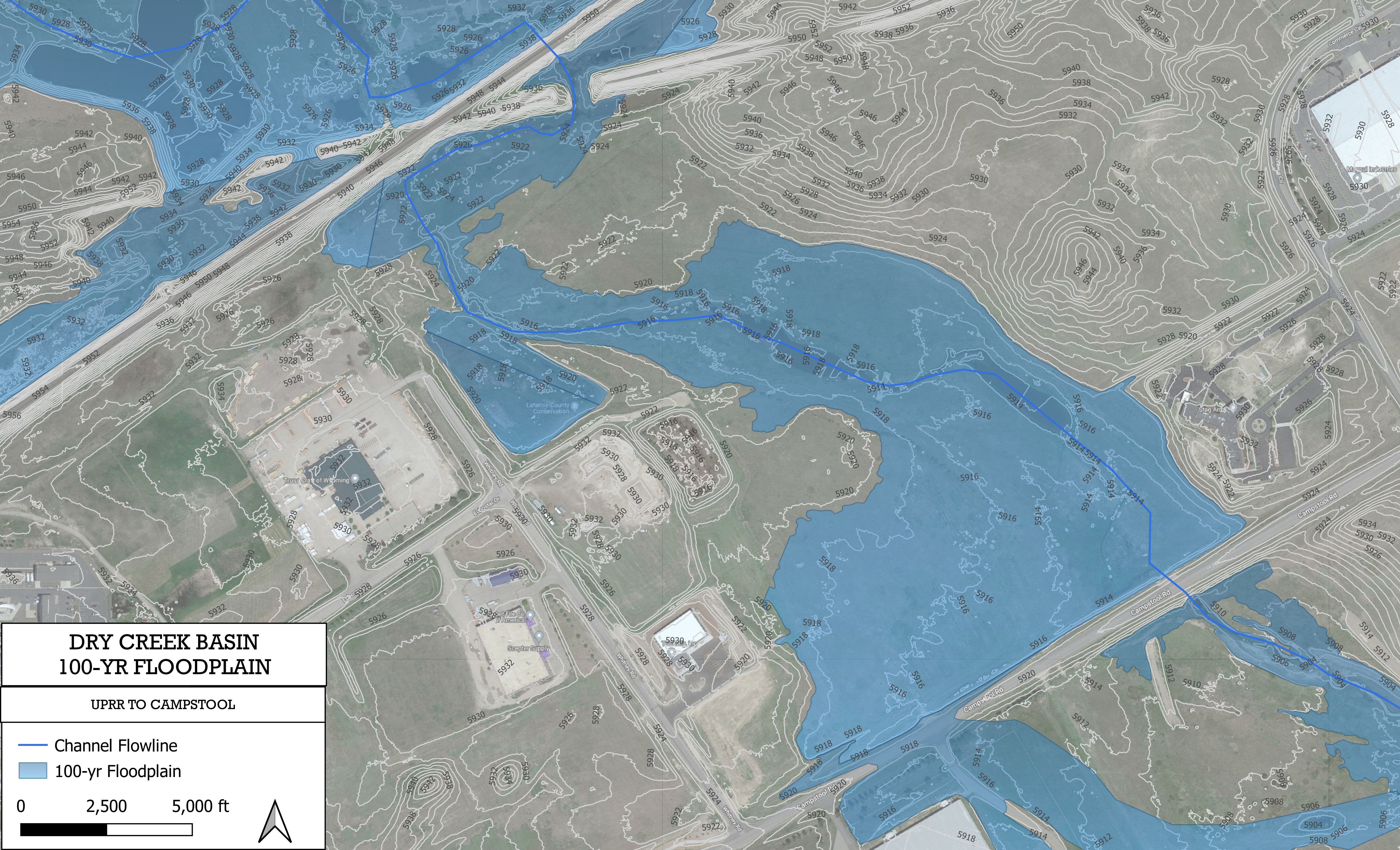

DRY CREEK BASIN
100-YR FLOODPLAIN
MOUNTAIN TO RIDGE ROAD
Channel Flowline
100-yr Floodplain
0
2,500
5,000 ft
Sheridan St
Dell Range Blvd
Ridge Rd
Windmill Rd
Powers Field
Menards
Rock Springs St
Gregg Way
Green River St


DRY CREEK BASIN
100-YR FLOODPLAIN
RIDGE ROAD TO ROCK SPRINGS
Channel Flowline
100-yr Floodplain
0
2,500
5,000 ft
Dell Range Blvd
Ridge Rd
Parkview Dr
Rio Verde St
Rock Springs St
Woodhaven Dr
Green River St
Land Ct
Sheridan St


DRY CREEK BASIN
100-YR FLOODPLAIN
ROCK SPRINGS TO US30
Channel Flowline
100-yr Floodplain
0
2,500
5,000 ft


DRY CREEK BASIN
100-YR FLOODPLAIN
US30 TO PERSHING BLVD
Channel Flowline
100-yr Floodplain
0
2,500
5,000 ft
E Pershing Blvd
Charles St
Lincoln Hwy
Dakota Dr
Indigo Dr
Meadow Dr
Capitol City Storage


DRY CREEK BASIN
100-YR FLOODPLAIN
PERSHING BLVD TO UPRR
Channel Flowline
100-yr Floodplain
0
2,500
5,000 ft
E Pershing Blvd


DRY CREEK BASIN
100-YR FLOODPLAIN
UPRR TO CAMPSTOOL
Channel Flowline
100-yr Floodplain
0
2,500
5,000 ft
Campstool Rd
Laramie County Conservation

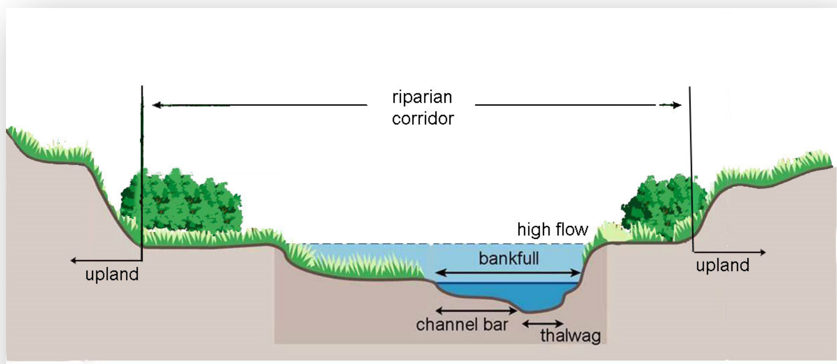

DRY CREEK BASIN
100-YR FLOODPLAIN
CAMPSTOOL TO CONFLUENCE
Channel Flowline
100-yr Floodplain
0
2,500
5,000 ft

VI. IDENTIFICATION OF CONSTRAINTS AND AREAS OF CONCERN

A. Identification of Life-Safety Issues, Property Damage Risk, Infrastructure Issues

There remain crossings that still have life-safety hazards due to overtopping conditions for less frequent flood events. The Education Drive crossing, Gateway Drive, Seminoe crossing, Prairie Avenue crossing, Hilltop Road crossing, Downstream Dell Range Blvd., Rawlins Street, E. Pershing Blvd., Union Pacific Railroad embankment, upper, and lower Campstool Road crossings remain hazardous crossings to the travelling public due to overtopping and/or roadway flooding. Property damage hazards due to flooding exist for the south fork between Vista Lane and I-25, Carlson Street/Westgate Drive, Hoy Road immediately upstream of Powderhouse Road, the Meadowbrooke subdivision immediately upstream of Carey Reservoir, the north side of Sheridan Street at Hilltop Road along with Dell Range Blvd., the reach immediately upstream of the College Drive crossing, properties in the county in the vicinity of Rock Springs Street, the Rawlins Street crossing, Wanandy Avenue, the original sump 130, and properties in the LEADS business park in the event of a Breach of the UPRR embankment.

There is a lack of water quality and nature-based solutions which would serve to improve the interaction between the creek and the community. There are significant reaches of Dry Creek that can be functionally restored. Addressing these reaches will reduce annual maintenance costs, eliminate nuisance flooding, lessen the risk of flood damage for larger events, and enhance the creek amenity for the community. A natural, healthy riparian corridor improves the function, diversity, and property value of adjacent land and the surrounding environment. A properly functioning river system supplies clean water, supports a variety of aquatic and terrestrial life forms, and provides an efficient, stable method of controlling flows and transporting water and sediment. This is true of urban drainageways, where restoration can enhance the overall quality of life. Steps to encourage the redevelopment of a habitat corridor and other water-based life through select reaches in the basin can be accomplished through additional steps, including more natural, lower height grade control stabilization, incorporation of riffles and pools, and adding riparian habitat suitable to the wildlife of the area. This in turn will reduce annual maintenance costs and improve conveyance of flow for more frequent flood events.



Strategically placed riparian plantings are needed to provide bank stability and structural habitat for terrestrial wildlife. The goal of the restoration is to replicate sections of the creek more resilient to flooding, but also recognize the need for simplified design procedures so that variations in construction experience and methods will be successful. ***Our field inspections have focused on five reaches of Dry Creek in need of functional improvement.***

- McCormick-Central Campus
- Yellowstone Road downstream reach to Sunset Dr. utility crossing
- Downstream of Townsend Place
- Between Powderhouse and Carey Reservoir
- Sheridan Reach

Additional consideration could be given to the open area between Rawlins Street and U.S. 30. An improved floodway and floodplain through this reach would require property acquisitions. Incorporation of riffles and pools is proposed for the Sheridan Reach Flood Control alignment in conjunction with the re-alignment of Dry Creek flow through this reach.

There are areas of bank erosion and instability through some of the above listed reaches which represent sedimentation issues and potential MS4 violations for the city. These reaches have excess sedimentation and vegetation issues all of which impact conveyance and water quality.

The Powderhouse Rd. to Carey Reservoir reach is identified in this study update as a significant property damage hazard. ***The HEC-RAS model shows no overtopping of the Powderhouse Rd. crossing*** resulting in an approximate 250cfs increase in discharge over that of the effective HEC-2 model. There is no debris blockage placed on the Powderhouse Rd. culverts in this study's HEC-RAS model (refer to the Debris Blockage discussion later in the report). The lack of overtopping for the Powderhouse Rd. crossing is not influenced by the absence of a debris blockage factor. This study's modeling indicates that the Powderhouse culverts have adequate capacity to convey the 100-year flood event with or without a debris blockage factor applied.

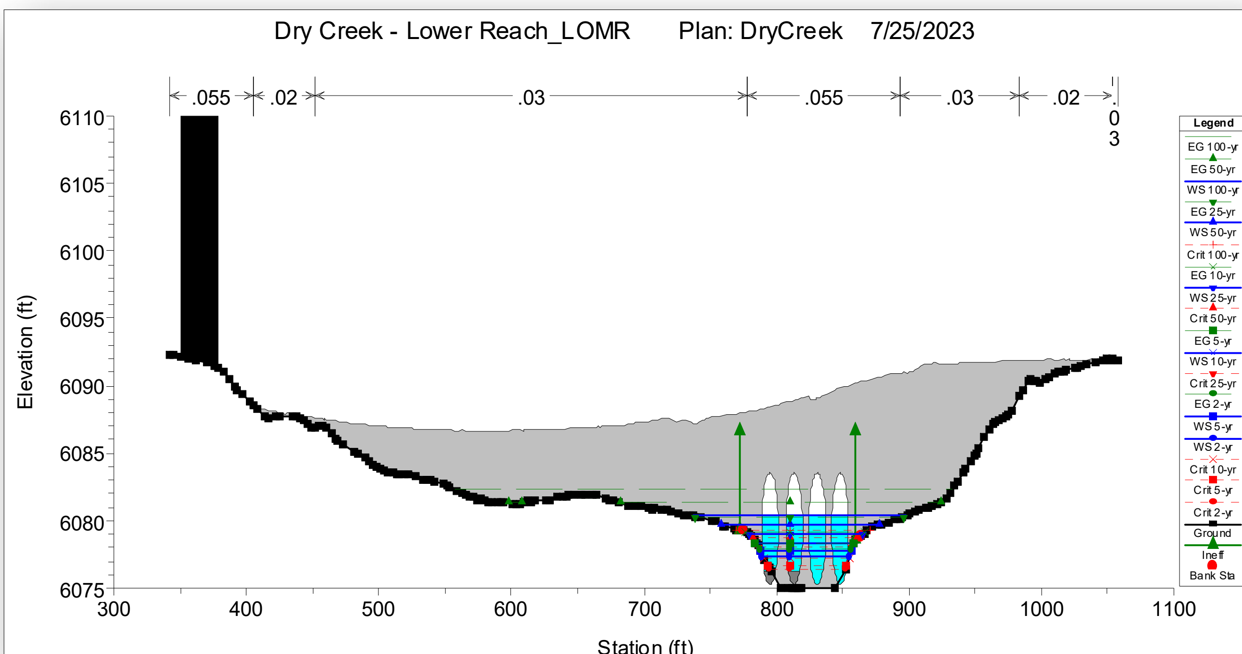


Figure51. Powderhouse Rd. Crossing from HEC-RAS Model

B. Discussion of Debris Blockage Assumptions/Policy

Debris blockage is a critical factor for consideration as it can significantly impact the hydraulic performance of channels and crossings and increase potential flood risks. That was the apparent case with the historic 1985 flood event and the underlying reason for the adoption of a debris blockage policy as part of the original 1988 master drainage plan for the basin. Analyzing debris blockage is critical for assessing flood hazards, the design of hydraulic structures, and for developing effective flood mitigation strategies.

The Federal Emergency Management Agency (FEMA) provides guidelines for analyzing debris blockage effects on flood profiles and water surface elevations in their publication titled "Guidelines and Specifications for Flood Hazard Mapping Partners" (commonly known as the FEMA Guidelines and Specifications Manual). The manual provides guidance to engineers, hydraulic modelers, and floodplain managers involved in flood hazard mapping and risk assessment. They are as follows:

Debris Assessment:

- Identify and locate potential sources of debris that may affect hydraulic structures, such as bridges, culverts, and flood control channels.
- Assess the type, size, and quantity of debris that can reasonably be expected to accumulate during a flood event.
- Consider the dynamics of debris transport and accumulation, including potential obstructions caused by fallen trees, large logs, or other objects.

Hydraulic Modeling:

- Incorporate debris blockage effects into hydraulic models using appropriate modeling software (e.g., HEC-RAS).
- Modify the hydraulic model to account for the increased roughness caused by debris accumulation.
- Adjust Manning's roughness coefficients or apply additional flow resistance to represent the presence of debris within the model.

Mitigation Measures:

- Assess the effectiveness of different mitigation measures to reduce the risk of debris blockage and associated flooding.
- Consider structural measures like debris deflectors, trash racks, or debris basins to prevent debris accumulation at critical locations.
- Evaluate maintenance practices and protocols for regular removal of debris to minimize the potential for blockage.

To assess debris blockage effects for this updated study, data was evaluated on the presence, size, and location of potential debris sources within the creek from aerial imagery analysis and from historical data on past blockages. Debris blockage values were evaluated in the hydraulic model by reducing hydraulic structure capacities accordingly. In lieu of placing debris blockage factors on some hydraulic structures, recommendations were made for structural measures and/or improved maintenance practices.

For the 1988 study, criteria for assigning debris blockages were developed with ***an awareness of the large potential margin of error*** inherent in trying to predict the mechanics of debris flow through a culvert. In the 88 study, it is stated that the primary consideration for determining a percent blockage was upstream potential for debris accumulation and that the secondary consideration was the actual size of the culvert opening(s). The study listed six criteria that percent blockage of culverts was based on. The most significant criteria appear to have been pipe diameter, different barrel sizes, odd-shaped culverts, even number of barrels, odd number of barrels, and a comparison of the flood profile with debris blockage factors applied with that of the 1985 flood profile.

The U.S. Department of Transportation (FHWA) Publication No. FHWA-IF-04-016 (October 2005) Hydraulic Engineering Circular No. 9 “Debris Control Structures Evaluation and Countermeasures, 3rd Edition” authored by WEST Consultants, Inc. does provide guidance on debris management and on the likelihood of debris jams occurring. It is important to note that FEMA does not have a specific policy or guideline that directly addresses debris blockage factors. However, FEMA provides resources and guidelines related to floodplain management, hazard mitigation, and emergency response, which indirectly touch upon the importance of managing debris blockage for effective flood risk reduction. Here are some relevant FEMA policies and guidelines related to debris blockage:

- National Flood Insurance Program (NFIP): FEMA administers the NFIP, which provides flood insurance to property owners and promotes floodplain management practices. **The NFIP emphasizes the importance of maintaining open channels, including culverts, to facilitate the unobstructed flow of water**. Property owners in Special Flood Hazard Areas (SFHAs) are encouraged to keep their drainage systems clear of debris to minimize flood risks.
- Hazard Mitigation Assistance (HMA) Programs: FEMA's HMA programs, including the Hazard Mitigation Grant Program (HMGP) and the Building Resilient Infrastructure and Communities (BRIC) program, support projects aimed at reducing the impacts of natural hazards. **These programs can potentially fund projects that address debris blockage, such as the removal of woody debris or the installation of debris control structures in culverts**.
- Emergency Response and Recovery: FEMA plays a key role in helping and with guidance during and after disasters. **In the aftermath of flood events, FEMA coordinates with state and local authorities to support debris removal efforts, including the clearing of culverts and other drainage infrastructure to restore normal flow conditions**.

For this update, we have attempted to put more weight on upstream conditions in evaluating the potential for debris blockage of culverts. Additionally, we are recommending criteria be established for the frequency of inspections and maintenance activities to remove debris from culverts. This ensures that regular inspections are conducted to identify blockages promptly and maintenance activities are scheduled to prevent significant accumulation of debris. We are also recommending at select sites that consideration be given to the installation of debris screens, grates, or other devices at the inlet of the culvert to prevent large debris from entering or accumulating within the culvert.

While there is not a universally applicable "rule of thumb" for setting debris blockage factors on culverts, some general guidelines and considerations can help in establishing appropriate factors.

- Culvert Size: Larger culverts typically have a greater capacity to handle debris without significant impacts. Smaller culverts may be more susceptible to debris blockage, so more conservative blockage factors might be appropriate.
- Debris Characteristics: Consider the types of debris typically encountered in the area, such as leaves, branches, trash, or sediment. The size, shape, and quantity of debris should be considered when determining blockage factors.
- Historical Data: Analyze any available historical data on debris blockage in similar culverts or drainage systems in the region. This data can provide insights into the frequency and severity of blockages and guide the selection of appropriate blockage factors.
- Consider Safety and Performance: Ensure that the selected blockage factors do not compromise the safety and performance of the culvert system. Adequate flow capacity should be maintained to prevent flooding, and **blockage factors should be conservative enough to minimize the risk of culvert failure or significant impacts on downstream areas**.

The FHWA Hydraulic Design Series No. 5 (HDS-5) provides limited guidance regarding debris considerations. “Debris accumulation is a major problem at many culvert locations. Flood flows often carry both floating and submerged debris that can obstruct the culvert entrance and/or accumulate in the barrel. At a minimum, debris accumulation will increase maintenance costs and at the extreme can lead to increased upstream flooding, potential overtopping and roadway embankment failure. Consideration of debris accumulation and the need for debris control structures should be an integral part of any culvert design. Both non-structural and structural methods have been used to prevent or reduce debris accumulation at culverts. Non-structural measures are primarily related to maintenance activities, both annual and on an emergency basis, to remove any debris that has collected at the entrance or in the barrel of the culvert. Structural measures include features that intercept debris upstream of the culvert, deflect debris near the culvert entrance, or orient debris to facilitate passage through the culvert. Regardless of the solution method employed, it may be desirable to provide a relief opening either in the form of a vertical riser or a relief culvert placed higher in the embankment”.

Based on the above discussion, debris blockage factors should be selected after careful consideration has been given to upstream debris characteristics, culvert characteristics, historical data, and engineering judgement. The blockage factors employed in the hydraulic model need to be crossing-specific rather than an across-the-board measure encompassing the entire main-stem reach of Dry Creek as was done for the 1988 study. Moreover, more consistent channel maintenance to remove vegetative debris along with recommendations of debris blockage countermeasures at select crossings should be considered. Recommendations for debris blockage at crossings along the creek from this study are as follows, beginning from the downstream Lower Campstool Rd. crossing.

- Zero percent blockage was used in the 1988 model for the Lower Campstool Rd. crossing and we are recommending the same approach due to overtopping of the structure and low potential for infrastructure and/or property damage due to blockage.

- Zero percent blockage was used in the 1988 model for the I-80 crossing and we concur with this approach for the updated model.
- Zero percent blockage was used in the 1988 model for the Upper Campstool Rd. crossing. We would propose consideration of steel debris deflectors installed at the culvert entrances. The roadway low spot is located several hundred feet to the west of the thalweg. Moreover, the channel is at a 60° skew to the culvert openings.

- Zero percent blockage was used in the 1988 model for the historic Union Pacific 6' x 8' masonry box arch culvert even though it was partially blocked by a refrigerator in the 1985 flood event. Since the 1988 report, the salvage yard located immediately upstream of the UPRR has ceased operations. The recommendation for reconfiguring sump 130 from this report will incorporate an outlet structure/riser which will effectively eliminate any debris blockage potential.
- The E. Pershing Blvd. structure has been reconstructed and the Charles Street structure has been removed since 1988. The E. Pershing Blvd. structure does not require a blockage factor for modeling purposes.
- A 49% blockage factor was applied to the U.S. 30 crossing in the 1988 model. This report recommendation is for a non-structural measure of consistent, annual maintenance in conjunction with a reduced blockage factor of 33% used in the updated model.
- A 50% blockage factor was applied to the Rawlins Street crossing in the 1988 model. We are in concurrence with this percentage for the updated model.
- A 50% blockage factor was applied to the N. College Dr. crossing in the 1988 model. This report recommendation is for a non-structural measure of consistent, annual maintenance in conjunction with a reduced blockage factor of 33% used in the updated model.
- A 33% blockage factor was applied to the Ridge Rd. crossing in the 1988 model. This report recommendation is for the removal of the debris blockage factor in the updated model in conjunction with the proposed improvements for the Sheridan Street Reach.
- A 33% blockage factor was applied to the downstream Dell Range Blvd. crossing in the 1988 model. This report recommendation is for the removal of the debris blockage factor in the updated model in conjunction with the proposed improvements for the Sheridan Street Reach.
- A 50% blockage factor was applied to the Hilltop Ave. crossing in the 1988 model. This report recommendation is for the removal of the debris blockage factor in the updated model in conjunction with the proposed improvements for the Sheridan Street Reach.
- A 33% blockage factor was applied to the Windmill Rd. crossing in the 1988 model. This crossing was blocked by a vehicle during the 1985 flood event. This report recommendation is for the removal of the debris blockage factor in the updated model in conjunction with the proposed improvements for the Sheridan Street Reach.
- A 50% blockage factor was applied to the Mountain Rd. crossing in the 1988 model. The report recommendation is for the removal of the debris blockage factor in the updated model

conjunction with the proposed improvements for the Sheridan Street Reach and the reconstruction of this crossing.

- The Converse Rd. crossing is scheduled for reconstruction and will not require a debris blockage factor in the updated model.
- A 50% debris blockage factor was applied to the upstream Dell Range Blvd. crossing in the 1988 model. This report recommendation is for a reduced debris blockage factor of 0% in the updated model.

- A 50% debris blockage factor was applied to the Powderhouse Rd. crossing in the 1988 model. The report recommendation is for the removal of the debris blockage factor in the updated model in conjunction with the construction of a rail debris rack just upstream of the greenway path.
- A 50% debris blockage factor was applied to the Prairie Ave. crossing in the 1988 model. The report recommendation is for removal of the Prairie Ave. structure.
- A 50% debris blockage factor was applied to the Seminoe Rd. crossing in the 1988 model and we concur with this approach for the updated model.
- A 33% debris blockage factor was applied to the Sunset Dr. crossing in the 1988 model. A private developer is improving this crossing and we would propose removal of the debris blockage factor in the updated model.
- The Yellowstone Rd. structure has been reconstructed and does not require a debris blockage factor in the updated model.
- A 50% debris blockage factor was applied to the Gateway Dr. crossing in the 1988 model. This report recommends removal of the debris blockage factor in conjunction with the reconstruction of the Westgate Pond outlet works with direct connection to the Gateway Dr. culverts.
- A 50% debris blockage factor was applied to the Education Dr. crossing in the 1988 model. This report recommendation is for a non-structural measure of consistent, annual maintenance in conjunction with a reduced blockage factor of 33% used in the updated model.
- A 50% debris blockage factor was applied to the South Fork Bishop Blvd./I-25 culvert in the 1988 model. The report recommendation is for the removal of the debris blockage factor in the updated model in conjunction with the construction of a steel debris rack on the upstream face of the culvert inlet.

- A 50% debris blockage factor was applied to the North Fork Bishop Blvd./I-25 culvert in the 1988 model. This system has been hydraulically connected to the recently constructed Evers Blvd. storm sewer and the debris blockage factor should be removed in the updated model.
- A 40% debris blockage factor was applied to the Vista Lane crossing in the 1988 model. This report recommendation is for the removal of the debris blockage factor in the updated model in conjunction with the proposed improvements for the F.E. Warren South Fork Dry Creek detention storage pond immediately upstream.
- A 100% debris blockage factor was applied to the Base boundary alley structure in the 1988 model, and we concur with this approach for the updated model.

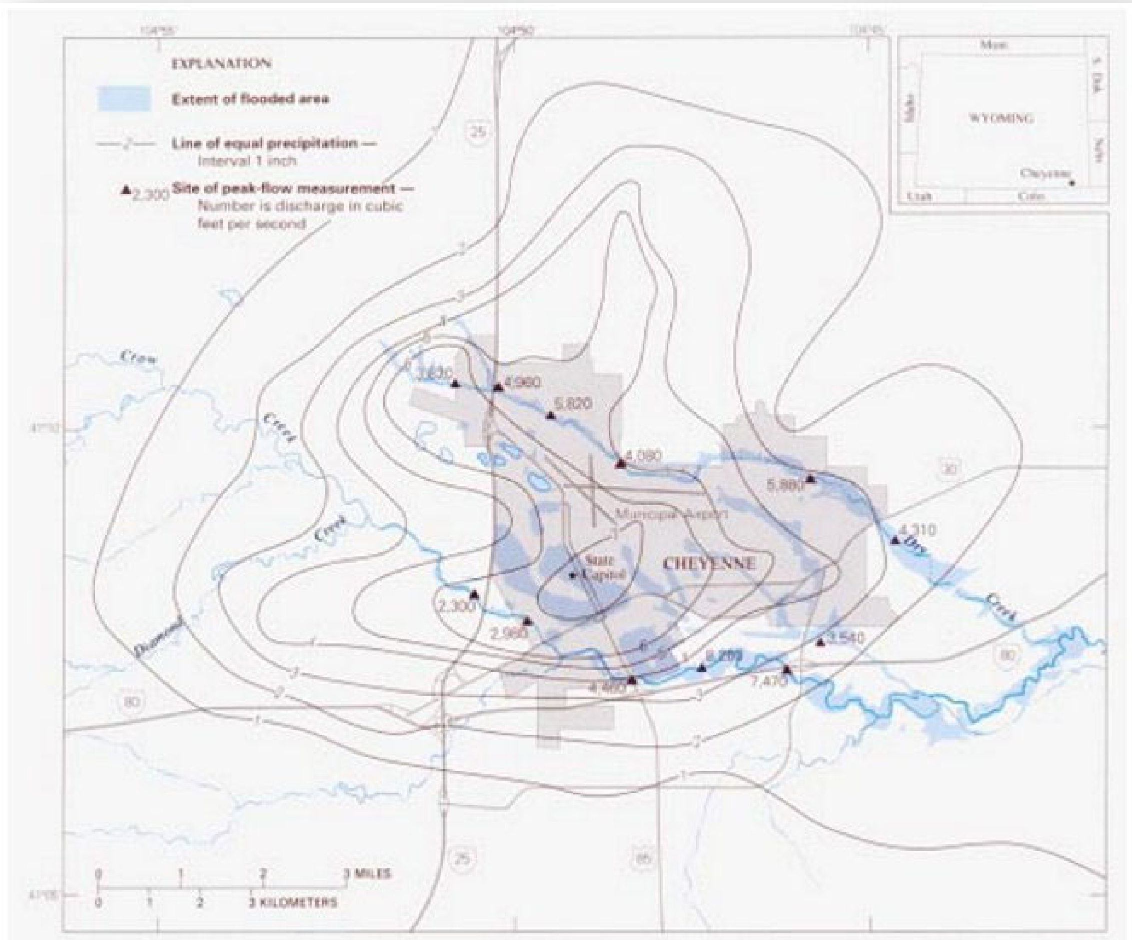
STRUCTURE	DEBRIS BLOCKAGE	POTENTIAL EROSION	POTENTIAL SEDIMENTATION	ROUGHNESS COEFICIENT	1988 REPORT	COMMENTS
Lower Campstool Road	Medium - 50%	H	L	0.012	0% Blockage Used	0%
I-80	Medium - 40%	L	M	0.012	0% Blockage Used	0%
Upper Campstool Road	Medium - 33%	L	L	0.012	0% Blockage Used	Debris blockage counter measures required
Union Pacific Railroad	Medium - 30%	M	L	0.012	0% Blockage Used	Was blocked by a refrigerator in 1985
E. Pershing Blvd.	N/A	Culvert	Replaced			0%
Charles Street	N/A	Culvert	Removed			N/A
U.S. 30	Medium - 50%	L	L	0.012	49% Blockage Used	Reduced to 33% for this Study
Rawlins Street	Medium - 50%	L	M	0.012	50% Blockage Used	Same for this Study
College Drive	Medium - 50%	L	H	0.012	50% Blockage Used	Reduced to 33% with Channel Maintenance
Ridge Road	Medium - 33%	L	M	0.012	33% Blockage Used	0% with Sheridan Reach Improvements
Dell Range Blvd.	Medium - 33%	L	M	0.012	33% Blockage Used	0% with Sheridan Reach Improvements
Hilltop Avenue	Medium - 50%	L	L	0.012	50% Blockage Used	0% with Sheridan Reach Improvements
Windmill Road	Medium - 33%	L	L	0.012	33% Blockage Used	0% with Sheridan Reach Improvements
Mountain Road	Medium - 50%	L	L	0.024	50% Blockage Used	0% with reconstruction of crossing
Converse Road	N/A	Culvert	Replaced			0%
Dell Range Blvd.	Medium - 50%	M	L	0.024	50% Blockage Used	0% with upstream Improvements
Powderhouse	Medium - 50%	L	L	0.033	50% Blockage Used	0% Debris blockage counter measures required
Prairie Avenue	Medium - 50%	L	L	0.028	50% Blockage Used	Same for this Study
Mylar Park Dam	High - 100%	L	L	0.012		
Semino Road	Medium - 50%	M	L	0.024	50% Blockage Used	Same for this Study
Townsend Place	Medium - 33%	L	L	0.028	33% Blockage Used	0% with improvements
Yellowstone Road	N/A	Culvert	Replaced			
Gateway Drive	Medium - 50%	L	L	0.028	50% Blockage Used	0% with reconstruction of Westgate outlet works
Education Drive	Medium - 50%	L	L	0.024	50% Blockage Used	33% with Channel Maintenance
Bishop Blvd. & I-25	Medium - 50%	L	L	0.024	50% Blockage Used	0% with mitigation measures applied
Vista Lane	Medium - 40%	M	M	0.024	40% Blockage Used	0% with Base improvements
Bishop Blvd. & I-25 (North Fork)	Medium - 50%	M	M	0.024	50% Blockage Used	N/A
Alley at Base Boundary	High - 100%	L	L	0.012	100% Blockage Used	Same

Table 8. Projected Debris Conditions at Crossing Structures

C. Benefit-Cost Discussion for Flood Control and Creek Restoration Options

As discussed in the 1988 study, the effects of the 1985 flood were well documented by both the USGS and the WyDOT. Several thunderstorms passing over the city combined to produce 6.06 inches of rain and hail between 6:20 p.m. and 9:45 p.m. The National Weather Service stated that 6.06 inches of precipitation was a record for 24-hour storms in Cheyenne. The following were estimated peak flows along Dry Creek. Overflow from Dry Creek inundated the corridor and all road crossings in the urbanized area were overtopped.

- Approximately 4,960 cfs at I-25
- 4,080 cfs at Powderhouse Road
- 5,880 cfs at Ridge Road
- 4,310 cfs at E. Pershing Blvd.



Precipitation and peak flows of Dry Creek, Crow Creek, and an unnamed tributary of Crow Creek resulting from the storm of August 1, 1985, Cheyenne, Wyoming. (Source: Precipitation data compiled by National Weather Service on U.S. Geological Survey base map, Cheyenne, 1981, scale 1:100,000, peak-flow data from U.S. Geological Survey files.)

Figure52. Perhaps the most famous Cheyenne, Wyoming Flood (1 August 1985, evening, 12 killed, 70 injured, $65 million in property damage)

The 1988 Lindner-Lunsford study that served as the basis for development of design storms for the Cheyenne area, determined that the August 1, 1985, storm event was an unusually intense storm and an outlier in their sampling data. Development of damages for a benefit-cost evaluation for this report are based on the HEC-RAS inundation mapping for the 2- through 100-year flood events in conjunction with FEMA's Benefit-Cost Calculator, Version 6.0. The damages by reach are as follows.

Vista Rd. to I-25 reach – There are twelve properties inundated in this reach for the 100-year storm event. Vista Rd. experiences roadway flooding and Bishop Blvd. is overtopped. The proposed FEW detention storage of South Fork Headwaters project was incorporated into the BCA V.6.0 calculator as riverine flood, drainage improvement with a corresponding 50-year Project Useful Life (PUL). 14-Acres for ecosystem services – 40% urban green open space and 60% inland wetlands assumed benefits for proposed project. Estimated $4,080,000 project cost for benefit-cost calculation.

Total benefits = $26,255,907
Total Costs = 4,080,000
BC Ratio 6.44
ESS benefits only = $25,779,683

715 Vista Ln., Cheyenne, Wyoming 82009
One Story residential (no basement)
2,090 s.f.
Damage curve = residential, one-story, USACE generic curve
Defaults for BRV, CRV, displacement
3 residents, 1 worker
Benefits = $44,448

619 Meadowlark Ln., Cheyenne, Wyoming 82009
One Story residential (with basement)
2,200 s.f.
Damage curve = residential, one-story, USACE generic curve
Defaults for BRV, CRV, displacement
3 residents, 1 worker
Benefits = $40,457

617 Meadowlark Ln., Cheyenne, Wyoming 82009
One Story residential (with basement)
2,667 s.f.
Damage curve = residential, one-story, USACE generic curve
Defaults for BRV, CRV, displacement
3 residents, 1 worker
Benefits = $119,654

613 Meadowlark Ln., Cheyenne, Wyoming 82009
One Story residential (with basement)
2,815 s.f.
Damage curve = residential, one-story, USACE generic curve
Defaults for BRV, CRV, displacement
2 residents, 1 worker
Benefits = $24,911

605 Meadowlark Ln., Cheyenne, Wyoming 82009
One Story residential (with basement)
2,716 s.f.
Damage curve = residential, one-story, USACE generic curve
Defaults for BRV, CRV, displacement

3 residents, 1 worker
Benefits = $32,927

601 Meadowlark Ln., Cheyenne, Wyoming 82009
One Story residential (with basement)
2,016 s.f.
Damage curve = residential, one-story, USACE generic curve
Defaults for BRV, CRV, displacement
2 residents, 1 worker
Benefits = $11,005

618 Manor Ln., Cheyenne, Wyoming 82009
One Story residential (with basement)
2,088 s.f.
Damage curve = residential, one-story, USACE generic curve
Defaults for BRV, CRV, displacement
3 residents, 1 worker
Benefits = $32,855

626 Manor Ln., Cheyenne, Wyoming 82009
One Story residential (with basement)
2,782 s.f.
Damage curve = residential, one-story, USACE generic curve
Defaults for BRV, CRV, displacement
2 residents, 1 worker
Benefits = $15,611

632 Manor Ln., Cheyenne, Wyoming 82009
One Story residential (with basement)
2,857 s.f.
Damage curve = residential, one-story, USACE generic curve
Defaults for BRV, CRV, displacement
3 residents, 1 worker
Benefits = $29,482

700 Manor Ln., Cheyenne, Wyoming 82009
One Story residential (with basement)
2,416 s.f.
Damage curve = residential, one-story, USACE generic curve
Defaults for BRV, CRV, displacement
3 residents, 1 worker
Benefits = $31,413

704 Manor Ln., Cheyenne, Wyoming 82009
One Story residential (with basement)
2,876 s.f.
Damage curve = residential, one-story, USACE generic curve
Defaults for BRV, CRV, displacement
3 residents, 1 worker
Benefits = $57,422

701 Vista Ln., Cheyenne, Wyoming 82009
One Story residential (with basement)
2,527 s.f.
Damage curve = residential, one-story, USACE generic curve
Defaults for BRV, CRV, displacement

2 residents, 1 worker
Benefits = $36,039

Education Dr. to Yellowstone Rd. reach – Both Education Dr. and Gateway Drive are overtopped for the 100-year storm event. There are three commercial properties and two residences inundated in this event. The proposed expansion of Westgate detention storage project was incorporated into the BCA V.6.0 calculator as riverine flood, drainage improvement with a corresponding 50-year PUL. 4-Acres for ecosystem services – 100% inland wetlands assumed benefits for proposed project. Estimated $2,000,000 project cost for benefit-cost calculation.

Total benefits = $1,366,244
Total Costs = 2,069,009
BC Ratio 0.66
ESS benefits only = $451,064

5701 Osage Ave., Cheyenne, Wyoming 82009
One Story Commercial property (no basement)
1,790 s.f.
COM4: commercial - professional/technical etc.
Damage curve = office, one-story
Defaults for BRV, CRV, displacement
AOB = $179,000
Benefits = $7,580

111 W. Carlson St., Cheyenne, Wyoming 82009
One Story Commercial property (no basement)
2,096 s.f.
COM4: commercial - professional/technical etc.
Damage curve = office, one-story
Defaults for BRV, CRV, displacement
AOB = $209,600
Benefits = $43,376

121 W. Carlson St., Cheyenne, Wyoming 82009
Two Story Commercial property (no basement)
6,000 s.f.
COM4: commercial - professional/technical etc.
Damage curve = office, one-story
Defaults for BRV, CRV, displacement
AOB = $600,000
Benefits = $125,168

200 Lakeshore Dr., Cheyenne, Wyoming 82009
One Story residential townhouse (with basement)
1,832 s.f.
Damage curve = residential, one-story, USACE generic curve
Defaults for BRV, CRV, displacement
3 residents, 1 worker
Benefits = $414,241

202 Lakeshore Dr., Cheyenne, Wyoming 82009
One Story residential townhouse (with basement)
1,832 s.f.
Damage curve = residential, one-story, USACE generic curve
Defaults for BRV, CRV, displacement
3 residents, 1 worker

Benefits = $325,815

Yellowstone Rd. to Sunset Dr. reach – There are three properties inundated for the 100-year event but no structures damaged. Sunset Dr. is overtopped north of the hydraulic structure. This reach is in need of a creek restoration project to improve conveyance of low flow and reduce deposition of sediment.

Sunset Dr. to Seminoe Rd. reach – There is one home and one apartment complex inundated for the 100-year event. Downstream Seminoe Rd. is severely overtopped. The proposed Melton Street project was incorporated into the BCA V.6.0 calculator as riverine flood, drainage improvement with a corresponding 50-year PUL. Estimated $500,000 project cost for benefit-cost calculation (This does not address Seminoe Rd. overtopping – just Melton Street flooding).

Total Benefits = $1,811,929
Total Costs = $507,135
BC Ratio = 3.57
ESS benefits only = $2,087,546

500 Ogallala Pl., Cheyenne, Wyoming 82009
One Story commercial (with basement)
1,800 sq.ft. Wood frame
COM4: commercial - professional/technical etc.
Damage curve = office, one-story
Defaults for BRV, CRV
AOB = $180,000
Benefits = $26,334

540 Melton Street, Cheyenne, Wyoming 82009
1 ½ Story Apartment complex (with basement)
7,212 sq.ft. Wood Frame
One Story residential (no basement)
Damage curve = residential, one-story, USACE generic curve
Defaults for BRV, CRV, displacement
10 residents, 5 worker
Benefits = $1,785,595

Prairie Ave. to Powderhouse reach – The Prairie Ave. crossing is severely overtopped in the 100-year event. There is one property inundated for this event. Prairie Ave. has an ADT of 3,353 vehicles per day.

Powderhouse Rd. to Carey Reservoir – There are nine commercial properties, five apartment complexes, and one home inundated with the 100-year event. The proposed Powderhouse to Carey Reservoir reach improvements/Stillwater Storm Sewer project was incorporated into the BCA V.6.0 calculator as riverine flood, drainage improvement with a corresponding 50-year PUL. Estimated $5,000,000 project cost for benefit-cost calculation.

Total Benefits = $1,715,387
Total Costs = $5,069,020
Benefit-Cost Ratio = 0.34
No ESS benefits apply

1625 Stillwater Ave., Cheyenne, Wyoming 82009
One Story Commercial property (no basement)
23,017 sq.ft. Wood Frame Motel
COM4: commercial - professional/technical etc.
Damage curve = hotel, one-story

Defaults for BRV, CRV
AOB = $2,301,700
Benefits = $13,638

1637 Stillwater Ave., Cheyenne, Wyoming 82009
One Story Commercial property (no basement)
12,000 sq.ft. Metal frame
COM4: commercial - professional/technical etc.
Damage curve = office, one-story
Defaults for BRV, CRV
AOB = $1,200,000
Benefits = $57,463

1659 Stillwater Ave., Cheyenne, Wyoming 82009
One Story Commercial property (no basement)
7,000 sq.ft. Masonry
COM4: commercial - professional/technical etc.
Damage curve = office, one-story
Defaults for BRV, CRV
AOB = $700,000
Benefits = $451,624

1671 Stillwater Ave., Cheyenne, Wyoming 82009
One Story Commercial property (no basement)
8,000 sq.ft. Metal frame
COM4: commercial - professional/technical etc.
Damage curve = office, one-story
Defaults for BRV, CRV
AOB = $800,000
Benefits = $65,670

1715 Stillwater Ave., Cheyenne, Wyoming 82009
One Story Commercial property (no basement)
13,993 sq.ft.Wood frame
COM4: commercial - professional/technical etc.
Damage curve = office, one-story
Defaults for BRV, CRV
AOB = $1,399,300
Benefits = $56,055

1706 Stillwater Ave., Cheyenne, Wyoming 82009
One Story Commercial property (no basement)
6,000 sq.ft. Metal frame
COM4: commercial - professional/technical etc.
Damage curve = office, one-story
Defaults for BRV, CRV
AOB = $600,000
Benefits = $66,839

4516 Stillwater Ave., Cheyenne, Wyoming 82009
One Story Commercial property (no basement)
11,070 sq.ft.Wood frame
COM4: commercial - professional/technical etc.
Damage curve = office, one-story
Defaults for BRV, CRV
AOB = $1,107,000
Benefits = $70,010

1734 Meadowland Dr., Cheyenne, Wyoming 82009
One Story Commercial property (no basement)
7,459 sq.ft. Wood frame
COM4: commercial - professional/technical etc.
Damage curve = office, one-story
Defaults for BRV, CRV
AOB = $745,900
Benefits = $131,149

1739 Meadowland Dr., Cheyenne, Wyoming 82009
One Story Commercial property (no basement)
8,631 sq.ft. Wood frame
COM4: commercial - professional/technical etc.
Damage curve = office, one-story
Defaults for BRV, CRV
AOB = $863,100
Benefits = $151,756

1764 Meadowland Dr., Cheyenne, Wyoming 82009
Two Story Apartment Complex (no basement)
3,876 sq.ft. Wood frame
Damage curve = residential
Defaults for BRV, CRV
Residents assumed on basis of 1ks.f. apartments (4 total) - 2 per structure = 8
Workers = 4 total
Benefits = $61,418

1772 Meadowland Dr., Cheyenne, Wyoming 82009
Two Story Apartment Complex (no basement)
3,876 sq.ft. Wood frame
Damage curve = residential
Defaults for BRV, CRV
Residents assumed on basis of 1ks.f. apartments (4 total) - 2 per structure = 8
Workers = 4 total
Benefits = $68,839

1815 Meadowland Dr., Cheyenne, Wyoming 82009
Two Story Apartment Complex (no basement)
3,876 sq.ft.Wood frame
Damage curve = residential
Defaults for BRV, CRV
Residents assumed on basis of 1ks.f. apartments (4 total) - 2 per structure = 8
Workers = 4 total
Benefits = $223,012

1807 Meadowland Dr., Cheyenne, Wyoming 82009
Two Story Apartment Complex (no basement)
3,876 sq.ft. Wood frame
Damage curve = residential
Defaults for BRV, CRV
Residents assumed on basis of 1ks.f. apartments (4 total) - 2 per structure = 8
Workers = 4 total
Benefits = $188,068

1805 Edgewater Ave., Cheyenne, Wyoming 82009
One Story residential (no basement)

2,191 sq.ft. Wood frame
Damage curve = residential
Defaults for BRV, CRV
Residents = 3
Workers = 1
Benefits = $19,997

1809 Edgewater Ave., Cheyenne, Wyoming 82009
Two Story Apartment Complex (no basement)
3,876 sq.ft. Wood frame
Damage curve = residential
Defaults for BRV, CRV
Residents assumed on basis of 1ks.f. apartments (4 total) - 2 per structure = 8
Workers = 4 total
Benefits = $79,920

The Sheridan Reach – Mountain Rd. to Hilltop Ave. reach – Both Mountain Rd. and Hilltop Ave. are overtopped with the 100-year event, Hilltop by more than 1-foot of flow. There are three homes and one apartment complex inundated for this event. The downstream Dell Range Blvd. is also overtopped at the hydraulic structure and with roadway flooding to the west of the structure caused by the Hilltop overtopping. The proposed Sheridan Street reach improvements project was incorporated into the BCA V.6.0 calculator as riverine flood, drainage improvement with a corresponding 50-year PUL. Estimated $3,000,000 project cost for benefit-cost calculation (This does not address overtopping of Mountain Rd, Hilltop Ave., or Dell Range Blvd.).

Total Benefits = $973,027
Total Costs = $3,035,677
BC Ratio = 0.32
No ESS

3020 Sheridan Street, Cheyenne, Wyoming 82009
One Story residential (no basement)
1,200 sq.ft. Metal frame
One Story residential (no basement)
Damage curve = residential, one-story, USACE generic curve
Defaults for BRV, CRV, displacement
3 residents, 1 worker
Benefits = $27,595

611 Sagebrush, Cheyenne, Wyoming 82009
One Story residential (no basement)
2,616 sq.ft Wood frame
Software did not recognize address – entered as "Cheyenne"
One Story residential (no basement)
Damage curve = residential, one-story, USACE generic curve
Defaults for BRV, CRV, displacement
3 residents, 1 worker
Benefits = $385,443

3000 Dell Range Blvd., Cheyenne, Wyoming 82009
One Story residential (no basement)
2,027 sq.ft Wood frame
One Story residential (no basement)
Damage curve = residential, one-story, USACE generic curve

Defaults for BRV, CRV, displacement
3 residents, 1 worker
Benefits = $55,015

4600 Hilltop Ave., Cheyenne, Wyoming 8200
Three Floor Apartment complex including basement
19,182 sq.ft Wood frame
One Story residential (no basement)
Damage curve = residential, one-story, USACE generic curve
Defaults for BRV, CRV, displacement
3 residents, 1 worker
Benefits = $504,974

College Dr. to Rock Springs Street reach – Portions of both Rock Springs Street and Cleveland Ave. are flooded for this event.

Rawlins Street to U.S. 30 reach – There are four homes inundated in this reach for the 100-year storm event. Rawlins Street is severely overtopped. Pierce Ave., Laramie Street, and Parsons Pl. experience considerable roadway flooding for this event. Proposed property acquisitions in conjunction with increasing the overbank floodplain was incorporated into the BCA V.6.0 calculator as property acquisitions and conversion to urban green open space with a corresponding 50-year PUL. 0.92-Acres for ecosystem services – 100% urban green open space assumed benefits for proposed project. Estimated $850,000 project cost for benefit-cost calculation.

Total Benefits = $314,345
Total Costs = $850,000
BC Ratio = 0.37

3621 Pierce Ave., Cheyenne, Wyoming 82009
One Story residential (no basement)
904 sq.ft. Wood frame

One Story residential (no basement)
Damage curve = residential, one-story, USACE generic curve
Defaults for BRV, CRV, displacement
3 residents, 1 worker
Benefits = $28,937

Threshold elevation = 5970.00
Streambed elevation = 5964.67
2-year WSEL before mitigation = 5966.61 2-year Q = 264 cfs
10-year WSEL before mitigation = 5967.12 10-year Q = 777 cfs
50-year WSEL before mitigation =5969.05 50-year Q = 1,582 cfs
100-year WSEL before mitigation =5971.00 100-year Q = 2,160 cfs

3615 Pierce Ave., Cheyenne, Wyoming 82009
One Story residential (no basement)
814 sq.ft. Wood frame

One Story residential (no basement)
Damage curve = residential, one-story, USACE generic curve
Defaults for BRV, CRV, displacement
3 residents, 1 worker

Benefits = $27,668

Threshold elevation = 5970.00
Streambed elevation = 5964.67
2-year WSEL before mitigation = 5966.61 2year Q = 264 cfs
10-year WSEL before mitigation = 5967.12 10-year Q = 777 cfs
50-year WSEL before mitigation =5969.05 50-year Q = 1,582 cfs
100-year WSEL before mitigation =5971.00 100-year Q = 2,160 cfs

3609 Pierce Ave., Cheyenne, Wyoming 82009
One Story residential (no basement)
1,106 sq.ft. Wood frame

One Story residential (no basement)
Damage curve = residential, one-story, USACE generic curve
Defaults for BRV, CRV, displacement
3 residents, 1 worker
Benefits = $23,050

Threshold elevation = 5970.00
Streambed elevation = 5964.67
2-year WSEL before mitigation = 5966.61 2-year Q = 264 cfs
10-year WSEL before mitigation = 5967.12 10-year Q = 777 cfs
50-year WSEL before mitigation =5969.05 50-year Q = 1,582 cfs
100-year WSEL before mitigation =5971.00 100-year Q = 2,160 cfs

904 Laramie Street, Cheyenne, Wyoming 82009
One Story residential (no basement)
720 sq.ft. Wood frame

One Story residential (no basement)
Damage curve = residential, one-story, USACE generic curve
Defaults for BRV, CRV, displacement
3 residents, 1 worker
Benefits = $43,978
BCA software did not recognize address – listed as "Cheyenne" with no address

Threshold elevation = 5969.00
Streambed elevation = 5964.67
2-year WSEL before mitigation = 5966.61 2-year Q = 264 cfs
10-year WSEL before mitigation = 5967.12 100-year Q = 777 cfs
50-year WSEL before mitigation =5969.05 50-year Q = 1,582 cfs
100-year WSEL before mitigation =5971.00 100-year Q = 2,160 cfs

U.S. 30 to E. Pershing Blvd. reach – There are six homes inundated in this reach by the 100-year storm event. E. Pershing Blvd. is overtopped east of the hydraulic structure by left overbank flooding and by Wenandy Ave. flow from Dakota Crossings. Proposed property acquisitions in conjunction with creek restoration project was incorporated into the BCA V.6.0 calculator as property acquisitions and conversion to urban green open space with a corresponding 50-year PUL. 30-Acres for ecosystem services – 50% urban green open space and 50% for inland wetlands assumed benefits for proposed project. Estimated $3,250,000 project cost for benefit-cost calculation.

Total Benefits = $5,656,298
Total Costs = $3,316.700
BC Ratio = 1.71
ESS benefits only = $3,497,821

5205 Charles Street, Cheyenne, Wyoming 82009
One Story residential (no basement)
Damage curve = residential, one-story, USACE generic curve
Defaults for BRV, CRV, displacement
3 residents, 1 worker
Benefits = $1,341,581

3409 Polk, Cheyenne, Wyoming 82009
One Story residential (no basement)
Damage curve = residential, one-story, USACE generic curve
Defaults for BRV, CRV, displacement
3 residents, 1 worker
Benefits = $57,662

5320 E. Pershing Blvd., Cheyenne, Wyoming 82009
One Story residential (no basement)1,464 sq.ft.stick built
Damage curve = residential, one-story, USACE generic curve
Defaults for BRV, CRV, displacement
3 residents, 1 worker
Benefits = $517,348

3307 Hayes Ave., Cheyenne, Wyoming 82009
One Story residential (with basement)
Damage curve = residential, one-story, USACE generic curve
Defaults for BRV, CRV, displacement
3 residents, 1 worker
Benefits = $48,831

5612 E. Pershing Blvd., Cheyenne, Wyoming 82009\
One Story residential (no basement)
Damage curve = residential, one-story, USACE generic curve
Defaults for BRV, CRV, displacement
3 residents, 1 worker
Benefits = $149,516

3312 Wenandy Ave., Cheyenne, Wyoming 82009
One Story residential (no basement)
Damage curve = residential, one-story, USACE generic curve
Defaults for BRV, CRV, displacement
3 residents, 1 worker
Benefits = $43,539

East Pershing Blvd. to the Union Pacific Railroad Embankment reach – There is one commercial building and ten homes inundated with floodwaters for the 100-year storm event. Impoundment of floodwaters against the Union Pacific embankment is not accounted for in this BCA. Proposed property acquisitions in conjunction with a reconfiguration of the existing sump 130 was incorporated into the BCA V.6.0 calculator as property acquisitions and conversion to urban green open space with a corresponding 50-year PUL. 10.4-Acres for ecosystem services – 80% urban green open space and 20% for inland wetlands assumed benefits for proposed project. Estimated $6,250,000 project cost for benefit-cost calculation.

Total Benefits = $19,637,178
Total Costs = $6,357,028
BC Ratio = 3.05
ESS benefits only = $2,087,546

5909 E. Pershing Blvd., Cheyenne, Wyoming 82009
One Story commercial (no basement)
3,519 sq.ftPole Bldg.
COM4: commercial - professional/technical etc.
Damage curve = office, one-story
Defaults for BRV, CRV
AOB = $351,900
Benefits = $0

2611 Whitney Rd., Cheyenne, Wyoming 82009
Property Acquisition
One Story residential (no basement)\
1,248 sq.ft. Masonry
One Story residential (no basement)
Damage curve = residential, one-story, USACE generic curve
Defaults for BRV, CRV, displacement
3 residents, 1 worker
Benefits = $4,153,880
FFE well below 2-year WSEL

2619 Whitney Rd., Cheyenne, Wyoming 82009
Property acquisition
One Story residential (no basement)
1,544 sq.ft.Wood frame
One Story residential (no basement)
Damage curve = residential, one-story, USACE generic curve
Defaults for BRV, CRV, displacement
3 residents, 1 worker
Benefits = $3,255,624
FFE well below 2-year WSEL

2617 Whitney Rd., Cheyenne, Wyoming 82009
Property acquisition
One Story residential (with basement)
2,710 sq.ft Wood frame

One Story residential (no basement)
Damage curve = residential, one-story, USACE generic curve
Defaults for BRV, CRV, displacement
3 residents, 1 worker
Benefits = $2,208,918
FFE well below 2-year WSEL

2615 Whitney Rd., Cheyenne, Wyoming 82009
Property acquisition
One Story residential (with basement)
2,340 sq.ft. Wood frame
One Story residential (no basement)
Damage curve = residential, one-story, USACE generic curve
Defaults for BRV, CRV, displacement
3 residents, 1 worker
Benefits = $4,921,973

FFE well below 2-year WSEL

2709 Whitney Rd., Cheyenne, Wyoming 82009
One Story residential (no basement)
Property acquisition
868 sq.ft.Wood frame
One Story residential (no basement)
Damage curve = residential, one-story, USACE generic curve
Defaults for BRV, CRV, displacement
3 residents, 1 worker
Benefits = $1,604,206
FFE well below 2-year WSEL

2811 Whitney Rd., Cheyenne, Wyoming 82009
Property acquisition
One Story residential (with basement)
2,600 sq.ft.Wood frame
One Story residential (no basement)
Damage curve = residential, one-story, USACE generic curve
Defaults for BRV, CRV, displacement
3 residents, 1 worker
Benefits = $709,161
FFE well below 2-year WSEL

2809 Whitney Rd., Cheyenne, Wyoming 82009
Property acquisition
One Story residential (no basement)
712 sq.ft. Wood frame
One Story residential (no basement)
Damage curve = residential, one-story, USACE generic curve
Defaults for BRV, CRV, displacement
3 residents, 1 worker
Benefits = $206,198
FFE well below 2-year WSEL

2905 Whitney Rd., Cheyenne, Wyoming 82009
Property acquisition
One Story residential (no basement)
672 sq.ft. Wood frame
One Story residential (no basement)
Damage curve = residential, one-story, USACE generic curve
Defaults for BRV, CRV, displacement
3 residents, 1 worker
Benefits = $195,542
FFE well below 2-year WSEL

UPRR to Upper Campstool Rd. reach – There is one commercial bldg. potentially inundated for the 100-year storm event. Upper Campstool Rd. is overtopped west of the hydraulic structure.

Pawnee Ave./Western Hills Blvd. – A significant amount of stormwater runoff overtops Western Hills Blvd. for the 100-year storm event. This flow is conveyed south into an open channel located on the east side of the McCormick campus. The ADT for Western Hills Blvd. west of Yellowstone Rd. is 4,411 vehicles per day.

Pineridge/Sheridan Street – There is 191cfs that overtops Sheridan Street at Pineridge. This stormwater runoff is conveyed into the Sheridan Street reach of Dry Creek for the 100-year storm event. The ADT for Sheridan Street west of Ridge Rd. is 1,285.

Messenger/McCann to Rock Springs Street – There is over 120cfs of overland flow that is directed at the Messenger/McCann intersection for the 100-year storm event. This runoff contributes to over 130cfs flooding Rock Springs Street where it is conveyed to Dry Creek.

Benefit-cost analysis (BCA) is a key eligibility requirement of FEMA programs under the Robert T. Stafford Disaster Relief Act ("Stafford Act"). BCAs are generally required to determine funding eligibility under the Stafford Act for mitigation projects that reduce the effects of natural hazards, including floods.

BCAs are a comparison of current flood risk (future losses) versus flood risk after a proposed mitigation project is implemented; the value of the risk reduction is then compared to the project cost. If the value of the long-term risk reduction (mitigation) is greater than the cost, then the project is considered cost-effective. Risk is defined as the expected future damages, in this case from either riverine or overland flow flooding. All such damages are monetized so that they can be compared to the project cost, which is expressed in dollars. Moreover, because benefits are worth more if they are experienced sooner, future benefits are then discounted by a rate set periodically by the US Office of Management and Budget (OMB).

For FEMA-related grants, there are several general categories of damages, which become benefits when mitigation projects are designed to reduce or eliminate them. These categories are: (1) direct physical damages to structures, infrastructure, contents of buildings, etc.; (2) losses of function, e.g., when public operations or systems like water, wastewater, electricity are lost or interrupted due to natural hazards; traffic interruptions/detours along with interruptions to emergency responders; and (3) injuries and fatalities (seldom used in flood BCAs). There are several sub-categories of damages as well, including displacement and loss of productivity. Each of these types of damage can be determined using established procedures, but it is a complex undertaking. For the initial BCA iterations for this study, we have incorporated a "*lower bound analysis*" for a more cost-effective approach before finalizing the BCAs in future grant applications.

The last basic element of a flood BCA is to determine the effectiveness of a proposed mitigation project in reducing future flood damages. This is typically a function of the project design, and is usually expressed in terms of probability, e.g., "*effective to a 50-year event*" for example. The basis of a BCA is then comparing the monetary value of losses before a project is implemented versus after, then dividing this value by the cost. ***The importance of effectively tying the hydrologic and hydraulic (H&H) approach to the development of project BCAs and an overall grant strategy cannot be overemphasized*** and will propel the improvements recommended from this study update into implementation.

D. Benefit-Cost Discussion for Voluntary Property Acquisitions

The Federal Emergency Management Agency (FEMA) has established property acquisition requirements as part of the Building Resilient Infrastructure and Communities (BRIC) program. Property acquisition is one of the eligible activities under BRIC for addressing repetitive loss properties or properties in high-risk areas. FEMA's property acquisition requirements typically target properties that have experienced repeated flooding or are situated in high-risk areas prone to natural disasters. To be eligible for property acquisition funding, the property must meet certain criteria established by FEMA.

Property acquisition for hazard mitigation purposes, including repetitive loss properties, is typically carried out through FEMA's Hazard Mitigation Grant Program (HMGP). The HMGP provides funding to states and local communities to implement projects that reduce the risk and impact of future disasters. Property acquisition is one of the eligible activities under the HMGP. When acquiring properties, FEMA requires an independent appraisal to determine the fair market value of the property. The fair market value is the price at which the property would change hands between a willing buyer and a willing seller. FEMA uses appraisal to establish the maximum amount of financial assistance it can provide for property acquisitions. FEMA Pre-Calculated Benefits requiring no Benefit-Cost Analysis for acquisition projects is currently set at $323,000 per structure. This may be adjusted in the upcoming NOI for BRIC.

FEMA emphasizes the provision of fair and equitable relocation assistance to property owners who participate in property acquisition programs. This may include financial assistance for relocation costs, such as moving expenses, searching for new housing, and re-establishment in a new location. FEMA encourages states and communities to provide relocation assistance that meets or exceeds the requirements established by the Uniform Relocation Assistance and Real Property Acquisition Policies Act. In most cases, properties acquired through FEMA's property acquisition programs are restricted from future development. This is to ensure that the acquired land remains in a natural state, allowing it to serve as a buffer or open space to mitigate future flood risks and enhance community resilience.

VII. PLAN DEVELOPMENT/CONCEPTUAL ALTERNATIVES

A. Preliminary Conceptual Project and Long-Term Maintenance Alternatives

Development of alternative plans for stormwater management and functionally restoring Dry Creek has been a collaborative effort between project team members, city staff, project stakeholders, and community participants. Key elements of our plan development process include:

- Stakeholder Engagement: We will actively seek input and involvement from a wide range of stakeholders, including community members, organizations, experts, and relevant agencies. We value your input and will provide opportunities for meaningful participation at various stages of the plan development.
- Data and Analysis: Our plan will be informed by rigorous data collection, analysis, and evaluation of existing conditions. We will utilize the best available information and employ appropriate methodologies to ensure the accuracy and reliability of our findings.
- Collaboration and Partnerships: We recognize the importance of collaboration and building partnerships to address complex challenges. We will actively engage with relevant organizations, agencies, and institutions to leverage resources, expertise, and knowledge for the successful implementation of the plan.
- Transparency and Communication: We are committed to maintaining transparency throughout the plan development process. We will provide regular updates, share progress reports, and actively communicate key findings, milestones, and decisions with all stakeholders.

To facilitate the consideration of plan alternatives, the main stem of Dry Creek has been divided into the following segments or analysis reaches as was done for the original 1988 study.

Headwaters to Yellowstone Reach (SubBasins 10, 20, 30, 40, 50, and 60 from 1988 study)

This segment includes the headwaters for the north fork including the FEW detention pond, potentially covered under Wyoming Safety of Dams (SubBasin 10), stormwater runoff from SubBasin 20, stormwater runoff from the bulk of Western Hills subdivision contributing flow to Evers Blvd. including runoff from Vandehei Avenue with continuing flooding issues for the drainage path from WyDOT Vandehei R.O.W. (SubBasin 30), headwaters for the south fork of Dry Creek (SubBasin 40), southern portion of Western Hills contributing flow to the south fork (SubBasin 50), and stormwater runoff from the North Cheyenne and Westgate subdivisions with significant overland flood risk between Western Hills Blvd. and Dry Creek (SubBasin 60).

Yellowstone Rd. to Powderhouse Reach (SubBasin 70 from 1988 study)

Indian Hills, North Gate, Villa Hills, Oakview, Skyline Ridge and several smaller subdivisions contribute flow to Dry Creek through SubBasin 70. Significant overland flow flood risk from surface water drainage between Storey Blvd. and the main stem of Dry Creek through the Indian Hills subdivision and immediately west of Indian Hills to Yellowstone Rd. Storm sewer outfalls from the Indian Hills system also contribute sediment to Dry Creek which is an ongoing issue at the Yellowstone Rd. outfall and overall, a MS4 concern for the City. A considerable stormwater discharge is also contributed from the Cheyenne Regional Airport in subbasin 70. The concern here revolves around the potential for PFAS contamination from the Air National Guard operations.

Powderhouse Rd. to Carey Reservoir Reach (SubBasin 80 from 1988 study)

The reach receives runoff from the Frontier Mall and commercial district along Dell Range Blvd. and from the former Cole property north of the mall (SubBasin 80). The Cole property when developed will have considerable overland flow directed at existing storm drainage infrastructure in Prairie Avenue from the west side of the property.

Sheridan Reach (SubBasins 90 and 100 from 1988 study)

The middle and east portions of the former Cole property along with the Buffalo Ridge subdivision contribute flow to the Sheridan Reach of Dry Creek (SubBasins 90 and 100). The middle section of the former Cole property contributes to existing city storm sewer systems where there may be capacity-related issues. Both subbasins 80 & 90 include the Dell Range commercial district where overland flooding of parking lots, particularly at WalMart cause flood risks as flow works its way to the main stem of Dry Creek. The east side of the Cole property and the buffalo Ridge subdivision contribute significant storm drainage flow to the Converse Avenue corridor with overland flood risks in Buffalo Ridge and significant flow into the Sheridan Reach of Dry Creek. There remain significant capacity issues and life-safety issues at the Hill Top Avenue crossing at the downstream end of the Sheridan reach. The Mountain Rd. crossing culvert mitered inlet and outlet are also in poor condition. This area of the master planning will need to be coordinated with the MPO with their Converse Corridor Plan.

Ridge Road to U.S. 30 Reach (SubBasin 110 from 1988 study)

This subbasin includes Whitney Ranch and future east side development (SubBasin 110). There is potential for overland, urban flood risk and capacity issues for the receiving city storm sewer systems. Discharge from this subbasin impacts low flow pedestrian crossings located between Ridge Rd. and US 30 as well as the downstream US 30 crossing. The master plan efforts will need to account for the future WyDOT U.S. 30 crossing replacement and will require coordination with both the City Engineer's Office and WyDOT staff.

U.S. 30 to E. Pershing Blvd. Reach (SubBasin 120 from 1988 study)

This reach of Dry Creek is a levied system with flap gates to allow discharge from the adjacent subbasin (SubBasin 120). This straightened channel was constructed by the County in the 1990s as a response to the 1985 flood event. It currently isn't mapped correctly, and the levy isn't certified. The master planning effort through this reach will need coordination with the ongoing E. Pershing Blvd. Plan. Along the west side of the levied creek, stormwater flow results in considerable overland flood risk including a life-safety hazard as it crosses Polk Avenue. Stormwater flow along the east side of the levied creek is contained and forced southward across E. Pershing towards a historic meander loop of Dry Creek where it has caused flooding on the Hess property. The Hess family has recently constructed a series of berms to better protect their horse stables from the annual flooding.

The Dakota Crossings subdivision contributes significant stormwater flow to this drainage path producing overtopping of E. Pershing for less frequent, major storm events. Overland flood risks are developed in this part of the subbasin as drainage flows south towards Dry Creek.

E. Pershing Blvd. to UPRR Crossing Reach (SubBasin 130 from 1988 study)

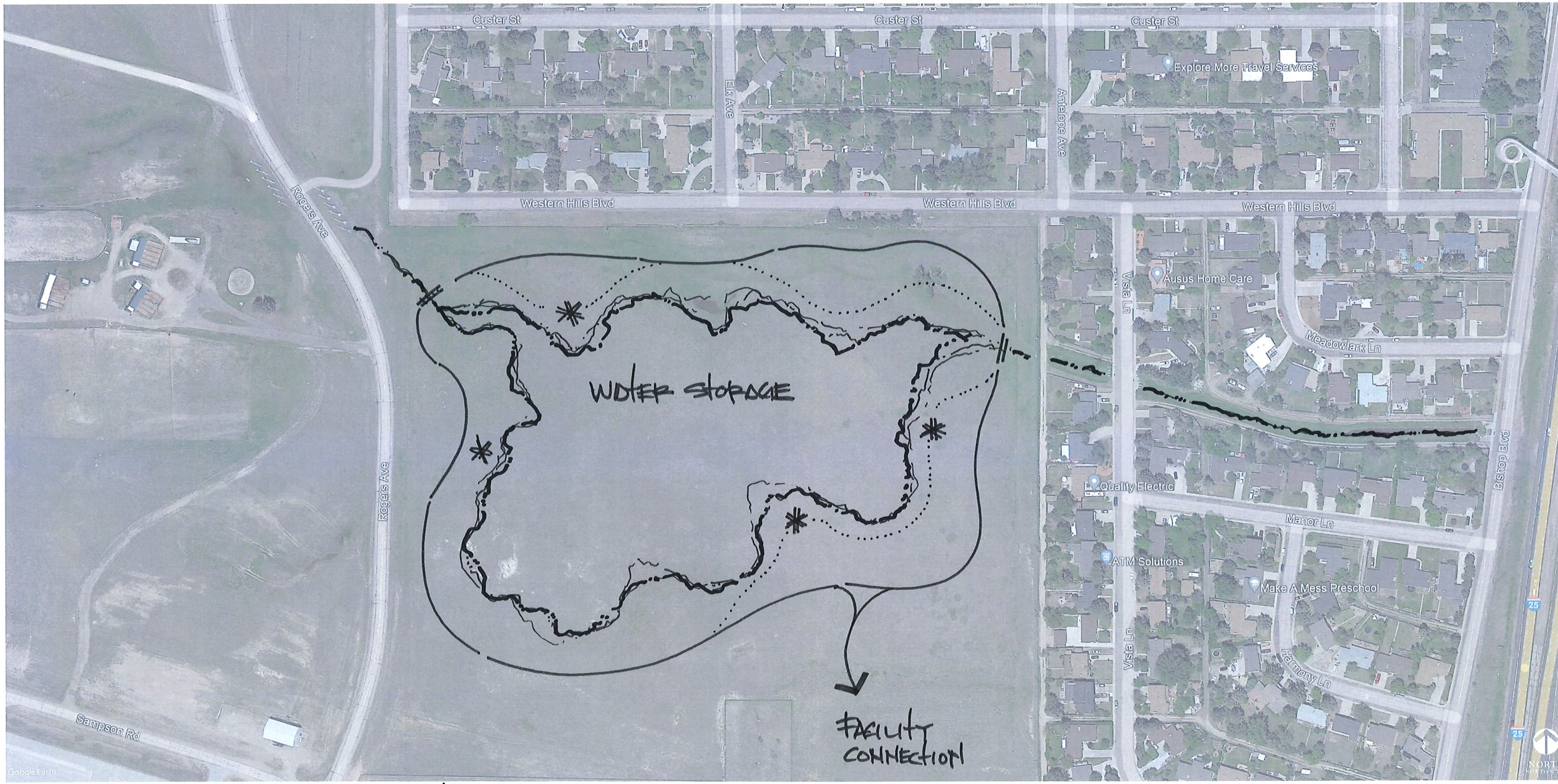
This reach has large subbasin encompassing the Saddle Ridge, Sun Valley, and Chucker Ridge subdivisions (SubBasin 130). There are considerable overland flow issues in this subbasin, particularly, for the Sun Valley subdivision where most of the stormwater flow is surface runoff through city streets – the majority of flow being discharged at the end of Atlantic Street. The UPRR embankment is the catchment design point for this subbasin as well as for the entire upstream drainage basin. There is significant potential to completely revise the existing UPRR storage area especially if the City is successful in acquiring the former Lincoln Valley Auto Salvage Yard. The reconfigured UPRR storage area would provide the following benefits.

- The project would address the potential breach risk for the UPRR embankment when it is holding impounded stormwater for any length of time.
- The project would provide potential use of the historic UPRR box-arch masonry culvert for Greater Cheyenne Greenway connectivity to the LCCD Headquarters open space immediately downstream and the Cheyenne LEADS Business Park.
- The project would provide additional storage to off-set future development in the lower basin and eliminate the need for a 20-year historic cap on developed stormwater discharge. This will facilitate development in the basin.
- The project will provide enhanced wetlands/water features for East Park including great vistas from the adjacent Greenway paths which will incentivize private sector development of the adjacent properties.

UPRR Crossing to Confluence with Crow Creek (SubBasin 140 from 1988 study)

SubBasin 140 is the furthest downstream subbasin to be modeled in the 1988 HEC-1 hydrologic model. It is the largest subbasin and encompasses the LEADS Business Park, the LCCD Headquarters open space area, both Campstool Rd. crossings, the downstream I-80 crossing, and the BOPU Dry Creek Wastewater Treatment Plant. Conveyance issues include how stormwater is conveyed to the upstream Campstool crossing and overtopping and capacity issues for the crossing. There was substantial head cutting in the reach between the upper Campstool Crossing and the I-80 crossing. This was a suggested location for additional storage in the 1988 study.

The initial conceptual projects focused on detention storage, creek restoration, and enhancement of greenway and park amenities along the creek and are presented in **Figures 53 through 70**. These conceptual alternatives were presented to staff and the project stakeholders for review and comments. Detention storage was proposed for the Headwaters to Yellowstone Rd. reach and for the Yellowstone to Powderhouse Rd. reach. Reconfiguration of the UPRR sump 130 was also brought forward for consideration by staff and the stakeholder's group. Creek restoration projects were conceptually proposed for the McCormick – Central campus, downstream Yellowstone reach, Smalley Park, Powderhouse reach, the Sheridan Flood Control alignment, the Sheridan Street reach and at the confluence. Trail and park amenities were proposed for the Powderhouse reach, along the Sheridan Flood Control alignment, and downstream of Ridge Rd. Amphitheaters were proposed for the Cahill Park area and the LCCD managed area south of the UPRR (The LCCD amphitheater had been master planned several years prior to this study update). Parks & Rec Frisbee golf course improvements at Mylar Park and upstream of U.S. 30 were also proposed and vetted by Mr. Jason Sanchez, Cheyenne Parks Department Director.



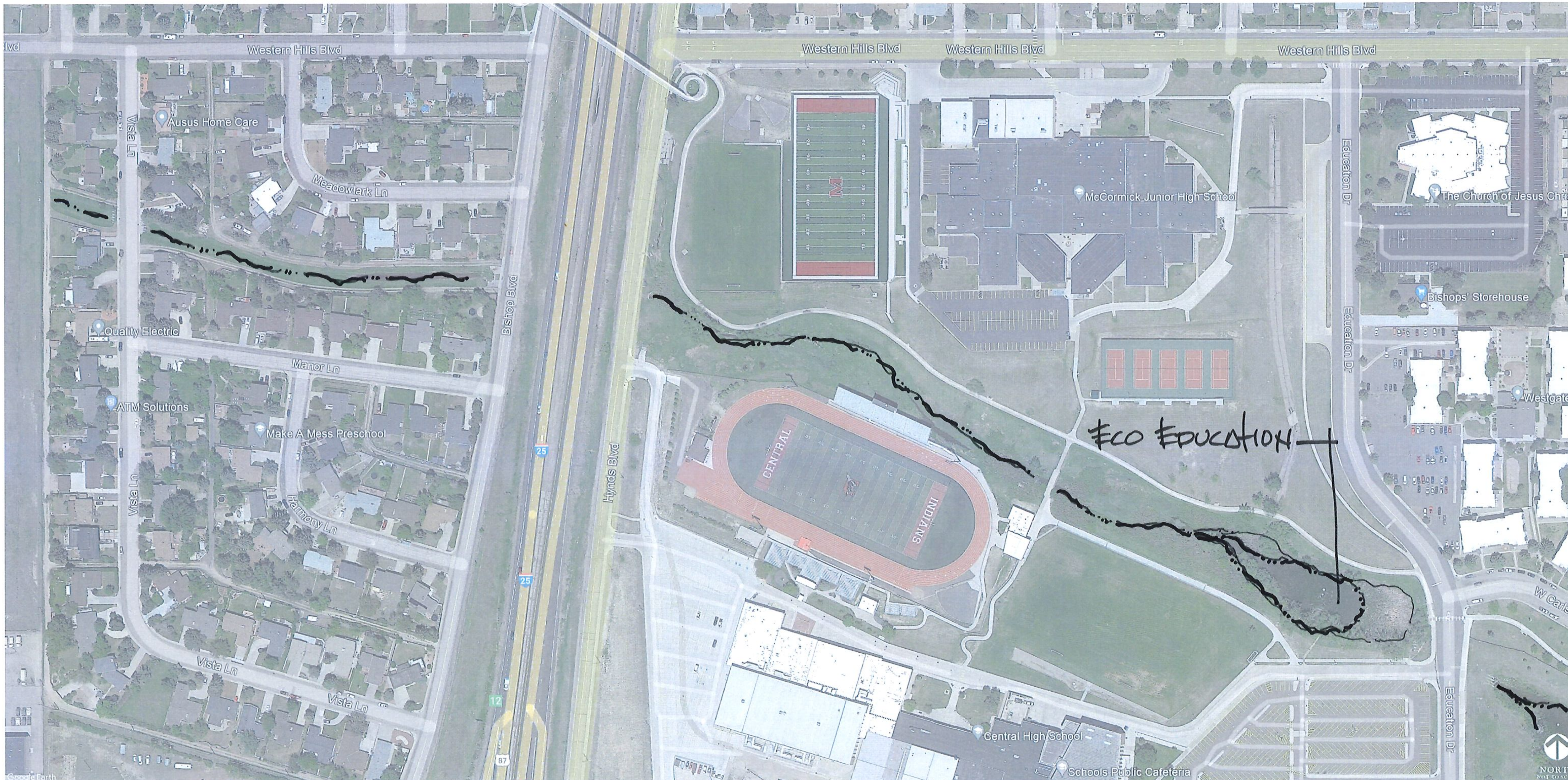
- WETLANDS
- OPEN SPACE
- LOOPED TRAILS
- SHADE STRUCTURES
- PED CONNECTIONS

OPEN SPACE CENTERED AROUND WATER RETENTION

CITY OF CHEYENNE

GLM Design Group

DHM DESIGN



- INTERPRETIVE SIGNAGE
- SOFT SURFACE TRAIL
- LOW MAINTENANCE ⟶ GEN. CLEAN UP?

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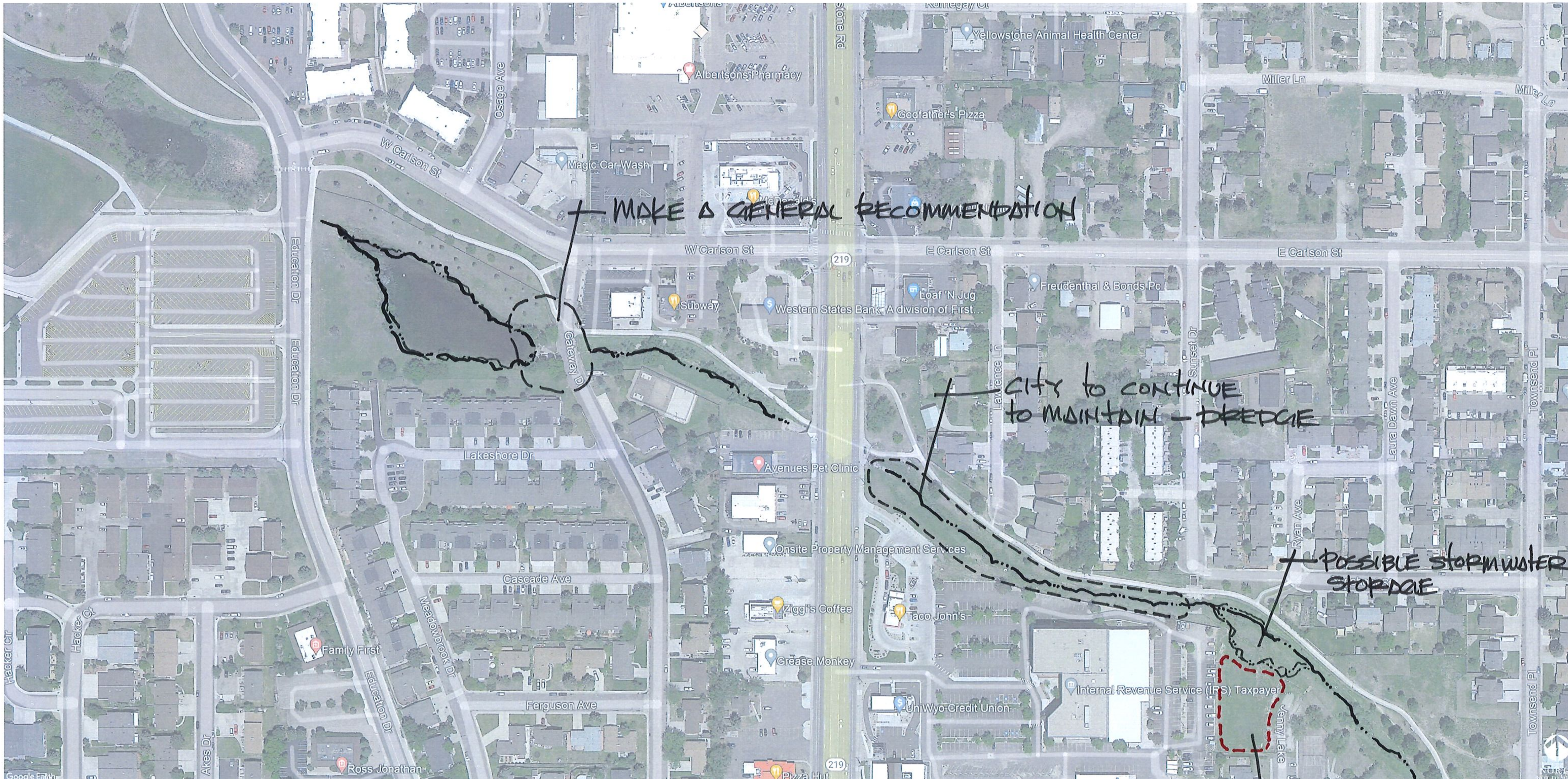
PROJECT AREA I U.S FISH & WILDLIFE POCKET PARK



POSSIBLE POCKET PARK
- MINOR PLAYGROUND
- SHELTER
- SMALL LOOPED TRAIL

CITY OF CHEYENNE

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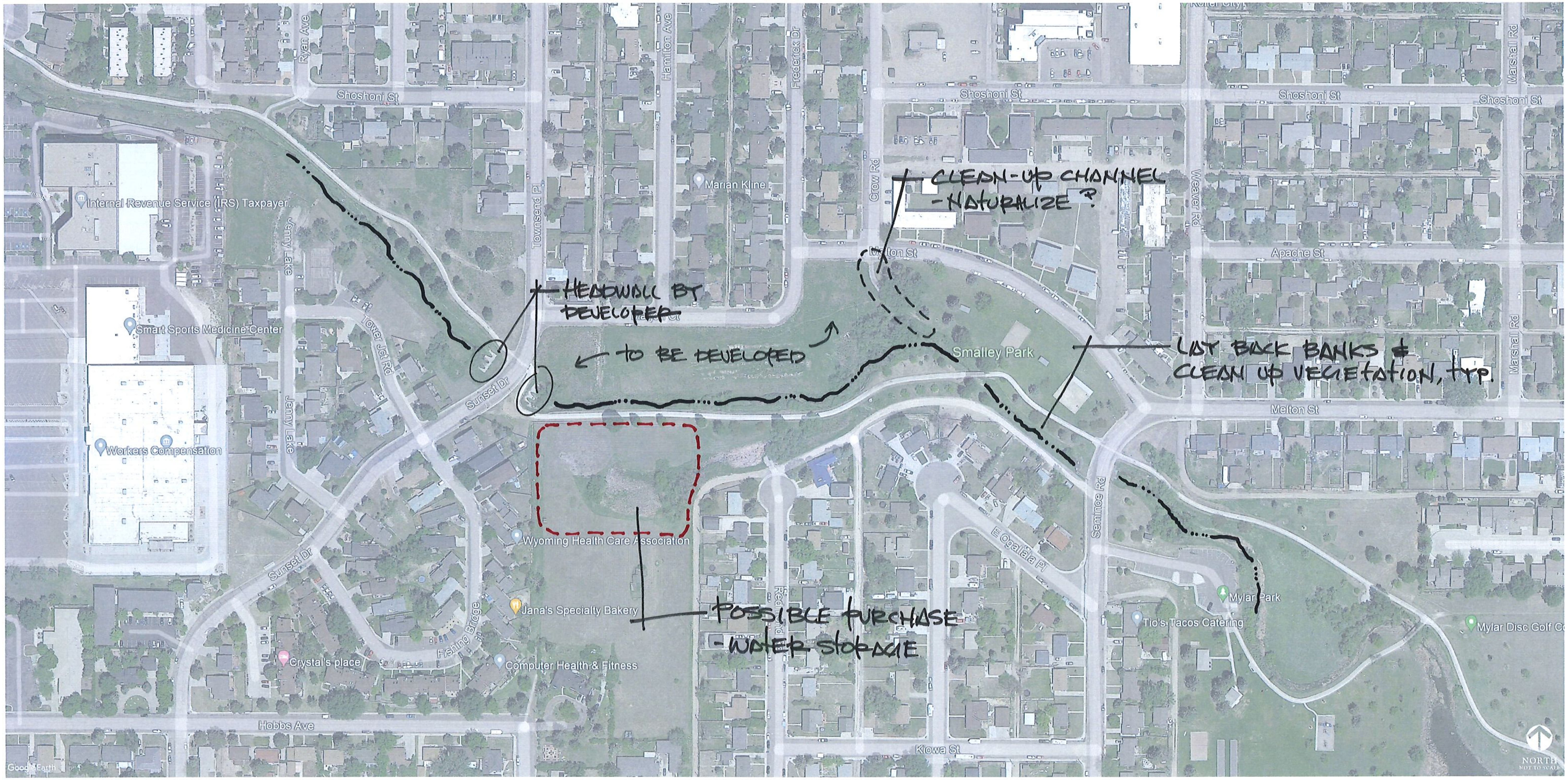
PROJECT AREA I SMALLEY PARK



CITY OF CHEYENNE

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PROJECT AREA I MYLAR PARK

SHEET 1 OF 2

CITY OF CHEYENNE

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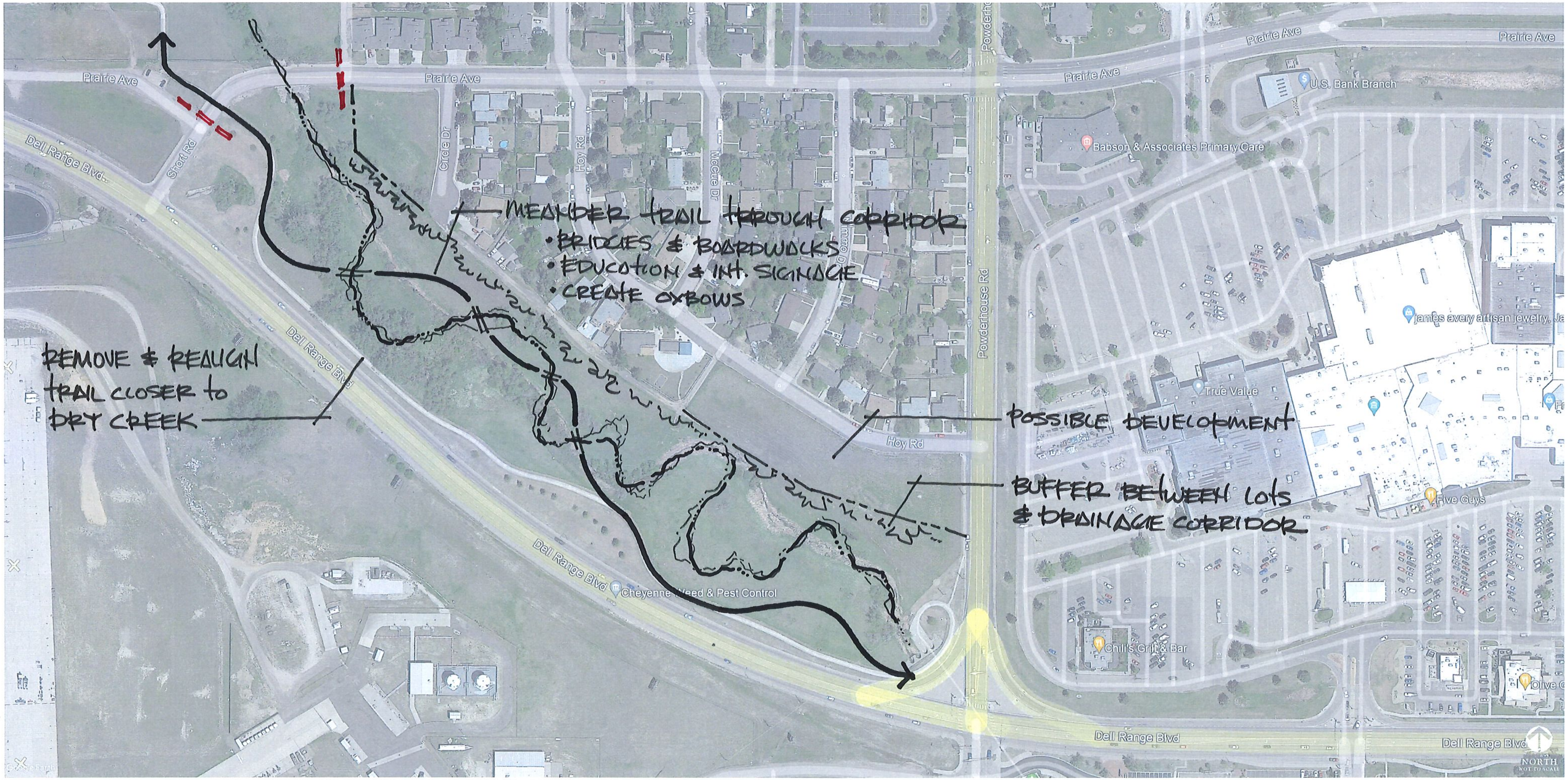
PROJECT AREA | MYLAR PARK

SHEET 2 OF 2



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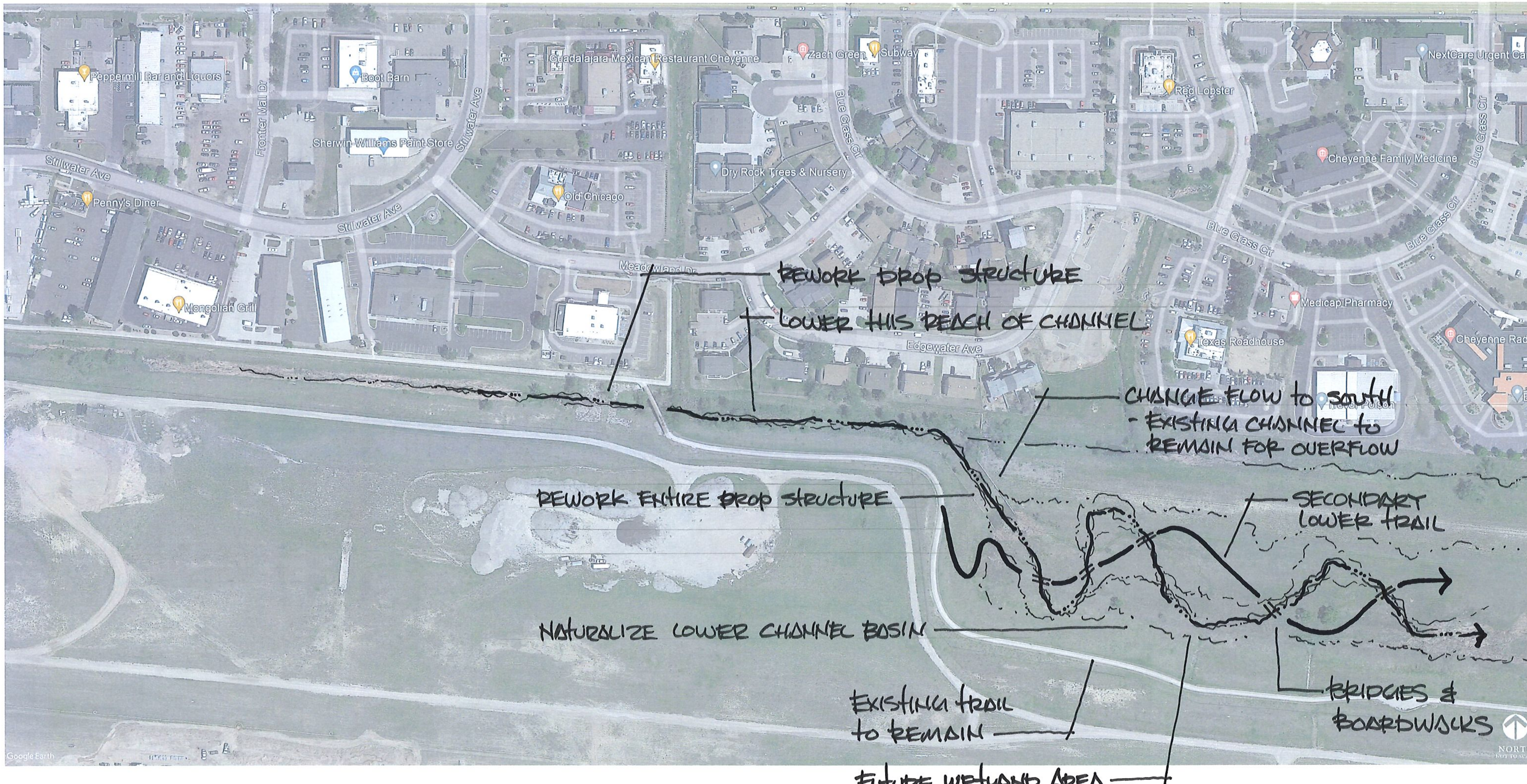

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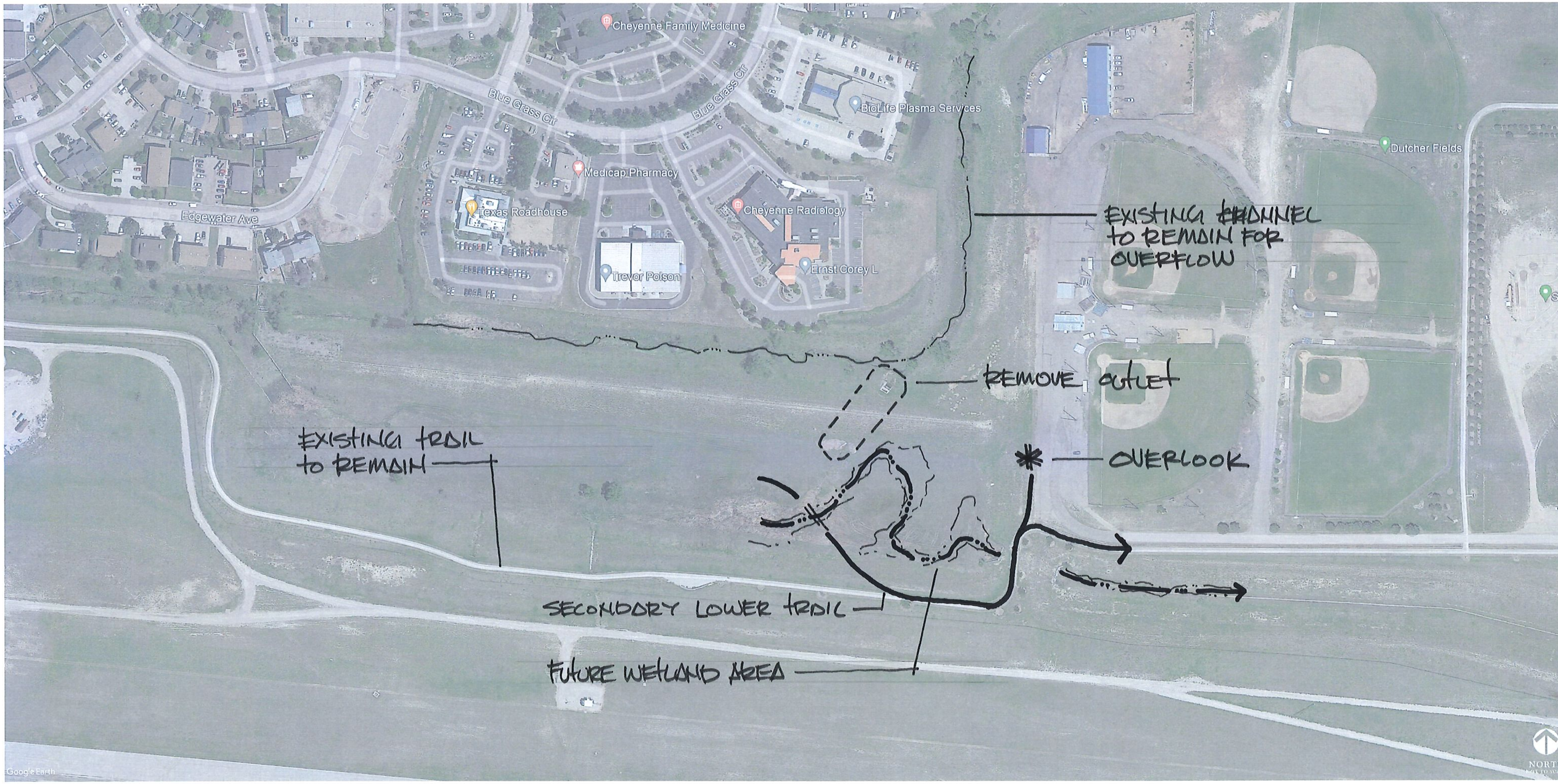
PROJECT AREA I CHEYENNE REGIONAL AIRPORT

SHEET 2 OF 2



GLM Design Group
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PROJECT AREA I WYOMING RACING CLUB — HAME?

SHEET 1 OF 2

CITY OF CHEYENNE

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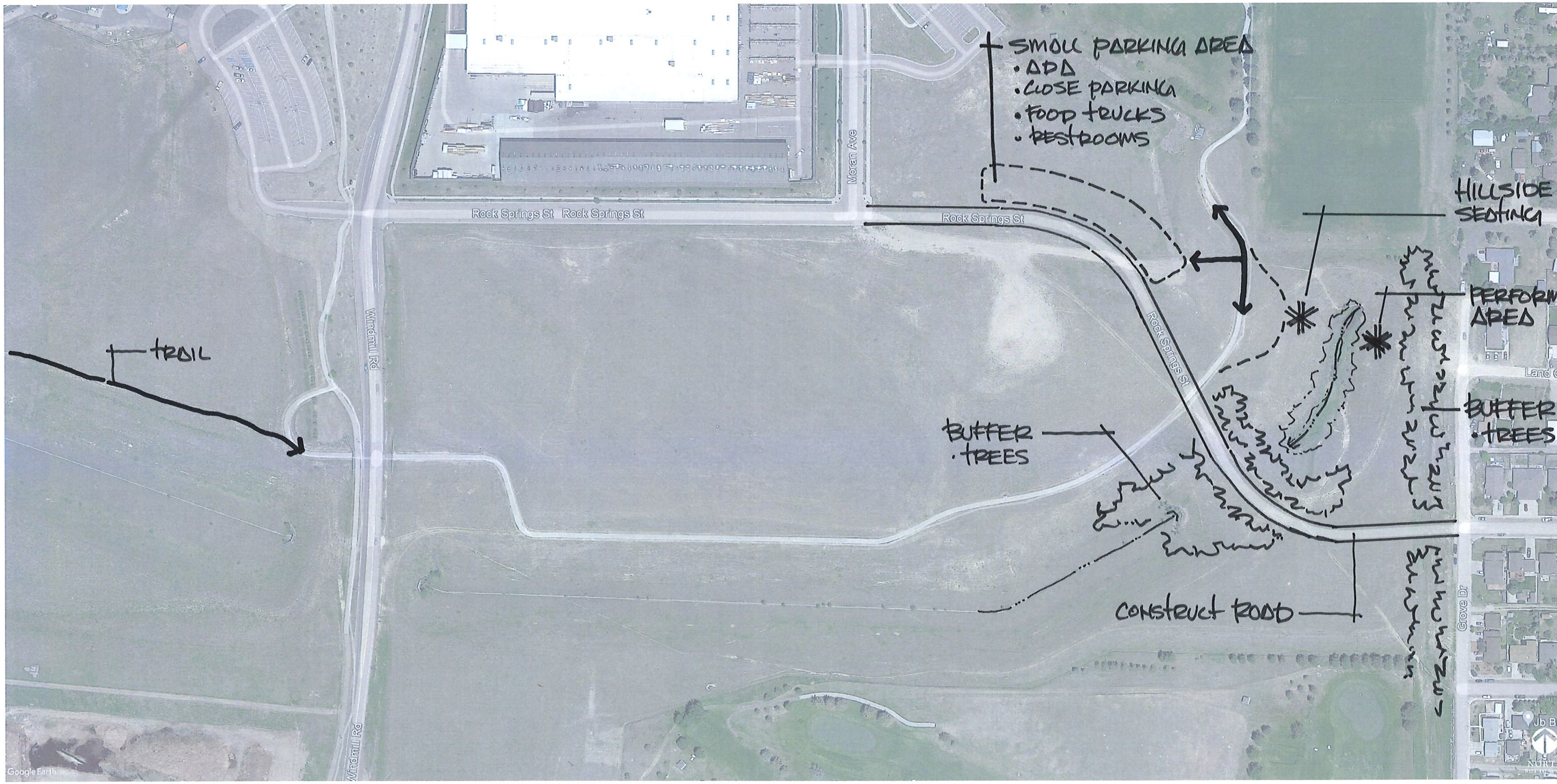
PROJECT AREA I WYOMING RACING CLUB —— NAME?

SHEET 2 OF 2



DRY CREEK CORRIDOR MASTER PLAN I CHEYENNE, WYOMING

CITY OF CHEYENNE

GLM Design Group

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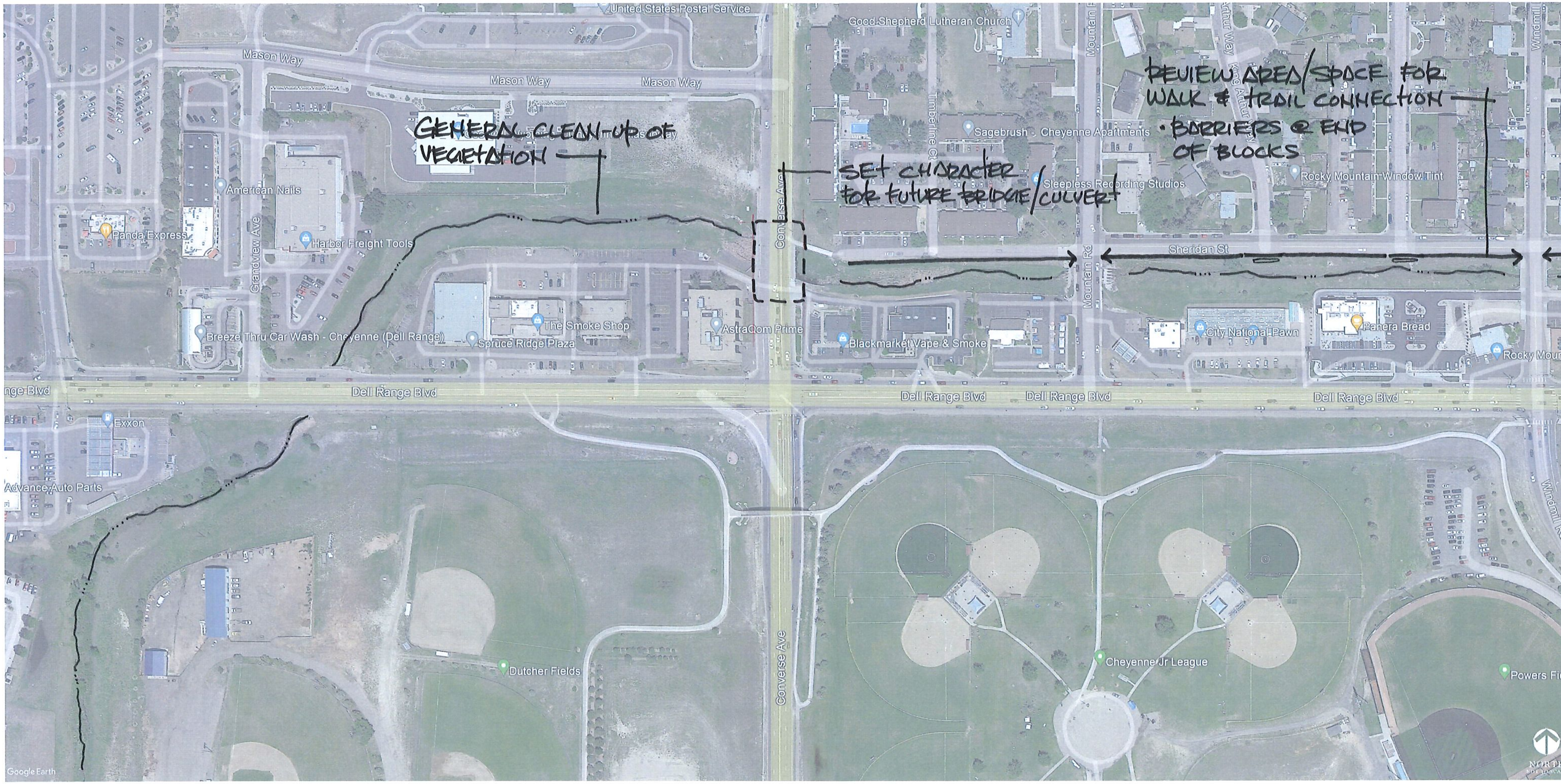
PROJECT AREA I SHERIDAN STREET CORRIDOR

SHEET 1 OF 2



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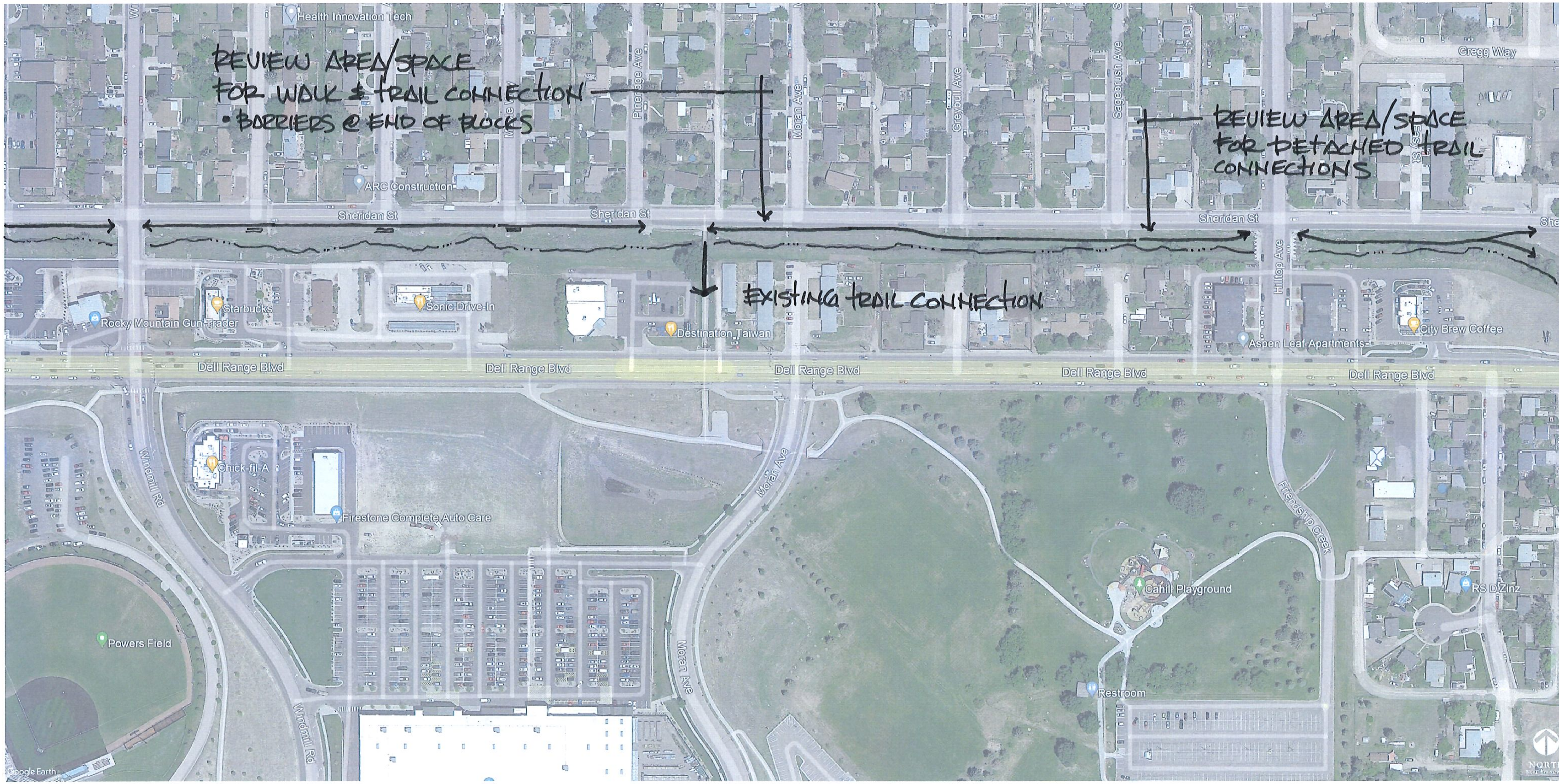

CITY OF CHEYENNE
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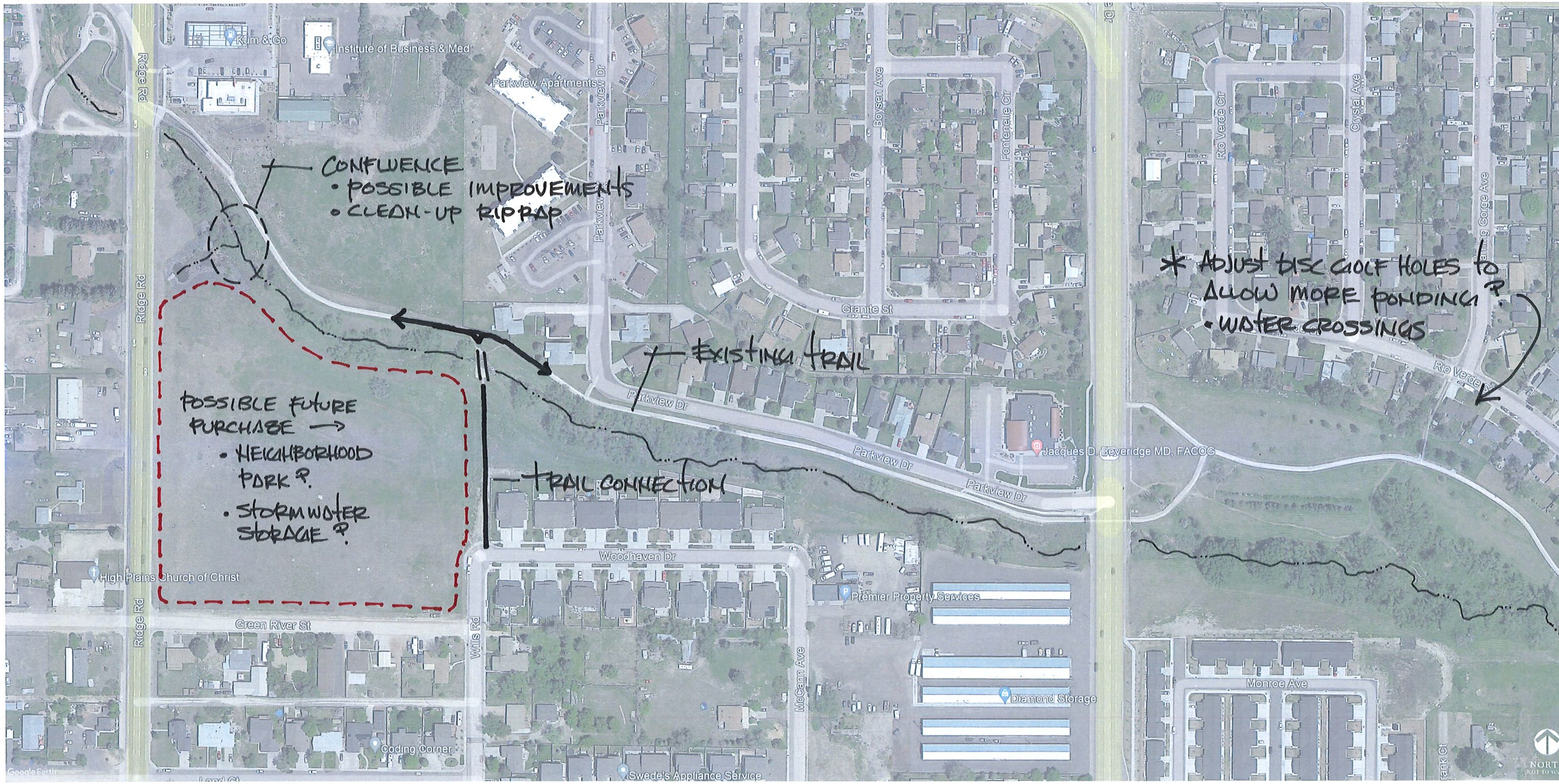

CONFLUENCE
• POSSIBLE IMPROVEMENTS
• CLEAN-UP RIPRAP
* Adjust disc golf holes to allow more ponding?
• water crossings
Existing trail
Possible future purchase →
• Neighborhood park?
• Stormwater storage?
trail connection
Kum & Go
Institute of Business & Med
Parkview Apartments
Ridge Rd
Parkview Dr
Boysen Ave
Fontenelle Cir
Granite St
Rio Verde Cir
Crystal Ave
Rio Verde
Jacques D. Beveridge MD, FACOG
Woodhaven Dr
High Plains Church of Christ
Green River St
Wills Rd
McCann Ave
Premier Property Services
Diamond Storage
Monroe Ave
Coding Corner
Swede's Appliance Service
Google Earth
NORTH
NOT TO SCALE

PROJECT AREA I DRY CREEK DISC GOLF COURSE

SHEET 1 OF 2

DRY CREEK CORRIDOR MASTER PLAN I CHEYENNE, WYOMING

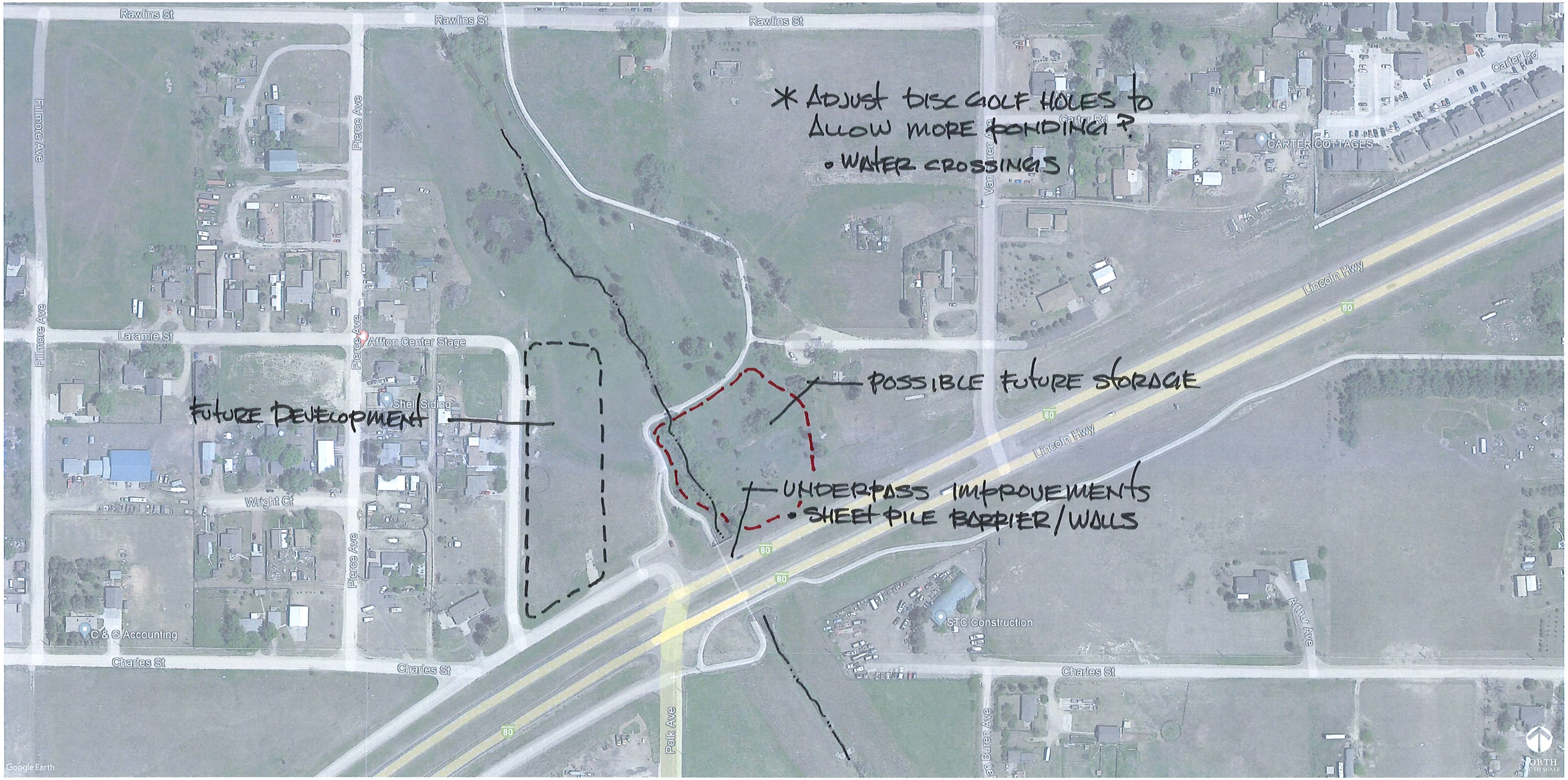
CITY OF CHEYENNE

GLM Design Group

DHM DESIGN

PROJECT AREA I DRY CREEK DISC GOLF COURSE

SHEET 2 OF 2



DRY CREEK CORRIDOR MASTER PLAN I CHEYENNE, WYOMING

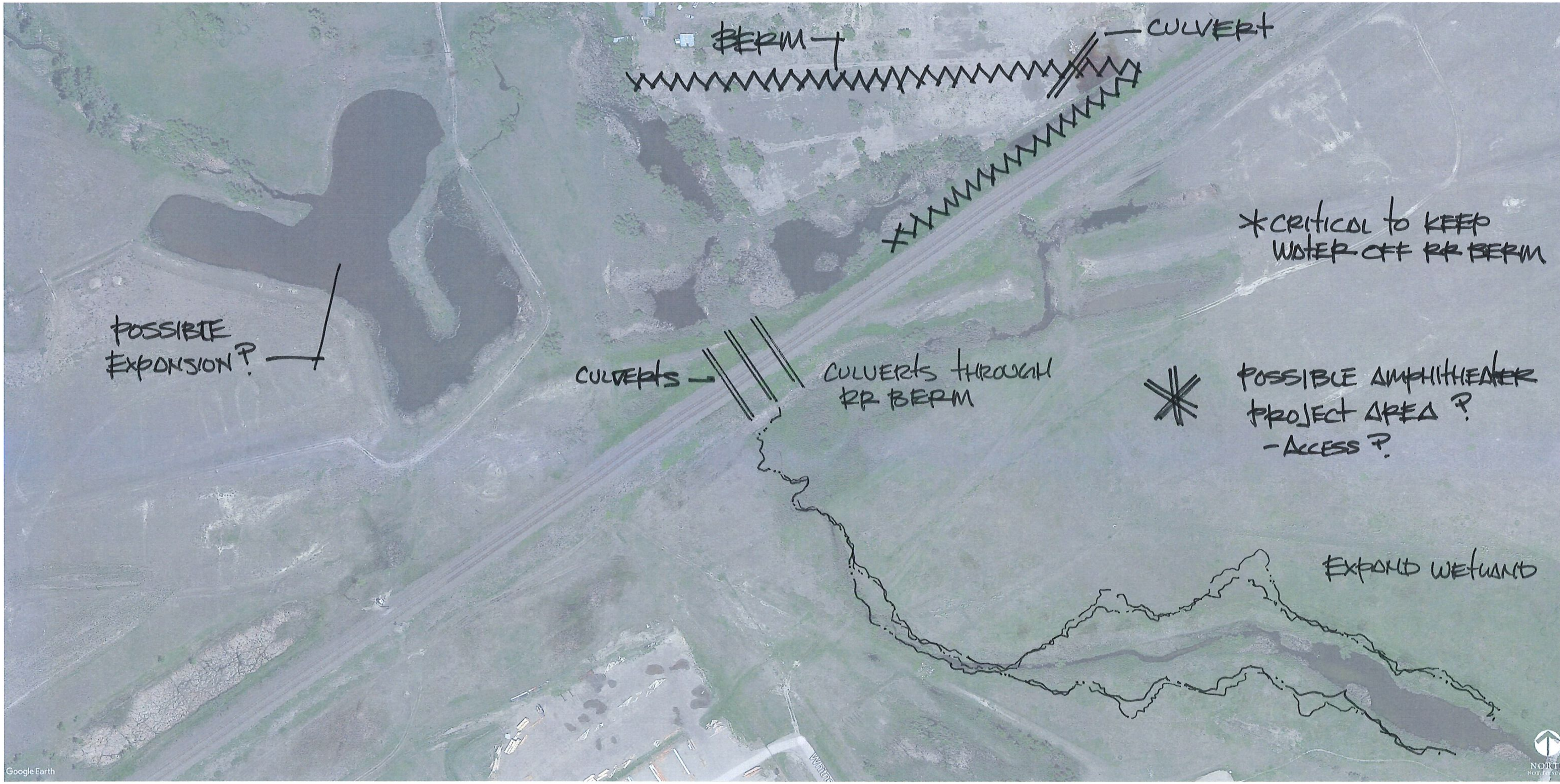
CITY OF CHEYENNE

GLM Design Group

DHM DESIGN

PROJECT AREA I KIWANIS PARK

SHEET 1 OF 3


BERM
CULVERT
*CRITICAL TO KEEP WATER OFF RR BERM
POSSIBLE EXPANSION?
CULVERTS
CULVERTS THROUGH RR BERM
POSSIBLE AMPHITHEATER PROJECT AREA ?
-ACCESS ?
EXPAND WETLAND
Google Earth
NORTH

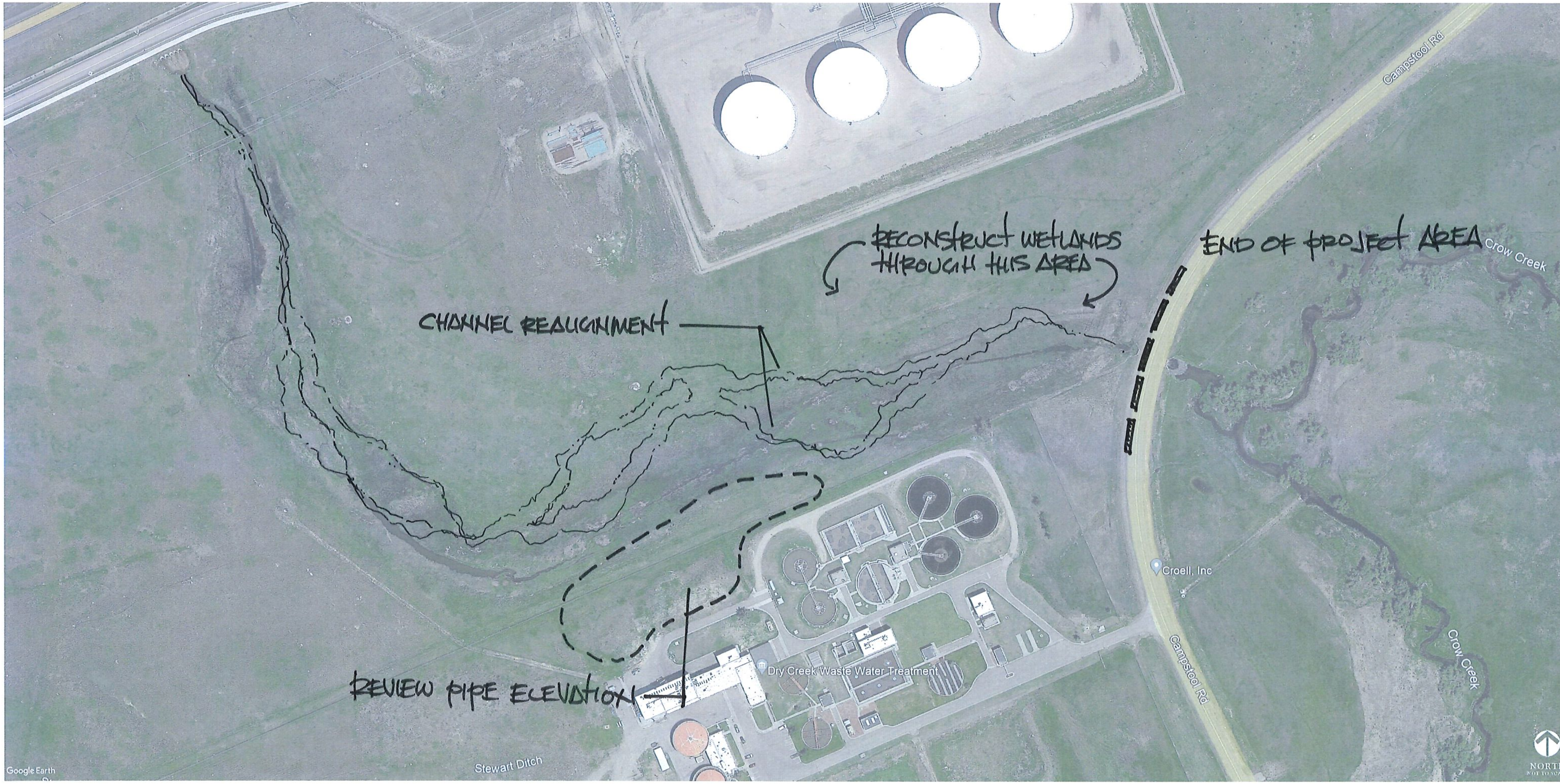
PROJECT AREA | KIWANIS PARK

SHEET 3 OF 3

GLM Design Group

DHM DESIGN

PROJECT AREA I DRY CREEK WATER TREATMENT PLANT



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i. Coordination with Staff and Steering Committee

The Plan Update Team has coordinated closely with city staff and the Project Steering Committee throughout the planning process. We have also coordinated with other city departments including Public Works for maintenance and development of a stormwater utility budget, Development Office for information on select development projects, Parks Department for discussions on potential park amenities, green space and greenway path alignments, and maintenance, and the contract drainage engineer for additional modeling information. A Design Decision Log was developed in coordination with city staff for documenting decisions made throughout the study update process. Staff coordinated with the project team in establishing decision categories as shown in **Table 8**.

Using the Design Decision Log developed with assistance from city staff for this plan update, key parameters have been noted for proposed plan recommendations. Additionally, we have also coordinated with the city's Grants Manager for discussions on grant strategy and potential project grant pursuits for plan recommended mitigation efforts.

Using the Design Decision Log, we will note key parameters for proposed solutions such as limits for slopes relative to mowing and revegetation, materials standards for walls and railings, and standards for paths and access routes. The Design Decision Log may note objectives such as providing minimum width equipment access routes for sediment pond clean out, aim for certain types of pollutant removals, and target certain types of habitat creation depending on City and Stakeholder goals. Early in the project our team will coordinate with public works and the parks department regarding maintenance practices and anticipated equipment to minimize cost, labor, and appropriately design solutions to match City expectations and allow new improvements to be long lasting, durable, and manageable.

Our planning/design coordination with project stakeholders will also touch on the potential integration of the mitigation recommendations into a future storm water utility, MS4 compliance response, and regulatory updates.

ii. Decision/Design Log

Documentation: The log provides a clear and concise record of design decisions, ensuring that the reasoning behind each choice is captured and documented. It serves as a valuable resource for future reference, audits, or reviews. It helps identify who made each decision, when it was made, and the information that informed the decision. This enhances transparency and facilitates effective communication among team members and stakeholders.

The log serves as a knowledge management tool. It allows for knowledge sharing and facilitates the transfer of information to future projects, enabling teams to build on past experiences and make informed design decisions. By recording design decisions, a log helps maintain consistency and continuity within a project. It provides a reference point for understanding the rationale behind previous choices, allowing for informed decision-making, and avoiding unnecessary rework or conflicts.

A design decision log fosters collaboration and communication among project stakeholders. It provides a platform for team members to share information, discuss alternatives, and document the consensus or resolution reached for each decision. This promotes effective teamwork and ensures that everyone is aligned with the project's design direction.

The log facilitates risk management by capturing the thought process and considerations behind design decisions. It helps identify potential risks and their associated decisions, enabling proactive risk mitigation strategies and minimizing the likelihood of costly or unintended consequences. In summary, a design decision log is a valuable tool for documenting, organizing, and communicating design decisions. It promotes transparency, knowledge management, and accountability while facilitating collaboration and risk management. By using a design decision log, project teams can enhance their efficiency, maintain consistency, and leverage valuable insights for future projects.

B. Decision Matrix/Staff Recommendations

The matrix elements that staff wanted to be included in the Prioritization Mitigation Action Plan for the Dry Creek Master Plan deliverables are presented below:

- Life Safety
- Social Impacts
  - This would be an aggregate of four of the criteria that were presented in your original matrix (economic impacts, recreational opportunities, community impacts, educational opportunities).
- Ability to Implement
  - Property acquisition
  - Federal Lands
  - Railroad Requirements
  - Etc.
- Protect Property
  - Both Public and Private
- Infrastructure Resilience
  - Long Term Viability
  - Maintenance
- Efficiency and Cost
  - BCA
- Protection of Critical Facilities
  - Interstate 80
  - Interstate 25
  - UPRR Tracks
  - BOPU Water Treatment Facility
- Environmental Resources
  - Aquatic Species

The Decision/Design log used for the plan update is shown in **Table 9**.

Dry Creek Drainage Masterplan Update - Design/Decision Matrix

Project Area / Weight	Potential Positive Drainage Impact to Corridor	Social Impacts Potential Positive Economic Impact Recreational Opportunities Educational Opportunities	Ability to Implement Including Potential Property Acquisitions Permitting	Address Property Damage Risk	Infrastructure Resilience	Possible Grant Funding Opportunity Cost-Effective	Environmental Resources	Protection of Critical Facilities Interstate Crossings UPRR Tracks BOPU Facility	Address Life-Safety Issues	Score
	1.00	1.00	1.25	1.50	1.50	1.50	1.00	1.00	2.00	X times weight
1. Warren Air Force Base										
- Creating a pond in the South Fork Headwaters adds positive impact further down stream	X	X	X	X	X	X	X	X		9.75
- Creates aesthetics/recreational opportunity for Air Force Base Personnel										
- Address emergency spillway for North Fork detention pond	X			X	X			X		4.5
2. McCormick Jr. High School										
- Add postive drainage impact/creek functionality to the main stem of Dry Creek	X	X	X		X		X			5.75
- Creates and opportunity for ecological education, around redesigned downstream pond	X	X	X		X		X			5.75
- Place campus east-side drainage channel into a storm sewer			X		X					2.75
3. Education Drive										
- Reduce overtopping of Education Drive	X		X	X	X	X			X	8.75
- Investigate potantial for directing overtopping to Westgate pond rather than Carlson Street										
4. Westgate Pond/Gateway Dr.										
- Repair Westgate Pond Dam and Outlet Works	X		X	X	X		X		X	8.25
- Eliminate piping and overtopping of Gateway Dr.	X		X	X	X	X			X	8.75
5. Yellowstone Downstream Channel										
- Potential channel restoration to address deposition and low flow capacity issues	X	X	X		X		X			5.75
6. Sunset Crossing										
- Reduce overtopping of Sunset crossing (***presently being addressed by local Developer***)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
7. Melton Street Storm Sewer										
- Address floodwaters on Melton upstream of Seminoe crossing	X		X	X	X					5.25
8. Sunset Downstream Channel										
- Realign channel along historic meanders/increase flood capacity for larger events	X	X			X		X			4.50
9. Seminoe Crossing										
- Reduce overtopping of Seminoe crossing	X		X	X	X	X			X	8.75
10. Mylar Park										
- Increase detention storage in the park	X	X	X	X	X	X	X		X	10.75
- Provides aesthetic/recreational improvements to the project site and downstream channel	X	X	X		X		X			5.75
- Creates and opportunity for ecological education, around the pond										
11. Prairie Ave. Crossing										
- Eliminate hazardous life-safety road overtopping condition	X		X	X	X	X			X	8.75
12. Powderhouse Corridor Drainageway										
- Water Quality and minor storage increase/coordination with Rotary	X	X	X	X	X	X	X			7.75
- Provides recreational improvements to the project site and adjacent Cheyenne Greenway										
- Reduction of floodplain extents										
- Creates and opportunity for ecological education, around the drainageway										
13. Powderhouse Rd. Crossing										
- Eliminate overtopping of Powderhouse Rd. crossing	X	X	X	X	X	X			X	9.75
- Install slotted drains in Powderhouse Rd. crossing	X	X	X		X					4.75
14. Powderhouse to Carey Reservoir Reach										
- Improves capacity into Carey Reservoir	X	X	X	X	X		X			7.25
15. Carey Reservoir Inlet Reconfiguration										
- Decreases Peak Discharges to Sheridan Street Reach	X	X	X	X	X	X			X	9.75
16. Sheridan Reach Flood Control Project										
- Re-align main channel of Dry Creek through Flood Control Alignment and away from Sheridan Street	X	X	X	X	X		X			7.25

Project Area / Weight	Potential Positive Drainage Impact to Corridor	Social Impacts Potential Positive Economic Impact Recreational Opportunities Educational Opportunities	Ability to Implement Including Potential Property Acquisitions Permitting	Address Property Damage Risk	Infrastructure Resilience	Possible Grant Funding Opportunity Cost-Effective	Environmental Resources	Protection of Critical Facilities Interstate Crossings UPRR Tracks BOPU Facility	Address Life-Safety Issues	Score
	1.00	1.00	1.25	1.50	1.50	1.50	1.00	1.00	2.00	X times weight
17. Sheridan Street Capacity Improvements										
- Increase low flow and flood capacities and reduce potential for bank erosion and scour	X	X	X	X	X		X			7.25
- Provides aesthetic improvements to the channel										
18. Moutain Rd. Crossing										
- Reduce overtopping of Mountain Rd. crossing	X		X	X	X				X	7.25
19. Hilltop ave. Crossing										
- Reduce overtopping of Hilltop Ave. crossing and eliminate floodplain north side of Sheridan Street	X	X	X	X	X	X			X	9.75
20. South Cahill Park Recreation Area										
- Provides recreational improvements to the project site	X	X	X							3.75
- Provides recreational/music venue destination to the Cheyenne community										
- Begins to activate an area that may not be used frequently, other than pedestrian connectivity										
21. Sheridan Reach Flood Control Outlet										
- Potential off-line storage	X			X	X					4.00
22. Reach Upstream of College Dr.										
- Increase low flow and flood capacities/reduce excess vegetation	X	X	X	X	X		X			7.25
23. Rawlins Street Crossing										
- Address hazardous life-safety road overtopping condition	X			X	X				X	6.00
24. Dry Creek Disc Golf Course										
- Provides recreational improvements to the project site	X	X	X		X		X			5.75
- Provides a positive community impact to the homes in the immediate area - Clean-up of the area										
25. U.S. 30 to E. Pershing Blvd. Reach										
- Property acquisitions and widening of channel/elimination of levee	X		X	X	X		X	X		7.25
26. E. Pershing Blvd. Crossing										
- Address split flow condition with main stem flow	X			X	X					4.00
- Reduce overtopping of E. Pershing Blvd. crossing	X	X		X	X					4.00
27. Lower Dry Creek/UPRR Sump - Kiwanis Park										
- Reconfiguration of storage/coordination with Wyoming SEO	X	X	X	X	X	X	X	X	X	11.75
28. Lower Dry Creek Drainageway										
- Drainage opportunities on LCCD area/coordination with LCCD and and local Audubon Society	X	X	X		X	X	X			7.25
29. Upper Campstool Rd. Crossing										
- Investigating relocating low spot/reducing roadway overtopping	X		X	X	X					5.25
30. Upper Campstool Rd. to I-80 Reach										
- Drainage opportunities on LCCD area/coordination with LCCD and and local Audubon Society	X	X	X		X		X			5.75
31. I-80 Crossing										
- Address remaining overtopping condition/Modleing issue	X	X			X	X		X	X	8.00
32. Lower Campstool Rd. Crossing										
- Address hazardous life-safety road overtopping condition	X		X		X				X	5.75
33. Debris Blockage Evaluation/Policy										
- Investigating potential for debris blockage of crossings and setting design criteria	X	X	X	X	X					6.25
- Recommendations for mitigative measures at select crossings	X	X	X	X	X	X				7.75
34. Revised Drainage Policy										
- Recommendations for policy measures to reduce overland flooding	X		X	X	X			X		6.25

Project Area / Weight	Potential Positive Drainage Impact to Corridor	Social Impacts Potential Positive Economic Impact Recreational Opportunities Educational Opportunities	Ability to Implement Including Potential Property Acquisitions Permitting	Address Property Damage Risk	Infrastructure Resilience	Possible Grant Funding Opportunity Cost-Effective	Environmental Resources	Protection of Critical Facilities Interstate Crossings UPRR Tracks BOPU Facility	Address Life-Safety Issues	Score
Weight	1.00	1.00	1.25	1.50	1.50	1.50	1.00	1.00	2.00	X times weight
35. Pine Ridge slotted inlets & storm sewer Improvements										
- Reduce overtopping of Sheridan Reach along with potential back scour & erosion of channel	X		X	X	X					5.25
36. Property acquisitions along Rock Springs Street and Cleveland Ave.										
- Reduce flooding & increase flooplain overbank area	X		X	X	X	X				6.25
37. Property acquisitions along east side Pierce Ave. and northern end of Parsons Pl.										
- Reduce flooding & increase flooplain overbank area	X		X	X	X	X			X	6.25
38. Add additional storm inlets & sewer for Western Hills Blvd. west of Education Dr.										
- Reduce overtopping of Western Hills Blvd. & directly convey runoff to new storm sewer	X		X	X	X					5.25
39. Add additional storm inlets & sewer for Prairie Ave. west of Frontier Dr.										
- Reduce overtopping of Prairie Ave.. & roadway flooding of Frontier Dr.	X		X	X	X					5.25
40. Modify Walmart outlet structure to reduce overtopping onto Dell Range Blvd.										
- Reduce roadway flooding of Dell Range Blvd. & potential flood damage to adjacent property	X		X	X	X					5.25
41. Add additional storm inlets & sewer for McCann Ave.										
- Reduce roadway flooding of McCann Ave.	X		X	X	X					5.25
42. Increase upstream detention storage for Cheyenne Street										
- Reduce overtopping of Polk Ave.	X		X	X	X				X	7.25
43. Adoption of a Storm Water Utility										
- Adoption of a Storm Water Utility to fund annual maintenance and a CIP list for the Basin	X		X	X	X		X	X	X	9.25

C. Preliminary Cost Estimates and Potential Grant Opportunities

Table 10. Preliminary Costs for Conceptual Alternatives			
Proposed Project	**Project Description**	**Estimated Cost**	**BCR**
FEW Detention Storage/Wetlands	This a new storage facility including wetlands for the South Fork headwaters	$4,080,000	6.44
Education Dr./Westgate Improvements	Expansion of Westgate Pond & Outlet Works Improvements & Conveyance Directed into Pond	$2,069,009*	0.66
McCormick Channel Restoration	Restoration of Creek Channel/Expansion of Pond/Conversion of Open Ditch to Storm Sewer	$3,763,720*	N/A
Melton Street Storm Sewer	Minor Storm Sewer	$500,000	3.57
Mylar Park Improvements	Expansion of Pond for Additional Storage with Downstream Channel Improvements	$4,594,652	N/A
Powderhouse Reach Improvements	Creek Restoration including Greenway & Wetlands Improvements	$1,495,652	N/A
Powderhouse to Carey Reach Improvements	Creek Restoration & Lowering of Grade for Increased Capacities	$5,069,020	0.34
Sheridan Street Reach Improvements	Creek Restoration Improvements	$3,035,677	0.32
Rawlins Street Reach Improvements	Property Acquisitions & Floodplain Expansion	$850,000*	0.37
U.S. 30 to E. Pershing Blvd. Reach Improvements	Property Acquisitions & Floodplain/Wetlands Expansion	$3,316,700*	1.71
E. Pershing Blvd. to UPRR Reach	Property Acquisitions & Detention Storage Reconfiguration/Expansion of Wetlands	$6,357,028*	3.05

Table 10. Preliminary Costs for Conceptual Alternatives

As shown in **Table 10**, the conceptual proposals for FEW detention storage, the minor storm sewer for Melton Street west of Seminoe Rd., the U.S. 30 to E. Pershing Blvd. reach improvements, and the improvements to the Union Pacific impoundment area all appear cost effective. The preliminary Benefit-Cost Analysis (BCA) for the Education Dr./Westgate improvements does not include impact from flooding of Education Dr. and Carlson Street nor overtopping of Gateway Dr. the three combined would completely isolate the Westgate subdivision until floodwaters receded including emergency response. The corresponding ADT for Education Dr. is 3,338 and for Carlson Street is 3,400 vehicles per day. While detour times would only amount to 5- or 10-minutes, factoring this information into the BCA might produce an eligible BCR for this project.

The Sheridan Street reach analysis does not factor in overtopping Mountain Road, Hilltop Ave., or Dell Range Blvd. The ADT for Dell Range Blvd. is 19,134 vehicles per day. The detour times would be sufficiently long to justify thinking that this project may have an eligible BCR. The cost data for the conceptual alternatives is attached on a thumb drive to this report.

The trail connections, frisbee golf course improvements, and amphitheaters are recommended as complimentary features to enhance the Greater Cheyenne Greenway and City Parks experience for residents.

VIII. PLAN DEVELOPMENT/PRELIMINARY DESIGN ALTERNATIVES DEVELOPMENT

A. Plan Summaries

This section summarizes the development of preliminary design alternatives for flood control and improvement of creek function. The conceptual mitigation measures and creek restoration projects were discussed with staff and presented to the stakeholder group. Like the 1988 approach, the basin was divided into smaller reaches with each reach then evaluated for drainage issues, impairment of natural creek function, long-term maintenance issues, park and greenway improvements, structural deficiencies, and potential outside funding sources.

There were thirty-five high life-safety hazard areas identified in the 1988 report. The major features of the 1988 selected plan included improved roadway crossings along the study reach; storm sewer along Evers Blvd. (North Fork Dry Creek); detention storage for the headwaters South Fork, Powderhouse, and between Upper Campstool Rd. and the UPRR. Of the thirty-five high life-safety hazard areas, twenty-one referenced roadway crossings. The 1988 selected plan had thirty-one recommended projects, seventeen of which were roadway crossing improvements. In 2023, There remain areas of concern and life-safety issues along the drainage. There are 11 roadway crossings overtopped by floodwaters in the updated model, five of which can be considered life-safety hazards, Gateway Dr., Seminoe Rd., Prairie Ave., Hilltop Ave., and the Rawlins Street crossing.

The 2023 plan development includes forty-three structural and nonstructural mitigation measures. Our structural measures include the following:

1. enhanced/expanded storage in key locations to attenuate and reduce peak discharge at design points along the study reach, reducing the size of required conveyance elements.
2. improve and enhance the existing conveyance in the study area and provide new conveyance elements where appropriate.
3. and creek restoration projects to reduce annual maintenance costs and complement greenway and park amenities.

Our nonstructural measures include a revised Debris blockage policy and an update to the city's Storm Drainage Criteria and specifically the 2014 UDC Article 3, Section 3.2 – Drainage Impact Studies. We are recommending consideration for adoption of a stormwater utility to help fund annual maintenance and a CIP list for Basin improvements. **Table 9** lists the 43 recommended structural and nonstructural recommendations along with their respective scores in the Design/Decision Matrix developed with guidance and assistance from city staff.

Our structural recommendations include detention storage/wetlands for the Headwaters of the South Fork Dry Creek, expanded storage/wetlands for the Westgate Pond, expanded storage/wetlands for the Mylar Park Pond, minor storage increase with expanded wetlands for the Powderhouse reach, realignment of the main channel of Dry Creek through the Sheridan Reach Flood Control alignment – effectively reducing peak discharges through the Sheridan Street reach, property acquisition and expansion of overbank floodplain storage between U.S. 30 and E. Pershing Blvd., and reconfiguration of the UPRR sump including potential property acquisitions for expanded storage/wetlands. The seven storage/wetlands project recommendations in this study update provide benefits for the entire length of the Dry Creek channel from the Headwaters of South Fork to the Union Pacific embankment in the southeast end of the Basin. **Figures 71 through 92** show more detailed information for both storage projects and proposed creek restoration projects.

There are seven creek restoration projects recommended in this study. An eighth, the Lower Dry Creek channel adjacent to the Cheyenne BOPU's Dry Creek Wastewater Treatment Plant was discontinued when determined to be unnecessary for BOPU operations. There were four channel improvement recommendations from the 1988 plan including the recommendation for construction of the levied system between U.S. 30 and E. Pershing Blvd. The others included improvements to the Sheridan Street reach, the South Fork channel between Vista Ln. and Bishop Blvd., and the channel immediately upstream of N. College Dr. The levee was constructed by the county in the early 1990s. The other projects were not constructed and remain issues in 2023. The creek restoration projects from this study include the following recommendations:

- Restoration of the channel on the McCormick – Central campus including an expansion of existing wetlands at the downstream end.
- Restoration of the channel immediately downstream of the Yellowstone Rd. crossing.
- Restoration of the channel immediately downstream of the Sunset Dr. crossing to follow its historic meandering (property acquisition required).
- Restoration of the creek downstream of the Mylar Park Pond and between Prairie Ave. and Powderhouse Rd. in collaboration with the Cheyenne Rotary Club.
- Restoration of the creek between Powderhouse Rd. and Carey Reservoir to include a lowering of the grade to increase capacities.
- Restoration of Sheridan Street reach between Converse Ave. and Dell Range Blvd.
- Restoration of the reach immediately upstream of N. College Dr. to include dredging and removal of excess vegetation.

There are ten roadway crossing improvements recommended in this study, one of which is being addressed as a public/private partnership by a local developer (Sunset Dr. crossing). For two of these crossings, Rawlins Street and Lower Campstool Rd., we are recommending signage as an appropriate mitigative measure. As mentioned above, there are five crossings, Gateway Dr., Seminoe Rd., Prairie Ave., Hilltop Ave., and the Rawlins Street crossing that can be considered life-safety hazards. We are recommending the following mitigative actions for these crossings:

- Improvements to the Westgate outlet structure to address Gateway Dr. overtopping and an existing piping condition under the roadway.
- Consideration of a larger box culvert to replace the (2) existing 7-foot diameter CMP for the Seminoe crossing.
- Elimination of the Prairie Ave. crossing and creation of additional parking for the greenway and Mylar Park.
- Replacement of the existing Hilltop structure with a new multiple cell box including provision for a lower invert through one of the boxes for the reconstructed upstream low flow channel.
- Signage for the Rawlins Street crossing.

There are five minor storm sewer systems recommended for consideration by staff but without cost estimates. There are five locations along the channel where we are recommending consideration be given to property acquisitions for purposes of expanding storage, wetlands, and overbank floodplain. There are three recommendations for nonstructural mitigative measures including the revision of a debris blockage factor for hydraulic modeling, update of the city's storm drainage criteria, and the adoption of a storm water utility. There are three recreational recommendations to improve the overall quality of resident's experience along the channel and in the city's Park facilities. Two additional recommendations for collaboration with the LCCD on properties that they manage between the UPRR and I-80. There were two additional recommendations for crossing improvements that modeling has determined are not necessary.

B. Conceptual Project and Long-Term Maintenance Alternatives Refined

Table 2 shows the refined list of twenty-five projects and their respective priority ranking based on the Design/Decision matrix. Included in the refined list are the seven storage/wetlands projects, six crossing improvements, six creek restoration projects, two property acquisition projects, two nonstructural actions, realignment of Dry Creek through the Sheridan Reach Flood Control path, additional storage offline for the Cheyenne Street drainage, and Disc Golf Course improvements.

C. Adoption of Debris Blockage Policy

Refer to **Table 8** – Project Debris Conditions at Crossing Structures. This study proposes to remove and or reduce debris blockage factors in conjunction with channel maintenance/improvements and construction of debris racks at select crossing locations.

D. Cost Refinement for Flood Control and Creek Restoration Options

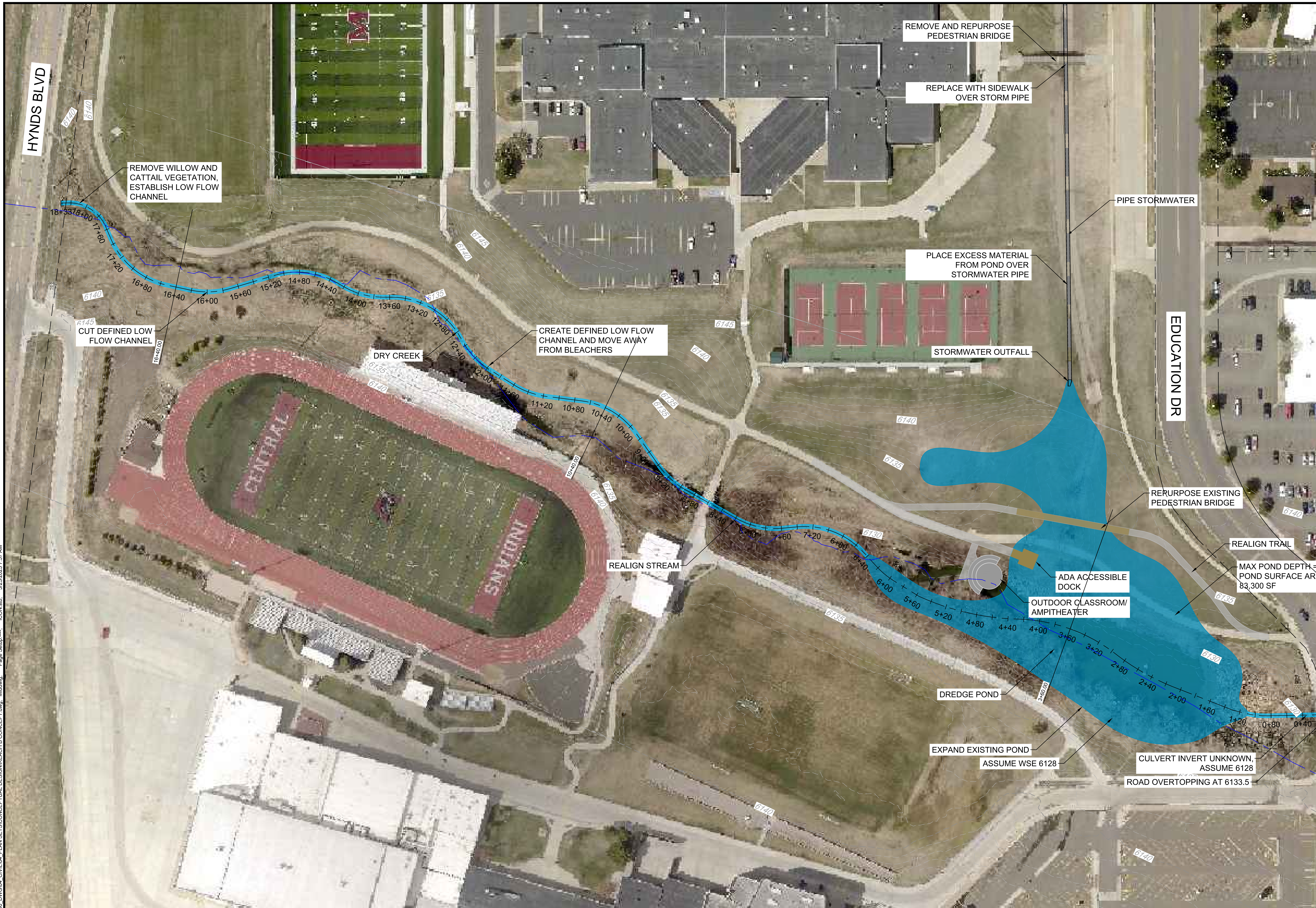
Table 11 shows the more detailed costs for five of the proposed creek restoration projects. Additional cost data is attached in a thumb drive to this report.

Table 11. Preliminary Costs for Creek Restoration Projects

Proposed Project	Project Description	Estimated Cost
McCormick Channel Restoration	Restoration of Creek Channel	$789,092
Downstream Yellowstone Reach Channel Improvements	Creek Restoration & Lowering of Grade for Increased Capacities	$1,169,229
Smalley Park Channel Restoration	Restoration of Creek Channel Relocating to Historic Meanders	$1,628,751
Powderhouse to Carey Reach Channel Improvements	Creek Restoration & Lowering of Grade for Increased Capacities	$4,579,437
Sheridan Street Reach Improvements	Creek Restoration Improvements	$3,031,391

Table 11. Costs for Channel Restoration Alternatives

PROJECT AREA | WARREN AIR FORCE BASE



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0 60' 120'

DESCRIPTION:

REALIGN AND GRADE IN POOL-RIFFLE CHANNEL. EXPAND EXISTING POND TO THE NORTHWEST AND INCORPORATE OUTDOOR CLASSROOM AREA AND DOCK. REMOVE EXISTING DRAINAGE PAN AND PIPE STORMWATER ALLOWING IT TO OUTFALL INTO THE POND. REPURPOSE EXISTING PEDESTRIAN BRIDGE SO IT CROSSES THE EXPANDED POND.

GOALS:

1. REDUCE SEDIMENTATION
2. ENHANCE STREAM CHANNEL
3. INCREASE STORAGE CAPACITY OF POND
4. PROVIDE ACCESS AND EDUCATION OPPORTUNITIES
5. INCREASE SANITARY SEWER MAINTENANCE ACCESS

POND STORAGE:

POND STORAGE = SA * ΔELEV
POND STORAGE = 83,241SF * 5 FT
POND STORAGE = 416,205 CF
POND STORAGE = 9.55 AC-FT

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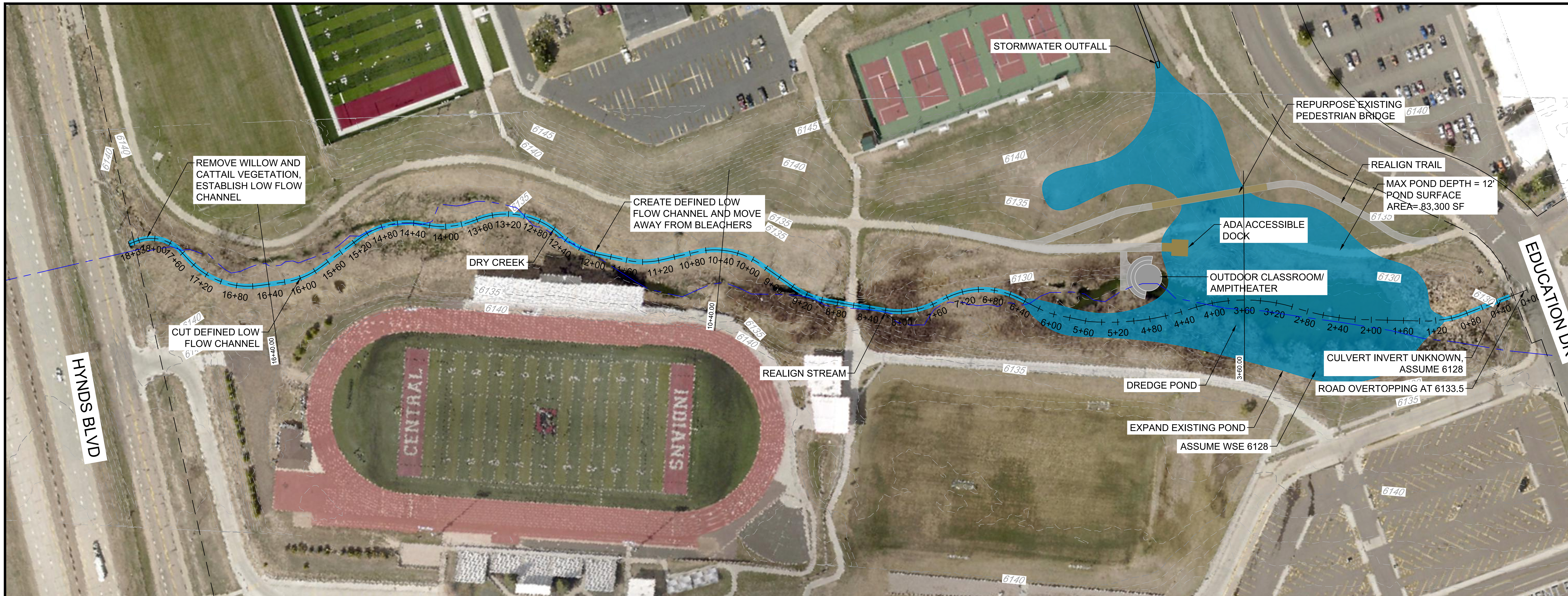

DESCRIPTION:

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GOALS:

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2. ENHANCE STREAM CHANNEL
3. INCREASE STORAGE CAPACITY OF POND
4. PROVIDE ACCESS AND EDUCATION OPPORTUNITIES
5. INCREASE SANITARY SEWER MAINTENANCE ACCESS

POND STORAGE:

POND STORAGE = SA * ΔELEV
POND STORAGE = 83,241SF * 5 FT
POND STORAGE = 416,205 CF
POND STORAGE = 9.55 AC-FT

PROFILE OF ALIGNMENT - CP-REACH B
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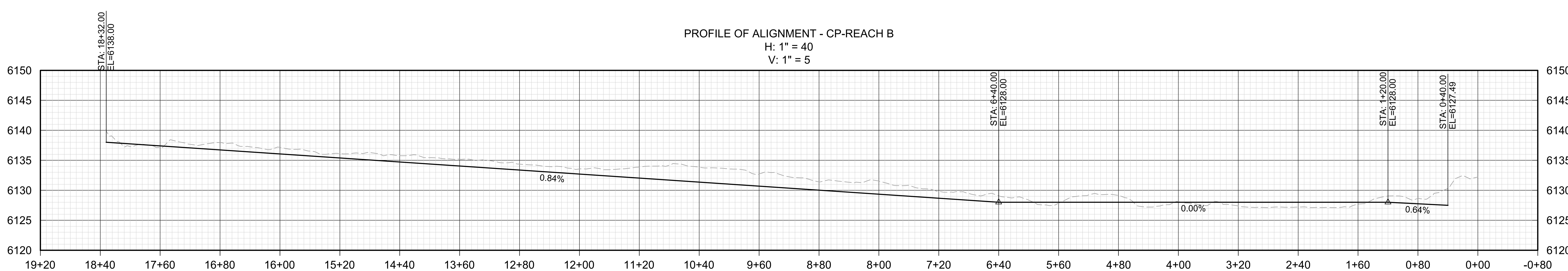
V: 1" = 5



SLOPE INCREASES FROM 0.6% TO 0.84%

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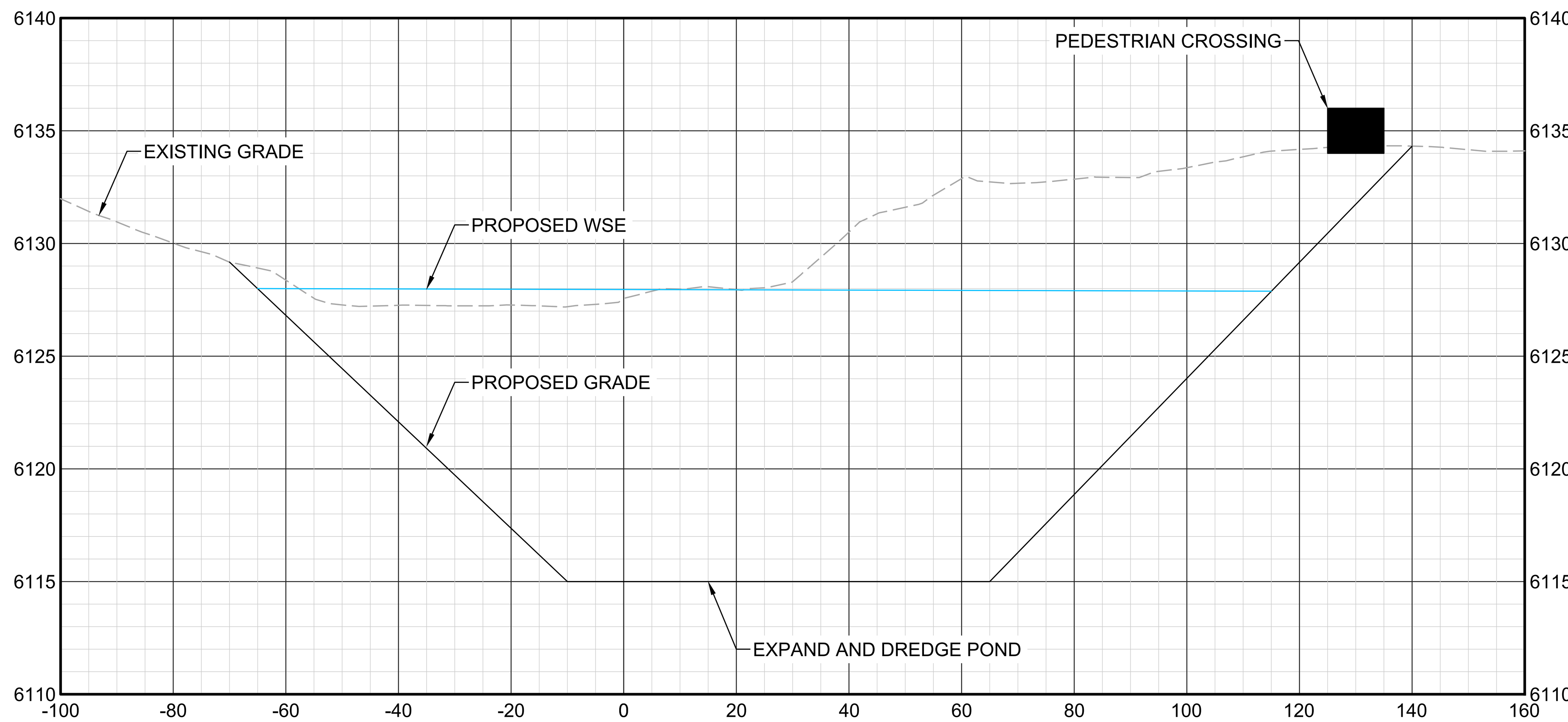

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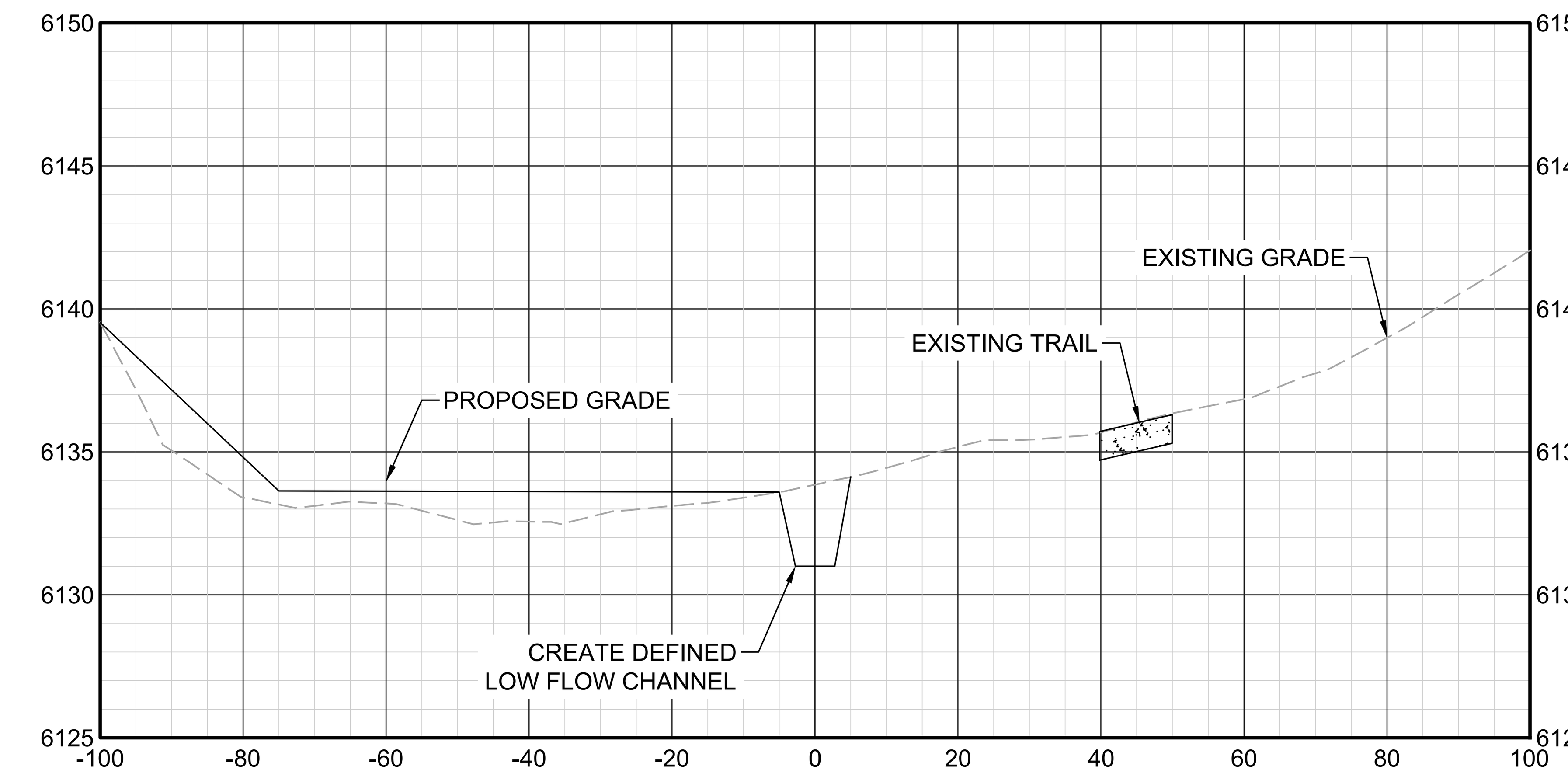

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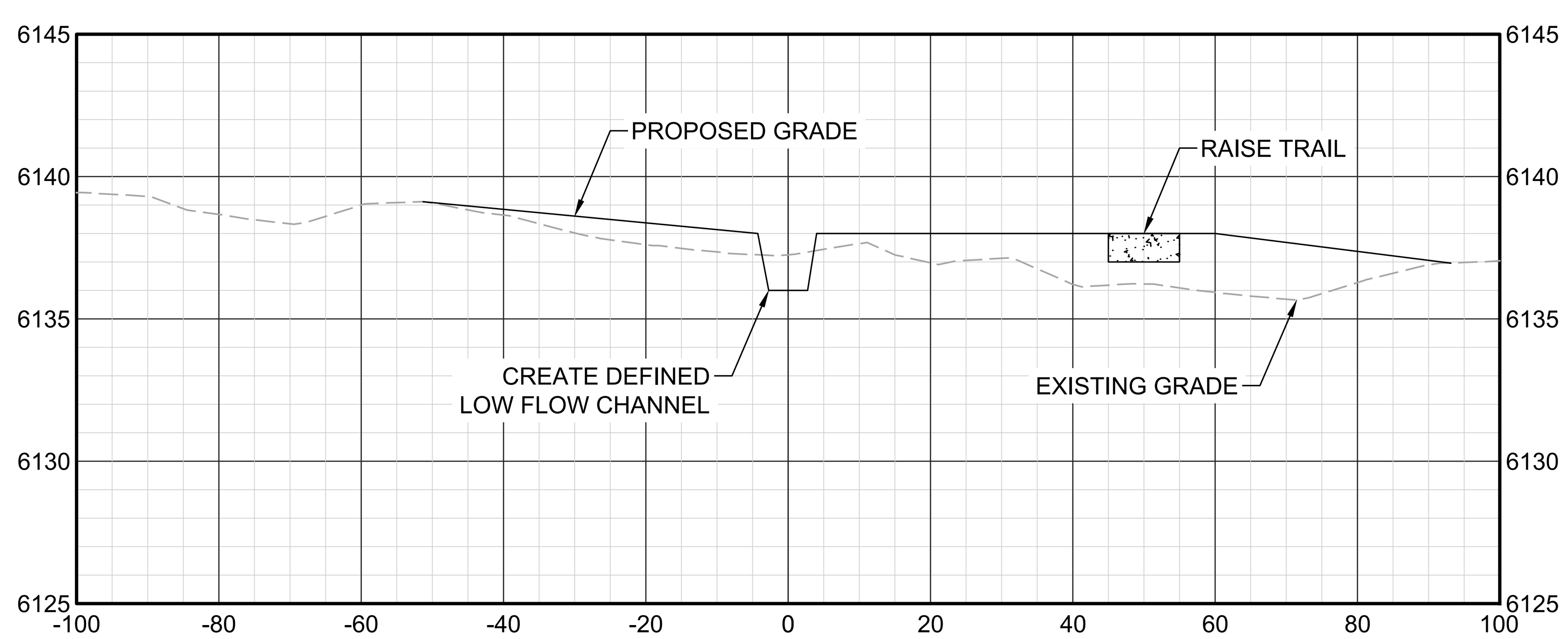

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0 20' 40'

DESCRIPTION:

REALIGN AND GRADE IN POOL-RIFFLE CHANNEL. EXPAND EXISTING POND TO THE NORTHWEST AND INCORPORATE OUTDOOR CLASSROOM AREA AND DOCK. REMOVE EXISTING DRAINAGE PAN AND PIPE STORMWATER ALLOWING IT TO OUTFALL INTO THE POND. REPURPOSE EXISTING PEDESTRIAN BRIDGE SO IT CROSSES THE EXPANDED POND.

GOALS:

1. REDUCE SEDIMENTATION
2. ENHANCE STREAM CHANNEL
3. INCREASE STORAGE CAPACITY OF POND
4. PROVIDE ACCESS AND EDUCATION OPPORTUNITIES
5. INCREASE SANITARY SEWER MAINTENANCE ACCESS

POND STORAGE:

POND STORAGE = SA * ΔELEV
POND STORAGE = 83,241SF * 5 FT
POND STORAGE = 416,205 CF
POND STORAGE = 9.55 AC-FT

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PROJECT AREA | McCORMICK JR. HIGH SCHOOL

CITY OF CHEYENNE
GLM Design Group
DHM DESIGN

N

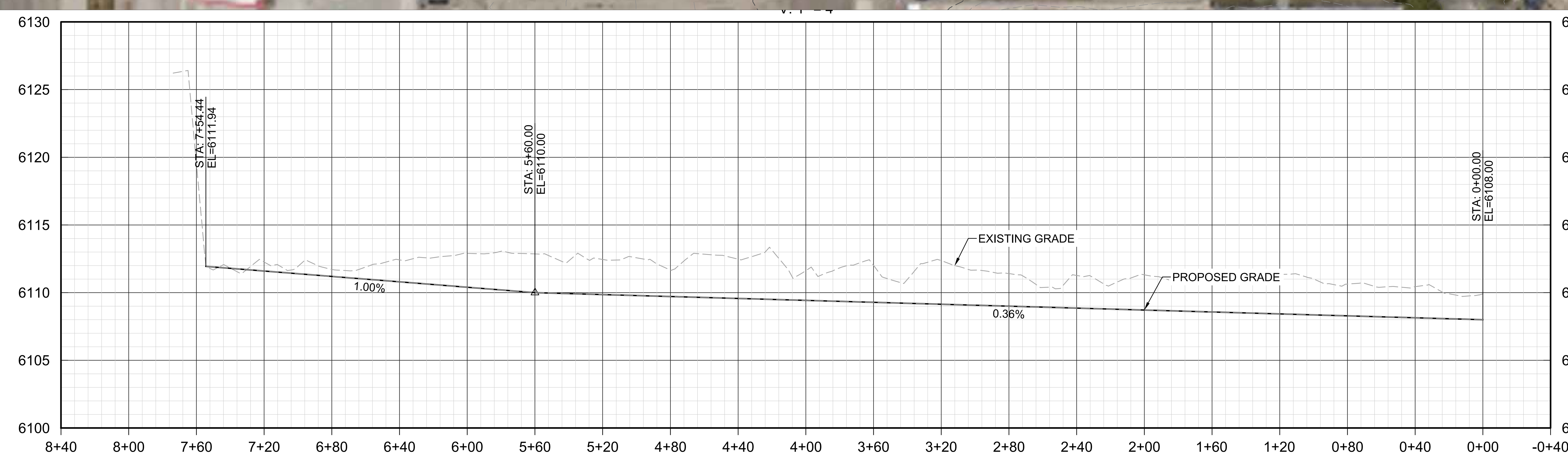
0 30' 60'

DESCRIPTION:

SOFTEN THE ALIGNMENT OF THE CHANNEL AND GRADE IN A MORE NARROW, DEEPER CHANNEL TO FACILITATE SEDIMENT TRANSPORT AND PREVENT CATTAIL GROWTH. RELOCATE SANITARY SEWER LINE SO MANHOLES ARE ACCESSIBLE FROM TRAIL

GOALS:

1. REDUCE SEDIMENTATION
2. ENHANCE STREAM CHANNEL
3. INCREASE SANITARY SEWER ACCESS



CHANNEL SLOPE INCREASES FROM 0.29% TO 0.52%

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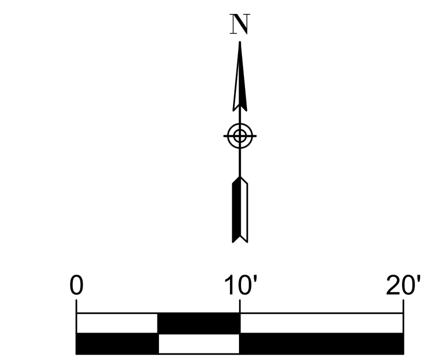
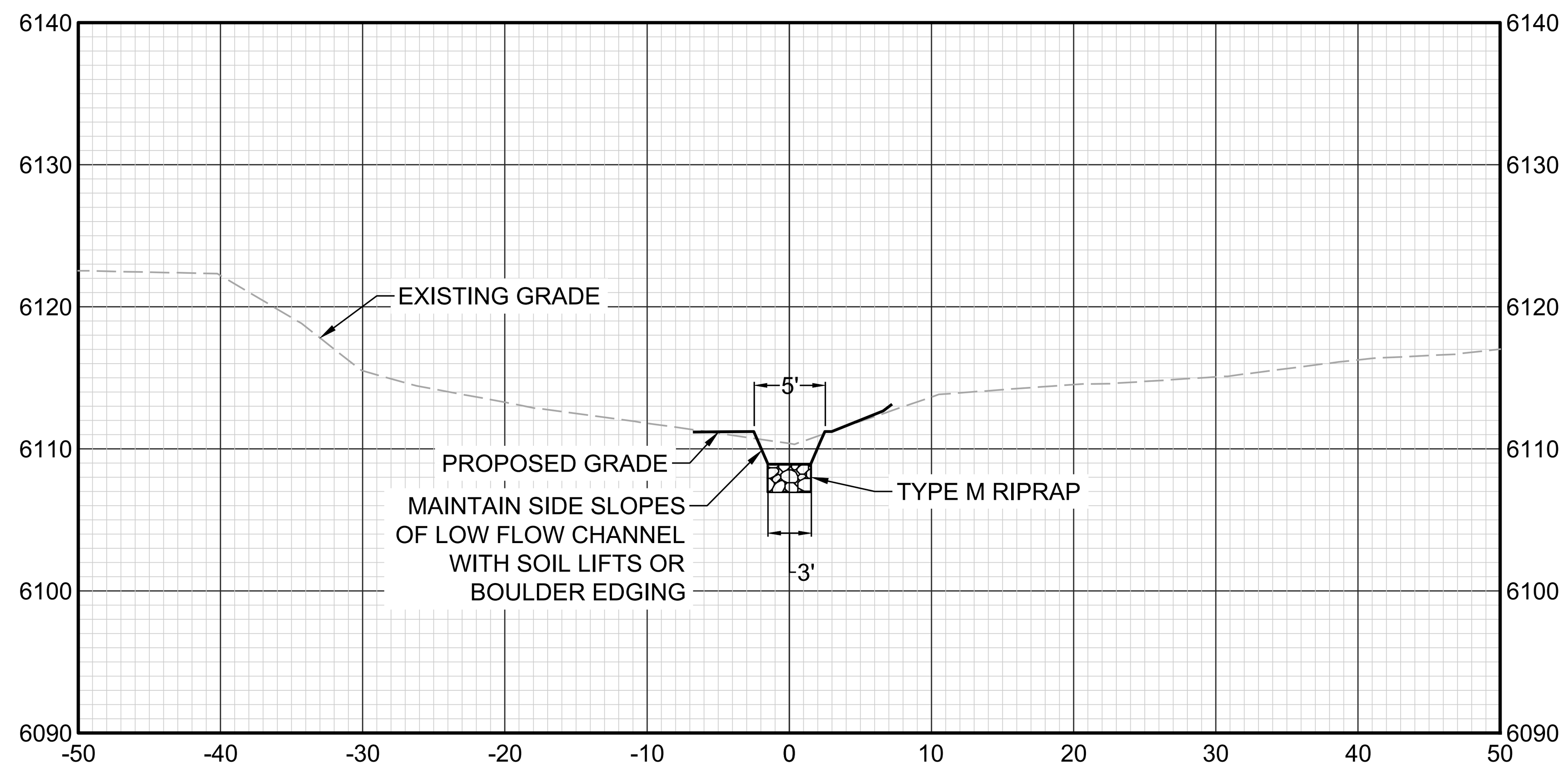


DESCRIPTION:

SOFTEN THE ALIGNMENT OF THE CHANNEL AND GRADE IN A MORE NARROW, DEEPER CHANNEL TO FACILITATE SEDIMENT TRANSPORT AND PREVENT CATTAIL GROWTH. RELOCATE SANITARY SEWER LINE SO MANHOLES ARE ACCESSIBLE FROM TRAIL

GOALS:

1. REDUCE SEDIMENTATION
2. ENHANCE STREAM CHANNEL
3. INCREASE SANITARY SEWER ACCESS



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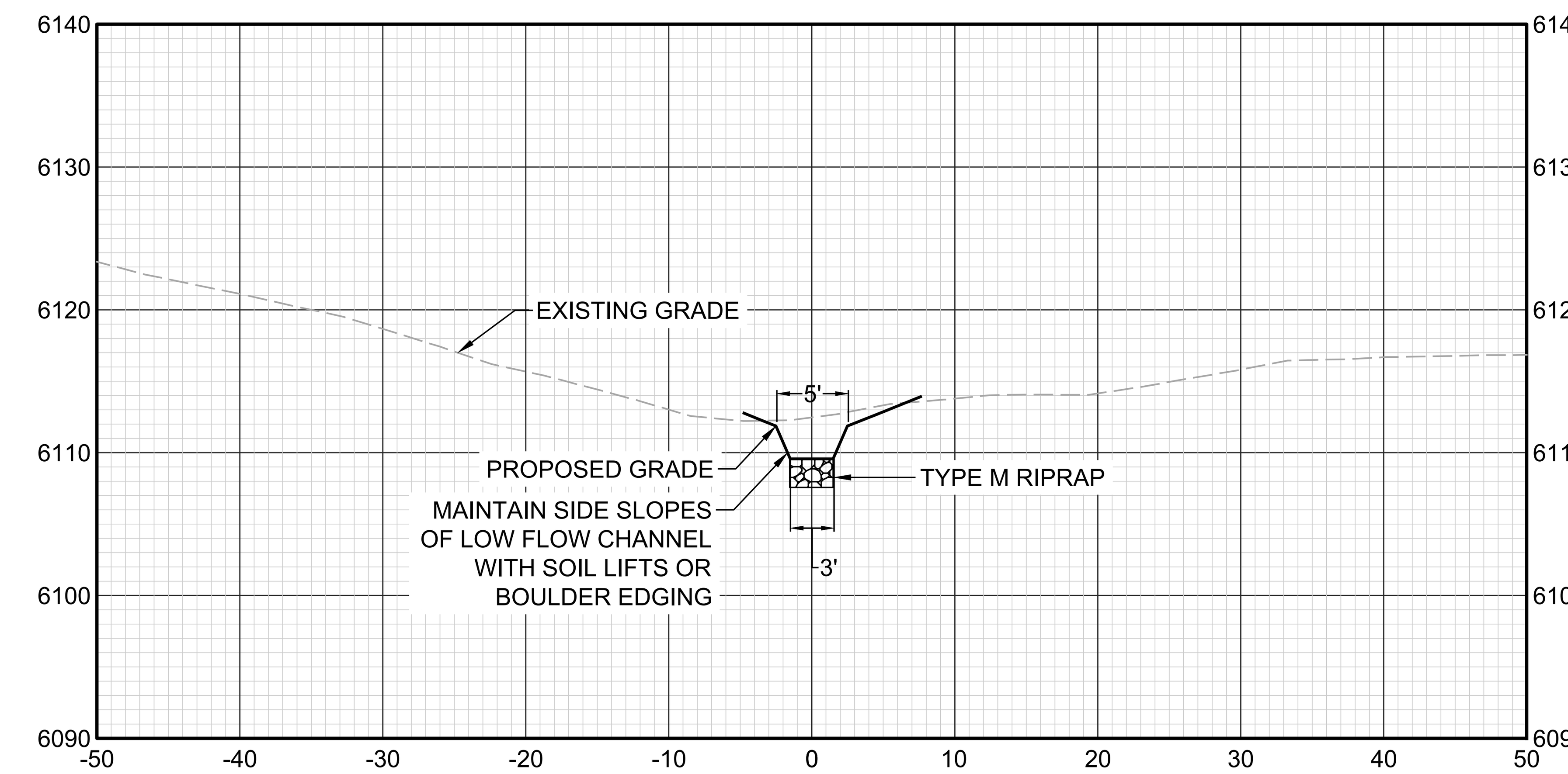

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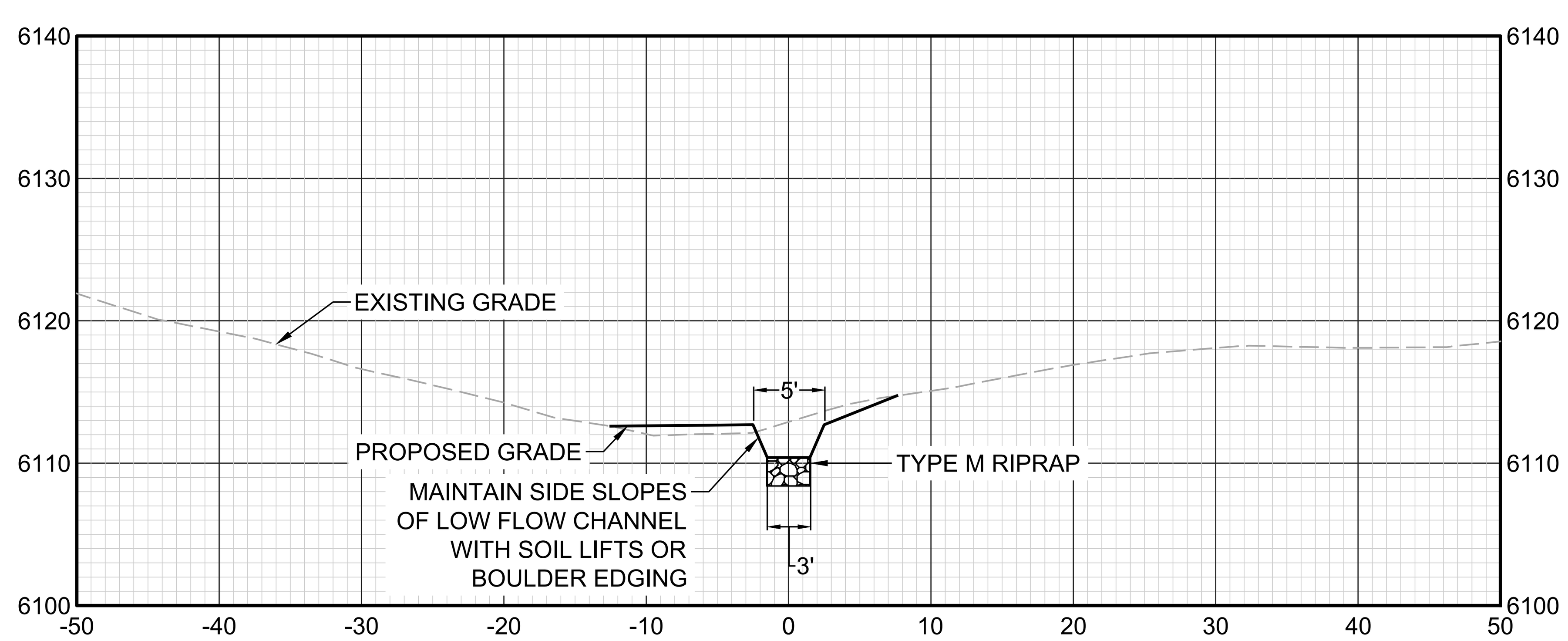

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SOIL LIFTS

BOULDER EDGING

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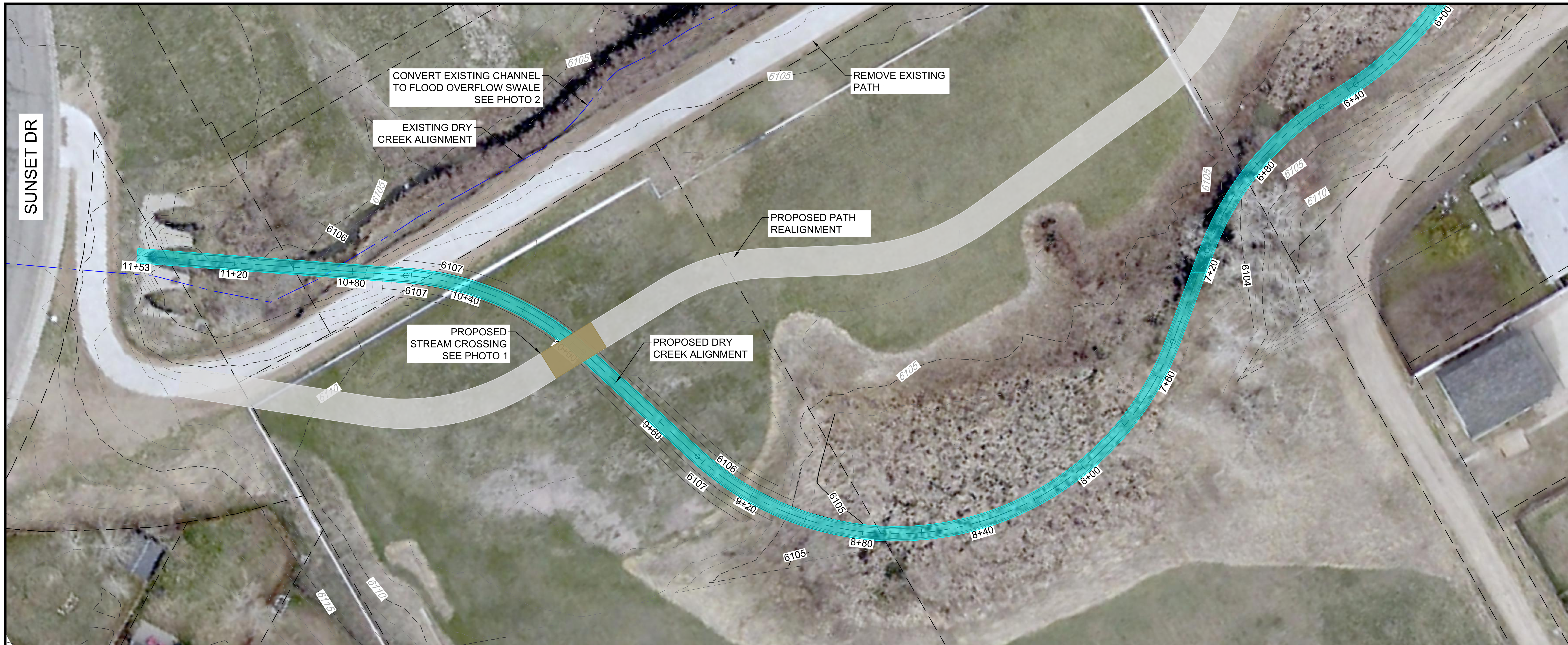

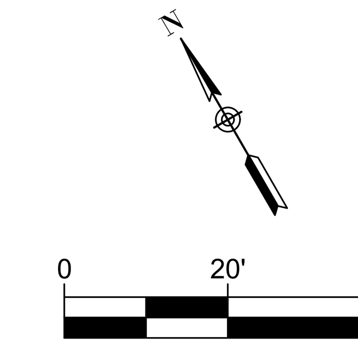


PHOTO 1: PEDESTRIAN BRIDGE


PHOTO 2: OVERFLOW SWALE

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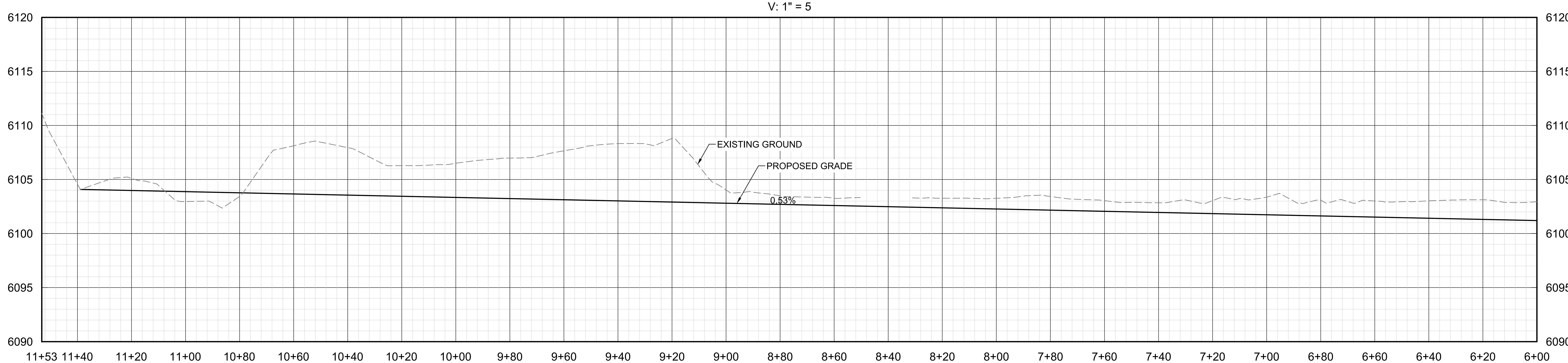
V: 1" = 5



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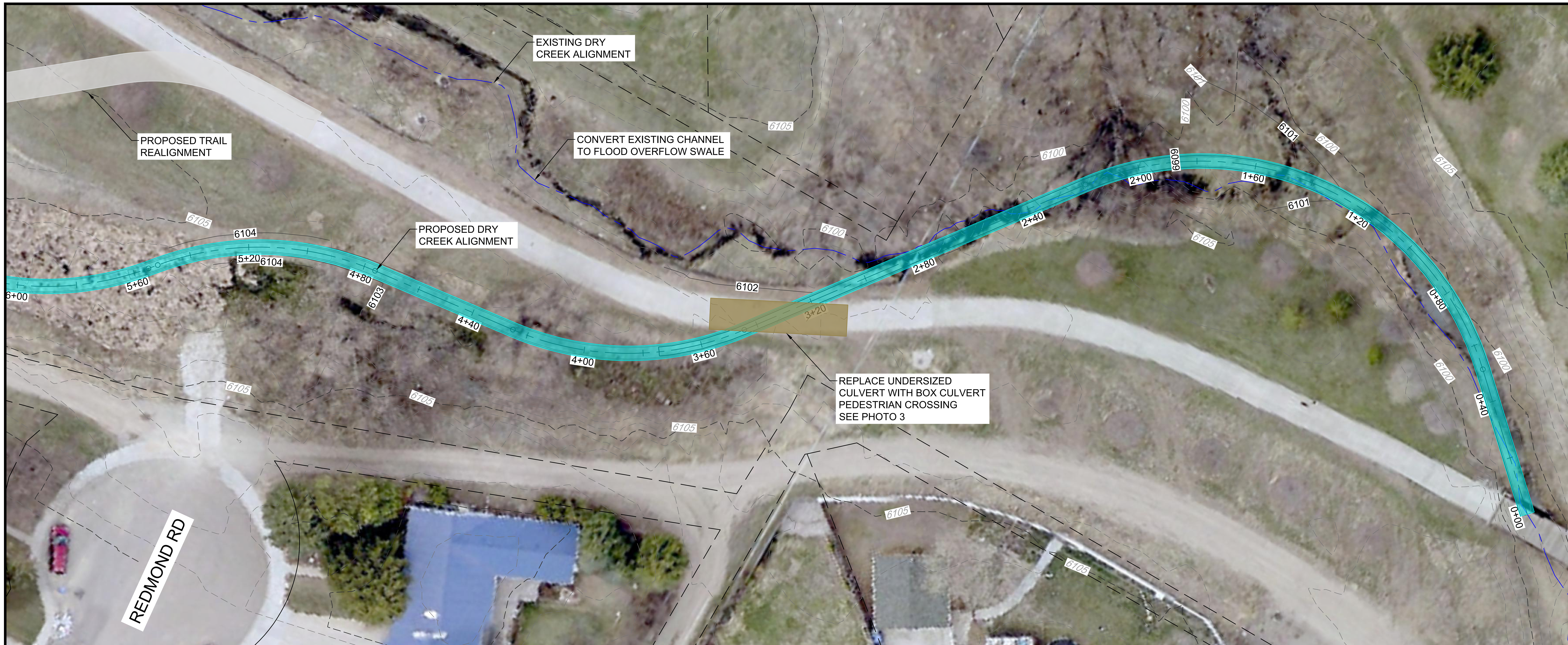

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0 20' 40'

PHOTO 3: BOX CULVERT

PROFILE OF ALIGNMENT - REACH E CONCEPT
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V: 1" = 5

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DATE
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7 OF 21

N

0 70' 140'

DESCRIPTION:

EXPAND THE FOOTPRINT OF THE EXISTING POND AND CREATE A SECONDARY POND TO THE NORTHWEST. SOFTEN THE ALIGNMENT OF THE CHANNEL AND GRADE IN A MORE NARROW, DEEPER CHANNEL TO FACILITATE SEDIMENT TRANSPORT AND PREVENT CATTAIL GROWTH. REALIGN THE PATH TO CREATE A LOOP AROUND THE EXISTING POND.

GOALS:

1. REDUCE SEDIMENTATION
2. ENHANCE STREAM CHANNEL
3. INCREASE STORMWATER DETENTION CAPACITY

POND STORAGE - NORTH:

POND STORAGE = SA * ΔELEV
POND STORAGE = 42,740 SF * 4 FT
POND STORAGE = 170,960 CF
POND STORAGE = 3.92 AC-FT

POND STORAGE - SOUTH:

POND STORAGE = SA * ΔELEV
POND STORAGE = 111,188 SF * 5FT
POND STORAGE = 555940 CF
POND STORAGE = 12.76 AC-FT

TOTAL STORAGE = 16.68 AC-FT

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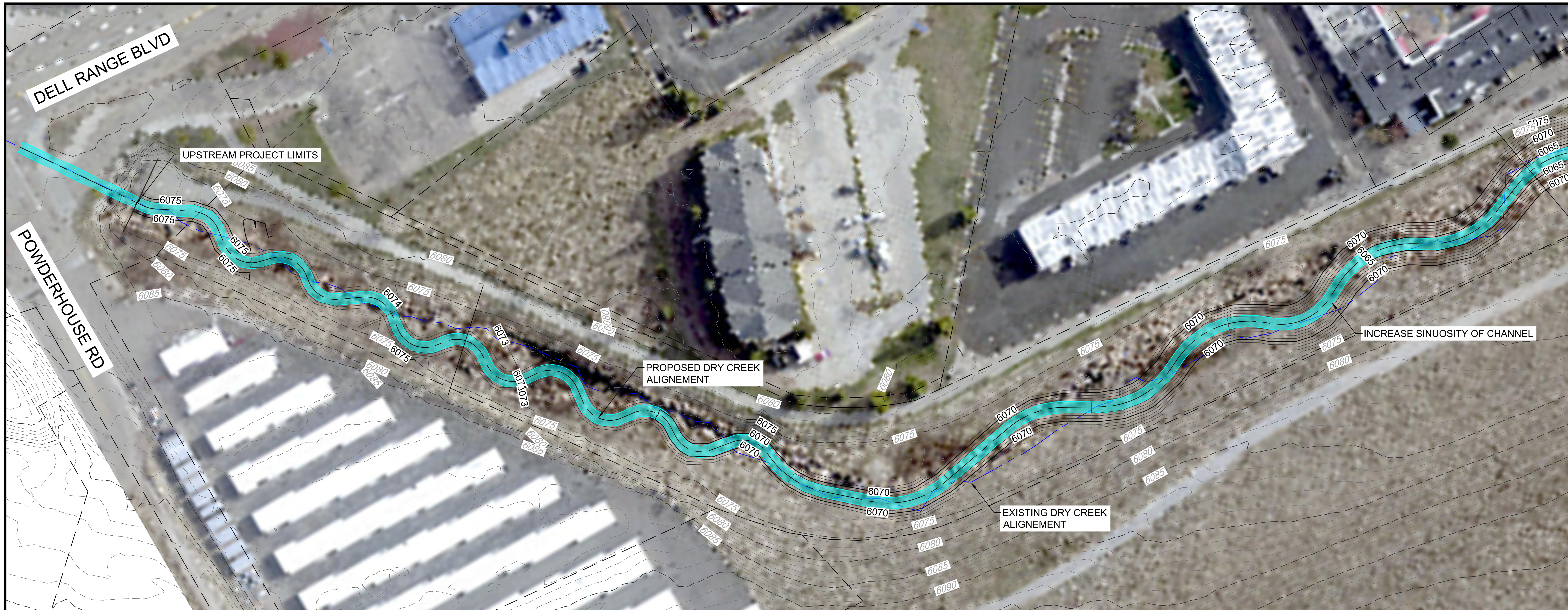
8 OF 21

PROJECT AREA | MYLAR PARK

CITY OF CHEYENNE
GLM Design Group
DHM DESIGN

PROJECT AREA | POWDERHOUSE CORRIDOR DRAINAGEWAY



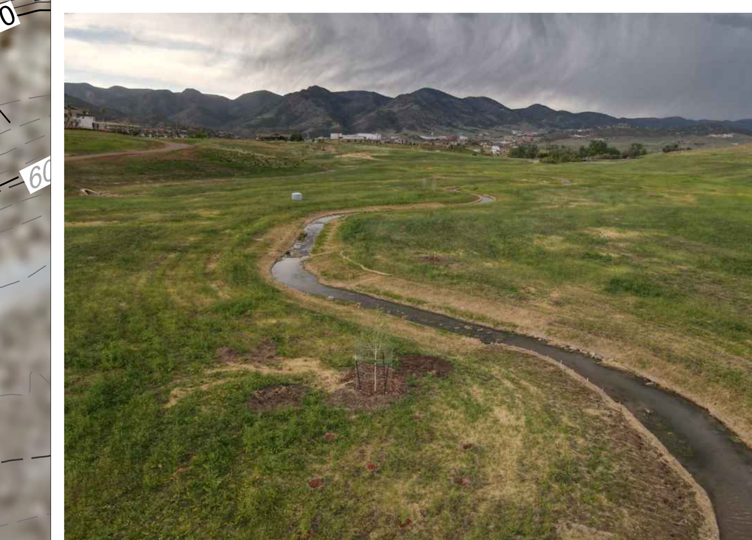


PHOTO 1: POOL RIFFLE CHANNEL

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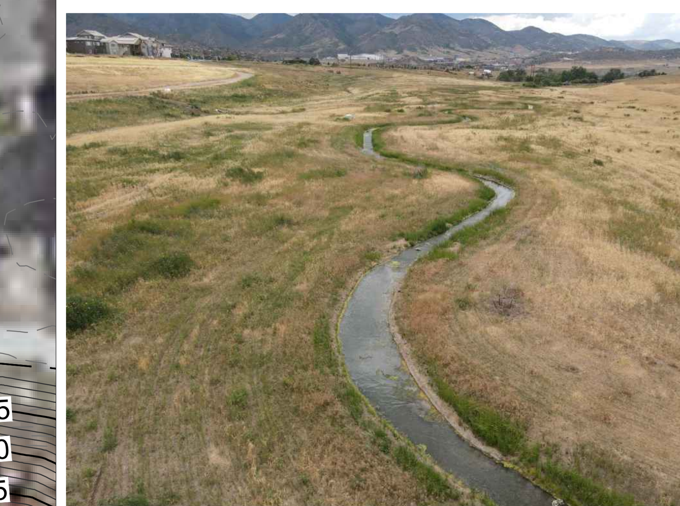

PHOTO 2: POOL RIFFLE CHANNEL

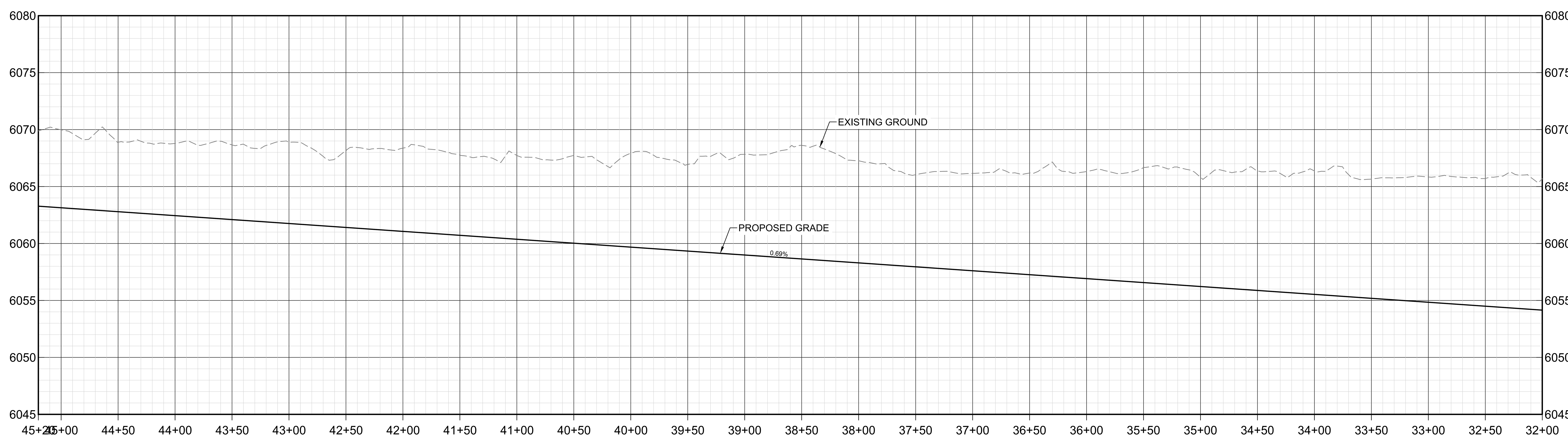

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PHOTO 3: POOL RIFFLE CHANNEL

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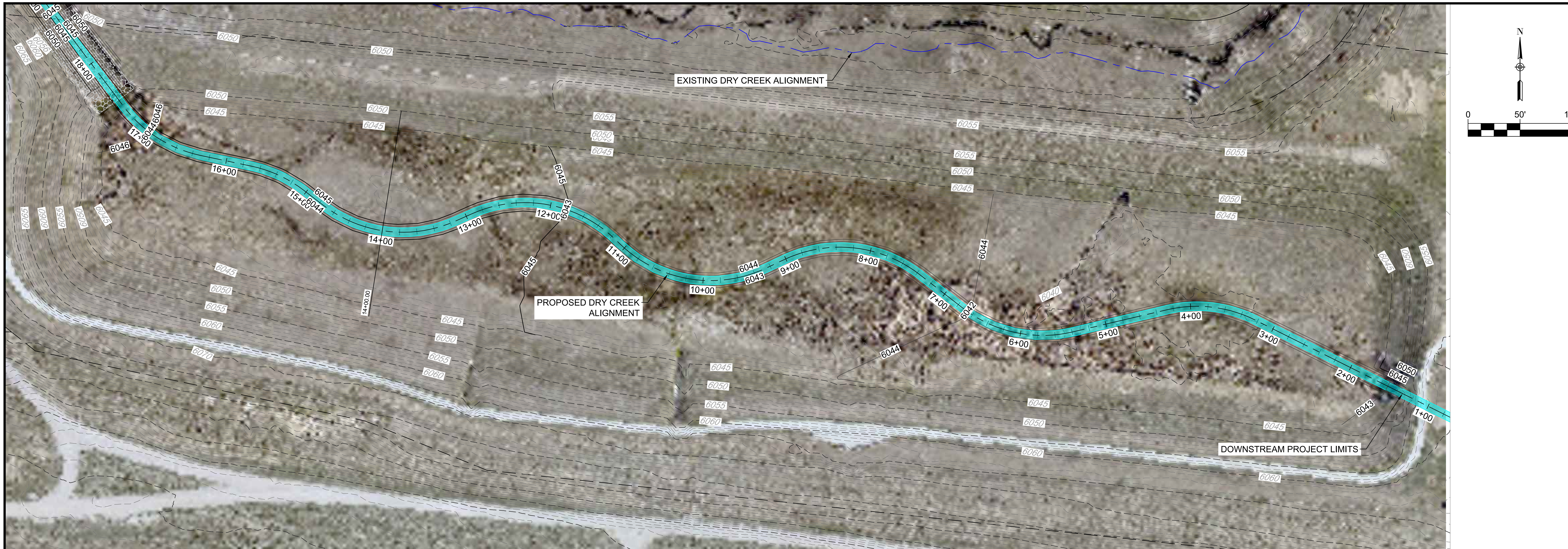

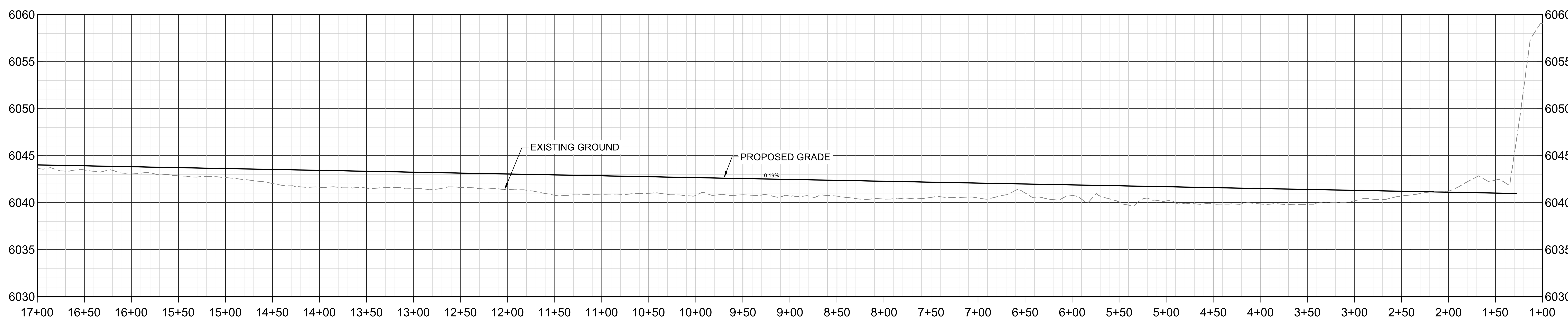

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CONCEPTUAL DESIGN

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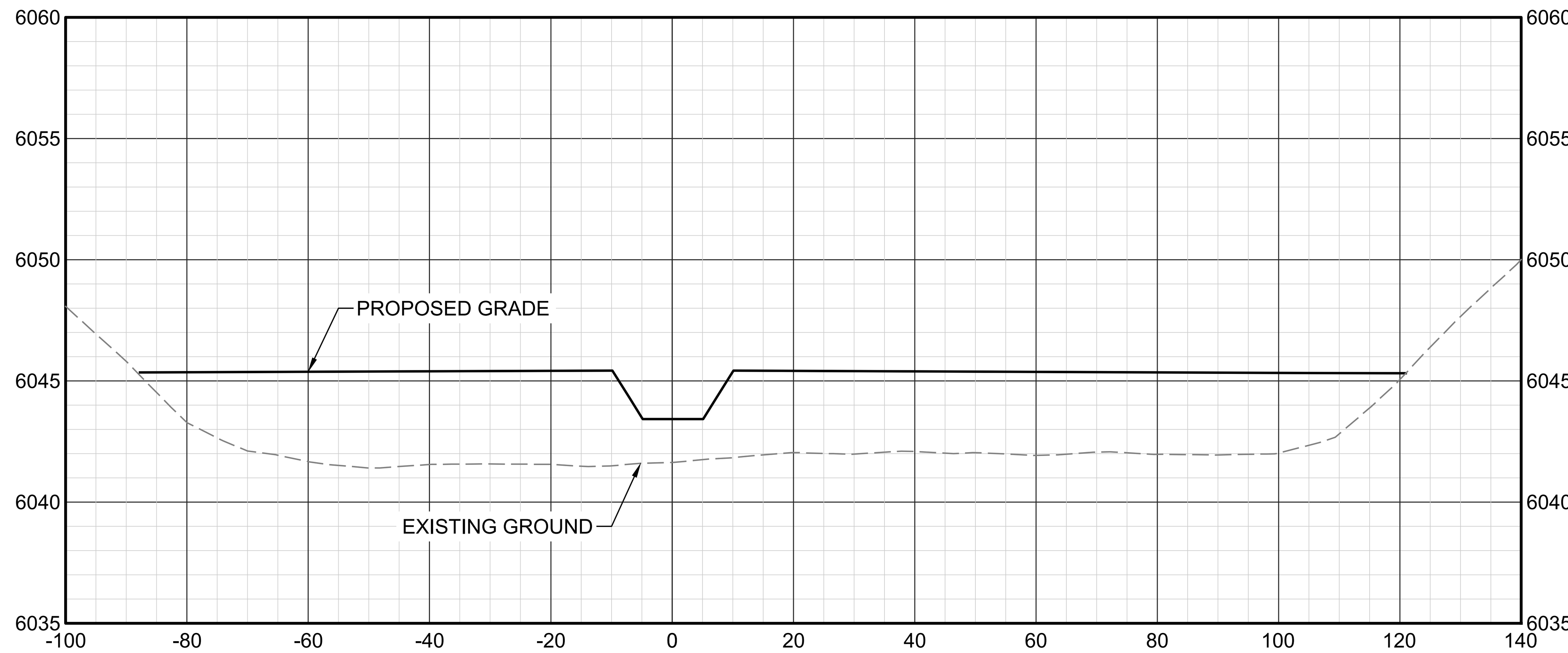

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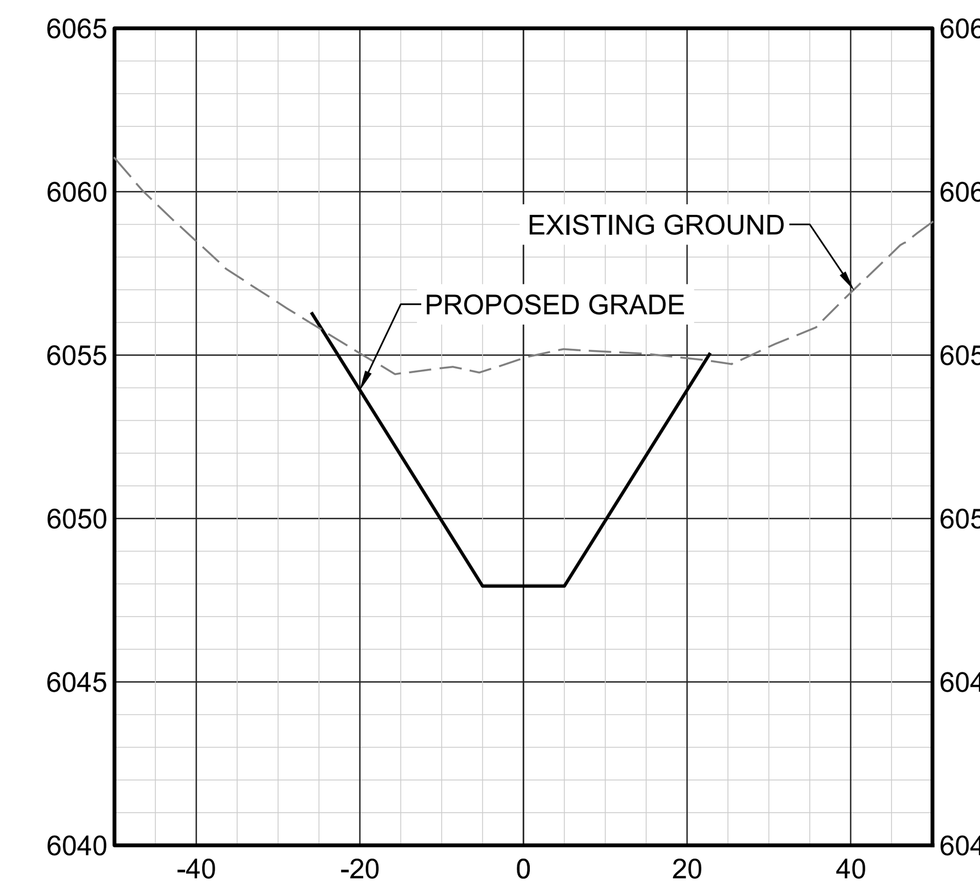

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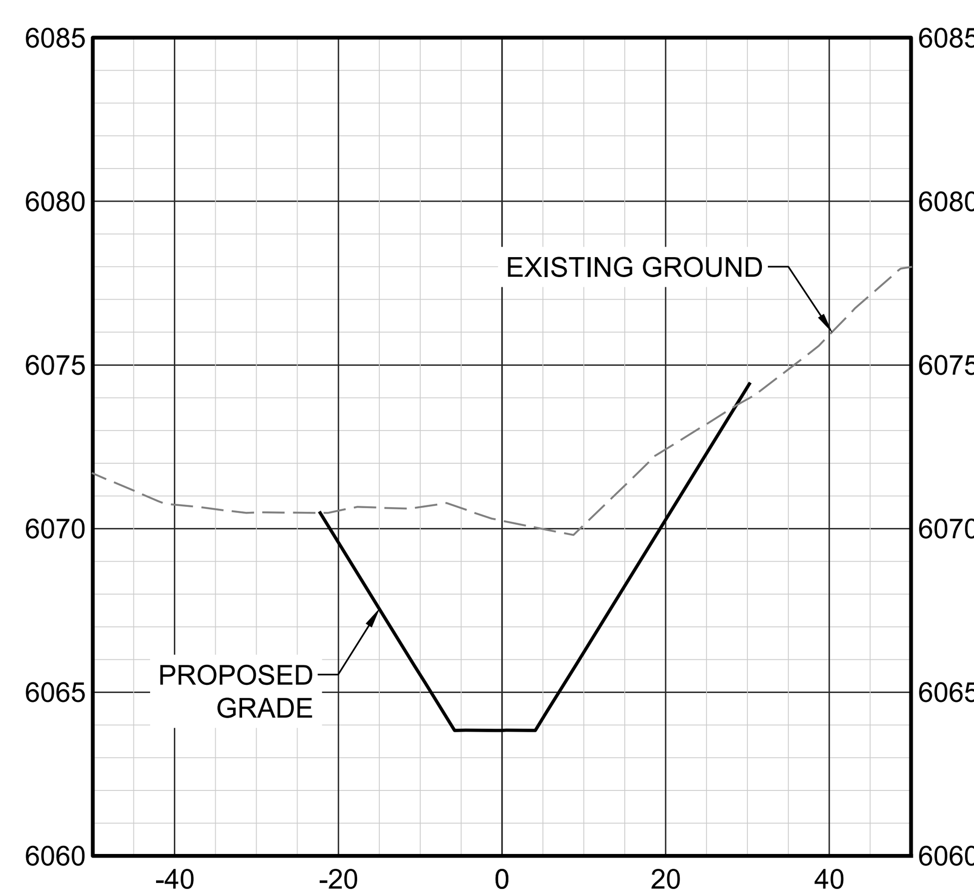

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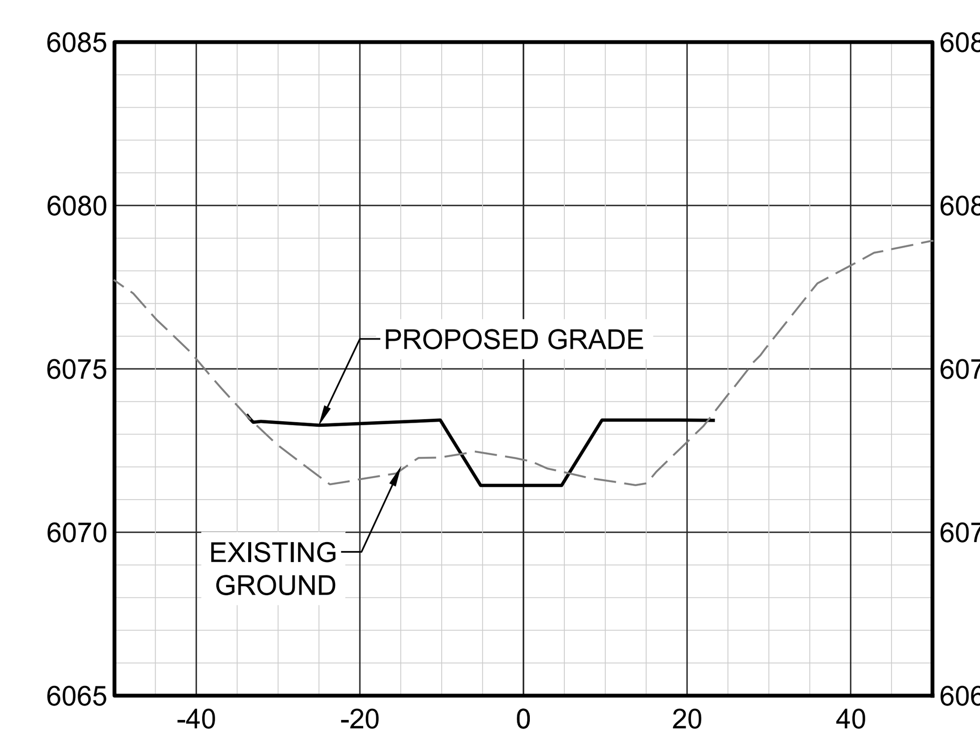

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DRY CREEK CHEYENNE

CONCEPTUAL DESIGN

REACH G CONCEPT - 5

23-011

DATE JUNE 2023

SHEET 13 OF 21

N

0 70' 140'

DESCRIPTION:

DREDGE CHANNEL TO EXPAND FLOODPLAIN CAPACITY. RELOCATE SANITARY SEWER LINE UNDER SHERIDAN. MAKE IMPROVEMENTS TO THE MOUNTAIN ROAD CROSSING.

GOAL:

1. REDUCE SEDIMENTATION
2. ESTABLISH LOW FLOW CHANNEL
3. IMPROVE HYDRAULIC CAPACITY AND FUNCTIONALITY OF CROSSINGS
4. INCREASE SANITARY SEWER MAINTENANCE ACCESS

PHOTO 1: CONVERSE STREET CROSSING

PHOTO 2: MOUNTAIN STREET CROSSING

PHOTO 3: EXPOSED SANITARY SEWER MANHOLE

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DRY CREEK CHEYENNE

CONCEPTUAL DESIGN

23-011

REACH H CONCEPT - 1

DATE

JUNE 2023

SHEET

14 OF 21

N

0 70' 140'

DESCRIPTION:

DREDGE CHANNEL TO EXPAND FLOODPLAIN CAPACITY. RELOCATE SANITARY SEWER LINE UNDER SHERIDAN. MAKE IMPROVEMENTS TO THE MOUNTAIN ROAD CROSSING.

GOAL:

1. REDUCE SEDIMENTATION
2. ESTABLISH LOW FLOW CHANNEL
3. IMPROVE HYDRAULIC CAPACITY AND FUNCTIONALITY OF CROSSINGS
4. INCREASE SANITARY SEWER MAINTENANCE ACCESS

PHOTO 4: BANK EROSION AROUND SANITARY SEWER MANHOLE

PHOTO 5: SCULPTED CONCRETE DROP STRUCTURE

PHOTO 6: CONFINED URBAN STREAM WITH DEFINED LOW FLOW CHANNEL

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DESIGNED BY:
APPROVED BY:

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PREPARED FOR: GLM Design Group

PREPARED BY: ICON ENGINEERING

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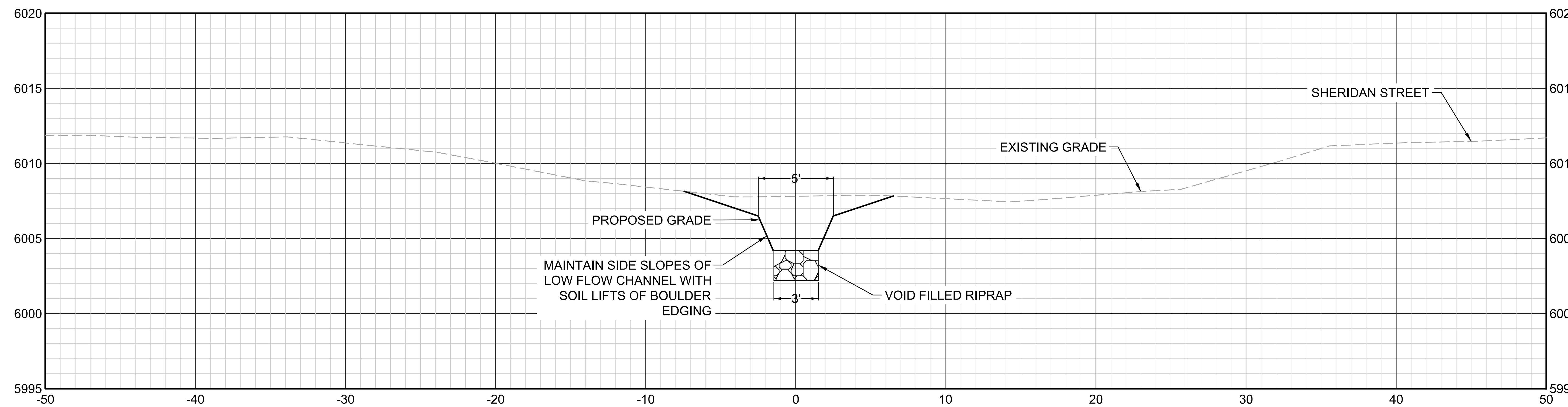
DRY CREEK CHEYENNE

CONCEPTUAL DESIGN

23-011

REACH H CONCEPT - 2

DATE
JUNE 2023
SHEET
15 OF 21



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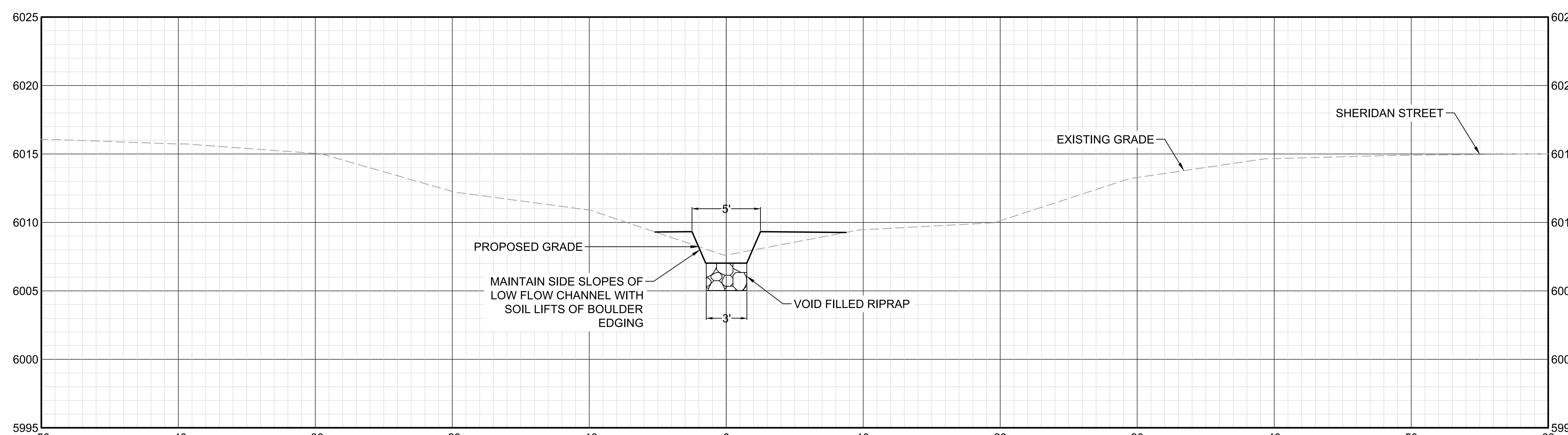

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CONCEPTUAL DESIGN

23-011

REACH H CONCEPT - 3

DATE

JUNE 2023

SHEET

16 OF 21

PROJECT AREA | DRY CREEK DISC GOLF COURSE

CITY OF CHEYENNE

GLM Design Group

DHM DESIGN

PROJECT AREA | DRY CREEK DISC GOLF COURSE

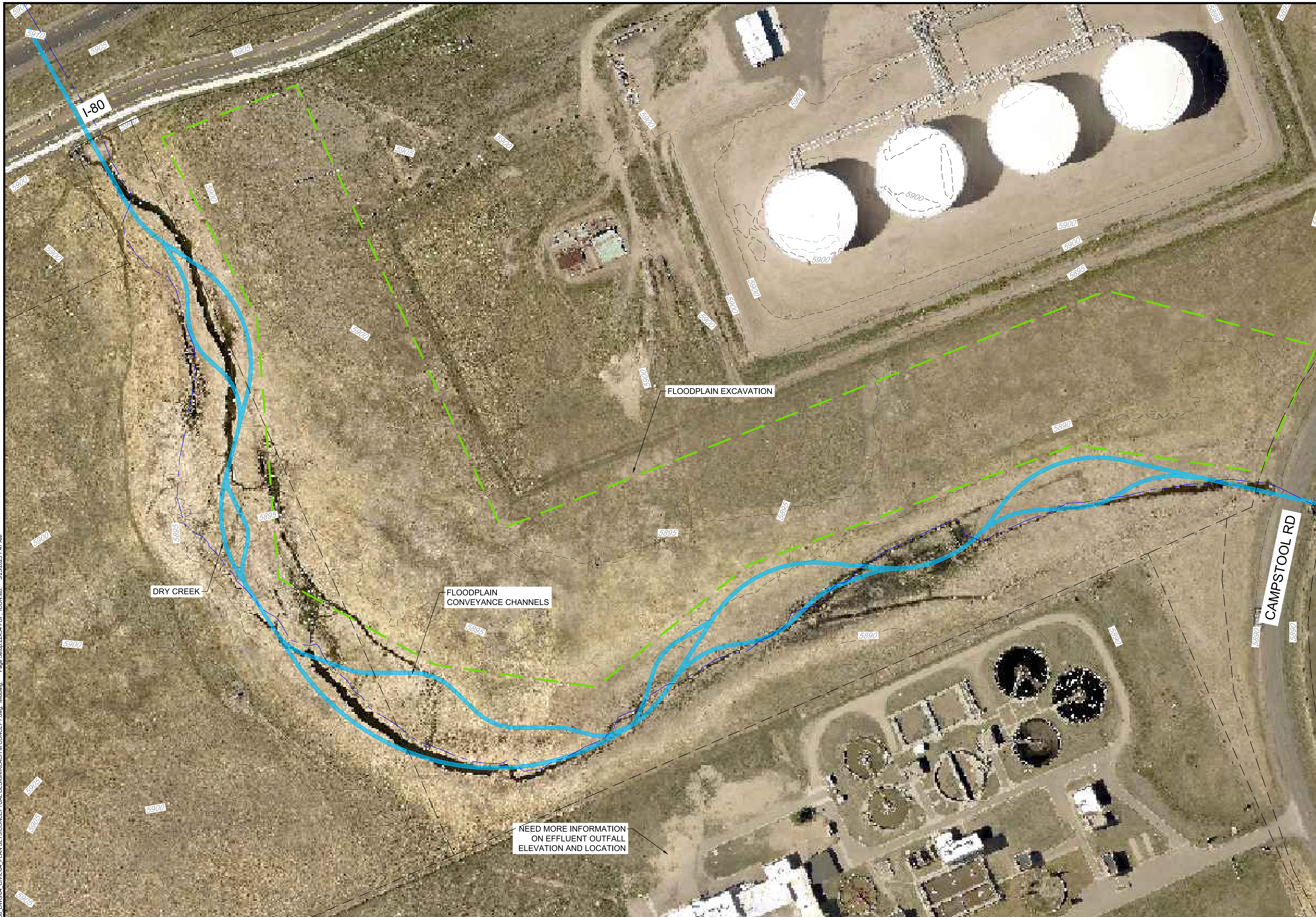
SHEET 2 OF 2

GLM Design Group

DHM DESIGN

CITY OF CHEYENNE, WY: EAST PARK
CONCEPTUAL DRAINAGE PLAN

2-12-2023



N

0 80' 160'

DESCRIPTION:

REALIGN CHANNEL, EXPLORE OPPORTUNITIES FOR BRAIDED CHANNEL. RECONSTRUCT WETLANDS.

GOALS:

1. INCREASE FLOODPLAIN CAPACITY
2. LOWER WSE

No.	DATE	REVISIONS	APPR.

DRAWN BY:

DESIGNED BY:

APPROVED BY:

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DRY CREEK CHEYENNE

CONCEPTUAL DESIGN

23-011 REACH M CONCEPTUAL DESIGN

DATE APRIL 2023

SHEET 17

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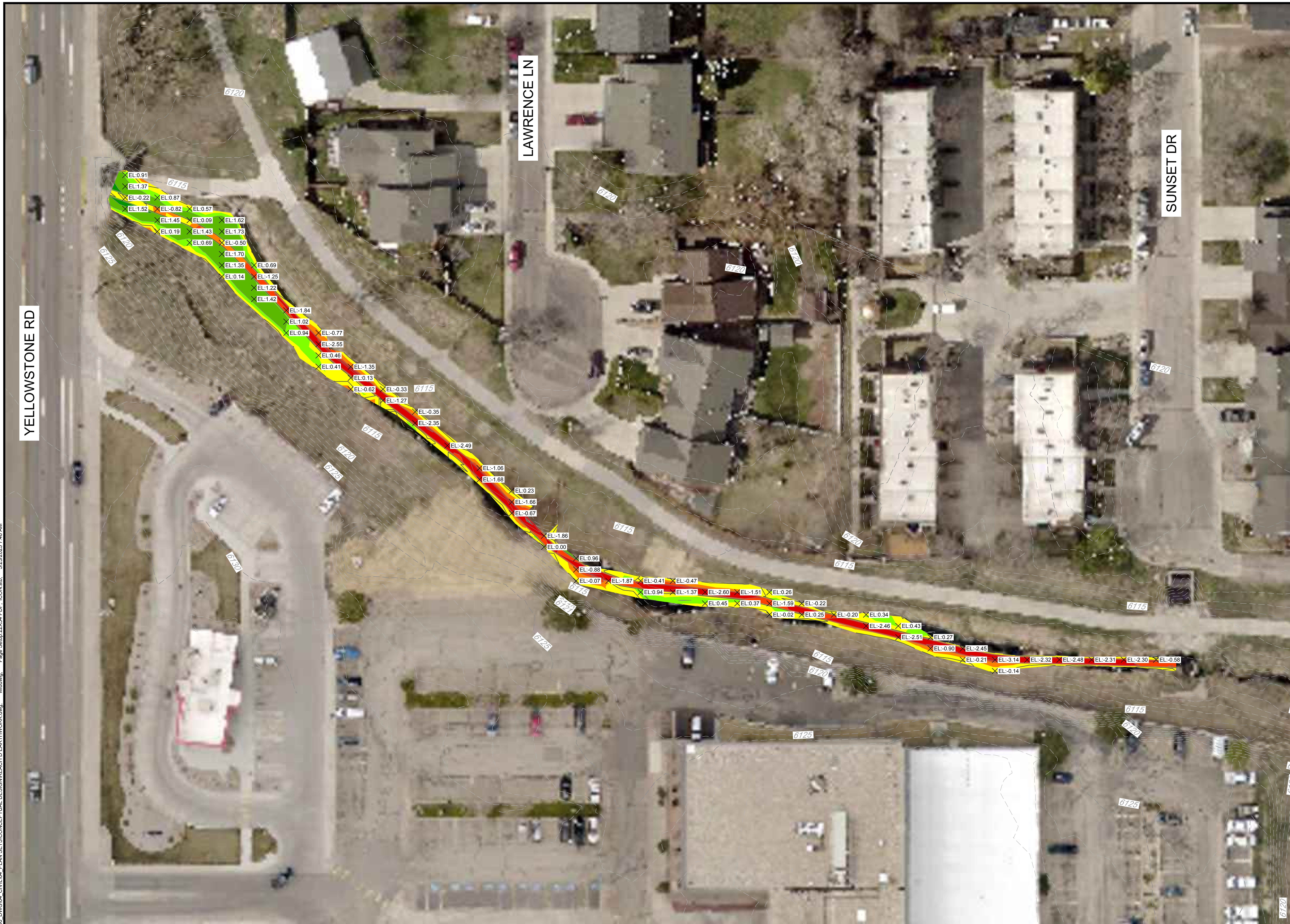

N

0 30' 60'

EARTHWORK:

CUT: 282 CY
FILL: 143 CY
NET: 282 CY

NOTES:

1. EARTHWORK QUANTITIES WERE CALCULATED AS THE DIFFERENCE BETWEEN THE EXISTING AND PROPOSED SURFACES AND DO NOT INCLUDE SOIL VOLUME ADJUSTMENTS RELATED TO RIPRAP OR CONCRETE INSTALLATION
2. MINIMIZE SURFACE AREA OF FILL AREA PER REACH OF THE PROJECT TO MINIMIZE REVEGETATION NEEDS.
3. CONTRACTOR SHALL STRIP AND REPLACE TOPSOIL AT THIS LOCATION TO A DEPTH OF 6 INCHES

Elevations Table

Number	Minimum Elevation	Maximum Elevation	Color
1	-4.00	-2.00	
2	-2.00	-1.00	
3	-1.00	-0.50	
4	-0.50	0.50	
5	0.50	1.00	
6	1.00	2.00	
7	2.00	4.00	

No.	DATE	REVISIONS	APPR.

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DESIGNED BY:
APPROVED BY:

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DRY CREEK CHEYENNE
CONCEPTUAL DESIGN
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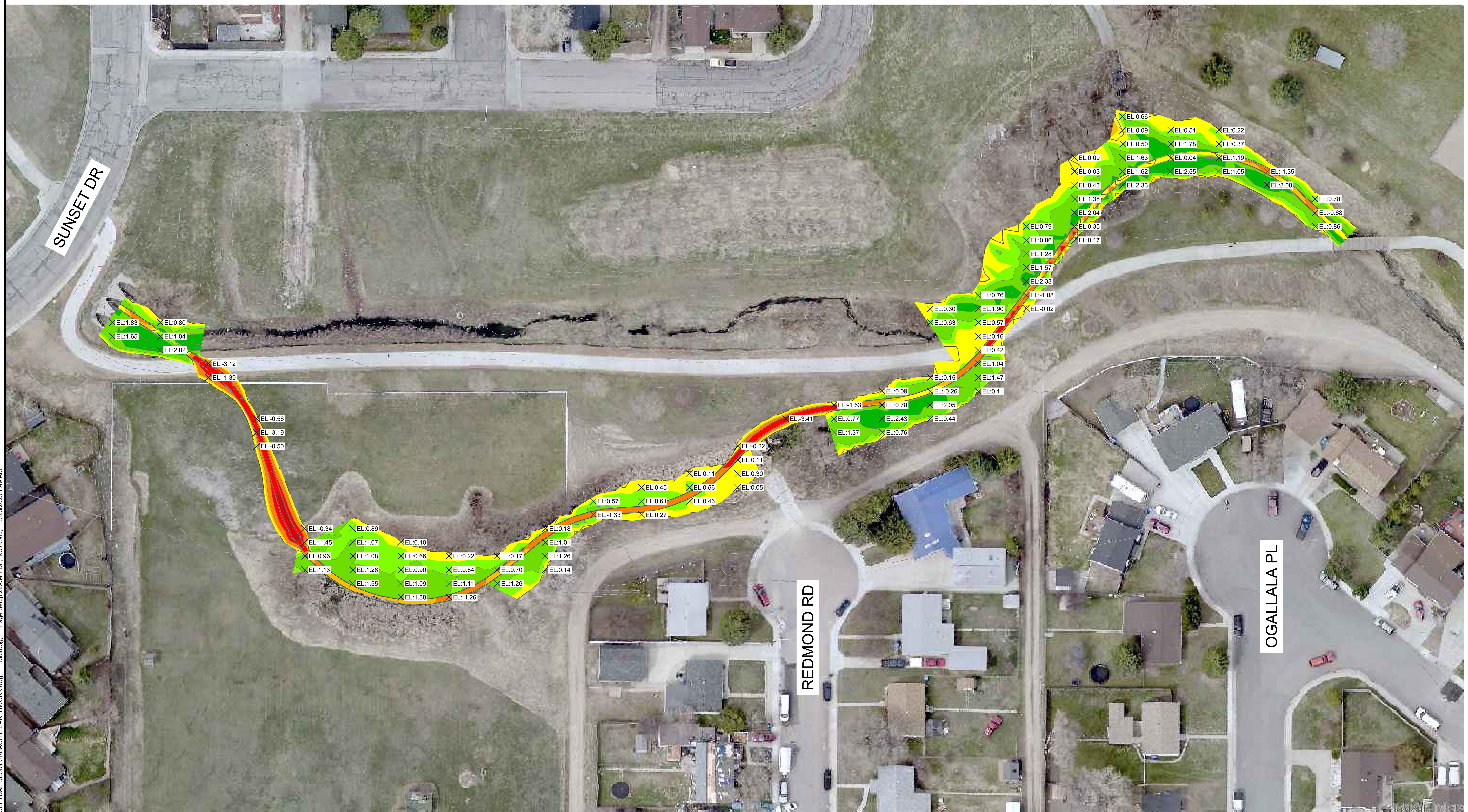
23-011

DATE: JUNE 2023

SHEET: 18 OF 21



N

0 40' 80'

EARTHWORK:

CUT: 346 CY
FILL: 1078 CY
NET: 732 CY

NOTES:

1. EARTHWORK QUANTITIES WERE CALCULATED AS THE DIFFERENCE BETWEEN THE EXISTING AND PROPOSED SURFACES AND DO NOT INCLUDE SOIL VOLUME ADJUSTMENTS RELATED TO RIPRAP OR CONCRETE INSTALLATION
2. MINIMIZE SURFACE AREA OF FILL AREA PER REACH OF THE PROJECT TO MINIMIZE REVEGETATION NEEDS.
3. CONTRACTOR SHALL STRIP AND REPLACE TOPSOIL AT THIS LOCATION TO A DEPTH OF 6 INCHES

Elevations Table

Number	Minimum Elevation	Maximum Elevation	Color
1	-10.00	-5.00	
2	-5.00	-2.00	
3	-2.00	-1.00	
4	-1.00	-0.50	
5	-0.50	0.50	
6	0.50	1.00	
7	1.00	2.00	
8	2.00	5.00	
9	5.00	10.00	

No.	DATE	REVISIONS	APPR.

DRAWN BY:

DESIGNED BY:

APPROVED BY:

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DRY CREEK CHEYENNE

CONCEPTUAL DESIGN

23-011

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DATE

JUNE 2023

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19 OF 21

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N

0 200' 400'

EARTHWORK:

CUT: 38,998 CY
FILL: 35,700 CY
NET: 3298 CY

NOTES:

1. EARTHWORK QUANTITIES WERE CALCULATED AS THE DIFFERENCE BETWEEN THE EXISTING AND PROPOSED SURFACES AND DO NOT INCLUDE SOIL VOLUME ADJUSTMENTS RELATED TO RIPRAP OR CONCRETE INSTALLATION
2. MINIMIZE SURFACE AREA OF FILL AREA PER REACH OF THE PROJECT TO MINIMIZE REVEGETATION NEEDS.
3. CONTRACTOR SHALL STRIP AND REPLACE TOPSOIL AT THIS LOCATION TO A DEPTH OF 6 INCHES

Elevations Table

Number	Minimum Elevation	Maximum Elevation	Color
1	-15.00	-5.00	
2	-5.00	-3.00	
3	-3.00	-1.50	
4	-1.50	-0.50	
5	-0.50	0.50	
6	0.50	1.50	
7	1.50	3.00	
8	3.00	5.00	
9	5.00	10.00	

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DRY CREEK CHEYENNE

CONCEPTUAL DESIGN

23-011

REACH G EARTHWORK

DATE JUNE 2023

SHEET 20 OF 21

N

0 50' 100'

EARTHWORK:

CUT: 342 CY
FILL: 255 CY
NET CUT: 87 CY

NOTES:

1. EARTHWORK QUANTITIES WERE CALCULATED AS THE DIFFERENCE BETWEEN THE EXISTING AND PROPOSED SURFACES AND DO NOT INCLUDE SOIL VOLUME ADJUSTMENTS RELATED TO RIPRAP OR CONCRETE INSTALLATION
2. MINIMIZE SURFACE AREA OF FILL AREA PER REACH OF THE PROJECT TO MINIMIZE REVEGETATION NEEDS.
3. CONTRACTOR SHALL STRIP AND REPLACE TOPSOIL AT THIS LOCATION TO A DEPTH OF 6 INCHES

Elevations Table

Number	Minimum Elevation	Maximum Elevation	Color
1	-5.00	-3.00	
2	-3.00	-1.50	
3	-1.50	-0.50	
4	-0.50	0.50	
5	0.50	1.50	
6	1.50	3.00	
7	3.00	5.00	

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DRY CREEK CHEYENNE

CONCEPTUAL DESIGN

23-011

REACH H EARTHWORK

DATE: JUNE 2023

SHEET: 21 OF 21

IX. PUBLIC PROCESS AND PROJECT STAKEHOLDER COORDINATION

A. Introduction

The public process and project stakeholder coordination for the plan update involved three meetings with the stakeholder group and two public open house meetings to gather public feedback. The GLM Design Team worked closely with City Engineer's Office Staff to establish the stakeholder group for the project and set the meeting schedule. The stakeholder group consisted of representatives from the Governing Body of the City of Cheyenne, Laramie County Public Works, WyDOT Hydraulics Section, F.E. Warren Air Force Base, and the Laramie County School District No.1 (LCSD #1). Additionally, GLM Design Team members met with the city's Director of Parks & Recreation, Cheyenne BOPU staff, the city's Greenway Coordinator, city GIS staff, Laramie County Conservation District (LCCD) staff, and the Wyoming State Engineer's Office to solicit input and guidance for mitigative measures recommended in the plan.

Two public Open House meetings were held to garner public input and to answer questions about the plan update. The goal of the open house meetings was to provide an informal and interactive environment where attendees could learn about the project, ask questions, and provide feedback to the design team. These meetings were both held at the local Laramie County Library and advertised ahead of time. Stations were set up with project exhibits and several GLM team members were present at each station to answer questions, clarify information, and provide technical insight about the project boards with attendees. The first open house meeting began with a brief welcome and comments explaining the purpose and goals of the plan update. The second open house meeting was less formal due to a smaller group of attendees.

There were thirty-one attendees who signed in for the first open house meeting. There were several more who did not sign in on the attendance sheet. GLM team and city staff members engaged the public for two hours in individual discussions about the projects and image boards.

The overwhelming concern of community members that we engaged with revolved around maintenance issues and the lack of maintenance generally being undertaken by the city for the Dry Creek channel. The creek restoration measures recommended in the plan update address many of the maintenance issues brought up by the public in the first open house meeting. Moreover, the plan recommendations for Mylar Park, the Powderhouse Open Space, Cahill Park Recreational area, and the disc golf course have been vetted by the Cheyenne Parks Director and Parks staff and have been designed to limit the amount of maintenance required by city staff. The plan recommendation for Kiwanis Park has been vetted by the city Greenway Coordinator/Project Manager for the East Park project. The improvements shown for LCCD managed areas downstream of the UPRR are taken from the LCCD master planning efforts for this area and have been coordinated with LCCD staff.

There were ten attendees for the second, less attended open house meeting. This meeting was more informal due to the size of the group. Maintenance issues were the main topic of conversation. Creek capacity for the Sheridan Street Reach was also discussed at length in this meeting. The plan update includes several mitigation recommendations for the Sheridan Reach to increase capacity and reduce overtopping of the Hilltop Ave. crossing. The hydrologic model also indicates the issues the city will face in the management of development of the former Cole property and properties north of Buffalo Ridge with respect to inadequate capacity of the Sheridan Reach to accommodate this flow. For both open house meetings, residents described their recollections of the 1985 flood event and the Sheridan Reach tragedies that occurred in that event. As of the 2023 plan update, the Sheridan Street Reach is still a drainage concern although not to the level it was in 1988.

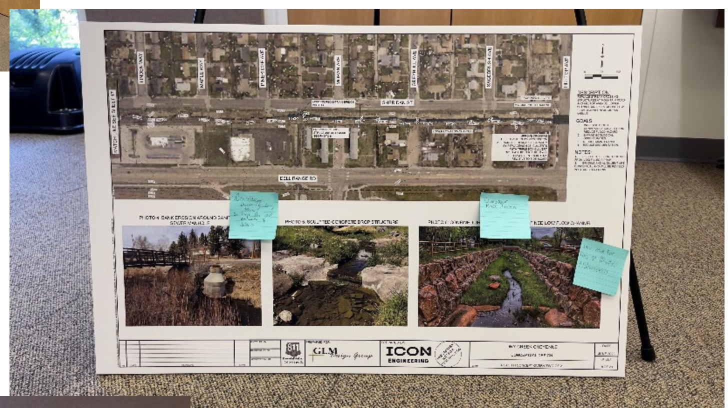
B. Project Stakeholder Meeting Summaries

GLM Team members and city staff met with the stakeholder group on three occasions to provide project progress reports and to engage group members in feedback on mitigation measures proposed in the plan update. Group members were shown modeling results and detailed aspects of the hydrologic model were explained at length. The stakeholder group has been consistently supportive of the creek restoration recommendations, recognizing the value these measures have with respect to reduced maintenance, increased capacity for the more frequent events, and improvement of the aesthetics along the channel. The group has been attentive to the modeling details and in agreement with the plan approach taken by the GLM Design Team for the update to the 1988 master plan.

Group members invited and who accepted their roles on the stakeholder group but did not attend include the representatives from the LCSD #1 and F.E. Warren Air Force Base. City staff has met separately with the school district and the mayor is facilitating a meeting with Base personnel to discuss the plan proposed detention/wetlands facility for the South Fork headwaters.

C. Public Meeting Summaries

The feedback generated from the public open house meetings was overwhelmingly positive. The creek restoration measures were embraced by attendees and welcomed as an approach by the city to address ongoing maintenance issues and concerns within the Dry Creek channel. The public also embraced the modeling approach and choice of EPA SWMM Hydrologic and USACE HEC-RAS Hydraulic models incorporated into the plan update. Most attendees voiced appreciation but also a lack of patience to see projects constructed and implemented along the channel.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PROJECT AREA I DRY CREEK DISC GOLF COURSE
DRY CREEK CORRIDOR MASTER PLAN I CHEYENNE, WYOMING

X. SELECTED PLAN

A. Plan Summaries

This section summarizes the development of the selected plan for flood control and improvement of creek function. The preliminary mitigation measures and creek restoration projects were discussed with staff and presented to the stakeholder group. Like the 1988 approach, the basin was divided into smaller reaches with each reach then evaluated for drainage issues, impairment of natural creek function, long-term maintenance issues, park and greenway improvements, structural deficiencies, and potential outside funding sources.

This section describes the selected plan as well as implementation priorities, operation and maintenance of proposed mitigative measures, traffic impacts due to flooding, administrative considerations, and nonstructural measures to be considered by city staff. As pointed out in the Preliminary plan development section of the report, there remain areas of concern and life-safety issues along the Dry Creek channel. There are 11 roadway crossings overtopped by floodwaters in the updated model, five of which can be considered life-safety hazards, Gateway Dr., Seminoe Rd., Prairie Ave., Hilltop Ave., and the Rawlins Street crossing.

The 2023 plan development includes forty-three structural and nonstructural mitigation measures. Our structural measures include the following:

1. enhanced/expanded storage in key locations to attenuate and reduce peak discharge at design points along the study reach, reducing the size of required conveyance elements.
2. improve and enhance the existing conveyance in the study area and provide new conveyance elements where appropriate.
3. and creek restoration projects to reduce annual maintenance costs and complement greenway and park amenities.

Our nonstructural measures include a revised Debris blockage policy and an update to the city's Storm Drainage Criteria and specifically the 2014 UDC Article 3, Section 3.2 – Drainage Impact Studies. ***We are recommending consideration for adoption of a stormwater utility to help fund annual maintenance and a CIP list for Basin improvements.*** **Table 9** lists the 43 recommended structural and nonstructural recommendations along with their respective scores in the Design/Decision Matrix developed with guidance and assistance from city staff. The matrix elements that staff wanted to be included in the Prioritization Mitigation Action Plan for the Dry Creek Master Plan update deliverables are presented below:

- Life Safety
- Social Impacts
    - This would be an aggregate of four of the criteria that were presented in your original matrix (economic impacts, recreational opportunities, community impacts, educational opportunities).
- Ability to Implement
    - Property acquisition
    - Federal Lands
    - Railroad Requirements
    - Etc.

- Protect Property
    - Both Public and Private
- Infrastructure Resilience
    - Long Term Viability
    - Maintenance
- Efficiency and Cost
    - BCA
- Protection of Critical Facilities
    - Interstate 80
    - Interstate 25
    - UPRR Tracks
    - BOPU Water Treatment Facility
- Environmental Resources
    - Aquatic Species

Unlike the 1988 plan, this plan update has a stronger focus on creek restoration projects and the benefits that water quality and nature-based solutions can provide to the community. These proposed restoration projects will serve to improve the interaction between the creek and the community. There are significant reaches of Dry Creek that can still be functionally restored. Addressing these reaches will reduce annual maintenance costs, eliminate nuisance flooding, lessen the risk of flood damage for larger events, and enhance the creek amenity for the community. A natural, healthy riparian corridor improves the function, diversity, and property value of adjacent land and the surrounding environment as well. Moreover, these projects will assist the city with its ongoing MS4 compliance efforts and its CRS participation under the National Flood Insurance Program (NFIP).

Our field inspections have focused on five reaches of Dry Creek in need of functional improvement.

- McCormick-Central Campus
- Yellowstone Road downstream reach to Sunset Dr. utility crossing
- Downstream of Townsend Place
- Between Powderhouse and Carey Reservoir
- Sheridan Reach

Additional consideration could be given to the open area between Rawlins Street and U.S. 30. An improved floodway and floodplain through this reach would require property acquisitions. Incorporation of riffles and pools is proposed for the Sheridan Reach Flood Control alignment in conjunction with the re-alignment of Dry Creek flow through this reach. There are areas of bank erosion and instability through some of the above listed reaches which represent sedimentation issues and potential MS4 violations for the city. These reaches have excess sedimentation and vegetation issues all which impact conveyance and water quality.

The report recommendations for creek restoration projects are a bit of a departure from previous drainage planning documents for the Dy Creek Basin. It is our belief that these projects once implemented will provide longevity to this plan update along with tangible benefits that the community will appreciate daily. Six of the seven plan recommended restoration projects in **Table 9** are included in the selected plan.

This plan update also has a stronger focus on the implementation of detention storage/wetlands facilities located throughout the Basin for more consistent attenuation of peak discharges. Six of the seven recommended storage/wetlands facilities listed in **Table 9** are included in the selected plan. These include reconfiguration and potential expansion of the UPRR sump, expansion of storage/wetlands for the Mylar Park Pond, creation of new storage/wetlands for the South Fork headwaters, expansion of storage/wetlands for the Westgate Pond, minor expansion of storage/wetlands for the Powderhouse corridor in collaboration with the Cheyenne Rotary Club, and realignment of the main channel of Dry Creek through the Sheridan Flood Control alignment which will attenuate additional flow upstream of the Sheridan Street reach as well as upstream of U.S 30 before the effects are dampened out. Moreover, the selected plan includes a recommendation for property acquisitions in conjunction with floodplain expansion between U.S. 30 and E. Pershing Blvd. which will attenuate peak discharges upstream of the Union Pacific Railroad crossing.

The selected plan includes six of the ten roadway crossing improvements recommended in this study. For two of these crossings, Rawlins Street and Lower Campstool Rd., we are recommending signage as an appropriate mitigative measure. As mentioned above, there are five crossings, Gateway Dr., Seminoe Rd., Prairie Ave., Hilltop Ave., and the Rawlins Street crossing that can be considered life-safety hazards. We are recommending the following mitigative actions for these crossings:

- Improvements to the Westgate outlet structure to address Gateway Dr. overtopping and an existing piping condition under the roadway.
- Consideration of a larger box culvert to replace the (2) existing 7-foot diameter CMP for the Seminoe crossing.
- Elimination of the Prairie Ave. crossing and creation of additional parking for the greenway and Mylar Park.
- Replacement of the existing Hilltop structure with a new multiple cell box including provision for a lower invert through one of the boxes for the reconstructed upstream low flow channel.
- Signage for the Rawlins Street crossing.

B. Design Alternatives Refined for each Project Area/Reach

Figures 71 through 97 show refined designs for projects recommended in this report. Table 2, shown again below is the selected plan summary of recommended improvements by implementation priority for the Basin.

Table 2. Selected Plan Summary of Improvements by Implementation Priority

Project Location	Description	Matrix Score	Rank
Union Pacific Railroad Crossing	Reconfiguration of Storage	11.75	1
Mylar Park Improvements	Increase storage/Wetlands	10.75	2
FEW South Fork Improvements	New Storage/Wetlands for South Fork	9.75	3

Carey Reservoir Modifications	Inlet Modifications	9.75	**4**
Hilltop Ave. Crossing	Reduce Overtopping	9.75	**5**
Prairie Ave. Crossing	Eliminate Crossing	8.75	**6**
Education Dr. Crossing	Reduce Overtopping & Redirect into Westgate Pond	8.75	**7**
Gateway Dr. Crossing	Eliminate Piping & Overtopping of Gateway Dr.	8.75	**8**
Seminoe Crossing	Eliminate Overtopping	8.75	**9**
Westgate Pond	Repair Outlet Works & Expand Storage/Wetlands	8.25	**10**
Debris Blockage Policy Revisions	Recommendations for Mitigative Measures	7.75	**11**
Powderhouse Corridor	Water Quality, Greenway Improvements, & Minor Storage	7.75	**12**
Realigned Sheridan Reach Flow	Realign Main Channel Flow	7.25	**13**
Sheridan Street Capacity Improvements	Increase Low Flow Capacities	7.25	**14**
U.S. 30 Levee Reach	Acquisition of Properties & Elimination of Levee	7.25	**15**
Cheyenne Street/Polk Ave.	Increase Upstream Storage to Reduce Overtopping of Polk Avenue	7.25	**16**
Powderhouse to Carey Reservoir	Lower Gradient & Improve capacities into Carey Reservoir	7.25	**17**
Reach Upstream of N. College Dr.	Reduce Excess Vegetation & Dredge Sediment Deposition	7.25	**18**
Mountain Rd. Crossing	**Reconstruct Hydraulic Structure**	**7.25**	19
McCormick/Central Campus Channel Improvements	Regrade, Dredge, & Remove Excess Vegetation for Positive Conveyance of Flow	5.75	**20**
Yellowstone Downstream Reach	Regrade, Dredge, & Remove Excess Vegetation for Positive Conveyance of Flow	5.75	**21**
Dry Creek Disc Golf Course	Minor Drainage and Recreational Improvements for this Reach of Dry Creek	5.75	**22**
Drainage Requirements	Revision of Current Drainage Regulations	6.25	**23**

Property Acquisitions	Property Acquisitions along the East Side of Pierce Ave. & the North End of Parsons Pl.	6.25	**24**
Property Acquisitions	Property Acquisitions along Rock Springs Street & Cleveland Ave.	6.25	**25**

C. Implementation Priorities and Considerations

Table 12 summarizes damages due to flooding for the 2- through 100-year flood events evaluated in the HEC-RAS model for the Basin. The selected plan addresses these damages due to flooding along with the critical roadway overtopping concerns. Project costs for each of these projects are detailed in the attached thumb drive to this report. Eight of the first fifteen priority projects are storage-related projects due to their cost effectiveness and overall benefit to the Basin. The UPRR Improvements, Mylar Park Pond Improvements, South Fork Storage, Westgate Pond Improvements, and U.S. 30 to E. Pershing Blvd. Improvements should all be competitive for outside federal funding opportunities. Prairie Ave., Hilltop Ave., and Dell Range Blvd. improvement projects may be competitive once traffic impacts are factored into the Benefit-Cost Analysis.

The Union Pacific improvements should be placed on the fast-track as the design is currently funded under a FEMA BRIC grant. This report recommends a proposed reconfiguration of the sump 130 area such that there is no impounded floodwater up against the Union Pacific embankment, and that there is provision for discharging the 100-year peak flow downstream. Moreover, the proposed pond must be completely empty in less than 24 hours with a spillway designed to convey the 500-year event to meet SEO requirements. The sump 130 pond currently empties in 27-hours for the existing condition creating the potential for a dam breach of the UPRR embankment for a large flood event.

For final design purposes, a breach analysis for one half of the Maximum Probable Flood (MPF) will be required by the SEO along with development of a downstream inundation map.

The Mylar Park Pond improvements and South Fork headwaters detention storage both provide significant benefit for the upper and mid portions of the Basin and both projects should be considered for FEMA grant applications in the upcoming BRIC Notice of Funding Opportunity. The Powderhouse corridor improvements must be made in collaboration with the Cheyenne Rotary Club and should be scheduled as soon as funding becomes available.

The city must establish an operation and maintenance plan for the Dry Creek channel. Adoption of a stormwater utility for the community would provide the necessary funding for equipment and personnel. A memorandum of understanding between the local U.S. Corp of Engineer's Office will be required for ongoing dredging and removal of excess vegetation and sediment in the channel. The city should focus first on the five reaches identified in this report in need of functional improvement. The O&M plan when developed should include the following actions:

- Regular removal of excess sediment & vegetation in the channel.
- Inspection and removal of debris that could potentially clog culverts and/or reduce channel capacities for flood events.
- Inspect and repair areas of bank scour and erosion.

- Annual inspection of culverts and storm sewer outfalls incorporating the AASHTO forms for continuity and making appropriate repairs to structures in a timely manner.
- Inspect detention pond outlet works and make appropriate repairs.

Education to Yellowstone Reach		
Address	**Benefits**	**Type**
5701 Osage Avenue	$7,580	Commercial
111 West Carlson Street	$43,376	Commercial
121 West Carlson Street	$125,168	Commercial
200 Lakeshore Drive	$414,241	Residential
202 Lakeshore Drive	$325,815	Residential
Powderhouse to Carey Reservoir Reach		
Address	**Benefits**	**Type**
1625 Stillwater Avenue	$13,638	Commercial
1637 Stillwater Avenue	$57,463	Commercial
1659 Stillwater Avenue	$451,624	Commercial
1671 Stillwater Avenue	$65,670	Commercial
1715 Stillwater Avenue	$56,055	Commercial
1706 Stillwater Avenue	$66,839	Commercial
4516 Stillwater Avenue	$70,010	Commercial
1734 Meadowland Drive	$131,149	Commercial
1739 Meadowland Drive	$151,756	Commercial
1764 Meadowland Drive	$61,418	Residential
1772 Meadowland Drive	$68,839	Residential
1815 Meadowland Drive	$223,012	Residential
1807 Meadowland Drive	$188,068	Residential
1805 Edgewater Avenue	$19,997	Residential
1809 Edgewater Avenue	$79,920	Residential
US 30 to East Pershing Road Reach		
Address	**Benefits**	**Type**
5205 Charles Street	$1,341,581	Residential, FFE very low vs WSEL
3409 Polk Street	$57,662	Residential
5320 East Pershing Road	$517,348	Residential, FFE very low vs WSEL
3307 Hayes Avenue	$48,831	Residential
5612 East Pershing Road	$149,516	Residential
3312 Wenandy Avenue	$43,539	Residential
East Pershing Road to UPRR Reach		
Address	**Benefits**	**Type**
5909 East Pershing Road	$0	Commercial
2611 Whitney Road	$4,153,880	Residential, FFE very low vs WSEL
2619 Whitney Road	$3,255,624	Residential, FFE very low vs WSEL
2617 Whitney Road	$2,208,918	Residential, FFE very low vs WSEL
2709 Whitney Road	$1,604,206	Residential, FFE very low vs WSEL
2811 Whitney Road	$709,161	Residential, FFE very low vs WSEL
2809 Whitney Road	$206,198	Residential, FFE very low vs WSEL
2905 Whitney Road	$195,541	Residential, FFE very low vs WSEL

Sheridan Reach		
Address	**Benefits**	**Type**
3020 Sheridan Street	$27,595	Residential
611 Sagebrush	$385,443	Residential
300 Dell Range Boulevard	$55,015	Residential
4600 Hilltop Avenue	$504,974	Residential
Sunset to Seminole Reach		
Address	**Benefits**	**Type**
500 Ogallala Place	$26,334	Commercial
540 Melton Street	$1,785,595	Residential
Rawlins Street to US 30 Reach		
Address	**Benefits**	**Type**
3621 Pierce Avenue	$28,937	Residential
3615 Pierce Avenue	$27,668	Residential
3609 Pierce Avenue	$23,050	Residential
904 Laramie Street	$43,978	Residential

Table 11. Costs for Channel Restoration Alternatives

XI. PLAN CERTIFICATION

"I hereby attest that the Dry Creek Drainage Master Update was prepared by me, or under my direct supervision, in accordance with the provisions of the City of Cheyenne's Unified Development Code for the responsible parties thereof and that I am a duly registered Professional Engineer under the laws of the State of Wyoming. I understand that the City of Cheyenne does not and shall not assume liability for drainage facilities designed by others."

____

WY 8891 Gene MacDonald

XII. REFERENCES

1. Urban Storm Drainage Criteria Manuals 2 and 3, Urban Drainage and Flood Control District, Denver, Colorado, November 2010 as currently (Feb 2018) amended.

2. Storm Water Management Model, Reference Manual Volume I, Hydrology, U.S. Environmental Protection Agency, January 2016.

3. Storm Water Management Model, Reference Manual Volume II, Hydraulics, U.S. Environmental Protection Agency, May 2017.

4. CH2M HILL 2 1988: CH2M HILL & States West Water Resources Corporation: Drainage Master Plan – Dry Creek.

5. U.S.G.S 1988: U.S. Geological Survey: Precipitation Records and Flood-Producing Storms in Cheyenne, Wyoming, Water-Resources Investigations Report 87-4225, 1988.

6. AASHTO Culvert and Storm Drain System Inspection Guide , 2018

7. Implementing the Drainage Master Plan for the Greater Cheyenne Area, Surface Water Drainage Committee Final Report, March 2000

8. Publication No. FHWA-IF-04-016 Hydraulic Engineering Circular No. 9 Debris Control Structures Evaluation and Countermeasures, 3rd Edition, October 2005

9. Hydraulic Engineering Circular No. 14 Hydraulic Design of Energy Dissipators for Culverts and Channels, September 1983

10. Federal Emergency Management Agency Flood Insurance Study for Laramie County Wyoming, and Incorporated Areas, January 17, 2007

11. Ayres Associates: Dry Creek Sheridan Reach Flood Control Improvements: Physical Map Revision – Data and Work map, June 25, 2010

12. USDA Soil Survey of Laramie County, Wyoming, Western Part, 1993

13. Hudspeth, Noblitt & Ball: City of Cheyenne Dry Creek Drainage Basin Study, October 1972

14. BRW/Noblitt and Wright-McLaughlin: City of Cheyenne and Laramie County Dry Creek Drainageway Planning, February 1979

15. CivilWorx: Dry Creek North Branch LOMR, 2023

XIII. EPA SWMM MODEL

EPA SWMM Model attached on Report Thumb Drive.

XIV. USACE HEC-RAS MODEL

USACE HEC-RAS Model attached on Report Thumb Drive.

XV. PROJECT COST DATA

Project Cost Data tabulations and spreadsheets attached on Report Thumb Drive

XVI. AASHTO INFRASTRUCTURE CONDITIONS ASSESSMENT FORMS

AASHTO Infrastructure Conditions Assessment Forms attached on Report Thumb Drive

XVII. STRUCTURE INVENTORY EXHIBITS

UPRR Historic Masonry Box-Arch Culvert

PREPARED XXXXX, 2023

REVISED: 7/17/2023

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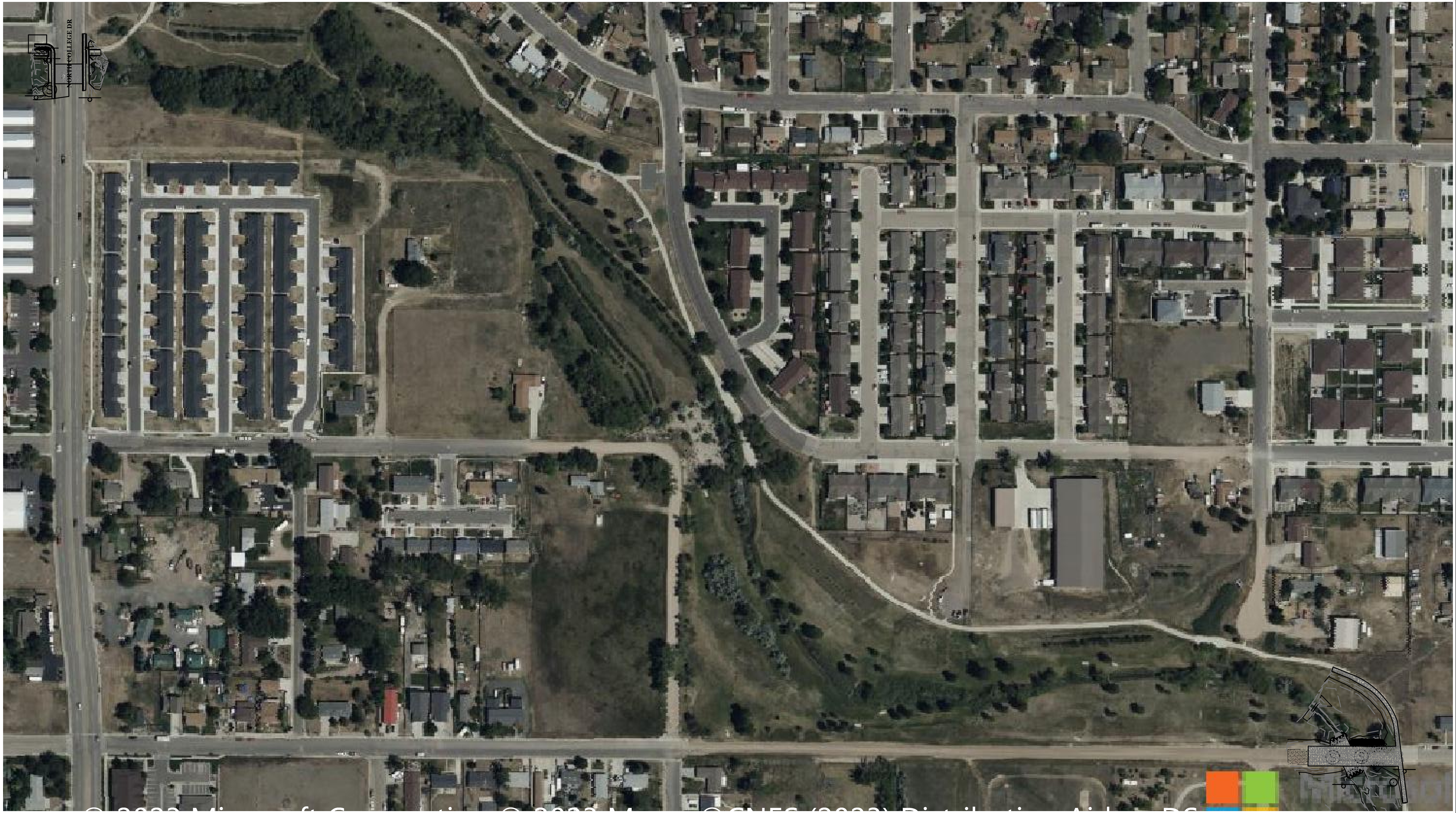

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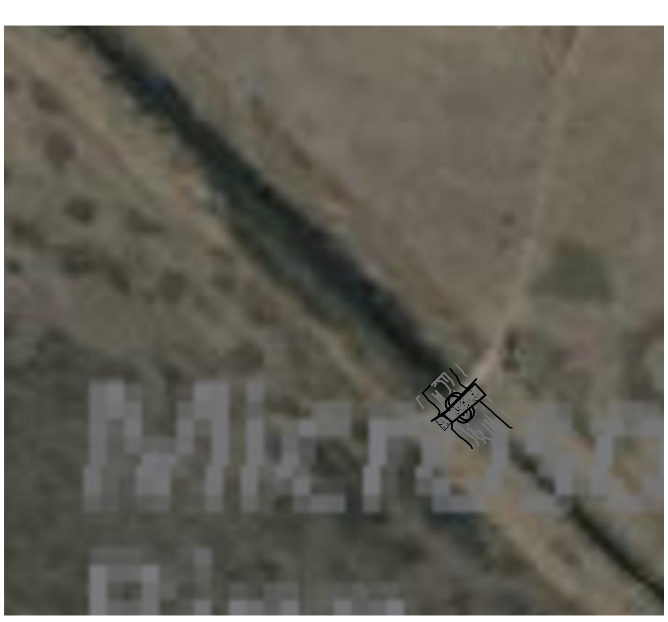

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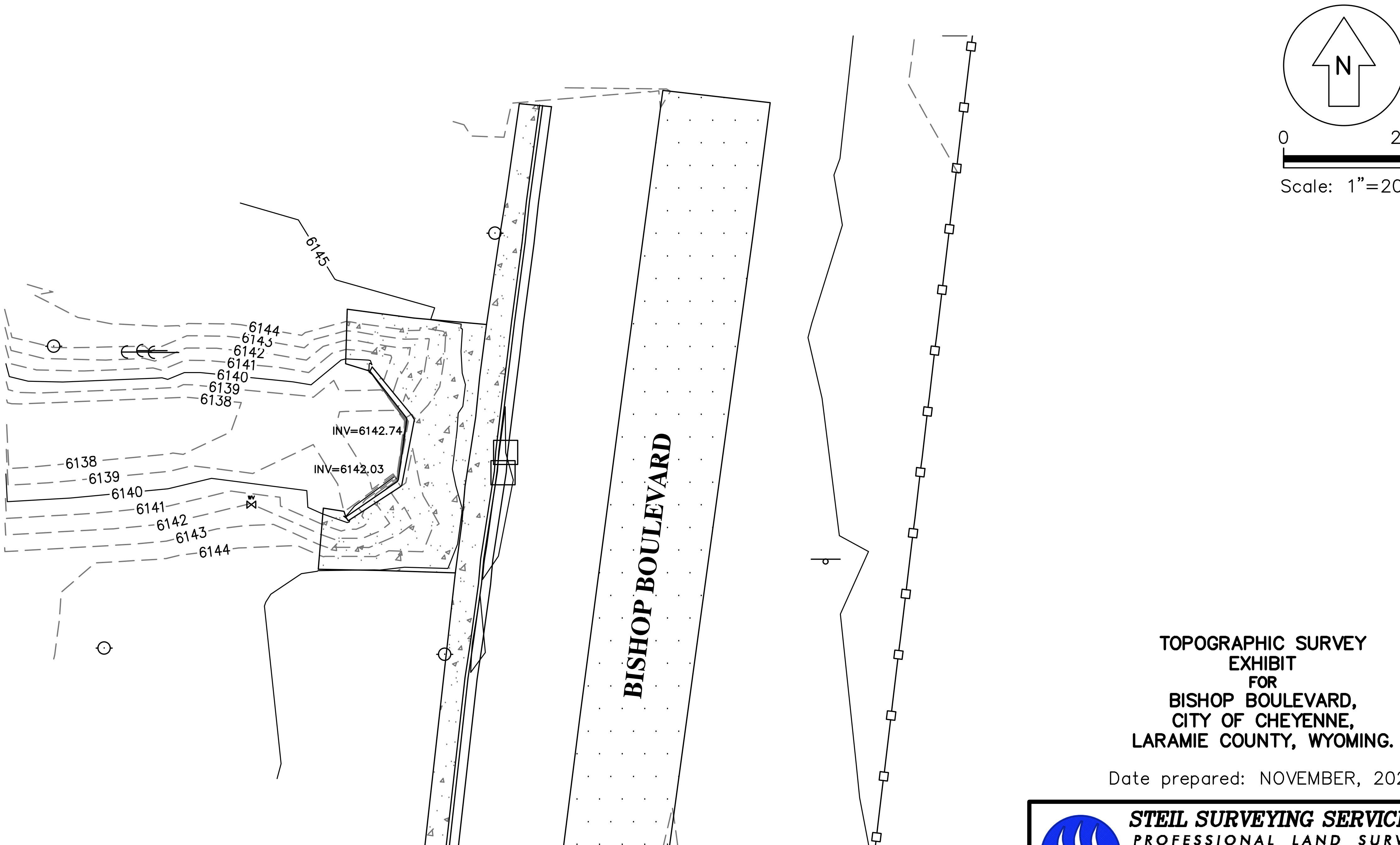

TOPOGRAPHIC SURVEY
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LARAMIE COUNTY, WYOMING.

Date prepared: NOVEMBER, 2022

REVISED: 11/9/2022
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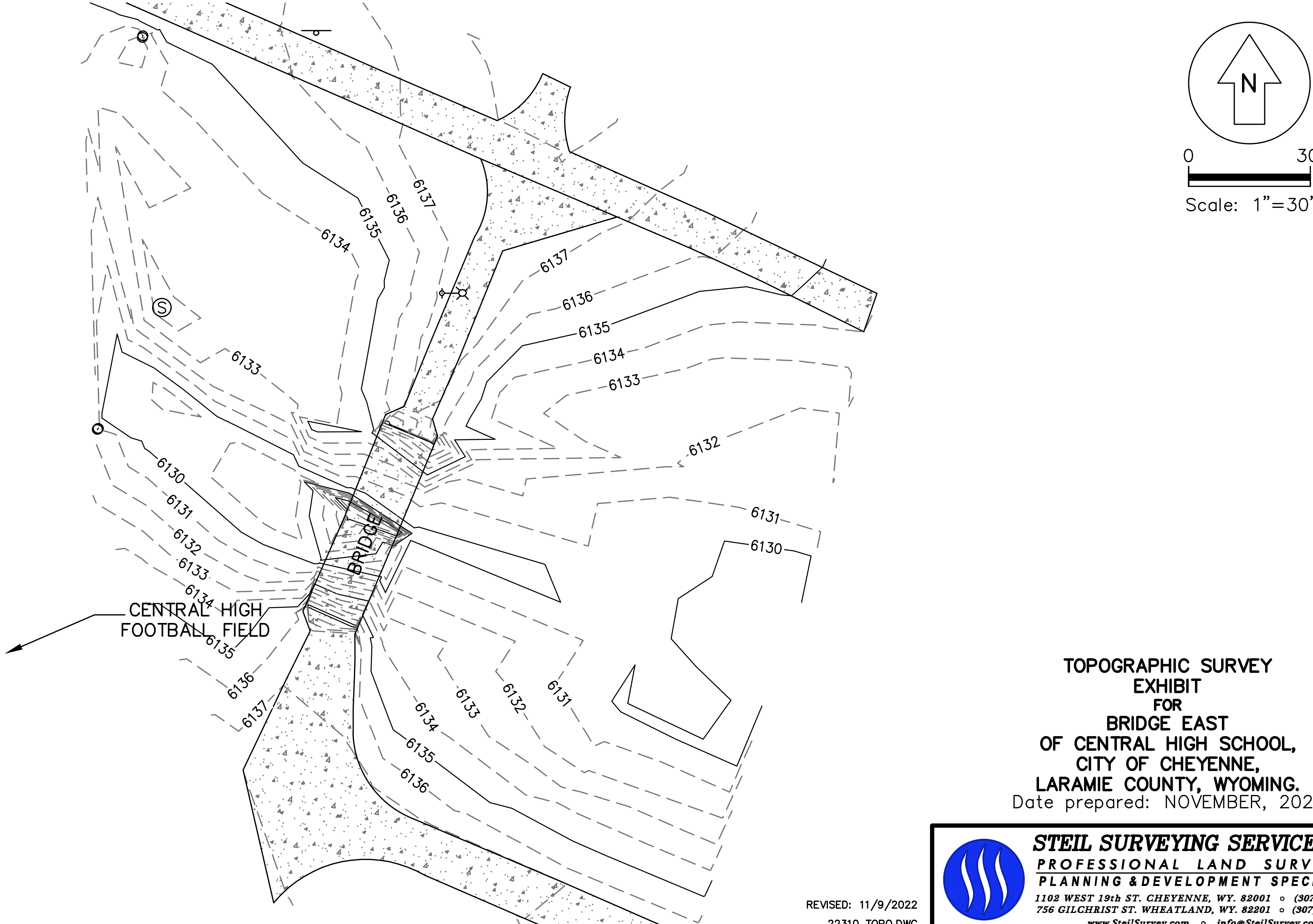

**TOPOGRAPHIC SURVEY
EXHIBIT
FOR
BRIDGE EAST
OF CENTRAL HIGH SCHOOL,
CITY OF CHEYENNE,
LARAMIE COUNTY, WYOMING.**
Date prepared: NOVEMBER, 2022

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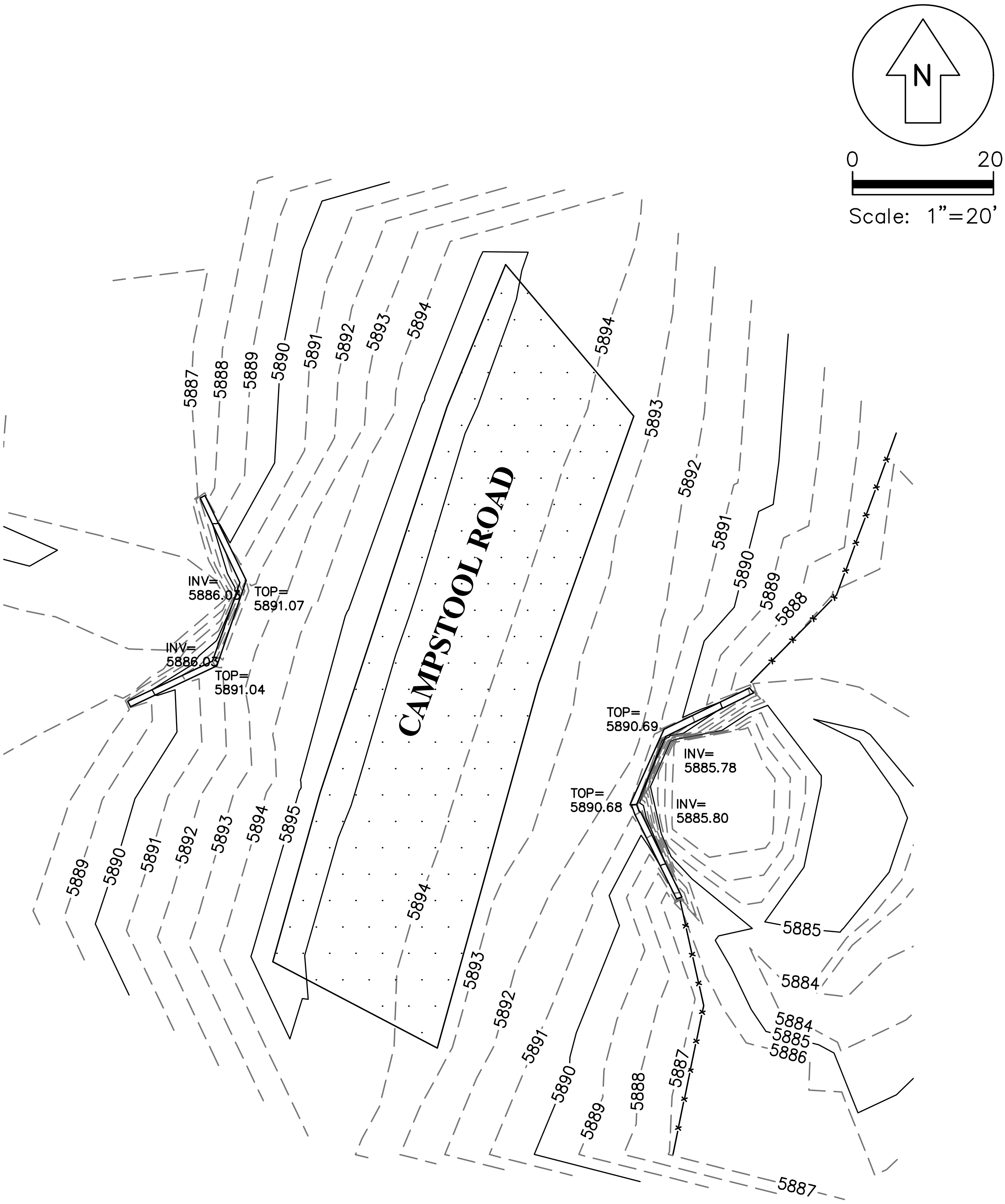

LEGEND

EXISTING BITUMINOUS SURFACE

—x— EXISTING FENCE LINE

TOPOGRAPHIC SURVEY
EXHIBIT
FOR
CAMPSTOOL ROAD,
CITY OF CHEYENNE,
LARAMIE COUNTY, WYOMING.

Date prepared: NOVEMBER, 2022

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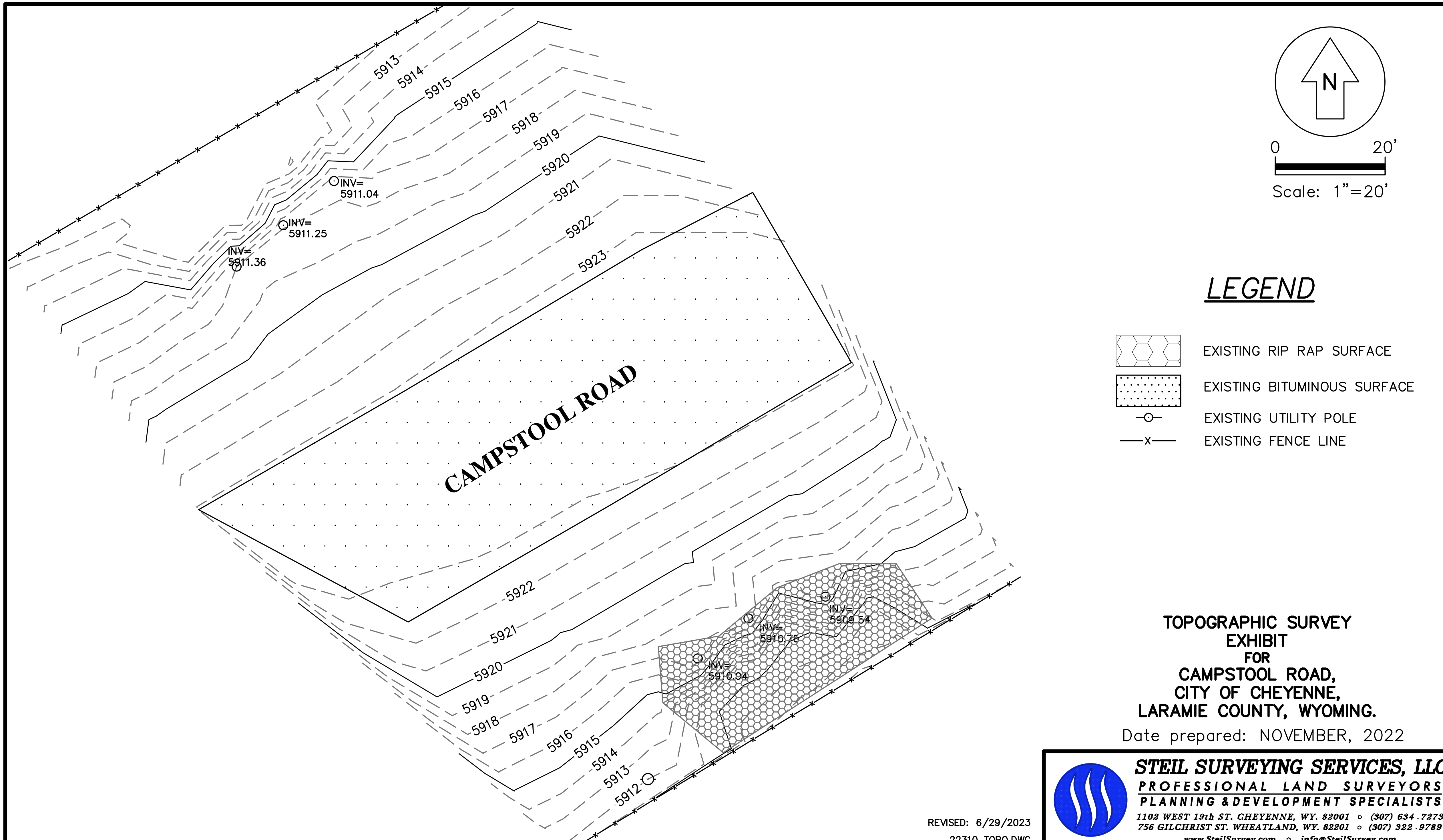

TOPOGRAPHIC SURVEY EXHIBIT FOR CAMPSTOOL ROAD, CITY OF CHEYENNE, LARAMIE COUNTY, WYOMING.

Date prepared: NOVEMBER, 2022

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Scale: 1"=20'

LEGEND

EXISTING CONCRETE SURFACE

EXISTING RIP RAP SURFACE

TOPOGRAPHIC SURVEY EXHIBIT FOR DRY CREEK, CITY OF CHEYENNE, LARAMIE COUNTY, WYOMING.

Date prepared: NOVEMBER, 2022

REVISED: 6/29/2023

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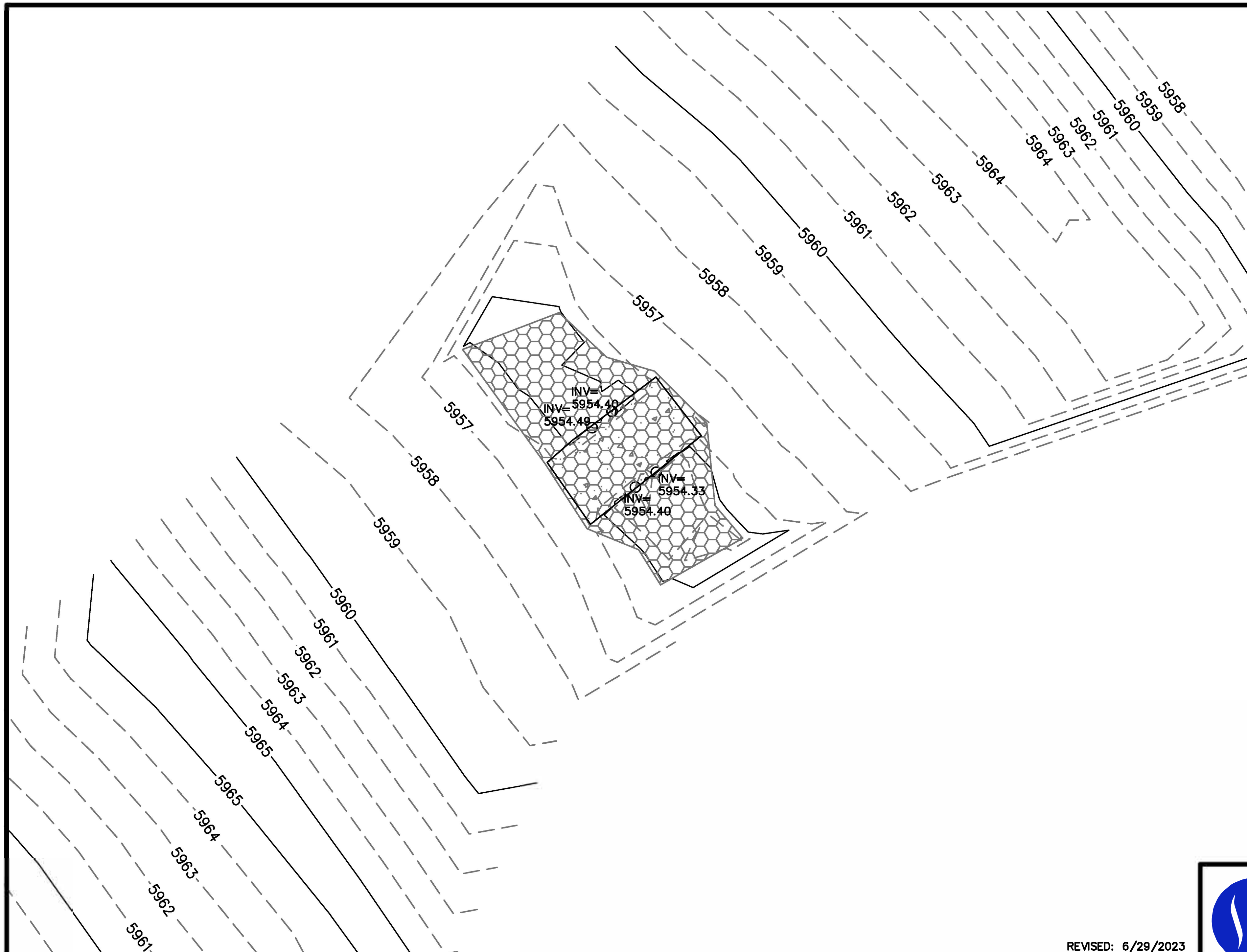

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LEGEND

EXISTING CONCRETE SURFACE

EXISTING RIP RAP SURFACE

TOPOGRAPHIC SURVEY
EXHIBIT
FOR
DRY CREEK,
CITY OF CHEYENNE,
LARAMIE COUNTY, WYOMING.

Date prepared: NOVEMBER, 2022

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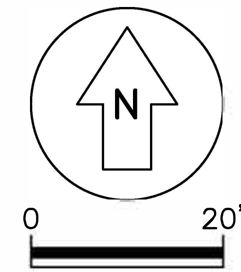

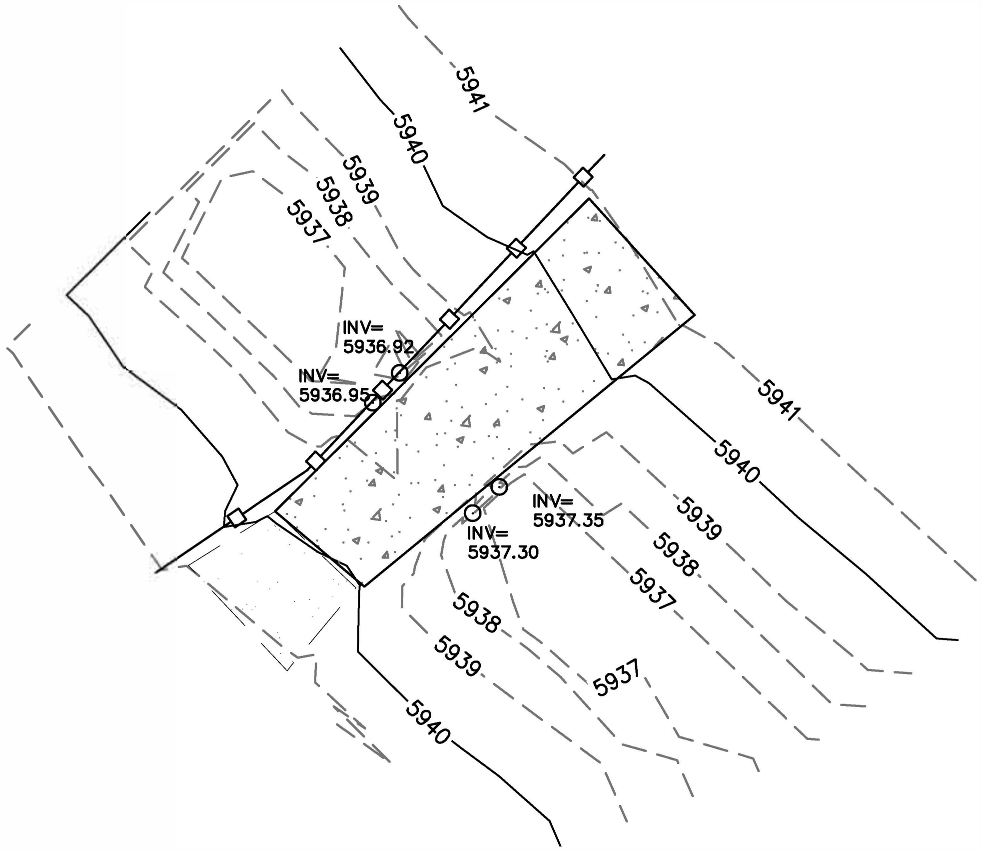

LEGEND

EXISTING GUARD RAIL

EXISTING CONCRETE SURFACE

EXISTING GRAVEL SURFACE

TOPOGRAPHIC SURVEY
EXHIBIT
FOR
DRY CREEK,
CITY OF CHEYENNE,
LARAMIE COUNTY, WYOMING.

Date prepared: NOVEMBER, 2022

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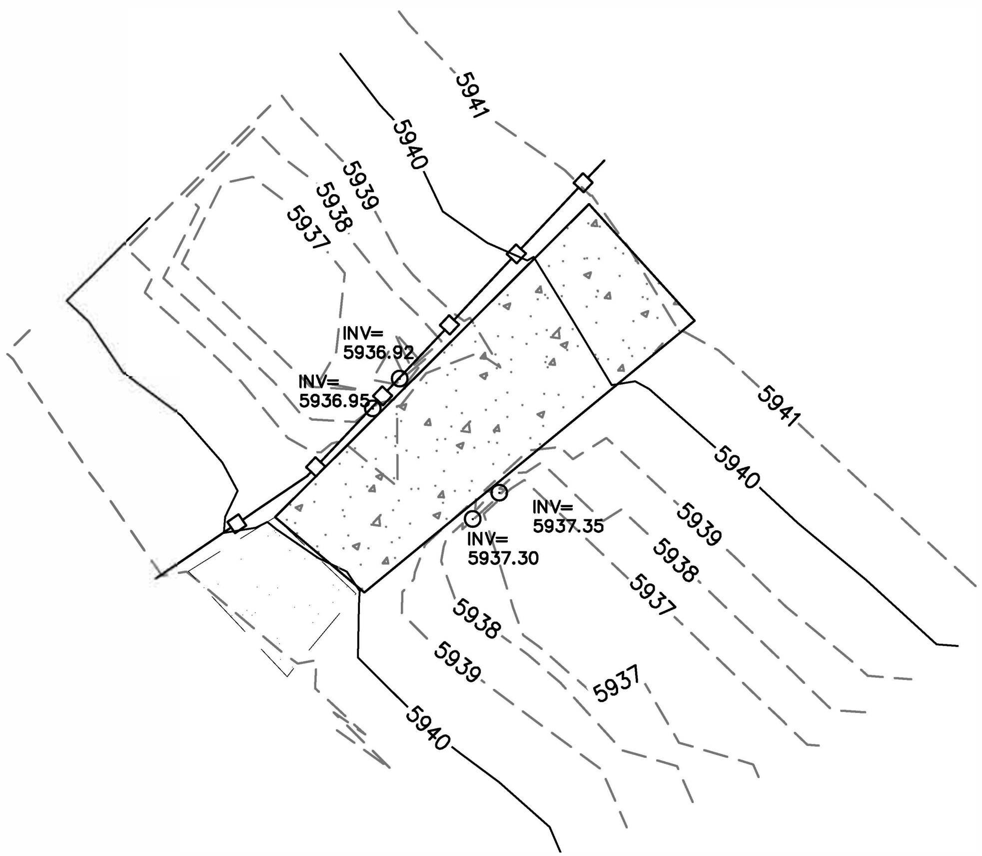

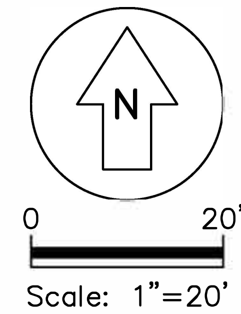

LEGEND

	EXISTING GUARD RAIL
	EXISTING CONCRETE SURFACE
	EXISTING GRAVEL SURFACE

TOPOGRAPHIC SURVEY
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DRY CREEK,
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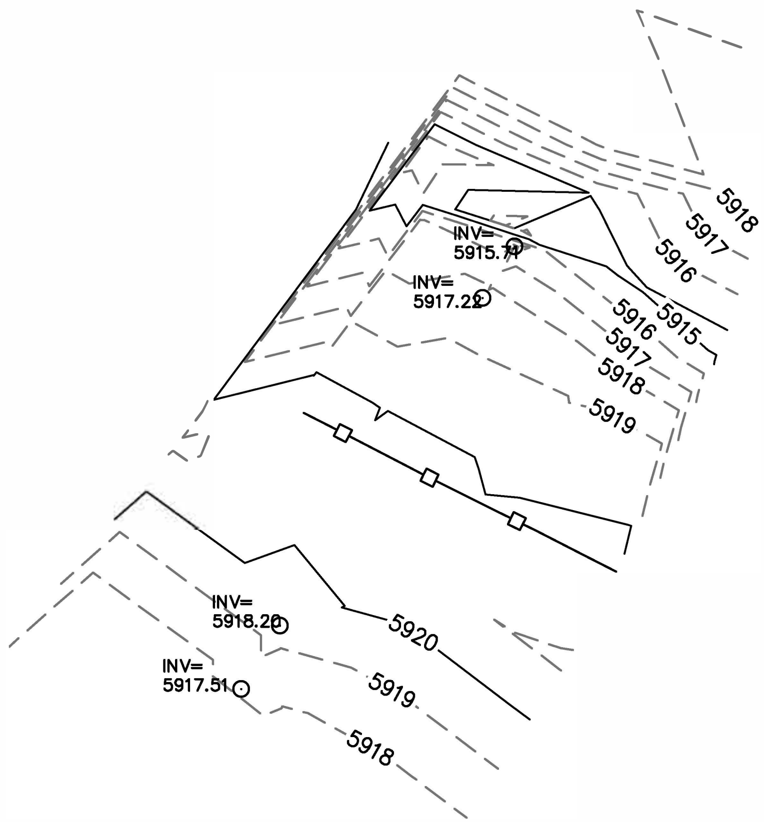

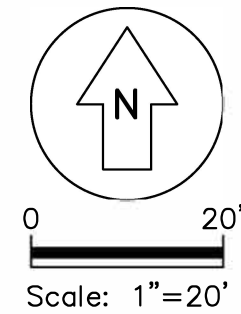

LEGEND

EXISTING GUARD RAIL

TOPOGRAPHIC SURVEY
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DRY CREEK,
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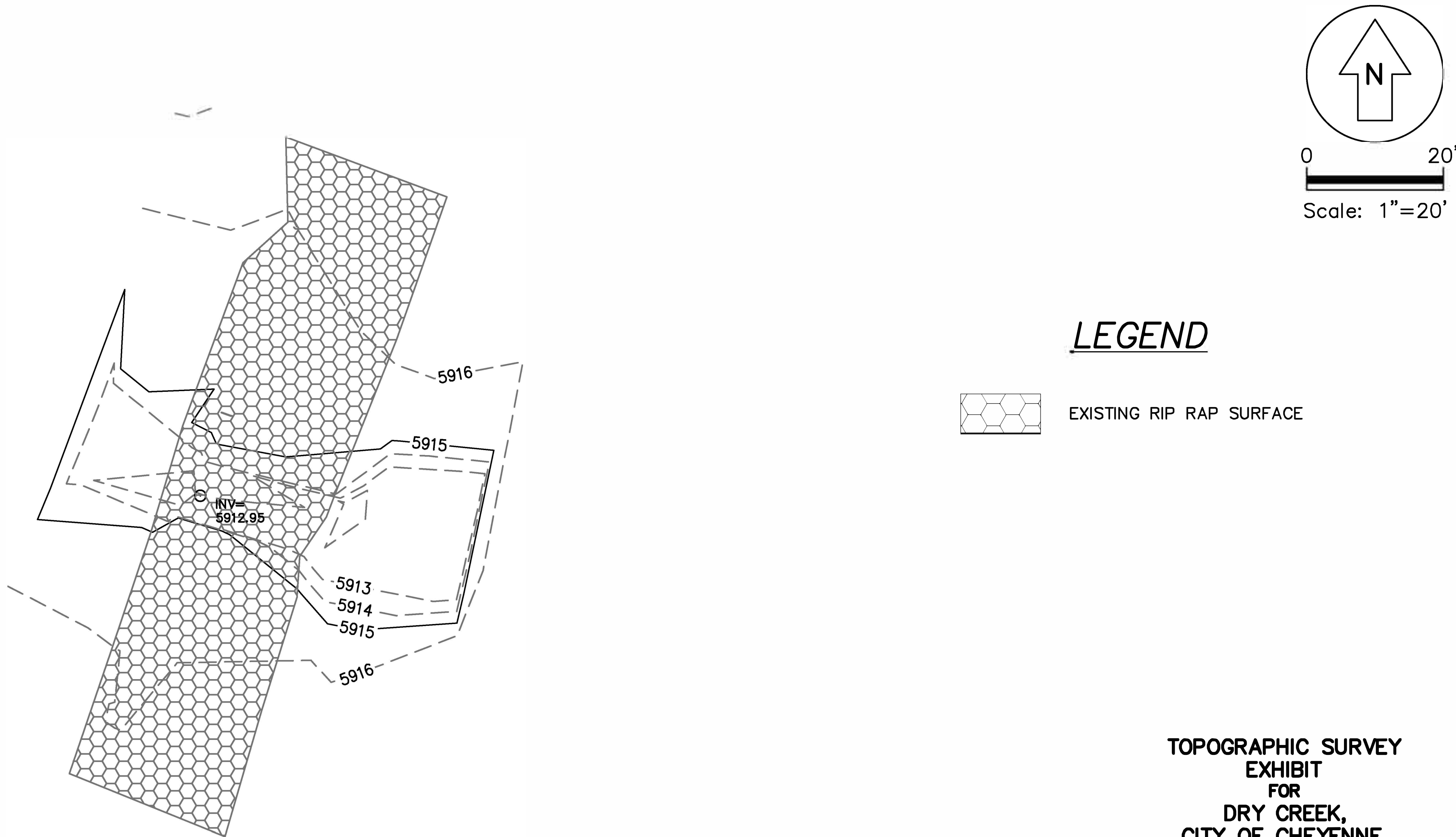

LEGEND

EXISTING RIP RAP SURFACE

TOPOGRAPHIC SURVEY EXHIBIT FOR DRY CREEK, CITY OF CHEYENNE, LARAMIE COUNTY, WYOMING.

Date prepared: NOVEMBER, 2022

REVISED: 6/29/2023

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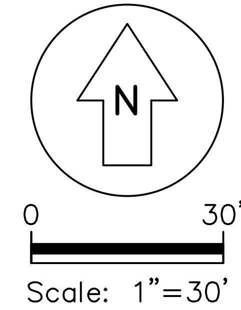

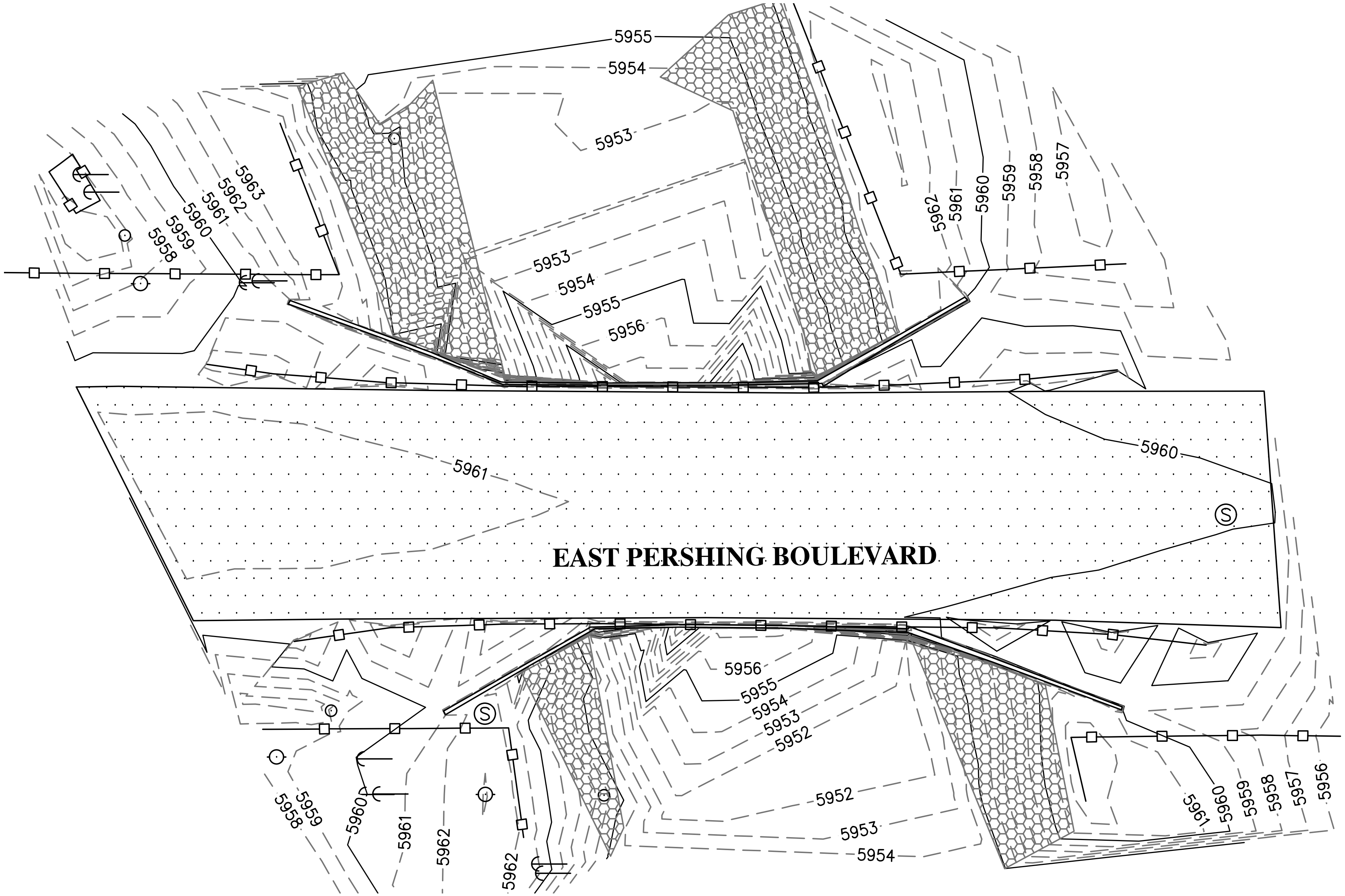

LEGEND

- EXISTING GUARD RAIL
- EXISTING UTILITY POLE
- EXISTING GUY WIRE
- EXISTING SANITARY SEWER MANHOLE
- EXISTING BITUMINOUS SURFACE
- EXISTING RIP RAP SURFACE

TOPOGRAPHIC SURVEY EXHIBIT FOR EAST PERSHING BOULEVARD, CITY OF CHEYENNE, LARAMIE COUNTY, WYOMING.

Date prepared: NOVEMBER, 2022

REVISED: 6/29/2023

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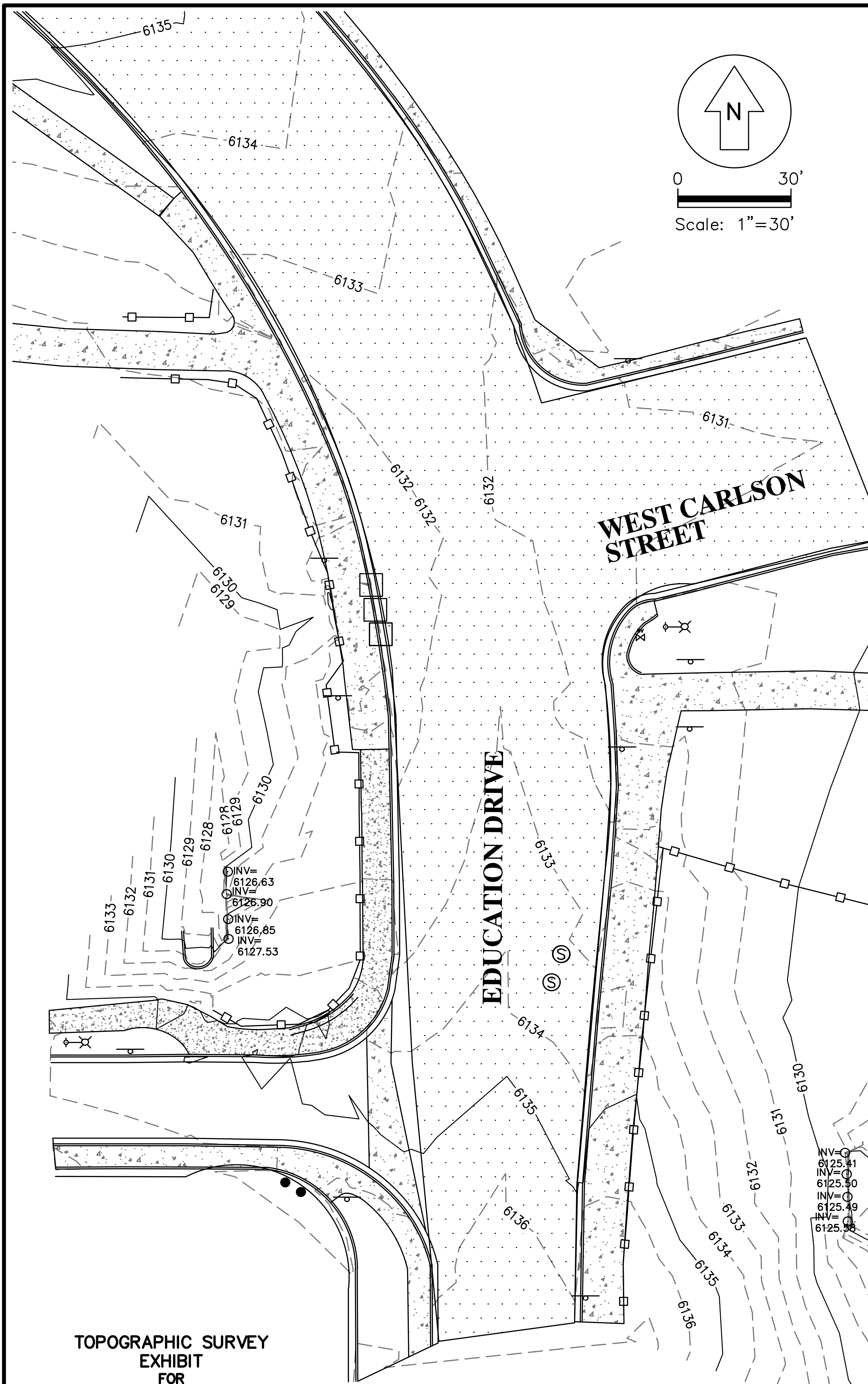

TOPOGRAPHIC SURVEY
EXHIBIT
FOR
EDUCATION DRIVE,
CITY OF CHEYENNE,
LARAMIE COUNTY, WYOMING.

Date prepared: NOVEMBER, 2022

REVISED: 11/9/2022

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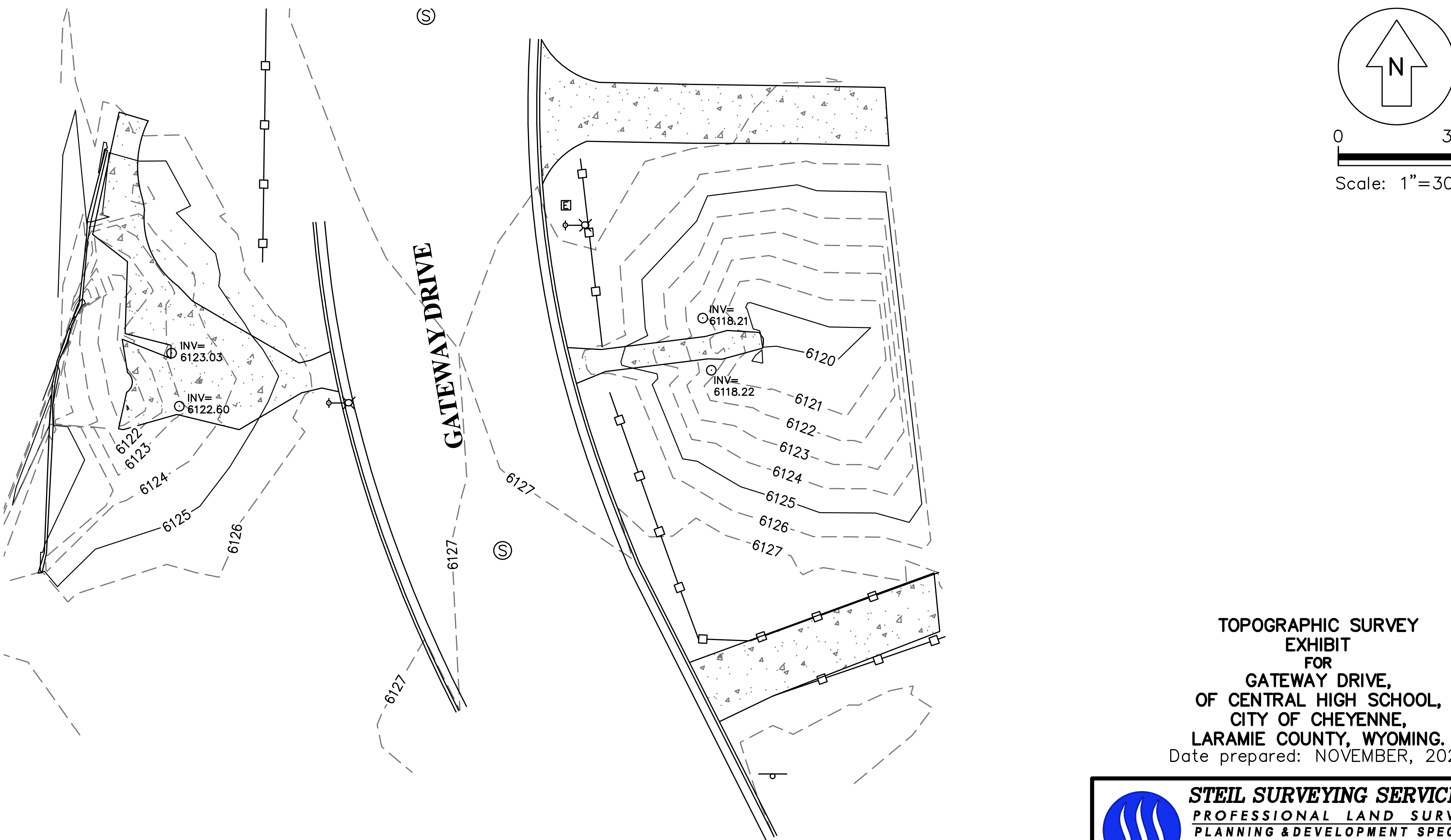

TOPOGRAPHIC SURVEY
EXHIBIT
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GATEWAY DRIVE,
OF CENTRAL HIGH SCHOOL,
CITY OF CHEYENNE,
LARAMIE COUNTY, WYOMING.
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LEGEND

EXISTING CONCRETE SURFACE

TOPOGRAPHIC SURVEY
EXHIBIT
FOR
GREENWAY,
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Date prepared: NOVEMBER, 2022

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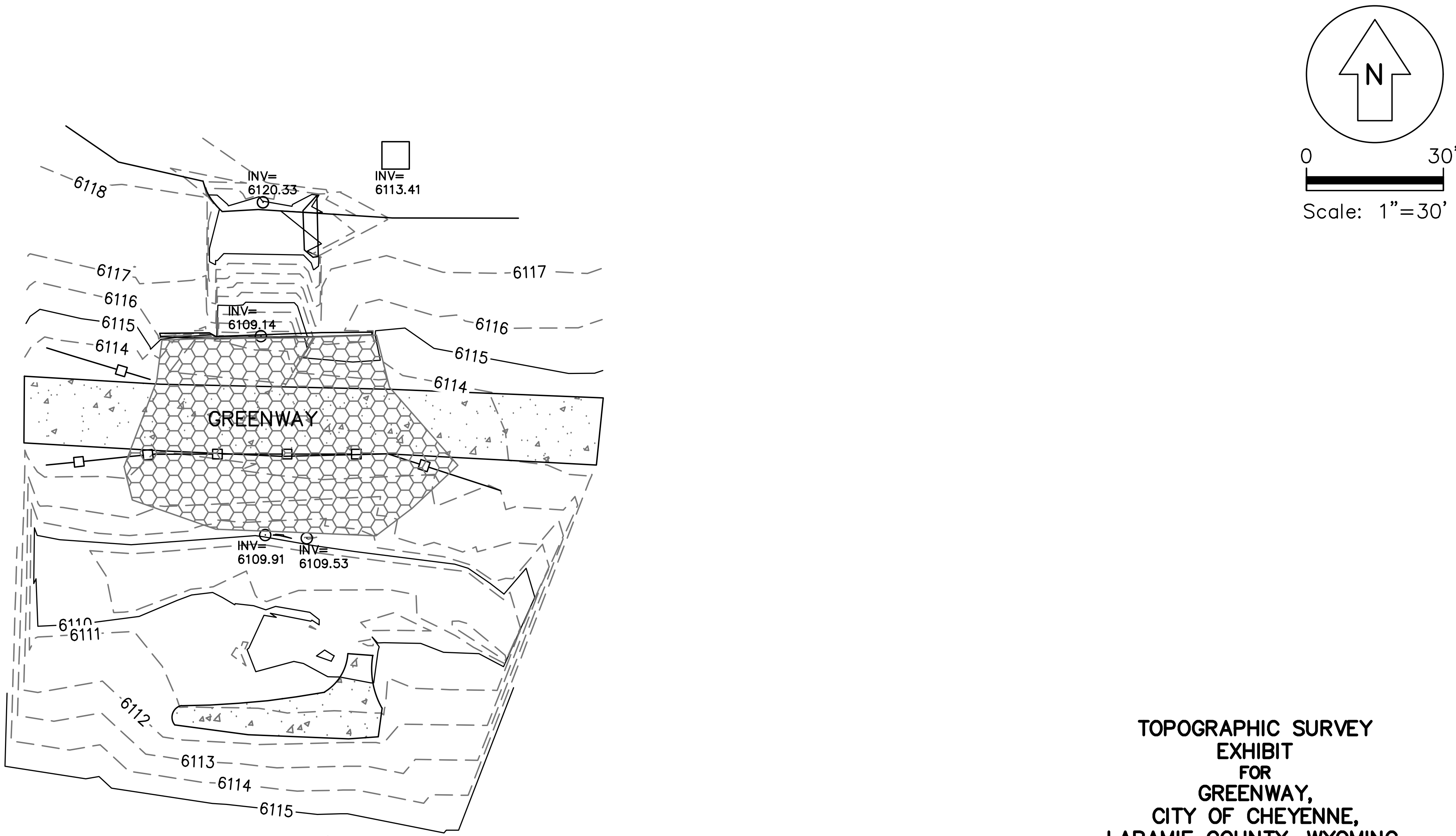

TOPOGRAPHIC SURVEY
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FOR
GREENWAY,
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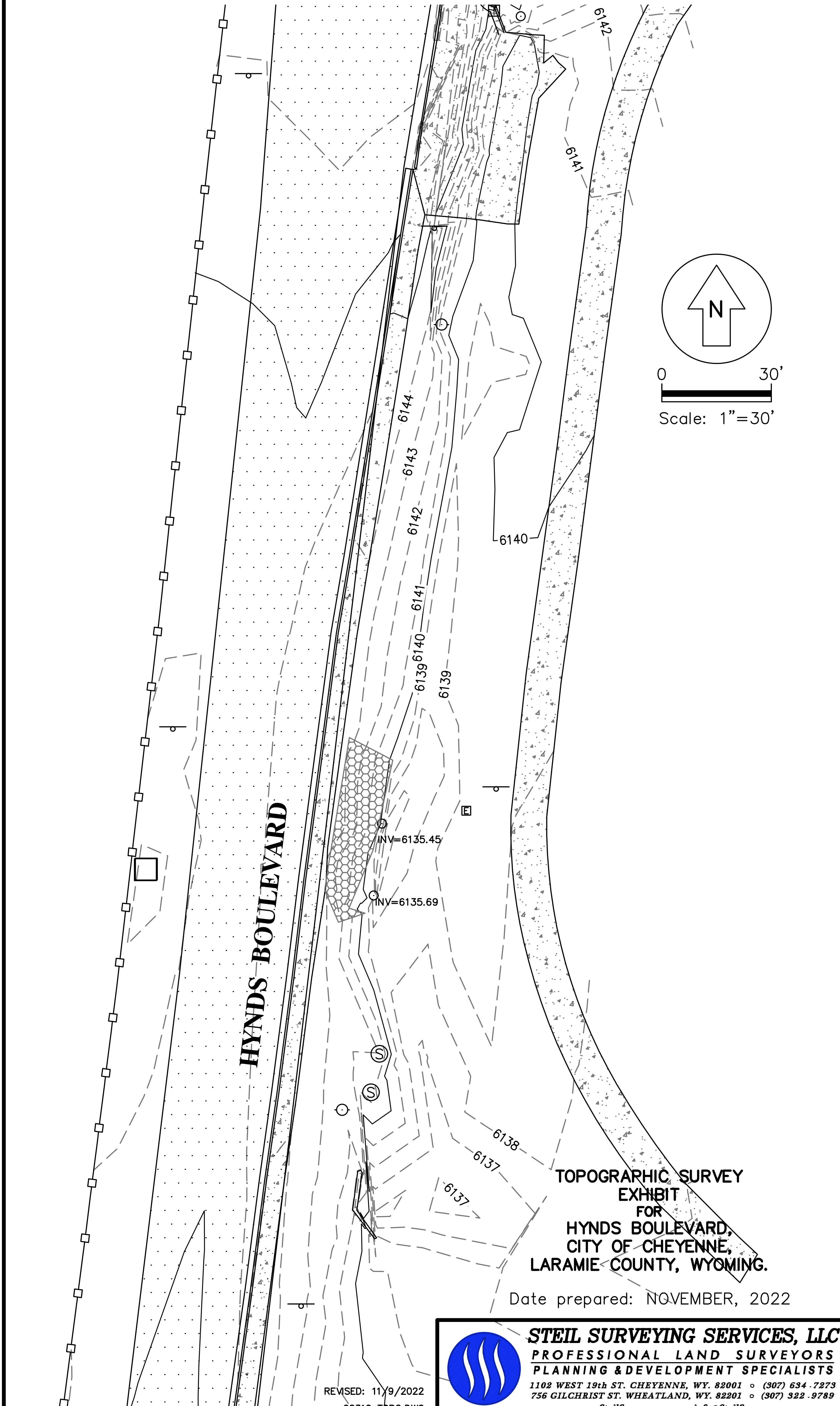

TOPOGRAPHIC SURVEY
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HYNDS BOULEVARD,
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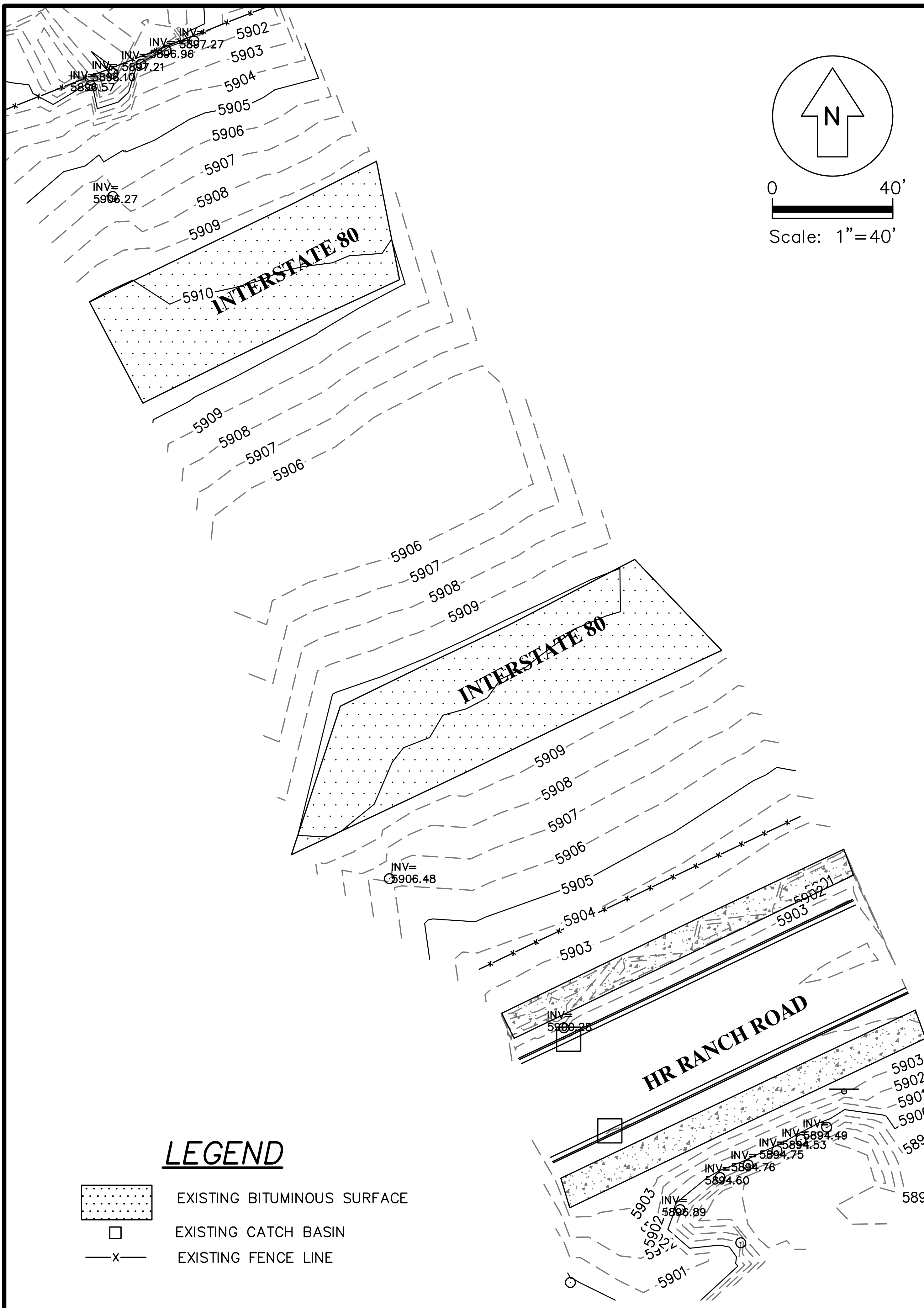
www.SteilSurvey.com ○ info@SteilSurvey.com



LEGEND

EXISTING BITUMINOUS SURFACE

EXISTING CATCH BASIN

EXISTING FENCE LINE

TOPOGRAPHIC SURVEY EXHIBIT FOR INTERSTATE 80 & HR RANCH ROAD, CITY OF CHEYENNE, LARAMIE COUNTY, WYOMING.

Date prepared: NOVEMBER, 2022

REVISED: 6/29/2023

22310 TOPO.DWG

STEIL SURVEYING SERVICES, LLC
PROFESSIONAL LAND SURVEYORS
PLANNING & DEVELOPMENT SPECIALISTS
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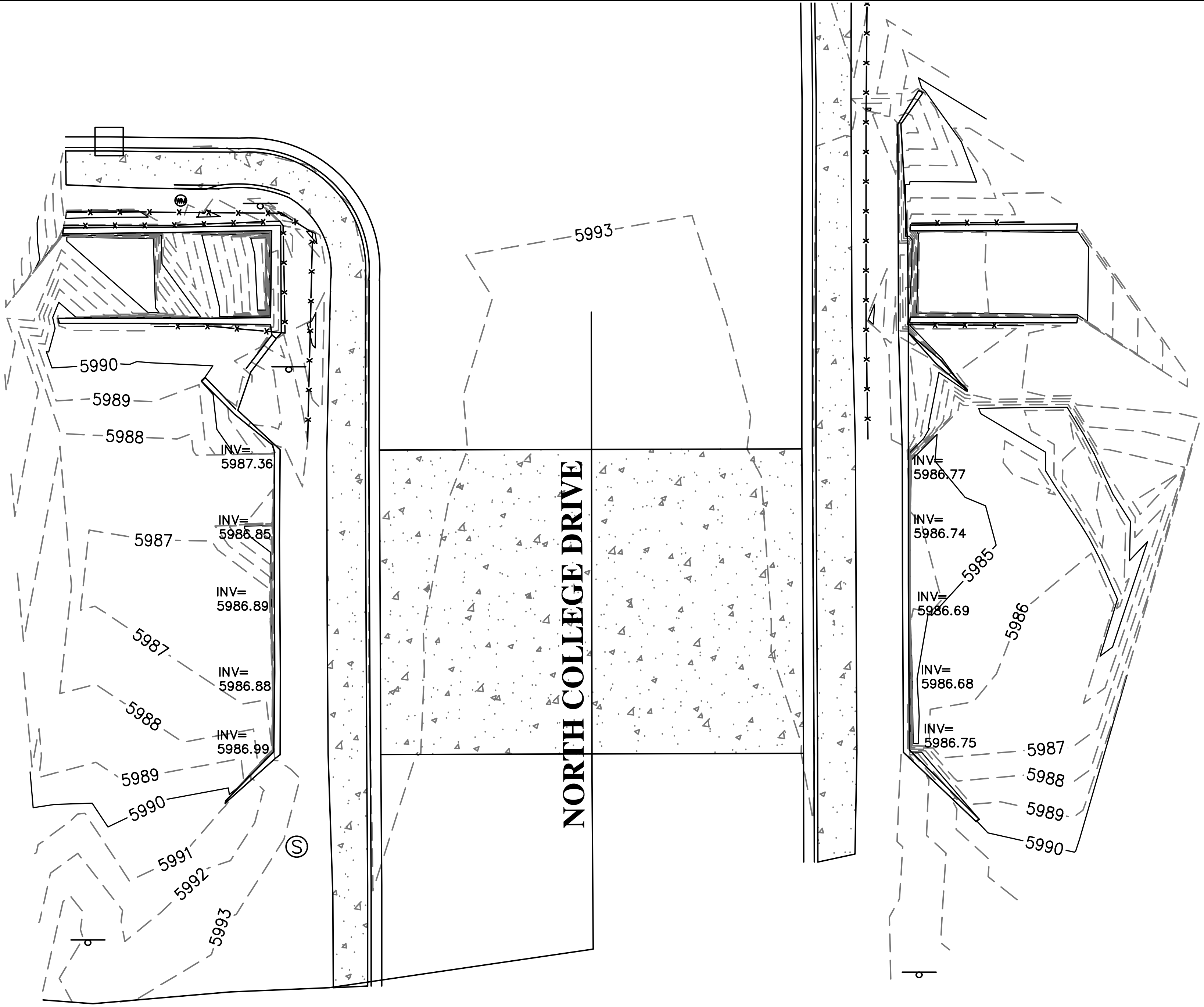

N

0 20'

Scale: 1"=20'

LEGEND

Ⓢ EXISTING SANITARY SEWER MANHOLE
□ EXISTING CATCH BASIN
—x— EXISTING FENCE LINE
EXISTING CONCRETE SURFACE

TOPOGRAPHIC SURVEY EXHIBIT FOR NORTH COLLEGE DRIVE, CITY OF CHEYENNE, LARAMIE COUNTY, WYOMING.

Date prepared: NOVEMBER, 2022

REVISED: 6/29/2023
22310 TOPO.DWG

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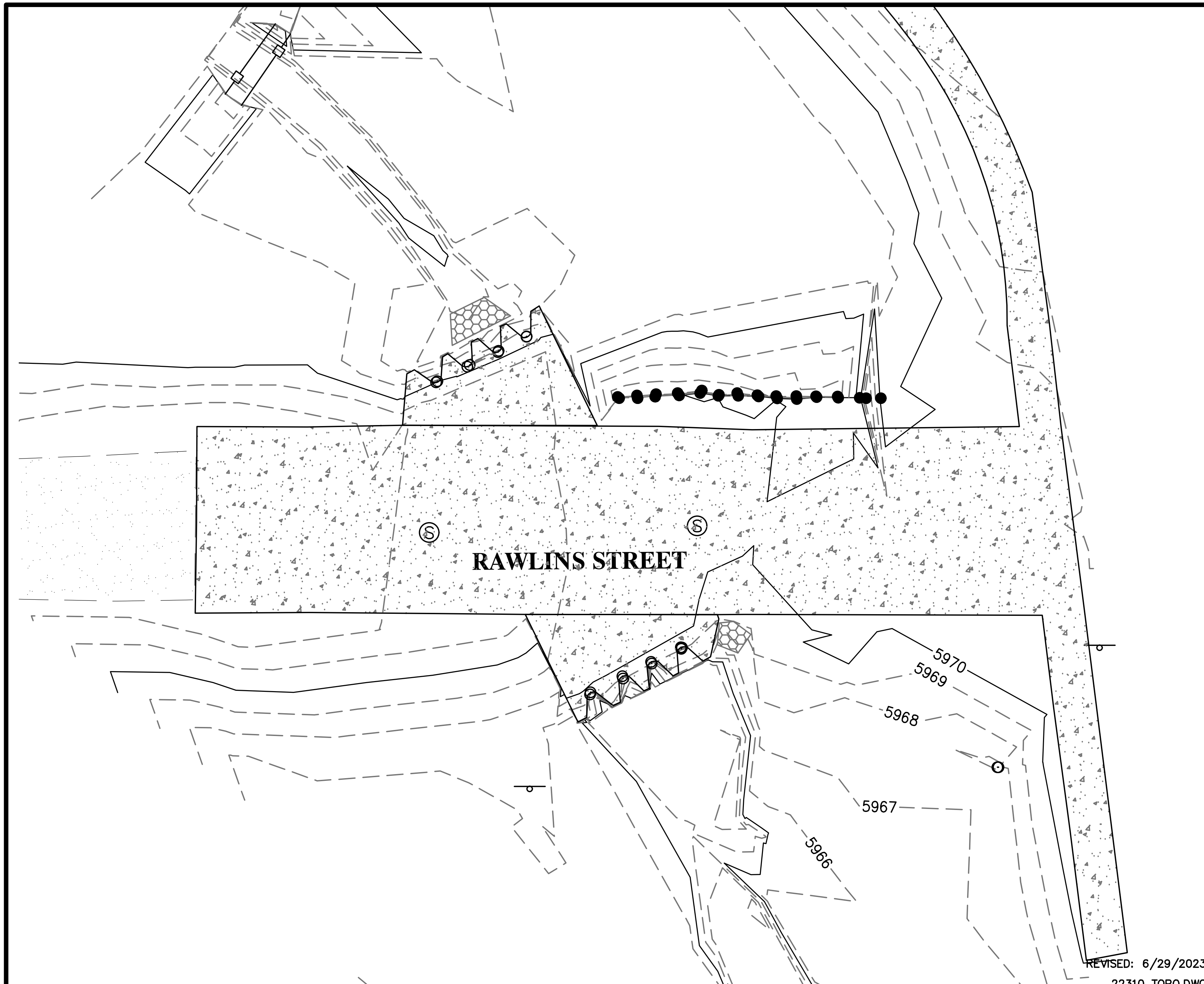

LEGEND

Ⓢ EXISTING SANITARY SEWER MANHOLE

EXISTING CONCRETE SURFACE

TOPOGRAPHIC SURVEY EXHIBIT FOR RAWLINS STREET, CITY OF CHEYENNE, LARAMIE COUNTY, WYOMING.

Date prepared: NOVEMBER, 2022

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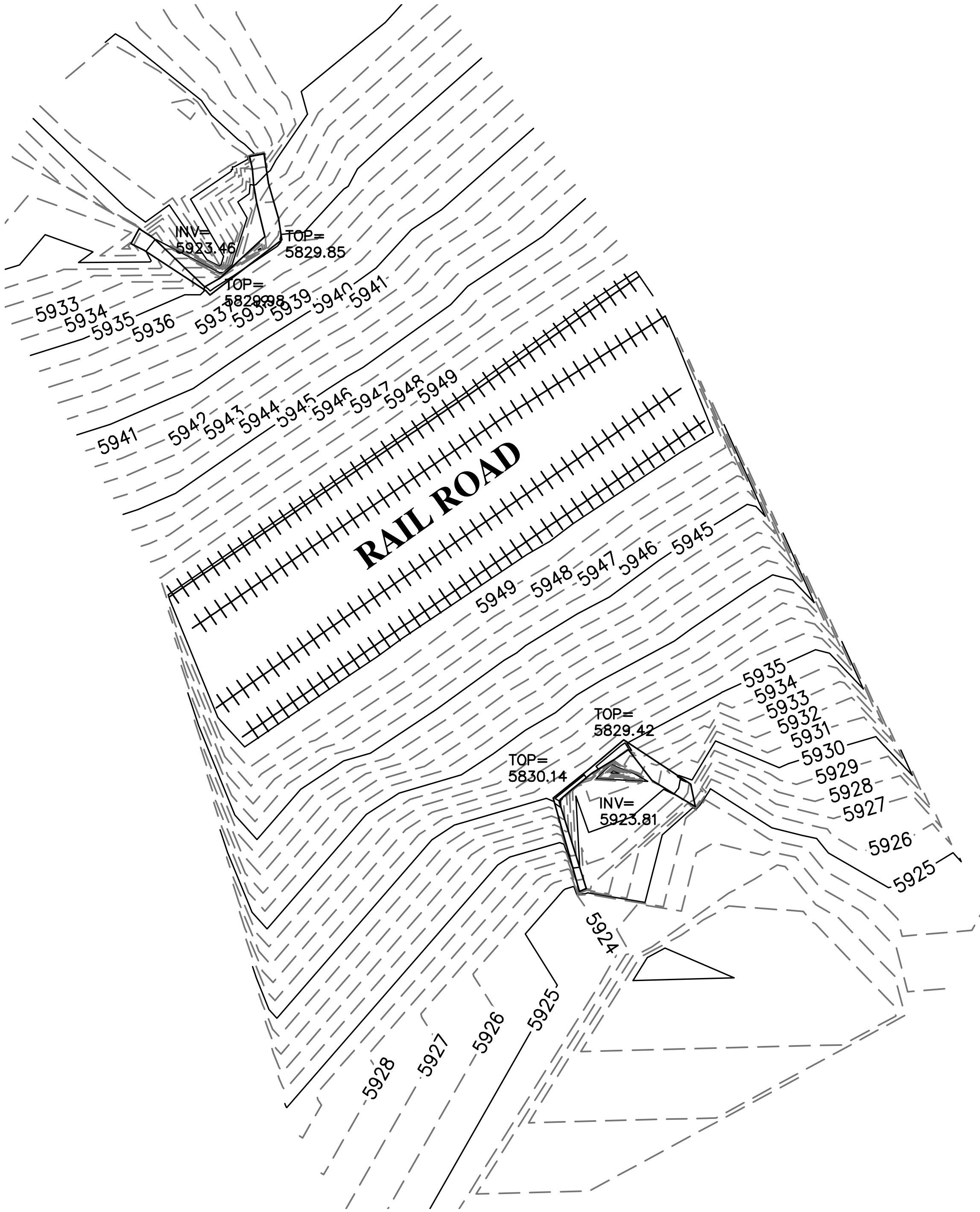

N

0 20'

Scale: 1"=20'

LEGEND

┼┼┼┼┼┼┼┼┼	EXISTING RAIL ROAD TRACTS

TOPOGRAPHIC SURVEY
EXHIBIT
FOR
UNION PACIFIC RAIL ROAD,
CITY OF CHEYENNE,
LARAMIE COUNTY, WYOMING.

Date prepared: NOVEMBER, 2022

REVISED: 6/29/2023

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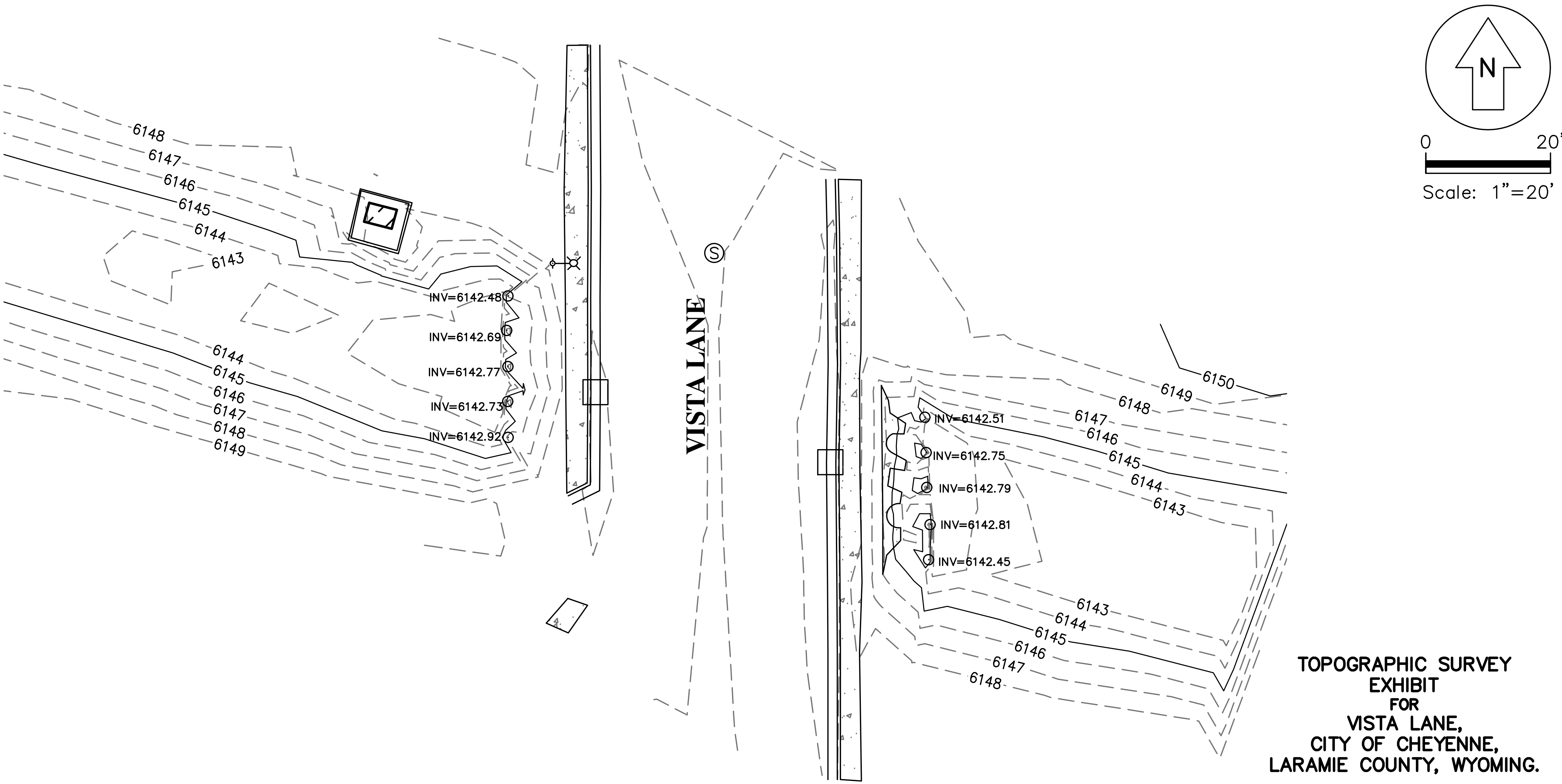

TOPOGRAPHIC SURVEY
EXHIBIT
FOR
VISTA LANE,
CITY OF CHEYENNE,
LARAMIE COUNTY, WYOMING.

Date prepared: NOVEMBER, 2022

REVISED: 11/9/2022
22310 TOPO.DWG

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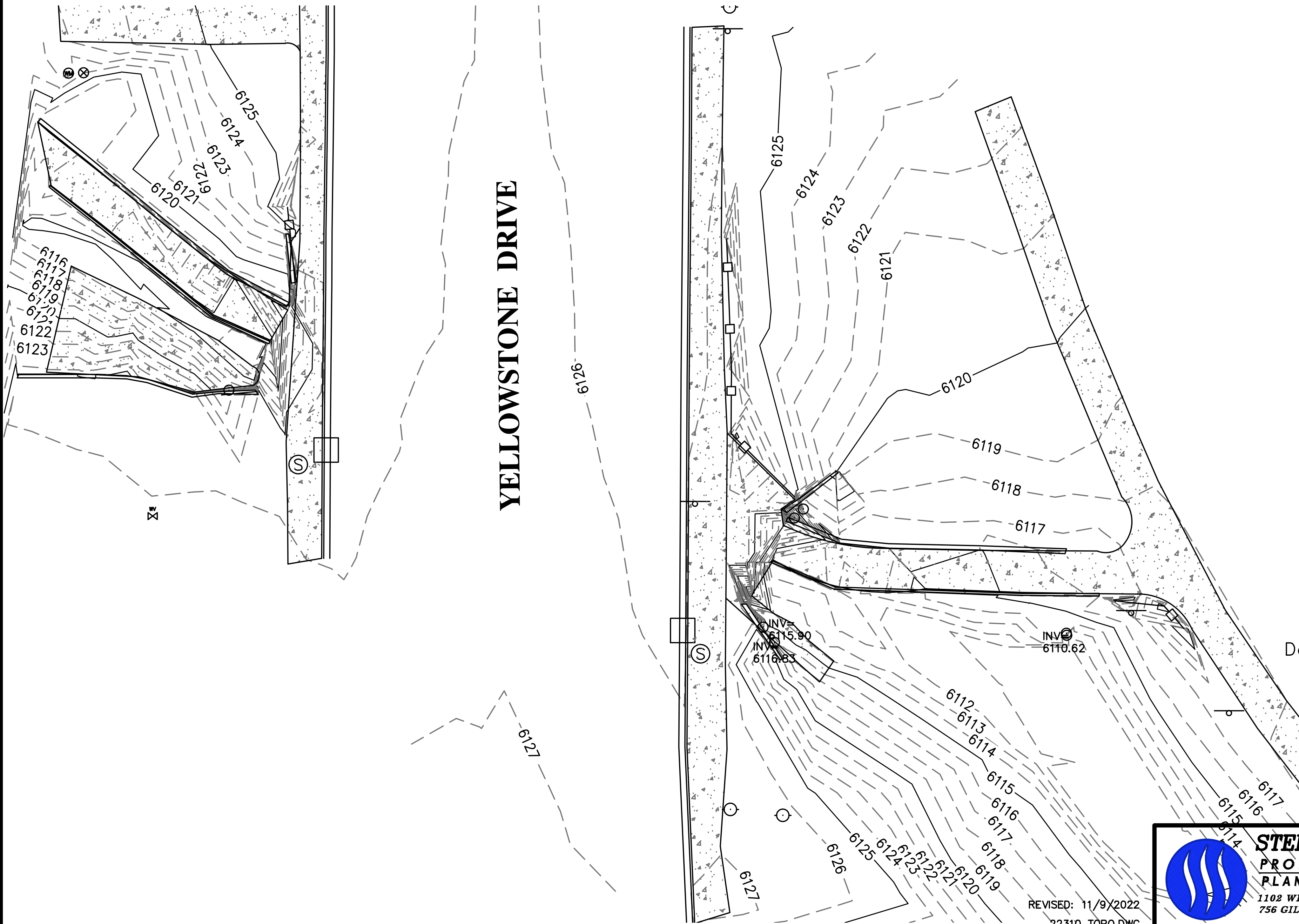

N

0 30'

Scale: 1"=30'

TOPOGRAPHIC SURVEY EXHIBIT FOR YELLOWSTONE DRIVE, CITY OF CHEYENNE, LARAMIE COUNTY, WYOMING.

Date prepared: NOVEMBER, 2022

REVISED: 11/9/2022
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