Storm Water Drainage Master Plan Report

Project

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Table of Contents

List of Tables

List of Figures

Section I – Introduction

A. Authorization

This Storm Water Drainage Master Plan is prepared as a supplemental section to the Civil Utilities Master Plan, authorized under the terms and conditions of Supplement No. 1 to the Architects/Engineers Agreement between the University of Colorado at Boulder and Boyle Engineering Corporation, Work Order Number 422623 / 000694, dated November 10, 2003.

B. Purpose and Scope

This Storm Water Drainage Master Plan report presents the formulation of the drainage master plan for the University of Colorado at Boulder (UCB) Main Campus and East Campus. The purpose of the study was to compile existing drainage information for the two campuses, perform a 5-year design storm event hydrologic and hydraulic analysis of the existing storm sewer system mainlines serving the campuses utilizing data from previous studies, identify and evaluate drainage improvements, and develop a comprehensive drainage master plan for a future build-out drainage system. The criteria for a 5-year design storm event was requested by UCB. The analyses performed for this study were limited to the main branches of the system and did not include an evaluation of the inlets, connecting laterals, roof drains, and other minor conveyance systems.

Background information on the existing storm sewer system is included in this report, as well as summaries of the 5-year hydrologic and hydraulic analyses developed for the existing and future drainage conditions. The details of the existing and future condition drainage systems evaluated during this study are discussed in the report and summarized in the appendices.

The concepts proposed in this report are intended to serve as a comprehensive summary of existing storm water infrastructure on the University's main and east campuses as well as provide a foundation for future storm water planning, final design of drainage infrastructure, and improvement implementation. The analyses and drawings prepared for this storm water drainage master plan are based on previous studies as well as surveyed information. This report represents preliminary and conceptual engineering and is subject to change as information is field verified.

Boyle has reviewed an extensive amount of site infrastructure information obtained from numerous sources, including UCB and the City of Boulder. Storm sewer system characteristics such as inlet grate elevations, manhole and inlet inverts, pipe lengths, pipe slopes, pipe sizes, pipe materials, and pipe shapes are based on researched as-built information, site surveys, and logical assumptions. Logical assumptions were required to evaluate sections of the system where as-built information was not available. Additional field surveys to confirm site features, utility information, and elevations should be conducted prior to final design of any future improvements.

C. Background

When the University of Colorado at Boulder was first planned and the first buildings were constructed, there were no drainage master plans for the campuses. Most of the surface runoff was either intercepted by irrigation ditches or conveyed along streets or other natural topographic features. Runoff was generally directed across campus to Boulder Creek. Roof drains were connected to foundation drains and foundation drains were connected to underground tunnel drainage systems. According to facility management personnel, tunnel systems were frequently flooded. Over the years, minor systems were constructed to alleviate surface flooding, but these systems were constructed on an "as-needed basis," without consideration for future development.

In the past ten years, major drainage system improvements have been designed and constructed on both the Main Campus and East Campus. Design reports, design drawings, and as-built plans were published to document drainage conditions and to propose storm water improvements for separate areas on campus. Because these separate projects were performed without the benefit of a master plan, the completed improvements were not documented in a comprehensive manner in order for the University to determine what areas of campus have adequate storm water infrastructure and what areas are deficient and may need future improvements.

In 1970, the University designed a storm drain near the current Student Recreation Center that collected a substantial amount of storm water runoff from the west side of the main campus. A set of record drawings for this storm drain line was prepared by the University (Reference 1).

In 1979, the University initiated the renovation and expansion of the Ramaley Building located in the north and center portion of the main campus. As part of the construction activities, improvements to the storm water drainage system in this area were constructed and set of design drawings were produced by Tri Consultants (Reference 2).

In 1984, the City of Boulder prepared a "Storm Water Collection System Master Plan" (Reference 3), which included the University campuses. In that study, existing drainage systems were shown on campus with a recommended new drainage system shown on Folsom Street to convey campus flows.

In 1991, the University began to expand and renovate the Student Recreation Center located south of Boulder Creek in the center of the main campus. As part of the construction activities, improvements to the storm water drainage system in this area were constructed that affected the drainage capacity of a large portion of the center of the main campus north and northwest of Colorado Avenue. A set of record drawings of the construction were prepared by John James Wallace & Associates (Reference 4).

In 1992, the Dal Ward Center was completed and as-built drawings were produced (Reference 5). As part of this construction, storm water improvements were constructed in the vicinity of Folsom Field.

In 1992, the MCDB Addition to the Biosciences Building (Reference 6) was completed to the west of Folsom Field. The construction of this building resulted in a significant amount of impervious area due to the completion of the building and the construction of an adjacent paved plaza.

In 1995, Boyle Engineering performed a study for the University's East campus called "Drainage Study For East Research Campus" (Reference 7). This study addressed the drainage requirements for the east campus northwest of Boulder Creek and bounded by Arapahoe Avenue to the North and 30th Avenue to the West. This analysis developed design criteria, estimated potential facility sizes, proposed the location of future improvements and estimated improvement costs.

In 1996, the University prepared construction documents for the "18th and Colorado Storm Drain Project" (Reference 8). This project involved abandoning an existing undersized storm pipe in Colorado Avenue and constructing a new 27" to 48" reinforced concrete pipe system.

In the spring of 1996, Boyle Engineering Corporation prepared construction documents for the "Research Laboratory No. 2 Foundation Design" (Reference 9). This project involved designing a system to control and capture groundwater seepage into Research Laboratory No. 2 and pumping it to Boulder Creek.

In 1998, the University prepared a "Storm Drainage Study for Storm Drainage & Roadway Improvements" (Reference 10), providing recommended drainage improvements for the drainage basin south and west of the intersection of Folsom Street and Colorado Avenue.

In 2000, the University prepared a drainage study entitled, "Schematic Design Phase Design Record Document - Southwest Quad Storm Sewer Upgrade" (Reference 11). This report outlined recommended drainage improvement designs for the drainage basin south and west of the intersection of Colorado Avenue and 18th Street.

In March of 2001, the University published a comprehensive master plan with the intention that this document would serve as "a guide for future physical development of the campus." This master plan addresses the University's future goals, history, facility needs, land planning, and implementation (Reference 12).

In May of 2002, Kirkham Michael Consulting prepared as-built drawings documenting the construction of storm sewer upgrades around the perimeter of the Sibell-Wolle building that tie-in to the 24-inch storm sewer line located in 18th Street (Reference 13).

In September 2002, Love & Associates, Inc. published a "Final Hydraulics Report for 28th Street Improvements" (Reference 14) for the City of Boulder. This report details improvements to the storm water drainage system that will be made along 28th Street during the construction of roadway improvements between Baseline Road and Arapahoe Avenue. Based on this study, several University pipes, adjacent to 28th Street are to be improved.

D. Mapping and Surveys

The University did not request a separate survey for the entire campus for this master planning project. The topography, utilities information, and base map used for this master plan were provided by the University's Facility Management Department. Elevation information was obtained from project as-built drawings, drainage studies, and site surveys. Boyle attempted to match elevations found on the as-built drawings, studies, and surveys with campus mapping However, elevations obtained from as-built drawings and drainage studies are not, in some instances, on the same datum as the UCB mapping. As a result, Boyle compiled as-built information to complete separate drainage analyses for various areas of campus. Boyle assumes no responsibility for the accuracy of the information provided by or obtained from the University.

Section II – Study Area Description

A. General

The study area for the Main Campus is approximately defined by Boulder Creek to the north of Folsom Field, Folsom Street to the east of Folsom Field, Colorado Avenue to the east of Folsom Street, 28th Street as the east boundary, the Kittredge Complex to the south, and Broadway as the southwest boundary from University Avenue to the Kittredge Complex (See Figure 1). The study area for East Campus is defined by Arapahoe Avenue to the North; 30th Avenue to the west; and Boulder Creek along the southeast (See Figure 6).

B. Topographic Features

The overall master plan area for the Main Campus slopes from the southwest to the northeast at a mild slope toward Colorado Avenue. The area north of Colorado Avenue slopes steeply toward Boulder Creek. The sub-basin slopes vary between four to five percent to nearly flat south of Colorado Avenue, and up to more than fifty percent north of Colorado Avenue. The East Campus area gently slopes south to Boulder Creek.

C. Existing Drainage Systems

The University's main campus is divided into 5 major drainage basins corresponding to 5 major storm sewer outfalls that convey storm water runoff away from the Main Campus. Refer to Figures 2 -6 for the location of major basins, sub-basins, and outfalls. The area of analysis for the University's East Campus is much smaller in comparison to the Main campus and is broken into several minor basins having independent outfalls to Boulder Creek.

Drainage Basin A – Kittredge Complex Outfall

The approximate boundaries of Drainage Basin A are as follows:

- 28th Street to the east
- Baseline Road to the south
- Broadway to the southwest, and
- A ridge between Fiske Planetarium and Coors Events Conference Center to the north

Generally, all flows within the Kittredge Loop Road are conveyed to a series of two ponds located in the middle of the Kittredge Complex. The upper pond near the Commons 408 building fills then overflows a weir structure to the lower pond near the Buckingham building. Flows from the lower pond then overflow another weir structure into a ditch that drains to an inlet and underground storm sewer system. Flows from this system are conveyed under 28th Street and continue eastward until they reach Boulder Creek. Based on data provided from the City of Boulder, the City's drainage system between 28th Street and Boulder Creek necks down from a 30-inch pipe to a 24-inch pipe. Jason Fell, a representative from the City of Boulder stated that the City's drainage systems generally convey the 2-year flow and are already overtaxed during frequent storm events.

The existing Kittredge Complex ponds provide only minor storm water attenuation. It is understood from conversations with UCB facilities management the ponds have accumulated a large amount of sediment, which has reduced their storage capacity. There appears to be sufficient relief in the topography for storm water to be conveyed away from the Kittredge Complex without significant damage to the surrounding buildings.

Drainage Basin B – 28th Street Outfall

Drainage Basin B is long and narrow and flows in a northeasterly direction towards the two University ponds located adjacent to the Regent Drive Autopark at the intersection of Colorado Avenue and 28th Street. The southern portion of Basin B on the main campus generally follows Regent Drive. The northern portion of Basin B drains north towards Colorado Avenue and then east towards 28th Street. The approximate boundaries of Drainage Basin B are as follows:

- 28th Street to the east
- A ridge between Fiske Planetarium and Coors Events Conference Center to the south
- Broadway to the southwest
- A ridge running east to west north of Willard Loop Drive then turning north along Cockrell Drive to Colorado Avenue
- Colorado to the North

Prior to recent drainage improvements on campus, it appeared that storm water runoff produced by Drainage Basins B and C was conveyed to an outfall southwest of the intersection of Colorado Avenue and 28th Street. In the spring of 1994, a new City storm pipe was designed and has since been installed in Folsom Street, separating Basins B and C.

There are two major storm pipe systems located within Basin B. Runoff in the vicinity of the Aerospace, Mechanical, Electrical, Civil, and Chemical buildings are intercepted by local drainage systems consisting of 6 to 24-inch piping that is conveyed to a major 30-inch storm pipe running north along Regent Drive that connects to a 24-inch storm pipe along the south side of Colorado Avenue. The 24-inch pipe discharges into the north pond located southwest of the intersection of Colorado and 28th Street. Flows are attenuated in the pond and then discharged into the City's storm pipe system along the west side of 28th Avenue.

The second major storm pipe system runs north-easterly along Regent Drive and discharges into a small pond located on the east side of the Regent Drive Autopark. Minor flows are attenuated in the pond and then discharged into the City's storm pipe system along the west side of 28th Avenue. A diversion structure is also located in the southern pond, diverting some flows to the north pond. Runoff from Regent Drive parking lots, Observatory Field, part of the Coors Events Conference Center, Business Field and the Police/Parking Center are intercepted by local inlets and conveyed in 18 to 48-inch storm piping to the south detention pond.

Drainage Basin C – Folsom Street Outfall

Drainage Basin C encompasses a large area of the central and southwestern portions of the main campus. A major storm system has been constructed along 18th Street and Colorado Blvd to intercept and convey 2-year flows from this area. The approximate boundaries of Drainage Basin C are as follows:

- A ridge running east to west north of Willard Loop Drive then turning north along Cockrell Drive to Colorado Avenue
- Broadway to the southwest, and
- A ridgeline running along the University Theatre and Dance, Ekeley Sciences, and Ketchum buildings, and Colorado Avenue to the north

18th Street serves as a drainage sub-basin division for Drainage Basin C. Runoff on the west side of 18th Street is intercepted by inlets and minor drainage conveyance systems, which then convey to a 24" storm pipe in 18th Avenue that drains north to the 36" and 42" storm pipes in Colorado Avenue. Runoff east of 18th Street and south of Colorado Avenue, with the exception of a small area behind the Environmental Design building, is intercepted and conveyed by a storm system that consists of piping ranging from 18 to 30 inches in diameter. This newly constructed system connects to a major 27 to 42-inch storm pipe system in Colorado Avenue. In addition, the piping system recently installed conveys flows captured south and east of the Math Building to the Folsom Street outfall.

Drainage Basin D – Dal Ward Athletic Center Outfall

Drainage Basin D generally encompasses a small area between Colorado Avenue and Boulder Creek. The approximate boundaries of Drainage Basin D are as follows:

- The east side of Folsom Field
- Colorado Avenue to the south
- Roof ridges between the Ramaley Building and the Balch Field House to the northwest, and
- Boulder Creek to the north

Drainage Basin D collects runoff generated in the plaza areas surrounding the MCDB, Ramaley, and Balch Field House buildings. The basin also collects runoff inside Folsom Field and an area surrounding the Dal Ward Athletic Center.

Drainage Basin E – Student Recreation Center Outfall

Drainage Basin E is located west of Drainage Basin D. The approximate boundaries of Drainage Basin E are as follows:

- Roof ridges between the Ramaley Building and the Balch Field House to the southeast
- A natural ridge on the northwest between Guggenheim and Pleasant Street, which continues northeasterly to the Student Recreation Center.
- A ridge running along the University Theatre and Dance, Ekeley Sciences, and between Ketchum and Norlin Library to the south

- Colorado Avenue to the south
- Broadway to the southwest, and
- Boulder Creek to the north

Other campus areas located north and west of Drainage Basin E have minor drainage systems and are not included in this master planning study as directed by Facilities Management.

East Campus Drainage Basin

The East Campus drainage basin included as part of this study has the following boundaries:

- Arapahoe Avenue to the north
- 30th Avenue to the west
- Boulder Creek to the south and east.

The majority of the east campus basin consists of impervious areas. The impervious areas are comprised of roadways, parking lots, and buildings. There are small areas of green space adjacent to the north embankment of Boulder Creek. Driveways and parking lots convey most of the storm water runoff.

Section III – Hydrologic Analysis

A. General

Hydrologic analyses for the majority of the recently constructed drainage systems on campus were performed in previous studies using the Rational Method as described by the Boulder County Storm Drainage Criteria Manual (BDSDCM) (Reference 17). This method is generally used for drainage basins less than 160 acres in size. The Rational Method computes the maximum rate of runoff using the formula:

Q=CIA	where:	Q	=	flow in cubic feet per second (cfs)
		C	=	runoff coefficient
		I	=	rainfall intensity in inches per hour
		A	=	basin area in acres

B. Rational Method Parameters

Composite runoff coefficients were established for each sub-basin. If basins or sub-basins were analyzed as part of a previous drainage study, the runoff coefficients from those studies were used in determining coefficients for this master plan. If basins or sub-basins were not modeled in the past, runoff coefficients were estimated using an area-weighted average based on the following values found in prior studies:

Table 1: Runoff Coefficients

Land Use	Runoff Coefficient 5-Yr. Frequency
Open Space	.10
Buildings and Paved Surfaces	.90

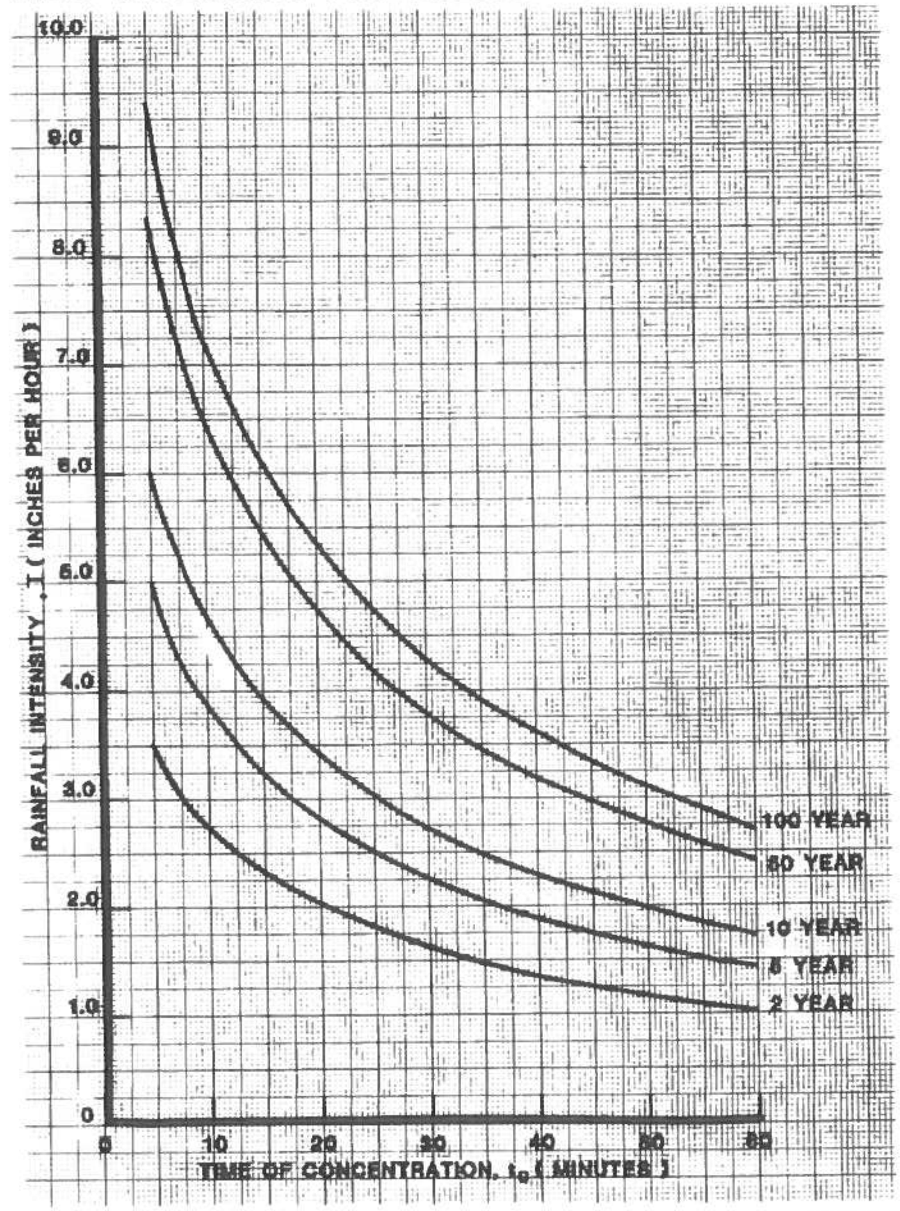
The drainage basins of the University's main and east campuses consist of buildings, roadways, and open space areas. Open spaces on campus typically include walkways and green spaces (such as Farrand Field) as well as landscaped areas. Each sub-basin was broken down into two categories, low impervious areas such as lawn and landscaped areas and highly impervious areas such as roof areas and paved areas. A composite runoff coefficient ("C"-value) was then calculated for each sub-basin based on the percentage of each area type within the sub-basin.

C. Rainfall Design

The BCSDCM divides Boulder County into four rainfall intensity zones. The City of Boulder and the University of Colorado at Boulder are included in Zone I. Therefore, the Time-Intensity-Frequency curves for Zone I were used to determine the rainfall intensity. Figure 502 from the BCSDCM presents the time-intensity-frequency curves used in previous studies and in this master plan.

BOULDER COUNTY STORM DRAINAGE CRITERIA MANUAL	FIGURE 502

TIME-INTENSITY-FREQUENCY CURVES ZONE I



WRC ENG.	REFERENCE: WRC TM-1 NOV. 1983

D. Basin Areas

Main Campus

The University's main campus, contained within a definable drainage basin and connected to an existing storm water drainage system, is approximately 202 acres. Each of the major basins, ranging in size from approximately 14 to 72 acres, was subdivided into sub-basins ranging in size from 0.2 to 7.3 acres. It should be noted there are areas on the main campus, specifically areas northwest of Basin E, which contain drainage piping but are not currently connected to a definable system. This area is located in the oldest portion of the main campus and is shown on Figure 1.

East Campus

The minor basins of the University's east campus range in size from 1.6 to 13.7 acres, with the entire study area being approximately 31 acres.

Table 2: Existing Storm Water Drainage Basins

Basin Areas		
Basin / Subbasin	**Contributing Area (Acres)**	**Service Area**
Main Campus		
A	39.9	Kittredge Complex
B	57.0	Regent Drive / Engineering Center
C	71.8	Center of Main Campus
D	14.1	Folsom Field Vicinity
E	19.1	Recreation Center
East Campus		
A	13.7	Marine Street and Parking Lot 578
B	7.3	Laboratories and Adjacent Parking Lots
C	1.5	
D	8.6	Warehouses and Grass Area adjacent to Boulder Creek

Section IV – Hydraulic Analysis

A. Overview

The hydraulic analyses performed for this Master Plan utilized information from several sources including hydraulic models used in the design of past storm water improvement projects, design and record drawings, existing storm water utilities maps, and field surveys. This information was supplied by the University's Facilities Management Department and no verification of pipe size, material, or condition was made prior to the hydraulic analysis performed for this study. Facilities Management personnel also obtained storm water pipe sizes, alignments, and elevations for portions of the system where existing information was either not documented or unclear. Data collected from these sources was analyzed for general design conformance and imported into the Urban Drainage and Flood Control District's UDSEWER program (Reference 18).

In order to properly analyze and determine areas of the campus that have sufficient storm water drainage capacity, individual major basins were modeled independently of each other. In some cases, individual basins were broken down into several models due to the as-built drawings of the entire basin not having the same vertical control. Basins with inconsistent datums were tied together at logical connection points, usually based on the division of individual storm drainage improvement projects.

No analyses of potential backwater effects from City storm sewers or from Boulder Creek floodwaters were performed. It was assumed that the City storm sewers flow 100% full during the 5-year storm event. It was also assumed that during the 5-year storm event floodwaters will not rise in Boulder Creek to a level that compromises the storm sewer outfalls from the main and east campuses.

B. Hydraulic Calculations

The University's storm water drainage system is a gravity flow system. Hydraulic analyses performed in the UDSEWER program are based on Manning's calculations. Manning's calculations take into account roughness coefficients (based on pipe material), pipe slope, pipe diameter, and an assumed depth of flow (based on an 80% depth-to-diameter ratio).

A key variable in the Manning's equation is the Roughness Coefficient, or 'n' value. The roughness coefficient is a measure of the friction incurred along the pipe and through the flow profile. A higher 'n' value produces greater friction losses in the pipe resulting in lower conveyance capacities. Generally accepted 'n' values for various pipe materials are published in most hydraulics textbooks or references. For the pipe materials modeled in these storm water models, two values were used: a value of 0.011 for pipes made of PVC, and 0.014 for pipes made of concrete. These values were used for all modeling conditions, existing and future. In addition to friction losses, the evaluation of the storm drainage system took into account line losses due to either bends in the pipe alignment or incoming laterals that create a branch in the system. Bend and lateral losses were based on pipe velocities and energy loss coefficients known as 'k' coefficients. For this analysis, bends of 300, 450, and 900 were assigned a 'k' coefficient of 0.10, 0.20, and 0.80, respectively. Lateral losses were assigned a 'k' coefficient of 0.30. Velocities typically are a function of pipe slope.

C. Modeling Constraints

Several design constraints were set in the UDSEWER program prior to creating each model. Maximum and minimum flow velocities were set to 15 feet per second and 3 feet per second, respectively. The minimum pipe size to be evaluated was 8 inches and in general only a few areas of campus relied on 8-inch storm sewer piping to drain a sub-basin.

D. Existing Drainage System Modeling Approach and Assumptions

The modeling effort for this study was an attempt to compile existing data, analyze the campuses drainage systems as a whole, and to determine what systems are generally deficient and how best to alleviate drainage problems. As mentioned previously, individual inlets, short stretches of piping, and small diameter piping were not modeled. Based on this approach, many individual roadway inlets were modeled as if directly connected to the main conveyance piping in the drainage systems. Roughness coefficients were based on previous hydrologic studies used for the design of the improvement projects discussed above or approximated based on commonly accepted 'C' values. In many instances where sub-basins in previous studies did not align with sub-basins created for this study, roughness coefficients were determined based on area-weighted averages of the roughness coefficients used in previous studies. It should also be noted that if existing system information critical to basin modeling was absent, but it was certain this infrastructure was directly tied to improvement projects shown on record drawings or design drawings, these segments of the system were modeled based on estimated rim/invert elevations and pipe lengths. The rim/invert elevations were approximated from estimated pipe slopes and existing topography supplied by the University. Pipe lengths were estimated based on measured lengths in the AutoCAD base maps also supplied by the University.

Drainage Basin A – Kittredge Complex Outfall

The Kittredge Complex Basin has an outfall to the City Sewer System in 28th Street north of the intersection at Baseline Road. Detailed hydraulic modeling of this basin was not performed as part of this study because the existing system consists of only a few major pipes. However, a few elementary calculations were run on the 58-inch x 91-inch elliptical reinforced concrete pipe. Several assumptions were made while analyzing Basin A. A significant amount of drainage structures were excluded from the analysis because they were considered minor conveyance elements. The majority of the piping around the Kittredge Complex involves small diameter pipe and relatively short stretches of pipe with the exception of the major conveyance line east of the Kittredge detention ponds. In most cases, the smaller diameter pipes connect to roof drain systems and convey runoff to the ponds located in the center of the complex. These small pipes and short reaches were not analyzed. The two ponds draining in series from west to east were ignored in the analysis and were assumed to have no attenuating effects on storm water runoff draining towards 28th Street. According to the University's Facility Management personnel, these ponds have been collecting silt for a significant amount of time and are now substantially shallower than when first designed and constructed. University personnel also stated that silt in the ponds may be considered contaminated and appropriate measures to remove this silt should be undertaken. Based on this discovery, it was assumed that the ponds had no storage capacity and all runoff continues east without delay. After overflowing the weir structures of the two ponds, runoff drains in a shallow drainage way north of Buckingham into the 58" x 91" RCPE on the west side of

Kittredge Loop Road. Flow is then conveyed towards the City's system located in 28th Street. Before entering the city system, the piping is reduced from a 58"x91" RCPE to a 30-inch RCP.

Drainage Basin B – 28th Street Outfall

It appears Basin B, draining to the 28th Street outfall, is not solely contained within the University's main campus. It is likely that additional storm water runoff originating from the City of Boulder, southwest of Broadway, is being routed through the University's system as evidenced by the large 42-inch storm line located along Regent Drive. There is also a report published for the construction of roadway improvements for 28th Street designed by Love & Associates, Inc. in September of 2002 **(Reference 14)**, indicating additional City flows utilize University piping. Approximately 92 off-site acres drain to and through Basin B. The exact conveyance across Broadway is unknown, but the area was delineated in the Love & Associates report. Boyle estimated the off-site quantity of flow in the UDSWER program, based on slopes and drainage flow path lengths across the delineated City property. Boyle inquired about a drainage easement for the City flows across UCB's property, but the City was unaware of any easement.

The Love & Associates report on the 28th Street improvements did not evaluate any campus storm drainage systems with the exception of several pipes located immediately adjacent to 28th Street. At the outset of this report, a limited amount of information on the existing storm water system for Basin B was available. During the course of this master planning process, the University had a survey performed to document existing infrastructure for Basin B. This survey was the basis for modeling Basin B and involved locating manholes and inlets along the major storm sewer lines of the system. In order to model Basin B properly it was divided into a north system and south system. The north and south systems were modeled independently of each other due to a portion of the basin draining to the north pond and the remaining and larger portion draining to the south pond. Downstream of the ponds, flows are directed to Basin B's outfall located at the southwest corner of the intersection of Colorado Avenue and 28th Street. Rim and invert elevations for the manholes and inlets surveyed were based on the NAVD 88 datum at the request of the University. A few manholes and inlets were either not found or covered with asphalt or grass. These manholes and inlets were inserted into the model using estimated elevations. It was assumed that the pipes at the north and south basin outfalls will be flowing full and the starting water surface elevations will be based on the crown elevations of these two pipes.

Drainage Basin C – Folsom Street Outfall

Drainage Basin C, the largest and most comprehensive basin on campus, outfalls to the City storm drainage system at the intersection of Folsom Street and Colorado Avenue. For the modeling of Basin C, several assumptions were made in light of uncertainties presented in the existing information available for this basin. It was assumed that the 30-inch pipe located in Folsom Street that accepts runoff flows from Basin C has the capacity to convey 5-year flows to Boulder Creek. For modeling purposes, this pipe will be assumed to be flowing full during the 5-year storm event and the crown elevation of this 30-inch pipe was used to establish the starting water surface elevation for the Basin C model. Due to separate datums on as-built drawings for the three major drainage projects within Basin C, the system was analyzed as three separate systems. The three improvement projects used as the basis for the Basin C analysis were record drawings for a recently installed 24 to 42-inch storm line located in 18th Street and Colorado Avenue (Reference 8), design drawings for recently constructed storm drainage improvements south of Colorado and east of 18th Street (Reference 10), and record drawings for recent improvements to the storm drainage system located adjacent to 18th street (Reference 13). Starting water surface elevations for the three models were based on an assumption that the downstream pipe was flowing full. The upstream crown elevation of this downstream pipe was used as the starting water surface elevation.

Drainage Basin D – Dal Ward Athletic Center Outfall

Drainage Basin D drains from southwest to northeast and its outfall is located on the south embankment of Boulder Creek northeast of the Dal Ward Athletic Center. No existing storm sewer studies or models were used in the modeling of Basin D. Due to confusion over the storm sewer system layout of Basin D that arose during this master planning process, the University had a survey performed to document locations and elevations of the major storm lines in the system between the storm sewer manhole southwest of Folsom Field and Basin D's outfall at Boulder Creek. This survey covered approximately one half of the Basin B's system. Information for the remaining portion of the system in the vicinity of the plaza southwest of Folsom Field was obtained from an existing utility survey used for the design of the MCDB Building Addition (Reference 6). Elevations for the new survey were set based on the NAVD 88 datum. Elevations derived from the existing utility survey were based on the NGVD 29 datum and were adjusted to the NAVD 88 datum in order to correctly model the entire basin as a whole.

Drainage Basin E – Student Recreation Center Outfall

Drainage Basin E also drains from southwest to northeast with its outfall located on the south embankment of Boulder Creek north of the northeast corner of the Student Recreation Center. As in the Basin D model, Basin E was modeled without the benefit of existing studies or models. For the modeling of Basin E, several assumptions were made. First, it was assumed that record drawings used for the creation of the model utilized the same datum in determining existing infrastructure elevations. The record drawing sets used were dated between 1970 and the early 1990's. The second assumption involved information on existing infrastructure supplied by the University. In areas where record drawings were not available and the existing system needed to be modeled, it was assumed that pipe alignments as shown on the University's utilities base map were accurate. Rim/invert elevations for these areas were estimated based on calculated slopes that tie to known elevations on the record drawings. Pipe lengths were estimated based on measured lengths in the AutoCAD base maps also supplied by the University.

East Campus Drainage Basin

The 1995 study (Reference 7) performed by Boyle is the foundation for discussing existing conditions and future improvements on the East Campus. Few basin characteristics have changed recently and there is a limited amount of elevation information available on the existing infrastructure. Known improvements that have been constructed since the report was published are included in the following discussion and analysis.

The East Campus drainage basin has a gentle slope generally from northwest to southeast towards Boulder Creek. During the 5-year storm event, the majority of the basin's runoff drains to Boulder Creek by sheet, gutter, and open channel flow. Basin A is the only basin on the east campus that has a significant amount of runoff collected in a closed storm water piping system. This 12-inch piping system drains west to east along Marine Street, turns near the Housing System Service System and continues to drain southeast towards an outfall on the north embankment of Boulder Creek. Basin B drains sheet flow across the parking lots east of Research Laboratory No. 2, Research Laboratory No. 4, and the Institute of Behavioral Genetics to a single inlet located in the southeast corner of the parking lot. From this inlet runoff is conveyed a short distance through a 15-inch CMP culvert to Boulder Creek. Basins C and D drain sheet flow across parking lots until runoff is collected and outfalls to open channels that drain to a local sump adjacent to Boulder Creek. It should be noted there is a closed conduit system that collects roof drain runoff from the Research Laboratory No. 2. This system connects to the foundation drain that conveys flows directly to Boulder Creek through 8-inch and 18-inch piping (Reference 9). These pipes run through a pollutant separation manhole, constructed after 1995, before discharging into Boulder Creek.

Section V – Existing Modeling Results and System Deficiencies

The University's storm water drainage system currently has areas that can be considered deficient in conveying storm water runoff produced by the 5-year storm event. The system's inadequacies center around areas of pressurized flow, unacceptable velocities, or locations where area inlets would be surcharged during the design storm event.

Pressure flow in a storm water pipe is considered an undesired condition because it may indicate the hydraulic grade line is rising to an elevation above the ground surface. A pressurized condition may result in shallow flooding due to water coming out of area inlets or the inability of area inlets to drain properly. However, if storm water piping is buried at a depth that the hydraulic grade line elevation is below the ground surface, shallow flooding will likely not occur and the main concern then becomes the structural integrity of the pipe and its joints to withstand pressure flow. Pressure flow is also a concern because it limits the amount of reserve in the storm water system that could be used to accept flows produced by storm events larger than the design event.

Unacceptable velocities in storm water piping are velocities outside the range of 3 to 15 feet per second. Velocities below 3 feet per second in a storm pipe may result in sediment accumulating in the pipe. Velocities above 3 feet per second generally keep sediment in the storm pipe in suspension and allows for its removal from the system. High velocities outside the range could be considered detrimental to the piping system based on sediment degrading the pipe walls. Depending on the anticipated sediment loads entering the pipe and the existing pipe material, this upper limit can fluctuate. On the University's campuses, the sediment load entering the system is anticipated to be low. Most areas on campus are established, containing either solid surfaces or areas of mature landscaping.

The subsequent sections describe these areas in further detail.

A. Drainage Basin A – Kittredge Complex Outfall

The 5-year flow generated in Basin A was calculated to be approximately 90 cfs. Approximately 40 cfs is runoff generated inside the Kittredge Loop Road in Basin A1. Approximately 50 cfs is runoff outside the Kittredge Loop Road in Basin A2. A detailed analysis of the existing system was not performed. However, a rudimentary hand calculation was performed on the 58"x 91" RCPE conveying flows generated inside the Kittredge Loop Road. From this calculation it appears the RCPE would be able to convey 40 cfs, but would depend on downstream conditions in the 30-inch RCP that it connects to. Conditions in the downstream 30-inch RCP could not be determined. Without obtaining detailed information on the entire system, including the City's system, an extensive analysis could not be performed. At this time, it cannot be conclusively determined whether the University's storm drainage system at the Kittredge Complex has sufficient capacity. However, there are several recommendations that would enable the storm drainage system in Basin A to function more effectively (See Section VII).

B. Drainage Basin B – 28th Street Outfall

According to modeling results, Basin B with an outfall southwest of the Colorado Avenue and 28th Street intersection has a few areas that are deficient during the 5-year design event (Table 3). The majority of the deficiencies in the system are located in the south system adjacent to Regent Drive. With significant flows originating from the City of Boulder outside of the main campus, several pipes in the south basin system experience pressurized flow conditions. The pressure flow conditions appear to be the result of undersized piping, inlets draining large contributing sub-basins, and the additional runoff contributed by the City of Boulder. The potential for shallow flooding due to surcharged inlets may exist west of Cockrell Drive near Observatory Field as well as an area along Regent Drive north and west of Fisk Planetarium. According to the model, only one pipe exceeds the 15 feet per second velocity criterion during the 5-year storm event. This pipe is a 12-inch pipe located under Cockrell Drive and drains east towards Observatory Field.

Table 3: Existing Storm Water Drainage System Deficiencies – Basin B, South System

Basin B		
Deficiency	**Pipe and Manhole ID**	**Service Area**
Pressurized Flow	P32	18" Pipe located southeast of the Police/Parking Center
Pressurized Flow	P1514, P1615, P1716, P1817, P1918, P2019, P2120	Observatory Field and West of Cockrell Ave.
Pressurized Flow	P2322, P2423, P2524	36" Pipe located parallel to Regent Drive adjacent to Fisk Planetarium
High Velocity	P2019	12" Pipe under Cockrell Drive
Potential for Shallow Flooding	MH16, MH17, MH18, MH19, MH20, MH21	Observatory Field and inlet west of Cockrell Drive.
Potential for Shallow Flooding	MH23, MH24, MH25	Area along Regent Drive adjacent to Fisk Planetarium.

In general, the north system of Basin B is operating sufficiently under existing conditions. However, there are few pipes operating under pressure, several pipes that exceed velocity requirements, and a small area with the potential for shallow flooding during the 5-year storm event (Table 4). Deficiencies for the north system are likely the result of impervious runoff surfaces. The majority of the north basin contains impervious surfaces such as roads, rooftops, and parking lots. These impervious surfaces appear to be quickly generating flows too large for portions of the system to properly handle. The specific areas of concern are in the vicinity of the Business, Civil, and Electrical Buildings. These areas contain pipes ranging from 6 to 24 inches in diameter and are experiencing pressure flow conditions. A small area northwest of the Business Building has the potential to experience shallow flooding during the 5-year storm. The potential for flooding in this area may be due to the 6-inch pipe north of the Business Building being undersized and creating high head losses. Three pipes in the system exceed velocity criteria. Two of the pipes are located just west of the north pond outlet and have velocities higher than 15 feet per second. The third pipe is a 24-inch pipe located west of the Civil Building that has a velocity less than 3 feet per second. These velocities do not appear to be excessive and will more than likely not adversely affect the operation of the system.

Table 4: Existing Storm Water Drainage System Deficiencies – Basin B, North System

Basin B		
Deficiency	**Pipe and Manhole ID**	**Service Area**
Pressurized Flow	P87	18" Pipe located between the Electrical Building and the Discovery Learning Center
Pressurized Flow	P1312	24" Pipe located northeast of the Civil Building
Pressurized Flow	P1514	24" Pipe located southeast of the Civil Building
Pressurized Flow	P2019, P2120, P2221, P2321	6-12" located adjacent to the Business Field and Business Building
High Velocity	P21	24" Outlet Pipe to the North Pond
High Velocity	P32	12" Pipe draining the parking lot north of the Police Station
Low Velocity	P1716	24" Pipe west of the Civil Building
Potential for Shallow Flooding	MH22	Northwest Corner of the Business Building

C. Drainage Basin C – Folsom Street Outfall

The majority of Drainage Basin C draining to Colorado Avenue, consisting of 42 to 27-inch piping, operates under a pressure flow condition with the exception being a segment of 36-inch pipe south of Folsom Field (Table 5). The pressurized conditions for this portion of Basin C do not result in surcharged inlets and will more than likely not result in shallow flooding during the 5-year event.

The portion of Basin C, located adjacent to 18th Street and bounded by Broadway to the south and west, has significant areas that are undersized to convey the 5-year storm. The primary issues involve multiple pipes operating under pressure flow and several areas where inlets are surcharged. There are also a few pipes where velocities do not meet the velocity criteria. The most recent drainage study by Kirkham Michael Consulting Engineers used the 2-year storm event as foundation for the design of storm water improvements in this area (Reference 11). When the 5-year storm event is applied to the existing system, as was for this study, it is not surprising that the system has significant areas that are inadequate in collecting and conveying runoff flows. The majority of the basin experiences pressure flow in its piping. Results also show that shallow flooding may occur in the plaza area west of Sibell-Wolle and north of UMC as well as small areas northwest of Regent Auto Park and northeast of Environmental Design. Shallow flooding adjacent to Regent Auto Park and Environmental Design will more than likely not present a problem because 18th Street was designed to convey excess flows not handled by area inlets. These findings and assumptions are consistent with results and discussions presented in the previous storm water study (Reference 11). Only a small number of pipes experience low velocities that theoretically could result in silt accumulation, but will more than likely not present a problem. Based on the surrounding landscape, it is not anticipated that the inlets connected to these pipes will collect a substantial amount of silt. Three pipes have velocities in excess of 15 feet per second. Two of the pipes are in the 24-inch line west of Sibell-Wolle and the third is a portion of the 18-inch line in 18th Street west of the Power House. The velocities in these lines exceed the 15 feet per second criterion by 1 to 2 feet per second and should not pose a problem.

The storm drainage system south of Colorado, east of 18th Street, and west of Cockrell Drive that drains north to Colorado Avenue has only a few deficiencies in conveying the 5-year storm event. The results showing the overall sufficiency of this system are more than likely due to recent improvements made to the system in the last few years. These improvements were based on a study with a 5-year design event and the system was designed to operate under open channel flow (Reference 10). However, several pipes in the system do operate under pressure flow. Two of the pipes are short stretches attached to area inlets that drain large basins east and west of Cockrell, Crossman, and Reed Halls. Other pipes operating under pressure flow conditions are between Colorado Avenue and the Math Building. A 24-inch pipe draining west to east north of the Math Building is operating under pressure flow as well as the 30-inch pipes that drain north to south under Colorado Avenue. It should be noted that these pipes were not installed as part of the recent improvements and may have been designed for a smaller design event than that used in this study. The pressurized conditions for these pipes do not result in surcharged inlets and will more than likely not result in shallow flooding during the 5-year event. The condition of the 24-inch line and its joints north of the Math Building is not known. How this pipe will withstand pressure flow has not been determined. Two pipes mentioned above also experience low velocities when flowing full. The pipes with low velocities are the 24-inch pipe north of the Math Building and one of the 18-inch pipes at the northeast corner of Cockrell.

Table 5: Existing Storm Water Drainage System Deficiencies – Basin C

Basin C		
Deficiency	**Pipe and Manhole ID**	**Service Area**
Pressurized Flow	P21, P32, P54, P65, P76, P87, P98, P109	Service Area includes Colorado Avenue and the majority of the center portion of the main campus
Pressurized Flow	P1918, P181	30" Piping Crossing Colorado
Pressurized Flow	P5419	24" Piping North of Math Building
Low Velocity	P5251	18" Piping Behind Cockrell Building
Low Velocity	P5419	24" Piping North of Math Building
Pressurized Flow	Majority of Basin C utilizing the 18- and 24-inch line in 18th St.	Area serviced by 18- and 24-inch line in 18th Street.
Low Velocity	P65	15" draining small area in northwest portion "Old Hunter" field
Low Velocity	P1918, P2019	18" draining small area south of Sibell-Wolle
High Velocity	P52	18" draining in 18th Street west of the Power House
High Velocity	P3736, P3837	24" draining south to north, west of Sibell-Wolle
Potential for Shallow Flooding	MHs 34-42	Area west of Sibell-Wolle and north of UMC
Potential for Shallow Flooding	MH33	Northwest of Regent Auto Park
Potential for Shallow Flooding	MH13	Northeast of Environmental Design

D. Drainage Basin D – Dal Ward Athletic Center Outfall

Basin D with an outfall to Boulder Creek northeast of the Dal Ward Athletic Center has significant areas that are deficient during the 5-year design event (Table 6). According to model results of the existing conditions, the majority of Basin D has the potential to experience shallow flooding during the 5-year storm event. The entire storm drainage system appears to be operating under pressure flow conditions with the exception of two pipes, a 24-inch pipe that outlets to Boulder Creek and a 24-inch pipe located east of the Dal Ward Athletic Center. Also, there are a numerous pipes that may experience velocities higher than the 15 feet per second velocity criterion. The potential system deficiencies during the 5-year storm could be the result of steep sub-basin slopes, high runoff coefficients, and undersized piping. Two of the largest sub-basins within Basin D are inside Folsom Field and have steep slopes. A large portion of Basin D consists of high runoff coefficients due to paved or rooftop drainage surfaces. These basin characteristics produce short time of concentrations resulting in the system's undersized pipes being overstressed.

Table 6: Existing Storm Water Drainage System Deficiencies – Basin D

Basin D		
Deficiency	**Pipe and Manhole ID**	**Service Area**
Pressurized Flow	-----	The majority of Basin D appears to be operating under pressure flow conditions
High Velocity	P21	24" Outfall Pipe to Boulder Creek
High Velocity	P43, P54, P65, P76, P87, P98, P109	15"-24" Piping around Folsom Field
Potential for Shallow Flooding	------	The majority of Basin D appears to have the potential for shallow flooding

E. Drainage Basin E – Student Recreation Center Outfall

According to modeling results, Basin E with an outfall northeast of the Student Recreation Center, has a few areas that are deficient during the 5-year design event (Table 7). The majority of the deficiencies in the system are located south of the Humanities Building. The piping connected to area inlets in the plaza area adjacent to Humanities drain under pressure flow conditions. The pressure flow conditions are the result of undersized piping and large contributing sub-basin areas. The piping is 12-inch PVC. However, even with small diameter piping and significant sub-basins areas, these area inlets do not become surcharged during the 5-year event. The velocities for this piping are below the minimum 3 feet per second criterion. There are also two pipes that exceed the 15 feet per second criterion. The first pipe is a 30-inch pipe located at the southwest corner of the Student Recreation Center tennis courts. The second pipe is an 8-inch pipe connected to an area drain on the northeast corner of Norlin Library.

The velocities in these two pipes range from 15.8 to 16.2 feet per second. These velocities only slightly exceed the velocity criterion and will more than likely not result in degradation of the pipes.

Table 7: Existing Storm Water Drainage System Deficiencies – Basin E

Basin E		
Deficiency	**Pipe and Manhole ID**	**Service Area**
Pressurized Flow	P1918, P2019, P2120, P2219	12" piping servicing the plaza area south of the Humanities Building
Pressurized Flow	P98	10" pipe located northeast of Ramaley
Low Velocity	P2019, P2120, P2219	12" piping servicing the plaza area south of the Humanities Building
High Velocity	P1312	8" pipe connected to area inlet northeast of Norlin Library
High Velocity	P54	30" pipe located at SW corner of Student Recreation Center tennis courts.

F. East Campus Drainage Basin

According to previous modeling performed on the east campus basin, there are several concerns involving the ability of the campus' existing storm water drainage system to properly convey runoff from the 5-year storm event towards Boulder Creek. The main concern highlighted in the previous study centers around Basin A located along Marine Street in the center of the study area. Basin A is the only basin on the east campus that has storm water infrastructure that contains area inlets connected to a closed conduit system. This 12-inch pipe is over capacity and several inlets southeast of the Housing Service center are inadequate in collecting runoff (Table 8).

There are also several isolated areas of concern on the east campus. The inlet and storm pipe at the southeast corner of the parking lot east of the Institute of Behavioral Genetics have insufficient capacity for the 5-year flow. The open channel or grass swale south of the Warehouse may not have proper capacity based on flows leaving the parking lots east and south of the Research Laboratories.

Table 8: Existing Storm Water Drainage System Deficiencies – East Campus

East Campus		
Deficiency	**Description**	**Service Area**
Pressurized Flow	Marine Street Piping	12" piping servicing areas adjacent to Marine Street.
Potential for Shallow Flooding	Marine Street Inlets South of Marine Street Science Center and southwest of the Housing Service Center	Upper Portions of Sub-basin A
Potential for Shallow Flooding	Inlet in Institute of Behavioral Genetics parking lot	Sub-basin B
Potential for Shallow Flooding	Grass Swale south of the Warehouses	Swale servicing Sub-basin D

Section VI – Build-out Campus and Impacts to the Existing Storm Pipe System

Based on a review of the University's 2001 Campus Master Plan (Reference 12), the University has a minimal amount of developable space remaining on the main campus. A build-out condition on the main campus is defined as "utilization of all potential development areas." Potential development areas are identified in the 2001 Master Plan on Exhibit IV-A-1, "Long-Term Potential Development Areas." According to the 2001 master plan, the combined potential development area is 37 acres, which is approximately 12% of the main campus's 306 acres. Half of the potential development areas are allocated to building expansion and the other half would be used for undefined stand-alone expansion. The majority of the potential development would occur either on existing paved surfaces or would be redevelopment of existing facilities in order to maximize land usage on the main campus. Based on the 2001 master plan, potential development on green spaces or recreation fields is not desirable from a safety and campus quality of life standpoint.

From a storm water management perspective, this approach to build-out on the main campus would allow for growth without substantially increasing runoff loads on the existing drainage systems. Replacing paved surfaces with buildings or replacing buildings with new buildings does not greatly increase the amount of storm water runoff that sub-basins generate. In order to service these potential development areas, small-scale improvements might be required such as roof drain systems, surface inlets, and short stretches of small diameter piping. These small-scale improvements would connect to the 'backbone' storm drainage system, which is being evaluated as part of this report.

Based on modeling efforts, it appears the University's existing storm water drainage system performs adequately under build-out conditions with the exception of a few areas on campus. In most cases, the portions of the drainage system that do not function properly under build-out conditions do not have the capacity to collect and convey the 5-year storm event at this time. The subsequent sections describe these areas in further detail. Refer to Figures7-11 for the locations of potential development in each of the basins.

A. Drainage Basin A – Kittredge Complex Outfall

According to the University's 2001 campus master plan, additional development may occur at the following locations in Drainage Basin A:

- In the vicinity of the tennis courts, south of the Kittredge Complex

Only a minor impervious area is impacted by future development in comparison to the overall drainage area, so increases in storm water runoff would be small. No additional system deficiencies in the storm drainage system for Basin A result from future development.

B. Drainage Basin B – 28th Street Outfall

Additional development may occur at the following locations in Drainage Basin B:

- Parking lots adjacent to Regent Drive
- South of the Business Building
- Observatory Field
- Sommers Bausch Observatory
- Parking lot between the Coors Events Conference Center and the Sommers Bausch Observatory
- To the north and east of the Coors Events Conference Center
- To the south of the I.T.L.L. building
- Environmental Health and Safety Center
- Parking lot to the west of the Environmental Health and Safety Center
- To the north and east of the Police/Parking Center
- Northeast of the Electrical Building

The majority of the future development for Basin B is projected to occur on top of existing impervious areas or around existing structures. No increased runoff should result from future development of the sub-basins contributing to the north system. However, in the south system, there are a few areas where open or green space has the potential to be developed. In these areas, the projected runoff would increase. The potential for increased runoff would occur around Observatory Field, north of Coors Events, and adjacent to Sommers Baush Observatory. There are a few system deficiencies in Basin B that result from build-out conditions. These deficiencies are the result of additional flows being applied to portions of the drainage system that are currently either overtaxed or approaching design capacity. Additional system deficiencies due to projected future development are listed in Table 9 below.

Table 9: Build-out Storm Water Drainage System Deficiencies – Basin B, South System

Basin B		
Deficiency	**Description**	**Service Area**
Pressurized Flow	P2214	36" Pipe parallel to Regent Drive west of Coors Events.
High Velocity	P2322, P2423	36" Pipe parallel to Regent adjacent to Fisk Planetarium.
Potential for Shallow Flooding	MH3	Manhole located north of the Environmental Health and Safety Building.

The pressure flow and high velocity in the system parallel to Regent Drive are illustrative of the concerns in this area that were highlighted in the existing conditions modeling and are only compounded when additional flow is added upon build out. However, the potential for shallow flooding north of the Environmental Health and Safety Building is due to increased flows resulting from changes in sub-basin characteristics.

C. Drainage Basin C – Folsom Street Outfall

Based on the University's 2001 campus master plan, additional development may occur at the following locations in Drainage Basin C:

- To the west, east, and south of the University Memorial Center
- At the Euclid Avenue Auto Park
- At and to the east of the Sibell-Wolle Fine Arts building
- An area in the northwest corner of 18th and Broadway
- On the south side of the Wardenburg building
- Parking lot area south of the Wardenburg building and west of the University Admin. Center.
- Small areas to the north and east of the Environmental Design building
- Parking lot area to the east of the Physics Laboratories
- Parking lot area to the east of the Benson Earth Sciences building

Most of the new development falls on existing impervious areas such as parking lots. Therefore the increase in runoff from potential development areas would be minimal. The modeling input tables located in Appendix D shows the comparison between existing runoff coefficients and build-out runoff coefficients for each drainage sub-basin area. Modeling output located in Appendix E shows the resulting runoff from the build-out conditions on the existing storm water system.

There are a few system deficiencies in Basin C resulting from build-out conditions. These deficiencies are the result of additional flow being generated in the basin and applied to portions of the drainage system that is currently overtaxed under existing conditions. The areas of concern are primarily located along 18th Street south of Colorado Avenue. The Basin C deficiencies are listed in the Table 10 below.

Table 10: Build-out Storm Water Drainage System Deficiencies – Basin C

Basin C		
Deficiency	**Description**	**Service Area**
Pressurized Flow	P5422	18” pipe draining east to west northeast of the Math Building. Service area includes sub-basin east of Cockrell Avenue
Pressurized Flow	P32	15” pipe connect to area inlet that services long and narrow sub-basin between Ketchum and Sibell-Wollle
Pressurized Flow	P2625, P2726, P2826	15’-18” piping located in Euclid Avenue at southeast corner of the Euclid Autopark
Potential for Shallow Flooding	MH10, MH11, MH13, MH21, MH24, MH24,	Area along 18th Street and Euclid Avenue
Potential for Shallow Flooding	MH52	East of the Environmental Design Building

D. Drainage Basin D – Dal Ward Athletic Center Outfall

Additional development may occur at the following locations in Drainage Basin D:

- At the northwest and northeast corners of the Folsom Field
- Along the east side of the Folsom Field

The majority of the future development areas in the vicinity of Folsom Field would either be redevelopment of existing impervious areas or areas that do not drain to the existing storm water drainage system. The areas of future development for Basin D producing additional storm water runoff during build out conditions are small areas located on the north side of Folsom Field adjacent to the Dal Ward Athletic Center. According to modeling results, increases in storm water runoff would be minimal and the system deficiencies would remain the same as those listed in Section V.

E. Drainage Basin E – Student Recreation Center Outfall

According to the University's 2001 master plan, additional development may occur at the following locations in Drainage Basin E:

- To the east of the University Theatre
- North of the Norlin Library
- On the east side of the parking lot north of the Norlin Library
- In the vicinity of the Tennis Courts on the south side of the Student Recreation Center

Future development in Basin E impacts existing pervious and impervious areas. As with Basin D, the areas of impacted by future development are small and additional runoff would be minor. Based on these observations, the system deficiencies would remain the same as those listed in Section V.

Modeling input located in Appendix D shows the comparison between existing runoff coefficients and build-out runoff coefficients for each drainage sub-basin area. Modeling output located in Appendix E shows the resulting runoff from the build-out campus on the existing storm water system.

F. East Campus Drainage Basin

Additional development may occur at the following locations in the east campus drainage basin:

- The area between the Life Sciences Research Lab No. 4 and the Institute of Behavioral Genetics
- To the west of the Marine Street Science Center
- Within the parking area to the east of the Administrative and Research Center
- To either side of the Housing System Maintenance Center
- To the west of the computing center

Additional development on the east campus would cover existing impervious areas. This development would not significantly increase storm water runoff and system deficiencies would remain the same as those listed in Section V. Modeling input located in Appendix D shows the comparison between existing runoff coefficients and build-out runoff coefficients for each drainage sub-basin area. Modeling output located in Appendix E shows the resulting runoff from the build-out campus on the existing storm water system.

Section VII – Future System Improvements

The University's storm water drainage system currently has the capacity to convey 5-year storm event flows at most locations on the main and east campuses. However, there are several areas that are deficient in conveying these flows. These areas may experience shallow flooding during the 5-year event and it is possible that additional flooding may occur during larger storm events. If future development on the University's campuses is significantly greater than that projected in the University's 2001 master plan, the potential for flooding would increase. Potential flooding could be a concern for the older portions of campus where no major storm drainage system exists. The following recommendations are made to each of the basins on the main and east campuses in order to increase capacity in an effort to allow the University's storm water drainage system to function properly under build-out conditions. Refer to Figures 12-16 for locations of recommended improvements.

A. Drainage Basin A – Kittredge Complex Outfall

The majority of stormwater runoff flows directly to a series of centrally located detention ponds with a single pipe outfall to the City drainage system under 28th Street. Since only the storm sewer mainline pipe systems were analyzed for this study, no detailed analysis was performed for the detention facilities. Improvements recommended in this section are based on discussions with University personnel and field observations. Final design will need to be performed on all of these recommendations prior to their implementation.

1. Increase detention capacity in the Kittredge Complex ponds by removing sediment. Prior to removing sediment that has collected in the ponds, the soil should be tested to characterize any contaminants that may be present. If the soil contains any contaminants, it should be removed and disposed of in a safe and appropriate manner. At the time of this report, Facilities Management was arranging for testing of the ponds.

2. Increase detention capacity in the Kittredge Complex ponds by lowering the normal water surface elevation. Construct a primary low flow discharge pipe at a foot or so lower than the existing overflow spillway to lower the normal water surface elevation. The additional foot of storage area in the ponds can be used to further attenuate storm water runoff. Sediment removal may be required. See item No. 1 above regarding sediment removal. Vegetation along the banks may be affected by the lower normal water surface elevation.

3. Increase the detention capacity of the area adjacent to the Kittredge Loop road by excavating additional volume in the vicinity of the small basketball court area. Then construct an outfall structure to attenuate the 5-year flow prior to discharging into the existing outfall pipe. If the groundwater elevation in this area is raised due to the pond outfall construction, a geo-membrane liner for the pond or other waterproofing measures should be considered to prevent water from infiltrating the University's underground tunnel system at this location.

4. Work with the City of Boulder to determine the size and capacity of the downstream storm water drainage system at 28th Street. If needed, increasing capacity in the City's system may allow additional flows to be conveyed in the University's piping at the Kittredge Complex.

5. It appears that a significant area of inundation would occur prior to overtopping the embankment between the pond outfall and the pedestrian underpass at 28th Street. Some buildings could be impacted by this inundation. It is recommended that an overflow area be created across the Kittredge Loop Road that would be below the flood elevations of the Kittredge Complex buildings. This could occur by regrading the area east of the Kittredge Loop road to a lower elevation.

B. Drainage Basin B – 28th Street Pond Outfall

The following improvements are suggested for the deficient areas of the Basin B pipe system:

1. Consider wetland enhancements in the ponds along 28th Street to improve water quality.

2. Replace approximately 640 lf of 36-inch pipe with 42-inch reinforced concrete pipe between design structures 22 through 25. This would require the replacement of the utility vault conflict structure between design structures 24 and 23.

3. As an alternative to replacing 36-inch pipe, a 12-inch pipe could be constructed parallel to the 36-inch pipe to increase the conveyance capacity upstream of the 42-inch pipe.

4. As an alternative constructing the 12-inch pipe and tying it into the 42-inch system, the 12-inch pipe could be constructed across Regent Drive and tied into the Observatory Field system.

5. Replace approximately 1,163 lf of 18-inch pipe with 24-inch reinforced concrete pipe in the Observatory Field.

6. Perform periodic monitoring and maintenance to the existing system in order to maximize its capacity.

C. Drainage Basin C – Folsom Street Outfall

Most of Drainage Basin C has already been developed, including the main stormwater pipe system. The southwest quadrant has a storm system that was designed for the 2-year frequency flood event. There is sufficient capacity, under pressure flow, for the 5-year event flows with the exception of the pipes at the upstream end near the University Memorial Center. Because these pipes are located in close proximity to buildings and under busy plaza areas, Facilities Management directed Boyle to leave the system operating under a 2-year flow and not make recommendations to properly increase the system to accommodate the 5-year flow. It should be noted that frequent flooding may occur in the plaza area north of the University Memorial Center.

Preliminary design has already been completed for a storm sewer system in the vicinity of the Cheyenne Arapahoe Hall. Boyle's hydraulic model only includes the pipe system that has been installed at the time of this report. The remaining pipe system yet to be installed is shown on Figure 14 as proposed improvements.

D. Drainage Basin D – Dal Ward Athletic Center Outfall

Based on the hydraulic analysis of the existing and build-out systems for Basin D, there is insufficient capacity to convey the 5-year flow in certain areas. The following improvements were chosen to meet constructability and topographic constraints. The proposed system will convey slightly less than the 5-year flow due to shallow pipe placement, minimum cover over the pipes, and established downstream systems inverts.

1. Replace approximately 135 lf of 8-inch pipe with 15-inch reinforced concrete pipe between design structures 23 and 22.

2. Replace approximately 390 lf of 15-inch pipe with a 19"x30" horizontal elliptical concrete pipe (24-inch equivalent) between design structures 14 through 18 and tie into manhole 10. This will maximize the flow area while minimizing the height of the pipe in shallow laying conditions.

E. Drainage Basin E – Student Recreation Center Outfall

Although various sections of the pipe throughout this system are pressurized and have high velocities, the 5-year storm event is conveyed in the system without surcharging. Since the system is operational without impacting existing structures, no improvements are listed for this area at the direction of Facilities Management. General maintenance is suggested to determine if the high velocities are causing damage to junction structures or to the pipe itself. The existing condition of the pipes in this system was not determined during this study.

F. East Campus Drainage Basin

Suggested improvements to the subbasins on the East Campus were outlined in the 1995 Drainage Study for East Research Campus. Figure 4 from that report is included in this report as Figure 16 for reference to the proposed drainage improvements. A summary of the proposed drainage improvements is listed below.

1. Construct a water quality pond that would intercept and treat all flows from East Campus prior to discharging into Boulder Creek. Due to discharge requirements involving protecting Boulder Creek during construction on the east campus, the University may want to construct the pond prior to undertaking other improvements. The outfall from this water quality pond would require a 48-inch RCP. The water quality pond could also function as an irrigation storage facility for the University.

2. In subbasin A, abandon the existing 12-inch storm pipe from the Housing System Service Center on Marine Street to Boulder Creek and construct a new 30-inch pipe system from Marine Street along a new alignment to a proposed water quality pond next to Boulder Creek. The existing 12-inch storm pipe along Marine Street would be replaced with a 21-inch storm pipe to convey the

5-year flow. It should also be noted that the existing inlets had small interception capacities and should be replaced with larger inlets.

3. In subbasin B, replace the existing inlet with a larger inlet at the southeast corner of the parking lot east of the Institute of Behavioral Genetics and remove and replace the existing 15-inch CMP culvert with an 18-inch pipe. Construct a new inlet in the parking lot east of Research Laboratory No. 2. This new inlet would connect to an 18-inch line that would replace a portion of the existing 8-inch drain leaving Research Laboratory No. 2. Both of the 18-inch lines would daylight to constructed grass swales that lead to the water quality pond. An existing portion of the 8-inch pipe dedicated to drainage leaving Research Laboratory No. 2 would be plugged and abandoned.

4. In subbasin D, improve the capacity of the grass swale south of the Warehouse.

Section VIII – Prioritization of System Improvements

Implementing system improvements will require guidelines for prioritization. Three factors were used to analyze the priority of the improvements; 1) potential threat to life, 2) potential damage to property, 3) and ease of constructability.

For each improvement, these factors were assigned a rating of: "-" signifies a low priority rating, "0" signifies a medium priority rating, or "+" signifies a high priority rating. System improvements were prioritized separately by Main Campus and East Campus. For the Main Campus, improvements are prioritized within each major drainage basin on a scale of 1 to 6 with 1 being the highest priority rating. (Tables 11-13)

Priorities for improvements for East Campus have already been created as outlined in the 1995 drainage study (Reference 7). The highest priority is Phase 1 work and the lowest priority is Phase 3 work. (Table 14)

The sequence of constructing storm water improvements should be based on the following priority Tables 11-14. Improvements that alleviate flood damage to structures should be undertaken first followed by improvements that alleviate shallow flooding in high population density areas such as typically congested travel corridors and roadways. Areas that experience shallow flooding but do not affect property or normal daily operations of the campus should be considered nuisance issues and would be last on the priority list.

The costs of the improvements are listed in Section IX.

Table 11: System Improvement Prioritization – Basin A

BASIN-IMPROVEMENT NUMBER	MAIN CAMPUS BASIN A DESCRIPTION	PRIORITIZATION FACTORS			PRIORITY RATING
		Potential Threat to Life	Potential Damage to Property	Ease of Constructability	
A1	Increase detention capacity in the Kittredge Complex ponds by testing and removing potentially contaminated sediment as well as lowering the normal water surface elevation. Construct a primary low flow discharge pipe at lower than the existing overflow spillway to lower the normal water surface elevation. The additional storage area in the ponds can be used to further attenuate storm water runoff. Lowering the water surface elevation of the ponds may also reduce the amount of ground water seepage into the University's tunnel system that is adversely impacting the Kittredge Commons Building. Vegetation along the banks may be affected by the lower normal water surface elevation.	-	+	+	1
A2	Increase the detention capacity of the area adjacent to the Kittredge Loop road by excavating additional volume in the vicinity of the small basketball court area. Then construct an outfall structure to attenuate the 5-year flow prior to discharging into the existing outfall pipe. Install pond lining or other waterproofing measures to prevent water infiltrating the existing tunnel system.	-	-	+	2
A4	It appears that a significant area of inundation would occur prior to overtopping the embankment between the pond outfall and the pedestrian underpass at 28th Street. Some buildings could be impacted by this inundation. It is recommended that an overflow area be created across the Kittredge Loop Road that would be below the flood elevations of the Kittredge Complex buildings. This could occur by regrading the area to the east of the Kittredge Loop road to a lower elevation.	0	0	+	3
A3	Work with the City of Boulder to determine the size and capacity of the downstream storm water drainage system at 28th Street. If needed, increasing capacity in the City's system may allow additional flows to be conveyed in the University's piping at the Kittredge Complex.	-	-	-	4

Table 12: System Improvement Prioritization – Basin B

BASIN-IMPROVEMENT NUMBER	MAIN CAMPUS BASIN B DESCRIPTION	PRIORITIZATION FACTORS			PRIORITY RATING
		Potential Threat to Life	Potential Damage to Property	Ease of Constructability	
B6	Perform periodic monitoring and maintenance to the existing system in order to maximize its capacity.	-	0	+	1
B3	As an alternative to replacing 36-inch pipe, a 12-inch pipe could be constructed parallel to the 36-inch pipe to increase the conveyance capacity upstream of the 42-inch pipe.	-	0	0	2
B5	Replace approximately 1,163 lf of 18-inch pipe with 24-inch reinforced concrete pipe.	-	-	+	3
B4	As an alternative constructing the 12-inch pipe and tying it into the 42-inch system, the 12-inch pipe could be constructed across Regent Drive and tied into the Observatory Field system.	-	0	0	4
B2	Replace approximately 640 lf of 36-inch pipe with 42-inch reinforced concrete pipe between design structures 22 through 25. This would require the replacement of the utility vault conflict structure between design structures 24 and 23.	-	0	-	5
B1	Improve the detention area capacity in the ponds along 28th Street to reduce off-site flows. Also consider wetland enhancement.	-	-	-	6

Table 13: System Improvement Prioritization – Basin D

BASIN-IMPROVEMENT NUMBER	MAIN CAMPUS BASIN D DESCRIPTION	PRIORITIZATION FACTORS			PRIORITY RATING
		Potential Threat to Life	Potential Damage to Property	Ease of Constructability	
D2	Replace approximately 390 lf of 15-inch pipe with a 19"x30" horizontal elliptical concrete pipe between design structures 14 through 18. This will allow for maximum flow area while minimizing the height of the pipe in shallow laying conditions.	-	+	-	1
D1	Replace approximately 135 lf of 8-inch pipe with 15-inch reinforced concrete pipe between design structures 23 and 22	-	+	-	2

Table 14: System Improvement Prioritization – East Campus

BASIN-IMPROVEMENT NUMBER	EAST CAMPUS DESCRIPTION	PRIORITIZATION FACTORS			PRIORITY RATING
		Potential Threat to Life	Potential Damage to Property	Ease of Constructability	
East Campus	In subbasin A, abandon the existing 12-inch storm pipe from the Housing System Service Center on Marine Street to Boulder Creek and construct a new 30-inch pipe system from Marine Street along a new alignment to a proposed water quality pond next to Boulder Creek. The existing 12-inch storm pipe along Marine Street would be replaced with a 21-inch storm pipe to convey the 5-year flow. It was also noticed that the existing inlets had small interception capacities and should be replaced with larger inlets.	-	-	+	1
East Campus	In subbasin B, replace the existing inlet at the southeast corner of the parking lot east of the Institute of Behavioral Genetics and remove and replace the existing 15-inch CMP culvert with an 18-inch pipe. Construct a new inlet in the parking lot east of Research Laboratory No. 2. This new inlet would connect to an 18-inch line that would replace a portion of the existing 8-inch drain leaving Research Laboratory No. 2. Both of the 18-inch lines would daylight to constructed grass swales that lead to the water quality pond. An existing portion of the 8-inch pipe dedicated to drainage leaving Research Laboratory No. 2 would be plugged and abandoned.	-	-	+	2
East Campus	In subbasin D, improve the capacity of the grass swale south of the Warehouse.	-	-	+	2
East Campus	Construct a water quality pond that would intercept and treat all flows from East Campus prior to discharging into Boulder Creek. Due to discharge requirements involving protecting Boulder Creek during construction on the east campus, the University may want to construct the pond prior to undertaking other improvements.	-	-	0	2

Section IX – Cost of System Improvements

Opinions of probable construction cost have been prepared based on proposed improvements within each basin of Main Campus and East Campus. The costs are summarized in the following Tables 15 through 18. They include construction costs, contingency, and engineering services. Construction costs of the proposed improvements are based upon the unit costs of similar construction in the Denver/Boulder area adjusted to the present (May 2004). A 15% contingency has been added due to unforeseen issues or additional work that may occur within each basin, and an allowance of 33% has been added for Engineering Design and Project Management. There are no proposed improvements as part of this report for Basins C and E per Facilities Management, and therefore, no associated cost.

Table 15: Opinion of Probable Construction Cost - Main Campus - Basin A, Kittredge Complex

ITEM NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COST ($/unit)	COST ($)
1	Low flow pipe in Detention Ponds 1 and 2 structure	4	LS	$1,000.00	$4,000
2	Test Soils/Excavate/Dredge Contaminated Detention Ponds	1	LS	$745,420.00	$745,420
3	Remove and Replace 24-inch RCP Storm Drain	235	LF	$75.00	$17,625
4	Construct outfall structure at Detention Pond 3	1	LS	$11,400.00	$11,400
5	Type II Bedding for Riprap	502	SY	$12.00	$6,024
6	Riprap, Type M	167	CY	$60.00	$10,020
7	Excavate Detention Pond 3	898	CY	$7.00	$6,286
8	Pond 3 Lining	1	LS	$42,055	$42,055
9	Reseeding and restoration	60,231	SF	$0.85	$51,196
	SUB-TOTAL				$894,026
	Contingency (15%)				$134,104
	Engineering Design and Project Management (33%)				$295,029
Total	*Rounded to nearest $1000*				***$1,323,000***

*Note: This cost figure is based on removing and disposing of 24,440 C.Y. of contaminated soil. If the soil tests indicate the soils are not contaminated, the cost for Line Item No. 2 would be reduced by approximately $324,000.

Table 16: Opinion of Probable Construction Cost - Main Campus - Basin B, Regent Drive

ITEM NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COST ($/unit)	COST ($)
Alternative 1					
1	Remove 36" RCP Storm Pipe	640	LF	$30	$19,200
2	Construct 42" RCP Storm Pipe	640	LF	$160	$102,400
3	Remove and Replace Utility Tunnel Conflict Structure	1	LS	$16,000	$16,000
4	Manholes	3	EA	$3,000	$9,000
5	Trenching	640	LF	$35	$22,400
6	Bedding	640	LF	$25	$16,000
7	Replace Asphalt	100	SY	$35	$3,500
8	Replace Curb and Gutter	640	LF	$55	$35,200
9	Replace Sidewalk	356	SY	$35	$12,460
10	Restoration and seeding	2,000	SF	0.85	$1,700
	SUB-TOTAL				$237,860
Alternative 2					
1	Construct 12" parallel RCP pipe	640	LF	$75	$48,000
2	Manholes	3	EA	$3,000	$9,000
3	Trenching	640	LF	$35	$22,400
4	Bedding	640	LF	$25	$16,000
5	Replace Asphalt	210	SY	$35	$7,350
6	Replace Curb and Gutter	640	LF	$55	$35,200
7	Replace Sidewalk	356	SY	$35	$12,460
8	Restoration and seeding	500	SF	$0.85	$425
	SUB-TOTAL				$150,835

ITEM NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COST ($/unit)	COST ($)
Alternative 3					
1	Construct 12" RCP to Observatory Field Pipe System	360	LF	$75	$27,000
2	Manholes	1	EA	$3,000	$3,000
3	Trenching	360	LF	$35	$12,600
4	Bedding	360	LF	$25	$9,000
5	Replace Asphalt	30	SY	$35	$1,050
6	Replace Curb and Gutter	20	LF	$55	$1,100
7	Replace Sidewalk	11	SY	$35	$385
8	Restoration and seeding	800	SF	$0.85	$680
	SUB-TOTAL				$54,815
Observatory Field					
1	Remove 18" RCP	1,163	LF	$25	$29,075
2	Construct 24" RCP	1,163	LF	$80	$93,040
3	Manholes	5	EA	$3,000	$15,000
4	Inlets	3	EA	$2,200	$6,600
5	Trenching	1,163	LF	$35	$40,705
6	Bedding	1,163	LF	$25	$29,075
7	Replace Asphalt	144	SY	$35	$5,040
8	Replace Curb and Gutter	20	LF	$55	$1,100
9	Replace Sidewalk	11	SY	$35	$385
10	Restoration and seeding	12,000	SF	0.85	$10,200
	SUB-TOTAL				$230,220
	Alternative 1 and Observatory Field Sub-total				$468,080
	Contingency (15%)				$70,212
	Engineering Design and Project Management (33%)				$154,466
Total	***Rounded to nearest $1000***				***$693,000***

ITEM NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COST ($/unit)	COST ($)
	Alternative 2 and Observatory Field Sub-total				$381,055
	Contingency (15%)				$57,158
	Engineering Design and Project Management (33%)				$125,748
Total	***Rounded to nearest $1000***				***$564,000***
	Alternative 3 and Observatory Field Sub-total				$285,035
	Contingency (15%)				$42,755
	Engineering Design and Project Management (33%)				$94,062
Total	***Rounded to nearest $1000***				***$422,000***

Table 17: Opinion of Probable Construction Cost - Main Campus - Basin D, Folsom Field

ITEM NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COST ($/unit)	COST ($)
1	Remove 8" PVC Storm Pipe	135	LF	$22	$2,970
2	Remove 15" RCP Storm Pipe	390	LF	$25	$9,750
3	Construct 15" RCP Storm Pipe	135	LF	$75	$10,125
4	Construct 19"x30" HERCP Pipe	390	LF	$100	$39,000
5	Manholes	3	EA	$3,000	$9,000
6	Inlet	3	EA	$2,200	$6,600
7	Trenching	525	LF	$35	$18,375
8	Bedding	525	LF	$25	$13,125
9	Replace Asphalt/stadium surfacing	100	SY	$130	$13,000
	SUB-TOTAL				$121,945
	Contingency (15%)				$18,292
	Engineering Design and Project Management (33%)				$40,242
Total	***Rounded to nearest $1000***				***$180,000***

Table 18: Opinion of Probable Construction Cost - East Research Campus - Proposed Drainage Improvements

ITEM NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COST ($/unit)	COST ($)
Phase 1:					
1	48" RCP Storm Sewer	100	LF	$175	$17,500
2	30" RCP Storm Sewer	480	LF	$140	$67,200
3	18" RCP Storm Sewer	55	LF	$80	$4,400
4	5 ft Curb Opening Inlet	3	EA	$2,200	$6,600
5	Manholes	4	EA	$3,000	$12,000
6	Trenching	580	LF	$35	$20,300
7	Bedding	580	LF	$25	$14,500
8	Replace Asphalt	250	SY	$35	$8,750
9	Water Quality Pond Outlet	1	EA	$8,000	$8,000
	SUB-TOTAL	*Rounded to nearest $1000*			$159,000
Phase 2:					
1	18" RCP Storm Sewer	410	LF	$80	$32,800
2	10 ft Curb Opening Inlet	2	EA	$3,200	$6,400
3	Manholes	2	EA	$3,000	$6,000
4	Trenching	410	LF	$35	$14,350
5	Bedding Replace Asphalt	410	LF	$25	$10,250
6	Replace Asphalt	40	SY	$35	$1,400
7	Water Quality Pond	1	LS	$15,000	$15,000
8	Grass Swale	700	LF	$12	$8,400
	SUB-TOTAL	*Rounded to nearest $1000*			$95,000
Phase 3:					
1	18" RCP Storm Sewer	230	LF	$80	$18,400
2	21" RCP Storm Sewer	380	LF	$100	$38,000
3	27" RCP Storm Sewer	70	LF	$110	$7,700

ITEM NO.	DESCRIPTION	QUANTITY	UNIT	UNIT COST ($/unit)	COST ($)
4	5 ft Curb Opening Inlet	3	EA	$2,200	$6,600
5	Manholes	5	EA	$3,000	$15,000
6	Trenching	610	LF	$35	$21,350
7	Bedding	610	LF	$25	$15,250
8	Replace Asphalt	5,475	SY	$35	$191,625
SUB-TOTAL		*Rounded to nearest $1000*			$314,000
	Phase 1				$159,000
	Contingency (15%)				$23,850
	Engineering Design and Project Management (33%)				$52,470
Sub-Total	***Rounded to nearest $1000***				***$235,000***
	Phase 2				$95,000
	Contingency (15%)				$14,250
	Engineering Design and Project Management (33%)				$31,350
Sub-Total	***Rounded to nearest $1000***				***$141,000***
	Phase 3				$314,000
	Contingency (15%)				$47,100
	Engineering Design and Project Management (33%)				$103,620
Sub-Total	***Rounded to nearest $1000***				***$465,000***
Total	***Rounded to nearest $1000***				***$841,000***

Note: Refer to 1995 Drainage Study (Reference 7) for original cost outline and phase reference.

Section X – References

Reference 1: "West Campus Sanitary and Site Drain" 'record' drawings, prepared by Department of Physical Plant, University of Colorado at Boulder, July 1, 1970.

Reference 2: "Ramaley Building Addition and Renovation", prepared by Tri-Consultants, Inc., March 1979.

Reference 3: "City of Boulder Stormwater Collection System Master Plan", prepared by WRC Engineering, Inc., December 1984.

Reference 4: "Student Recreation Center Addition and Renovation" 'record' drawings, prepared by John James Wallace & Associates, January 24, 1991.

Reference 5: "The Dal Ward Center" 'as-built' drawings, prepared by Drexel Barrell, March 24, 1992.

Reference 6: "MCDB Addition to Biosciences Building", prepared by OZ Architecture, November 1992.

Reference 7: "Drainage Study For East Research Campus", prepared by Boyle Engineering Corporation, April 3, 1995.

Reference 8: "18th Street and Colorado Avenue Storm Drainage Improvements Project, Schematic Design Phase Design Record Document," by Merrick & Company, January 1996.

Reference 9: "University of Colorado, Research Laboratory No. 2 Foundation Drainage Design", prepared by Boyle Engineering Corporation, March 1998.

Reference 10: "University of Colorado Storm Drainage Study for Storm Drainage & Roadway Improvements," prepared by WRC Engineering, Inc., October 1998.

Reference 11: "Schematic Design Phase Design Record Document Southwest Quad Storm Sewer Upgrade," prepared by Kirkham Michael, June 2000.

Reference 12: "Campus Master Plan", prepared by the University of Colorado at Boulder, March 2001.

Reference 13: "Storm Sewer Upgrade Project" record drawings, prepared by Kirkham Michael Consulting Engineers, May 13, 2002.

Reference 14: "Final Hydraulics Report for 28th Street Improvements", prepared by Love & Associates, Inc., September 27, 2002.

Reference 15: Storm Water Utilities base map (strm.dwg, AutoCAD), prepared by Facilities Management, University of Colorado at Boulder, December 2003.

Reference 16: "Urban Storm Drainage Criteria Manual," Urban Drainage and Flood Control District.

Reference 17: BCSDCM Boulder County Storm Design Criteria Manual.

Reference 18: UDSEWER, Urban Drainage and Flood Control District

Appendix A – Figures, Existing Conditions

Appendix D – Storm Sewer Modeling Data

BASIN B (NORTH)
UDSEWER DATA INPUT SUMMARY
EXISTING STORM PIPE SYSTEM

BOYLE ENGINEERING CORPORATION

CLIENT: University of Colorado at Boulder
PROJECT: Storm Water Master Plan
SUBJECT: Modeling Information
DETAILS Basin B Info (North)

PROJECT NO: DN-C09-402-01
BY: DRR
CHECKED BY: DPS

UCB Map		U/S Model	D/S Model			(1)									Existing	Build-out	Sheet Flow		Shallow Conc. Flow	
U/S Node	D/S Node	Node	Node	U/S Inv	D/S Inv	Length (ft)	Slope (ft/ft)	U/S Rim	D/S Rim	Pipe Size (in)	Notes	U/S Crown	Sub Basin No.	Area (ac)	C5	C5	Length (ft)	Slope (%)	Length (ft)	Vel. (ft/sec)
SD0060	POND	2	1	5319.20	5315.78	71	0.0482	5325.32	5317.78	24	RCP	5321.20								
4006	SD0060	3	2	5324.65	5319.30	42	0.1274	5326.37	5325.32	12	SD0060 Inv Est from 4006	5325.65	B1N	3.52	0.70		300	1.83	500	3.0
SD0061	SD0060	4	2	5332.95	5319.30	328	0.0416	5339.86	5325.32	24	RCP	5334.95								
SD 'U'	SD0061	5	4	5336.85	5333.60	142	0.0229	5343.87	5339.86	24	RCP	5338.85								
SD0062	SD 'U'	6	5	5338.45	5337.05	41	0.0341	5346.54	5343.87	24	RCP	5340.45								
SD 'D'	SD0062	7	6	5342.80	5338.55	129	0.0329	5350.64	5346.54	24	RCP	5344.80								
Inlet 'K'	SD 'D'	8	7	5344.15	5343.35	102	0.0078	5351.91	5350.64	18	RCP	5345.65	B2N	4.07	0.88		300	2.67	420	3.3
SD0065	SD 'D'	9	7	5349.90	5342.90	183	0.0383	5357.66	5350.64	24	RCP	5351.90								
4011	SD0065	10	9	5354.65	5349.95	101	0.0465	5357.51	5357.66	24	RCP	5356.65	B3N	0.36	0.50		50	8.33	250	2.0
New MH	SD 'U'	11	5	5338.35	5337.45	211	0.0043	5346.85	5343.87	30	MH-DLC Plan, Inv/Rim adj	5340.85								
SD0064	New MH	12	11	5338.85	5338.55	46	0.0065	5352.55	5346.85	24	MH-DLC Plan, Inv/Rim adj	5340.85								
SD0205	SD0064	13	12	5339.65	5339.05	152	0.0039	5353.70	5352.55	24	RCP	5341.65								
Junction	SD0205	14	13	5356.50	5342.60	427	0.0326	5360.00	5353.70	12	Jct 12"/8" Pipe, Inv/Rim Est	5357.50								
Inlet 'H'	Junction	15	14	5364.20	5356.50	117	0.0658	5368.20	5360.00	8	RCP	5364.87	B4N	0.95	0.74		90	6.67	160	1.4
												0.00								
4072	SD0205	16	13	5340.40	5339.75	88	0.0074	5354.48	5353.70	24	RCP	5342.40	B5N	3.01	0.88		200	3.00	300	3.0
SD0204	4072	17	16	5340.60	5340.55	36	0.0014	5355.34	5354.48	24	RCP	5342.60								
SD0202	SD0204	18	17	5343.80	5340.65	71	0.0444	5356.24	5355.24	24	RCP	5345.80								
SD0200	SD0202	19	18	5350.90	5347.20	129	0.0287	5359.68	5356.24	12	RCP	5351.90								
SD0199	SD0200	20	19	5354.15	5353.55	70	0.0086	5362.10	5359.68	12	RCP	5355.15								
SD0198	SD0199	21	20	5355.20	5354.20	181	0.0055	5368.41	5362.10	12	RCP	5356.20								
Inlet H	SD0198	22	21	5356.95	5355.25	125	0.0136	5368.41	5368.41	6	RCP	5357.45	B6N	1.06	0.50		100	5.00	100	2.0
4059	Inlet H	23	21	5356.90	5355.25	368	0.0045	5369.06	5368.41	12	RCP	5357.90	B7N	0.77	0.50		100	8.00	50	2.0

Notes:
1) Lengths rounded to the nearest foot

BASIN B (SOUTH)
UDSEWER DATA INPUT SUMMARY
EXISTING STORM PIPE SYSTEM

BOYLE ENGINEERING CORPORATION

CLIENT: University of Colorado at Boulder
PROJECT: Storm Water Master Plan
SUBJECT: Modeling Information
DETAILS Basin B Info (South)

PROJECT NO: DN-C09-402-01
BY: DRR
CHECKED BY: DPS

UCB Map		U/S Model	D/S Model			(1)									Existing	Build-out	Sheet Flow		Shallow Conc. Flow	
U/S Node	D/S Node	Node	Node	U/S Inv	D/S Inv	Length (ft)	Slope (ft/ft)	U/S Rim	D/S Rim	Pipe Size (in)	Notes	U/S Crown	Sub Basin No.	Area (ac)	C5	C5	Length (ft)	Slope (%)	Length (ft)	Vel. (ft/sec)
4014	Outlet	2	1	5330.15	5327.08	87	0.0353	5335.61	5331.08	48	RCP	5334.15	B1S	3.89	0.66	0.78	300	4.50	300	3.3
											RCP									
SD0265	4014	3	2	5331.90	5330.15	121	0.0145	5337.13	5335.61	18	SD0265 Elevs Est	5333.40								
SD0264	SD0265	4	3	5339.35	5331.90	166	0.0449	5343.16	5337.13	18	RCP	5340.85								
SD0207	SD0264	5	4	5340.00	5339.65	60	0.0058	5343.83	5343.16	18	RCP	5341.50	B2S	1.36	0.90		250	0.50	70	1.5
SD0208	SD0264	6	4	5349.45	5339.40	218	0.0461	5354.45	5343.16	18	RCP	5350.95								
4010	SD0208	7	6	5351.80	5349.55	71	0.0317	5354.75	5354.45	18	RCP	5353.30								
4009	4010	8	7	5352.00	5351.85	27	0.0056	5355.02	5354.75	24	CMP	5354.00	B3S	3.12	0.18		300	2.17	300	1.1
SD0209	SD0208	9	6	5353.70	5349.80	167	0.0234	5357.73	5354.45	18	RCP	5355.20								
4012	SD0209	10	9	5353.95	5353.75	24	0.0083	5357.46	5357.73	18	RCP	5355.45								
4011	4012	11	10	5354.70	5354.00	44	0.0159	5357.51	5357.46	18	D/S Inv. Estimated	5356.20	B4S	3.89	0.46		300	4.00	555	2.5
Inlet	4014	12	2	5336.45	5330.05	310	0.0206	5343.73	5335.61	48	RCP	5340.45	B5S	5.98	0.50	0.58	250	12.80	730	3.0
4015	Inlet	13	12	5338.55	5336.50	75	0.0273	5345.46	5343.73	48	D/S Inv. Estimate	5342.55								
SD0192	4015	14	13	5345.85	5339.40	179	0.0360	5361.58	5345.46	42	RCP	5349.35								
SD0191	SD0192	15	14	5353.86	5352.05	179	0.0101	5364.00	5361.58	18	SD0191 Rim and Inv Est	5355.36								
SD0190	SD0191	16	15	5355.70	5353.91	165	0.0108	5366.00	5364.00	18	SD0190 Rim and Inv Est	5357.20								
SD0189	SD0190	17	16	5357.60	5355.75	171	0.0108	5365.36	5366.00	18	RCP	5359.10	B6S	3.20	0.12	0.50	100	2.00	400	2.4
SD0188	SD0189	18	17	5361.00	5357.65	234	0.0143	5369.55	5365.36	18	RCP	5362.50								
SD0187	SD0188	19	18	5365.30	5361.10	187	0.0225	5374.98	5369.55	18	RCP	5366.80								
4049	SD0187	20	19	5370.10	5370.25	54	-0.0028	5375.58	5374.98	12	Inv. Slope based on survey	5371.10	B7S	5.94	0.70		280	3.21	1000	3.8
3015	4049	21	20	5373.40	5371.15	173	0.0130	5375.45	5375.58	12	RCP	5374.40	B8S	2.97	0.50		250	7.60	550	3.4
4056	SD0192	22	14	5361.05	5345.95	447	0.0338	5367.56	5361.58	36	RCP	5364.05	B9S	4.37	0.38	0.43	300	3.33	570	1.8
4040	4056	23	22	5371.50	5361.15	547	0.0189	5377.91	5367.56	36	RCP	5374.50								
4040a	4040	24	23	5371.50	5371.50	13	0.0000	5378.00	5377.91	36	RCP	5374.50								
Pond Inlet	4040a	25	24	5374.57	5371.50	79	0.0389	5377.57	5378.00	36	RCP	5377.57	B10S	100.57	0.65		300	8.33	3750	3.5

Notes:
1) Lengths rounded to the nearest foot

BASIN C
UDSEWER DATA INPUT SUMMARY
EXISTING STORM PIPE SYSTEM

BOYLE ENGINEERING CORPORATION

CLIENT: University of Colorado at Boulder
PROJECT: Storm Water Master Plan
SUBJECT: Modeling Information
DETAILS Basin C Info (System along Colorado Avenue)

PROJECT NO: DN-C09-402-01
BY: DRR
CHECKED BY: DPS

UCB Map		U/S Model	D/S Model			(1)									Existing	Build-out	Sheet Flow		Concentrated Flow	
U/S Node	D/S Node	Node	Node	U/S Inv	D/S Inv	Length (ft)	Slope (ft/ft)	U/S Rim	D/S Rim	Pipe Size (in)	Notes	U/S Crown	Sub Basin No.	Area (ac)	C5	C5	Length (ft)	Slope (%)	Length (ft)	Vel (ft/sec)
3017	SD0068	18	1	5351.81	5351.40	56	0.0074	5363.86	5365.60	30	Crosses Colorado	5354.31	Basin 'C1', Inflow	36.77						
SD0069	SD0068	2	1	5355.65	5354.30	241	0.0056	5368.12	5365.60	42	P-9 (2), RCP	5359.15	C1	0.64	0.85		70	1.43	435	2.3
SD0070	SD0069	3	2	5356.81	5355.67	253	0.0045	5372.66	5368.12	42	P-8 (2), RCP	5360.31	C2	0.45	0.85		50	1.40	275	2.0
3019	SD0070	11	3	5359.33	5359.21	37	0.0032	5371.73	5372.30	27	RCP	5361.58	C5	1.55	0.85		300	2.03	85	2.9
SD0088	SD0070	4	3	5361.74	5357.90	344	0.0112	5374.88	5372.66	36	P-7 (2), RCP	5364.74	C3	1.72	0.77		170	3.35	280	2.1
SD0096	SD0088	5	4	5364.35	5362.31	156	0.0131	5376.69	5374.88	30	P-6 (2), RCP	5366.85								
SD0099	SD0096	6	5	5366.76	5364.57	83	0.0264	5377.95	5376.69	30	P-5 (2), RCP	5369.26								
SD0098	SD0099	7	6	5368.58	5366.97	52	0.0310	5379.03	5377.95	30	P-4 (2), RCP	5371.08								
SD0103	SD0098	8	7	5374.05	5368.80	166	0.0316	5385.13	5379.03	30	P-3 (2), RCP	5376.55	C4	2.04	0.64		80	1.88	400	2.7
SD0104	SD0103	9	8	5375.54	5374.26	63	0.0203	5389.04	5385.13	30	P-2 (2), RCP	5378.04								
SD0105	SD0104	10	9	5378.67	5376.26	126	0.0191	5393.17	5389.04	27	P-1 (2), RCP	5380.92	Basin 'C2', Inflow	26.81						

Notes:
1) Lengths rounded to the nearest foot
2) Pipe designation from Southwest Quad Storm Sewer Upgrade by Kirkham Michael Consulting Engineers dated June 21, 2000

BASIN C
UDSEWER DATA INPUT SUMMARY
EXISTING STORM PIPE SYSTEM

BOYLE ENGINEERING CORPORATION

CLIENT: University of Colorado at Boulder
PROJECT: Storm Water Master Plan
SUBJECT: Modeling Information
DETAILS Basin C1 Info (South of Colorado)

PROJECT NO: DN-C09-402-01
BY: DRR
CHECKED BY: DPS

UCB Map		U/S Model	D/S Model			(1)									Existing	Build-out	Sheet Flow		Concentrated Flow	
U/S Node	D/S Node	Node	Node	U/S Inv	D/S Inv	Length (ft)	Slope (ft/ft)	U/S Rim	D/S Rim	Pipe Size (in)	Notes	U/S Crown	Sub Basin No.	Area (ac)	C5	C5	Length (ft)	Slope (%)	Length (ft)	Vel (ft/sec)
		18	1	5351.81	5351.40	56	0.0074	5363.86	5365.60	30	Crosses Colorado	5354.31	C8	2.06	0.71	0.73	210	2.60	280	2.0
---	3017	19	18	5352.45	5351.91	17	0.0327	5364.45	5363.86	30	WRC Line A	5354.95								
SD0074	---	54	19	5354.50	5352.55	197	0.0099	5366.83	5364.45	24	Existing around Benson	5356.50								
SD0073	SD0074	20	54	5355.38	5354.50	77	0.0115	5370.50	5366.83	24	Existing around Benson	5357.38								
3022	SD0073	21	20	5362.70	5355.38	158	0.0465	5370.80	5370.50	24	Existing around Benson	5364.70	C9	1.03	0.48		220	1.36	40	1.1
SD0072	SD0073	56	20	5355.71	5355.38	16	0.0210	5368.50	5370.50	24	Existing around Benson	5357.71								
SD0071	SD0072	12	56	5358.00	5355.71	211	0.0109	5372.00	5368.50	24	Existing around Benson	5360.00								
SD0085	SD0071	13	12	5358.81	5358.00	62	0.0131	5372.50	5372.00	24	Existing around Benson	5360.81								
SD0084	SD0085	14	13	5359.97	5358.81	77	0.0152	5374.20	5372.50	24	Existing around Benson	5361.97								
---	SD0084	15	14	5368.50	5365.42	154	0.0200	5377.00	5374.20	18	WRC Line B	5370.00	C6	4.33	0.29		170	3.82	490	0.5
---	---	16	15	5372.60	5368.50	406	0.0101	5380.50	5377.00	18	WRC Line B	5374.10								
---	---	17	16	5373.60	5372.60	100	0.0100	5387.00	5380.50	18	WRC Line B	5375.10	C7	0.88	0.35	0.36	90	4.44	100	1.0
---	---	22	19	5354.32	5354.13	12	0.0158	5364.70	5364.75	30	WRC Line A	5356.82								
SD0067	---	45	22	5357.11	5354.52	116	0.0224	5364.25	5364.70	18	Existing Line	5358.61								
4068	SD0067	46	45	5359.90	5357.11	125	0.0223	5366.25	5364.25	18	Existing Line	5361.40	C10	1.26	0.30		210	1.90	160	0.7
SD0075	4068	47	46	5360.87	5359.90	44	0.0223	5367.75	5366.25	18	Existing Line	5362.37								
SD0076	SD0075	48	47	5362.76	5360.87	85	0.0223	5368.50	5367.75	18	Existing Line	5364.26								
SD0077	SD0076	49	48	5363.71	5362.76	43	0.0224	5369.50	5368.50	18	Existing Line	5365.21								
SD0078	SD0077	50	49	5364.76	5363.71	47	0.0224	5370.50	5369.50	18	Existing Line	5366.26								
SD0083	SD0078	51	50	5366.61	5364.76	83	0.0223	5370.00	5370.50	18	WRC Line C	5368.11								
---	SD0083	52	51	5367.10	5366.61	50	0.0098	5370.00	5370.00	18	WRC Line C	5368.60	C13	2.92	0.45		190	3.68	620	0.9
3032 / 3033	SD 0083	53	51	5366.84	5366.61	24	0.0098	5371.00	5370.00	6	Ex. Line behind Cockrell	5367.34	C14	5.51	0.37		300	4.17	950	1.0
---	---	23	22	5357.00	5355.20	178	0.0101	5367.25	5364.70	30	WRC Line A	5359.50								
---	---	24	23	5359.20	5357.00	202	0.0109	5371.00	5367.25	30	WRC Line A	5361.70								
---	---	43	24	5364.60	5363.52	54	0.0200	5371.80	5371.00	24	WRC Line A-4	5366.60								
---	---	44	43	5365.00	5364.60	19	0.0211	5371.90	5371.80	24	WRC Line A-5, Typ R	5367.00	C11	1.70	0.45		95	7.37	390	2.6
---	---	25	24	5361.50	5359.20	210	0.0110	5374.00	5371.00	30	WRC Line A	5364.00								
---	---	26	25	5362.80	5361.50	110	0.0118	5376.30	5374.00	30	WRC Line A	5365.30								
---	---	42	26	5368.50	5362.80	82	0.0695	5373.60	5376.30	18	WRC Line A-3, Typ C	5370.00	C12	0.61	0.37		230	3.91	35	1.3
SD0185	---	27	26	5367.80	5362.80	238	0.0210	5381.20	5376.30	30	WRC Line A	5370.30								
---	SD0185	28	27	5368.50	5367.80	28	0.0250	5381.75	5381.20	30	RC Line A, 'R' Inlet brought to	5371.00	C15	2.05	0.61		40	5.00	470	1.5
---	---	55	28	5371.50	5368.50	100	0.0300	5384.00	5381.75	30	WRC Line A	5374.00								
---	---	29	55	5373.90	5371.50	86	0.0279	5386.00	5384.00	30	WRC Line A	5376.40	C16	5.29	0.31		300	3.67	365	2.7
SD0129	---	35	29	5376.50	5373.90	234	0.0111	5387.50	5386.00	24	WRC Line A-2	5378.50								
SD0128	SD0129	36	35	5379.50	5376.50	279	0.0108	5389.60	5387.50	24	WRC Line A-2	5381.50								
3015	SD0128	37	36	5386.80	5379.50	62	0.1177	5393.50	5389.60	18	WRC Line A-2, Typ R Inlet	5388.30	C17	1.88	0.66		230	2.30	460	0.9
SD0163	3015	38	37	5389.50	5386.80	60	0.0450	5398.00	5393.50	18	WRC Line A-2	5391.00								
SD0164	SD0163	39	38	5390.10	5389.50	28	0.0214	5397.10	5398.00	18	WRC Line A-2	5391.60								
SD0166	SD0164	40	39	5394.40	5390.10	207	0.0208	5402.50	5397.10	18	WRC Line A-2	5395.90								
---	SD0166	41	40	5397.20	5394.40	45	0.0622	5405.50	5402.50	18	WRC Line A-2, Typ R Inlet	5398.70	C19	2.79	0.63	0.68	165	2.91	425	3.2

BASIN C
UDSEWER DATA INPUT SUMMARY
EXISTING STORM PIPE SYSTEM

BOYLE ENGINEERING CORPORATION

CLIENT: University of Colorado at Boulder
PROJECT: Storm Water Master Plan
SUBJECT: Modeling Information
DETAILS Basin C1 Info (South of Colorado)

PROJECT NO: DN-C09-402-01
BY: DRR
CHECKED BY: DPS

UCB Map		U/S Model	D/S Model			(1)									Existing	Build-out	Sheet Flow		Concentrated Flow	
U/S Node	D/S Node	Node	Node	U/S Inv	D/S Inv	Length (ft)	Slope (ft/ft)	U/S Rim	D/S Rim	Pipe Size (in)	Notes	U/S Crown	Sub Basin No.	Area (ac)	C5	C5	Length (ft)	Slope (%)	Length (ft)	Vel (ft/sec)
---	---	30	29	5383.00	5373.90	297	0.0306	5390.80	5386.00	24	WRC Line A, Wardenburg Driv	5385.00								
---	---	31	30	5385.00	5383.00	58	0.0345	5392.70	5390.80	24	RC Line A, R Inlets brought to	5387.00	C18	3.01	0.55		190	5.79	320	1.2
---	---	32	31	5389.70	5385.00	115	0.0409	5396.75	5392.70	24	WRC Line A, Wardenburg Driv	5391.70								
---	---	33	32	5396.80	5389.70	248	0.0286	5405.00	5396.75	18	RC Line A, East of Cheyenne-A	5398.30								
3112	---	34	33	5397.70	5396.80	99	0.0091	5402.00	5396.75	18	VRC Line A, Connect to Ex. Inl	5399.20	C20	3.51	0.48	0.50	300	3.83	300	0.9

Notes:
1) Lengths rounded to the nearest foot
2) Shaded cells indicate elevations that were estimated

BASIN C
UDSEWER DATA INPUT SUMMARY
EXISTING STORM PIPE SYSTEM

BOYLE
ENGINEERING CORPORATION

CLIENT: University of Colorado at Boulder
PROJECT: Storm Water Master Plan
SUBJECT: Modeling Information
DETAILS Basin C2 Info (Southwest Quadrant)

PROJECT NO: DN-C09-402-01
BY: DRR
CHECKED BY: DPS

UCB Map		U/S Model	D/S Model			(1)										Existing	Build-out	Sheet Flow		Shallow Conc. Flow	
U/S Node	D/S Node	Node	Node	U/S Inv	D/S Inv	Length (ft)	Slope (ft/ft)	U/S Rim	D/S Rim	Pipe Size (in)	Notes		U/S Crown	Sub Basin No.	Area (ac)	C5	C5	Length (ft)	Slope (%)	Length (ft)	Vel. (ft/sec)
SD0105	SD0104	2	1	5378.67	5376.26	126	0.0191	5392.17	5389.04	27	P27	(2)	5380.92								
3060	SD0105	3	2	5385.87	5385.23	21	0.0305	5392.48	5392.17	15	P24	(2)	5387.12	C32	2.05	0.80		300	3.30	560	3.3
3059	SD0105	32	2	5383.30	5380.00	73	0.0452	5391.70	5392.17	15	P26	(2)	5384.55	C31	1.16	0.10		200	2.80	260	2.7
3061	SD0105	4	2	5386.99	5385.16	25	0.0732	5392.71	5392.17	15	P25	(2)	5388.24	C33	0.17	0.88		25	1.00	110	1.8
SD0107	SD0105	5	2	5380.05	5379.52	53	0.0100	5393.15	5392.17	24	P23	(2)	5382.05								
3063	SD0107	6	5	5385.93	5385.15	21	0.0371	5395.00	5393.21	15	Sibell-Wolle	(3)	5387.18	C34	0.14	0.20		90	3.33	20	1.6
SD0258	SD0107	7	5	5383.10	5382.14	96	0.0100	5395.33	5393.21	24	Sibell-Wolle	(3)	5385.10								
3176	SD0258	43	7	5388.22	5383.30	196	0.0250	5398.40	5395.33	24	Sibell-Wolle	(3)	5390.22								
SD0259	3176	8	43	5388.68	5388.42	26	0.0101	5399.30	5398.40	24	Sibell-Wolle	(3)	5390.68								
---	SD0259	34	8	5390.42	5388.92	135	0.0111	5399.87	5399.30	24	Sibell-Wolle	(3)	5392.42								
---	---	35	34	5391.01	5390.62	39	0.0099	5399.90	5399.87	24	Sibell-Wolle	(3)	5393.01								
---	---	36	35	5391.60	5391.21	39	0.0100	5399.12	5399.90	24	Sibell-Wolle	(3)	5393.60								
??	SD0262	37	36	5391.72	5391.60	12	0.0104	5399.12	5399.12	24	Sibell-Wolle	(3)	5393.72	C40	1.36	0.80		135	8.30	195	3.5
SD0154	??	38	37	5392.50	5391.72	27	0.0289	5404.00	5399.12	18	Sibell-Wolle	(3)	5394.00								
SD0155	SD0154	39	38	5397.25	5392.50	95	0.0500	5406.60	5404.00	10	Sibell-Wolle	(3)	5398.08	C42	2.15	0.80		300	3.80	270	1.0
$$	SD0154	40	38	5400.78	5397.25	75	0.0471	5404.00	5404.00	18	Sibell-Wolle	(3)	5402.28								
SD0153	??	41	40	5400.80	5400.78	1	0.0200	5408.00	5404.00	18	Sibell-Wolle	(3)	5402.30								
3172	SD0153	42	41	5401.94	5400.80	82	0.0139	5408.00	5408.00	18	Sibell-Wolle	(3)	5403.44	C41	7.30	0.80		300	5.00	290	4.0
---	SD0107	9	5	5381.00	5380.35	84	0.0077	5393.20	5393.15	24	P21	(2)	5383.00								
3067	---	10	9	5388.18	5382.80	25	0.2152	5392.48	5393.20	15	P20	(2)	5389.43	C36	0.25	0.88		20	0.75	270	1.8
3066	---	11	9	5381.67	5381.25	17	0.0247	5392.67	5393.20	15	P19	(2)	5382.92	C39	1.76	0.30	0.40	300	2.20	305	3.1
2020	---	12	9	5386.40	5382.00	168	0.0262	5395.90	5393.20	15	P18	(2)	5387.65	C35	1.15	0.30	0.49	90	3.30	150	3.0
SD0121	---	14	9	5382.45	5381.65	114	0.0070	5393.97	5393.20	24	P17	(2)	5384.45								
---	SD0121	50	14	5383.74	5382.75	59	0.0167	5394.90	5393.97	18	EnvDesign	(4)	5385.24								
---	---	51	50	5384.91	5383.94	81	0.0119	5396.28	5394.90	18	EnvDesign	(4)	5386.41								
---	---	52	51	5385.44	5385.11	32	0.0102	5393.60	5396.28	18	EnvDesign	(4)	5386.94								
---	---	53	52	5387.22	5386.40	79	0.0104	5395.80	5393.60	18	EnvDesign	(4)	5388.72	C37	0.51	0.88		40	8.30	200	2.8
SD0120	SD0121	15	14	5382.61	5382.45	24	0.0067	5394.25	5393.97	24	P16	(2)	5384.61								
3068	SD0120	13	15	5389.27	5386.15	18	0.1733	5393.17	5394.25	15	P15	(2)	5390.52	C38	0.95	0.88		15	2.00	400	3.3
SD0123	SD0120	16	15	5383.31	5382.61	185	0.0038	5398.57	5394.25	18	P14	(2)	5384.81								
SD0122	SD0123	18	16	5393.75	5389.50	55	0.0773	5400.20	5398.57	18	P35	(2)	5395.25								
---		19	18	5397.06	5394.35	138	0.0196	5403.40	5400.20	18	P34	(2)	5398.56								

BASIN C
UDSEWER DATA INPUT SUMMARY
EXISTING STORM PIPE SYSTEM

BOYLE ENGINEERING CORPORATION

CLIENT: University of Colorado at Boulder
PROJECT: Storm Water Master Plan
SUBJECT: Modeling Information
DETAILS Basin C2 Info (Southwest Quadrant)

PROJECT NO: DN-C09-402-01
BY: DRR
CHECKED BY: DPS

UCB Map		U/S Model	D/S Model			(1)									Existing	Build-out	Sheet Flow		Shallow Conc. Flow	
U/S Node	D/S Node	Node	Node	U/S Inv	D/S Inv	Length (ft)	Slope (ft/ft)	U/S Rim	D/S Rim	Pipe Size (in)	Notes	U/S Crown	Sub Basin No.	Area (ac)	C5	C5	Length (ft)	Slope (%)	Length (ft)	Vel. (ft/sec)
---		20	19	5398.37	5397.06	67	0.0196	5404.00	5430.40	18	P33 (2)	5399.87	C43	0.18	0.10		10	2.70	110	1.4
SD0161	SD0123	21	16	5389.96	5387.43	79	0.0320	5400.49	5398.57	18	P12 (2)	5391.46								
SD0160	SD0161	33	21	5392.45	5392.09	28	0.0129	5401.68	5400.49	12	P11 (2)	5393.45	C44	1.07	0.95		20	0.50	300	1.5
SD0159	SD0161	22	21	5391.59	5390.75	107	0.0079	5403.29	5400.49	18	P10 (2)	5393.09								
2022	SD0159	23	22	5392.34	5391.59	89	0.0084	5406.00	5403.29	18	P8 (2)	5393.84	C45	1.88	0.88		20	2.00	700	1.1
2024	2022	24	23	5399.04	5397.04	64	0.0313	5407.04	5406.00	18	P7 (2)	5400.54	C49	1.79	0.88		300	4.40	40	4.3
SD0158	SD0159	25	22	5397.50	5395.20	36	0.0639	5404.01	5403.29	12	P6 (2)	5398.50								
SD0157	SD0158	26	25	5403.40	5401.01	54	0.0443	5406.10	5404.01	12	P5 (2)	5404.40								
2025	SD0157	27	26	5403.60	5403.50	32	0.0031	5406.10	5406.10	12	P4 (2)	5404.60	C48	2.21	0.10		150	3.10	330	3.1
2026	SD0157	28	26	5403.90	5403.53	13	0.0285	5406.90	5406.10	12	P3 (2)	5404.90	C46	0.29	0.88		20	2.00	280	2.9
SD0156	SD0157	29	26	5409.66	5403.40	80	0.0783	5411.44	5406.10	12	P2A (2)	5410.66								
2093	SD0156	30	29	5410.20	5409.66	24	0.0225	5411.90	5411.44	12	P2 (2)	5411.20								
2091	2093	31	30	5411.45	5410.20	81	0.0154	5412.70	5411.90	12	P1 (2)	5412.45	C47	0.51	0.88		20	2.00	760	2.3

Notes:
1) Lengths rounded to the nearest foot
2) Pipe designation from Southwest Quad Storm Sewer Upgrade by Kirkham Michael Consulting Engineers dated June 21, 2000
3) Pipe data obtained from as-built drawings for a storm sewer upgrade adjacent to Sibell-Wolle dated May 13th, 2002 produced by Kirkham Michael Consulting Engineers
4) Pipe data obtained from as-built drawings for a storm sewer upgrade east and north of Environmental design dated January 27, 1197 produced by Merrick, Inc.

BASIN D
UDSEWER DATA INPUT SUMMARY
EXISTING STORM PIPE SYSTEM

BOYLE ENGINEERING CORPORATION

CLIENT: University of Colorado at Boulder
PROJECT: Storm Water Master Plan
SUBJECT: Modeling Information
DETAILS Basin D Info (North to Boulder Creek)

PROJECT NO: DN-C09-402-01
BY: DRR
CHECKED BY: DPS

UCB Map		U/S Model	D/S Model			(1)									Existing	Build-out	Sheet Flow		Shallow Conc. Flow	
U/S Node	D/S Node	Node	Node	U/S Inv	D/S Inv	Length (ft)	Slope (ft/ft)	U/S Rim	D/S Rim	Pipe Size (in)	Notes	U/S Crown	Sub Basin No.	Area (ac)	C5	C5	Length (ft)	Slope (%)	Length (ft)	Vel. (ft/sec)
SD0055	Outfall	2	1	5323.90	5303.84	156	0.1287	5343.96	5305.84	24	RCP	5325.90	D1	1.37	0.70	0.75	167	10.78	355	4.0
SD0054	SD0055	3	2	5325.10	5324.20	75	0.0121	5344.96	5343.96	24	RCP	5327.10								
SD0052	SD0054	4	3	5330.65	5325.20	88	0.0620	5336.42	5344.96	24	RCP	5332.65								
Inlet 'M'	SD0052	5	4	5331.30	5330.75	35	0.0157	5337.43	5341.84	18	RCP	5332.80	D2	3.76	0.88		180	66.00	360	1.5
SD0053	Inlet 'M'	6	5	5331.45	5331.40	17	0.0029	5336.76	5337.43	15	RCP	5332.70								
SD 'N'	SD0053	7	6	5331.35	5331.55	23	-0.0087	5336.65	5336.76	15	RCP	5332.60								
Inlet 'P'	SD 'N'	8	7	5331.72	5331.40	137	0.0023	5336.77	5336.65	15	RCP	5332.97	D3	2.80	0.88		117	66.00	350	1.5
SD0051	Inlet ' P'	9	8	5331.75	5331.72	21	0.0014	5336.87	5336.77	15	RCP	5333.00								
Intersection	SD0051	10	9	5333.18	5331.85	276	0.0048	5336.65	5336.87	15	RCP	5334.43								
Clean-out	Intersection	11	10	5336.60	5333.18	43	0.0795	5340.01	5336.65	12	RCP	5337.60								
SD0050	Cleanout	12	11	5368.20	5336.60	177	0.1785	5400.00	5340.01	12	RCP	5369.20								
SD0039	SD0050	13	12	5370.10	5368.20	192	0.0099	5402.50	5400.00	12	RCP	5371.10	D4	0.98	0.88		130	8.30	105	1.8
SD 'Q'	Intersection	14	10	5333.85	5333.18	90	0.0074	5336.42	5336.65	15	RCP	5335.10								
SD 'R'	SD 'Q'	15	14	5334.00	5333.90	15	0.0067	5336.33	5336.42	15	RCP	5335.25								
SD0056	SD ' R'	16	15	5334.45	5334.05	58	0.0069	5336.78	5336.33	15	RCP	5335.70								
Inlet 'S'	SD0056	17	16	5334.70	5334.50	16	0.0125	5337.02	5336.78	15	RCP	5335.95								
SD0089	Inlet 'S'	18	17	5360.70	5334.70	211	0.1232	5376.56	5337.02	15	RCP	5361.95	D5	1.98	0.88		190	66.00	216	1.5
SD0090	SD0089	19	18	5361.24	5361.10	31	0.0045	5376.39	5376.56	12	RCP	5362.24								
3072	SD0090	20	19	5361.41	5361.30	25	0.0044	5375.81	5376.39	12	RCP	5362.41	D6	0.53	0.88		85	0.72	150	1.7
SD0256	3072	21	20	5361.84	5361.51	130	0.0025	5378.14	5375.81	12	RCP	5362.84	D7	0.54	0.88		40	5.00	142	2.0
SD0102	SD0256	22	21	5361.77	5361.94	58	-0.0029	5378.56	5378.14	18	RCP	5363.27								
3070	SD0102	23	22	5376.22	5374.02	135	0.0163	5380.20	5378.56	8	RCP	5376.89	D8	1.13	0.88		130	2.00	133	4.0
3034	SD0102	24	22	5362.14	5361.87	85	0.0032	5379.31	5378.57	18	RCP	5363.64								
SD0047	3034	25	24	5363.02	5362.24	106	0.0074	5380.52	5379.31	18	RCP	5364.52	D9	0.98	0.88		113	8.30	110	3.3

Notes:
1) Lengths rounded to the nearest foot

BASIN E
UDSEWER DATA INPUT SUMMARY
EXISTING STORM PIPE SYSTEM

BOYLE ENGINEERING CORPORATION

CLIENT: University of Colorado at Boulder
PROJECT: Storm Water Master Plan
SUBJECT: Modeling Information
DETAILS Basin E Info (Drains to Rec Center Outfall)

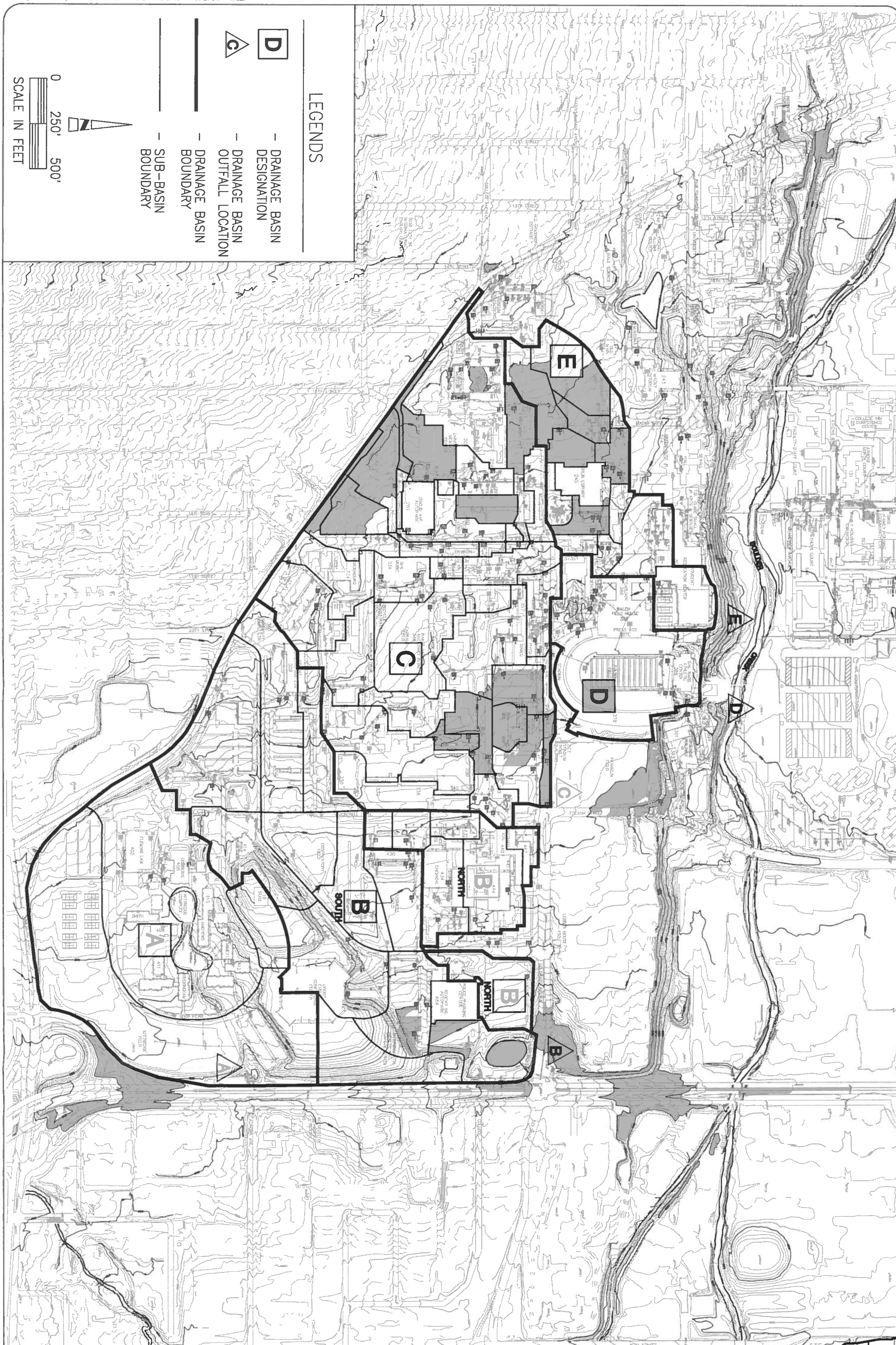
PROJECT NO: DN-C09-402-01
BY: DRR
CHECKED BY: DPS

UCB Map		U/S Model	D/S Model			(1)									Existing	Build-out	Sheet Flow		Shallow Conc. Flow	
U/S Node	D/S Node	Node	Node	U/S Inv	D/S Inv	Length (ft)	Slope (ft/ft)	U/S Rim	D/S Rim	Pipe Size (in)	Notes	U/S Crown	Sub Basin No.	Area (ac)	C5	C5	Length (ft)	Slope (%)	Length (ft)	Vel. (ft/sec)
SD0035	Outfall	2	1	5347.55	5347.14	104	0.0040	5368.00	5350.14	36	RCP	5350.55	E1	2.67	0.88		80	2.00	560	2.5
SD0036	SD0035	3	2	5350.55	5347.55	300	0.0100	5377.10	5368.00	36	RCP	5353.55								
Vert. Bend	SD0037	24	3	5353.14	5351.22	293	0.0066	5376.19	5377.10	36	RCP	5356.14								
SD0037	Vert. Bend	4	24	5356.63	5353.14	7	0.4685	5376.19	5376.19	36	RCP	5359.63								
SD0038	SD0037	5	4	5358.30	5357.63	10	0.0670	5378.00	5376.19	30	RCP	5360.80								
SD0029	SD0038	6	5	5360.50	5358.30	193	0.0114	5381.25	5378.00	30	RCP	5363.00	E2	2.78	0.34		230	3.70	115	0.7
SD0042	SD0029	7	6	5365.60	5360.50	200	0.0255	5380.55	5381.25	24	RCP	5367.60	E4	0.65	0.46		80	8.75	35	1.5
SD0043	SD0042	8	7	5366.97	5365.60	75	0.0183	5387.00	5380.55	24	RCP	5368.97								
SD0044	SD0043	9	8	5367.87	5366.97	45	0.0200	5389.00	5387.00	10	Assumed 2% slope	5368.70								
SD0045	SD0044	10	9	5368.57	5367.87	35	0.0200	5391.00	5389.00	10	Assumed 2% slope	5369.40	E5	0.57	0.90		100	2.00	215	1.5
SD0033	SD0043	11	8	5368.72	5366.97	95	0.0184	5390.00	5387.00	24	RCP	5370.72	E6	0.96	0.10		100	2.00	190	0.5
SD0031	SD0033	12	11	5370.25	5368.72	83	0.0184	5392.00	5390.00	24	Estimated Rims	5372.25								
2003	SD0031	13	12	5387.28	5372.65	75	0.1951	5389.80	5392.00	8	RCP	5387.95	E8	1.35	0.82		260	2.00	80	2.0
SD0032	SD0031	25	12	5370.84	5370.25	25	0.0236	5392.00	5392.00	15	RCP	5372.09								
NONE	SD0032	14	25	5376.78	5370.84	150	0.0396	5391.50	5392.00	12	Assume 12" to MH	5377.78	E7	0.76	0.90		190	4.74	125	2.2
SD0030	SD0029	15	6	5366.00	5360.50	295	0.0186	5391.50	5381.25	24	RCP	5368.00	E3	0.69	0.38	0.43	100	3.00	60	1.8
SD0024	SD0030	16	15	5368.50	5366.00	210	0.0119	5394.50	5391.50	24	RCP	5370.50	E9	1.06	0.50	0.56	180	3.89	50	1.5
SD0025	SD0024	17	16	5372.50	5368.50	268	0.0149	5400.00	5394.50	24	RCP	5374.50	E12	0.35	0.50		160	2.20	85	1.8
NONE	SD0025	18	17	5376.00	5372.50	137	0.0255	5402.50	5400.00	24	RCP	5378.00	E11	0.95	0.50		250	3.60	80	2.0
2032	NONE	19	18	5377.25	5376.00	15	0.0833	5402.72	5402.50	12	PVC	5378.25								
2031	2032	20	19	5378.24	5377.25	39	0.0254	5401.92	5402.75	12	PVC	5379.24								
NONE	2031	21	20	5380.06	5378.24	142	0.0128	5401.54	5401.92	12	PVC	5381.06	E10	1.05	0.26		190	1.89	50	1.8
2033	2032	22	19	5379.51	5377.25	64	0.0353	5401.98	5402.75	12	PVC	5380.51	E13	3.12	0.18		300	4.17	300	3.0
SD0150	NONE	23	18	5380.00	5376.00	185	0.0216	5408.25	5402.50	24	RCP	5382.00	E14	2.09	0.42		300	2.67	275	2.8

Notes:
1) Lengths rounded to the nearest foot

Appendix E – Storm Sewer Modeling Output

DWG: Z:_DENVER PROJECTS\C09\402\01\CAD\DESIGN\WORKING DRAWING\DRAIN BASIN MAP.dwg USER: mrau
DATE: Sep 02, 2004 4:39pm XREFS: C-UP-STM C-LP C-SV-TOP CU-EX-STM IMAGES:

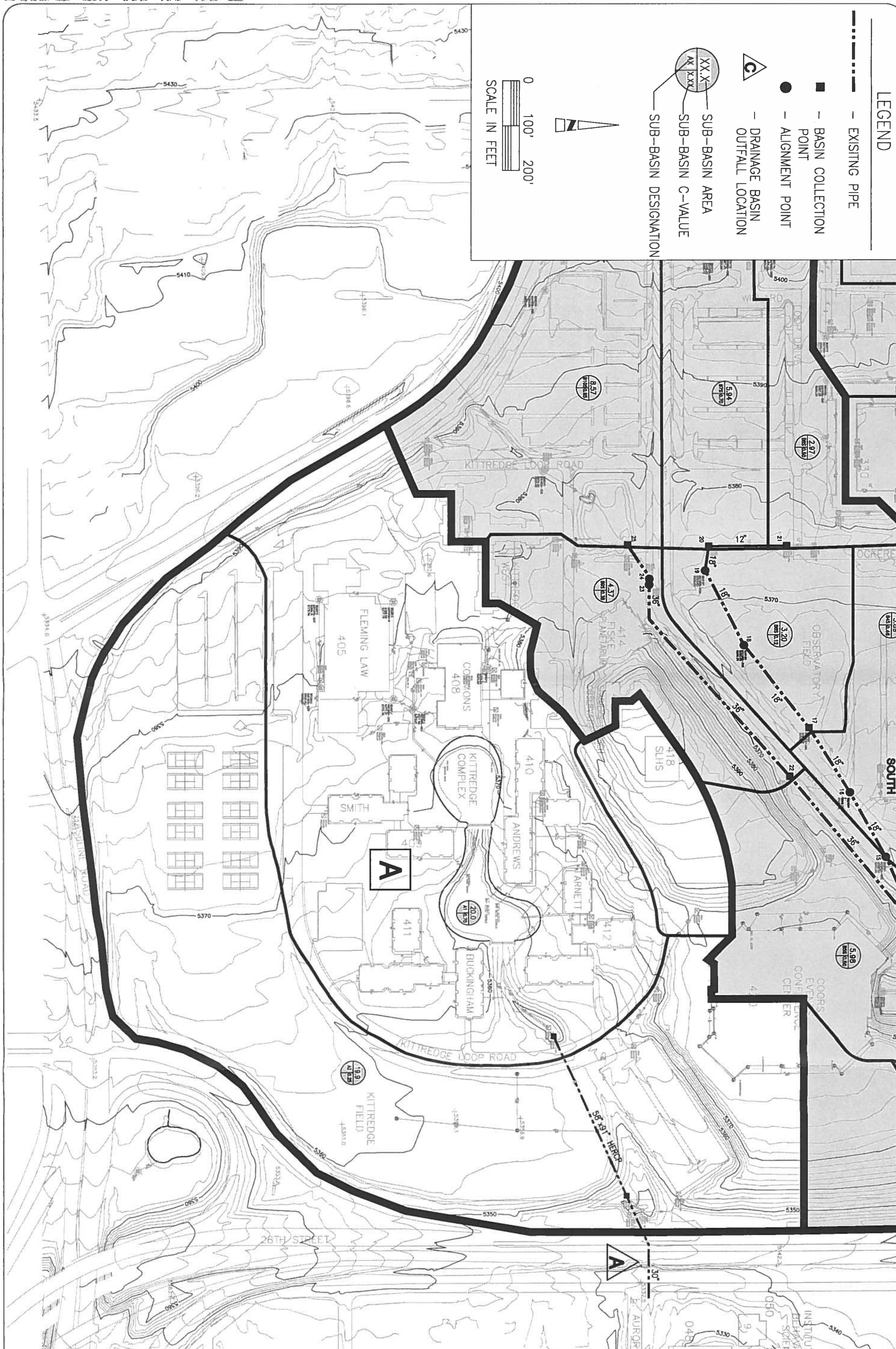


BOYLE ENGINEERING CORPORATION

UNIVERSITY OF COLORADO - MAIN CAMPUS
MAIN CAMPUS DRAINAGE BASIN MAP

FIGURE 1

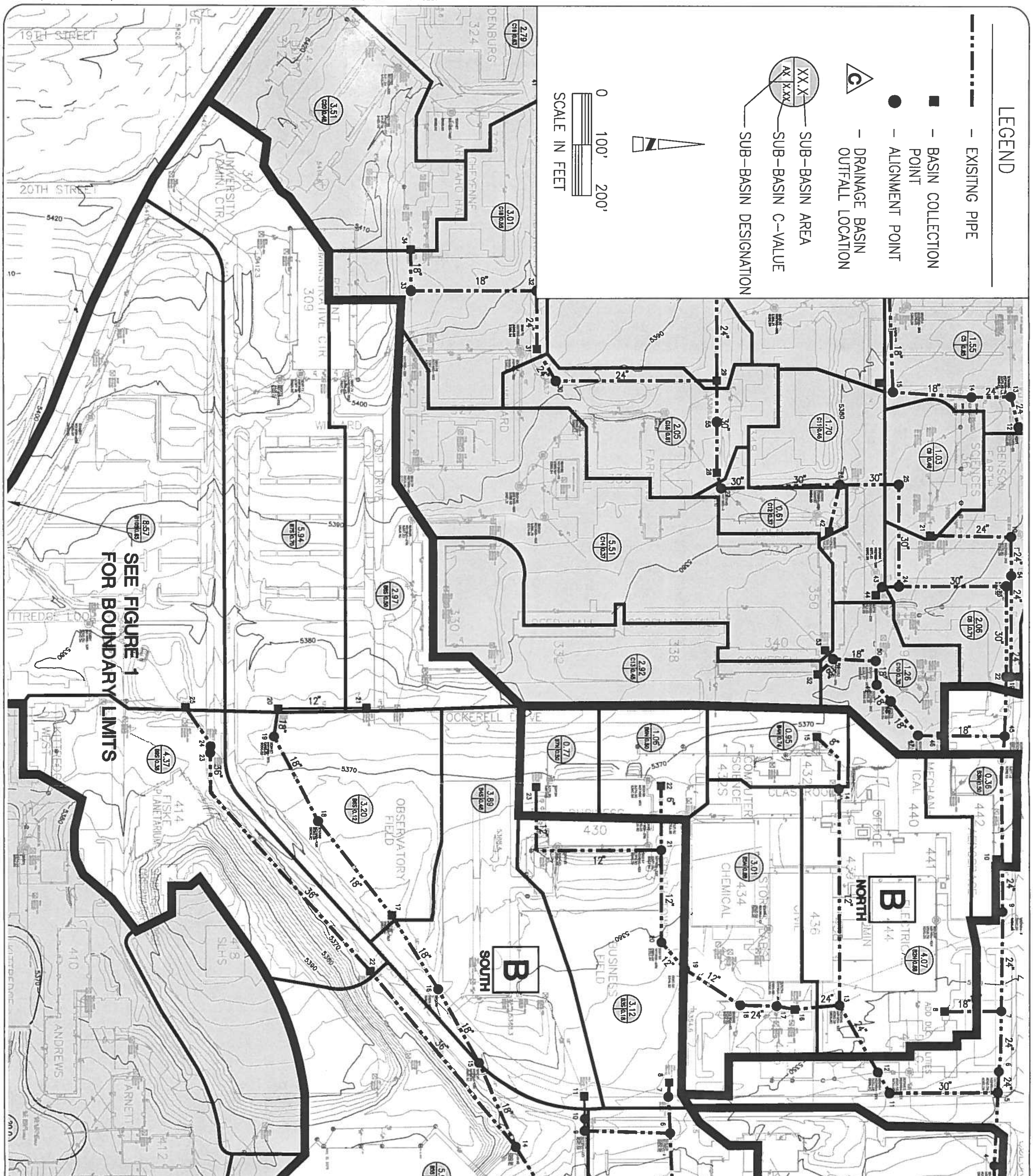
DWG: Z:_DENVER PROJECTS\C09\402\01\CAD\DESIGN\WORKING DRAWING\EX CONDITIONS.dwg USER: mrau
DATE: Sep 02, 2004 4:39pm XREFS: C-LP CU-EX-STM C-SV-TOP C-UP-STM IMAGES:



BOYLE ENGINEERING CORPORATION

UNIVERSITY OF COLORADO - MAIN CAMPUS
DRAINAGE BASIN A - EXISTING CONDITIONS

FIGURE 2

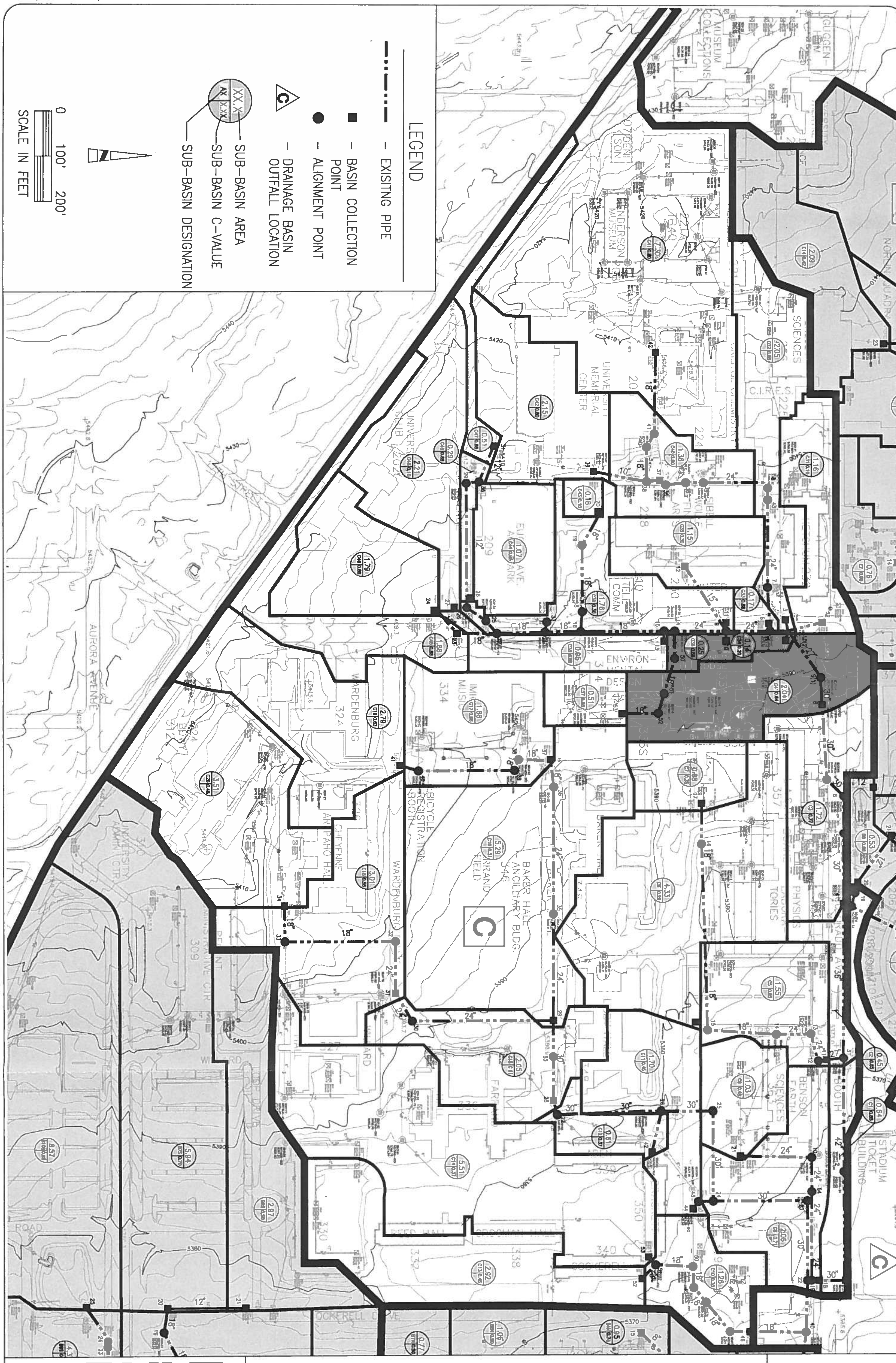


BOYLE ENGINEERING CORPORATION

UNIVERSITY OF COLORADO - MAIN CAMPUS
DRAINAGE BASIN B - EXISTING CONDITIONS

FIGURE 3

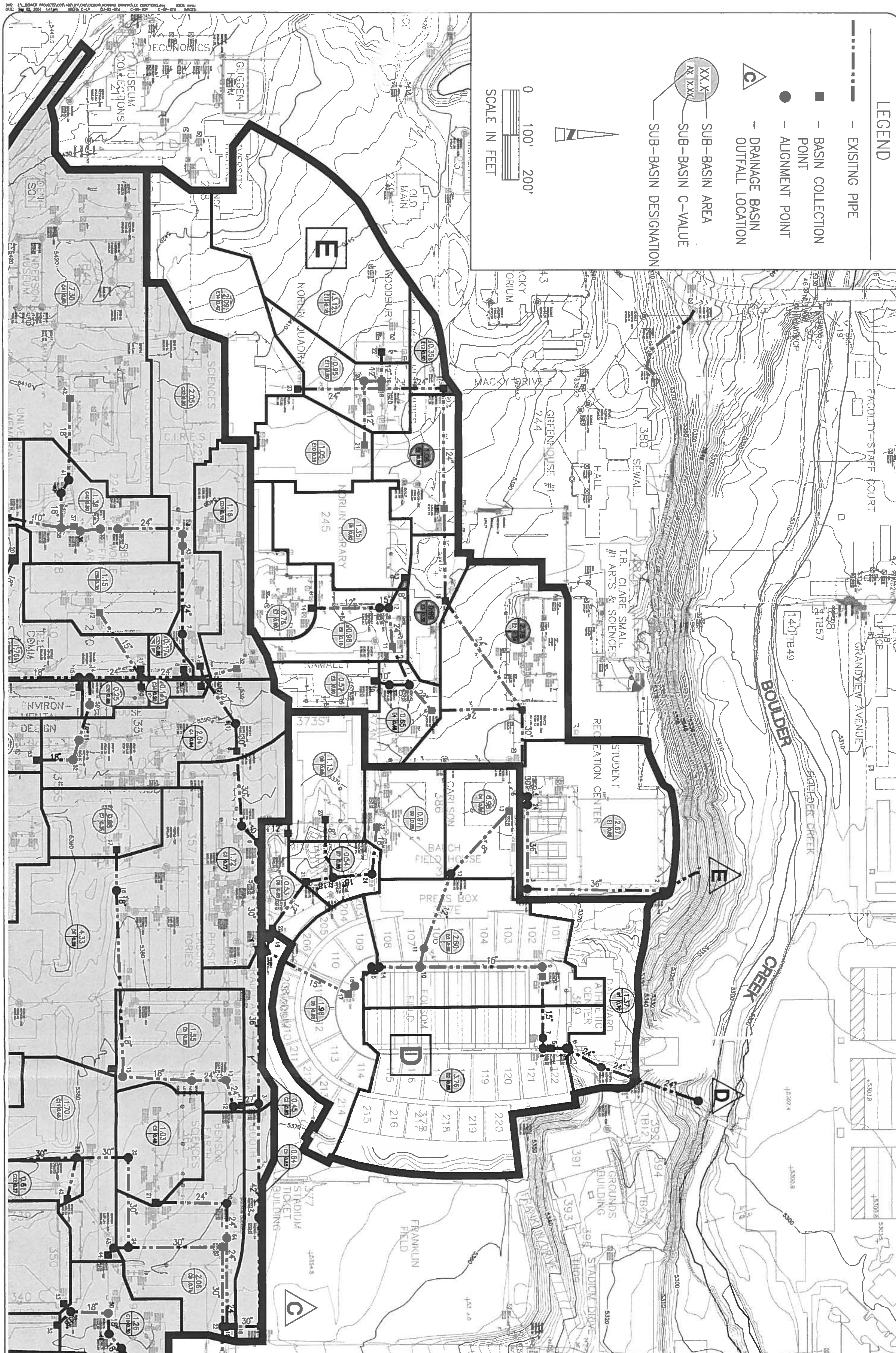
DWG: Z:_DENVER PROJECTS\C09\402\01\CAD\DESIGN\WORKING DRAWING\EX CONDITIONS.dwg USER: mrau
DATE: Sep 02, 2004 4:41pm XREFS: C-LP CU-EX-STM C-SV-TOP C-UP-STM IMAGES:



BOYLE ENGINEERING CORPORATION

UNIVERSITY OF COLORADO - MAIN CAMPUS
DRAINAGE BASIN C - EXISTING CONDITIONS

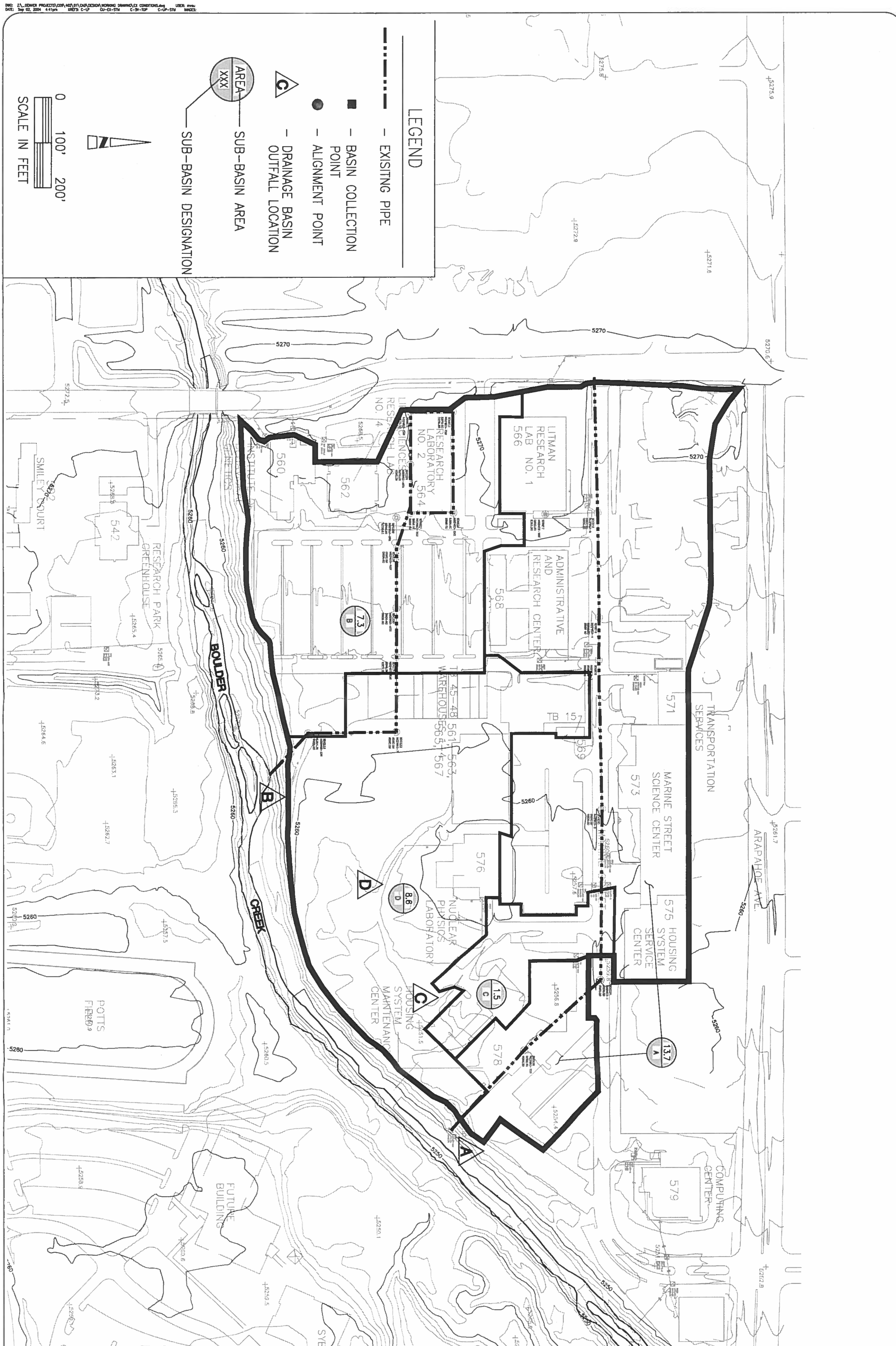
FIGURE 4



BOYLE ENGINEERING CORPORATION

UNIVERSITY OF COLORADO - MAIN CAMPUS
DRAINAGE BASIN D AND E - EXISTING CONDITIONS

FIGURE 5

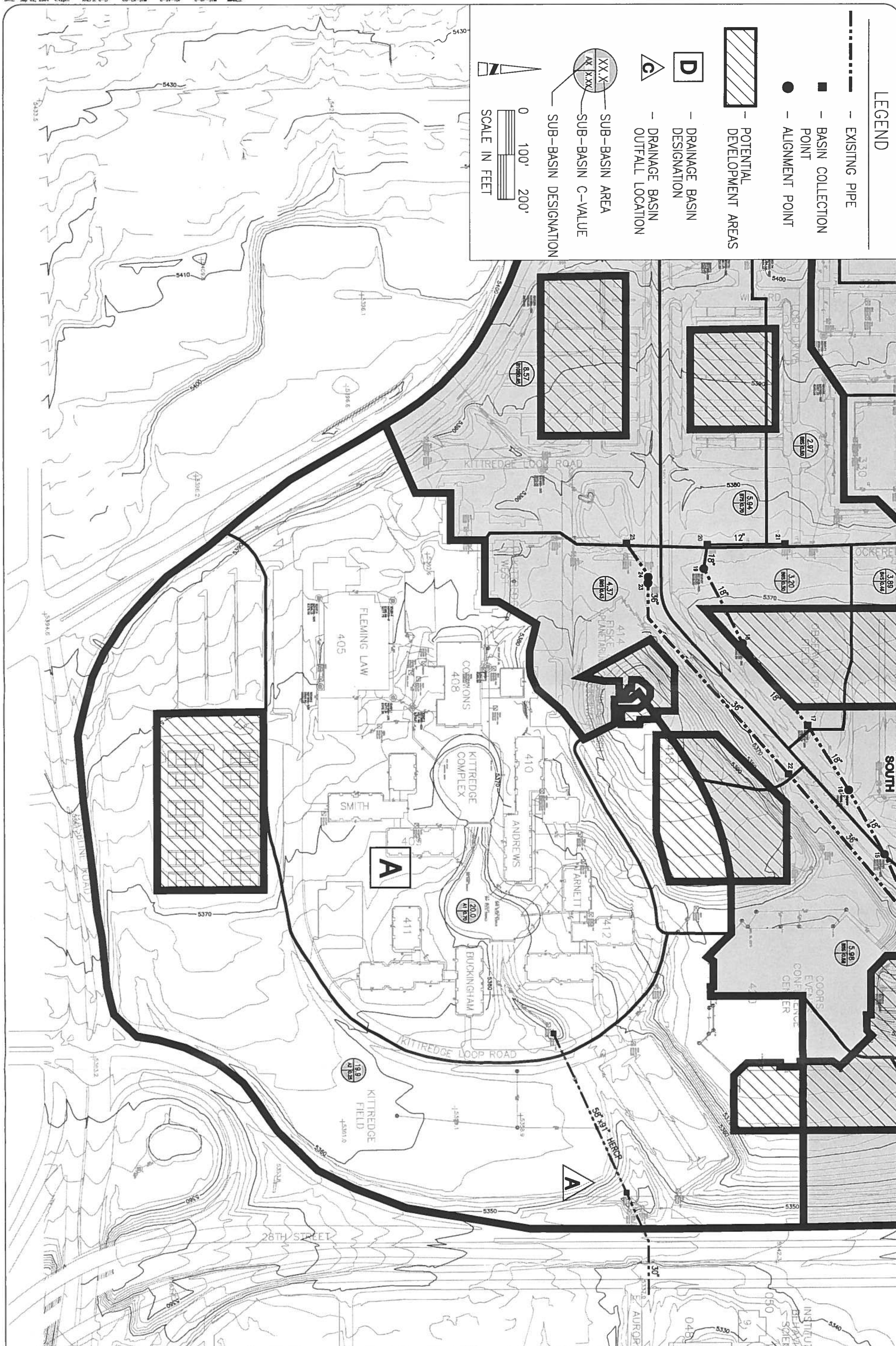


BOYLE ENGINEERING CORPORATION

UNIVERSITY OF COLORADO - EAST CAMPUS
EAST CAMPUS DRAINAGE BASIN - EXISTING CONDITIONS

FIGURE 6

DWG: Z:_DENVER PROJECTS\COB\402\01\CAD\DESIGN\WORKING DRAWINGS\BUILD OUT.dwg USER: mrau
DATE: Sep 02, 2004 4:43pm XREFS: C-LP CU-EX-STM C-SV-TOP C-UP-STM IMAGES:

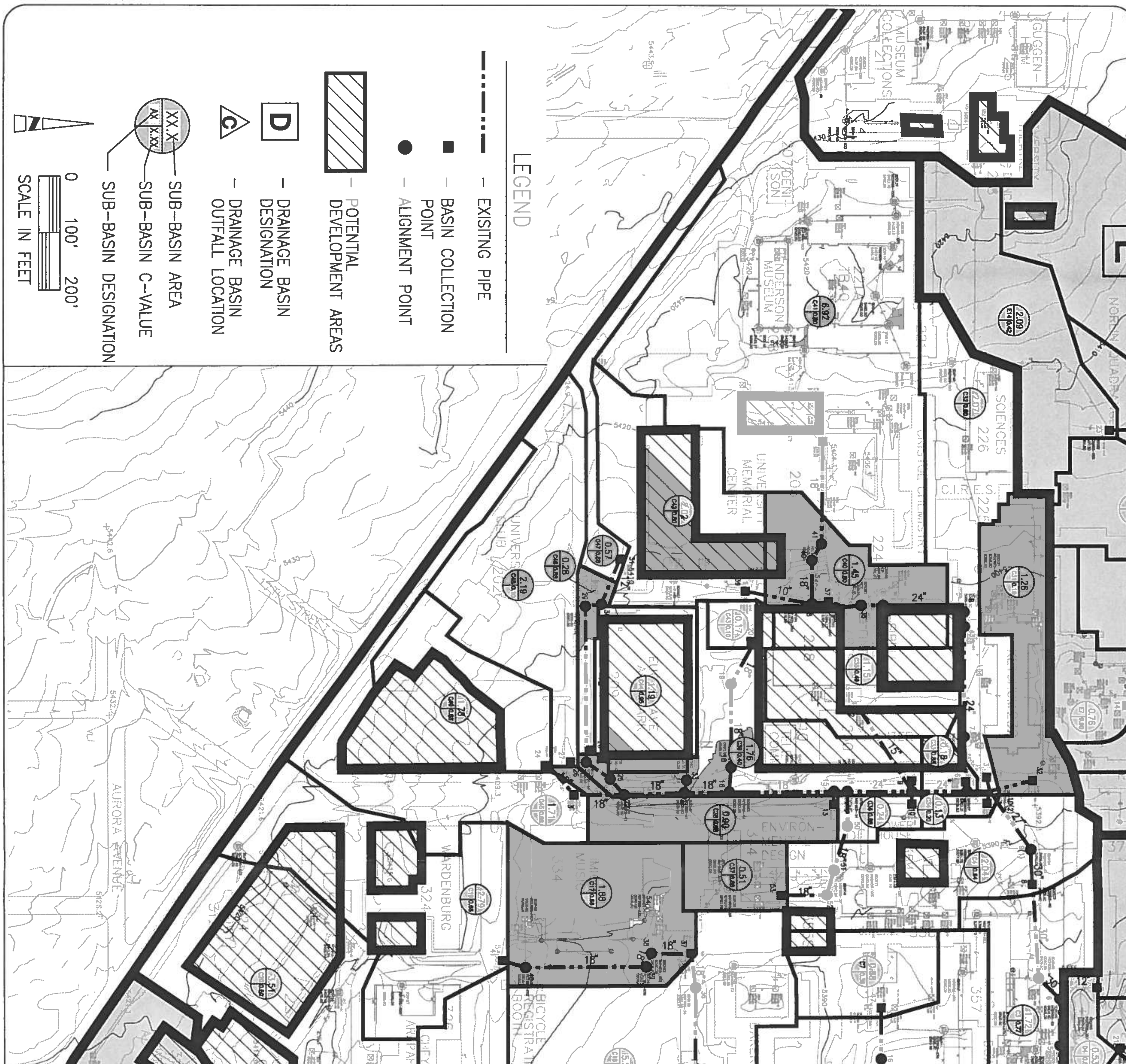


UNIVERSITY OF COLORADO - MAIN CAMPUS
DRAINAGE BASIN A - BUILD-OUT CONDITIONS

BOYLE ENGINEERING CORPORATION

FIGURE 7

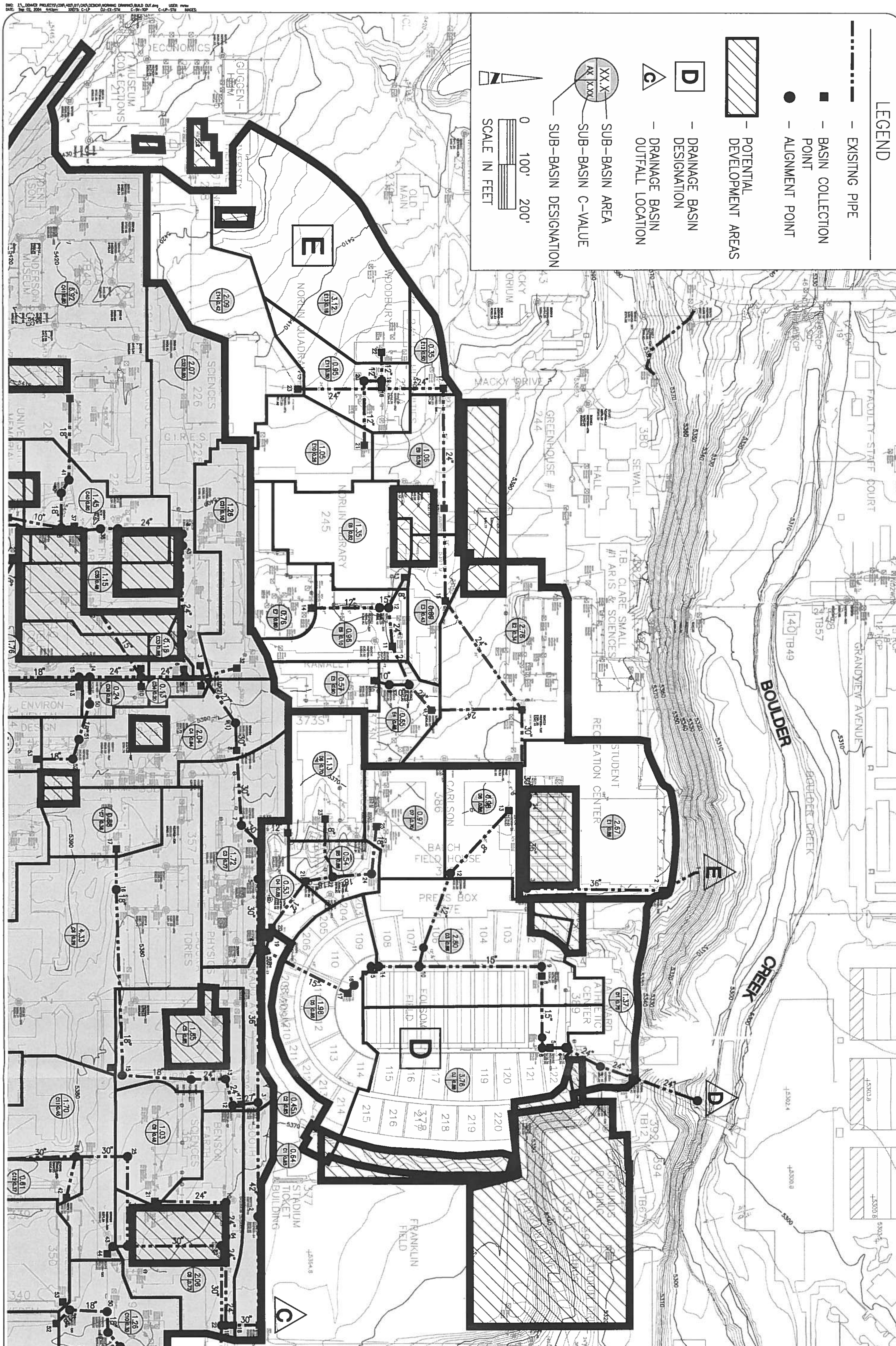
DWG: Z:_DENVER PROJECTS\C09\402\01\CAD\DESIGN\WORKING DRAWING\BUILD OUT.dwg USER: mrau
DATE: Sep 02, 2004 4:43pm XREFS: C-LP CU-EX-STM C-SV-TOP C-UP-STM IMAGES:



BOYLE ENGINEERING CORPORATION

UNIVERSITY OF COLORADO - MAIN CAMPUS
DRAINAGE BASIN C - BUILD-OUT CONDITIONS

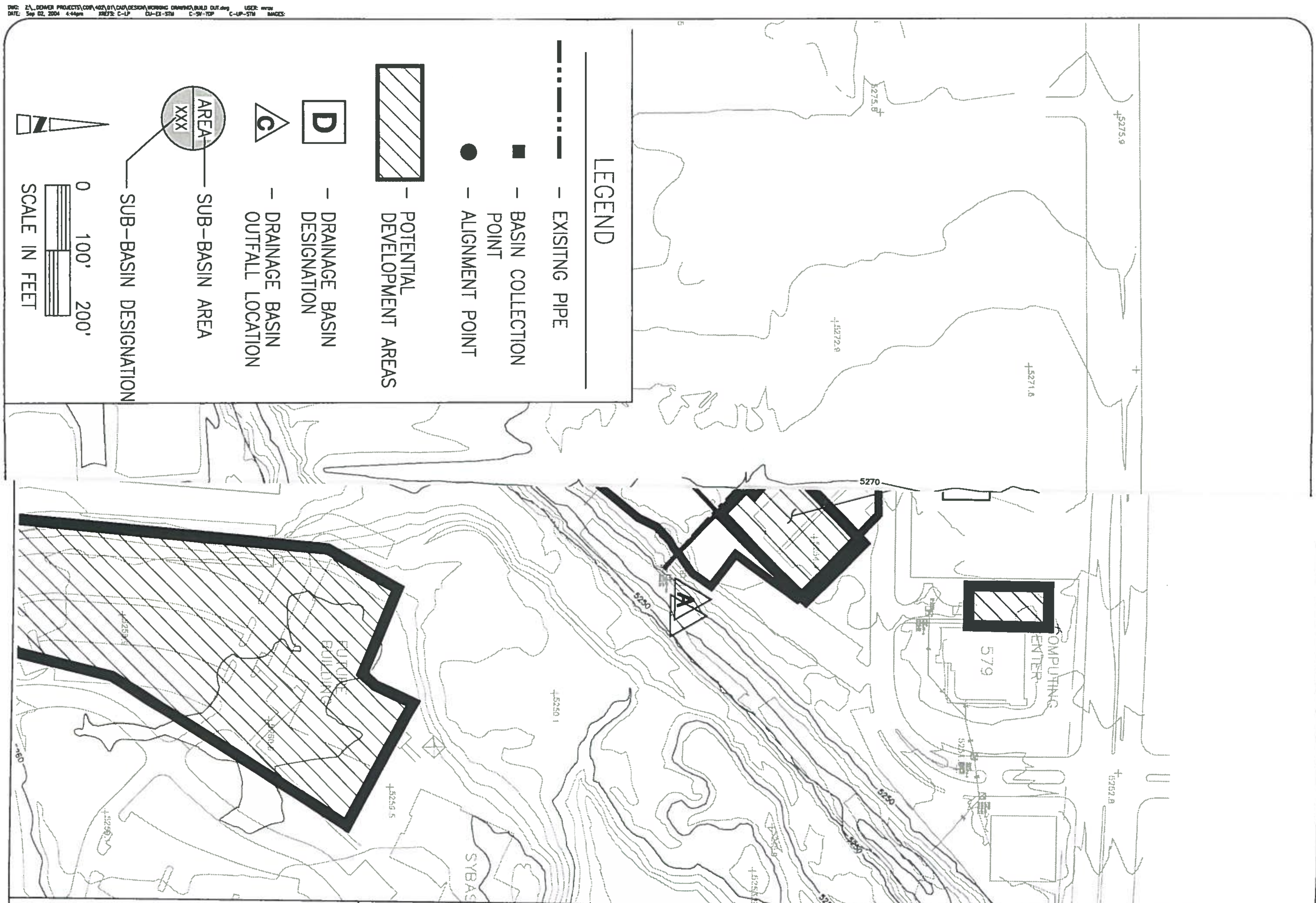
FIGURE 9



BOYLE ENGINEERING CORPORATION

UNIVERSITY OF COLORADO - MAIN CAMPUS
DRAINAGE BASIN D AND E - BUILD-OUT CONDITIONS

FIGURE 10



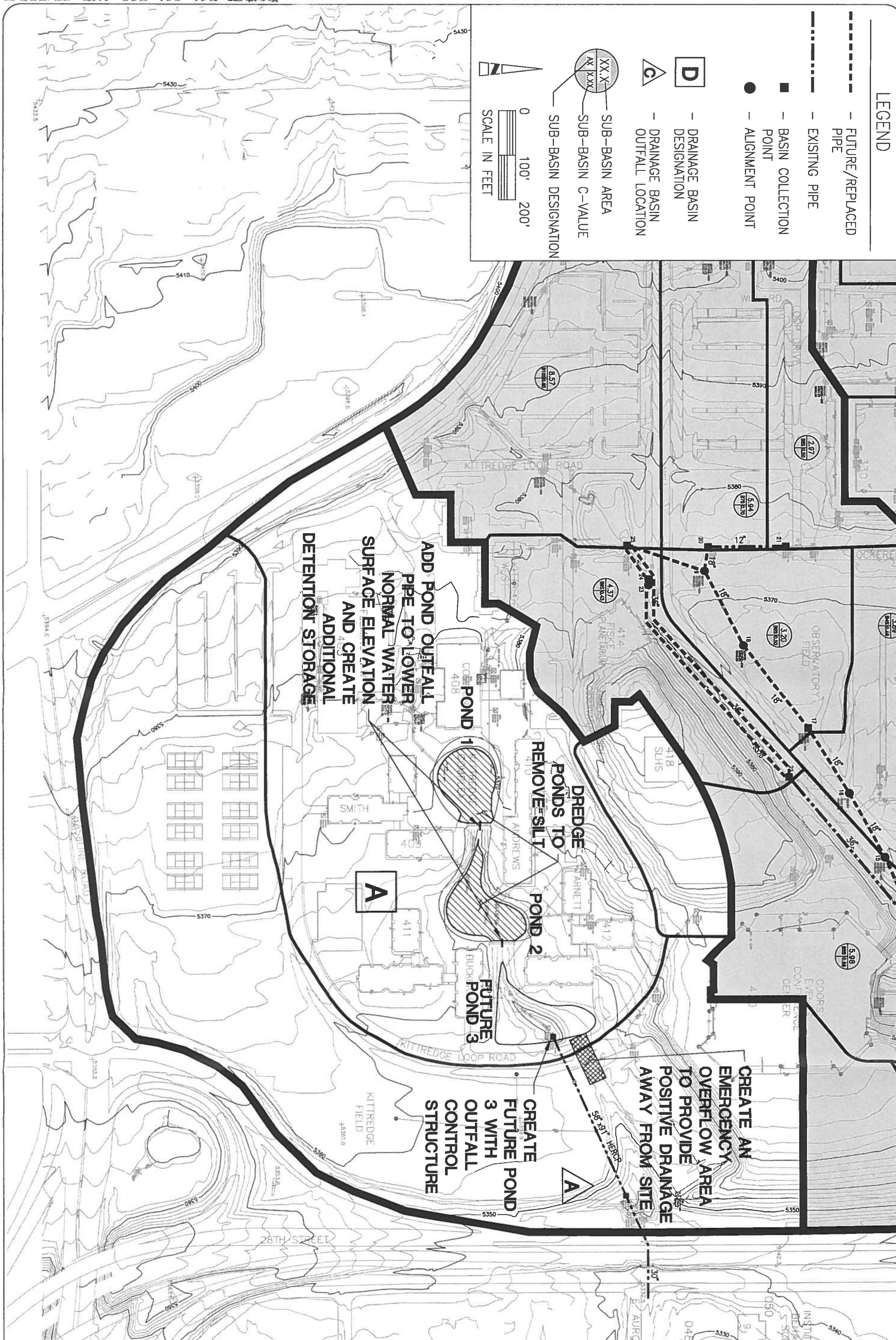
BOYLE ENGINEERING CORPORATION

UNIVERSITY OF COLORADO - EAST CAMPUS

EAST CAMPUS DRAINAGE BASIN - BUILD-OUT CONDITIONS

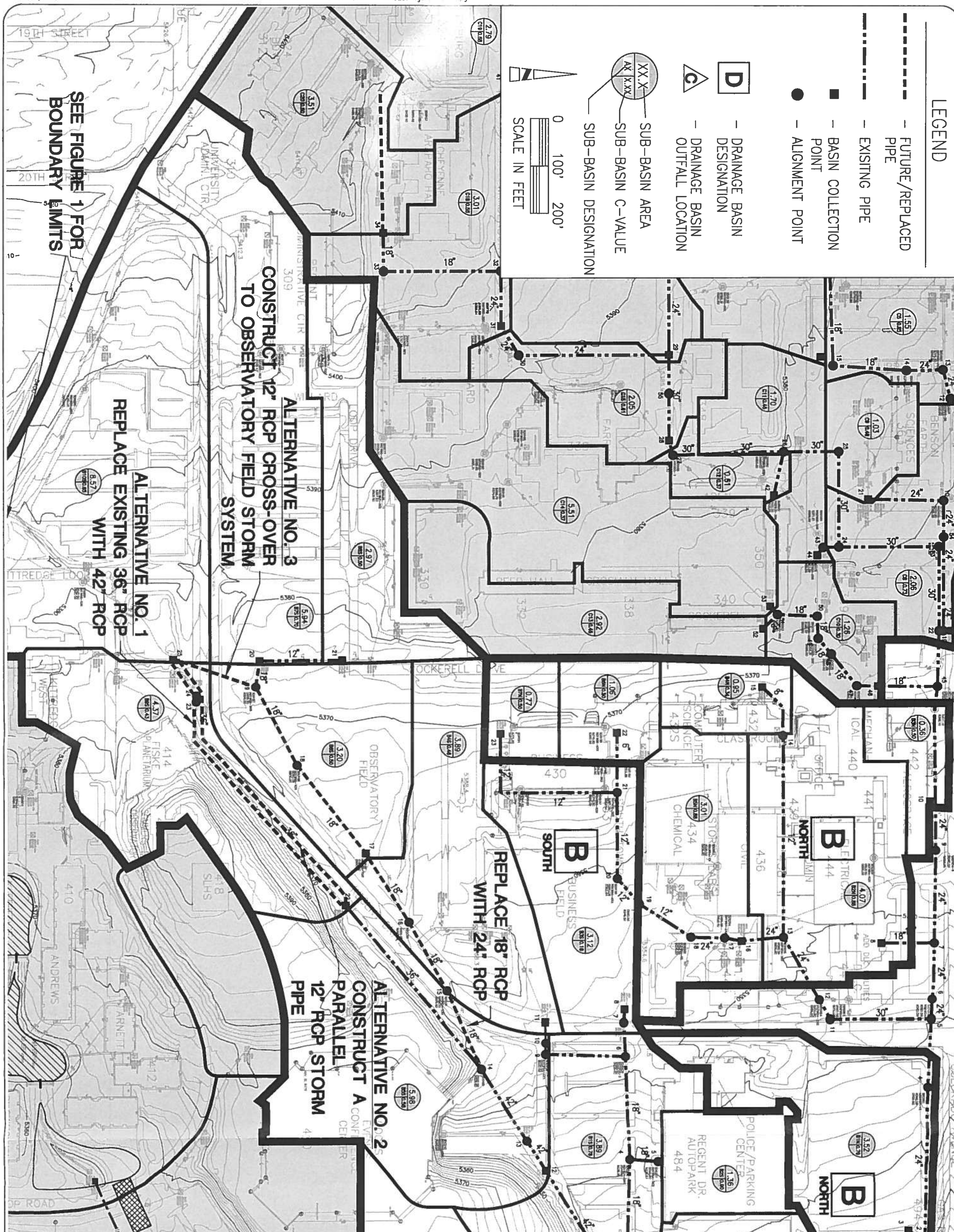
FIGURE 11

DWG: Z:_DENVER PROJECTS\COS\402\01\CAD\DESIGN\WORKING DRAWING\FUTURE IMPROVE.DWG USER: mrou
DATE: Sep 03, 2004 9:07am XREFS: C-LP CU-EX-STM C-SV-TOP C-UP-STM IMAGES: figure-16-fi.jpg

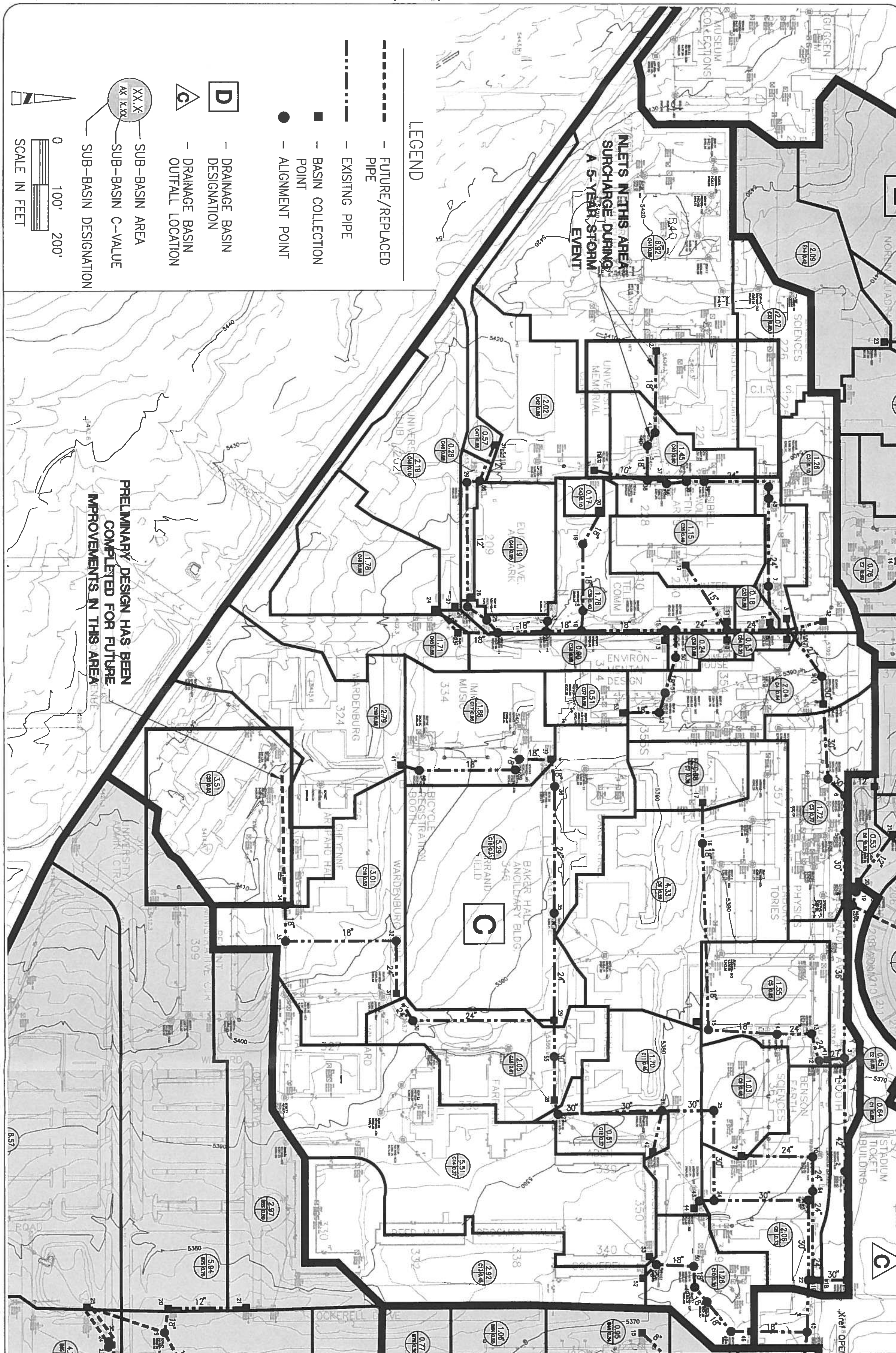


BOYLE ENGINEERING CORPORATION	UNIVERSITY OF COLORADO - MAIN CAMPUS DRAINAGE BASIN A - FUTURE IMPROVEMENTS	FIGURE 12

DWG: Z:_DENVER PROJECTS\C09\402\01\CAD\DESIGN\WORKING DRAWING\FUTURE IMPROVE.DWG USER: mrau
DATE: Sep 03, 2004 9:08am XREFS: C-LP CU-EX-STM C-SV-TOP C-UP-STM IMAGES: figure-1...pg



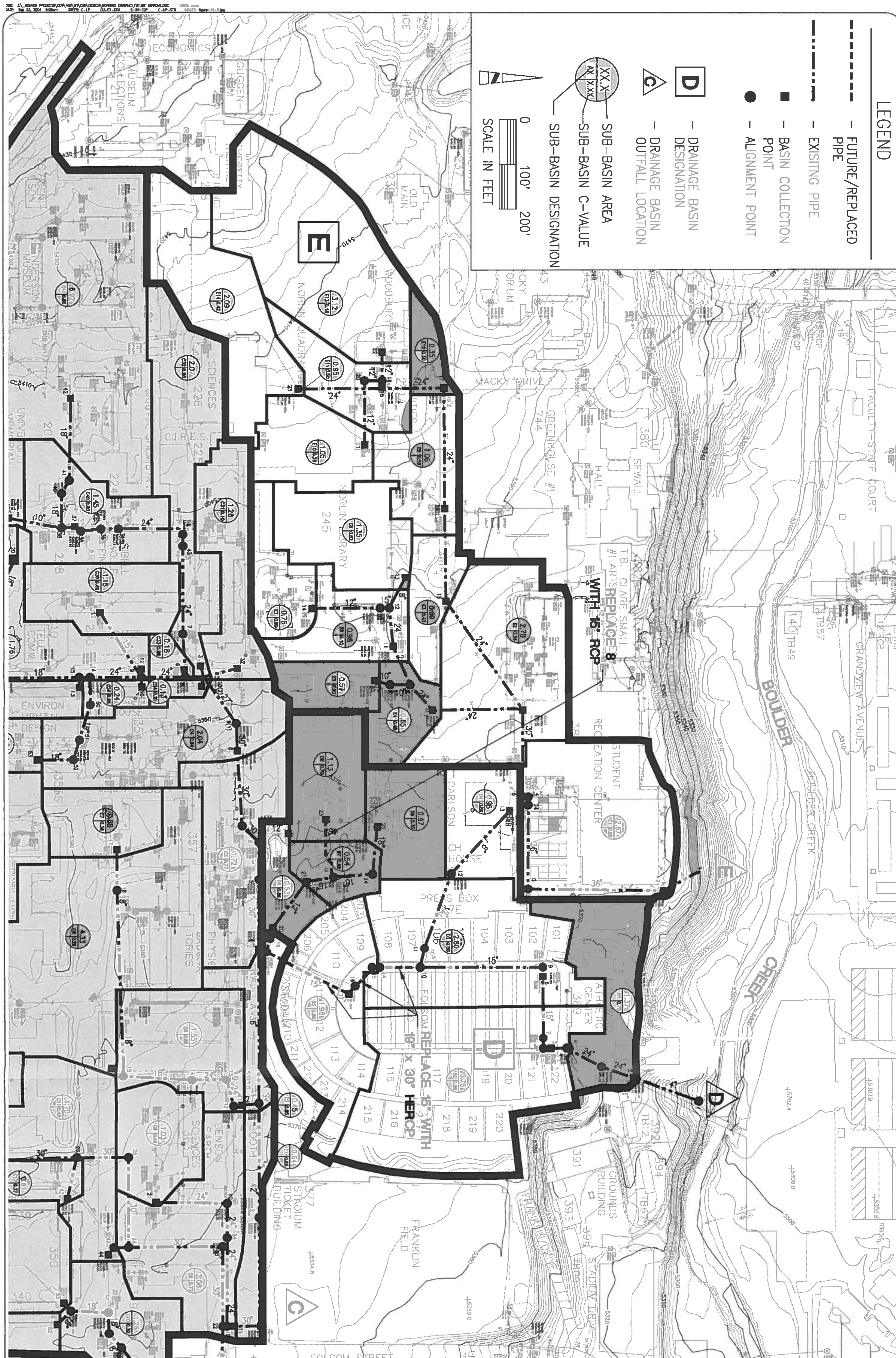
BOYLE ENGINEERING CORPORATION	UNIVERSITY OF COLORADO - MAIN CAMPUS DRAINAGE BASIN B - FUTURE IMPROVEMENTS	FIGURE 13



BOYLE ENGINEERING CORPORATION

UNIVERSITY OF COLORADO - MAIN CAMPUS
DRAINAGE BASIN C - FUTURE IMPROVEMENTS

FIGURE 14

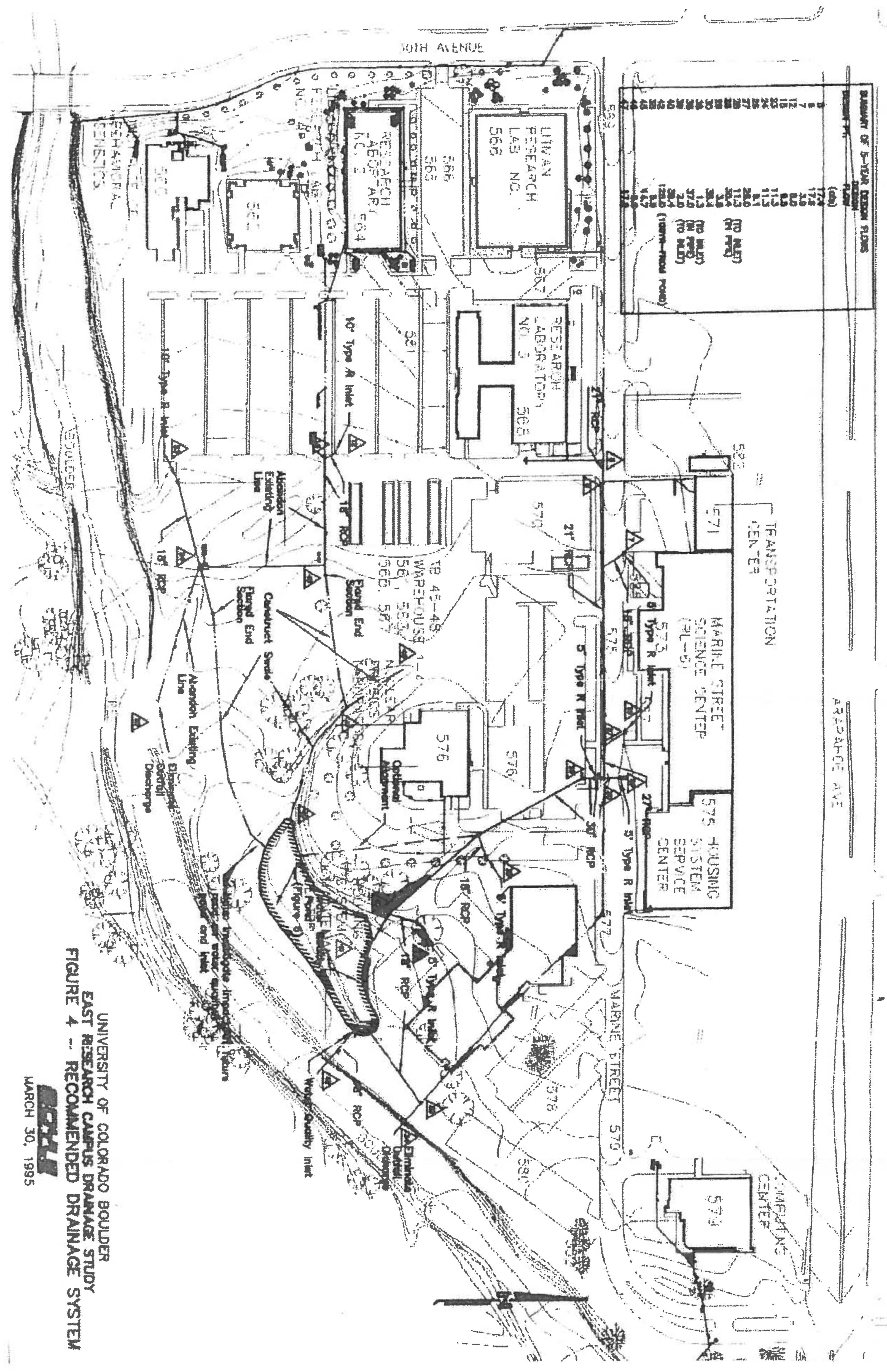


BOYLE ENGINEERING CORPORATION

UNIVERSITY OF COLORADO - MAIN CAMPUS
DRAINAGE BASIN D AND E - FUTURE IMPROVEMENTS

FIGURE 15

DWG: Z:_DENVER PROJECTS\COB\402\01\CAD\DESIGN\WORKING DRAWING\FUTURE IMPROVE.DWG USER: mrau
DATE: Sep 03, 2004 9:10am XREFS: C-LP CU-EX-STM C-SV-TOP C-UP-STM IMAGES: figure-16-R.jpg



BOYLE ENGINEERING CORPORATION

UNIVERSITY OF COLORADO - EAST CAMPUS
EAST CAMPUS DRAINAGE BASIN - FUTURE IMPROVEMENTS

FIGURE 16