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SALT LAKE COUNTY

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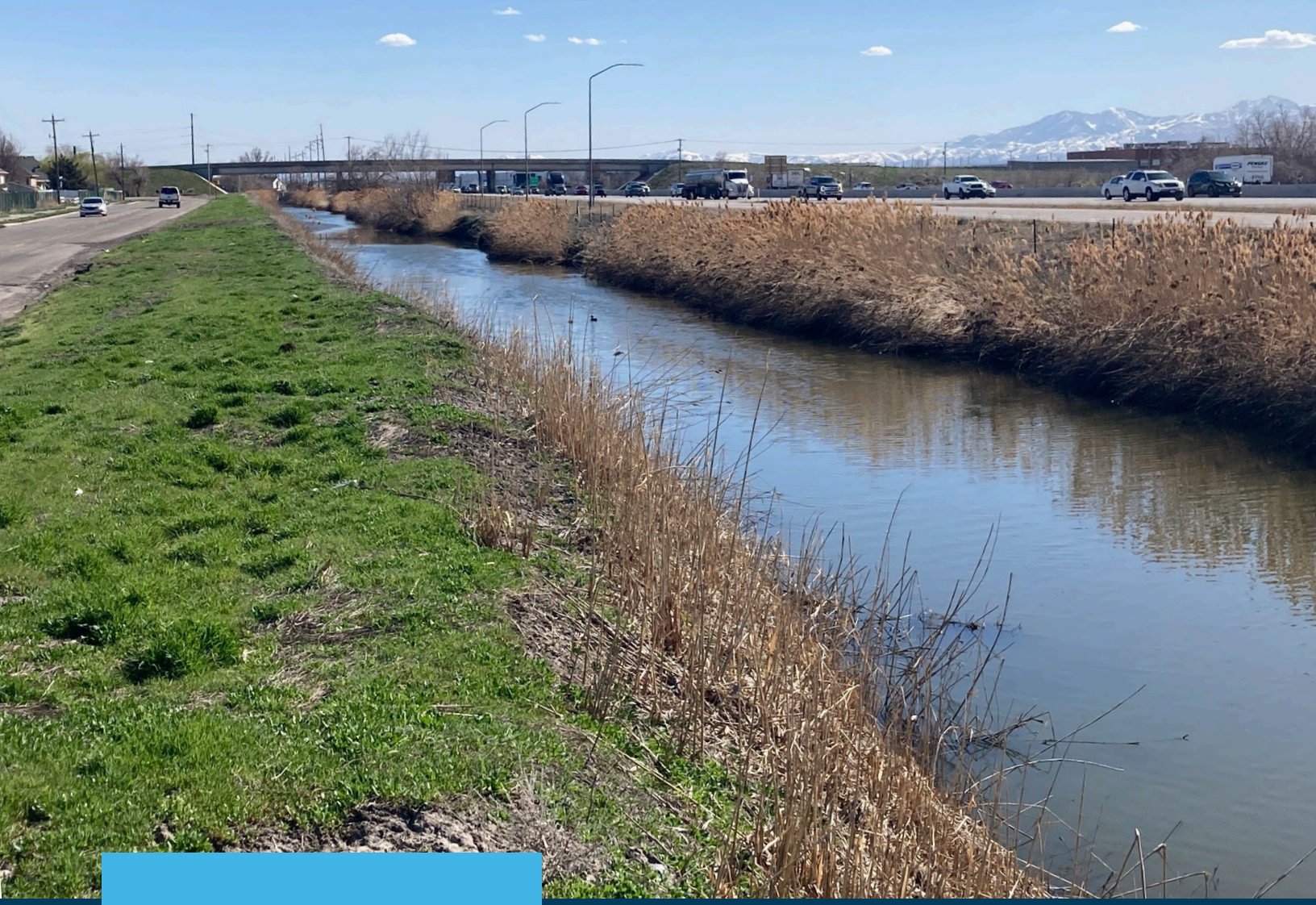
BOWEN COLLINS & ASSOCIATES



SALT LAKE COUNTY

February 2025

SEWAGE CANAL & CITY DRAIN LIFT STATION

SEWAGE CANAL & CITY DRAIN LIFT STATION

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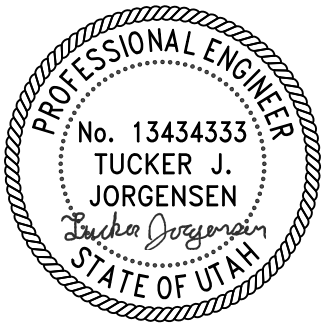

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CHAPTER 1 – INTRODUCTION

The Sewage Canal, City Drain, and CWA Drains collectively make up the Sewage Canal System. This canal system is a major storm water conveyance facility just west of the Jordan River in Salt Lake City, Utah, which discharges into the Great Salt Lake. There is little-to-no slope along the City Drain and Sewage Canal. To facilitate flow towards the Great Salt Lake, there is a lift station at approximately 2100 North on the City Drain. The existing City Drain Lift Station is no longer able to function as originally designed as not all the pumps are operational, and the associated mechanical piping is corroding and deteriorating. The purpose of this report is to document the hydrologic and hydraulic analysis of the existing Sewage Canal System and recommend improvements to the system, including development of a recommended design flow for a replacement City Drain Lift Station.

BACKGROUND INFORMATION

General History of the Canals and the County's Jurisdiction

The Sewage Canal was originally constructed in 1911 to remove wastewater from the Jordan River and convey it directly to the Great Salt Lake. It was later expanded in 1924. Photo 1-1 shows construction on the northern part of the sewage canal during the 1924 expansion. As evidenced in the photo, the original sewage canal was expanded significantly in 1924 and it appears that the channel banks were cut at a very steep angle as part of that expansion.

Photo 1-1: 1924 Construction Photo of Sewage Canal
(Photo courtesy of Utah State Historical Society https://history.utah.gov/)

Since the original construction and expansion of the Sewage Canal, Salt Lake City (SLC or the City) has built a Wastewater Treatment Plant (WWTP) that discharges treated sewage effluent into the Northwest Canal, which then discharges into the Sewage Canal just north of I-215 and Legacy Parkway interchange. With the City Drain and CWA Drains no longer collecting any sewage (raw or treated), the Sewage Canal System has been modified to collect storm water runoff from a portion of SLC and North Salt Lake City. The City and Salt Lake County (SLCo or the County) agreed on ownership and maintenance management for the major storm runoff conveyance facilities. The County has jurisdiction of the Sewage Canal system.

Current Conditions

The Sewage Canal system has relatively flat and wide channels. These physical characteristics result in a relatively large volume of water being stored in the channel during large storm events. As a result, the Sewage Canal system generally acts as a large linear detention basin in addition to being a conveyance facility for storm water runoff. While this provides the benefit of handling large peak storm flows, it also has the potential to create backwater conditions in upstream storm drain systems that may overtop both roadway crossings and channel banks. To increase flow in the downstream direction, a lift station was constructed at approximately 2100 North on the City Drain.

City Drain Lift Station History

The City Drain Lift Station was designed and built in the mid-1980s to facilitate converting the Sewage Canal System into a storm water runoff conveyance facility. An embankment or "dam" was constructed across the canal at approximately 2100 North to minimize backwater effects from the downstream Sewage Canal and Great Salt Lake. Three (3) 60-inch diameter pipes were placed through the embankment to facilitate low flows without using the pumps. Two (2) small capacity 16-inch diameter pumps were installed to be used in low flow events. Three (3) large capacity 36-inch diameter pumps were installed to be used during larger storm events. Water is pumped over the embankment into the downstream channel. Documentation of the design size for the pumps is included on the design drawings of the City Drain Lift Station and appears to be the same as the capacity of an identical lift station designed and built in a similar time frame on the Northwest Canal. Based on this information, the design capacity of the small pumps was 4 cfs each and about 50 cfs each for the large pumps. This resulted in a total design capacity of just over 150 cfs.

Over time, the pumps and lift station have begun to degrade and fall apart. Maintenance crews have been able to harvest the parts from one of the large pumps to keep the other two large pumps functional. However, since the pumps are old and corroded, they constantly break down and require continual maintenance. Based on conversations with the lift station operators, someone needs to be on site whenever the pumps are in use to verify that they do not stop working and do not cause flooding downstream or upstream of the lift station. In 2005, an automation system was installed with the goal of removing some of the need for on-site personnel. For a variety of reasons, the automation system never functioned properly. In addition to the reliance on on-site personnel while the pumps are running, County personnel rely on local residents to notify them when storm water depths are elevated in the City Drain and the City Drain Lift Station needs to be activated.

STUDY AREA

For the purposes of this study, the Sewage Canal System typically refers to the Sewage Canal, the City Drain, and the CWA drains as shown on Figure 1-1. The Main Channel in the Sewage Canal System includes the Sewage Canal, City Drain, CWA-1 Drain, and CWA-3 Drain. The CWA-2 Drain and CWA-3 Extension Drains are branches of the Main Channel but were also studied as part of this project. The Northwest Canal is a majority tributary of the Sewage Canal system and includes the SLC WWTP effluent as well as storm water runoff from a portion of Northwestern SLC and a portion of North Salt Lake City. The hydrology of the Northwest Canal was also included with this study. The City Drain has been converted into a storm water conveyance facility which includes the runoff from areas adjacent to the City Drain, the CWA-1, CWA-2, CWA-3 and CWA-3 Extension Canals as well as some storm water trunklines from part of central Salt Lake City and the Salt Lake International Airport.

PURPOSE OF STUDY

This study will be completed in multiple stages:

- Stage 1 will include a hydrologic and hydraulic analysis of the Sewage Canal and its tributaries to identify deficiencies and make recommended improvements. Stage 1 will also include a pre-design analysis of the City Drain Lift Station, including a design flow rate. Recommended improvements will be prioritized for construction.
- Stage 2 will include the design and construction of the replacement City Drain Lift Station as well as the design and construction of other critical system improvements.
- Stage 3 will include acquiring easements or Right of Way (ROW) for the Sewage Canal as well as bank stabilization of the Sewage Canal downstream of I-215.

SCOPE OF WORK

The general scope of this project involves a thorough analysis of the County's Sewage Canal system and its ability to meet the present and future storm water runoff needs. As part of this project, the following tasks will be completed:

Stage 1

Task 1: Review of Data and Reports

Task 2: Field Reconnaissance

Task 3: Hydrologic and Hydraulic Analysis

Task 4: Prioritized Project Recommendations

Stage 2 – Pump Station Design

Task 5: Project Selection and Scoping Meeting

Task 6: Design Drawings

Task 7: Project Status Meetings

Task 8: Bidding Process

Task 9: Permitting

Stage 3 – Bank Stabilization

Task 10: ROW and Property Acquisition

Task 11: Bank Remediation and Stabilization

This report has been prepared as part of Task 4. Stage 2 and associated tasks will be completed in the future.

PROJECT STAFF

This project work was performed by the BC&A team members listed below. Team members' roles on the project are also listed. The project was completed in BC&A's Draper, Utah office. Technical questions may be addressed to Kameron Ballentine, Project Manager, at (801) 495-2224.

Craig Bagley and Keith Larson	Principal-In-Charge
Kameron Ballentine	Project Manager
Tucker Jorgensen	Project Engineer

LEGEND

- Sewage Canal*
- City Drain*
- CWA-1 Drain
- CWA-2 Drain*
- CWA-3 Drain*
- CWA-3 Drain Extension
- Jordan River
- Northwest Canal
- Sewage Canal Study Area
- Municipal Boundaries
- Northwest Canal Study Area**

* The Sewage Canal, City Drain, CWA-2 Drain, and CWA-3 Drain together make up the Main Channel.

** A hydrologic analysis was completed, however, a hydrologic analysis for Northwest Canal study area was not part of this study. Flow rates and analysis were taken from ongoing Salt Lake City Project studying the canal.

Unincorporated
Salt Lake County

Salt Lake City

North Salt Lake City

Salt Lake City

Sewage Canal

Jordan River

Northwest Canal

Lakeside Golf Course

West Bountif

Woods Cros

W 400 S

W 500 S

W 1100 N

W 900 N

W 2300 N

W 2100 N

W 1700 N

W 1000 N

W 700 N

W 600 N

W 500 N

W Center St

North Salt Lake

Eaglewood Golf Course

Upper Bonneville Canal

Lime Canyon

Jones Canyon

Hell Canyon

City Creek

City Creek Watershed

Rose Park

Westpointe

Fairpark

Salt Lake City International Airport

Jordan Meadows

Wingpoint Golf Course

Earl D Gray

Terminal

Glendale

Glendale Golf Course

Indiana Ave

California Ave

Directors Row

W North Temple

Downtown Salt Lake City

Central City

East Central

Central 9th

Ball Park

Liberty Wells

Central City-Liberty Wells

East Liberty Park

Sugar House

South Salt Lake

Warm Springs Rd

N Redwood Rd

Industrial Rd

S Bangerter Hwy

N 3200 W

N 4000 West St

N 2450 W

N 700 W

N 400 W

N 1400 W

N 1300 W

N 900 W

S 1000 W

S 600 W

S 500 W

S 400 W

S 800 W

S 900 W

S 1200 W

S 700 W

S 3600 W

S 4400 W

S 4800 W

S 5500 W

S 5070 W

S 4650 W

S 5370 W

S 3270 W

S Pioneer Rd

Gladiola St

Navajo St

S 625 W

4206 ft

4219 ft

4223 ft

4274 ft

6152 ft

6210 ft

4307 ft

Riter Canal

Chesterfield

BOWEN COLLINS & ASSOCIATES	SALT LAKE COUNTY SEWAGE CANAL & CITY DRAIN LIFT STATION	SEWAGE CANAL SYSTEM STUDY AREA	NORTH: NORTH	SCALE: 0 2,250 4,500 Feet FIGURE NO. 1-1

P:\Salt Lake County\022-23-03 Sewage Canal\4.0 GIS\4.4 APRX\Sewage Canal v02.aprx rbutters 6/10/2024

CHAPTER 2 – EXISTING CONDITIONS

INTRODUCTION

Several sources of data regarding the existing development and hydrologic/hydraulic conditions of the Sewage Canal were collected and analyzed as part of this project. Some of those data sets included topographic information, field survey of bridges and culverts, and field reconnaissance observations. A visual assessment of the general conditions of the study reaches of the Sewage Canal was also completed. The purpose of this chapter is to summarize the general conditions that currently exist in the Sewage Canal and other relevant areas and to summarize what other data was collected, reviewed, and used to perform the technical analyses.

DATA COLLECTION

This section discusses the data collection and analyses associated with topography, survey, and field reconnaissance. The primary goals of this task were to compile a detailed inventory of the structures involved in the Sewage Canal operation, identify condition-related deficiencies, and to collect information needed to develop hydraulic models of the area.

Topography & Aerial Data

Topographic and aerial photographic mapping along the Sewage Canal were collected from the Utah Geospatial Resource Center (UGRC). The aerial photography used was the 2021 High Resolution Imagery, and the topography was the bare earth LiDAR data from 2013-14 with 0.5-foot contours. The aerial photographs were used for the backgrounds on most of the figures used in this report.

Field Survey and Reconnaissance

Channel cross sections of the study reach of the Sewage Canal, City Drain, and CWA channels were field surveyed at about 1,000-foot intervals through the open channel sections of the creeks. Survey data which characterized the bridges, culverts, and lift station was also collected.

Salt Lake City Storm Drain Database

Salt Lake City provided their GIS database for the storm drain system in the City. This database included storm drain facilities including pipe diameter, material, and general drainage outfall location. No survey data was included or collected on the storm drain system.

Easements Along Canal

No easements were identified based on Recorder's Office documentation. It is likely that easements were not recorded during canal construction because construction was done in the early 1900s. Based on discussion with current Salt Lake City officials, we found that there are some documented easement agreements along a portion of the Sewage Canal. These easement agreements should be reviewed by a lawyer. The agreements should be recorded at the recorder's office if they are legally binding. Below are brief statements summarizing the agreements:

- Easement agreements on the Sewage Canal extend from 2350 North to about 1,800 feet downstream Cudahy Lane.
- Upstream of the Northwest Canal inflow to 2350 North, the easements would typically be 80 feet wide. Based on aerial imagery, it appears that this width would be enough for the canal and potential access roads.

- Downstream of the Northwest Canal inflow, the agreements are only 35 feet wide. Based on aerial imagery, this may not be wide enough to include the full top-width of the canal.

The easement agreement locations are included in Appendix A. Locations shown in the appendix are approximate only. Further analysis should be performed to verify actual agreement metes and bounds and to determine if they can be recorded and become easements.

INVENTORY OF STRUCTURES

This section presents an inventory of the existing structures along the study reaches of the Sewage Canal system. The inventory of structures is summarized in Figure 2-1.

Bridges and Culverts

There are 44 culverts and nine bridges on the Sewage Canal and its tributaries (excluding the Northwest Canal). Each of these structures is identified in Figure 2-1. Field survey of each structure was collected and used to develop the hydraulic models as described in Chapter 5. Photos of individual bridges and culverts are included in Appendix B. Most bridges and culverts appeared to be in good condition at the time the photos were taken. Various Corrugated Metal Pipe (CMP) culverts have been constructed along the City Drain and have become rusted or corroded. Culverts with CMP are shown in Figure 2-2. Two culverts (identified in Figure 2-2) have corroded to the point of collapsing. Further condition observations are included in a later section of this Chapter. The hydraulic analysis of the bridges and culverts is discussed in Chapter 5.

Lift Station

There is one lift station located on the City Drain at approximately 2100 North (see Photo 2-1). Original design drawings of the Lift Station were provided by the County and are included in Appendix C for convenience. A berm is placed across the City Drain with culvert pipes and multiple sizes of pumps to convey water downstream. Original design information about the City Drain Lift Station is summarized in Table 2-1.

Table 2-1
Original Lift Station Design

Component	Estimated Capacity[1]	Use
Two 16-inch Electric Pumps	4 cfs each	Low Flow Bypass
Three 36-inch Diesel Pumps	50 cfs each	Large flood events
Three 60-inch Culvert Pipes	N/A[2]	Low flows through lift station berm
16-foot Tall Berm	N/A	Prevent flows from downstream going upstream

[1] Estimated capacities were taken from the identical lift station on the Northwest Canal and are approximations only.
[2] The culvert pipes are only used during typical non-runoff or low flows conditions. At elevated flows, the culvert is blocked off to prevent backflow and the large pumps are turned on to convey water over the embankment.

Additional field observations of the Lift Station are discussed in a later section.

Photo 2-1: Existing Lift Station Pumps

In-Line Structures

There is only one in-line structure along the Sewage Canal system, located just upstream of the 2200 West Crossing within the Military Complex of the Salt Lake City Airport (see Photo 2-2). The location of this in-line structure is shown in Figure 2-2. Unlike other large conveyance facilities in the Salt Lake Valley, the Sewage Canal system is not used for irrigation water, nor is it steep enough to require grade control. As a result, there is not a conveyance need to include in-line structures to either elevate water surface elevations or to protect from channel bed scour or erosion. Documentation for the original design of the in-line structure was not readily available; however, it does not appear that this structure is needed. If it becomes a restriction and causes adverse conditions within the City Drain it should be removed.

Photo 2-2: In-line structure at 2200 West Crossing

SUMMARY OF OBSERVATIONS

A visual assessment of the Sewage Canal and its tributaries was completed. The purpose of this visual assessment was to observe general conditions of the canals/drains and identify potential hazards, issues, and concerns. This section summarizes the observations noted during the visual assessment. Observed issues and concerns are identified in Figure 2-2.

General Observed Risks

The visual assessment took place in 2023. The following potential issues and concerns were observed along the channel of the Sewage Canal and its tributaries:

- Crushed and CMP Culverts
- Trash Racks
- Berms/Embankments
- Phragmites
- Vertical/Over-Steepened Banks
- Storm Drain Outfalls
- Riprap/Concrete Debris on Banks
- Corrosion/Degradation of Lift Station, Deisel Tank, & Hydraulic Pumps

Each of those potential issues and concerns are discussed below.

Crushed and CMP Culverts

Corrugated Metal Pipe (CMP) was often used for culvert crossings in recent decades. The useful lifespan of CMP is much shorter than that of other culvert materials such as reinforced concrete pipe (RCP). A full condition assessment of the structures was not performed as part of this study. However, serious condition deficiencies were observed during the field visit. Since construction of some of the culverts, the CMP has begun to rust and corrode. This has happened on multiple culvert crossings downstream of the existing lift station at 2800 North Rose Park Ln. and 2441 North Rose Park Ln. (see Photo 2-3). Both of these culverts have collapsed as a result of rust and corrosion. Fill has been placed to fill the void on the culverts where they collapsed to allow for the crossing to be used. Those two culverts do not have capacity to pass the required flow, significantly backing up water upstream when the lift station pumps are in use. Additionally, there are seven (7) other CMP culvert crossings within the Sewage Canal system. The other seven CMP culvert crossings appear to be in better condition than the collapsed culverts, but they should be monitored and replaced before they fail.

Photo 2-3: Example of Collapsed Culvert at 2441 North Rose Park Ln.

Trash Racks

At sites where trash racks prevent debris from entering culverts, debris can block or damage the grates and restrict flow during flood events (see Photo 2-4). In order to maintain optimal function of the Sewage Canal, these racks need to be regularly inspected and maintained. There are two (2) trash racks within the Sewage Canal System, one upstream of the airport pipe system and one upstream of the lift station. Both trash racks are needed to prevent clogs in the long pipe network and to protect the lift station. The bars on the trash rack are bent (see Photo 2-4), indicating that debris is removed with a track-hoe or other heavy equipment either during or after a storm event. If these trash racks become damaged, they should be replaced.

Photo 2-4: Trash at Entrance to Airport Pipeline

Berms/Embankments

Some berms are present along the Sewage Canal and City Drain that could impound water above the natural ground. These berms are not likely to meet FEMA levee criteria, however, meeting FEMA levee criteria is not of immediate concern as this is a manmade channel and not evaluated for flood risk by FEMA. The berms should be monitored to make sure that there is no seepage/piping of water through the banks, scour/erosion or collapsing of the banks, or development encroachment next to the banks. While there is not much potential for future development adjacent to the canal, there is a portion of the City Drain berms that are immediately adjacent to the backyards of private residences.

Phragmites

Phragmites are an invasive plant that have inundated many of the open channel storm drain facilities in SLCo. As phragmites grow uncontrolled within the channels, they can significantly reduce the conveyance capacity of the channel. This occurs because of how thick the phragmites can grow on not just the banks, but also along the channel bottom. Most of the Sewage Canal system is at least partially impacted by phragmites. In areas of high concern, including just downstream of the Lift Station, the phragmites have begun to grow not just on the sides of the channel but also the bottom of the channel (see Photo 2-6). Other areas are only of low concern; in these areas, the phragmites are still primarily contained to the sides of the channel (see Photo 2-5). Portions of the Sewage Canal without consistent phragmite growth on the banks and no growth along the channel bottom would be considered as areas of minimal concern. Areas of high and low phragmite concern are identified on Figure 2-2. Note that phragmites are at least intermittently present (minimal concern) on nearly the entire length of the Sewage Canal and its tributaries.

Photo 2-5: Low Phragmites

Photo 2-6: High Phragmites

High phragmites growth needs to be addressed as soon as possible, in particular the reach downstream of the City Drain Lift Station. While the channel can continue to allow some flow, it is possible that the growth combined with debris could result in the phragmites blocking off most or all of the capacity of the channel. Low phragmites growth should then be prioritized to prevent the growth from increasing into a serious problem. The rest of the canal system (e.g. areas of minor phragmite concern) should be maintained and inspected to prevent future serious phragmite growth.

Vertical/Over-Steepened Banks

There are multiple sections of the system where the banks are nearly vertical at the top. The sediment in these sections of the canal has sloughed off the banks and has deposited at the toe of the channel. An example of vertical banks with sediment deposition at the toe of the bank is shown in Photo 2-7. Low flow velocities were observed in many of these areas as the top width and flow depth for the channel is significant (often 50+ feet wide and 3+ feet deep in low flow condition). It does not appear that the vertical banks are primarily caused by soil scour/erosion, but by other factors which are discussed in Chapter 6. The vertical banks are an area of concern because they tend to be unstable and are prone to further collapse. As the banks continue to collapse, there is potential for the toe sediment depositions to change flow patterns within the channel and for the top widths of the channels to encroach onto private property past existing easements.

Photo 2-7: Vertical Banks on the Sewage Canal with Sediment Deposited at Toe of Bank

Storm Drain Pipe Outfalls

Since the Sewage Canal system has been converted into a storm drain facility, there are many storm drain pipes that now discharge into the canals. As water levels in the canal rise in response to a storm event, there is potential for canal water to back up into the storm drain system. Many of these storm drain pipe outfalls do not have backflow preventors to keep canal water from backing up into the pipe. An example of a storm drain pipe with a backflow preventor and one without are shown in Photos 2-8a and 2-8b, respectively. There is a particular pipe along the Salt Lake City portion of the City Drain that consistently has canal water back into the pipe and bubble up into the road to the point that residents in the vicinity call either the City or the County to complain about flooding (location of inlet is identified on Figure 2-2).

(a) ***(b)***

Photo 2-8: Storm Drain Pipes with (a) and without (b) back flow preventor

Riprap/Concrete Debris on Banks

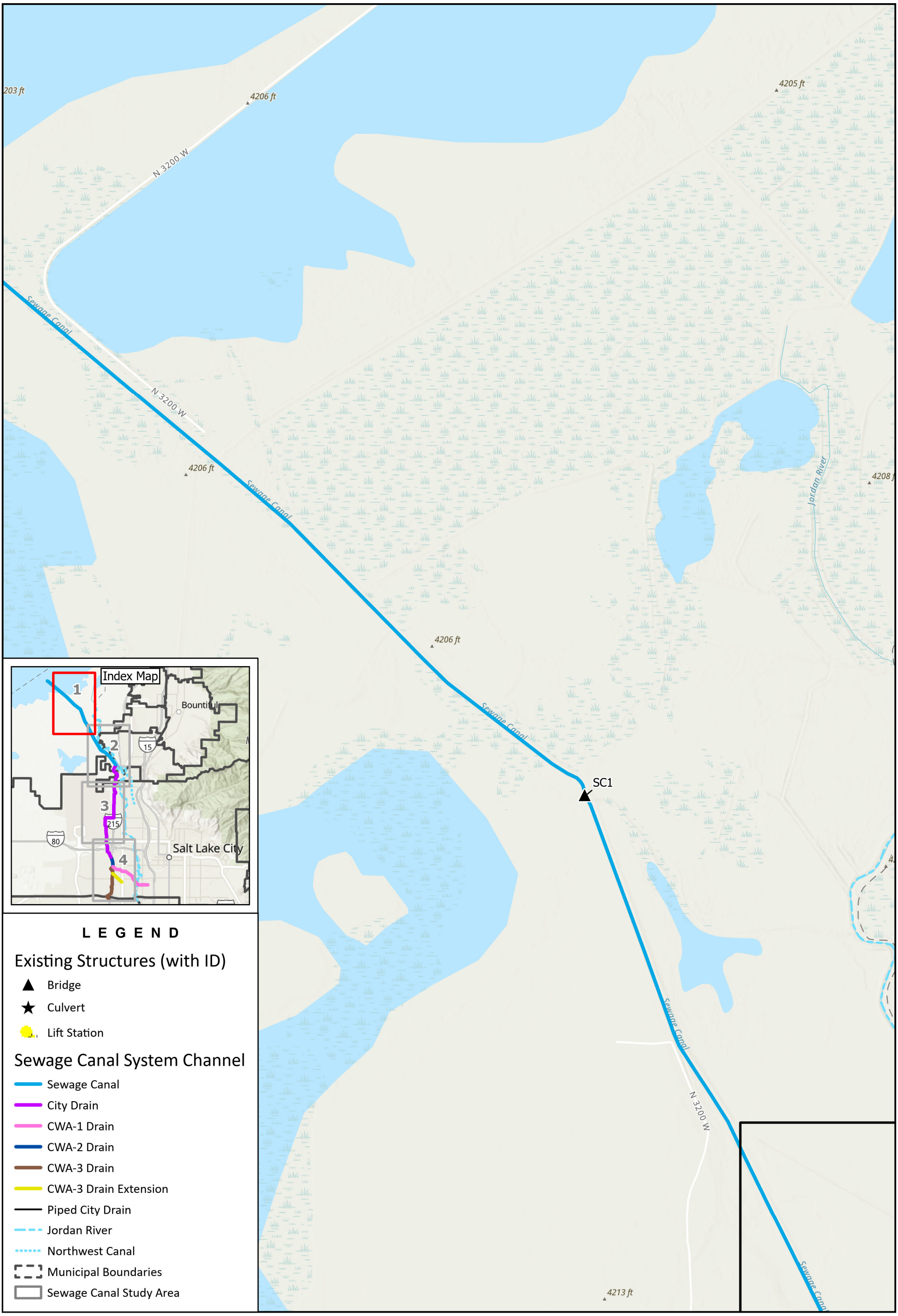
There are several segments along the Sewage Canal where rounded riprap or concrete debris has been placed to armor the banks. An example of this is shown in Photo 2-9. Riprap channel armoring should be angular and engineered so it can lock together and be sufficiently thick to adequately provide the required embankment protection. Where present, it does appear that the riprap and concrete debris is stabilizing the banks; however, since it does not appear to be engineered, it likely is not stable or suitable for long-term application.

Photo 2-9: Concrete Debris on Bank of Sewage Canal

Corrosion/Degradation of Lift Station, Diesel Tank, & Hydraulic Pumps, etc.

The existing City Drain Lift Station was originally constructed in 1984. In the time since, there have been condition issues related to rust and corrosion of lift station components. The pumps and a significant portion of the pipes are exposed to air and water. As the pumps continue to age, there is an increased risk of the remaining operable pumps breaking down. Thus, it is necessary to replace the existing lift station with a new lift station.

Photo 2-10: Evidence of Corrosion and Rust on Existing Lift Station



L E G E N D

Existing Structures (with ID)

- Bridge
- Culvert
- Lift Station

Sewage Canal System Channel

- Sewage Canal
- City Drain
- CWA-1 Drain
- CWA-2 Drain
- CWA-3 Drain
- CWA-3 Drain Extension
- Piped City Drain
- Jordan River
- Northwest Canal
- Municipal Boundaries
- Sewage Canal Study Area

BOWEN COLLINS & ASSOCIATES

SALT LAKE COUNTY

SEWAGE CANAL & CITY DRAIN LIFT STATION

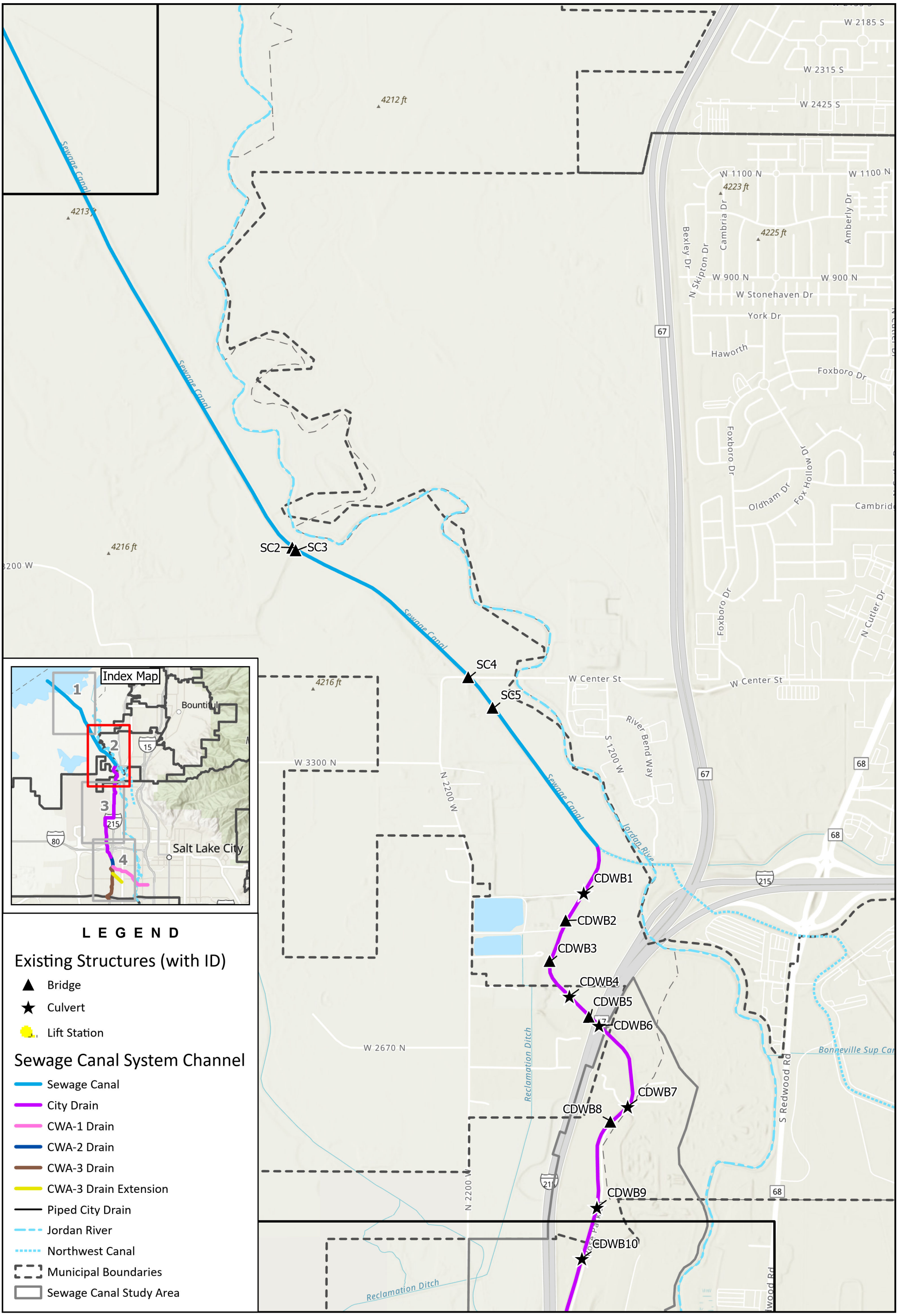
EXISTING STRUCTURE INVENTORY

NORTH: NORTH

SCALE: 0 600 1,200 Feet

FIGURE NO. 2-1

P:\Salt Lake County\022-23-03 Sewage Canal\4.0 GIS\4.4 APRX\Sewage Canal v02.aprx rbutters 6/10/2024



SALT LAKE COUNTY

SEWAGE CANAL & CITY DRAIN LIFT STATION

EXISTING STRUCTURE INVENTORY

BOWEN COLLINS & ASSOCIATES

NORTH:

SCALE: 0 600 1,200 Feet

FIGURE NO. 2-1

P:\Salt Lake County\022-23-03 Sewage Canal\4.0 GIS\4.4 APRX\Sewage Canal v02.aprx rbutters 6/10/2024

CDWB10
Reclamation Ditch
4221 ft
4219 ft
W 2100 N
Reclamation Ditch
4223 ft
City Drain
Lift Station
CDWB12
N 2450 W
N 3200 W
CDWB13
CDWB14
N 2200 W
215
W 1700 N
68
Niles Ave
Miami Park
4225 ft
4225 ft
Salt Lake City
International
Airport
Mandalay Rd
N Miami Rd
Westpointe
N Morton Dr
Westpointe
Park
W 1100 N
Jorda
Golf
N 2450 W
N Flyer Way
CDWB18
CDWB16
CDWB15
CDWB17
W 900 N
68
End of Piped
City Drain
Salt Lake City
Airport Ags
Sir Philip Dr
W 800 N
N Starcrest Dr
4242 ft
W 700 N
W 650 N
N 2360 W
N Morton Dr
W 600 N
N 1700 W
W 500 N
W 500 N
W 400 N
N 2370 W
W 340 N
N 2200 W
N 1950 W
N Redwood Rd
215
Beginning of Piped
City Drain
W North Temple
68

Index Map
1
2
3
4
Bountiful
Salt Lake City
15
215
80

LEGEND

Existing Structures (with ID)

- Bridge
- Culvert
- Lift Station

Sewage Canal System Channel

- Sewage Canal
- City Drain
- CWA-1 Drain
- CWA-2 Drain
- CWA-3 Drain
- CWA-3 Drain Extension
- Piped City Drain
- Jordan River
- Northwest Canal
- Municipal Boundaries
- Sewage Canal Study Area

BOWEN COLLINS & ASSOCIATES

SALT LAKE COUNTY

SEWAGE CANAL & CITY DRAIN LIFT STATION

EXISTING STRUCTURE INVENTORY

NORTH:

NORTH

SCALE:

0 600 1,200

Feet

FIGURE NO. 2-1

P:\Salt Lake County\022-23-03 Sewage Canal\4.0 GIS\4.4 APRX\Sewage Canal v02.aprx rbutters 6/10/2024

Beginning of Piped City Drain

CDWB19
CDWB21
CDWB22A
CDWB22B
CDWB23
CDWB23B
CDWB24
CDWB25
CWA2D1
CWA3D1
CWA3D2
CWA3D3
CWA1D1
CWA1D2
CWA1D3
CWA3D5
CWA3D6
CWA3DE1
CWA3D7
CWA3DE2
CWA3DE3
CWA3D8
CWA3DE4
CWA3DE5
CWA3D9
CWA3D11
CWA3D12

4261 ft
4257 ft
4255 ft
4274 ft
4258 ft
4242 ft

W North Temple
W Northtemple St
N 2400 W
Surplus Canal
Earl D Grays
S 2650 W
Union Pacific
SLGW
Orange St
W South Temple St
Jordan River
Navajo St
W 200 S
Adam Galvez St
345 S
Sherwood Park
Iowa Ave
W 400 S
W Pacific Ave
W 500 S
Fulton St
Chestnut St
Delong St
Cheyenne St
W 600 S
Arapahoe Ave
W 700 S
Pueblo St
S 1300 W
W 800 S
Indiana Ave
W 900 S
Hayes Ave
American Ave
S 1200 W
W 1040 S
Glenrose Dr
Glendale Dr
S Redwood Dr
Montgomery St
Concord St
W 1300 S
California Ave
Utah St
W 1500 S
Swaner Rd
Fortune Rd
Wallace Rd
Industrial Rd
Empire Rd
Bennett Rd
W 1700 S
Custer Rd
Bridger Rd
Fremont Dr
W 1900 S
Glendale Golf Course
Glendale Park
W 2200 S
Camellia St
Azalea St

Index Map
Bountiful
Salt Lake City

LEGEND

Existing Structures (with ID)
- Bridge
- Culvert
- Lift Station

Sewage Canal System Channel
- Sewage Canal
- City Drain
- CWA-1 Drain
- CWA-2 Drain
- CWA-3 Drain
- CWA-3 Drain Extension
- Piped City Drain
- Jordan River
- Northwest Canal
- Municipal Boundaries
- Sewage Canal Study Area

BOWEN COLLINS & ASSOCIATES

SALT LAKE COUNTY

SEWAGE CANAL & CITY DRAIN LIFT STATION

EXISTING STRUCTURE INVENTORY

NORTH:

SCALE: 0 600 1,200 Feet

FIGURE NO. 2-1

P:\Salt Lake County\022-23-03 Sewage Canal\4.0 GIS\4.4 APRX\Sewage Canal v02.aprx rbutters 6/10/2024

To Great Salt Lake

SC1

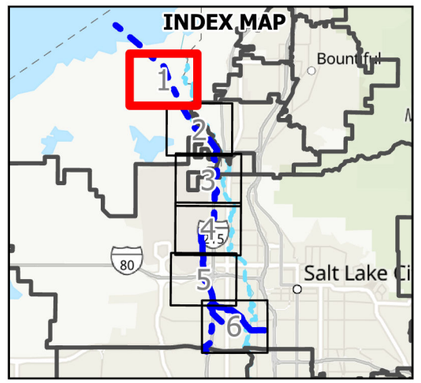
DAVIS COUNTY

LEGEND

Existing Structure
- Bridge
- Culvert
- Lift Station

Sewage Canal & Tributary
- Open Channel
- Enclosed/ Piped
- Northwest Canal
- Jordan River

Condition Deficiency
- Collapsed CMP Culvert
- CMP Culvert
- Trash Rack
- In-line Structure
- Phragmite - High
- Phragmite - Low
- Debris
- Oversteep Banks
- Berm



NORTH:

SCALE: 0 500 1,000 Feet

SUMMARY OF FIELD OBSERVATIONS & CONDITION DEFICIENCIES

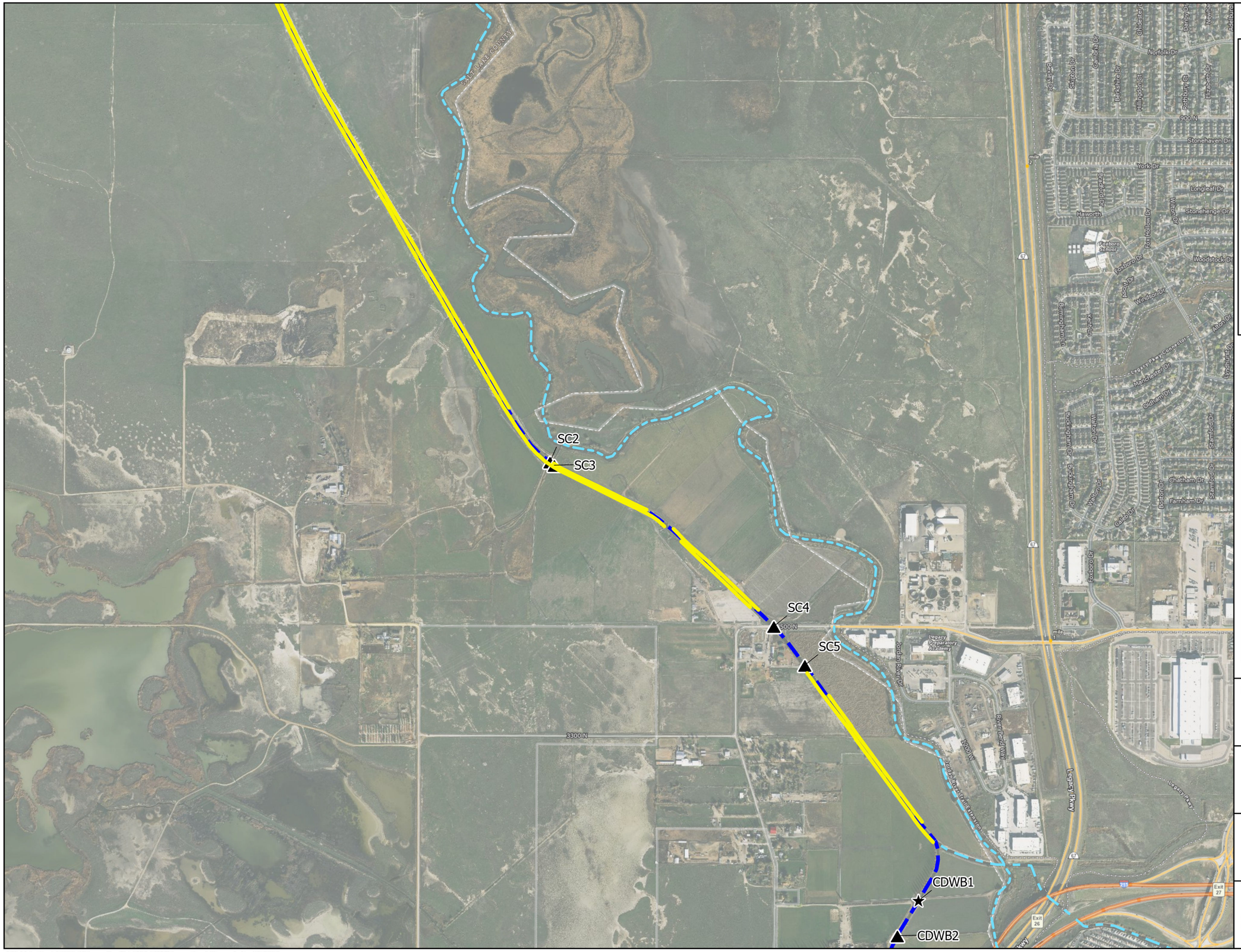
SALT LAKE COUNTY

SEWAGE CANAL & CITY DRAIN LIFT STATION

BOWEN COLLINS & ASSOCIATES

FIGURE NO. 2-2

P:\Salt Lake County\022-23-03 Sewage Canal\4.0 GIS\4.4 APRX\Sewage Canal v02.aprx rbutters 6/10/2024



LEGEND

Existing Structure
- Bridge
- Culvert
- Lift Station

Sewage Canal & Tributary
- Open Channel
- Enclosed/ Piped
- Northwest Canal
- Jordan River

Condition Deficiency
- Collapsed CMP Culvert
- CMP Culvert
- Trash Rack
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- Phragmite - Low
- Debris
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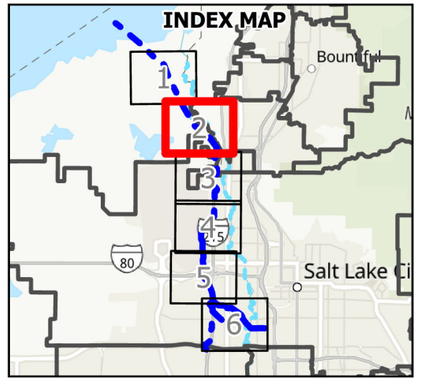

NORTH:

SCALE: 0 500 1,000 Feet

SUMMARY OF FIELD OBSERVATIONS & CONDITION DEFICIENCIES

SALT LAKE COUNTY
SEWAGE CANAL & CITY DRAIN LIFT STATION

BOWEN COLLINS & ASSOCIATES

FIGURE NO.
2-2

P:\Salt Lake County\022-23-03 Sewage Canal\4.0 GIS\4.4 APRX\Sewage Canal v02.aprx rbutters 6/10/2024

CDWB2
CDWB3
CDWB4
CDWB5
CDWB6
CDWB7
CDWB8
CDWB9
CDWB10
City Drain
Lift Station
CDWB12
CDWB13
CDWB14

LEGEND

Existing Structure
- Bridge
- Culvert
- Lift Station

Sewage Canal & Tributary
- Open Channel
- Enclosed/ Piped
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- Jordan River

Condition Deficiency
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- Berm

INDEX MAP

NORTH:

SCALE:
0 500 1,000
Feet

SUMMARY OF FIELD OBSERVATIONS & CONDITION DEFICIENCIES

SALT LAKE COUNTY
SEWAGE CANAL & CITY DRAIN LIFT STATION

BOWEN COLLINS & ASSOCIATES

FIGURE NO.
2-2

P:\Salt Lake County\022-23-03 Sewage Canal\4.0 GIS\4.4 APRX\Sewage Canal v02.aprx rbutters 6/10/2024

CDWB14

CDWB18 CDWB17 CDWB16 CDWB15

Location of inlet where canal water consistently bubbles up.

LEGEND

Existing Structure
- Bridge
- Culvert
- Lift Station

Sewage Canal & Tributary
- Open Channel
- Enclosed/ Piped
- Northwest Canal
- Jordan River

Condition Deficiency
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- CMP Culvert
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- Berm

INDEX MAP

NORTH:

SCALE: 0 500 1,000 Feet

SUMMARY OF FIELD OBSERVATIONS & CONDITION DEFICIENCIES

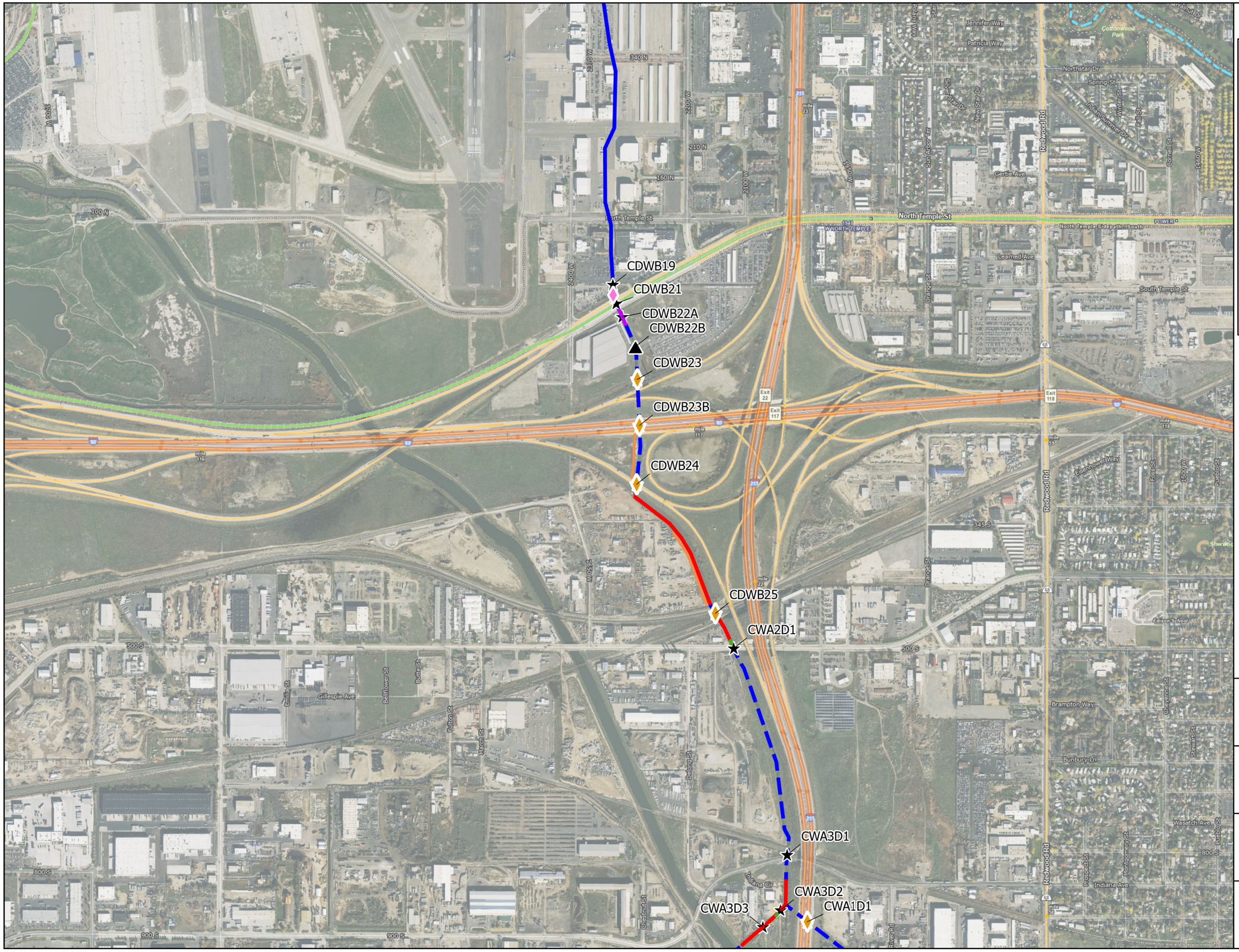
SALT LAKE COUNTY

SEWAGE CANAL & CITY DRAIN LIFT STATION

BOWEN COLLINS & ASSOCIATES

FIGURE NO. 2-2

P:\Salt Lake County\022-23-03 Sewage Canal\4.0 GIS\4.4 APRX\Sewage Canal v02.aprx rbutters 6/10/2024



LEGEND

Existing Structure
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- Culvert
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- Open Channel
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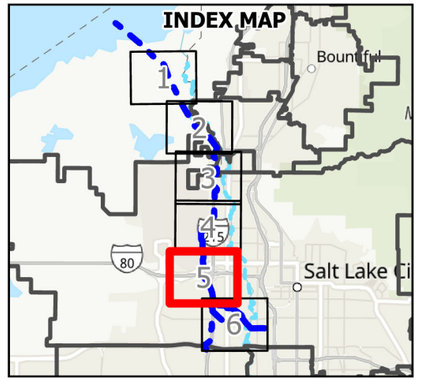

NORTH:

SCALE: 0 500 1,000 Feet

SUMMARY OF FIELD OBSERVATIONS & CONDITION DEFICIENCIES

SALT LAKE COUNTY

SEWAGE CANAL & CITY DRAIN LIFT STATION

BOWEN COLLINS & ASSOCIATES

FIGURE NO. 2-2

P:\Salt Lake County\022-23-03 Sewage Canal\4.0 GIS\4.4 APRX\Sewage Canal v02.aprx rbutters 6/10/2024

CWA3D2
CWA3D3
CWA1D1
CWA1D2
CWA1D3
CWA3D5
CWA3D6
CWA3DE1
CWA3D7
CWA3DE2
CWA3DE3
CWA3D8
CWA3DE4
CWA3DE5
CWA3D9
CWA3D11
CWA3D12

LEGEND

Existing Structure
- Bridge
- Culvert
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Sewage Canal & Tributary
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INDEX MAP

NORTH:

SCALE: 0 500 1,000 Feet

SUMMARY OF FIELD OBSERVATIONS & CONDITION DEFICIENCIES

SALT LAKE COUNTY

SEWAGE CANAL & CITY DRAIN LIFT STATION

BOWEN COLLINS & ASSOCIATES

FIGURE NO. 2-2

P:\Salt Lake County\022-23-03 Sewage Canal\4.0 GIS\4.4 APRX\Sewage Canal v02.aprx rbutters 6/10/2024

CHAPTER 3 – PREVIOUS ANALYSIS

EARLY CANAL HISTORY

The Sewage Canal was originally constructed in 1911 to remove wastewater from the Jordan River and convey it directly to the Great Salt Lake. Raw, untreated sewage was collected and conveyed to the Sewage Canal. In 1924, the Sewage Canal was expanded to increase the capacity of the channel. In 1965, Salt Lake City's Water Reclamation Plant was constructed and began treatment of the sewage and discharged sewage effluent into the Northwest Drain.

In addition to receiving and conveying sewage, the Northwest Drain was used as the outfall for the oil drain for the American Oil refinery. While it no longer acts as an oil drain, much of the soil along the Northwest Drain has become contaminated with hydrocarbons. It is possible that hydrocarbon contamination has made it to the Sewage Canal.

As Salt Lake City grew, the need for storm water runoff conveyance increased. In addition to the Sewage Canal taking treated effluent to the Great Salt Lake, it also became a major storm water conveyance facility for portions of the City. The CWA drains were originally constructed to drain high groundwater/swampy areas of Salt Lake City to the Sewage Canal and then to the Great Salt Lake. The drain portion of the Sewage Canal system was slowly expanded to provide storm water conveyance. This included connecting multiple storm water trunklines to the CWA drains.

DIFFERENT SLC MASTER PLAN STUDIES

Since its construction and subsequent conversion into a storm water conveyance facility, the Sewage Canal system has never been studied in its entirety. However, portions of the canal were studied as part of multiple previous SLC storm water master plans as well as the Salt Lake City International Airport (SLC Airport) master plan. These studies primarily focused on the discharge into the canal system, and not on the conveyance capacity of the canals, particularly for the City Drain and the Sewage Canal. Short descriptions of the studies follow.

CWA Drainage Study (1986)

In the early 1980s, there were consistent flooding issues in the area of 900 West and California Ave. This study focused on the CWA drains and a portion of the City Drain ending at about I-80. This study identified that the potential 10-year runoff was significantly higher than the capacity of many of the CWA drains. Based on this study, two new storm drain lift stations were constructed to take water from the CWA-1 Drain to the Surplus Canal and to remove much of the drainage area associated with the stretch from the 2100 South area to the Jordan River. In addition, a large detention basin was constructed to decrease flows into the CWA-2 Drain. This study recommends that the lift stations primarily be used in large flow events; low flows would continue to go into the CWA drain portion of the system.

CWA/1700 South Study Area (1993)

The CWA drains were further studied in 1993 by RB&G engineering. Similar to the 1986 study, it was recommended to increase the detention on the upstream ends of each of the CWA drains. In addition, further capacity for the lift station to the Surplus Canal was recommended.

Salt Lake City Airport Master Plan (Late 1990's)

The SLC Airport manages all of its own storm water runoff independent of the rest of Salt Lake City. SLC Airport completed a Storm Drain Master Plan in the late 1990's. This master plan identified that

the majority of the airport runoff is directed to the south and west of the airport and from there, on to the Surplus Canal. Only the East side of the airport has storm water runoff that goes into the City Drain. This includes the Military Complex portion of the airport (including the associated runway) as well as the open fields just east of the main commercial airport. While the majority of the SLC Airport has undergone significant remodeling since the Storm Drain Master Plan was completed, the portion of the airport that goes into the City Drain has remained relatively untouched. There has been some additional development in the north-east portion of the airport since the 1990s. Our hydrologic analysis included the additional flows from that area. Most of the flows from the SLC Airport property were based on their Storm Drain Master Plan study. Specific information on subbasins and flow rates is presented in Chapter 4.

FEMA GREAT SALT LAKE STUDY

The 100-year floodplain elevation for the Great Salt Lake is currently being updated. The previous study established the static water elevation as 4215 feet with the potential for 3-foot wave runup on the south side of the Lake (making 4218-feet the 100-year WSE for the Sewage Canal study area). Based on some preliminary values provided by the State of Utah Department of Emergency Management, it appears that the new elevations will be similar to the current values. Based on the ground surface elevations from 2013-14 LiDAR, much of the overbanks surrounding the Sewage Canal and connecting portions of the City Drain and Northwest Drain will be within the new Great Salt Lake floodplain.

Based on the Great Salt Lake floodplain elevation, new development along the Sewage Canal will need to place fill to elevate structures above approximately 4218 feet. Since this value is typically above the banks of the Sewage Canal, the Great Salt Lake floodplain will be the major controlling factor for development along the Sewage Canal. During this project, the water surface elevations of the Great Salt Lake were significantly lower than the 100-year elevations. However, while looking at historical imagery, an aerial view of the sewage canal in 1985 shows that the overbanks were flooded due to high water levers in the Great Salt Lake. The historic aerial is included in Appendix D.

CHAPTER 4 – HYDROLOGIC ANALYSIS

A hydrologic computer model of the Sewage Canal and its tributaries was developed using the Autodesk Storm and Sanitary Analysis (ASSA) computer software. The model was used to estimate storm water runoff volumes and peak discharges generated by a design storm event and to develop runoff hydrograph inflows for the Sewage Canal, City Drain, and CWA drains (Sewage Canal System) for both the existing and full build-out conditions. This chapter focuses on the process and assumptions used to develop the hydrologic model for the study area. The methods used to estimate the hydraulic capacity of the Sewage Canal system and its related hydraulic structures are discussed in Chapter 5.

PREVIOUS MODELS

Previous studies of the City Drain and CWA drains used HEC-1 for the hydrologic analysis. HEC-1 models are out of date and are not recommended for use anymore. As a result, the model used for this study was developed from scratch. The methodology used to develop the hydrologic model parameters is similar to what has been done for nearby hydrologic studies. The process used to develop the hydrologic model is outlined in the following general steps, with detailed information on each step provided below:

1. Delineate Drainage Basins
2. Develop Hydrologic Modeling Parameters
3. Develop Design Storm Parameters
4. Calibrate Hydrologic Model

DRAINAGE BASIN AND SUBBASIN DELINEATION

The Sewage Canal System drainage basin boundaries and related subbasin boundaries were delineated based on storm drain GIS inventory data provided by Salt Lake City, in conjunction with topographic data. The topographic data used for this study was developed using LiDAR data collected in 2013-2014, available on the UGRC website. Aerial photographs taken in 2022, available from UGRC, were also used to develop the subbasins. The Sewage Canal system drainage basin and subbasin boundaries developed as part of this study are shown on Figure 4-1.

The drainage basin area associated with the Northwest Drain was not studied as part of this analysis. Flow rates were taken from the recent Salt Lake City Storm Drian Master Plan update of the Northwest Drain as well as from the ongoing Northwest Drain and Lift Station hydraulic analysis. The hydrologic computer model of the Northwest Drain was provided to us by the City and we utilized the hydrographs from that model in our analysis of the Sewage Canal.

Based on existing contours and drainage systems, little-to-no significant runoff from the areas adjacent to the Sewage Canal will get into the Sewage Canal System. As a result, this runoff was not included in the existing drainage area.

HYDROLOGIC MODEL PARAMETERS

ASSA uses the United States Army Corps of Engineers HEC-HMS hydrologic engine based on SCS Curve Number methodology to estimate runoff for each subbasin. ASSA uses the HEC-1 hydrologic engine to estimate runoff. This method requires lag time, CN value, percent impervious, and area for each subbasin as hydrologic input parameters. A description of each of these items is included below. The hydrologic model parameters are summarized in Appendix E. Hydrologic model parameters were developed using a methodology adapted from the ongoing Salt Lake City Storm Drain Master Plan. This was done to simplify the calibration process and to have values/results more consistent with the Salt Lake City Master Plan when it is complete.

Curve Number

The Curve Number (CN) was estimated for the pervious portion of each subbasin based on the hydrologic soil type and land cover. The CNs used in this study do not account for impervious land cover types such as pavement. The methodology used in this study accounts for directly-connected impervious area by inputting that value in the model as a percentage of the area of each drainage subbasin that is impervious. Using this approach is necessary for Salt Lake Valley's climate and geology as peak runoff values from the 3-hour design storm are severely underestimated for areas with Hydrologic Soil Groups (HSG) A and B when a "composite" CN is used instead of entering impervious land cover separately. The hydrologic soil type and land cover was obtained from the Meter-scale Urban Land Cover (MULC) dataset for Salt Lake City. The MULC uses the hydrologic soil types developed by the NRCS. Table 4-1 shows the CN used in this study, based on soil type and the assumed ground cover. The soil types are identified in Figure 4-2 and MULC land cover is identified on Figure 4-3.

Table 4-1
SCS Curve Number

MULC Grid Code	MULC Description	Equivalent Land Type Based on TR-55 Manual	CN Value for Hydrologic Soil Type[1]			
			A	B	C	D
10	Open Water	Water	98	98	98	98
30	Bare Earth	Bare Soil	77	86	91	94
40	Trees/Forest	Woods, fair	36	60	73	79
52	Shrub/Scrub	Oak-aspen, fair	30*	48	57	63
70	Herbaceous	Open Space, good	39	61	74	80
91	Wetlands, woody	NRCS 650: Swamps	85	85	85	85
92	Wetlands, emerging	NRCS 650: Swamps	85	85	85	85

[1] The CN values are from the TR-55 manual, Table 2-2a

Drainage and Subbasin Areas

Subbasin areas were calculated using computerized GIS technology and the delineated subbasin boundaries.

Directly-Connected Impervious Area

The MULC dataset includes information on whether an area is impervious or not. This data was developed using aerial imagery and LiDAR. Typically, directly-connected impervious area represents only the impervious areas that generate runoff which will only flow over impervious areas prior to being collected in the storm drain system (e.g. roadways, driveways, and some rooftops). Due to the presence of trees (identified as pervious area) over homes and the majority of the impervious area being in commercial/industrial areas where all the impervious areas are directly connected, this study assumes that all the MULC-identified impervious areas for a given subbasin would be directly-connected. The percentage of the total subbasin that is directly-connected impervious area was estimated based on this assumption.

Lag Time

Lag time was calculated for subbasins using Worksheet 3 from the TR-55 manual.

DESIGN STORM PARAMETERS

A design storm has a specified depth and temporal precipitation distribution. The design storm was applied to the entire study area using the "nested" Farmer-Fletcher temporal distribution. This distribution is a typical standard for most municipalities along the Wasatch Front. The specified depth for a design storm is typically determined by a desired return period and storm duration. A cloudburst storm event of three hours was selected for this study to remain consistent with design standards throughout the Wasatch Front. Typical design storm return periods include 10 years and 100 years for storm drain pipes and large storm drain facilities (e.g. detention basins, canals, and creeks), respectively. Both return periods were analyzed for this study.

The following parameters were used to develop the synthetic design storm:

- Storm Duration: 3 hours
- Temporal Precipitation Distribution: Modified Farmer-Fletcher
- Storm Recurrent Intervals: 10-year and 100-year
- Design Storm Depth (From NOAA Atlas 14): (10-year) 1.05 inches (100-year) 1.86 inches

EXISTING DETENTION

The majority of the area surrounding the City Drain and CWA-drain upstream of City Drain pump station have been built-out for a few decades. As a result, much of the development does not include detention areas. The only major exceptions to this are the two Utah Department of Transportation (UDOT) detention basins located at the interchange of I-215 and I-80. Both detention basins are large, flat areas with a large storage volume (based on 2013-14 LiDAR, the combined volume is almost 100 acre-feet). Typically, detention basins of this size would be included in a hydrologic model. However, as discussed further in Chapter 5, the hydraulic model methodology chosen includes hydrograph inflow data. As a result, the detention basins were included in the hydraulic model and only the hydrographs for the UDOT area were considered in the hydrologic model.

MODEL CALIBRATION

The final step in the hydrologic modeling process was model calibration. In general, calibration of a hydrologic model of an urban area refers to the process of adjusting model parameters to achieve results consistent with available reference information, such as gauge flow data, in nearby areas. As is common in urban area rainfall-runoff models, the study area does not have a stream gauge or measured flow data, so gauge data was unavailable for use as a calibration standard. Instead, the model was calibrated to a target range based on available urban runoff studies.

Calibration Target Range

The Sewage Canal hydrologic model was calibrated to the peak runoff values identified in the Water-Resources Investigations Report 89-4095, entitled "Peak-Flow Characteristics of Small Urban Drainages along the Wasatch Front, Utah" from the U.S. Geological Survey published in 1989. After calibration of the rainfall-runoff model, peak runoff rates for the 10-year 3-hour storm event for the subbasins ranged from 0.08 cfs/acre for low-density areas to 0.99 cfs/acre for heavily commercial regions. This range is consistent with the values defined in the study. Values for runoff were expected

to be on the lower end, as this study focuses on the Salt Lake County valley floor where slopes are mild, reducing the peak runoff response compared to the foothills along the Wasatch Front.

AIRPORT HYDROLOGY

Some subbasins, which together represented the whole SLC Airport region draining to the City Drain, were calibrated to the SLC Airport Storm Drain Master Plan from the late 1990s. These subbasins are identified on Figure 4-1. A short description of each subbasin from the SLC Airport master plan is given below. Additional data from the SLC Airport Storm Drain Master Plan is included in Appendix F.

- **Subbasin CD-05:** This subbasin is the area east of the main commercial airport to about I-215 and generally south of about 1350 North. The military and other airport buildings are included within this portion as well as a small amount of commercial development. Based on the master plan, this area is detained to a peak flow rate of 40 cfs into the City Drain
- **Subbasin CD-03:** This subbasin is the area east of the main commercial airport to about I-215 and generally north of about 1350 North to 2400 North. The majority of this subbasin is undeveloped and is not planned for significant development (it is within the flight path of one of the runways).

The model parameters of the subbasins listed above were adjusted until the runoff values was similar to the peak flow rates identified in the SLC Airport Storm Drain Master Plan.

HYDROLOGIC MODELING ASSUMPTIONS

The following general assumptions were made in completing the hydrologic analyses of the study area:

1. Rainfall return frequency is equal to associated runoff return frequency.
2. Design storm rainfall has a uniform spatial distribution over each drainage basin.
3. Normal (SCS Type 2) antecedent soil moisture conditions exist at the beginning of the design storm.
4. The hydrologic computer model adequately simulates watershed response to precipitation.

Additional assumptions and adjustments to the hydrologic modeling are described in the following sections.

Storm Drain Inlet and System Capacity

Urban storm drain inlets and pipe systems are typically designed to capture and convey storm water runoff associated with the 10-year design storm. This flow would then be conveyed to a larger facility (such as the Sewage Canal), or to detention basins, to reduce the peak flow rate. In the drainage area for the Sewage Canal System, the majority of the storm water runoff is anticipated to make it to the main trunkline pipes of the storm drain system. No plans are in place to increase the capacity of the trunklines beyond the 10-year design storm event.

Flows in excess of the 10-year storm (i.e. the 50-yr or 100-yr storm) would be collected within the street Right-of-Way and conveyed to the outfall. Unlike other large conveyance facilities in Salt Lake County, the Sewage Canal and its tributaries are either bermed or are not the local low spot for collection of runoff. As a result, flows from the 100-year event cannot be conveyed into the Sewage Canal System. Rather, in those large events, storm water will pond up in the streets or will be

conveyed to the Jordan River/Surplus Canal or other nearby drains. Therefore, the peak flow into the Sewage Canal system will be the same for both the 10-year and 100-year design storm events. These results are consistent with other studies in the area. In addition to this, the ongoing Salt Lake City Storm Drain Master Plan effort has identified portions of the system that can't convey the 10-year design storm. More discussion on these areas is included in the following section.

Salt Lake City Storm Drain Master Plan

The Salt Lake City Storm Drain Master Plan identifies multiple trunklines that don't have adequate capacity for the 10-year design storm runoff. This means that for the 10-year design storm, not all of the runoff will be safely conveyed to the Sewage Canal system. The City does not have plans to increase the capacity of many of these pipes to the Sewage Canal system, based on their master plan and input from Salt Lake City Personnel.

Salt Lake City does have plans to improve portions of the system; however, any improvements made would result in detention or diverting storm water away from the Sewage Canal. The 10-year design storm event will be a more-than-adequate representation of the peak flow and volume into the canal system.

Future Development

The majority of the existing Sewage Canal drainage area is already fully, or nearly fully, developed. Future development opportunities are primarily located on the downstream side of I-215, with a small portion of redevelopment possible between the City Drain Lift Station and I-215. Based on this, future development is anticipated to have little-to-no impact on the volume of runoff and peak flow rates that go into the Sewage Canal.

AREAL REDUCTION OF PRECIPITATION DEPTH

Intense summer cloudburst events typically move across the Salt Lake Valley and rarely cover a large area. Precipitation depth reduction factors for larger drainage basins are typically utilized in hydrologic analysis procedures to adjust point precipitation values for large areas. The NOAA Atlas 2 (1973) recommends a storm-centered areal reduction of 0 to 15 percent for 3-hour storm cells ranging from 0 to 100 square miles in area. This was not used for this study primarily for the following reasons:

- The design storm recurrence interval for this study is already less than is typical. Most large conveyance facilities in the Salt Lake Valley are analyzed using a 100-year recurrence interval; the Sewage Canal study will be analyzed using a 10-year recurrence interval.
- The channels in the Sewage Canal system act like linear detention basins, attenuating peak flows significantly within the system. Hydraulic analysis, discussed further in Chapter 5, found that volumes were a controlling factor of the system in addition to the peak flow rates. We are not using an areal reduction results in a more conservative volume.

RESULTS AND CONCLUSIONS

The design storm recommended for the Sewage Canal is a 10-year 3-hour storm. The 10-year storm is recommended rather than a 100-year storm to account for the limited capacity of the pipe system upstream of the canals. Almost all of the runoff associated with events greater than a 10-year storm event would not make it into the Sewage Canal System. This is because the majority of the SLC storm drain system cannot handle flow rates above the 10-year 3-hour storm event. The City does not have plans to significantly improve the storm drain system to the Sewage Canal and CWA drains. Instead,

most major changes will involve detention and taking flow to either the Jordan River or the Surplus Canal. Thus, limiting design capacity to the 10-year event is appropriate.

The estimated peak hydrologic inflows for the design storm event into the Sewage Canal System are presented in Figure 4-4 and summarized in Table 4-2. Hydrographs of the inflows are included in Appendix G. In Table 4-2, the "Hydrologic Element Type" refers to either the subbasin or link where all or only a limited portion of design storm runoff enters into the Sewage Canal System, respectively.

Table 4-2
Major Hydrologic Inflows into the Sewage Canal System

Hydrologic Model Element	HEC-RAS Inflow Channel – Station	Peak Flow Rate		Hydrologic Model Element	HEC-RAS Inflow Channel - Station	Peak Flow Rate
Subbasin	CWA-3 -EXT 4699	146 cfs		Subbasin	CWA3 – 80508	28 cfs
Subbasin	CWA-3 79317	64 cfs		Link	CWA-3 – 77210	78 cfs
Subbasin	CWA-3 76266	116 cfs		Link	CWA-1 – 71997	113 cfs
Subbasin	CWA-1 – 70686	90 cfs		Subbasin	CWA-2 71561	199 cfs
Subbasin	CWA-2 – 69946	100 cfs		Subbasin	CWA-2 – 68916.62	6 cfs
Link	City Drain 68056.81	33 cfs		Link	City Drain – 65879	24 cfs
Link	City Drain – 65721.24	117 cfs		Subbasin	City Drain - 64367	4 cfs
Subbasin	City Drain 63155.49	56 cfs		Subbasin	City Drain - 61793.16	65 cfs
Subbasin	City Drain – 52785	40 cfs		Link	City Drain - 50692.24	121 cfs
Subbasin	City Drain – 45487	46 cfs		Subbasin	City Drain – 48376	29 cfs
Link	City Drain – 40938	66 cfs		Subbasin	City Drain – 36461	58 cfs
Subbasin	Existing Northwest Drain	248 cfs				

LEGEND

- Sewage Canal
- City Drain
- CWA-1 Drain
- CWA-2 Drain
- CWA-3 Drain
- CWA-3 Drain Extension
- Subbasin Boundaries
- Sewage Canal System Drainage Area
- Jordan River
- Salt Lake City Storm Drain Pipe

Note:
The Northwest Canal Drainage Area hydrology was studied by Salt Lake City for a Master Plan
Sewage Canal has berms on both sides making any existing runoff minimal. Future development should either go to Jordan River or minimize detention.

CD-01
CD-02
CD-03
CD-04
CD-05
CD-06
CD-07
CD-08
CD-09
CD-10
CD-11
CD-12
CWA2-01
CWA2-02
CWA1-02
CWA3-01
CWA2-03
CWA1-01
CWA3-02
CWA1-03
CWA1-04
CWA1-05
CWA3E-01
CWA3-03
CWA3-04
CWA3-06
CWA3-05
CWA1-06
I-215
I-80
I-15
SR-201
Jordan River
Salt Lake City
South Salt Lake
Salt Lake City International Airport
Redwood Rd
3200 W
3600 W
Constitution Blvd
Victory Rd
LDS Business College
Ensign Peak 5413 Feet
Main St
State St

BOWEN COLLINS & ASSOCIATES

SALT LAKE COUNTY

SEWAGE CANAL & CITY DRAIN LIFT STATION

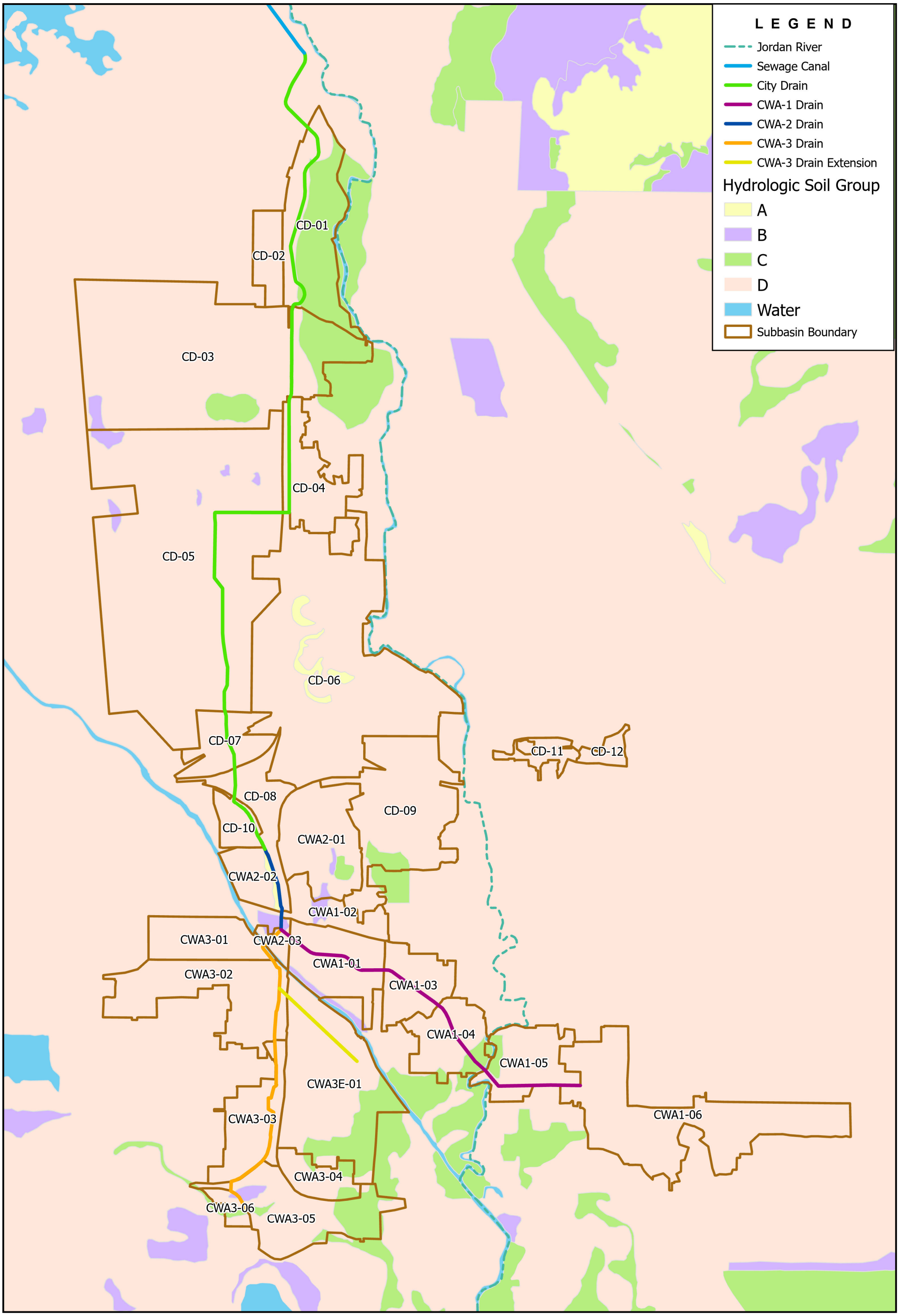
SEWAGE CANAL SUBBASIN BOUNDARY

NORTH:

SCALE: 0 1,500 3,000 Feet

FIGURE NO. 4-1

P:\Salt Lake County\022-23-03 Sewage Canal\4.0 GIS\4.4 APRX\Sewage Canal v02.aprx tjorgensen 5/25/2024



BOWEN COLLINS & ASSOCIATES

SALT LAKE COUNTY

SEWAGE CANAL & CITY DRAIN LIFT STATION

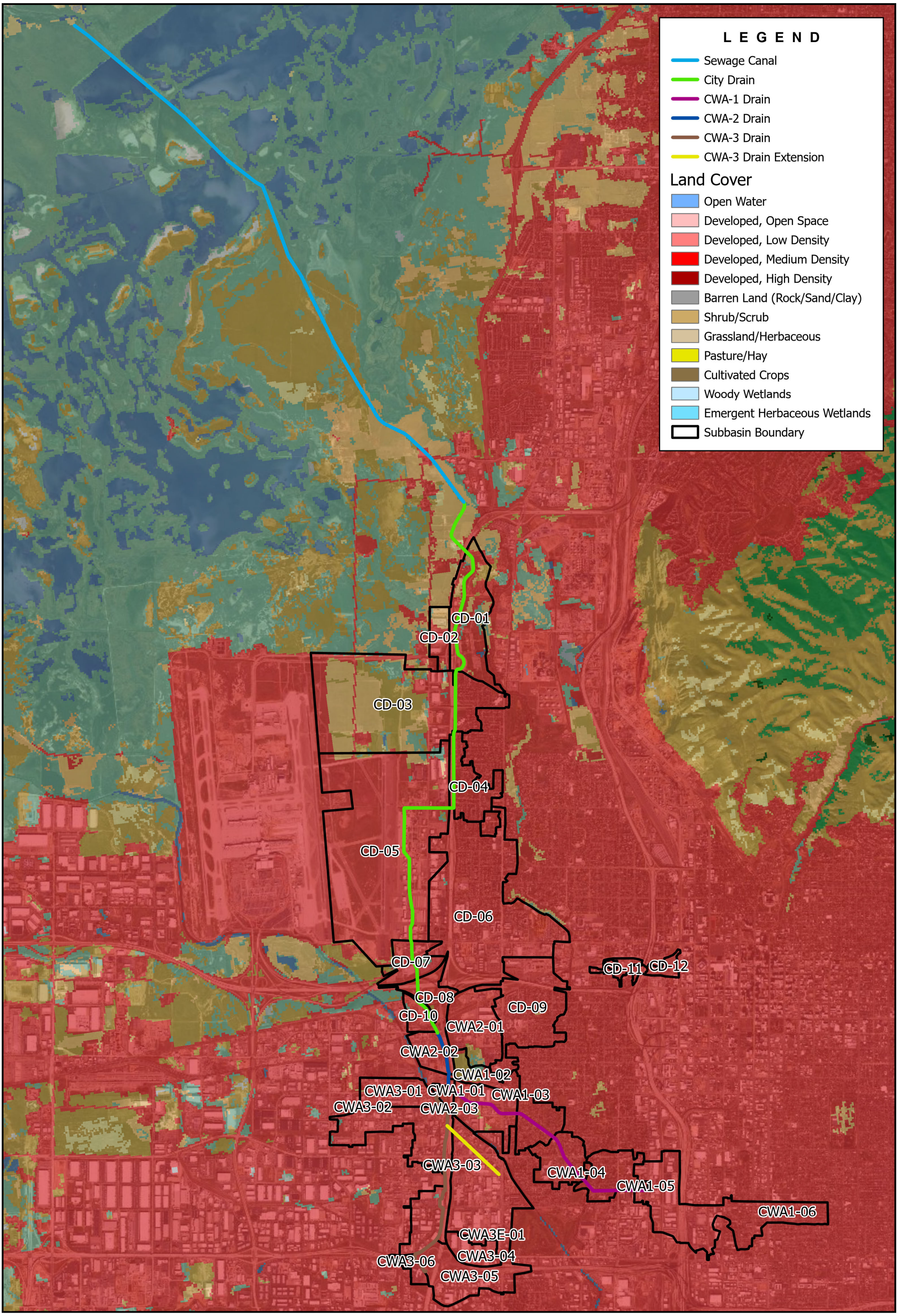
URBAN LAND COVER HYDROLOGIC SOIL GROUP

NORTH:

SCALE: 0 1,500 3,000 Feet

FIGURE NO. 4-2

P:\Salt Lake County\022-23-03 Sewage Canal\4.0 GIS\4.4 APRX\Sewage Canal v02.aprx rbutters 6/11/2024



BOWEN COLLINS & ASSOCIATES

SALT LAKE COUNTY

SEWAGE CANAL & CITY DRAIN LIFT STATION

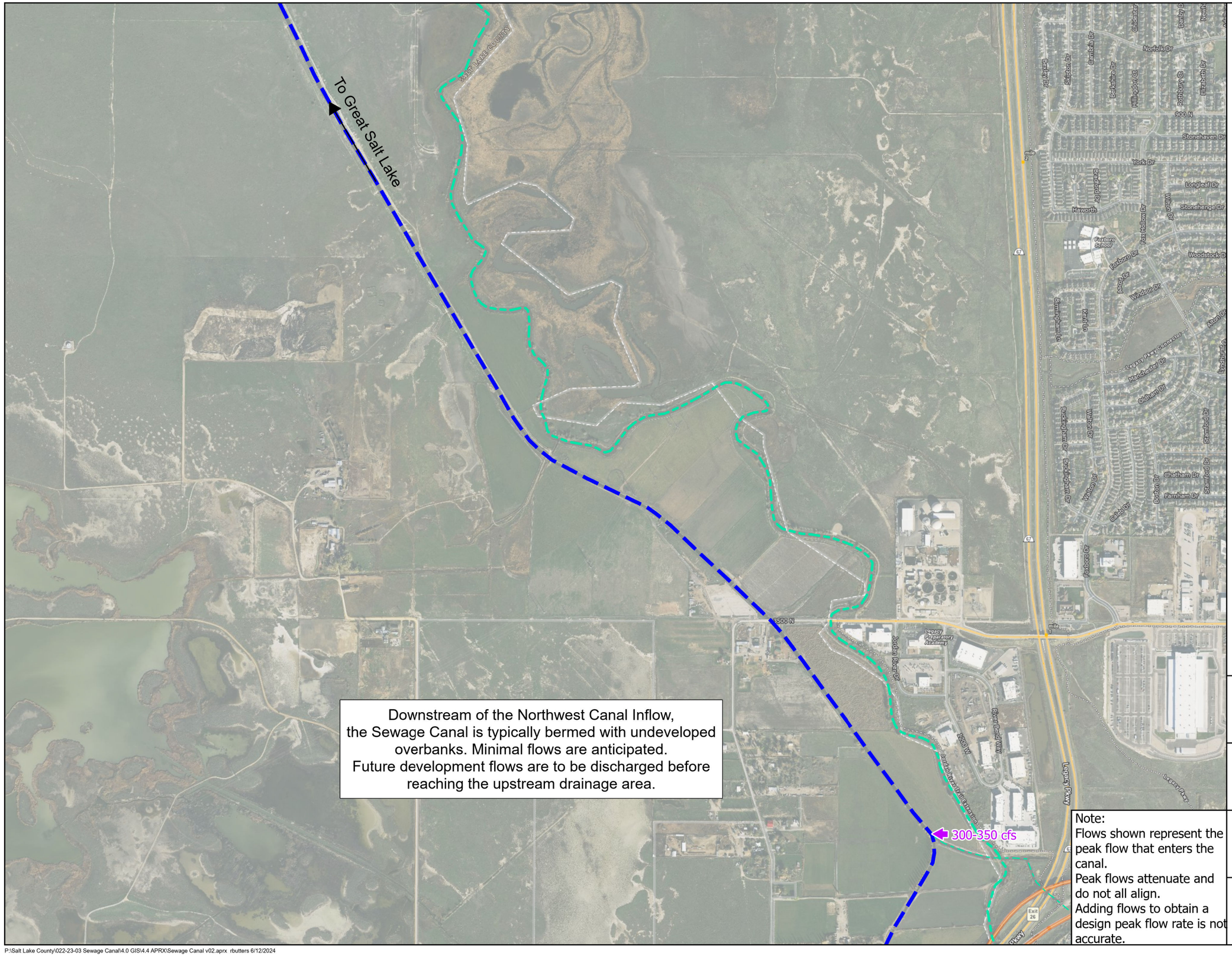
URBAN LAND COVER DATA

NORTH:

SCALE: 0 2,250 4,500 Feet

FIGURE NO. 4-3

P:\Salt Lake County\022-23-03 Sewage Canal\4.0 GIS\4.4 APRX\Sewage Canal v02.aprx rbutters 6/11/2024



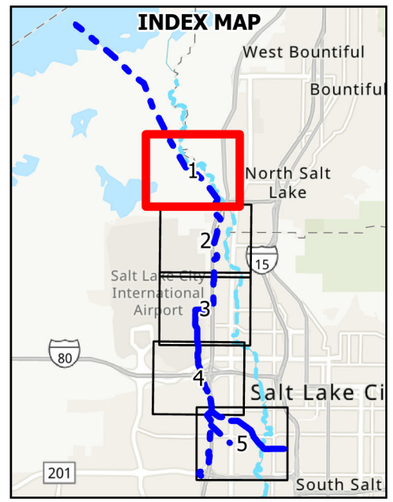
Downstream of the Northwest Canal Inflow, the Sewage Canal is typically bermed with undeveloped overbanks. Minimal flows are anticipated. Future development flows are to be discharged before reaching the upstream drainage area.

LEGEND

- Major Inflows (#cfs)
- City Drain Lift Station

Sewage Canal & Tributary

- Open Channel
- Enclosed Pipe
- Northwest Canal
- Salt Lake City Storm Drain Pipe
- Jordan River



NORTH:

SCALE: 0 500 1,000 Feet

Note:
Flows shown represent the peak flow that enters the canal.
Peak flows attenuate and do not all align.
Adding flows to obtain a design peak flow rate is not accurate.

HYDROLOGIC INFLOWS TO THE SEWAGE CANAL SYSTEM

SALT LAKE COUNTY

SEWAGE CANAL & CITY DRAIN LIFT STATION

BOWEN COLLINS & ASSOCIATES

FIGURE NO. 4-4

P:\Salt Lake County\022-23-03 Sewage Canal\4.0 GIS\4.4 APRX\Sewage Canal v02.aprx rbutters 6/12/2024

58 cfs

66 cfs

46 cfs

City Drain Lift Station

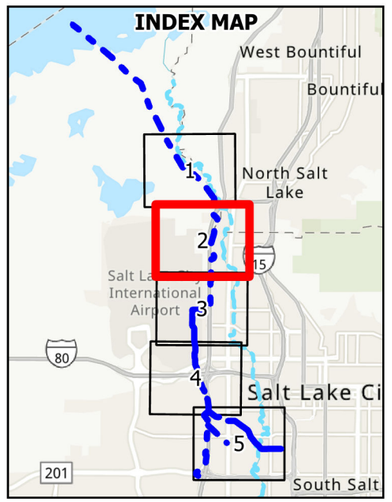
LEGEND

- Major Inflows (#cfs)
- City Drain Lift Station

Sewage Canal & Tributary

- Open Channel
- Enclosed Pipe
- Northwest Canal
- Salt Lake City Storm Drain Pipe
- Jordan River

INDEX MAP



NORTH:

SCALE: 0 500 1,000 Feet

Note:
Flows shown represent the peak flow that enters the canal.
Peak flows attenuate and do not all align.
Adding flows to obtain a design peak flow rate is not accurate.

HYDROLOGIC INFLOWS TO THE SEWAGE CANAL SYSTEM

SALT LAKE COUNTY

SEWAGE CANAL & CITY DRAIN LIFT STATION

BOWEN COLLINS & ASSOCIATES

FIGURE NO. 4-4

P:\Salt Lake County\022-23-03 Sewage Canal\4.0 GIS\4.4 APRX\Sewage Canal v02.aprx rbutters 6/12/2024

46 cfs

Peak flow based on
Salt Lake Airport
Storm Drain Master Plan

29 cfs

Peak flow based on
Salt Lake Airport
Storm Drain Master Plan

40 cfs

121 cfs

Peak flow is limited
by upstream pipe capacity.
Excess flows would pond
or flow to the Jordan River.

Flow from this
development area is
accounted for with
inflow from the airport
storm drain master plan.

This portion of the City
Drain is owned
and maintained by
Salt Lake City.

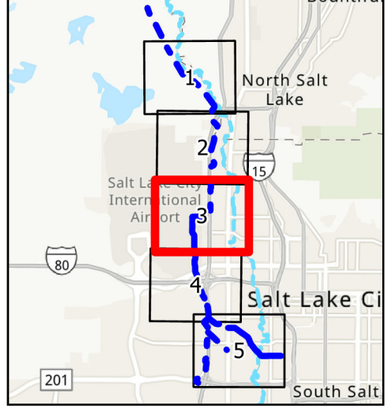
LEGEND

- Major Inflows (#cfs)
- City Drain Lift Station

Sewage Canal & Tributary

- Open Channel
- Enclosed Pipe
- Northwest Canal
- Salt Lake City Storm Drain Pipe
- Jordan River

INDEX MAP



NORTH:

SCALE: 0 500 1,000 Feet

Note:
Flows shown represent the peak flow that enters the canal.
Peak flows attenuate and do not all align.
Adding flows to obtain a design peak flow rate is not accurate.

HYDROLOGIC INFLOWS TO THE SEWAGE CANAL SYSTEM

SALT LAKE COUNTY
SEWAGE CANAL &
CITY DRAIN LIFT STATION

BOWEN COLLINS & ASSOCIATES

FIGURE NO.
4-4

Flow from this development area is accounted for with inflow from the airport storm drain master plan.

65 cfs

56 cfs

Flow from Freeway Interchange is detained by regional detention ponds.

4 cfs

117 cfs

24 cfs

Flow is limited by the last section of the storm drain pipe. Excess flows would pond up on the east side of I-215.

33 cfs

6 cfs

Note:
Flows shown represent the peak flow that enters the canal.
Peak flows attenuate and do not all align.
Adding flows to obtain a design peak flow rate is not accurate.

LEGEND

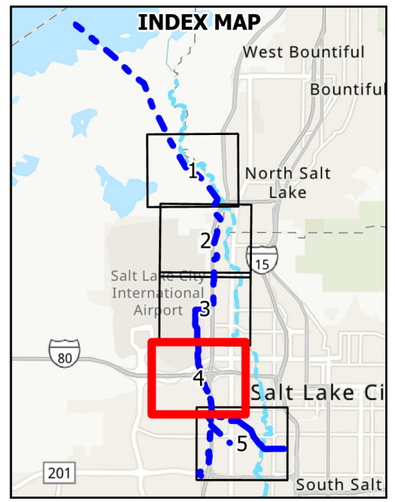
- Major Inflows (#cfs)
- City Drain Lift Station

Sewage Canal & Tributary

- Open Channel
- Enclosed Pipe

- Northwest Canal
- Salt Lake City Storm Drain Pipe
- Jordan River

INDEX MAP



NORTH:

SCALE: 0 500 1,000 Feet

HYDROLOGIC INFLOWS TO THE SEWAGE CANAL SYSTEM

SALT LAKE COUNTY
SEWAGE CANAL & CITY DRAIN LIFT STATION

BOWEN COLLINS & ASSOCIATES

FIGURE NO. 4-4

P:\Salt Lake County\022-23-03 Sewage Canal\4.0 GIS\4.4 APRX\Sewage Canal v02.aprx rbutters 6/12/2024

6 cfs

100 cfs

Flow will be limited to a pipe under the surplus canal. The lift station takes excess flows to the surplus canal.

90 cfs

112 cfs

Peak flow is limited by upstream pipe capcity. Excess flows would pond and runoff to the Surplus Canal.

146 cfs

116 cfs

Pipe capacity exceeded during the 10-yr design storm event. Excess flows won't reach Canal System.

78 cfs

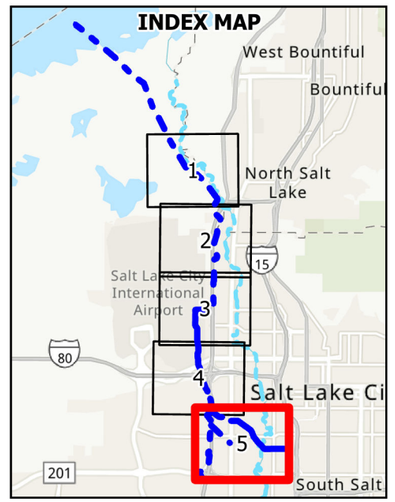
64 cfs

28 cfs

L E G E N D

- Major Inflows (#cfs)
- City Drain Lift Station
- Sewage Canal & Tributary
  - Open Channel
  - Enclosed Pipe
- Northwest Canal
- Salt Lake City Storm Drain Pipe
- Jordan River

INDEX MAP



NORTH:

SCALE: 0 500 1,000 Feet

Note:
Flows shown represent the peak flow that enters the canal.
Peak flows attenuate and do not all align.
Adding flows to obtain a design peak flow rate is not accurate.

HYDROLOGIC INFLOWS TO THE SEWAGE CANAL SYSTEM

SALT LAKE COUNTY
SEWAGE CANAL & CITY DRAIN LIFT STATION

BOWEN COLLINS & ASSOCIATES

FIGURE NO. 4-4

P:\Salt Lake County\022-23-03 Sewage Canal\4.0 GIS\4.4 APRX\Sewage Canal v02.aprx rbutters 6/12/2024

CHAPTER 5 – HYDRAULIC ANALYSIS

A hydraulic analysis was performed on the channels of the Sewer Canal and its tributaries with their associated culverts and other structures. The purpose of this analysis was to determine existing conveyance capacities and to identify where deficiencies exist in the study area. This chapter summarizes how the hydraulic analyses were performed.

A HEC-RAS hydraulic computer model of the Sewer Canal and its tributaries was developed utilizing topographic data, survey data of channel cross sections and hydraulic structures, and aerial photographs. Version 6.4.1 of the HEC-RAS computer program, developed by the United States Army Corps of Engineers, was used to perform the hydraulic modeling for this study. The purpose of this chapter is to describe the process used to develop the hydraulic models and to summarize the modeling results associated with the hydraulic analyses. No prior model was available for the Sewage Canal system.

HYDRAULIC MODEL DEVELOPMENT

This section outlines the general methodology and approach used to complete the hydraulic modeling of the creek channels that were studied in detail as part of this project.

Basic Information

Data acquisition and hydraulic model development tasks were completed in accordance with FEMA Guidelines and Specifications.

Topographic Data

Channel cross sections were surveyed at approximately 1,000-foot intervals through the study reaches of the Sewer Canal and its tributaries. Then, 2013-14 LiDAR data from UGRC was used to extend the limits of the surveyed channel cross sections across the channel overbanks, enabling the retrieval of geometric data needed to develop the open channel model at each cross section. Field survey data of hydraulic structures was used to develop the geometry data for hydraulic structures on the creeks.

Downstream and Junction Boundary Conditions

The Sewage Canal discharges into Farmington Bay on the Great Salt Lake. The downstream boundary condition selected was normal depth calculation with a slope of 0.00013 ft/ft. This boundary condition was compared to various scenarios of the current Great Salt Lake water surface elevations (WSEs). A normal depth boundary condition resulted in WSE within the sewage canal similar to the 5-year to 10-year WSE in the Great Salt Lake. If the Great Salt Lake WSE were at the 100-year levels, the static water elevation would be above the sewage canal banks for much of the channel downstream of the City Drain Lift Station, regardless of the flow rate within the canal system. This means that the Sewage Canal system will most likely not operate as evaluated for this study if the Great Salt Lake reaches the 100-year WSE. Plans should be in place to protect low-lying development from the Great Salt Lake backing up into the sewage canal. As discussed previously, the majority of new potential development in the vicinity of the Sewage Canal is in or near the Great Salt Lake floodplain and will need to be elevated above the 100-year WSE for flood protection.

In addition to a boundary condition for the Sewage Canal, there are two junctions within the hydraulic HEC-RAS model of the system. These junctions act as boundary conditions and are placed at the following locations: the confluence for the CWA-3 Extension and CWA-3; and the confluence of

the CWA-2 and the CWA-1 drains. HEC-RAS 6.4.1 has two options for junction boundary conditions: force same WSE or energy balance. Typical junctions in riverine systems have the same WSE on all three channels. However, for the Sewage Canal System, both the CWA-3 Extension and the CWA-2 drain are flowing in from a culvert. Using the force same WSE boundary condition results in the model having increased errors and instability at high WSEs. To be more consistent with the channel conditions and account for energy loss across the culverts, the balance energy boundary condition was used for this model.

Manning's "n" Values and Expansion/Contraction Coefficients

Values for channel overbank roughness coefficients, or Manning's "n" coefficients, were estimated based on field observations, aerial photography, and engineering judgment. As a general rule, Manning's "n" values were selected that would result in subcritical flow conditions. Generally, the Manning's "n" value used for the overbank was 0.060, and 0.045 was used for the channel. Those Manning's "n" values are within an acceptable range that reflect the channel conditions and are close to the values used in previous studies for the area.

Modeling Phragmites

An investigation was made to determine if the phragmites significantly restrict the flow by utilizing the ineffective flow option method in HEC-RAS to limit the effective flow area. During the design (or high flow) scenario the downstream conditions create enough of a tailwater impact that unless most of the channel is "blocked off" using ineffective flow areas, there are only minimal changes to the peak water surface elevation. This is because the water surface elevation in the City Drain is largely governed by the back-water conditions of a relatively flat channel with a relatively large flow as discussed later in this report.

We also changed Manning's "n" values for high and low phragmite growth (see Chapter 2) to try to evaluate the restrictive growth from the phragmites (up to a value of 0.1), which would be one method for modeling phragmites in a channel. However, it was found that when adjusting the roughness from a low value to a higher value (0.1), there was minimal change in the maximum water surface elevation due to the low velocities during the peak discharge. In other words, increasing the Manning's "n" values in the channel due to high phragmite growth made very little difference to the water surface elevation because the velocities are so low due to the backwater conditions as discussed later in this chapter.

It is very likely that during a lower flow scenario (e.g. when there are more localized storms) the impact of the heavy phragmite growth has a significant impact on the water surface elevation. While this would result in an increased water surface elevation in the low flow condition, it wouldn't increase the peak water surface elevation above the design (or high flow) scenario analyzed and discussed later in this chapter. It should be noted that if the phragmite growth blocks off the entire cross-sectional area of the channel or if debris blocks off the channel there could be significant flooding issues. The impacts that phragmites have on debris would be difficult to model and is beyond the scope of this project.

Canal Layout and Cross Section Locations

The centerlines of the Sewage Canal and its tributaries were digitized using the ArcGIS software and the aerial imagery available from UGRC website. Channel cross sections were surveyed and entered into the hydraulic model at intervals with a typical maximum of 1000-feet. The cross sections

included the top of bank, top of channel banks, flow line, and other grade breaks. The geometry data for the overbank areas for the cross sections were collected by extending the cross sections' limits across the overbank and floodplain using the digital 2013-14 LiDAR data and GIS tools. Survey data of the hydraulic structures was used to develop the geometry data for hydraulic structures on the Sewage Canal and its relevant tributaries. The model includes approximately 53 structures. The City Drain Lift Station was modeled using a pump element.

CALIBRATION

Calibration of a hydraulic computer model generally consists of measuring actual flow conditions in the field and comparing these measurements with those predicted by the model. There are no gauges or defined references within the Sewage Canal to which the model could be calibrated. Instead, calibration was done based on known historic flooding and field visits. Inlet nomographs were used to compare inlet nomographs on culverts that are inlet control. The inlet nomograph is included in Appendix H.

EVALUATION CRITERIA

Separate evaluation criteria were developed for channel- and structure-related deficiencies, as described in the following sections.

Recommended Channel Freeboard

The recommended minimum freeboard on the Sewage Canal System channels is one (1) foot for design and capacity evaluation purposes. In performing the detailed hydraulic analyses, channel reaches where the hydraulic model indicates that there is at least one (1) foot of freeboard were considered to have adequate capacity to convey the design storm event runoff. If an area had between zero (0) and one (1) foot of freeboard (i.e. it is not flooding, but has little freeboard), it was considered to have a potential capacity deficiency, but no project would be considered to increase capacity or freeboard. If the hydraulic computer model predicted that a reach of channel may be overtopped during the design storm event, that reach would be compared to known flooding events. If that area did not have flooding concerns, it was placed on a watch list. Channel banks that overtopped in the model and were correlated to flooding concerns were considered deficient. A project would be recommended based on the potential cause of the high-water levels.

Structure Restrictions

Culverts and bridges were considered to be capacity-deficient if they overtopped, or if they restricted flow in the channel and created an upstream freeboard deficiency.

HYDRAULIC MODELING RESULTS

The hydraulic model of the canals/drains was run for the 10-year hydrographs based on existing conditions identified in Chapter 4. The model was run with an unsteady-state flow regime, which was selected to better approximate channel attenuation, as discussed in following sections. Observations about the results are presented below.

Special Modeling Considerations

In-Channel Peak Flow Attenuation

Typically, a HEC-RAS 1-D model is run with steady state flow representing the peak flow rates in the channel developed during the hydrologic analysis. This is a conservative approach that represents systems with extended-duration peaks and is consistent with FEMA HEC-RAS modeling standards.

Typically, any minor channel attenuation is approximated using the hydrologic modeling software. The sewage canal has potential for significant in-channel attenuation due a few factors:

- **Little-to-no slope**: This results in slow velocities (less than one (1)) foot per second in most areas) within the main channel, even during peak flow rates. This is similar to a detention basin or a reservoir.
- **Relatively wide and deep channels**: The channels are relatively wide and deep. This provides for significant storage volumes within the channels themselves, particularly as the depth of flow increases.
- **Reduced capacity at culverts:** Some of the culvert crossings within the Sewage Canal System have a reduced capacity compared to the channel upstream and downstream. This results in the channel behaving like a linear detention pond, with the culverts acting as the flow restriction.

For these reasons, the channel was analyzed using an unsteady-flow regime. A comparison was done during the development of the model to verify that using an unsteady flow was appropriate. The peak flow rate was approximated at the City Drain Lift Station without any attenuation vs with in-channel attenuation. If the flow rates were not attenuated in HEC-RAS, the peak flow rate was over 450 cfs at the Lift Station. This is three (3) times the design capacity of the station. It is likely that a 10-year storm event has occurred in the last 40 years. If a flow rate of this magnitude were to have reached the lift station, it would have overtopped the berm across the channel and caused significant flooding in the existing development. Based on discussions with SLCo and SLC maintenance personnel and nearby residents, this event has not occurred. Thus, it appears that the attenuated flow is more realistic. The attenuated flow rate of 150-180 cfs is assumed to be a more reasonable flow rate within the system.

UDOT Detention Basins

On the City Drain, there are multiple large UDOT regional detention basins that are hydraulically connected to the City Drain channel near the I-80/I-215 interchange just south of the SLC Airport. Just downstream of these detention basins, there is a 48-inch reinforced concrete pipe (RCP) that is the entrance into the airport pipeline, which runs over 1,000-feet in length before increasing in diameter. For existing conditions, this 48-inch opening acts as a major restriction to the capacity of the system, causing the water to back up in the upstream channel. A significant volume of water then flows "backwards" into the UDOT detention basins. These detention basins facilities were included in the hydraulic model as storage areas with culvert connections to and from the main channel.

While these detention basins were most likely constructed primarily to attenuate runoff from the freeway and the freeway interchange, they appear to have capacity to attenuate flows from the canal as well. Based on discussions with the City and the County, there are no plans to modify how the canal operates in that area. If that changes, the hydraulic analysis from this study will need to be updated. We recommend that the system continue to function with the additional attenuation from the UDOT detention basins, otherwise there may need to be significant improvements to the downstream canal facilities.

Surplus Canal Lift Station

The CWA-3 Drain crosses the Surplus Canal in a 48-inch RCP culvert at approximately 1000 South. This culvert restricts flow to between 40 and 60 cfs (depending on tailwater conditions). Excess flows are pumped into the Surplus Canal through a lift station and do not continue through the Sewage Canal System. The lift station was best represented by a lateral structure in the hydraulic model.

Flows in excess of the culvert capacity "exit the model" similar to how runoff in excess of the culvert capacity will leave the Sewage Canal system via the Surplus Canal lift station.

Existing Conditions Results

Two existing conditions scenarios were analyzed for this study. The only change between the two scenarios was the capacity of the existing lift station. First, the existing City Drain Lift Station was analyzed with a capacity of only 50 cfs, which is the current estimated capacity of the lift station. For the second scenario, the lift station capacity was increased to 180 cfs to represent how the existing channel would respond based on the improved lift station.

Both scenarios were needed to identify any additional improvements needed based on the improved pump capacity. Figure 5-1 shows the deficiencies and peak flow rates associated with the first condition (50 cfs capacity lift station) and Figure 5-2 shows the same information for the second condition (180 cfs capacity lift station). Existing condition deficiencies and recommended improvements are discussed in the following section.

Deficiencies

Typically, the worst deficiencies upstream of the lift station are associated with the 50 cfs scenario and the 180 cfs scenario for downstream. Identified deficiencies have been described below:

- **City Drain Lift Station:** The existing capacity of the City Drain Lift Station is inadequate. With a capacity of only 50 cfs, the lift station cannot convey storm water runoff in the downstream direction to prevent flooding upstream. The City Drain Lift Station deficiency causes or makes worse channel and culvert capacity deficiencies upstream. City Drain channel banks would potentially be overtopped and flood developments to the east during the design storm event. It is known that storm water has previously been backing up into the connecting storm drain pipes and bubbling up in low spots of the roadway via inlets and manholes. In addition, elevated WSE could result in multiple culverts overtopping between the piped SLC Airport section and I-215. As can be seen by comparing Figure 5-1 and Figure 5-2, increasing the capacity of the pumps removes these deficiencies, with the exception of the directly-connected storm drain pipes along the City Drain. A flap gate, or similar, should be installed on the City Drain side of storm drain connections to keep water from bubbling up into the nearby streets. Due to the increasingly deteriorated state of the existing lift station, repairs and improvements should be made as soon as possible to prevent the pumps from failing completely, making the upstream channel inoperable.
- **CDWB7 (2800 North) and CDWB9 (2350 North):** Two culverts have collapsed and significantly reduce the capacity of the channel. This results in banks potentially overtopping downstream of the City Drain Lift Station. Based on conversations with County maintenance personnel, someone needs to remain at the lift station when it is turned on, in part, to turn off the lift station if the downstream channel is too full and at risk of bank overtopping. The pump station is manually turned off until the water recedes, and the lift station can be turned back on. Increasing the capacity of the City Drain Lift Station under current conditions means that the pump station will not be able to operate at its full capacity until the culverts are replaced. Design of the new Lift Station will include sensors to turn off the pumps automatically if the downstream water levels get too deep (meaning, someone does not have to be onsite to turn off the pumps). If the downstream culverts are not replaced, the channel will not have capacity to use the full capacity of the new lift station. These culverts should be improved as soon as possible so the pump station can be used at its full capacity.

- **Phragmite Growth in the Channel Downstream of City Drain:** There is significant phragmite growth downstream of the City Drain Lift Station, particularly north of CDWB7. Phragmite growth has nearly covered the entire channel width in this area. The phragmite growth could limit the capacity in the channel by capturing debris, or by inundating the channel. If the peak flow from the lift station exceeds the capacity of this section of channel, flooding over the banks is likely to occur. To be able to use the full capacity of the improved Lift Station, the phragmites from this section of channel should be removed. Otherwise the sensors will cause the pumps to turn off or use a reduced capacity during large storm events.
- **CDWB4 (2800 North):** The culvert is elevated above the channel invert and restricts the flow downstream of the City Drain Lift Station. Restricting the flow causes the water to back up and results in little-to-no freeboard for the 150 cfs scenario just upstream of the I-215 culvert. The CDWB4 culvert should be removed and replaced with a free span bridge.
- **CDWB13 (Access Bridge by 1700 North):** This culvert invert is significantly higher than the channel bottom, resulting in permanent standing water below this elevation. This structure acts like an in-channel contracted broad-crested weir, limiting the flow that can pass through this part of the canal. It restricts the flow to the lift station and causes an elevated WSE upstream by reducing the capacity of the channel. The right bank of the channel has berms that protect residential neighborhoods for this section of the City Drain. Increasing the water surface in this area increases the likelihood of overtopping, berm failure, or piping through the berms. The culvert crossing protects a sewer pipe crossing for SLC; based on design drawings, the pipe is only 1.1 feet below the bottom of the culvert. This culvert crossing does not appear to access anything. If that is the case, the culvert could be removed. There is a steel casing to protect the sewer pipe, so the culvert isn't needed to protect the sewer pipe. If needed, a concrete cap or riprap could be placed over the sewer pipe to provide additional protection, however, this may not be required. Removing the culvert and restoring the channel would eliminate the restriction and increase the flow to the lift station while also lowering the WSE in this section of the City Drain.
- **I-215 Crossing for CWA-1 Drain and CWA1D (Bending River Rd.):** The culvert crossing underneath I-215 for the CWA-1 drain has limited capacity caused by the backwater conditions from the downstream channel. There are smaller berms along a section of channel between I-215 and Bending River Rd. The limited capacity of the crossing causes the berms and culvert between I-215 and Bending River Rd. to overtop. Increasing the capacity of the lift station pumps lowers the water surface enough that only the berms would overtop, not Bending River Rd. Based on LiDAR of the overbank, high water should be contained to the overbanks area adjacent to the channel and does not flood nearby structures. If the berms on the channel banks are overtopped, the banks should be raised.
- **I-215 Culvert for CWA-3 Extension:** The I-215 culvert for the CWA-3 Extension is both undersized and has an adverse slope. This raises the WSE upstream by more than two (2) feet compared to the downstream channel, resulting in much of the extension channel banks being overtopped. Flooding in this area due to the CWA-3 Extension has not been reported. It is likely that the elevated WSE would result in a condition where water at inlets would bubble up. Excess flows would then flow within the street ROW to the west towards the storm drain infrastructure that ultimately drains into Salt Lake City's Lee Drain. This portion should be monitored to make sure that flooding from the CWA-3 Extension does not occur. If flooding concerns persist, either the I-215 culvert should be replaced, or the channel banks should be raised.

- **Railyard and 500 South:** The banks through the railyard just north of 500 South may be overtopped during the design storm runoff. Both the railroad and 500 south culvert crossings will overtop. With an increased pump capacity at the City Drain Lift Station, the WSE will be lowered such that the culverts may not overtop, however, there will be little to no freeboard. These areas should be watched to determine if the banks overtop and need to be raised.
- **Misc. Banks on CWA-3 and CWA-2:** Along both of these drains, the model identifies sections where the water may overtop the banks during the design storm event. However, no known flooding has occurred for these locations. This could be due to the limited capacity of the channel, leading to a WSE that backs up into the storm drain system.
- **Culverts Between California Ave. and Surplus Crossing:** There are three railroad culverts between the Surplus Canal crossing and California Ave. (CWA3D7, CWA3D6, and CWA3D5). These culverts would potentially be overtopped during the design storm runoff. No known flooding has occurred in this area, potentially due to the majority of runoff not reaching this portion of the canal. Due to the complexity and cost of replacing railroad culverts, this area should be watched. If flooding is confirmed, increasing the Surplus Canal lift station capacity is most likely the more economical alternative.

Appendix I includes maximum WSE profiles for the Sewage Canal system channels (CWA-3, CWA-2, City Drain, and Sewage Canal).

Sewage Canal Bank "Collapsing"

As discussed in Chapter 2, the banks of the Sewage Canal are "collapsing" into the channel downstream of the Northwest Canal confluence. Peak channel velocity along this section of the system is no greater than two (2) feet per second. Based on this velocity, it is unlikely that the channel "collapsing" is due to bank erosion. There is a significant rise and fall of the WSE in this reach of the channel between normal operating conditions (only a few feet deep) to the maximum flood water depths (close to 10 feet deep). This WSE rise and fall cycle results in a wetting and drying cycle for the channel banks. Once the banks are saturated and the water recedes, the banks are no longer stable and "collapse" into the channel. This issue is further discussed and addressed in Chapter 6.

LIFT STATION FLOW RATES

The HEC-RAS model developed for the Sewage Canal System was used to size the new City Drain Lift Station pumps. Since the City Drain acts like a long linear detention basin or a wet well for a lift station, we looked at various flow rates to determine an appropriate design flow rate to lower the WSE upstream of the lift station. The following observations on the relationship between peak capacity and upstream WSE were made:

- For a peak capacity less than 110 cubic feet per second (cfs), the lift station would not be able to pump enough water downstream to significantly lower the upstream WSE and protect the City Drain banks from potentially overtopping.
- Between 110-150 cfs capacity in the lift station, the upstream channel would not likely overtop, but there would be less than one (1) foot of freeboard on the channel banks.
- The original estimated design capacity of 150 cfs would be adequate to reduce the flood risk upstream of the lift station.

Based on these findings, it is recommended that the City Drain Lift Station have a minimum design capacity of 150 cfs. We recommended providing a safety factor, and sizing the lift station with

additional space for an extra pump so it can be expanded to 180 cfs in the future if needed. These flow rates are reflected in the pre-design report of the new lift station, provided in Appendix C.

CONCLUSIONS AND RECOMMENDATIONS

The hydraulic analysis of the existing Sewage Canal System resulted in the following major conclusions:

- The Sewage Canal System acts like a long, linear detention facility. This results in significantly attenuated peak flows compared to the peak hydrologic inflows. As a result, the canal system is best analyzed using an unsteady flow regime based on volume instead of typical steady state flow.
- A large portion of the City Drain is a 48-inch pipe through the SLC Airport starting just upstream of North Temple St. The entrance to the 48-inch pipe acts as a major restriction to flow in the City Drain. This restriction does not cause flooding, because the backwater flows into UDOT detention ponds. The peak flow downstream of North Temple St. is significantly reduced by the restriction of the piped section. Maintaining this operational condition is critical to limiting the peak flow in the downstream channel and minimizing capacity issues and potential flooding. The size of the 48-inch pipe should not be increased and connections into the UDOT detention ponds need to be maintained.
- The existing capacity of the City Drain Lift Station is inadequate to safely convey the design flow through the City Drain during the design event. Water depths in the channel will most likely overtop the banks and cause flooding east of the City Drain. Even for lower flow rates, the existing lift station will result in water backing up into the connecting storm drain system and bubbling up into roadways via inlets/manholes. Impacts from the undersized lift station extend all the way upstream to the Surplus Canal.
- The new pump capacity for the City Drain Lift Station should be at least 150 cfs. It is recommended that a safety factor be provided on the lift station. This can be achieved with additional space for an extra pump so it can be expanded to 180 cfs in the future if needed.
- There are two culverts downstream of the lift station that must be replaced. If these culverts are not replaced, the channel will not be able to pass the full design flow from the new lift station. This will result in the sensor system shutting down the pumps prematurely to protect from downstream flooding. Otherwise, the main road will probably overtop, causing flood damage in the adjacent homes. In addition, the channel at the downstream I-215/Legacy culvert is nearly full of phragmites and should also be improved. The phragmites should be removed to minimize potential flooding.
- As discussed before, multiple culverts and banks upstream of the lift station may overtop during the design storm event. This includes multiple railroad crossings and banks as well as portions of the CWA-2 Drain and CWA-3 Extension Drian. No flooding issues have been reported to SLCo or SLC in these areas. It is likely that the limited capacity of the storm drain system prevents storm water runoff from getting into the channels. These areas should be watched and, if storm drain system improvements cause flooding, improvements to the Sewage Canal System should be constructed.

To Great Salt Lake

Limit of Detailed Study.
WSE downstream controlled by Great Salt Lake.

SC1

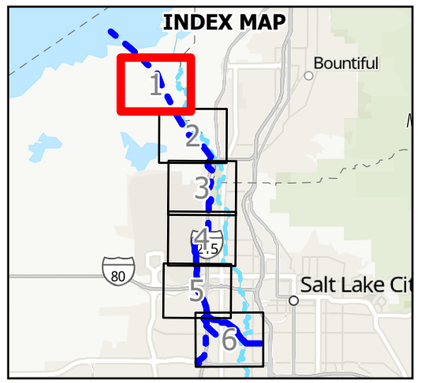
LEGEND

Existing Structure
- Bridge
- Culvert
- Pump

Sewage Canal & Tributary
- Open Channel
- Enclosed/Piped
- Jordan River/Northwest Canal

Existing Structure Deficiency
- Culvert - Restricts Flow Causing Upstream Deficiency
- Culvert - Overtops
- Pump - Restricts Flow Causing Upstream Deficiency
- Proposed Tide Flex Gates

Existing Condtions Freeboard (50 cfs Capacity)
- Bank Overtops
- 0 - 6 inches
- 6 - 12 inches
- 12+ inches
- HEC-RAS Cross-Sections



NORTH:

SCALE: 0 500 1,000 Feet

EXISTING CONDITIONS DEFICIENCIES - LIFT STATION AT 50 CFS

SALT LAKE COUNTY
SEWAGE CANAL & CITY DRAIN LIFT STATION

BOWEN COLLINS & ASSOCIATES

FIGURE NO.
5-1

P:\Salt Lake County\022-23-03 Sewage Canal\4.0 GIS\4.4 APRX\Sewage Canal v02.aprx tjorgensen 2/21/2025

SC2
SC3
SC4
SC5
CDWB1
CDWB2

Maximum channel velocity is less than 2 feet/second. Not the primary cause for the exapnding channel banks.

Northwest Canal inflow is limited by the Sihpon and Tailwater in the Sewage Canal. Not part of this study.

LEGEND

Existing Structure
- Bridge
- Culvert
- Pump

Sewage Canal & Tributary
- Open Channel
- Enclosed/Piped
- Jordan River/Northwest Canal

Existing Structure Deficiency
- Culvert - Restricts Flow Causing Upstream Deficiency
- Culvert - Overtops
- Pump - Restricts Flow Causing Upstream Deficiency
- Proposed Tide Flex Gates

Existing Condtions Freeboard (50 cfs Capacity)
- Bank Overtops
- 0 - 6 inches
- 6 - 12 inches
- 12+ inches
- HEC-RAS Cross-Sections

INDEX MAP

NORTH:

SCALE: 0 500 1,000 Feet

EXISTING CONDITIONS DEFICIENCIES - LIFT STATION AT 50 CFS

SALT LAKE COUNTY
SEWAGE CANAL & CITY DRAIN LIFT STATION

BOWEN COLLINS & ASSOCIATES

FIGURE NO. 5-1

P:\Salt Lake County\022-23-03 Sewage Canal\4.0 GIS\4.4 APRX\Sewage Canal v02.aprx tjorgensen 2/21/2025

CDWB2

CDWB3

CDWB4

CDWB5

CDWB6

Channel in nearly full of Fragmites. Must be removed to increase capacity of the system.

CDWB7

CDWB8

Culvert has collapsed and must be replaced. See Figure 5-2 for more detail.

CDWB9

Culvert has collapsed and must be replaced. See Figure 5-2 for more detail.

CDWB10

City Drain Lift Station

CDWB12

City Drain Lift Station does not have enough capacity for Design Storm Event. This raises the WSE and causes significant upstream flooding.

Culvert invert is elevated, further increasing upstream WSE and flooding.

CDWB13

CDWB14

LEGEND

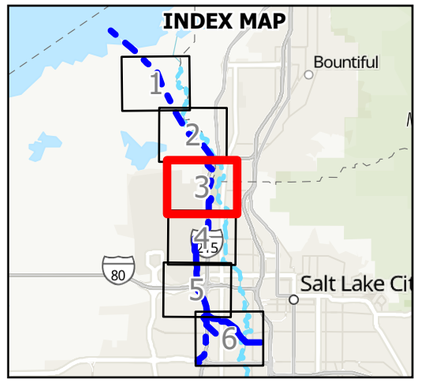
Existing Structure
- Bridge
- Culvert
- Pump

Sewage Canal & Tributary
- Open Channel
- Enclosed/Piped
- Jordan River/Northwest Canal

Existing Structure Deficiency
- Culvert - Restricts Flow Causing Upstream Deficiency
- Culvert - Overtops
- Pump - Restricts Flow Causing Upstream Deficiency
- Proposed Tide Flex Gates

Existing Condtions Freeboard (50 cfs Capacity)
- Bank Overtops
- 0 - 6 inches
- 6 - 12 inches
- 12+ inches
- HEC-RAS Cross-Sections

INDEX MAP



NORTH:

SCALE: 0 500 1,000 Feet

EXISTING CONDITIONS DEFICIENCIES - LIFT STATION AT 50 CFS

SALT LAKE COUNTY

SEWAGE CANAL & CITY DRAIN LIFT STATION

BOWEN COLLINS & ASSOCIATES

FIGURE NO. 5-1

P:\Salt Lake County\022-23-03 Sewage Canal\4.0 GIS\4.4 APRX\Sewage Canal v02.aprx tjorgensen 2/21/2025

CDWB14

CDWB18 CDWB17 CDWB16 CDWB15

Culvert is overtopped due to limited City Drain Lift Station capacity.

Stormdrain Pipe backs up due to limited City Drain Lift Station Capacity and causes flodding in this area.

LEGEND

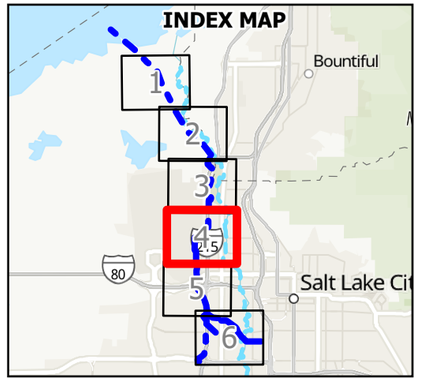
Existing Structure
- Bridge
- Culvert
- Pump

Sewage Canal & Tributary
- Open Channel
- Enclosed/Piped
- Jordan River/Northwest Canal

Existing Structure Deficiency
- Culvert - Restricts Flow Causing Upstream Deficiency
- Culvert - Overtops
- Pump - Restricts Flow Causing Upstream Deficiency
- Proposed Tide Flex Gates

Existing Condtions Freeboard (50 cfs Capacity)
- Bank Overtops
- 0 - 6 inches
- 6 - 12 inches
- 12+ inches
- HEC-RAS Cross-Sections

INDEX MAP



NORTH:

SCALE: 0 500 1,000 Feet

EXISTING CONDITIONS DEFICIENCIES - LIFT STATION AT 50 CFS

SALT LAKE COUNTY
SEWAGE CANAL & CITY DRAIN LIFT STATION

BOWEN COLLINS & ASSOCIATES

FIGURE NO.
5-1

P:\Salt Lake County\022-23-03 Sewage Canal\4.0 GIS\4.4 APRX\Sewage Canal v02.aprx tjorgensen 2/21/2025

Piped section restricts flow. Elevated WSE would cause minor local bank overtopping with majority of runoff going into the UDOT Detention Basins.

CDWB19

CDWB21

CDWB22A

CDWB22B

CDWB23

CDWB23B

UDOT Detention Basin

Backflow into UDOT Detention Basins.

CDWB24

UDOT Detention Basin

CDWB25

CWA2D1

CWA3D1

CWA3D2

CWA3D3

CWA1D1

LEGEND

Existing Structure
- Bridge
- Culvert
- Pump

Sewage Canal & Tributary
- Open Channel
- Enclosed/Piped
- Jordan River/Northwest Canal

Existing Structure Deficiency
- Culvert - Restricts Flow Causing Upstream Deficiency
- Culvert - Overtops
- Pump - Restricts Flow Causing Upstream Deficiency
- Proposed Tide Flex Gates

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- Bank Overtops
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- 12+ inches
- HEC-RAS Cross-Sections

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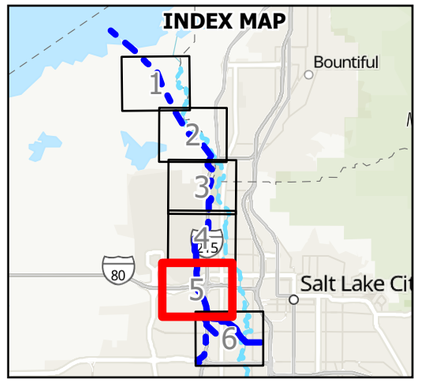

NORTH:

SCALE:

0 500 1,000 Feet

EXISTING CONDITIONS DEFICIENCIES - LIFT STATION AT 50 CFS

SALT LAKE COUNTY
SEWAGE CANAL & CITY DRAIN LIFT STATION

BOWEN COLLINS & ASSOCIATES

FIGURE NO.
5-1

P:\Salt Lake County\022-23-03 Sewage Canal\4.0 GIS\4.4 APRX\Sewage Canal v02.aprx tjorgensen 2/21/2025

CWA3D2
CWA3D3
CWA1D1
CWA1D2
CWA1D3
CWA3D5
CWA3D6
CWA3DE1
Backwater from CWA3DE1 causes bank and culvert overtopping upstream. Excess runoff would go into the Lee Drain Stormdrain System West of I-215.
CWA3D7
CWA3DE2
CWA3DE3
CWA3DE4
CWA3D8
CWA3DE5
CWA3D9
CWA3D11
Flooding has not been observed. Likely that not all runoff predicted reaches the canal system.
CWA3D12

LEGEND

Existing Structure
- Bridge
- Culvert
- Pump

Sewage Canal & Tributary
- Open Channel
- Enclosed/Piped
- Jordan River/Northwest Canal

Existing Structure Deficiency
- Culvert - Restricts Flow Causing Upstream Deficiency
- Culvert - Overtops
- Pump - Restricts Flow Causing Upstream Deficiency
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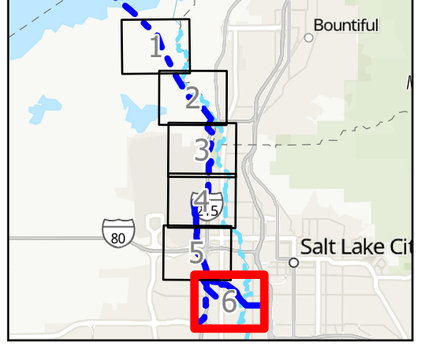


NORTH:

SCALE: 0 500 1,000 Feet

EXISTING CONDITIONS DEFICIENCIES - LIFT STATION AT 50 CFS

SALT LAKE COUNTY
SEWAGE CANAL & CITY DRAIN LIFT STATION

BOWEN COLLINS & ASSOCIATES

FIGURE NO.
5-1

P:\Salt Lake County\022-23-03 Sewage Canal\4.0 GIS\4.4 APRX\Sewage Canal v02.aprx tjorgensen 2/21/2025

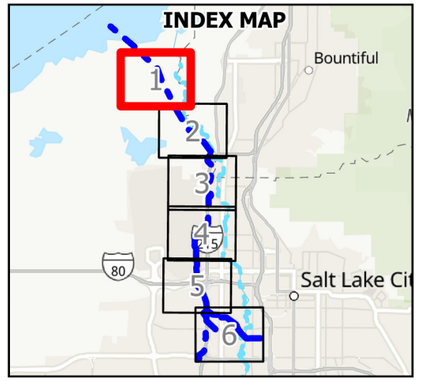
LEGEND

Existing Structure
- Bridge
- Culvert
- Pump

Sewage Canal & Tributary
- Open Channel
- Enclosed/Piped
- Jordan River/Northwest Canal

Existing Structure Deficiency
- Bridge - Restricts Flow Causing Upstream Deficiency
- Bridge - Overtops
- Culvert - Restricts Flow Causing Upstream Deficiency
- Culvert - Overtops
- Culvert - Little to no Freeboard
- Proposed Tide Flex Gates

Existing Condtions Freeboard (180 cfs Capacity)
- Bank Overtops
- 0 - 6 Inches
- 6 - 12 Inches
- 12+ Inches
- HEC-RAS Cross-Sections



NORTH:

SCALE: 0 500 1,000 Feet

SEWAGE CANAL DEFICIENCIES FOR LIFT STATION AT 180 CFS

SALT LAKE COUNTY

SEWAGE CANAL & CITY DRAIN LIFT STATION

BOWEN COLLINS & ASSOCIATES

FIGURE NO. 5-2

P:\Salt Lake County\022-23-03 Sewage Canal\4.0 GIS\4.4 APRX\Sewage Canal v02.aprx rbutters 8/23/2024

SC2
SC3
SC4
SC5
CDWB1
CDWB2
3300 N
900 N
Stonehaven Dr
York Dr
Longleaf Dr
Stonehenge Dr
Haworth
Woodstock Dr
Windsor Dr
Legacy Parkway connector
Manchester Dr
Oldham Dr
Chatham Dr
Farnham Dr
Boston Dr
Norfolk Dr
Foxboro School
Legacy Preparatory Academy
Maximum channel velocity is less than 2 feet/second. Not the primary cause for the exapnding channel banks.
Northwest Canal inflow is limited by the Sihpon and Tailwater in the Sewage Canal. Not part of this study.

LEGEND

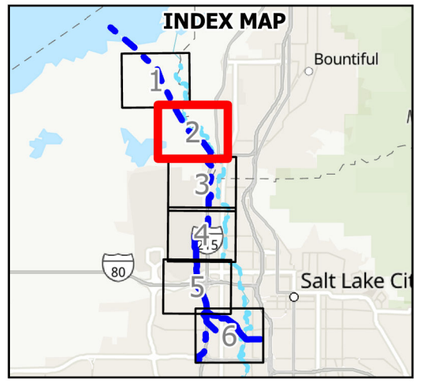
Existing Structure
- Bridge
- Culvert
- Pump

Sewage Canal & Tributary
- Open Channel
- Enclosed/Piped
- Jordan River/Northwest Canal

Existing Structure Deficiency
- Bridge - Restricts Flow Causing Upstream Deficiency
- Bridge - Overtops
- Culvert - Restricts Flow Causing Upstream Deficiency
- Culvert - Overtops
- Culvert - Little to no Freeboard
- Proposed Tide Flex Gates

Existing Condtions Freeboard (180 cfs Capacity)
- Bank Overtops
- 0 - 6 Inches
- 6 - 12 Inches
- 12+ Inches
- HEC-RAS Cross-Sections

INDEX MAP



NORTH:

SCALE: 0 500 1,000 Feet

SEWAGE CANAL DEFICIENCIES FOR LIFT STATION AT 180 CFS

SALT LAKE COUNTY

SEWAGE CANAL & CITY DRAIN LIFT STATION

BOWEN COLLINS & ASSOCIATES

FIGURE NO. 5-2

P:\Salt Lake County\022-23-03 Sewage Canal\4.0 GIS\4.4 APRX\Sewage Canal v02.aprx rbutters 8/23/2024

CDWB2

CDWB3

CDWB4

CDWB5

CDWB6

Channel in nearly full of Fragmites. Must be removed to increase capacity of the system.

CDWB7

CDWB8

If culvert is not replaced the channel won't have capacity for the full deisng flow from the new lift station. This will reduce the efficiency of the lift station minimizing the improvement to flooding upstream.

CDWB10

City Drain Lift Station

CDWB12

Culvert invert is elevated, further increasing upstream WSE and flooding.

CDWB13

CDWB14

LEGEND

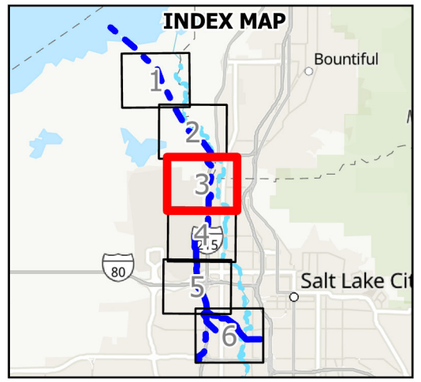
Existing Structure
- Bridge
- Culvert
- Pump

Sewage Canal & Tributary
- Open Channel
- Enclosed/Piped
- Jordan River/Northwest Canal

Existing Structure Deficiency
- Bridge - Restricts Flow Causing Upstream Deficiency
- Bridge - Overtops
- Culvert - Restricts Flow Causing Upstream Deficiency
- Culvert - Overtops
- Culvert - Little to no Freeboard
- Proposed Tide Flex Gates

Existing Condtions Freeboard (180 cfs Capacity)
- Bank Overtops
- 0 - 6 Inches
- 6 - 12 Inches
- 12+ Inches
- HEC-RAS Cross-Sections

INDEX MAP



NORTH:

SCALE: 0 500 1,000 Feet

SEWAGE CANAL DEFICIENCIES FOR LIFT STATION AT 180 CFS

SALT LAKE COUNTY

SEWAGE CANAL & CITY DRAIN LIFT STATION

BOWEN COLLINS & ASSOCIATES

FIGURE NO. 5-2

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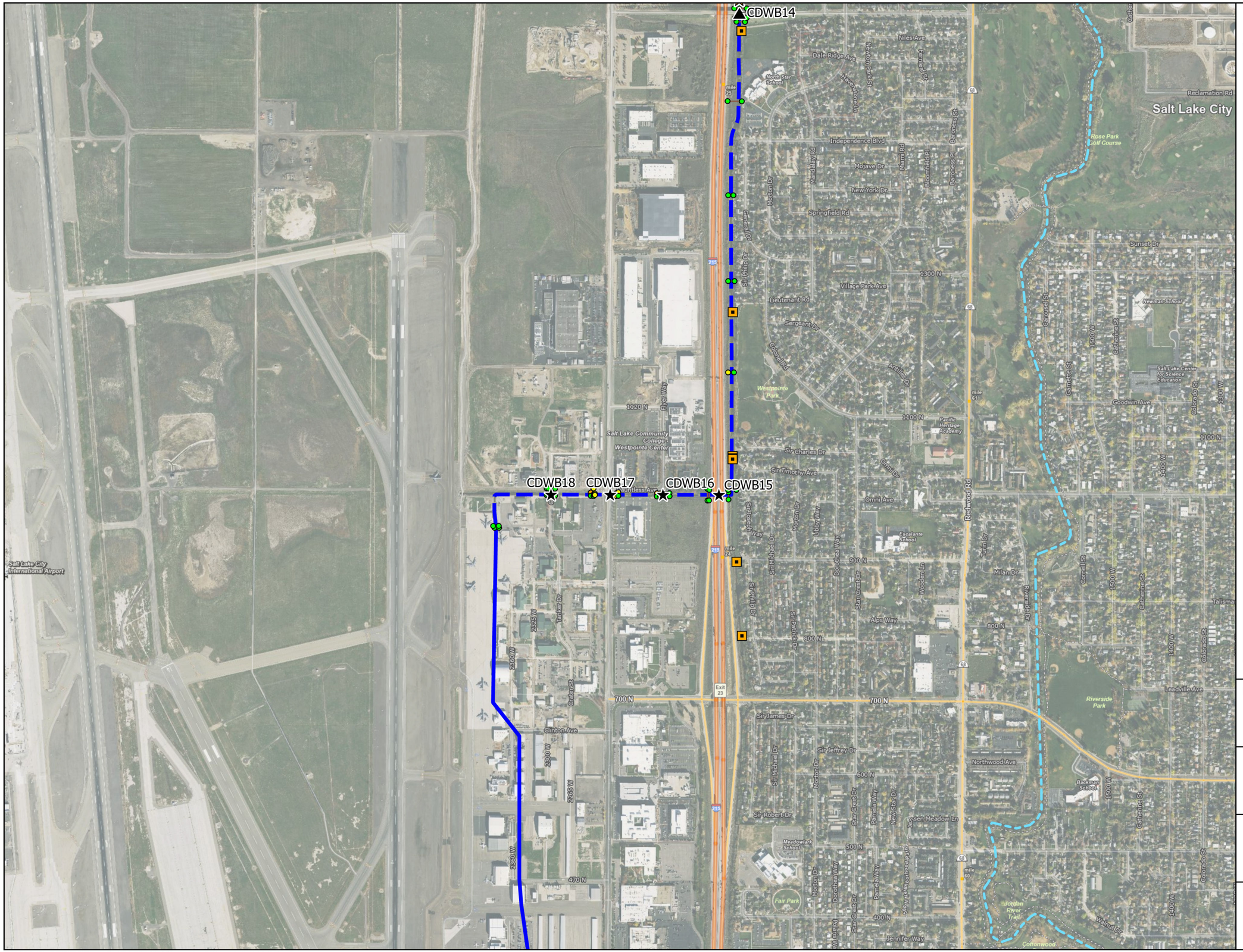

LEGEND

Existing Structure
- Bridge
- Culvert
- Pump

Sewage Canal & Tributary
- Open Channel
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Existing Structure Deficiency
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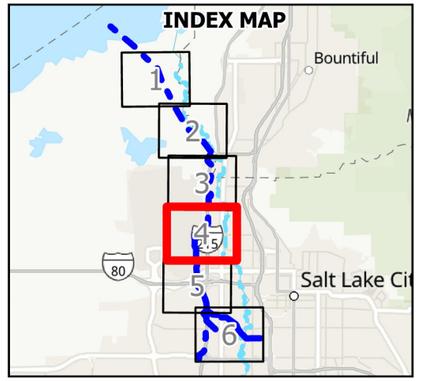

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SEWAGE CANAL DEFICIENCIES FOR LIFT STATION AT 180 CFS

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SEWAGE CANAL & CITY DRAIN LIFT STATION

BOWEN COLLINS & ASSOCIATES

FIGURE NO. 5-2

P:\Salt Lake County\022-23-03 Sewage Canal\4.0 GIS\4.4 APRX\Sewage Canal v02.aprx rbutters 8/23/2024

Piped section restricts flow. Elevated WSE would cause minor local flooding with majority of runoff going into the UDTO Detention Basins.

CDWB19

CDWB21

CDWB22A

CDWB22B

CDWB23

CDWB23B

Water "Backflows" into existing UDOT Detention Basins.

CDWB24

CDWB25

CWA2D1

CWA3D1

CWA3D2

CWA3D3

CWA1D1

LEGEND

Existing Structure
- Bridge
- Culvert
- Pump

Sewage Canal & Tributary
- Open Channel
- Enclosed/Piped
- Jordan River/Northwest Canal

Existing Structure Deficiency
- Bridge - Restricts Flow Causing Upstream Deficiency
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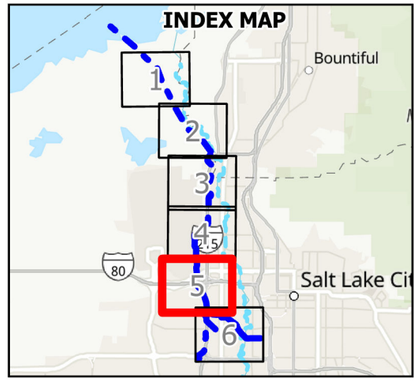

NORTH:

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SEWAGE CANAL DEFICIENCIES FOR LIFT STATION AT 180 CFS

SALT LAKE COUNTY

SEWAGE CANAL & CITY DRAIN LIFT STATION

BOWEN COLLINS & ASSOCIATES

FIGURE NO. 5-2

P:\Salt Lake County\022-23-03 Sewage Canal\4.0 GIS\4.4 APRX\Sewage Canal v02.aprx rbutters 8/23/2024

CWA3D2
CWA3D3
CWA1D1
CWA1D2
CWA1D3
CWA3D5
CWA3D6
CWA3DE1
Backwater from CWA3DE1 causes bank and culvert overtopping upstream. Excess runoff would go into the Lee Drain Stormdrain System West of I-215.
CWA3D7
CWA3DE2
CWA3DE3
CWA3DE4
CWA3D8
CWA3DE5
CWA3D9
CWA3D11
Flooding has not been observed. Likely that not all runoff predicted reaches the canal system.
CWA3D12

LEGEND

Existing Structure
- Bridge
- Culvert
- Pump

Sewage Canal & Tributary
- Open Channel
- Enclosed/Piped
- Jordan River/Northwest Canal

Existing Structure Deficiency
- Bridge - Restricts Flow Causing Upstream Deficiency
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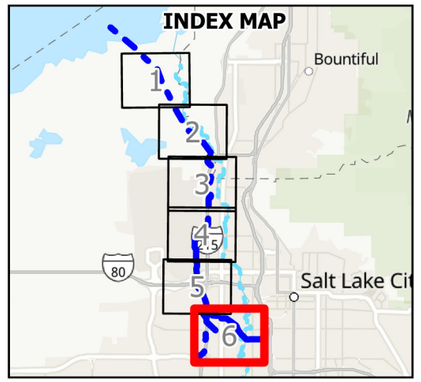

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SCALE: 0 500 1,000 Feet

SEWAGE CANAL DEFICIENCIES FOR LIFT STATION AT 180 CFS

SALT LAKE COUNTY
SEWAGE CANAL & CITY DRAIN LIFT STATION

BOWEN COLLINS & ASSOCIATES

FIGURE NO. 5-2

P:\Salt Lake County\022-23-03 Sewage Canal\4.0 GIS\4.4 APRX\Sewage Canal v02.aprx rbutters 8/23/2024

CHAPTER 6 – BANK STABILIZATION AND EASEMENT ACQUISITION

A major concern identified by Salt Lake County personnel at the start of this study was the moving banks of the Sewage Canal between the inflow from the Northwest Canal and Cudahy Ln (Center St.). Field visits by BC&A found that several stretches of the banks in this area have become vertical with what appears to be soil deposits at the toe of the slope. Concrete debris has been placed on the top of the banks to stabilize the slopes. The concern from the County stems from complaints received by local property owners stating that the canal has been moving laterally, taking a portion of their property. This chapter discusses the findings and recommendations for bank stabilization.

HISTORY OF BANK MOVEMENT

BC&A used aerial imagery to determine the scope of the bank movement. Historical aerial imagery for the Sewage Canal channel was obtained from the Utah Geological Survey for the years 1937, 1958, 1971, and 1985. Additional historical imagery was obtained from Google Earth for the year 2006. Existing channel bank locations were compared to the Google Earth 2023 aerial imagery. Note that a significant portion of the channel upstream of the Northwest Canal inflow appears to have been moved sometime between 1937 and 1958.

The top of bank location for the Sewage Canal channel was delineated using GIS software. The top of bank location was determined visually and mapped as an approximate line. Delineated top of bank locations are shown in Figure 6-1. Based on the lines delineated from the aerial imagery, it appears that the left bank has moved between 10 and 20 feet, while the right bank appears to be stable. Aerial imagery was corroborated by field visits. Delineations based on aerial imagery are only approximate.

Concrete debris and large-diameter rocks were placed along much of the right bank, potentially stabilizing the bank (see Photo 6-1). While this has worked to stabilize the banks so far, it should be noted that the stabilization does not appear to have been engineered and is inconsistent. This may result in the debris failing and needing constant replacement to provide the protection needed. The left bank was vertical for large portions of the canal and appears to have collapsed with soil deposits scattered along the toe of the channel. In one spot along the channel, there is an old fence and drainage pipe which extend past the edge of the existing channel bank (see Photo 6-2). The fence has collapsed into the channel and the end of the pipe is probably 10-15 feet from the existing top of bank.

Photo 6-1: Example of Concrete Debris on Right Bank of Sewage Canal

Photo 6-2: Pipe and Fence on Left Bank of Sewage Canal

CAUSE OF BANK MIGRATION

Based on the analysis done in Chapter 5 of the hydraulics of the Sewage Canal, the peak velocities in the channel are generally less than two (2) feet per second. This is consistent with field observations of the low flow velocity as well. This velocity is not generally quick enough to cause significant scour

and erosion of channel banks and bottoms. However, the channel does experience significant rises in water depth during large storm events (rise of over six (6) feet being possible for the design storm event). The cycle between typical low flow to max water depth and back to low flow depths can take anywhere between 8 and 24 hours. Due to this length of time, it is very likely that the rise in water depth results in fully saturated soils on the banks of the channels. Then, as the water recedes, the banks (which are much heavier than normal due to the saturated soil condition) collapse into the channel. This process is similar to what can happen to the banks of a pond that does not have properly engineered sides, resulting in a pond that expands in surface area, despite little to no water movement along the banks. Additional analysis is needed to verify this preliminary assessment and to recommend improvements specific to the banks of the Sewage Canal downstream of I-215.

GEOTECHNICAL ANALYSIS

The banks of the Sewage Canal need to be stabilized. Prior to making final recommendations on size and extent of the remediation, a detailed geotechnical analysis should be performed. The analysis will need to include the following:

- Soil Sample – Drill Test Holes
- Geotechnical Field Visit
- Laboratory Studies/Testing
- Slope Stability Analysis
- Contamination Evaluation
- Recommendation Regarding Side-Stabilization and Treatment
- Geotechnical Report

Based on preliminary analysis, it is likely that the side treatment will be on a 2:1 to 4:1 side slope. This geotechnical analysis was not included with the scope for this project.

CONCLUSION AND RECOMMENDATIONS

The top of bank of the Sewage Canal has moved since construction of the channel in the early 1900's. This is evidenced by both aerial imagery and field visits along the channel. In particular, there are vertical banks along the left bank of the channel and concrete debris along the right bank. Based on a preliminary geotechnical analysis and the maximum channel velocity, it is unlikely that the expanding bank issues are caused by scour or erosion. The most likely cause of the expanding banks is the wetting and drying cycle of the banks caused by the rise and recession of storm runoff in the channel, causing an unstable bank. The geotechnical analysis will make the final determination on the cause of the bank collapsing issue. Below are preliminary recommendations on remediating the expanding banks.

Potential Remediation Methods

Based on the preliminary analysis, the following points should be considered for the remediation of the channel banks. As stated earlier, the final recommended improvements will need to be identified after a detailed geotechnical analysis is completed. An example of a typical cross section for the

potential remediation is shown in Figure 6-2. Below is a list of potential improvements that should be considered for the Sewage Canal downstream of I-215.

- **Bank Slope of 2:1 to 4:1:** This will most likely include a combination of placing fill along the existing toe of the channel and laying back the existing slope. Final determination of bank slope can only be made after the geotechnical analysis is completed.
- **Minimum Bottom Width of Five (5) Feet:** While the project should prioritize minimal expansion of the channel top width by placing fill to obtain the required side slope, a minimum bottom width of 5 feet must be maintained for hydraulic conveyance of low flows.
- **Minimum Channel Depth of Nine (9) Feet:** The sewage canal system needs a minimum flow depth of nine (9) feet to convey the design storm runoff. This may require portions of the channel to have berms placed along the banks to provide adequate freeboard.
- **15-Foot-Wide Access Roads:** Currently, the County maintenance crew cannot access significant portions of the Sewage Canal channel. This makes it difficult to maintain and inspect the channel, which may have led to some of the issues with expanding banks. Providing permanent access to the channel should be a priority. Due to the size of the channel, it is recommended that 15-foot-wide access roads should be built along the top of both channel banks.
- **Side Slope Treatment:** Placing fill/laying back the slopes will most likely not be adequate on its own to fully protect the banks from the wetting and drying cycle associated with rising and falling water depths downstream of I-215. Side slope treatment will most likely include additional erosion control measures such as riprap, plantings, engineered soil treatment, etc.
- **FEMA 100-year Great Salt Lake Elevation:** Future development should be required to build above the FEMA 100-year elevation for the Great Salt Lake of about 4218 feet (final elevations are expected to be determined and mapped by FEMA in 2024). When fill is placed on the channel banks, new access roads need to be constructed above the 100-year Great Salt Lake WSE. If the access roads are also to be raised, the easement width may need to be increased to maintain the side slope up to new access road.

Combined, all these recommendations result in an easement or ROW width between 70 and 115 feet.

Easement Acquisition

As discussed in Chapter 2, the County most likely does not have adequate easements along the Sewage Canal system downstream of I-215. The County has had difficulty in accessing and maintaining the Canal in this section. There are no access roads or public ROWs along the canal that the County can use. The County should begin the process of acquiring temporary easements now to provide access during the geotechnical analysis. Once the geotechnical analysis is complete and final recommendations are made, permanent easements or ROWs should be acquired. It is recommended that the easement acquisition process include the following:

- Detailed review of existing agreements for SLCo and SLC along all Sewage Canal System canals. Potentially record easements where feasible.
- Development of a County or City ordinance requiring easements or Right-of-Way (ROW) for the Sewage Canal to be provided to the County by developers. The easements or ROW should include the Sewage Canal and 15 feet on either side of the canal for access roads.

Figure 6-3 shows the approximate width and extents of easements that need to be acquired for the section of the Sewage Canal that currently has bank stabilization issues. Note, all of the channels

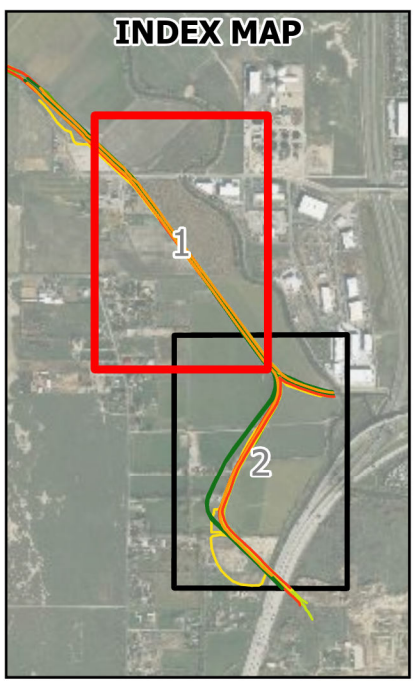
should be considered for adding easements and improving access. The focus along the Sewage Canal downstream of I-215 is due to the lack of access to the canal and the collapsing banks in this area.

L E G E N D

Approximate Top of Bank

- Bank in 1937
- Bank in 1958
- Bank in 1971
- Bank in 1985
- Bank in 2006
- Bank in 2023

INDEX MAP



BOWEN COLLINS & ASSOCIATES

Salt Lake County

SEWAGE CANAL & CITY DRAIN LIFT STATION

LATERAL BANK MIGRATION ALONG SEWAGE CANAL

NORTH:

NORTH

SCALE:

0 100 200

Feet

FIGURE NO.

6-1

Page 1 of 2

P:\Salt Lake County\022-23-03 Sewage Canal\4.0 GIS\4.4 APRX\Sewage Canal v02.aprx rbutters 6/12/2024

LEGEND

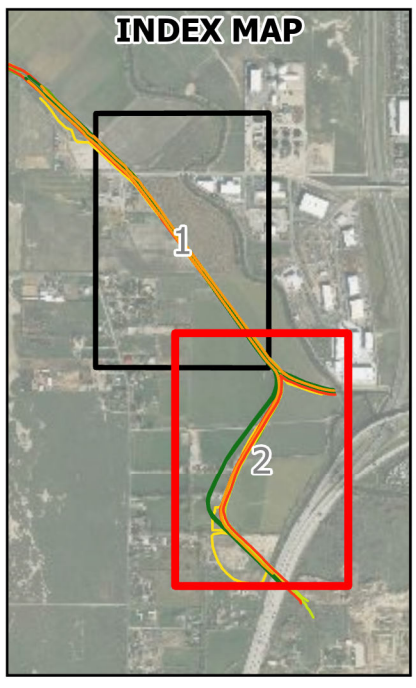
Approximate Top of Bank

- Bank in 1937
- Bank in 1958
- Bank in 1971
- Bank in 1985
- Bank in 2006
- Bank in 2023

1958 - Channel Moved

1985 - Channel Widened

INDEX MAP



Salt Lake County

SEWAGE CANAL & CITY DRAIN LIFT STATION

LATERAL BANK MIGRATION ALONG SEWAGE CANAL

NORTH:

NORTH

SCALE: 0 100 200 Feet

FIGURE NO. 6-1

BOWEN COLLINS & ASSOCIATES

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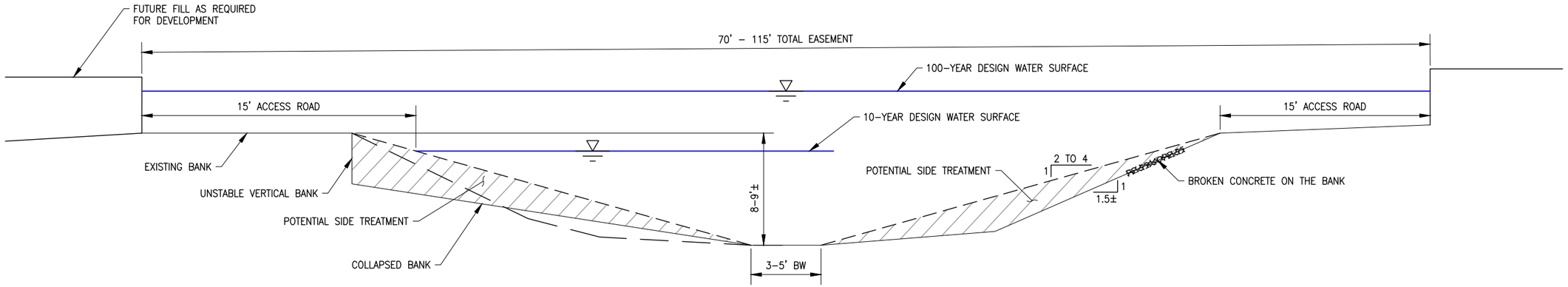


CONCEPT DESIGN FOR SEWAGE CANAL IMPROVEMENT

NOT TO SCALE

BOWEN COLLINS & ASSOCIATES

PRELIMINARY

NOT FOR CONSTRUCTION
FOR REVIEW ONLY

REVISIONS

NO.	DATE	REV. BY	DESCRIPTION

VERIFY SCALE
BAR IS ONE INCH ON ORIGINAL DRAWING

REVIEW
CHECKED
APPROVED

DESIGN
DESIGN
DRAWN

Figure 6-2

PROJECT NUMBER

DATE:

DRAWING NO.

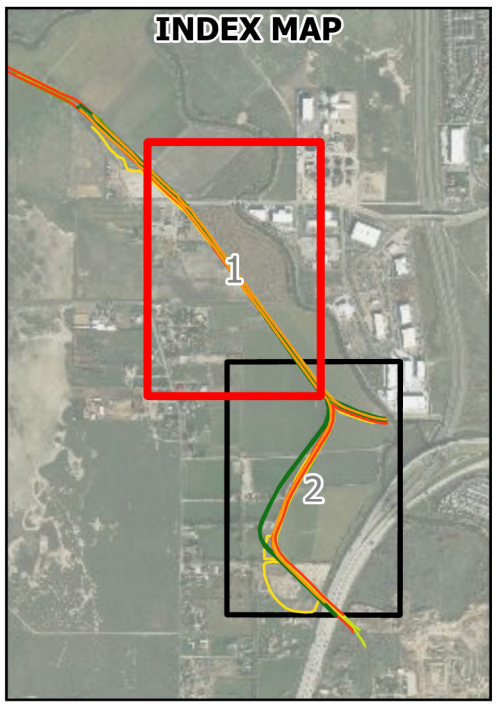
SHEET ____ OF ____

P:\Salt Lake County\022-23-03 Sewage Canal\7.0 Drawings\0222303_GC-01.dwg Plotted: 6/12/2024 1:38 PM By: Tim Anderson

L E G E N D

- Sewage Canal & Tributary
- Approximate Extent of Required Easements
- Approximate Boundary of Property Agreements Provided by Salt Lake City

INDEX MAP



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Salt Lake County

SEWAGE CANAL & CITY DRAIN LIFT STATION

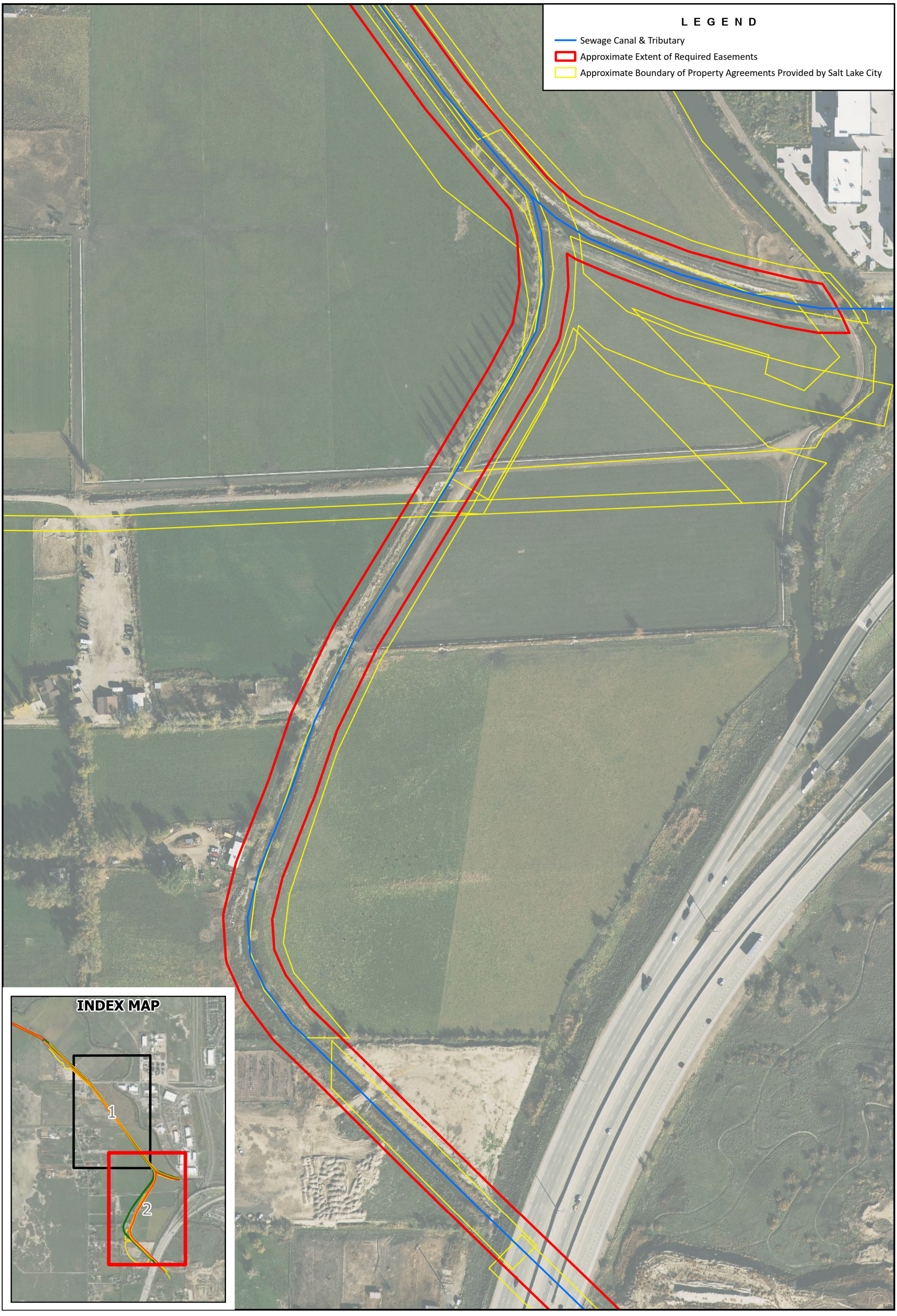
APPROXIMATE EXTENTS OF THE REQUIRED EASEMENTS

NORTH:

SCALE: 0 100 200 Feet

FIGURE NO. 6-3

P:\Salt Lake County\022-23-03 Sewage Canal\4.0 GIS\4.4 APRX\Sewage Canal v02.aprx rbutters 6/10/2024



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Salt Lake County

SEWAGE CANAL & CITY DRAIN LIFT STATION

APPROXIMATE EXTENTS OF THE REQUIRED EASEMENTS

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SCALE: 0 100 200 Feet

FIGURE NO. 6-3

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CHAPTER 7 – IMPROVEMENTS & RECOMMENDATIONS

INTRODUCTION

The primary purpose of this study is to identify channel deficiencies and recommended improvements within the Sewage Canal System and establish design criteria for a new City Drain Lift Station. As indicated in Chapter 3, the entire Sewage Canal System (including the Sewage Canal, City Drain, CWA-1 Drain, CWA-2 Drain, CWA-3 Drain, and CWA-3 Extension) has not previously been studied. Prior studies focused on the CWA drains and the upper portion of the City Drain (upstream of North Temple St.). Based on the results from the existing conditions analysis, multiple alternatives were evaluated to determine the sizing of the new City Drain Lift Station and to identify other recommended improvements.

ALTERNATIVES

Several potential alternatives were considered in addressing deficiencies within the Sewage Canal System. This included the following City Drain Lift Station alternatives:

1. Pump runoff collected in the City Drain to the Jordan River at the existing City Drain Lift Station site.
2. Pump runoff collected in the CWA-3 Drain to the Surplus Canal at the existing Surplus Canal Lift Station site.
3. Remove the channel berm and permanently remove the lift station and pumps.
4. Detain the runoff upstream of the lift station in either the channel or the Salt Lake City Storm Drain System.
5. Replace the existing lift station, including installing new pumps; various sizing options are discussed in the following section.

Excluding Alternative 5, each of the alternatives were deemed unfeasible for the corresponding reasons:

1. At this location, the Jordan River does not have additional capacity for more runoff during a large citywide storm event (similar to the Sewage Canal System design storm). As a result, pumping City Drain runoff to the Jordan River could cause flooding to homes/structures along the Jordan River. Increasing the capacity of the Jordan River to receive this runoff would be cost-prohibitive and was not pursued further.
2. Similar to the Jordan River, the Surplus Canal has limited capacity for additional runoff. In addition, the flows coming in from the CWA-3 Drain to the City Drain and the Sewage Canal represent a small portion of the total volume in the system, and removing the entire flow would have a limited impact on the downstream deficiencies. In addition, the City Drain Lift Station would still need to be improved in this scenario. This alternative would provide minimal benefit and would be cost-prohibitive.
3. This alternative represents how the system operates during normal or low flow conditions. The invert of the channel downstream of the pump station is two (2) feet higher than the invert of the channel upstream of the pump station. The backwater in the canal during high flows would increase significantly, increasing the flood potential compared to existing conditions. In addition, the berm in the channel also prevents high tailwater from the Great Salt Lake from going further upstream, allowing for the City Drain to function (albeit in a reduced capacity) even if the WSE in the Great Salt Lake is elevated.

4. Hydraulic modeling found that the flows upstream of the City Drain Lift Station are already being significantly detained via the UDOT detention basins. Much of the area that drains to the Sewage Canal system is already fully developed, making it difficult and cost-prohibitive to acquire property for additional detention storage. Since the channels are already acting like detention facilities, it was determined that the system should continue to operate as it is without attempting to significantly increase detention.

Alternative 5 is the recommended alternative and was further evaluated, as discussed in the following section.

LIFT STATION AND CULVERT IMPROVEMENTS

At a minimum, the City Drain Lift Station needs to be improved due to the condition deficiencies discussed in Chapter 2. The hydraulic analysis of the Sewage Canal System included an evaluation of various potential peak capacities of the improved lift station. Peak capacities of the lift station ranged from 50 cfs to 210 cfs. Hydraulic analysis found that any flow rate less than 110 cfs would be inadequate to prevent channel deficiencies in the City Drain upstream of the City Drain Lift Station. If the capacity of the lift station is expanded to 150 cfs, the upstream deficiencies were typically resolved. In addition, increasing the capacity of the pumps above 180 cfs had diminished returns (i.e. continuing to increase pump capacity did not yield a significant corresponding decrease in upstream water depth). To be conservative, it is recommended that the new City Drain Lift Station peak capacity be 180 cfs in order to provide additional capacity in excess of the peak flow in the City Drain channel. Further discussion about the new lift station is included in a technical memorandum found in Appendix J.

There are two collapsed culverts and a section of phragmite-filled channel downstream of the City Drain Lift Station site. If these deficiencies are not resolved, the increased capacity of the pumps will not be fully utilized as the downstream highwater sensors will cause the pumps to shut-off prematurely. To take full advantage of the improved lift station, the two collapsed culverts and phragmite-filled channel deficiencies should be resolved as soon as possible. Improving the lift station remains the highest priority as the pumps continue to deteriorate potentially resulting in loss of the lift station completely.

CULVERT/BRIDGE IMPROVEMENTS

As discussed in Chapter 5, there are multiple deficient culverts/bridges in the Sewage Canal System. Improving the City Drain capacity will resolve several of these issues, but some deficiencies will still remain. Figure 7-1 identifies the recommended culvert/bridge improvements. Following is a prioritization of the improvements.

Prioritization Criteria

Creating a list of projects is only useful to SLCo if the projects are completed. As with all flood control agencies, there is only a certain amount of available funds in any given year with which to maintain and construct flood control facilities. Prioritizing the list of recommended projects gives County personnel the ability to determine which projects should be pursued first, and which projects they may be able to delay until further funding is either acquired or budgeted. Prioritization criteria used for this study are as follows:

- **Known Flooding Issue:** Recommended projects associated with known flooding issues should typically be resolved sooner than later. These areas oftentimes have a flooding problem with a return interval less than the design storm event.

- **Known Condition Issues:** Projects to address known condition deficiencies should typically be done before the condition can deteriorate further, oftentimes making them more important.
- **Magnitude of Hydraulic Restriction:** Projects that alleviate multiple deficiencies are given higher priority than projects that only address deficiencies in the immediate vicinity.
- **Potential for Flooding/Damages:** Projects that will only cause local flooding with low possibility of damaging structures or private property are a lower priority then projects that would directly reduce the risk of property damage.

Based on this criteria, the recommended culvert/bridge projects have been broken into three different categories.

1. The first category represents high-priority culvert/bridge projects that need to be finished as soon as possible. The City Drain Lift Station and its associated culvert improvements are considered high-priority projects because they have created known flooding issues (both upstream and downstream), have known condition issues, impact multiple deficiencies, and have the potential to cause property damage.

2. The second category represents medium-priority projects, like culverts/bridges that have known flooding or condition deficiencies, but won't have an impact on multiple projects or do not have a high potential for property damage.

3. The final category represents low-priority/watch projects, which are in areas without known prior flooding issues, low magnitude of restriction, and minimal risk of flooding and property damage.

Table 7-1 lists all the recommended projects with a short description, location, and priority. Figure 7-1 shows the location of each project. A more detailed description for each project follows.

CHANNEL MAINTENANCE

Channel maintenance projects are based on condition deficiencies identified during the study field visits and discussed in Chapter 2. These deficiencies are broken down into high and low priorities as defined below:

- **High-Priority:** Channel maintenance concerns with this priority are portions of the canals that are known to currently restrict the capacity or are active maintenance concerns identified by Salt Lake County or Salt Lake City personnel. Primarily, this is caused by excessive phragmite growth not only on the banks but within the main channel as well.
- **Low-Priority/Watch:** These areas include portions of the channels that need to be addressed, but do not currently appear to significantly restrict the channel, nor have they been identified as current maintenance concerns. Most of these issues are related to phragmite growth on the banks of the channel, but not along the bottom of the channel.

Sewage Canal System channel maintenance projects have been identified in Figure 7-1 and Tables 7-1 and 7-2. Although only a portion of the total channel length has been identified as project area based on this study, the entire system needs to be managed. This is because there are phragmites and potential for phragmite growth along all open channel sections of the system. If not maintained, the phragmites could significantly limit the capacity of the channel.

Table 7-1
High and Medium Priority Recommended Improvements

Project ID	Project Location	Project Description	Priority Level	Estimated Cost
Phase 1a: Improvements to Bridges/Culverts and Phragmites Downstream of Lift Station[1]				
2	CDWB7 – 2800 North Rose Park Ln.	Replace existing culvert with a free span bridge.	High	$ 360,000
3	CDWB9 – 2441 North Rose Park Ln.	Replace existing culvert with a free span bridge.	High	$ 360,000
4	CDWB13 – Access Bridge 1700 North	Remove existing culvert crossing.	High	$ 100,000
5	CDWB4 – Farm Culvert	Replace existing culvert with free span bridge.	High	$ 360,000
	Channel between Lift Station and I-215	Remove all phragmite growth between the lift station and I-215.	High	--
Total Estimated Cost of Phase 1a				**$ 1,180,000**
Phase 1b: City Drain Lift Station improvements[1]				
1	City Drain Lift Station	Construct new City Drain Lift Station with peak capacity of 180 cfs.	High	$ 4,528,800
Total Estimated Cost of Phase 1b				**$ 4,528,800**
Phase 2: Acquire funding and construct medium priority projects				
6	CDWB10 – 2350 North Rose Park Ln.	Replace CMP culvert with equal or larger area RCP or box culvert.	Medium	$ 360,000
9	CDWB5 – North of I-215	Remove bridge crossing channel.	Medium	$ 100,000
10	Misc. Storm drain Pipes along City Drain	Install backflow preventors (e.g. gate valves, tide-flex valves, etc.) on all storm drain pipes that connect into the City Drain between the lift station and 700 North.	Medium	$ 18,000
Total Estimated Cost of Phase 2				**$ 478,000**
Phase 3: Acquire funding for Sewage Canal bank geotechnical study and easement acquisition				
7	Between I-215 and Cudahy Ln.	Perform slope remediation of the Sewage Canal.	Medium	$ 40,000[2]
8	Downstream of Cudahy Ln.	Perform slope remediation of the Sewage Canal.	Medium	$ 40,000[2]
Total Estimated Cost of Phase 3				**$ 80,000**
Total Cost of Projects in Phases 1-3				**$ 6,266,800**

[1] Phase 1a should be completed as soon as possible. Phase1b should be completed immediately, but will be at a reduced capacity/efficiency until Phase 1a projects have been completed.

[2] Phase 3 cost estimates only include the geotechnical analysis. Once that analysis is completed, final recommendations can be made and conceptual cost estimates developed.

Table 7-2
Low/Watch Priority Recommended Improvements

Project ID	Project Location	Project Description	Priority Level
11	CDWB19 – Airport Culvert Inlet	Construct berms around the inlet to prevent nearby flooding. DO NOT increase capacity of inlet.	Low/Watch
12	Right Bank of City Drain	Raise the right bank of the City Drain to be above the Great Salt Lake WSE.	Low/Watch
13	Left Bank Along Salvage Yard	Raise the left bank of channel between 500 South and I-80.	Low/Watch
14	SC1 – Near End of Sewage Canal	Replace existing bridge.	Low/Watch
15	CDWB8 – Upstream of 2800 North Rose Park Ln.	Remove/replace existing bridge and raise low spot of the channel banks.	Low/Watch
16	CDWB15 – I-215 at 1000 North	Replace culvert or raise channel banks.	Low/Watch
17	CDWB17 – 2200 West and 1000 North	Replace culvert or raise channel banks.	Low/Watch
18	CDWB22B – New Park and Go Bridge	Replace bridge or raise channel banks.	Low/Watch
19	Left Bank by I-80	Add erosion control measure to stabilize bank and protect from collapsing into channel.	Low/Watch
20	CDWB25 – Railroad Crossing	Replace culvert and raise nearby banks.	Low/Watch
21	CWA2D1 – 500 South	Replace culver and raise nearby banks.	Low/Watch
22	CWA1D – I-215 Crossing for CWA-1 Drain	Raise banks along CWA-1 Drain.	Low/Watch
23	CWA3D5, CWA3D6, and Left bank along Railyard	Raise left bank of channel from Surplus Canal to approximately 1300 South.	Low/Watch
24	CWA3DE1 – I-215 for CWA.-3 Drain Extension	Raise banks along CWA-3 Drain Extension to Wallace Rd.	Low/Watch
25	3WA3D11 – 1700 South	Replace culvert and raise surrounding banks.	Low/Watch
26	Phragmite Growth Removal (see Figure 2-2)	Remove excessive phragmite growth as identified in Figure 2-2. Create a maintenance plan for all channels to remove future phragmite growth.	Low/Watch

RECOMMENDATIONS

In general there are three different sets of recommendations made as a result of this study; channel banks slope stability, detention requirements, and capacity improvements. A description of each type of recommendation follows.

Channel Banks Slope Stability

General

Maintaining the existing channel shape is important to protect existing infrastructure and to maintain channel conveyance capacity. Due to the relatively flat slope of the channels, the peak water velocity within the channel is not going to cause significant erosion or scour. Instead, channel banks are more likely susceptible to instability due to the rise and fall of water depths. This is not typically a concern throughout the entire Sewage Canal system, but as phragmites are removed, bank slopes should be monitored for new instabilities.

Sewage Canal

As identified in Chapter 2, there is a stretch of the Sewage Canal that has a vertical bank on the left-hand side downstream of I-215. Based on our observations during the field visit, this bank is likely unstable. Stabilizing the banks will probably require establishing a consistent side slope between 2:1 and 4:1 and adding side treatment (such as riprap, plantings, or engineered soil) to the banks. Laying the banks back is probably not feasible because the banks of the channel have moved over the years and have removed portions of private property in the area. Instead, it is most likely that the banks will need to be restored by placing fill on the banks of the channel in an effort to re-establish the original channel (or something similar to the original channel) and stabilize the side slope. See Chapter 6 for more detailed information. While this deficiency does not currently risk significant property damage or create a flood risk, it has the potential to continue to get worse with time as the banks continue to collapse. For this reason, we have determined that channel bank improvements should be performed in this area and are medium priority projects.

Fill will need to be placed prior to development occurring along the Sewage Canal downstream of I-215. This fill will need to be placed by the developer, but establishing an appropriate setback and granting easements or ROW for the canal will be essential for the County. The needed easement or ROW width will need to be determined after an analysis of the banks downstream of I-215 is completed. A project related to this work has been included in the capacity recommended improvements for planning and funding convenience.

Detention Requirements

Figure 7-2 presents the recommended detention requirements based on location for the Sewage Canal System drainage area. As can be seen in Figure 7-2, all new development and redevelopment upstream of I-215 should detain peak runoff to 0.2 cfs per acre.

The existing drainage area downstream of I-215 has been divided into two portions: east of the Sewage Canal and west of the Sewage Canal. Based on existing grading, the area east of the Sewage Canal currently flows towards the Jordan River. Future development should continue to drain to the Jordan River at a peak discharge of 0.2 cfs per acre. The area to the west of the Sewage Canal channel should not be allowed to discharge into the Sewage Canal. However, the following considerations should be made.

1. Existing drainage has little to no runoff discharging to the sewage canal north of I-215. Future development should minimize the increase in peak flow to Sewage Canal by prioritizing LID as much as possible and utilizing other natural drainages to the west.
2. Peak flow in the Sewage Canal is governed by the runoff from the upstream drainage area. Care should be taken to minimize detention to avoid lengthening the time of the peak discharge and avoid overlapping with the upstream peak flow rate. This will likely require limiting detention to meet the water quality requirements.
3. Development must comply with all City and UPDES requirements. This will require at least some retention and or detention for smaller storm events.

The Salt Lake City Airport storm drain master plan reports a maximum peak discharge of 69 cfs to the City Drain at full build-out conditions. The peak flow rate of 69 cfs was used in the future condition analysis and to identify recommendations in this report. Future development or expansion of the Salt Lake City Airport should limit storm water runoff discharge into the Sewage Canal system to a peak flow rate of 69 cfs to be consistent with the storm drain master plan and the recommendations identified in this report.

Capacity Recommended Improvements

Based on the hydrologic and hydraulic analyses performed for this study, we have developed the following list of recommended improvements. The improvements have been broken down into 4 phases based on project priority

Phase 1a: Replace Bridges/Culverts and Remove Phragmites Downstream of Lift Station.

As shown in Table 7-1, this phase includes replacing the two damaged culverts and clearing the phragmite-inundated channel downstream of the City Drain Lift Station, as shown on Figure 7-1. These projects should be completed as soon as possible. Otherwise the new lift station will operate at a lower flow than it will be designed. This will likely reduce flooding in the City Drain, but the pump station will not be able to operate at its full capacity until the culverts downstream are replaced.

Phase 1b: City Drain Lift Station Replacement

This phase only includes improvements to the City Drain Lift Station. The existing lift station no longer functions as designed and does not have adequate capacity for the design storm event. In addition, if the pumps were to fail completely the City Drain and Sewage Canal system in general may not be able to function during high flow events. Work on this phase has already begun and is expected to be completed by 2026.

Phase 2: Medium-Priority Projects

In the next 3-5 years, funding should be acquired to design and construct the remaining high-priority and medium-priority projects. These projects need to be done to mitigate potential future flooding. Phase 2 should start with the remaining high-priority projects not completed with Phase 1, then move to the medium-priority projects.

Phase 3: Acquire Funding for Sewage Canal Bank Geotechnical Study and Easement Acquisition

The County has had difficulty accessing and maintaining the Sewage Canal in the past downstream of I-215. They should begin to acquire easements as soon as possible, beginning with acquiring temporary easements along the Sewage Canal channel to complete a geotechnical analysis. The

geotechnical analysis should be done in the next couple of years to be able to determine the full extent of the required permanent easements or ROWs needed on the Sewage Canal and provide a final recommendation on the channel design. Remediation of the channel should then be performed after permanent easements or ROWs are acquired. If the County is unable to acquire easements or ROWs from current property owners, consideration should be given to waiting to improve the banks of the Sewage Canal until the area develops. Most of the property along the Sewage Canal downstream of I-215 is currently farm land or open space. The improvements along the banks of the Sewage Canal downstream of I-215 will prevent the banks from collapsing further, and will be necessary to protect future development, but is not necessary to complete these projects immediately because there is little critical infrastructure in the area.

Phase 4: Acquire Funding to Address Watches and Low-Priority Projects

All remaining projects and improvements should be planned to be done beyond the next 10 years. Many of these projects are on the "watch list" and should be observed so that a more informed decision can be made on whether or not the improvement should be constructed. If flooding or issues are observed at any time during the next 10 years, the timeline for projects addressing the relevant deficiencies should be accelerated. As many of these projects may not be constructed because they may not be needed, cost estimates were not provided for low-priority/watch projects.

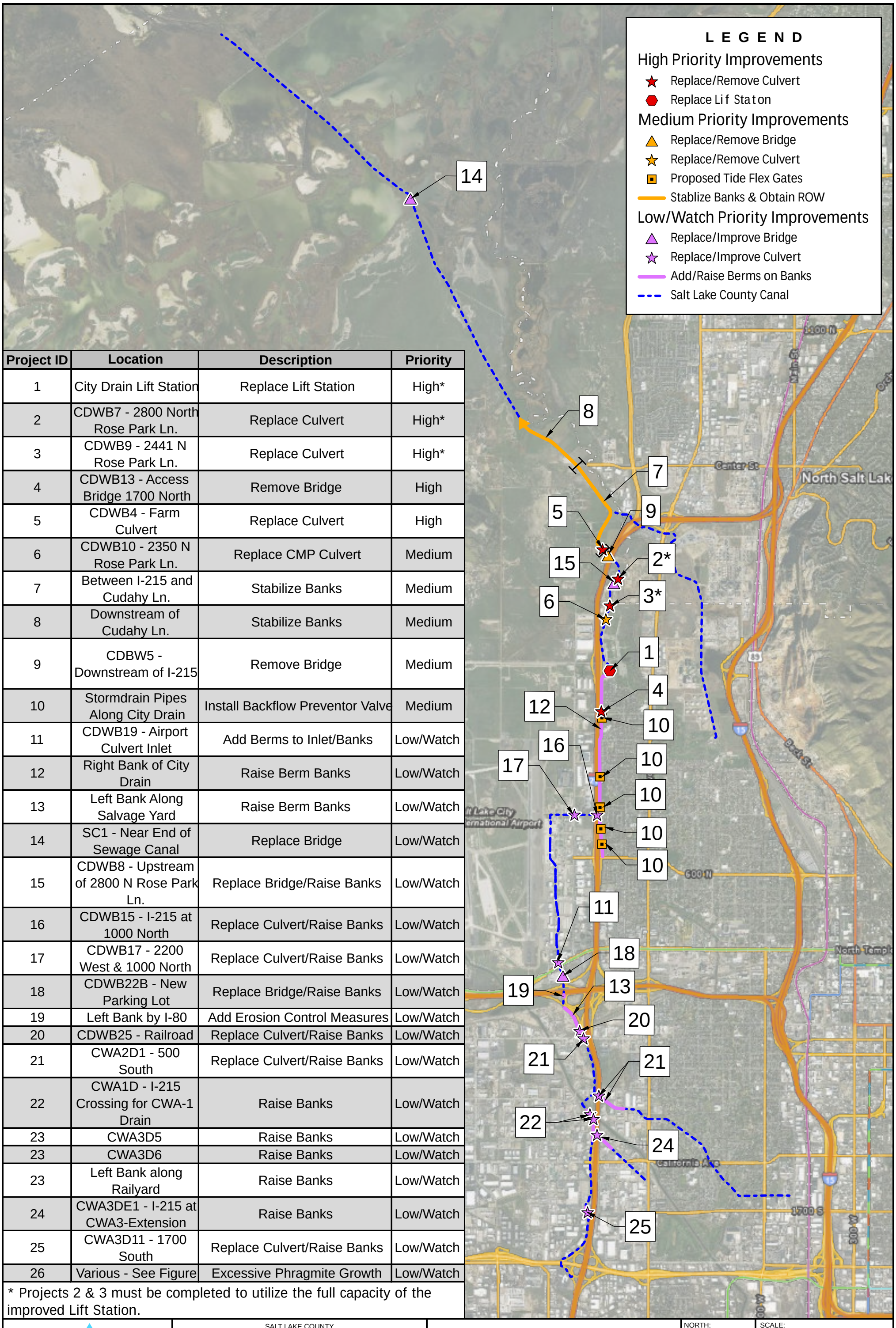
Cost Estimates

Summary

Conceptual cost estimates were developed for all high- and medium-priority improvements. Cost estimates for low-priority/watch projects were not included because it is unlikely that these projects will be completed and providing a cost is not likely to provide any benefit. The total conceptual cost estimates are shown in Table 7-1.

Project ID	Location	Description	Priority
1	City Drain Lift Station	Replace Lift Station	High*
2	CDWB7 - 2800 North Rose Park Ln.	Replace Culvert	High*
3	CDWB9 - 2441 N Rose Park Ln.	Replace Culvert	High*
4	CDWB13 - Access Bridge 1700 North	Remove Bridge	High
5	CDWB4 - Farm Culvert	Replace Culvert	High
6	CDWB10 - 2350 N Rose Park Ln.	Replace CMP Culvert	Medium
7	Between I-215 and Cudahy Ln.	Stabilize Banks	Medium
8	Downstream of Cudahy Ln.	Stabilize Banks	Medium
9	CDBW5 - Downstream of I-215	Remove Bridge	Medium
10	Stormdrain Pipes Along City Drain	Install Backflow Preventor Valve	Medium
11	CDWB19 - Airport Culvert Inlet	Add Berms to Inlet/Banks	Low/Watch
12	Right Bank of City Drain	Raise Berm Banks	Low/Watch
13	Left Bank Along Salvage Yard	Raise Berm Banks	Low/Watch
14	SC1 - Near End of Sewage Canal	Replace Bridge	Low/Watch
15	CDWB8 - Upstream of 2800 N Rose Park Ln.	Replace Bridge/Raise Banks	Low/Watch
16	CDWB15 - I-215 at 1000 North	Replace Culvert/Raise Banks	Low/Watch
17	CDWB17 - 2200 West & 1000 North	Replace Culvert/Raise Banks	Low/Watch
18	CDWB22B - New Parking Lot	Replace Bridge/Raise Banks	Low/Watch
19	Left Bank by I-80	Add Erosion Control Measures	Low/Watch
20	CDWB25 - Railroad	Replace Culvert/Raise Banks	Low/Watch
21	CWA2D1 - 500 South	Replace Culvert/Raise Banks	Low/Watch
22	CWA1D - I-215 Crossing for CWA-1 Drain	Raise Banks	Low/Watch
23	CWA3D5	Raise Banks	Low/Watch
23	CWA3D6	Raise Banks	Low/Watch
23	Left Bank along Railyard	Raise Banks	Low/Watch
24	CWA3DE1 - I-215 at CWA3-Extension	Raise Banks	Low/Watch
25	CWA3D11 - 1700 South	Replace Culvert/Raise Banks	Low/Watch
26	Various - See Figure	Excessive Phragmite Growth	Low/Watch

* Projects 2 & 3 must be completed to utilize the full capacity of the improved Lift Station.



BOWEN COLLINS & ASSOCIATES

SALT LAKE COUNTY

SEWER CANAL & CITY DRAIN LIFT STATION

RECOMMENDED IMPROVEMENTS

NORTH:

SCALE: 0 2,250 4,500 Feet

FIGURE NO. 7-1

P:\Salt Lake County\022-23-03 Sewage Canal\4.0 GIS\4.4 APRX\Sewage Canal v02.aprx tjorgensen 8/30/2024

LEGEND

- Sewage Canal
- City Drain
- CWA-1 Drain
- CWA-2 Drain
- CWA-3 Drain
- CWA-3 Drain Extension

Maximum Allowable Discharge Rate

- 0.2 cfs/acre
- 0.2 cfs/acre to Jordan River (see Note 1)
- Minimal Detention (see Note 2)
- SLC Airport Drainage (see Note 3)

Note:

1. This area should not discharge into the Sewage Canal.
2. The goal of discharging into the sewage canal in this region is to avoid extended peak discharges that will overlap with peak discharges from upstream.
   Water quality goals and retention requirements will still need to be met as required by the UPDES permit.
3. SLC Airport should maintain peak discharge of 69 cfs as reported in the SLC Airport Storm Drain Master Plan.

BOWEN COLLINS & ASSOCIATES

Salt Lake County

SEWER CANAL & CITY DRAIN LIFT STATION

DRAINAGE REQUIREMENT RECOMMENDATIONS

NORTH:

SCALE: 0 2,000 4,000 Feet

FIGURE NO. 7-2

P:\Salt Lake County\022-23-03 Sewage Canal\4.0 GIS\4.4 APRX\Sewage Canal v02.aprx tjorgensen 1/29/2025

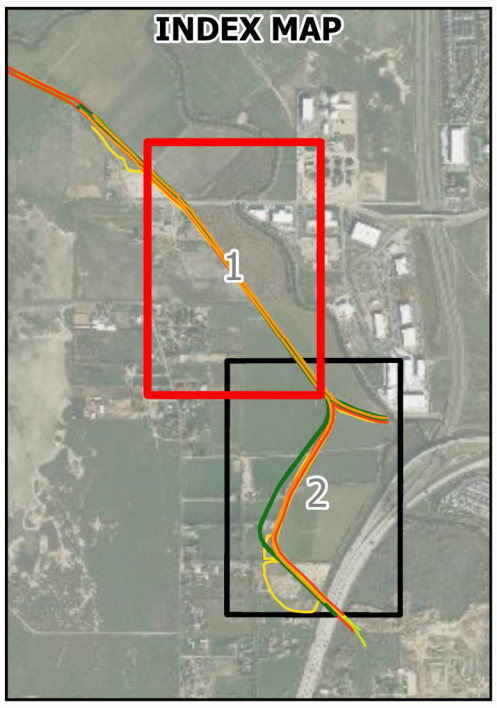
APPENDIX A

Approximate Easement Agreement Boundaries

L E G E N D

- Sewage Canal
- Approximate Boundary of Property Agreements Provided by Salt Lake City

INDEX MAP



BOWEN COLLINS & ASSOCIATES

Salt Lake County

SEWAGE CANAL & CITY DRAIN LIFT STATION

APPROXIMATE EXTENTS OF THE REQUIRED EASEMENTS

NORTH:

NORTH

SCALE:

0 100 200

Feet

FIGURE NO.

6-3

Page 1 of 2

P:\Salt Lake County\022-23-03 Sewage Canal\4.0 GIS\4.4 APRX\Sewage Canal v02.aprx syoung 6/11/2024

L E G E N D

Sewage Canal

Approximate Boundary of Property Agreements Provided by Salt Lake City

INDEX MAP

1

2

Salt Lake County

SEWAGE CANAL & CITY DRAIN LIFT STATION

APPROXIMATE EXTENTS OF THE REQUIRED EASEMENTS

BOWEN COLLINS & ASSOCIATES

NORTH:

NORTH

SCALE:

0 100 200

Feet

FIGURE NO.

6-3

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APPENDIX B

Structure Photo Log

SEWAGE CANAL

Photo 1: Pipe bridge over canal.

Photo 2: Looking downstream at SC2 farm bridge.

Photo 3: Looking upstream at SC3 farm bridge.

Photo 4: Looking upstream at SC4 bridge at Cudahy Lane.

Photo 5: Looking downstream at SC5 farm bridge.

CITY DRAIN

Photo 6: Looking downstream at CDWB1 8ft CMP culvert.

Photo 7: Looking downstream at CDWB2 farm bridge.

Photo 8: Looking downstream at CDWB3 farm bridge.

Photo 9: Standing on top of CDWB4 8ft RCP culvert looking downstream.

Photo 10: Standing on top of CDW5 bridge looking upstream at CDW6 I-215/Legacy Parkway double 13-ft x 7-ft culvert.

Photo 11: Looking downstream at CDWB7 double 6-ft CMP culvert.

Photo 12: Looking downstream at CDWB8 private bridge.

Photo 13: Looking downstream at CDWB9 2250 North double 5-ft CMP culvert.

Photo 14: Looking downstream at CDWB10 5-ft CMP and 6-ft CMP culvert.

Photo 15: Looking downstream at lift station on Rose Park Ln.

Photo 16: Looking downstream at CDWB12 1990 West double 64-ft wide bridge.

Photo 17: Looking downstream at CDWB13 1800 North 11-ft x 5-ft box culvert.

Photo 18: Looking downstream at CDWB14 1700 North bridge.

Photo 19: Looking upstream at CDWB15 I-215 6-ft RCP culvert.

Photo 20: Looking downstream at CDWB16 13-ft x 4-ft culvert.

Photo 21: Looking downstream at CDWB17 2200 West double 4-ft RCP culvert.

Photo 22: Looking downstream at CDWB18 2360 West 8-ft x 5-ft culvert.

Photo 23: Looking downstream at CDWB19 airport entrance.

Photo 24: Looking upstream at CDWB21 North Temple 9-ft CMP culvert.

Photo 25: Looking downstream at CDWB22A 8-ft RCP culvert.

Photo 26: Looking downstream at CDWB22B Private Road bridge.

Photo 27: Looking downstream at CDWB23 I-20 Extension 4-ft CMP culvert.

Photo 28: Looking downstream at CDWB23B I-80 9-ft CMP culvert.

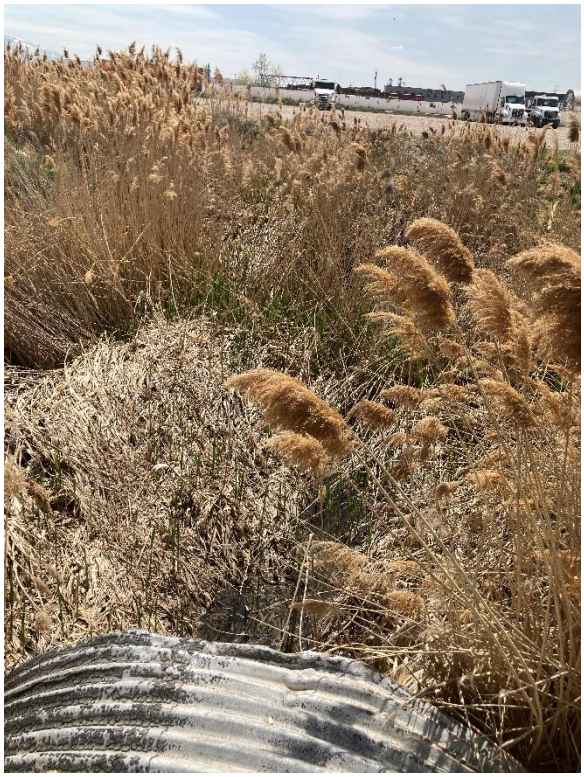


Photo 29: Standing on CDWB24 1-80 SB exit 9 f-ft CMP culvert looking upstream.

Photo 30: Looking upstream at CDWB25 4-ft CMP and 4.25-ft CMP culvert.

CWA-2 DRAIN

Photo 31: Looking upstream at CWA2D1 500 South 7-ft RCP culvert.

Photo 32: Looking downstream at CWA3D1 Indiana Ave 7-ft RCP culvert.

CWA-3 DRAIN

Photo 33: Looking downstream at CWA3D2 5-ft RCP culvert.

Photo 34: Looking upstream at CWA3D3 4-ft culvert.

Photo 35: Standing on CWA3D5 5-ft RCP culvert looking downstream.

Photo 36: Standing on CWA3D7 6-ft RCP culvert looking downstream.

Photo 37: Looking downstream at CWA3D8 California Ave. 7-ft x 5-ft box culvert.

Photo 38: Looking upstream at CWA3D9 Swaner Rd. 11.5-ft wide culvert.

Photo 39: Standing on CWA3D11 1700 South 3-ft RCP culvert.

Photo 40: Standing on CWA3D12 2100 South 7-ft x 5-ft box culvert looking downstream.

CWA-1 DRAIN

Photo 41: Standing on CWA1D1 I-215 3-ft RCP culvert looking downstream.

Photo 42: Standing on CWA1D2 Bending River Rd. 6-ft RCP culvert looking downstream.

CWA-3 DRAIN EXTENSION

Photo 43: Looking downstream at CWA3DE1 I-215 Double 3-ft RCP culvert.

Photo 44: Looking downstream at CWA3DE2 Wallace Rd. 3.5-ft RCP culvert.

Photo 45: Looking downstream at CWA3DE3 double 3-ft CMP culvert.

Photo 46: Looking downstream at CWA3DE4 California Ave. 4-ft x 4-ft box culvert.

Photo 47: Looking upstream at CWA3DE5 3-ft RCP culvert.

APPENDIX C

City Drain Lift Station Design Drawings

PROJECT NO.	CITY	COUNTY	SHEET NO.	TOTAL SHEETS
FV-840006	SALT LAKE	SALT LAKE	1	10

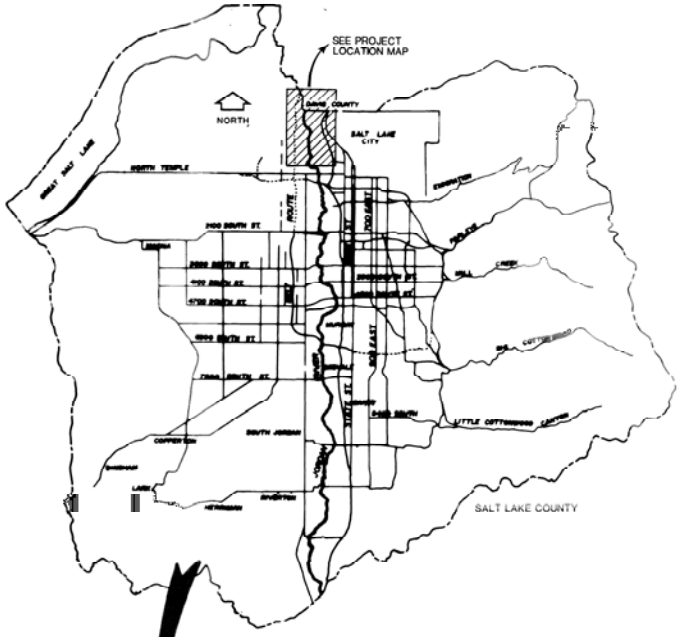
SALT LAKE COUNTY
PUBLIC WORKS PROJECT

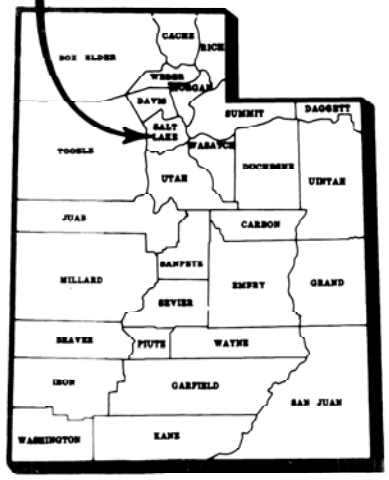
CITY DRAIN PUMP STATION
PROJECT NUMBER FV-840006

LOWER JORDAN / CITY DRAIN
FLOOD CONTROL PROJECT

INDEX OF DRAWINGS

SHT. NO.	DESCRIPTION
1	COVER SHEET & INDEX OF DRAWINGS
2	KEY MAP & MISC. IMPROVEMENTS
3	SITE PLAN
4	BUILDING FOUNDATION & ROOF PLAN
5	BUILDING ELEVATIONS
6	BUILDING MECHANICAL
7	PUMPS & TRASH RACK DETAILS
8	DETAILS
9	ELECTRICAL SITE & BUILDING PLAN
10	LIGHTING & SINGLE LINE DIAGRAM





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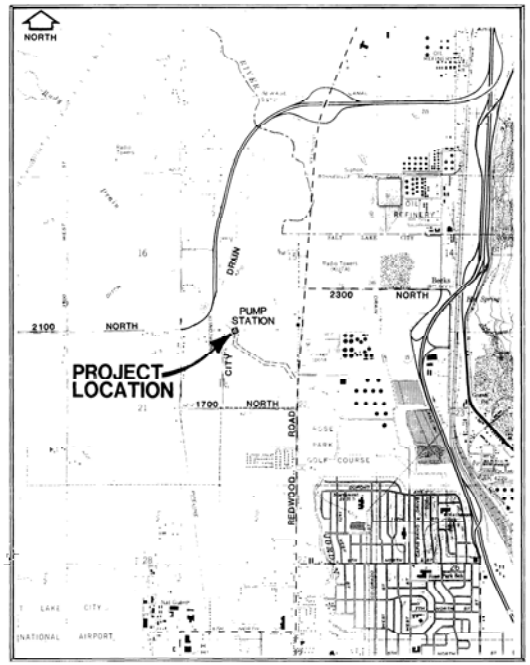


SALT LAKE COUNTY FLOOD CONTROL DIVISION
RECOMMENDED FOR APPROVAL
R.T. Hildreth by [illegible] 6-12-84
DIRECTOR DATE

SALT LAKE COUNTY PUBLIC WORKS DEPARTMENT
RECOMMENDED FOR APPROVAL
DIRECTOR DATE

DATE

DATE

DATE

ECKHOFF, WATSON and PREATOR ENGINEERING

LOWER JORDAN / CITY DRAIN
FLOOD CONTROL PROJECT
CITY DRAIN PUMP STATION

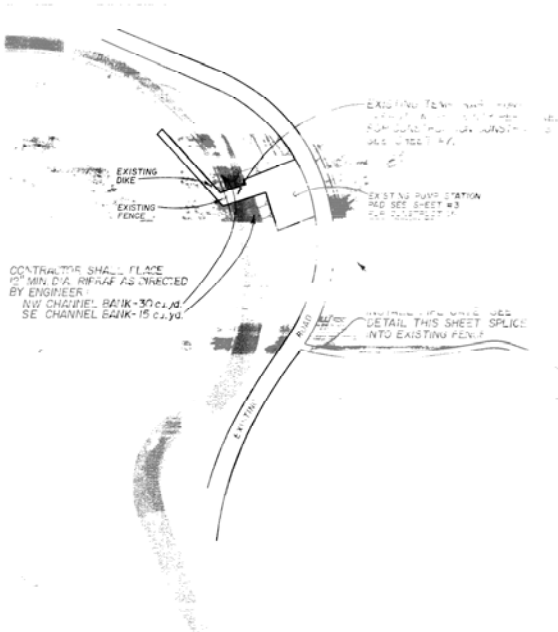
DESIGN	CHECK	REVIEW
DRAWN	CHECK	
QUANT. GS	CHECK	

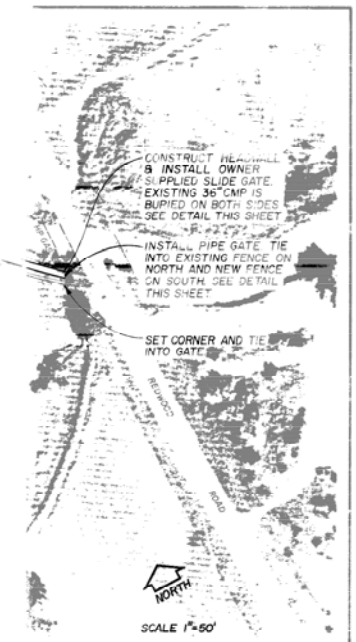
CORPORATE RECOMM. DATE 7/16/84 PROJ. DESIGN ENGINEER
APPROVED 7/16/84 DATE PROJECT MANAGER

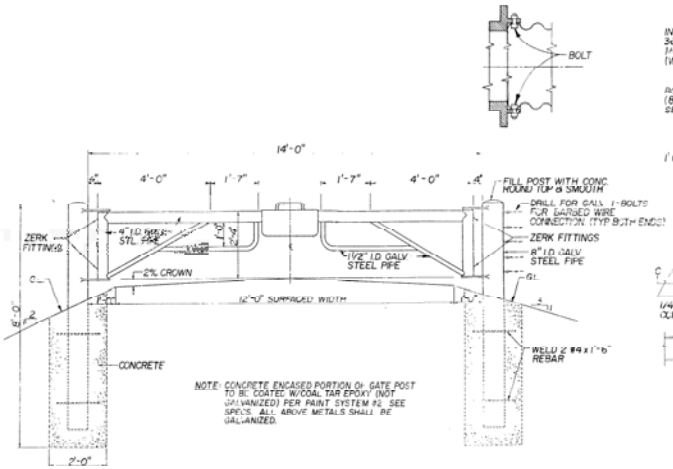
SALT LAKE COUNTY
PROJECT NUMBER
SHEET 1 OF 10

NO.	BY	DATE	TYPE	REMARKS
				REVISIONS

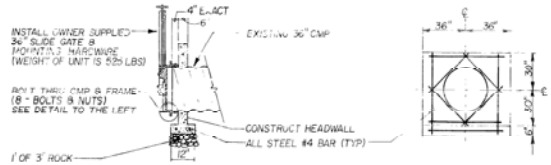
2700.10



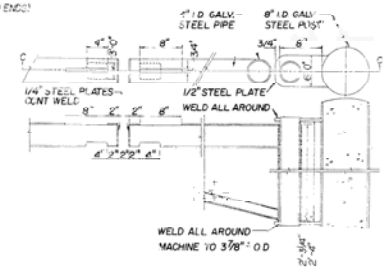




PIPE GATE
2 REQUIRED



SLIDE GATE DETAIL



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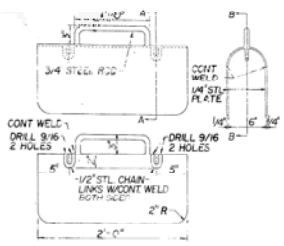

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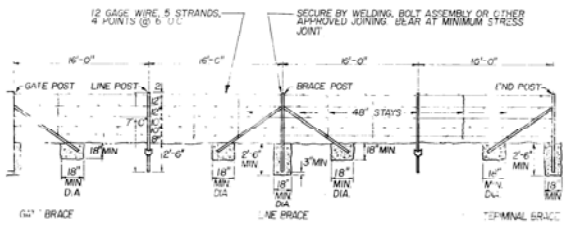
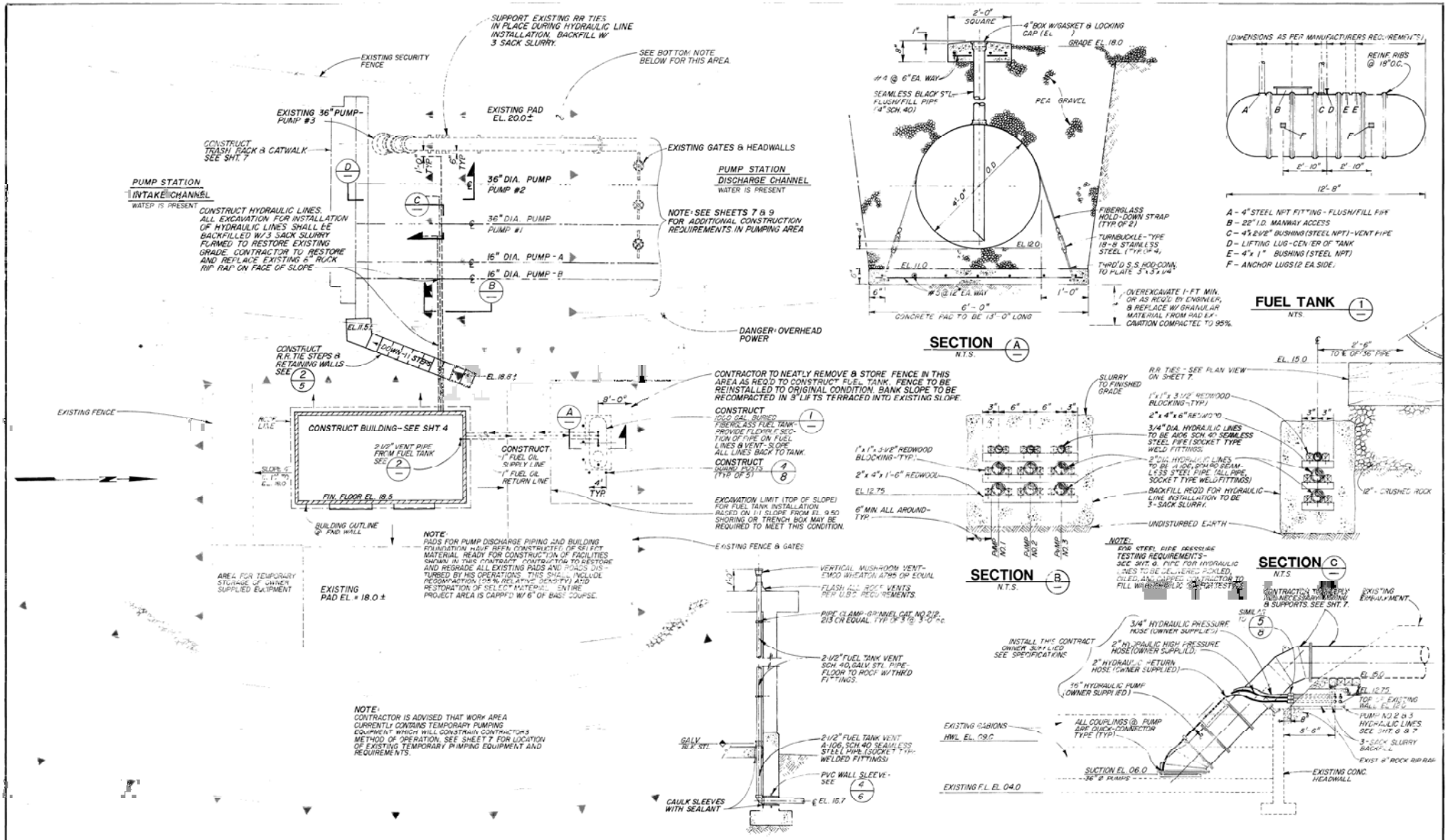


LINE POSTS SHALL BE TEE CHANNEL OR Y OR U SECTIONS & SHALL HAVE A NOMINAL WT OF 3.53 LBS PER FT WITH BRACE & END POSTS SHALL BE 2 1/2"x2 1/2" x 1/4" ANGLES AND SHALL HAVE A NOMINAL WT OF 4.10 LBS/FT. INCLINED BRACES SHALL BE 2"x 2" x 1/4" ANGLES & SHALL HAVE A NOMINAL WEIGHT 3.19 LB/FT. POSTS SHALL BE 7'-1" LONG. ALL POST BRACING SHALL BE 12" TO 16" FROM TOP OF POST. BRACES SHALL BE EMBEDDED IN CONC. A MIN. OF 12 IN. ALL OF 12' POSTS & BRACES SHALL CONFORM TO A-36 OR EQUAL

LINE POSTS AND BRACES SHALL BE TEE, U OR Y CHANNEL, ANGULAR OR OTHER APPROVED SHAPES 7' LONG. ALL POST BRACING SHALL BE 12" TO 16" FROM TOP OF POST. BRACES SHALL BE EMBEDDED IN CONC. A MIN. OF 12 IN.

FENCE DETAIL



ECKHOFF, WATSON and PREATOR ENGINEERING

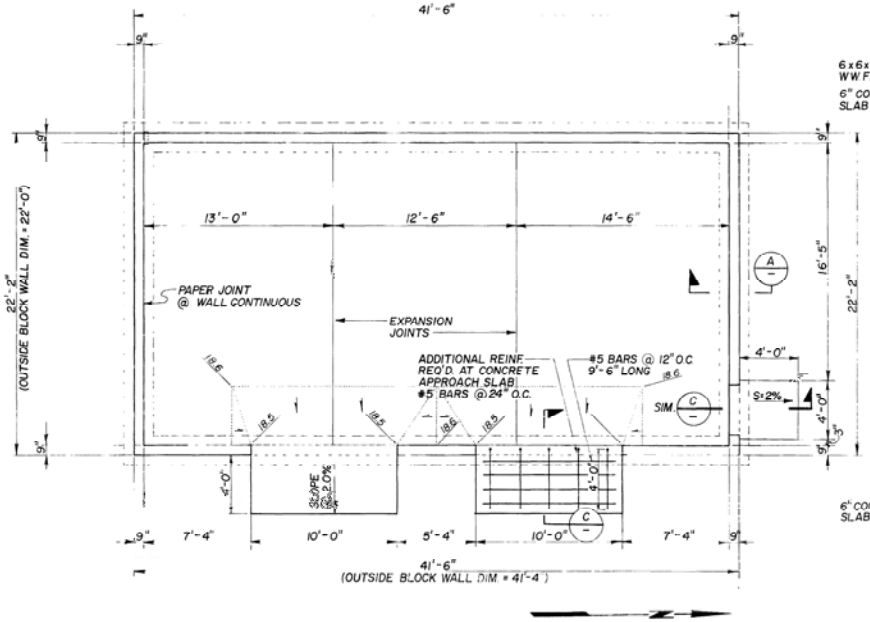
LOWER JORDAN / CITY DRAIN FLOOD CONTROL PROJECT

CITY DRAIN PUMP STATION

SITE PLAN

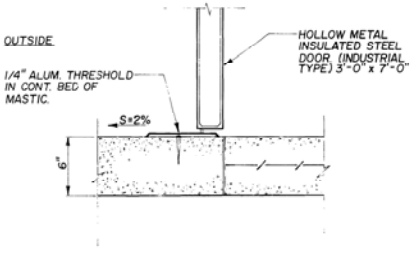
SHEET 3 OF 10

2700.10

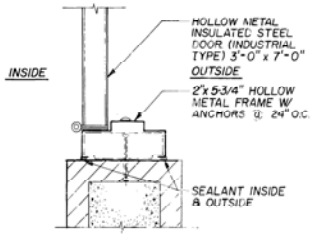


FOUNDATION PLAN
SCALE: 1/4" = 1'-0"

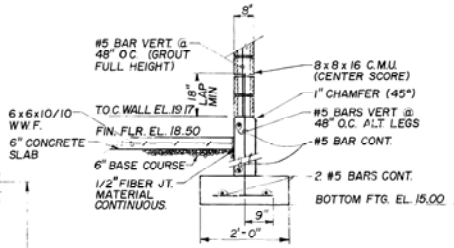
NOTE: 1- RAFTERS & PLATES & BLOCKING: PS-20, DOUGLAS FIR, LARCH, DENSE NO. 2 (1600 f-1-6-E) MIN. GRADE.
2- SOFTWOOD PLYWOOD SHEATHING: PS 1, C-D 32/16 INTERIOR - APA GRADE.
3- WOOD IN CONTACT WITH CONCRETE BLOCK, MORTAR, OR GROUT SHALL BE PRESERVATIVE TREATED.



SILL @ ENTRY DOOR

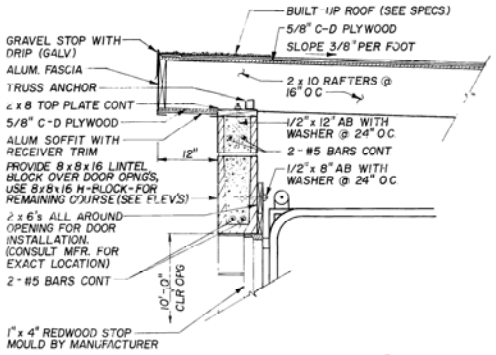


JAMB/HEAD @ ENTRY DOOR

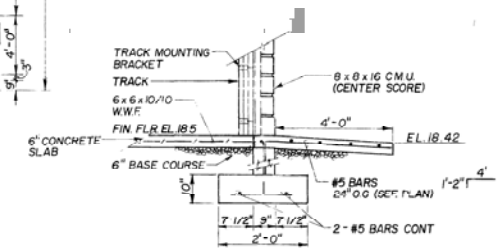


WALL SECTION (A) (TYPICAL)

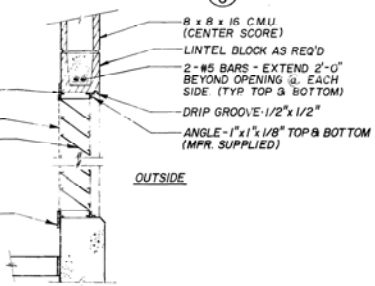
NOTE: PROVIDE WIRE LADDER TYPE TIES EVERY OTHER COURSE.



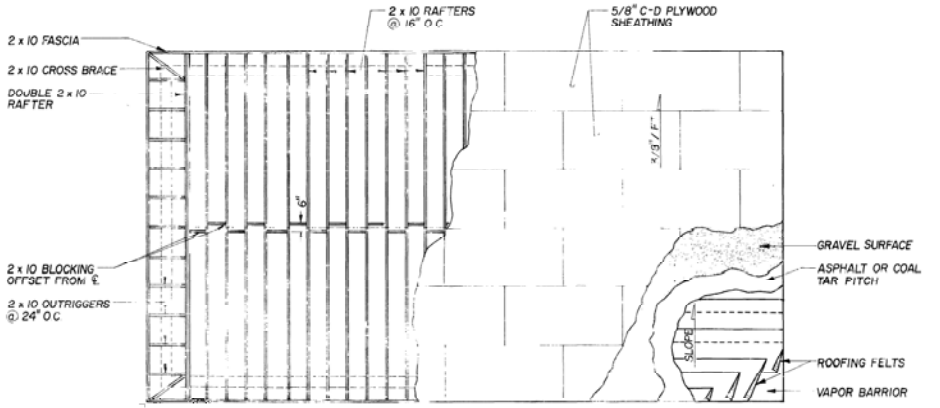
SECTION @ ROLL-UP DOOR (B/5)



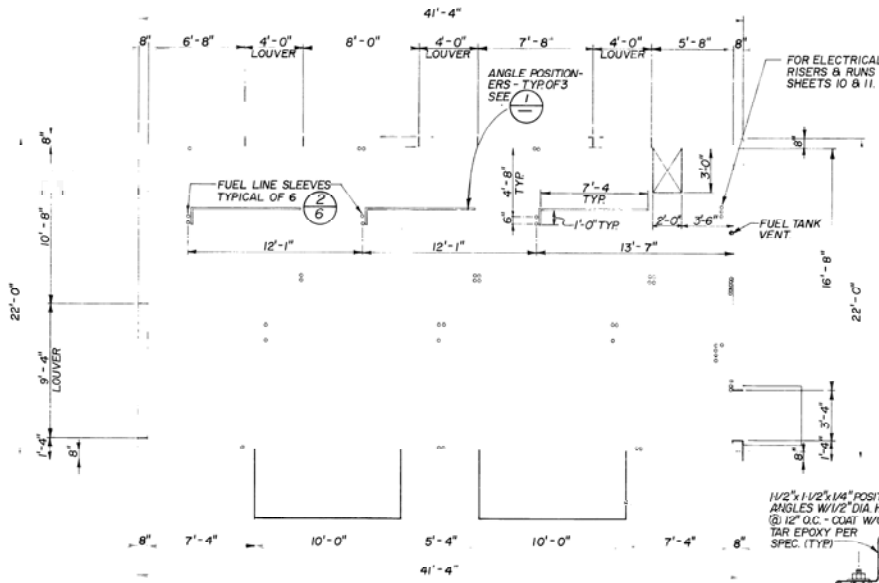
SECTION @ DRIVE APPROACH (C/—)



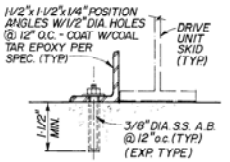
WALL LOUVER SECTION (D/5)
TYPICAL



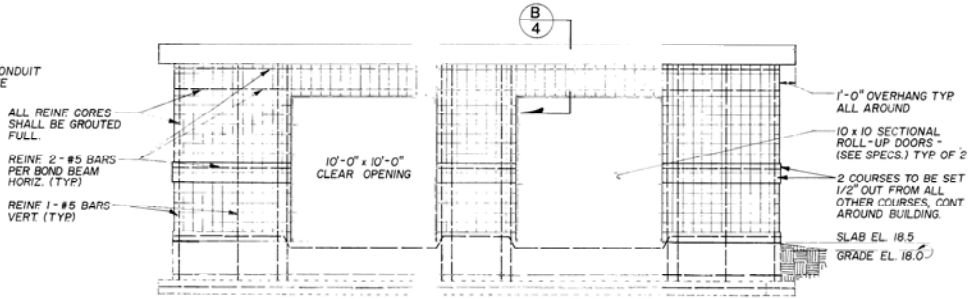
ROOF PLAN



SLAB BLOCKOUTS AND BLOCK WALL PLAN
SCALE: 1/4" = 1'-0"

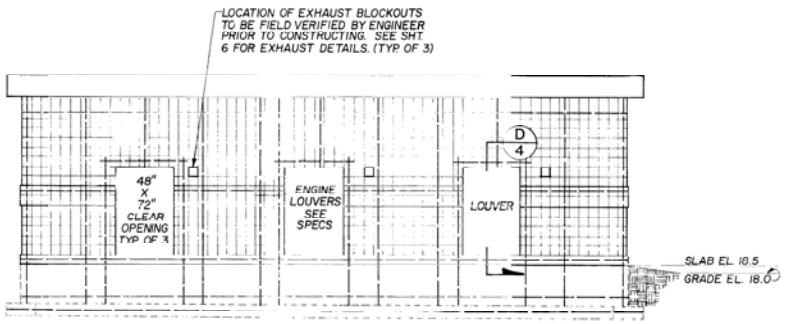


ANGLE SKID POSITIONERS 1/1



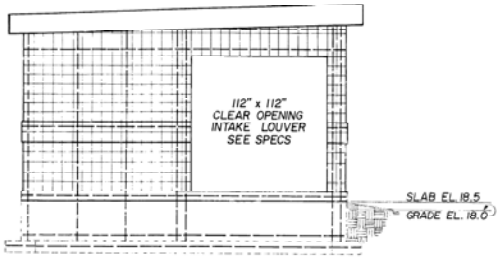
NOTES ON EAST ELEVATION ARE TYPICAL FOR ALL ELEVATIONS.

EAST ELEVATION
SCALE: 1/4" = 1'-0"

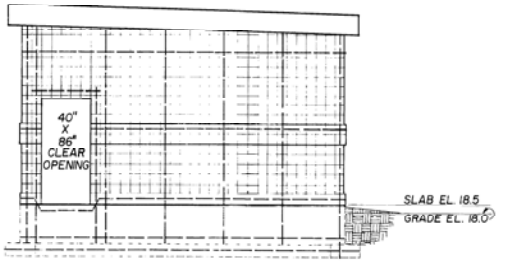


WEST ELEVATION
SCALE: 1/4" = 1'-0"

NOTE: ALL C.M.U. ABOVE LOUVER OPENINGS TO HAVE 1/2" x 1/8" DRIP GROOVE.

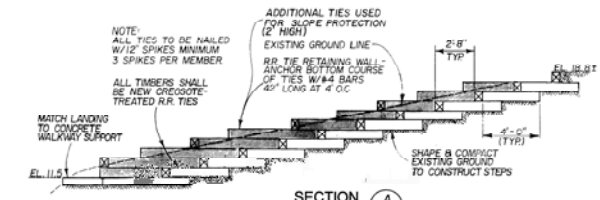


SOUTH ELEVATION
SCALE: 1/4" = 1'-0"

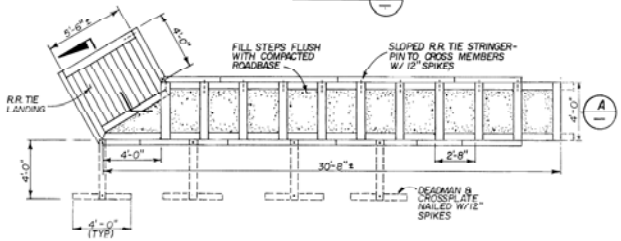


NORTH ELEVATION
SCALE: 1/4" = 1'-0"

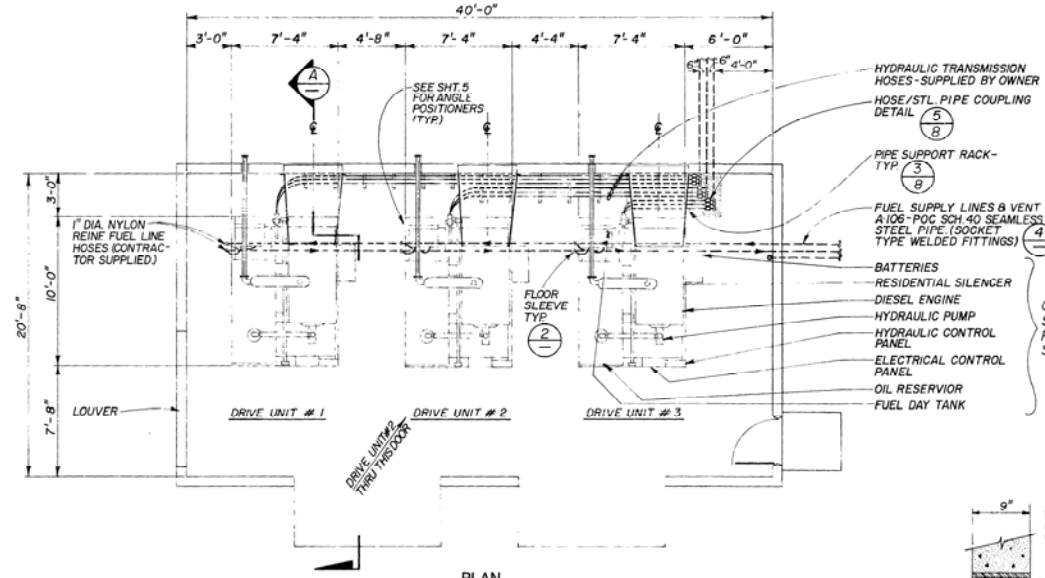
NOTE: ALL EXTERIOR MASONRY TO BE WATER PROOFED. (SEE SPECS.)



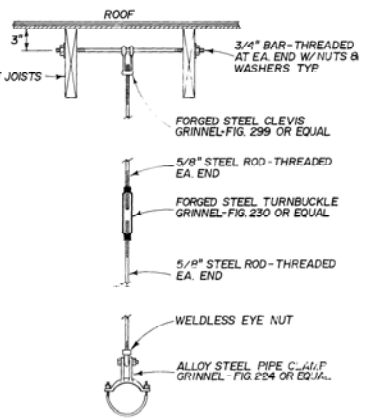
SECTION A/—



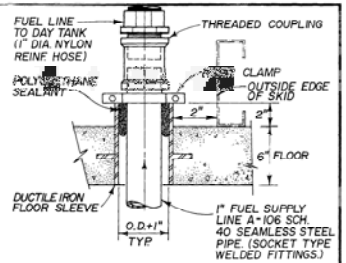
RAILROAD TIE STEPS 2/3
SCALE: 1/4" = 1'-0"



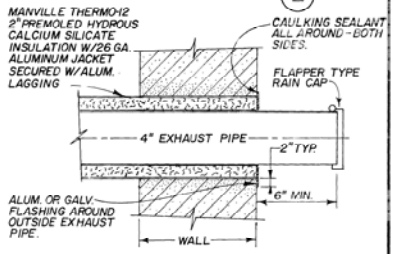
PLAN
SCALE 1/4"=1'0"



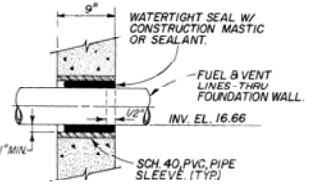
EXHAUST HANGER DETAIL 1/-



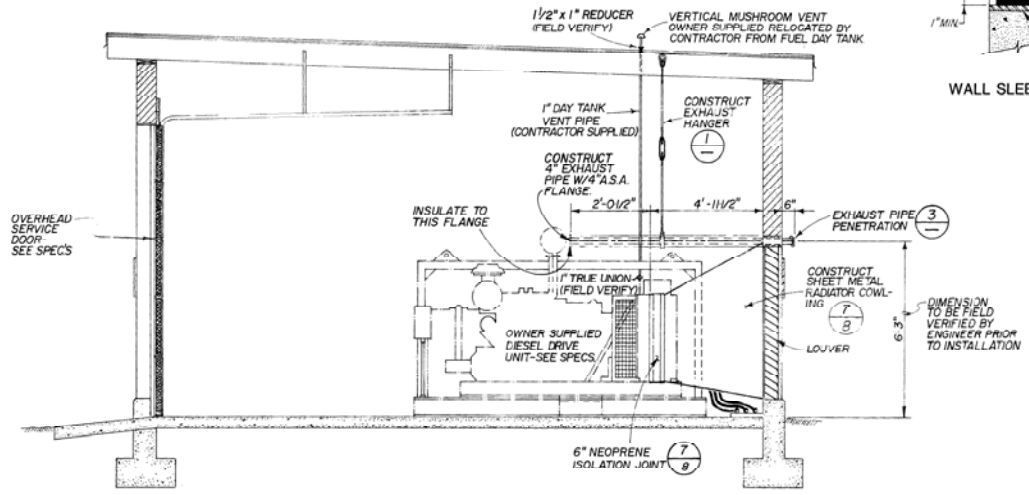
FLOOR SLEEVE DETAIL 2/-



EXHAUST PIPE PENETRATION DETAIL 3/-

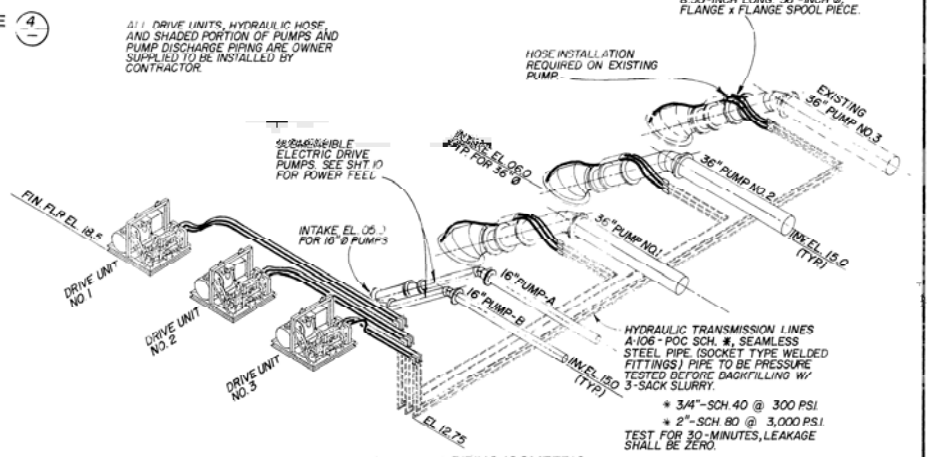


WALL SLEEVE 4/-

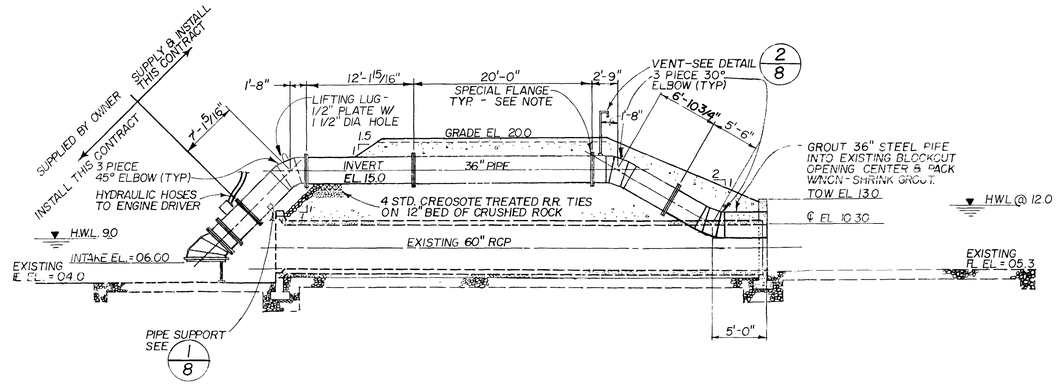


SECTION (TYP) A/-
SCALE 1/2"=1'0"

ALL DRIVE UNITS, HYDRAULIC HOSE AND SHADED PORTION OF PUMPS AND PUMP DISCHARGE PIPING ARE OWNER SUPPLIED TO BE INSTALLED BY CONTRACTOR.



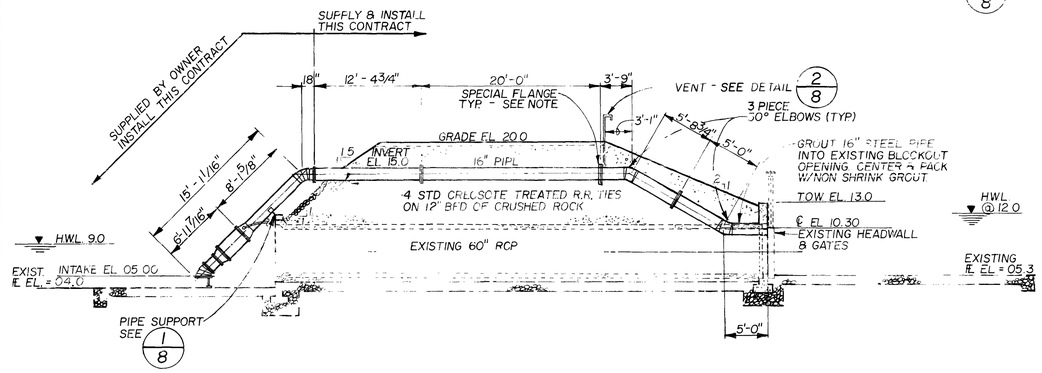
ILLUSTRATIVE PIPING ISOMETRIC



36" DIA. PUMP & DISCHARGE PIPING SECTION

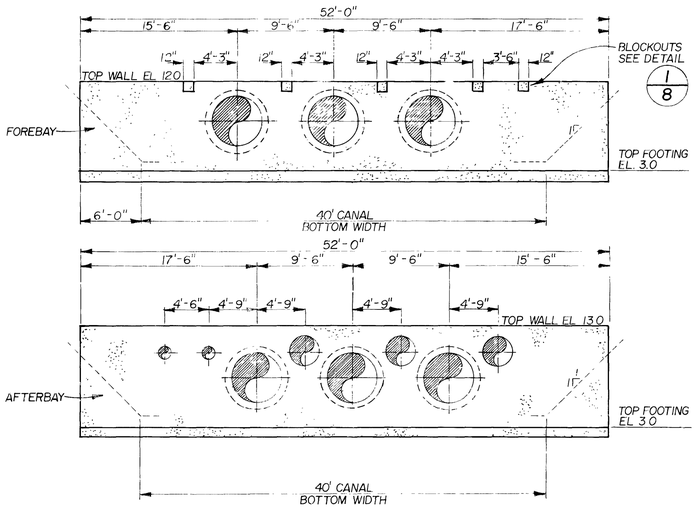
SCALE 1/8"=1'-0"

NOTE: SPECIAL PIPE FLANGES REQ'D. FOR CONTRACTOR SUPPLIED PIPING SEE DETAIL 6/8



16" DIA. PUMP & DISCHARGE PIPING SECTION

SCALE 1/8"=1'-0"



EXISTING HEADWALLS & BLOCKOUTS

N.T.S.

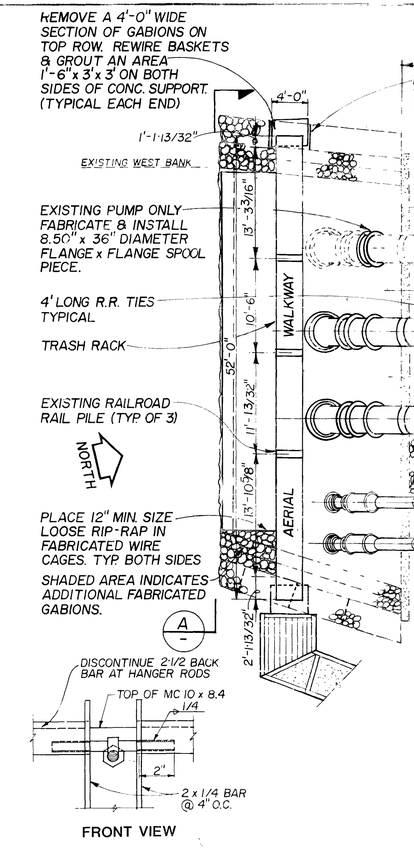
NOTES FOR THIS SHEET

1- RECOMPACT ALL EXCAVATION TO 95% STD. PROCTOR. AREA IS CAPPED W/6" OF BASE COARSE. SEGREGATE & REPLACE OVER EXCAVATED AREAS.

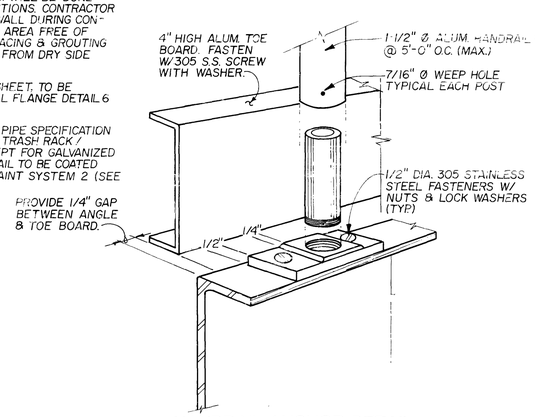
2- PIPE LAYING & GROUTING OPERATIONS ON DOWNSTREAM SIDE OF DAM WILL BE DONE UNDER HIGH WATER CONDITIONS. CONTRACTOR TO PLATE FACE OF HEADWALL DURING CONSTRUCTION & KEEP WORK AREA FREE OF STANDING WATER. ALL PLACING & GROUTING OPERATIONS TO BE DONE FROM DRY SIDE OF HEADWALL.

3- ALL PIPE FLANGES THIS SHEET TO BE CONSTRUCTED PER SPECIAL FLANGE DETAIL 6 ON SHEET 8

4- PIPING TO BE COATED PER PIPE SPECIFICATION SECTION. ALL METALS ON TRASH RACK / CATWALK ASSEMBLY EXCEPT FOR GALVANIZED DECK & ALUMINUM HANDRAIL TO BE COATED W/COAL TAR EPOXY PER PAINT SYSTEM 2 (SEE SPECIFICATIONS.)

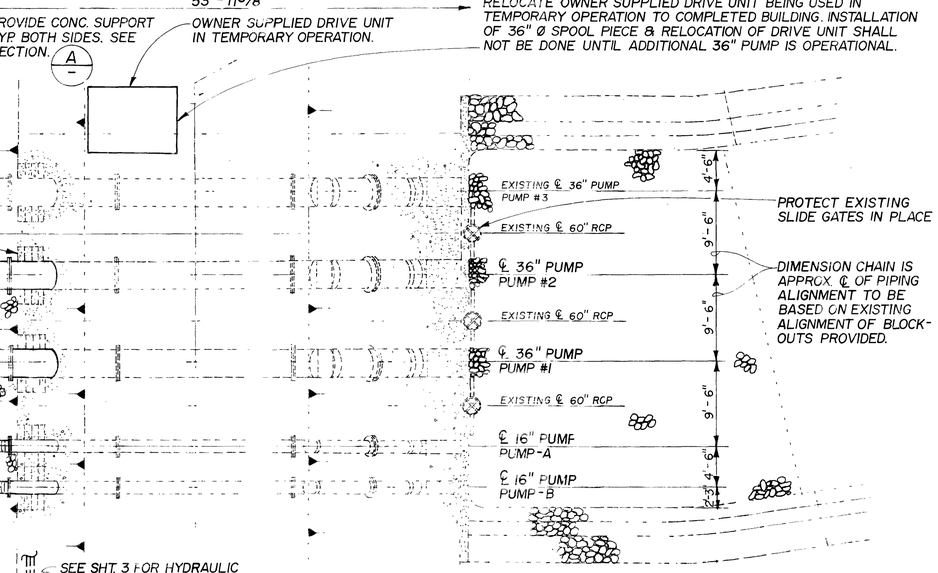


HANGER ROD DETAIL



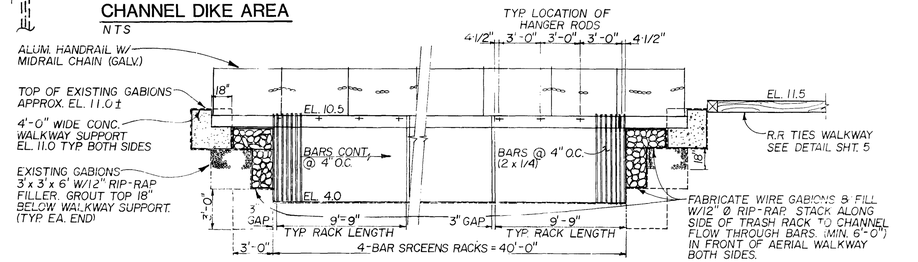
HANDRAIL ANCHOR DETAIL

NOTE: TEMPORARY PUMPING FACILITIES IN OPERATION BY COUNTY ON WEST BANK OF CHANNEL. ALL ACCESS TO JOBSITE BY CONTRACTOR SHALL BE FROM THE EAST. CONTRACTOR SHALL RELOCATE OWNER SUPPLIED DRIVE UNIT BEING USED IN TEMPORARY OPERATION TO COMPLETED BUILDING. INSTALLATION OF 36" Ø SPOOL PIECE & RELOCATION OF DRIVE UNIT SHALL NOT BE DONE UNTIL ADDITIONAL 36" PUMP IS OPERATIONAL.

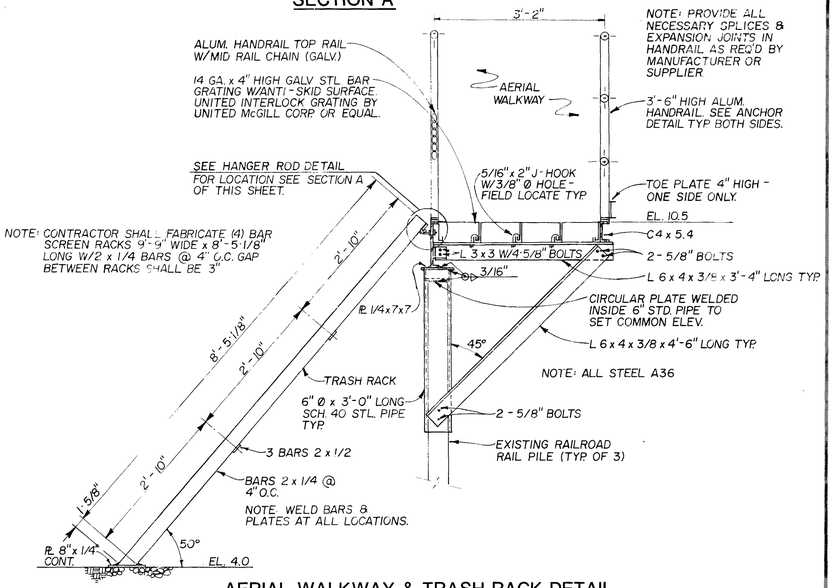


CHANNEL DIKE AREA

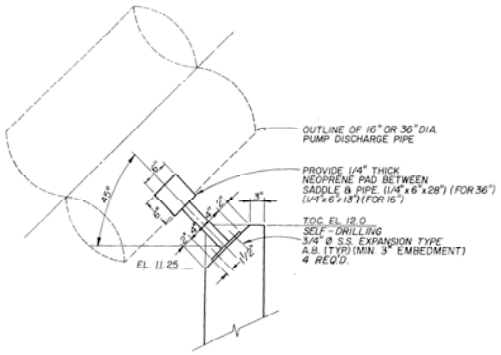
N.T.S.

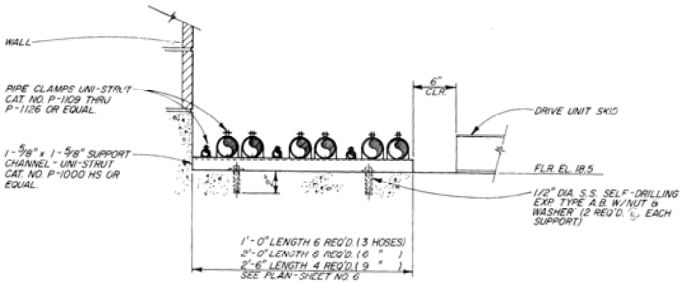


SECTION A



AERIAL WALKWAY & TRASH RACK DETAIL



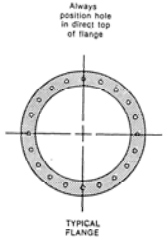


PIPE SUPPORT RACK 3/6

NOTE: PIPE CLAMPS & SUPPORT CHANNELS TO BE HOT-DIPPED GALVANIZED. NUTS, SPRINGS & WASHERS SHALL BE ELECTRO-GALVANIZED.

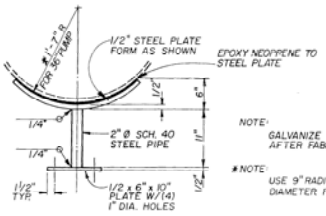
FLANGE ARRANGEMENT

NOMINAL PIPE SIZE IN inches	NO. OF HOLES	DIAMETER OF HOLES inch	DIAMETER OF HOLES mm	BOLT CIRCLE DIAMETER inch	BOLT CIRCLE DIAMETER mm	OUTER DIAMETER inch	OUTER DIAMETER mm
6	12	.203	5.18	8.25	210	9.0	229
8	8	.5625	14.3	10.75	273	12.75	324
12	12	.5625	14.3	14.875	378	16.0	406
16	12	.5625	14.3	19.0	483	20.8125	529
18	16	.5625	14.3	20.25	514	22.5	572
20	18	.5625	14.3	22.0	559	24.125	613
24	20	.5625	14.3	26.375	670	28.625	727
30	24	.5625	14.3	32.75	832	34.125	867
36	28	.75	19.05	40.625	1032	43.125	1095
42	30	.75	19.05	45.5	1156	49.5	1257

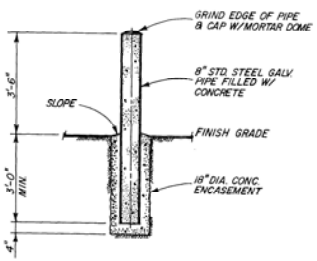


SPECIAL FLANGES 6/7

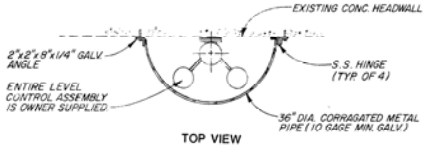
MIN. FLANGE "THICKNESS" 3/4"



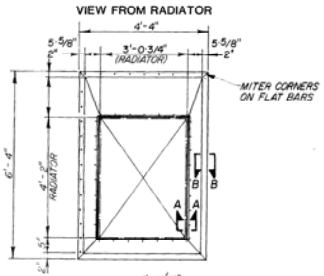
PIPE SUPPORT DETAIL 1/7

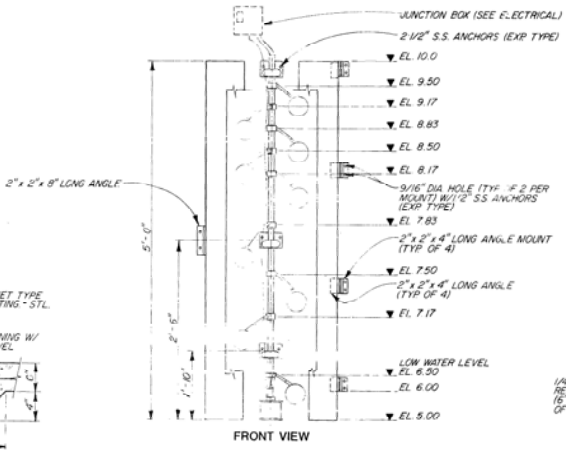


GUARD POST (BOLLARD) 4/3

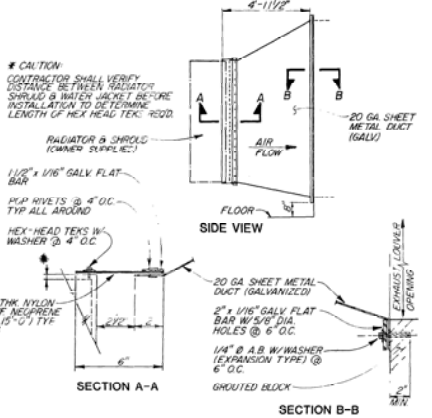


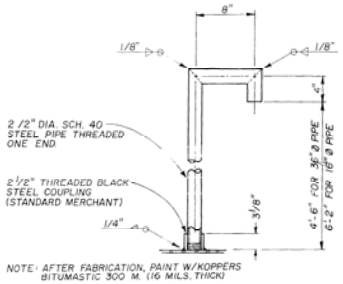
TOP VIEW



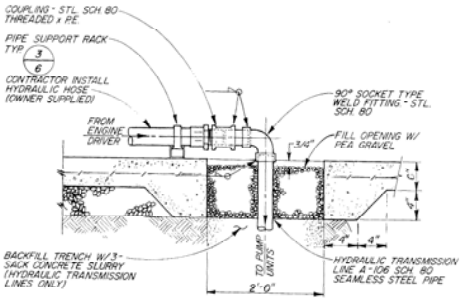


FRONT VIEW





VENT DETAIL 2/7

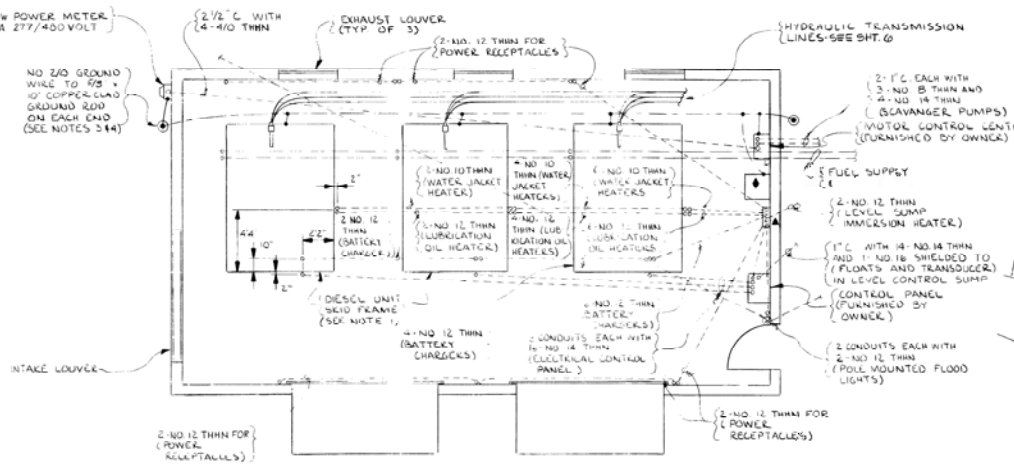


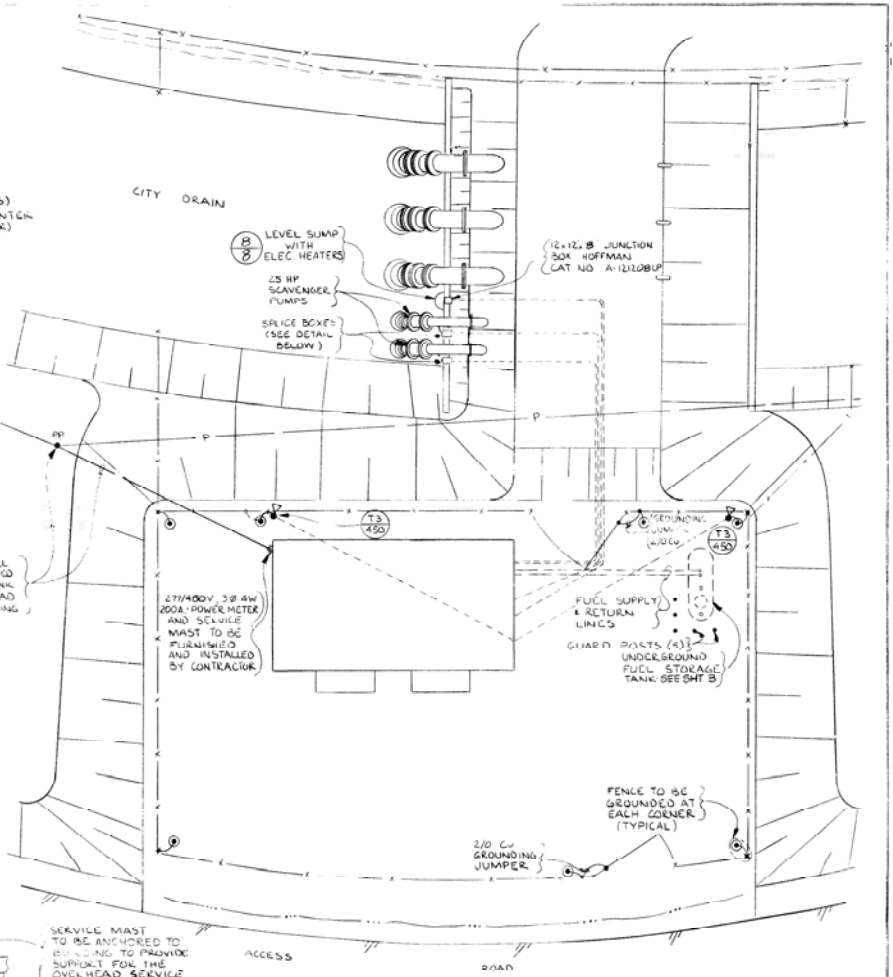
HOSE/STEEL PIPE COUPLING 5/6

NOTE: SEE SHEET 2 FOR ISOMETRIC LAYOUT OF HYDRAULIC PIPING. NTS

FLOAT SWITCH MOUNTING DETAIL 7/10

RADIATOR/EXHAUST SHROUD 8/6



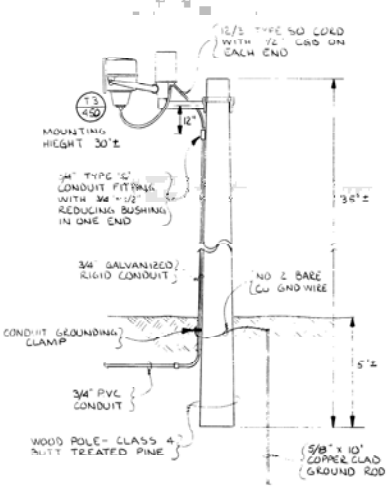


NOTES:

1. DIESEL UNIT SHOWN ARE TYPICAL FOR THE CONDUIT RISERS AT EACH DIESEL UNIT SKID FRAME. THE EXACT LOCATION OF EACH DIESEL UNIT SKID FRAME TO BE DETERMINED FROM BUILDING LAYOUT DRAWINGS BEFORE CONDUIT IS INSTALLED.
2. ALL UNDERGROUND PVC CONDUIT TO CONTAIN A SIZED GROUND WIRE SIZED PER THE NEC.
3. ALL GROUNDING CONNECTIONS BELOW GRADE TO BE MADE BY THERMITE PROCESS.
4. A NO. 2/0 GROUND WIRE PIGTAIL IS TO BE PROVIDED AND CONNECTED TO EACH DIESEL UNIT SKID FRAME, THE MOTOR CONTROL CENTER, THE SOLA TRANSFORMER, AND THE 3Ø POWER METER.
5. ◉ 5/8 x 10' COPPERCLAD GROUND ROD. DRIVEN FOR ENTIRE LENGTH.
6. —— 2/0 GROUND WIRE.
7. ------ CONDUIT BELOW GRADE. PVC CONDUIT WITH GALVANIZED RIGID CONDUIT RISERS. 3/4 DIA. UNLESS OTHERWISE NOTED.
8. ◆ SOLA TRANSFORMER, 480V- 120/240V, 1Ø, DRY TYPE, FLOOR MOUNT SQ 'D' CAT. NO. 50S3H.
9. PP. EXISTING POWER POLE.
10. OP-EXISTING OVERHEAD POWER LINE.
11. ▲ PANEL 'A', 120/240V SQ 'D' CAT. NO. QO 40M 225 WITH COVER QOC 42 US
12. LEVEL CONTROL UNITS TO BE FURNISHED BY THE OWNER. THIS DOES NOT INCLUDE THE LEVEL SUMP ENCLOSURE, THE IMMERSED ELECTRIC HEATER CONNECTING WIRE OR CONDUIT OR OTHER MISCELLANEOUS MATERIAL. THE CONTRACTOR SHALL FURNISH AT NO ADDITIONAL CHARGE TO THE OWNER, ALL REQUIRED MATERIAL TO COMPLETE THE INSTALLATION AS SPECIFIED.
13. LEVEL SUMP ELECTRIC HEATER, FAST HEAT MFG CO MODEL NO 42-5 1000 WATT 120V

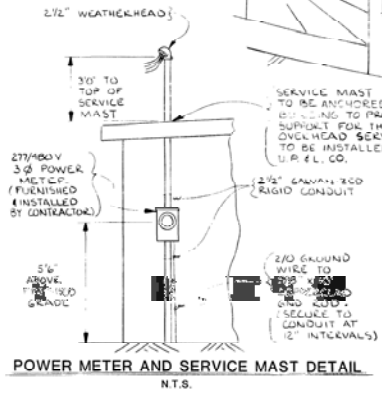
UNDERGROUND CONDUIT AND GROUNDING PLAN

SCALE: 1/8" = 1'0"



POLE MOUNTED FLOOD LIGHT DETAIL

N.T.S.

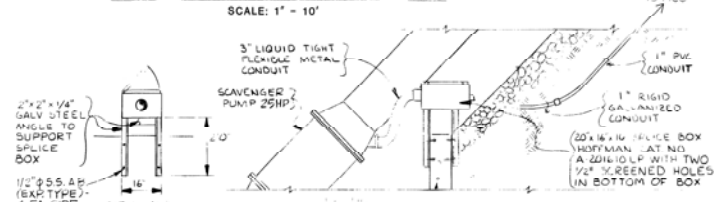


POWER METER AND SERVICE MAST DETAIL

N.T.S.

SITE GROUNDING AND ELECTRICAL PLAN

SCALE: 1" = 10'



SCAVENGER PUMP SPLICE BOX DETAIL

SCALE: 1/2" = 1'0"

REGISTERED PROFESSIONAL ENGINEER No. 3234 FREDERICK C. KIDSTON STATE OF UTAH

REQUIREMENTS AND SCHEDULE

1. THE EXISTING TEMPORARY PUMPING CONDITIONS SHOWN ON THIS SHEET ARE REQUIRED TO PUMP THE FLOW IN THE CITY DRAIN OVER THE DIKE. CAPACITY IS AVAILABLE TO PUMP MAXIMUM ANTICIPATED STORM FLOW. OPERATION AND MAINTENANCE OF SAID PUMPING EQUIPMENT IS BY OWNER'S PERSONNEL.

2. CONTRACTOR SHALL DISMANTLE AND/OR MOVE THE TEMPORARY 24-INCH PUMPING FACILITIES AS REQUIRED TO ACCOMPLISH THE INSTALLATION OF THE FACILITIES SHOWN IN THIS CONTRACT PROVIDED THAT COMPLIANCE WITH NOTE 3 IS ACHIEVED.

3. SUFFICIENT PUMPING CAPACITY MUST REMAIN OPERATIONAL DURING CONSTRUCTION OF THE FACILITIES SHOWN IN THIS CONTRACT TO HANDLE ANTICIPATED FLOWS. FOR PURPOSES OF THIS CONTRACT, SUFFICIENT OPERATIONAL PUMPING CAPACITY IS DEFINED AS FOLLOWS:

   A) AT ALL TIMES, CAPACITY EQUAL TO ONE 36-INCH PUMP PLUS ONE 24-INCH TEMPORARY PUMP.

   B) IF RAIN IS FORECAST WITHIN THE 48-HOUR WEATHERCAST, CAPACITY EQUAL TO ONE 36-INCH PUMP PLUS TWO 24-INCH TEMPORARY PUMPS.

   C) AS SOON AS TWO 36-INCH PUMPS ARE OPERATIONAL, ALL 24-INCH PUMPS CAN BE PERMANENTLY DISMANTLED. THE EXISTING 36-INCH PUMP QUALIFIES IN A & B ABOVE.

4. THE TEMPORARY 24-INCH PUMPING FACILITIES, AS WELL AS THE DRIVE UNIT FOR THE 36-INCH PUMP, ARE EQUIPMENT RENTED BY THE OWNER. THE OWNER DESIRES TO PLACE THE PERMANENT EQUIPMENT INTO OPERATION IN A TEMPORARY MODE IN ORDER TO RELEASE THE RENTAL EQUIPMENT.

5. WORK WHICH MUST BE ACCOMPLISHED PRIOR TO RELEASING THE 24-INCH PUMPING EQUIPMENT AND WORK WHICH THE CONTRACTOR MUST ACCOMPLISH ACCORDING TO THE SCHEDULE LISTED IN NOTE 6 IS AS FOLLOWS:

   A) COMPLETE INSTALLATION AND TESTING OF ALL SCHEDULE 40, 3/4-INCH AND SCHEDULE 80, 2-INCH STEEL HYDRAULIC LINES.

   B) FABRICATION AND INSTALLATION OF ONE OF THE TWO 36-INCH PUMP DISCHARGE PIPING ASSEMBLIES (INCLUDING PIPE SUPPORT AND VENT) REQUIRED BY THIS CONTRACT.

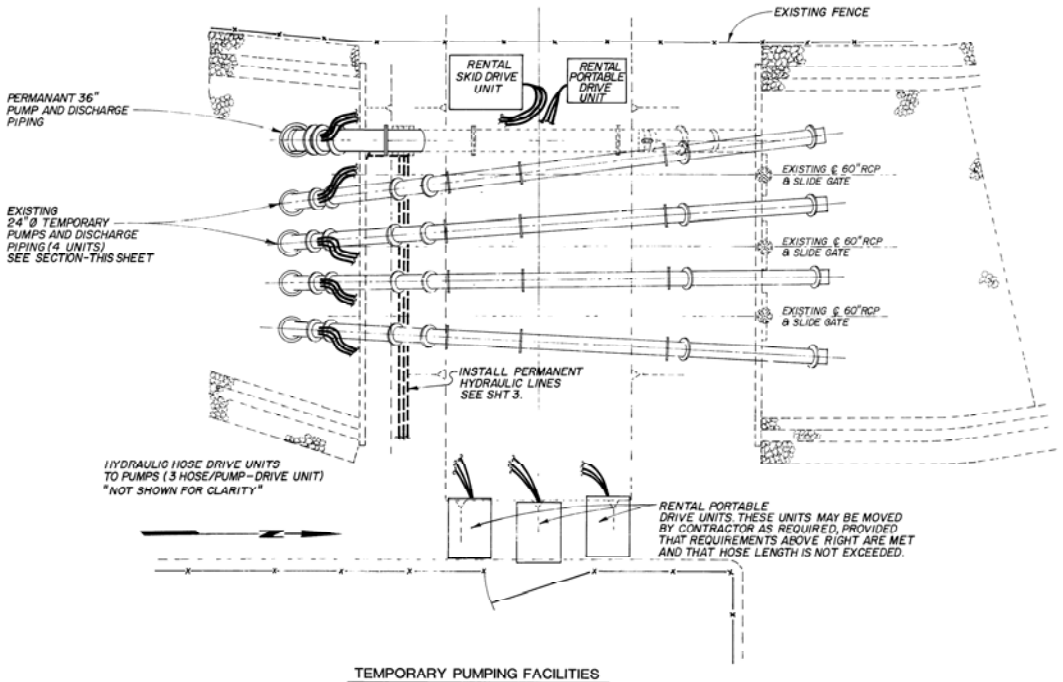
   C) CONNECTION OF THE 36-INCH PUMP DRIVE UNITS, INCLUDING HOSES, TO THE PUMPS. THE DRIVE UNITS CAN BE PLACED IN ANY LOCATION DESIRED BY THE CONTRACTOR PROVIDED THAT THE HYDRAULIC HOSES REACH THE PIPING. THE UNITS NEED NOT BE IN THE BUILDING FOR THIS TEMPORARY MODE.

6. THE SCHEDULE FOR COMPLETION OF THE WORK LISTED IN NOTE 5 SHALL BE AS FOLLOWS AND SHALL BE SUBJECT TO THE LIQUIDATED DAMAGES SPECIFIED IN SECTION 01012 OF THE SPECIFICATIONS:

   * FOR 5A - 10 DAYS FROM NOTICE-TO-PROCEED

   * FOR 5B AND 5C - 14 DAYS FROM NOTICE-TO-PROCEED

7. UPON COMPLETION OF THE WORK LISTED IN NOTE 5, OWNER WILL ISSUE A WRITTEN NOTICE OF SUBSTANTIAL COMPLETION FOR THE WORK FOR NOTE 5. IF WEATHER CONDITIONS PREVENT RELOCATION OR DISMANTLING OF THE 24-INCH PUMPS DUE TO NEED FOR PUMPING CAPACITY, EQUIVALENT TIME EXTENSION WILL BE PROVIDED.



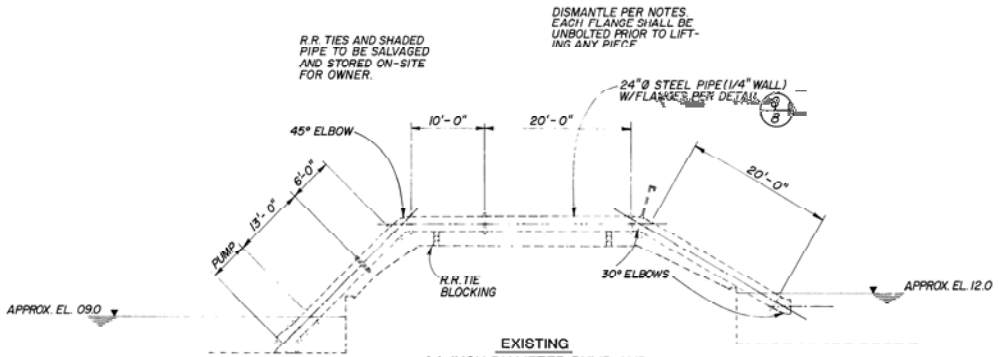
TEMPORARY PUMPING FACILITIES

NOTES:

1. CONTRACTOR SHALL DISMANTLE 24" DIAMETER PUMPING EQUIPMENT INCLUDING PUMPS, PIPING AND DRIVE UNITS, SAID EQUIPMENT SHALL THEN BE NEATLY STORED ON-SITE BY THE CONTRACTOR. SUBSEQUENTLY, CONTRACTOR SHALL LOAD SAID 24" DIAMETER PUMPING EQUIPMENT ON THREE OWNER-SUPPLIED FLAT BED TRUCKS. INCLUDED IN THIS WORK ITEM SHALL BE ONE SKID DRIVE UNIT FOR THE 36" PUMP AS WELL AS 60 FEET OF 36" DIAMETER PIPE. CONTRACTOR WILL BE RESPONSIBLE FOR HOISTING AND POSITIONING LOADS ON THE TRAILER. SECURING THE LOADS ON THE TRAILER WILL BE THE RESPONSIBILITY OF OWNER.

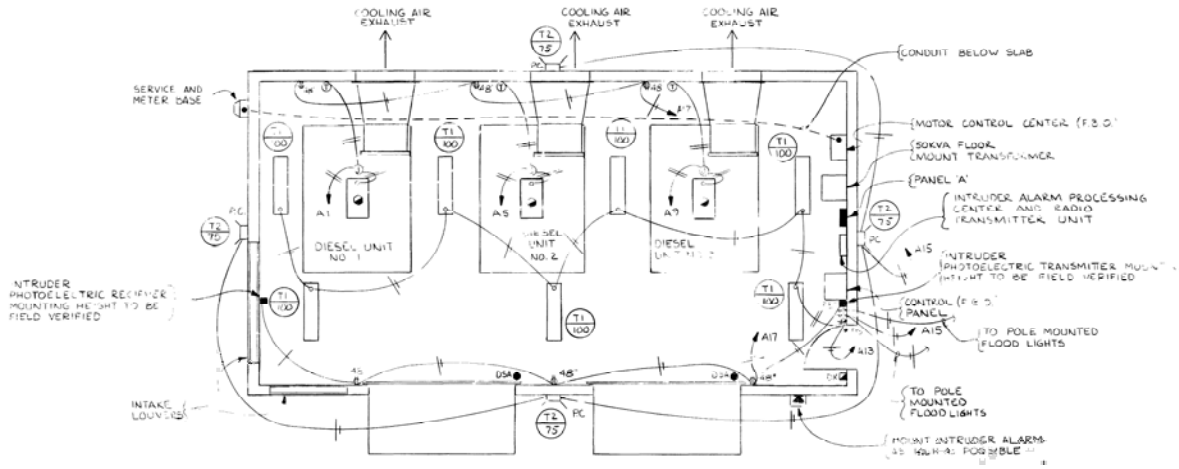
2. THE 24" DIAMETER PIPE AND FITTINGS OWNED BY THE COUNTY WILL BE STORED ON-SITE FOR THE DURATION OF THE WORK.

3. PIPE AND FITTINGS SHALL BE LIFTED WITH NYLON STRAPS. CHAIN OR WIRE ROPE WILL NOT BE ALLOWED.



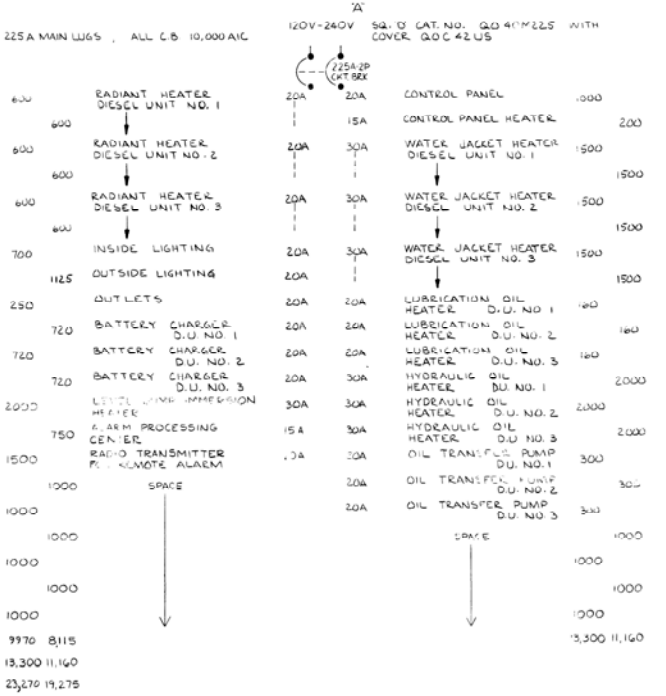
EXISTING
24-INCH DIAMETER PUMP AND DISCHARGE PIPING (TYPICAL)

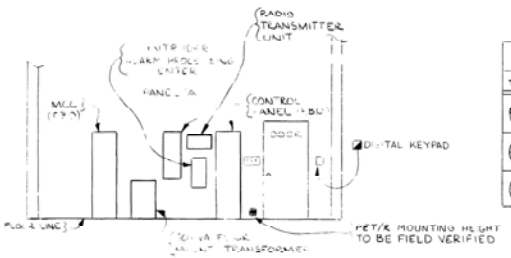
NOTE: DIESEL UNITS NO. 1, 2, AND 3 ARE FURNISHED BY OWNER



PUMPHOUSE ELECTRICAL PLAN

SCALE: 1/4" = 1'0"





ELECTRICAL PANEL MOUNTING DETAIL

SCALE: 1/4" = 1'0"

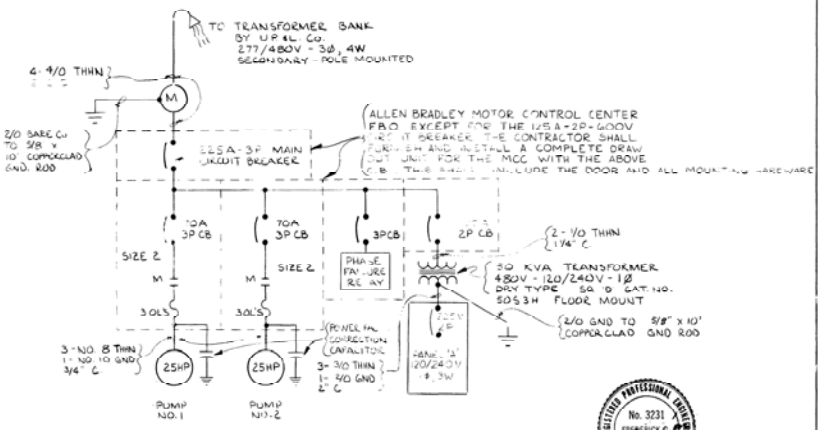
9. ● DSA - DOOR SWITCH OVERHEAD TYPE SENTROL CAT. NO. 2207A-H
10. ✳ DSB - DOOR SWITCH TYPE SENTROL CAT. NO. 1088T
11. ■ PE - PHOTOELECTRIC TRANSMITTER/RECIEVER PACKAGE ADEMCO CAT. NO. 1338
12. ◪ DK - DIGITAL KEYPAD ADEMCO CAT. NO. 5240
13. APC - ALARM PROCESSING CENTER ADEMCO CAT. NO. 1023
14. ▲ SS - SONALERT SIREN ADEMCO CAT. NO. 702
SIREN ENCLOSURE ADEMCO CAT. NO. 716
TAMPER SWITCHES ADEMCO CAT. NO. 19
15. F.O. - FURNISHED BY OWNER

LIGHTING FIXTURE SCHEDULE

TYPE	MANUFACTURER, CAT. NO., & DESCRIPTION	MOUNTING	LAMPS
T1 100	LITHONIA CAT. NO. 240 WITH 120V BALLAST	SUSPENDED FROM CEILING BY CHAIN 10' ABOVE FLOOR	2-40 W FLUORESCENT
T2 75	HI-TEK TWP 70S 120 PE WITH PHOTO CELL	WALL SURFACE	1-70W H.P.S.
T3 450	WIDE-LITE FS-400-D-QV WITH POLYCARBONATE LENS COMPLETE WITH FACTORY MOUNTING BRACKET	POLE MOUNT	1-400 W H.P.S.

NOTES:

1. ◉ RADIANT HEATER - CHROMALOX CAT. NO. RBC-31220 PCN 115051, 240V, 1.2 KW - SUSPEND HEATERS BY CHAIN 6" BELOW CEILING
2. Ⓣ THERMOSTAT - CHROMALOX CAT. NO. WX-80, PCN 263177, 40°-80°F
3. PC PHOTO CELL CONTROLED LIGHTING FIXTURE
4. ⊖ DUPLEX OUTLET - MOUNTED 48" ABOVE FINISHED FLOOR
5. $ LIGHT SWITCH
6. ◎ JUNCTION BOX - CEILING MOUNTED
7. D.U. - DIESEL UNITS
8. ALL ITEMS NOT SHOWN AS FURNISHED BY OWNER SHALL BE FURNISHED BY THE CONTRACTOR.



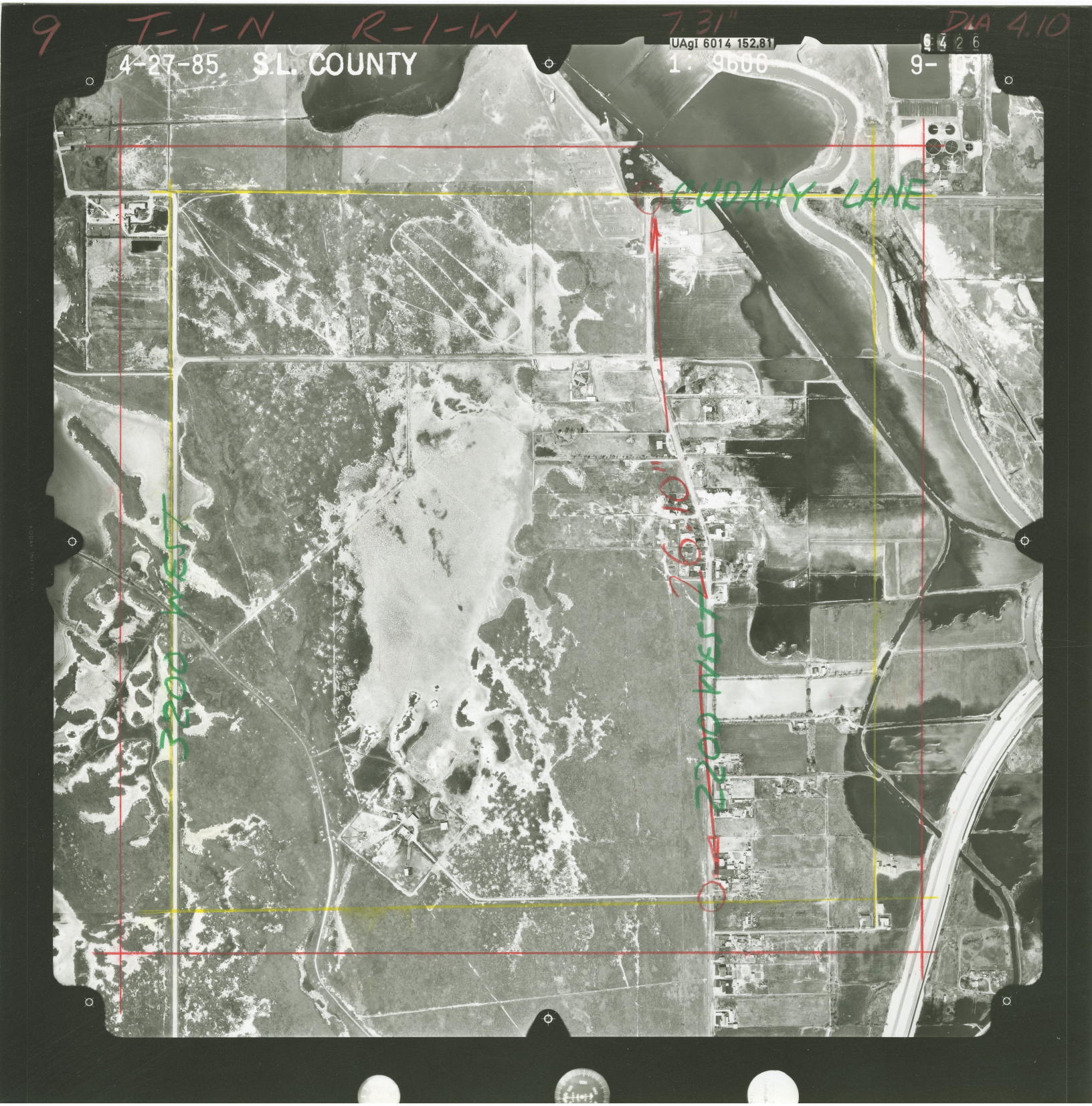
SINGLE LINE DIAGRAM

REGISTERED PROFESSIONAL ENGINEER No. 3231 FREDERICK G. HOSTON STATE OF UTAH

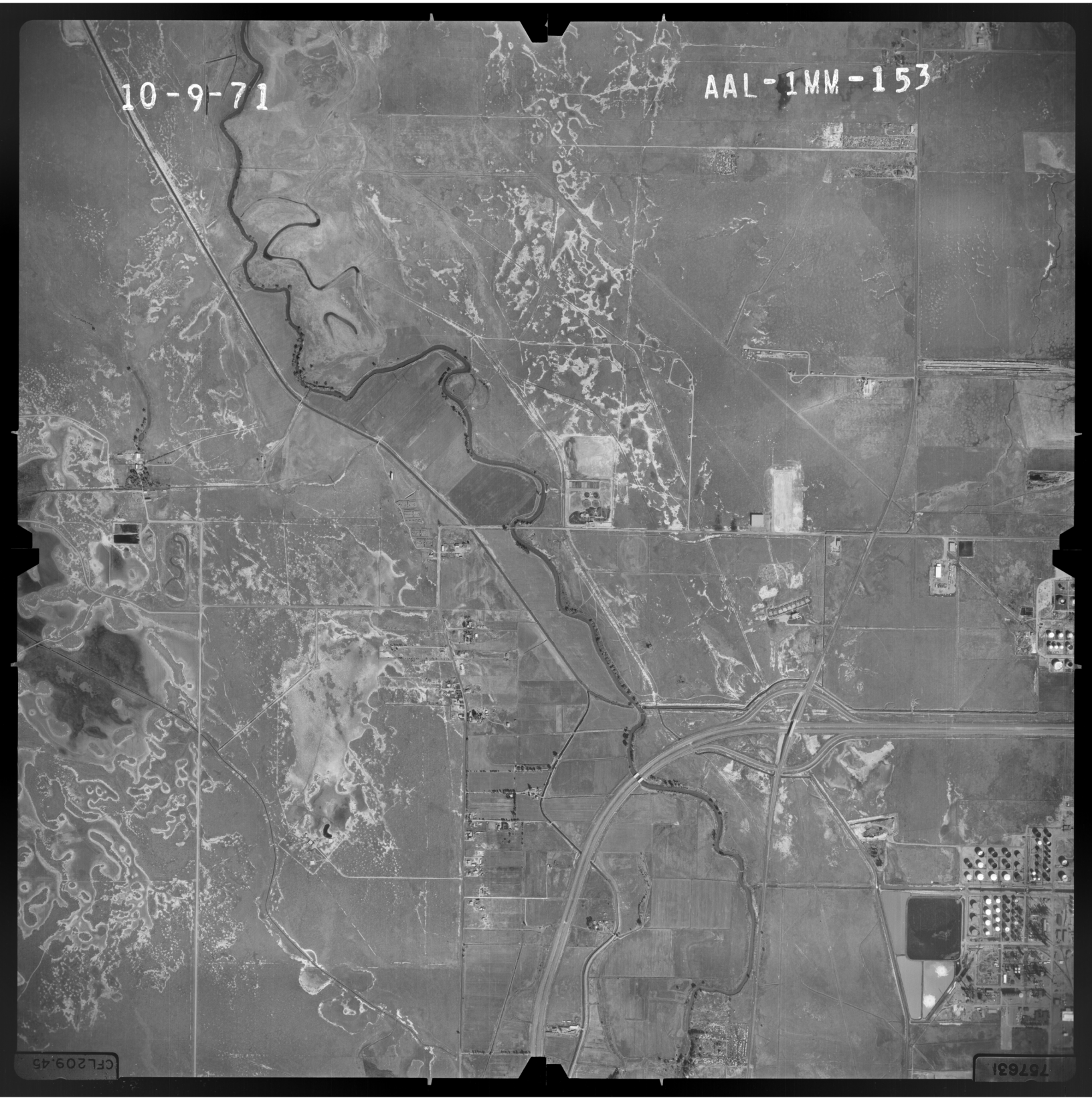
APPENDIX D

Historic Aerial Images

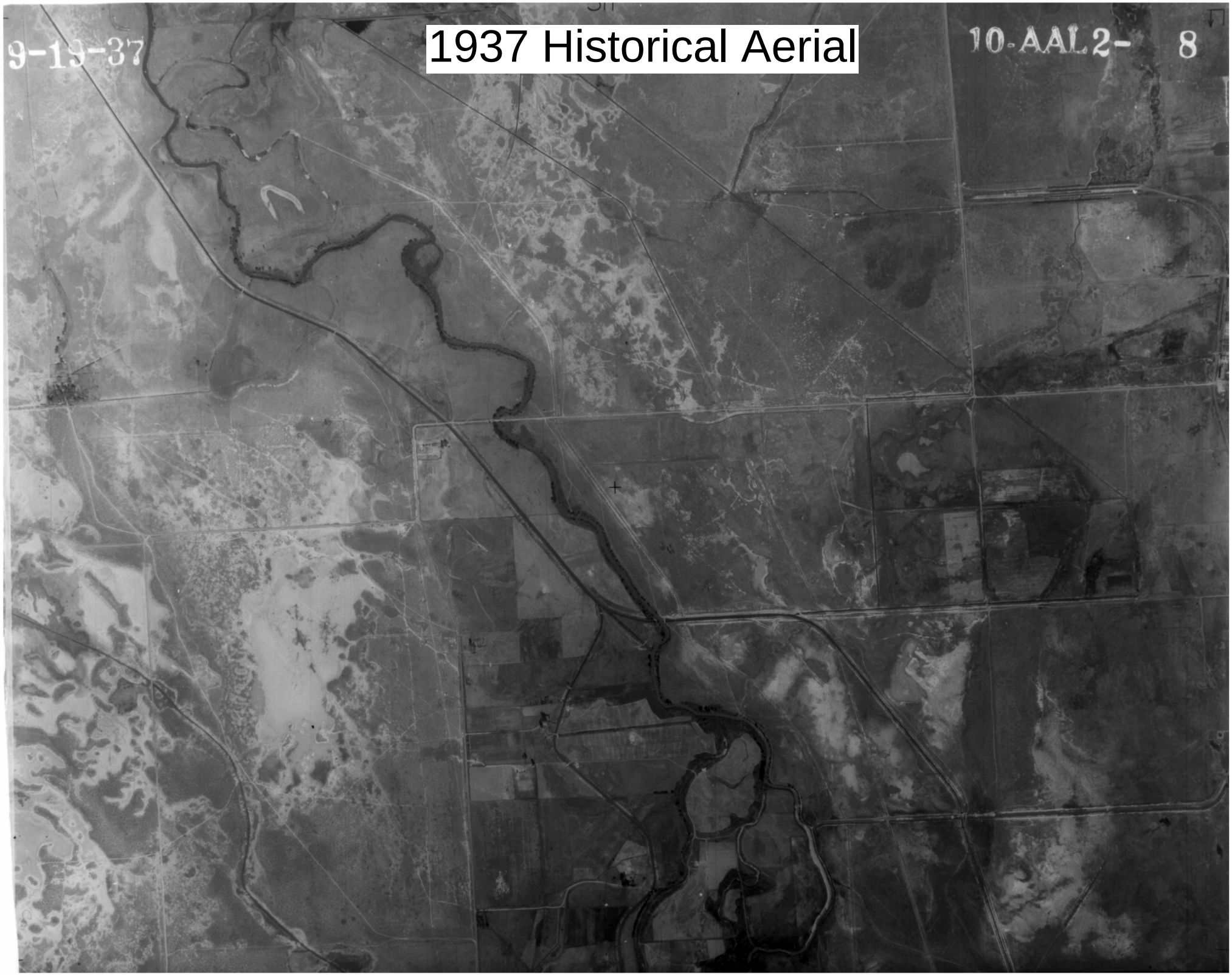
1985 Historical Aerial



1971 Historical Aerial



1958 Historical Aerial


9-13-37
1937 Historical Aerial
10-AAL2- 8

APPENDIX E

Hydrologic Subbasin Parameters

Existing Conditions Subbasin Parameters

Subbasin ID	Area (ac)	CN Value	% Impervious	Lag Time (hr)	Peak Runoff (cfs)
CD-01	294.02	81.6	14	0.40	58.22
CD-02	74.86	80.5	70	0.30	66.91
CD-03	950.21	77.5	20	0.70	152.39
CD-04	167.54	75.2	25	0.40	45.62
CD-05	1393.20	75.9	45	0.78	437.15
CD-06	931.08	72.9	62	0.59	483.40
CD-07	119.19	75.3	50	0.39	65.39
CD-08	122.72	78.3	41	0.39	56.40
CD-09	374.87	73.7	40	0.58	127.54
CD-10	55.27	48.8	5	0.39	4.38
CD-11	42.64	72.5	50	0.41	22.71
CD-12	30.20	71.5	70	0.37	23.68
CWA1-01	179.43	74.8	50	0.45	89.84
CWA1-02	87.84	74.3	37	0.44	32.95
CWA1-03	127.18	75.3	32	0.42	42.88
CWA1-04	146.41	74.3	35	0.40	55.52
CWA1-05	152.74	75.2	40	0.47	59.98
CWA1-06	475.83	72.6	65	1.00	176.61
CWA2-01	227.62	73.0	50	0.43	117.25
CWA2-02	73.82	69.8	30	0.40	23.93
CWA2-03	26.49	75.6	20	0.33	6.47
CWA3-01	135.37	73.1	73	0.44	99.98
CWA3-02	282.95	71.9	80	0.55	199.21
CWA3-03	160.40	72.0	81	0.54	115.62
CWA3-04	79.78	70.6	92	0.41	78.25
CWA3-05	102.15	74.9	60	0.42	64.34
CWA3-06	27.84	71.1	85	0.35	27.63
CWA3E-01	212.83	71.2	80	0.57	146.34

APPENDIX F

Salt Lake City Airport Storm Drain Master Plan

Sub-area U—General Aviation Area, Utah Air National Guard (UANG) Base

It is recommended that runoff from this sub-area be conveyed by a gravity system discharging to a detention basin located on the UANG base. Runoff to the City Drain should be limited by the capacity of the existing 48-inch culvert under 2200 West at approximately 1000 North.

As discussed in chapter 4, the existing 48-inch pipeline conveying offsite runoff through airport property currently operates at capacity (40 cfs) and experiences flooding during the 10-year, 3-hour storm event. Projected future additional offsite storm runoff generated south of Interstate 80 will increase the peak offsite discharge to approximately 60 cfs. Salt Lake City drainage capital improvement plans recommend a new conduit and open-channel ditch system to convey runoff generated south of Interstate 80 around the study area and to abandon the existing 48-inch pipe. To convey the projected future storm runoff from airport property and prevent flooding, portions of this pipeline should be upgraded from a 48-inch-diameter to a 60-inch-diameter.

Remaining improvements recommended for sub-area U are as follows:

- A new 24-inch trunkline should be designed to provide conveyance for future development north of the ANG base.
- It is recommended that the existing detention basin be increased in size to an estimated usable detention volume of 18 ac-ft. Expansion of the detention facility could alleviate existing flooding problems along the 48-inch trunkline by reducing backwater effects.
- The capacity of only one of the two existing 48-inch culverts under 2200 West should be necessary to convey runoff to the City Drain. The proposed system, in conjunction with one 48-inch culvert, should limit the flow to the City Drain at 1000 North to approximately 40 cfs. City requirements of 0.2 cfs/acre limit the total discharge from this sub-area to 63 cfs.

Sub-area V—Future Development, Southwest Reservation Center

It is recommended that this sub-area be drained using a new gravity drainage system. No drainage facilities currently exist. Proposed drainage improvements to sub-area V include:

- A new detention basin adjacent to an existing 36-inch culvert under 2200 West (1450 North) draining to the City Drain. The detention basin should have an estimated usable detention storage of approximately 31 ac-ft, a bottom elevation of 4207.00, and occupy approximately 4.5 acres of land. The basin should be designed with excess capacity to allow for sedimentation. The proposed drainage improvements should limit the discharge to the City Drain to approximately 16 cfs. City requirements of 0.2 cfs/acre limit the total discharge from this sub-area to the City Drain to 47 cfs. A new UPDES permit will be required for this outfall.
- Runoff from the study area between the proposed airplane storage area and the McDonnell Douglas facility should be conveyed by a new 30-inch trunkline system.
- A new trunkline system should be designed to convey the 10-year, 3-hour storm event from north of the proposed detention facility.

Additional development since the 1998 master plan was completed has increased the flow from 16 cfs to 29 cfs from this portion of the airport.

APPENDIX G

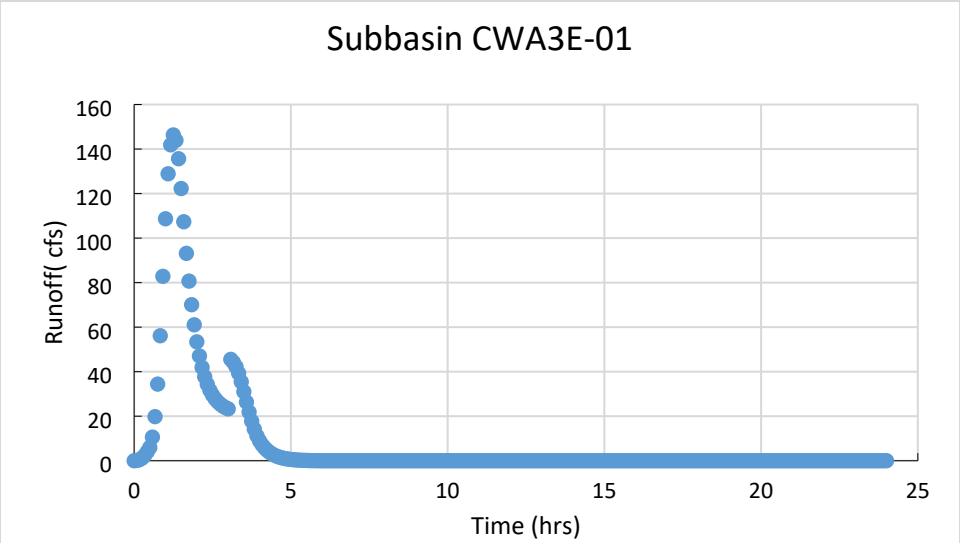
Inflow Hydrographs

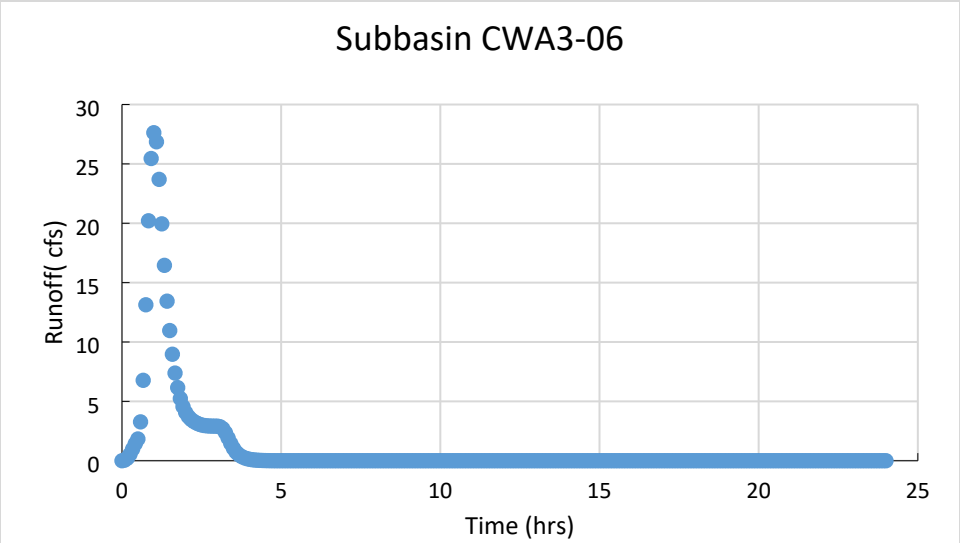
	Subbasin CWA3E-01	Subbasin CWA3-06	Subbasin CWA3-05	Link 24	Subbasin CWA3-03	Node 46	Subbasin CWA1-01	Subbasin CWA3-02	Subbasin CWA3-01	Subbasin CWA2-03	Link 12	Link 10	Link 9	Subbasin CD-10	Subbasin CD-08	Subbasin CD-07	Subbasin CD-05	Link 22	Subbasin CD-04	Subbasin CD-03	Link 23	Subbasin CD-01	Northwest Canal
Peak Flow:	146	28	64	78	116	113	90	199	100	6	33	24	117	4	56	65	40	121	46	29	66	58	248
Reach:	CWA3-EXT	CWA3	CWA3	CWA3	CWA3	CWA1	CWA1	CWA2	CWA2	CWA2	City Drain	City Drain	City Drain	City Drain	City Drian	City Drain	City Drain	City Drain	City Drain	City Drain	City Drain	City Drain	City Drain
Station:	4699	80508	79317	77210	76266	71997	70686	71561	69946	68916.62	68056.81	65879	65721.24	64367	63155.49	61793.16	52785	50692.24	45487	48376	40938	36461	33178
Time (hrs)	**Runoff(cfs)**	**Runoff(cfs)**	**Runoff(cfs)**	**Runoff(cfs)**	**Runoff(cfs)**	**Runoff(cfs)**	**Runoff(cfs)**	**Runoff(cfs)**	**Runoff(cfs)**	**Runoff(cfs)**	**Runoff(cfs)**	**Runoff(cfs)**	**Runoff(cfs)**	**Runoff(cfs)**	**Runoff(cfs)**	**Runoff(cfs)**	**Runoff(cfs)**	**Runoff(cfs)**	**Runoff(cfs)**	**Runoff(cfs)**	**Runoff(cfs)**	**Runoff(cfs)**	**NW Drain**
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	213.26
0.0833	0.1160	0.0510	0.0860	0	0.1020	0.0000	0.1080	0.1690	0.1260	0.0130	0.0000	0	0	0.0050	0.0840	0.0990	0.0000	0.0000	0.0660	0.0000	0.0000	0.0650	213.29
0.1667	0.4630	0.2110	0.3500	0	0.4020	0.0000	0.4350	0.6700	0.5060	0.0550	0.0258	0.0253	0.0969	0.0190	0.3420	0.4050	0.1160	0.0045	0.2690	0.0712	0.1184	0.2640	213.31
0.2500	1.1440	0.5400	0.9000	0	1.0050	0.0031	1.1050	1.6700	1.2900	0.1380	0.1354	0.1263	0.5014	0.0490	0.8880	1.0520	0.4923	0.0651	0.6950	0.2915	0.6120	0.6830	213.34
0.3333	2.3110	0.9790	1.7450	0	2.0320	0.0111	2.1880	3.3750	2.5400	0.2440	0.3806	0.3473	1.4316	0.0920	1.6800	1.9890	1.2070	0.4363	1.3260	0.7141	1.5794	1.3030	213.34
0.4167	3.9710	1.4320	2.7370	0.1011	3.4450	0.0312	3.5100	5.7560	4.0420	0.3500	0.7855	0.6817	2.9354	0.1410	2.5580	3.0280	2.3710	1.2622	2.0380	1.4108	2.7474	2.0030	213.39
0.5000	5.9470	1.8320	3.7300	1.6937	5.0740	0.0744	4.8860	8.5200	5.5850	0.4380	1.2777	1.061	4.7457	0.1870	3.3990	4.0240	4.1265	2.6671	2.7340	2.4594	3.8390	2.6860	213.41
0.5833	10.6080	3.2720	6.5260	5.0515	9.0060	0.1762	8.5760	15.1420	9.7890	0.7910	1.7929	1.4334	6.5895	0.3280	5.9700	7.0680	6.5729	4.5033	4.7950	3.8596	4.6996	4.7120	213.43
0.6667	19.7930	6.7720	12.6650	7.7314	16.7630	0.5189	16.3870	28.2010	18.7990	1.6900	3.1139	2.4941	11.389	0.6490	11.8200	13.9940	11.6028	6.7937	9.4290	6.7709	8.6265	9.2750	213.46
0.7500	34.4150	13.1340	23.5850	14.345	29.5340	1.5453	29.9070	49.4590	34.5290	3.2890	5.9975	4.9102	22.0388	1.2500	22.5630	26.7000	18.6639	12.8715	17.8360	12.5016	19.4912	17.9210	213.71
0.8333	56.1370	20.2090	38.1230	28.5185	48.4230	4.1186	48.8970	80.9520	56.3510	4.9620	11.0939	9.3205	40.9846	2.0560	35.9530	42.4540	22.0516	27.4976	28.5150	17.9380	38.0035	29.6840	215.58
0.9167	82.8270	25.4540	51.6860	47.6958	70.6080	10.4178	67.7800	118.6950	77.4610	6.0990	18.2350	14.9517	67.0184	2.8670	47.4440	55.8090	23.7928	47.8203	37.8990	20.3384	55.2750	41.5170	218.9
1.0000	108.6820	27.6260	60.8960	64.0555	90.9420	23.9139	81.9390	153.7040	92.7610	6.4690	25.2504	19.9076	91.9083	3.5830	54.5130	63.7260	25.5548	68.1995	43.8590	21.7422	64.8626	51.1570	222.53
1.0833	128.8900	26.8610	64.3390	74.8259	105.9430	45.8965	89.2730	180.0790	99.9820	6.1280	30.4416	23.0281	109.4963	4.1110	56.3960	65.3900	27.3430	87.0515	45.6240	23.1316	65.9765	56.8350	225.16
1.1667	141.8860	23.6960	62.7860	78.2442	114.1990	67.6965	89.8440	195.5610	99.5700	5.3820	32.9516	23.9099	117.1622	4.3760	53.5630	61.5150	29.1211	103.5097	43.7790	24.4752	58.5904	58.2170	226.67
1.2500	146.3410	19.9500	56.8520	75.3991	115.6230	90.3954	84.6180	199.2100	92.3650	4.5730	32.8865	22.8038	115.8346	4.3830	47.5170	53.9770	30.8332	116.9900	39.0490	25.3198	49.1600	55.5280	228.2
1.3333	143.9010	16.4550	49.1600	67.3031	111.5010	113.2457	74.9810	193.5520	80.9440	3.8410	30.6831	20.1386	106.1656	4.2240	40.7830	45.8090	32.4349	120.8162	33.6990	26.1137	39.9118	50.8900	229.79
1.4167	135.6540	13.4380	41.5800	57.6164	102.2950	112.3021	64.5970	179.2460	69.0100	3.2080	27.0776	17.1299	92.5796	3.9540	34.5310	38.3970	33.9000	113.1276	28.7030	26.9033	31.8813	45.3820	231.17
1.5000	122.2600	10.9640	34.9650	48.3645	90.2630	82.0702	54.9360	159.1000	58.2610	2.6840	23.2575	14.3348	78.725	3.6170	29.0480	32.0270	35.2202	110.1176	24.3510	27.6343	25.4938	39.8490	232.53
1.5833	107.3500	8.9680	29.3450	40.3731	78.3030	79.4601	46.6140	138.5640	49.0810	2.2560	19.7908	11.6887	66.4109	3.2710	24.4120	26.7100	36.3949	108.5534	20.6320	28.2159	20.4466	34.7830	233.77
1.6667	93.1460	7.3820	24.6600	33.6348	67.4030	96.4593	39.5270	119.6160	41.2790	1.9140	16.8121	9.5733	55.925	2.9460	20.5730	22.3460	37.4281	90.7269	17.5240	28.5569	16.5514	30.3320	234.93
1.7500	80.6830	6.1570	20.8260	28.2744	58.1690	64.6679	33.6210	103.4150	34.8390	1.6490	14.2652	7.8863	47.0945	2.6580	17.4590	18.8320	38.3294	78.3563	14.9830	28.6541	13.5827	26.5560	236.03
1.8333	70.0780	5.2360	17.7470	23.8489	50.2980	50.2556	28.8060	89.5790	29.6450	1.4510	12.1471	6.6185	39.8277	2.4220	15.0140	16.0840	39.1073	79.8121	12.9680	28.6325	11.3752	23.4880	237.04
1.9167	61.0540	4.5560	15.3390	20.2981	43.5720	50.1915	24.9470	77.6390	25.5340	1.3090	10.4287	5.6519	33.9498	2.2390	13.1480	13.9930	39.7680	88.1459	11.4260	28.5411	9.7757	21.1060	237.96
2.0000	53.3950	4.0640	13.4960	17.5205	38.0290	54.1069	21.9140	67.8470	22.3430	1.2140	9.0655	5.0015	29.3073	2.1040	11.7500	12.4260	40.2132	94.9198	10.2690	28.4082	8.6683	19.3030	238.8
2.0833	47.0510	3.7220	12.1040	15.4014	33.5370	59.8677	19.5720	59.8420	19.8930	1.1530	8.0068	4.413	25.7416	2.0110	10.7270	11.2780	40.3166	98.8525	9.4270	28.2553	7.9212	17.9930	239.56
2.1667	41.9160	3.4860	11.0720	13.7918	29.9050	65.3760	17.7990	53.3140	18.0400	1.1140	6.9490	3.9788	23.0461	1.9530	9.9940	10.4500	40.2989	101.1358	8.8290	28.0818	7.4011	17.0780	240.29
2.2500	37.7330	3.3150	10.3090	12.5797	26.9670	70.2829	16.4800	48.0670	16.6500	1.0880	6.0584	3.6667	21.035	1.9200	9.4770	9.8630	40.2311	102.8368	8.4120	27.8757	7.0186	16.4520	240.97
2.3333	34.3240	3.1870	9.7510	11.6682	24.6700	74.4176	15.4930	43.9060	15.5990	1.0710	5.7255	3.4459	19.2434	1.9040	9.1190	9.4520	40.1862	104.1761	8.1310	27.6437	6.7484	16.0380	241.56
2.4167	31.6450	3.0860	9.3520	10.995	22.8740	75.6989	14.7530	40.6250	14.8160	1.0630	5.4011	3.2964	17.5545	1.9010	8.8620	9.1540	40.1330	104.8623	7.9440	27.4079	6.5782	15.7730	242.09
2.5000	29.5220	3.0110	9.0610	10.498	21.4570	73.9004	14.2110	38.0320	14.2480	1.0630	5.1941	3.1927	16.1566	1.9060	8.6740	8.9310	40.0314	105.6588	7.8170	27.1759	6.4780	15.6120	242.61
2.5833	27.8210	2.9650	8.8380	10.1191	20.3360	72.4020	13.8220	35.9920	13.8270	1.0670	5.1058	3.1188	17.4398	1.9180	8.5290	8.7560	39.9037	106.7291	7.7310	26.9405	6.4195	15.5230	243.03
2.6667	26.4750	2.9380	8.6640	9.8184	19.4480	72.3301	13.5310	34.3650	13.4970	1.0750	5.0424	3.0662	16.0166	1.9330	8.4160	8.6140	39.7797	107.3808	7.6700	26.7009	6.3860	15.4780	243.48
2.7500	25.3940	2.9230	8.5190	9.5632	18.7460	70.5386	13.3050	33.0550	13.2320	1.0840	5.0891	3.029	15.856	1.9530	8.3560	8.5340	39.6523	106.2747	7.6400	26.4644	6.3662	15.4750	243.86
2.8333	24.5190	2.9150	8.4040	9.3502	18.1950	69.8290	13.1250	32.0380	13.0080	1.0940	5.2199	3.0042	16.4063	1.9750	8.3330	8.4970	39.5178	101.8280	7.6460	26.2347	6.3547	15.5150	244.22
2.9167	23.8330	2.9110	8.3380	9.1997	17.7790	70.9754	12.9720	31.2530	12.8150	1.1050	5.0813	2.9984	16.1413	1.9990	8.3350	8.4880	39.3874	98.5875	7.6750	26.0125	6.3484	15.5860	244.56
3.0000	23.3020	2.9100	8.3050	9.1039	17.4550	72.2212	12.8630	30.6510	12.6950	1.1160	5.0624	3.004	15.4204	2.0250	8.3520	8.4960	39.2658	96.1806	7.7200	25.8014	6.3452	15.6810	244.89
3.0833	45.5360	2.8580	8.1970	9.0443	17.0840	72.2871	12.6800	29.9940	12.4950	1.1030	5.0046	3.0191	15.6376	2.0220	8.2590	8.3940	39.1469	93.7402	7.6680	25.6049	6.3431	15.5760	245.18
3.1667	44.1580	2.6960	7.9010	8.9172	16.5490	72.2218	12.2740	29.0660	12.0620	1.0370	4.9553	2.9969	15.5716	1.9550	7.9260	8.0490	39.0268	91.9895	7.4000	25.4223	6.1903	15.0340	245.45
3.2500	42.1900	2.3620	7.2890	8.5975	15.7300	72.1438	11.4820	27.6840	11.2220	0.8940	4.8039	2.891	14.787	1.7830	7.1880	7.2950	38.9083	90.3820	6.7730	25.2504	5.6915	13.7610	245.7
3.3333	39.3020	1.9160	6.3450	7.9453	14.4940	72.0306	10.2090	25.6130	9.8990	0.7070	4.4854	2.6461	13.7449	1.5190	6.1030	6.1920	38.7933	87.9594	5.8140	25.0870	4.7342	11.8130	245.92
3.4167	35.4540	1.4550	5.2370	6.9416	12.8750	71.7330	8.6540	22.8680	8.3170	0.5210	3.9765	2.2712	12.2031	1.2210	4.8930	4.9630	38.6827	84.4022	4.7170	24.9310	3.5979	9.5840	246.12
3.5000	30.9870	1.0480	4.1260	5.7503	11.0920	71.2819	7.0330	19.7850	6.6930	0.3630	3.3530	1.8423	10.1301	0.9320	3.7300	3.7830	38.5791	79.3078	3.6380	24.7806	2.5402	7.3930	246.32
3.5833	26.3360	0.7280	3.1330	4.5401	9.2930	70.7339	5.5080	16.6630	5.1910	0.2480	2.7122	1.4213	8.0197	0.6820	2.7310	2.7690	38.4852	72.8376	2.6980	24.6343	1.7005	5.4810	246.51
3.6667	21.8300	0.5150	2.3080	3.4532	7.5860	70.2932	4.1830	13.6760	3.9000	0.1730	2.1114	1.0542	6.2502	0.4910	1.9660	1.9940	38.4007	65.6966	1.9510	24.4920	1.1505	3.9630	246.68
3.7500	17.7580	0.3650	1.7080	2.5556	6.0600	69.9537	3.1270	10.9980	2.9050	0.1200	1.6016	0.7624	4.6774	0.3590	1.4370	1.4570	38.3231	58.4842	1.4350	24.3542	0.7347	2.9160	246.8
3.8333	14.1840	0.2570	1.2750	1.9052	4.7510	69.9024	2.3720	8.6730	2.1910	0.0830	1.1864	0.5603	3.4202	0.2630	1.0530	1.0670	38.2495	51.6403	1.0580	24.2204	0.4393	2.1500	246.97
3.9167	11.1990	0.1800	0.9530	1.4295	3.7220	69.5167	1.8020	6.8090	1.6570	0.0570	0.8932	0.4133	2.578	0.1920	0.7660	0.7770	38.1762	45.6270	0.7760	24.0892	0.2715	1.5780	247.09
4.0000	8.9070	0.1260	0.7070	1.0763	2.9440	68.3867	1.3680	5.4020	1.2470	0.0390	0.6881	0.3033	1.9925	0.1390	0.5560	0.5640	38.1000	40.4569	0.5670	23.9585	0.2057	1.1520	247.23
4.0833	7.1230	0.0880	0.5240	0.8084	2.3310	66.8948	1.0330	4.2920	0.9340	0.0270	0.5143	0.2213	1.4594	0.1010	0.4030	0.4090	38.0190	36.2207	0.4150	23.8254	0.1629	0.8420	247.34
4.1667	5.7090	0.0610	0.3880	0.6124	1.8490	65.2630	0.7820	3.4160	0.7030	0.0180	0.3871	0.1622	1.0596	0.0730	0.2920	0.2960	37.9310	33.0671	0.3020	23.6876	0.1041	0.6140	247.44
4.2500	4.5670	0.0430	0.2860	0.4639	1.4580	63.4191	0.5890	2.7050	0.5270	0.0120	0.2963	0.1181	0.8354	0.0530	0.2100	0.2130	37.8351	30.5587	0.2200	23.5433	0.0627	0.4460	247.54
4.3333	3.6430	0.0290	0.2110	0.3517	1.1480	61.5129	0.4430	2.1380	0.3940	0.0080	0.2160	0.0861	0.6234	0.0380	0.1510	0.1530	37.7321	28.3654	0.1600	23.3920	0.0633	0.3250	247.64
4.4167	2.9010	0.0200	0.1550	0.2696	0.9060	59.4496	0.3320	1.6980	0.2940	0.0050	0.1566	0.062	0.4097	0.0270	0.1080	0.1100	37.6227	26.5660	0.1160	23.2345	0.0700	0.2350	247.73
4.5000	2.3150	0.0130	0.1130	0.2076	0.7140	57.2116	0.2490	1.3420	0.2180	0.0030	0.1205	0.045	0.3229	0.0190	0.0760	0.0770	37.4867	35.4174	0.0830	23.0704	0.0497	0.1680	247.78
4.5833	1.8450	0.0080	0.0820	0.1594	0.5600	55.0110	0.1860	1.0580	0.1610	0.0020	0.0860	0.032	0.2753	0.0130	0.0530	0.0540	37.3322	35.0367	0.0590	22.8871	0.0291	0.1190	247.87
4.6667	1.4660	0.0040	0.0590	0.1249	0.4400	52.8723	0.1380	0.8360	0.1180	0.0010	0.0587	0.0229	0.1611	0.0090	0.0360	0.0370	37.2100	25.2452	0.0410	22.6848	0.0356	0.0830	247.91
4.7500	1.1640	0.0020	0.0420	0.0971	0.3460	50.8176	0.1010	0.6590	0.0850	0.0000	0.0485	0.016	0.0993	0.0060	0.0240	0.0240	37.0840	27.7332	0.0280	22.4908	0.0463	0.0570	247.97
4.8333	0.9260	0.0000	0.0290	0.0761	0.2700	48.8407	0.0740	0.5180	0.0610	0.0000	0.0326	0.011	0.1173	0.0030	0.0140	0.0140	36.9330	32.8942	0.0170	22.3107	0.0343	0.0360	247.87
4.9167	0.7330	0.0000	0.0180	0.0609	0.2100	46.9205	0.0520	0.4050	0.0430	0.0000	0.0204	0.007	0.0755	0.0020	0.0070	0.0070	36.7787	28.2863	0.0100	22.1250	0.0262	0.0200	247.71
5.0000	0.5780	0.0000	0.0100	0.0475	0.1630	45.0744	0.0360	0.3160	0.0280	0.0000	0.0200	0.004	0.0111	0.0010	0.0020	0.0020	36.6473	23.7296	0.0040	21.9286	0.0397	0.0090	247.56
5.0833	0.4540	0.0000	0.0050	0.0381	0.1250	43.5421	0.0220	0.2450	0.0160	0.0000	0.0152	0.0021	0.0367	0.0000	0.0000	0.0000	36.5172	24.7545	0.0010	21.7387	0.0358	0.0020	247.45
5.1667	0.3540	0.0000	0.0010	0.0307	0.0950	42.3275	0.0120	0.1880	0.0080	0.0000	0.0060	0	0.048	0.0000	0.0000	0.0000	36.3790	22.0981	0.0000	21.5609	0.0124	0.0000	247.33
5.2500	0.2740	0.0000	0.0000	0.0253	0.0720	41.0603	0.0060	0.1430	0.0030	0.0000	0.0056	0	0	0.0000	0.0000	0.0000	36.2479	19.0807	0.0000	21.3877	0.0062	0.0000	247.18
5.3333	0.2110	0.0000	0.0000	0.0236	0.0530	39.6714	0.0010	0.1070	0.0000	0.0000	0.0055	0	0	0.0000	0.0000	0.0000	36.1198	19.1695	0.0000	21.2171	0.0036	0.0000	246.96
5.4167	0.1590	0.0000	0.0000	0.0212	0.0370	38.1905	0.0000	0.0780	0.0000	0.0000	-0.0021	0	0	0.0000	0.0000	0.0000	35.9867	19.0432	0.0000	21.0488	0.0024	0.0000	246.73
5.5000	0.1160	0.0000	0.0000	0.0199	0.0240	36.6729	0.0000	0.0530	0.0000	0.0000	-0.0005	0	0	0.0000	0.0000	0.0000	35.8531	17.7894	0.0000	20.8787	0.0016	0.0000	246.41
5.5833	0.0800	0.0000	0.0000	0.0187	0.0140	35.1564	0.0000	0.0340	0.0000	0.0000	0.0034	0	0	0.0000	0.0000	0.0000	35.7266	16.3453	0.0000	20.7067	0.0012	0.0000	246
5.6667	0.0520	0.0000	0.0000	0.0169	0.0070	33.6738	0.0000	0.0190	0.0000	0.0000	-0.0025	0	0	0.0000	0.0000	0.0000	35.6001	16.1317	0.0000	20.5384	0.0009	0.0000	245.61
5.7500	0.0300	0.0000	0.0000	0.016	0.0020	32.2286	0.0000	0.0080	0.0000	0.0000	-0.0029	0	0	0.0000	0.0000	0.0000	35.4703	15.2691	0.0000	20.3744	0.0007	0.0000	245.11
5.8333	0.0140	0.0000	0.0000	0.0151	0.0000	30.8267	0.0000	0.0020	0.0000	0.0000	0.0027	0	0	0.0000	0.0000	0.0000	35.3444	14.1384	0.0000	20.2112	0.0005	0.0000	244.53
5.9167	0.0040	0.0000	0.0000	0.0137	0.0000	29.5058	0.0000	0.0000	0.0000	0.0000	-0.0009	0	0	0.0000	0.0000	0.0000	35.2207	13.9020	0.0000	20.0491	0.0004	0.0000	243.98
6.0000	0.0000	0.0000	0.0000	0.0131	0.0000	28.2664	0.0000	0.0000	0.0000	0.0000	-0.0026	0	0	0.0000	0.0000	0.0000	35.0952	13.3357	0.0000	19.8890	0.0003	0.0000	243.54
6.0833	0.0000	0.0000	0.0000	0.0123	0.0000	27.0643	0.0000	0.0000	0.0000	0.0000	0.0038	0	0	0.0000	0.0000	0.0000	34.9718	12.5683	0.0000	19.7297	0.0003	0.0000	243.19
6.1667	0.0000	0.0000	0.0000	0.0112	0.0000	25.8136	0.0000	0.0000	0.0000	0.0000	0.0032	0	0	0.0000	0.0000	0.0000	34.8505	12.5604	0.0000	19.5717	0.0002	0.0000	242.88
6.2500	0.0000	0.0000	0.0000	0.0109	0.0000	24.5277	0.0000	0.0000	0.0000	0.0000	-0.0002	0	0	0.0000	0.0000	0.0000	34.7277	12.3913	0.0000	19.4158	0.0002	0.0000	242.6
6.3333	0.0000	0.0000	0.0000	0.0101	0.0000	23.2812	0.0000	0.0000	0.0000	0.0000	0.0065	0	0	0.0000	0.0000	0.0000	34.6059	11.8159	0.0000	19.2605	0.0001	0.0000	242.34
6.4167	0.0000	0.0000	0.0000	0	0.0000	22.0509	0.0000	0.0000	0.0000	0.0000	0.0061	0	0	0.0000	0.0000	0.0000	34.4860	11.4862	0.0000	19.1055	0.0001	0.0000	242.08
6.5000	0.0000	0.0000	0.0000	0	0.0000	20.8742	0.0000	0.0000	0.0000	0.0000	0.0022	0	0	0.0000	0.0000	0.0000	34.3659	11.1930	0.0000	18.9519	0.0001	0.0000	241.85

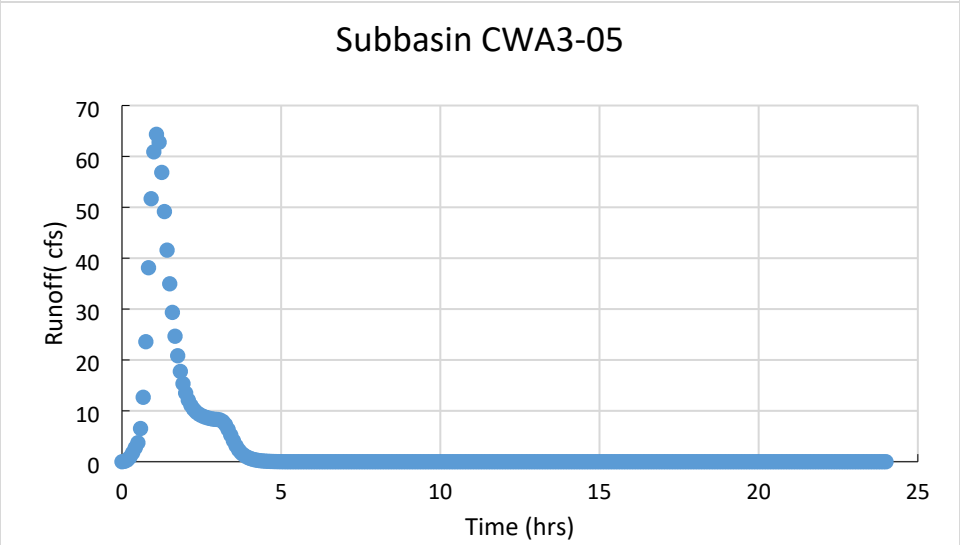
6.5833	0.0000	0.0000	0.0000	0	0.0000	19.7804	0.0000	0.0000	0.0000	0.0000	0.0086	0	0	0.0000	0.0000	0.0000	34.2460	10.7846	0.0000	18.7994	0.0001	0.0000	241.63
6.6667	0.0000	0.0000	0.0000	0	0.0000	18.7739	0.0000	0.0000	0.0000	0.0000	0.0092	0	0	0.0000	0.0000	0.0000	34.1276	10.5194	0.0000	18.6477	0.0001	0.0000	241.42
6.7500	0.0000	0.0000	0.0000	0	0.0000	17.8483	0.0000	0.0000	0.0000	0.0000	0.0051	0	0	0.0000	0.0000	0.0000	34.0095	10.2834	0.0000	18.4971	0.0000	0.0000	241.21
6.8333	0.0000	0.0000	0.0000	0	0.0000	16.9873	0.0000	0.0000	0.0000	0.0000	0.0105	0	0	0.0000	0.0000	0.0000	33.8913	9.9452	0.0000	18.3476	0.0000	0.0000	240.98
6.9167	0.0000	0.0000	0.0000	0	0.0000	16.1667	0.0000	0.0000	0.0000	0.0000	0.0110	0	0	0.0000	0.0000	0.0000	33.7740	9.6508	0.0000	18.1987	0.0000	0.0000	240.78
7.0000	0.0000	0.0000	0.0000	0	0.0000	15.4017	0.0000	0.0000	0.0000	0.0000	0.0072	0	0	0.0000	0.0000	0.0000	33.6572	9.4160	0.0000	18.0505	0.0000	0.0000	240.61
7.0833	0.0000	0.0000	0.0000	0	0.0000	14.6803	0.0000	0.0000	0.0000	0.0000	0.0119	0	0	0.0000	0.0000	0.0000	33.5397	9.1679	0.0000	17.9030	0.0000	0.0000	240.43
7.1667	0.0000	0.0000	0.0000	0	0.0000	14.0134	0.0000	0.0000	0.0000	0.0000	0.0127	0	0	0.0000	0.0000	0.0000	33.4216	8.9195	0.0000	17.7554	0.0000	0.0000	240.26
7.2500	0.0000	0.0000	0.0000	0	0.0000	13.3970	0.0000	0.0000	0.0000	0.0000	0.0088	0	0	0.0000	0.0000	0.0000	33.3030	8.6756	0.0000	17.6068	0.0000	0.0000	240.07
7.3333	0.0000	0.0000	0.0000	0	0.0000	12.8034	0.0000	0.0000	0.0000	0.0000	0.0135	0	0	0.0000	0.0000	0.0000	33.1833	8.4587	0.0000	17.4569	0.0000	0.0000	239.91
7.4167	0.0000	0.0000	0.0000	0	0.0000	12.2389	0.0000	0.0000	0.0000	0.0000	0.0140	0	0	0.0000	0.0000	0.0000	33.0625	8.1677	0.0000	17.3056	0.0000	0.0000	239.76
7.5000	0.0000	0.0000	0.0000	0	0.0000	11.7189	0.0000	0.0000	0.0000	0.0000	0.0103	0	0	0.0000	0.0000	0.0000	32.9410	7.8285	0.0000	17.1526	0.0000	0.0000	239.62
7.5833	0.0000	0.0000	0.0000	0	0.0000	11.2363	0.0000	0.0000	0.0000	0.0000	0.0152	0	0	0.0000	0.0000	0.0000	32.8187	7.5383	0.0000	16.9982	0.0000	0.0000	239.47
7.6667	0.0000	0.0000	0.0000	0	0.0000	10.7803	0.0000	0.0000	0.0000	0.0000	0.0143	0	0	0.0000	0.0000	0.0000	32.6954	7.2278	0.0000	16.8427	0.0000	0.0000	239.31
7.7500	0.0000	0.0000	0.0000	0	0.0000	10.3388	0.0000	0.0000	0.0000	0.0000	0.0114	0	0	0.0000	0.0000	0.0000	32.5721	6.8929	0.0000	16.6861	0.0000	0.0000	239.14
7.8333	0.0000	0.0000	0.0000	0	0.0000	9.9177	0.0000	0.0000	0.0000	0.0000	0.0170	0	0	0.0000	0.0000	0.0000	32.4488	6.6109	0.0000	16.5289	0.0000	0.0000	239.01
7.9167	0.0000	0.0000	0.0000	0	0.0000	9.5386	0.0000	0.0000	0.0000	0.0000	0.0148	0	0	0.0000	0.0000	0.0000	32.3254	6.3095	0.0000	16.3720	0.0000	0.0000	238.85
8.0000	0.0000	0.0000	0.0000	0	0.0000	9.1829	0.0000	0.0000	0.0000	0.0000	0.0139	0	0	0.0000	0.0000	0.0000	32.2021	5.9489	0.0000	16.2153	0.0000	0.0000	238.7
8.0833	0.0000	0.0000	0.0000	0	0.0000	8.8526	0.0000	0.0000	0.0000	0.0000	0.0190	0	0	0.0000	0.0000	0.0000	32.0791	5.6930	0.0000	16.0589	0.0000	0.0000	238.54
8.1667	0.0000	0.0000	0.0000	0	0.0000	8.5496	0.0000	0.0000	0.0000	0.0000	0.0148	0	0	0.0000	0.0000	0.0000	31.9559	5.4917	0.0000	15.9029	0.0000	0.0000	238.37
8.2500	0.0000	0.0000	0.0000	0	0.0000	8.2545	0.0000	0.0000	0.0000	0.0000	0.0167	0	0	0.0000	0.0000	0.0000	31.8326	5.1989	0.0000	15.7471	0.0000	0.0000	238.19
8.3333	0.0000	0.0000	0.0000	0	0.0000	7.9784	0.0000	0.0000	0.0000	0.0000	0.0194	0	0	0.0000	0.0000	0.0000	31.7092	4.9672	0.0000	15.5913	0.0000	0.0000	237.99
8.4167	0.0000	0.0000	0.0000	0	0.0000	7.7180	0.0000	0.0000	0.0000	0.0000	0.0148	0	0	0.0000	0.0000	0.0000	31.5853	4.8503	0.0000	15.4355	0.0000	0.0000	237.79
8.5000	0.0000	0.0000	0.0000	0	0.0000	7.4581	0.0000	0.0000	0.0000	0.0000	0.0197	0	0	0.0000	0.0000	0.0000	31.4606	4.7013	0.0000	15.2792	0.0000	0.0000	237.57
8.5833	0.0000	0.0000	0.0000	0	0.0000	7.2117	0.0000	0.0000	0.0000	0.0000	0.0181	0	0	0.0000	0.0000	0.0000	31.3352	4.5189	0.0000	15.1219	0.0000	0.0000	237.38
8.6667	0.0000	0.0000	0.0000	0	0.0000	6.9703	0.0000	0.0000	0.0000	0.0000	0.0169	0	0	0.0000	0.0000	0.0000	31.2089	4.4030	0.0000	14.9635	0.0000	0.0000	237.18
8.7500	0.0000	0.0000	0.0000	0	0.0000	6.7471	0.0000	0.0000	0.0000	0.0000	0.0213	0	0	0.0000	0.0000	0.0000	31.0815	4.3233	0.0000	14.8038	0.0000	0.0000	236.98
8.8333	0.0000	0.0000	0.0000	0	0.0000	6.4708	0.0000	0.0000	0.0000	0.0000	0.0166	0	0	0.0000	0.0000	0.0000	30.9531	4.2034	0.0000	14.6428	0.0000	0.0000	236.78
8.9167	0.0000	0.0000	0.0000	0	0.0000	6.1729	0.0000	0.0000	0.0000	0.0000	0.0186	0	0	0.0000	0.0000	0.0000	30.8240	4.0918	0.0000	14.4804	0.0000	0.0000	236.6
9.0000	0.0000	0.0000	0.0000	0	0.0000	6.0841	0.0000	0.0000	0.0000	0.0000	0.0197	0	0	0.0000	0.0000	0.0000	30.6941	4.0336	0.0000	14.3169	0.0000	0.0000	236.4
9.0833	0.0000	0.0000	0.0000	0	0.0000	6.0258	0.0000	0.0000	0.0000	0.0000	0.0180	0	0	0.0000	0.0000	0.0000	30.5636	3.9606	0.0000	14.1525	0.0000	0.0000	236.17
9.1667	0.0000	0.0000	0.0000	0	0.0000	5.9163	0.0000	0.0000	0.0000	0.0000	0.0198	0	0	0.0000	0.0000	0.0000	30.4328	3.8534	0.0000	13.9876	0.0000	0.0000	235.92
9.2500	0.0000	0.0000	0.0000	0	0.0000	5.7174	0.0000	0.0000	0.0000	0.0000	0.0178	0	0	0.0000	0.0000	0.0000	30.3015	3.7815	0.0000	13.8225	0.0000	0.0000	235.59
9.3333	0.0000	0.0000	0.0000	0	0.0000	5.4583	0.0000	0.0000	0.0000	0.0000	0.0214	0	0	0.0000	0.0000	0.0000	30.1698	3.7320	0.0000	13.6572	0.0000	0.0000	235.31
9.4167	0.0000	0.0000	0.0000	0	0.0000	5.2327	0.0000	0.0000	0.0000	0.0000	0.0182	0	0	0.0000	0.0000	0.0000	30.0377	3.6481	0.0000	13.4918	0.0000	0.0000	235.04
9.5000	0.0000	0.0000	0.0000	0	0.0000	5.1077	0.0000	0.0000	0.0000	0.0000	0.0196	0	0	0.0000	0.0000	0.0000	29.9051	3.5641	0.0000	13.3263	0.0000	0.0000	234.79
9.5833	0.0000	0.0000	0.0000	0	0.0000	5.0084	0.0000	0.0000	0.0000	0.0000	0.0220	0	0	0.0000	0.0000	0.0000	29.7718	3.5135	0.0000	13.1606	0.0000	0.0000	234.58
9.6667	0.0000	0.0000	0.0000	0	0.0000	4.8794	0.0000	0.0000	0.0000	0.0000	0.0168	0	0	0.0000	0.0000	0.0000	29.6379	3.4561	0.0000	12.9946	0.0000	0.0000	234.41
9.7500	0.0000	0.0000	0.0000	0	0.0000	4.8016	0.0000	0.0000	0.0000	0.0000	0.0223	0	0	0.0000	0.0000	0.0000	29.5031	3.3765	0.0000	12.8279	0.0000	0.0000	234.22
9.8333	0.0000	0.0000	0.0000	0	0.0000	4.6770	0.0000	0.0000	0.0000	0.0000	0.0190	0	0	0.0000	0.0000	0.0000	29.3673	3.3106	0.0000	12.6606	0.0000	0.0000	234.07
9.9167	0.0000	0.0000	0.0000	0	0.0000	4.5184	0.0000	0.0000	0.0000	0.0000	0.0208	0	0	0.0000	0.0000	0.0000	29.2304	3.2600	0.0000	12.4922	0.0000	0.0000	233.9
10.0000	0.0000	0.0000	0.0000	0	0.0000	4.4439	0.0000	0.0000	0.0000	0.0000	0.0203	0	0	0.0000	0.0000	0.0000	29.0922	3.1961	0.0000	12.3227	0.0000	0.0000	233.73
10.0833	0.0000	0.0000	0.0000	0	0.0000	4.3660	0.0000	0.0000	0.0000	0.0000	0.0202	0	0	0.0000	0.0000	0.0000	28.9529	3.1276	0.0000	12.1519	0.0000	0.0000	233.6
10.1667	0.0000	0.0000	0.0000	0	0.0000	4.2535	0.0000	0.0000	0.0000	0.0000	0.0217	0	0	0.0000	0.0000	0.0000	28.8124	3.0567	0.0000	11.9799	0.0000	0.0000	233.47
10.2500	0.0000	0.0000	0.0000	0	0.0000	4.1403	0.0000	0.0000	0.0000	0.0000	0.0182	0	0	0.0000	0.0000	0.0000	28.6708	2.9434	0.0000	11.8066	0.0000	0.0000	233.35
10.3333	0.0000	0.0000	0.0000	0	0.0000	4.0277	0.0000	0.0000	0.0000	0.0000	0.0240	0	0	0.0000	0.0000	0.0000	28.5282	2.8443	0.0000	11.6324	0.0000	0.0000	233.22
10.4167	0.0000	0.0000	0.0000	0	0.0000	3.9228	0.0000	0.0000	0.0000	0.0000	0.0179	0	0	0.0000	0.0000	0.0000	28.3845	2.7858	0.0000	11.4575	0.0000	0.0000	233.11
10.5000	0.0000	0.0000	0.0000	0	0.0000	3.8557	0.0000	0.0000	0.0000	0.0000	0.0227	0	0	0.0000	0.0000	0.0000	28.2400	2.7067	0.0000	11.2821	0.0000	0.0000	232.98
10.5833	0.0000	0.0000	0.0000	0	0.0000	3.8108	0.0000	0.0000	0.0000	0.0000	0.0200	0	0	0.0000	0.0000	0.0000	28.0945	2.6096	0.0000	11.1063	0.0000	0.0000	232.89
10.6667	0.0000	0.0000	0.0000	0	0.0000	3.7192	0.0000	0.0000	0.0000	0.0000	0.0216	0	0	0.0000	0.0000	0.0000	27.9479	2.5452	0.0000	10.9302	0.0000	0.0000	232.77
10.7500	0.0000	0.0000	0.0000	0	0.0000	3.6318	0.0000	0.0000	0.0000	0.0000	0.0207	0	0	0.0000	0.0000	0.0000	27.8001	2.4901	0.0000	10.7538	0.0000	0.0000	232.68
10.8333	0.0000	0.0000	0.0000	0	0.0000	3.5723	0.0000	0.0000	0.0000	0.0000	0.0210	0	0	0.0000	0.0000	0.0000	27.6511	2.4115	0.0000	10.5768	0.0000	0.0000	232.57
10.9167	0.0000	0.0000	0.0000	0	0.0000	3.4924	0.0000	0.0000	0.0000	0.0000	0.0221	0	0	0.0000	0.0000	0.0000	27.5008	2.3410	0.0000	10.3991	0.0000	0.0000	232.47
11.0000	0.0000	0.0000	0.0000	0	0.0000	3.4307	0.0000	0.0000	0.0000	0.0000	0.0195	0	0	0.0000	0.0000	0.0000	27.3490	2.2923	0.0000	10.2207	0.0000	0.0000	232.37
11.0833	0.0000	0.0000	0.0000	0	0.0000	3.3782	0.0000	0.0000	0.0000	0.0000	0.0231	0	0	0.0000	0.0000	0.0000	27.1958	2.2347	0.0000	10.0416	0.0000	0.0000	232.28
11.1667	0.0000	0.0000	0.0000	0	0.0000	3.3050	0.0000	0.0000	0.0000	0.0000	0.0197	0	0	0.0000	0.0000	0.0000	27.0409	2.1689	0.0000	9.8616	0.0000	0.0000	232.2
11.2500	0.0000	0.0000	0.0000	0	0.0000	3.2360	0.0000	0.0000	0.0000	0.0000	0.0229	0	0	0.0000	0.0000	0.0000	26.8843	2.1187	0.0000	9.6807	0.0000	0.0000	232.11
11.3333	0.0000	0.0000	0.0000	0	0.0000	3.1852	0.0000	0.0000	0.0000	0.0000	0.0196	0	0	0.0000	0.0000	0.0000	26.7260	2.0725	0.0000	9.4987	0.0000	0.0000	232.04
11.4167	0.0000	0.0000	0.0000	0	0.0000	3.1353	0.0000	0.0000	0.0000	0.0000	0.0238	0	0	0.0000	0.0000	0.0000	26.5659	2.0151	0.0000	9.3157	0.0000	0.0000	231.94
11.5000	0.0000	0.0000	0.0000	0	0.0000	3.0769	0.0000	0.0000	0.0000	0.0000	0.0190	0	0	0.0000	0.0000	0.0000	26.4039	1.9623	0.0000	9.1318	0.0000	0.0000	231.87
11.5833	0.0000	0.0000	0.0000	0	0.0000	3.0333	0.0000	0.0000	0.0000	0.0000	0.0238	0	0	0.0000	0.0000	0.0000	26.2402	1.9215	0.0000	8.9470	0.0000	0.0000	231.8
11.6667	0.0000	0.0000	0.0000	0	0.0000	2.9874	0.0000	0.0000	0.0000	0.0000	0.0196	0	0	0.0000	0.0000	0.0000	26.0746	1.8769	0.0000	8.7616	0.0000	0.0000	231.72
11.7500	0.0000	0.0000	0.0000	0	0.0000	2.9241	0.0000	0.0000	0.0000	0.0000	0.0235	0	0	0.0000	0.0000	0.0000	25.9072	1.8268	0.0000	8.5757	0.0000	0.0000	231.65
11.8333	0.0000	0.0000	0.0000	0	0.0000	2.8800	0.0000	0.0000	0.0000	0.0000	0.0195	0	0	0.0000	0.0000	0.0000	25.7378	1.7840	0.0000	8.3895	0.0000	0.0000	231.58
11.9167	0.0000	0.0000	0.0000	0	0.0000	2.8373	0.0000	0.0000	0.0000	0.0000	0.0239	0	0	0.0000	0.0000	0.0000	25.5666	1.7456	0.0000	8.2032	0.0000	0.0000	231.51
12.0000	0.0000	0.0000	0.0000	0	0.0000	2.7874	0.0000	0.0000	0.0000	0.0000	0.0195	0	0	0.0000	0.0000	0.0000	25.3933	1.7026	0.0000	8.0167	0.0000	0.0000	231.43
12.0833	0.0000	0.0000	0.0000	0	0.0000	2.7511	0.0000	0.0000	0.0000	0.0000	0.0235	0	0	0.0000	0.0000	0.0000	25.2178	1.6599	0.0000	7.8305	0.0000	0.0000	231.36
12.1667	0.0000	0.0000	0.0000	0	0.0000	2.7137	0.0000	0.0000	0.0000	0.0000	0.0199	0	0	0.0000	0.0000	0.0000	25.0403	1.6230	0.0000	7.6474	0.0000	0.0000	231.31
12.2500	0.0000	0.0000	0.0000	0	0.0000	2.6688	0.0000	0.0000	0.0000	0.0000	0.0235	0	0	0.0000	0.0000	0.0000	24.8608	1.5875	0.0000	7.4678	0.0000	0.0000	231.24
12.3333	0.0000	0.0000	0.0000	0	0.0000	2.6291	0.0000	0.0000	0.0000	0.0000	0.0195	0	0	0.0000	0.0000	0.0000	24.6797	1.5500	0.0000	7.2870	0.0000	0.0000	231.19
12.4167	0.0000	0.0000	0.0000	0	0.0000	2.5977	0.0000	0.0000	0.0000	0.0000	0.0238	0	0	0.0000	0.0000	0.0000	24.4966	1.5128	0.0000	7.1052	0.0000	0.0000	231.15
12.5000	0.0000	0.0000	0.0000	0	0.0000	2.5615	0.0000	0.0000	0.0000	0.0000	0.0196	0	0	0.0000	0.0000	0.0000	24.3111	1.4789	0.0000	6.9241	0.0000	0.0000	231.08
12.5833	0.0000	0.0000	0.0000	0	0.0000	2.5211	0.0000	0.0000	0.0000	0.0000	0.0234	0	0	0.0000	0.0000	0.0000	24.1226	1.4463	0.0000	6.7446	0.0000	0.0000	231.02
12.6667	0.0000	0.0000	0.0000	0	0.0000	2.4902	0.0000	0.0000	0.0000	0.0000	0.0199	0	0	0.0000	0.0000	0.0000	23.9310	1.4128	0.0000	6.5665	0.0000	0.0000	230.97
12.7500	0.0000	0.0000	0.0000	0	0.0000	2.4548	0.0000	0.0000	0.0000	0.0000	0.0233	0	0	0.0000	0.0000	0.0000	23.7363	1.3798	0.0000	6.3888	0.0000	0.0000	230.92
12.8333	0.0000	0.0000	0.0000	0	0.0000	2.4184	0.0000	0.0000	0.0000	0.0000	0.0199	0	0	0.0000	0.0000	0.0000	23.5385	1.3488	0.0000	6.2114	0.0000	0.0000	230.87
12.9167	0.0000	0.0000	0.0000	0	0.0000	2.3942	0.0000	0.0000	0.0000	0.0000	0.0230	0	0	0.0000	0.0000	0.0000	23.3375	1.3175	0.0000	6.0348	0.0000	0.0000	230.84
13.0000	0.0000	0.0000	0.0000	0	0.0000	2.3651	0.0000	0.0000	0.0000	0.0000	0.0203	0	0	0.0000	0.0000	0.0000	23.1331	1.2756	0.0000	5.8596	0.0000	0.0000	230.79
13.0833	0.0000	0.0000	0.0000	0	0.0000	2.3321	0.0000	0.0000	0.0000	0.0000	0.0225	0	0	0.0000	0.0000	0.0000	22.9251	1.2109	0.0000	5.6862	0.0000	0.0000	230.75
13.1667	0.0000	0.0000	0.0000	0	0.0000	2.3051	0.0000	0.0000	0.0000	0.0000	0.0206	0	0	0.0000	0.0000	0.0000	22.7134	1.1500	0.0000	5.5148	0.0000	0.0000	230.7
13.2500	0.0000	0.0000	0.0000	0	0.0000	2.2787	0.0000	0.0000	0.0000	0.0000	0.0221	0	0	0.0000	0.0000	0.0000	22.4980	1.1301	0.0000	5.3456	0.0000	0.0000	230.66
13.3333	0.0000	0.0000	0.0000	0	0.0000	2.2502	0.0000	0.0000	0.0000	0.0000	0.0212	0	0	0.0000	0.0000	0.0000	22.2787	1.1273	0.0000	5.1793	0.0000	0.0000	230.64
13.4167	0.0000	0.0000	0.0000	0	0.0000	2.2236	0.0000	0.0000	0.0000	0.0000	0.0211	0	0	0.0000	0.0000	0.0000	22.0551	1.1053	0.0000	5.0164	0.0000	0.0000	230.59
13.5000	0.0000	0.0000	0.0000	0	0.0000	2.2004	0.0000	0.0000	0.0000	0.0000	0.0221	0	0	0.0000	0.0000	0.0000	21.8269	1.0804	0.0000	4.8568	0.0000	0.0000	230.57
13.5833	0.0000	0.0000	0.0000	0	0.0000	2.1740	0.0000	0.0000	0.0000	0.0000	0.0203	0	0	0.0000	0.0000	0.0000	21.5939	1.0702	0.0000	4.7006	0.0000	0.0000	230.54

13.6667	0.0000	0.0000	0.0000	0	0.0000	2.1478	0.0000	0.0000	0.0000	0.0000	0.0225	0	0	0.0000	0.0000	0.0000	21.3557	1.0568	0.0000	4.5479	0.0000	0.0000	230.5
13.7500	0.0000	0.0000	0.0000	0	0.0000	2.1279	0.0000	0.0000	0.0000	0.0000	0.0198	0	0	0.0000	0.0000	0.0000	21.1121	1.0343	0.0000	4.3988	0.0000	0.0000	230.48
13.8333	0.0000	0.0000	0.0000	0	0.0000	2.1040	0.0000	0.0000	0.0000	0.0000	0.0229	0	0	0.0000	0.0000	0.0000	20.8627	1.0204	0.0000	4.2539	0.0000	0.0000	230.46
13.9167	0.0000	0.0000	0.0000	0	0.0000	2.0786	0.0000	0.0000	0.0000	0.0000	0.0195	0	0	0.0000	0.0000	0.0000	20.6069	1.0141	0.0000	4.1134	0.0000	0.0000	230.41
14.0000	0.0000	0.0000	0.0000	0	0.0000	2.0589	0.0000	0.0000	0.0000	0.0000	0.0227	0	0	0.0000	0.0000	0.0000	20.3447	0.9998	0.0000	3.9773	0.0000	0.0000	230.39
14.0833	0.0000	0.0000	0.0000	0	0.0000	2.0378	0.0000	0.0000	0.0000	0.0000	0.0198	0	0	0.0000	0.0000	0.0000	20.0752	0.9810	0.0000	3.8460	0.0000	0.0000	230.37
14.1667	0.0000	0.0000	0.0000	0	0.0000	2.0153	0.0000	0.0000	0.0000	0.0000	0.0220	0	0	0.0000	0.0000	0.0000	19.7982	0.9695	0.0000	3.7199	0.0000	0.0000	230.36
14.2500	0.0000	0.0000	0.0000	0	0.0000	1.9954	0.0000	0.0000	0.0000	0.0000	0.0204	0	0	0.0000	0.0000	0.0000	19.5129	0.9602	0.0000	3.5991	0.0000	0.0000	230.32
14.3333	0.0000	0.0000	0.0000	0	0.0000	1.9761	0.0000	0.0000	0.0000	0.0000	0.0212	0	0	0.0000	0.0000	0.0000	19.2189	0.9454	0.0000	3.4841	0.0000	0.0000	230.29
14.4167	0.0000	0.0000	0.0000	0	0.0000	1.9558	0.0000	0.0000	0.0000	0.0000	0.0213	0	0	0.0000	0.0000	0.0000	18.9152	0.9311	0.0000	3.3751	0.0000	0.0000	230.28
14.5000	0.0000	0.0000	0.0000	0	0.0000	1.9357	0.0000	0.0000	0.0000	0.0000	0.0200	0	0	0.0000	0.0000	0.0000	18.6011	0.9215	0.0000	3.2723	0.0000	0.0000	230.24
14.5833	0.0000	0.0000	0.0000	0	0.0000	1.8977	0.0000	0.0000	0.0000	0.0000	0.0221	0	0	0.0000	0.0000	0.0000	18.2757	0.9108	0.0000	3.1757	0.0000	0.0000	230.24
14.6667	0.0000	0.0000	0.0000	0	0.0000	1.8196	0.0000	0.0000	0.0000	0.0000	0.0193	0	0	0.0000	0.0000	0.0000	17.9378	0.8969	0.0000	3.0857	0.0000	0.0000	230.21
14.7500	0.0000	0.0000	0.0000	0	0.0000	1.7270	0.0000	0.0000	0.0000	0.0000	0.0223	0	0	0.0000	0.0000	0.0000	17.5861	0.8852	0.0000	3.0023	0.0000	0.0000	230.2
14.8333	0.0000	0.0000	0.0000	0	0.0000	1.6578	0.0000	0.0000	0.0000	0.0000	0.0194	0	0	0.0000	0.0000	0.0000	17.2193	0.8759	0.0000	2.9254	0.0000	0.0000	230.19
14.9167	0.0000	0.0000	0.0000	0	0.0000	1.6169	0.0000	0.0000	0.0000	0.0000	0.0218	0	0	0.0000	0.0000	0.0000	16.8356	0.8649	0.0000	2.8553	0.0000	0.0000	230.15
15.0000	0.0000	0.0000	0.0000	0	0.0000	1.5906	0.0000	0.0000	0.0000	0.0000	0.0200	0	0	0.0000	0.0000	0.0000	16.4328	0.8527	0.0000	2.7921	0.0000	0.0000	230.16
15.0833	0.0000	0.0000	0.0000	0	0.0000	1.5689	0.0000	0.0000	0.0000	0.0000	0.0206	0	0	0.0000	0.0000	0.0000	16.0085	0.8427	0.0000	2.7358	0.0000	0.0000	230.16
15.1667	0.0000	0.0000	0.0000	0	0.0000	1.5494	0.0000	0.0000	0.0000	0.0000	0.0210	0	0	0.0000	0.0000	0.0000	15.5596	0.8334	0.0000	2.6861	0.0000	0.0000	230.12
15.2500	0.0000	0.0000	0.0000	0	0.0000	1.5351	0.0000	0.0000	0.0000	0.0000	0.0195	0	0	0.0000	0.0000	0.0000	15.0821	0.8227	0.0000	2.6428	0.0000	0.0000	230.13
15.3333	0.0000	0.0000	0.0000	0	0.0000	1.5198	0.0000	0.0000	0.0000	0.0000	0.0216	0	0	0.0000	0.0000	0.0000	14.5712	0.8119	0.0000	2.6059	0.0000	0.0000	230.11
15.4167	0.0000	0.0000	0.0000	0	0.0000	1.4902	0.0000	0.0000	0.0000	0.0000	0.0189	0	0	0.0000	0.0000	0.0000	14.0206	0.8028	0.0000	2.5752	0.0000	0.0000	230.12
15.5000	0.0000	0.0000	0.0000	0	0.0000	1.4465	0.0000	0.0000	0.0000	0.0000	0.0215	0	0	0.0000	0.0000	0.0000	13.4216	0.7937	0.0000	2.5511	0.0000	0.0000	230.1
15.5833	0.0000	0.0000	0.0000	0	0.0000	1.4071	0.0000	0.0000	0.0000	0.0000	0.0191	0	0	0.0000	0.0000	0.0000	12.7641	0.7837	0.0000	2.5333	0.0000	0.0000	230.09
15.6667	0.0000	0.0000	0.0000	0	0.0000	1.3898	0.0000	0.0000	0.0000	0.0000	0.0207	0	0	0.0000	0.0000	0.0000	12.0339	0.7745	0.0000	2.5222	0.0000	0.0000	230.1
15.7500	0.0000	0.0000	0.0000	0	0.0000	1.3916	0.0000	0.0000	0.0000	0.0000	0.0199	0	0	0.0000	0.0000	0.0000	11.2078	0.7666	0.0000	2.5182	0.0000	0.0000	230.09
15.8333	0.0000	0.0000	0.0000	0	0.0000	1.3949	0.0000	0.0000	0.0000	0.0000	0.0193	0	0	0.0000	0.0000	0.0000	10.2480	0.7580	0.0000	2.5217	0.0000	0.0000	230.07
15.9167	0.0000	0.0000	0.0000	0	0.0000	1.3871	0.0000	0.0000	0.0000	0.0000	0.0207	0	0	0.0000	0.0000	0.0000	9.0863	0.7483	0.0000	2.5338	0.0000	0.0000	230.08
16.0000	0.0000	0.0000	0.0000	0	0.0000	1.3658	0.0000	0.0000	0.0000	0.0000	0.0184	0	0	0.0000	0.0000	0.0000	7.5753	0.7398	0.0000	2.5564	0.0000	0.0000	230.07
16.0833	0.0000	0.0000	0.0000	0	0.0000	1.3388	0.0000	0.0000	0.0000	0.0000	0.0209	0	0	0.0000	0.0000	0.0000	5.2670	0.7324	0.0000	2.5935	0.0000	0.0000	230.08
16.1667	0.0000	0.0000	0.0000	0	0.0000	1.3153	0.0000	0.0000	0.0000	0.0000	0.0183	0	0	0.0000	0.0000	0.0000	0.1621	0.7244	0.0000	2.6549	0.0000	0.0000	230.07
16.2500	0.0000	0.0000	0.0000	0	0.0000	1.2968	0.0000	0.0000	0.0000	0.0000	0.0203	0	0	0.0000	0.0000	0.0000	0.0752	0.7160	0.0000	2.7651	0.0000	0.0000	230.08
16.3333	0.0000	0.0000	0.0000	0	0.0000	1.2807	0.0000	0.0000	0.0000	0.0000	0.0188	0	0	0.0000	0.0000	0.0000	0.0755	0.7085	0.0000	2.8935	0.0000	0.0000	230.07
16.4167	0.0000	0.0000	0.0000	0	0.0000	1.2718	0.0000	0.0000	0.0000	0.0000	0.0190	0	0	0.0000	0.0000	0.0000	0.0734	0.7014	0.0000	2.9889	0.0000	0.0000	230.06
16.5000	0.0000	0.0000	0.0000	0	0.0000	1.2712	0.0000	0.0000	0.0000	0.0000	0.0195	0	0	0.0000	0.0000	0.0000	0.0902	0.6937	0.0000	3.0438	0.0000	0.0000	230.07
16.5833	0.0000	0.0000	0.0000	0	0.0000	1.2713	0.0000	0.0000	0.0000	0.0000	0.0180	0	0	0.0000	0.0000	0.0000	0.0956	0.6860	0.0000	3.0601	0.0000	0.0000	230.06
16.6667	0.0000	0.0000	0.0000	0	0.0000	1.2625	0.0000	0.0000	0.0000	0.0000	0.0198	0	0	0.0000	0.0000	0.0000	0.0987	0.6790	0.0000	3.0547	0.0000	0.0000	230.07
16.7500	0.0000	0.0000	0.0000	0	0.0000	1.2435	0.0000	0.0000	0.0000	0.0000	0.0174	0	0	0.0000	0.0000	0.0000	0.0889	0.6721	0.0000	3.0544	0.0000	0.0000	230.08
16.8333	0.0000	0.0000	0.0000	0	0.0000	1.2207	0.0000	0.0000	0.0000	0.0000	0.0196	0	0	0.0000	0.0000	0.0000	0.0865	0.6648	0.0000	3.0567	0.0000	0.0000	230.07
16.9167	0.0000	0.0000	0.0000	0	0.0000	1.2024	0.0000	0.0000	0.0000	0.0000	0.0175	0	0	0.0000	0.0000	0.0000	0.0906	0.6578	0.0000	3.0457	0.0000	0.0000	230.08
17.0000	0.0000	0.0000	0.0000	0	0.0000	1.1928	0.0000	0.0000	0.0000	0.0000	0.0187	0	0	0.0000	0.0000	0.0000	0.0857	0.6513	0.0000	3.0254	0.0000	0.0000	230.09
17.0833	0.0000	0.0000	0.0000	0	0.0000	1.1891	0.0000	0.0000	0.0000	0.0000	0.0179	0	0	0.0000	0.0000	0.0000	0.0815	0.6446	0.0000	3.0020	0.0000	0.0000	230.09
17.1667	0.0000	0.0000	0.0000	0	0.0000	1.1852	0.0000	0.0000	0.0000	0.0000	0.0177	0	0	0.0000	0.0000	0.0000	0.0837	0.6378	0.0000	2.9659	0.0000	0.0000	230.09
17.2500	0.0000	0.0000	0.0000	0	0.0000	1.1793	0.0000	0.0000	0.0000	0.0000	0.0182	0	0	0.0000	0.0000	0.0000	0.0912	0.6313	0.0000	2.9071	0.0000	0.0000	230.12
17.3333	0.0000	0.0000	0.0000	0	0.0000	1.1717	0.0000	0.0000	0.0000	0.0000	0.0168	0	0	0.0000	0.0000	0.0000	0.0867	0.6251	0.0000	2.8474	0.0000	0.0000	230.1
17.4167	0.0000	0.0000	0.0000	0	0.0000	1.1616	0.0000	0.0000	0.0000	0.0000	0.0183	0	0	0.0000	0.0000	0.0000	0.0843	0.6187	0.0000	2.7954	0.0000	0.0000	230.12
17.5000	0.0000	0.0000	0.0000	0	0.0000	1.1479	0.0000	0.0000	0.0000	0.0000	0.0162	0	0	0.0000	0.0000	0.0000	0.0842	0.6124	0.0000	2.7412	0.0000	0.0000	230.14
17.5833	0.0000	0.0000	0.0000	0	0.0000	1.1325	0.0000	0.0000	0.0000	0.0000	0.0180	0	0	0.0000	0.0000	0.0000	0.0806	0.6063	0.0000	2.6840	0.0000	0.0000	230.14
17.6667	0.0000	0.0000	0.0000	0	0.0000	1.1194	0.0000	0.0000	0.0000	0.0000	0.0159	0	0	0.0000	0.0000	0.0000	0.0787	0.6004	0.0000	2.6237	0.0000	0.0000	230.14
17.7500	0.0000	0.0000	0.0000	0	0.0000	1.1119	0.0000	0.0000	0.0000	0.0000	0.0175	0	0	0.0000	0.0000	0.0000	0.0795	0.5944	0.0000	2.5601	0.0000	0.0000	230.16
17.8333	0.0000	0.0000	0.0000	0	0.0000	1.1093	0.0000	0.0000	0.0000	0.0000	0.0156	0	0	0.0000	0.0000	0.0000	0.0782	0.5885	0.0000	2.4982	0.0000	0.0000	230.17
17.9167	0.0000	0.0000	0.0000	0	0.0000	1.1076	0.0000	0.0000	0.0000	0.0000	0.0169	0	0	0.0000	0.0000	0.0000	0.0756	0.5827	0.0000	2.4413	0.0000	0.0000	230.17
18.0000	0.0000	0.0000	0.0000	0	0.0000	1.1025	0.0000	0.0000	0.0000	0.0000	0.0152	0	0	0.0000	0.0000	0.0000	0.0749	0.5771	0.0000	2.3871	0.0000	0.0000	230.17
18.0833	0.0000	0.0000	0.0000	0	0.0000	1.0926	0.0000	0.0000	0.0000	0.0000	0.0163	0	0	0.0000	0.0000	0.0000	0.0748	0.5714	0.0000	2.3328	0.0000	0.0000	230.19
18.1667	0.0000	0.0000	0.0000	0	0.0000	1.0804	0.0000	0.0000	0.0000	0.0000	0.0147	0	0	0.0000	0.0000	0.0000	0.0731	0.5659	0.0000	2.2796	0.0000	0.0000	230.21
18.2500	0.0000	0.0000	0.0000	0	0.0000	1.0690	0.0000	0.0000	0.0000	0.0000	0.0157	0	0	0.0000	0.0000	0.0000	0.0717	0.5606	0.0000	2.2288	0.0000	0.0000	230.21
18.3333	0.0000	0.0000	0.0000	0	0.0000	1.0594	0.0000	0.0000	0.0000	0.0000	0.0140	0	0	0.0000	0.0000	0.0000	0.0712	0.5558	0.0000	2.1796	0.0000	0.0000	230.22
18.4167	0.0000	0.0000	0.0000	0	0.0000	1.0516	0.0000	0.0000	0.0000	0.0000	0.0146	0	0	0.0000	0.0000	0.0000	0.1054	0.5508	0.0000	2.1318	0.0000	0.0000	230.23
18.5000	0.0000	0.0000	0.0000	0	0.0000	1.0456	0.0000	0.0000	0.0000	0.0000	0.0130	0	0	0.0000	0.0000	0.0000	0.0091	0.5453	0.0000	2.0862	0.0000	0.0000	230.24
18.5833	0.0000	0.0000	0.0000	0	0.0000	1.0410	0.0000	0.0000	0.0000	0.0000	0.0067	0	0	0.0000	0.0000	0.0000	0.0090	0.5401	0.0000	2.0422	0.0000	0.0000	230.26
18.6667	0.0000	0.0000	0.0000	0	0.0000	1.0371	0.0000	0.0000	0.0000	0.0000	0.0039	0	0	0.0000	0.0000	0.0000	0.0090	0.5355	0.0000	1.9988	0.0000	0.0000	230.25
18.7500	0.0000	0.0000	0.0000	0	0.0000	1.0321	0.0000	0.0000	0.0000	0.0000	0.0025	0	0	0.0000	0.0000	0.0000	0.0757	0.5308	0.0000	1.9568	0.0000	0.0000	230.27
18.8333	0.0000	0.0000	0.0000	0	0.0000	1.0245	0.0000	0.0000	0.0000	0.0000	0.0017	0	0	0.0000	0.0000	0.0000	0.0754	0.5256	0.0000	1.9167	0.0000	0.0000	230.28
18.9167	0.0000	0.0000	0.0000	0	0.0000	1.0141	0.0000	0.0000	0.0000	0.0000	0.0012	0	0	0.0000	0.0000	0.0000	0.0752	0.5207	0.0000	1.8776	0.0000	0.0000	230.28
19.0000	0.0000	0.0000	0.0000	0	0.0000	1.0032	0.0000	0.0000	0.0000	0.0000	0.0009	0	0	0.0000	0.0000	0.0000	0.0750	0.5163	0.0000	1.8395	0.0000	0.0000	230.3
19.0833	0.0000	0.0000	0.0000	0	0.0000	0.9949	0.0000	0.0000	0.0000	0.0000	0.0007	0	0	0.0000	0.0000	0.0000	0.0747	0.5117	0.0000	1.8028	0.0000	0.0000	230.3
19.1667	0.0000	0.0000	0.0000	0	0.0000	0.9899	0.0000	0.0000	0.0000	0.0000	0.0005	0	0	0.0000	0.0000	0.0000	0.0751	0.5069	0.0000	1.7672	0.0000	0.0000	230.32
19.2500	0.0000	0.0000	0.0000	0	0.0000	0.9865	0.0000	0.0000	0.0000	0.0000	0.0004	0	0	0.0000	0.0000	0.0000	0.0739	0.5024	0.0000	1.7324	0.0000	0.0000	230.33
19.3333	0.0000	0.0000	0.0000	0	0.0000	0.9830	0.0000	0.0000	0.0000	0.0000	0.0003	0	0	0.0000	0.0000	0.0000	0.0725	0.4981	0.0000	1.6986	0.0000	0.0000	230.34
19.4167	0.0000	0.0000	0.0000	0	0.0000	0.9782	0.0000	0.0000	0.0000	0.0000	0.0002	0	0	0.0000	0.0000	0.0000	0.0711	0.4937	0.0000	1.6659	0.0000	0.0000	230.37
19.5000	0.0000	0.0000	0.0000	0	0.0000	0.9717	0.0000	0.0000	0.0000	0.0000	0.0002	0	0	0.0000	0.0000	0.0000	0.0699	0.4892	0.0000	1.6342	0.0000	0.0000	230.37
19.5833	0.0000	0.0000	0.0000	0	0.0000	0.9643	0.0000	0.0000	0.0000	0.0000	0.0002	0	0	0.0000	0.0000	0.0000	0.0686	0.4850	0.0000	1.6035	0.0000	0.0000	230.39
19.6667	0.0000	0.0000	0.0000	0	0.0000	0.9567	0.0000	0.0000	0.0000	0.0000	0.0001	0	0	0.0000	0.0000	0.0000	0.0672	0.4809	0.0000	1.5738	0.0000	0.0000	230.41
19.7500	0.0000	0.0000	0.0000	0	0.0000	0.9494	0.0000	0.0000	0.0000	0.0000	0.0001	0	0	0.0000	0.0000	0.0000	0.0659	0.4767	0.0000	1.5450	0.0000	0.0000	230.42
19.8333	0.0000	0.0000	0.0000	0	0.0000	0.9427	0.0000	0.0000	0.0000	0.0000	0.0001	0	0	0.0000	0.0000	0.0000	0.0989	0.4725	0.0000	1.5169	0.0000	0.0000	230.44
19.9167	0.0000	0.0000	0.0000	0	0.0000	0.9373	0.0000	0.0000	0.0000	0.0000	0.0001	0	0	0.0000	0.0000	0.0000	0.0977	0.4685	0.0000	1.4894	0.0000	0.0000	230.44
20.0000	0.0000	0.0000	0.0000	0	0.0000	0.9331	0.0000	0.0000	0.0000	0.0000	0.0001	0	0	0.0000	0.0000	0.0000	0.0964	0.4645	0.0000	1.4626	0.0000	0.0000	230.46
20.0833	0.0000	0.0000	0.0000	0	0.0000	0.9295	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0.0000	0.0000	0.0000	0.0952	0.4605	0.0000	1.4366	0.0000	0.0000	230.48
20.1667	0.0000	0.0000	0.0000	0	0.0000	0.9251	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0.0000	0.0000	0.0000	0.0941	0.4566	0.0000	1.4111	0.0000	0.0000	230.49
20.2500	0.0000	0.0000	0.0000	0	0.0000	0.9193	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0.0000	0.0000	0.0000	0.0929	0.4528	0.0000	1.3863	0.0000	0.0000	230.52
20.3333	0.0000	0.0000	0.0000	0	0.0000	0.9123	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0.0000	0.0000	0.0000	0.0918	0.4490	0.0000	1.3620	0.0000	0.0000	230.53
20.4167	0.0000	0.0000	0.0000	0	0.0000	0.9049	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0.0000	0.0000	0.0000	0.0906	0.4452	0.0000	1.3384	0.0000	0.0000	230.55
20.5000	0.0000	0.0000	0.0000	0	0.0000	0.8984	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0.0000	0.0000	0.0000	0.0896	0.4415	0.0000	1.3152	0.0000	0.0000	230.56
20.5833	0.0000	0.0000	0.0000	0	0.0000	0.8932	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0.0000	0.0000	0.0000	0.0885	0.4378	0.0000	1.2925	0.0000	0.0000	230.57
20.6667	0.0000	0.0000	0.0000	0	0.0000	0.8889	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0.0000	0.0000	0.0000	0.0866	0.4342	0.0000	1.2703	0.0000	0.0000	230.59

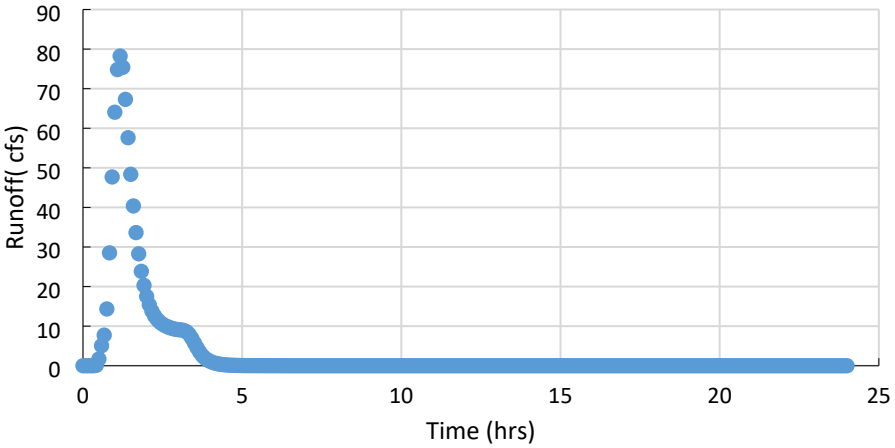
20.7500	0.0000	0.0000	0.0000	0	0.0000	0.8848	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0.0000	0.0000	0.0000	0.0854	0.4306	0.0000	1.2486	0.0000	0.0000	230.6
20.8333	0.0000	0.0000	0.0000	0	0.0000	0.8803	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0.0000	0.0000	0.0000	0.0842	0.4271	0.0000	1.2274	0.0000	0.0000	230.61
20.9167	0.0000	0.0000	0.0000	0	0.0000	0.8754	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0.0000	0.0000	0.0000	0.0830	0.4237	0.0000	1.2066	0.0000	0.0000	230.61
21.0000	0.0000	0.0000	0.0000	0	0.0000	0.8700	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0.0000	0.0000	0.0000	0.0819	0.4204	0.0000	1.1863	0.0000	0.0000	230.63
21.0833	0.0000	0.0000	0.0000	0	0.0000	0.8641	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0.0000	0.0000	0.0000	0.0807	0.4170	0.0000	1.1666	0.0000	0.0000	230.64
21.1667	0.0000	0.0000	0.0000	0	0.0000	0.8580	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0.0000	0.0000	0.0000	0.0796	0.4137	0.0000	1.1475	0.0000	0.0000	230.66
21.2500	0.0000	0.0000	0.0000	0	0.0000	0.8521	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0.0000	0.0000	0.0000	0.0785	0.4104	0.0000	1.1289	0.0000	0.0000	230.66
21.3333	0.0000	0.0000	0.0000	0	0.0000	0.8468	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0.0000	0.0000	0.0000	0.0774	0.4067	0.0000	1.1107	0.0000	0.0000	230.68
21.4167	0.0000	0.0000	0.0000	0	0.0000	0.8372	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0.0000	0.0000	0.0000	0.0763	0.4033	0.0000	1.0927	0.0000	0.0000	230.7
21.5000	0.0000	0.0000	0.0000	0	0.0000	0.7886	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0.0000	0.0000	0.0000	0.0753	0.4008	0.0000	1.0750	0.0000	0.0000	230.72
21.5833	0.0000	0.0000	0.0000	0	0.0000	0.6943	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0.0000	0.0000	0.0000	0.0743	0.3980	0.0000	1.0576	0.0000	0.0000	230.72
21.6667	0.0000	0.0000	0.0000	0	0.0000	0.6866	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0.0000	0.0000	0.0000	0.0733	0.3941	0.0000	1.0407	0.0000	0.0000	230.74
21.7500	0.0000	0.0000	0.0000	0	0.0000	0.8081	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0.0000	0.0000	0.0000	0.0723	0.3910	0.0000	1.0242	0.0000	0.0000	230.74
21.8333	0.0000	0.0000	0.0000	0	0.0000	0.8953	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0.0000	0.0000	0.0000	0.0713	0.3890	0.0000	1.0079	0.0000	0.0000	230.75
21.9167	0.0000	0.0000	0.0000	0	0.0000	0.8867	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0.0000	0.0000	0.0000	0.0703	0.3862	0.0000	0.9920	0.0000	0.0000	230.75
22.0000	0.0000	0.0000	0.0000	0	0.0000	0.8400	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0.0000	0.0000	0.0000	0.0694	0.3822	0.0000	0.9764	0.0000	0.0000	230.77
22.0833	0.0000	0.0000	0.0000	0	0.0000	0.7759	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0.0000	0.0000	0.0000	0.0684	0.3792	0.0000	0.9611	0.0000	0.0000	230.79
22.1667	0.0000	0.0000	0.0000	0	0.0000	0.7236	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0.0000	0.0000	0.0000	0.0675	0.3775	0.0000	0.9460	0.0000	0.0000	230.79
22.2500	0.0000	0.0000	0.0000	0	0.0000	0.7118	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0.0000	0.0000	0.0000	0.0666	0.3749	0.0000	0.9312	0.0000	0.0000	230.8
22.3333	0.0000	0.0000	0.0000	0	0.0000	0.7325	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0.0000	0.0000	0.0000	0.0657	0.3710	0.0000	0.9168	0.0000	0.0000	230.81
22.4167	0.0000	0.0000	0.0000	0	0.0000	0.7654	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0.0000	0.0000	0.0000	0.0000	0.3682	0.0000	0.9026	0.0000	0.0000	230.82
22.5000	0.0000	0.0000	0.0000	0	0.0000	0.7824	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0.0000	0.0000	0.0000	0.0729	0.3668	0.0000	0.8887	0.0000	0.0000	230.83
22.5833	0.0000	0.0000	0.0000	0	0.0000	0.7713	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0.0000	0.0000	0.0000	0.0907	0.3642	0.0000	0.8751	0.0000	0.0000	230.84
22.6667	0.0000	0.0000	0.0000	0	0.0000	0.7677	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0.0000	0.0000	0.0000	0.0059	0.3603	0.0000	0.8617	0.0000	0.0000	230.85
22.7500	0.0000	0.0000	0.0000	0	0.0000	0.7887	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0.0000	0.0000	0.0000	0.0000	0.3576	0.0000	0.8486	0.0000	0.0000	230.85
22.8333	0.0000	0.0000	0.0000	0	0.0000	0.7847	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0.0000	0.0000	0.0000	0.0080	0.3563	0.0000	0.8357	0.0000	0.0000	230.84
22.9167	0.0000	0.0000	0.0000	0	0.0000	0.7414	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0.0000	0.0000	0.0000	0.0079	0.3537	0.0000	0.8231	0.0000	0.0000	230.87
23.0000	0.0000	0.0000	0.0000	0	0.0000	0.7045	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0.0000	0.0000	0.0000	0.0078	0.3501	0.0000	0.8110	0.0000	0.0000	230.88
23.0833	0.0000	0.0000	0.0000	0	0.0000	0.6910	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0.0000	0.0000	0.0000	0.0077	0.3478	0.0000	0.7992	0.0000	0.0000	230.88
23.1667	0.0000	0.0000	0.0000	0	0.0000	0.6982	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0.0000	0.0000	0.0000	0.0076	0.3464	0.0000	0.7876	0.0000	0.0000	230.9
23.2500	0.0000	0.0000	0.0000	0	0.0000	0.7265	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0.0000	0.0000	0.0000	0.0075	0.3438	0.0000	0.7763	0.0000	0.0000	230.89
23.3333	0.0000	0.0000	0.0000	0	0.0000	0.7548	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0.0000	0.0000	0.0000	0.0075	0.3405	0.0000	0.7652	0.0000	0.0000	230.89
23.4167	0.0000	0.0000	0.0000	0	0.0000	0.7625	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0.0000	0.0000	0.0000	0.0074	0.3383	0.0000	0.7542	0.0000	0.0000	230.9
23.5000	0.0000	0.0000	0.0000	0	0.0000	0.7472	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0.0000	0.0000	0.0000	0.0073	0.3368	0.0000	0.7434	0.0000	0.0000	230.91
23.5833	0.0000	0.0000	0.0000	0	0.0000	0.7160	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0.0000	0.0000	0.0000	0.0072	0.3344	0.0000	0.7329	0.0000	0.0000	230.92
23.6667	0.0000	0.0000	0.0000	0	0.0000	0.6901	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0.0000	0.0000	0.0000	0.0071	0.3313	0.0000	0.7225	0.0000	0.0000	230.92
23.7500	0.0000	0.0000	0.0000	0	0.0000	0.6874	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0.0000	0.0000	0.0000	0.0070	0.3292	0.0000	0.7122	0.0000	0.0000	230.93
23.8333	0.0000	0.0000	0.0000	0	0.0000	0.6950	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0.0000	0.0000	0.0000	0.0069	0.3277	0.0000	0.7022	0.0000	0.0000	230.93
23.9167	0.0000	0.0000	0.0000	0	0.0000	0.6947	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0.0000	0.0000	0.0000	0.0068	0.3254	0.0000	0.6924	0.0000	0.0000	230.95
24.0000	0.0000	0.0000	0.0000	0	0.0000	0.6932	0.0000	0.0000	0.0000	0.0000	0.0000	0	0	0.0000	0.0000	0.0000	0.0067	0.3227	0.0000	0.6827	0.0000	0.0000	230.75


Subbasin CWA3E-01
Runoff(cfs)
160
140
120
100
80
60
40
20
0
0
5
10
15
20
25
Time (hrs)

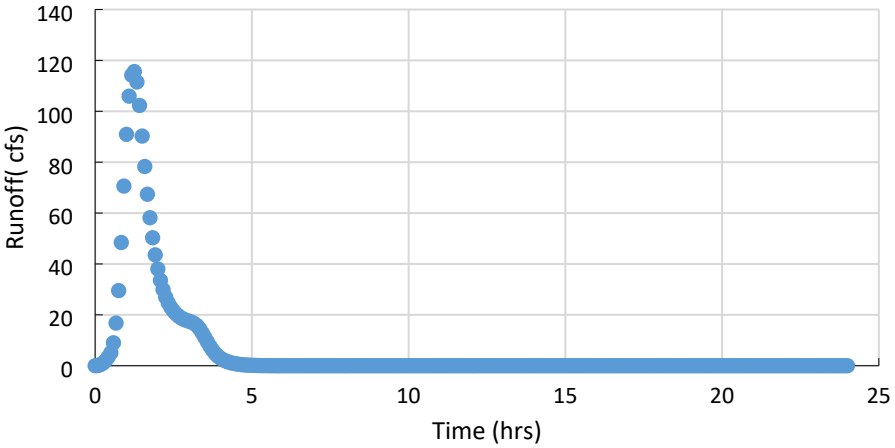

Subbasin CWA3-06
Runoff(cfs)
30
25
20
15
10
5
0
0
5
10
15
20
25
Time (hrs)


Subbasin CWA3-05
Runoff(cfs)
70
60
50
40
30
20
10
0
0
5
10
15
20
25
Time (hrs)

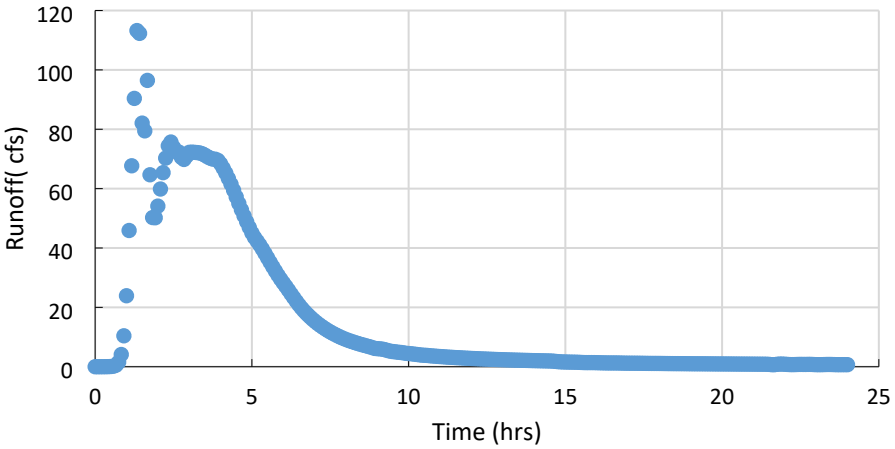
Link 24

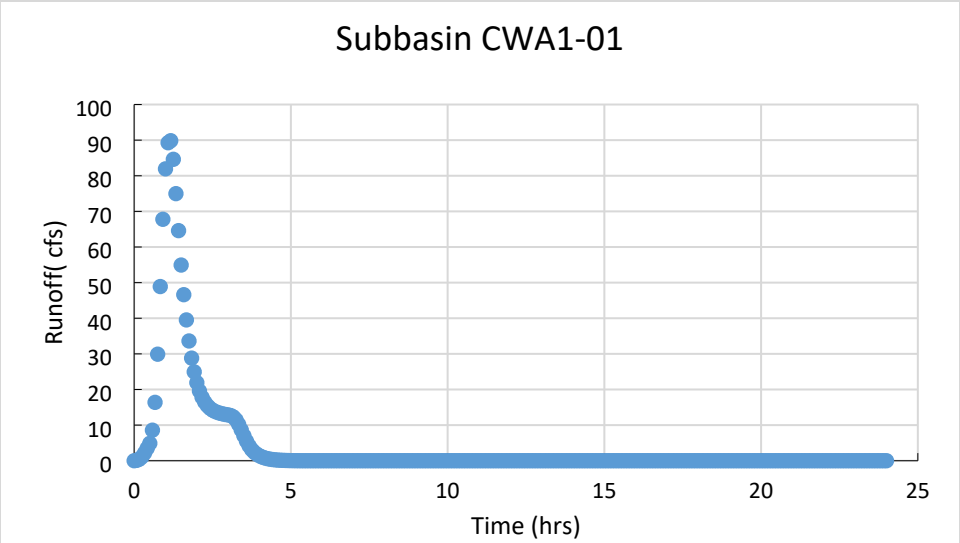


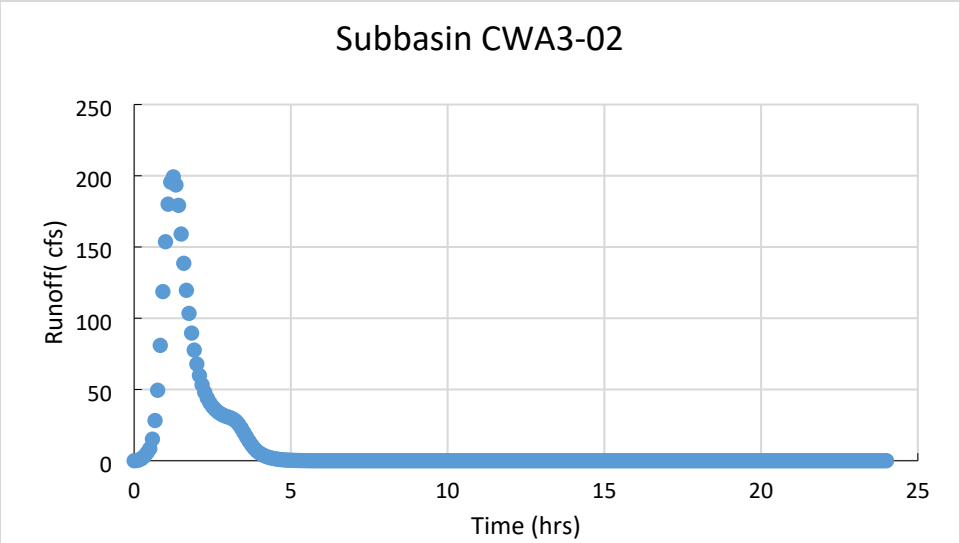
Subbasin CWA3-03

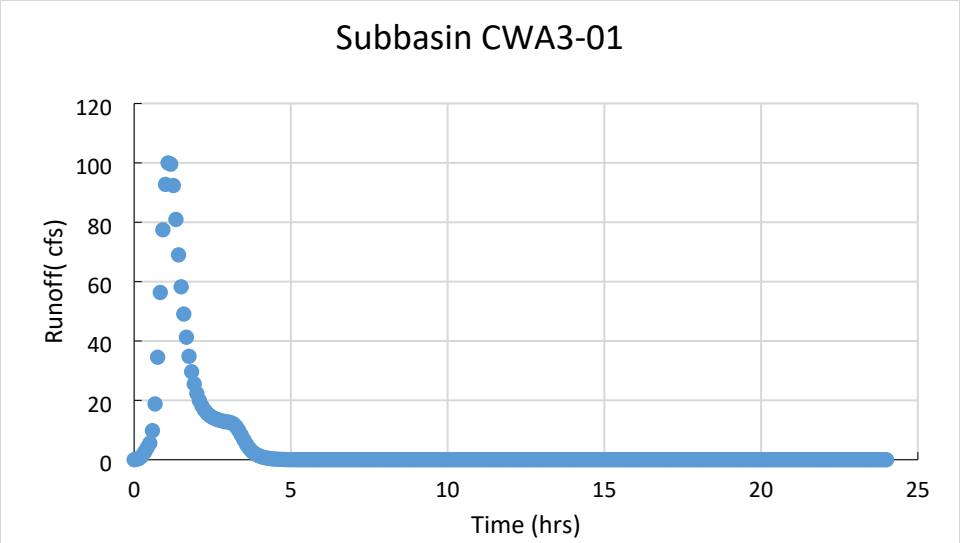


Node 46

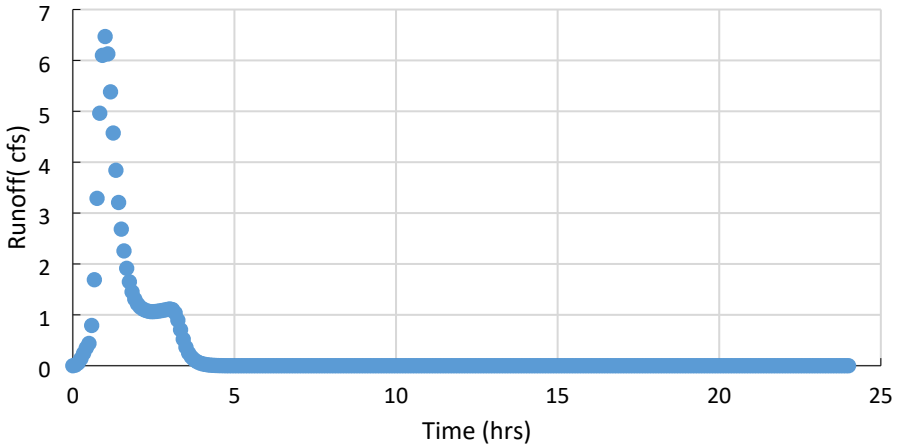



Subbasin CWA1-01
Runoff(cfs)
100
90
80
70
60
50
40
30
20
10
0
0
5
10
15
20
25
Time (hrs)

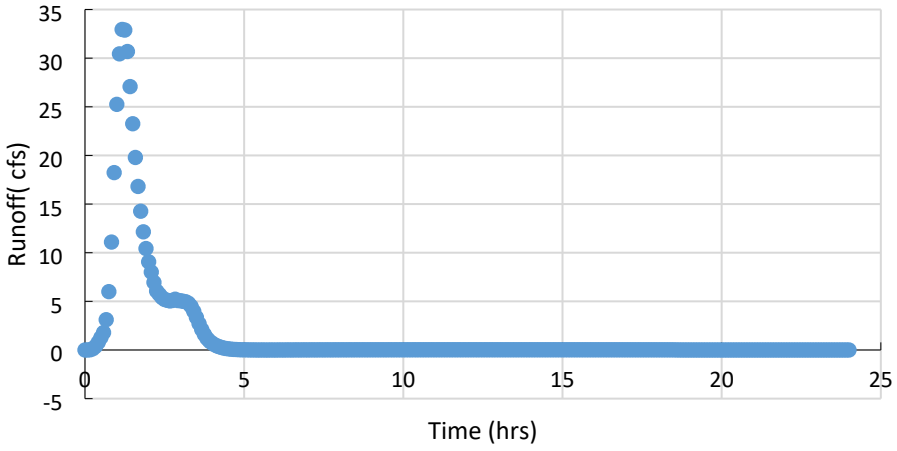

Subbasin CWA3-02
Runoff(cfs)
250
200
150
100
50
0
0
5
10
15
20
25
Time (hrs)


Subbasin CWA3-01
Runoff(cfs)
120
100
80
60
40
20
0
0
5
10
15
20
25
Time (hrs)

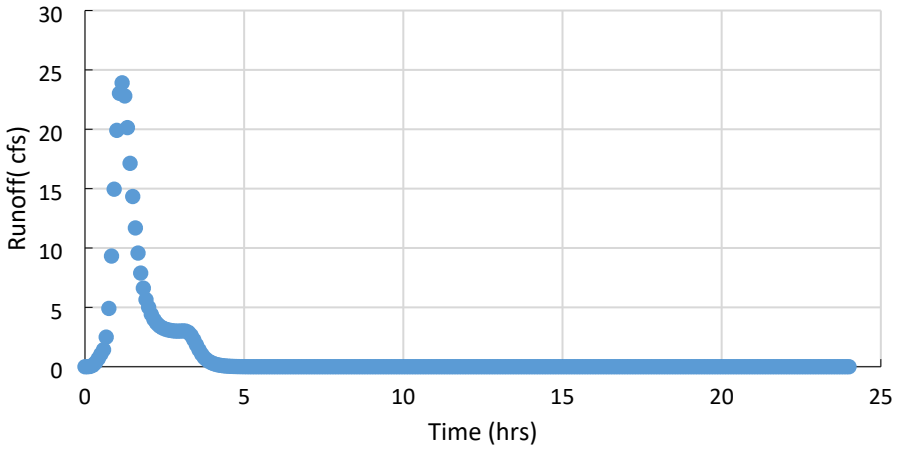
Subbasin CWA2-03



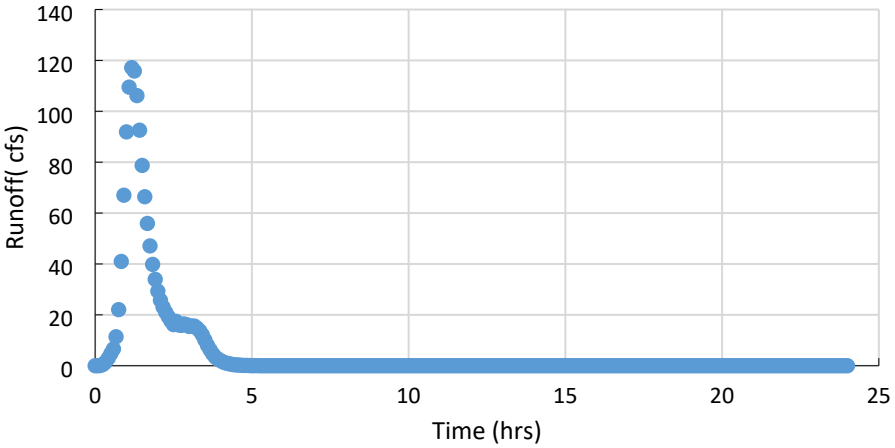
Link 12



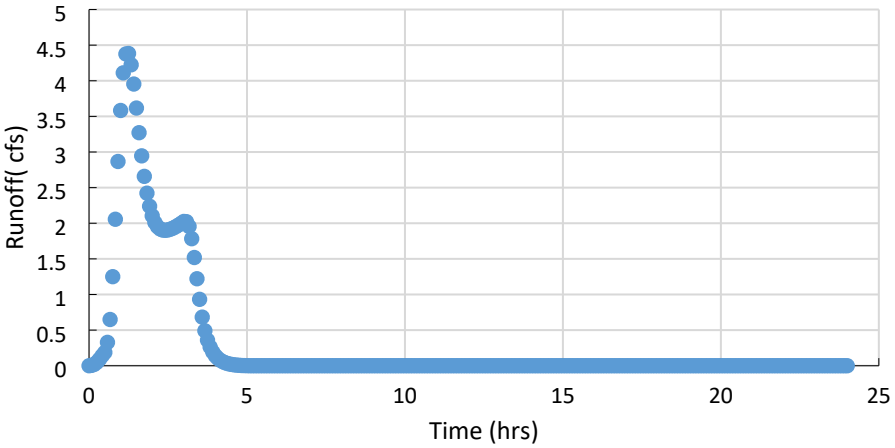
Link 10



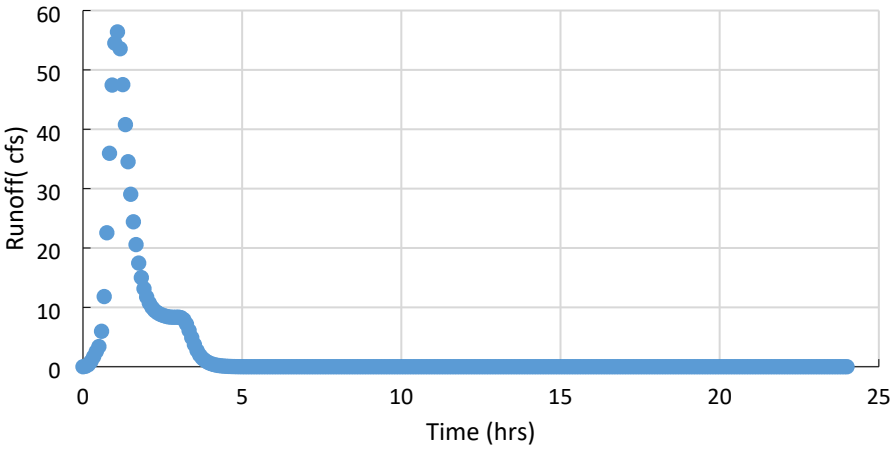
Link 9



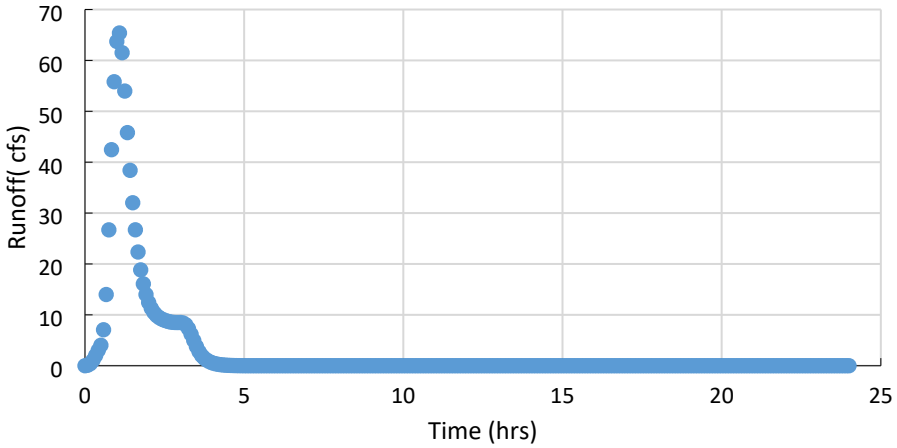
Subbasin CD-10



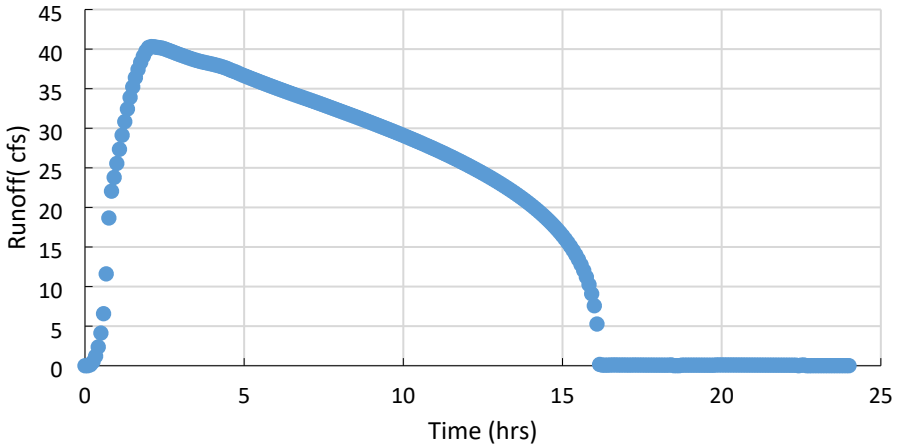
Subbasin CD-08



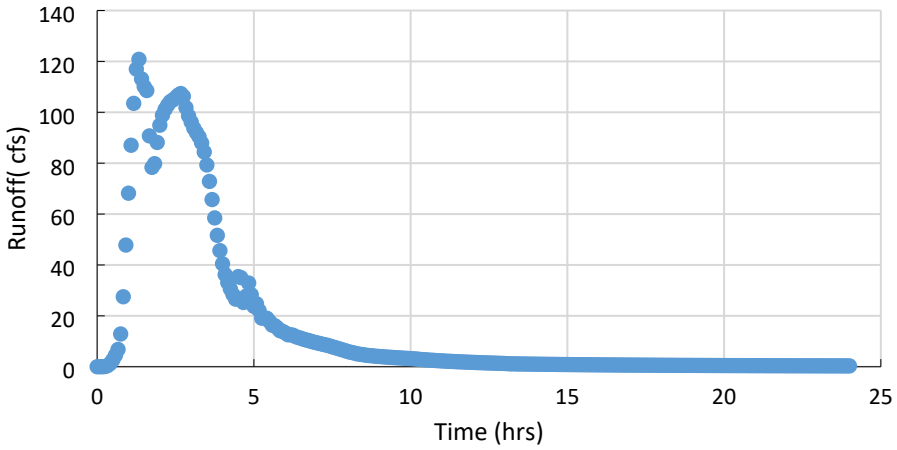
Subbasin CD-07



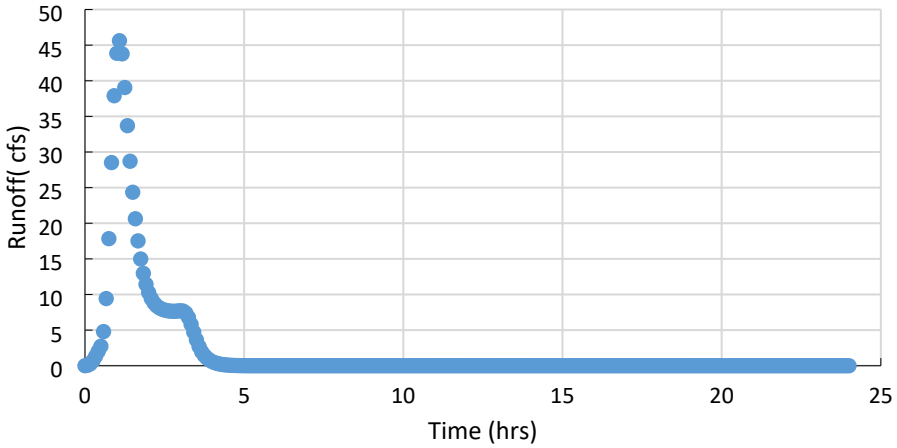
Subbasin CD-05



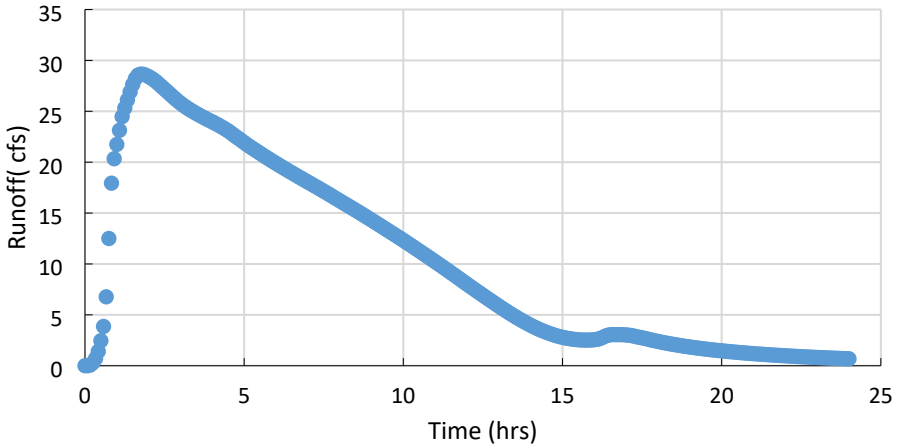
Link 22



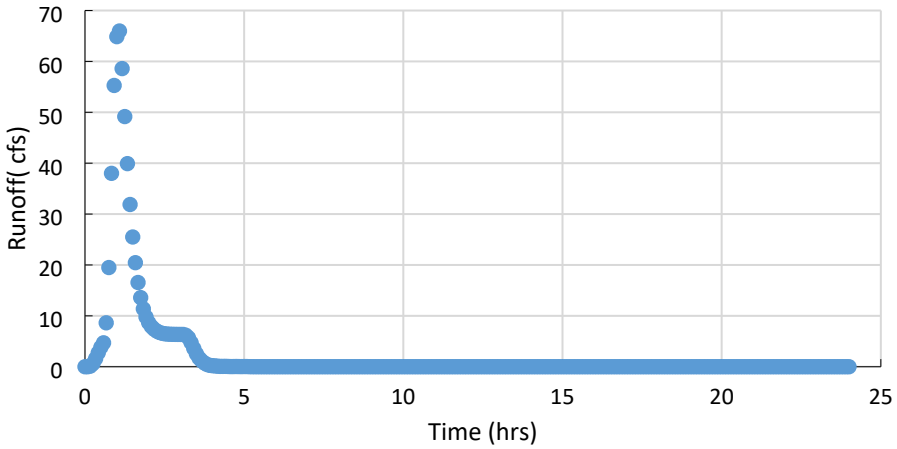
Subbasin CD-04

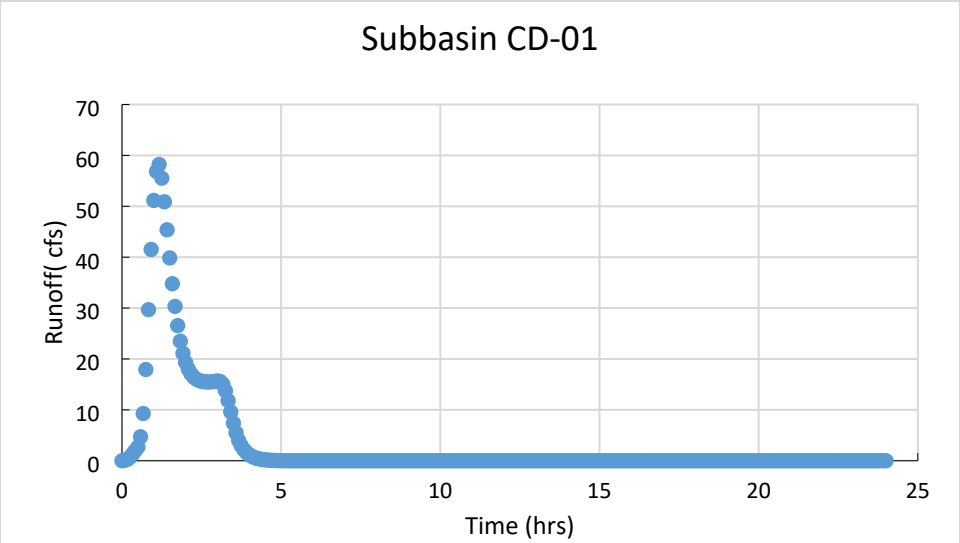


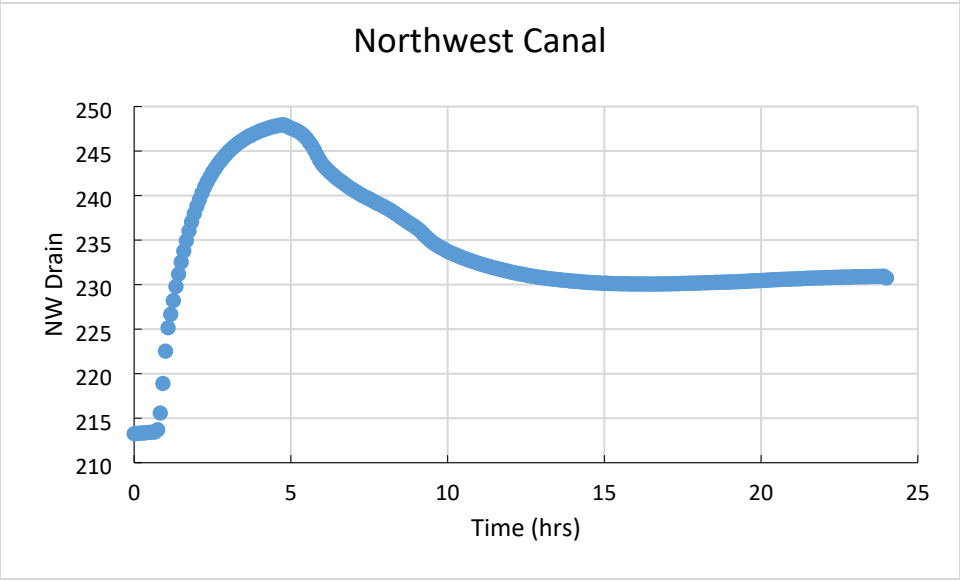
Subbasin CD-03



Link 23



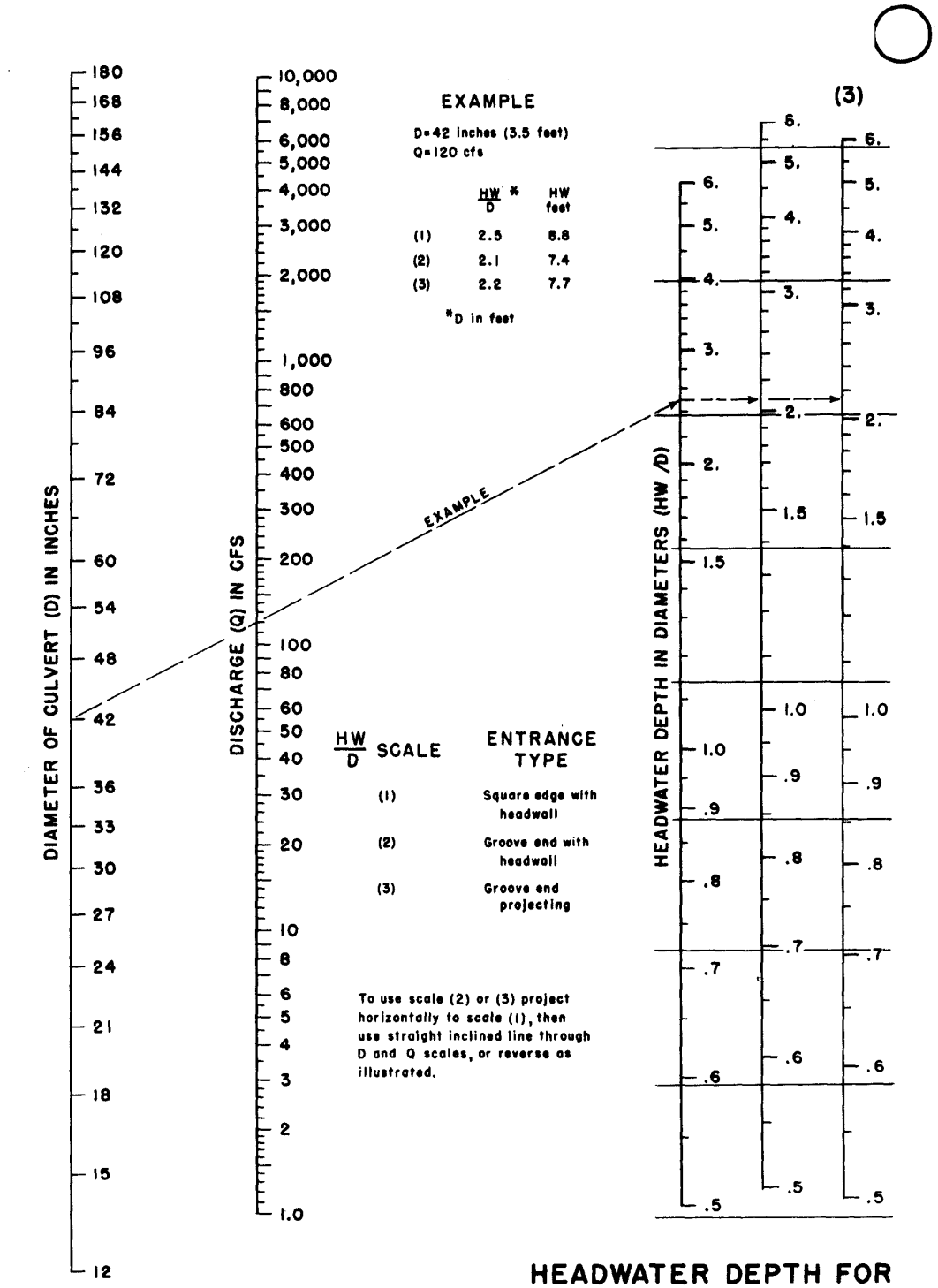

Subbasin CD-01
Runoff(cfs)
70
60
50
40
30
20
10
0
0
5
10
15
20
25
Time (hrs)


Northwest Canal
NW Drain
250
245
240
235
230
225
220
215
210
0
5
10
15
20
25
Time (hrs)

APPENDIX H

Inlet Nomograph of Airport Pipeline

CHART 1B



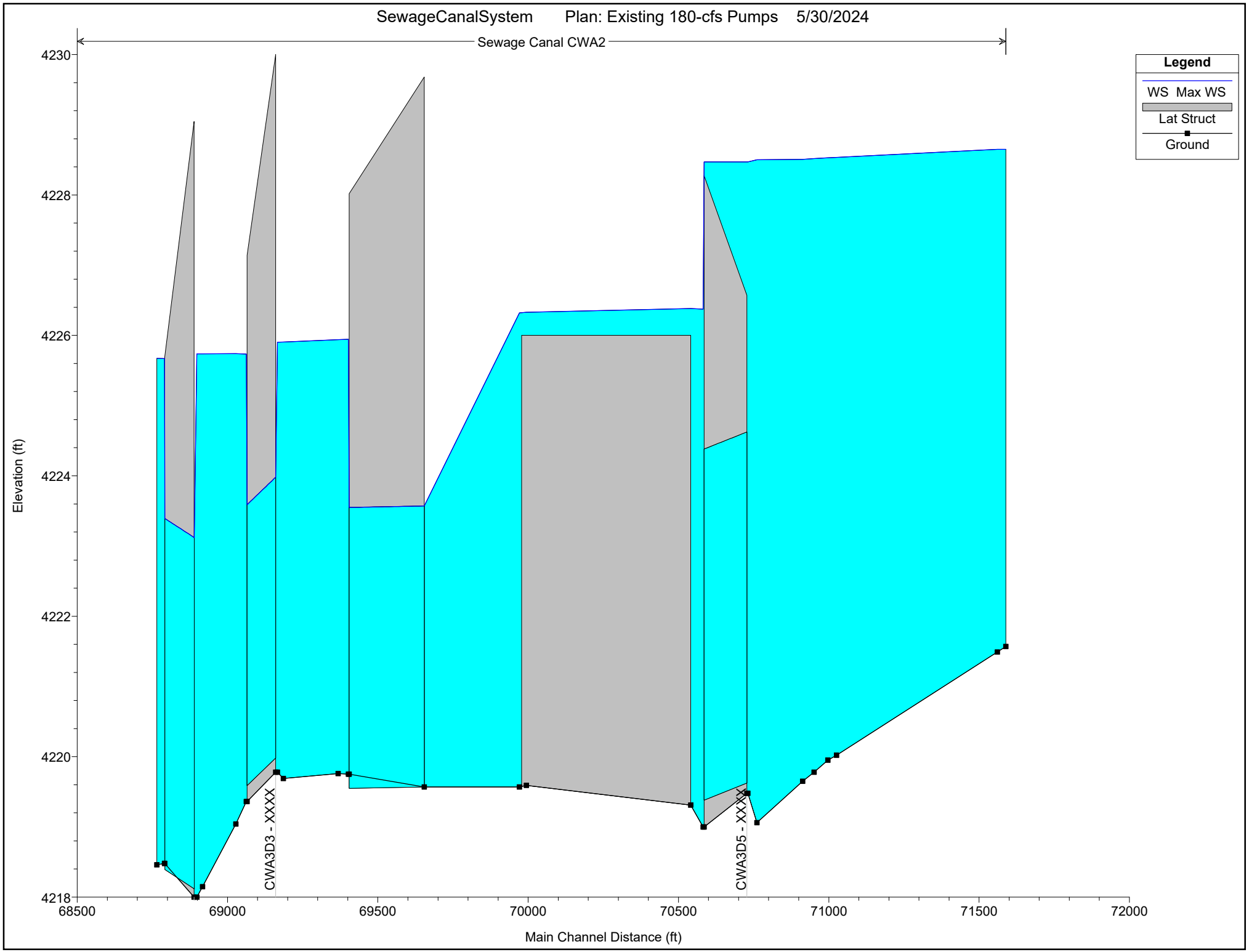
HEADWATER SCALES 2&3
REVISED MAY 1964

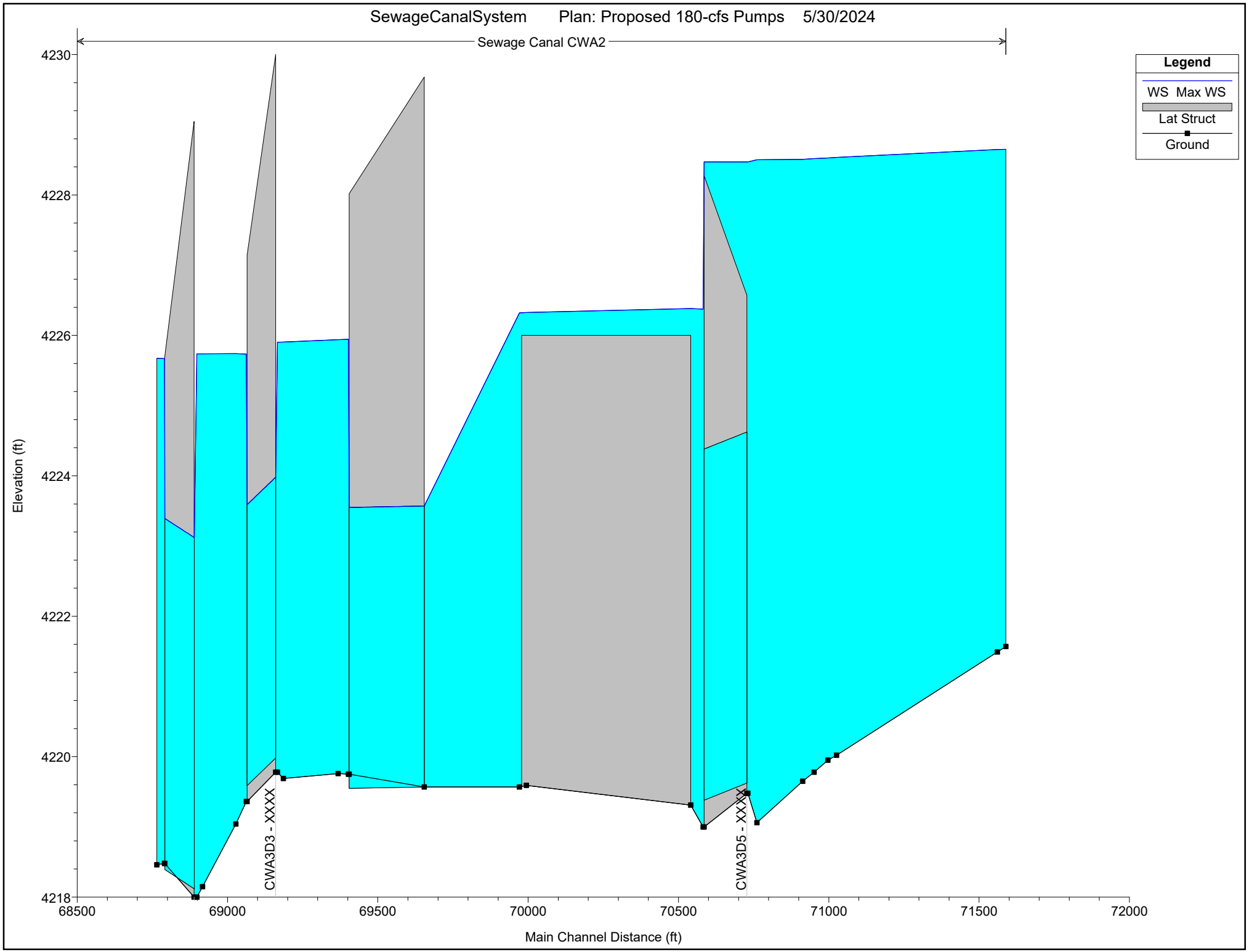
BUREAU OF PUBLIC ROADS JAN. 1963

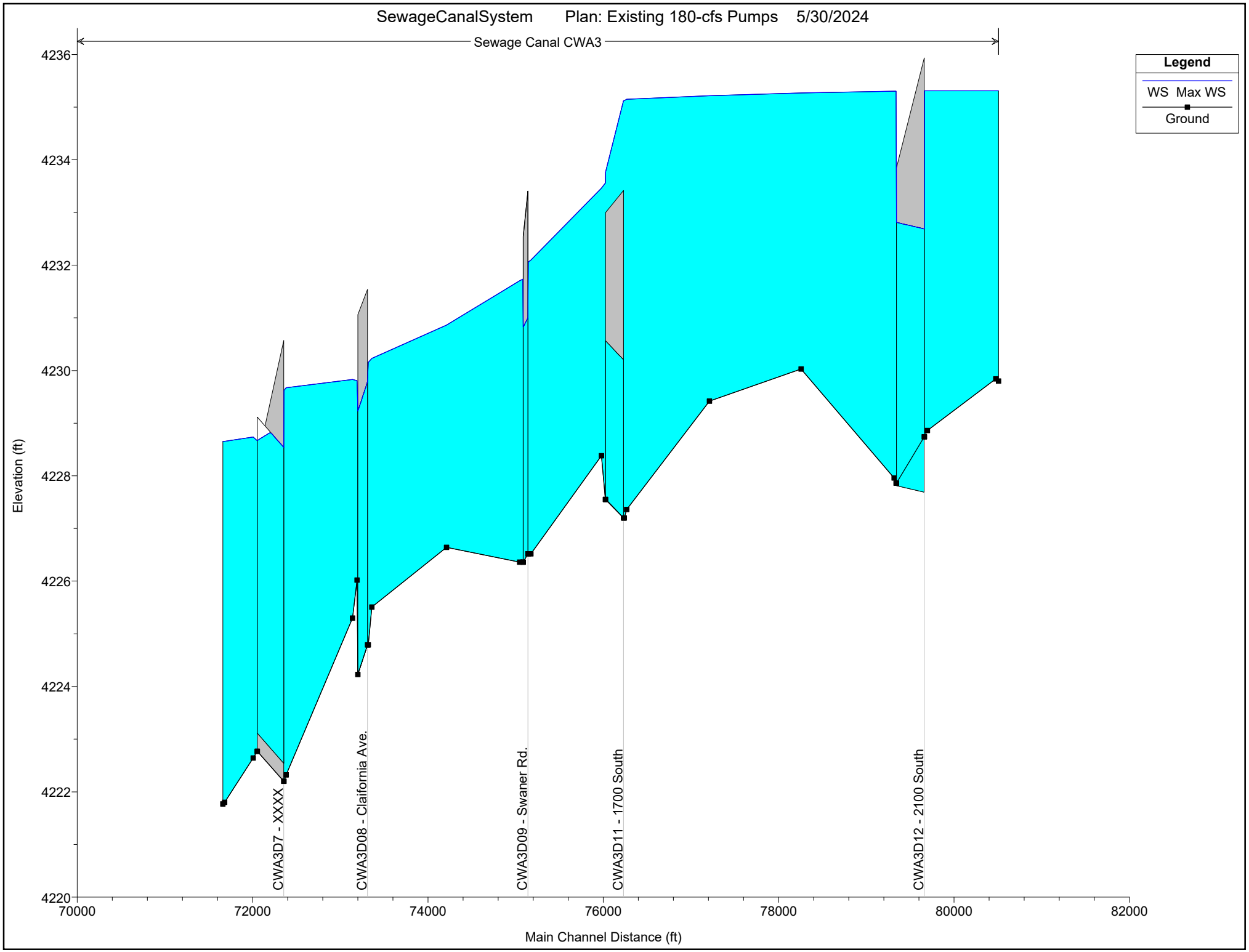
HEADWATER DEPTH FOR CONCRETE PIPE CULVERTS WITH INLET CONTROL

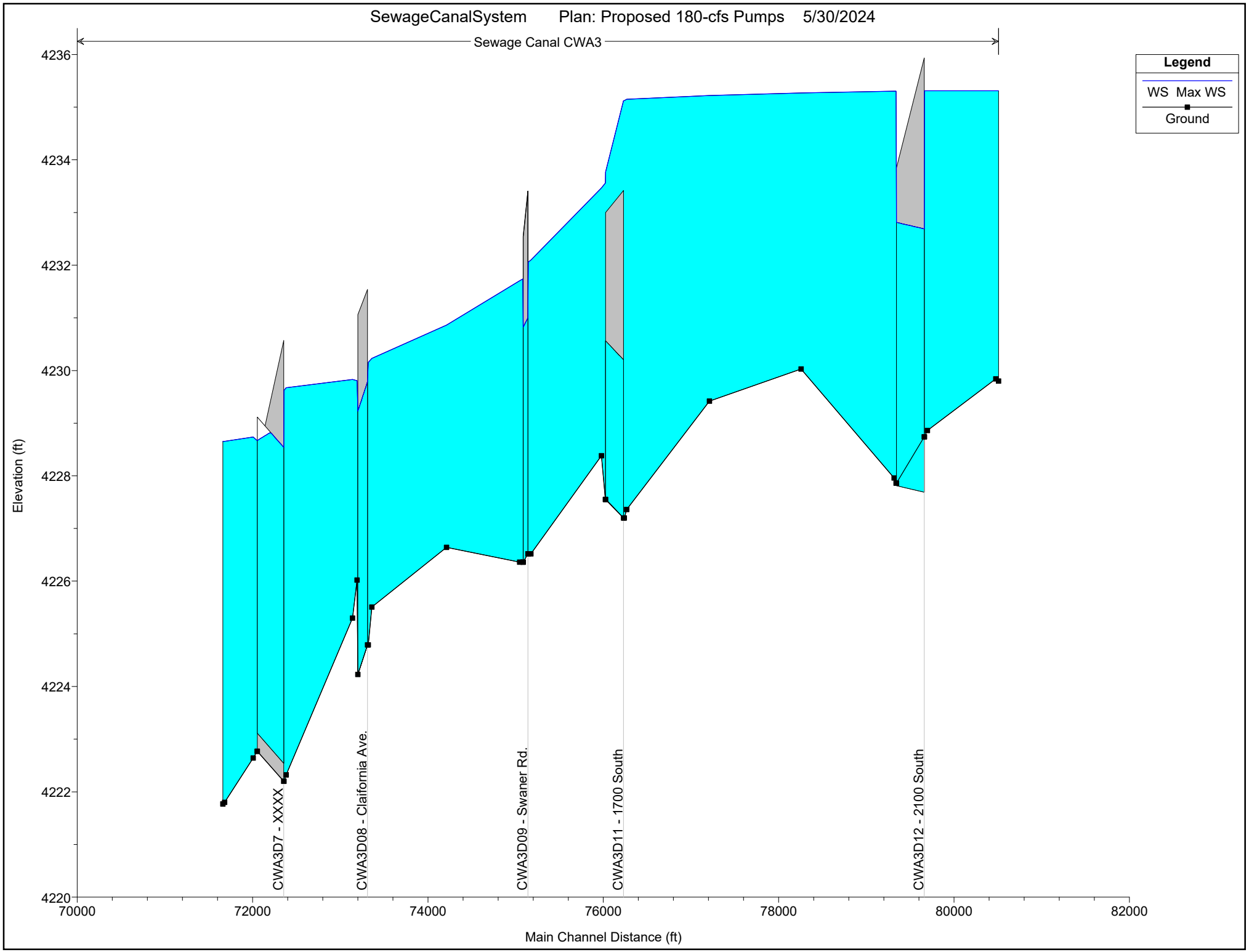
APPENDIX I

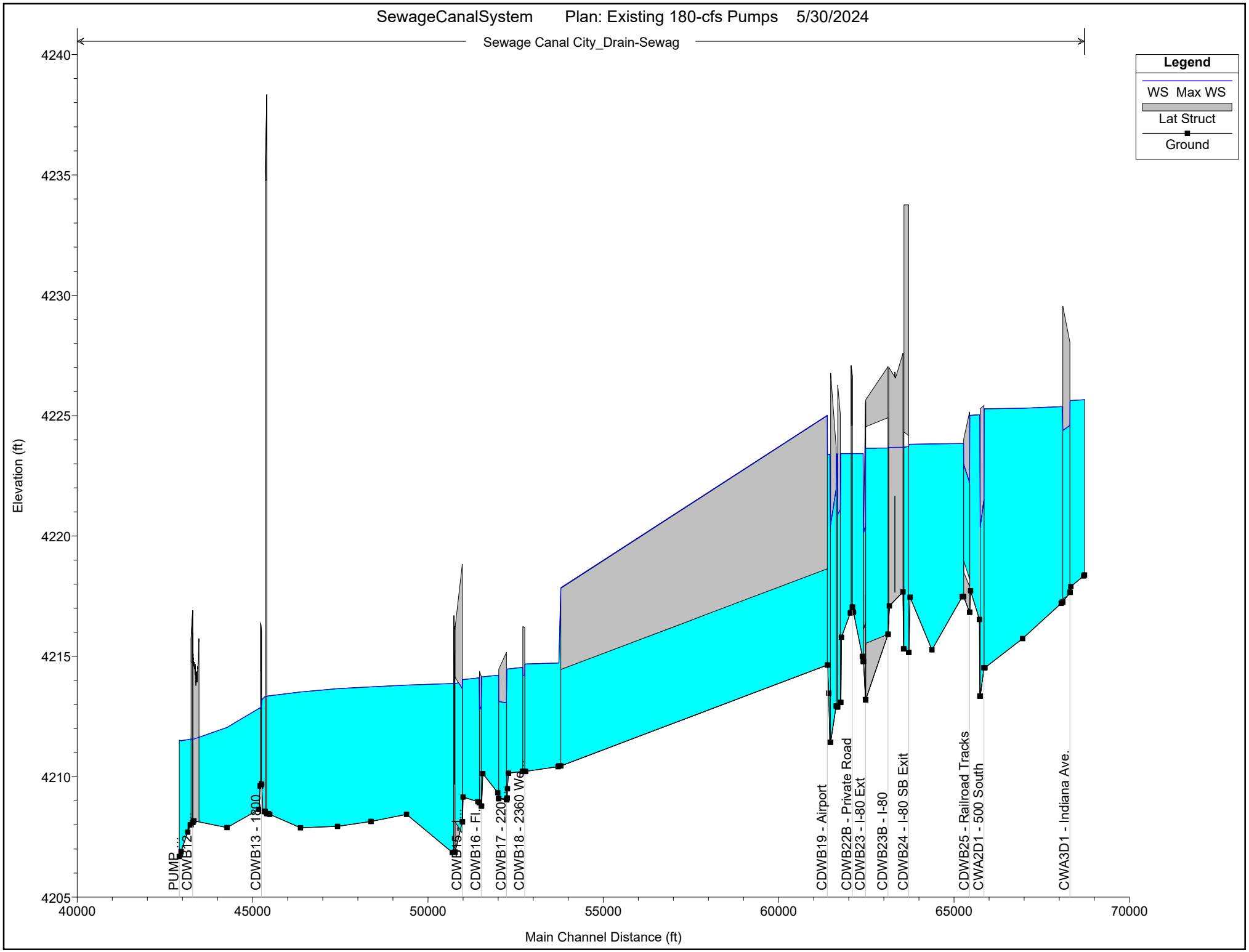
Peak Water Surface Elevation Profiles

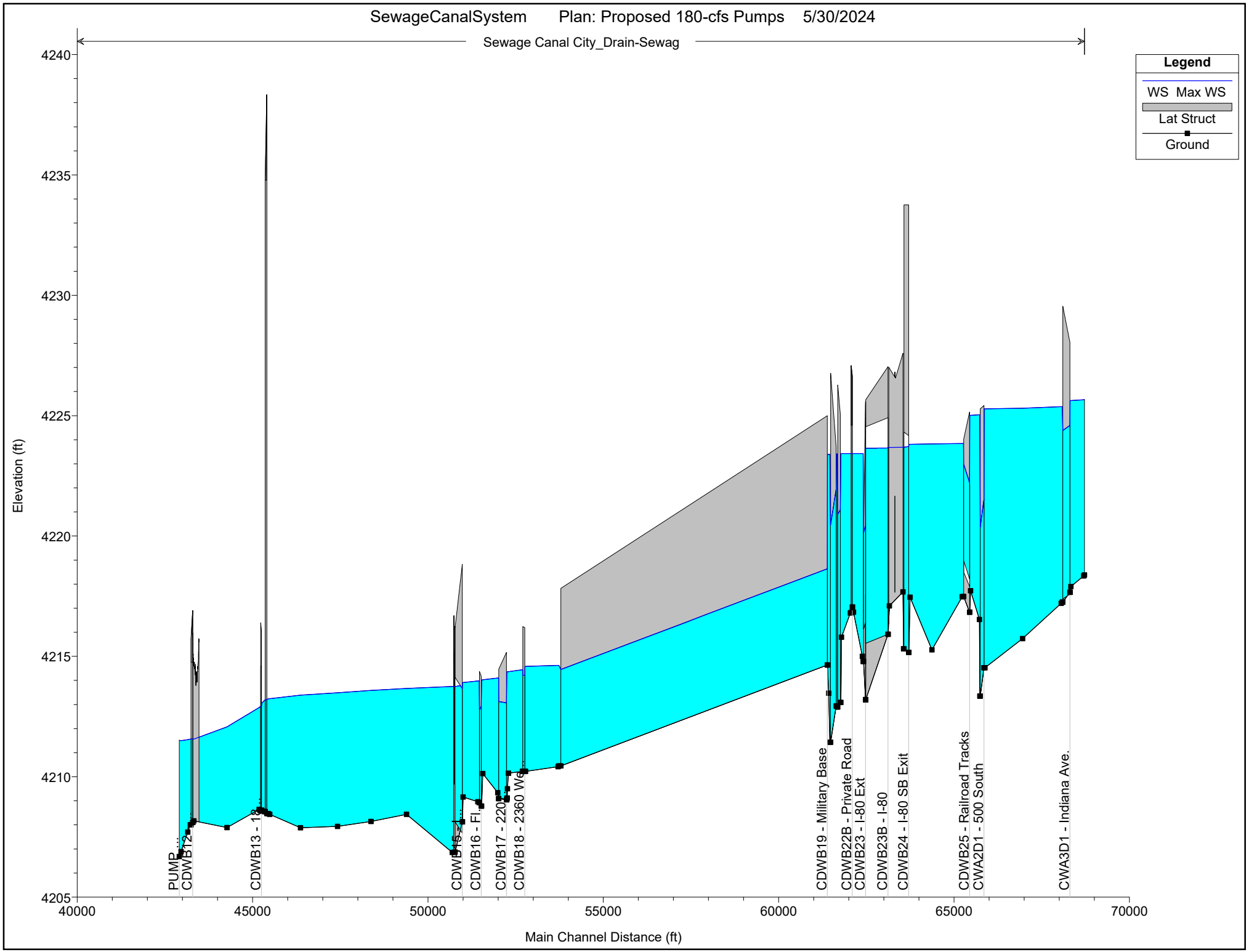

SewageCanalSystem Plan: Existing 180-cfs Pumps 5/30/2024
Sewage Canal CWA2
Legend
WS Max WS
Lat Struct
Ground
Elevation (ft)
4230
4228
4226
4224
4222
4220
4218
68500
69000
69500
70000
70500
71000
71500
72000
Main Channel Distance (ft)
CWA3D3 - XXXX
CWA3D5 - XXXX

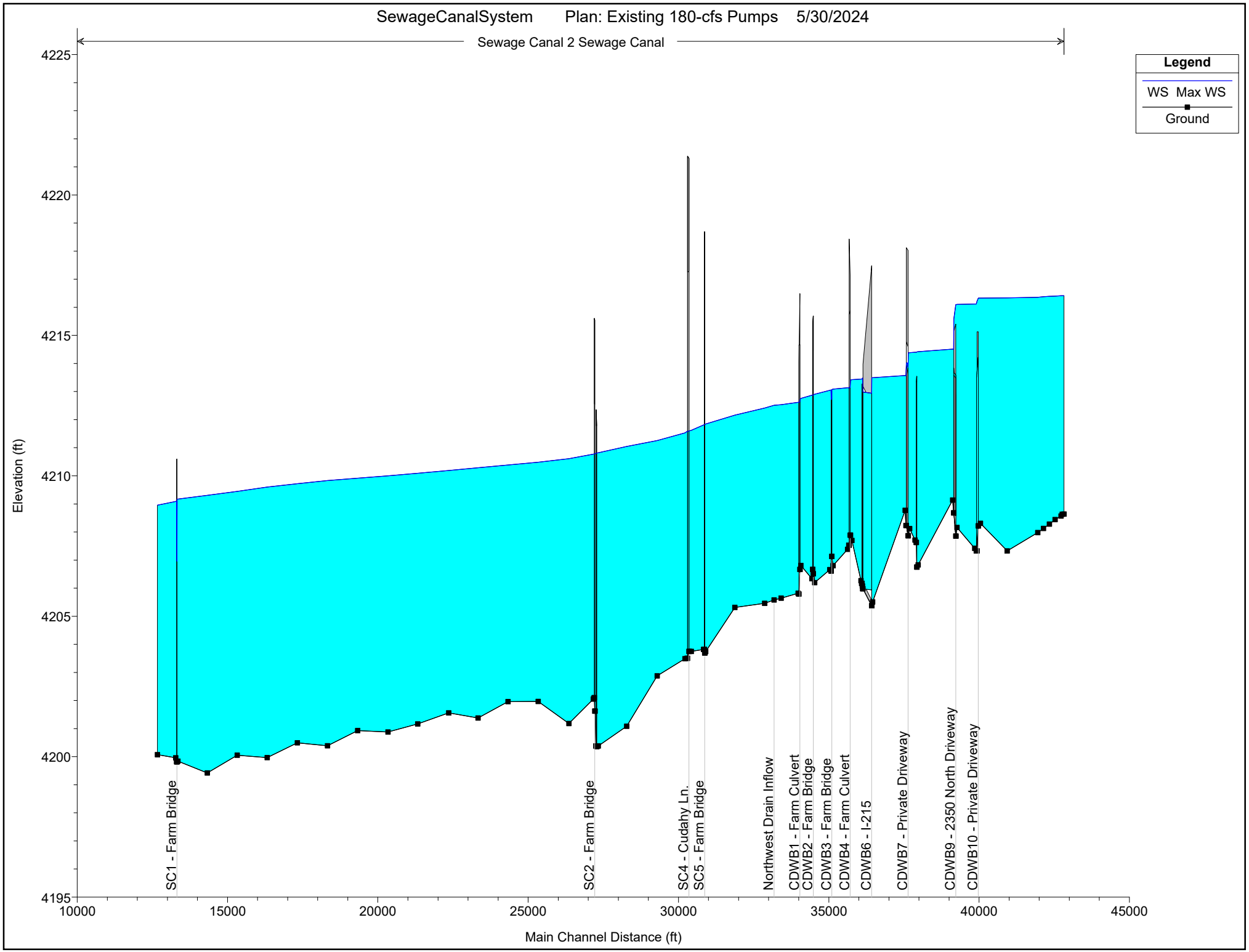

SewageCanalSystem Plan: Proposed 180-cfs Pumps 5/30/2024
Sewage Canal CWA2
Legend
WS Max WS
Lat Struct
Ground
Elevation (ft)
4230
4228
4226
4224
4222
4220
4218
68500
69000
69500
70000
70500
71000
71500
72000
Main Channel Distance (ft)
CWA3D3 - XXXX
CWA3D5 - XXXX

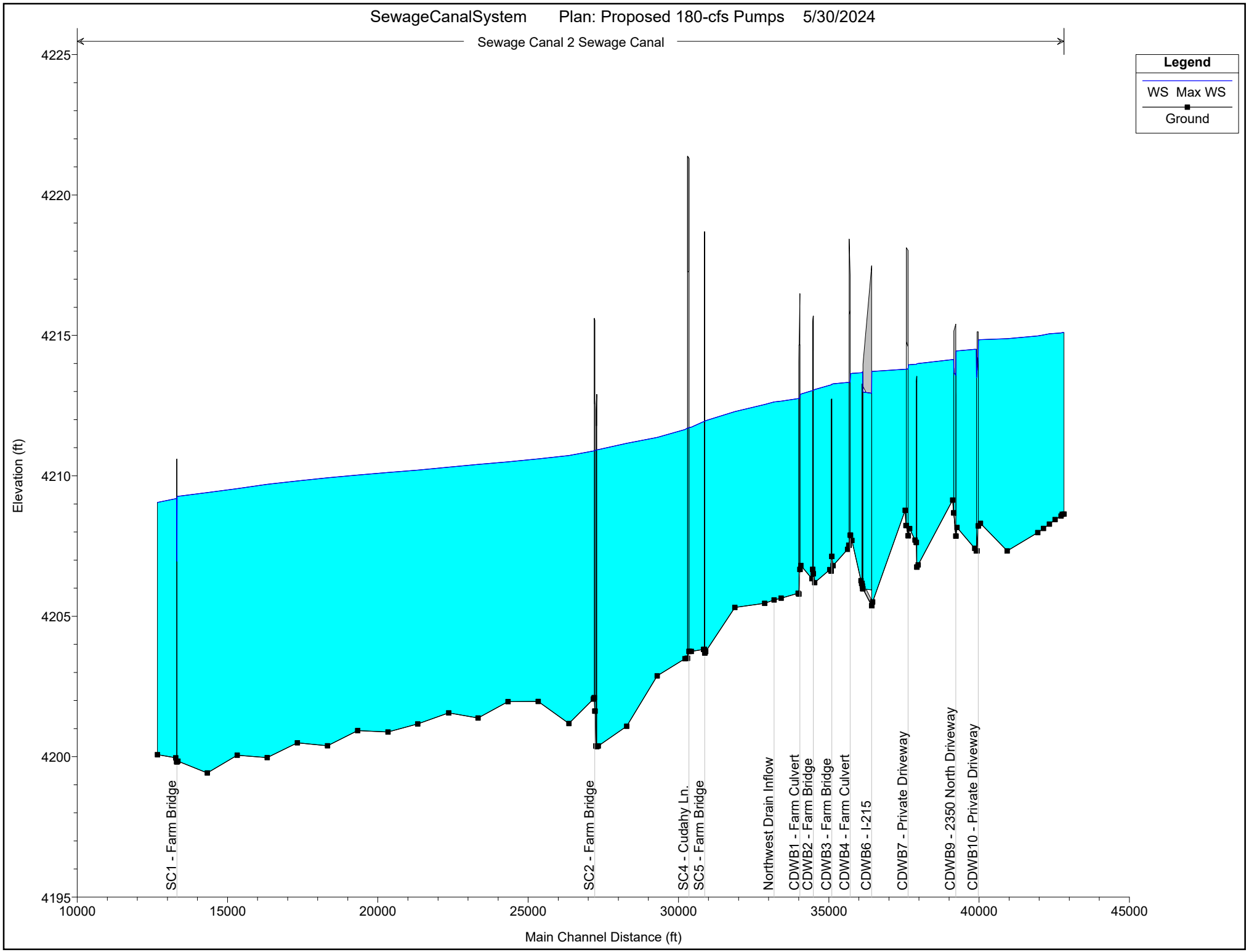

SewageCanalSystem Plan: Existing 180-cfs Pumps 5/30/2024
Sewage Canal CWA3
Legend
WS Max WS
Ground
Elevation (ft)
4236
4234
4232
4230
4228
4226
4224
4222
4220
70000
72000
74000
76000
78000
80000
82000
Main Channel Distance (ft)
CWA3D7 - XXXX
CWA3D08 - Claifornia Ave.
CWA3D09 - Swaner Rd.
CWA3D11 - 1700 South
CWA3D12 - 2100 South


SewageCanalSystem Plan: Proposed 180-cfs Pumps 5/30/2024
Sewage Canal CWA3
Legend
WS Max WS
Ground
Elevation (ft)
4236
4234
4232
4230
4228
4226
4224
4222
4220
70000
72000
74000
76000
78000
80000
82000
Main Channel Distance (ft)
CWA3D7 - XXXX
CWA3D08 - Claifornia Ave.
CWA3D09 - Swaner Rd.
CWA3D11 - 1700 South
CWA3D12 - 2100 South


SewageCanalSystem Plan: Existing 180-cfs Pumps 5/30/2024
Sewage Canal City_Drain-Sewag
Legend
WS Max WS
Lat Struct
Ground
Elevation (ft)
4240
4235
4230
4225
4220
4215
4210
4205
40000
45000
50000
55000
60000
65000
70000
Main Channel Distance (ft)
PUMP...
CDWB12...
CDWB13 - 1800...
CDWB15 - ...
CDWB16 - Fl...
CDWB17 - 220...
CDWB18 - 2360 We...
CDWB19 - Airport
CDWB22B - Private Road
CDWB23 - I-80 Ext
CDWB23B - I-80
CDWB24 - I-80 SB Exit
CDWB25 - Railroad Tracks
CWA2D1 - 500 South
CWA3D1 - Indiana Ave.


SewageCanalSystem Plan: Proposed 180-cfs Pumps 5/30/2024
Sewage Canal City_Drain-Sewag
Legend
WS Max WS
Lat Struct
Ground
Elevation (ft)
4240
4235
4230
4225
4220
4215
4210
4205
40000
45000
50000
55000
60000
65000
70000
Main Channel Distance (ft)
PUMP...
CDWB12...
CDWB13 - 1...
CDWB15 - ...
CDWB16 - Fl...
CDWB17 - 220...
CDWB18 - 2360 We...
CDWB19 - Military Base
CDWB22B - Private Road
CDWB23 - I-80 Ext
CDWB23B - I-80
CDWB24 - I-80 SB Exit
CDWB25 - Railroad Tracks
CWA2D1 - 500 South
CWA3D1 - Indiana Ave.


SewageCanalSystem Plan: Existing 180-cfs Pumps 5/30/2024
Sewage Canal 2 Sewage Canal
Legend
WS Max WS
Ground
Elevation (ft)
4225
4220
4215
4210
4205
4200
4195
10000
15000
20000
25000
30000
35000
40000
45000
Main Channel Distance (ft)
SC1 - Farm Bridge
SC2 - Farm Bridge
SC4 - Cudahy Ln.
SC5 - Farm Bridge
Northwest Drain Inflow
CDWB1 - Farm Culvert
CDWB2 - Farm Bridge
CDWB3 - Farm Bridge
CDWB4 - Farm Culvert
CDWB6 - I-215
CDWB7 - Private Driveway
CDWB9 - 2350 North Driveway
CDWB10 - Private Driveway


SewageCanalSystem Plan: Proposed 180-cfs Pumps 5/30/2024
Sewage Canal 2 Sewage Canal
Legend
WS Max WS
Ground
Elevation (ft)
4225
4220
4215
4210
4205
4200
4195
10000
15000
20000
25000
30000
35000
40000
45000
Main Channel Distance (ft)
SC1 - Farm Bridge
SC2 - Farm Bridge
SC4 - Cudahy Ln.
SC5 - Farm Bridge
Northwest Drain Inflow
CDWB1 - Farm Culvert
CDWB2 - Farm Bridge
CDWB3 - Farm Bridge
CDWB4 - Farm Culvert
CDWB6 - I-215
CDWB7 - Private Driveway
CDWB9 - 2350 North Driveway
CDWB10 - Private Driveway

APPENDIX J

City Drain Lift Station Pre-Design Report

CRS ENGINEERS
Answers to Infrastructure®

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To Andrew Barney, P.E.
From Mark Chandler P.E., P.G., CFM
Date February 14, 2024
Re Pump Selection Evaluation for the City Drain Lift Station Replacement

DRAFT

Introduction

Salt Lake County's City Drain plays a crucial role in the County's stormwater management and is susceptible to various challenges. Some of these challenges include an aging lift station, vulnerability to flooding, and corrosive conditions. Major components include drainage ditches, and various culverts. Currently, this pathway functions as the conduit for stormwater from I-215 just south of 2100 North and heading north, CWA – 1, 2, & 3, and the Salt Lake City International Airport to ultimately discharge into the Great Salt Lake as shown below.

The current infrastructure, established in the 1970's, has experienced deterioration over time due to various factors including age and difficulty obtaining replacement pumping parts. The county has decided that the lift station needs to be rebuilt and the existing pumps will be replaced. This memorandum evaluates three different pumps that could be implemented at the new lift station and makes a recommendation to use Archimedes screw pumps. As the county proceeds with other improvements on the City Drain system, this lift station will need to be replaced.

Beyond the immediate benefits of infrastructure reconstruction, the project will enhance the overall functionality and resilience of the stormwater collection system. Additionally, the project aligns with a broader vision of Salt Lake County Public Works Engineering (Public Works) of ensuring the preservation and performance of the storm drainage system.

Background

Existing City Drain Lift Station

The existing lift station employs three large diesel powered hydraulically driven pumps, two smaller similar pumps and a submersible pump. The lift station also employs three large diameter culverts with a headgate on the downstream end. The culverts act as a pass throw during normal flows, while the pumps provide additional flows during storm events. The diesel engines for the pumps are in the engine building to the east of the lift station and a separate diesel fuel tank is located on site. The current operating capacity of the pump station is 100 cfs. The channel, if all maintenance was completed and deficiencies corrected could produce as much as 180 cfs in the 10-year buildout. The pumps will need to provide at least 6 feet of vertical lift.

Future Capacity

There is an unlikely chance that other impacts from UDOT and other users increase flows to as much as 300 cfs, but this rate is not recommended for the pump station. As the modeling has been evaluated, it is recommended that the replacement pump station provide approximately 30 cfs from one smaller pump and an additional 150 cfs through three separate pumps of 50 cfs each. This would provide the total needed capacity of 180 cfs and in most cases will provide redundant flow capacity. The following section evaluates three separate pump configurations that could meet this demand.

Pumps

In our evaluation of this site, we have considered three primary pumping alternatives. These include an Archimedes screw pump, a vertical turbine pump and a submersible pump application. Each of these applications has its benefits that will be outlined below. With each of the alternatives, additional channel improvements and wet-well modifications would be completed to improve overall pump station operations.

Archimedes Screw Pump

Archimedes screw pumps provide high flow to low head with few moving parts. These pumps are ideal for widely ranging storm flows because of the variable capacity while operating at a constant speed. With this constant speed, the screw pump is mechanically efficient as it uses less power for the same capacity. This results in minimum wear and maintenance required on the screw pumps. Additionally, screw pumps can deal with medium to small sized debris, that may come from storm events, with little possibility of clogging. However, screw pumps have a larger footprint compared to the vertical turbine pump and the submersible pump. This larger footprint would include a concrete trough to house the screw pumps. This style of pump can function under a range of conditions that is less sensitive to the level of the canal upstream of the pumps and can even run dry without causing significant damage to the pumps, which limits potential for operation error impacting the pump station. The screws would be essentially open with fiberglass grates about 1.5-2 feet above the screws to protect against anyone or anything falling in, and to provide visibility to any blockages that potentially develop. These fiberglass screens can also be easily removed by county staff if necessary to remove blockages that develop. The attached exhibits show a plan and section view of the lift station as well as a plan view with an optional 5th pump slot overlaid on an aerial to show the size of the station at the current site as well as other site design considerations. This additional slot would provide some additional redundancy for the County in extreme conditions.

The 50 cfs pumps (84-inch diameter and 60 hp) would cost approximately $200,000 per pump and the smaller 30 cfs pump (72-inch diameter 40 hp) would cost approximately $160,000 just for the fabrication and delivery of the pumps.

Vertical Turbine Pump

Vertical turbine pumps (VTP) can provide high flow to low head but have more moving parts than the screw pump. With a variable frequency drive (VFD), the VTP can handle various flows. Varying the speed that the motor needs to run will increase the wear and maintenance required on the pump. Finally, after a storm event, the number of solids and debris in the water in the canal will increase. As a result, screens with smaller openings will need to be installed to help prevent damage to the pump's impellers. VTP require an additional wet well to provide additional head on the pump to prevent cavitation and is very sensitive to the water level to maintain the necessary suction head on the pumps. Problems with debris and the higher potential for damages if operations are not carefully monitored made this pump system less desirable.

The 50 cfs pumps would cost approximately $250,000 per pump and the smaller pump would cost approximately $200,000 just for the fabrication and delivery of the pump.

Submersible Pump

Submersible pumps are like the vertical turbine pumps and require similar screening needs. They will require a VFD to account for the various flows, which will increase the maintenance on the pump. Debris and sediment in the canal can increase the possibility of additional wear on the pump's impellers, and a wet well(s) will need to be added as part of the infrastructure. However, a submersible will also require a sleeve over the pump to force water to flow past the motor to prevent the motor from burning up. This also means that the most likely failure point, the motor, will be submerged. Due to the limitation of access to the motor, we do not recommend that the submersible pump option be pursued.

Additional Appurtenances and Considerations

The completion of the lift station will include several other appurtenances including electrical systems, controls (SCADA), backup power, screening grates, and a weir on the downstream end of the lift station. This section will evaluate each of these appurtenances.

Site Demolition

The site will require significant demolition to accommodate construction of the new structure. The existing pump and dam structure will be removed, and the subgrade will be excavated to allow for structural fill to be placed prior to construction of the structure. The existing low flow pipes and headgates will be impacted by this excavation and should be replaced as part of this effort. We recommend that the existing diesel drive building should be emptied of all current equipment and controls and the building should be upgraded with lights, insulation, and climate controls to house the electrical controls without risking damage from extreme heat or cold. Much of the building will be converted to additional storage for the County. While not necessary, the County should consider how to either abandon in place or remove the existing diesel storage tank buried on the east side of the property.

Electrical Systems

The proposed pumps will run on 3 phase electricity. There are power pole next to the pump station site. We will connect into the power poles to run the pumps and apertures. The pumps will also be fitted with a soft start system to minimize the start-up power costs.

SCADA Controls

Based on the current operations and observations, we will set initial on/off points in the SCADA that will automatically turn the pumps on and off as water levels upstream and downstream of the pump station rise from storm events. Measurements will be read on the channel depth upstream and downstream of the station, at the outflow pad to measure flows generated. Controls will be programmed for each of the pumps and the headgate on the bypass piping. We recommend that the SCADA be programmed to provide remote visibility of how the station is operating as well as remote control capabilities. The remote observation and controls will also be programmed with pre-determined operating conditions to automate the pump station in most situations. Integrated with the SCADA controls is the ability to manually over-ride the controls, when necessary, at the site. We recommend integrating a security camera with the SCADA to allow remote observation of the channel both upstream and downstream and debris collection. This will provide the County with additional visibility and allow for more proactive maintenance of the system.

Site Security

Due to the sensitivity of this facility, we recommend that the site be fully fenced and enclosed wit razor wire topped chain link fence similar to the current site along with a locking gate. Much of the existing fencing can remain as well. We also recommend that additional security cameras be installed focused to the controls building and roadway for security purposes.

Low Flow Conditions

Currently, the County has low flow culverts with downstream headgates for when flows exceed downstream capacity and the channel begins to back up. In these conditions, the county closes the head gate to prevent backflow and turns on the pumps to provide the additional head to the flows to keep the water moving in the downstream channel. This same operability will be provided through two culverts but will now be controlled through actuated valves controlled by the SCADA system monitoring water levels in the downstream channel. As the water levels downstream rise, causing backups in the channel, the gates will automatically close as the pumps turn on to push more water into the downstream channel. Because of the significant excavation that will be required to both demolish the existing pump station and to provide the necessary over-excavation to provide an adequate base, we recommend that the low flow pipes and headgate be removed and replaced as part of this project.

Backup Power

The current pumps run are diesel powered and hydraulically driven. The new pumps will be directly electric powered from the local power grid. But due to the importance of this facility, we recommend that the County provide a backup generator that has the capacity to power all four of the pumps. This would also be connected to an automatic transfer switch to fire up the generator and switch the source line from the grid to the generator in the event of a power outage. Final pump sizing and configuration will provide the generator sizing requirements. The County could consider both diesel and natural gas options for this generator. Another consideration for the backup power is whether to use a stationary or

portable generator. The portable option would not provide the automatic transfer of power and would have to be diesel powered, but could provide some flexibility in how the site operates if desired.

Screening Grates

While the screw pumps are able to handle large debris with minimal issues, this lift station is the most logical location to remove debris that could cause issues downstream. This location has historically operated in this manner to allow the County to remove material that could also cause damage to the lift station. The intent of these structures is to provide a simple way for the County to clean out the floating debris in the channel that is larger sized. It is not the intent of this structure to remove all possible debris. The grates will likely cross the channel at an angle to pull debris to the east bank near the controls station and simplify removal from the channel.

Outflow Controls

Moving 180 cfs over the top of the lift station and back into the channel will require some controls to manage and minimize turbulence and downstream erosion. The plan is to have a downstream apron that feeds into an ogee cress style outflow to minimize turbulence as the flows re-enter the main canal flow. This design will help to minimize turbulence and control the energy dissipation needed at the top of the lift. This control will also direct flows to the middle of the channel to avoid impacts to the banks downstream of the channel.

Permitting

As the county moves forward with design and construction of the lift station we have identified two primary permits that will be needed- County Flood Control and Stream Alteration. These permits will need to follow the standard process for each and will likely require some coordination meetings with the State for the stream alteration permit.

Recommendation

Comparing the three types of pumps, we have evaluated each on ease of operation, maintenance, screening, up-front costs, and long-term costs as well as ease of obtaining parts and support by pump suppliers. As previously stated, we do not recommend that the County move forward with a submersible pump. The remaining two pump types, vertical turbine and Archimedes screw, will be relatively similar at approximately $3.5 million. The vertical turbine pumps will need a deeper forebay to maintain net positive suction head above the pumps, where the screw pumps will not run the similar risk of cavitation when water levels drop. But the anticipated constructability, maintenance requirements, operating costs, simplicity of operations and availability of service and parts for the screw pumps is expected to be much simpler than the vertical turbine pumps.

Based on these criteria, we recommend that the County proceed with an Archimedes screw pump station with three 84-inch diameter screws (50 cfs each) and one 72-inch screw (30 cfs) to provide the necessary lift to at this location in the canal. This configuration will exceed current capacity and should meet the county's needs as upgrades and modifications are completed both upstream and downstream of the lift station.

We also recommend that all of the appurtenances outlined above be incorporated into the design and construction of the replacement lift station.

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